USGS
science for a changing world

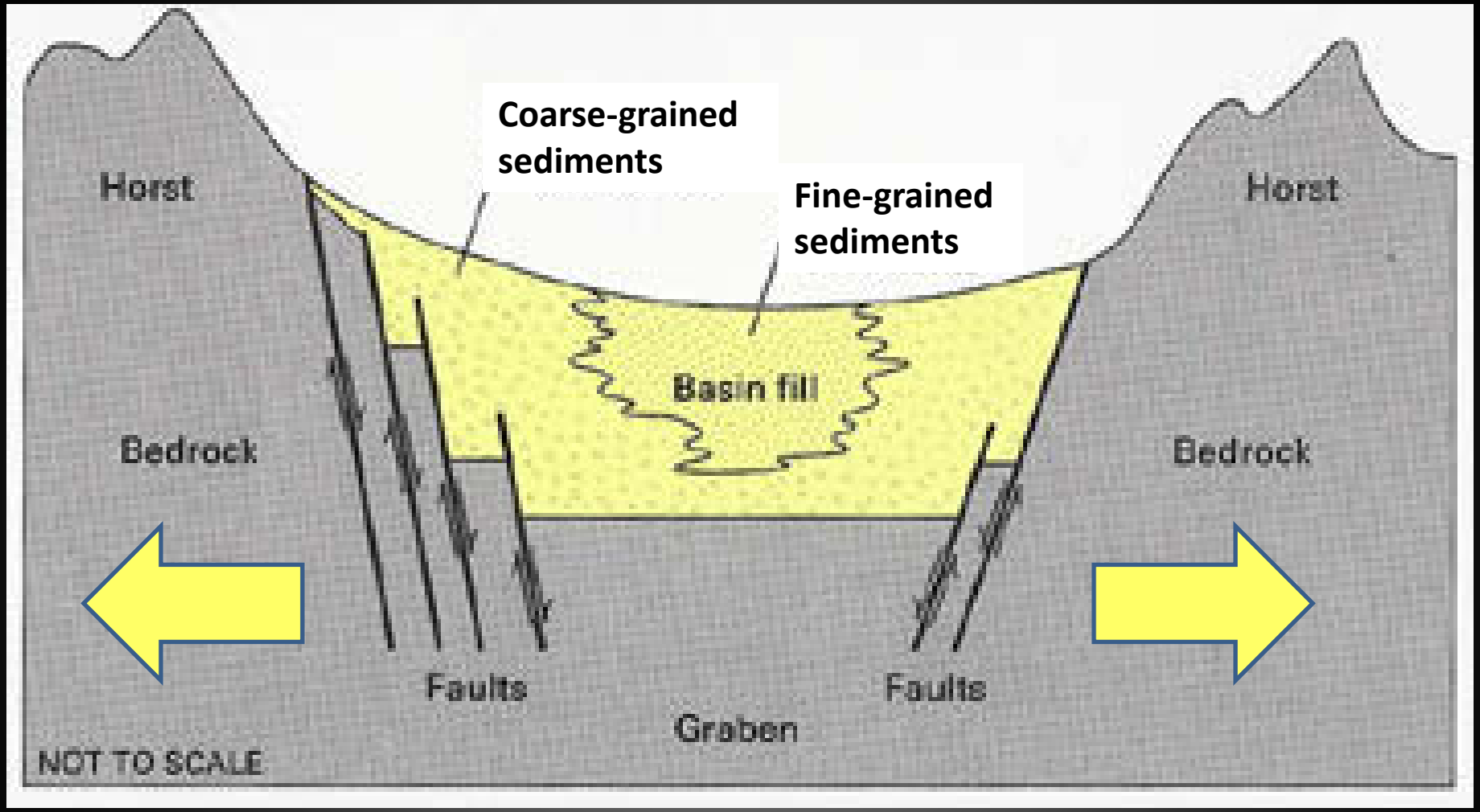
# Hydrology of Closed-Basin Drainages

Harney Basin Study Advisory Committee
20 April 2017

Hank Johnson, U.S. Geological Survey

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


**Image credit:**
By Kmusser - Own work, Elevation data from SRTM, all other features from the National Atlas. Rand McNally, The New International Atlas, 1993 used as reference., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=12079426




USGS

**Image credit:**
Robson, S. G and Banta, E.R., 1995, Ground Water Atlas of the United States: Arizona, Colorado, New Mexico, Utah: U.S. Geological Survey Hydrologic Atlas 730-C.

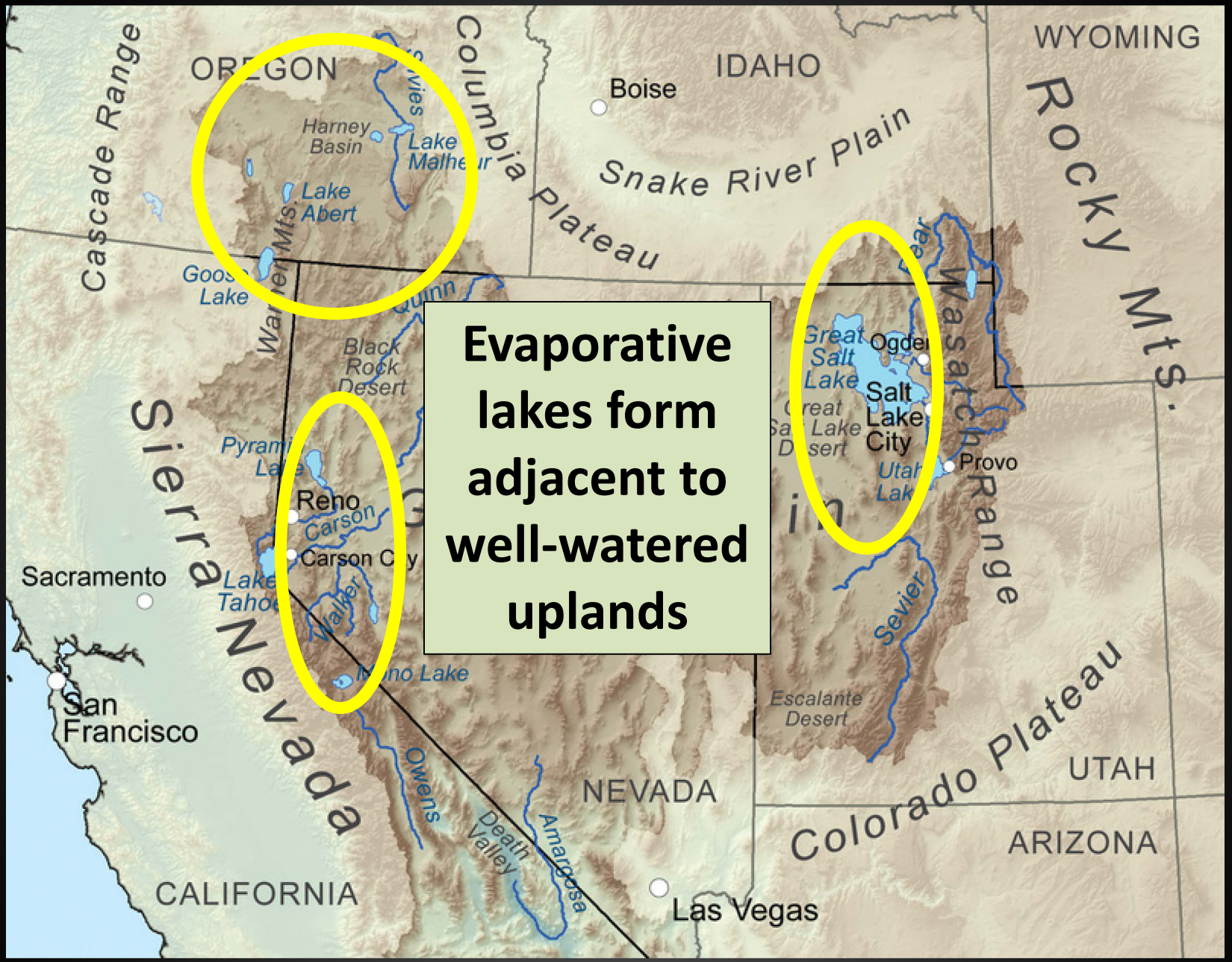
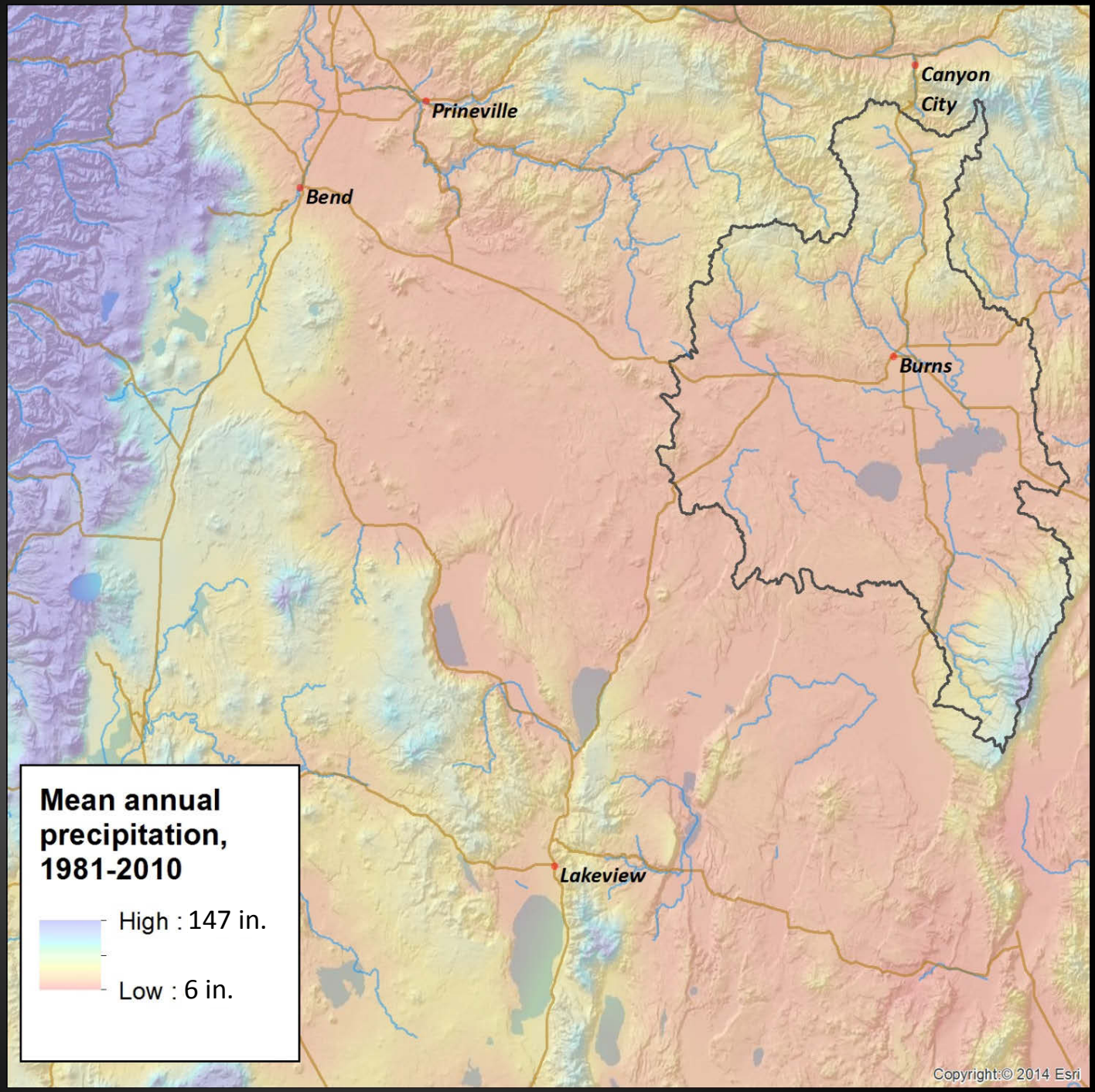
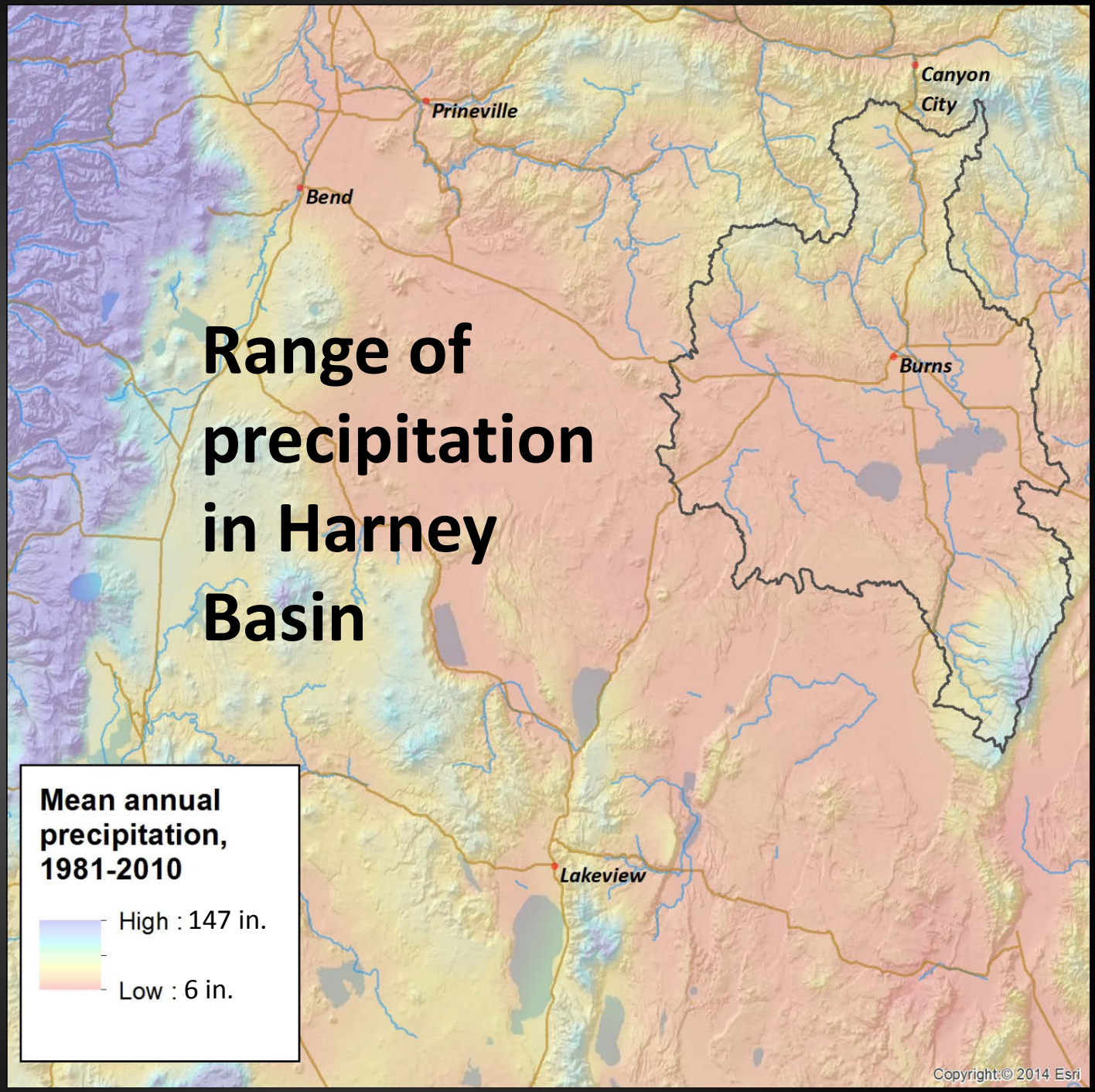


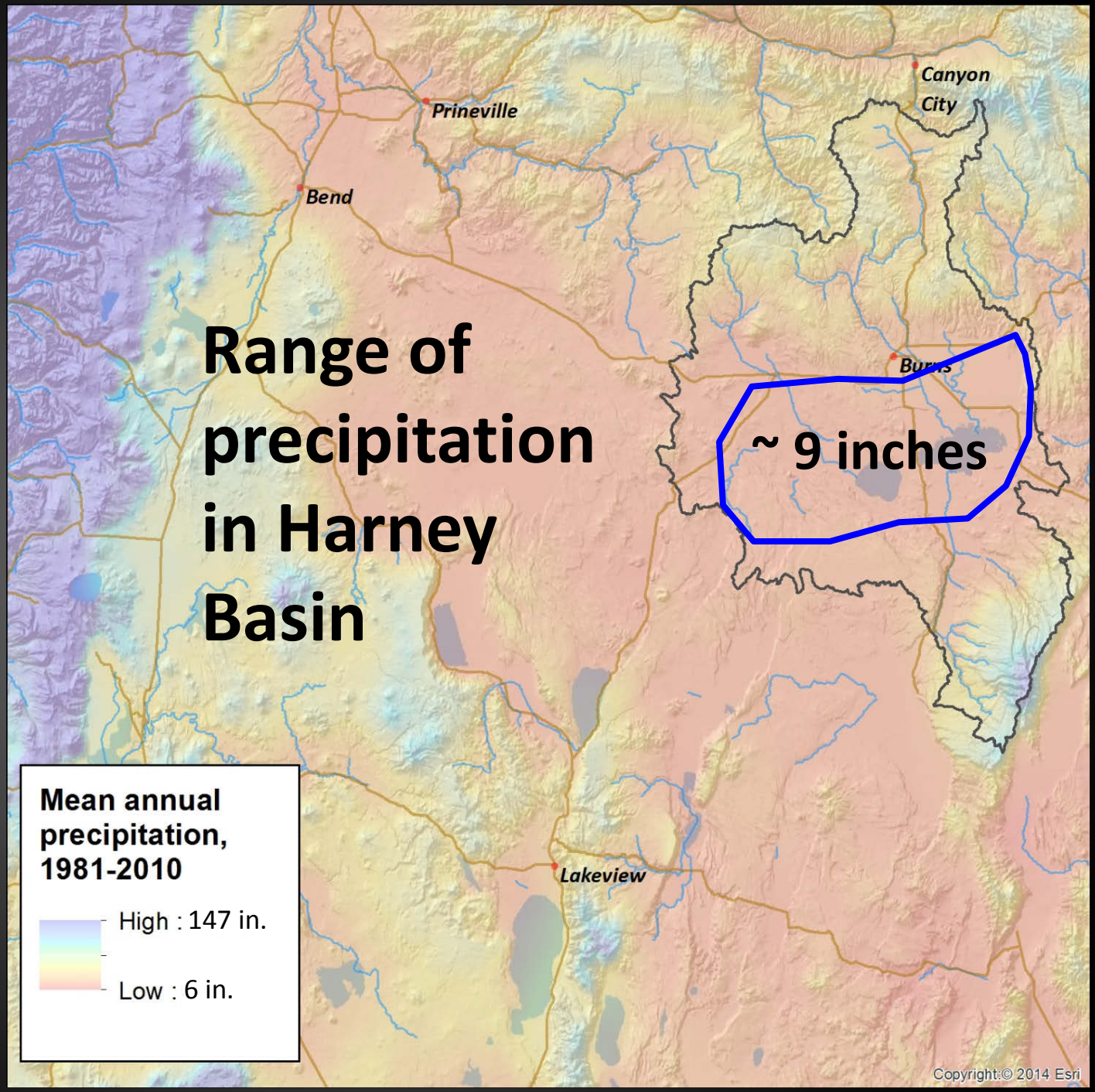

**Image credit:**
By Kmusser - Own work, Elevation data from SRTM, all other features from the National Atlas. Rand McNally, The New International Atlas, 1993 used as reference., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=12079426

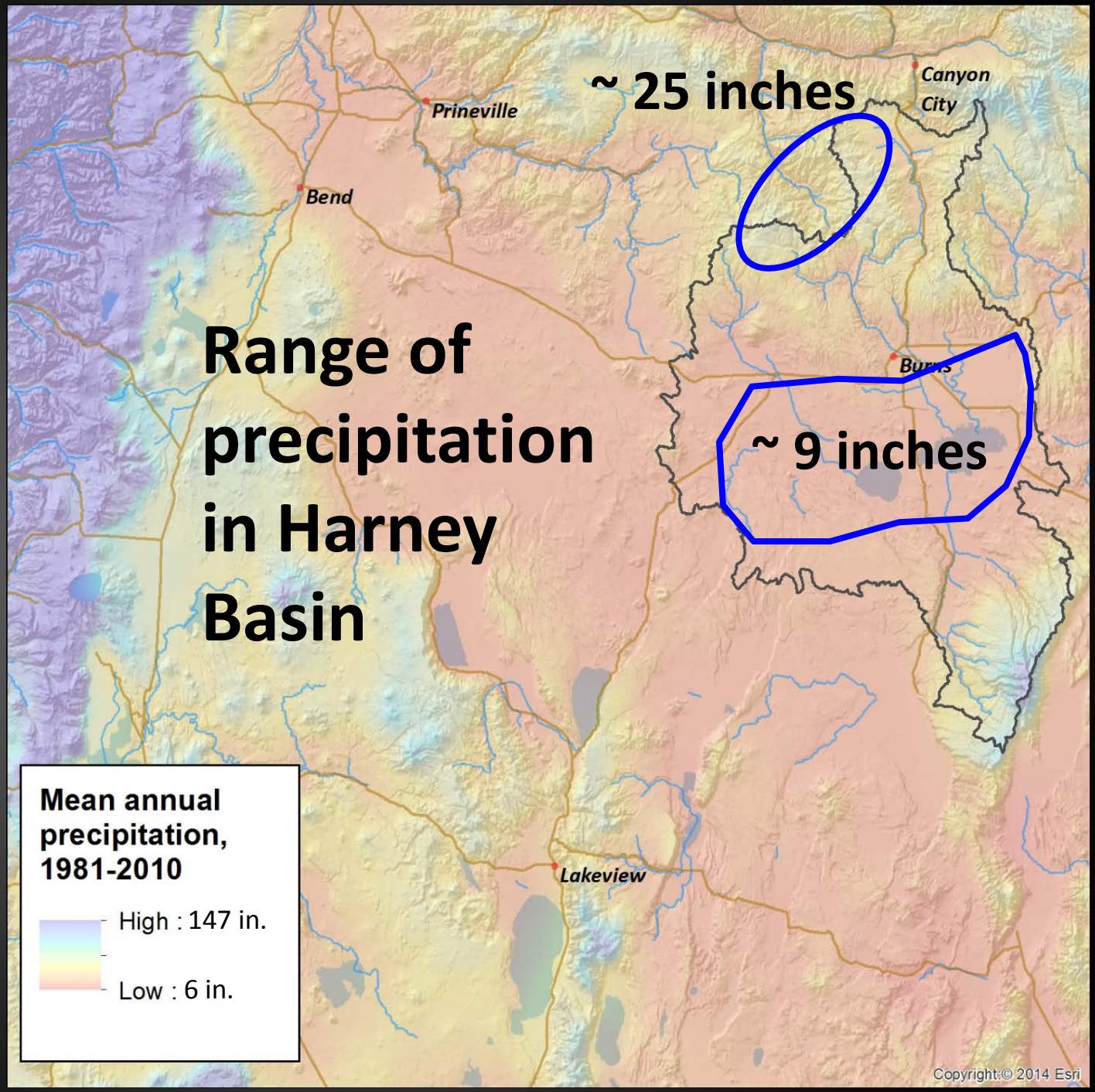
# Arid with islands of moisture



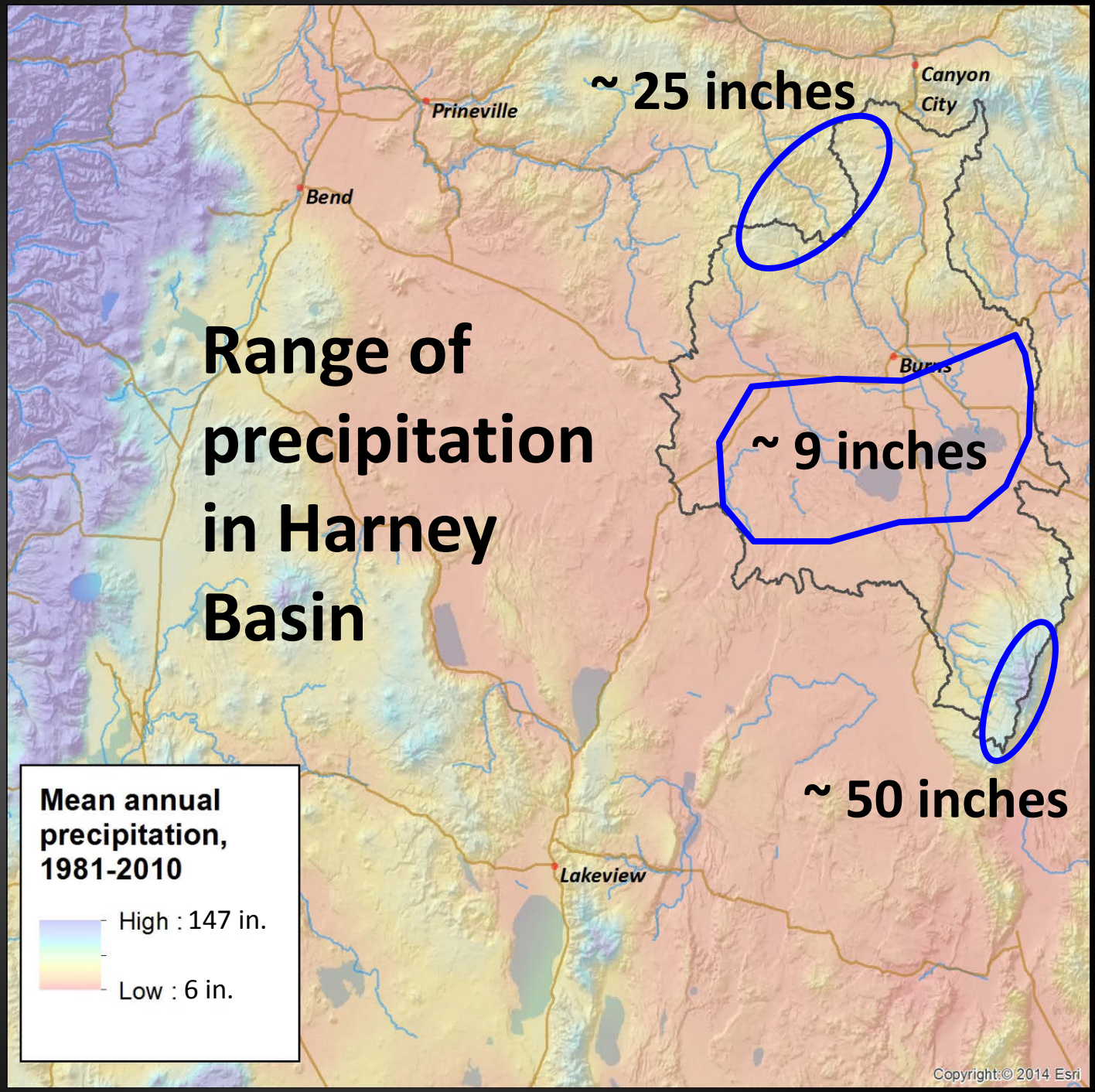

USGS


Canyon City
Prineville
Bend
Burns
Lakeview
Range of precipitation in Harney Basin
Mean annual precipitation, 1981-2010
High : 147 in.
Low : 6 in.
Copyright© 2014 Esri


Canyon City
Prineville
Bend
Burns
Lakeview
Range of precipitation in Harney Basin
~ 9 inches
Mean annual precipitation, 1981-2010
High : 147 in.
Low : 6 in.
Copyright© 2014 Esri


~ 25 inches
Canyon City
Prineville
Bend
Range of precipitation in Harney Basin
Burns
~ 9 inches
Mean annual precipitation, 1981-2010
High : 147 in.
Low : 6 in.
Lakeview
Copyright© 2014 Esri

USGS


~ 25 inches
Canyon City
Prineville
Bend
Range of precipitation in Harney Basin
~ 9 inches
Burns
~ 50 inches
Lakeview
Mean annual precipitation, 1981-2010
High : 147 in.
Low : 6 in.
Copyright© 2014 Esri

USGS

Winter Ridge and Summer Lake

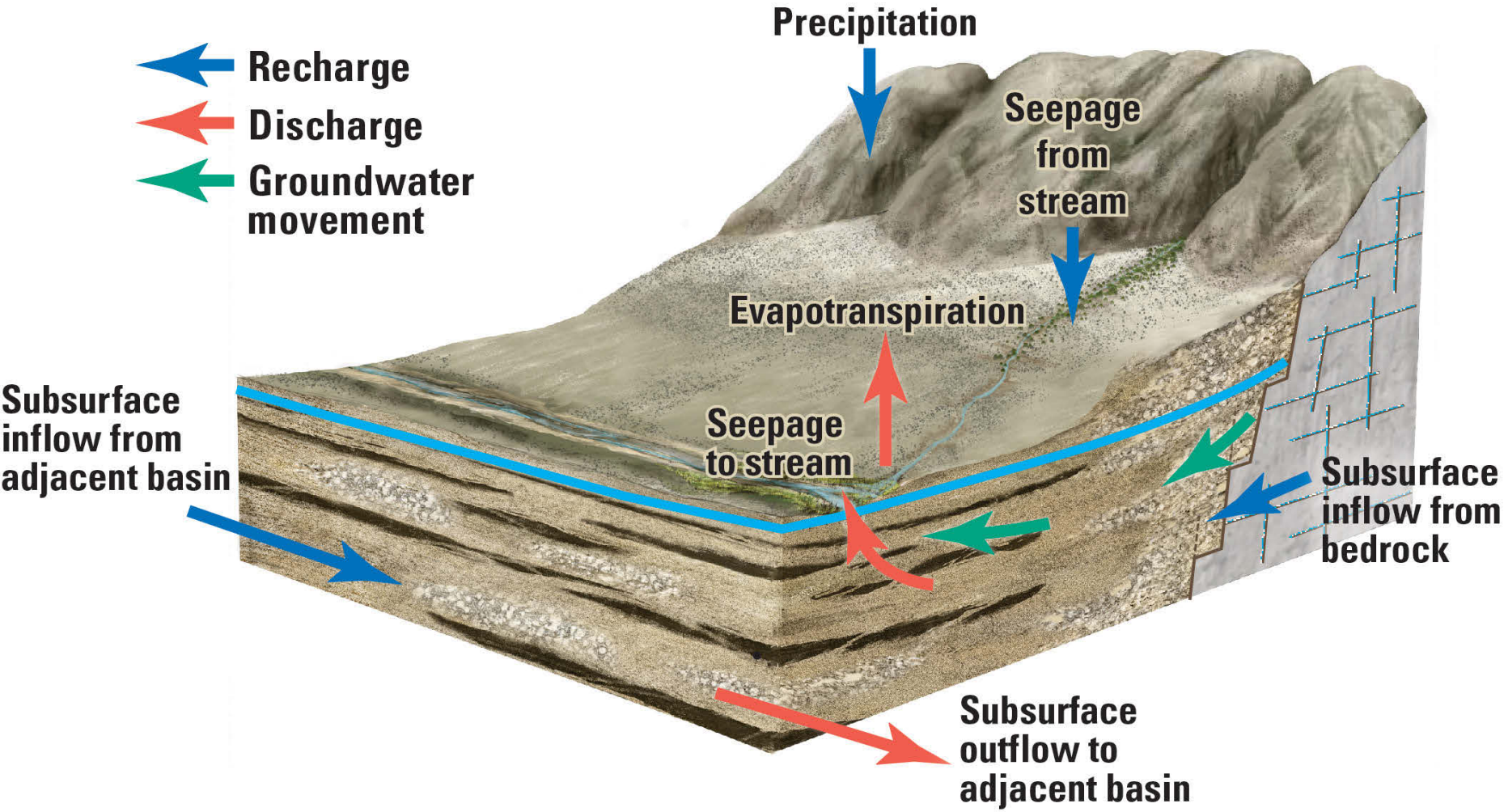
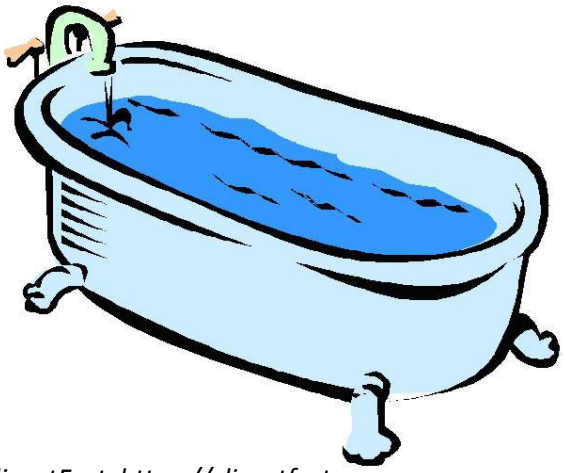



*Figure modified from: Thiros, S.A., Paul, A.P., Bexfield, L.M., and Anning, D.W., 2014, The quality of our Nation's waters: Water quality in basin-fill aquifers of the southwestern United States: Arizona, California, Colorado, Nevada, New Mexico, and Utah, 1993-2009: U.S. Geological Survey Circular 1358, 113 p.*

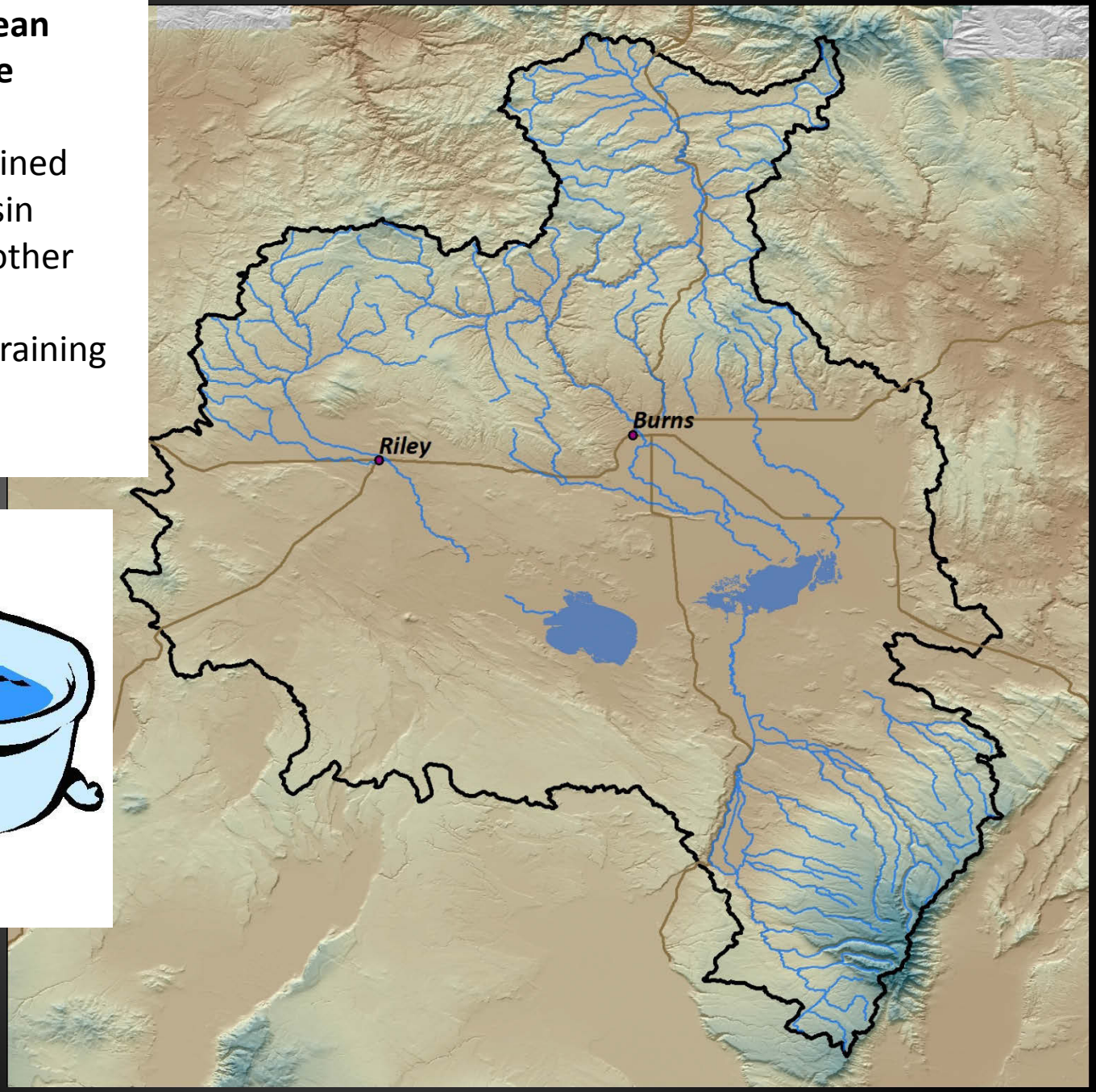
USGS

**What do hydrologists mean when they talk about the Harney Basin?**

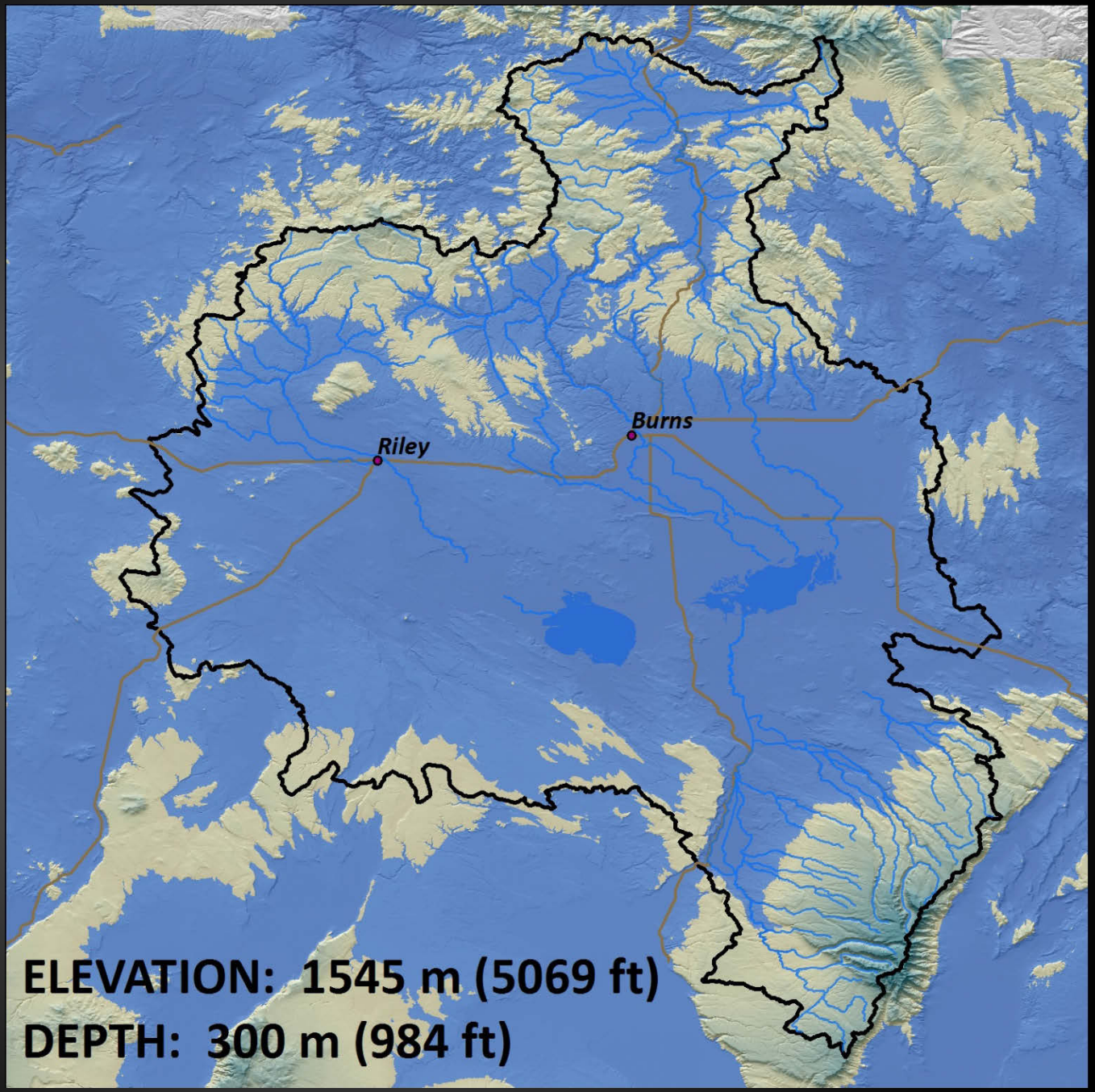
- Topographically contained
- Water outside the basin boundary flows in another direction
- Can be visualized as draining a bathtub



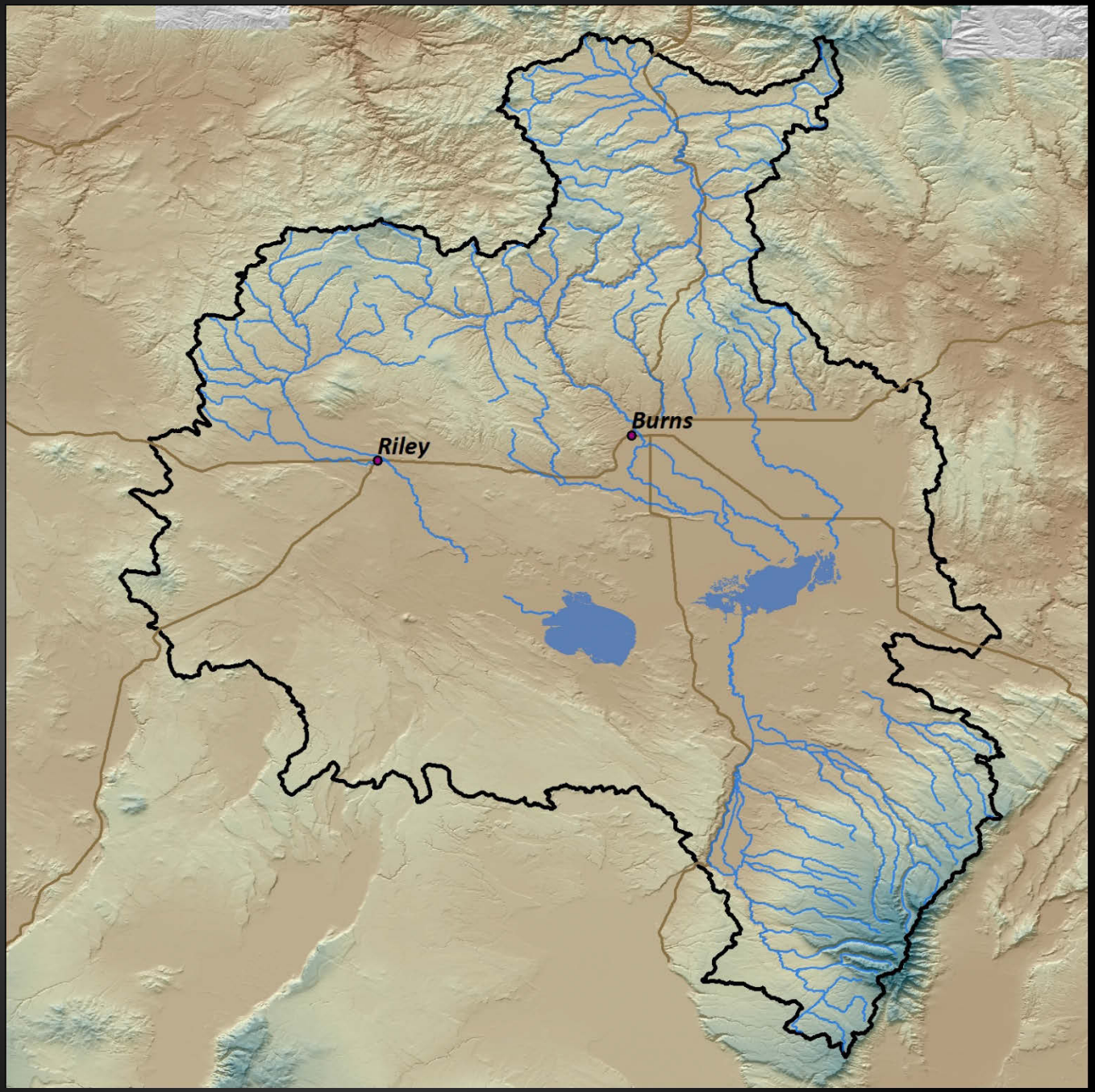
*ClipartFest, https://clipartfest.com*




USGS




USGS




USGS

# Hydrologic Budget

*Image source: Microsoft PowerPoint Clip Art Gallery*
*Used with permission from Microsoft.*

USGS

# IN


# OUT


*Image sources: Microsoft PowerPoint Clip Art Gallery*
*Used with permission from Microsoft.*

# NET CHANGE IN ACCOUNT

USGS

# Hydrologic Budget

IN = OUT ± CHANGE
IN
STORAGE

*Image source: Microsoft PowerPoint Clip Art Gallery*
*Used with permission from Microsoft.*

USGS

# Hydrologic Budget

IN = OUT ± CHANGE IN STORAGE

**IN**

- Precipitation (Recharge)
- Interbasin groundwater flow
- Interbasin transfer of water

**OUT**

- Streamflow
- Evapotranspiration (ET)
- Interbasin groundwater flow
- Interbasin transfer of water
- Commodity export

USGS

# Hydrologic Budget

IN = OUT ± CHANGE IN STORAGE

**IN**

- Precipitation (Recharge)
- Interbasin groundwater flow
- ~~Interbasin transfer of water~~

**OUT**

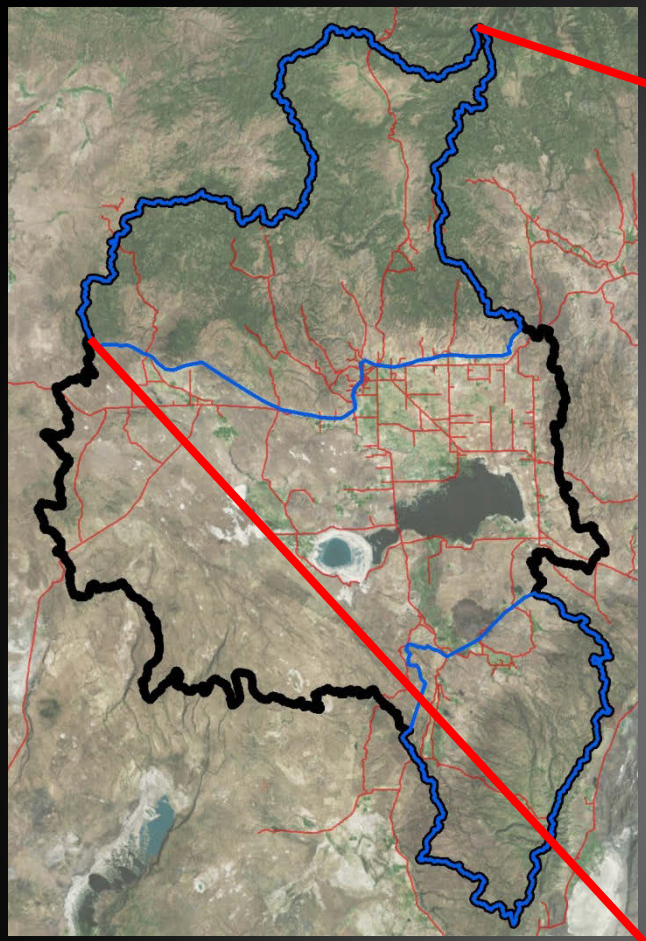
- ~~Streamflow~~
- Evapotranspiration (ET)
- Interbasin groundwater flow
- ~~Interbasin transfer of water~~
- ~~Commodity export~~

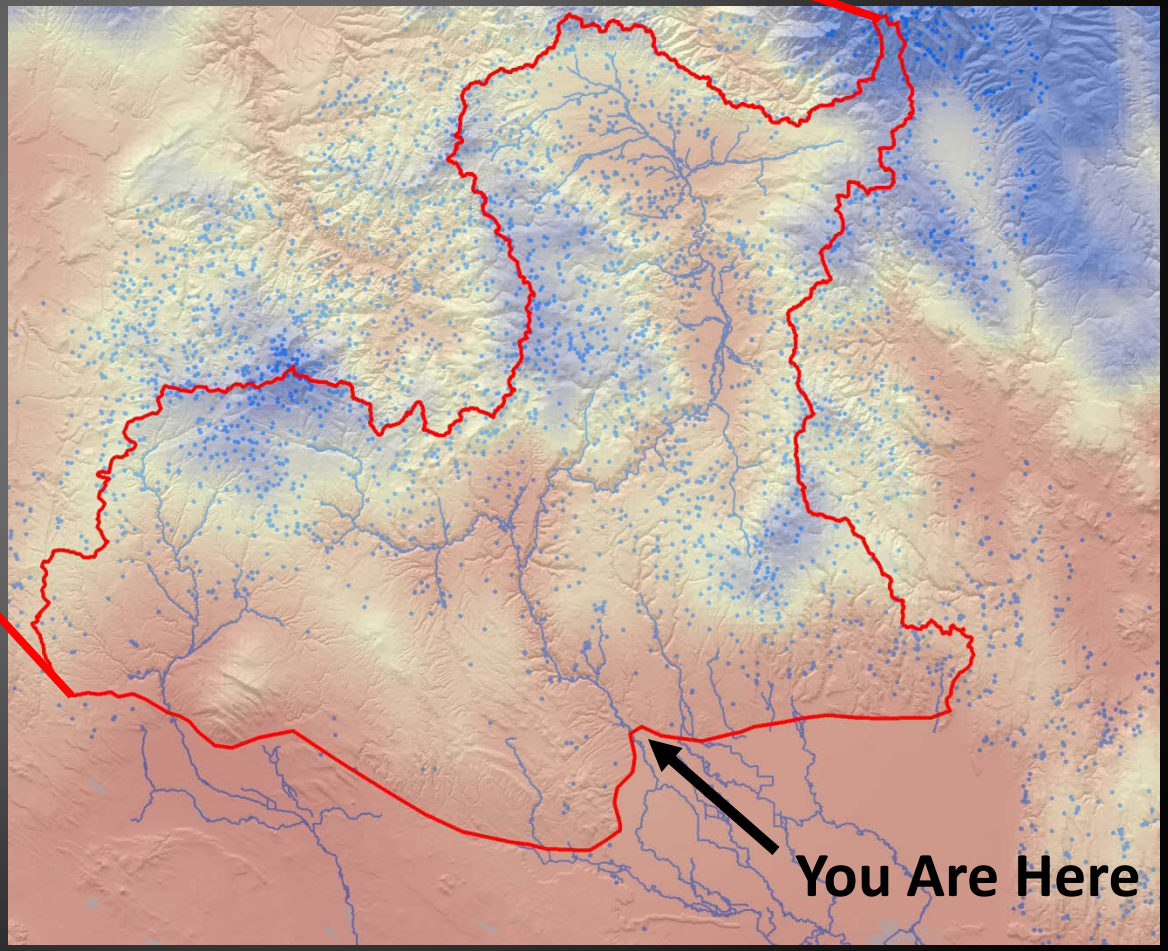
USGS

# A
# VERY PRELIMINARY
# Water Budget for the Blue Mountains and Steens Mountain Recharge Areas

USGS

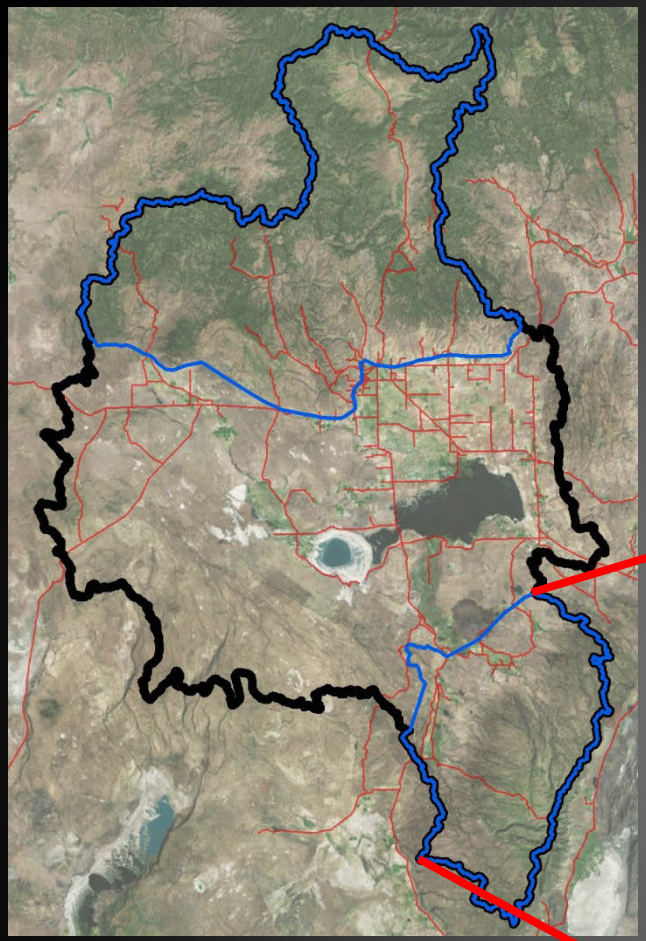
# BLUE MOUNTAINS RECHARGE AREA

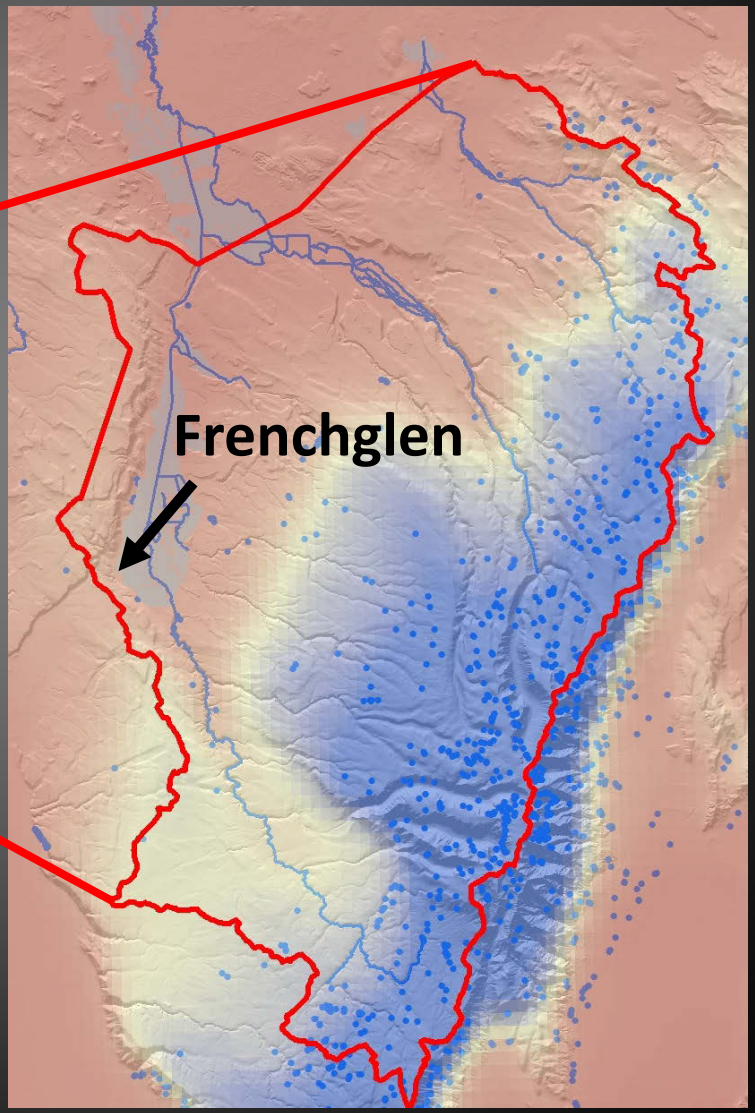





USGS

# STEENS MOUNTAIN RECHARGE AREA






USGS

# IN = OUT ± CHANGE IN STORAGE

| | – PROVISIONAL DATA – SUBJECT TO REVISION | Blue Mountains | Steens Mountain |
|---|---|---|---|
| IN | Precipitation | | |
| | | | |
| OUT | Evapotranspiration (ET) | | |
| | Streamflow | | |
| | | | |
| | DIFFERENCE | | |

USGS

# IN = OUT ± CHANGE IN STORAGE

| | – PROVISIONAL DATA – SUBJECT TO REVISION | Blue Mountains | Steens Mountain |
|---|---|---|---|
| IN | Precipitation | 18” | |
| | | | |
| OUT | Evapotranspiration (ET) | 5” | |
| | Streamflow | 2” | |
| | | | |
| | DIFFERENCE | 11” | |

USGS

# IN = OUT ± CHANGE IN STORAGE

| | – PROVISIONAL DATA – SUBJECT TO REVISION | Blue Mountains | Steens Mountain |
|---|---|---|---|
| IN | Precipitation | 18” | 22” |
| | | | |
| OUT | Evapotranspiration (ET) | 5” | 2” |
| | Streamflow | 2” | 4” |
| | | | |
| | DIFFERENCE | 11” | 16” |

USGS

# IN = OUT ± CHANGE IN STORAGE

| | – PROVISIONAL DATA – SUBJECT TO REVISION | Blue Mountains | Steens Mountain |
|---|---|---|---|
| IN | Precipitation | 18” | 22” |
| | | | |
| OUT | Evapotranspiration (ET) | 5” | 2” |
| | Streamflow | 2” | 4” |
| | | | |
| | DIFFERENCE | 11” | 16” |

Groundwater recharge
Sublimation of snow
Error

USGS

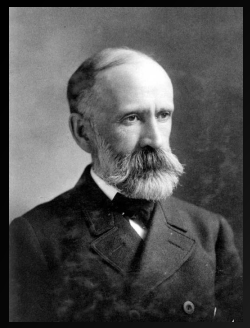
# “Recharge” as Percent of Precipitation

| Preliminary Calculations for Harney Basin | | |
|---|---|---|
| Blue Mountains | 61% | |
| Steens Mountains | 73% | |
| | | |
| **Other Studies** | | |
| Upper Umatilla Basin | 36% | Herrera and other, in press |
| Klamath Basin | 20% | Gannett and others, 2009 |
| Deschutes Basin | 35-40% | Gannett and others, 2001 |

**Underestimate of ET is the likely culprit**

USGS

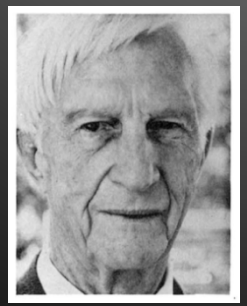
preliminary data, subject to revision



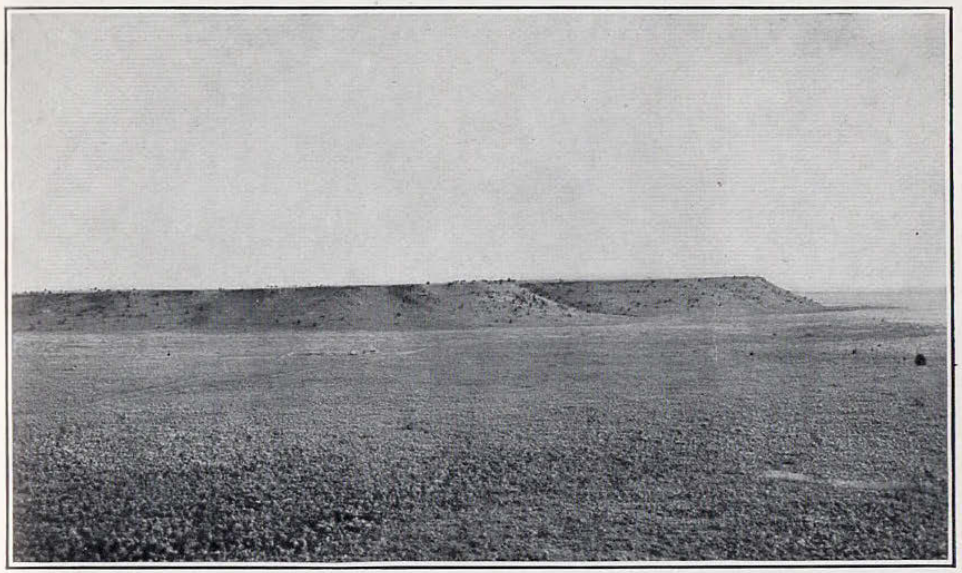

## Pre-Development

- LOTS of variability – annual, decadal, even centuries
- On average, the water budget was balanced

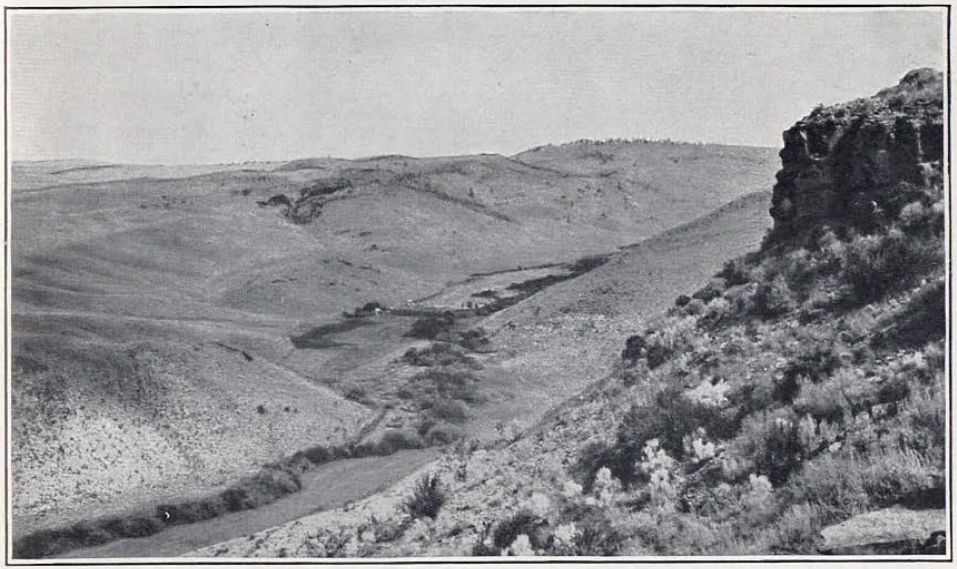
## Quasi-Equilibrium



USGS




*A.* CHARACTERISTIC SCARP AT WEST EDGE OF HARNEY VALLEY.



*B.* VALLEY OF RATTLESNAKE CREEK ABOVE HARNEY.

## Surface water diversion and irrigation

- Some effect on ET

## Groundwater development

- Large increases in ET
- Depletion of storage = declining GW levels


USGS

# Hydrologic Budget

IN = OUT ± CHANGE IN STORAGE

**IN**

- Precipitation (Recharge)
- Interbasin groundwater flow
- ~~Interbasin transfer of water (*e.g.* canal)~~

**OUT**

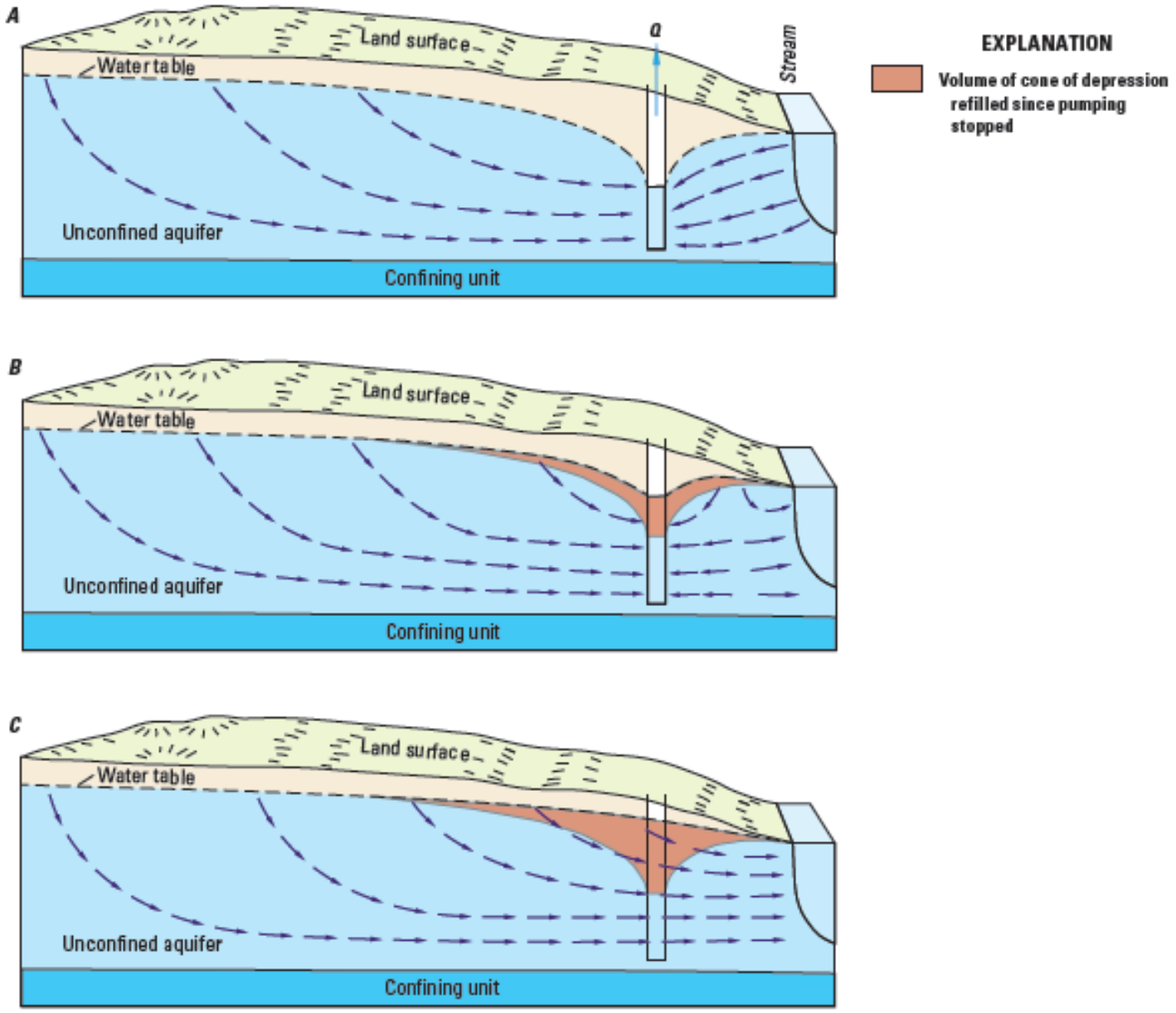
- ~~Streamflow~~
- Evapotranspiration
- Interbasin groundwater flow
- ~~Interbasin transfer of water~~
- ~~Commodity export~~

USGS

# Toward a New Quasi-Equilibrium

- Lower water levels in aquifers
- Reduction or loss of streamflow
- Reduction or loss of spring flow
- Decreasing groundwater quality
- Lower lake levels and smaller areal extent

USGS




Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells--Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, 84 p.

USGS
science for a changing world

# Investigation of the Groundwater System of the Harney Basin, Oregon

Stephen B. Gingerich

For the
Greater Harney Valley Groundwater Study
Advisory Committee
April 20, 2017

Burns, OR

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

Image from Google Earth

# Some questions to be addressed

- How much water enters the Harney Basin (recharge)?
- How much water leaves the Harney Basin (discharge)?
- How might water-level declines progress in the future?
- How can water-level declines be managed?
- How does pumping affect surface-water discharge?
- To what degree are different parts of the basin hydrologically connected?

USGS

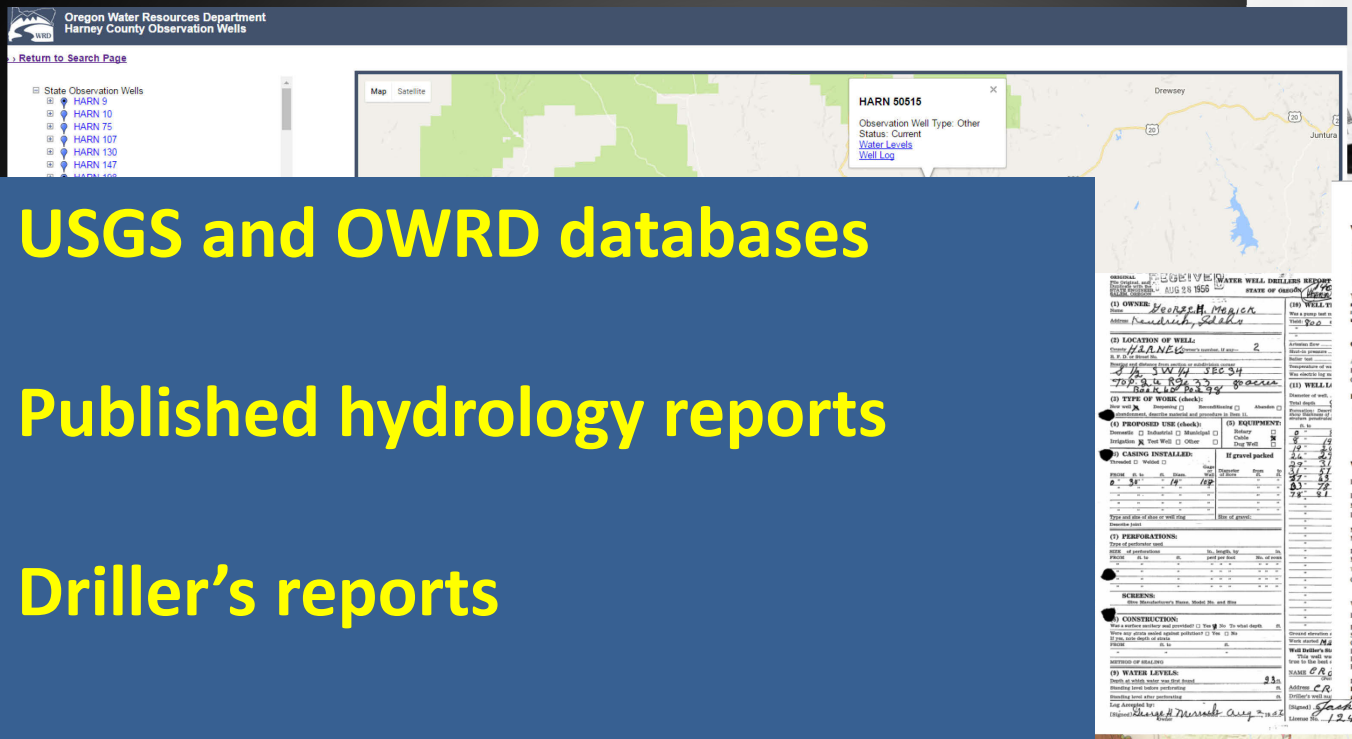
# Study Approach

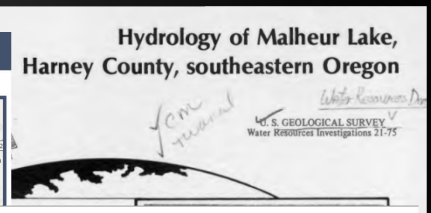
- Compile, review, and analyze existing hydrologic data
- Develop an understanding of the groundwater-flow system
- Collect additional hydrologic data in areas with gaps
- Develop hydrologic budget to estimate water flow in and out of the system
- Develop a numerical groundwater flow model to test our understanding of the flow system and evaluate management options

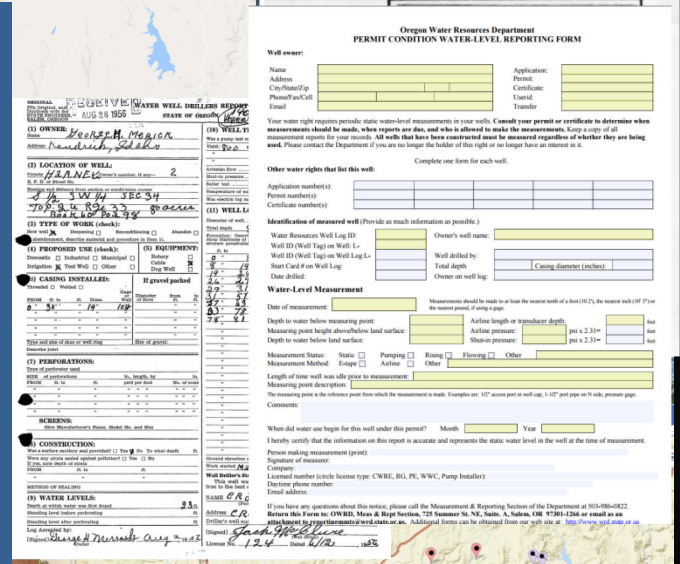
USGS

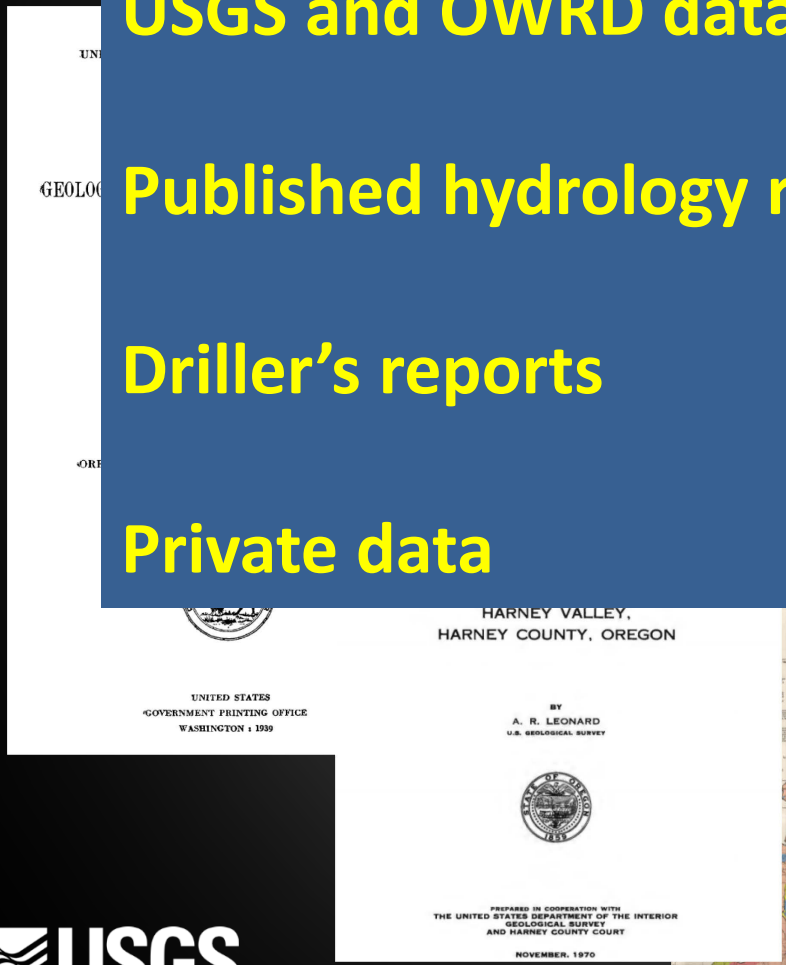
# Compile existing hydrologic data

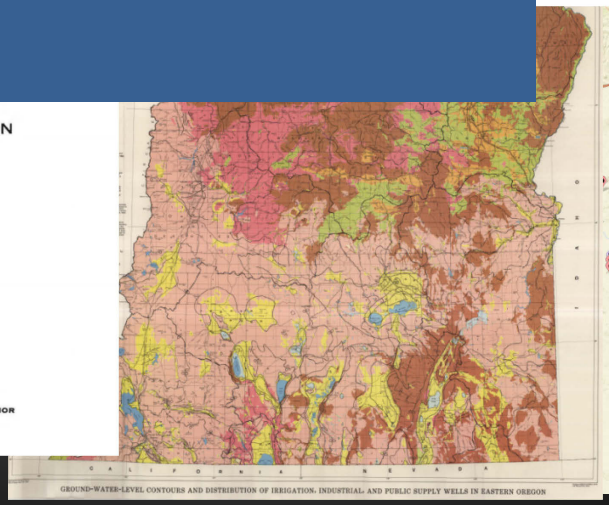
- USGS and OWRD databases
- Published hydrology reports
- Driller's reports
- Private data

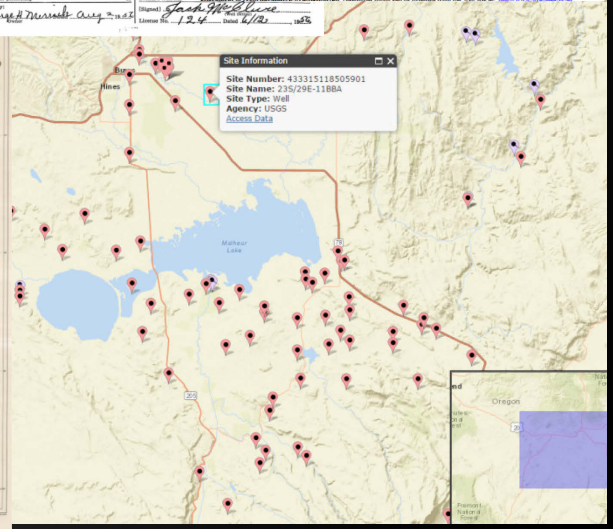


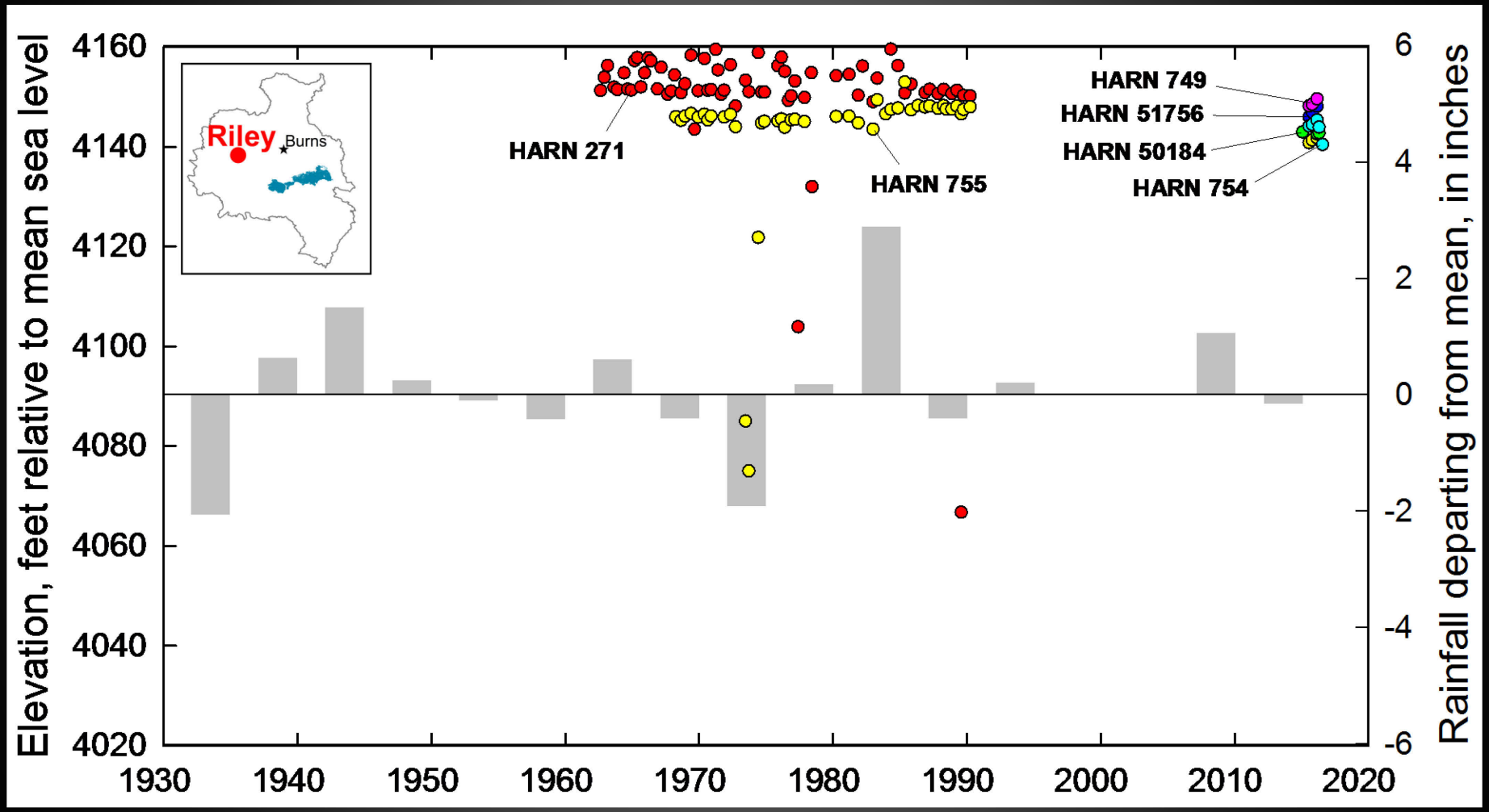




USGS

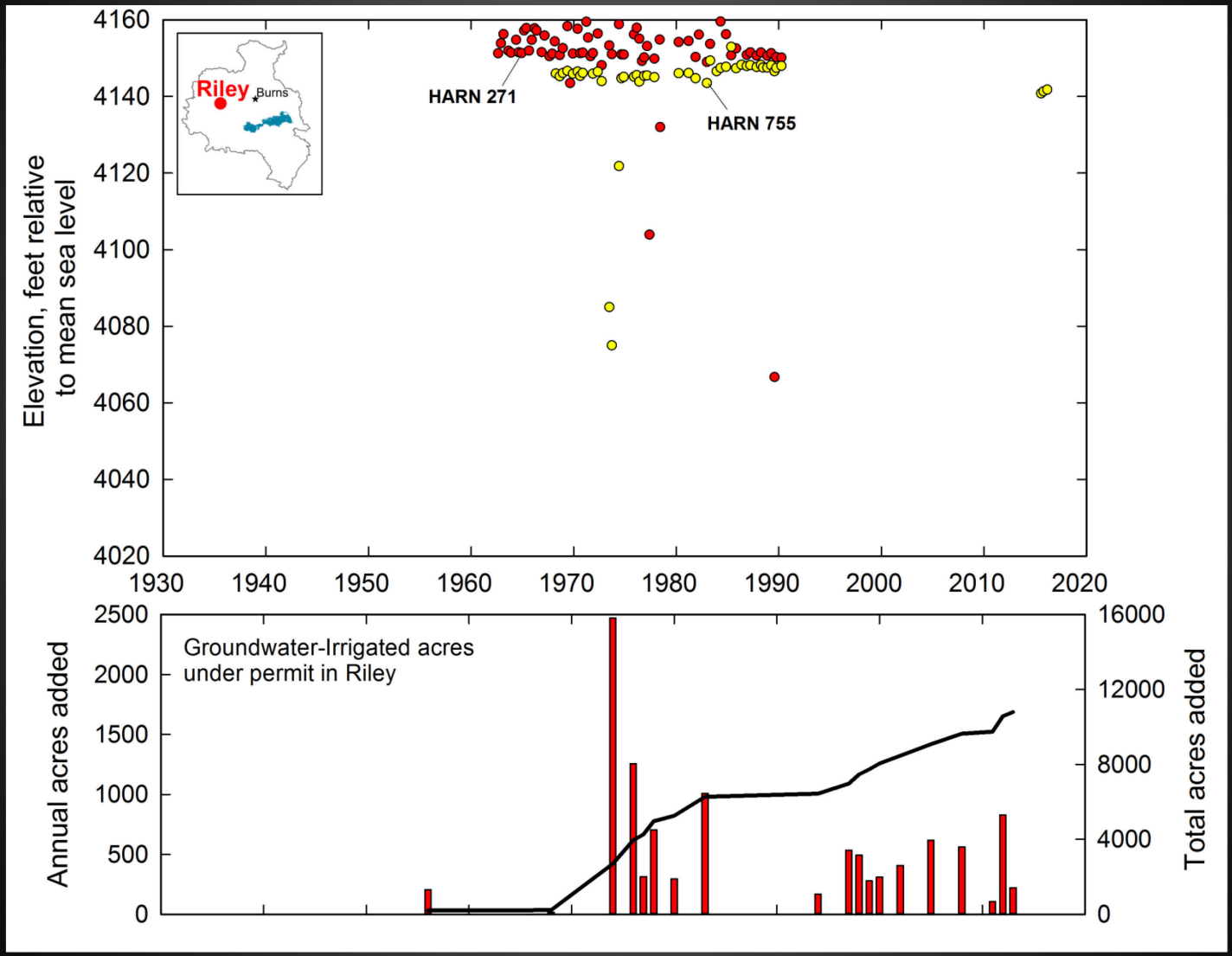
# Harney Basin water levels




USGS

preliminary data, subject to revision

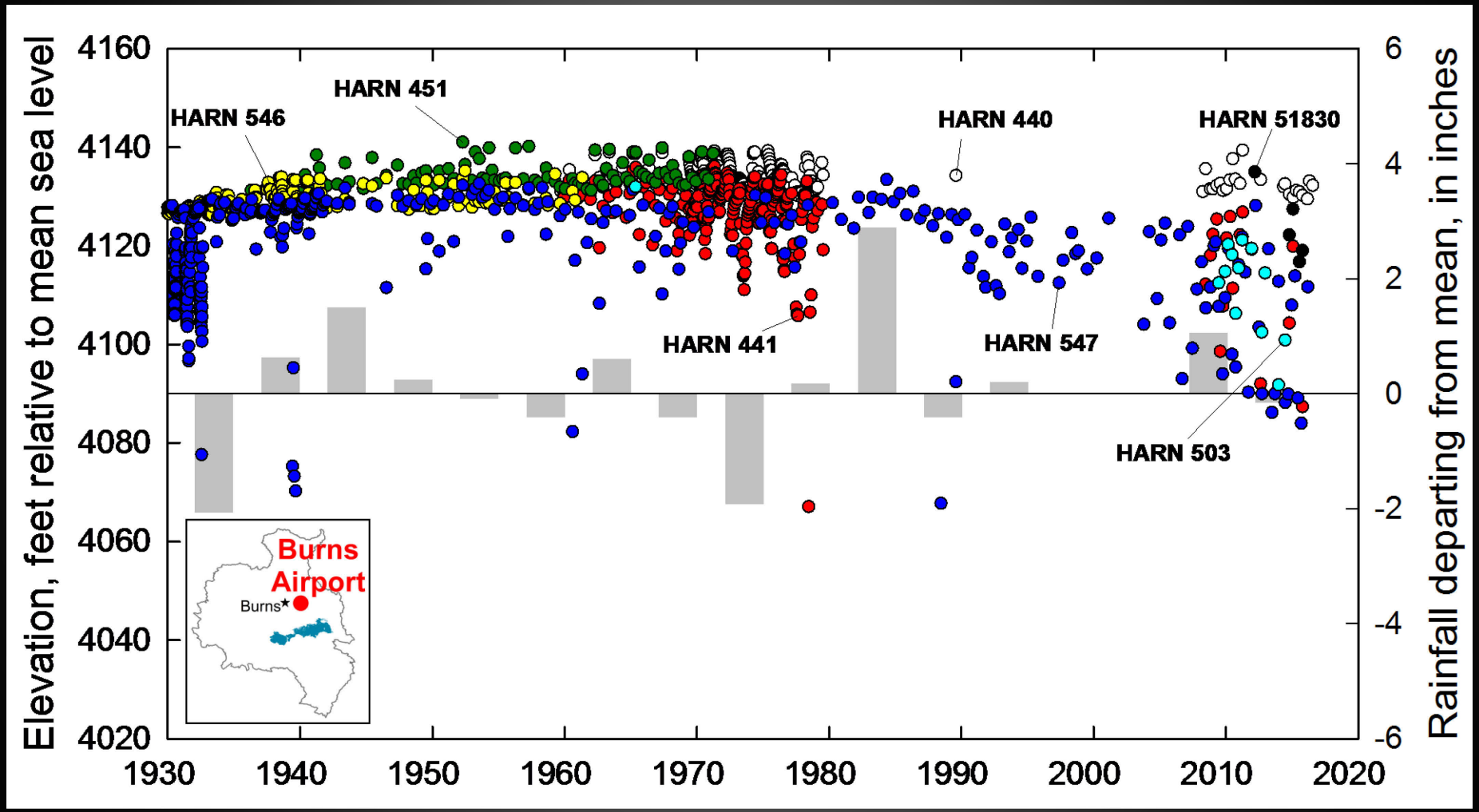
# Harney Basin water levels




USGS

preliminary data, subject to revision

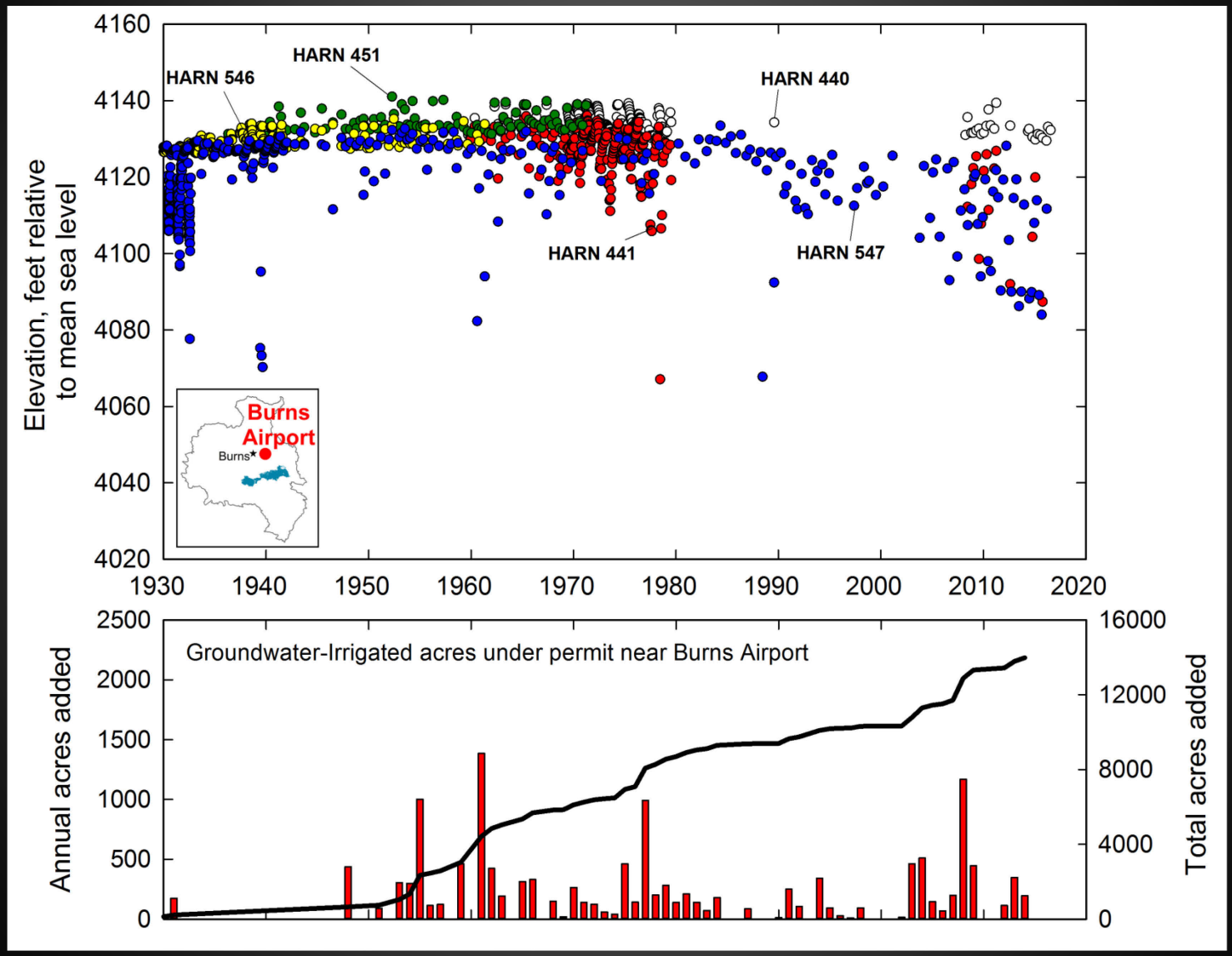
# Harney Basin water levels






preliminary data, subject to revision

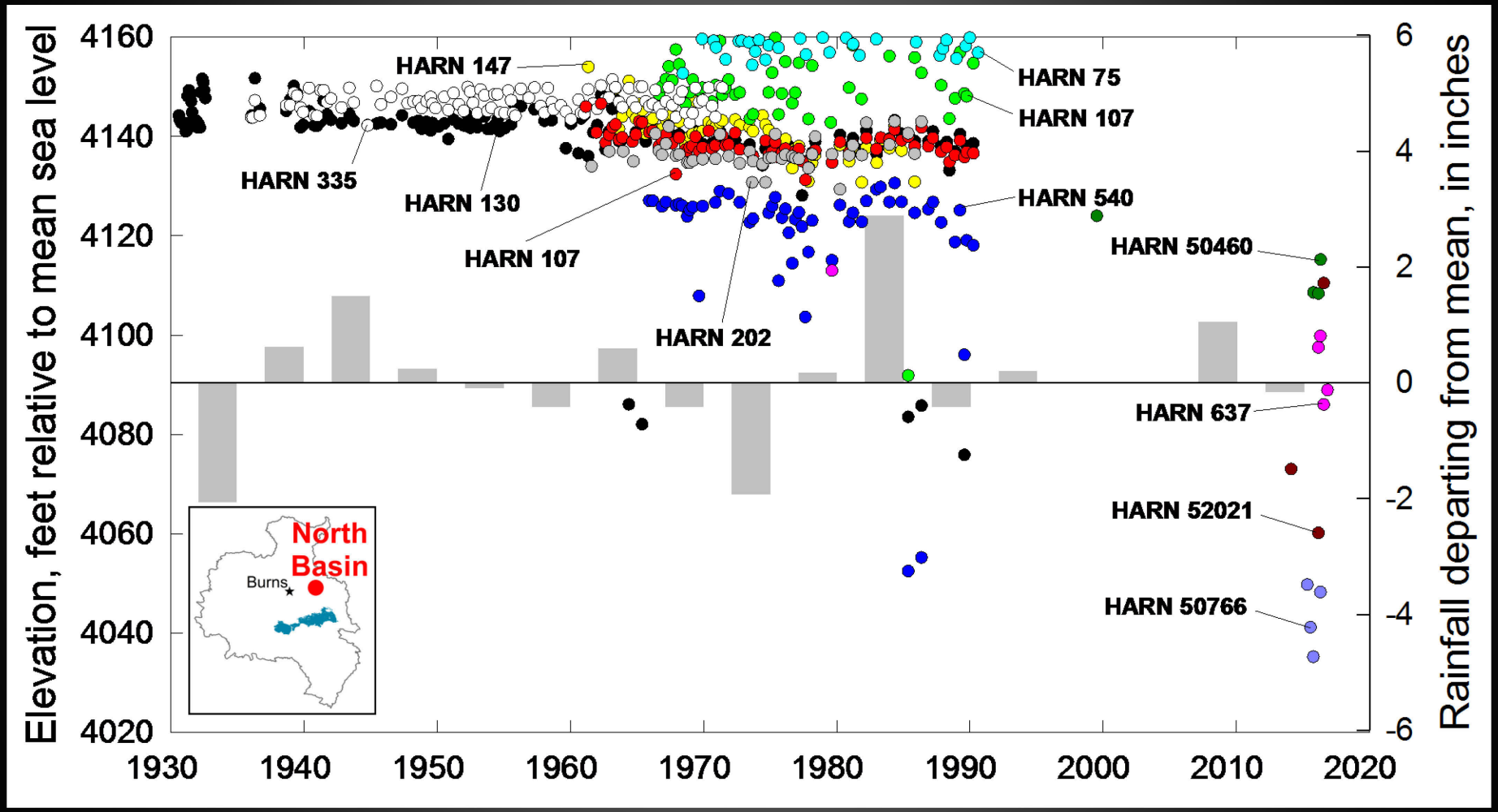
# Harney Basin water levels




USGS

preliminary data, subject to revision

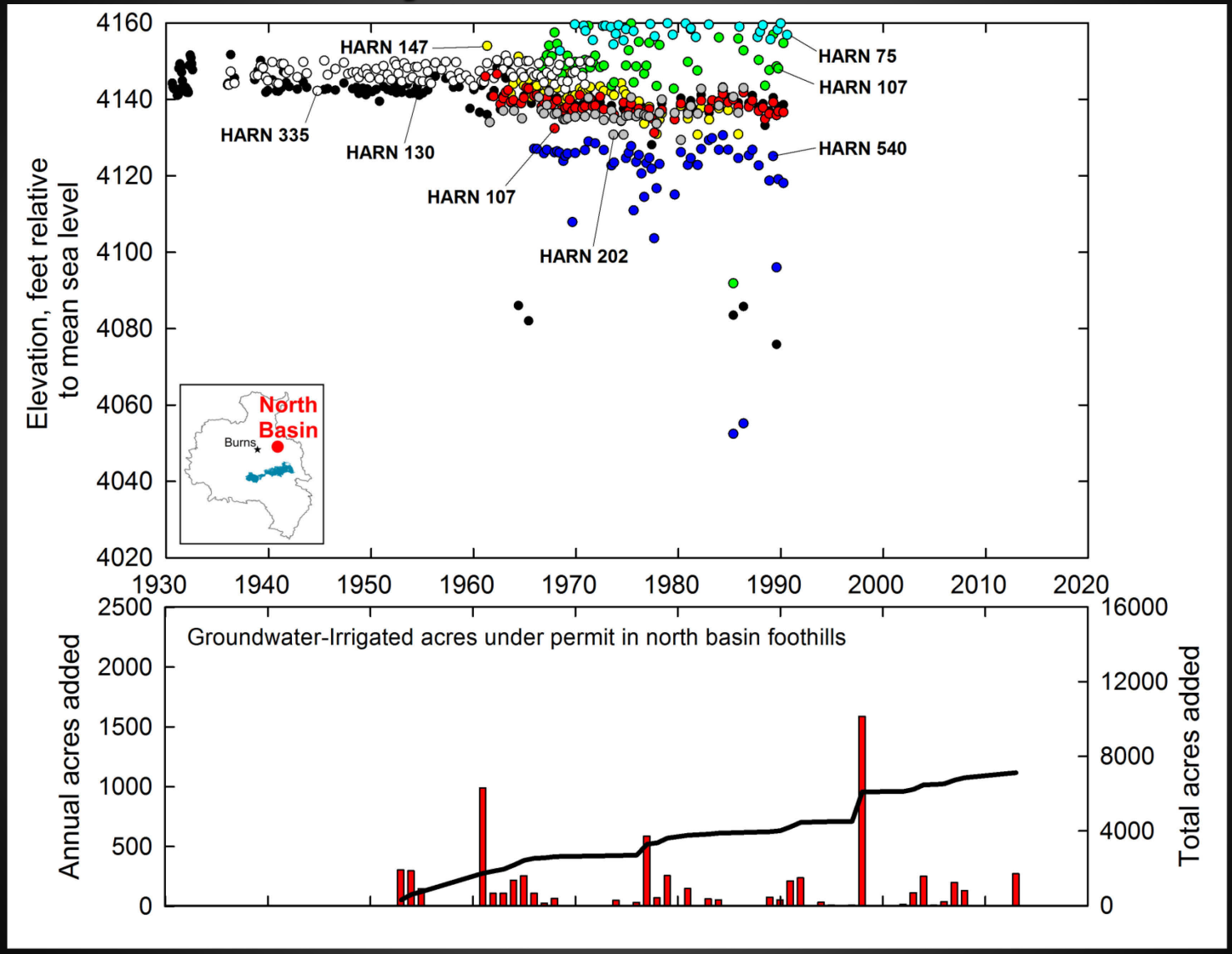
# Harney Basin water levels




USGS

preliminary data, subject to revision

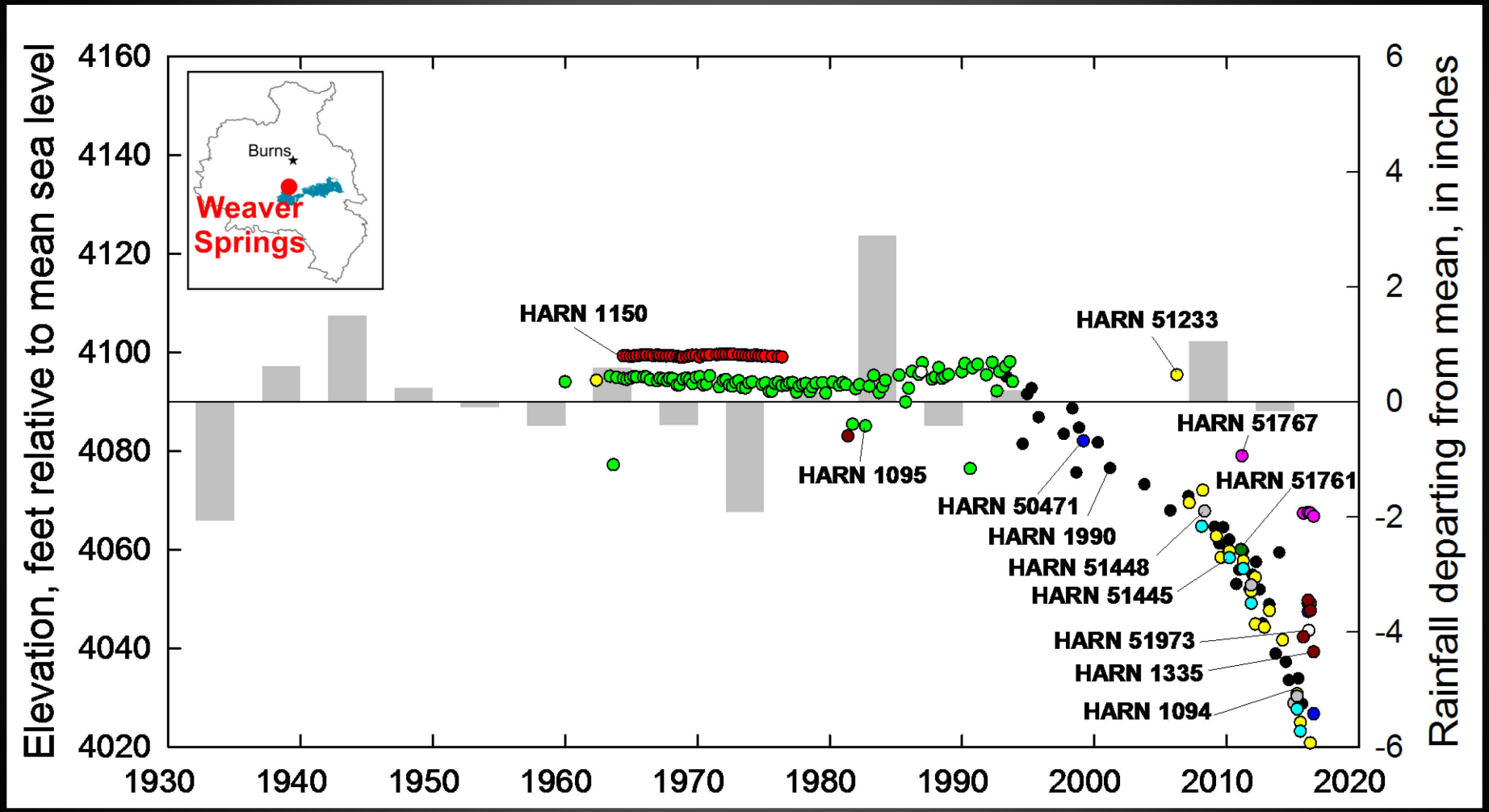
# Harney Basin water levels




USGS

preliminary data, subject to revision

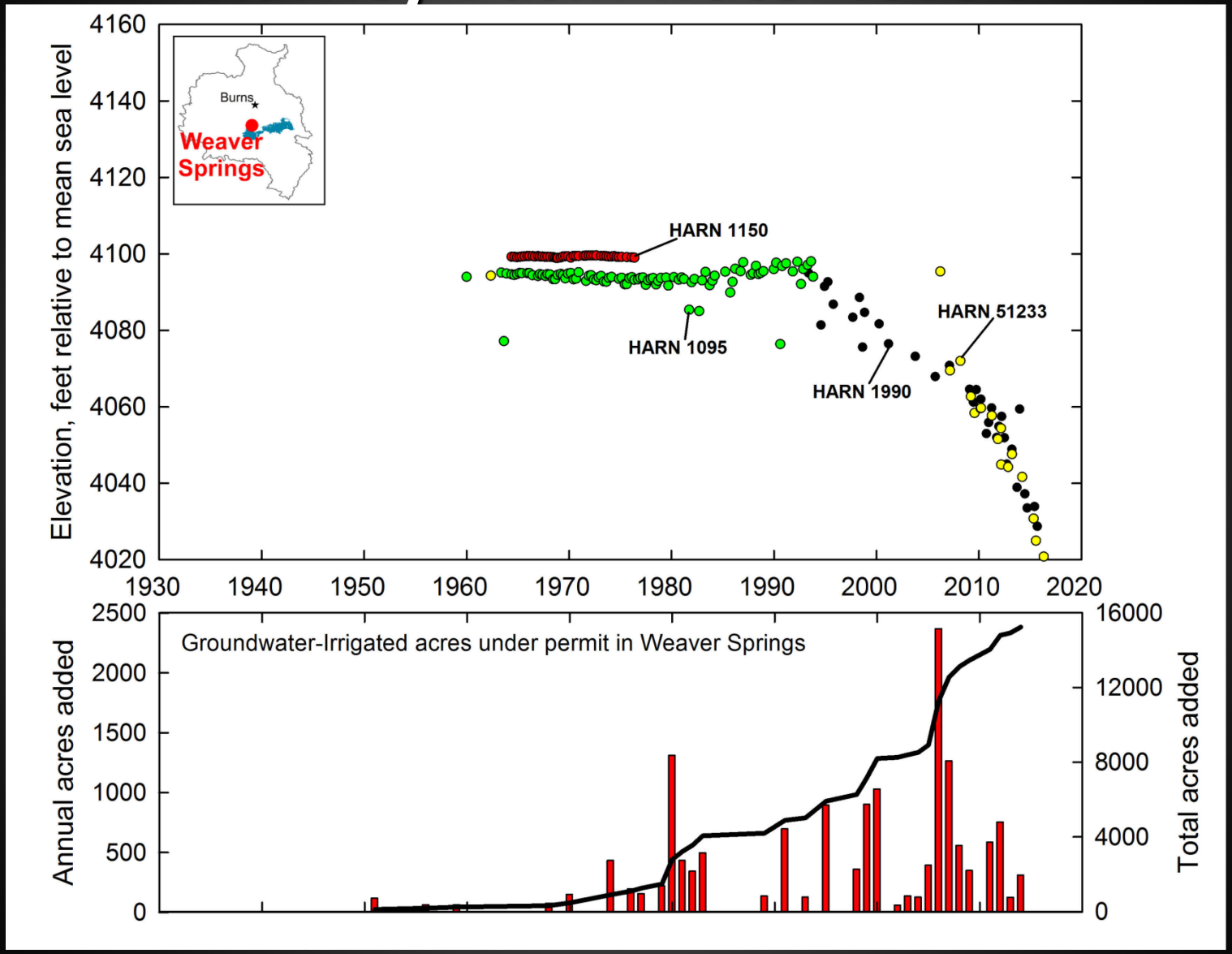
# Harney Basin water levels




USGS

preliminary data, subject to revision

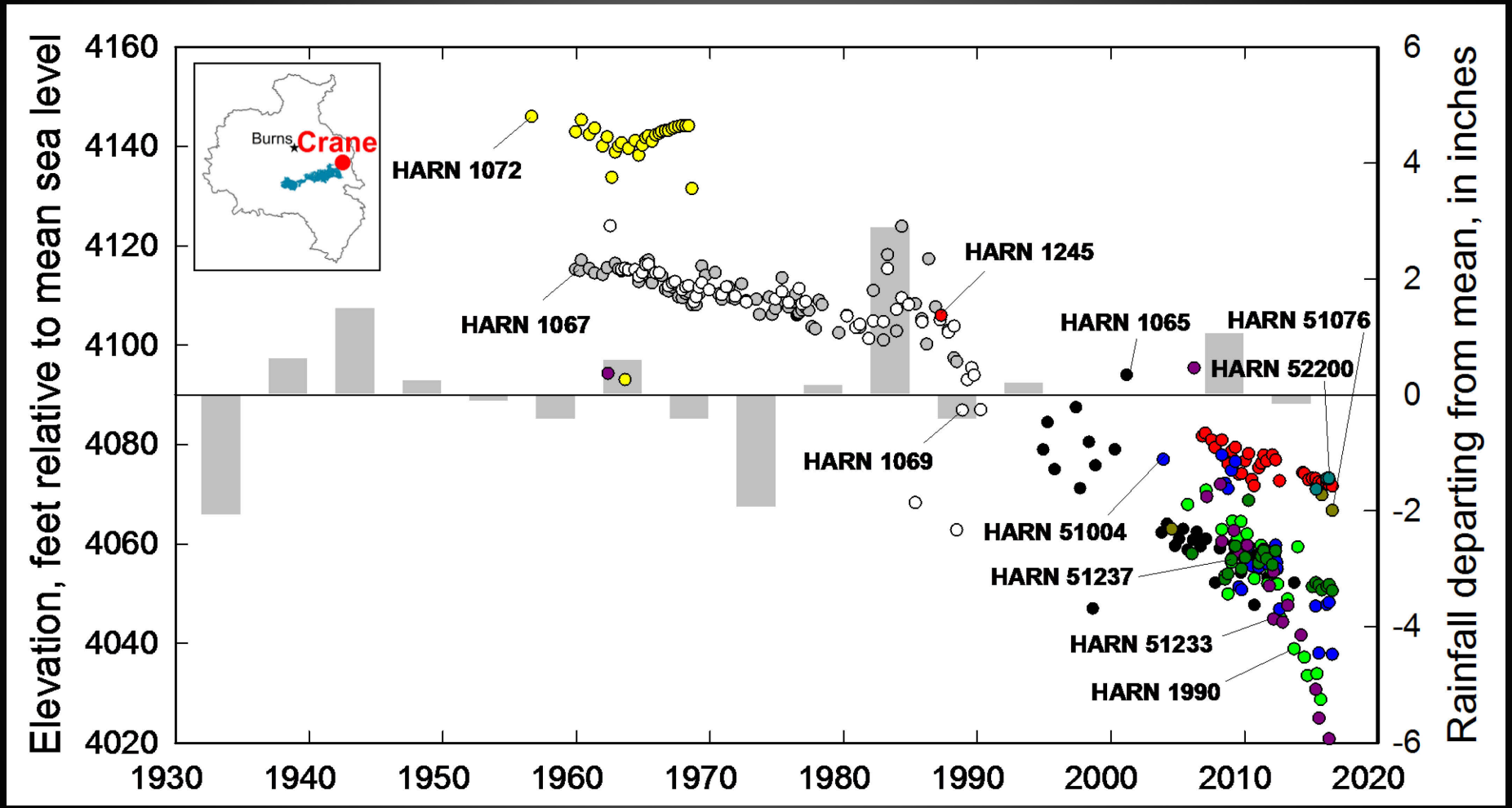
# Harney Basin water levels




USGS

preliminary data, subject to revision

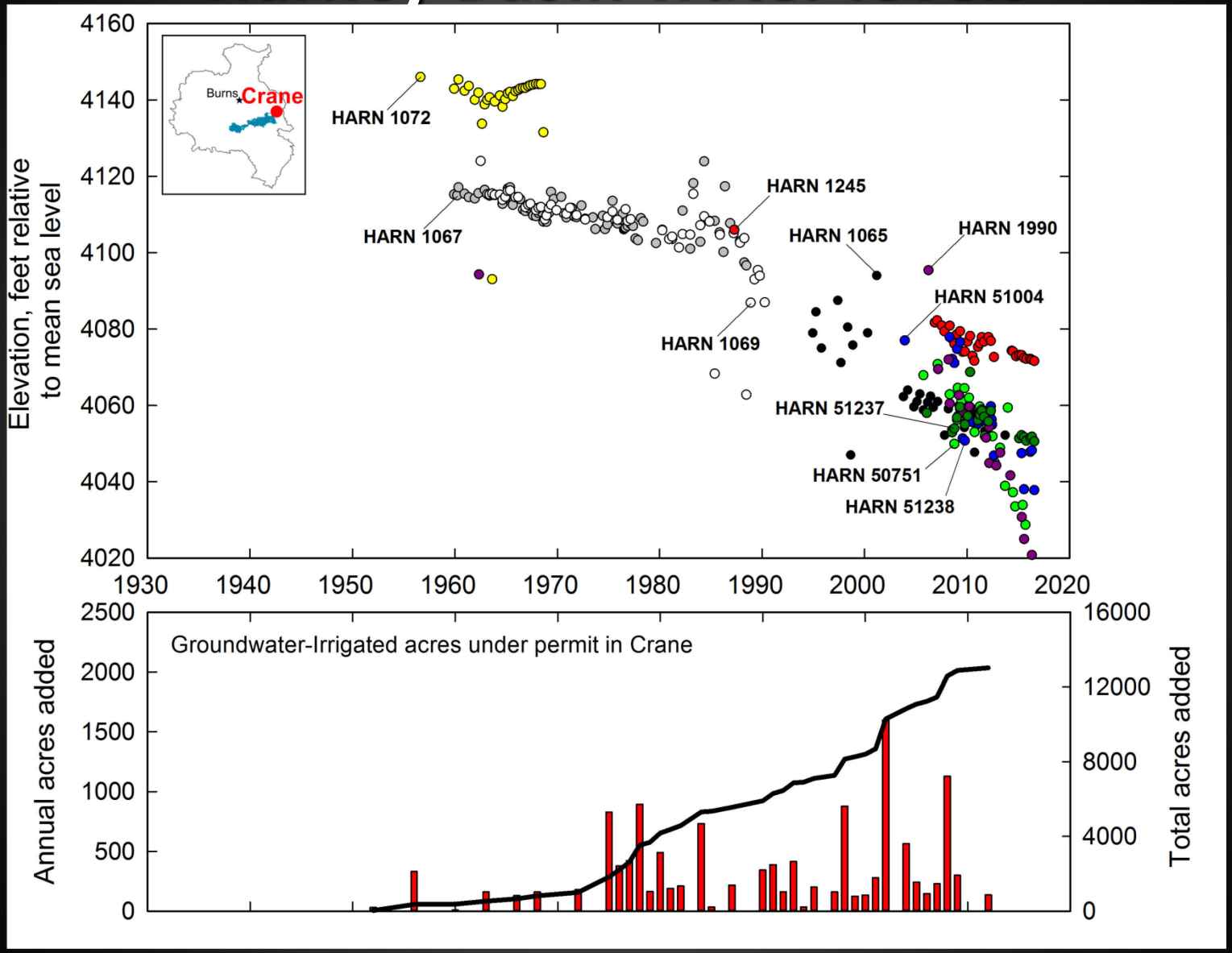
# Harney Basin water levels




USGS

preliminary data, subject to revision

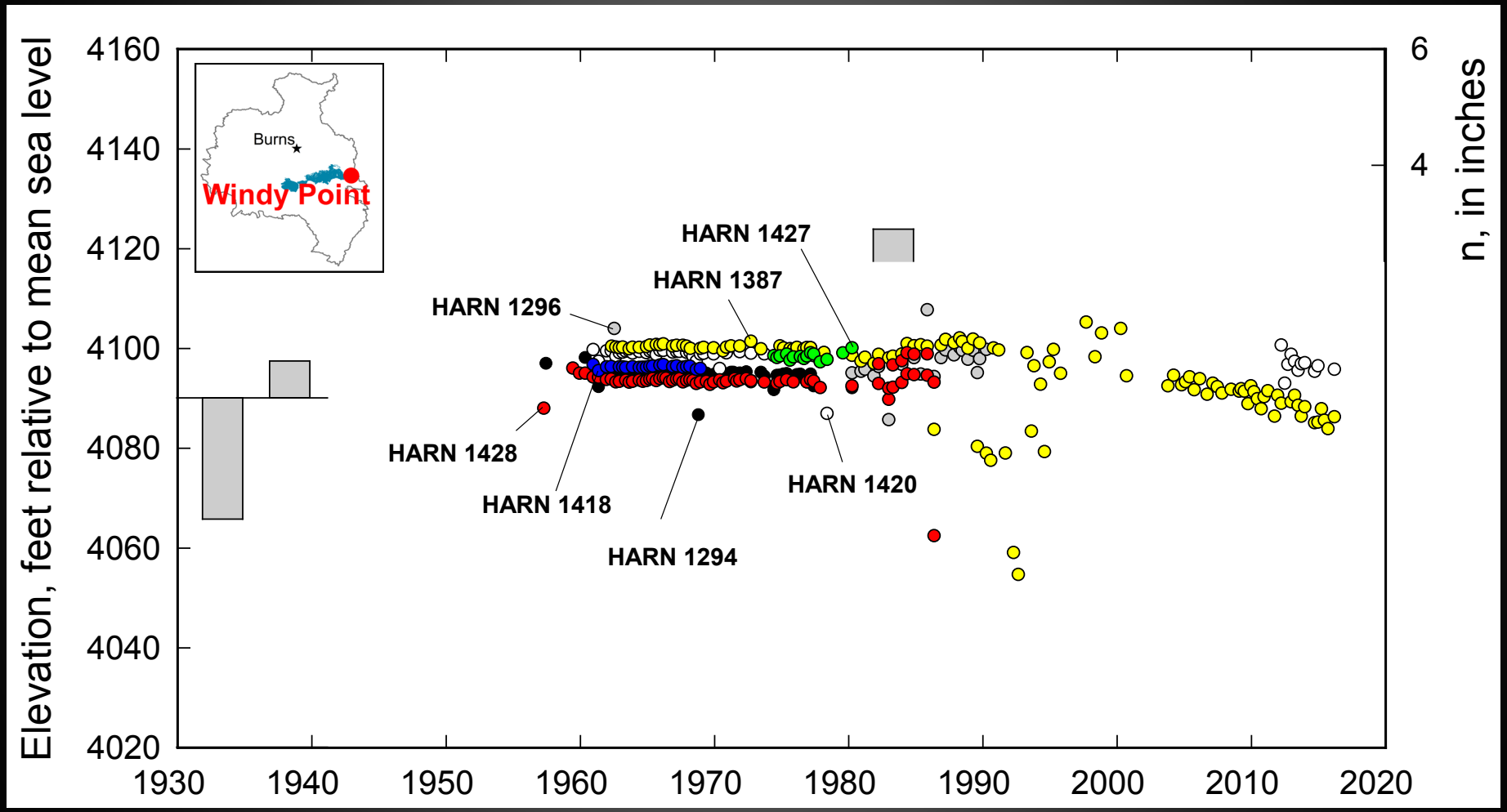
# Harney Basin water levels




USGS

preliminary data, subject to revision

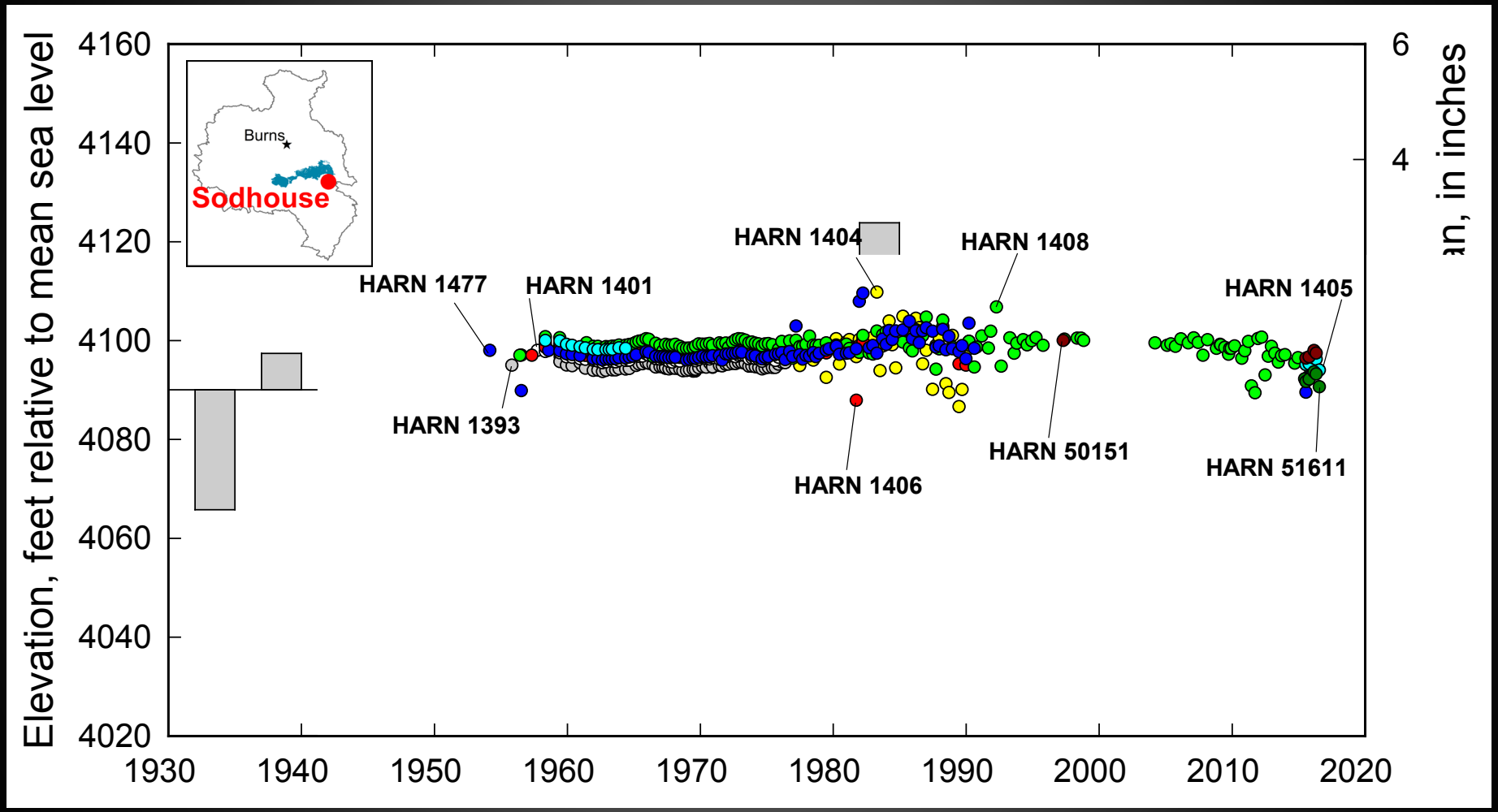
# Harney Basin water levels




USGS

preliminary data, subject to revision

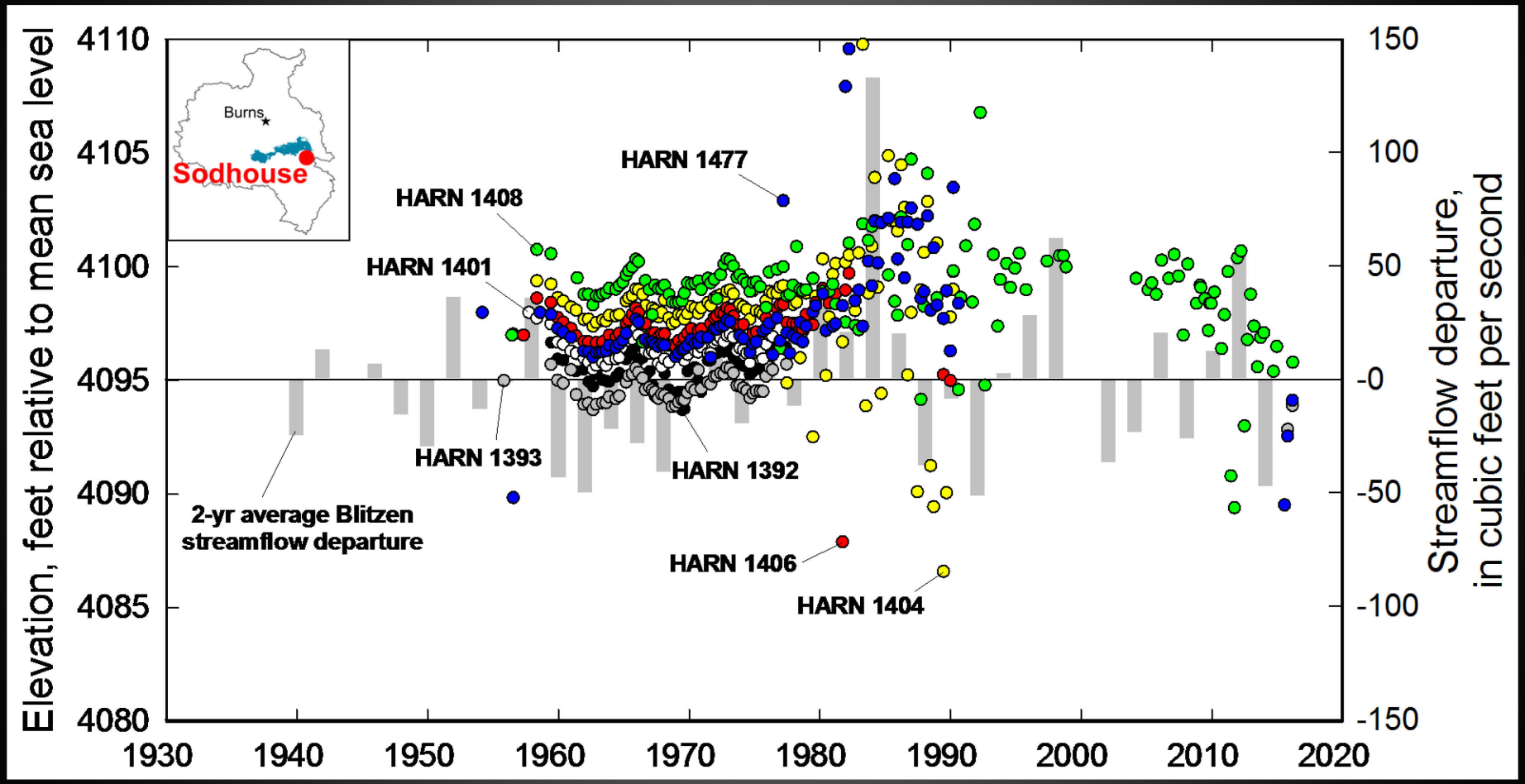
# Harney Basin water levels




USGS

preliminary data, subject to revision

# Harney Basin water levels




USGS

preliminary data, subject to revision

# Next steps

- Continue developing hydrogeologic framework
- Develop and assemble water-budget components

# End of Presentation