Middle Santa Ana River Bacteria Synoptic Study and TMDL Triennial Report

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Submitted to:

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Acronyms

Basin Plan	Water Quality Control Plan for the Santa Ana Region
BMP	Best Management Practice
BPS	Bacteria Prioritization Score
°C	Degrees Celsius
CBRP	Comprehensive Bacteria Reduction Plan
CCWRP	Carbon Canyon Water Recycling Plant
CEDEN	California Environmental Data Exchange Network
cfs	cubic feet per second
cfu	Colony Forming Unit
cm	centimeter
COC	Chain of Custody
DL	Detection Limit
DWF	Dry Weather Flow
E. coli	*Escherichia coli*
EEES	Essential Environmental and Engineering Systems
gal/ac/day	gallons/acre/day
gc	gene copies
HF	Human Feces
HF183	*Bacteroides* Human-host Specific Marker
IEUA	Inland Empire Utilities Agency
IEWK	Inland Empire Waterkeeper
JCSD	Jurupa Community Services District
kg	kilogram
LA	Load allocation
LSD	Log Standard Deviation
m^2	square meter
mL	milliliter
µL	microliters
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
MSAR	Middle Santa Ana River
MSAR TMDL	Middle Santa Ana River Bacterial Indicator TMDL
MST	Microbial Source Tracking
MW District	Metropolitan Water District

n	Number of Samples
ND	Not Detected
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly-owned Treatment Works
ppth	part per thousand
Q	Flow
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
qPCR	Quantitative Real-time Polymerase Chain Reaction
RBMP	Regional Bacteria Monitoring Program
RCFC&WCD	Riverside County Flood Control & Water Conservation District
REC1	Water Contact Recreation
Riverside RWQCP	Riverside Regional Water Quality Control Plant
RIX	Rapid Infiltration and Extraction Facility
RP1	IEUA Regional Water Recycling Plant No. 1
Santa Ana Water Board	Santa Ana Regional Water Quality Control Board
SAWPA	Santa Ana Watershed Project Authority
SBCFCD	San Bernardino County Flood Control District
State Water Board	State Water Resources Control Board
Task Force	MSAR Watershed TMDL Task Force
TMDL	Total Maximum Daily Load
USEP	Urban Source Evaluation Plan
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WDR	Waste Discharge Requirement
WLA	Wasteload allocation
WWTP	Wastewater Treatment Plant

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1. Background and Purpose

1.1 Regulatory Background

1.1.1 Middle Santa Ana River Bacterial Indicator TMDL

On August 26, 2005, the Santa Ana Regional Water Quality Control Board (Santa Ana Water Board) adopted Middle Santa Ana River (MSAR) Bacterial Indicator Total Maximum Daily Loads (TMDL) ("MSAR TMDL") for Reach 3 of the Santa Ana River, Mill Creek (in the Prado area), Reach 1 of Cucamonga Creek, Reaches 1 and 2 of Chino Creek, and the Prado Park Lakes (Resolution No. R8-2005-0001). The adopted TMDL was approved by the State Water Resources Control Board (State Water Board) on May 15, 2006 (Resolution No 2006-030) and by the United States Environmental Protection Agency (USEPA) Region 9 on May 16, 2007.

The MSAR TMDL established fecal coliform and *Escherichia coli* (*E. coli*) wasteload allocations (WLA) for urban Municipal Separate Storm Sewer System (MS4) and confined animal feeding operation discharges and load allocations (LAs) for agricultural and natural sources:

- Fecal coliform: 5-sample/30-day logarithmic mean (or geometric mean) less than 180 organisms/100 mL and not more than 10 percent of the samples exceed 360 organisms/100 mL for any 30-day period.[1]
- *E. coli*: 5-sample/30-day logarithmic mean (or geometric mean) less than 113 organisms/100 mL and not more than 10 percent of the samples exceed 212 organisms/100 mL for any 30-day period.

Soon after the adoption of the MSAR TMDL by the Santa Ana Water Board and prior to the effective TMDL date, the responsible parties named in the TMDL established the MSAR Watershed TMDL Task Force ("Task Force") to work collaboratively on the implementation of requirements established in the TMDL's Implementation Plan. Among these requirements were the establishment of watershed-wide compliance monitoring program and development of an Urban Source Evaluation Plan (USEP) that was to include the steps needed to identify specific activities, operations, and processes in urban areas that contribute bacterial indicators to MSAR watershed waterbodies.

The USEP (SAWPA 2008), which was approved April 18, 2008 (Resolution No. R8-2008-0044), included a number of investigations to identify the most significant sources of bacterial contamination to the impaired waterbodies, including, for example, studies in

[1] The WLAs and LAs for fecal coliform are no longer applicable following USEPA's 2015 approval of the 2012-adopted Basin Plan amendment to revised bacterial indicator objectives in the Santa Ana Region for inland freshwaters (see Section 1.1.3).

Carbon Canyon Creek, Cypress Channel, lower Deer Creek subwatershed (Chris Basin), Box Springs Channel, and Chino Creek. Data generated from the USEP studies was used to develop the first risk-based scoring system to help prioritize project implementation and measure progress towards improving water quality.

1.1.2 Comprehensive Bacteria Reduction Plans

On January 29, 2010, the Riverside and San Bernardino County MS4 Permits were re-authorized by the Santa Ana Water Board (Resolution Nos. R8-2010-0033 and R8-2010-0036, respectively). These permits required the development of Comprehensive Bacteria Reduction Plans (CBRP) to address urban sources of bacterial indicators during the dry season from April 1 to October 31. These CBRPs, which were submitted to the Santa Ana Water Board on June 28, 2011 (RCFC&WCD 2011; SBCFCD 2011), were subsequently approved by the Santa Ana Water Board on February 10, 2012 (Resolution Nos. R8-2012-0015 and R8-2012-0016, respectively).

Portions of the Cities of Pomona and Claremont lie within the MSAR watershed. Accordingly, in 2012 the reauthorization of the Los Angeles County MS4 Permit included requirements for these cities to comply with the MSAR TMDL (Resolution No. R4-2012-0175). The Santa Ana Water Board subsequently adopted a resolution requiring these cities to comply with MSAR TMDL requirements, including development of CBRPs for their respective jurisdictions (Resolution No. R8-2013-0043). These CBRPs were submitted to the Santa Ana Water Board on January 14, 2014 (City of Claremont 2014; City of Pomona 2014).

As part of the development of the CBRPs, the risk-based approach first developed for the USEP, was updated and used to form the foundation for the development of CBRP implementation priorities. The MS4 Permittees in the MSAR watershed have been implementing their respective CBRPs since submittal – collaboratively with their respective MS4 Programs, individually as an MS4 Permittee or collectively through the Task Force.

In December 2017, the Riverside and San Bernardino County MS4 Programs received notice from the Santa Ana Water Board that their respective CBRPs were being audited to evaluate compliance with the CBRP requirements. The outcome of this effort was the finding in the CBRP Audit Reports for each County that the MS4 Programs are in compliance with their respective CBRPs (Santa Ana Water Board October 2018a,b). In addition, the audits recommended revision to the CBRPs *but only* after the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) and MSAR TMDL are revised to be current with state and/or regional regulations to protect recreational uses.

1.1.3 Recreational Use Protection

In 2012, the Santa Ana Water Board adopted an amendment to the Basin Plan that revised bacterial indicator objectives in the Santa Ana Region for inland freshwaters (R8-2012-

0001). That Basin Plan amendment was subsequently approved by the State Water Board on January 21, 2014 (Resolution No. 2014-0005) and by USEPA on April 8, 2015.

Recently in 2018, the State Water Board amended the Water Quality Control Plan for Inland Surface Waters to establish new statewide water quality standards for pathogen indicator bacteria (Resolution No. 2018-0038, August 7, 2018). These new standards supersede some portions of the Santa Ana Region's 2012 Basin Plan amendment. Both the 2012 Santa Ana Water Board Basin Plan amendment and 2018-adopted State Water Board statewide bacteria water quality standards provisions impact the basis for establishment of the 2005-adopted MSAR TMDL, which in turn impacts the basis for the MS4 Program CBRPs.

In March 2019, the MSAR Task Force recommended that the Santa Ana Water Board address the need to revise the Basin Plan and the MSAR TMDL by requesting that the following initiatives be included as a high priority during the Board's next triennial review planning period (SAWPA 2019a):

- Revise the water quality objectives for pathogen indicator bacteria in the Santa Ana region's Basin Plan to be consistent with those recently approved by the State Water Board as amendments to the Basin Plan (State Water Board 2018):
  - The bacteria water quality objective for all waters where the salinity is equal to or less than 1 part per thousand (ppth) 95 percent or more of the time during the calendar year is: a six-week rolling geometric mean of *E. coli* not to exceed 100 colony forming units (cfu) per 100 milliliters (mL), calculated weekly, and a statistical threshold value of 320 cfu/100 mL not to be exceeded by more than 10 percent of the samples collected in a calendar month, calculated in a static manner.
- Update "Table 5-REC2 Only Targets-FW" table in Section 5 of the Basin Plan (freshwater antidegradation indicator bacteria targets for waterbodies that have had REC1 removed by an approved UAA);
- Update the MSAR TMDL to take into account changes to statewide water quality standards for bacterial indicators and changes to the Basin Plan to protect inland freshwaters.

These recommendations were included in the Santa Ana Water Board's final Triennial Review Priority List and Work Plan (Fiscal Years 2019-2022) (Resolution No. R8-2019-055).

1.2 Project Purpose

The existing MSAR TMDL requires stakeholders to submit a Triennial Report to the Santa Ana Water Board every three years after the 2007 TMDL effective date. To date, three such reports have been prepared and delivered (SAWPA 2010a, 2013, 2017). Normally, the next Triennial Report would have been due in 2019. However, an outcome of the CBRP audits was a determination that the 2019 Triennial Report should be deferred for one year until

February 2020 in order to provide time to undertake a MSAR Bacteria Synoptic Study of bacterial sources and loads in the watershed (Santa Ana Water Board 2018a,b). The new study would update work originally completed as part of the USEP and development and implementation of the CBRPs. The purpose of this report is to not only provide the findings from the 2019 Synoptic Study, which will support planned revisions to the MSAR TMDL, but also to serve as the fourth Triennial Report for the MSAR TMDL.

1.3 Project Objectives

The Task Force has identified the following project objectives to be addressed by the Synoptic Study:

1) Characterize the current concentration of *E. coli*, including the associated variability, in the waterbodies named in the TMDL. This water quality monitoring effort should be coordinated, to the maximum extent practicable, with the existing Regional Bacteria Monitoring Program (RBMP)[2] to avoid duplication of effort and minimize redundant costs.

2) Characterize the flows and concentrations of *E. coli* being discharged into the waterbodies named in the TMDL from all major tributaries and discharges to those waterbodies.

3) Identify additional sources of data from similar fecal indicator bacteria monitoring programs conducted by other agencies or organizations (e.g., Inland Waterkeeper, United States Geological Survey, Orange County Water District, State Division of Drinking Water, county health departments, water supply agencies, etc.) and obtain copies if possible. Add all data collected during the study to the Santa Ana Watershed Project Authority's (SAWPA) existing water quality database and upload qualified data to the California Environmental Data Exchange Network (CEDEN) when directed to do so by the Task Force.

4) Characterize any significant changes in the concentration and mass of *E. coli* that have occurred during the period of TMDL implementation. Determine if there is any discernable trend in the receiving water and discharge data for both *E. coli* and *Bacteroides* (or other human-associated DNA markers selected for the study).

5) Use appropriate Microbial Source Tracking (MST) techniques to determine the extent to which human sources may or may not be contributing to elevated *E. coli* concentrations in the samples collected.

6) Update the Risk-Based Prioritization Score, reflected in Table 3-6 and Figure 3-8 in the 2013 TMDL Triennial Report for all sites evaluated as part of the new Synoptic Study and summarize how these scores have changed since the previous ranking was prepared in 2013 (SAWPA 2013).

[2] https://sawpa.org/task-forces/regional-water-quality-monitoring-task-force/#geographic-setting

7) Evaluate and quantify the degree to which dry weather urban flows have declined in the time since the TMDL was approved in 2005. Estimate the net change in bacterial mass loads associated with the reduction in dry weather flows (DWF) discharged from the stormwater conveyance system.

8) Confirm what specific areas of the MSAR watershed have been hydrologically-disconnected from the receiving streams identified in the TMDL, during dry weather conditions, and update the GIS maps accordingly.

9) Update and revise the *E. coli* mass balance analyses shown in Figures 4-9, 4-10 and 4-11 of the 2016 TMDL Triennial Report (SAWPA 2017).

10) Determine whether the estimated bacterial load reductions described in Tables 3-2, 3-3 and 3-4 of Riverside County's CBRP and San Bernardino County's CBRP (RCFC&WCD 2011; SBCFCD 2011) have been achieved and evaluate the net effect of the actual reductions achieved on receiving water quality at the primary instream compliance stations. Update the estimated load reductions required to achieve compliance with the *E. coli* targets identified in the 2005-adopted TMDL.

1.4 Synoptic Study Project

The Synoptic Study was implemented as a collaborative effort that included the following agencies:

- Riverside County Flood Control & Water Conservation District (RCFC&WCD)
- San Bernardino Flood Control District (SBCFCD)
- City of San Bernardino Municipal Water Department
- City of Rialto
- Inland Empire Utilities Agency (IEUA)
- Riverside Regional Water Quality Control Plant (Riverside RWQCP)

The Synoptic Study consisted of a comprehensive six-week data collection effort during dry weather conditions within the MSAR watershed. Sample collection began the week of July 29, 2019 and ended the week of September 3, 2019; samples were collected over a two-day period each week. The selection of sample locations was designed to meet the project objectives described above within areas of the MSAR watershed that are hydrologically connected to impaired waterbodies, e.g., Santa Ana River Reach 3). Data collection occurred at a total of 28 sample locations in the watershed (**Table 1-1** and **Figure 1-1**):

- Fourteen Tier 1 sites (defined as locations where urban sources of (DWF) may directly discharge to a downstream watershed-wide compliance site);
- Two Tier 2 sites (defined as sites that are tributary to a downstream Tier 1 site);

- Five Publicly-owned Treatment Works (POTW) (sample collection from fully treated effluent prior to discharge to the receiving water) (**Table 1-2**);
- Four MSAR watershed-wide compliance sites (existing compliance sites regularly sampled as part of MSAR TMDL implementation); and
- Three Santa Ana River Reach 3 mainstem sites (additional mainstem Santa Ana River sites that are not MSAR TMDL watershed-wide compliance sites).

During all sample events, field measurements, including flow, were made and water samples were collected for *E. coli* and *Bacteroides* analysis. Each week field measurements and water sample collections were coordinated within subwatersheds draining to a watershed-wide compliance site to facilitate development of *E. coli* mass balance analyses. For example, all sample locations within the area draining to the Santa Ana River at MWD Crossing site (i.e., POTW, watershed-wide compliance, mainstem river and Tier 1 sites) were sampled on the same day during each week of the sample program. The Study Plan and Quality Assurance Project Plan (QAPP) for the Synoptic Study were submitted to the MSAR Task Force in July 2019 (SAWPA 2019c,d). These documents fully describe the field and laboratory methods used to collect the data needed to meet the objectives of the study.

1.5 Synoptic Study Report

This Synoptic Study Report includes the following key sections :

- *Section 2: Watershed Information and Data Sources* – Summarizes relevant Task Force studies completed to date and other watershed data and studies acquired to support understanding of water quality in the watershed as it relates to fecal indicator bacteria (FIB) in general and
E. coli and *Bacteroides* in particular.
- *Section 3: Synoptic Study Findings* – Reports the findings from the Synoptic Study from 2019 data collection activities within the context of the other data sources summarized in Section 2.
- *Section 4: Findings and Recommendations* – Provides a summary of key conclusions and recommendations to the Task Force.
- *Section 5*: *References*
- *Appendices*: Appendix A provides upstream and downstream photographs of each sample location; Appendix B provides the field and laboratory sample results for flow, dissolved oxygen, temperature, pH, specific conductance, turbidity and *E. coli*. Appendix C is the quality assurance/quality control (QA/QC) report for the Synoptic Study. Appendix D provides the laboratory QA/QC reports.

Table 1-1 Synoptic Study Sample Locations

Site Category	Site ID	Site Description	Latitude	Longitude
Mainstem Santa Ana River	64THST	Santa Ana River at 64th St	33.96884	-117.48779
	MISSION	Santa Ana River at Mission Boulevard Bridge	33.99062	-117.39509
	P3-SBC1	Santa Ana River Reach 4 above South Riverside Avenue Bridge	34.02479	-117.36303
POTW	CCWRP	IEUA Carbon Canyon Water Recycling Plant treated effluent	33.97978	-117.69431
	Rialto WWTP	Rialto Wastewater Treatment Plant (WWTP) treated effluent	34.04816	-117.35658
	Riverside RWQCP	Riverside Regional Water Quality Control Plant treated effluent	33.96344	-117.46140
	RIX	Rapid Infiltration and Extraction Facility treated effluent	34.04159	-117.35482
	RP1	IEUA Regional Water Recycling Plant No. 1 treated effluent	34.02450	-117.59962
Tier 1	T1-ANZA	Anza Drain	33.96058	-117.46488
	T1-BRSC	Boys Republic South Channel	34.00208	-117.72618
	T1-BXSP	Box Springs Channel	33.97574	-117.39938
	T1-CCCH	Carbon Canyon Creek Channel	33.98620	-117.71561
	T1-CHINOCRK	Chino Creek Upstream of San Antonio Channel	34.01343	-117.73057
	T1-CUCAMONGA	Cucamonga Creek at Hellman	33.94936	-117.61034
	T1-CYP	Cypress Channel	33.96821	-117.66039
	T1-DAY	Day Creek	33.96710	-117.53175
	T1-LLSC	Lake Los Serranos Channel	33.97543	-117.69107
	T1-MCSD	Magnolia Center Storm Drain	33.96570	-117.41561
	T1-PHNX	Phoenix Storm Drain	33.96368	-117.42718
	T1-SACH	San Antonio Channel	34.02442	-117.72815
	T1-SNCH	Sunnyslope Channel	33.97615	-117.42618
	T1-SSCH	San Sevaine Channel	33.97465	-117.50551
Tier 2	T2-CYP2	Cypress Channel Upstream of California Institute of Men's agricultural fields	33.98583	-117.66577
	T2-HOLE	Anza Drain Upstream of Hole Lake	33.94854	-117.45649
MSAR TMDL Watershed-wide Compliance Sites	WW-C7	Chino Creek at Central Ave	33.97414	-117.68911
	WW-M6	Mill-Cucamonga Creek	33.92663	-117.62484
	WW-S1	Santa Ana River at MWD Crossing	33.96840	-117.44839
	WW-S4	Santa Ana River at Pedley Avenue	33.95527	-117.53301

Table 1-2. POTWs Discharging Treated Effluent within the Synoptic Study Project Area

Facility	Description	Waste Discharge Requirements
Rialto Wastewater Treatment Plant effluent (Rialto WWTP)	Treats wastewater from the City of Rialto. Tertiary treated recycled water effluent is discharged into Santa Ana River Reach 4. Effluent from the Rialto WWTP is one of the major components of Santa Ana River Reach 3 & 4 baseflow.	Order No. R8-2014-0010; NPDES[1] No. CA0105295
Riverside Regional Water Quality Control Plant effluent (Riverside RWQCP)	Treats wastewater from the City of Riverside and the Community Service Districts of Edgemont, Rubidoux, and Jurupa. Tertiary treated effluent is discharged into Santa Ana River Reach 3.	Order No. R8-2013-0016; NPDES No. CA0105350
Rapid Infiltration and Extraction Facility effluent (RIX)	Receives treated wastewater from San Bernardino Municipal Water Department's Water Reclamation Plant and Colton's wastewater treatment facility. RIX provides tertiary treatment to the wastewater effluent received from those facilities and discharges into Santa Ana River Reach 4. Effluent from RIX is one of the main components of Santa Ana River Reach 3 & 4 baseflow.	Order No. R8-2013-0032; NPDES No. CA8000304
Carbon Canyon Water Recycling Plant effluent (CCWRP)[1]	Treats wastewater from Chino, Chino Hills, Montclair, and Upland. A portion of the tertiary treated recycled water effluent is discharged into Chino Creek.	Order No. R8-2015-0036; NPDES No. CA8000409
IEUA Regional Water Recycling Plant No. 1 effluent (RP1)	Treats wastewater from Chino, Fontana, Montclair, Ontario, Rancho Cucamonga, and Upland. A portion of the tertiary treated recycled water effluent is discharged into Cucamonga Creek.	

[1] National Pollutant Discharge Elimination System (NPDES)
[2] CCWRP did not discharge to Carbon Canyon Creek Channel during the six-week sample period of the Synoptic Study. Therefore, no samples were collected from this POTW.

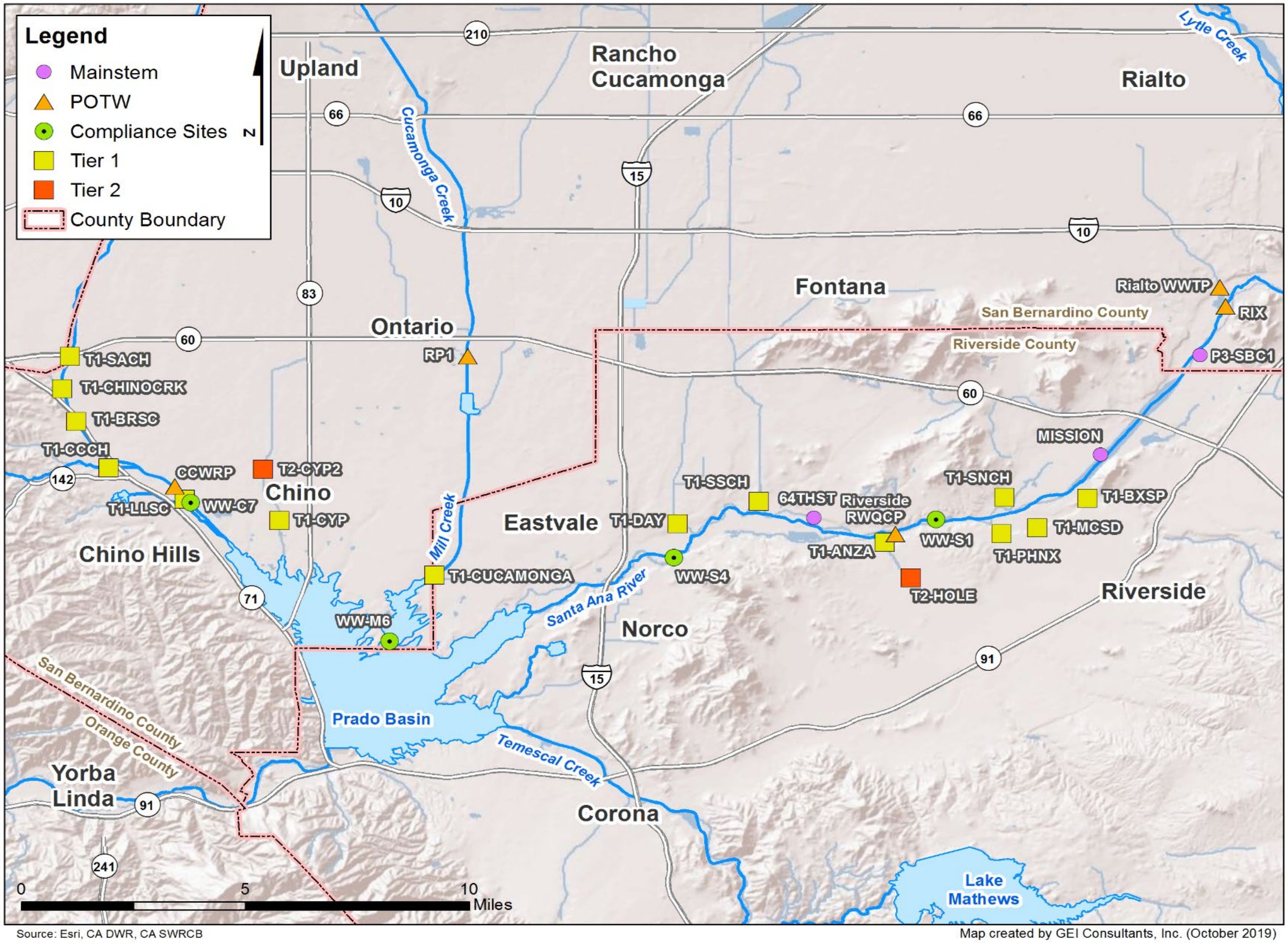

Figure 1-1. Locations of Sample Sites Included in the 2019 Synoptic Study (see Table 1-1)

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2. Watershed Information and Data Sources

This section provides an overview of the water quality data, studies and reports identified for the MSAR watershed that are relevant to the objectives of this report and provide foundation for the interpretation of study results. This information is developed in the following two sections:

- *Section 2.1 – MSAR Task Force and MS4 Permittees*: Provides an annotated bibliography of studies/reports previously developed by the Task Force or MS4 Permittees. For the most part, the findings from these studies provide the basis for evaluating long-term trends in the MSAR watershed.
- *Section 2.2 – Other Watershed Sources*: Summarizes other data collection efforts, studies or reports completed or ongoing in the watershed that may have some bearing on the development of study findings and recommendations in Section 4.

2.1 MSAR Task Force and MS4 Permittees

As noted above, MSAR Task Force members work collaboratively on complying with the requirements in the MSAR TMDL. In addition, the MS4 Permittees in the watershed, which are responsible for compliance with the TMDL WLAs applicable to urban runoff, have been working through their respective County MS4 programs to comply with TMDL requirements. Much of this work is conducted through the implementation of each County's MS4 Program CBRP (see Section 1.1.2). The sections below summarize key studies and reports developed since the TMDL 2007 effective date that provided baseline data to support development of the Synoptic Study and interpretation of sample results. For each cited reference, a link is provided to a copy of the full report.

2.1.1 Regional Bacterial Monitoring Program

The MSAR TMDL required urban and agricultural dischargers to implement a watershed-wide compliance monitoring program. The MSAR Task Force initiated this program in July 2007.[3] In 2016, this monitoring program was incorporated into the Santa Ana River Watershed RBMP. This program produces annual reports that document *E. coli* concentrations at five TMDL compliance sites: Chino Creek at Central Avenue, Mill-Cucamonga Creek, Santa Ana River at MWD Crossing, Santa Ana River at Pedley Avenue and Prado Park Lake (see SAWPA 2019b for the most recent report).

Figures 2-1 through **2-5** illustrate the long term trends in *E. coli* geomean concentrations at each of these sites since implementation of the CBRPs began in 2012. With the exception of Prado Park Lake (Figure 2-5), the other four watershed-wide compliance sites were included in this Synoptic Study.

[3] Original TMDL Monitoring Plan and QAPP adopted by Santa Ana Water Board Resolution No. 2008-0044; https://www.waterboards.ca.gov/santaana/water_issues/programs/tmdl/msar_tmdl.html

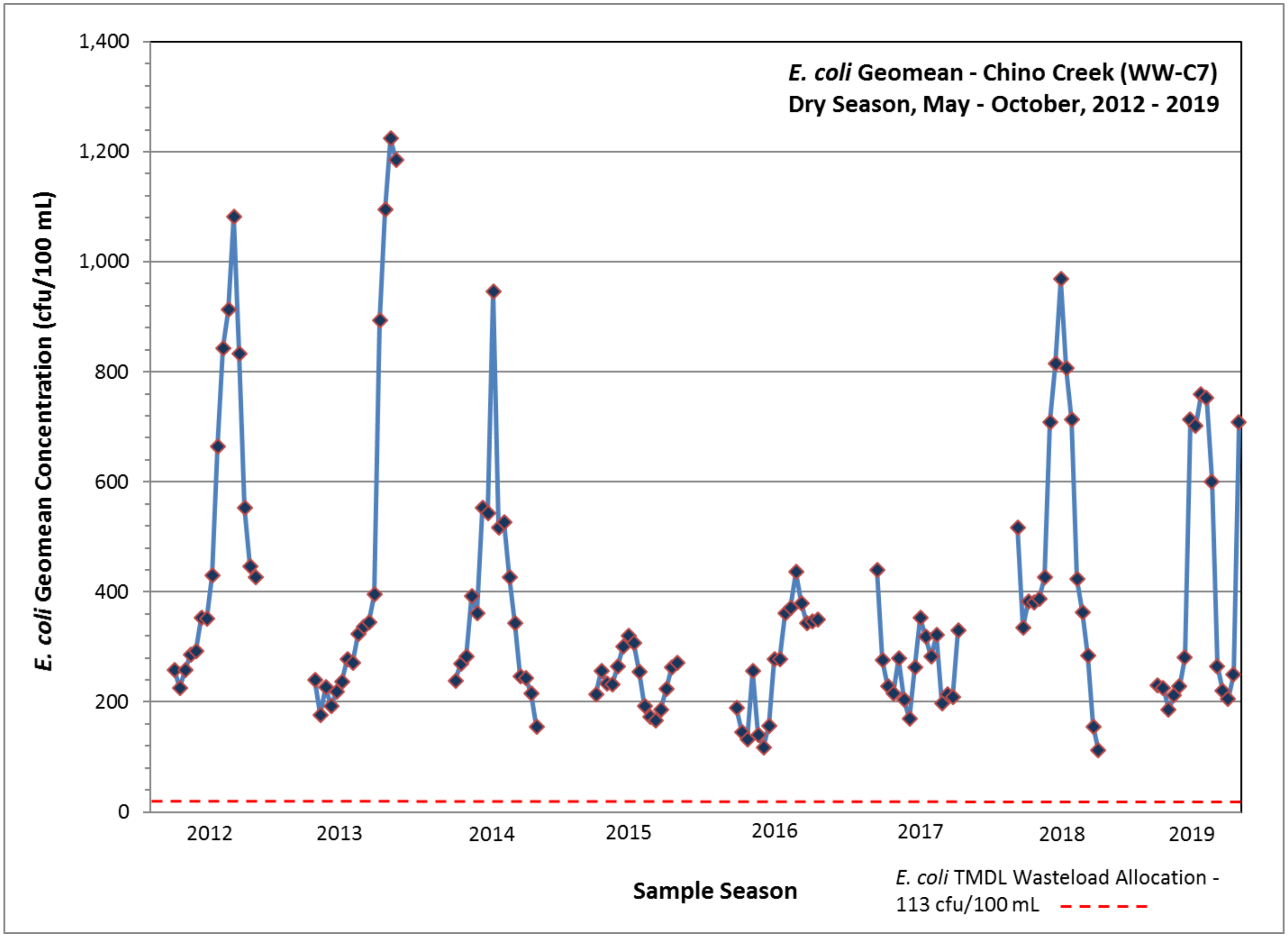

Figure 2-1. Time Series of *E. coli* Geomean Observations during the Dry Season (May to October) at the Chino Creek at Central Avenue Watershed-wide Compliance Site (WW-C7), 2012 – 2019

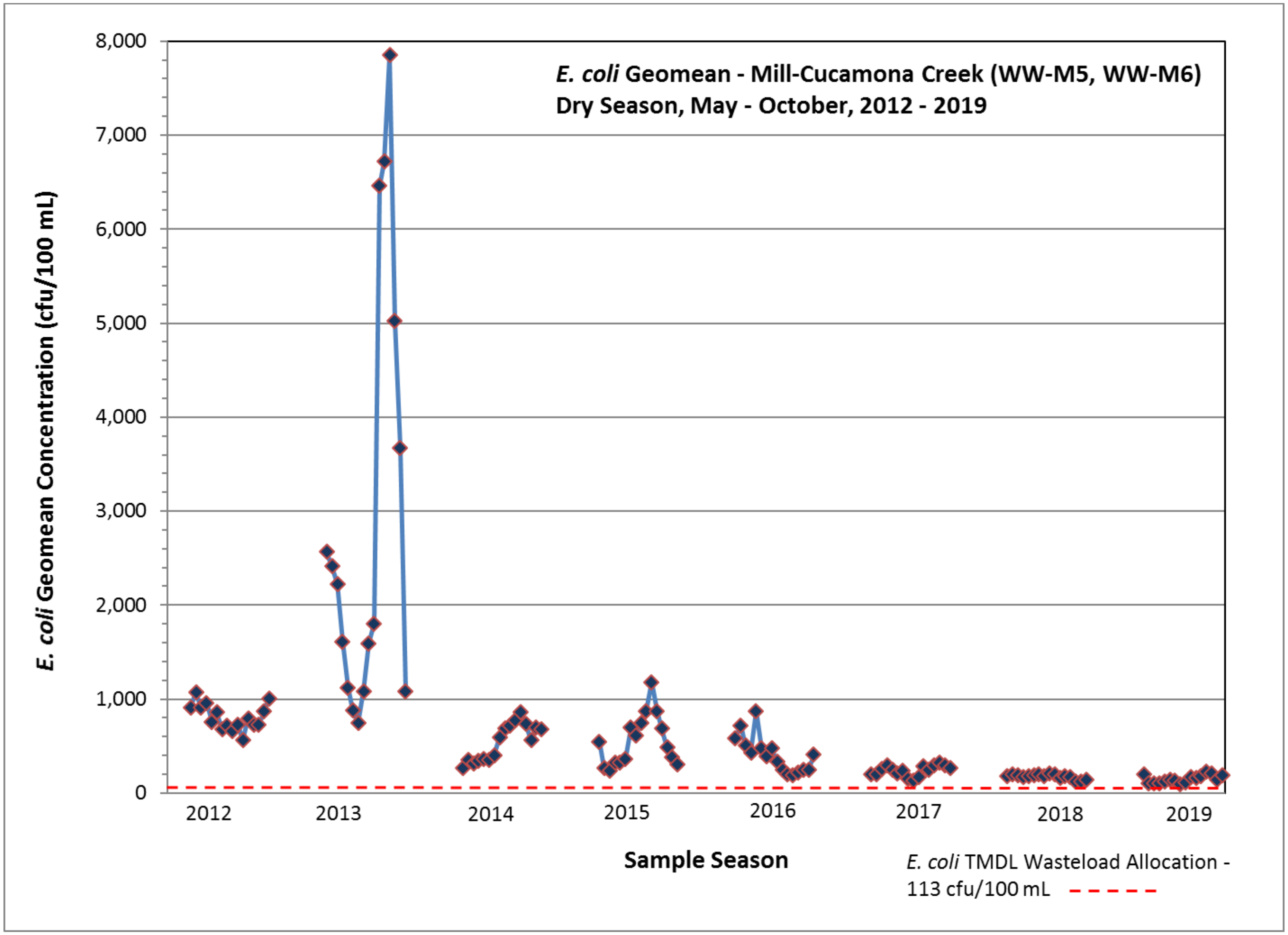

Figure 2-2. Time Series of *E. coli* Geomean Observations during the Dry Season (May to October) at the Mill-Cucamonga Creek Watershed-wide Compliance Site (WW-M6), 2012 – 2019 (Note: In 2016, the compliance site was changed from WW-M5 (Chino-Corona Rd) to WW-M6 (Below Mill Creek Wetland)

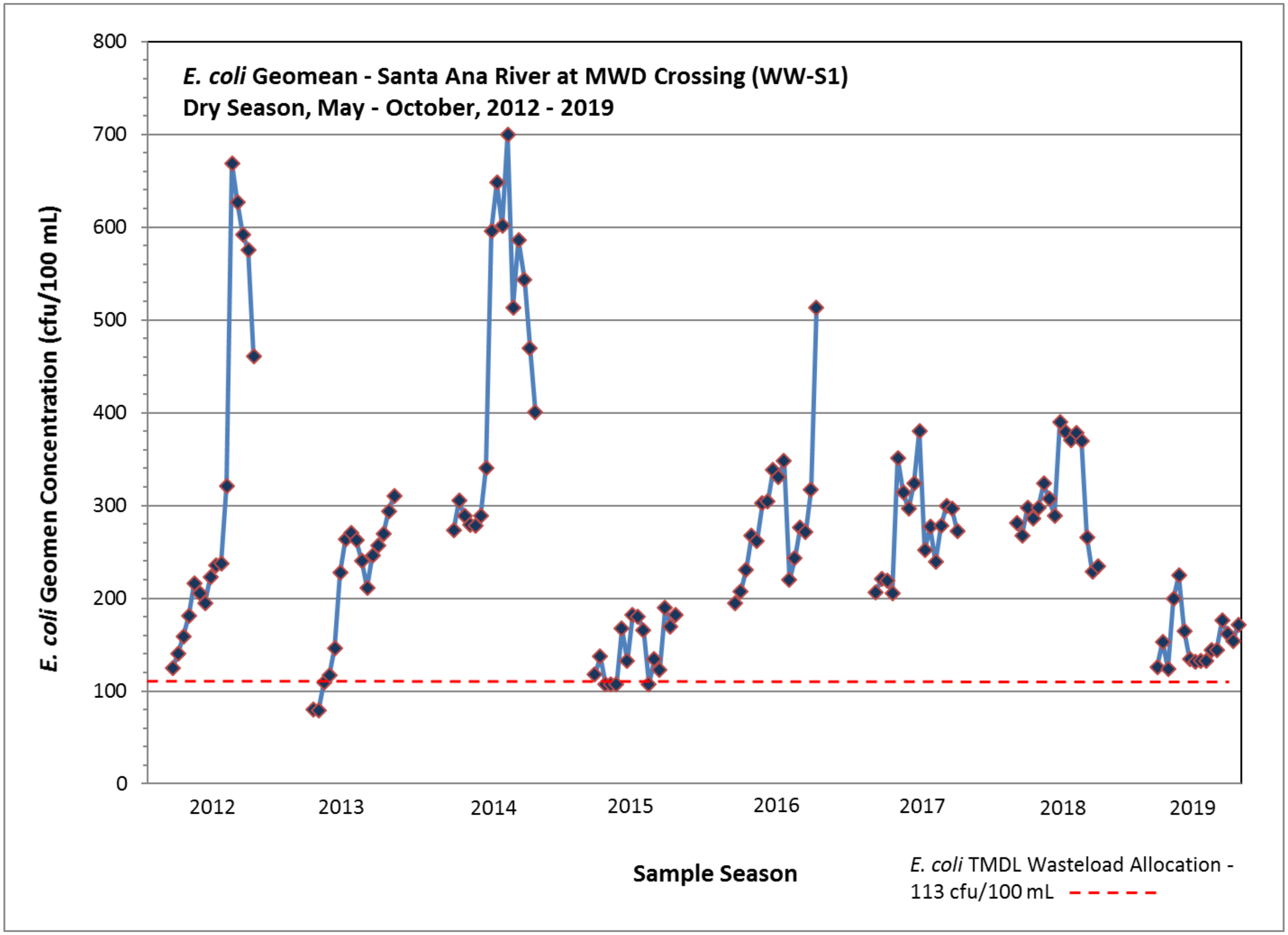

Figure 2-3. Time Series of *E. coli* Geomean Observations during the Dry Season (May to October) at the Santa Ana River at MWD Crossing Watershed-wide Compliance Site (WW-S1), 2012 – 2019

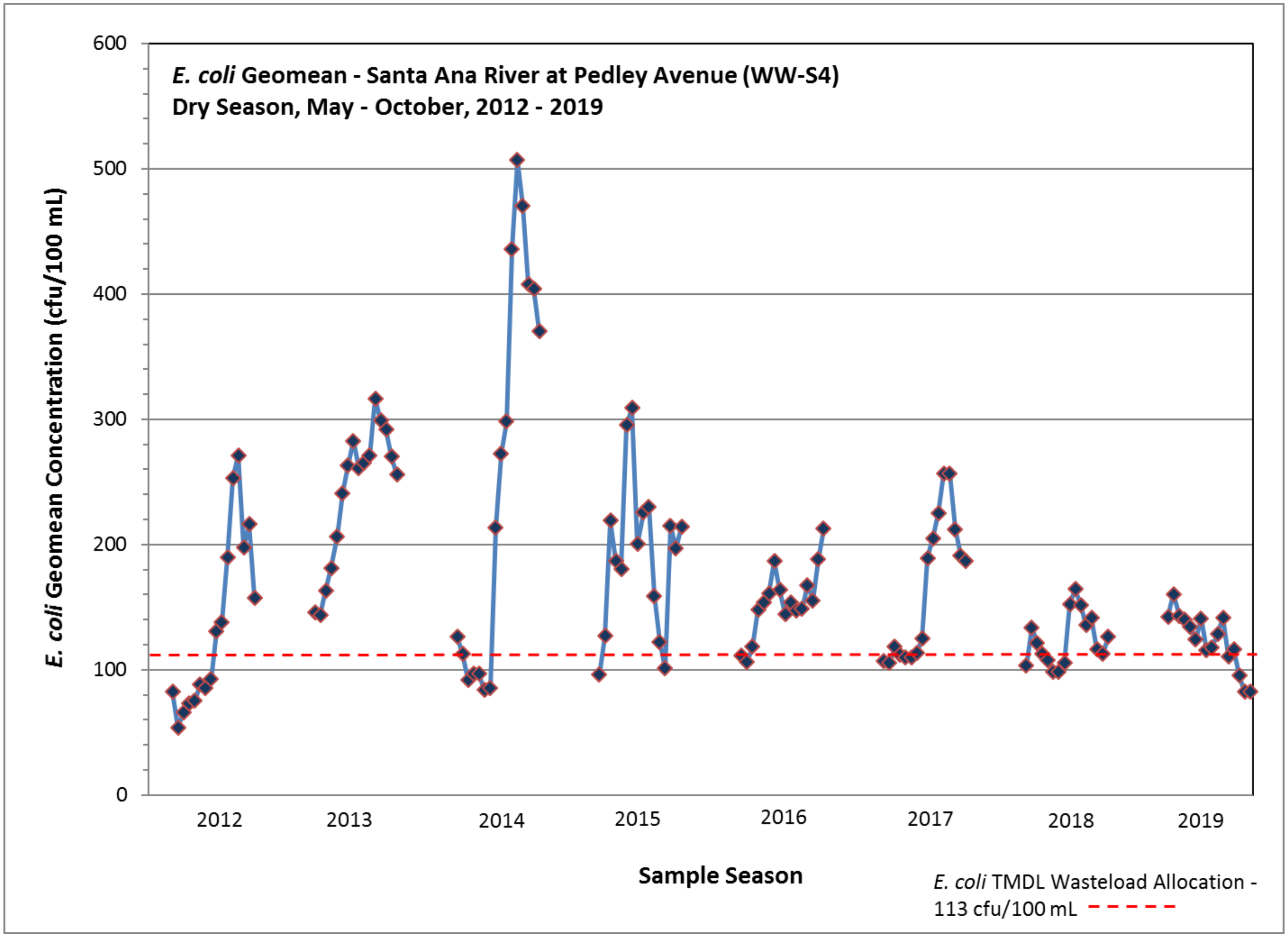

Figure 2-4. Time Series of *E. coli* Geomean Observations during the Dry Season (May to October) at the Santa Ana River at Pedley Avenue Watershed-wide Compliance Site (WW-S4), 2012 – 2019

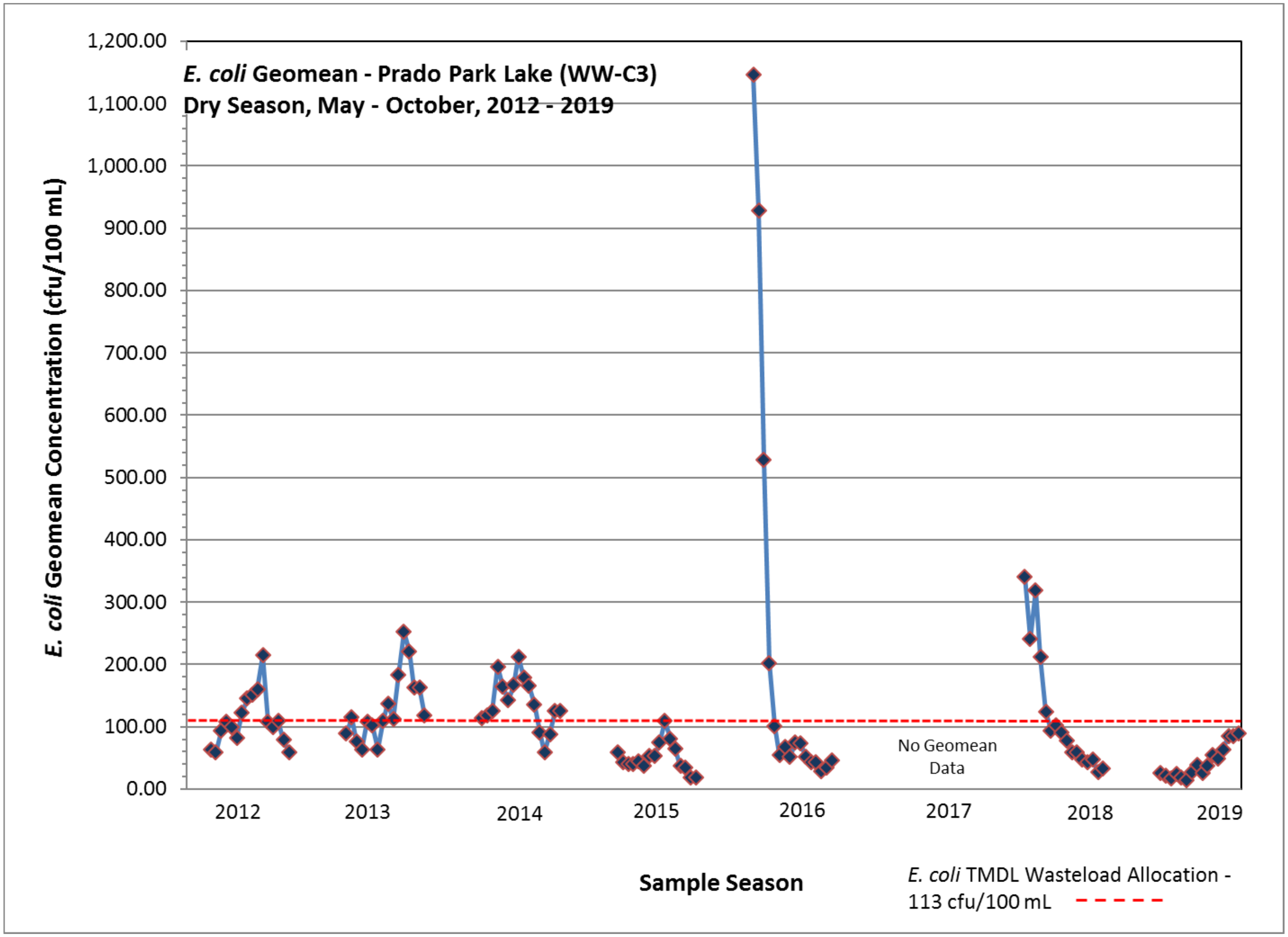

Figure 2-5. Time Series of *E. coli* Geomean Observations during the Dry Season (May to October) at the Prado Park Lake Outfall Watershed-wide Compliance Site (WW-C3), 2012 – 2019 (Note: Lake was drained in 2017 to facilitate replacement of pipeline under the lake)

To illustrate long term trends, **Figure 2-6** illustrates the dry season *E. coli* geomeans calculated for each site for each year from 2012 through 2019. Sites that show a general trend in reduced *E. coli* concentrations include Santa Ana River at Pedley Avenue (WW-S4) and Mill-Cucamonga Creek (WW-M6). Year-to-year results have been variable at Chino Creek at Central Avenue (WW-C3) and Santa Ana River at MWD Crossing (WW-S1). *E. coli* dry season geomean concentrations at Prado Park Lake have declined since a pipeline that carries stormwater under the lake was replaced in 2017 (lake was dry during construction activity; thus, no seasonal geomean is reported for 2017).

The RBMP annual reports prepared since 2017 may be found here: https://sawpa.org/task-forces/regional-water-quality-monitoring-task-force/#geographic-setting. Earlier monitoring reports may be obtained by contacting SAWPA.

2.1.2 TMDL Triennial Reports

The TMDL requires preparation of a Triennial Report every three years that assesses the data collected for the preceding three year period and evaluates progress towards achieving the WLAs and LAs in the MSAR TMDL. The three Triennial Reports prepared to date evaluate the findings from each of the following three-year periods of TMDL implementation: 2007-2009, 2010-2012 and 2013-2015. The selection of Tier 1 sites in the Synoptic Study considered the findings from these reports. In addition, where appropriate, the results from the Synoptic Study (DWF, bacteria loads and prioritization of Tier 1 sites) are compared to findings previously documented in these reports. The subsections below summarize each of the previously developed Triennial Reports.

2.1.2.1 2010 Triennial Report

This first Triennial Report (*Middle Santa Ana River Watershed Bacterial Indicator TMDL: Triennial Report*), which was submitted to the Santa Ana Water Board in 2010, provided a water quality and compliance assessment based on data collected from the 2007 effective date of the TMDL through 2009 (SAWPA 2010a). The report included findings from the first watershed-wide assessment conducted at multiple sites in the MSAR watershed (reported in SAWPA 2009, see Section 2.1.4.1) and wet weather findings from storm event sampling of agricultural runoff.

The complete report may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2010_Triennial-Report.pdf.

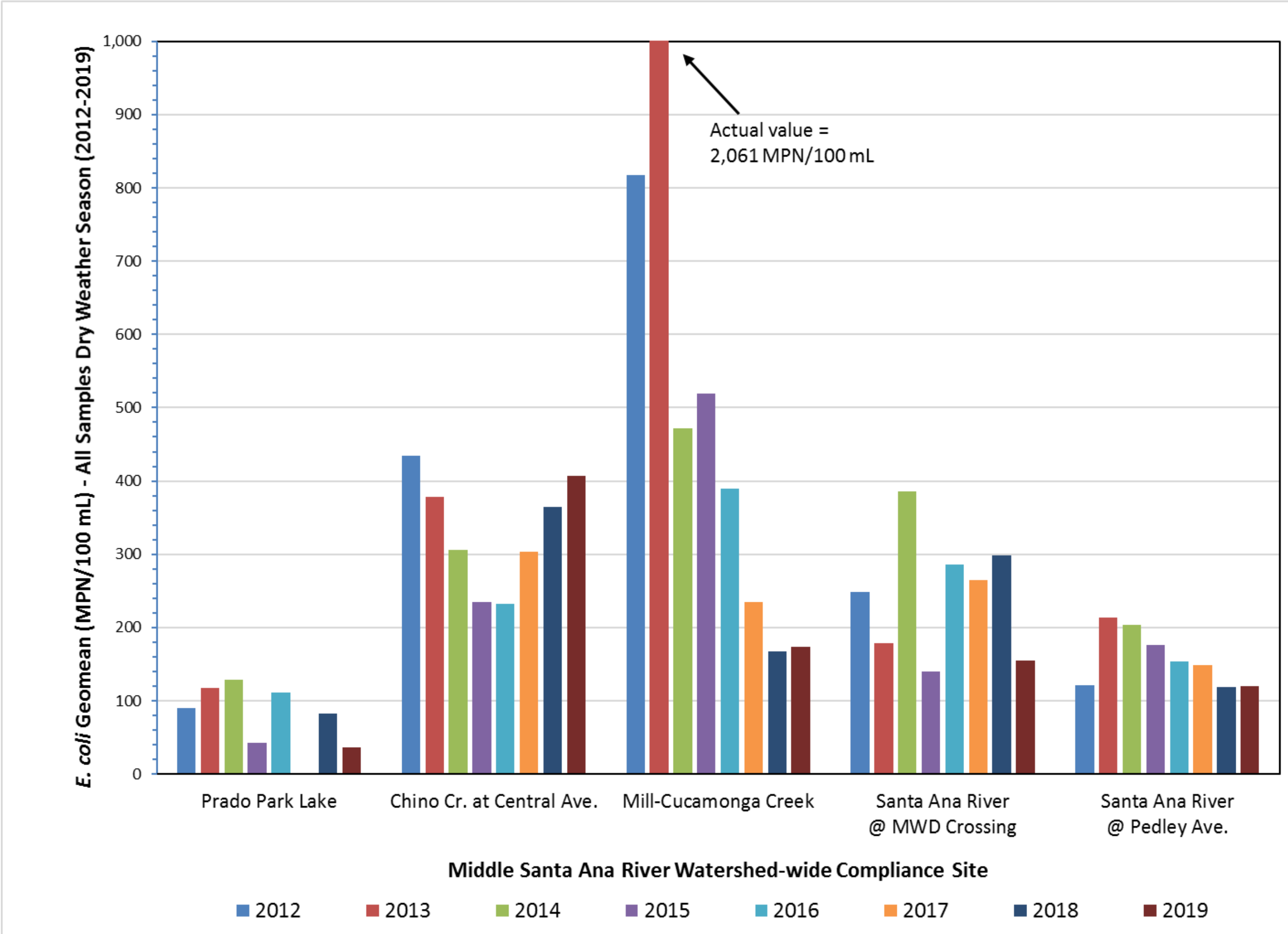

Figure 2-6. Dry Season (May to October) *E. coli* Geomean at Watershed-wide Compliance Sites, 2012 – 2019

2.1.2.2 2013 Triennial Report

The second Triennial Report (*Middle Santa Ana River Bacterial Indicator TMDL Implementation Report*) not only evaluated the status of compliance with urban WLAs as required by the TMDL but also provided the results from source evaluation studies conducted as part of the implementation of the Riverside and San Bernardino County MS4 program CBRPs (SAWPA 2013). Key findings from this 2013 report are described below.

Status of Compliance with Urban WLAs for Dry Weather

- Bacterial indicator concentrations and frequency of WLA exceedances remained generally constant at all watershed-wide compliance sites during the six years sampling had occurred to date. No stations reported a marked increase or decrease in concentration from 2007 to 2012.
- During each year of dry season sampling, the highest bacterial indicator concentrations were observed at the Mill-Cucamonga Creek and Chino Creek sites.
- With the exception of 2009, for the period from 2007 through 2012 Prado Park Lake generally remained below the *E. coli* WLA (on an annual basis) during the dry season.
- Analyses of bacterial indicator data suggested that natural or uncontrollable sources[4] of bacterial indicators may be important contributors to bacterial indicator concentrations at the watershed-wide compliance sites.
- Seasonal increases in bacterial indicators were regularly observed at the watershed-wide compliance monitoring sites. Understanding the cause of these increases may provide information regarding controllable and uncontrollable sources of bacterial indicators in the watershed.

Tier 1 Source Evaluation Data Analysis Activities

- DWF rates from MS4 outfalls were low in most places where there were no known sources of rising groundwater.
- Bacterial water quality observed in DWFs from MS4 outfalls was highly variable across the MSAR watershed.
- *E. coli* concentrations in samples that also had a detection of the *Bacteroides* human marker were higher than in samples with no *Bacteroides* human marker detection.
- Data results provided the basis for prioritizing MS4 subwatersheds for subsequent CBRP compliance activities within the MSAR watershed.
- In some weeks, a close correlation existed between the estimated *E. coli* concentration expected from blended MS4 outfall flows, and POTW discharges. However, in a number

[4] The Basin Plan defines "uncontrollable sources" as: wildlife activity and waste; bacterial regrowth within sediment or biofilm; resuspension from disturbed sediment; concentrations (flocks) of semi-wild waterfowl; shedding during swimming (Santa Ana Water Board 2016).

of cases, the observed *E. coli* concentrations were substantially higher than expected suggesting that additional sources of *E. coli* had not yet been accounted for.

- Data analysis identified the key MS4 outfalls within each impaired waterbody (based on DWFs and *E. coli* concentrations) where subsequent source evaluation work could provide the most benefit with regards to meeting bacterial indicator water quality objectives at watershed-wide compliance sites.

The complete report may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2013-Triennial-Report_Tier-1-Source-Evaluation-Final.pdf.

2.1.2.3 2016 Triennial Report

The third Triennial Report (*Middle Santa Ana River Bacterial Indicator TMDL Implementation Final Report*) provided an update on the status of compliance with the TMDL and also summarized findings from other studies completed in the watershed (SAWPA 2017). Below is a summary of the findings from that report:

- The Permittees fulfilled the requirements established in the four base CBRP elements through: (1) revision and enforcement of city water conservation and stormwater ordinances; (2) deployment of a range of water quality best management practices (BMPs) to reduce DWF (e.g., through implementation of water conservation BMPs) or control sources of fecal bacteria within the MSAR watershed; (3) implementation of a source evaluation program and set of supplementary studies; and (4) completion of regional BMPs to provide additional treatment of DWFs.

- Prado Park Lake had bacteria concentrations that were consistently close to water quality objectives. In the 2015 dry season a significant reduction was observed (geometric mean of *E. coli* of 40 cfu/100 mL; see Figures 2-5 and 2-6), which might have been attributable to a revision in the way IEUA delivers treated effluent to the lake. Thus, there is reason to believe lower bacteria levels may continue in the future, which would support delisting this waterbody and removing it from the TMDL in the future.

- Updates to the source contribution analysis for MS4 and POTW inputs to each of the impaired waters showed that the expected bacteria concentration at four of five of the watershed-wide compliance monitoring sites was below water quality objectives (only Mill-Cucamonga had estimated MS4+POTW blend concentrations over the water quality objective). However, monitoring data showed that exceedances of the water quality objectives continued to occur at varying frequencies at all of the sites.

- Since the TMDL was adopted, there has been a continuous decline in POTW effluent discharges to each of the impaired waterbodies caused by indoor water conservation measures and increasing reuse of wastewater, such as in the IEUA service area. Per the source contribution analysis, this would naturally result in an increase in the estimated flow-weighted average concentration that may be expected at the downstream compliance monitoring sites. No such rise in fecal bacteria has been observed at any of the watershed-wide compliance monitoring sites.

The complete report may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2016_Triennial-Report-June-2017.pdf.

2.1.3 Special Studies

The Task Force or MS4 Permittees have implemented a number of special studies since 2007. The findings from these studies and their relevance to this Synoptic Study are described below.

2.1.3.1 MSAR Bacterial Indicator TMDL Data Analysis Report

The first comprehensive analysis of bacterial indicators, bacteria sources and DWF in the MS4 within the MSAR watershed was conducted in 2007-2008. The findings are provided in the MSAR Bacterial Indicator TMDL Data Analysis Report (SAWPA 2009). Sample locations included both the watershed-wide compliance sites and a number of Tier 1 sites. Where possible in Section 3, the results from the Synoptic Study (DWF, bacteria loads and prioritization of Tier 1 sites) are compared to the 2007 data results provided in this report.

The complete report may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2009_Final-Data-Analysis-Report_033109.pdf.

2.1.3.2 Urban Source Evaluation Studies

The findings from the 2009 MSAR Bacterial Indicator TMDL Data Analysis Report (SAWPA 2009) identified priorities for additional mostly site-specific studies to evaluate urban sources of bacterial indicators. Findings from these early Task Force studies, which are documented in the following series of technical memoranda, informed the selection of sites for the Synoptic Study:

- *Final Technical Memorandum – Dry Weather Runoff Controllability Assessment for Lower Deer Creek Subwatershed (Chris Basin) Special Study* (SAWPA 2010b): Data collected in 2007 and 2008 resulted in the Lower Deer Creek subwatershed in the Cucamonga Creek watershed receiving a high priority ranking for subsequent bacteria mitigation work. This controllability assessment evaluated two potential options to control dry weather runoff from Chris Basin before it was discharged into mainstem Cucamonga Creek.

  The complete Technical Memorandum may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2010_Chris-Basin-Final-TM.pdf.

- *Final Technical Memorandum – Source Evaluation Activities in Carbon Canyon Creek and Cypress Channel* (SAWPA 2010c): Data collected in 2007 and 2008 resulted in a high priority ranking for Cypress Channel for subsequent source evaluation activities. A study was initiated to identify potential sources of bacteria.[5] Carbon Canyon Creek received a very low priority ranking because of low bacteria concentrations as compared to other subwatersheds. Of interest to the Task Force was evaluating the subwatershed to identify potential site-specific characteristics which could be factors contributing to reduced bacterial concentrations.

The Technical Memorandum summarized the source evaluation findings for Cypress Channel and provided recommendations for follow-up actions for both MS4 Permittees and Santa Ana Water Board staff. The evaluation of Carbon Canyon Creek identified the presence of flow dissipation structures in the segment upstream of the Tier 1 sample location. These structures greatly reduce flow rates. It was hypothesized that these structures provide increased opportunity for natural reduction of bacteria via filtering processes through the structures and increased exposure to sunlight. It was concluded that the flow dissipation structures could be a potential BMP for use in other channels, where structurally appropriate.

The complete Technical Memorandum may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2010_Cypress_CarbonCyn_TM.pdf.

- *Final Submittal - Source Evaluation Project Activities for Middle Santa Ana River, TMDL Program Support, 2010-2011* (SAWPA 2011): The Task Force identified five source evaluation activities for implementation in 2010-2011. The findings from these five activities were summarized in a series of Technical Memoranda:
  - *Box Springs Channel Follow-up Study* - The Box Springs Channel (T1-BXSP) site was originally sampled in 2007- 2008. During that sample period, human source bacteria were regularly detected and high bacterial indicator concentrations were present. Following a local investigation in 2008, a sanitary/storm sewer cross connection was identified and corrected. The purpose of this study was to conduct follow-up sampling to evaluate current bacterial indicator levels and verify that human source bacteria were no longer present. The follow-up study confirmed human source bacteria were no longer present.
  - *Preliminary Characterization of Bacteria Loading from MS4 in Pomona and Claremont* –The purpose of this task was to gather dry weather condition bacterial indicator data during the dry season to provide a preliminary characterization of potential bacteria loading and presence/absence of human sources of bacteria from the portion of the MSAR watershed located within the jurisdictions of the Cities of Pomona and Claremont (this portion of the MSAR watershed was not included in the original 2007-2008 data collection activity, as reported in SAWPA 2009).
  - *Survey of Dry Weather Flows from MS4 Outfalls to Major Tributaries* - The purpose of this source evaluation study was to gain additional information regarding the

[5] This type of study was later referred to as a Tier 2 study in the CBRPs, which were developed at a later date (see Section 1.1.2 above for discussion of the CBRPs)

variability of DWFs in stormwater channels/outfalls in the MSAR watershed. The information gained from this effort, combined with other available DWF data, supported characterizations of typical DWFs in the area and facilitated compliance analyses to provide input to the development of the CBRPs.

- *Calculate Mass Balance for Dry Weather Conditions* – The purpose of this activity was to quantify, to the extent possible, the mass balance of bacterial indicators under dry weather conditions based on known dry weather hydrology, source of flow, and available bacteria concentration data. The resulting mass balance characterizations supported development of the compliance analysis contained within the CBRPs.
- *Calculate Site-specific Log Standard Deviation at Monitoring Sites* – The USEPA uses a default log standard deviation (LSD) of 0.4 for *E. coli* when calculating single sample maximum criteria. A site-specific LSD may be substituted for the default value where such data exist, which would result in different single sample maximum criteria. The potential to use site-specific LSDs to establish site-specific single sample criteria had been incorporated into the Basin Plan amendment under development by the Stormwater Quality Standards Task Force at that time. The purpose of this task was to calculate LSD values for MSAR watershed sample sites.

The five completed Technical Memoranda may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2011_Source-Evaluation-Project-Activities.pdf.

2.1.3.3 Tier 2 Source Evaluation Assessment

Based on the Tier 1 prioritization analysis developed as part of the second Triennial Report (see Section 2.1.2.2 above), the MS4 Permittees in Riverside and San Bernardino Counties implemented Tier 2 source evaluations within the drainage areas of the highest priority Tier 1 sites. These evaluations focused on identifying sources of bacteria within the stormwater networks of the MS4 facilities draining to these Tier 1 sites. The findings, provided in SAWPA (2014), have facilitated efforts within each MS4 Program to implement projects to manage sources of DWF and bacteria within the MS4.

The complete report may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2014_Tier-2-_2013-Evaluation_Final.pdf.

2.1.3.4 Uncontrollable Bacteria Sources Study

Implemented by the Riverside County MS4 Program, the Uncontrollable Bacteria Sources Study, evaluated the potential importance of various non-MS4 sources of bacteria in the MSAR watershed (RCFC&WCD 2016). By process of elimination, the study's findings suggested that the majority of *E. coli* in the impaired waters may be from releases from naturalized colonies in channel bottom sediment and biofilms. Fecal bacteria from a specific host released to the environment can settle to the channel bottom and survive within sediments or biofilms for weeks or months over a wide range of temperature and moisture conditions. Growth of these initially deposited fecal bacteria within channel bottom sediments and biofilms results in colonies, where the majority of the population may be considered naturalized, reproducing outside of a specific organism. The Basin Plan categorizes bacteria regrowth within sediment and biofilm as an uncontrollable source of fecal bacteria (Santa Ana Water Board 2016). The report concluded that additional study would be necessary to better understand the potential for naturalized bacteria colonies to contribute to bacteria concentrations in overlying waters and the transport process by which bacteria is released. This findings from this study were considered in this Synoptic Study as part the analysis of non-MS4 sources of bacteria.

The complete report may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2016_Uncontrollable-Bacteria-Sources-Final-Report.pdf.

2.1.3.5 Residential Property Scale Bacteria Study

Implemented by the San Bernardino County MS4 Program, the Residential Property Scale Bacteria Water Quality Study was able to demonstrate support for the hypothesis that extreme variability in concentrations at MS4 outfalls is linked to the quantity and quality of irrigation excess runoff from individual properties (CDM Smith 2015). Unlike rainfall driven runoff, where rain is spread across the entire watershed, the primary source of DWF in an urban catchment at any given point in time is outdoor water use by a single or small group of properties. The statistically randomized study found that irrigation excess from a majority of properties (*n=80*) would be expected to meet WLAs in the TMDL. The reason for very high bacteria concentrations at some sites may be partially due to the sampling method, whereby samples collected from a wetted street gutter had significantly greater bacteria concentrations than those collected from the edge of the lawn.

The complete report may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/2015_Residential-Property-Scale-Bacteria-Study-Interim-Data-Analysis.pdf.

2.1.3.6 Cucamonga Creek Data Collection

The San Bernardino County MS4 Program collected DWF and bacteria data from a number of locations in the Cucamonga Creek watershed in 2016, 2017 and 2018 (SBCFCD 2016, 2017 and 2018). These data provided information to support the findings from Synoptic Study data collected at the T1-CUCAMONGA Tier 1 site.

2.1.3.7 Arlington Study

The Task Force conducted a preliminary bacteria and flow source investigation in the Arlington Area of Riverside County in 2017 (SAWPA 2018). The investigation sought to answer the following study questions: (a) What is the status of DWF leaving the Monroe Retention Basin; (b) What are the predominant sources of DWF in the Arlington Area; (c)

What are the magnitude and sources of *E. coli* in observed DWF; and (d) Are the observed *E. coli* from human sources?

This study confirmed that DWF from the MS4 is continuous both into and out of the Monroe Retention Basin, which is hydrologically connected to the Anza Drain Tier 1 Site. This study also confirmed that grove irrigation from agricultural land uses is contributing flow and bacteria to the MS4 in the Arlington Area, though grove irrigation is not the sole contributor. Controlling or reducing flows both in upstream agricultural land uses and downstream urban land uses would help reduce bacteria loads to/from the Monroe Retention Basin. Human source marker HF183 was quantifiable in only two of 21 samples analyzed. Human source bacteria were not detected in DWFs originating from agriculture land uses. The two samples where the human source marker was quantifiable were from mixed land use monitoring locations. Where detected, the concentrations were low and not persistent.

The complete report may be reviewed here: https://www.sawpa.org/wp-content/uploads/2018/04/FinalDeliverable_2018.pdf.

2.1.3.8 City of Claremont Tier 2 Field Study

The City of Claremont has the potential to contribute DWF to the Chino Creek subwatershed from only a very small area. This area, 397 acres, can potentially contribute DWF via an underground storm drain which is connected to the City of Pomona's MS4 (City of Claremont 2017). This underground storm drain eventually discharges to San Antonio Creek about two miles upstream of its confluence with Chino Creek (four miles upstream of the Chino Creek at Central Avenue watershed-wide compliance site (WW-C7)). The remainder of DWFs from the City of Claremont is captured in retention basins.

The City of Claremont conducted a Tier 2 study in 2013 to characterize DWFs that have the potential to leave the City and enter the City of Pomona MS4 (City of Claremont 2017). Field surveys were conducted for eight weeks in the summer of 2013. No flow was recorded on six of eight site visits; in the other two visits, the estimated flow averaged less than 0.0018 cubic feet/second (cfs; ≈ 0.8 gallons/minute). Based on these DWF results, the total dry weather discharge found to emanate from the City is less than 2.8 gallons per acre per day (gal/ac/day). Based on these findings, it was determined that "*dry weather flow from the City of Claremont is minimal and does not influence downstream concentrations*" and per the City's CBRP, "*targeted E. coli reduction needed from the City of Claremont MS4 contribution was estimated to be negligible.*"

The City of Claremont (2017) also reported reductions in DWF from ongoing coordination with the Golden State Water Company to improve outdoor water use efficiency (consistent with CBRP requirements to implement water conservation practices) and reduce DWF from areas that may potentially drain to Chino Creek. These efforts have been successful. Long-term monitoring data showed that the median annual flow measured by the United States Geological Survey (USGS) gauge in San Antonio Creek (#11073300) had declined by 75%

over the last 15 years - from 0.75 cfs in 2002 to less than 0.2 cfs in 2016-17 (City of Claremont 2017). The City of Claremont contributes less than one-half of 1% of the total DWF measured at this stream gauge.

2.1.3.9 Magnolia Street Center Drain Data Collection

As part of its core MS4 monitoring program, RCFC&WCD has collected water quality samples from the Magnolia Center Storm Drain (T1-MCSD) outfall since 2005 (RCFC&WCD 2019). **Figure 2-7** provides a historical plot of *E. coli* concentrations from dry weather core MS4 Program samples (filled diamonds) along with samples (white circles) collected from the same location as part of the 2012 Tier 1 source evaluation study (SAWPA 2013). *E. coli* exceeded 1,000 Most Probable Number (MPN)/100 mL at this site in all 17 samples collected in the past five years since the 2014 dry season. Prior to 2014, a greater range in *E. coli* concentration was observed including 17 of 34 samples below the single threshold value established by the new statewide bacteria provisions (320 MPN/100 mL) (State Water Board Resolution No. 2018-0038).

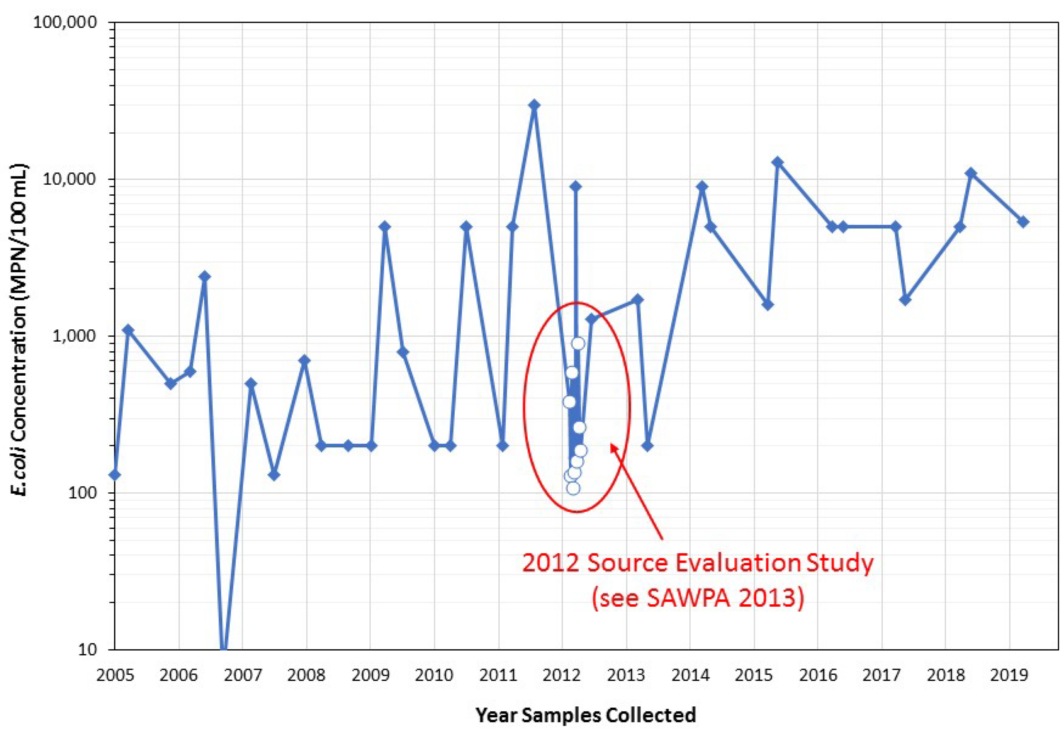

Figure 2-7. Historical *E. coli* Data Record at Magnolia Center Storm Drain (T1-MCSD) (MS4 Program Core Samples = Blue-filled Diamonds; 2012 Source Evaluation Study Samples reported in SAWPA 2013– Open Circles)

2.2 Other Watershed Sources

As part of the Synoptic Study other sources of relevant bacterial indicator or DWF data were identified. Following is a summary of data sources considered as part of evaluation of findings from this study:

2.2.1 California State University Fullerton Santa Ana River Study

California State University, Fullerton, conducted a study to characterize water quality issues in Santa Ana River Reach 3 as part of an effort to evaluate concerns of people in homeless encampments along the river being exposed to poor water quality. Specifically, the study evaluated the relationship between areas with high human activity and water quality using MST through quantitative real-time polymerase chain reaction (qPCR) analysis of samples for host-specific indicators of human and animal interaction. Per the study's executive summary, "*While human activities were implicated as a potential source of fecal contamination in the Santa Ana River, [the study was] unable to differentiate among the diverse human-related activities occurring in the Santa Ana River such as wastewater effluent discharges, recreational uses, and/or homeless populations.*" (Gedalanga et al. 2019). The findings from this work were considered in the interpretation of the Synoptic Studies HF183 *Bacteroides* findings.

2.2.2 Santa Ana River Reach 3 Bacteria Source Tracking Study

University of California, Irvine conducted a quantitative sanitary survey of the MSAR utilizing a variety of bacteria source tracking tools, including the human fecal marker HF183 *Bacteroides* (Litton et al. 2010). The findings from this work were considered in the interpretation of the Synoptic Study HF183 *Bacteroides* findings.

2.2.3 Inland Empire Waterkeeper

The Inland Empire Waterkeeper (IEWK) has been collecting water quality data from Santa Ana River Reach 3 for a number of years. IEWK provided *E. coli* data results collected at three locations (Martha McLean Park, Van Buren Bridge, and Santa Ana River Regional Park at 64th and Downey Street) for the period from March 2014 to April 2019. These findings were considered during development of this Synoptic Study Report.

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3. Synoptic Study Findings

This section provides the findings from the 2019 Synoptic Study as they relate to the objectives of the study. The findings are based on data collected during the 2019 six-week sample period and other studies that have been conducted in the watershed, as summarized in Section 2. Findings are presented in the following three sections:

- *Section 3.1: Characterization of Dry Weather Flow and* E. coli *in the MSAR Watershed* – This section reports on current findings and provides a comparison between 2019 study findings and previous analyses based on 2007 and 2012 data. In addition, this section updates previous *E. coli* loading analyses on a subwatershed basis and evaluates sources of bacteria, including both MS4 and non-MS4 sources.
- *Section 3.2: Bacteroides Analyses* – This section summarizes the findings from the analysis of all samples for the human marker HF183.
- *Section 3.3: Tier 1 Prioritization Analysis* – Based on the findings in Sections 3.1 and 3.2, this section provides the outcome of the prioritization of Tier 1 MS4 outfalls for additional work to mitigate controllable sources of *E. coli*. The resulting prioritization updates previous prioritization analyses completed for the MSAR watershed.

3.1 Characterization of Dry Weather Flow and *E. coli* in the MSAR Watershed

3.1.1 Dry Weather Flow Characterization

3.1.1.1 Sources of Flow

The primary source of DWF in impaired waters in the MSAR watershed is treated effluent from five POTWs (see Table 1-2). This regular DWF is supplemented by numerous other non-POTW sources, including:

- Turnouts of imported water by the Metropolitan Water District (MW District);
- Well blow-offs;
- Water transfers;
- Inputs from rising groundwater;
- Urban water waste from excess irrigation and other outdoor water uses;
- Other authorized discharges (as defined by the MS4 or Santa Ana Region General Waste Discharge Requirements (WDR) for de minimis discharges (R8-2015-0004); and
- Non-permitted, prohibited discharges.

Each of these non-POTW sources of flow in the watershed has the potential to transport bacteria to or within an impaired waterbody. Thus, it is important to understand the relative role of each of these categories of DWF.[6] Additionally, some sources of bacteria are not transported to receiving waters through DWF, e.g., fecal deposition from wildlife, re-suspension of bacteria in channel bottom sediments, shedding from swimmers, or activities around transient encampments.

The 2019 Synoptic Study focused sample collection only on waterbodies that are known to contribute DWF to the impaired waters – a total of 14 sites. Areas that do not contribute DWF were excluded from the study; these sites were identified based on findings from previous studies in the watershed (e.g., SAWPA 2009, 2013) and knowledge gained by MS4 Permittees over time.

3.1.1.2 Hydrological Disconnection in the MSAR Watershed

The MSAR watershed covers approximately 477,000 acres, including the Temescal Creek watershed (which is not listed as impaired for bacterial indicators). **Table 3-1** summarizes how this acreage is categorized by jurisdiction. **Figure 3-1** illustrates the categorization of the drainage areas upstream of Synoptic Study Tier 1 sites, including the portions of the watershed that are either hydrologically disconnected or contribute only minimal flow to an impaired waterbody during dry weather conditions.

The extent of hydrologically disconnected areas has been refined over time through the implementation of source evaluation studies. For example, in 2012 DWFs were evaluated at a total of 30 Tier 1 sites. In 2019, the number of Tier 1 outfalls with DWF was reduced to 14.[7] The combined drainage area of these 14 sites that contribute urban DWF to an impaired downstream waterbody is approximately 78,000 acres (or about 16% of the MSAR watershed). The DWFs at these Tier 1 sites comprise over 99% of all DWF from urban sources in the MSAR watershed. This contributing drainage area includes a mix of urban and agricultural land uses, intersects multiple jurisdictions, and experience different non-MS4 discharges during dry weather. The remaining 84% of the MSAR watershed includes drainage areas described as follows (see Figure 3-1):

[6] Note: To date there has been no study conducted to estimate the relative roles of different types or sources of DWF in the MSAR watershed. Generally, it has been assumed that the majority of day to day DWF reaching a Tier 1 site is from excess irrigation runoff. However, spikes in DWF (e.g., from well blow offs, water transfers or unauthorized discharges) do occur periodically. Determining the relative role of these various sources of DWF at any given Tier 1 site and their potential impact on *E. coli* loading would likely require implementation of a short-term intensive site-specific study.

[7] Some of the change in number of Tier 1 sites between 2012 and 2019 is attributable to the removal of the REC1 beneficial use from Cucamonga Reach 1 (see Section 3.1.1.4)

Table 3-1. Categorized Acreage in Each Jurisdiction within the MSAR Watershed

Jurisdiction	Measured DWF	Other Areas with Minimal Infrastructure	Temescal Watershed	Hydrologically Disconnected	Prado Park Lake Watershed	Grand Total
San Bernardino County						
Chino	4,266	12,492	--	--	2,279	19,038
Chino Hills	6,498	7,026	--	--	--	13,524
Colton	--	--	--	5,154	--	5,154
Fontana	939	--	--	26,602	--	27,541
Montclair	740	--	--	2,817	--	3,557
Ontario	15,830	244	--	12,095	3,785	31,954
Rancho Cucamonga	--	--	--	25,676	--	25,676
Rialto	--	--	--	11,752	--	11,752
San Bernardino	--	--	--	819	--	819
San Bernardino County	1,657	473	--	48,775	--	50,905
Upland	--	--	--	10,035	--	10,035
Riverside County						
Corona	--	1,154	21,616	--	--	22,770
Eastvale	2,652	4,812	--	961	--	8,426
Jurupa Valley	10,198	4,296	--	13,446	--	27,940
Lake Elsinore	--	--	12,618	--	--	12,618
Moreno Valley	--	--	--	2,034	--	2,034
Norco	--	6,587	2,362	--	--	8,948
Riverside	24,935	3,438	12,028	11,194	--	51,595
Riverside County	4,263	4,131	85,155	31,428	--	124,977

Table 3-1. Categorized Acreage in Each Jurisdiction within the MSAR Watershed

Jurisdiction	Measured DWF	Other Areas with Minimal Infrastructure	Temescal Watershed	Hydrologically Disconnected	Prado Park Lake Watershed	Grand Total
Los Angeles County						
Claremont	--	--	--	2,958	--	2,958
Pomona	6,290	--	--	498	--	6,789
Los Angeles County	47	--	--	5,938	--	5,938
Orange County						
Orange County	--	--	1,413	--	--	1,413
Grand Total	**78,269**	**44,652**	**135,192**	**214,188**	**6,064**	**478,364**

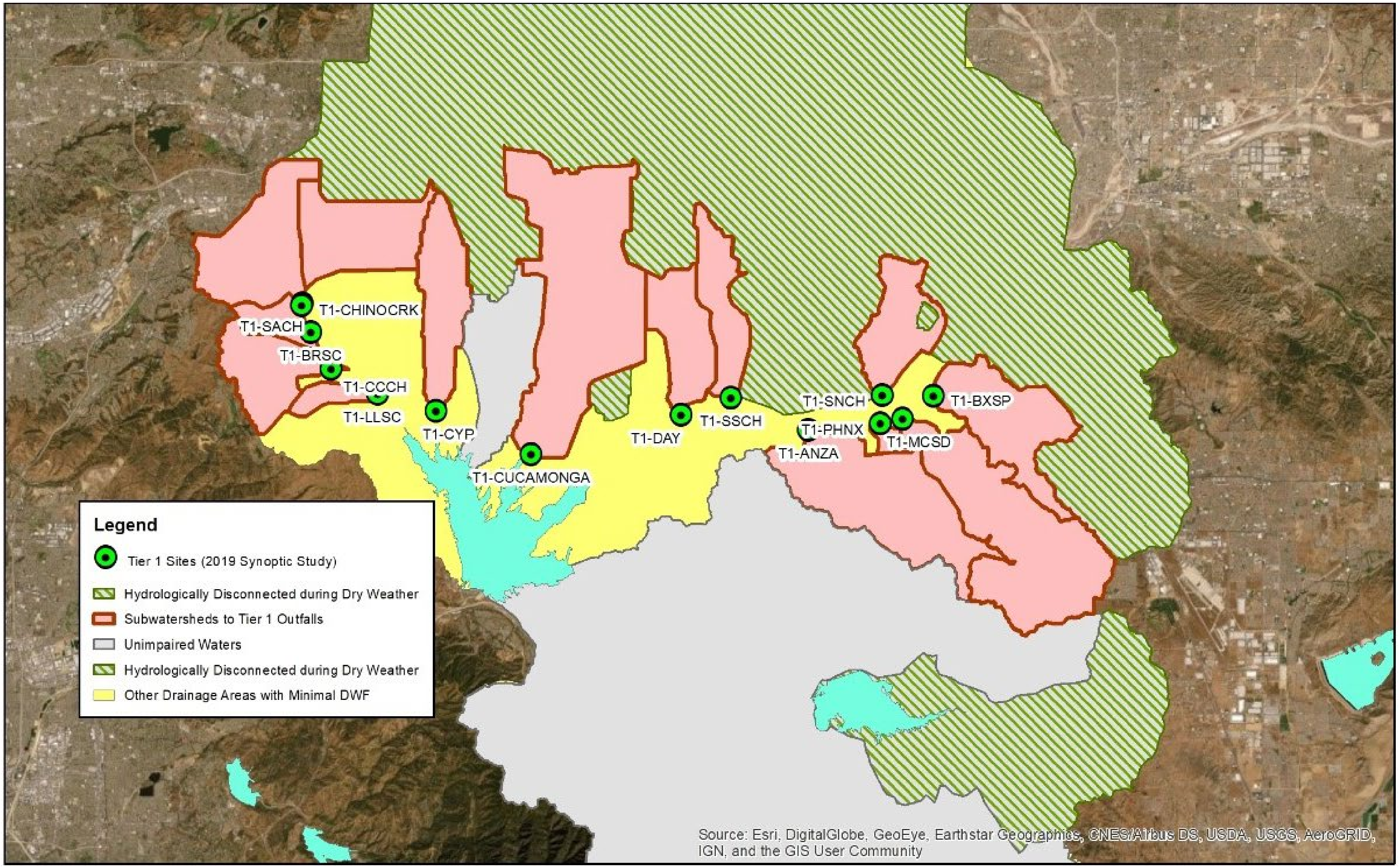

Figure 3-1. Map of Tier 1 Subwatersheds and Hydrologically Disconnected Drainage Areas during Dry Weather

- Hydrologically disconnected during dry weather conditions (45%);
- Not tributary to an impaired waterbody (e.g., Temescal Creek) (28%); and
- Limited drainage infrastructure or evidence of DWF connectivity (10%). These areas include riparian zones where no MS4 infrastructure is present and the agricultural area in the Chino basin (e.g., around Prado Lake).

3.1.1.3 Dry Weather Flow – 2007 to 2019

Table 3-2 shows that the DWF rate (cfs) at each of the Tier 1 sites has declined since 2007 (see Table B-1 for DWFs observed at Tier 1 sites during the current study). **Figure 3-2** shows that when Tier 1 sites are aggregated by the nearest downstream compliance site, the reductions achieved exceed the targeted DWF reduction needed to comply with WLAs for MS4s reported in Table 3-4 of the CBRPs for Riverside County (RCFC&WCD 2011) and San Bernardino County (SBCFCD 2011) (**Table 3-3**).[8] The observed decline in DWF at the Tier 1 MS4 outfalls is the result of better water management/conservation and coordination between water purveyor and stormwater agencies.

POTW effluent comprises the majority of total flow in the impaired waters and must be accounted for in the source contribution analysis. In recent years, POTW effluent discharge rates to Chino Creek, Cucamonga Creek, and the Santa Ana River have declined as a result of increased recycling of POTW effluent to serve reuse projects. **Figure 3-3** shows long-term decreasing trends of dry season POTW effluent discharge (cfs) at the five discharge locations upstream of the TMDL compliance monitoring locations (see also Table 3-1).

Other de minimis discharges to MS4s occur in the MSAR watershed upstream of Tier 1 sites (see above for examples of de minimis discharges types), but these are intermittent and not reported at the daily or sub-daily timesteps needed to accommodate inclusion in the source contribution analysis. Examples of these discharges occurred during the Synoptic Study:

- *Hole Lake* – On August 27 a significant increase in flow was observed at T2-HOLE. During that event, flow was measured at 7.29 cfs. During all other sample events flows ranged from 0.98 to 1.6 cfs (see Table B-1). The source of this discharge is unknown.
- San Antonio Channel – During the final week of the study (week of September 3) a valve to capture recycled water for groundwater recharge in the San Antonio Channel functioned improperly resulting in increased flow at Tier 1 site T1-SACH. On that sample date flow was measured as 3.24 cfs. On all other five sample dates, flow ranged from 0.008 to 0.018 cfs (see Table B-1).

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[8] Compliance analysis for the CBRP did not include DWF from the newly developed areas tributary to Eastvale Lines A and B. DWF was measured from these outfalls in 2012. At that time, flow from these MS4 outfalls accounted for ~50 percent of the total MS4 inflow to Cucamonga Creek. These outfalls were not revisited in the 2016-2018 SBCFCD surveys, nor were they included in the 2019 Synoptic Study. This is because Eastvale Lines A & B were reclassified from Tier 1 to Tier 2 sites following the removal of REC1 from Cucamonga Creek Reach 1 (also see discussion in Section 3.1.4.4) . To assess DWF reductions that have occurred in Cucamonga Creek, it will be necessary to complete a Tier 2 study in this subwatershed.

Table 3-2. Comparison of Average DFW Measurements at Tier 1 Sites for 2007, 2012 and 2019

Compliance Site	Tier 1 Site	Average MS4 Dry Weather Flow (cfs)		
		2007	2012	2019
Chino Creek at Central Avenue (WW-C7)	T1- CHINOCRK - Chino Creek Upstream of San Antonio Channel	Not Measured	1.70	0.53
	T1- BRSC - Boys Republic South Channel	Not Measured	0.44	0.13
	T1-CCCH - Carbon Canyon Creek	6.5	4.52	0.46
	T1-SACH - San Antonio Channel[1]	0.7	0.01	0.01
	T1-LLSC – Lake Los Serranos Channel	Not Measured	0.02	0.00
	OTHER (2007 estimate)[2]	1.7	N/A	N/A
	Subtotal (WW-C7)	**9.1**	**6.69**	**1.13**
Santa Ana River at MWD Crossing (WW-S1)	T1-MCSD – Magnolia Center Storm Drain	No Hydro Connection	0.91	0.33
	T1-SNCH – Sunnyslope Channel	2.0	2.42	0.39
	T1-BXSP – Box Springs Channel	1.8	1.19	0.13
	T1-PHNX – Phoenix Storm Drain	No Hydro Connection	0.01	0.01
	OTHER (2007 estimate)[2]	0.9	N/A	N/A
	Subtotal (WW-S1)	**4.7**	**4.53**	**0.86**
Santa Ana River at Pedley Avenue (WW-S4)	T1-ANZA – Anza Drain	2.6	3.29	1.35
	T1-SSCH – San Sevaine Channel	1.3	0.50	0.36
	T1-DAY – Day Creek	0.5	0.22	0.19
	OTHER (2007 estimate)[2]	1.0	N/A	N/A
	Subtotal (WW-S4)	**6.0**	**4.01**	**1.90**
Other Sites	T1-CYP – Cypress Channel	Not Measured	0.002	Dry
	T1-CUCAMONGA – Cucamonga Creek at Hellman Avenue[3]	3.8	1.4	2.2
	Total DWF Flow	**--**	**16.63**	**6.09**

[1] Values from the September 3, 2019 sampling event were excluded from the average because an upstream valve to capture recycled water for groundwater recharge was not functioning properly on this date.

[2] 2007 estimate for unmonitored areas was based on an assumed DWF rate of 100 gallons/acre/day.

[3] Flow measurements were not collected at this Tier 1 site in 2012 or 2019. Values shown represent the sum of flows measured at MS4 outfalls to Cucamonga Creek in 2012 Tier 1 source evaluation (SAWPA 2013) and from 10-week sampling program in 2016-2018 (SBCFCD 2016, 2017, and 2018).

Table 3-3. CBRP Estimate of Required DWF Reduction Compared to Observed DWF Reduction Since 2012 (see RCFC&WCD 2011; SBCFCD 2011)

MSAR Watershed Compliance Site	CBRP – Estimated DWF Reduction to Comply with WLAs	Actual DWF Reduction Since 2007 Analysis (cfs)
Santa Ana River at MWD Crossing (WW-S1)	305,000 gal/day / 0.47 cfs	3.84
Santa Ana River at Pedley Avenue (WW-S4)	206,000 gal/day / 0.32 cfs	4.1
Mill-Cucamonga Creek (WW-M6)[1]	1,481,465 gal/day / 2.29 cfs	2.4
Chino Creek (WW-C7)	767,082 gal/day / 1.19 cfs	7.97

[1] Data shown do not include DWF at outfalls from Eastvale Lines A and B. The drainage areas to these outfalls was undeveloped in 2007 and therefore was not accounted for in the CBRP compliance analysis.

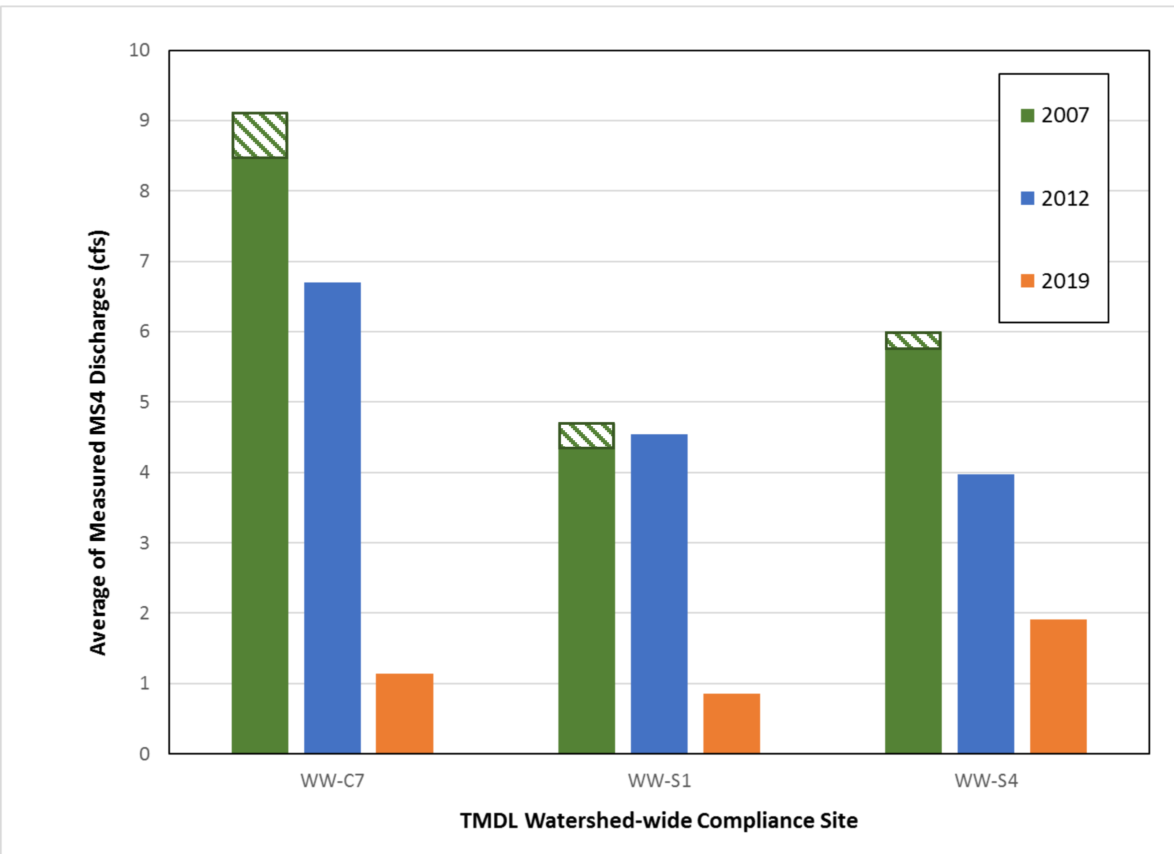

Figure 3-2. Reduction in DWF from MS4 Outfalls Upstream of the Chino Creek and the Santa Ana River Compliance Monitoring Sites (Note: Reduction in MS4 DWF from 2007 to 2019 exceeded the target DWF reduction (hatched area of 2007 bars) established in the CBRPs to demonstrate compliance with WLAs)

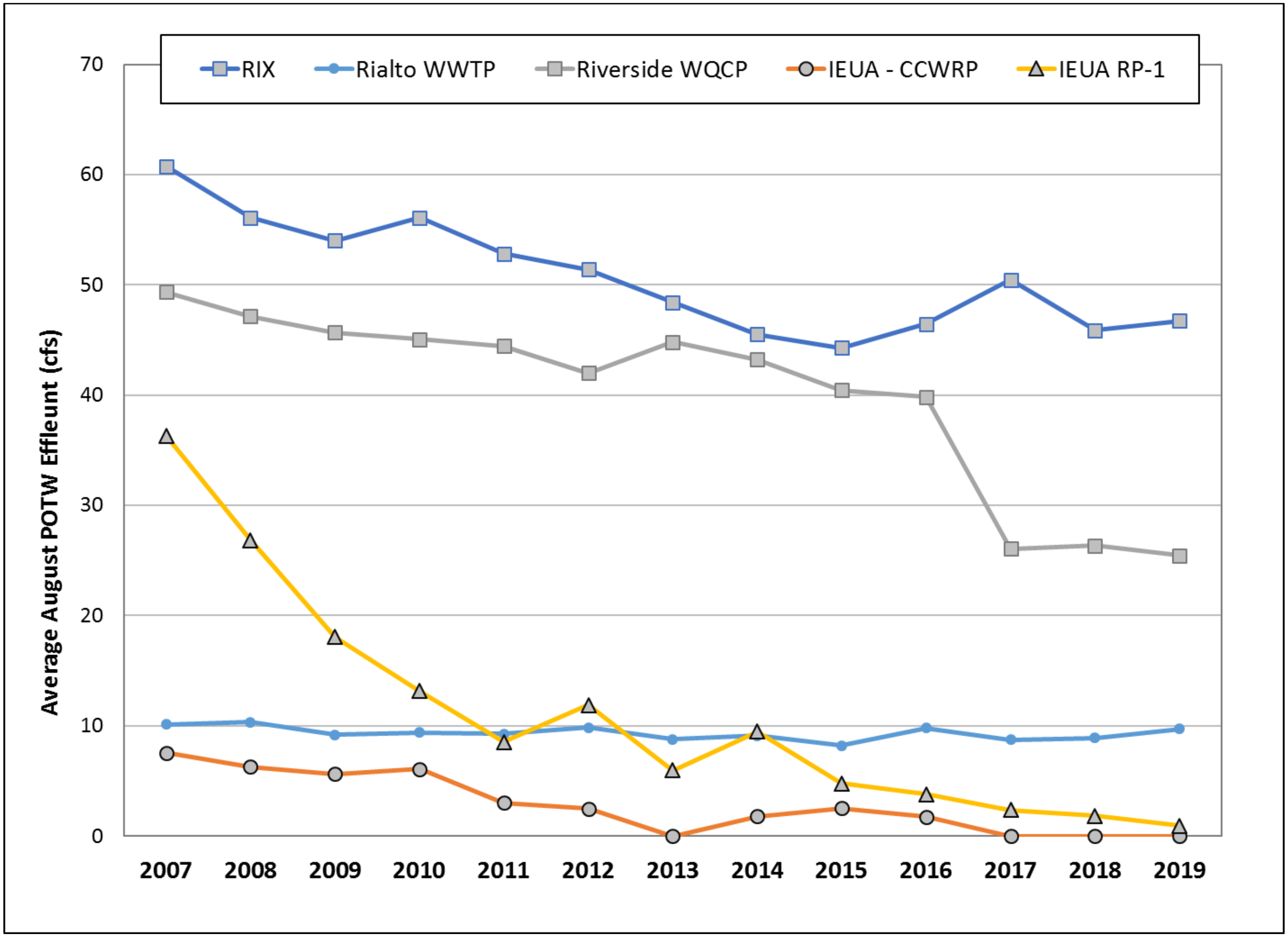

Figure 3-3. Average August POTW Effluent Flow to Impaired Waters (2007-2019)

3.1.2 E. coli Observations

Analysis of *E. coli* concentration data from the 2019 Synoptic Study showed that bacterial water quality in DWF within impaired waters and at Tier 1 sites is highly variable, and typically exceeds the WLA for *E. coli* of 113 MPN/100 mL (**Figure 3-4**). Some Tier 1 sites had significantly greater *E. coli* concentrations than others, e.g..T1-MSCD and T1-BRSC (see Table B-2 for sample results for each site over the six-week sample period).

Most of the Tier 1 sites had at least one sample with an *E. coli* concentration greater than 1,000 MPN/100 mL (exceptions include T1-CCCH with maximum of 410 MPN/100 mL and T1-LLSC with maximum of 800 MPN/100 mL). **Figure 3-5** shows the changes in geomean concentrations that have occurred at each Tier 1 site from 2012 to 2019. Concentrations have increased at some sites (e.g., T1-MSCD) and decreased at others (T1-BXSP).

3.1.3 Bacteria Load Analysis

The potential for DWF at a Tier 1 site to impact water quality at a downstream compliance site can be evaluated through a bacteria load analysis, which considers both the DWF volume and *E. coli* concentration. **Table 3-4** reports estimated loads for each Tier 1 site based on the average DWF rate and *E. coli* geomean concentration measured over the 6-week Synoptic Study in 2019 and the 10-week Tier 1 source evaluation study completed in 2012 (SAWPA 2013).

For the current study, it was assumed that if flow was observed at the Tier 1 sample location then that flow was connected to the downstream receiving water, e.g., Santa Ana River or Chino Creek. In some cases, this assumption could be confirmed visually (e.g., Boys Republic South Channel is a concreted-lined channel that discharges into a portion of Chino Creek which is also concrete-lined); however, at some sites this assumption could not be confirmed visually (e.g., Phoenix Storm Drain, where below the sample location there is dense vegetation which obscures the channel and its confluence with the downstream mainstem Santa Ana River). Even if unconfirmed visually, for the purposes of the bacteria load analysis it was assumed that the flow did connect with the downstream receiving water.

When taking into account changes in DWF, water quality as measured by *E. coli* loads has generally improved at Tier 1 sites. Moreover, when data are aggregated by compliance site, an assessment of the total *E. coli* load from Tier 1 sites has declined in all impaired waters since 2007 (**Figure 3-6**). With the exception of the Chino Creek subwatershed, the bacteria load reduction goals established in the CBRPs to assure compliance with the bacteria concentration targets established by the TMDL have been met. For Chino Creek, approximately 80% of the estimated bacteria load reduction needed to assure compliance with the bacteria concentration targets established by the TMDL has been achieved.

Table 3-4. Comparison of Median *E. coli* Load Estimates at Tier 1 Sites in 2007, 2012 and 2019

Compliance Site	Tier 1 Site	Median *E. coli* Load (Billion MPN/Day)			
		2007	2012	2019	Change in Load 2012 to 2019
Chino Creek at Central Avenue (WW-C7)	T1-CHINOCRK	Not Measured	22.2	14.3	- 7.9
	T1-BRSC	Not Measured	6.9	4.8	- 2.1
	T1-CCCH	22.0	7.5	0.7	- 6.8
	T1-SACH	7.0	0.1	0.1	0.0
	T1-LLSC	Not Measured	0.001	0.1	+ 0.1
	OTHER (2007 est.)[2]	24.0	N/A	N/A	N/A
	Subtotal (WW-C7)	**53.0**	**36.7**	**20.0**	**- 16.7**
Santa Ana River at MWD Crossing (WW-S1)	T1-MCSD	No Hydro Connection	4.9	35.3	+ 30.4
	T1-SNCH	9.0	15.6	7.0	- 8.6
	T1-BXSP	75.0	25.5	3.1	- 22.4
	T1-PHNX	No Hydro Connection	0.0	0.0	0.0
	OTHER (2007 est.)[2]	10.0	N/A	N/A	N/A
	Subtotal (WW-S1)	**94.0**	**46.0**	**45.4**	**- 0.6**
Santa Ana River at Pedley Avenue (WW-S4)	T1-ANZA	31.0	16.9	7.3	- 9.6
	T1-SSCH	10.0	29.3	4.6	- 24.7
	T1-DAY	7.0	1.9	1.3	- 0.6
	OTHER (2007 est.)[2]	14.0	N/A	N/A	N/A
	Subtotal (WW-S4)	**62.0**	**48.1**	**13.2**	**- 34.9**
Other Sites	T1-CYP	Not Measured	11.5	Dry	- 11.5
	T1-CUCAMONGA[1]	82.0	44.7	14.3	- 30.4
	Total *E. coli* Load	**--**	**317.8**	**171.5**	**-146.3**

[1] 2007 estimate for unmonitored areas based on *E. coli* concentration of 600 MPN/100 mL, which was the geomean of all MS4 outfall samples in 2007.

[2] This Tier 1 site is downstream of the RP1 discharge. Flow measurements were not collected at this Tier 1 site in 2012 or 2019. Values represent the sum of bacteria loads estimated from SBCFCD MS4 inputs only (CHRIS + HWY60) in 2012 Tier1 source evaluation and from 10-week sampling program in 2016-2018 (SBCFCD 2016, 2017, 2018).

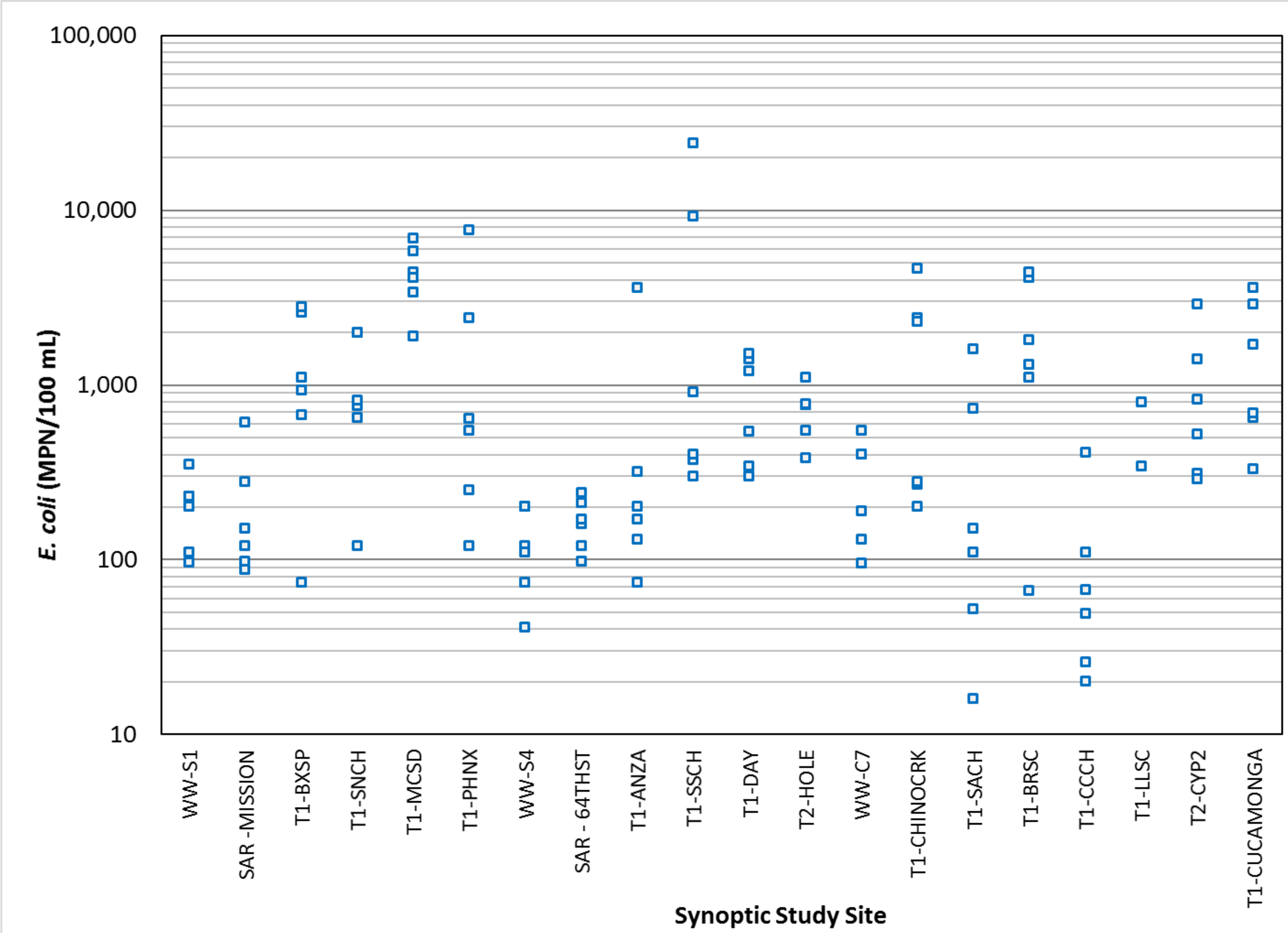

Figure 3-4. Range of *E. coli* Concentrations from all 2019 Synoptic Study Sites (Note log scale on y-axis)

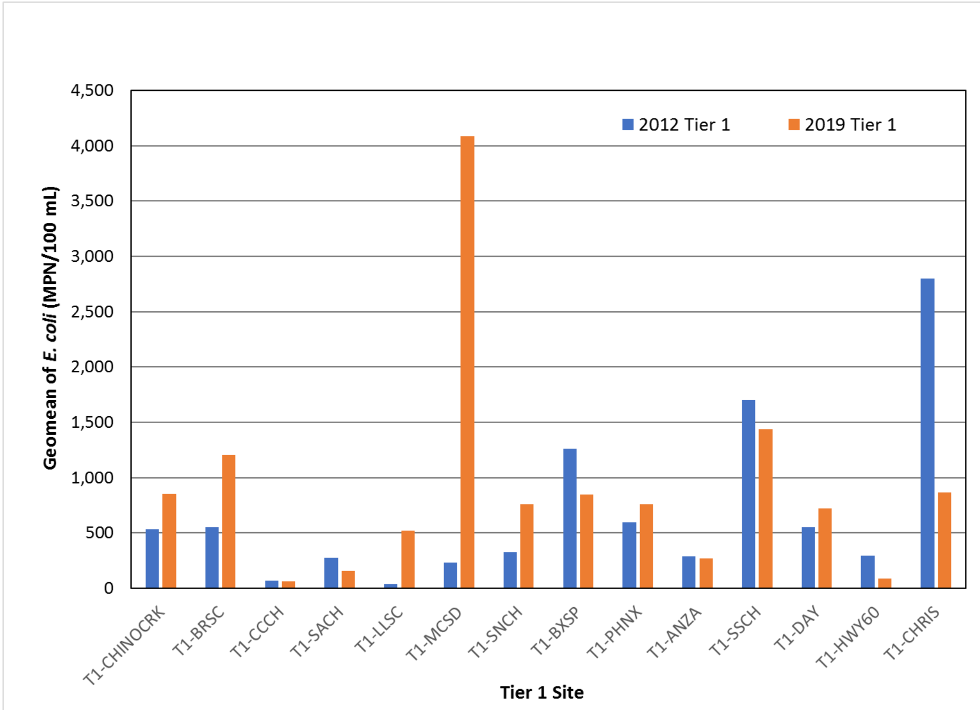

Figure 3-5. Comparison of 2019 Tier 1 Site *E. coli* Geomeans with Previous Studies (Sites T1-HWY60 and T1-CHRIS from SBCFCD, 2016-2018)

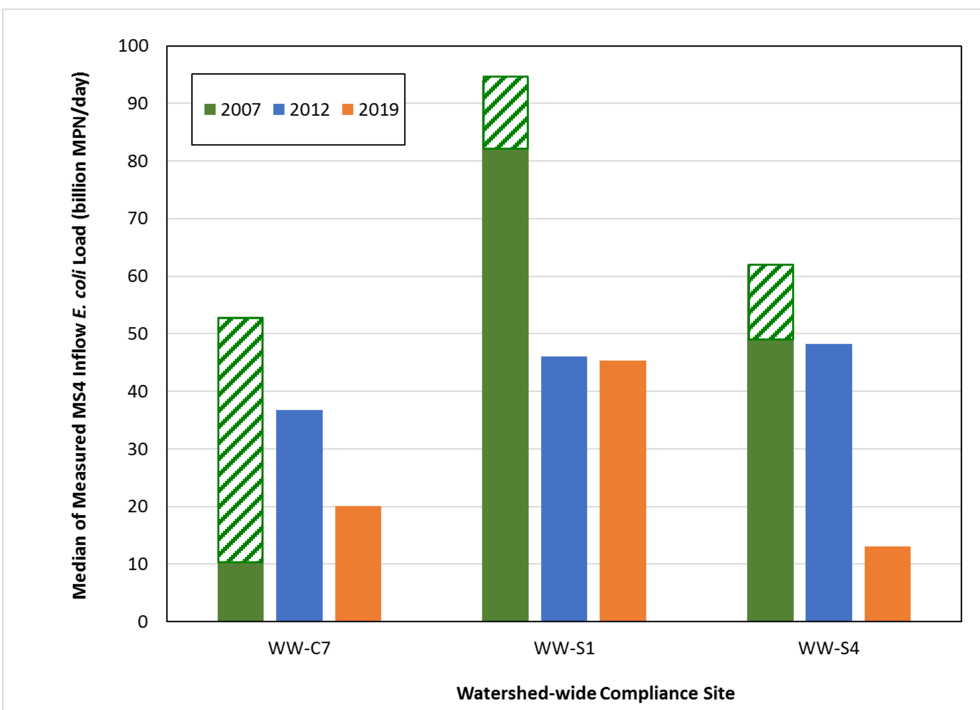

Figure 3-6. Median MS4 *E. coli* Load from Tier 1 Sites Tributary to the Chino Creek and the Santa Ana River Watershed-wide Compliance Sites (Note: Reduction in MS4 bacteria load targeted by CBRP implementation to demonstrate compliance with the WLAs Shown as hatched area of the 2007 bars)

Reductions in *E. coli* loading to impaired waters were observed at all Tier 1 sites except two: T1-MCSD and T1-LLSC (see Table 3-4). The *E. coli* load from these two sites was much greater in 2019 versus 2012. For the T1-MCSD site, an evaluation of the historical data shows that *E. coli* concentrations have generally risen over time (see Figure 2-6), and the *E. coli* concentrations observed during the 2019 Synoptic Study are substantively greater than observed in 2012 (SAWPA 2013) (**Figure 3-7**). Specifically, the geometric mean increased from 234 MPN/100 mL in 2012 to 4,087 MPN/100 mL in 2019. The load analysis indicates a seven-fold rise in *E. coli* loading between 2012 and 2019 (35.3 billion MPN/day in 2019 versus 4.9 billion MPN/day in 2012). This increase affected the prioritization category assigned to the T1-MCSD site (see Section 3.3 below).

The observed bacteria load reductions result from both reduced DWF (from better water management and coordination between water purveyor and stormwater agencies) and reduced *E. coli*, e.g., through focused deployment of Tier 2 inspections that have successfully identified and eliminated illicit connections and illegal discharges within the MS4s.

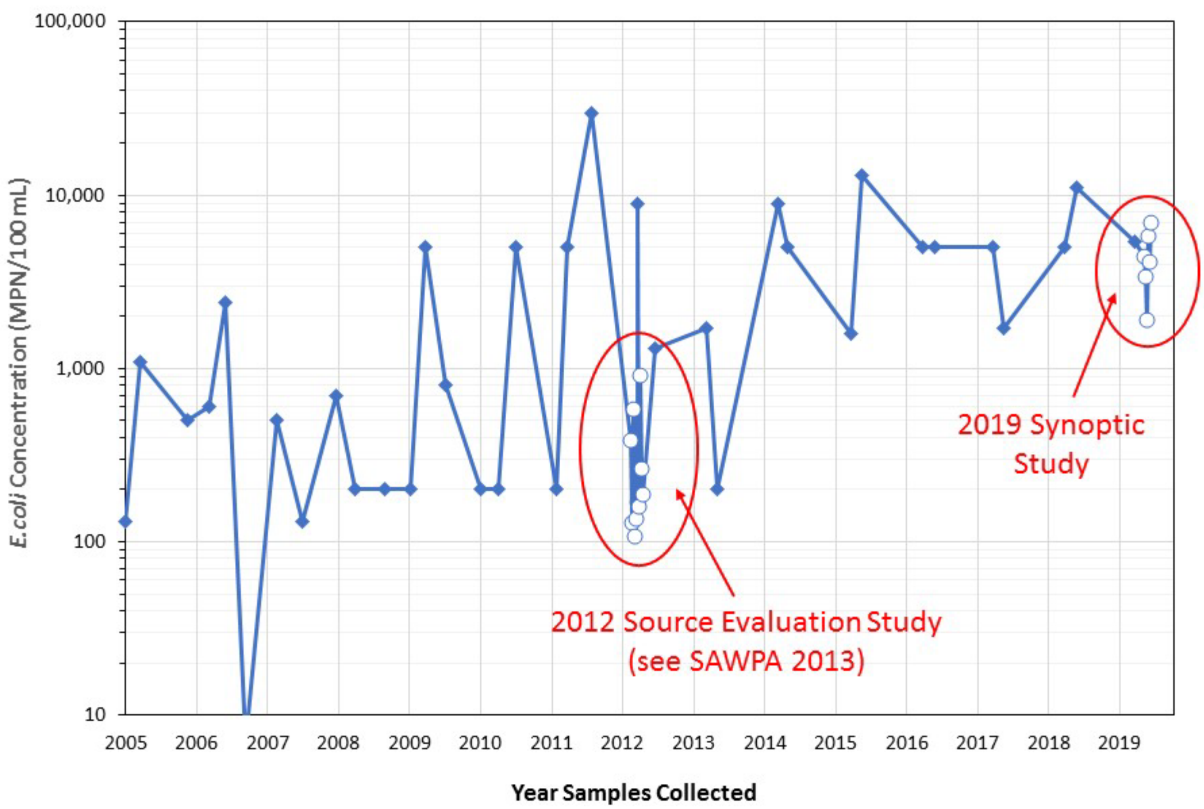

Figure 3-7. Historical *E. coli* Data Record at Magnolia Center Storm Drain Compared with Synoptic Study *E. coli* Results (T1-MCSD) (MS4 Program Core Samples = Blue-filled Diamonds; 2012 Source Evaluation and 2019 Synoptic Study Samples – Open Circles)

3.1.4 Source Evaluation

This study provides the opportunity to update previous estimates (SAWPA 2013, 2017) of total MS4 loading of *E. coli* to impaired waters during dry weather. When DWF from MS4s is blended with tertiary treated POTW effluent (compliant with the facility's *E. coli* effluent limit),[9, 10] a mass balance calculation can approximate the expected *E. coli* concentrations ($C_{MS4+POTW}$) within each impaired water (omitting any instream losses or gains).

The difference ($C_{Non\text{-}MS4}$) between the blended concentration and *E. coli* measurements at downstream compliance sites (C_{WW}) provides an estimate of the nature of *E. coli* losses or gains that occur instream. Instream losses of *E. coli* may be attributed to natural degradation processes in the environment and instream gains of *E. coli* may come from new sources of bacteria, including, but not necessarily limited to shedding from swimmers, fecal deposition by wildlife, impacts from homeless encampments, and scouring of naturalized *E. coli* colonies in sediment/biofilms.

Instream sources are collectively referred to as "Non-MS4" sources in this report.[11] The relative portion of downstream water quality associated with non-MS4 sources is thus estimated as follows:

$$C_{MS4+POTW} = \frac{\left[\sum_i^j (Q_{MS4} * C_{MS4})\right]}{(Q_{MS4} + Q_{POTW})}$$

$$C_{NonMS4} = C_{WW} - C_{MS4+POTW}$$

The source evaluation approach described above is equivalent to the analyses completed for the CBRPs (RCFC&WCD 2011; SBCFCD 2011) and subsequent TMDL Triennial Reports (SAWPA 2013, 2017). In the following subsections we first provide the source evaluation analysis results for the MSAR watershed as a whole based on the 2019 Synoptic Study data. This analysis is followed by a source evaluation analysis for each impaired waterbody and its associated subwatershed, where we provide the following comparable series of figures:

- Schematic of MS4 and POTW inflows to the waterbody, key retention facilities, and nearest downstream compliance monitoring site;
- Weekly time series plot of the MS4 + POTW blended concentration compared with concentrations measured at the downstream compliance monitoring locations; and
- Proportion of each Tier 1 MS4 drainage area that is included in the estimated blended bacterial indicator concentration.

[9] See specific WDR for each POTW (Table 1-2 provides the WDR Order No. for permits issued by the Santa Ana Water Board) and/or discussion in the Synoptic Study Plan (see Section 1.4 of the Study Plan)
[10] All of the POTWs confirmed via email that their respective facilities were in compliance with their *E. coli* permit effluent limits during the Synoptic Study.
[11] Note: In past Triennial Reports "Non-MS4" sources were referred to as "unaccounted-for sources" or "*e*" (e.g., see SAWPA 2013)

3.1.4.1 MSAR Watershed – Overall Analysis

The bacterial load reduction estimates in the CBRPs were based on the existing MSAR watershed flow conditions at the time of the preparation of the CBRPs, i.e., existing POTW effluent discharge volumes coupled with MS4 DWFs. However, as shown in Figure 3-3, over time these effluent discharge volumes have decreased substantially throughout the watershed. To understand the importance of this decline to *E. coli* concentrations, geometric means from the 2019 dry season were adjusted to account for the more substantial dilution that was present in the impaired waters during 2007. If POTW effluent was returned to 2007 conditions, the expected *E. coli* concentrations at the watershed-wide compliance sites would be expected to be well below the TMDL target values for dry weather (**Figure 3-8**). During the 2018 CBRP audit, this same analysis which relied on data available prior to the Synoptic Study was employed to approximate apparent upstream *E. coli* load reductions in the MS4 to estimate the effectiveness of CBRP implementation.[12] A key objective of the 2019 Synoptic Study was to collect upstream data to verify these estimated MS4 *E. coli* load reductions at Tier 1 sites that drain to impaired receiving waters.

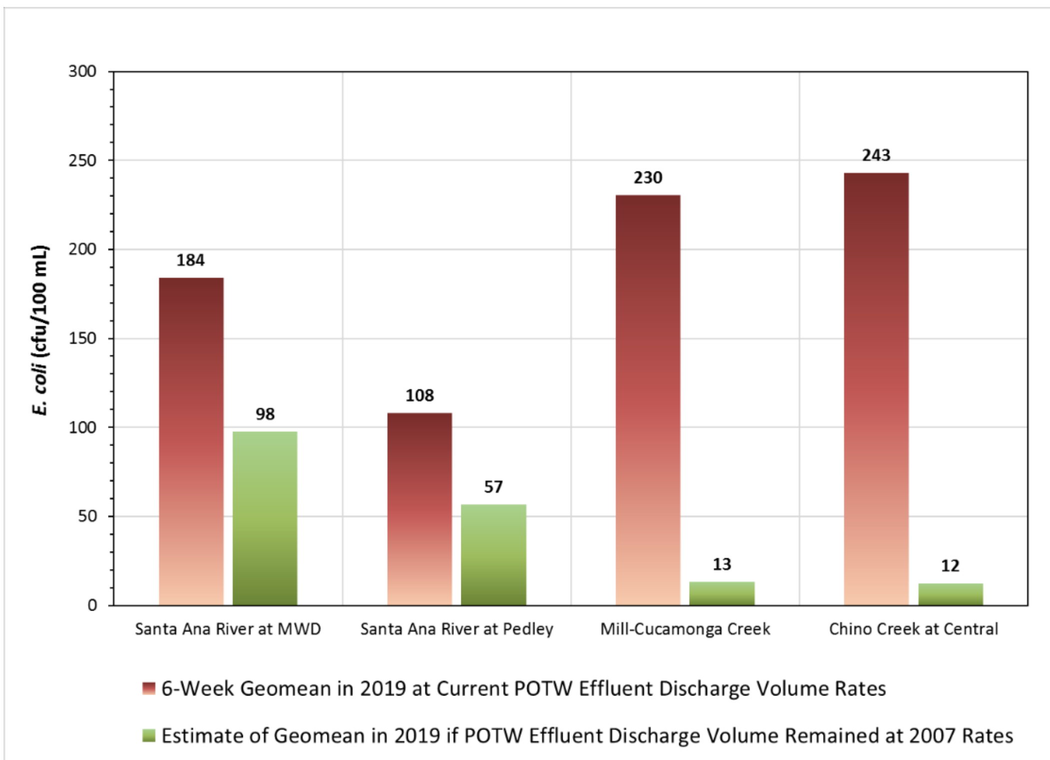

Figure 3-8. Evaluation of *E. coli* Concentrations at Watershed-wide Compliance Sites Taking Into Account Changes in POTW Effluent Discharge Volumes in the MSAR Watershed Since 2007

[12] *Comprehensive Bacteria Reduction Plans: Status of Implementation*. Riverside and San Bernardino County MS4 Program Briefing to the Santa Ana Water Board, February 13, 2018.

3.1.4.2 Chino Creek Subwatershed

Figure 3-9 provides a schematic of the Chino Creek subwatershed, including sources of flow (e.g., POTWs and Tier 1 sites) and flow diversions. DWF from most of the Chino Creek subwatershed does not reach the downstream compliance site at Central Avenue (WW-C7) because of diversions. For example, DWF in San Antonio Channel, the largest tributary to Chino Creek, is diverted into a series of retention basins that span from San Antonio Dam in the upper part of the subwatershed to Brooks Basin in the City of Montclair. Downstream of the diversion to Brooks Basin, there are five MS4 outfalls to Chino Creek that comprise nearly all the DWF (see Figure 3-9).

During the 2019 dry season and the Synoptic Study, IEUA's Carbon Canyon WRP, the only source of treated effluent to Chino Creek, discharged no effluent to Chino Creek. Consequently, the source evaluation analysis for the Chino Creek watershed involves computation of a flow-weighted concentration for the five Tier 1 MS4 outfalls with DWF. The estimated blended *E. coli* concentration was found to be greater than the concentration of *E. coli* at the downstream watershed-wide compliance monitoring site at Central Avenue (**Figure 3-10**). This finding suggests that in-stream processes yield a net decay in fecal bacteria between upstream sources and the impaired portion of Chino Creek, and that non-MS4 sources of *E. coli* in Chino Creek are likely to be minimal during dry weather.

Figure 3-11 shows that significant week to week variability exists in the relative *E. coli* load to Chino Creek among Tier 1 sites. Because multiple sites contribute the majority of *E. coli* loads during some weeks, future *E. coli* mitigation activities may need to address multiple drainages within the Chino Creek subwatershed to effectively reduce the *E. coli* load to meet the MS4 WLA.

3.1.4.3 Santa Ana River Subwatershed

Figure 3-12 provides a schematic of the Santa Ana River Reach 3 subwatershed, including sources of flow to the river. The source evaluation analysis for this subwatershed involved computation of a blended *E. coli* concentration from MS4 outfalls and the three POTWs that discharge treated effluent in this subwatershed: City of Riverside's RWQCP, City of Colton and San Bernardino RIX facility, and the City of Rialto WWTP (medians of weekly calculations shown in schematic of 33 MPN/100 mL at WW-S1 and 35 MPN/100 mL at WW-S4). Seven Tier 1 sites accounted for all DWF and associated *E. coli* bacteria from MS4 sources.

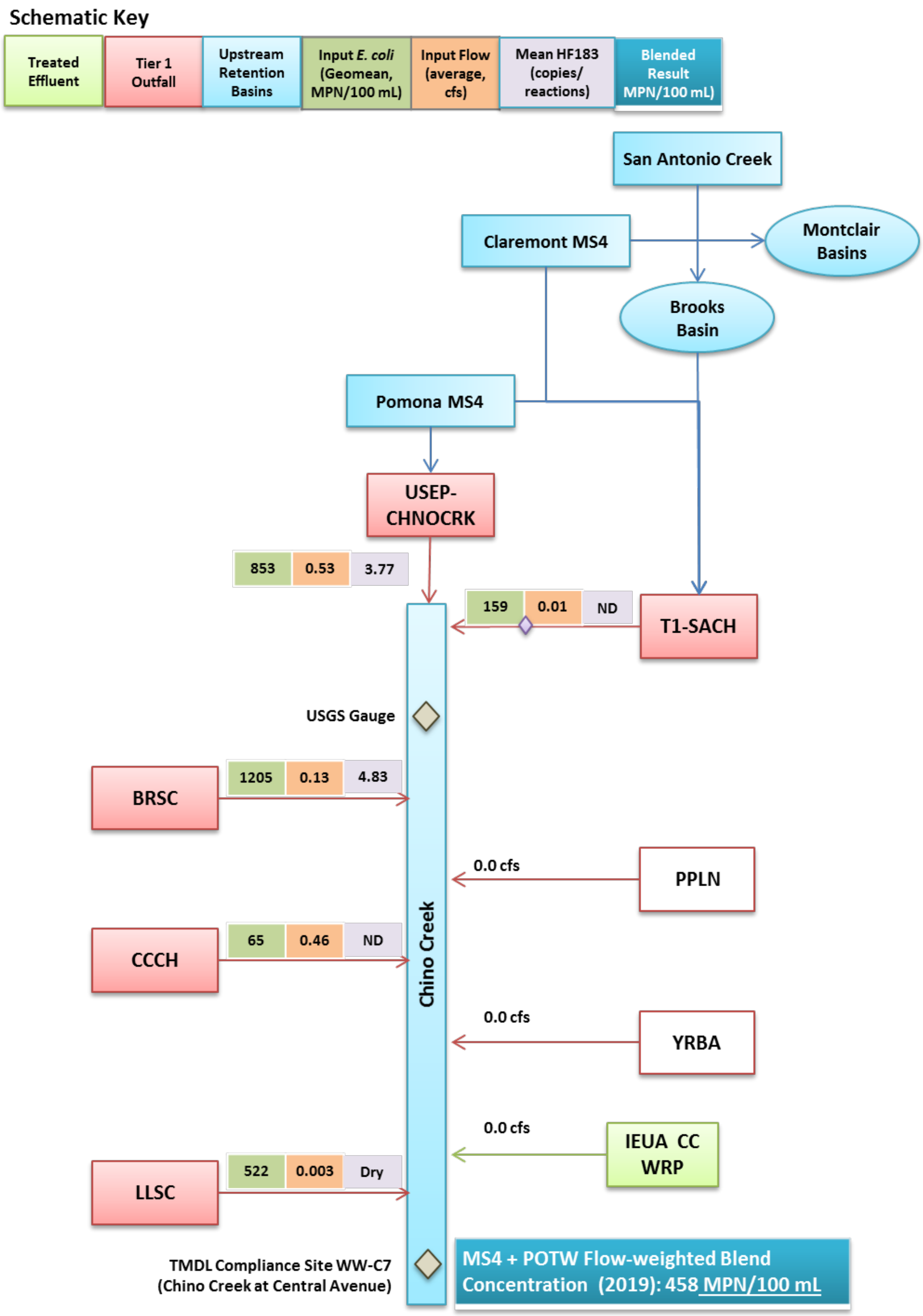

Figure 3-9. Schematic Showing Known Bacteria Inputs (*E. coli* and *Bacteroides* HF183 Human Marker), DWF Inflows and POTW Effluent Discharges to Chino Creek in Relation to Downstream Compliance Monitoring Site

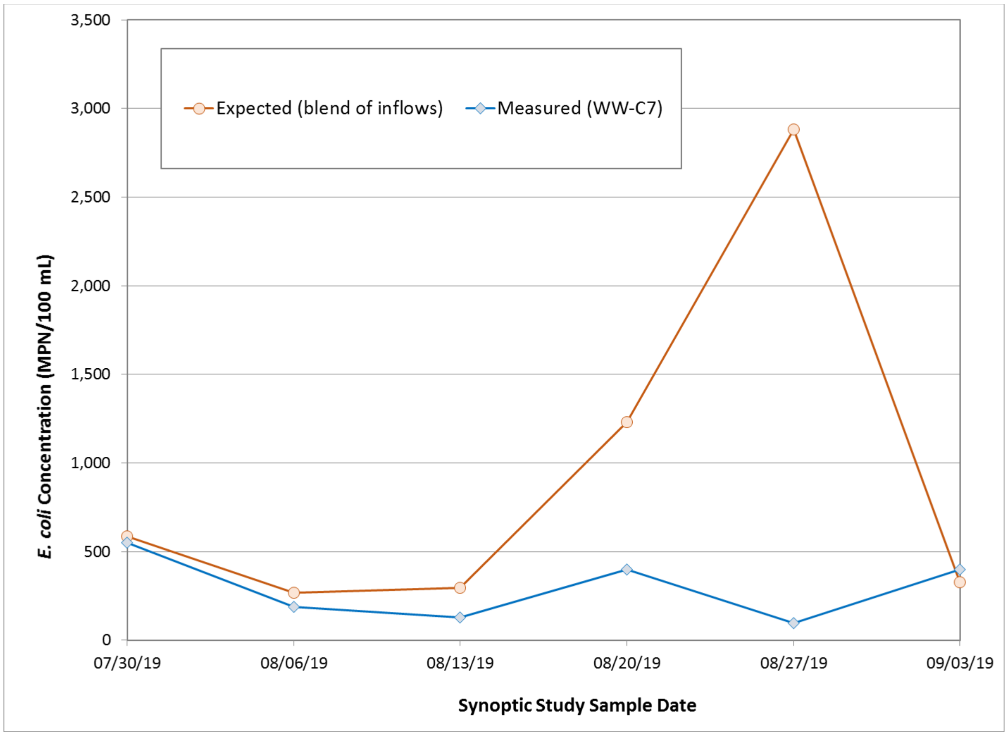

Figure 3-10. Comparison of Estimated Blended *E. coli* Concentration of MS4 Inflows with Downstream Watershed-wide Compliance Site Data for Chino Creek at Central Avenue

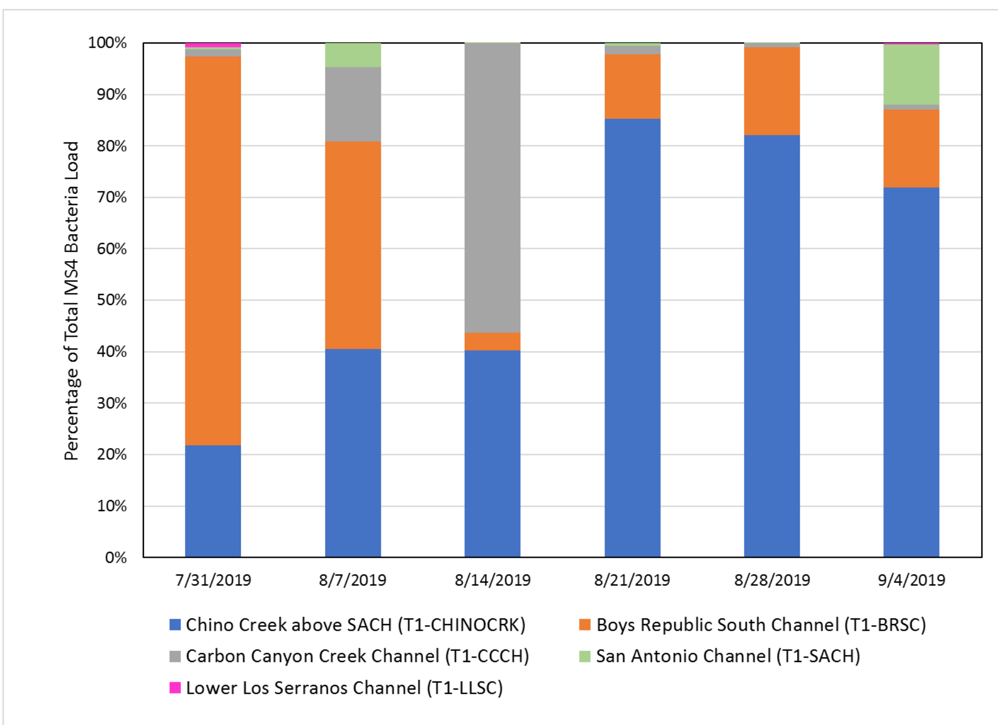

Figure 3-11. Relative Loading from Tier 1 Sites to Total MS4 *E. coli* Load to the Chino Creek at Central Avenue Compliance Site

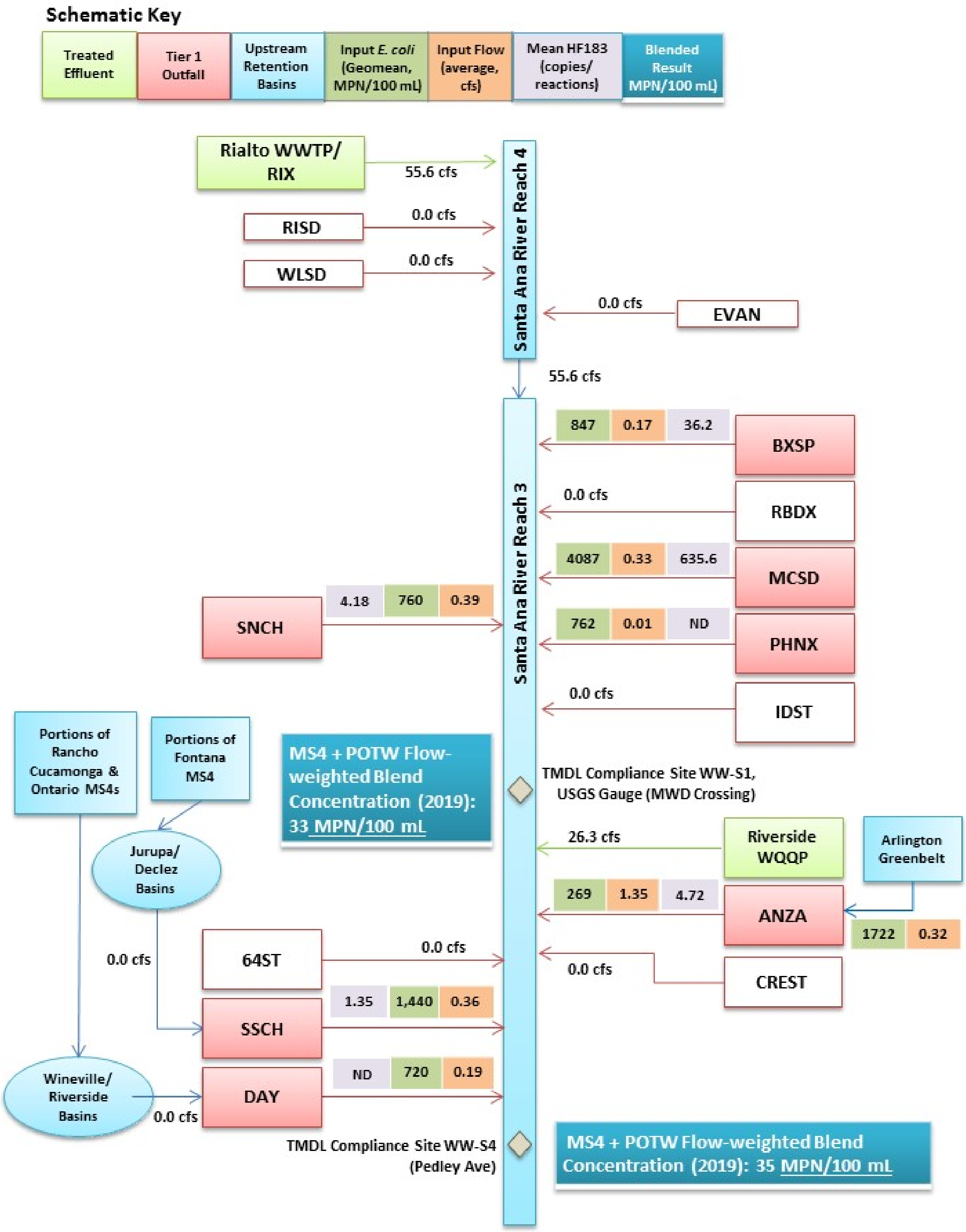

Figure 3-12. Schematic Showing Known Bacteria Inputs (*E. coli* and *Bacteroides* HF183 Human Marker), DWF Inflows and POTW Effluent Discharges to the Santa Ana River in Relation to Downstream Compliance Monitoring Sites

The estimated *E. coli* concentration in the MS4 and POTW blend was compared with actual concentrations in the Santa Ana River at MWD Crossing (WW-S1, **Figure 3-13**) and Santa Ana River at Pedley Avenue (WW-S4, **Figure 3-14**). These comparisons suggest the presence of additional non-MS4 sources of *E. coli* within this subwatershed, which is consistent with findings in previous mass balance analyses (e.g., SAWPA 2013).

For each sample week during the study, we computed the *E. coli* loading contributed by each site relative to the total MS4 inflow load immediately upstream of WW-S1 (T1-BXSP, T1-SNCH, T1-MCSD, and T1-PHNX) and between WW-S1 and WW-S4 (T1-ANZA, T1-SSCH, and T1-DAY). **Figure 3-15** shows that the subwatersheds to two Tier 1 sites consistently accounted for at least 85 percent of the *E. coli* load from MS4s discharging to the Santa Ana River upstream of the MWD Crossing compliance site:

- Magnolia Center Storm Drain (T1-MCSD) – DWF mostly from the City of Riverside underground MS4 system; and
- Sunnyslope Channel (T1–SNCH) - Open channel; DWF likely a combination of urban runoff from residential areas in Jurupa Valley and potentially rising groundwater.

For the three Tier 1 sites located between WW-S1 (MWD Crossing) and WW-S4 (Pedley Avenue), the site that comprised the majority of *E. coli* load to this reach of the Santa Ana River varied from week to week (**Figure 3-16**).

3.1.4.4 Cucamonga Creek Subwatershed

On April 8, 2015, USEPA approved the use attainability analysis that removed thee water contact recreation beneficial use (REC1) use from Cucamonga Creek Reach 1.[13, 14] Prior to this regulatory decision, numerous drainages that discharge to Cucamonga Creek Reach 1 were classified as Tier 1 sites; thus, the 2012 source contribution analysis included an evaluation of nine MS4 outfalls that discharged into Cucamonga Creek between 23rd Street in Upland at the upper end of the reach and Hellman Avenue Bridge, at the lower end of the reach. With the de-designation of REC1, all of these 2012 Tier 1 sites became Tier 2 and the only Tier 1 site in this subwatershed is where Cucamonga Creek Reach 1 drains into Mill-Cucamonga Creek downstream of Hellman Avenue (T1-CUCAMONGA).

Per the objectives of the Synoptic Study, flow and bacteria data from the T1-CUCAMONGA site were used to prioritize the site along with all other Tier 1 sites in the watershed. While useful from an overall watershed standpoint, the findings from this site on their own do not provide information regarding where to prioritize future DWF/*E. coli* mitigation activities within the Cucamonga Creek subwatershed. To assist with that evaluation, data collected during the dry-season over a ten-week period in 2016, 2017, and 2018 were evaluated for the purposes of this report (SBCFCD 2016, 2017, 2018).

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[13] https://www.waterboards.ca.gov/santaana/water_issues/programs/basin_plan/docs/2015/Santa_Ana_Basin_UAA_Approval_Letter_040815.pdf
[14] https://www.waterboards.ca.gov/santaana/water_issues/programs/basin_plan/docs/rec_standards/UAA/Cucamonga_UAA_10-7-13_Final.pdf

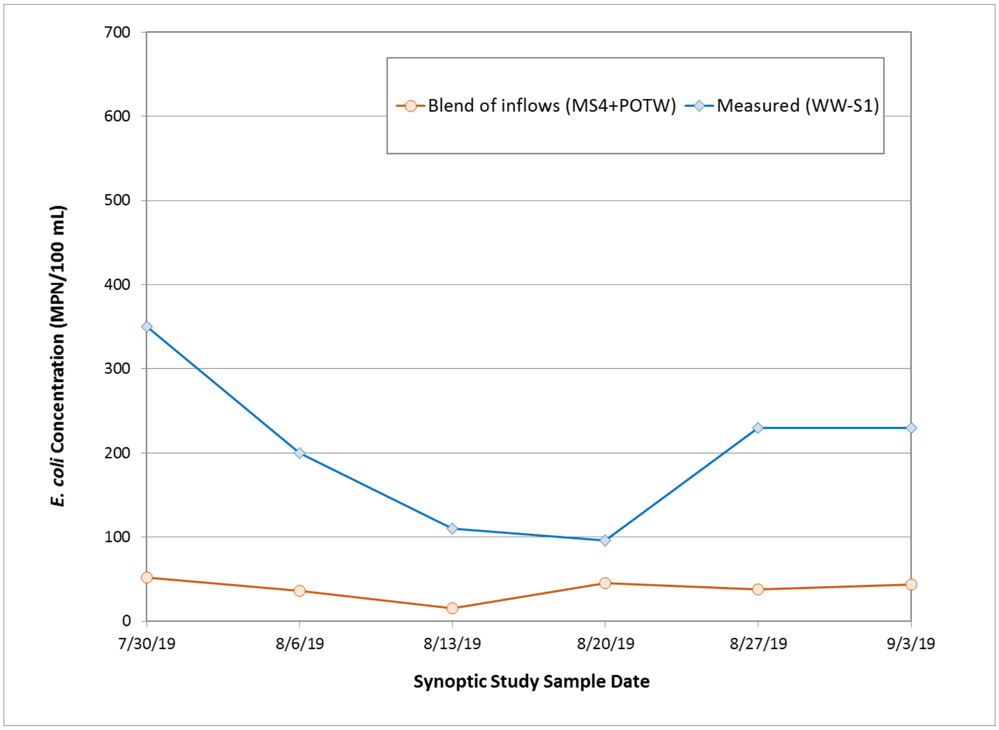

Figure 3-13. Comparison of Estimated Blended *E. coli* Concentration of MS4 Inflows with Downstream Watershed-wide Compliance Monitoring Data for Santa Ana River at MWD Crossing

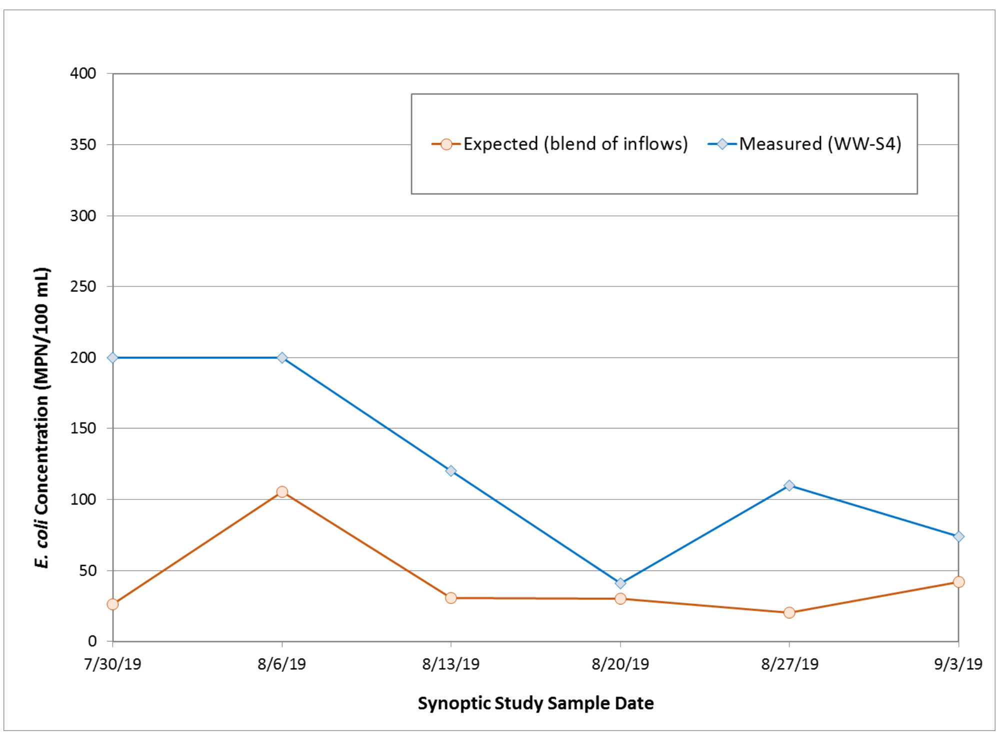

Figure 3-14. Comparison of Estimated Blended *E. coli* Concentration of MS4 Inflows with Downstream Watershed-wide Compliance Monitoring Data for Santa Ana River at Pedley Avenue

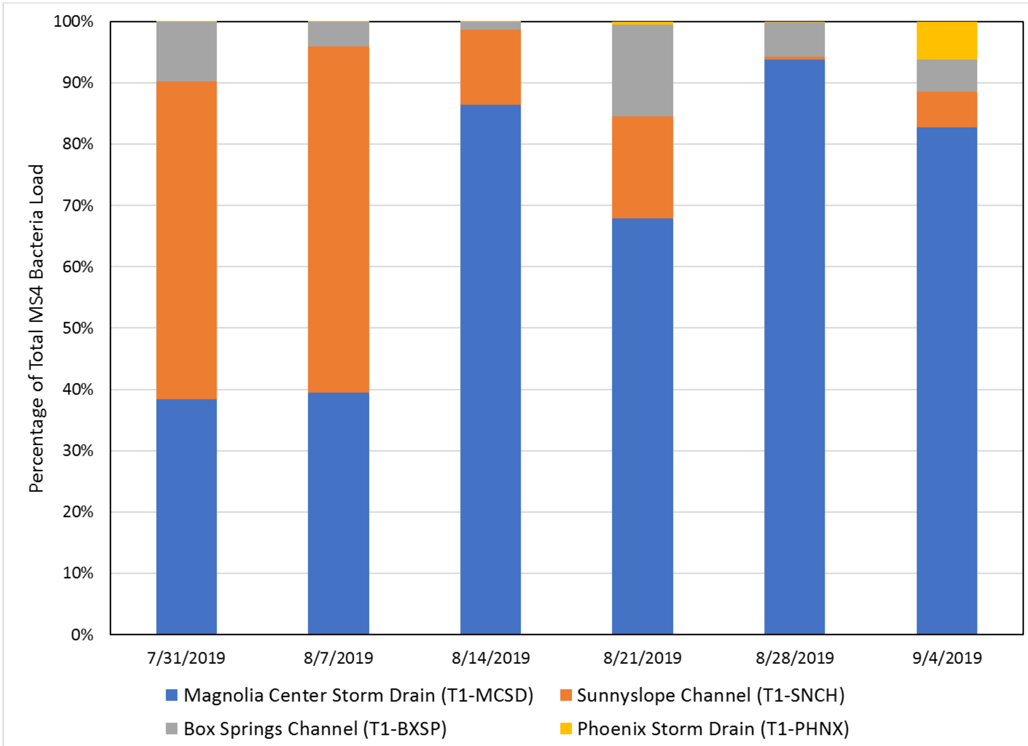

Figure 3-15. Relative Loading from Tier 1 Sites to Total MS4 *E. coli* Load to the Santa Ana River at MWD Crossing Compliance Site

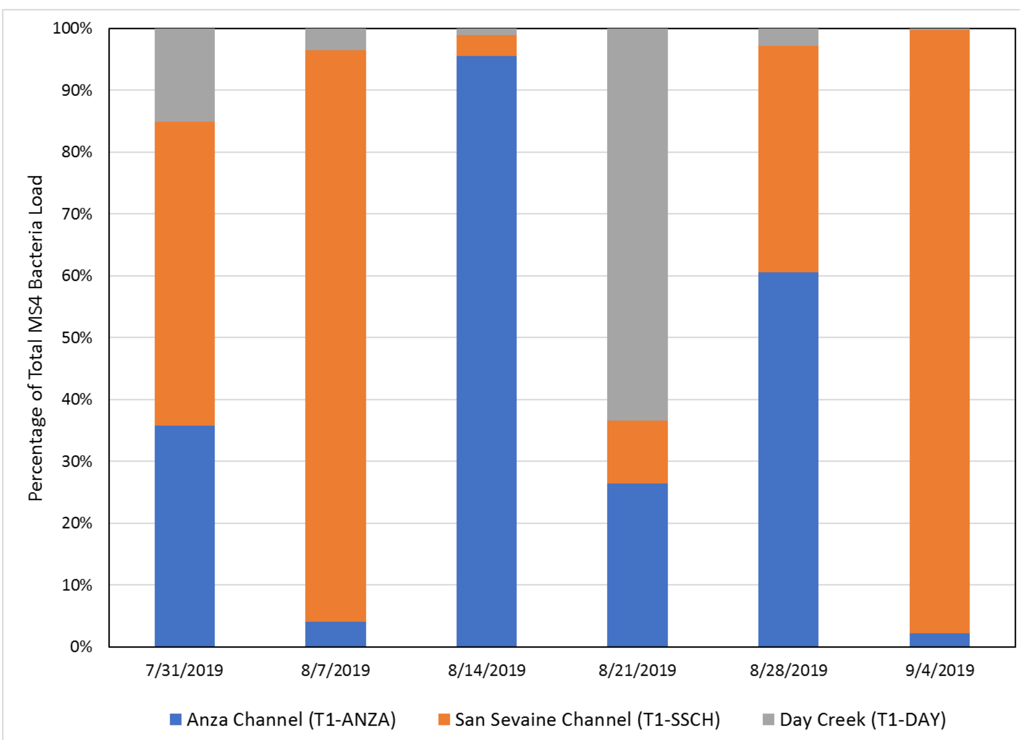

Figure 3-16. Relative Loading from Tier 1 Sites to Total MS4 *E. coli* Load at the Santa Ana River at Pedley Avenue TMDL Compliance Monitoring Location

During the 10-week sampling program in each year from 2016 to 2018, samples of DWF at T2-SR60 had relatively low concentrations of *E. coli* (geomean of 87 MPN/100 mL). These concentrations were even lower when evaluating data from only 2017 and 2018 (geomean of 20 MPN/100 mL). As noted above, four other Tier 2 sites convey DWF from MS4 outfalls to Cucamonga Creek downstream of T2-SR60. These sites and the availability of data for this analysis include:

- T2-CHRIS - SBCFCD collected 30 samples at the Chris Basin outflow; these data show there is a persistent *E. coli* load coming from the Lower Deer Creek subwatershed through Chris Basin;
- T2-CLCH – No DWF was observed on any sample date during the 2016 to 2018 data collection period; and
- T2-EVLA and T2-EVLB - Data were not collected by SBCFCD at either of these two Eastvale MS4 outfalls during the 10-week 2016-2018 sample program. As a substitute, data from 2012 were used for the purpose of this source evaluation analysis.

Figure 3-17 provides a schematic of the portion of the Cucamonga Creek watershed that has the potential to contribute DWF and bacteria to the downstream T1-CUCAMONGA site.[15] The remaining portion of the subwatershed is hydrologically disconnected during dry weather due to diversions for groundwater recharge at Turner and Ely Basins. Downstream of these retention basins, there are nine major MS4 outfalls to Cucamonga Creek that were key sources of DWF and *E. coli* data for the 2012 Tier 1 source evaluation (SAWPA 2013). Four of these sites (T2-CAPT, T2-CNRW, T2-CFRN, and T2-WCUC) are upstream of the Cucamonga Creek at State Route 60 (T2-SR60) location; these sites can be represented by data collected from this one monitoring location. Figure 3-17 shows how sources of DWF and *E. coli* to Cucamonga Creek translate to an expected downstream *E. coli* concentration at the Tier 1 site (T1-CUCAMONGA). For example, downstream of T2-SR60 four Tier 2 sites convey DWF from the MS4 to Cucamonga Creek Reach 1: (a) T2-CHRIS and T2-CLCH in San Bernardino County; and (b) T2-EVLA and T2-EVLB in Riverside County.

IEUA's RP1 treated effluent is an important source of DWF to Cucamonga Creek Reach 1 (Figure 3-17). During the dry seasons of 2016 to 2018 effluent flow varied from 0 to 14 cfs, with day-to-day fluctuations as great as 8.1 cfs and 1.7 cfs on average. Effluent rates were not obtained for sub-daily timesteps, but it is reasonable to assume variability over a few hours could be substantial during periods when IEUA's operations require more or less water be added to their recycled water system. Thus, the effluent rate used in the mass balance analysis may not be representative of the volume from RP1 at the time samples were collected downstream. This reality makes it difficult to design a study that accurately balances DWF volume on sampled dates. The long-term average flow shown in Figure 3-17

[15] Because the most recent comprehensive data set available from this subwatershed is for 2018, this schematic shows 2018 data from the T1-CUCAMONGA site rather than the 2019 Synoptic Study data.

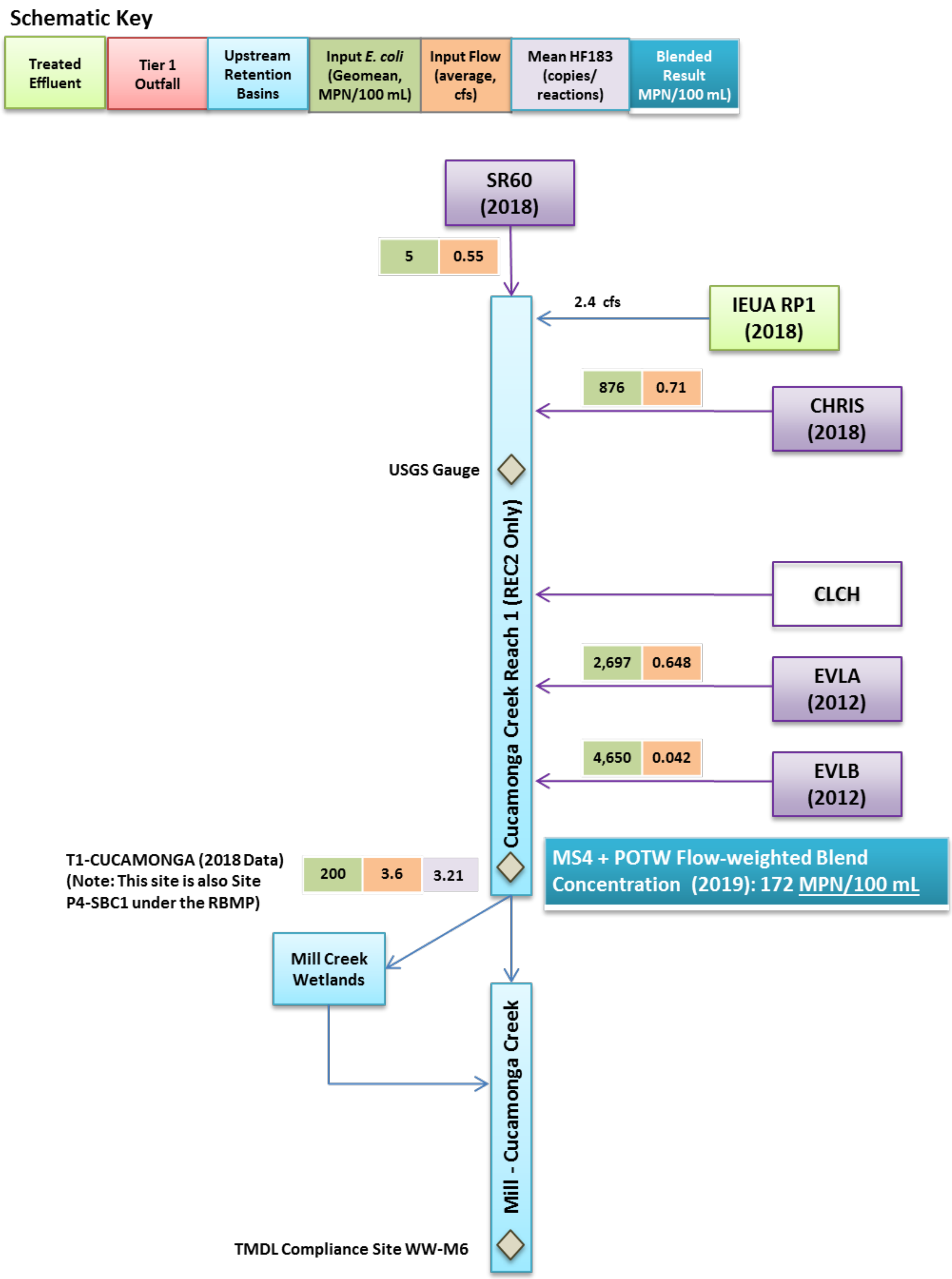

Figure 3-17. Schematic Showing Known Bacteria Inputs (*E. coli* and *Bacteroides* HF183 Human Marker), DWF Inflows and POTW Effluent Discharges to Cucamonga Creek Reach 1 in Relation to the Downstream Compliance Monitoring Site.

may be the best estimate of relative source contribution because such extremes are averaged. On the other hand, as noted above, the presence of an average condition is not typical with regard to effluent discharge from RP1.

DWF and *E. coli* data were evaluated over the 2016 to 2018 time period. **Figure 3-18** plots the expected blend of MS4 and POTW effluent against measured *E. coli* at T1-CUCAMONGA). Results suggest that the MS4 inflows adequately account for the measured *E. coli* downstream on most sampled dates and that there is likely a net decay within stream between the SR60 and Hellman Avenue bridges. These results are based on MS4 inflows from Eastvale (T2-EVLA and T2-EVLB) that are assumed to be unchanged since the 2012 source evaluation. As part of future Tier 2 source evaluation efforts, it may be appropriate to collect updated data from these Eastvale Tier 2 sites to support future estimates of sources of bacteria loads to the downstream Tier1 site (T1-CUCAMONGA).

Downstream of Hellman Avenue, a portion of DWF is diverted to the Mill Creek Wetlands for treatment. The remainder is required to stay within Mill-Cucamonga Creek to support riparian habitat. The diversion flow restrictions are documented in a streambed alteration agreement. This agreement is based on older DWF records during a period when RP1 discharge rates were 5-10 times greater than current conditions. Currently, diversions to the Mill Creek Wetlands occurs on a regular basis, but no continuous metering is conducted on this flow split; therefore, it is challenging to balance upstream and downstream volumes.

Data collected under the RBMP has shown a steady decline in *E. coli* concentrations at the Mill-Cucamonga Creek compliance site (WW-M6). However, to date, no relationship between concentrations of *E. coli* at the upstream Tier 1 site (T1-CUCAMONGA) and *E. coli* concentrations at this compliance site has been found (**Figure 3-19**).

3.1.5 Uncontrollable, Non-MS4 Bacteria Sources

Consistent with the many iterations of the source contribution analyses completed over a number of years, studies have shown that sources of fecal bacteria exist in the MSAR watershed that cannot be attributed solely to MS4 discharges. Historically, the basis for quantifying non-MS4 sources has involved a process of elimination, subtracting measured inflows from the MS4 from measured loads within the receiving waters.

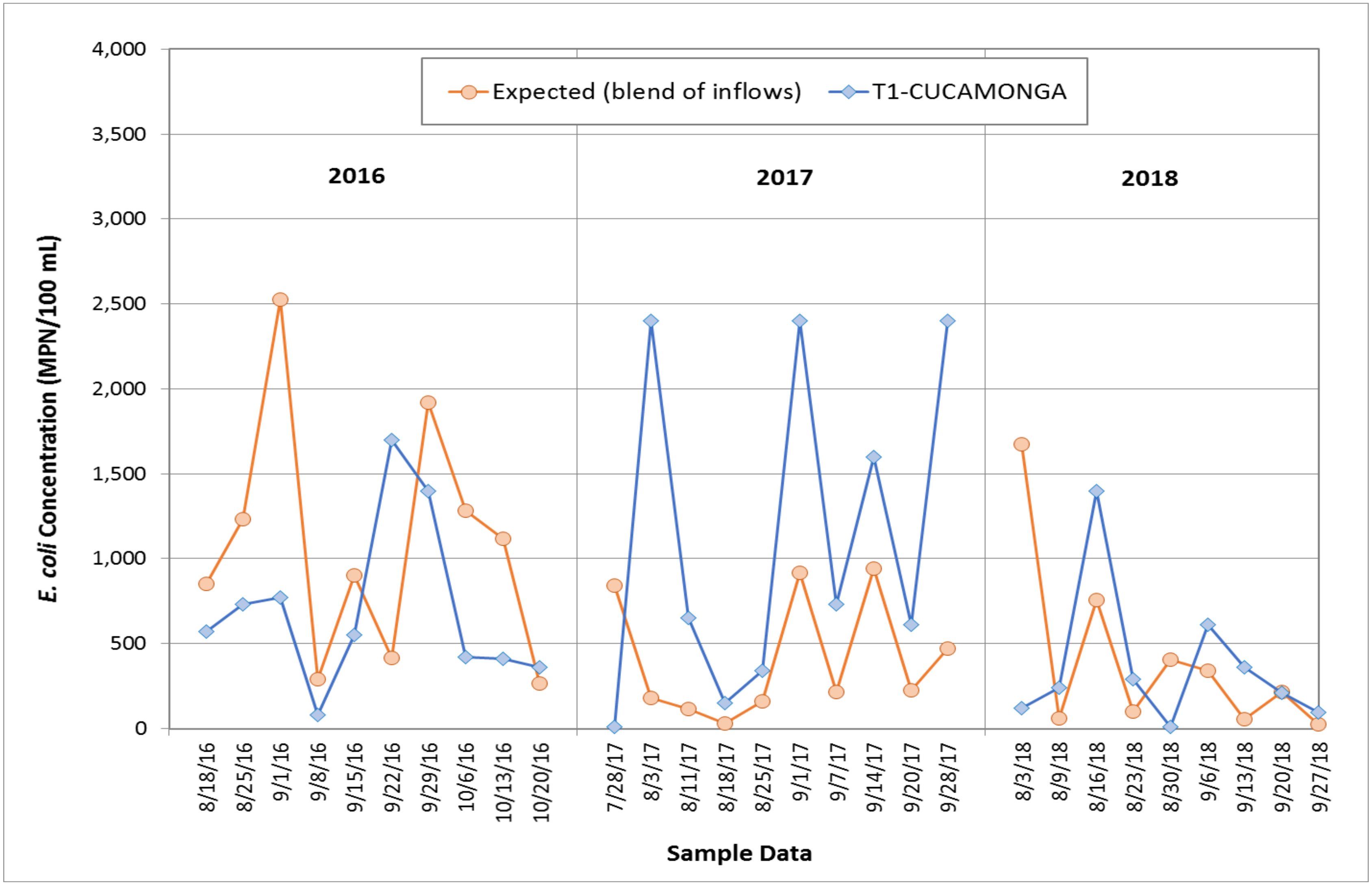

Figure 3-18. Comparison of Estimated Blended *E. coli* Concentrations in MS4 Inflows with Downstream Data from Cucamonga Creek at Hellman Avenue (T1-CUCAMONGA) (Note: Expected blend of inflows assumes 2019 DWF from Eastvale sites EVLA and EVLB remains unchanged from 2012 (see text)

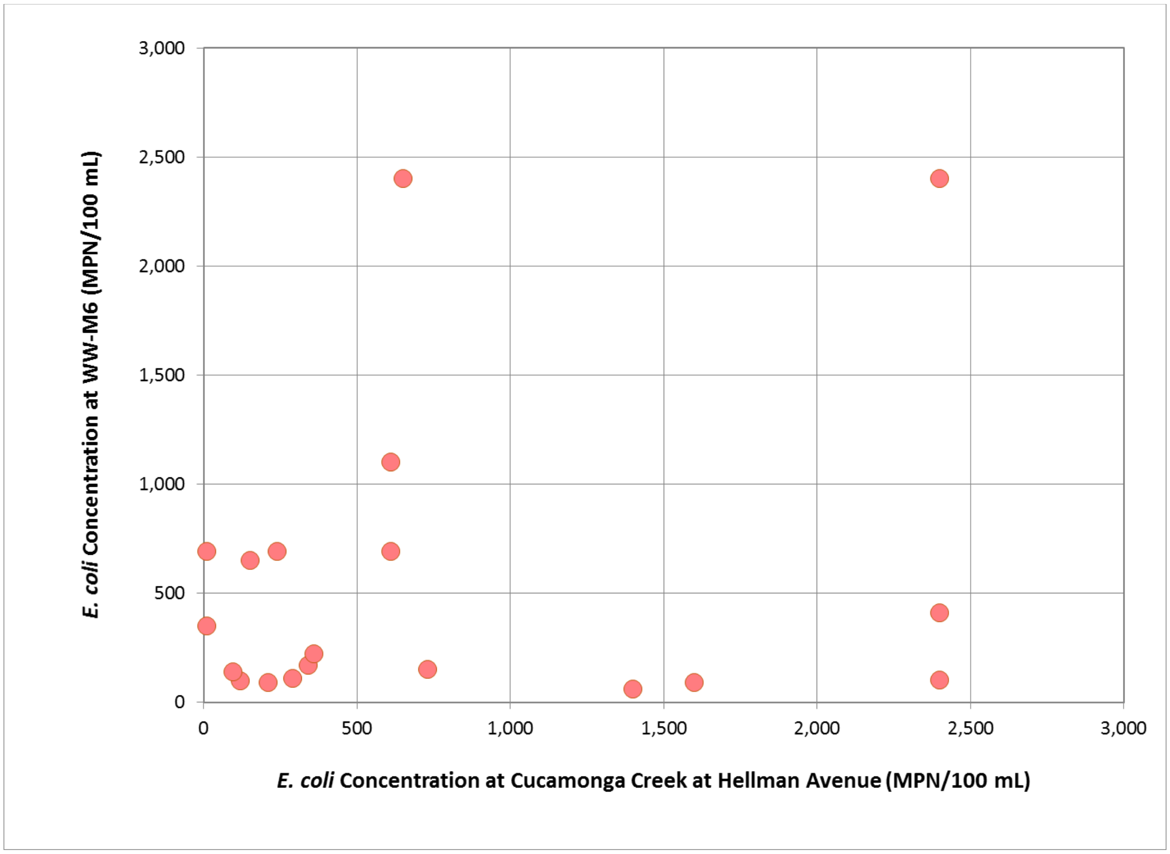

Figure 3-19. Comparison of *E. coli* Concentration at Cucamonga Creek at Hellman Avenue (T1-CUCAMONGA) Site (Upstream of Mill Creek Wetlands) and Mill-Cucamonga Creek Watershed-wide Compliance Site (WW-M6) (Downstream of Mill Creek Wetlands)

In 2015, RCFC&WCD implemented the Uncontrollable Bacteria Sources Study (RCFC&WCD 2016), which evaluated the potential for uncontrollable sources of *E. coli* to influence *E. coli* concentrations in the MSAR watershed.[16] For example, this study found that *E. coli* levels were higher in biofilm/sediment samples than levels in overlying water samples by as much as four orders of magnitude, indicating that biofilm/sediment behave as a reservoir for *E. coli*. In contrast, the outcome from investigations of other potential uncontrollable sources, e.g., bird activity, did not point to any predominant sources responsible for elevated levels of *E. coli*. The following sections discuss different potential types of non-MS4 sources of bacteria to the MSAR watershed.

3.1.5.1 Bacterial Indicators Upstream of MS4 Inputs

The Uncontrollable Bacteria Sources Study (RCFC&WCD 2016) evaluated a segment of Santa Ana River upstream from Riverside Avenue to the Rialto WWTP discharge to evaluate

[16] The Basin Plan defines "uncontrollable sources" as: wildlife activity and waste; bacterial regrowth within sediment or biofilm; resuspension from disturbed sediment; Concentrations (flocks) of semi-wild waterfowl; shedding during swimming (Santa Ana Water Board 2016).

non-MS4 sources of bacteria in a reach where the only potential sources of dry weather flow are from two locations:

- Cactus Channel MS4 outfall (also known as the Rialto Channel) above the Rialto WWTP - As part of the City of Rialto's on-going documentation of hydrologic disconnection, the City conducts photographic surveys of the Cactus Channel above the Rialto WWTP on a daily basis (e.g., City of Rialto 2018). Findings from these surveys show that dry weather flows rarely occur in the Cactus Channel.
- Drainage area in the City of Colton with an on-site detention basin located south of Agua Mansa Road, east of Riverside Avenue and west of the Cactus Channel - This drainage area only discharges to the Santa Ana River during very high rain events.

For the Uncontrollable Bacteria Sources Study samples were collected from near the RIX facility discharge downstream to the Santa Ana River at the Riverside Avenue Bridge (RCFC&WCD 2016). This site was selected because:

- The only documented source of water to this portion of the Santa Ana River during dry weather conditions was tertiary treated effluent from the Rialto WWTP and RIX Facility (approximately 56 cfs). Upstream of these POTWs the Santa Ana River bed was dry.
- Under dry weather conditions, the site is upstream of all sources of MS4-related flow to Santa Ana River Reach 3 and thus the MS4 could not be causing or contributing *E. coli* bacteria to the impaired waterbody and the *E. coli* observed at this location must be, for the most part, resulting from uncontrollable sources.[17]

Given the expected lack of any source of MS4-related dry weather flows from this reach of the Santa Ana River, quantification of bacteria from non-MS4 sources from within this river reach could be further evaluated during the Synoptic Study. Accordingly, during the six-week 2019 Synoptic Study, *E. coli* samples were collected at the Riverside Avenue bridge and the Mission Boulevard bridge, which is the most downstream site within the segment of the Santa Ana River where there were no expected MS4 dry weather flow discharges (Note: The lack of dry weather flow from the Cactus Channel and drainage area within the City of Colton was confirmed on a daily basis during implementation of the Synoptic Study [personal communication, Lynn Merrill and Associates, Inc., February 5, 2020]).

Figure 3-20 identifies the locations and monitoring programs that have collected *E. coli* samples from this particular reach of the Santa Ana River. Results from all of these sampling efforts were pooled to develop a rigorous estimate of *E. coli* concentration and load from non-MS4 and non-POTW sources in the WW-S1 subwatershed (**Figure 3-21**).[18]

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[17] See footnote 4 for Basin Plan definition of "uncontrollable"

[18] For this study, it was confirmed from POTW monitoring reports that the treated effluent discharged to this Santa Ana River reach was in compliance with their *E. coli* effluent limits at the time samples were collected in the river (< 2.2 MPN/100 mL additional *E. coli* load to the Santa Ana River Reach 3).

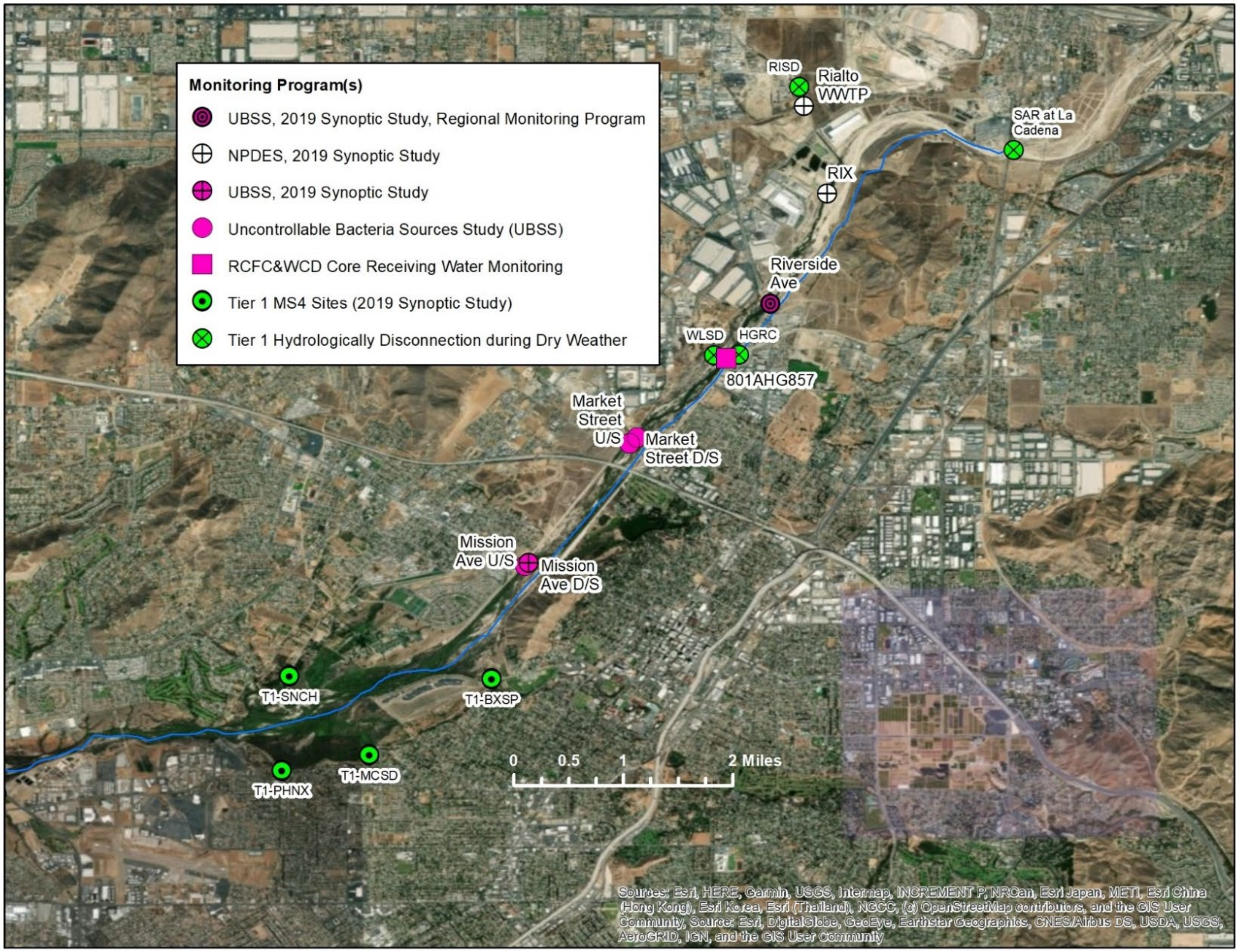

Figure 3-20. Map of Monitoring Locations in Santa Ana River Segment with No MS4 Discharges (UBSS = Uncontrollable Bacteria Sources Study)

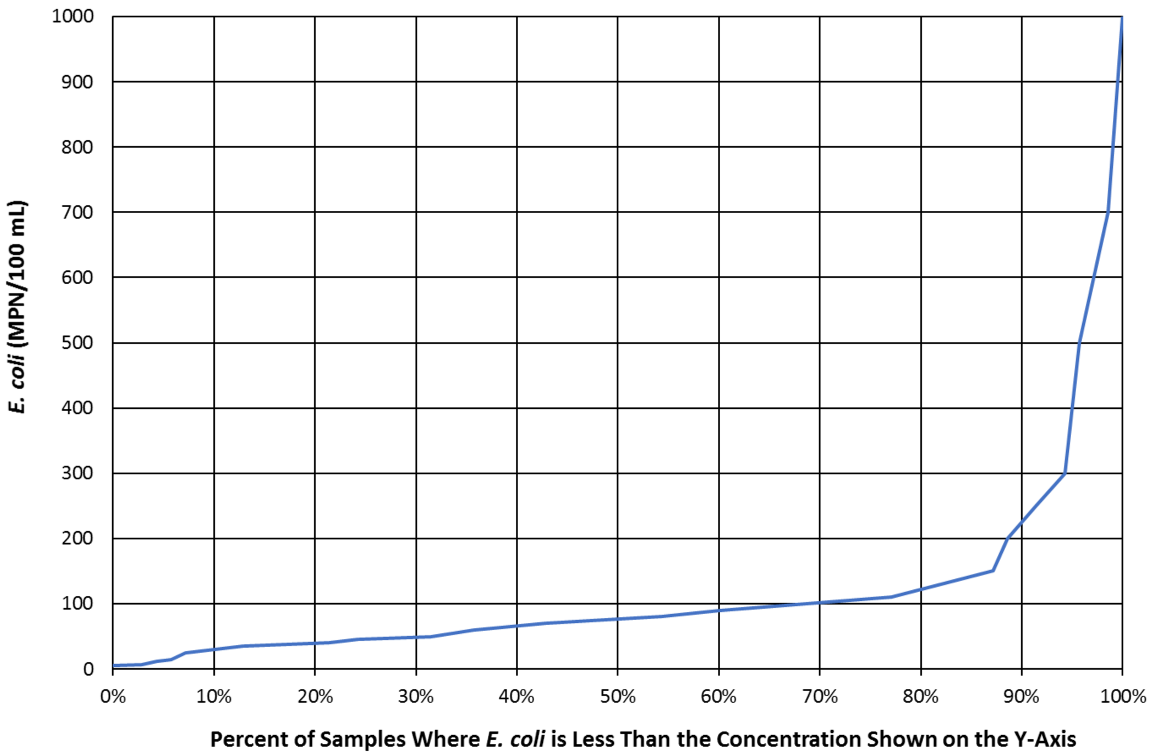

Figure 3-21. *E. coli* Concentrations in Santa Ana River Reach 3 Upstream of All MS4 Outfalls (based on pooled data from all sources)

During the Synoptic Study, Non-MS4 *E. coli* loads at the MISSION site averaged 307 billion MPN/day (ranging from 121 to 831 billion MPN/day), which is significantly greater than the total *E. coli* load from all MS4 inflows upstream of the WW-S1 location which average 55 billion MPN/day (ranging from 22 to 75 billion MPN/day). When the quantified non-MS4 load is accounted for in the source contribution analysis for WW-S1 (see Figures 3-12 and 3-13 above) over the six-week Synoptic Study, the following is apparent:

- Upstream *E. coli* sources (MS4 + non-MS4) more closely explain downstream observations;
- Majority of *E. coli* load comes from non-MS4 sources; and
- Weekly fluctuations in MS4 loads may not translate to measured differences within the Santa Ana River Reach 3 (**Figure 3-22**).

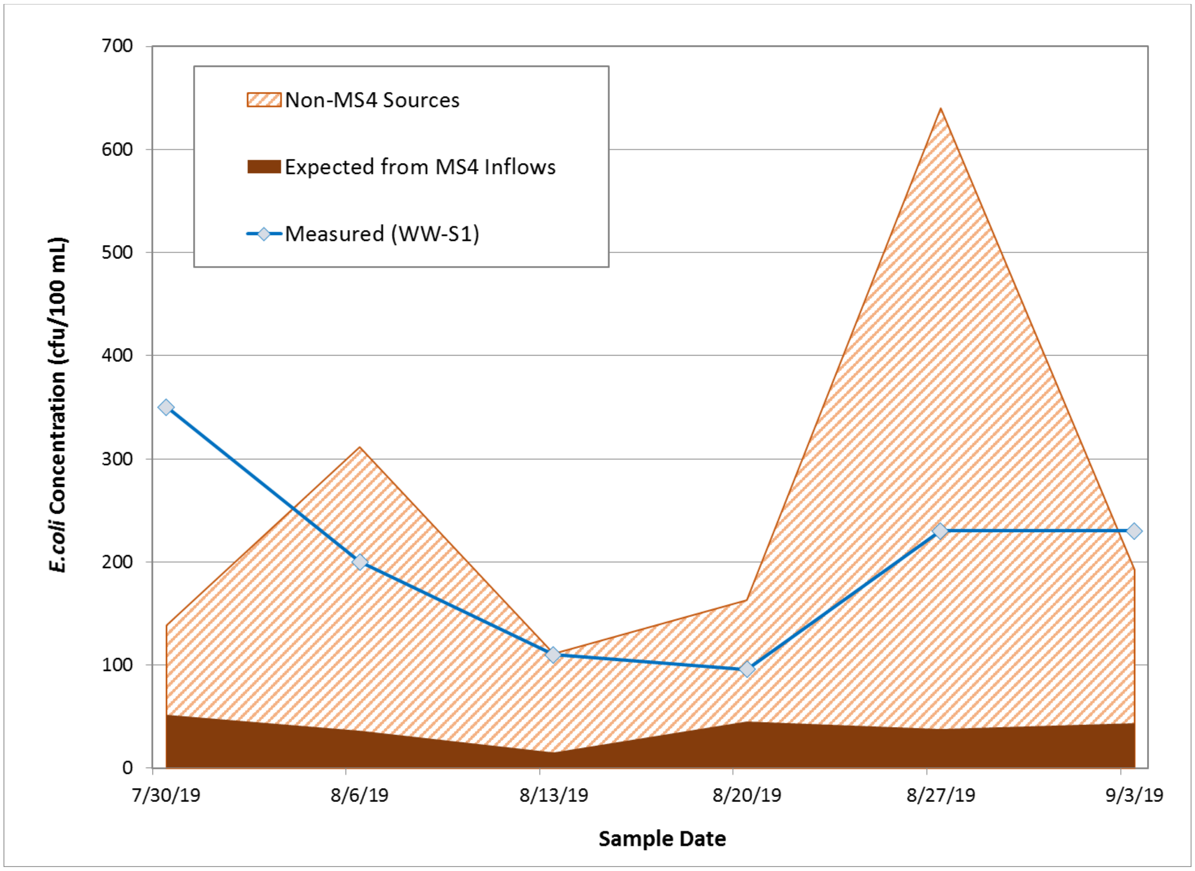

Figure 3-22. Comparison of Estimated Blended *E. coli* Concentrations of MS4 Inflows Plus Non-MS4 Inflows (at the MISSION site) with Downstream Watershed-wide Compliance Data at the Santa Ana River MWD Crossing Site

3.1.5.2 Role of Naturalized Bacteria Colonies

Fecal bacteria from a specific host released to the environment can settle to the channel bottom and survive within sediments or biofilms for weeks or months over a wide range of temperature and moisture conditions (Balzer et al 2010). Colonization by these initially deposited fecal bacteria within channel bottom sediments and biofilms results in colonies, where the majority of the population may be considered naturalized (Ishii et al. 2007; Byappanahalli et al. 2012; Ran et al. 2013). The 2015 Uncontrollable Bacteria Sources Study (RCFC&WCD 2016) found that fecal indicator bacteria in sediment or biofilms from Anza Channel, Eastvale Line E, and Sunnyslope Channel were 1-5 orders of magnitude higher than in overlying water, demonstrating that they may be able to integrate into existing sediment/biofilms and multiply – and thus, be a reservoir for indicator bacteria in the environment (**Table 3-5**). Per the Basin Plan, resuspension of bacteria from sediment and regrowth of bacteria in sediment/biofilms are uncontrollable sources of bacteria (Santa Ana Water Board 2016).

Table 3-5. *E. coli* Concentrations in Sediment/Biofilm and Overlying Water from Stormwater Channels in the MSAR Watershed (adapted from RCFC&WCD 2016)

Date	Anza Channel		Eastvale Line E		Sunnyslope Channel	
	Water (cfu/100 mL)	Sediment (cfu/100 g)	Water (cfu/100 mL)	Sediment (cfu/100 g)	Water (cfu/100 mL)	Sediment (cfu/100 g)
May 13, 2015	400	60,000	400	500,000	90	1,000
July 9, 2015	300	3,000	2,000	8,000	200	5,000
Oct 13, 2015	9	100,000	500	1,000,000	200	200,000
Jan 6, 2016	300	100,000	3,000	300,000	200	200

Processes including sloughing, desorption, and shearing can release bacteria from sediment and biofilms to the water column and may be just as important as factors that control colonization and growth (Litton et al. 2011). Shearing or scour of sediment particles has been identified as a source of bacteria to overlying water, generally in wet weather conditions when high flows mobilize the sediment (Byappanahalli et al. 2003; Jamieson et al. 2005; Reeves et al. 2003; Solo-Gabriele and Perkins 1997; Whitman and Nevers 2003). Scour events can also occur during dry weather conditions in the MSAR watershed, as evidenced by sharp increases in flow rate from de minimis discharges. Releases from naturalized colonies also occur under quiescent flow conditions by way of desorption and sloughing. The potential for such releases from colonies of *E. coli* to contribute to observed in-stream loads in the segment of the Santa Ana River during dry weather between the Rialto WWTP discharge and MISSION site was approximated. This approximation finds:

- The potential total population of naturalized *E. coli* in the top one centimeter (cm) of bottom sediments contained in this segment of the Santa Ana River is estimated to be 2,000 billion MPN based on a value of 2,000,000 MPN/kilogram (kg) of sediment/biofilm (see Table 3-5) multiplied by an approximated mass of 1,000,000 kg (68,000 m^2 * 0.01 meter of sediment * 1,500 kg/m^3 bulk density).
- The average in-stream load at the MISSION site of 300 billion MPN/day could be explained by a shedding rate of ~15 percent per day from the top cm of river bottom sediments. This in-stream load averaged over the wetted bottom of the Santa Ana River from the Rialto WWTP discharge downstream to Mission Boulevard (~ 4.25 river miles) amounts to approximately 50 MPN per square meter (m^2) of river bottom per second.

The above approximation is intended to assess the possibility that sloughing from naturalized colonies of *E. coli* may be of sufficient magnitude to account for measured loads at the MISSION site. The basis for this analysis involves the use of sediment concentrations from tributary sites and relies on planning level assumptions about the rate of sloughing from attached colonies during dry weather. Site specific data and analysis would be needed to estimate the actual, rather than the possible upper bound, of *E. coli* releases from sediment in the non-MS4 influenced reach of the Santa Ana River.

Another supplemental study in the Chino Creek watershed investigated the role of physical scour by collecting samples downstream of a large MW District water turnout (SBCFCD 2016). From June to August 2016, the MW District delivered water to Orange County Water District by using turnout OC59 within San Antonio Channel (at Baseline Avenue in the City of Upland) and wheeling the water down Chino Creek and through Prado Basin to Reach 2 of the Santa Ana River. The average DWF in Chino Creek downstream from the turnout increased from ~1 cfs to over 70 cfs over 92 consecutive days. SBCFCD collected water quality samples during five events at stations from the turnout site to the watershed-wide compliance site at Chino Creek at Central Avenue (WW-C7) (**Figure 3-23**).

Results showed that the MW District water entered San Antonio Channel essentially free of fecal bacteria, but this did not translate to significant dilution at the downstream watershed-wide compliance monitoring site at WW-C3. Instead, the longitudinal sampling suggests that a large in-stream fecal bacteria source exists, which may come from scour of naturalized colonies in the channel bottom. **Table 3-6** provides a simple enumeration of fecal bacteria load for the entire Chino Creek system during dry weather in the 2016 dry season. This analysis shows that more than 95 percent of the load at the watershed-wide compliance site likely originated from within the channel. This in-stream load of *E. coli*, theorized to be associated with shearing of natural colonies, is ten times the load approximated for sloughing related releases from the Santa Ana River bottom presented above.

Table 3-6. Source Contribution Analysis for *E. coli* Load in Chino Creek during the MW District Turnout in the 2016 Summer Dry Season (see Figure 3-23 for Site Locations)

Site	Distance to Turnout (mi)	Flow (cfs)	Concentration (MPN/100 mL)	Load (MPN/Day)
OC59	0	73.4	2	4.0
San Antonio Channel at Walnut	7	73.4	9	16.6
T1-CHINOCRK	7.7	0.5	256	3.3
T1-BRSC[1]	8.6	0.1	1205	3.8
T1-CCCH[1]	10.3	0.5	65	0.7
T1-LLSC[1]	11.4	0.003	522	0.03
Other In-Stream Sources[2]	N/A	N/A	N/A	519.1
Chino Creek at Central Avenue (WW-C7)	11.6	74.5	298	543.6

[1] Samples not collected during 2016 study; average flow rate/geomean concentration taken from 2019 Synoptic Study results

[2] Calculated load as difference between all upstream sources and downstream load at compliance site WW-C7

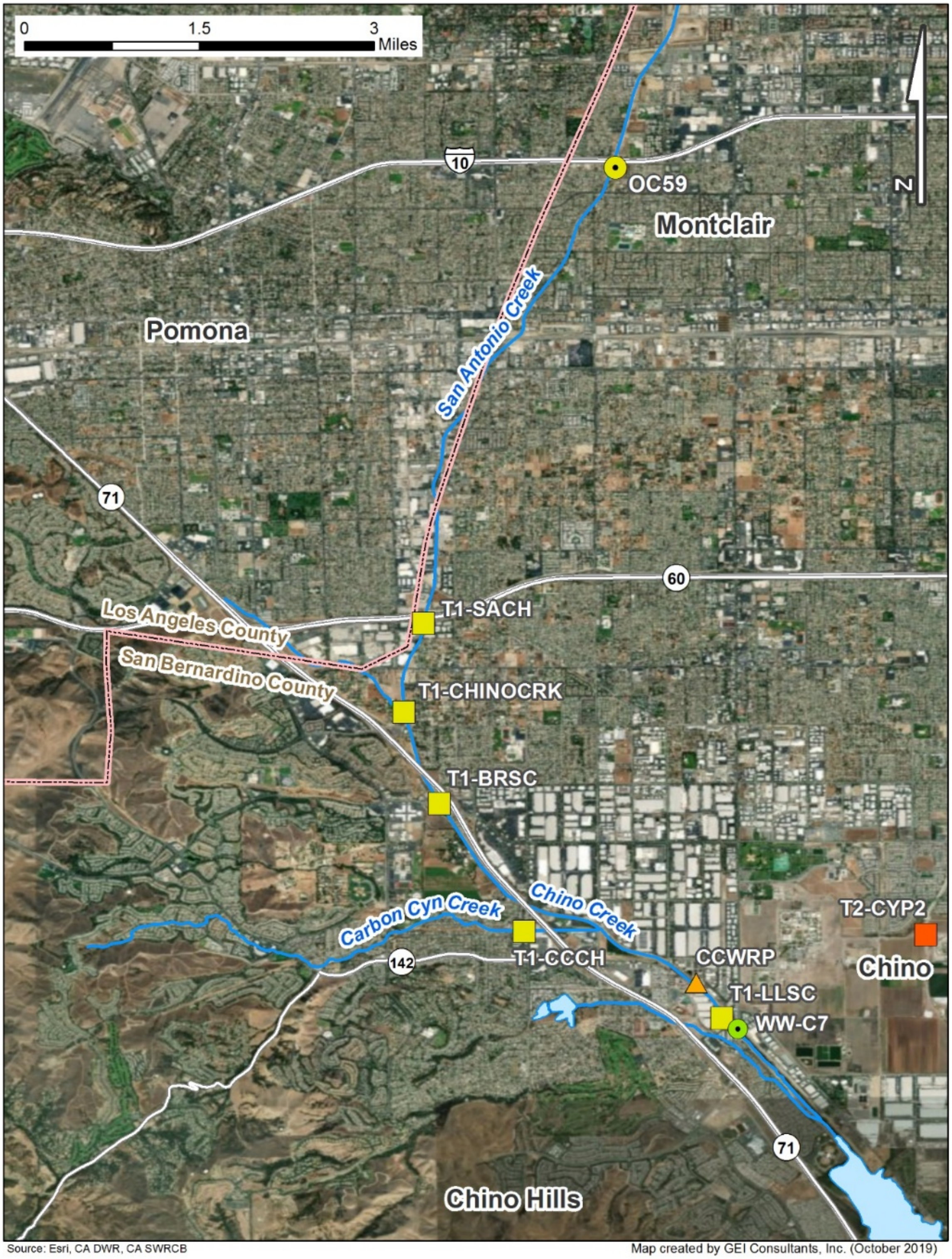

Figure 3-23. Water Quality Sample Collection Locations from San Antonio Channel, Chino Creek and Tributaries during the Summer 2016 MW District Turnout (Turnout at OC-59) (Also shown are nearby sites included in the 2019 Synoptic Study)

3.1.6 Tier 2 Hole Lake Site in Anza Drain Subwatershed

The Synoptic Study and previous source investigations have collected water quality monitoring data from within the ~10,000 acre area that drains to Santa Ana River Reach 3 via the Anza Drain (T1-ANZA). This drainage area captures DWF from the Arlington citrus area in its headwaters as well as a large portion of the City of Riverside MS4. The most downstream open channel segment (referred to as Hole Lake) has been an area where homeless encampments have been documented at high densities in recent years, ultimately leading up to a cleanup action on August 21, 2019.[19, 20] **Table 3-7** summarizes each sampling event, including the lead agency, period of sampling, and site locations. **Figure 3-24** illustrates the location of these sampling locations relative to the overall Anza Drain drainage area.

There are many potential types of fecal bacteria sources as well as subareas across the entire Anza watershed. Data collected in 2017-2019 build upon Tier 2 source evaluations performed during the 2013 and 2014 dry seasons (SAWPA 2017). **Table 3-8** summarizes the *E. coli* concentrations reported in 2017-2019. Where flow data were available,[21] these concentrations were converted into average *E. coli* loads (**Table 3-9**).

Table 3-7. Monitoring Conducted within the Anza Drain Subwatershed, 2017-2019

Lead Agency (Source)	Period of Sampling	Sites	Analytes
Task Force (Synoptic Study)	7/30/19 – 9/3/19	T1-ANZA, T2-HOLE	*E. coli*, *Bacteroides* HF183, flow rate, field parameters
City of Riverside Unpublished Data	5/30/19 – 7/3/19	T1-ANZA (RIV-4), RIV-3, T2-HOLE (RIV-2), RIV-1, RIV-5	*E. coli*, nutrients, flow rate, field parameters
Task Force (SAWPA 2018)	9/11/17 – 9/18/17	ARL-1, ARL-2, ARL-3	*E. coli*, *Bacteroides* HF183, flow rate, field parameters

[19] https://www.pe.com/2019/08/21/after-warnings-riverside-county-and-city-officials-dismantle-hole-lake-homeless-camp/

[20] Field notes from the sampling teams regularly documented the presence of homeless encampment activity in this subwatershed. After the cleanup action occurred on August 21, 2019 an increase in homeless encampment activity occurred downstream near the T1-ANZA.

[21] Continuous flow meters were deployed at the Arlington Greenbelt sites ARL-1, ARL-2, and ARL-3 (see Attachment D in SAWPA 2018). Field measurements of flow were collected at the time of sampling during the 2019 Synoptic Study for sites T2-HOLE and T1-ANZA.

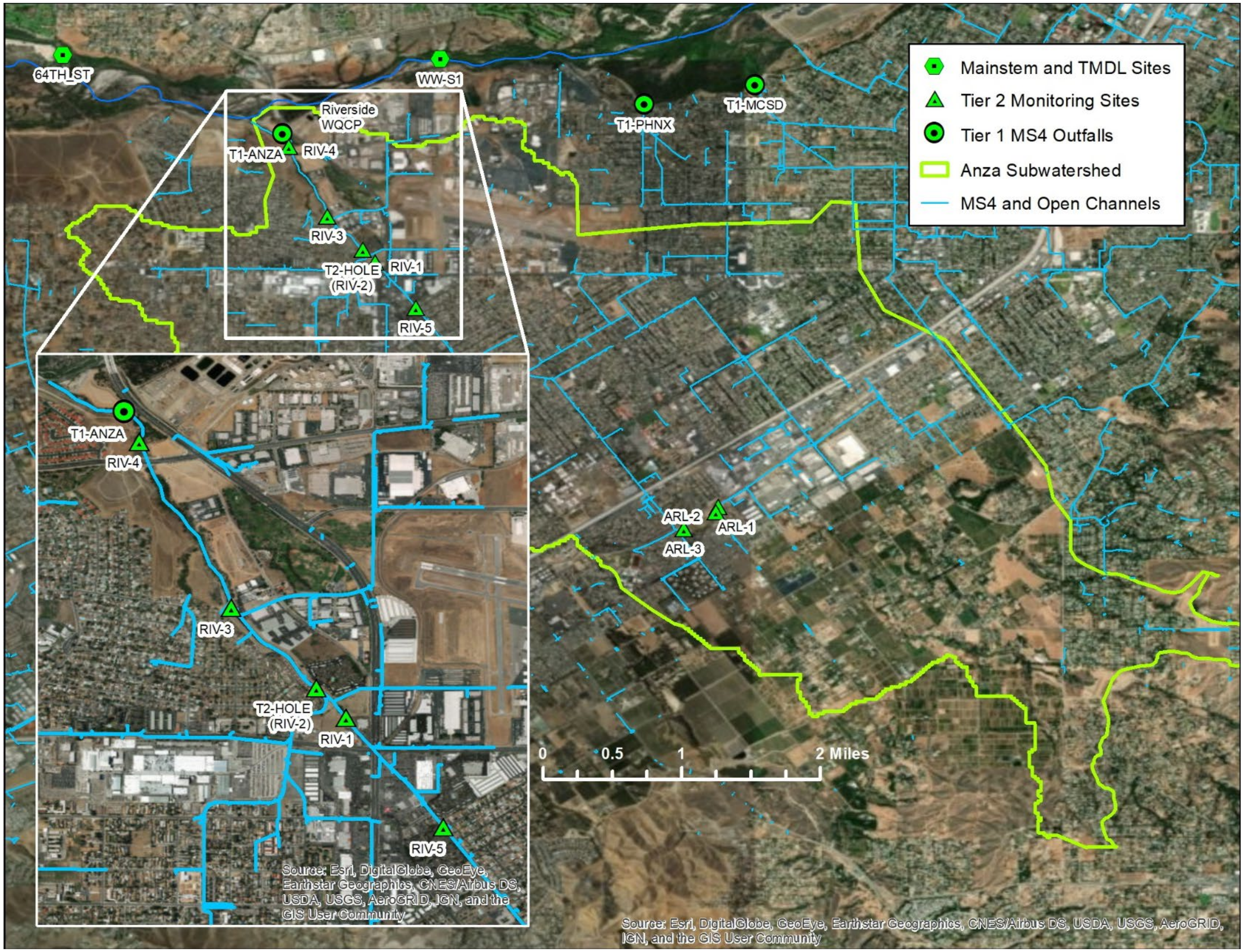

Figure 3-24. Monitoring Site Locations in the Anza Drain Watershed (2017-2019)

Table 3-8. *E. coli* Concentrations in Samples from Anza Drain Subwatershed in 2017-2019

Site	ARL-1	ARL-2	ARL-3	RIV-5	RIV-1	T2-HOLE (RIV-2)	RIV-3	T1-ANZA (RIV-4)
9/11/2017	1,600	490	520	--	--	--	--	--
9/13/2017	1,300	4,900	1,300	--	--	--	--	--
9/18/2017	13,000	1,600	1,900	--	--	--	--	--
5/30/2019	--	--	--	--	610	2,400	2,400	180
6/4/2019	--	--	--	--	870	770	820	240
6/12/2019	--	--	--	--	870	1,300	650	1,100
6/18/2019	--	--	--	--	2,400	150	820	150
6/25/2019	--	--	--	--	690	520	650	130
7/3/2019	--	--	--	68	1,600	920	920	410
7/30/2019	--	--	--	--	--	380	--	130
8/6/2019	--	--	--	--	--	770	--	200
8/13/2019	--	--	--	--	--	1,100	--	3,600
8/20/2019	--	--	--	--	--	770	--	320
8/27/2019	--	--	--	--	--	550	--	170
9/3/2019	--	--	--	--	--	780	--	74

Table 3-9. Average *E. coli* Load from Sites within the Anza Drain Subwatershed

Site	Number of Samples (n)	Average DWF (cfs)	Average *E. coli* Load (Billion MPN/Day)	Range of *E. coli* Load (Billion MPN/Day)
ARL-1	3	0.09	1.0	0.2 – 2.1
ARL-2	3	0.21	7.0	1.2 – 12.5
ARL-3	3	0.21	8.8	1.6 – 19.7
T2-HOLE	6	2.27	35.1	14.9 – 98.1
T1-ANZA	6	1.35	17.7	1.7 – 73.0

Key findings from the analysis of the pooled water quality data from the Anza Drain subwatershed include:

- The Synoptic Study dataset performed well in representing temporal variability as shown by deviations of less than five percent of six-week geomeans (n = 6) compared to pooled data (n = 12) when including samples from the City of Riverside in the 2019 dry season.
- Low level amplification of the *Bacteroides* HF183 human marker was found in one of six samples at the T1-ANZA and T2-HOLE sites during the Synoptic Study (see Section 3.2.2.4 below). The amplification did not occur on concurrent days at both locations; thus, it was found that the signal degraded prior to reaching the outfall. The HF183

human marker was observed at the downstream site with no evidence of an upstream MS4 source.[22]

- The total load from subwatersheds to Monroe Basin, including the Arlington Greenbelt and some MS4 areas (16.8 billion MPN/Day) is about half of the total load measured downstream of the Monroe Channel and Anza Drain confluence (35.1 billion MPN/day).
- In the 1.1-mile open channel segment downstream from T2-HOLE to T1-ANZA outfall, there is about a 50 percent reduction in *E. coli* load from naturally occurring decay.

3.2 *Bacteroides* Analysis

Elevated levels of FIB have been observed in waterbodies in the MSAR watershed; however, not all sources of bacteria are known. Regulatory agencies commonly assess the microbial river water quality by determining the concentration of FIB using culture-based assays for total coliforms, fecal coliforms and *E. coli*, because these assays are quick and economical. However, FIB measurements cannot determine whether the bacteria originate from human, animal, or natural sources (i.e., plants, sediments, etc.) (Litton et al. 2010). Understanding the sources and categories of FIB is important so that the various contributions of FIB can be determined and public health risks can be assessed (Soller et al. 2010, 2014).

3.2.1 Use of Microbial Source Tracking Techniques in the Synoptic Study

An important objective of the Synoptic Study was to use appropriate MST techniques to determine the extent to which human sources may or may not be contributing to elevated *E. coli* concentrations in the samples collected. The USEPA recommends use of MST techniques: (a) as a TMDL support tool; (b) for prioritizing impaired sites for remediation; (c) for evaluating BMPs; (d) as a tool to support stormwater discharge management; and (e) as an investigative tool to assess potential waterborne health risks (Shanks 2018). Consistent with USEPA, the analysis of human source bacteria for the Synoptic Study was done solely to provide information to support ongoing efforts to implement CBRP requirements to mitigate controllable sources of *E. coli*. The microbial source analysis provides no information regarding compliance with Basin Plan *E. coli* objectives to protect the REC1 beneficial use. Thus, any results from the Synoptic Study microbial source analysis are informational only and have no bearing on compliance with water quality objectives or TMDL WLAs.

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[22] Detections of the *Bacteroides* HF183 human marker were also measured in two of 21 samples tested in September 2017 and were of moderate magnitude both occurring on 9/18/17 (133 gene copies/100 mL at ARL-1 and 226 gene copies/100 mL at ARL-2) (SAWPA 2018). The source was not persistent and was not able to be related to downstream conditions because samples were not collected at the ANZA Drain Tier 1 location during the Arlington Greenbelt study.

Host-associated genetic markers that allow for the identification of human gut bacteria, *Bacteroides,* by qPCR have been widely used and recently approved by USEPA as standard method 1696 (USEPA 2019). This method, which targets the HF183 16S rRNA gene cluster of *Bacteroides*, was used in the Synoptic Study to determine the presence or absence and the relative concentration of the human-host *Bacteroides* HF183 marker (or human marker) in water or effluent samples collected during this study. The amplification of the HF183 gene in *Bacteroides* by qPCR is the process in which a single gene copy, or very low levels of the HF183 gene, is exponentially copied, resulting in over one million copies of the gene so that it can be detected in a sample.

To facilitate understanding of the findings from this study, the following section provides additional information regarding sample collection, laboratory analysis and data interpretation (also see the Study Plan and QAPP for the Synoptic Study for additional information; SAWPA (2019a,b). Data results are provided in subsequent sections.

3.2.2 Evaluation of the HF183 Human Marker at Synoptic Study Sites

As described above, water samples were collected from all study sites to determine (a) *E. coli* concentrations; and (b) the presence/absence and estimated concentration of the *Bacteroides* HF183 gene. The estimated concentration of the HF183 gene was achieved by verifying that each sample replicated during the reaction and that gene copies/reaction were estimated using calibration curves. The estimated concentration of the HF183 gene was calculated as described in standard method 1696 (USEPA 2019).

To improve the detection of the HF183 marker, a total volume of 200 mL was analyzed for all samples, except where noted in tables of results. Additionally, the standard curves for all qPCR reactions passed the acceptance criteria with amplification efficiencies in the range of 0.90 to 1.10 with $R^2 > 0.98$ (USEPA 2019). All qPCR reactions were run in triplicate, including field blanks. Both positive controls that contain reference DNA material and negative controls that contain no DNA material were run in triplicate for proper implementation of the qPCR assay to obtain high quality data. If low levels of the human marker was detected in any of the negative controls, as per the QAPP, a value was reported (USEPA 2019).

For the purposes of this study, a sample result was reported as not detected (ND) if the gene copy number was below the detection limit (DL) of the assay as defined by the approved method, i.e., 10 gene copies (gc)/2 microliters (µL); however, if the HF183 gene was amplified in any of the three replicates through acceptable laboratory procedures, then the HF183 gene was considered present and further quantified per appropriate methods even when the concentration of the gene was below the DL of 10 gc/2 µL. This conservative approach was applied to be more protective of public health because it reasons that low levels of HF183 genes could warrant further investigations, and because not all qPCR replicates will amplify when the HF183 gene copy number is at the DL or lower. However, while use of this conservative approach provides information regarding the potential need for additional investigation, it provides no information regarding compliance with water quality objectives or WLAs.

The above described approach of reporting low concentrations of HF183 genes has been consistently applied in other studies (Cao et al. 2017) and will be used here. Specifically, for the Synoptic Study, the frequencies and mean concentrations were reported using the following accepted approach (Cao et al. 2016):

- A positive sample is any sample in which the HF183 gene was amplified in any of the three qPCR replicates.
- A negative sample is a sample where the results are ND for the HF183 gene copies.
- Where results were below the DL but gene copies were determined to be present, the number of gene copies could be estimated through amplification and were included in mean calculations. This can occur in environmental samples when the measurement of gene copies is lower than the positive standard sample that can be reliably quantified. As described above, this increases the sensitivity of the assay.
- The mean concentration was calculated by summing the results (gene copies/reaction) from all positive samples and dividing by the total number of positive samples observed during the study. For this study, the mean concentration of gene copies is provided as a quantifiable estimation of the human host genes present that can be compared within a given site or over time. This is additional information that was used to prioritize sites; it has no implications towards compliance with water quality objectives or TMDLs.

3.2.2.1 *Bacteroides* HF183 Gene Concentrations in POTW Effluent Samples

The human marker HF183 gene was ND in all of the POTW effluent samples (**Table 3-10**). In these samples, the concentration of HF183 gene was too low to be amplified using the described qPCR assay (i.e., no Amplified Value is provided in Table 3-10). In a recently completed study in the MSAR watershed, Gedalanga et al. (2019) reported that the human marker HF183 gene was detected in all Santa Ana River samples (except on 10/26/2018 when an effluent sample was below detection for the HF183 gene). During the Gedalanga et al. study, the sensitivity for detecting the human marker was enriched by analyzing 1,000 mL of water. The findings of Gedalanga et al. (2019) are similar to those reported in previous studies by Bae and Wuertz (2009). In this latter study *Bacteroides* gene copies were detected in untreated influent, heat-treated influent, and UV-treated effluent samples collected directly from the University of California, Davis wastewater treatment plant using a different human-host specific gene, the BacHum gene, and 2,000 mL of sample. In contrast, Litton et al. (2010) reported that HF183 was below detection in three different effluent samples in which 2,000 mL of water was collected from the Riverside RWQCP discharge location.

Table 3-10. *Bacteroides* Human-host Specific Marker (HF183) Results for POTW Effluent Samples (ND = Below detection limit of assay, 10 gene copies/2 µL)

Site ID	7/30-7/31/19		8/06-8/07/19		8/13-8/14/19		8/20-8/21/19		8/27-8/28/19		9/03-9/04/19	
	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value
Rialto WWTP	ND	--	ND	--	ND	--	ND	--	ND	--	ND	--
RIX	ND	--	ND	--	ND	--	ND	--	ND	--	ND	--
Riverside RWQCP	ND	--	ND	--	ND	--	ND	--	ND	--	3ND	--
RP-1	ND	--	ND	--	ND	--	ND	--	ND	--	ND	--

The differences observed from analyzing effluent samples reported in the studies noted above and the findings from the Synoptic Study are likely due to the volume of water used for analysis. In the Synoptic Study, 200 mL of post-disinfected and chlorinated effluent samples were analyzed, whereas, in the reported studies above much greater volumes of water were processed for the analysis of the human marker (i.e., 1-2 liters).

3.2.2.2 *Bacteroides* HF183 Gene Concentrations at Watershed-wide and Mainstem Santa Ana River Sites

The human marker at the watershed wide compliance sites and other mainstem Santa Ana River sites was amplified at a frequency of 54.5% with a range of 0.6 to 100 copies of HF183 genes, with a mean concentration of 6.98 HF183 gene copies amplified (**Table 3-11**).[23] For the Chino Creek and Mill-Cucamonga sites, *Bacteroides* HF183 was only amplified in the last sample collected from each site (September 3). In contrast, *Bacteroides* HF183 was amplified during most sample events at mainstem Santa Ana River sites, but data results varied during the study. For example, during the week of July 29, most Santa Ana River sites were negative for the human marker, whereas, during the week of September 3 all sites were positive for the human marker, although at relatively low concentrations (see Table 3-11).

The human marker was detected at all mainstem Santa Ana River sites for at least one sampling event with the highest frequencies observed the last two weeks of the Synoptic Study (**Figure 3-25**). The highest numbers of copies/reaction were observed the week of August 12 with two sites showing results higher than the detection limit of 10 gc/2 µL. The highest observed result was at the Santa Ana River Mission Boulevard Bridge site (MISSION) during the week of August 12 (100 gene copies/reaction).

The MISSION results are of particular interest in this study, given this site does not receive any MS4 discharges during dry weather. The human marker was not amplified in any of the effluent samples analyzed from the Rialto WWTP or RIX, and these effluent discharges were the only known sources of flow at the MISSION site on the sampled dates (see also Section 3.1.5.1 regarding other sources of flow in this reach). Therefore, POTW and MS4 discharges *account for none* of the human bacteria at the MISSION site. A potential non-MS4 human source of bacteria in the area is homeless encampment activity. Field notes from the sample teams noted the presence of numerous homeless encampments upstream and downstream of the MISSION water quality sample site. Interestingly, while human source bacteria was detected at this site, at the same time *E. coli* concentrations were relatively low (97 MPN/100 mL), suggesting that the human source is not driving the *E. coli* levels.

[23] The mean concentration of gene copies is provided as a quantifiable estimation of the human host genes that can be compared within a given site or over time. This is additional information to prioritize sites and evaluate management practices but has no implications towards compliance with water quality objectives or TMDLs.

Table 3-11. *Bacteroides* Human-host Specific Marker (HF183) Results at Watershed-wide Compliance Sites and Other Non-Compliance Sites in the Mainstem Santa Ana River (ND = Below detection limit of assay, 10 gene copies/2 µL)

Site ID	7/30-7/31/19		8/06-8/07/19		8/13-8/14/19		8/20-8/21/19		8/27-8/28/19		9/03-9/04/19	
	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value
Santa Ana River Sites												
P3-SBC1 (Upstream)	ND	--	ND	--	ND	--	ND	--	ND	0.94	ND	1.68
MISSION	ND	--	ND	2.72	Detected	100	ND	1.38	ND	5.84	ND	3.76
WW-S1	ND	--	ND	2.05	ND	6.87	ND	2.41	ND	1.95	ND	4.33
64THST	ND	1.08	ND	2.01 (duplicate = 0.96)	ND	--	ND	1.02	ND	2.24	ND	2.49
WW-S4 (Downstream)	ND	--	ND	0.6	Detected	10.82	ND	--	ND	6.31	ND	0.96
Chino Creek and Mill-Cucamonga Creek												
WW-C7	ND	--	ND	--	ND	--	ND	--	ND	--	ND	1.89
WW-M6	ND	--	ND	--	ND	--	ND	--	ND	--	ND	3.21

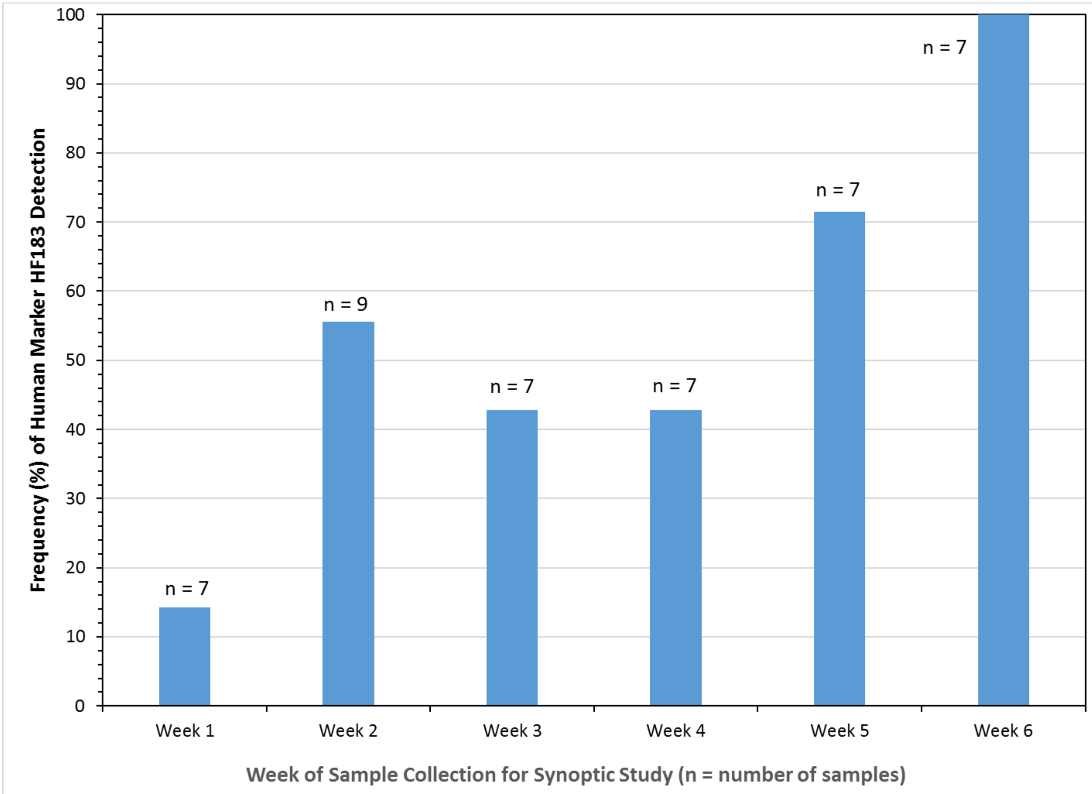

Figure 3-25. Frequency of *Bacteroides* Human-host Specific Marker (HF183) at Mainstem and Watershed-wide Santa Ana River Sites (see Table 3-10)

3.2.2.3 *Bacteroides* HF183 Gene Concentrations at Tier 1 Sites

For Tier 1 sites the human marker was amplified at a frequency of 30% with the amplified values ranging from 0.83-1,643.4 copies of HF183 genes (**Table 3-12**). For all Tier 1 sites the mean concentration was 168.4 HF183 gene copies. The human marker was amplified with the highest percentage of positive samples identified during the week of August 12 (week 3) and the lowest during the week of August 5 (week 2) (**Figure 3-26**).

The variability in both the human marker and *E. coli* concentrations across the Tier 1 sites is consistent with previous findings by Gedalanga et al. (2019) and Litton et al. (2010); however, these previous findings are based on studies in receiving waters and not an MS4. Variable results may occur because there are many different factors that influence bacteria concentrations and persistence of *Bacteroides* in surface waters including temperature, ultraviolet inactivation by sunlight, and predation by other microbial species (Kreader 1998; Bell et al. 2009; Boehm et al. 2018; Ahmed et al. 2019). It has been shown that *Bacteroides* can persist between 1-14 days in surface water depending on environmental conditions with an average of 3-4 days. Bell et al. (2009) demonstrated that *Bacteroides* can decay at a much slower rate at lower temperatures than at higher temperatures (i.e., 25 Celsius [°C]).

Table 3-12. *Bacteroides* Human-host Specific Marker (HF183) Results at Tier 1 and Tier 2 Sites (ND = Below detection limit of assay, 10 gene copies/2 µL)

Site ID	7/30-7/31/19		8/06-8/07/19		8/13-8/14/19		8/20-8/21/19		8/27-8/28/19		9/03-9/04/19	
	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value
T1-ANZA	ND	--	ND	--	ND	4.72	ND	--	ND (duplicate = ND)	--	ND	--
T1-BRSC	ND	1.2	ND	--	ND	1.7	ND (duplicate = 2.94)[1]	--	ND	9.84	ND	0.83
T1-BXSP	ND	8.07	ND	--	Detected	131.91	ND (duplicate = 7.71)[2]	7.52	ND	1.73	Detected	31.69[3]
T1-CCCH	ND	--	ND (duplicate = ND)	--	ND	--	ND	--	ND	--	ND	--
T1-CHINOCRK	ND	3.77	ND	--	ND	--	ND	--	ND (duplicate = ND)	--	ND	--
T1-CUCAMONGA	ND	--	ND	--	ND (duplicate = ND)	--	ND	--	ND	--	ND	2.76
T1-CYP	Dry	--	Dry	--	Dry	--	Dry	--	Dry	--	Dry	--
T1-DAY	ND	--	ND	--	ND	--	ND	--	ND	--	ND (duplicate = ND)	--
T1-LLSC	ND	--[4]	Dry	--	Dry	--	Dry	--	Dry	--	Dry	--
T1-MCSD	Detect	279.19	Detect	158.43	Detect	1643.36	Detect	281.02	Detect	951.71	Detect	499.82
T1-PHNX	ND	--	ND	--	ND (duplicate = ND)	--	ND	--	ND	--	ND	--
T1-SACH	ND	--	ND	--	ND	--	ND	--	ND	--	ND	--
T1-SNCH	ND	5.63	ND	--	ND	5.24	ND	4.09	ND	1.76	ND	--
T1-SSCH	ND	--	ND	--	ND	--	ND	1.35	ND	--	ND	--

Table 3-12. *Bacteroides* Human-host Specific Marker (HF183) Results at Tier 1 and Tier 2 Sites (ND = Below detection limit of assay, 10 gene copies/2 µL)

Site ID	7/30-7/31/19		8/06-8/07/19		8/13-8/14/19		8/20-8/21/19		8/27-8/28/19		9/03-9/04/19	
	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value	Result	Amplified Value
T2-CYP2	ND (duplicate = ND)[4]	--	ND	--	ND	--	ND	--	ND	--	ND (duplicate = ND)	--
T2-HOLE	ND (duplicate = ND)	--	ND	--	ND	--	ND	--	ND	1	ND	--

[1] Three blank replicate samples/reaction were run. One of the three replicates amplified at estimated concentration of 0.97 copies/reaction

[2] Three blank replicate samples/reaction were run. One of the three replicates amplified at estimated concentration of 0.37 copies/reaction

[3] Total volume analyzed was 150 mL instead of 200 mL

[4] Total volume analyzed was 100 mL instead of 200 mL

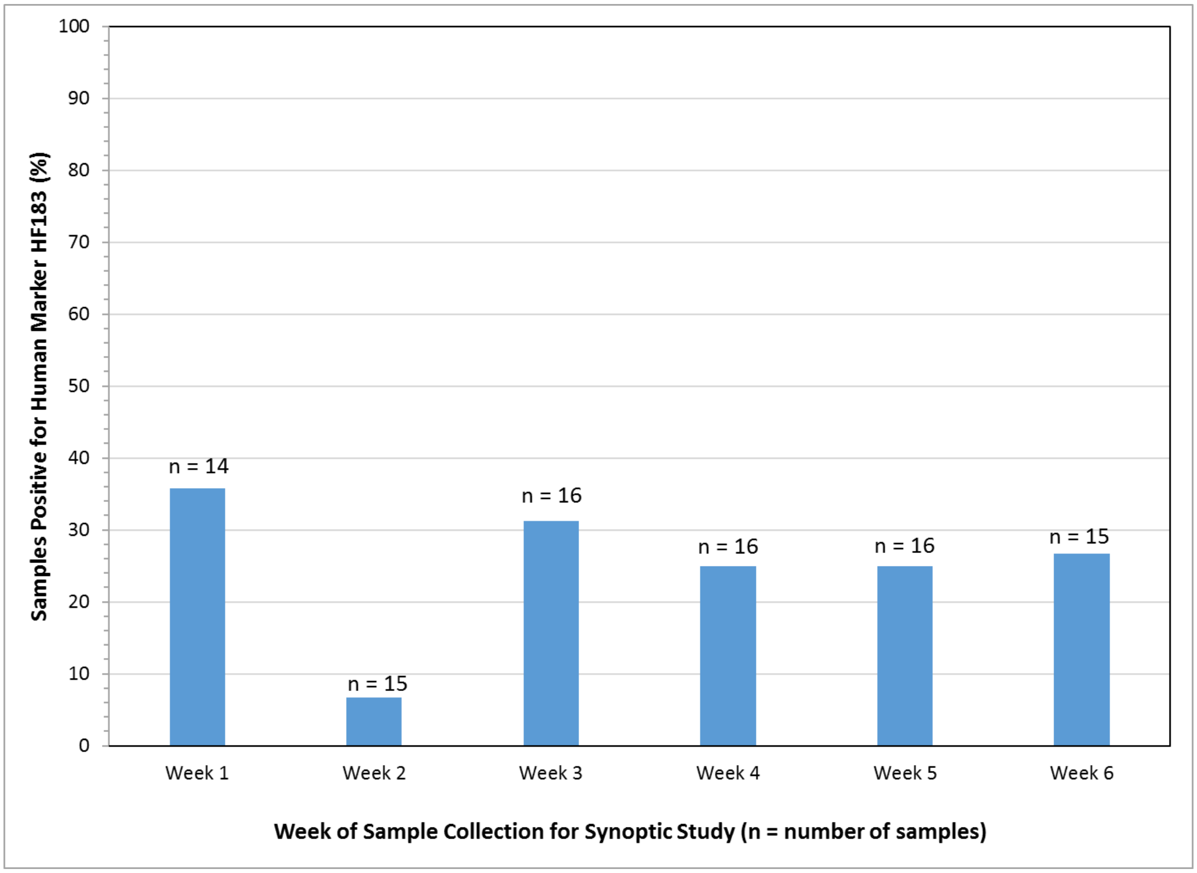

Figure 3-26. Frequency of *Bacteroides* Human-host Specific Marker (HF183) at Tier 1 Sites (see Table 3-12)

For this study, the frequency of the human marker was compared with water temperature at Tier 1 sites (**Figure 3-27**). However, no clear discernable relationship was observed from this data set. For example, relatively low temperatures were observed at Magnolia Center Storm Drain (T1-MCSD) and Sunnyslope Channel (T1-SNCH), but the frequency of the human marker was generally higher than other sites. At the site with the lowest observed temperature of approximately 20 °C (San Sevaine Channel, T1-SSCH), the frequency of human marker detection was also low (16.6%). Conversely, the frequency of the human marker at T1-ANZA was very low (10%) but the temperature was relatively high (23.8 °C). Therefore, the differences in the frequency of the human marker do not appear to be related to temperature, at least based on the available data set. Moreover, because the characteristics of each site vary and are complex (e.g., variable DWF, predation, dilution, decay rates, etc.), site-specific investigations would be necessary to further understand relationships between *Bacteroides* and *E. coli* and environmental factors in this watershed.

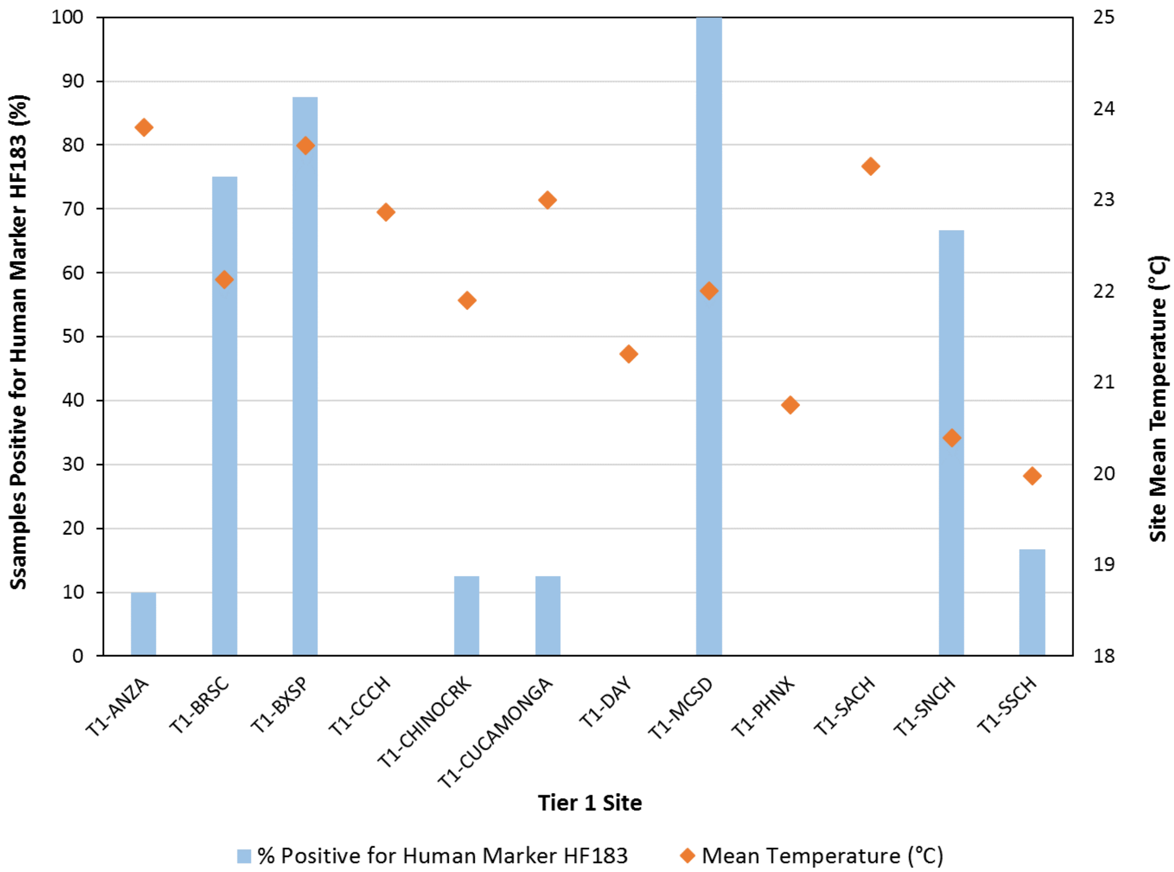

Figure 3-27. Frequency (%) of *Bacteroides* HF183 at Tier 1 Sites Compared to the Mean Water Temperature (°C) during the Synoptic Study

3.2.2.4 *Bacteroides* HF183 Gene Concentrations at Tier 2 Sites

The T2-HOLE site was included to isolate the *E. coli* load and evaluate the presence/absence of the human marker in the Hole Lake area upstream of the Tier 1 Anza Drain site (T1-ANZA). The T2-CYP2 site was included in the Synoptic Study to evaluate *E. coli* loads and human marker presence/absence in the City of Chino MS4 area upstream of the California Institute of Men agricultural fields. As shown in Table 3-12, the human marker was observed only once at T2-HOLE, during the sample event on August 27 (corresponding *E. coli* concentration was approximately 550 MPN/100 mL).[24] The HF183 human marker was not detected during any week of the study at the T2-CYP2 site.

[24] A large homeless encampment was removed in the area of this site on August 21. Even with that removal action, field notes indicate presence of tents upstream of this sample location and presence of people in the area.

3.2.3 Relationship between E. coli Concentrations and Bacteroides Detections

The relationship between human *Bacteroides* presence and *E. coli* concentration data shows the effectiveness of using the combination of bacterial indicators to assess potential health risks to recreational users. The *E. coli* data were divided into two datasets:

- *E. coli* concentrations of sample results where no HF183 human marker was amplified; and
- *E. coli* concentrations associated with sample results where an amplified value of the HF183 human marker could be estimated.

Figure 3-28 compares these datasets for (a) all Santa Ana River sites (Watershed-wide compliance and Mainstem River sites); and (b) all MS4 sites (Tier 1 and Tier 2). The difference in the stratified datasets was shown to be statistically significant (p value < 0.05) for MS4 sites (**Table 3-13**) but not for Santa Ana River sites (**Table 3-14)**.

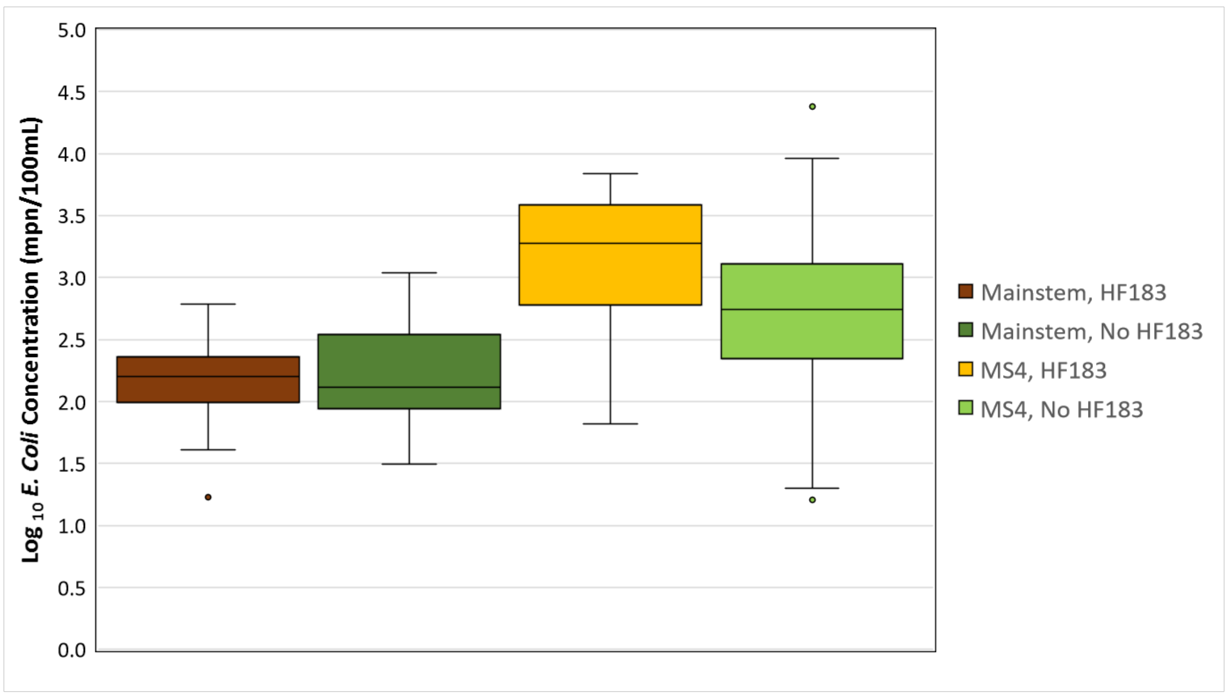

Figure 3-28. Box-Whisker Plots of *E. coli* Concentrations in Samples with/without Detection/Amplification of *Bacteroides* Human Marker HF183 for all MS4 Sites (Tier 1 and 2) and Santa Ana River Sites

Table 3-13. Student T-Test Results Comparing *E. coli* Concentrations in Samples with/without Detection/Amplification of *Bacteroides* Human Marker HF183 for all Tier-1 and 2 Sites

E. coli Data Set	n	*E. coli* Geomean (MPN/100 mL)	P-Value[1]
Human Marker HF183 Detected/Amplified	25	1,270	0.008*
Human Marker HF183 Not Detected or Amplified	61	509	

[1] Statistically significant, p-value < 0.05

Table 3-14. Student T-Test Results Comparing *E. coli* Concentrations in Samples with/without Detection/Amplification of Human Marker HF183 for Mainstem Samples

E. coli Data Set	n	*E. coli* Geomean (MPN/100 mL)	P-Value
Human Marker HF183 Detected/Amplified	23	142	0.932
Human Marker HF183 Not Detected or Amplified	19	157	

The geomean of *E. coli* concentration was approximately 250 percent greater in samples from MS4 sites where a human source was detected (Table 3-13). The findings from this analysis suggest that the presence of human sources may be an important factor that can impact the concentration and loading of FIB at MS4 outfalls. Conversely, the same analysis for the Santa Ana River samples did not show a statistically significant difference, most likely due to the low levels of the human marker relative to the total *E. coli* load in the river (Table 3-14), indicating that non-human sources are more likely to drive the *E. coli* load in the Santa Ana River. This same relationship has been evaluated and shown to have mixed results elsewhere (e.g., Ahmed et al. 2016).

The positive correlation between human marker presence and *E. coli* concentrations is clear for samples at Magnolia Center Storm Drain (T1-MCSD). Relatively high concentrations of the human marker were persistently amplified at the Magnolia Center Storm Drain site (T1-MCSD) where the mean concentration was 635.6 HF183 gene copies, with an estimated highest concentration at 1,636 copies/reaction. High *E. coli* concentrations corresponded with the high gene copy numbers at T1-MCSD, especially during the weeks of August 12 and August 27 when *E. coli* concentrations were 1,900 and 4,100 MPN/100 mL, respectively. Some exceptions to the correlation of human marker amplification and *E. coli* concentration do exist. For example, at the Phoenix Storm Drain site (T1-PHNX), high concentrations of *E. coli* were observed, but the human marker was consistently absent. A similar pattern was observed at San Sevaine Channel (T1-SSCH), where high concentrations of *E. coli* (> 1,000 MPN/100 mL) were routinely observed but the concentration of the human marker was absent in 5 of 6 samples and relatively low when amplified in Week 4 (1.35 gene copies/reaction).

3.3 Tier 1 Site Prioritization

3.3.1 Prioritization Analysis

Based on the findings from the Synoptic Study, Tier 1 sites were prioritized for further source evaluation activities. This is the third prioritization of Tier 1 sites since implementation of the TMDL began in 2007. Previous prioritizations were completed in 2009 (SAWPA 2009), following implementation of the first MSAR watershed TMDL-related studies in 2007-2008, and 2013, as an outcome of the 2012 Tier 1 source evaluation study (SAWPA 2013).

The 2019 prioritization update was performed on the complete set of Tier 1 sites (seven sites in Bernardino County and seven sites in Riverside County). The number of sites included in this study is significantly reduced from the 2012 Tier 1 source evaluation because more information was available to exclude persistently dry outfalls and because of the change in the Cucamonga Creek Reach 1 recreational use designation.

The prioritization methodology applied to this study differs from the approach previously used (SAWPA 2009, 2013). For this prioritization, the relative rankings of each site based on application of four criteria were used to create a composite ranking for Tier 1 MS4 outfall. These criteria included:

- *Criterion 1* - Average DWF generation rate (gal/ac/day) from the subwatershed that drains to the Tier 1 site. **Figure 3-29** illustrates DWF generation rates at each Tier 1 site over the study period. Days with no flow were included in the analysis as zeros.
- *Criterion 2* - Average *E. coli* loading (MPN/day) (previously based on *E. coli* concentration). **Figure 3-30** illustrates *E. coli* loads observed at each Tier 1 site over the study period.
- *Criterion 3* - Frequency of human *Bacteroides* HF183 amplification (based on percent of the total number of samples, including duplicates, where an amplified value could be estimated). **Figure 3-31** illustrates the frequency of HF183 *Bacteroides* marker amplification at each Tier 1 site.
- *Criterion 4* - Risk of exposure rating (low or high) with regards to recreation activity.

The first three criteria are computed from data collected during the six weeks of consecutive monitoring at each Tier 1 site from the week of July 28, 2019 through the week of September 1, 2019. For the risk of exposure criterion, each site was assigned either a low (0) or high score (100) based on the following principles, regardless of the degree of hydrologic connectivity observed during field visits:

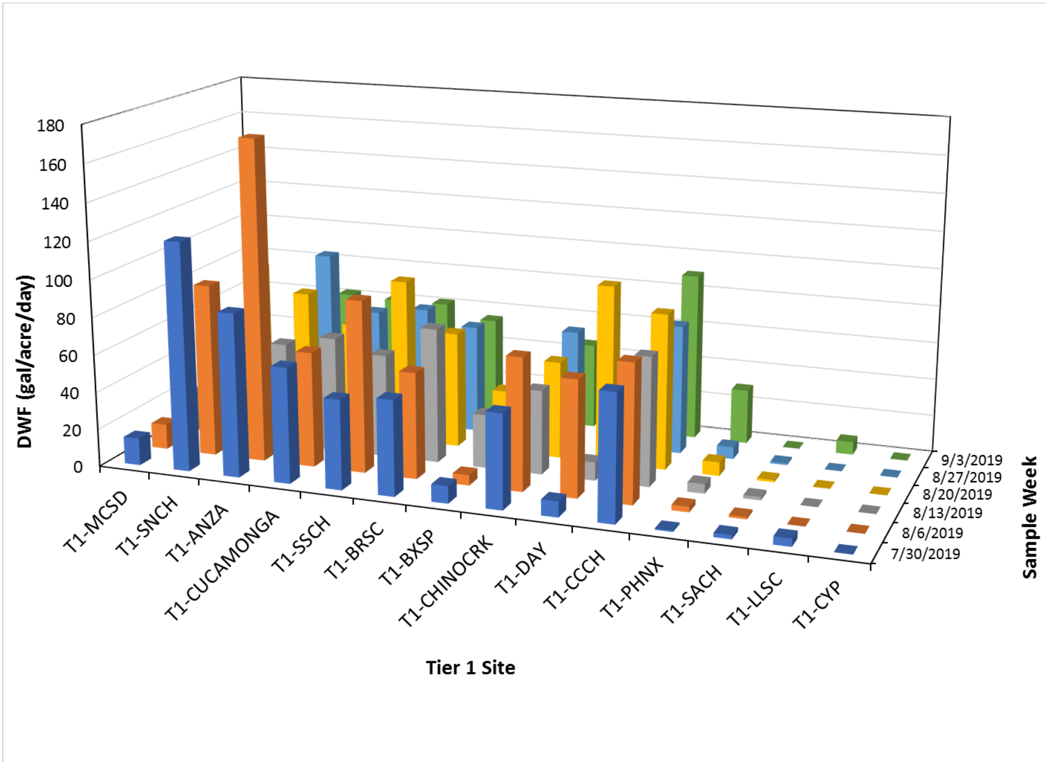

Figure 3-29. DWF Generation Rates (gal/acre/day) at Each Tier 1 Site on Each Sample Date

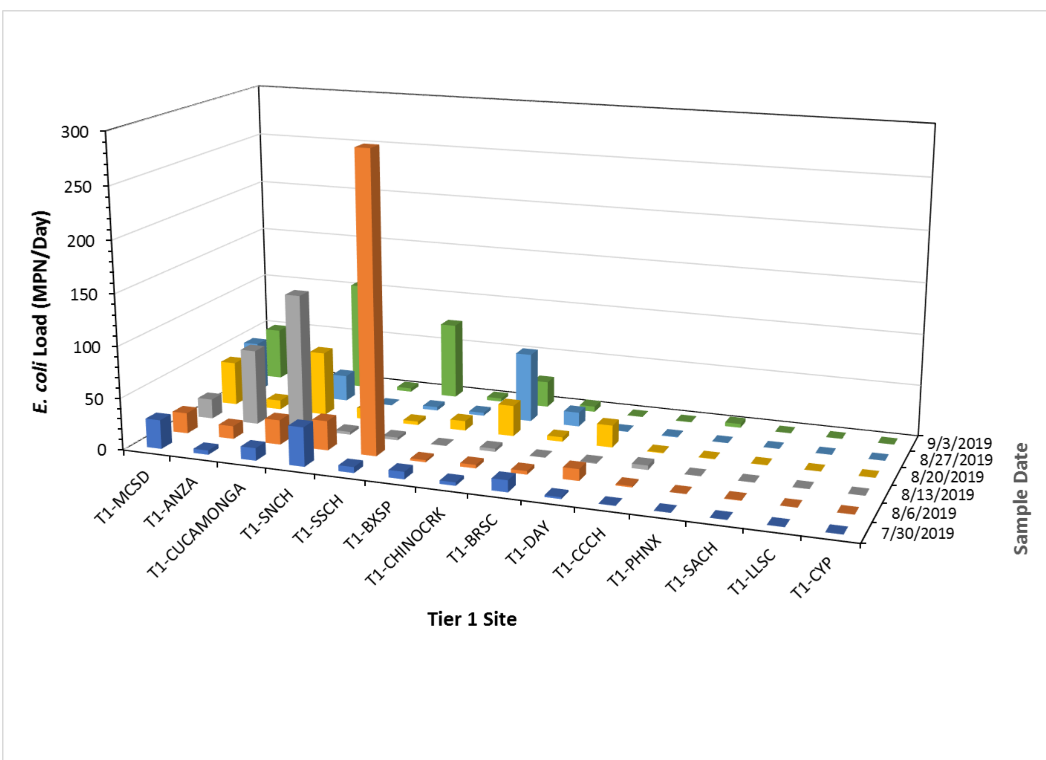

Figure 3-30. *E. coli* Load (MPN/Day) at Each Tier 1 Site on Each Sample Date

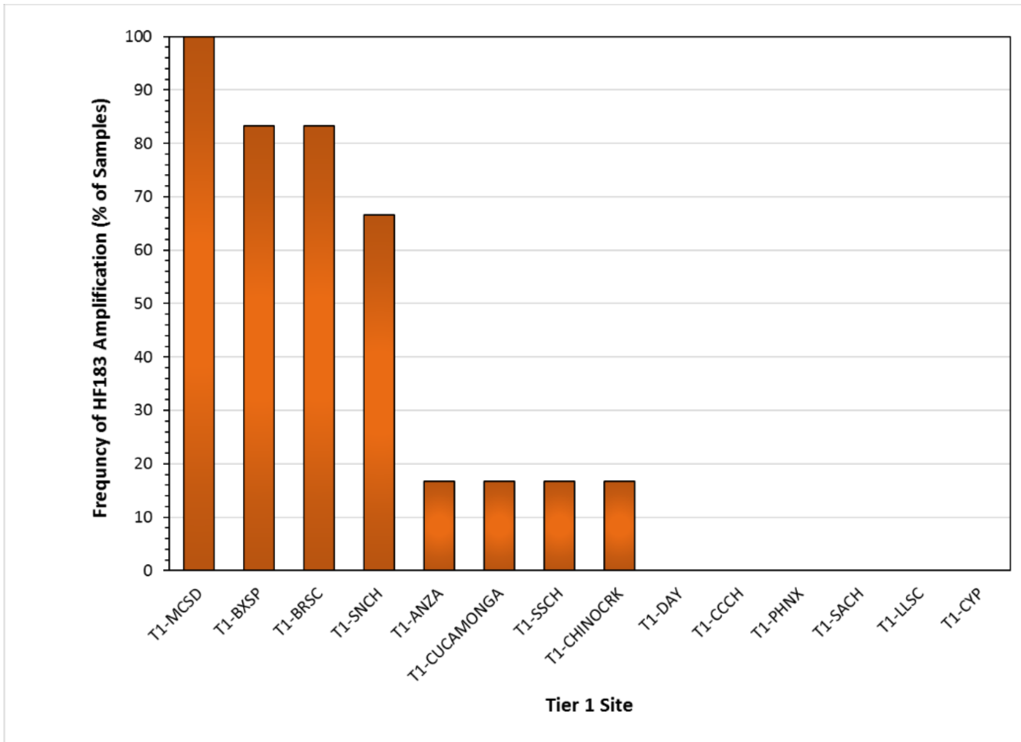

Figure 3-31. Frequency of HF183 Amplification (% of Total Samples) at Each Tier 1 Site

- *Low* – Completely concrete-lined MS4 channel that outfalls to a concrete-lined receiving waterbody segment.
- *High* – Natural channel characteristics are present anywhere within MS4 channel and/or the Tier 1 outfall discharges to a natural channel segment of a receiving waterbody.

The composite Bacteria Prioritization Score (BPS) was computed through completion of the following calculation/categorization activities:

- For Criteria 1 through 3, determine the relative rank of the site among the 14 Tier 1 sites. This ranking was determined by (a) calculating the average value of the criterion at each site over the six-week sample period; and then (b) normalizing the relative rank of the range of observed average values to a range of 0 to 100. Normalization is done by applying the PERCENTRANK function in Excel to the range of average values observed at all Tier 1 sites. For example, the average DWF (gal/ac/day) at the 14 sites ranged from 0 to 91. Applying the PERCENTRANK statistical function normalizes the range to 0 to 100 with the site with a 91 gal/ac/day given a rank value of 100 and the dry site with 0 gal/ac/day given a rank value of 0.
- For Criterion 4 (risk of exposure), sites with high risk (sites with at least some natural characteristics) were given a relative rank of 100 and sites with low risk (concrete-lined, engineered sites) are given a relative rank of 0.

- To calculate the composite BPS for each site, weighting factors were applied as multipliers to each of the four criteria:
  - Criterion 1: DWF generation rate = 0.3 (30% weight)
  - Criterion 2: Average *E. coli* load = 0.3 (30% weight)
  - Criterion 3: Frequency of *Bacteroides* HF183 detection = 0.3 (30% weight)
  - Criterion 4: Risk of exposure = 0.1 (10% weight)

The composite BPS for each Tier 1 site is computed as the sum-product of the rank value of each criterion multiplied by the appropriate weighting factor (see above), e.g., BPS = [(Criteria 1 * weighting factor) + (Criteria 2 * weighting factor) + (Criteria 3 * weighting factor) + (Criteria 4 * weighting factor)]. The resulting score is rounded to the nearest whole number. For example, the BPS score for the T1-MCSD site is calculated as follows:

$$BPS = [(38 * 0.3) + (85 * 0.3) + (100 * 0.3) + (100 * 0.1)] = 76.9 \text{ or } 77$$

Table 3-15 provides the normalized ranked scores for each criterion for each site and the resulting composite BPS score (right hand column). **Figure 3-32** categorizes the sites as high (BPS score = 67-100; red), Medium (BPS score = 34-66, yellow) or Low (BPS score = 0-33, green) priority. **Figure 3-33** shows the locations of the prioritized Tier 1 subwatersheds in the MSAR watershed.

3.3.2 Changes in Tier 1 Site Prioritization Over Time

The 2019 Synoptic Study results are compared to outcomes from previous prioritization analyses completed for the Riverside and San Bernardino MS4 Programs CBRPs (RCFC&WCD 2011; SBCFCD 2011) and 2013 Triennial Report (SAWPA 2013) (**Table 3-16**). Sites categorized as high priority in 2019 are substantially different from previous analyses. Changes in the prioritization may be attributed to effective CBRP implementation in some subwatersheds (e.g., T1-BRSC, Boys Republic South Channel) or issues that have arisen from potentially new bacteria sources in other subwatersheds (e.g., T1-MSCD, Magnolia Center Storm Drain). Other considerations that affected the changes in prioritization included:

- Transition of all sites upstream of Cucamonga Creek at Hellman (T1-CUCAMONGA) from Tier 1 to Tier 2 sites (result of removal of REC1 beneficial use on Cucamonga Creek upstream of Hellman Avenue);
- Exclusion of sites downstream of any watershed-wide compliance monitoring location in the Synoptic Study design; and
- Differences in the prioritization methods over the three independent analyses (e.g., use of bacteria load instead of concentration and consideration of potential area contributing to DWF rather than just the average DWF rate).

Table 3-15. Relative Rank Results for each Prioritization Criterion and the Final Composite Score for each Tier 1 Site (see discussion in text regarding use of weights)

Tier 1 Site	Relative Rank (0 to 100) for Prioritization Criteria				Composite BPS
	Criterion 1 DWF (gal/acre/day) Weight = 0.3	Criterion 2 *E. coli* Loading (MPN/Day) Weight = 0.3	Criterion 3 *Bacteroides* Amplification Frequency (%) Weight = 0.3	Criterion 4 Risk of Exposure Weight = 0.1	
T1-MCSD	38	85	100	100	77
T1-SNCH	77	62	67	100	72
T1-ANZA	100	69	17	100	66[1]
T1-CUCAMONGA	69	92	17	100	63
T1-SSCH	85	100	17	0	60
T1-BRSC	62	54	83	0	60
T1-BXSP	31	38	83	100	56
T1-CHINOCRK	54	77	17	0	44
T1-DAY	46	46	0	100	38
T1-CCCH	92	31	0	0	37
T1-PHNX	23	23	0	100	24
T1-SACH	8	15	0	0	7
T1-LLSC	15	8	0	0	7
T1-CYP	0	0	0	0	0

[1] Given the closeness of this score (66) to the high priority category (67-100), this site was categorized as high priority.

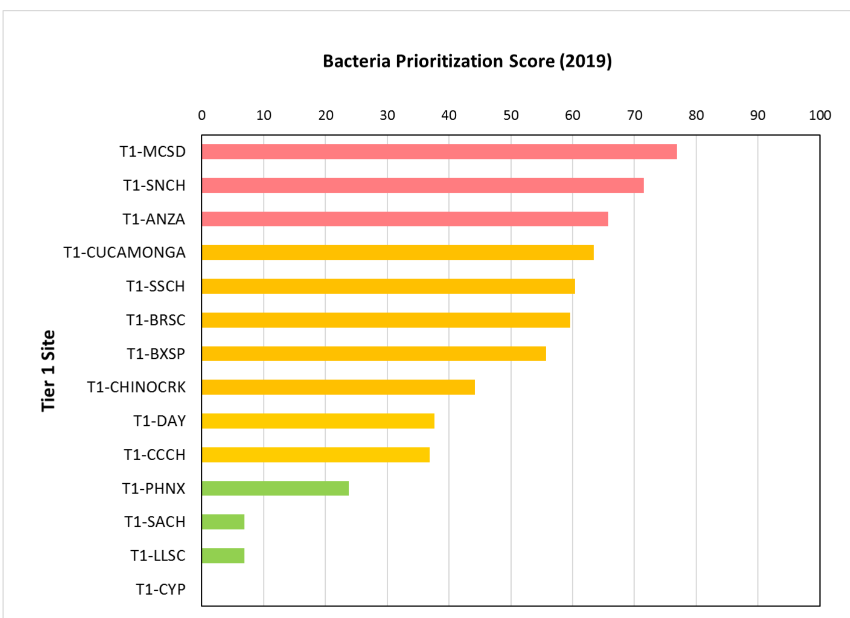

Figure 3-32. Bacteria Prioritization Score for Tier 1 MS4 Outfalls. Red – High Priority; Yellow – Medium Priority; Green – Low Priority (Note: T1-CYP was dry for the entire study period)

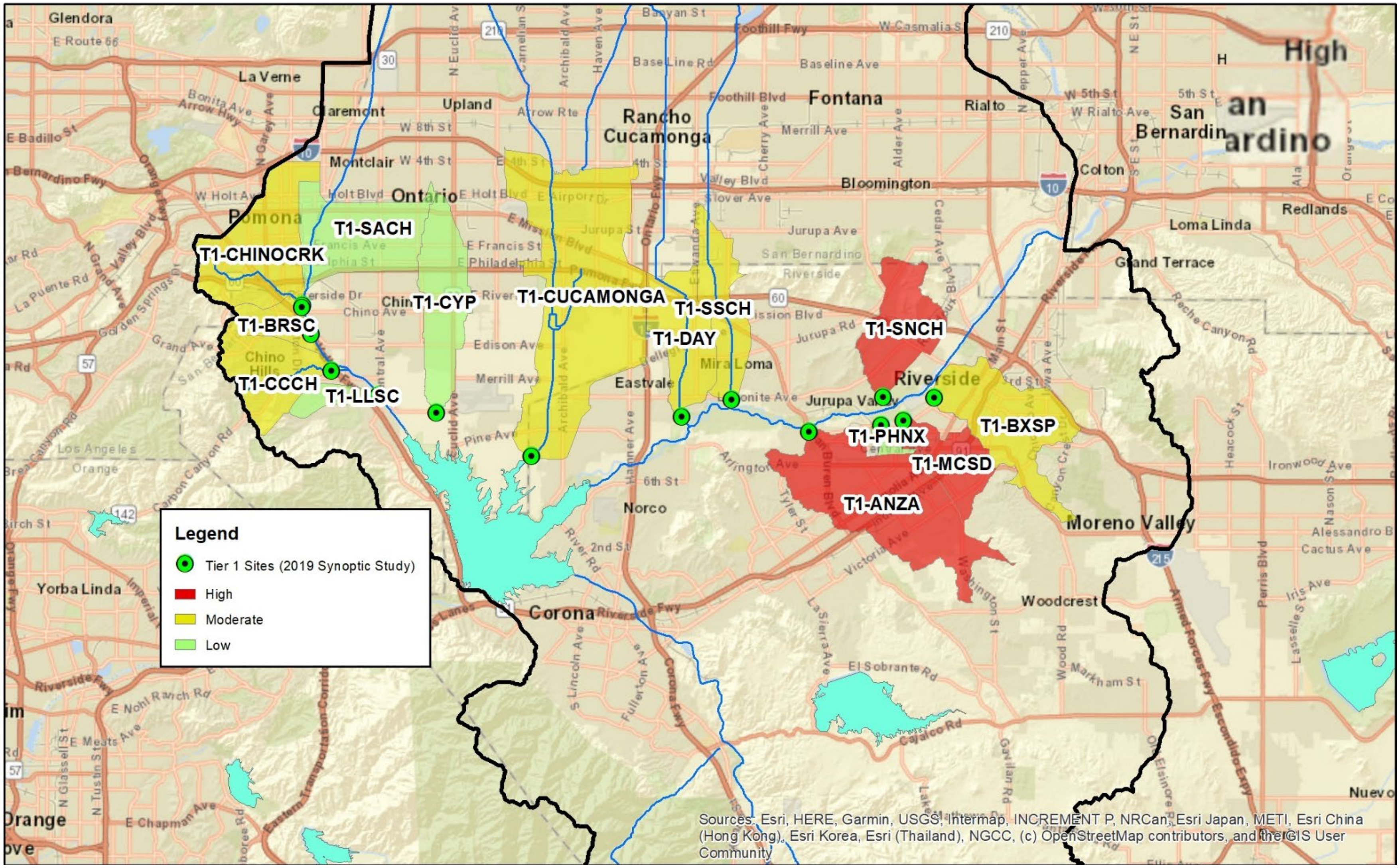

Figure 3-33. Location of High, Medium and Low Priority Tier 1 Sites in the MSAR Watershed Based on Updated Prioritization Analysis

Table 3-16. Changes to Prioritization Category for Tier 1 Subwatersheds Since TMDL Implementation Initiated in 2007 (NM = Not Measured; Dry = Sites estimated to be hydrologically disconnected during dry weather)

Tier 1 Site	Prioritization Outcome		
	CBRP[1] (Based on 2007-2008 Data)	2013 Triennial Report[2] (Based on 2012 Data)	2019 Synoptic Study Findings
T1-MCSD	NM	Low	High
T1-SNCH	Low	Low	High
T1-ANZA	Low	High	High
T1-CUCAMONGA[3]	NM	NM	Medium
T1-SSCH	Medium	High	Medium
T1-BRSC	NM	High	Medium
T1-BXSP	High	Low	Medium
T1-CHINOCRK	NM	High	Medium
T1-DAY	Medium	Low	Medium
T1-CCCH	Low	Low	Medium
T1-PHNX	NM	Low	Low
T1-SACH	Medium	Low	Low
T1-LLSC	NM	Low	Low
T1-CYP	Medium	High	Low (Dry)
T1-EVLD[4]	NM	High	NM
T1-EVLE[4]	NM	High	NM
T1-EVLB[3]	NM	High	NM
T1-EVLA[3]	NM	High	NM
US-TEMESCAL[5]	Low	NM	NM
T1-CHRIS[3]	High	High	NM
T1-CLCH[3]	High	Low	NM
T1-CFRN[3]	NM	Low	NM
T1-CNRW[3]	NM	Low	NM
T1-SR60[3]	Low	Low	NM
T1-CAPT[3]	NM	High	NM
T1-YRBA	NM	Low	NM
T1-PPLN	NM	Low	NM
T1-CYP	Medium	High	Dry
T1-WLSD	NM	Low	Dry
T1-WCUC[3]	NM	Low	Dry
T1-64ST	NM	Dry	Dry
T1-CBLD[5]	NM	Dry	Dry
T1-CREST	NM	Dry	Dry
T1-EVAN	NM	Dry	Dry
T1-IDST	NM	Dry	Dry
T1-RBDX	NM	Dry	Dry
T1-RISD	NM	Dry	Dry

[1] RCFC&WCD 2011; SBCFCD 2011
[2] SAWPA 2013
[3] Re-categorized as Tier 2 after REC1 use removed from Cucamonga Creek Reach 1 (see text)
[4] Dry weather diversion project in development for T1-EVLD/T1-EVLE; thus, sites not included in Synoptic Study
[5] Site is not downstream of a watershed-wide compliance monitoring site; not measured in the Synoptic Study

3.3.3 Mitigation Activities at High Priority Tier 1 Sites

The findings from previous prioritization analyses have provided the basis for the development and implementation of BMP projects in the subwatersheds with the highest priority rankings. Examples of project completed, ongoing or planned include:

- The Mill Creek Wetlands was completed in 2014 in the Cucamonga Creek subwatershed. The 52-acre facility was designed to regionally divert and treat up to 15 cfs of existing dry- and wet-weather flows in Cucamonga Creek. The completed project also provides 147 acre-feet of extended detention basin treatment capacity for stormwater runoff from urban developments in the area of the wetlands. In addition to improving water quality in Mill-Cucamonga Creek, the project also serves as a multi-benefit project that facilitates groundwater recharge, provides wildlife habitat and enhances recreational opportunities.
- The City of Riverside in collaboration with RCFC&WCD continues to develop the Phoenix Avenue Storm Drain (T1-PHXN) DWF diversion project to reduce *E. coli* loads to the Middle Santa Ana River. The planned project will divert up to one cfs of DWF into a nearby sewer line. This project is the first stormwater-diversion-to-sewer project in Riverside County and will serve as a pilot project for potential future DWF diversion projects to support compliance with the MSAR TMDL. The project is currently at the 60% design level with the goal to implement construction in 2020.
- A DWF alternatives analysis completed for T1-EVLD and T1-ELVE determined that the most effective solution to mitigate DWF in these storm drains is to divert the flow to the Jurupa Community Services District (JCSD). RCFC&WCD has completed water quality monitoring required to determine if diverted DWF would meet JCSD water quality acceptance criteria. Coordination with JCSD on this project is continuing.
- SBCFCD developed a plan to modify the flowline through Chris Basin from straight-line (inlet to outlet) to meandering. The project will create berms that force DWF to traverse the basin floor more slowly, increasing the potential for bacteria to degrade before discharging to Cucamonga Creek. The plan to modify the floor of Chris Basin triggered numerous environmental regulatory requirements that must be satisfied before the project can be implemented. Final environmental regulatory approvals (e.g., CWA Section 404, 401, and CDFG Section 1600) are anticipated within calendar year 2020. Implementation of basin floor modifications will follow once environmental regulatory approvals are received.

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4. Findings and Recommendations

Considering the results from the Synoptic Study and other work completed in the MSAR watershed to date, this section provides key findings and recommendations for next steps by the MSAR Task Force or MS4 Permittees.

4.1 Synoptic Study Findings

Taking into account the body of research related to TMDL implementation that has been completed to date in the MSAR watershed, key findings include:

- The MS4 Programs met the CBRP goals to significantly reduce DWF to the waterbodies named in the TMDL, e.g.:
  - The MS4 Programs have hydrologically-disconnected the majority (66%) of the upper MSAR watershed during dry weather conditions through infiltration in unlined flood control channels, retention basins, and other flow diversion projects. These areas no longer cause or contribute to exceedances of the water quality objectives for pathogen indicator bacteria (evaluated as concentrations of *E. coli*) in the downstream receiving waters during dry weather conditions.
  - Long-term monitoring data shows DWFs from MS4 conveyance facilities are substantially lower continuing a downward trend that has been observed since 2007 (the first year of TMDL implementation).
  - The City of Claremont has effectively eliminated dry weather runoff from its jurisdiction and is no longer causing or contributing to downstream exceedances.
- With the exception of the Chino Creek subwatershed, the MS4 Programs also met the bacteria load reduction goals established in the CBRPs as necessary to assure compliance with the bacteria concentration targets established by the TMDL (in fact, bacterial loads were reduced from MS4 inflows to the Santa Ana River much more than was required by the CBRP). For Chino Creek, the MS4 Programs have achieved approximately 80% of the estimated bacteria load reduction needed to assure compliance with the bacteria concentration targets established by the TMDL.
- At Prado Park Lake a major engineering project has been completed that repaired and restored the MS4 conveyance system so that it properly bypasses the lake. Data from the watershed-wide compliance site at Prado Park Lake shows that water quality at this site often meets the TMDL *E. coli* targets. When sufficient data have been collected to demonstrate consistent long-term compliance, this site should be considered for de-listing. If not delisted when the MSAR TMDL is revised, no dry weather WLA should be assigned to the MS4s for this waterbody, because no DWF is discharged to this waterbody from an MS4.

- Unidentified non-point sources now account for the majority (77%) of the total bacteria load in the Santa Ana River. As has been demonstrated, based on source analyses completed in 2007, 2012, and now 2019, the Santa Ana River would be in compliance with the TMDL targets and the state's new water quality standards for pathogen indicator bacteria were it not for the excessive loads from these unknown non-point sources which are not conveyed through the MS4.
- Sampling data from Reach 4 of the Santa Ana River shows that bacteria loads from unknown non-point sources contribute about 300 billion MPN/day, which is enough to consume nearly 100% of the total allowable load for *E. coli* bacteria in the receiving water.
- Examples of de minimis discharges within the MS4 network continue to be evident in the watershed. During just the six-week study we observed DWF volume anomalies at two locations (San Antonio Channel and Anza Drain).
- Quantification of the load of HF183 gene copies in the MS4 provides insight into the extent of human fecal contamination from MS4 sources. The maximum measured load of HF183 from a Tier 1 MS4 site (8,282 gc/day in Week 3 from T1-MCSD) may be associated with approximately 1.5 grams/day of human feces (HF) based on pooled data from multiple studies translating gene copies of HF183 to mass of HF (Ahmed et al. 2016). Thus, a small amount of HF contamination can cause HF183 amplification downstream and contribute to a sharp rise in fecal bacteria concentrations at MS4 outfalls. This finding is important because it shows that source tracking and elimination of isolated cases of HF contamination can be highly effective in improving water quality at MS4 outfalls in the MSAR watershed. Evidence of this has been reported following prior Tier 2 investigations conducted by MS4 Permittees.
- The maximum load of HF183 from within the mainstem of the Santa Ana River (69,727 gc/day in week 3 from MISSION) is eight times greater than the maximum load of HF183 measured at any of the Tier 1 MS4 outfalls. This much larger human fecal load at the MISSION site was demonstrated to be entirely associated with a source that does not originate from within MS4 drainages, nor could it be attributed to non-viable genetic material from POTW effluent. This finding is important because efforts to mitigate sources of *E. coli* bacteria within MS4 jurisdictions alone will not be enough to attain the *E. coli* water quality objectives at downstream watershed-wide compliance sites.
- There appears to be lower (less frequent and smaller magnitude) human signal present in 2019 compared to the previous Synoptic Study performed in 2012. This indicates that recent efforts to regulate septic systems and better maintain sewer collection systems have been effective. The relative absence of significant human signal strongly suggests that the *E. coli* observed in the receiving waters is more likely coming from natural background sources (sediment, biofilms, wildlife) than from homeless encampments, water recreation activities, or other controllable anthropogenic sources.

4.2 Recommendations

- *Special Studies* – The Task Force should consider the implementation of the following special studies to gather data to support the upcoming TMDL revision:
  - *Releases from Naturalized E. coli in Santa Ana River Bottom* – This special study would be designed to collect site-specific data to assess the extent to which naturalized *E. coli* exists in the bottom sediments or biofilms of the Santa Ana River. This study would include collection of surface sediment and/or biofilm samples for enumeration of attached *E. coli* at multiple sites within the Santa Ana River during different seasons. Also, the study design should include collection of data that may facilitate quantification of key factors influencing colony formation and growth (e.g., nutrients, dissolved organic carbon, and temperature), as well as provide information regarding processes that drive the release of *E. coli* colonies to the overlying water.
  - *Mill Creek Wetlands Special Study* – The purpose of this special study would be to evaluate the performance of Mill Creek Wetlands. Based on available data, it is currently difficult to fully quantify the water quality benefits of this wetlands. Findings from this study can also support development of future agreements regarding operation of the facility.
- *Tier 2 Source Investigations* – MS4 Programs should initiate Tier 2 source investigations as described below for each subwatershed:
  - *Santa Ana River Reach 3 Subwatersheds* – Three sites received a high priority ranking in the areas draining to the Santa Ana River watershed-wide compliance sites: Magnolia Center Storm Drain [T1-MCSD], Sunnyslope Channel [T1-SNCH] and ANZA Drain [T1-ANZA]. Of these three sites, it is recommended that a Tier 2 investigation be initiated as soon as possible within Magnolia Center Storm Drain drainage area given the persistent presence of the human marker HF183 *(Note: Based on the results of the Synoptic Study, the RCFC&WCD and City of Riverside have already initiated the first steps in a Tier 2 investigation at this site)*.
  - *Cucamonga Creek Subwatershed* - For Cucamonga Creek, it is assumed that the Chris Basin Project (see Section 3.3.3) will address a majority of the bacteria load reaching the Tier 1 CUCAMONGA site. However, it is recommended that a Tier 2 investigation be initiated by the Cities of Ontario and Eastvale in coordination with the implementation of the Chris Basin Project to verify expected bacterial load reductions following completion of that project. Implementation of these studies could also provide additional information from sites not sampled during the Synoptic Study (Eastvale Lines A and B) that may be needed to support the planned TMDL revision for this subwatershed.
  - *Chino Creek Subwatershed* - Consistent with CBRP implementation, additional Tier 2 investigations are recommended within individual subwatersheds to further

identify sources of bacteria and DWF in the MS4 and options to mitigate those sources.

- *Water Quality Monitoring Program Enhancements* – Addition of the Santa Ana River MISSION site to the RBMP as part of the TMDL compliance monitoring program. Regular sample collection from this location will provide data to support the upcoming revision of the TMDL by providing information on bacteria loads in the river that are not derived from an MS4 source.
- *Preparation for TMDL Revision* – The Task Force should begin work on a strategy for TMDL revision, including developing the approach to revise the WLAs and LAs, identifying the components that should be revised, e.g., dry/wet seasons vs. weather, identifying any additional data needs to effectively revise the TMDL, and an approach for addressing the wet weather component of the TMDL given the allowable high flow suspension in the Basin Plan.
- *Preparation for Potential Basin Plan Revision* – In addition to developing a strategy for TMDL revision, the Task Force should also begin work on a strategy for a potential Basin Plan revision, if determined necessary. The Basin Plan revision strategy may include consideration of unidentified nonpoint sources, dry/wet seasons versus dry and wet weather, and implementation of the State Board's Inland Surface Waters Plan.

5. References

Ahmed, W., B. Hughes and V.J. Harwood. 2016. *Current Status of Marker Genes of Bacteroides and Related Taxa for Identifying Sewage Pollution in Environmental Waters*. Integrative Biology Faculty and Staff Publications, University of South Florida. 360.

Ahmed, W., S. Payyappat, M. Cassidy, and C. Besley. 2019. *Enhanced Insights from Human and Animal Host-associated Molecular Marker Genes in a Freshwater Lake Receiving Wet Weather Overflows*. Scientific Reports 9: 1-13.

Bae, S.W. and S. Wuertz. 2009. *Discrimination of Viable and Dead Fecal Bacteroidales Bacteria by Quantitative PCR with Propidium Monoazide*. Applied Environmental Microbiology 75: 2940–2944.

Balzer, M., N. Witt, H.-C. Fleming, and J. Wingender. 2010. *Faecal Indicator Bacteria in River Biofilms.* Water Science and Technology 61: 1105-1111.

Bell, A., A.C. Layton, L. McKay, D. Williams, R. Gentry, and G.S. Sayler. 2009. *Factors Influencing the Persistence of Fecal Bacteroides in Stream Water*. Journal of Environmental Quality 38: 1224-1232.

Boehm, A.B., E.K. Graham, and W.C. Jennings. 2018. *Can We Swim Yet? Systematic Review, Meta-analysis, and Risk Assessment of Aging Sewage in Surface Waters*. Environmental Science & Technology 52: 9634–9645.

Byappanahalli, M.N., M. Fowler, D. Shively, and R. Whitman. 2003. *Ubiquity and Persistence of Escherichia coli in a Midwestern Coastal Stream.* Applied Environmental Microbiology 69: 4549–4555.

Byappanahalli, M.N., T. Yan, M.J. Hamilton, S. Ishii, R.S. Fujioka, R.L. Whitman, and M.J. Sadowsky. 2012. *The Population Structure of Escherichia coli Isolated from Subtropical and Temperate soils.* Science of the Total Environment 417-418, 273–279.

Cao, Y., M.R. Raith, and J.F. Griffith. 2016. *A Duplex Digital PCR Assay for Simultaneous Quantification of the Enterococcus spp. and the Human Fecal-associated HF183 Marker in Waters*. Journal of Visualized Experiments 109: e53611.

Cao, Y., M.R. Raith, P.D. Smith, J.F. Griffith, S.B. Weisberg, A. Schriewer, A. Sheldon, C. Crompton, G.G. Amenu, J. Gregory, J. Guzman, K.D. Goodwin, L. Othman, M. Manasjan, S. Choi, S. Rapoport, S. Steele, T. Nguyen and X. Yu. 2017. *Regional Assessment of Human Fecal Contamination in Southern California Coastal Drainages.* International Journal of Environmental Research and Public Health 14: 874.

CDM Smith. 2015. *Residential Property Scale Bacteria Water Quality Study – Interim Data Analysis.* Technical Memorandum prepared for the City of Chino Hills, City of Chino and San Bernardino County Flood Control District. April 15, 2015.

City of Claremont. 2014. *Comprehensive Bacteria Reduction Plan*. Prepared by CDM Smith on behalf of the City of Claremont. January 14, 2014.

City of Claremont. 2017. *Middle Santa Ana River Bacterial Indicator TMDL 2016/2017 Annual Report.* Prepared by the Colbert Environmental Group on behalf of the City. November 15, 2017.

City of Pomona. 2014. *Comprehensive Bacteria Reduction Plan*. Prepared by CDM Smith on behalf of the City of Claremont. January 14, 2014.

City of Rialto. 2018. *CBRP Audit: City of Rialto Summary.* Prepared by Lynn Merrill and Associates, Inc. on behalf of the City of Rialto. March 29, 2018.

Gedalanga, P., L. Nguyen, and C. Puga. 2019. *Microbial Source Tracking at the Santa Ana Watershed.* California State University, Fullerton. August 2018 - June 2019.

Ishii S., D.L. Hansen, R.E. Hicks, M.J. Sadowsky. 2007. B*each Sand and Sediments are Temporal Sinks and Sources of Escherichia coli in Lake Superior*. Environmental Science and Technology 41: 2203-2209.

Jamieson, R.C., D.M. Joy, H. Lee, R. Kostacschuk, and J.R. Gordon. 2005. *Resuspension of Sediment-associated Escherichia coli in a Natural Stream.* Journal of Environmental Quality 34: 581–859.

Kreader, C.A. 1998. *Persistence of PCR-detectable Bacteroides Distasonis from Human Feces in River Water.* Applied Environmental Microbiology 64: 4103-4105.

Litton, R.M., J.H Ahn, B. Sercu, P.A. Holden, D.L. Sedlak, and S.B. Grant. 2010. *Evaluation of Chemical, Molecular, and Traditional Markers of Fecal Contamination in an Effluent-dominated Urban Stream.* Environmental Science & Technology 44: 7369-7375.

Ran, Q., B.D. Badgley, N. Dillon, G.M. Dunny and M.J. Sadowsky. 2013. *Occurrence, Genetic Diversity, and Persistence of Enterococci in a Lake Superior Watershed*. Applied and Environmental Microbiology 79: 3067-3075.

Reeves, R.L., S.B. Grant, R.D. Morse, C.M.C. Oancea, B.F. Sanders, and A.B. Boehm. 2003. *Scaling and Management of Fecal Indicator Bacteria in Runoff from a Coastal Urban Watershed in Southern California*. Environmental Science and Technology 38: 2637–2648.

Riverside County Flood Control & Water Conservation District (RCFC&WCD). 2011. *Comprehensive Bacteria Reduction Plan*. Prepared by CDM Smith on behalf of RCFC&WCD. June 28, 2011.

RCFC&WCD. 2016. *Middle Santa Ana River Watershed: Uncontrollable Bacterial Sources Study*. Prepared by CDM Smith on behalf of RCFC&WCD. June 2016.

RCFC&WCD 2019. *Unpublished Data from Magnolia Center Storm Drain.* Collected by the Riverside County MS4 Monitoring Program.

San Bernardino County Flood Control District (SBCFCD). 2011. *Comprehensive Bacteria Reduction Plan.* Prepared by CDM Smith on behalf of the SBCFCD. June 28, 2011.

SBCFCD. 2016. *Unpublished Data from San Antonio Channel*. Collected by the San Bernardino County MS4 Program.

SBCFCD. 2016, 2017, and 2018. *Unpublished Data from Cucamonga Creek Subwatershed Field Studies.* Collected by the San Bernardino County MS4 Program.

Santa Ana Regional Water Quality Control Board (Santa Ana Water Board). 2016. Water Quality Control Plan for Santa Ana River Region. Santa Ana Water Board, February 2016 (as amended).

Santa Ana Water Board. 2018a. *MSAR Comprehensive Bacteria Reduction Plan Audit Report, Riverside County, R8-2020-0033.* October 2018.

Santa Ana Water Board. 2018b. *MSAR Comprehensive Bacteria Reduction Plan Audit Report, San Bernardino County, R8-2020-0036.* October 2018.

Santa Ana Watershed Project Authority (SAWPA). 2008. *Middle Santa Ana River Bacterial Indicator TMDL Urban Source Evaluation Plan.* Prepared by CDM on behalf of SAWPA and the MSAR TMDL Task Force. March 21, 2008.

SAWPA. 2009. *Middle Santa Ana River Bacterial Indicator TMDL Data Analysis Report.* Prepared by CDM on behalf of SAWPA and the MSAR TMDL Task Force, March 19, 2009.

SAWPA. 2010a. *Middle Santa Ana River Watershed Bacterial Indicator TMDL: Triennial Report.* Prepared by CDM on behalf of SAWPA and the MSAR TMDL Task Force. February 15, 2010.

SAWPA. 2010b. *Final Technical Memorandum - Dry Weather Runoff Controllability Assessment for Lower Deer Creek Subwatershed (Chris Basin) Special Study*. Prepared by CDM on behalf of SAWPA and the MSAR TMDL Task Force. September 30, 2010.

SAWPA. 2010c. *Final Technical Memorandum – Source Evaluation Activities in Carbon Canyon Creek and Cypress Channel.* Prepared by CDM on behalf of SAWPA and the MSAR TMDL Task Force. October 27, 2010.

SAWPA 2011. *Final Submittal - Source Evaluation Project Activities for Middle Santa Ana River, TMDL Program Support, 2010-2011*. Prepared by CDM on behalf of SAWPA and the MSAR TMDL Task Force. September 30, 2011.

SAWPA. 2013. *Middle Santa Ana River Bacterial Indicator TMDL Implementation Report.* Prepared by CDM Smith on behalf of SAWPA and the MSAR TMDL Task Force. February 2013.

SAWPA. 2014. *Middle Santa Ana River Bacterial TMDL 2013 Dry Season Tier 2 Source Assessment Final Report.* Prepared by CDM Smith on behalf of SAWPA and the MSAR TMDL Task Force. November 2014.

SAWPA. 2017. *Middle Santa Ana River Bacterial Indicator TMDL Implementation Final Report.* Prepared by CDM Smith on behalf of SAWPA and the MSAR TMDL Task Force. June 2017.

SAWPA. 2018. *Technical Memorandum: Tier 2 Arlington Area Bacteria and Flow Source Investigation.* Prepared by AMEC Foster Wheeler on behalf of SAWPA and the MSAR TMDL Task Force. January 2018.

SAWPA. 2019a. *MSAR Bacteria TMDL Task Force Comments on the 2019 Triennial Review*. Letter to the Santa Ana Water Board. Prepared by Risk Sciences on behalf of the MSAR TMDL Task Force. March 8, 2019.

SAWPA. 2019b. *Santa Ana River Watershed Bacteria Monitoring Program Annual Report: 2018-2019.* Prepared by CDM Smith on behalf of SAWPA and the Regional Water Quality Monitoring Task Force. June 2019.

SAWPA. 2019c. *Middle Santa Ana River Bacteria Synoptic Study: Final Study Plan.* Prepared by GEI Consultants, CDM Smith and Essential Environmental Engineering Systems on behalf of SAWPA and the MSAR TMDL Task Force. July 10, 2019.

SAWPA. 2019d. *Middle Santa Ana River Bacteria Synoptic Study: Quality Assurance Project Plan.* Prepared by GEI Consultants, CDM Smith and Essential Environmental Engineering Systems on behalf of SAWPA and the MSAR TMDL Task Force. July 2019.

Shanks, O. 2018. *Use of Microbial Source Tracking Tools in Waterborne Disease Outbreak Response*. Safe and Sustainable Water Resources Webinar. Cincinnati, OH. June 27, 2018. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=341843

Soller, J.A., M.E. Schoen, T. Bartrand, J.E. Ravenscroft, and N.J. Ashbolt. 2010. *Estimated Human Health Risks from Exposure to Recreational Waters Impacted by Human and Non-human Sources of Faecal Contamination.* Water Research 44: 4674-4691.

Soller, J.A., M.E. Schoen, A. Varghese, A.M. Ichida, A.B. Boehm, S. Eftim, and J.E. Ravenscroft. 2014. *Human Health Risk Implications of Multiple Sources of Faecal Indicator Bacteria in a Recreational Waterbody.* Water Research 66: 254-264.

Solo-Gabriele, H.M. and F.E. Perkins. 1997. *Streamflow and Suspended Sediment Transport in an Urban Environment*. Journal of Hydraulic Engineering 123: 807–811.

State Water Resources Control Board. 2018. *Part 3 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California, Bacteria Provisions and a Water Quality Standards Variance Policy, August 7, 2018.* Adopted by Resolution No. 2018-0038.

United States Environmental Protection Agency (USEPA). 2019. *Method 1696: Characterization of Human Fecal Pollution in Water by HF183/BacR287 TaqMan® Quantitative Polymerase Chain Reaction (qPCR) Assay.* EPA 821-R-19-002, Office of Research and Development. March 2019.

Whitman, R.L., and M.B. Nevers. 2003. *Foreshore Sand as a Source of Escherichia coli in Nearshore Water of a Lake Michigan Beach*. Applied Environmental Microbiology 69: 5555–5562.

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Appendix A – Site Photographs

Tier 1 (T1) and Tier 2 (T2) Sites

Watershed-wide Compliance Sites

Additional Mainstem Santa Ana River Sites

Figure A-1. San Antonio Channel (T1-SACH). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; August 27, 2019

Figure A-2. Chino Creek Upstream of San Antonio Channel (T1-CHINOCRK). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; August 27, 2019

Figure A-3. Boys Republic South Channel (T1-BRSC). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; September 3, 2019

Figure A-4. Carbon Canyon Creek Channel (T1-CCCH). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; September 3, 2019

Figure A-5. Lake Los Serranos Channel (T1-LLSC). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; September 3, 2019

Figure A-6. Box Springs Channel (T1-BXSP). Left Photo: Looking Upstream; Right Photo: Looking Downstream; September 4, 2019

Figure A-7. Magnolia Center Storm Drain (T1-MCSD). Left Photo: Looking Upstream; Right Photo: Looking Downstream; September 4, 2019

Figure A-8. Sunnyslope Channel (T1-SNCH). Left Photo: Looking Upstream; Right Photo: Looking Downstream; August 6, 2019

Figure A-9. Phoenix Storm Drain (T1-PHNX). Left Photo: Looking Upstream; Right Photo: Looking Downstream; August 27, 2019

Figure A-10. Anza Drain (T1-ANZA). Left Photo: Looking Upstream; Right Photo: Looking Downstream; September 4, 2019

Figure A-11. San Sevaine Channel (T1-SSCH). Left Photo: Looking Upstream; Right Photo: Looking Downstream; September 4, 2019

Figure A-12. Day Creek (T1-DAY). Left Photo: Looking Upstream; Right Photo: Looking Downstream; August 27, 2019

 

Figure A-13. Hole Lake (T2-HOLE). Left Photo: Looking Upstream; Right Photo: Looking Downstream; September 3, 2019

Figure A-14. Cucamonga Creek at Hellman (T1-CUCAMONGA). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; September 4, 2019

Figure A-15. Cypress Channel (T1-CYP). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; September 4, 2019

Figure A-16. Cypress Channel Upstream of the California Institute of Men's Agricultural Fields (T2-CYP2). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; September 4, 2019

Figure A-17. Watershed-wide Compliance Site: Chino Creek at Central Avenue (WW-C7). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; August 27, 2019

Figure A-18. Watershed-wide Compliance Site: Mill-Cucamonga Creek (WW-M6). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; August 27, 2019

Figure A-19. Watershed-wide Compliance Site: Santa Ana River at MWD Crossing (WW-S1). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; September 4, 2019

Figure A-20. Watershed-wide Compliance Site: Santa Ana River at Pedley Avenue (WW-S4). Upper Photo: Looking Upstream; Lower Photo: Looking Downstream; September 4, 2019

Figure A-21. Santa Ana River Reach 4 above South Riverside Avenue Bridge (P3-SBC1). Left Photo: Looking Upstream; Right Photo: Looking Downstream; September 4, 2019

Figure A-22. Santa Ana River at Mission Boulevard (MISSION). Left Photo: Looking Upstream; Right Photo: Looking Downstream; August 28, 2019

Figure A-23. Santa Ana River at 64th Street (64THST). Left Photo: Looking Upstream; Right Photo: Looking Downstream; August 28, 2019

Appendix B – Water Quality Results

Table B-1. Field Estimated DWF (cfs) at Tier 1 and Tier 2 Synoptic Study Sites, July 30 – September 4, 2019 (DWF estimates at T1-CUCAMONGA and Santa Ana River sites were not field estimated – see text)

Site Type	Location	Sample Week					
		Week 1 7/30-7/31	Week 2 8/6 – 8/7	Week 3 8/13 – 8/14	Week 4 8/20 – 8/21	Week 5 8/27 – 8/28	Week 6 9/3-9/4
Tier 1	T1-SACH	0.018	0.010	0.015	0.010	0.008	3.240
	T1-CHINOCRK	0.490	0.690	0.440	0.510	0.595	0.450
	T1-BRSC	0.112	0.125	0.159	0.137	0.129	0.121
	T1-CCCH	0.409	0.450	0.420	0.510	0.425	0.550
	T1-LLSC	0.006	Dry	Dry	Dry	Dry	0.010
	T1-CYP	Dry	Dry	Dry	Dry	Dry	Dry
	T1-BXSP	0.086	0.052	0.267	0.31	0.162	0.14
	T1-MCSD	0.260	0.240	0.412	0.300	0.490	0.300
	T1-SNCH	0.770	0.582	0.170	0.560	0.080	0.177
	T1-PHNX	0.001	0.002	0.003	0.005	0.004	0.020
	T1-ANZA	1.300	2.560	0.829	1.140	1.360	0.930
	T1-SSCH	0.255	0.490	0.294	0.470	0.350	0.330
	T1-DAY	0.051	0.380	0.060	0.585	0.036	0.030
Tier 2	T2-CYP2	0.201	1.50	0.195	0.207	0.245	0.19
	T2-HOLE	1.6	1.6	0.985	1.179	7.29	0.98

Table B-2. *E. coli* (MPN/100 mL) at Synoptic Study Sites, July 30 – September 4, 2019

Site Type	Location	Sample Week					
		Week 1 7/30-7/31	Week 2 8/6 – 8/7	Week 3 8/13 – 8/14	Week 4 8/20 – 8/21	Week 5 8/27 – 8/28	Week 6 9/3-9/4
Watershed-wide Compliance	WW-C7	550	190	130	400	95	400
	WW-M6	350	1,100	130	190	63	250
	WW-S1	350	200	110	96	230	230
	WW-S4	200	200	120	41	110	74
Santa Ana River Mainstem	64THST	160	170	120	98	230	230
	MISSION	88	280	97	120	610	150
	P3-SBC1	78	74	31	130	17	50
Tier 1	T1-SACH	150	1,600	16	730	110	52
	T1-CHINOCRK	270	200	280	2,400	4,600	2,300
	T1-BRSC	4,100	1,100	66	1,300	4,400	1,800
	T1-CCCH	20	110	410	49	67	26
	T1-LLSC	800	Dry	Dry	Dry	Dry	340
	T1-CYP	Dry	Dry	Dry	Dry	Dry	Dry
	T1-CUCAMONGA	2,900	650	3,600	1,700	690	330
	T1-BXSP	2,600	670	74	2,800	930	1,100
	T1-MCSD	4,400	3,400	1,900	5,800	4,100	6,900
	T1-SNCH	2,000	2,000	650	760	120	810
	T1-PHNX	250	550	120	2,400	640	7,700
	T1-ANZA	130	200	3,600	320	170	74
	T1-SSCH	910	24,000	370	300	400	9,200
	T1-DAY	1,400	1,200	540	1,500	300	340
Tier 2	T2-CYP2	310	520	820	2,900	1,400	290
	T2-HOLE	380	770	1,100	770	550	780

Table B-3. Turbidity (Nephelometric Turbidity Units, NTU) at Synoptic Study Sites, July 30 – September 4, 2019

Site Type	Location	Sample Week					
		Week 1 7/30-7/31	Week 2 8/6 – 8/7	Week 3 8/13 – 8/14	Week 4 8/20 – 8/21	Week 5 8/27 – 8/28	Week 6 9/3-9/4
Watershed-wide Compliance	WW-C7	0.4	1.3	0.8	0.8	1.6	1.5
	WW-M6	1.4	3.7	1.1	1.2	0.7	4.5
	WW-S1	2.2	2	2	2.5	2.2	3.6
	WW-S4	2.6	0.6	1.5	1.5	2.3	1.7
Santa Ana River Mainstem	64THST	9.5	13.9	4.5	23.1	20.5	6
	MISSION	8.8	3.2	2.2	12.5	10	11.6
	P3-SBC1	0	2.2	0.1	0.2	0.7	0.3
Tier 1	T1-SACH	2.9	6.3	4.4	6.5	1.2	12.8
	T1-CHINOCRK	4.5	14.4	9.5	3.6	8.6	4.8
	T1-BRSC	3.6	3.8	5.7	1.2	3	12.8
	T1-CCCH	7.8	8.6	5.1	2.6	2.6	13.8
	T1-LLSC	10.8	Dry	Dry	Dry	Dry	102
	T1-CYP	Dry	Dry	Dry	Dry	Dry	Dry
	T1-CUCAMONGA	5.9	17	22.2	9.8	17	6.5
	T1-BXSP	31.3	7.3	0	25.1	26.4	8.2
	T1-MCSD	11.8	14	8	22.5	22.8	5.2
	T1-SNCH	10.3	0.8	0	0	5.2	1.7
	T1-PHNX	0	3	0	12.5	15.8	3.4
	T1-ANZA	0.2	23.9	1.3	18.5	9.8	11.6
	T1-SSCH	0.1	0	11.6	17.2	3.9	5.6
	T1-DAY	0	8.8	6.9	8.8	7.7	6.0
Tier 2	T2-CYP2	3.4	3	2.8	2.3	0	6.8
	T2-HOLE	11.6	1.5	1.9	20.1	9.2	3.3

Table B-4. Dissolved Oxygen (mg/L) at Synoptic Study Sites, July 30 – September 4, 2019

Site Type	Location	Sample Week					
		Week 1 7/30-7/31	Week 2 8/6 – 8/7	Week 3 8/13 – 8/14	Week 4 8/20 – 8/21	Week 5 8/27 – 8/28	Week 6 9/3-9/4
Watershed-wide Compliance	WW-C7	7.77	5.66	5.71	6.26	5.42	7.3
	WW-M6	5.8	6.23	6.13	6.35	6.09	5.19
	WW-S1	8.53	8.48	8.22	8.08	8.18	8.12
	WW-S4	8.32	8.17	8.16	7.52	7.68	7.65
Santa Ana River Mainstem	64THST	7.42	7.43	7.8	7.81	7.67	7.49
	MISSION	7.36	7.55	7.55	7.94	7.73	7.75
	P3-SBC1	8.32	8.07	7.97	7.75	7.78	7.72
Tier 1	T1-SACH	6.88	6.88	6.76	4.58	6.68	6.15
	T1-CHINOCRK	7.06	6.78	6.37	6.94	6.68	5.19
	T1-BRSC	7.13	5.63	6.98	5.66	4.98	5.5
	T1-CCCH	5.56	6.85	6.58	5.46	4.7	4.76
	T1-LLSC	6.14	Dry	Dry	Dry	Dry	6.29
	T1-CYP	Dry	Dry	Dry	Dry	Dry	Dry
	T1-CUCAMONGA	7.37	7.57	5.82	7.24	5.94	6.37
	T1-BXSP	13.28	10.58	10.45	6.94	5.14	3.47
	T1-MCSD	7.91	7.81	7.21	7.1	7.01	5.33
	T1-SNCH	6.7	8.58	5.13	5.61	4.2	4.38
	T1-PHNX	7.87	6.96	5.95	6.82	5.89	8.23
	T1-ANZA	6.79	6.54	6.31	6.39	5.91	6.13
	T1-SSCH	8.55	6.84	7.81	6.7	7.05	8.46
	T1-DAY	11.84	7.82	9.15	6.99	7.96	8.9
Tier 2	T2-CYP2	4.79	7.08	6.88	6.41	6.71	6.38
	T2-HOLE	7.73	7.78	12.82	9.04	6.82	5.99

Table B-5. pH (Standard Units) at Synoptic Study Sites, July 30 – September 4, 2019

Site Type	Location	Sample Week					
		Week 1 7/30-7/31	Week 2 8/6 – 8/7	Week 3 8/13 – 8/14	Week 4 8/20 – 8/21	Week 5 8/27 – 8/28	Week 6 9/3-9/4
Watershed-wide Compliance	WW-C7	8.06	7.86	7.86	7.91	7.82	8.02
	WW-M6	7.64	7.65	7.61	7.69	7.71	7.59
	WW-S1	8.12	8.17	8.13	8.13	8.13	8.07
	WW-S4	8.28	8.37	8.21	8.29	8.3	8.24
Santa Ana River Mainstem	64THST	8.17	8.15	8.08	8.1	8.11	8.28
	MISSION	8.29	8.27	8.19	8.26	8.24	8.47
	P3-SBC1	7.77	7.75	7.69	7.65	7.68	7.67
Tier 1	T1-SACH	10.44	9.84	10.4	9.98	9.19	9.7
	T1-CHINOCRK	8.82	9.15	9.17	9.13	9.05	9.03
	T1-BRSC	8.77	8.96	9.15	8.92	9.04	9.07
	T1-CCCH	8.1	8.37	8.61	8.62	8.56	8.69
	T1-LLSC	10.58	Dry	Dry	Dry	Dry	10.71
	T1-CYP	Dry	Dry	Dry	Dry	Dry	Dry
	T1-CUCAMONGA	9.36	9.16	9.28	9.1	9.29	9.5
	T1-BXSP	9.3	8.92	8.9	8.05	8.41	8.55
	T1-MCSD	8.58	8.53	8.43	8.47	8.45	8.76
	T1-SNCH	7.99	7.52	7.73	7.7	7.68	7.23
	T1-PHNX	8.36	8	8.07	8.31	8.31	8.37
	T1-ANZA	8.16	8.07	7.97	8.06	8.07	8.24
	T1-SSCH	8.47	8.45	8.23	8.25	8.35	8.45
	T1-DAY	8.79	8.28	9.05	8.1	8.27	8.28
Tier 2	T2-CYP2	8.67	8.76	8.67	8.93	8.92	9.02
	T2-HOLE	8.04	7.94	8.15	7.89	8.02	7.91

Table B-6. Specific Conductance (microsiemens/centimeter, μS/cm) at Synoptic Study Sites, July 30 – September 4, 2019

Site Type	Location	Sample Week					
		Week 1 7/30-7/31	Week 2 8/6 – 8/7	Week 3 8/13 – 8/14	Week 4 8/20 – 8/21	Week 5 8/27 – 8/28	Week 6 9/3-9/4
Watershed-wide Compliance	WW-C7	849	1354	1300	1284	1644	870
	WW-M6	1100	1307	1369	1420	1515	1184
	WW-S1	1027	1034	1026	1029	1030	1056
	WW-S4	1068	1067	1061	1081	1067	1077
Santa Ana River Mainstem	64THST	1064	1044	1062	1066	1061	1066
	MISSION	850	837	846	844	834	844
	P3-SBC1	843	848	833	840	840	874
Tier 1	T1-SACH	651	934	895	722	1120	713
	T1-CHINOCRK	1140	1130	1090	1190	1120	1080
	T1-BRSC	1270	1280	1230	1250	1230	1280
	T1-CCCH	1530	1410	1330	1300	1340	1370
	T1-LLSC	461	Dry	Dry	Dry	Dry	992
	T1-CYP	Dry	Dry	Dry	Dry	Dry	Dry
	T1-CUCAMONGA	690	781	737	756	754	717
	T1-BXSP	695	749	700	7940	910	910
	T1-MCSD	911	993	870	827	909	800
	T1-SNCH	1022	924	1002	992	999	978
	T1-PHNX	725	705	1020	885	750	990
	T1-ANZA	1169	1059	1315	1160	919	1620
	T1-SSCH	917	934	1067	590	769	712
	T1-DAY	581	1145	510	573	520	605
Tier 2	T2-CYP2	690	754	779	767	724	760
	T2-HOLE	1254	1179	1311	1470	980	1520

Table B-7. Temperature (°Celsius, °C) at Synoptic Study Sites, July 30 – September 4, 2019

Site Type	Location	Sample Week					
		Week 1 7/30-7/31	Week 2 8/6 – 8/7	Week 3 8/13 – 8/14	Week 4 8/20 – 8/21	Week 5 8/27 – 8/28	Week 6 9/3-9/4
Watershed-wide Compliance	WW-C7	19.4	20.7	19.9	19.2	21	21.5
	WW-M6	22.7	21.7	21.1	20.1	21.5	23.5
	WW-S1	21	20.7	24.4	24.6	24.1	24.1
	WW-S4	21.8	22.1	23.5	28	27.8	27.2
Santa Ana River Mainstem	64THST	22.9	23.5	22.16	21.64	23.36	23.84
	MISSION	28.5	25.18	26.92	23.25	25.68	24.85
	P3-SBC1	27.5	26.9	26.9	26.3	26.4	26.7
Tier 1	T1-SACH	23.82	22.91	23.02	22.41	22.24	25.81
	T1-CHINOCRK	22.86	22.01	21.05	20.46	21.92	23.8
	T1-BRSC	22.58	21.44	21.55	21.28	22.29	23.61
	T1-CCCH	23.45	22.38	21.62	21.84	23	24.89
	T1-LLSC	30.59	Dry	Dry	Dry	Dry	33.54
	T1-CYP	Dry	Dry	Dry	Dry	Dry	Dry
	T1-CUCAMONGA	22.52	20.81	21.02	19.49	21.36	23.54
	T1-BXSP	26.79	22.93	27.57	19.38	21.97	22.9
	T1-MCSD	22.43	22.6	22.66	21.62	23.19	23.25
	T1-SNCH	20.69	19.78	19.16	18.94	21.25	22.53
	T1-PHNX	21	20.66	20.48	20.05	20.88	21.42
	T1-ANZA	25.28	24.97	21.62	22.25	25.06	23.56
	T1-SSCH	20.39	21.42	18.96	17.5	20.58	21
	T1-DAY	21.62	22.01	22.18	19.36	20.87	21.84
Tier 2	T2-CYP2	22.21	20.98	20.1	20.19	21.55	22.65
	T2-HOLE	22.66	22.42	23.84	22.5	22.86	23.79

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Appendix C – Sampling QA/QC Report

Introduction

This section provides the QA/QC evaluation for samples and data collected for the MSAR Synoptic Study from the week of July 29, 2019 through the week of September 3, 2019. The basis for this evaluation is the approved QAPP (SAWPA 2019d), which supported the collection of the following data:

- Field measurements were made for the following constituents: Conductivity, dissolved oxygen, pH, turbidity, water temperature, and flow.
- Water quality samples were collected for laboratory analysis of two constituents: *E. coli* and *Bacteroides* HF183.

Field data were checked to ensure that all required data were gathered and recorded. This check included a data review to ensure correct units of measurements were reported and that reported values were within expected ranges. Water quality data validation included a check to ensure that samples were delivered to laboratories within required holding times and that all sample handling and custody protocols were followed. Field/equipment blank and duplicate results were evaluated against various reporting requirements and data were checked to ensure correct units of measurement were reported. The following sections summarize the results of the QA/QC evaluation for this study.

Field Measured Parameters

The MSAR Synoptic Study was conducted for six weeks during dry weather conditions in the dry weather season. Planned field measurements varied by site type. With the exception of flow, field measurements were planned at 14 Tier 1 sites, two Tier 2 sites, four MSAR watershed-wide compliance sites, and three Santa Ana River Reach 3 mainstem sites (23 total sites over six week period for a total of 138 planned measurements).

For flow, field measurements were planned for the 13 of 14 Tier 1 sites (flow for the T1-CUCAMONGA site was obtained from a nearby USGS gauge station) and two Tier 2 sites. Flow at watershed-wide compliance sites (WW-S1, WW-S4, WW-C7 and WW-M6) and additional Santa Ana River sites (64THST, MISSION, P3-SBC1) were not field estimated. The resulting planned number of field flow measurements was 90.

Completeness

Table C-1 summarizes the completeness of field measurements made during the study. Completeness is the percent of samples collected versus number of samples planned. All deviations from 100% completeness resulted from a sample location being dry:

- T1-CYP, Cypress Channel, was not flowing during the study period. Therefore, no field measurements were collected, resulting in six uncollected measurements for each parameter.
- T1-LLSC, Lake Los Serranos Channel, was not flowing during weeks two through five of the study. The lack of flow resulted in four uncollected measurements for each parameter.

Table C-1. Field Parameter Completeness Summary

Parameter	Planned	Collected	% Complete
Conductivity	138	128	92.8%
Dissolved Oxygen	138	128	92.8%
Flow	90	80	88.9%
pH	138	128	92.8%
Temperature	138	128	92.8%
Turbidity	138	128	92.8%

Accuracy and Precision

Field staff used a Horiba multi-parameter probe (or equivalent) to collect *in situ* field measurements for conductivity, dissolved oxygen, pH, turbidity and water temperature at all sample locations during each sample event. Flow was measured with a Marsh-McBirney Flo-Mate meter, or using alternative flow measurement methods where flow was very shallow (see QAPP, SAWPA 2019d). Field staff calibrated each of the water quality meters prior to each sample event to ensure accuracy and precision of the measurements. **Table C-2** summarizes the accuracy and precision associated with the use of each meter.

Table C-2. Summary of Accuracy and Precision for Field Measurement Equipment

Parameter	Accuracy	Precision
Conductivity	± 5%	± 5%
Dissolved Oxygen	± 0.5 mg/L	± 0.5 mg/L or 10%; whichever is greater
Flow (visual estimate)	± 25% or 0.25; whichever is greater	± 25% or 0.25; whichever is greater
Flow (via flow instruments)	± 10% or 0.1; whichever is greater	± 10% or 0.1; whichever is greater
pH	± 0.5 units	± 0.5 or 5%; whichever is greater
Temperature	± 0.5°C	± 0.5 or 5%; whichever is greater
Turbidity	± 10% or 0.1; whichever is greater	± 10% or 0.1; whichever is greater

Laboratory Constituents

Field/Equipment Blanks

Table C-3 describes the number of grab water samples planned versus actual samples collected. Planned sample collection included collection of water samples for *E. coli* and *Bacteroides* analysis from the 23 sites described above, as well as additional *Bacteroides* samples from five POTWs, for a total of 138 *E. coli* samples and 168 *Bacteroides* samples. There were no exceedances of holding time requirements for any of the samples.

The QAPP requires a field equipment blank be collected for each day of sampling for the project as a whole. The site selected for collection of blank samples was selected on a rotational basis. In total, 12 blank samples were collected for this 6-week study, which corresponds to one sample for each sample day as samples were collected on two days each week.

Per the QAPP, the target reporting limit for *E. coli* was 1 MPN/100 mL, and for *Bacteroides* the target limit was 10 gene copies/reaction. Field equipment blank results were all below detectable counts for *E. coli* (< 1 MPN/100 mL) and *Bacteroides* (< 10 gene copies/reaction).

Field Replicates

The QAPP requires a field replicate sample be collected for each day of sampling for the project as a whole. The site selected for collection of replicate samples was selected on a rotational basis at the same site the field blank was collected. In total, 12 replicate samples were collected for this 6-week study, which corresponds to one sample for each sample day.

To determine the precision of the duplicate analysis for each bacterial indicator the following method was used:[25]

- Calculate the logarithm of each sample and associated duplicate ("laboratory pair")
- Determine the range for each laboratory pair (R_{log})
- Calculate the mean of the ranges (Mean R_{log})
- Calculate the precision criterion, where the precision criteria = 3.27 * Mean R_{log}
- Compare R_{log} for each duplicate pair with the calculated precision criterion for the data set to determine if R_{log} is less than the precision criterion.

[25] Standard Methods, Section 9020B, https://www.standardmethods.org/doi/10.2105/SMWW.2882.180

Table C-3. Summary of Water Sample Collection Activity for MSAR Synoptic Study (shaded cells are sites where *Bacteroides* only water samples were collected)

Site ID	Site Location	Planned	Collected	Missed
CCWRP[1]	IEUA CCWRP treated effluent	6	0	6
Rialto WWTP	Rialto WWTP treated effluent	6	6	0
Riverside RWQCP	Riverside RWQCP treated effluent	6	6	0
RIX	RIX treated effluent	6	6	0
RP1	IEUA RP1 treated effluent	6	6	0
64THST	Santa Ana River at 64th St	6	6	0
MISSION	Santa Ana River at Mission Boulevard Bridge	6	6	0
P3-SBC1	Santa Ana River Reach 4 above South Riverside Avenue Bridge	6	6	0
T1-ANZA	Anza Drain	6	6	0
T1-BRSC	Boys Republic South Channel	6	6	0
T1-BXSP	Box Springs Channel	6	6	0
T1-CCCH	Carbon Canyon Creek Channel	6	6	0
T1-CHINOCRK	Chino Creek Upstream of San Antonio Channel	6	6	0
T1-CUCAMONGA	Cucamonga Creek at Hellman	6	6	0
T1-CYP[2]	Cypress Channel	6	0	6
T1-DAY	Day Creek	6	6	0
T1-LLSC[3]	Lake Los Serranos Channel	6	2	4
T1-MCSD	Magnolia Center Storm Drain	6	6	0
T1-PHNX	Phoenix Storm Drain	6	6	0
T1-SACH	San Antonio Channel	6	6	0
T1-SNCH	Sunnyslope Channel	6	6	0
T1-SSCH	San Sevaine Channel	6	6	0
T2-CYP2	Cypress Channel Upstream of California Institute of Men's agricultural fields	6	6	0
T2-HOLE	Anza Drain Upstream of Hole Lake	6	6	0
WW-C7	Chino Creek at Central Ave	6	6	0
WW-M6	Mill-Cucamonga Creek	6	6	0
WW-S1	Santa Ana River at MWD Crossing	6	6	0
WW-S4	Santa Ana River at Pedley Avenue	6	6	0
	Totals	**168**	**152**	**16**

[1]Carbon Canyon Water Recycling Plant was not discharging for the duration of the study.
[2]Cypress Channel was dry for the duration of the study.
[3]Lake Los Serranos Channel was dry for weeks 2-5 of the study.

Table C-4 summarizes the field replicate analysis results for *E. coli*. Five duplicate pairs for *E. coli* exceeded the calculated precision criterion (bolded in Table C-4). The exceedances included: (a) 7/31/19, T2-CYP2 (160 vs. 310 cfu/100 mL); (b) 8/6/19, T1-CCCH (140 vs. 110); (c) 8/13/19, T1-PHNX (250 vs. 120); (d) 8/20/19, T1-BRSC (1900 vs. 1300) and (e) 8/21/19, T1-BXSP, (2200 vs. 2800). Two of these five outcomes were very close to meeting the precision criterion (T1-CCCH and T1-BXSP). For the others, approximately one order of magnitude difference in replicate bacteria samples is common and within reason (SAWPA 2019b). None of the replicate comparisons were close to this magnitude of difference.

Table C-4. Results of Field Duplicates Analysis for *E. coli* Samples

Sample Date	Site ID	Site Location	Duplicate Result (cfu/100 ml)	Sample Result (cfu/100 ml)	Log of Duplicate Result (L_1)	Log of Sample Result (L_2)	Range of Logs (L_1-L_2) or R_{log})
7/30/2019	T2-HOLE	Anza Drain upstream of Hole Lake	470	380	2.6721	2.5798	0.0923
7/31/2019	T2-CYP2	Cypress Channel upstream of California Institute of Men's agricultural fields	160	310	2.2041	2.4914	-0.2872
8/6/2019	T1-CCCH	Carbon Canyon Creek Channel	140	110	2.1461	2.0414	0.1047
8/7/2019	64THST	SAR at 64th St.	150	170	2.1761	2.2304	-0.0544
8/13/2019	T1-PHNX	Phoenix Storm Drain	250	120	2.3979	2.0792	0.3188
8/14/2019	T1-CUCAMONGA	Cucamonga Creek at Hellman	3700	3600	3.5682	3.5563	0.0119
8/20/2019	T1-BRSC	Boys Republic South Channel	1900	1300	3.2788	3.1139	0.1648
8/21/2019	T1-BXSP	Box Springs Channel	2200	2800	3.3424	3.4472	-0.1047
8/27/2019	T1-CHINOCRK	Chino Creek upstream of San Antonio Channel	4600	4600	3.6628	3.6628	0.0000
8/28/2019	T1-ANZA	Anza Drain	170	170	2.2304	2.2304	0.0000
9/3/2019	T1-DAY	Day Creek	400	340	2.6021	2.5315	0.0706
9/4/2019	T2-CYP2	Cypress Channel upstream of California Institute of Men's agricultural fields	310	290	2.4914	2.4624	0.0290
						Sum of R_{log}	**0.3457**
						Mean R_{log}	**0.0288**
					Precision Criterion (3.27*Mean R_{log})		**0.0942**

Appendix D – Laboratory QA/QC Reports

Appendix D-1 Orange County Public Health Laboratory

Appendix D-2 Babcock Laboratories (requested, but not yet provided)

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health CARE AGENCY

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DATE: **January 27, 2020**

TO: **Richard Meyerhoff**
Suzanne Pargee

FROM: Joseph Guzman, Water Quality Lab Supervisor

SUBJECT: **MSAR Synoptic Study HF183 qPCR QA/QC Report for samples received 07/30/19 thru 09/04/19**

This report covers QA/QC for the MSAR Synoptic Study samples collected between 07/30/19 thru 09/04/19. For this study 176 water samples were submitted to the OC Public Health Water Quality Laboratory (ELAP #2545) for human source tracking marker HF183 analysis by quantitative real-time polymerase chain reaction (qPCR) methodology.

I. Data Completeness (QAPP Table 7-3)

The QAPP states a target of 90% completeness for data. Of the 176 samples submitted, 175 had usable data for 99.4% completeness. One of the 176 samples was reported to contain inhibitors.

II. Field Sampling Quality Control (QAPP Table 14-2)

A. Equipment Blanks

There were 12 field blanks submitted for the 13 sampling days with all blanks being reported as HF183 Not Detected.

B. Cooler Temperature

It is routine laboratory policy to record the temperature of the samples upon receipt in the lab. For this set of samples the temperature at time of receipt was not always documented. Temperature for 121 samples were documented to be within the 1-10°C acceptable range, but for 55 samples the temperature was not recorded. Although all samples were received in coolers with plenty of ice to maintain a temperature of <10°C during transport.

C. Holding Times

All samples were received in the lab within 6 hours of collection and were filtered for qPCR within 24 hours of collection.

D. Field Replicate Pairs

There were 12 field replicates submitted for this study. With approximately 15 samples submitted on each day of collection, the frequency of field replicate submission was 6.7% (1/15) and all replicate results were within the 25% RPD.

III. Laboratory Analytical Quality Control (QAPP Table 14-3)

A. Method Blanks

23 qPCR method blanks were analyzed along with the samples which is in keeping with the guidelines listed in Table 2 of EPA Method 1696. All method blanks were negative for HF183 detection.

B. Laboratory Duplicates

EPA Method 1696 does not require testing laboratory duplicates, so lab duplicates were not included. Each sample extract is tested in triplicate which eliminated the need for running laboratory duplicates.

C. Laboratory Control sample

Although not required by EPA Method 1696, the lab includes positive control samples with each run that is tested in triplicate. 13 positive control samples were run along with the samples, all with Cq values within the 22-24 acceptable range.

D. Additional Lab Quality Control per Table 2 of EPA Method 1696

1. **R^2 for Calibration Curve ≥ 0.98**

   The range of R^2 for all qPCR runs was 0.989 to 0.999, within acceptable limits

2. **Amplification Efficiency for Calibration Curve is 0.90 to 1.10**

   Amplification efficiency for all qPCR runs was in the range of 0.90 to 1.07, within acceptable limits.

3. **Internal Amplification Control Cq Standard deviation ≤1.16**

   All QC parameters for IAC were acceptable.
   The samples demonstrated consistent IAC DNA recovery compared to the average Cq for the No-template controls with ≤1.16 standard deviation.

4. **Sketa22 Assay for Inhibition**

   All QC parameter for Sketa were acceptable.
   The samples demonstrated consistent Sketa DNA recovery compared to the Cq for the Method Blank Controls + 3 standard deviation with the exception of one sample, which was reported as inhibited.

Appendix D-2: Babcock Laboratories QA/QC Report

BABCOCK Laboratories, Inc.
The Standard of Excellence for Over 100 Years

Quality Assurance / Certification Statement

GEI Consultants, Inc. – MSAR Synoptic Study 2019

There were a total of 122 samples submitted, which includes 98 site samples, 12 field duplicate samples and 12 field blanks. Samples were analyzed for Total Coliform and E. Coli. The *sampling period spanned* July 2019 *through* September 2019.

All samples were received in good condition, meeting temperature guidelines of <10 ° C, or having been sampled and placed on ice immediately for transport and received within 6 hours.

All samples were received within acceptable holding times for the analyses requested.

The samples received under this project were analyzed with Good Laboratory Practices. The following items listed pertain to all samples submitted to our laboratory.

1) The method specified QC was performed on all batches containing project samples.
2) All sample parameters requested were reported, unless otherwise notified.
3) All batch acceptance criteria was met prior to reporting results, except as noted below.

Exceptions to Standard Quality Control Procedures

This report is organized into three sections:

Section I details Batch QC. An analytical batch includes the analysis of Method Blanks and Blank Spikes as applicable, also knowns as Laboratory Control Samples. If a batch has been qualified due to this type of failure, the end user should weigh the results associated with the batch according to its intended use. Often, the presence of trace contamination will have little to no effect on the usefulness of the reported result. Failed Blank Spikes are flagged with "Data Suspect".

Section II lists the qualifiers associated with samples that have been fortified with known quantities of target and/or non-target surrogate compounds, whose purpose is to monitor analyte recovery in "real-world' samples and to note any matrix interference. Also included in this section is precision information provided by duplicate analyses and/or fortified-sample duplicate analyses. Since the *information included in this section is unique to each individual sample, the acceptance of the analytical* batch is not controlled by the results of these bias and precision parameters.

Section III of the report identifies individual samples that have been qualified for various reasons. Missed holding times, improper sample preservation, etc. must carefully be evaluated using professional judgement regarding the acceptability of the data for its intended use.

Section 1

All Laboratory Control Samples analyzed for Total Coliform and E. Coli were within acceptance criteria.

All Method Blanks analyzed for Total Coliform and E. Coli were within acceptance criteria.

Section II

All other project source samples used for duplicates met acceptance criteria for precision.

Field duplicate precision was not calculated, duplicates were ran as actual samples.

Section II

All sample holding times were met. All samples were received with proper preservation.

No other sample or data qualifiers were necessary for project samples.

Note:

All reports were prepared and all analyses were performed in accordance with a system designed to assure that qualified personnel perform the analyses, use specified EPA approved methods and review the data before it is reported.

Cindy Waddell, Project Manager

Cindy Waddell