Field-scale sediment feed flume: Upper Santa Ana River, California

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Extended Abstract

The Santa Ana River moves water and sediment from the headwaters in southern California's San Gabriel and San Bernardino Mountains to the Pacific Ocean near Newport Beach. Along the San Bernardino Valley, the river decreases in slope, increases in width, and deposits particles from boulders to sand as it loses transport capacity. Episodic rainfalls feed very large winter floods, but dry summer and fall periods lead to extensive dry alluvial reaches due to surface water infiltration into subsurface aquifers. Within one of these dry reaches, a small inset channel has developed to effectively convey year-round wastewater discharges. The inset channel is about 10-m wide, and during dry phases, is the only surface water present within the larger 250-m wide flood channel (Figure 1). This flow creates a coarse bed substrate composed of gravel and cobble that is home for diatoms and algae, the diet for the Santa Ana Sucker, a threatened native fish. Below we explore the sediment transport dynamics and conditions necessary to maintain a coarse bed substrate to host food for the Santa Ana Sucker.

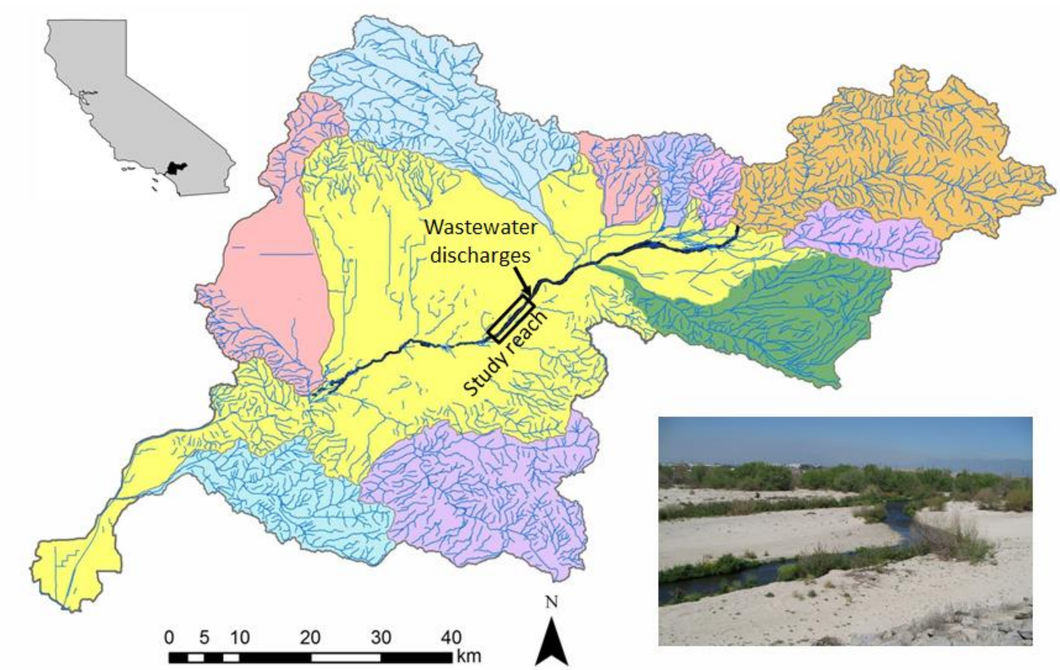

Figure 1. Map of the Santa Ana watershed showing the location of the wastewater discharges and the study reach. The study reach is in the San Bernardino Valley at an elevation of about 300 m; the high elevations in the tributary basins exceed 3000 m. Photo shows the inset channel immediately downstream from the wastewater discharges.

We began with a conceptual model in which the inset channel behaves like a sediment feed flume, with upstream supplies of water and sediment that are mostly independent. Sediment (primarily sand during most flows) moves into the reach with infrequent upstream flow during winter runoff. During these events, the inset channel can fill almost completely with sand, and/or avulse across the floodplain. During the dry season, the previously deposited sands are winnowed from the inset channel by constant, clear-water releases from the wastewater plants, exposing gravel and cobble.

This conceptual model is based in well-established theory, and supported by field-based observations:

- Shear stresses in the inset channel are capable of transporting sand as bedload, but not gravel and cobble. Bedload measurements (at several locations and times under wastewater discharge conditions) indicate that about 90% of the bedload is sand. The median grain size of bedload samples is consistently in the 0.5–1-mm range with little longitudinal variability.

- The upstream supply of sand decreases through time as winnowing proceeds in the downstream direction. Bedload transport rates increase in the downstream direction by an order of magnitude over just 7 km, despite the fact that water discharge decreases downstream due to infiltration (typically by 25–50% over the 7-km reach).

- The location of the gravel-to-sand bed transition is variable from year to year and is related to the amount of time that has elapsed since the most recent upstream runoff event. These events supply new sediment to the reach and reset the winnowing process.

- Direct observations of the inset channel following upstream runoff events revealed many instances of large areas of substantial sand deposition in the channel, in areas that were previously entirely gravel and cobble sizes.

In summary, the bed substrate of the inset channel at any given time and location is a function of 1) the distance downstream from the wastewater discharges, 2) the time since the most recent upstream sediment-supplying runoff event, and 3) the wastewater discharge levels and infiltration rates in the reach. The wastewater discharge levels are of particular interest to local managers because proposals have been made to change release levels. Altering the discharge levels could affect the amount of coarse sediment (gravel and cobble) available or the amount of time required to expose the coarse sediment, impacting native fish.

To assess this effect, we are developing a one-dimensional model of bedload transport and bed substrate in the study reach. Preliminary results indicate that the winnowing process is quite sensitive to wastewater discharge levels, a likely result of the non-linear relationship between bedload transport and shear stress. The calibrated model can be used to assess how treatment plant discharge levels might be used to strategically manage winnowing rates and the amount of gravel and cobble exposed on the bed in the reach. Future model applications will be focused on evaluating the effects of various discharge scenarios on winnowing rates and coarse sediment exposure.