Toxicity of Surface Runoff in Southern California

A 1987 study of storm water runoff in the Los Angeles and San Gabriel rivers and Ballona Creek demonstrated that toxicity varies within and between storms on the same channel, and between storms on different channels (SCCWRP 1989). We repeated these studies on samples collected from the Los Angeles, Santa Ana, San Diego, and Tijuana rivers in 1988. Storm water toxicity was measured by the Microtox™ analyzer system, a photometric bioassay that uses marine luminescent bacteria. The general health of the bacteria is indicated by their light production. When exposed to an aqueous toxicant, the bacteria produce less light.

The Los Angeles River drains 2,155 km^2 of western Los Angeles County from the San Fernando Valley through the City of Los Angeles to Long Beach (Figure 1). It discharged 217 x 10^6 m^3 of runoff to the Southern California Bight in 1988. The Santa Ana River drains 4,406 km^2 from its headwaters in the San Bernardino Mountains through Riverside to Huntington Beach. It discharged 26 x 10^6 m^3 of water to the Bight in 1988. The San Diego River drains 1119 km^2 from the San Ysabel Valley through San Diego to Mission beach. It discharged 28 x 10^6 m^3 of runoff to the Bight in 1988. The Tijuana River is formed by the confluence of Cottonwood Creek, which originates in the United States, and the Rio de Las

Storm drain output to Los Angeles River.

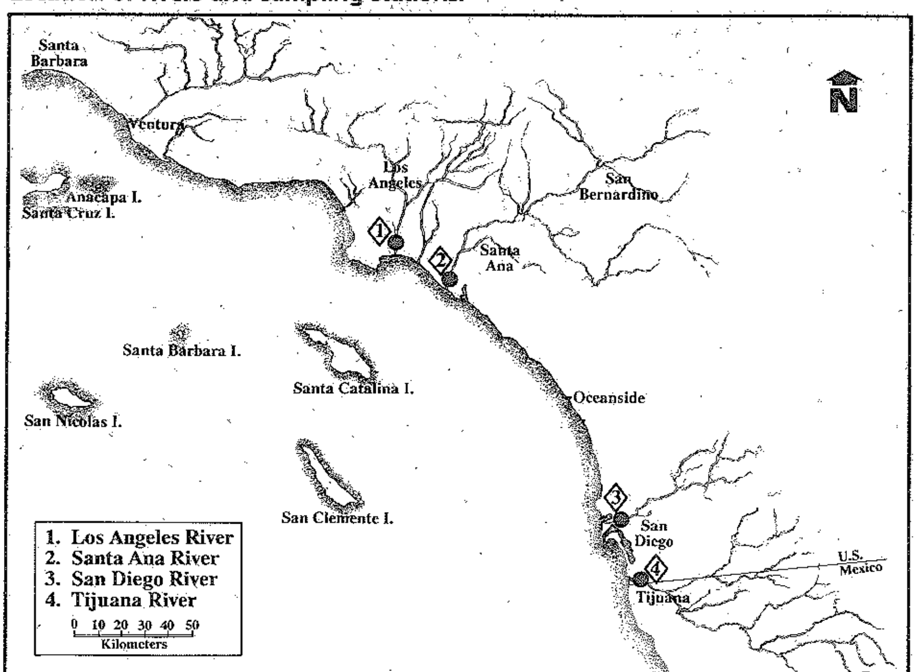
Palmas, which originates in Mexico. The river flows northwesterly through Tijuana into the United States to Imperial Beach; 27% of the drainage basin lies in the U.S. and 73% lies in Mexico. The river drains 4483 km^2 of land and discharged 40 x $10^6 m^3$ of runoff to the Bight in 1988.

Materials and Methods

We collected samples from the Los Angeles, San Diego, and Tijuana rivers on January 17-18, 1988; from the San Diego and Tijuana rivers on April 14-15, 1988; and from the Santa Ana River on April 20-21, 1988. We collected low flow samples from the Los Angeles River on October 31, 1986 and from the San Diego and Tijuana rivers on September 22, 1987. Samples were collected from the Los Angeles River at Willow Street in Long Beach; from the Santa Ana River at Hamilton Avenue on the border between Huntington Beach and Costa Mesa; from the San Diego River at Fashion Valley Road in San Diego; and from the Tijuana River at Dairy Mart Road in San Diego.

Seven to 10 samples were collected from each channel during each storm, usually at hourly intervals (see *Mass Emission Estimates for Selected Constituents from the Los Angeles River* in this volume for a description of the sampler). An aliquot for the toxicity assay was poured into a 25 ml unused and unwashed scintillation vial. The samples were placed on ice and transported to the laboratory where they were stored at 4°C. We usually tested the samples within two days using the Microtox™ analyzer system (Beckman Instruments, Inc. 1982). Particles were allowed to settle before a sub-sample was removed by pipet for testing. Turbid samples were centrifuged. Salinity was adjusted to 20 ppt by adding a concentrated sodium chloride solution. The concentration of storm water in the final assay was 45%. The toxicity (percent light loss) of a sample was the difference in bacterial light output normalized to a 20 ppt saline control before and after a 30 min exposure to the river runoff sample. We calculated a flow-weighted mean toxicity for each storm by summing individual flow-weighted toxicities (percent light loss multiplied by flow rate at sampling) and dividing by the sum of the flow rates. We estimated the standard error with a jackknife resampling technique (Efron 1982).

Figure 1.
Location of rivers and sampling stations.



Results

Relative toxicities were generally highest at the beginning of a storm and decreased as the storm progressed (Figure 2). During storms, toxicity varied by a factor of 1.5-3.5. Figure 2 does not show all the storms that were sampled. Light loss was 5-17% for San Diego River samples collected during the January storm. During the April storms, light loss was 17-27% for Tijuana River samples and 5-18% for Santa Ana River samples. Samples collected from the Los Angeles River in 1987 and 1988 illustrate the variability in toxicity within and between storms (Figure 3).

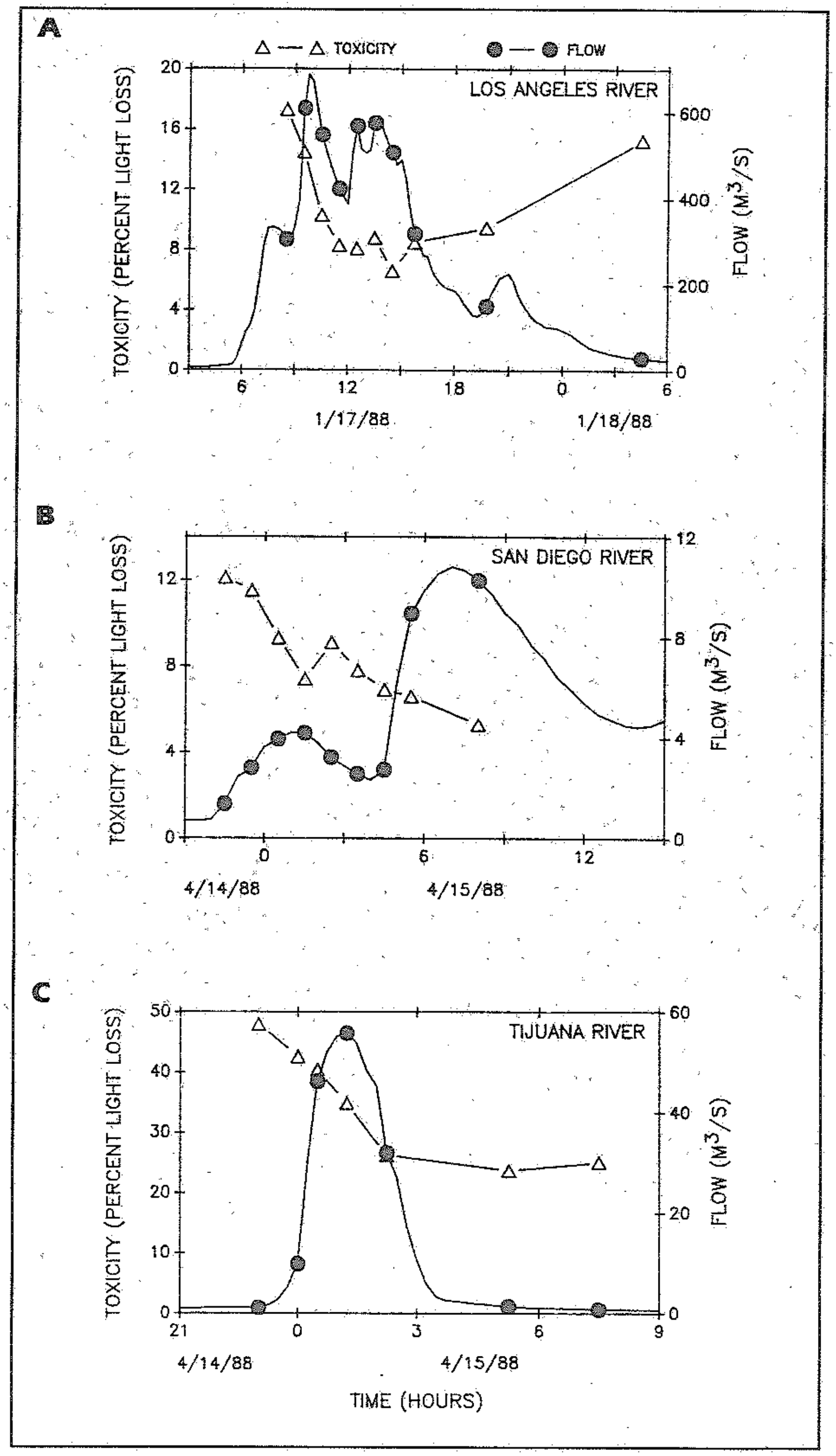
Toxicity and river flow rate form a loop when plotted by the time sequence of sampling (Figure 4). The plots have a clockwise rotation and toxicity was generally highest early in the storm. The time sequence plot for samples collected from Tijuana River in January is not as circular as the others, probably because sampling did not cover the entire storm event.

Storm samples from the Los Angeles and Tijuana rivers, and low flow samples from the Tijuana River, had the highest flow-weighted-mean toxicities (Figure 5). The flow-weighted toxicity of samples collected from the Los Angeles River during the January 1988 storm was lower than the flow-weighted toxicity of the four storms sampled in 1987 (mean 25%, range 13-45%; SCCWRP 1989). Low flow samples were generally more toxic than storm samples from the same channel (Figure 5).

Discussion

Runoff samples collected at low flow and early in storms generally had the highest toxicities. Toxicity decreased as river discharge increased. This is opposite of the trend for particle-associated contaminants. In runoff samples from the Los Angeles River, the concentration of suspended solids, trace metals, and chlorinated hydrocarbons increased with increasing river discharge (see *Mass Emission Estimates for Selected Constituents from the Los Angeles River* in this volume). Dissolved constituents may cause the toxicity observed in the Microtox™ test of runoff samples. The source of the dissolved constituents probably

Figure 2.
Relationship between toxicity, river discharge, and sampling time for runoff in the: A) Los Angeles, B) San Diego, and C) Tijuana rivers. Toxicity is percent light loss relative to control.



changes before, during, and after storms, contributing to the substantial variability observed.

The source of some dissolved material during the early phase of a storm may be the first flush of water soluble compounds from impermeable urban surfaces. The source of some dissolved material at low flow may be municipal or industrial effluents discharged into the rivers. From September 1987 to August 1988 for example, effluents from the Tillman, Los Angeles-Glendale, and Burbank water reclamation plants constituted 85% of the volume discharged by the Los Angeles River at low flow (<5 m^3/s).

Samples from the Tijuana River had the highest flow-weighted toxicity in 1988, due perhaps to raw sewage, industrial wastes, and agricultural wastes that are discharged into the river south of the International Border. The toxicity of Tijuana River samples was comparable to the toxicity of Los Angeles River samples in 1987 (SCCWRP 1989). Samples from the Santa Ana and San Diego rivers had the lowest toxicity in 1988. The San Diego River basin is one of the least modified basins in southern California.

There was substantial within- and between-storm variability in toxicity measured by the Microtox™ test. Serial correlations cause the loop, which is known as hysteresis, in the toxicity-river discharge relation (Whitfield and Schreier 1981). Between-storm variability in toxicity was high for runoff samples from the Tijuana and Los Angeles rivers, and low for samples from the San Diego River. Between-storm variations and serial correlations in toxicity

Figure 3.
Toxicity of water samples collected from the Los Angeles River during storms in 1987 and 1988.

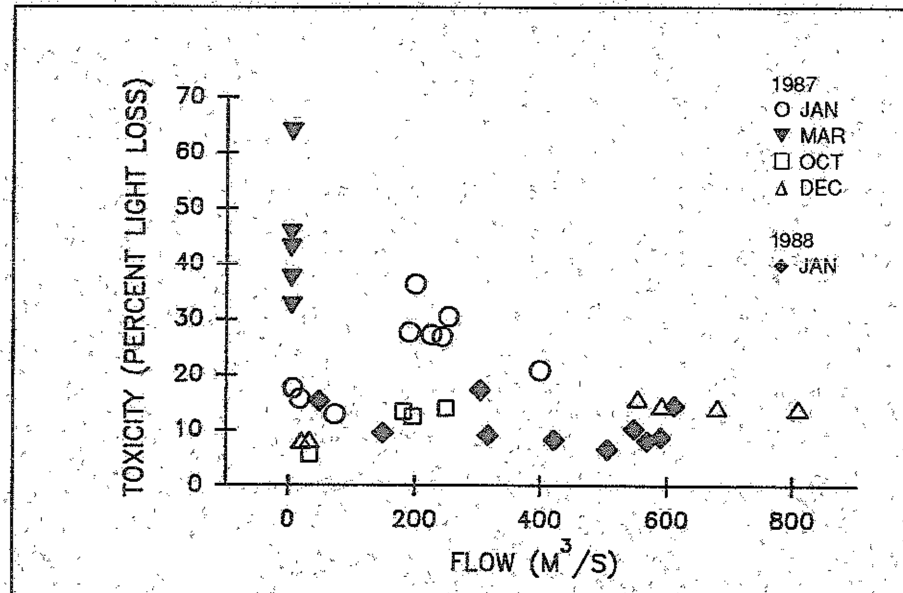
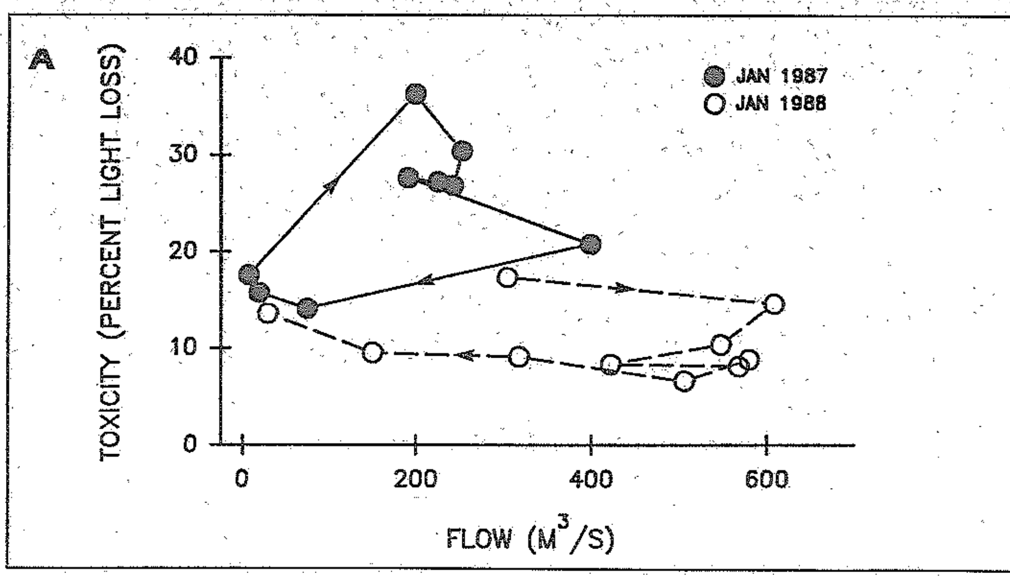


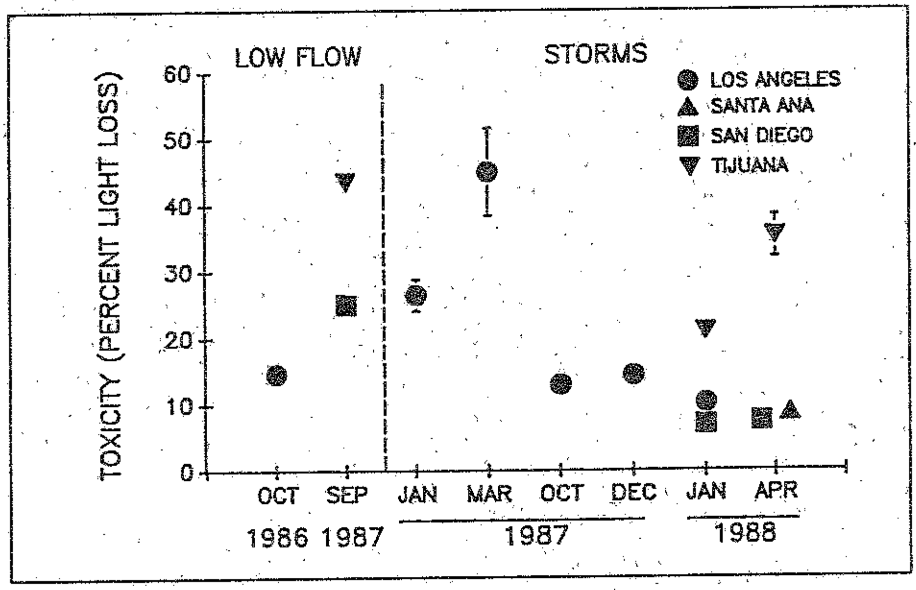
Figure 4.
Relationship between toxicity and discharge for: A) the Los Angeles River during the January 1987 and January 1988 storms, and B) the Tijuana River during the January 1988 and April 1988 storms. Time sequence of sampling indicated by arrows.

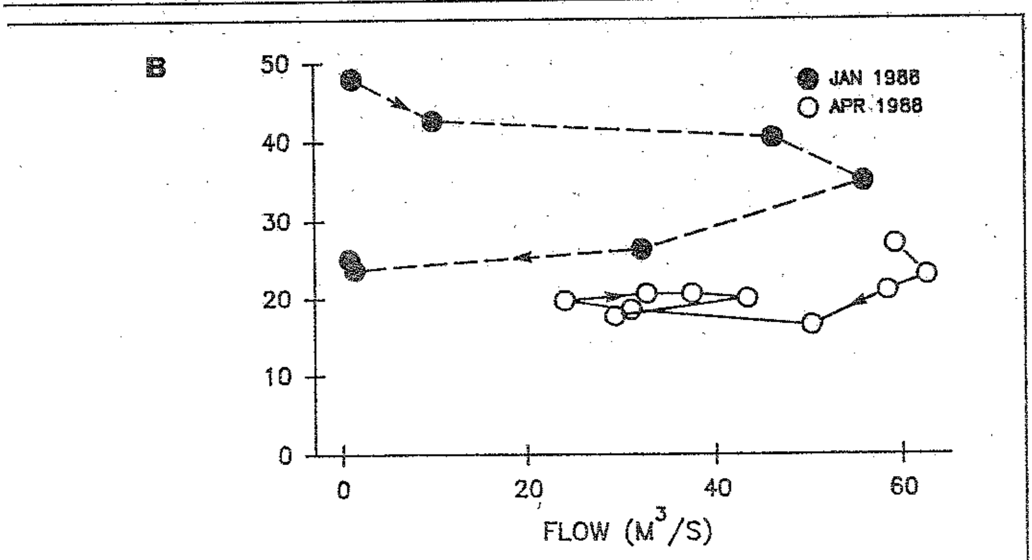


result from time differences in river conditions, biological processes, source contributions, and storage-discharge relationships (Whitfield and Schreier 1981). Toxicity is not an independent random variable and cannot be analyzed by standard parametric statistical methods.

Storm water is one of several sources of toxic constituents to the Southern California Bight. To understand its impact on marine organisms, more work needs to be done on the composition of dissolved constituents, and more bioassays need to be conducted with indigenous marine organisms. ■

Figure 5.
Flow-weighted mean toxicity and standard error for storms and low flows sampled from 1986 to 1988. One low flow sample was collected per channel. Standard error bar cannot be seen if <1.5%.





References

Beckman Instruments, Inc. 1982. Microtox™ System Operating Manual. Beckman Instructions. 015-555879, Microbics Corp. Carlsbad, CA. 59 p.

Efron, B. 1982. The jackknife, the bootstrap, and other resampling plans. Society for Industrial and Applied Mathematics. Philadelphia, PA. 92 p.

SCCWRP. 1989. Toxicity of storm water runoff in Los Angeles County. *In*: Southern California Coastal Water Research Project 1988-89 Annual Report. P.M. Konrad, ed. Southern California Coastal Water Research Project, Long Beach, CA. pp. 66-71.

Whitfield, P.H. and H. Schreier. 1981. Hysteresis in relationships between discharge and water chemistry in the Fraser River basin, British Columbia. *Limnol. Oceanogr.* 26:1179-1182.

Acknowledgements

Author Valerie Raco thanks Steven Bay, Dario Diehl, Bob Eganhouse, Karen Englehart, Richard Gossett, Darrin Greenstein, Patrick Hershelman, Rika Jain, Jim Laughlin, Henry Schafer, Harold Stubbs, Peter Szalay, David Tsukada, Charles Ward, Skip Westcott, and Jeff Cross. The author also thanks Nellie Gonda (Los Angeles Department of Water and Power), Casey Speigel, James Bowers, Randy Jensen (U.S. Geological Survey), and Thomas Smith (International Boundary Water Commission) for help with this project.