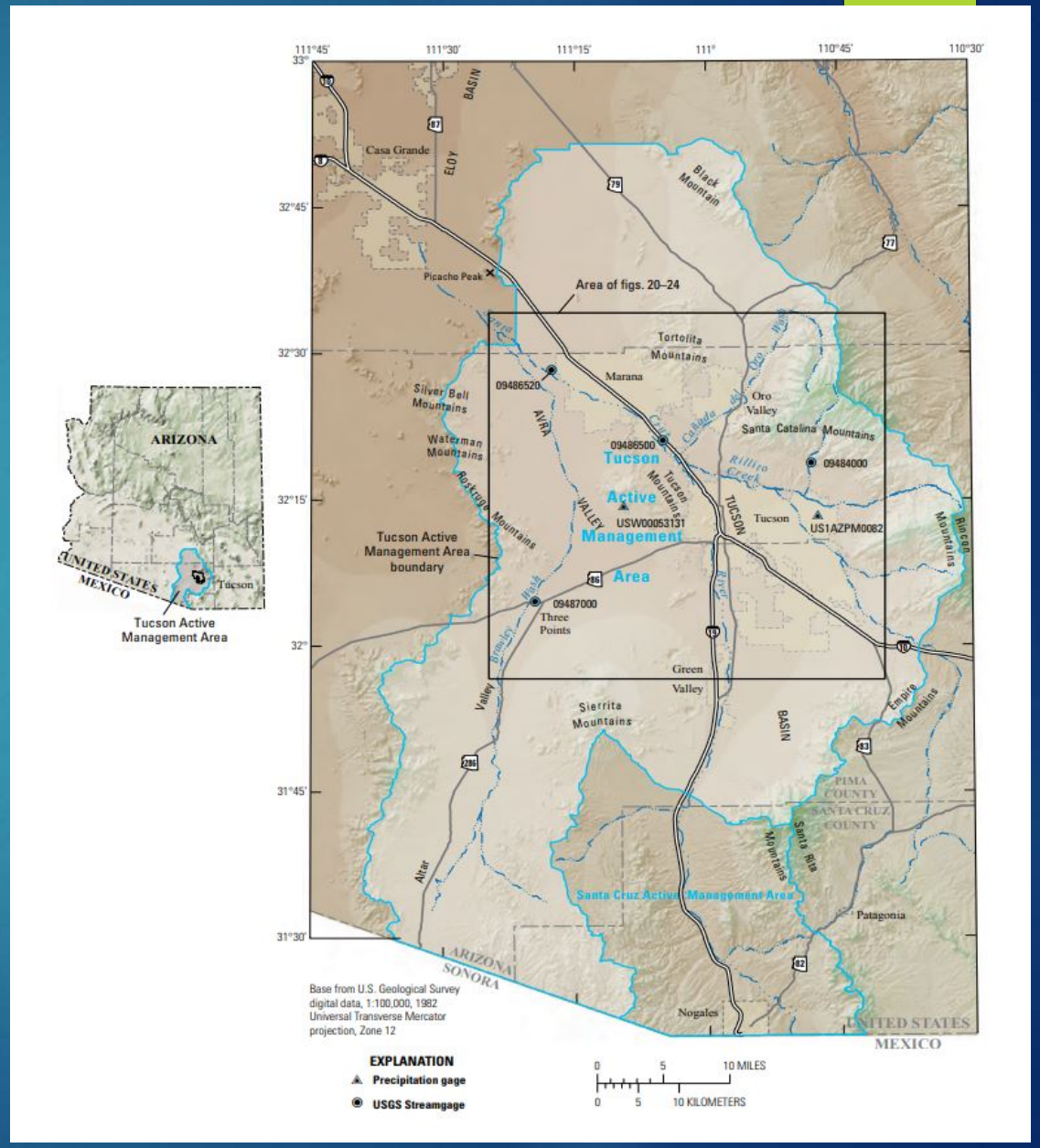
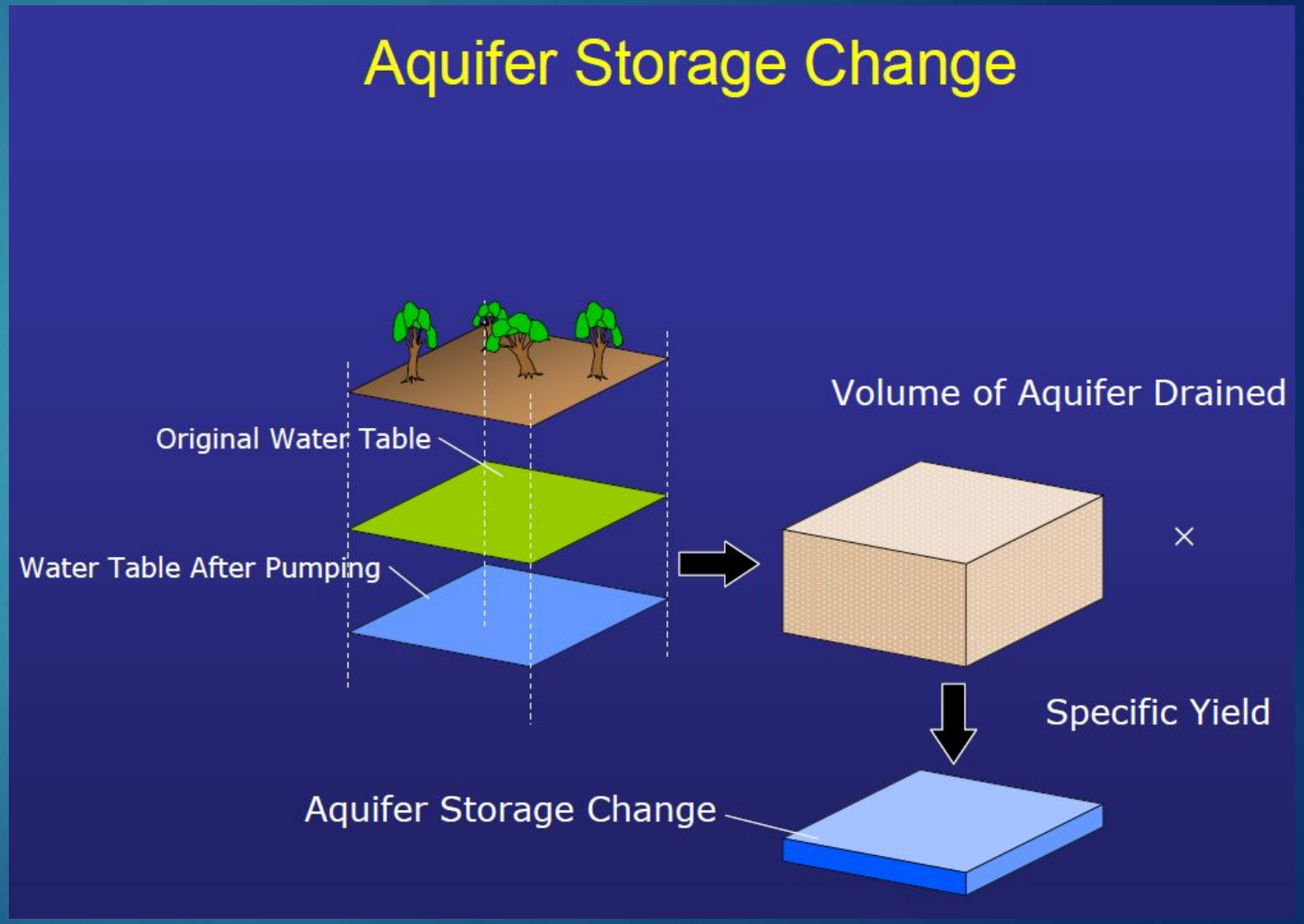
Aquifer-Storage Change Monitoring in the Tucson Active Management Area



Objective

- **Monitor aquifer-storage change**
  - Addressed by measuring changes in gravity. As water is added or removed from the aquifer, there is a change in mass and a corresponding measurable change in gravity.
  - For storage change in feet of water and gravity in µGal (1 µGal = 0.00000001 $m/s^{2)}$:

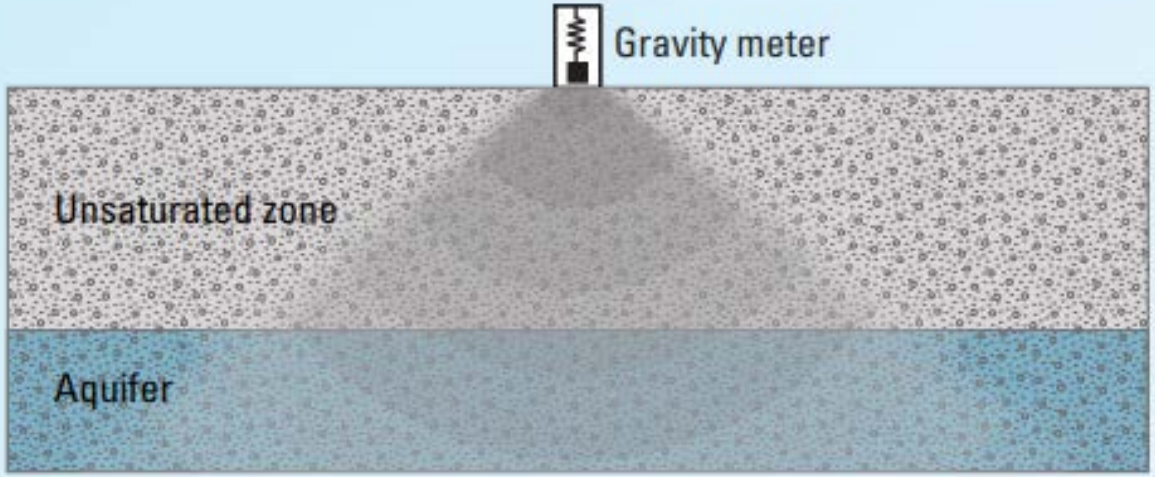
$$\Delta Storage = \frac{\Delta g}{12.77}$$



Why monitor aquifer-storage change with gravity?

USGS

- Direct estimate of storage change – doesn't rely on other estimates of inflows and outflows
- Does not rely on assumptions about aquifer properties
- Fast response to change
- Relatively non-invasive measurement, instruments can be deployed on existing sidewalks, etc.
- When coupled with water level changes can provide estimates of specific yield

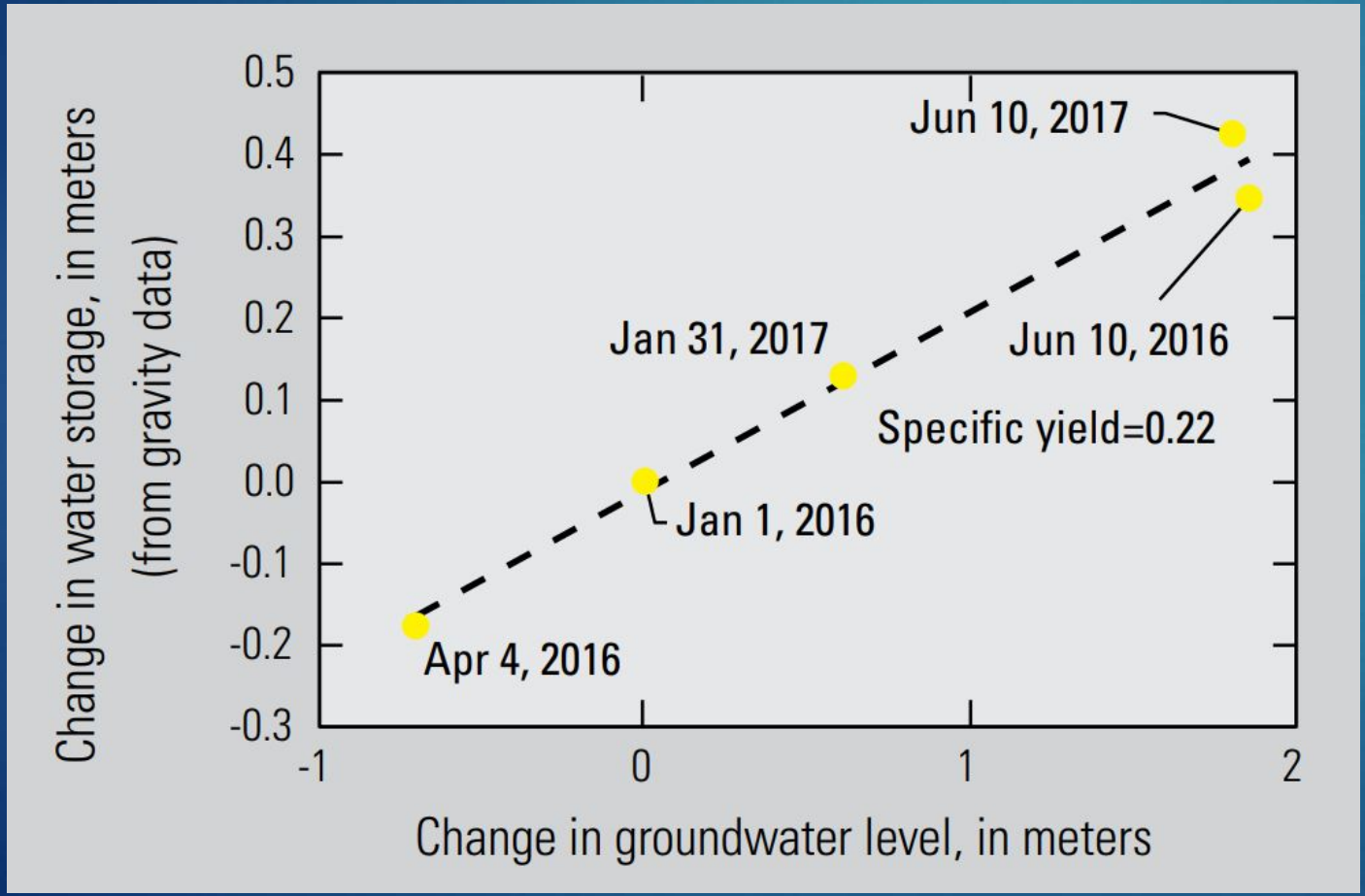


As generalized in this image, a gravity measurement is sensitive to a cone-shaped region of the subsurface—as depth increases, the sensitivity to individual water molecules decreases, but the region of sensitivity expands. The result is that for a given height of water-storage change, the corresponding gravity change is the same (1 meter of water=42×10^{-8} meters per second squared), regardless of whether the water is stored near the land surface or at depth. The amount of gravity change is also independent of the porosity of the aquifer or soil.

- Higher measurement uncertainty than a water level change (+/- 0.23 feet of storage change)
- Cannot differentiate between storage change in unsaturated vs saturated zones
- Relatively insensitive to confined aquifer storage changes

$$Sy = \frac{\Delta Storage}{\Delta Water\ level}$$

BUT: accuracy of water level may be to a hundredth of a foot, while a gravity observation is +/- three µGal, or +/- 0.23 feet.

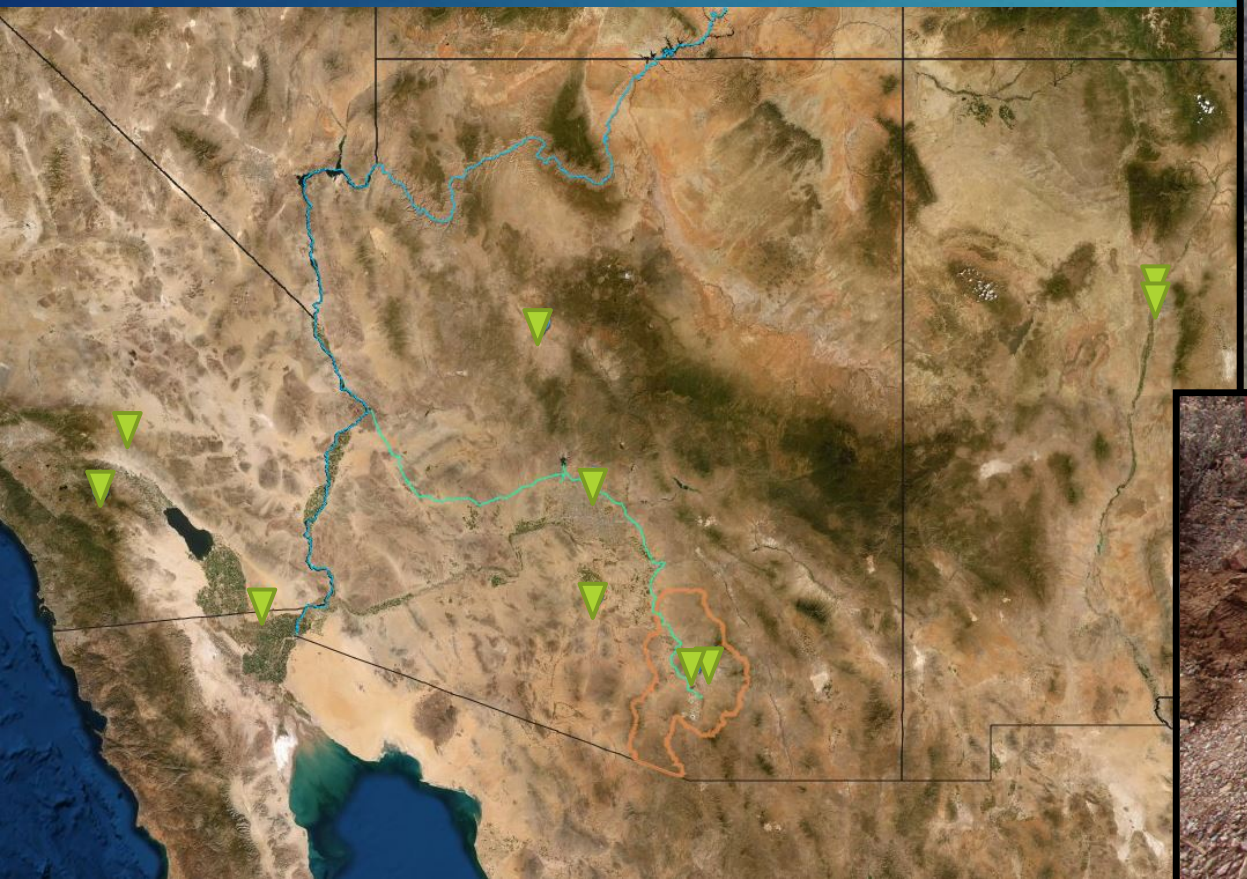


The specific yield is the slope of a best-fit line relating the change in storage (volume of water per unit area) as estimated by the change in gravity to the change in groundwater level (plot based on USGS data from Mesilla Valley, New Mexico).

Specific yield values for this project would require more frequent gravity observations throughout the year.

USGS Southwest Gravity Program:

Collaboration between the AZ, NM, and CA USGS Water Science Centers (**https://tinyurl.com/y6fcbdrt)**



USGS gravity and Tucson…

- **1996** – Began seasonal storage-change monitoring in TAMA
- **1997 – Report on ephemeral recharge monitoring along the Rillito, 1992-1993**
- **1998** – Expanded network
- **1999** – **Report for 1996-98**
- **2003** – Combined Avra and Tucson programs
- **2007** – **Report on 1998-2002 TAMA monitoring results**
- **2016 – Journal article from gravity monitoring at SAVSARP**
- **2018** – **Report on 2003 – 2016 TAMA monitoring results (https://tinyurl.com/ug9ypbz)**
- **2019** – Field work concluded, data published online (**https://tinyurl.com/suh846h)**
- Current funding agreement expires after 2020 field season

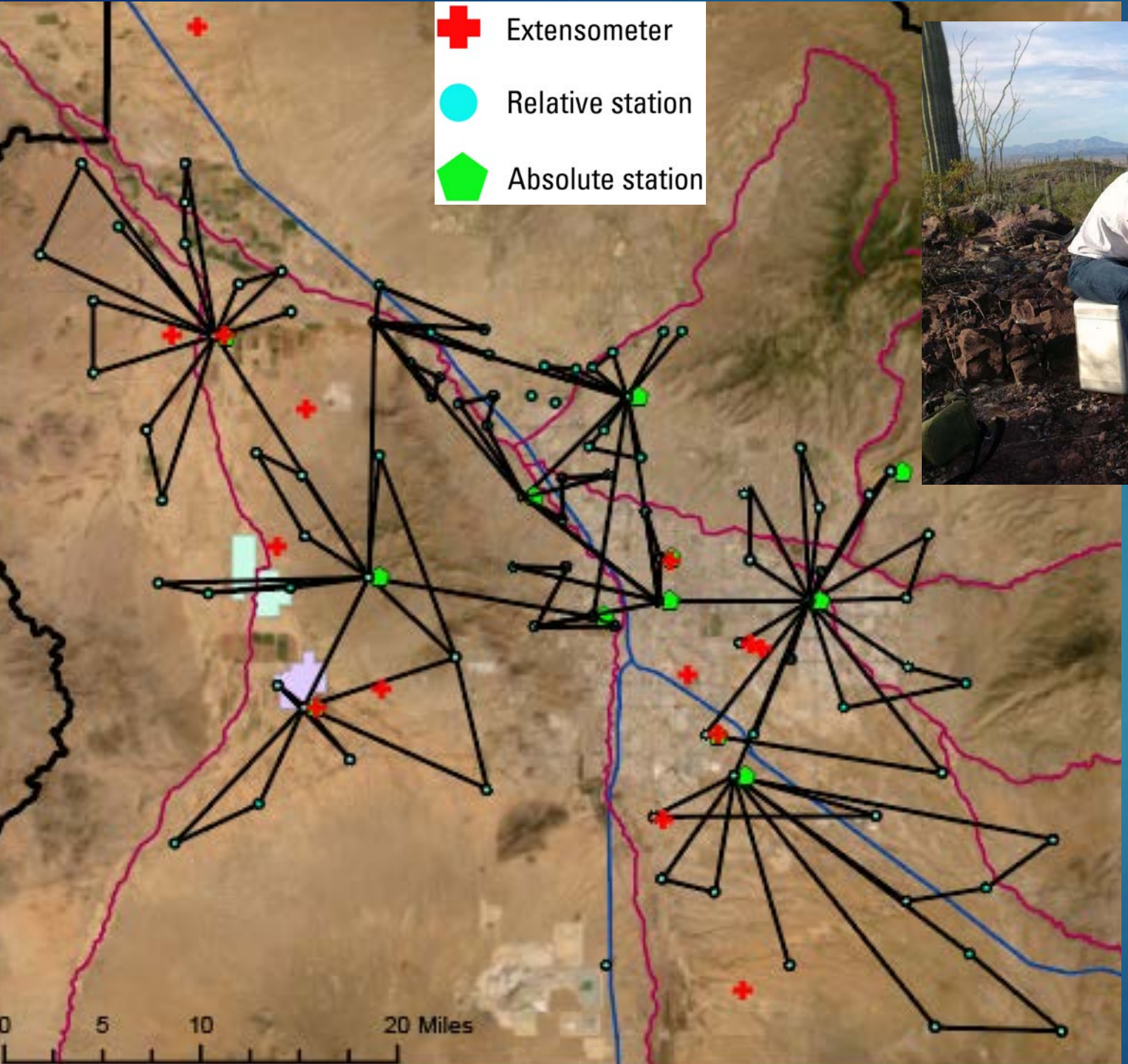
Current cooperators:

Arizona Department of Water Resources

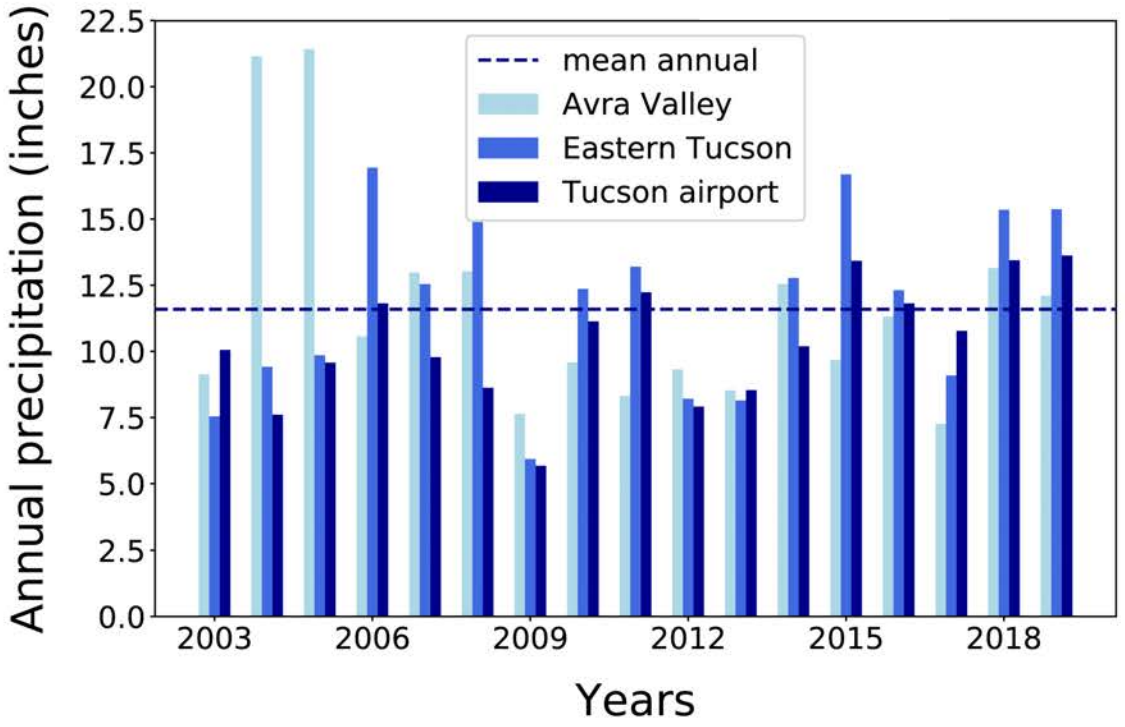
Pima County

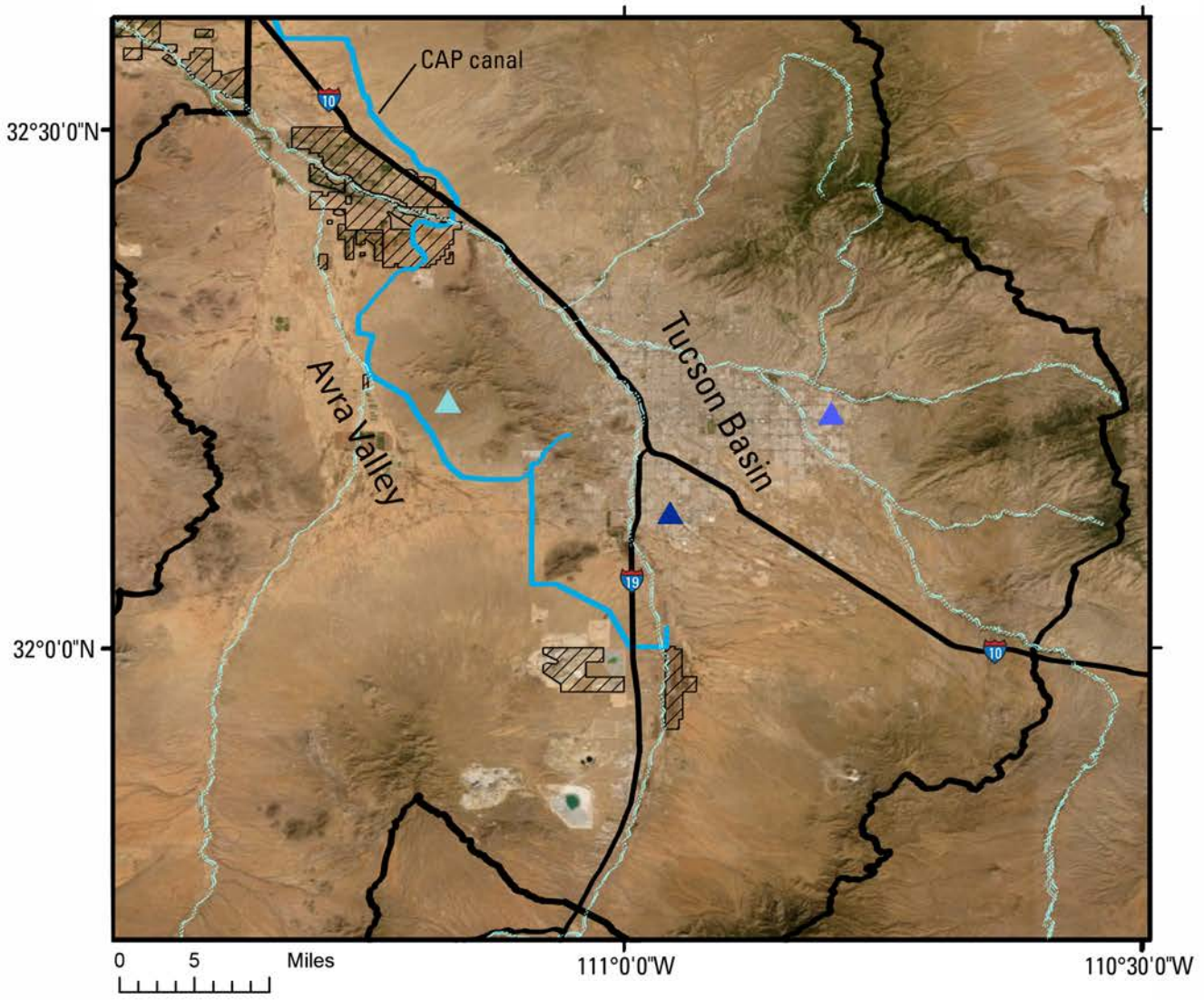
Town of Marana

USGS


Extensometer
Relative station
Absolute station
0
5
10
20 Miles

Precipitation data from NOAA:





Explanation

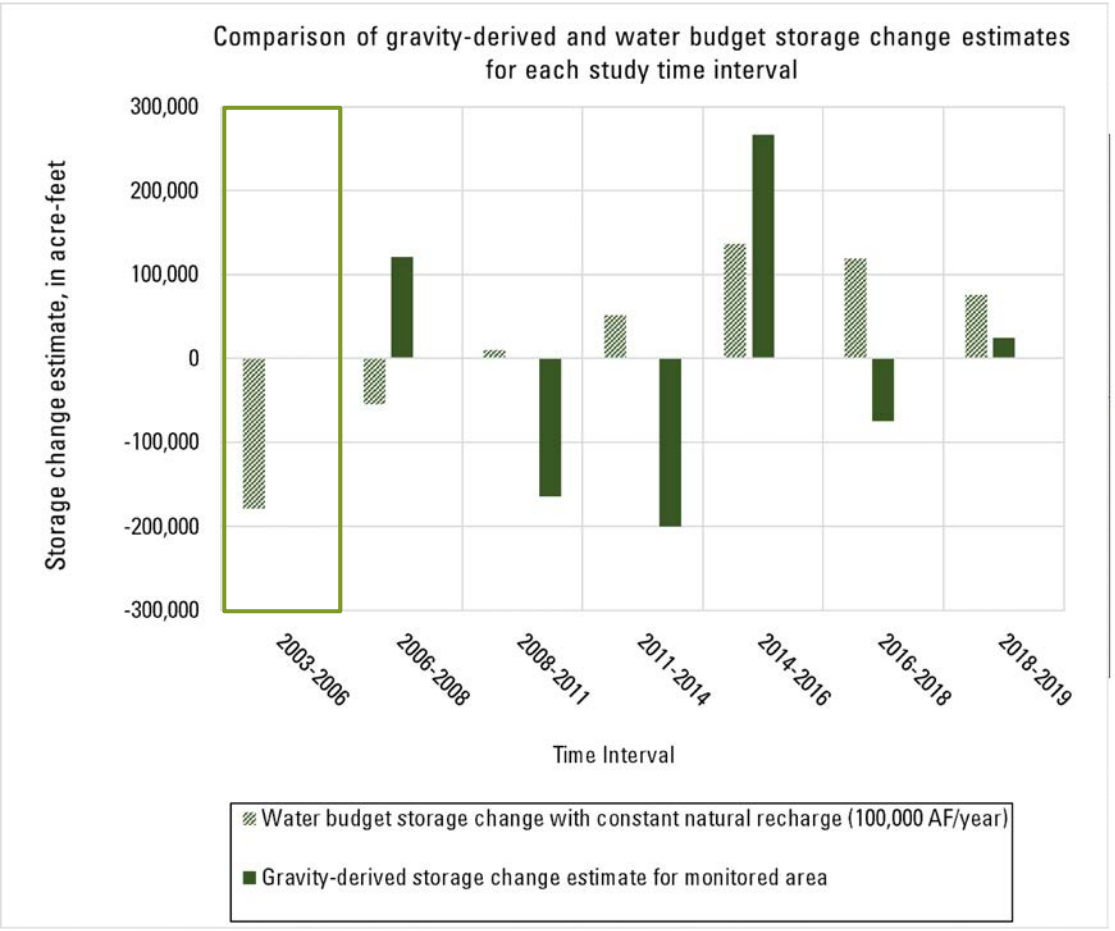
Precipitation station names and identifiers

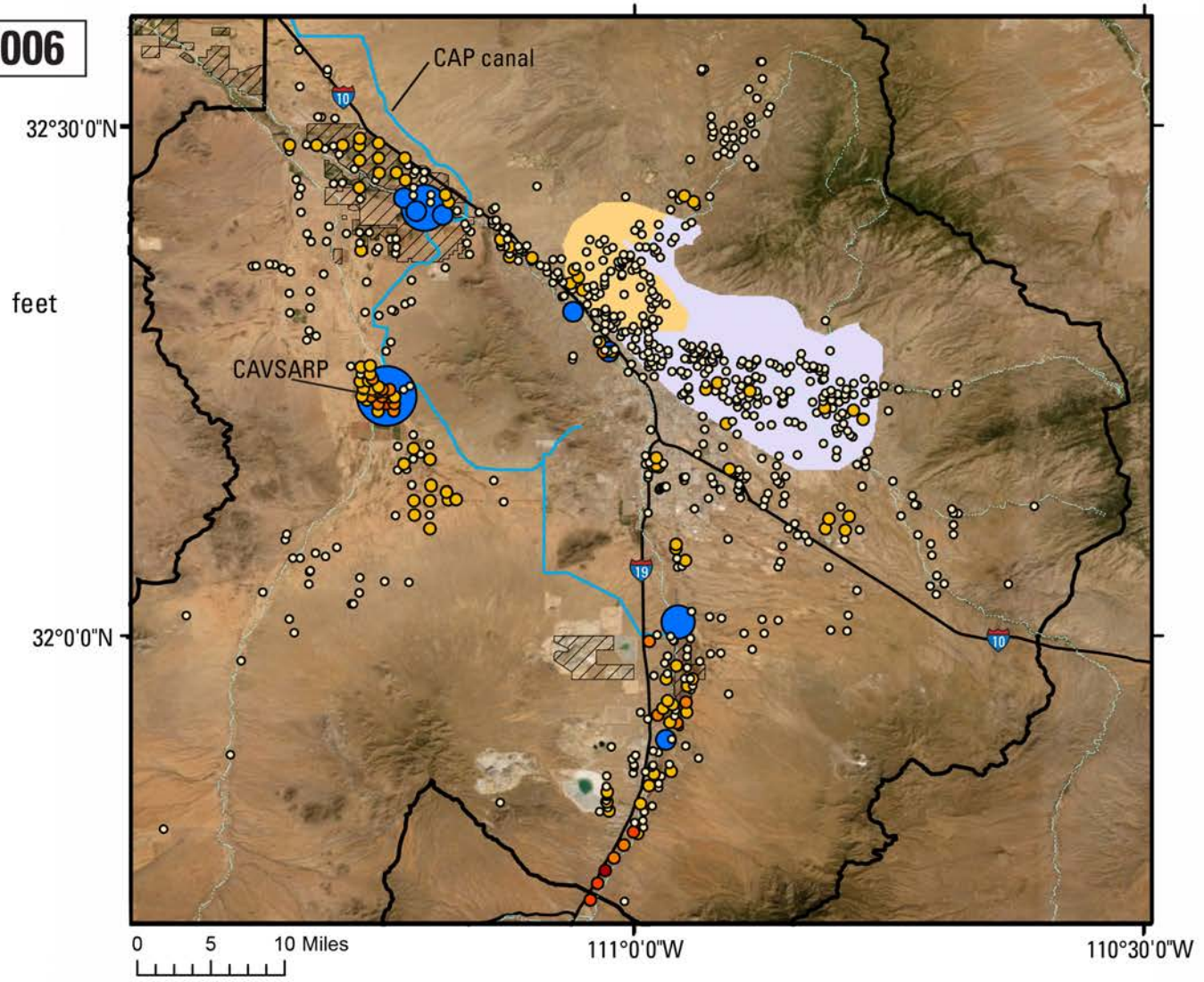
- Avra Valley (USW00053131)
- Eastern Tucson (US1AZPM0082)
- Tucson airport (USW00023160)

Groundwater savings facilities

Groundwater withdrawal and recharge volumes provided by ADWR public records request. Data are provisional and subject to revision.

2003 - 2006





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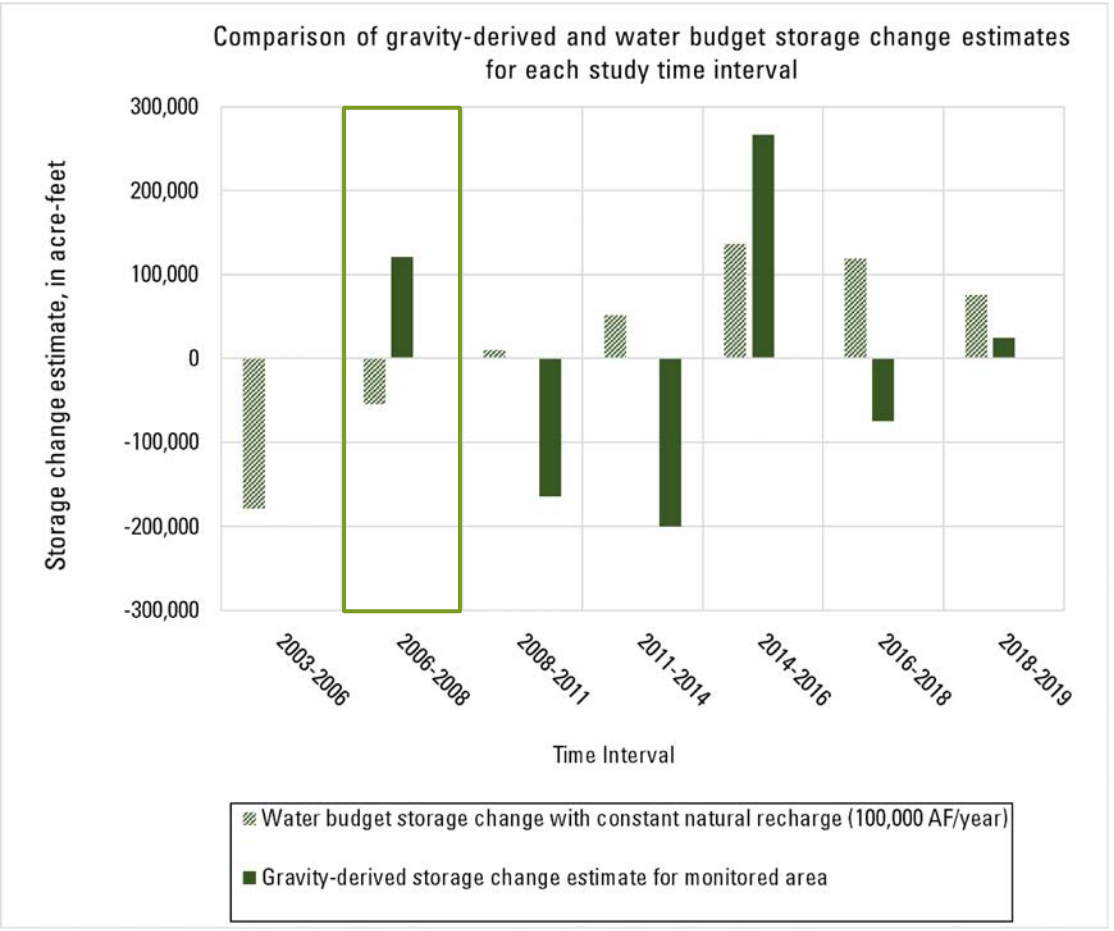
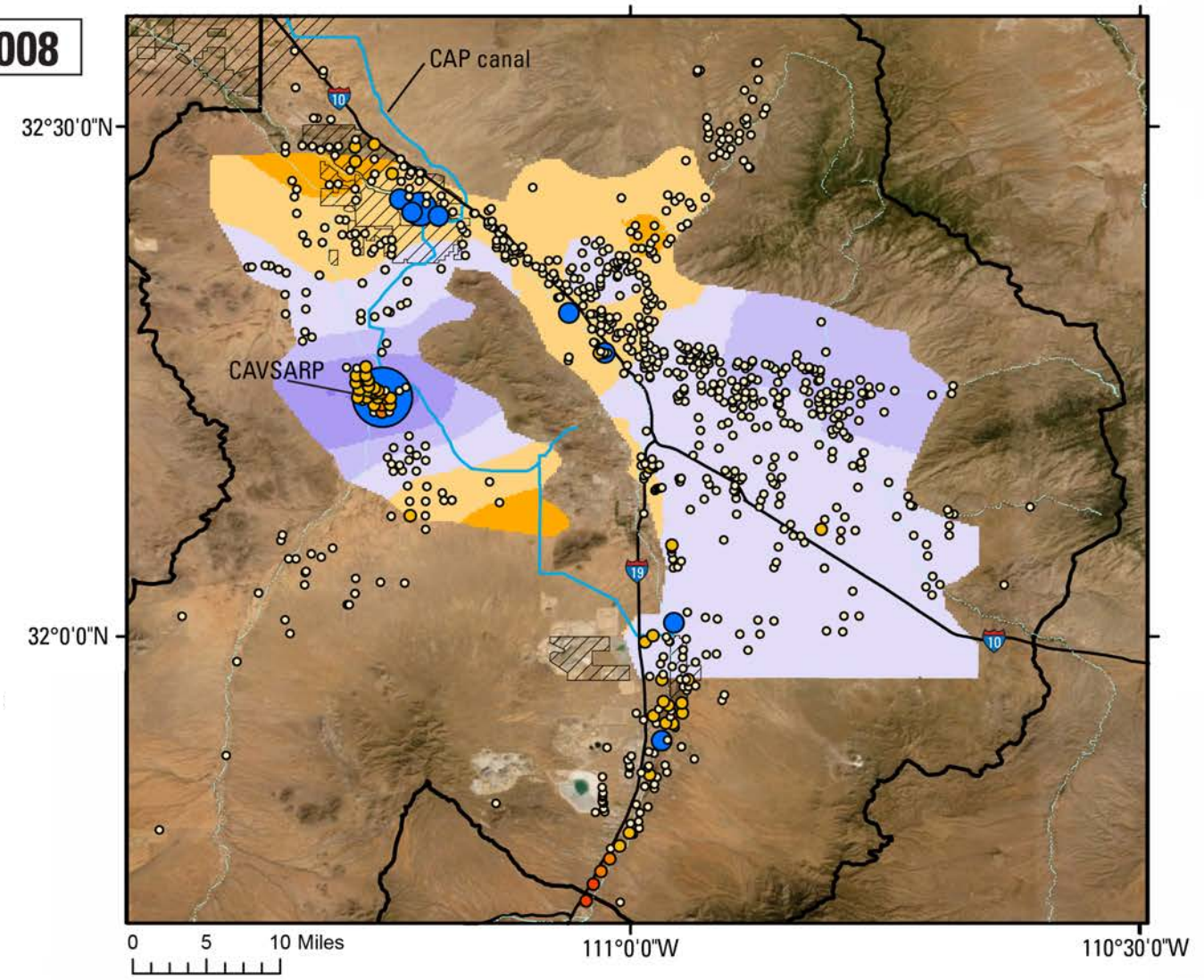
2006 - 2008





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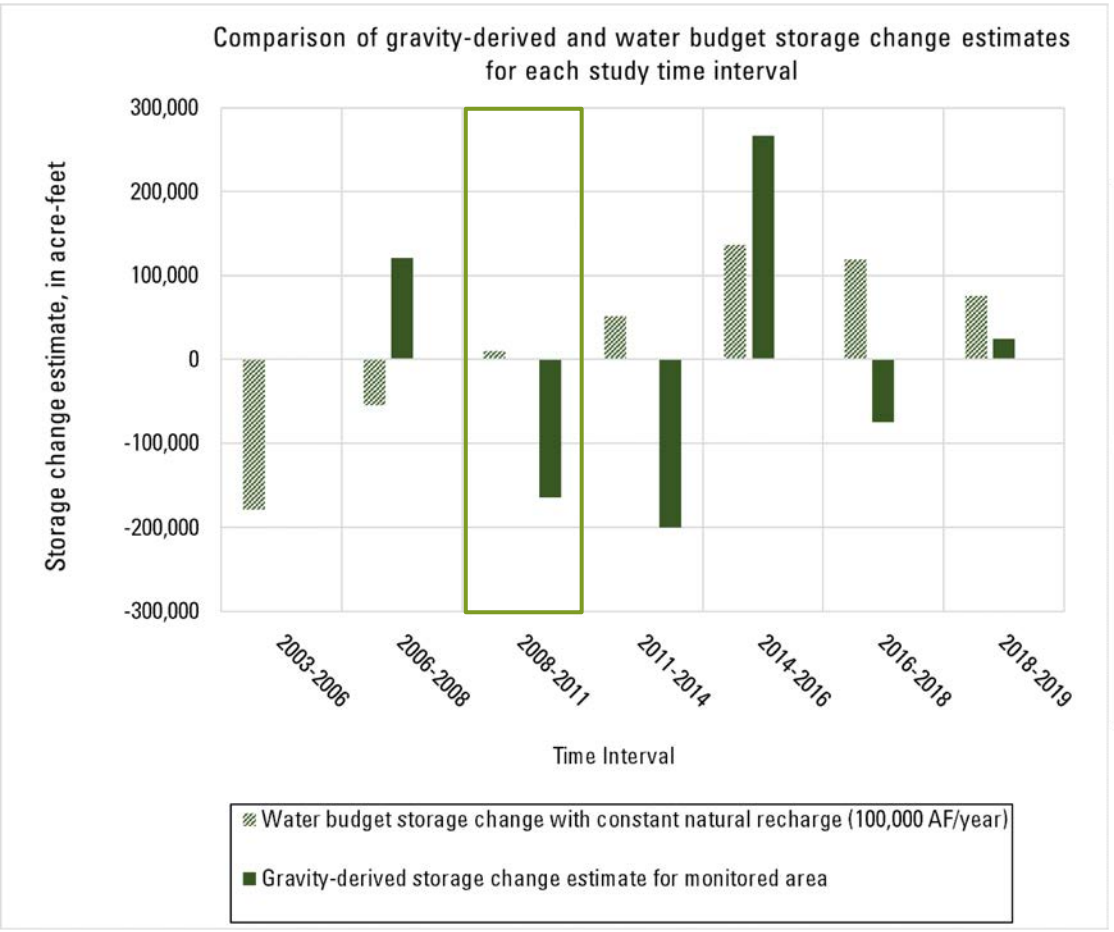
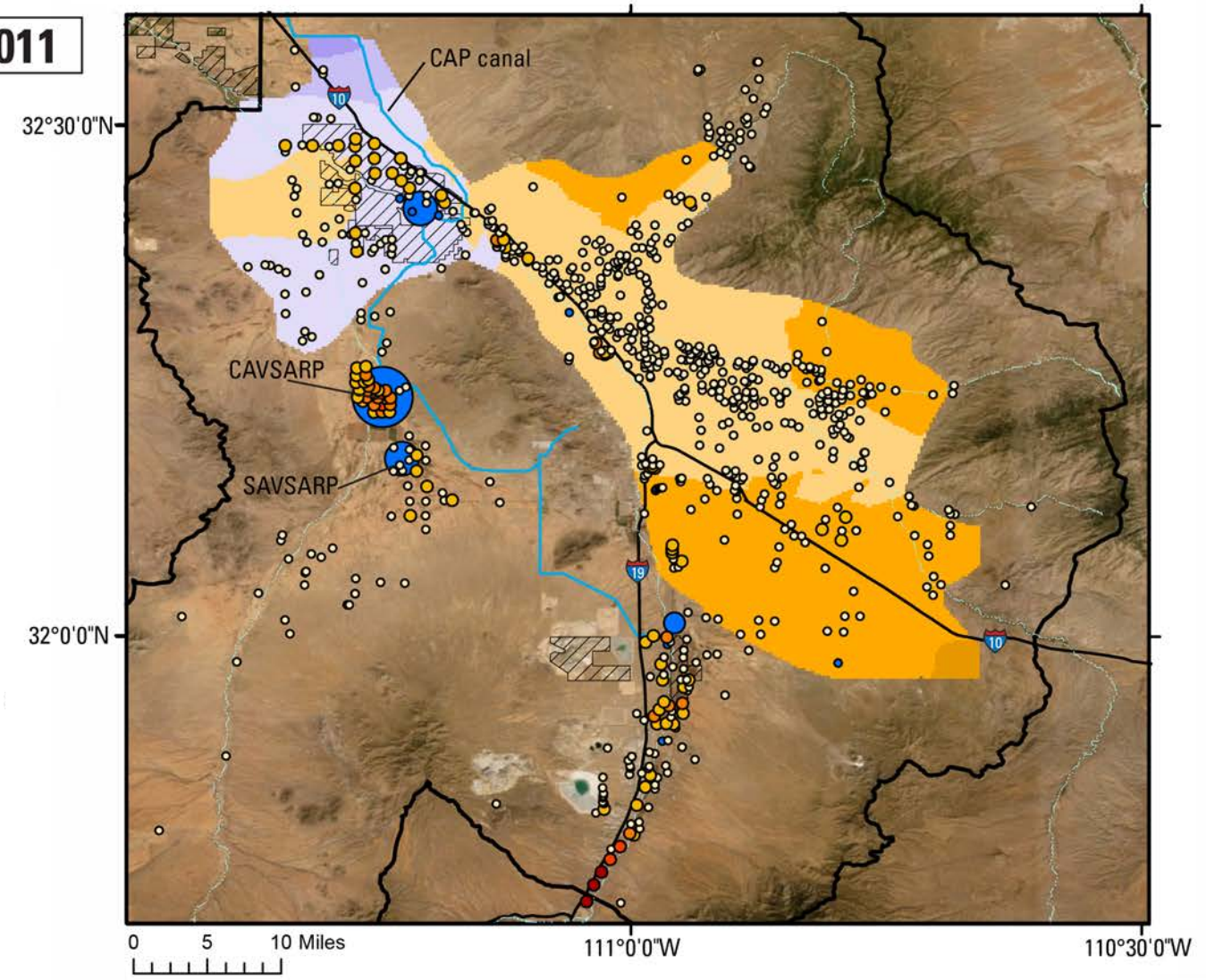


2008 - 2011



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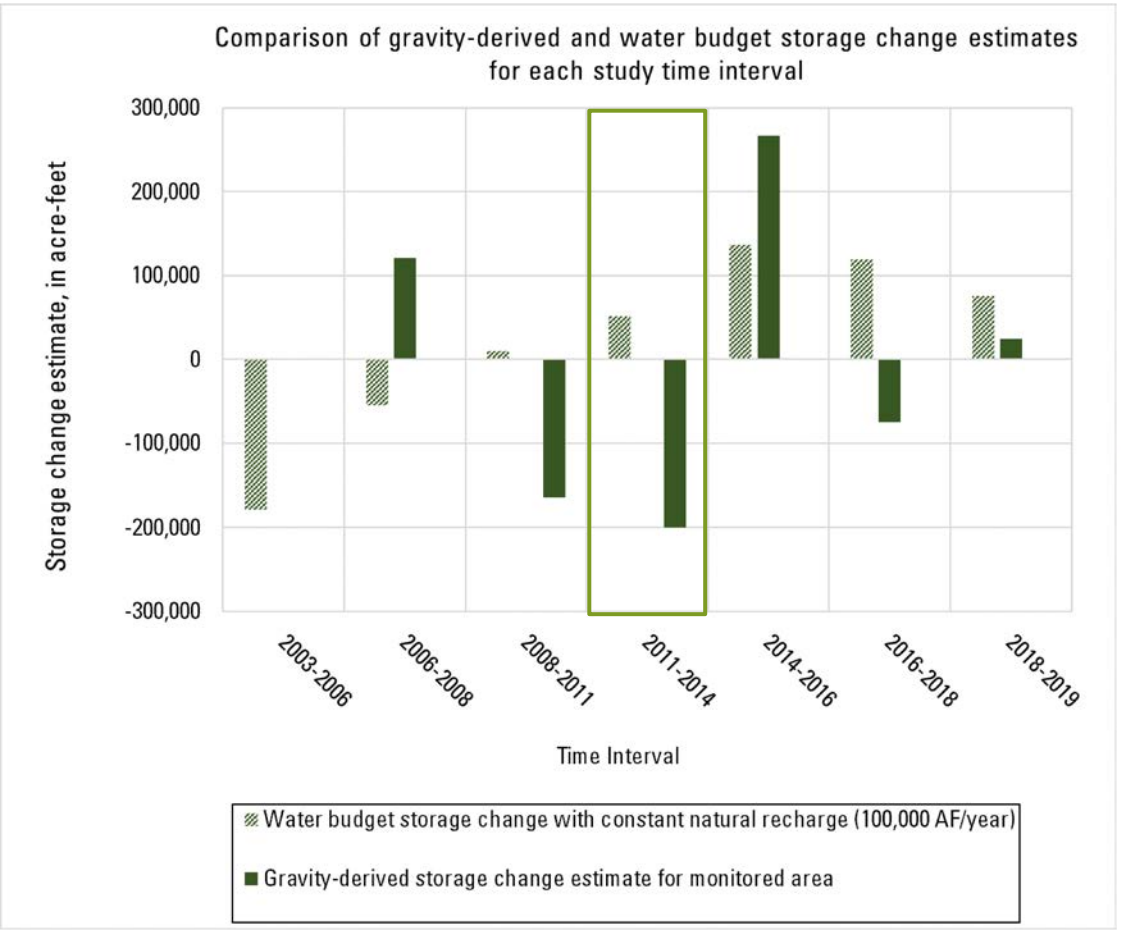
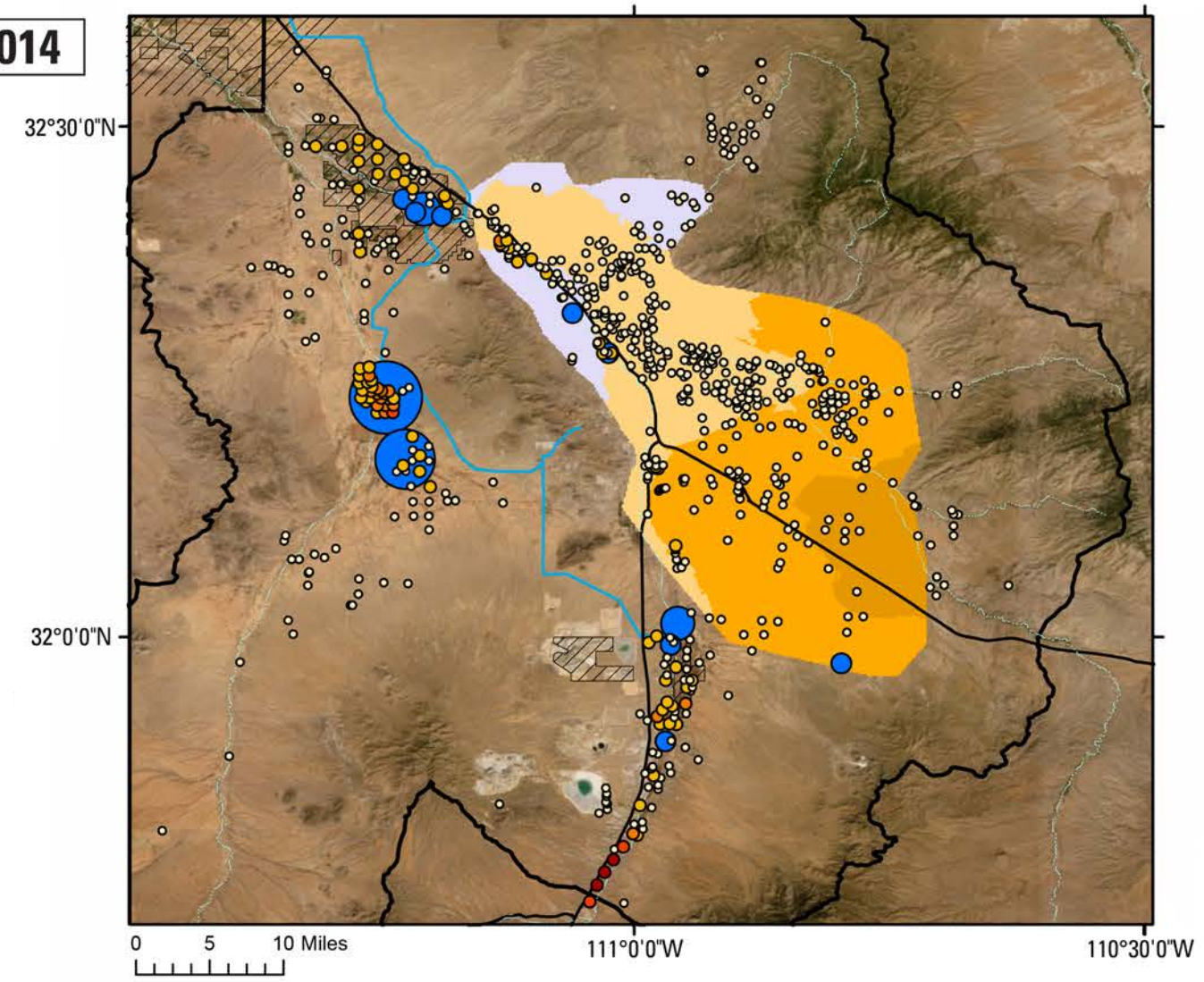


2011 - 2014



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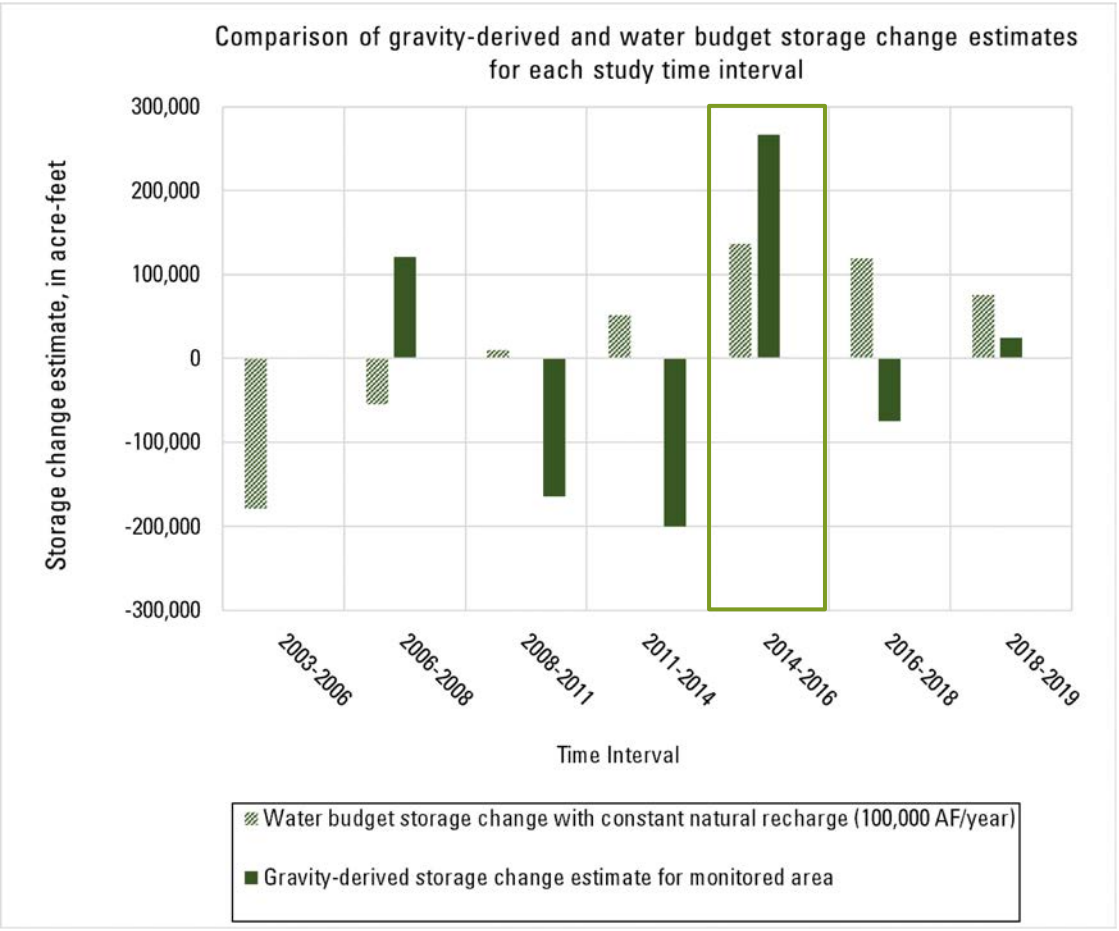
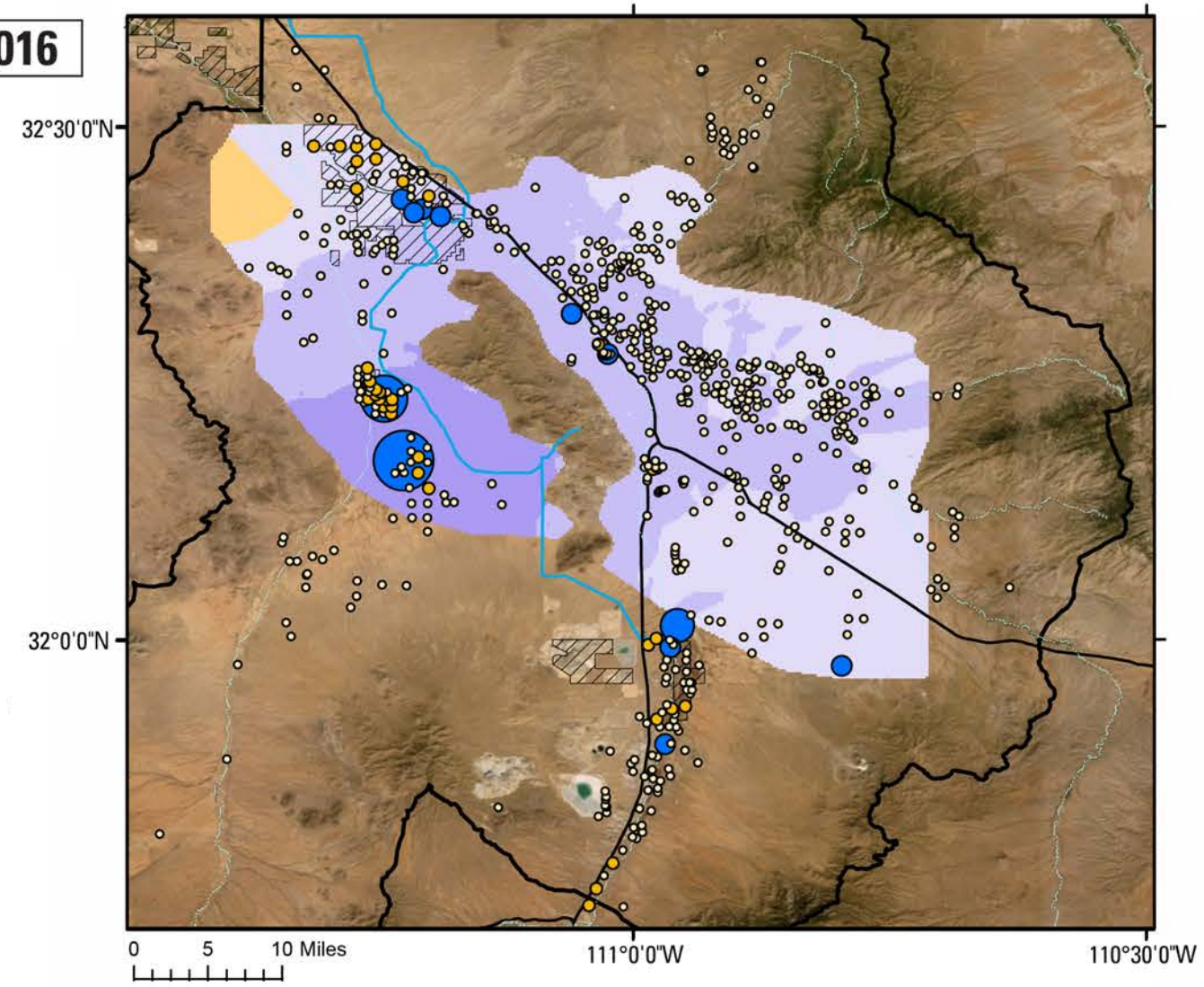
2014 - 2016





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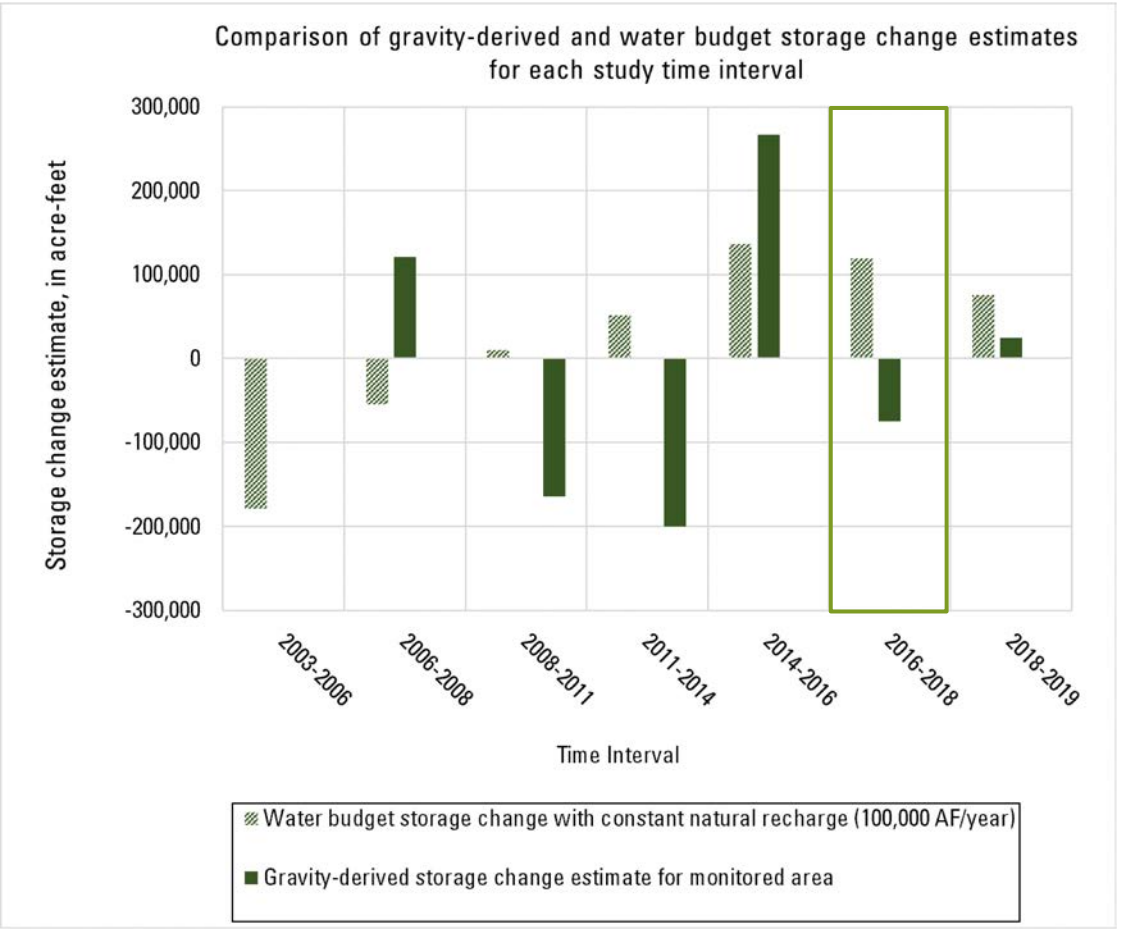
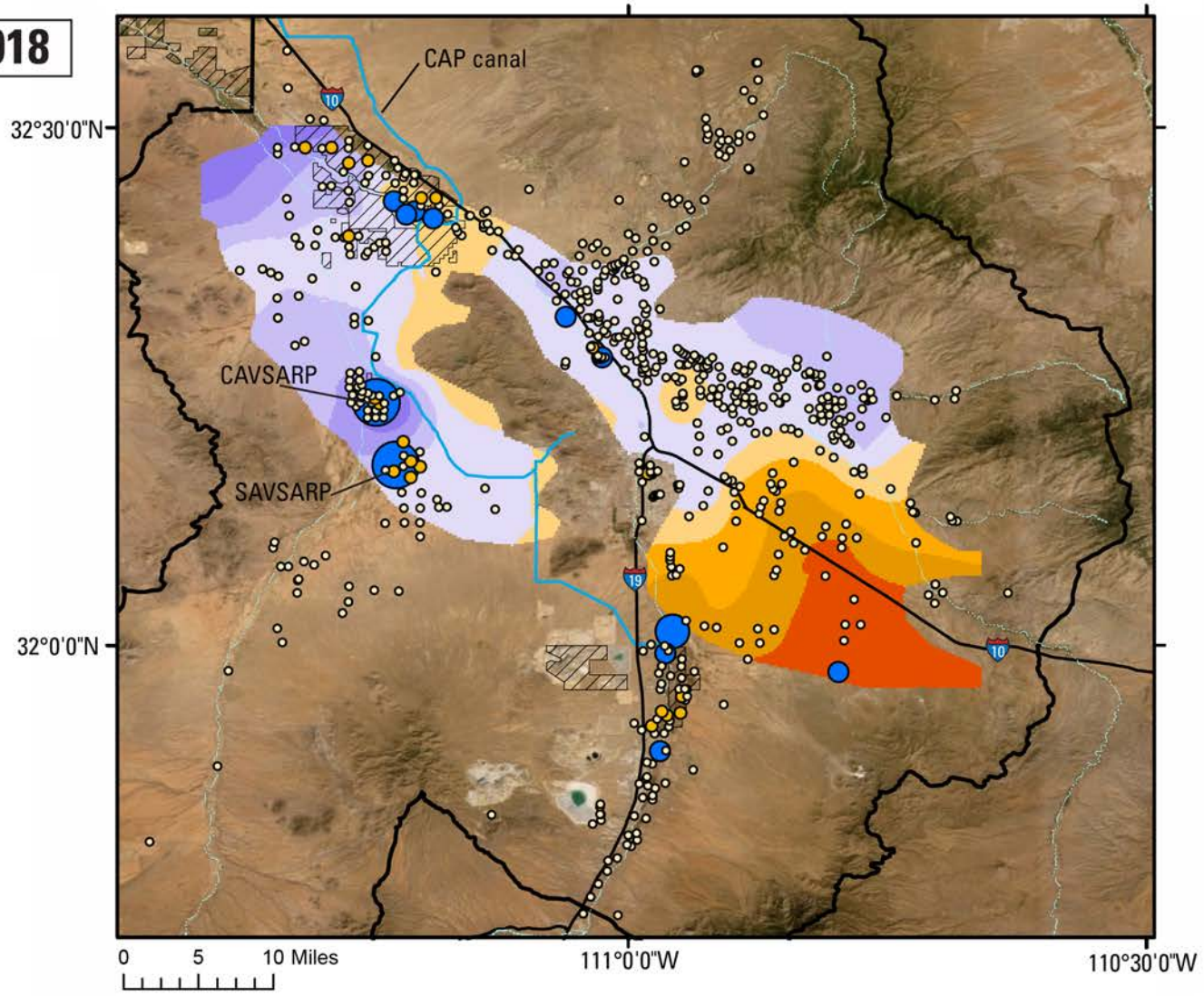
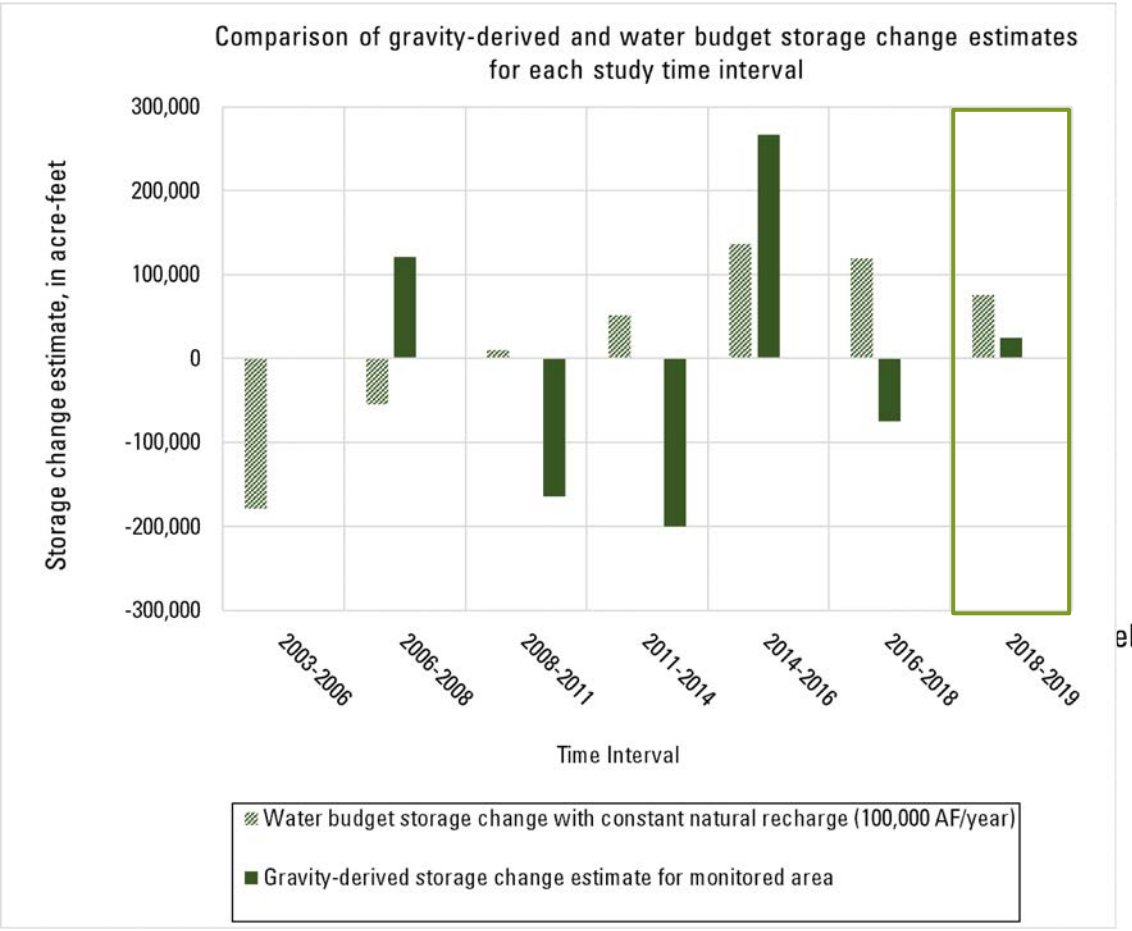
2016 - 2018





Groundwater withdrawal and recharge volumes provided by ADWR public records request. Data are provisional and subject to revision.

2018 - 2019



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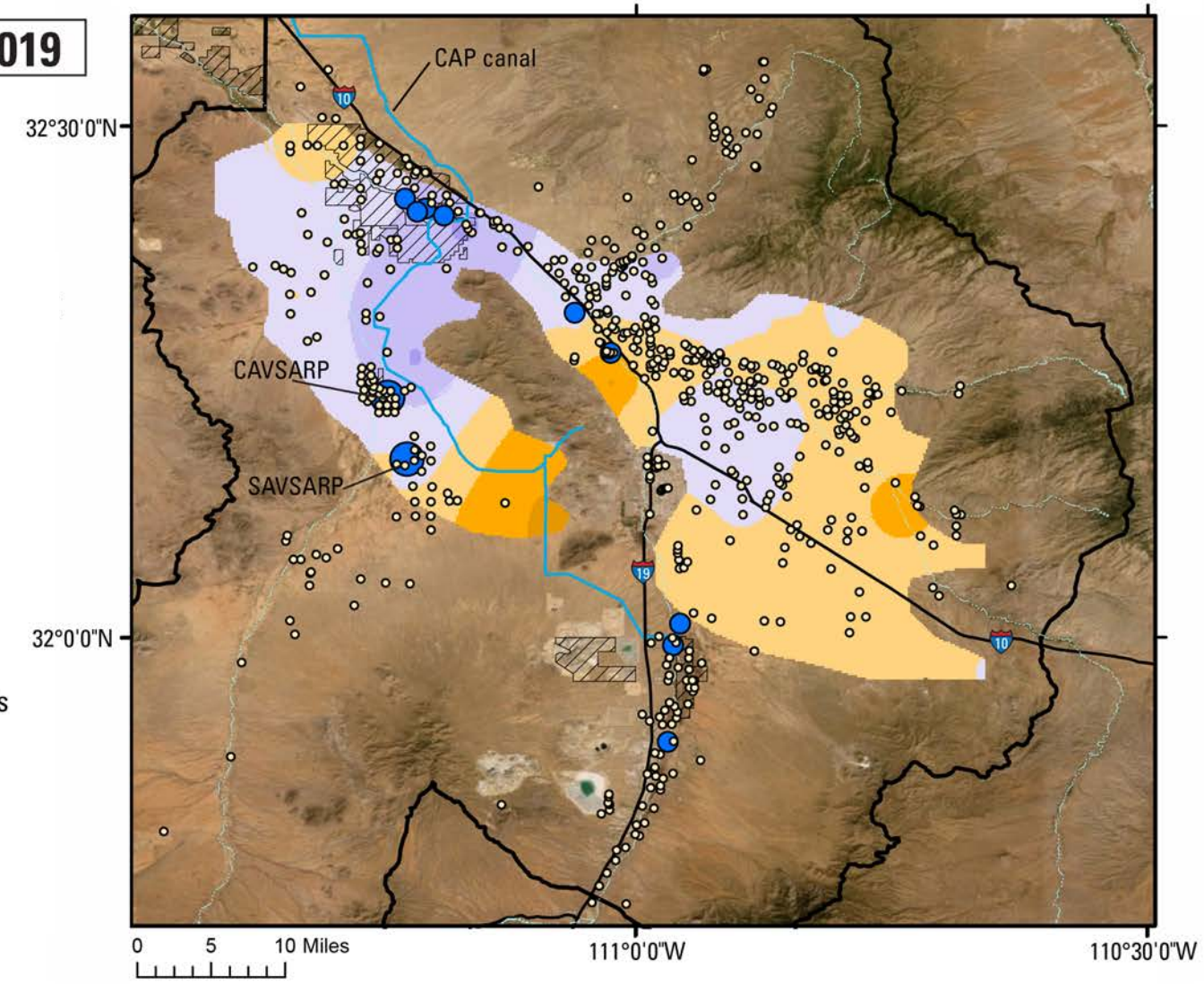

Summary of findings:

Overall, reduced groundwater withdrawals and increased artificial recharge in the Tucson AMA have led to greater balance between groundwater withdrawals and recharge.

The gravity monitoring has been useful for understanding the spatial distribution of storage change and in separating natural recharge from artificial recharge across the study area.

The ability of the method to capture total storage change also eliminates uncertainty introduced by using long-term averages for water budget components that are more difficult to quantify, such as natural recharge.

Questions?

Project website
https://tinyurl.com/yx56lygs

Project reports
https://tinyurl.com/w5e94kq

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