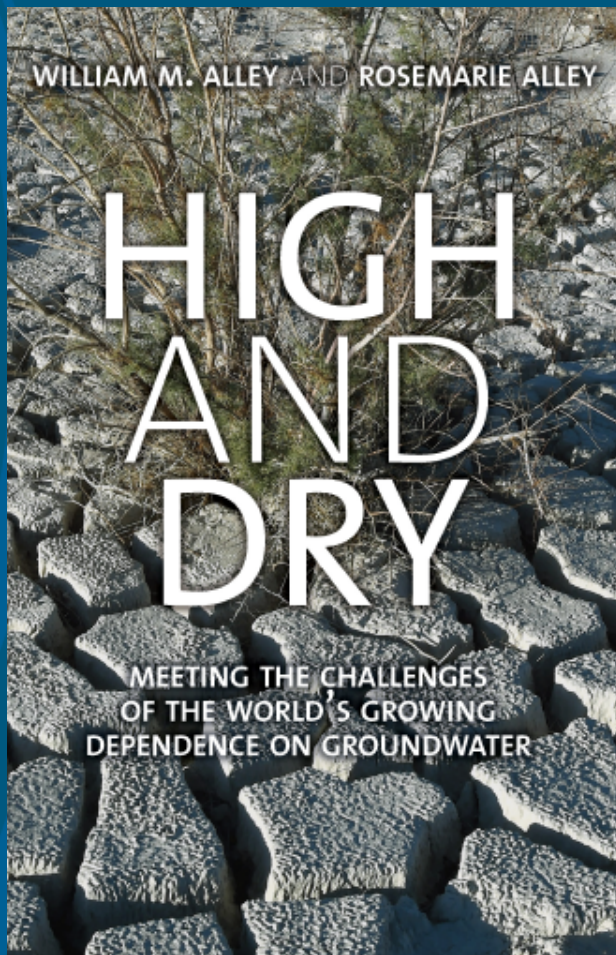


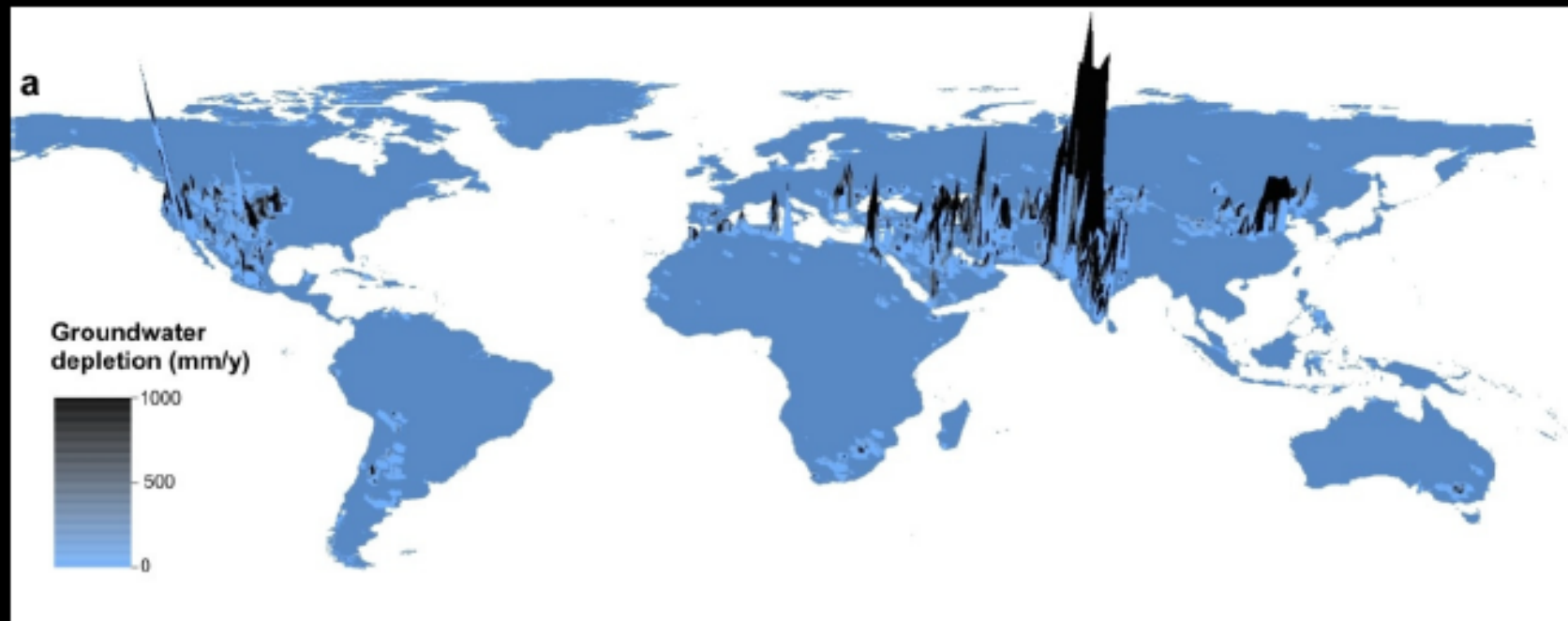
Communicating About Groundwater Depletion



William M. Alley
Director, Science and Technology
National Ground Water Association

GSA North-Central Annual Meeting
Ames, Iowa
April 17, 2018

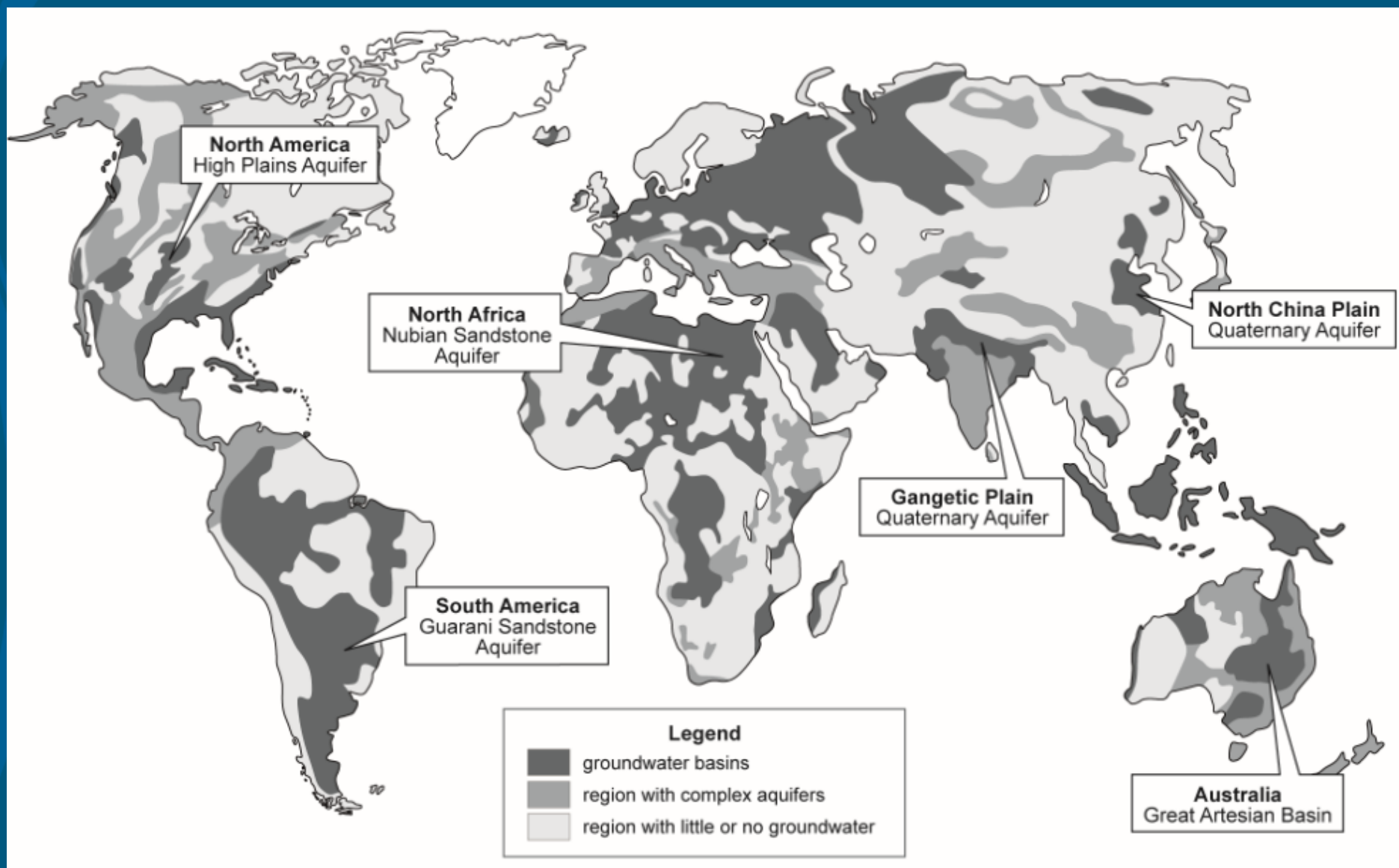
Global groundwater depletion



Wada et al (2009) remapped by Aeschbach-Hertig and Gleeson (2012)

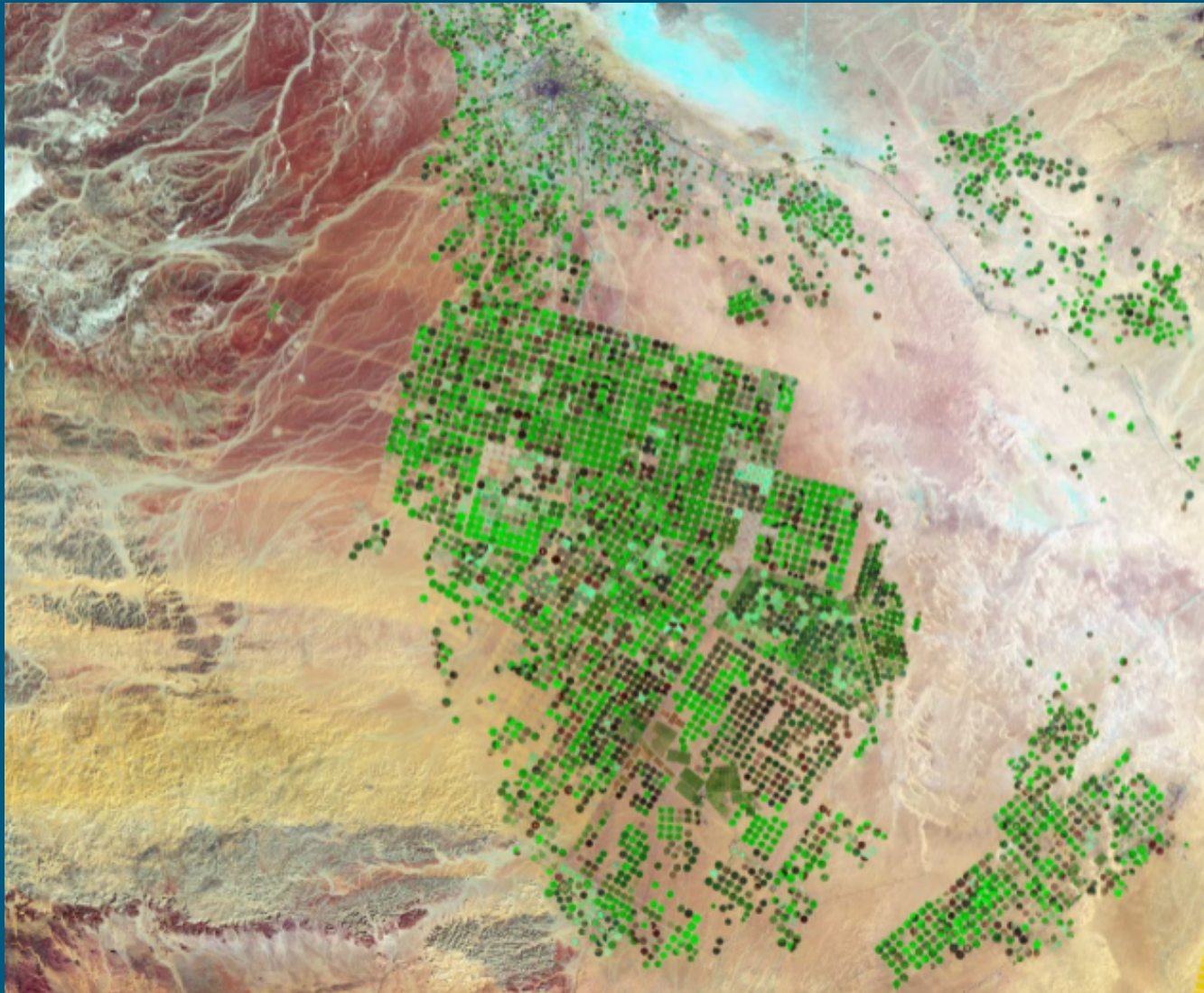
Five countries account for 60% of the world's groundwater use

- India (25%)
- United States (11%)
- China (11%)
- Pakistan (7%)
- Iran (6%)



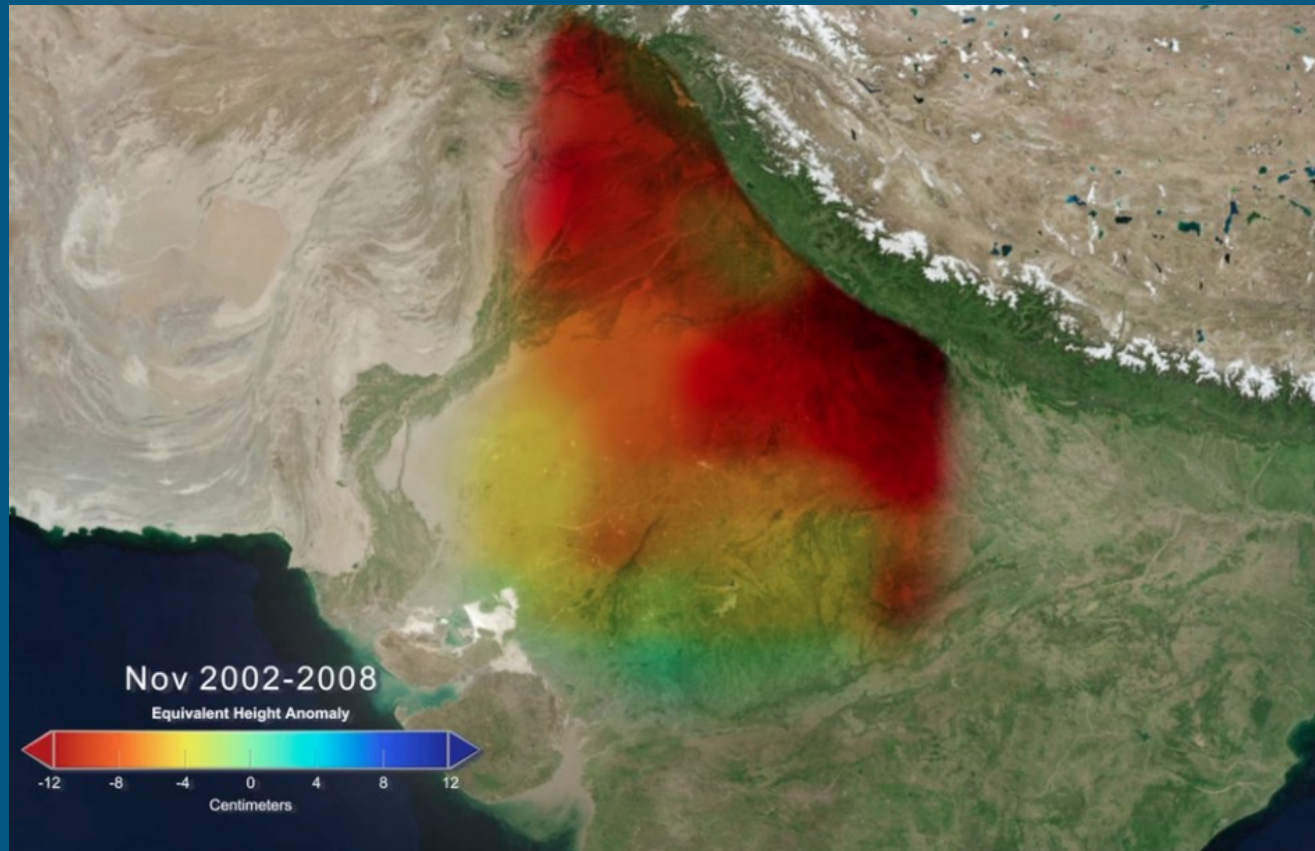
Foster and Cilton (2003)

“Houston, we have a problem,” Apollo 13



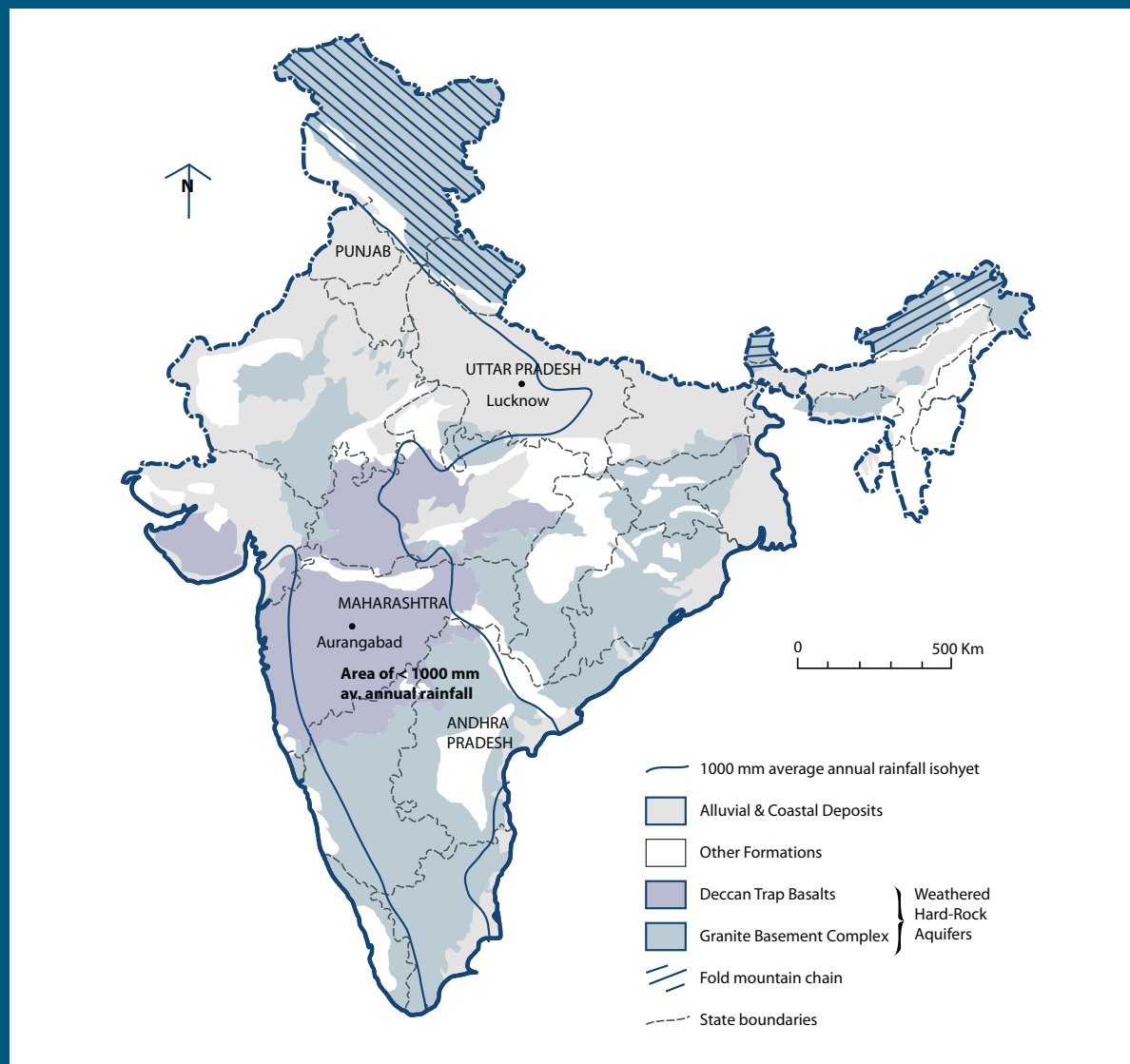
NASA photo

Northwest India: Groundwater Depletion from GRACE



Rodell et al (2009) Nature

Main Hydrogeological Provinces of India



Arsenic in Groundwater



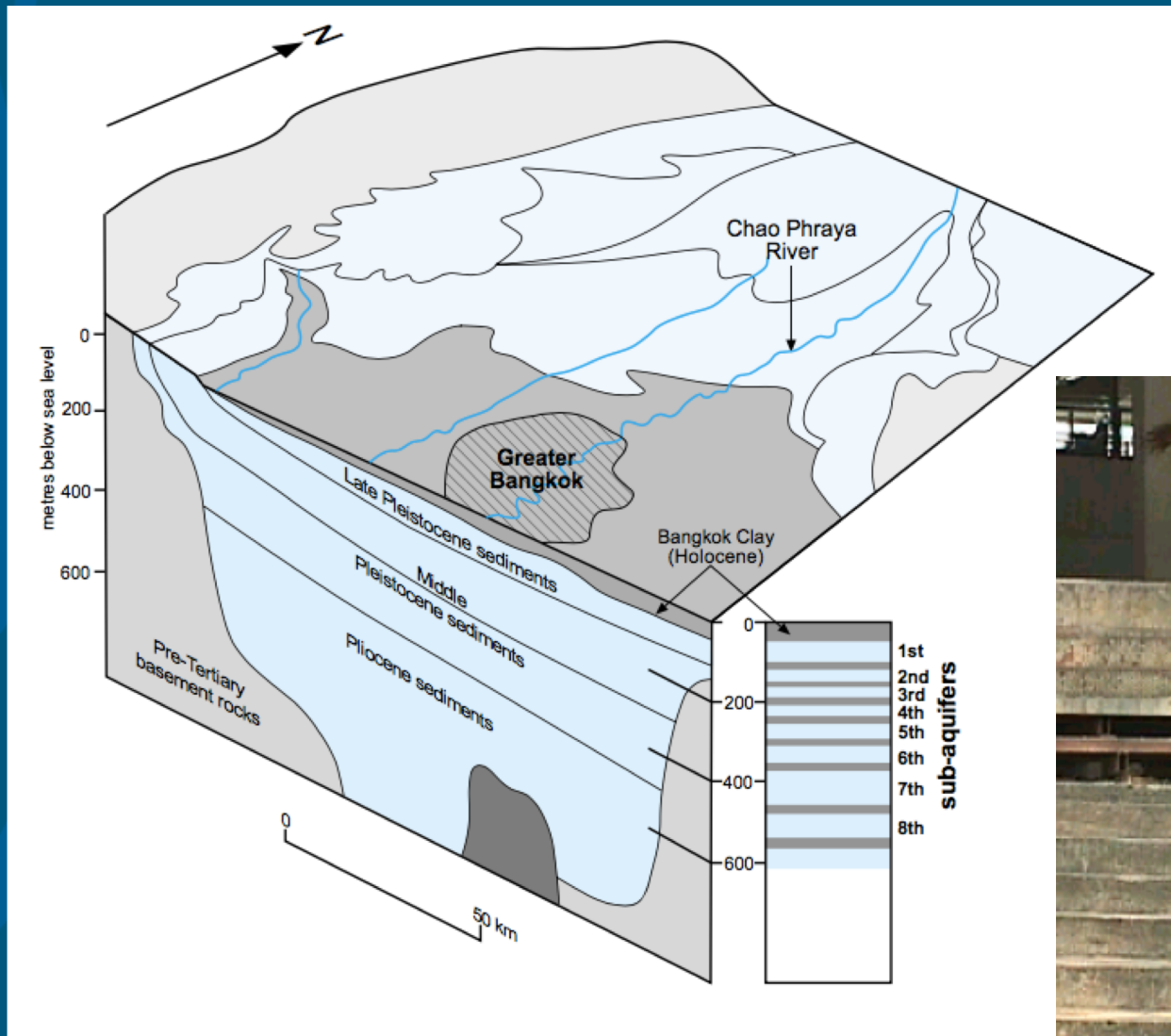
The greatest shortcoming of groundwater governance has been called “its failure to grasp the central importance of the human dimension ... and the consequent neglect of stakeholders in governance and management.”

Global Environment Facility et al. 2016

Hydrologic Cooperation Versus Hydrologic Insubordination

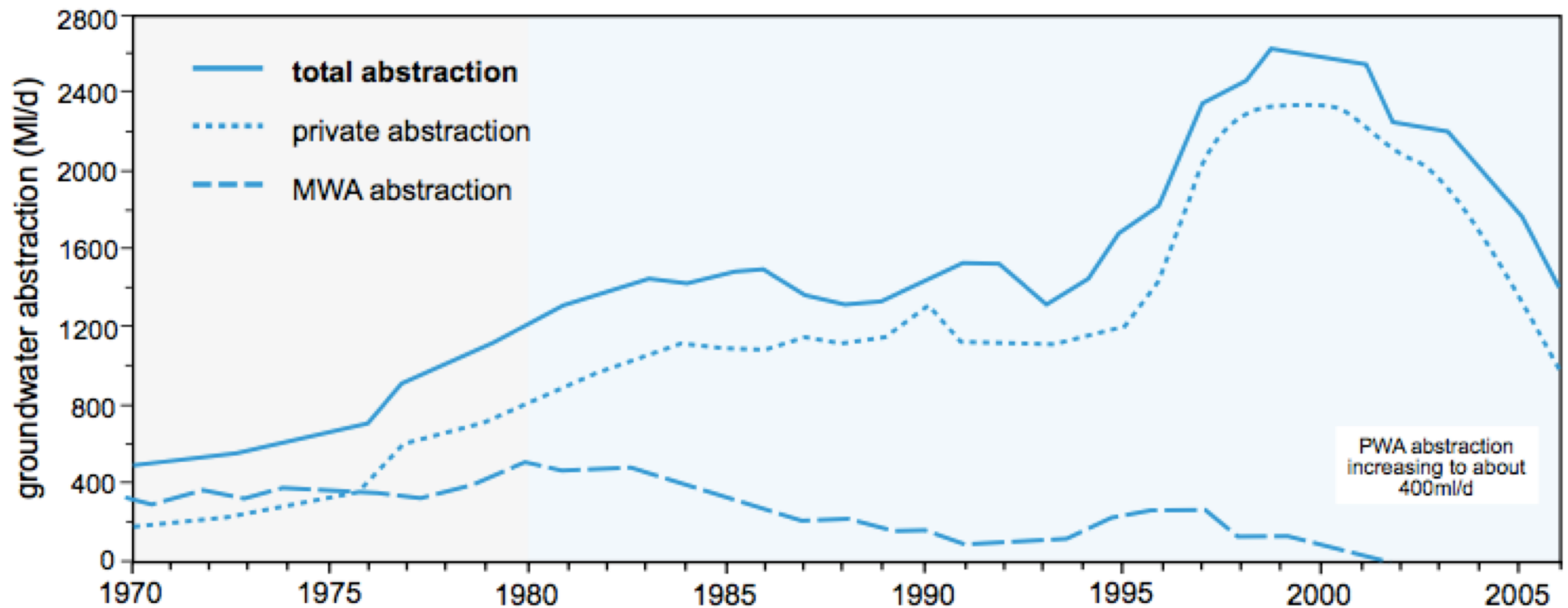


Bangkok, Thailand



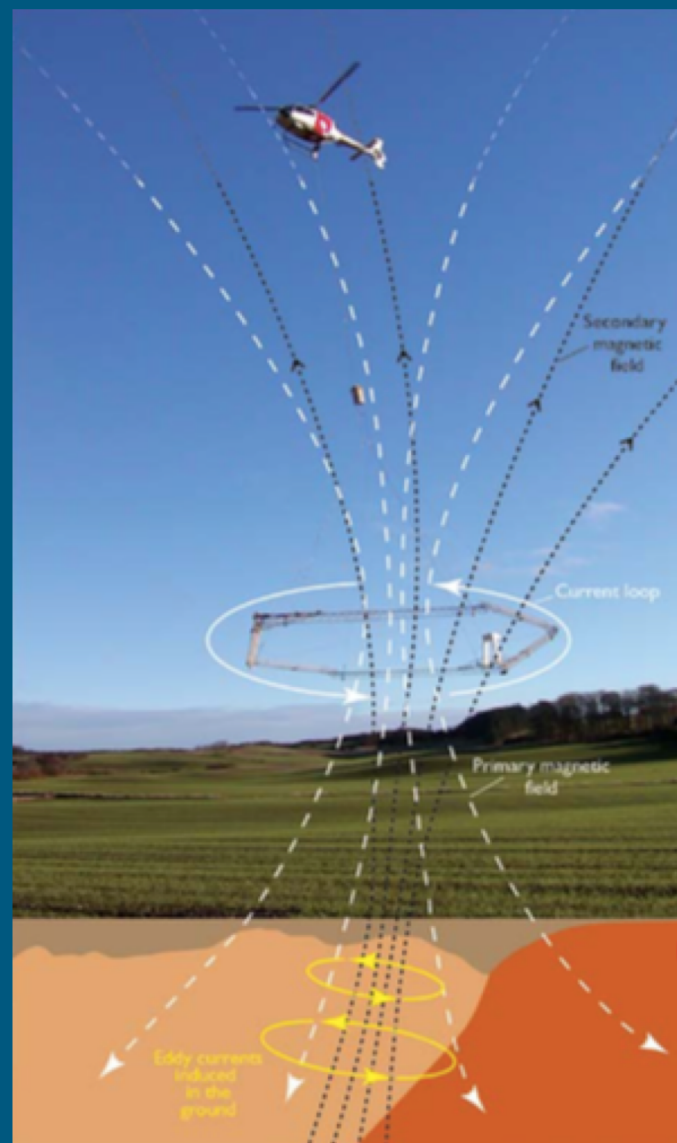
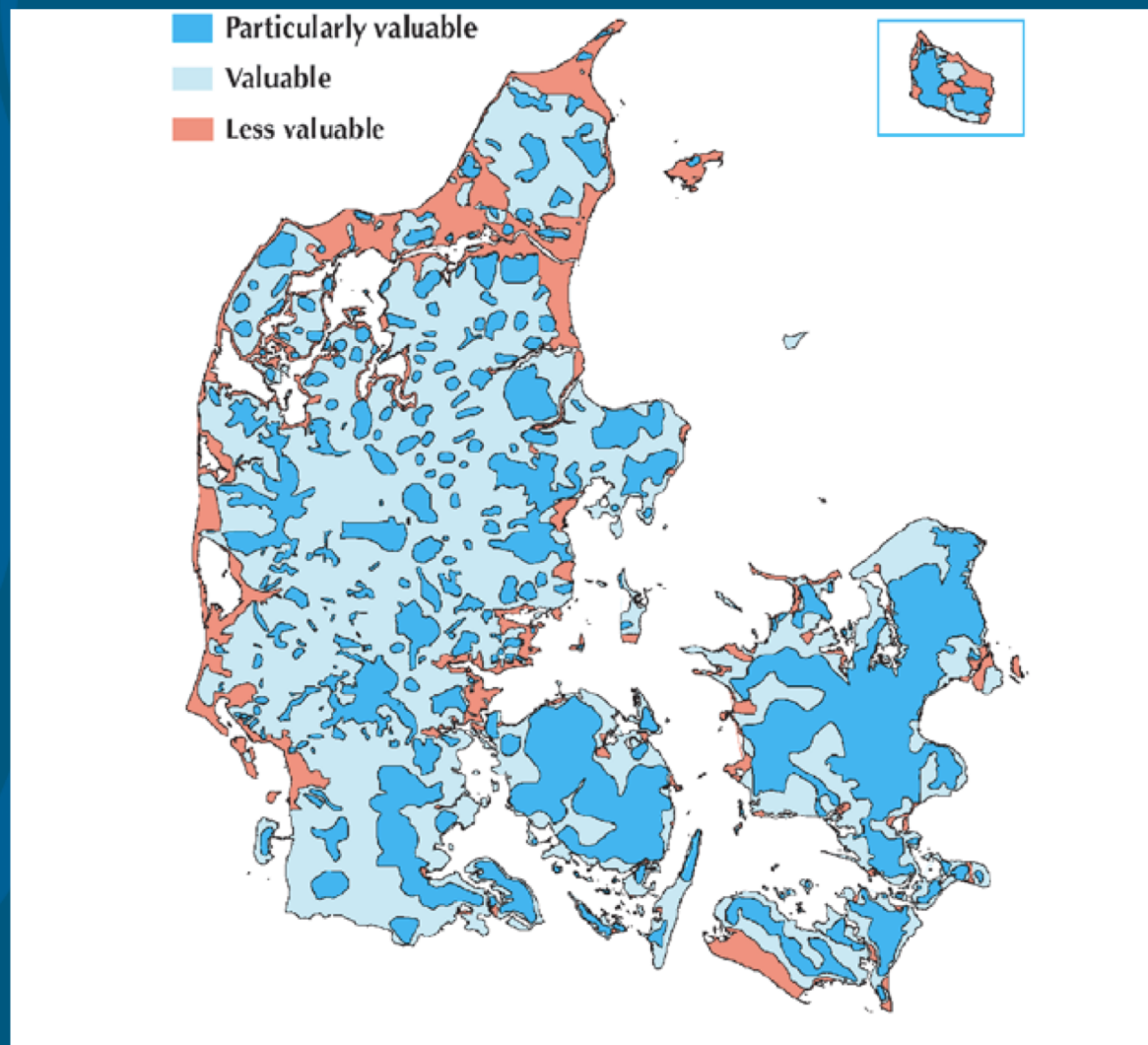
Buapeng and Foster, 2008

Bangkok, Thailand



Buapeng and Foster, 2008

Denmark: Aquifer Protection



GEUS: Danish Geological Survey

Collaborative Modeling and Citizen Scientists— San Pedro River, AZ



Depletion of a small part of the total volume of groundwater can have large effects on surface water, water quality, or subsidence which become limiting factors to development



**Upper San Pedro Basin,
AZ**



Houston, TX



Edwards Aquifer, TX



**Republican River Basin,
CO, KS, NE**

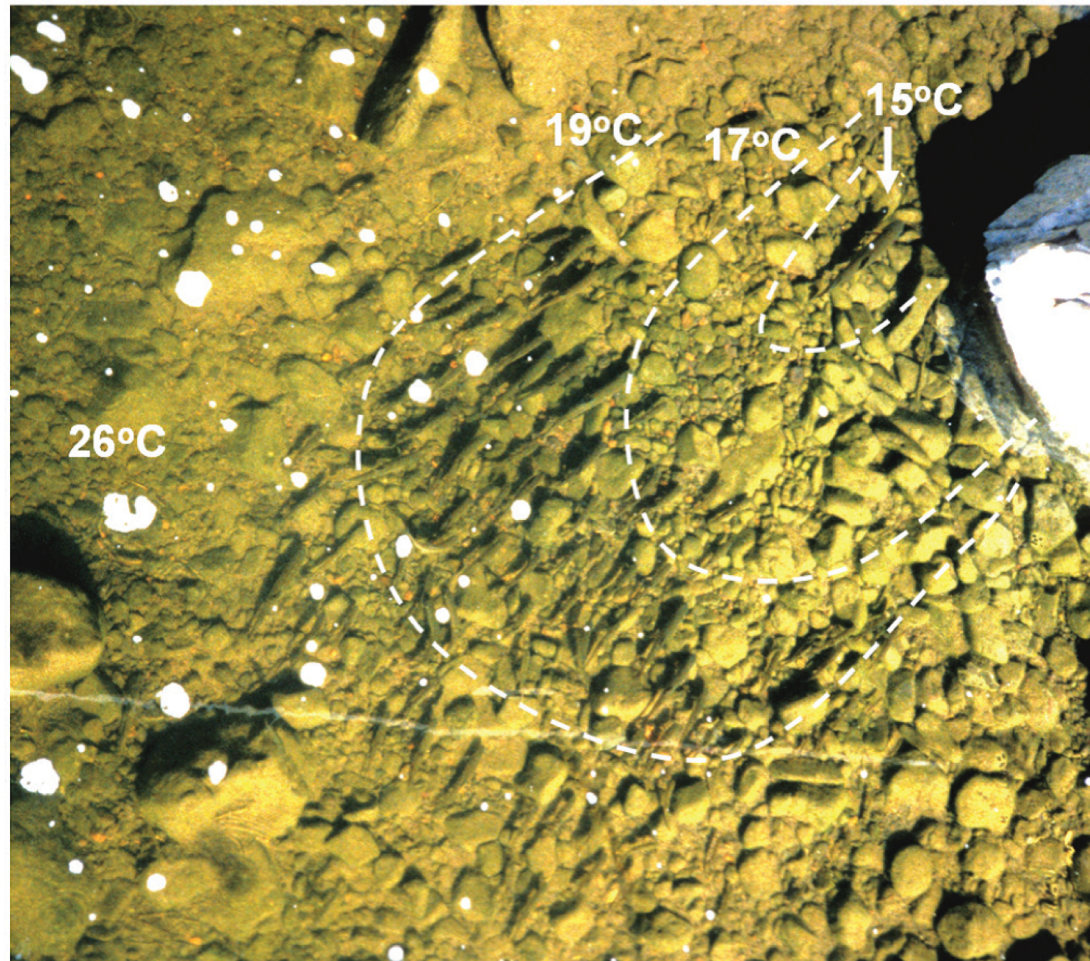
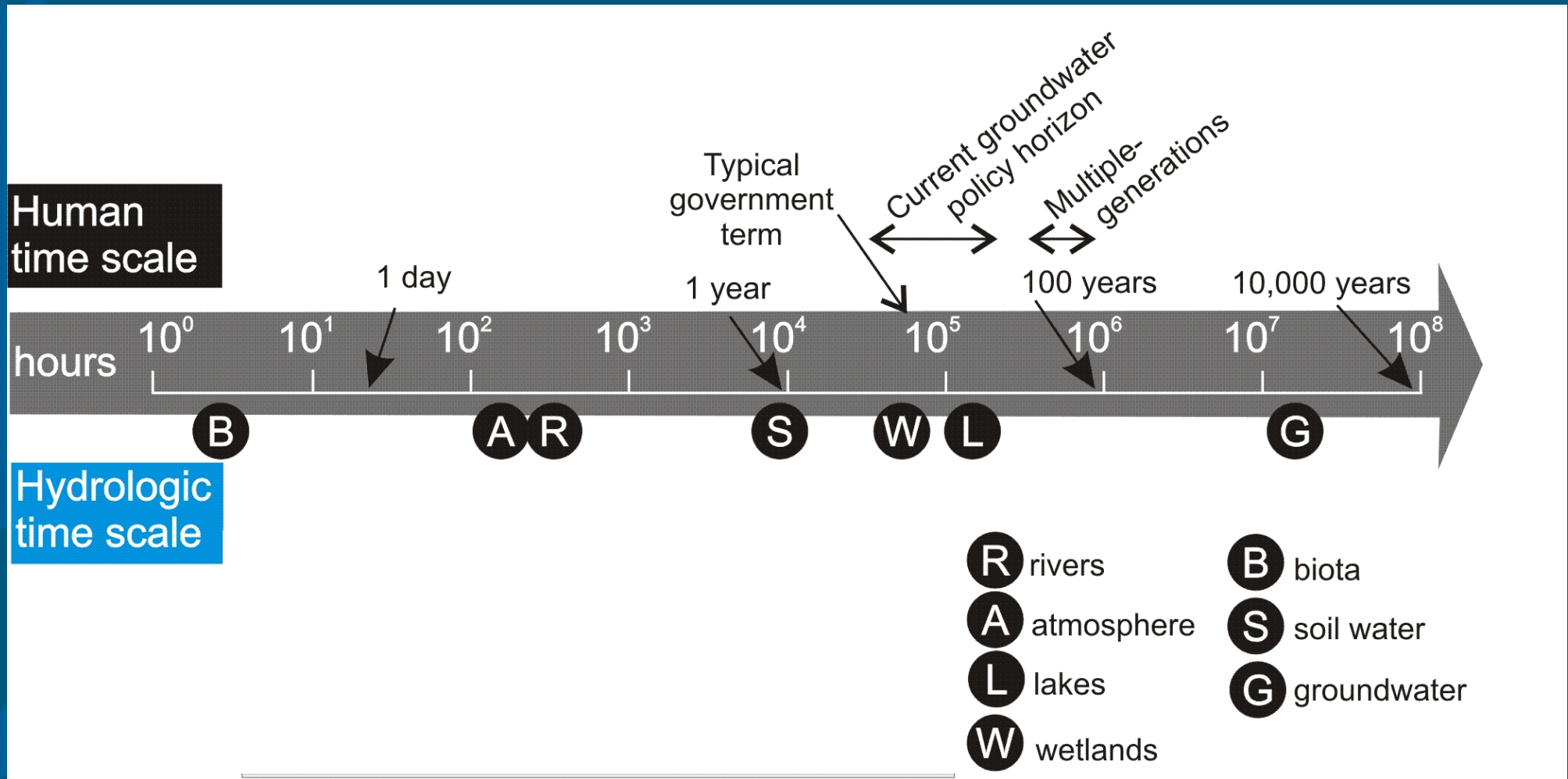


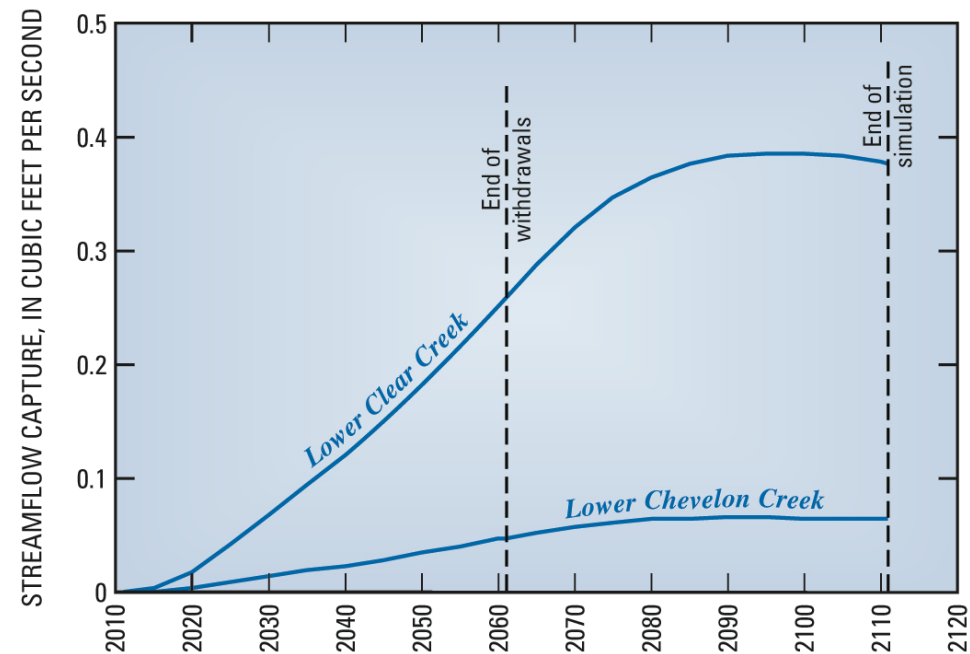
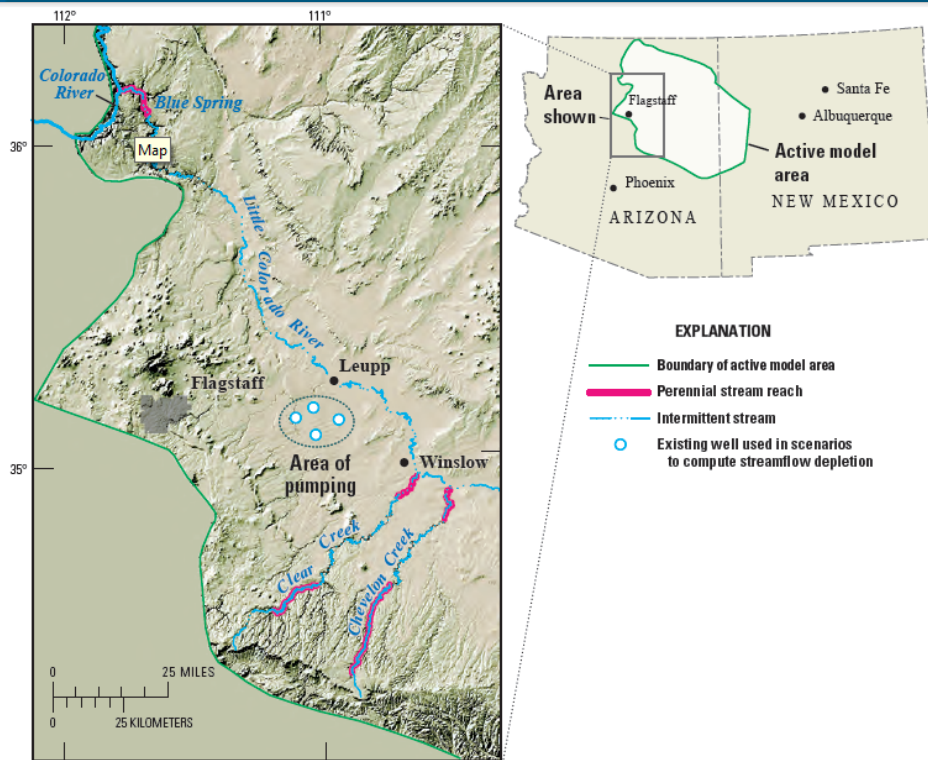
Figure 2.4.1.2. Rainbow trout in Joseph Creek in northeastern Oregon exhibit size hierarchy in occupying a cold-water refuge, with the largest individual in the coldest thermal zone (see Ebersole and others, 2001). When the availability and size of cold-water areas is limited, fish may elect habitats that are less desirable for growth and disease resistance (i.e., through crowding) in order to minimize deleterious physiological effects of high water temperature. Photograph taken by J. Ebersole in 1994.⁷⁷

Human vs Hydrologic Time Scales



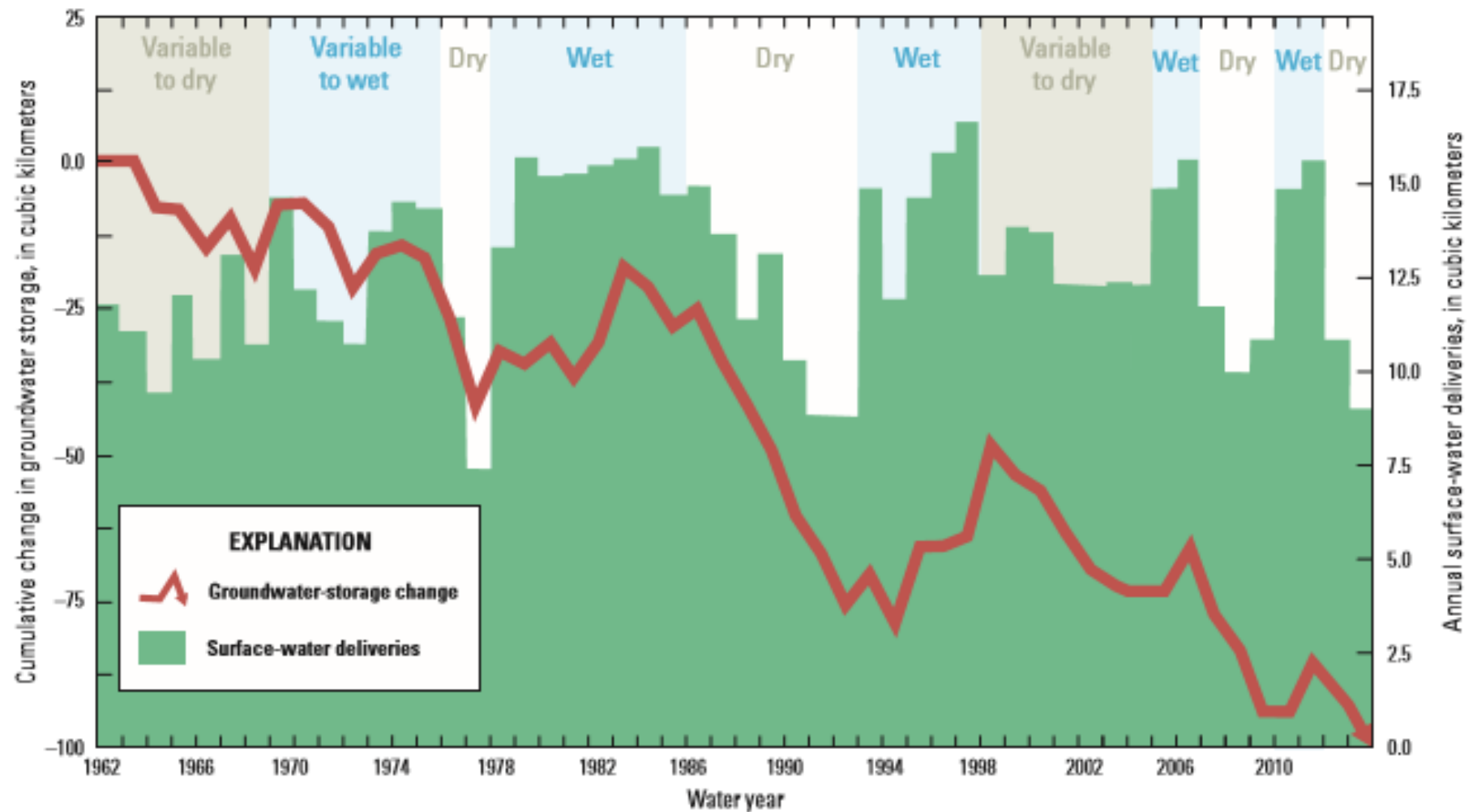
Gleeson et al. (2012)

Streamflow Capture: Arizona



Leake, Hoffmann, and Dickinson, 2005

How resilient is groundwater?



Drought-proofing Groundwater

- Analyze GW systems for their resilience and vulnerability to climate perturbations rather than just assuming groundwater is a convenient backup supply
- Raise awareness about maintaining groundwater as a reserve
 - Monitoring water use and water levels
 - Potential for managed aquifer recharge
- Work toward laws, regulations, and incentives that encourage use of surface water during wet periods and **prepare** for increased groundwater use during droughts

(Alley, "Drought-Proofing Groundwater," *Groundwater*, May-June 2016)

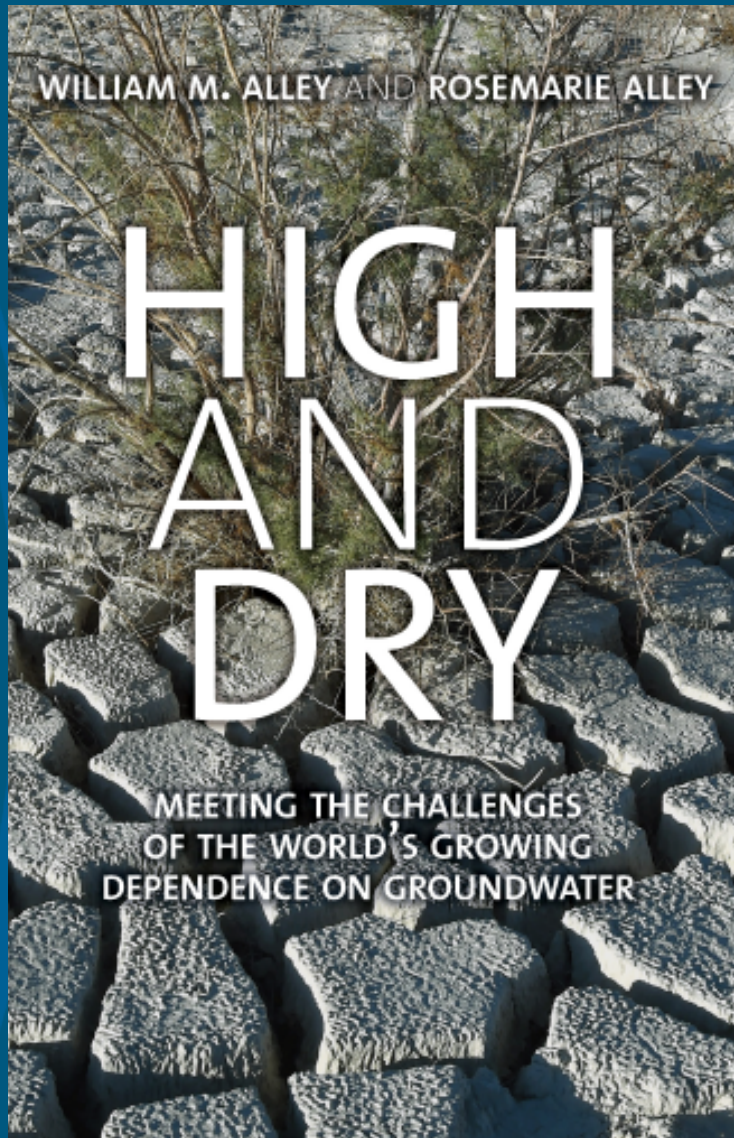
Factors Contributing to Good Groundwater Governance

- Recognizing surface water and groundwater as a single resource
- Active engagement of local stakeholders in the decision-making process
- Pressure from external bodies to achieve suitable and workable solutions
- Public education on groundwater and its importance
- An emphasis on public guardianship and collective responsibility
- Integration of GW considerations into other policies (agriculture, energy, etc.)

Factors Contributing to Good Groundwater Governance (cont.)

- Adequate laws and enforcement
- Adequately funded and properly staffed groundwater management agencies
- Characterization of major aquifer systems
- Effective monitoring of groundwater status and trends by an independent agency
- Recognizing the long-term response of groundwater systems
- Recognizing the feedbacks between groundwater and climate
- Community leadership

Questions?



"Imagine a book about groundwater that reads like a novel, and is overflowing with interesting and essential knowledge about a much-neglected topic. This is the book."

Bruce Babbitt, former US Secretary of the Interior (and AZ Governor)