WATER STEWARDSHIP IN THE RIO GRANDE CORRIDOR: THE VALUE OF AN ECOHYDROLOGICAL PERSPECTIVE

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ABSTRACT

Many of our current (and future) problems involving water in the Rio Grande Corridor involve what the National Research Council has termed the "Critical Zone": the heterogeneous, near-surface environment in which complex interactions between rock, soil, water, air, and living organisms regulate the natural habitat and determine the availability of life-sustaining resources (National Research Council, 2001a). Complex environmental problems such as water stewardship thus require an interdisciplinary ecohydrological perspective. This is especially true for semiarid landscapes such as the Rio Grande Corridor where sensitivity to environmental change is high and where competition for water resources is acute.

Ecohydrology is the hybrid discipline shared by the ecological and hydrological sciences that seeks to elucidate (a) how hydrological processes influence the distribution, structure, and function of ecosystems, and (b) how feedbacks from biotic processes impact the water cycle. There are compelling reasons why an ecohydrological perspective should be an important component of water stewardship in the Rio Grande Corridor. First, the need for nontraditional interdisciplinary approaches has been emphasized by multiple agencies and the scientific community (IBRCS, 2003; National Research Council, 2001a; NRC, 2001b; Newman et al., 2003; Nuttle, 2002; Rodriguez-Iturbe, 2000). These reports have pointed out that water resource environmental issues are extremely dynamic in space and time, necessitating that problem-solving approaches cross-traditional disciplinary and societal boundaries. These reports also call for the development of novel research tools to study hydrologic and environmental problems as integrated, hierarchical systems of interacting components and processes. A comprehensive "Ecohydrologic" understanding is not available for the Rio Grande Corridor, yet such an understanding is critical to making sound, cost effective, management and policy decisions regarding water supply and water quality issues. By way of example, some of the scientific and societal challenges that require an ecohydrological perspective that pertain to issues in the Rio Grande Corridor are discussed below.

VERTICAL FLUXES

Our understanding of the spatial and temporal variability in vertical fluxes associated with infiltration, percolation, and groundwater recharge in semiarid landscapes is limited. These processes are typically episodic, and recent investigations (e.g., Walvoord et al. 2002), show a pronounced influence of vegetation on shallow and deep vadose zone water movement. However, there is much uncertainty regarding how plant species, precipitation rates, and vadose zone hydraulic properties interact to regulate downward (and upward) water flow. A related societal concern is the widespread conversion of grasslands and savannas to shrublands in semiarid ecosystems worldwide over the last 50 to 100 years and the invasion of exotic plant species in riparian areas. These land cover changes have provoked a great deal of debate about ecological health and impacts on water resources. Such changes place enormous pressure on agencies responsible for environmental management. However, adequate supporting science is not typically available for managers to make sound resource management decisions (Wilcox, 2002).

<u>Coupled Water, Plant, & Nutrient Interactions</u>: Hydrological processes and vegetation are intimately linked; however, the additional linkage with nutrient dynamics is often overlooked or examined in isolation of either hydrology or plant dynamics. For example, in dryland environments, water has often been treated as the main limiting resource controlling plant growth and community structure. However, nutrient availability (especially nitrogen) is also an important ecological determinant. Archer and Bowman (2002) review arguments suggesting the importance of nutrients has been underestimated, and that research focusing solely on water may be overlooking a critical coupling. They suggest field experiments should be designed to monitor and gain process level understanding of the linked water, plant, nutrient system if we are to build a fundamental understanding sufficient to make good environmental management decisions.

<u>Spatial Complexity and Scaling</u>: Scaling from point, to plot, to watershed, to region has long been an important focus in hydrology, most notably in models of rainfall-runoff and river network dynamics. However, there is an urgent need for understanding the spatial interaction of heterogeneities in traditional hydrologic conditions (e.g., topography, soils, rainfall) and the ecosystems, communities and ecotonal boundaries developed on this template. Field experiments in the form of continuous monitoring and spatially-extensive campaigns at multiple scales are needed if we are to elucidate hydrological, ecological, and

nutrient dynamics and processes at scales relevant to land management and policy (Newman et al., 2003; Rodriguez-Iturbe, 2000). By embedding ecohydrologic dynamics within distributed hydrologic models, the scientific community can explore the multi-directional interaction between hydrologic organizing principles and spatial-temporal ecosystem dynamics (e.g., Fernandez-Illescas and Rodriguez-Iturbe, 2004; Milne et al., 2002) to better understand the benefits and consequences of environmental management decisions.

In terms of technologies and capabilities, researchers at LANL have been working on ecohydrological studies for several years and can contribute a great deal to experimental and monitoring design, measurement and monitoring technologies, and coupled modeling of the Rio Grande Corridor.

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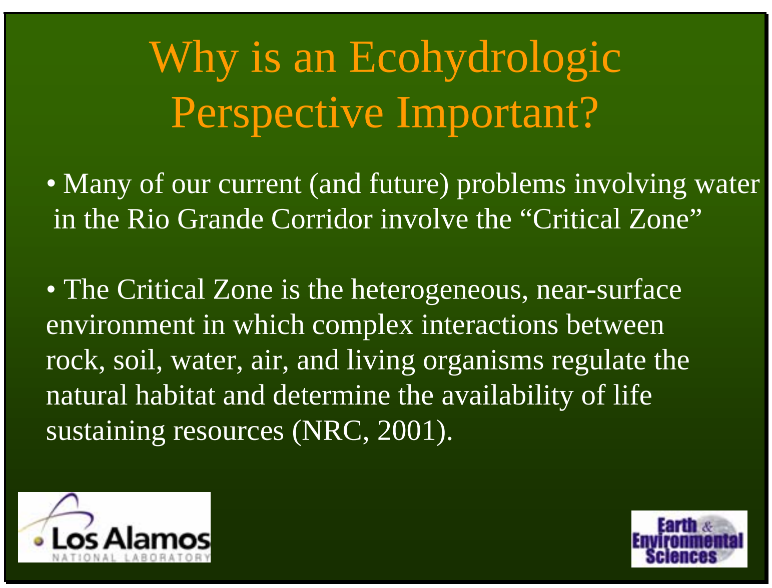

What is Ecohydrology?

- Ecohydrology is the hybrid discipline shared by the ecological and hydrological sciences that seeks to elucidate (a) how hydrological processes influence the distribution, structure, and function of ecosystems, and (b) how feedbacks from biotic processes impact the water cycle.

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Presentation Objectives

- Discuss examples of why ecohydrology is important in the Rio Grande Corridor
  - significant gap in our understanding of fundamental ecohydrologic processes along the Rio Grande
- Describe some of the technologies & approaches that are available to address ecohydrological issues along the Rio Grande

Woody Plant Encroachment

- Widespread conversion of grasslands and savannas to shrublands and woodlands in semiarid environments worldwide
  - Encroachment has been dramatic over the last 50-100 years (e.g., piñon, juniper, mesquite, creosote)
  - Related problem is invasion of exotic species in riparian areas
- What is the impact of woody plant encroachment?
  - Do woody plants decrease streamflow and recharge?
- What are the best management approaches?

Woody Plant Encroachment

- Studies of streamflow and recharge as a result of vegetation change are mixed
  - Some studies show a significant response to vegetation change, while others do not (Wilcox, 2002).
  - Precipitation is a fundamental factor
    - **"there is little if any real potential for increasing streamflow where annual precipitation is below about 500 mm (Hibbert, 1983 and Wilcox, 2002)**
- Adequate supporting science is not typically available for policy makers and managers to make sound resource management decisions (Wilcox, 2002).

How do we quantitatively determine the recharge of an area?

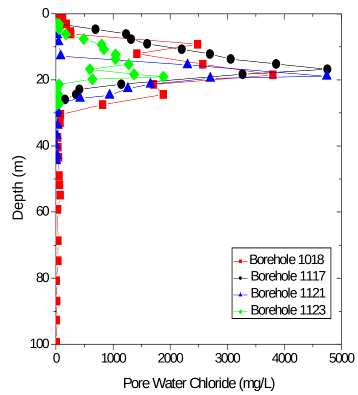
- One successful approach is the chloride mass balance method
- Chloride in the vadose zone "records" the effects of evaporation and transpiration.
  - Recent work shows a strong influence of vegetation on shallow and deep water movement (Walvoord et al., 2002)
  - Can be used to estimate recharge rates and vadose zone residence times
  - Can provide both vertical and horizontal information about recharge

Chloride Mass Balance

1. Flux (m/yr) = $(Cl_p P)/Cl_{sw}$
2. Residence Time (yr) = $Cl_{cum}/(Cl_p P)$

– where P is the average annual precipitation rate (m/yr); Cl_p is average chloride concentration in precipitation (g/m^3); Cl_{sw} is the average pore water chloride concentration (g/m^3); and Cl_{cum} is the average pore water chloride concentration in a given depth interval (g/m^3)

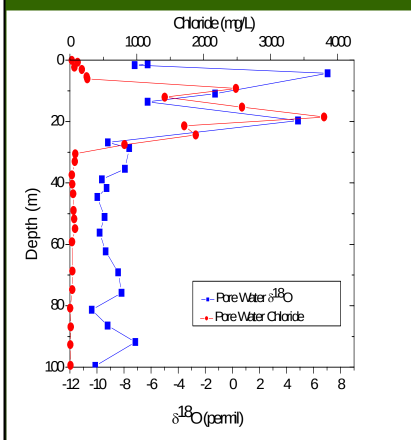
- Flux is inversely proportional to chloride content in the rock.
- Age or residence time is proportional to chloride content in the rock.



Chloride Profiles from Mesita del Buey Boreholes

Chloride Mass Balance Results

- Downward Fluxes < 1 mm/yr
- Residence times 1,300 to 18,000 years



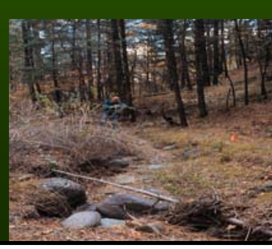
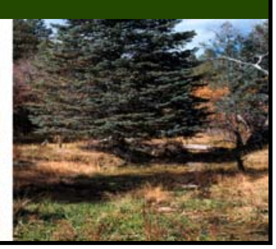
Borehole 1018, Pore Water Chloride and $\delta^{18}O$

Oxygen and hydrogen stable isotopes can be used to identify sources of water and quantify processes such as evaporation

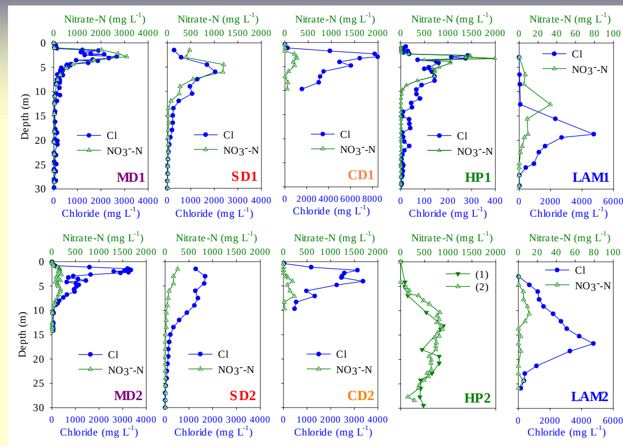
- Unsaturated Zone Pore Waters
- Groundwaters
- Surface waters

Nitrate

- Nitrate is an important nutrient and contaminant in semiarid systems such as the Rio Grande Corridor
- Vadose zone nitrate concentrations
- Vadose Zone Nitrogen Stable Isotope example

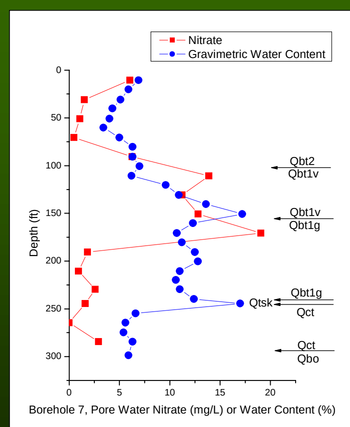



Mojave Desert | Sonoran Desert | Chihuahuan Desert | High Plains | Los Alamos Mesa

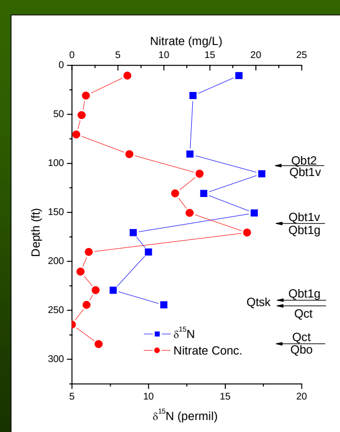


[from *Walvoord et al*., Science, 2003]

Example: What was the source of nitrate in this Los Alamos Mesa?



The highest nitrate concentrations are associated with $\delta^{15}N$ values over ten permil, strongly suggesting a sewage source. Subsequent investigations revealed that sanitary waste was released on the mesa top



Conclusions

- We need to know more about the fundamental interactions between ecological and hydrological processes
  - Need to know what you have and how the system works
  - Where will management practices be best applied
  - Helps identify what the best approaches are

- Multiple technologies are required
  - Chloride mass balance
  - Vadose and Saturated Zone Stable Isotopes

Acknowledgments

- Los Alamos National Laboratory Environmental Restoration Project
- Los Alamos National Laboratory Groundwater Monitoring Program
- MDA G Performance Assessment Project

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