Overview of Nevada groundwater systems and evolution of groundwater investigations

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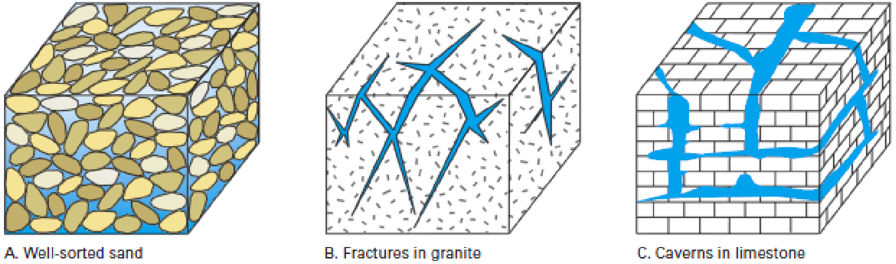
Overview of groundwater in Nevada

- Nevada groundwater systems
- What is perennial yield?
- How was perennial yield initially determined?
- How have the methods evolved over time?
- How do early estimates differ from recent estimates?
- What are limitations of perennial yield concept?
- What is groundwater sustainability?

What is groundwater?

- Liquid water in the subsurface.
- Water occupies spaces between sand, silt, and gravel in fill; or fractures and cavities in rocks.
- Water movement through and storage within the subsurface is governed by aquifer properties.

Permeability is ability of water to move through material.



Storage is amount of water stored in a given volume of aquifer.

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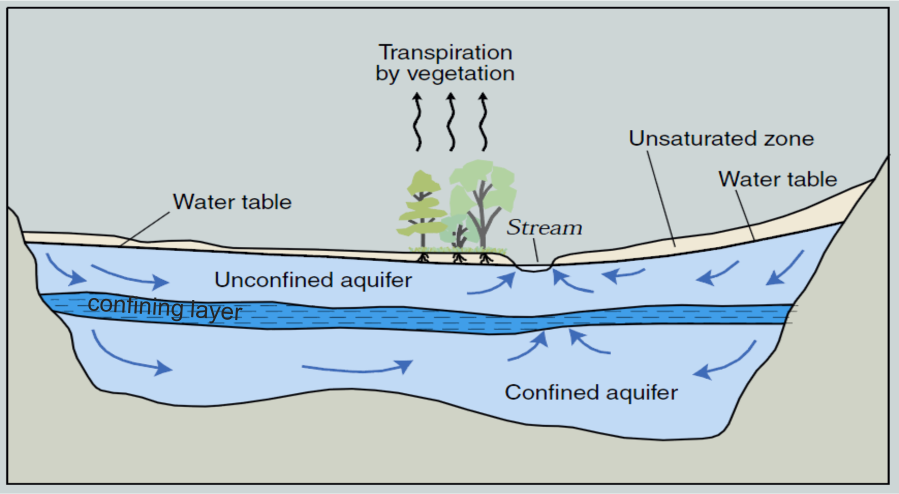
What is groundwater?

Aquifers exist where groundwater can be developed to provide adequate supply to wells.

- **Groundwater flows from areas of recharge to areas of discharge.**



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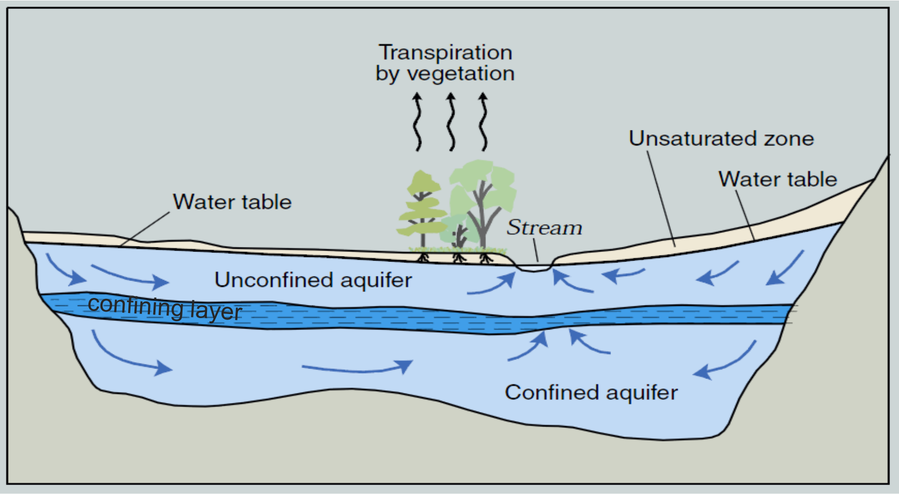
Groundwater Budgets

- **Summarize hydrologic inflows and outflows from a groundwater basin.**
- **Prior to groundwater development; water entering a groundwater system is equal to water leaving the system.**
- **Once groundwater development begins; pumping and storage change become part of the budget.**



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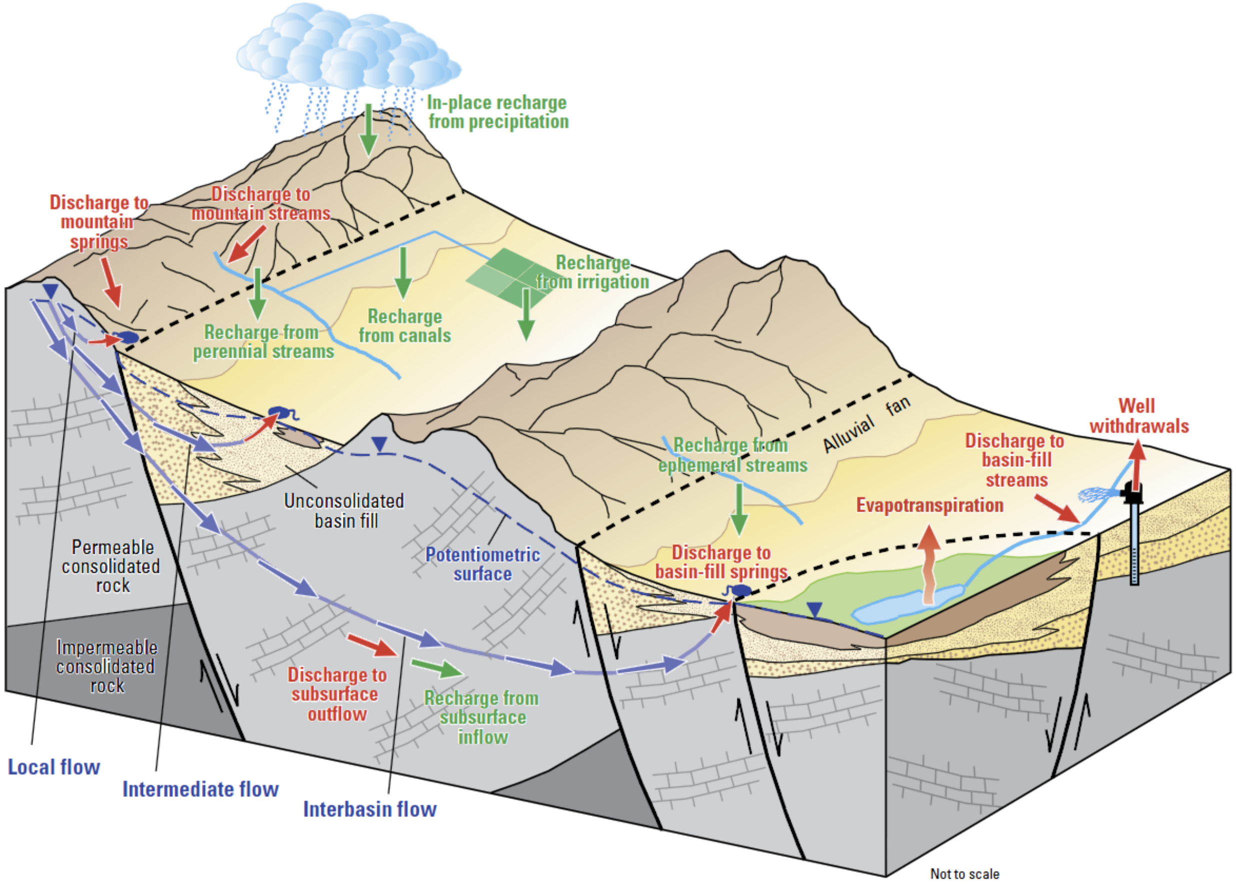
Groundwater Budget Components



Recharge is water inflow to groundwater system:

From precipitation, streams, irrigation, and subsurface inflows.

Storage change:

Change in amount of water in aquifer; change in water level.

Discharge is water outflow from groundwater system:

Streams and Springs.

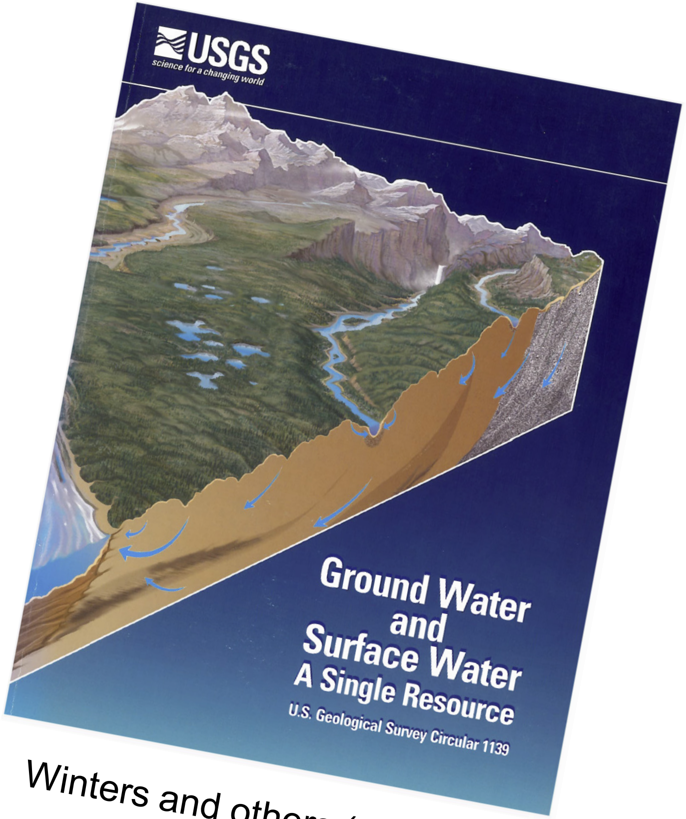
Pumping and subsurface outflow.

Evapotranspiration includes evaporation from soil and transpiration from groundwater dependent vegetation.

Groundwater and Surface Water are a single resource

Important concept for understanding how groundwater works.

And how Nevada's water resources should be conceptualized.



Winters and others (1998)

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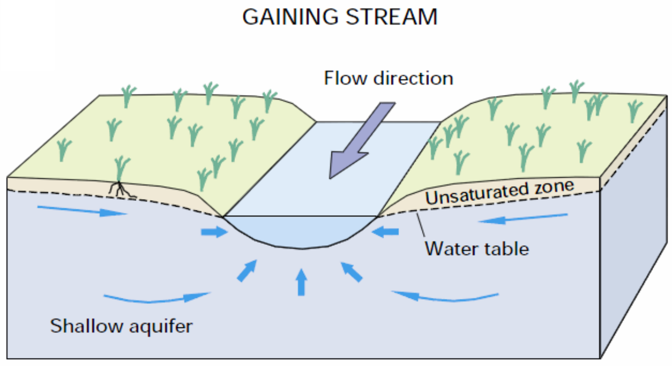
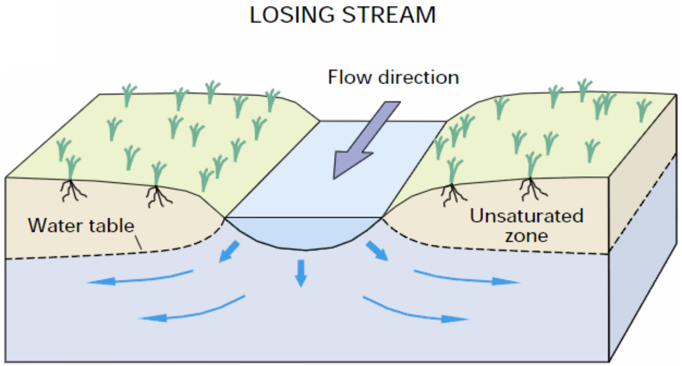
Groundwater and Surface water are a single resource

- Streams flowing year-round are connected with groundwater.
- Groundwater can:
  - Discharge to a stream (gaining stream).
  - Receive water from a stream (losing stream).
- Streams can:
  - Lose water to groundwater (losing).
  - Gain water from groundwater (gaining).





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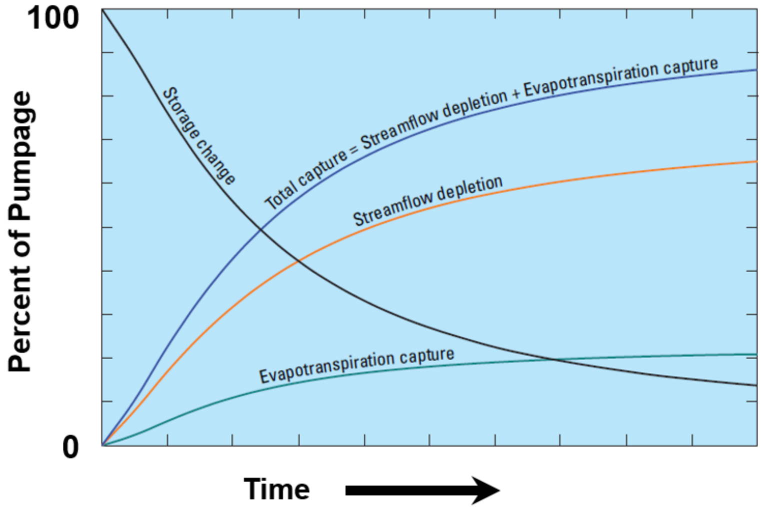
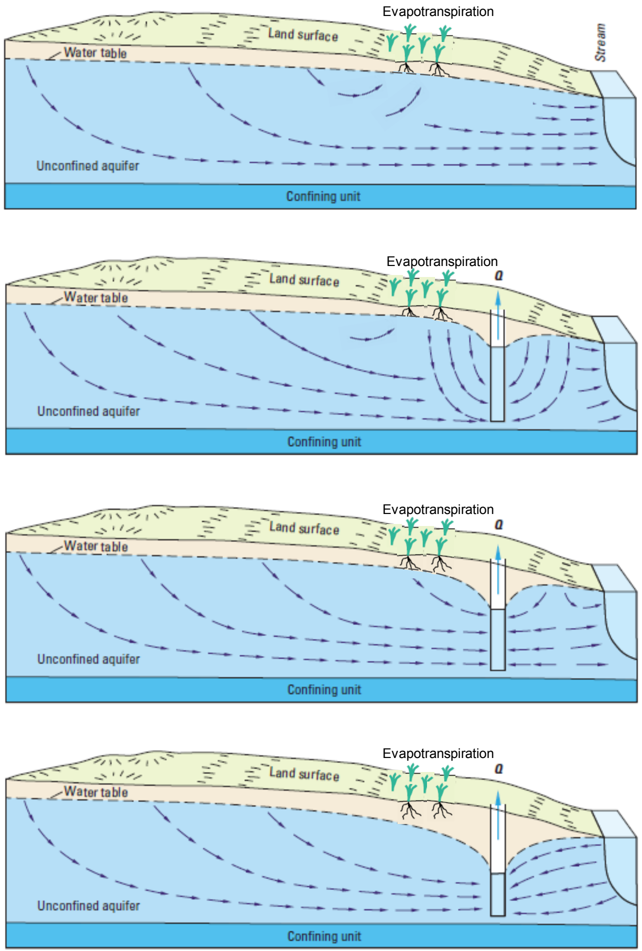
Source of water to wells

- Storage change – water from ground near well.
- Streamflow depletion – diversion from stream.
- Evapotranspiration capture – water intercepted from plant use and evaporation.





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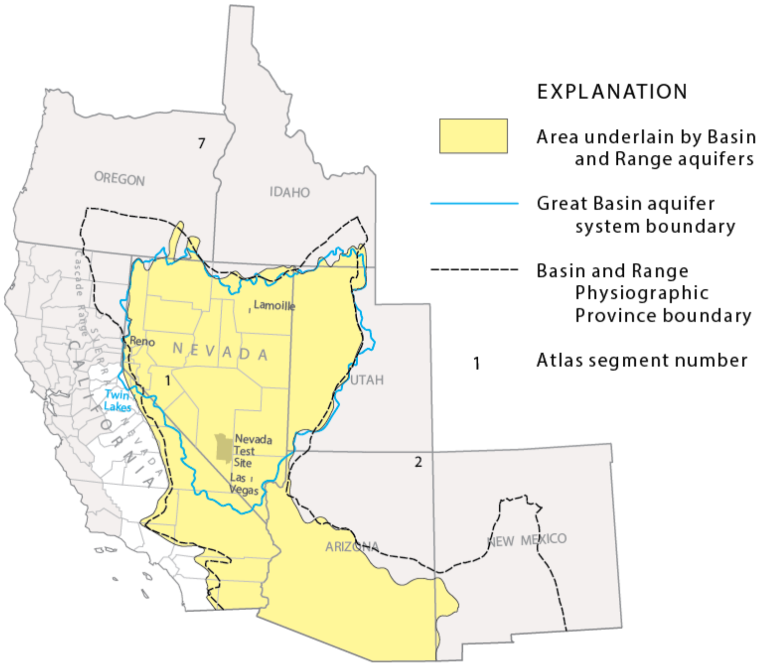
Nevada Groundwater Systems

- **Basin and Range aquifers.**

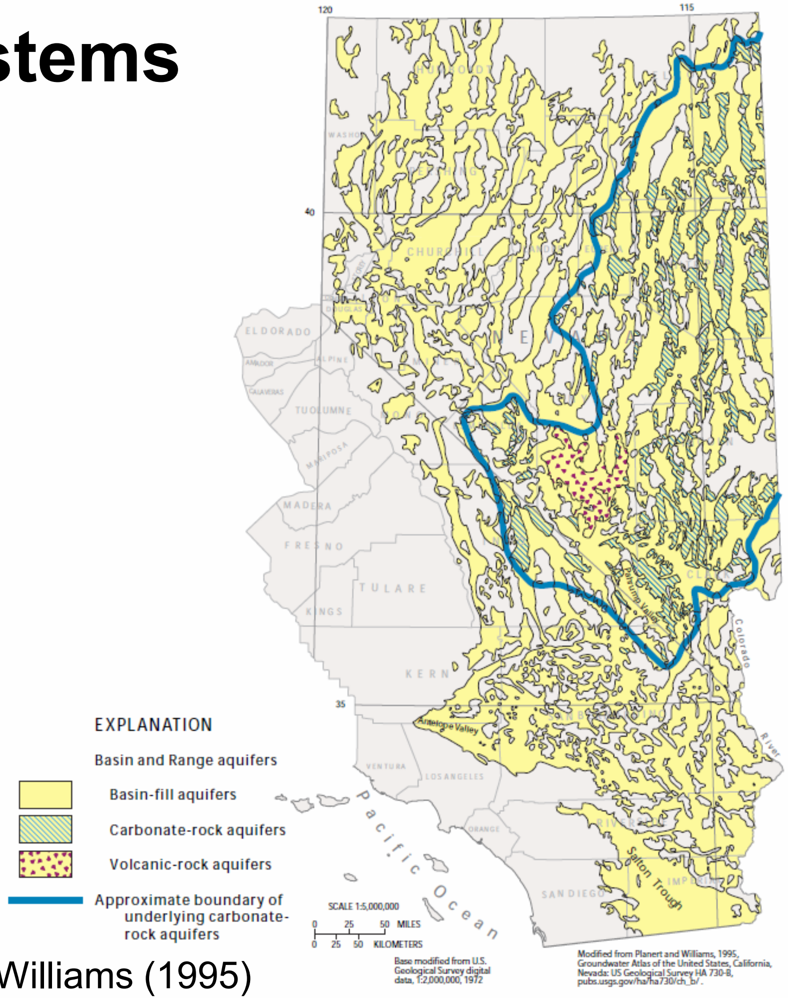


Planert and Williams (1995)

USGS

Nevada Groundwater Systems

- **General aquifer types.**
  - **Basin-Fill Aquifers**
  - **Carbonate-Rock Aquifers**
  - **Volcanic-Rock Aquifers**



Planert and Williams (1995)

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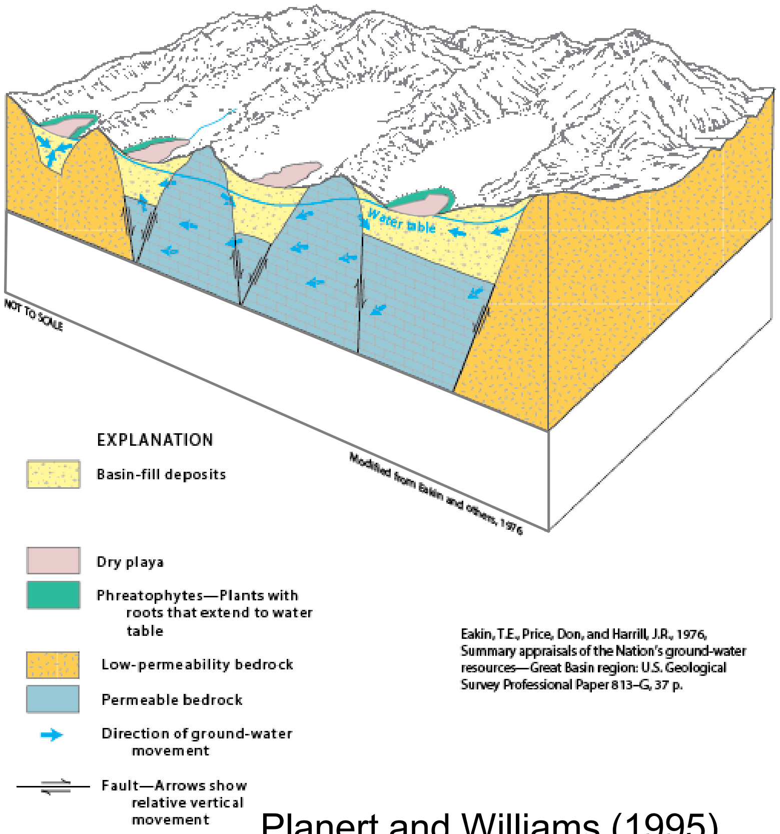
Nevada Groundwater Systems

- Hydrologic basin types.
  - Undrained closed basin.
  - Partly drained closed basin.
  - Connected basin flow systems.



Eakin, T.E., Price, Don, and Harrill, J.R., 1976, Summary appraisals of the Nation's ground-water resources—Great Basin region: U.S. Geological Survey Professional Paper 813–G, 37 p.

Planert and Williams (1995)

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Nevada Groundwater Systems

- River connected flow systems.
  - 25 percent of the states groundwater systems.
  - Potential for conflict between groundwater and surface water users due to shared nature of resource.

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Perennial Yield

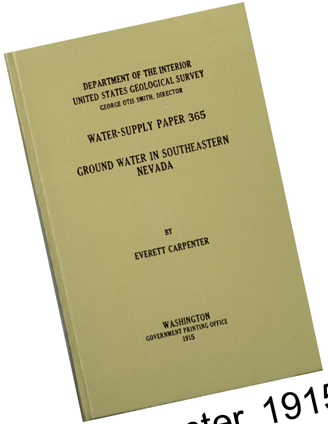
"Perennial yield is the maximum amount of groundwater that can be salvaged each year over the long term without depleting the groundwater reservoir."

source: Nevada Water Law 101
http://dcnr.nv.gov/documents/documents/nevada-water-law-101/

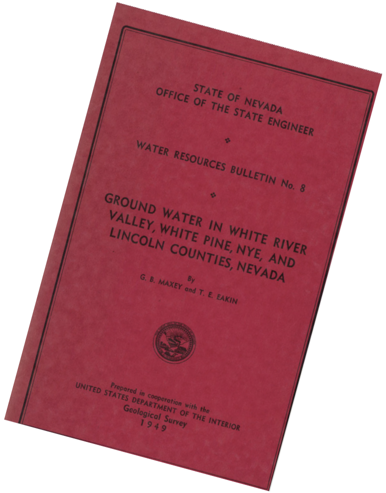
- Amount of groundwater in a given hydrographic area available for appropriation.
- Perennial yield is determined from estimated groundwater budgets for each of the hydrographic areas.

Early Investigations of Groundwater

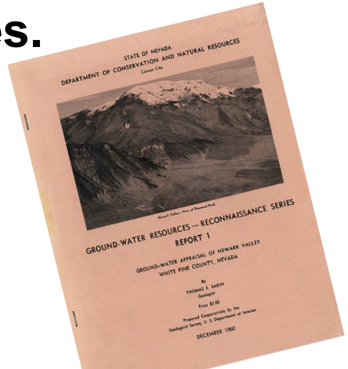
- **1915 – USGS first groundwater investigation in NV.**
- **1938 – Cooperative water program began in NV.**
- **1944 – Systematic investigations began.**
- **1946 – Beginning of Water Resources Bulletin Series.**
- **1960 – Beginning of Groundwater Resources Reconnaissance Series.**



(Carpenter, 1915)



http://water.nv.gov/home/publications/bulletins/



http://water.nv.gov/home/publications/recon/

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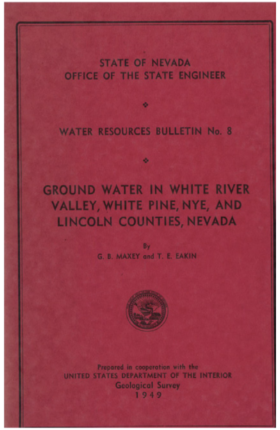
Early methods of estimating groundwater budgets

- **Discharge**
  - **Mapped discharge area.**
  - **Assigned evapotranspiration rates.**
  - **Estimates highly uncertain.**
  - **Basis for evaluating potential for groundwater development in basins.**

$$Discharge\ area\ \times ET\ rate = Discharge\ rate$$

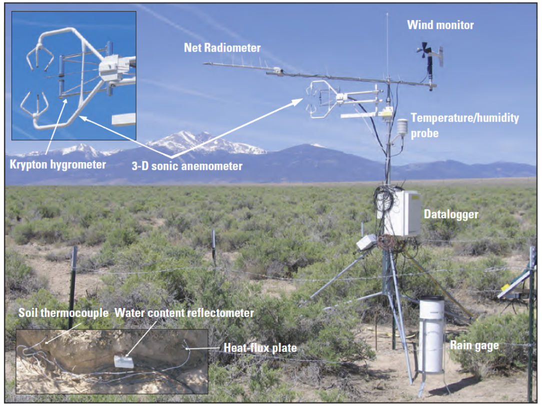
- **Recharge**
  - **Initially assumed equal to discharge.**
  - **Maxey – Eakin method developed in 1949.**
  - **M-E method used extensively to independently estimate recharge.**

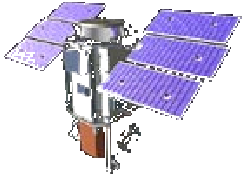


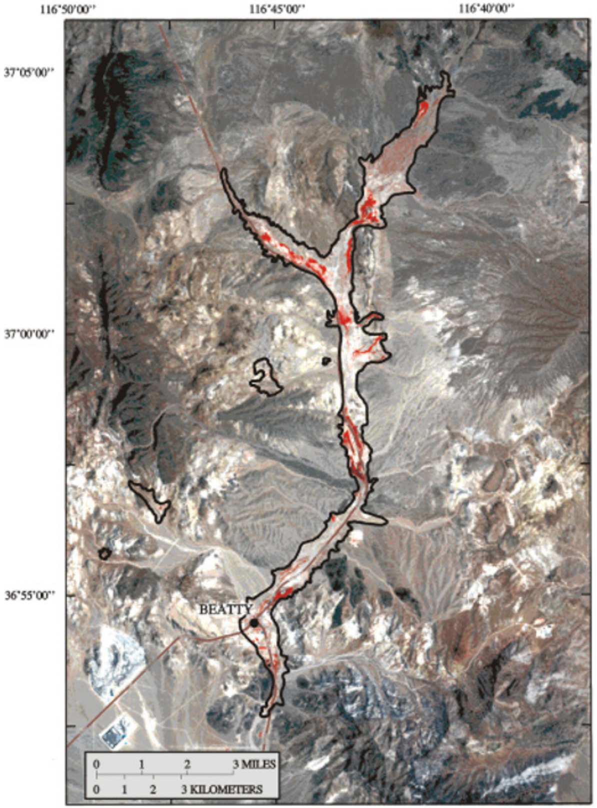
(Maxey and Eakin, 1949)

(Hardman, 1936)

Evolution of methods – Measurement based approach







Oasis Valley - Color Infrared Composite

- Evapotranspiration stations.
- Landsat imagery.
- Budget estimates more certain; improved confidence.

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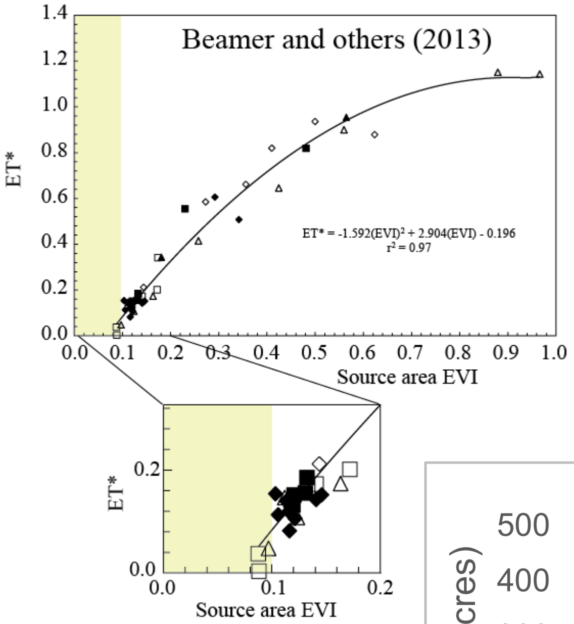
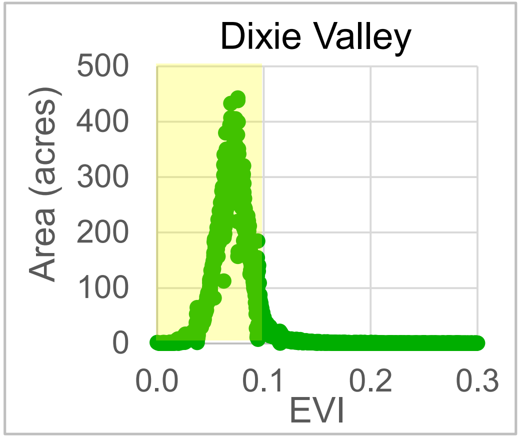
Evolution of methods – Recent remote sensing methods

- **Vegetation Index models.**
  - **Vegetation index derived from remote sensing.**
  - **Estimate evapotranspiration (ET) directly from vegetation index.**
- **Estimates derived more quickly.**
- **Lower cost.**
- **Some ambiguity in low-density vegetation.**
- **Uncertainty still being evaluated.**

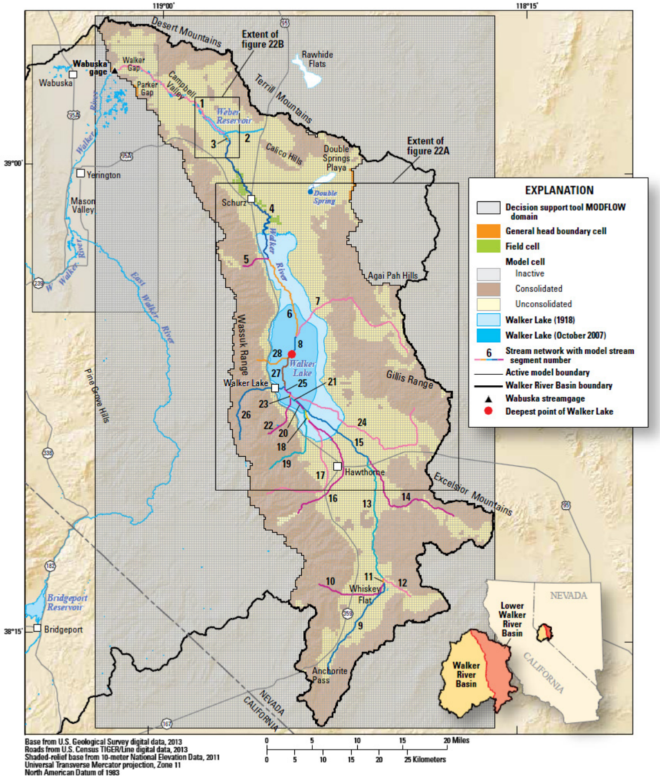


EVI = Enhanced Vegetation Index



Evolution of methods – Groundwater models

- **Simulate hydrologic systems based on principles, aquifer properties, and boundary conditions.**



(Allander and others, 2014)

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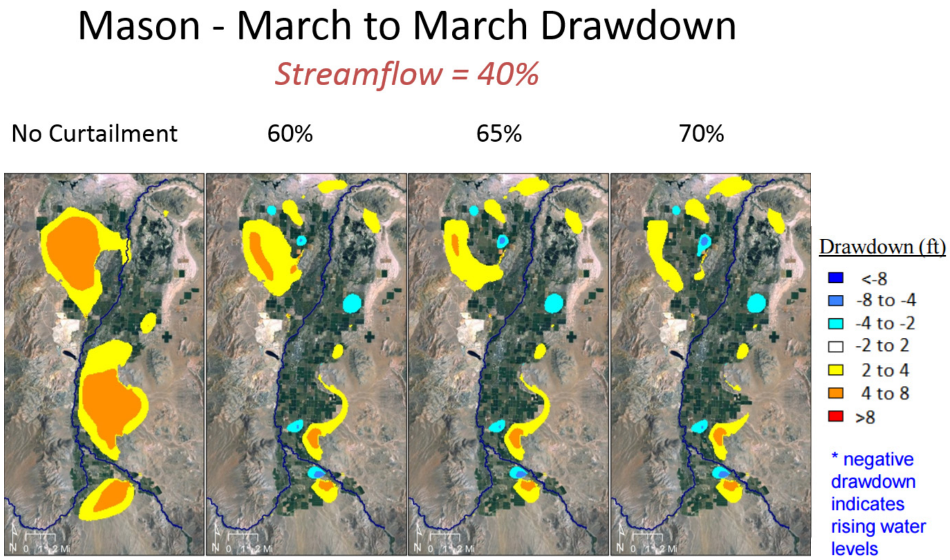
Evolution of methods – Groundwater models

- **Used for understanding complex system interactions and testing effects of actions.**



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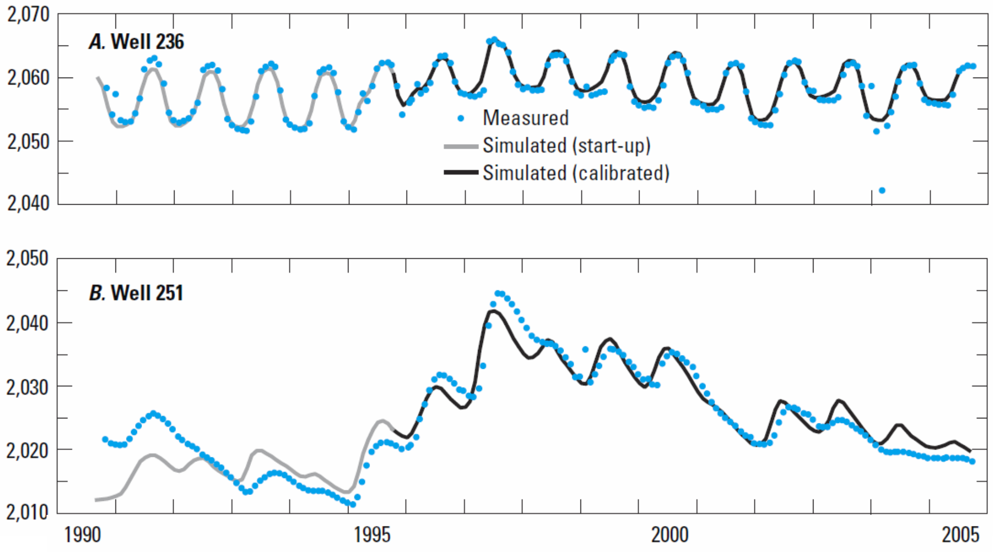
http://water.nv.gov/documents/Walker_River_July2015_presentation.pdf

Evolution of methods – Groundwater models

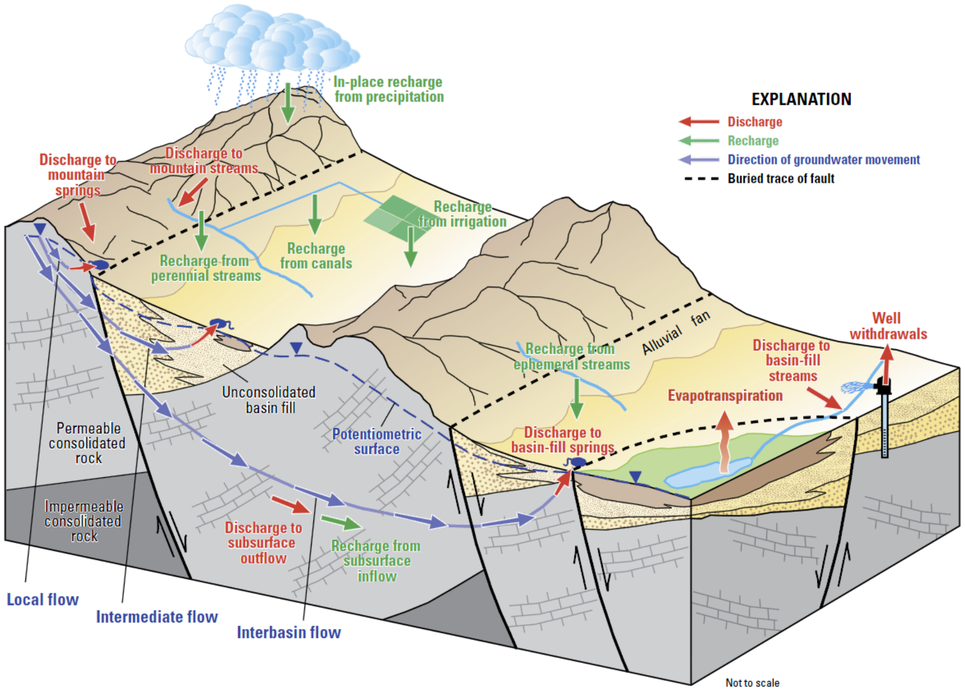


(Hsieh and others, 2007)

- **Properties controlling flow in model are adjusted (calibrated) using observation data.**

Evolution of methods – Groundwater models

- **Refine water budget estimates.**



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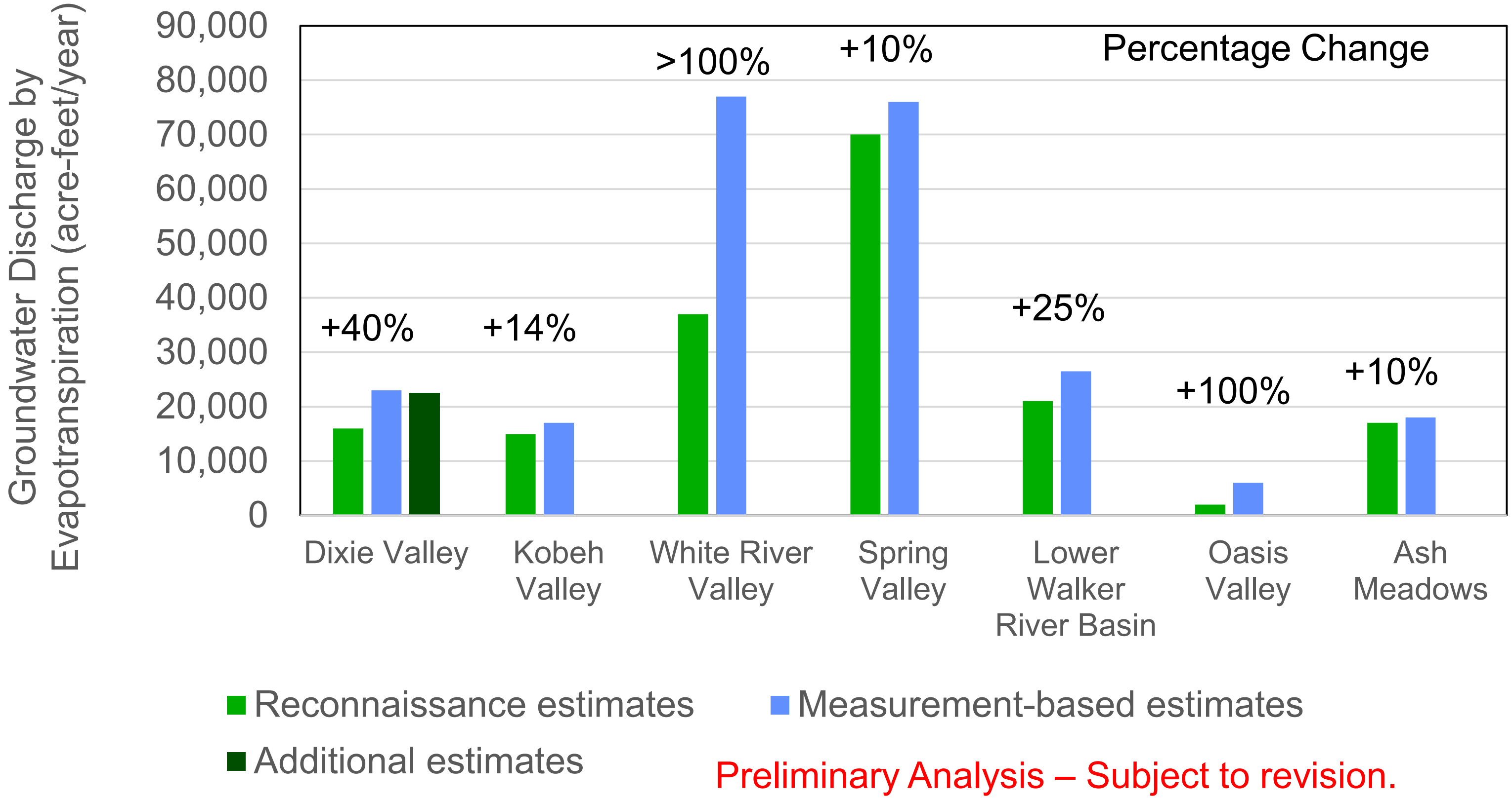
How do early discharge estimates differ from recent measurement-based estimates?



Preliminary Analysis – Subject to revision.

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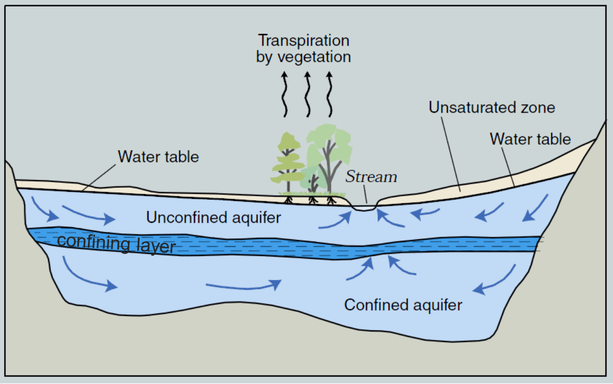
Limitations of Perennial Yield concept

- Under ideal conditions, perennial yield is effective concept.
- Has constrained over-development of groundwater resources Nevada.
- In many basins, groundwater discharges to streams, springs, and wetlands.
- Estimates of perennial yield usually include this discharge.
- But streams and springs are often already appropriated for beneficial use or provide critical habitat.



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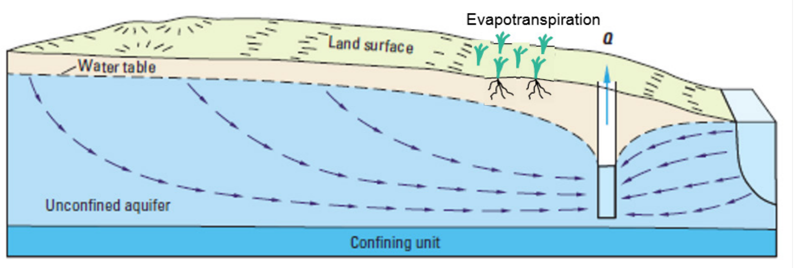
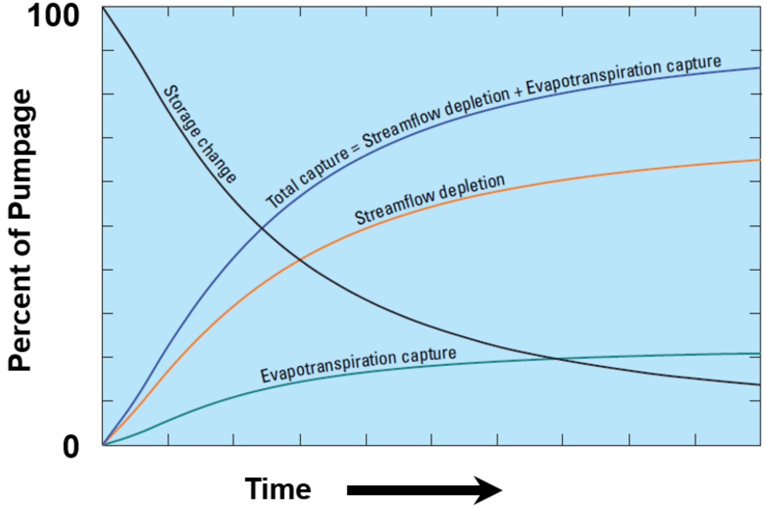
“Perennial yield is the maximum amount of groundwater that can be salvaged each year over the long term without depleting the groundwater reservoir.”

Limitations of Perennial Yield concept

- Groundwater and surface water are a single resource
- Cannot capture evapotranspiration without also depleting springs and streams.
- A new perspective for groundwater management needed.





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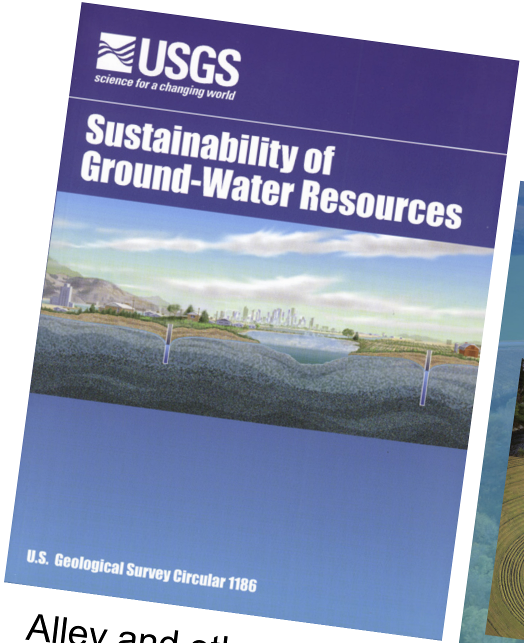
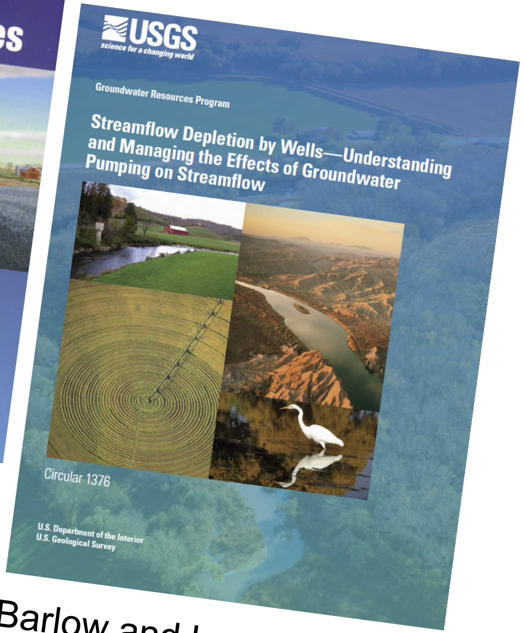
What is Sustainability of Groundwater Resources?

- **A different perspective for thinking about groundwater.**
- **Perspective changes from 'How much flow is entering system' to 'What are acceptable changes to the system'?**
- **Recognizes interrelation of groundwater and surface water.**
- **About understanding effect of pumping on *timing, rates,* and *locations* of depletions (diversions).**



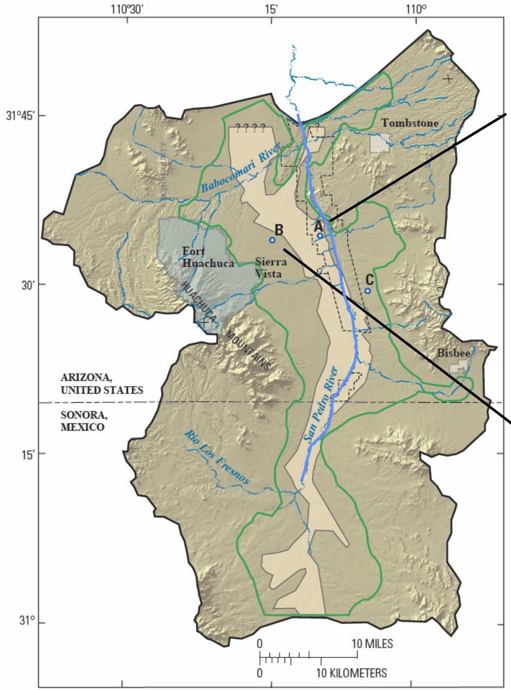
Alley and others (1999)



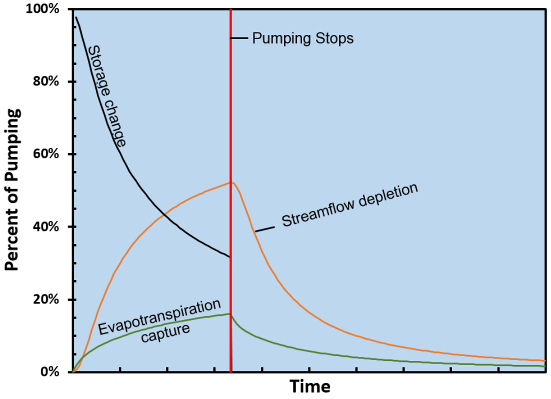
Barlow and Leake (2012)

Sustainable groundwater – Illustration of concept

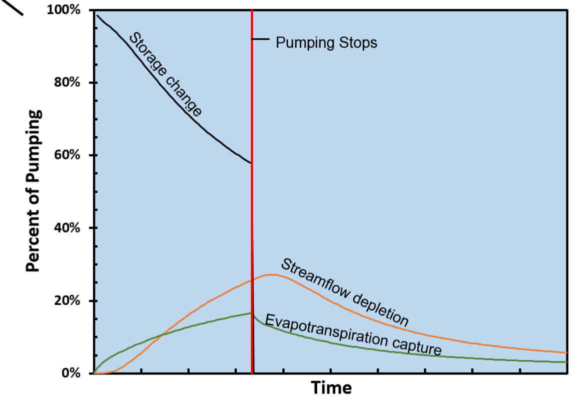
- **Understanding that wells at different distances from river will:**
  - **Get their water at varying proportions from storage, streamflow depletion, and captured evapotranspiration.**
  - **The closer well (Well A), takes a greater proportion of water from the stream sooner.**
  - **The further well (Well B), takes a smaller proportion from stream, but for a longer duration after pumping stops.**



Well A



Well B



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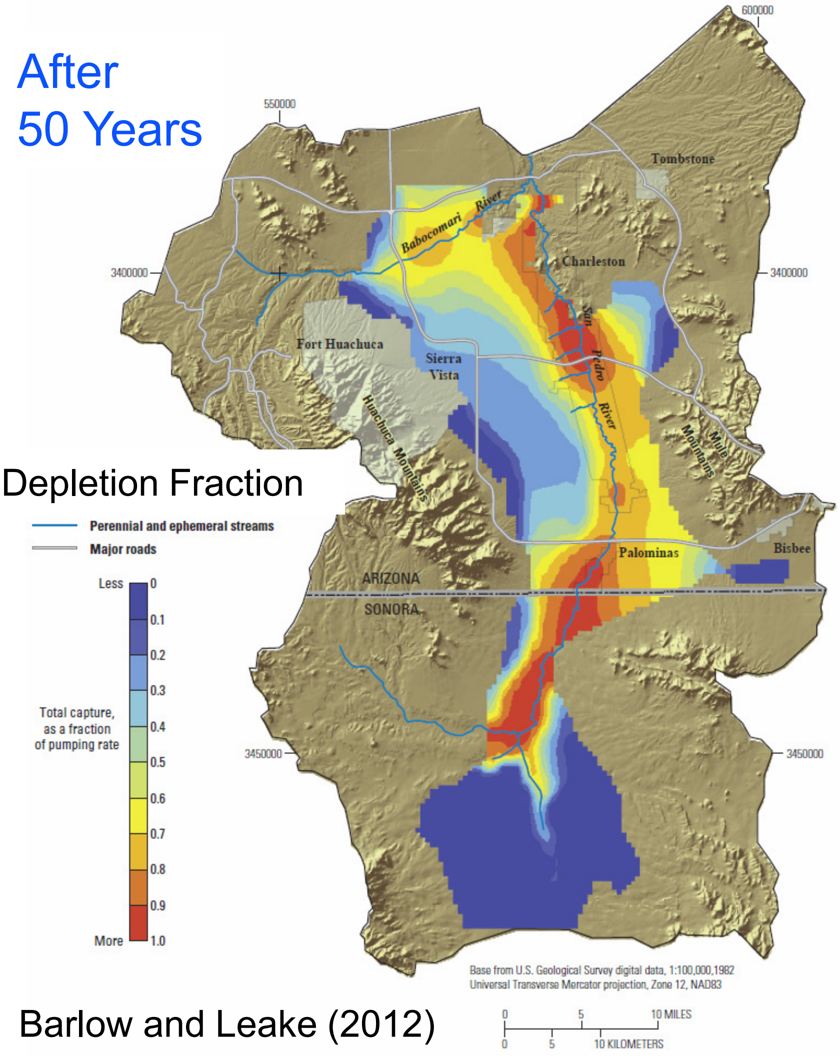
Sustainable groundwater – Capture maps

- Provide estimates of pumping impacts on other resources based on location and properties of system.
- Are for select durations of pumping.
- Developed using ‘calibrated’ groundwater flow models.



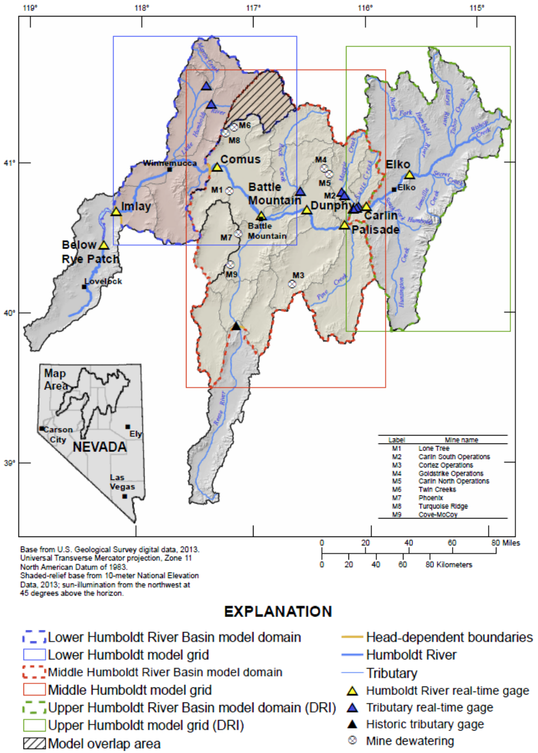
Barlow and Leake (2012)

USGS

Sustainable groundwater – Working toward a sustainable future

Collaborative effort

- **State Engineers office.**
  - **Great understanding of Nevada's water resources and issues.**
  - **Recognizes the challenge.**
  - **Moving toward sustainability concepts.**
  - **Within legal framework provided.**
- **Humboldt River Basin example.**
  - **Understanding the effect of pumping on *timing, rates,* and *locations* of depletions (diversions).**
  - **Information needed for transition of management.**



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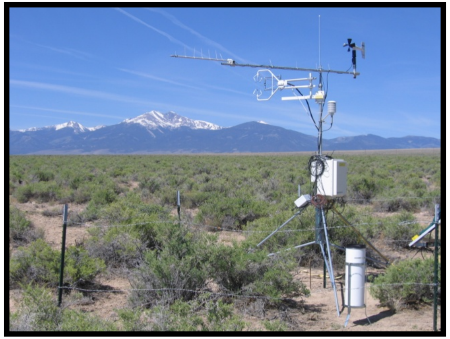
http://water.nv.gov/HumboldtRiver/Humboldt_Modeling_Workshop_Nov2-3_2015.pdf

Importance of monitoring data

- Critical for successful management of water resources.
- Data provide the information we need to determine properties of the system.
- The properties of the system govern the processes and interactions.
- Our ability to understand, model, and predict system processes and interactions is greatly improved with long-term data.



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