Title
A short-term assessment of spatial and temporal variations in water quality of the San Lorenzo River

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A Short-Term Assessment of Spatial and Temporal Variations in Water Quality of the San Lorenzo River

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A report prepared for partial fulfillment of requirements for ENVS183

I. Introduction

The San Lorenzo River has nine major tributaries and is approximately twenty-eight miles long. The San Lorenzo River basin drains 135 square miles of land and empties into the northern end of Monterey Bay. An estimated 41,000 people and 17,174 developed parcels surround the upper reaches of the watershed; 13,000 properties dispose of sewage onsite (CSCWRP, 2001). A majority of the developed parcels are in towns (Felton, Mt. Hermon, Ben Lomond, Brookdale, Boulder Creek, Lompico and Zayante) that remain unincorporated under county jurisdiction. Zoning issues remain a major challenge in efforts to maintain water quality standards in the San Lorenzo River basin due to the unregulated nature of water that drains from properties as a result of failed or outdated septic systems, polluted runoff, and excessive sedimentation.

The San Lorenzo River is also a valuable habitat for many aquatic organisms, including the federally protected and endangered species, *Oncorhynchus mykiss* (Steelhead trout) and *Oncorhynchus kisutch* (Coho salmon). The San Lorenzo River historically supported one of the largest populations of steelhead south of San Francisco, with an estimated 20,000 spawning adults (Johansen, 1975). Water quality standards are particularly important for satisfying the needs of threatened or endangered species that depend on the surface waters (Killam, 2005). Regional water quality objectives have not been prioritized to suit standards warranted by the presence of federally protected species such as Steelhead and Coho salmon. At least partially as a result of this, local populations of both species have declined significantly over the past several decades, with Coho salmon thought to be approaching regional extinction within the next decade, and Steelhead stocks now comprising only ~500 spawning adults (Busby et al., 1996).

The San Lorenzo River system provides additional important ecosystem services to surrounding local communities. Primary beneficial uses of this watershed include designations for municipal water supply, contact water recreation, non-contact water recreation and uses associated with endangered species. Each listed beneficial use has a specific set of water quality standards that state regulatory authorities (including regional water quality control boards) are responsible for enforcing. The aforementioned uses are particularly threatened by the increased presence of nitrate, pathogens, turbidity, and toxic compounds within the watershed (CSCWRP, 2001).

Although total maximum daily load standards (TMDLs) have been set for the previously mentioned parameters, current general water quality data is insufficient for ensuring the San

Lorenzo River surface waters are at or below objective levels for multiple parameters that are unaccounted for in county records. Long term in-stream monitoring of the San Lorenzo River is necessary to assess normal deviations in criteria due to temporal and spatial variation as well as to ensure compliance with water quality standards.

I have completed a short-term water quality monitoring project to assess current conditions at two sites on the San Lorenzo River. Results of this work can be combined with other synoptic studies to assess longer-term trends, and can be used to design a more comprehensive monitoring program.

II. Setting

Ten sites were sampled along the San Lorenzo River (Figure II-1). Sampling intervals were site dependent; stream sites SL-3 and SL-9 were monitored daily, and all ten sites were monitored weekly. Weekly-monitored stream sites spanned the majority of urban areas situated alongside the river and covered the lower ~70% of the San Lorenzo River. Daily-monitored stream sites were chosen based upon variation in proximity to urban areas, distance from creek confluences, and ease of access. This paper focuses on sites SL-3 and SL-9 during the time period of 11 April 2011 – 9 May 2011. This period includes part of the transition from wet season (winter) to dry season (summer) conditions.

Sites SL-3 and SL-9 are located in the lower San Lorenzo River and are separated by ~10 km (Table II-1). Site SL-3 is located within Henry Cowell State Park, just south of Felton. Site SL-9 is located within downtown Santa Cruz, a heavily urbanized area, just upstream from the confluence with Branciforte Creek. Both sites are subjected to contamination issues believed to be primarily due to ambient waste management practices originating on public and private properties along the river.

III. Methods

A. Field Methods

Data was collected during thirty-three field sampling events. A multi-parameter water quality meter was used to measure physical and chemical water quality. Field measurements were made daily; data produced using the multi-parameter water quality meter include water temperature, pH, conductivity, oxidation-reduction potential, and total dissolved solids. Air temperature was determined using a digital thermometer. Both instruments were manually calibrated using calibration standards at weekly intervals.

Samples taken in the field for laboratory analysis were placed in two separate pre-washed containers; one sealed 100 ml container was used for bacteria samples, and one 500 ml plastic container was used for general water quality panel analysis. The samples were taken mid-stream at approximately 0.2 m depth with sterile gloves; both bottles were kept closed until submerged. Samples were immediately placed within an ice chest kept at 10°C and driven directly to the laboratory for analysis. Collection to delivery time of samples averaged no more than 90 minutes. The general water quality panel bottle had 2 ml of nitric acid added to it immediately upon arrival at the laboratory to increase holding time.

B. Laboratory Methods

Stream samples were taken to Monterey Bay Analytical Services for laboratory analysis. Weekly laboratory sampling events were conducted on five consecutive Monday mornings to control for potential temporal variances in analytes. Each sample was analyzed (using well-established laboratory methods) for the following components (with associated units): pH, electrical conductivity (µmhos/cm), alkalinity (mg/l), bicarbonate (mg/l), chloride (mg/l) , *E.coli* coliform (MPN/100 ml), total coliform (MPN/100 ml), calcium (mg/l) , dissolved oxygen (mg/l), fluoride (mg/l) , hardness (mg/l) , iron (µg/l), magnesium (mg/l) , manganese (µg/l) , nitrate (mg/l), o-phosphate (mg/l), potassium (mg/l), sodium (mg/l), sulfate (mg/l), total suspended solids (mg/l), and total dissolved solids (mg/l) (Table III-1).

IV. Results

Physical parameters such as water and air temperature fluctuated as expected. Site SL-9 showed consistently higher water temperature values relative to site SL-3. The pH readings at site SL-3 ranged from 7.49 to 7.89; similarly, pH at site SL-9 varied from 7.62 to 8.34 (Table IV-1). Field results demonstrate negative correlations between total dissolved solids and discharge as well as conductivity and discharge (Figure IV-1). Decreases in discharge dramatically lower the dilution rate of chemicals entering a stream; the results support this trend.

Chemical variables such as potassium, sulfate, hardness (as $CaCO_3$), and iron were spatially and temporally variable as well (Table IV-2). Common anions generally showed similar levels at both sites. More specifically, nitrate levels remained relatively constant at about 1 mg/l throughout the three weeks following April 11th. Iron levels tripled at both sites between April 11th and April 18th. *E.coli* abundance increased overall at both sites during the evaluation period, excluding an anomalous drop on April 25th. Total coliform increased progressively at similar intervals. Sodium levels showed gradual increases for both sites as well. Sulfate concentrations were nearly identical between the two sites; concentrations peaked on April 25th, and subsequently dropped the following week, only to begin rising again on May 9th (Figure IV-2).

V. Discussion

Most physical parameters remained within defined objective limits for both sites. Chemical parameters showed both spatial and temporal variations.

The pH at site SL-9 surpassed the upper objective limit (8.3) set by several primary beneficial uses 15.2% of the time. Site SL-3 remained within the upper and lower limits of its specified pH range (6.5-8.3) over the entire monitoring period.

Sulfate levels exceeded surface water quality objectives for each monitoring event at site SL-9. Objectives suggest concentrations no greater than 30 mg/l. Each sampling event detected levels ranging from 36% to 83% above 30 mg/l. Sodium surface water quality objectives were violated consistently at site SL-9 with levels reaching nearly 89% greater than the objective value of 0.2 mg/l.

The upper nitrate concentration limit for municipal and drinking water supply is 10 mg/l. Past water quality monitoring events demonstrate spring time nitrate averages close to 0.35 mg/l in the San Lorenzo River (SCCHS, 1995). Nitrate concentrations remained constant at 1 mg/l for both sites between April 11th and April 25th. Quantitative limitations of laboratory equipment prevented any measurements of nitrate higher than 1 mg/l from being detected, so it is not possible to say if nitrate concentration were above or below the upper objective concentration limit during times when 1 mg/l was reported. The San Lorenzo River is biologically limited by nitrate. Elevated levels of nitrate can cause blooms of harmful algal species that may further contaminate surface waters destined for municipal water supply or used for recreation. Additionally, the compounds that are produced from freshwater phytoplankton blooms, when mixed with additives from water treatment facilities, can produce carcinogenic byproducts that end up in drinking water (CSCWRP, 2001). Nitrate induced blooms may also have negative implications for trophically-associated species such as Coho salmon and Steelhead trout.

E.coli levels were slightly lower than the TMDL established limit of 126 MPN/100 ml between April 11th and May 2nd . However, the final week of sampling showed significant increases in *E.coli* above the established TMDL. *E.coli* acts as an indicator species for the presence of sewage or fecal waste in water wherein its abundance is closely associated with pathogen abundance. High levels of *E.coli* can severely hamper a water body's appropriated recreational beneficial uses, and have significant negative effects on human health.

VI. Summary

The San Lorenzo River was monitored for a variety of water quality parameters during a five week period using both field and laboratory measurements. Although many of the measured variables remained within water quality standards as determined by the Basin Plan in accord with the Clean Water Act, the results did indicate several violations. Violations occurred for pH, sodium, *E.coli*, and sulfate within this watershed. Many of the violations were spatially dependent and limited to site SL-9.

Water quality violations should be taken seriously due to the negative impact that elevated levels of the aforementioned surface water constituents can have on ecosystems and human health. This short-term study of water quality suggests that there is an increasing need for long-term water quality monitoring within the San Lorenzo River Watershed. The violations that occurred in the five week period are likely not limited to this time interval. As stream discharge decreases due to seasonal changes in precipitation, many parameters measured in this study will change dramatically. Additionally, important analytes such as trace metals were not evaluated; trace metals can have significant deleterious effects on human and ecosystem health in very small doses. The San Lorenzo River has numerous beneficial uses that may be unknowingly threatened due to this lack of monitoring, regulation and enforcement.

VII. References

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. "Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California." U.S. Department of Commerce, National Oceanic and Atmospheric Administration. NOAA Technical Memorandum NMFS-NWFSC-27, 275 pp.

County of Santa Cruz Water Resources Program 2001. Watershed Management Plan Update.

Johansen, R.R. 1975. State of California Resources Agency Department of Fish and Game. San Lorenzo River (Santa Cruz County) Winter Steelhead and Salmon Fishery, 1971-72 and 1972-73 Seasons.

Killam, Gayle. 2005. The River Network. The Clean Water Act: Owner’s Manual.

Santa Cruz County Health Services Agency. 1995. San Lorenzo Nitrate Management Plan, Phase II Final Report.

List of Figures

Figure II-1. Regional map of study locations. Open squares indicate field sites that were monitored, but not included within this paper. Closed squares are labeled by site, and were discussed within this paper.

Figure IV-1. Discharge and water quality parameters measured daily. A. Average daily discharge of San Lorenzo River, measured at USGS sites 11160500 (SL-3) and 11161000 (SL-9). B. Daily field measurements of total dissolved solids at stream sites SL-3 and SL-9. C. Daily field measurements of conductivity at stream sites SL-3 and SL-9.

Figure IV-2. Analyte concentrations measured weekly for five weeks. A. Sulfate concentrations for stream sites SL-3 and SL-9. B. Sodium concentrations for stream sites SL-3 and SL-9. C. *Escherichia coli* coliform concentrations for stream sites SL-3 and SL-9. D. Total coliform concentrations for stream sites SL-3 and SL-9, sampled for five weeks at weekly intervals for laboratory analysis.

List of Tables

Table II-1. List of study locations included within this paper with associated latitudinal and longitudinal coordinates.

Table III-1. List of standard laboratory methods for measuring listed analytes.

Table IV-1. Field measurements of various physical and chemical parameters at two stream sites and thirty-three time periods. Variables include water temperature (W. Temp.), air temperature (A. Temp.), pH, conductivity (E.C.), oxidation-reduction potential (ORP), total dissolved solids (TDS), and discharge (Discharge).

Table IV-2. Laboratory results from samples at two stream sites and six time periods. Analytes include pH, specific conductivity (E.C.), alkalinity, bicarbonate, chloride, *E.coli* coliform, total coliform, calcium, dissolved oxygen, fluoride, hardness, iron, magnesium, manganese, nitrate, o-phosphate, potassium, sodium, sulfate, total suspended solids (TSS), and total dissolved solids (TDS).

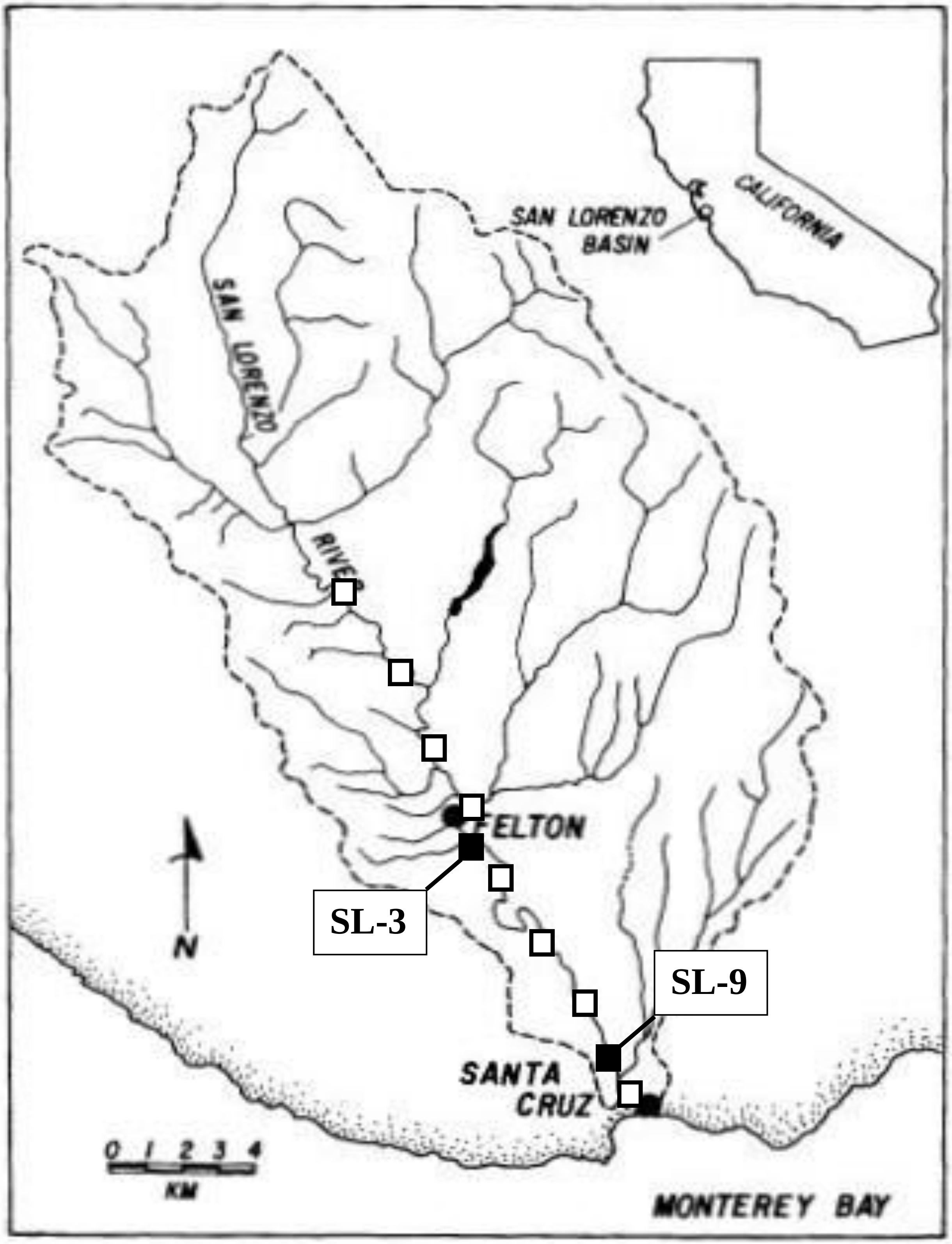
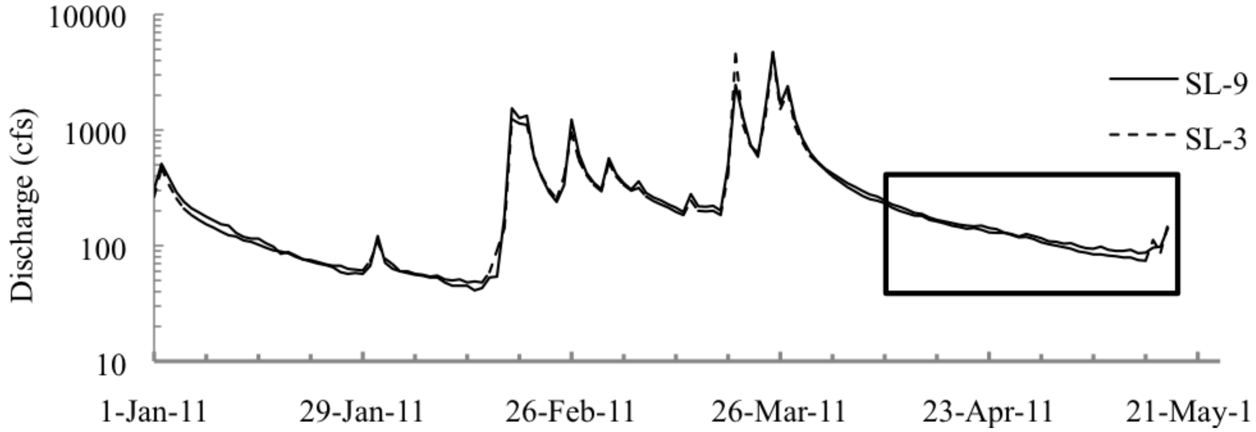

SAN LORENZO
BASIN
CALIFORNIA
SAN LORENZO
RIVER
FELTON
SL-3
SL-9
N
SANTA
CRUZ
0 1 2 3 4
KM
MONTEREY BAY

Figure II

A



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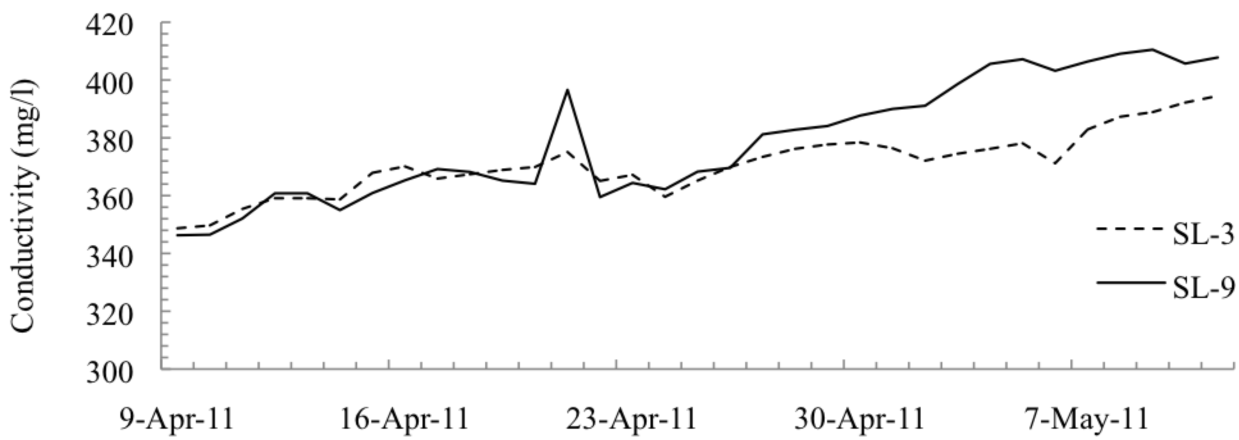

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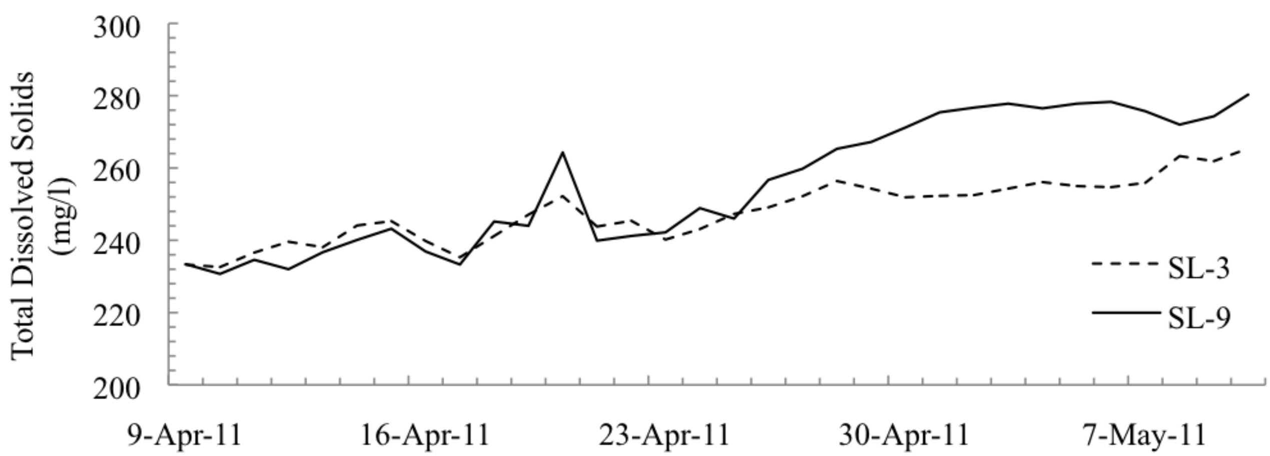
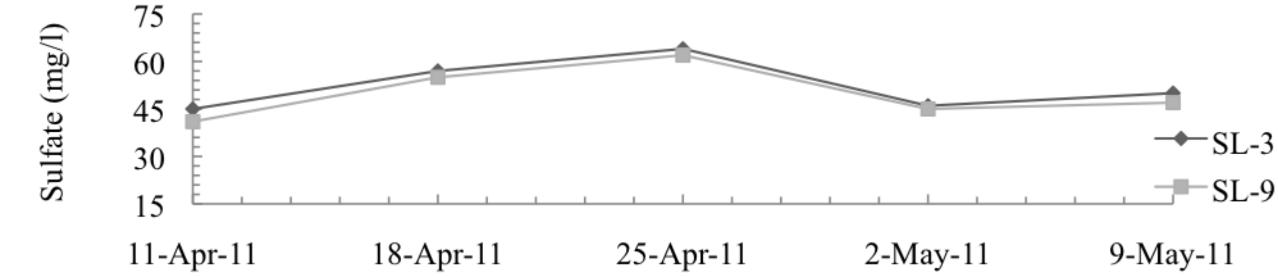


Figure IV-1

A



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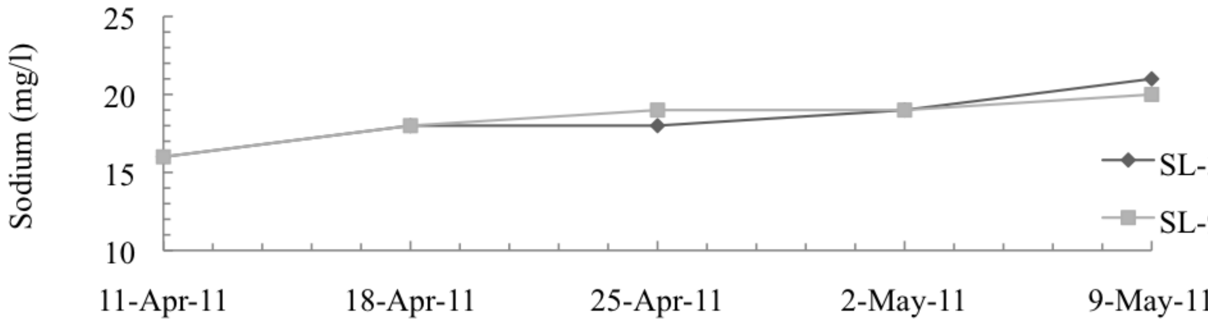

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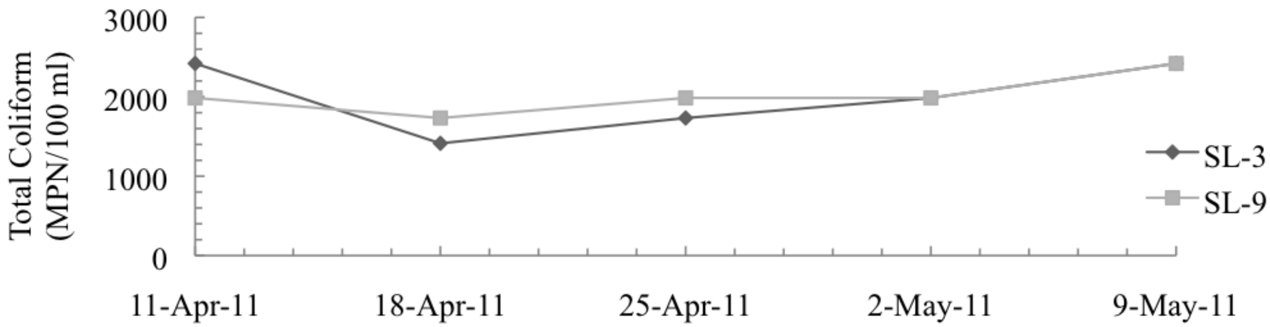

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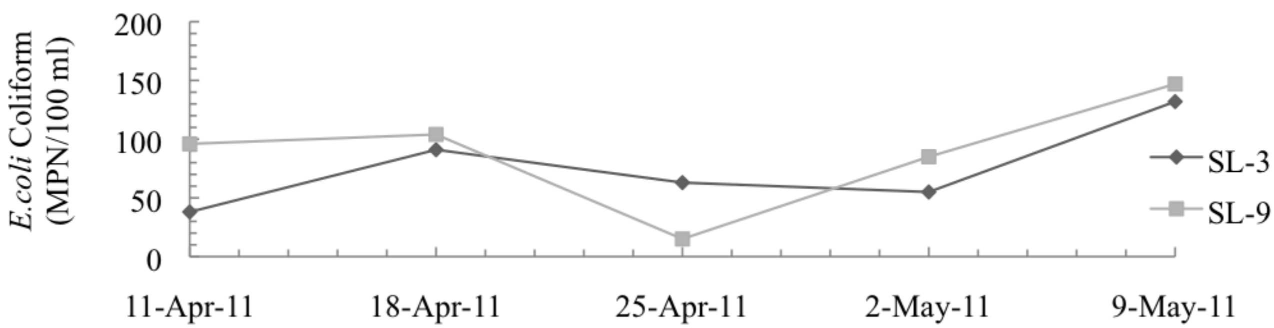

Figure IV-2

Table II-1

Site Description	**Site Tag**	**Latitude**	**Longitude**
SLR at Henry Cowell Bridge	SL-3	37.0440	-122.0713
SLR at San Lorenzo Park	SL-9	36.9771	-122.0240

Table III-1

Analyte	**Method**
pH	4500-H+B
E.C.	2510B
Alkalinity	2320B
Bicarbonate	2320B
Chloride	EPA300.0
Coliform, *E.coli*	9223
Coliform, total	9223
Calcium	EPA200.7
Dissolved Oxygen	4500-O G
Fluoride	EPA300.0
Hardness	2340B
Iron	EPA200.7
Magnesium	EPA200.7
Manganese	EPA200.7
Nitrate	EPA200.7
o-Phosphate	EPA300.0
Potassium	EPA200.7
Sodium	EPA200.7
Sulfate	EPA300.0
TDS	2540C
TSS	SM2540D

Table IV-1

Site	Date	Time	W. Temp. (°C)	A. Temp. °C)	pH	E.C. (μs)	ORP (ohms)	TDS (ppm)	Discharge (cfs)
SL-3	9-Apr	1:07 PM	9.3	20	7.65	348.7	215	233.3	233
SL-9	9-Apr	4:01 PM	11.9	21	8.01	346.3	183	233.4	246
SL-3	10-Apr	11:55 AM	10.6	16	7.65	349.7	179	232.6	213
SL-9	10-Apr	12:20 PM	11.9	17	7.92	346.5	147	230.7	227
SL-3	11-Apr	8:15 AM	10.1	15	7.59	355.4	257	236.6	200
SL-9	11-Apr	8:35 AM	10.4	15	8.19	352.1	204	234.6	217
SL-3	12-Apr	8:30 AM	9.8	16	7.6	359.1	241	239.6	191
SL-9	12-Apr	10:40 AM	11.3	16	7.89	360.8	232	232	205
SL-3	13-Apr	4:00 PM	11.9	19	7.54	358.7	266	238.1	182
SL-9	13-Apr	4:30 PM	12.2	19	7.62	355	234	236.7	192
SL-3	14-Apr	11:00 AM	10.2	14	7.49	367.9	273	244.1	181
SL-9	14-Apr	11:30 AM	11.9	14	7.62	360.9	181	240.1	188
SL-3	15-Apr	9:02 AM	10.8	16	7.83	370.1	270	245.3	167
SL-9	15-Apr	9:40 AM	11.7	16	8.12	365.3	176	243.2	175
SL-3	16-Apr	8:12 AM	11.6	16	7.76	365.9	265	239.8	162
SL-9	16-Apr	8:49 AM	12.8	16	8.23	369.2	191	236.9	167
SL-3	17-Apr	9:00 AM	12.5	17	7.75	367.4	260	235.3	156
SL-9	17-Apr	9:30 AM	12.9	17	8.34	368.2	185	233.3	162
SL-3	18-Apr	9:04 AM	12	16	7.8	368.9	254	241.2	149
SL-9	18-Apr	9:45 AM	12.8	16	8.12	365.2	196	245.2	157
SL-3	19-Apr	11:15 AM	13.1	16	7.58	369.9	277	247.1	145
SL-9	19-Apr	12:05 PM	14.8	17	8.06	364.1	214	244	152
SL-3	20-Apr	6:00 PM	14.8	16	7.68	375.1	252	252.2	140
SL-9	20-Apr	6:39 PM	15.6	16	8.32	396.6	176	264.3	149
SL-3	21-Apr	12:00 PM	12.9	15	7.59	365.1	271	243.8	142
SL-9	21-Apr	12:20 PM	14.5	15	7.96	359.5	226	239.9	147
SL-3	22-Apr	11:00 AM	12.1	17	7.76	367.2	269	245.4	137

SL-9	22-Apr	11:30 AM	13	17	8.01	364.4	231	241.2	149
SL-3	23-Apr	1:34 PM	13.9	16	7.8	359.6	171	240.2	130
SL-9	23-Apr	3:30 PM	15.3	16	8.34	362.2	165	242.2	142
SL-3	24-Apr	9:00 AM	12.4	15	7.78	365.2	180	243.1	129
SL-9	24-Apr	9:34 AM	13	16	8.1	368.3	172	248.9	139
SL-3	25-Apr	9:38 AM	12.1	16	7.76	369.9	276	247.3	129
SL-9	25-Apr	10:45 AM	12.7	16	7.98	369.6	232	246	130
SL-3	26-Apr	8:03 AM	11.2	15	7.7	373.4	264	248.4	124
SL-9	26-Apr	8:37 AM	12.1	15	8.02	381.2	198	252.3	126
SL-3	27-Apr	8:49 AM	11.8	16	7.81	376.2	247	249.1	118
SL-9	27-Apr	9:14 AM	12.5	16	8.12	382.8	196	256.7	120
SL-3	28-Apr	9:39 AM	11.9	17	7.89	377.7	231	252.2	119
SL-9	28-Apr	10:01 AM	12.7	17	8.23	384.1	191	259.8	126
SL-3	29-Apr	8:40 AM	12.2	17	7.75	378.4	222	256.4	114
SL-9	29-Apr	9:05 AM	13.3	17	8.34	387.7	186	265.3	121
SL-3	30-Apr	9:03 AM	11.5	16	7.84	376.4	219	254.3	107
SL-9	30-Apr	9:29 AM	12.8	16	8.24	390	190	267.2	116
SL-3	1-May	10:49 AM	12.6	17	7.69	372.1	238	251.9	103
SL-9	1-May	11:15 AM	13.6	17	8.09	391.1	179	271.2	109
SL-3	2-May	8:33 AM	11	15	7.79	374.5	245	252.3	100
SL-9	2-May	9:01 AM	12.3	15	8.15	398.6	184	275.4	108
SL-3	3-May	11:35 AM	14.6	19	7.77	376.2	253	252.5	97
SL-9	3-May	12:01 PM	15.3	20	8.33	405.6	172	276.7	104
SL-3	4-May	8:25 AM	10.9	15	7.86	378.1	243	254.3	94
SL-9	4-May	8:57 AM	11.8	15	8.19	407.2	187	277.8	105
SL-3	5-May	9:03 AM	12.1	16	7.78	371.2	235	256.1	89
SL-9	5-May	9:34 AM	13.4	16	8.13	403.2	171	276.5	99
SL-3	6-May	8:01 AM	11.6	15	7.71	382.9	222	255	87
SL-9	6-May	8:42 AM	13	15	8.23	406.4	179	277.8	95

SL-3	7-May	9:04 AM	11.8	16	7.75	387.3	234	254.7	84
SL-9	7-May	9:30 AM	12.4	16	8.16	409.1	184	278.3	94
SL-3	8-May	10:02 AM	12.6	17	7.65	388.9	256	255.9	84
SL-9	8-May	10:28 AM	13.8	17	8.01	410.5	188	275.7	98
SL-3	9-May	9:00 AM	11.5	15	7.69	392.2	275	263.3	82
SL-9	9-May	9:25 AM	12.6	15	7.94	405.7	184	272	92
SL-3	10-May	8:45 AM	11.2	16	7.79	394.5	272	261.9	81
SL-9	10-May	9:17 AM	11.9	16	7.97	407.8	178	274.3	90
SL-3	11-May	10:00 AM	12.1	17	7.56	397.1	269	265.4	79
SL-9	11-May	10:29 AM	12.9	18	7.92	408.3	168	280.3	90
SL-3	12-May	9:35 AM	11.8	16	7.68	395.8	270	267.4	79
SL-9	12-May	10:00 AM	11.4	16	8.09	402.3	172	279.3	92
SL-3	13-May	8:01 AM	11.2	16	7.77	396.9	265	263.4	75
SL-9	13-May	8:43 AM	11.9	16	8.15	400.1	179	269.9	86
SL-3	14-May	10:01 AM	12.8	17	7.84	393.3	224	260.9	74
SL-9	14-May	10:39 AM	13.6	17	8.34	394.4	186	267.8	87
SL-3	15-May	8:24 AM	11.1	16	7.79	396.7	232	262.5	112
SL-9	15-May	9:02 AM	12.6	16	8.26	401.2	190	270.4	96
SL-3	16-May	10:39 AM	13.8	17	7.8	398.9	228	264.4	87
SL-9	16-May	11:14 AM	14.8	17	8.19	402.3	176	271.4	98

Table IV-2

	SL-3	SL-9	SL-3	SL-9	SL-3	SL-9	SL-3	SL-9	SL-3	SL-9
Date	11-Apr	11-Apr	18-Apr	18-Apr	25-Apr	25-Apr	2-May	2-May	9-May	9-May
pH	7.9	8	7.9	8	7.8	7.9	7.9	8.2	7.8	8.1
E.C. (µmhos/cm)	334	336	349	338	340	343	349	356	364	353
Alkalinity (mg/l)	92	91	97	98	100	101	106	107	108	109
Bicarbonate (mg/l)	ND	ND	118	120	122	123	129	131	132	133
Chloride (mg/l)	13	13	13	14	17	17	15	16	17	18
Coliform, *E.coli* (MPN/100 ml)	38	96	91	104	63	15	55	85	132	147
Coliform, total (MPN/100 ml)	2420	1986	1414	1733	1733	1986	1986	1986	>2420	2420
Calcium (mg/l)	36	36	41	40	41	40	44	42	44	42
Dissolved Oxygen (mg/l)	11.7	11.1	10.9	10.9	10.91	10.89	10.7	11.5	11.3	11.8
Fluoride (mg/l)	0.09	0.09	0.1	0.1	0.09	0.09	0.12	0.11	0.14	0.13
Hardness (mg/l)	123	123	139	133	139	137	143	142	147	142
Iron (µg/l)	51	44	139	147	132	144	123	145	60	150
Magnesium (mg/l)	8	8	9	8	9	9	8	9	9	9
Manganese (µg/l)	14	11	18	15	18	15	23	20	ND	24
Nitrate (mg/l)	1	1	1	1	1	ND	ND	0.29	1	ND
o-Phosphate (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potassium (mg/l)	1.6	1.7	1.9	1.9	1.8	2.2	1.8	1.9	1.8	1.8
Sodium (mg/l)	16	16	18	18	18	19	19	19	21	20
Sulfate (mg/l)	45	41	57	55	64	62	46	45	50	47
TDS (mg/l)	228	236	243	245	225	220	235	220	250	248
TSS (mg/l)	ND	6	ND	ND	ND	ND	ND	ND	ND	ND

*ND signifies that the analyte was not detected in the water sample.