Effluent for environmental flows: a sustainable solution?

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Impacts of using high-nutrient water to feed a river

The Santa Cruz River provides an interesting case study of reclaimed water being used to sustain surface water flow and thus sustain riparian vegetation. After groundwater pumping caused the water table to drop and the river to cease flowing, Tucson and Nogales created permanent flow in the river by discharging treated wastewater directly into the river.

What we have noticed:

- Recharge rates of surface effluent water to the stream aquifer decline in the absence of strong floods
- Recharge increases and the distance the river flows downstream can drop by half following a flood
- Large tree die-offs next to the river (**Figure 1**)
- Visual indications of high microbial activity near the wastewater treatment plant

These impacts may be the result of a clogging layer forming in the river sediments. Clogging is a general term for the reduction in permeability of a porous medium. **We hypothesize that the clogging layer is formed by microorganisms**. Numerous laboratory studies have shown that microbes and their by-products can clog sediments, but this phenomenon has not been well-studied in rivers.

Goals:

- Determine when and where clogging develops in the rive and determine if this correlates with microbial abundance.
- Determine what environmental variables might promote a clogging layer to develop, through controlled laboratory experiments and field observations
- Look for functional groups (such as denitrifiers) that might be associated with clogging layers

Study Area

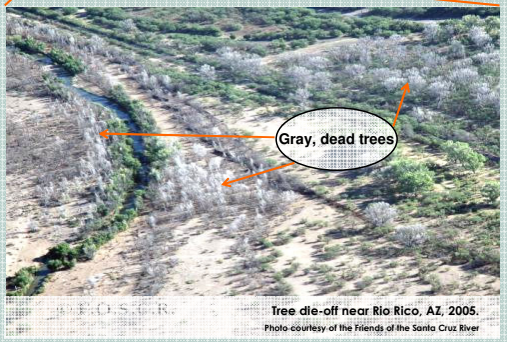

Figure 1. The Santa Cruz River is an **effluent-dominated** river that receives water from treatment plants that discharge tertiary treated effluent into the river bed at Nogales and Tucson. The San Pedro, a **non effluent-dominated** river to the east, serves as a control site. An aerial view shows a recent tree die-off near the river.

A conceptual model of what might be happening in the river

A four-stage process of:

- Stage 1: Following a flood, water from the river freely infiltrates to the water table below.
- Stage 2: As time passes without subsequent flooding, small clogged patches develop.
- Stage 3: The clogged patches grow larger, forming large areas that are impermeable to water. This leaves an unsaturated zone in the sediments, reducing available water for surrounding tree roots. Trees show signs of water stress.
- Stage 4: A storm moves in and flooding scours the river bottom, removing the clogging layer.

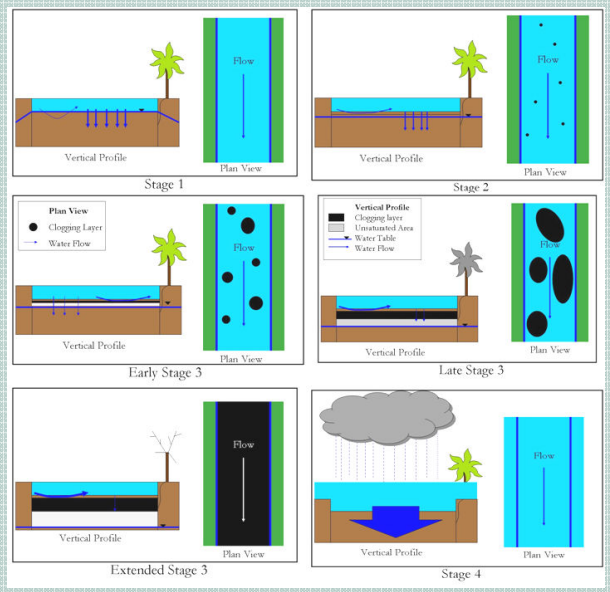

Figure 2. Based on observation and theory, hydrologists developed a model to describe the clogging process in the river. The model illustrates the temporal development of clogging, with floods serving as disturbance that resets the system.

Image provided by Dr. Tom Meixner and Samantha Treese, University of Arizona

Locating and characterizing the clogging layer

Site selection: 3 sites progressing downstream from both the Tucson and Nogales discharge, and 2 sites on the control river. Each site contains 3 transects, 100 m apart.

Sampling schedule: quarterly and following flood events.

Measured variables:

- **Hydrology** – Locate areas of reduced infiltration, or clogging
  Methods: Falling head test using standpipes in the river (**Figure 3**)
- **Microbiology*** – Measure abundance and types of microorganisms in the sediments
  Methods: Direct cell counts, plate counts, polysaccharide assay, fingerprint bacterial community
- **Physiochemical** – Look for conditions that promote microbial growth
  Methods: Measure temperature, pH, flow, redox, dissolved oxygen, ammonia, nitrate, phosphate, and carbon in the river
- **Laboratory experiments*** – Columns designed to mimic river conditions will test the effects of single variables on microbial clogging

*These measurements have not yet been conducted

Preliminary findings and predictions

For all parameters measured, the Santa Cruz had elevated levels compared to the control river. Interestingly, the three reaches span a gradient of water quality. The data below were collect from surface water in December 2009.

	Temp (C)	DO (mg/l)	ORP (mV)	NO3/NO2 (mg/l)	NH4 (mg/l)	TOC (mg/l)
San Pedro	4.8	13.2	151	0.018	0.003	2.02
Santa Cruz, Nogales	17.9	8.78	134	4.15	0.253	4.54
Santa Cruz, Tucson	23.5	7.69	155	3.15	9.47	10.00

This research is in its preliminary stages, but based on the temperature and nutrient results above, we expect to find that sediment microorganisms will:

- be higher in the effluent-dominated river
- be higher in clogged areas
- decline in parallel with clogging after a flood and will steadily recover after the flood
- correlate with physiochemical variables such as flow, oxygen, or nitrogen
- have differences in community structure between the two rivers, and certain groups may be affiliated with clogging

Field Methods

Figure 3. Standpipes used to measure the rate of infiltration of water through the sediments. A close inspection of one of the pipes reveals visible signs of microbial activity – gas bubbles and a black zone of FeS precipitates.

Summary

- Clogging in rivers is not well-understood. It is difficult to study *in situ* because it spatially intermittent and challenging to measure without disrupting the layer. More research in this area is needed.
- Our initial findings indicate that the effluent-dominated river is warmer and contains more nutrients compared to a control river; such conditions may promote development of bacterial growth in sediments and thereby influence surface-groundwater interactions.
- This research should improve our understanding of the impacts of using effluent to support riparian ecosystems. It may also be useful to stakeholders in water management who use rivers to purify reclaimed water and recharge the aquifer.

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