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Road Map to a Water Budget
Aquifer Storage

Harney Basin Study Advisory Committee
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U.S. Department of the Interior
U.S. Geological Survey

Water Budget Road Map

STORAGE CHANGE

- Groundwater-level change
- Lake-volume change

INFLOW

- Precipitation – primary
- Irrigation – secondary
- Interbasin flow?

OUTFLOW

- Evapotranspiration (ET)
  - Natural
  - Irrigation
- Spring discharge
- Interbasin flow?
- Other consumptive use
  - Domestic
  - Agricultural

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Image source: openclipart.org

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Water Budget Road Map
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Water Budget Road Map
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INFLOW
USGS
Image source: openclipart.org

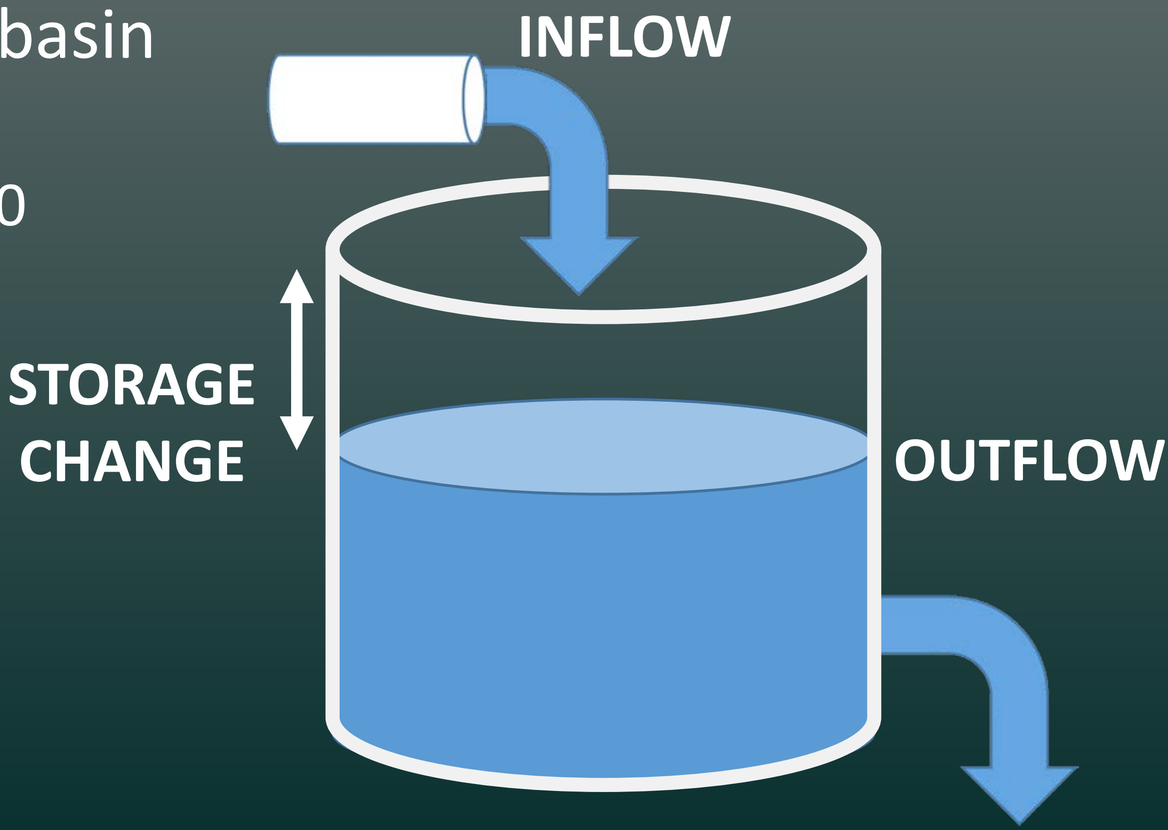
Basin Water Budget

↓INFLOW = ↑OUTFLOW ± CHANGE IN STORAGE

Steady-state closed basin

- Inflow = Outflow
- Storage change = 0

  (no water-level decline)



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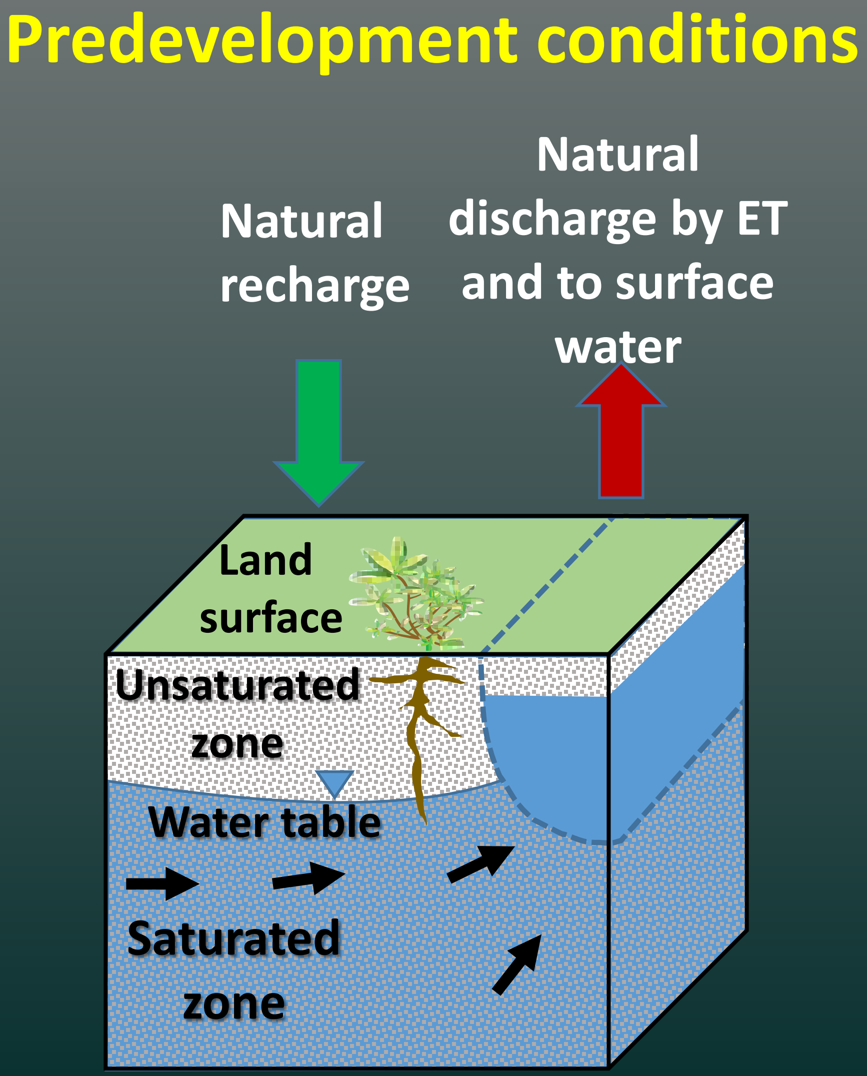
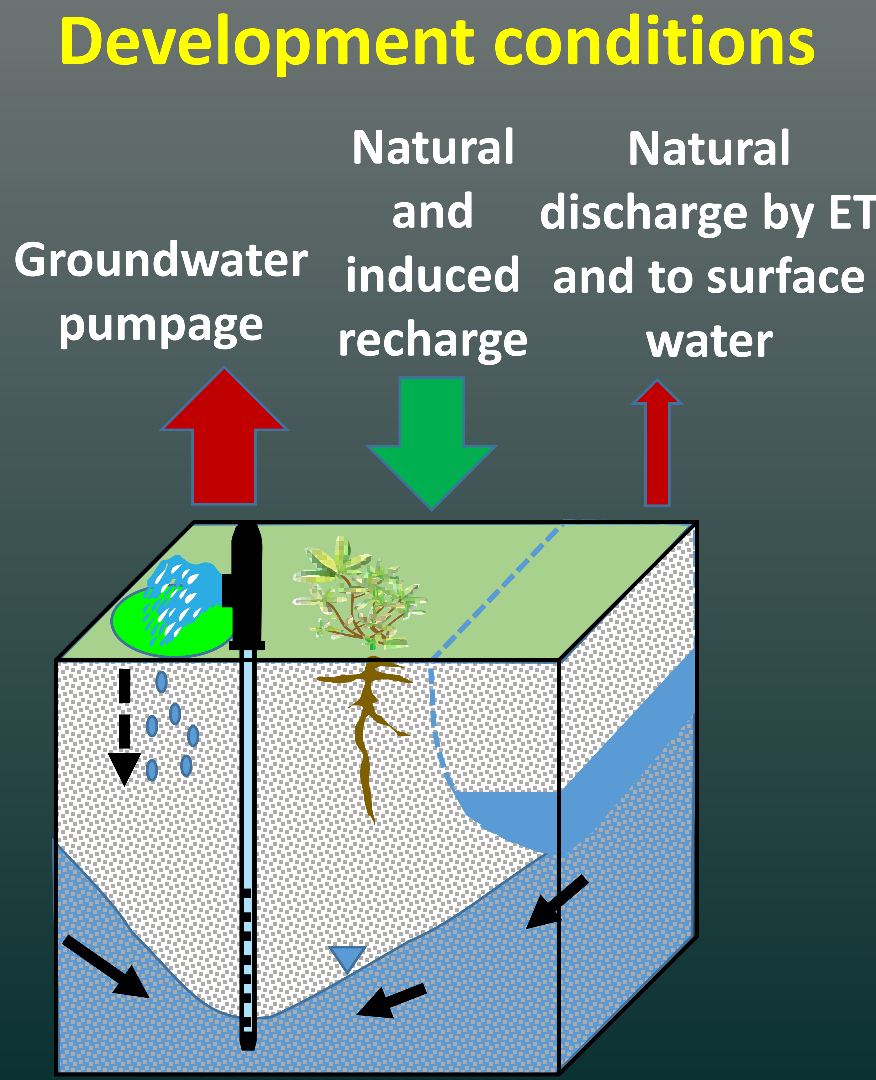
Groundwater Storage Depletion





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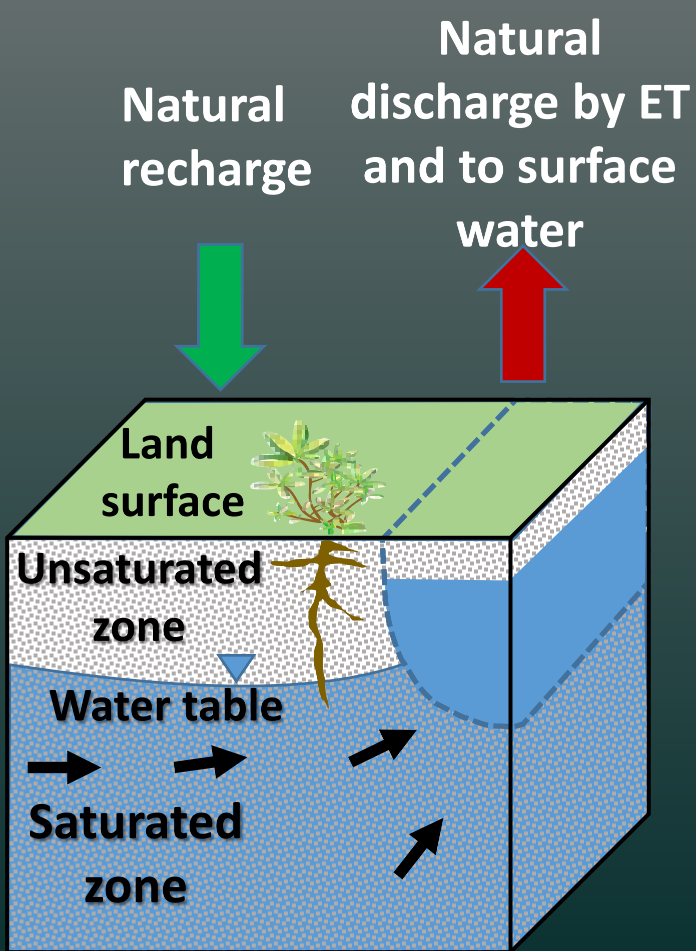
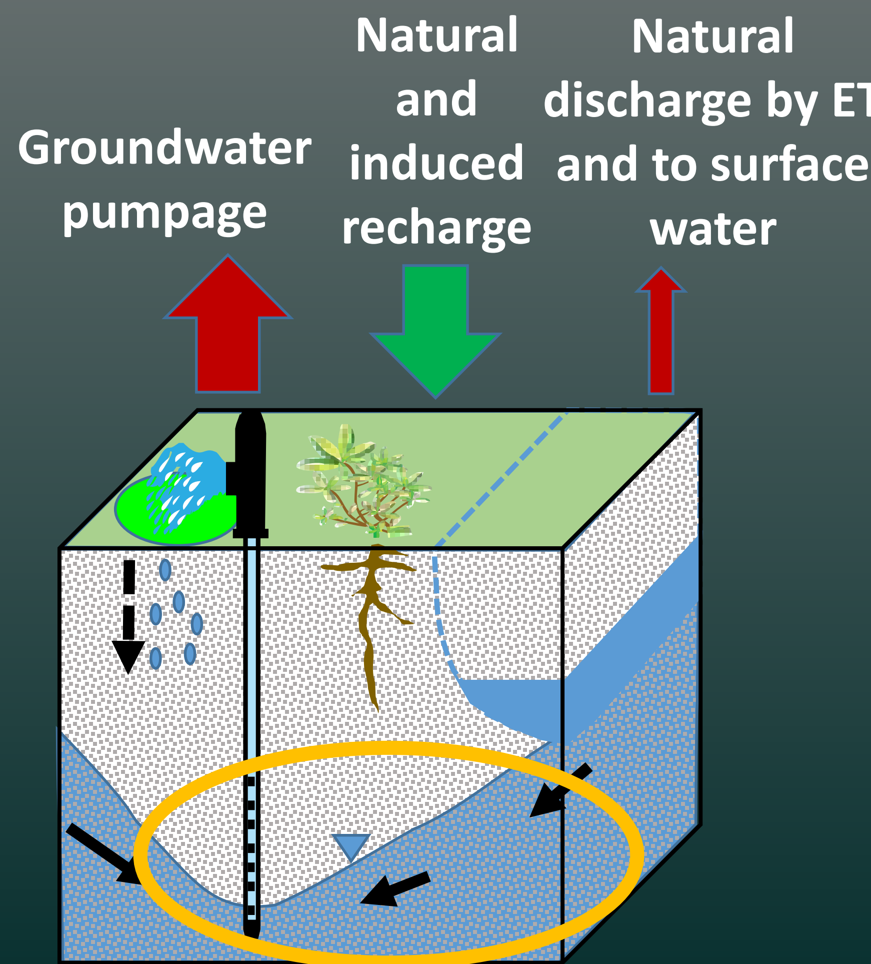
Groundwater Storage Depletion

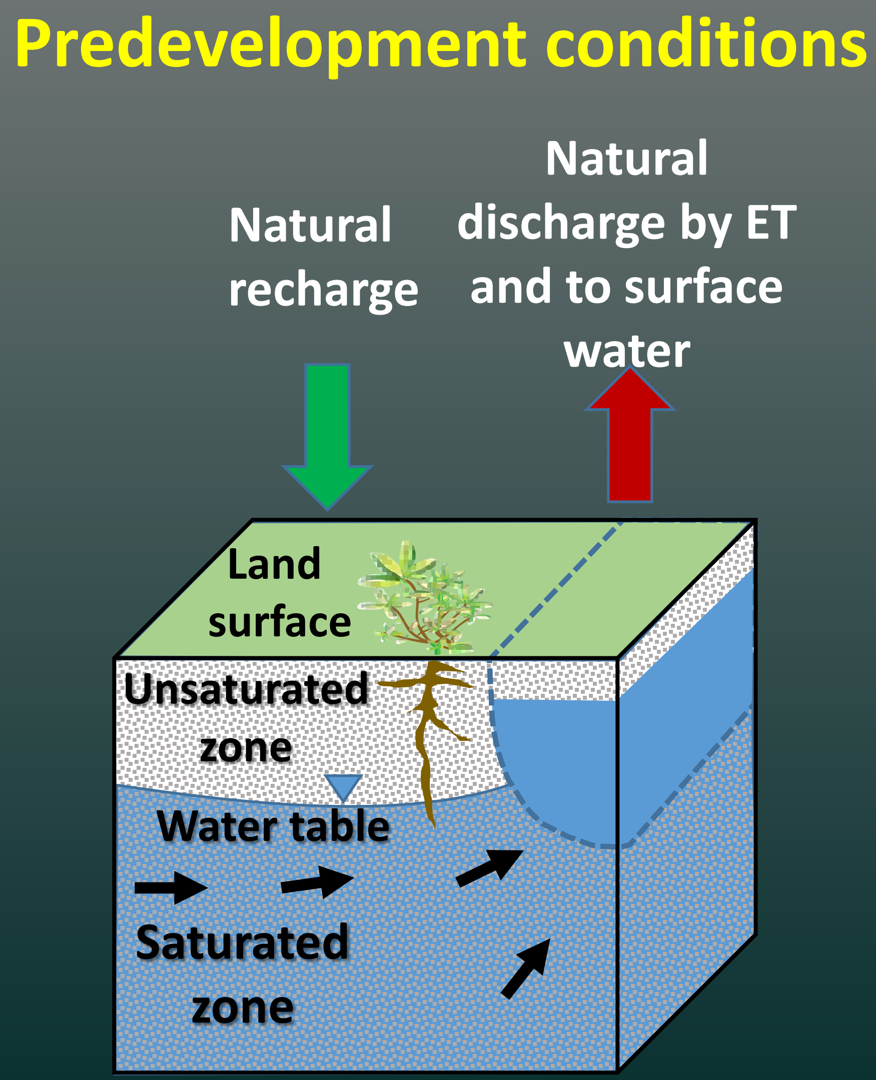
Predevelopment conditions

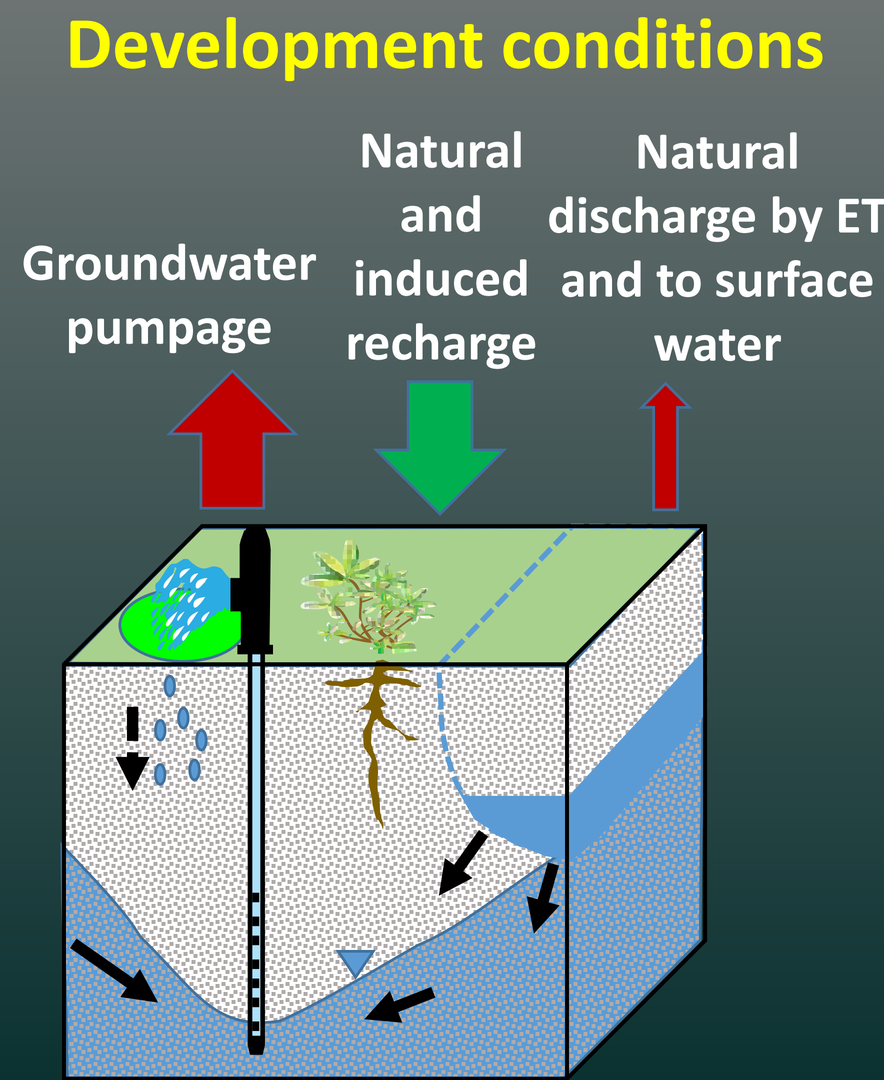


Development conditions



Groundwater Storage Depletion





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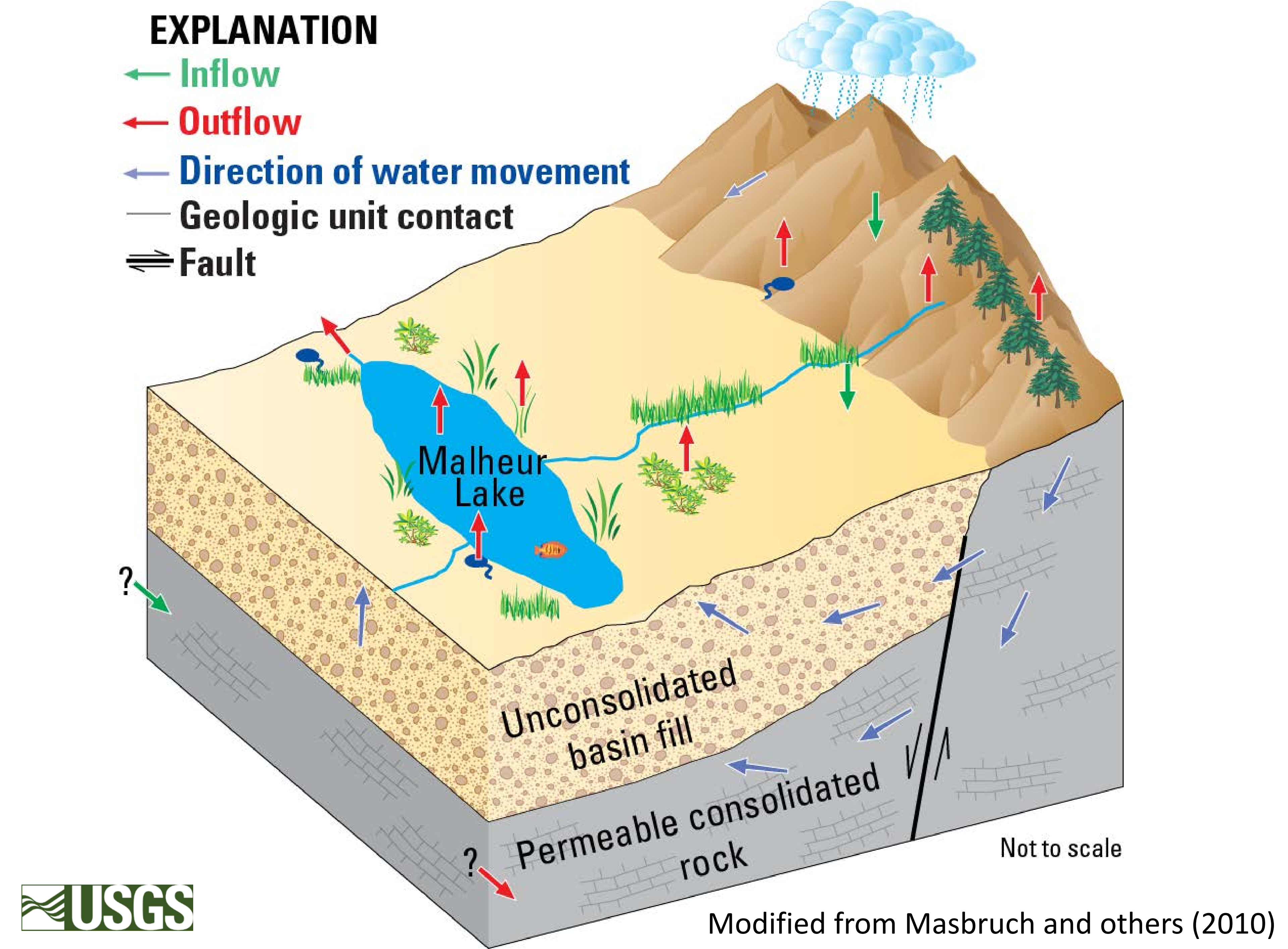
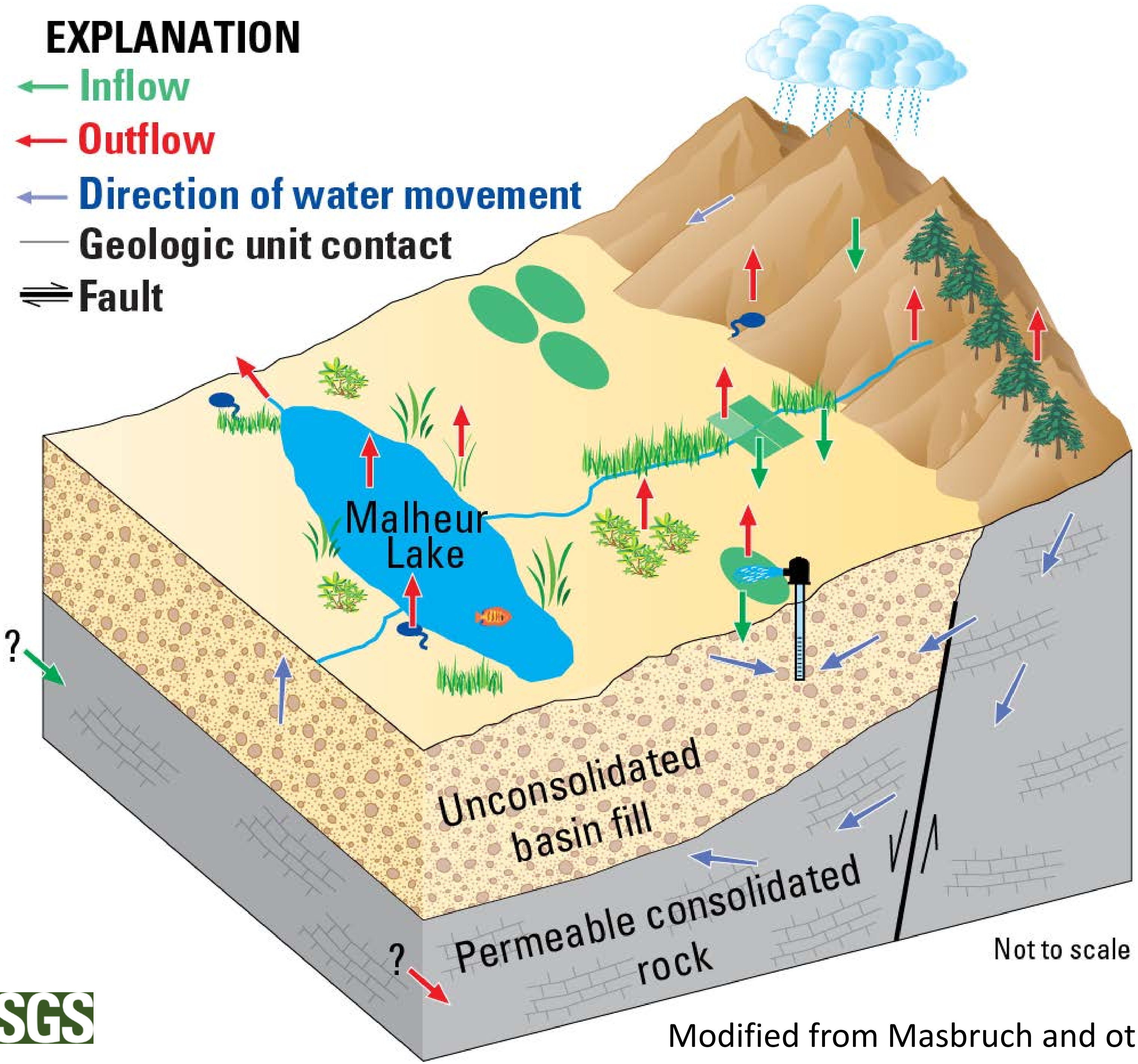


Modified from Masbruch and others (2010)



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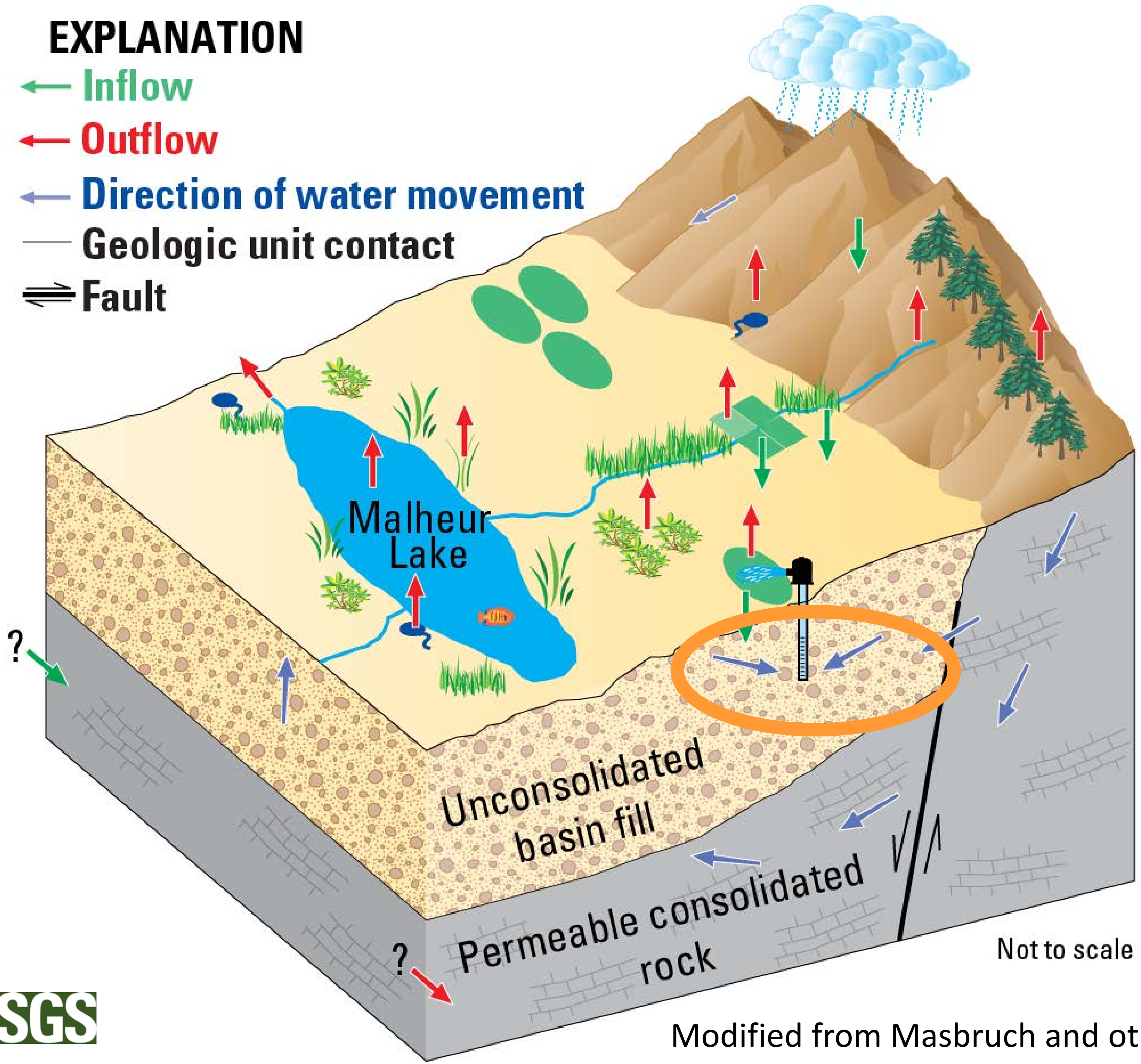

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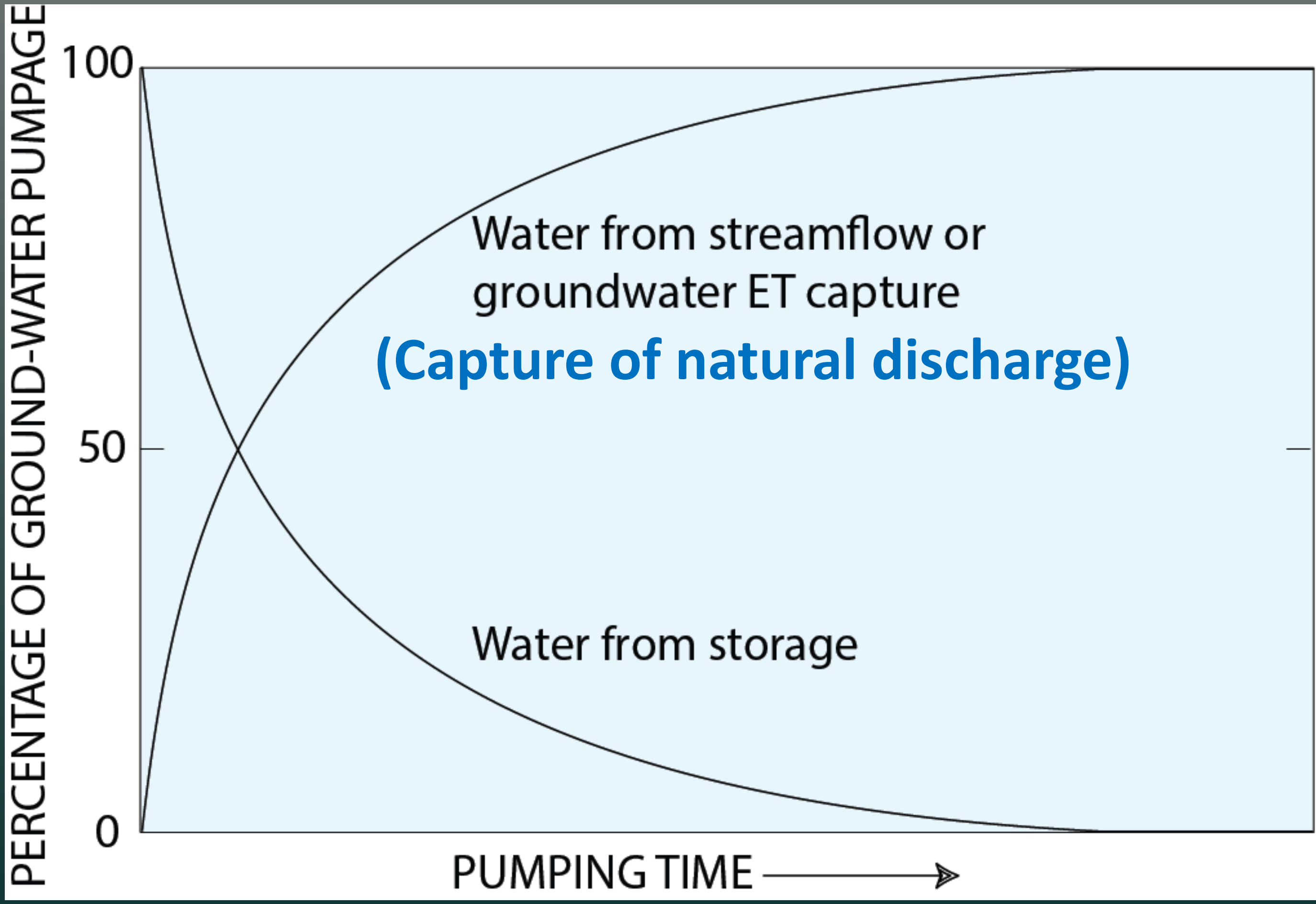
Source of Water to a Well

- Water source is either
- 1) capture of discharge or
- 2) storage depletion
- Source contribution varies in time and space

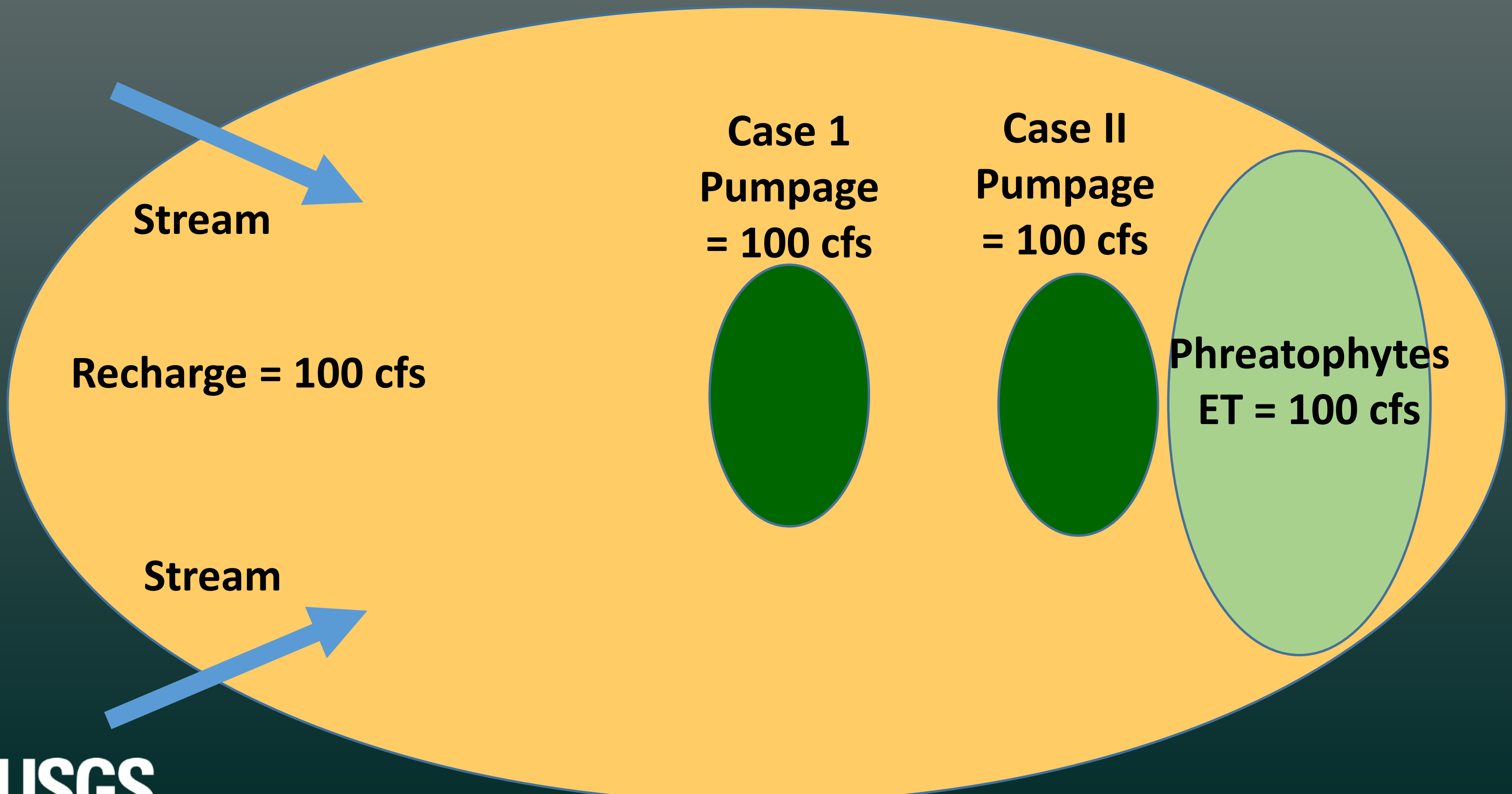


Alley and others (1999)

Hypothetical Model

From Bredehoeft and others (2009)

- Evaluate system response to pumping and time to reach a new equilibrium
- Pumped groundwater comes from aquifer storage (water-level declines), capture of natural discharge by phreatophyte ET, or a combination of the two



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Hypothetical Model

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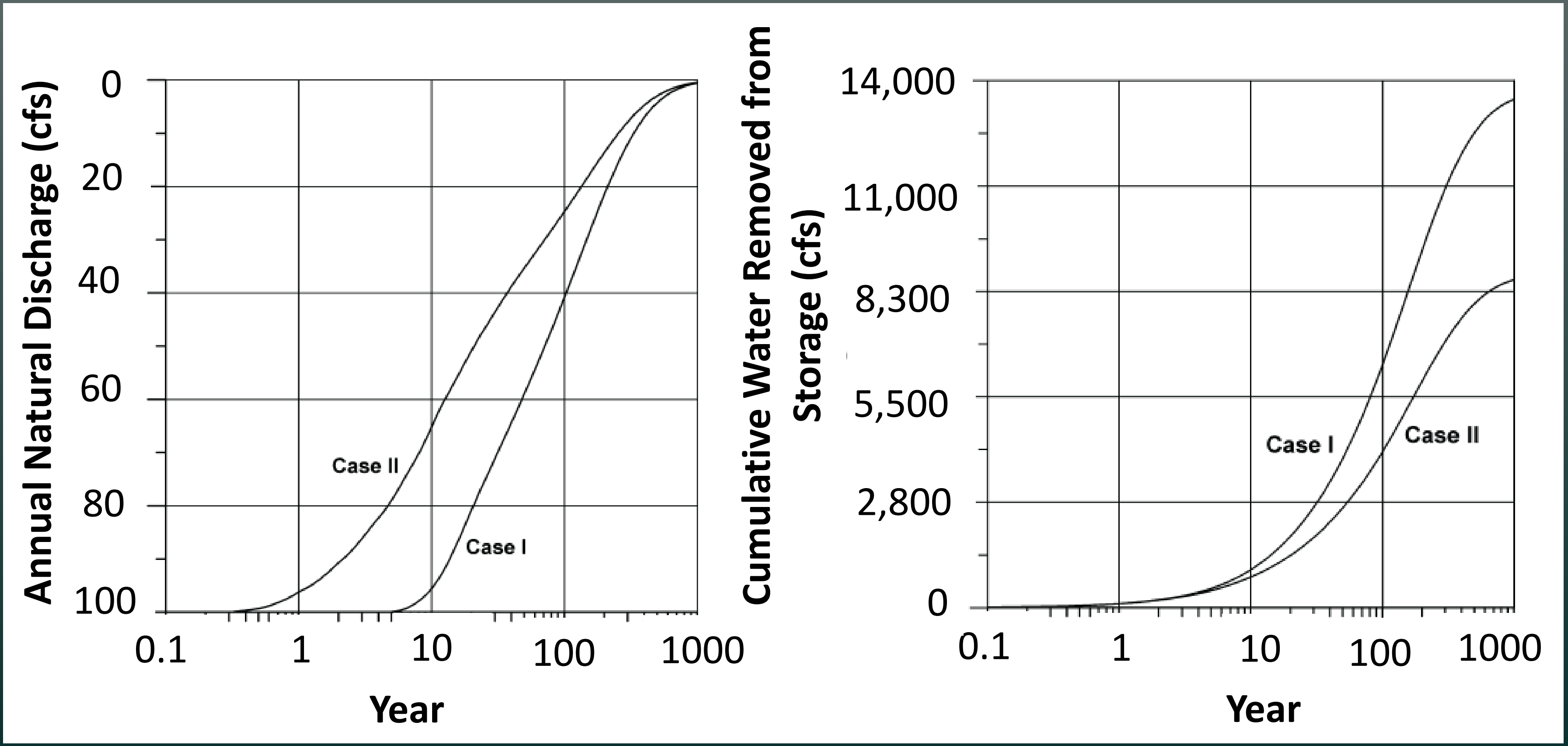

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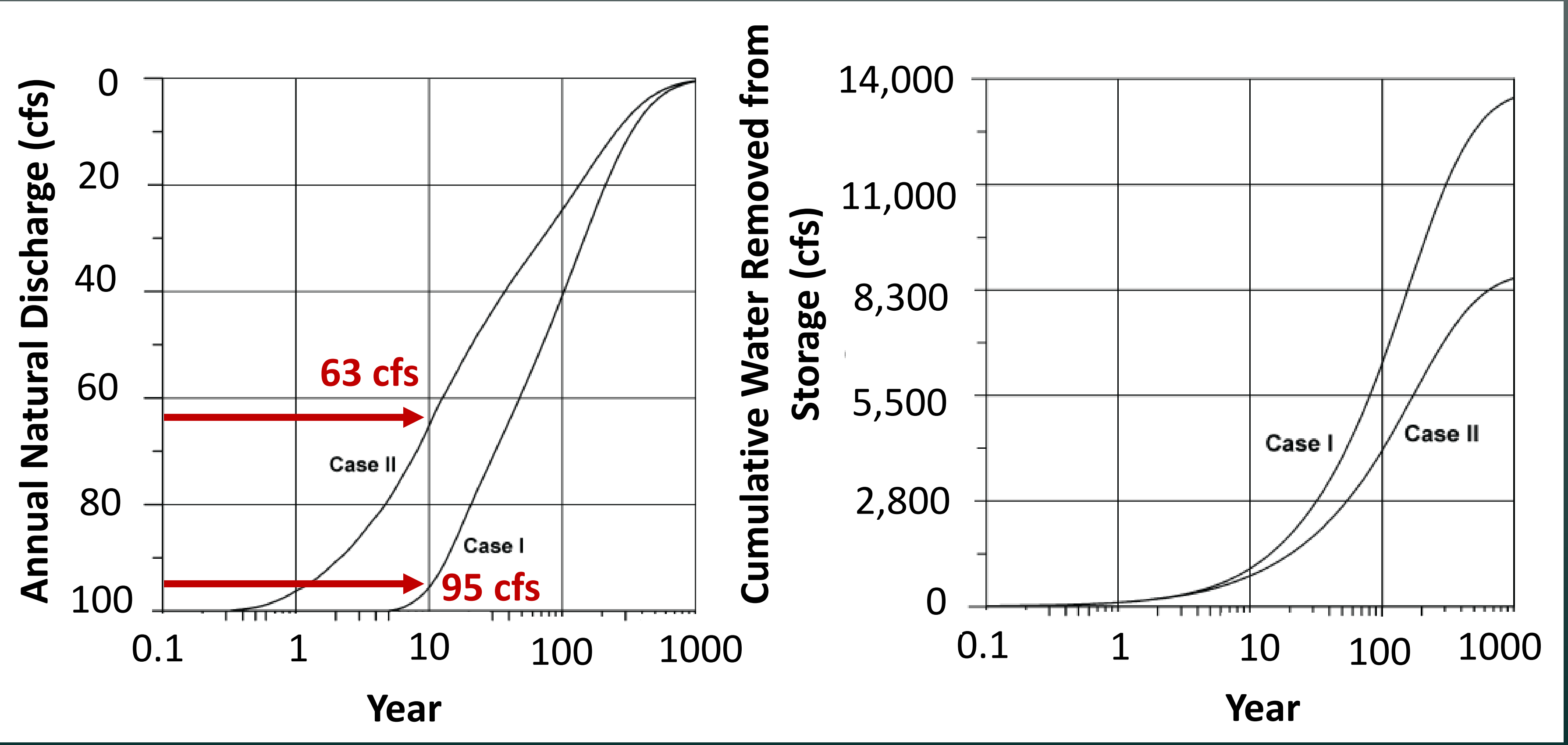
Hypothetical Model

From Bredehoeft and others (2009)

- **After 10 years pumpage totals 1,000 cfs**
  Case I – 2% from capture of discharge, 98% from storage
  Case II – 24% from capture of discharge, 76% from storage

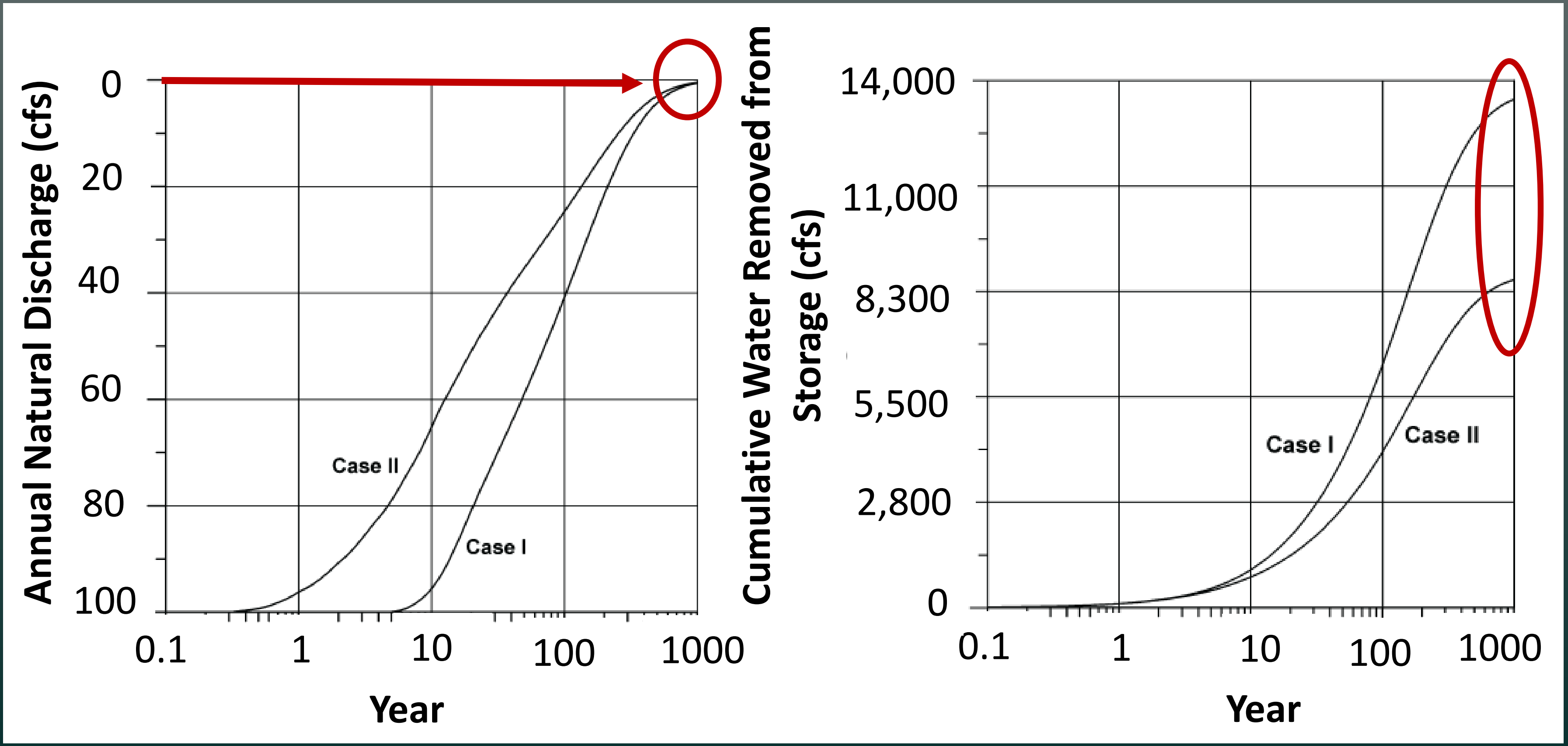


Hypothetical Model

From Bredehoeft and others (2009)

- **1000 years to capture natural discharge of 100 cfs**
- **Amount of water removed from storage for Case I is nearly 2× Case II**

  → **Case I requires larger cone of depression to capture natural discharge**



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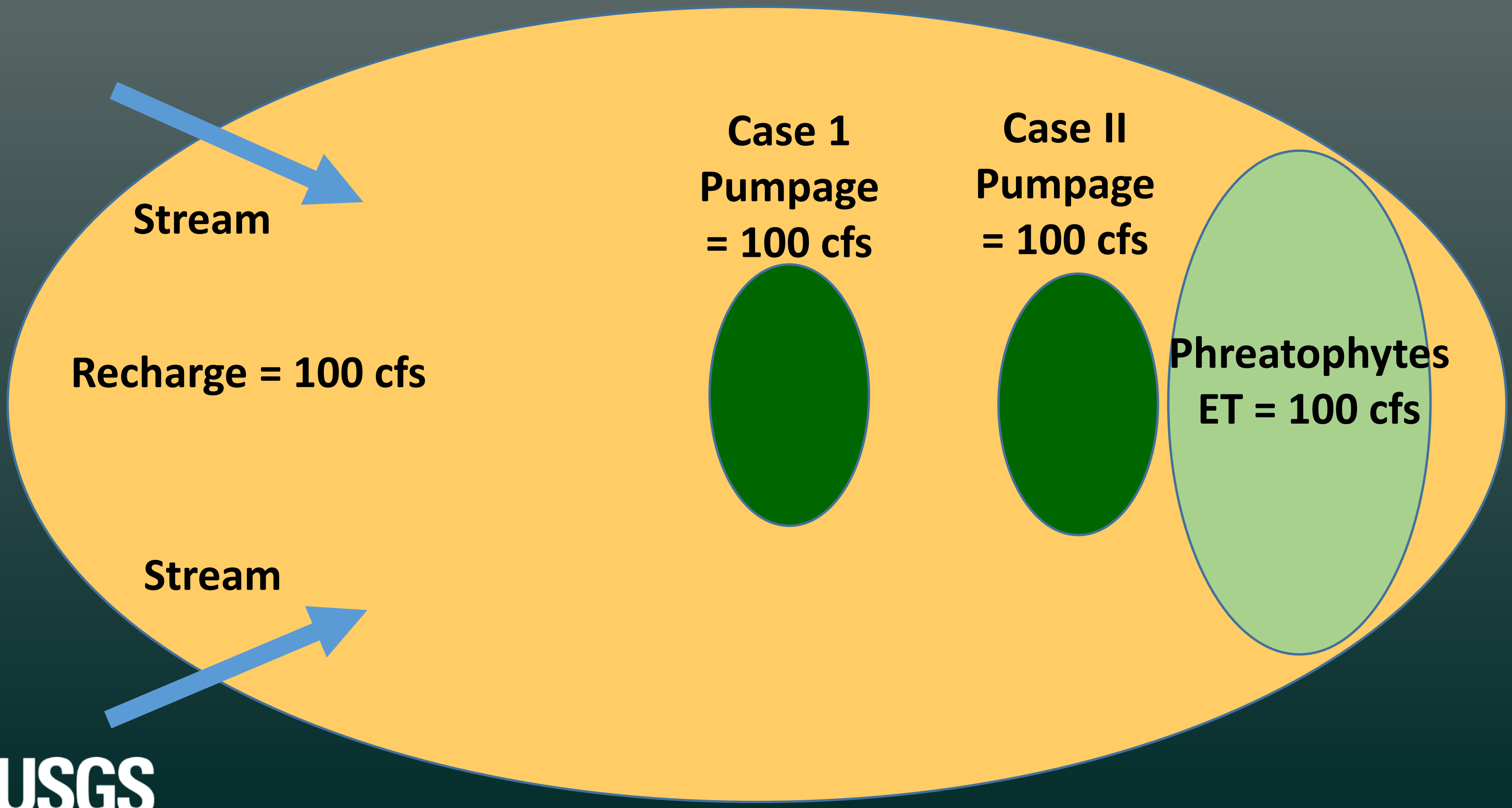

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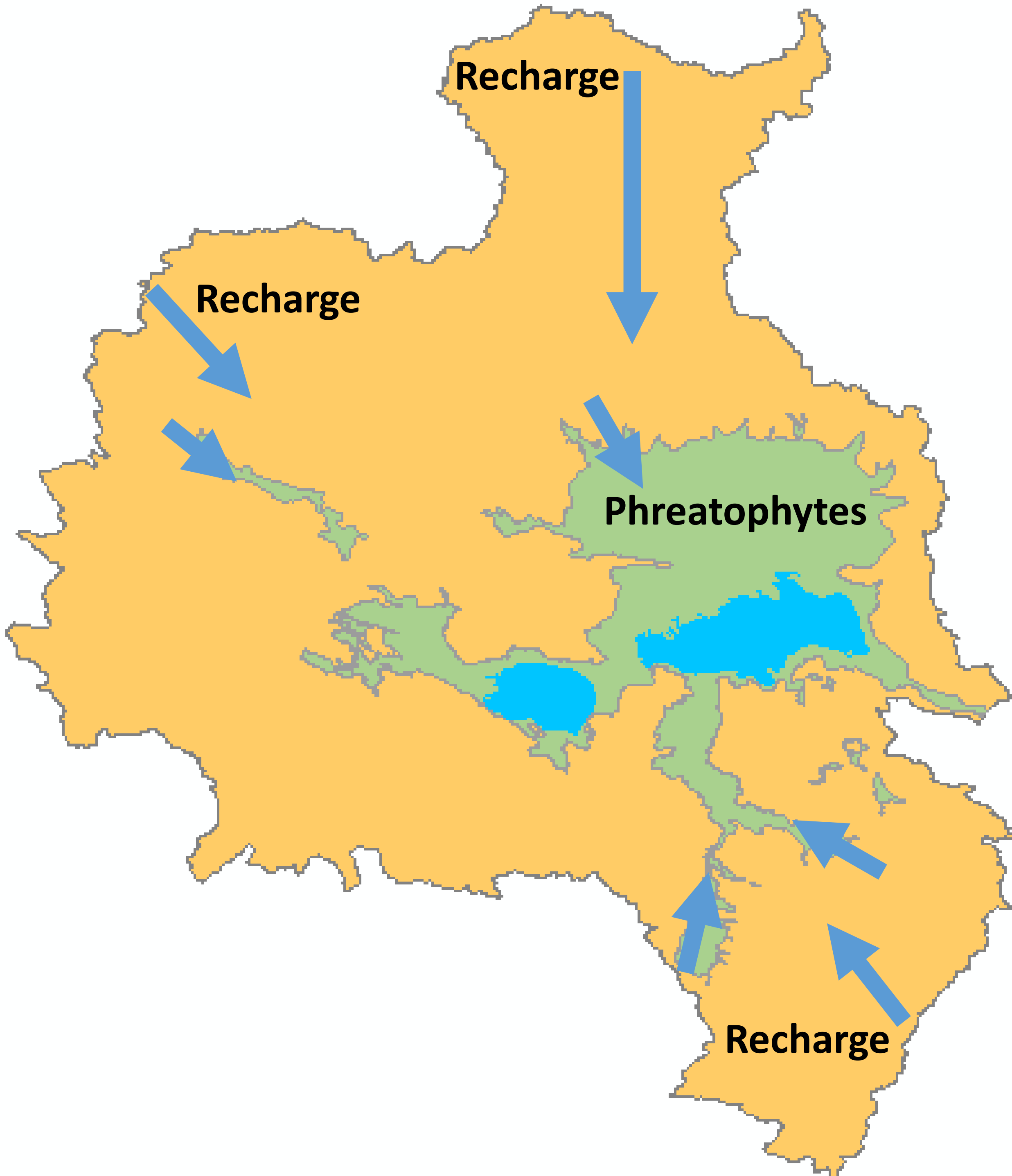
Harney Basin



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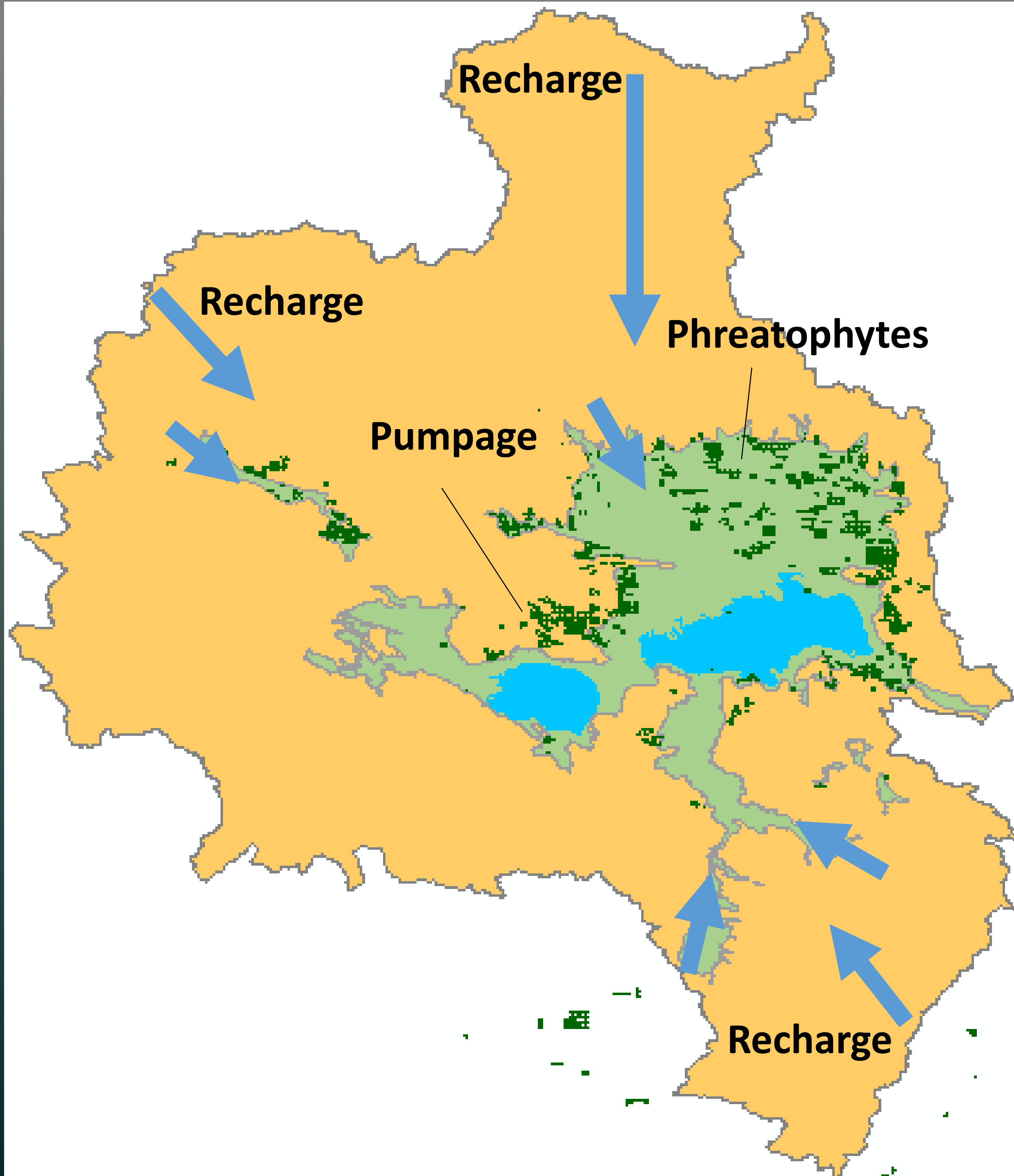
Harney Basin

- Pumpage inside and outside of phreatophyte area



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Harney Basin

- Pumpage inside and outside of phreatophyte area
- Largest groundwater declines observed near pumpage

➔ Pumpage removing water from storage

➔ Groundwater declines could decouple groundwater and phreatophytes, limiting natural discharge

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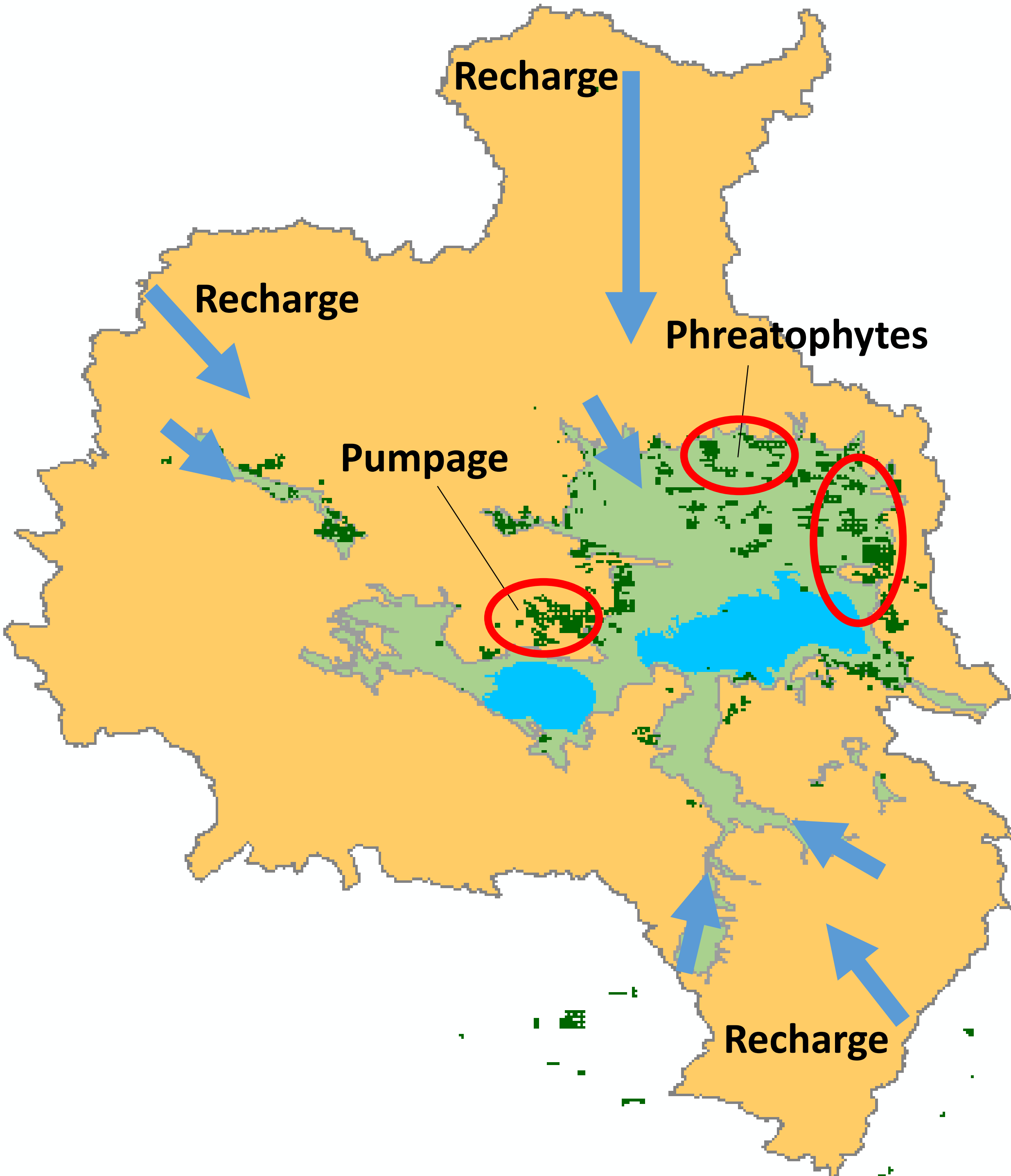

So What?

- In Harney County, aquifer storage depletion could
  - Dry wells
    - Well deepening
    - More energy required to pump water from greater depths
  - Reduced water in streams, lakes, and wetlands
  - Land subsidence
- Travel time between recharge and discharge areas likely >100 years

→ Time to reach a new equilibrium much longer than 100 years

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How Do We Estimate Aquifer Storage Change?

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Estimating Aquifer Storage Change in Harney Basin

1) Groundwater levels

- Groundwater levels reflect stored volume of water
- Net change in water levels reflects the net change in storage

2) Groundwater use

- Storage change reflects groundwater use
- Most groundwater pumpage is used for irrigation
- Net ET = volume of pumpage consumed by ET
- Residual pumpage = groundwater pumpage – net ET
  - Infiltrates and recharges the aquifer
  - Runs off and is consumed by ET downgradient

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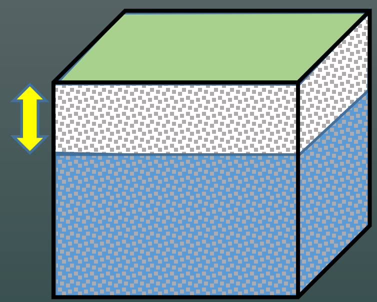
Storage Change from Water-level Declines

- Local change from groundwater trends in wells
- Regional change from water-level maps

Storage change = **Change in Saturated volume**  × **Storage coefficient**

- Change in saturated volume from differencing water-level maps
- Storage coefficient
  - Represents fillable pores in the aquifer material
  - Estimated from literature / aquifer tests

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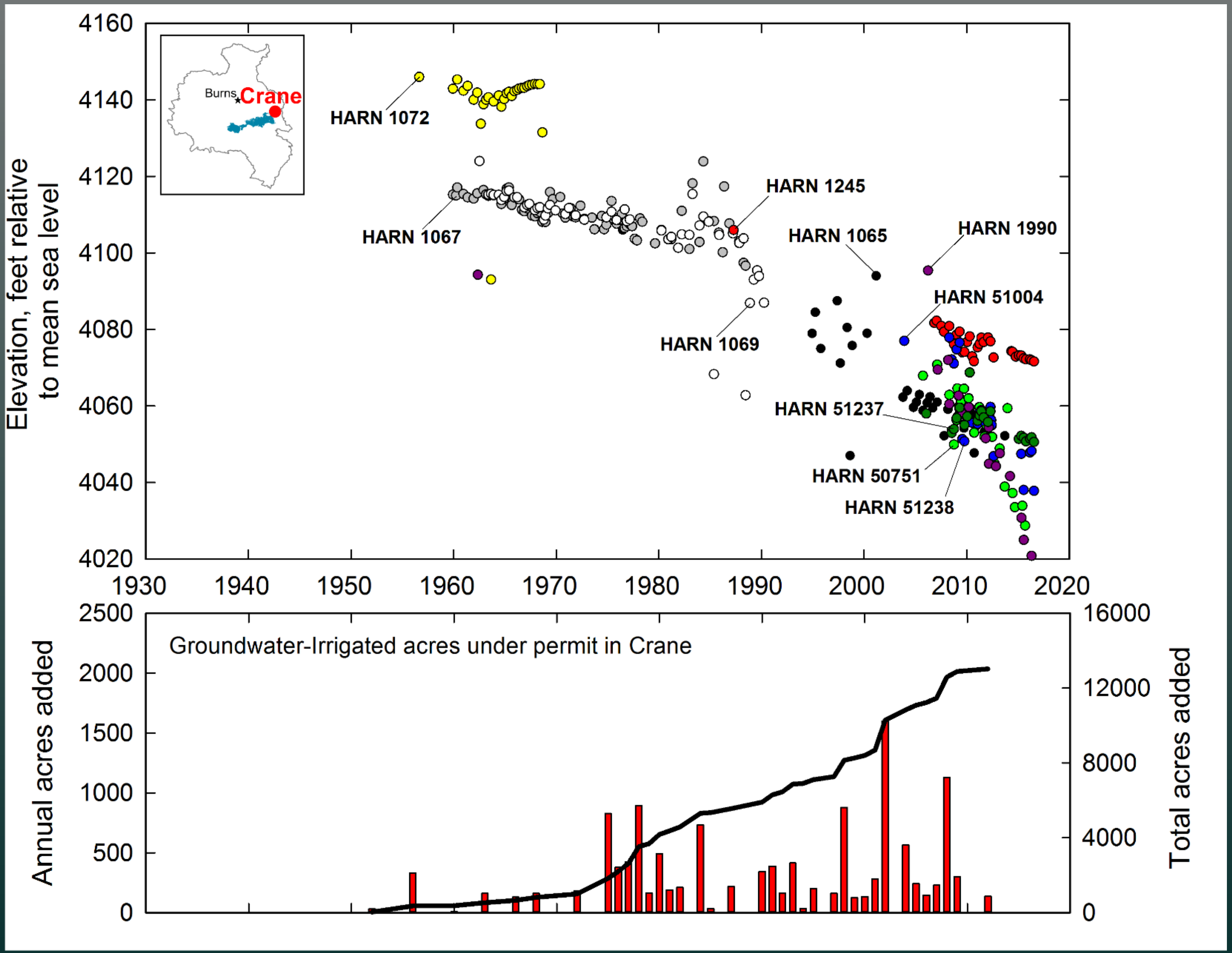
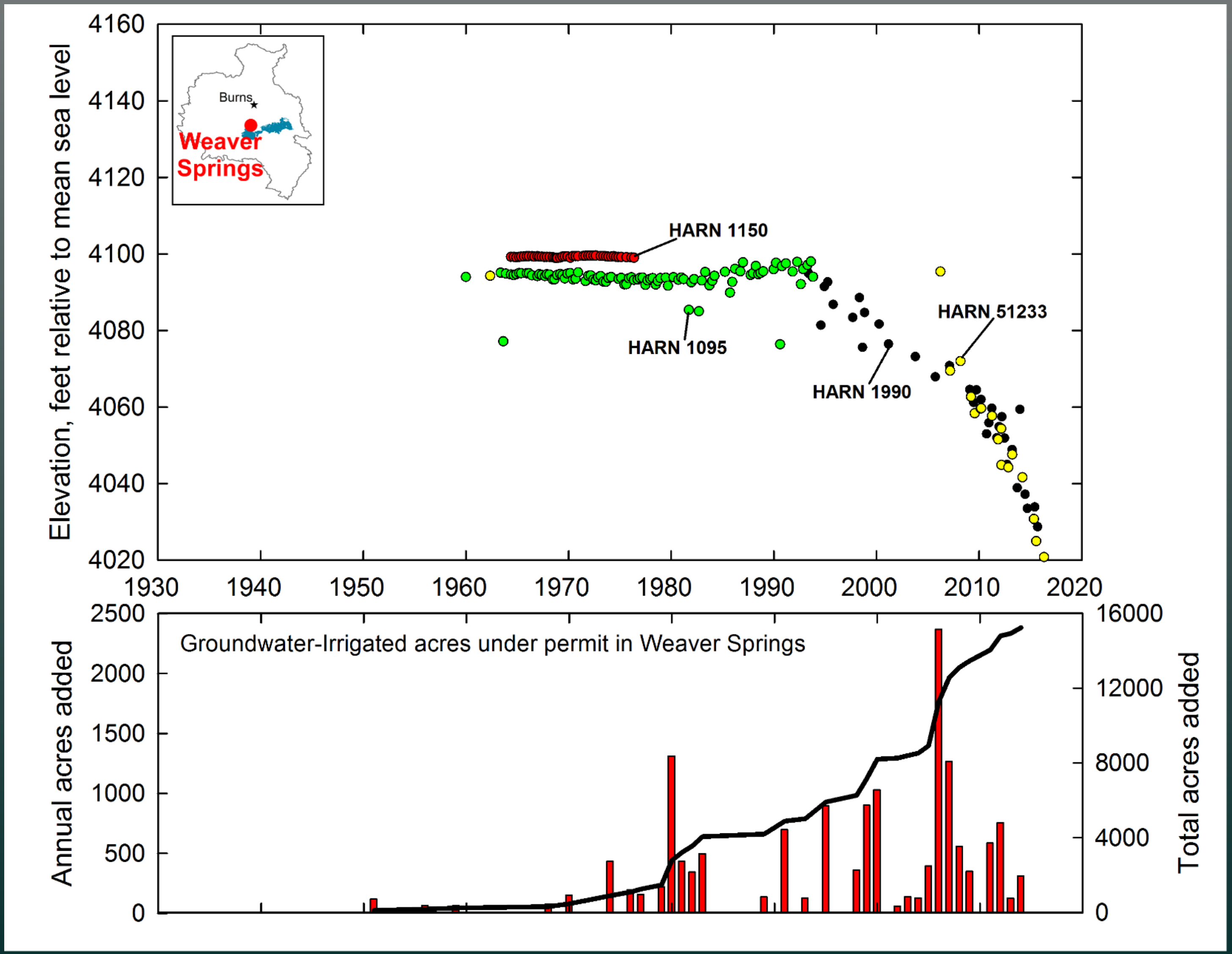
Local Change from Water-level Trends



Oregon Water Resources Department Groundwater Database (2017)

Local Change from Water-level Trends



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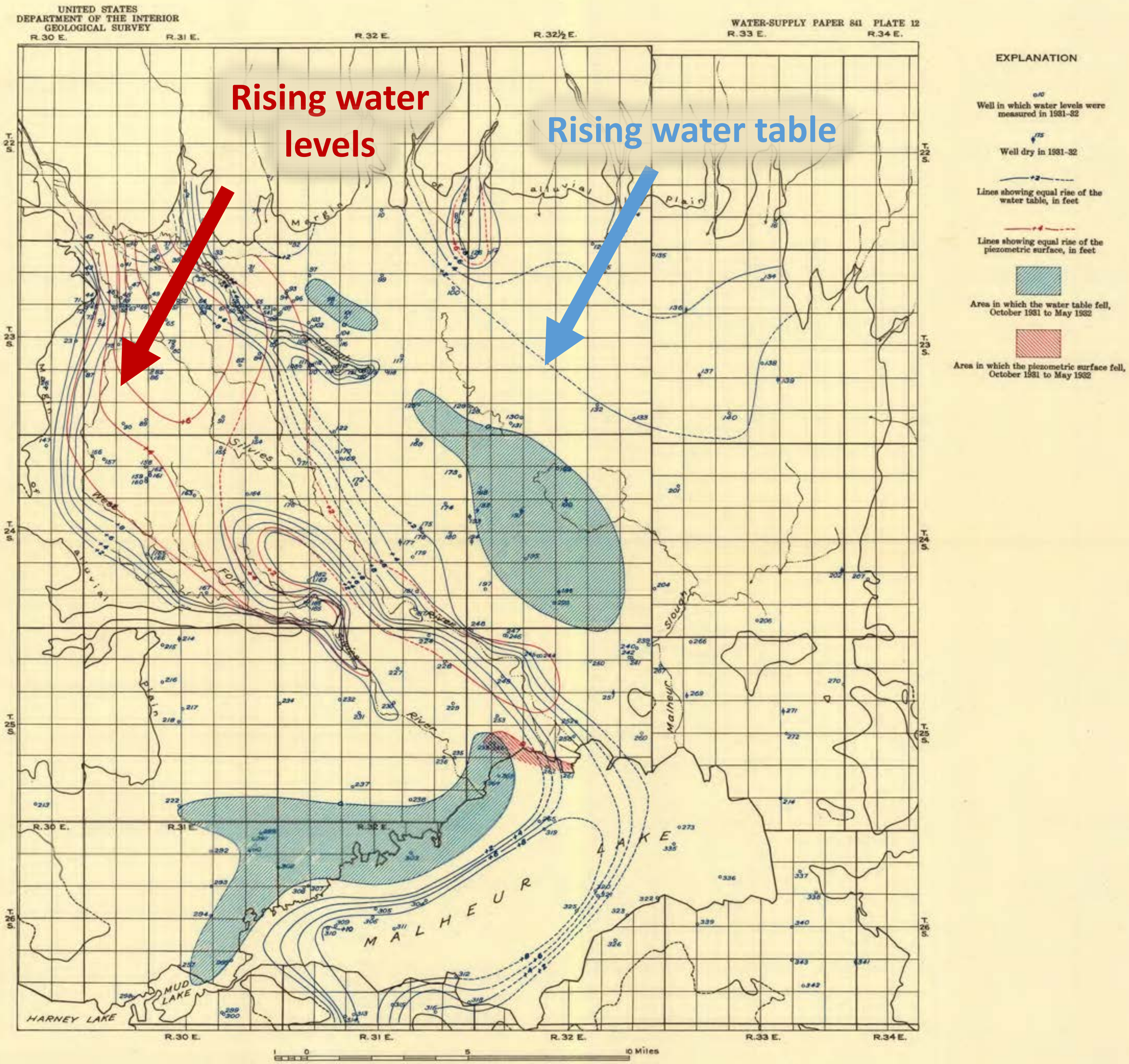
Oregon Water Resources Department Groundwater Database (2017)

Water-level Change Map

Oct. 1931 – May 1932

Piper and others (1932)

- Silvies basin
- Mostly rising water table
- Change in saturated volume = 485,000 acre-ft
- Storage coeff = 13%
- Storage increase = +61,000 acre-ft



MAP SHOWING APPROXIMATE CHANGE IN GROUND-WATER LEVELS IN THE CENTRAL PART OF THE HARNEY BASIN, OREGON, FROM OCTOBER 1931 TO MAY 1932

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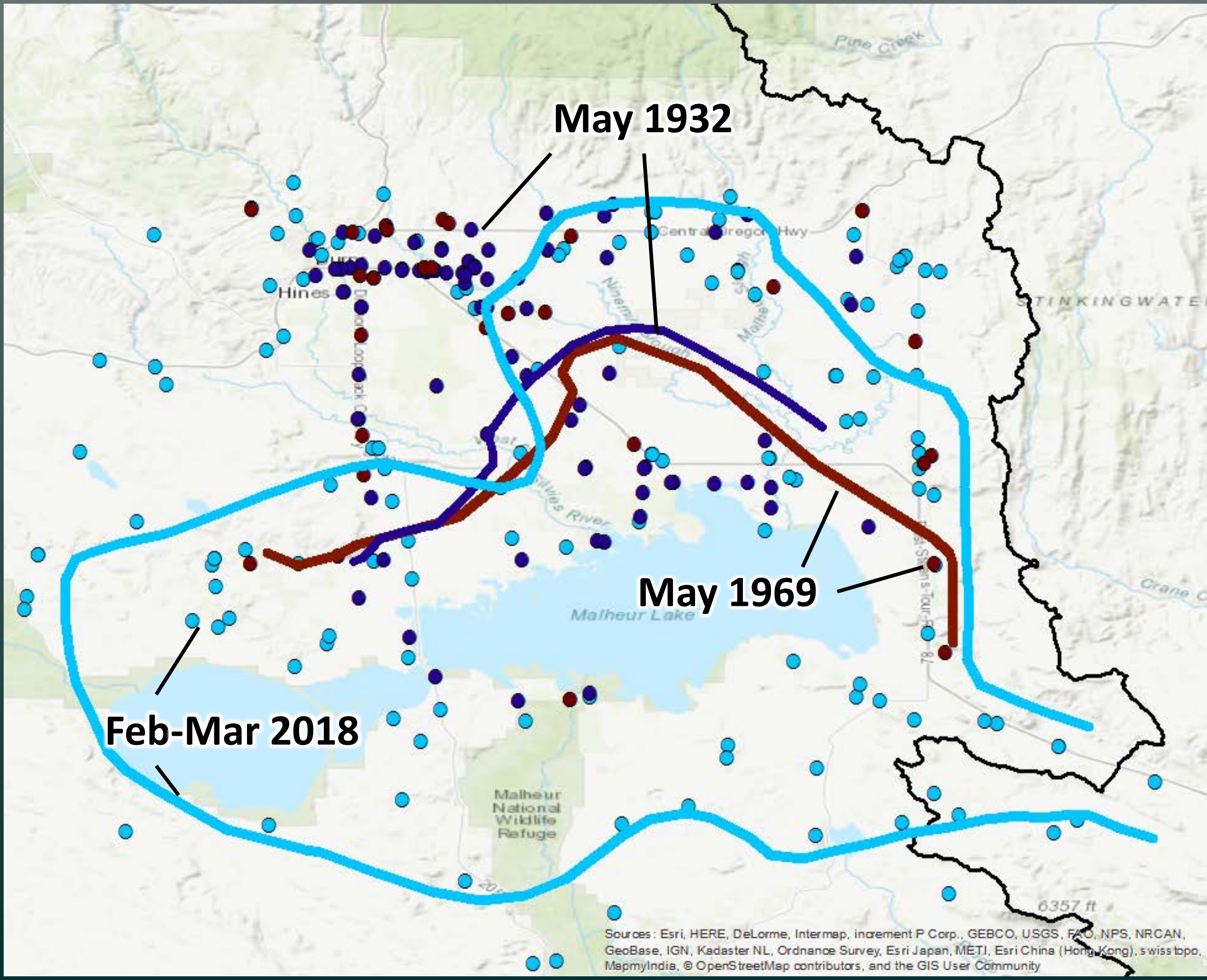
Preliminary Water-level Change Map (1932/1969 – 2018)

- 4100-ft contours
  - 1932 ≈ 1969

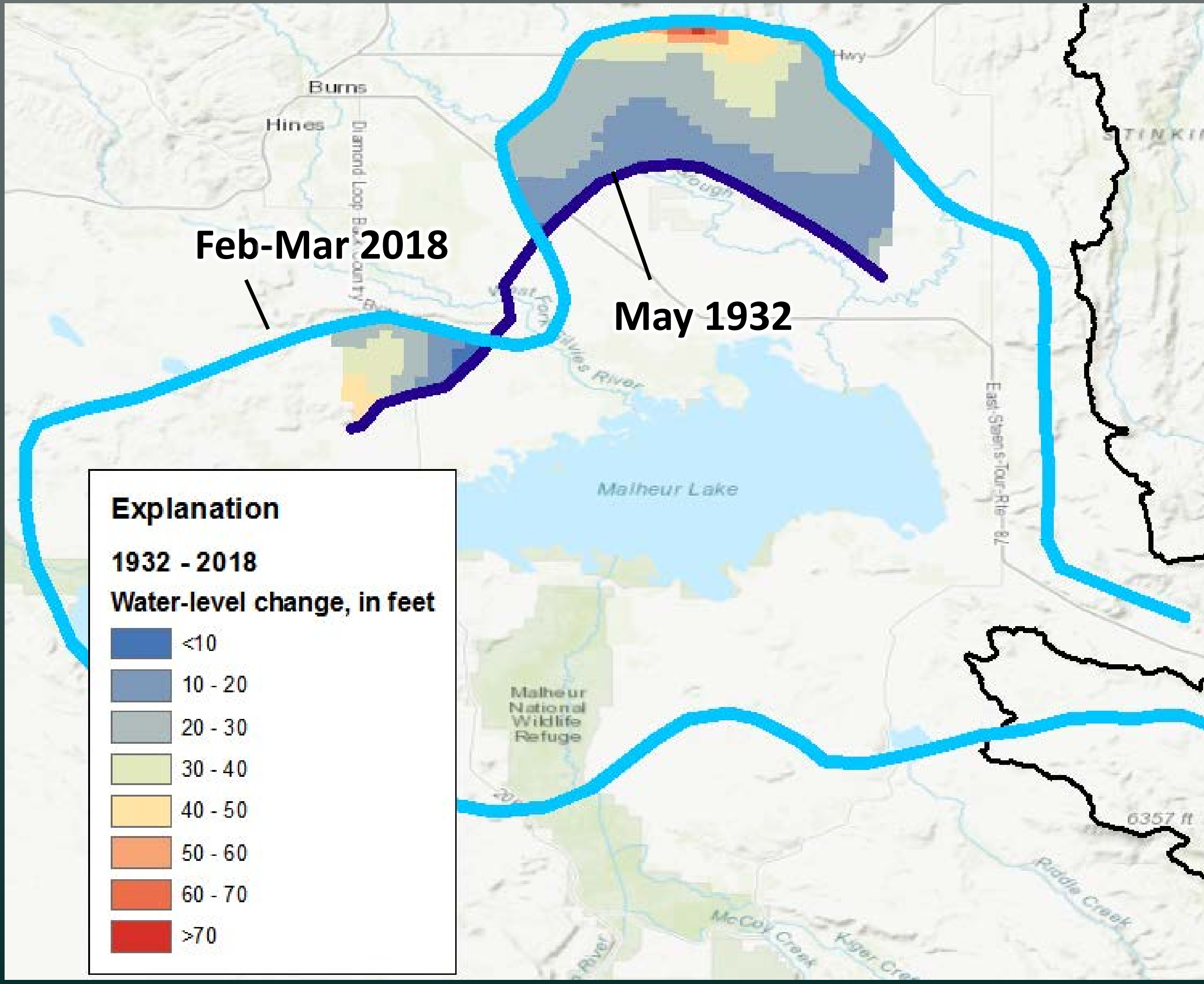


Unpublished data, subject to revision. Do not cite.

Piper and others (1932), Leonard (1970)

Preliminary Water-level Change Map (1932/1969 – 2018)

- 4100-ft contours
  - 1932 ≈ 1969
- Water-level change 0 - >70 ft



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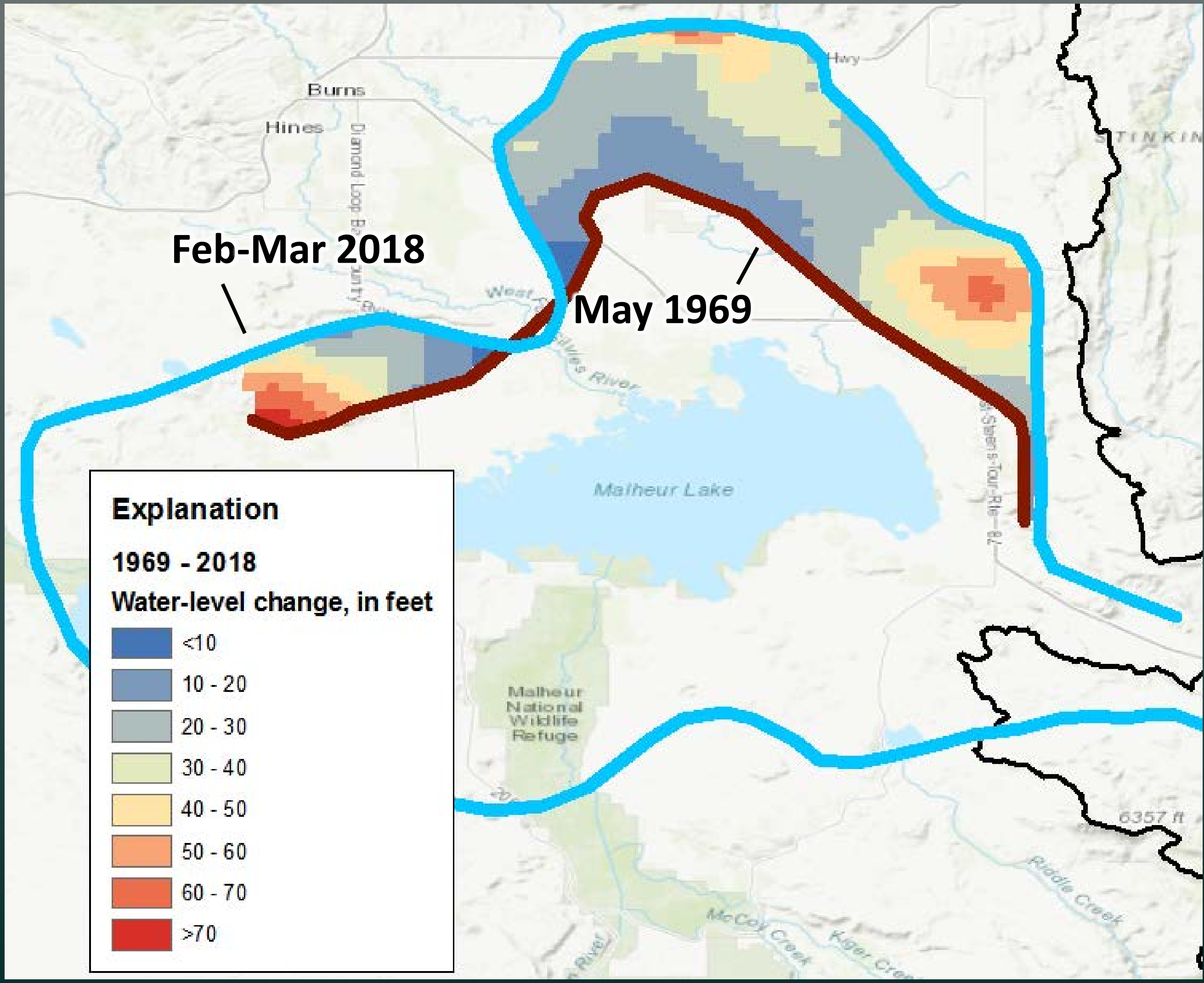
Piper and others (1932)

Preliminary Water-level Change Map (1932/1969 – 2018)

- 4100-ft contours
  - 1932 ≈ 1969
- Water-level change 0 - >70 ft
- Storage coeff = 13%
- Storage change between 4,100-ft contours =
  - 440,000 acre-ft (1969 – 2018)



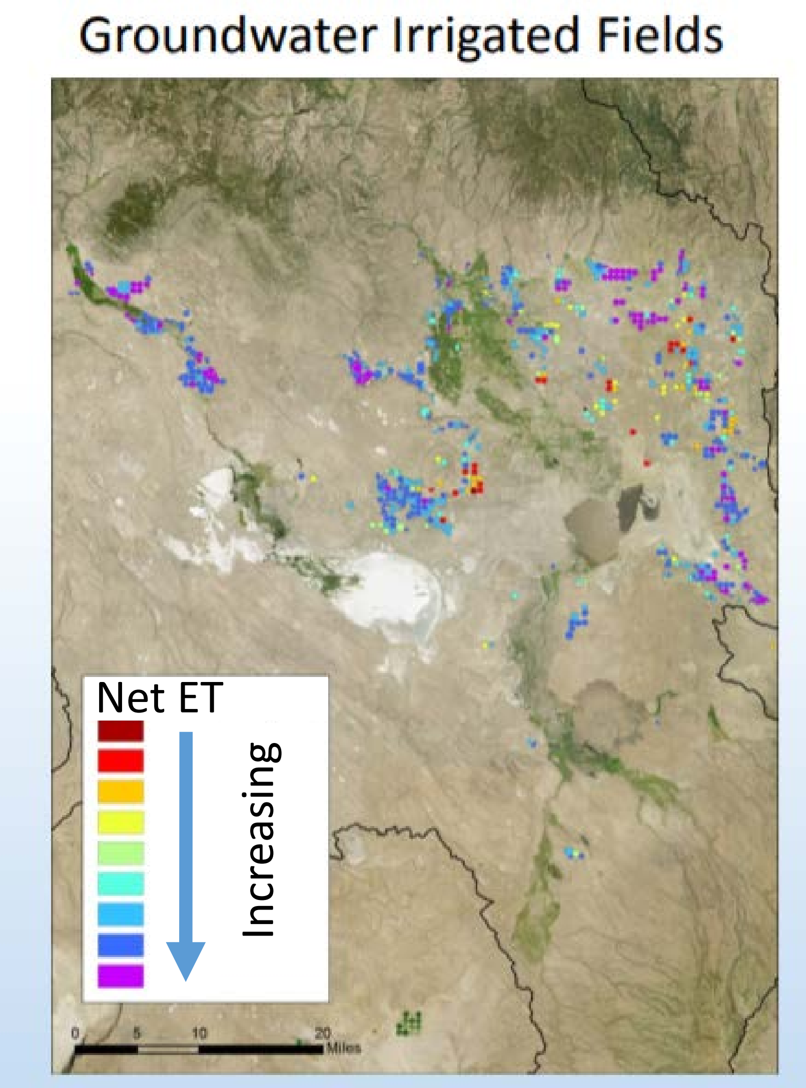
Unpublished data, subject to revision. Do not cite.

Leonard (1970)

Storage Change from Groundwater-Use Estimates

- Irrigated acreage × net ET
  - Map irrigated acreage
  - Net ET from remote sensing (METRIC)

  - Assumes most residual groundwater recharges aquifer
  - Assumes pumpage minimally captures natural ET discharge or induced recharge from irrigation



USGS Unpublished data, subject to revision. Do not cite.

Modified from Beamer (2018, written commun.)

Estimates of Aquifer Storage Change Improved with Numerical Model

- Groundwater-flow model
  - Fit to recharge, discharge, and groundwater levels by spatially adjusting aquifer properties
- More accurately represents spatial variability in
  - Water levels
  - Aquifer properties

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Next Steps for Storage Change

- **Incorporate new MPs into water-level elevations**
- **Contour basin-wide water-levels**
- **Create water-level change maps**
- **Compile aquifer-test data**
- **Refine groundwater-use estimates**

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References

- Alley, W.M., Reilly, T.E., and Franke, O.L., 1999, Sustainability of ground-water resources: U.S. Geological Survey Circular 1186, 79 p.
- Bredehoeft, J., and Durbin, T., 2009, Ground water development – The time to full capture problem: Groundwater, v. 47, no. 4, p. 506-514.
- Leonard, A.R., 1970, Ground-water resources in Harney Valley, Harney County, Oregon, Oregon State Engineer Ground Water Report No. 16, 85 p.
- Masbruch, M.D., Heilweil, V.M., Buto, S.G., Brooks, L.D., Susong, D.D., Flint, A.L., Flint, L.E., and Gardner, P.M., 2011, Chapter D: Estimated groundwater budgets, *in* Heilweil, V.M., and Brooks, L.E., eds., Conceptual model of the Great Basin carbonate and alluvial aquifer system: U.S. Geological Survey Scientific Investigations Report 2010-5193, 191 p. Available online at: https://pubs.usgs.gov/sir/2010/5193/PDF/GreatBasinChapterD.pdf.
- Piper, A.M., Robinson, T.W., and Park, C.F., 1939, Geology and ground-water resources of the Harney Basin, Oregon, U.S. Geological Survey Water-Supply Paper 841, 189 p.