Technical Memorandum 3
Flow and Water Quality Data Inventory and Characterization

Data Inventory

Flow Data Inventory

Numerous flow monitoring stations are operated by several agencies throughout the Santa Ana River Watershed. The location of each station was mapped and described within the Receiving Water and Watershed Inventory Mapping technical memorandum. The data record available at each location varies in length of time, and interval of measurement (daily readings vs. hourly readings). Some flow gauging stations were operational for very short periods, such as for a targeted wet season and then removed. Many of the currently operating flow gauging stations implemented smaller interval (15 or 30 minute) flow measurement in the late 1980s or early 1990s. Mean daily flow records are available for longer periods of record at these and other sites, generally dating back to the 1960s and 1970s.

The US Geological Survey (USGS) has flow records for 140 gauging stations within the Santa Ana River Watershed. Many of these stations have been removed or were passed on to local flood control districts and therefore are no longer operated by the USGS. Some of these USGS flow gauging stations monitor effluent channels, power plant outtakes, and other diversions of runoff. There are also many USGS flow gauging stations that record runoff rates in inland surface waters. The Riverside County Flood Control District is operating 4 flow gauging stations within the Santa Ana River Watershed. These stations began recording in the beginning of 2001. The San Bernardino County Flood Control District has flow records for 40 gauges within the Santa Ana River Watershed, 31 of which are located in the Chino basin. Few flow gauging stations are operated along mountain streams in the San Bernardino National Forest or along tributaries to Big Bear Lake. The Orange County Resource and Development Management Department (RDMD) is currently operating 13 flow gauging stations in the Santa Ana River Watershed. These stations are primarily along channels that have been modified or engineered to facilitate urban flood hazard protection.

Bacteriological Data Inventory

Available indicator bacteriological water quality data collected from receiving waters within the Santa Ana River Watershed during dry weather and wet weather seasonal sampling was requested from Storm Water Quality Task Force members as well as participants from other agencies. This request was made specifically with the County of Orange, County of Riverside, County of San Bernardino, Santa Ana Watershed Protection Authority (SAWPA), and the Regional Water Quality Control Board (RWQCB) - Region 8. Each agency responded to these requests as part of its participation on the Task Force. Requests of, and responses from these and other agencies are summarized below.

The Orange County Health Care Agency (OCHCA) conducts the Bacteriological Monitoring Program for the County of Orange. OCHCA provided a list of inland receiving water sampling locations within Orange County. Of those locations, two sampling locations lie within the Santa Ana River Watershed and also are upstream of tidal influence. The remaining sample locations are either beach sampling locations or located within tidal influence.

The Orange County Water District (OCWD) also provided bacteria sampling data for a sampling period between 1958 and 2004. The majority of the data is from the OCWD internal water quality database, while additional data for a period from 1999 to 2004, was extracted from the OCWD Santa Ana River Water Quality and Health (SARWQH) Study. The SARWQH Study was finalized Summer 2004.

The RWQCB provided data for sampling efforts for Chino Basin, Big Bear Lake, Santa Ana River, Lake Elsinore, Moro Canyon, San Jacinto River, and Canyon Lake. The majority of the data is from sampling efforts conducted by the RWQCB staff. The RWQCB also provided additional data not specifically collected by RWQCB staff. This particular data included bacteriological results for Big Bear Lake and Canyon Lake which were collected by Big Bear Municipal Water District (BBMWD) and Elsinore Valley Municipal Water District (EVMWD) staff, respectively.

The San Bernardino County Flood Control District (SBCFCD) represented the County of San Bernardino in providing bacteria data collected for the urbanized area NPDES stormwater program between 2000 and 2003.

The Riverside County Flood Control District (RCFCD) represented the County of Riverside in providing bacteria data. The RCFCD provided a set of bacteriological data for locations along the Santa Ana River. The data includes bacteriological data from samples collected not only by the Riverside County Health Department (1981 to 1991) but also bacteriological results from sampling along the Santa Ana River conducted by the OCHCA (1981 to 1993).

Additionally, bacteriological data was obtained from the Riverside County Health Care Department for bacteria data collected in 1985.

Additional data was obtained from agencies or organizations such as the United States Geologic Survey (USGS), Orange County Coastkeeper, and United States Environmental Protection Agency (USEPA) via its STORET Legacy Data Center.

Table 1 further describes the water quality data received from the source agencies and describes the data format, sampling dates, and agency contact information.

Data Management

Flow Data Management

For this study, available flow record data was not compiled into a single study database. Due to the ease of accessibility of flow data records, data was retrieved for each flow monitoring station as needed. Additionally, compiling a single database given the number of flow monitoring stations and the lengthy data record maintained for each station would require considerable effort.

Bacteria Data Management

Water quality data was submitted in varying formats and levels of detail. Data was provided in either hard copy format only or in electronic format from the source agencies. The data received from the source agencies all included a sampling location name, sample date, and bacteriological results. Some data, particularly samples collected more recently was provided in electronic format and included additional information such as sample time, analytical method, and sample location coordinates, etc.

Data Entry

For older sets of data, only hard copy documents were provided by the source agency. Data entry procedures and quality assurance checks were established and implemented for these datasets. These datasets included that which was provided by the RCFCD and Riverside County Health Department. Another source of data which required data entry was the Santa Ana Use Attainability study dataset obtained by Risk Sciences, Inc.

Table 1
Storm Water Quality Standards Study
Data Source Summary

Title/File Name	Description	Date	Agency From Which CDM Received Data
County of Orange			
Handout3.xls	Table showing sampling locations for OCHCA and OCSD	Jun 2004	Orange County Health Care Agency/ Monica Mazur
Bacteriological Data downloaded via the www.ocbeachinfo.com website	Sampling locations include: San Diego Creek/Campus Dr. (1994 to 2004); Santa Ana Delhi Channel (1986 to 2004)	Various	Orange County Health Care Agency/ www.ocbeachinfo.com
BacterialData_Database.xls	From OCWD water quality database	Various	Orange County Water District/ Nira Yamachika
MicrobialData_OCWD_CDM.xls	From OCSD SAR Water Quality and Health (SARWQH) Study	1999-2004	Orange County Water District/ Nira Yamachika
Feb03_BactiData.xls	Mill Creek and SAR at Imperial Highway	Feb 2004	Orange County Water District/ Nira Yamachika
Regional Water Quality Control Board (RWQCB) - Region 8			
Chino Basin			
Chino_TMDL_JanFeb04.xls	Data for Chino Basin TMDL	Jan - Feb 2004	Santa Ana RWQCB/ David Woelfel/ Bill Rice
Chino_TMDL_FebMar04.xls	Data for Chino Basin TMDL	Feb - Mar 2004	Santa Ana RWQCB/ David Woelfel/ Bill Rice
Chino_TMDL_MarApr04.xls	Data for Chino Basin TMDL	Mar - April 2004	RWQCB/ David Woelfel; Bill Rice
Big Bear Lake			
SARWQCB Knickerbocker Results_totals.xls	Knickerbocker Creek as part of pathogen TMDL	June 2003-April 2003	RWQCB/ Heather Boyd
Path_bbl.xls	RWQCB data collected in 1985, 1992, 1993, 1994, 1998; Big Bear Municipal Water District (BBMWD) data in 1994 & 1996	Various	RWQCB/ Heather Boyd

Table 1 (continued)
Storm Water Quality Standards Study
Data Source Summary

Title/ Electronic File Name	Description	Date	Agency From Which CDM Received Data
Santa Ana River			
SARBact 84.xls	Santa Ana River data collected from 1984	1984	RWQCB/ David Woelfel
SARBact 85.xls	Santa Ana River data collected from 1985	1985	RWQCB/ David Woelfel
85associatedlab.pdf	RWQCB sampling effort from 1985; Analyzed by Associated Labs	August 1985	RWQCB/ David Woelfel
Lake Elsinore			
LakeElsinoreStudy_MaySept03.xls	Lake Elsinore Bacteriology Results	May - Sept 2003	RWQCB/ Vitale Pavlova
San Jacinto River			
Lab Data For San Jacinto River Watershed	San Jacinto River data	Feb 2003; Feb 2004	RWQCB/ Cindy Li
Canyon Lake			
CL Bacterial 90-02.xls	Canyon Lake sampling data from Elsinore Valley Municipal Water District (EVMWD)	2002	RWQCB/ Cindy Li
CL Dock Sites 03-04 received 05-25-04.xls	Data from RWQCB and EVMWD	2003	RWQCB/ Cindy Li; Original data source: EVMWD/ Chantel Stapleton provided additional information for sample site locations
Santa Ana Watershed Project Authority (SAWPA)			
Summary WQ data Chino TMDL.xls	Water quality bacteria data summarizing sampling for Chino Basin TMDL	2002-2003	SAWPA/ Rick Whetsel
County of San Bernardino			
Bacteria sampling results (hard copy)	Hard copy report of laboratory results from E.S. Babcock Lab	2000 -2003	San Bernardino County Flood Control District/ Janet Dietzman

Table 1 (continued)
Storm Water Quality Standards Study
Data Source Summary

Title/File Name	Description	Date	Agency From Which CDM Received Data
County of Riverside			
Handwritten table of bacteria data – Total Coliform, Fecal Coliform, Enterococcus, E.coli	Handwritten table of data from 1985	1985	Riverside County Health Care Department/ Damian Meins
PDF files on CD	CD contains PDF of hard copy handwritten sampling results from Santa Ana River locations. Sampling was conducted originally by the Orange County Health Care Agency and the Riverside County Health Department.	1981 - 1994	Riverside County Flood Control District / Tom Rheiner
USEPA			
STORET Data	Pre-1999 data downloaded from USEPA website; No matches for post-1999 data	Various	Data downloaded from USEPA STORET Legacy Data Center website. Original data source: Orange County Environmental Management Agency & California Department of Water Resources
USGS			
USGS_SantaAna11074000.txt USGS_SantaAna11075600.txt	USGS Sampling stations: Prado Dam and Santa Ana River at Imperial Highway	2000 - 2001	Downloaded from USGS website
Additional Sources			
Bacteria Monitoring Results (hard copy)	Report: "Santa Ana Use Attainability Analysis Water Quality," Section 4 - Relationship to the Use-Attainability Analysis; contains bacteria data from 1991	May 1992	Report Prepared by: Regulatory Management, Inc./ Copy of data provided by Tim Moore
Citizen Monitoring Database (Access)	MS Access database of monitoring data	2002 - 2004	Orange County Coastkeeper/ Mina Danieli

Duplicate Data by Source

Data was checked to ensure it was not duplicate data submitted by differing agencies. Queries were performed on the database based on sample location, sample date, parameter and analytical results value to verify that data was not appended to the database in a duplicative manner. The potential for duplicate data may have occurred in situations in which the originating sampling agency (e.g., County) provided sampling data which was also submitted by the RWQCB. An example of this occurrence involves the electronic data provided by the RWQCB for sampling conducted along the Santa Ana River in 1985. The same data was also provided by the Riverside County Health Department in a hard copy format.

Duplicate Sampling Data

Queries were performed based on sample location, sample date, parameter, and sampling time (if available) to determine cases where duplicate samples were collected. In many cases multiple samples were collected but analyzed under different analytical testing methods. These samples were treated as distinct sample results and not averaged.

Database Development

Data was provided in various formats (electronic and hard copy) and was compiled and integrated into one overall database. Each sample result and its related information such as date, sample location, and bacteriological result was established as a data field as part of a distinct data record. Table 2 lists the relevant fields included in the database.

Table 2
Database Fields

Field Name	Description
DB_ID	Database record number – this number is unique to the each record of the database
Location_ID	Sample Location Name (see Table 2-3)
Bacteria_ID	Constituent Analyzed – Total Coliform, Fecal Coliform, E.Coli, or Enterococcus
Date	Date (month, day, and year)
Time	Sampling time (very limited data records include time)
Result	MPN /100 ml
Qualifier	Data Qualifiers
Source_ID	Source agency that provided the bacteria data.
Comments	Any relevant information provided by the source agency
Analytical Method	Analytical Method

Database Identification Number (DB_ID)
A numbering system was established to differentiate between individual records. This number is unique to each water quality sample and allows for establishing the order in which data was incorporated into the database.

Sample Location Identification (Location_ID)
Each source of data included locations at which samples were collected. Samples often were collected at the same locations or general vicinity by various agencies. Table 3 lists the data sources, sampling locations, and the number of samples collected at each sample location.

From examining the overall data set, common sampling locations were identified among the various data sources. After integrating the numerous datasets, queries were conducted to determine the number of samples collected for each sampling location.

For instance, sampling locations were often described by a cross-street or bridge overpass near the water body, (i.e, Santa Ana River (SAR) at Imperial Highway, SAR at Van Owen). In order to analyze data, sampling locations were mapped in GIS Arcview. In cases where GPS coordinates were not available or recorded, mapping of sampling locations was determined by any additional location information provided by the data source. For purposes of data analyses, sampling locations in the same location also were identified under one common name.

Bacteria Result (Bacteria_ID)
The bacteriological parameters analyzed for in the various datasets included:

- Total Coliform
- Fecal Coliform
- E. coli
- Enterococcus
- Fecal Streptococcus

Date
The date of sample collection is included in this data field.

Time
The recorded time of sample collection is included where available.

Result
The bacteriological results are listed in MPN/100ML units.

Table 3
List of Sampling Locations and Number of Samples by Source

Data Source	E. Coli	Enterococci	Fecal Colif.	Fecal Strep.	Total Colif.
Big Bear Municipal Water District					
200' Downstream from MWDC9	2	2	2		
At Forest Road 2N08			1		
At Forest Road 2N08 at Hairpin	2	2	2		1
Big Bear Lake – Center			3		2
Big Bear Lake - East Area			1		2
Big Bear Lake - Near Dam			3		3
Big Bear Lake - West Area			1		1
Big Bear Lake - West Center			3		2
Knickerbocker Creek at Big Bear Lake	19	18	20		11
Metcalf Creek at Big Bear Lake			1		1
Rathbun at Big Bear Lake			1		1
Elsinore Valley Municipal Water District					
East Bay	37	22	7		40
Indian Beach	37	22	7		42
Intakes	40	22	7		45
North Causeway	38	22	7		41
Sierra Park	37	22	7		40
Orange County Coastkeeper					
133 Freeway	29				30
Bake Parkway	15				15
Civic Center	31				30
Gold Star 2	28				30
Gold Star 3	25		1		28
Gold Star Creek 1	28		1		29
Katella	12				13
Lakeview	30				30
Lincoln	28				30
Maple Springs	18				18
Michelson	28				30
Mill Creek 1	22				24
Mill Creek 3	24				25
Modjeska Canyon	23				23
Sand Canyon	20				21
Santiago Oaks Park	22				26
SAR at Green River Rd	30				31
SAR at Gypsum Canyon Rd	26				31
Slide Zone	24				27
Smisek	22				24
Temescal Creek 1	25		1		29
Temescal Creek 2	29				31
Temescal Creek at Lincoln Ave	27		1		29
Woodbridge	28				29
Yorba Linda Regional Park	29				30
Featherly Park East			102		103
Featherly Park West			108		107
San Diego Creek at Campus Dr		274	421		430

Table 3 (continued)
List of Sampling Locations and Samples by Source

Data Source	E. Coli	Enterococci	Fecal Colif.	Fecal Strep.	Total Colif.
Orange County Health Care Agency					
Santa Ana Delhi Channel/Back Bay		274	695		679
SAR at Green River Rd			416		420
SAR at Gypsum Canyon Rd			105		107
SAR at Imperial Highway			416		423
SAR at Lincoln Ave			174		174
Orange County Water District					
Chino Creek at Euclid Ave			3		3
Chino Creek at Prado GC			1		1
Inlet to OCWD wetlands; east side of service road	56	61	40		63
Knickerbocker Creek at Hwy 18	1	1	6	4	2
OC Wetlands Effluent	49	57	39		59
Rathbun at Big Bear Lake			2		2
SAR at Imperial Highway	71	66	56		92
SAR at La Palma Ave			1		1
SAR at Prado Dam	63	60	63		126
SAR at River Rd	1		5		4
Slide Zone	1				
Temescal Creek at Lincoln Ave			1		1
Riverside County Flood Control District					
Fair Weather Dr. storm drain in Canyon Lake			2	2	2
Salt Creek at Murrieta Rd			1	1	1
SAR at Market St			26	23	26
SAR at Mission Blvd			1	1	1
SAR at Norco Bluffs			1	1	1
SAR at Pueblo St			24	22	24
SAR at River Rd			25	21	25
SAR at Van Buren			2	1	2
Sierra Park			2	2	2
Riverside County Health Department					
Chino Regional WRP #1	10	10	7		10
Chino Regional WRP #2	10	10	10		10
Colton STP	7	7	6		7
Riverside STP	9	9	7		9
San Bernardino STP	9	9	7		9
SAR at Green River Rd	12	12	64		63
SAR at Imperial Highway	12	11			2
SAR at La Cadena Dr	12	12	12		12
SAR at Mission Blvd	12	12	76		78
SAR at MWD Crossing	12	10			1
SAR at North Main/Hamner	12	12	103		79
SAR at Prado Dam	12	12	14		15
SAR at River Rd	12	11	76		81
SAR at Riverside Ave	12	10	46		80
SAR at Van Buren			74		77

Table 3 (continued)
List of Sampling Locations and Samples by Source

Data Source	E. Coli	Enterococci	Fecal Colif.	Fecal Strep.	Total Colif.
County of San Bernardino					
Cucamonga Canyon	10	10	11	8	10
Cucamonga Creek at Hellman Ave	1	1	1	1	1
Forest Falls	11	11	11	10	11
Seven Oaks Dam	10	10	11	8	10
Santa Ana Regional Water Quality Control Board					
Big Bear Lake – East End			1		1
Big Bear Lake - Near Dam				1	1
Big Bear Lake at Pine Knot Landing					1
Bon View at Merrill	13	13	13		13
Boulder Bay Creek at Hwy 18			1	1	
Center of Lake Elsinore		19	19		19
Chino Creek Above Wetlands	30	30	30		30
Chino Creek at Central	15	15	15		15
Chino Creek at Prado Golf Course	15	15	15		15
Chino Creek at Schaeffer Ave	45	45	45		45
Chino Creek Below Wetlands	17	17	17		17
Colton STP			3		3
Cucamonga Creek at Merrill Ave	43	43	43		43
Elm Grove		19	19		19
Elsinore West Marina		19	19		18
Fair Weather Dr storm drain in Canyon Lake	2	2	2	2	2
Four Corners		19	19		19
Grout Creek Headwaters	1	1	1		1
Hemet Channel at Sanderson Ave	2	2		2	2
Icehouse Canyon	43	43	43		43
Inlet Area		19	19		19
Knickerbocker Creek at Hwy 18	2	2	2		2
Knickerbocker Creek at Stocker Rd		19	19		19
Lake Elsinore Outlet Channel in Elsinore		19	19		19
Lakeland Park		19	19		18
Meadow Creek at Bike Trail			1	4	1
Metcalf Bay				1	1
Metcalf Creek at Hwy 18	1	1	5	4	2
Metcalf Creek, East Fork (.3 mi from West Fork and Cedar Lake Camp Rd.)	1	1	1		1
Metcalf Creek, West Fork Cedar Lake Camp Rd.	1	1	1		1
Mill Creek at Chino Corona Rd	45	45	45		45
Mill Creek at Chino Creek	45	45	45		45
N Side Ramona Expressway at Warren Rd	1	1	1		1
OC Wetlands Effluent	30	30	30		30

Table 3 (continued)
List of Sampling Locations and Samples by Source

Data Source	E. Coli	Enterococci	Fecal Colif.	Fecal Strep.	Total Colif.
Perris Valley Storm Drain at Nuevo	1	1	1		1
Playland Park		19	19		19
Prado Park Outlet at Chino Creek	42	42	42		42
Rathbun - Below Zoo			4		4
Rathbun Creek at Swan Dr.			1	1	
Rialto STP at Divers			2		2
Salt Creek at Murrieta Rd	3	3	2	2	3
San Bernardino STP			3		3
San Jacinto River at Bridge St	1	1	1		1
SAR at Etiwanda Channel	15	15	15		15
SAR at Green River Rd	12	12	12		12
SAR at Greenspot Rd			2		2
SAR at Gypsum Canyon Rd		1	2	1	2
SAR at I-10			3		3
SAR at Imperial Highway	12	12	12		12
SAR at Mission Blvd	12	13	15		16
SAR at Mt Vernon Ave			3		3
SAR at MWD Crossing	56	57	59	1	59
SAR at North Main/Hamner	12	13	14	1	14
SAR at Prado Dam	58	57	57		57
SAR at River Rd	12	13	14	1	14
SAR at Riverside Ave	12	13	15	1	16
SAR at Van Buren		1	1		1
SAR at Warm Creek East			4		2
SAR at Waterman			1	1	1
Sierra Park Drain in Canyon Lake	3	2	3	2	3
State Park		19	19		19
Summit Creek at Mouth			2	2	
Warm Creek at "F" St			2		2
Warm Creek at STP			1		1
Warm Lytle Creek Confluence			1		1
Weekend Paradise		19	19		19
Santa Ana Use Attainability Analysis Report					
Center of Lake Elsinore			2	2	2
Chino Regional WRP #1			2	2	2
Chino Regional WRP #2			2	2	2
Colton STP			2	2	2
Mill Creek at Chino Creek			2	2	2
Rialto STP at Divers			2	2	2
Riverside STP			2	2	2
San Bernardino STP			2	2	2
SAR at Gypsum Canyon Rd			2	2	2
SAR at Gypsum Canyon Rd			2	2	2
SAR at La Cadena Dr			1	1	1
SAR at Mission Blvd			2	2	2
SAR at MWD Crossing			2	2	2
SAR at Prado Dam			2	2	2
SAR at River Rd			1	1	1

Table 3 (continued)
List of Sampling Locations and Samples by Source

Data Source	E. Coli	Enterococci	Fecal Colif.	Fecal Strep.	Total Colif.
USEPA - STORET					
Hicks Canyon Wash at Culver Blvd			21	5	23
Peters Canyon Wash at Irvine Blvd			16	2	16
Peters Canyon Wash East Side of Jeffrey Rd			7		7
Peters Canyon Wash NE Santa Ana Fwy			36	3	36
Rattlesnake Canyon Wash at Jeffrey Rd			20	3	26
San Diego Creek at Campus Dr Bridge			25	23	166
San Timoteo Creek at Waterman Ave.			2		3
Santa Ana Delhi Channel at Irvine Ave			25	22	168
Santa Ana River Basin at Jamboree, North of Main					9
Santiago Creek at Santiago Canyon Rd Bridge					11
SAR Basin at Jeffrey Rd at Hines Nursery			20		26
SAR Basin at San Diego Creek Confluence					10
SAR Basin Culver at University, Irvine					13
SAR at Prado Dam			10		12
USGS					
SAR at Imperial Highway	65	65	14		14
SAR at Prado Dam			144	148	

Qualifier
In cases where the bacteriological result is qualified, this field includes symbols such as <, >, ≤, and ≥ to denote cases in which data is qualified.

Source_ID
The source of the data is an important data field included in the database. This information is valuable in order contact the source if questions arise related to the sample water quality data.

Comments
Any relevant information describing the data record is included in this field.

Analytical Methods

The vast majority of data received did not include the analytical methods conducted to perform the analyses. Phase II of the Water Quality Standards Study should further investigate and research the types of analytical methods performed in the course of analyses.

Table 4 lists the specific analytical methods applied by each agency, where provided, in its analyses of the samples collected from specific water bodies.

Table 4
Analytical Methods

Water Body	Total Coli form	Fecal Coli form	E.Coli	Enterococci
Santa Ana Regional Water Quality Control Board				
Lake Elsinore/ Canyon Lake	SM9221B	SM9221C	SM9221F	SM9230C
Chino Basin	SM9222B [1]	SM9222D [1]	Modified E.Coli (USEPA 1998)	SM9230B [1]
Orange County Coastkeeper				
Various OC Locations	Colilert 18 /24 IDEXX	NA	Colilert 18 / 24 IDEXX	NA
(1) Standard Methods 20th Edition				

Data Characterization

Flow Data Characterization

Data from flow gauging stations along inland surface waters within the Santa Ana River Watershed show some similarities in the pattern of average annual hydrographs. Long periods of generally persistent low flow occur during dry weather months (April through November) and dry periods during winter months in many surface waters. The source of this flow is POTW effluent in a few locations, nuisance urban runoff (irrigation, car washing, etc.), and groundwater seepage in mountain streams. On average, wet weather induced high flow events occur between 10-20 times during the winter months, rapidly increasing flow by 1 to 2 orders of magnitude. Following individual wet weather events, urban streams tend to return to a level very close to summer dry weather flow. Conversely, inland surface waters with drainage areas in the San Bernardino and Angeles National Forests or Santa Ana Mountains tend to have a slower recession of high flow resulting from wet weather events. Snowmelt tends to occur soon after wet weather, thus maintaining a higher flow rate in these waters.

There are also a number of dam releases, flow diversions, and water importing that influence flow in certain inland surface waters. There are 85 dams and other runoff impoundments that control runoff within the Santa Ana River Watershed. Response to wet weather of inland surface waters downstream of these impoundments is attenuated, with a more steady flow regime that is controlled by dam operators. Also, 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. Imported water used to recharge groundwater can increase dry weather flow upstream of these basins.

Flow within the main stem of the Santa Ana River is influenced at different times and locations from urban runoff, POTW effluent discharges, dam releases, and groundwater recharge diversions.

Receiving waters either receiving or downstream of area POTW discharges include Reach 3 of the Santa Ana River, Prado Lake, Chino Creek, and Cucamonga Creek. Reaches downstream of major controlled dam releases include the Santa Ana River, receiving releases from Prado Dam, and Chino Creek, receiving releases from the San Antonio Dam. Releases of imported water occur within Chino Creek.

Bacteria Data Characterization

Different data was compiled from many discrete locations into a study GIS database. Watershed wide analyses were developed to guide the Stormwater Standards Task Force by portraying water quality within channels. The resulting spatial representation of water quality facilitates a basin wide understanding of existing or potential recreational uses and compliance with water quality objectives in these waterbodies.

Methods

Queries of the study database were performed to compare data with existing fecal coliform water quality objectives in sampled inland surface waterbodies and also with proposed E. coli objectives based upon current EPA guidance criteria.

Existing Bacteria Water Quality Objectives

The following water quality objectives for fecal coliform have been established for the protection of recreational uses in freshwaters within the Santa Ana Region:

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.*

REC-2 *Fecal coliform: average less than 2000 organisms/100 mL and not more than 10% of samples exceed 4000 organisms/100 mL for any 30-day period*

Ocean Beaches - Coastal areas of California are currently subject to bacteria water quality objectives established by the California Department of Health Services (DHS). The objectives to protect ocean waters at beaches are:

Geometric Mean Limits

a. Total coliform density shall not exceed 1,000/100 ml.
b. Fecal coliform density shall not exceed 200/100 ml.
c. Enterococcus density shall not exceed 35/100 ml.

Single Sample Limits

a. Total coliform density shall not exceed 10,000/100 ml.
b. Fecal coliform density shall not exceed 400/100 ml.
c. Enterococcus density shall not exceed 104/100 ml.
d. Total coliform density shall not exceed 1,000/100 ml, if the ratio of fecal-to-total coliform exceeds 0.1.

Potential Future Bacteria Water Quality Objectives

The EPA published new bacteria guidance in 1986, which advised states to change their bacteria criteria from fecal coliform for fresh and marine waters to *Escherichia coli* (*E. coli*) for freshwaters and *Enterococcus* for marine waters. The basis for this change was new data which showed that increased *E. coli* (a subset of fecal coliforms) and *Enterococcus* concentrations showed a better correlation with an increased frequency of gastroenteritis than increased concentrations of fecal coliforms. *E. coli* and *Enterococcus* serve as pathogen indicators meaning that when concentrations of these bacteria are elevated there is an increased likelihood that many other potential human pathogens, e.g., viruses and protozoans such as *Giardia* and *Cryptosporidium*, are also elevated to unsafe levels.

The *E. coli* and *Enterococcus* objectives are based on studies conducted by EPA in the early 1980's. These studies were conducted at three marine and two freshwater locations over several years. Information on the frequency of gastroenteritis and related water quality were obtained by conducting surveys of individual swimmers and non-swimmers while at the same time collecting water quality data from the selected study sites. The resulting data, average illness rate and geometric mean of water quality, were used to calculate risk-based levels of protection for locations where primary contact recreation occurred, e.g., swimming.

EPA guidance is based on acceptable levels of protection for freshwaters of 8 to 10 swimmers per 1000 and for marine waters of 8 to19 swimmers per 1000 getting gastroenteritis as a result of swimming activities. For each level of protection, the EPA provides recommended geometric mean criteria and corresponding statistically derived single sample limits based on varying upper percentile values (75^{th} to 95^{th} percentile) of allowable densities. For freshwaters, Table 5 lists recommended criteria for risk levels ranging from 8 to 10 swimmers/1000 are as follows:

Table 5					
Risk Level (% of swimmers)	**Geometric Mean Density** (per 100 ml)	**Upper Percentile Value Allowable Density (per 100 ml)**			
		75th Percentile	**82nd Percentile**	**90th Percentile**	**95th Percentile**
0.8	126	236	299	409	576
0.9	161	301	382	523	736
1.0	206	385	489	668	940

For example, for *E. coli* if the acceptable geometric mean value is 126, the corresponding single sample value using the 75th percentile of the data distribution of all values is 236. If a 95th percentile is acceptable, then the corresponding single sample value would be 576.

REC-1 use bacteria objectives for basin plan waterbodies are based upon a 30-day rolling set of data. In order to develop complex queries for all locations where bacteria data was historically collected, calendar months are used as a surrogate to the rolling 30-day time period. Actual rolling 30-day compliance criteria are assessed at six study sites and are presented in the Detailed Study Site Characterization section of this technical memorandum.

Results from queries of the database are joined to the GIS layer of "Bacteria Stations" using a reference location identification number. New fields in the point attribute table of this layer, resulting from the join are then used to symbolize sampling locations in the GIS model. The points on these maps are symbolized by two attributes, the 1) fraction of non-compliant calendar months and 2) number of non-compliant calendar months when sufficient data was present to determine compliance. These attributes are depicted as varying intervals of color and size of points, respectively. Several different queries are used to assess the relationship between compliance with REC-1 bacteria standards and flow condition, season, and time period.

Limited instances of concurrent flow data for all inland surface waterbodies where bacteria samples were collected over the past 30+ years resulted in a decision to use data from a set of daily rainfall stations rather than flow records to assess the presence or absence of wet weather conditions. Eight rainfall stations were used to represent rainfall across the basin (Figure 1). Although the distribution of stations was relatively course, it was suitable for purposes of this analysis, considering the flow condition only requires a distinction between wet and dry weather. Samples collected on days when there was greater than or equal to 0.1 inches of rainfall, as measured at the nearest reference rainfall station, were considered wet weather samples.

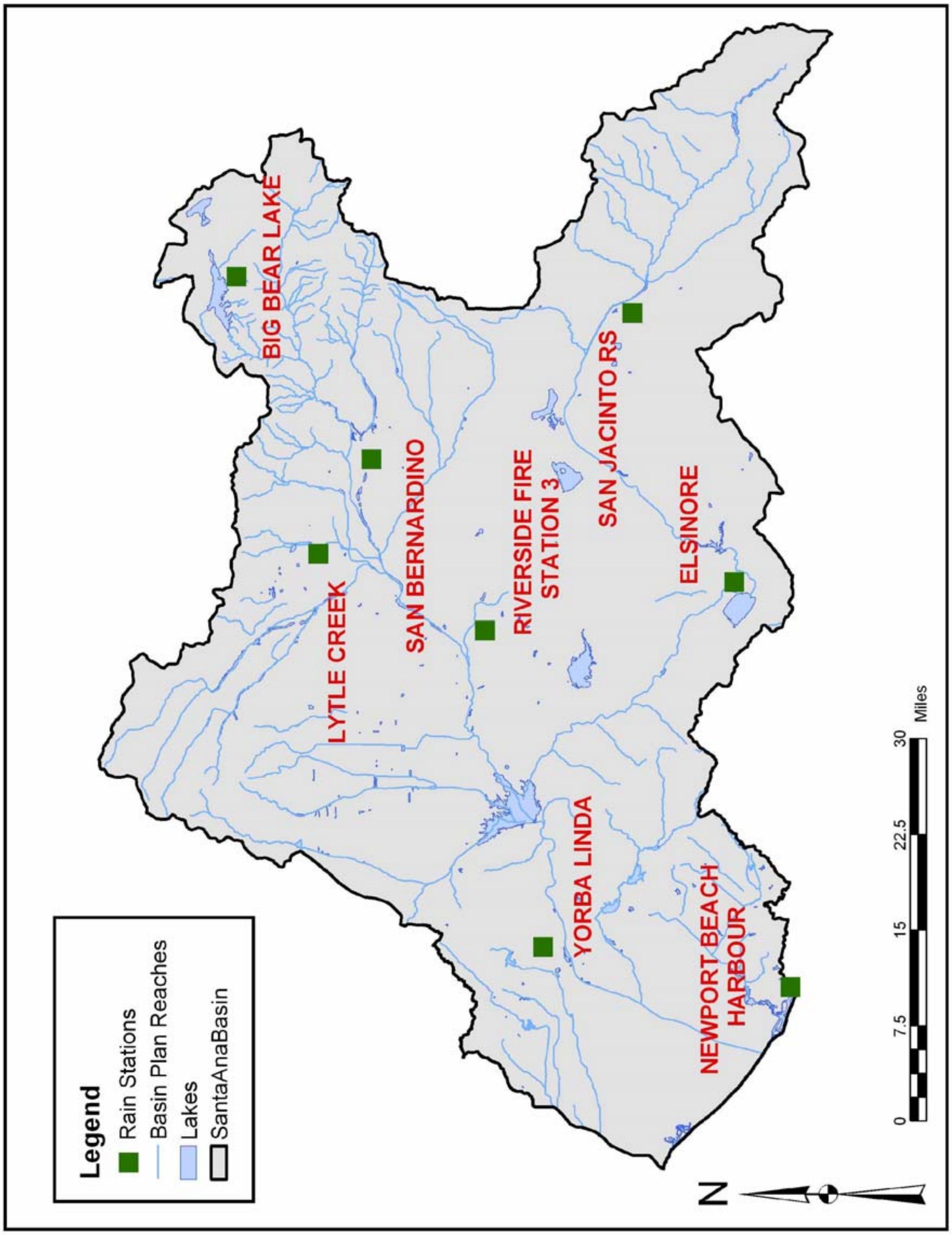

Figure 1
Rainfall Stations Used to Identify Wet/Dry Days for Nearby Bacteria Stations

The relationship between the layers "Bacteria Stations" and "Rainfall Stations" was developed by using the ESRI Spatial Analyst extension for ArcGIS 8.3®. The straight line allocation function was employed to create a raster dataset of nearest rainfall station. The raster data conversion function of Spatial Analyst was then used to convert the grid of the nearest rain station to a polygon layer of distinct rainfall regions. Lastly, a spatial join was used to assign rainfall stations to the bacteria stations that fell within each respective region. The updated point attribute table resulting from the spatial join was exported as a database file and imported to the Stormwater Standards Study database to support the creation of wet weather and dry weather queries.

Dry weather samples, on days without rain or when less than 0.1 inches was recorded, were further distinguished between winter and summer dry weather flows. Bacteria samples collected between April 1 and October 31 were categorized as summer dry weather samples and those collected between November 1 and March 31 were categorized as winter dry weather samples.

Lastly, fecal coliform and E. coli bacteria water quality data was assessed for three different time periods. November 28, 1975 and January 1, 1996 are delineators of critical events that may impact actual bacteria counts or reach-specific recreational use designation in waterbodies of the Santa Ana Basin. November 28, 1975 marks the date when the Clean Water Act's antidegradation laws were implemented, disallowing any reduction in water quality in surface waters of the United States. The second date is an approximate estimate of when most POTW effluent discharges in the Santa Ana Basin met Title 22 tertiary treatment requirements, although some began adding tertiary treatment beginning in the late 1970's.

All Samples

Figures 2 through Figure 5 show Santa Ana Basin maps with the results of each of the bacteria data queries performed upon the entire dataset. The maps generated using all samples provide a comparison to REC-1 use bacteria objectives in the Santa Ana Basin. The percentage of calendar months with sample results potentially exceeding objectives and the size of the bacteria record at each location improve our current understanding of water quality associated with recreational use in Santa Ana Basin surface waterbodies.

Table 6 provides the number of sampling locations with sufficient data to compare to water quality objectives and proposed criteria.

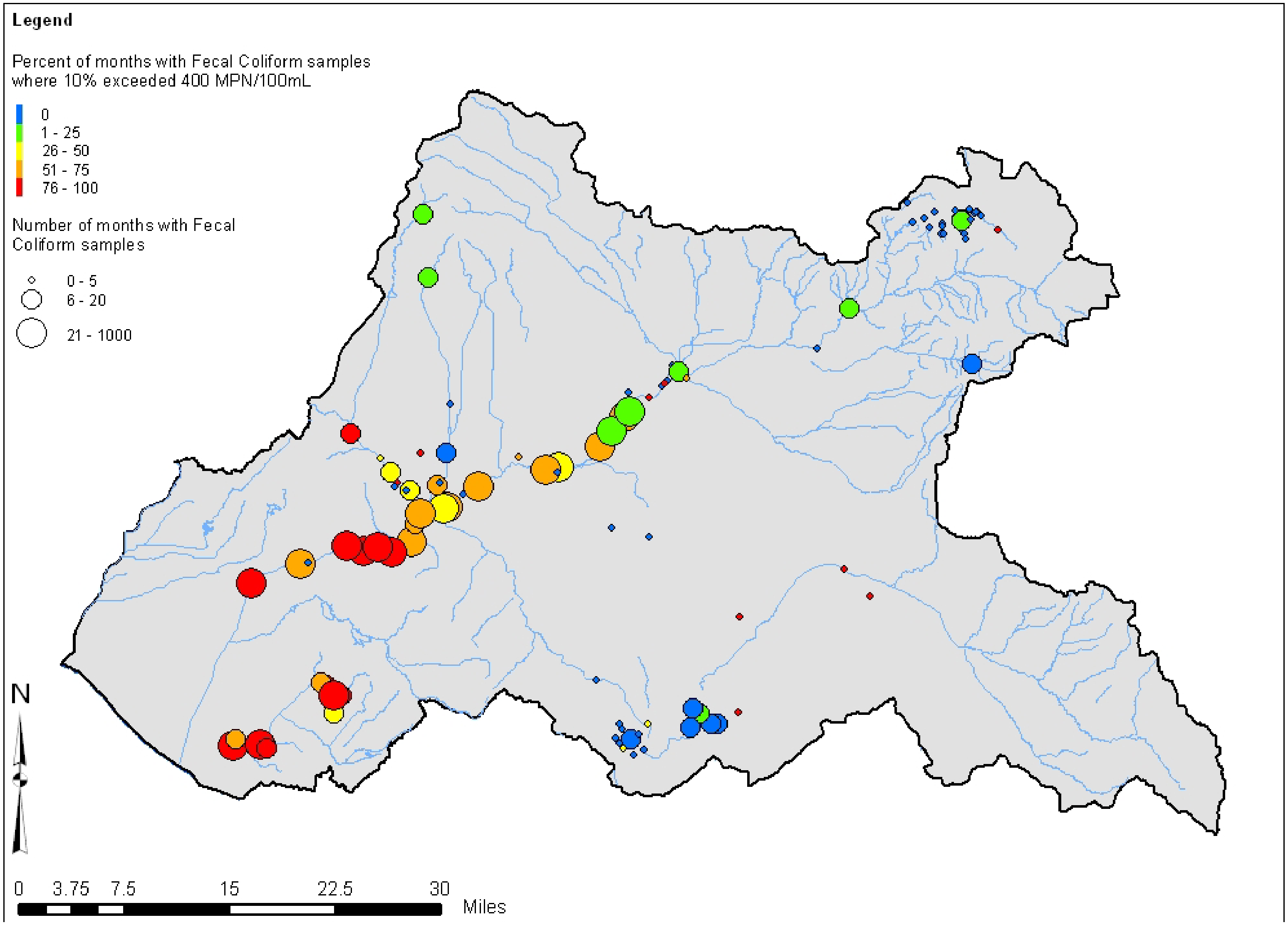

Figure 2
Fecal Coliform Analysis 10% of Samples Exceedence Criteria

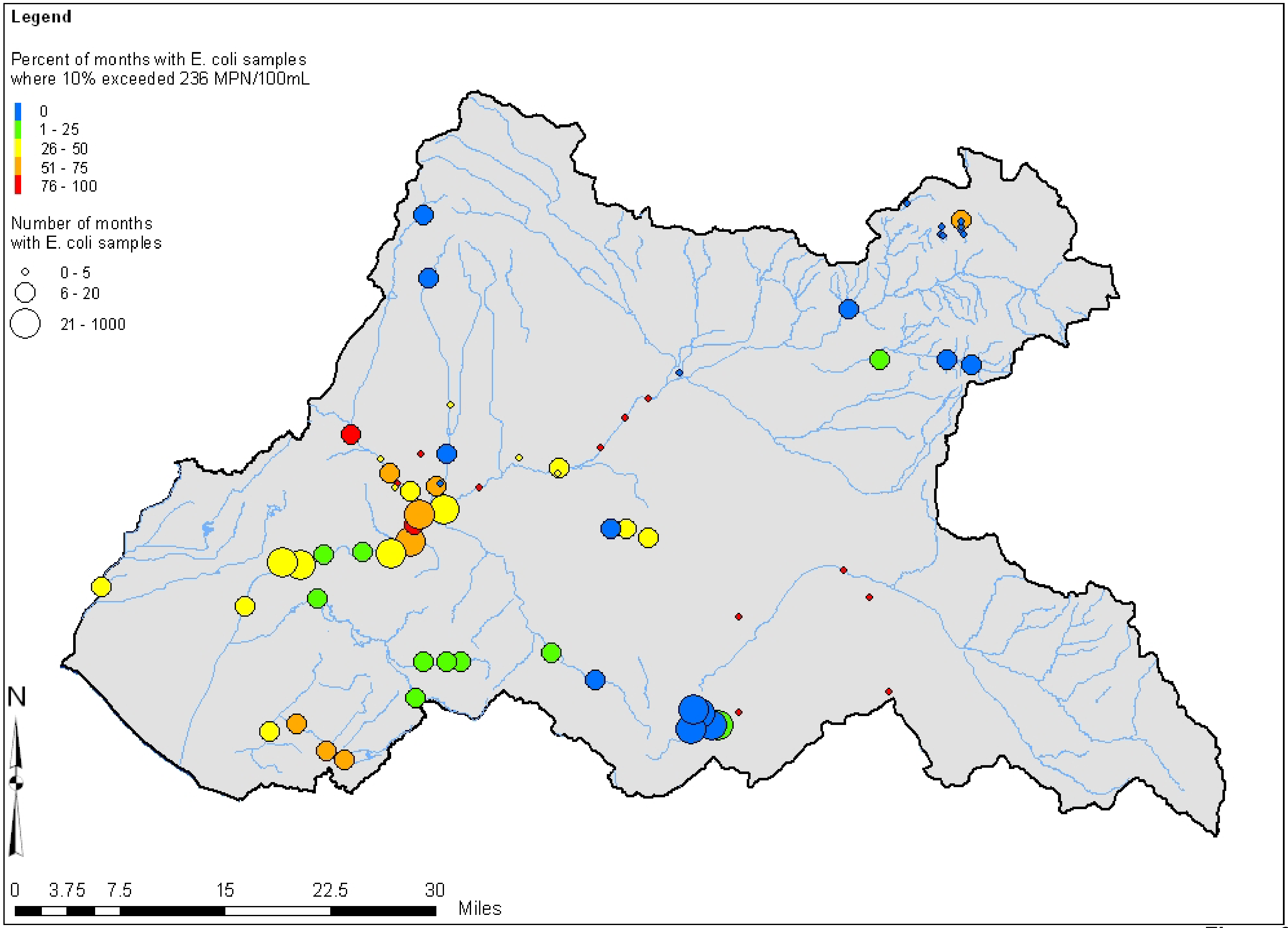

Figure 3
E. coli Analysis 10% of Samples Exceedence Criteria

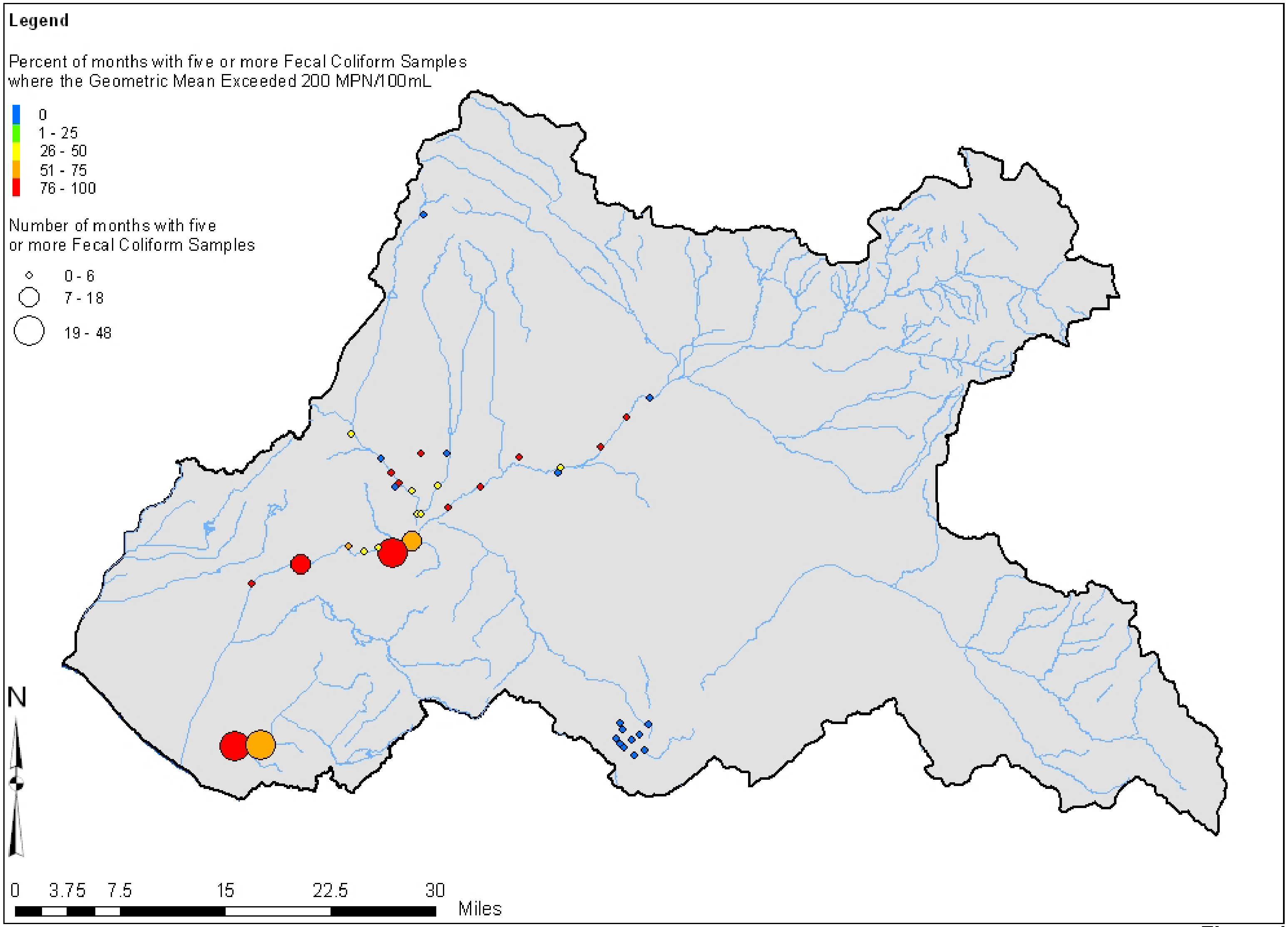

Figure 4
Fecal Coliform Analysis Geometric Mean Criteria

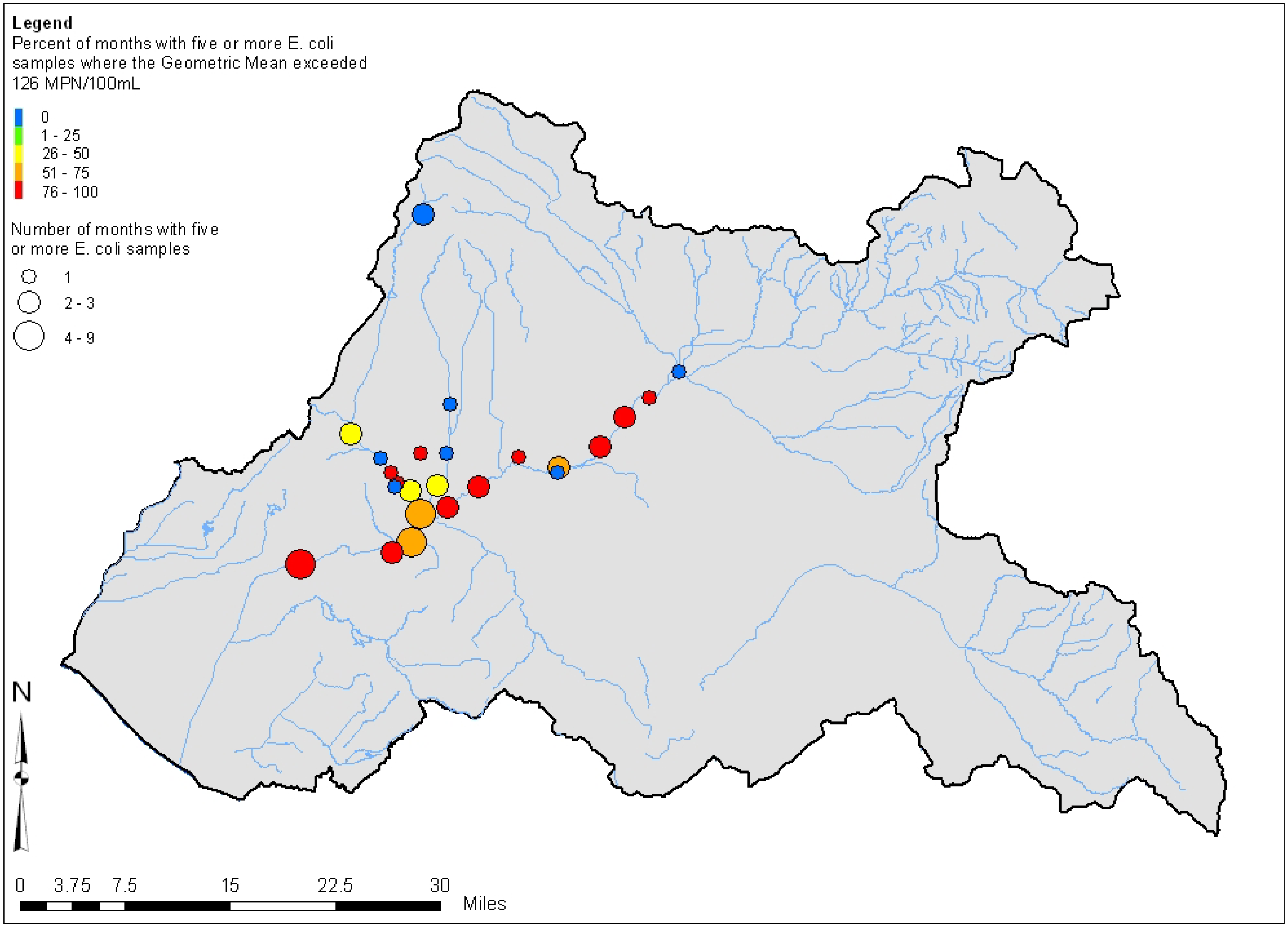

Figure 5
E. coli Analysis Geometric Mean Criteria

Table 6
Number of Sampling Locations Compared to Objectives/Criteria

Criteria	All Samples	Wet Weather	Summer Months, Dry Weather	Winter Months, Dry Weather
Fecal Coliform: 10% of Samples Collected within a 30 days	110	44	94	68
Fecal Coliform: Geometric Mean of 30-day Periods with 5 or More Samples	39	0	28	22
E. coli: 10% of Samples Collected within 30 days	77	45	69	54
E. coli: Geometric Mean of 30-day Periods with 5 or More Samples	25	1	14	15

Potential exceedences of REC-1 bacteria objectives were observed at most Basin Plan reaches with sample results, including high order rivers such as the Santa Ana, medium sized inland surface streams such as Chino Creek, small urban channels such as Salt Creek near Lake Elsinore, and mountain streams such as Knickerbocker Creek in Big Bear Lake. There is more sampling data available from more urbanized areas of the basin than areas less impacted by urbanization.

When comparing available fecal coliform data to the 10% exceedence criteria (Figure 2), the data query shows that sampling performed upon the Santa Ana River and other waterbodies heavily influenced by urbanization may exceed water quality objectives in all months sampled. Querying results from less urbanized areas, especially around inland lake areas, available data shows several locations that may meet objectives, however some less urbanized areas have months where objectives may be exceeded.

When comparing available E. coli data to the 10% exceedence criteria (Figure 3), the data query shows similar results to the fecal coliform analysis, however most locations have fewer months exceeding proposed E. coli objectives than fecal coliform objectives, and more locations may meet proposed E. coli objectives.

When comparing available fecal coliform data to the geometric mean exceedence criteria (Figure 4), the data query shows that fewer locations have sufficient data to perform the comparison. For the locations with enough sampling to perform the comparison, again sampling performed upon waterbodies heavily influenced by urbanization may exceed water quality objectives in all months sampled. Less urbanized areas may meet the objective, though the amount of data is limited in order to support.

When comparing available E. coli data to the geometric mean exceedence criteria (Figure 5), the data query shows a larger number of months with enough data for comparison, with most locations potentially exceeding proposed E. coli objectives, and some less urbanized locations potentially able to meet proposed objectives.

Wet Weather

There were relatively few wet weather samples collected by the various agencies over the period of record (1958-2004). Wet weather samples were collected at select locations, primarily along the Santa Ana River. Figure 6 and Figure 7 present a summary of wet weather fecal coliform and E. coli data, respectively. The charts represent each sample result and the median of wet weather sampling performed at locations where more than one wet weather sample was collected. In almost all cases, median values at each of the locations may exceed objectives. The limited number of wet weather samples resulted in a small number of sites where the data could be compared to objectives.

When comparing available wet weather fecal coliform data to the 10% exceedence criteria (Figure 8), the data query shows similar results as to the all samples query, waterbodies heavily influenced by urbanization may exceed water quality objectives in all months sampled, with some exceptions in less urbanized areas.

When comparing available wet weather E. coli data to the 10% exceedence criteria (Figure 9), more locations have enough sampling to perform a comparison to objectives. Per this query, more locations may exceed proposed E. coli objectives in all months sampled as compared to fecal coliform data.

When comparing available wet weather fecal coliform data to the geometric mean criteria, there were no calendar months with five or more wet weather samples collected at any bacteria monitoring location within the available data.

When comparing available wet weather E. coli data to the geometric mean (Figure 10), five or more E. coli samples were collected during three wet weather events at the Santa Ana at Imperial Highway monitoring station. Proposed objectives were exceeded in each month. The pattern of bacteria results in relation to storm hydrographs is shown later in this technical memorandum, within the Detailed Study Site Characterization section.

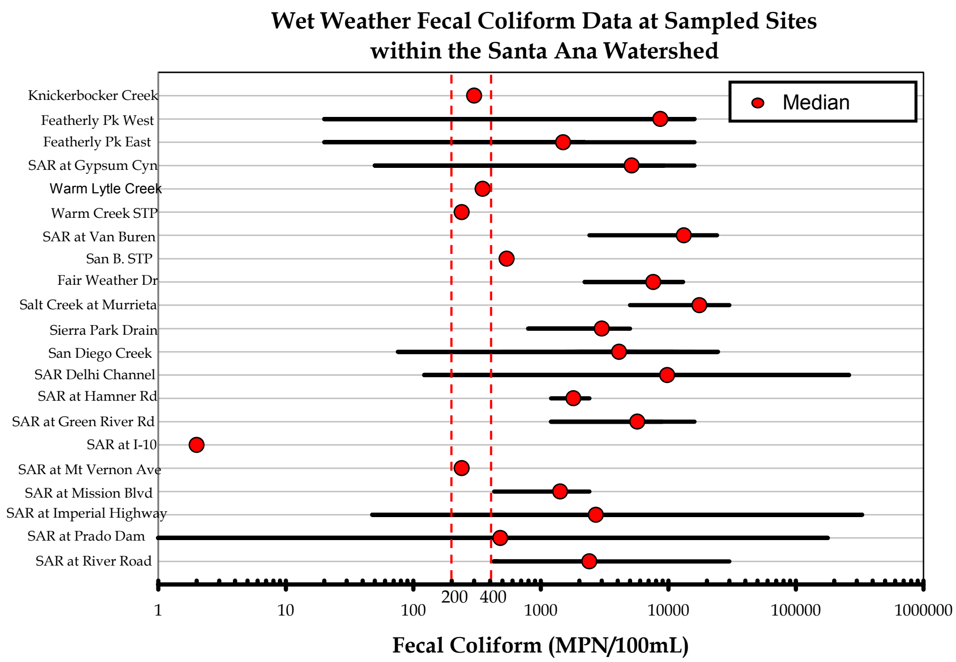

Figure 6
Fecal Coliform in Samples Collected During Wet Weather Days

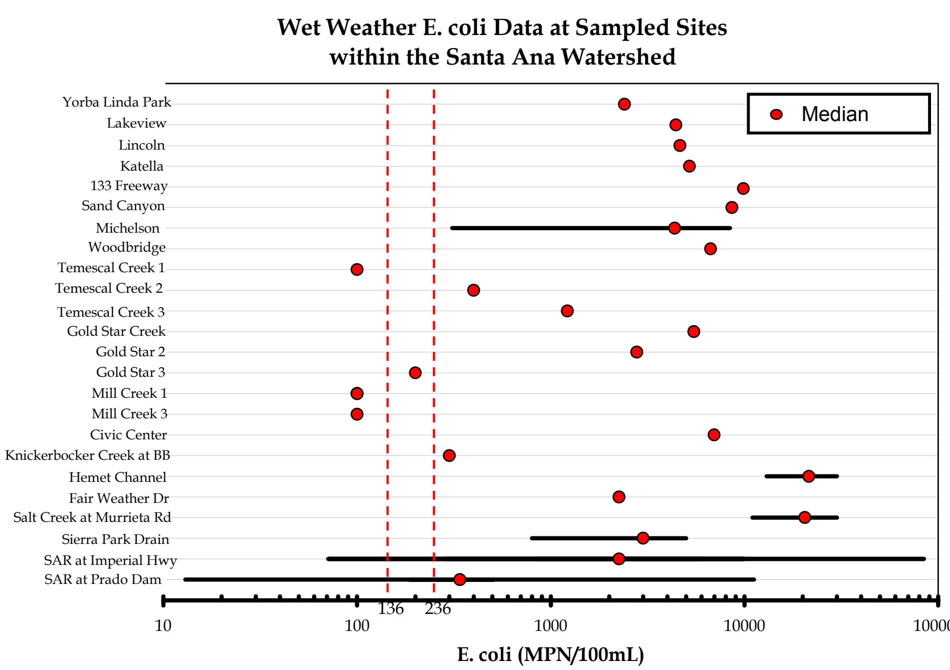

Figure 7
E. coli in Samples Collected During Wet Weather Days

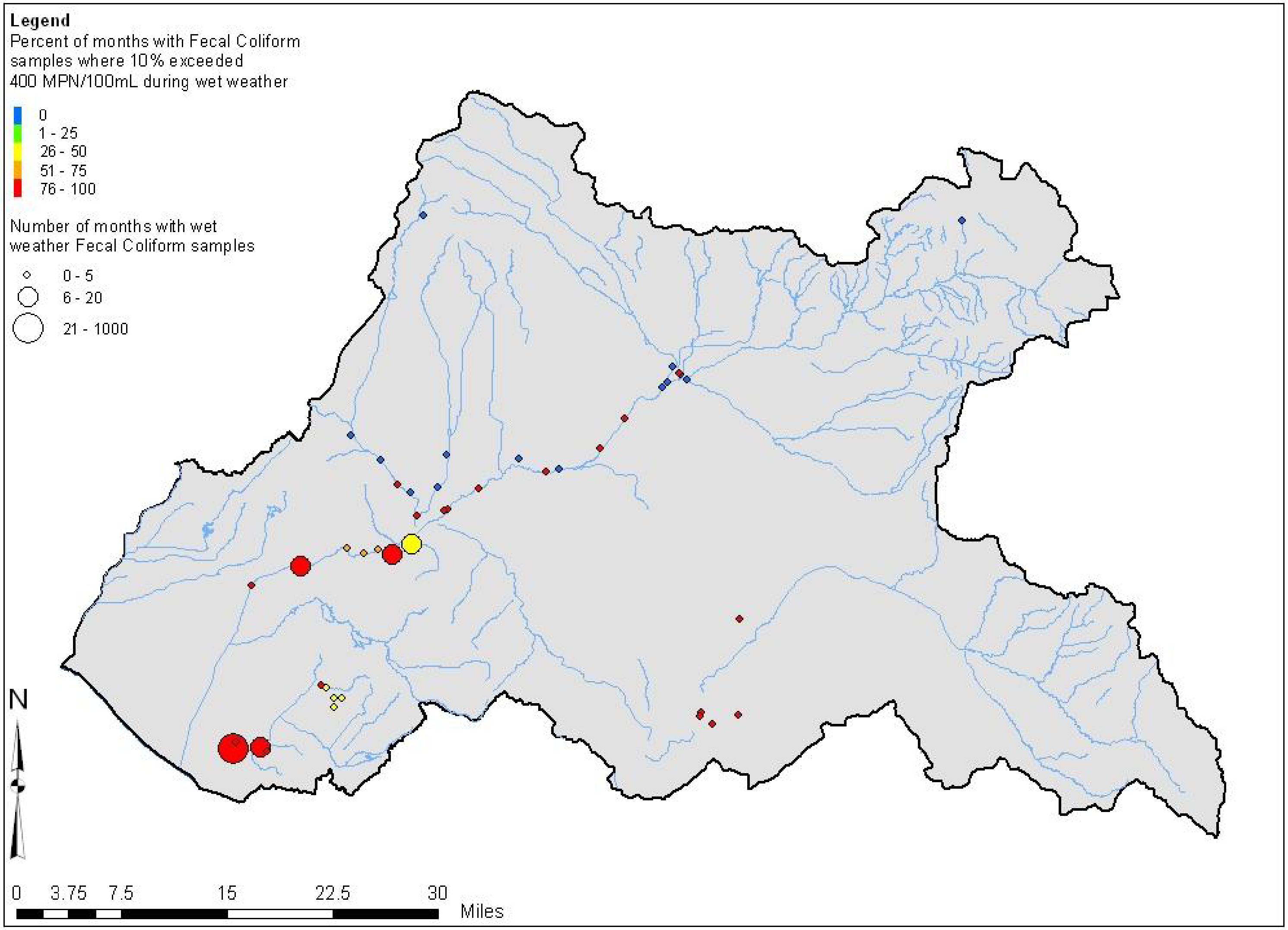

Figure 8
Fecal Coliform Analysis 10% of Samples Exceedence Criteria-Wet Weather

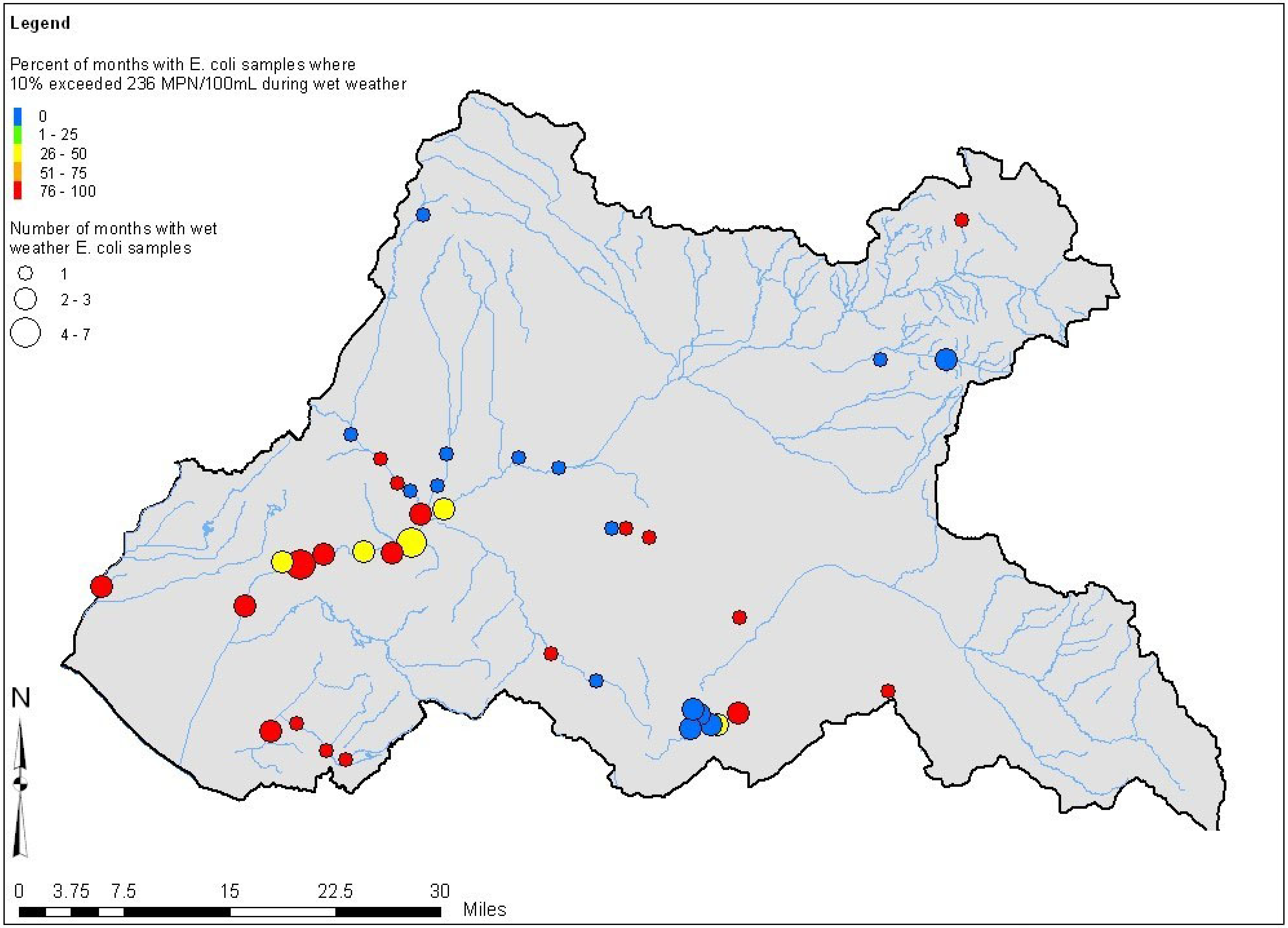

Figure 9
E. coli Analysis 10% of Samples Exceedence Criteria - Wet Weather

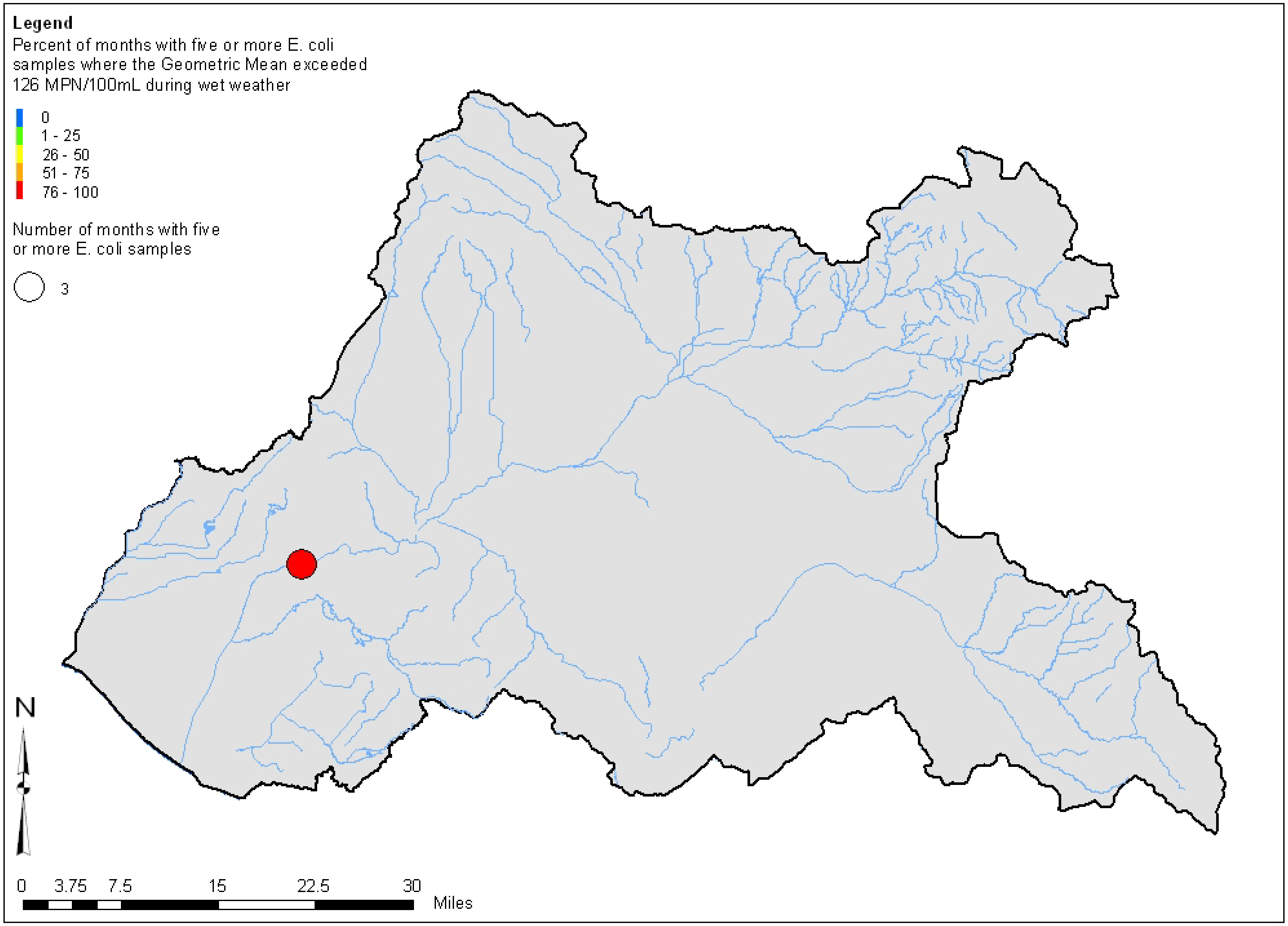

Figure 10
E. coli Analysis Geometric Mean Criteria - Wet Weather

Dry Weather

To analyze data from dry weather periods, the available sample database was divided into summer dry weather (April through November) and winter dry weather (December through March) periods based upon flow records. Figures 11 through 18 present the results from several dry weather data queries. As most available samples within the database were collected during dry weather periods, queries that compare only summer dry weather data to water quality objectives look very similar to comparisons of the entire database of sample results (Figures 11 through 14).

When comparing available winter dry weather fecal coliform data to the 10% exceedence criteria (Figure 15), the data query shows that comparatively more locations in urbanized areas may meet objectives during winter dry weather periods. More locations may meet the proposed 10% exceedence criteria for E. coli during winter dry weather periods as well (Figure 16).

When comparing available winter dry weather fecal coliform and E.coli data to the geometric mean exceedence criteria (Figures 17 & 18), query results follow the results found for all samples waterbodies heavily influenced by urbanization may exceed water quality objectives in all months sampled, and results from less urbanized areas may meet objectives, though the data set is limited.

Detailed Study Site Characterization

Data availability varies significantly among sample locations within the Santa Ana basin. As a consequence, performing a detailed characterization of water quality and waterbody conditions, and comparing the data with waterbody characteristics at every location where bacteria samples have been collected would be extremely resource intensive. As an alternative for study purposes, study sites were selected to serve as surrogates for different types of waterbodies. At each study site, site-specific water quality and site characteristics were documented to characterize recreational quality.

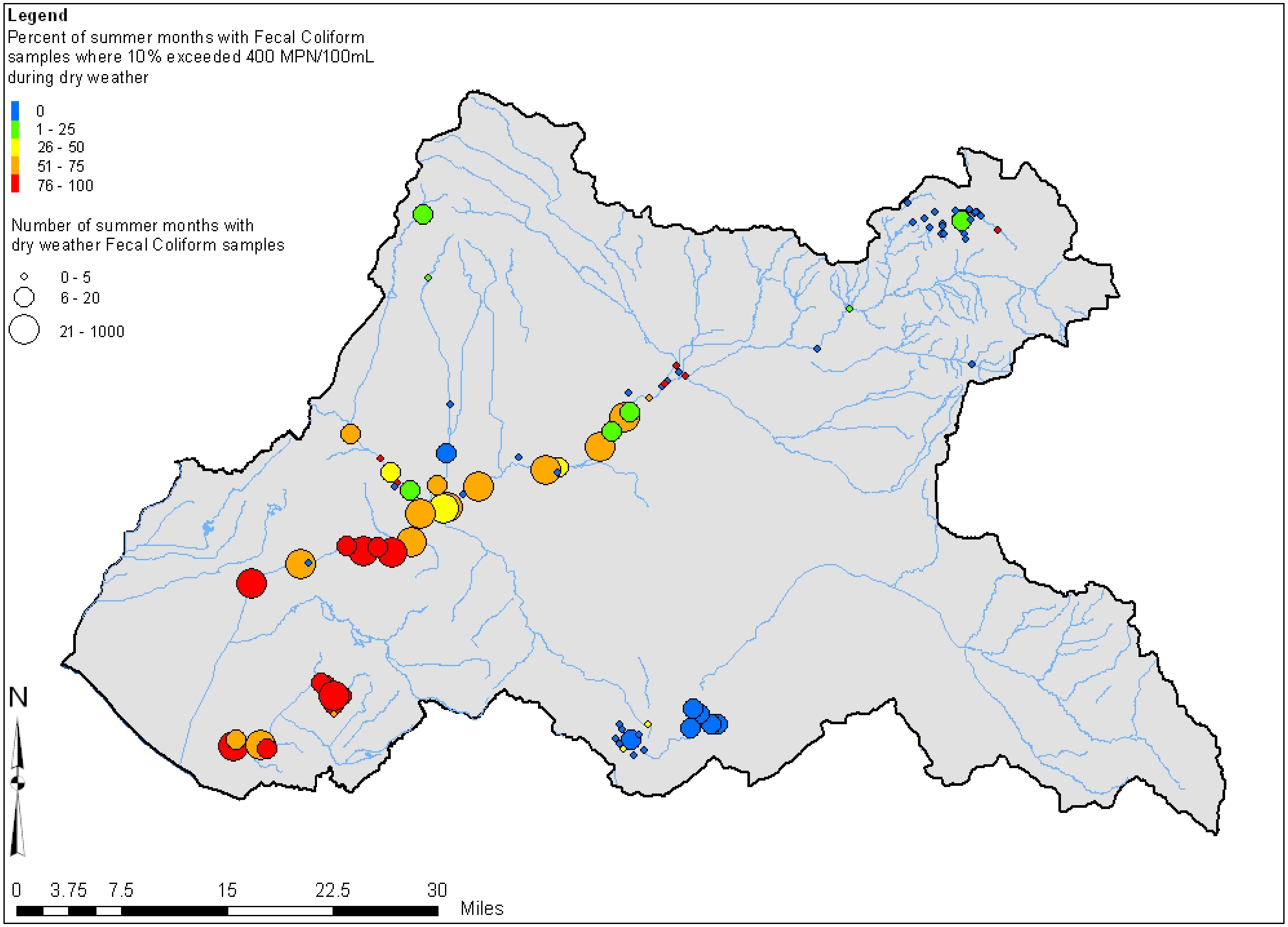

Figure 11
Fecal Coliform Analysis 10% of Samples Exceedence Criteria - Dry Weather – April through November

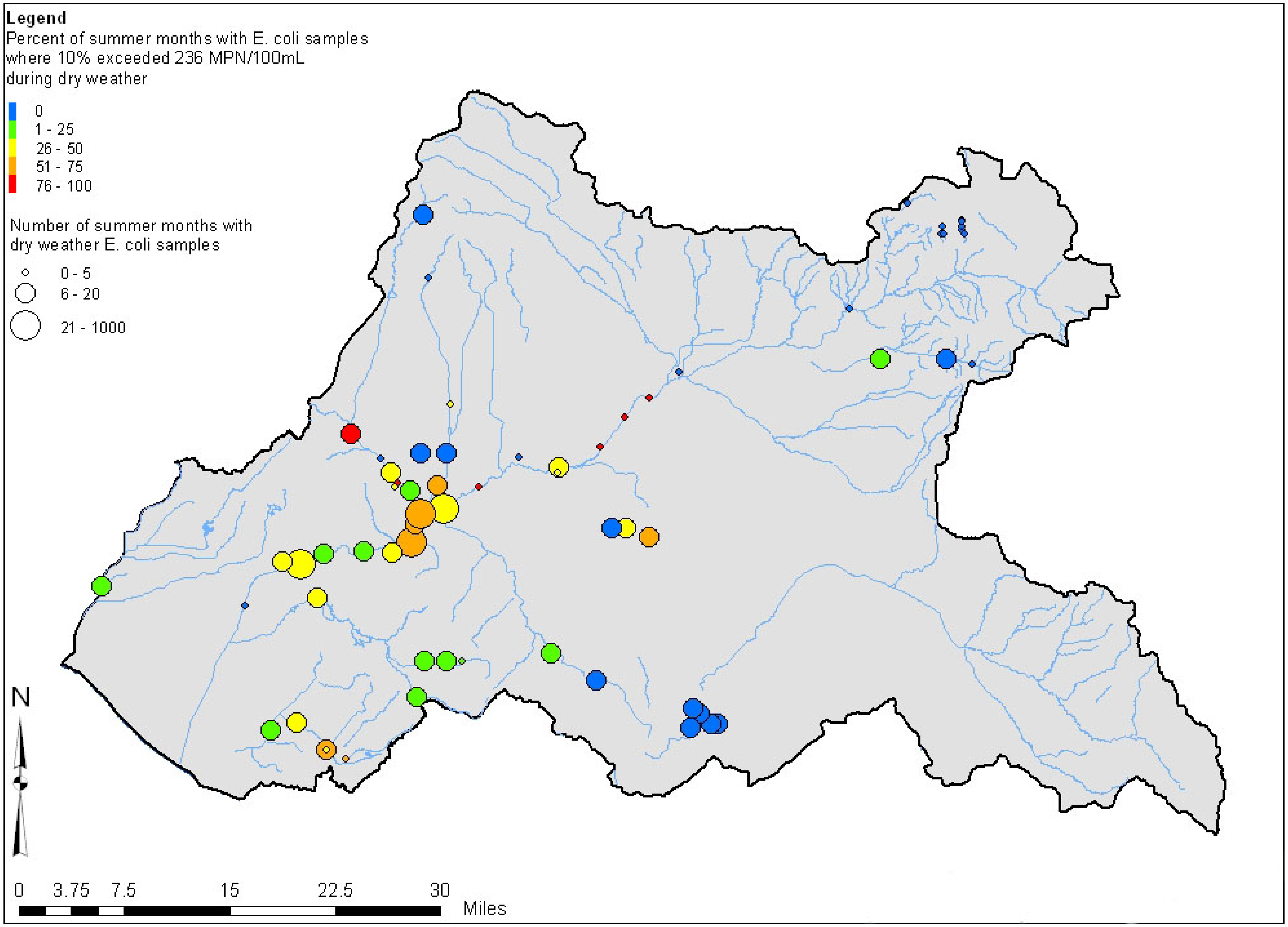

Figure 12
E. coli Analysis 10% of Samples Exceedence Criteria - Dry Weather – April through November

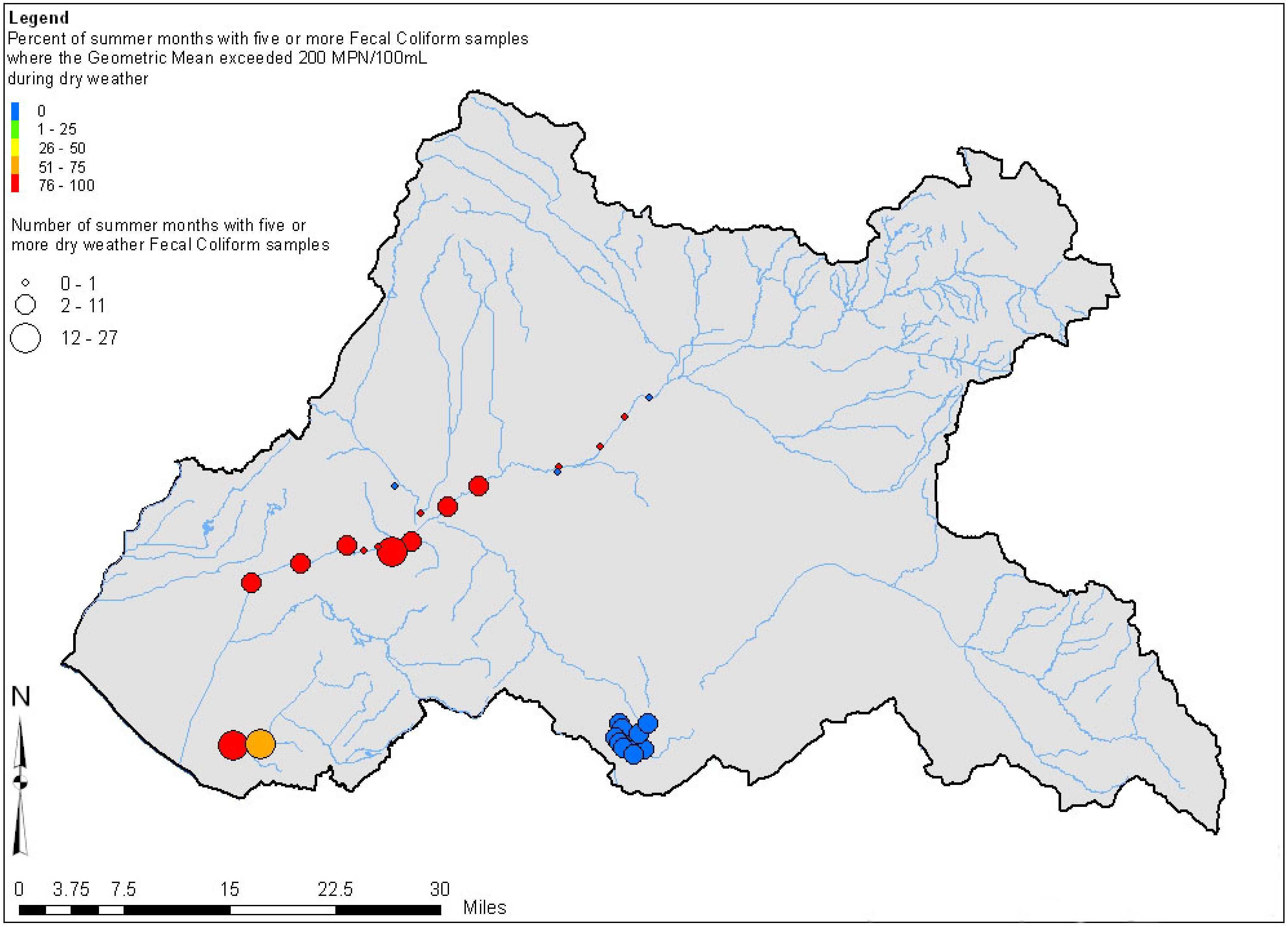

Figure 13
Fecal Coliform Analysis Geometric Mean Criteria - Dry Weather – April through November

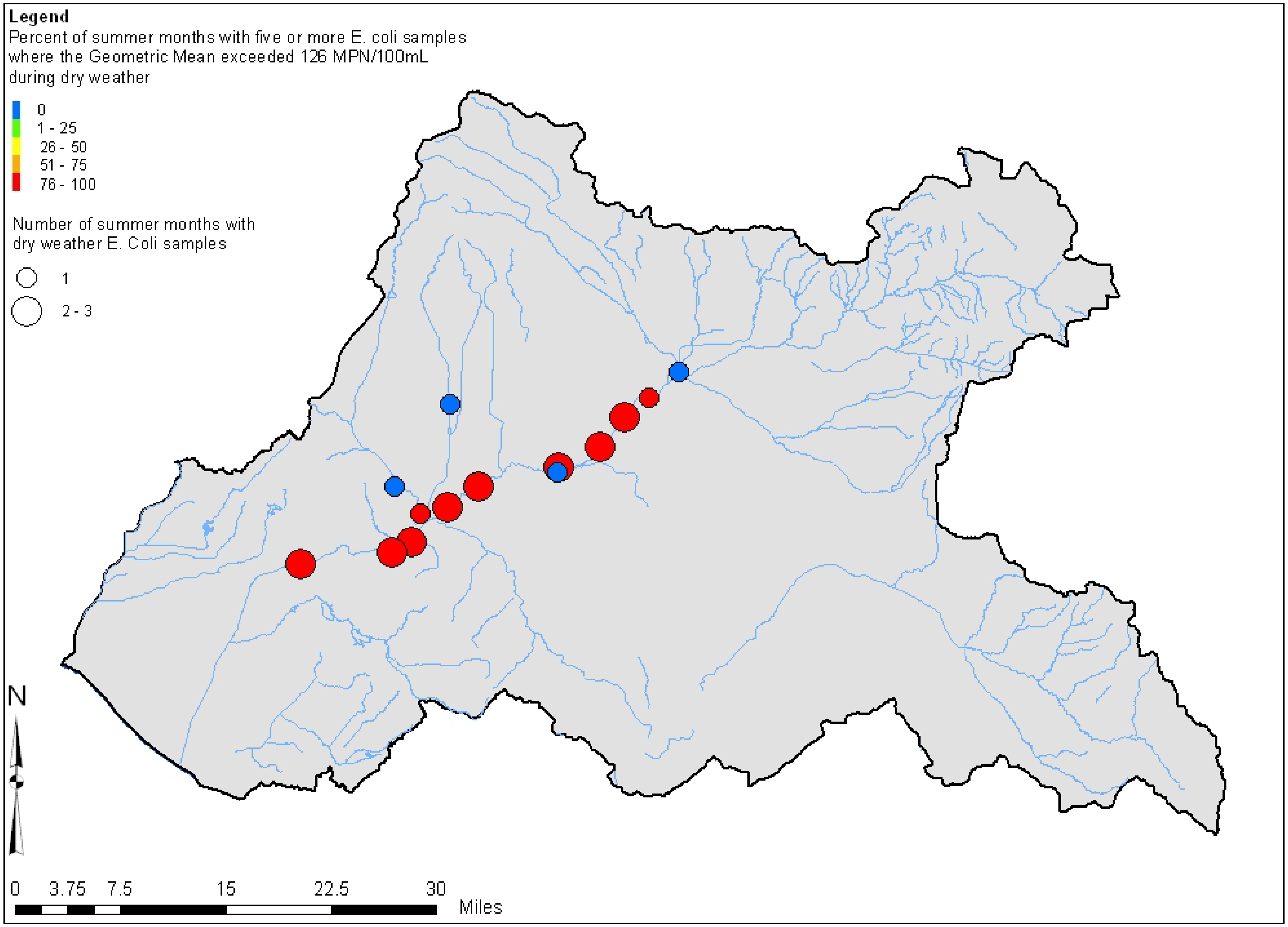

Figure 14
E. coli Analysis Geometric Mean Criteria - Dry Weather – April through November

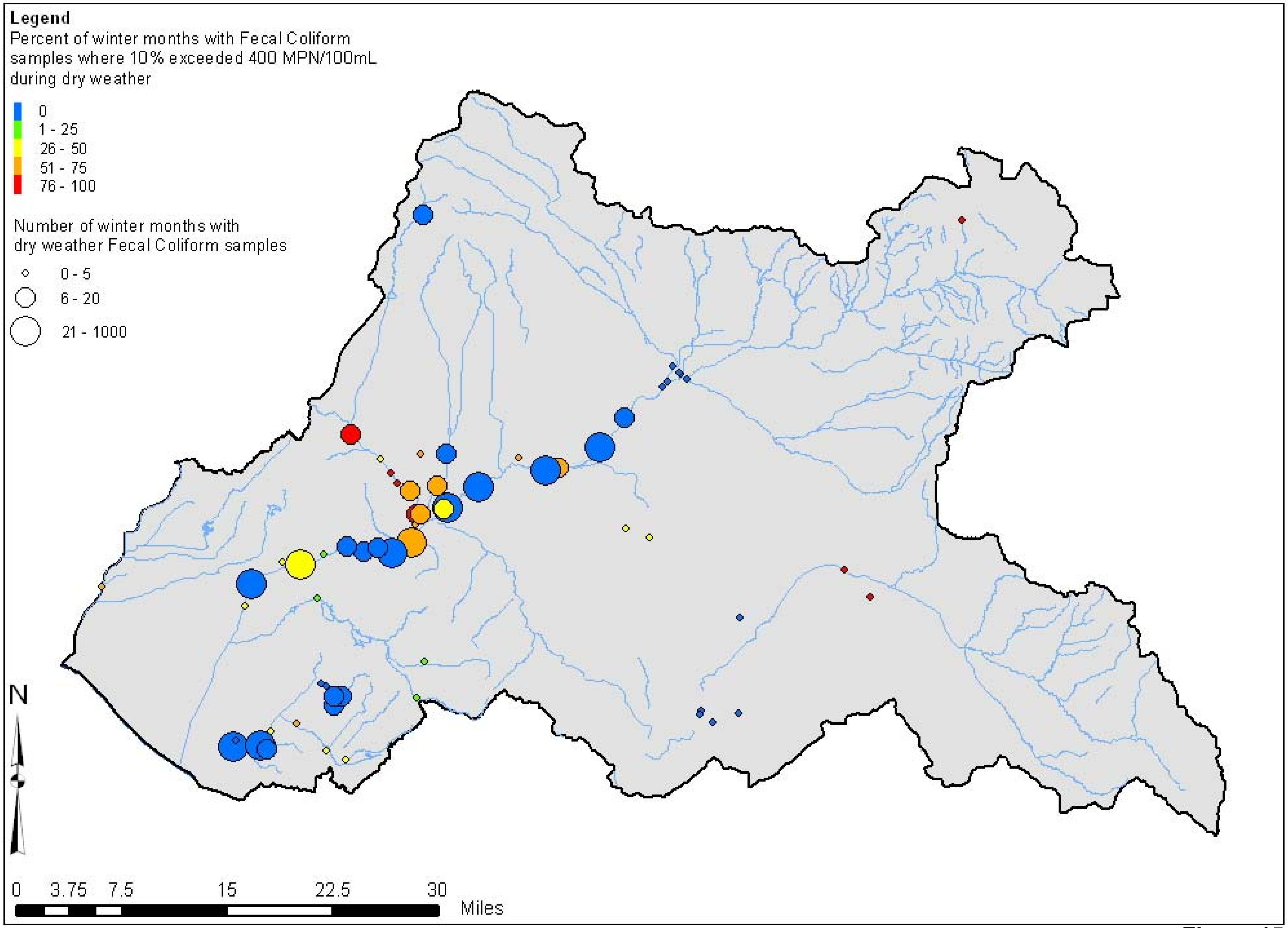

Figure 15
Fecal Coliform Analysis 10% of Samples Exceedence Criteria - Dry Weather – December through March

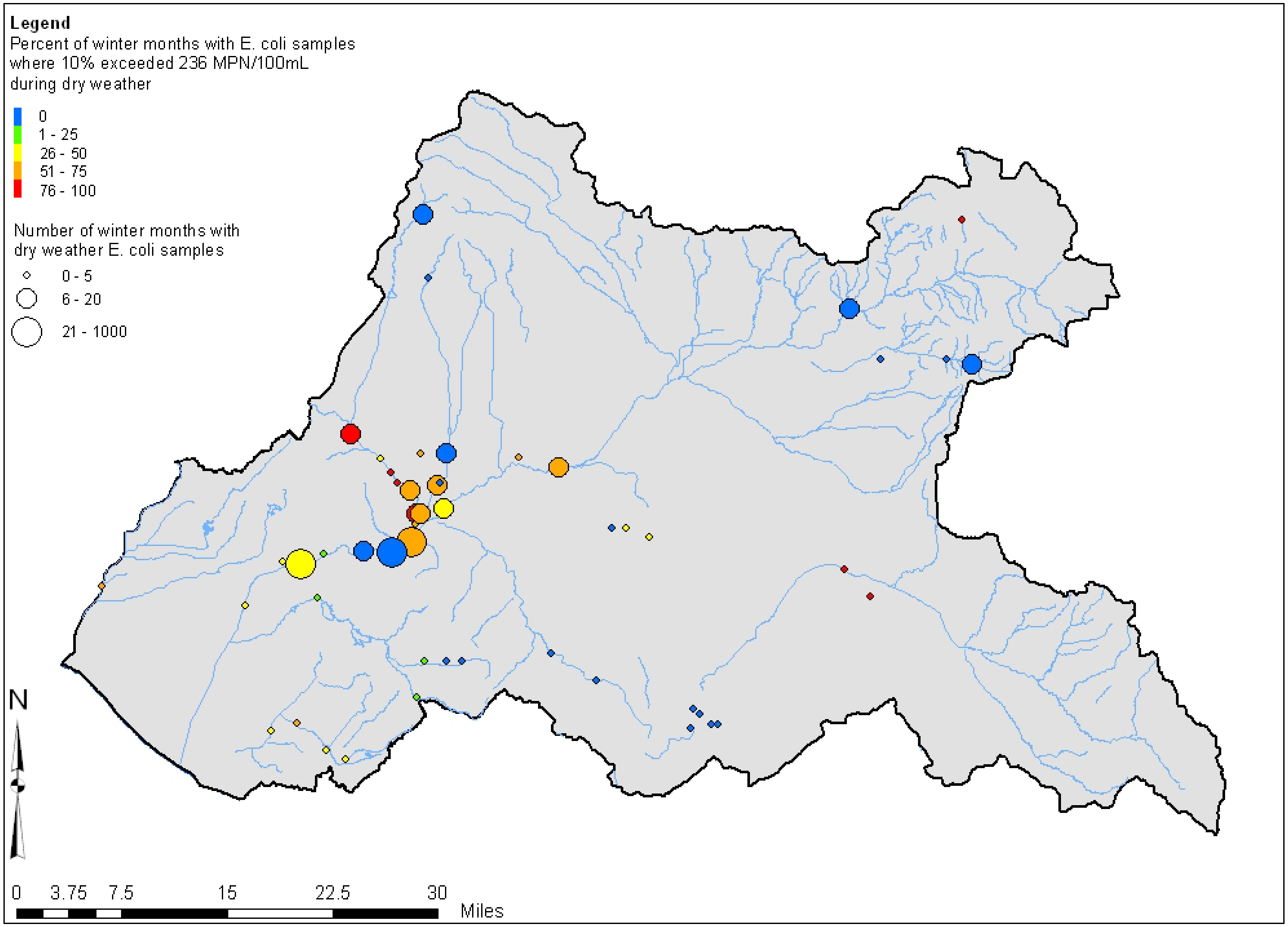

Figure 16
E. coli Analysis 10% of Samples Exceedence Criteria - Dry Weather – December through March

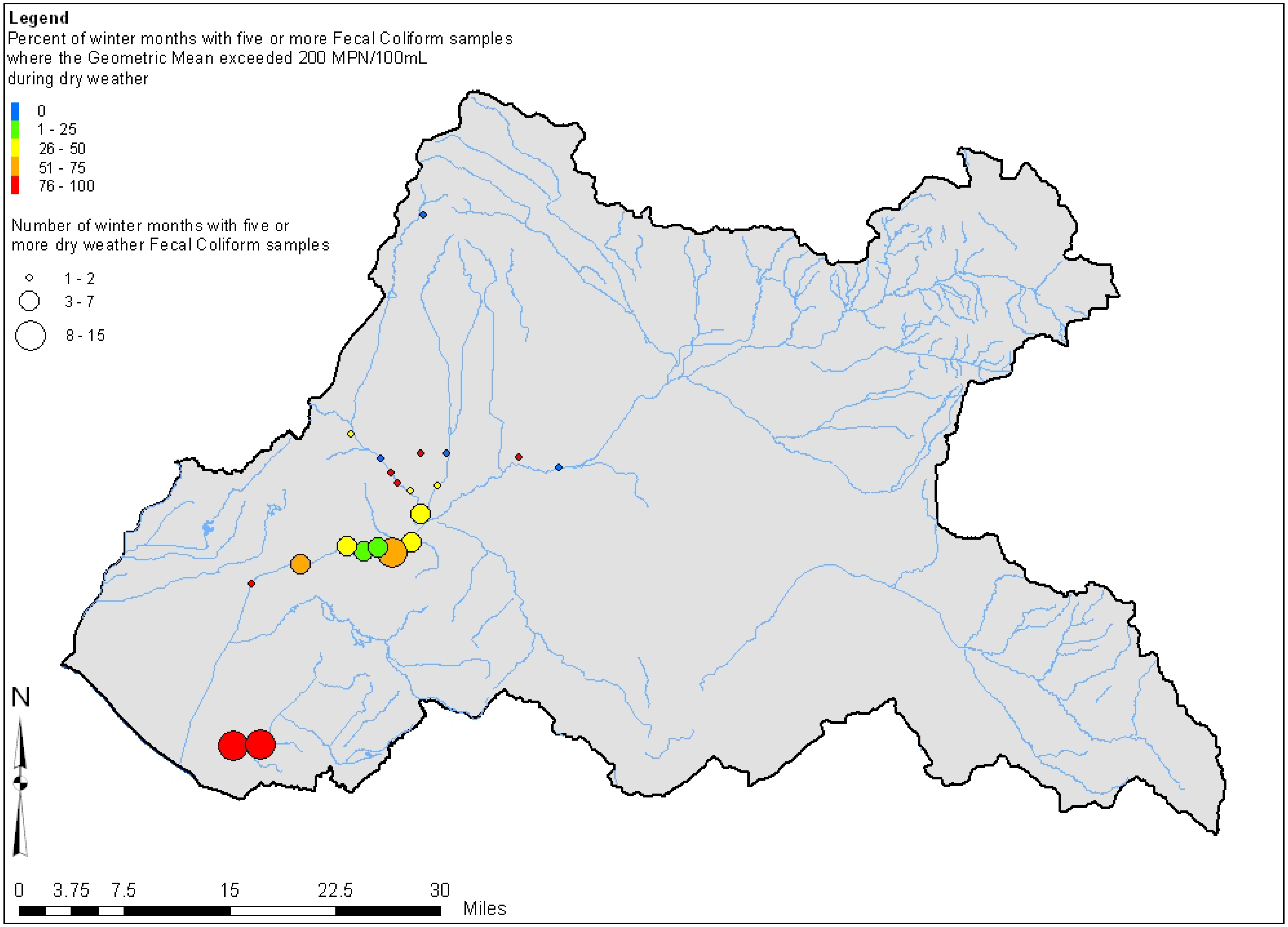

Figure 17
Fecal Coliform Analysis Geometric Mean Criteria - Dry Weather – December through March

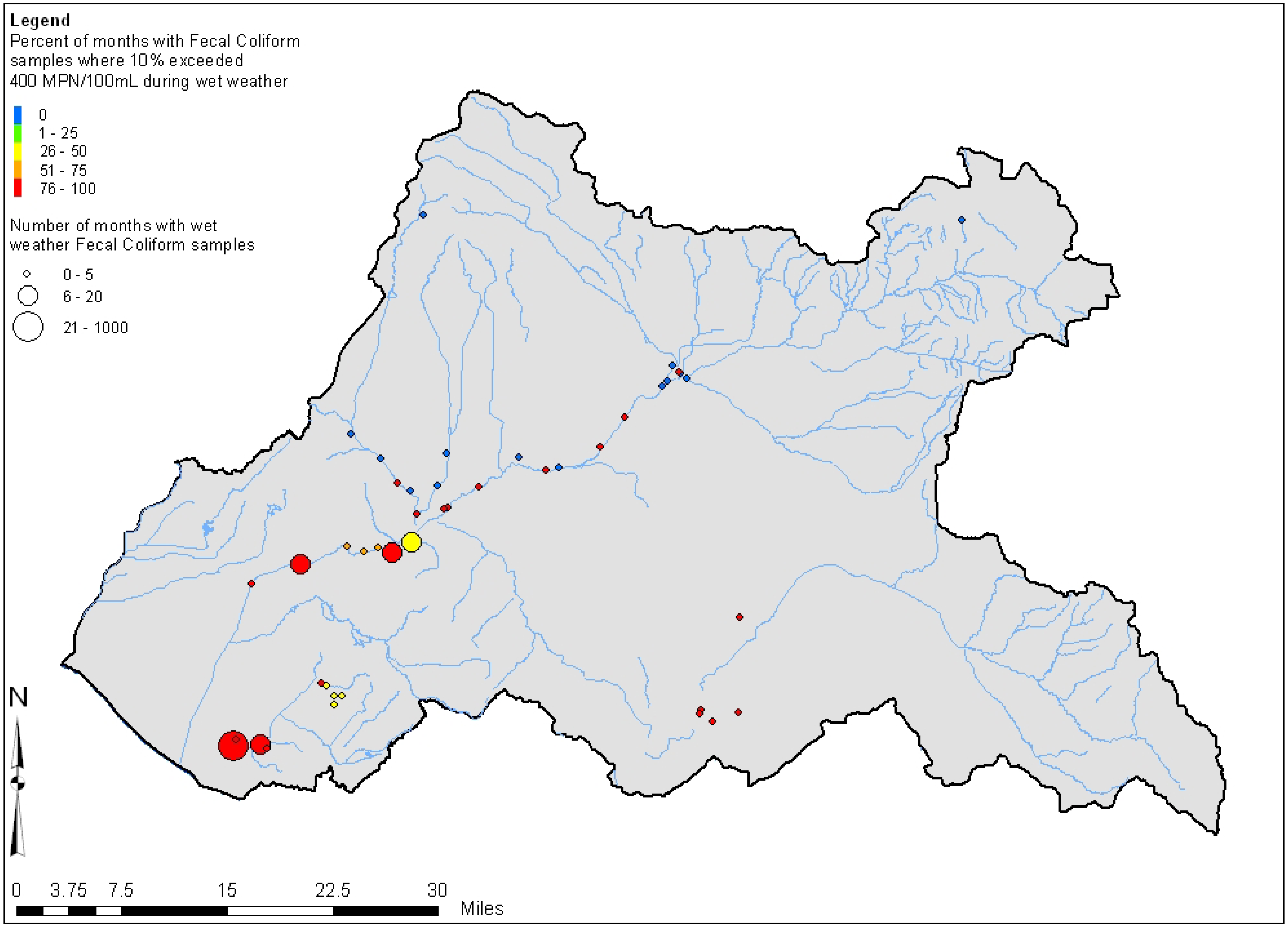

Figure 18
E. coli Analysis Geometric Mean Criteria - Dry Weather – December through March

Methods

Selection of Study Sites

Study sites were selected to facilitate detailed analysis of varying channel types and conditions in the Santa Ana basin, including natural channels, channels with both natural and modified portions (e.g., natural bottom, but concrete or rip-rap banks), and channels completely constructed with concrete. The availability of flow and bacteria data at the potential sites representing these various channel conditions was assessed. Based on this evaluation, the following five study sites were recommended to the Stormwater Standards Task Force:

- Chino Creek at Schaeffer Avenue (100% concrete channel in mixed land use area)
- Santa Ana Delhi Channel (100% concrete in highly urbanized area)
- Temescal Creek at Lincoln Avenue (mixed concrete/rip-rap; natural channel)
- Santa Ana River at Imperial Highway (mixed concrete/rip-rap; natural channel)
- Santa Ana River at MWD Crossing (natural channel in urbanized area)

The Task Force supported these recommendations, but also recommended the inclusion of Icehouse Canyon as a site to provide information at and above which no urbanization has occurred (Figure 19).

Channel and Stream Attributes

Attributes of channels at each study site were identified by reviewing collected GIS layers and verifying this information during field visits. Lack of published data for channel dimensions along the Santa Ana River at some study sites led to the use of high resolution aerial photography or distance meters to estimate channel widths. Channel slopes at study sites more estimated in the field to estimate cross-sectional area. In generally natural reaches, where the channel was wide, the channel slope did not significantly impact cross sectional area

Channel attributes that could affect recreational appeal were evaluated for each of the study sites. Photographs were taken of direct and indirect evidence of recreational use and of conditions that could affect recreational use. These study site attributes were summarized in a checklist, prepared by Risk Sciences, Inc, discussed within Technical Memorandum 2

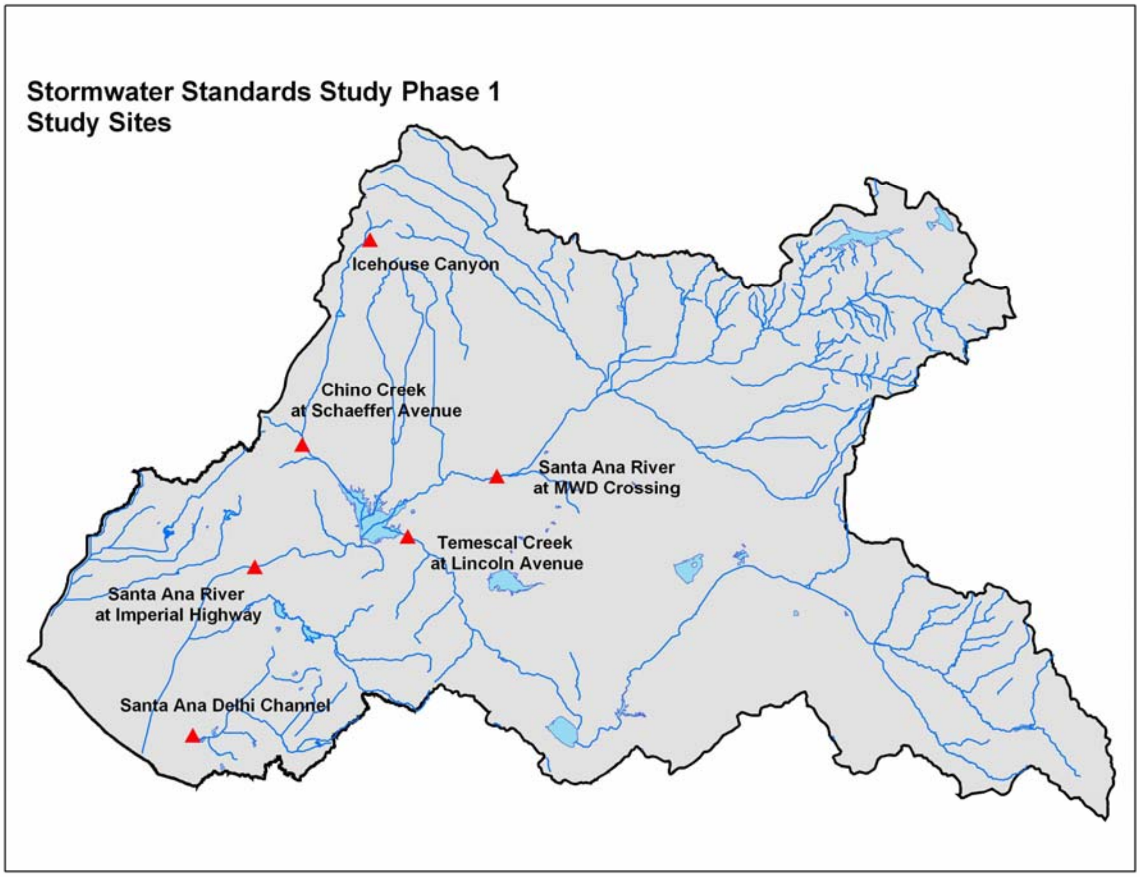

Figure 19
Study Sites Selected for Detailed Analysis

Drainage Area Characteristics & Land Use

To characterize land use adjacent to and in the tributary watershed to the study sites, the drainage areas of three study sites were determined using a digital elevation model (DEM) of the Santa Ana basin provided by SAWPA. Arc Hydro, a tool created for ESRI ArcGIS 8.3® documented in Maidment [2002], was used to delineate the drainage area of each study site. This tool "burns" the section of channel onto the DEM and through a series of pre- and post-conditioning processes, determines cells, i.e., small areas that will drain to the reach based solely upon topography. In urbanized areas where drainage network information was available, flow path alterations resulting from urban development were accounted for by manually editing the Arc Hydro derived polygons.

Following drainage area delineation, land use layers of the Santa Ana basin from 1990, 1993, and 2000 provided by Southern California Area Governments (SCAG) were clipped to the watershed areas. The attributes of the clipped land use layers were summarized to create land use distributions.

Recreational Appeal

The recreational appeal of each study site was evaluated with a field observation checklist prepared by Risk Sciences, Inc, discussed within Technical Memorandum 2. This checklist evaluates factors that may influence the potential for a site to be used for recreational activity. All criteria were ranked from 0 (poor recreational habitat and/or appeal) to 3 (good recreational habitat and/or appeal):

- Direct Evidence of Water Contact Recreation – Direct observations of people recreating in the water (0 = no observation; 3 = people actually in the water).
- Indirect Evidence of Recreational Activity – Measures evidence that people are occasionally present at the site, e.g., graffiti, recreational trash (beer bottles, sodas, etc), fishing line, and human paths to the channel; however, no evidence exists that visitors actually enter the water (0 = no evidence of recreational activity; 3 = evidence observed, e.g., fishing line, footprints, graffiti).
- Ease of Access – Measure of degree of difficulty to access the waterbody because of fencing, gates, locks, etc. (0 = inaccessible; 3 = easily accessible).
- Channel Slope – Measure of the type of slope, e.g., trapezoidal vs. rectangular (0 = box channel, 90° slopes; 3 = gentle slope)
- Channel Type – Measure of degree of naturalness, ranging from completely natural bottom and banks to completely constructed concrete channel (0 = bottom and banks are concrete; 3 = natural bank and channel bottom).
- Flow Depth & Volume – Measure of the degree that instream flow is sufficient for water contact recreation, including consideration of children (0 = minimal flow, not possible for adults or children to immerse themselves in the water; 3 = sufficient flow for immersion at least by children).
- Flow Velocity – Measure of the degree that flow velocity is dangerous for recreational activity (0 = high velocity, flow is dangerous; 3 = velocity is safe for recreational activity).
- Water Quality (Aesthetics) – Measure of how appealing the water is for recreation (0 = poor quality, e.g., lots of algae, trash; 3 = very appealing, water is an attractant).

- Vegetation Quality – Measure of quality of bank habitat for recreational activity (0 = no cover or shade for visitors; 3 = sufficient cover or shade).
- Adjacent Land Use – Measure of type of nearby land use (0 = site is adjacent to industrial parks; 3 = site is in a residential area).

Flow Data

Available flow data at each study site were collected and processed to facilitate time series plotting and frequency distribution analyses. In general, the collected data included mean daily flow for the entire period of record and, where appropriate, 15 or 30 minute interval flow data for a subset of the data record. Observations of the flow record at each site led to more detailed investigation of the sources of flow. Frequency distributions of flow rates, depths, and velocities were generated at each study site to assess the likelihood of the occurrence of certain flow conditions within the channel. The smaller interval of measurements relative to mean daily flow provided a more accurate analysis of instantaneous flow in the channel.

The Stormwater Standards Task Force is evaluating the appropriateness of establishing a high flow suspension of REC-1 water quality standards when the beneficial use is not attainable due to dangerous flow conditions. To identify potentially dangerous flow conditions at each site, two criteria, which have been used to define flow conditions where recreational activities are dangerous, were evaluated: (1) flow velocities greater than 8 ft/sec [Helsinki University of Technology, "The Use of Physical Models in Dam-Break Flood Analysis", RESCDAM, 2000]; and (2) a 10 ft^2/sec threshold depth-velocity product, above which wading is considered unsafe [USGS, Book 9 of the National Field Manual for the Collection of Water Quality Data, 2004]. Cumulative frequency curves of flow velocities and depth-velocity products were generated at each study site to determine the likelihood of occurrence of these potentially dangerous flow conditions.

Bacteria Data

Bacteria data collected at each of the study sites differed with regard to the length of record, frequency of sampling, constituents that were measured, and availability of concurrent flow data. Consequently, analyses of bacteria data were tailored as needed for each study site based on data availability. In general, the following methods were applied to when bacteria data were available:

- Time series plots of bacteria counts and flow were generated for the entire period of record at each study site to illustrate the relationship between bacteria concentrations and REC-1 standards and to identify any general trends. Where appropriate, these time series plots were related to flow data to evaluate the relationship between bacteria concentrations and wet or dry weather.

- Evaluation of changes in bacteria concentrations over the course of a specific storm.

- Bivariate plots of fecal coliform and E. coli were created for each study site to evaluate the relationship between bacteria types.

- Analysis of compliance with existing REC-1 fecal coliform water quality objectives and potential E. coli water quality objectives based on draft EPA guidance [USEPA, Implementation Guidance for Ambient Water Quality Criteria for Bacteria, November 2003 Draft]:

  - Fecal coliform: log or geometric 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

  - E.coli: log or geometric mean less than 126 organisms/100 mL based on five or more samples/30 day period, and a single sample maximum of 235 organisms/100 mL.

Bacteria concentrations under both dry and wet weather conditions were analyzed. Wet weather conditions were determined according to the method described previously within this memorandum. For this analysis, calendar months were used as a surrogate for the rolling 30-day period that is part of the existing fecal coliform water quality objectives. Thus, geometric means were calculated for calendar months in which there were 5 or more samples, and the 10% exceedance threshold was calculated on samples collected during a single calendar month.

Results

Chino Creek at Schaeffer Avenue

Channel Section

The Chino Creek at Schaeffer Avenue study site is located where California State Route 71 crosses Chino Creek (Figure 20 and Figure 21). The study reach consists of a trapezoidal concrete-lined channel with 2.25:1 side slopes and a bottom width of 60 feet. The bed slope of the channel at this site is 3 percent. Flow is recorded in this section of Chino Creek by the US Geological Survey [USGS Gage 11073360] (Figure 22).

Figure 20
Aerial Photograph of the Chino Creek at Schaeffer Avenue Study Site

Figure 21
Chino Creek Looking Upstream from USGS Flow Gage

Figure 22
USGS Flow Gage for the Chino Creek at Schaeffer Avenue Study Site

Drainage Area Characteristics

Land use in this watershed is predominantly residential, natural/vacant land, and commercial (Figure 23**)**. A portion of the drainage area, which lies upstream of San Antonio Dam, is comprised almost entirely of natural/vacant land in the San Gabriel Mountains. The drainage area below the dam is a mixed land use region which is primarily residential. Growth in residential and commercial land use in the area was observed between the years 1990 and 2000; however these changes have been minor (Figure 24). Runoff from the mountains that reaches the San Antonio Dam is diverted into the San Antonio Spreading Grounds (SASG) for recharge of the Six Basin Groundwater Management Area. The Pomona Valley Protective Association, owner of the SASG, spreads most of the runoff from above the dam during years with average runoff and the majority of flows from above average rainfall years. Occasional bypass of the spreading grounds, which routes excess runoff to San Antonio Creek, a major tributary of Chino Creek, occurs in high rainfall years. If the natural/vacant land upstream of San Antonio Dam is excluded from the analysis, residential is the primary land use in the primary contributing watershed to the Chino Creek at Schaeffer Avenue site (Figure 25**).**

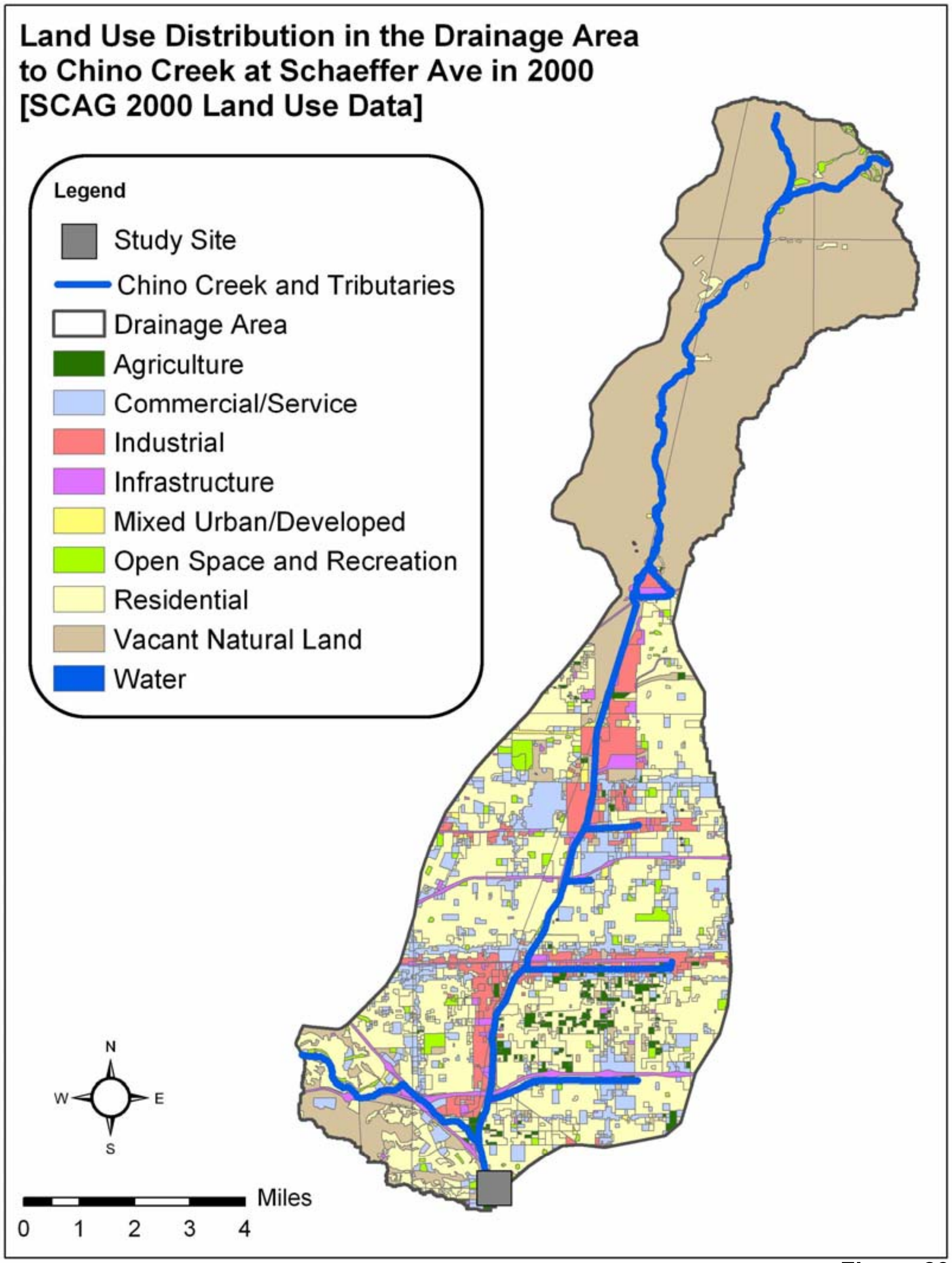

Figure 23
Land Use within Drainage Area to Chino Creek at Schaeffer Avenue Study Site

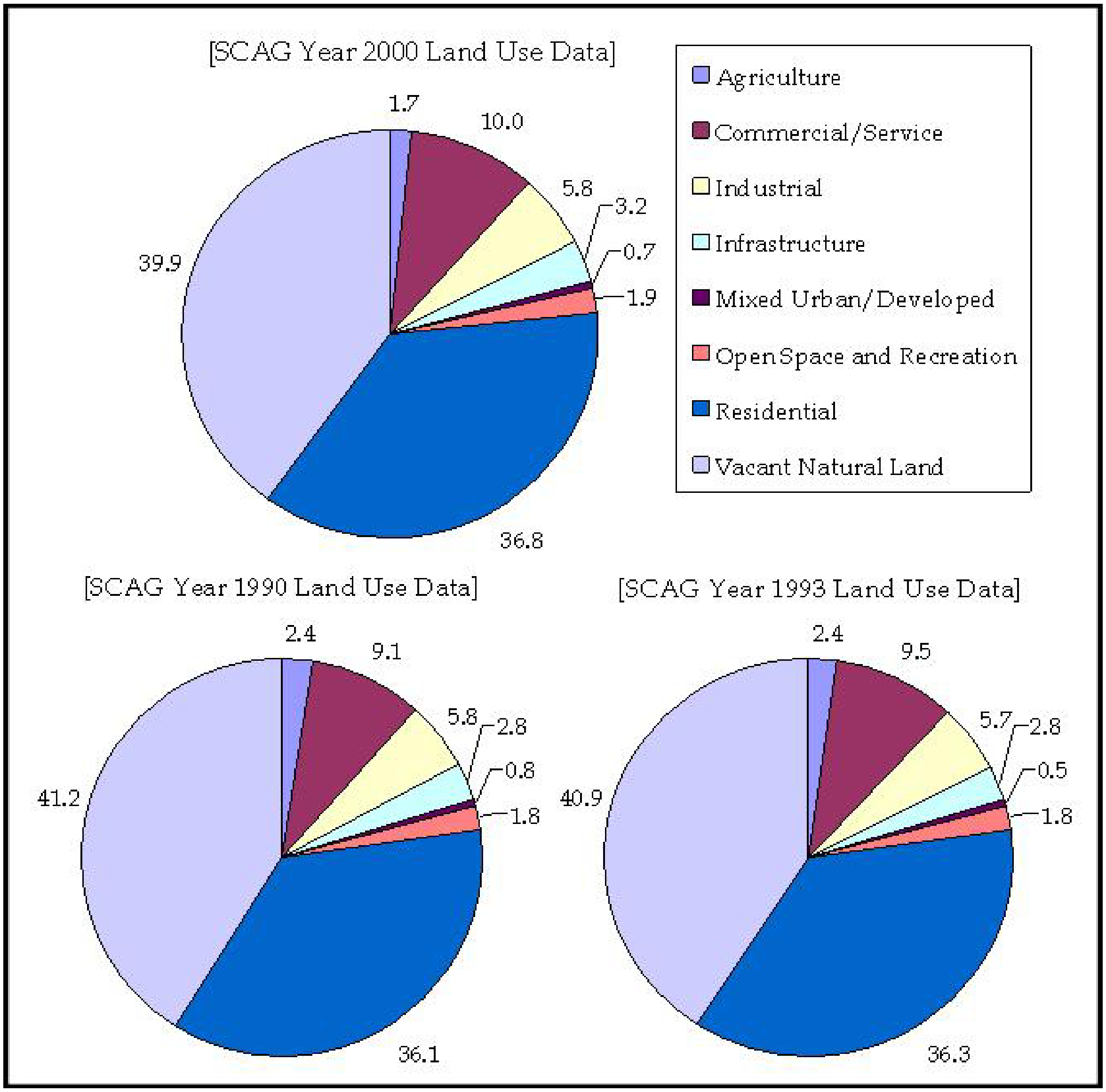

Figure 24
Relative Distribution (%) of Land Use Types in Chino Creek at Schaeffer Avenue Watershed, 1990, 1993, and 2000

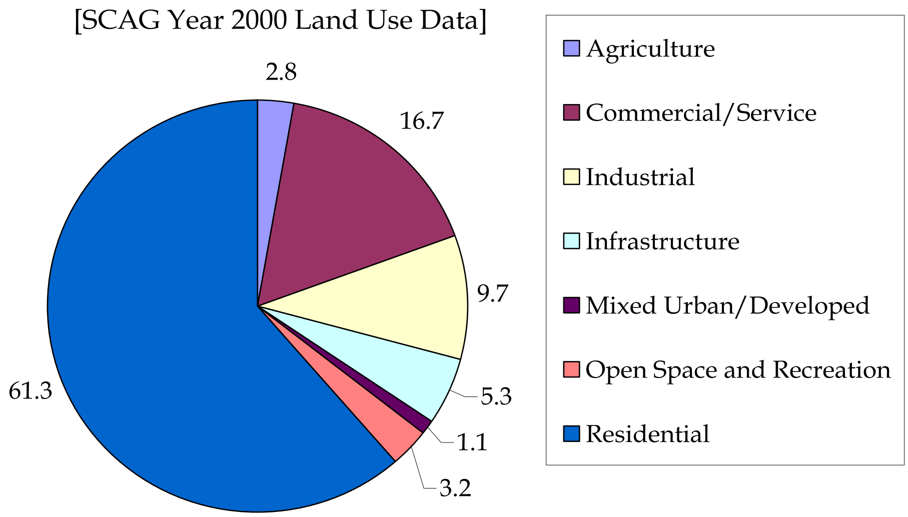

Figure 25
Relevant Distribution (%) of Land Use Types in Chino Creek at Schaeffer Avenue Watershed, Downstream of San Antonio Dam

Evidence of Recreational Activity

During the CDM site visit, the channel access gate was unlocked allowing easy access to the water. The gentle side slope of the channel would enable visitors to easily walk to the stream; and in fact the presence of graffiti and trash provided evidence that people had recently accessed this section of Chino Creek (Figure 26). This section of Chino Creek is located within a highly developed area of the city of Chino, with State Route 71 on the left bank and a shopping plaza on the right bank (Figure 27). With regards to the sites recreational appeal, the site generally received low scores (Figure 28).

Figure 26
Graffiti in bottom of Chino Creek

Figure 27
Surrounding area along Chino Creek near the Schaeffer Avenue Study Site

Evaluation Criteria (Scale = Low - 0 to High - 3)	Chino Creek at Schaeffer Avenue
Direct Evidence of Water Contact Recreation	0
Indirect Evidence of Recreational Activity	1
Ease of Access	1
Channel Slope	2
Concrete to Natural	0
Flow Depth and Volume	0
Flow Velocity	1
Water Quality Aesthetics	0
Vegetation Quality	1
Adjacent Land Use	0

Figure 28
Field Observation Checklist for the Chino Creek at Schaeffer Avenue Study Site

Flow

The USGS mean daily flow record from 1969 through 2004 was used to plot a time series of flow at this site and to compare flow in the channel to other measured parameters, including rainfall and bacteria (Figure 29). Flow in Chino Creek is primarily urban dry weather. As observed, the channel experiences predominantly low flows much of the year, typically averaging about 5 cfs, and periodic elevated flow typically correlated with rainfall event runoff.

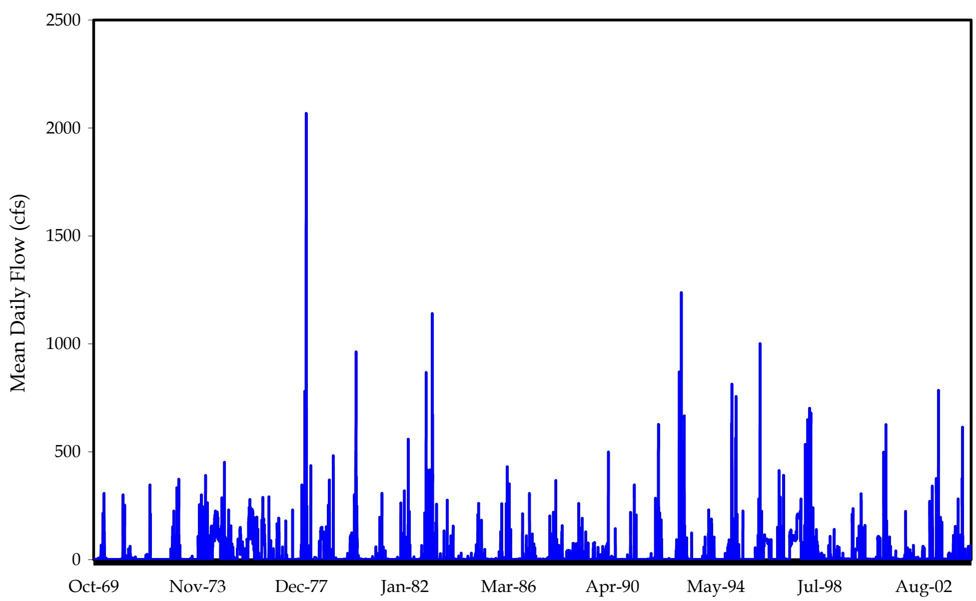

Figure 29
Mean Daily Flow in Chino Creek at Schaeffer Avenue between 1969 and 2004

However several instances of elevated flow occur without a corresponding rainfall event. During such periods, measured flow is elevated from typical dry weather baseflow (1 to 5 cfs) by one order of magnitude for about 30 days. Consultation with Orange County Water District (OCWD) indicated that these prolonged non-rainfall high flow events are the result of a water purchase from the State Water Project (SWP) or conveyed via Chino Creek to increase groundwater recharge downstream of Prado Dam in Orange County. A subset of the mean daily flow record provides an example of one of these water purchase events in August 2002 (Figure 30).

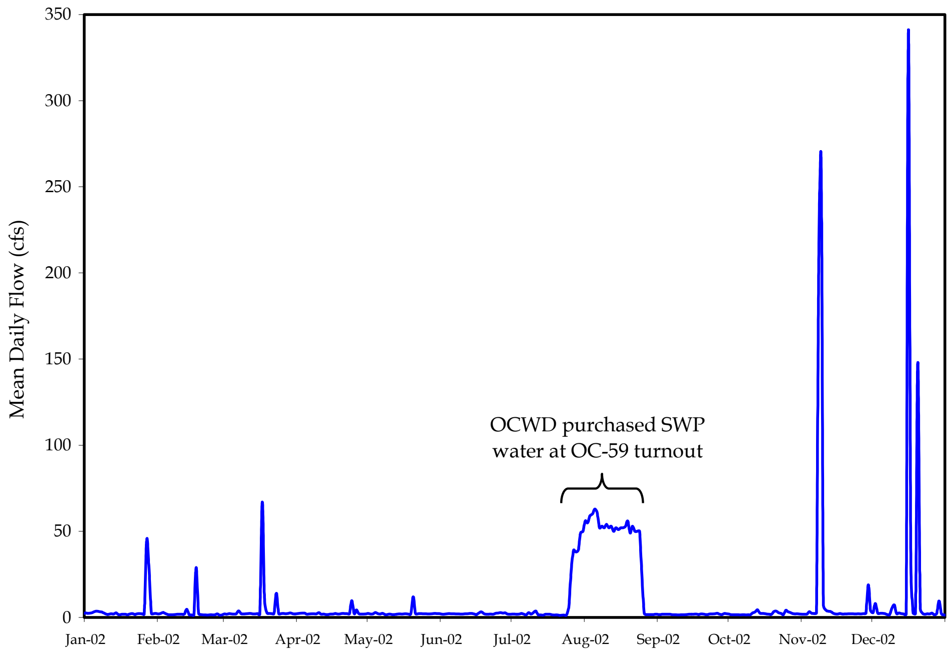

Figure 30
Mean Daily Flow in Chino Creek at Schaeffer Avenue during 2002

Flow data was recorded in 15 minute intervals by the USGS in Chino Creek at Schaeffer Avenue between 1988 and 2004. These data were used to develop a frequency distribution of flow rate and depth in the channel (Figure 31 and Figure 32), as well as flow velocity and the depth-velocity product. Both Figures 31 & 32 provide an illustration of the complete distribution, and the top 10th percentile of flow rate and depth.

To estimate the frequency of potentially dangerous flows at this site, cumulative frequency curves of flow velocities and depth-velocity products were developed. Figure 33 shows that an 8 ft/sec velocity is exceeded about 2.5% of the time, and Figure 34 shows that the depth-velocity product exceeds 10 ft^2/sec about 0.5% of the time.

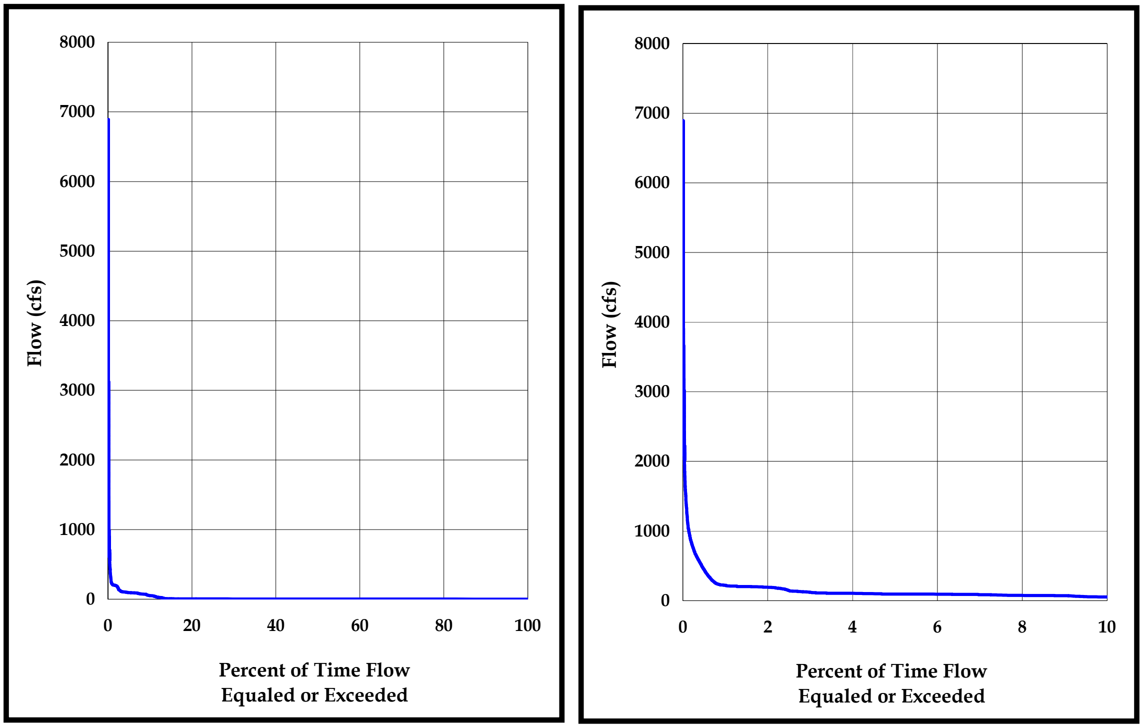

Figure 31
Channel Flow Curves for Chino Creek at Schaeffer Avenue (1988 – 2004)

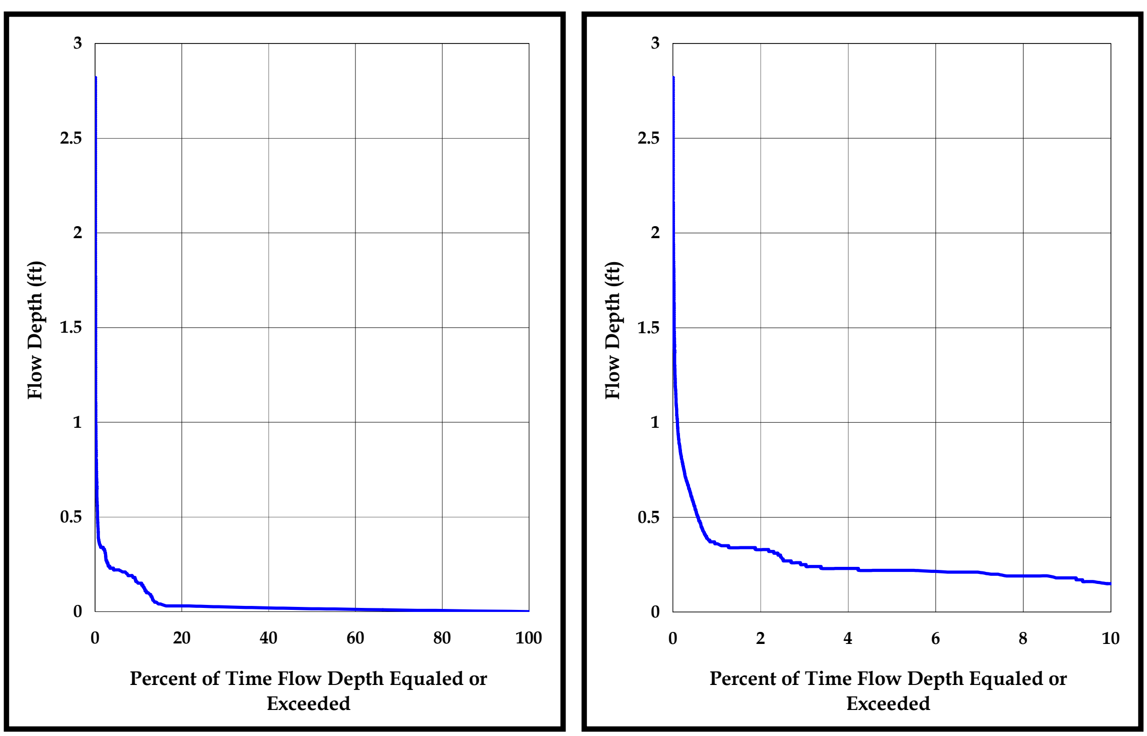

Figure 32
Channel Depth Curve for Chino Creek at Schaeffer Avenue (1988 – 2004)

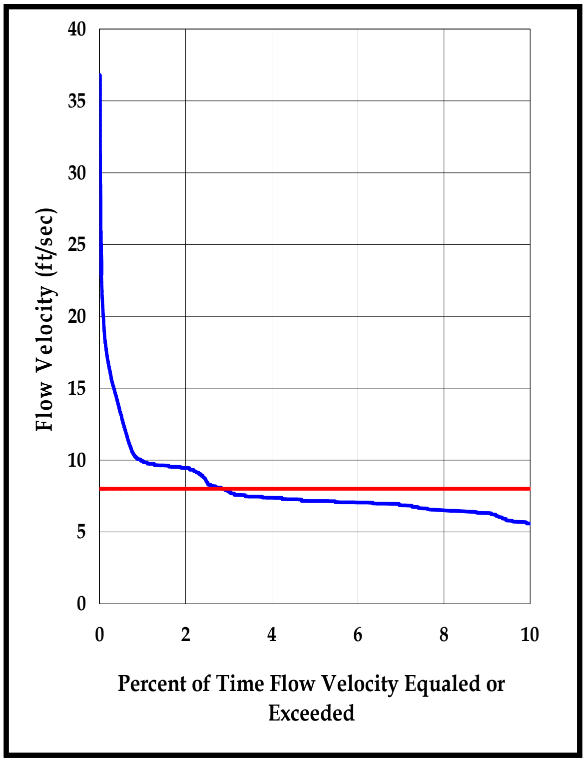

Figure 33
Channel Velocity Curve for Chino Creek at Schaeffer Ave (1988-2004)

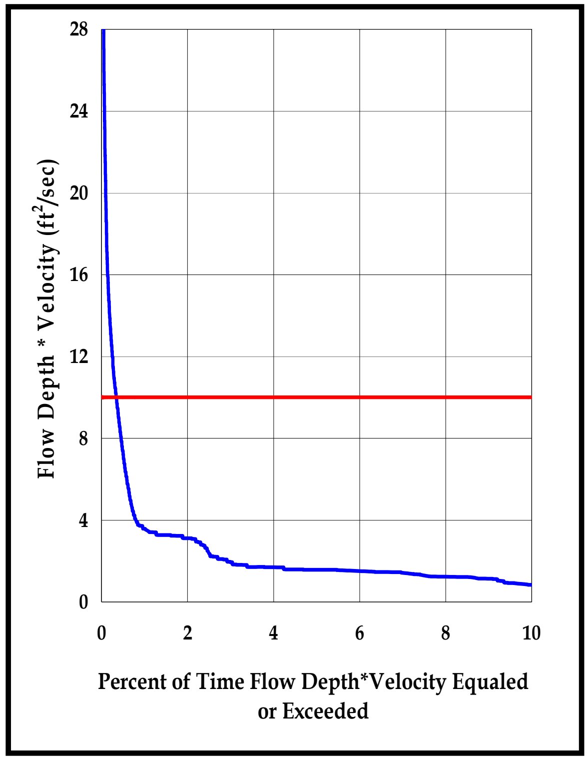

Figure 34
Channel Depth*Velocity Curve for Chino Creek at Schaeffer Ave (1988-2004)

Analysis of Bacteria Data

Fecal coliform and E. coli bacteria samples were collected in Chino Creek at Schaeffer Avenue as part of the Chino Basin TMDL monitoring program. Weekly bacteria samples were collected at this site during wet weather months from February 2002 to present. Weekly samples were also collected during the summer of 2002.

Bacteria Trends

Between 2002 and 2004, both fecal coliform and E. coli concentrations frequently exceed the 10% exceedance thresholds of 400 and the EPA proposed criteria of 236 MPN/100 mL, respectively (Figure 35). The data also suggest that high flow events are not correlated with high bacterial counts.

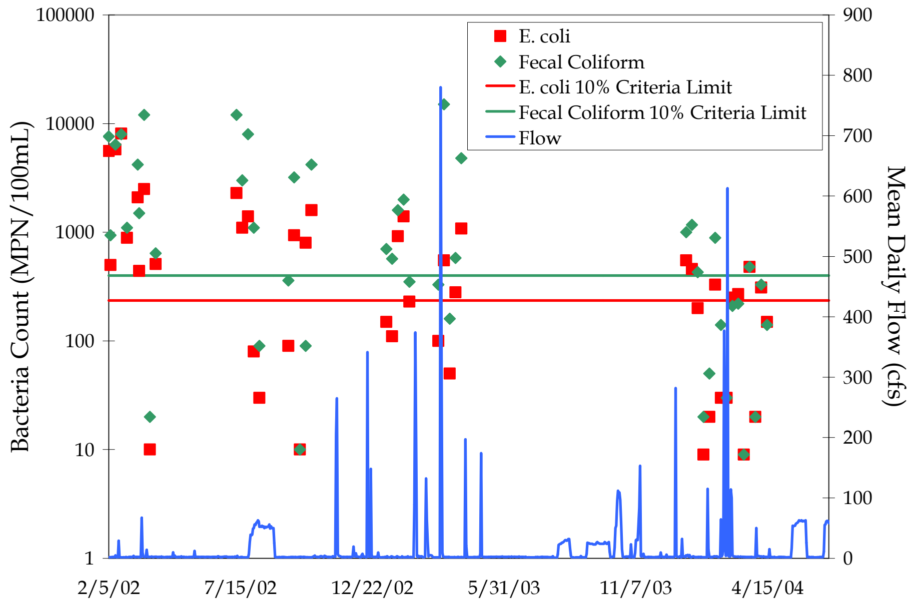

Figure 35
Time Series of Bacteria Counts and Flow at the Chino Creek at Schaeffer Avenue Study Site

Table 7 summarizes geometric means of fecal coliform and E. coli bacteria sample results for all calendar months (Note: in some cases the number of samples/month was less than five; however, geometric means were still calculated to provide a method to evaluate any trends in mean bacteria concentrations. Both fecal coliform and E. coli bacteria concentrations generally exceed existing and or anticipated geometric mean water quality objectives, assuming 5 or more samples were collected in a given month (Figure 36). The data also suggest that monthly geometric means decreased gradually between 2002 and 2004. The strong correlation between fecal coliform and E. coli concentrations in Chino Creek at the Schaeffer Avenue study site indicate that regardless of the pathogen indicator used, exceedences of water quality objectives would have occurred (Figure 37**).**

Table 7 Monthly Fecal Coliform and E. coli Concentrations (Geometric Mean) in Chino Creek at Schaeffer Avenue			
Month	**E. coli Geometric Mean**	**Fecal Coliform Geometric Mean**	**Sample Size**
Feb-02	2592	3318	5
Mar-02	390	1109	4
Apr-02	510	640	1
Jul-02	730	4219	4
Aug-02	30	90	1
Sep-02	95	226	3
Oct-02	1131	615	2
Jan-03	382	1063	4
Feb-03	230	350	1
Mar-03	140	925	3
Apr-03	550	1669	2
Jan-04	94	216	3
Feb-04	49	117	4
Mar-04	90	83	5
Apr-04	216	215	2

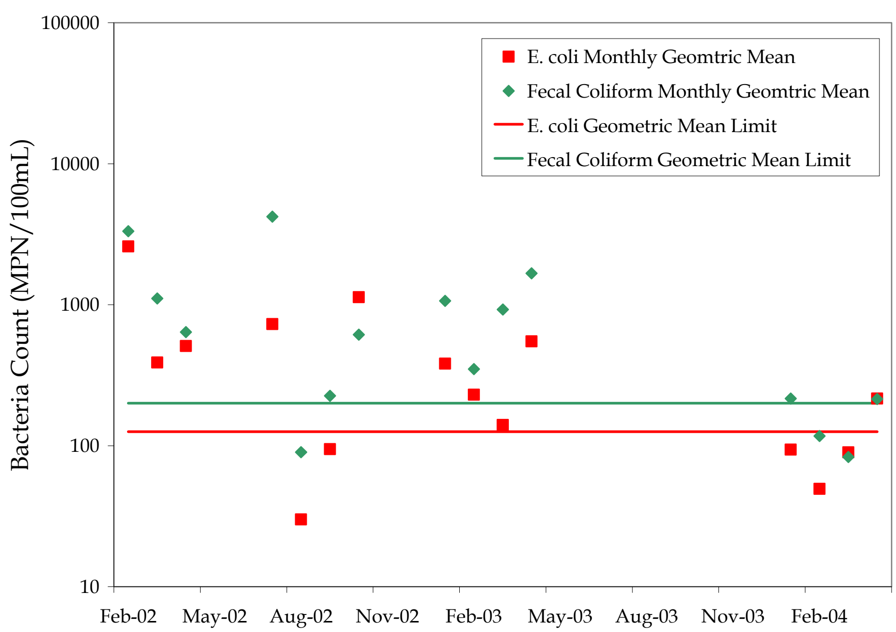

Figure 36
Monthly Bacteria Geometric Mean Concentrations at Chino Creek at Schaeffer Avenue

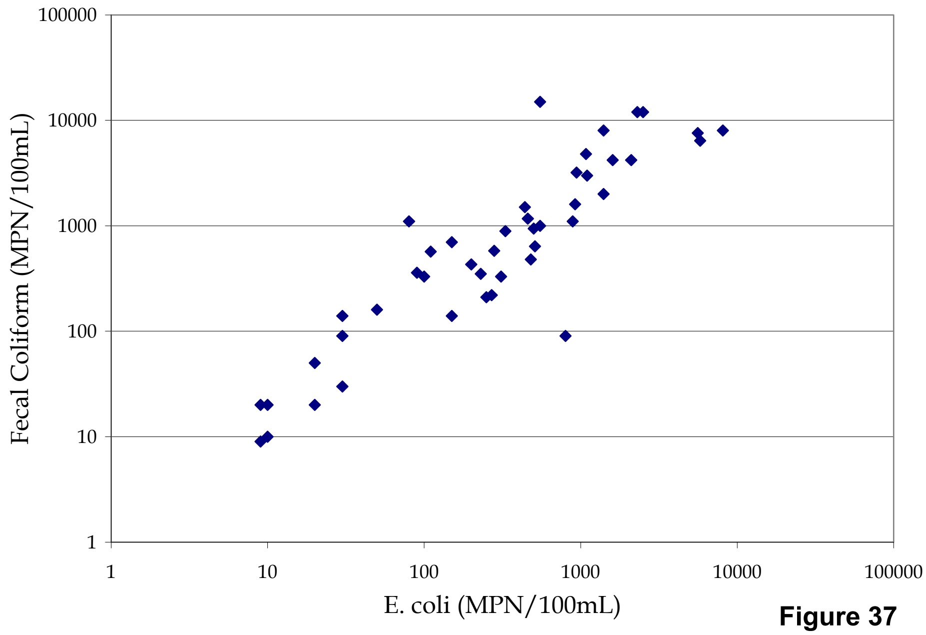

Figure 37
Relationship between E. coli and Fecal Coliform concentrations at Chino Creek at Schaeffer Avenue

Bacteria Water Quality Objectives Compliance

Analysis of bacteria compliance showed that exceedences of water quality objectives may occur during dry weather flows during both summer and winter months (Figure 38). This figure shows the number of calendar months when sufficient water quality data was available to be compared to objectives (number at the end of each bar) and the percent of those calendar months that may have exceeded water quality objectives. In contrast, of the two wet weather samples collected in February 2004 during two separate rainfall events, neither sample exceeded bacteria water quality objectives.

Santa Ana Delhi Channel

Channel Section

The Santa Ana Delhi Channel (Figure 39) extends from the city of Santa Ana to Upper Newport Bay. At Irvine Avenue, the conveyance is a concrete lined rectangular channel with a 55 ft bottom width (Figure 40 and Figure 41). Channel attribute information was provided by Orange County Flood Control District and field verified during a site visit. The bed slope of the channel at this site is 2.5 percent.

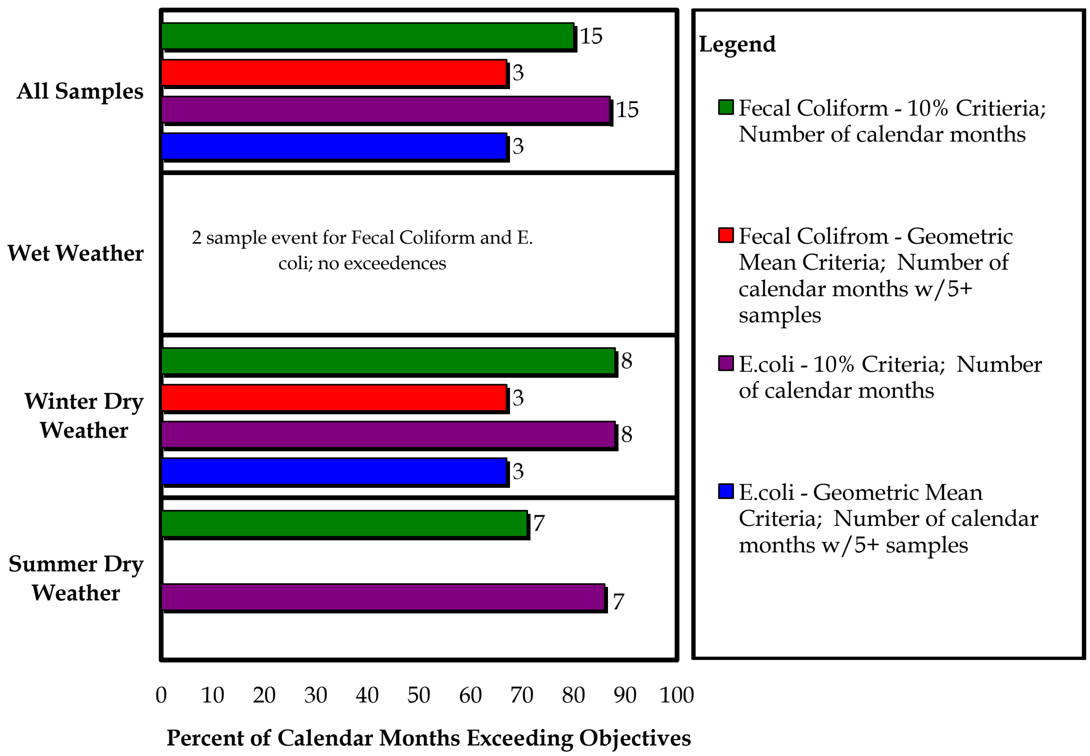

Figure 38
Comparison with Existing and Potential Bacteria Water Quality Objectives

Figure 39
Aerial Photograph of the Santa Ana Delhi Channel Study Site

Figure 40
Santa Ana Delhi Channel Downstream from Irvine Avenue

Figure 41
USGS Flow Gage at Newport Beach Golf Course Upstream of Irvine Avenue

Drainage Area Characteristics

The channel and its tributaries are primarily engineered flood control facilities that capture urban stormwater and dry weather runoff from commercial and residential land uses (Figure 42). The watershed is primarily comprised of an older urbanized part of Orange County, which has not undergone significant land use change between 1990 and 2000 (Figure 43).

Evidence of Recreational Activity

Direct or indirect evidence of recreational use of the Santa Ana Delhi Channel was not observed during site visits and, accordingly, the site was scored low in terms of recreational appeal (Figure 44).

The steep side slopes, fencing, and restrictive signs minimize the likelihood of recreational use at this study site (Figure 45 and Figure 46). Although recreational use is not likely to occur within the Santa Ana Delhi Channel itself, the site is immediately upstream of Upper Newport Bay, an inland surface water that supports a diversity of REC-1 uses (Figure 47).

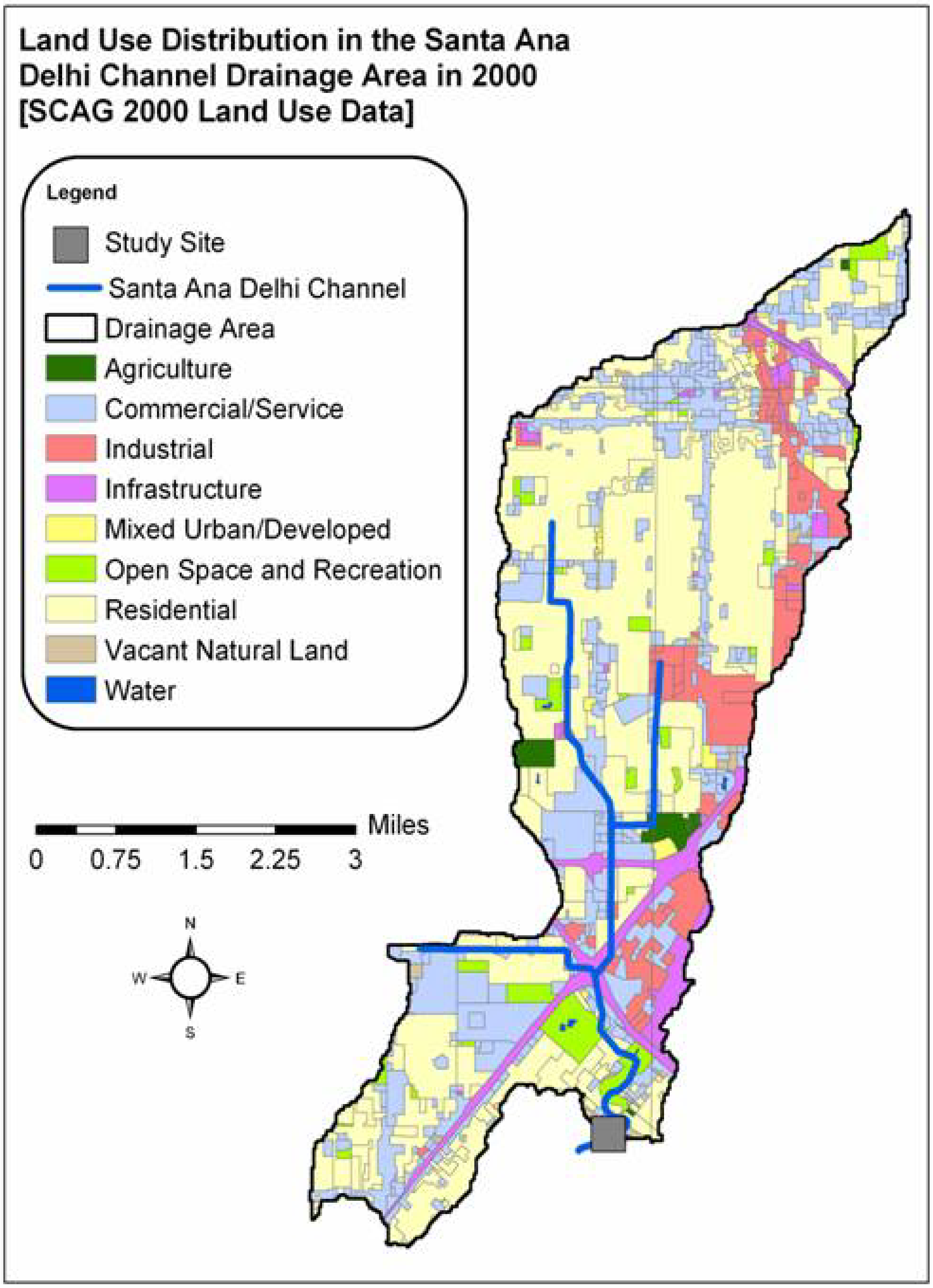

Figure 42
Land Use within Drainage Area to Santa Ana Delhi Channel Study Site

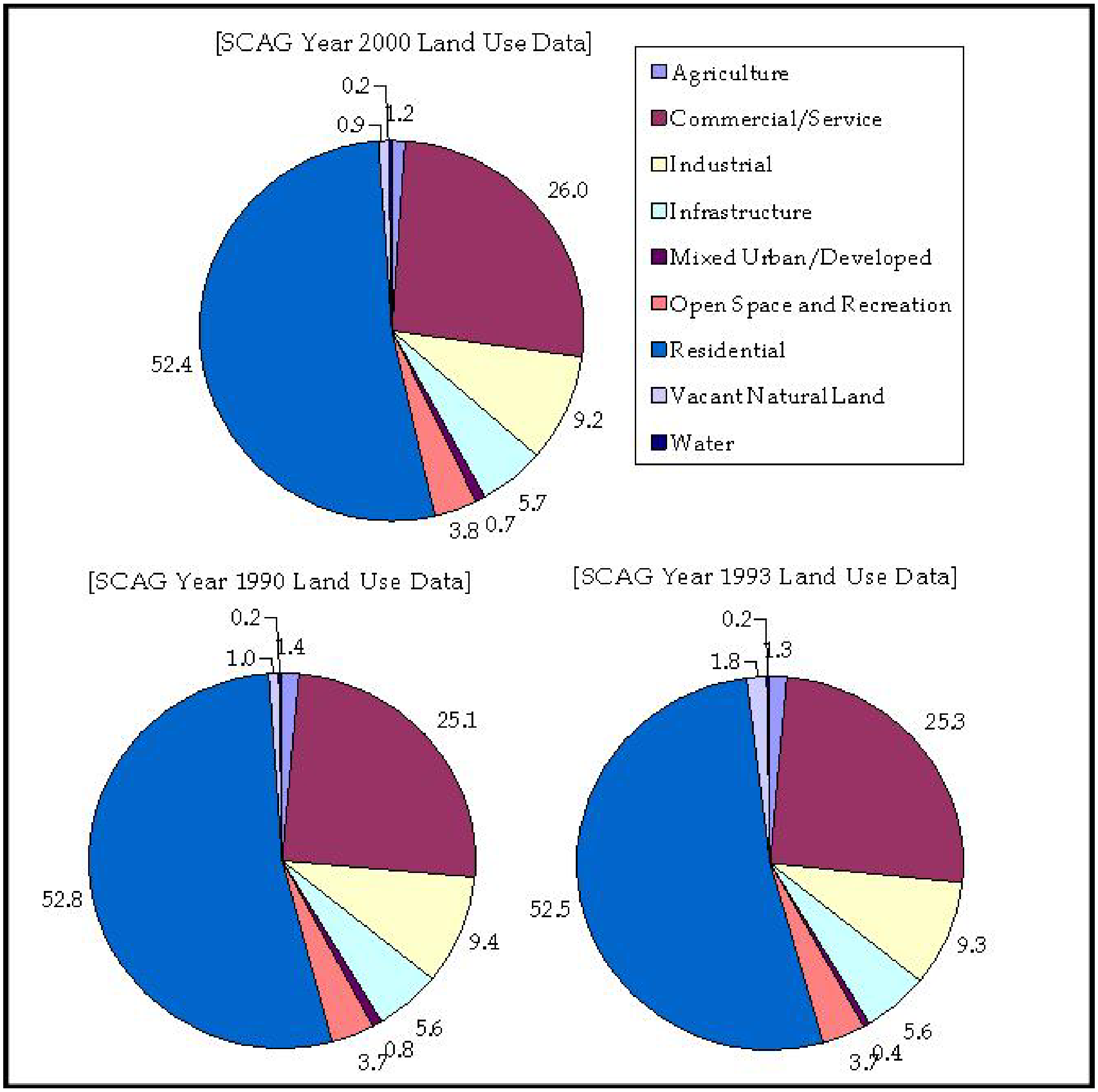

Figure 43
Relative Distribution (%) of Land Use Types in the Santa Ana Delhi Channel Watershed during 1990, 1993, and 2000

Evaluation Criteria (Scale = Low - 0 to High - 3)	Santa Delhi Channel at Irvine Ave.
Direct Evidence of Water Contact Recreation	0
Indirect Evidence of Recreational Activity	0
Ease of Access	0
Channel Slope	0
Concrete to Natural	0
Flow Depth and Volume	0
Flow Velocity	1
Water Quality Aesthetics	0
Vegetation Quality	0
Adjacent Land Use	1

Figure 44
Field Observation Checklist for the Santa Ana Delhi Channel Study Site

Figure 45
Fencing around Santa Ana Delhi Channel Prevents Access to Waterbody

Figure 46
Restrictive Signs around Santa Ana Delhi Channel

Figure 47
Upper Newport Bay near Santa Ana Delhi Channel Outfall

Flow

The Orange County Public Facilities and Resources Department (PFRD) records flow at 30-minute intervals in the Santa Ana Delhi Channel at a gage located upstream of the Irvine Avenue bridge (Figure 39). Flow records were available for the period between 1992 and 2004. Figure 48 illustrates a subset of the flow record to provide a better picture of flow during a typical year. Flow during dry weather periods typically is comprised of residential/commercial irrigation overflow, car washing, and other nuisance flow sources.

Cumulative frequency curves of the top 10^{th} percentile of flow rate and depth were generated from the 30-minute interval flow data (Figure 49 and Figure 50). Cumulative frequency curves of flow and velocities and depth-velocity products, which occurred in the Santa Ana Delhi Channel between 1992 and 2004, are shown in Figure 51 and Figure 52. Between 1992 and 2004, flow velocity in the Santa Ana Delhi Channel exceeds 8 ft/sec about 1.5 % of the time and the depth-velocity product exceeds 10 ft^2/sec about 1.0% of the time. These statistics are relatively similar to those observed at the Chino Creek study site.

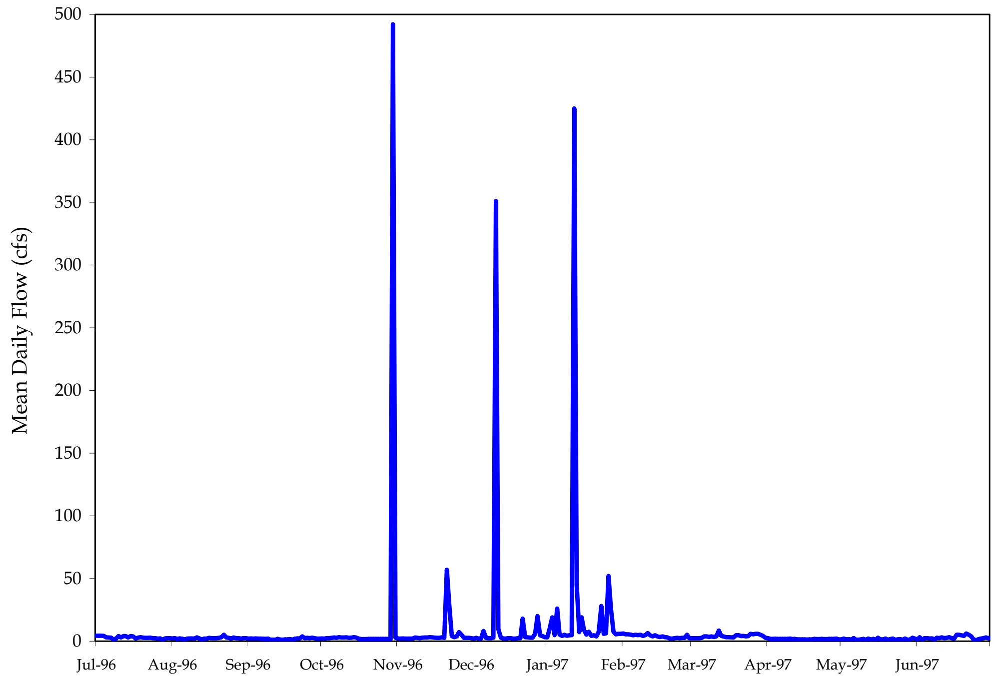

Figure 48
Mean Daily Flow in Santa Ana Delhi Channel during 1996-1997

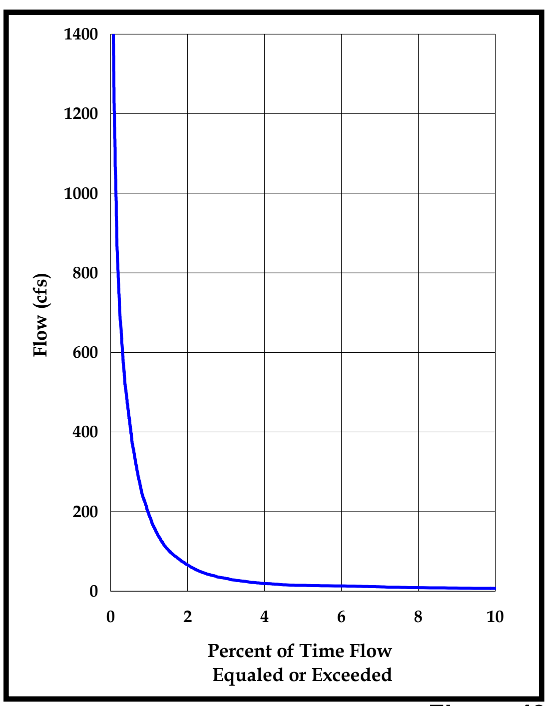

Figure 49
Channel Flow Duration Curve for Santa Ana Delhi Channel near Irvine Avenue (1992-2004)

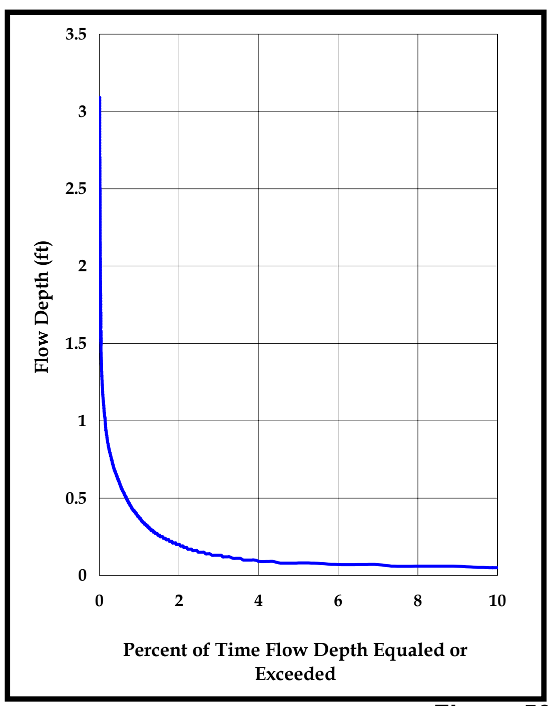

Figure 50
Channel Depth Curve for Santa Ana Delhi Channel near Irvine Avenue (1992-2004)

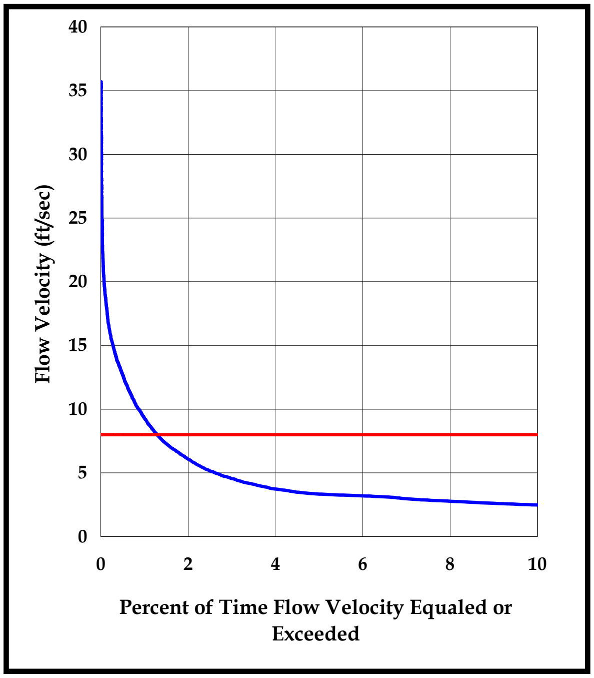

Figure 51
Channel Velocity Curve for Santa Ana Delhi Channel near Irvine Avenue (1992-2004). Red line denotes potentially dangerous condition

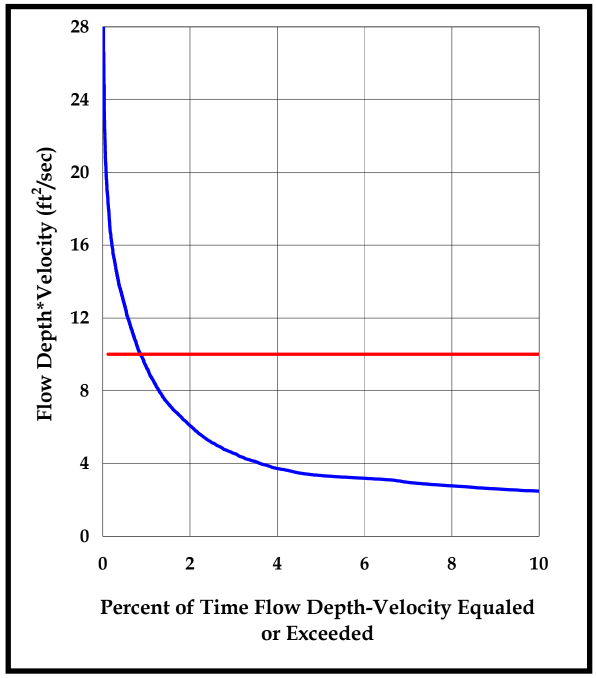

Figure 52
Channel Depth-Velocity Curve for Santa Ana Delhi Channel near Irvine Avenue (1992-2004) Red line denotes potentially dangerous condition

Bacteria Trends

Bacteria samples have been collected in two locations near this study site: at the Irvine Avenue Bridge and about ¾ mile downstream where the rectangular channel transitions to a natural wetlands area (Santa Ana Channel – Backbay). Fecal coliform samples collected between 1973 and 1976 were taken at the Irvine Avenue Bridge. Samples gathered between 1985 and 2004 were collected at the Santa Ana Delhi Channel - Backbay.

Fecal coliform concentrations have remained generally the same in the Santa Ana Delhi Channel - Backbay between 1991 and 2004 (Figure 53). By looking at a subset of this record, it is also evident that the bacteria limit for 10% of samples per 30-day period is regularly exceeded and there is no obvious connection between bacteria concentrations and wet weather events (Figure 54).

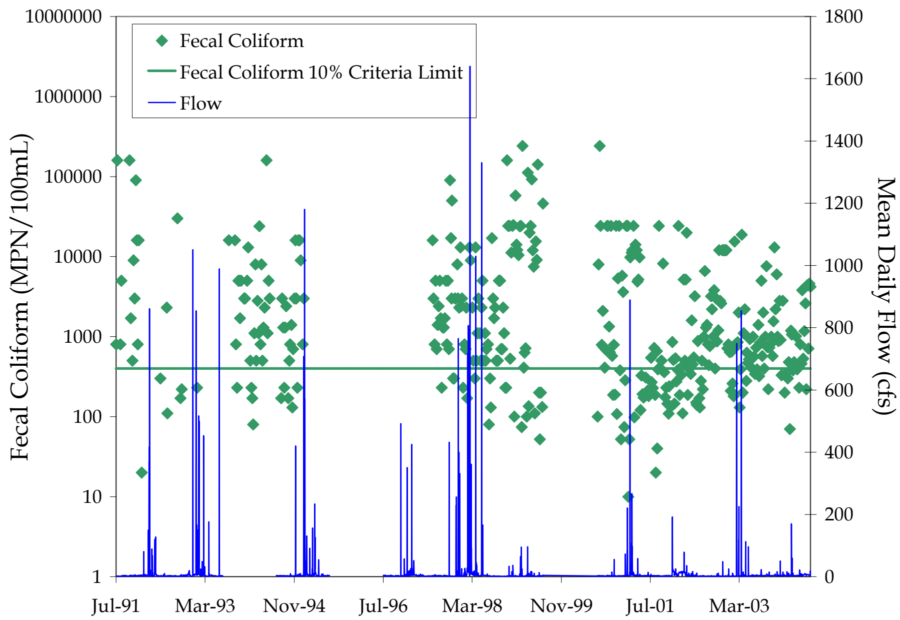

Figure 53
Time Series of Bacteria Concentrations and Flow in the Santa Ana Delhi Channel - Backbay

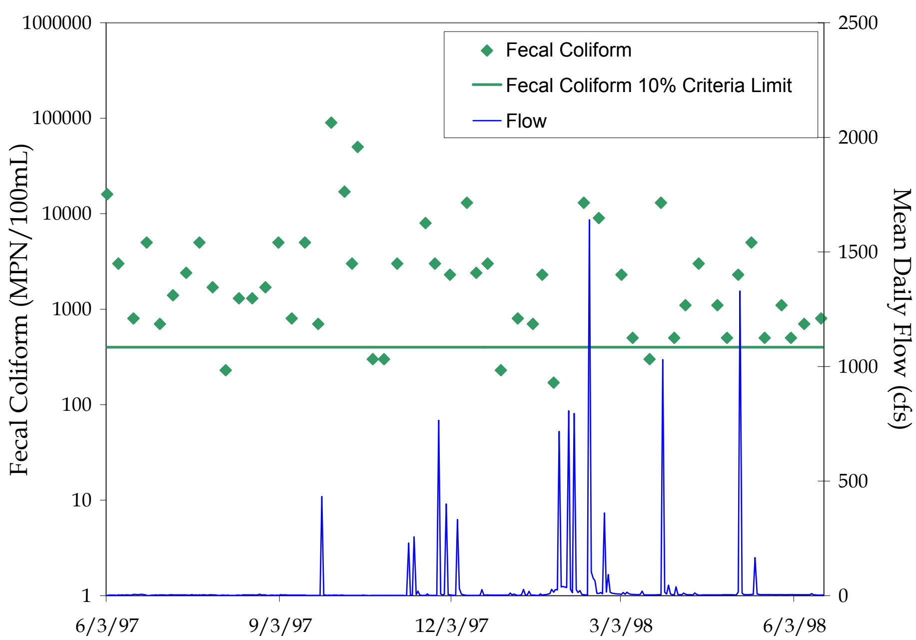

Figure 54
Time Series of Bacteria Concentrations and Flow in the Santa Ana Delhi Channel – Backbay between 1997and 1998

Annual geometric means of bacterial data at both sites in the Santa Ana Delhi Channel were calculated and are listed with the sample size in Table 8 and shown graphically in Figure 55. The geometric means exceeds the fecal coliform water quality objective (200 MPN/100mL) for every year for which data was available. Monthly geometric means for the more recent time period from January 2000 to June 2004 were also calculated (Table 9) (note: geomtric means were calculated for each month regardless of whether the five sample threshold was reached). While the majority of monthly geometric means exceed the fecal coliform geometric mean water quality objective, bacteria concentrations tend to be lower during late spring (Figure 56).

Table 8
Annual Geometric Means Santa Ana Delhi Channel

Year	Fecal Coliform Geometric Mean at Irvine Ave	Fecal Coliform Geometric Mean at Back Bay	Sample Size
1973	3715		1
1974	258		9
1975	798		13
1976	460		1
1985		700	1
1986		1654	51
1987		543	50
1988		651	46
1989		5251	41
1990		1403	44
1991		2329	26
1992		663	6
1993		2961	13
1994		1469	39
1995		3000	1
1997		2515	31
1998		1722	50
1999		2561	52
2000		560	52
2001		1141	52
2002		900	52
2003		676	49
2004		275	23

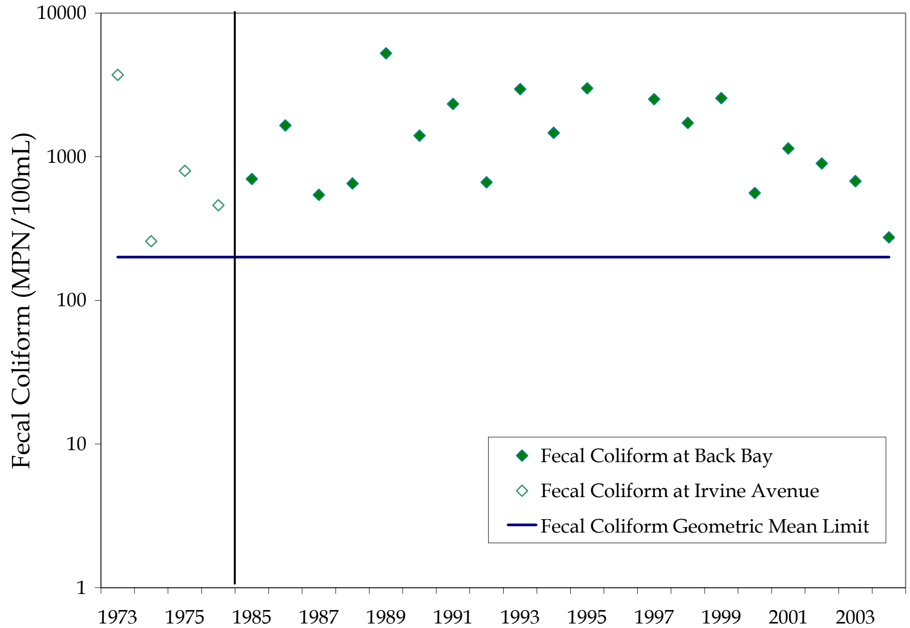

Figure 55
Annual Geometric Means of Fecal Coliform in the Santa Ana Delhi Channel

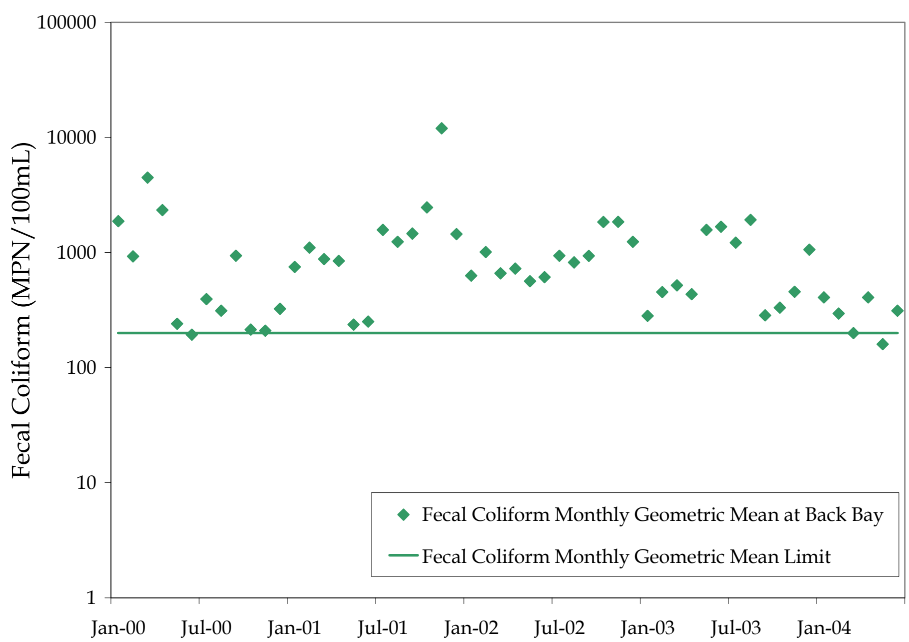

Figure 56
Monthly Geometric Means of Fecal Coliform in the Santa Ana Delhi Channel

Table 9
Monthly Geometric Means Santa Ana Delhi Channel

Month	Fecal Coliform Geometric Mean at Back Bay	Sample Size	Month	Fecal Coliform Geometric Mean at Back Bay	Sample Size
Jan-00	1874	4	Apr-02	725	5
Feb-00	928	5	May-02	563	4
Mar-00	4481	4	Jun-02	611	4
Apr-00	2340	4	Jul-02	940	5
May-00	240	4	Aug-02	822	4
Jun-00	194	4	Sep-02	937	5
Jul-00	394	4	Oct-02	1841	4
Aug-00	312	6	Nov-02	1846	4
Sep-00	938	4	Dec-02	1239	4
Oct-00	214	4	Jan-03	282	4
Nov-00	210	5	Feb-03	454	4
Dec-00	324	4	Mar-03	518	4
Jan-01	751	5	Apr-03	434	4
Feb-01	1101	4	May-03	1573	4
Mar-01	878	4	Jun-03	1677	5
Apr-01	845	5	Jul-03	1220	4
May-01	237	4	Aug-03	1924	4
Jun-01	252	4	Sep-03	284	5
Jul-01	1572	5	Oct-03	332	4
Aug-01	1239	4	Nov-03	456	3
Sep-01	1461	4	Dec-03	1058	4
Oct-01	2466	5	Jan-04	407	4
Nov-01	12000	4	Feb-04	295	4
Dec-01	1447	4	Mar-04	199	4
Jan-02	629	5	Apr-04	408	4
Feb-02	1011	4	May-04	160	4
Mar-02	661	4	Jun-04	312	2

Figure 57 shows the number of calendar months when sufficient water quality data was available to be compared to objectives (number at the end of each bar) and the percent of those calendar months that may have exceeded water quality objectives. This may occur regularly regardless of flow conditions in the Santa Ana Delhi Channel.

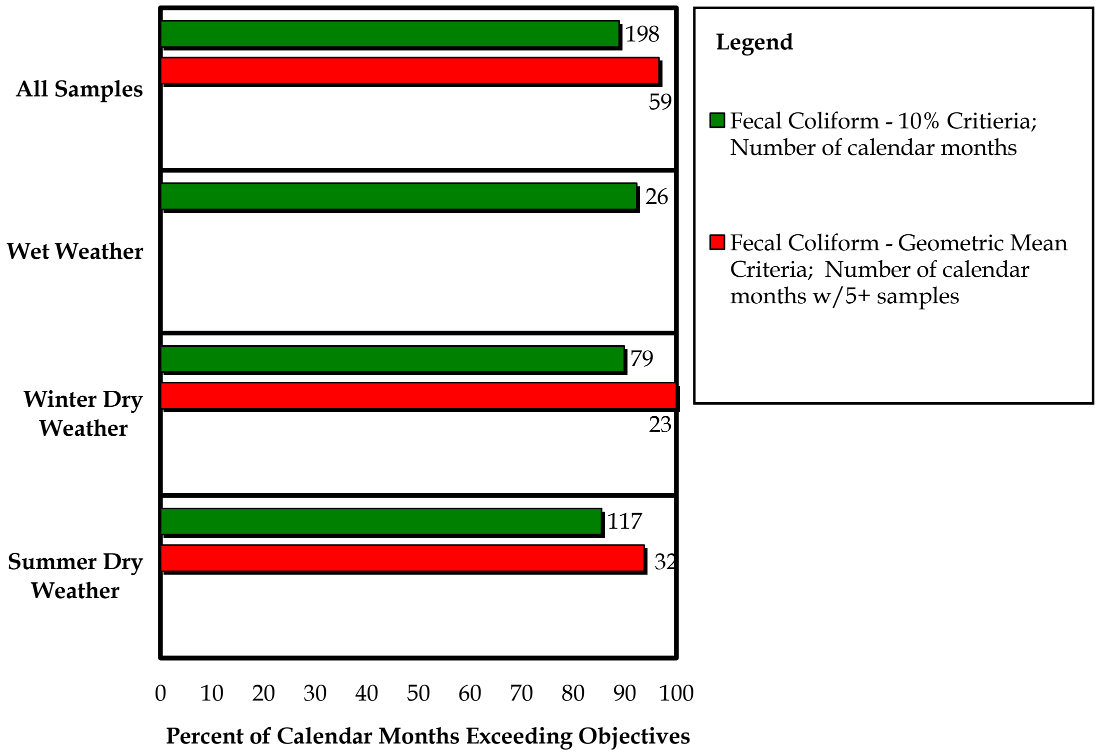

Figure 57
Comparison with Existing and Potential Bacteria Water Quality Objectives

Temescal Creek at Lincoln Avenue

Channel Section

Temescal Creek is a concrete lined trapezoidal channel upstream of Lincoln Avenue. Downstream of Lincoln Avenue the channel transitions from concrete lined to a more natural channel (Figure 58 through Figure 60). The concrete trapezoidal channel section has a 60 ft bottom width and 1.5:1 side slopes; the channel bed slope is 2.0 %. Flow is monitored in Temescal Creek near Main Street, approximately 1 mile upstream of the bacteria sampling location.

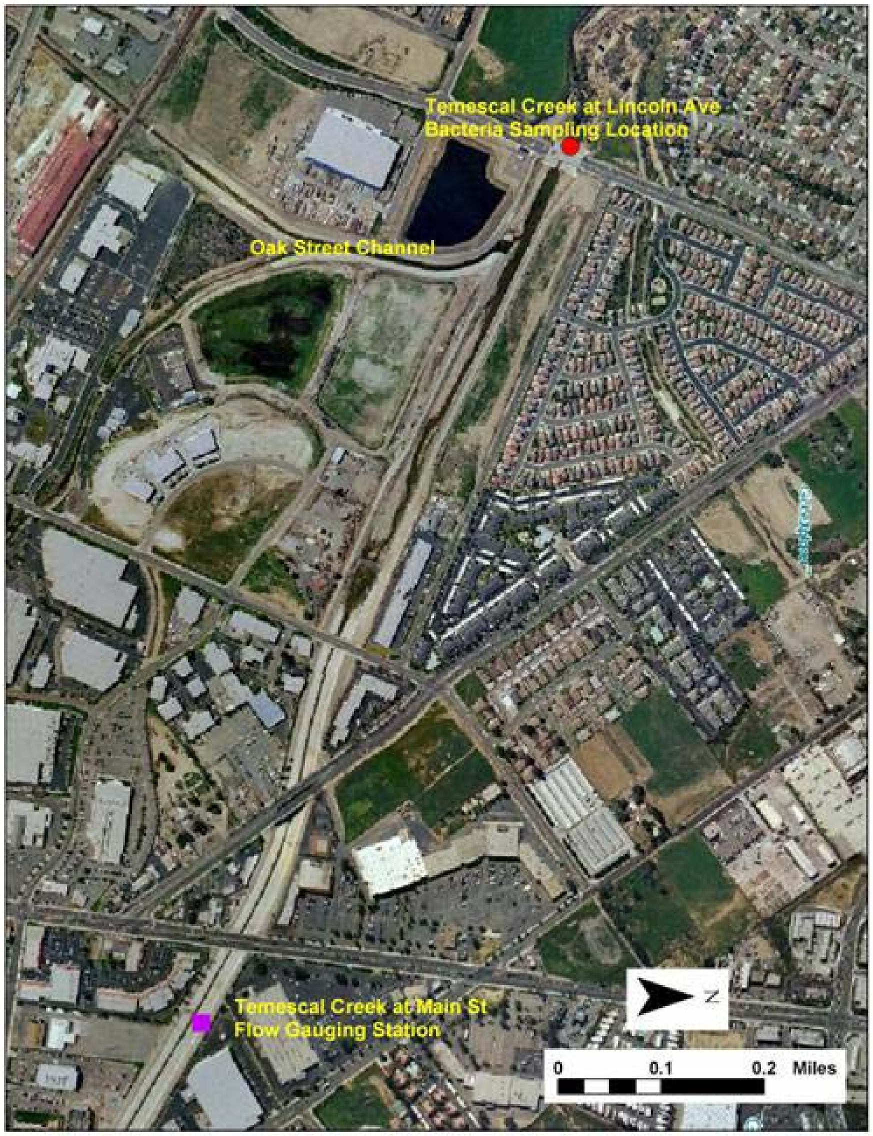

Figure 58
Aerial Photograph of the Temescal Creek at Lincoln Avenue Study Site

Figure 59
Temescal Creek transitions from concrete lined to natural below Lincoln Avenue Bridge

Figure 60
Temescal Creek downstream of Lincoln Avenue bridge, looking upstream

Drainage Area Characteristics

The Temescal Creek watershed is very large and includes both the Lake Elsinore and Lake Matthews subwatersheds. However, for the purpose of this analysis both of these subwatersheds were excluded. Lake Mathews is a terminal reservoir for storage of imported Colorado River water supply and outflow from Lake Matthews is routed into the water supply system and not into Temescal Creek. Lake Elsinore and its contributing area were also excluded from the Temescal Creek study site drainage area. The outlet of Lake Elsinore does not overflow in most years, due to high evaporation losses in the lake, low inflow volume due to channel bottom infiltration of flows in the San Jacinto River and its tributaries, and the objective to manage high lake levels to maintain recreational use and prevent algal blooms.

Because a large portion of the upper watershed of Temescal Creek is undeveloped, the dominant land use in the Temescal Creek watershed is vacant or natural land (Figure 61). The majority of the vacant/natural land is within the Cleveland National Forest and Lake Matthews Estelle Mountain Reserve. From 1990 to 2000 agricultural land use has declined while residential land use has increased (Figure 62). The Temescal Creek drainage area will likely continue to develop as space for new development in more accessible areas of the Santa Ana basin decreases.

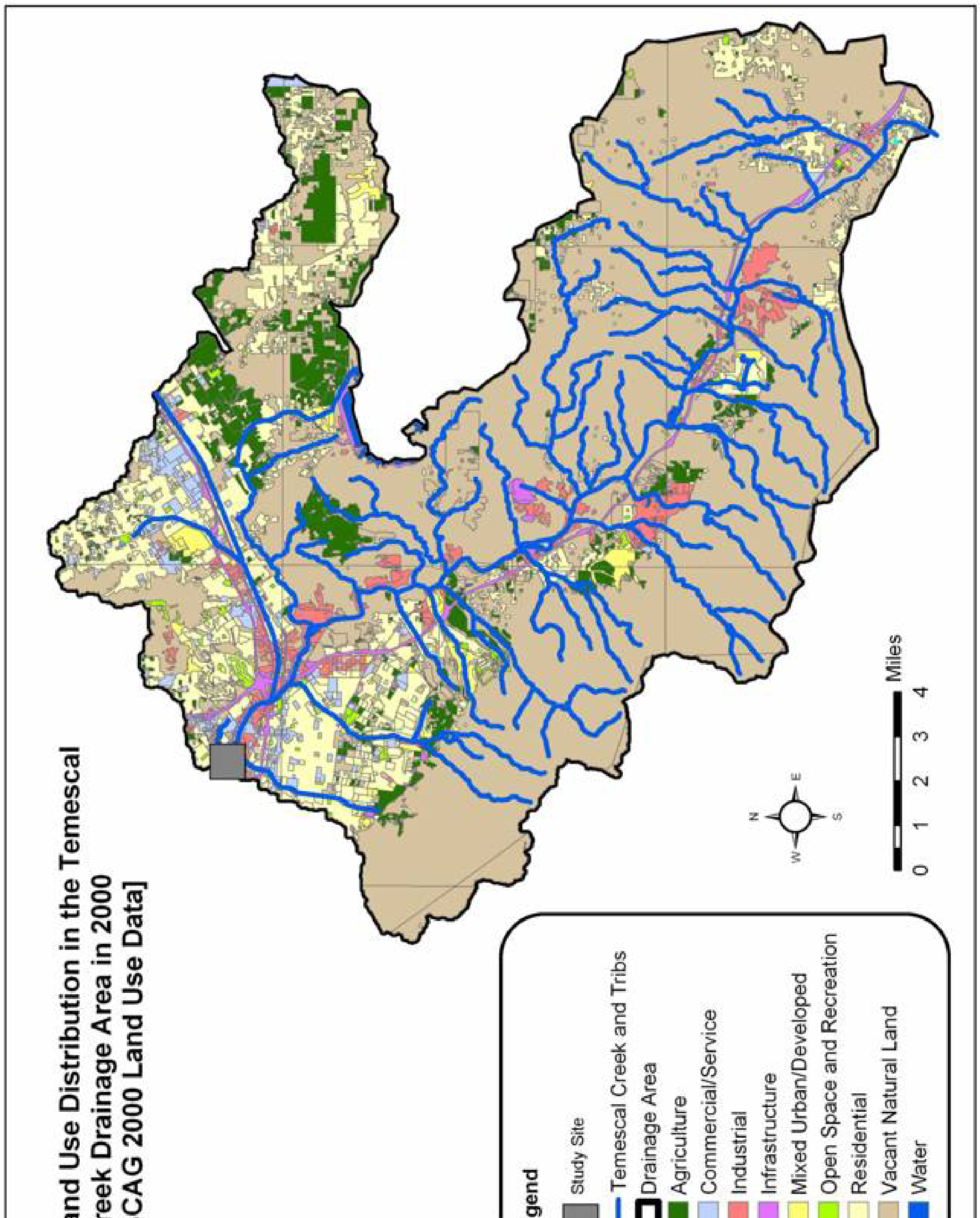

Figure 61
Land Use within Drainage Area to Temescal Creek Study Site

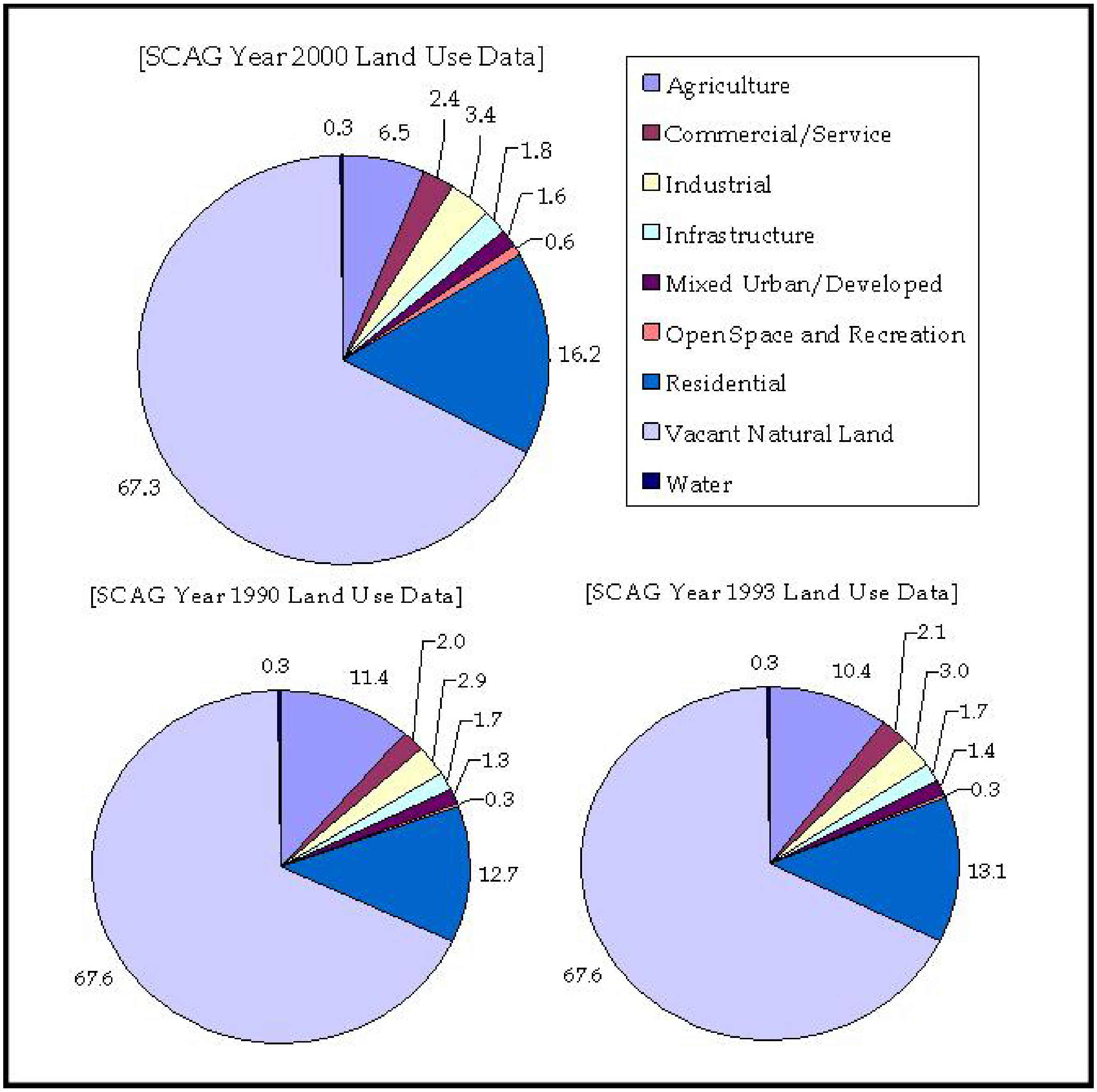

Figure 62
Relative Distribution (%) of Land Use Types in the Temescal Creek Watershed during 1990, 1993, and 2000

Evidence of Recreational Activity

Two locations were evaluated for recreational appeal at the Temescal Creek study site, upstream and downstream of the Lincoln Avenue Bridge (Figure 63). At the Lincoln Avenue bridge, the site was fenced and signs were posted prohibiting trespassing; however, the fence could be easily bypassed (Figure 64). Upstream of the Lincoln Avenue Bridge, where Temescal Creek is concrete lined, no direct and little indirect evidence of recreation activity was observed. In the natural channel section downstream of the Lincoln Avenue Bridge, trails with recent footprints led from the road to the stream, indicating that people do access this reach of Temescal Creek (Figure 65). Upstream and downstream of Lincoln Avenue, the channel side slopes are gradual enough to provide easy access to the stream.

Flow

Flow in Temescal Creek is recorded by the USGS approximately 1 mile upstream of the Lincoln Avenue Bridge, where Temescal Creek passes under Main Street in Corona [USGS Gage 11072100] (Figure 66). Additional ungauged flow enters Temescal Creek from the Oak Street channel, between the USGS gage and bacteria monitoring locations. Flow in these tributaries is relatively small compared to Temescal Creek, but must be considered when relating bacteria to flow for the study site.

Evaluation Criteria (Scale = Low - 0 to High - 3)	**Temescal Creek at Lincoln Ave.**	**Temescal Creek Natural Channel Section**
Direct Evidence of Water Contact Recreation	0	1
Indirect Evidence of Recreational Activity	2	2
Ease of Access	2	3
Channel Slope	2	3
Concrete to Natural	1	3
Flow Depth and Volume	1	2
Flow Velocity	2	2
Water Quality Aesthetics	1	2
Vegetation Quality	0	3
Adjacent Land Use	1	1

Figure 63
Field Observation Checklist for the Temescal Creek Study Site

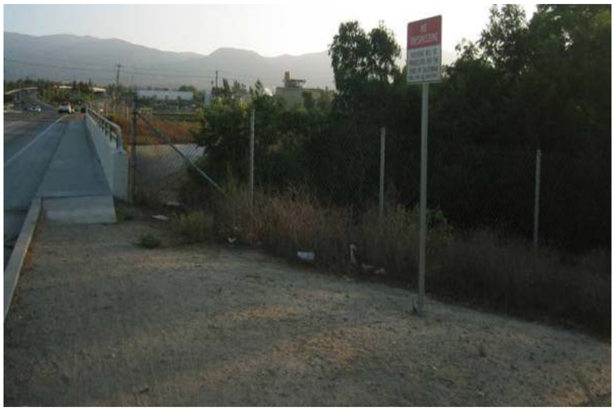

Figure 64
Fencing and signs prohibiting access to Temescal Creek from the Lincoln Avenue Bridge

Figure 65
Trash and other indirect evidence of recreational activity along Temescal Creek, downstream of Lincoln Avenue

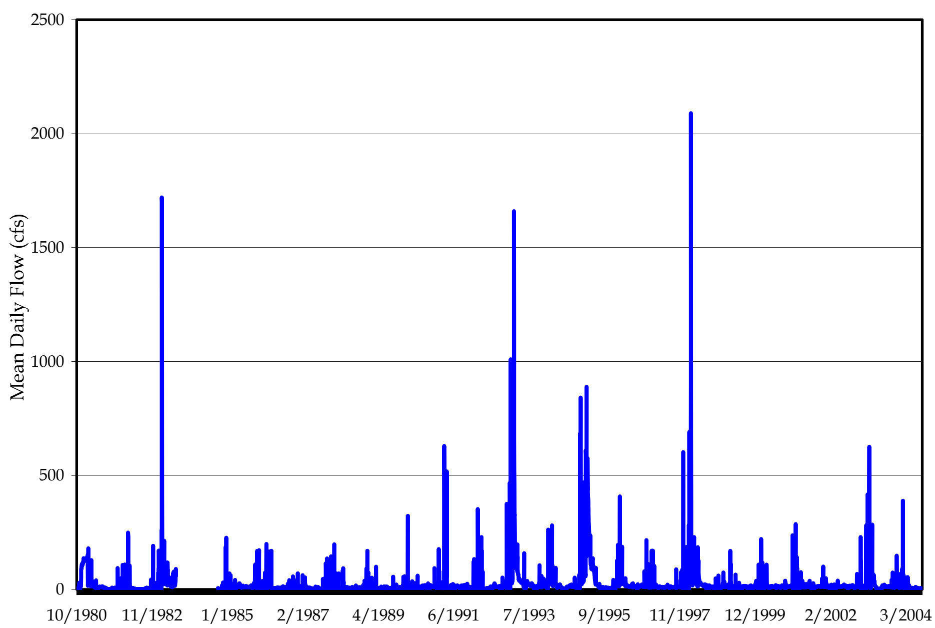

Figure 66
Mean Daily Flow in Temescal Creek at Main Street between 1980 and 2004

Figure 67 shows flow in Temescal Creek during a high rainfall year (7/1/92 through 6/30/93). High flows in Temescal Creek include both urban stormwater runoff and runoff from upstream mountain canyons. Spring-fed flow from canyons of the Santa Ana Mountains along the western boundary of the Temescal Creek watershed is more pronounced in the flow record following rainy seasons with greater than average precipitation, as was the case in the spring of 1993 (Figure 67). Runoff in Temescal Creek during summer months is typically dry weather runoff from residential/commercial areas and agricultural irrigation

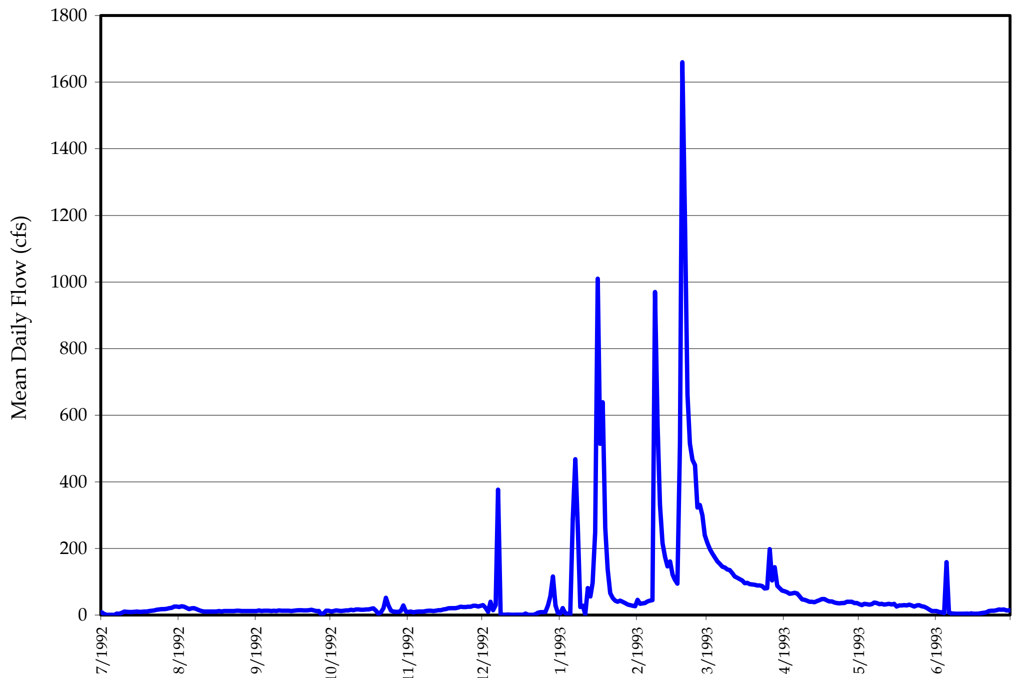

Figure 67
Mean Daily Flow in Temescal Creek at Main Street during the 1992-1993 Water Year

overflow.

Cumulative frequency curves of the top 10th percentile of flow rate and depth were generated from 15-minute interval flow USGS data (Figure 68 and Figure 69). Cumulative frequency curves of flow velocities and depth-velocity products are used to assess the likelihood of occurrence of dangerous flow conditions. Between 1988 and 2004, flow velocities in Temescal Creek at the Main Street Bridge exceed 8 ft/sec about 2.0 % of the time and the depth-velocity product exceeds 10 ft^2/sec about 0.8% of the time (Figure 70 and Figure 71), again, similar frequencies to the other two urban channel study sites.

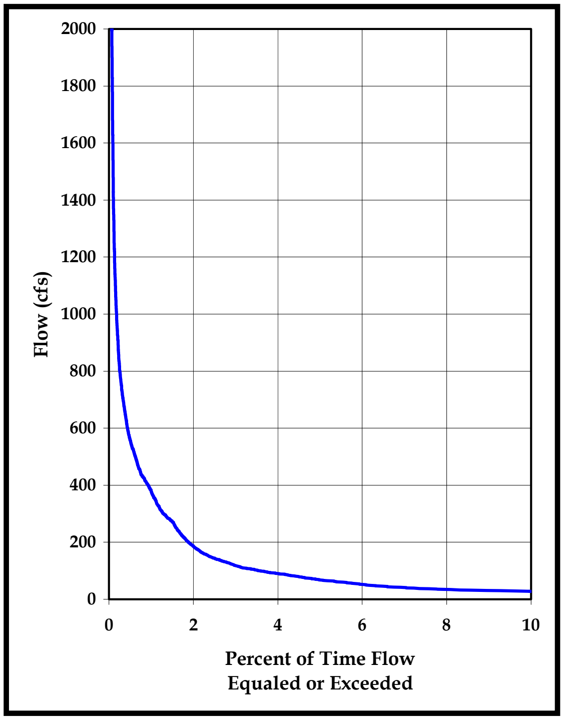

Figure 68
Channel Flow Duration Curve for Temescal Creek at Main Street (1988-2004)

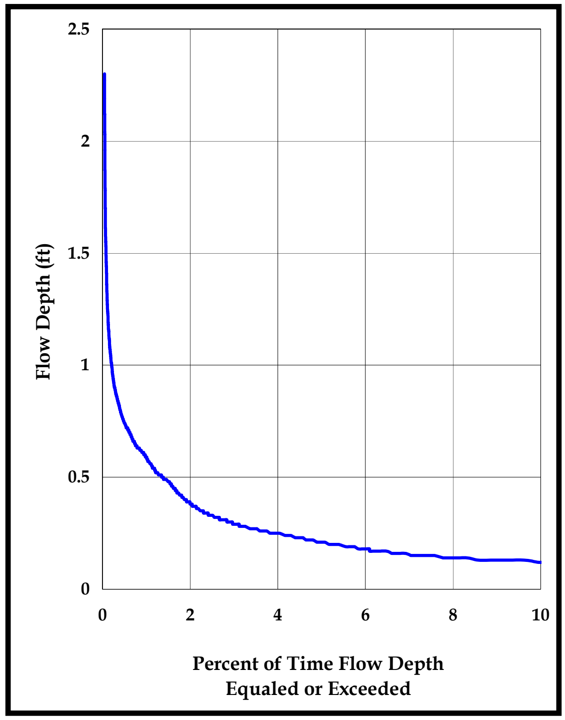

Figure 69
Channel Depth Curve for Temescal Creek at Main Street (1988-2004)

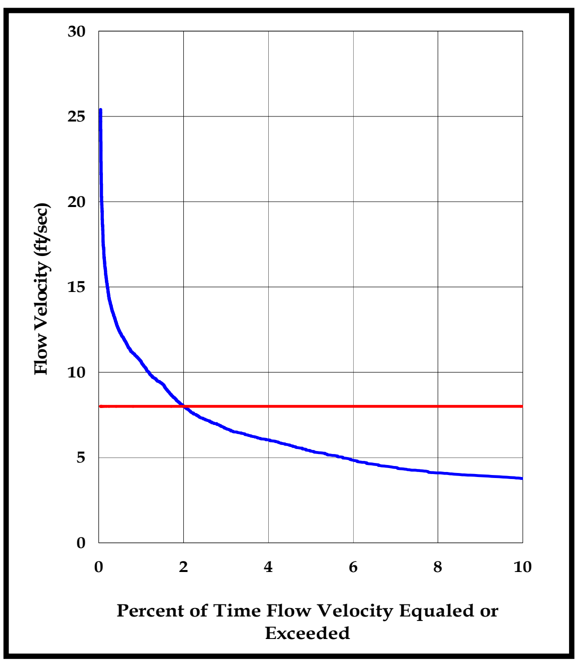

Figure 70
Channel Velocity Curve for Temescal Creek at Main Street (1988-2004)

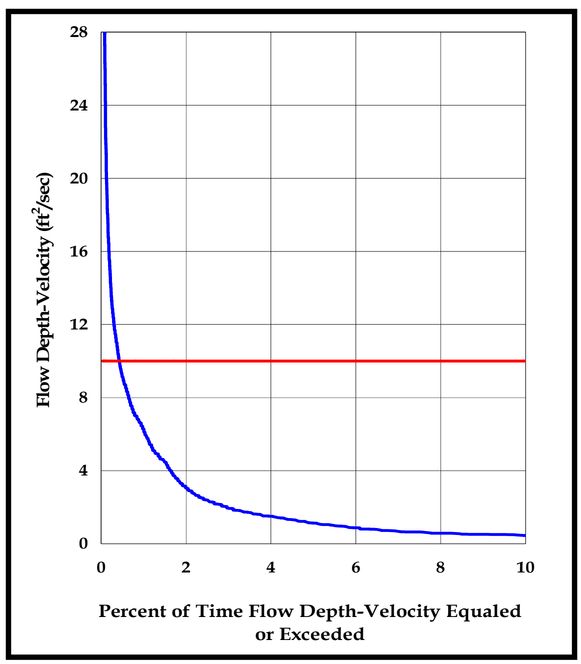

Figure 71
Channel Depth*Velocity Curve for Temescal Creek at Main Street (1988-2004)

Analysis of Bacteria Data

E. coli bacteria samples were collected from Temescal Creek at the Lincoln Avenue Bridge by Orange County Coastkeeper approximately once each month between 2002 and 2004. Fecal coliform was measured twice; 100 MPN/100mL on 1/26/1993 (OCWD) and 900 MPN/100mL on 3/24/03 (Orange County Coastkeeper).

Bacteria Trends

No obvious increasing or decreasing trend in E. coli bacteria concentrations occurred between 2002 and 2004 (Figure 72). E. coli concentrations increased during the winter months of 2002 - 2003 and concentrations regularly exceeded the potential single sample water quality objective for E. coli (236 MPN/100 mL). It is unclear whether this increase in E. coli concentration is directly related to wet weather events. With the exception of a few months, the monthly sample result or geometric mean of the sample result exceeded the anticipated 30-day geometric mean water quality objective of 126 MPN/100mL (Table 10/ Figure 73).

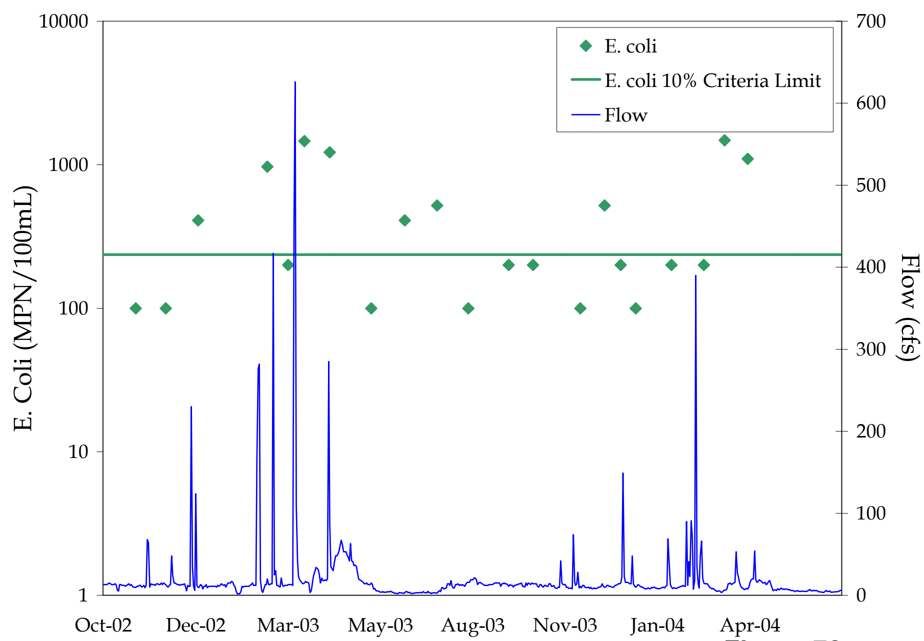

Figure 72
Time Series of Bacteria Concentrations and Flow in Temescal Creek from October 2002 to April 2004

Table 10
Monthly E. coli Geometric Means at Temescal Creek

Year	E. coli Concentration (Monthly Single Sample or Geometric Mean)	Sample Size
Oct-02	100	1
Nov-02	100	1
Dec-02	410	1
Feb-03	970	1
Mar-03	540	2
Apr-03	1220	1
May-03	100	1
Jun-03	410	1
Jul-03	520	1
Aug-03	100	1
Sep-03	200	1
Oct-03	200	1
Nov-03	100	1
Dec-03	322	2
Jan-04	100	2
Feb-04	200	1
Mar-04	544	2
Apr-04	1100	1

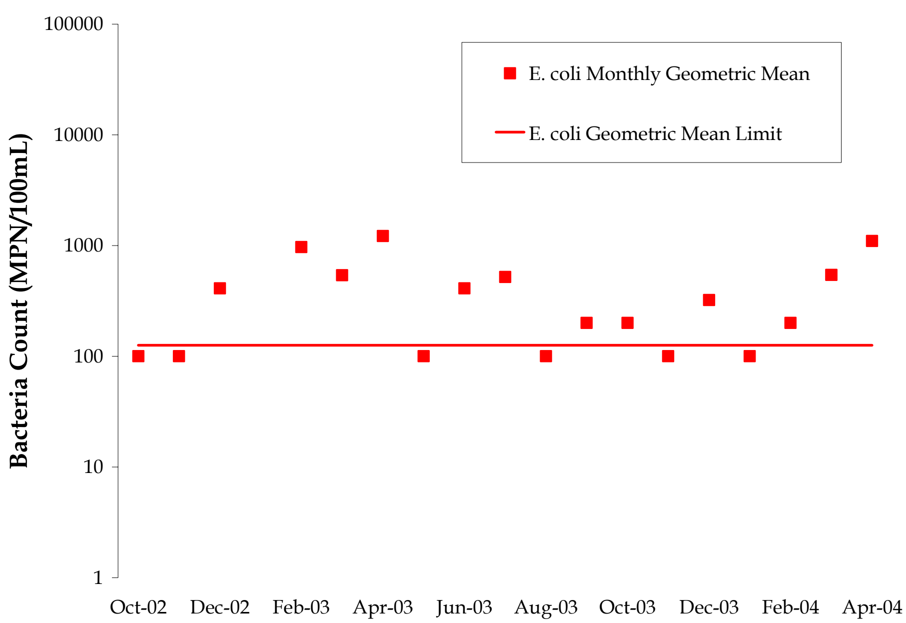

Figure 73
Monthly Single Sample Result or Geometric Mean of Sample Results for E. coli in Temescal Creek from October 2002 to April 2004

Figure 74 shows the percentage of calendar months when available fecal coliform and E. coli bacteria counts may have exceeded water quality objectives. This figure shows the number of calendar months when sufficient water quality data was available to be compared to objectives (number at the end of each bar) and the percent of those calendar months that may have exceeded water quality objectives. Results of this comparison show potential exceedences of the fecal coliform water quality objectives in one of two winter months when fecal coliform was sampled. E. coli was sampled more frequently at this study site and potential exceedences were observed in approximately 50% of dry weather samples during both summer and winter months. One wet weather sample was collected on April 15, 2003, following a wet weather event the preceding day. The E. coli bacteria concentration during the recession of the high flow was 1,220 MPN/100mL.

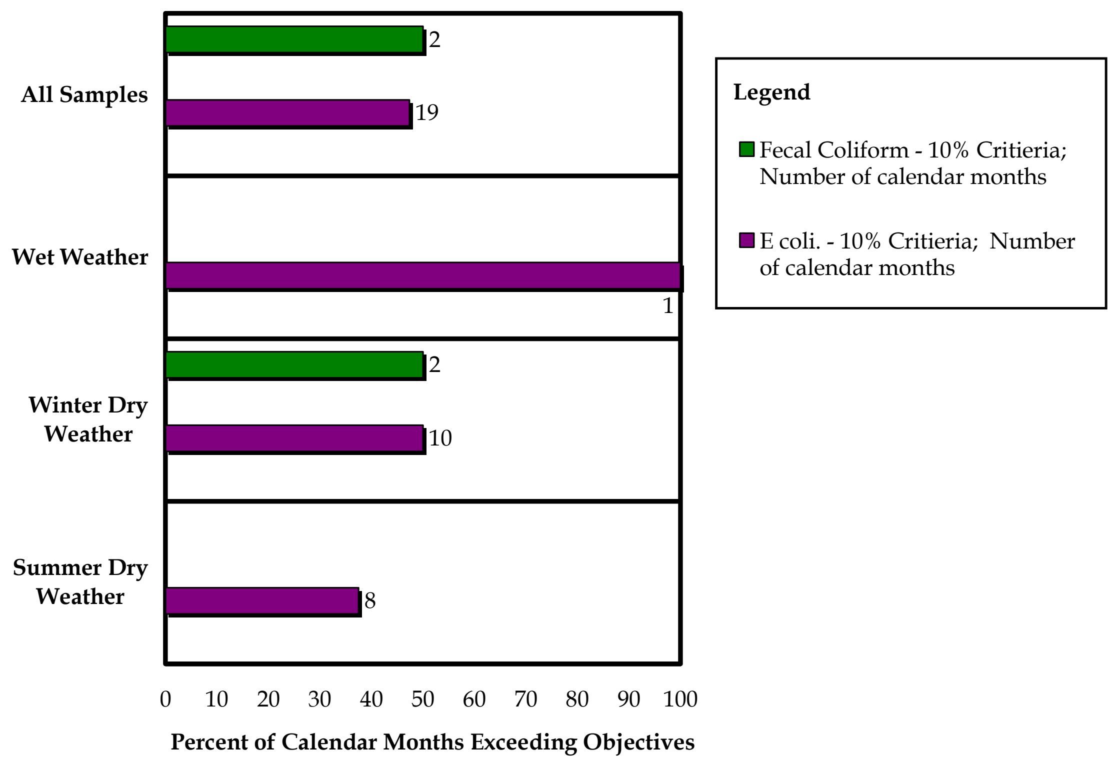

Figure 74
Comparison with Existing and Potential Bacteria Water Quality Objectives

Santa Ana River at Imperial Highway

Channel Section

This reach of the Santa Ana River at Imperial Highway has a natural bottom and is about 200 ft wide (Figure 75 and Figure 76). The river banks, which have an approximately 1:1 side slope, are reinforced with riprap in some locations (Figure 77). The bed slope of the channel is 2.0 %.

Figure 75
Aerial Photograph of the Santa Ana River at Imperial Highway Study Site

Figure 76
Santa Ana River downstream of Imperial Highway

Figure 77
Side Slopes of Santa Ana River downstream of Imperial Highway

Drainage Area Characteristics
Imperial Highway crosses Reach 2 of the Santa Ana River downstream of Prado Dam. There is also some local drainage within Santa Ana Canyon that enters the river in this reach. Prado Dam captures flows from all of the upper portions of the Santa Ana River watershed in Riverside and San Bernardino Counties. The majority of base flow reaching Prado Dam from upstream is tertiary effluent from river discharging POTWs. Releases from Prado Dam are highly regulated, and make up the majority of flow tributary to Imperial Highway. Accordingly, any potential relationship between land use in the watershed and bacteria concentrations in the Imperial Highway reach of the Santa Ana River are likely masked by the interception of flows by Prado Dam.

Recreational Use
Evidence of the potential for recreational activity in the Santa Ana River at the Imperial Highway crossing was assessed during a site visit (Figure 78). This site was entirely fenced, and posted signs prohibited entrance to the river (Figure 79). Regardless, indirect evidence of recreational activity was observed, e.g., human footprints, trails that were traced to the waters edge, and trampled vegetation. In this reach, water depths were much greater than what was observed at most other sites due to continued releases from Prado Dam(Figure 80).

Evaluation Criteria (Scale = Low - 0 to High - 3)	Santa Ana River at Imperial Highway
Direct Evidence of Water Contact Recreation	1
Indirect Evidence of Recreational Activity	3
Ease of Access	3
Channel Slope	2
Concrete to Natural	3
Flow Depth and Volume	3
Flow Velocity	3
Water Quality Aesthetics	3
Vegetation Quality	3
Adjacent Land Use	3

Figure 78
Field Observation Checklist for the Santa Ana River at Imperial Highway Study Site

Figure 79
Signs prohibiting entrance into Santa Ana River at the Imperial Highway

Figure 80
Flow in the Santa Ana River at the Imperial Highway

Flow

Flow in the Santa Ana River at Imperial Highway study site is largely comprised of outflow from Prado Dam, but also includes some stormwater runoff and dry weather flow from small tributaries in northeastern Orange County. Downstream of this reach there is a rubber dam, which is the primary diversion facility used to route water to several Orange County Water District groundwater recharge basins located adjacent to this reach of the Santa Ana River. Based on USGS data from 1998 to 2001, baseflow in this reach ranges between 200 and 400 cfs (USGS Gage 11075610) (Figure 81).

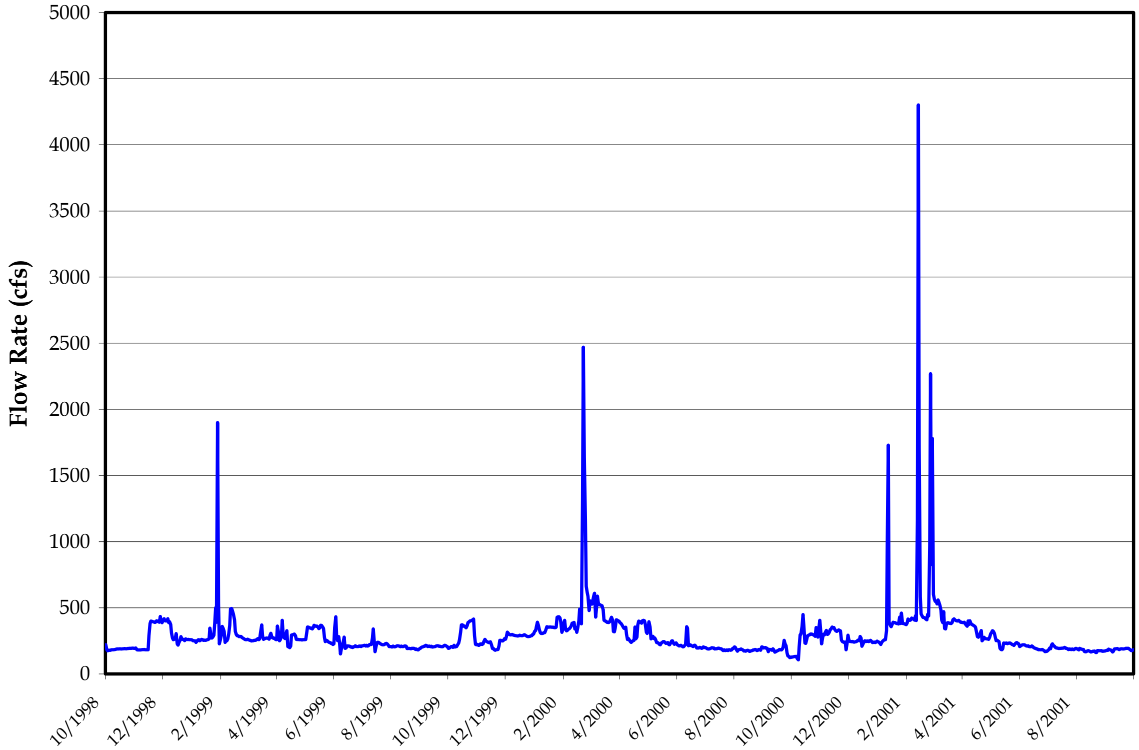

Figure 81
Mean Daily Flow in the Santa Ana River at the Imperial Highway Study Site (10/1998 to 9/2001)

Bacteria Trends

Fecal coliform samples were collected at the Imperial Highway location between 1981 and 1994, and again between 1998 and 2004. E. coli samples were collected in 1985 and between the years of 1998 and 2004. Figure 82 provides a time series plot of bacteria concentrations over the entire bacteria sampling record. Figure 83 provides a time series plot of bacteria data collected during the period when flow records are available.

Most sample results from 1981 to 1994 exceed bacteria objectives, while most results from 1998 to the present fall at or below bacteria objectives, possibly indicating improvement in bacteria quality over the period of record.

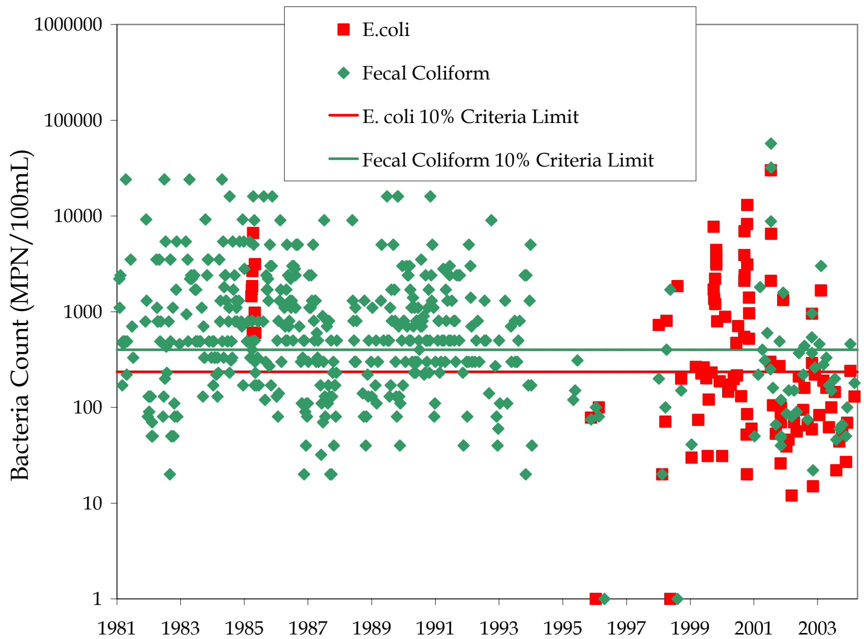

Figure 82
Time Series of Bacteria Concentrations for the Entire Period of Record in the Santa Ana River at the Imperial Highway Study Site

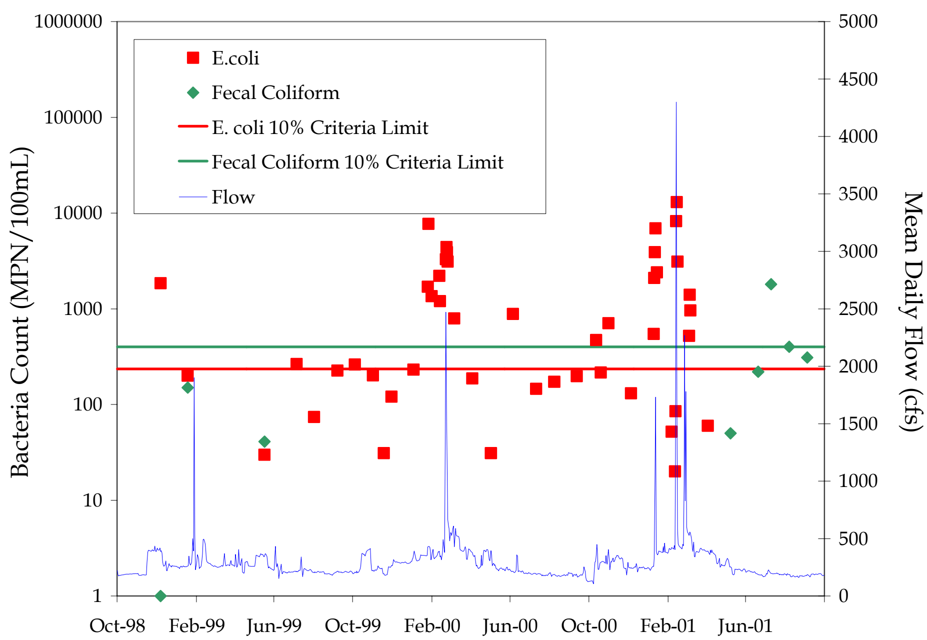

Figure 83
Time Series of Bacteria Concentrations and Flow in the Santa Ana River at the Imperial Highway Study Site

Two separate high flow events (January 2001 & February 2001) were further analyzed with E. coli data to describe the relationship between wet weather flow and bacteria concentrations. Figure 84 and Figure 85 indicate that E. coli concentrations increased during the high flow event and then remained high for one to two days after the high flow event had ended. A recently completed study that characterized bacteria concentrations in the lower Santa Ana River during stormwater runoff events also observed this same pattern (Izbicki et al. 2004). Izbicki speculated that the elevated bacteria concentrations that persist for a few days after a wet weather event result from the re-suspension of bacteria in sediments.

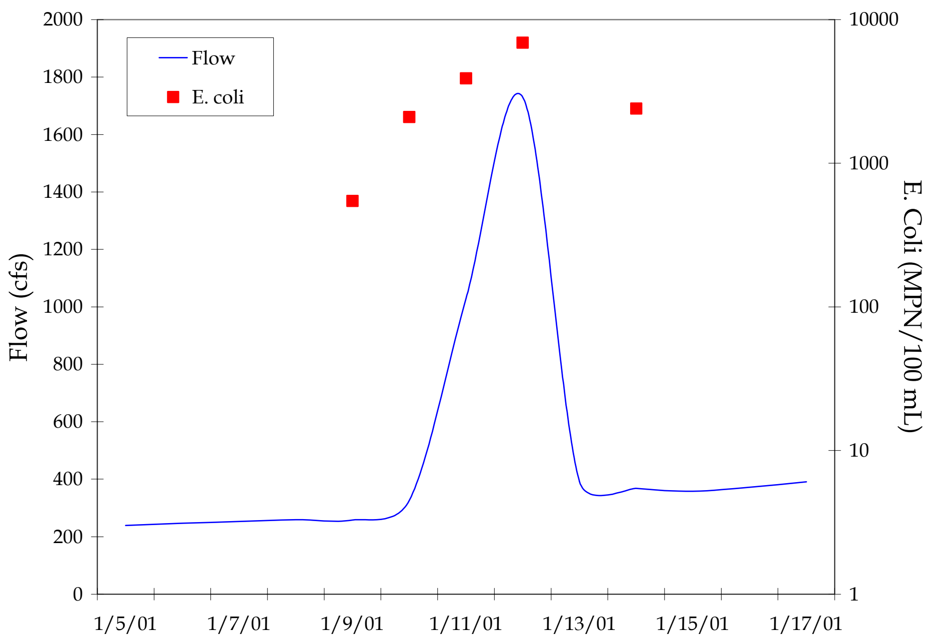

Figure 84
January 2001 Wet Weather E. coli Sampling Event

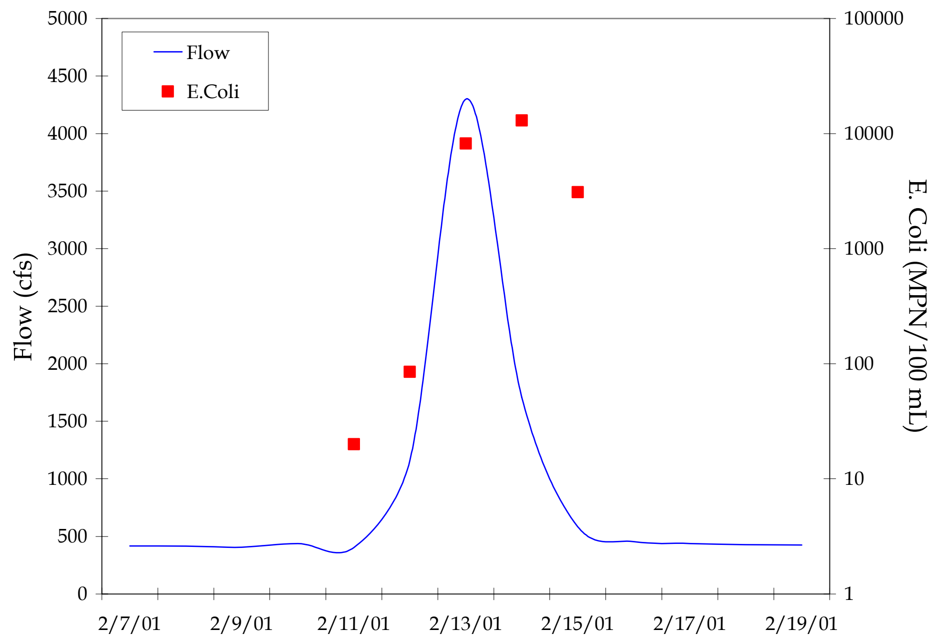

Figure 85
February 2001 Wet Weather E. coli Sampling Event

Monthly geometric means of bacteria counts measured in the Santa Ana River at the Imperial Highway study site were calculated and are shown in Figure 86**.** The figure potentially indicates a slight improving trend in sample results over time.

The strong correlation between fecal coliform and E. coli concentrations at the Santa Ana River at Imperial Highway study site indicates that regardless of the pathogen indicator used, exceedences of water quality objectives would have occurred (Figure 87).

Figure 88 shows the percentage of calendar months when available fecal coliform and E. coli bacteria counts may have exceeded water quality objectives. This figure shows the number of calendar months when sufficient water quality data was available to be compared to objectives (number at the end of each bar) and the percent of those calendar months that may have exceeded water quality objectives. Potential exceedences of fecal coliform and potential E. coli water quality objectives occurred during all flow conditions.

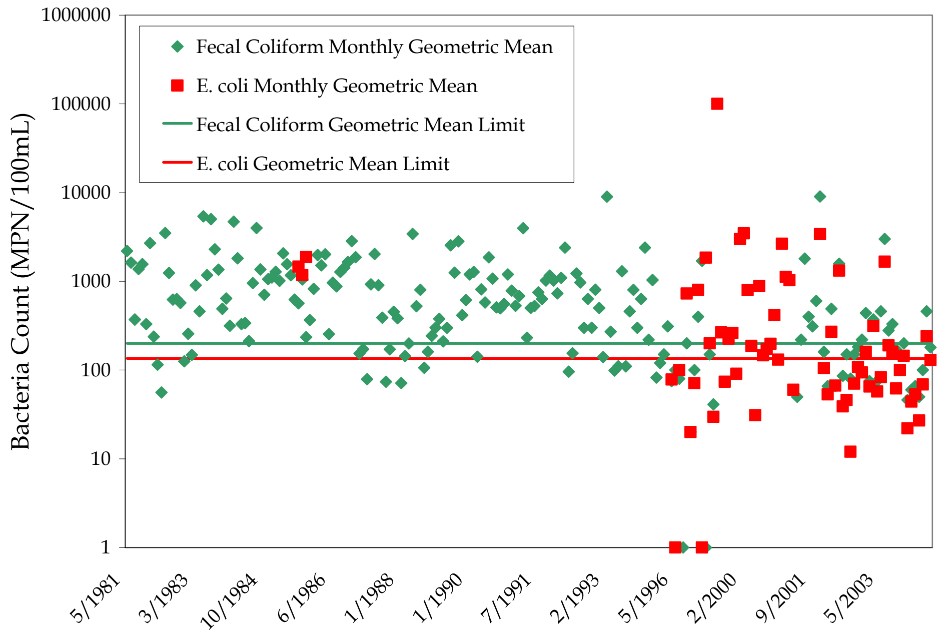

Figure 86
Monthly Single Sample Result or Geometric Mean of Sample Results for Fecal Coliform and E. coli in the Santa Ana River at the Imperial Highway Study Site

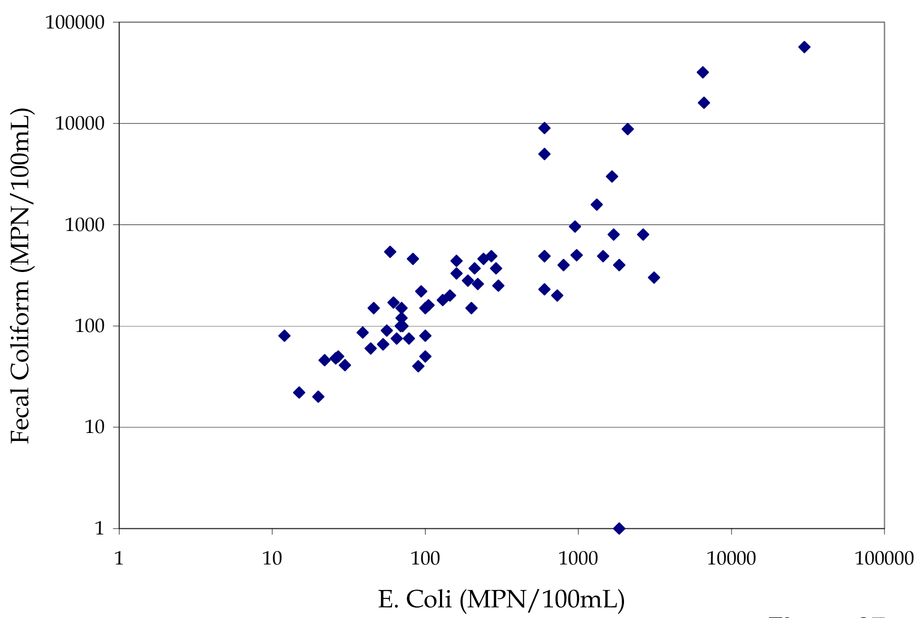

Figure 87
Bivariate Plot of Fecal Coliform and E. coli for samples collected in the Santa Ana River at the Imperial Highway Study Site

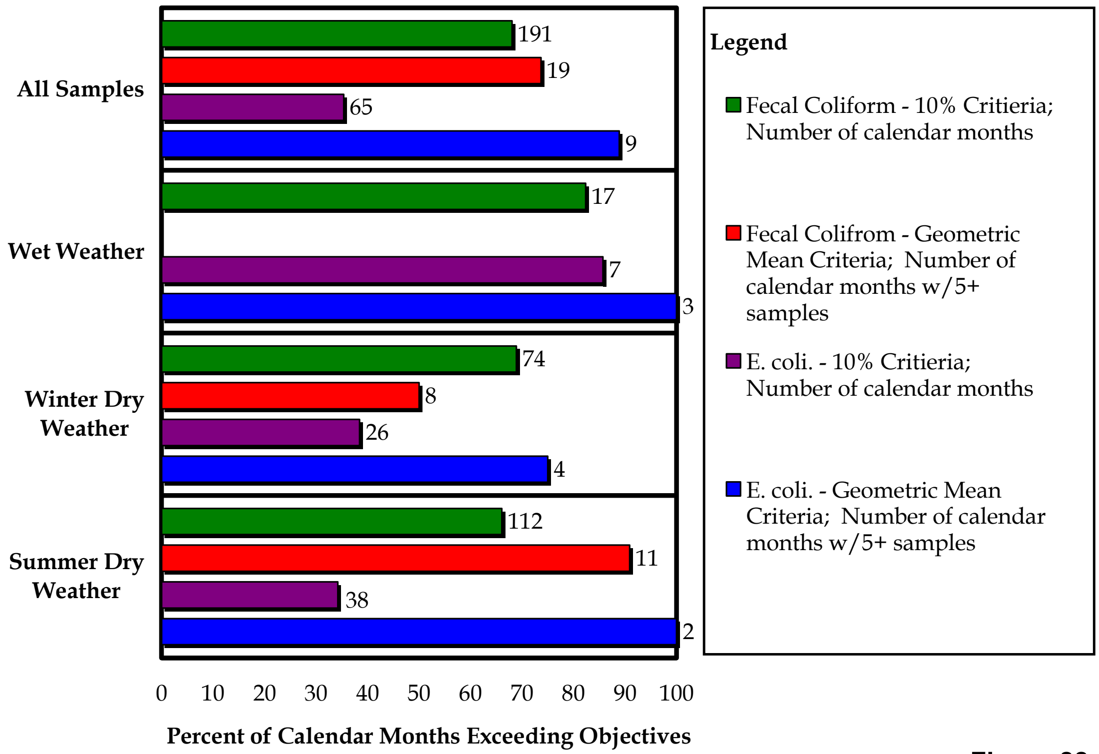

Figure 88
Comparison with Existing and Potential Bacteria Water Quality Objectives

Santa Ana River at MWD Crossing

Channel Section

This reach of the Santa Ana River exists within a predominantly naturally carved floodplain (Figure 89). Based on aerial photography it was estimated that the bankfull width of the Santa Ana River at MWD crossing is approximately 150 feet. Side slopes of 1:1 were estimated from field observations of the channel. The bed slope of the channel at this site is 2.0%. The study site is located upstream of the City of Riverside waste water treatment plant (WWTP) effluent channel (Figure 90)

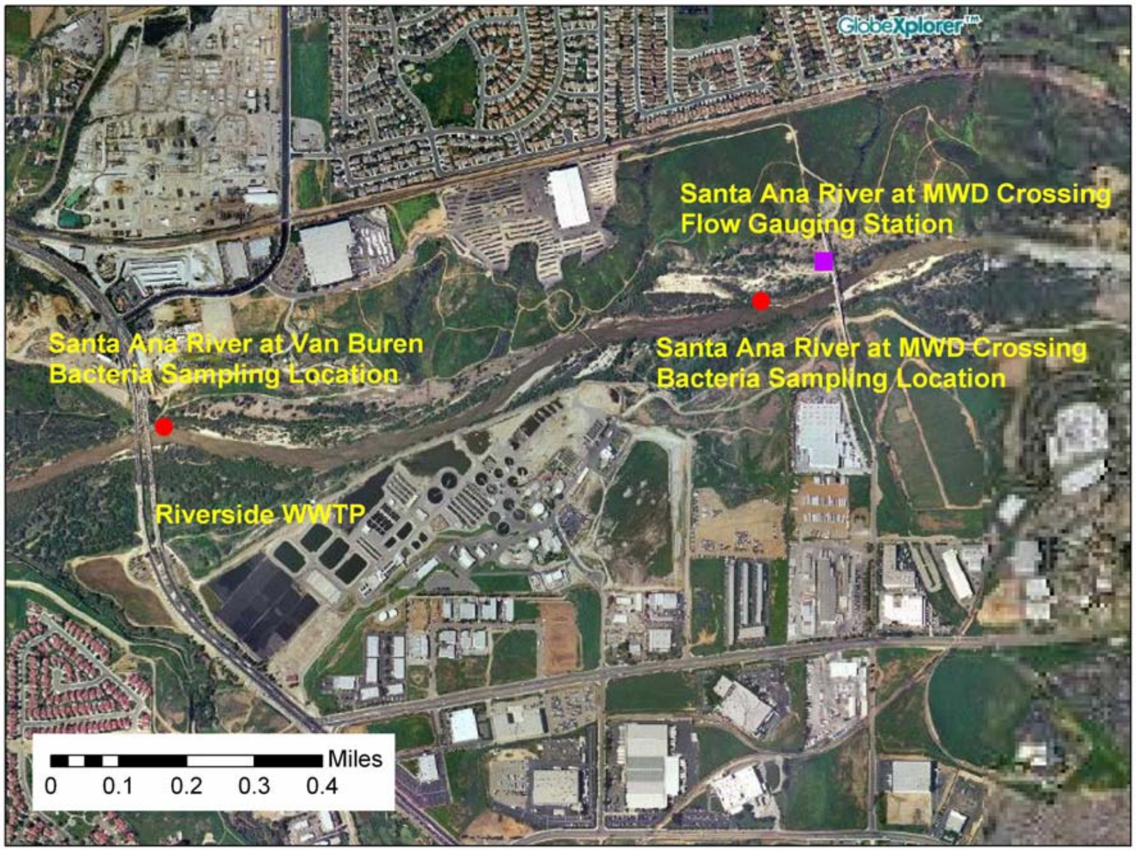

Figure 89
Aerial Photograph of the Santa Ana River at MWD Crossing Study Site

Figure 90
City of Riverside WWTP Effluent Channel

Drainage Area Characteristics

The watershed above the Santa Ana River at MWD Crossing is large and land use is diverse. The lower part of the watershed is a combination of commercial, residential, industrial, and agricultural lands. The upper part of the watershed includes natural undeveloped lands. Runoff from the San Bernardino National Forest enters the Santa Ana River upstream of the MWD crossing study site. Runoff from agricultural lands is routed to the Santa Ana River from areas south of the river. Runoff from industrial areas is routed to the river from the cities of San Bernardino, Colton, Rialto, Fontana, and Riverside. Residential land is dispersed throughout the contributing area.

Evidence of Recreational Activity

No direct evidence of recreational use was observed during the field visit. However, this site is a known recreational area for nearby communities, in spite of warnings in the form of international signs and newspaper announcements to not swim or bath in this section of the Santa Ana River. A limited use survey conducted from July to October 2004 occasionally observed swimmers in the area – either in the Santa Ana River or in an adjacent channel that carries treated effluent from the Riverside Regional Water Quality Treatment Plant to the Santa Ana River. In addition, a helicopter flyover video of the middle portion of the Santa Ana River showed people bathing in this reach of the river.

The recreational appeal of this site was evaluated during a site visit (Figure 91). There is plenty of space to park and the stream is easily accessible. Although no one was observed recreating in the water during this visit, the site scored relatively high in terms of recreational appeal.

Flow

The USGS mean daily flow record [USGS Gage 11066460] from 1970 through 2004 was used to plot a time series of flow at this site. Sources of water to this reach are varied. Streams such as Mill Creek and Lytle Creek route snowmelt from the San Bernardino Mountains to the Santa Ana River, although much of this runoff is captured for recharge within the San Bernardino groundwater basin. Effluent from WWTPs enters the Santa Ana River upstream of the MWD crossing in Colton and Rialto. These sources of water, in addition to urban dry weather flows and rising ground waters at Riverside Narrows, result in a year-round baseflow of 50-100 cfs in the river at the MWD crossing study site (Figure 92). Stormwater runoff from urban and mountain watersheds creates sharp increases in flow, as shown in the winter months of 1993-1994 (Figure 93).

Flow data was recorded in 15 minute intervals by the USGS at the Santa Ana River at MWD Crossing gauging station between 1988 and 2004. These data were used to develop frequency distributions of flow rate and depth in the channel (Figure 94 and Figure 95). Over the 15 year period, flow rates exceeded 1,000 cfs 1.5% of the time and flow depths exceeded 5 feet 2 % of the time.

Evaluation Criteria (Scale = Low - 0 to High - 3)	**Santa Ana River at Van Buren Blvd.**
Direct Evidence of Water Contact Recreation	0
Indirect Evidence of Recreational Activity	3
Ease of Access	2
Channel Slope	3
Concrete to Natural	3
Flow Depth and Volume	3
Flow Velocity	3
Water Quality Aesthetics	2
Vegetation Quality	2
Adjacent Land Use	1

Figure 91
Field Observation Checklist for the Santa Ana River at MWD Crossing Study Site

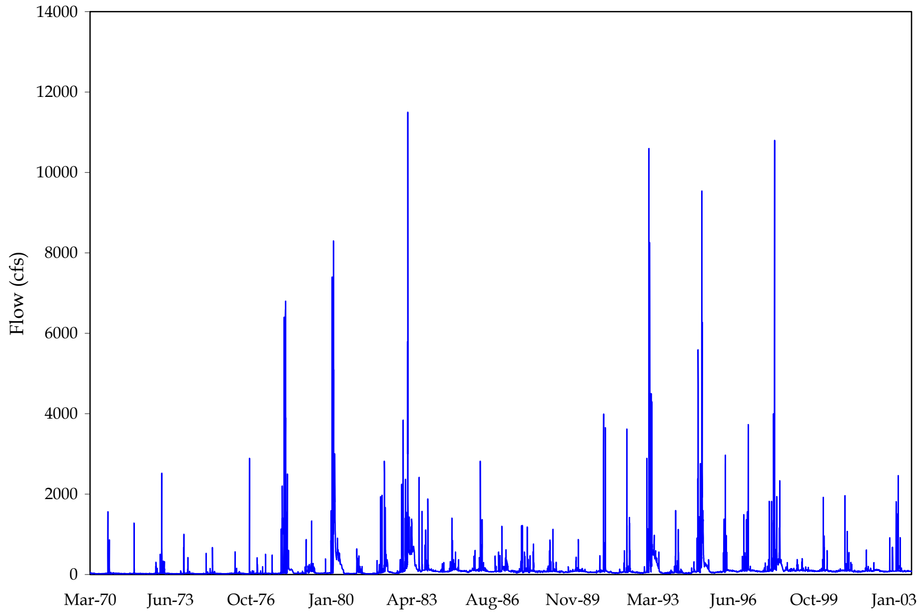

Figure 92
Mean Daily Flow in the Santa Ana River at MWD Crossing Study Site between 1969 and 2003

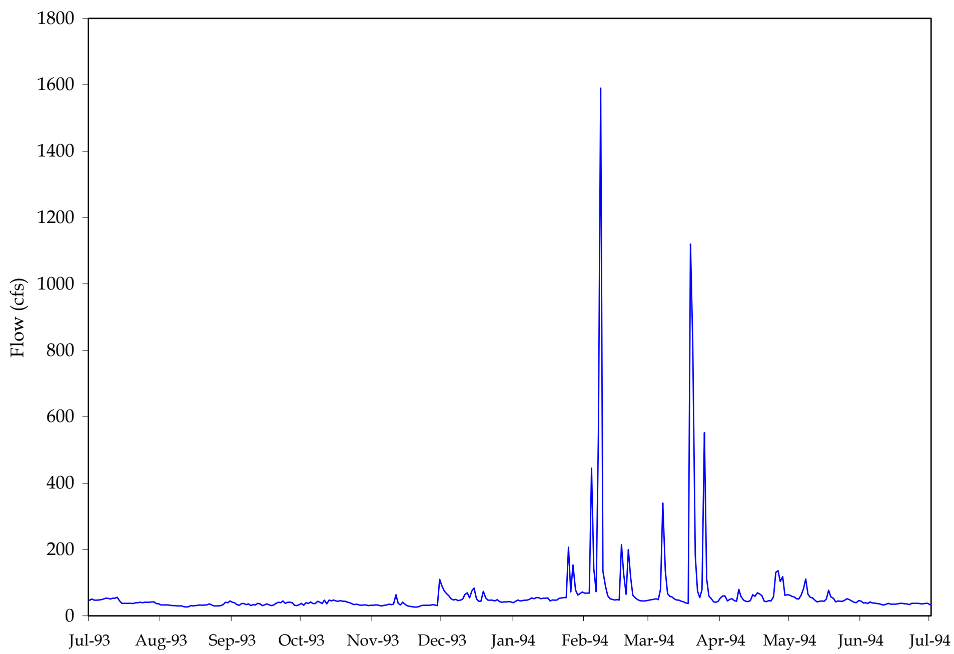

Figure 93
Mean Daily Flow in the Santa Ana River at MWD Crossing Study Site (7/1993 to 7/1994)

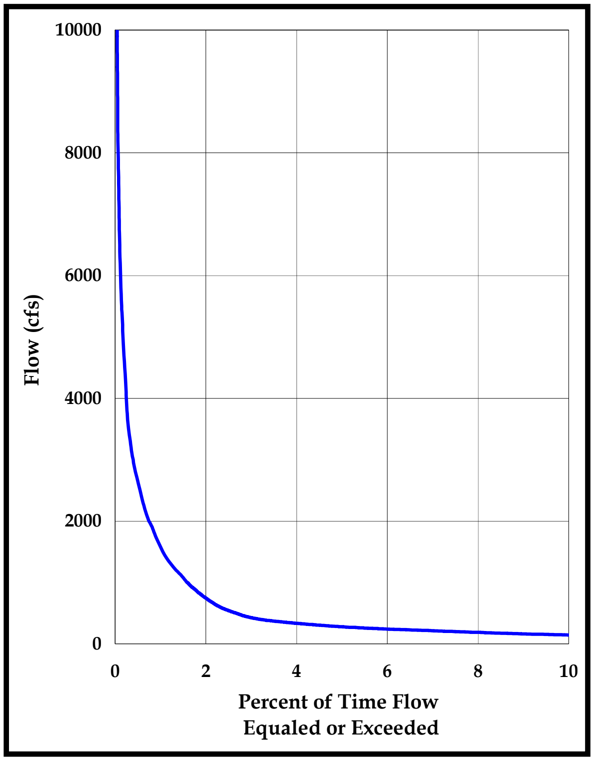

Figure 94
Channel Flow Curve for Santa Ana River at MWD Crossing (1988 – 2004)

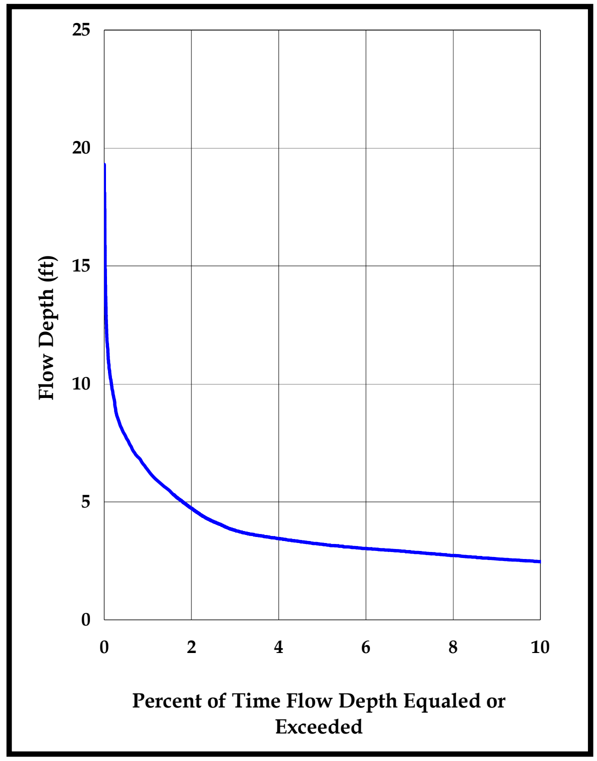

Figure 95
Channel Depth Curve for Santa Ana River at MWD Crossing (1988 – 2004)

Cumulative frequency curves of flow velocity and depth-velocity product between 1988 and 2004, are shown in Figure 96 and Figure 97. Between 1988 and 2004, flow velocities in the Santa Ana River at the MWD crossing study site exceeded 8 ft/sec for 0.5 % of the time and the depth-velocity product exceeded 10 ft^2/sec for 1% of the time.

Analysis of Bacteria Data

Fecal coliform and E. coli bacteria samples were collected from the Santa Ana River at the MWD crossing study site by the Riverside County Health Department and the Santa Ana Regional Water Quality Control Board between 1984 and 2004. Sampling occurred 3 times in 1984, weekly during the summer of 1985, twice during the summer of 1991 (as part of the Santa Ana Use Attainability Analysis Study), and about weekly since February of 2002.

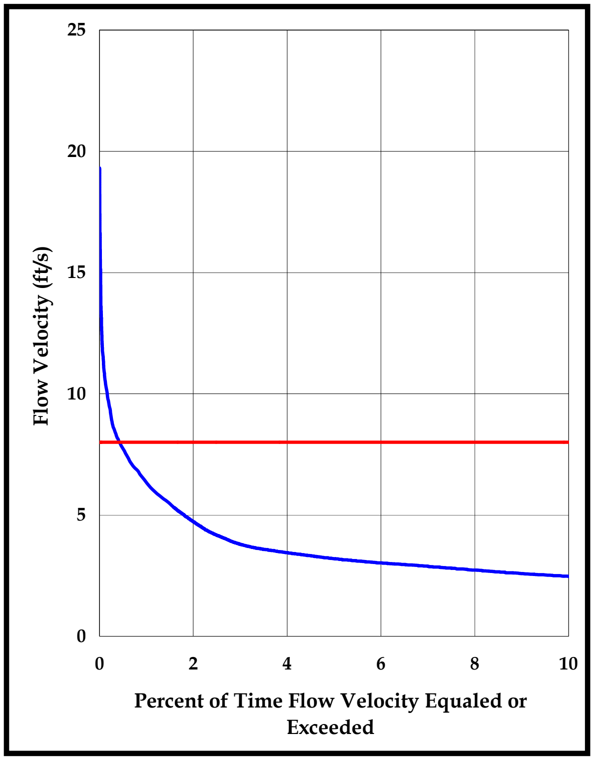

Figure 96
Channel Velocity Curve for the Santa Ana River at MWD Crossing Study Site (1988-2004)

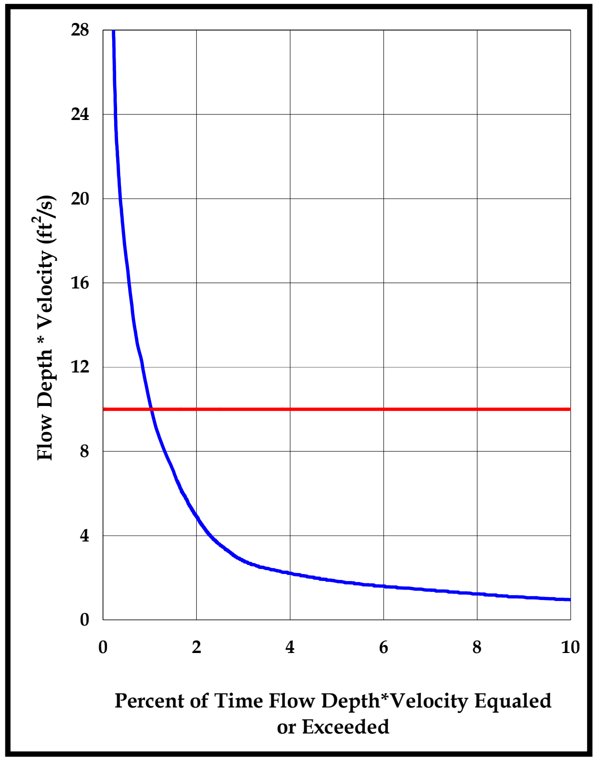

Figure 97
Channel Depth*Velocity Curve for the Santa Ana River at MWD Crossing Study Site (1988-2004)

Bacteria Trends

Figure 98 and Figure 99 provide time series plots of fecal coliform and E. coli bacteria concentrations and flow recorded in the Santa Ana River during summer 1985 and between December 2001 and June 2004, respectively. During summer 1985, fecal coliform and E. coli concentrations were regularly higher than the 10% of samples exceedance objective of 400 and 236 MPN/100mL, respectively. However, in recent years, fecal coliform and E. coli concentrations have only occasionally exceeded the 10% of samples exceedance threshold of 400 and 236 MPN/100mL, respectively. Both time series plots suggest that high flow events are not necessarily correlated with high bacteria counts.

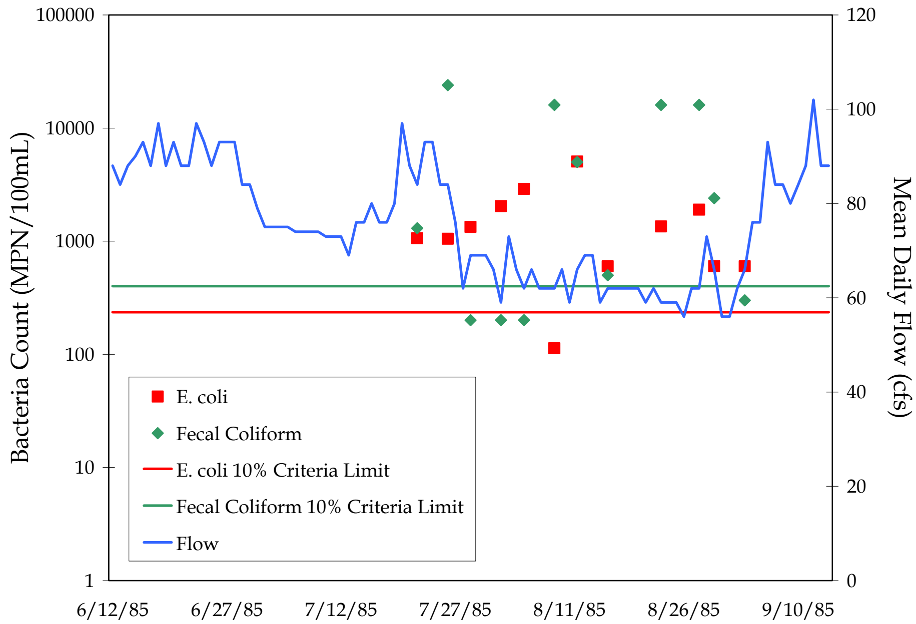

Figure 98
Time Series of Bacteria Concentrations and Flow in the Santa Ana River at the MWD Crossing Study Site

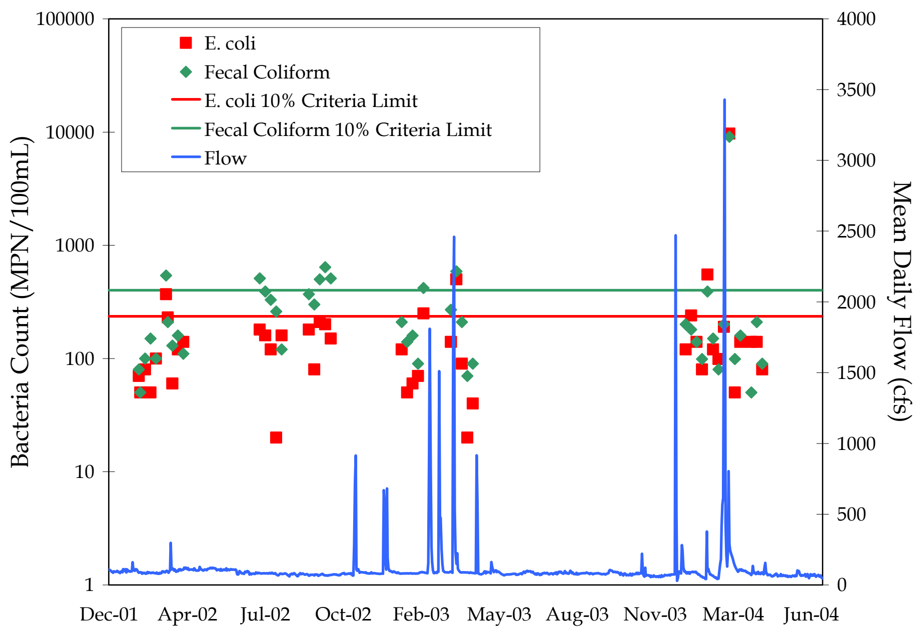

Figure 99
Time Series of Bacteria Concentrations and Flow in the Santa Ana River at the MWD Crossing Study Site

Single monthly results or monthly geometric means of bacteria data gathered during the last two years are summarized in Table 11 and plotted in Figure 100. Monthly geometric means for E. coli exceed proposed bacteria water quality objectives approximately two thirds of the time, while fecal coliform geometric means exceed existing water quality objectives approximately fifty percent of the time. There are no obvious trends in the data during this time period.

Table 11
Fecal Coliform and E. coli Concentrations in the Santa Ana River at MWD Crossing

Month	E. Coli Monthly Geometric Mean or Single Sample Results	Fecal coliform Monthly Geometric Mean or Single Sample Results	Sample Size
Jul-85	1141	1841	3
Aug-85	1152	2366	8
Sep-85	600	300	1
Feb-02	67	90	5
Mar-02	157	220	4
Apr-02	140	110	1
Jul-02	91	361	4
Aug-02	160	120	1
Sep-02	145	381	3
Oct-02	173	571	2
Jan-03	59	126	3
Feb-03	250	420	1
Mar-03	185	322	3
Apr-03	28	79	2
Jan-04	134	149	4
Feb-04	188	175	4
Mar-04	312	291	4
Apr-04	106	137	2

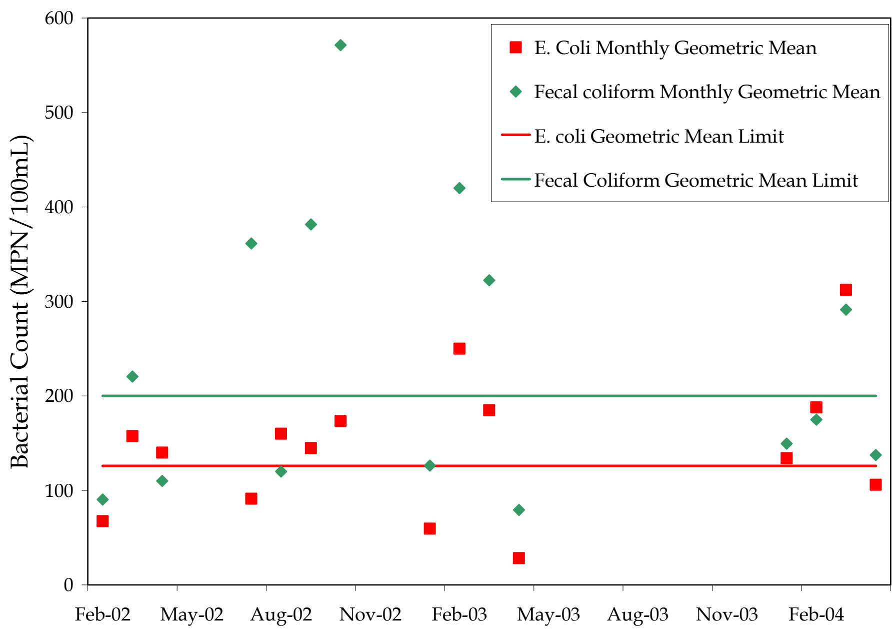

Figure 100
Monthly Single Sample Result or Geometric Mean of Sample Results for fecal coliform and E. coli in the Santa Ana River at the MWD crossing

The relatively strong correlation between fecal coliform and E. coli concentrations in the Santa Ana River at MWD Crossing indicates that regardless of the pathogen indicator used, exceedences of water quality objectives would have occurred (Figure 101).

Figure 102 shows the percentage of calendar months when existing fecal coliform and E. coli bacteria counts may have exceeded objectives. This figure shows the number of calendar months when sufficient water quality data was available to be compared to objectives (number at the end of each bar) and the percent of those calendar months that may have exceeded water quality objectives. Potential exceedences occurred during dry weather flows during both summer and winter months.

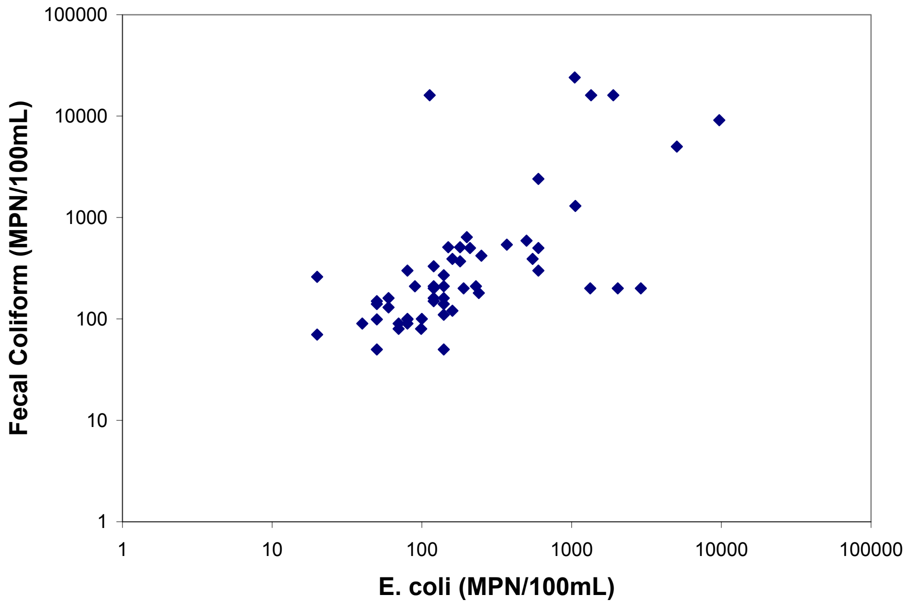

Figure 101
Relationship between E. coli and Fecal Coliform in the Santa Ana River at the MWD Crossing

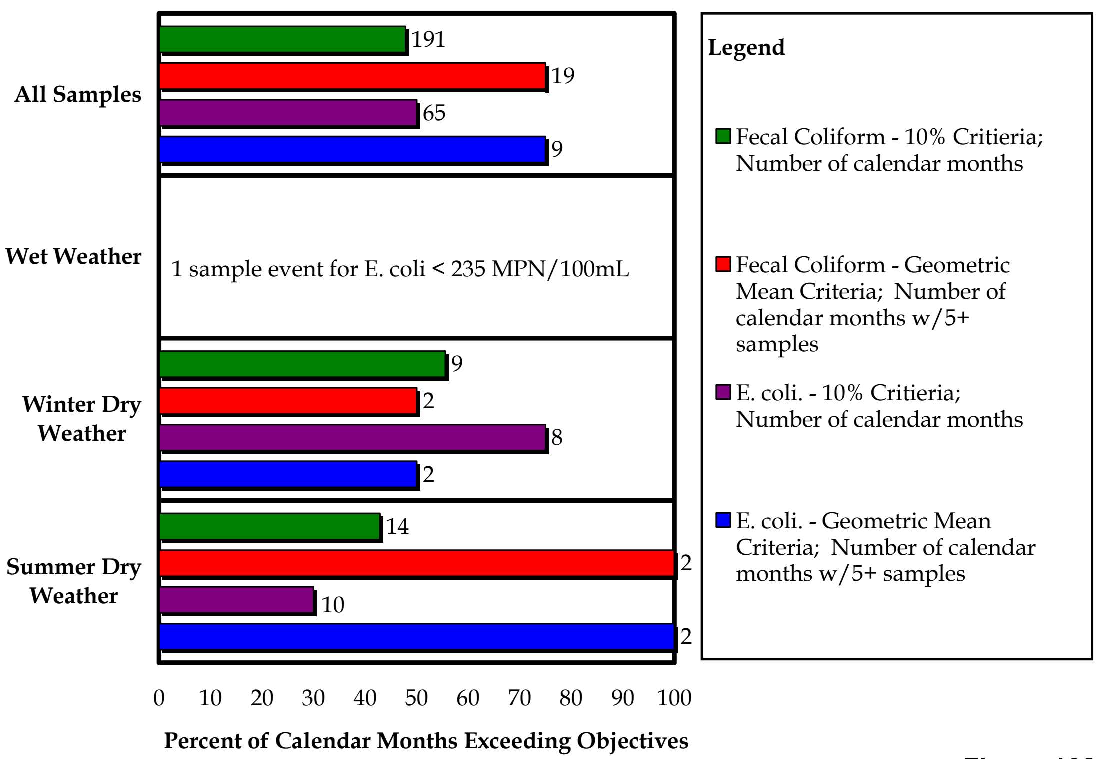

Figure 102
Comparison with Existing and Potential Bacteria Water Quality Objectives

Icehouse Canyon Creek

Channel Section

The Icehouse Canyon Creek study site is located in the Angeles National Forest at 5,100 feet above mean sea level at the Icehouse Canyon trailhead (Figure 103). The channel is a natural mountain stream about 10 feet wide with a bed slope that is significantly steeper than the other study site channels (Figure 104). This predominantly gravel bottom stream also includes large boulders and waterfalls in sections. Ambient water temperature is significantly lower than water temperatures in surface waters at lower elevations (Figure 105). These water temperatures were recorded at the time sample collection. The Icehouse Canyon Creek study site is included in the analysis to identify a background or naturally occurring bacteria condition.

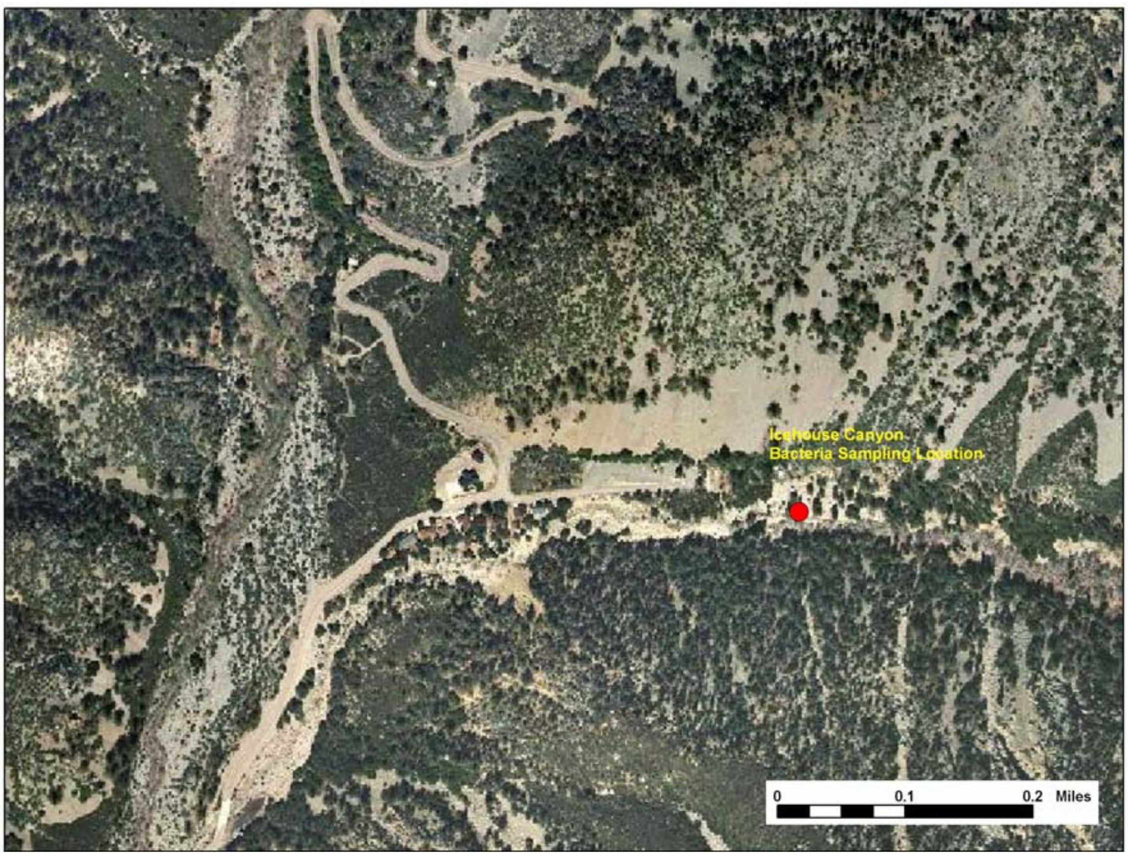

Figure 103
Aerial Photograph of the Icehouse Canyon Creek Study Site

Figure 104
Icehouse Canyon Creek Study Site

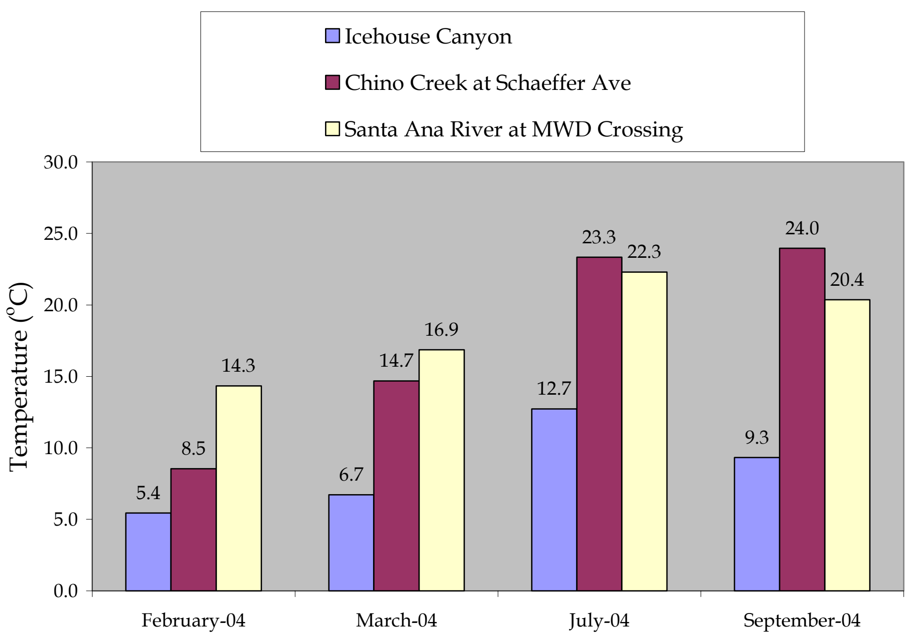

Figure 105
Water Temperature in Icehouse Canyon, Chino Creek at Schaeffer Ave, and Santa Ana River at MWD Crossing Study Sites

Drainage Area Characteristics

Icehouse Canyon Creek is a small headwater stream. The Icehouse Canyon Creek watershed is comprised of undeveloped land in the San Gabriel Mountains. The drainage area is very steep with intermittently dispersed trees and shrubs.

Evidence of Recreational Activity

Icehouse Canyon Creek is located alongside a regularly utilized hiking trail in the Angeles National Forest. The creek includes several pools and other areas where visitors can recreate. Although no one was observed recreating in the water, the results of the field observation checklist illustrate the recreational appeal of this site (Figure 106).

Evaluation Criteria (Scale = Low - 0 to High - 3)	**Santa Ana River at Van Buren Blvd.**
Direct Evidence of Water Contact Recreation	0
Indirect Evidence of Recreational Activity	3
Ease of Access	2
Channel Slope	3
Concrete to Natural	3
Flow Depth and Volume	3
Flow Velocity	3
Water Quality Aesthetics	2
Vegetation Quality	2
Adjacent Land Use	1

Figure 106
Field Observation Checklist for the Icehouse Canyon Study Site

Flow

This site does not have a flow gage; therefore, no data was available to characterize flow. Based on observations, spring flow provides a year-round water source during most years. Rocky ground cover coupled with steep watershed slopes will facilitate a quick increase in streamflow during wet weather events.

Analysis of Bacteria Data

Fecal coliform and E. coli bacteria samples were taken in Icehouse Canyon Creek as part of the Chino Basin TMDL monitoring program. Weekly bacteria samples were collected during wet weather months from February 2002 to present and during summer 2002.

Bacteria Trends

Figure 107 provides a time series plot of fecal coliform and E. coli bacteria concentrations recorded in Icehouse Canyon Creek. With one exception all sample results complied with existing or anticipated bacteria water quality objectives.

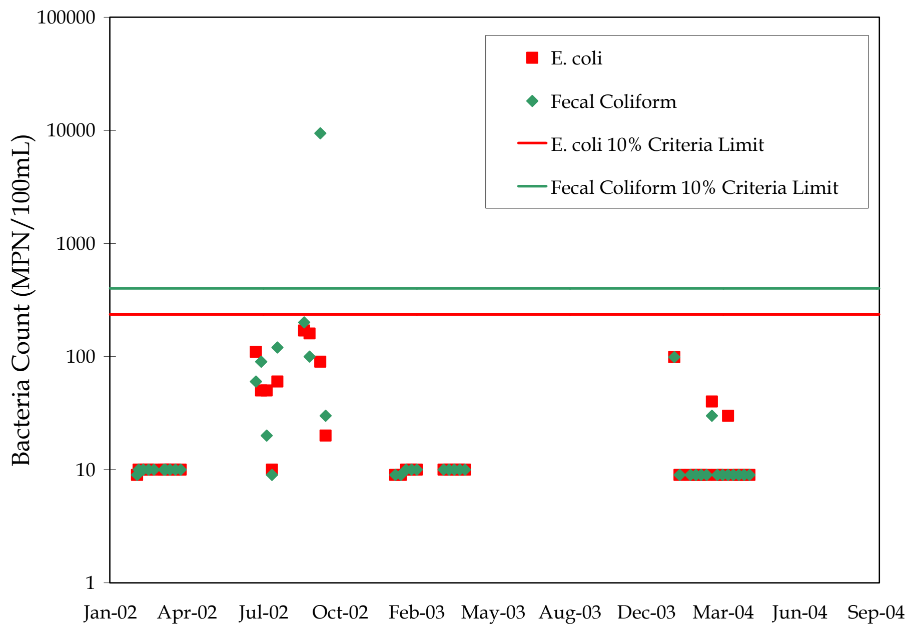

Figure 107
Time Series of Bacteria Counts and Flow in Icehouse Canyon Creek Study Site

Monthly single sample results or monthly geometric means of bacteria data for Icehouse Canyon Creek are summarized in Table 12 and plotted in Figure 108**.** With the exception of the summer of 2002, E. coli and fecal coliform monthly geometric means are relatively low.

The relatively strong correlation between fecal coliform and E. coli concentrations in Icehouse Canyon Creek indicates that regardless of the pathogen indicator used, exceedences of water quality objectives would have occurred (Figure 109).

Existing data shows that fecal coliform water quality objectives may have been exceeded on one occasion, with a bacteria count of 9,400 MPN/100mL on October 2, 2002. Excluding the sample size limitation, the proposed E. coli geometric mean standard of 126 MPN/100mL may have been exceeded in September and October of 2002 (Figure 110). This figure shows the number of calendar months when sufficient water quality data was available to be compared to objectives (number at the end of each bar) and the percent of those calendar months that may have exceeded water quality objectives.

Table 12
Fecal Coliform and E. coli Concentrations in Icehouse Canyon Creek

Month	E. coli Monthly Geometric Mean or Single Sample Results	Fecal coliform Monthly Geometric Mean or Single Sample Results	Sample Size
Feb-02	10	10	5
Mar-02	10	10	4
Apr-02	10	10	1
Jul-02	41	31	4
Aug-02	60	120	1
Sep-02	165	141	2
Oct-02	165	141	2
Jan-03	9	9	4
Feb-03	10	10	1
Mar-03	10	10	2
Apr-03	10	10	1
Jan-04	20	20	3
Feb-04	13	12	4
Mar-04	11	9	5
Apr-04	9	9	2

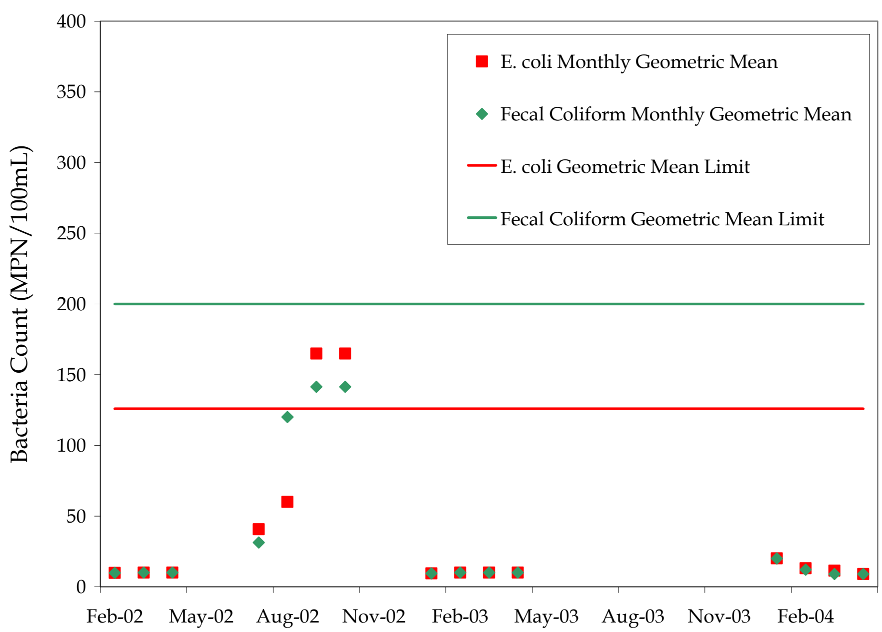

Figure 108
Monthly Single Sample Result or Geometric Mean of Fecal Coliform and E. coli in Icehouse Canyon Creek Study Site

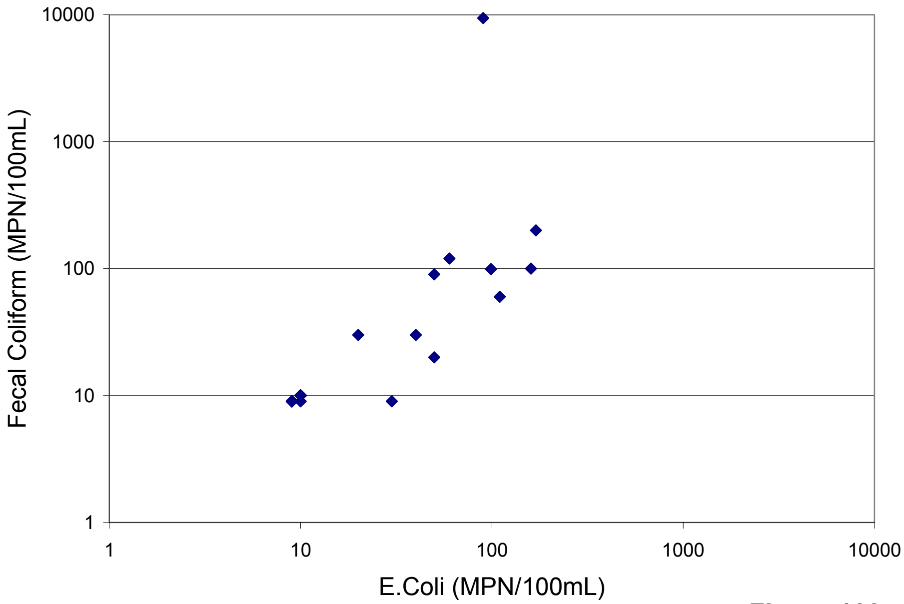

Figure 109
Relationship between E. coli and Fecal Coliform Concentrations in Icehouse Canyon Creek Study Site

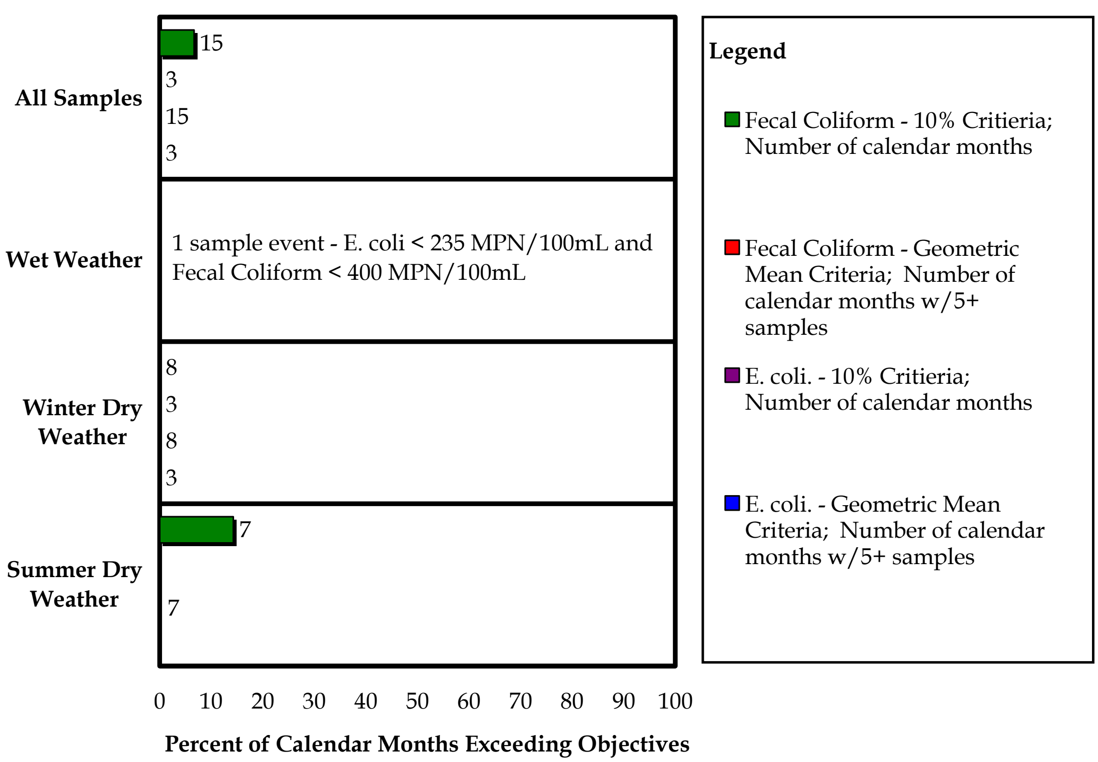

Figure 110
Comparison with Existing and Potential Bacteria Water Quality Objectives