Characterization of water quality in the Los Angeles River

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ABSTRACT - The Los Angeles River is one of the most highly modified water systems in the world. Dramatic engineering modifications to control the river have successfully reduced flooding and property damage, but little of this design has incorporated water quality improvements. The goal of this study was to identify sources of potential pollutants and characterize water quality along the river's seven reaches during dry weather. The three primary sources of potential pollutants included water reclamation plants (WRPs), major tributaries, and storm drain outfalls.

The three WRPs discharged the majority (72%) of the volume flowing in the Los Angeles River during this study. Likewise, the three WRPs discharged the highest concentrations and greatest mass emissions of nutrients including nitrate, nitrite, ammonia, and total phosphate. In contrast, 66 flowing storm drains and 6 flowing tributaries had the highest concentrations and mass emissions of bacteria including total coliform, *E. coli*, and *Enterococcus*.

Water quality in the Los Angeles River responded to inputs of these pollutants. Levels of nutrients were generally low upstream and downstream of the WRPs (<0.1 mg/L ammonia), but were greatest in the immediate vicinity of the WRPs (approximately 6 mg/L ammonia). Concentrations of bacteria were generally high upstream and downstream of the WRPs (ca. 10^4 MPN/100 mL *E. coli*), but were lowest in the immediate vicinity of the WRPs (ca. 10^2 MPN/100 mL *E. coli*).

INTRODUCTION

The Los Angeles River drains most of Los Angeles County and may be one of the most highly modified watersheds in the world (Brownlie and Taylor 1981). The watershed is 49% developed and 30% impervious. Much of the channel is concrete-lined, an effort to reduce flooding and to protect property. However, the successful efforts at flood control have resulted in loss of habitat and degraded water quality throughout much of the river system (Cross *et al.* 1992, LADPW 2000).

Habitat and water quality degradation has prompted the Los Angeles Regional Water Quality Control Board (LARWQCB) to add much of the river and many of its tributaries to the state/federal list of impaired waterbodies, the §303(d) list. The Clean Water Act stipulates that waterbodies on the §303(d) list are required to develop total maximum daily loads (TMDLs). The goal of TMDLs is to achieve water quality objectives in the receiving waterbody. As part of the TMDL process, there is a need to characterize the problem (impairment) that led to the listing, identify the sources of pollutant inputs, establish the target needed to achieve water quality standards, conduct a linkage analysis whereby the sources are linked to receiving waterbody impairment, and finally establish waste load and load allocations for each point and nonpoint source in order to reduce the loading.

The goal of this study was characterize the water quality in the Los Angeles River and the various loads to the system.

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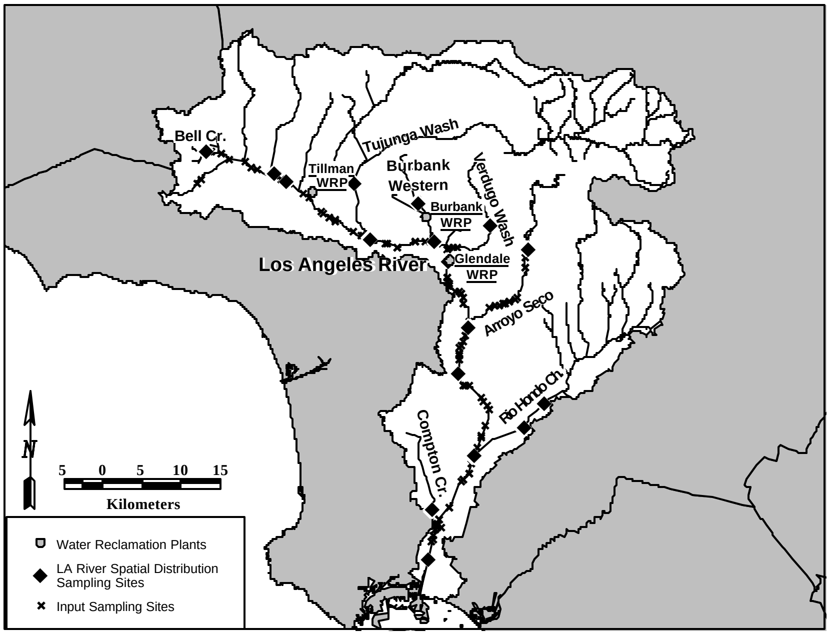

Figure 1. Map of the Los Angeles River watershed, listed streams, and sampling locations along the mainstem, at the head of tributaries, at point sources, and at storm drain outfalls to the river.

METHODS

This study was comprised of two parts. The first identified and sampled the inputs to the Los Angeles River and major tributaries. The second sampled the mainstem of Los Angeles River to assess spatial distributions of water quality. The input monitoring was conducted using citizen volunteers. Monitoring the spatial distribution of water quality was conducting using professionals. Samples from both surveys were submitted to a state-certified laboratory for chemical analysis.

The Watershed

The Los Angeles River extends 56 miles, starting from its headwaters in the San Fernando Valley, flowing past downtown Los Angeles, and eventually draining to San Pedro Bay near Long Beach (Figure 1). The watershed is 834 mi^2 and is comprised of residential (35%), commercial (5%), industrial (8%), and open land (51%) uses. The river is divided into nine reaches and seven tributary reaches. The mainstem and tributaries are listed as impaired waterbodies for many constituents including nutrients (N), bacteria (fecal coliform), and trace metals (copper, lead, and zinc).

Input Sampling

Inputs to the Los Angeles River were sampled on September 10, 2000. Input sources included three water reclamation plants (WRPs) that use tertiary treatment for municipal and industrial wastes and discharge their effluents to the river. Glendale WRP discharges directly to the Los Angeles River. Tillman WRP discharges through three outfalls; approximately 37% of the flow discharges to a recreational lake and 11% of the flow discharges to a wildlife lake, both of which ultimately discharge to the Los Angeles River. The third outfall, comprising approximately 52% of the Tillman WRP flow, discharges directly to the Los Angeles River. The Burbank WRP discharges to the Burbank-Western Channel, a major tributary, which is just upstream of its confluence with the Los Angeles River. Numerous industrial facilities discharge to the Los Angeles River, but the vast majority only discharge surface runoff during storm events.

Unlike WRP or industrial facilities, the municipal storm drainage system has hundreds of outfalls that receive no treatment prior to discharge to the Los Angeles River. During this study, citizen monitors walked 54 miles of the river and 15 miles of tributaries identifying, documenting, and eventually sampling each flowing outfall encountered. The volunteers had been trained to collect samples in accordance with standard protocols during a one-day class held prior to their field assignment.

Visual observations were made of the outfall size and location, flow, and general characteristics (such as water discoloration; the presence of foam or oily sheens, trash or algae; and water quality). Flow was measured using either timed-volumetric or depth-velocity methods. Water quality parameters included flow, total suspended solids (TSS), total organic carbon (TOC), biological oxygen demand (BOD_5), nutrients (nitrate, nitrite, ammonia, TKN, and total phosphorous), and trace metals (cadmium, chromium, copper, iron, lead, nickel, mercury, and zinc). All laboratory analyses followed protocols approved by the U.S. EPA (1983) and Standard Methods (APHA 2000).

Spatial Distribution Sampling

Sampling of eight locations along the mainstem of the Los Angeles River, and at the head of all seven tributaries, was accomplished on September 11, 2000. Each location represents each of the 303(d) listed reaches in the watershed. Sampling was conducted by collecting a single composite sample that consisted of three grab samples combined over a 10-minute period. A second composite sample was collected 20 minutes later, and a third composite was collected 40 minutes after the initial composite. Existing flow gages maintained by the Los Angeles County Department of Public Works provided flow information.

RESULTS

Our survey of the Los Angeles River identified 127 storm drain outfalls. Of these, 105 were flowing and 87 discharged sufficient volume to sample for water quality. Seventy-seven percent of the outfalls discharged directly to the Los Angeles River and the remainder discharged to the major tributaries.

The majority of the flow on September 10 and 11, 2000, was treated wastewater discharges from the three WRPs on the Los Angeles River. A combined 74.6 MGD comprised approximately 72% of the dry-weather flow. Roughly 14.7 MGD (14%) arose from discharges out of six of the seven tributaries that discharge to the Los Angeles River. The Rio Hondo tributary was not flowing at the confluence to the Los Angeles River at the time of sampling. Roughly 13.8 MGD (13%) arose from discharges out of the 66 storm drain outfalls that discharged directly to the Los Angeles River mainstem.

The presence of algae and trash were consistently observed at the mouths of storm drain outfalls to the Los Angeles River (Figure 2), (Table 1). The amount of trash varied from drain to drain, with 23% of the outfalls categorized as having “dense” (>50%) surface coverage. However, 70% of the outfalls had algae that exceeded 50% surface coverage. The presence of foam, oily sheens, and odd colors were inconsistently observed.

The concentrations of inputs to the Los Angeles River differed among the three sources for general classes of constituents (Table 2). The highest concentrations of nutrients were found in WRP discharges. For example, concentrations of ammonia in WRP effluents were twice the level found in the tributaries and an order of magnitude higher than the concentrations found in storm drain discharges. In

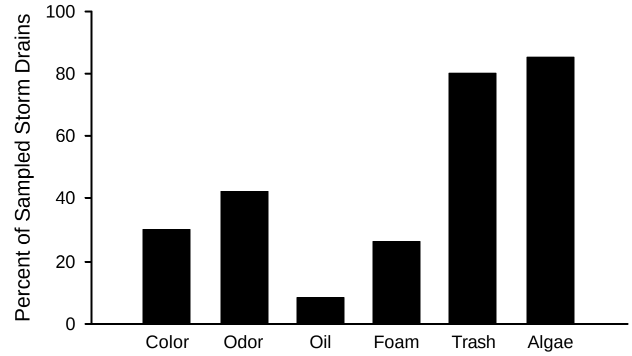

Figure 2. Percent of storm drains with observable signs of trash, algae, foam, water discoloration, or oily sheens.

Table 1. Spatial coverage (as percent of area) of trash and algae near storm drains discharging to the Los Angeles River on September 10, 2001.

<table>
<tr><th rowspan="2">Spatial Coverage
(Percent of area)</th><th colspan="2">Percent of Storm Drains</th></tr>
<tr><th>Algae</th><th>Trash</th></tr>
<tr><td>None (0%)</td><td rowspan="2">8</td><td>17</td></tr>
<tr><td>Light (<6%)</td><td>15</td></tr>
<tr><td>Moderate (6-10%)</td><td rowspan="2">13</td><td>14</td></tr>
<tr><td>High (11-25%)</td><td>12</td></tr>
<tr><td>Somewhat Dense (26-50%)</td><td>9</td><td>16</td></tr>
<tr><td>Dense (51-75%)</td><td>21</td><td rowspan="2">23</td></tr>
<tr><td>Very Dense (>75%)</td><td>49</td></tr>
<tr><td>Not Recorded</td><td></td><td>3</td></tr>
</table>

contrast, the highest concentrations of bacteria were found in discharges from storm drains. Concentrations of *E. coli* were four orders of magnitude higher for storm drains than WRPs, which were below method reporting levels (< 2 MPN/100 mL). Concentrations of trace metals were generally low from all sources; most average concentrations were below method reporting levels. The WRP effluents had higher concentrations of copper and zinc than discharges from tributaries or storm drains.

The relative contributions of pollutants to the Los Angeles River differed among the three sources of inputs between general classes of constituents (Table 3). The greatest mass emissions of nutrients were from WRPs. For example, WRPs contributed 85% of the ammonia and 82% of the total phosphate relative to tributaries and storm drains. In contrast,

Table 2. Average concentrations of water quality parameters from three major sources of potential pollutants to the Los Angeles River on September 10-11, 2000.

Constituent		Units	WRPs	Tributaries	Storm Drains
Bacteria					
	E. coli	MPN/100mL	ND	1,307	21,199
	Enterococcus	MPN/100mL	2	1,033	4,124
	Total Coliforms	MPN/100mL	288	76,525	79,593
Metals					
	Chromium	mg/L	<0.01	<0.01	<0.01
	Copper	mg/L	0.011	<0.01	<0.01
	Iron	mg/L	<0.2	<0.2	0.54
	Lead	mg/L	<0.01	<0.01	<0.01
	Nickel	mg/L	<0.02	<0.02	<0.02
	Zinc	mg/L	0.04	0.02	0.01
Nutrients					
	Ammonia-N	mg/L	12	5.6	<0.2
	Nitrate-N	mg/L	0.5	1.4	2.7
	TKN	mg/L	14	7.9	1.5
	Total Phosphate-P	mg/L	1.7	0.9	0.3

ND = nondetectable.

nearly 100% of the *Enterococcus, E. coli,* and total coliform mass emissions were from storm drain discharges and tributaries, not from WRPs. The relative mass emissions of trace metals varied among sources by metal. The WRPs accounted for 73% and 79% of the copper and zinc, respectively. On the other hand, tributaries and storm drains cumulatively accounted for 100% of the lead and nickel mass emissions to the Los Angeles River.

The spatial distribution of water quality concentrations reflected the sources that contributed the pollutants to the Los Angeles River (Figure 3). For example, mean concentrations of ammonia were <0.1 mg/L upstream of the Tillman WRP, then increased to 6 mg/L following the three WRP discharges. The WRP had the highest concentrations and largest nutrient mass emissions. In contrast, mean concentrations of *E. coli* were near 10^3 MPN/100 mL prior to reaching the WRP, then decreased to 10^2 MPN/100 mL following the WRP discharges. Concentrations increased back to 10^3 MPN/100 mL downstream of the WRP as more storm drain discharges accumulated in the river. Storm drain discharges had the highest concentrations and mass emissions of bacteria.

Although the spatial patterns of nutrients and bacteria were dissimilar, both groups of constituents were characterized as having highly variable concentrations (Figure 3). For example, the minimum and maximum concentrations extended from 4 mg/L to more than 14 mg/L ammonia following the inputs from the Tillman WRP at river mile 38. Similarly, concentrations of *E. coli* ranged from 10^1 MPN/100 mL to 10^5 MPN/100 mL upstream of the Tillman WRP at river mile 43.

DISCUSSION

The study was designed to investigate the loadings to the Los Angeles River and the effects of those loadings on water quality. Early September was chosen to best sample steady-state river conditions over the sampling period. The input and spatial distribution sampling occurred over a sufficiently short period and at the same time over the two days that this approximation was valid.

The Los Angeles River is an effluent-dominated waterbody. Nearly 70% of the volume in the Los Angeles River arose from WRP tertiary-treated effluent discharged during this study. Although groundwater interactions existed (particularly in the Glendale Narrows and Arroyo Seco tributary), the majority of storm drain discharges were assumed to arise from urban discharges. Less than 0.1 MGD of flow was measured at the mouth of the Los Angeles River during dry-weather periods in 1930, when the population in the county was approximately 2 million. More than 100 MGD was measured at the mouth of the river during this study, when county population estimates exceeded 9.5 million.

Storm drain discharges are known sources of bacteria in southern California (Schiff 1997, Noble *et*

Table 3. Total pollutant loads and the relative contributions among major sources to the Los Angeles River on September 10-11, 2000.

Constituent		Total Mass Emissions	Units	% Contribution		
				POTWs	Tributaries	Storm Drains
Bacteria						
	E. coli	12,022	(10^9)/day	0	11	89
	Enterococcus	2,948	(10^9)/day	0	33	67
	Total Coliforms	113,854	(10^9)/day	1	65	35
Metals						
	Copper	3.7	kg/day	73	22	6
	Iron	39	kg/day	4	23	73
	Lead	0.53	kg/day	0	54	46
	Nickel	0.19	kg/day	0	0	100
	Zinc	11	kg/day	79	17	4
Nutrients						
	Ammonia-N3,357	kg/day	85	14	0	
	Nitrate-N	361	kg/day	32	35	34
	TKN	4,066	kg/day	82	17	2
	Total Phosphate-P	512	kg/day	82	15	2

al. 2000). The City of Los Angeles (1997) has measured concentrations of 10^6 *E. coli* in storm drains that discharge to the Los Angeles River, resulting from defecation of homeless encampments. Bacteria concentrations from WRPs, which treat municipal sewage, is low to nondetectable because the WRPs disinfect their effluents prior to discharge. As is more often the case, the bacteria sources are often diffuse and complex (Schiff and Kinney 2001). Unlike nutrients, where remedying the problem lies predominantly with the WRPs, resolving bacterial water quality problems will be challenging because the sources are numerous and their loads not as easily quantified.

Analytical reporting levels have the potential to bias mass emission results when many measurements are below detection limits. The bias occurs when scientists estimate concentrations for these truncated values. This issue is important with trace metals; concentrations of most trace metals were low to nondetectable from all sources investigated. During this study, we assumed all values reported as nondetectable were actually zero. However, the true concentration may be nearly as high as the reporting level. In the case of WRPs, low levels of trace metals equate to large mass emissions because of the sheer volume of WRP discharges. For example, the mass emissions of lead was estimated to be 0.5 kg/day, but if the zeros assigned to nondetectable values were actually as high as the reporting level, the mass emissions would have been 4.1 kg/day; an 8-fold increase. This also changes the relative contribution among sources. If nondetectable quantities were treated as zero, storm drains are the major (92%) source. However, if nondetectable quantities were treated as the reporting level, then the WRPs are the major (72%) source. Minimum detection limits were an issue to metals, but not bacteria and nutrients, and affected loading estimates but not water quality threshold evaluations.

The measured in-river concentrations were variable, as can be seen in Figure 3. Compositing the samples, during the spatial distribution sampling was used to minimize the very short-term variability in the samples with the triplicate samples addressing the more generalized temporal variability. The variability shown in the *E. coli* and ammonia longitudinal distribution was echoed in the other sampled constituents. The variability most likely was due to the nonpoint sources.

The use of volunteers, if properly trained and organized, represented a powerful mechanism for accomplishing large-scale sampling tasks. In this study, we needed to cover more than 54 river miles and more than an additional 15 tributary miles in less than 5 h. The volunteer monitoring effort helped us to accomplish this large-scale effort without injury or major deviations from monitoring protocols. However, this success occurred because tremendous effort was expended on logistics, preparation, and training. The more than 85 volunteers who walked, biked, drove, and canoed ranged in age from 10 to 65. The citizen activism in this watershed is to be commended.

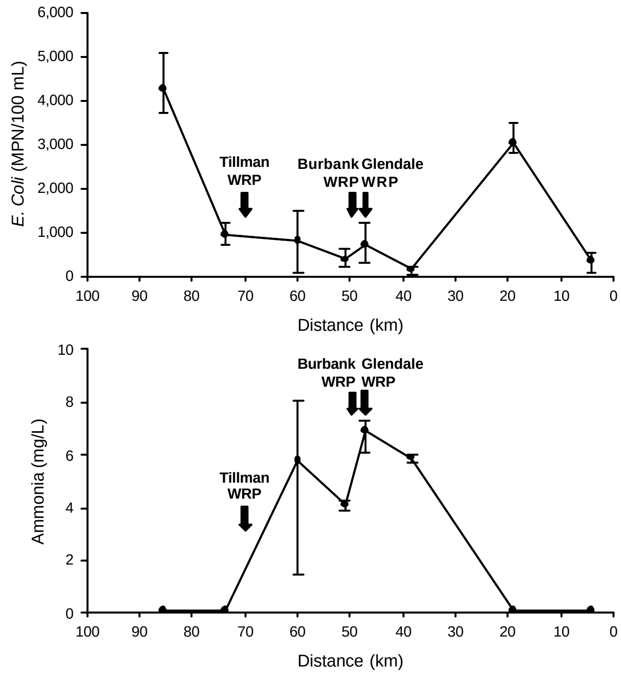

Figure 3. Longitudinal mean concentrations (min, max) of nutrients and bacteria along the Los Angeles River. Arrows indicate input locations from water reclamation plants (WRPs).

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