New tools assess seepage and nitrate dynamics in a losing stream

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Project Goals

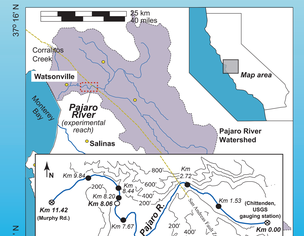
- Quantify dynamics of stream seepage (recharge, hyporheic flow, baseflow), influence on water supply and quantity.
- Quantify dynamics of nitrate cycling (where, how much, how quickly), influence on water quality.
- Evaluate effectiveness of tracer-dilution methods to quantify seepage within a strongly-losing stream.
- Develop method for using time-series, streambed temperature measurements to quantify seepage
- Compare and contrast conditions within several streams in coastal basins.

Technical Abstract

The Pajaro River, central coastal California, loses 0.2-0.4 m³/s of discharge through streambed seepage along an 11-km reach during the dry half of the water year. This loss could contribute ~20-40% of current sustainable basin yield, 6,000-12,000 ac-ft/year. Differential gauging and tracer dilution experiments reveal significant storage exchange and dilution fluxes associated with streambed seepage. A new method for using streambed thermal records to measure seepage rates shows that seepage is highly variable in location and rate. This method is based on an analysis of time series records collected in shallow piezometers installed in the streambed. At the same time as the stream loses discharge, nitrate concentrations decrease along the reach by ~30%; as a result, the Pajaro River loses ~50% of its nitrate along this reach, a removal rate of 200 - 400 kg/day N-NO_3. Most nitrate loss occurs where seepage exchange of water occurs. Stable isotopes of nitrate show streambed and downstream enrichment associated with denitrification. When discharge is greater and storage exchange is most vigorous, denitrification is least efficient and isotopic fractionation is greatest. When discharge is lower and storage exchange is more sluggish, denitrification is more efficient, resulting in lower isotopic fractionation. Resource managers can use this information to protect and enhance conditions that allow denitrification, improving water quality.

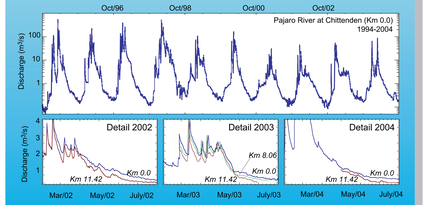
Field Area

- The Pajaro Basin adjacent to Monterey Bay, central coastal CA.
- 11.42-km long experimental reach of the Pajaro River.
- Basin extensively developed for agriculture, some urban.
- Precipitation highly seasonal: short wet season in winter.
- Ground water overdraft around lower basin is ~60% of pumping.



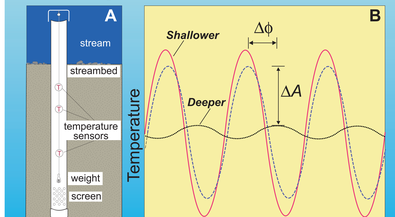
The Pajaro River is a "Losing Stream"

- Multiple continuous gauging stations, numerous seepage runs.
- Consistent channel losses 0.2-0.4 m³/s, equivalent to 6,000-12,000 ac-ft/year, 20-40% of estimated sustainable basin yield.
- Very little channel loss from ET; most is seepage loss that may become recharge to underlying aquifer(s).
- Tracer tests show considerable hyporheic exchange between the stream and the stream bed.



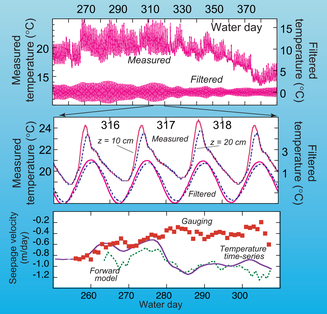
Heat is a Tracer of Stream Seepage

- Streambed piezometers hold small temperature sensor-loggers.
- Daily changes in stream temperature move downward into the streambed.
- Daily peaks are reduced (ΔA) and arrive later (Δϕ) with depth.
- Temperature variations with depth depend on seepage rate and direction, along with streambed thermal properties.



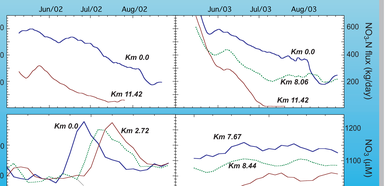
Temperature Reveals Seepage Dynamics

- Measured data filtered to extract daily variations, amplitude and timing of peaks shifts with depth, as influenced by seepage.
- Method compares favorably with forward models, shows greater variability than differential gauging.



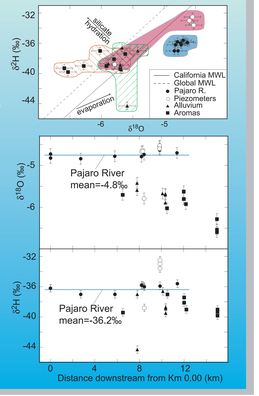
Net Removal of Nitrate from Stream

- 200-400 kg/day N-NO_3 is removed from channel.
- Half of removal is seepage loss, half is some "in stream" process other than not dilution (which does not occur during most of year).
- Lower part of reach is more efficient at removing NO_3 than is upper part of reach; why?



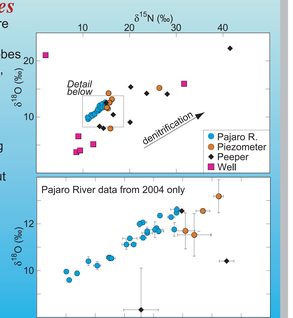
Water Isotopes

- Tight clustering of Pajaro River samples relative to ground water, streambed water
- Larger-scale trend shows that evaporation has influenced stream water isotopes upstream from experimental reach.
- No down-stream trend; values remain constant.
- Results consistent with minimal evaporation along the reach.
- Other data and calculations suggest that transpiration is also minimal.
- Virtually all channel loss results from seepage downward into streambed.



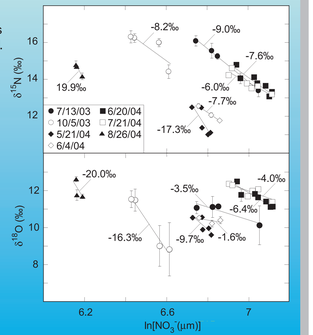
Nitrate Isotopes

- Isotopes of nitrate are changed by microbial ***denitrification;*** microbes prefer lighter isotopes, leaving heavier residual nitrate.
- Denitrification converts nitrate to N_2 gas, causes strong isotopic fractionation.
- Data from throughout Pajaro Basin show consistent denitrification trend.
- Data from Pajaro River in 2004 are particularly consistent with denitrification.



Nitrate Isotope Fractionation

- Isotopic fractionation is rate of enrichment as element is transformed.
- Fractionation determined in surface water samples, but data suggest that enrichment occurs in regions such as the streambed that become anoxic, where there is little nitrate limitation.
- Denitrification limited by diffusive exchange with the streambed when and where there is little hyporheic flux.



Implications, Publications

- Streambed seepage can be an important component of a basin hydrologic budget.
- Seepage is highly dynamic and can influence the qualtiy of water in a stream.
- Managing water resources requires taking into account seepage processes.

Work presented in this poster comprises a small part of data and analyses shown in three papers:

Ruehl, C., A. T. Fisher, C. Hatch, M. Los Huertos, G. Stemler, and C. Shennan. 2006. Differential gauging and tracer tests resolve seepage fluxes in a strongly-losing stream. *Journal of Hydrology: in press*.

Hatch, C. E., A. T. Fisher, J. S. Revenaugh, J. Constantz, and C. Ruehl. 2006. Quantifying surface water - ground water interactions using time series analysis of streambed thermal records: method development. *Water Resources Research: in review.*

Ruehl, C., A. T. Fisher, M. Los Huertos, S. Wankel, C. Kendall, C. Hatch, and C. Shennan. 2006. Nitrate dynamics within the Pajaro River, a nutrient-rich, losing stream. Journal of Environmental Quality, *in review.*

Please visit the web site of the first author of this poster (http://es.ucsc.edu/~afisher/CVpubs/pubs.htm) or contact the first author for information and/or preprints (afisher@ucsc.edu).

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