



Middle Santa Ana River Bacterial Indicator TMDL 2008 Dry Season Report

March 19, 2009

CDM

ON BEHALF OF

Santa Ana Watershed Project Authority
San Bernardino County Stormwater Program
County of Riverside
Cities of Chino Hills, Upland, Montclair, Ontario,
Rancho Cucamonga, Rialto, Chino, Fontana,
Norco, Corona, Riverside, Pomona, and Claremont
Agricultural Operators

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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 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 warm, dry 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 bacteria 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 various waterbodies in the MSAR watershed to the state 303(d) list of impaired waters. The MSAR Watershed TMDL Task Force ("TMDL Task Force"), which includes representation by many key watershed stakeholders, was subsequently formed to address bacterial indicator impairments in the following waterbodies:

- 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 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.

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 (2009) summarizes the findings from the first year of dry and wet season monitoring. This report provides the findings from the second year of dry season monitoring.

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

Section 2

Study Area

This section describes the study area and identifies the watershed-wide compliance monitoring locations sampled during the 2008 warm, dry season. SAWPA (2009) 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.

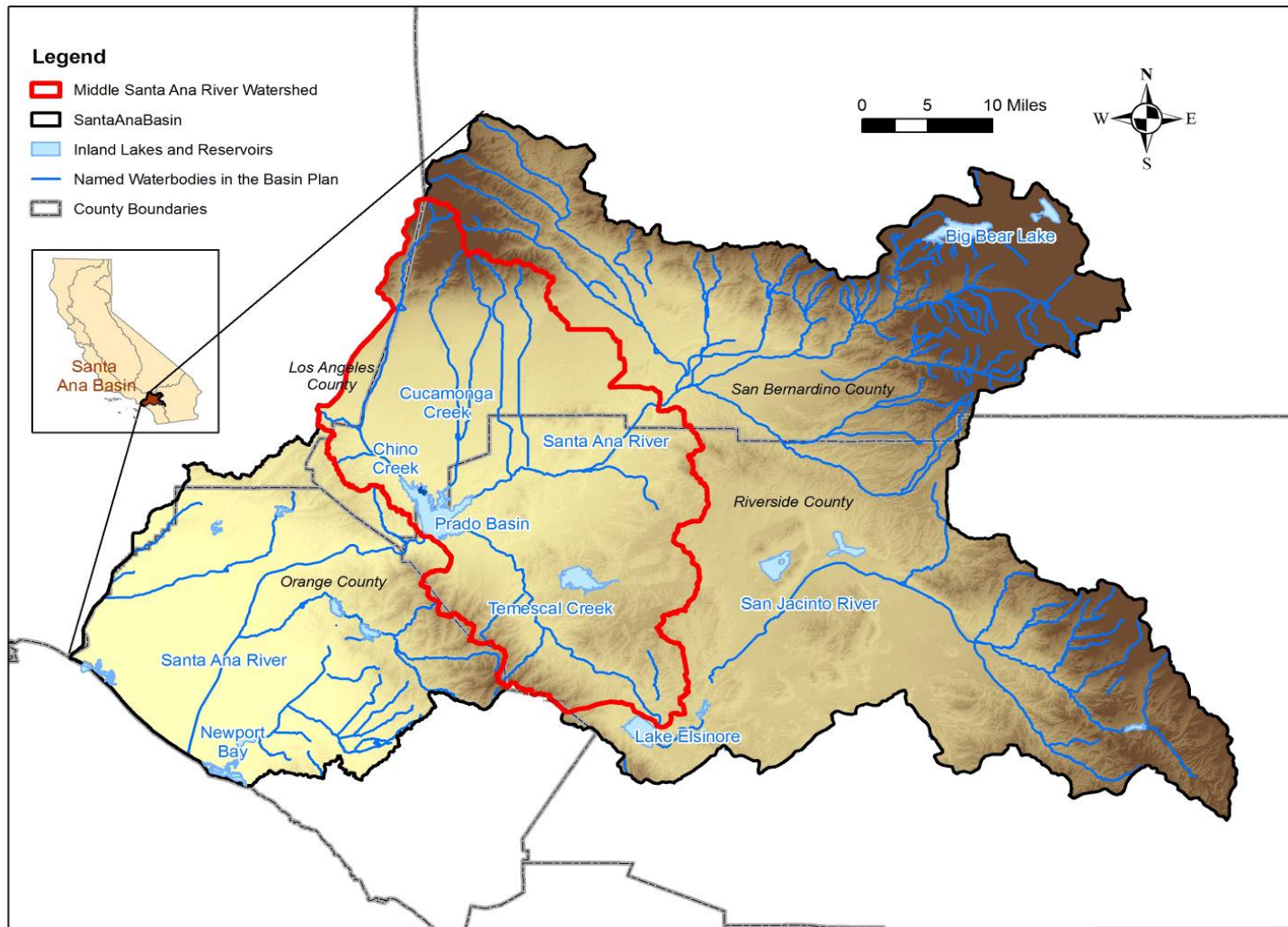


Figure 2-1. Location of the Middle Santa Ana River watershed (red outline) within the Santa Ana River watershed in southern California

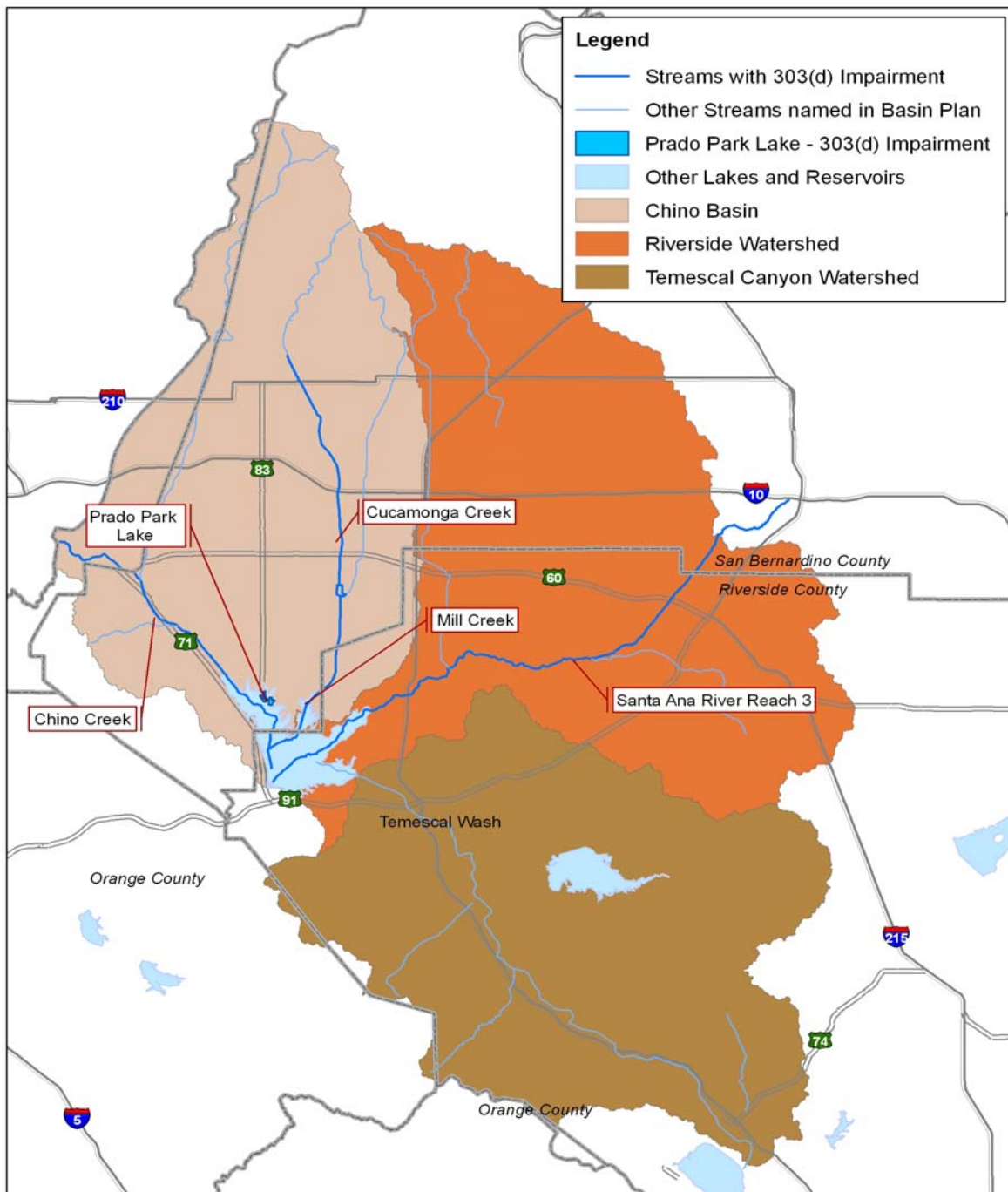


Figure 2-2. Major geographic areas of the Middle Santa Ana River watershed

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, 2009). 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.

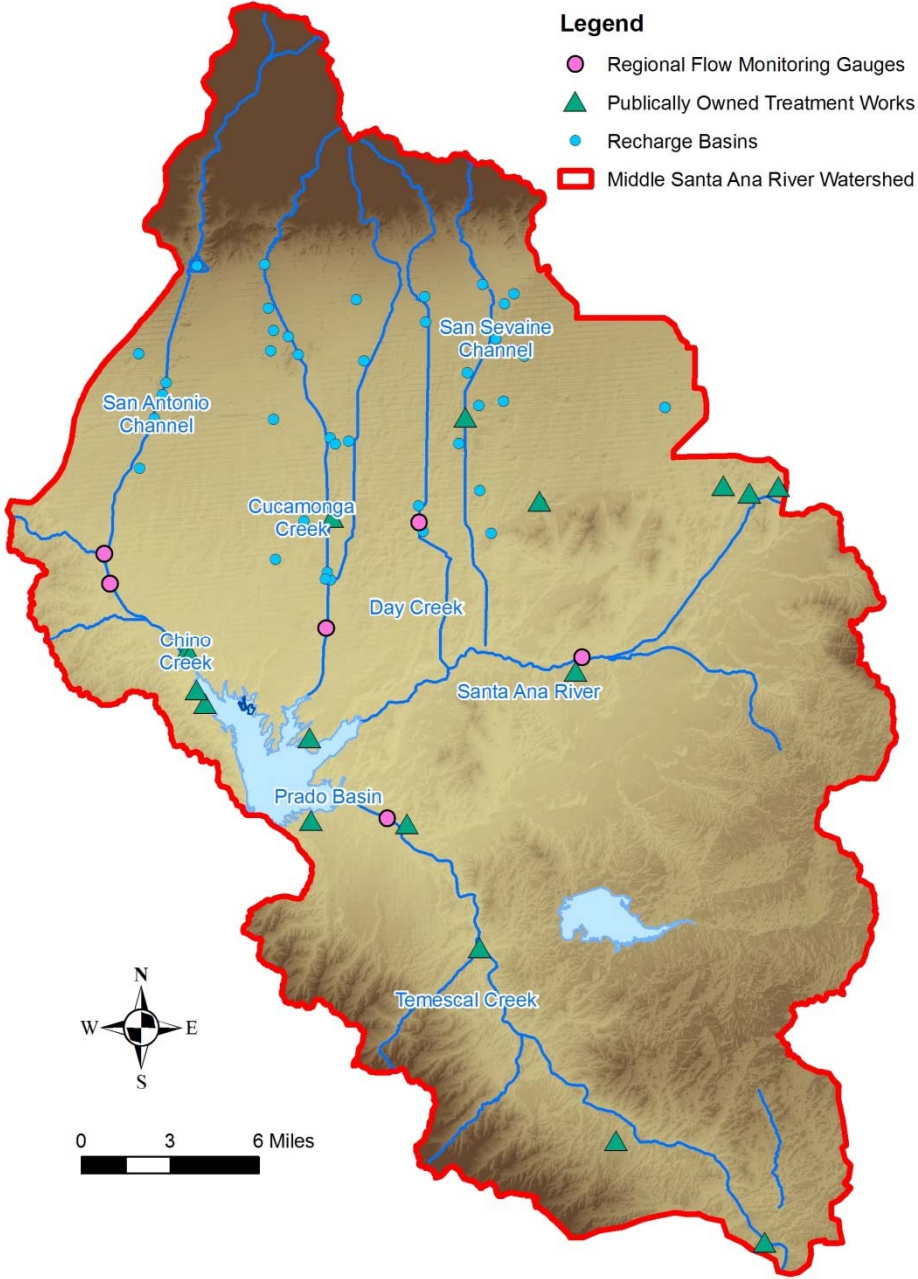


Figure 2-3. Location of recharge basins and publicly owned treatment works that influence instream flows in Middle Santa Ana River waterbodies

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 taken is 10.06 inches/year. During the same period when the 2008 warm, dry season samples were collected (May to November), the long-term average annual precipitation at this gauge is 1.42 inches.

In 2008, the Riverside Fire Station #3 rain gauge reported only 0.32 inches – all of this rain occurred during one storm on May 22, 2008. In addition, a minor rain event occurred in the area during the period when the final sample event occurred during the week of November 5th. The Riverside Fire Station #3 gauge reported no precipitation, but field notes from the Chino Creek site indicate rain had occurred immediately prior to sampling.

Temperature

Table 2-2 provides the 30-year long-term average and 2008 monthly temperatures for the study area during the months of May through November. These data show that the 2008 sampling period was warmer than normal during the entire period.

Water Quality

Bacterial indicator water quality data have been collected for many years in the MSAR watershed. SAWPA 2009 references and summarizes the findings from previous studies in the MSAR watershed.

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 dry season precipitation compared to the 2008 precipitation measured during the warm, dry season (measured at Riverside Fire Station #3)

Measurement	Precipitation (Inches)
Average Annual Precipitation (1977 – 2007)	10 .06
Average Seasonal Precipitation (May 1 to November 15, 1977-2007)	1.42
2008 Seasonal Precipitation (May 1 to November 15, 2008)	0.32 ¹

¹ – Occurred during one storm event on 5/22/08

Table 2-2. Long term average monthly dry season temperature compared to the 2008 warm, dry season temperature (measured at Riverside Fire Station #3)

Month	Average (1977-2007)	2008
May	68	69
June	74	78
July	79	80
August	80	81
September	76	79
October	69	73
November	60	65

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
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
Prado Lake	Prado Lake Outlet	WW-C3

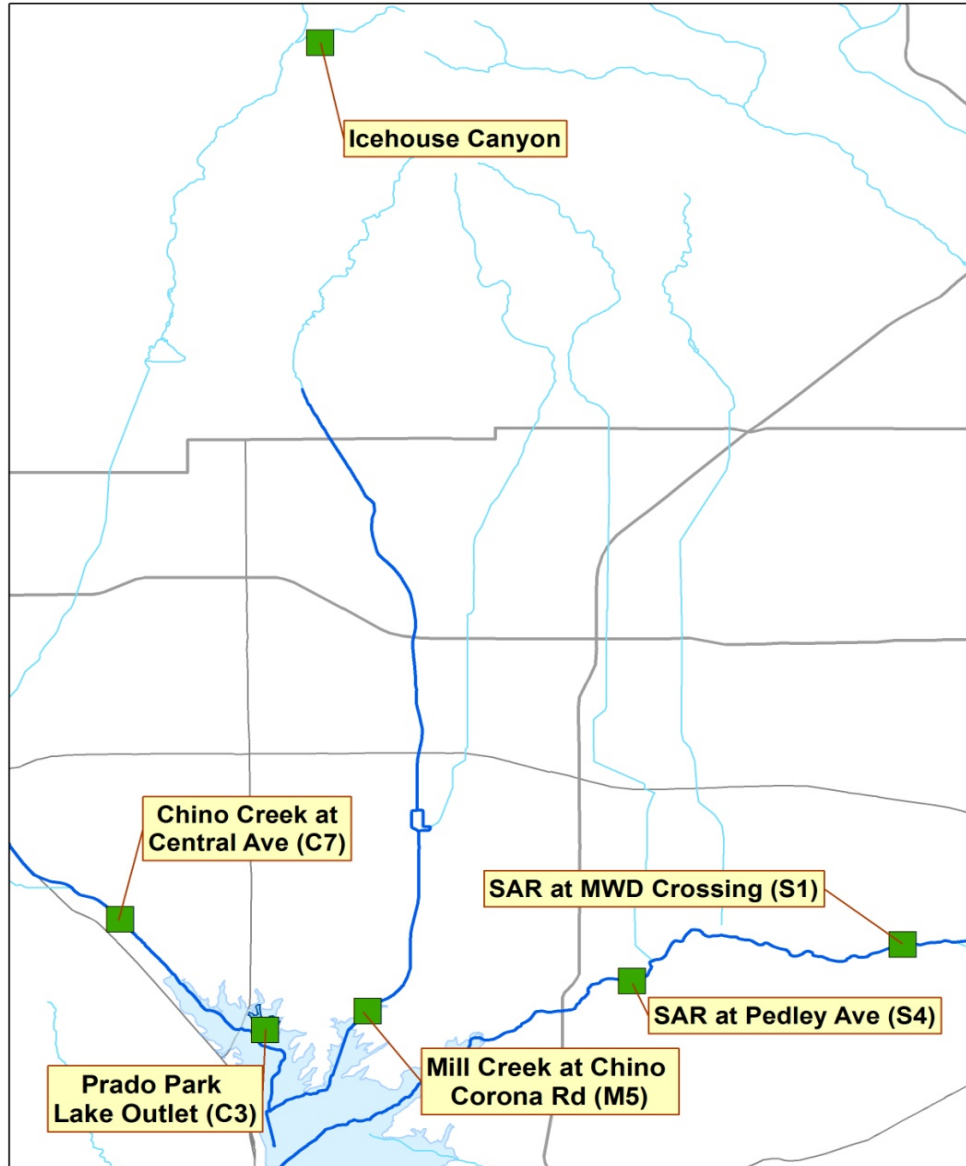


Figure 2-4. Location of watershed-wide compliance monitoring program sample locations in the Middle Santa Ana River watershed

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 included the collection of field parameter data and water samples for laboratory analysis:

- *Field Measurement:* 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, the warm, dry season sample dates were planned as follows: Collect weekly samples over a 20 week period from the week ending May 17 to the week ending October 4.

During 2008, dry season sampling began as scheduled. However, laboratory contract problems, which prevented the laboratory from accepting samples for analysis, resulted in the suspension of sampling for a six week period from the week of July 20 through the end of August. Once the contract issues were resolved, weekly sample collection resumed the week of September 1. To ensure the collection of 20 warm, dry season samples in 2008, the TMDL Task Force agreed to extend the sample period into the first week of November. Table 3-1 summarizes the results of the 2008 warm, dry season sampling effort.

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.

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.

Table 3-1. Summary of water sample collection activity during 2008 warm, dry season

Sample Month	Planned ¹	Collected	Site Dry	Samples Missed (Cause)
May	18	17	0	1 (road closure in Icehouse Canyon due to fire)
June	24	24	0	0
July ²	18	18	0	0
August ²	0	0	0	0
September	27	27	0	0
October	27	27	0	0
November	6	6	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 May six sites were planned for sampling during each of three weeks for a total of 18 samples.

² – Sample program suspended for six weeks during months of July and August (see text for discussion)

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 2009). Accordingly, prior to conducting statistical analyses, the bacterial indicator data were log transformed.

Section 4

Sample Results

This section provides a summary of the results of data analyses applied to the 2008 warm, dry season data set. Where appropriate to provide context, data results are compared to water quality results previously reported (SAWPA 2009).

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 week. No data outliers were identified in the data set. However, it is notable that during the last week of sampling (week of November 5, 2008), elevated bacterial indicator concentrations were observed in the area, especially at the Chino Creek sample location. The field notes indicate that rain fell in the area within a short time of when sampling occurred.

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 warm, dry season. Because bacterial indicator concentrations at the Icehouse Canyon site are relatively low compared to other sites, Table 4-4 provides the 2008 data distribution with and without inclusion of the Icehouse Canyon 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 data.

Tables 4-5 and 4-6 summarize the geometric mean, median, and coefficient of variation of the fecal coliform and *E. coli* concentration data for each site, respectively. The 2008 warm, dry season concentrations for fecal coliform were substantially lower in 2008 than in 2007 at four sites: Chino Creek, Mill Creek and both Santa Ana River sites. Prado Park Lake concentrations were a little higher in 2008 when compared to 2007. For *E. coli*, the same pattern was observed; however, the differences between years were less substantive. It is unknown whether these differences are meaningful given that the 2007 warm, dry season sampling period (July to October) was not the same as the 2008 sampling period (May - to mid-July; September to early November).

Figure 4-1 summarizes fecal coliform and *E. coli* concentrations for each sample site using Box and Whisker box plots (see text box on page 4-2 for explanation of the box plots). The substantial breadth of the “whiskers” at most sites is indicative of the high variability of bacterial indicator concentrations observed.

Table 4-1. Summary of water quality monitoring data collected during the 2008 warm, dry 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	19	20	20	20	20	20
Median	9	175	720	1400	255	210
Range	9 - 40	30 - 500	200 - 36000	40 - 18000	50 - 2700	40 - 5600
E. coli (cfu/100 ml)						
N	19	20	20	20	20	20
Median	9	120	460	760	155	145
Range	9 - 40	20 - 670	210 - 33000	140 - 8700	40 - 470	40 - 690
TSS (mg/L)						
n	19	20	20	20	20	20
Median	1.0	21.0	9.5	7.7	7.8	8.7
Range	0.2 - 7.5	8.4 - 39.6	3.6 - 93.7	3.8 - 13	4 - 31.8	4.5 - 65.2
Dissolved Oxygen (mg/L)						
n	19	20	19	18	19	19
Median	9.0	7.8	8.9	6.9	8.6	8.3
Range	7.2 - 10.2	5.3 - 10.9	6.4 - 10.6	2.3 - 13.6	8 - 9.6	7.2 - 9.3
pH (standard units)						
N	19	20	20	20	20	20
Median	6.7	7.8	7.9	7.8	7.5	7.7
Range	5.5 - 7.7	7 - 8.4	6.9 - 8.5	7.3 - 8.9	6.8 - 8.1	7.1 - 8.2
Turbidity (NTU)						
n	19	20	20	20	20	20
Median	0.9	11.4	5.5	4.9	4.8	5.1
Range	0.5 - 2.4	1.8 - 25.3	2 - 72.7	1.9 - 9	3 - 13.2	3.2 - 25.4
Water Temperature (°C)						
n	19	20	20	20	20	20
Median	10.1	23.6	22.5	21.6	19.5	21.2
Range	0.9 - 11.5	18.2 - 26.8	18.6 - 29.1	17.2 - 25	15.7 - 22.8	16.9 - 24.7
Flow (cfs)						
n	19	20	20	20	20	20
Median	0.9	5.5	29.3	31.3	63.1	155.2
Range	0.2 - 10.2	0 - 23.3	7.8 - 217.4	11.4 - 93.2	53.9 - 135.8	0 - 283.7
Conductivity (µS/cm)						
n	19	20	20	20	20	20
Median	197	729	907	654	669	828
Range	156 - 2020	520 - 940	25 - 1150	535 - 752	104 - 948	556 - 1040

Table 4-2. Fecal coliform (cfu/100 ml) concentrations observed at watershed-wide compliance sites during the 2008 warm, dry season

Sample Date (Week of)	Icehouse Canyon (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)
5/13/08	No Sample (Dry)	99	280	1,000	340	180
5/20/08	< 9	60	200	540	110	40
5/27/08	< 9	60	590	3,500	500	690
6/3/08	< 9	90	470	3,000	820	670
6/10/08	< 9	30	3,200	1,140	390	380
6/17/08	< 9	40	1,000	1,400	90	280
6/24/08	< 9	> 400	2,700	1,400	580	3,900
7/1/08	< 9	490	580	1,300	340	240
7/8/08	< 9	420	560	5,900	380	210
7/15/08	< 9	70	9,600	> 3,400	230	190
9/2/08	< 9	290	8,100	1,600	350	2,300
9/9/08	30	170	2,400	590	280	320
9/16/08	40	> 500	3,800	380	190	210
9/23/08	20	230	850	2,800	50	140
9/30/08	< 9	260	560	490	220	60
10/7/08	< 9	200	380	40	130	110
10/14/08	< 9	200	210	18,000	150	70
10/21/08	< 9	160	920	1,700	70	90
10/28/08	< 9	110	230	420	140	160
11/4/08	< 9	180	36,000	3,800	2,700	5,600

Table 4-3. *E. coli* (cfu/100 ml) concentrations observed at watershed-wide compliance sites during the 2008 warm, dry season

Sample Date (Week of)	Icehouse Canyon (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)
5/13/08	No Sample (Dry)	100	350	1,260	470	110
5/20/08	< 9	40	210	590	160	90
5/27/08	< 9	80	320	700	270	200
6/3/08	< 9	20	500	1,180	> 160	> 200
6/10/08	< 9	70	610	1,030	150	370
6/17/08	< 9	90	310	1,240	110	310
6/24/08	< 9	340	440	810	180	170
7/1/08	< 9	670	480	620	180	140
7/8/08	< 9	360	310	8,700	200	130
7/15/08	< 9	140	1,610	1,100	40	70
9/2/08	< 9	160	850	790	180	690
9/9/08	40	50	1,000	540	140	190
9/16/08	30	350	1,130	730	130	90
9/23/08	30	230	710	2,100	80	40
9/30/08	< 9	240	620	720	150	90
10/7/08	< 9	240	320	140	60	150
10/14/08	< 9	220	260	2,800	120	90
10/21/08	< 9	50	210	420	90	140
10/28/08	< 9	40	230	340	200	320
11/4/08	< 9	99	33,000	440	340	620

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

Statistic	2008 w/o Icehouse Canyon		2008 w/ Icehouse Canyon	
	<i>E. coli</i>	Fecal coliform	<i>E. coli</i>	Fecal coliform
Sample Size (n)	100	100	119	119
Geometric Mean	270	437	162	242
10 th Percentile	79	70	9	9
25 th Percentile	138	178	80	80
50 th Percentile (median)	235	380	190	260
75 th Percentile	595	1000	455	680
90 th Percentile	1037	3410	880	3040

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

Site	2008				2007			
	N	Geometric Mean	Median	Coefficient of Variation ²	N	Geometric Mean	Median	Coefficient of Variation ²
Icehouse Canyon ¹	19	11	9	0.19	0	n/a	n/a	n/a
Prado Park Lake	20	152	175	0.17	15	114	140	0.25
Chino Creek	20	1,116	720	0.20	15	1,678	1,800	0.11
Mill Creek	20	1,334	1,400	0.18	15	2,240	2,300	0.09
SAR @ MWD Crossing	20	251	255	0.17	15	572	420	0.18
SAR @ Pedley Ave.	20	283	210	0.24	15	773	550	0.19

¹ – Some results less than detection level of 9 cfu/100 mL

² - Coefficient of variation was calculated using natural log-transformed data

Table 4-6. Summary of *E. coli* concentrations (cfu/100 mL) and data variability by sample location during the 2007 and 2008 warm, dry seasons

Site	2008				2007			
	N	Geometric Mean	Median	Coefficient of Variation ²	N	Geometric Mean	Median	Coefficient of Variation ²
Icehouse Canyon ¹	19	11	9 ¹	0.20	0	n/a	n/a	n/a
Prado Park Lake	20	124	120	0.19	15	90	110	0.27
Chino Creek	20	570	460	0.18	15	676	770	0.09
Mill Creek	20	855	760	0.13	15	979	780	0.09
SAR @ MWD Crossing	20	148	155	0.17	15	204	220	0.18
SAR @ Pedley Ave.	20	162	145	0.24	15	187	150	0.19

¹ - Actual results less than detection level of 9 cfu/100 mL

² - Coefficient of variation was calculated using natural log-transformed data

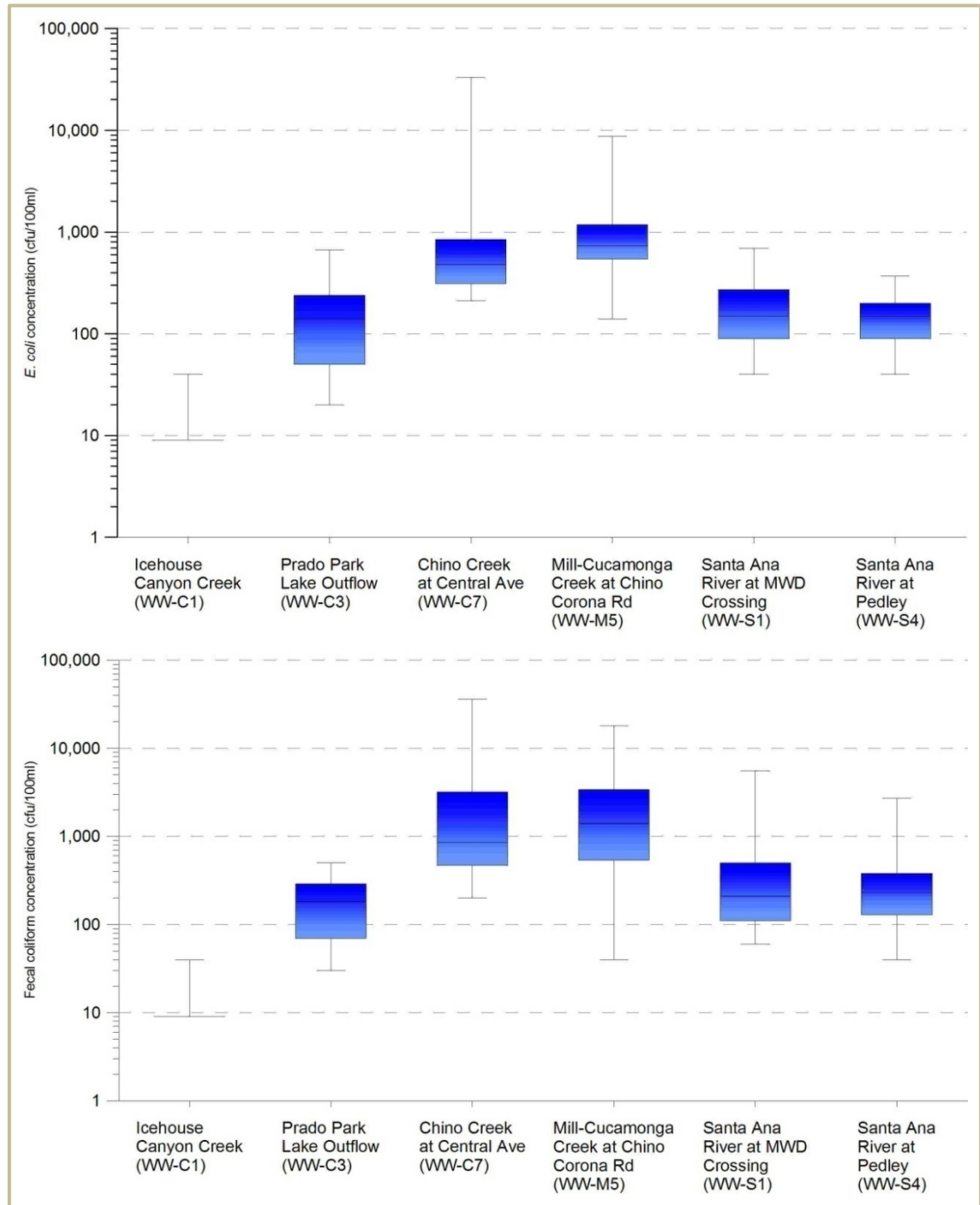
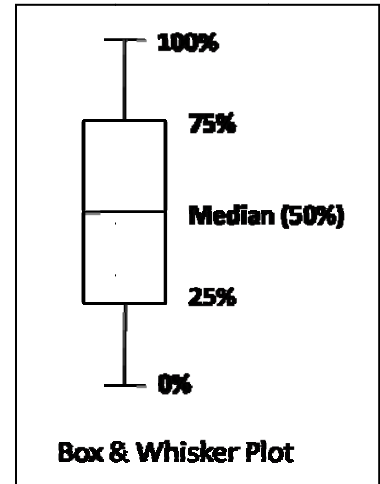


Figure 4-1. Statistical distribution of bacterial indicator data during the 2008 warm, dry season (fecal coliform, lower figure; *E. coli*, upper figure) illustrated using Box & Whisker box plots (see Section 4.2 for explanation of how to interpret Box & Whisker box plots).

Icehouse Canyon (9 cfu/100 mL - essentially non-detect) and Prado Park Lake Outlet (175 cfu/100 mL) had the lowest observed median fecal coliform concentrations. The Mill Creek site had the highest observed concentrations (1400 cfu/100 mL) (see Figure 4-1).

Sites with the highest and lowest *E. coli* concentrations were the same as those observed for fecal coliform. Icehouse Canyon (9 cfu/100 mL - essentially non-detect) and Prado Park Lake Outlet (120 cfu/100 mL) had the lowest median *E. coli* concentrations. The Mill Creek site had the highest median concentrations (760 cfu/100 mL) (see Figure 4-1).



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 REC-1 *E. coli* objectives under development by the SWQSTF. Compliance was evaluated for the geometric mean of bacterial indicator concentrations and the single sample exceedance frequency. Geometric means were calculated only when at least five sample results were available from the previous five week period. 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

No exceedances of the *E. coli* or fecal coliform single sample or geometric mean objectives were observed at Icehouse Canyon Creek (Tables 4-7 and 4-8). Among the other watershed-wide compliance sites, the fecal coliform single sample exceedance frequency ranged from 15% at Prado Park Lake to 90% at Mill Creek. For *E. coli*, the single sample exceedance frequency ranged from 30% at Prado Park Lake to 95% at Mill Creek.

Table 4-7. Bacterial indicator compliance frequency for fecal coliform during the 2008 warm, dry season

Site	Single Sample Criterion Exceedance Frequency (%)	Geometric Mean Criterion Exceedance Frequency (%)
Icehouse Canyon Creek	0%	0%
Prado Park Lake	15%	33%
Chino Creek	75%	100%
Mill Creek	90%	100%
SAR @ MWD Crossing	20%	58%
SAR @ Pedley Ave.	25%	67%

Table 4-8. Bacterial indicator compliance frequency for *E. coli* during the 2008 warm, dry season

Site	Single Sample Criterion Exceedance Frequency (%)*	Geometric Mean Criterion Exceedance Frequency (%)*
Icehouse Canyon Creek	0%	0%
Prado Park Lake	30%	50%
Chino Creek	85%	100%
Mill Creek	95%	100%
SAR @ MWD Crossing	15%	58%
SAR @ Pedley Ave.	25%	75%

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

The geometric mean exceedance frequency for fecal coliform ranged from 33% at Prado Park Lake to 100% at Chino and Mill Creeks (Tables 5-7 and 5-8). The geometric mean exceedance frequency for *E. coli* ranged from 33% at Prado Park Lake to 100% at Chino and Mill Creeks.

Figures 4-2 and 4-3 illustrate the geometric mean values for fecal coliform and *E. coli*, respectively, for the period beginning with the 2007 warm, dry season through the end of the 2008 warm, dry season. This extended period is illustrated to put the 2008 results in context with 2007.

4.4 Correlation Analysis

Table 4-9 summarizes the results of a correlation analysis between fecal coliform and *E. coli* concentrations. A significant correlation was observed at all watershed-wide compliance sites, with the best correlation ($r=0.96$) at Chino Creek. Observation of a significant correlation between bacterial indicators is consistent with previous findings at these sample locations (e.g., see SAWPA 2009).

Table 4-10 summarizes the results of all correlation analyses between bacterial indicators and other field parameters measured during each sample event. A very strong correlation was observed between bacterial indicator concentrations and TSS and turbidity. Bacterial indicators did not correlate with any other field parameters.

Table 4-9. Correlation of natural log *E. coli* concentrations (cfu/100 mL) and natural log fecal coliform concentrations (cfu/ 100 mL) during the 2008 warm, dry season

Site	Pearson's r coefficient	Degrees of freedom (n - 2)	t-statistic	p-value	Significant? ¹
Icehouse Canyon	0.90	17	8.5	< 0.001	Yes +
Prado Park Lake	0.87	18	7.3	< 0.001	Yes +
Chino Creek	0.96	18	14.2	< 0.001	Yes +
Mill Creek	0.44	18	2.1	< 0.05	Yes +
SAR @ MWD Crossing	0.49	18	2.4	0.027	Yes +
SAR @ Pedley Ave.	0.65	18	3.6	0.002	Yes +

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

Table 4-10. Correlation among bacterial indicator concentrations and measured field parameters during the 2008 warm, dry season

Data Subset/ Comparison	Pearson's r coefficient	Degrees of freedom (n - 2)	Student-t statistic	p-value
Fecal Coliform vs.				
Conductivity	0.001	117	0.01	0.99
Dissolved Oxygen	-0.07	112	0.7	0.49
pH	0.06	117	0.6	0.55
Total Suspended Solids	0.49	117	6.0	< 0.001*
Temperature	0.10	117	1.1	0.27
Turbidity	0.64	117	8.9	< 0.001*
<i>E. coli</i> vs.				
Conductivity	-0.06	117	0.6	0.55
Dissolved Oxygen	-0.02	112	0.2	0.84
pH	-0.03	117	0.4	0.69
Total Suspended Solids	0.59	117	7.8	< 0.001*
Temperature	0.08	117	0.8	0.43
Turbidity	0.74	117	11.8	< 0.001*

* - Significance determined by a p-value < 0.05

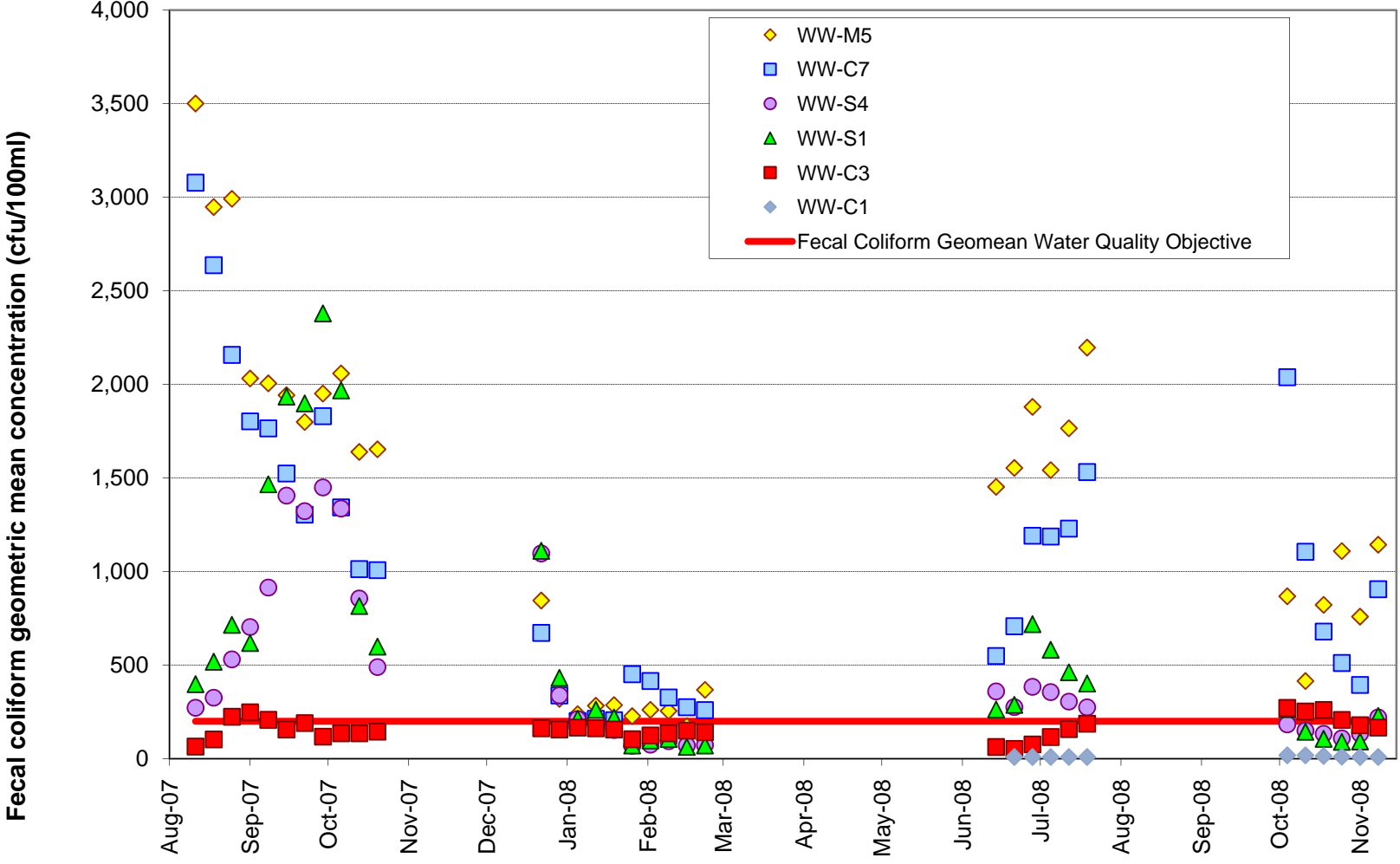


Figure 4-2. Time series plot of fecal coliform geometric means for samples collected from July 2007 through November 2008. A geometric mean was calculated only if five samples were collected during the previous five weeks.

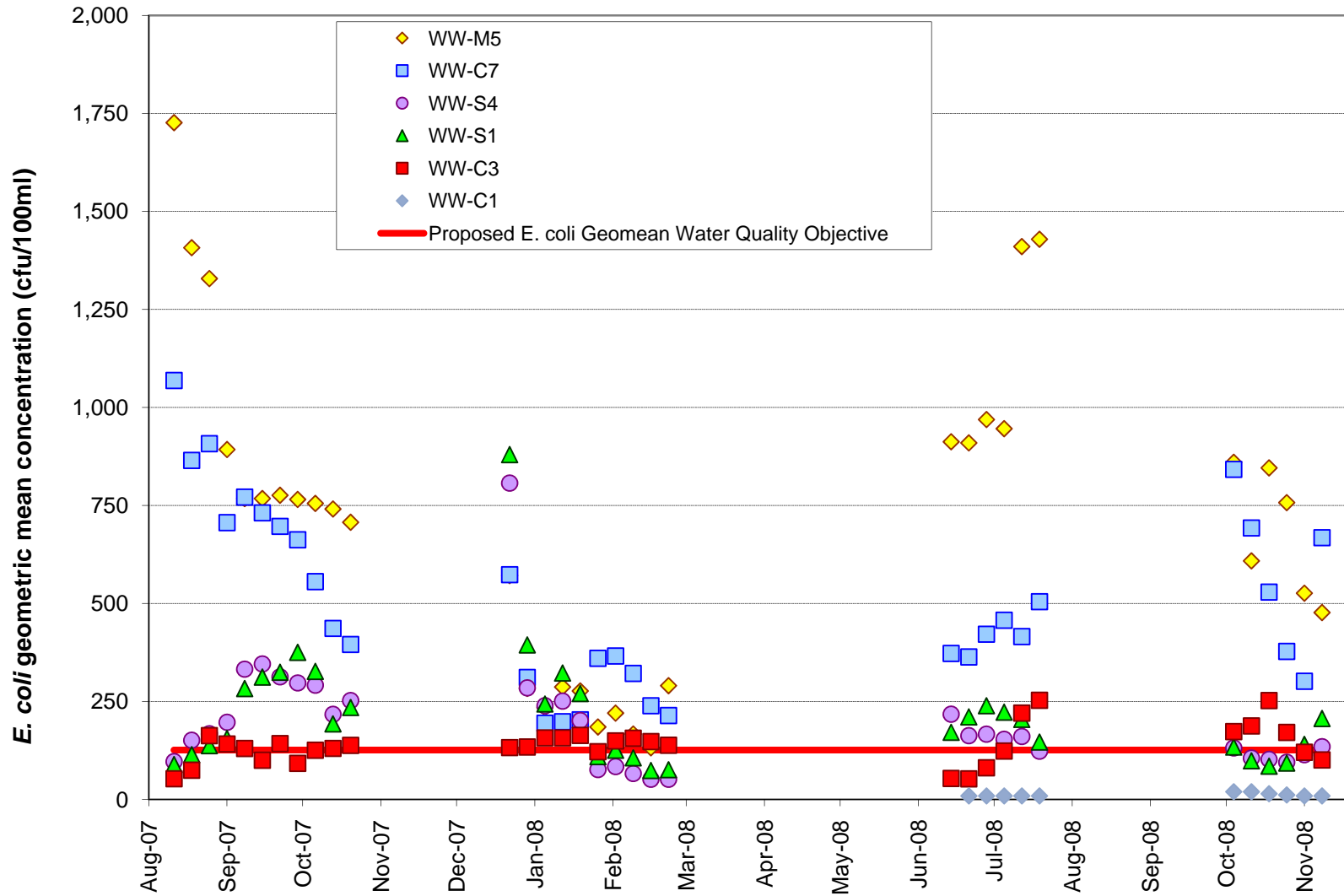


Figure 4-3. Time series plot of *E. coli* geometric means for samples collected from July 2007 through November 2008. A geometric mean was calculated only if five samples were collected during the previous five weeks.

Section 5

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