CWEMF 2024 Annual Meeting

Hydrological Modeling and Climate Change Analysis to Support Pajaro Valley Ecological Floodplain Inundation Potential (EcoFIP)

Presenters: Tapash Das and Syed Azhar Ali (Jacobs)

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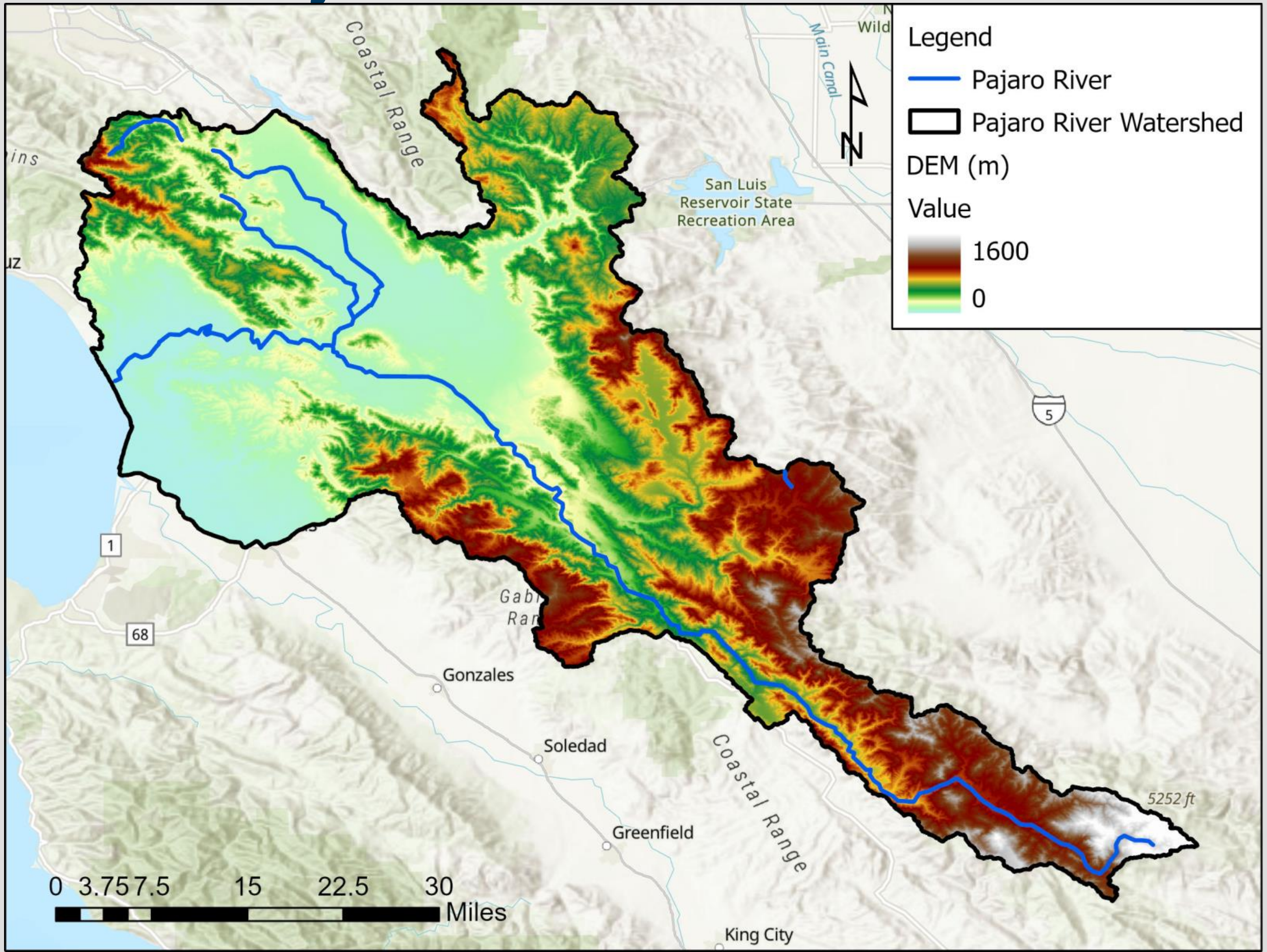
September 2024

Agenda

- Hydrologic Model Purpose
- Model Calibration
- Climate Change Hydrology
- Summary

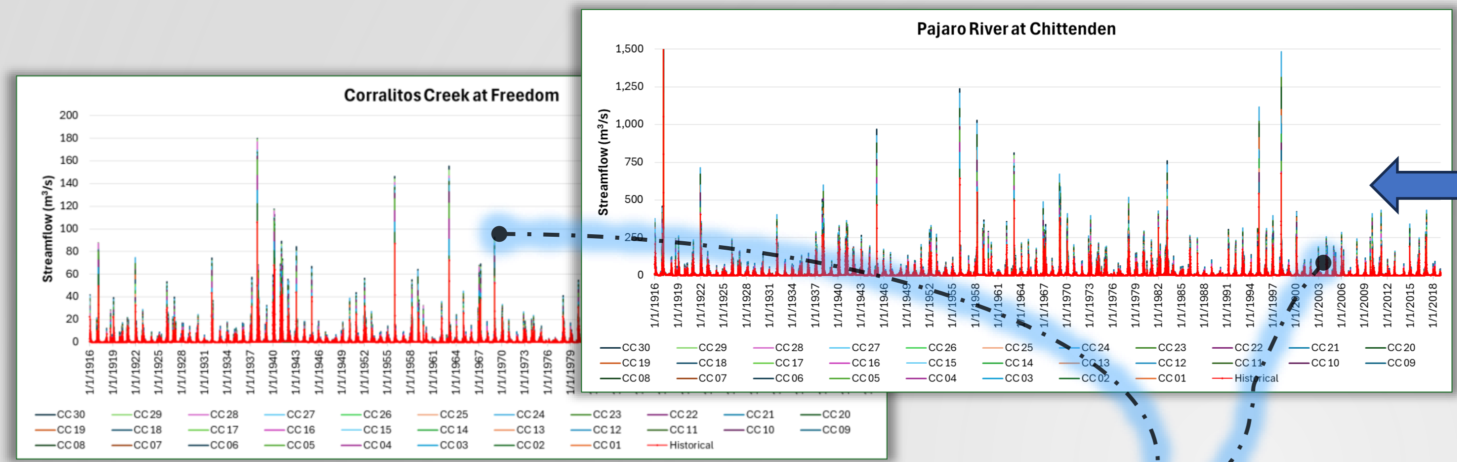
Study Area

Pajaro River Watershed



Pajaro River Levee Setback, Floodplain Restoration, and Managed Aquifer Recharge Opportunities Analysis

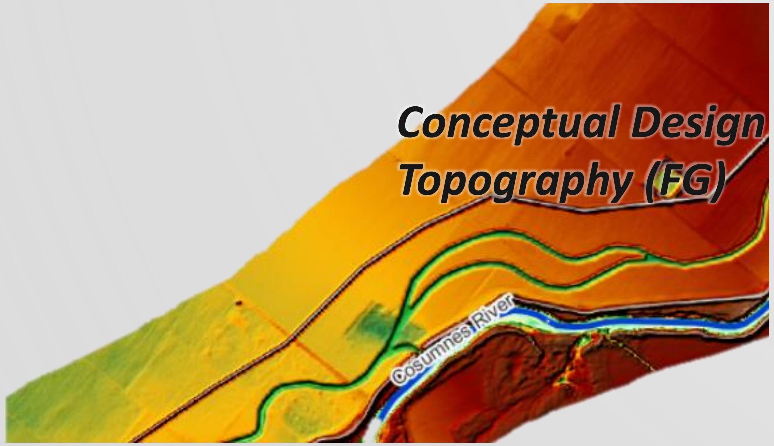
Baseline and Climate Scenarios representing 100-years of daily streamflow

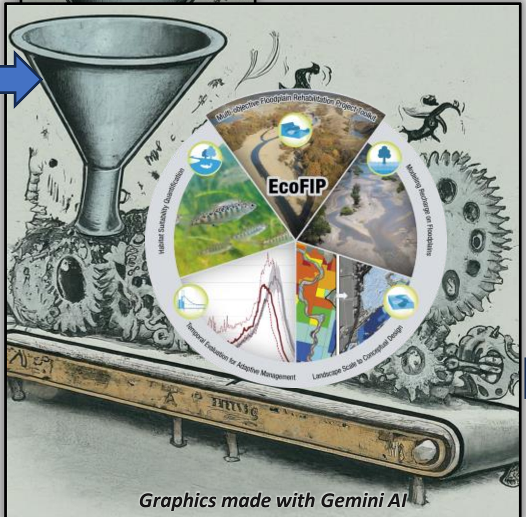


Hydrological modeling using Weather Generator daily datasets

Daily Streamflow (at key input locations)

Existing Terrain (EG)

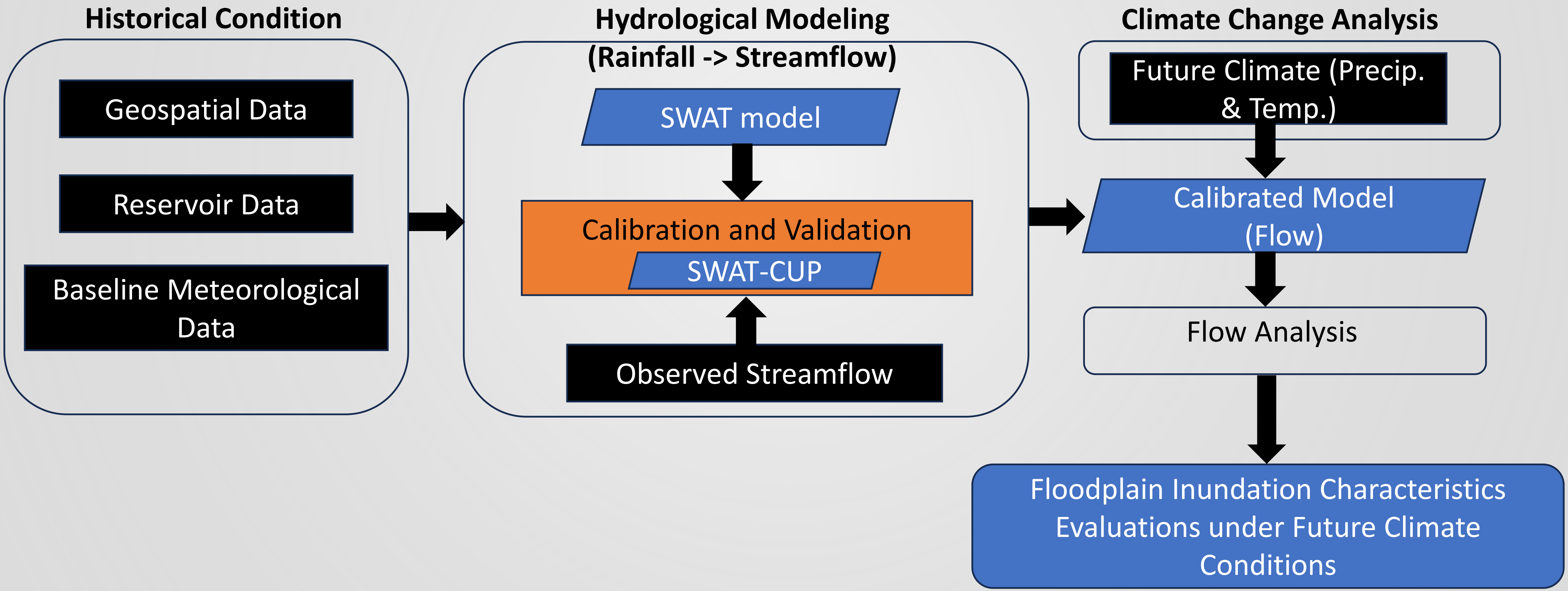




Ecological Floodplain Inundation Potential (EcoFIP) Analysis

EcoFIP has been evaluated how change in hydrology will impact floodplain inundation, habitat, and recharge for existing system and for conceptual designs

Hydrologic Modeling and Climate Change Analysis Workflow



Hydrologic Model

- The hydrologic model was developed using the Soil and Water Assessment Tool (SWAT).
- The SWAT model was used to simulate hydrology under future climate change scenarios.
- Future climate change scenarios were developed using the decision-scaling method
- Output hydrographs under future climate change scenarios informed the EcoFIP analysis.

Q: What is a Hydrologic Model?

A: Simplified representation of rainfall conversion to streamflow in the watershed

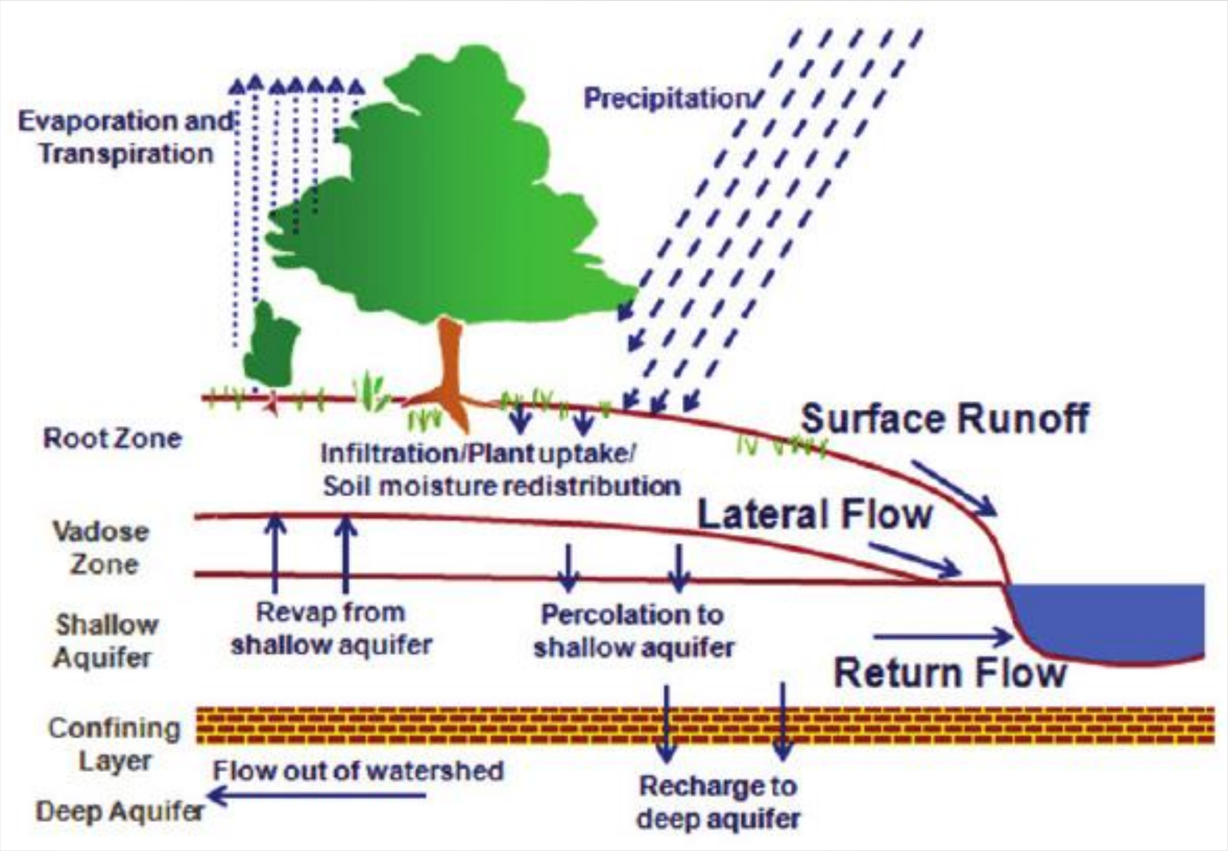
Q: Why create a hydrologic model?

A: Need to plan and represent future scenarios like changing management or climate scenarios

SWAT Hydrologic Model

Rainfall -> Runoff

https://swat.tamu.edu/software/



- The Soil & Water Assessment Tool (SWAT) is a small watershed to river basin-scale model used to simulate the quality and quantity of surface and ground water.

- The SWAT model is used to predict the environmental impact of land use, land management practices, and climate change.

SWAT Model Development Data

Data for the simulation of the SWAT model:

- **DEM**: 90m USGS SRTM (Shuttle Radar Topography Mission)
- **Land Cover**: USGS 2021 NLCD (National Land Cover Database)
- **Soil**: USDA SSURGO (Soil Survey Geographic Database)
- **Meteorological Data**:
  - Precipitation: Pierce et al. (2021) daily (6 km)
  - Minimum and maximum temperatures: Livneh et al. (2013, updated thereafter) extended and bias-corrected using PRISM
- **Reservoir Data:** USACE NID (National Inventory of Dams)

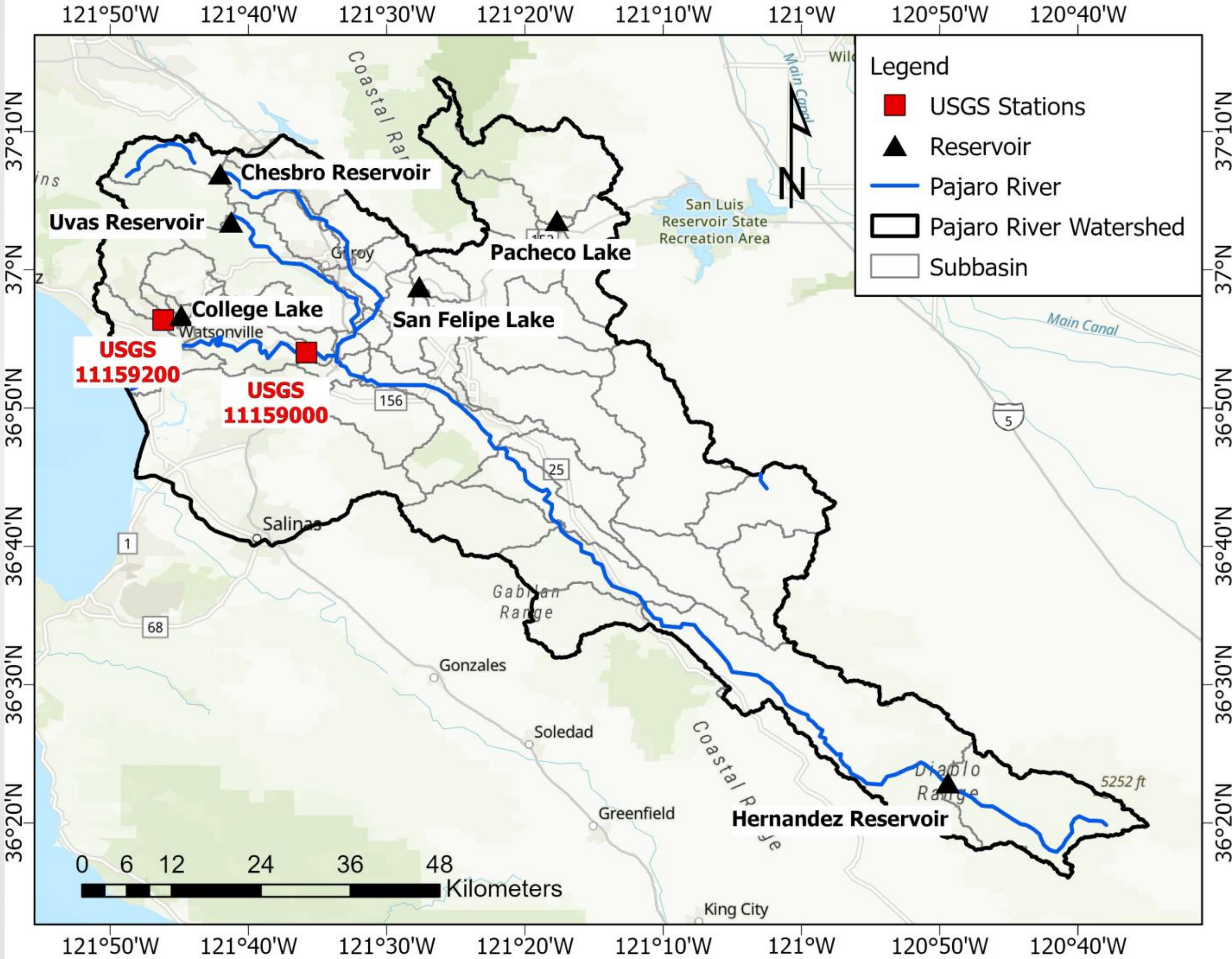
SWAT model was calibrated using the automatic calibration tool for USGS gage stations:

- **Calibration**: 1/1/1971 to 12/31/2000
- **Validation**: 1/1/2011 to 12/31/2018

Future scenarios was simulated using the projected climate change datasets.

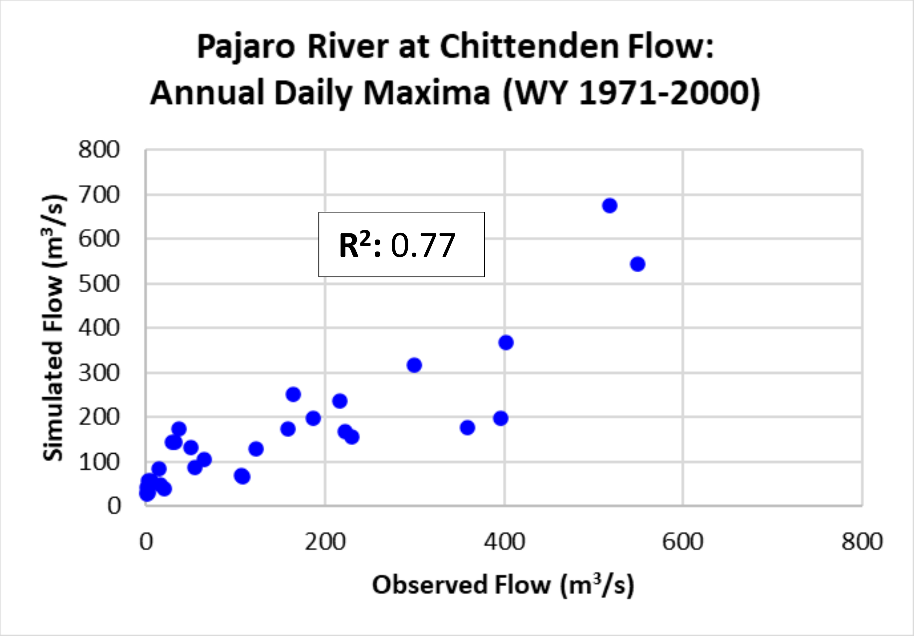
Model Setup and Simulation

- The model uses the DEM, Land Cover, Soil data to simulate hydrologic processes over the watershed
- In each of the 45 watersheds, we can extract daily values for each represented process
- By extracting streamflow from watershed nearby streamflow gauges, we can compare simulated to observed values to calibrate the model
- How did we do?



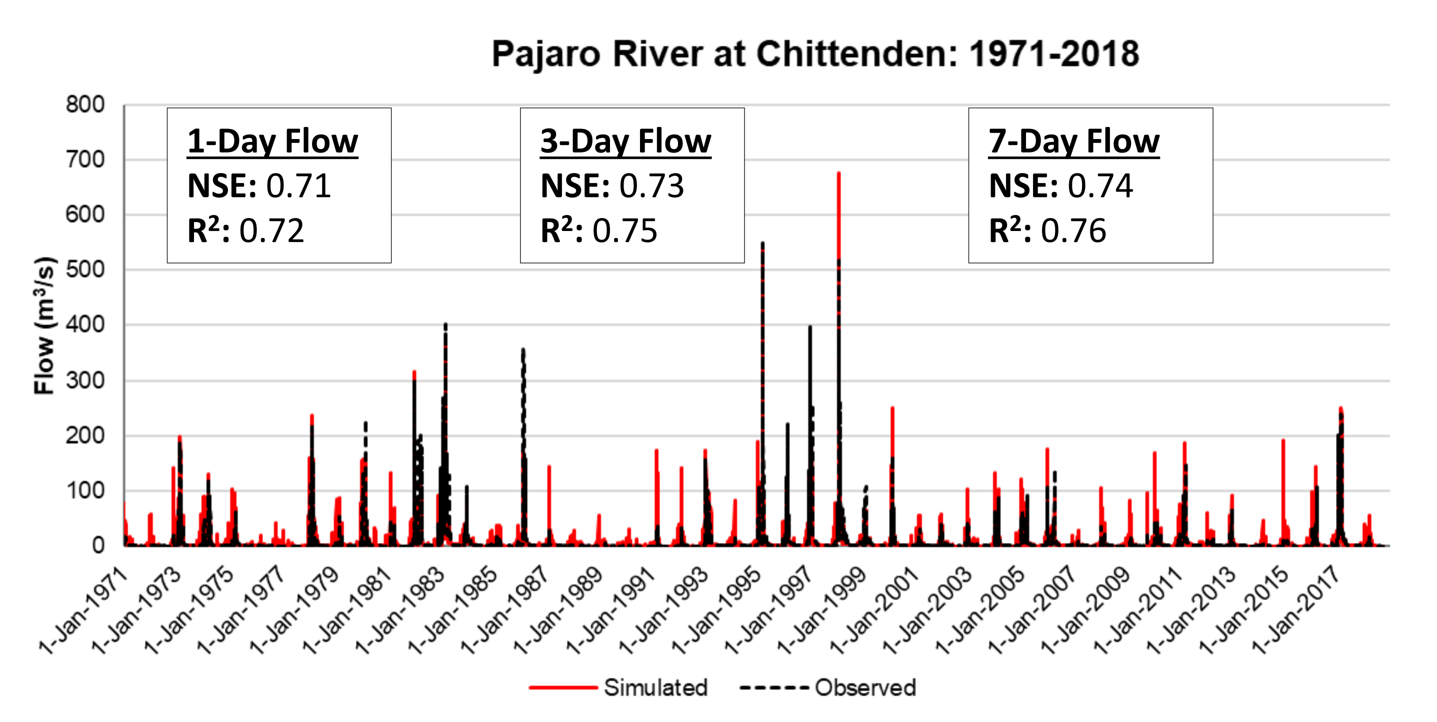
Pajaro River at Chittenden Flow

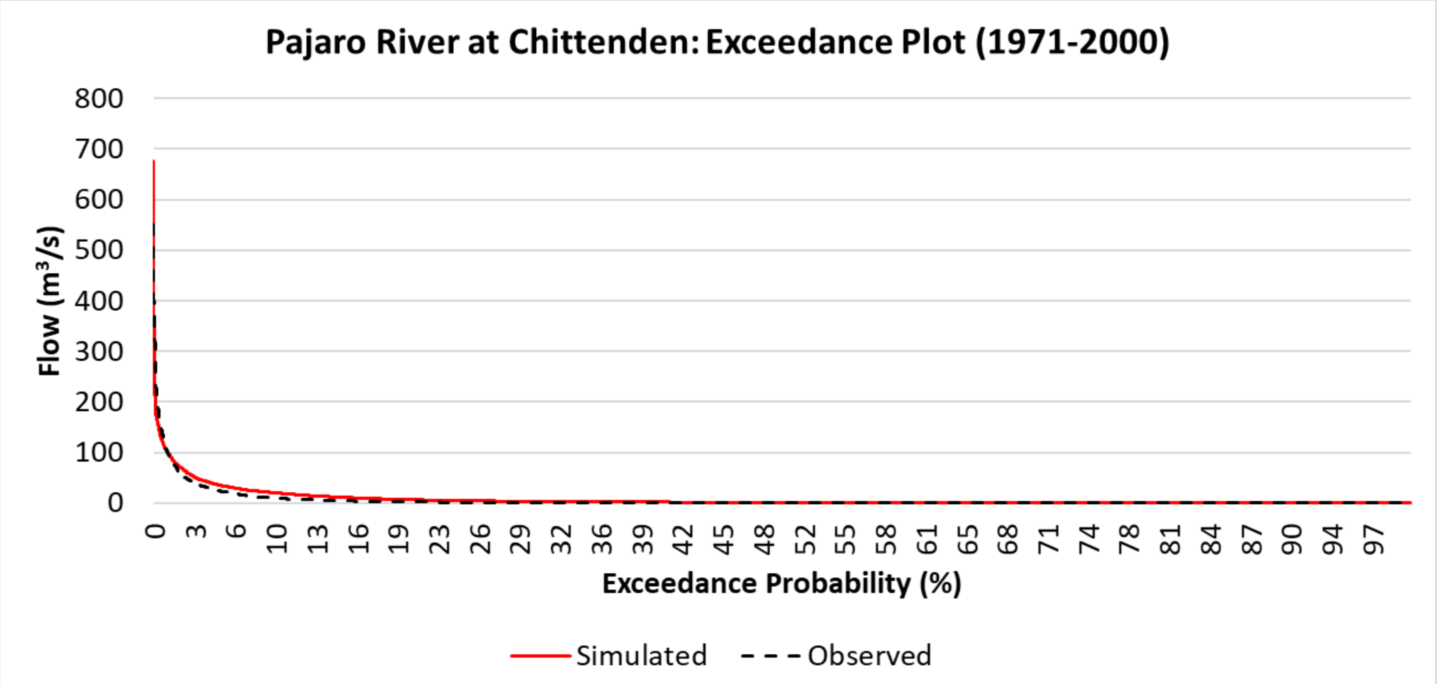
Calibration Period: 1971-2000



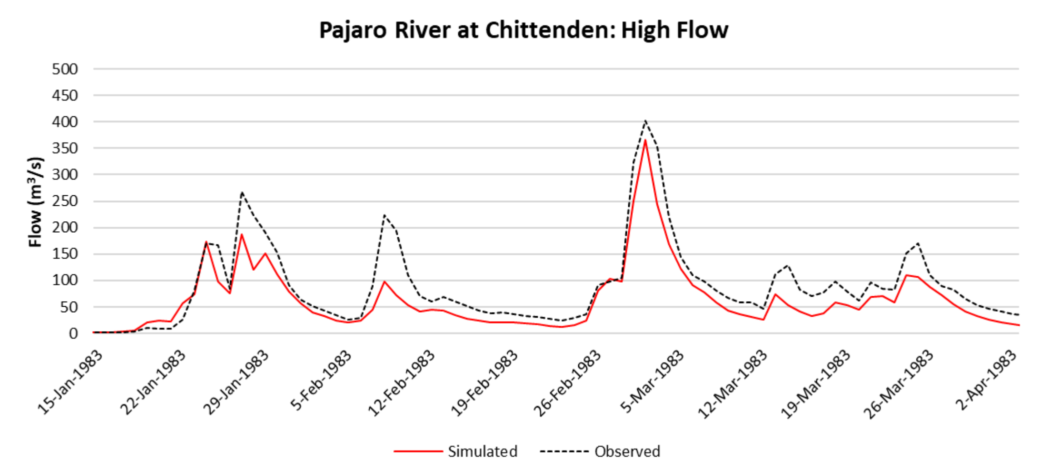
The Nash–Sutcliffe efficiency coefficient (NSE) ranges between −∞ and 1. It indicates a perfect match between observed and predicted values when NSE = 1

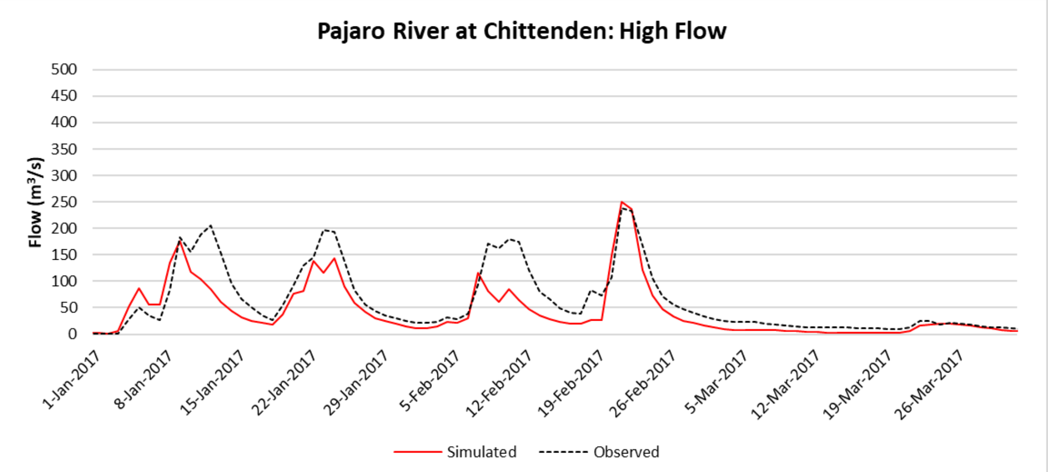
R^2 ranges from 0 to 1, a value close to 0 means very low correlation whereas a value close to 1 represents high correlation between observed and simulated discharge.

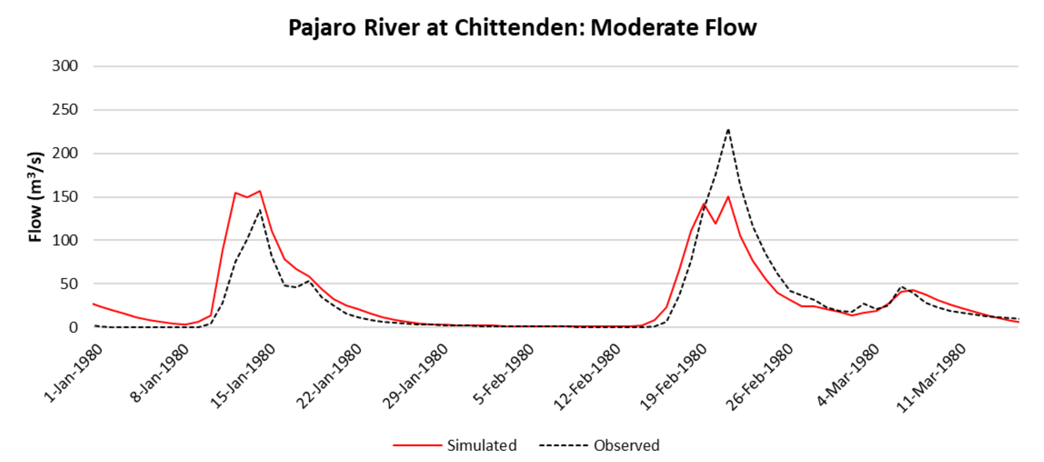


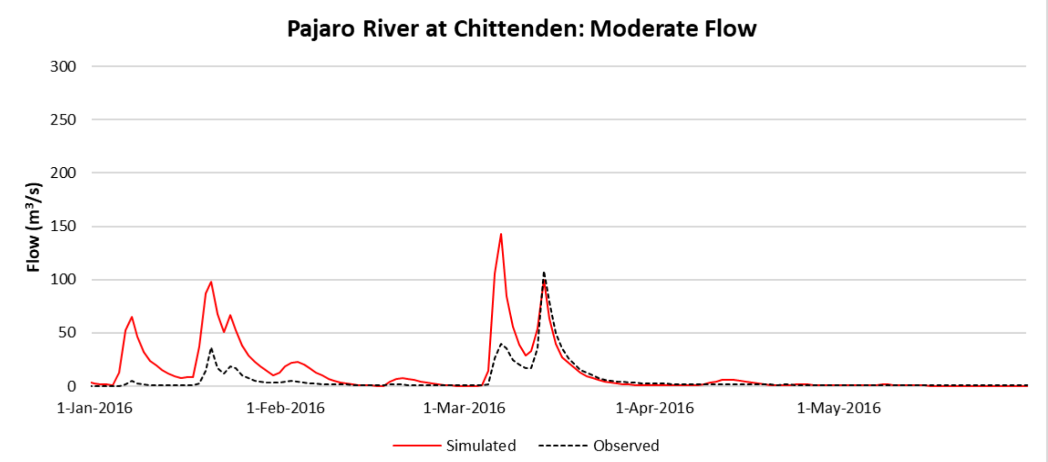


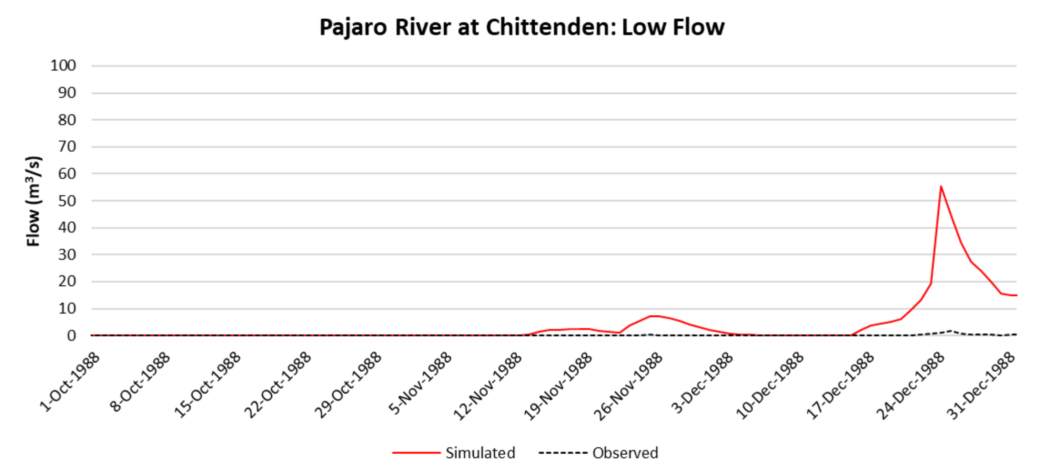
Pajaro River at Chittenden

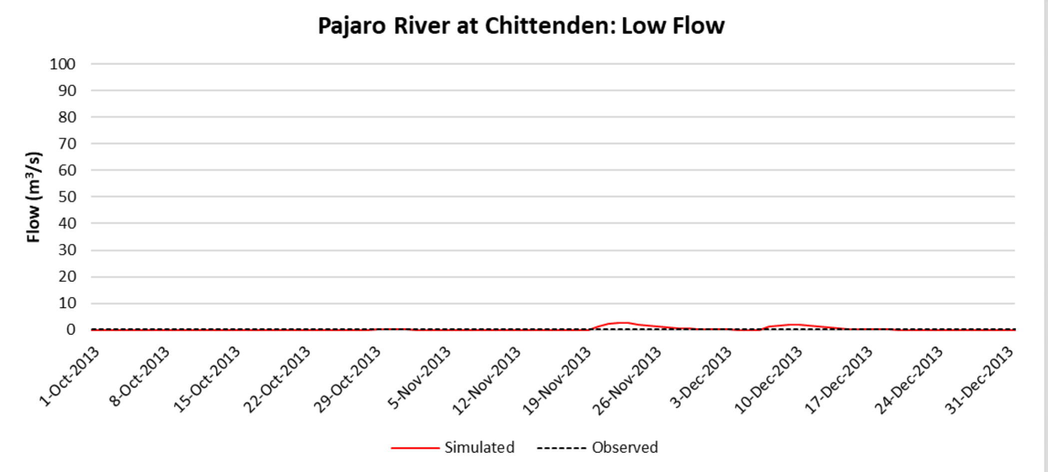












Model Calibration Results

- The model performed well for the following:
  - ✓ Representing range of flows that has been evaluated for floodplain events
  - ✓ Spanning long enough temporal period
  - ✓ Performed well in several areas of the Pajaro watershed spanning different physiographic locations
- Now that we have a well calibrated model, what's next?
  - ➢ Represent future climate scenarios in the hydrologic model
  - ➢ Perform statistical analysis on climate scenarios oriented towards flood events
  - ➢ Run climate scenarios in EcoFIP to understand how floodplain inundation might change in the future

Climate Modeling: Decision Scaling

Using DWR's most recent guidance, decision scaling provides a range of climate scenarios to stress test the system.

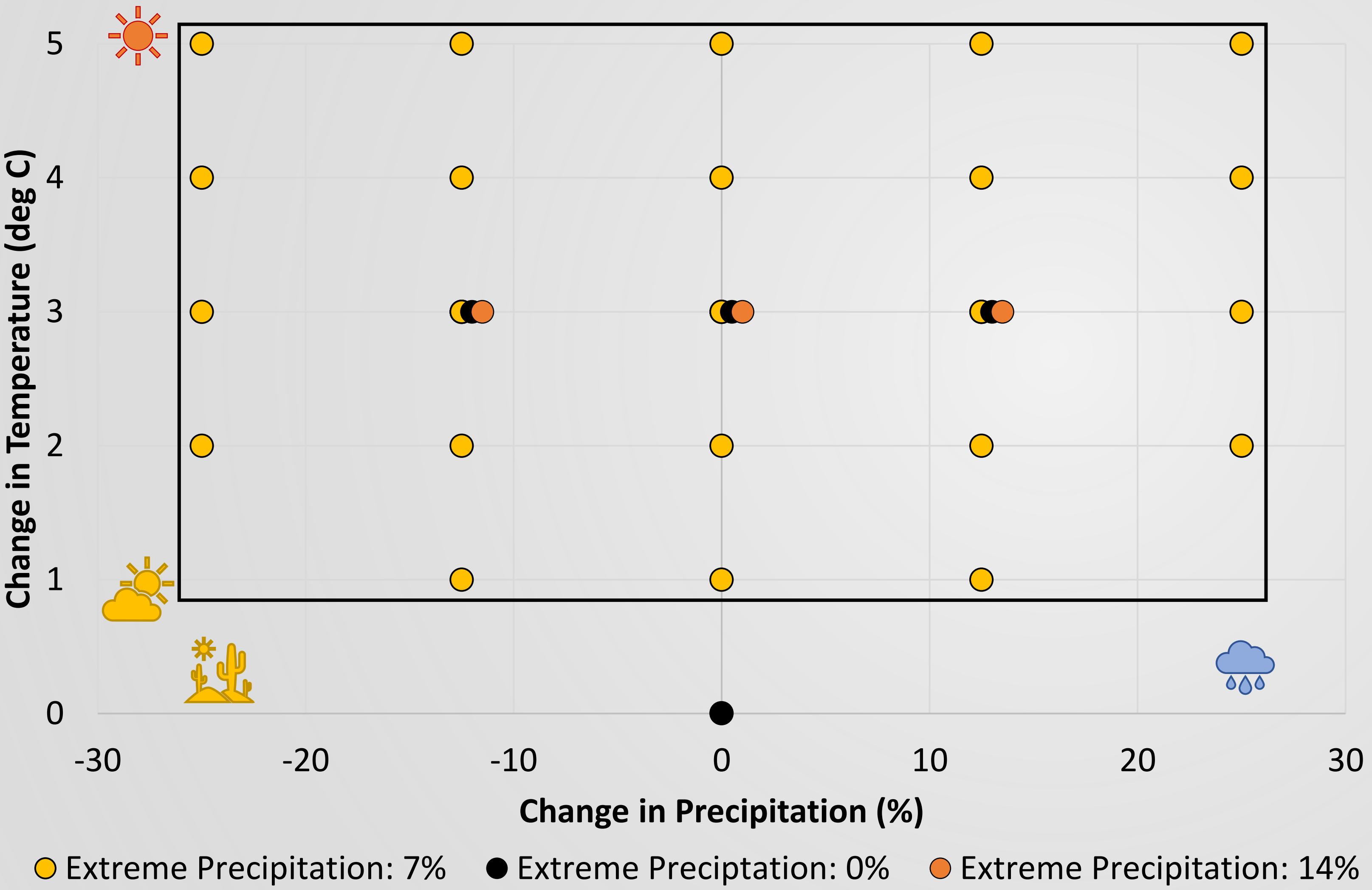
Climate change does not happen all at once – These results help us understand how the system will respond as temperature warms and account for uncertainty in projections.

What do we know?

- Temperatures are increasing (current planning roughly 2 °C by 2050, 3 °C by 2070)
- Extreme Precipitation will increase. We represent this as a function of temperature.
- We don't have a great confidence in trend for mean precipitation. We represent a range to reflect this.

Scenario Number	Scenario Name	Temperature Change (^oC)	Mean Precipitation Change (%)	Extreme Precipitation Change (% per ^oC)
1	CC 01	0	0	0
2	CC 02	2	-25	7
3	CC 03	3	-25	7
4	CC 04	4	-25	7
5	CC 05	5	-25	7
6	CC 06	1	-12.5	7
7	CC 07	2	-12.5	7
8	CC 08	3	-12.5	7
9	CC 09	4	-12.5	7
10	CC 10	5	-12.5	7
11	CC 11	1	0	7
12	CC 12	2	0	7
13	CC 13	3	0	7
14	CC 14	4	0	7
15	CC 15	5	0	7
16	CC 16	1	12.5	7
17	CC 17	2	12.5	7
18	CC 18	3	12.5	7
19	CC 19	4	12.5	7
20	CC 20	5	12.5	7
21	CC 21	2	25	7
22	CC 22	3	25	7
23	CC 23	4	25	7
24	CC 24	5	25	7
25	CC 25	3	-12.5	0
26	CC 26	3	0	0
27	CC 27	3	12.5	0
28	CC 28	3	-12.5	14
29	CC 29	3	0	14
30	CC 30	3	12.5	14

Climate Change Sensitivity Scenarios



- 30 Climate Change Scenarios
  - Precipitation: -25% to +25%
  - Temperature: 0 to +5
  - Extreme Precipitation: 0%, +7% and +14% per °C
- 24+6 runs

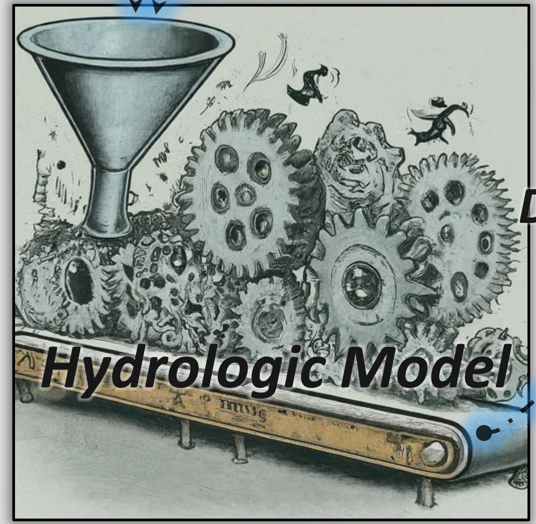
Change in Extreme Precipitation:
0% per °C
+7% per °C
+14% per °C

- Data Period: 1915 to 2018

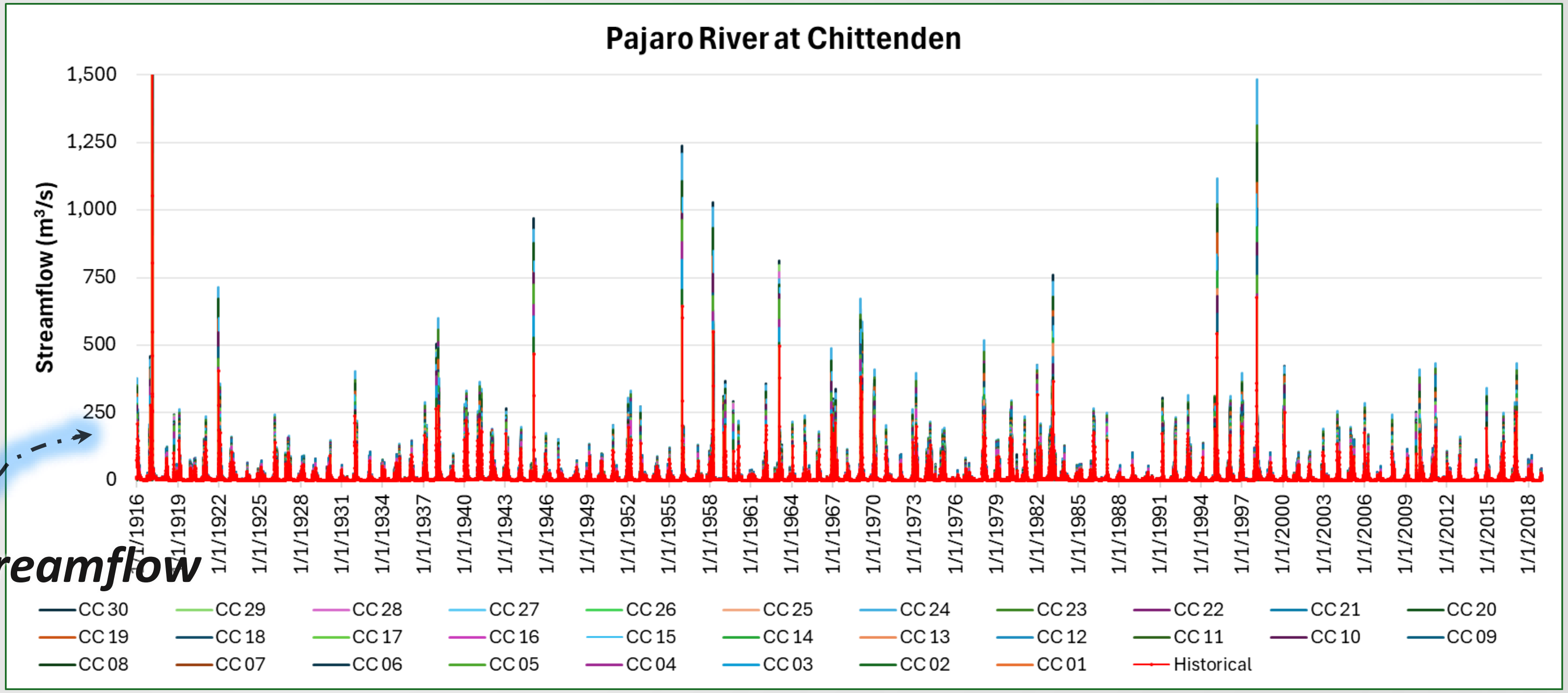
Climate Scenarios Simulated in Hydrologic Model

Climate model Inputs for 30 scenarios over 100-year period

Precipitation ***Temperature***



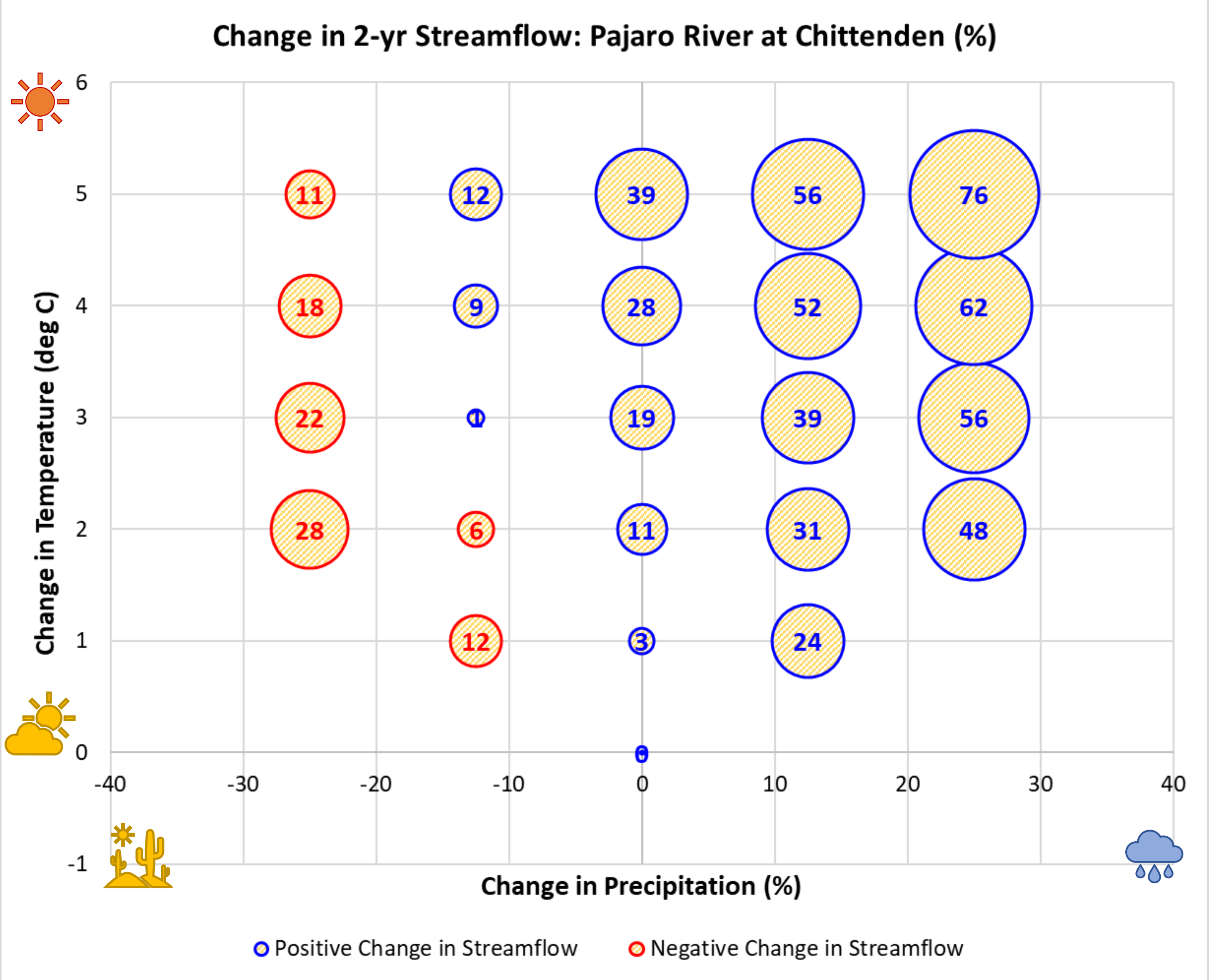
Daily Streamflow

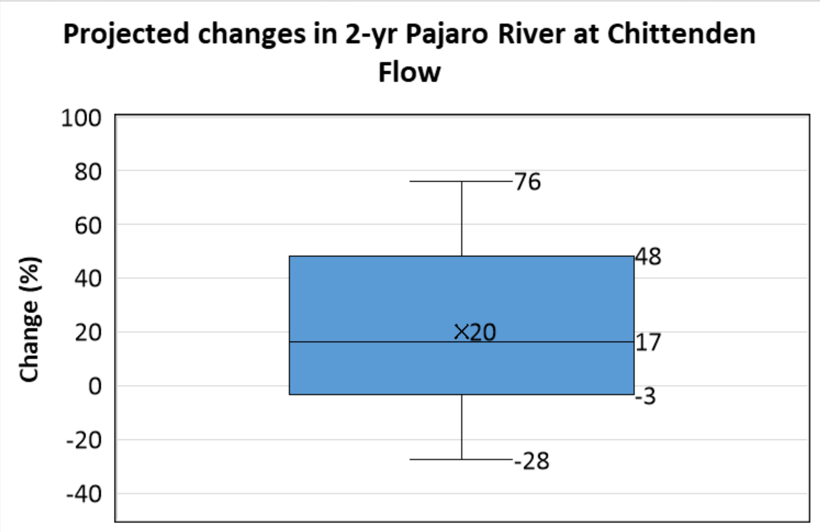


Graphics made with Gemini AI

Okay, we now have 3,000 years of daily streamflow data at several locations. How can we use this?

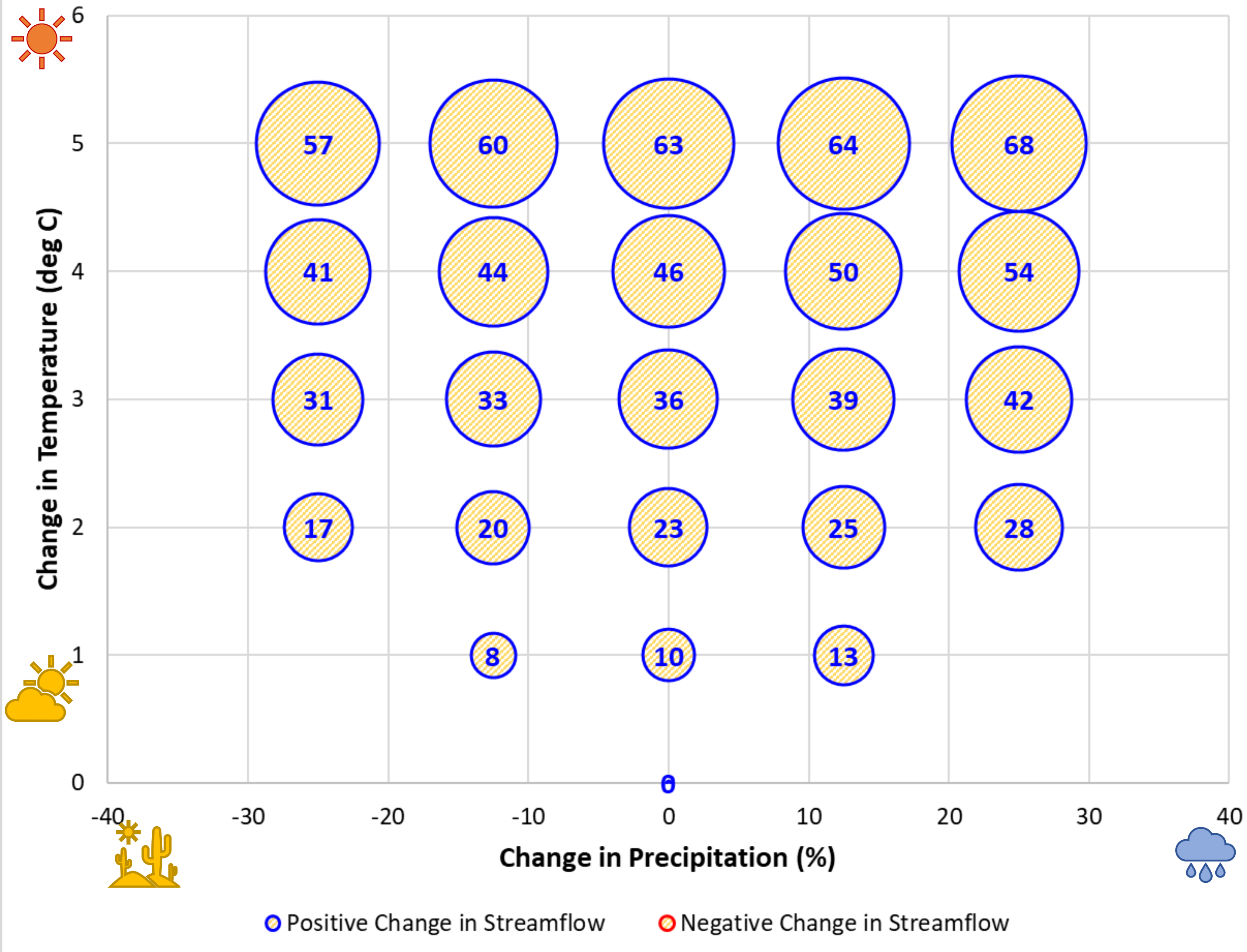
Projected Changes in 2-year Daily Streamflow: Pajaro River at Chittenden

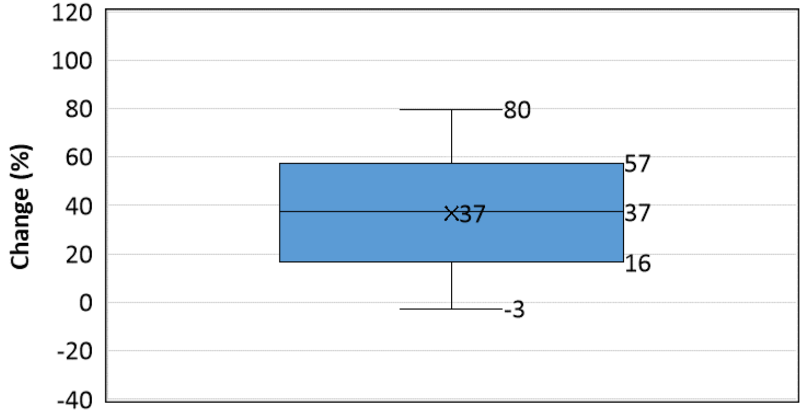




Scenario Name	Change
CC 01	0.1%
CC 02	-28%
CC 03	-22%
CC 04	-18%
CC 05	-11%
CC 06	-12%
CC 07	-6%
CC 08	1%
CC 09	9%
CC 10	12%
CC 11	3%
CC 12	11%
CC 13	19%
CC 14	28%
CC 15	39%
CC 16	24%
CC 17	31%
CC 18	39%
CC 19	52%
CC 20	56%
CC 21	48%
CC 22	56%
CC 23	62%
CC 24	76%
CC 25	-19%
CC 26	-3%
CC 27	16%
CC 28	18%
CC 29	49%
CC 30	73%

Projected Changes in 100-year Daily Streamflow: Pajaro River at Chittenden





Scenario Name	Change
CC 01	0.1%
CC 02	17%
CC 03	31%
CC 04	41%
CC 05	57%
CC 06	8%
CC 07	20%
CC 08	33%
CC 09	44%
CC 10	60%
CC 11	10%
CC 12	23%
CC 13	36%
CC 14	46%
CC 15	63%
CC 16	13%
CC 17	25%
CC 18	39%
CC 19	50%
CC 20	64%
CC 21	28%
CC 22	42%
CC 23	54%
CC 24	68%
CC 25	-3%
CC 26	-1%
CC 27	3%
CC 28	73%
CC 29	76%
CC 30	80%

Summary

- The SWAT hydrological model has been developed for the Pajaro watershed, including Corralitos regions. The model was calibrated and performs well!
- The climate change analysis was performed by simulating 30 future climate change scenarios using DWR's Weather Generator.
- Projected changes in 2-year and 100-year flows for Pajaro River at Chittenden and Corralitos Creek at Freedom were estimated. These results show how flood risk is likely to increase in response to a warming climate.
- The future change scenarios data were used to inform EcoFIP analysis for Floodplain inundation characteristics projection at key reaches (Corralitos Creek and the Pajaro River adjacent to Watsonville).

Questions

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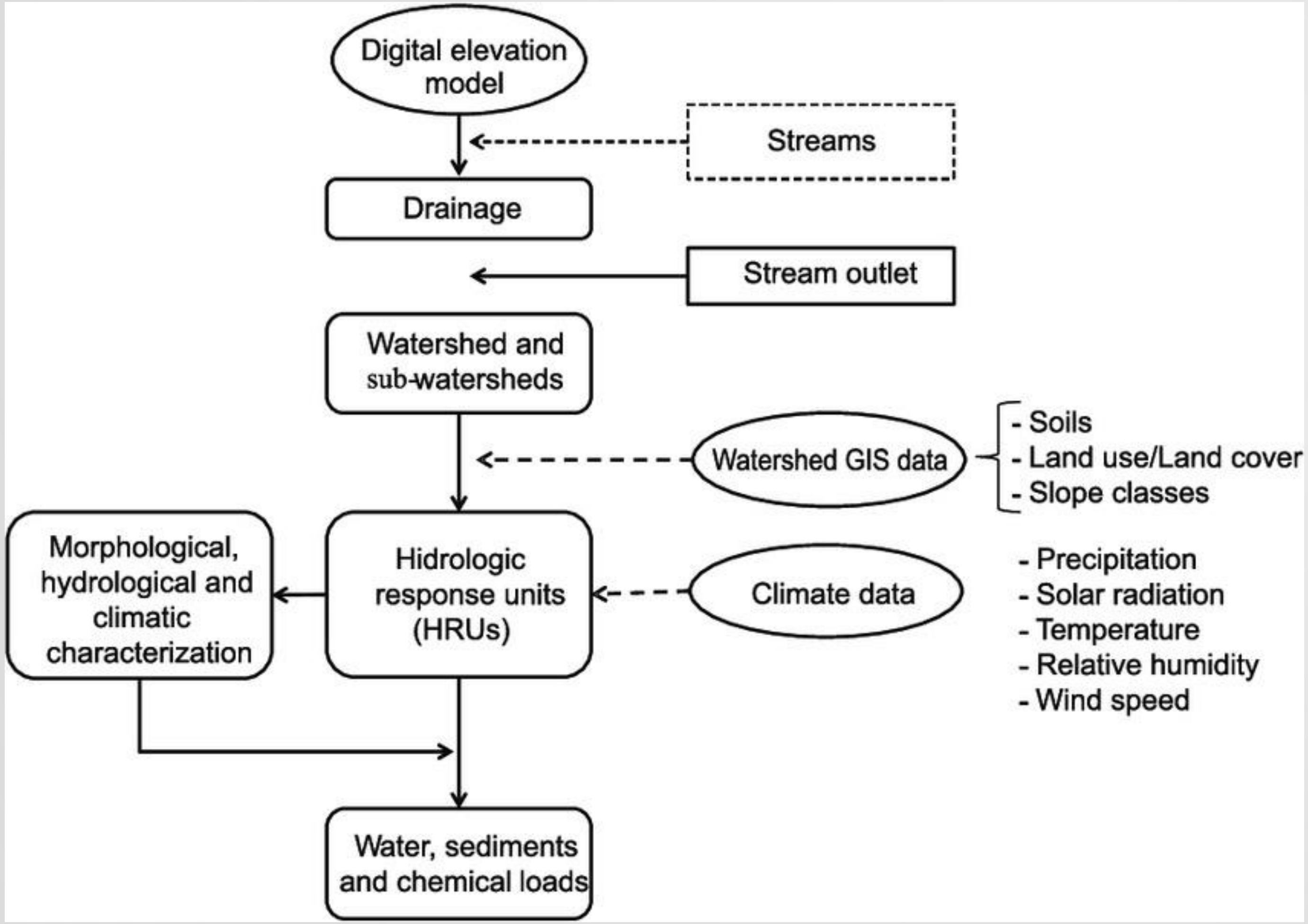
Extra Slides

Hydrologic Modeling

SWAT Model Schematic
https://swat.tamu.edu/software/



Calibration Parameters

S. No.	Calibration Parameter	Process affected	Description
1	CN2	Surface flow	SCS curve number
2	ALPHA_BF	Baseflow	Base flow alpha factor (1/days)
3	GW_DELAY	Baseflow	Delay time for aquifer recharge
4	GWQMN	Baseflow	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H2O)
5	SURLAG	Surface flow	Surface runoff lag coefficient
6	SOL_AWC()	Soil	Available water capacity of the soil layer (mm/mm)
7	SOL_K()	Soil	Soil saturated hydraulic condictivity (mm/h)
8	ESCO	Soil	Soil evaporation compensation factor
9	EPCO	Surface flow	Plant uptake compensation factor
10	CH_K2	Surface flow	Effective channel hydraulic conductivity (mm/h)
11	GW_REVAP	Baseflow	Groundwater revap coefficient
12	REVAPMN	Baseflow	Threshold depth of water in the shallow aquifer for revap or percolation to the deep aquifer to occur (mm)
13	ALPHA_BNK	Surface flow	Baseflow alpha factor for bank storage (days)
14	RCHRG_DP	Baseflow	Deep aquifer percolation fraction

Bhandari, R., Kalra, A., & Kumar, S. (2020). Analyzing the effect of CMIP5 climate projections on streamflow within the Pajaro River Basin. *Open Water Journal*, *6*(1), 5.

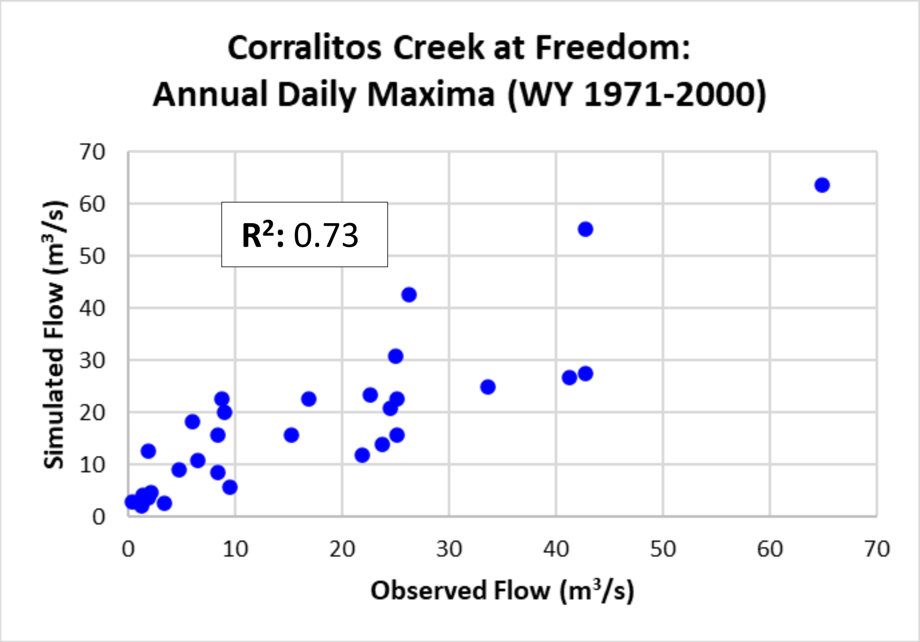
Calibration Parameters

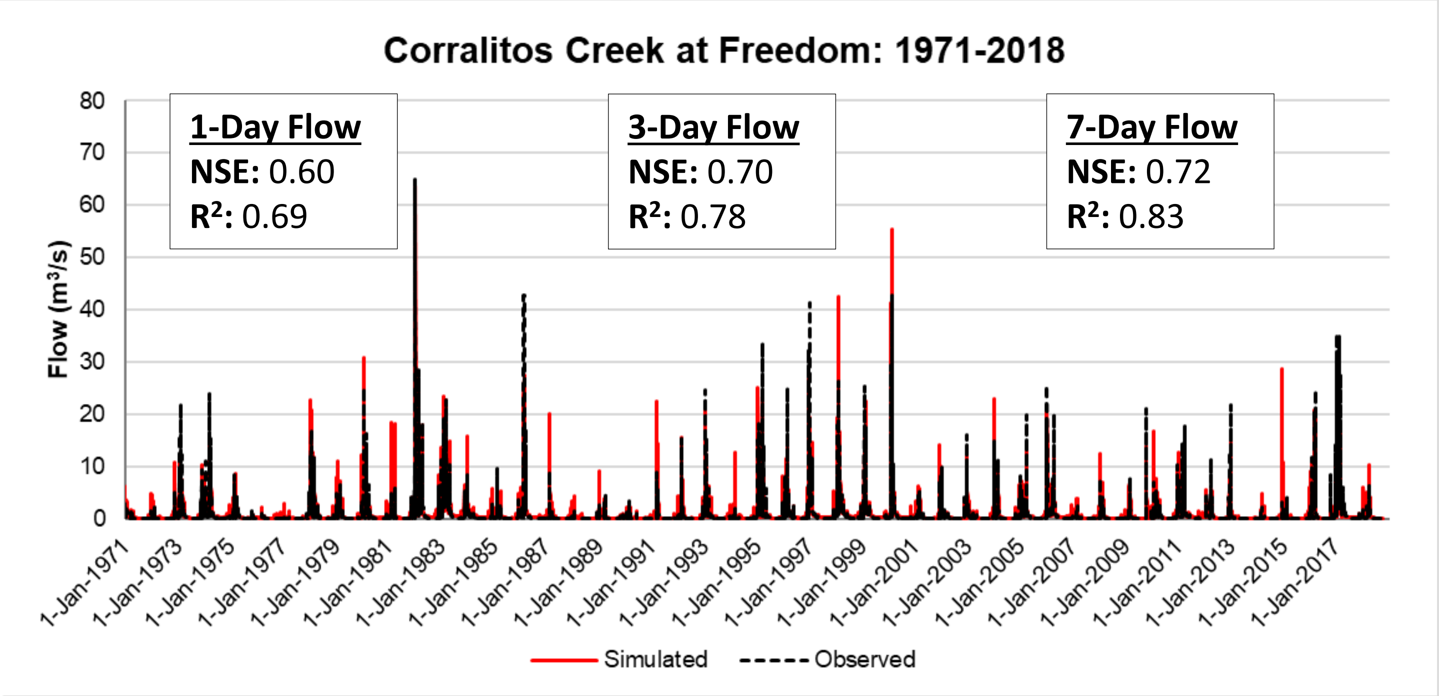
S. No.	Calibration Parameter	Change	Minimum	Maximum	Pajaro Calibrated	Corralitos Calibrated
1	CN2	Relative	-0.5	0.5	-0.2325	-0.0075
2	ALPHA_BF	Replace	0	1	0.6325	0.2675
3	GW_DELAY	Replace	0	500	256.25	441.25
4	GWQMN	Replace	0	5000	787.5	3337.5
5	SURLAG	Relative	-0.3	0.3	-0.2655	-0.2655
6	SOL_AWC()	Relative	-0.3	0.3	0.0075	-0.0885
7	SOL_K()	Relative	-0.3	0.3	-0.1125	-0.0105
8	ESCO	Replace	0	1	0.3075	0.5425
9	EPCO	Replace	0	1	0.7875	0.4575
10	CH_K2	Replace	0	500	153.75	41.25
11	GW_REVAP	Replace	0.02	0.2	0.17885	0.17075
12	REVAPMN	Relative	-0.3	0.3	0.2535	0.2745
13	ALPHA_BNK	Replace	0	1	0.9675	0.2975
14	RCHRG_DP	Replace	0	1	0.0325	0.0725

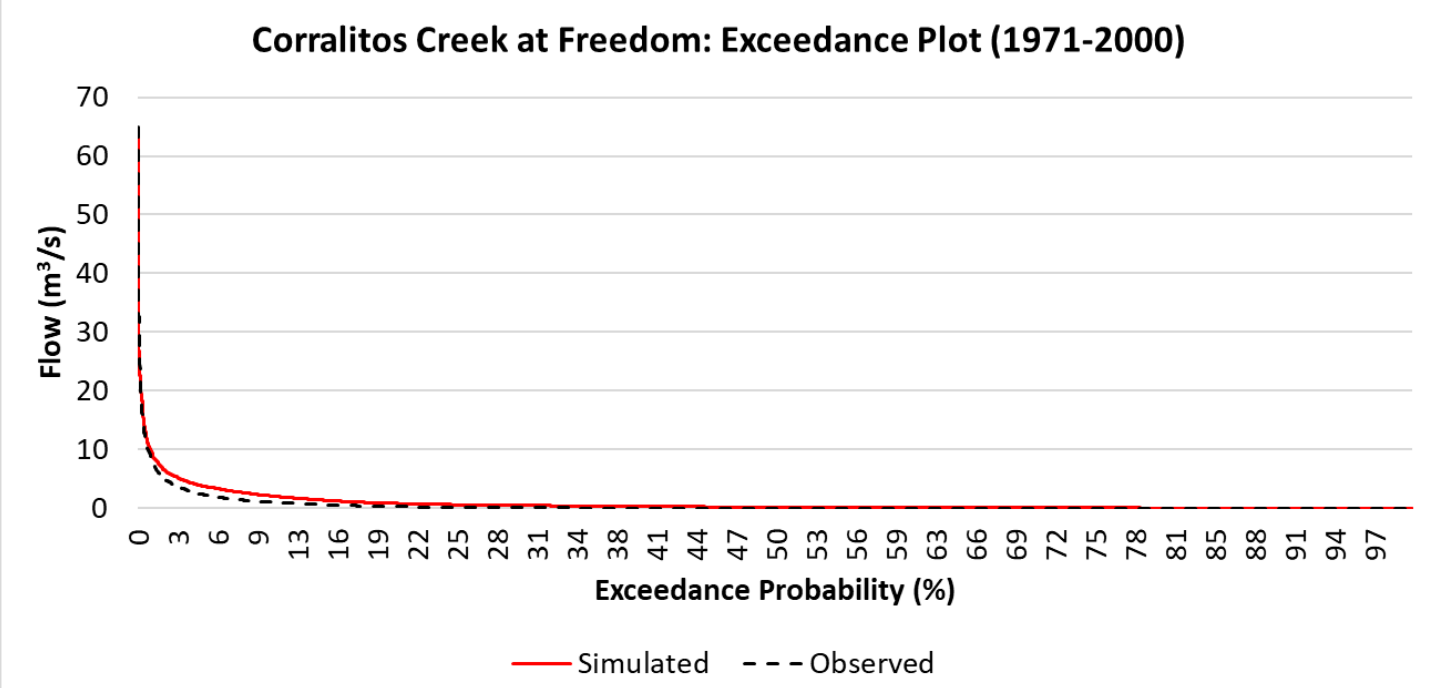
Bhandari, R., Kalra, A., & Kumar, S. (2020). Analyzing the effect of CMIP5 climate projections on streamflow within the Pajaro River Basin. *Open Water Journal*, *6*(1), 5.

Corralitos Creek at Freedom Flow

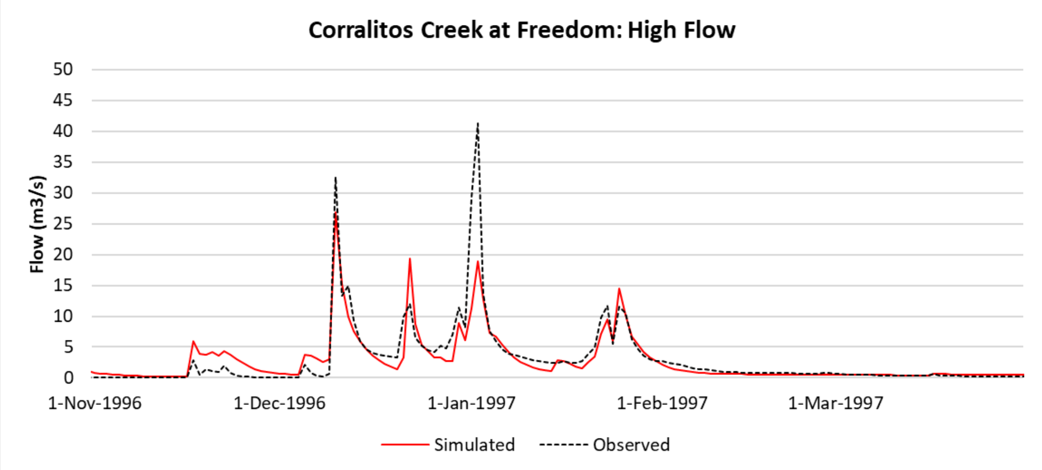
Calibration Period: 1971-2000

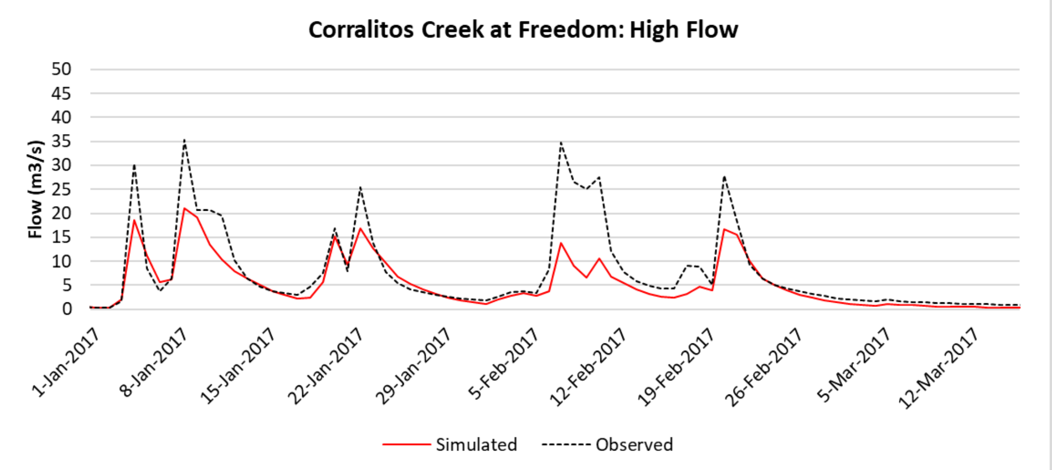


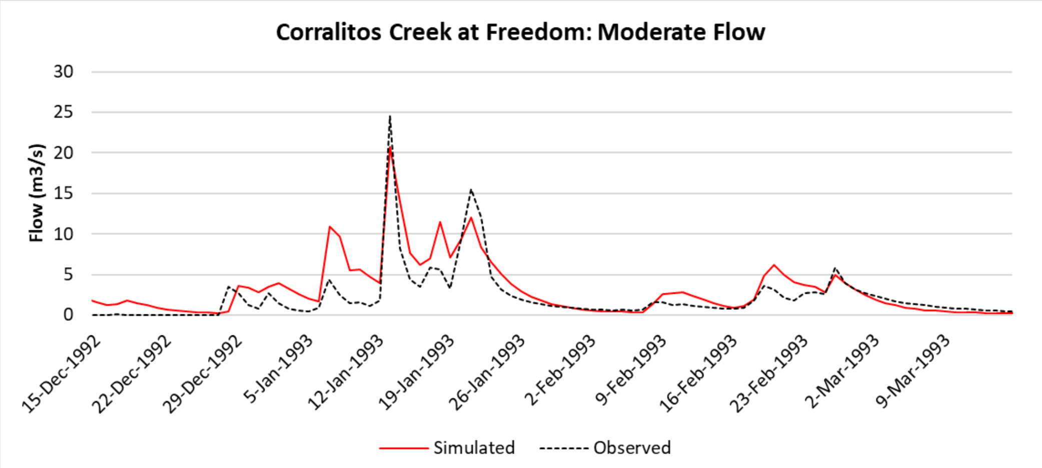


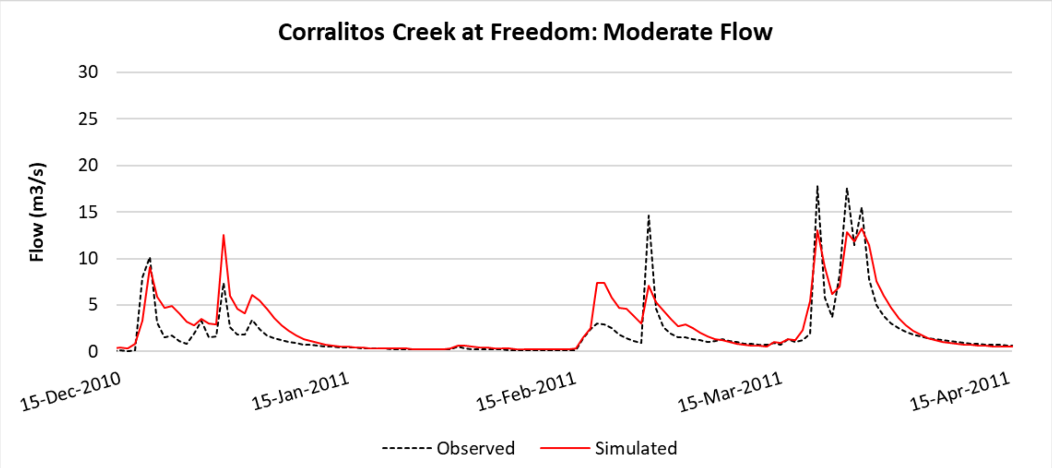


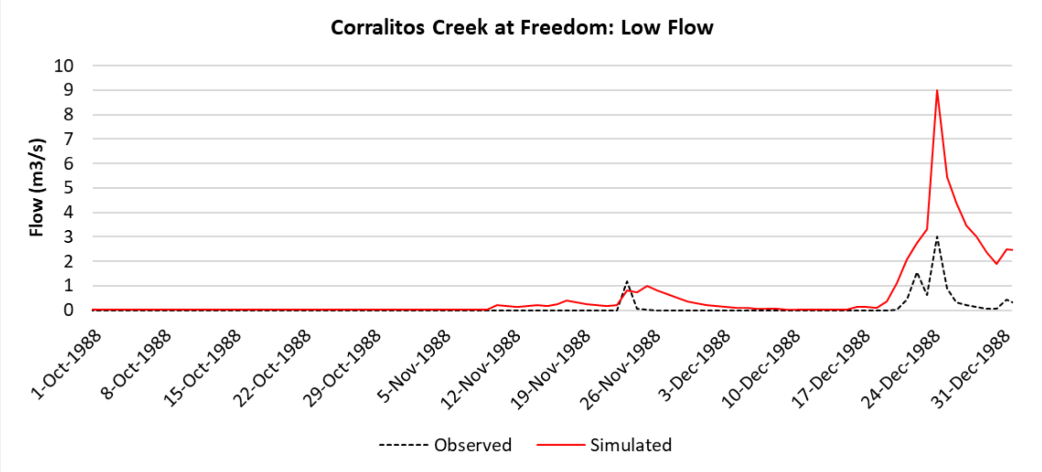
Corralitos Creek at Freedom

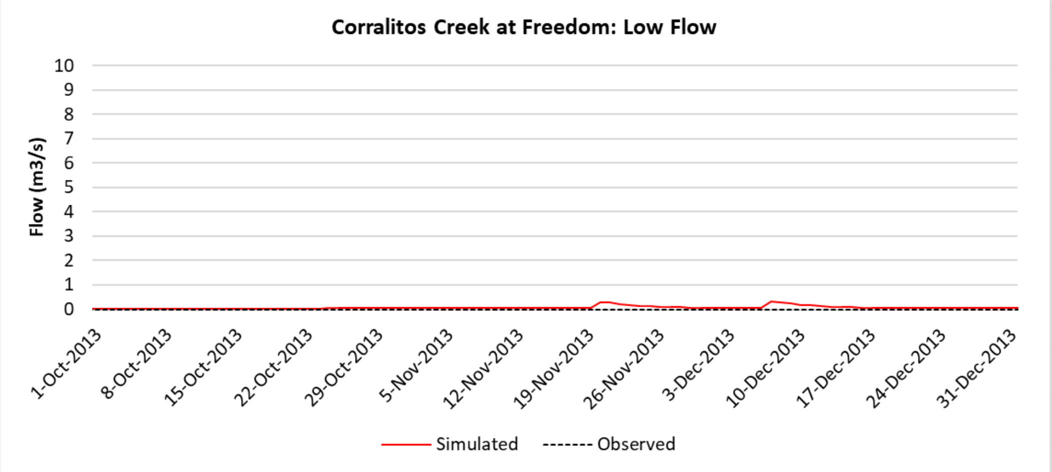






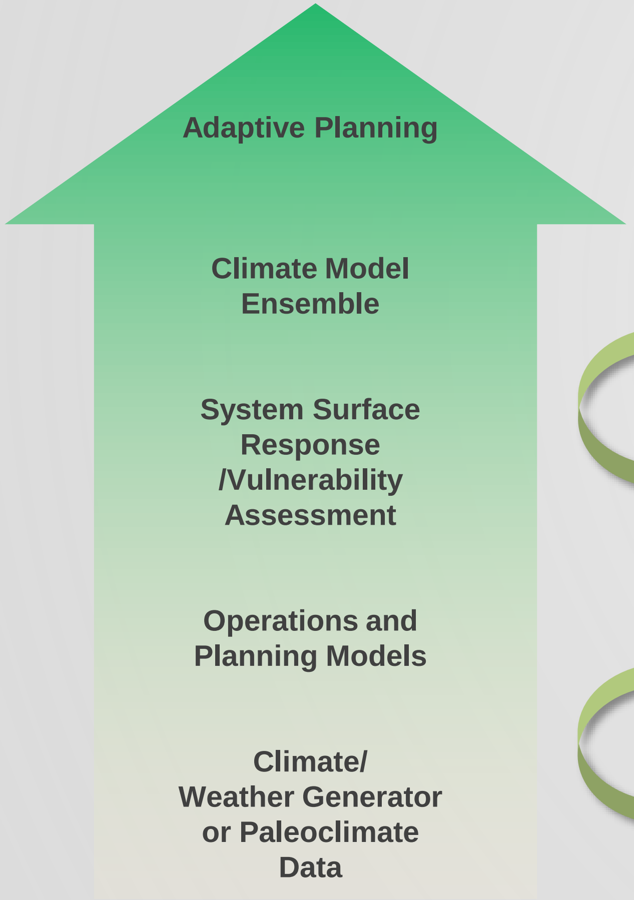


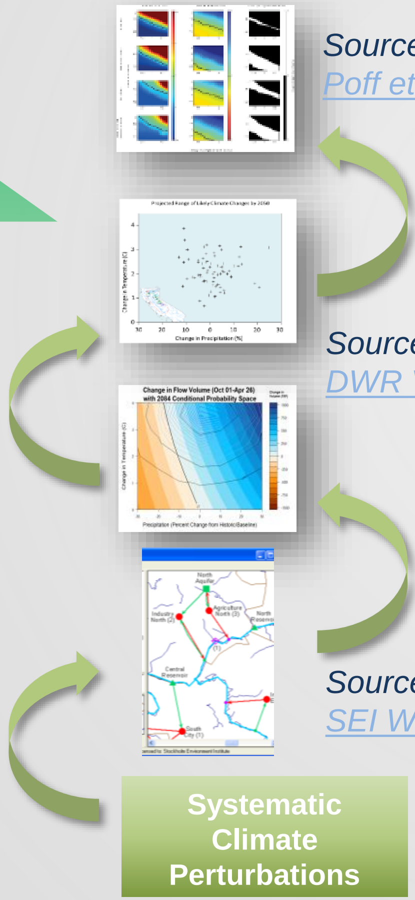




Using Climate Projections at DWR

"Bottom Up" or **Decision Scaling** Approach





Source: Poff et al. (2016)

Source: DWR VA

Source: SEI WEAP

Other images source: Wikimedia Commons

A way to prepare when you aren't sure what's coming (Stress Test)

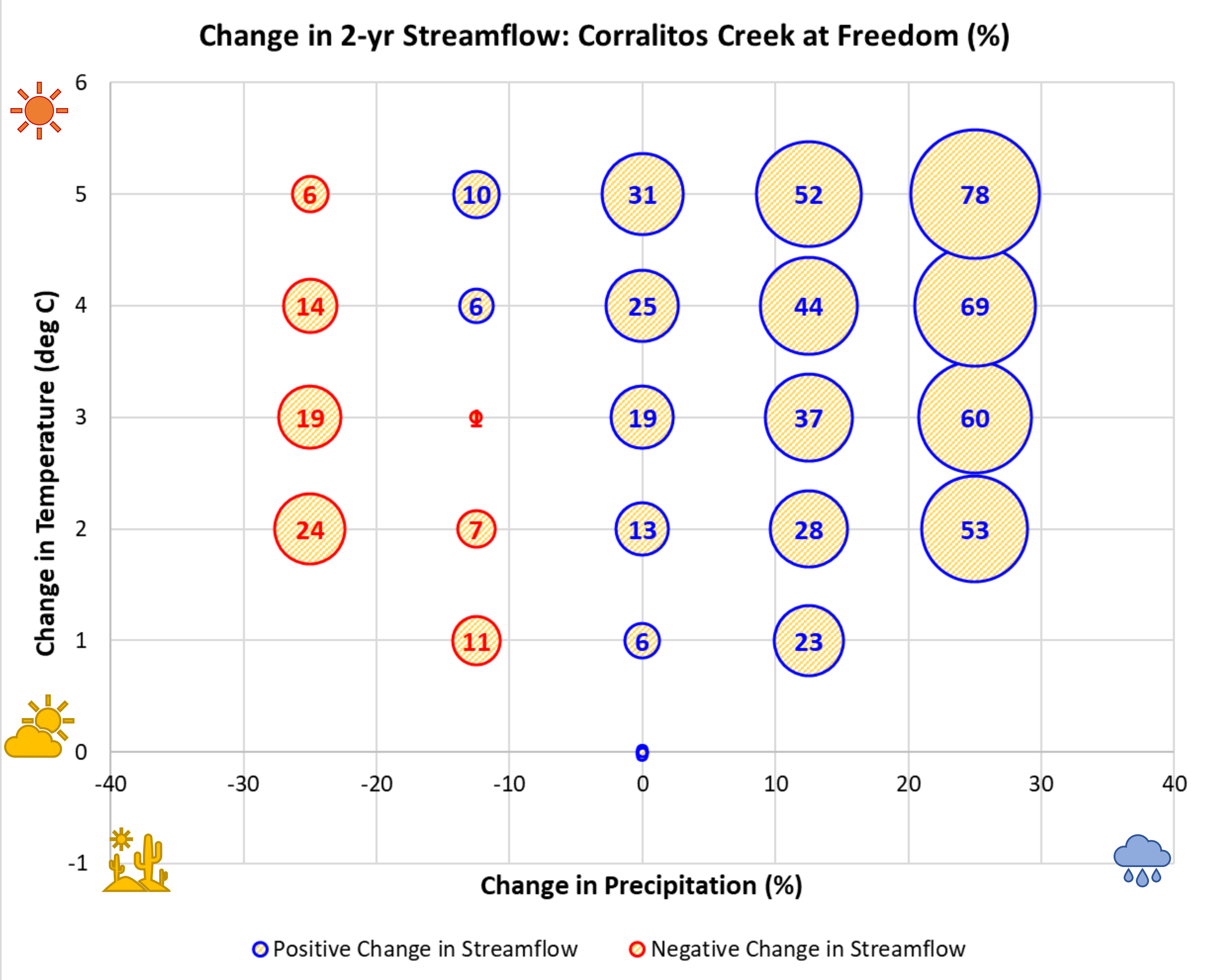
→ Determine the sensitivity of a water system to a range of stress (weather or climate possibilities). **Where is our system vulnerable?**

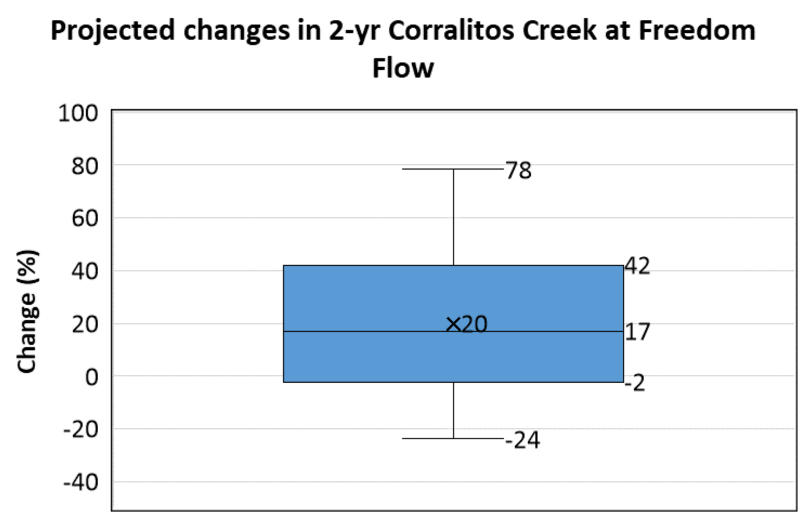
→ Determine what threshold of performance is unacceptable or 'breaks' the system. **Find tipping points.**

→ Determine how likely that is to happen. **Incorporate original climate projections to assess the risk of these "unacceptable outcomes."**

→ **ADAPT!** Take decision(s) toward what is "most" likely and/or "most" acceptable based on this risk assessment.

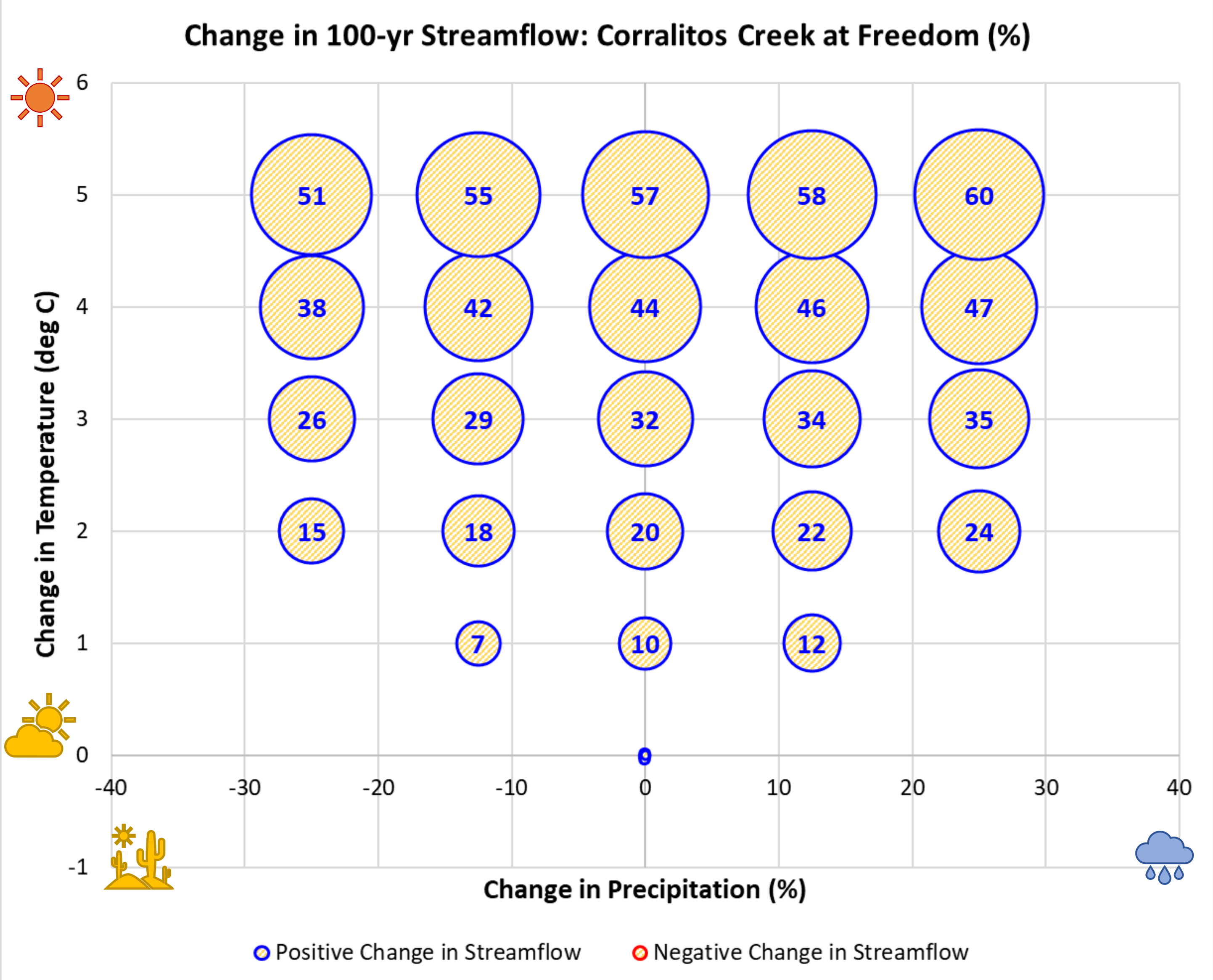
Projected Changes in 2-year Daily Streamflow: Corralitos Creek at Freedom

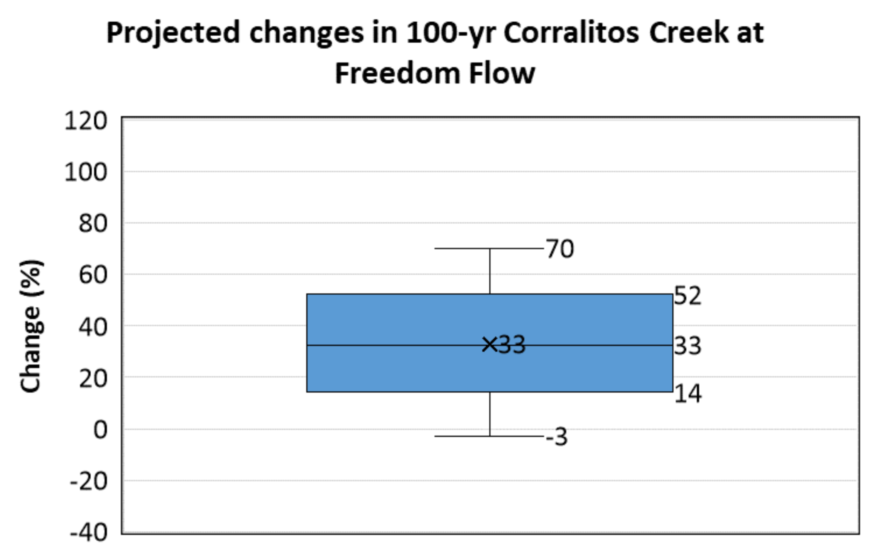




Scenario Name	Change
CC 01	0.5%
CC 02	-24%
CC 03	-19%
CC 04	-14%
CC 05	-6%
CC 06	-11%
CC 07	-7%
CC 08	-1%
CC 09	6%
CC 10	10%
CC 11	6%
CC 12	13%
CC 13	19%
CC 14	25%
CC 15	31%
CC 16	23%
CC 17	28%
CC 18	37%
CC 19	44%
CC 20	52%
CC 21	53%
CC 22	60%
CC 23	69%
CC 24	78%
CC 25	-18%
CC 26	-1%
CC 27	16%
CC 28	18%
CC 29	42%
CC 30	65%

Projected Changes in 100-year Daily Streamflow: Corralitos Creek at Freedom





Scenario Name	Change
CC 01	0.4%
CC 02	15%
CC 03	26%
CC 04	38%
CC 05	51%
CC 06	7%
CC 07	18%
CC 08	29%
CC 09	42%
CC 10	55%
CC 11	10%
CC 12	20%
CC 13	32%
CC 14	44%
CC 15	57%
CC 16	12%
CC 17	22%
CC 18	34%
CC 19	46%
CC 20	58%
CC 21	24%
CC 22	35%
CC 23	47%
CC 24	60%
CC 25	-3%
CC 26	0%
CC 27	2%
CC 28	67%
CC 29	69%
CC 30	70%