The Kings River Experimental Watersheds: New Findings about Headwater Streams of the Southern Sierra Nevada

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The Kings River Experimental Watersheds (KREW) study was designed to (1) characterize the variability in watershed attributes considered important to understanding processes and health of headwater streams and forest watersheds and (2) evaluate forest restoration treatments—mechanical thinning and understory prescribed fire. Prior to KREW being established, no long-term watershed research experiment was functioning in the mountain source waters despite the importance of water to California. KREW also is ideally suited to address climate change because of its location; rain-dominated lower elevation watersheds, that also receive snow, provide a surrogate for how snow-dominated, higher elevation watersheds, could function with climate change.

The KREW is a paired watershed experiment located in the headwaters of the Kings River Basin (Fig. 1) which started collecting data in 2002. Two sites are instrumented with four watersheds each: the Providence Site between 1,500 and 2,100 m elevation and the Bull Site between 2,000 and 2,500 m. At each site one watershed is a control (no treatment), one has been thinned, one will be burned, and one will be both thinned and burned. A unique aspect of the study is that the control watershed in the Teakettle Experimental Forest can be considered "undisturbed" since it has no roads or history of timber harvesting; thus, it provides a "natural range of variability" while the other watersheds provide the "current range of variability." The forest at KREW is mixed conifer growing in soils derived from granite and sustained by a Mediterranean climate. The pre-treatment phase of nine years will end with tree thinning completed in 2012 and prescribed fire planned for 2013-2014. The experiment was designed to provide information for adaptive management by evaluating the integrated condition of the perennial streams and their associated watersheds before and after fuels reduction and restoration treatments. To accomplish this goal, a diverse set of measurements are made.

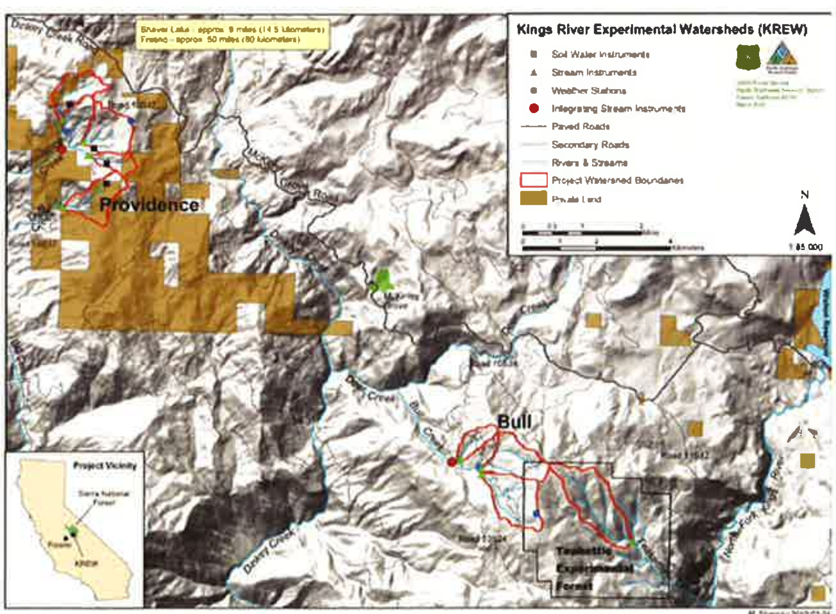

Figure 1. The Kings River Experimental Watersheds (KREW) research is located on headwater tributaries of the Kings River in the Sierra National Forest, east of Shaver Lake, CA. KREW consists of two sites approximately 15 km apart: Providence shown at the top of the figure, and Bull shown at the bottom of the figure.

- Physical measurements include upland erosion, turbidity (suspended sediment), stream temperature, streamflow, channel characteristics, and weather conditions.
- Chemical measurement for stream water, shallow soil water, precipitation, and snowmelt include nutrients (nitrate, ammonium, phosphate), chloride, sulfate, calcium, magnesium, potassium, sodium, pH, and electrical conductivity.
- Biological measurements include stream invertebrates, algae, and riparian and upland vegetation.

New information has been gained about Sierra headwater streams during the first nine years of the KREW study.

Water Budget: Stream Discharge, Precipitation, and Evapotranspiration

(Hunsaker et al. 2012, Bales et al. 2011)

The information learned on this topic is important for understanding how water yield may change with changing climate (Fig. 2).

- Precipitation amount and timing were very similar for all four KREW meteorology stations (75-200 cm) despite the nearly 700 m difference in elevation. This supports previous observations that precipitation on the west side of the Sierra Nevada reaches a maximum at about 1200 m.
- The annual runoff ratio (stream discharge divided by precipitation) increased about 0.1 per 300 m of mean catchment elevation over the range 1,800-2,400 m.
- The larger, snow-dominated watersheds (75-90% of precipitation is snow) have two to three times the stream discharge of the lower elevation watersheds.

Figure 2. One watershed in the Teakettle Experimental Forest is used as a control watershed; it has never been disturbed by roads or timber harvests. This photo shows the Teakettle stream at the Bull Site in winter; the weir and basin were constructed in the 1940s, and retrofitted with modern instruments for KREW measurements. Photo: S. Eagan

- Peak discharge lagged peak snow accumulation on the order of 60 days at the higher elevations and 20-30 days at the lower elevations.
- At the Providence Site, total annual evapotranspiration for water year 2009 was estimated to be approximately 76 cm. Trees at this elevation are growing and using water more than expected during the winter.

Flow Pathways

(Liu et al. 2012)

Processes controlling stream flow generation can be determined using water chemistry measurements.

- Streamflow in these headwaters was dominated by subsurface flow (about 60% of discharge), while snowmelt runoff contributed less than 40%, and fall storm runoff less than 7%.
- Subsurface flow is likely generated from the soil-bedrock interface through preferential pathways and is not very sensitive to snow-rain proportions.

Nitrogen Deposition and Movement through Ecosystem Compartments

(Hunsaker et al. 2007)

Nitrogen is an important indicator of the overall health of a forest, and knowing its concentration over time in atmospheric deposition, vegetation, soils, and water provides a useful assessment tool. Nitrogen is an essential nutrient, but if its concentrations become too high it can cause problems like acidification, excessive aquatic plant growth, and low oxygen concentrations in water (Fig. 3).

- Atmospheric nitrogen inputs to the research area are above known effects levels for sensitive lichens (3-5 kg/ha) and often exceed > 17 kg/ha, a level that is known to affect 26% of fine roots and could result in leaching to stream water.
- Despite the moderately high atmospheric inputs of nitrogen, soil water and stream water nitrogen concentrations seldom exceed 0.05 mg/L, an indication that the forest ecosystem is utilizing the incoming nitrogen.
- Interflow between the organic layer (e.g., needles, leaves, twigs) and mineral soil was measured and was enriched with nutrients. This could be an explanation for how soil nutrient "hotspots" are caused. Ammonium-nitrogen concentrations ranged from < 0.1 to 6.3 mg/L and nitrate-nitrogen ranged from < 0.1 to 8.7 mg/L, values that exceed those found in soil solutions and stream water.

Figure 3. Nitrogen deposition from the atmosphere to the ground and movement from the ground into the mineral soil is measured each year with resin lysimeters (shown in plastic bag in photo foreground) at hundreds of points across the watersheds. This photo shows a team of Sierra High School students installing resin lysimeters at a Providence watershed in 2012. Photo: C. Hunsaker

Soils

(Johnson et al. 2011)

Soil carbon and nutrient contents were characterized during the pre-treatment years to be able to understand how tree thinning and prescribed fire change these important attributes.

- The Bull Site watersheds had significantly greater carbon and nitrogen, likely because of slower decomposition rates at colder, higher elevations. Calcium, magnesium, and pH were lower at the higher elevation site because of higher leaching rates with more snow.
- These data showed that carbon and nutrient contents in soil would have been overestimated by 16% and 43% if quantitative pits were not dug and large rocks accounted for in calculations.
- Although soil ammonium nitrogen was high, the carbon to nitrogen ratio (a measure of soil condition) was normal (20-22).

Sediment

(Hunsaker and Neary 2012)

- The current range of variability in sediment loads of headwater streams in managed (roads and previous timber harvest) watersheds ranged between 2 and 17 kg/ha with standard deviations of similar magnitude (Fig 4).
- The natural range of variability for sediment loads in an undisturbed watershed was the same order of magnitude as for managed watersheds (16 ± 21 kg/ha).
- Fine and coarse particulate organic matter makes up 30-50% of the material collected in the sediment basins; this high proportion of organic matter is logical for headwater streams where organic matter provides the energy/food source for stream organisms like invertebrates (heterotrophic).

The publications that document these findings are available at www.treesearch.fs.fed.us; search for "Hunsaker" as an author. For more information about KREW visit the Pacific Southwest Research Station's web site www.fs.fed.us/psw/topics/water.

Figure 4. Fiberglass flumes provide a uniform stream cross-section for accurate stream discharge measurements. This photo shows high flow at a Providence Site stream during a rain-on-snow event that created stream turbidity (suspended sediment) which is measured at KREW. Photo: T. Whitaker

The University of Nevada at Reno, the University of California at Santa Barbara, and the U.S. Geological Survey, Sacramento have collaborated on KREW since the start. KREW has hosted the National Science Foundation's Southern Sierra Critical Zone Observatory (http://criticalzone.org/sierra) since 2007 and will be part of their Domain 17 of the National Ecological Observatory Network (www.neoninc.org).

From 2005 through 2010 KREW received funding from the CalFed Bay Delta Program under Proposition 50 (State Water Resources Control Board Grant Agreement 04-186-555-0). The KREW provided much needed information on headwater ecosystems in the southern Sierra Nevada to assist with CALFED's actions "to reduce or eliminate parameters that degrade water quality at its source" and to understand "watershed processes and their relationships with one another." Because of the limited watershed research in the southern Sierra Nevada, KREW findings are important for the Integrated Regional Water Management Plan process and the work of the State Water Quality Control Board.

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Castilleja applegatei. Photo: J. Blanchard

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