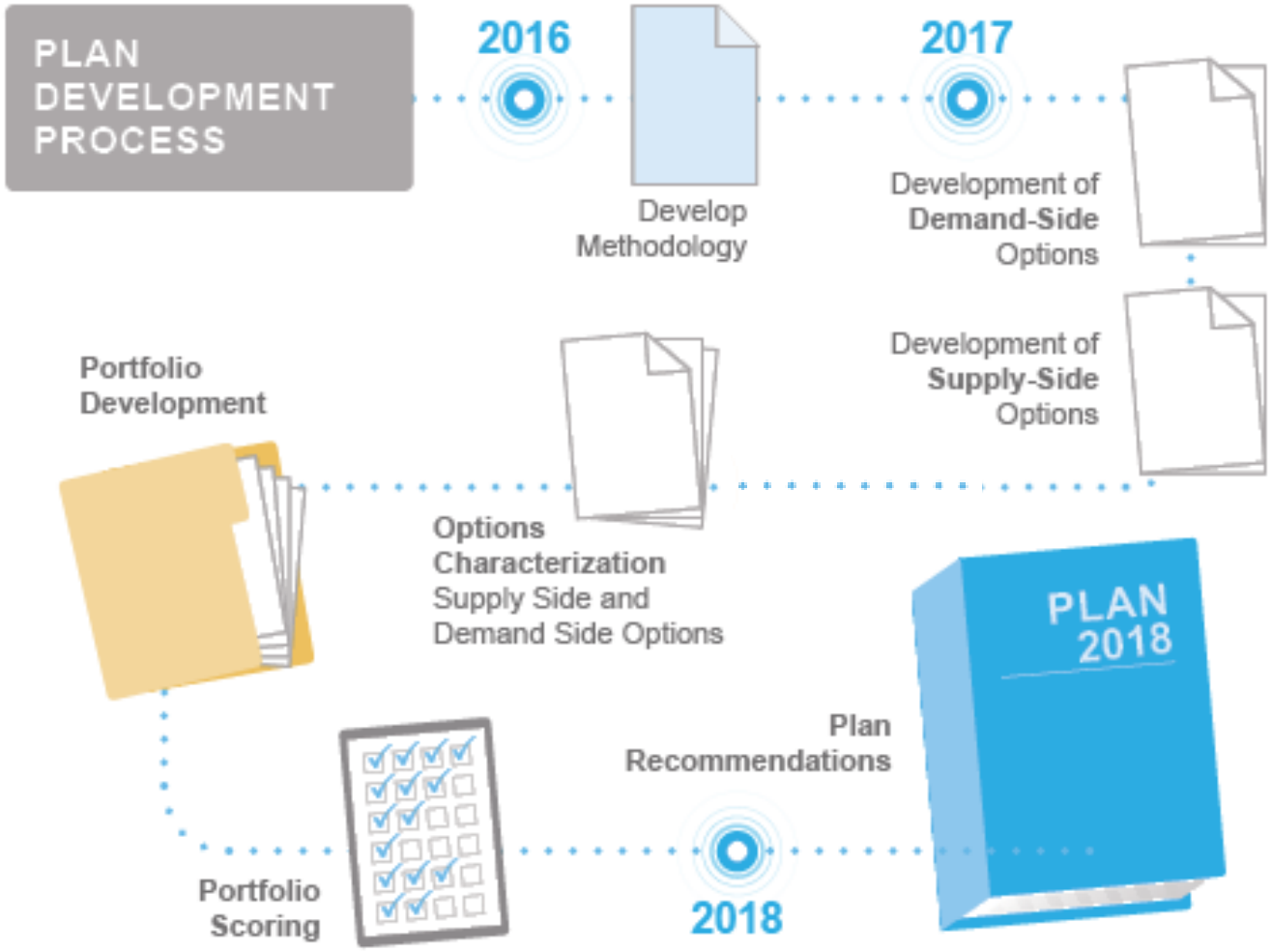
Austin WATER

WATER FORWARD
INTEGRATED WATER RESOURCE PLAN

Region K Water Modeling Committee
June 27, 2018

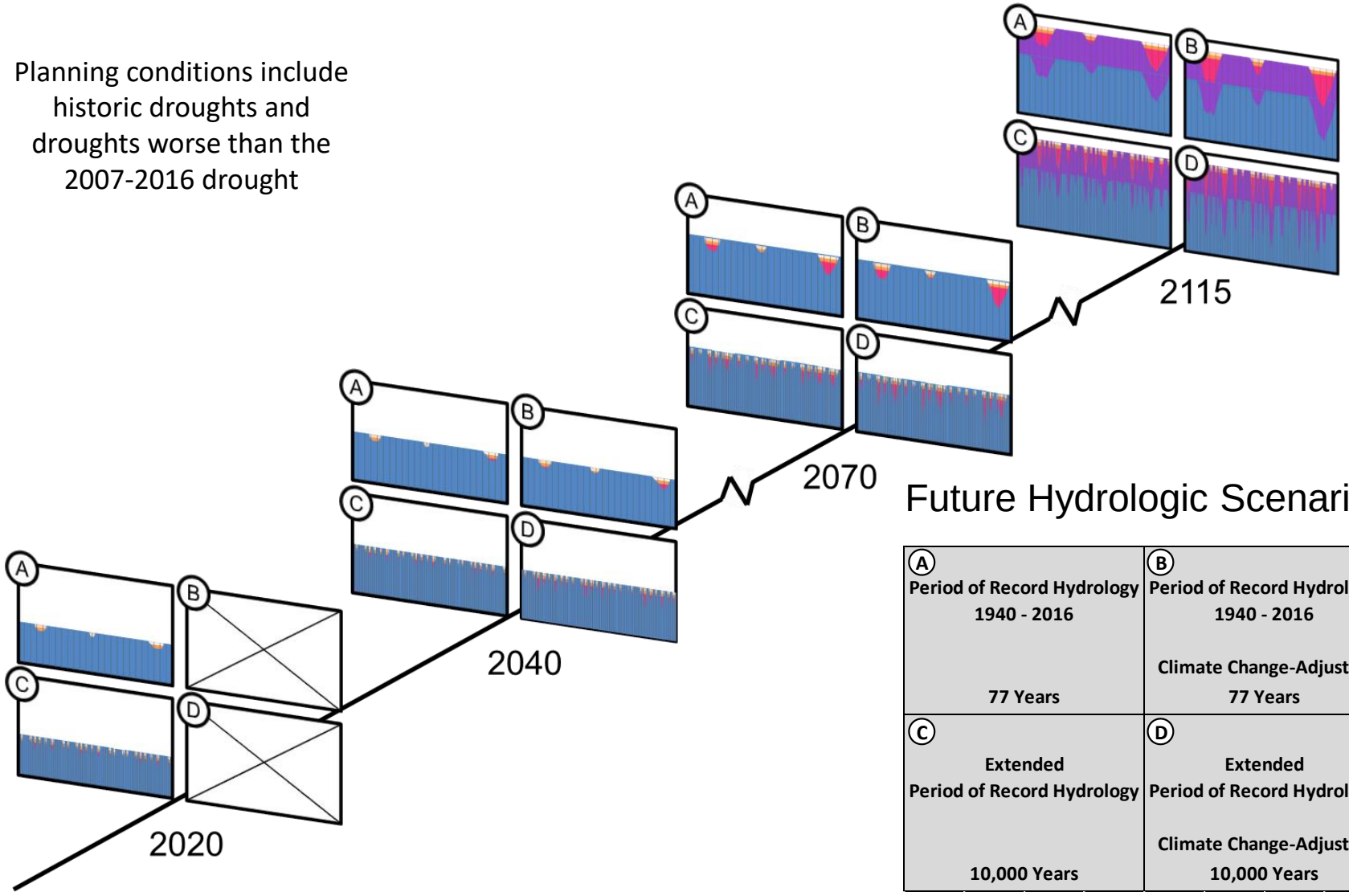
IWRP Development Process



We will be gathering public input throughout the plan process

Planning For Change and Uncertainties

Planning conditions include historic droughts and droughts worse than the 2007-2016 drought



Future Hydrologic Scenarios

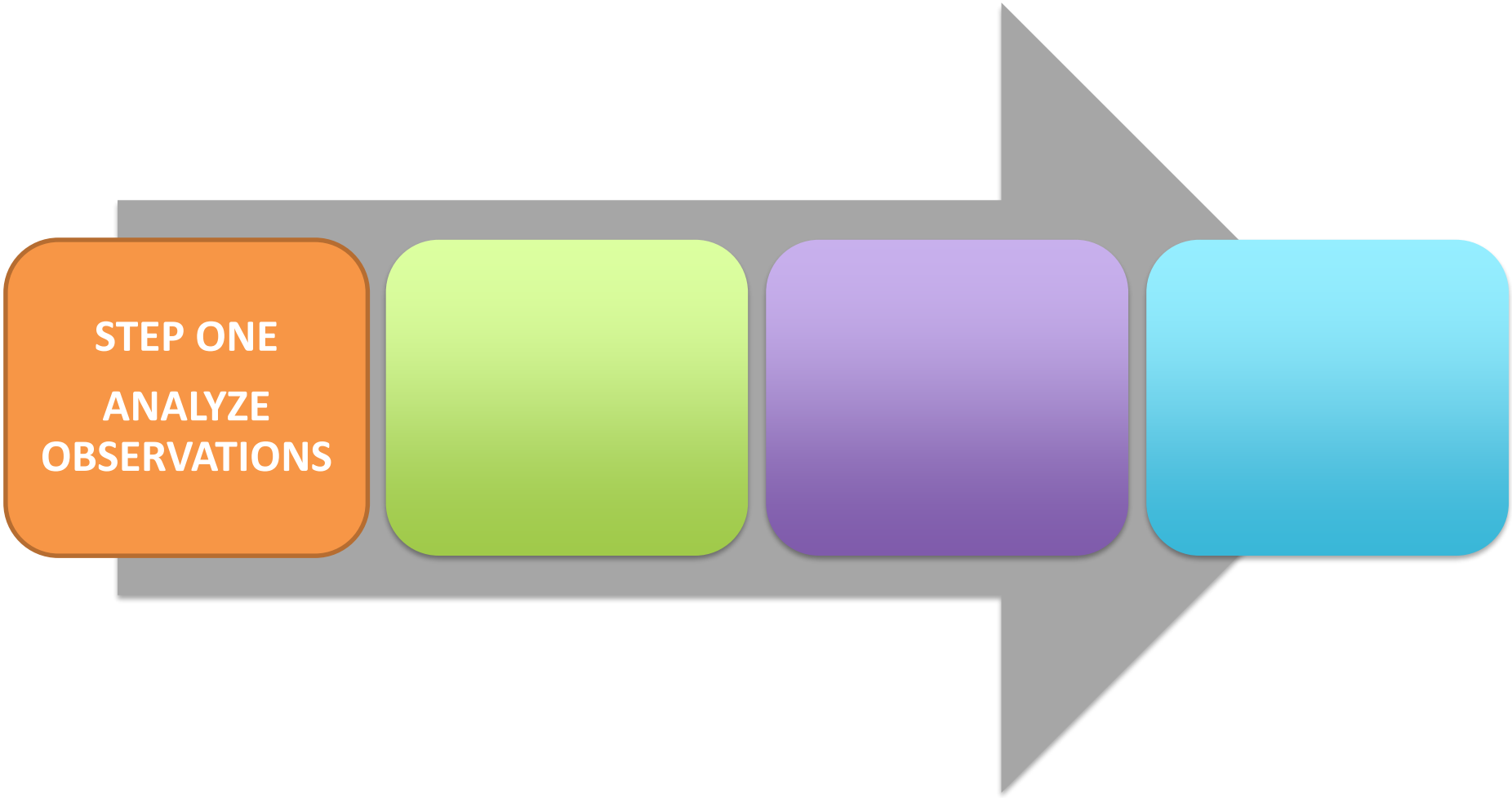
(A) Period of Record Hydrology 1940 - 2016 77 Years	(B) Period of Record Hydrology 1940 - 2016 Climate Change-Adjusted 77 Years
(C) Extended Period of Record Hydrology 10,000 Years	(D) Extended Period of Record Hydrology Climate Change-Adjusted 10,000 Years

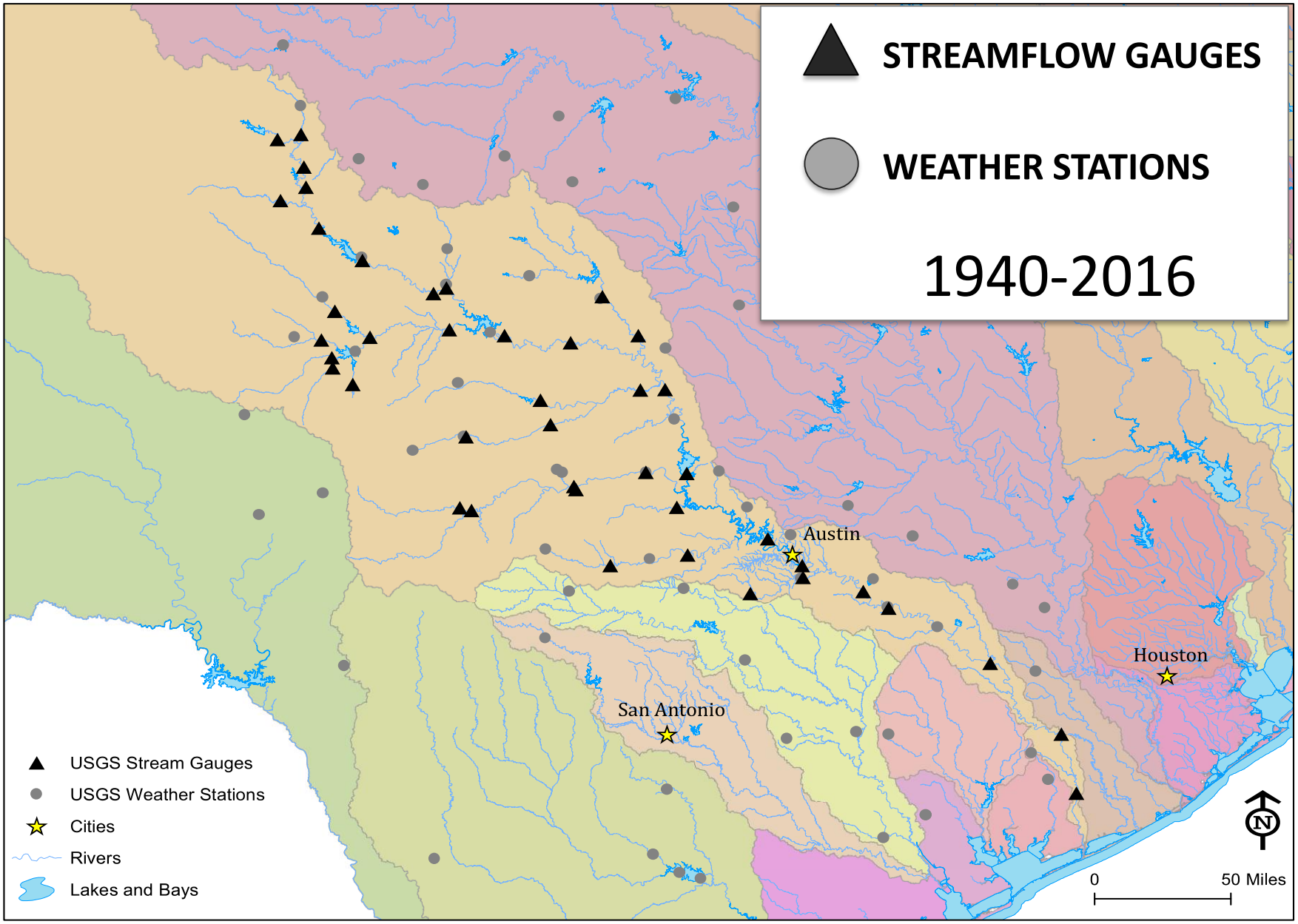
CLIMATE IMPACTS ON WATER SUPPLY
AN AUSTIN CASE STUDY

Marisa Flores Gonzalez, Katharine Hayhoe, Richard Hoffpauir

MOTIVATION

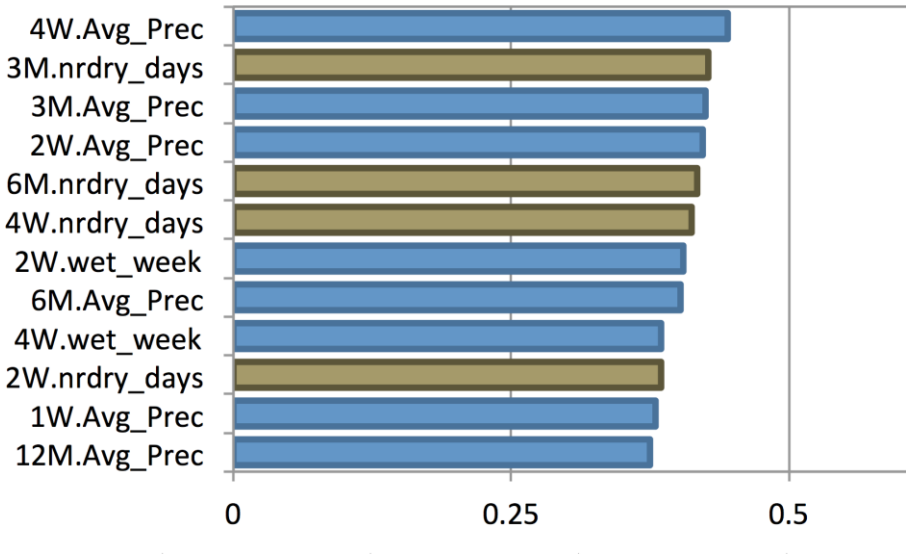
- Texas is already naturally at risk from regularly-occurring droughts and heavy rainfall events.
- The risks we face are not static: they are rising
- Warmer temperatures accelerate evaporation and increase water vapor in the atmosphere
- **This exacerbates the duration & severity of droughts *and* increases the frequency of heavy rainfall events**


STEP ONE
ANALYZE OBSERVATIONS

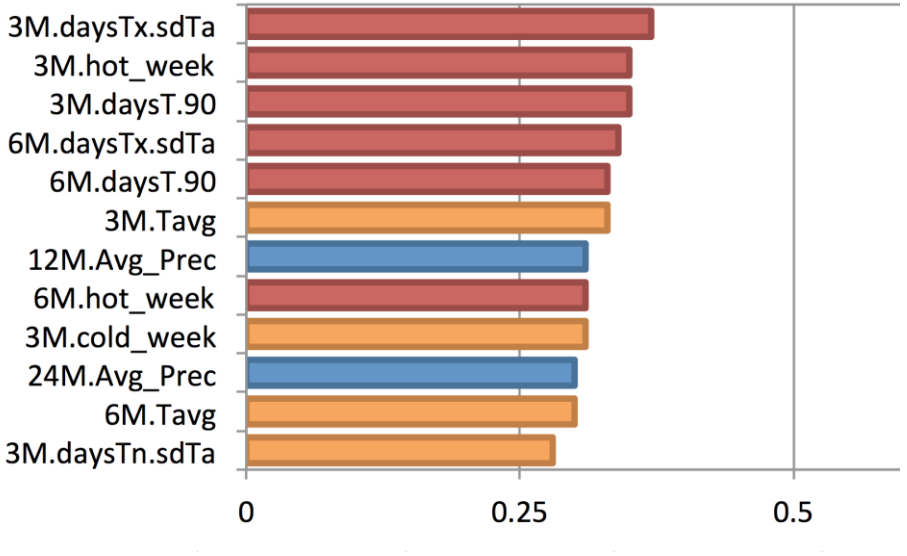

STREAMFLOW GAUGES
WEATHER STATIONS
1940-2016
Austin
Houston
San Antonio
USGS Stream Gauges
USGS Weather Stations
Cities
Rivers
Lakes and Bays
N
0
50 Miles

TOP STREAMFLOW PREDICTORS

Colorado River at Austin



Llano River at Llano

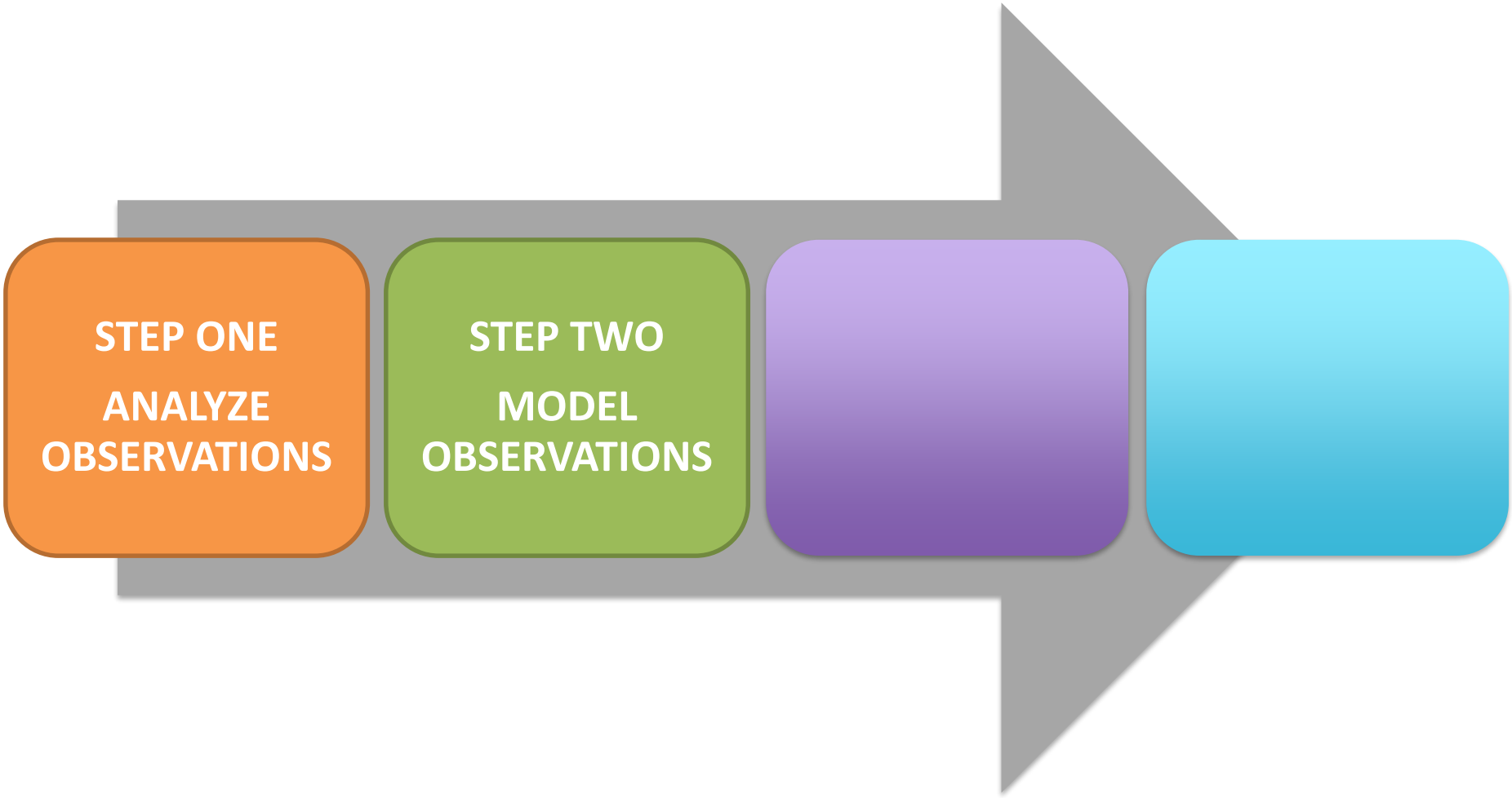


AVERAGE PRECIPITATION

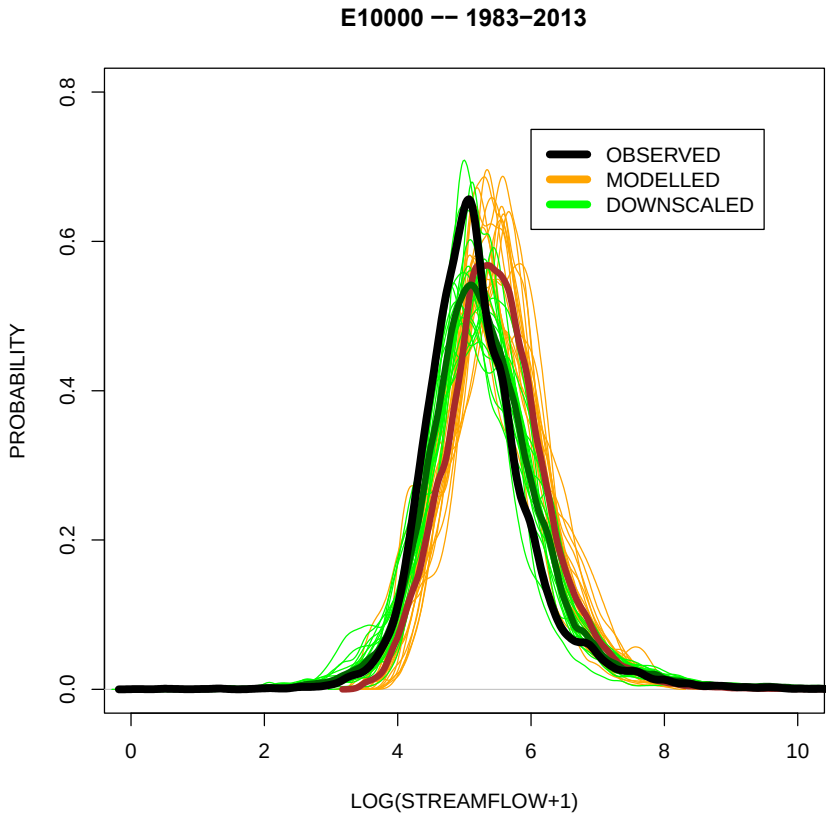
DRY DAYS

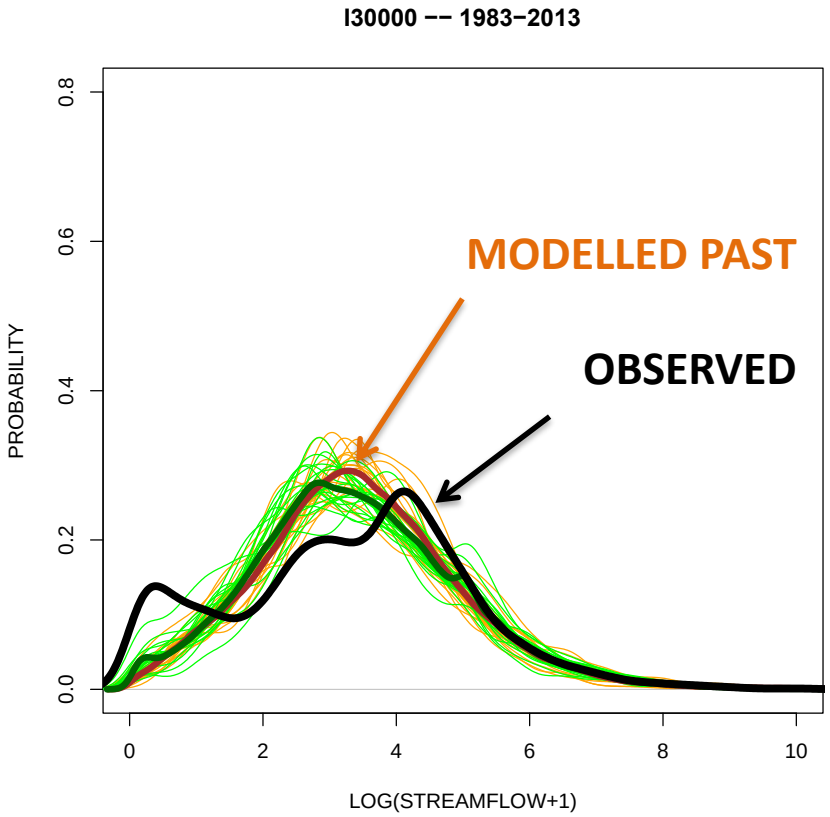
AVERAGE TEMPERATURE

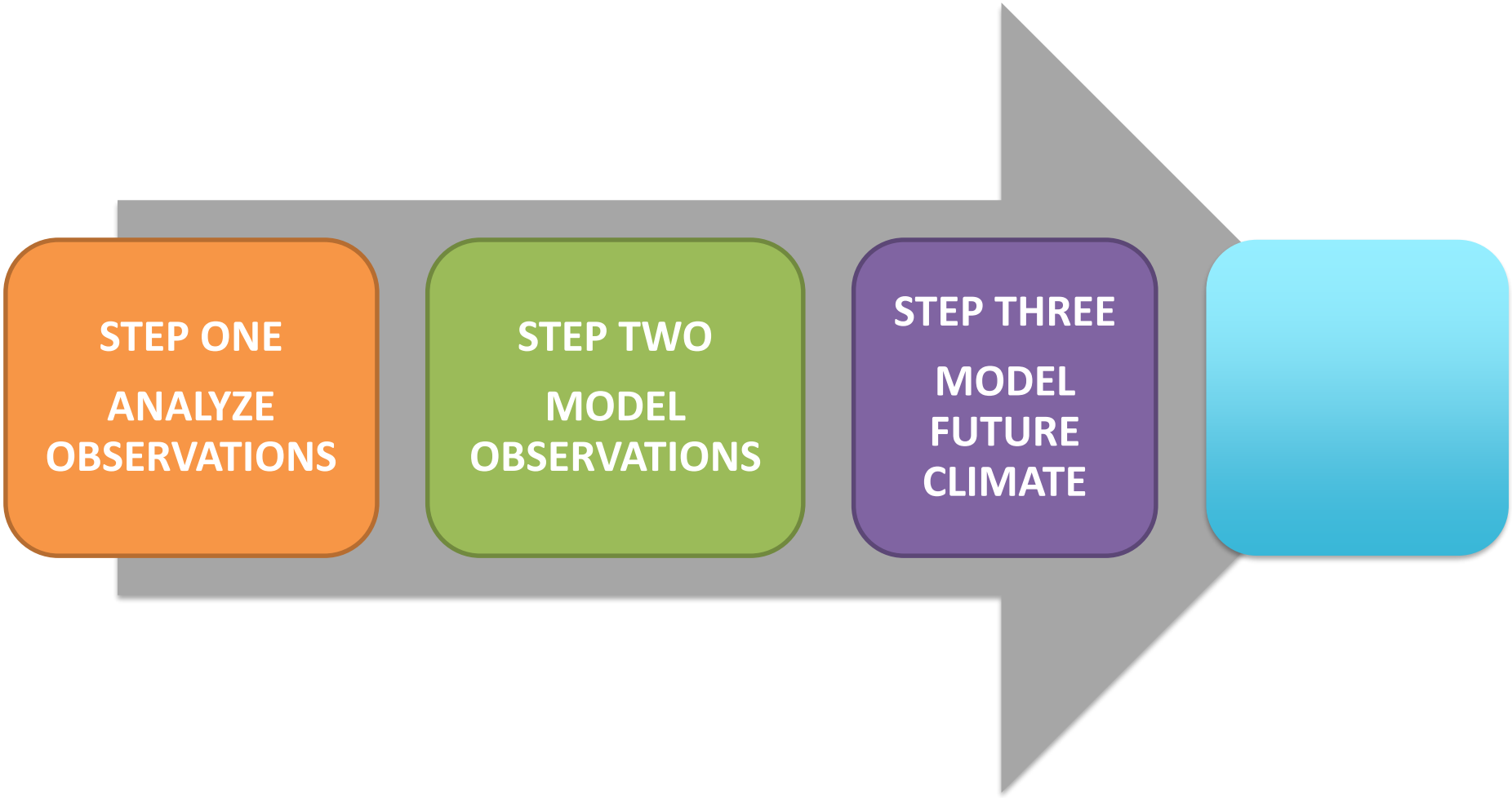
EXTREME TEMPERATURE


STEP ONE
ANALYZE OBSERVATIONS
STEP TWO
MODEL OBSERVATIONS

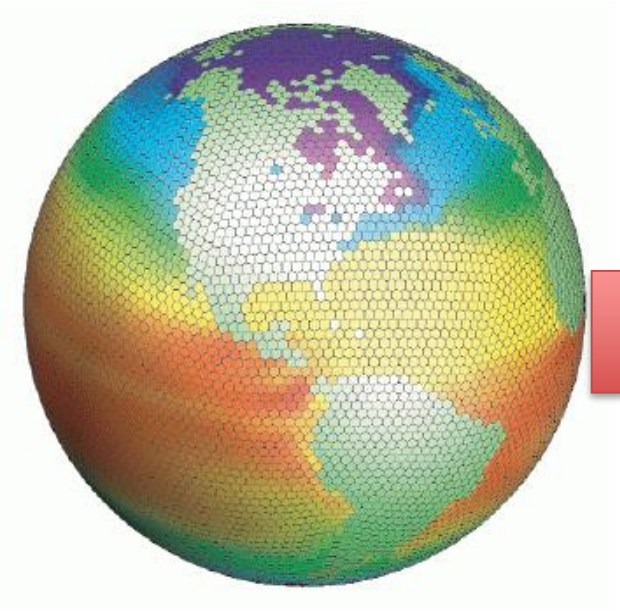
COMPARING OBSERVED AND MODELED STREAMFLOW






STEP ONE
ANALYZE OBSERVATIONS
STEP TWO
MODEL OBSERVATIONS
STEP THREE
MODEL FUTURE CLIMATE

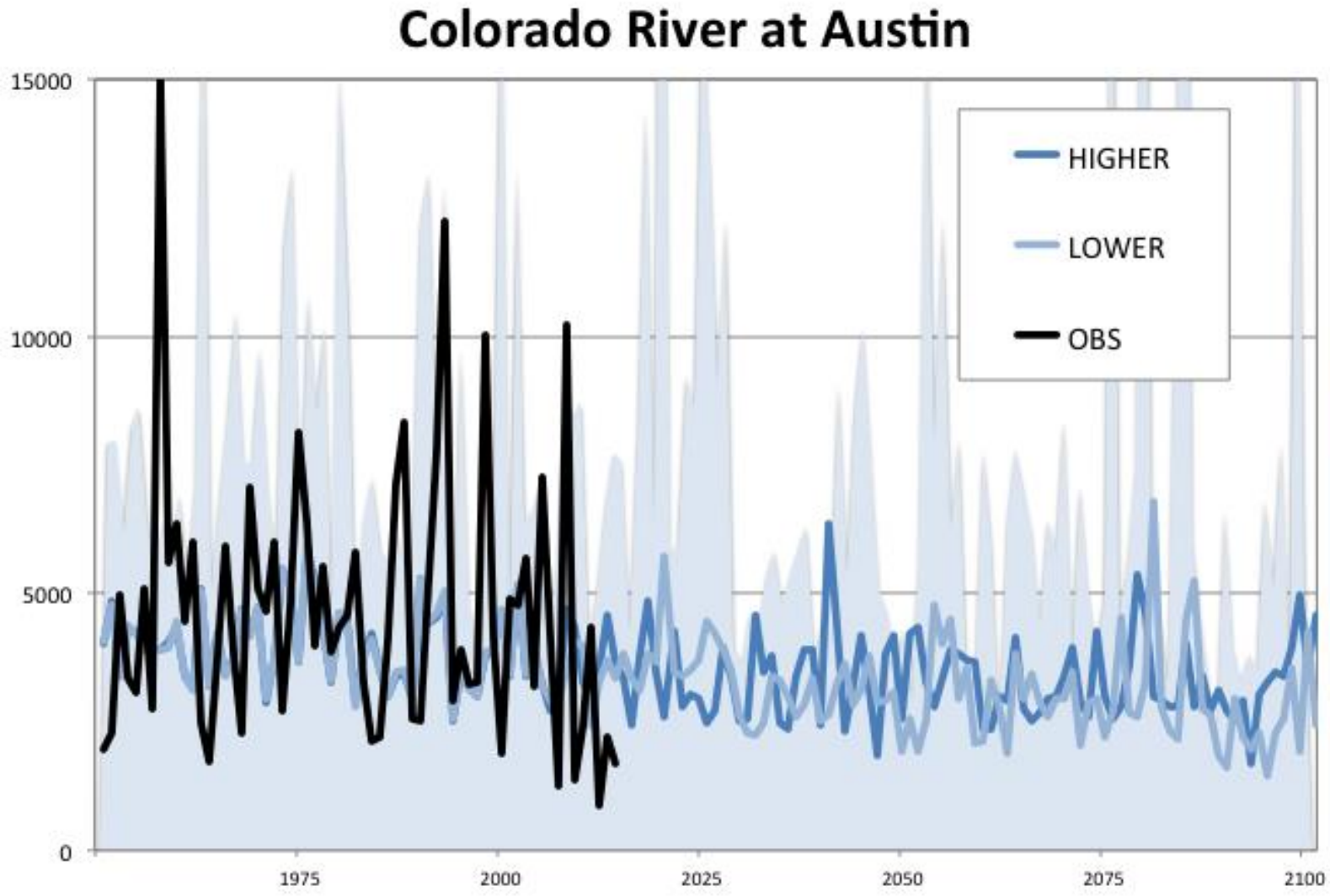
GAUGE-SPECIFIC FUTURE PROJECTIONS

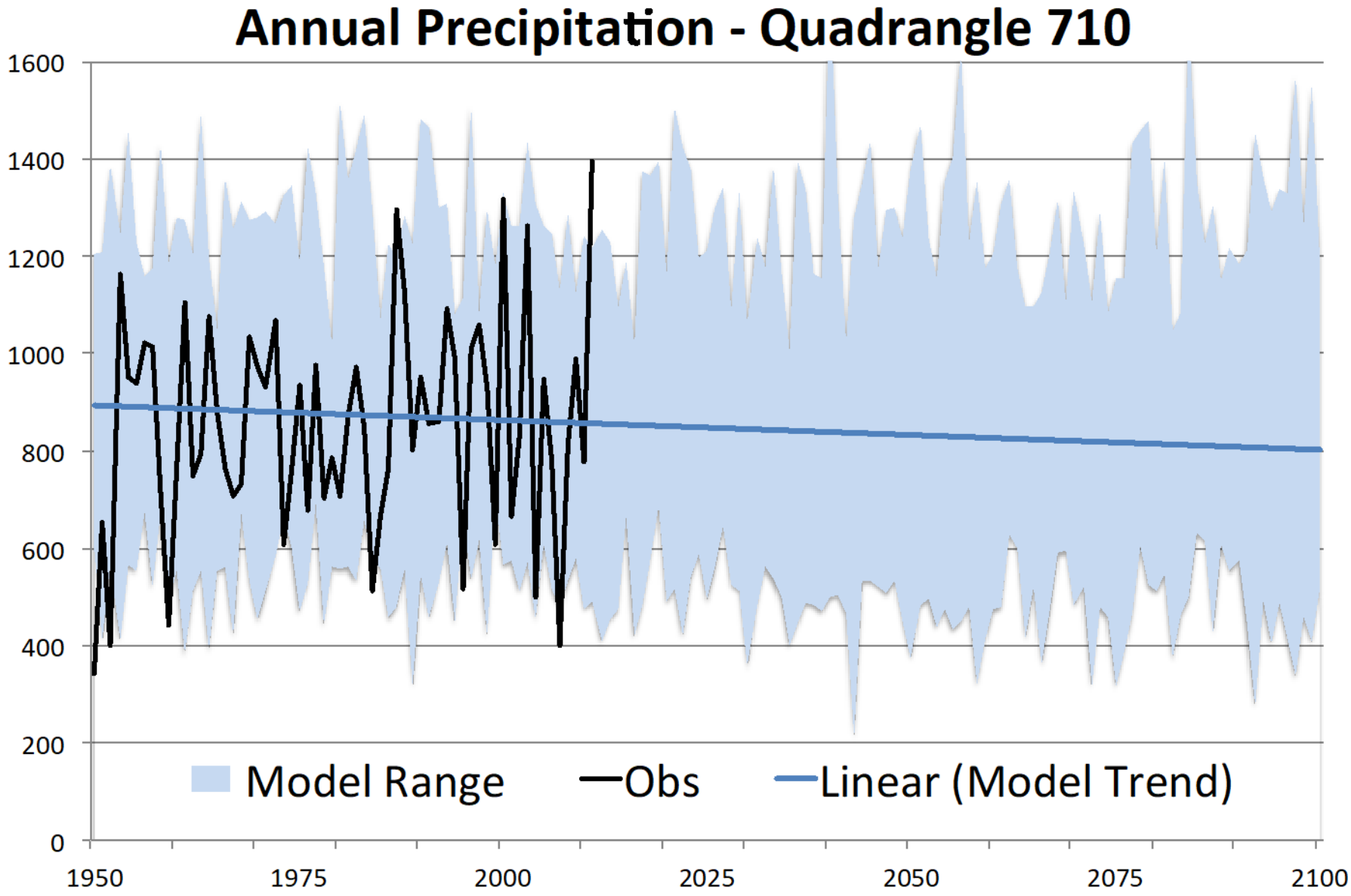


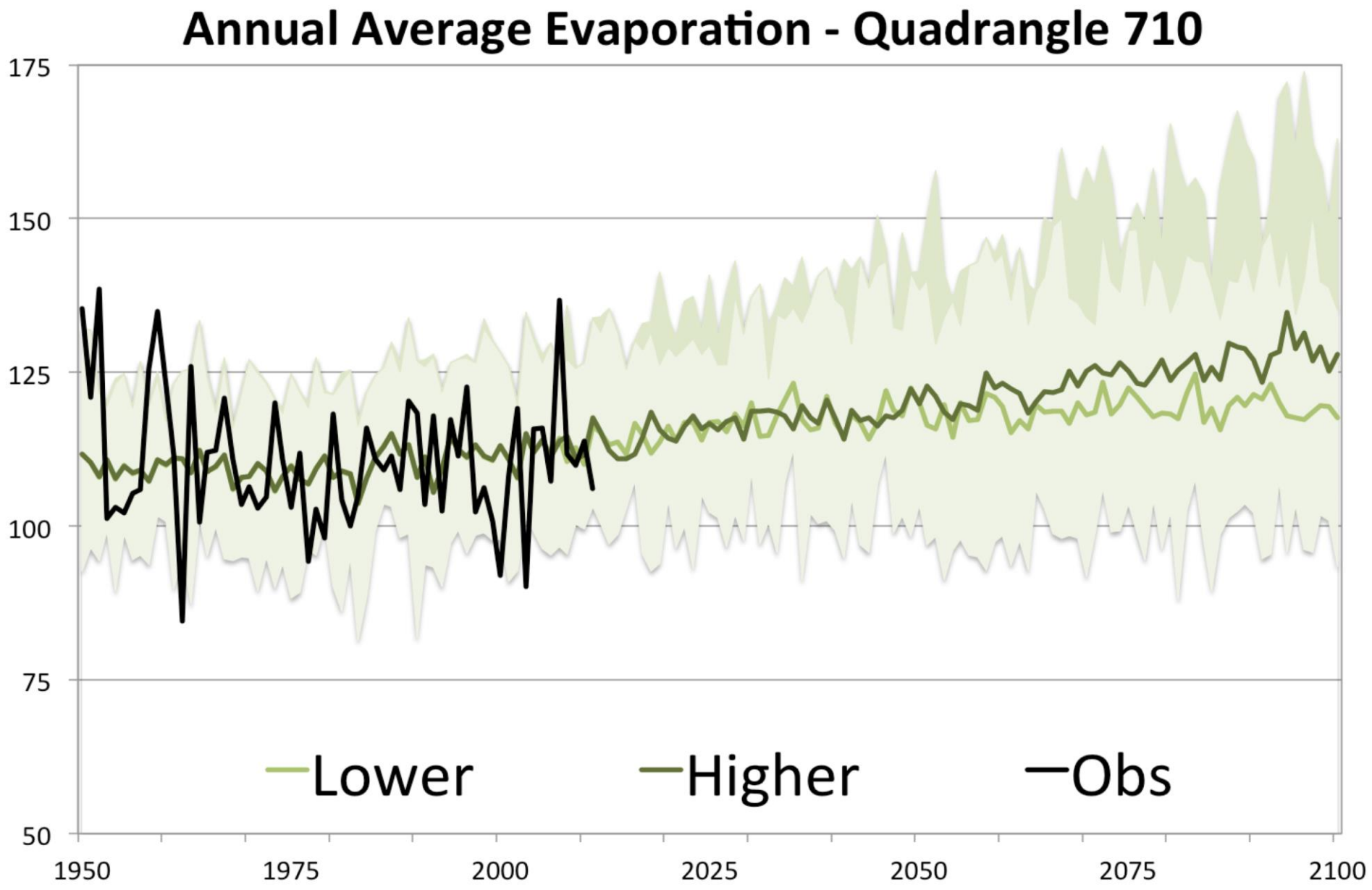
20 GLOBAL CLIMATE MODELS

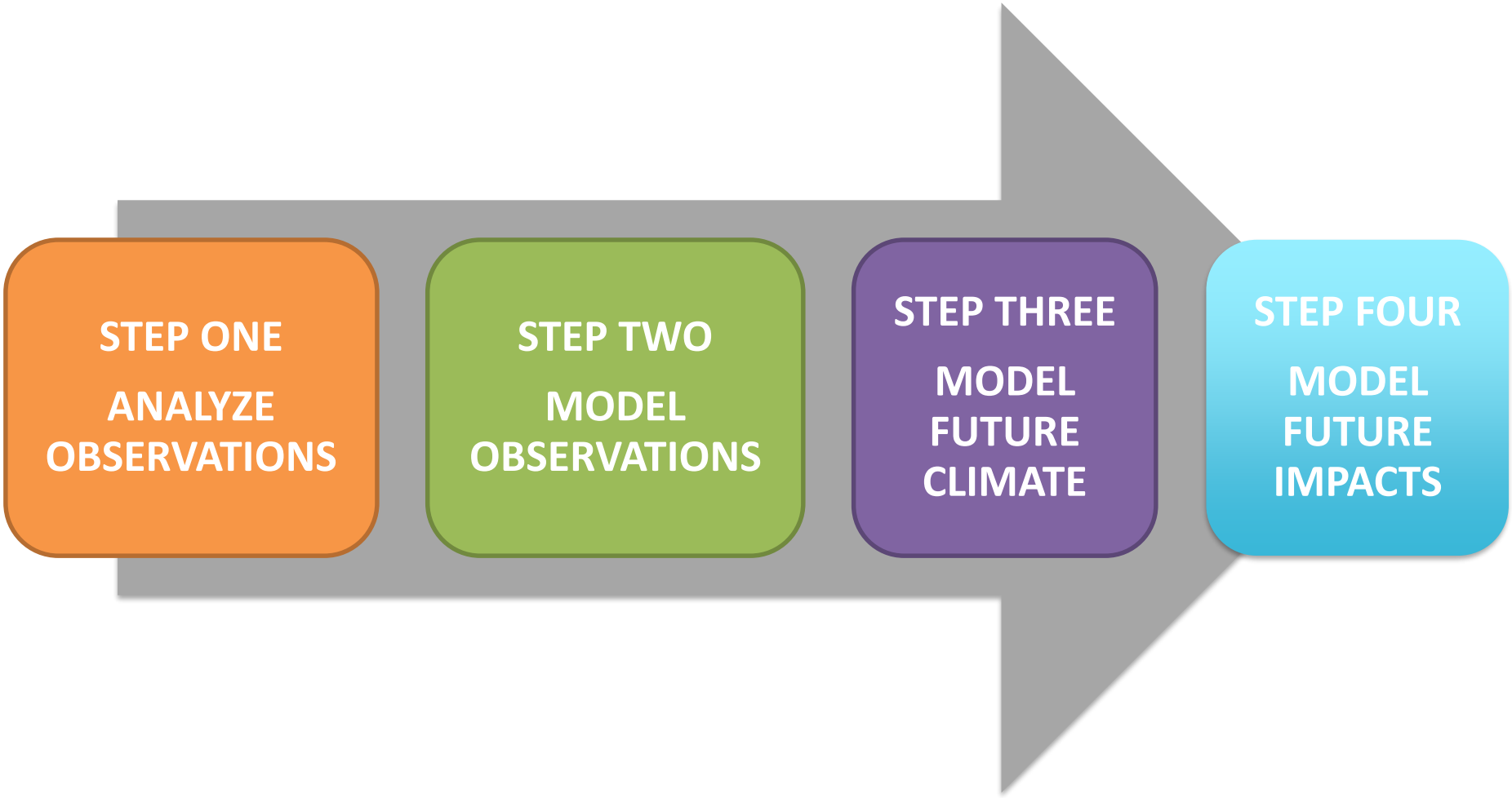
OUR STREAMFLOW MODEL BASED ON HISTORICAL OBSERVATIONS

ANNUAL AVERAGE STREAMFLOW




Annual Precipitation - Quadrangle 710
1600
1400
1200
1000
800
600
400
200
0
1950
1975
2000
2025
2050
2075
2100
Model Range
Obs
Linear (Model Trend)


Annual Average Evaporation - Quadrangle 710
175
150
125
100
75
50
1950
1975
2000
2025
2050
2075
2100
Lower
Higher
Obs


STEP ONE
ANALYZE OBSERVATIONS
STEP TWO
MODEL OBSERVATIONS
STEP THREE
MODEL FUTURE CLIMATE
STEP FOUR
MODEL FUTURE IMPACTS

Water Forward WAM Hydrologic Data

- Existing period of record naturalized flows and net evaporation-precipitation (77 years)
- Hydrology derived from 20 global climate models (GCMs) through year 2100 climate conditions.
- **Goal**: Generate WAM hydrologic inputs to reflect future climate trends and select candidate drought worse than the drought of record (DWDR) events.

Water Forward WAM Modeling

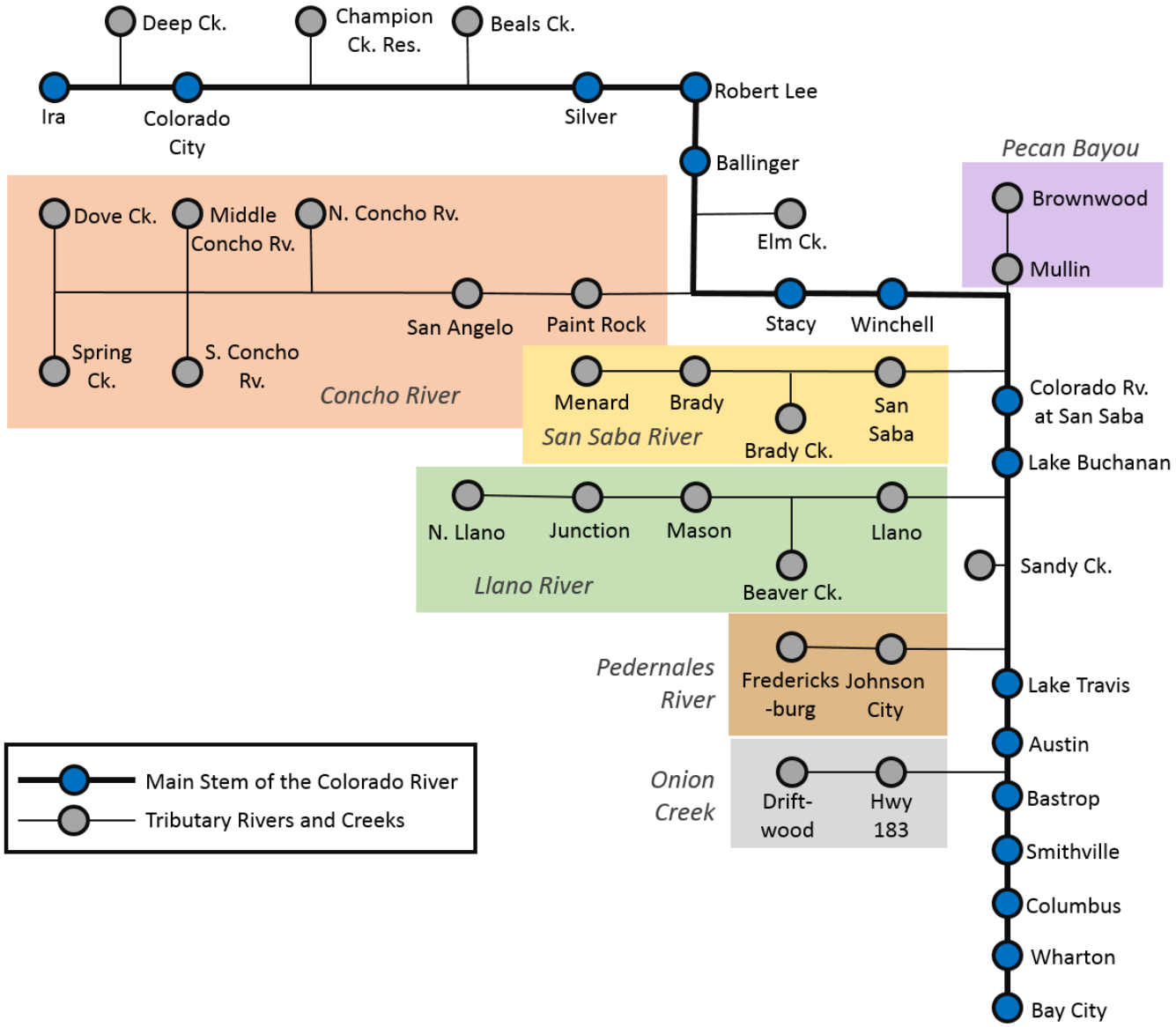
Perform water availability simulations for
4 different future demand projection horizons
with different hydrologic scenarios

Demand Projection Years
2020
2040
2070
2115

X

	Observed Historical Hydrology, No Adjustment	Future Climate Adjusted Hydrology
Results for Drought of Record	77 Years of Observed Historical Hydrology, 1940 – 2016	77 Years of Future Climate Adjusted Hydrology
Results for Droughts Worse than the Drought of Record	Stochastically Sampled Observed Historical Hydrology	Stochastically Sampled Future Climate Adjusted Hydrology

Colorado WAM Stream Gauges (primary CP's)



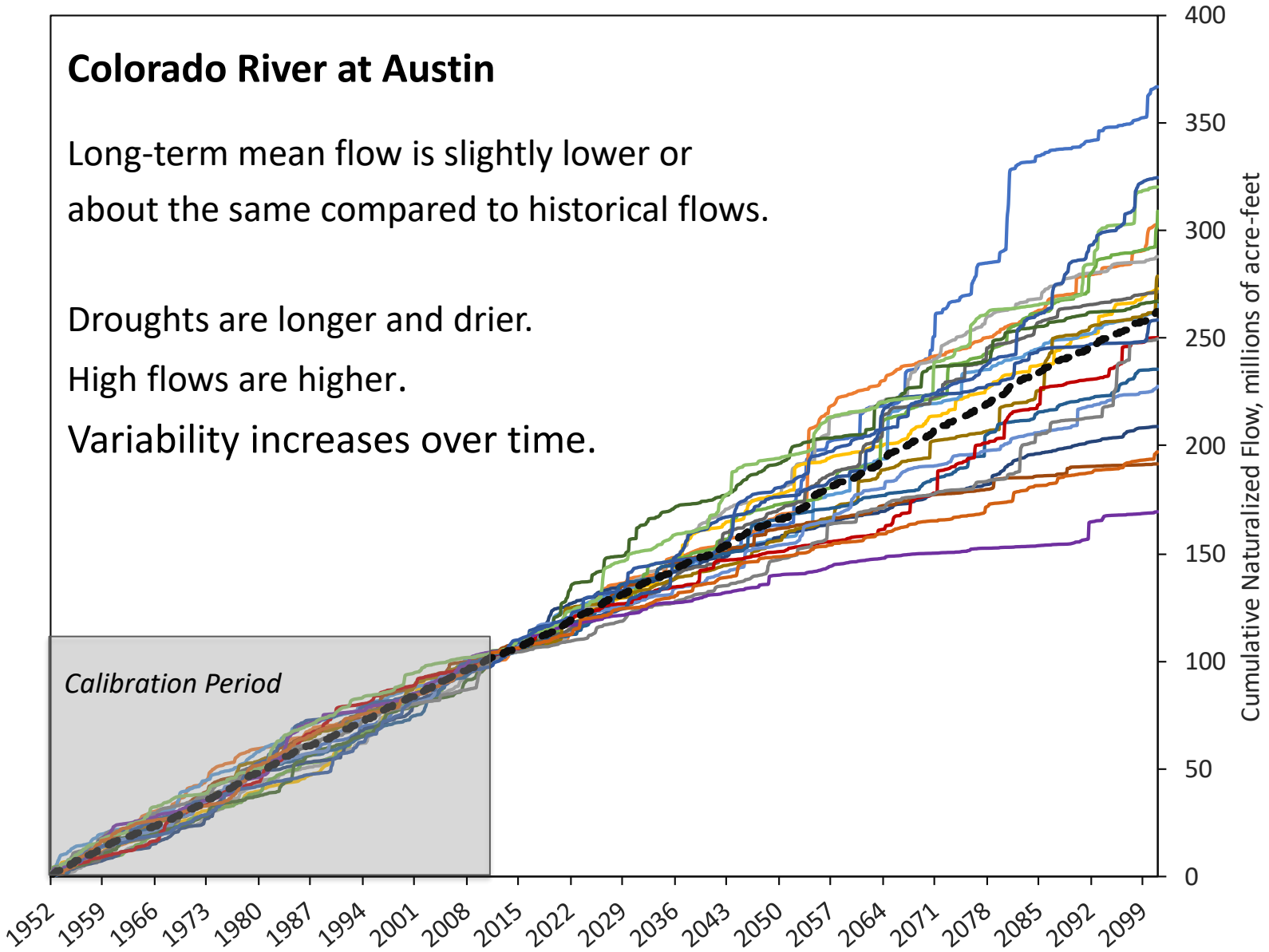
43 naturalized flow primary control points

48 net evap-precip (not shown here)

Hydrology from Climate Models

- 20 climate models with climate trend on a current trajectory (RCP 8.5 scenario)
- Monthly time series from 1952 through 2100 derived from each of the 20 climate models.
  - 43 streamflow gauges
  - 20 quadrangles of precipitation and evaporation used to calculate net evap-precip at 48 locations
- Hydrology from climate models changes from 1952 through 2100 as the climate warms

Naturalized Flow Results from 20 Climate Models



Consolidating Hydrology Derived from Climate Models

- Demand projections represent future snapshots in time. The simulated hydrologic conditions should match the same snapshots in time.
- Create one additional hydrologic data set per demand horizon beyond 2020 with adjustment for future climate conditions.

- 2020 demand vs. Historical Hydrology
- 2040 demand vs. Historical & 2040 Climate Adjusted Hydrology
- 2070 demand vs. Historical & 2070 Climate Adjusted Hydrology
- 2115 demand vs. Historical & 2100 Climate Adjusted Hydrology

- *7 WAM simulations in total*

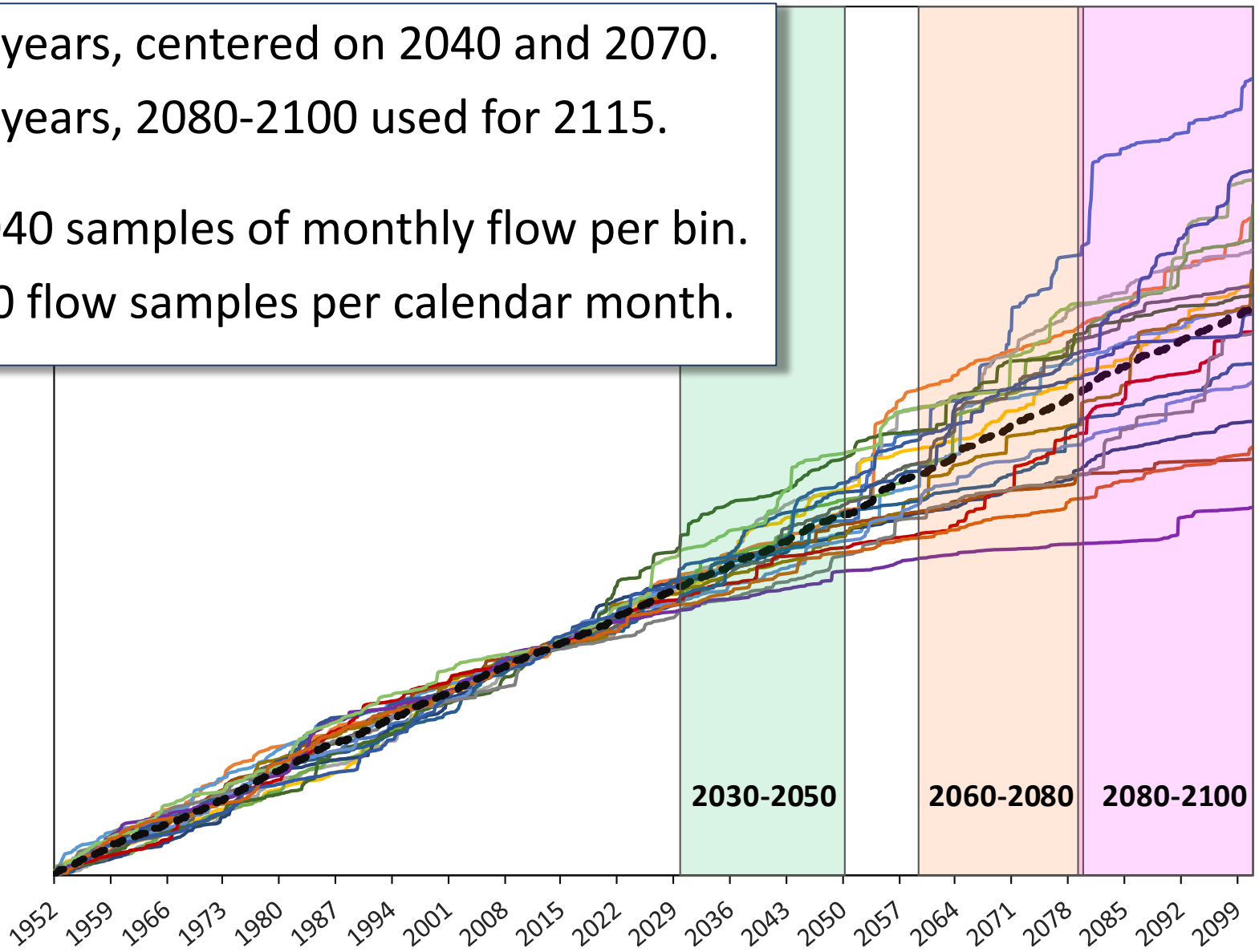
Example of Bins for 20 Streamflow Models of Future Climate

21 years, centered on 2040 and 2070.

21 years, 2080-2100 used for 2115.

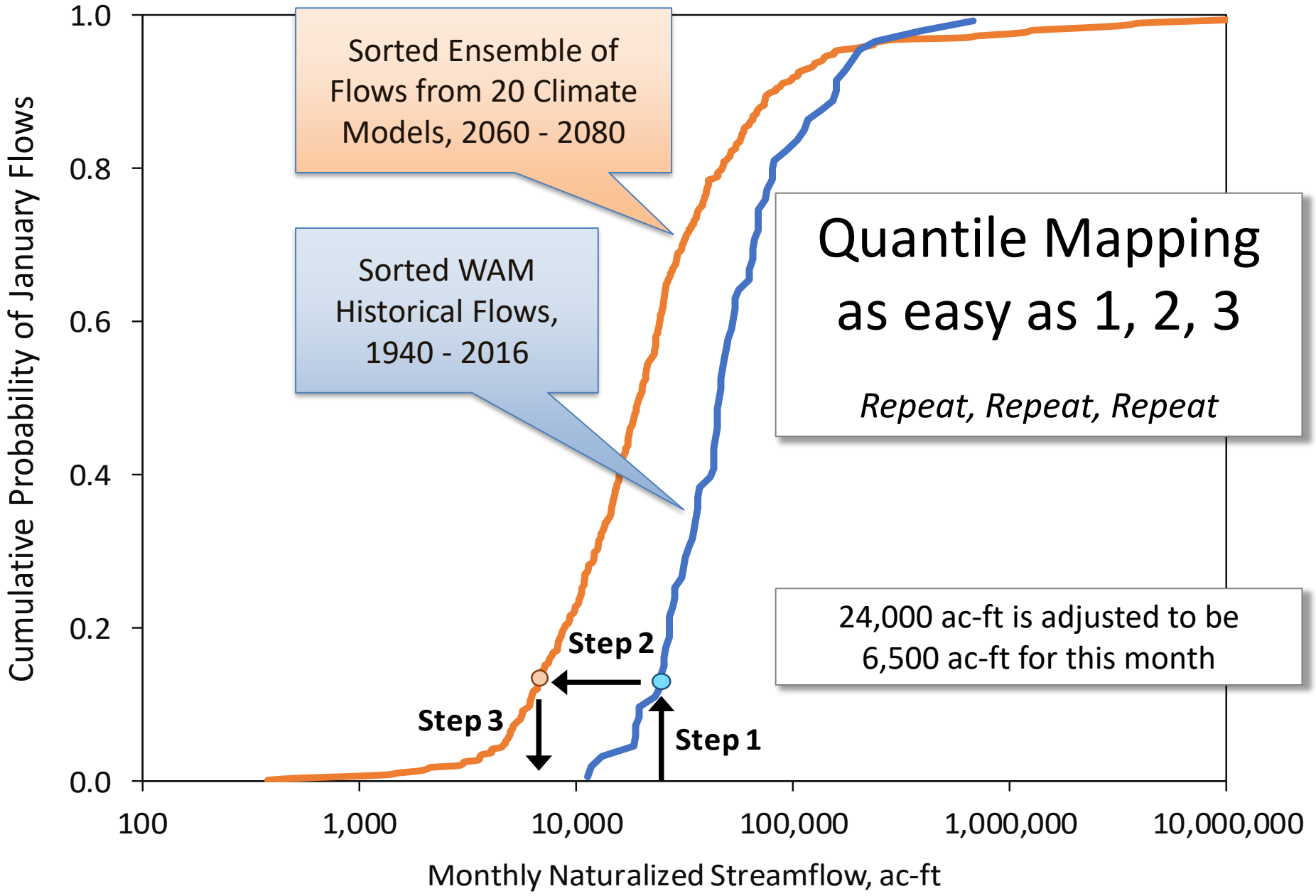
5,040 samples of monthly flow per bin.

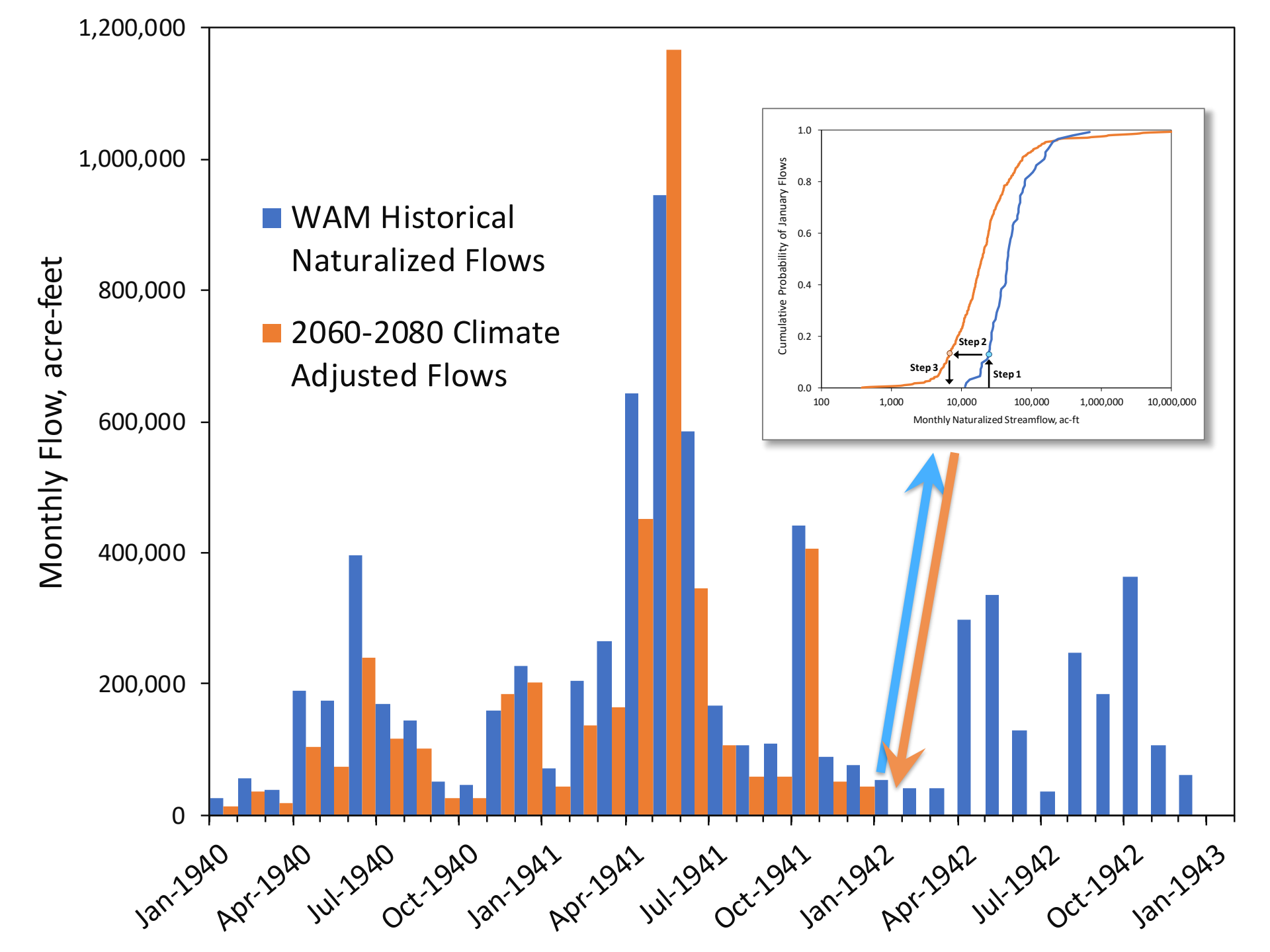
420 flow samples per calendar month.



Consolidation Process

- Use an **ensemble** of 20 climate model results to adjust the WAM's historical hydrologic data.
- Bin the 20 results around 2040, 2070, and **2100**.
- Adjust 1940-2016 WAM historical hydrology to reflect the range of hydrology in the ensemble/bins of 20 climate model results.
- Month-by-month adjustments of WAM historical hydrology at each control point.
- "Quantile Mapping"


Sorted Ensemble of Flows from 20 Climate Models, 2060 - 2080
Sorted WAM Historical Flows, 1940 - 2016
Quantile Mapping as easy as 1, 2, 3
Repeat, Repeat, Repeat
24,000 ac-ft is adjusted to be 6,500 ac-ft for this month
Step 1
Step 2
Step 3
Cumulative Probability of January Flows
1.0
0.8
0.6
0.4
0.2
0.0
100
1,000
10,000
100,000
1,000,000
10,000,000
Monthly Naturalized Streamflow, ac-ft


1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Monthly Flow, acre-feet
WAM Historical Naturalized Flows
2060-2080 Climate Adjusted Flows
Jan-1940
Apr-1940
Jul-1940
Oct-1940
Jan-1941
Apr-1941
Jul-1941
Oct-1941
Jan-1942
Apr-1942
Jul-1942
Oct-1942
Jan-1943
Cumulative Probability of January Flows
1.0
0.8
0.6
0.4
0.2
0.0
Step 1
Step 2
Step 3
100
1,000
10,000
100,000
1,000,000
10,000,000
Monthly Naturalized Streamflow, ac-ft

Historical and Adjusted WAM Naturalized Flows for Austin's IWRP

77 Years, 1940 - 2016

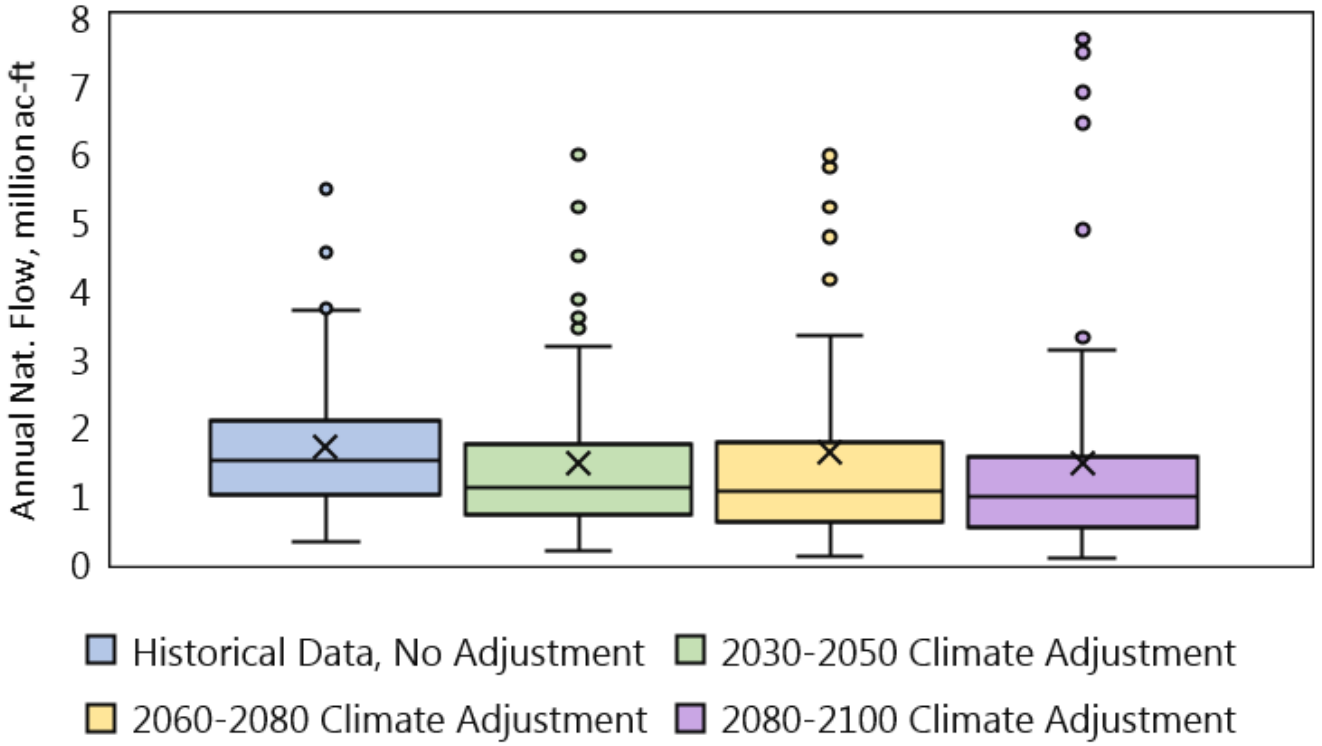
Colorado River at Austin

Long-term mean flow is the same to slightly lower depending on the group of future conditions.

Droughts are longer and drier.

High flows are higher.

Variability increases with future conditions.



Historical and Adjusted WAM Naturalized Flows for Austin's IWRP

77 Years, 1940 - 2016

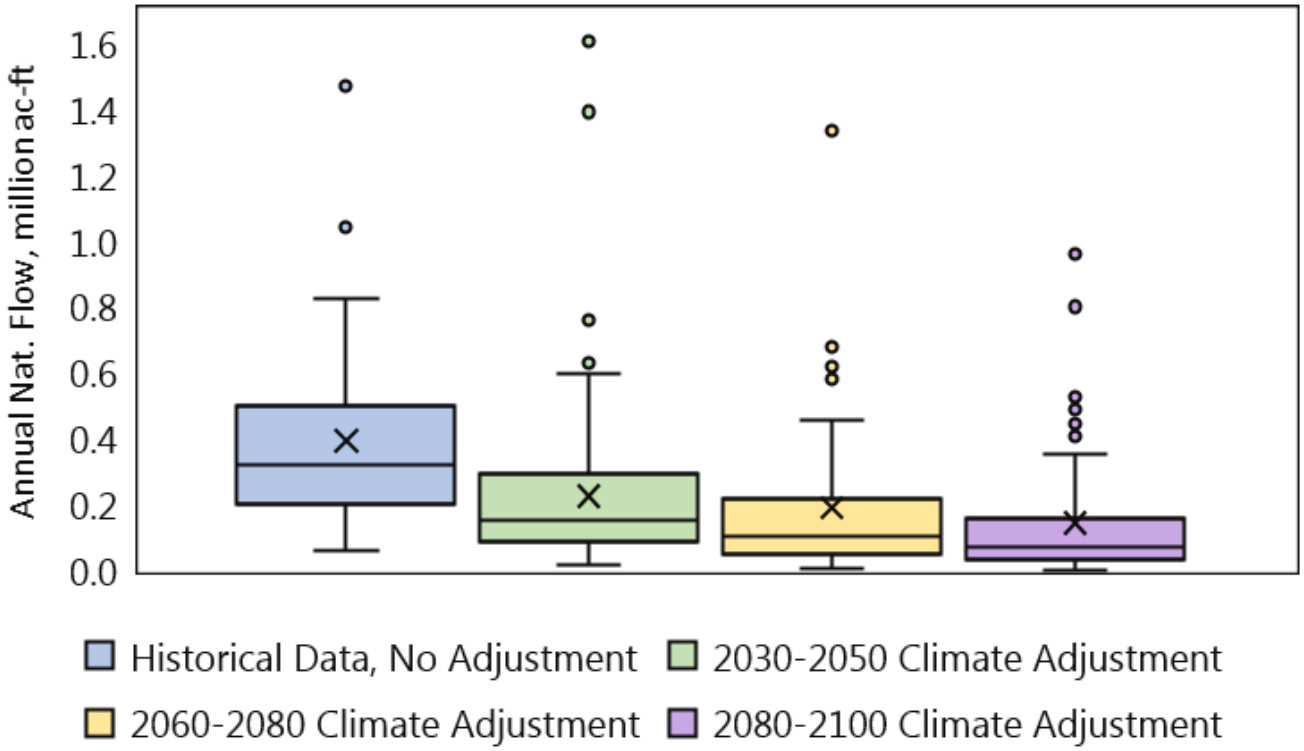
Colorado River at Winchell

Long-term mean flow decreases with future conditions.

Droughts are longer and drier.

High flows are about the same or lower.

Variability decreases with future conditions.



Historical and Adjusted WAM Net Evap-Precip

Reservoir	Historical WAM Net Evap-Precip	2030-2050 Climate Adjustment	2060-2080 Climate Adjustment	2080-2100 Climate Adjustment
	Average Annual Net Evap-Precip 1940-2016, feet			
Lake O.H. Ivie	3.5	3.8	4.3	4.6
Lake Buchanan	2.2	2.6	2.9	3.3
Lake Travis	1.9	2.3	2.6	2.9
Bay City Dam	1.5	1.4	1.6	1.8
	Average Annual Net Evap-Precip 2008-2015, feet			
Lake O.H. Ivie	4.2	4.5	5.1	5.4
Lake Buchanan	2.4	2.7	3.1	3.4
Lake Travis	2.1	2.4	2.7	3.1
Bay City Dam	1.5	1.4	1.6	1.8

Planning For Uncertainties: Potential for Droughts Worse than the Drought of Record

Beyond the 2010's Drought for Austin's IWRP

- The period of record contains 2 major droughts.
- For Austin's Water Forward IWRP, consideration of droughts worse than the drought of record (DWDR's) incorporated as prudent risk management for long-term planning.
- DWDR's by definition are not part of the historical record, and thus could "play out" in many different ways.
- **Goal for DWDR Selection in Austin's IWRP**: Select candidate DWDR events that represent a variety of drought duration and severity combinations. Water supply reliability metrics developed for candidate droughts.

Steps for DWDR Development For Austin's IWRP

1. Create a long sequence of hydrology from sampling of the period of record.
2. Identify droughts in the long sequence.
3. Assign probability of occurrence to the droughts (return periods).
4. Based on return periods, select candidate DWDR events for planning analyses.

Step 1. Markov Chain Monte Carlo Sampling

High, Upper 1/3
Medium, Middle 1/3
Low, Lower 1/3

Step #1 Classify each year in period of record based on annual flow volumes

1940	1950	1960	1970	1980	1990	2000	2010
1941	1951	1961	1971	1981	1991	2001	2011
1942	1952	1962	1972	1982	1992	2002	2012
1943	1953	1963	1973	1983	1993	2003	2013
1944	1954	1964	1974	1984	1994	2004	2014
1945	1955	1965	1975	1985	1995	2005	2015
1946	1956	1966	1976	1986	1996	2006	2016
1947	1957	1967	1977	1987	1997	2007	
1948	1958	1968	1978	1988	1998	2008	
1949	1959	1969	1979	1989	1999	2009	

Step #2 Calculate transition probability between states based on the observed transitions

		Annual Transition State		
		Low	Med	High
Prior Annual State	Low	42.3%	38.5%	19.2%
	Med	26.9%	26.9%	46.2%
	High	33.3%	33.3%	33.3%

Step #3 Select sequence of states

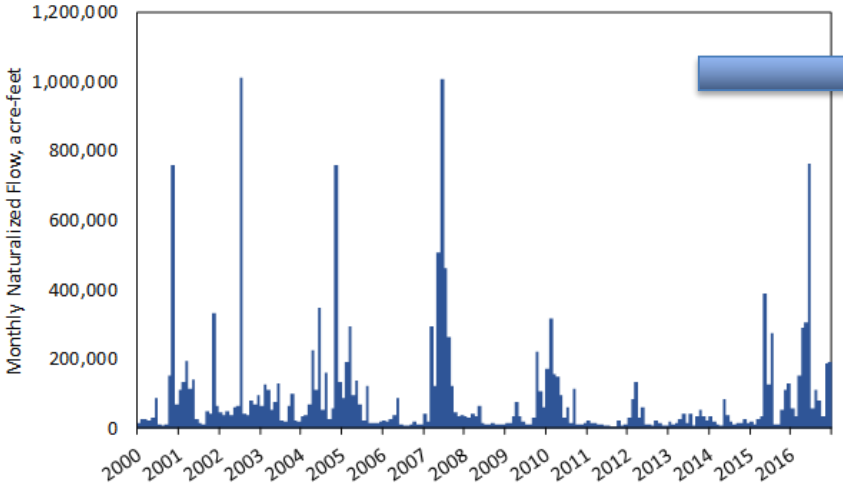
Step #4 Select specific year

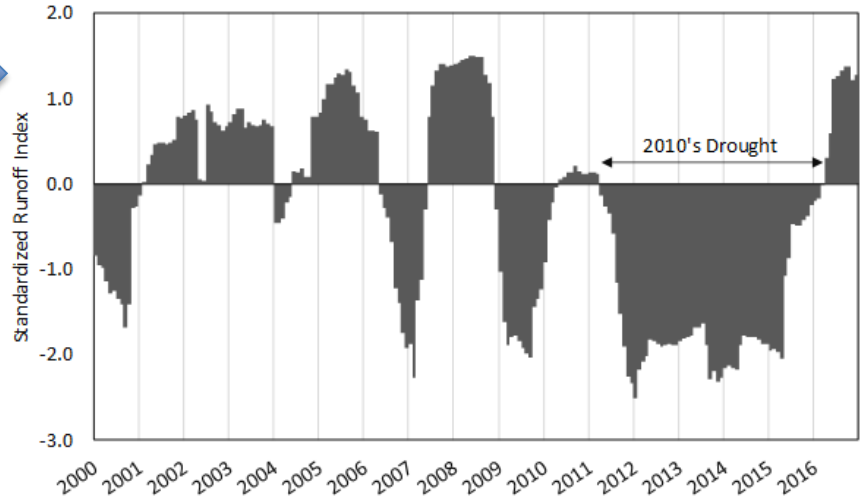
Step #3	Step #4
High	2007
Med	1985
Med	1966
Low	2012
Low	1947
Med	1995
Low	2006
Low	1972
Low	1993
High	1957
High	1965
Med	2000
Med	1994
Low	2011
Med	1978
High	1951
High	1989

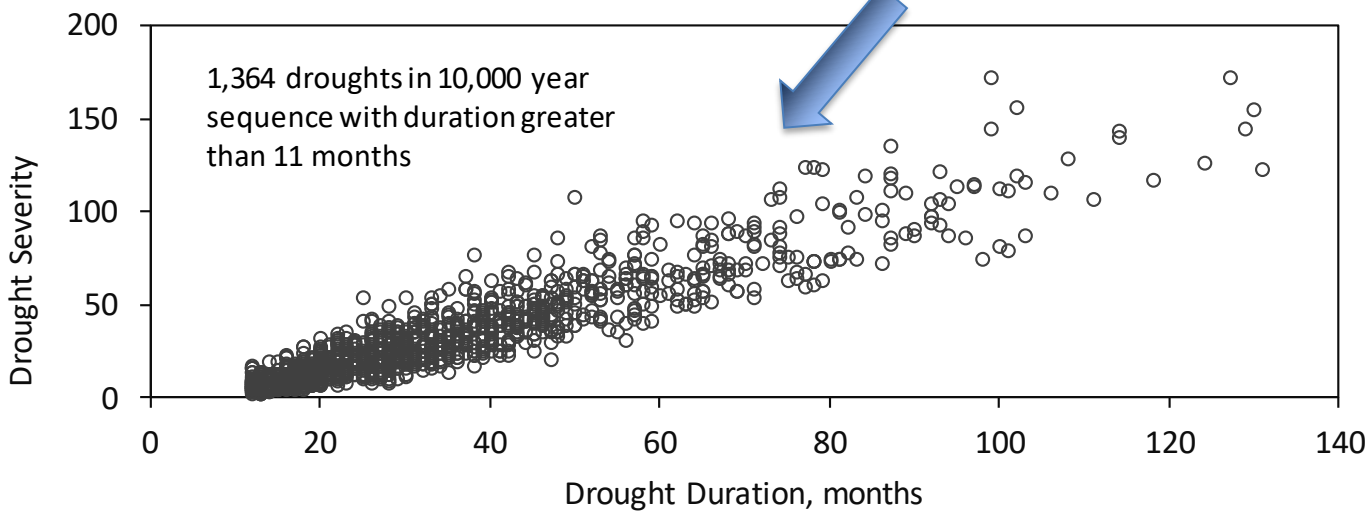
Step #5 Build extended WAM hydrology input files according to the sequence of selected years

Step 2. Identify Droughts

- Apply the Standardized Runoff Index (SRI) technique to obtain duration and severity of droughts over 10,000 year sequence.

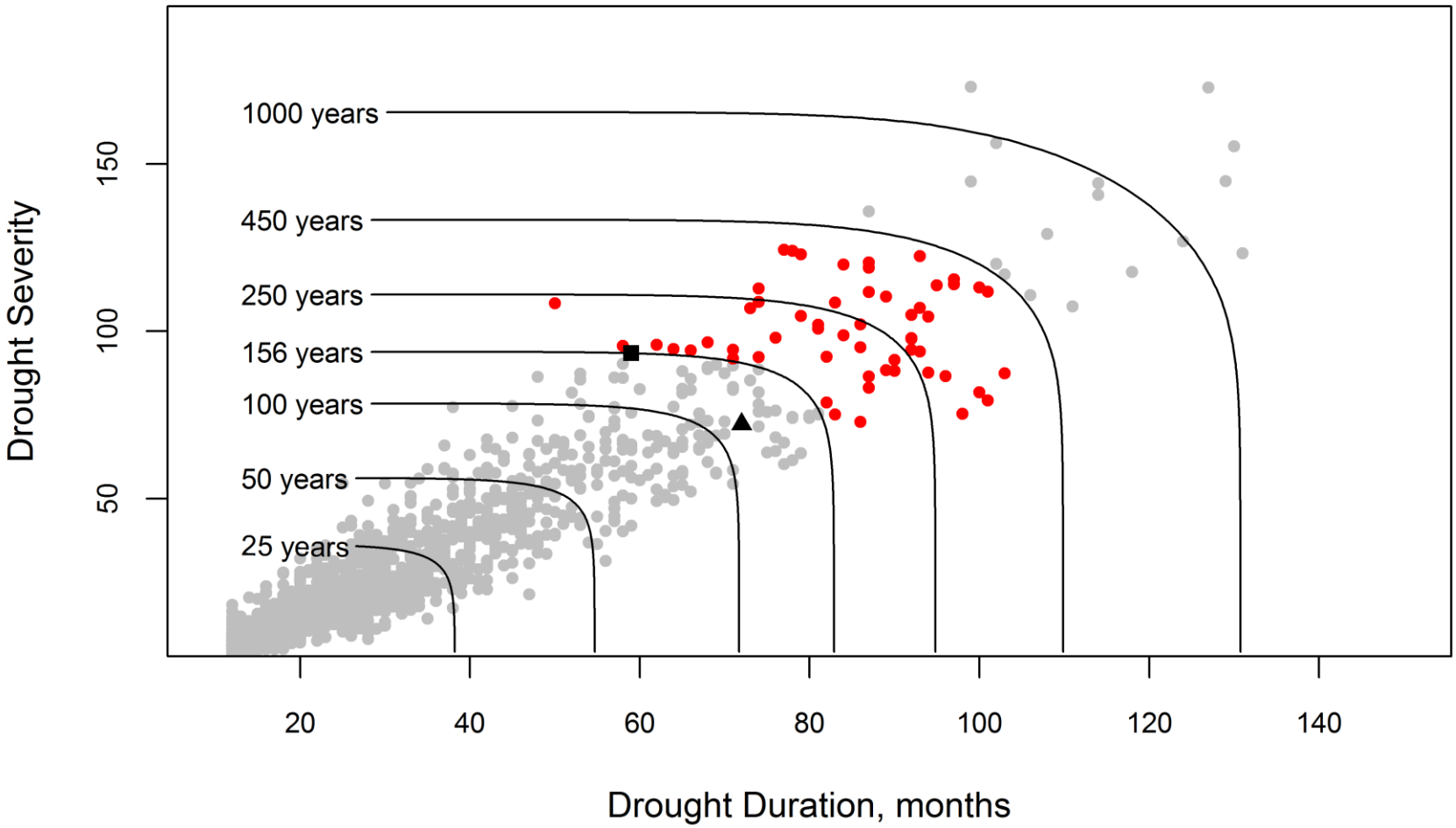






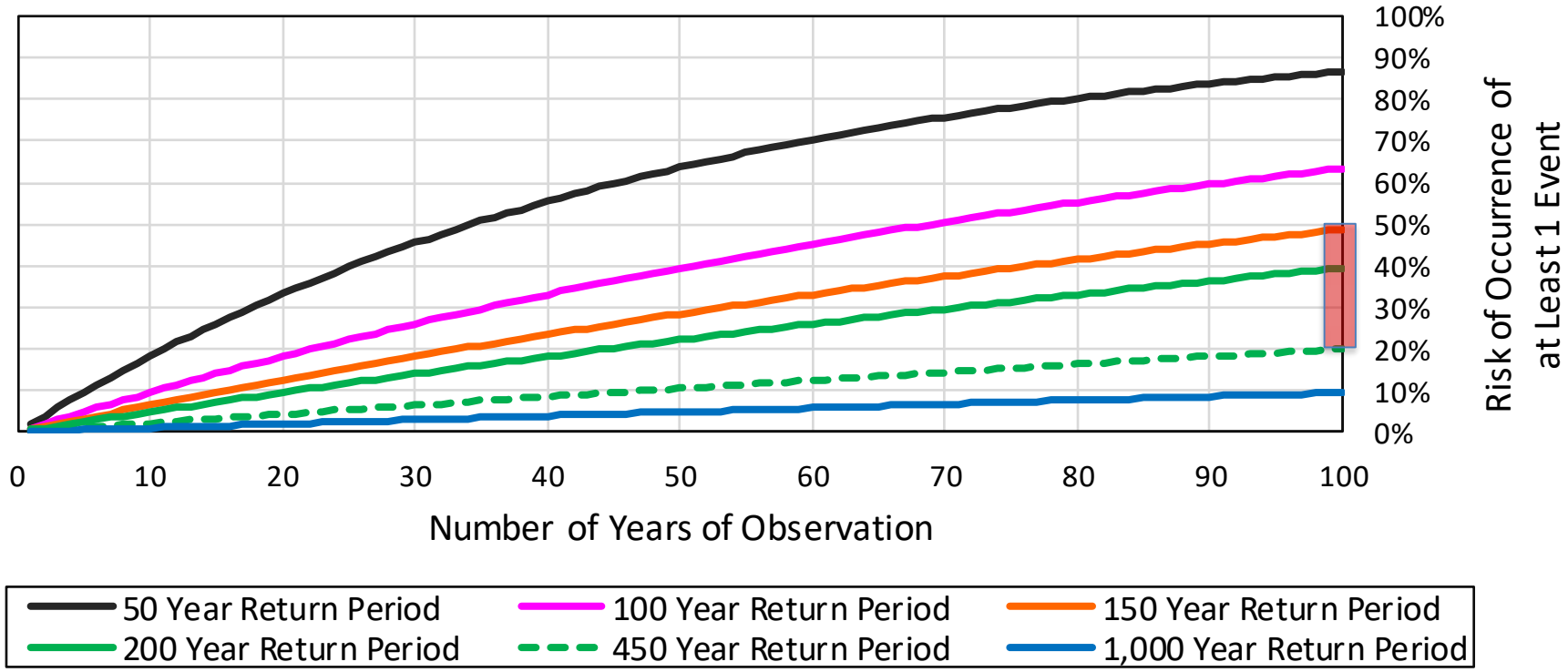
Step 3. Drought Return Periods

- Assign probabilities to duration, severity, and joint probability of duration & severity. Return period calculated for the occurrence of duration and severity both exceeding the levels shown.



Step 4. Candidate DWDR Selection

- Select droughts with lower chance of occurrence than 2010's drought, but greater than 20% chance in 100 years.



Summary

- Austin's Water Forward IWRP is nearing completion.
- Like Region K's Plan, regular IWRP updates will address new information.
- Historical hydrology is a key component of long-term planning, however for Austin's IWRP it was also important to consider planning for change and uncertainties.
- For Austin's IWRP, prudent risk management for long-term planning considers:
  - potential changes to hydrology based on the best available science, and
  - drought scenarios that differ from and are worse than the past.

Thank You

You can follow the process
and
find more information at:

austintexas.gov/
waterforward