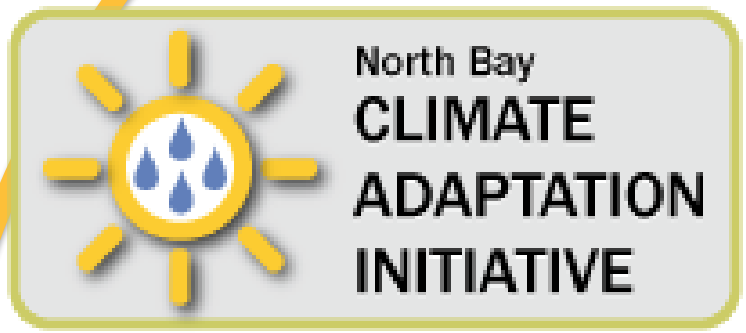
Climate Ready North Bay

Translating a landscape-level climate-hydrology database into inputs for long-term planning

For North Bay Watershed Association

North Bay Climate Adaptation Initiative
Sonoma Ecology Center

SONOMA ECOLOGY CENTER



Pepperwood
PRESERVE
Inspiring conservation through science

SONOMA
ECOLOGY
CENTER

Gold Ridge
Resource Conservation District

RCPA
regional climate protection authority

SONOMA
COUNTY
WATER
AGENCY

Point Blue
Conservation
Science

Laguna
de Santa Rosa
Foundation

SONOMA LAND TRUST

SONOMA COUNTY
AGRICULTURAL PRESERVATION
AND OPEN SPACE DISTRICT

ag
INNOVATIONS
collaboration with impact

COMMUNITY
FOUNDATION
SONOMA COUNTY

SAN FRANCISCO BAY
JOINT VENTURE

CLIMATE
PROTECTION
CAMPAIGN

SONOMA
STATE UNIVERSITY
FIELD STATIONS &
NATURE PRESERVES

USGS
science for a changing world

THE UNIVERSITY OF CALIFORNIA BERKELEY
1868

PRUNUSKE CHATHAM, INC.

Coastal
Conservancy

AUDUBON CANYON RANCH

Creekside Center
for Earth Observation

North Bay CLIMATE ADAPTATION INITIATIVE

Future-Proofing

A Roadmap for Climate Resilience in Sonoma County

You've heard the saying 'It takes a village to raise a child.'
Well, it takes a village with a plan to respond to climate change!

Justin Witt, Brelje & Race, Sonoma County Climate Adaptation Forum, April, 2015

Sonoma County is a leader in reducing emissions to slow down climate change. However, even with these measures, serious climate hazards cannot be avoided. Climate resilience or climate readiness means we are prepared to deal with the hazards of climate change, we are reducing our vulnerabilities to the hazards, and we are set up to maintain or even improve our quality of life despite climate stresses.

We're all in it together. It will take action by all kinds of people in Sonoma County to achieve climate resilience. Climate resilience can improve nearly all aspects of life in Sonoma County, including general quality of life, social equity, ecological functions, water supply, wildlife and open space protection, economic stability, and safety.





NBCAI

The Climate Resilience Roadmap Overview

A Climate-Resilient Vision for Sonoma County

Extreme Heat · Frequent Drought · More Wildfires · Warmer Winters · More Floods · Higher Seas

9 CLIMATE RESILIENCE GOALS

1. Promote healthy, safe communities
2. Protect water resources
3. Promote a sustainable, climate-resilient economy
4. Mainstream the use of climate projections
5. Manage buffer zones
6. Promote ag preparedness and food security
7. Protect infrastructure
8. Increase emergency preparedness and prevention
9. Monitor climate and its effects

Process

1 Vulnerable communities' resilience
2 Connect community
3 Use less water
4 Use less water
5 Manage water as one
6 Diversify agriculture
7 Seize opportunities
8 Build resilient supply chain
9 Quantify benefits
10 Make room for water
11 Align plans with hazards
12 Farm carbon, water & diverse crops
13 Subsidize local food
14 Position your business
15 Reduce forest flammability
16 Prepare yourself
17 Invest in radical collaboration
18 Reality check
19 Align investments with values
20 Measure resilience

6 CLIMATE HAZARDS ADDRESSED

COMMUNITY RESOURCES AFFECTED

People and social systems
Built systems
Natural and working lands

TOP 20 ACTIONS

These are the highest priority actions from a longer list in the complete Roadmap document, distilled from over 125 raw actions from dozens of contributors and vetted by NBCAI and other experts.

For the full list of actions, see the complete Roadmap at northbayclimate.org.

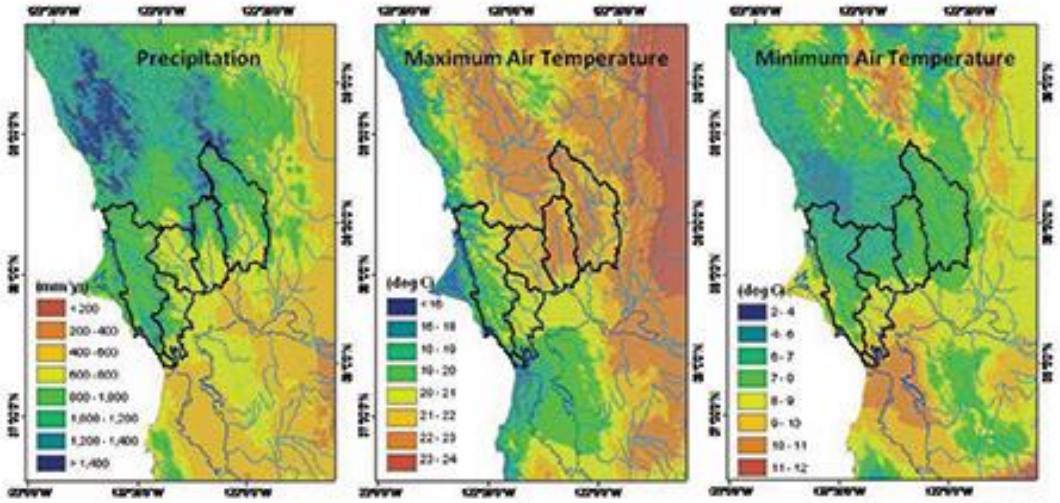
We must ALL participate for our community to be climate-resilient. Every person (and actor) has a part to play—school child, designer, official, tradesperson, farmer, retiree—to lead us to the resilient future we know is possible.

5 ACTORS

Working Lands Managers · Businesses · Individuals · Households · Government · Nonprofits · Faith Community & Philanthropy · Academic Institutions

Adapting to Climate Change
State of the Science for North Bay Watersheds
A Guide for Managers

December 2010



Average annual temperatures and precipitation, 1971-2000

A report prepared for the North Bay Watershed Association by the Dwight Center for Conservation Science at Pepperwood in partnership with the US Geological Survey and the Bay Area Open Space Council

Lisa Micheli, Pepperwood
Lorraine Flint, US Geological Survey
Alan Flint, US Geological Survey
Morgan Kennedy, Pepperwood
Stuart Weiss, Creekside Center for Earth Observations and
Ryan Branciforte, Bay Area Open Space Council

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Inspiring conservation through science

Project Context:
Making good on NBWA's early investment in climate adaptation planning

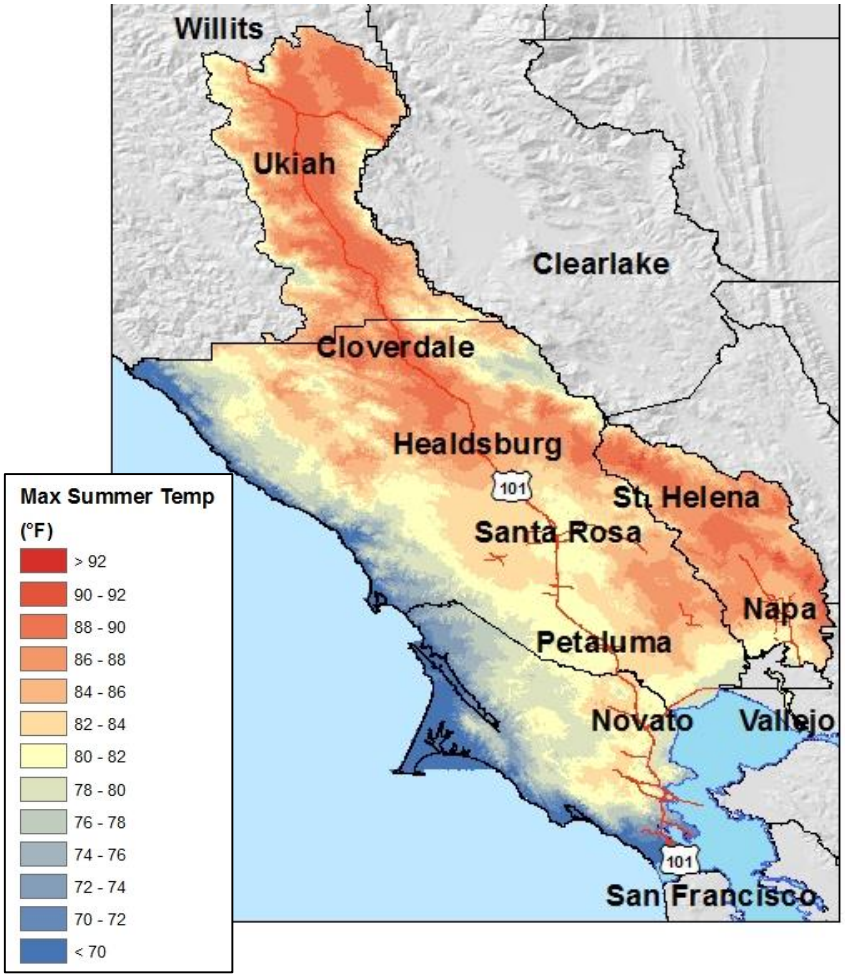
Project Context:
Regional Water Management

- DWR's IRWMP Guidelines: "address the effects of climate change on the region," adapt "to changes in the amount, intensity, duration, timing, and quality of runoff and recharge," "address sea level rise"
- 2013 SFBIRWMP Climate Change chapter: averaged 6 GCMs, gave Bay-wide average results, 3 outputs: air temperature, annual and seasonal rainfall, and sea-level rise. So… "Total precipitation is not projected to change significantly"

Project Context:
More from 2013 SFIRWMP Plan

- "…there is relatively little information that presents specific tools for how to apply impacts in the context of addressing climate change impacts on water resources." BETTER
- "…far less information is available on subregional or local geographic areas because the spatial resolution of the existing climate change models is still quite low." FIXED
- "…precipitation projections cannot be easily converted directly into surface runoff and groundwater recharge to connect changes with local water resources planning activities." FIXED
- Good performance metrics. Good recommendations for informing better vulnerability assessments.
- BCM data is available statewide and could be used in the next IRWM Plan update.

Climate Ready North Bay: translating a landscape-level climate-hydrology database into inputs for long-term planning



- Warmer temperatures
- Greater hydrologic variability
- Greater evapotranspiration
- Increased water demand
- Variable runoff and recharge
- Shifts in natural vegetation types
- Increased wildfire risk
- (Not sea level rise!)

Leading Regional Research

Berkeley
UNIVERSITY OF CALIFORNIA

Moritz
Ackerly

cri
CLIMATE READINESS INSTITUTE

USGS
science for a changing world

Flint & Flint

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

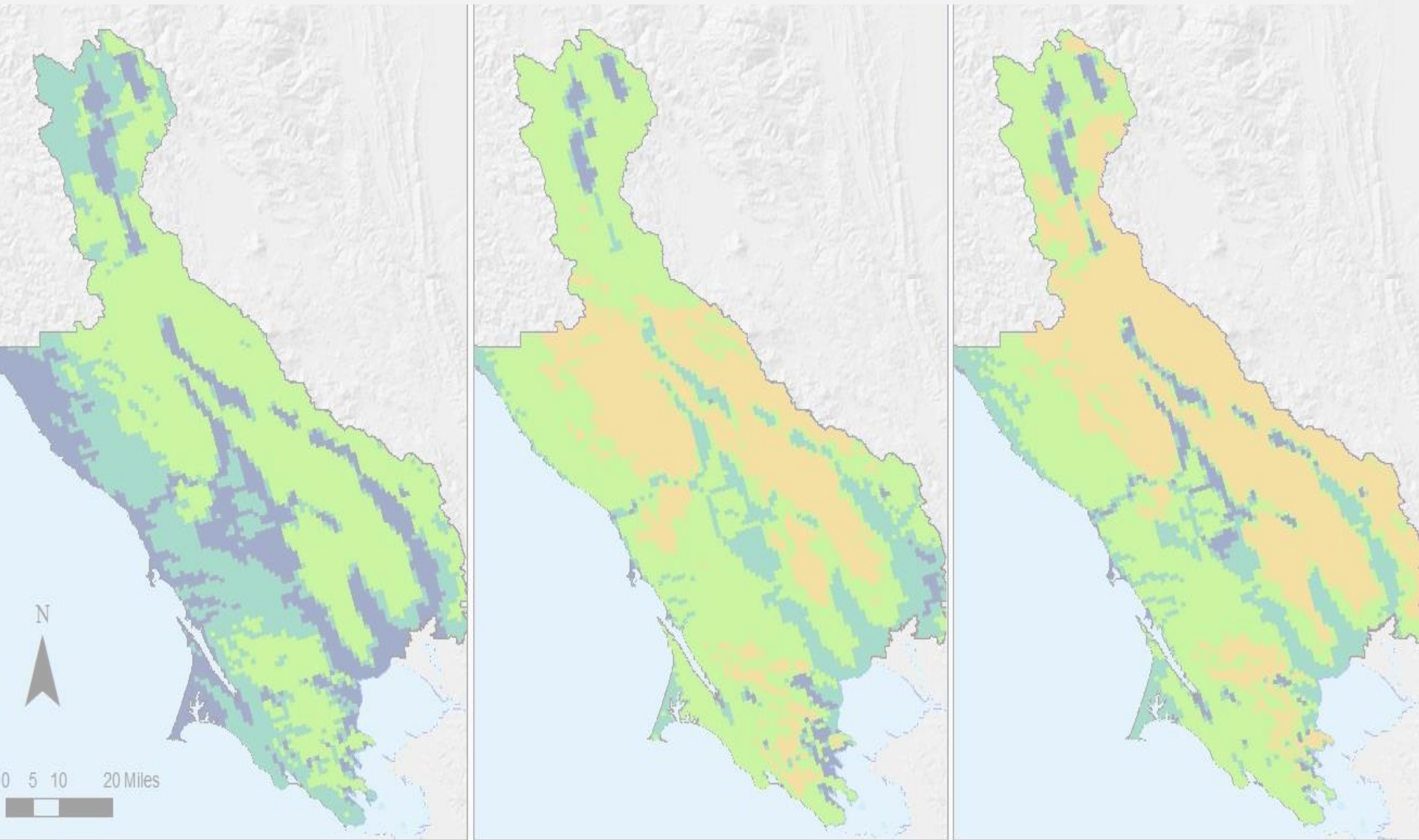
Point Blue
Conservation
Science

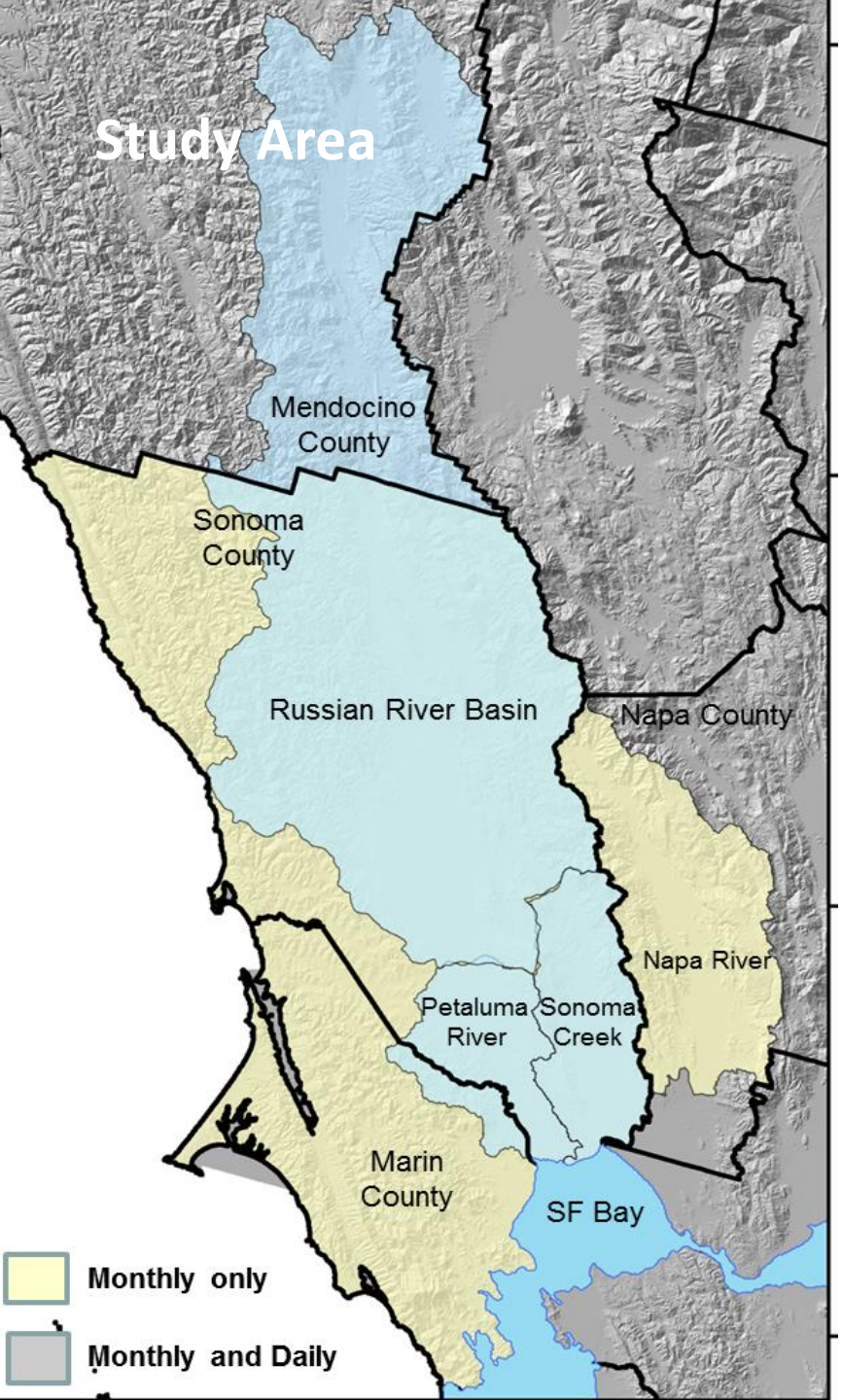
Pepperwood
PRESERVE
Inspiring conservation through science

Project Context: Timeline

- USGS Basin Characterization Model, UCB vegetation response, UCD fire frequency. 2012-current.
- **Climate Ready North Bay phase 1**. 2014-2016. Funding: Coastal Conservancy, So Co Water Agency, MMWD, Napa County, Gordon & Betty Moore Foundation. Team:
  - Sonoma County Water Agency
  - Marin Municipal Water District
  - Napa County planning, flood control
  - Sonoma County parks and open space agencies
  - Sonoma County Regional Climate Protection Authority
- **Climate Ready North Bay phase 2.** 2016. Funding: North Bay Watershed Association, Community Foundation Sonoma County.
  - Working Session 1, July 2016: understand information resource, identify management questions
  - Working Session 2, September 2016: in each "watershed," apply findings/tools to management questions
- **Challenge**: connect tools with users, answer new questions

Climate Ready North Bay
Phase 1



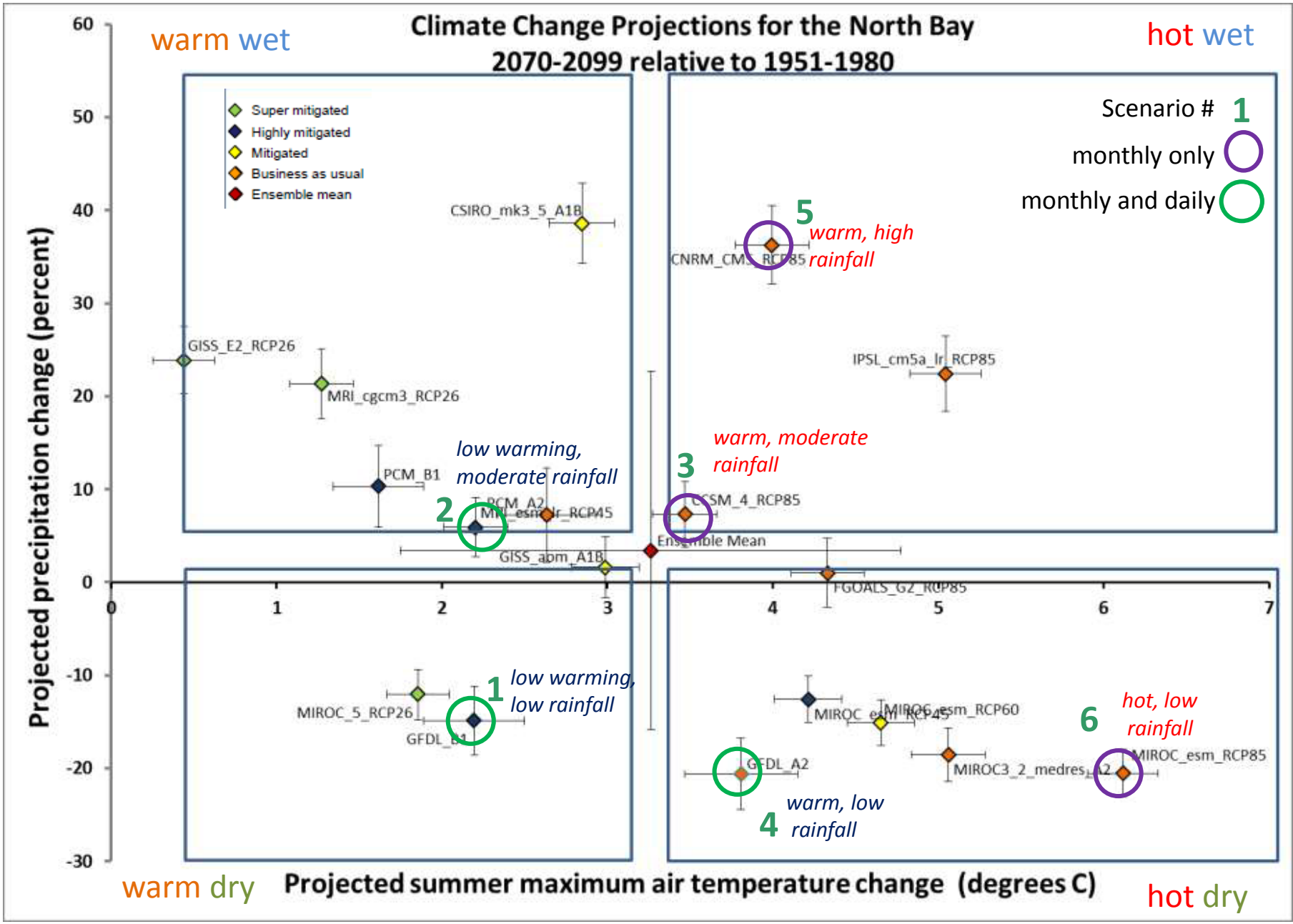


North Bay Climate Ready Phase 1

Serving natural resource agencies in Marin, Sonoma, Napa and Mendocino Counties

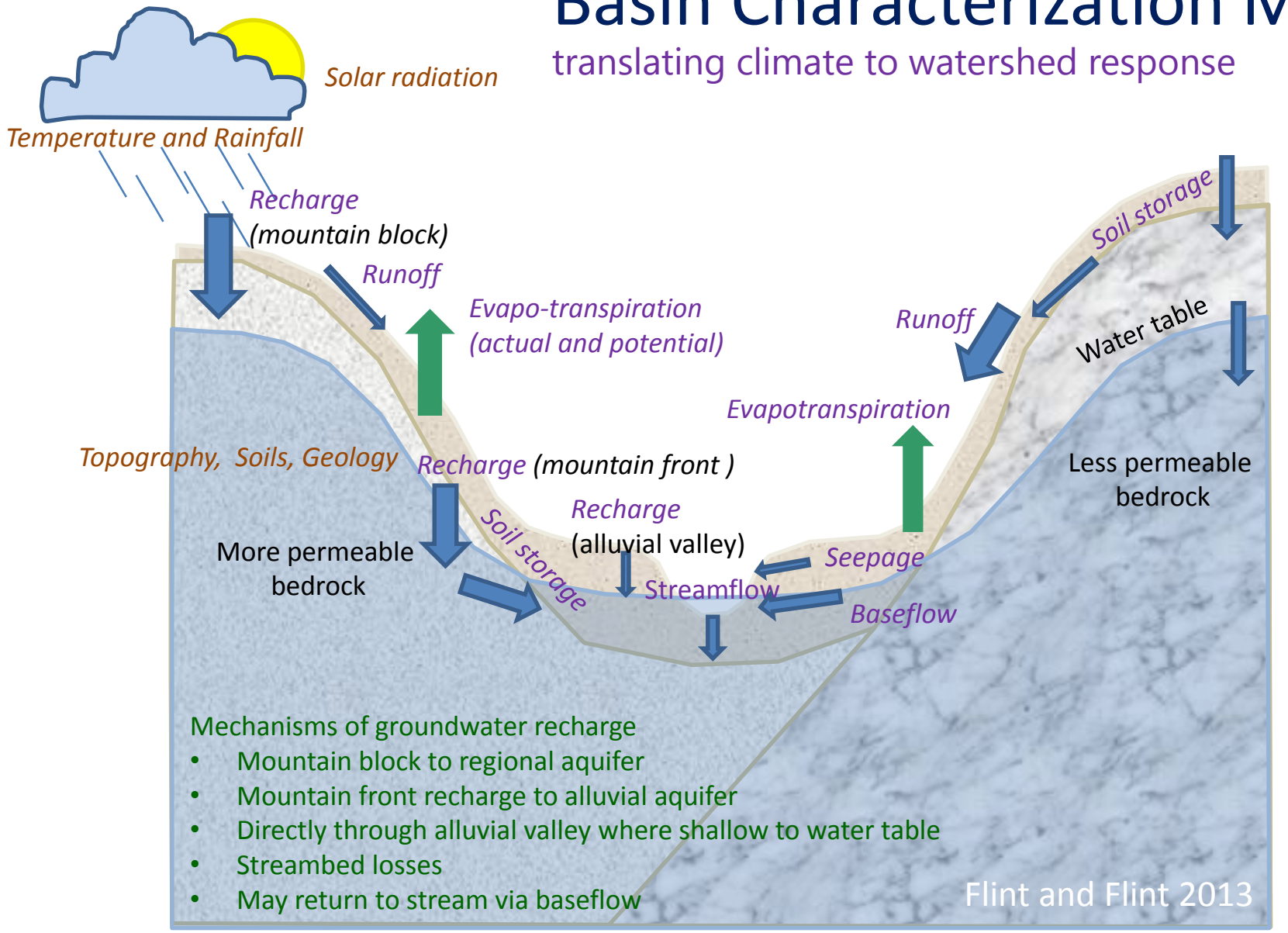
North Bay Climate Ready: Selected Futures for Regional Vulnerability Assessment

map products in red, daily products available for Russian River basin only



Basin Characterization Model

translating climate to watershed response



Size of arrows reflect relative magnitude of water flow

USGS science for a changing world

Brown text is BCM input, Purple text is BCM output

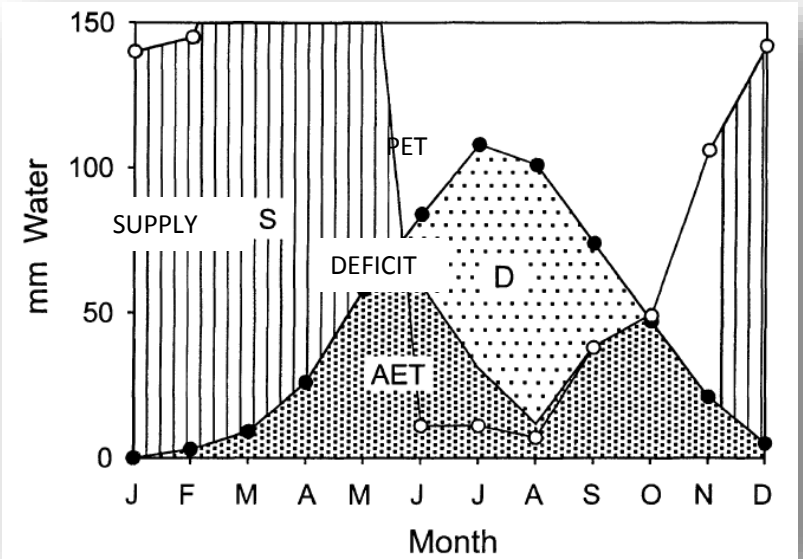
Pepperwood PRESERVE

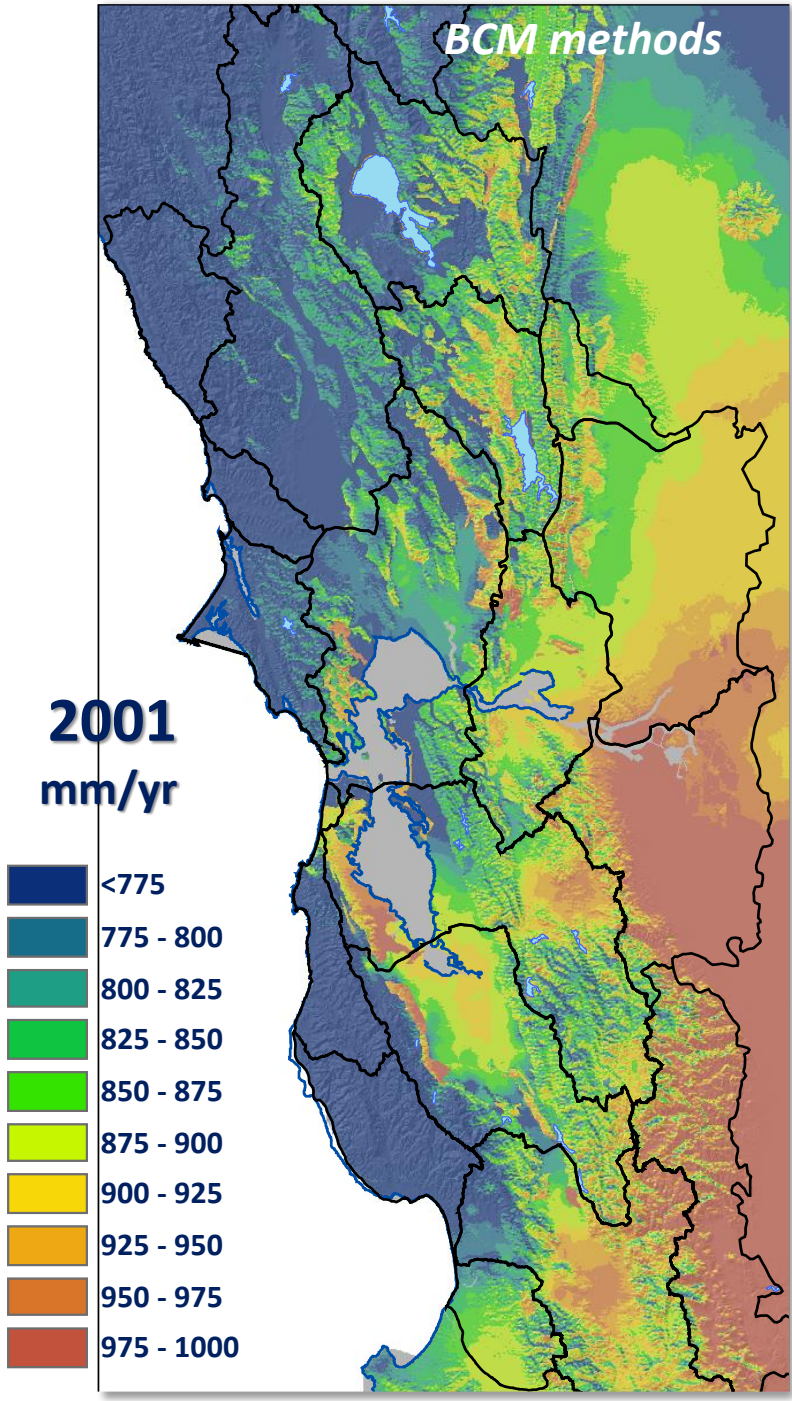
BCM output: Climatic Water Deficit

Annual evaporative demand that exceeds available water= drought stress

Potential – Actual Evapotranspiration

- Integrates climate, energy loading, drainage, and available soil moisture storage
- Vegetation independent (indicator)
- Surrogate for irrigation demand
- Generally increases with all future climate scenarios
- Correlates with vegetation type and fire risk





Climate Ready data menu

Primary BCM outputs:

Temperature Rainfall Runoff Groundwater recharge
Evapotranspiration Soil moisture Climatic water deficit

Secondary variables:

Fire frequency (% annual likelihood of fire, or annual return interval)

Potential native vegetation transitions

Time scales: historical (1910-2010) and projected (2010-2100)

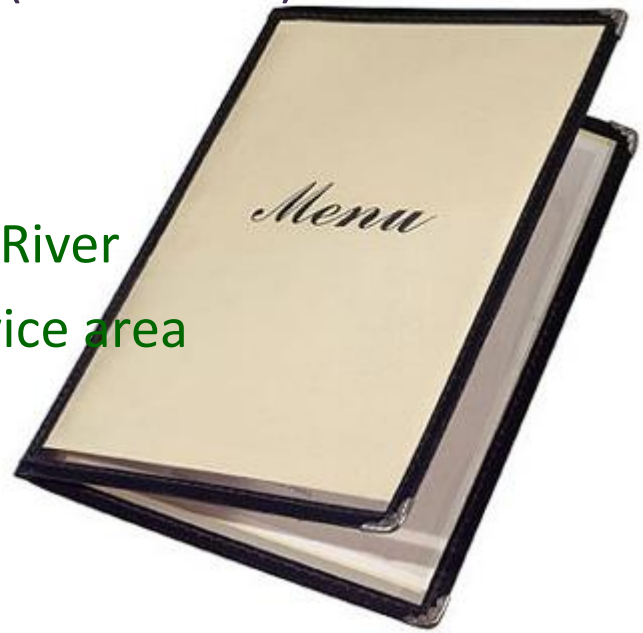
30-yr average, annual, or monthly/seasonal

Spatial scales:

Regional: North Bay watersheds plus Russian River

Sub-regional: watershed, landscape unit, service area

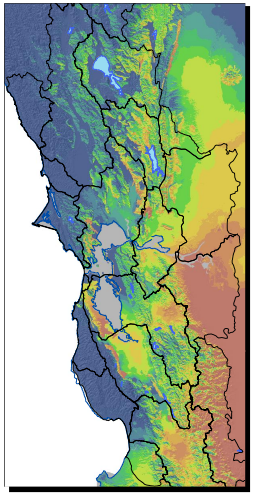
County Large parcels



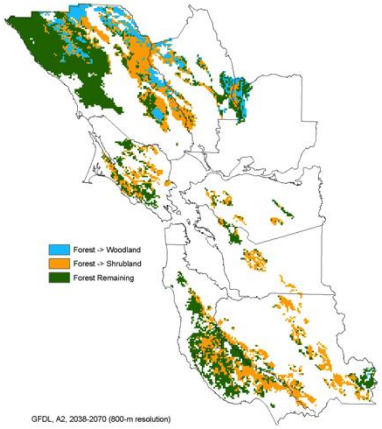
A climate adaptation knowledge base for application to North Bay watersheds

Climate + Topography

Watershed Hydrology + Topo-climate



Vegetation Cover + Fire Risks



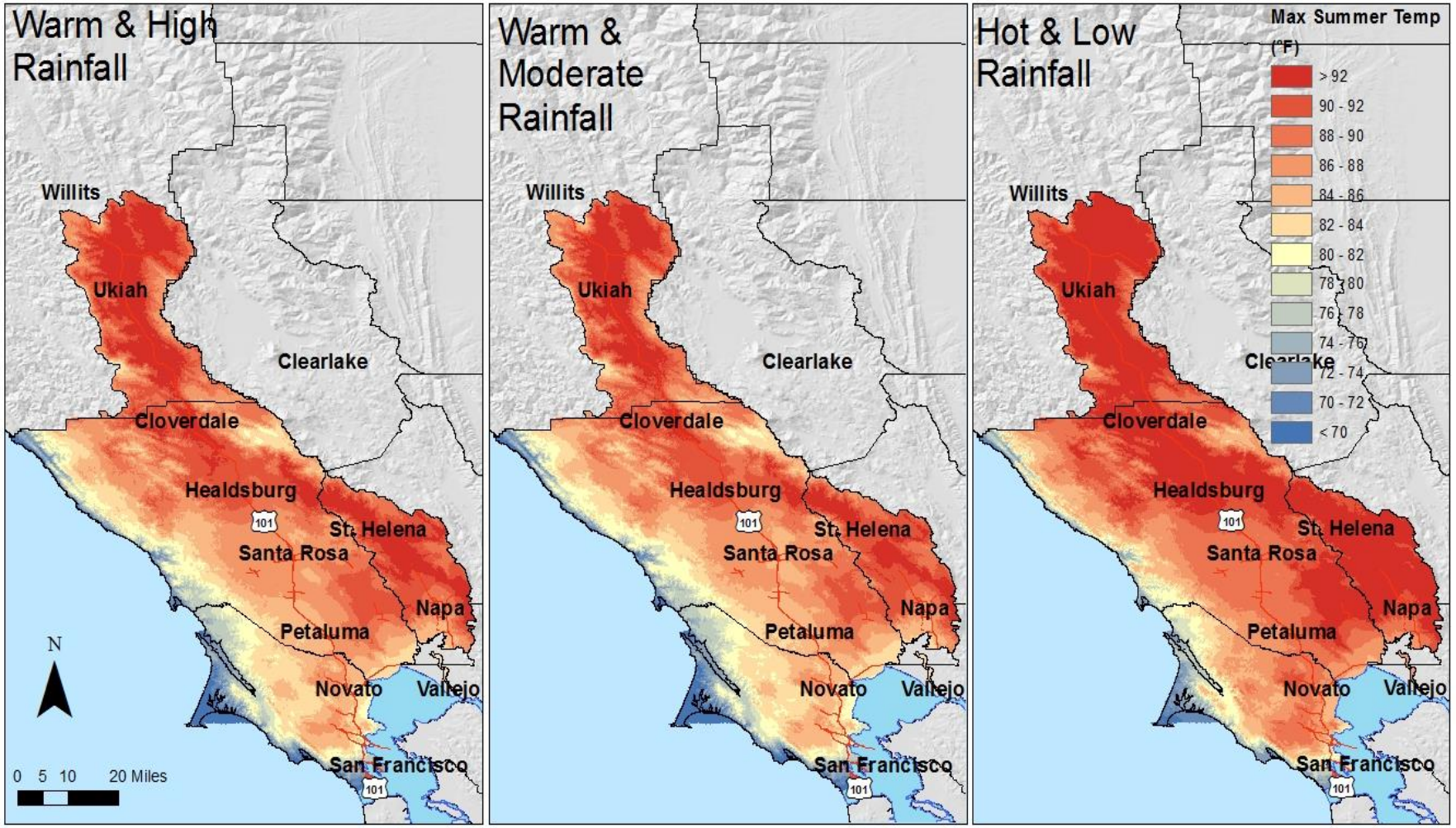
Species Distributions

generating an ensemble of projections for use in scenario planning

Caveats

- All climate models equally likely
- Dealing with uncertainty and multiple scenarios
- Calls for real-time empirical monitoring
- Spatial resolution (270 m, 18 ac): best for subwatersheds or parcels ~ 100s of acres
- Temporal resolution: limitations

Projected Maximum Summer Air Temperature, 2040-2069



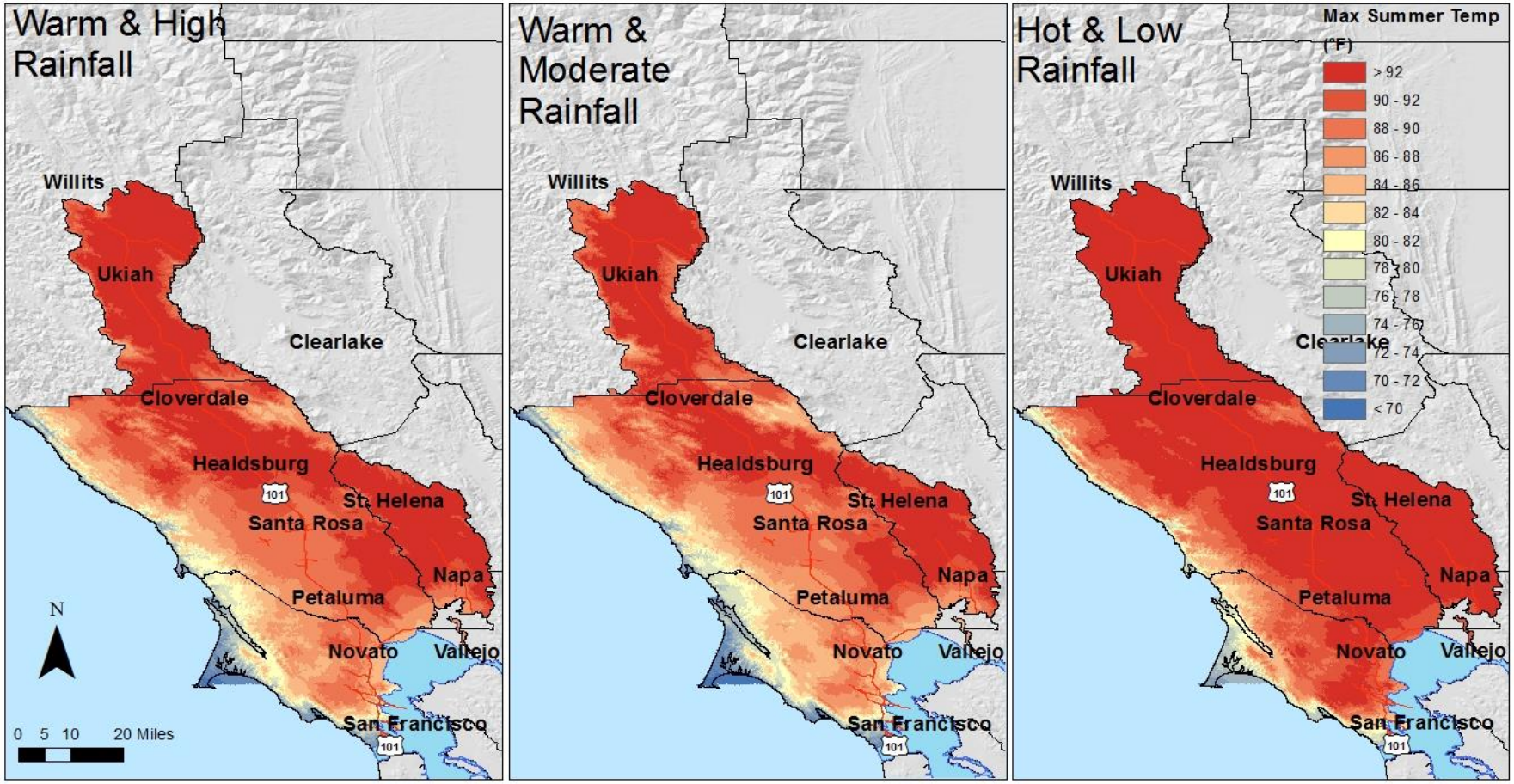
86.4 average
+4.2 deg F

86.0 average
+3.8 deg F

89.2 average
+7.0 deg F

"business as usual" mid-century temperatures - 30 y average

Projected Maximum Summer Air Temperature, 2070-2099



89.4 average
+7.2 deg F

88.5 average
+6.3 deg F

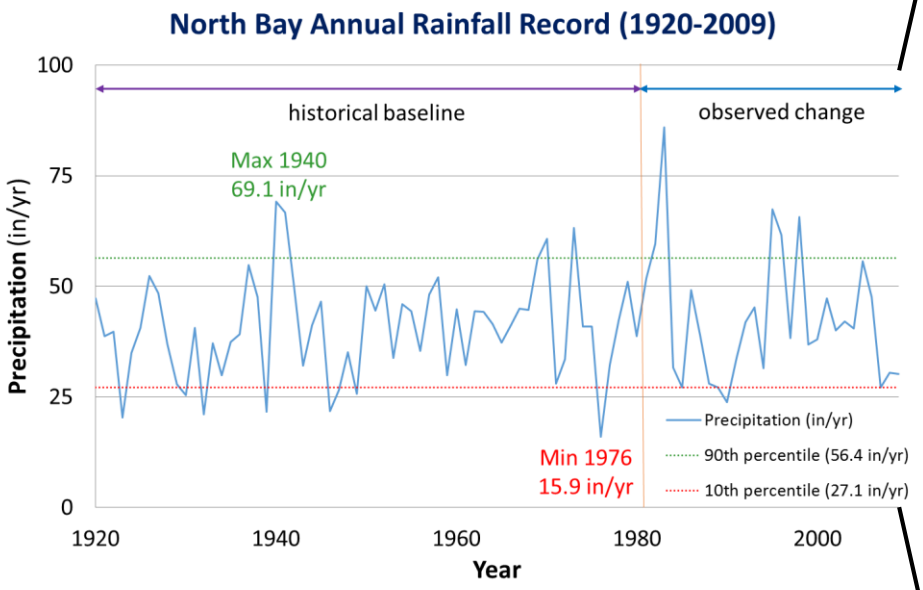
93.4 average
+11.2 deg F

"business as usual" end of century temperatures- 30 y average

North Bay Climate Ready

Regional Annual Rainfall: Historical and Projected

(comparison of 90-year periods)



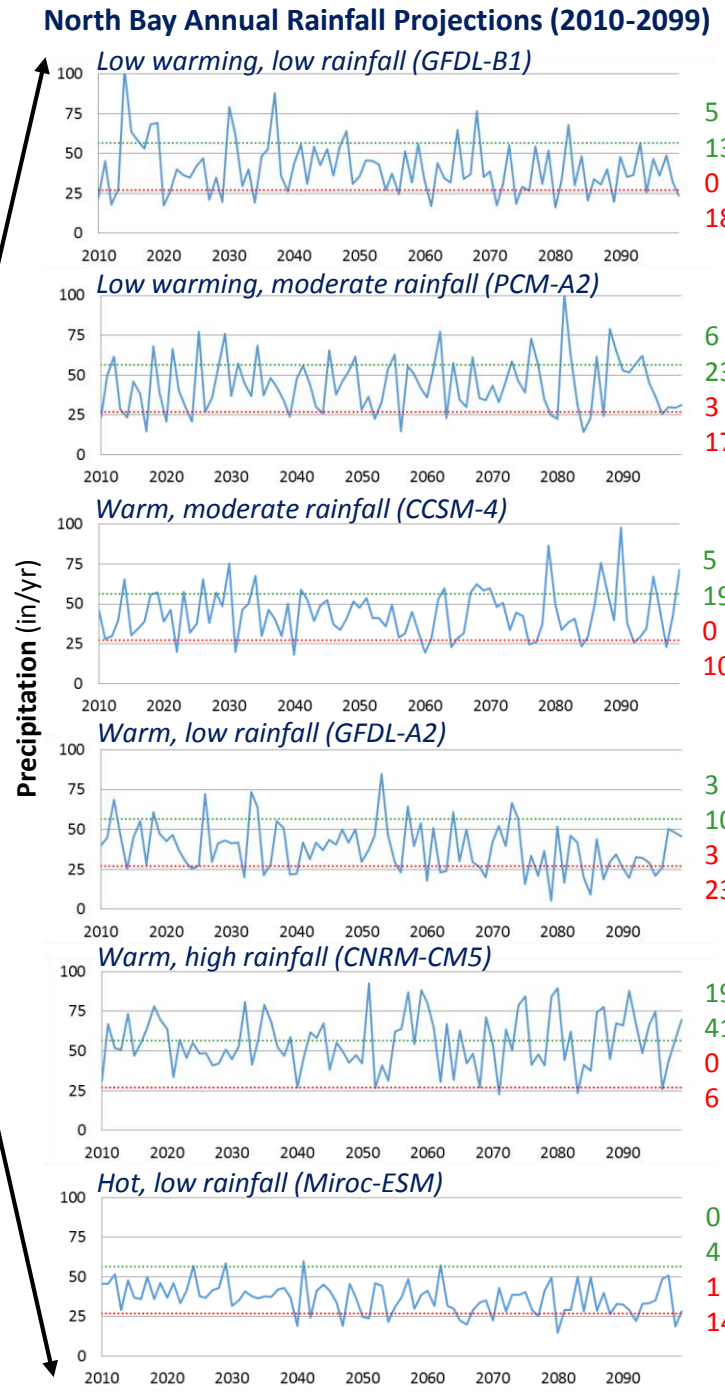
Extremes (1920-2009)

2 events >=1940

9 events >90th % (56.4in/y)*

1 events <=1976

9 events <10th % (27.1 in/y)*



Scenario 1
5 events >=1940
13 events >90th %
0 events <=1976
18 events <10th %

Scenario 2
6 events >=1940
23 events >90th %
3 events <=1976
17 events <10th %

Scenario 3
5 events >=1940
19 events >90th %
0 events <=1976
10 events <10th %

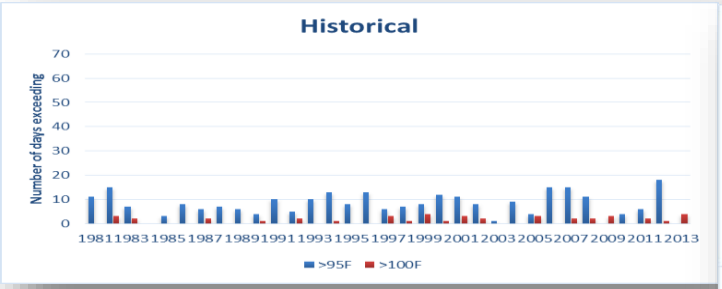
Scenario 4
3 events >=1940
10 events >90th %
3 events <=1976
23 events <10th %

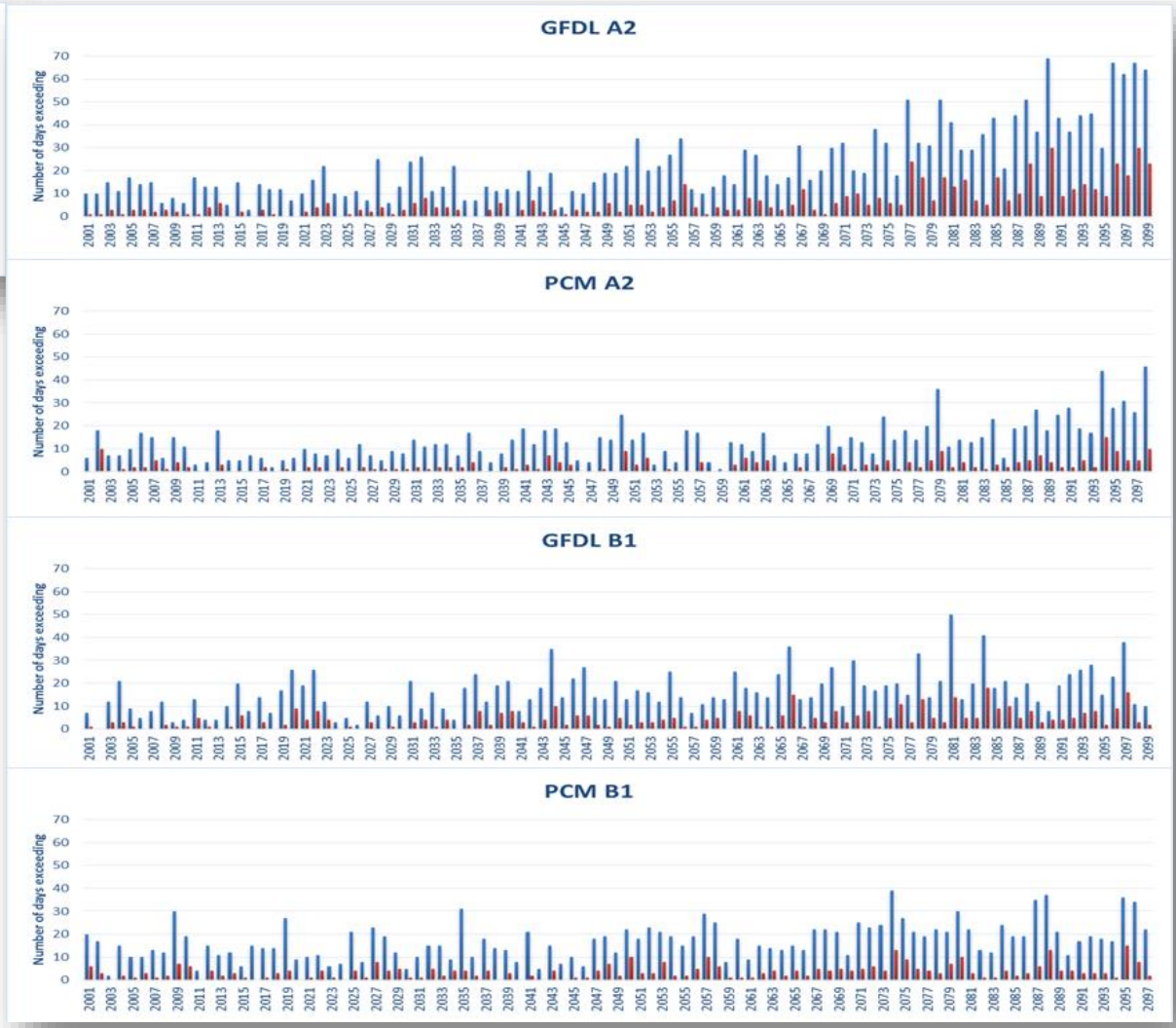
Scenario 5
19 events >=1940
41 events >90th %
0 events <=1976
6 events <10th %

Scenario 6
0 events >=1940
4 events >90th %
1 events <=1976
14 events <10th %

* 10th and 90th percentile benchmarks based on 1920-2009 record

Three-day Heat Waves
Santa Rosa Plain





Number of events of 3 or more days in a row where Tmax exceeds 95F for the Santa Rosa Plain.

	# of events	Tmax	Tmin
1981-2010	26	95.7	93.4
2010-2039	39	96.5	93.3
2040-2069	55	96.4	93.5
2070-2099	148	97.3	93.5

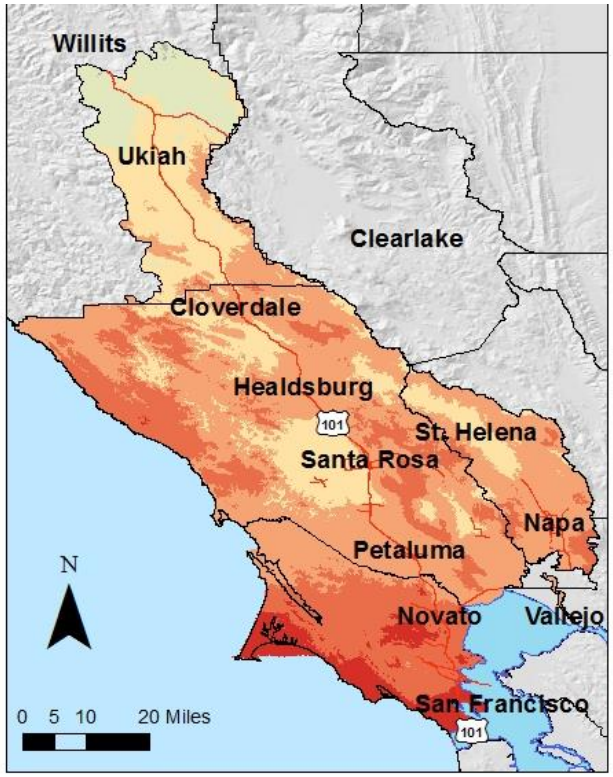
PCM wet model
GFDL dry model

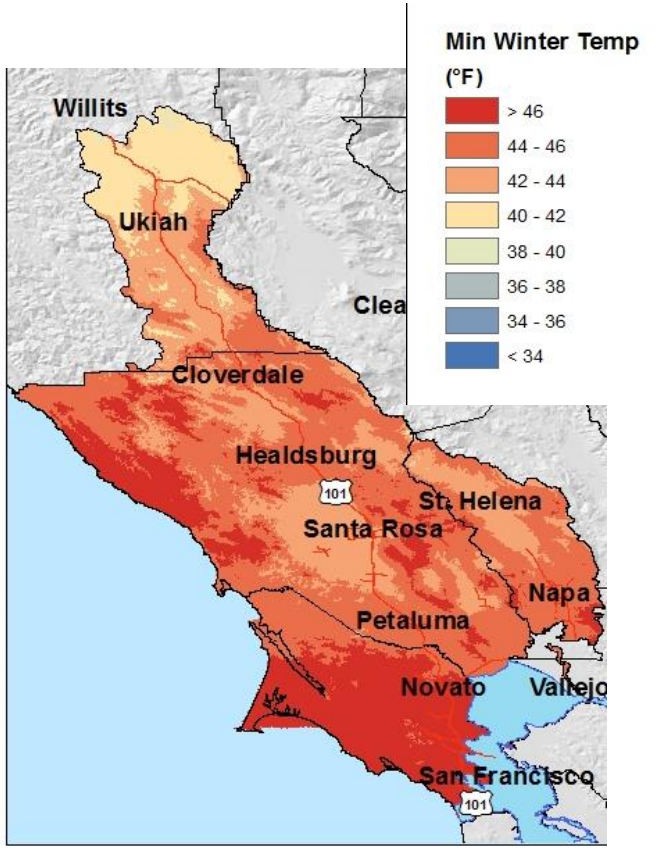
>95F >100F

Minimum winter temperature (monthly) (degF)

30-year average, current-moderate warming (projected)

(mod rainfall scenario)





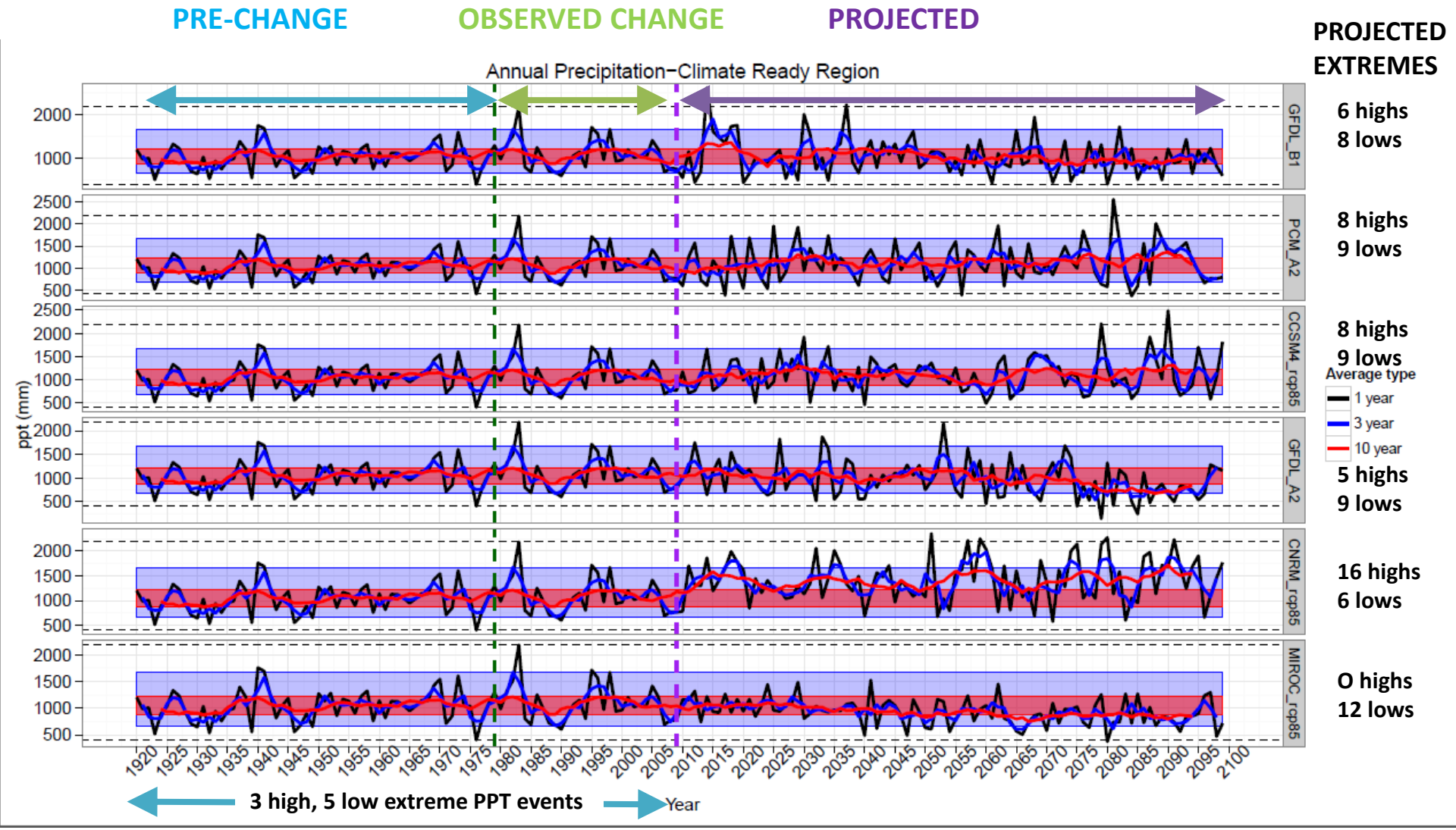
Current 1981-2010
39.7 average

Projected 2040-2069
43.0 average

Projected 2070-2099
44.8 average

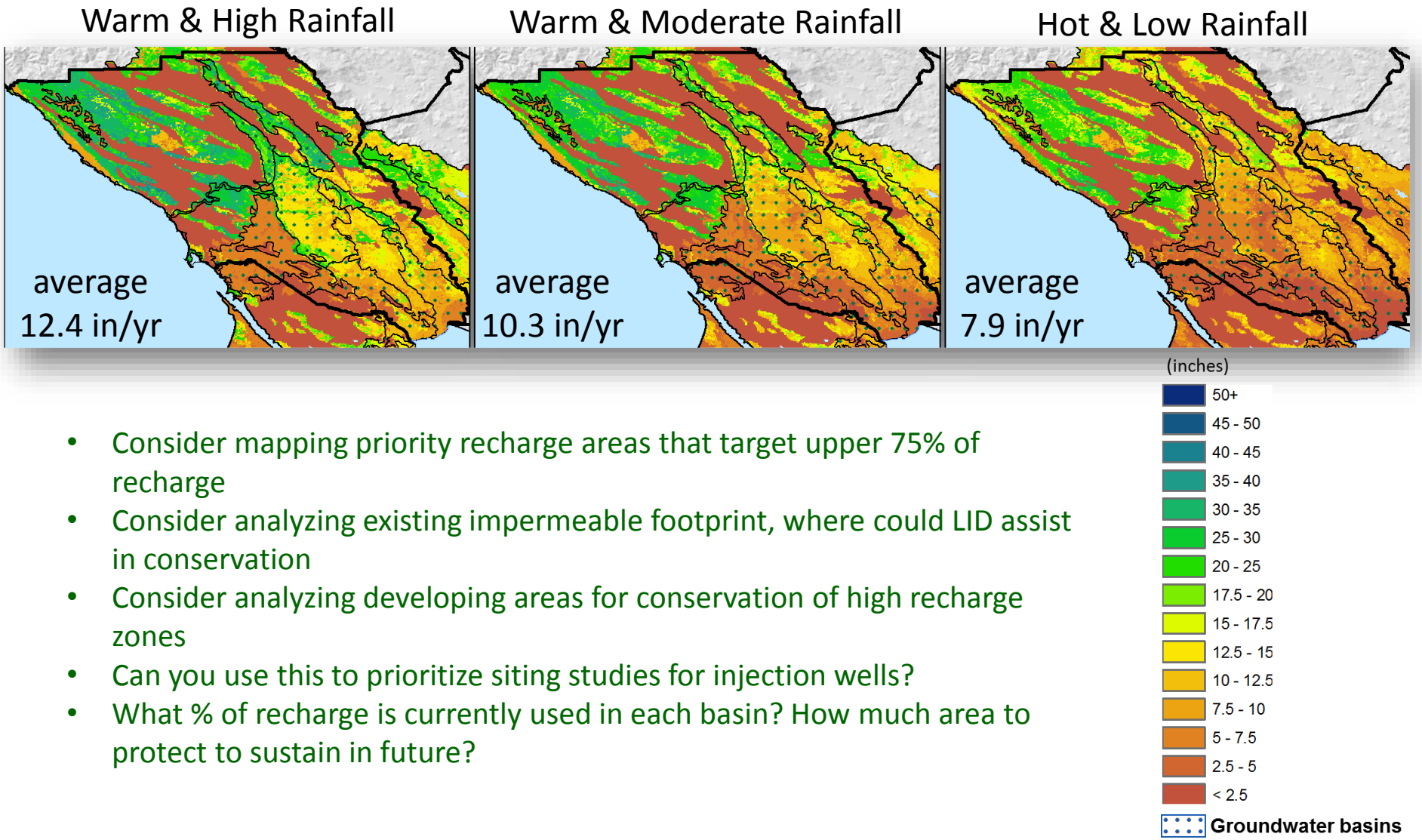
5.1 deg F greater by end of century than current

Annual Precipitation-North Bay Region



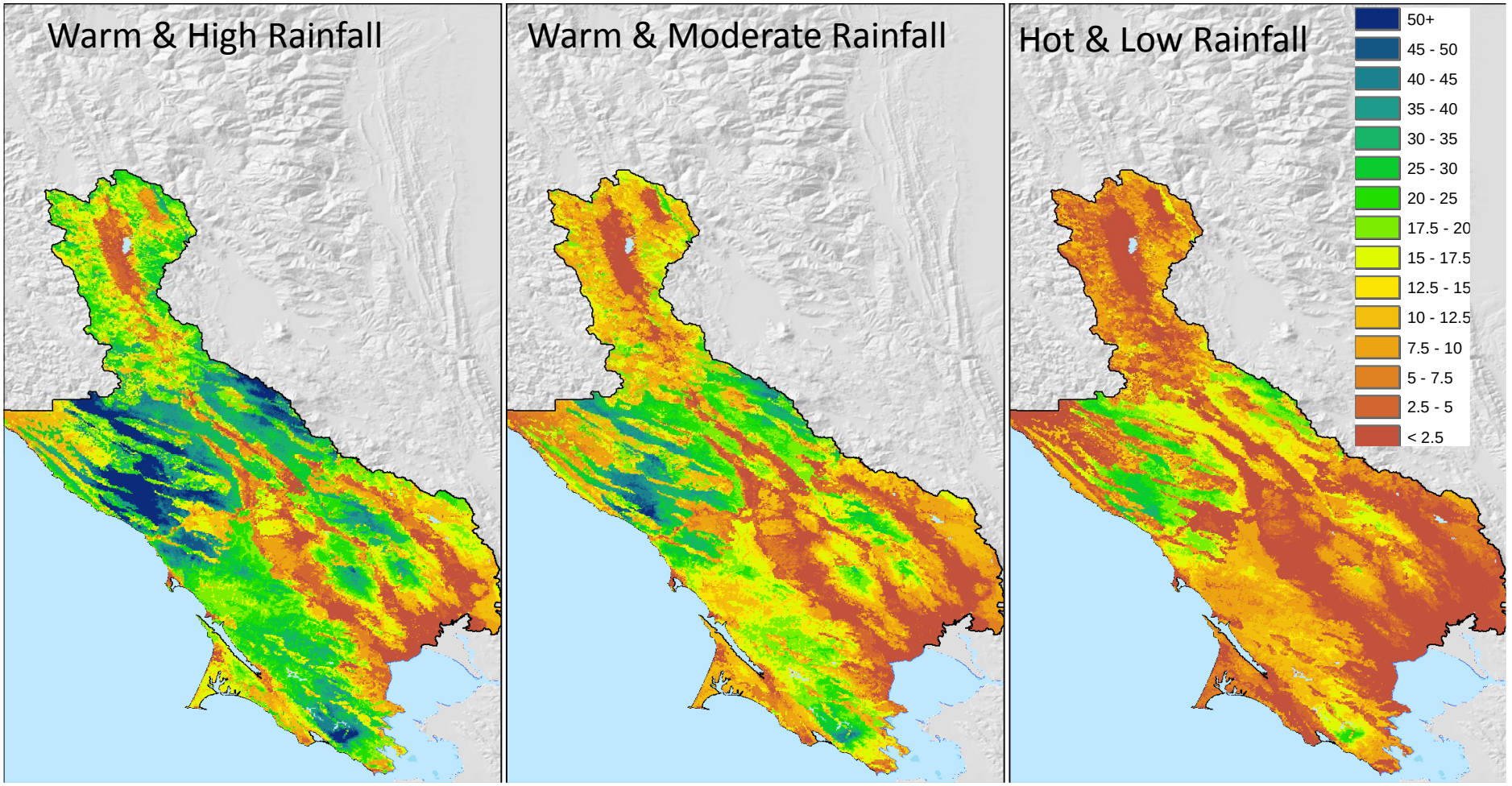
high and low extremes expected to approximately double frequencies in projections

Projected Groundwater Recharge 2040-2069



- Consider mapping priority recharge areas that target upper 75% of recharge
- Consider analyzing existing impermeable footprint, where could LID assist in conservation
- Consider analyzing developing areas for conservation of high recharge zones
- Can you use this to prioritize siting studies for injection wells?
- What % of recharge is currently used in each basin? How much area to protect to sustain in future?

Projected Runoff 2070-2099



27 in/y average

+83%

17 in/y average

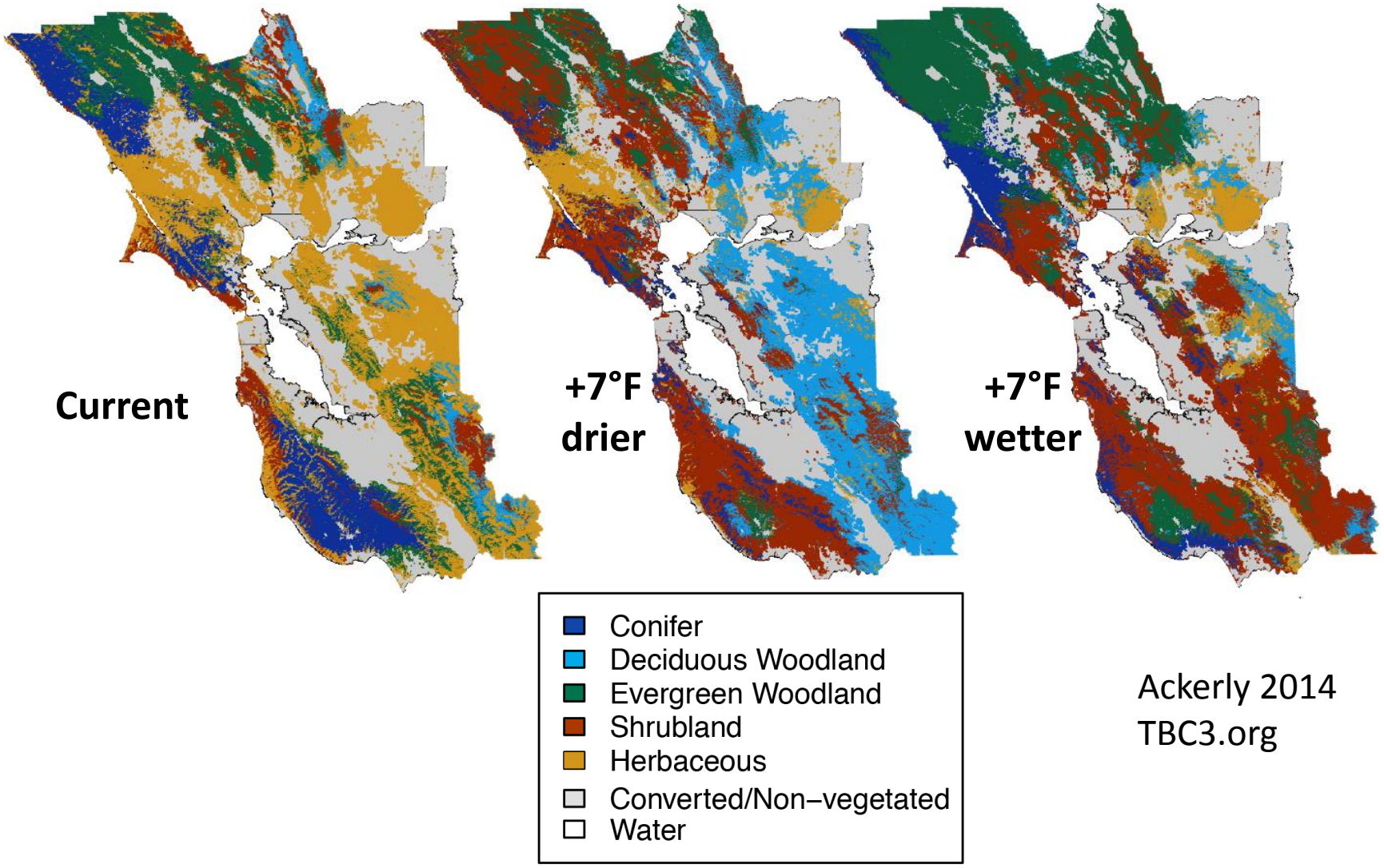
+22%

9 in/y average

-31%

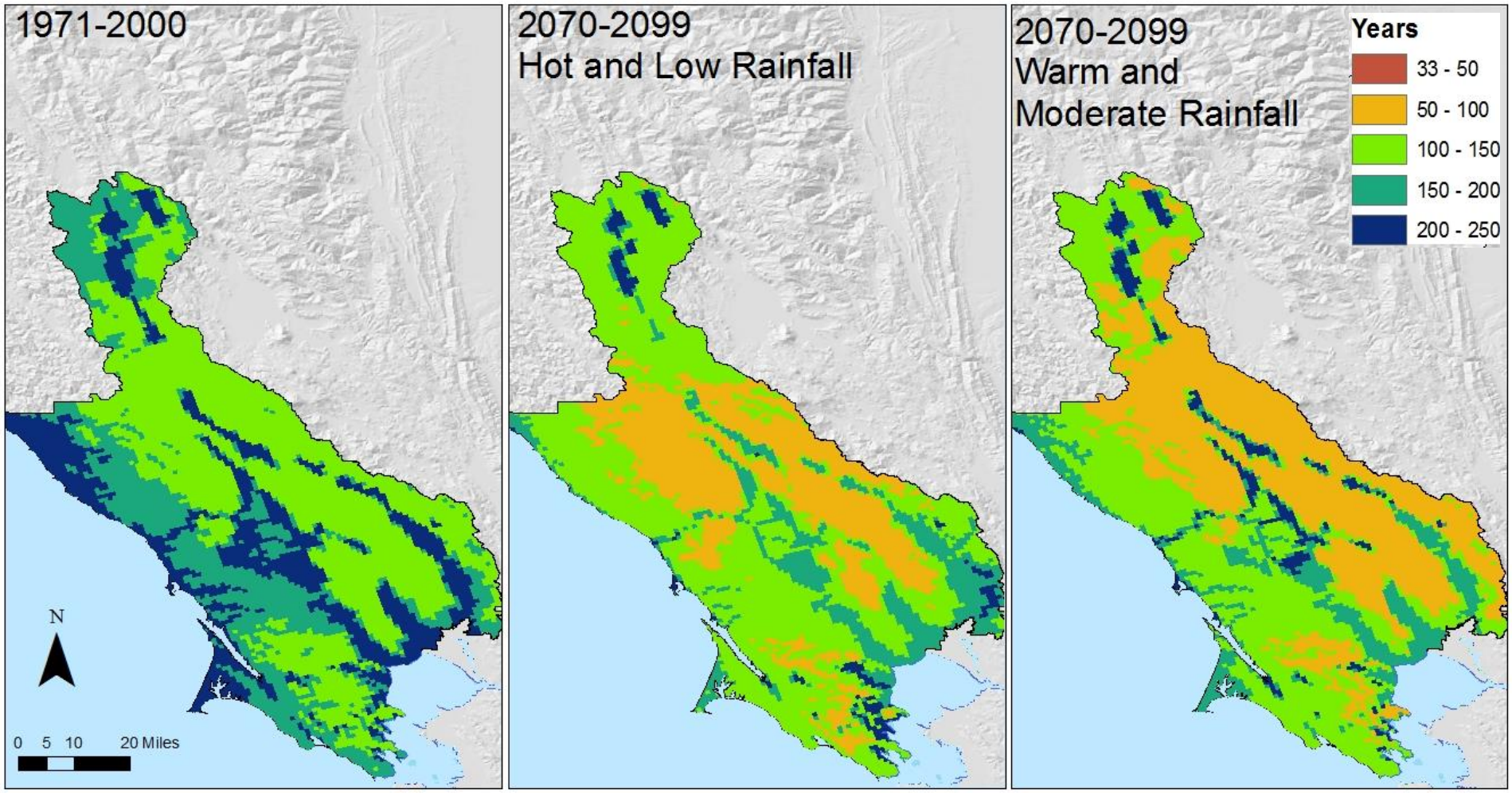
Change relative to current (1981-2010)

what might the Bay Area vegetation of the future look like?



Ackerly 2014
TBC3.org

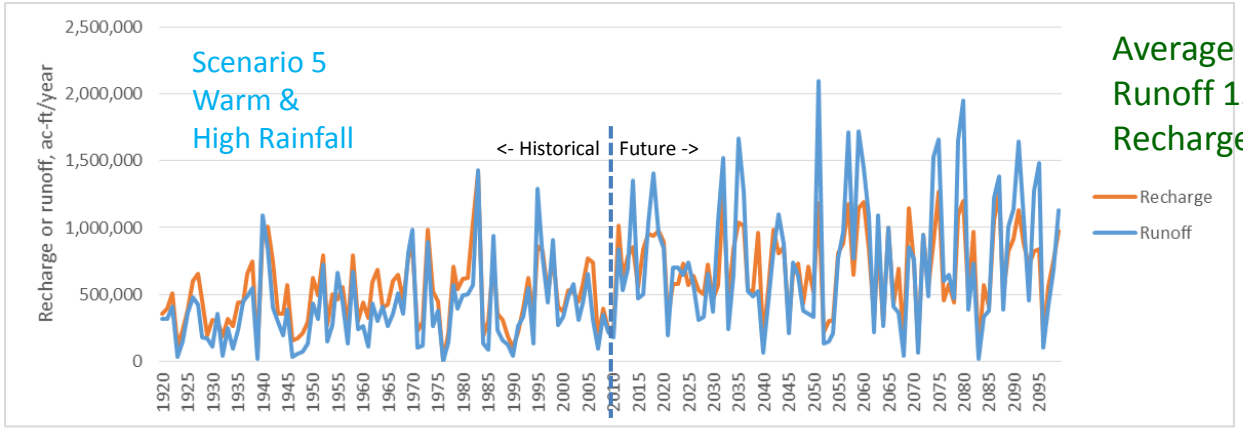
Change in Projected Fire Return Interval



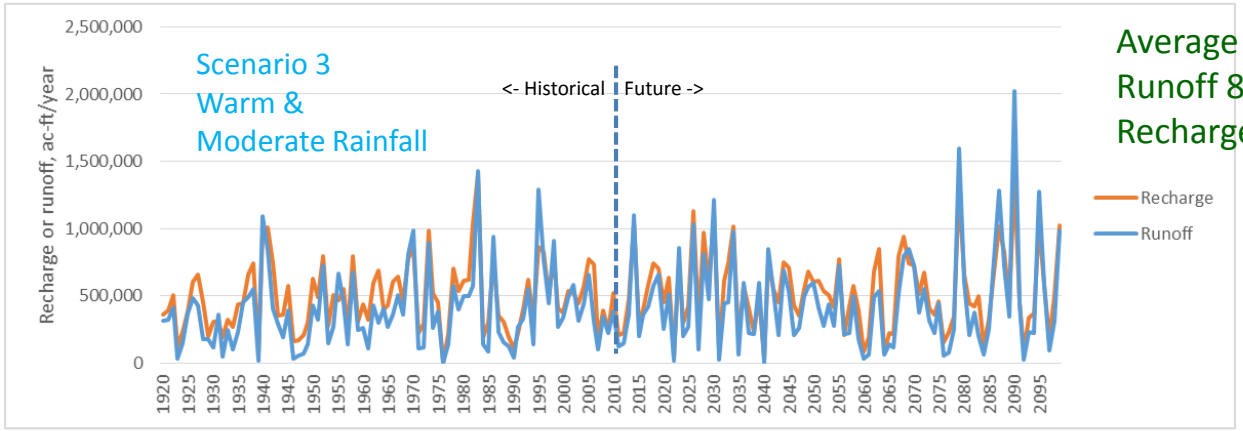
Fire return intervals reduced by approximately 25%

Napa Valley: Recharge and Runoff Comparison

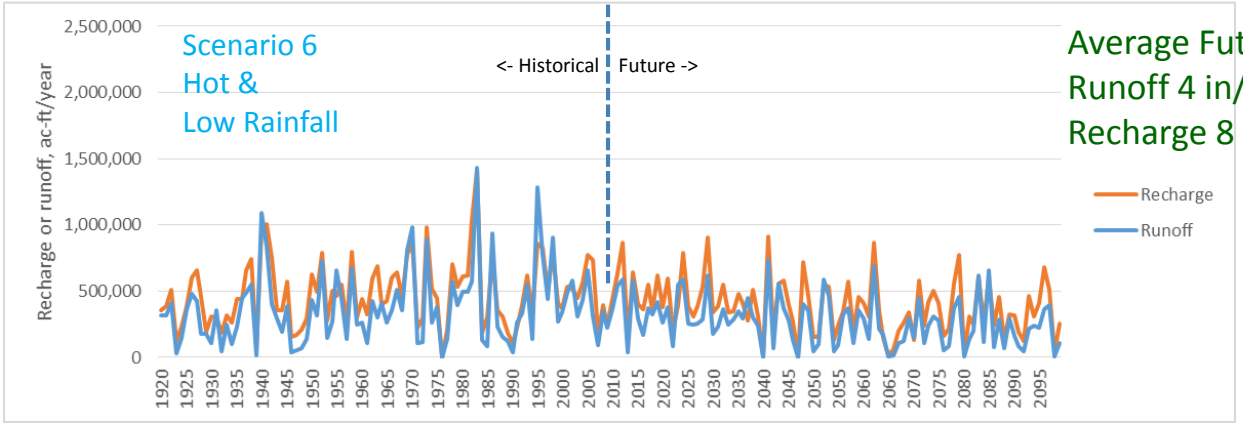
Average Historical
Runoff 8 in/yr
Recharge 11 in/yr



Average Future
Runoff 15 in/yr
Recharge 10 in/yr



Average Future
Runoff 8 in/yr
Recharge 11 in/yr



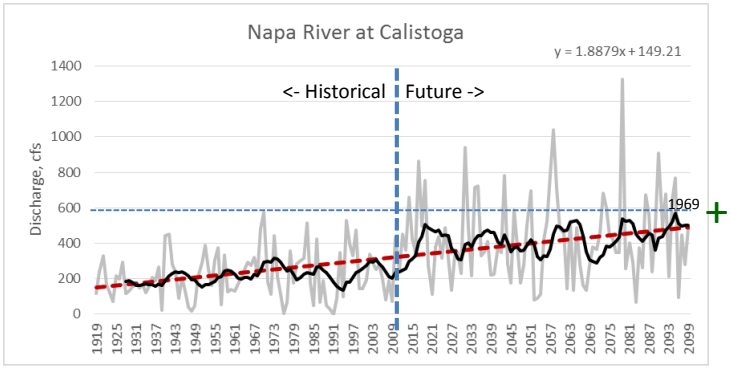
Average Future
Runoff 4 in/yr
Recharge 8 in/yr

Napa River Upstream

Winter peaks (Dec-Jan-Feb)

1969 is reference peak "year" of historical record

Scenario 5
Warm &
High Rainfall



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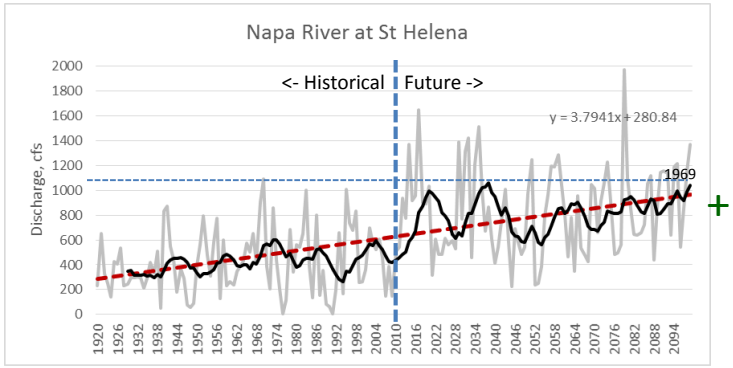
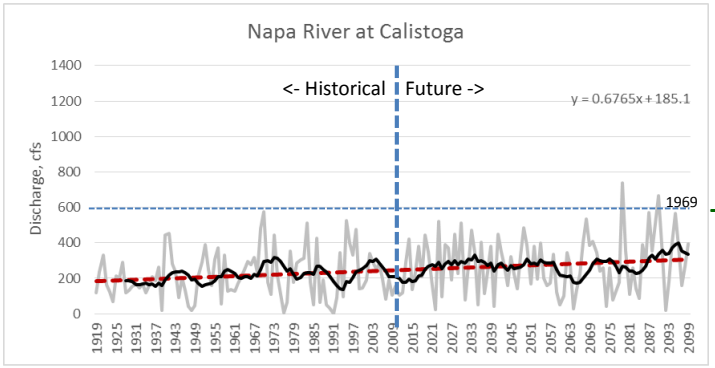


+19

Scenario 3
Warm &
Moderate
Rainfall



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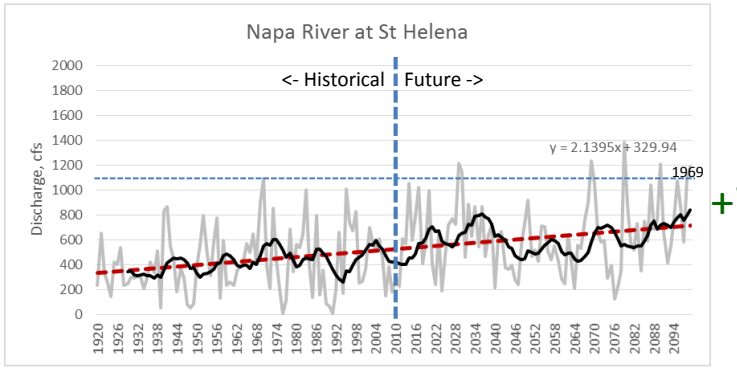

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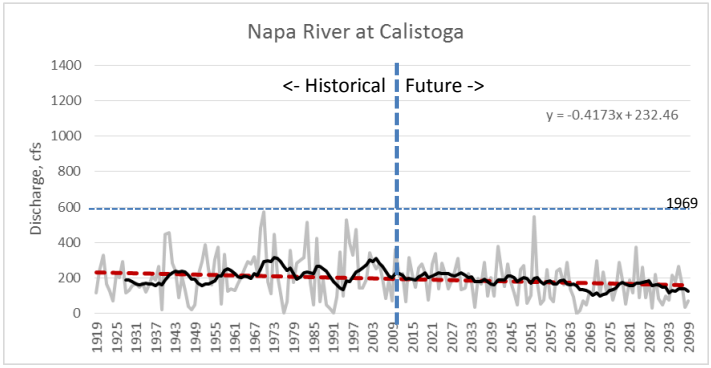
Scenario 6
Hot &
Low Rainfall



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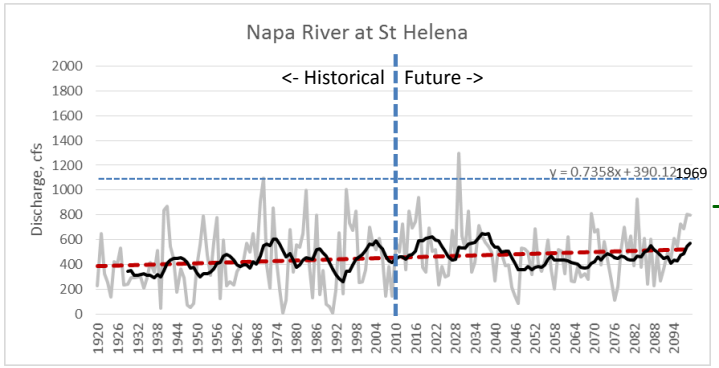

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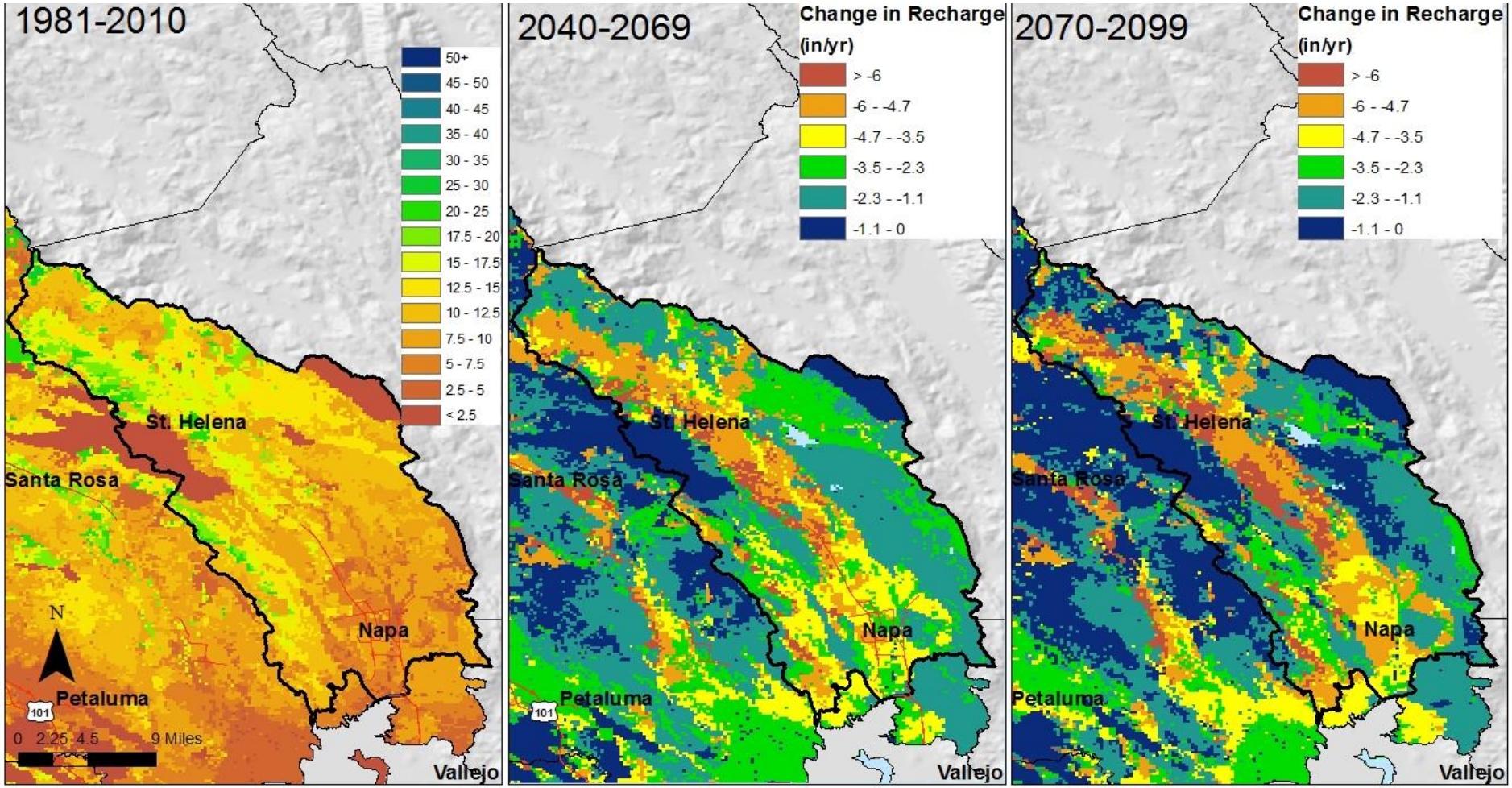
Napa River Valley Groundwater Recharge

Mid- and end-century change compared to current, Scenario 6-hot and low rainfall



11 in/y average for valley

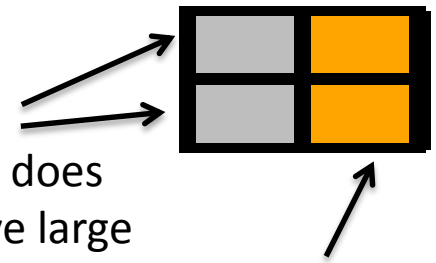
29% reduction
to 7.5 in/y average for valley

27% reduction
to 7.8 in/y average for valley

Low rainfall scenario results in losses of 2.5 inches of groundwater recharge per unit area annually

Vegetation change: 4-square diagrams

Example: *Redwood Forest is sensitive to temperature in Sonoma's Coast Range*



Rainfall does not have large affect

Significant declines emerge at hotter temperatures.

Color-coding the square quadrants shows the direction of change in percent cover in suitable climate for veg type (current to 2050)

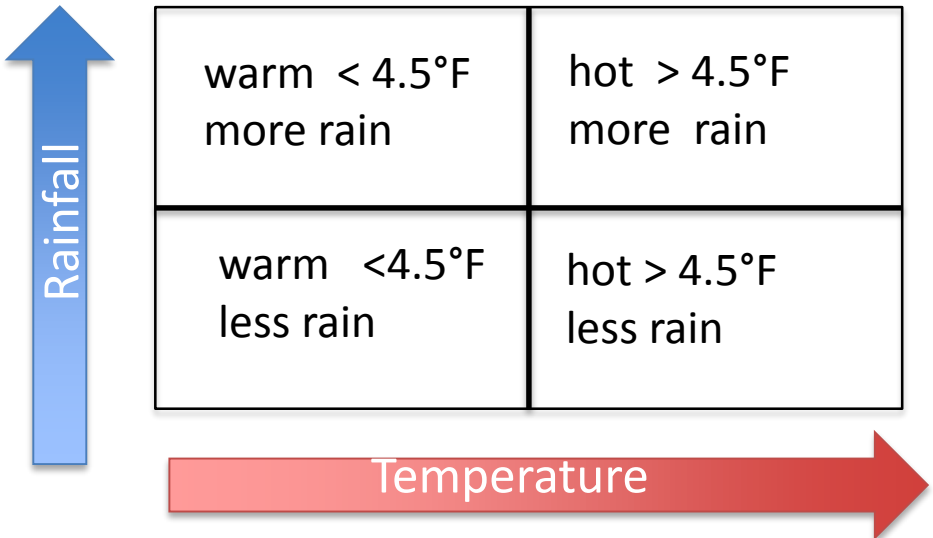
Red: Dramatic Decline (<25% of current)

Orange: Moderate Decline (25-75% of current)

Gray: Relative Stability (75-125% of current)

Green: Increase (>125% of current)

Each quadrant in the square higher or lower temperature and rainfall



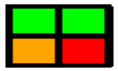
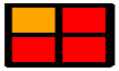
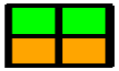
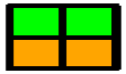
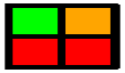
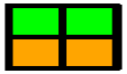
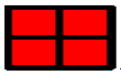
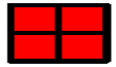
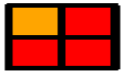
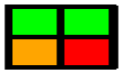
Four Square Diagrams: The prognosis for the 22 vegetation types in each landscape unit are shown below divided into 4 climate scenarios. Comparing the landscape units reveals differential vulnerability of vegetation across Napa County.

The color shows the direction of change in percent cover between current and 2050.

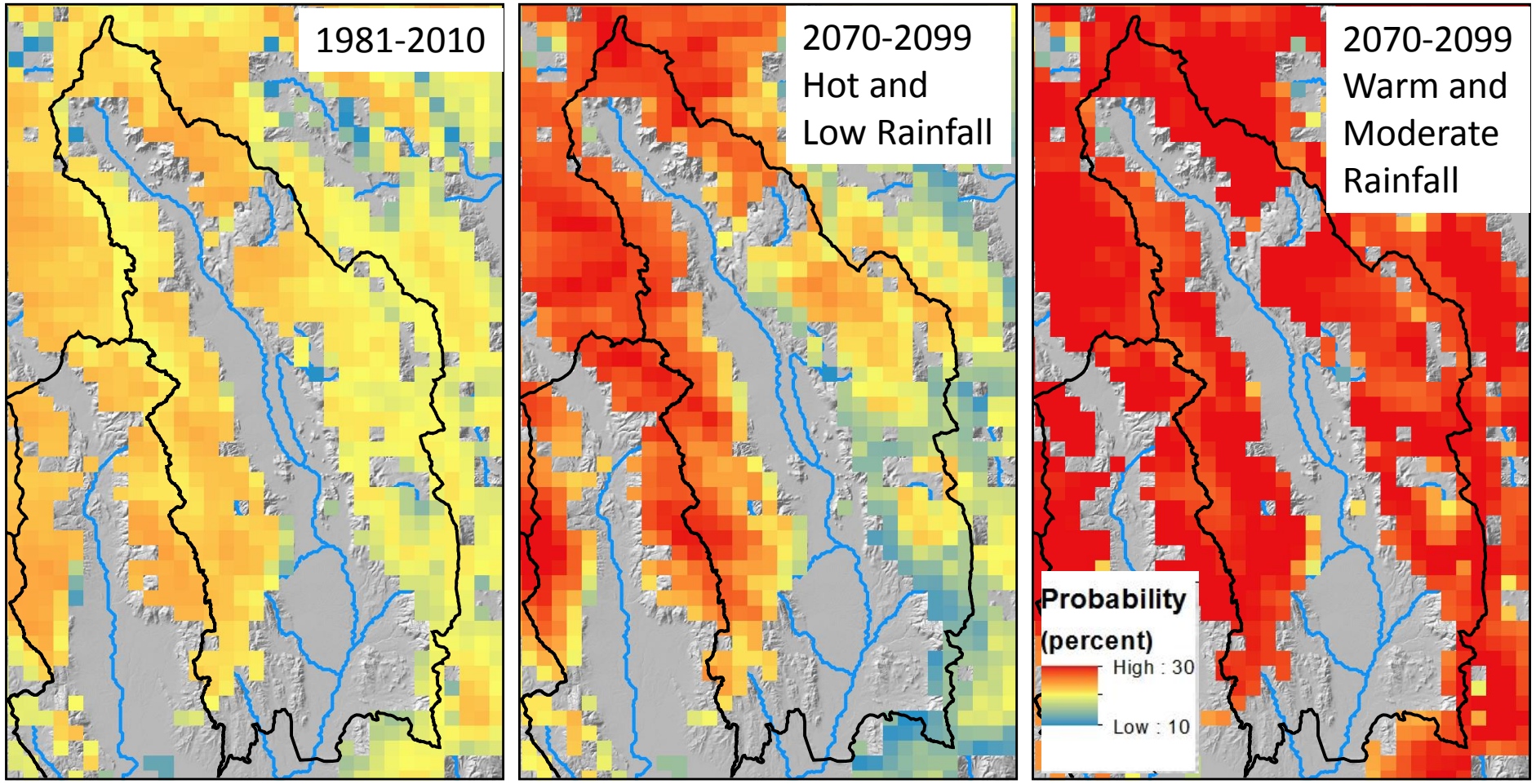
- Red: Dramatic Decline (<25% of current)
- Orange: Moderate Decline (25-75% of current)
- Gray: Relative Stability (75-125% of current)
- Green: Increase (>125% of current)

The position shows the scenario

Rainfall \ Temperature	Warm < 4.5°F	Hot > 4.5°F
High rain	Warm < 4.5°F High rain	Hot > 4.5°F High rain
Low rain	Warm < 4.5°F Low rain	Hot > 4.5°F Low rain

	Northern Mayacamas	Southern Mayacamas	Vaca Mountains West	Blue Ridge Berryessa	Napa Valley
Redwood Forest					
Douglas Fir Forest					
Ponderosa Pine Forest Nonmaritime					
Knobcone Pine Forest					
Tanoak Forest					
Canyon Live Oak Forest					
Black Oak Forest Woodland					
Oregon Oak Woodland					
Blue Oak Forest Woodland					

Change in Projected Probability of Burning One or More Times



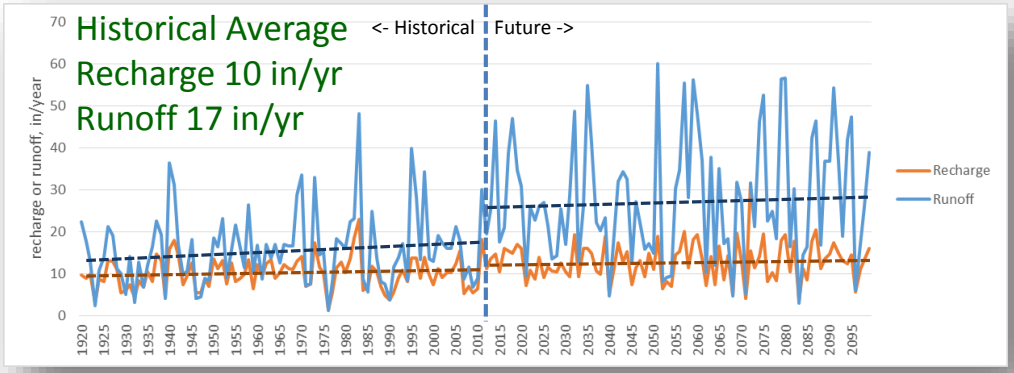
Probability of fire doubles in some locations

Urban and agricultural areas masked out

		Current	Hot, Low Rainfall	Moderate Rainfall
Variable	Units	1971-2000	2070-2099	2070-2099
Probability of burning 1	Percent	21%	22%	29%
or more times	SD	2%	5%	3%

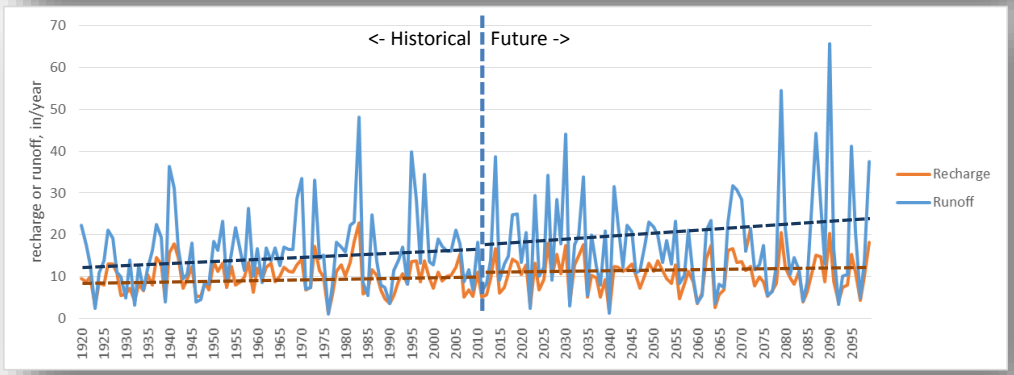
Sonoma County Recharge and Runoff

Warm &
High Rainfall



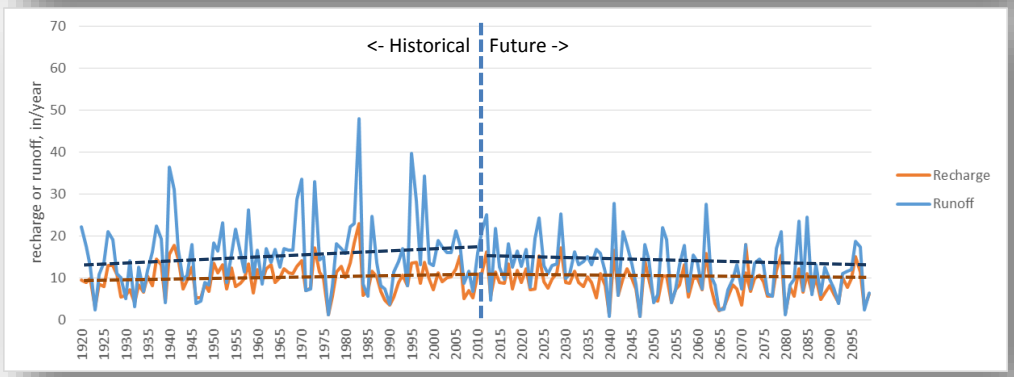
Warm & high rainfall future Averages
Recharge 13 in/yr
Runoff 28 in/yr

Warm &
Moderate
Rainfall



Warm & mod rainfall future Averages
Recharge 10 in/yr
Runoff 18 in/yr

Hot &
Low Rainfall



Hot and low rainfall future Averages
Recharge 8 in/yr
Runoff 11 in/yr

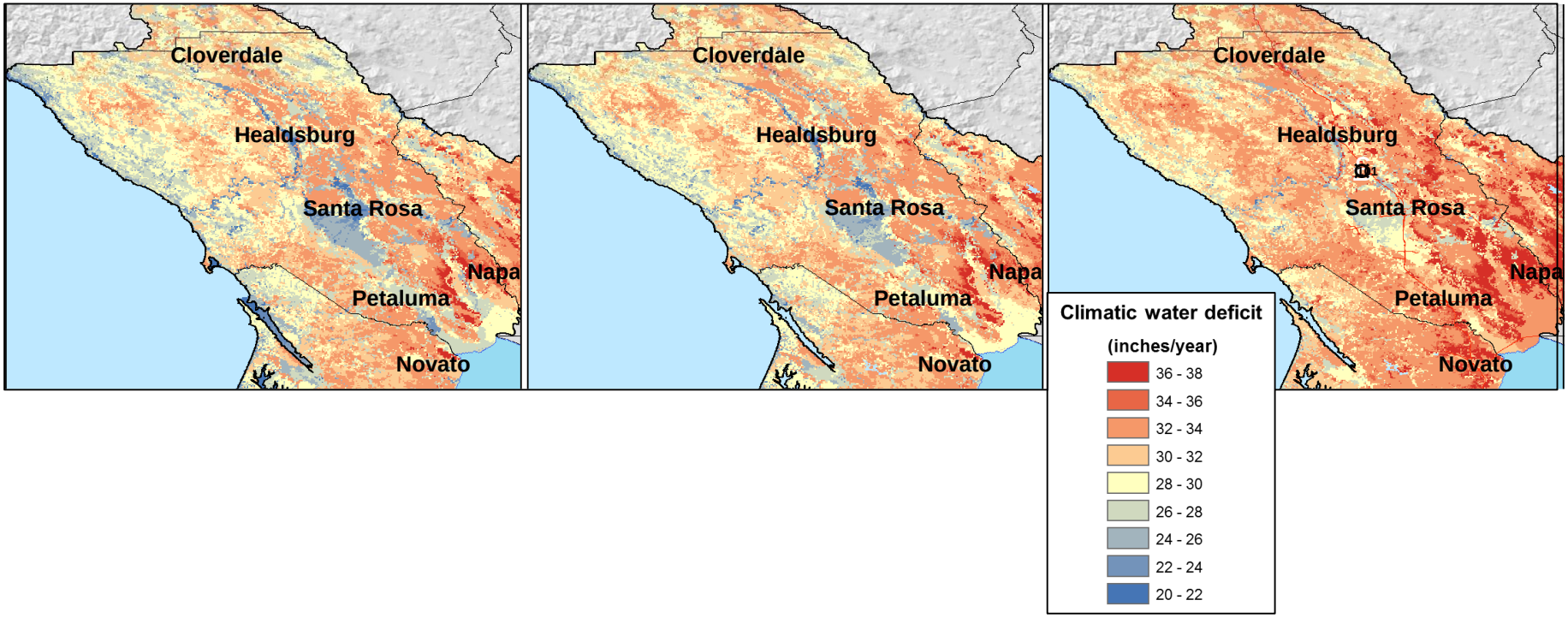
Recharge changes much less than runoff for all futures

Projected Climatic Water Deficit 2040-2069

Warm & High Rainfall

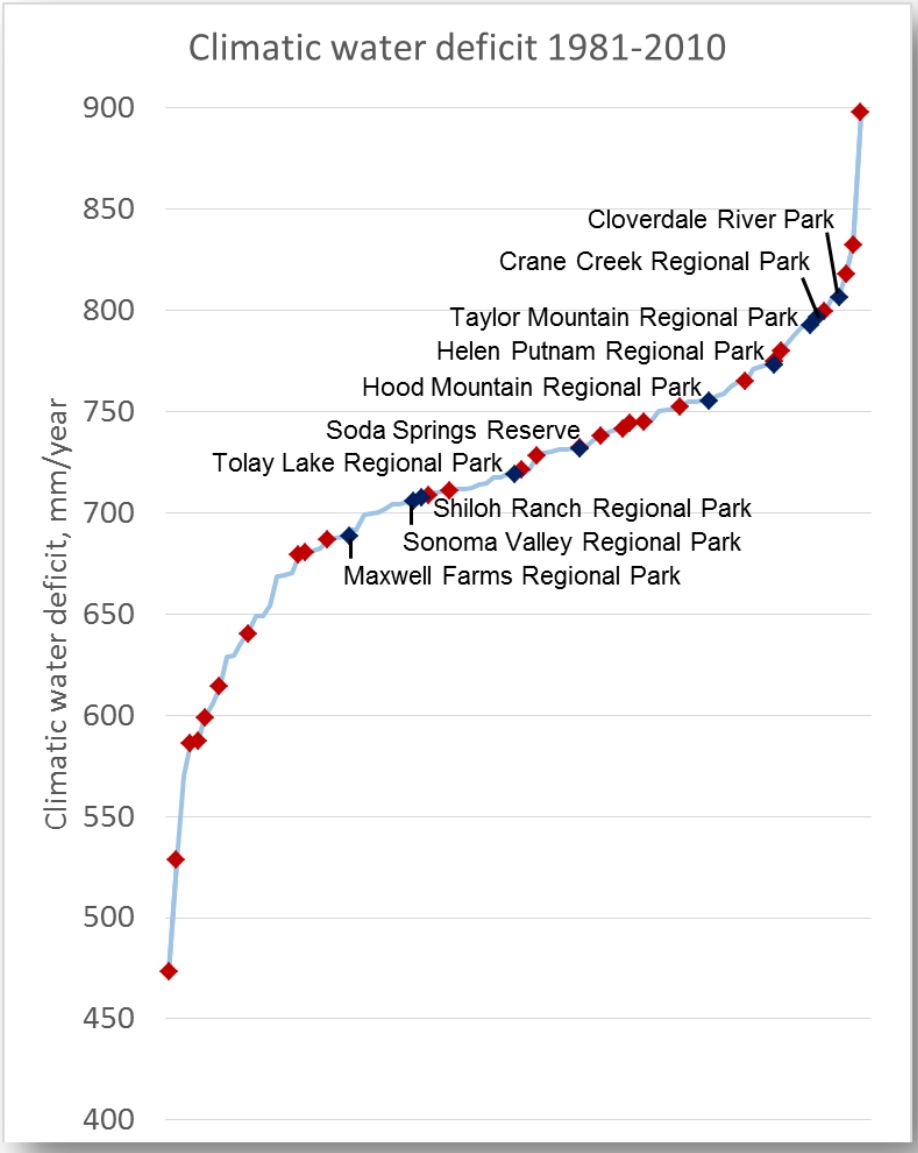
Warm & Moderate Rainfall

Hot & Low Rainfall



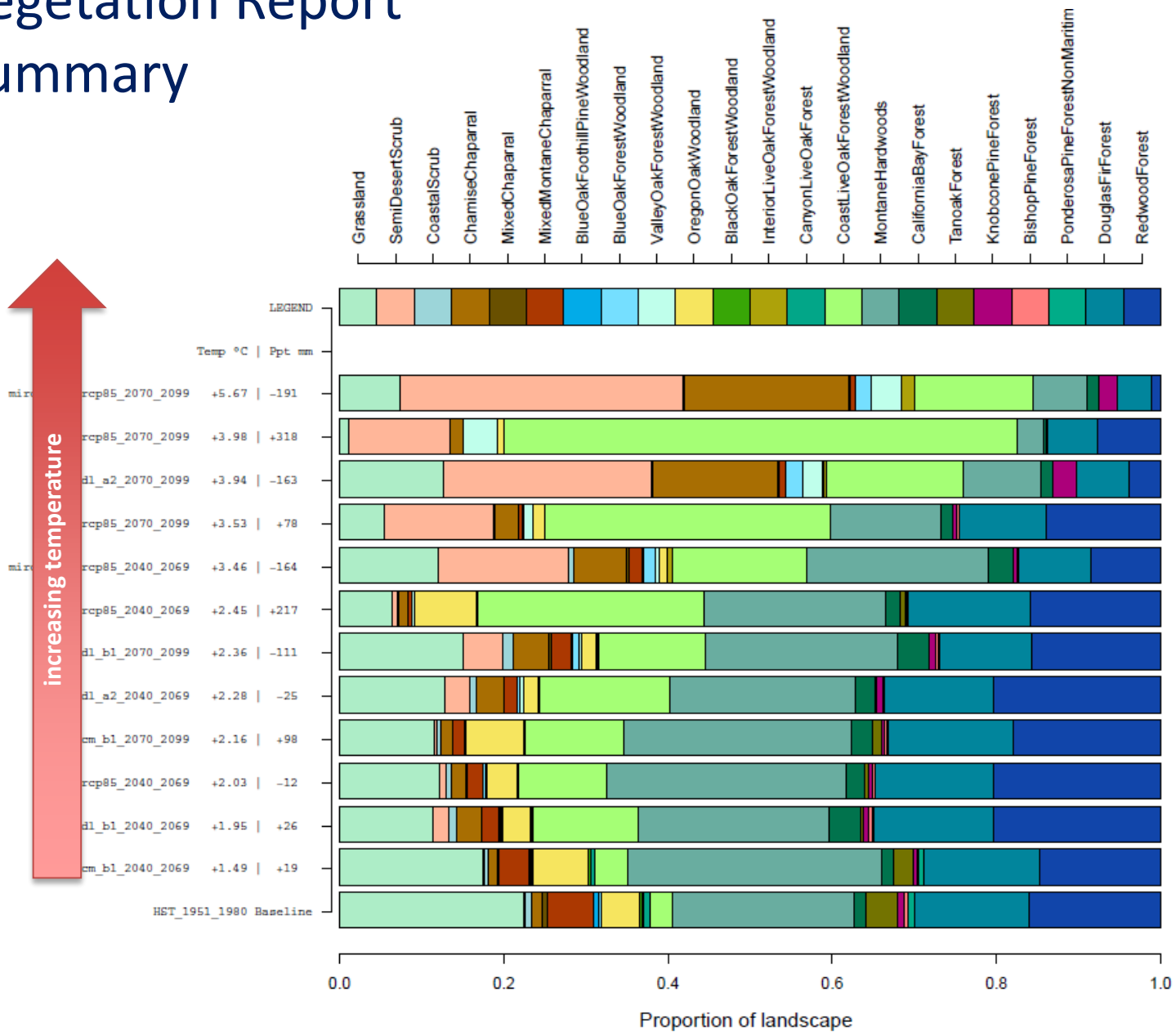
- CWD raises by mid-century due to increases in air temperature and evapotranspiration for all scenarios
- Increases are mostly in the lower elevation locations in the southern-most parts of Sonoma County
- CWD correlates to irrigation demand, landscape stress, vegetation distributions

How do the Regional Parks and District parcel CWD values compare with the distribution for all Sonoma County watersheds?



- Represented in the context of all Sonoma County watersheds parks tend to be located in the drier watersheds with the highest deficits
- OSD parcels span the entire range of CWD for all watersheds
- Maxwell Farms, Sonoma Valley, and Shiloh Ranch are the parks with the lowest deficits
- Cloverdale River, Crane Creek and Taylor Mtn are the parks with the highest deficits

Sonoma County Vegetation Report Summary

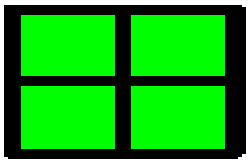


Reduced suitability for redwood, doug-fir, and montane hardwoods,

Increased suitability for coast live oak, semi-desert scrub, chamise chaparral

Sonoma Coast Range Examples

Coast Live Oak

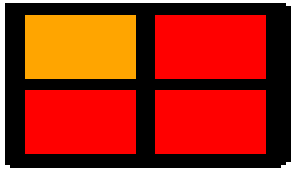


does well in all future scenarios regardless of warming magnitude and rainfall

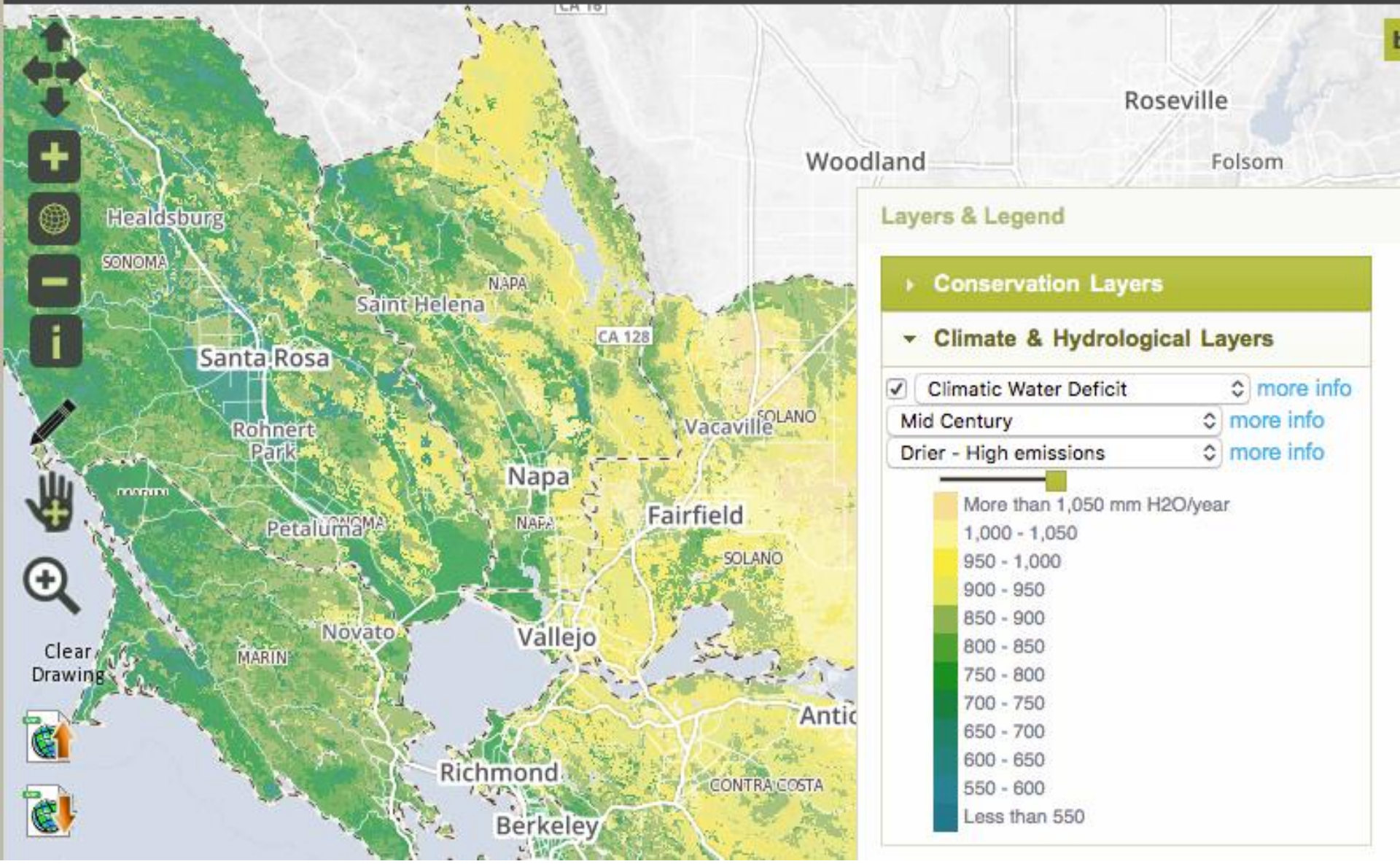
California Bay *is sensitive to rainfall*

does well in moderate scenario,
but declines in hot and low rainfall

Tan Oak *is sensitive to rainfall and temperature*



shows declines in all scenarios


Roseville
Woodland
Folsom
Healdsburg
SONOMA
NAPA
Saint Helena
CA 128
Santa Rosa
Rohnert Park
Vacaville
SOLANO
Napa
Fairfield
Petaluma
SONOMA
NAPA
SOLANO
Novato
Vallejo
MARIN
Clear Drawing
Richmond
CONTRA COSTA
Berkeley
Layers & Legend
Conservation Layers
Climate & Hydrological Layers
Climatic Water Deficit
more info
Mid Century
more info
Drier - High emissions
more info
More than 1,050 mm H2O/year
1,000 - 1,050
950 - 1,000
900 - 950
850 - 900
800 - 850
750 - 800
700 - 750
650 - 700
600 - 650
550 - 600
Less than 550

San Francisco Bay Area Climate-Smart Watershed Analyst - Beta Release

How is climate change shaping the future of the Bay Area's natural resources?

The Watershed Analyst lets you access climate and hydrology data to help your community get climate ready.

You can explore historic climate and water patterns and compare with modeled future scenarios, create graphs, and download climate-water summaries for your watershed.

explore your watershed

The Watershed Analyst is a project of TBC3, Pepperwood Foundation, Point Blue Conservation Science, and the Climate Commons, and was funded by the Gordon and Betty Moore Foundation. This is a beta release.

Climate Ready data menu

Primary BCM outputs:

Temperature Rainfall Runoff Groundwater recharge
Evapotranspiration Soil moisture Climatic water deficit

Secondary, derived variables:

Fire frequency (% annual likelihood of fire, or annual return interval)

Potential native vegetation transitions

Time scales: historical (1910-2010) and projected (2010-2100)

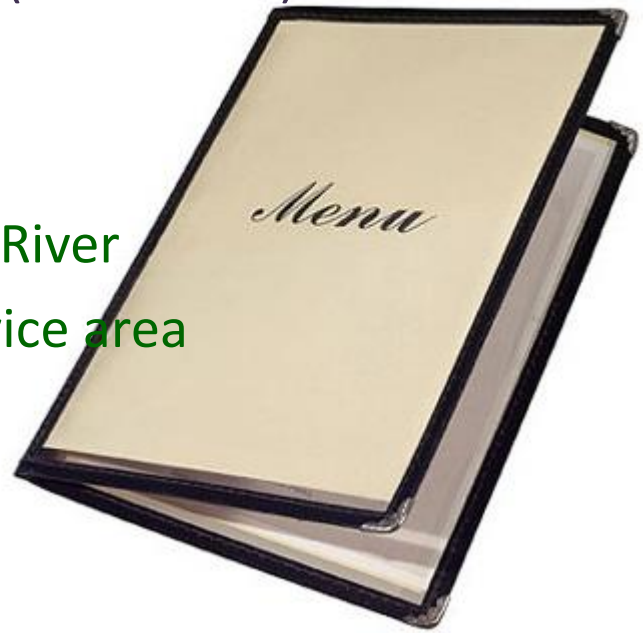
30-yr average, annual, or monthly/seasonal

Spatial scales:

Regional: North Bay watersheds plus Russian River

Sub-regional: watershed, landscape unit, service area

County Large parcels



California Landscape Conservation Cooperative

Climate Commons

Home | Datasets | Documents | Web Resources | CA LCC Projects | Get Started | Contact Us

Climate Ready North Bay

A climate adaptation knowledge base for planning the future of North San Francisco Bay Area watersheds. About the Climate Ready North Bay Project.

Climate Ready Exchange Pages

North Bay Region:

Methodology and Supporting Information
Key Vulnerability Assessment Findings
Lessons Learned and Applications
Vegetation Reports

Russian River Watershed:

Sonoma County Water Agency and Mendocino County Water Conservation and Flood District
Domain: Sonoma County plus Russian River Basin of Mendocino County

Napa Valley Watershed:

Napa County, Departments of Planning and Public Works and Watershed Protection District
Domain: Napa Valley

Sonoma County Municipalities:

Regional Climate Protection Authority PAC and TAC Users
Domain: Sonoma County and sub-watersheds
Climate Action 2020 Chapter 6: Sonoma County Climate Readiness

http://climate.calcommons.org/crnb/home

SonomaEcologyCenter.org
NorthBayClimate.org
caitlin@sonomaecologycenter.org

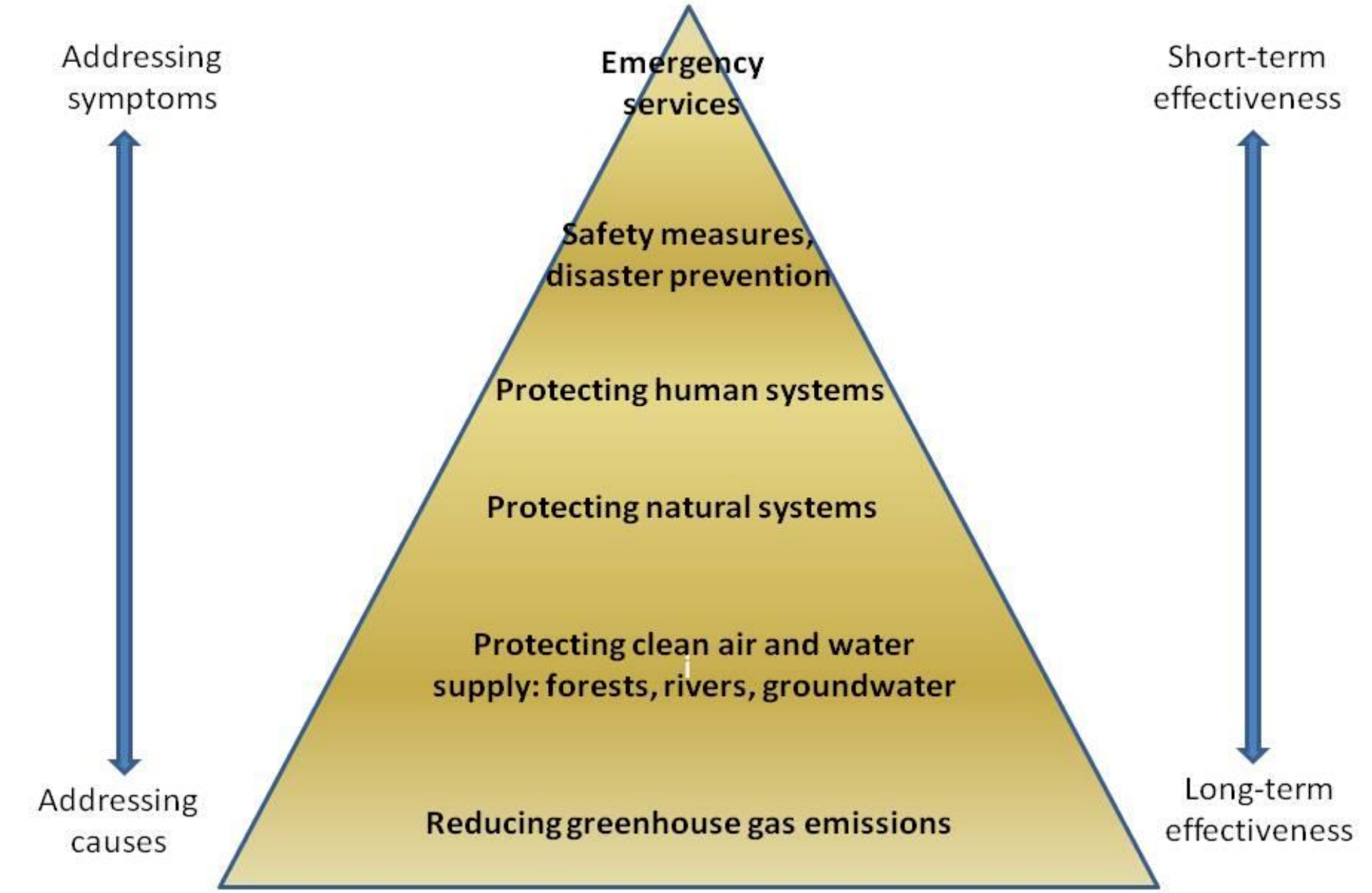
Sicke, Lund, Medellín-Azuara UC Davis, for CEC, 2012

- Bay-wide urban water supply crisis constraints and opportunities, pays little attention to local supplies
- Emphasizes importance of interties and ability to transfer water
- Emphasizes low cost and effectiveness of urban water conservation

Water Quality Vulnerabilities

- From IRWMP Climate Change chapter: Water quality will be impacted by more frequent intense storms, which can result in high turbidity that can result in water treatment plant operational challenges and in sediment transport issues in surface streams. Water stored in subregional reservoirs is vulnerable to increased taste and odor events in dry seasons due to increased temperature. Agencies depending on the North Bay Aqueduct (NBA) water may also experience increased issues with DBPs because of increased TOC in the source water. Potential vulnerability for increased salinity in delta supplies, increased potential for algae and turbidity in imported and local water, and concentrated runoff in rivers and creeks.

Building Blocks of Climate Response

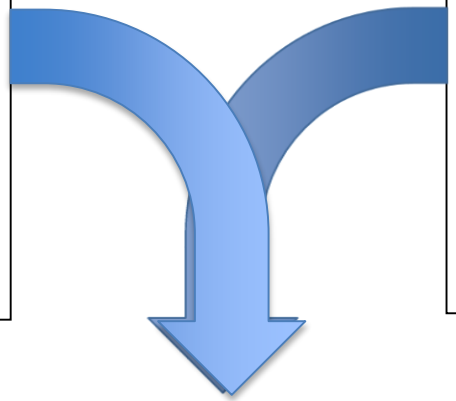


oncept: Sara Moore.

“If you find yourself in a hole, stop digging.”

Will Rogers

Mitigation
Reduce greenhouse gas emissions, sequester carbon



Adaptation
Protect communities from inevitable impacts of climate change

WIN-WIN-WIN

- Water efficiency
- Energy efficiency
- Local power
- Local food
- Natural water infrastructure
- Compact development
- Diverse agriculture
- Biodiversity-oriented forestry