Middle Santa Ana River Bacterial Indicator TMDL 2009-2010 Wet Season Report

May 19, 2010

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 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 2009-20010 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), SAWPA (2009c), and SAWPA (2009d) summarize the findings from the 2008 dry, 2008-2009 wet, and 2009 dry seasons, respectively. This report provides the findings from the 2009-2010 wet season.

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[1] The Middle Santa Ana River Monitoring Plan and Quality Assurance Project Plan are available at hhttp://www.waterboards.ca.gov/santaana/water_issues/programs/tmdl/msar_tmdl.shtml

Section 2
Study Area

This section describes the study area and identifies the watershed-wide compliance monitoring locations sampled during the 2009-2010 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, Los Angeles, 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 and San Bernardino Counties) – Surface drainage in this area is generally northwestward or southwestward from the incorporated and unincorporated areas of Riverside and San Bernardino Counties to Reach 3 of the Santa Ana River.

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

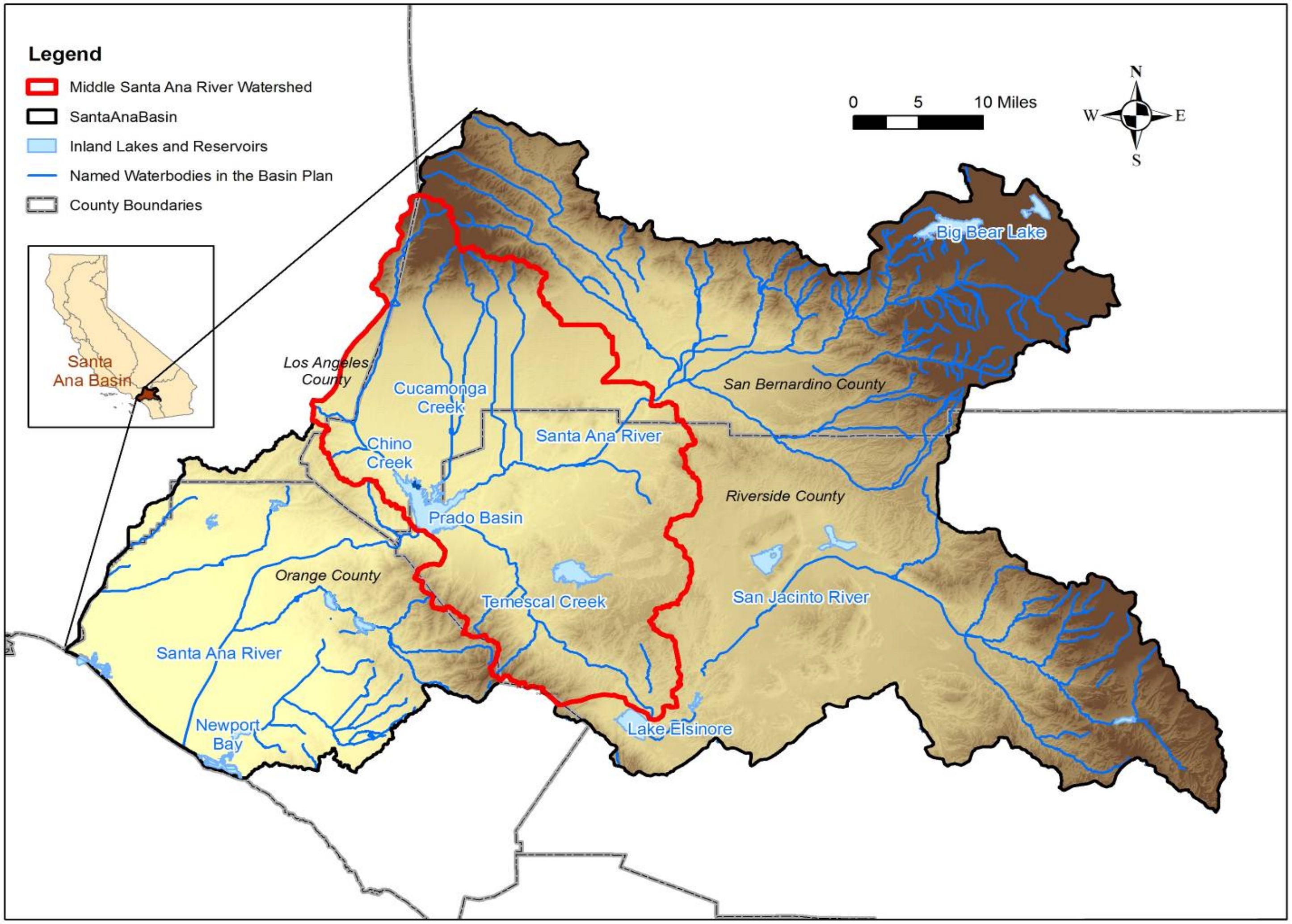


Figure 2-1. Location of the Middle Santa Ana River watershed (red outline) within the Santa Ana River watershed in southern California

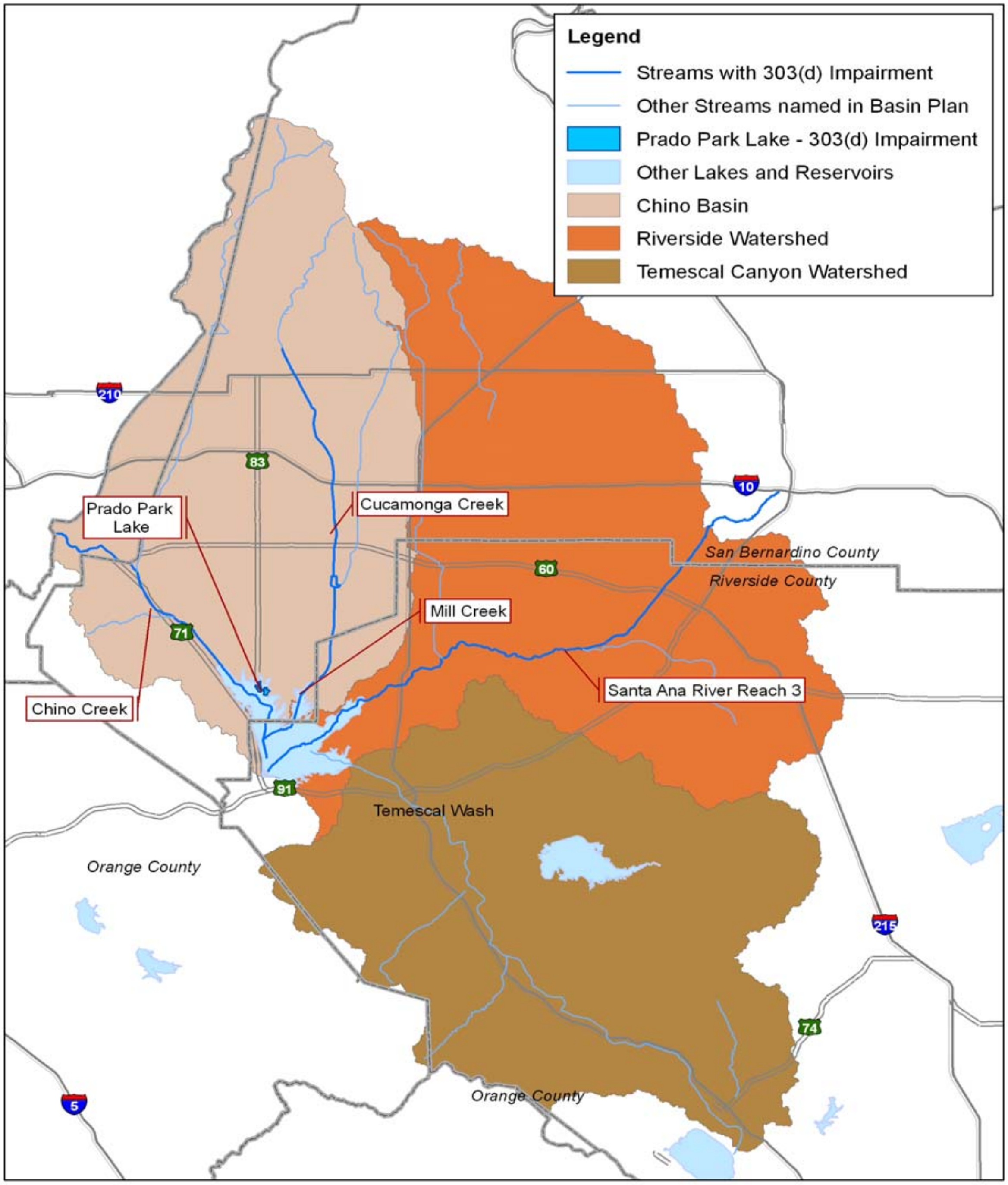


Figure 2-2. Major geographic areas of the Middle Santa Ana River watershed

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. At the time of TMDL development the area contained approximately 300,000 cows (RWQCB 2005). As of January 2009, this number was down to about 138,500 (email communication, Ed Kashak [RWQCB] to Pat Boldt, December 8, 2009). In recent years, 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 30-year average annual precipitation at this location is 10.06 inches/year.

Table 2-1. Average annual precipitation in the study area as measured at Riverside Fire Station #3

Measurement	Precipitation (inches)
Average Annual Precipitation	10.06
Maximum Recorded Annual Precipitation	22.72
Minimum Recorded Annual Precipitation	1.07

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, 2009b, 2009c, and 2009d report bacterial indicator data collected since summer 2007.

2.2 Watershed-Wide Compliance Monitoring Sites

The TMDL Task Force established the watershed-wide compliance monitoring sites in the MSAR watershed. Table 2-2 and Figure 2-4 identify the location of each site sampled in 2009-2010. Attachment A of the Monitoring Plan (see footnote 1) provides additional information about each sample location.

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

Waterbody	Sample Location	Site Code
Prado Lake	Prado Lake Outlet	WW-C3
Chino Creek	Central Avenue	WW-C7
Mill-Cucamonga Creek	Chino-Corona Road	WW-M5
Santa Ana River	MWD Crossing	WW-S1
Santa Ana River	Pedley Avenue	WW-S4

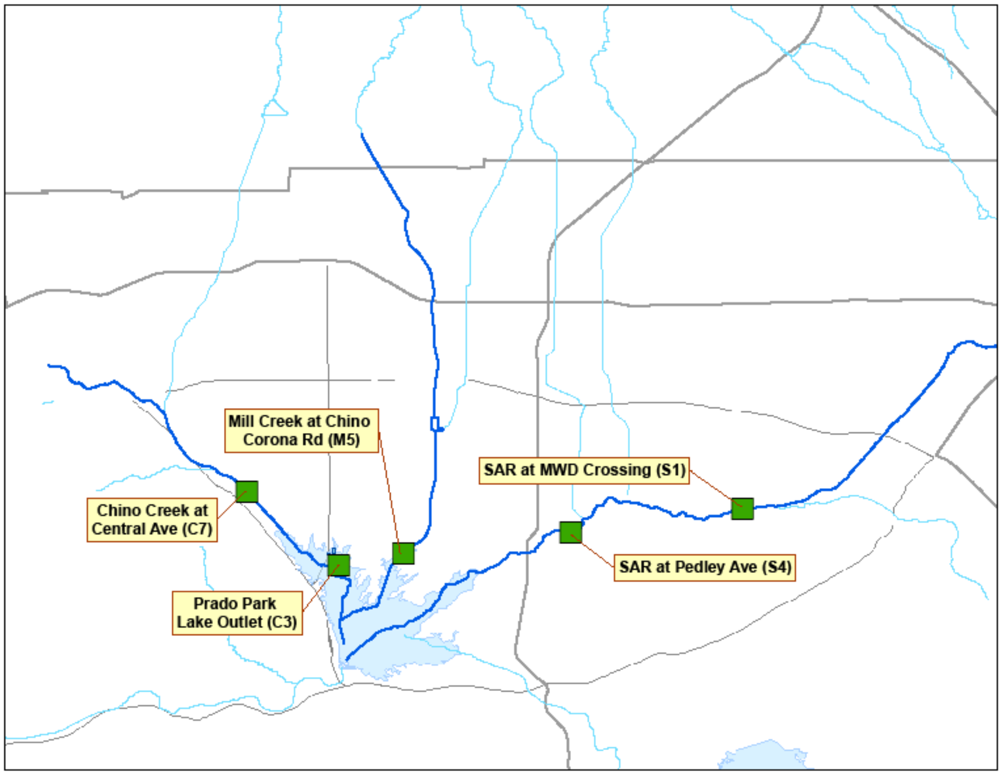


Figure 2-4. Location of watershed-wide compliance monitoring program sample locations in the Middle Santa Ana River watershed.

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 2009-2010, the wet season sample dates were planned as follows: Collect weekly samples over an 11 week period from the week ending December 26, 2009 to the week ending March 6, 2010.

In addition to regular weekly collections, 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. This past season a storm event occurred early during the month of October. Although outside of the normal wet season period, after consultation with the RWQCB, it was agreed that the storm event could be sampled. Accordingly, storm event samples were collected on October 14, 2009. Additional samples were collected 48, 72 and 96 hours after the storm event on October 16th, 17th and 18th, respectively.

Table 3-1 summarizes the results of the 2009-2010 sampling effort. All planned bacterial 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 2009-2010 wet season

Sample Month	Planned[1]	Collected	Site Dry	Samples Missed
Weekly Sampling				
December	10	10	0	0
January	20	20	0	0
February	20	20	0	0
March	5	5	0	0
Storm Event Sampling				
October 14 – 18, 2009	20	20	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 January five sites were planned for sampling during each of four weeks for a total of 20 samples.

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

The 2009-2010 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 2009-2010 wet season

Site	Sample Date	Preceding 3-Day Rainfall (inches)	Measured Flow (cfs)	Approximate Baseflow (cfs)
Prado Park Lake Outflow	10/14/09	0.51	19.1	16
	1/19/10	1.97	8.2	16
Chino Creek at Central Ave	10/14/09	0.51	430.0	33
	12/22/09	0.08	72.9	33
	1/19/10	1.97	97.6	33
Mill Creek at Chino Corona Rd	10/14/09	0.28	496.0	73
	12/22/09	0.11	103	73
	1/19/10	1.66	307	73
	2/9/10	0.47	202	56
Santa Ana River at MWD Crossing	10/14/09	0.16	49[1]	80
	12/22/09	0.16	94[1]	80
	1/19/10	0.90	435[1]	80
Santa Ana River at Pedley Ave	10/14/09	0.16	50[1]	139
	12/22/09	0.16	103[1]	139
	1/19/10	0.90	553[1]	139

[1] Flow recorded at USGS gauge at MWD Crossing at time of sample collection downstream at Pedley Avenue Site.

Section 4
Sample Results

This section summarizes the results of data analyses applied to the 2009-2010 wet season dataset. Where appropriate to provide context, data results are compared to water quality results previously reported (SAWPA 2009a, 2009b, 2009c, 2009d).

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 2009-2010 wet season.

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. Both Tables 4-5 and 4-6 include the comparative results from the two previous wet seasons.

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. Table 4-8 provides the *E. coli* results for the samples collected only during dry weather conditions. Both Tables 4-7 and 4-8 include the comparative results from the two previous wet seasons.

The 2009-2010 wet season fecal coliform and *E. coli* geometric mean concentrations (regardless of wet or dry weather conditions) varied in terms of whether the observed concentrations were higher or lower than previous seasons. In contrast, geometric mean bacterial indicator concentrations observed under dry conditions were often somewhat higher during the 2009-2010 wet season than the previous 2008-2009 wet season. This observation was particularly true at the Santa Ana River and Prado Park Lake sites.

Table 4-1. Summary of water quality monitoring data collected during the 2009-2010 wet season

Constituent	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	15	15	15	15	15
Median	280	320	450	160	210
Range	20 – 2400	110 - 9100	30 - 12000	9 - 4600	60 - 6200
***E. coli* (cfu/100 mL)**					
n	15	15	15	15	15
Median	250	390	820	140	160
Range	20 – 2300	60 – 15000	9 – 4400	40 – 3700	40 - 5500
Total Suspended Solids (mg/L)					
n	15	15	15	15	15
Median	17.3	4.1	11	21.4	62.5
Range	8.9 – 47.0	1.1 – 42.0	5.5 – 83.4	3.6 – 1575.0	6.2 – 2368.0
Dissolved Oxygen (mg/L)					
n	14	14	14	14	14
Median	6.96	7.01	8.05	7.27	6.56
Range	4.8 – 15.4	5.5 – 13.55	5.55 – 13.09	5.84 – 12.46	4.75 – 9.07
pH (Standard Units)					
n	15	15	15	15	15
Median	7.7	8.4	8.3	7.8	7.8
Range	7.1 – 8.7	7.2 – 8.8	7.6 – 8.8	6.8 – 8.0	7.5 – 8.9
Turbidity (NTU)					
n	14	14	14	14	14
Median	15.1	3.4	8.4	9.2	28.5
Range	9.1 – 24.3	1.9 – 47.1	3.3 – 78.6	2.7 – 119.0	4.7 – 150.0
Water Temperature (^{O}C)					
n	14	15	15	15	15
Median	14.9	20.9	17.0	14.0	14.5
Range	11.6 – 23.4	16.9 – 28.4	12.1 – 20.4	11.7 – 19.4	11.9 -19.2
Flow (cfs)					
n	15	15	15	14	14
Median	11.1	45.9	101.8	117.2	190.5
Range	4.1 – 19.1	24.1 – 430.4	33.4 – 496.7	30.6 – 151.1	82.7 – 470.9
Conductivity (uS/cm)					
n	15	15	15	15	15
Median	735	812	593	711	746
Range	630 - 800	263 - 921	96 - 945	304 - 840	311 - 865

Table 4-2. Fecal coliform (cfu/100 mL) concentrations observed at watershed-wide compliance sites during the 2009-2010 wet season

Sample Date	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					
12/22/09	280	1,040	4,200	3,100	3,100
12/29/09	610	320	30	9	160
1/5/10	600	450	450	90	170
1/12/10	400	200	2,400	40	60
1/19/10	1,290	1,700	2,200	4,600	6,200
1/26/10	440	300	110	380	200
2/2/10	170	180	60	50	210
2/9/10	760	270	330	200	210
2/16/10	30	110	40	80	80
2/23/10	50	160	210	380	350
3/2/10	2,400	110	12,000	210	170
Storm Event					
10/14/09	90	9,100	3,900	160	4,800
10/16/09	40	3,700	4,500	260	570
10/17/09	20	3,200	430	100	260
10/18/09	40	880	2,200	100	< 270

Table 4-3. *E. coli* (cfu/100 mL) concentrations observed at watershed-wide compliance sites during the 2009-2010 wet season

Sample Date	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					
12/22/09	250	990	2,900	2,200	2,500
12/29/09	760	330	130	140	70
1/5/10	750	430	550	130	120
1/12/10	610	390	2,300	100	40
1/19/10	1,750	2,800	2,100	3,700	5,500
1/26/10	340	210	9	120	1,100
2/2/10	220	210	80	60	190
2/9/10	750	200	360	210	160
2/16/10	110	60	80	40	50
2/23/10	50	180	240	260	340
3/2/10	2,300	130	1,700	210	190
Storm Event					
10/14/09	70	15,000	4,400	110	4,200
10/16/09	40	610	2,200	200	150
10/17/09	60	780	850	90	110
10/18/09	20	390	820	140	< 120

Table 4-4. Statistical distribution of bacterial indicator data (cfu/100 mL) during the 2009-2010 wet season

Statistic	2009 – 2010 Wet Season	
	E. coli	**Fecal coliform**
Sample Size (n)	75	75
Geometric Mean	309	339
10^{th} Percentile	60	44
25^{th} Percentile	115	110
50^{th} Percentile (median)	210	270
75^{th} Percentile	800	960
90^{th} Percentile	2,420	3,820

Table 4-5. Summary of fecal coliform concentrations (cfu/100 mL) and data variability by sample location during the 2007-2008, 2008-2009 and 2009-2010 wet seasons

Site	2009-2010				2008-2009				2007-2008			
	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]
Prado Park Lake	15	199	280	0.28	14	230	170	0.32	14	144	130	0.14
Chino Creek	15	552	320	0.22	14	776	380	0.23	14	365	230	0.26
Mill-Cucamonga Creek	15	635	450	0.30	14	595	420	0.18	14	431	215	0.26
SAR @ MWD Crossing	15	176	160	0.30	14	188	135	0.35	14	196	140	0.36
SAR @ Pedley Ave.	15	363	210	0.24	14	266	125	0.32	14	219	165	0.34

[1] - Coefficient of variation was calculated using natural log-transformed data

Table 4-6. Summary of dry weather fecal coliform concentrations (cfu/100 mL) and data variability by sample location during the 2007-2008, 2008-2009, and 2009-2010 wet seasons

Site	2009-2010				2008-2009				2007-2008			
	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]
Prado Park Lake	13	184	280	0.29	9	113	80	0.28	13	137	130	0.15
Chino Creek	12	378	285	0.20	10	366	255	0.18	13	283	230	0.22
Mill-Cucamonga Creek	11	430	430	0.33	10	365	380	0.11	12	297	190	0.21
SAR @ MWD Crossing	12	106	100	0.11	9	58	60	0.23	12	118	120	0.24
SAR @ Pedley Ave.	12	193	205	0.23	9	87	85	0.15	11	102	90	0.24

[1] - Coefficient of variation was calculated using natural log-transformed data

Table 4-7. Summary of *E. coli* concentrations (cfu/100 mL) and data variability by sample location during the 2007-2008, 2008-2009 and 2009-2010 wet seasons

Site	2009-2010				2008-2009				2007-2008			
	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]
Prado Park Lake	15	235	250	0.27	14	335	275	0.28	14	138	120	0.11
Chino Creek	15	445	390	0.22	14	806	450	0.27	14	311	225	0.23
Mill-Cucamonga Creek	15	521	820	0.28	14	718	585	0.15	14	323	200	0.25
SAR @ MWD Crossing	15	189	140	0.23	14	148	100	0.35	14	165	120	0.36
SAR @ Pedley Ave.	15	276	160	0.28	14	257	190	0.32	14	214	125	0.34

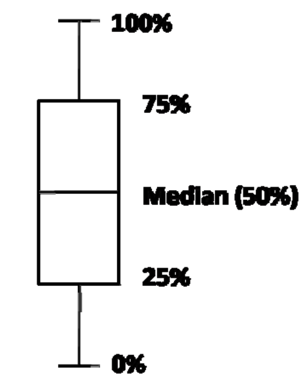
[1] - Coefficient of variation was calculated using natural log-transformed data

Table 4-8. Summary of dry weather *E. coli* concentrations (cfu/100 mL) and data variability by sample location during the 2007-2008, 2008-2009, and 2009-2010 wet seasons

Site	2009-2010				2008-2009				2007-2008			
	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]
Prado Park Lake	13	221	250	0.26	10	183	115	0.23	13	137	120	0.12
Chino Creek	12	266	270	0.13	10	386	399	0.27	13	251	220	0.19
Mill-Cucamonga Creek	11	335	550	0.30	9	474	580	0.08	12	226	175	0.22
SAR @ MWD Crossing	12	125	135	0.18	8	48	50	0.35	12	104	115	0.36
SAR @ Pedley Ave.	12	143	135	0.11	8	83	100	0.32	11	104	80	0.34

[1] - Coefficient of variation was calculated using natural log-transformed data

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 2009-2010 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.



Box & Whisker Plot

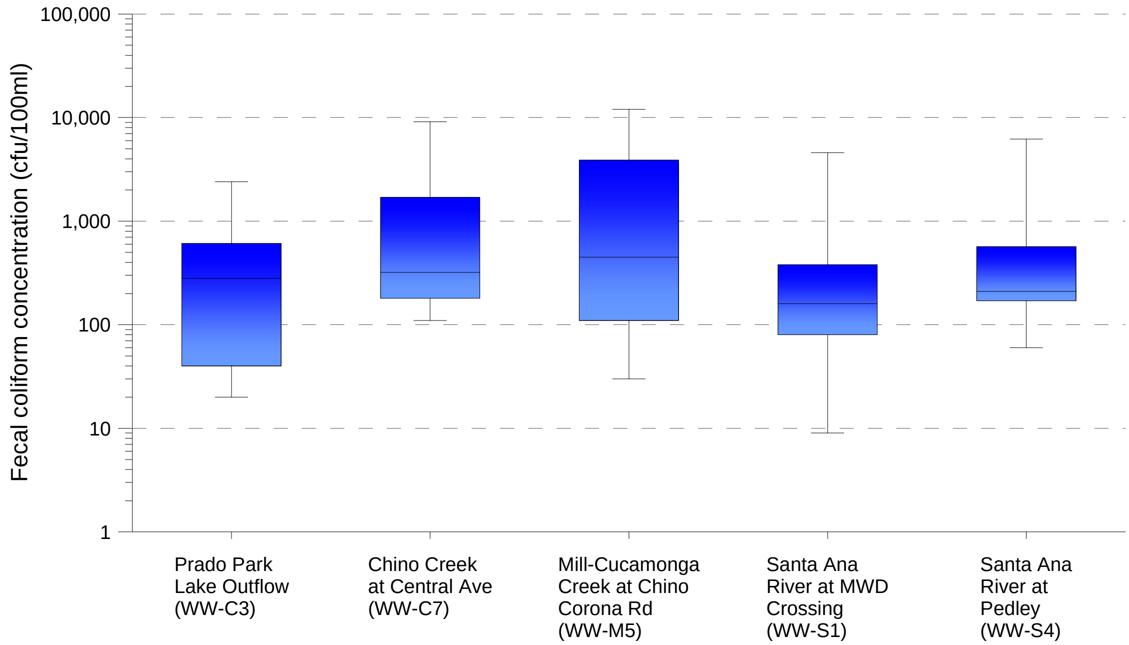
For samples collected under both wet and dry weather conditions, the lowest observed median concentrations occurred at the two Santa Ana River sites. In contrast, the Mill-Cucamonga Creek and Chino Creek sites had the highest observed median bacterial indicator concentrations (fecal coliform: 450 cfu/100 mL and 320 cfu/100 mL, respectively; *E. coli*: 820 cfu/100 mL and 390 cfu/100 mL, respectively) (see Figures 4-1 and 4-2 [upper]; Tables 4-5 and 4-7).

Under dry weather conditions, the lowest median concentrations were observed for *E. coli* at both Santa Ana River sites (135 cfu/100 mL). For fecal coliform, the Santa Ana River @ MWD Crossing site had the lowest observed median concentration (100 cfu/100 mL); the fecal coliform concentration at the Santa Ana River @ Pedley Avenue was higher at 205 cfu/100 mL). Highest concentrations were observed at Mill-Cucamonga Creek with median fecal coliform and E. coli concentrations of 430 and 550 cfu/100 mL (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 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 <u>only</u> 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.



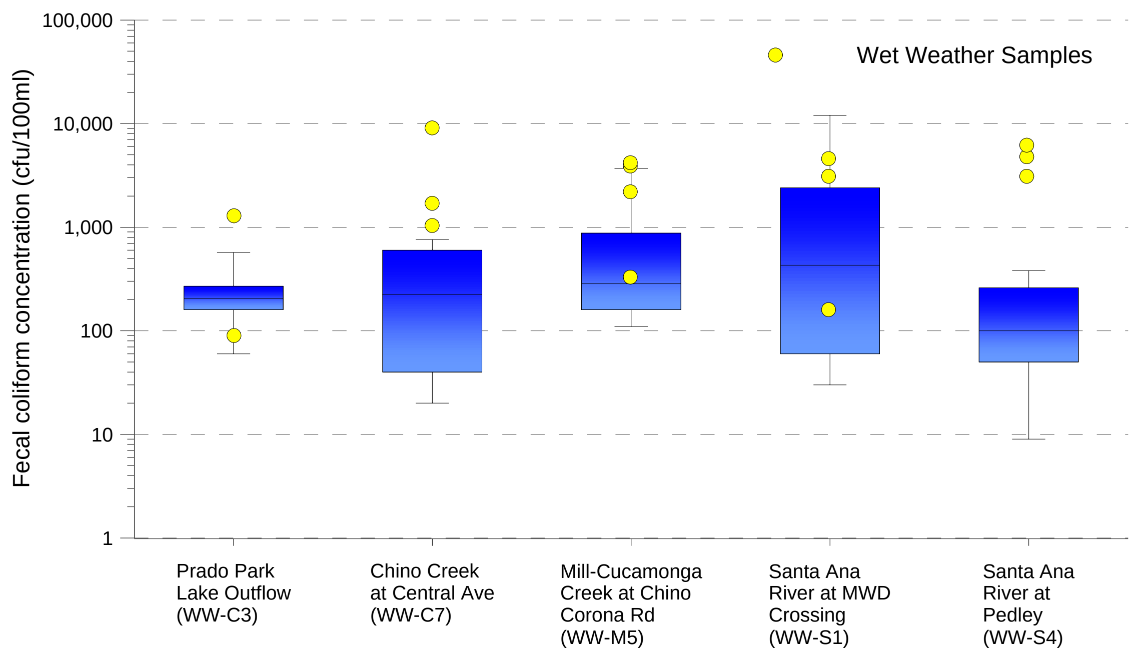
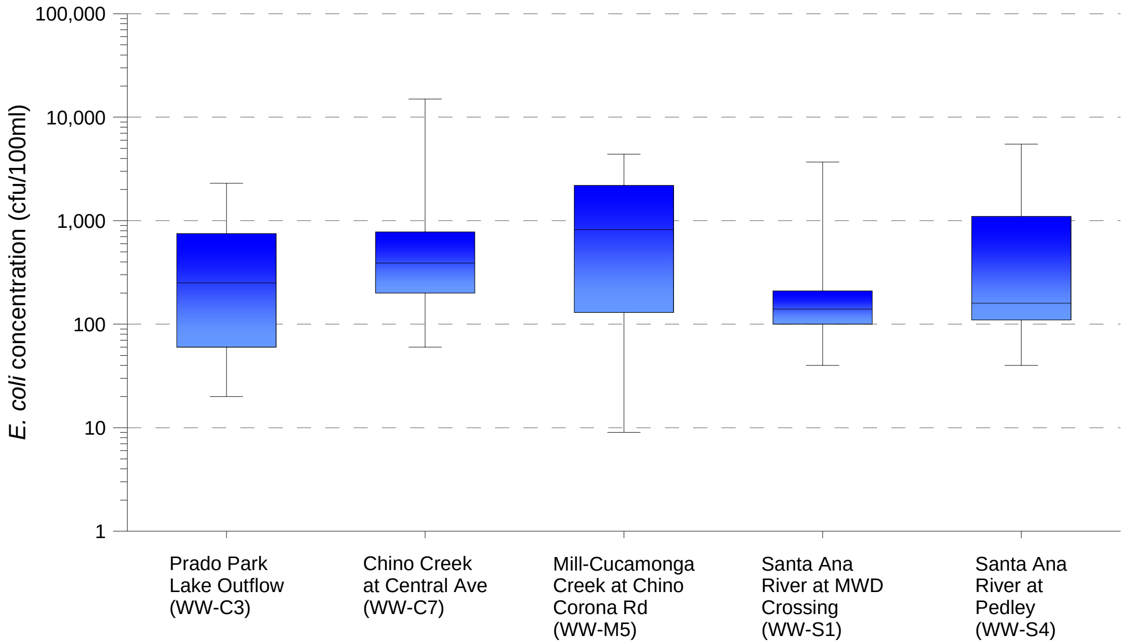


Figure 4-1. Statistical distribution of fecal coliform data collected during the 2009-2010 wet season illustrated using Box & Whisker box plots. *Upper Figure*: All samples collected under wet and dry conditions. *Lower Figure*: Box & Whisker box plot is for samples collected only under dry weather conditions; sample results classified as wet weather are show as yellow circles.



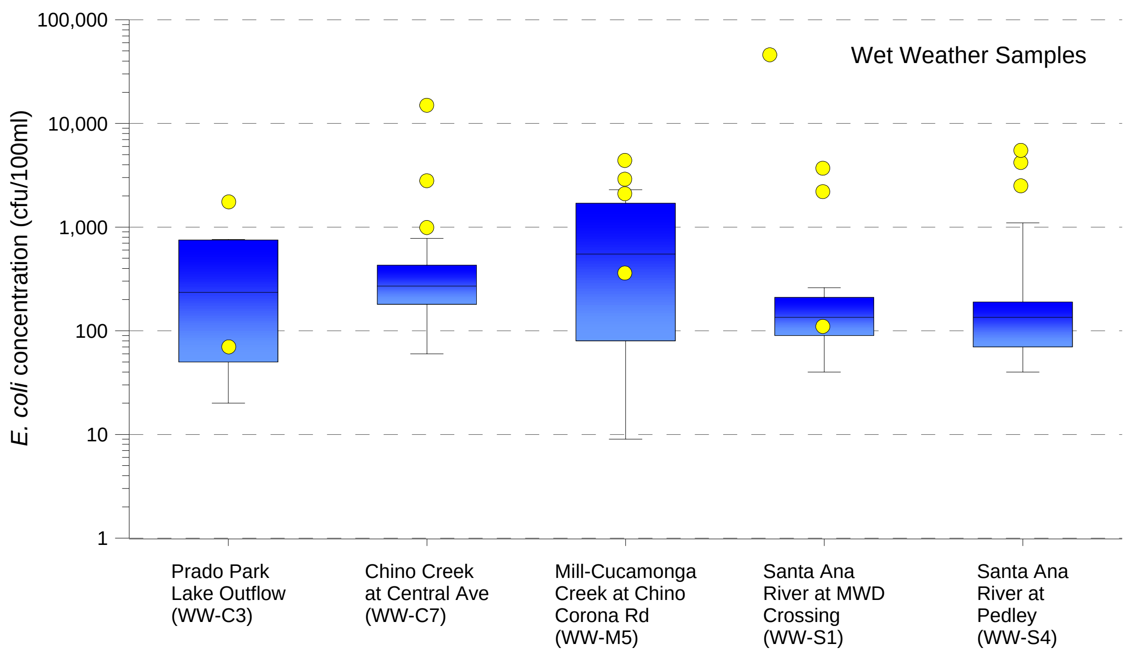


Figure 4-2. Statistical distribution of *E. coli* results collected during the 2009-2010 wet season illustrated using Box & Whisker box plots. *Upper Figure*: All samples collected under wet and dry conditions. *Lower Figure*: Box & Whisker box plot is for samples collected only under dry weather conditions; sample results classified as wet weather are show as yellow circles.

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, the fewest exceedances of the fecal coliform and *E. coli* single sample objectives occurred at the Santa Ana River sites, ranging from 0 to 17% of observations (Tables 4-9 and 4-10). The frequency of single sample exceedances during dry weather conditions at other sites ranged from 33 to 38% for fecal coliform and 50 to 55% for *E. coli* (Tables 4-9 and 4-10).

During wet weather, exceedances of the single sample objectives were common at all sites. At the Santa Ana River sites the exceedance frequency of single sample bacterial indicator objectives ranged from 67 to 100%. The exceedance frequency for fecal coliform and *E. coli* was 50% at Prado Park Lake, 75% at Mill-Cucamonga Creek and 100% at Chino Creek (Tables 4-9 and 4-10).

The geometric mean exceedance frequency was 36% and 82% for fecal coliform at the Santa Ana River @ Pedley and Santa Ana River @ MWD Crossing sites, respectively. The exceedance frequency for *E. coli* was higher at these sites, ranging from 82 to 100%. The geometric mean exceedance frequency at Prado Park Lake was 64% for fecal coliform and 82% for *E. coli*. The geometric mean exceedance frequency at Chino Creek and Mill-Cucamonga Creek was higher, ranging from 82% to 100%.

Figures 4-3 through 4-7 illustrate the single sample and rolling geometric mean values for fecal coliform since the 2007 dry season. Figures 4-8 through 4-12 illustrate the results for *E. coli*. Providing the extended period of record illustrates how the 2009-2010 wet season results compare to previous wet seasons. For the most part, the observations at the Chino Creek and Mill Creek sites are similar from season to season. For the remaining sites, Prado Park Lake and the two Santa Ana River sites, bacterial indicator concentrations were generally higher during the most recent wet season.

Table 4-9. Bacterial indicator compliance frequency for fecal coliform during the 2009-2010 wet season

Site	Single Sample Criterion Exceedance Frequency (%)		Geometric Mean Criterion Exceedance Frequency (%)
	Dry	Wet	
Prado Park Lake	38%	50%	64%
Chino Creek	33%	100%	82%
Mill Creek	36%	75%	82%
SAR @ MWD Crossing	0%	67%	82%
SAR @ Pedley Ave.	8%	100%	36%

Table 4-10. Bacterial indicator compliance frequency for *E. coli* during the 2009-2010 wet season

Site	Single Sample Criterion Exceedance Frequency (%)*		Geometric Mean Criterion Exceedance Frequency (%)
	Dry	Wet	
Prado Park Lake	54%	50%	82%
Chino Creek	50%	100%	100%
Mill Creek	55%	75%	91%
SAR @ MWD Crossing	8%	67%	100%
SAR @ Pedley Ave.	17%	100%	82%

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

4.4 Correlation Analysis

Table 4-11 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= 0.94) at Prado Park Lake. Observations of significant correlations between bacterial indicators are consistent with previous findings at these sample locations (e.g., see SAWPA 2009a).

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 conductivity; and (2) *E. coli* concentrations and TSS, conductivity and pH.

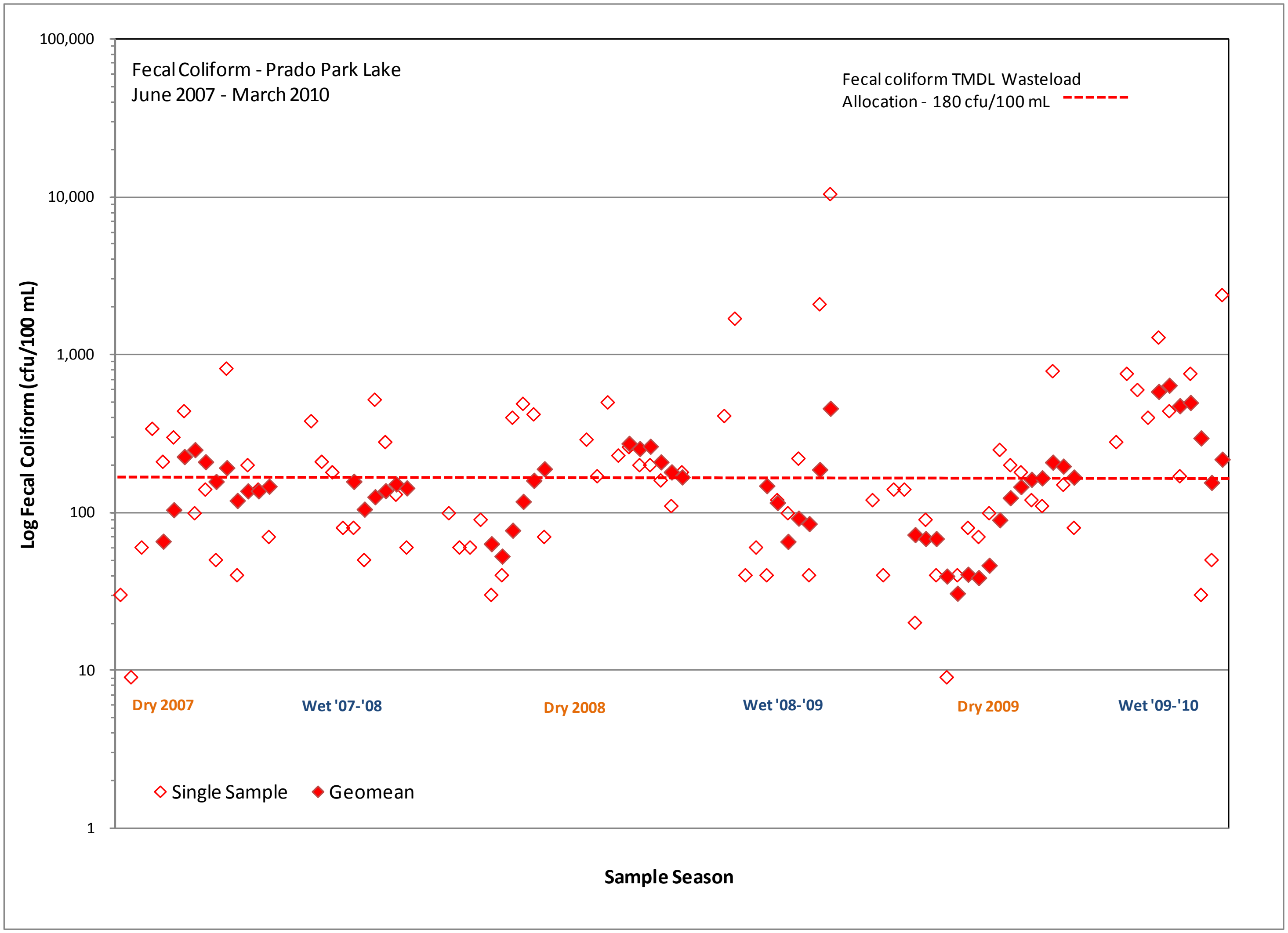


Figure 4-3. Time series plot of fecal coliform single sample and geometric mean results for samples collected from July 2007 through March 2010 at Prado Park Lake. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

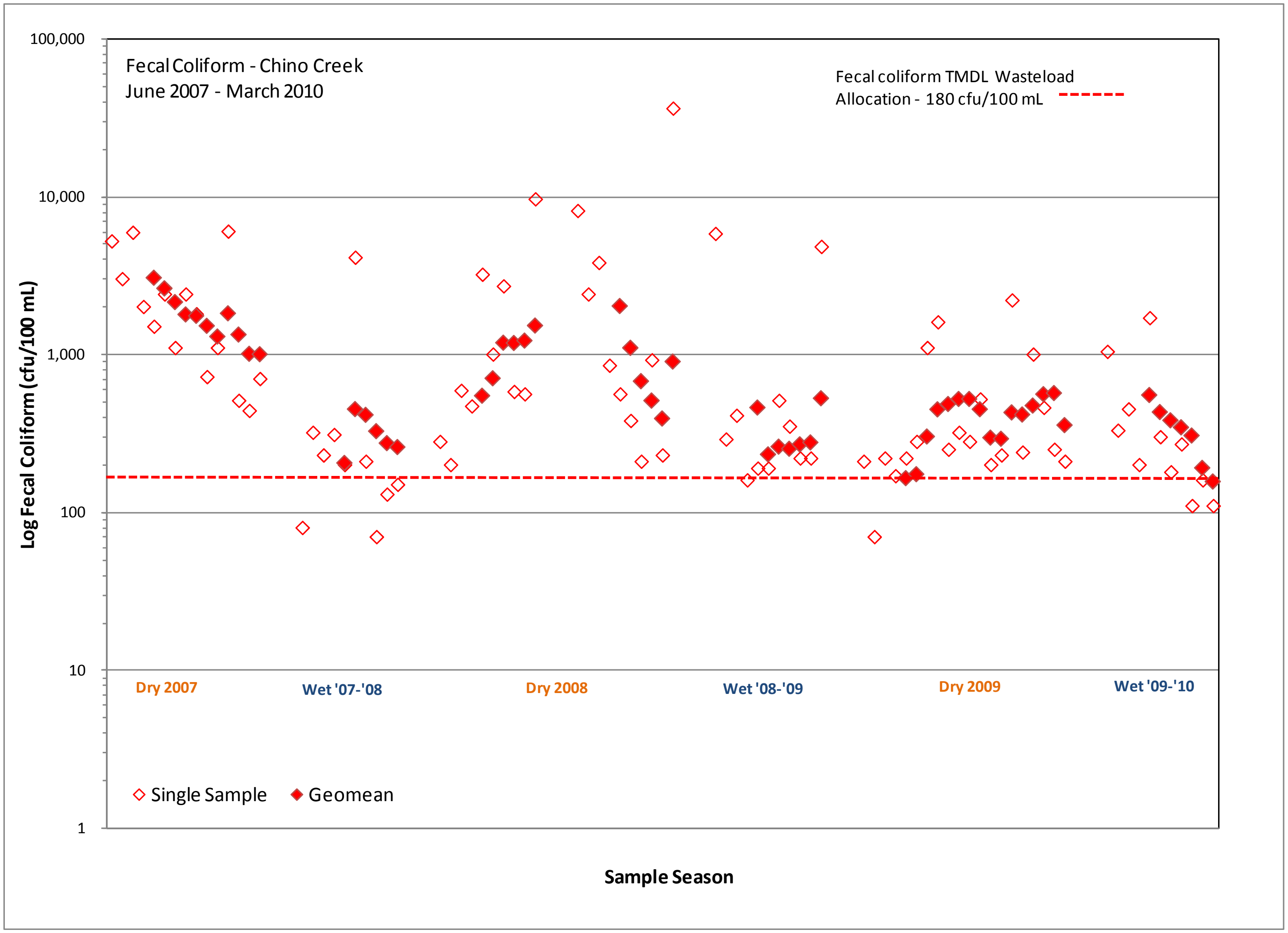


Figure 4-4. Time series plot of fecal coliform single sample and geometric mean results for samples collected from July 2007 through March 2010 at Chino Creek. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

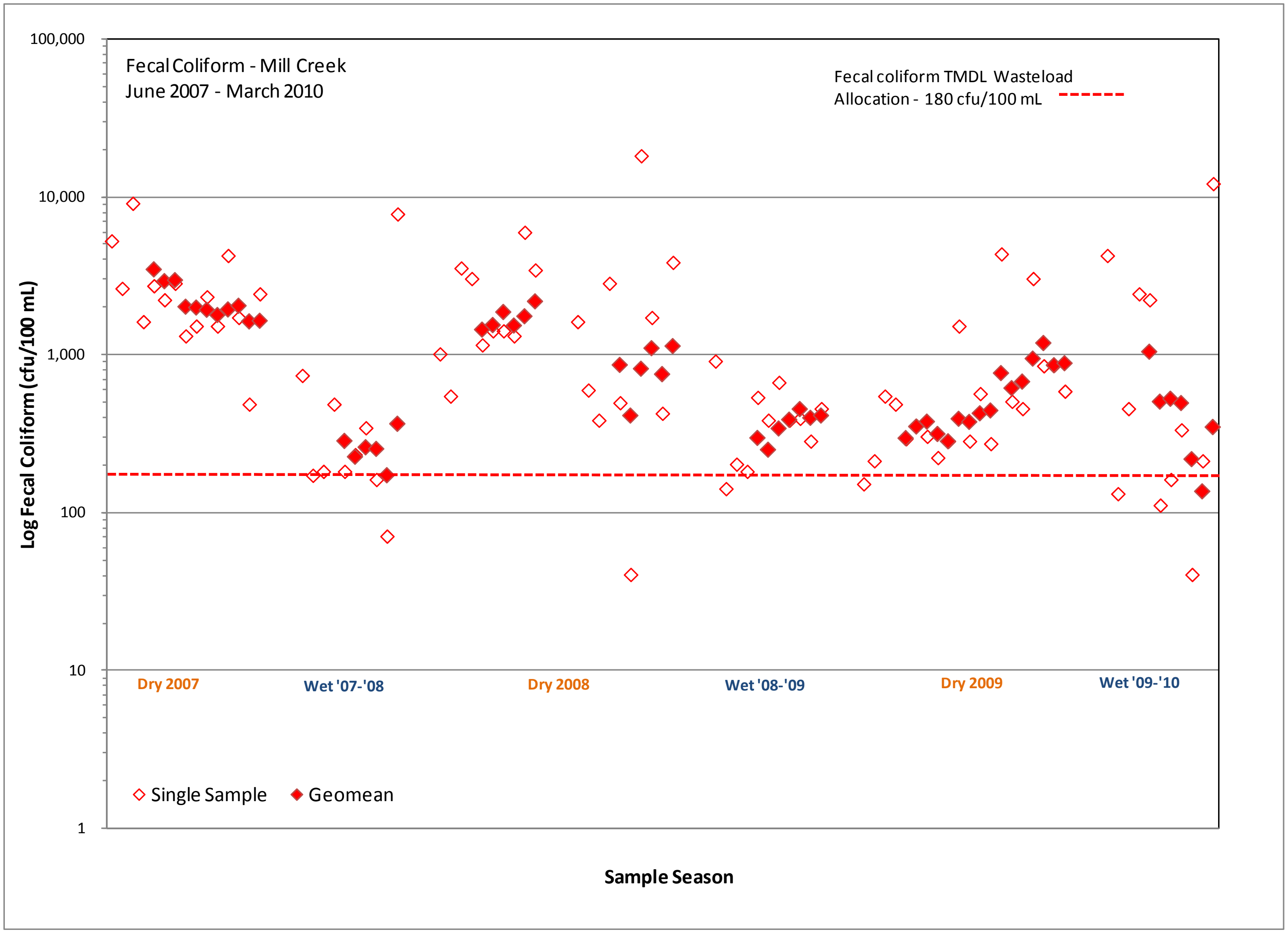


Figure 4-5. Time series plot of fecal coliform single sample and geometric mean results for samples collected from July 2007 through March 2010 at Mill-Cucamonga Creek. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

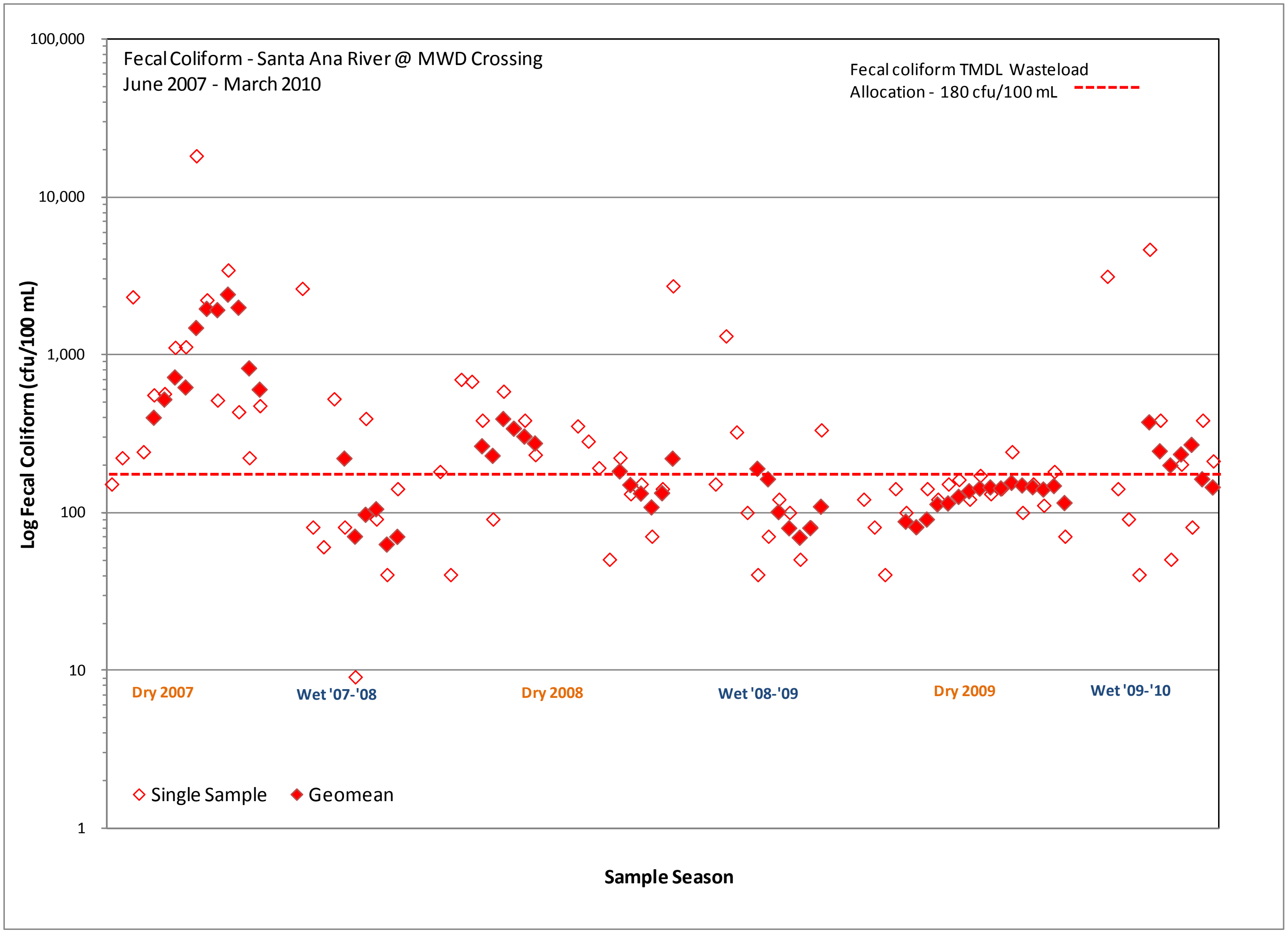


Figure 4-6. Time series plot of fecal coliform single sample and geometric mean results for samples collected from July 2007 through March 2010 at Santa Ana River @ MWD Crossing. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

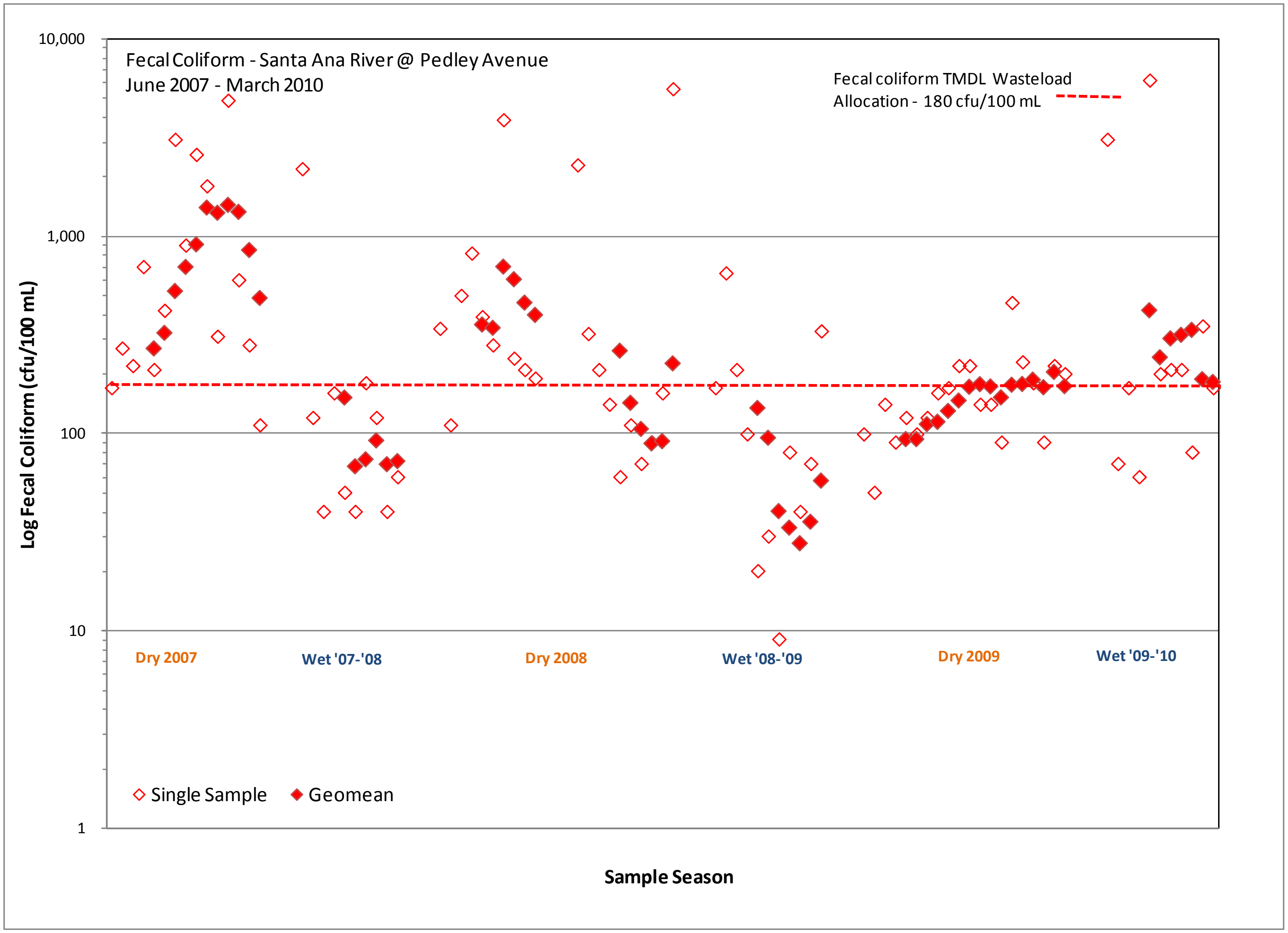


Figure 4-7. Time series plot of fecal coliform single sample and geometric mean results for samples collected from July 2007 through March 2010 at Santa Ana River @ Pedley Avenue. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

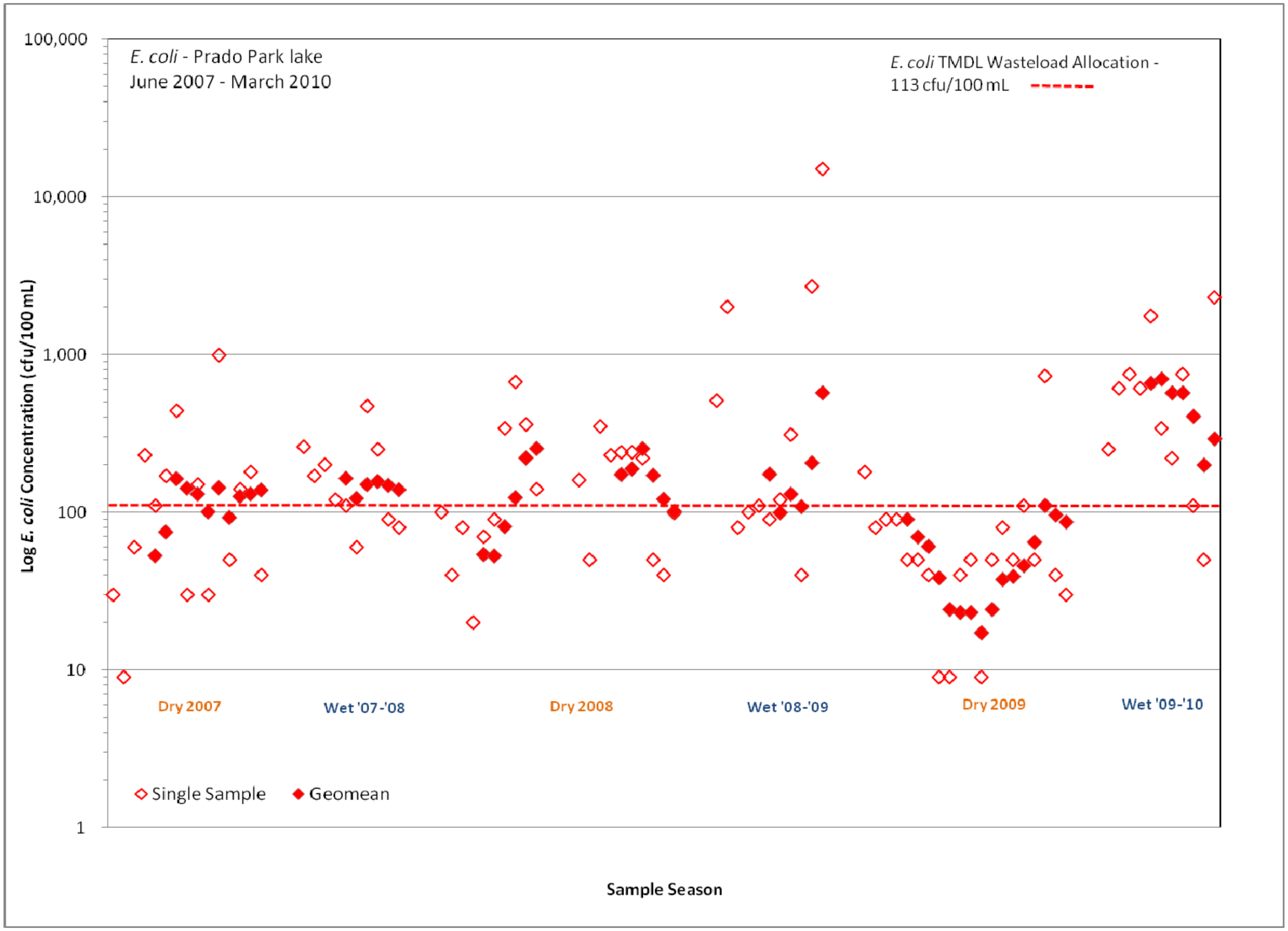


Figure 4-8. Time series plot of *E. coli* single sample and geometric mean results for samples collected from July 2007 through March 2010 at Prado Park Lake. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

Figure 4-9. Time series plot of *E. coli* single sample and geometric mean results for samples collected from July 2007 through March 2010 at Chino Creek. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

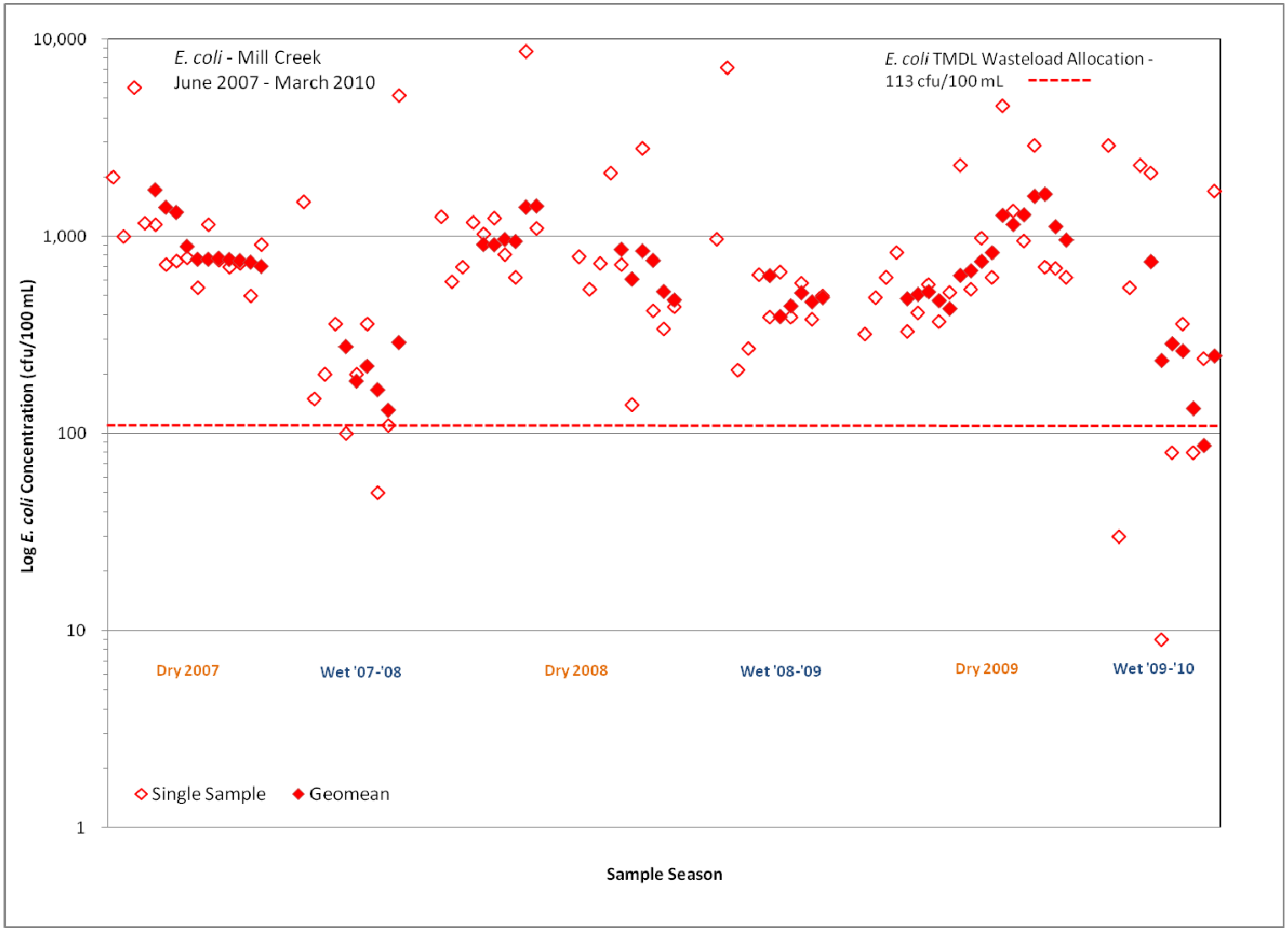


Figure 4-10. Time series plot of *E. coli* single sample and geometric mean results for samples collected from July 2007 through March 2010 at Mill-Cucamonga Creek. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

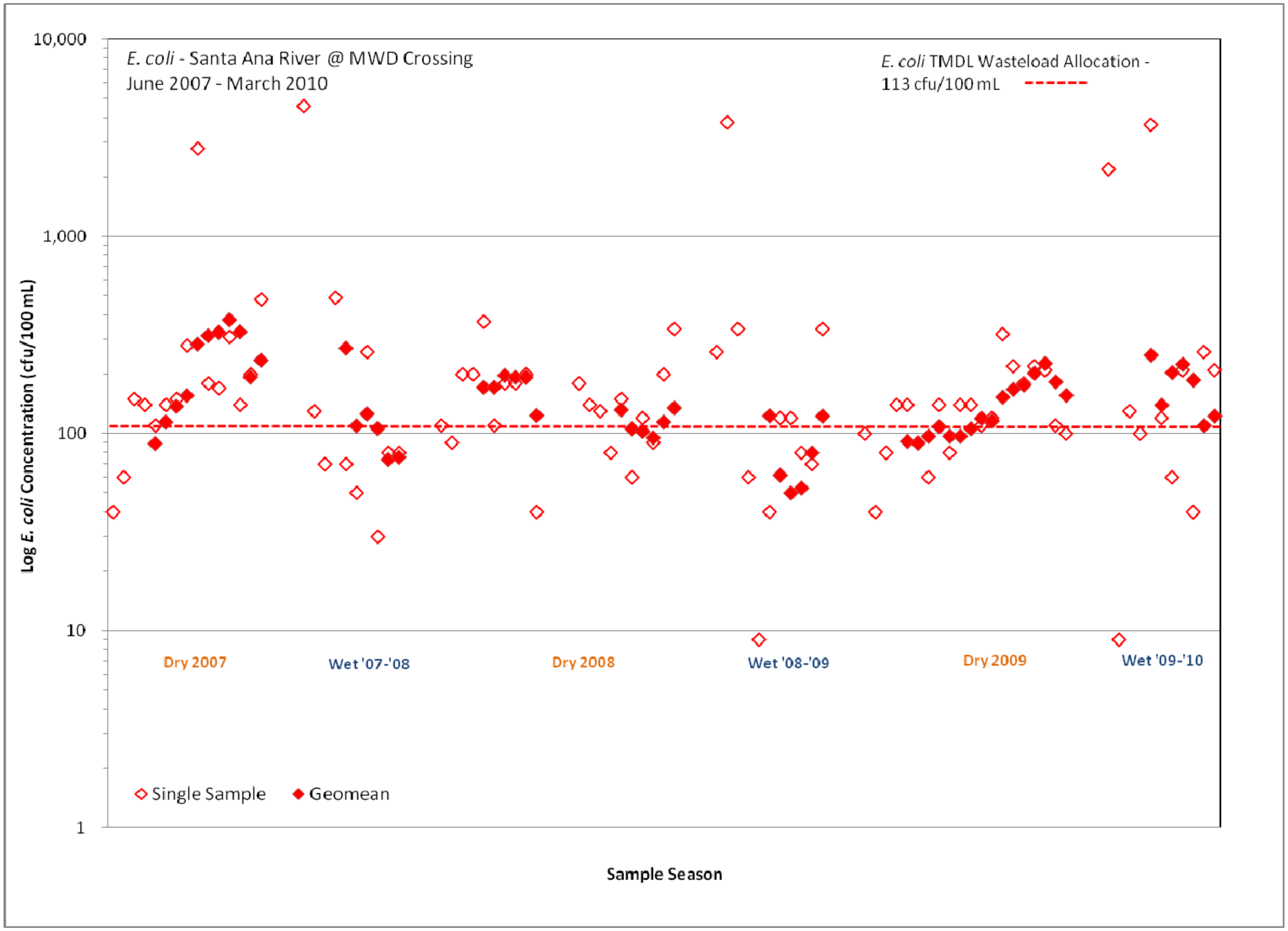


Figure 4-11. Time series plot of *E. coli* single sample and geometric mean results for samples collected from July 2007 through March 2010 at Santa Ana River at MWD Crossing. Time periods representing wet seasons are labeled in blue. A geometric mean was calculated only if five samples were collected during the previous five weeks.

Figure 4-12. Time series plot of *E. coli* single sample and geometric mean results for samples collected from July 2007 through March 2010 at Santa Ana River at Pedley Avenue. Time periods representing wet seasons are labeled in blue. 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 2009-2010 wet season

Site	Pearson's r coefficient	Degrees of freedom (n - 2)	t-statistic	p-value	Significant?[1]
Prado Park Lake	0.94	13	10.2	< 0.001	Yes +
Chino Creek	0.87	13	6.3	< 0.001	Yes +
Mill Creek	0.85	13	5.8	< 0.001	Yes +
SAR @ MWD Crossing	0.90	13	7,7	< 0.001	Yes +
SAR @ Pedley Ave.	0.83	13	5.4	< 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 2009-2010 wet season

Data Subset/Comparison	Pearson's r coefficient	Degrees of freedom (n - 2)	Student-t statistic	p-value*
Fecal Coliform vs.				
Conductivity	-0.54	73	5.4	< 0.001
Dissolved Oxygen	-0.07	68	0.6	0.55
pH	-0.12	73	1.0	0.32
Suspended Solids	0.34	73	3.0	0.004
Temperature	0.10	72	0.8	0.47
Turbidity	0.14	68	1.1	0.28
***E. coli* vs.**				
Conductivity	-0.60	73	6.5	< 0.001
Dissolved Oxygen	-0.06	68	0.5	0.62
pH	-0.25	73	2.2	0.03
Suspended Solids	0.32	73	2.9	0.005
Temperature	-0.03	72	0.2	0.84
Turbidity	0.14	68	1.1	0.28

* - 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. With the exception of a weak correlation between fecal coliform and temperature, no correlations were identified between either bacterial indicator and a field parameter.

4.5 Storm Event Data

Figures 4-13 and 4-14 illustrate bacterial indicator concentrations at Chino Creek and the Santa Ana Rivers sites during and after the storm event that began on October 14, 2009. These figures show bacterial indicator concentrations in the context of the local hydrograph recorded at the nearest USGS gauge. For this storm event a clear relationship between bacterial indicator concentrations and flow is apparent at the Chino Creek site. However, in comparison, no change in the hydrograph or bacterial indicator concentrations was observed at the Santa Ana River sites. This difference is a reflection of the nature of the storm event which yielded variable amounts of rain in the area.

Figures 4-15 through 4-17 illustrate bacterial indicator concentrations observed around other storm events that occurred during the wet season. In each case, bacterial indicator concentrations were elevated as a result of the storm event. This is demonstrated by a review of the fecal coliform and *E. coli* concentration data (see Tables 4-2 and 4-3 for specific bacterial indicator results) which show that before or after the storm event bacterial indicator concentrations were much lower.

Table 4-13. Correlation analysis between bacterial indicator concentrations and field parameters during dry weather conditions for the 2009-2010 wet season

Data Subset/Comparison	Pearson's r coefficient	Degrees of freedom (n - 2)	Student-t statistic	p-value
Fecal Coliform vs.				
Conductivity	-0.16	58	1.2	0.24
Dissolved Oxygen	-0.07	53	0.5	0.62
pH	0.11	58	0.8	0.43
Suspended Solids	-0.09	58	0.7	0.49
Temperature	0.26	57	2.0	0.05
Turbidity	0.05	58	0.4	0.69
***E. coli* vs.**				
Conductivity	-0.20	58	1.6	0.12
Dissolved Oxygen	-0.14	53	1.0	0.32
pH	-0.02	58	0.2	0.84
Suspended Solids	0.02	58	0.2	0.84
Temperature	0.03	57	0.2	0.84
Turbidity	0.08	58	0.6	0.55

* - Significance determined by a p-value < 0.05

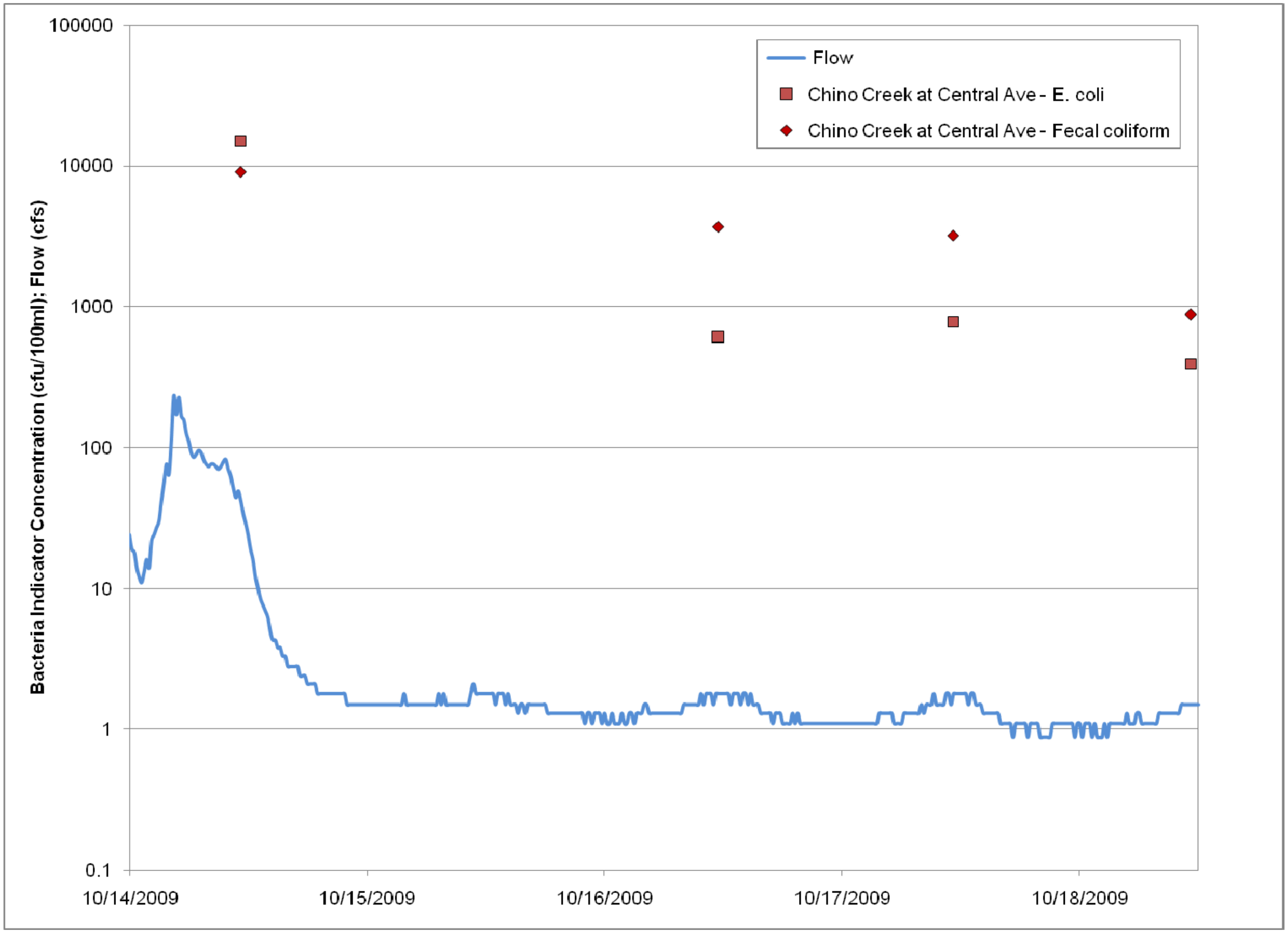


Figure 4-13. Bacterial indicator concentrations (cfu/100 mL) observed at the Chino Creek site during and after the October 14, 2009 storm event (as shown by the hydrograph from USGS gauge 11073360, Chino Creek at Schaefer Avenue).

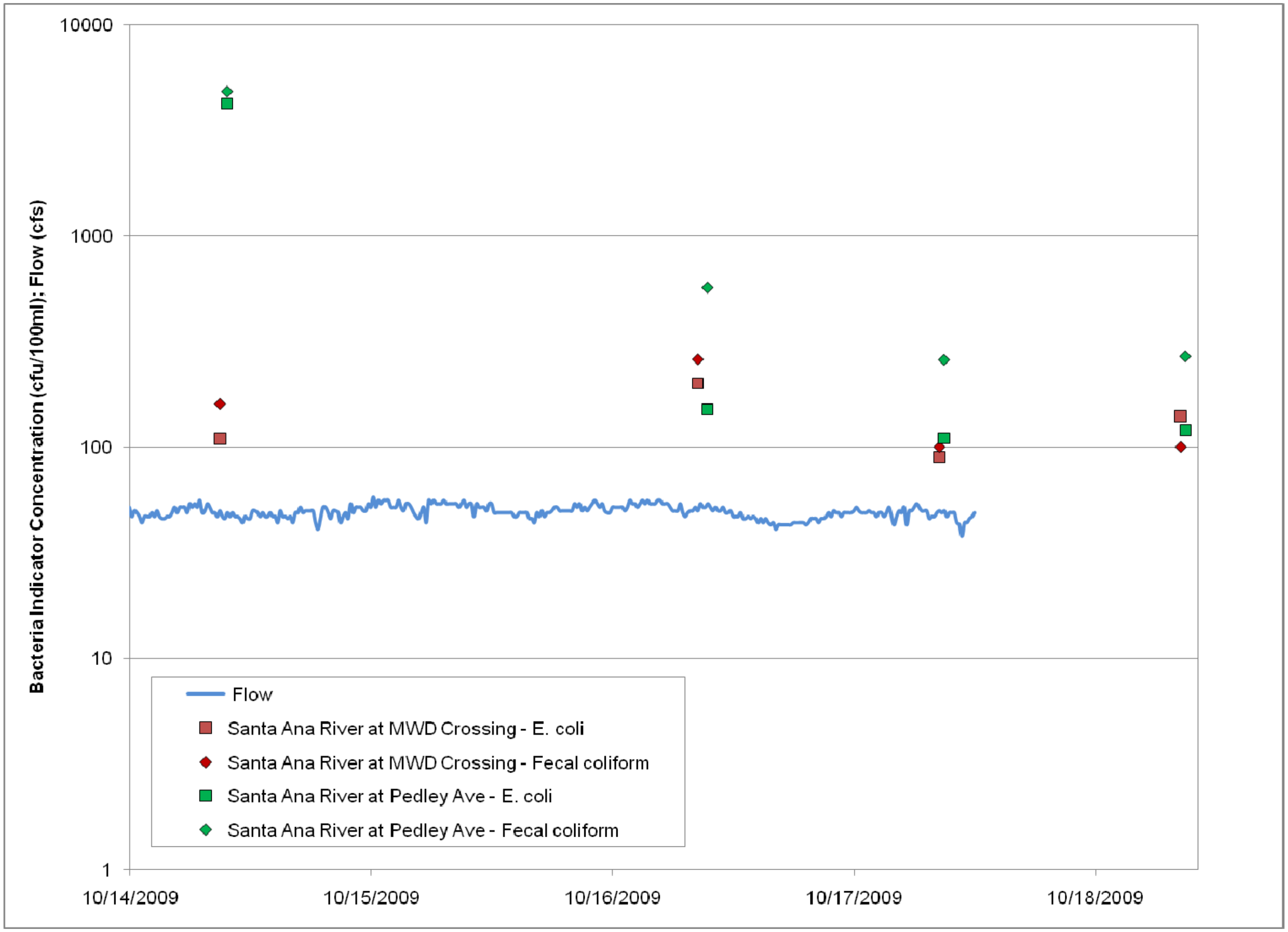


Figure 4-14. Bacterial indicator concentrations (cfu/100 mL) and flow (cfs) observed at the Santa Ana River sites during and after the October 14, 2009 storm event (hydrograph from USGS Gauge 11066460 at Santa Ana River at MWD Crossing). Note that the area storm event did not affect flow or bacterial indicator concentrations at this site on these dates.

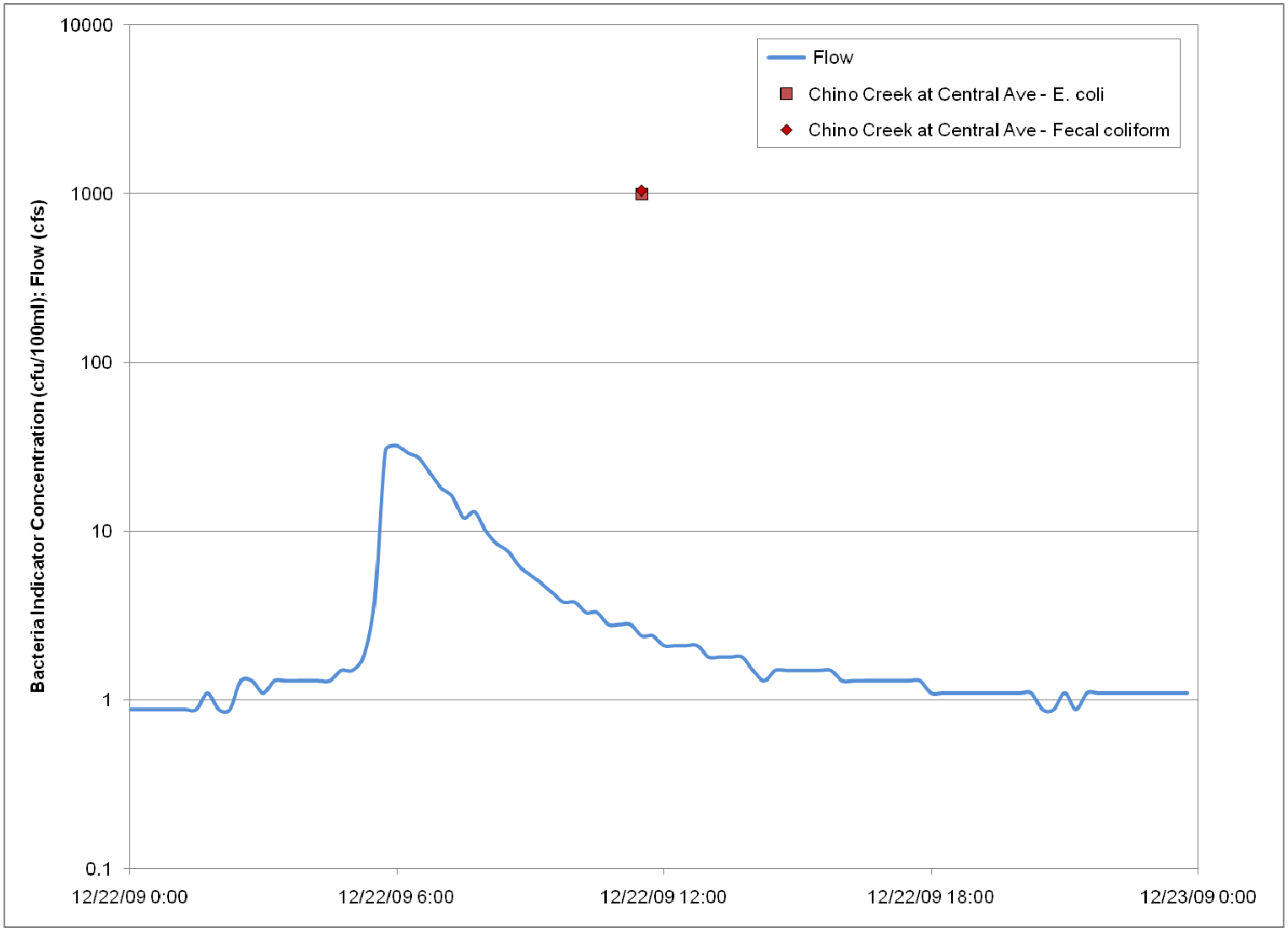


Figure 4-15. Bacterial indicator concentrations (cfu/100 mL) and flow observed at the Chino Creek site shortly after a December 22, 2009 area storm event (hydrograph from USGS Gauge 11073360 at Chino Creek and Schaefer Avenue). No comparative samples were taken the week before, but bacterial indicator concentrations a week later on December 29, 2009 were considerably lower at 320 and 330 cfu/100 mL for fecal coliform and *E. coli*, respectively.

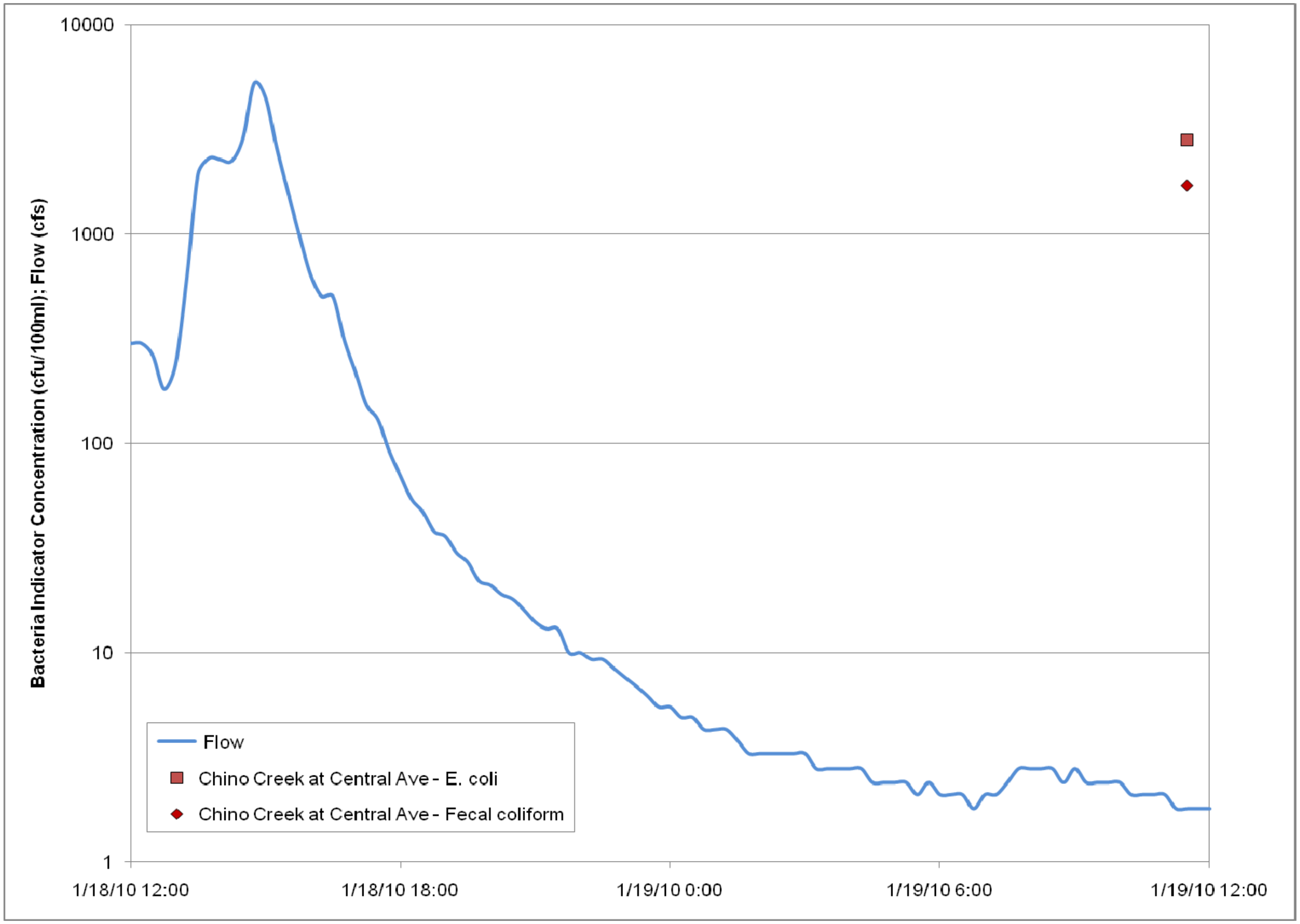


Figure 4-16. Bacterial indicator concentrations (cfu/100 mL) and flow observed at the Chino Creek site shortly after a January 19, 2010 area storm event (hydrograph from USGS Gauge 11073360 at Chino Creek and Schaefer Avenue). Before and after this storm event, bacterial indicator concentrations were much lower, e.g., one week before on January 12th fecal coliform and *E. coli* concentrations were 200 and 390 cfu/100 mL, respectively. One week after the storm event on January 26th fecal coliform and *E. coli* concentrations were 300 and 210 cfu/100 mL, respectively.

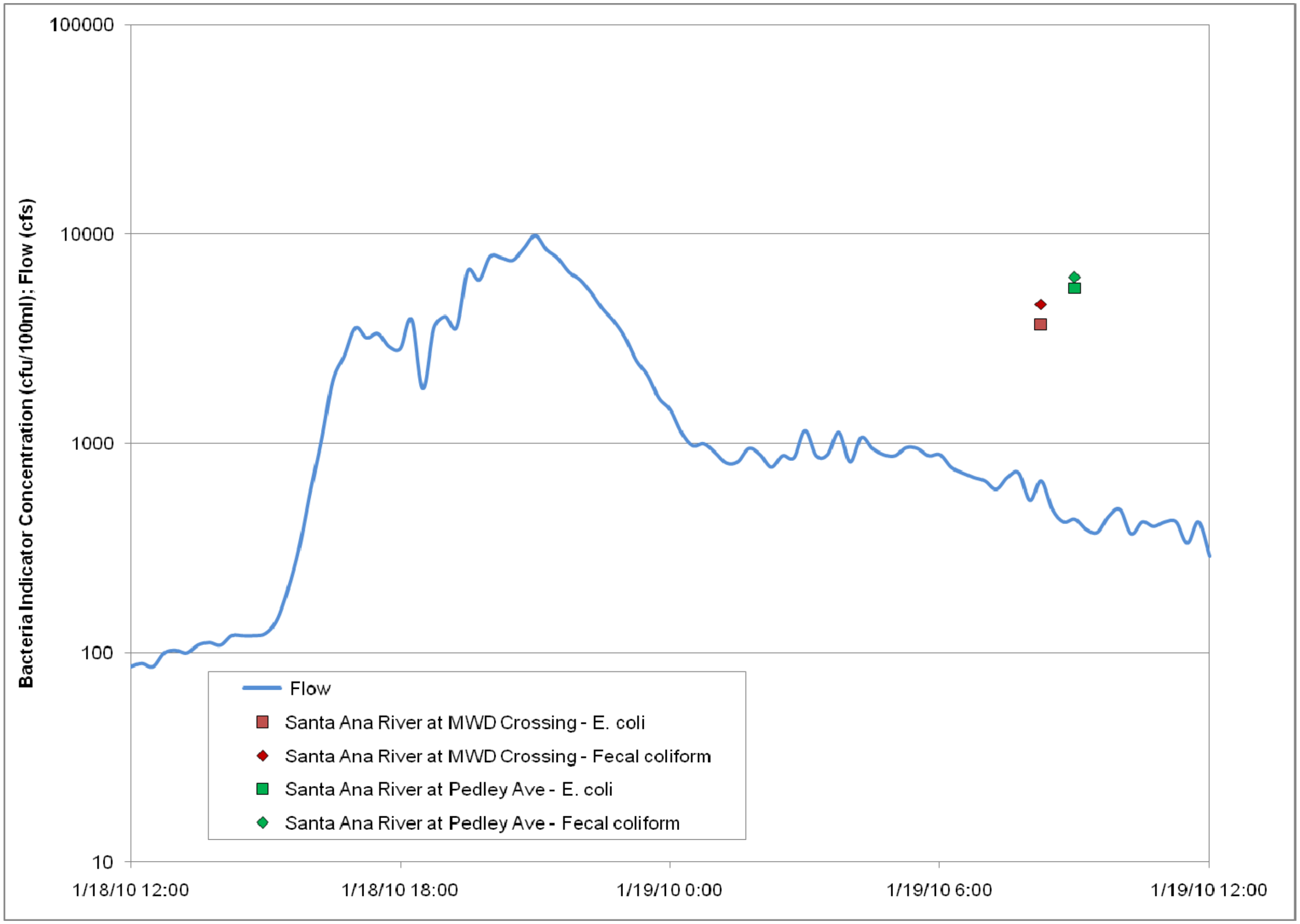


Figure 4-17. Bacterial indicator concentrations (cfu/100 mL) and flow observed at the Santa Ana River sites shortly after a January 19, 2010 area storm event (hydrograph from USGS Gauge 11066460 at Santa Ana River at MWD Crossing). Before and after this storm event, bacterial indicator concentrations were much lower, e.g., one week before on January 12th fecal coliform and *E. coli* concentrations were 40 and 100 cfu/100 mL, respectively. One week after the storm event on January 26th fecal coliform and *E. coli* concentrations were 380 and 120 cfu/100 mL, respectively.

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