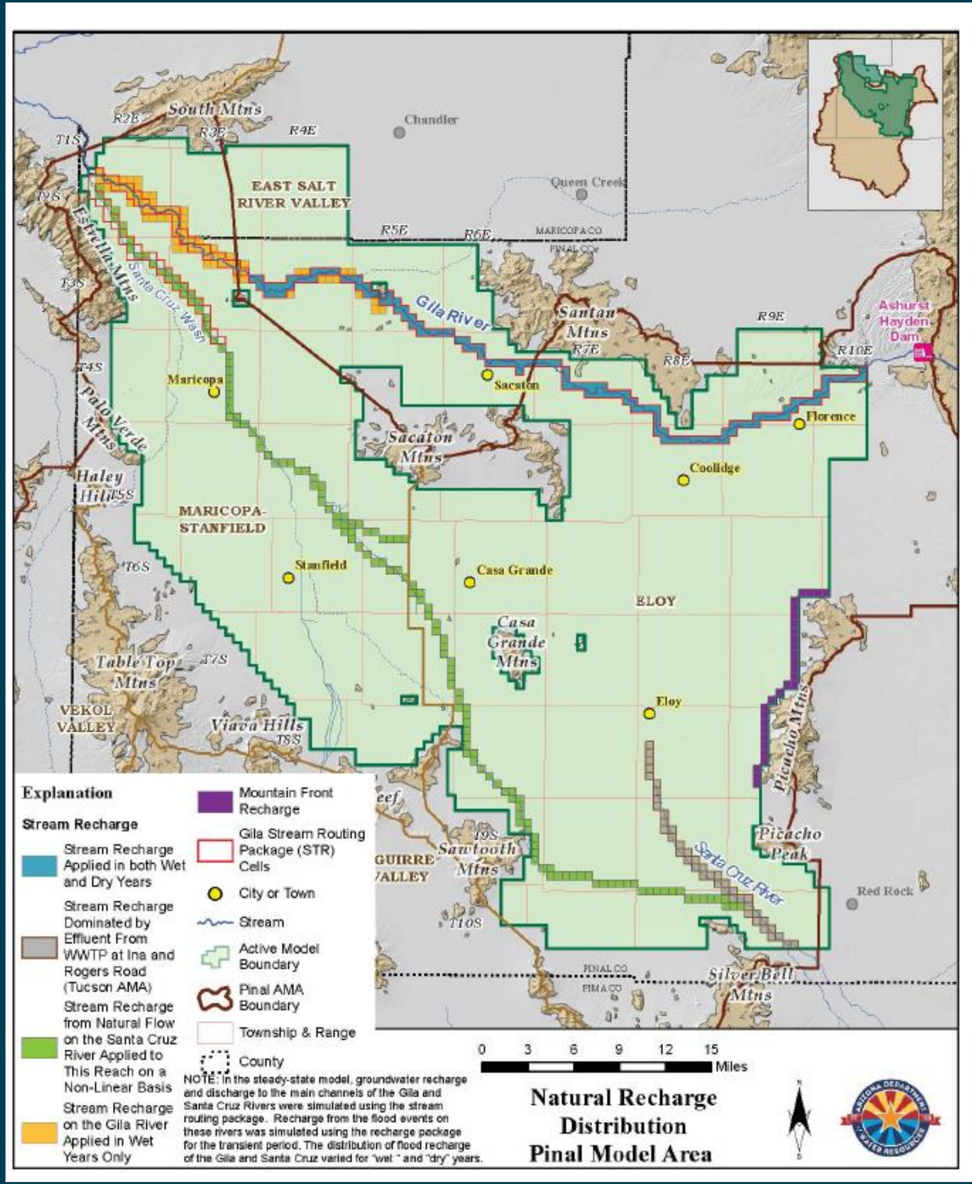
EMS Basin Study:

Future Climate and Recharge Scenarios

Presented by: Kristin Mikkelson

on 9.29.20 to Basin Study Team & Stakeholders



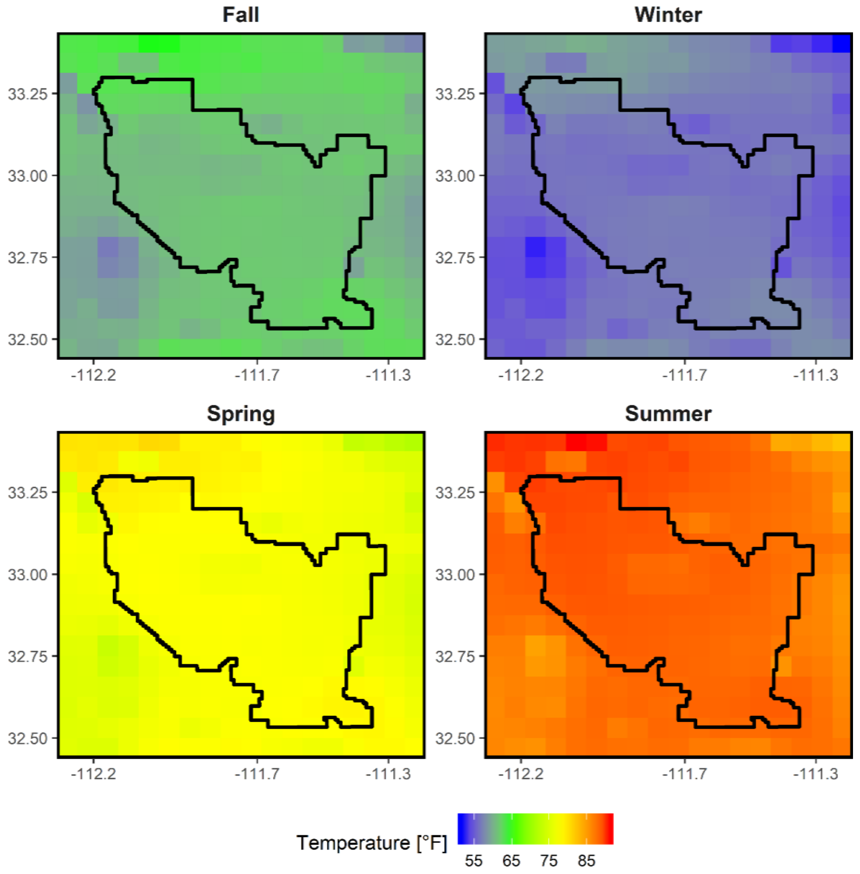
Stakeholders

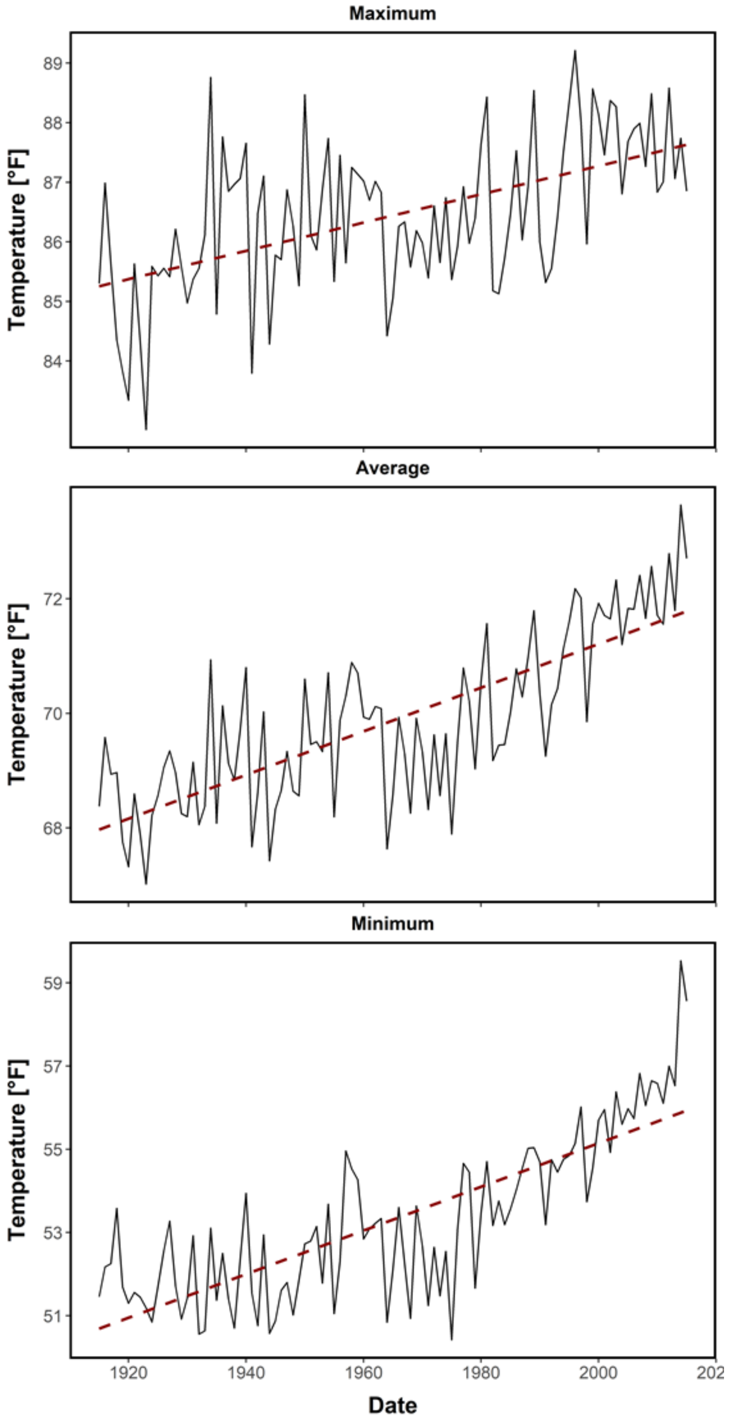
Outline

- Characterization of historical climate
- Development of future climate scenarios
  - Projection ensemble
  - HDe scenario methodology
  - Five future climate scenarios: HW, HD, CT, WW, WD
- Development of future recharge scenarios
  - Implementation of natural recharge in groundwater model
  - Rainfall-runoff modeling of precip/temp & streamflow
  - Five future recharge scenarios for the Gila & Santa Cruz Rivers: HW, HD, CT, WW, WD

Historical Climate - Temperature

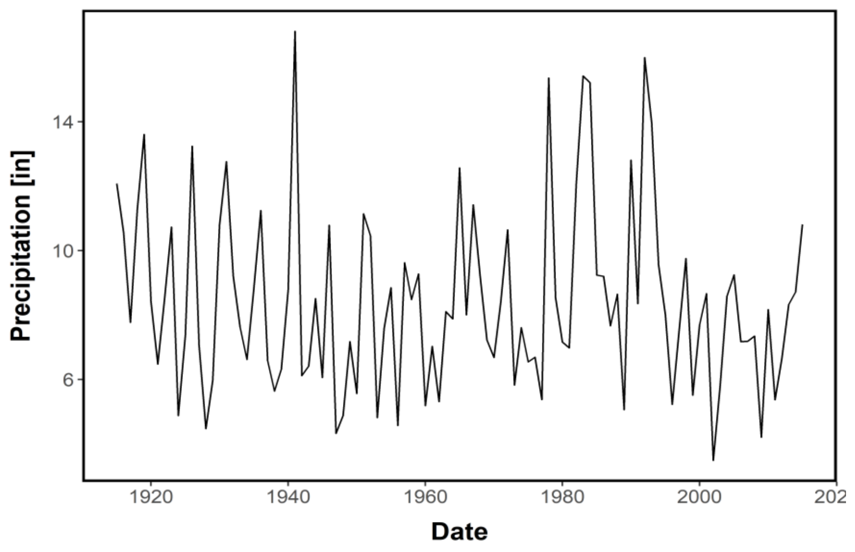
- Little spatial variability across study area but large temporal variability
- Strong seasonality
- Significant increase in temperatures over the past century
    - Tmax – 2.3 °F
    - Tmin – 5.3 °F
    - Tavg – 3.9 °F

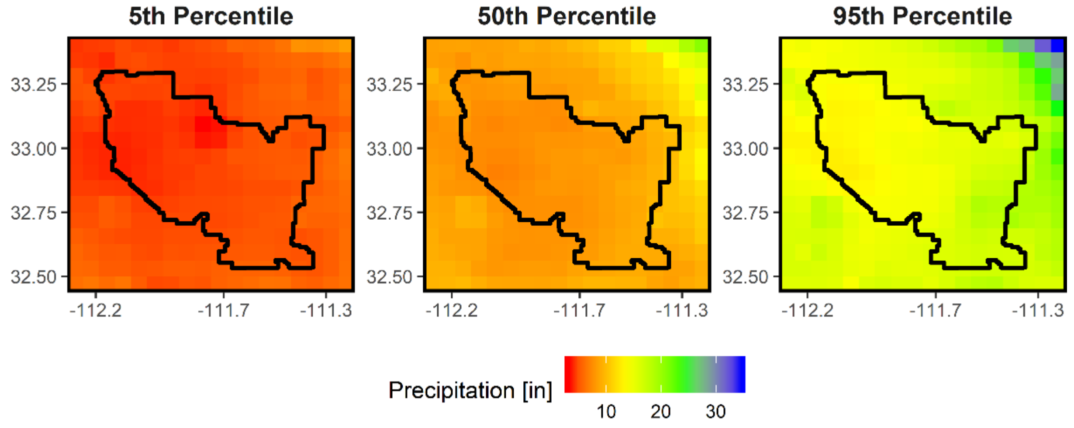


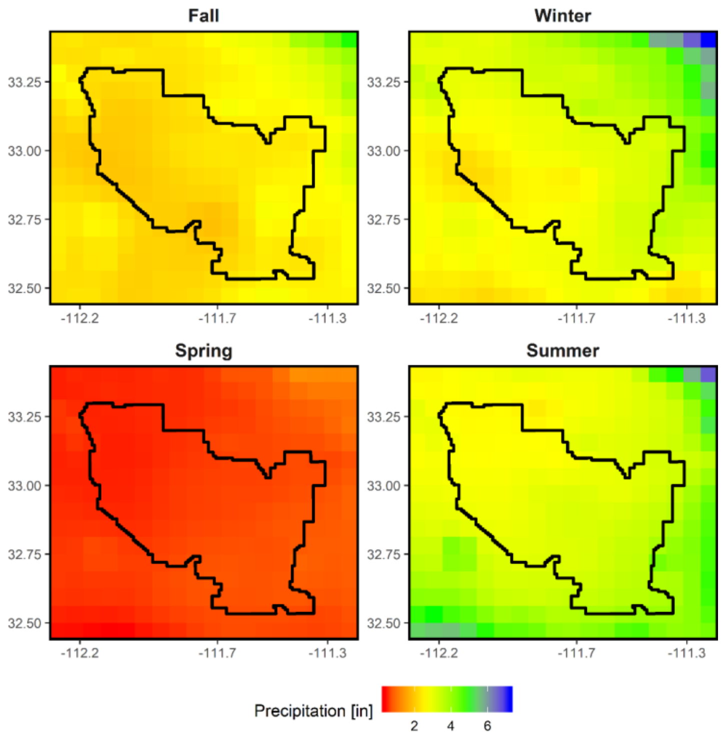


Historical Climate - Precipitation

- Little spatial variability across study area but large temporal (interannual) variability
  - Some years < 5 inches
  - Other years > 14 inches
- Precipitation occurs mostly in winter and the monsoon/summer seasons
- No significant change in annual precipitation over past century







Future Climate - Projections

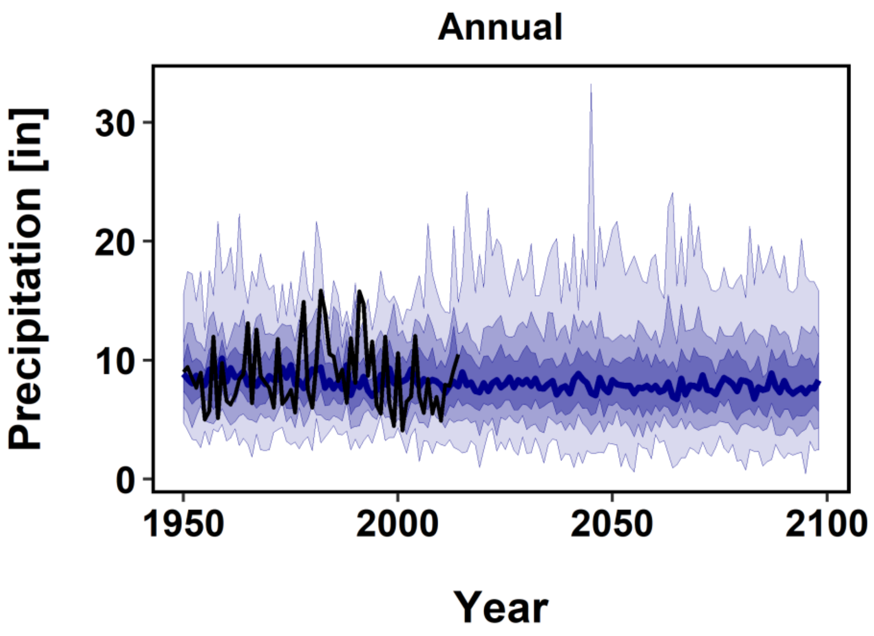
- LOCA 64 projection ensemble
  - ➢ 32 GCMs under two future scenarios: RCP 4.5 and 8.5
  - ➢ Downscaled to same 1/16th degree grid as Livneh
  - ➢ Simulate 1950 – 2099 climate
  - ➢ Historic simulations from 1950 – 2005 using observed Livneh data

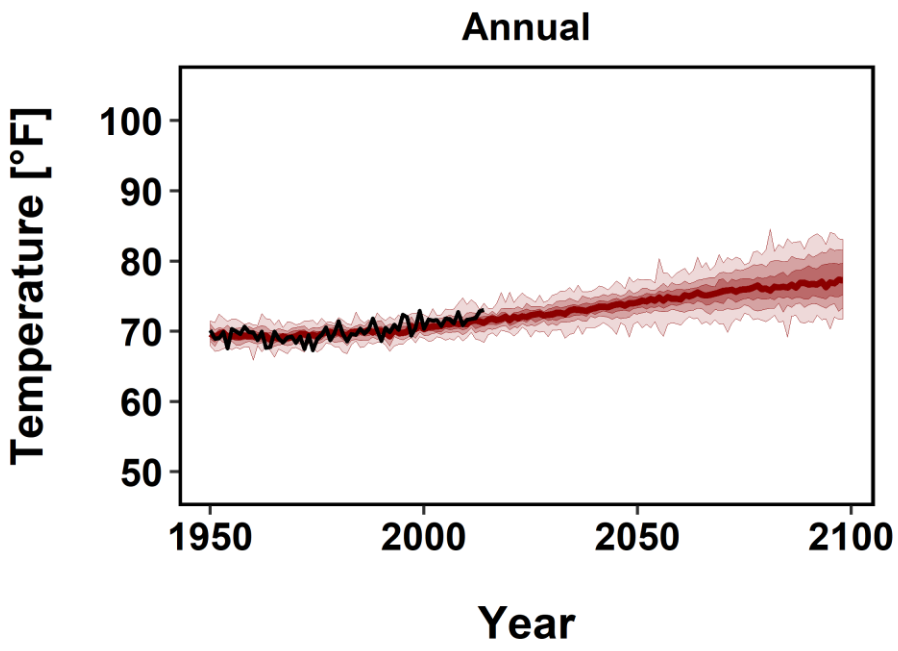
Future Temperature Trends

- All projections indicate an increase in temperature
- Median projected increase in average annual temperature by 2080 is approximately 6 °F

Future Precipitation Trends

- Over half the projections suggest a decrease in annual precipitation while the others suggest an increase
- Median projected change in average annual precipitation by 2080 is a 5.3 % decrease

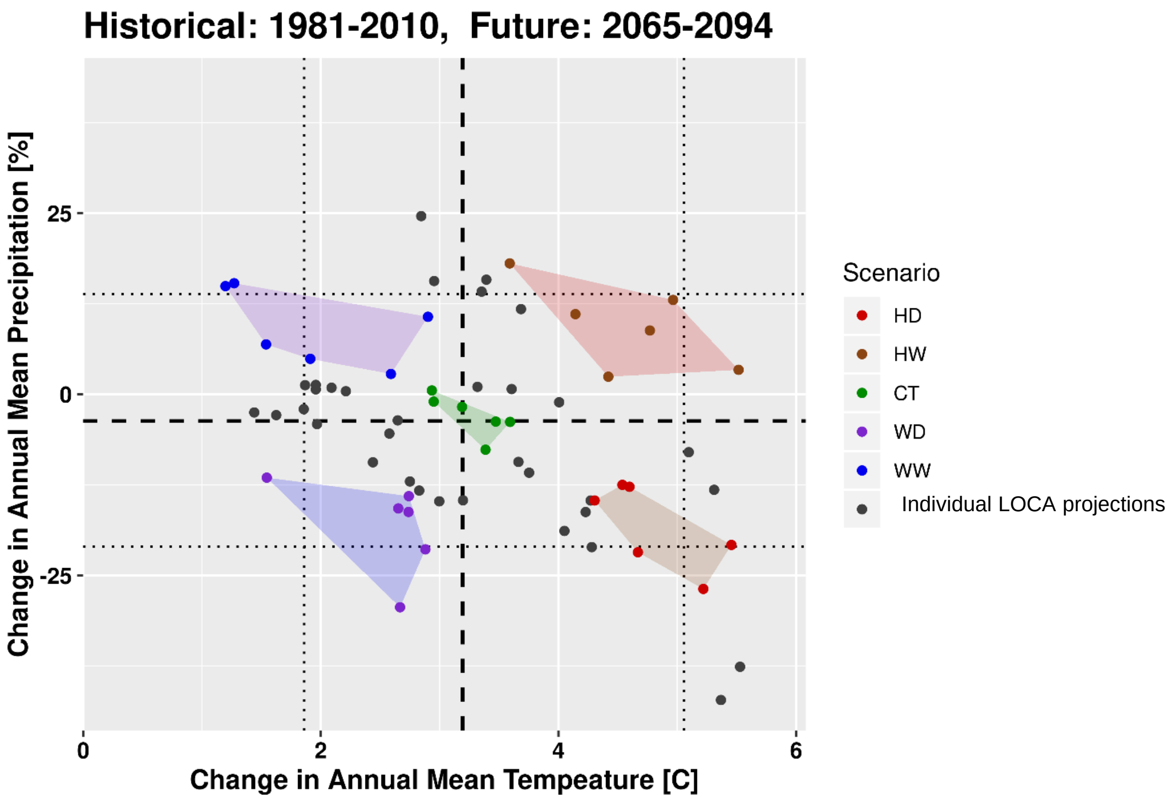




Future Climate Scenarios: Ensemble-Informed Hybrid-Delta method (HDe)

Three Primary Steps:

1. Selection of climate projections for each scenario
2. Development of quantile-based climate change factors
3. Application of quantile-based change factors to an observed historical dataset (i.e. Livneh)



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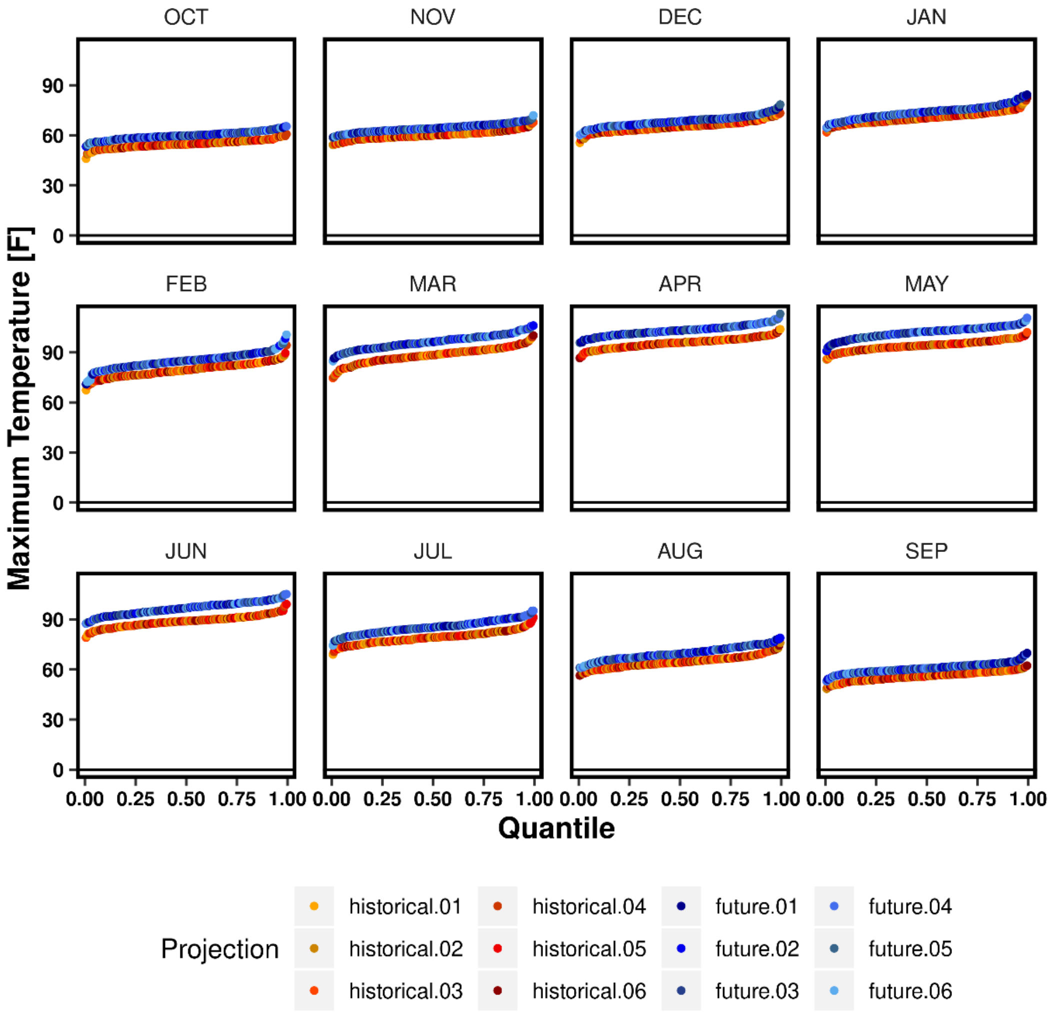

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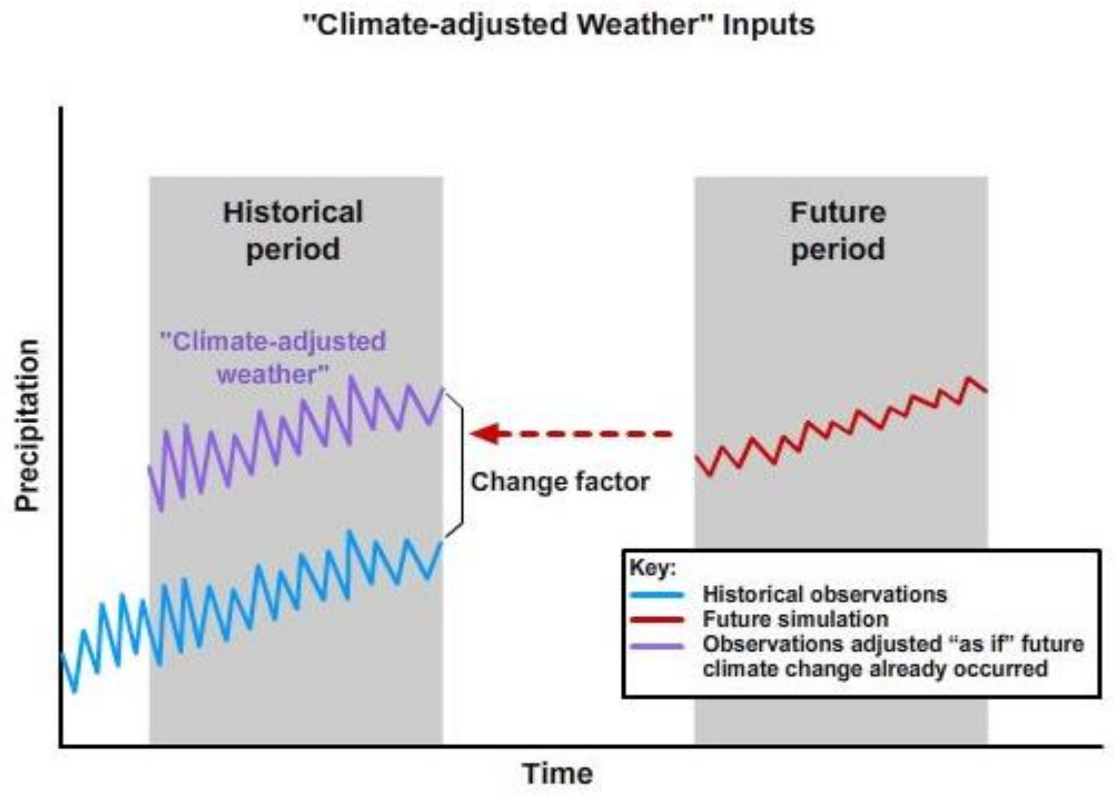

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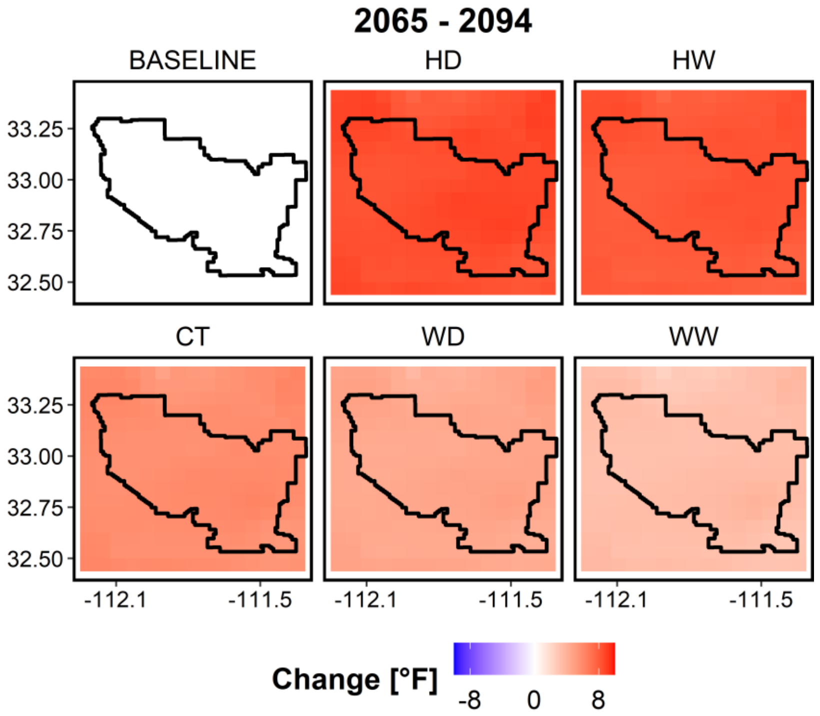
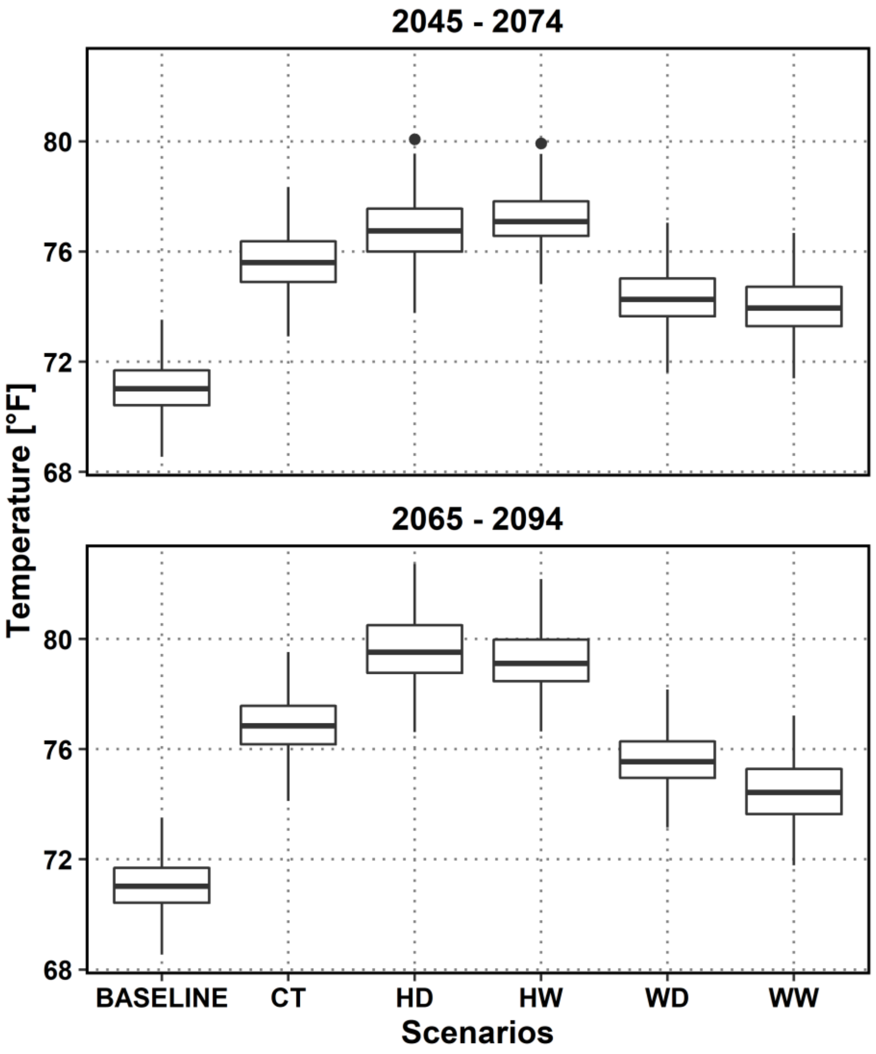
Future Climate - Temperature

- All scenarios indicate an increase in avg. annual temps across study area
  - warm-wet scenario suggests 3.4 °F increase by 2080 and the hot-dry scenario suggests an 8.6 °F increase by 2080

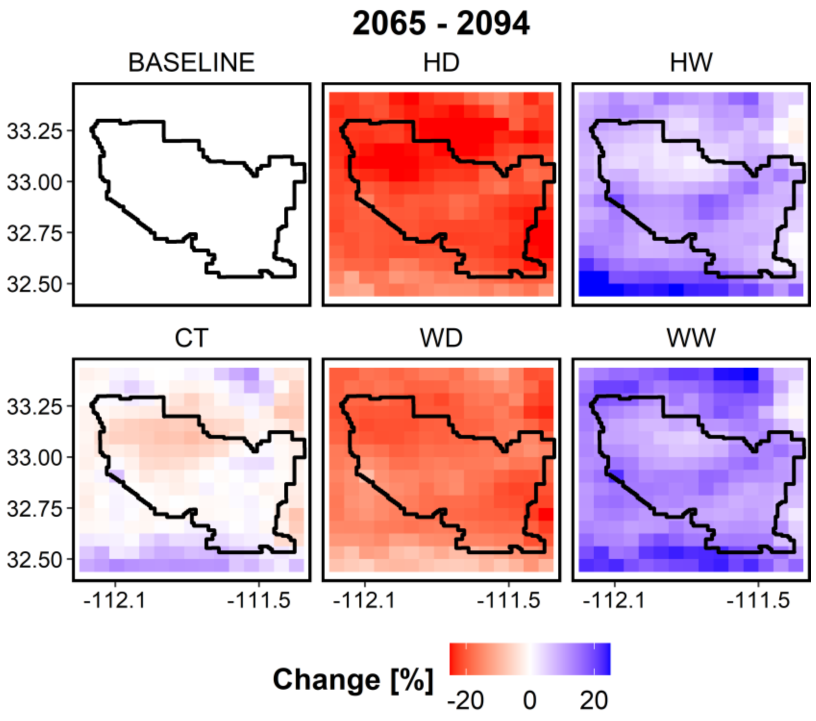
- Temperatures are projected to increase more during fall and summer than during spring and winter

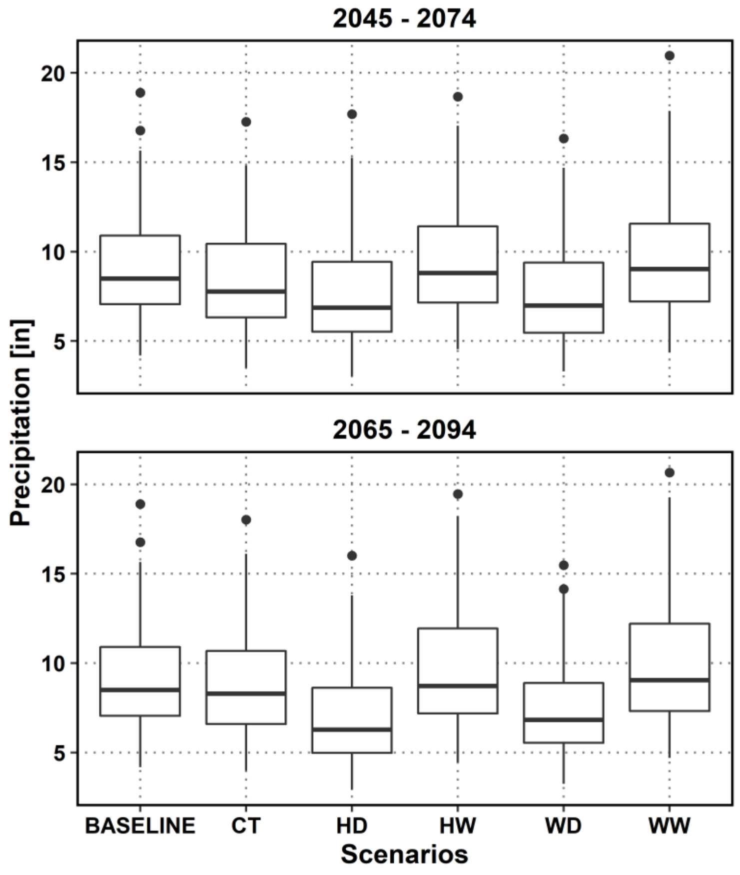




Future Climate - Precipitation

- Future precipitation scenarios are less certain
  - Wet scenarios indicate < 1 inch increase in annual precip
  - Dry scenarios indicate ~2 inch decrease in annual precip

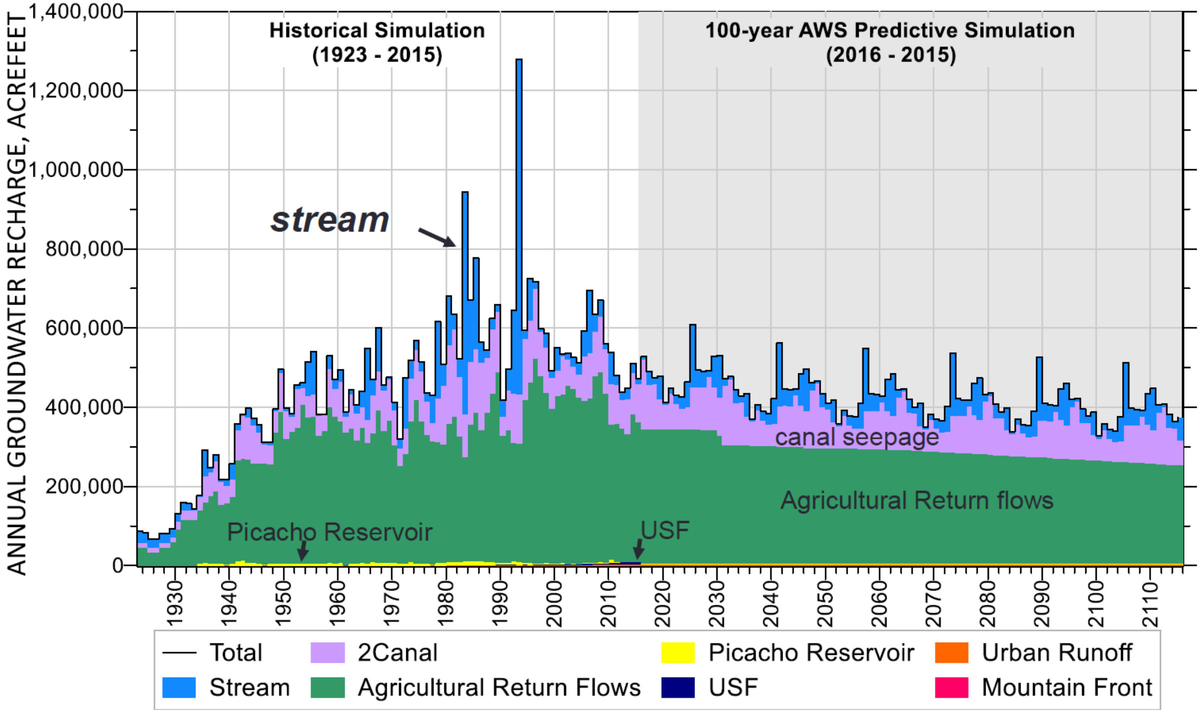




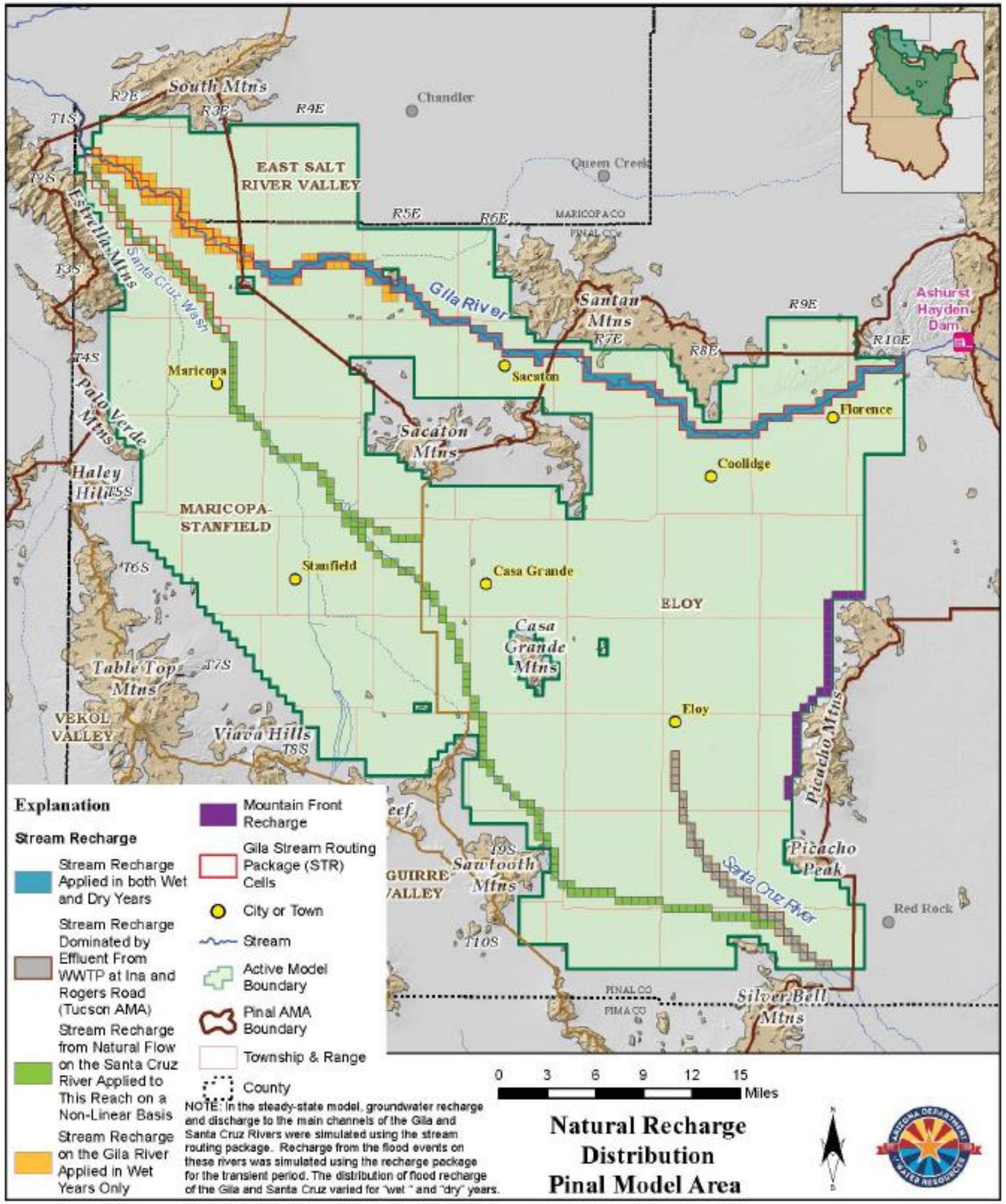
- Wet scenarios project an increase in ‘extremely’ wet years
- Dry scenarios project an increase in ‘extremely’ dry years

Historical Natural Recharge

Recharge Divided into 7 Sources



*Montgomery & Associates



Rainfall-Runoff Modeling of Natural Recharge/Streamflow

Methods

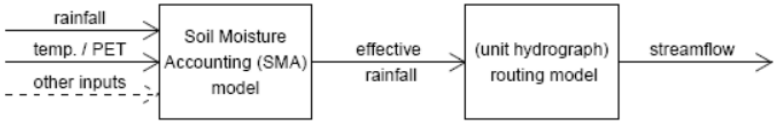
1. Developed five future climate scenarios spanning the range of uncertainty in future projections (Hot-Wet, Hot-Dry, Warm-Wet, Warm-Dry and the Central Tendency Scenarios).

2. Investigated different types of rainfall-runoff models:

   A. Empirical rainfall-runoff model: Multivariate regressions (linear, power, autoregressive, etc.)

$$\text{Streamflow}(t) \leftarrow c + a*\text{Precip}(t)^{b}$$

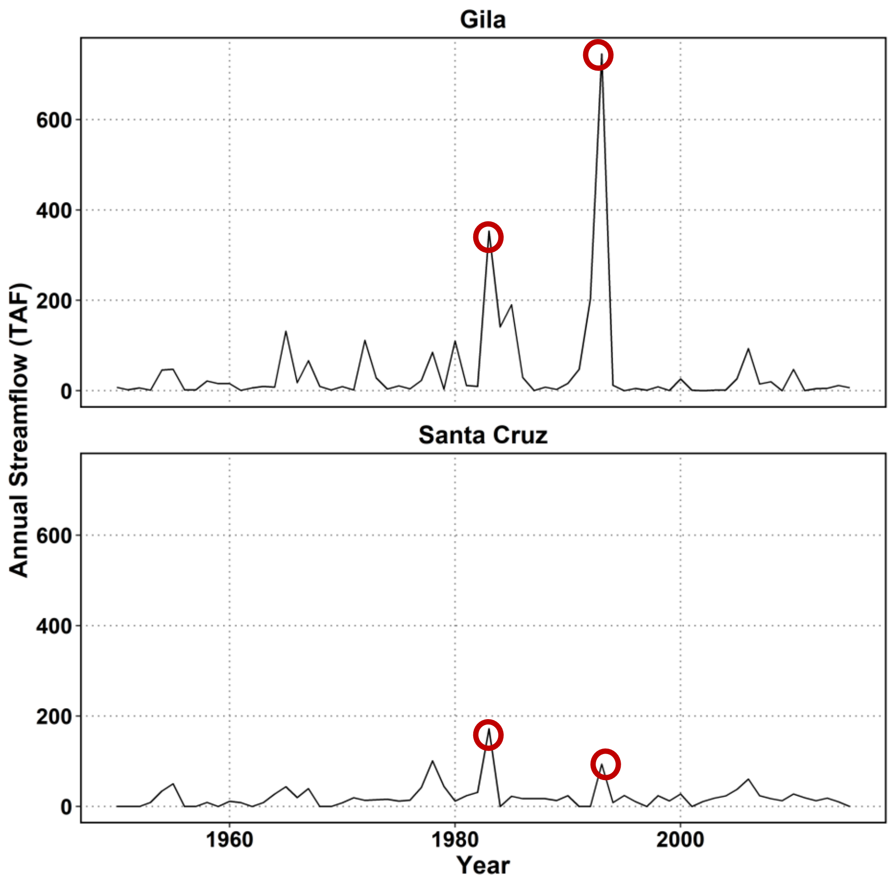
   B. Hybrid empirical-conceptual rainfall-runoff models: Identification of Hydrographs and Components from Rainfall, Evaporation and Streamflow data (IHACRES)



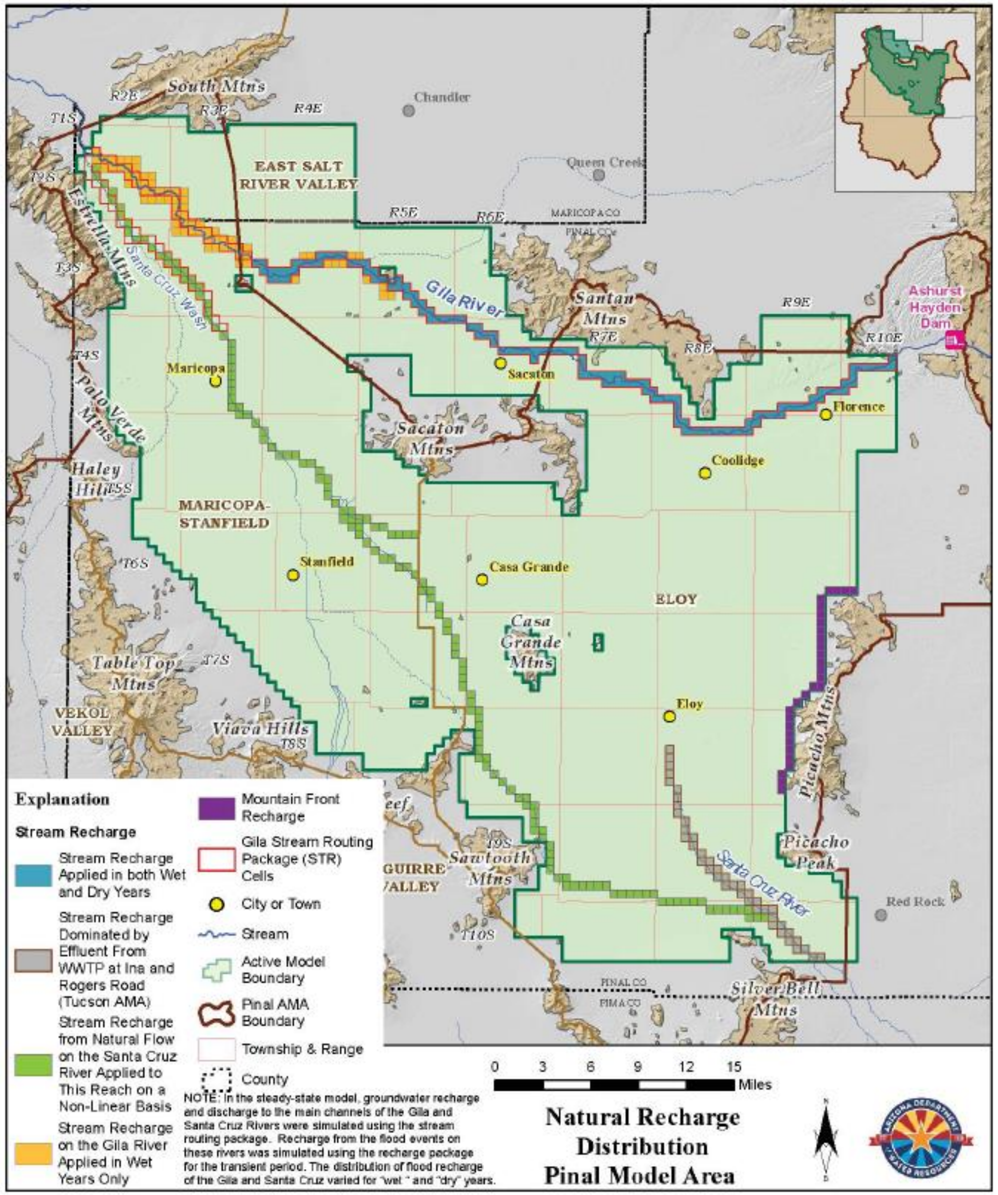
3. Applied the most robust and accurate model between precip/temp and streamflow to project future natural streambed recharge in the Pinal Model domain.

Dependent variables

Annual Streamflows

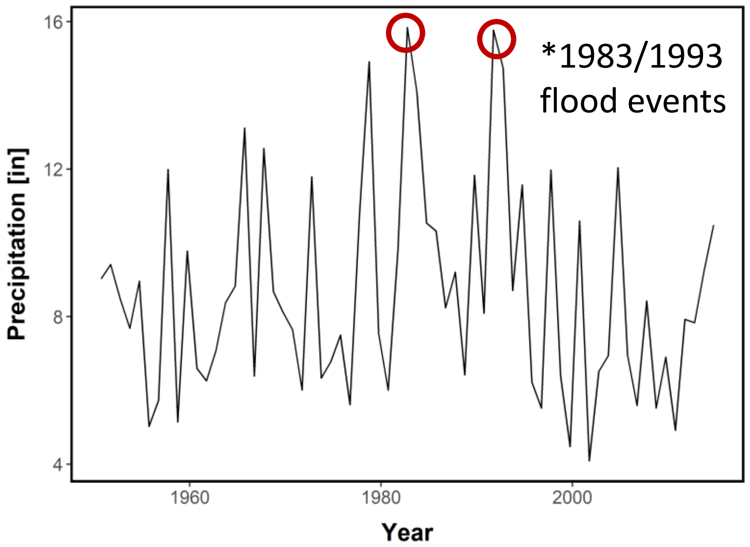


- Inflow: SCIP annual Ashurst Hayden Dam release reports.
- Outflow: Maricopa or Laveen USGS gages
- Stream recharge from natural flow applied along green Santa Cruz reach.

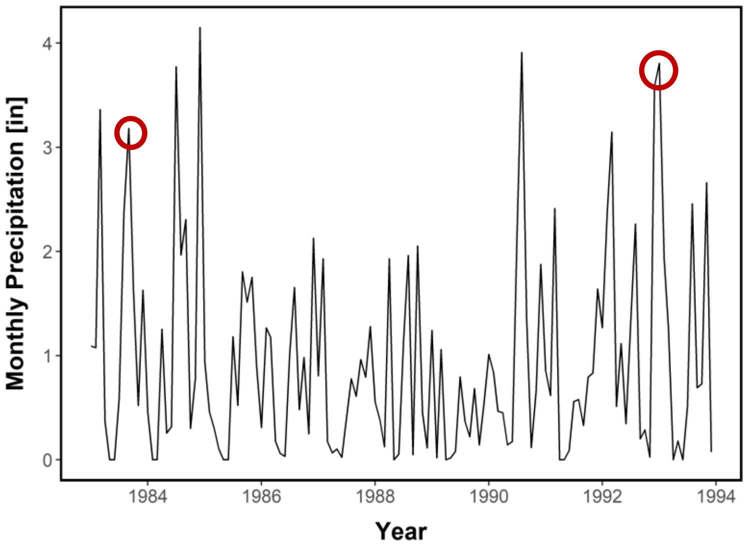


Independent variables

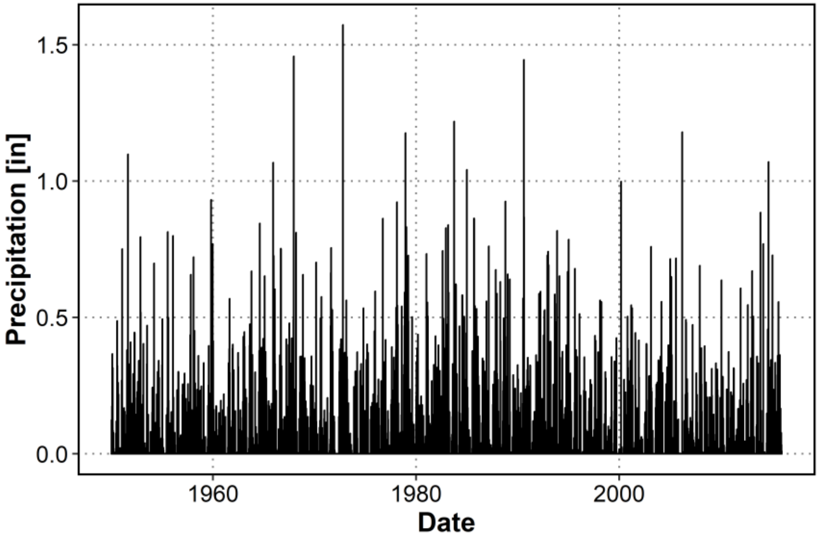
Annual Precipitation



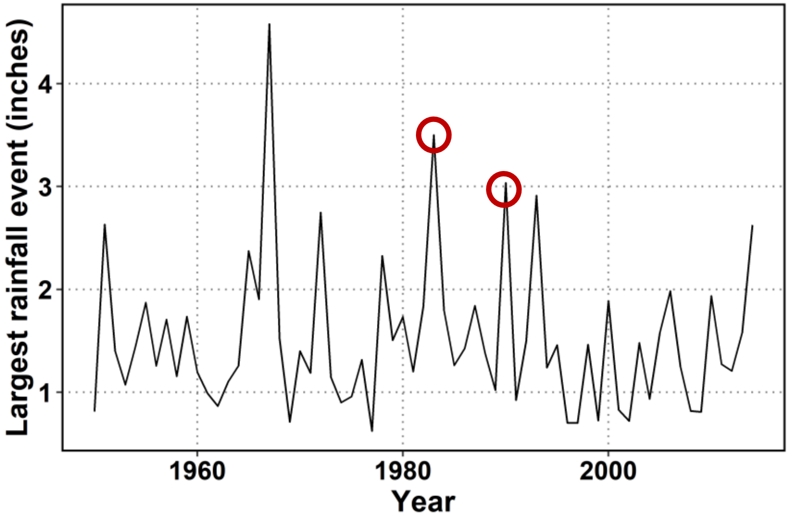
Monthly Precipitation



Daily Precipitation



Largest Annual Rainfall Event



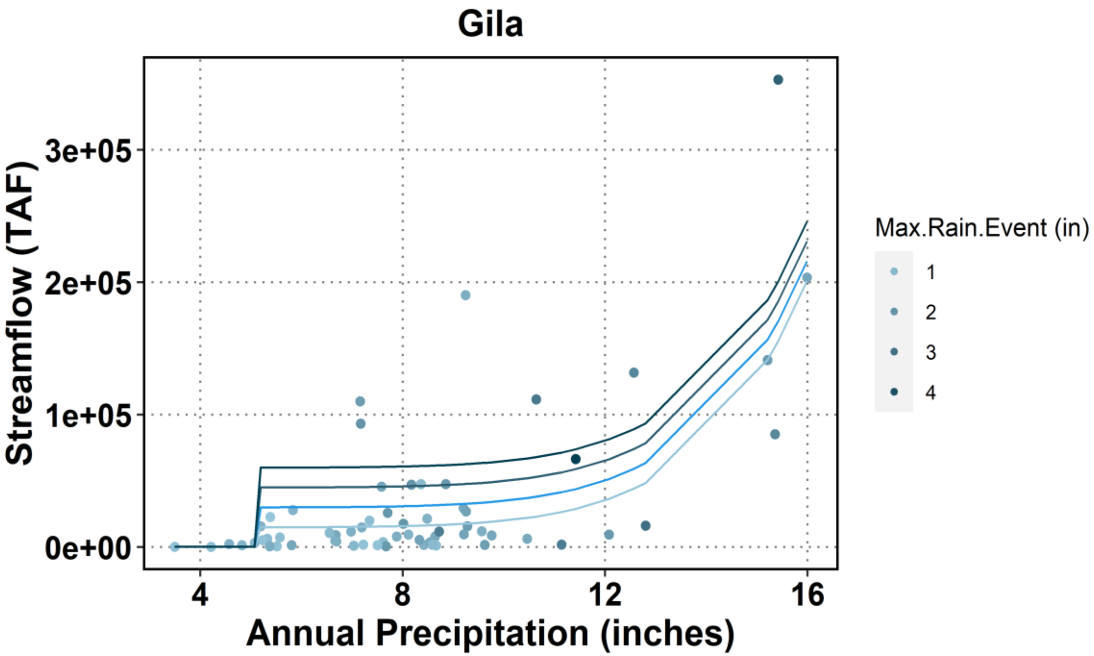
Gila River Annual Regression

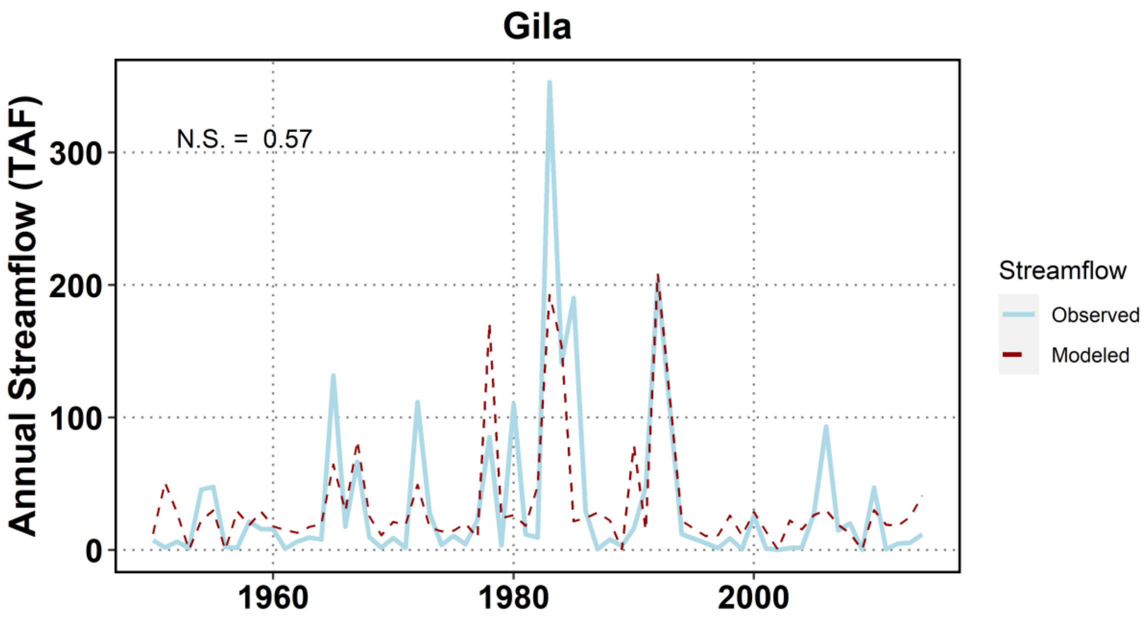
If Precip < 5.1 inches

Streamflow(t) = 250 acre-feet

If Precip >= 5.1 inches

Streamflow(t) <- 0.0001*Precip(t)$^{7.7}$ + 15000*Max.Rain.Event(t)





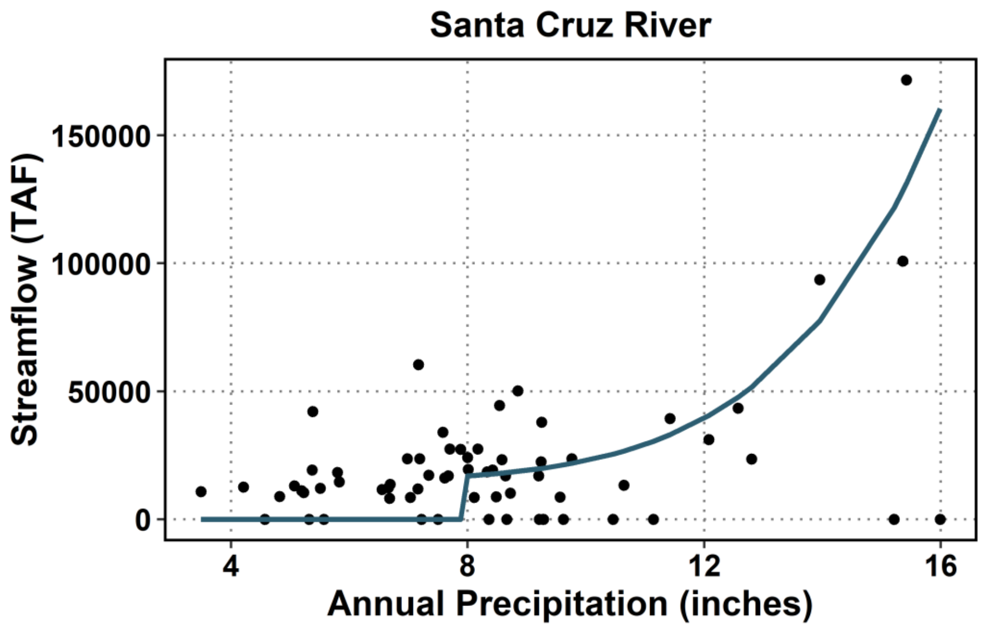
Total streamflow from 1950 – 2015:

Observed: 2.11 million acre-feet

Modeled: 2.10 million acre-feet

~0.4% difference

Santa Cruz River Annual Regression

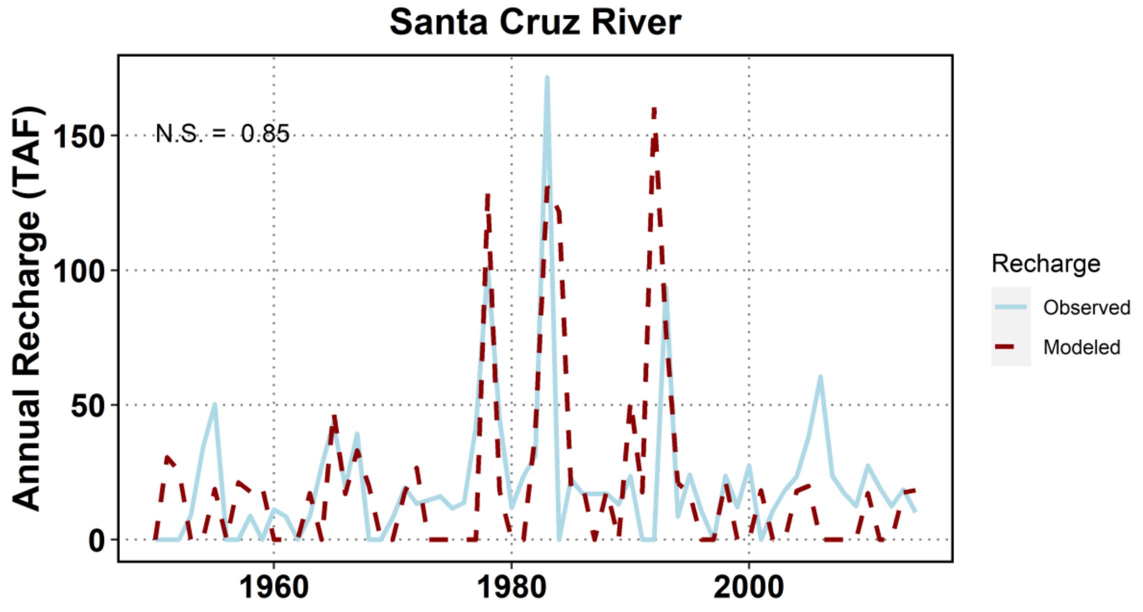


If Precip < 7.9 inches

Streamflow(t) <- 0

If Precip >= 7.9 inches

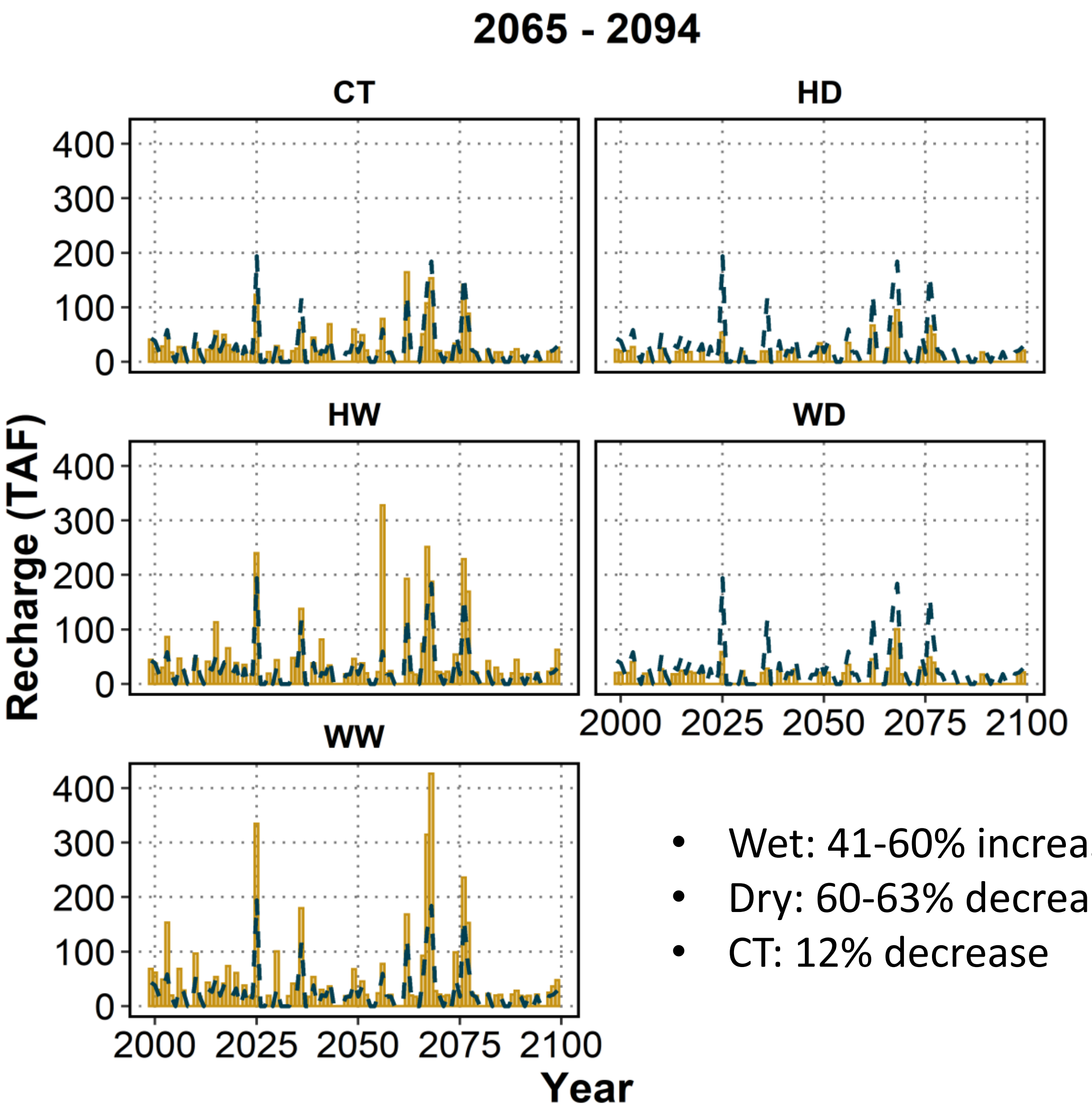
Streamflow(t) <- 15,000 + 0.005*Precip(t)$^{6.2}$



Total streamflow from 1950 – 2015:
Observed: 1.38 million acre-feet
Modeled: 1.29 million acre-feet
~7% difference

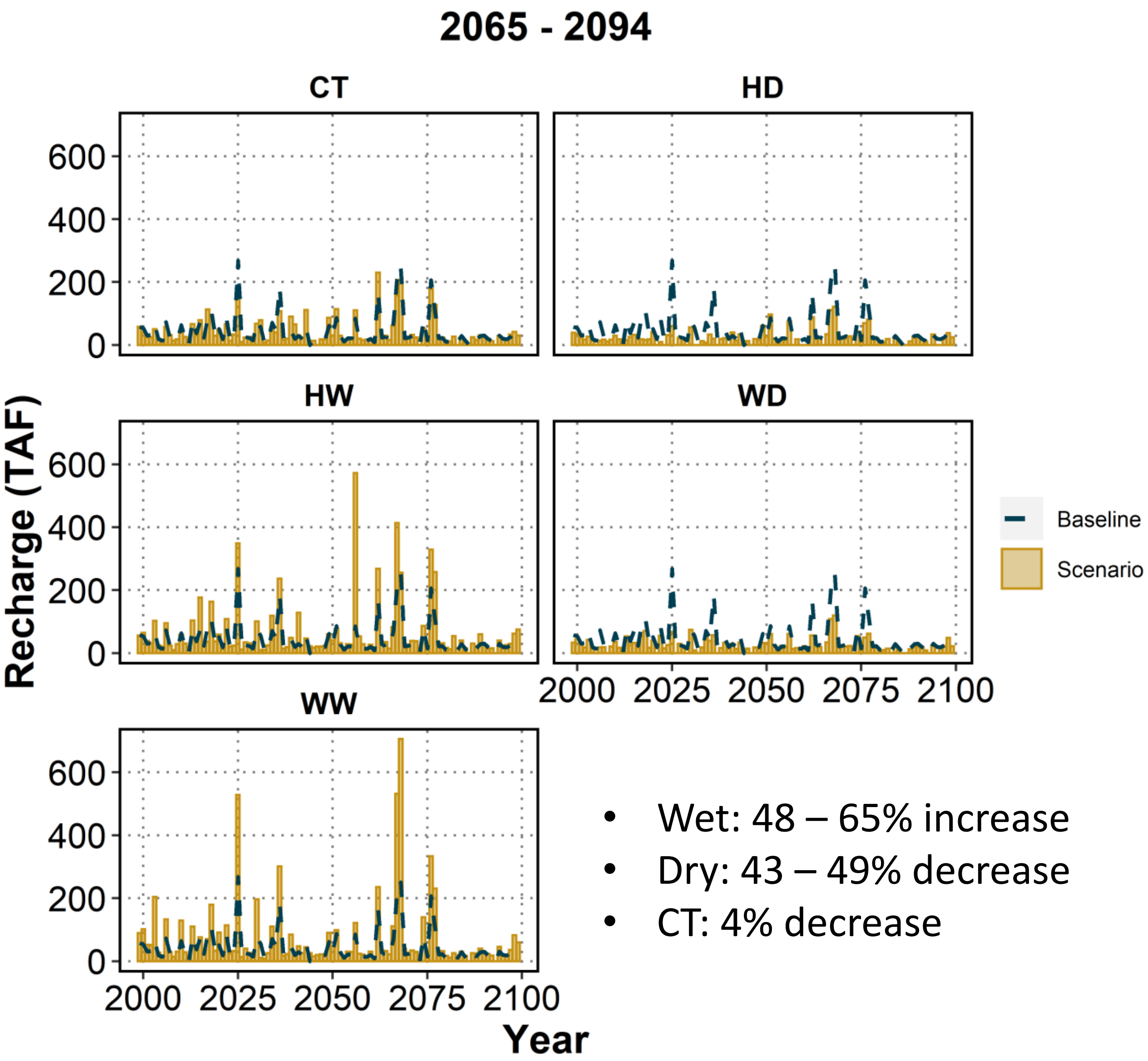
Future Natural Recharge Scenarios

Santa Cruz River



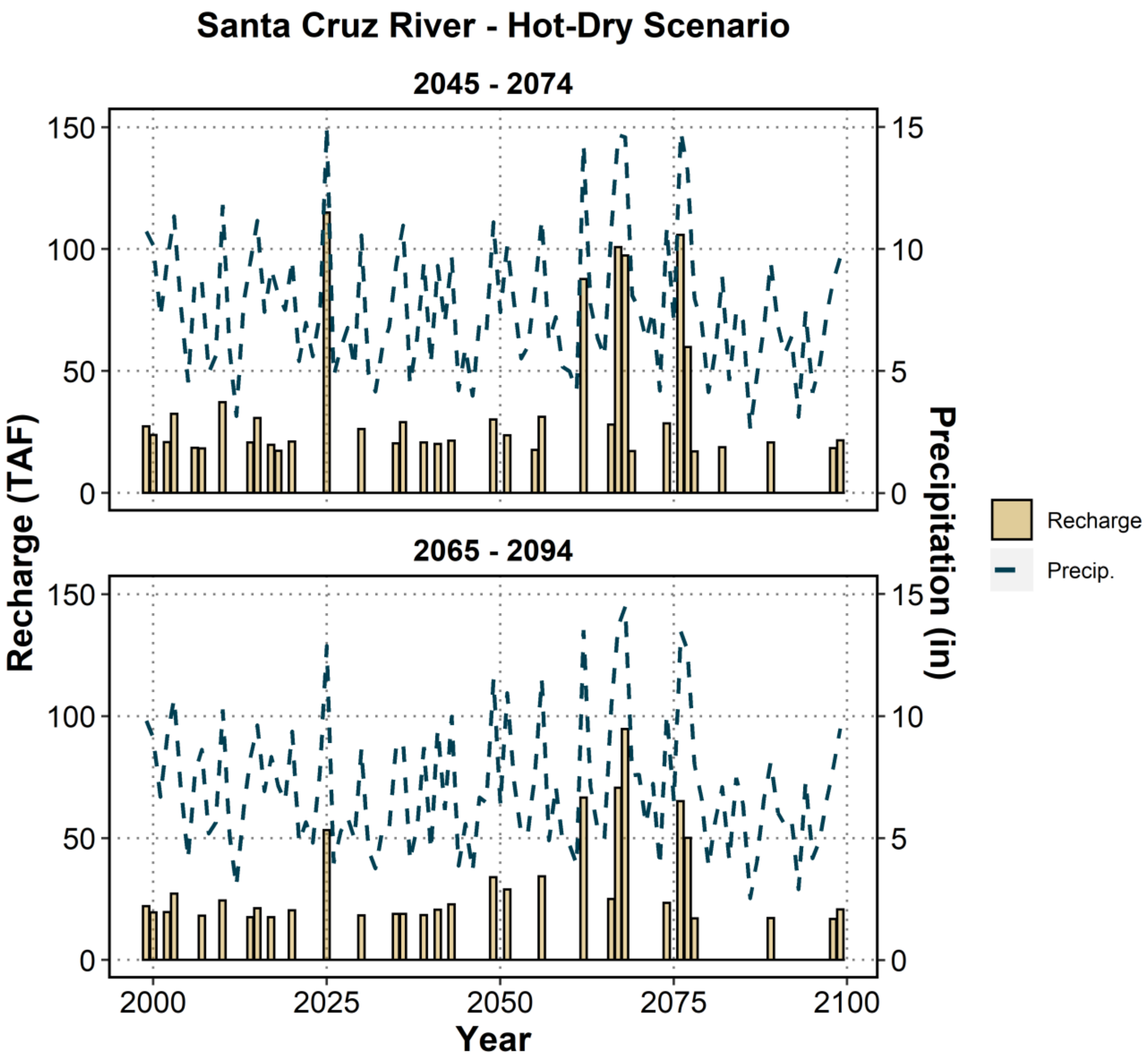
- Wet: 41-60% increase
- Dry: 60-63% decrease
- CT: 12% decrease

Gila River



- Wet: 48 – 65% increase
- Dry: 43 – 49% decrease
- CT: 4% decrease

Future Natural Recharge Scenarios – Increase in 'extremely' dry years

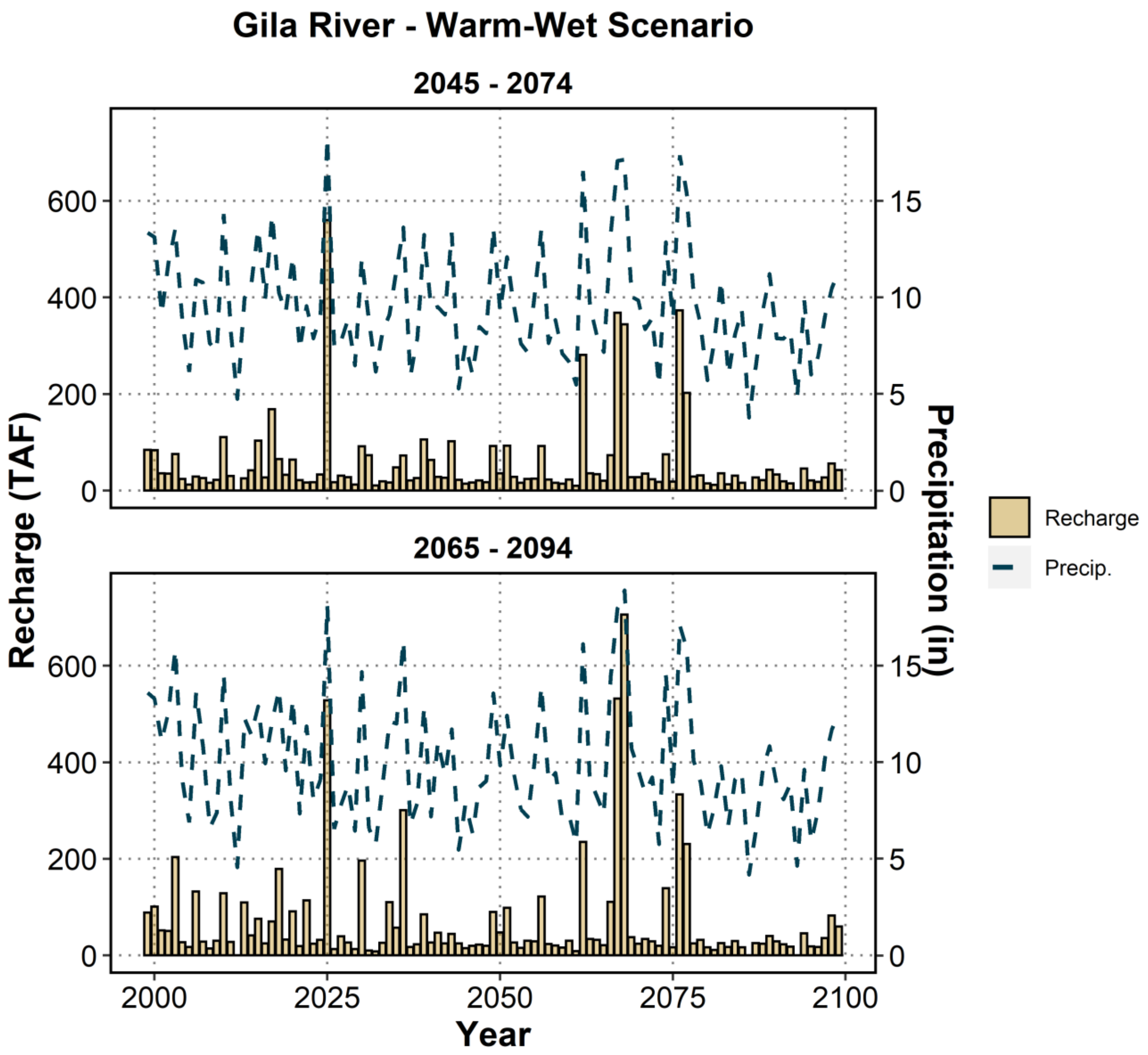


Historic 5th percentile:
- Gila – 250 AF
- Santa Cruz – 0 AF

Santa Cruz River
- During baseline (1981 – 2010) there were 10 years with no natural recharge
- Dry Scenarios (2065 – 2094) CT – 12 years; HD/WD – 22 years
- Wet Scenarios (2065 – 2094) HW – 9 years; WW – 8 years

Gila River
- During baseline (1981 – 2010) there were 3 years with minimum natural recharge (250 AF)
- Dry Scenarios (2065 – 2094) CT – 4 years; HD/WD – 7 years
- Wet Scenarios (2065 – 2094) HW/WW – 2 years

Future Natural Recharge Scenarios – Increase in 'extremely' wet years



Historic 95th percentile:

- Gila – 207 TAF
- Santa Cruz – 150 TAF

Gila River

- During baseline (1981 – 2010) there were 2 years with >= 207 TAF
- Dry Scenarios (2065 – 2094) CT/HD/WD – 0 years
- Wet Scenarios (2065 – 2094) HW/HD - 4 years

Santa Cruz River

- During baseline (1981 – 2010) there were 2 years with >= 150 TAF
- Dry Scenarios (2065 – 2094) CT – 1 years; HD/WD – 0 years
- Wet Scenarios (2065 – 2094) HW/HD - 4 years

BUREAU OF RECLAMATION

Future Climate and Recharge Scenarios

Questions?