CALIFORNIA DEPARTMENT OF WATER RESOURCES

Decision Scaling: How

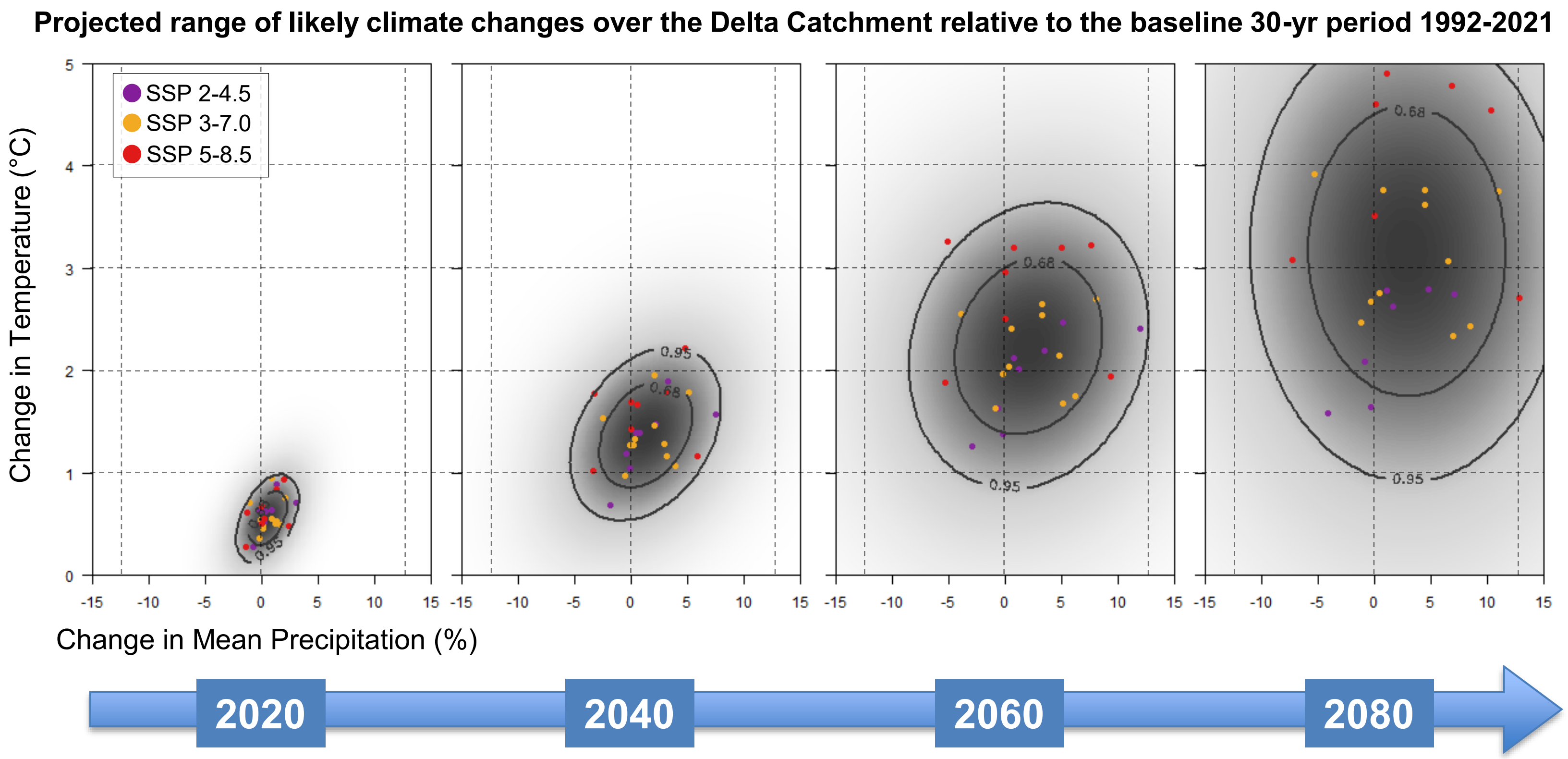
CWEMF Annual Meeting

May 14th, 2025

Overview

- **Climate Change Analysis**
  - GCM Projections
  - Decision Scaling
  - System-risk Informed Scenarios
- **Application 1: California Water Plan 2023**
- **Application 2: SJR Flood-MAR Watershed Studies**

Climate Change Analysis
Wrestling with uncertainty



Each dot:

- *One of the 27 CMIP6/LOCA-2 downscaled projections of temperature and precipitation*
- *Spatial averaging over watersheds draining into the Sacramento-San Joaquin Delta*

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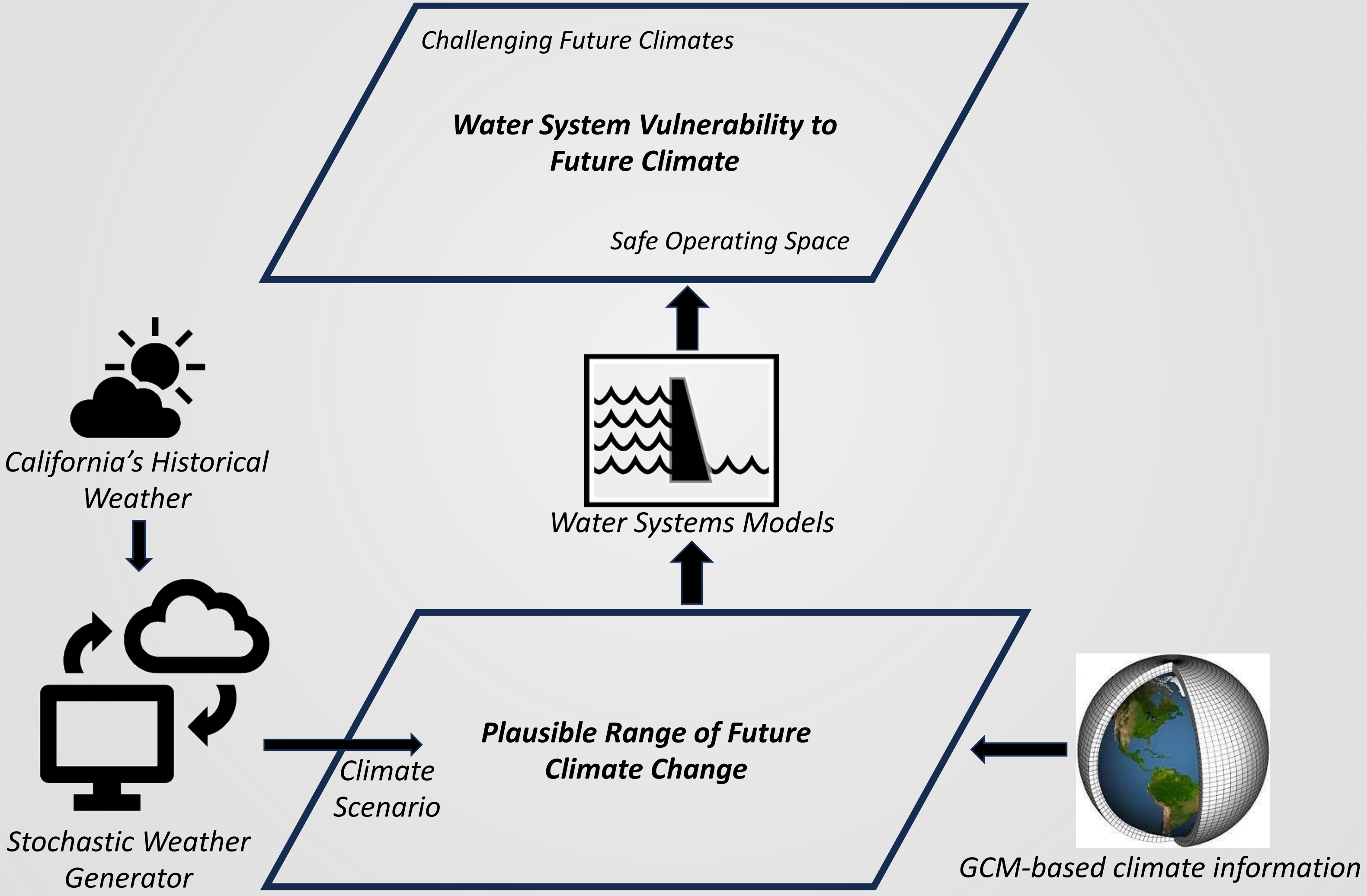
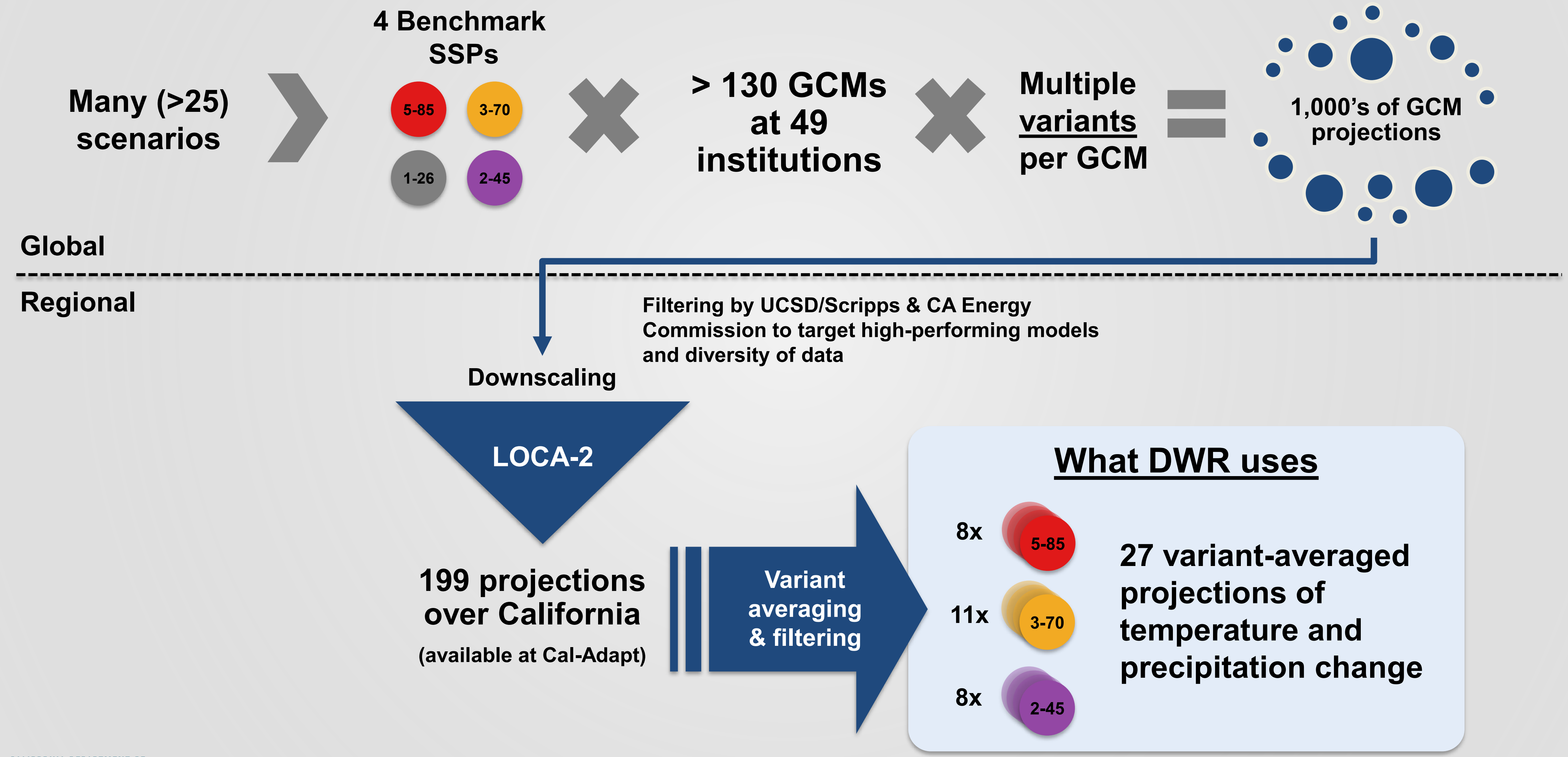
WATER RESOURCES

Decision Scaling Analysis
A Bottom-up Framework

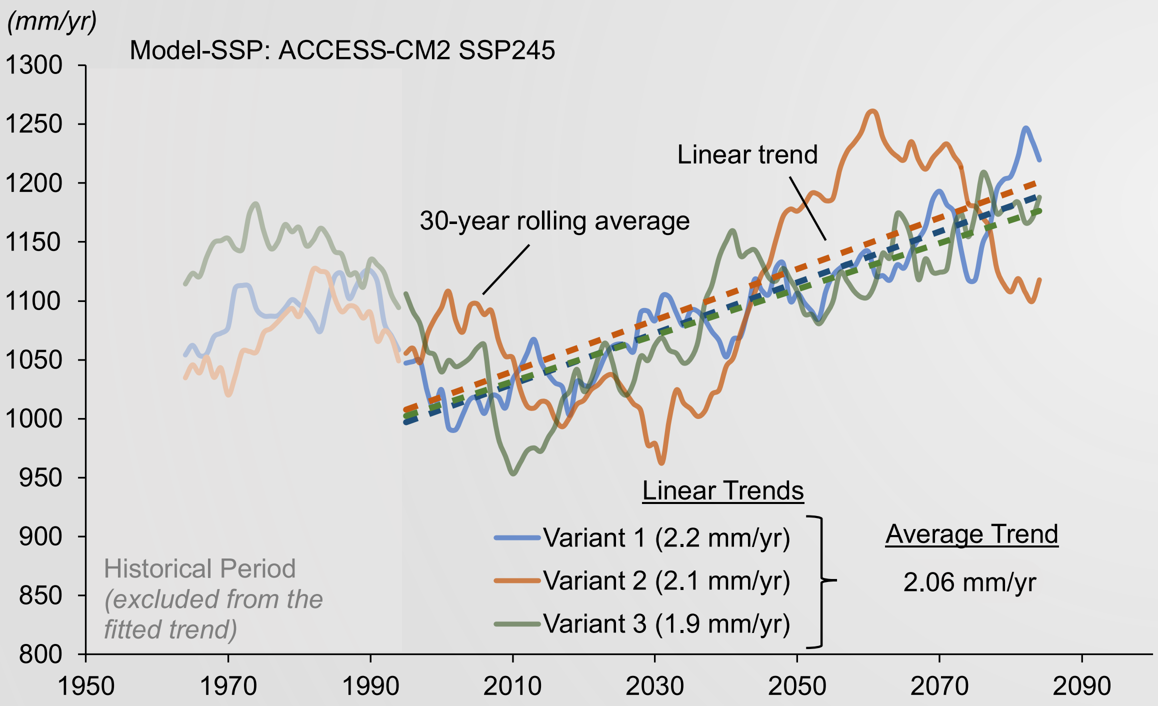


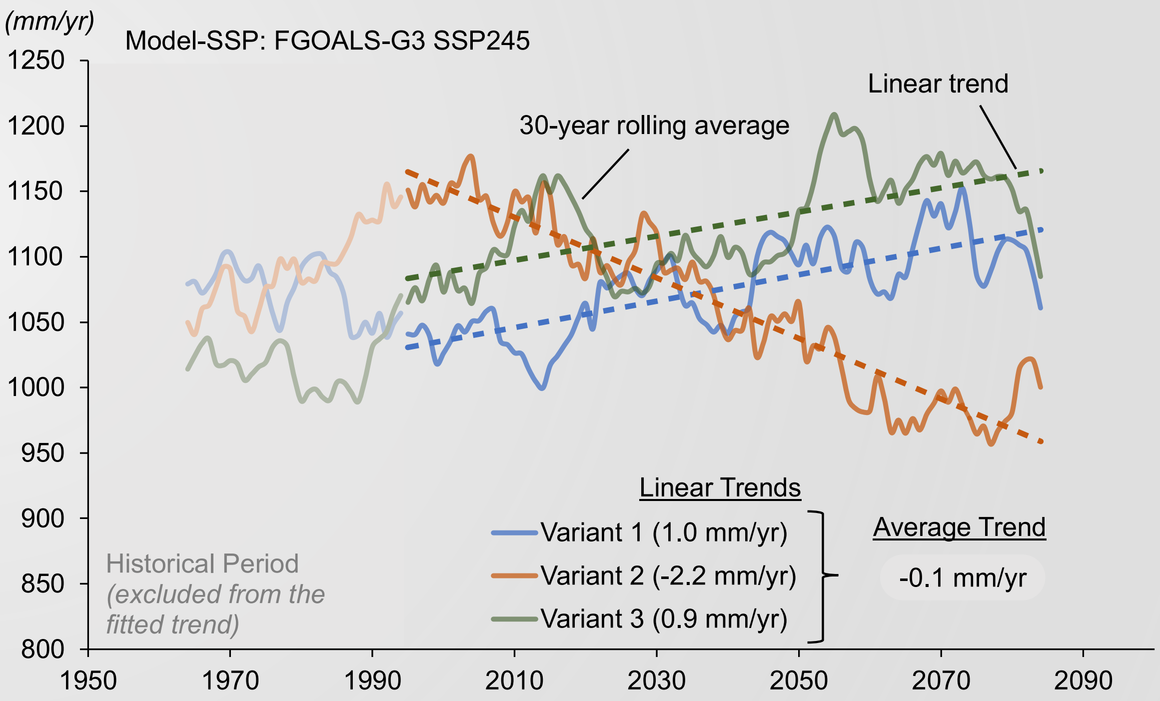
Climate Change Projections



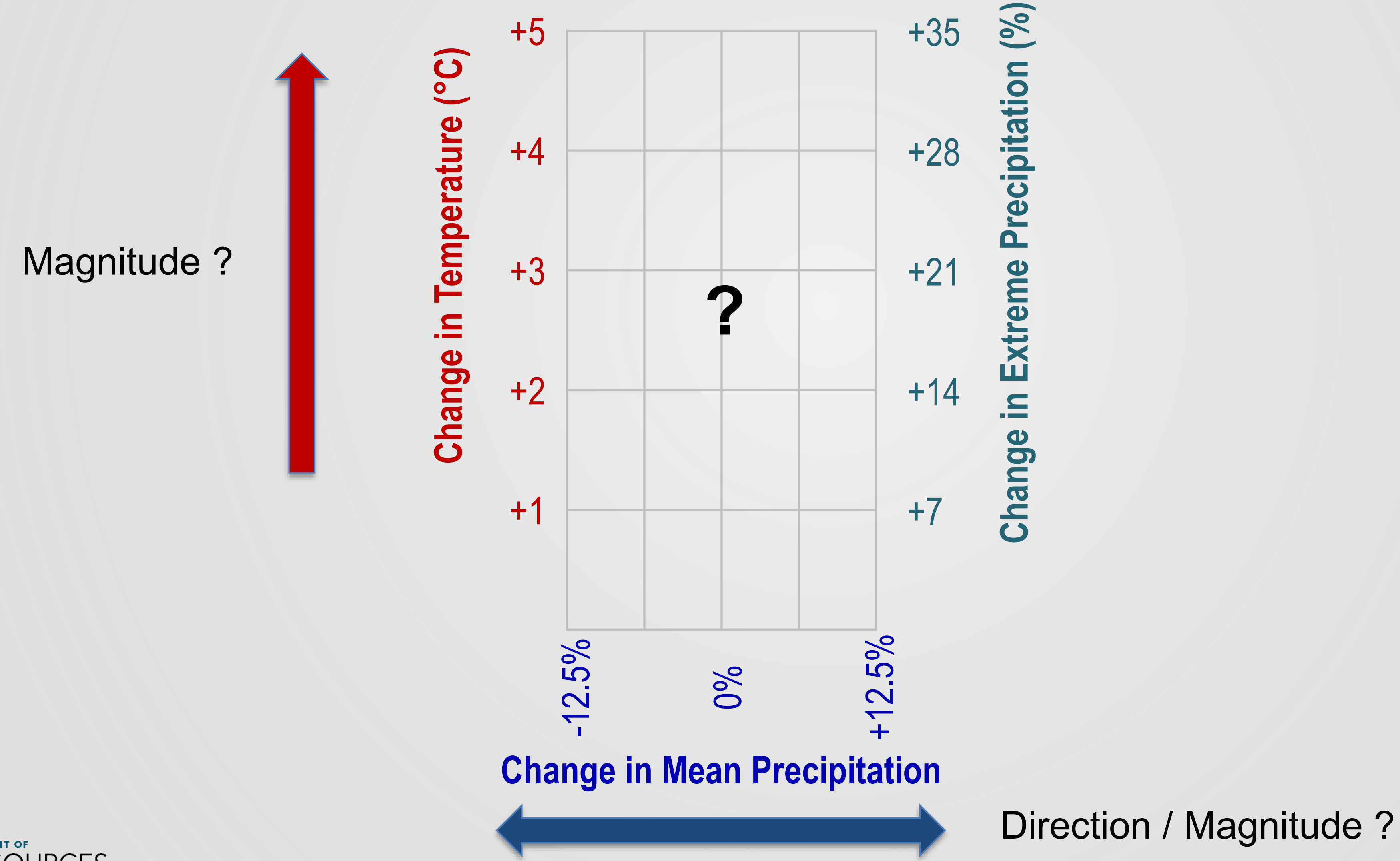
Climate Change Projections
Why variant-averaging?

Long-term mean precipitation changes appear mostly driven by natural variability





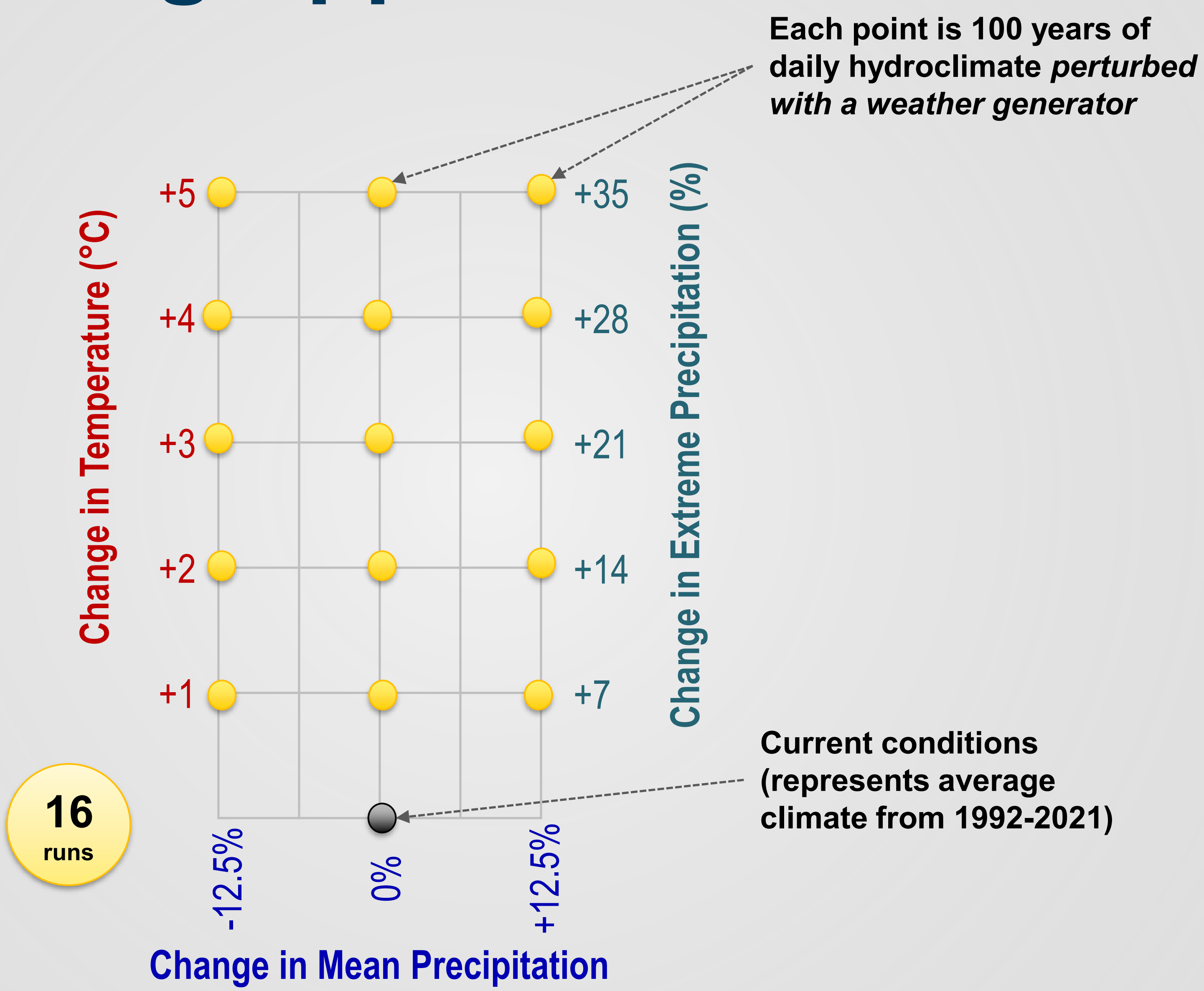
Climate Change Analysis
Wrestling with uncertainty



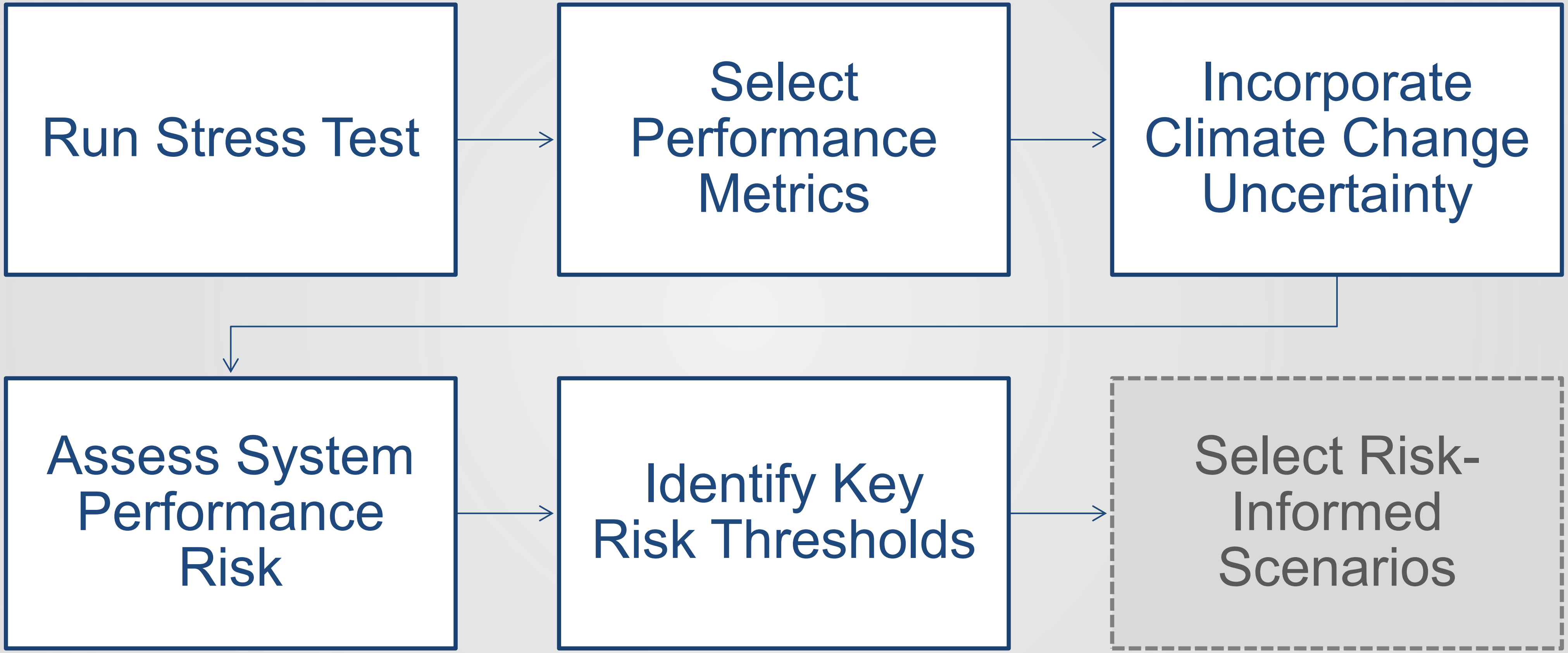
Decision Scaling Approach

Stress testing

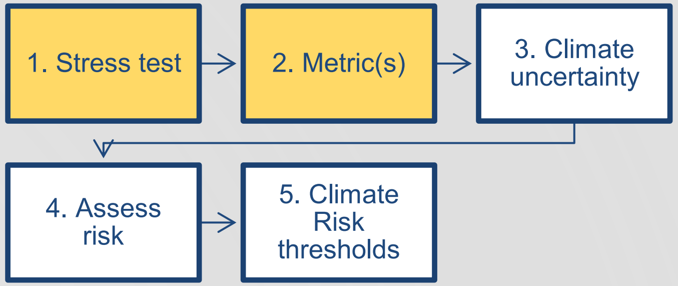
- Instead of "picking" one future or selecting a handful of models etc. …
- …**simulate the whole range, _incrementally_**
- Provides a stress (or sensitivity) test, independent of GCM model assumptions



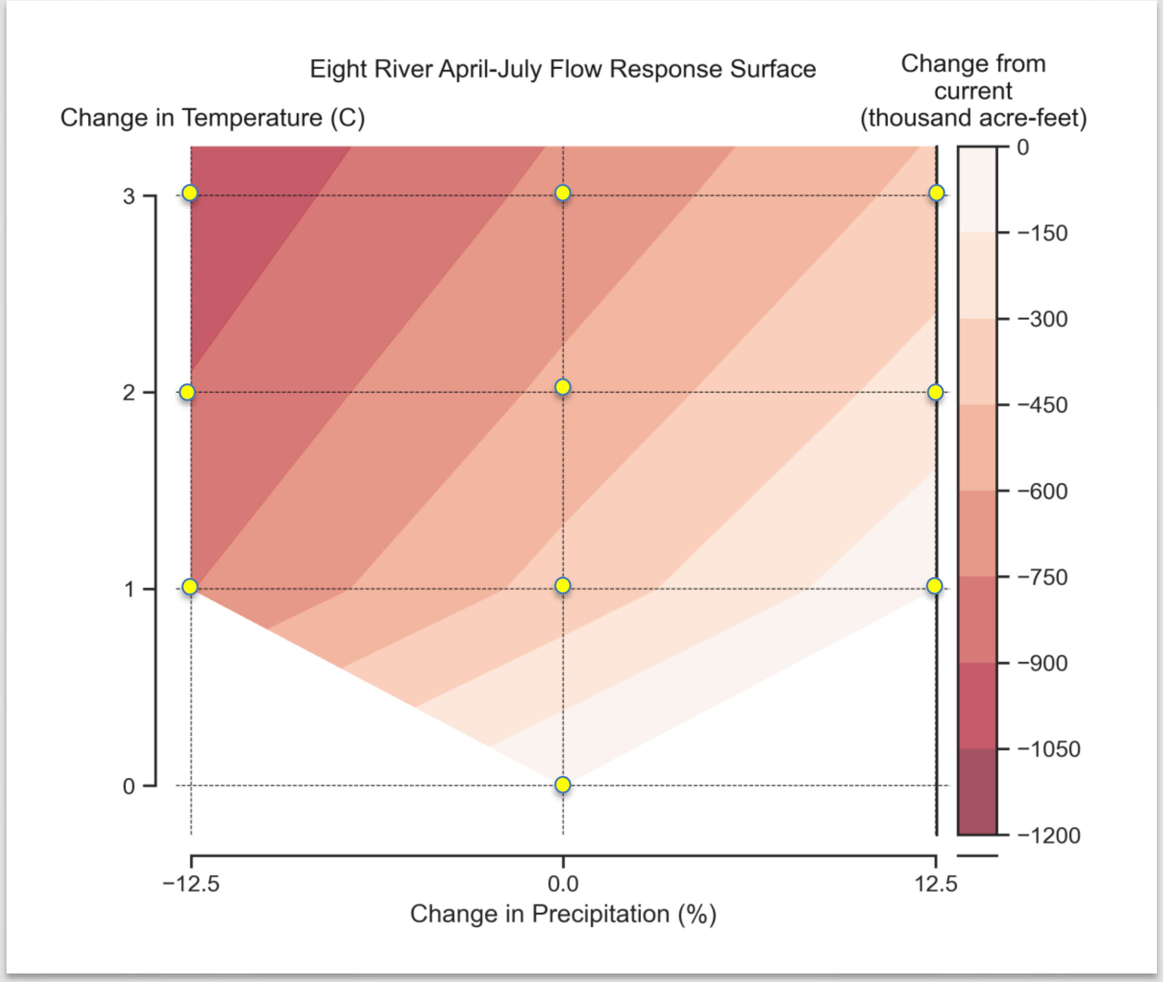
Decision Scaling Process Steps



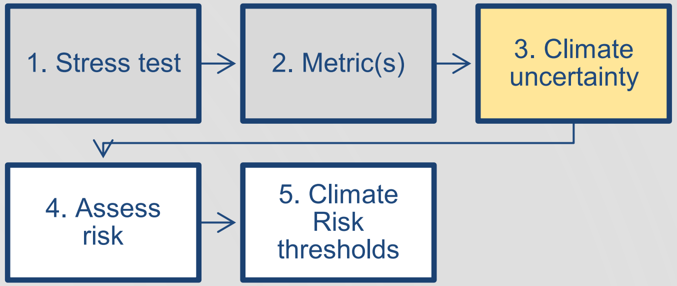
Building the Response Surface



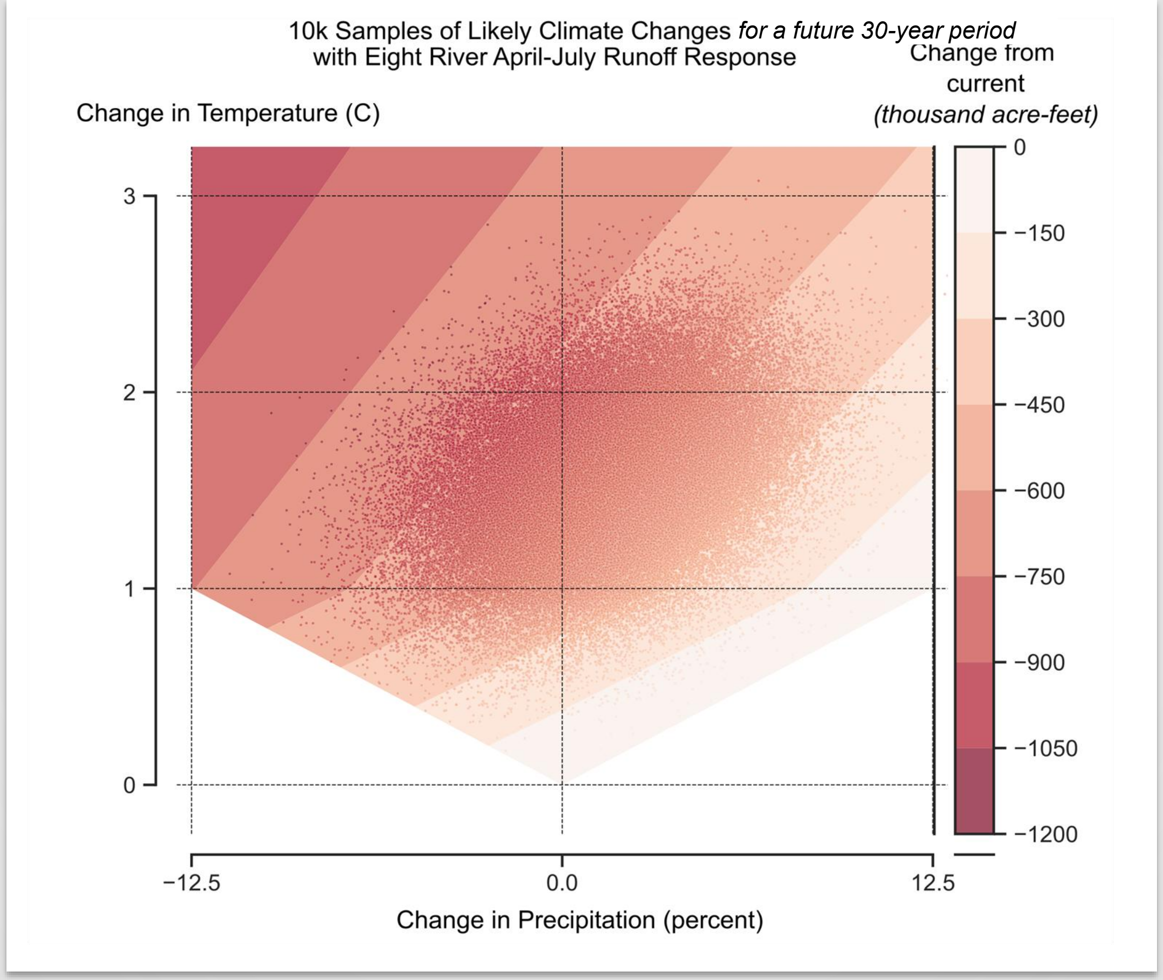
1. Simulate models for each combination of temperature and precipitation
2. Calculate indicators/metrics of performance based on the simulation time-series
3. Interpolate to create the system response surface

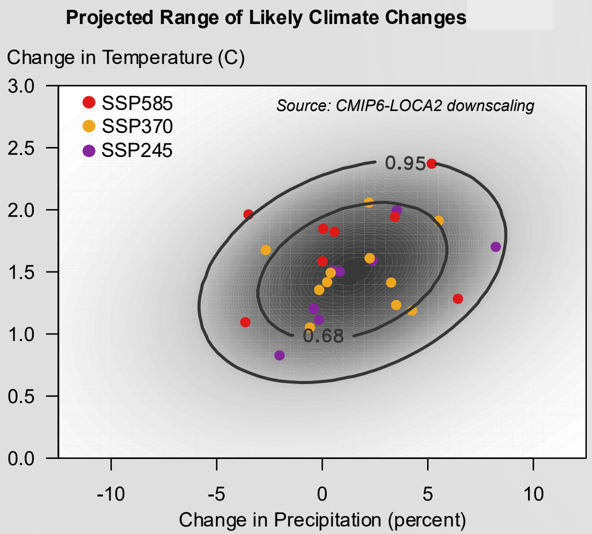


Calculating Climate Change Risk

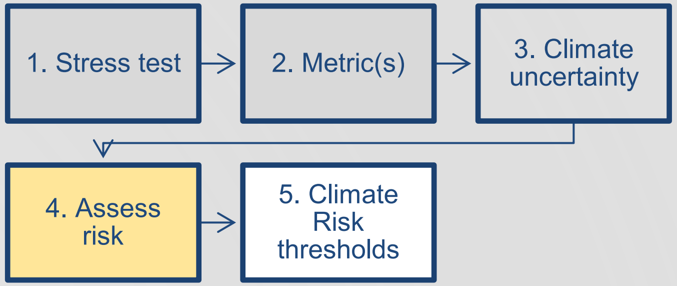


1. Sample the PDF of changes in temperature and precipitation projected by GCMs





Calculating Climate Change Risk



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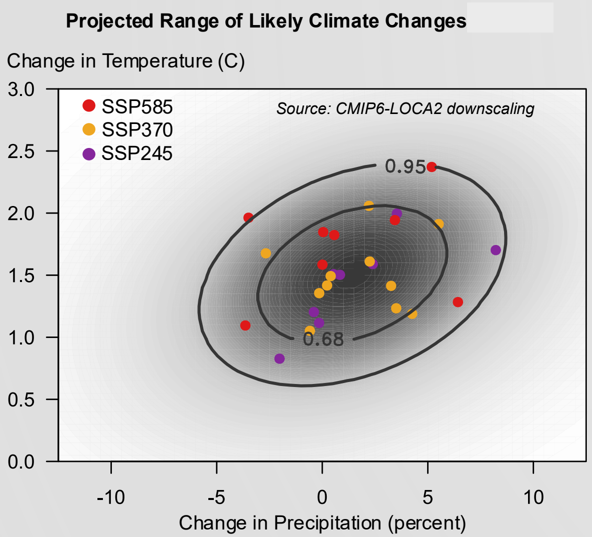
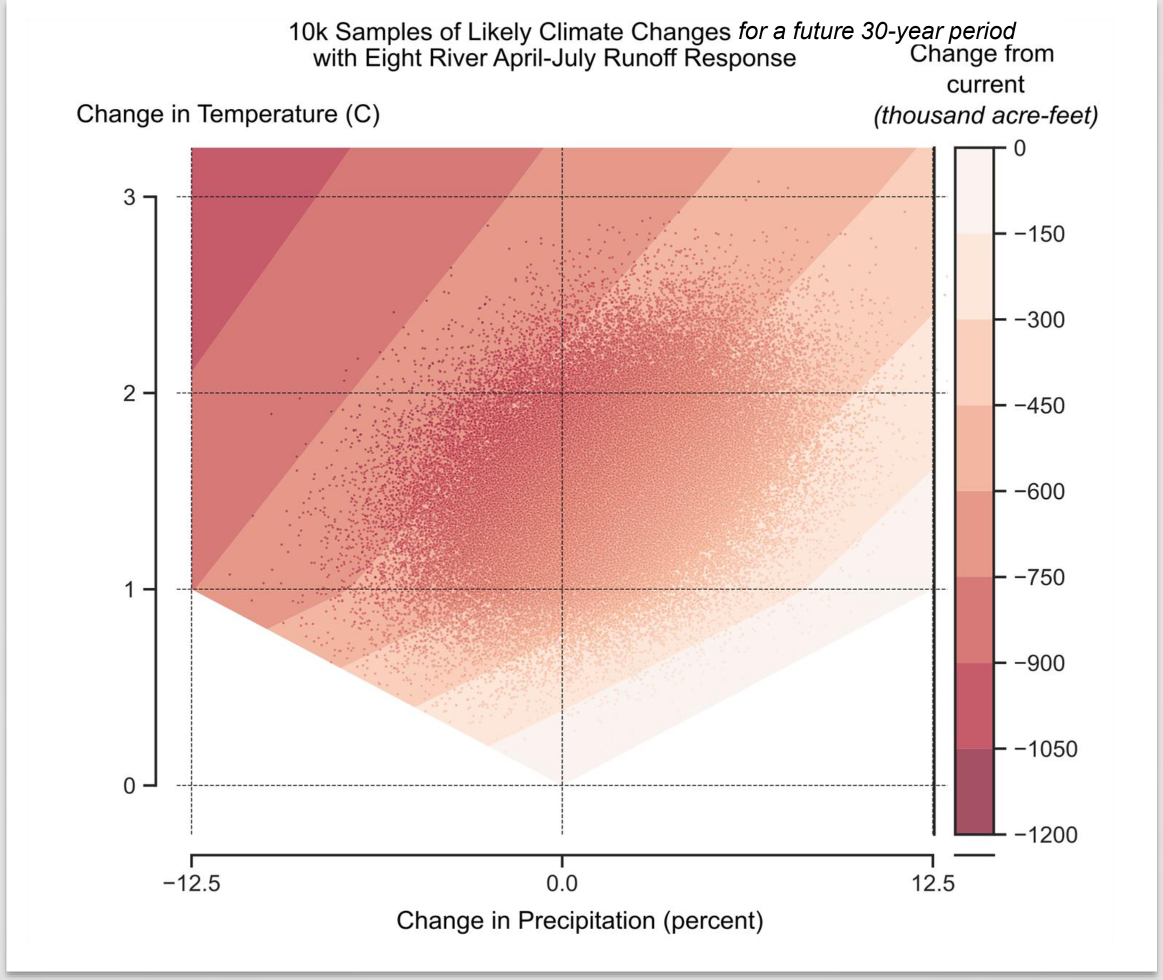
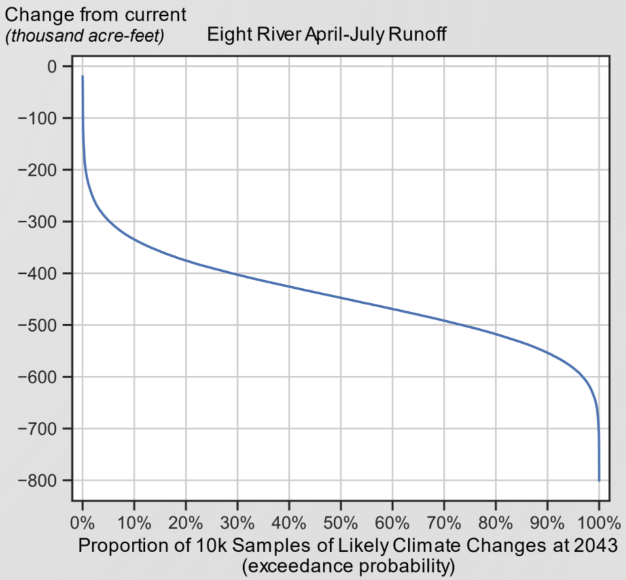




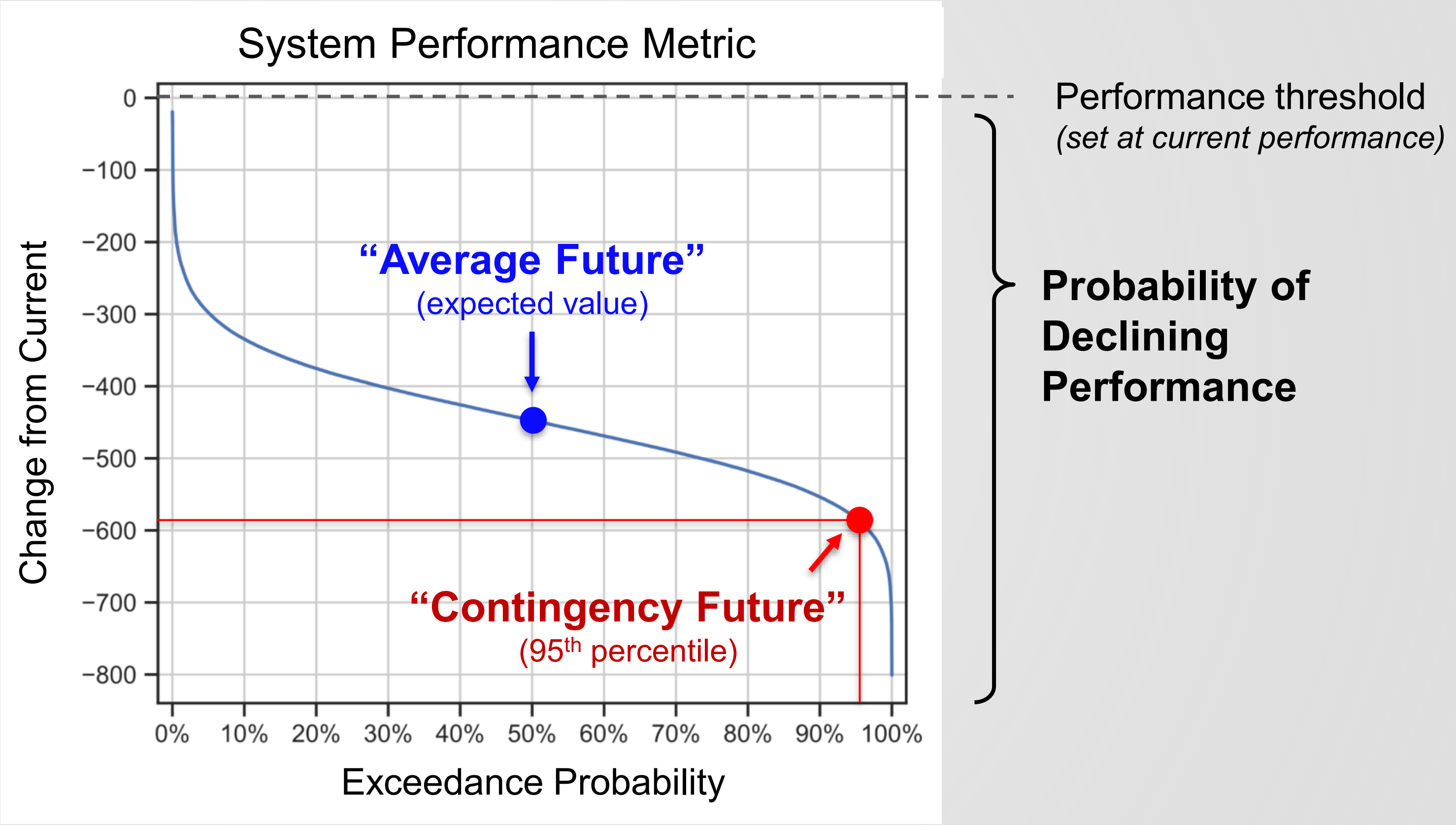
2. CDF of system performance conditioned on climate PDF



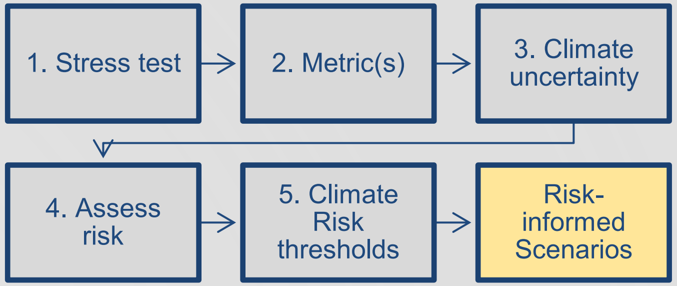
Climate Change Risk Reporting

1. Stress test → 2. Metric(s) → 3. Climate uncertainty → 4. Assess risk → **5. Climate Risk thresholds**

- What to expect
- If worse, by how much (5% chance)?
- Likelihood of being worse (by any amount)



System Risk-Informed Scenarios



Q: Great. But what if I have a really, really, complex (and awesome) system model and multiple other complex system models that depend on that complex model's output ???

A: Risk-informed scenarios, a.k.a. "Level of Concern" (LOC)

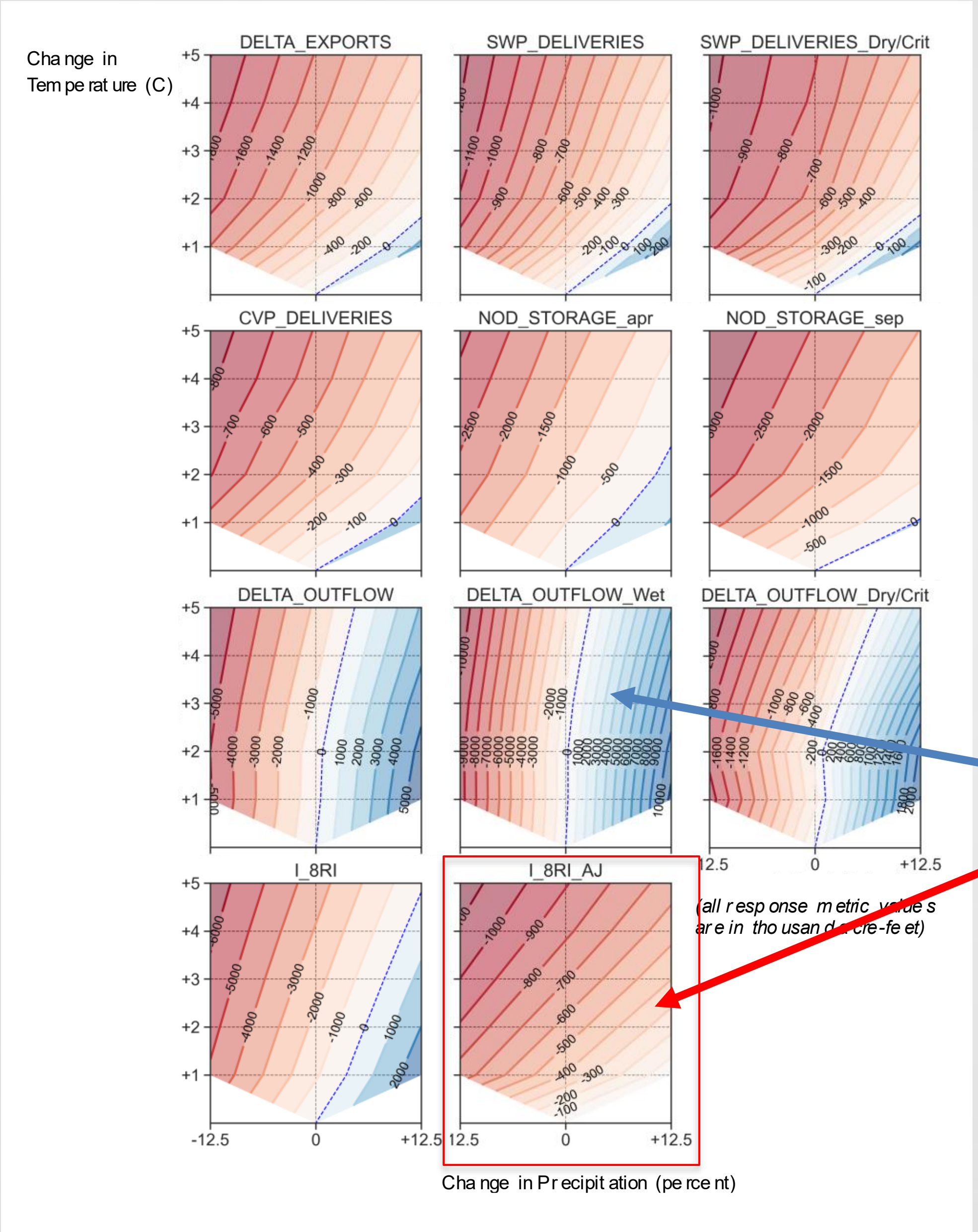
System Risk-Informed Scenarios

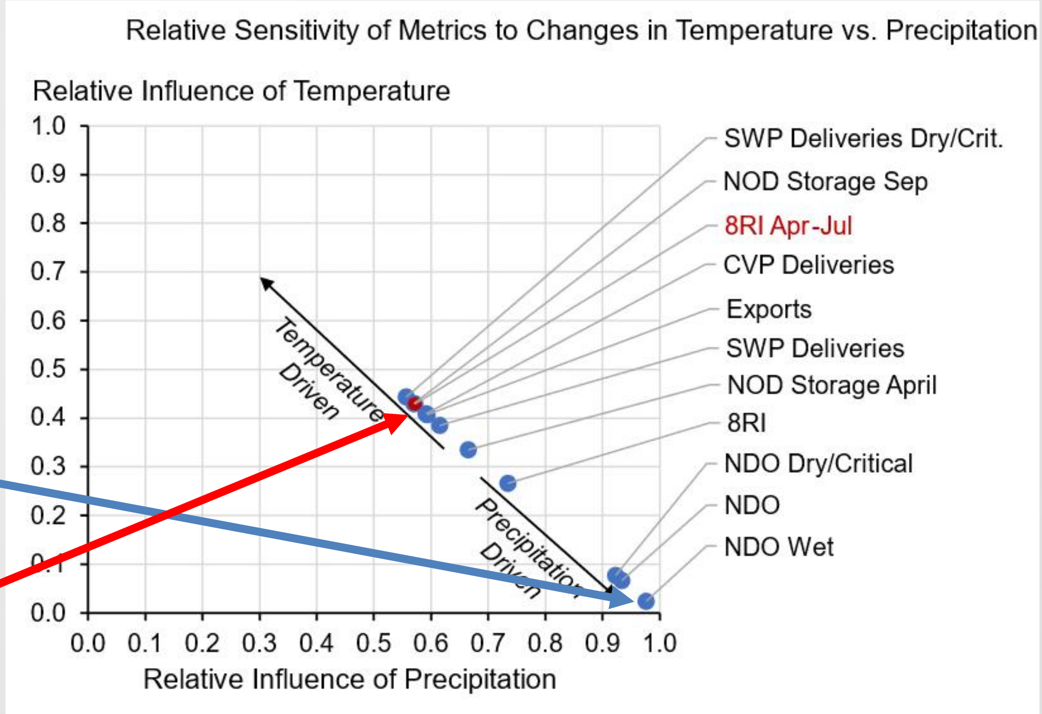
1. Stress test → 2. Metric(s) → 3. Climate uncertainty → 4. Assess risk → 5. Climate Risk thresholds → Risk-informed Scenarios

Part 1:

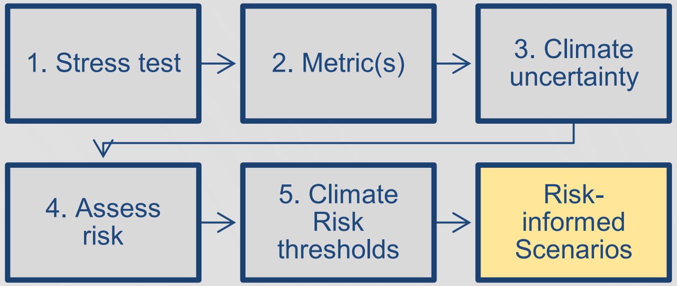
Use your ***screening model to:***

1. Select a key metric that reflects systemwide risk





System Risk-Informed Scenarios

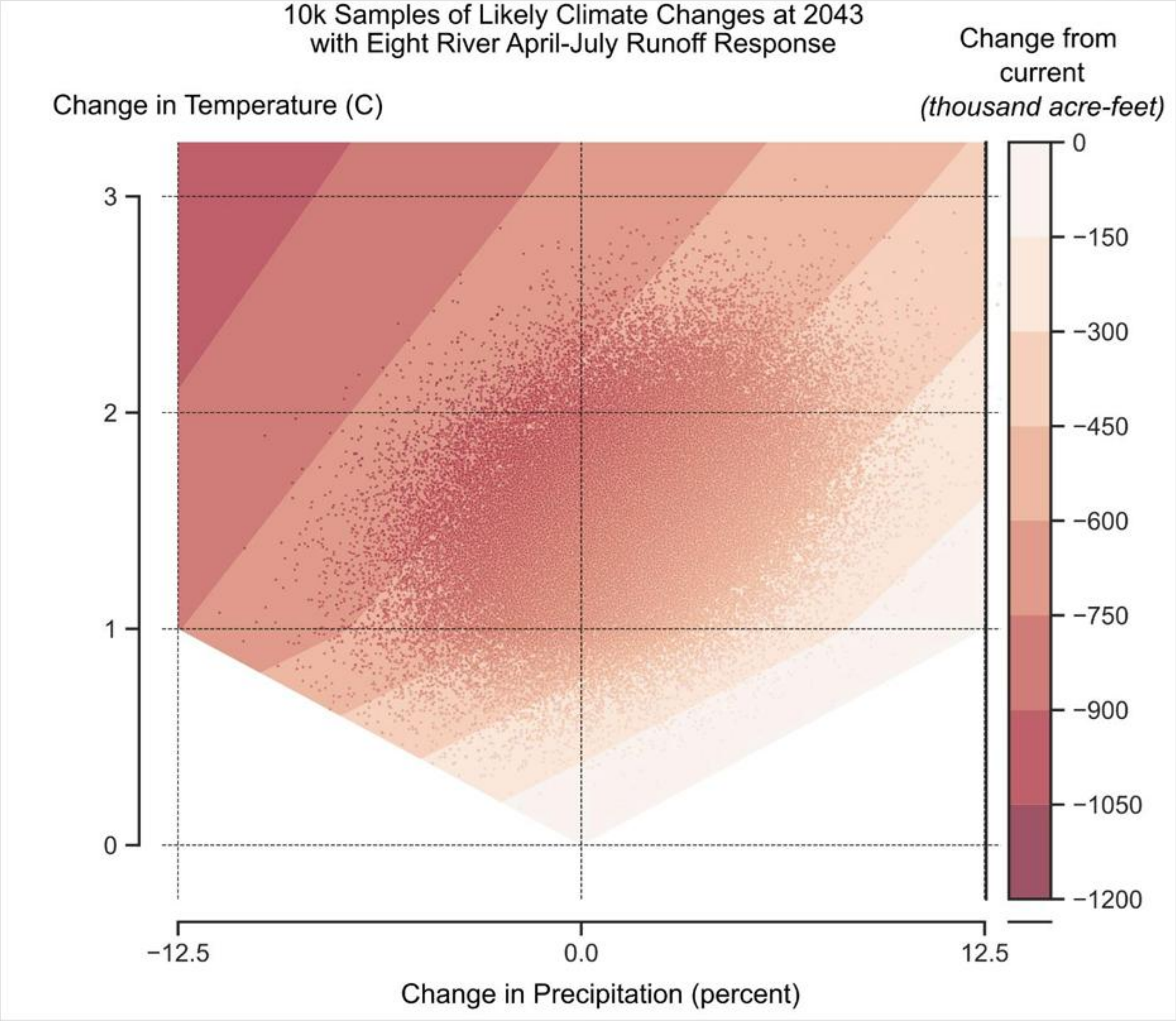


Part 1:

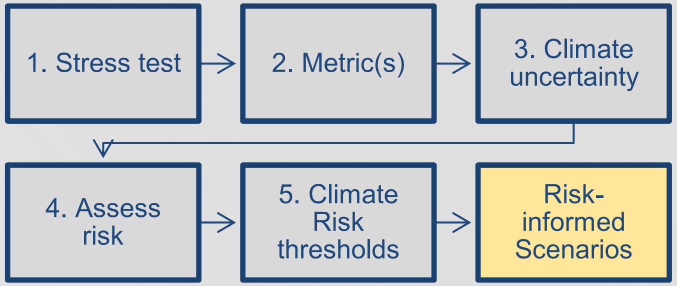
Use your *screening model to:*

1. Select a key metric that reflects systemwide risk

2. Response surface with climate PDF

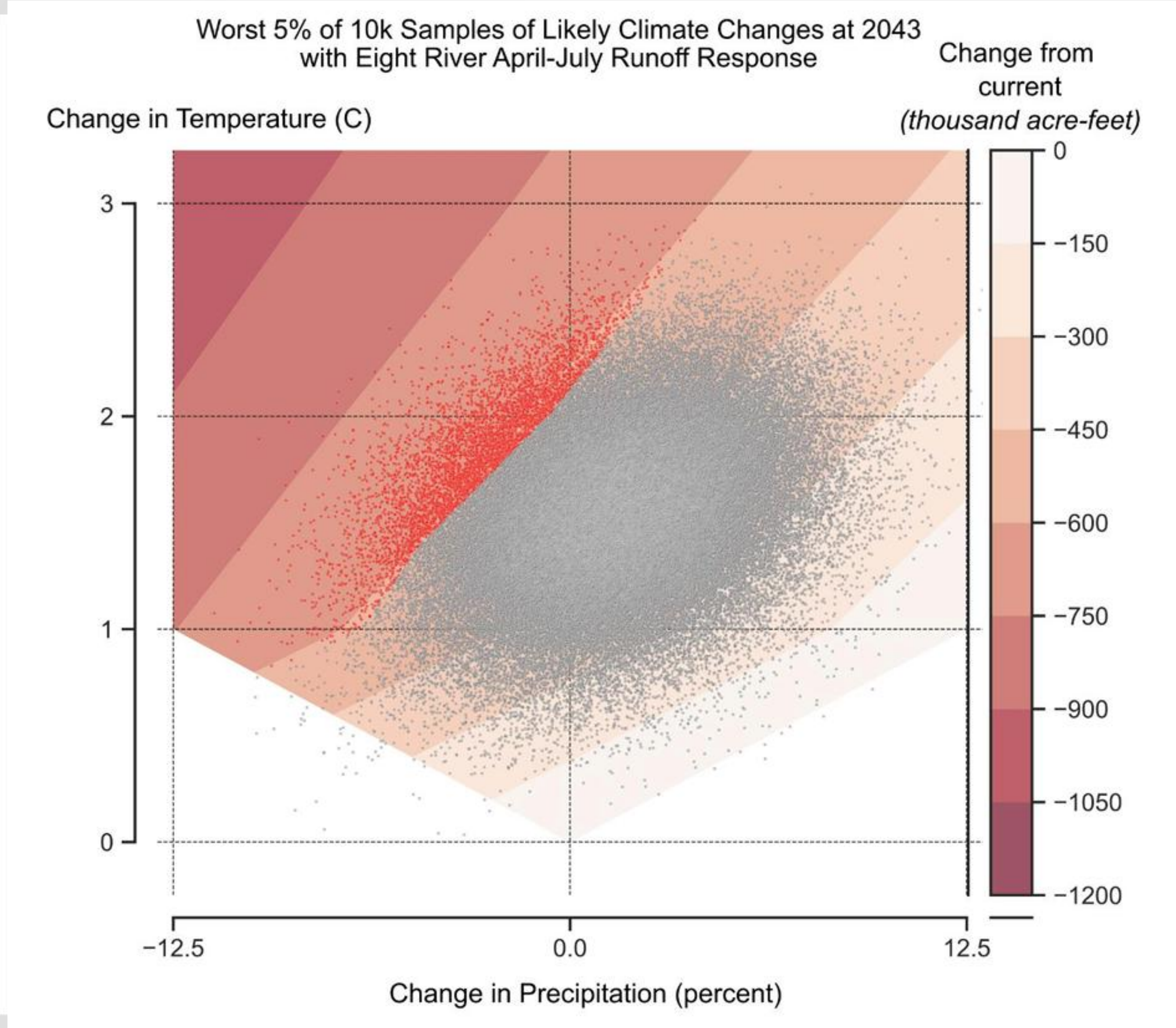


System Risk-Informed Scenarios



Part 1:
Use your *screening model to:*

1. Select a key metric that reflects systemwide risk
2. Response surface with climate PDF
3. Isolate sampled points along the X percentile "Level of Concern"



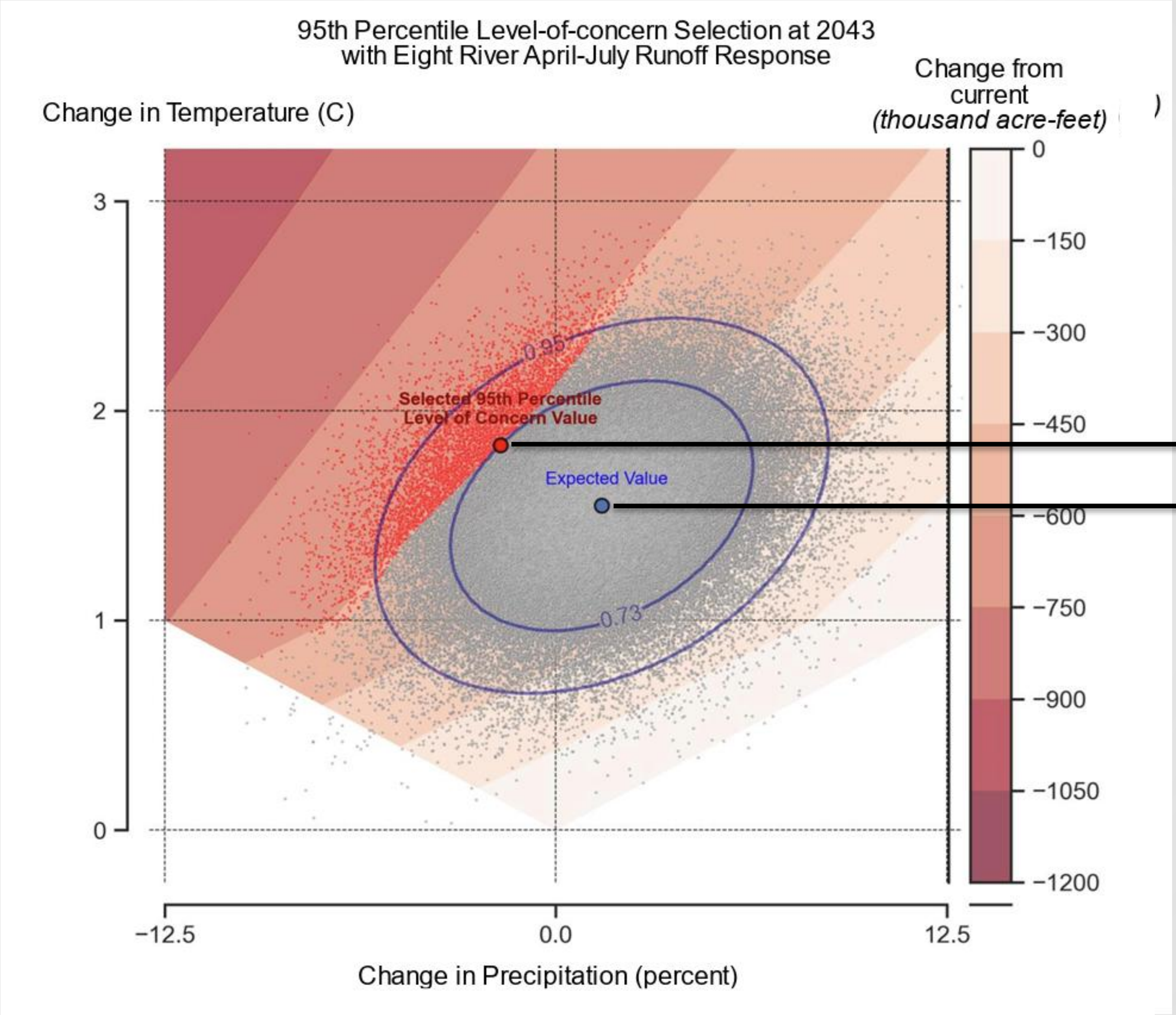
System Risk-Informed Scenarios

1. Stress test → 2. Metric(s) → 3. Climate uncertainty → 4. Assess risk → 5. Climate Risk thresholds → Risk-informed Scenarios

Part 1:

Use your *screening model to:*

1. Select a key metric that reflects systemwide risk
2. Response surface with climate PDF
3. Isolate sampled points along the X percentile “Level of Concern”
4. Select the point closest to the center of the climate PDF density



System-Risk Informed T/P Scenarios:

95th LOC: -1.8% Pr, +1.8°C

50th LOC: +1.5% Pr, +1.5°C

LOC = Level of Concern

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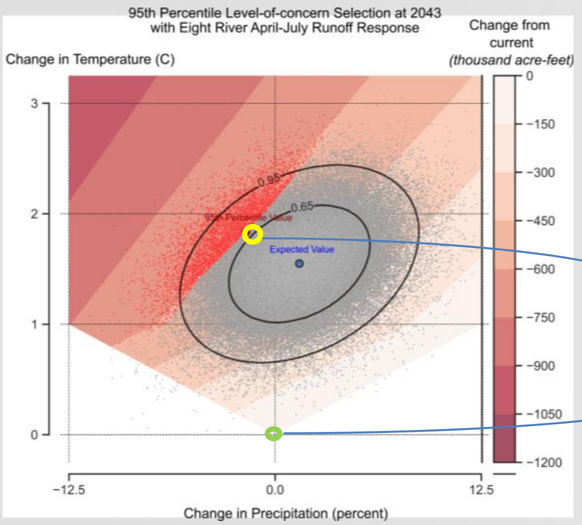
System Risk-Informed Scenarios

1. Stress test → 2. Metric(s) → 3. Climate uncertainty → 4. Assess risk → 5. Climate Risk thresholds → Risk-informed Scenarios

Part 2:

Generate the risk-based T/P scenarios with Weather Generator and input them to the detailed, complex model:



System-Risk Informed T/P Scenarios:

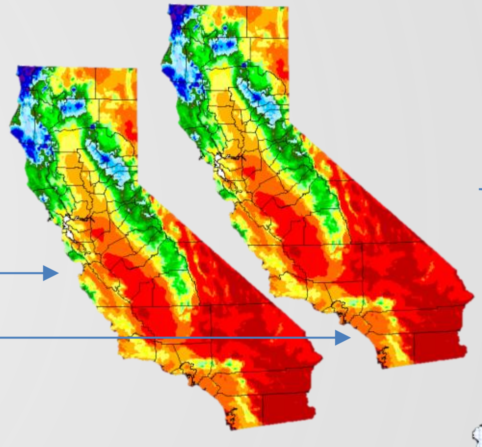
95th LOC: -1.8% Pr, +1.8°C

50th LOC: +1.5% Pr, +1.5°C

LOC = Level of Concern

Weather Generator

(Najibi and Steinschneider, 2023)



Hydrologic Model

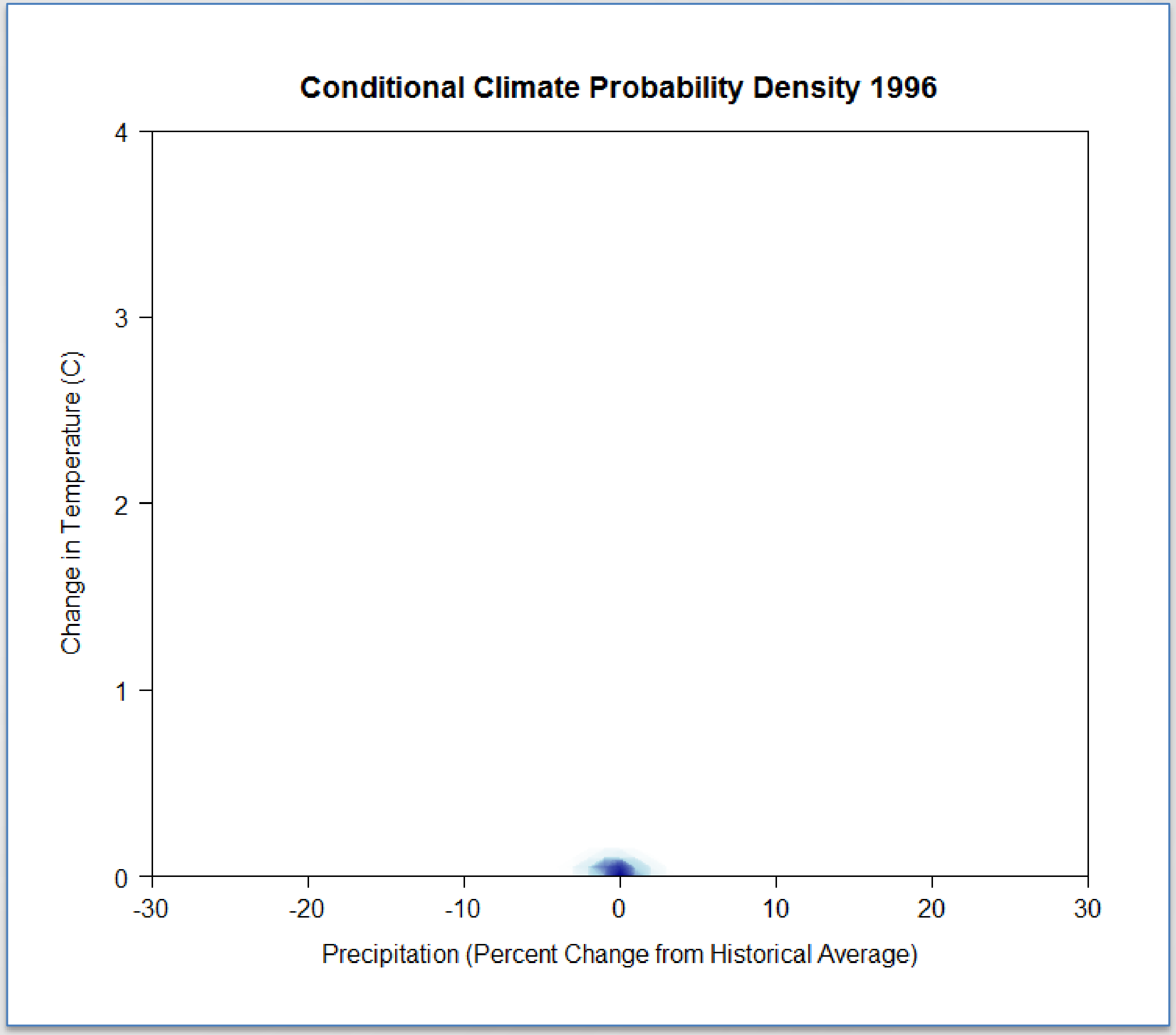
Adjust inputs to CalSim3

CalSim3 Climate Scenario Runs/Operational Adjustments and Refinements

Application 1:
Water Plan Update 2023

Decision Scaling

- A stress test under the *full* range of *relevant* and *credible* changes
- Estimate risk conditional on climate projection-based evidence



How to apply decision Scaling

1. Select an appropriate model
2. Identify a representative hydrology
3. Simulate conditions and extract model results
4. Plot model results for metrics on response surface
5. Apply GCM projections to response surface to develop probability of occurrence
6. Sum probabilities of occurrence to develop CDFs for risk-based assessments
7. Identify a risk threshold and assess adaptations to meet that threshold

Example models for decision scaling analysis

1. **WEAP**

   Simulates physically based interactions through a simplified model allowing for very low run times

2. **CalLite**

   Simplified version of Calsim very effective for anything depending on SWP or CVP deliveries

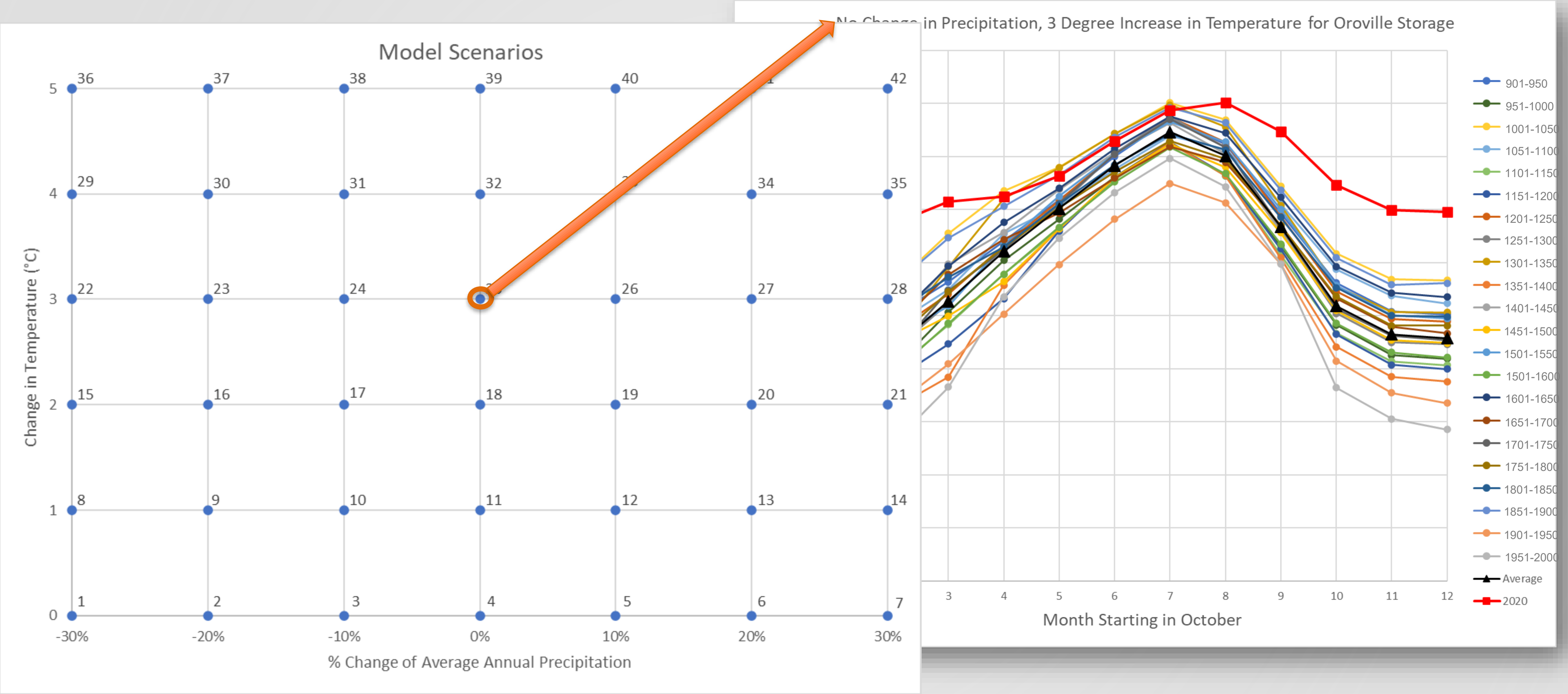
3. **Other models with shorter run times**

   Theoretically, any model with enough cloud computing could run fast enough to do decision scaling, just be aware of when cost of cloud computing exceeds benefit of the more detailed modeling

Identify a representative hydrology

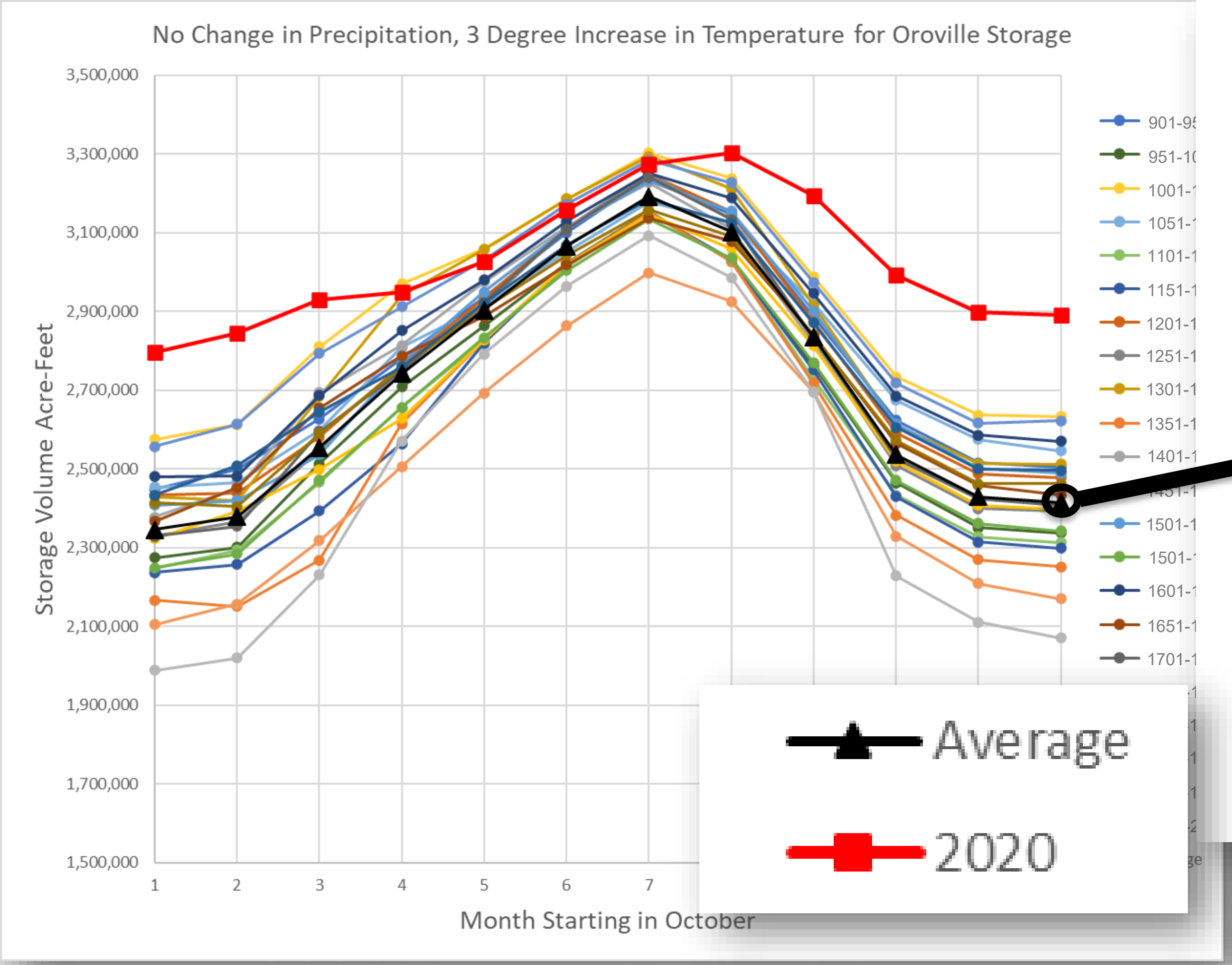
1. Gridded Weather Generator Perturbations of Historical Detrended and Stochastically Generated Temperature and Precipitation for the State of CA and HUC8s
2. Paleo-Dendrochronological "Tree-Ring" Hydroclimatic Reconstructions for Northern and Southern California River Basins
3. Other datasets as available that capture possible future conditions

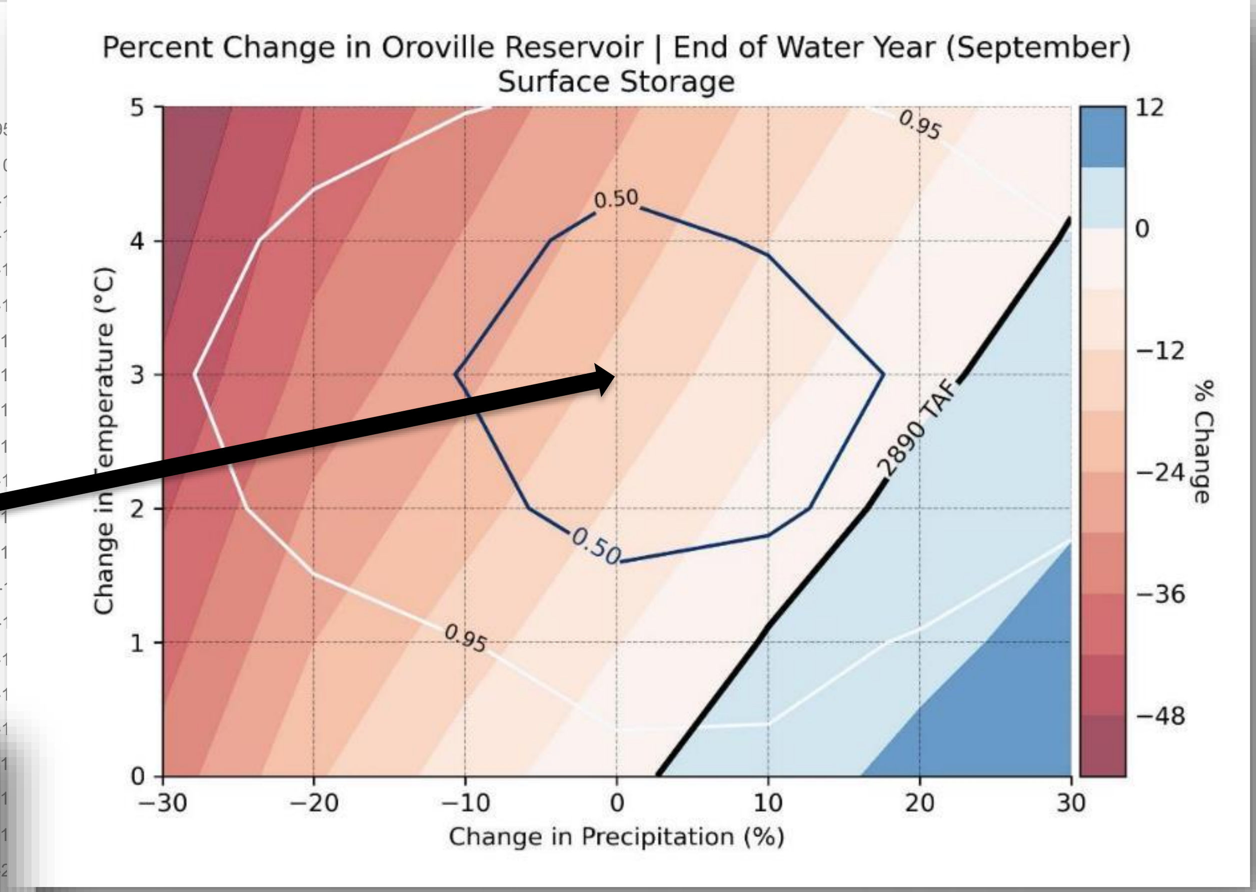
Simulate conditions and extract model results



Each run represents 50 years where the only change is the long-term climate variability. Average results are then developed from the runs. Model was reset every 50-years to mitigate any effects of long term draw down.

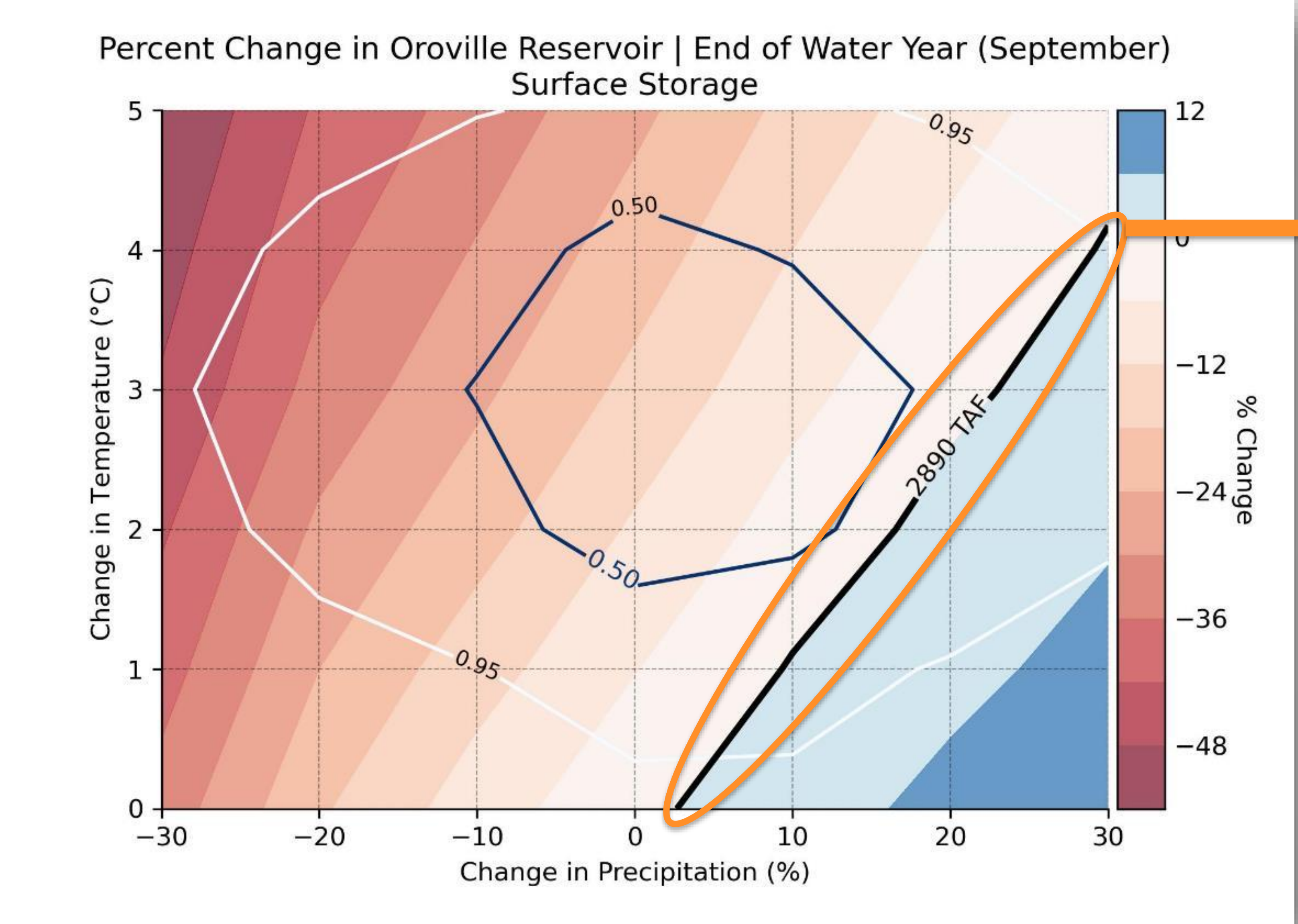
Plot model results for metrics on response surface





APPLY GCM PROJECTIONS TO RESPONSE SURFACE TO DEVELOP PROBABILITY OF OCCURRENCE

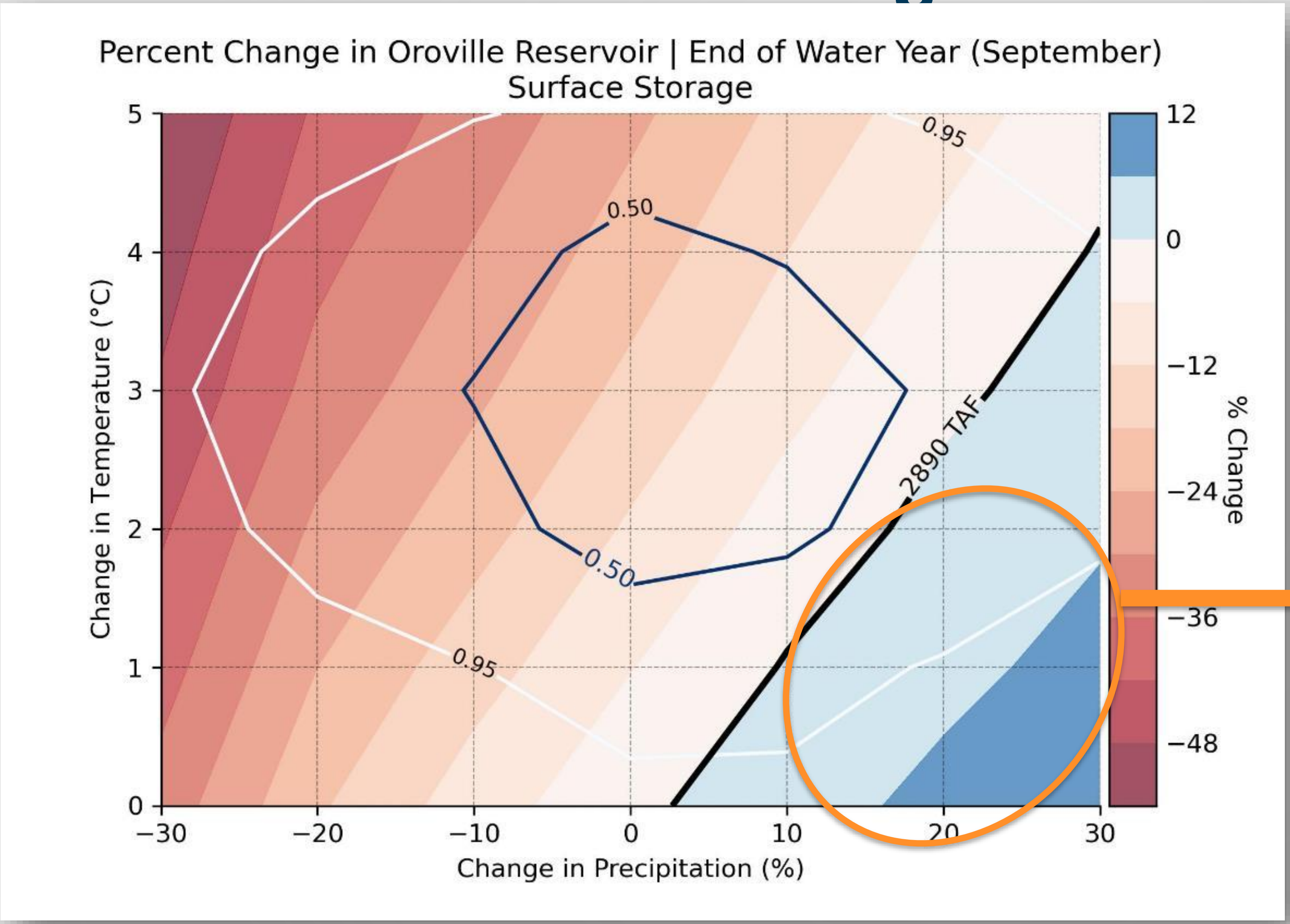
Metric 1 Surface Storage – Oroville



The black line represents the combination of climate conditions that would result in performance similar to existing conditions. For this study, existing conditions is the target performance threshold.

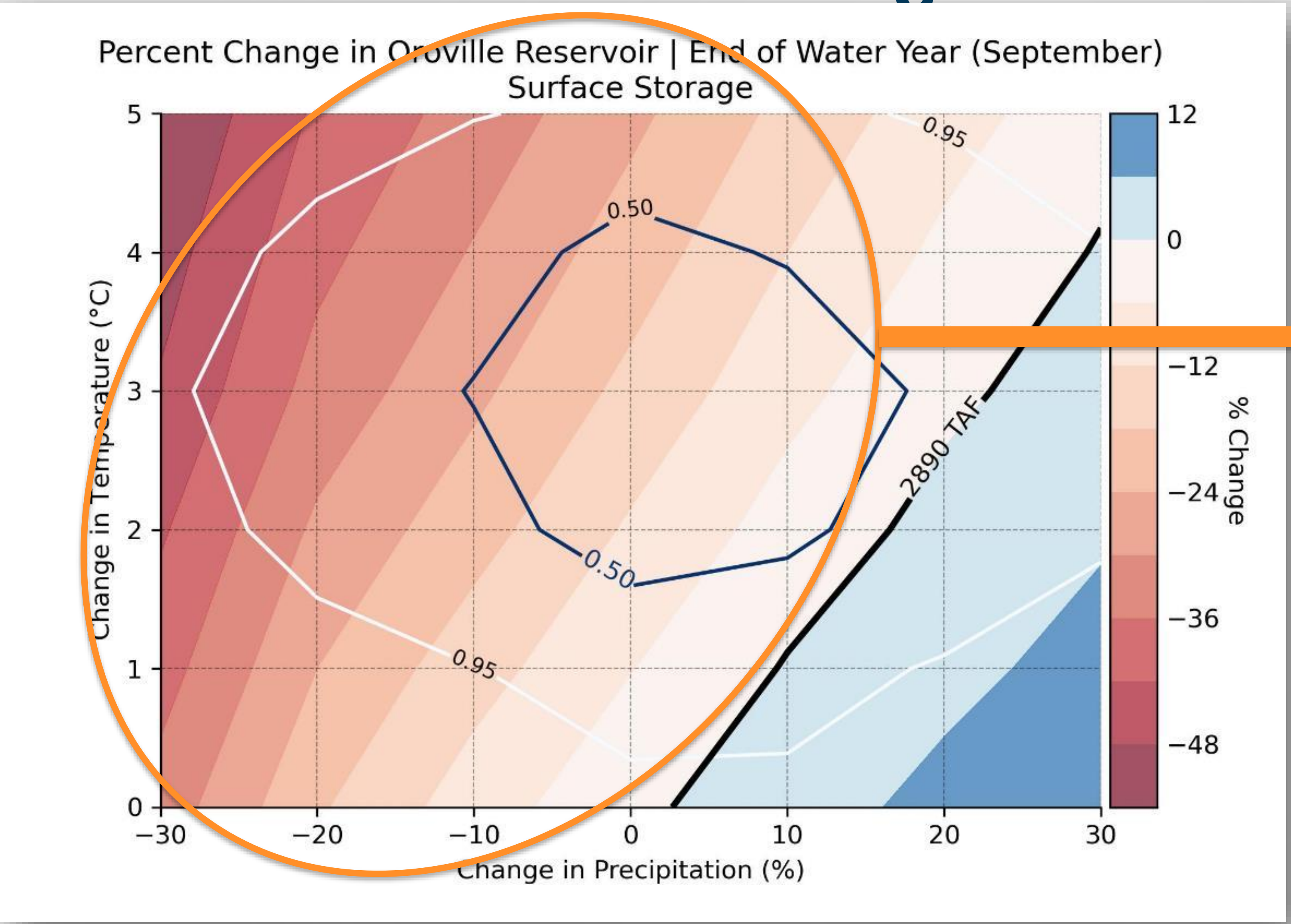
Color bars represent lines of consistent performance.

Metric 1 Surface Storage – Oroville



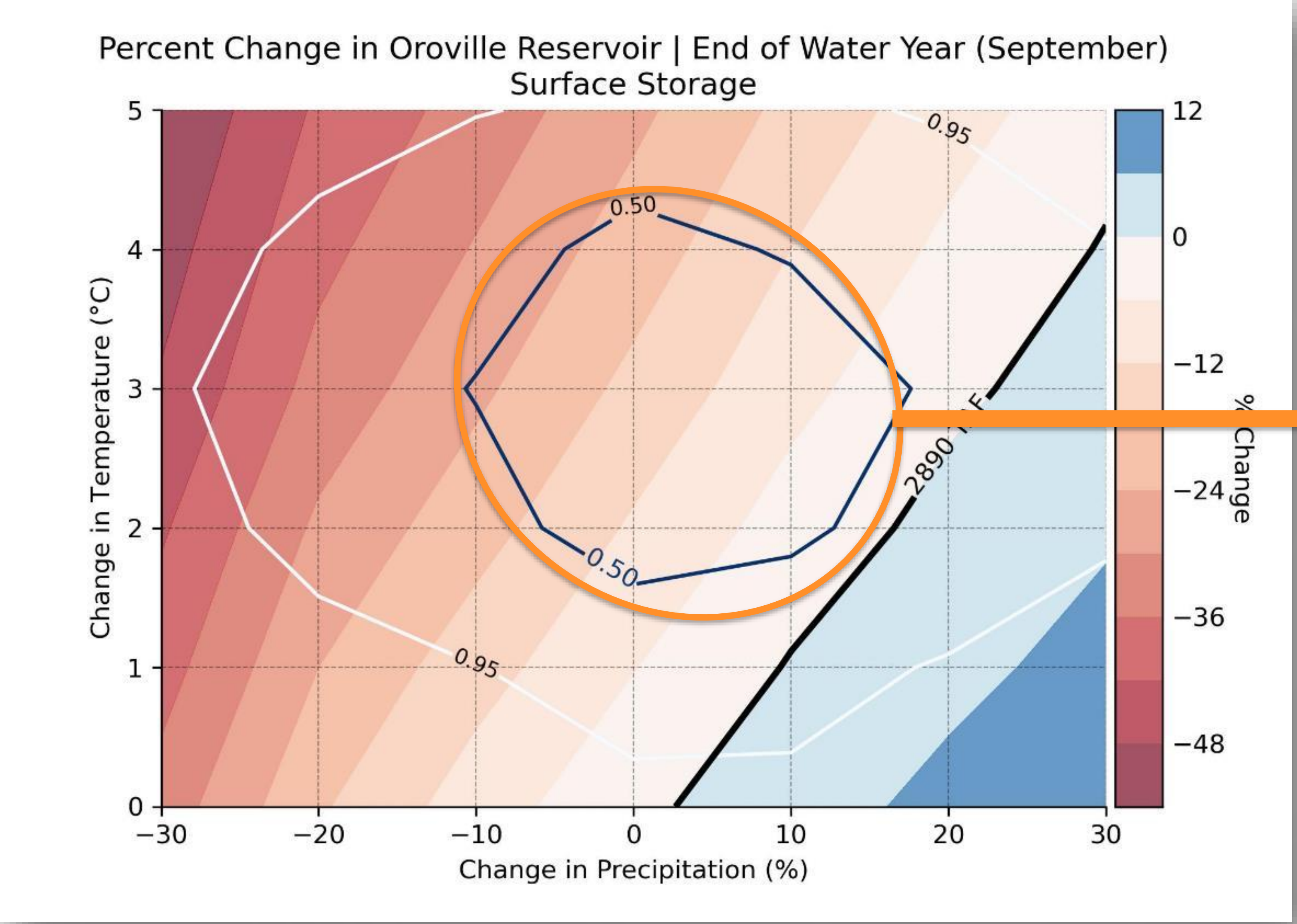
Blue areas indicate improved system performance

Metric 1 Surface Storage – Oroville



Red areas indicate areas of decreased performance.

Metric 1 Surface Storage – Oroville

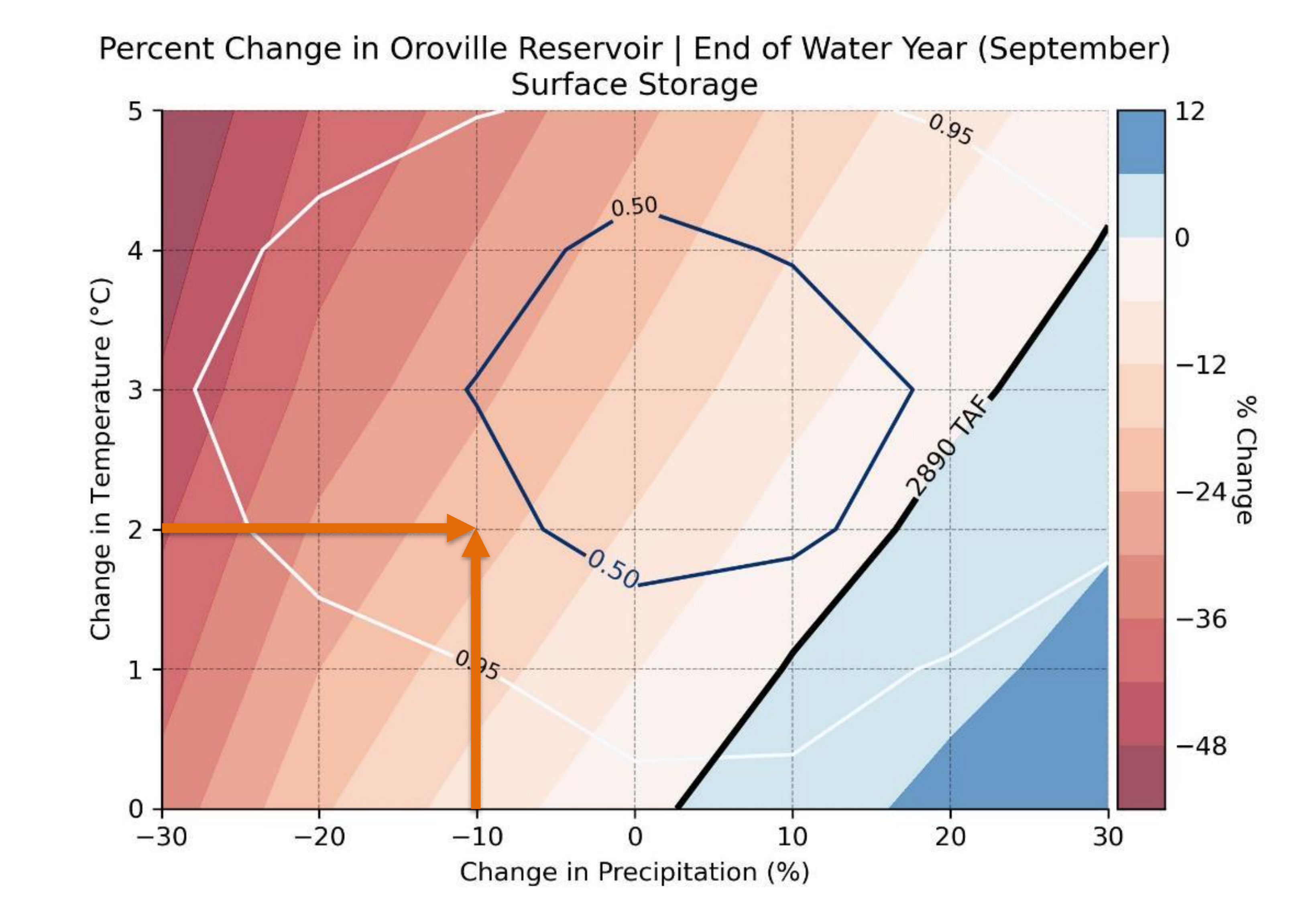


The contours represent the probability of occurrence based on GCM projections.

The center of the circle is the central tendency or expected value.

Areas further out are plausible but less and less likely the further from the center.

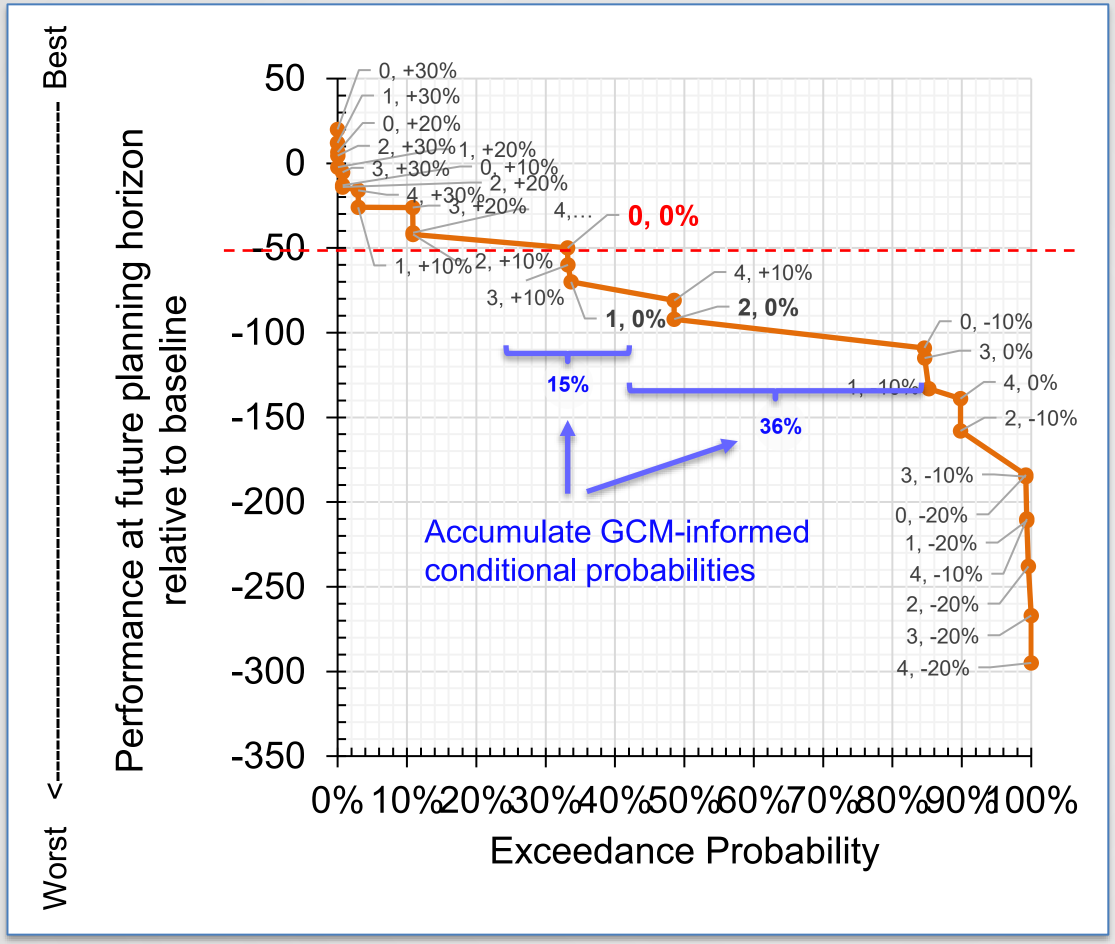
Metric 1 Surface Storage – Oroville



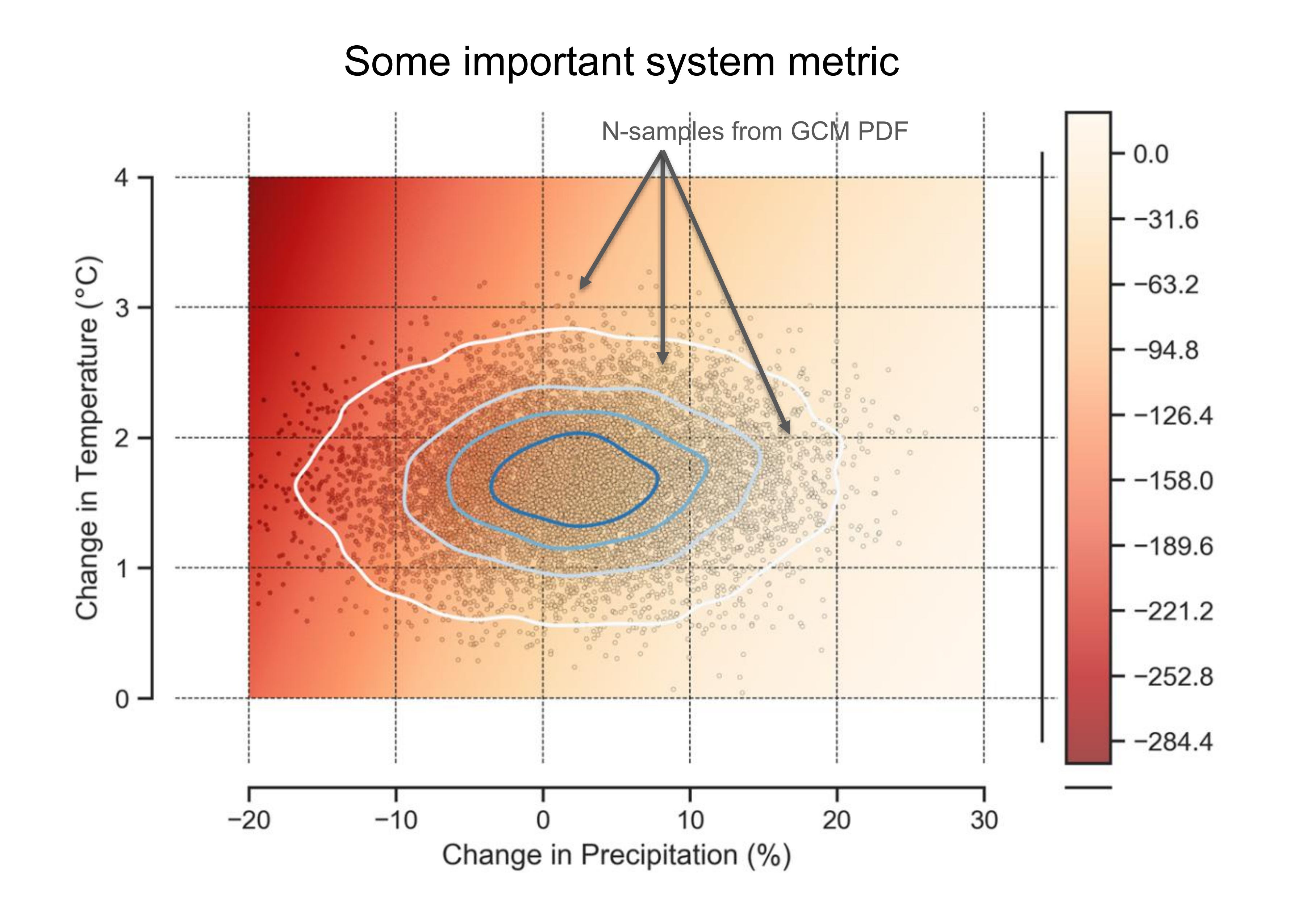
Response surfaces can be used to look at any combination of temperature and precipitation you are interested in regardless of probability of occurrence.

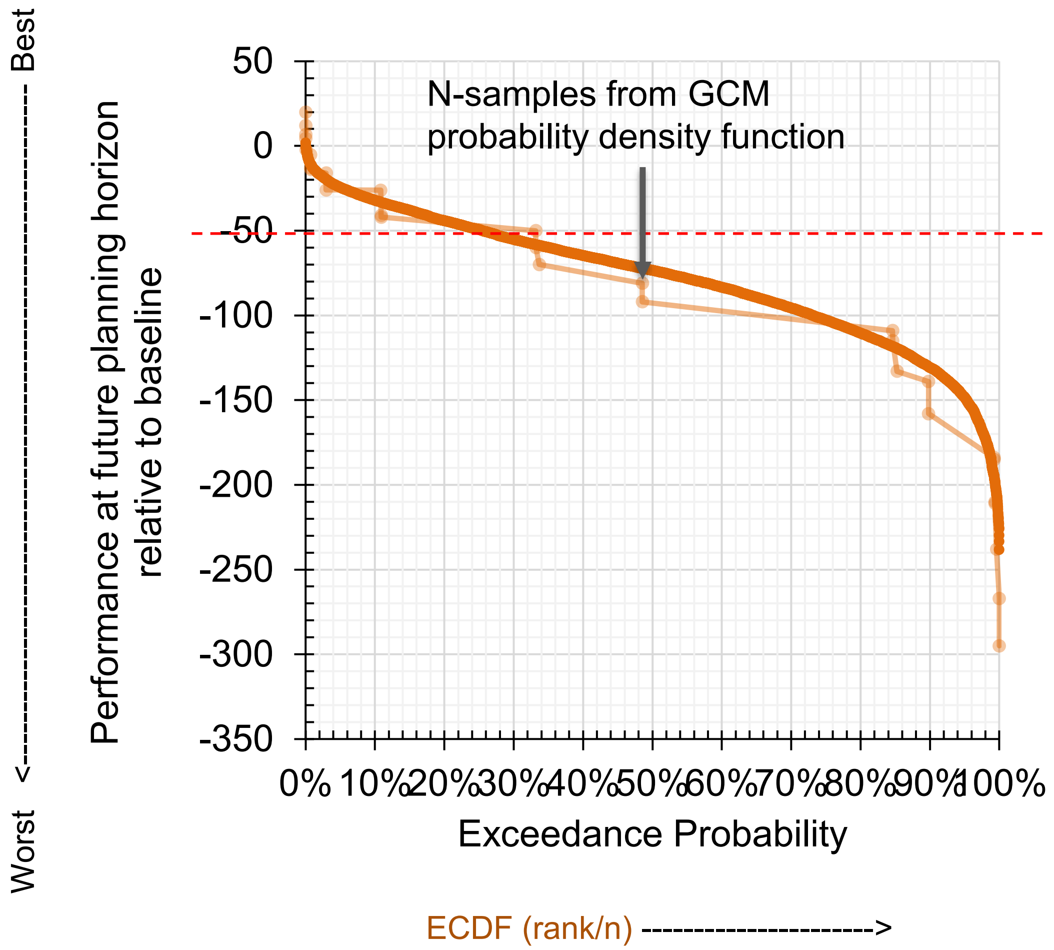
Response surfaces themselves are based on system parameters and are independent of the GCM probabilities.

SUM PROBABILITIES OF OCCURRENCE TO DEVELOP CDFS FOR RISK-BASED ASSESSMENTS



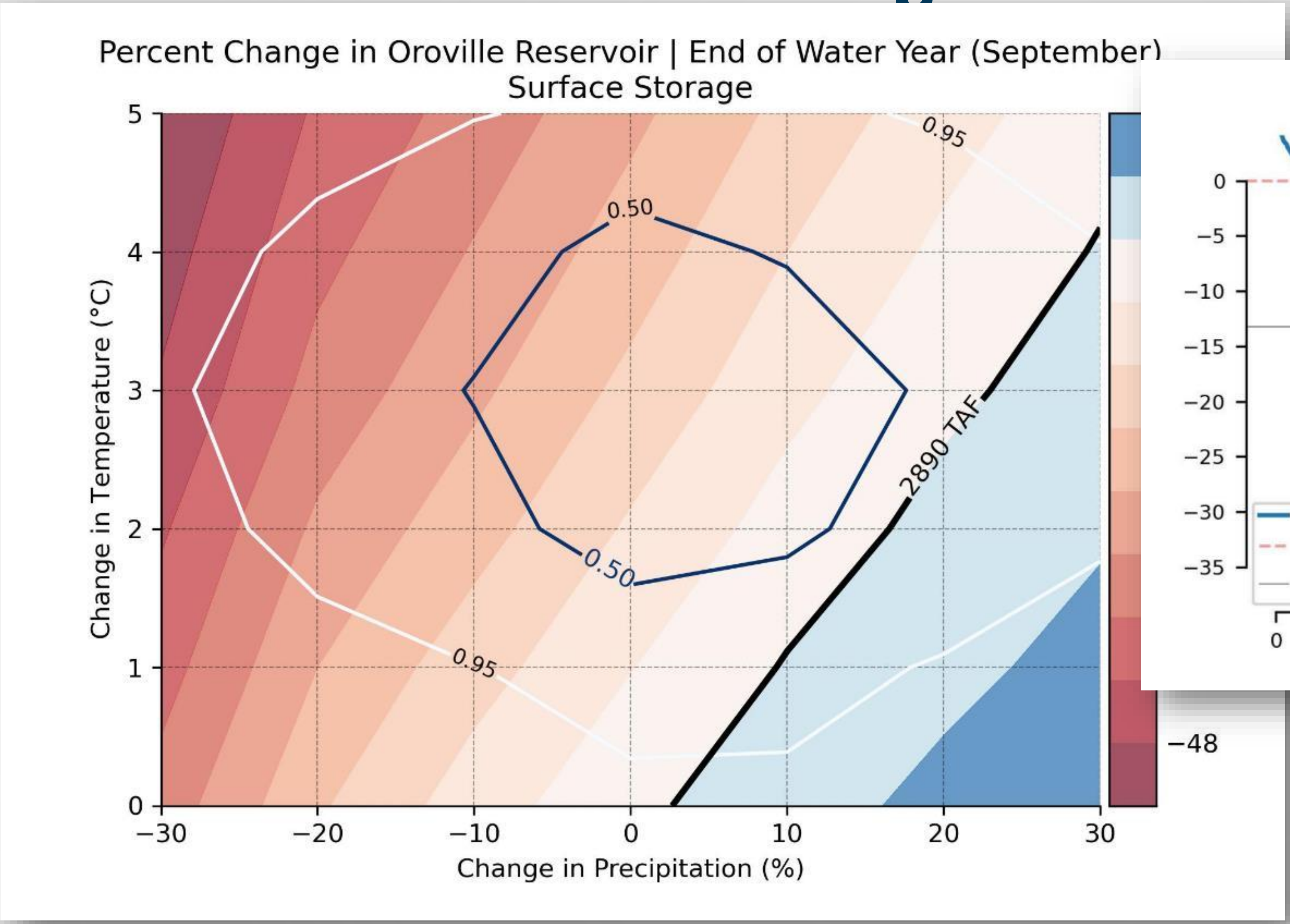
Best
Worst
Performance at future planning horizon relative to baseline
Exceedance Probability
0, 0%
1, 0%
2, 0%
3, 0%
4, 0%
15%
36%
Accumulate GCM-informed conditional probabilities

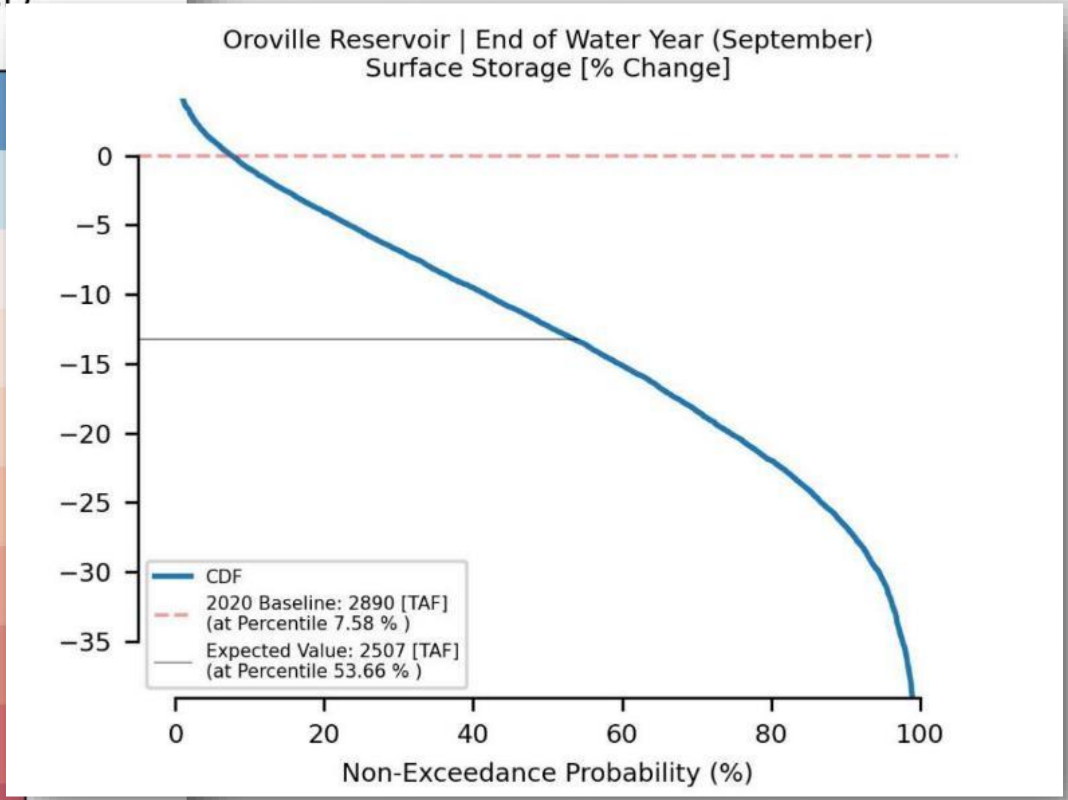

Some important system metric
N-samples from GCM PDF
Change in Temperature (°C)
Change in Precipitation (%)
0
1
2
3
4
−20
−10
0
10
20
30
0.0
−31.6
−63.2
−94.8
−126.4
−158.0
−189.6
−221.2
−252.8
−284.4



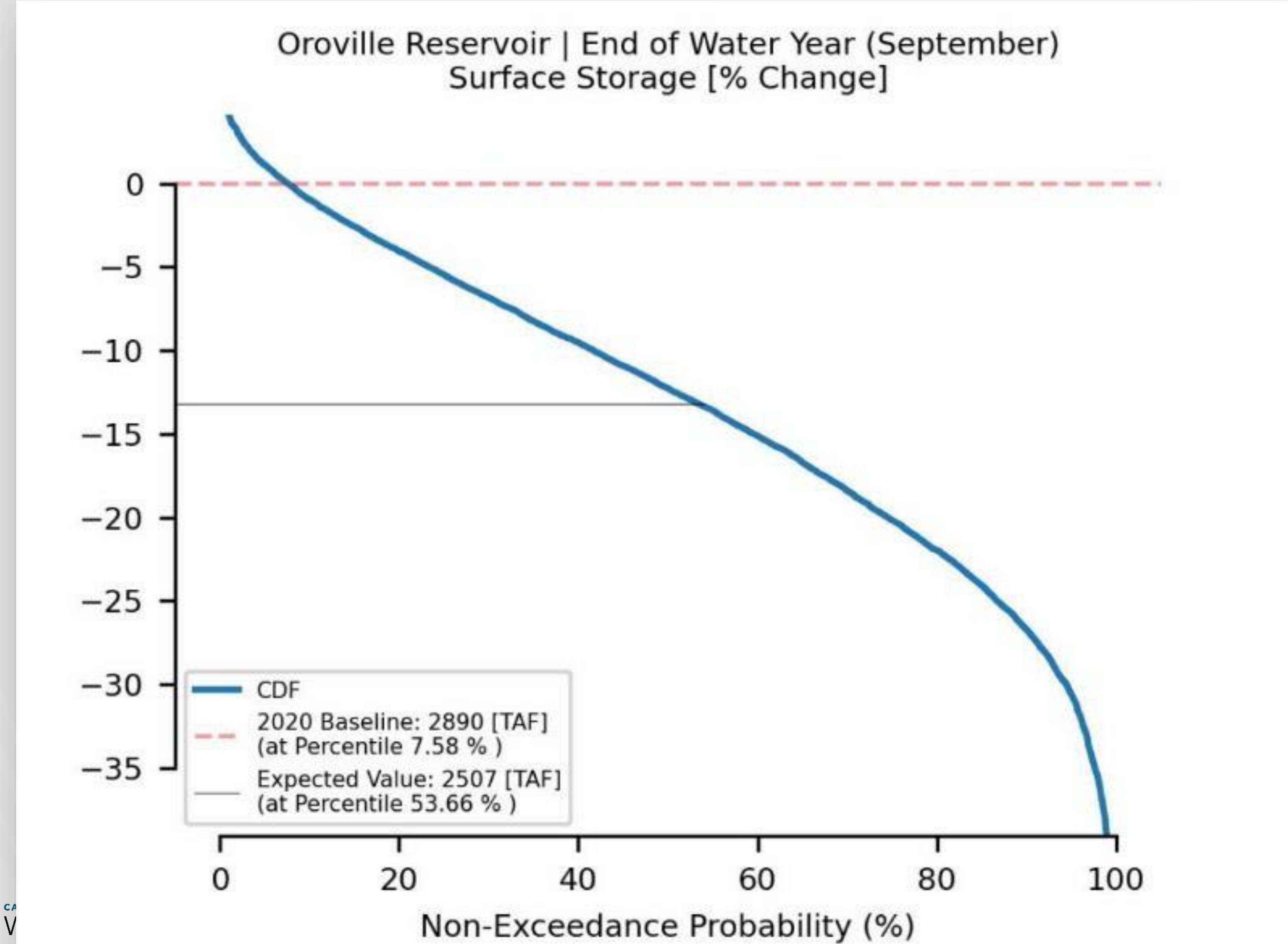
Best
Worst
Performance at future planning horizon relative to baseline
50
0
-50
-100
-150
-200
-250
-300
-350
N-samples from GCM probability density function
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Exceedance Probability
ECDF (rank/n) ---------------------->

Metric 1 Surface Storage – Oroville



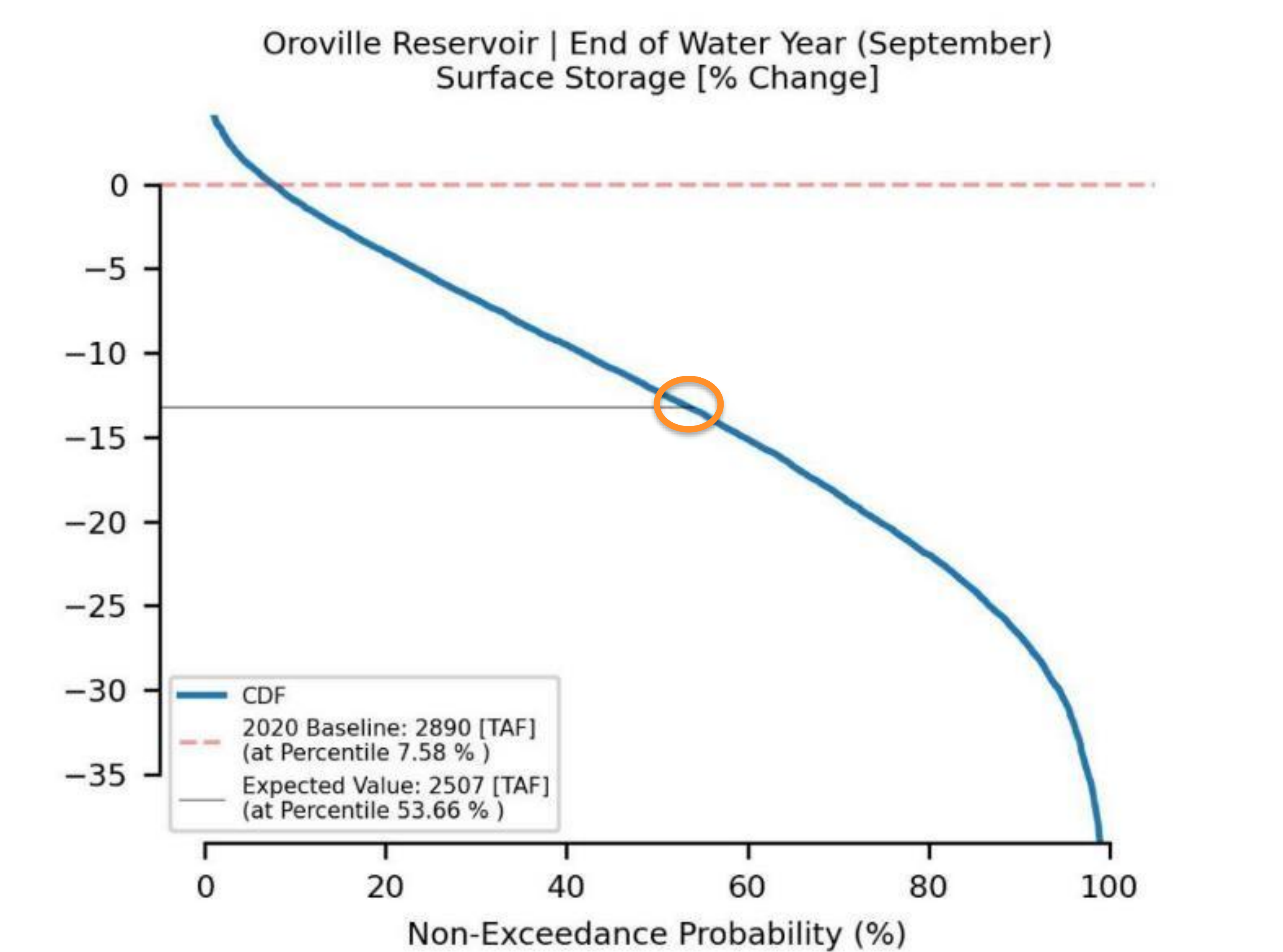


Metric 1 Surface Storage – Oroville



CDFs provide a probabilistic framework for the outcomes.

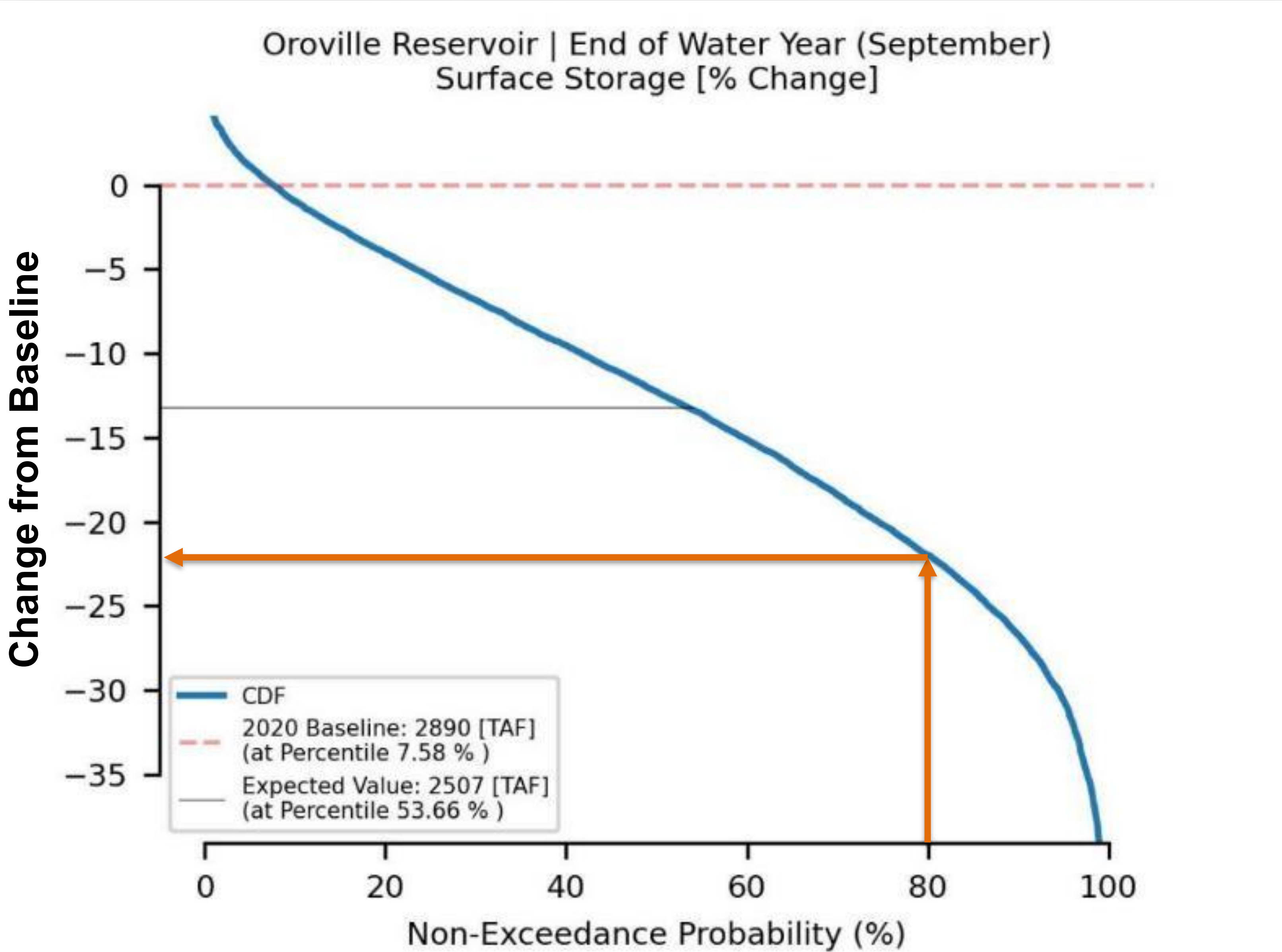
Metric 1 Surface Storage – Oroville



CDFs provide a probabilistic framework for the outcomes. These let you identify most likely conditions …

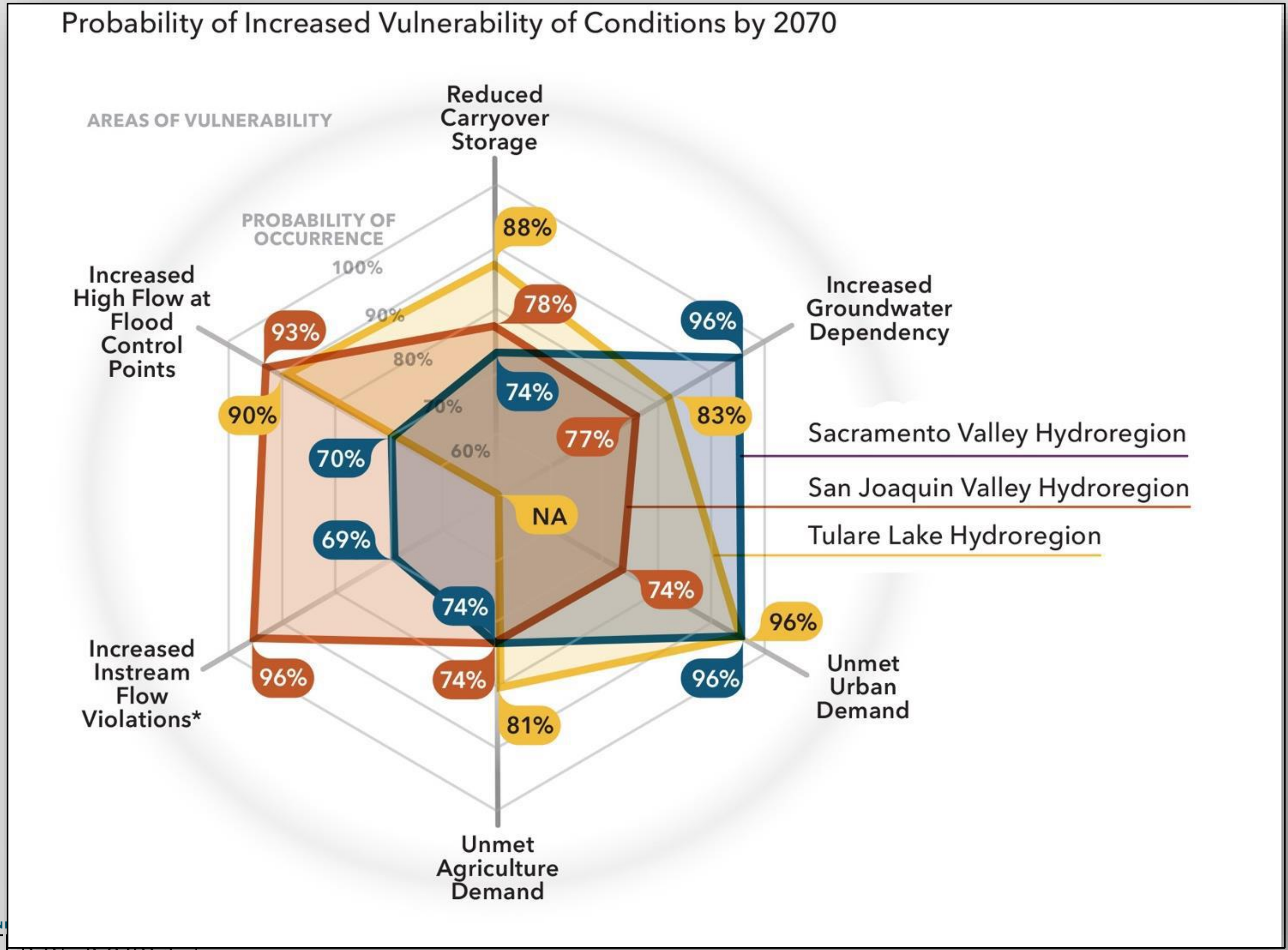
IDENTIFY A RISK THRESHOLD AND ASSESS ADAPTATIONS TO MEET THAT THRESHOLD

Metric 1 Surface Storage – Oroville



CDFs provide a probabilistic framework for the outcomes. These let you identify most likely conditions but they also let you set your own risk thresholds.

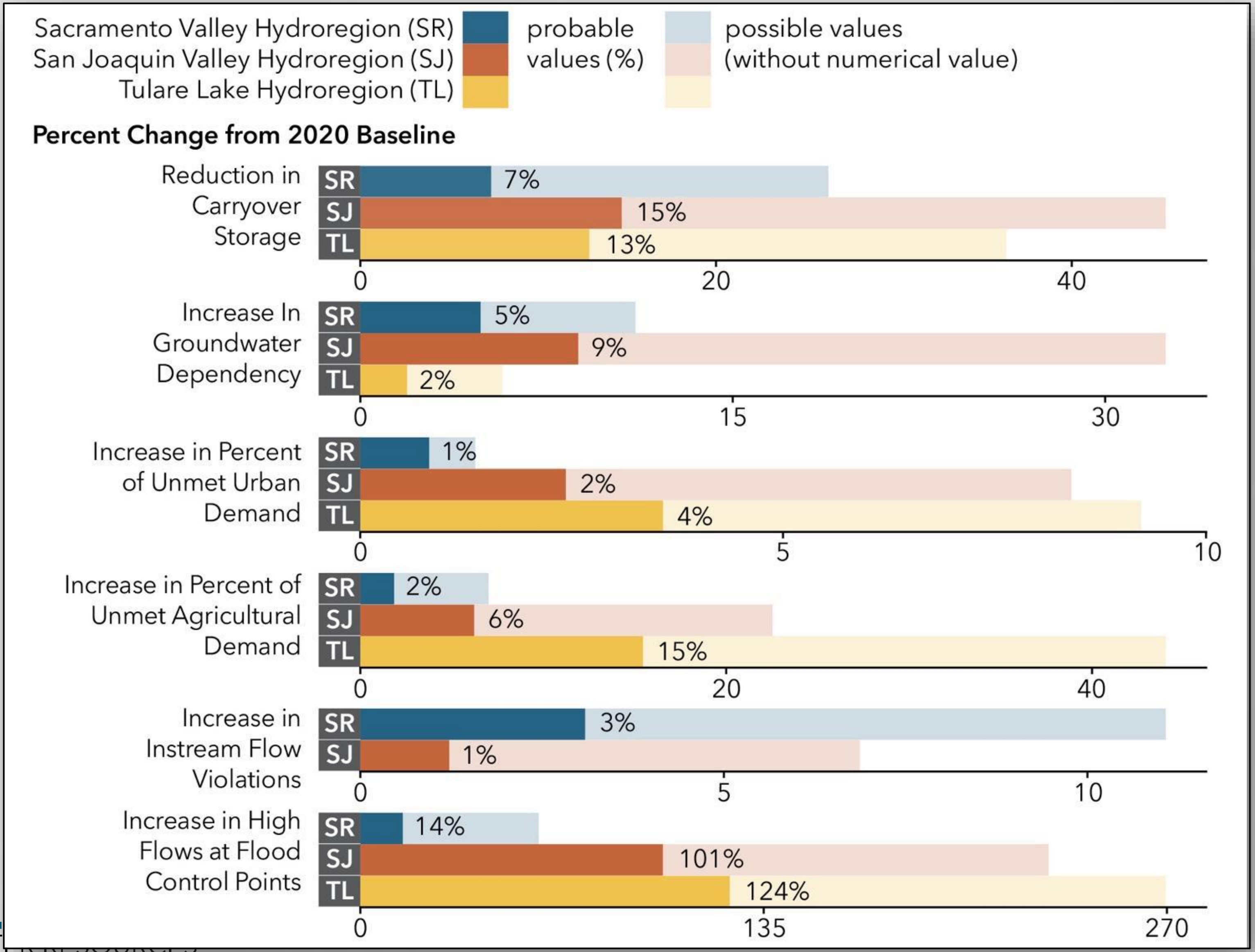
Figure 2-8 The Central Valley Is Likely to be Increasingly Vulnerable in 2070 Based on Six Water Metrics



Results of decision scaling analysis as depicted in the California Water Plan Update 2023.

This figure provides the likelihood of future conditions being worse than current conditions in 2070 for each metric.

Figure 2-9 Bar Plot Shows Large Magnitude Changes for Six Water Metrics by 2070

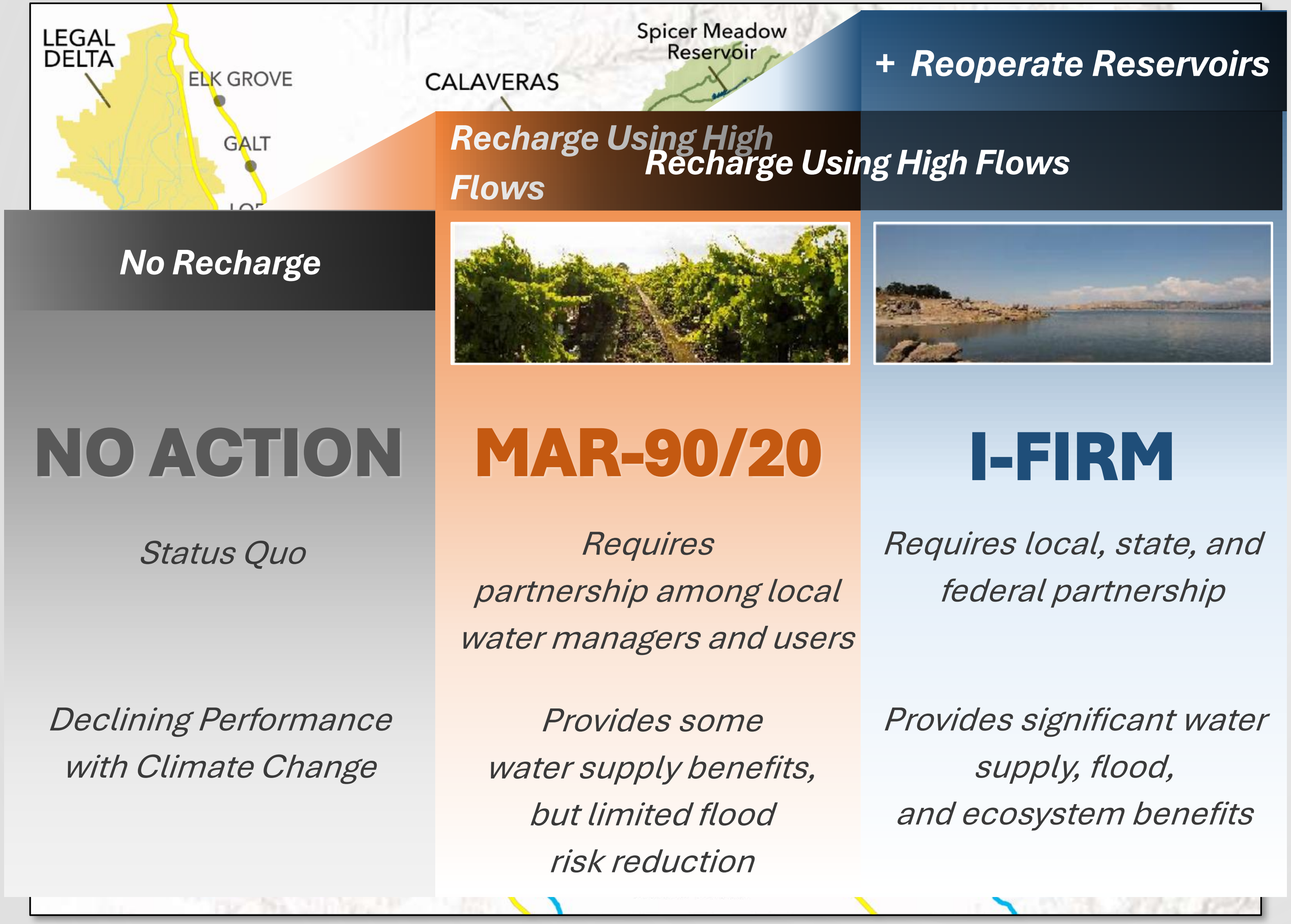


Results of decision scaling analysis as depicted in the California Water Plan Update 2023.

This figure provides the expected magnitudes of change as well as the 95th percentile value for extreme possible changes in the metrics.

Application 2:
San Joaquin Basin Flood-MAR Watershed Studies

San Joaquin Watershed Studies Overview



- Five watersheds on the eastern side of the San Joaquin Basin
- 16 climate conditions
- 100-year hydrologic sequence
- Three recharge actions
  1. No Action – status quo, maintain baseline operations
  2. MAR 90/20 – opportunistically recharge high flows
  3. I-FIRM – integrate recharge and forecast-informed reservoir operations

Study Objectives

Assess and Quantify Multi-Sector Vulnerability to Climate Change

Assess and Quantify Multi-Sector Flood-MAR Adaptation Performance

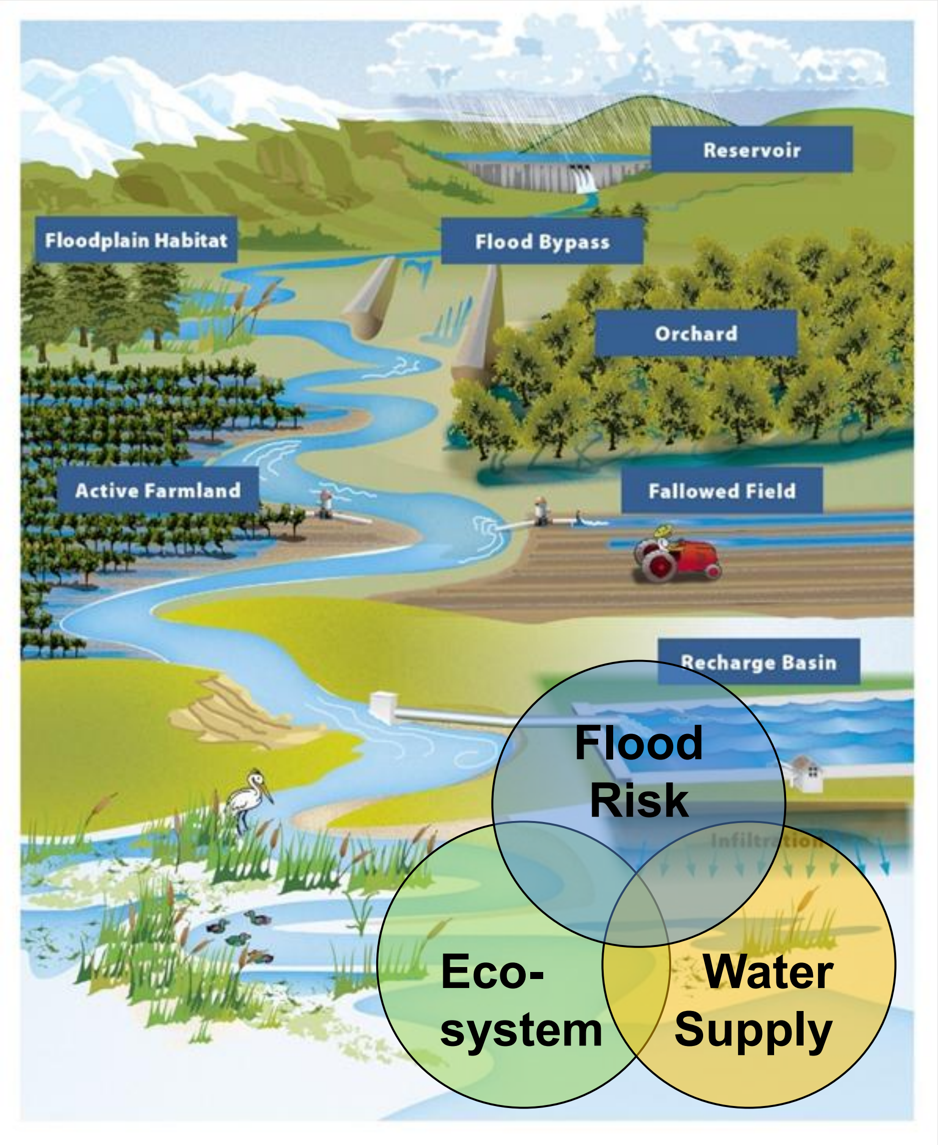
Watershed Studies

Report Results from the Local-Watershed-Basinwide scale

Foundation to Support Coordination, Alignment and Implementation

Metric Selection Process

- Track systemwide performance
- Three major water management sectors
- Reliably measured using the available toolset resolution



Performance Metrics

182 Metrics	174 Reporting Units
• Watershed Conditions – 13 • Flood Risk – 18 • Groundwater – 32 • Surface Water – 29 • Ecosystem – 67 • Flood-MAR – 23	• GW Sub-basin – 6 • SW Watershed – 5 • District – 38 • Reservoir – 8 • Control Point – 17 • Stream Reach (GW) – 8 • ResSim Diversion – 59 • WAFR Source – 33

1632 Reported Metrics × 3 Adaptation Strategies × 16 Climate Conditions × 100-year Continuous Timeseries = **7.8 Million** data points at annual timestep

Performance to Planning

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WATER RESOURCES

METRICS DASHBOARD

SAN JOAQUIN BASIN WATERSHED STUDIES

Start by selecting a page below.

- Vulnerability with Respect to Temperature
- Vulnerability with Respect to Precipitation
- Average and Contingency Performance
- Adaptation Performance (Climate Condition)
- Adaptation Performance (Time Horizon)
- Total Risk
- Sensitivity and Salience
- Explore Metrics by Location

Disclaimer:
The information presented on this dashboard is intended for **planning-level purposes only** and is provided as an **extension of the results documented in the Watershed Study Reports** available on the California Department of Water Resources' (DWR) website at https://water.ca.gov/programs/all-programs/flood-mar. The results displayed reflect the application of various models and analytical approaches based on a series of **specific study assumptions** regarding hydrology, infrastructure, operations, and other input parameters.

Dashboard Design Objectives

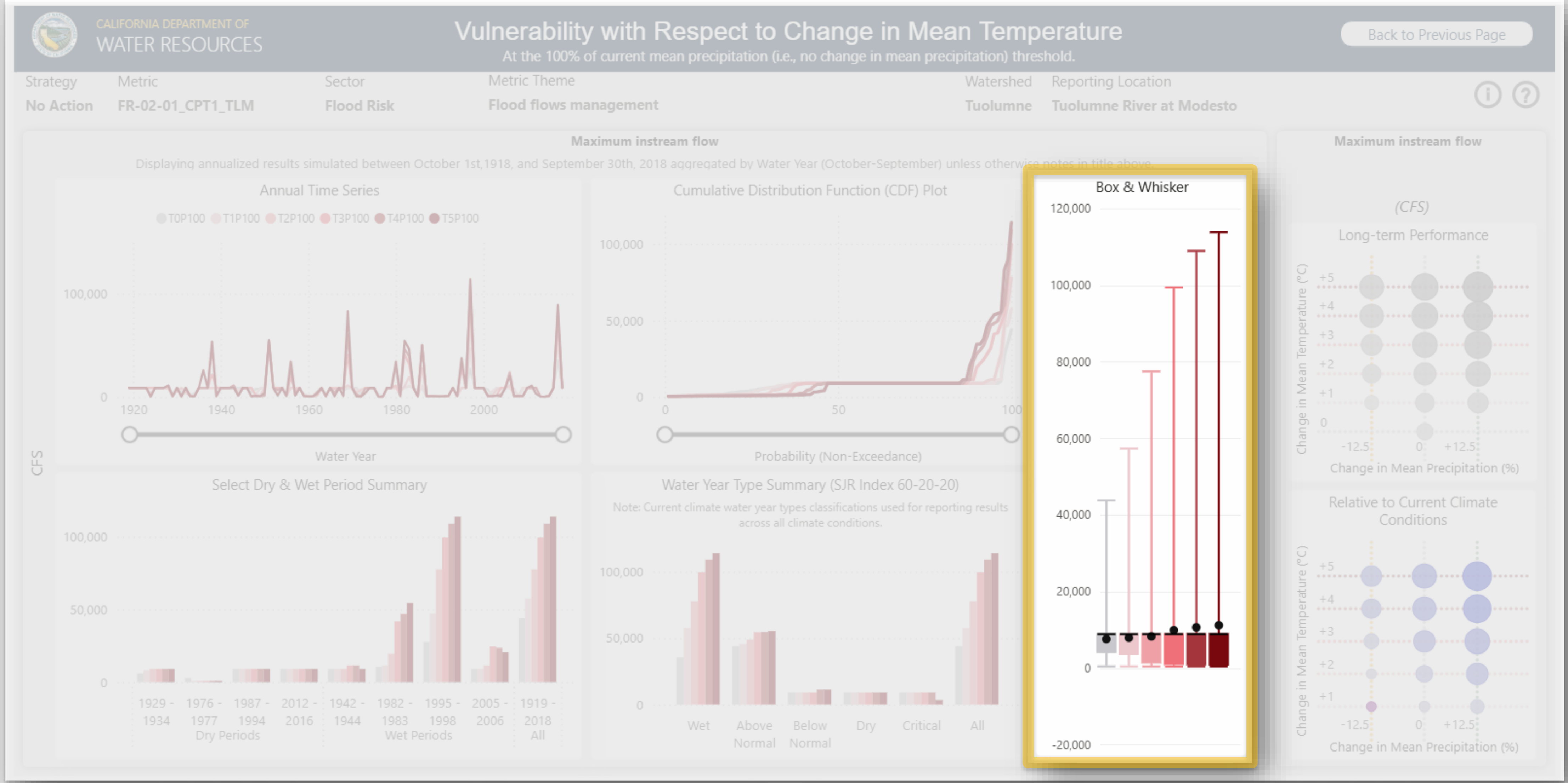
1. Understand performance trends
2. Evaluate projected future performance
3. Assess sensitivity
4. Demonstrate adaptation potential

Performance Trends

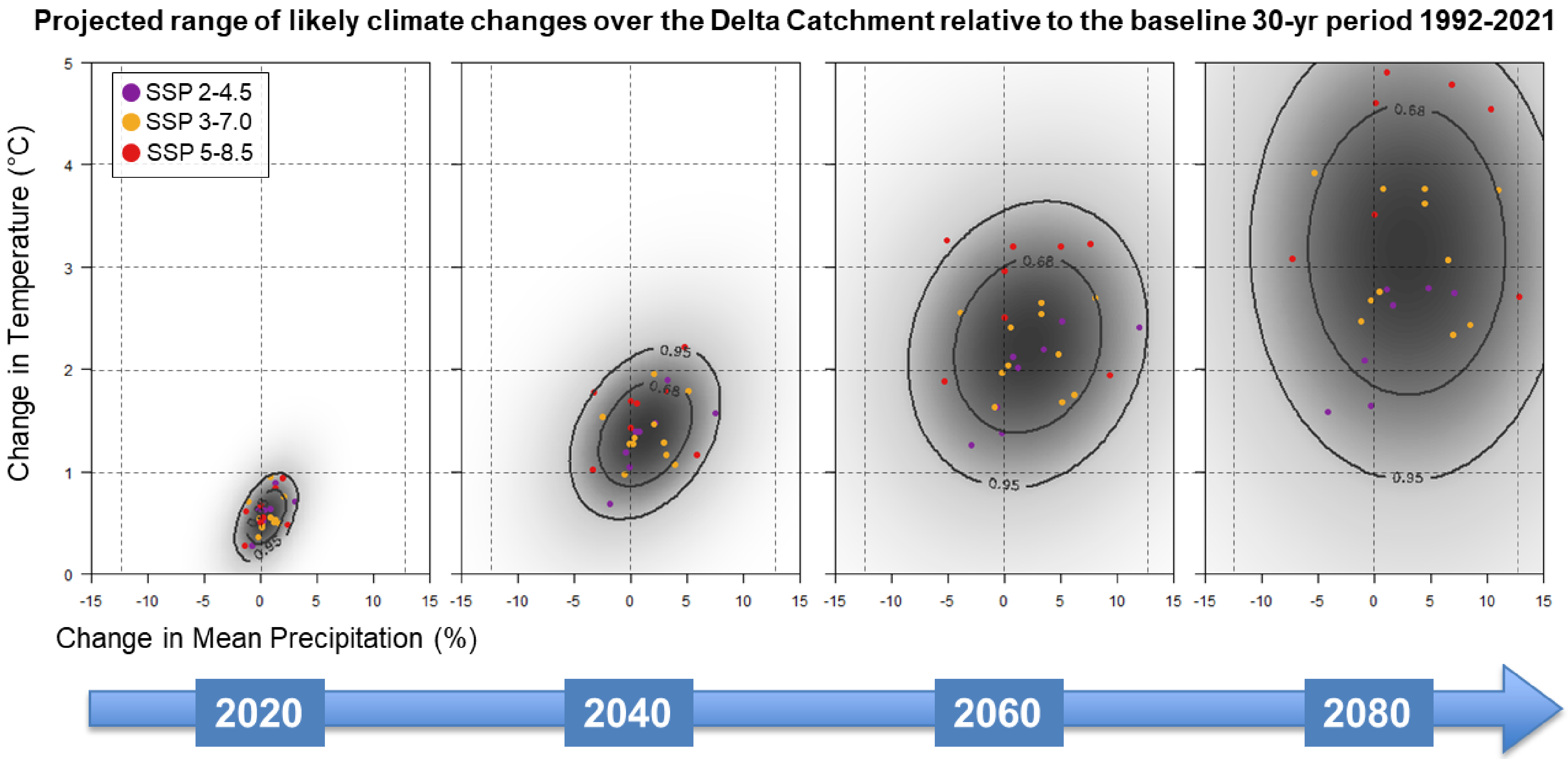
Vulnerability with Respect to Temperature

Vulnerability with Respect to Precipitation

Q. How is the peak flow in the Tuolumne River changing with temperature warming?



Projected Future Performance

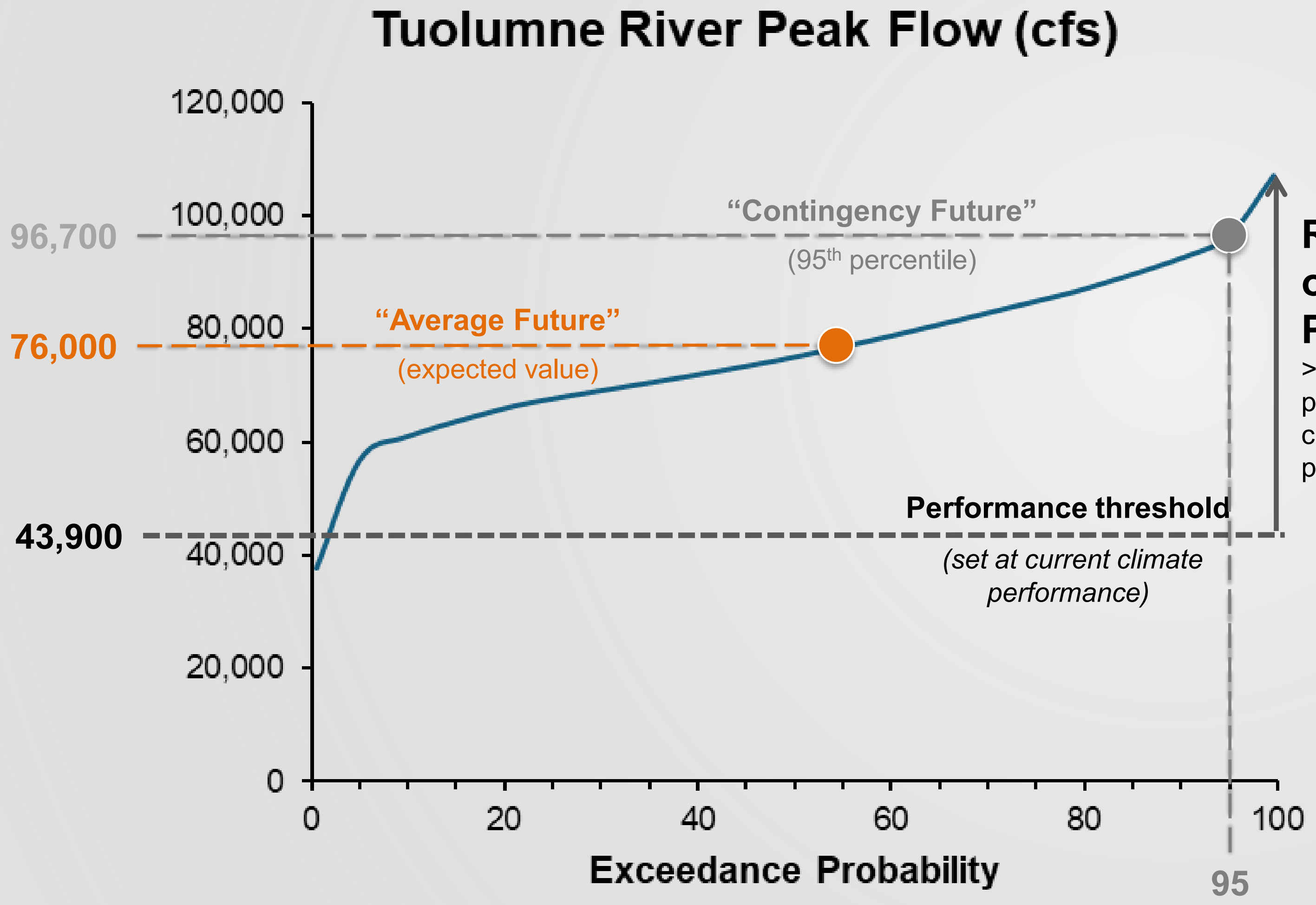


Each dot:

- *One of the 27 CMIP6/LOCA-2 downscaled projections of temperature and precipitation*
- *Spatial averaging over watersheds draining into the Sacramento-San Joaquin Delta*

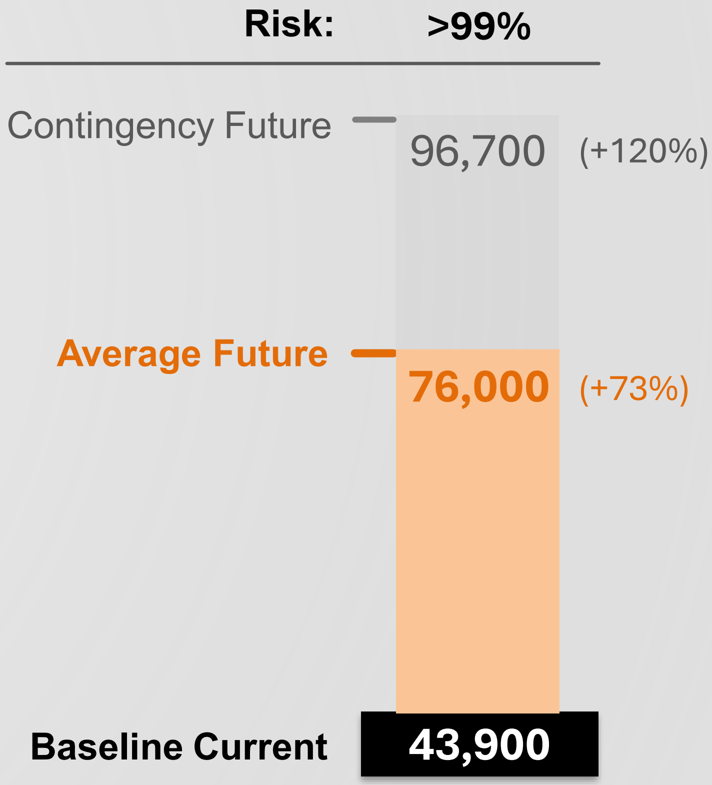
Projected Future Performance

Q. What is the likely peak flow in the Tuolumne River by 2050?



Risk: "Probability of Declining Performance"

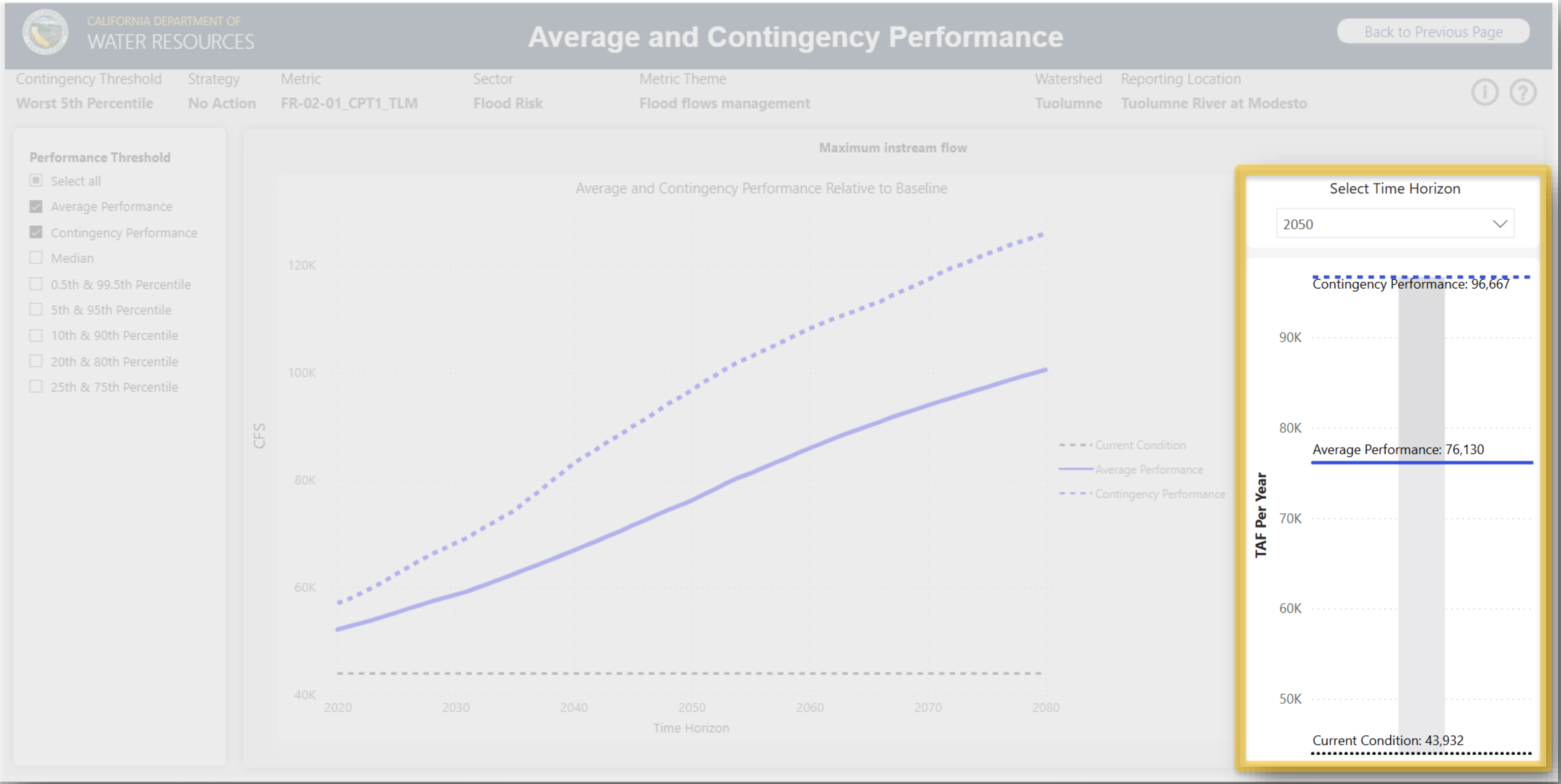
>99% probability that performance under future climate will be worse than performance threshold



Projected Future Performance

Average and Contingency Performance

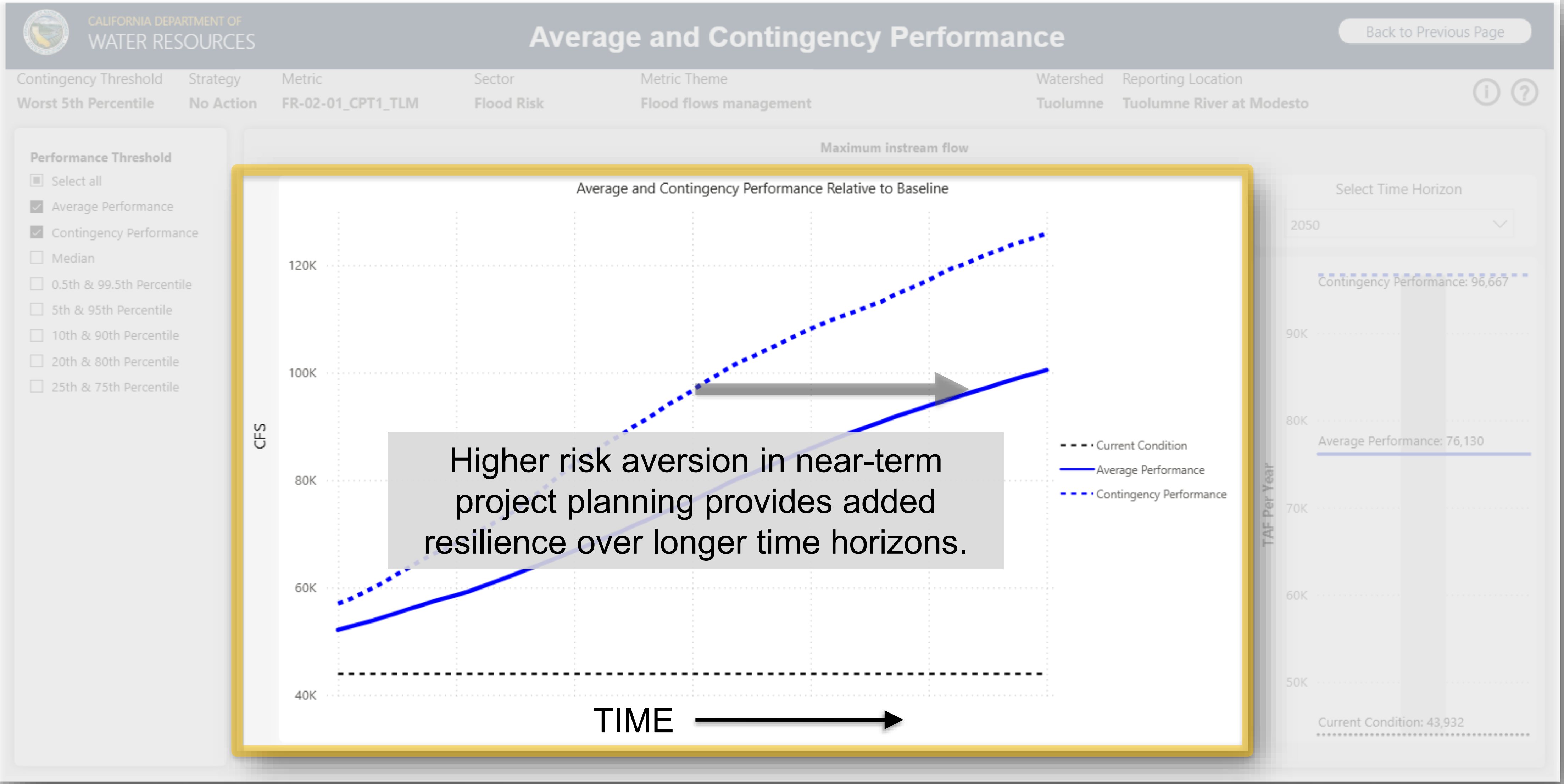
Q. What is the likely peak flow in the Tuolumne River by 2050?



Projected Future Performance

Average and Contingency Performance

Q. How does the peak flow vary for longer or shorter planning horizons?



Projected Future Performance

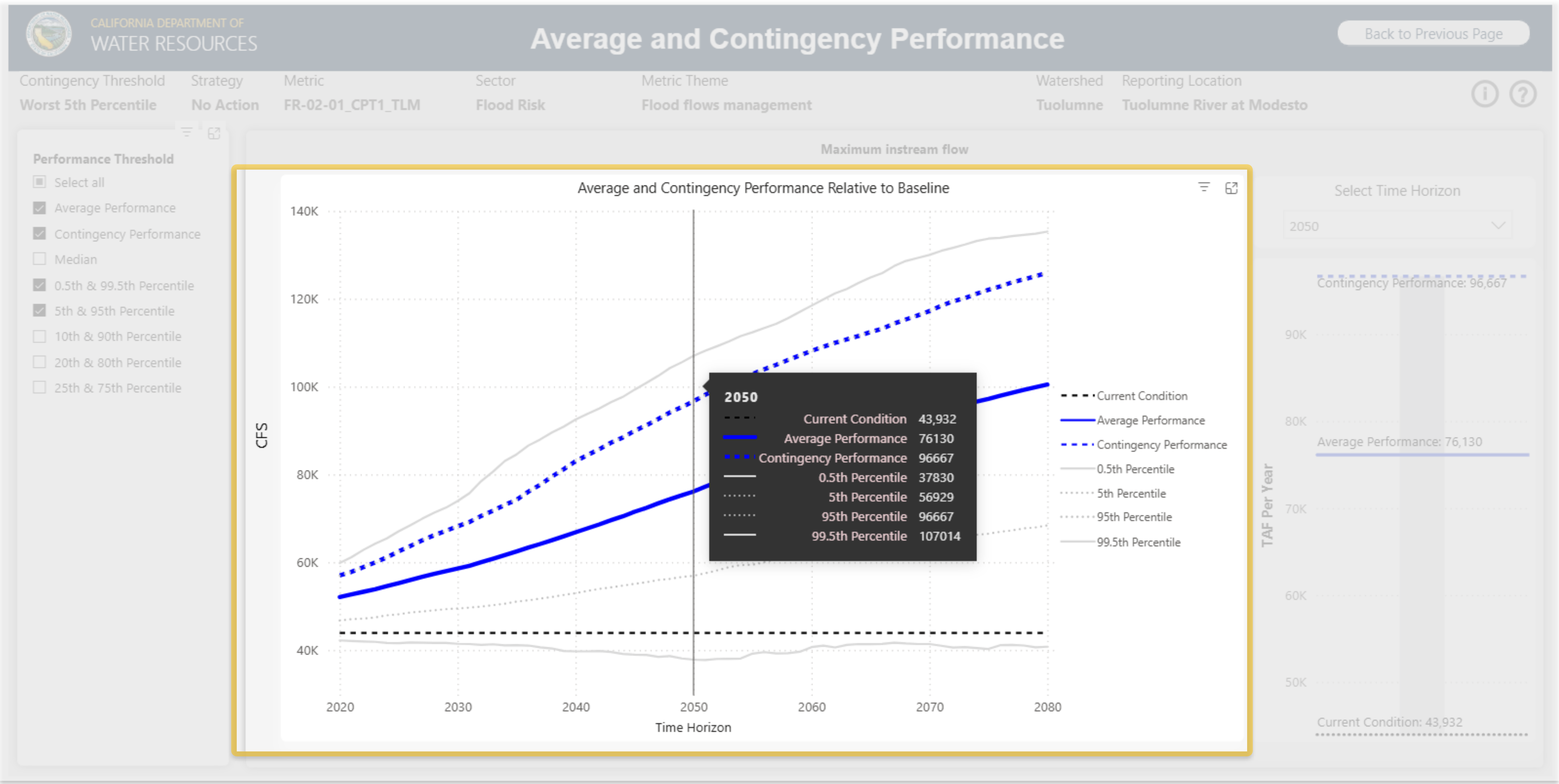
Average and Contingency Performance

Q. What if you want to plan for a higher or lower level of concern?

Projected Future Performance

Average and Contingency Performance

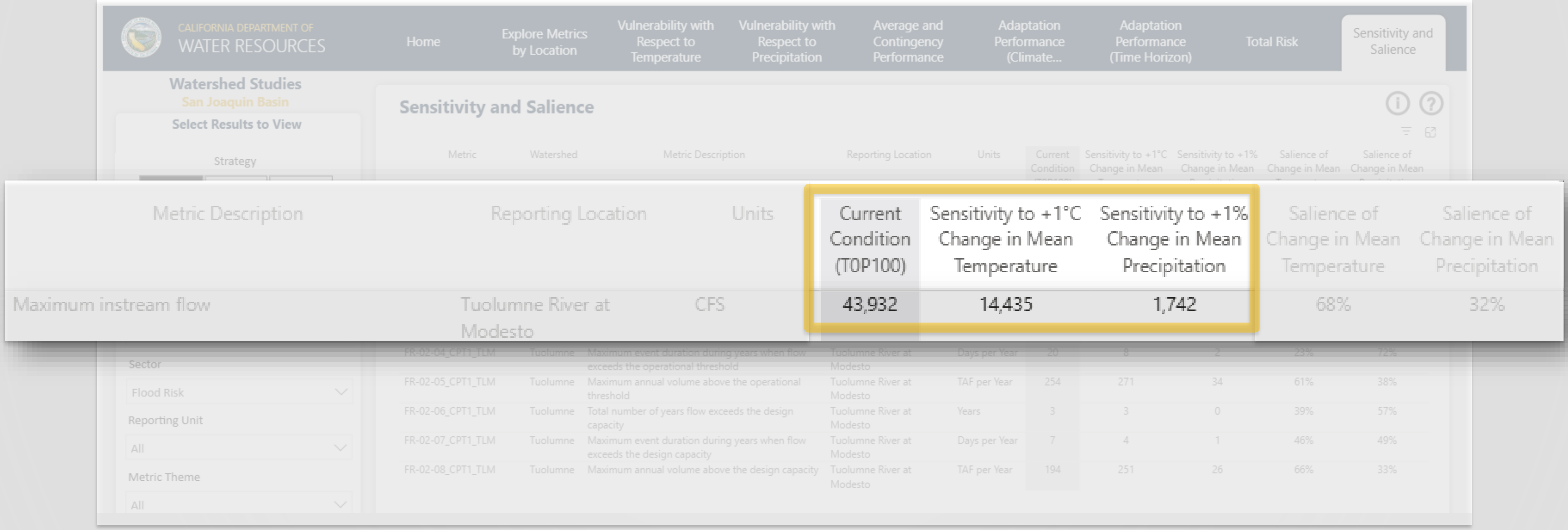
Q. What if you want to plan for higher or lower levels of concern?



Sensitivity to Climate Drivers

Sensitivity and Salience

Q. How will the peak flow change with a per-unit change in temperature or precipitation?

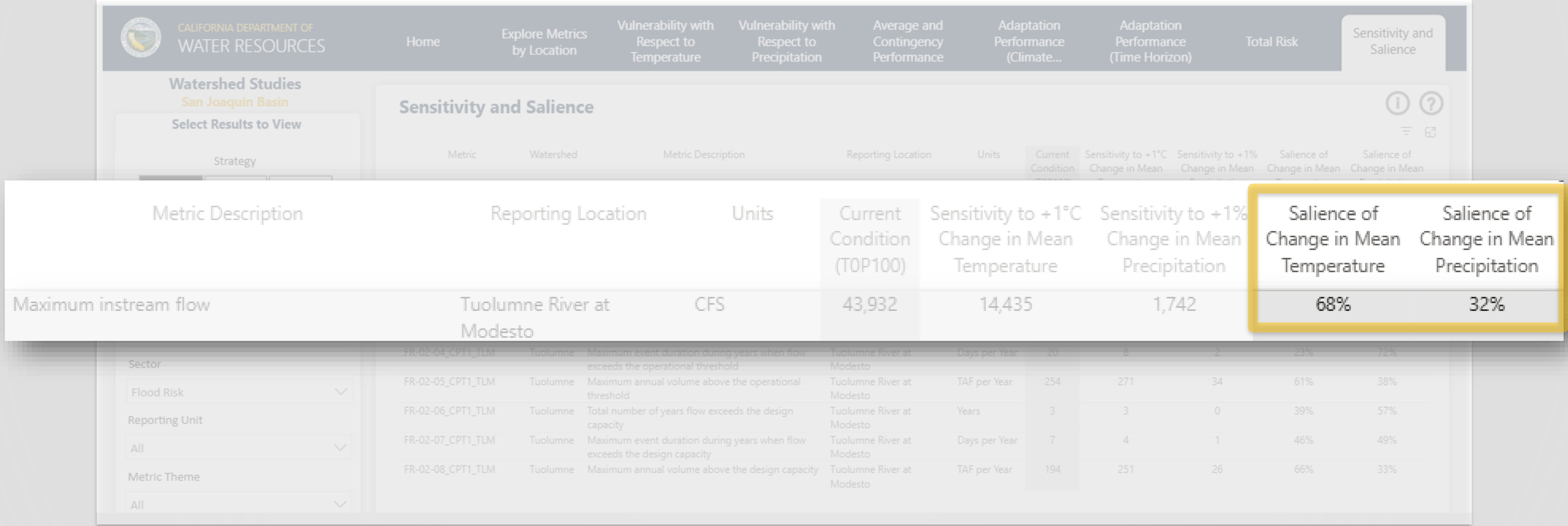


Sensitivity to Climate Drivers

Sensitivity and Salience

Q. How will the peak flow change with a per-unit change in temperature or precipitation?

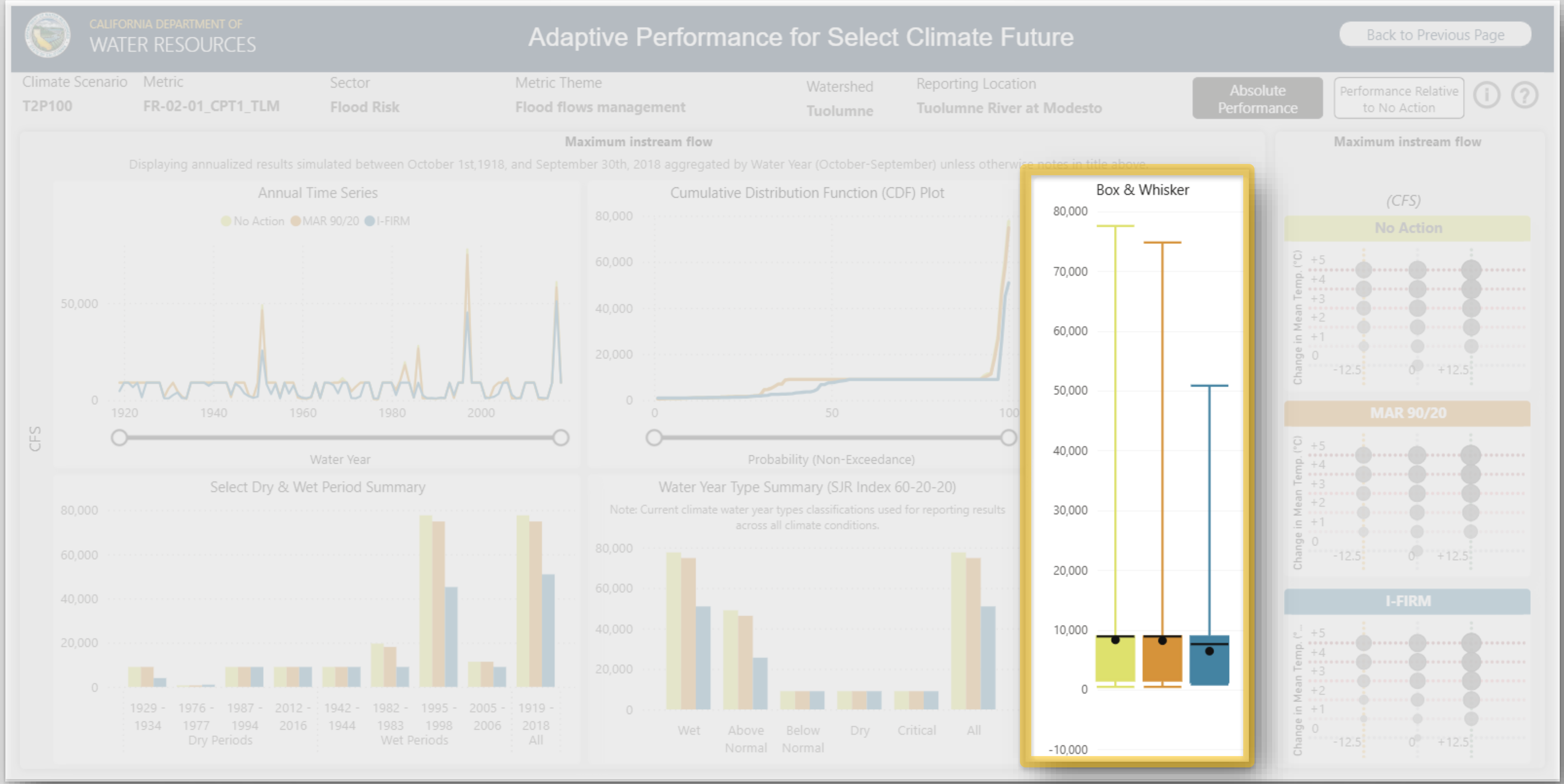
Q. Which factor – temperature or precipitation – has a greater influence on future performance?



Adaptation Potential

Adaptation Performance (Climate Condition)

Q. How does peak flow in the Tuolumne River respond to the adaptation strategies?

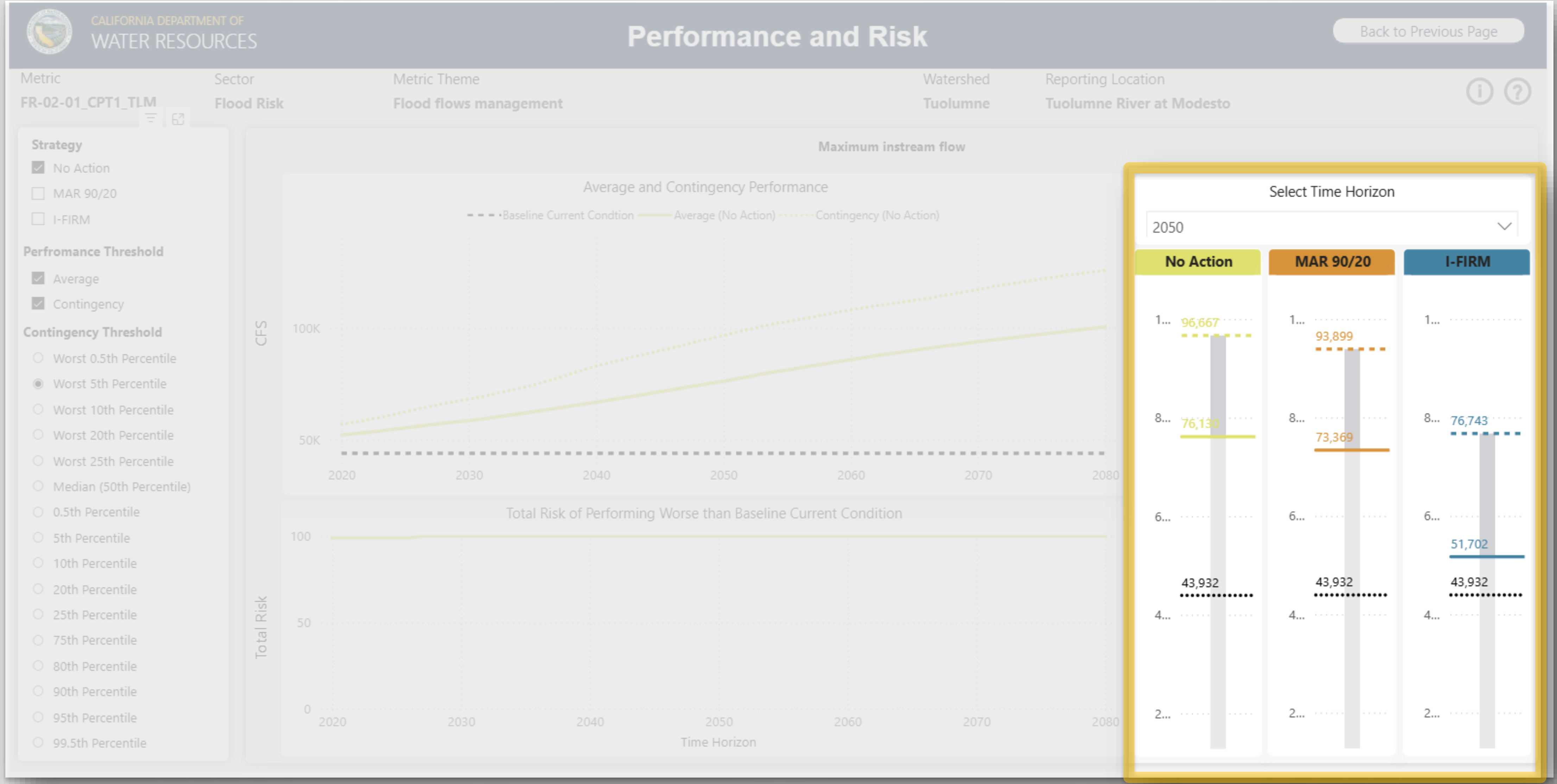


Adaptation Potential

Adaptation Performance (Time Horizon)

Total Risk

Q. How does peak flow in the Tuolumne River respond to the adaptation strategies?



Adaptation Potential

Adaptation Performance (Time Horizon)

Total Risk

E.g., How does the peak flow in the Tuolumne River respond to the adaptation strategies?

Average and Contingency **Future Performance**

Can also be evaluated at different management thresholds

Risk: probability that future performance will fall below baseline (no-action) conditions.

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