

**Title:** FENS AS INDICATORS OF CHANGES IN GROUNDWATER RECHARGE

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**Background:** Climate models for the Sierra Nevada region of California predict that there will be earlier snowmelt and less snowfall as a percent of total precipitation (Dettinger et al. 2004, Cayan et al. 2008). These changes are likely to pose major challenges regarding the availability and distribution of water supplies to millions of Californians and the large agricultural sector, which both rely on the Sierra snowpack to supply water during the dry spring and summer months (Luers et al. 2006). In addition to changes in streamflow, earlier snowmelt and less snowpack could decrease groundwater recharge, because, in arid and semi-arid regions, groundwater recharge occurs primarily from snowmelt (Winograd et al. 1998). Because groundwater recharge is crucial for maintaining soil moisture and down-slope groundwater discharge, reductions in recharge could result in loss of wetland habitat (Winter 2000), forest die-off (Breshears et al. 2005), and increased incidence of wildfires (Westerling and Bryant 2008). It is unclear, however, how groundwater recharge is changing in the Sierra or elsewhere as a result of climate change, because little research has been done on the subject (Goderniaux et al. 2009).

Groundwater-fed peatlands called fens are ideal ecosystems for studying changes in groundwater recharge, because they are groundwater discharge sites that rely upon corresponding recharge sites for their sustenance (Siegel 1983). Fens are broadly distributed in temperate and boreal regions of the world (Gore 1983), including the Sierra Nevada (David Weixelman, USDA Forest Service, pers. comm.). They are commonly found where a sudden break of slope causes the water table to meet the land surface (Cooper and Wolf 2006). Because fens are so intricately tied to groundwater flow systems, changes in the supply of groundwater can quickly be recognized by changes in fen properties. For example, if changes occur in groundwater supply, fens respond by shrinking or expanding their perimeters (Bartolomme et al. 1990). The relative change in wetland area depends on the magnitude of change in groundwater flow as well as whether the site receives groundwater from local-, intermediate, and/or regional flow systems (Winter 1999).

**Objectives:** The purpose of this project is to use fens to study temporal changes in groundwater recharge in the Sierra Nevada. Specifically, we will seek to determine temporal changes in fen area through time.

The major research question this project seeks to answer is whether or not the areal extent of fens has changed during the past 50-60 years due to reduced groundwater discharge in the Sierra Nevada. The information gathered in this study will serve as a broad baseline against which future comparisons can be made. In addition, this study will provide the basis for future field investigations of groundwater age and groundwater flow patterns in fens.

**Approach:** We will determine whether the areal extent of fens has changed through time by conducting a thorough analysis of aerial photographs, which are available from the late 1930s to the present for the Sierra Nevada. Originally we considered trying to use LANDSAT imagery for this purpose, but image resolution (30 m at best) is insufficient for the needs of this study.

We will start the aerial photo analysis by first identifying regions in the Sierra Nevada that contain the most complete, long-term photo records. Once these regions are identified, we will choose three study areas of the Sierra Nevada that fall along a north-south transect. We will identify three study fens in each of the three study areas (for a total of nine sites) using National Wetlands Inventory maps, USDA Forest Service inventory maps, and results from a Sierra-wide study by Cooper and Wolfe (2006). We will choose medium to large fens ranging from one half to over one hectare in size.

Next we will use the aerial photos to determine the area of each fen during each decade over the past 60+ years to see whether these sites have changed in size through time. An interval of approximately a decade (depending on the imagery available) will be used because changes in area will most likely be small and require significant time periods to become apparent. If fens become dryer through time due to diminished groundwater flows, their size shrinks, and non-fen vegetation such as pines expands into former fen habitat (Bartolomne et al. 1990). Conversely, if fens become wetter due to increased groundwater flows, meadow habitat expands into forested areas. Therefore, we will track the area of fens by examining whether there have been incursions of coniferous trees at their boundaries or conversely whether meadow habitat has spread to neighboring forested areas. Aerial photos will be obtained from the USGS Center for Earth Resources Observation and Science in Sioux Falls, South Dakota.

**Related Projects:** This project is part of a new research effort aimed at studying how climate change and more localized disturbances, such as grazing and nutrient loading, may be impacting the hydrologic and biogeochemical processes in fen ecosystems in the Sierra Nevada. We have recently submitted a companion proposal to the USGS/National Park Service (NPS) Park Oriented Biological Support program to determine the age, peat accretion rates, and carbon sequestration rates of fens in Yosemite National Park. We also plan to submit a proposal on fen nutrient status to the NPS/USGS Water Quality partnership program in 2010.

**Products:** The product of this project will be a manuscript that will be submitted to a peer-reviewed journal. The paper will focus on documenting changes in fen area through time. Any data suitable for geographic display, such as changes in fen area, will be developed into a GIS for the Sierra Nevada region.

**Schedule:** This project is planned to take place over two years. The first 3-6 months will be devoted to selecting sites with the longest and most complete aerial photograph record. The next 6 months will be devoted to measuring changes in area through time. The last year of the project will be devoted to manuscript preparation. *However, if funding is uncertain for the second year, we can intensify our efforts and complete the project in one year.*

**Budget:** The following table contains the budget breakdown for this study. The budget can be compressed into one year, if necessary, due to uncertain funding levels in the future.

<b>Budget Breakdown for Two-Year Study.</b>			
<b>Category</b>	<b>Year 1</b>	<b>Year 2</b>	<b>Total</b>
<b>Labor</b>			
Drexler	\$23,412 (300 hrs)	\$31,220 (400 hrs)	\$54,632
Knifong	\$14,760 (250 hrs)	\$9,445 (160 hrs)	\$24,205
<b>Travel (to conference)</b>		\$1,000	\$1,000
<b>Equipment &amp; Supplies</b>	\$500	\$200	\$700
<b>Communications</b>	\$250	\$250	\$500
<b>Indirect Costs</b>	\$13,805	\$15,120	\$28,925
<b>Total</b>	<b>\$52,727</b>	<b>\$57,235</b>	<b>\$109,962</b>

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**Personnel:**

**Judith Z. Drexler:** Ph.D. 1996, Natural Resources, Cornell University, Ithaca, NY  
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**Judith Z. Drexler** is a wetland ecologist at the CAWSC who has studied a wide range of wetland and near-shore environments ranging from temperate peatlands and marshes to tropical mangrove forests. She is currently carrying out a two projects in the San Francisco Bay Estuary: (1) a project called REPEAT (Rates and Evolution of Peat Accretion through Time in the Delta) in which she is studying vertical peat accretion and carbon sequestration in marshes in the San Francisco Bay Estuary over the past 6,000 years, and (2) a joint project with Dr. John Callaway (University of San Francisco) in which they are measuring recent rates of peat accretion and carbon sequestration throughout the Estuary. During her postdoc with the USDA Forest Service she studied the hydrological linkages between coastal mangrove ecosystems and freshwater swamps in the Federated States of Micronesia. For 18 years, her research has melded ecology and hydrology by focusing on abiotic factors (e.g., groundwater flow patterns, nutrient loading, geochemistry, and sedimentation) and their ability to control wetland formation, plant community dynamics, and long-term wetland sustainability.

Some relevant publications:

- Drexler, J.Z., de Fontaine, C.S., and Deverel, S.J. 2009. The legacy of wetland drainage on the peat resource in the Sacramento – San Joaquin Delta, CA, USA. *Wetlands* 29(1): 372-386.
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**Donna L. Knifong:** B.S. 1989, Geology, San Jose State University, San Jose, CA.

**Donna L. Knifong** is a geographer with broad knowledge of GIS and aerial photometry, who has worked at the USGS since 1987 and at the CAWSC since 1992. She has been the CAWSC GIS coordinator for the past 5 years. She is the database manager for the Sacramento and San Joaquin-Tulare Basin Study Units of the National Water Quality Assessment program and the GIS specialist for the PRMS modeling of surface water run-off in the Yuba River Basin. Through her work, she has contributed her GIS expertise on numerous projects including acid mine drainage, debris flow modeling, pesticide application and transport, and groundwater modeling.