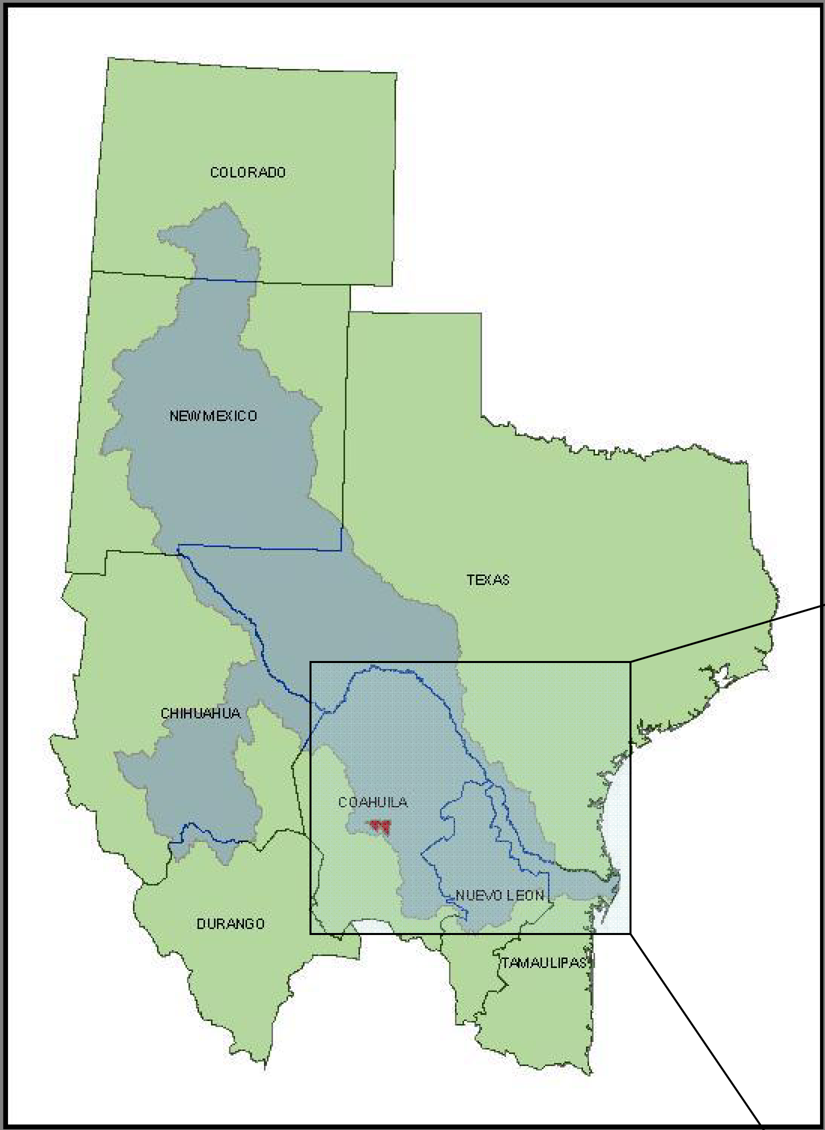
Groundwater systems in the Cuatrociénegas basin: comparing two conceptual flow models and related implications for groundwater management strategies



Suzanne A. Pierce, Shanna B. Evans, and John M. Sharp jr.
Jackson School of Geosciences, The University of Texas at Austin

The Cuatrociénegas Aquifer System

What we know. . .

- **Complex Groundwater Behavior**

  Karst features are adjacent to playa lakes within the valley and the actual groundwater flowpaths are unclear. Fracture dominated aquifer overlain by porous aquifer. Salinity issues. This system exhibits evidence of widely varied processes in a very small scale.

- **Groundwater Dependent Ecosystem Setting**

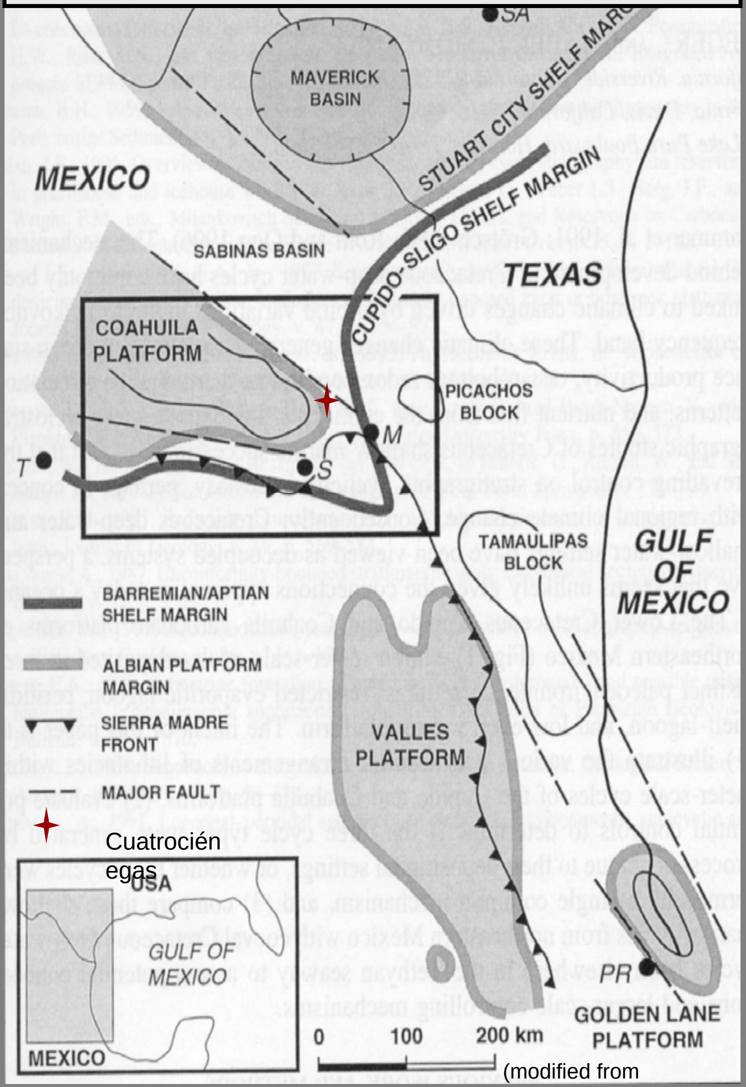
  In the Chihuahuan Desert, over 167 Springs and surface water expressions unique level of biodiversity .

- **Human Induced Change within the System**

  Naturally a closed or partially closed system, but due to use outside of the valley the system has become an artificially open one. Recently, decreases in water levels within the valley are disrupting the surface ecosystems and raising doubts about the future viability of continued irrigation within the valley.

The Cuatrociénegas Basin Geologic Setting

Tectonic and Structural Overview of Northeastern Mexico



(modified from Lehmann, 1998)

Steeply dipping anticline with **alluvial valley fill** in between

Bounding mountain ranges are dominated by **massive limestone** and **detrital shed** (McKee, 1990).

The **interior** of the valley is primarily unconsolidated **evaporite deposits.**

Boundaries

Northwest = thrust faults along the flanks of the Sierra de San Madera (Lesser, 2001).
Southern = combination of thrust and normal faulting from uplift of the Sierra de San Marcos or Sierra de la Fragua (Lesser, 2001).

Hydrogeologic Inputs + Outputs

Recharge
Probably precipitation in upland areas
Arid climate = Chihuahuan Desert
Annual precipitation = 200 mm
Temperature ranges = 44^{o}C to 0^{o}C in the winter (Minckley, 1969 and Pronatura, 1998).

Discharge
Natural = Evaporation and Evapotranspiration,
Artificial = Irrigation and Municipal Demand
(water table drop 30-60 cm past 5 years – Lesser, 2001)

Hydrogeologic Character

Two Aquifers

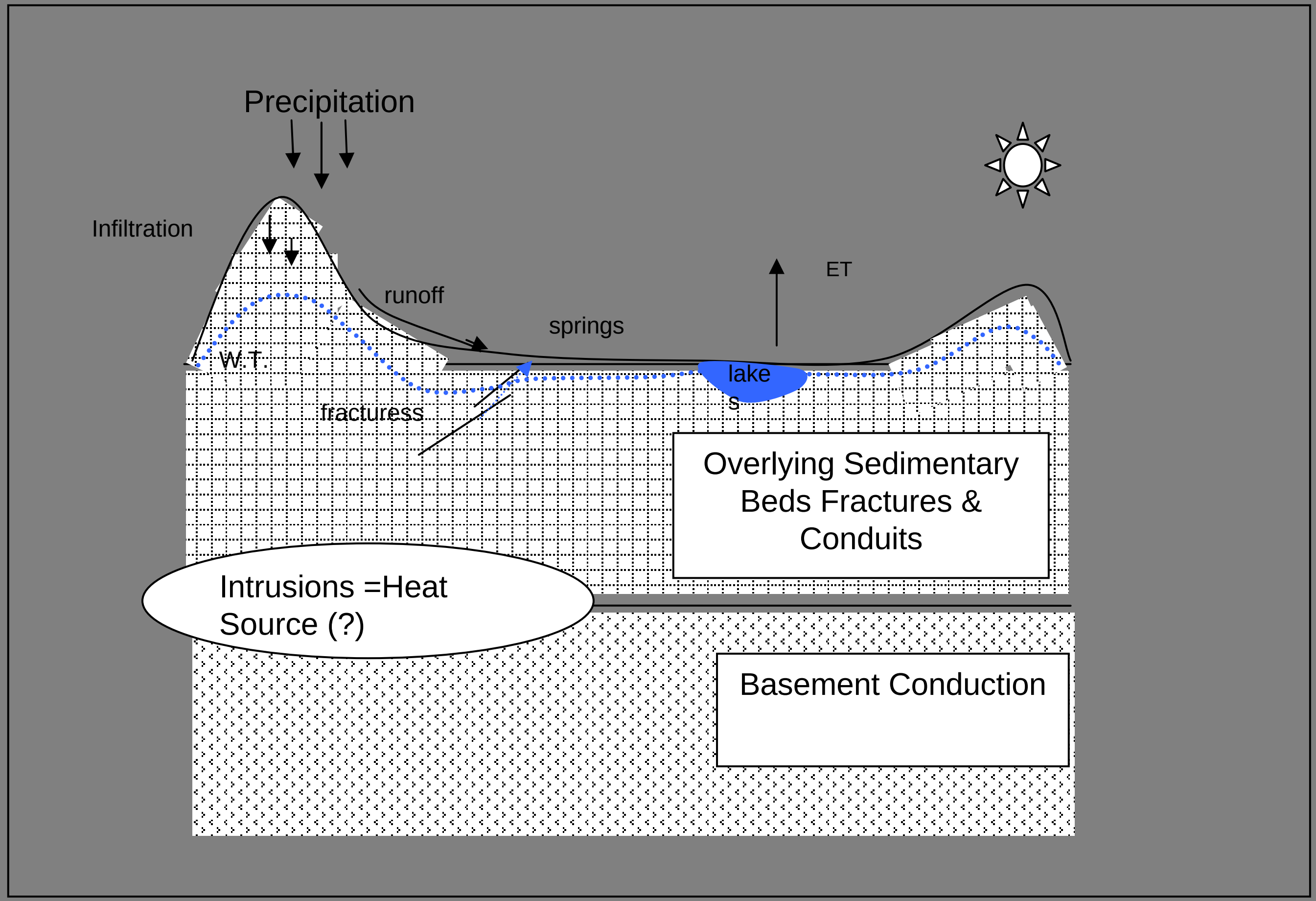
Shallow Unconfined

(shallow alluvial)

Over

Deeper Confined

(secondary porosity)



Storage = 0.022 – 0.0003

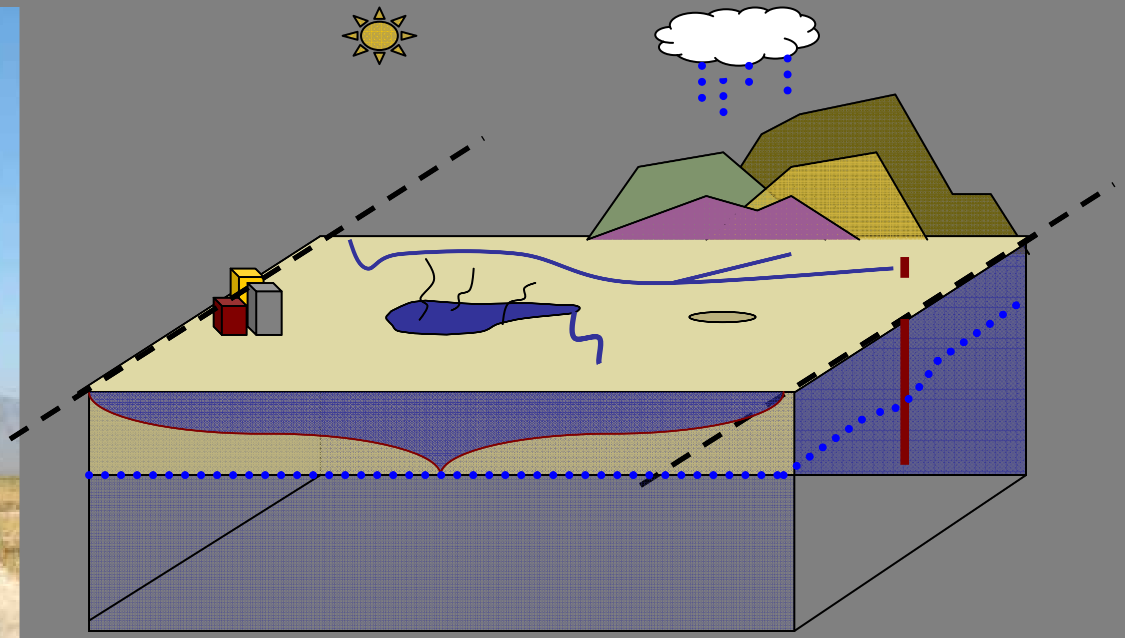
But no good estimates for transmissivity evapotranspiration, or discharge rates

Hydrostratigraphic Units

Tertiary Quaternary	Alluvium & Colluvium	Uncolsolidated gravels, sands, evaporite deposits	Permeable
	Lake Deposits	Clays	Impermeable
Cretaceous	Eagle Ford	Sandy clays, lutites and limestone	Impermeable
	Buda	Limestone	Permeable
	Del Rio	Lutites	Impermeable
	Georgetown	Limestone	Permeable
	Kiamichi	Lutites & limestones	Impermeable
	Aurora	Platform limestones	Permeable
	Cañon de Barril Viejo (or La Pena)	Mixed terrigenous and marine carbonate (interfingered)	_____
	Cupido	Graded limestone cyclical lithofacies transitions, massive limestone	Permeable
Late Jurassic	La Virgen	Gypsum interbedded with limestone sabkha on alluvial surface	Semipermeable
	La Mula	Sand-shale facies and lime-shale facies detrital deposition	Impermeable
	Padilla	Dolomite lagoonal environment	Semipermeable
	San Marcos	Basal arkose sandstone	Semipermeable
Pre-Jurassic	Basement	Igneous lithologies primarily dacites & granidorites	_____

(Modified primarily from McKee, et. al., 1990 and Martinez, 2000)

The basin is a naturally undrained and closed

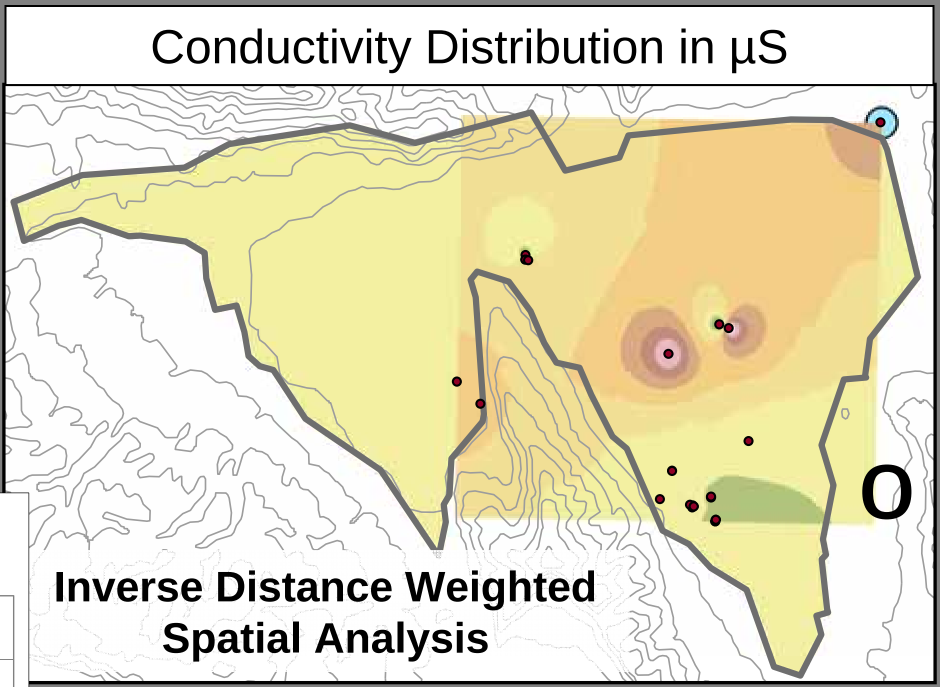


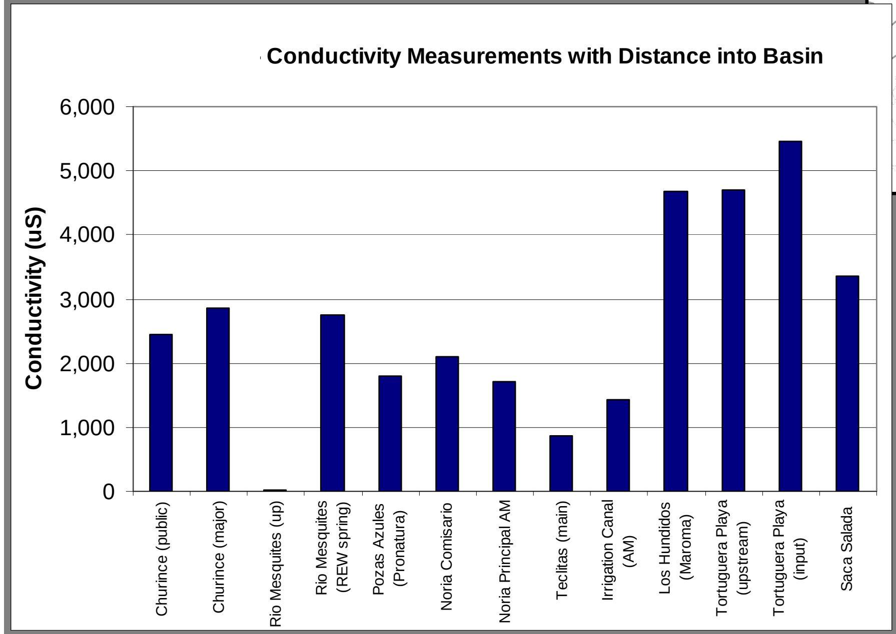
Under natural conditions the principle means of discharge within the basin would be through evaporation & evapotranspiration

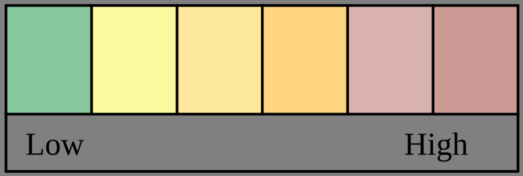
Today it is behaving as an artificially open-system with the largest component of discharge due to inter-basin transfers for use in irrigation and municipal water sources.

Spatial evaluation of hydrochemical data

Flanks of mountains exhibit lower salinity waters
and
Water quality degrades as the central sections of the basin are approached







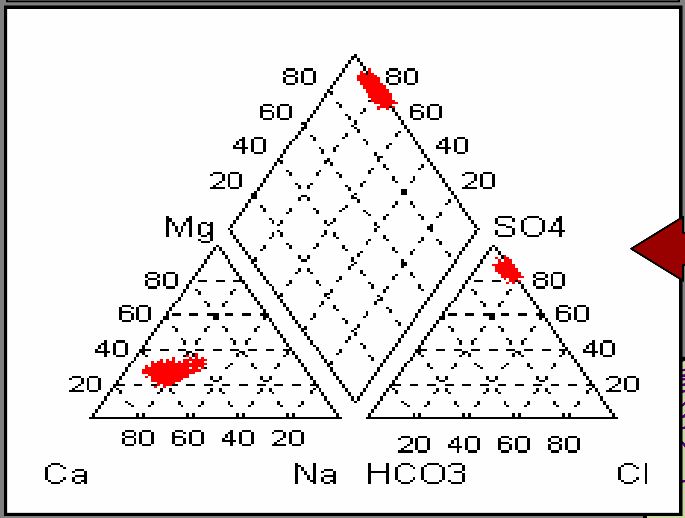
Springs near flanks = lowest

Playa, karst features, basin floor = highest

Hydrochemistry holds with a simple closed basin interpretation

An analysis of major water chemistry for surface water expressions within the basin reflect remarkable homogeneity

Piper Diagram

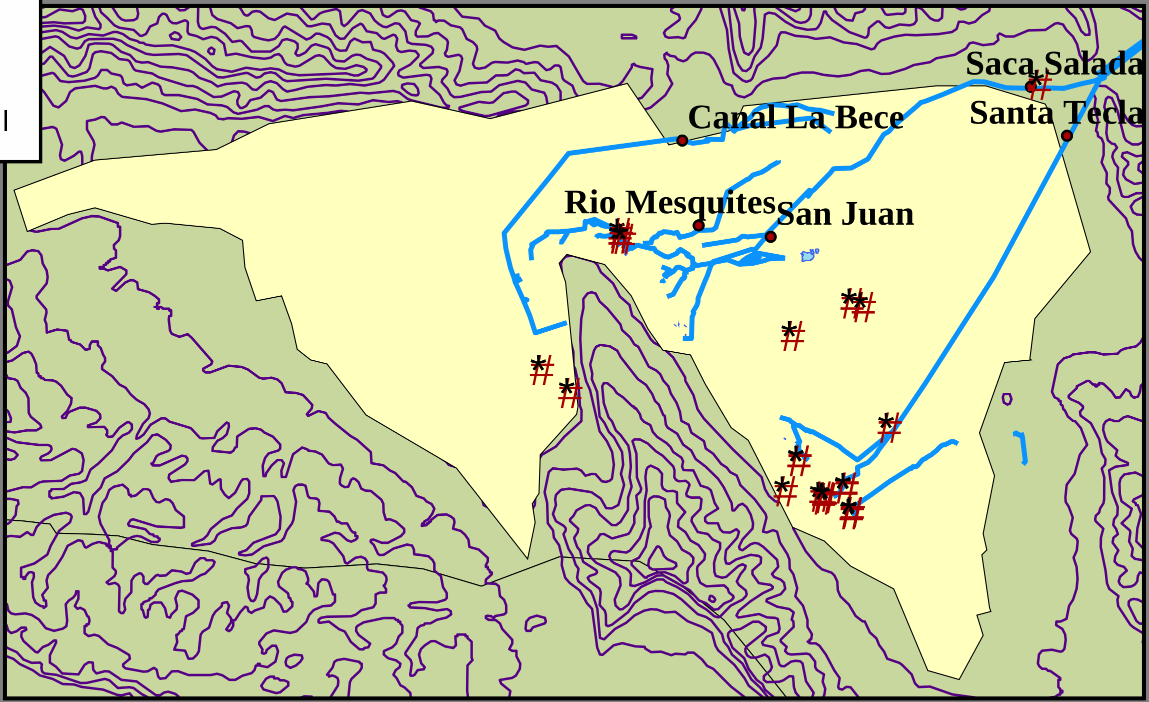


Dominant water type = Calcium-Sulfate

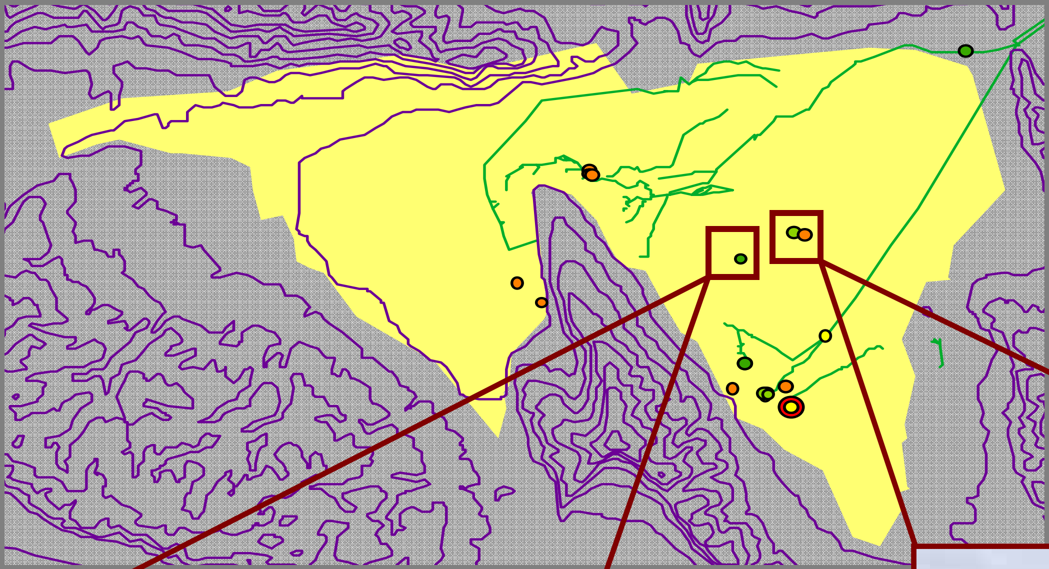
Evaporation

along flowpaths is one of the easily observable trends

Minor constituents may provide more clues



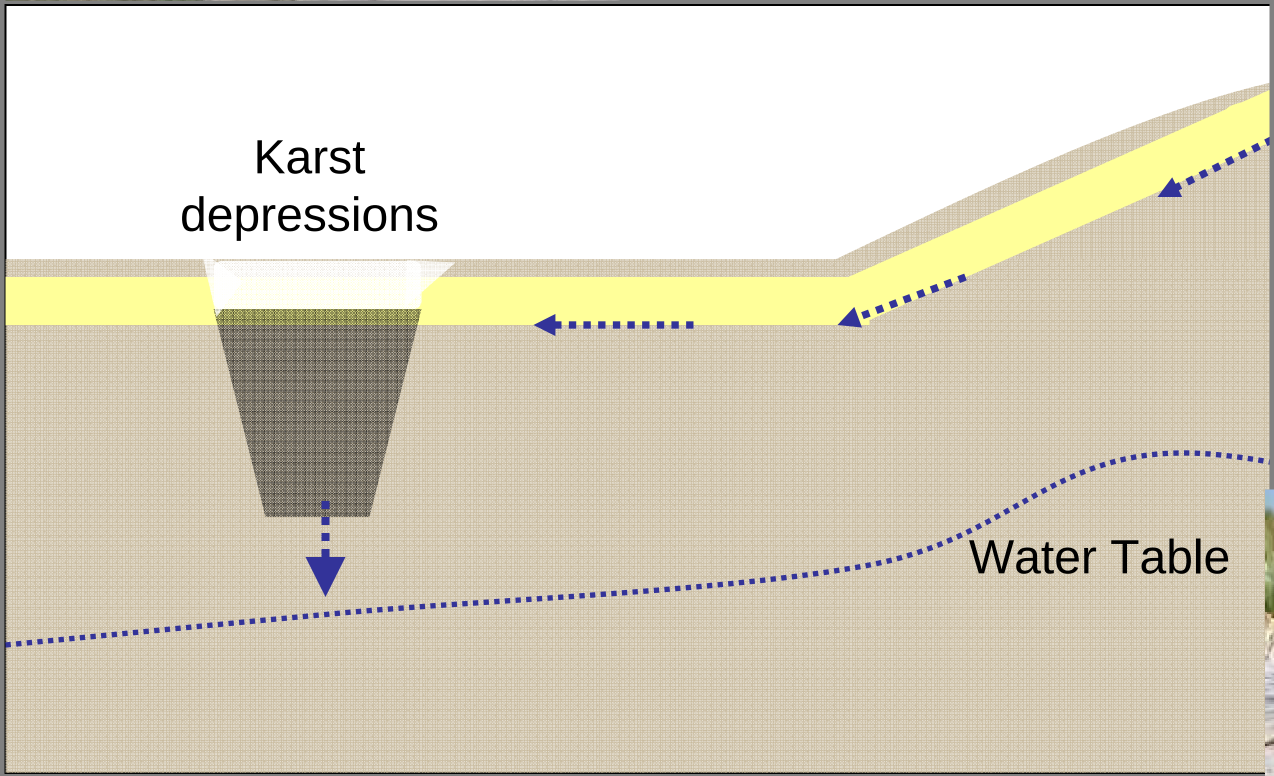
And then . . .



Comparing hydrochemistry and geomorphology

Playa basin features forming adjacent to karst features does not fit with the undrained, closed basin flow regime

Shallow groundwater flows within basin are dominated by subflow processes

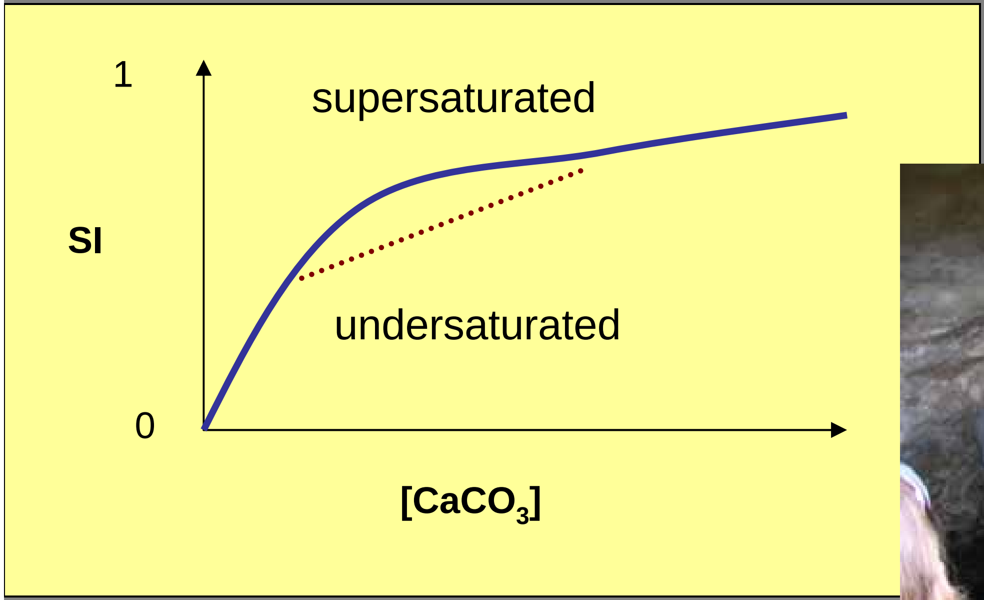


Doline Formation

Diffuse recharge becomes concentrated in subcutaneous zone

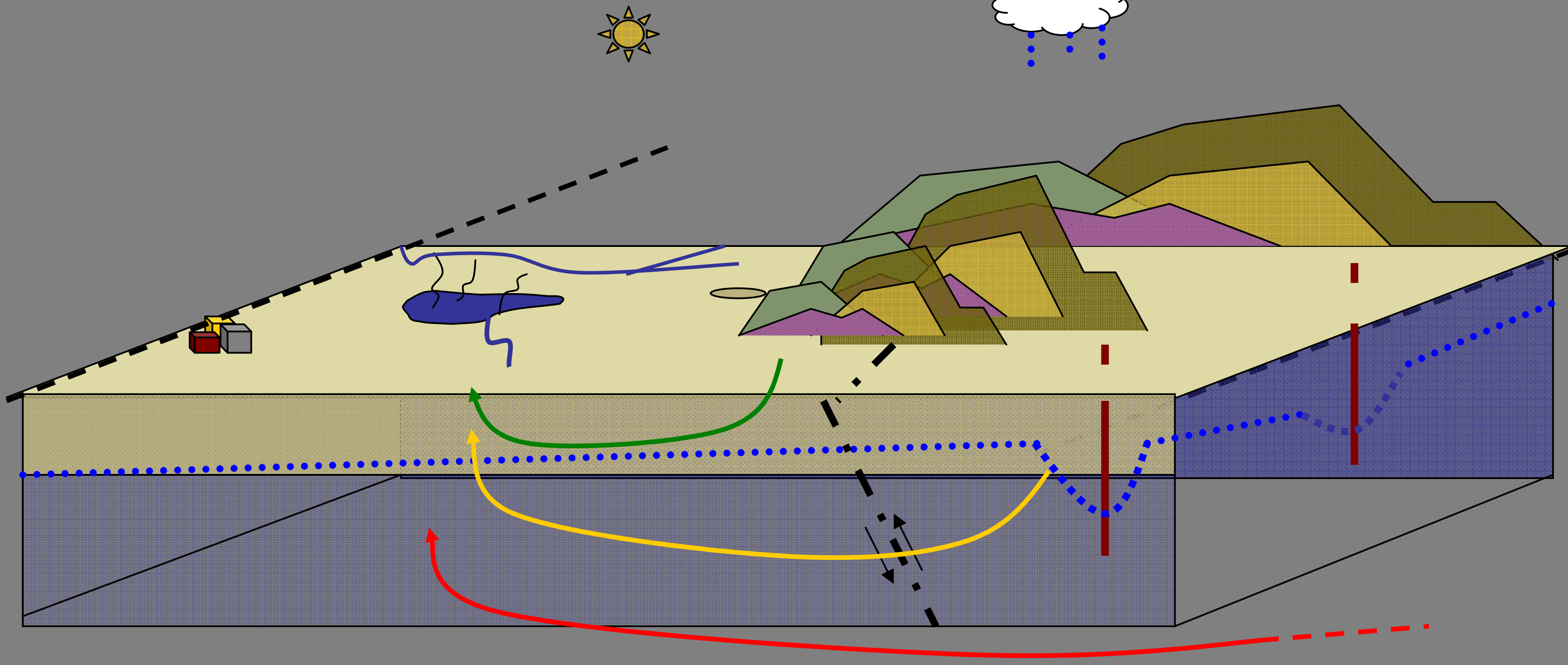
This supports an epi-karst aquifer overlying a deeper seated groundwater source

Doline Direction



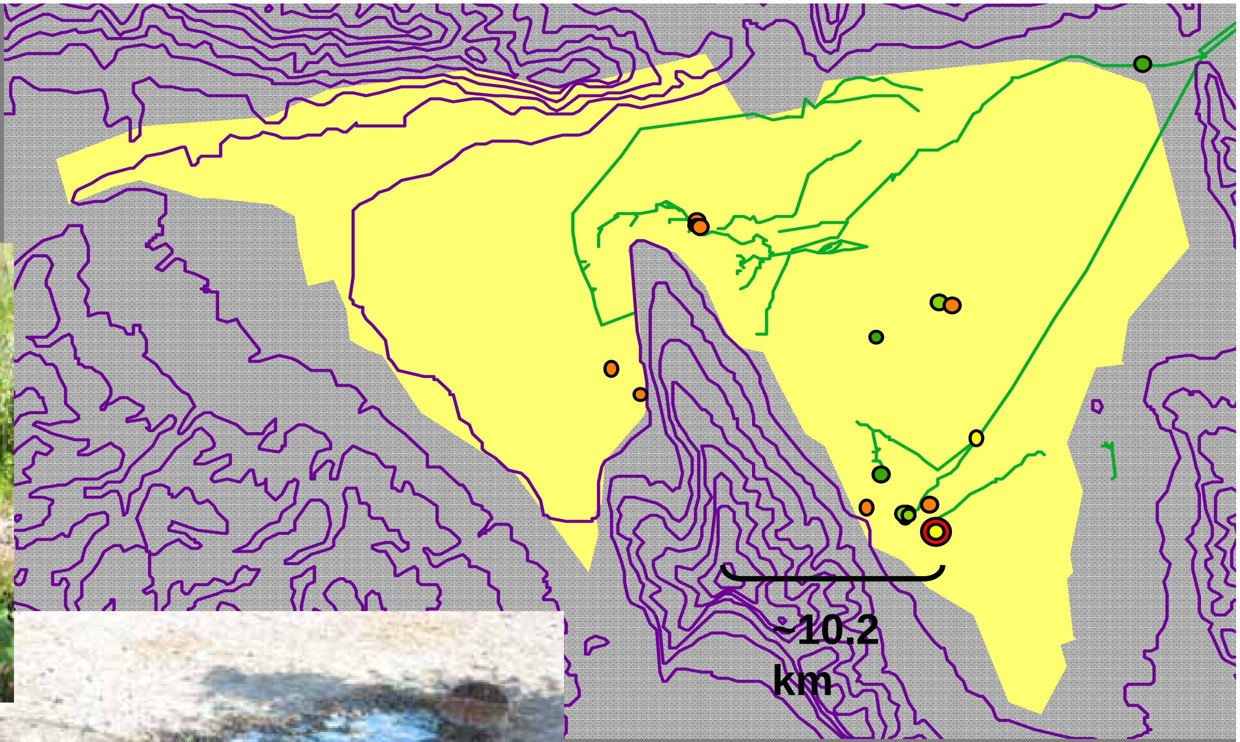
. . . Dissolution & Mixing

Partly Drained, Closed Basin



If solution mixing contributes to doline formation, then what is the secondary source of groundwater?

Upward flow



Temperature (C)

WQPoint Events

T_WA_

Local Flow — 27 - 28; 29

Intermediate Flow — 30 - 31; 32 - 33

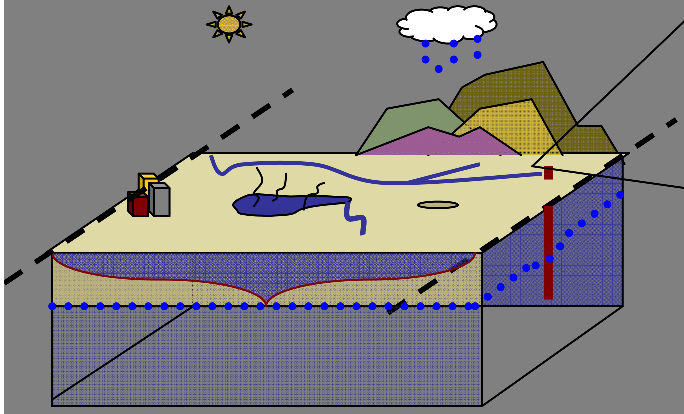
Regional Flow ? — 34 - 38

(modified from Carrillo-Rivera, 2000)

Human Impacts

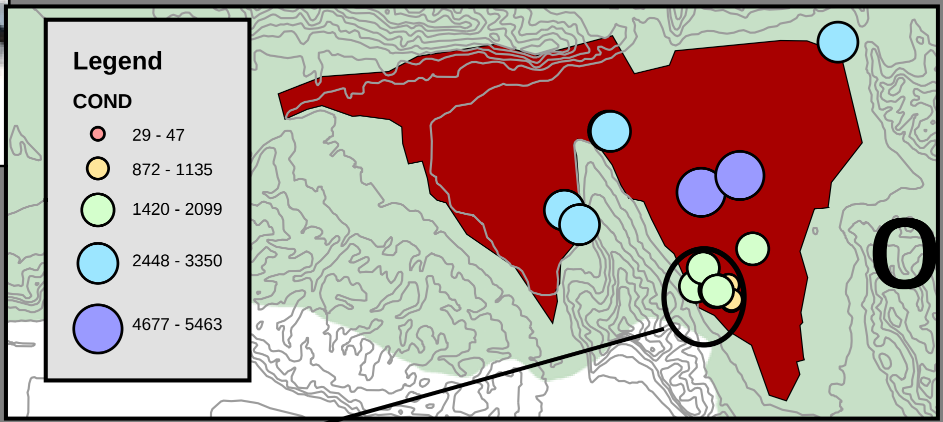
<u>Irrigation canals discharge points and recharge points</u>

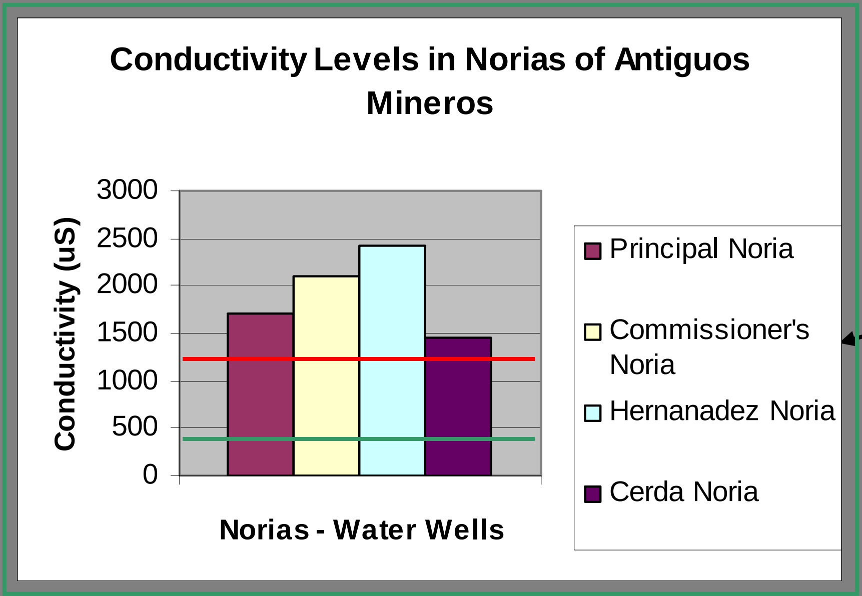
Agriculture is probably the major demand for water from the basin, but the canals also provide distributed recharge and return flows



In Addition, there are a wide-range of practical problems to be solved. For example,

Water Quality Analysis for Ejido Antiguos Mineros





Accessible Water Resource Management

Tools can be developed using simple water quality parameters and spatially related datamodels

1. Develop a water budget/balance for the basin (focus on surface water flows and ET estimates to start)
2. Clarify southwestern boundary conditions (geophysical methods)
3. Use existing hydrochemical data to model flow paths
4. Quantify hydrologic parameters (Drill long-term groundwater monitoring wells and conduct pump tests)
5. Finally, priority tasks should be internal to the CC basin, the effect of drawdown due to extra-basin pumping is most likely a secondary issue, for now.