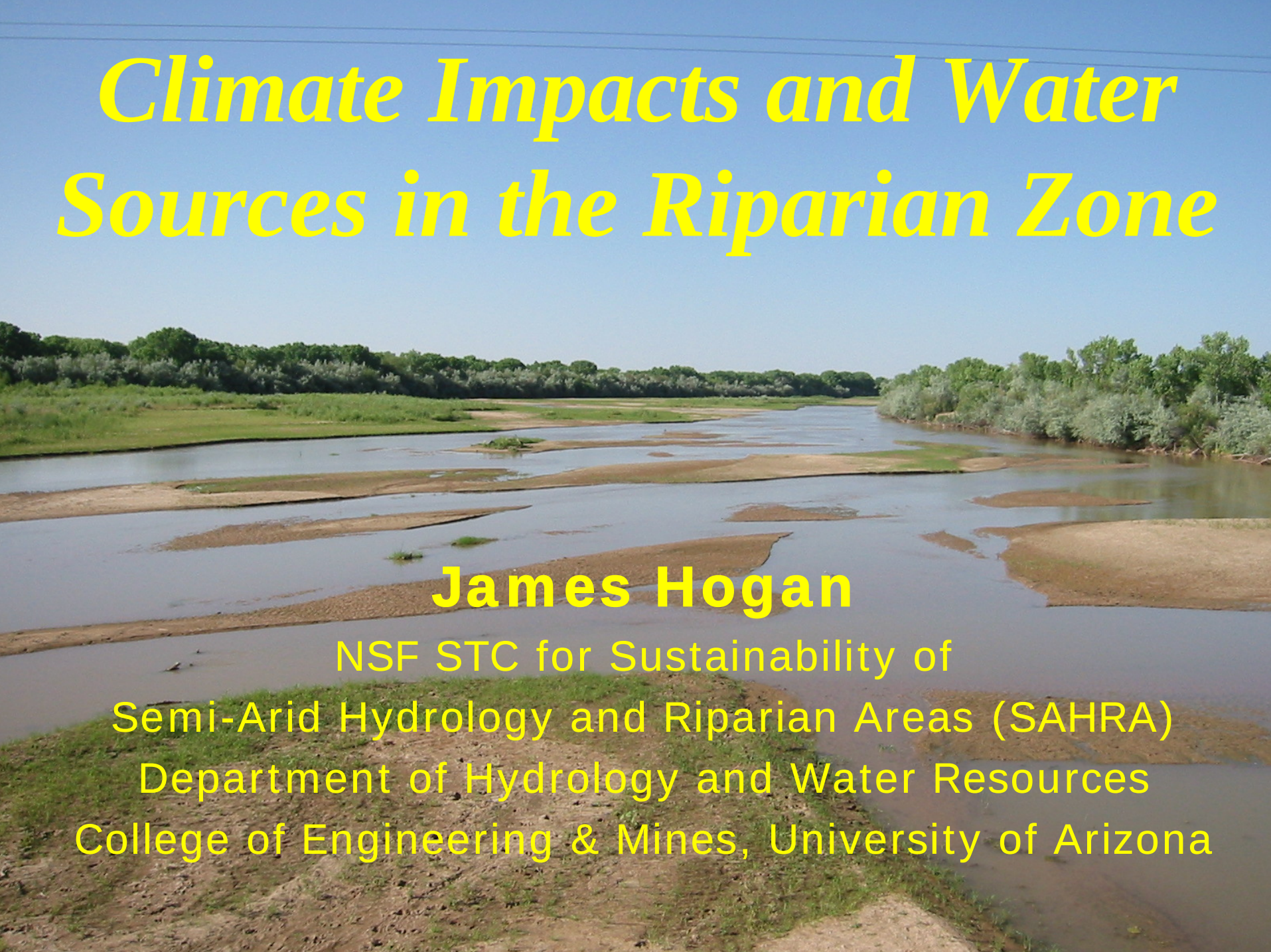
Climate Impacts and Water Sources in the Riparian Zone



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Semi-Arid Hydrology and Riparian Areas (SAHRA)
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College of Engineering & Mines, University of Arizona

Overview

- Riparian Water Sources
  - Basin groundwater
  - Flood driven bank storage and riparian aquifer recharge
  - Human related sources – agricultural returns and WWTP
- Climate Change and Variability
  - Seasonality of flooding – winter vs summer vs managed
- Controls on Flood Recharge
  - Geology – scale of river / scale of basin aquifer system
  - Hydrologic status – gaining vs losing
- Contrasting Examples
  - San Pedro
  - Rio Grande
- Management Implications

Acknowledgements

Funding

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WaterSustainability
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The University of Arizona
Tucson Arizona

UACJ
Universidad Autónoma de Ciudad Juárez

SAHRA

New Mexico Tech
Science-Engineering-Research-University

CEA-CREST

Stakeholders/ Additional Support

The Nature Conservancy
Saving the last great places on earth

Forest Service
US
Department of Agriculture

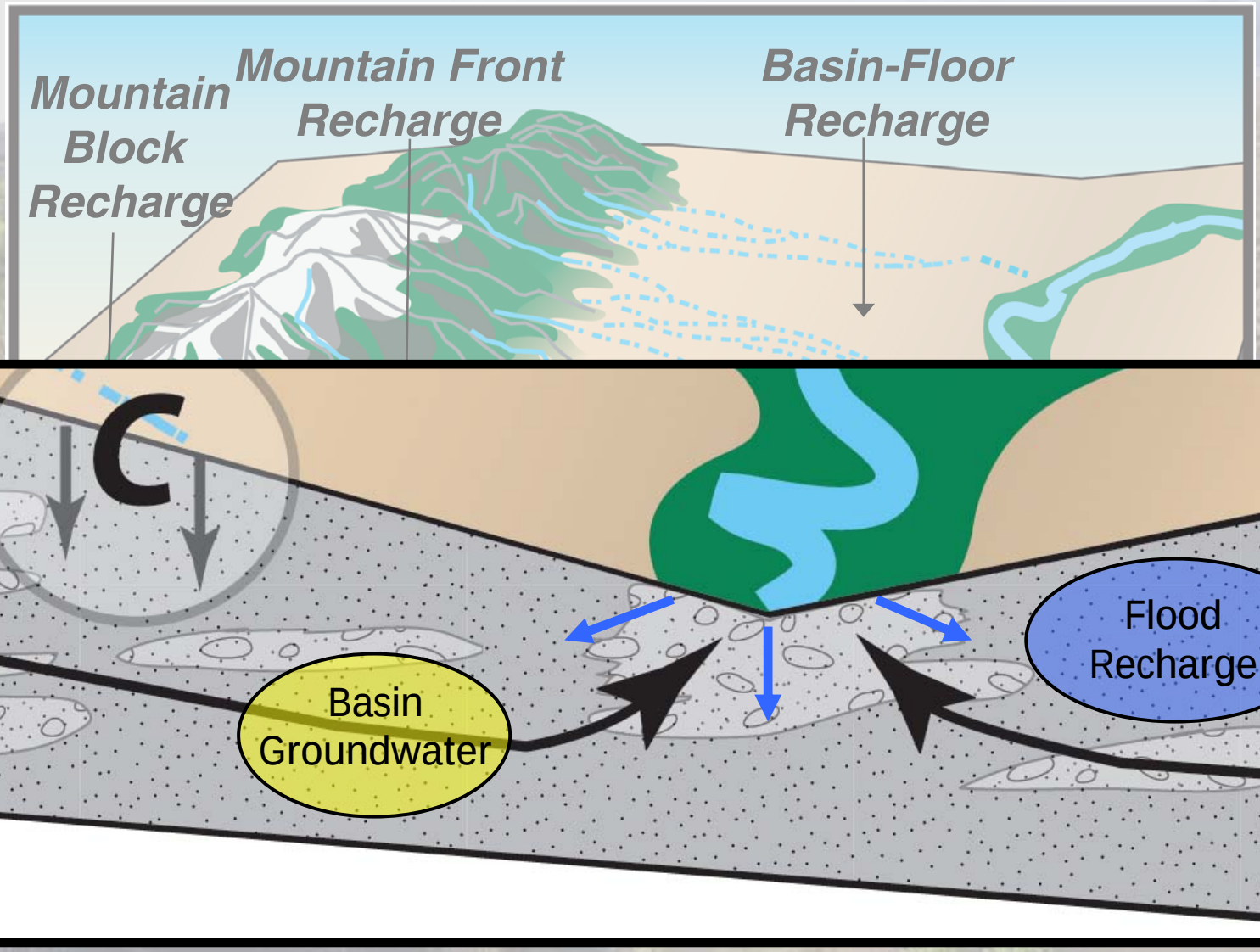
Bella Vista Water Company

USGS
science for a changing world

U.S. Department of the Interior
Bureau of Land Management

El Paso Water Utilities
Public Service Board

Riparian Water Sources



Riparian Water Sources

Fundamental control

Ratio of basin groundwater flux : flood runoff volume

Controls on this ratio

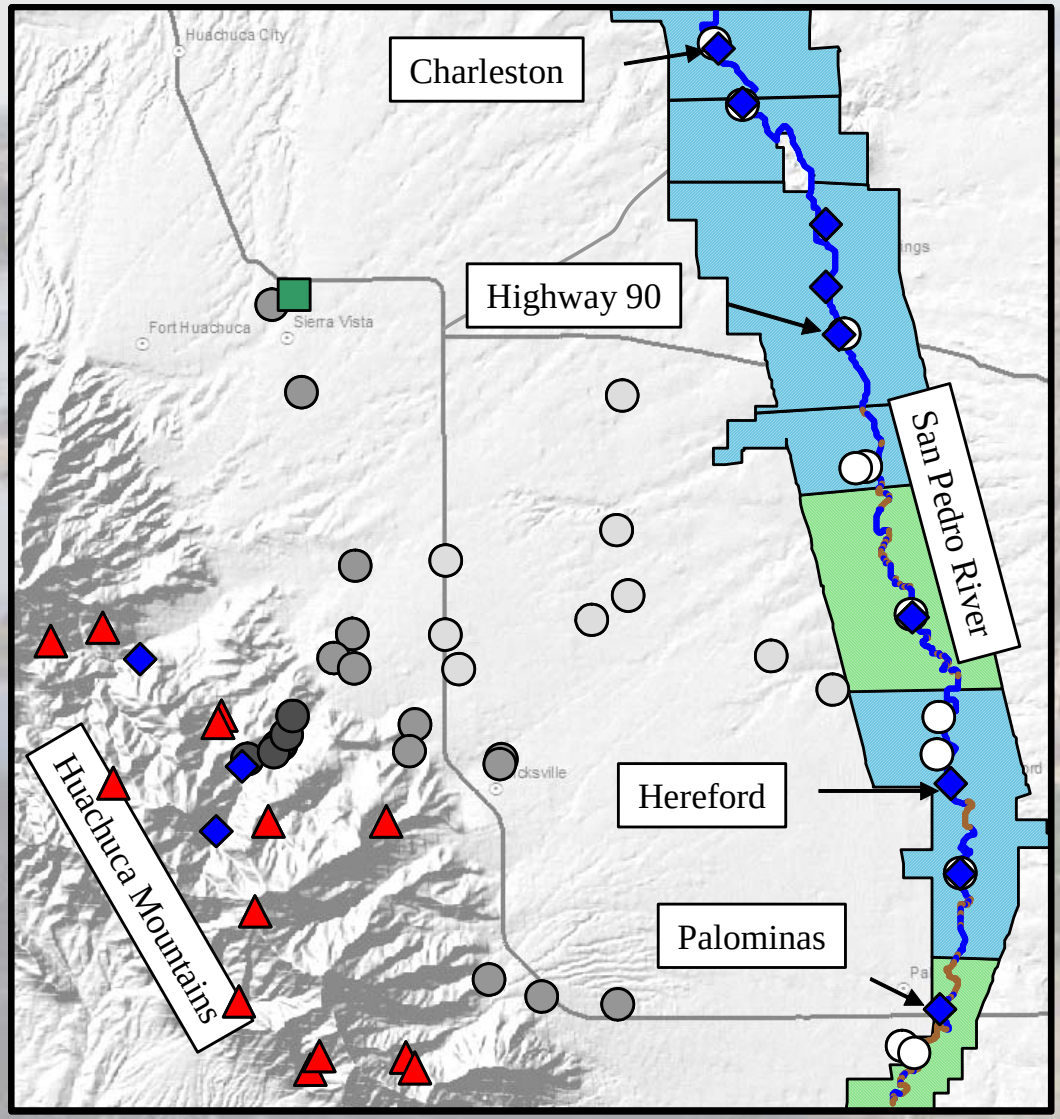
Seasonality of flooding – winter vs summer
Runoff volumes – upstream area/flood generation
Basin recharge – size of basin / aquifer character
Human alteration – GW pumping / WWTP discharge
changes in runoff

Two contrasting examples

San Pedro – small basin, monsoon flood recharge, moderate basin recharge, "natural"

Hueco Bolson/Rio Grande – very large basin, snowmelt dominated, very little basin recharge, "managed"

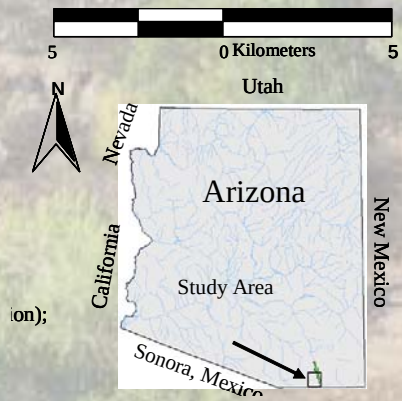
Upper San Pedro Basin



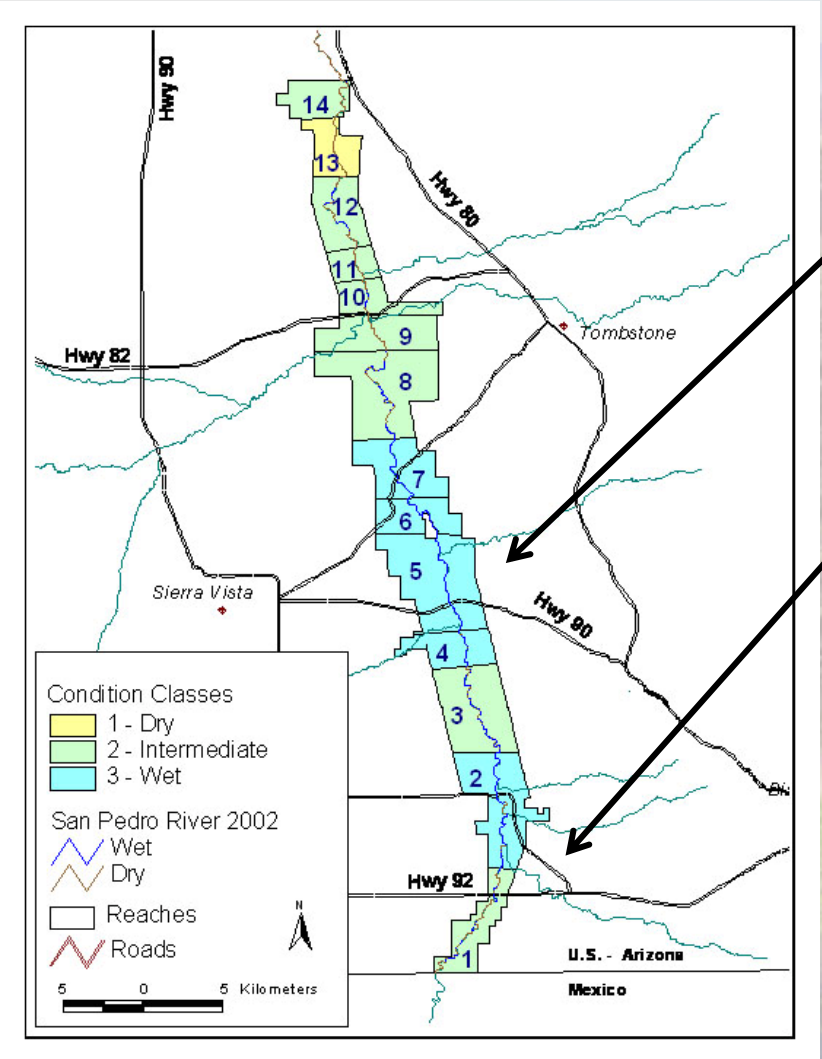
Legend:

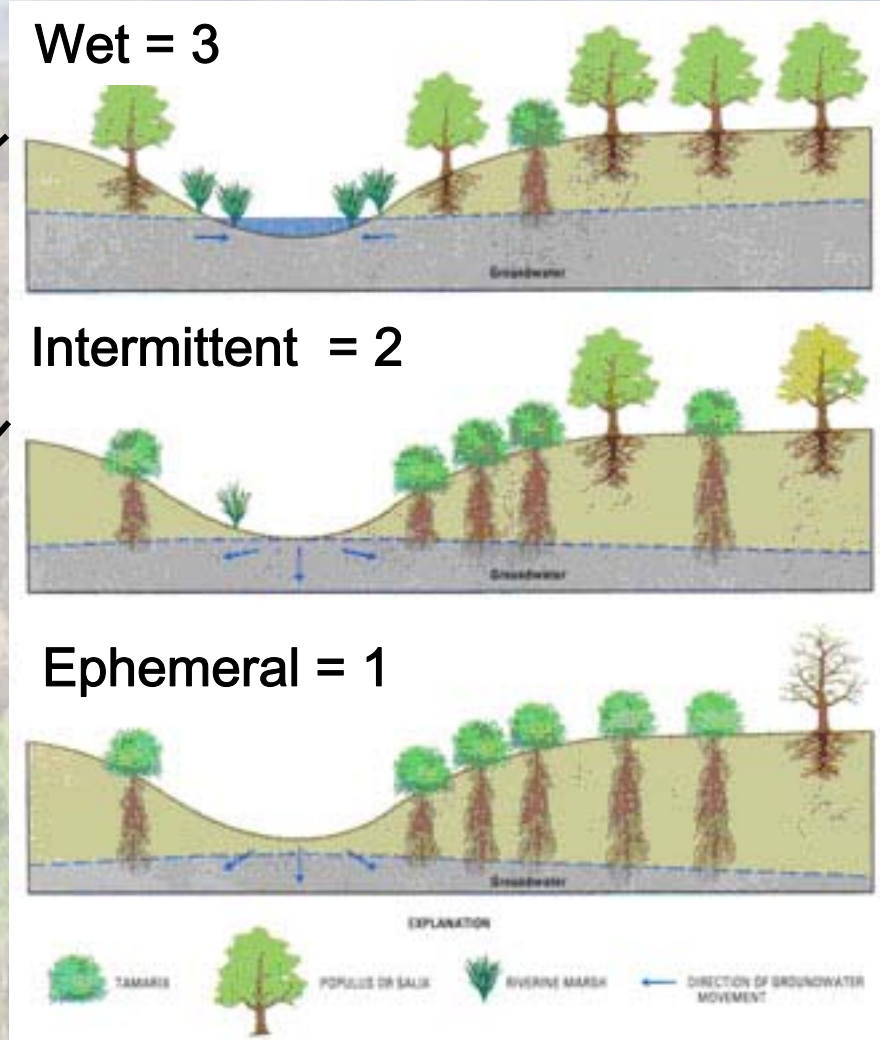
- Springs
- Mountain Block Wells
- Mountain Front Wells
- Basin Wells
- Riparian Wells
- Surface Water
- Precipitation
- Gaining Reach
- Losing Reach
- Perennial Stream
- Intermittent Stream

Losing/Gaining reach data from Stromberg et al. (in preparation
flow permanence data from the Nature Conservancy



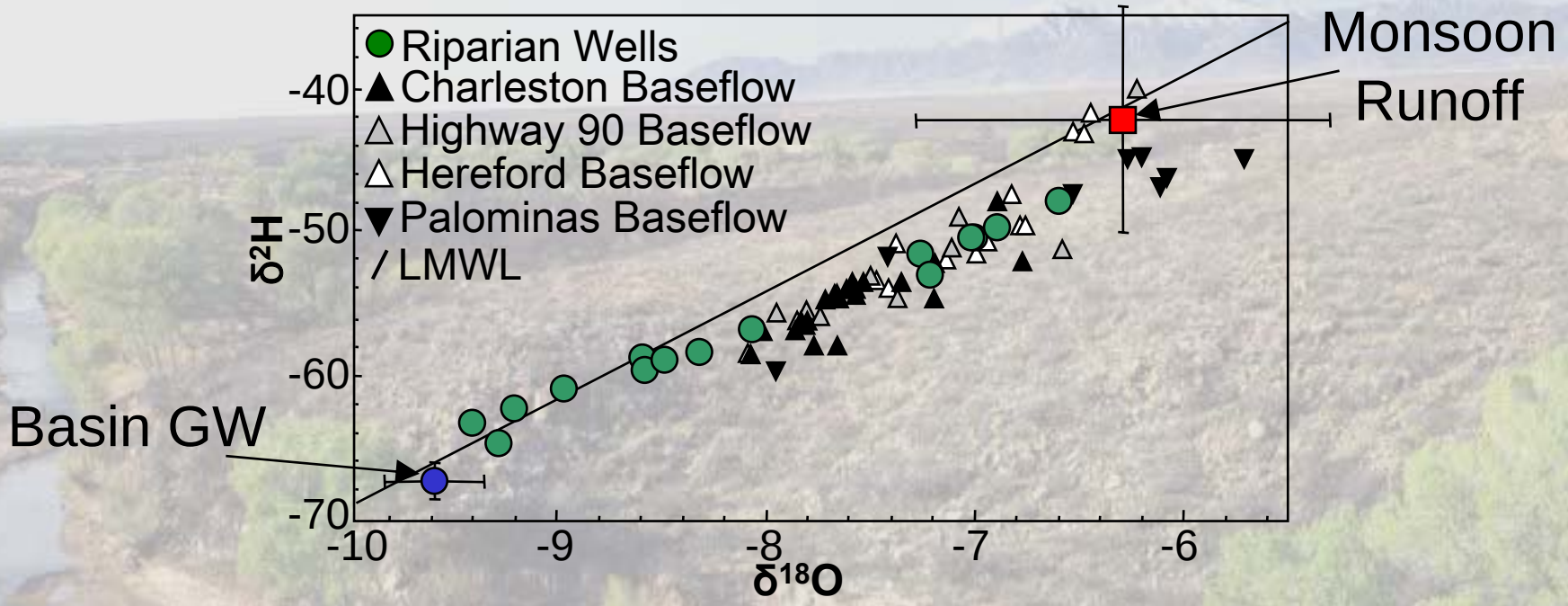
Condition Class Model





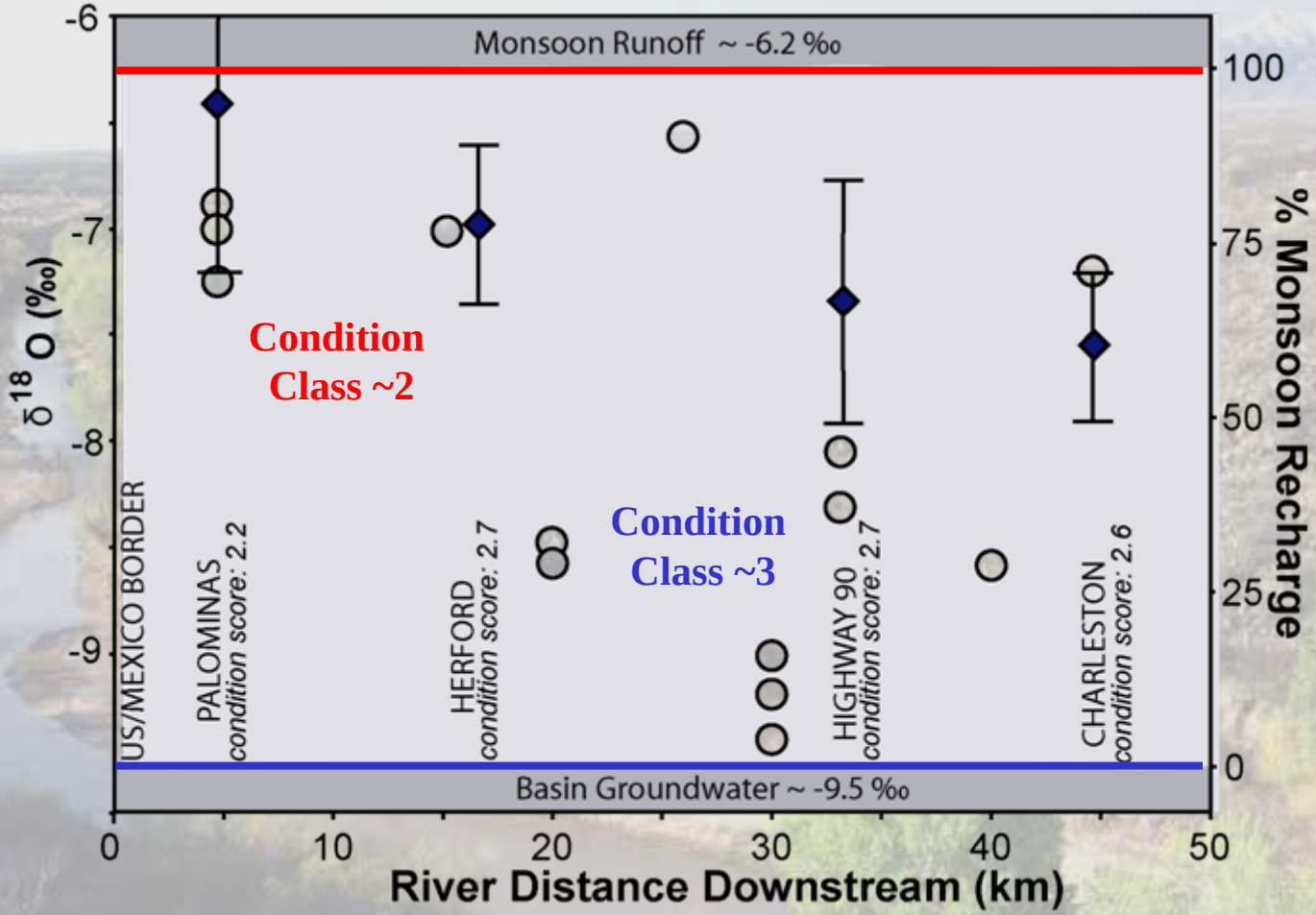
Stromberg et al. 2006

Riparian Water Source



- Isotopes of water – natural tracer of source
- Riparian wells span range between end members
- Baseflow skewed toward monsoon runoff
- Quantify % using simple mixing model
- Uncertainty associated with runoff end member

Riparian Water Sources

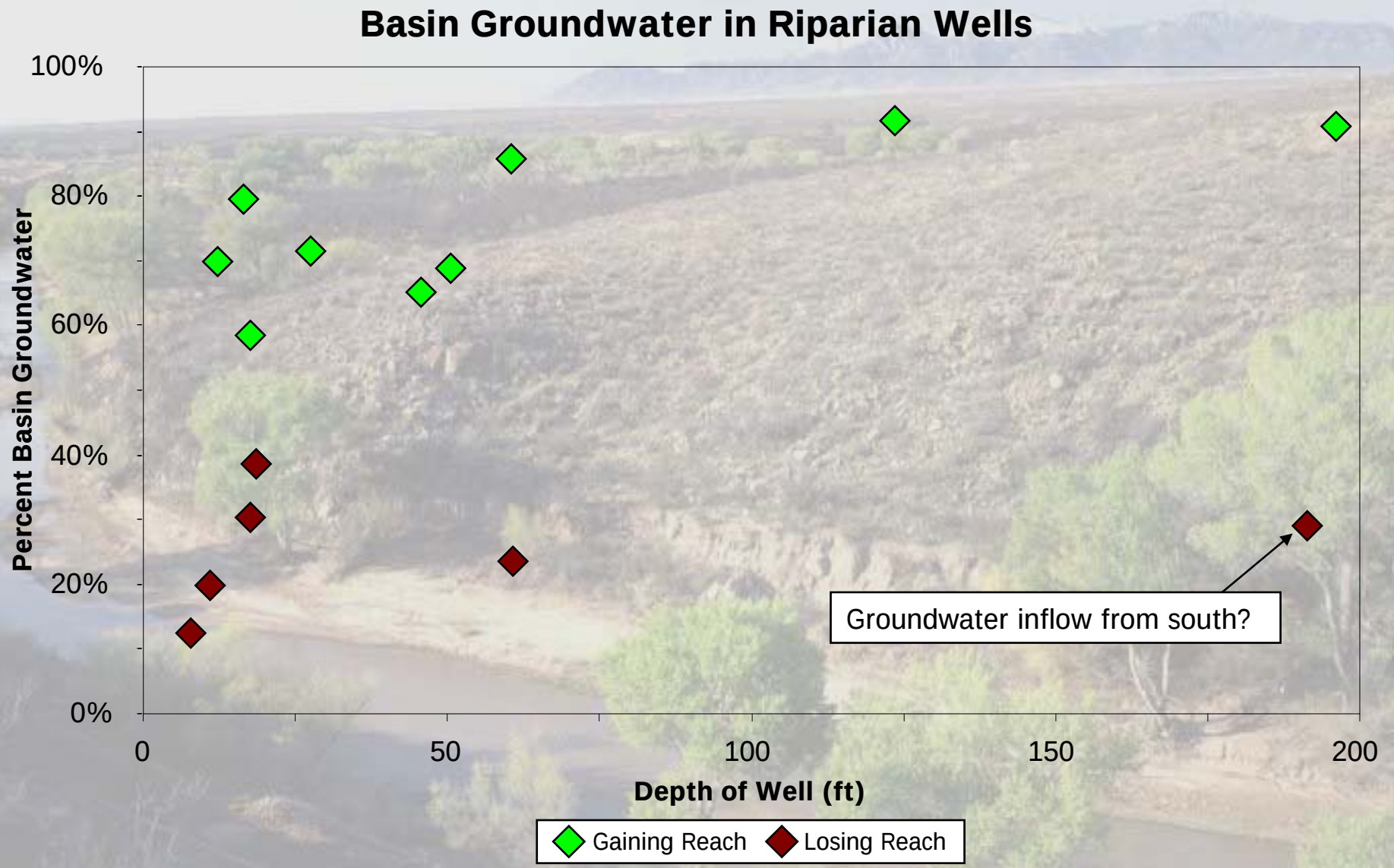


Baseflow

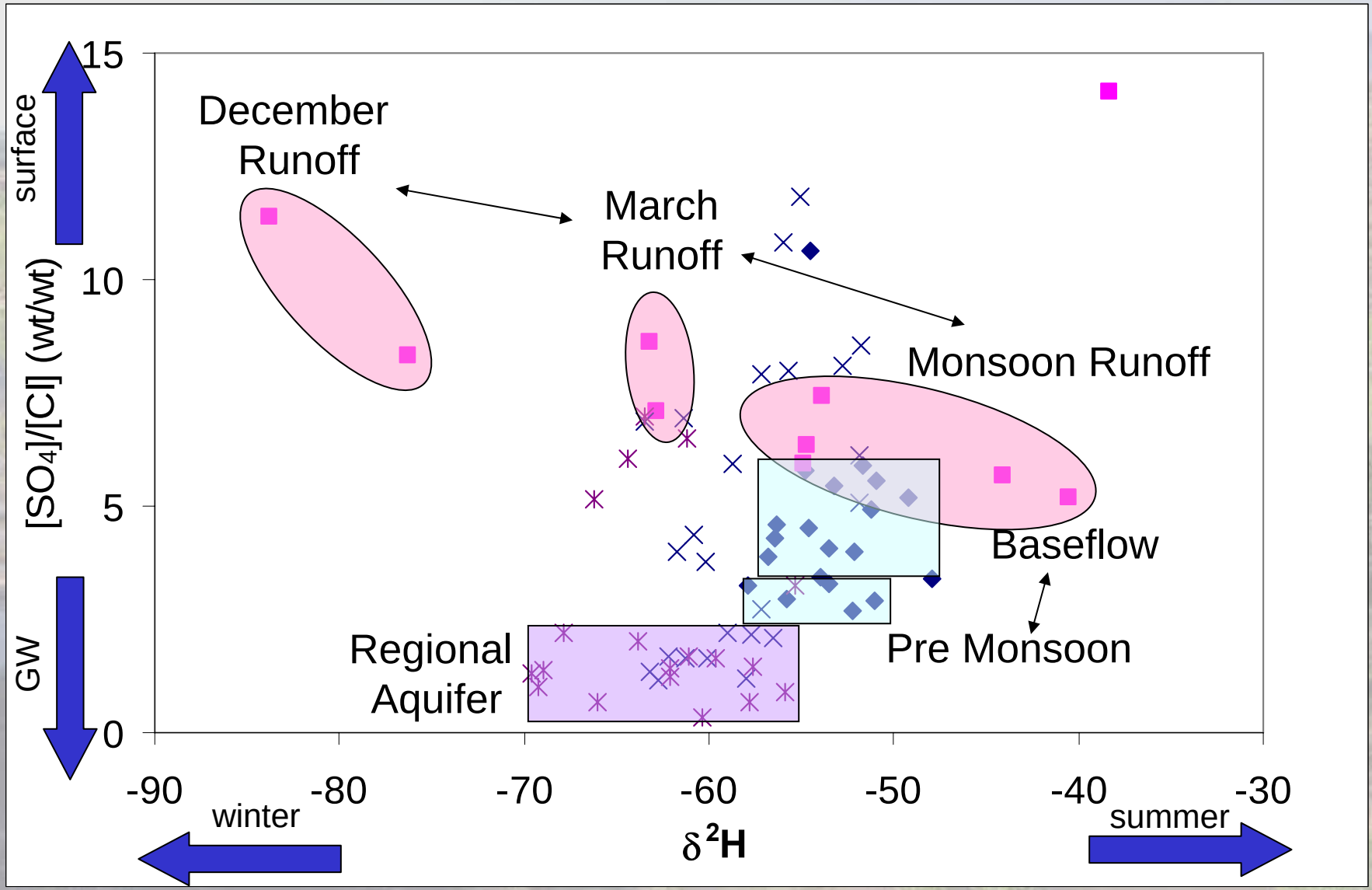
Riparian Groundwater

- Baseflow >50% monsoon runoff regardless of season
- Riparian Groundwater relates to condition class
- Control on this? Gaining vs Losing

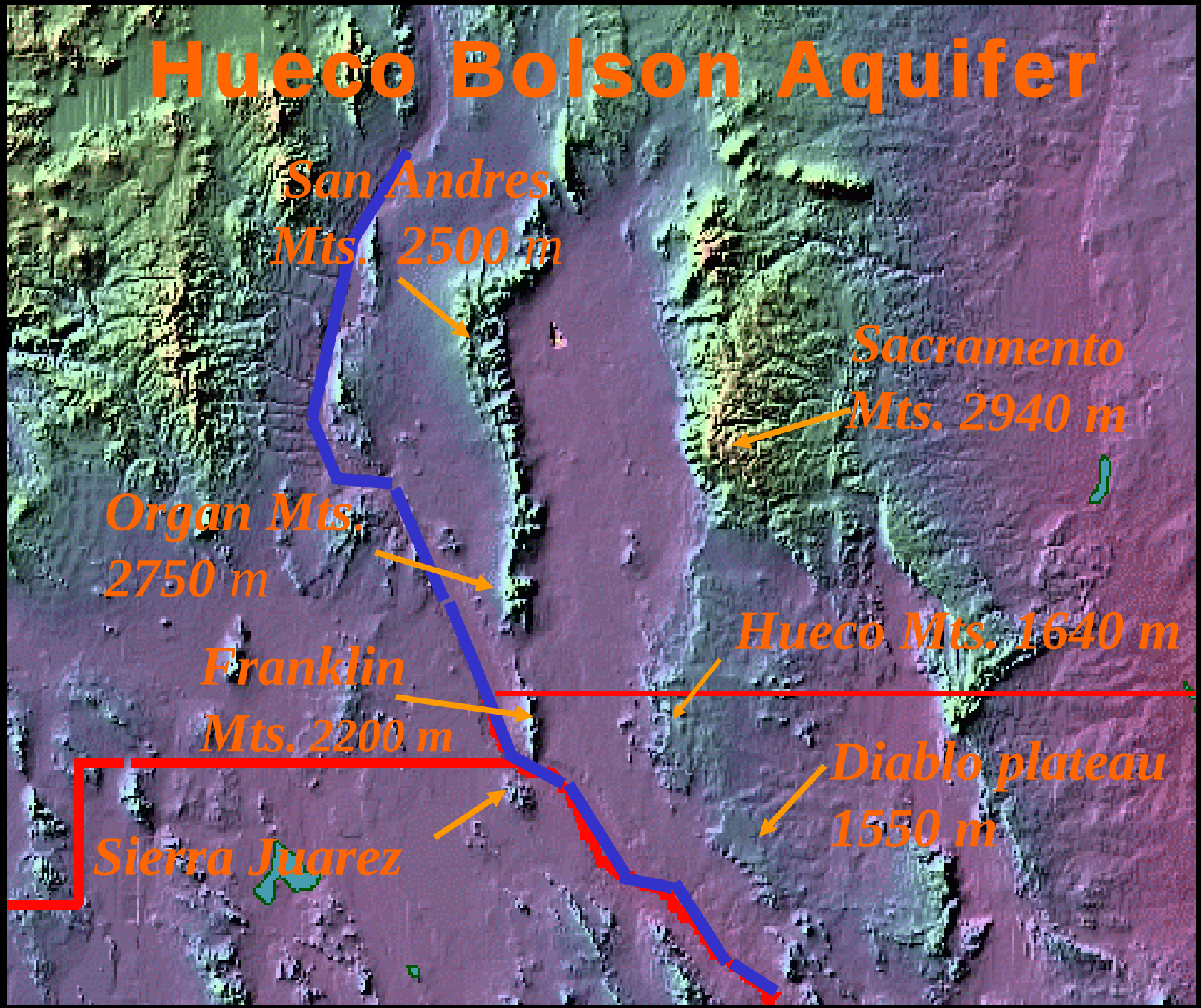
Gaining vs Losing



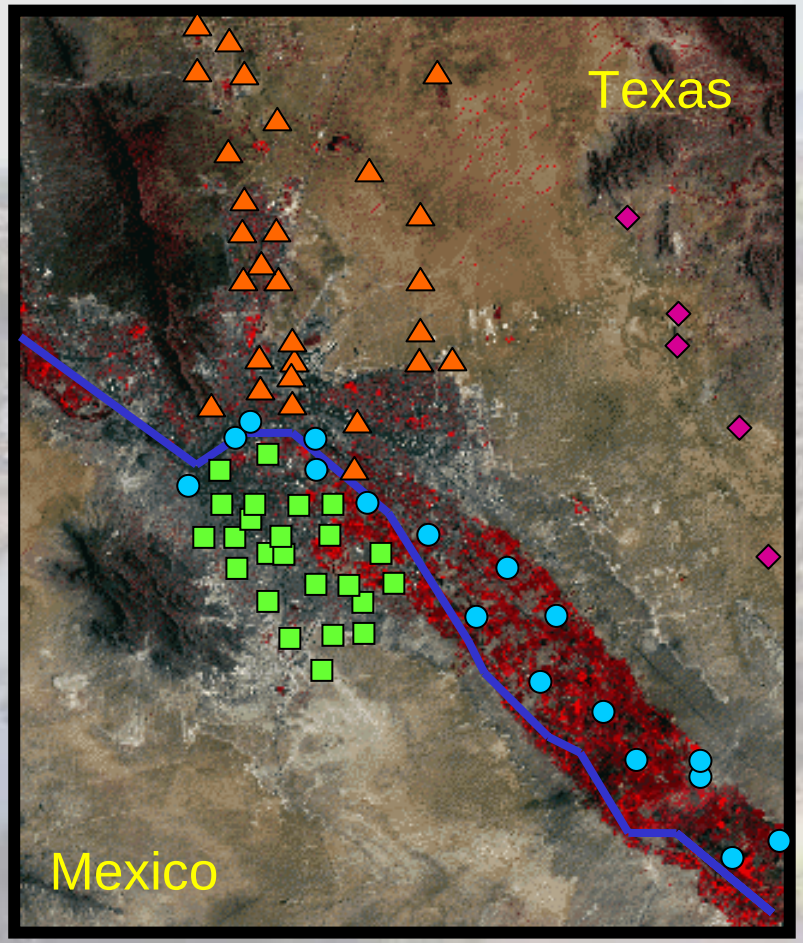
Seasonal Changes?

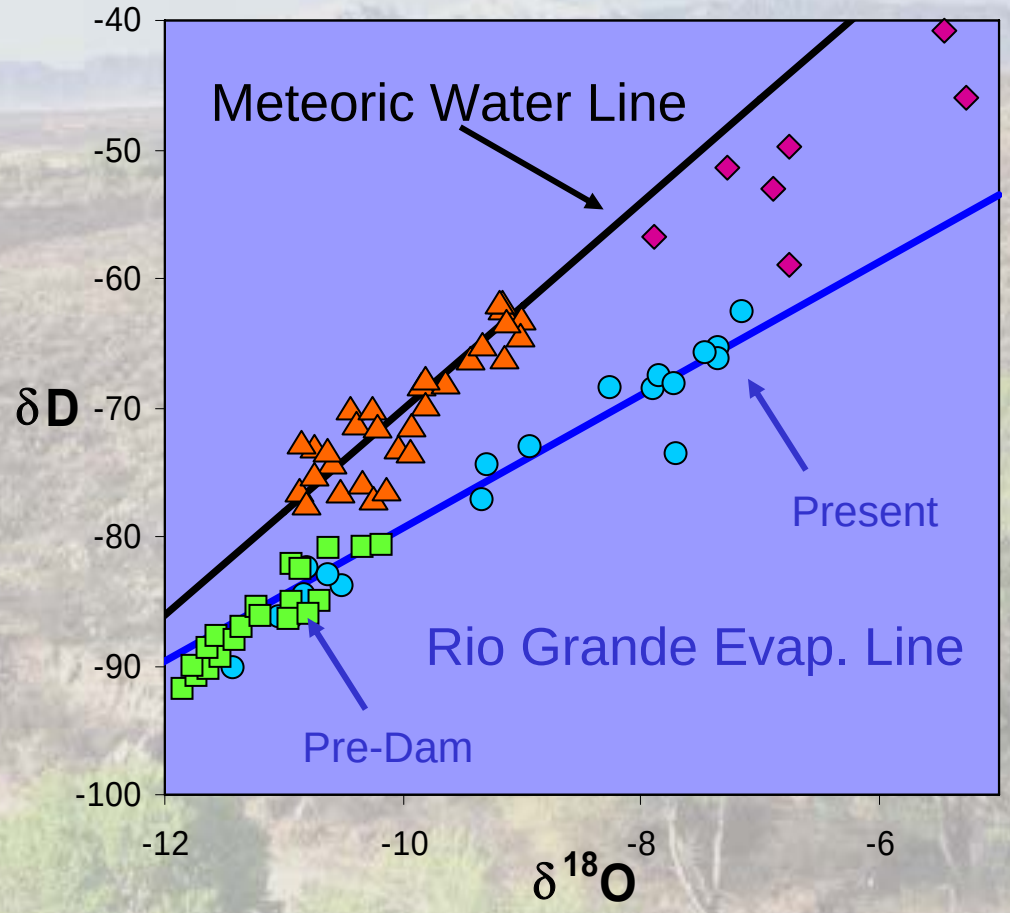


Data from Pool and Coes, 1999


Hueco Bolson Aquifer
San Andres
Mts. 2500 m
Sacramento
Mts. 2940 m
Organ Mts.
2750 m
Hueco Mts. 1640 m
Franklin
Mts. 2200 m
Diablo plateau
1550 m
Sierra Juarez

Water Sources



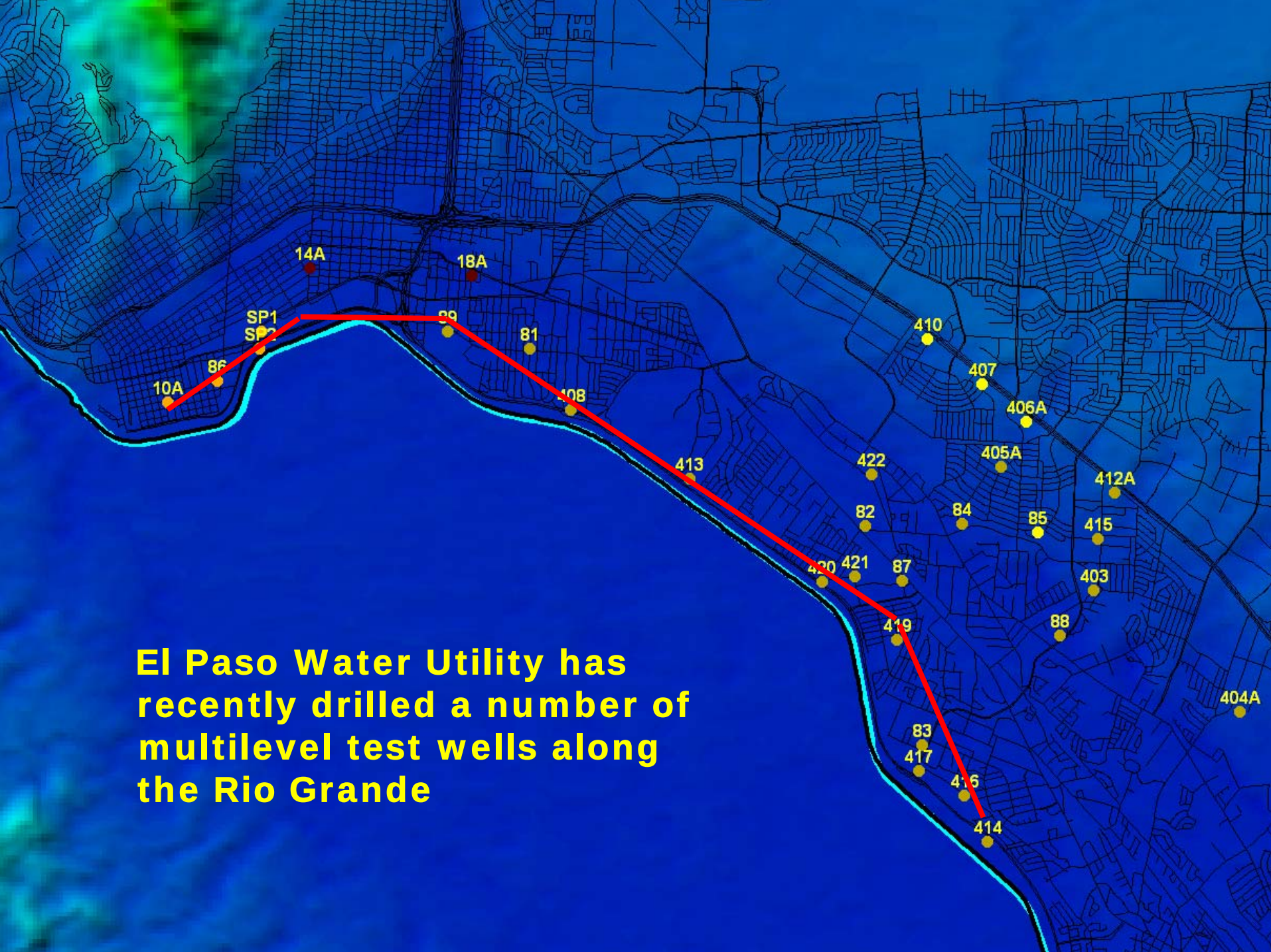


Rio Grande water distinct from basin recharge

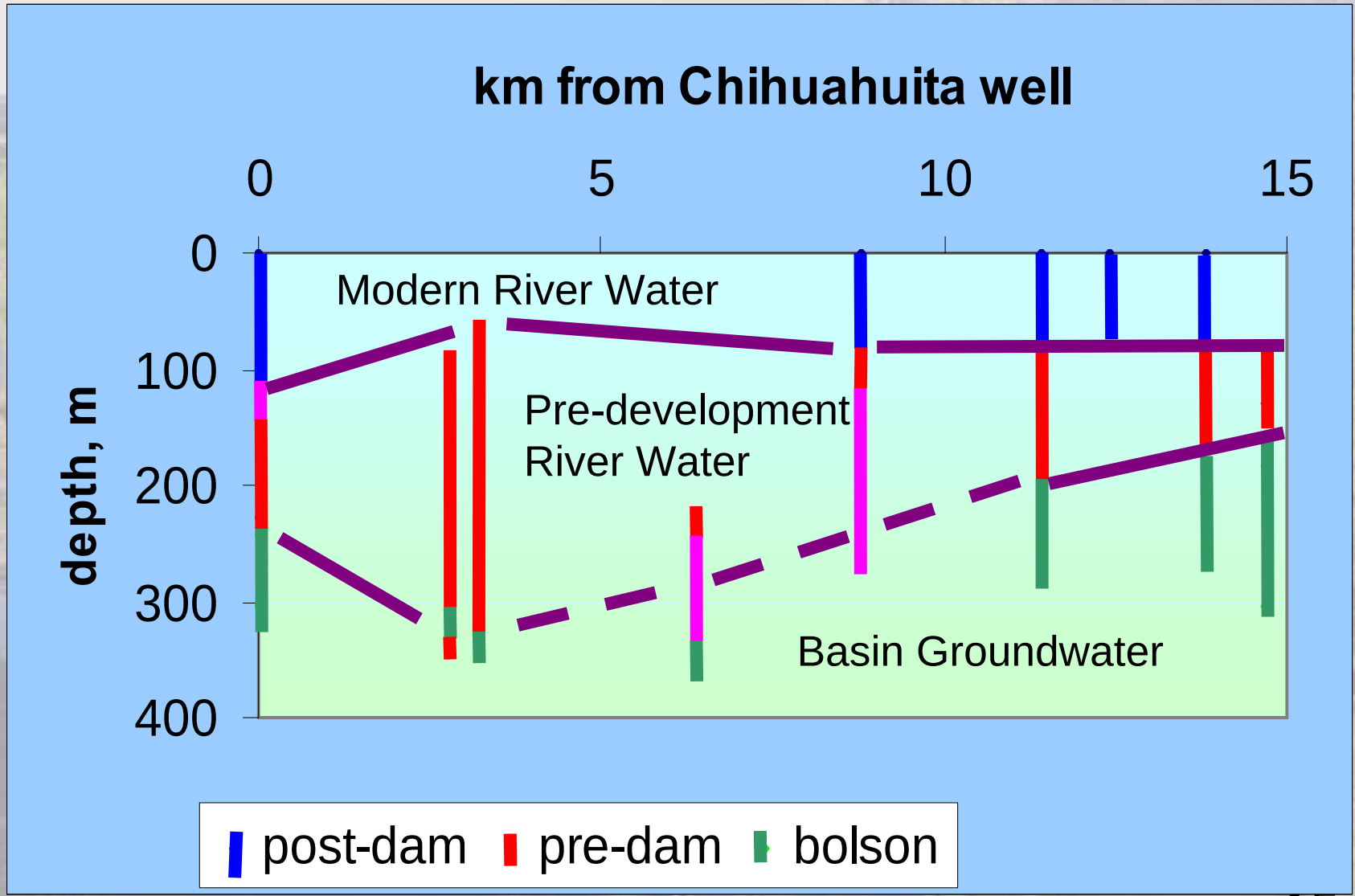
- Snowmelt southern Rocky Mountains

Reservoir development imprints and evaporation signal

- Trace pre / post development groundwater


14A
18A
SP1
86
10A
81
410
407
406A
405A
422
413
412A
82
84
85
415
421
87
403
419
88
404A
83
417
414
El Paso Water Utility has recently drilled a number of multilevel test wells along the Rio Grande

Groundwater Profile

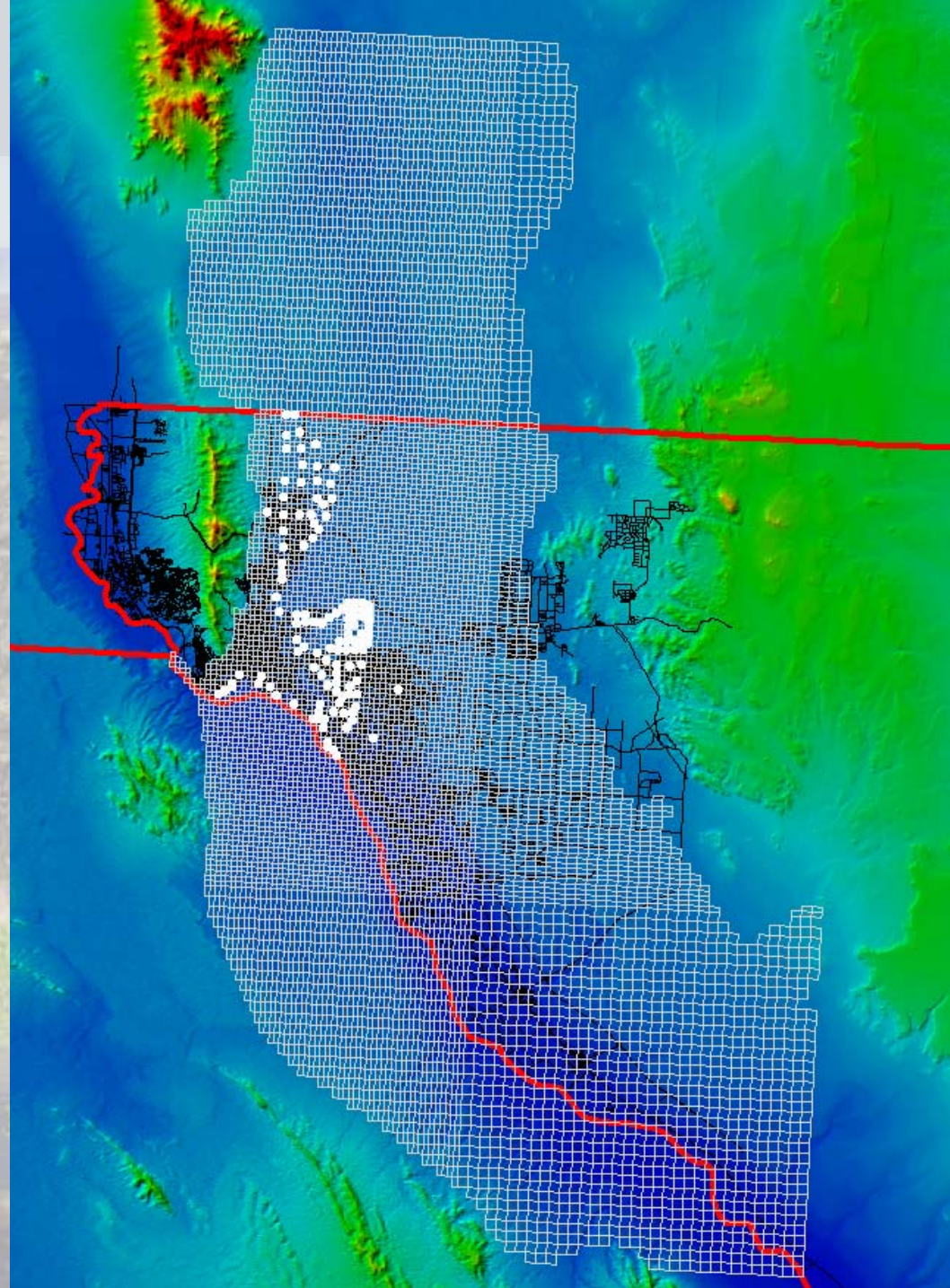


SAHRA

Hueco GW Model

USGS Model Grid for Hueco Bolson

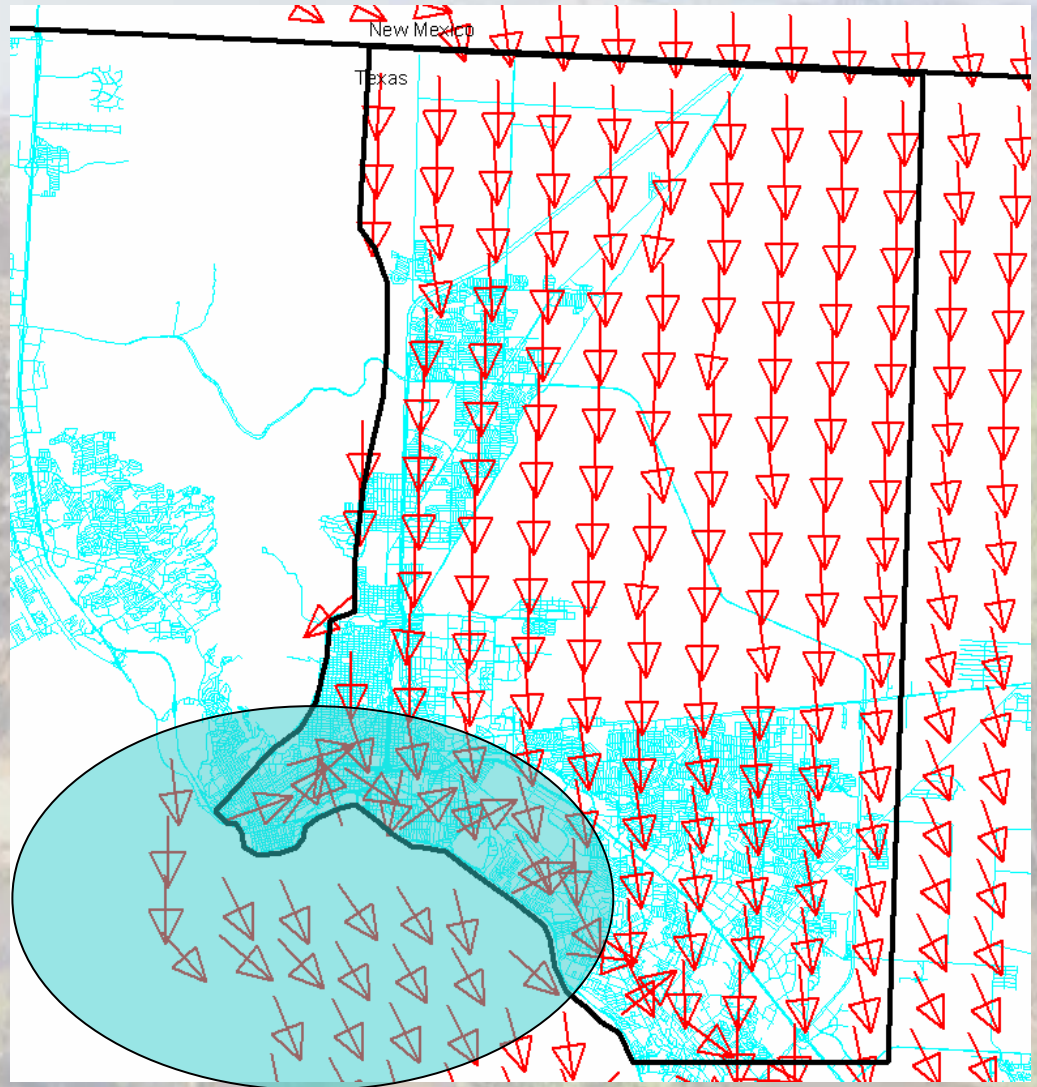
Update to include river recharge



From Bill Hutchison - EPWU

Hueco GW Model

1903 Flow

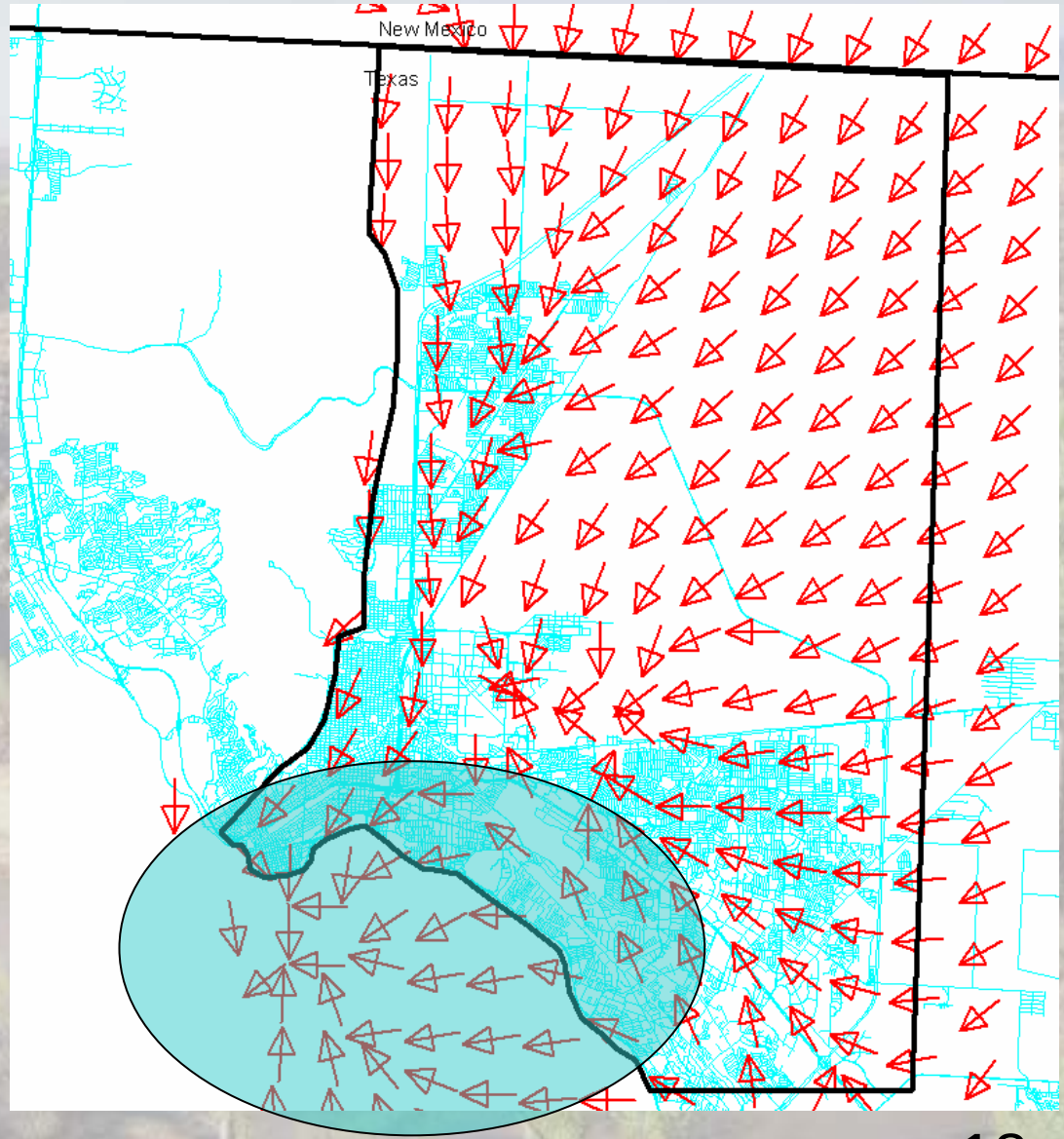


River recharge for Juarez!!

From Bill Hutchison - EPWU

Hueco GW Model

1996 Flow



Juarez recharge?

From Bill Hutchison - EPWU

Management Implications

- Evaluate riparian water sources and the climate "sensitivity" of these sources
- Need to worry not just about impacts of groundwater pumping, but also about potential changes to flood runoff
- Groundwater models used for riparian management need to include local riparian recharge and ideally should be calibrated using isotopic data
- Isotopes are a useful tool for analyzing changes in riparian water sources; changes in water chemistry may manifest before changes in baseflow. Thus, monitoring changes in riparian groundwater and baseflow chemistry can be an early indicator for changes in sources

Climate Sensitivity

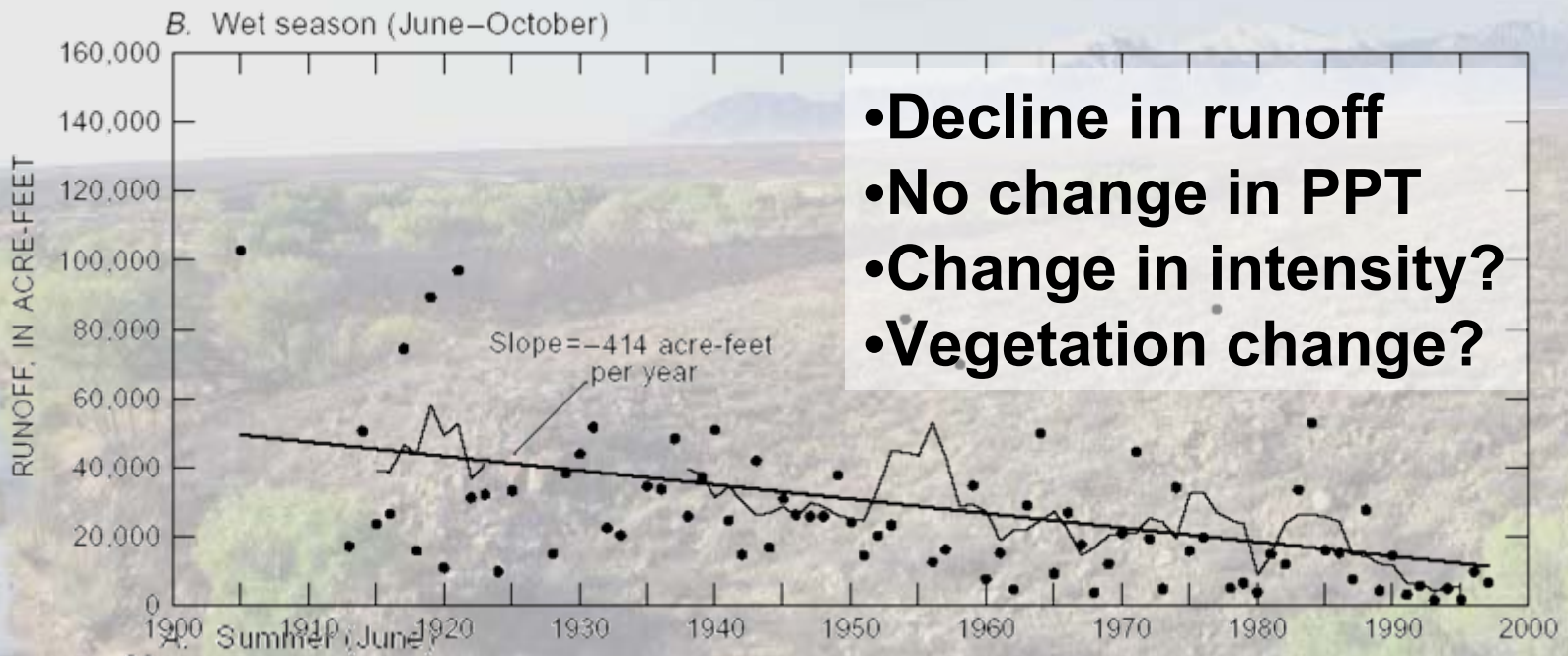
more ← Flood Frequency → less

more ↑ Basin GW ↓ less

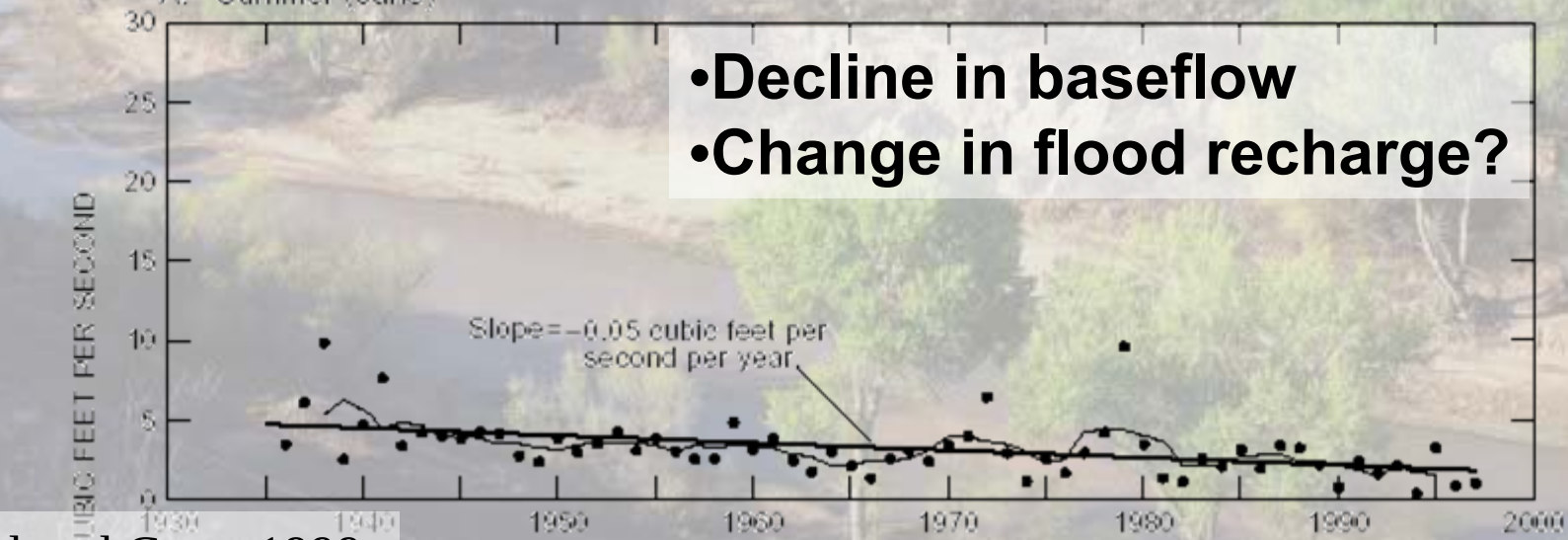
Table 3. Sensitivity Matrix for Woody Riparian Vegetation

Groundwater depth and water source	*Frequency of Seasonal Flooding* High	Moderate	Low
High/stable (basin GW)	• Stable established populations, low risk to recruitment • Low sensitivity to climate change	• Stable established populations, moderate risk to recruitment • Low to moderate sensitivity to climate	• Stable established populations, recruitment at high risk • Moderate sensitivity to climate change
Moderate (mixed)	• Moderate risk to established populations, no risk to recruitment • Low sensitivity to climate change	• Moderate risk to established populations and recruitment • Moderate sensitivity to climate change	• High risk to established populations and recruitment • High sensitivity to climate change
Deep (flood recahrge)	• Moderate to high risk to populations, no risk to recruitment • Moderate sensitivity to climate change	• High risk to populations, moderate risk to recruitment • High sensitivity to climate change	• Transition to upland very likely • High sensitivity to climate change

San Pedro Changes in Runoff



- Decline in runoff
- No change in PPT
- Change in intensity?
- Vegetation change?

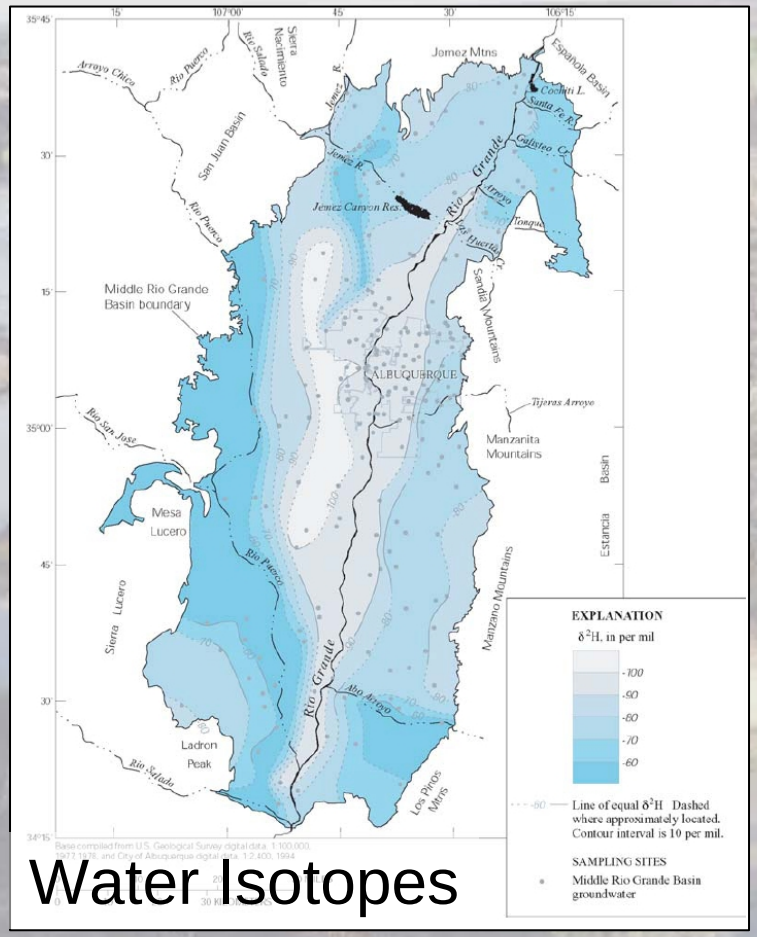


- Decline in baseflow
- Change in flood recharge?

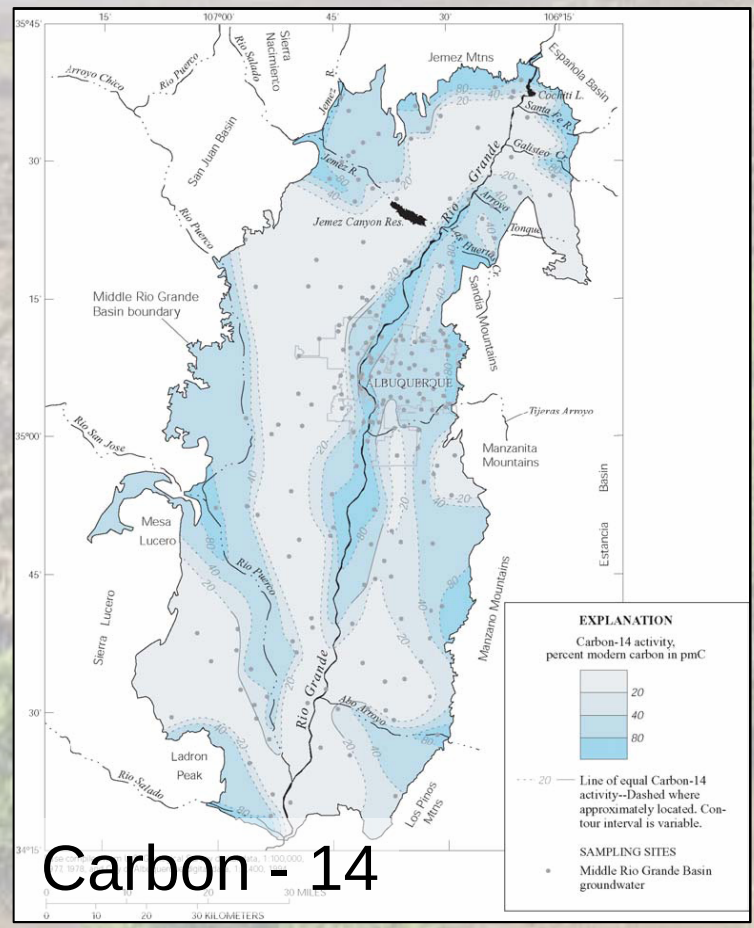
Pool and Coes, 1999

Basin GW Budgets / Models

USGS Albuquerque Basin Study



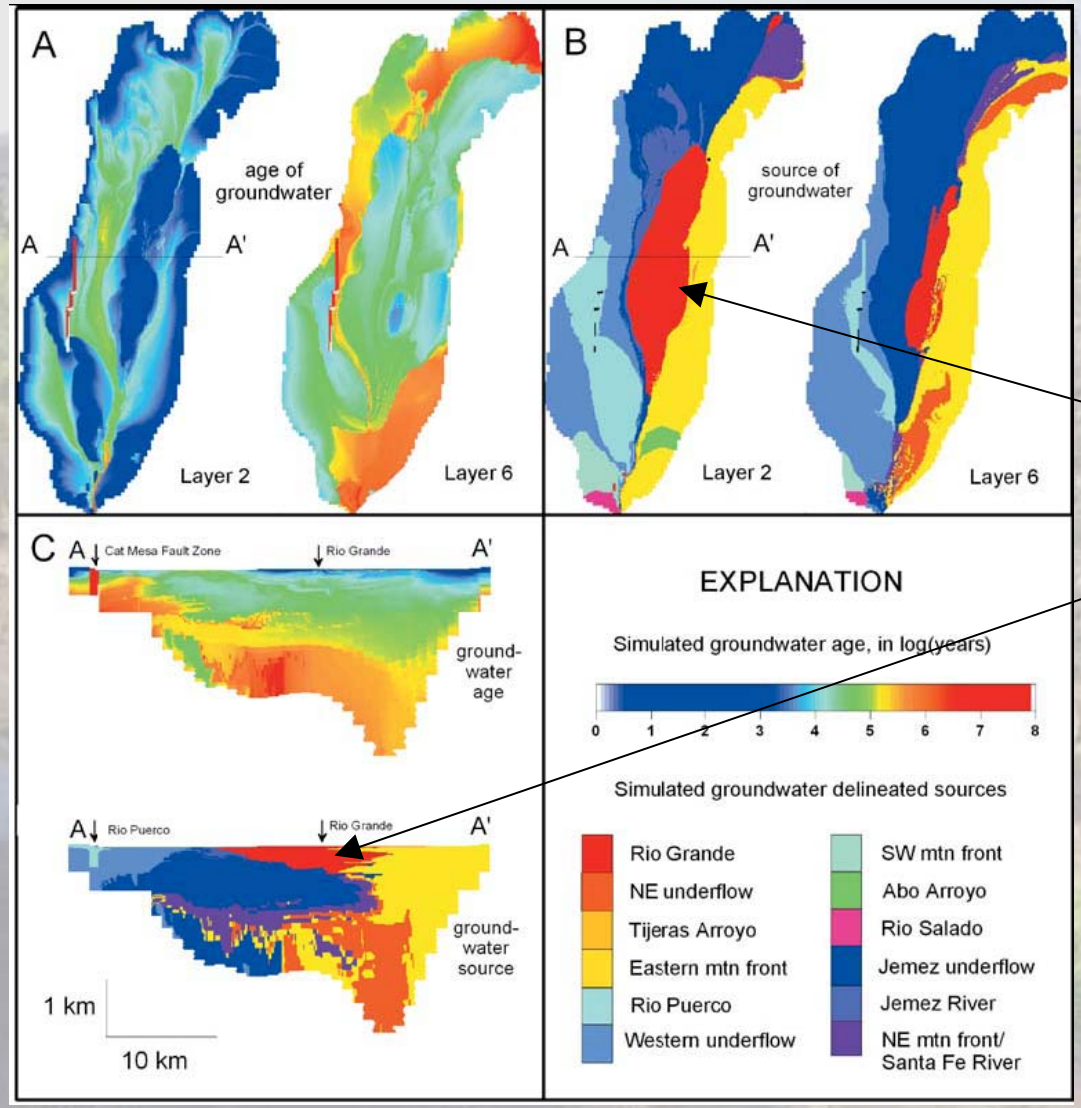
Water Isotopes



Carbon - 14

Plummer, L.N., et al., 2004, Hydrochemical tracers in the Middle Rio Grande Basin, USA: 1. Conceptualization of groundwater flow, *Hydrogeol. J.*

Basin GW Budgets / Models



Rio Grande Water
~10 km wide
~500 m deep

Sanford, W. E. et al., 2004, Hydrochemical tracers in the Middle Rio Grande Basin, USA: 2. Calibration of a groundwater model, *Hydrogeol. J.*,

Basin GW Budgets / Models

Region	Kernodle et al. (1995)	Tiedeman et al. (1998)	Anderholm (2001)	McAda and Barroll (2002)	This study
Jemez Mountains	0.56	0.27	N/A	0.58	0.08
Western boundary	0.18	0.18	N/A	0.07	0.06
Southwest boundary	0.30	0.09	N/A	0.03	0.17
San Juan Basin	0.05	0.05	N/A	0.04	0.27
Hagan/Espanola Basin	0.21	0.49	N/A	0.55	0.03
Northeast rivers	0.32	0.30	N/A	0.21	0.18
Tijeras Arroyo	0.41	0.41	0.07	0.03	0.00
Abo Arroyo	0.62	0.60	0.05	0.05	0.04
Rio Puerco	0.23	0.12	N/A	0.04	0.14
Jemez River	0.48	0.48	N/A	0.59	0.01
Rio Grande[a]	~0	~0	N/A	N/A	0.78
Rio Salado	0.28	0.28	N/A	0.08	0.06
Sandia Mtn front	0.74	0.41	0.16	0.21	0.16
Southeast Mtn front	1.06	1.16	0.19	0.16	0.17
Total	5.45	4.86	N/A	2.63	2.14

Overall budget with isotopic data – little change

River recharge – significant increase

Basin Source – significant decrease

Sanford, W. E. et al., 2004, Hydrochemical tracers in the Middle Rio Grande Basin, USA: 2. Calibration of a groundwater model, *Hydrogeol. J.*,

Take Home Messages

- **Know your riparian water sources**
  - Basin GW – Flood Recharge – Human Related Source
- **Assess potential for climate impacts on sources**
  - Basin GW – often little impact as residence time long
  - Flood recharge – consider seasonality
  - Human sources?
- **Assess human / other impacts on these sources**
  - Runoff volumes due to uplands vegetation change
  - Groundwater pumping
  - Reservoirs / irrigation management
- **Management implications**
  - Evaluate climate sensitivity
  - Potential for change in runoff – uplands issues
  - Need for GW models with water source accounting
  - Isotopes as tracer of riparian hydrologic change

Future Questions

- **Are other places like San Pedro and Rio Grande?**
  - Stromberg et al. Are condition classes transferable?
  - de la Cruz - PhD student UA - How do alluvial aquifers function on the Verde and Rio San Miguel?
  - Simpson- soon to matriculate PhD student at UA - How do alluvial aquifers function in Hassayampa and Bill Williams
- **How do alluvial aquifer systems influence sustained water quality?**
  - Soto-Lopez - Spatial and temporal variability and structure?
  - Oelsner - Large floodplain agricultural system of Rio Grande interaction with river?
- **What is mechanism of surface-groundwater interaction**?
  - Simpson - UA MS Hydrometric isotopic tracer linkage
  - Treese - UA MS - Biological or physical clogging – importance of floods
  - Coupling KINEROS MODFLOW - Vionet and MS student Kilb
- **What is role and impact of decadal-scale climate variability?**
  - Hogan, Baird, Meixner Stromberg EPA project
  - H. Ajami PhD UA
  - Simpson soon PhD UA
  - Kilb MS UA