Table of Contents

List of Figures

Section 2

Section 3

Section 4

List of Tables

Section 2

Section 3

Section 4

Section 1
Introduction

Various waterbodies in the Middle Santa Ana River (MSAR) watershed are listed on the state 303(d) list of impaired waters due to high levels of fecal coliform bacterial indicators. The Santa Ana Regional Water Quality Control Board (RWQCB) adopted the MSAR Bacterial Indicator Total Maximum Daily Load (TMDL) in 2005 (RWQCB 2005) to address the fecal coliform bacterial indicator impairments. Following approval by the State Water Resources Control Board, the Environmental Protection Agency (EPA) Region 9 approved the TMDL on May 16, 2007 making the TMDL effective.

The TMDL requires implementation of a watershed-wide compliance monitoring program for bacterial indicators. This program was initiated in July 2007. This report summarizes the findings from water quality monitoring conducted during the 2008-2009 wet season.

1.1 Regulatory Background

Table 3-1 of the Santa Ana Regional Water Quality Control Plan (Basin Plan) designates beneficial uses for surface waters in the Santa Ana River watershed (RWQCB 1995). The beneficial uses applicable to waterbodies in the MSAR watershed include Water Contact Recreation (REC-1), which is defined in the Basin Plan as follows:

> "waters are used for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses may include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, whitewater activities, fishing, and use of natural hot springs" (Basin Plan, page 3-2).

The Basin Plan (Chapter 4) specifies fecal coliform as a bacterial indicator for pathogens ("bacterial indicator"). Fecal coliform present at concentrations above certain thresholds are believed to be an indicator of the presence of fecal pollution and harmful pathogens, thus increasing the risk of gastroenteritis in bathers exposed to the elevated levels. The Basin Plan currently specifies the following water quality objectives for fecal coliform:

> ***REC-1*** *- Fecal coliform: log mean less than 200 organisms/100 mL based on five or more samples/30 day period, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.*

The EPA published new bacterial indicator guidance in 1986 (EPA 1986). This guidance advised that for freshwaters *Escherichia coli* (*E. coli*) is a better bacterial indicator than fecal coliform. Specifically, epidemiological studies found that the positive correlation between *E. coli* concentrations and the frequency of gastroenteritis

was better than the correlation between fecal coliform concentrations and gastroenteritis.

The RWQCB is currently considering replacing the REC-1 bacteria water quality objectives for fecal coliform with *E. coli* objectives. This evaluation is occurring through the work of the Stormwater Quality Standards Task Force (SWQSTF), comprised of representatives from various stakeholder interests, including the Santa Ana Watershed Protection Authority (SAWPA), the counties of Orange, Riverside, and San Bernardino, Orange County Coastkeeper, Inland Empire Waterkeeper, the RWQCB, and EPA Region 9.

In 1994 and 1998, because of exceedances of the fecal coliform objective established to protect the REC-1 use, the RWQCB added the following waterbodies in the MSAR watershed to the state 303(d) list of impaired waters:

- Santa Ana River, Reach 3 – Prado Dam to Mission Boulevard
- Chino Creek, Reach 1 – Santa Ana River confluence to beginning of hard lined channel south of Los Serranos Road
- Chino Creek, Reach 2 – Beginning of hard lined channel south of Los Serranos Road to confluence with San Antonio Creek
- Mill Creek (Prado Area) – Natural stream from Cucamonga Creek Reach 1 to Prado Basin
- Cucamonga Creek, Reach 1 – Confluence with Mill Creek to 23rd Street in City of Upland
- Prado Park Lake

The 2005 RWQCB-adopted TMDL for these waters established compliance targets for both fecal coliform and *E. coli*:

- Fecal coliform: 5-sample/30-day logarithmic mean less than 180 organisms/ 100 mL and not more than 10% of the samples exceed 360 organisms/100 mL for any 30-day period.
- *E. coli*: 5-sample/30-day logarithmic mean less than 113 organisms/100 mL and not more than 10% of the samples exceed 212 organisms/100 mL for any 30-day period.

To focus TMDL implementation efforts, the MSAR Watershed TMDL Task Force ("Task Force") was established. This Task Force, which meets regularly to coordinate water quality management activities, includes representation by key watershed stakeholders, including urban stormwater dischargers, agricultural operators, and the RWQCB.

1.2 Watershed-Wide Compliance Monitoring

The MSAR Bacterial Indicator TMDL requires urban and agricultural dischargers to implement a watershed-wide bacterial indicator monitoring program by November 2007 (RWQCB 2005). The dischargers worked collaboratively through the TMDL Task Force to develop this program and prepare a Monitoring Plan (SAWPA 2008a) and Quality Assurance Project Plan (SAWPA 2008b)[1]. The TMDL Task Force implemented the monitoring program in July 2007 following RWQCB approval of program documents.

SAWPA (2009a) summarizes the findings from the first year of dry and wet season monitoring (2007-2008). SAWPA (2009b) summarizes the findings from the 2008 warm, dry season. This report provides the findings from the 2008-2009 wet season.

[1] The Middle Santa Ana River Monitoring Plan and Quality Assurance Project Plan are available at http://www.sawpa.org/tmdl/Middle_SA_River.html [NOTE: SAWPA WEBPAGE UNDER REVISION; LINK WILL BE UPDATED WHEN POSSIBLE.]

Section 2
Study Area

This section describes the study area and identifies the watershed-wide compliance monitoring locations sampled during the 2008-2009 wet season. SAWPA (2009a) provides a more detailed characterization of the watershed.

2.1 Middle Santa Ana River Watershed

2.1.1 General Description

The Santa Ana River watershed, located in southern California, is approximately 2800 square miles in size. Surface water flows begin in the San Bernardino and San Gabriel Mountains and flow in a generally northwest to southwest direction to the Pacific Ocean. The MSAR watershed is 488 square miles in size and located generally in the north central portion of the Santa Ana River watershed. The watershed includes the southwestern part of San Bernardino County, the northwestern part of Riverside County, and a small portion of Los Angeles County (Figure 2-1).

Lying within an arid region, limited natural perennial surface water is present in the watershed. Flows derived from mountain areas (snowmelt or storm runoff) are mostly captured by dams or percolated in recharge basins. In the transition zone from mountains to lower lying valley areas, the sources of surface water flows vary, e.g., dry weather urban runoff, such as occurs from irrigation, stormwater runoff during rain events, highly treated wastewater effluent, or rising groundwater.

The largest order waterbody in the MSAR watershed is Reach 3 of the Santa Ana River which flows from La Cadena to the Prado Basin, where Prado Dam controls flows from the middle to the lower part of the Santa Ana River watershed. A number of major tributaries to the MSAR exist, many of which have been modified for flood control purposes.

Three major geographic areas comprise the MSAR watershed (RWQCB 2005) (Figure 2-2):

- *Chino Basin* (San Bernardino County, Los Angeles County, and Riverside Counties) – Surface drainage in this area, which is directed to Chino Creek and Mill-Cucamonga Creek, flows generally southward, from the San Gabriel Mountains toward the Santa Ana River and the Prado Flood Control Basin.

- *Riverside Watershed* (Riverside County) – Surface drainage in this area is generally northwestward or southwestward from the incorporated and unincorporated areas of Riverside County to Reach 3 of the Santa Ana River.

- *Temescal Canyon Watershed* (Riverside County) – Surface drainage in this area is generally northwest to Temescal Creek.

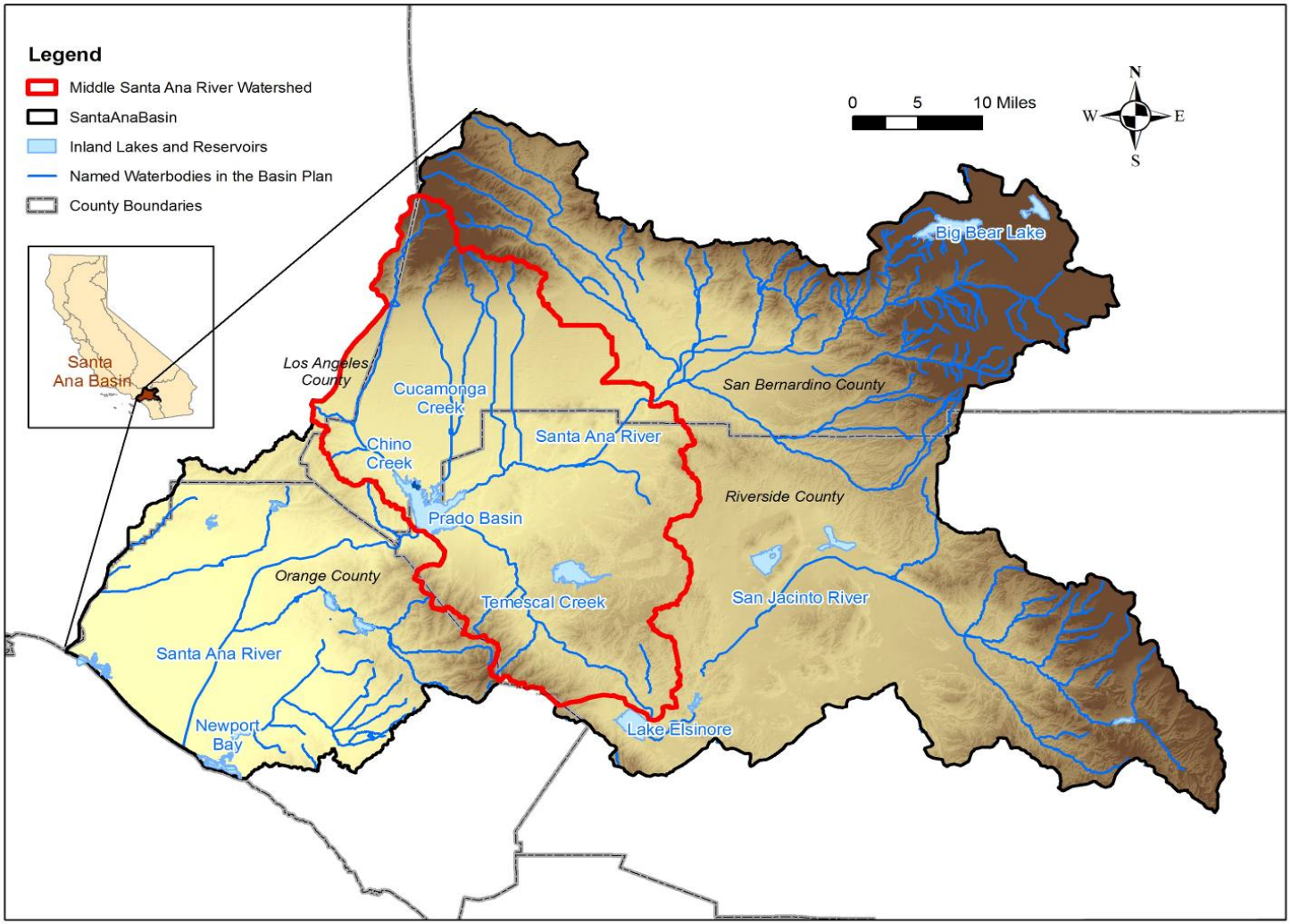


Figure 2-1. Location of the Middle Santa Ana River watershed (red outline) within the Santa Ana River watershed in southern California

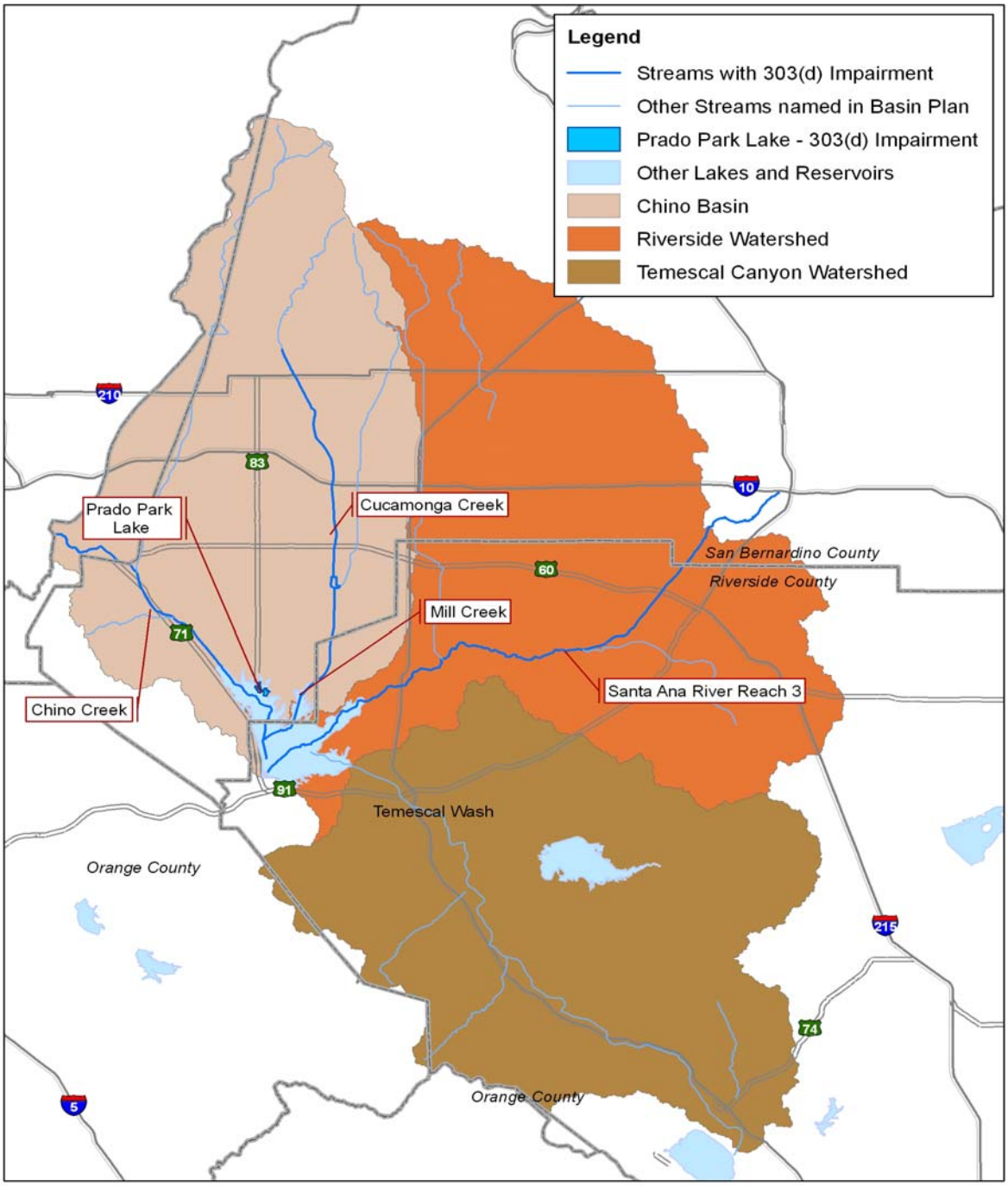


Figure 2-2. Major geographic areas of the Middle Santa Ana River watershed

Based on 2000 census data, the population of the watershed is approximately 1.4 million people. Much of the lowland areas are highly developed; however, a portion of the watershed remains largely agricultural - the area formerly known as the Chino Dairy Preserve. This area is located in the south central part of the Chino Basin subwatershed and contains approximately 300,000 cows (although this number is quickly declining as the rate of development increases) (RWQCB 2005). Recently, the cities of Ontario, Chino, and Chino Hills annexed the San Bernardino County portions of this area. The remaining portion of the former preserve, which is in Riverside County, remains unincorporated (RWQCB 2005).

2.1.2 Physical Description

The following sections summarize the regional hydrology, annual precipitation and temperature, and sources of information for previously reported bacterial indicator concentrations in the study area.

Regional Hydrology

The Santa Ana River watershed experiences a Mediterranean type climate with hot, dry summers, and cooler, wetter winters. Average annual precipitation varies and ranges from 12 inches per year in the lower watershed along the Pacific coast to 18 inches per year in the inland valleys. In the mountains of the northern and eastern parts of the watershed annual precipitation may reach 40 inches per year. Most precipitation falls between November and March and may include variable amounts of snow in the higher mountains (SAWPA 2005).

On average, instream flows are typically low; however, periods of significant precipitation or localized intense rain events can result in rapid increases in surface flows by 1 to 2 orders of magnitude. Following such an event, streams tend to return to baseflow conditions quickly (SAWPA 2005, 2009a). Instream flows in the watershed are influenced by the following (Figure 2-3):

- Dams capture wet weather flows in some subwatersheds resulting in attenuated flows in downstream waters. For example, the Chino Creek subwatershed receives releases from San Antonio Dam via its San Antonio Channel tributary.

- The effort to recharge groundwater by facilitating infiltration of surface water runoff reduces runoff in receiving waters by diversion and spreading of runoff in basins with high infiltration capacity.

- The importation of water to the watershed increases surface flows in certain areas, e.g., importation of water to Chino Creek.

- A number of publicly owned treatment works discharge highly treated effluent to MSAR waterbodies, e.g., a significant portion of the flow along segments of Reach 3 of the Santa Ana River is comprised mostly of treated effluent.

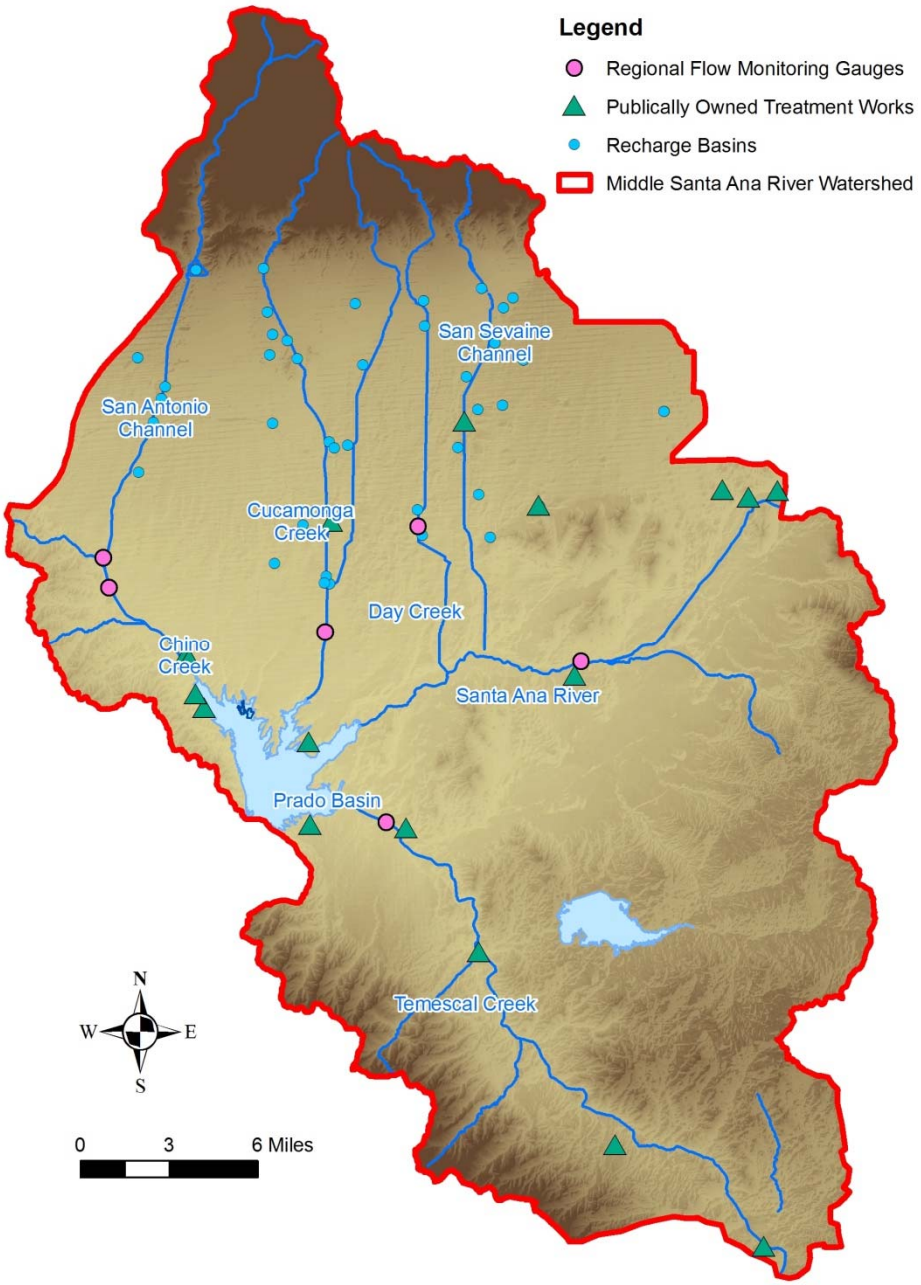


Figure 2-3. Location of recharge basins and publicly owned treatment works that influence instream flows in Middle Santa Ana River waterbodies

Precipitation
Table 2-1 summarizes the precipitation statistics for a rainfall gauge located within the study area (Riverside Fire Station #3). The long-term average annual precipitation at this location for the period during which samples were collected is 10.06 inches/year. For the wet season (November to March), the long-term average annual precipitation at this gauge is 8.29 inches. From November 2008 to March 2009, the Riverside Fire Station #3 rain gauge reported [XXXX] inches (NOTE: these data are not yet available; data will be included in final document).

Temperature
Table 2-2 provides the 30-year long-term average and 2008-2009 monthly average temperatures for the study area during the wet season months of November 2008 through March 2009 (NOTE: Official temperature data for February and March 2009 are not yet available; will be included in final report).

Water Quality
Bacterial indicator water quality data have been collected for many years in the MSAR watershed. SAWPA (2009a) references and summarizes the findings from MSAR watershed studies conducted prior to 2007. SAWPA 2009a and 2009b report bacterial indicator data collected since 2007.

2.2 Watershed-Wide Compliance Monitoring Sites

The TMDL Task Force established the watershed-wide compliance monitoring sites in the MSAR watershed. Table 2-3 and Figure 2-4 identify the location of each site. Attachment A of the Monitoring Plan (see footnote 1) provides additional information about each sample location.

Table 2-1. Long-term average wet season precipitation compared to the precipitation measured during the 2008-2009 sample period (measured at Riverside Fire Station #3)

Measurement	Precipitation (Inches)
Average Annual Precipitation (1977 – 2007)	10.06
Average Seasonal Precipitation (November 1 to March 31, 1977-2007)	8.29
2008-2009 Seasonal Precipitation (November 1, 2008 – March 31, 2009)	TBD

Table 2-2. Long term average monthly wet season temperature compared to the 2008-2009 sample period (measured at Riverside Fire Station #3)

Month	Average (1977-2007)	2008-2009
November	68	64
December	74	54
January	79	61
February	80	TBD
March	76	TBD

Table 2-3. Watershed-wide compliance monitoring program sample locations

Waterbody	Sample Location	Site Code
Icehouse Canyon Creek	Near Icehouse Canyon Trailhead Parking Lot	WW-C1
Prado Lake	Prado Lake Outlet	WW-C3
Chino Creek	Central Avenue	WW-C7
Mill Creek	Chino-Corona Road	WW-M5
Santa Ana River	MWD Crossing	WW-S1
Santa Ana River	Pedley Avenue	WW-S4

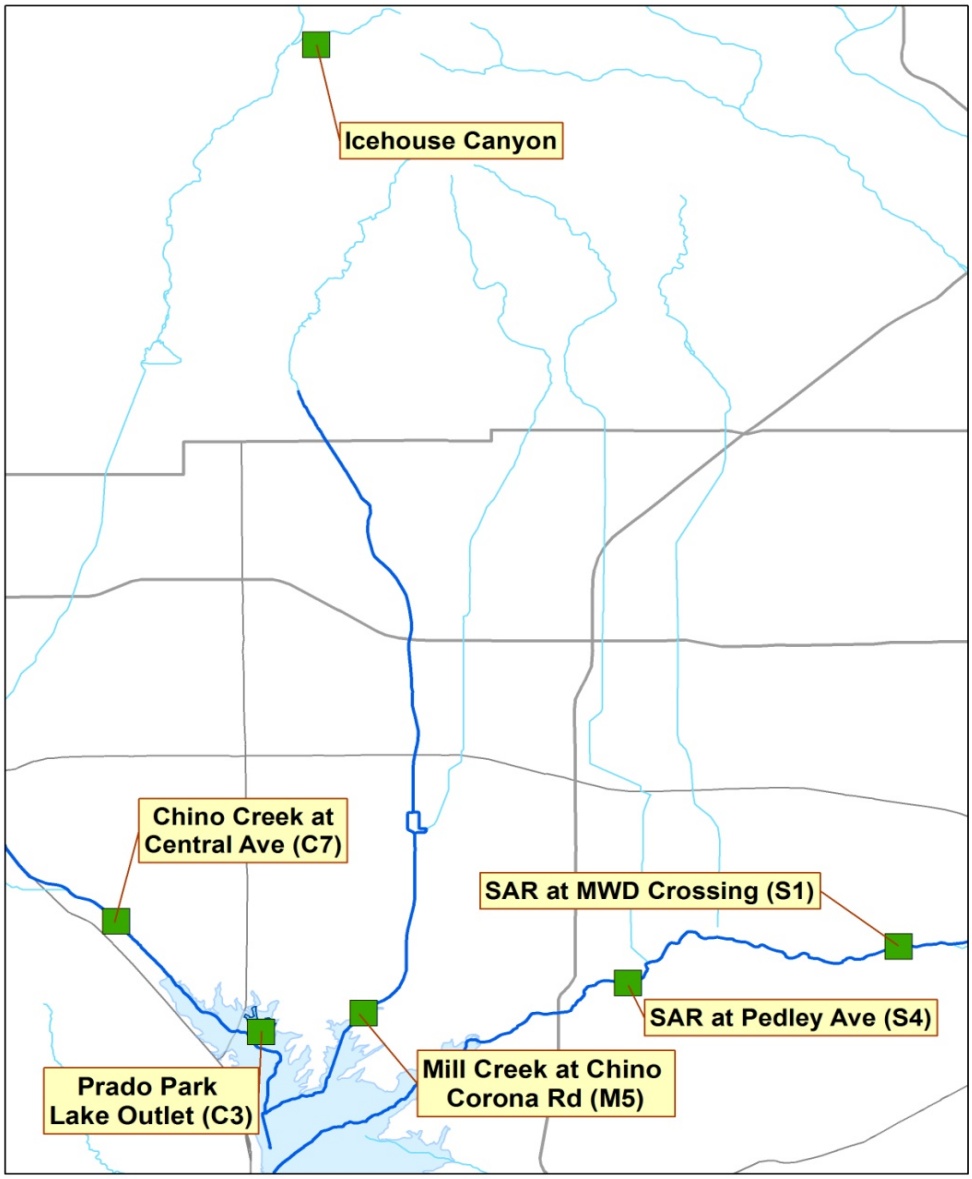


Figure 2-4. Location of watershed-wide compliance monitoring program sample locations in the Middle Santa Ana River watershed

Section 3
Methods

The RWQCB-approved Monitoring Plan and Quality Assurance Project Plan (see footnote 1) provide detailed information regarding the collection and analysis of field data and water quality samples. The following sections provide a summary of these methods.

3.1 Water Quality Measurements

At each sample site water quality measurements include the collection of field parameter data and water samples for laboratory analysis:

- *Field Measurements*: Flow, temperature, conductivity, pH, dissolved oxygen, and turbidity.
- *Laboratory Analysis*: Fecal coliform, *E. coli*, and total suspended solids (TSS).

3.2 Sample Frequency

The Monitoring Plan established sample collection dates for each year of the monitoring program. During 2008-2009, the wet season sample dates were planned as follows: Collect weekly samples over an 11 week period from the week ending December 13, 2008 to the week ending February 21, 2009. In addition, the Monitoring Plan requires the collection of samples during one storm event as follows: (1) collect samples on the day of the storm event; (2) collect additional samples 48, 72 and 96 hours after the onset if the storm event.

In the event that the storm event occurs during a regular weekly sampling event, the storm event sampling protocol substitutes for the regular sampling protocol. This occurred during the 2008-2009 sampling period when a storm event occurred on December 15th, 2008. The regularly weekly sampling occurred on the first day of the storm event. Additional samples were collected 48, 72 and 96 hours after the storm event on December 17th, 18th and 19th, respectively.

Table 3-1 summarizes the results of the 2008-2009 sampling effort. All planned water quality samples were successfully collected.

3.3 Data Collection

San Bernardino County Flood Control District staff collected the field measurements and water quality samples. CDM coordinated the activities of the sample team and the submittal of samples to the laboratory for analysis.

Table 3-1. Summary of water sample collection activity during 2008-2009 wet season

Sample Month	Planned[1]	Collected	Site Dry	Samples Missed
Weekly Sampling				
December	24	24[2]	0	0
January	24	24	0	0
February	18	18	0	0
Storm Event Sampling				
December 15-19[2]	24	24	0	0

[1] – Number of planned samples depends on the number of sample weeks per month times the number of sites planned for sampling. For example, in December six sites were planned for sampling during each of four weeks for a total of 24 samples.

[2] – Collection of weekly samples planned for week of December 15 coincided with collection of samples during the first day of a storm event. Accordingly, the first day storm event sample represented the regular weekly sampling event.

3.4 Sample Handling

Sample collection and laboratory delivery followed approved chain of custody procedures, holding time requirements, and required storage procedures for each water quality analysis. The Orange County Health Care Agency Water Quality Laboratory conducted all analyses for fecal coliform, *E. coli,* and TSS.

3.5 Data Handling

CDM and SAWPA maintain a file of all laboratory and field data records (e.g., data sheets, chain of custody forms) as required by the Quality Assurance Project Plan. CDM entered all field measurements and laboratory analysis results into a project database that is compatible with guidelines and formats established by the California Surface Water Ambient Monitoring Program. CDM periodically submits to SAWPA updates of this for incorporation into the Santa Ana Watershed Data Management System (SAWDMS), which SAWPA manages. Prior to a data submittal to SAWPA, CDM completes a QA/QC review of the data.

3.6 Data Analysis

Data analysis relied primarily on the use of descriptive and correlation statistics. For any statistical analyses, the bacterial indicator data were assumed to be log-normally distributed as was observed in previous studies (SAWPA 2009a). Accordingly, prior to conducting statistical analyses, the bacterial indicator data were log transformed.

Data results varied depending on whether samples were collected under dry or wet weather conditions. Sampling was purposefully conducted during a storm event on December 15, 2008. Figure 3-1 illustrates the relationship between this sampled storm event and the long term flow duration curve at the Santa Ana River @ MWD Crossing site (NOTE: Awaiting data to create figure). Although the frequency of this type of flow event is low, flow conditions quickly returned to baseline levels at all sites soon after the rain event. Accordingly, samples collected 96 hours after the storm event, were collected at relatively normal baseflow conditions.

[Figure to be inserted – awaiting USGS gage information for period]

Figure 3-1. Long-term flow duration curve for the Santa Ana River at MWD Crossing flow gauge (1970-2007). Note where the December 15, 2008 wet weather sample event falls on the curve.

The 2008-2009 wet season sampling program only targeted one storm event for sampling. However, during regular weekly sampling activities, samples could still have been collected at times when a sample location was influenced by wet weather conditions.

Given the potential for wet weather conditions to be present at different times, the following data sources/criteria were evaluated to provide a basis for classifying a sample as having been collected during wet or dry weather conditions:

- Rainfall recorded at a nearby meteorological station;
- Daily flow record from several U.S. Geological Survey (USGS) or San Bernardino County Flood Control District operated flow gauges in the watershed; and
- Comparison of the flow measurement taken at the time of sample collection to the typical site baseflow observed during the sample period.

Table 3-2 summarizes the sample results classified as being influenced by a wet weather flow condition. All remaining samples were classified as dry weather.

Table 3-2. Summary of samples classified as wet weather samples during 2008-2009 wet season

Site	Sample Date	Preceding 3-Day Rainfall (inches)	Measured Flow (cfs)	Approximate Baseflow (cfs)
Icehouse Canyon Creek	12/15/08	2.21	0.8	0.8
	12/17/08	3.09	0.2	0.8
	12/18/08	0.96	0.3	0.8
	2/10/09	1.10	5.6[1]	0.8
	2/17/09	1.73	3.8	0.8
Prado Park Lake Outflow	12/15/08	1.85	58	16
	12/17/08	2.79	21	16
	12/18/08	0.94	29	16
	2/17/09	1.26	23	16
Chino Creek at Central Ave	12/15/08	1.78	994	33
	12/17/08	2.56	408	33
	12/18/08	0.82	117	33
	12/19/08	0.82	130	33
	2/17/09	1.42	378	33
Mill Creek at Chino Corona Rd	12/15/08	1.85	1733	73
	12/17/08	2.79	185	73
	12/18/08	0.94	350	73
	2/13/09	0.47	219	73
	2/18/09	1.26	274	73
Santa Ana River at MWD Crossing	12/15/08	1.45	125	80
	12/17/08	2.30	96	80
	12/18/08	0.87	355	80
	12/19/08	0.86	158	80
	2/13/09	0.20	112	80
	2/18/09	0.50	292	80
Santa Ana River at Pedley Ave	12/15/08	1.45	1679	139
	12/17/08	2.30	639	139
	12/18/08	0.87	639	139
	12/19/08	0.86	244	139
	2/13/09	0.20	165	139
	2/18/09	0.50	406	139

[1] - Snowmelt event in Icehouse Canyon Creek

Section 4
Sample Results

This section summarizes the results of data analyses applied to the 2008-2009 wet season dataset. Where appropriate to provide context, data results are compared to water quality results previously reported (SAWPA 2009a).

4.1 Water Quality Observations

Table 4-1 provides the median value and range of observations for each sampled water quality constituent. Tables 4-2 and 4-3 summarize the fecal coliform and *E. coli* concentrations, respectively, observed during each sample event. No data outliers were identified in the data set.

4.2 Characterization of Bacterial Indicators

Table 4-4 summarizes the distribution of the fecal coliform and *E. coli* data collected from all sites over all sample dates during the 2008-2009 wet season. Because bacterial indicator concentrations at the Icehouse Canyon Creek site are relatively low compared to other sites, Table 4-4 provides the 2008-2009 data distribution with and without inclusion of the Icehouse Canyon Creek data. As would be expected, the overall geometric mean and bacterial indicators concentrations by percentile of the data set are lower when the analysis includes the Icehouse Canyon Creek data.

Table 4-5 summarizes the geometric mean, median, and coefficient of variation of the fecal coliform data for all samples collected regardless of whether the sample was classified as being a wet or dry weather sample (See Section 3.6 for classification of samples as wet weather samples). Table 4-6 provides the fecal coliform results for the samples collected only during dry weather conditions.

Table 4-7 summarizes the geometric mean, median, and coefficient of variation of the *E. coli* data for all samples collected regardless of whether the sample was classified as being a wet or dry weather sample (See Section 3.6 for classification of samples as wet weather samples). Table 4-8 provides the *E. coli* results for the samples collected only during dry weather conditions.

The 2008-2009 wet season fecal coliform and *E. coli* geometric mean concentrations (regardless of wet or dry weather conditions) were substantially higher than the 2007-2008 wet season geometric mean concentrations at Chino Creek and Mill Creek. Prado Park Lake and Santa Ana River @ Pedley Avenue bacterial indicator concentrations were a little higher in 2008-2009 when compared to 2007-2008. Concentrations at the Santa Ana River @ MWD Crossing site were slightly lower in the most recent wet season (Tables 4-5 and 4-7).

Table 4-1. Summary of water quality monitoring data collected during the 2008-2009 wet season

Constituent	Icehouse Canyon Creek (WW-C1)	Prado Park Lake Outflow (WW-C3)	Chino Creek at Central Ave (WW-C7)	Mill-Cucamonga Creek (WW-M5)	Santa Ana River at MWD Crossing (WW-S1)	Santa Ana River at Pedley (WW-S4)
Fecal coliform (cfu/100 mL)						
n	14	14	14	14	14	14
Median	9	170	380	420	134.5	124.5
Range	9 - 90	40 - 10500	160 - 10300	140 - 5900	20 - 3800	40 - 4700
***E. coli* (cfu/100 mL)**						
n	14	14	14	14	14	14
Median	9	275	450	585	100	190
Range	9 - 90	40 - 15000	30 - 12900	210 - 7200	9 - 3400	9 - 4600
Total Suspended Solids (mg/L)						
n	14	14	14	14	14	14
Median	1.2	21.7	4.9	9.9	14.3	28.5
Range	0 - 202.267	12 - 52.8	0.625 - 108.333	2.63 - 119.25	7.5 - 802	14 - 1516
Dissolved Oxygen (mg/L)						
n	14	14	14	14	14	14
Median	9.8	9.7	10.6	10.4	9.5	9.8
Range	8.06 - 10.77	8.02 - 13.35	9.99 - 11.26	9 - 13.63	8.4 - 10.53	8.31 - 10.5
pH (Standard Units)						
n	14	14	14	14	14	14
Median	8.3	8.1	8.4	8.4	8.2	8.4
Range	7.4 - 8.7	7.5 - 8.6	7.6 - 8.9	8 - 8.7	7.6 - 8.6	7.6 - 8.7
Turbidity (NTU)						
n	14	14	14	12	11	11
Median	4.9	18.8	8.3	9.0	9.9	10.3
Range	0.57 - 28.2	5.83 - 80.1	2.88 - 134	4.92 - 108	6.26 - 258	6.97 - 575
Water Temperature (^{O}C)						
n	13	14	14	14	14	14
Median	5.0	14.4	17.8	13.4	12.4	13.0
Range	1.7 - 7.7	13 - 15.8	8.6 - 21.4	8.5 - 19	8.9 - 16	8.8 - 17.3
Flow (cfs)						
n	14	14	14	14	14	14
Median	0.8	18.3	40.0	88.7	98.2	189.3
Range	0.1 - 5.6	3.4 - 58	12.3 - 994.3	30.9 - 1732.5	46 - 354.5	75.1 - 1678.7
Conductivity (uS/cm)						
n	14	14	14	14	14	14
Median	195	940	743	631	708	782
Range	183 - 232	690 - 1130	130 - 1270	65 - 1050	196 - 1110	263 - 1050

Table 4-2. Fecal coliform (cfu/100 mL) concentrations observed at watershed-wide compliance sites during the 2008-2009 wet season

Sample Date (Week of)	Icehouse Canyon Creek (WW-C1)	Prado Park Lake Outlet (WW-C3)	Chino Creek @ Central Avenue (WW-C7)	Mill Creek @ Chino-Corona Rd (WW-M5)	SAR @ MWD Crossing (WW-S1)	SAR @ Pedley Avenue (WW-S4)
Regular Sampling Events						
12/8/08	< 9	410	5,800	900	170	150
12/22/08	< 9	40	410	200	210	320
12/29/08	< 9	60	160	180	99	99
1/5/09	< 9	40	190	530	20	40
1/12/09	< 9	120	190	380	30	70
1/19/09	< 9	99	640	850	20	50
1/26/09	< 9	220	350	380	80	99
2/2/09	9	40	220	390	40	50
2/9/09	< 9	2,100	220	280	70	80
2/16/09	< 9	10,500	4,800	450	330	330
Storm Event						
12/15/08	< 90	1,700	4,300	4,800	2,400	4,200
12/17/09	20	480	10,300	1,700	3,700	4,700
12/18/09	< 9	400	3,100	5,900	3,800	3,900
12/19/09	< 9	40	290	140	650	1,300

Table 4-3. *E. coli* (cfu/100 mL) concentrations observed at watershed-wide compliance sites during the 2008-2009 wet season

Sample Date (Week of)	Icehouse Canyon Creek (WW-C1)	Prado Park Lake Outlet (WW-C3)	Chino Creek @ Central Avenue (WW-C7)	Mill Creek @ Chino-Corona Rd (WW-M5)	SAR @ MWD Crossing (WW-S1)	SAR @ Pedley Avenue (WW-S4)
Regular Sampling Events						
12/8/08	< 9	510	12,900	970	90	260
12/22/08	< 9	80	2,100	210	210	340
12/29/08	< 9	100	210	270	60	60
1/5/09	< 9	110	30	640	30	9
1/12/09	< 9	90	150	390	40	40
1/19/09	< 9	120	510	660	< 9	120
1/26/09	< 9	310	320	390	110	120
2/2/09	9	40	160	580	20	80
2/9/09	< 9	2,700	280	380	60	70
2/16/09	< 9	15,000	6,200	500	220	340
Storm Event						
12/15/08	< 90	2,000	5,700	7,200	1,700	3,800
12/17/09	9	290	7,600	1,400	1,400	2,500
12/18/09	< 9	600	2,500	4,200	3,400	4,600
12/19/09	< 9	260	390	590	880	2,400

Table 4-4. Statistical distribution of bacterial indicator data (cfu/100 mL) during the 2008-2009 wet season

Statistic	2008-2009 without Icehouse Canyon Creek Data		2008-2009 with Icehouse Canyon Creek Data	
	E. coli	**Fecal coliform**	***E. coli***	**Fecal coliform**
Sample Size (n)	70	70	84	84
Geometric Mean	375	351	207	198
10^{th} Percentile	40	40	9	9
25^{th} Percentile	110	99	55	40
50^{th} Percentile (median)	330	305	240	195
75^{th} Percentile	1400	1200	715	643
90^{th} Percentile	4240	4340	3680	4110

Table 4-5. Summary of fecal coliform concentrations (cfu/100 mL) and data variability by sample location during the 2007-2008 and 2008-2009 wet seasons

Site	2008-2009				2007-2008			
	N	Geometric Mean	Median	Coefficient of Variation[2]	N	Geometric Mean	Median	Coefficient of Variation[2]
Icehouse Canyon Creek	14	11	9[1]	0.26	0[3]	n/a	n/a	n/a
Prado Park Lake	14	230	170	0.32	14	144	130	0.14
Chino Creek	14	776	380	0.23	14	365	230	0.26
Mill Creek	14	595	420	0.18	14	431	215	0.26
SAR @ MWD Crossing	14	188	135	0.35	14	196	140	0.36
SAR @ Pedley Ave.	14	266	125	0.32	14	219	165	0.34

[1] – Some results less than detection level of 9 cfu/100 mL
[2] - Coefficient of variation was calculated using natural log-transformed data
[3] – Site was dry during wet season of 2007-2008.

Table 4-6. Summary of dry weather fecal coliform concentrations (cfu/100 mL) and data variability by sample location during 2007-2008 and 2008-2009 wet seasons

Site	2008-2009				2007-2008			
	N	Geometric Mean	Median	Coefficient of Variation[2]	N	Geometric Mean	Median	Coefficient of Variation[2]
Icehouse Canyon Creek	9	9[1]	9[1]	0.00	0[3]	n/a	n/a	n/a
Prado Park Lake	10	113	80	0.28	13	137	130	0.15
Chino Creek	10	366	255	0.18	13	283	230	0.22
Mill Creek	9	365	380	0.11	12	297	190	0.21
SAR @ MWD Crossing	8	58	60	0.23	12	118	120	0.24
SAR @ Pedley Ave.	8	87	85	0.15	11	102	90	0.24

[1] - Actual results less than detection level of 9 cfu/100 mL
[2] - Coefficient of variation was calculated using natural log-transformed data
[3] – Site was dry during wet season of 2007-2008.

Table 4-7. Summary of *E. coli* concentrations (cfu/100 mL) and data variability by sample location during the 2007-2008 and 2008-2009 wet seasons

Site	2008-2009				2007-2008			
	N	Geometric Mean	Median	Coefficient of Variation[2]	N	Geometric Mean	Median	Coefficient of Variation[2]
Icehouse Canyon Creek	14	11	9[1]	0.26	0[3]	n/a	n/a	n/a
Prado Park Lake	14	335	275	0.28	14	138	120	0.11
Chino Creek	14	806	450	0.27	14	311	225	0.23
Mill Creek	14	718	585	0.15	14	323	200	0.25
SAR @ MWD Crossing	14	148	100	0.35	14	165	120	0.36
SAR @ Pedley Ave.	14	257	190	0.32	14	214	125	0.34

[1] - Actual results less than detection level of 9 cfu/100 mL
[2] - Coefficient of variation was calculated using natural log-transformed data
[3] – Site was dry during wet season of 2007-2008.

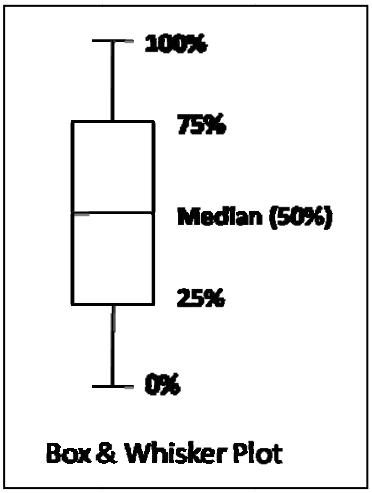
Table 4-8. Summary of dry weather *E. coli* concentrations (cfu/100 mL) and data variability by sample location during the 2007-2008 and 2008-2009 wet seasons

Site	2008-2009				2007-2008			
	N	Geometric Mean	Median	Coefficient of Variation[2]	N	Geometric Mean	Median	Coefficient of Variation[2]
Icehouse Canyon Creek	9	9[1]	9[1]	0.00	0[3]	n/a	n/a	n/a
Prado Park Lake	10	183	115	0.23	13	137	120	0.12
Chino Creek	10	386	300	0.27	13	251	220	0.19
Mill Creek	9	474	580	0.08	12	226	175	0.22
SAR @ MWD Crossing	8	48	50	0.35	12	104	115	0.36
SAR @ Pedley Ave.	8	83	100	0.32	11	104	80	0.34

[1] - Actual results less than detection level of 9 cfu/100 mL
[2] - Coefficient of variation was calculated using natural log-transformed data
[3] – Site was dry during wet season of 2007-2008.

For dry weather samples only, similar results were observed at the Chino Creek, Mill Creek and Prado Park Lake sites, i.e., the 2008-2009 geometric mean bacterial indicator concentrations were higher than the 2007-2008 geometric mean concentrations. However, the geometric mean concentrations were substantively lower at the Santa Ana River sites in 2008-2009 as compared to the 2007-2008 wet season (Tables 4-6 and 4-8).

Figures 4-1 and 4-2 summarize fecal coliform and *E. coli* concentrations, respectively, for each sample site using Box and Whisker box plots (see text box for explanation of the box plots). Box and Whisker box plots are shown for (1) all samples collected during the 2008-2009 wet season, and (2) samples collected only during dry weather conditions. For the latter presentation, wet weather sample results are shown individually (yellow circles) to illustrate the substantial difference in bacterial indicator concentrations typically observed in samples collected under wet weather conditions.



For samples collected under both wet and dry weather conditions, Icehouse Canyon Creek had the lowest observed median fecal coliform and *E. coli* concentrations (9 cfu/100 mL – essentially non-detect). The Mill Creek and Chino Creek sites had the highest observed median bacterial indicator concentrations (fecal coliform: 420 cfu/100 mL and 380 cfu/100 mL, respectively; *E. coli*: 585 cfu/100 mL and 480 cfu/100 mL, respectively) (see Figures 4-1 and 4-2 [upper]; Tables 4-5 and 4-7).

Under dry weather conditions, Icehouse Canyon Creek continued to have the lowest observed median fecal coliform and *E. coli* concentrations (9 cfu/100 mL – essentially non-detect). However, low median fecal coliform and *E. coli* concentrations were also observed at Santa Ana River @ MWD Crossing, Santa Ana River @ Pedley Avenue, and Prado Park Lake (Fecal coliform: 75 cfu/100 mL , 90 cfu/100 mL, and 110 cfu/100 mL, respectively; *E. coli*: 60 cfu/100 mL, 100 cfu/100 mL, and 115 cfu/100 mL, respectively) (see Figures 4-1 and 4-2 [lower]; Tables 4-6 and 4-8).

Figures 4-1 and 4-2 (lower) illustrate the differences in bacterial indicator concentrations observed during wet versus dry weather conditions. With few exceptions, the bacterial indicator concentrations observed during wet weather (yellow circles) were well above the median values observed during dry weather conditions.

4.3 Bacterial Indicator Compliance Analysis

The compliance analysis compared the bacterial indicator data for existing REC-1 fecal coliform and *E. coli* to the existing fecal coliform objectives and the proposed REC-1 *E. coli* objectives under development by the SWQSTF. Compliance was

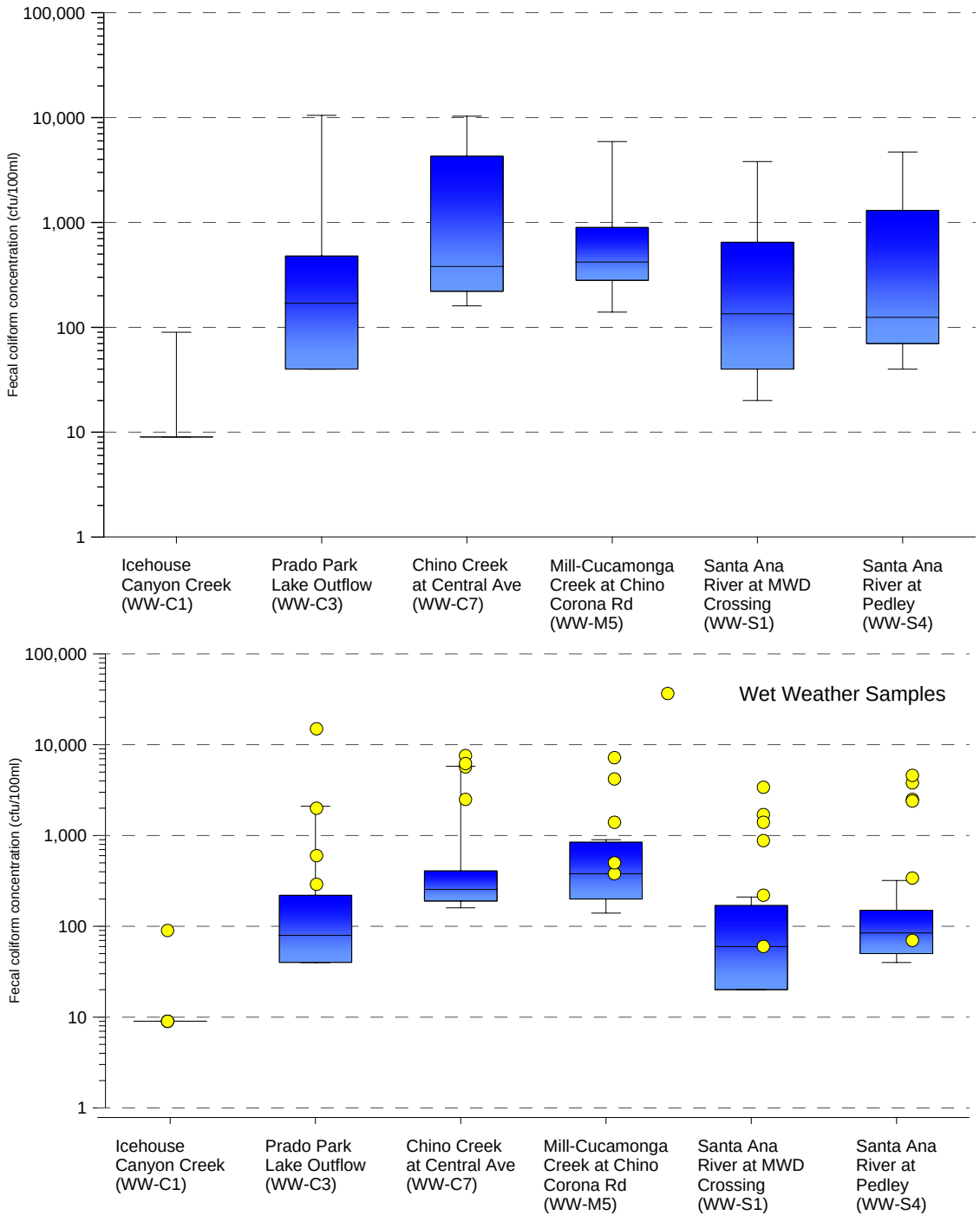


Figure 4-1. Statistical distribution of fecal coliform data collected during the 2008-2009 wet season illustrated using Box & Whisker box plots. *Upper Figure*: All samples collected under wet and dry conditions. *Lower Figure*: Box & Whisker box plot is for samples collected only under dry weather conditions; sample results classified as wet weather are show as yellow circles.

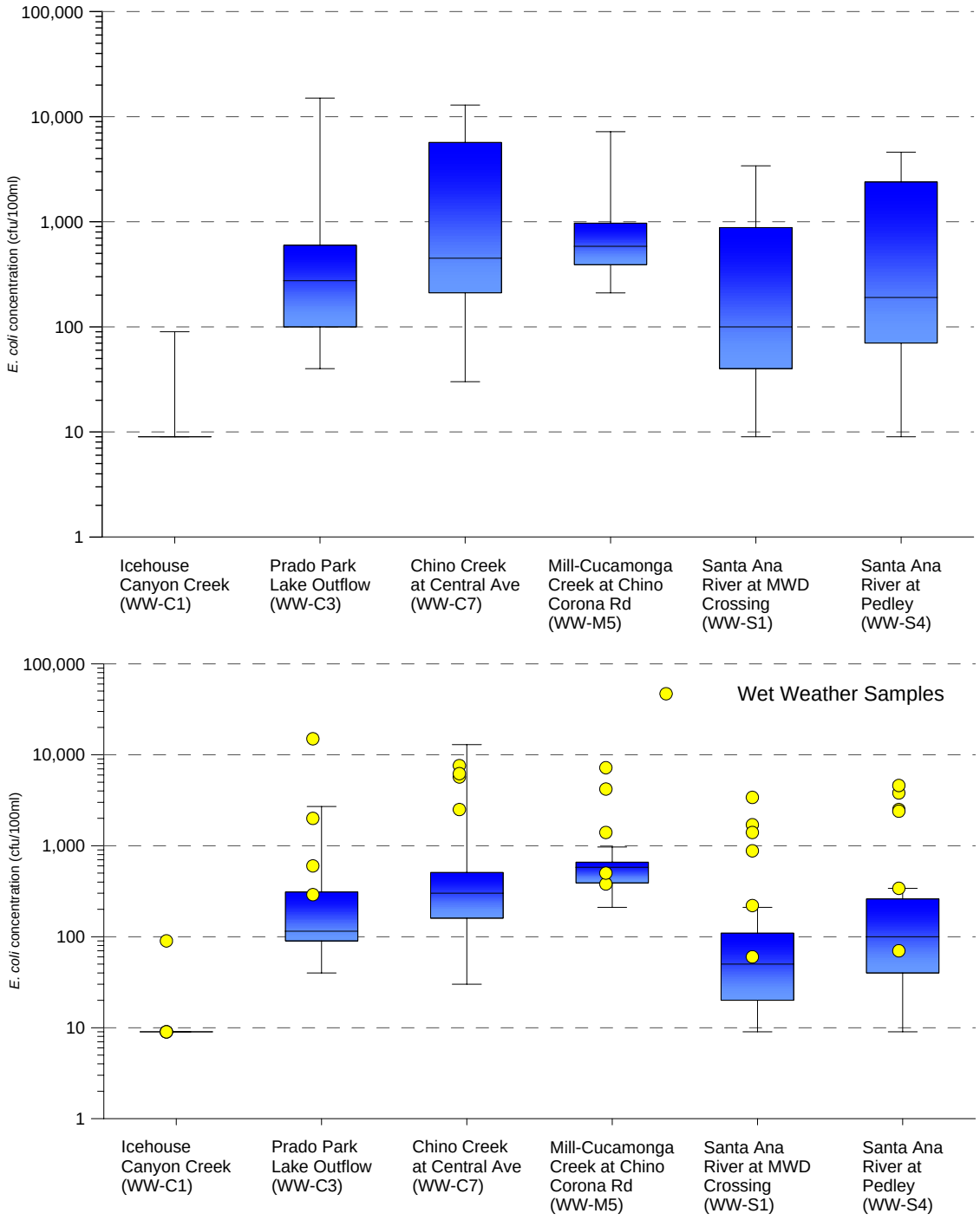


Figure 4-2. Statistical distribution of *E. coli* results collected during the 2008-2009 wet season illustrated using Box & Whisker box plots. *Upper Figure*: All samples collected under wet and dry conditions. *Lower Figure*: Box & Whisker box plot is for samples collected only under dry weather conditions; sample results classified as wet weather are show as yellow circles.

evaluated for the geometric mean and single sample exceedance frequency of bacterial indicator concentrations. The single sample exceedance frequency was calculated separately for dry and wet weather conditions. Geometric means were calculated only when at least five sample results were available from the previous five week period. Geometric mean calculations included all data regardless of whether the sample was collected under dry or wet weather conditions.

The calculated geometric means were compared to the following fecal coliform Basin Plan objective and proposed *E. coli* objective:

- Fecal coliform: log mean less than 200 organisms/100 mL based on five or more samples/30 day period

- *E. coli*: log mean less than 126 organisms/100 mL based on five or more samples/30 day period

The single sample exceedance frequency analysis was completed by calculating the frequency that all fecal coliform and *E. coli* sample results exceeded the following single sample objectives:

- Fecal coliform: 400 cfu/100 mL

- *E. coli*: 235 cfu/100 mL

During dry weather, no exceedances of the *E. coli* or fecal coliform single sample objectives occurred at Icehouse Canyon Creek or Santa Ana River @ MWD Crossing sites (Tables 4-9 and 4-10). At the Santa Ana River @ Pedley Avenue site the fecal coliform objective was not exceeded during dry weather; however, the exceedance frequency of the *E. coli* objective was 25% during dry weather. The frequency of single sample exceedances during dry weather conditions at other sites ranged from 20 to 30% for fecal coliform and 40 to 89% for *E. coli*. The Chino Creek and Mill Creek sites had the highest exceedance frequencies (Tables 4-9 and 4-10).

During wet weather, no exceedances of the *E. coli* or fecal coliform single sample objectives occurred at Icehouse Canyon Creek. At the Santa Ana River sites the exceedance frequency of single sample bacterial indicator objectives ranged from 67 to 83%. The exceedance frequency for fecal coliform ranged from 75 to 100% for the Prado Park Lake, Chino Creek and Mill Creek sites. For *E. coli*, the exceedance frequency was 100% for these same sites (Tables 4-9 and 4-10).

At Icehouse Canyon Creek the geometric mean exceedance frequency (which includes both dry and wet weather conditions) was 0% for fecal coliform and *E. coli*. The geometric mean exceedance frequency was 40% at both Santa Ana River sites for both bacterial indicators. The geometric mean exceedance frequency at Prado Park Lake ranged from 30 to 70% for fecal coliform and *E. coli*, respectively. At the Chino Creek

Table 4-9. Bacterial indicator compliance frequency for fecal coliform during the 2008-2009 wet season

Site	Single Sample Criterion Exceedance Frequency (%)		Geometric Mean Criterion Exceedance Frequency (%)
	Dry	Wet	
Icehouse Canyon Creek	0%	0%	0%
Prado Park Lake	20%	75%	30%
Chino Creek	30%	100%	100%
Mill Creek	33%	80%	100%
SAR @ MWD Crossing	0%	67%	40%
SAR @ Pedley Ave.	0%	67%	40%

Table 4-10. Bacterial indicator compliance frequency for *E. coli* during the 2008-2009 wet season

Site	Single Sample Criterion Exceedance Frequency (%)*		Geometric Mean Criterion Exceedance Frequency (%)
	Dry	Wet	
Icehouse Canyon Creek	0%	0%	0%
Prado Park Lake	40%	100%	70%
Chino Creek	60%	100%	100%
Mill Creek	89%	100%	100%
SAR @ MWD Crossing	0%	67%	40%
SAR @ Pedley Ave.	25%	83%	40%

* - Evaluation of compliance based on proposed water quality objectives. See Section 1.1

and Mill Creek sites the geometric mean exceedance frequency was 100% for both bacterial indicators.

Figures 4-3 and 4-4 illustrate the rolling geometric mean values for fecal coliform and *E. coli*, respectively, for the period beginning with the 2007 dry season through the end of the 2008-2009 wet season. Providing the extended period of record illustrates how the 2008-2009 wet season results compare to previous rolling seasonal geometric mean observations.

4.4 Correlation Analysis

Table 4-11 summarizes the results of a correlation analysis between fecal coliform and *E. coli* concentrations. A highly significant correlation was observed at all watershed-wide compliance sites, with the best correlation (r= 1.00, rounded from 0.99897) at Prado Park Lake. Observations of significant correlations between bacterial indicators is consistent with previous findings at these sample locations (e.g., see SAWPA 2009a, b).

Table 4-12 summarizes the results of correlation analyses between bacterial indicators and field parameters measured during each sample event using all sample data regardless of whether the sample was collected during dry or wet conditions. Significant correlations were observed between (1) fecal coliform concentrations and TSS and turbidity; and (2) *E. coli* concentrations and TSS.

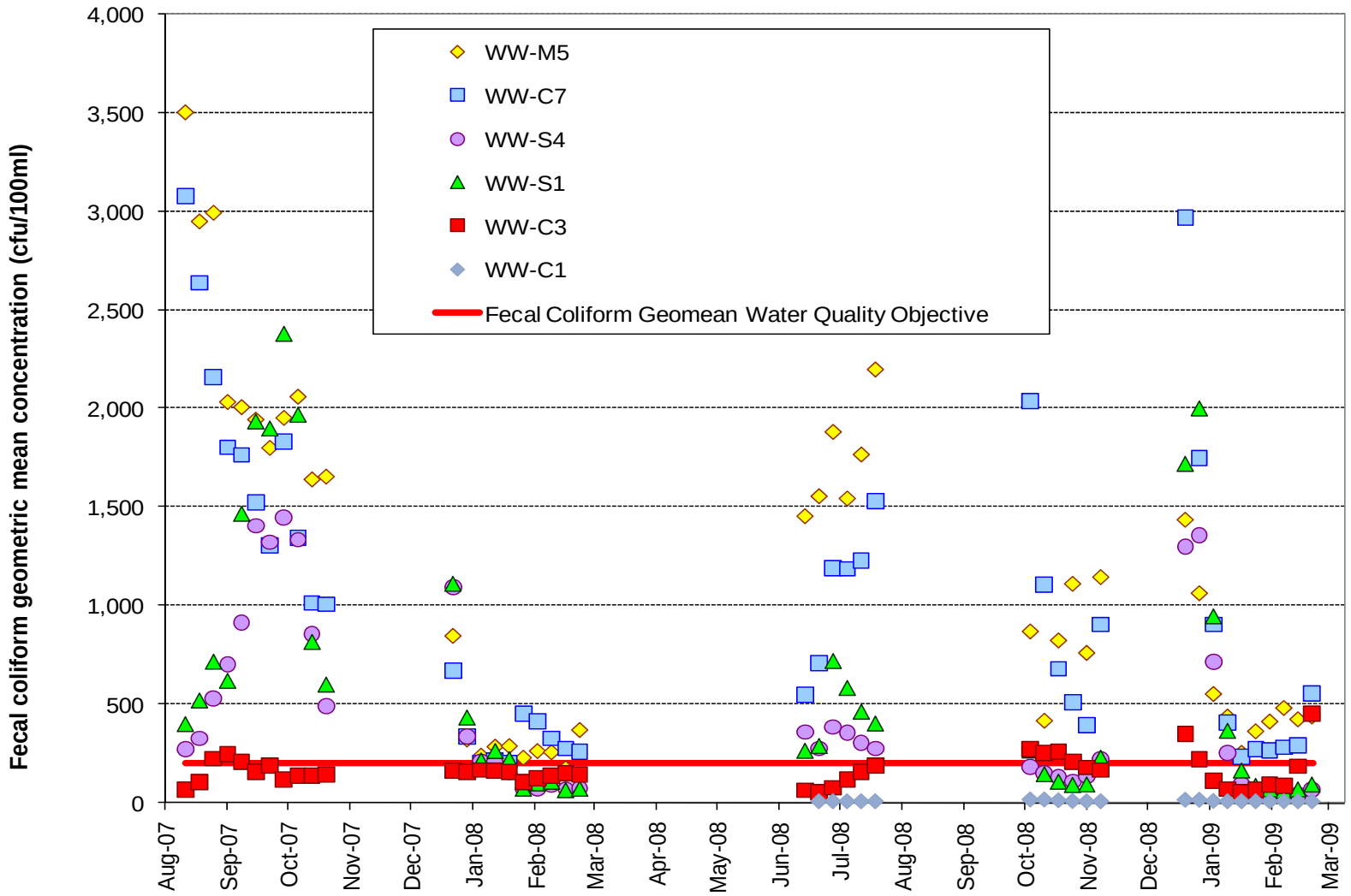


Figure 4-3. Time series plot of fecal coliform geometric means for samples collected from July 2007 through February 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks.

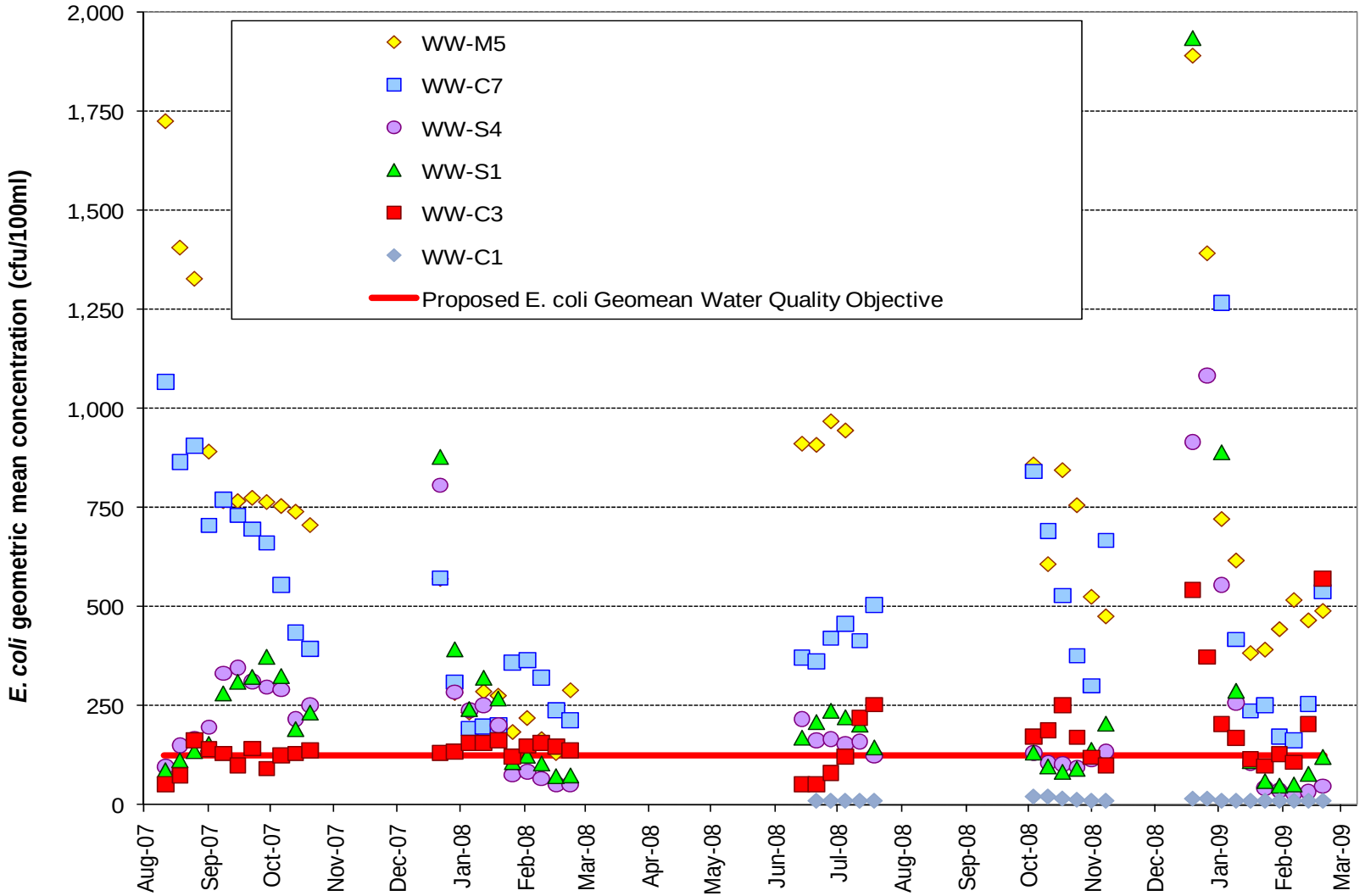


Figure 4-4. Time series plot of *E. coli* geometric means for samples collected from July 2007 through February 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks.

Table 4-11. Correlation of natural log *E. coli* concentrations (cfu/100 mL) and natural log fecal coliform concentrations (cfu/ 100 mL) during the 2008-2009 wet season

Site	Pearson's r coefficient	Degrees of freedom (n - 2)	t-statistic	p-value	Significant?[1]
Icehouse Canyon Creek	0.99	12	25.3	< 0.001	Yes +
Prado Park Lake	1.00	12	76.3	< 0.001	Yes +
Chino Creek	0.83	12	5.3	< 0.001	Yes +
Mill Creek	0.91	12	7.5	< 0.001	Yes +
SAR @ MWD Crossing	0.91	12	7.7	< 0.001	Yes +
SAR @ Pedley Ave.	0.91	12	7.7	< 0.001	Yes +

[1] – Significance determined by p value < 0.05; (-) = negative correlation; (+) = positive correlation

Table 4-12. Correlation analysis between bacterial indicator concentrations and field parameters during the 2008-2009 wet season

Data Subset/Comparison	Pearson's r coefficient	Degrees of freedom (n - 2)	Student-t statistic	p-value*
Fecal Coliform vs.				
Conductivity	-0.19	82	1.76	0.08
Dissolved Oxygen	-0.05	82	0.5	0.62
pH	0.14	82	1.3	0.2
Suspended Solids	0.28	82	2.6	0.01*
Temperature	0.01	82	0.1	0.92
Turbidity	0.33	74	3.0	0.004*
***E. coli* vs.**				
Conductivity	-0.10	82	0.9	0.37
Dissolved Oxygen	-0.05	82	0.4	0.69
pH	0.14	82	1.3	0.2
Suspended Solids	0.22	82	2.1	0.04*
Temperature	0.06	82	0.6	0.55
Turbidity	0.18	74	1.6	0.11

* - Significance determined by a p-value < 0.05

Table 4-13 provides correlation results between bacterial indicators and field parameters, but only for samples collected under dry weather conditions. The only correlations identified were between *E. coli* and temperature and pH. In contrast to the all sample analysis (Table 4-12), no correlations were observed between turbidity or TSS and either bacterial indicator.

4.5 Storm Event Data

Figures 4-5 thru 4-10 illustrate bacterial indicator concentrations during and immediately after the storm event that began on December 15, 2009. Where local flow information was available, the flow (cfs) is provided in the context of the bacterial indicator results (see Figures 4-7, 4-9, and 4-10).

During the December storm, rainfall occurred over an extended period resulting in two peak flow events on December 15 and 17, 2008. About one week after the initiation of the storm event, bacterial indicator concentrations had generally returned to baseline conditions.

Table 4-13. Correlation analysis between bacterial indicator concentrations and field parameters during the 2008-2009 wet season

Data Subset/Comparison	Pearson's r coefficient	Degrees of freedom (n - 2)	Student-t statistic	p-value
Fecal Coliform vs.				
Conductivity	0.20	52	1.48	0.14
Dissolved Oxygen	0.07	52	0.5	0.62
pH	0.23	52	1.7	0.10
Suspended Solids	0.03	52	0.2	0.84
Temperature	0.35	52	2.7	0.09
Turbidity	-0.04	52	0.3	0.77
***E. coli* vs.**				
Conductivity	0.19	52	1.4	0.17
Dissolved Oxygen	0.04	52	0.3	0.77
pH	0.28	52	2.1	0.04*
Suspended Solids	-0.02	52	0.2	0.84
Temperature	0.30	52	2.2	0.03*
Turbidity	-0.02	52	0.2	0.84

* - Significance determined by a p-value < 0.05

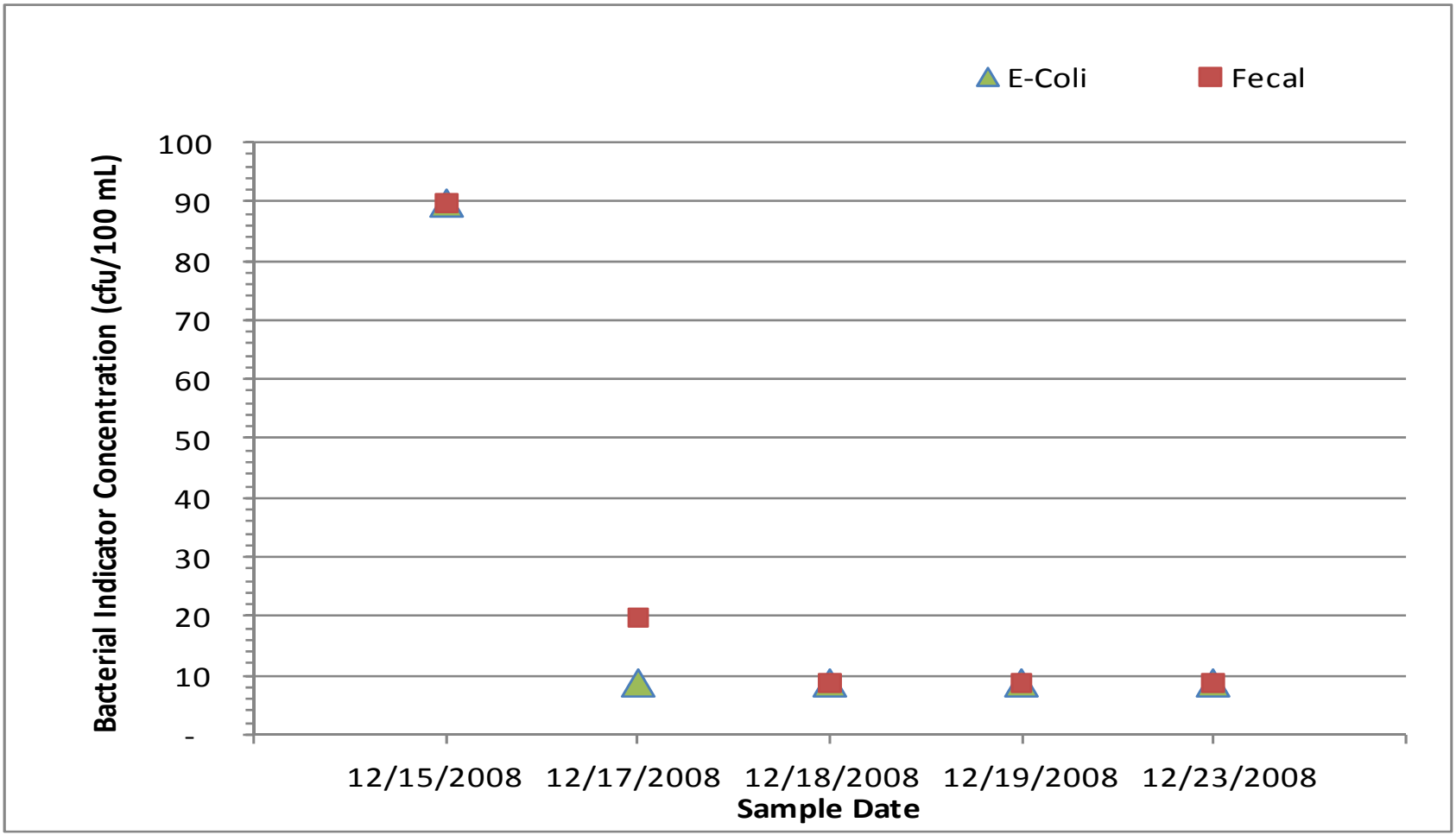


Figure 4-5. Bacterial indicator concentrations (cfu/100 mL) observed at Icehouse Canyon Creek site during and after a Decemberf 15, 2008 storm event

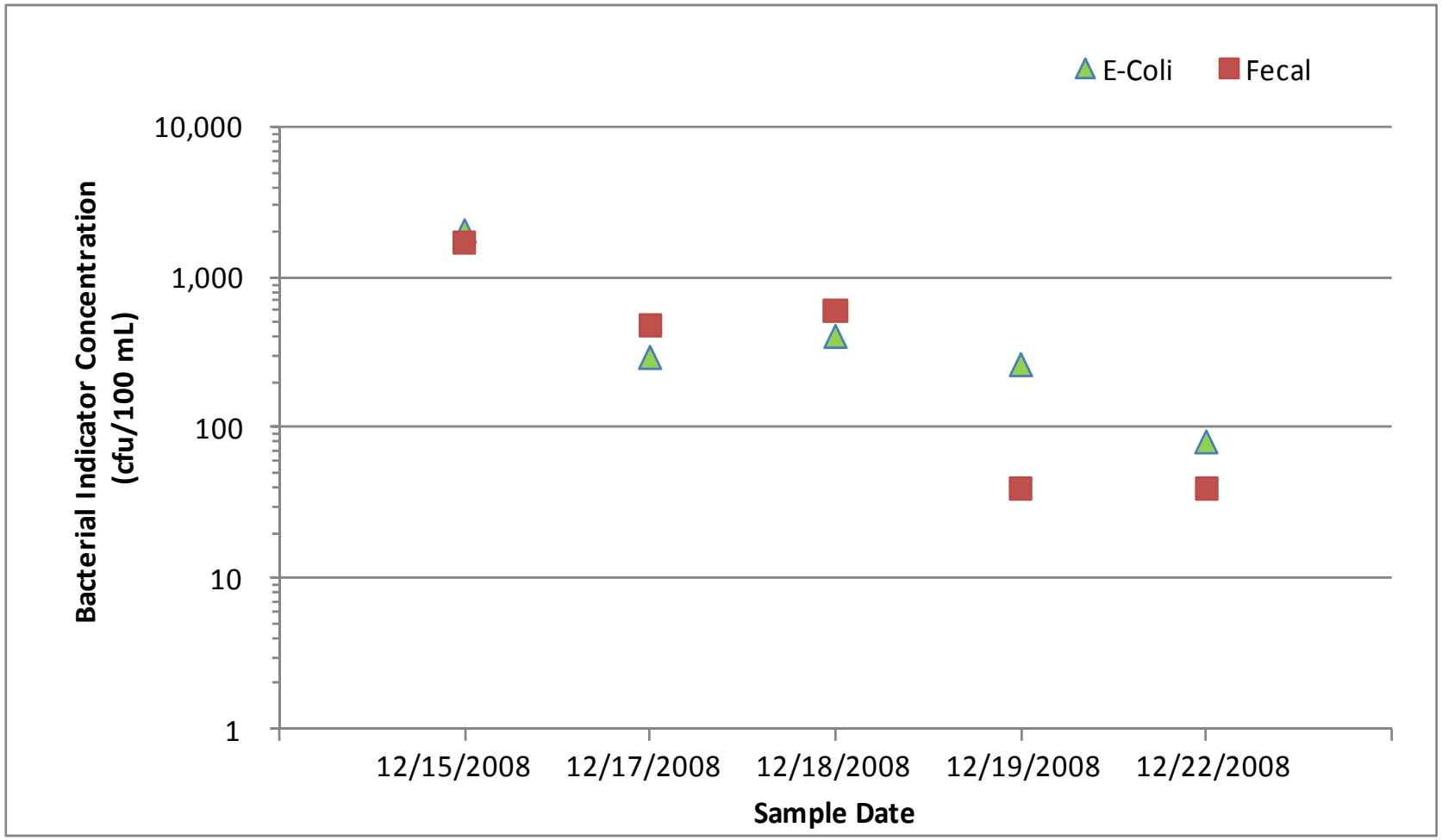


Figure 4-6. Bacterial indicator concentrations (log cfu/100 mL) observed at Prado Park Lake site during and after a December 15, 2008 storm event.

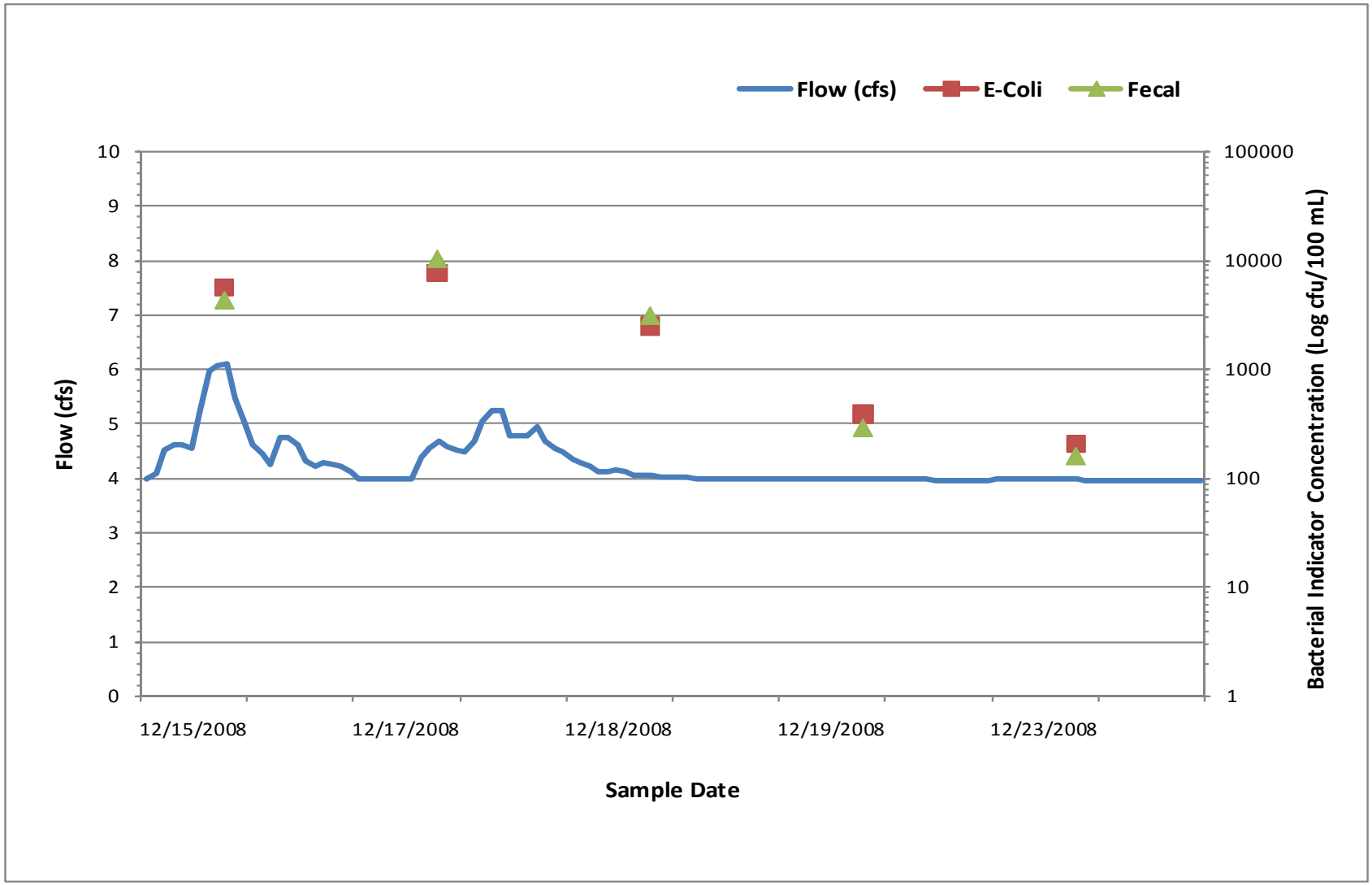


Figure 4-7. Bacterial indicator concentrations (log cfu/100 mL) and flow (cfs) observed at Chino Creek site during and after a December 15, 2008 storm event. Flow was measured at USGS gauge 11073360, Chino Creek at Schaefer Avenue.

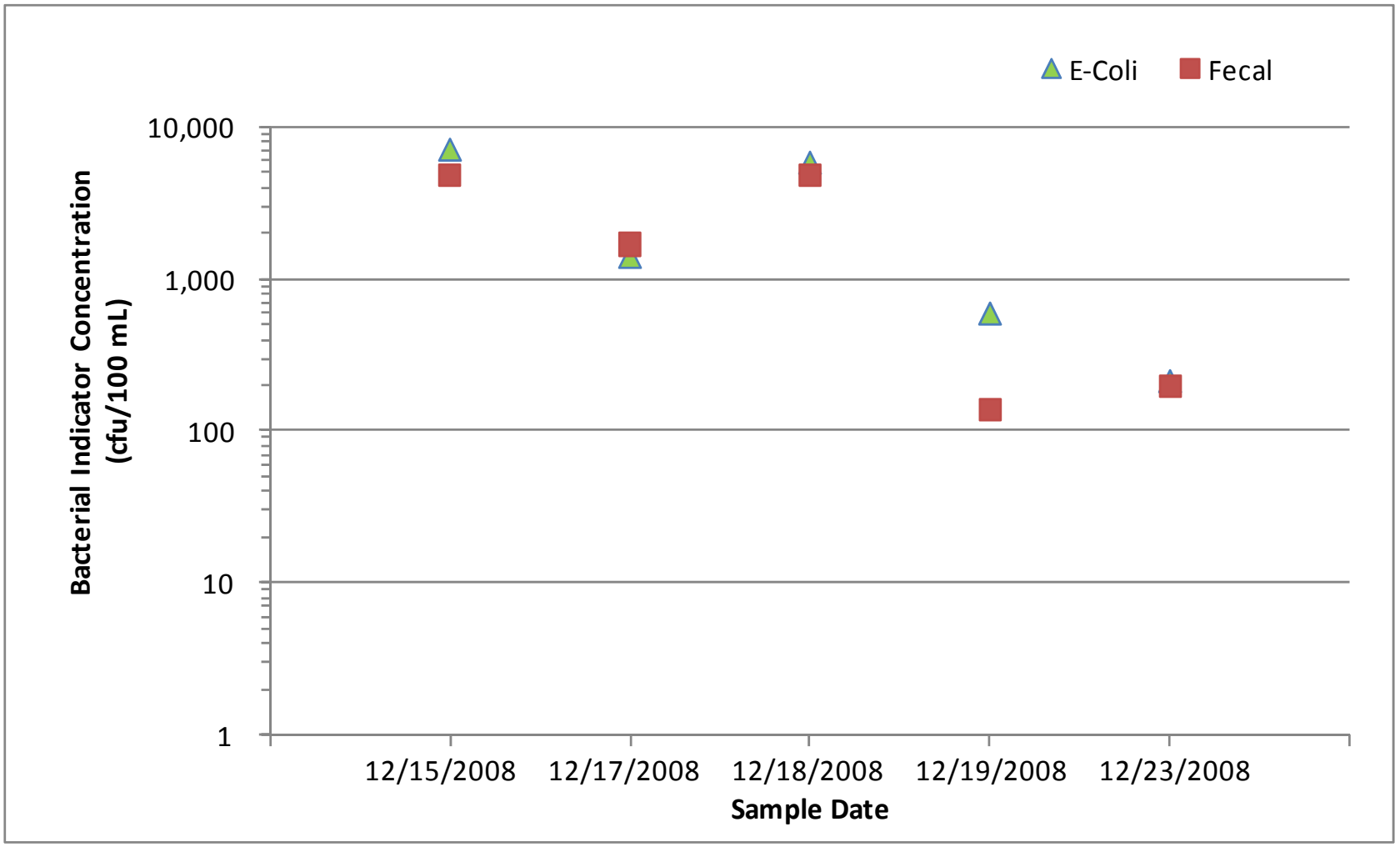


Figure 4-8. Bacterial indicator concentrations (log cfu/100 mL) observed at the Mill Creek site during and after a December 15, 2008 storm event.

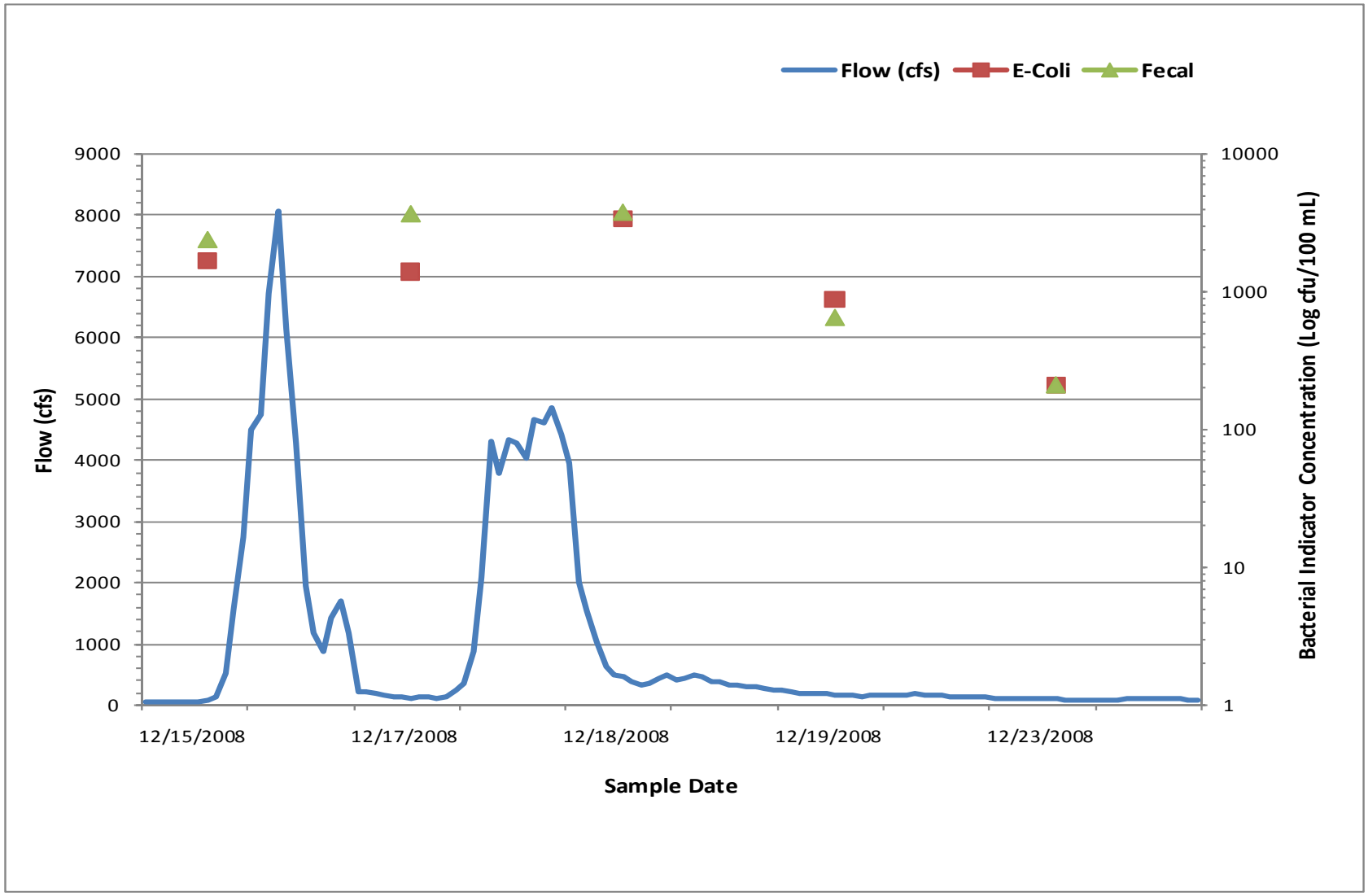


Figure 4-9. Bacterial indicator concentrations (log cfu/100 mL) and flow (cfs) observed at the Santa Ana River at MWD Crossing site during and after a December 15, 2008 storm event. Flow was measured at USGS gauge 11066460, Santa Ana River at MWD Crossing.

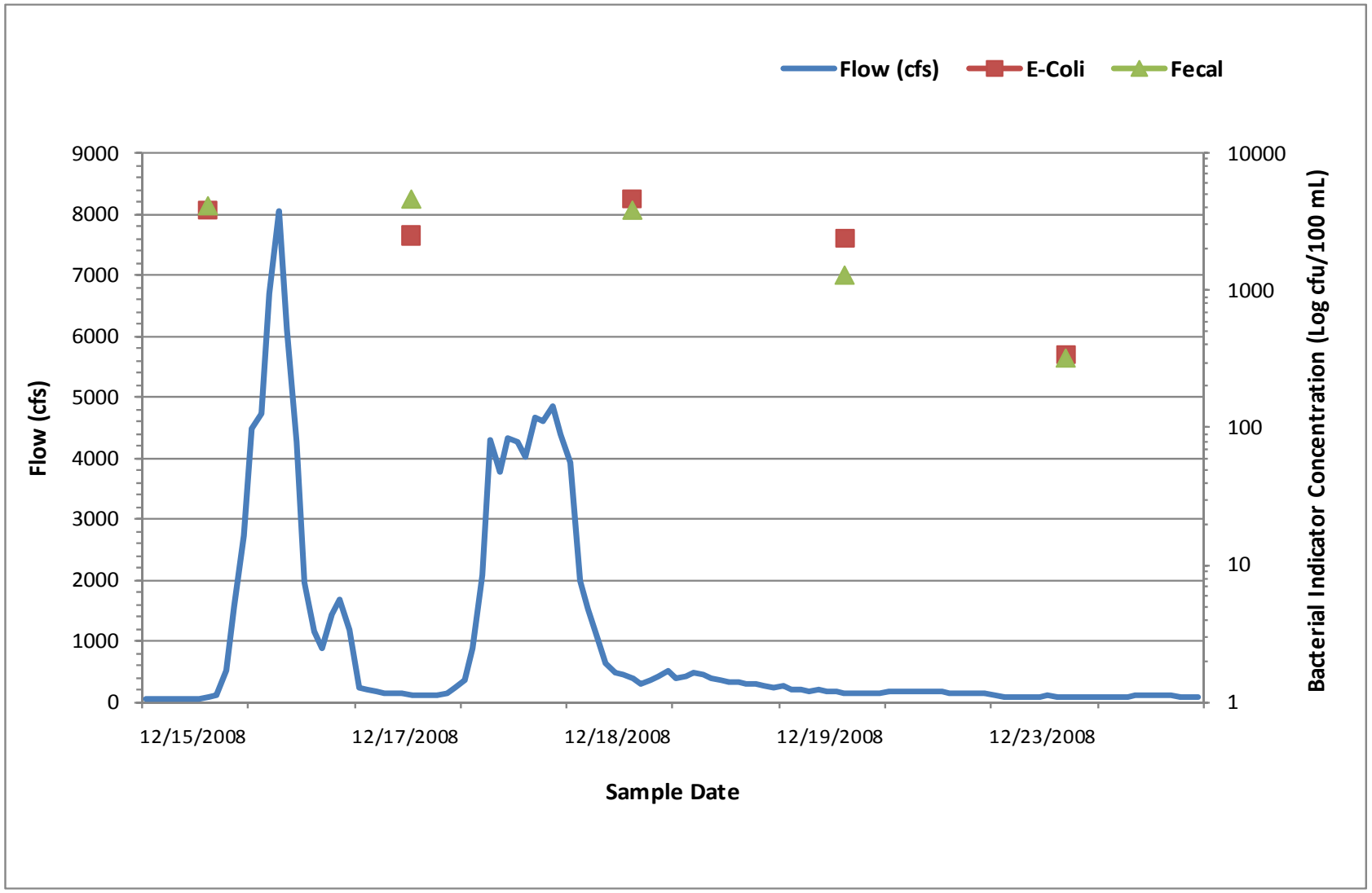


Figure 4-10. Bacterial indicator concentrations (log cfu/100 mL) and flow (cfs) observed at Santa Ana River at Pedley Avenue site during and after a storm event. Flow was measured at USGS gauge 11066460, Santa Ana River at MWD Crossing.

Section 5
References

Environmental Protection Agency (EPA). 1986. *Ambient Water Quality Criteria for Bacteria – 1986*. EPA Office of Water, Washington, DC. EPA 440/5-84-002.

Regional Water Quality Control Board (RWQCB). 1995 (and subsequent amendments). *Water Quality Control Plan Santa Ana River Basin*. Santa Ana Regional Water Quality Control Board, Riverside, CA.

RWQCB. 2005. *Resolution Amending the Water Quality Control Plan for the Santa Ana River Basin to Incorporate Bacterial Indicator Total Maximum Daily Loads (TMDLs) for Middle Santa Ana River Watershed Waterbodies.* Regional Board Resolution R8-2005-0001.

Santa Ana Watershed Project Authority (SAWPA). 2005. *Santa Ana Integrated Watershed Plan, 2005 Update, An Integrated Regional Water Management Plan*. SAWPA, Riverside, CA.

SAWPA. 2008a. *Middle Santa Ana River Water Quality Monitoring Plan*. Prepared by CDM on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. April, 2008.

SAWPA. 2008b. *Quality Assurance Project Plan for the Middle Santa Ana River Pathogen TMDL – BMP Implementation Project*. Prepared by CDM on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. April, 2008.

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

SAWPA. 2009b. *Middle Santa Ana River Bacterial Indicator TMDL 2008 Dry Season Report*. Prepared by CDM on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. March, 2009.