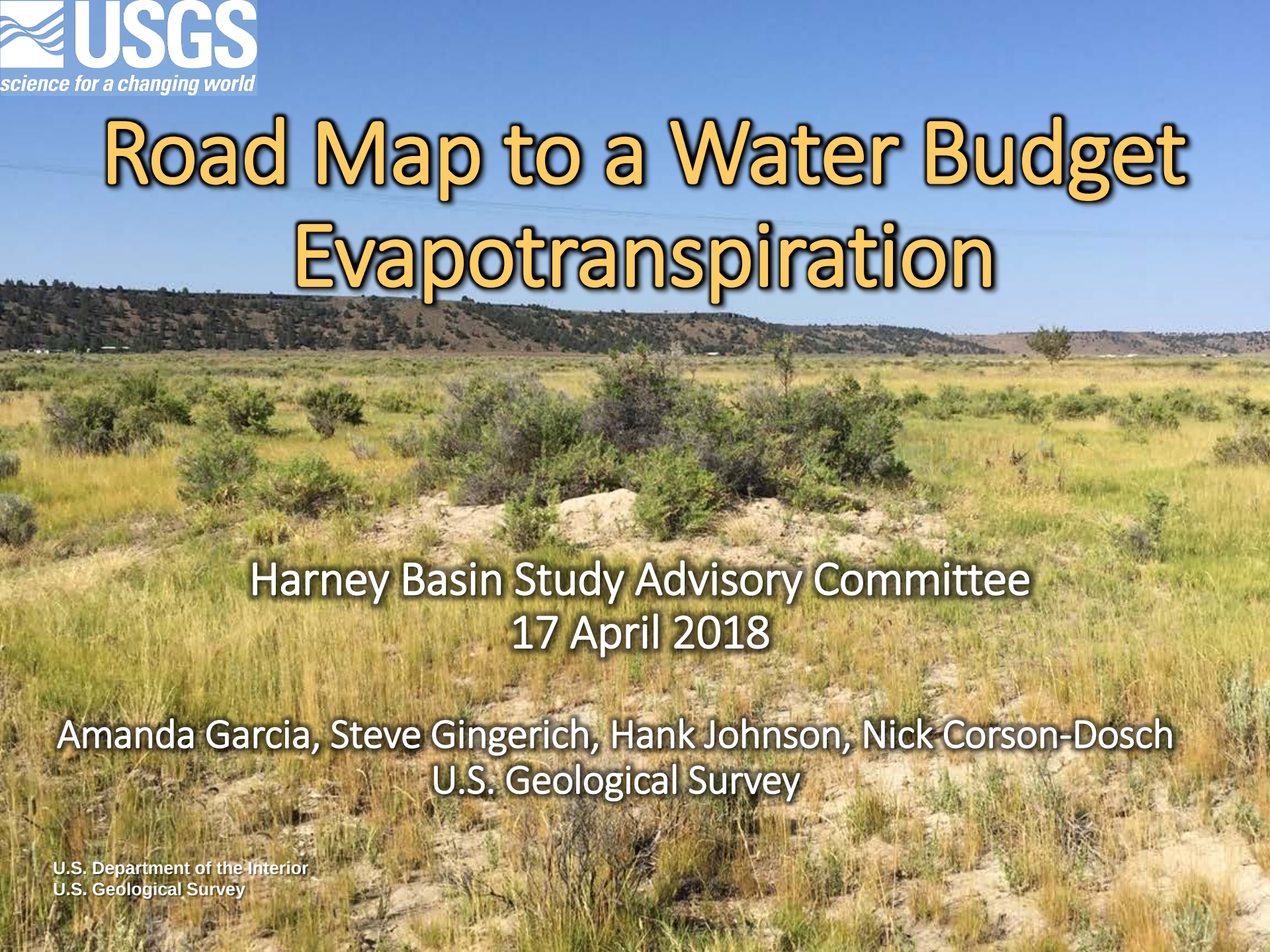


Road Map to a Water Budget
Evapotranspiration

Harney Basin Study Advisory Committee
17 April 2018

Amanda Garcia, Steve Gingerich, Hank Johnson, Nick Corson-Dosch
U.S. Geological Survey

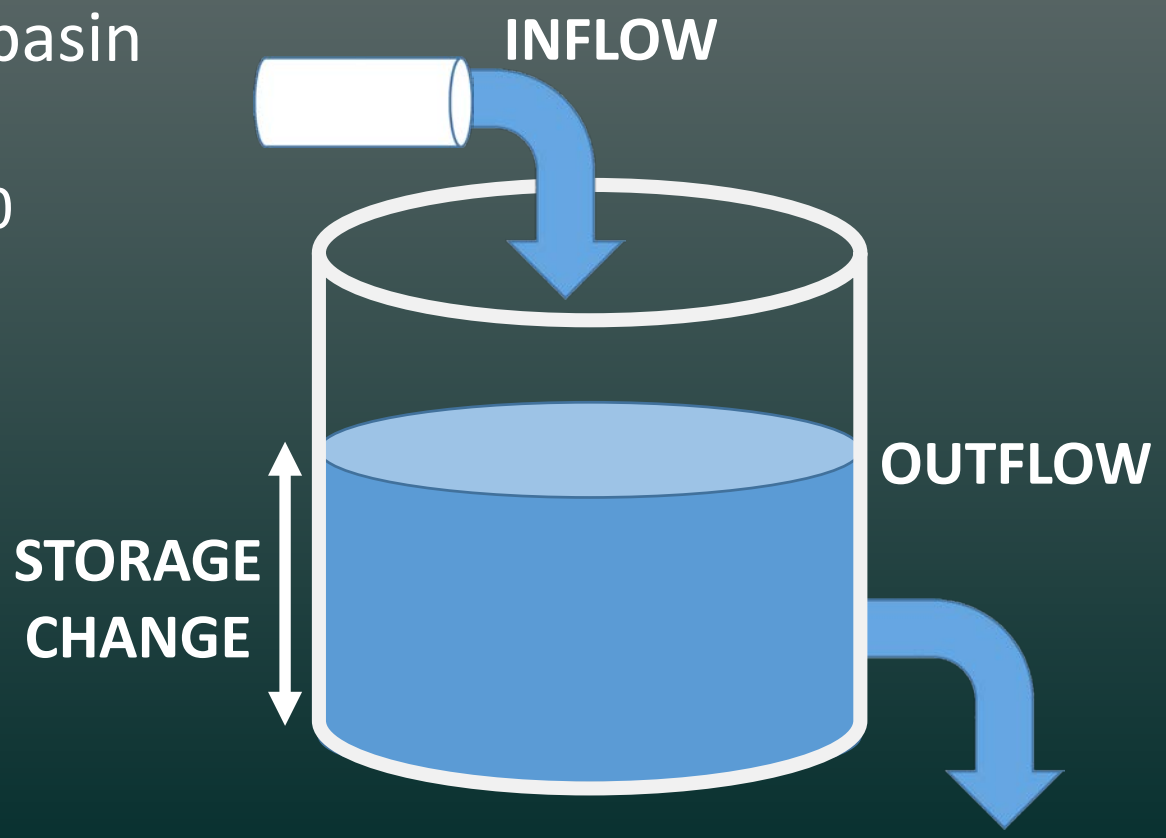
U.S. Department of the Interior
U.S. Geological Survey

Basin Water Budget

↓INFLOW = ↑OUTFLOW ± CHANGE IN STORAGE

Steady-state closed basin

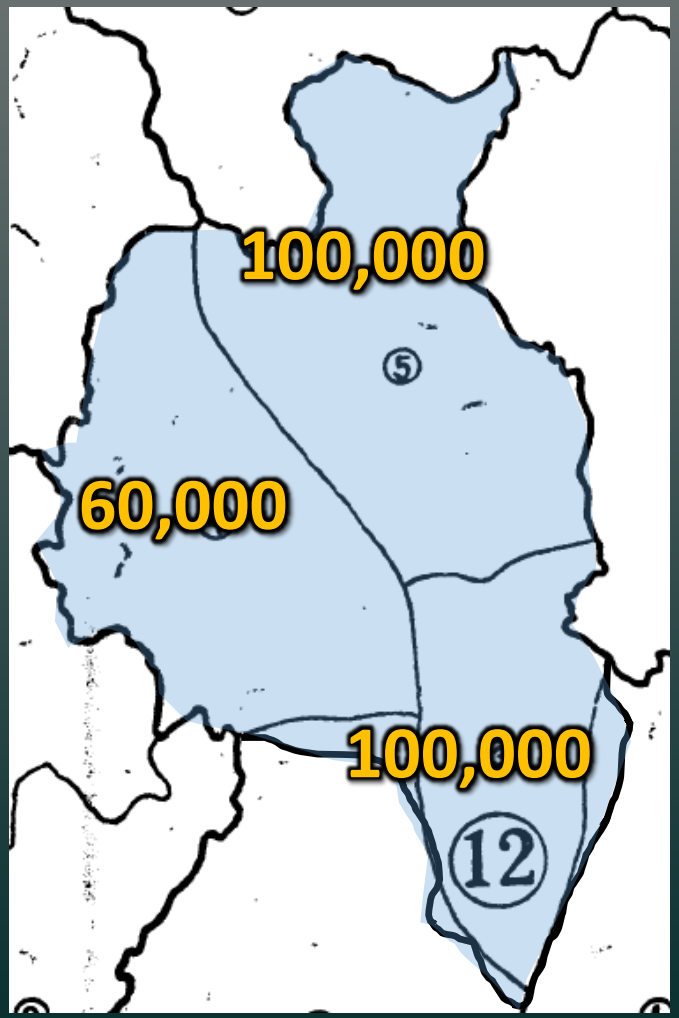
- Inflow = Outflow
- Storage change = 0
  (no water-level decline)



USGS

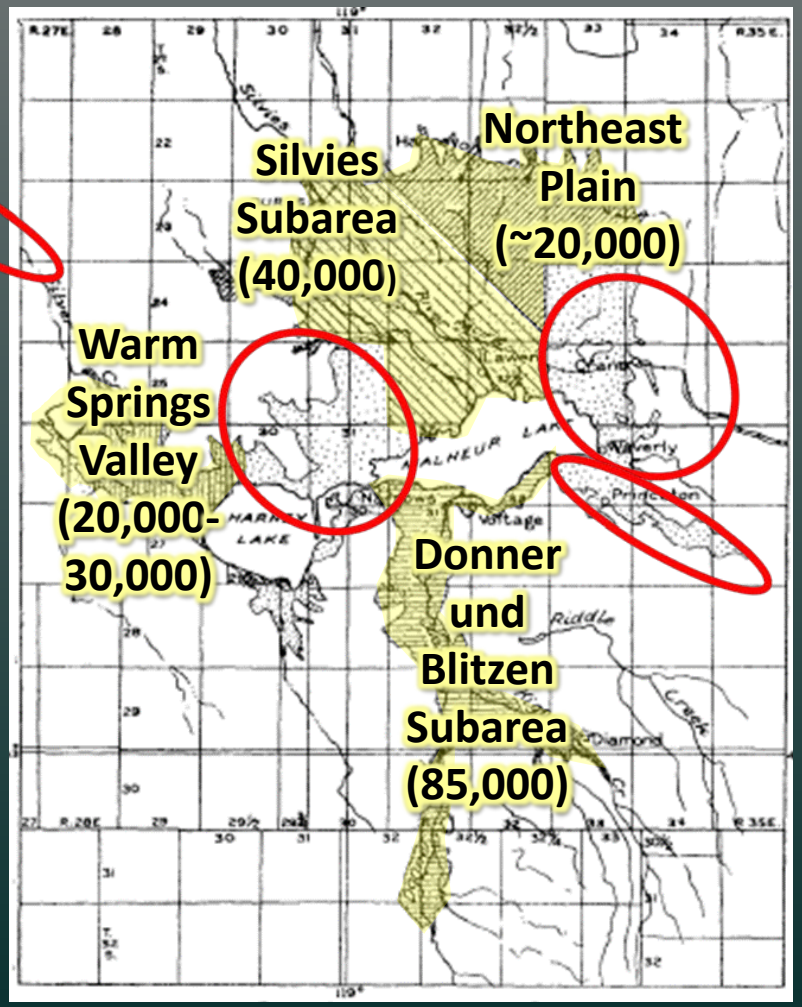
Previous Water-Budget Estimates

RECHARGE = 260,000 AF/Y



Robison (1968)

DISCHARGE ≈ 170,000 AF/Y



Piper and others (1939)

USGS

Water Budget Road Map

USGS

Image source: openclipart.org

Water Budget Road Map

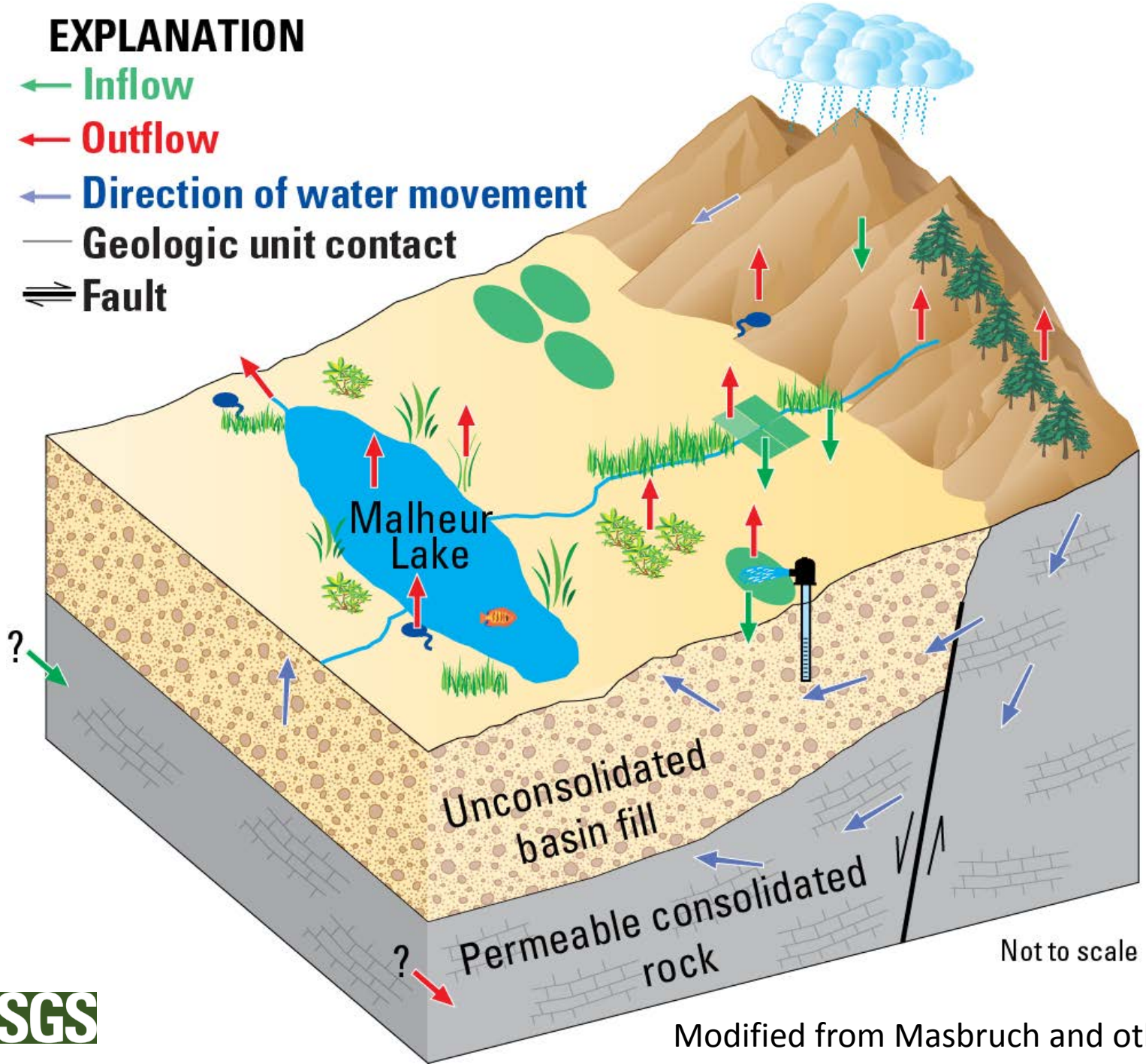
USGS

Image source: openclipart.org

Water Budget Road Map

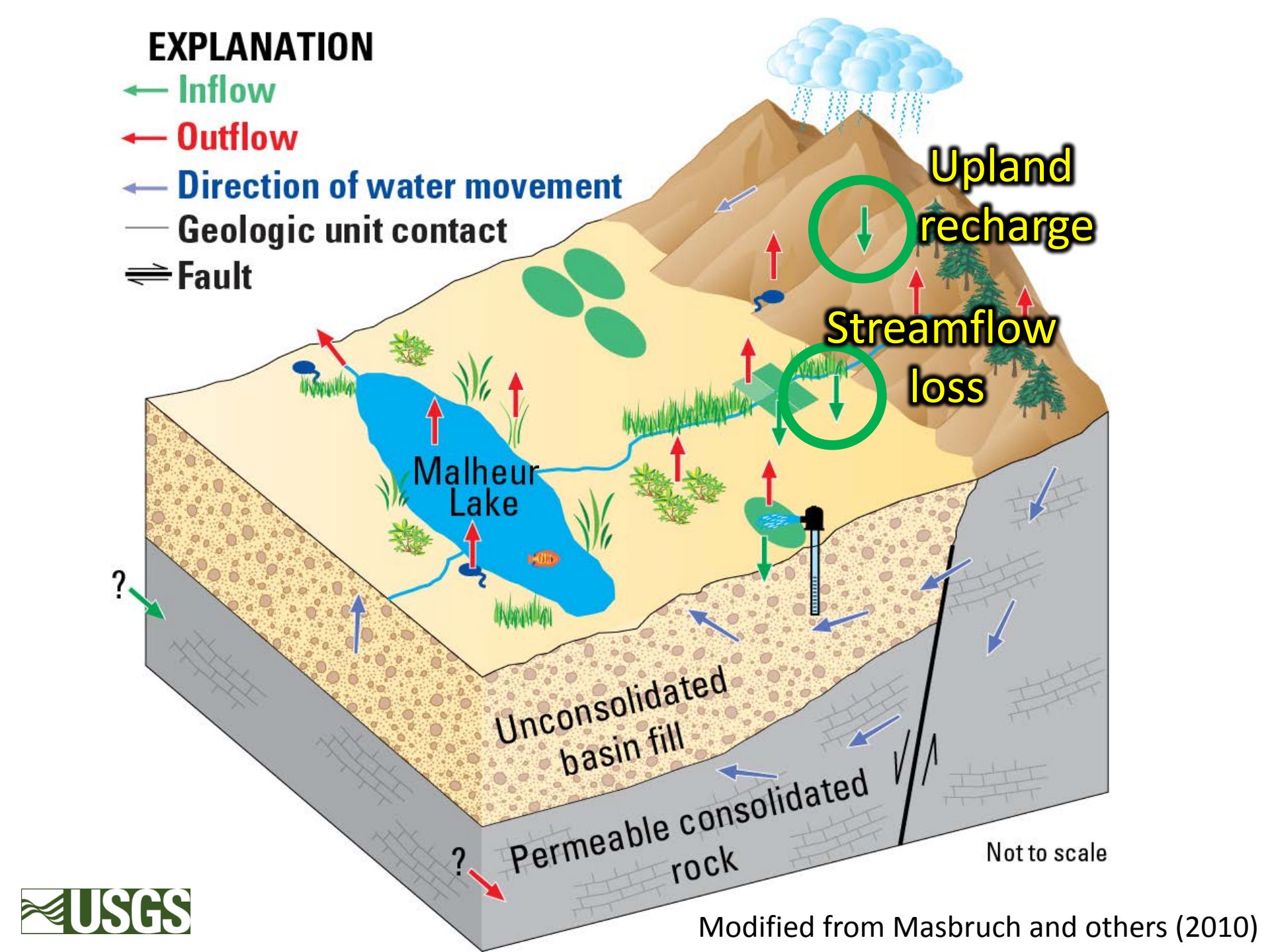
USGS

Image source: openclipart.org



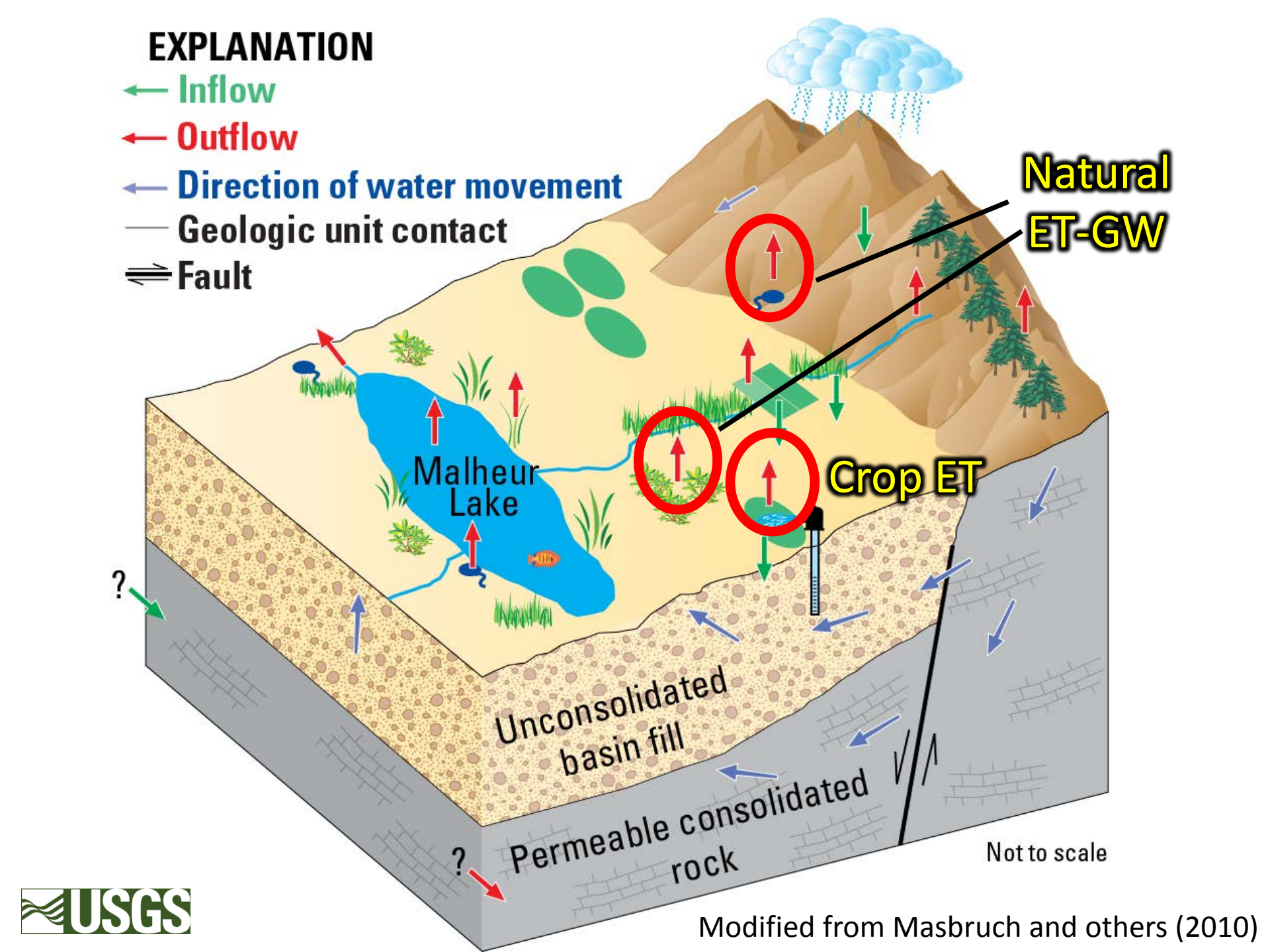
USGS

Modified from Masbruch and others (2010)



USGS

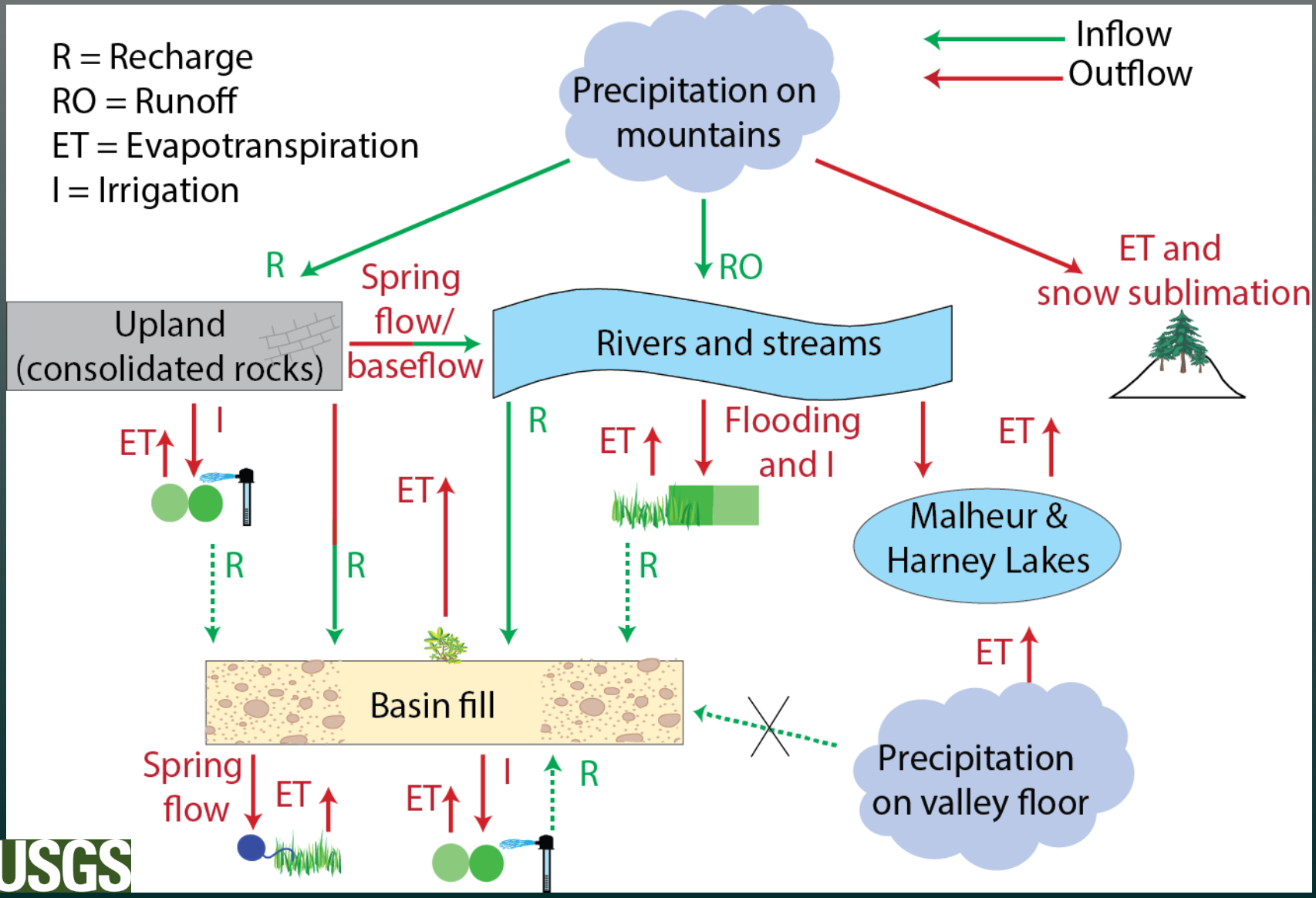
Modified from Masbruch and others (2010)



USGS

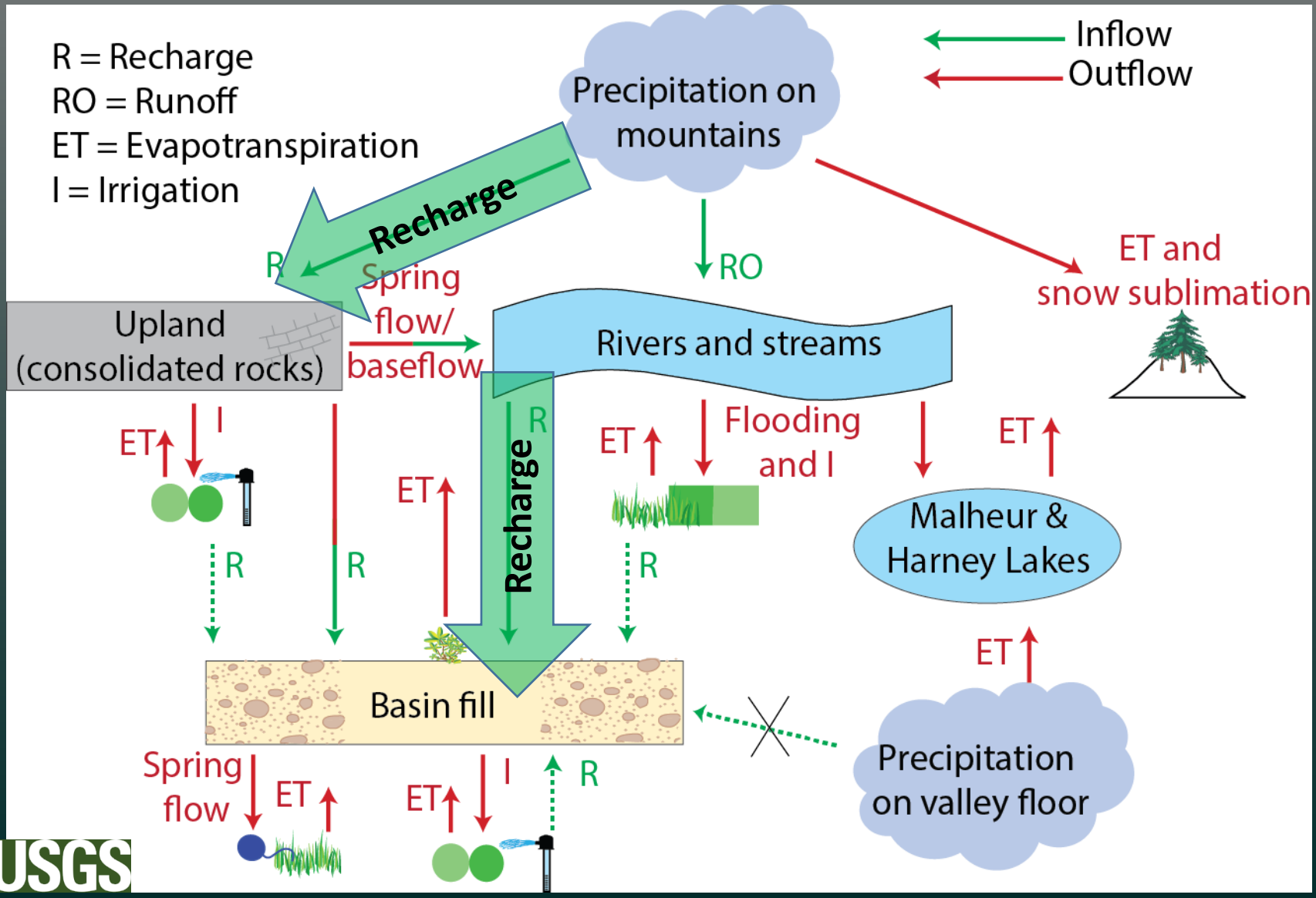
Modified from Masbruch and others (2010)

Harney Basin Water Budget



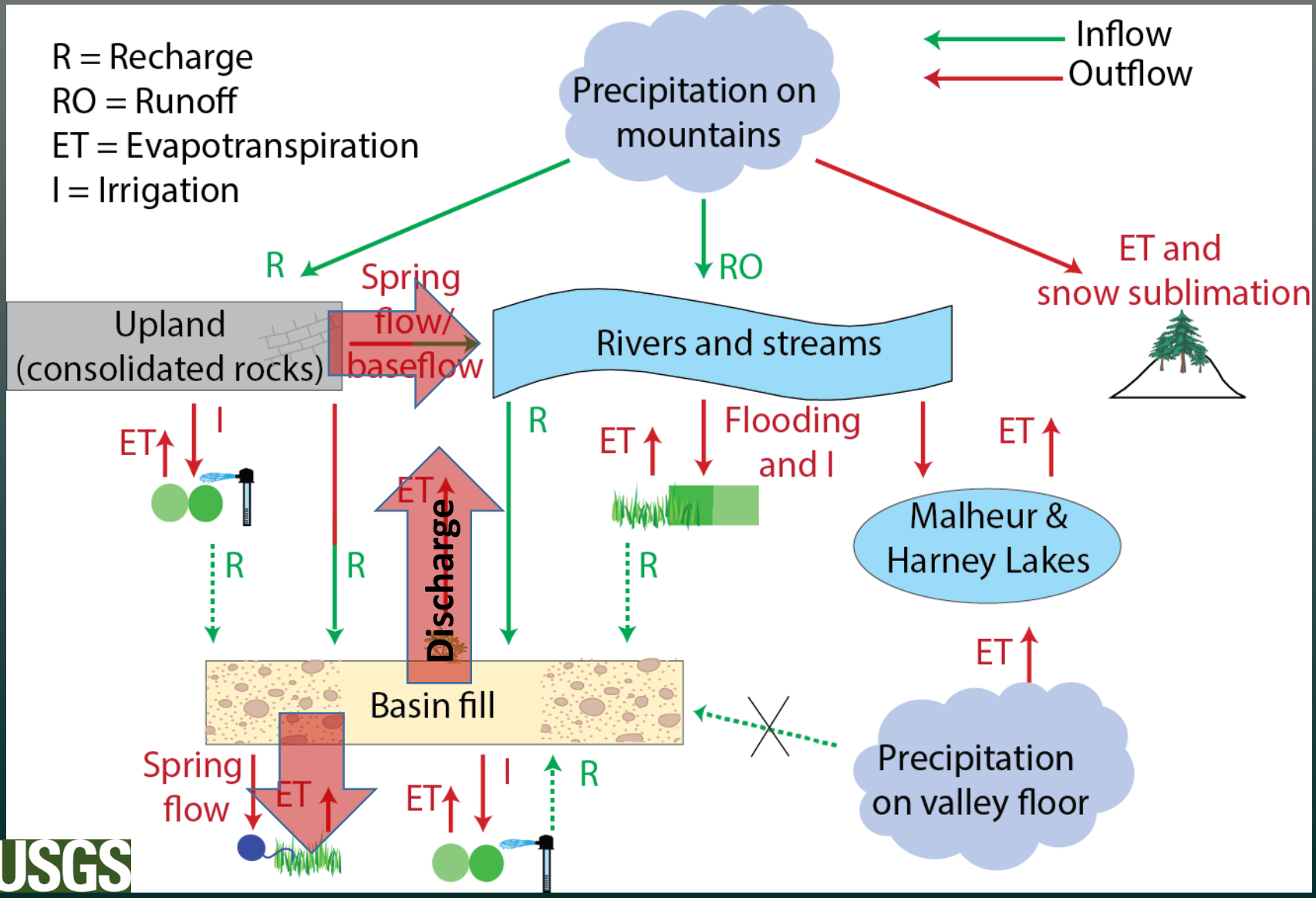
USGS

Harney Basin Water Budget



USGS

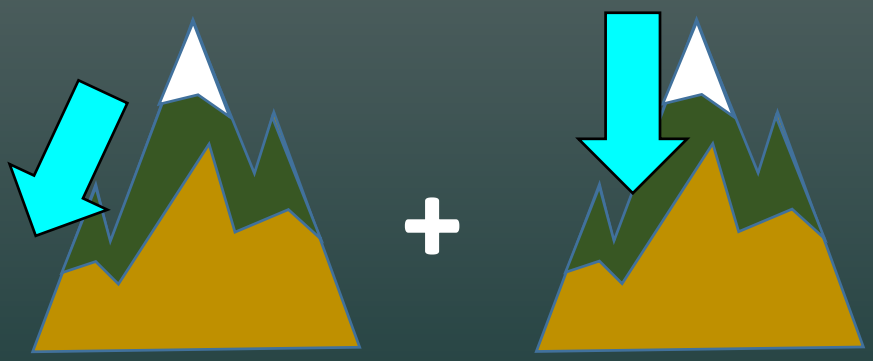
Harney Basin Water Budget



Upland Recharge – Two Approaches

Empirical method[1]

Runoff



Upland recharge

Soil Water Balance (SWB)[2] method

Upland recharge

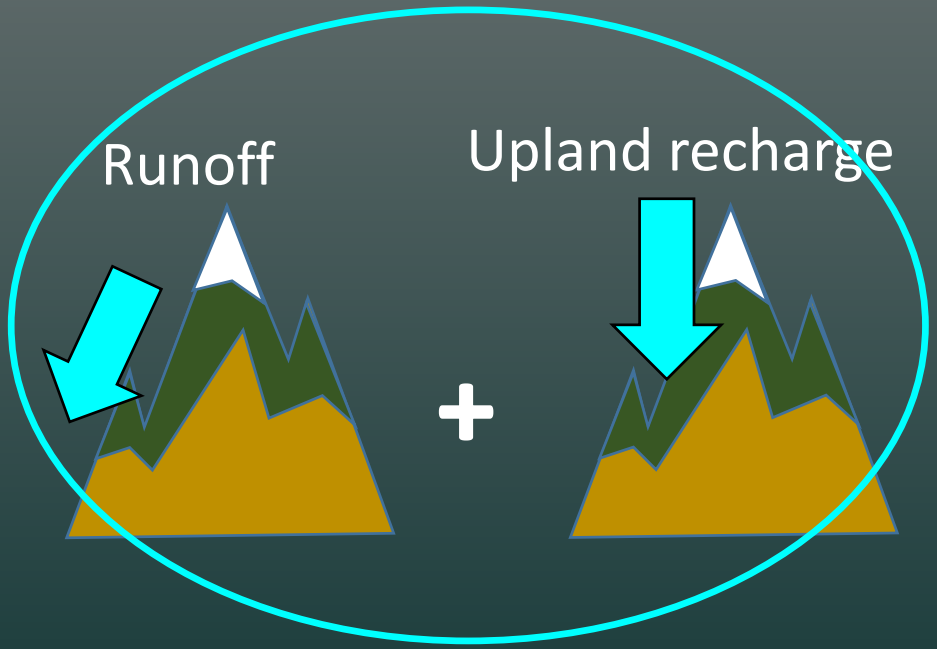
[1]Modified Maxey-Eakin approach (Epstein and others, 2010)

[2]Westenbroek and others (2010)

USGS

Upland Recharge – Two Approaches

Empirical method[1]



Total available water

Soil Water Balance (SWB)[2] method

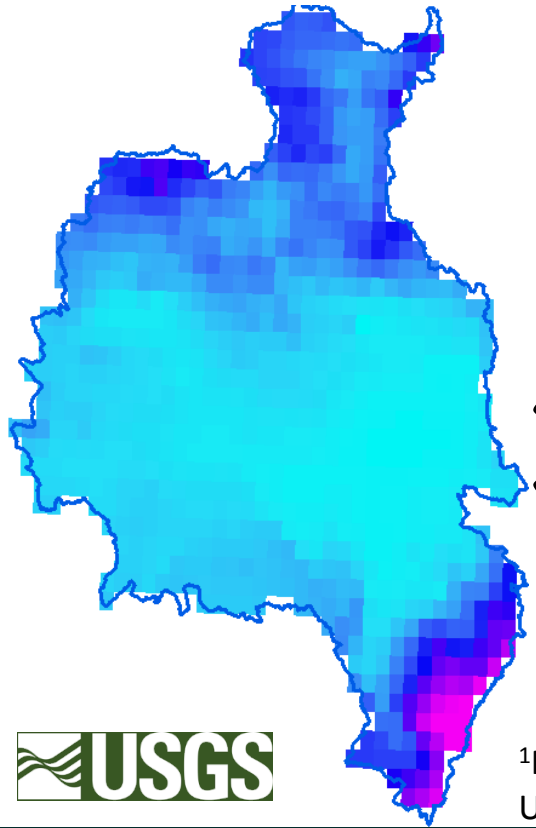
[1]Modified Maxey-Eakin approach (Epstein and others, 2010)

[2]Westenbroek and others (2010)

USGS

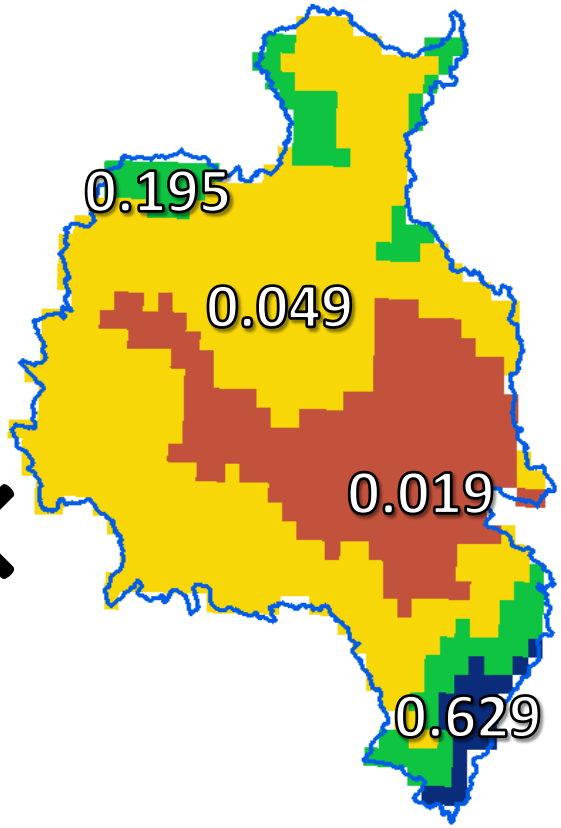
Recharge – Empirical Method

30-yr average precipitation 1961-1990[1]



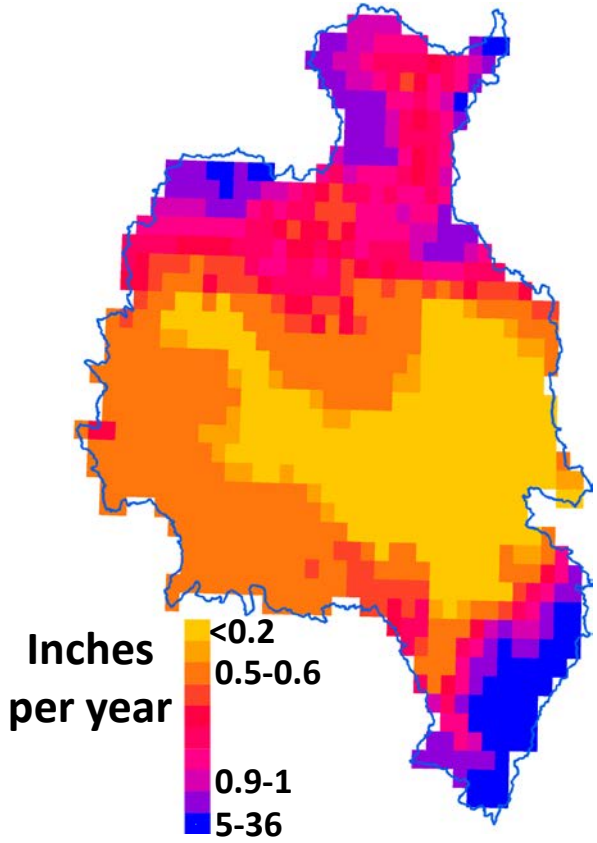
×

Coefficient[2]



=

Total available water[3]



USGS

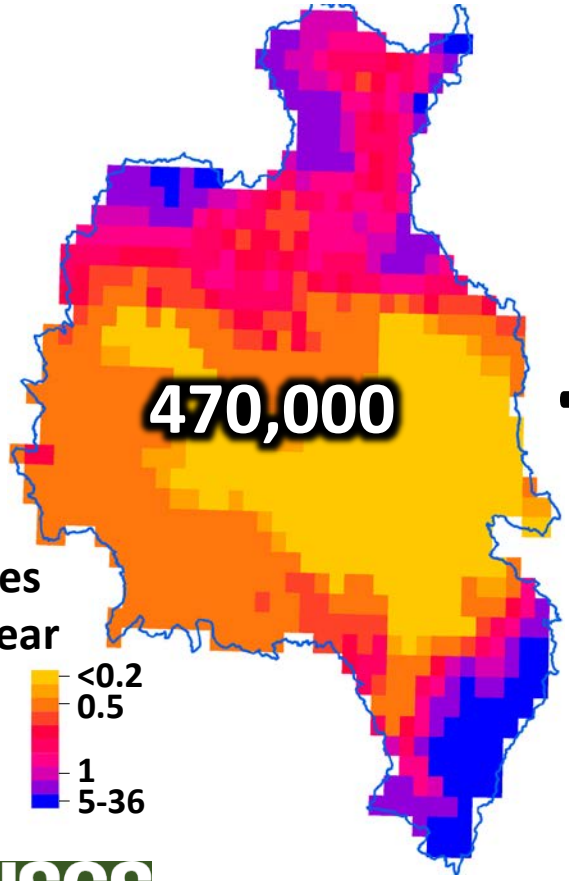
[1]PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu

[2]Epstein and others (2010)

[3]Unpublished data subject to revision

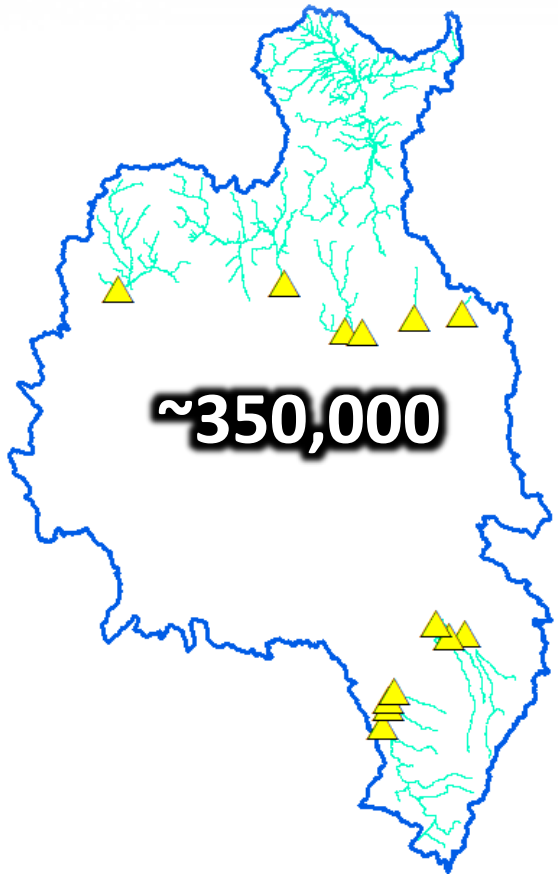
Recharge – Empirical Method

Upland available water (acre-feet/year, AFY)



—

Mean annual runoff (AFY, needs refinement)



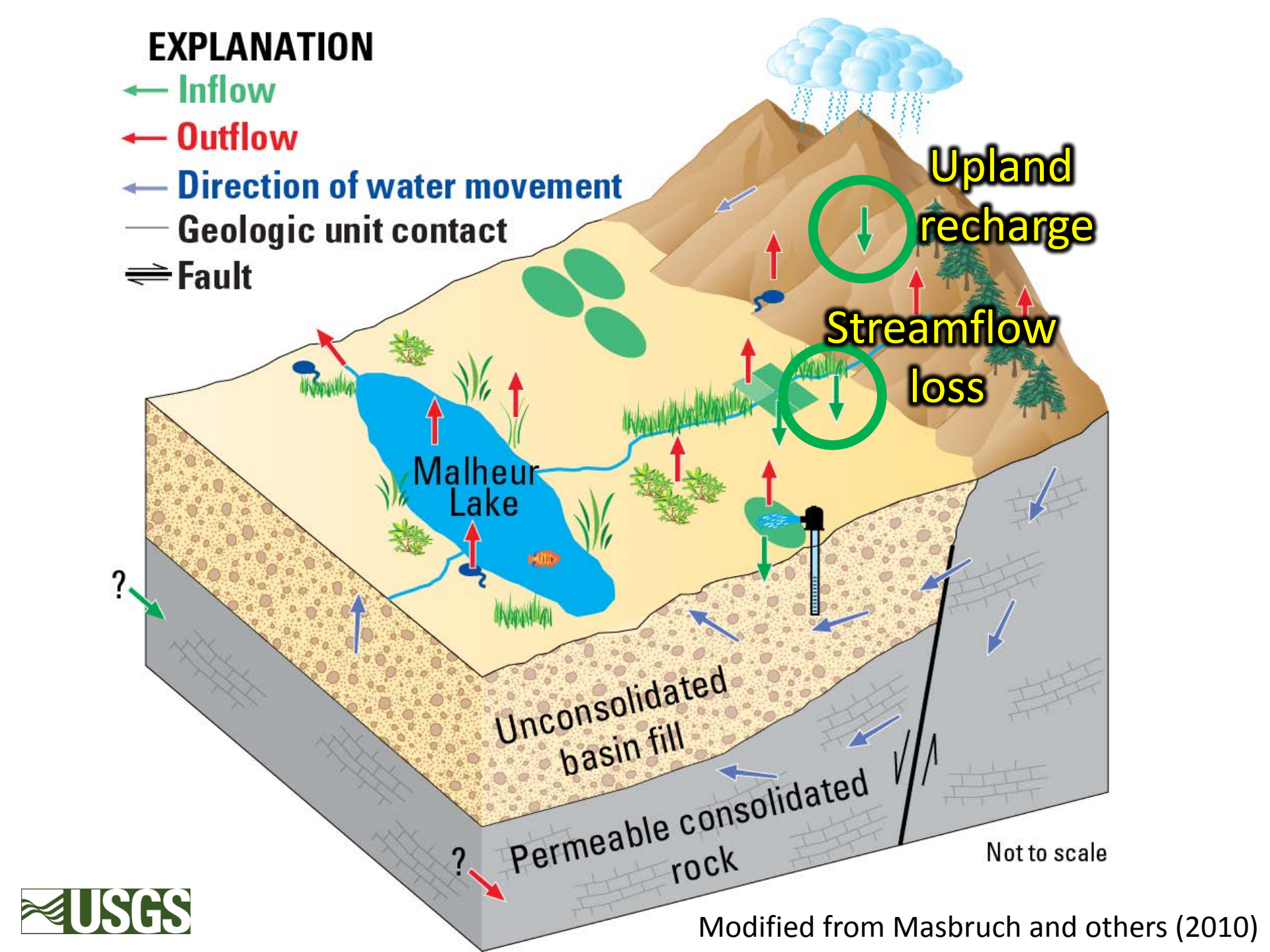
=

Upland recharge (AFY)

120,000

USGS

Unpublished data subject to revision. Do not cite.

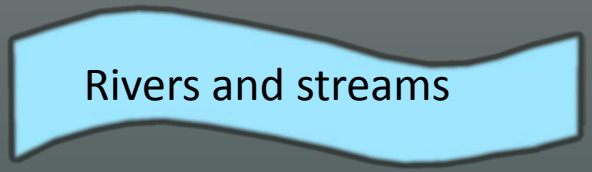


USGS

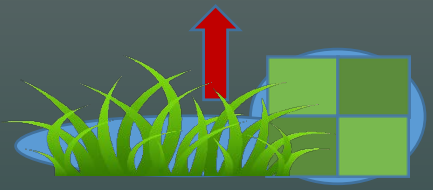
Modified from Masbruch and others (2010)

Recharge – Streamflow Loss

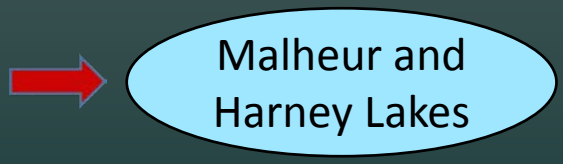
Streamflow



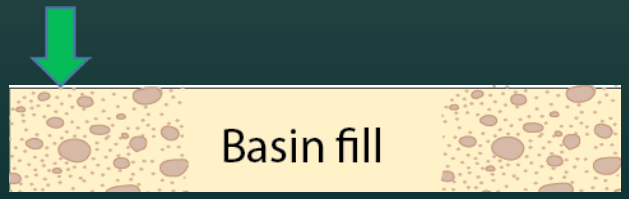
– ET from surface-water flooding and irrigation



– Streamflow to lakes



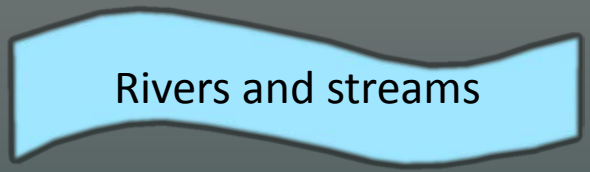
Basin-fill recharge



USGS

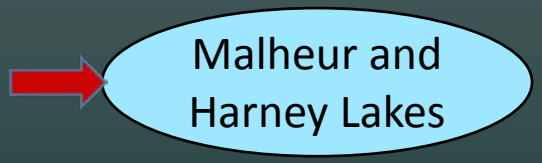
Recharge – Streamflow Loss

350,000[1] AFY

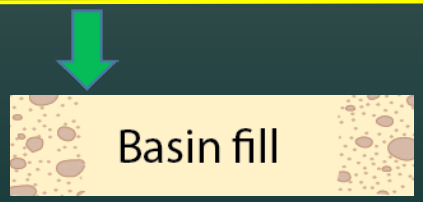


– ~150,000 – 300,000[2] AFY

– ~50,000 – 150,000[1,3] AFY



≈ 50,000 – 150,000 AFY



USGS

Unpublished data subject to revision. Do not cite.

[1]Based on OWRD (1967), OWRD water availability estimates, NWIS
[2]Cuenca (1992), USDA common land units, OWRD place of use
[3]Hubbard (1975)

Total Recharge (Primary)

Upland recharge ≈ 120,000 AFY

+

Streamflow loss ≈ 50,000 – 150,000 AFY

Total recharge ≈ 170,000 – 270,000 AFY

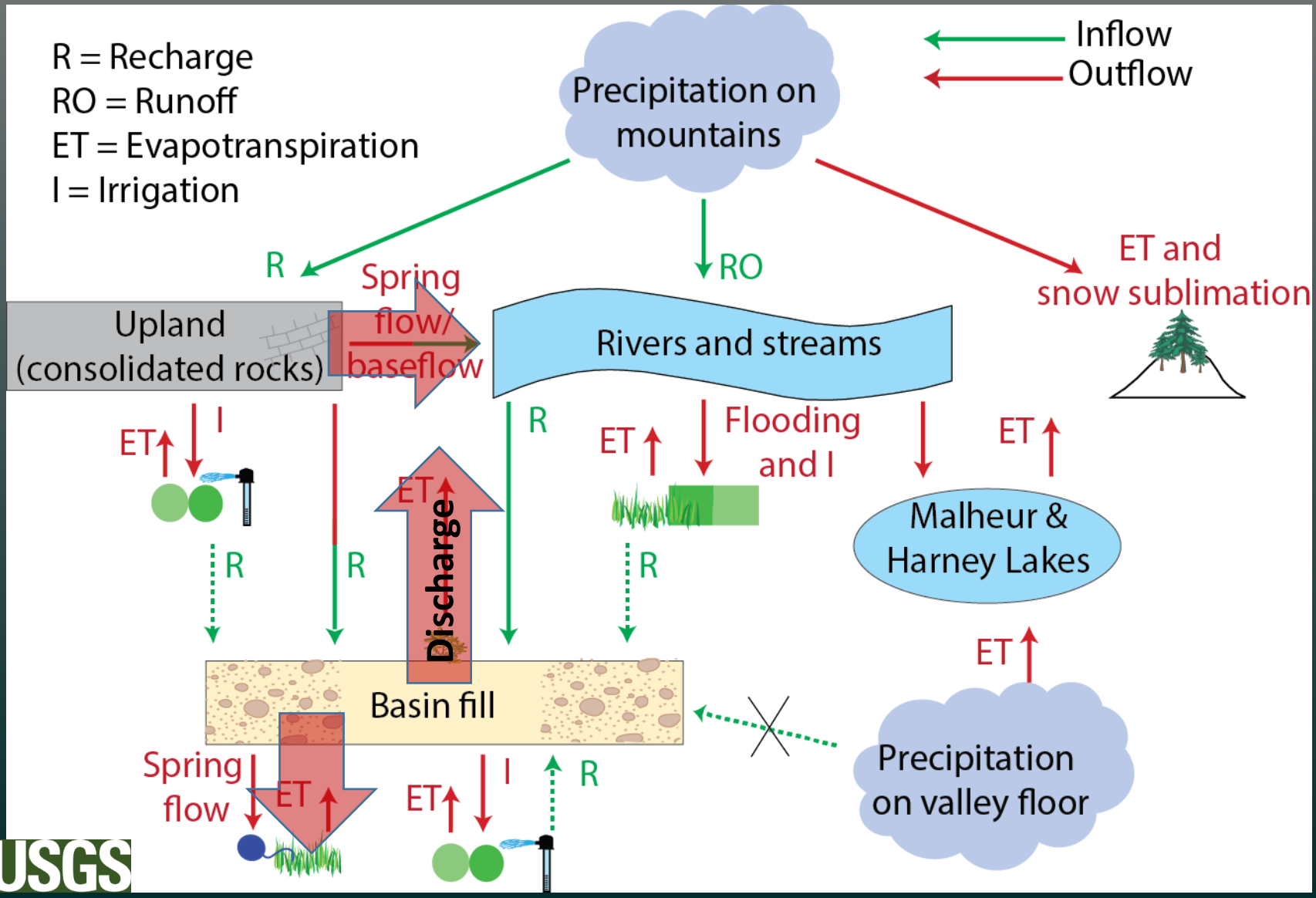
Similar to range in previous estimates (170,000 – 260,000 AFY)

Water Budget Road Map

USGS

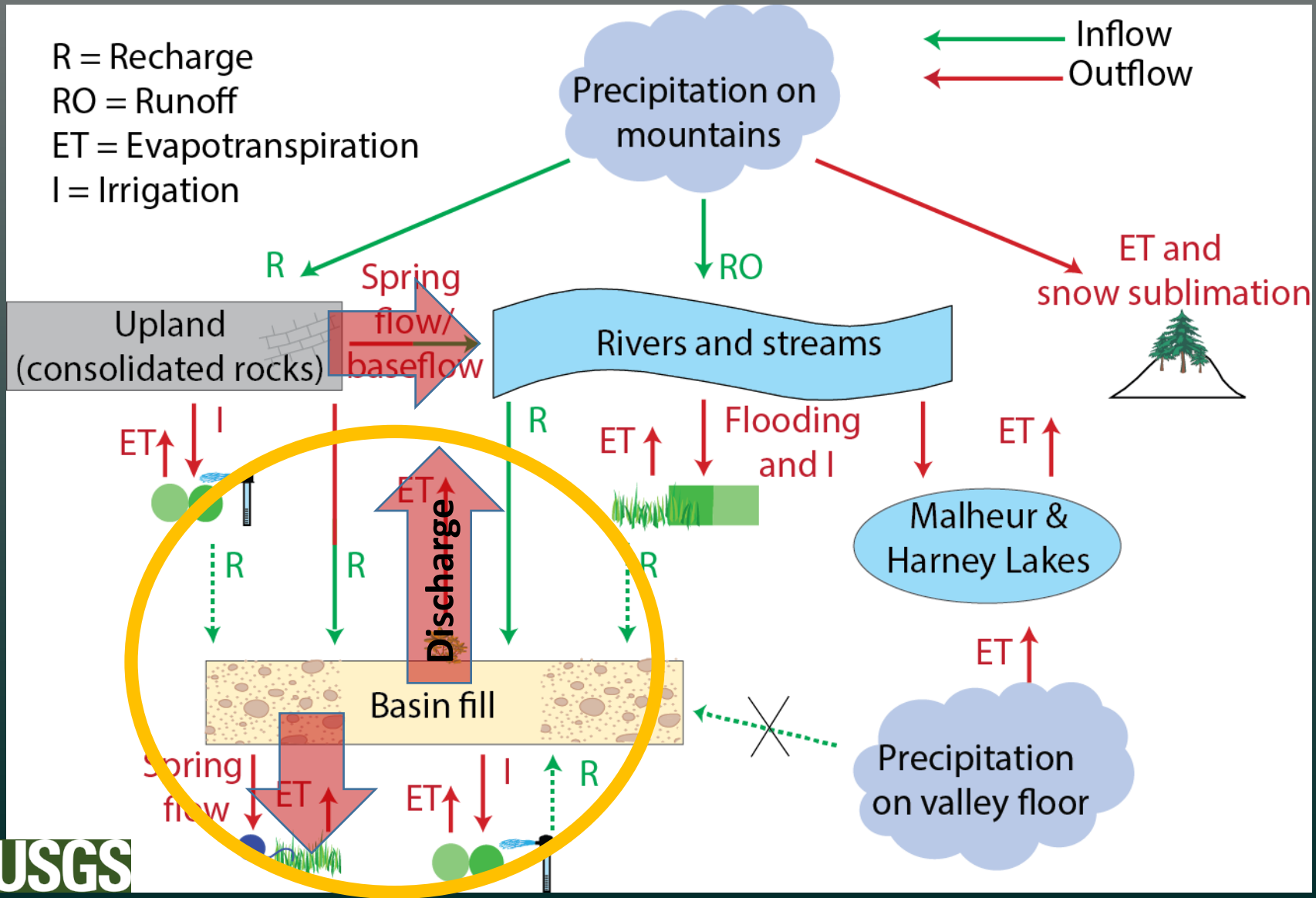
Image source: openclipart.org

Harney Basin Water Budget



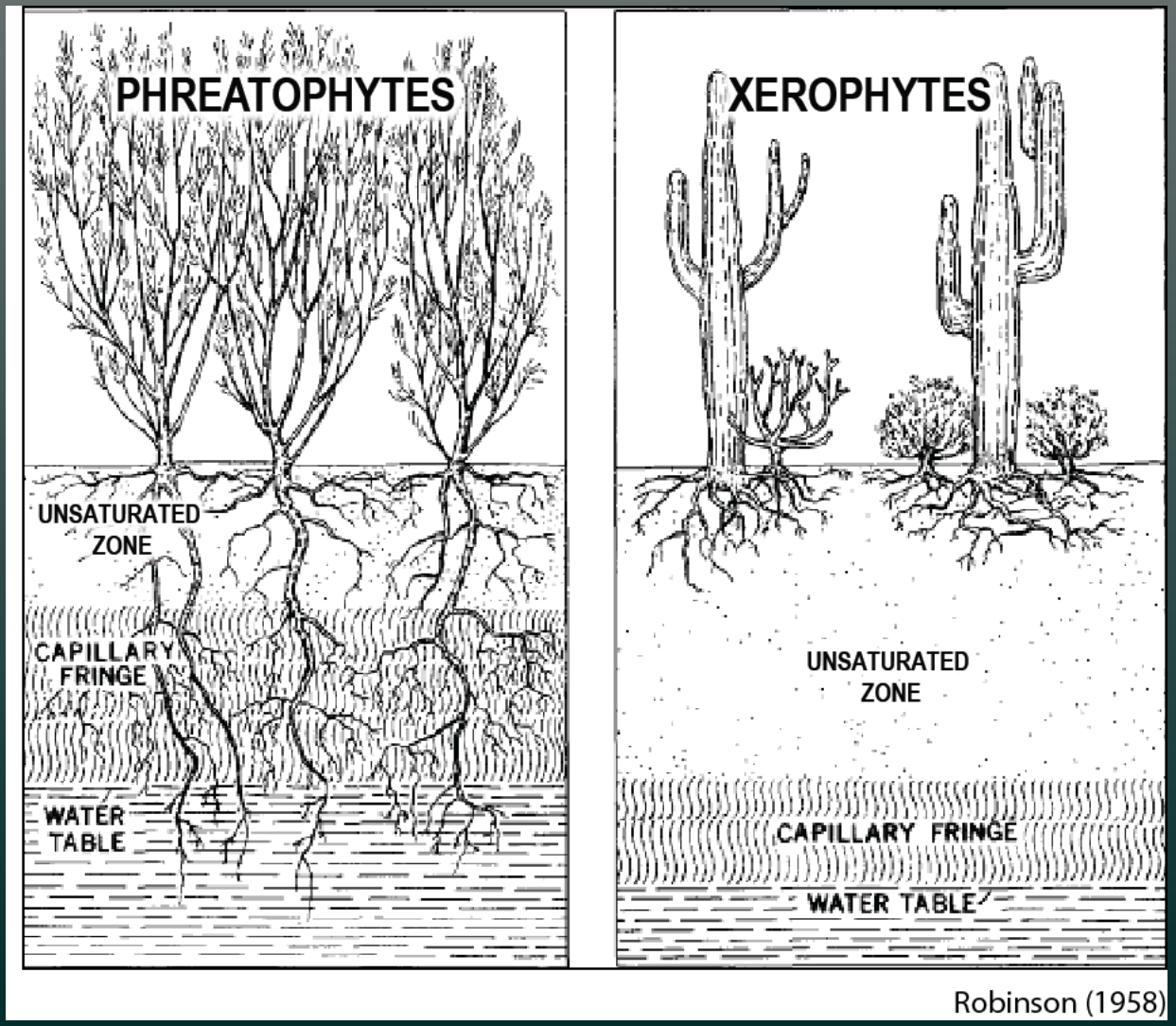
USGS

Harney Basin Water Budget



USGS

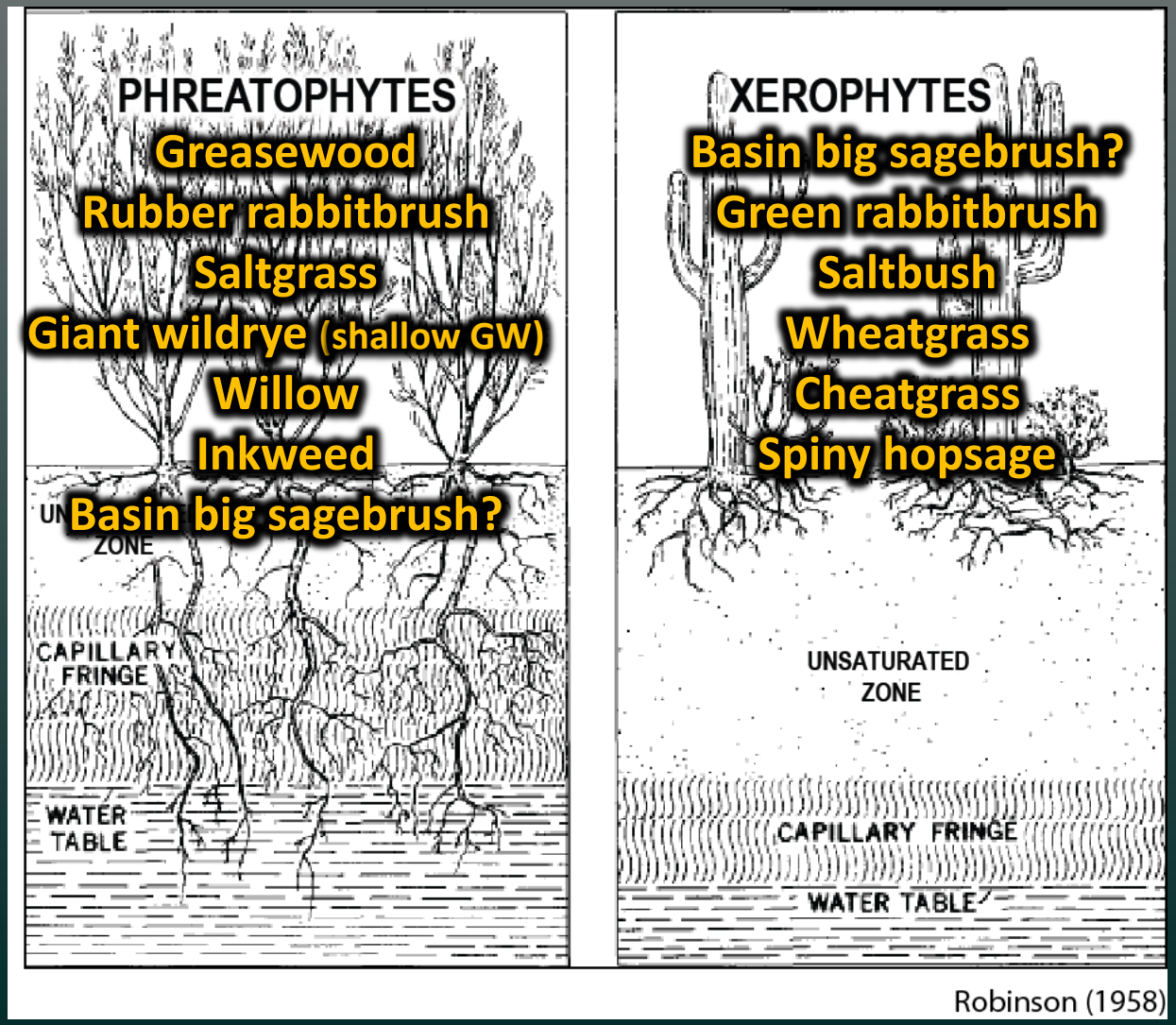
Natural Groundwater Discharge by ET



Robinson (1958)

USGS

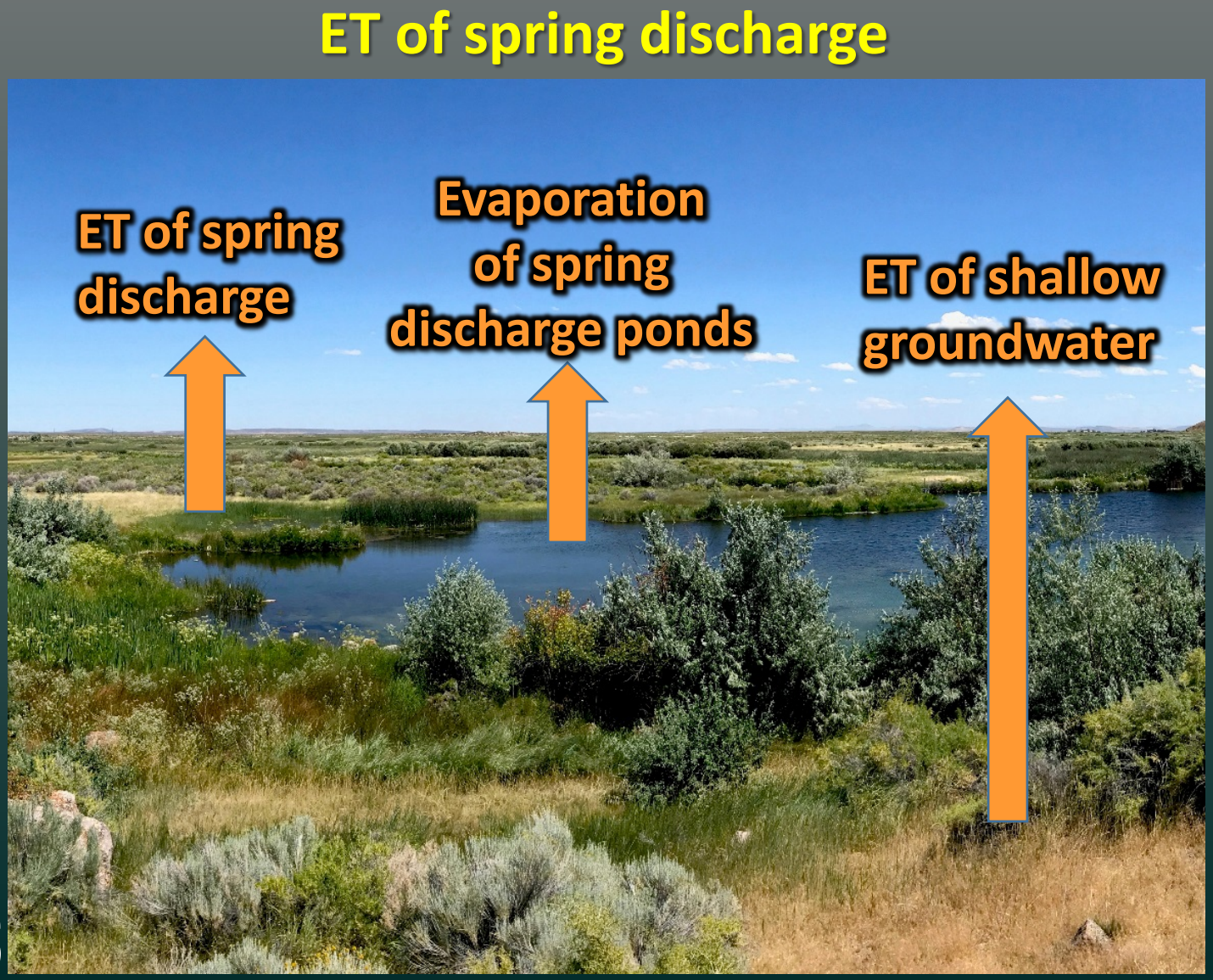
Natural Groundwater Discharge by ET



Robinson (1958)

USGS

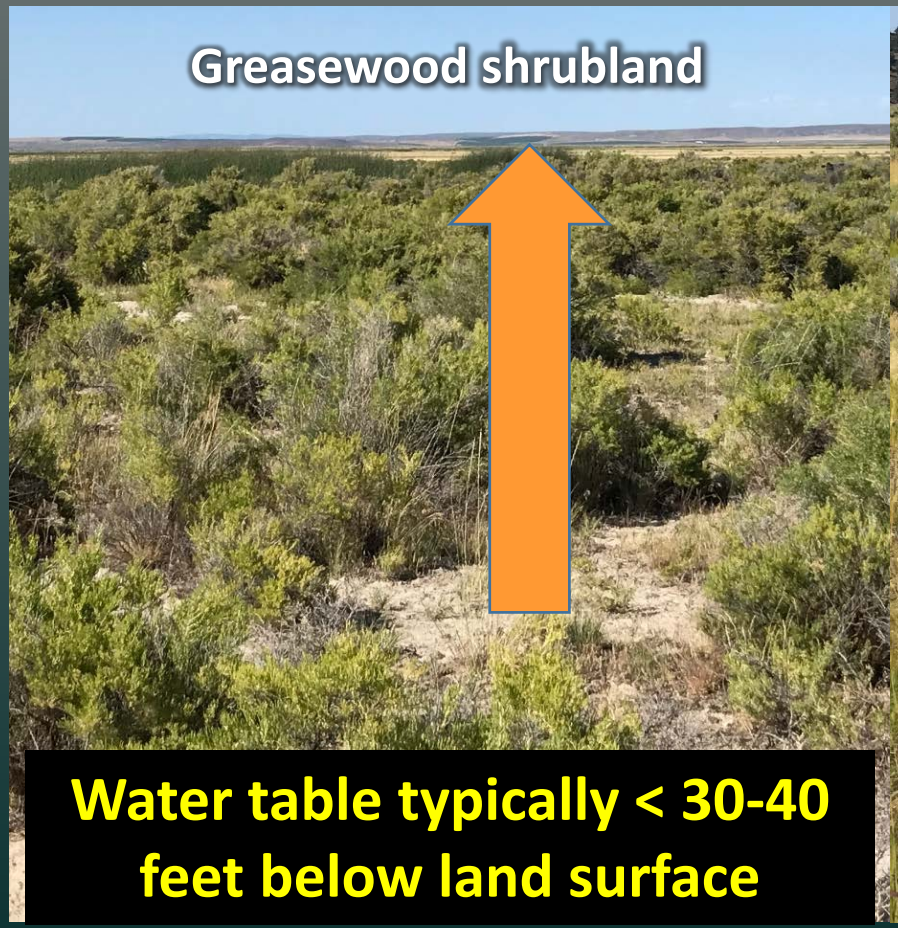
Natural Groundwater Discharge by ET

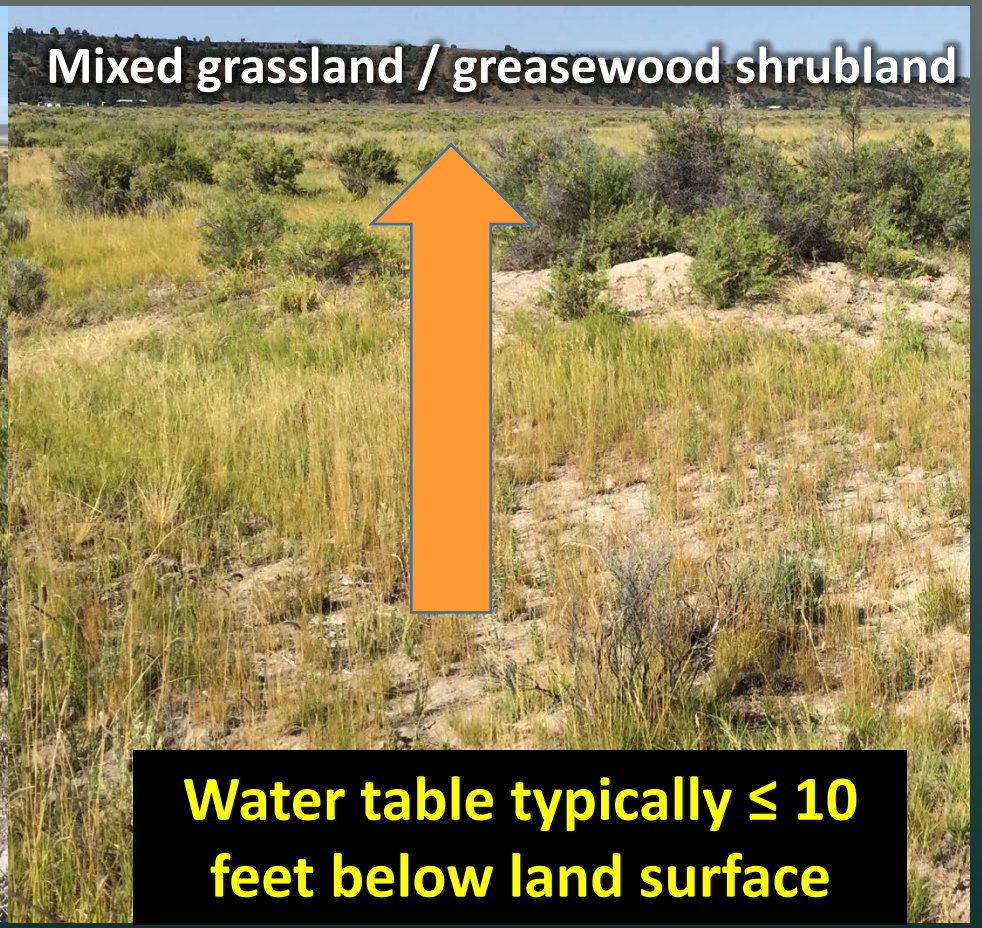


USGS

Natural Groundwater Discharge by ET

ET of shallow groundwater

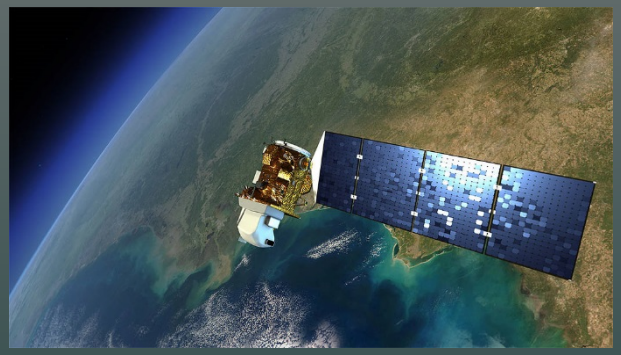




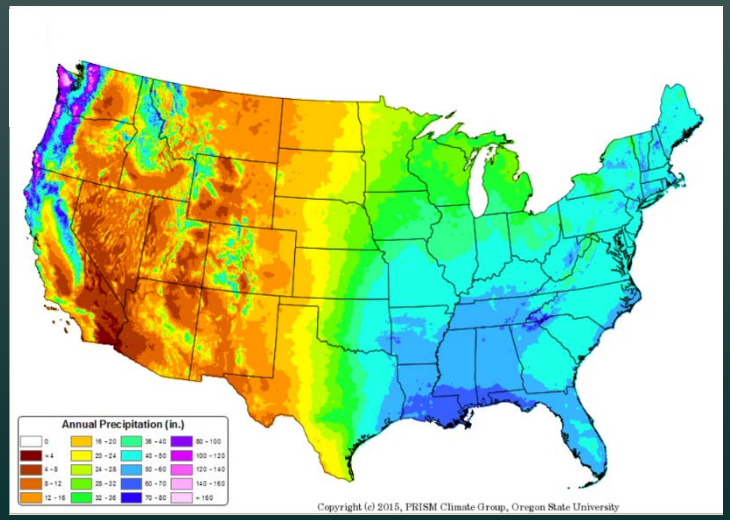
USGS

Natural Groundwater Discharge by ET

Advancements in remote sensing and recent site-based ET measurements in Oregon and Nevada provide a basis for refining groundwater-budget estimates established 50 years ago



NASA: https://www.nasa.gov/sites/default/files/ldcm.jpg



PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu

Stannard and others (2013)

USGS

Estimating Natural Groundwater Discharge by ET

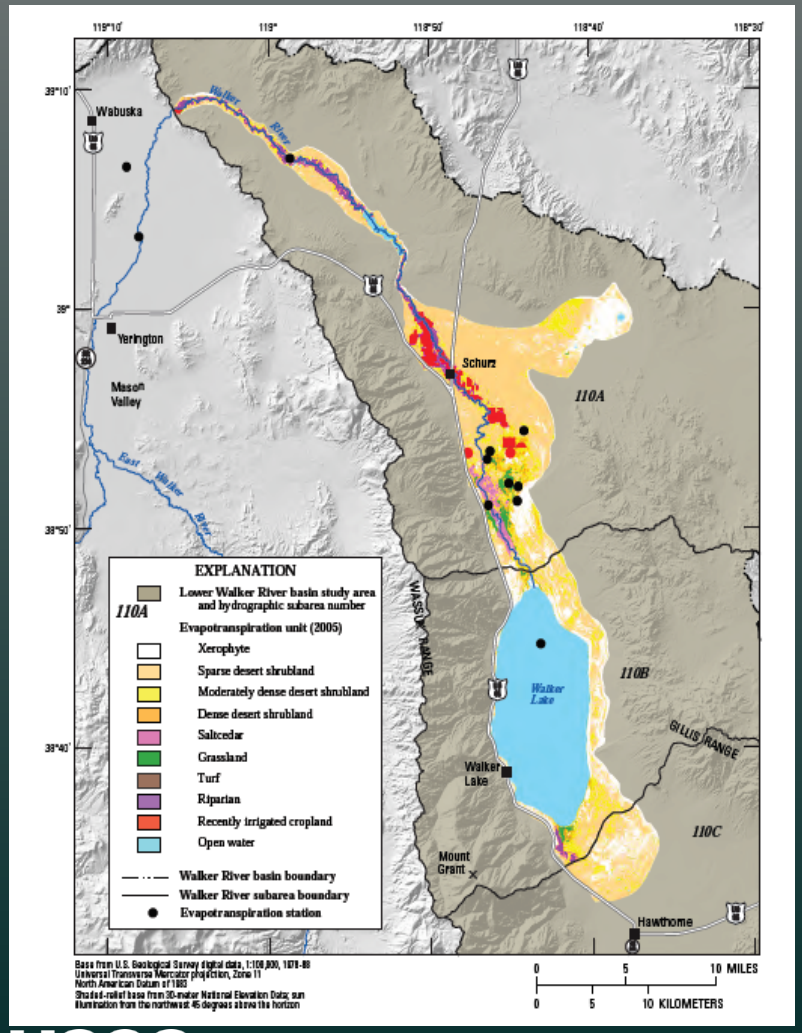
$$ET_{GW} = ET_{actual} - P - ET_{SW}$$

- Actual ET estimated from multiple methods
- Precipitation (P) from weather stations
- ET_{SW}
  - Estimated using crop ET estimates
  - Flooded areas mapped with Landsat

USGS

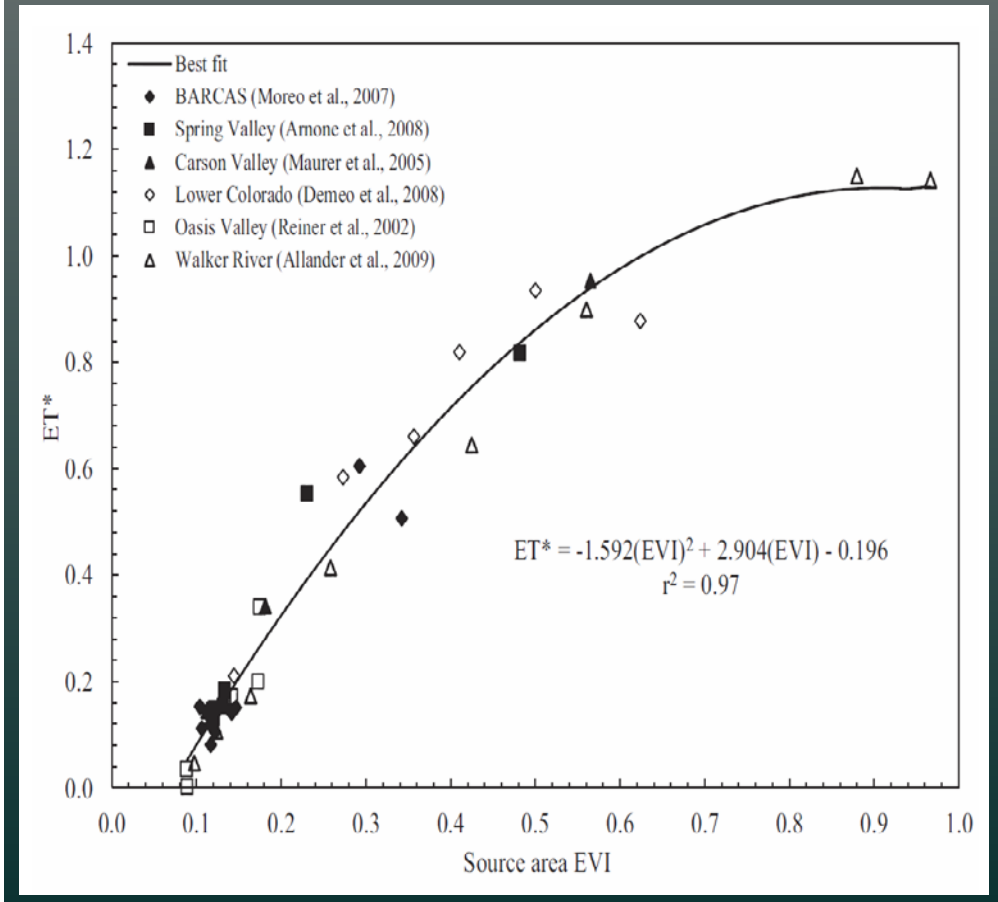
Natural Discharge by ET –Two Approaches

ET Unit



Allander and others (2009)

Enhanced Vegetation Index (EVI) model

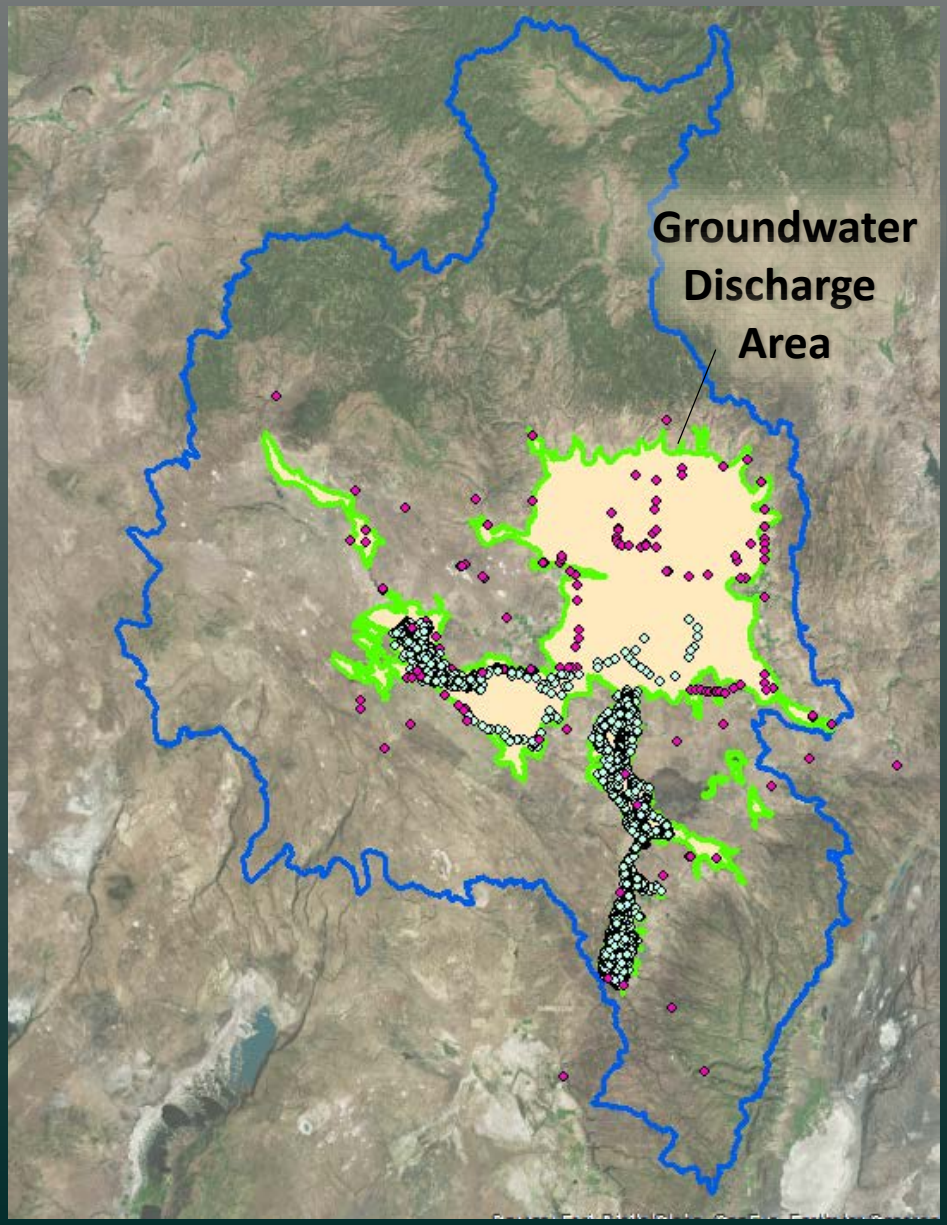


Beamer and others (2013)

USGS

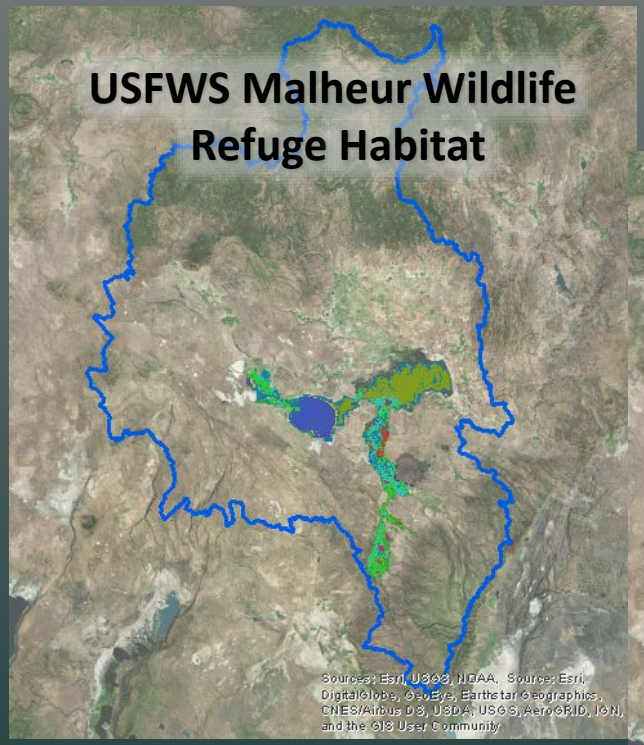
ET Units - Approach

- Discharge = Area x Rate
- Map vegetation area
- Published rates
- SSEBop ET rates

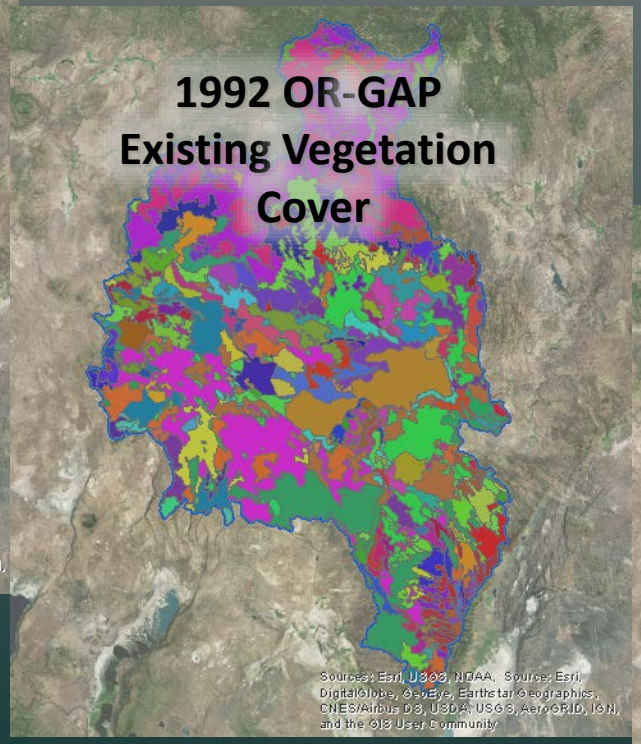


USGS

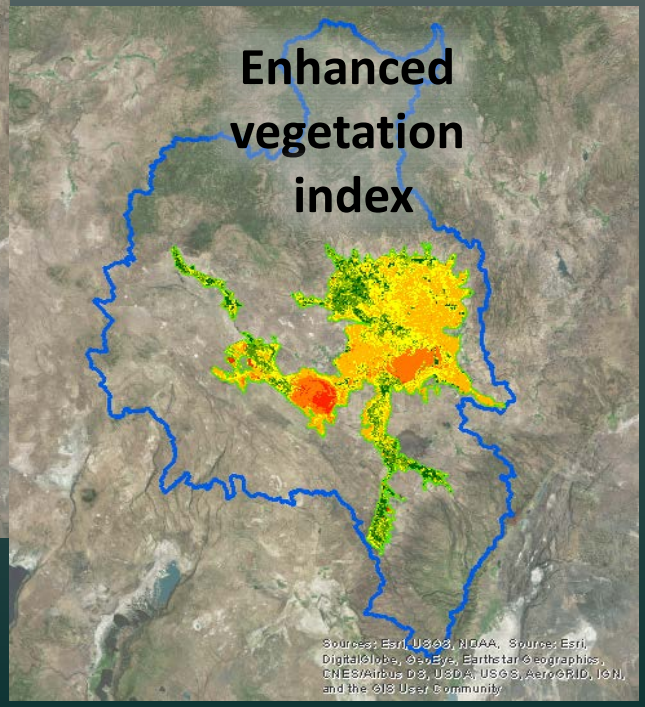
ET Units – Map Vegetation Areas



USFWS, unpublished data



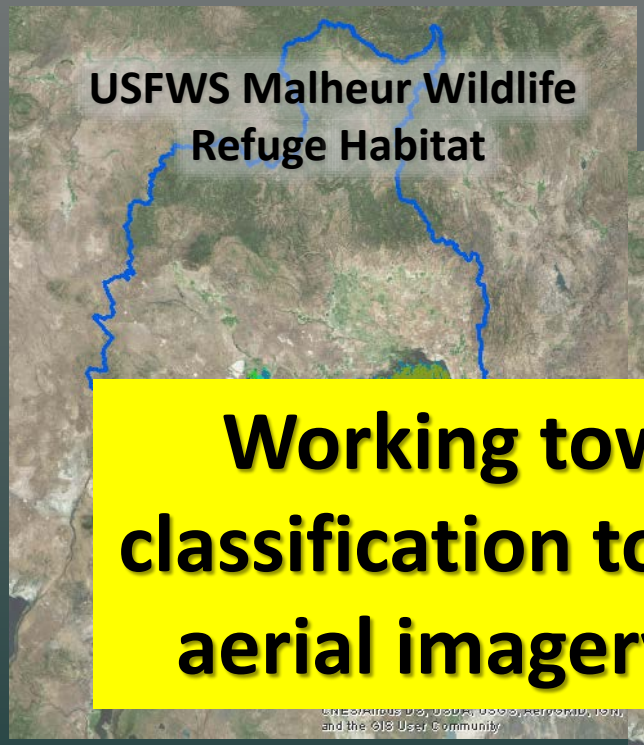
Kagan and Caicco (1992)



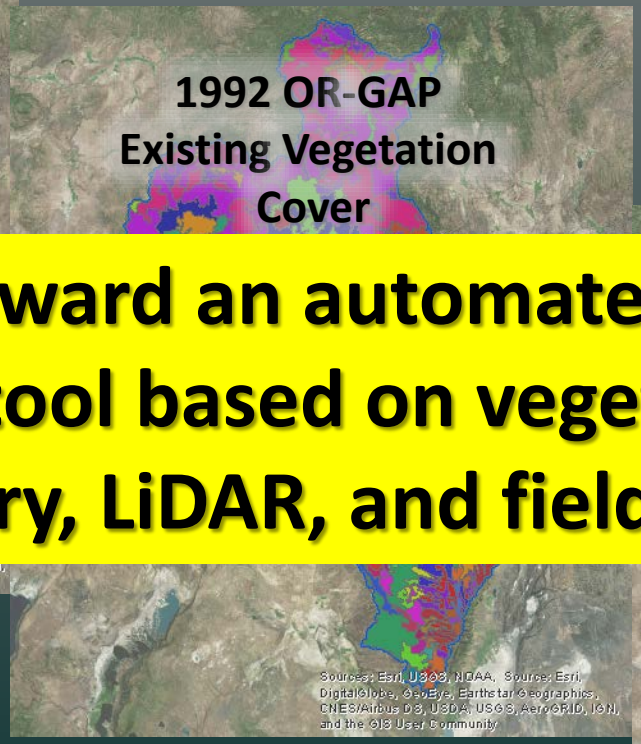
Landsat (July 2005)

USGS

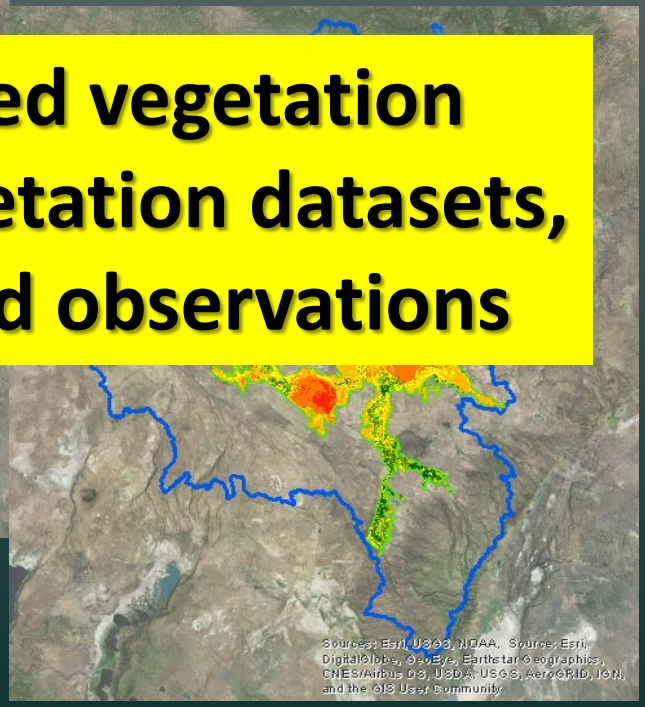
ET Units – Map Vegetation Areas



USFWS, unpublished data



Kagan and Caicco (1992)



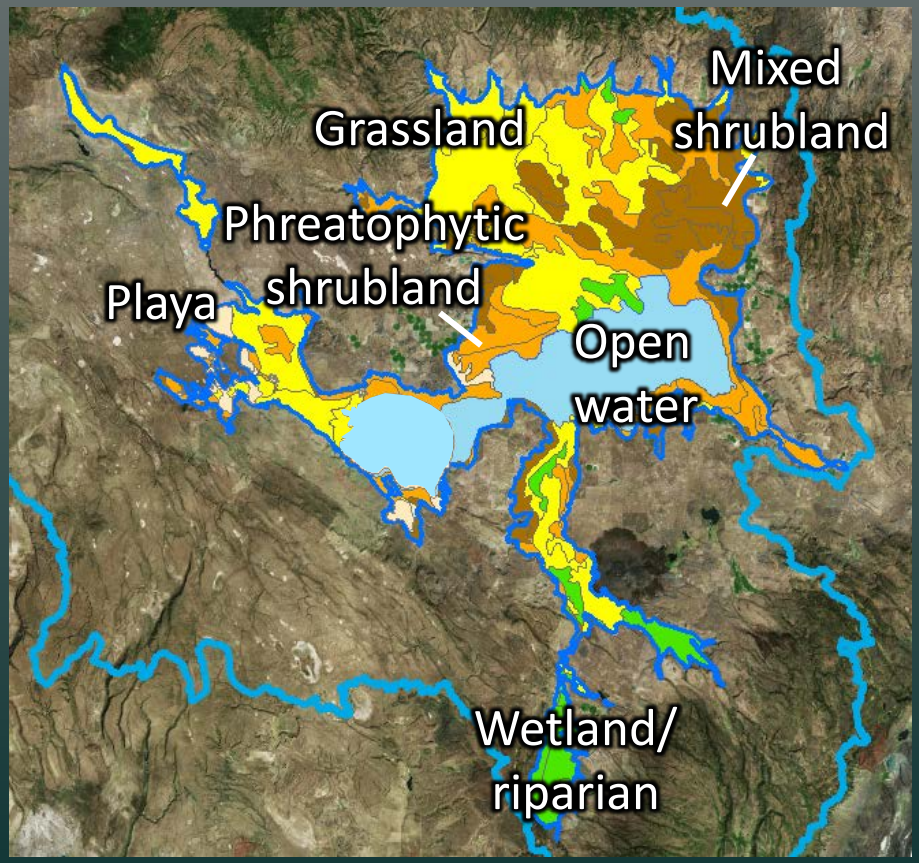
Landsat (July 2005)

Working toward an automated vegetation classification tool based on vegetation datasets, aerial imagery, LiDAR, and field observations

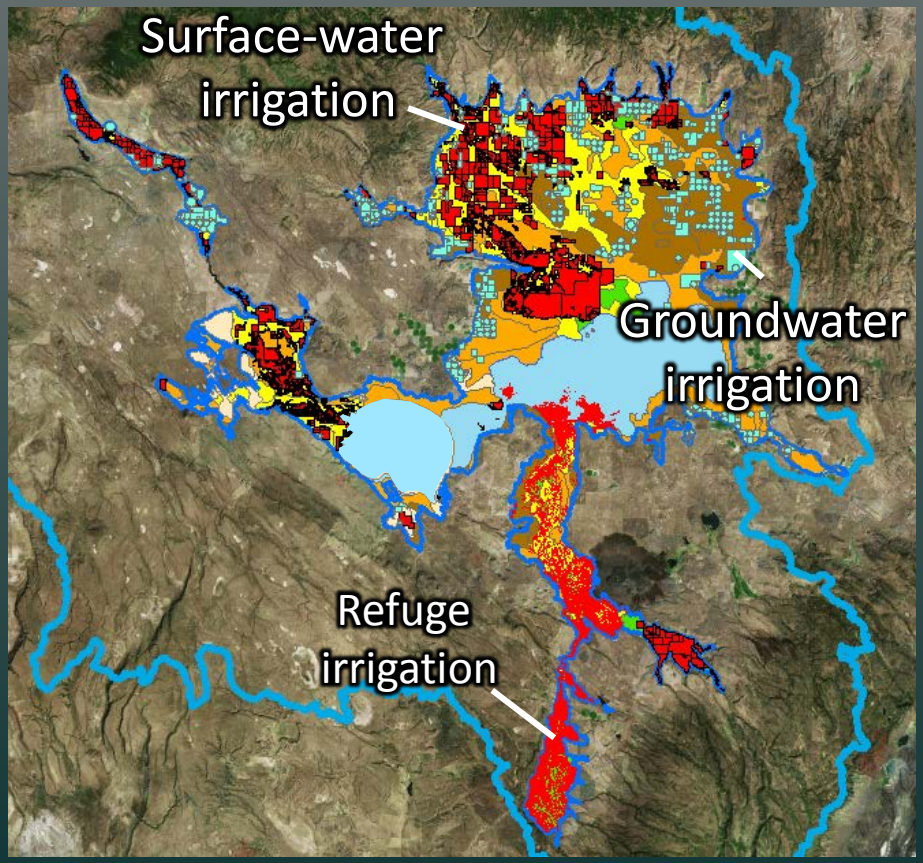
USGS

ET Units – Map Vegetation Areas

ET units



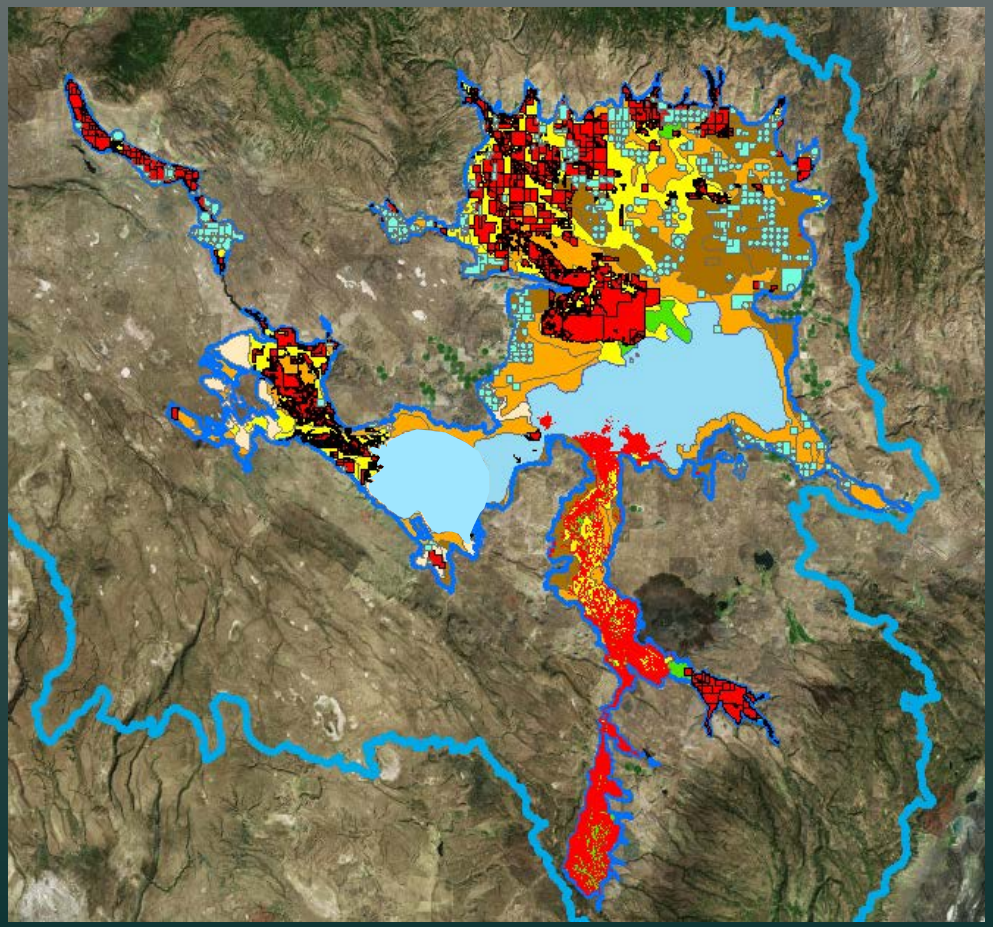
ET units + irrigation

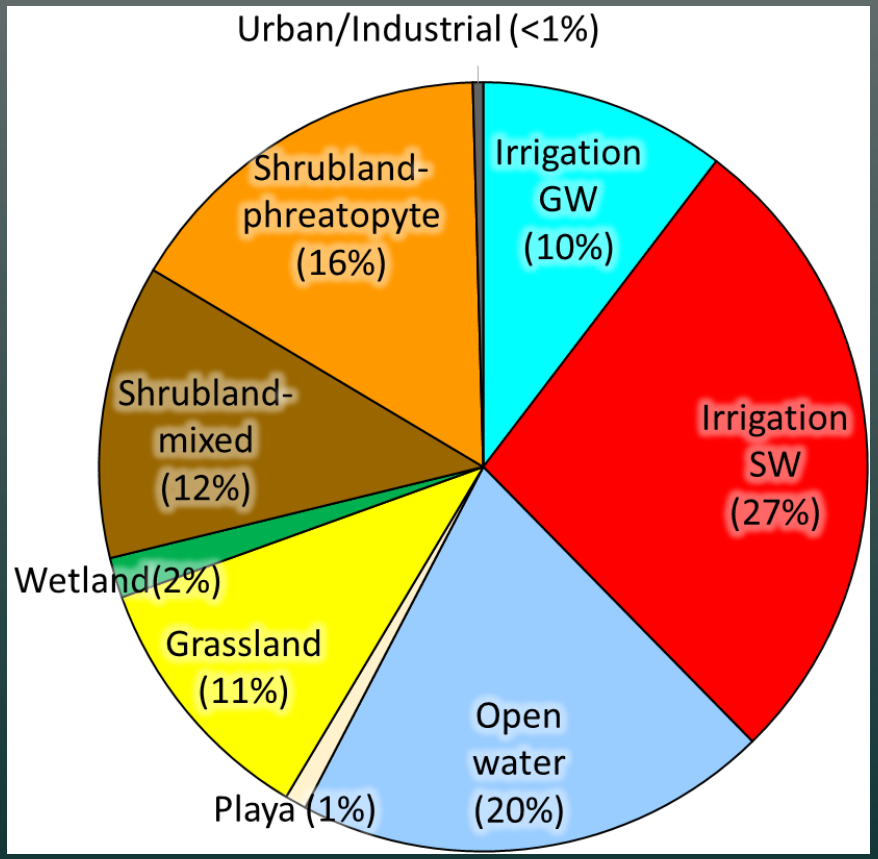


USGS

ET Units – Vegetation Distribution

ET units + irrigation

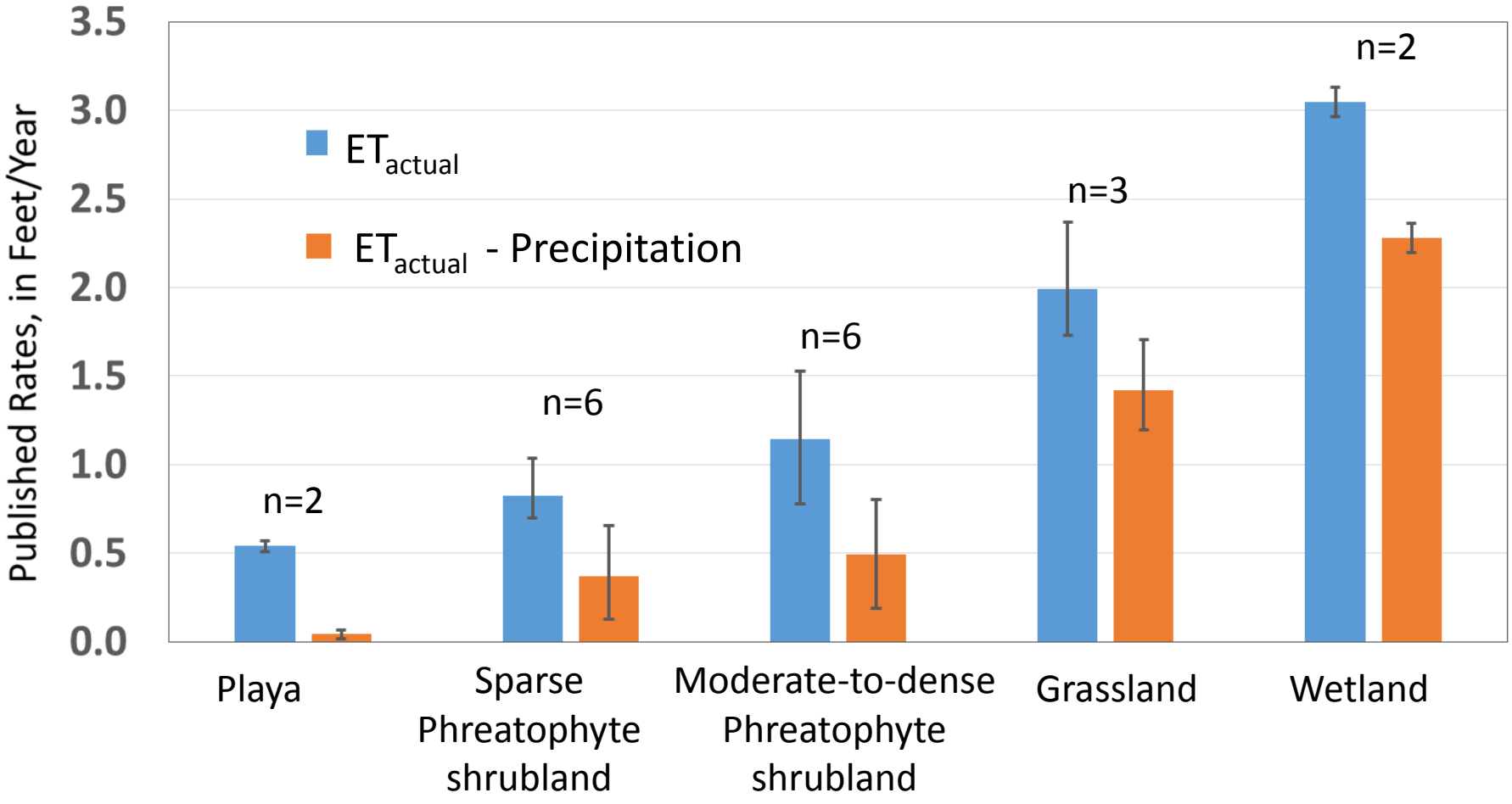




USGS

ET Units – Published Rates

Measured in OR and NV using eddy-covariance instruments



USGS

*Rates will be scaled to the Harney Basin using reference ET

ET Units – SSEBop ET Rates

(Operational Simplified Surface Energy Balance Model)

Landsat Data

Land-surface temperature
Air temperature

Weather Data

Net radiation,
Air temperature, Wind speed,
Relative humidity, Air pressure

ET_f
(scale factor)

Reference ET

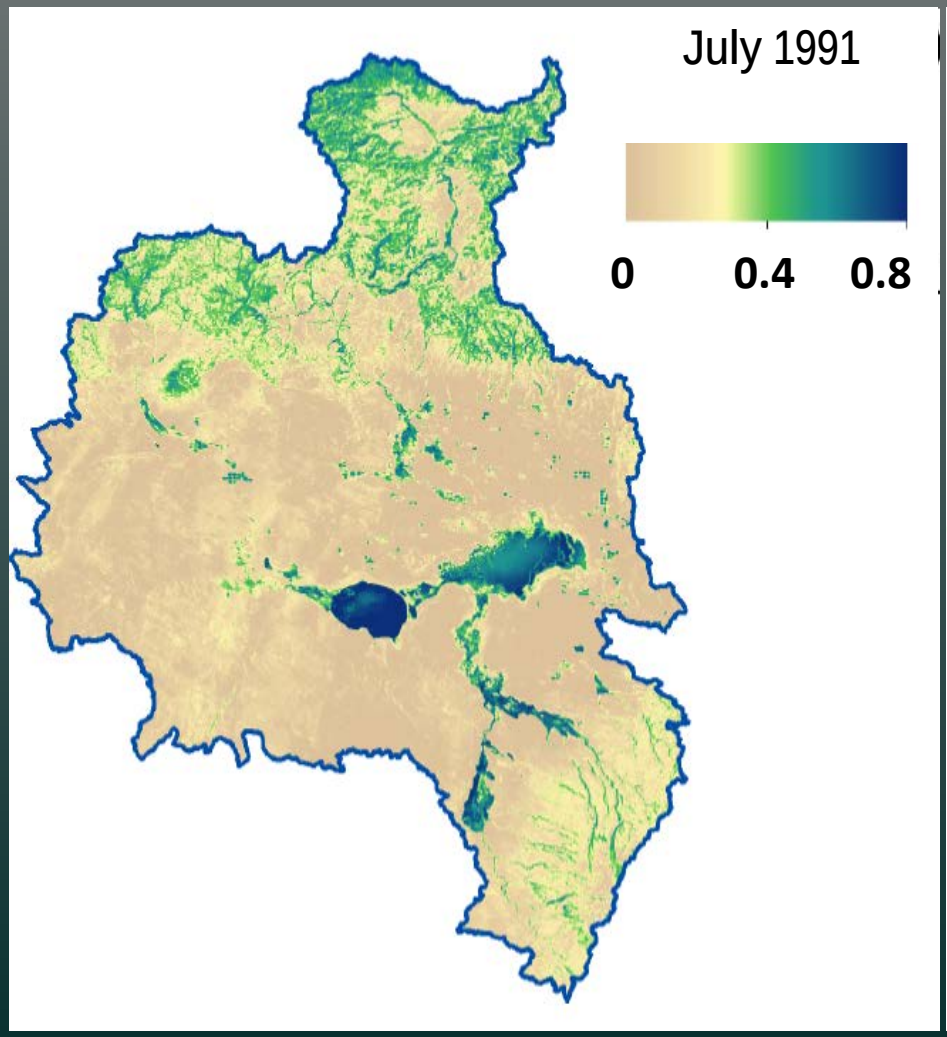
ET_{actual}

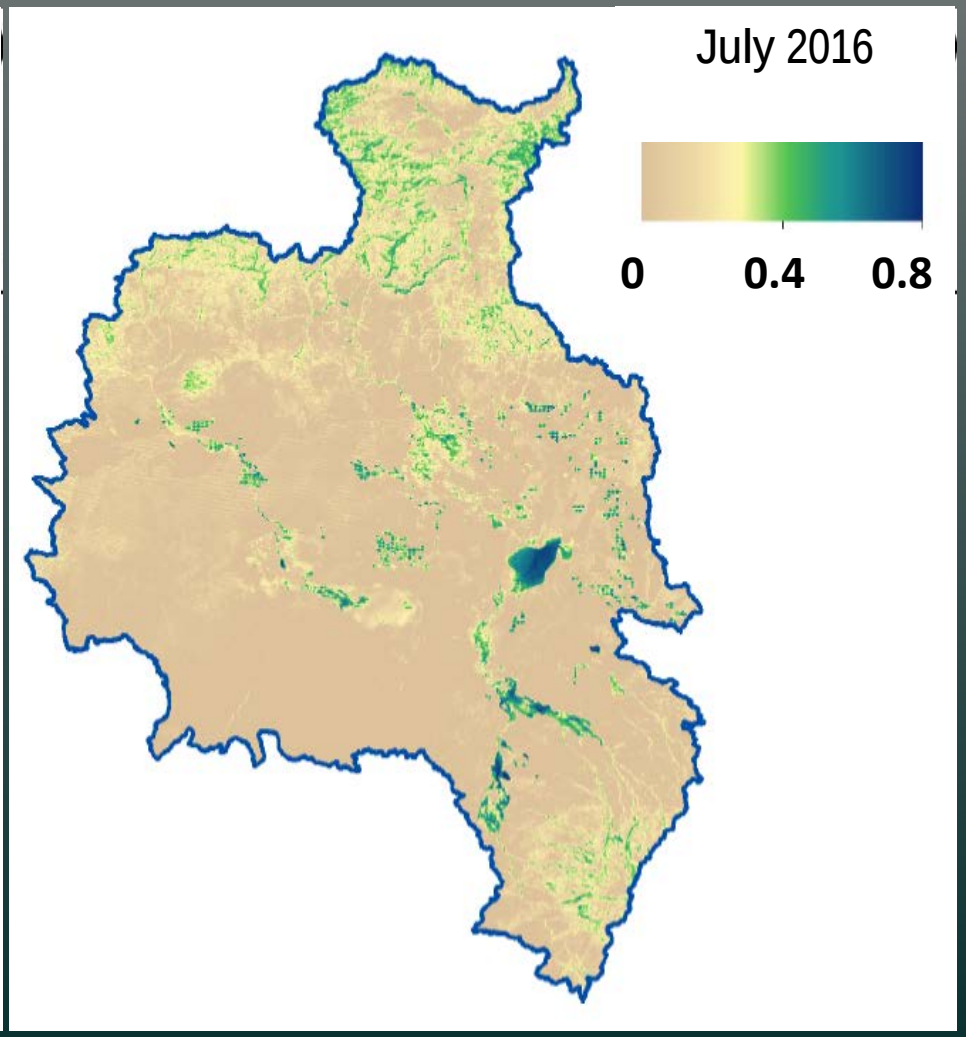
USGS

Senay and others (2013)

ET Units – SSEBop ET Rates

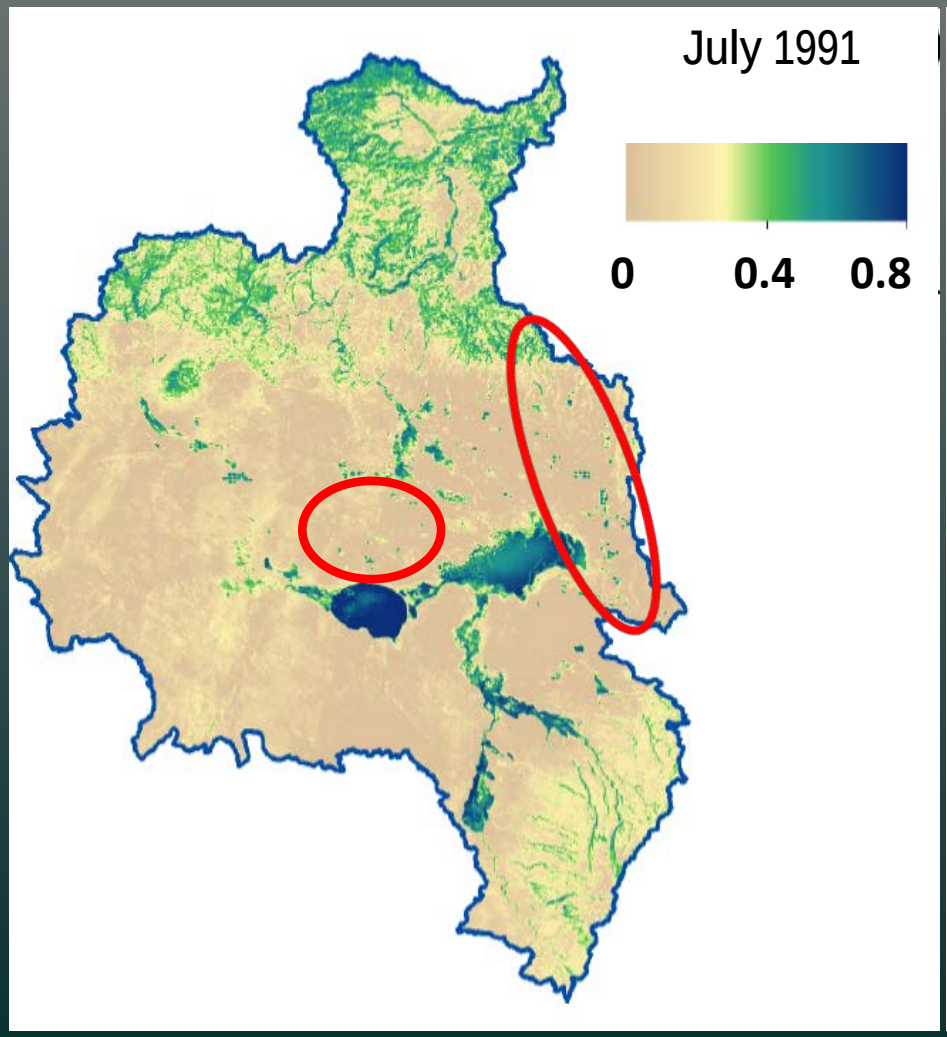
Estimated monthly ET_{actual} (feet)

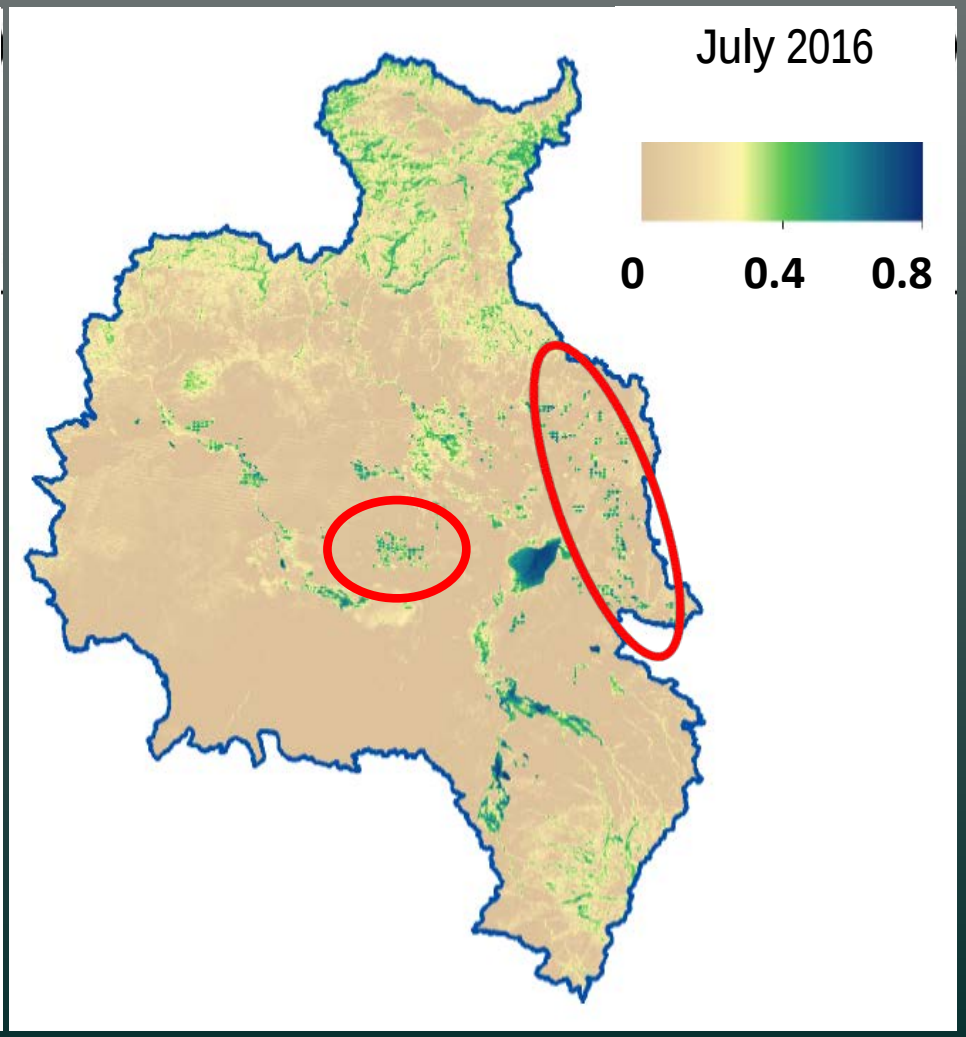




ET Units – SSEBop ET Rates

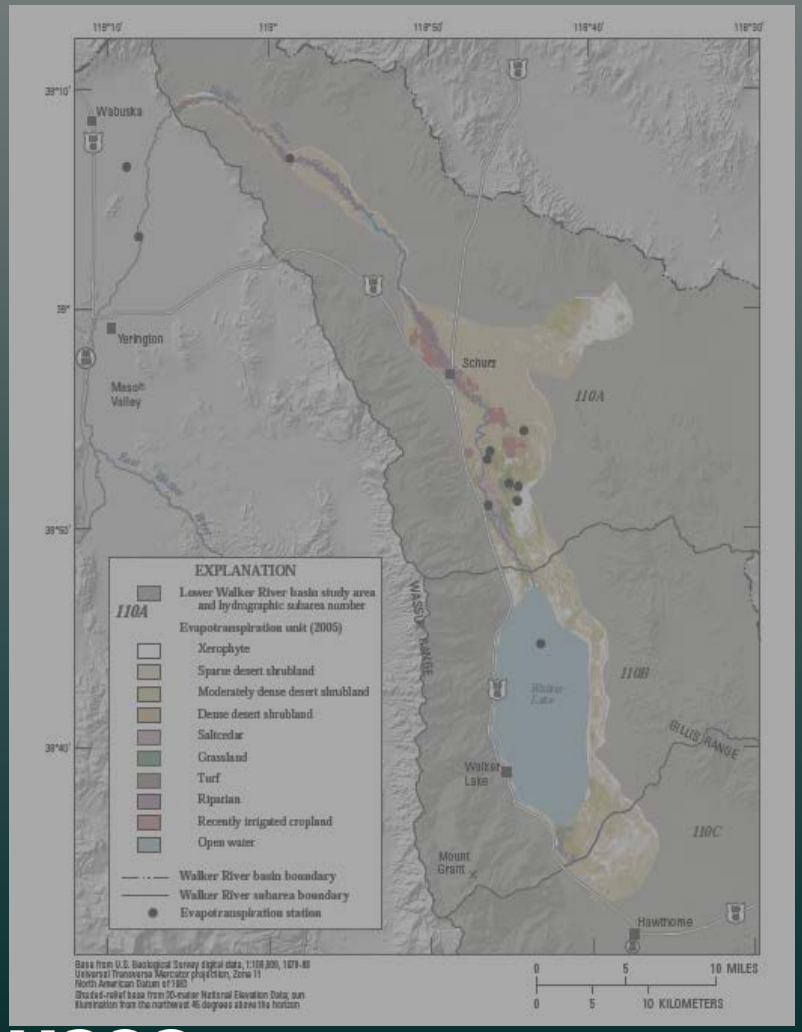
Estimated monthly ET_{actual} (feet)





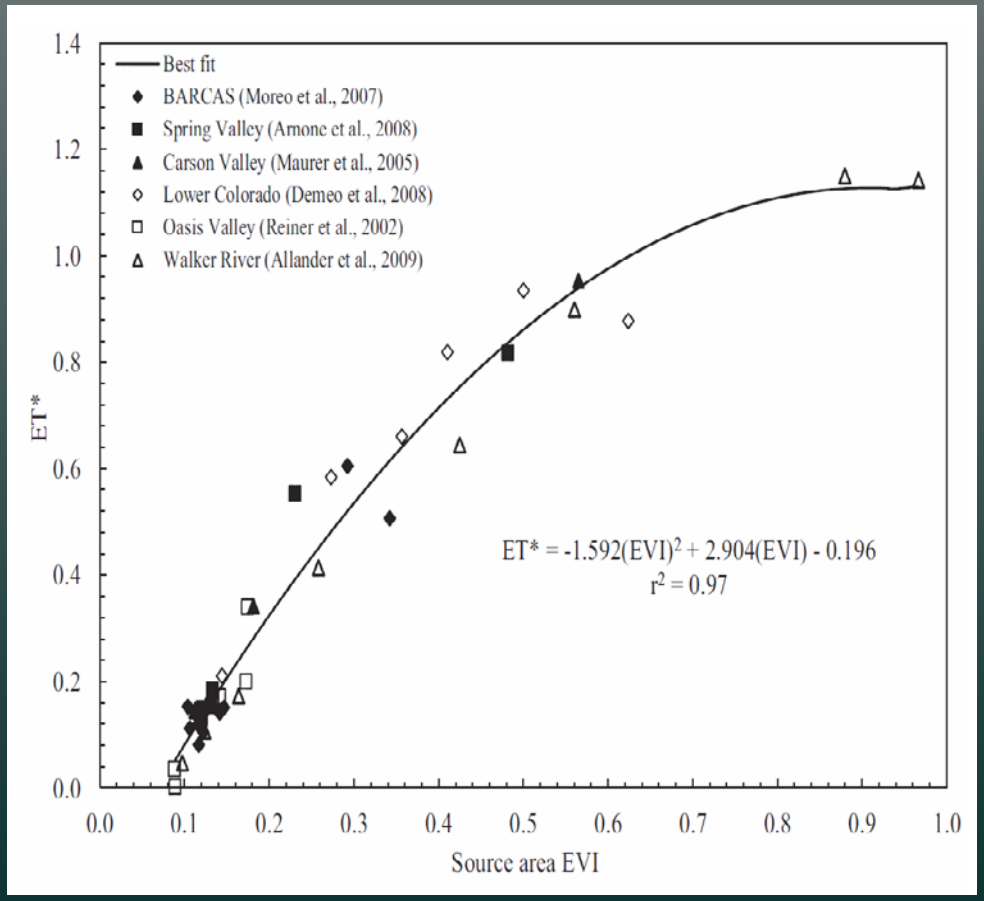
Natural Discharge by ET – Two Approaches

ET Unit



Allander and others (2009)

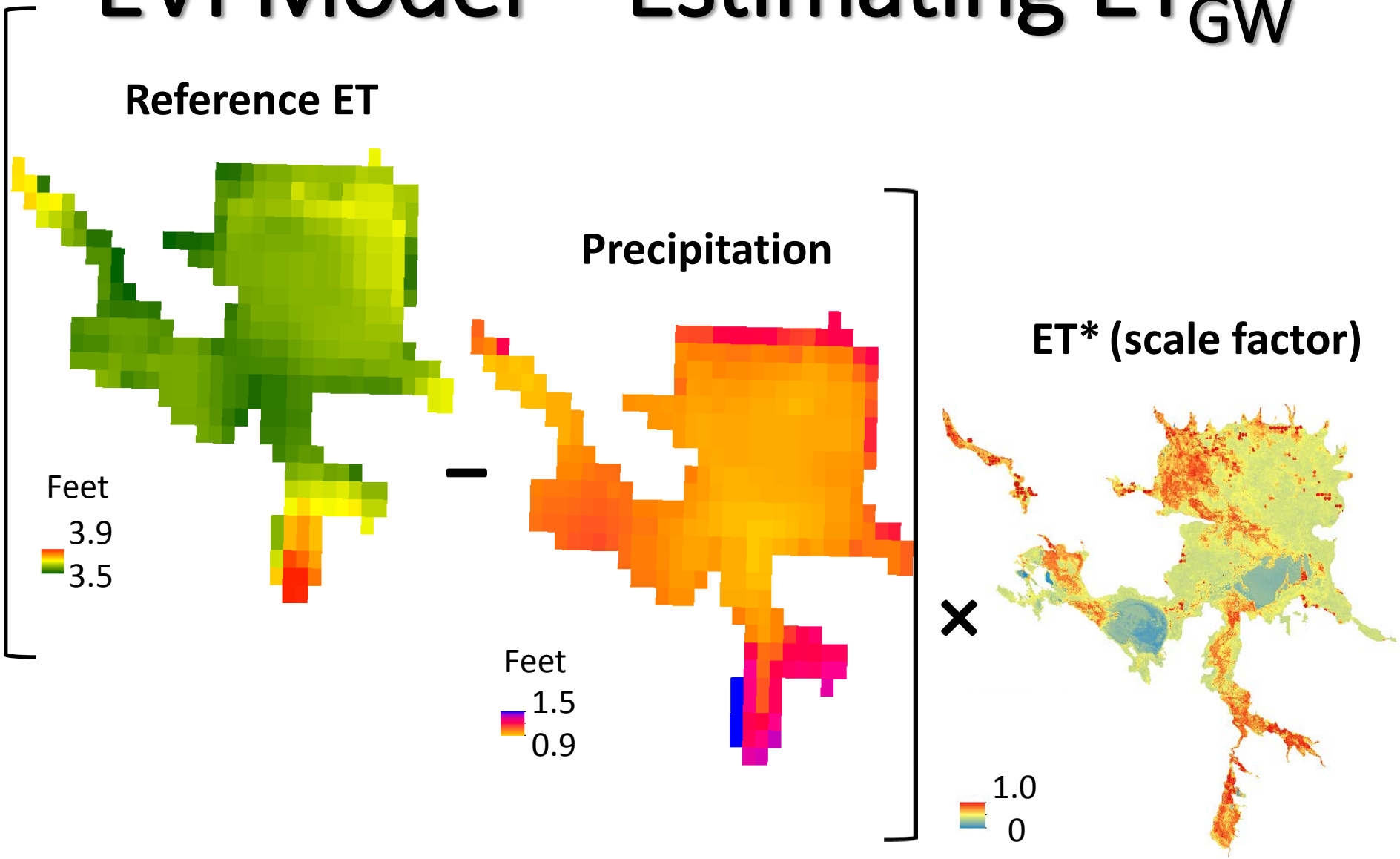
Enhanced Vegetation Index (EVI) model



Beamer and others (2013)

USGS

EVI Model – Estimating ET_{GW}



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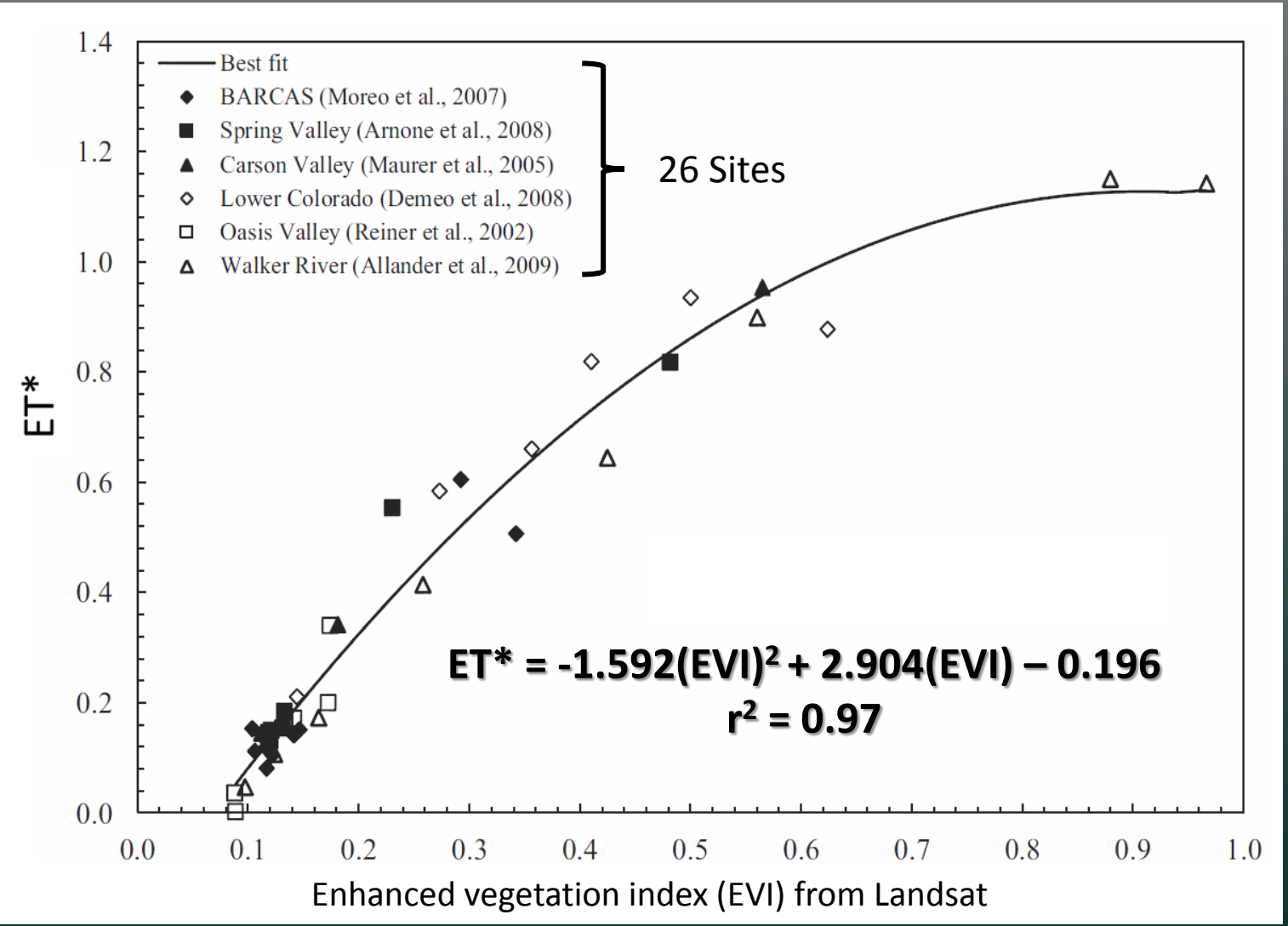
ASCE (2005)
GRIDMET weather data, Abatzoglou (2013)
Beamer and others (2013)

Unpublished data subject to revision. Do not cite.

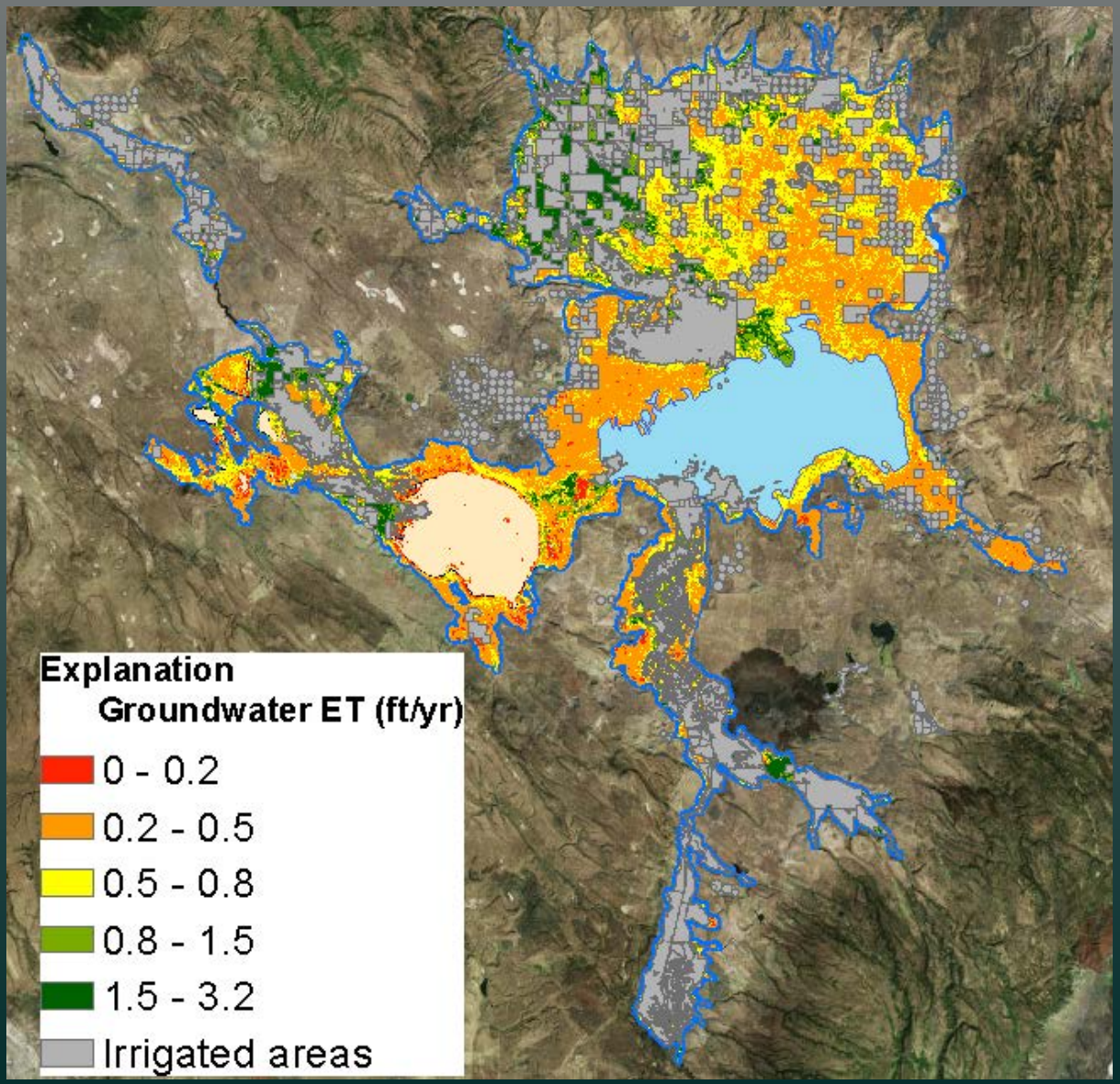
VI Model – Scale Factor (ET*)



USGS

Beamer and others (2013)

EVI Model – ET_{GW}



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Natural Groundwater Discharge by ET (Very Preliminary Estimates)

ET UNITS

- 180,000 - 220,000 AFY
- Estimated using published ET_{GW} rates

ET-EVI MODEL

- 220,000 – 240,000 AFY
- Estimated from single representative Landsat scene

- **Estimates similar to each other**
- **Within range of previous estimates (170,000 – 260,000 AFY)**
- **Need refinement**

Next Steps for ET Refinement

- **Refine mapped vegetation areas**
- **Evaluate EVI model across multiple years**
- **Evaluate portion of SW-irrigated areas using GW**
- **Compare/scale estimates with ET measurements in Harney Basin**

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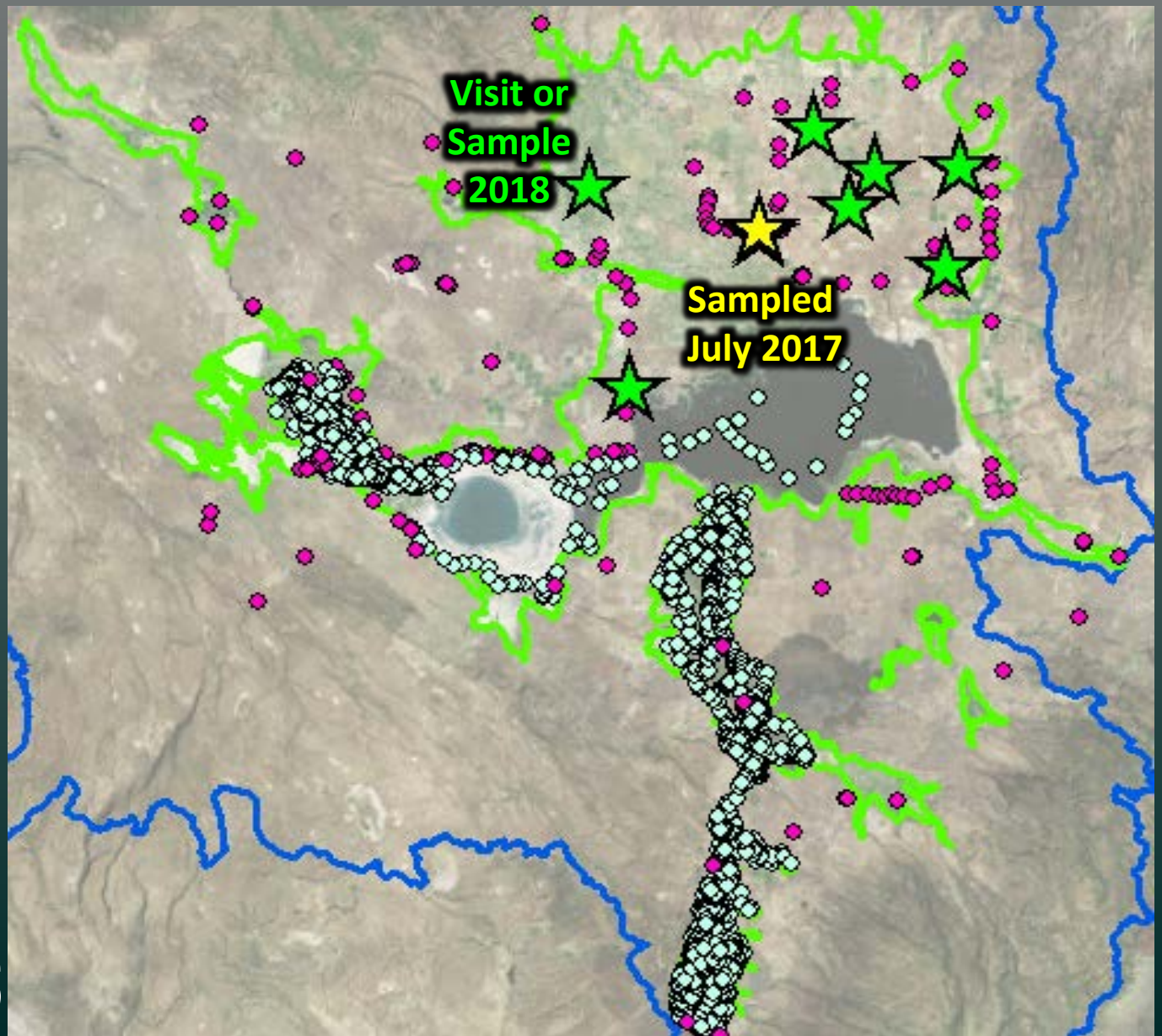
Field Verification of Mapped Vegetation



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Distinguish Vegetation Type Using small Unmanned Aerial Systems (sUAS)

- USGS pilot study
- Map vegetation using sUAS
- Small (18” x 18”) quadcopter
- Collect high-resolution multispectral imagery (similar to Landsat)
- Imagery will improve automated vegetation classification

Photo: USGS National UAS Office

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Water Budget Road Map

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Image source: openclipart.org

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