Water Sustainability Indicator System

Fraser Shilling
University of California Davis
fmshilling@ucdavis.edu

Sustainable Water Resources Roundtable
Tuesday, December 6, 2011
University of California, Davis

Acknowledgements

Department of Water Resources & Others – DWR: Stefan Lorenzato, Abdul Khan, Rich Juricich, Kamyar Guivetchi); EPA: Vance Fong, Don Hodge; & CALFED Watershed Program

UC Davis Crew: a) Jennifer Hemmert, Allan Hollander, Ph.D., Keir Keightley, David Waetjen, Emil Aalto, Lisa Komoroske; b) Iara Lacher, Susana Cardenas, Caitlin Cornwall

Sacramento River Watershed Project

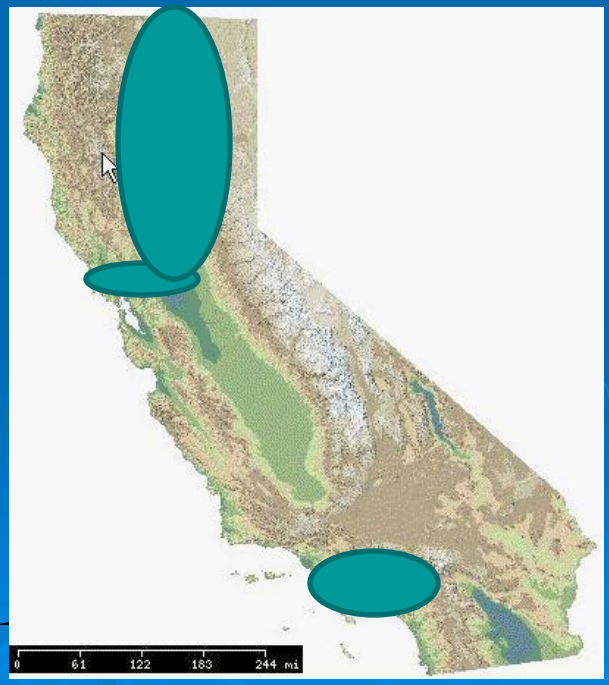
- Mary Lee Knecht (Sacramento River Watershed Project)
- Carol Murray, Darcy Pickard, Katherine Wieckowski, & Marc Porter (ESSA)
- Carrie Monahan (The Sierra Fund)
- Jim Wilcox & Kara Rockett (Feather River Coordinated Resource Management)

North Bay Project (Napa County)

- Frances Knapczyk & Bob Zlomke (Napa County Resource Conservation District)
- Caitlin Cornwall, Deanne DiPietro, Zhahai Stewart, Arthur Dawson, Liz Lotz(Sonoma Ecology Center, Sonoma)
- Jeff Sharp & Lynsey Kelly (Napa County Conservation, Development and Planning Department, Napa)
- Rich Adams (Oregon State University, Agricultural and Resource Economics Department)

Southern California Watersheds Project (LASGRWC)

- Mike Antos , Jason Casanova & Nancy Steele (Los Angeles San Gabriel Rivers Watershed Council)
- Stephanie Pincetl (US Forest Service)
- Terri Hogue (UCLA)
- Bob Vos & Travis Longcore (USC)

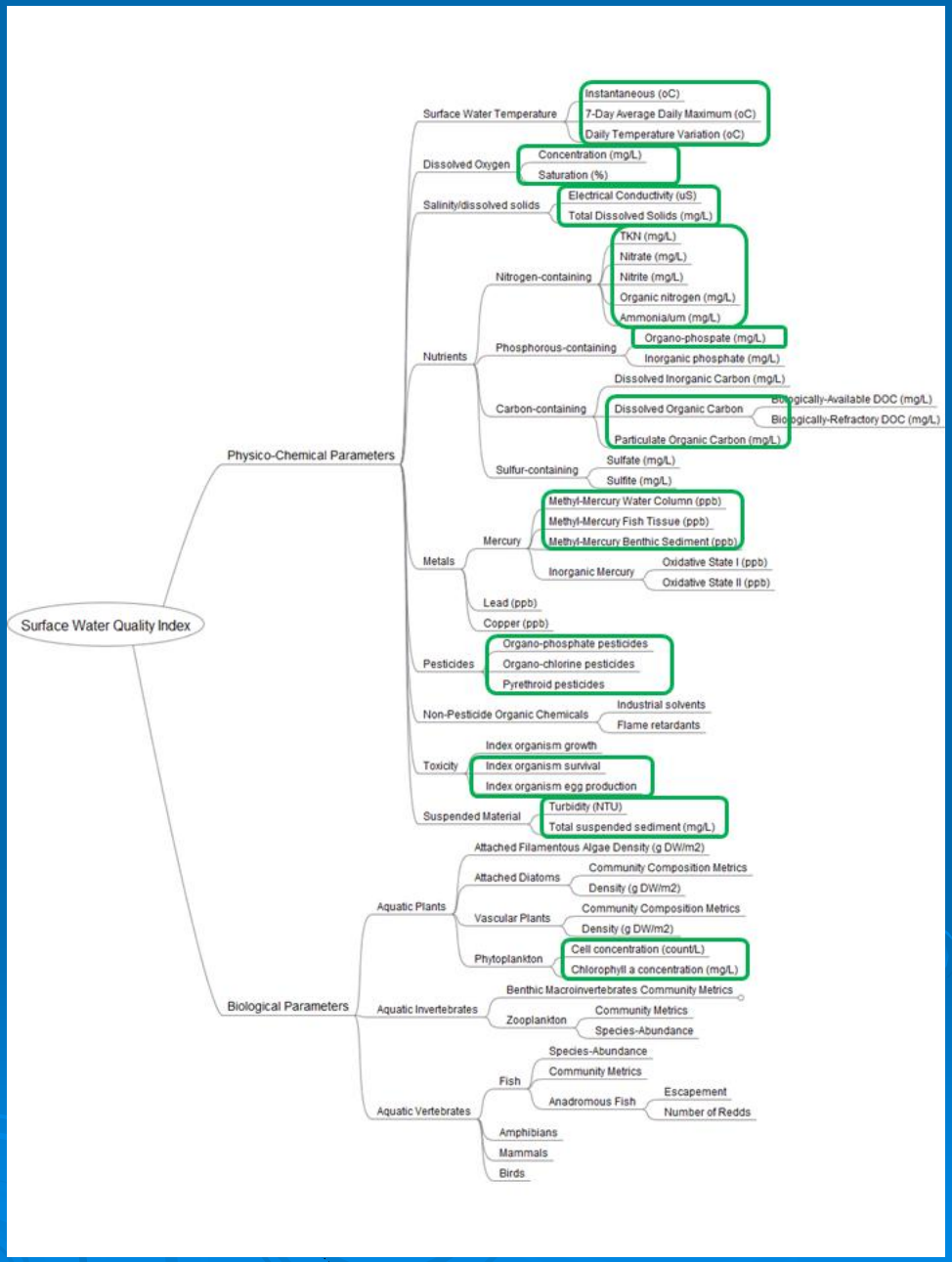


Overview

- California water sustainability goals and objectives
- Methods
- Interface with IRWM
- Phase II – regional and statewide proof of concept

Terminology

- Metrics
- Performance Measures
- Indicators
- Domains
- Objectives
- Goals
- Vision
- Sustainability



Assumptions

People/agencies/decision-makers want to know how environmental (community, nature) conditions are doing and changing.

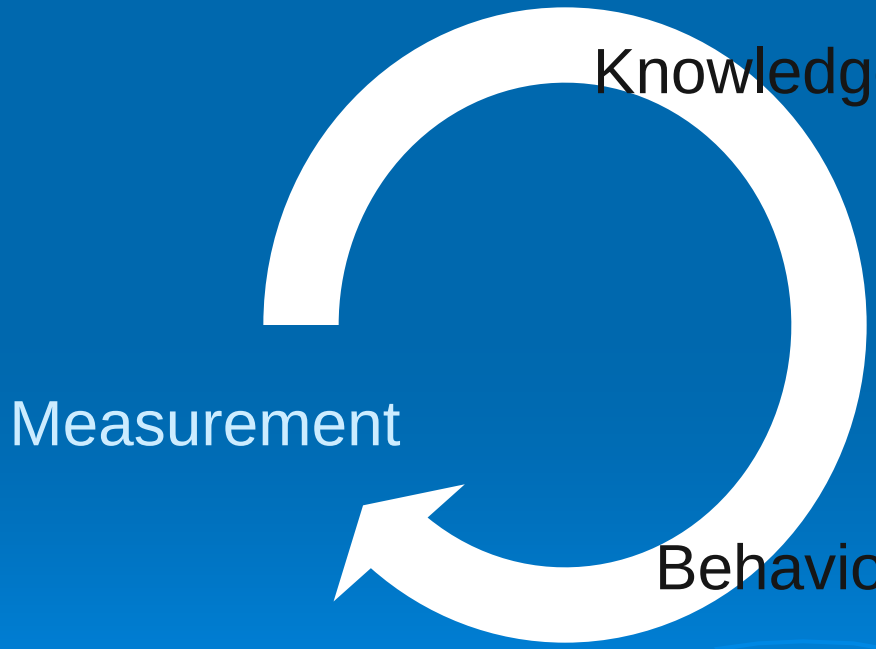
Indicators and report cards can be used to share with the public simplified interpretations of condition of a system and trends over time.

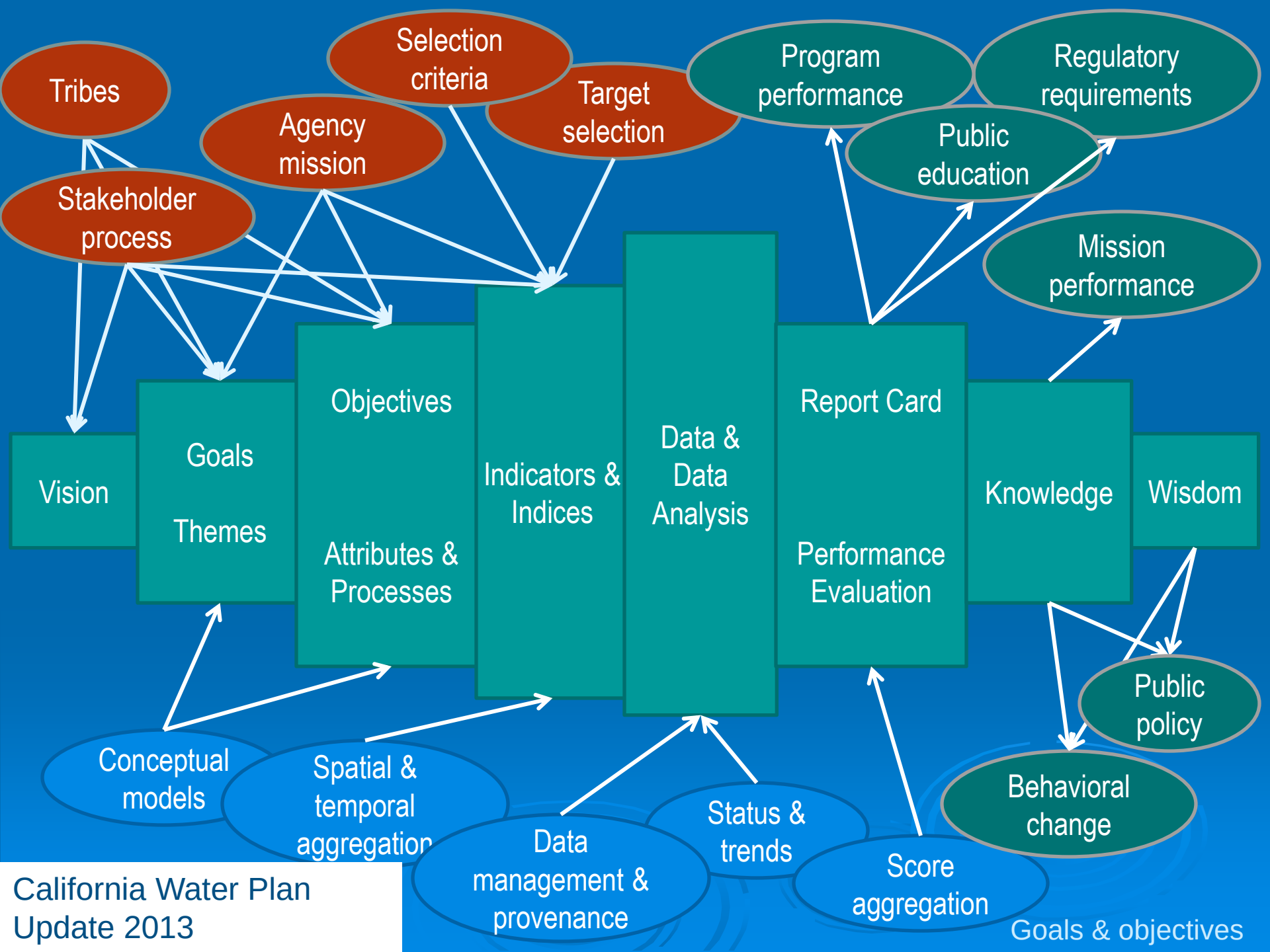
Indicators represent the system(s) in question and can be analyzed over time as a way of measuring the pulse of the system(s).

Searching for Sustainability: Continuum

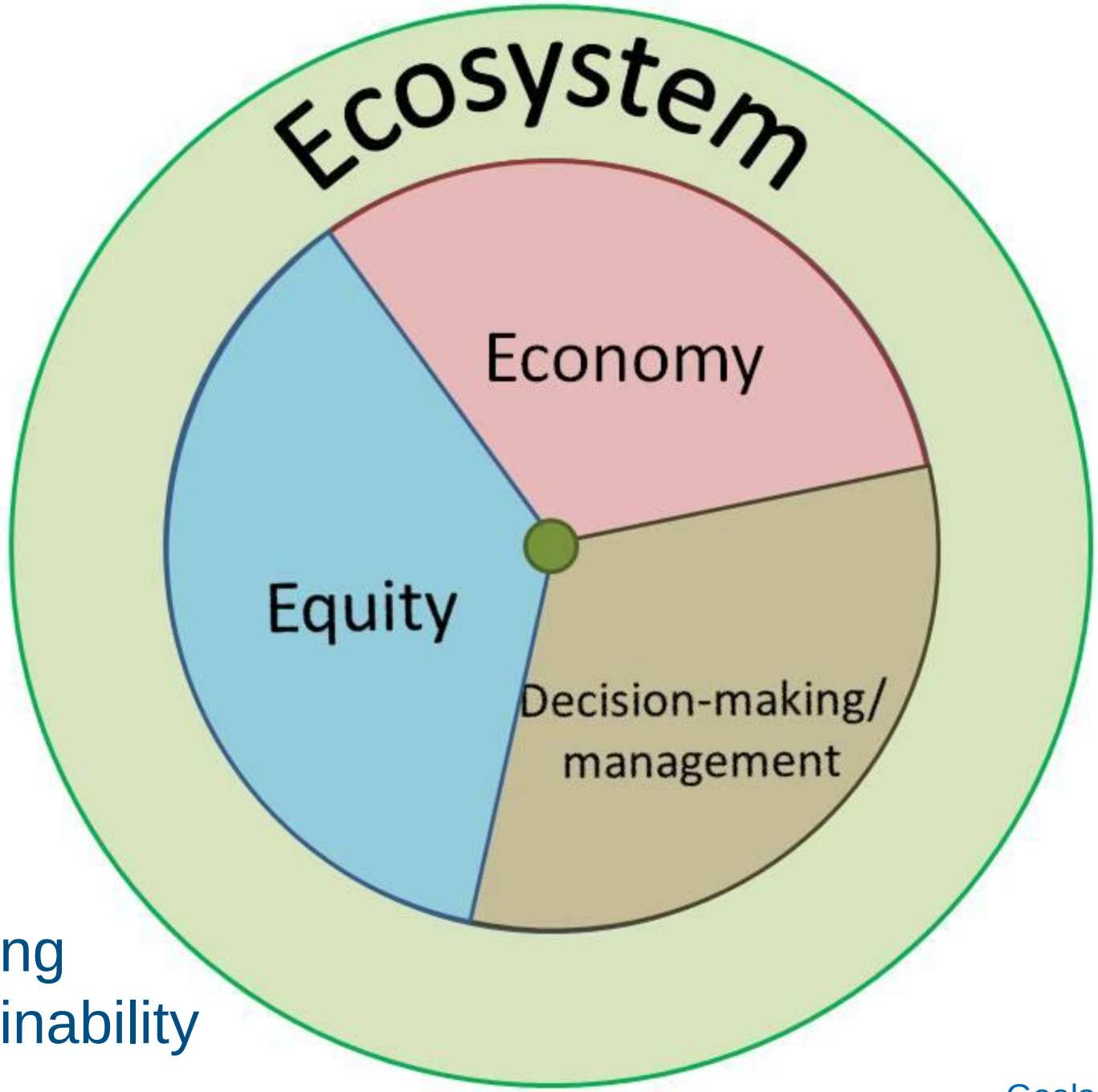
Commodity Resource Life-blood Legacy

Searching for Sustainability: Model Approach



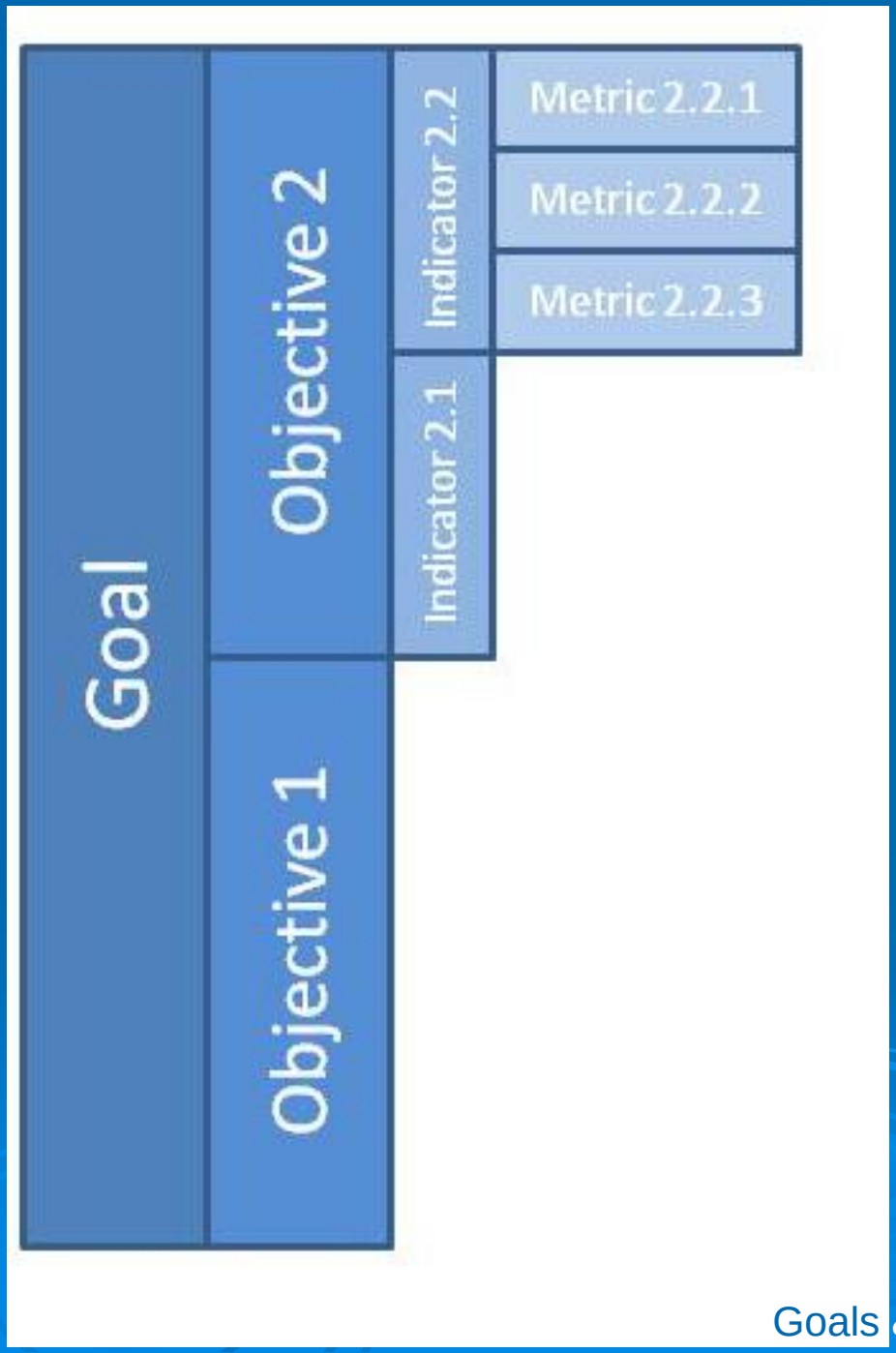


California Water Plan Update 2013



Defining Sustainability

Organizing sustainability indicators



Goals & objectives

Proposed Sustainability Goals and Objectives
Goal 1: Manage and make decisions about water in a way that integrates water availability, environmental conditions, and community well-being for future generations.
Goal 2. Improve water supply reliability to meet human needs, reduce energy demand, and restore and maintain aquatic ecosystems and processes Objectives: Improve water use efficiency; Increase water recycling; and Increase water conservation.
Goal 3. Contribute to social and ecological beneficial uses and reduce impacts associated with inter-basin water transfers and to the Delta. Objectives: Improve regional water movement operations and efficiency; Investigate new water technologies.
Goal 4. Increase quantity, quality, and reliability of drinking water, irrigation water, and in-stream flows Objectives: Increase conjunctive management of new and recycled water from multiple sources.
Goal 5. Safeguard human and environmental health and secure California water supplies Objectives: Protect and restore surface water and groundwater quality; Protect the natural systems that maintain these services.
Goal 6. Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and processes Objectives: Practice, promote, improve, and expand environmental stewardship.
Goal 7. Integrate flood risk management with other water and land management and restoration activities.
Goal 8. Support decision-making, especially in light of uncertainties, that support integrated regional water management and flood and water resources management systems Objectives: Improve and expand monitoring, data management, and analysis.

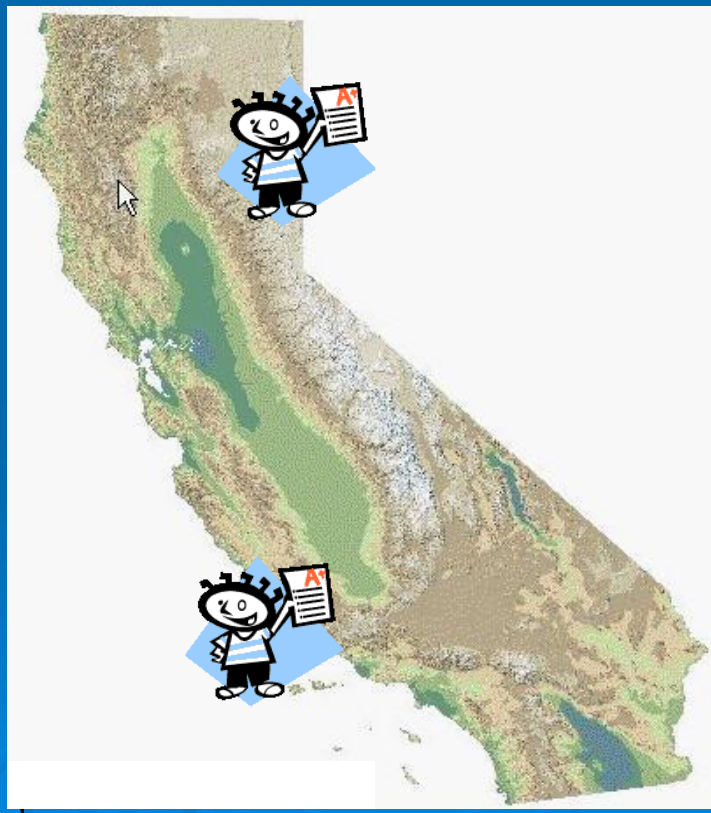
Sustainability Goal	Related CWP Objective and RMS	Example Indicators	Relevance to Sustainability Objective
2. Improve water supply reliability to meet human needs, reduce energy demand, and restore and maintain aquatic ecosystems and processes. Objectives: Improve water use efficiency; Increase water recycling; and Increase water conservation.	CWP Objective 2, 9; RMS Reduce demand	Energy required per unit of clean drinking water	Reduce energy demand for providing water
		Water-miles, distance traveled by units of water used	
		Residential outdoor water use per year per capita, 20% reduction by 2020	Increase water conservation
		Sufficient flows and timing of flows for maintaining historically-present native aquatic fauna	Restore and maintain native ecosystems
		Magnitude and timing of managed system flows suitable for native riparian habitats and geomorphic processes	

Quantitative & Qualitative Indicators: Selection Criteria

- Availability of high-quality data
- Data affordability
- System representation
- Ability to detect change over time
- Independence of indicators from one another
- Supports management decisions and actions
- Can be reported and understood in public arenas

How Should We Measure Sustainability – Status?

Choose regionally-specific targets for social, economic, ecological, and management-system indicators



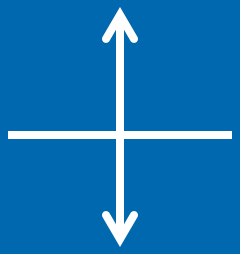
Measuring Performance

We are almost always measuring condition against some standard. It is unlikely that report cards and indicators would be useful without this comparison. This approach is called normalization or re-scaling. The specific approach used is “distance to target”, measuring distance to “poor” or “good” conditions. This grounds indicator evaluation and allows inter-indicator and inter-regional comparison.

Boundaries, limits, targets, & thresholds

Desired condition

Departure from good condition



Upper withdrawal limits: social, ecological limits

Departure from poor condition

Lower withdrawal limits: social, economic limits

Un-desired condition

Normalization Methods

Empirical normalization

$Y = X - Min/(Max - Min)$

Axiological normalization

undesirable condition = 0, desirable = 1

Alt1: $Y = X_{obs}/X_{exp}$

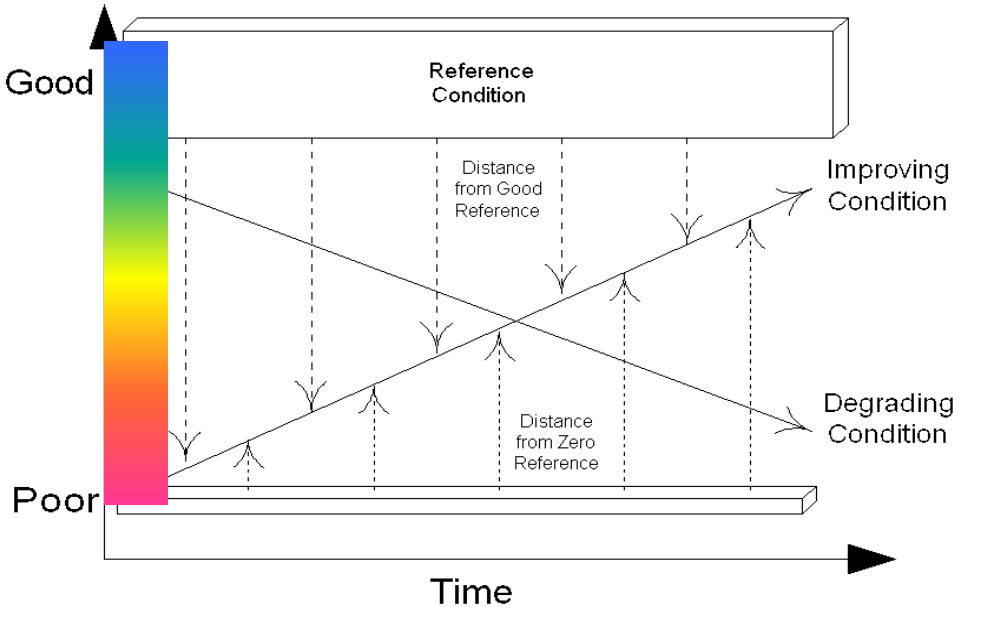
Alt2: Comparison of ratio of $X:X_{exp}$ to 1+threshold value

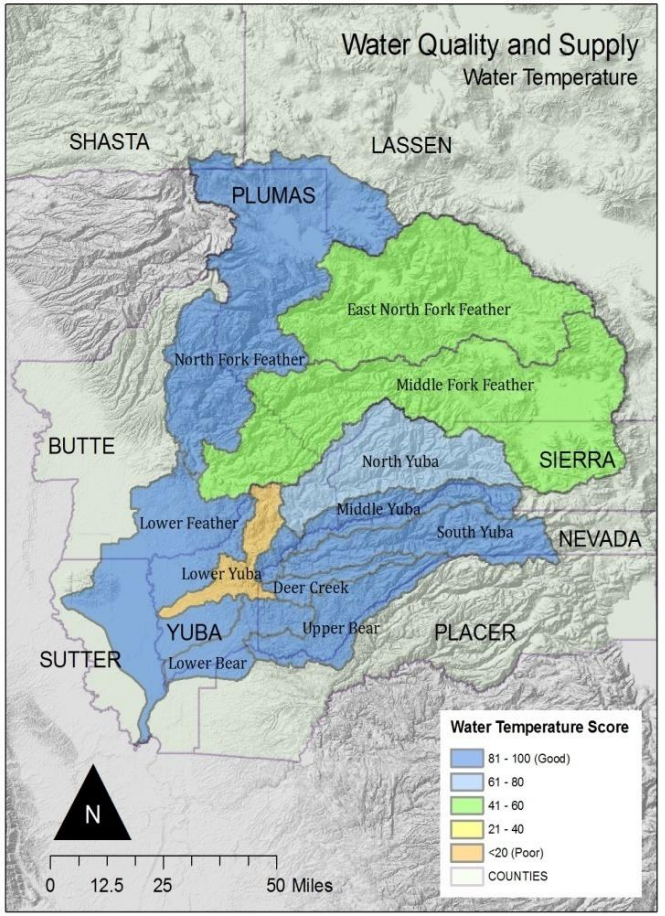
Mathematical normalization (values calculated using function)

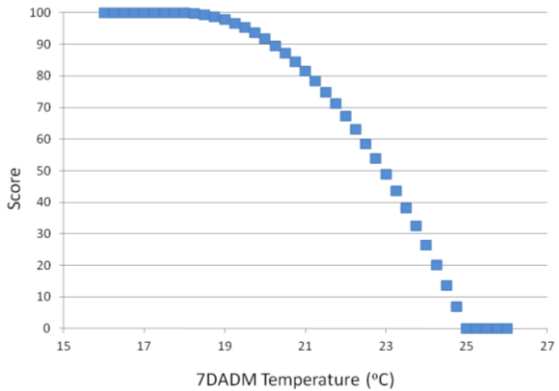
Statistical normalization (values expressed as SD around mean)

Trend normalization (value = statistically significant trend, direction and magnitude)

“Distance to Target”
(axiological normalization)

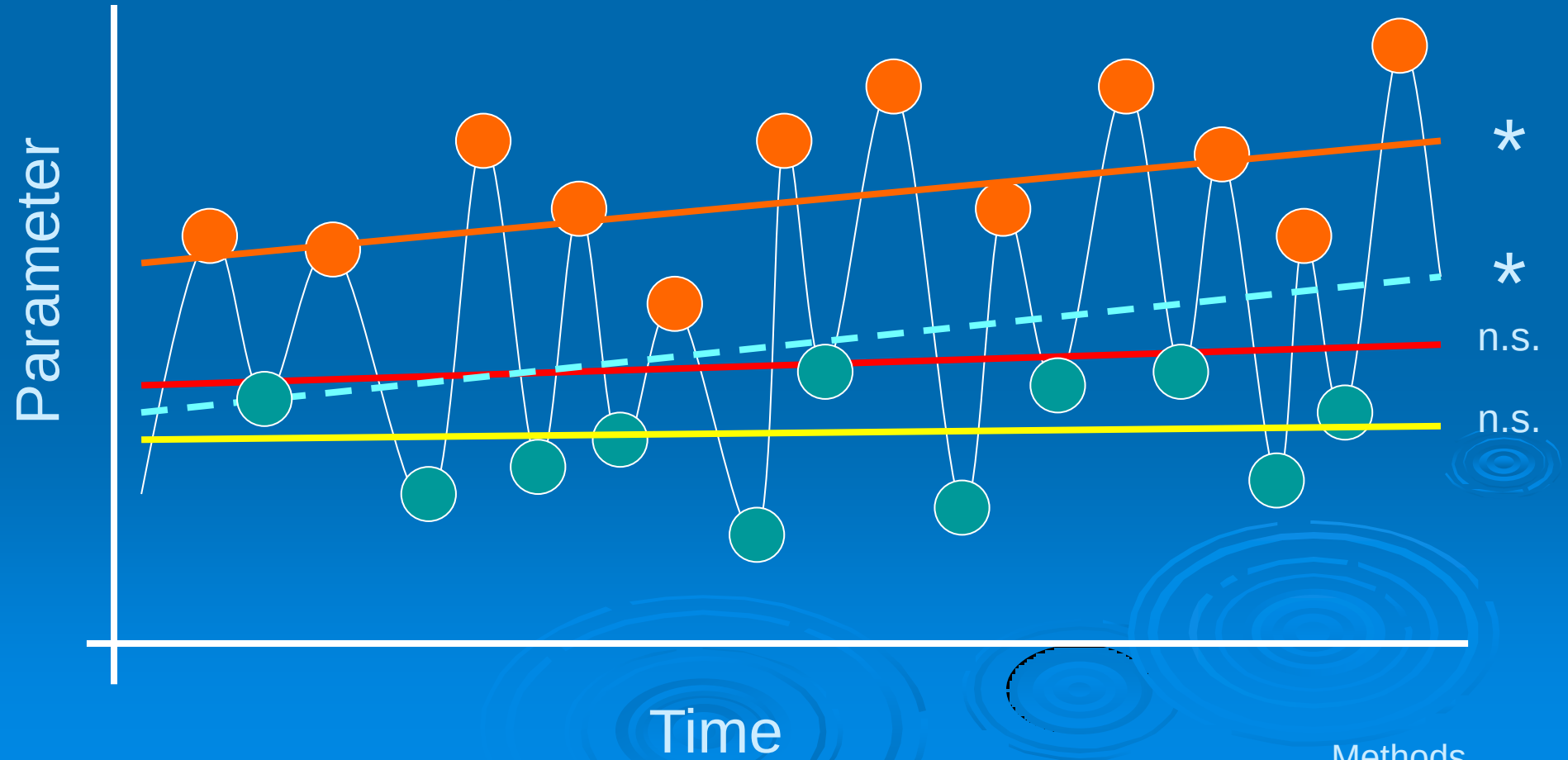






How Should We Measure Sustainability – Trends?

Appropriate trends analysis (non-parametric tests to control for seasonal periodicity, sometimes parametric – log-transform).



Trend analysis

Very few indicator and report card efforts use the right statistics to measure trends

Non-Parametric Approaches -- Mann-Kendall Family

- Insensitive to non-normal data, tolerates missing values, unaffected by skew and extreme values
- Output = trend slope magnitude and statistical significance

- Seasonal-Kendall
  - Separate trends analysis for each season, controlling for periodicity. Appropriate for complete data over >5-7 year periods
  - Output = trend slope and statistical significance
- Regional-Kendall
  - Comparison of trends for regions (e.g., individual monitoring locations)

See Nadav Nur 2011 contribution to State of the Bay report for log-transform example

Confidence

Conveying confidence improves trust in the use of indicators in the report card process

- Indicators appropriate
  - Importance in system, understanding, scientific rigor, feasibility
- Accurate reflection of real status and trend
  - Measurement error, uncertain interpretation of sampling frame (does sampling fit the question), sampling error (because of sampling rather than censusing), process error (natural variability)

Who Should Measure Sustainability?

Academia (Objective, trusted, place of learning and investigation)

Public (Audience, ultimate decision-makers in democracy, actors)

Agencies (Intermediaries, rule setters, policy implementers, regulators)

Elected Officials (Respond to social priorities, set policy, direct agencies)

Consultants (Technical, familiar)

State (Summarizing regions, comparison among regions, priorities)

Region (Largest participation extent, first aggregation of jurisdictional and natural boundaries)

County (Unit of measure, unit of action)

City (Unit of measure, unit of action)

Why? Show connections between condition and the changes needed to be sustainable

Sustainability Objective	Example Indicators	Value	Influences	Management Responses
Goal 5. Safeguard human and environmental health and secure California water supplies Objectives: Protect and restore surface water and groundwater quality; Protect the natural systems that maintain these services.	Ratio of observed to expected native aquatic species	47	Invasive weeds, water temperature, migration barriers, inadequate flows	Weed abatement, increased summer flows, fish ladders or barrier removal
	Surface-water Water Quality Index	63	Discharge to waterways, inadequate summer flows, invasive weeds, water withdrawals/transfers, climate change	Improved discharge treatment, weed abatement, incentives for regional water supply and against inter-basin
	Groundwater Water Quality Index	82	Agricultural chemicals, irrigation and drinking water withdrawals, inadequate septic, impermeable surface development	Best management practices for agriculture, conjunctive water management, wastewater treatment, improve regional development and redevelopment standards

Report Cards

Complex versions

Napa River Watershed Health Report Card

Each watershed subregion was evaluated for its condition relative to targets for each indicator. Scores close to 100 reflect excellent watershed health. The subregions are: WM - Western Mountains, LW - Lower Watershed, EM - Eastern Mountains, SVF - South Valley Floor, NVF - North Valley Floor. Trend was evaluated from a combination of trend assessments from each subregion. Confidence refers to quantitative and professional assessment of confidence in the result. ND indicates that the score or trend was not determined because data were not available or sufficient. Go to http://sfcommons.org/scorecards/waf/napa for more detailed information.

Goals	Indicators	Watershed Subregion Condition Score					Watershed Condition Score	Trend	Confidence for Subregion Scores
		WM	LW	EM	SVF	NVF			
Improve and protect geomorphic and hydrologic processes	Impervious area	ND	ND	ND	ND	ND	75	Declining	Moderate
Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making	Local media coverage of watershed topics	ND	ND	ND	ND	ND	46	No trend	High
	Access to public open space	2	22	1	74	58	38	ND	Low - High
Conserve, protect and improve native plant, wildlife and fish habitats and their communities	Fish community	ND	37	ND	78	ND	ND[1]	ND	Moderate
	Habitat fragmentation and connectivity	77	34	100	29	51	67	ND	High
	Sensitive bird species	64	77	82	88	60	74	No trend	Low
	Aquatic insects	59	33	53	39	41	45	ND	Moderate - High
	Fire recurrence	84	80	42	99	48	65	ND	Moderate
Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity	Groundwater	Spring: Main Basin = 100, MST Basin = 29; Fall: Main Basin = 67, MST Basin = 7					ND[1]	ND	Moderate
	Water conservation	ND	ND	ND	39	ND	ND[1]	ND	High
	Stream temperature	100	81	ND	87	54	82	No trend	Moderate
Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change	Carbon storage and net primary productivity	98	100	97	93	94	97	No trend	Moderate
Support community planning and management actions that further the goal of a healthy, happy, and economically just community	School lunch program enrollment	ND	45	55	70	61	58	Declining	Low - High
	Housing affordability	66	60	66	57	40	58	Declining	Moderate - High

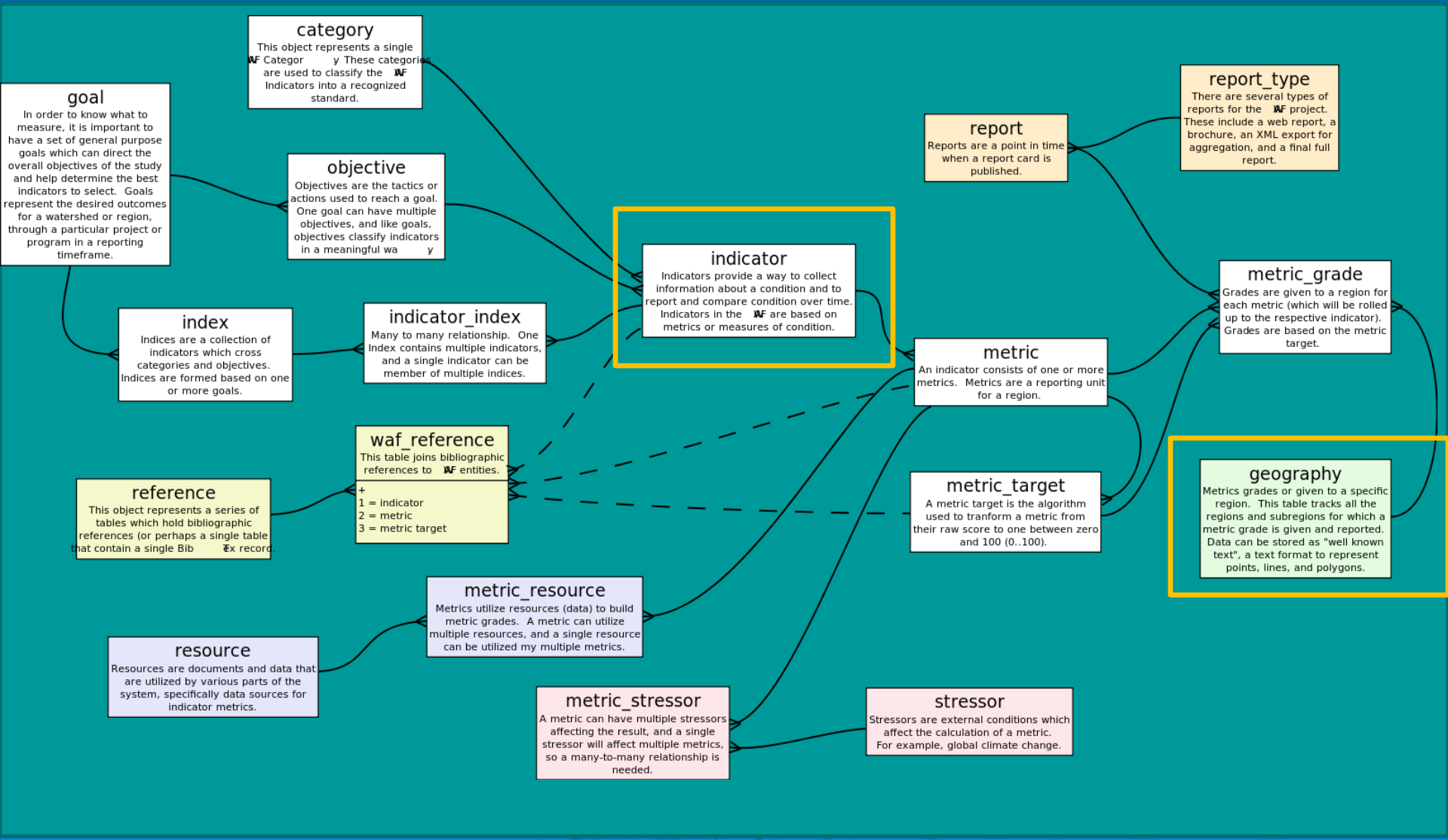
[1]No watershed score was calculated for Fish Community, Groundwater and Water Conservation as data for these indicators was available for only for a few select subregions of the watershed.

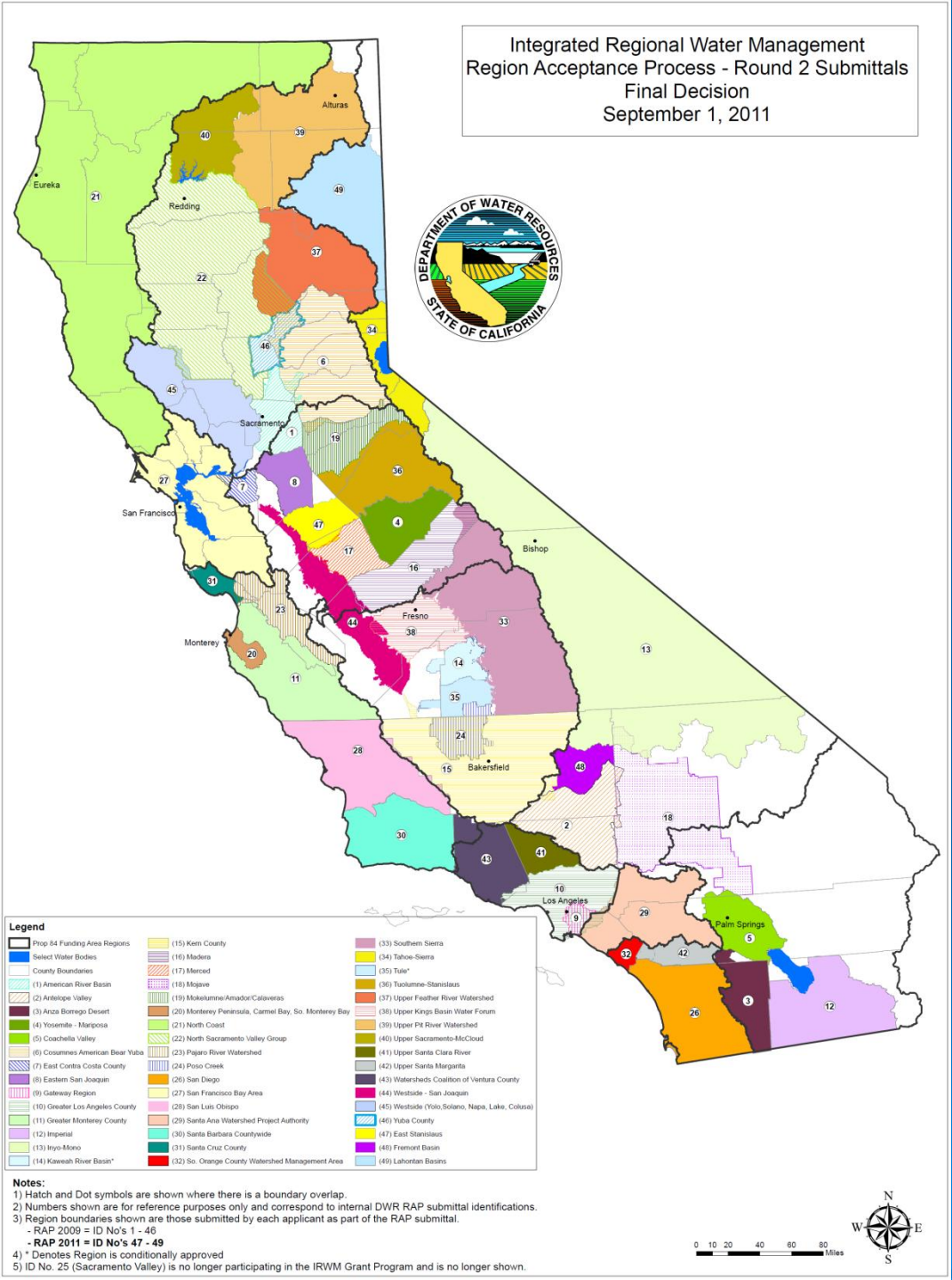
Sacramento River Watershed

Sub-Watershed Condition Score (0 – 100)

Goals	Measurable Objective	Indicators	ENFF	NFF	MFF	LF	NY	MY	SY	DC	LY	UB	LB	Trend	Confidence
Water quality and supply for natural and human communities	Water quality for aquatic health	Water temperature, algae, mercury in fish	73	75	38	50	53	47	39	35	13	40	61	↔	medium-high
	Maintain natural stream flows	Current flow vs. historical flow	69	n/a	n/a	54	n/a	n/a	n/a	63	40	60	41	n/a	medium
Protect and restore native animals and plants	Native birds	Bird species richness	100	n/a	100	100	100	100	100	n/a	100	100	100	↔	medium
	Protect native aquatic communities	Land disturbance, aquatic insects, fish	69	64	69	61	66	69	62	47	55	61	82	↔	high
Protect and enhance habitats, ecosystems, and watersheds	Protect aquatic connections	Barriers to aquatic organism movement	77	82	76	82	82	76	79	69	77	67	79	n/a	medium-high
	Protect landscape connections	Barriers to wildlife movement	23	81	44	5	54	27	100	5	11	14	2	n/a	high
	Maintain natural production and nutrient cycles	Carbon storage and sequestration, nitrogen loads	88	93	63	94	93	89	93	48	96	91	96	↓	medium
Maintain and restore natural disturbance	Restore natural fire regimes	Fire frequencies compared to expected frequency	2	9	14	39	2	3	4	12	15	0	4	↔	medium
	Encourage natural flooding, while protecting people	Floodplain access	n/a	n/a	n/a	43	n/a	n/a	n/a	n/a	70	n/a	38	n/a	low
Improve social and economic conditions & benefits from	Enhance wildlife-friendly agriculture	Pesticide use and organic agriculture	100	99	100	51	n/a	98	100	100	17	100	62	↑	medium-high
	Improve community economic status	Poverty measure	49	52	54	34	64	32	40	73	35	70	61	↓	high

Web Reporting

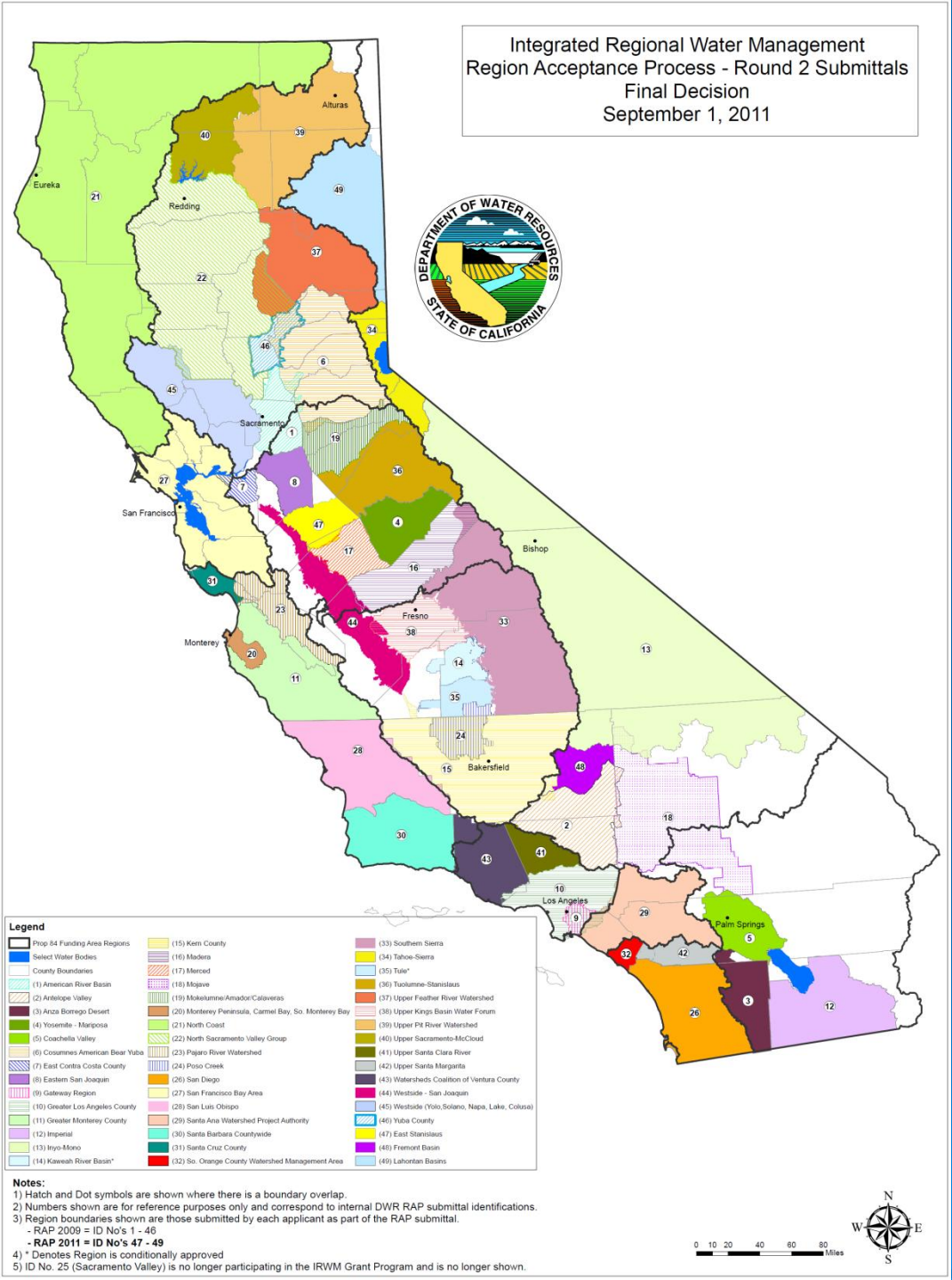




IRWM regions and process

- What is a region?
- Combination of hydrologic and jurisdictional boundaries
- Vary considerably in size, shape, land-uses, and capacity*

*N = 49

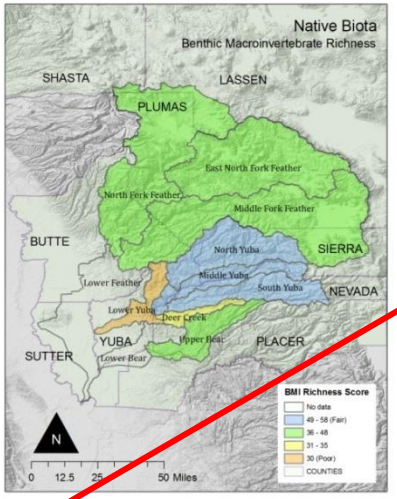


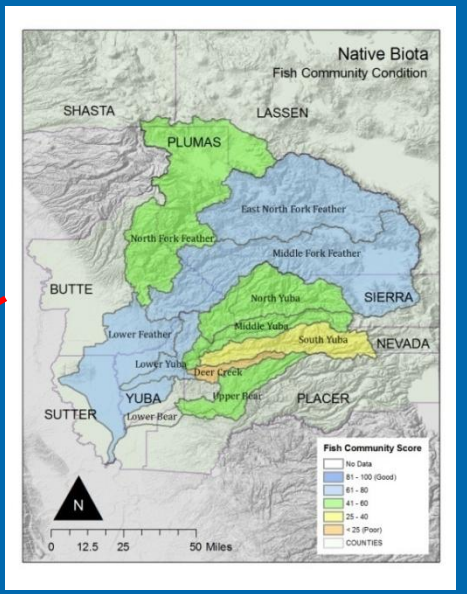
Role of indicators in IRWM

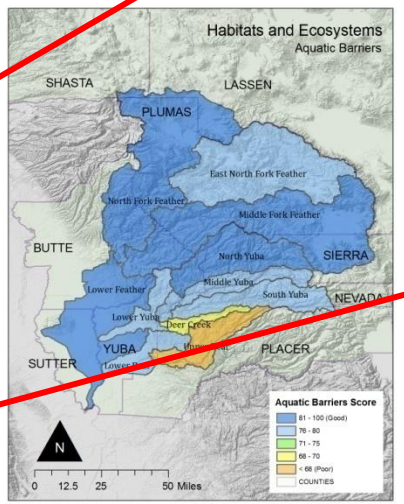
- Prioritize actions
- Measure ecological, economic, and equity outputs of projects
- Measure individual and integrated ecological, economic, and equity outcomes of program

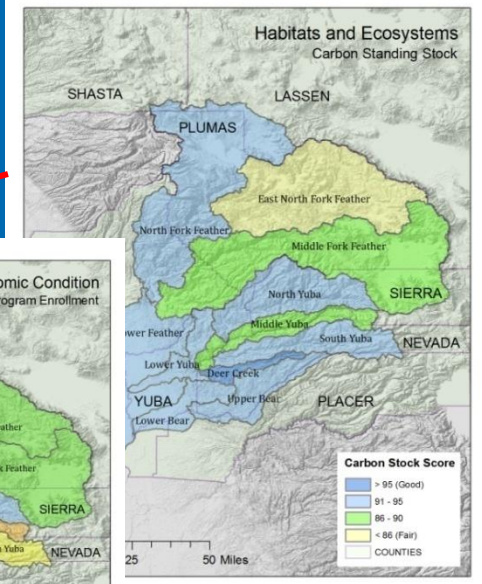
Sub-unit Reporting, within IRWM regions

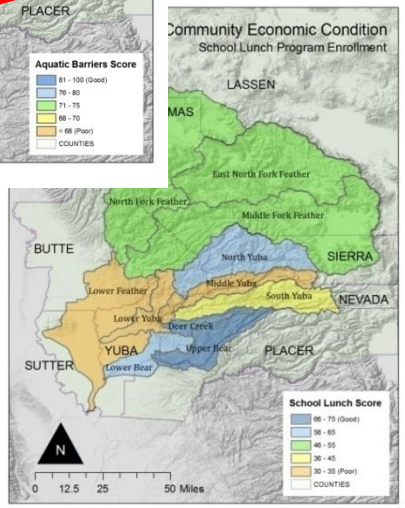
Goals	Measurable Objective	Condition	Trend	Confidence
Water quality and supply for natural and human communities	Water quality for aquatic health	51	↔	Medium-high
	Maintain natural stream flows	55	n/a	Medium
Protect and restore native animals and plants	Native birds	100	↔	Medium
	Native invertebrates	46	↔	High
	Native fish	49	↔	High
	Agricultural/urban development	90	n/a	Medium
Protect and enhance habitats, ecosystems, and watersheds	Protect aquatic connections	77	n/a	Medium-high
	Protect landscape connections	33	n/a	High
	Maintain natural production and nutrient cycles	82	↓	Medium
Maintain and restore natural disturbance	Restore natural fire regimes	9	↔	Medium
	Encourage natural flooding, while protecting people	50	n/a	Low
Improve social and economic conditions & benefits from healthy watersheds	Enhance wildlife-friendly agriculture	83	↑	Medium-high
	Improve community economic status	51	↓	High











IRWM Nexus

IRWM regions and process

- Regional stakeholders & forums
- Regional goals
- Regional actions, funding

- Local jurisdictions
- Local needs and priorities
- Local projects and audiences

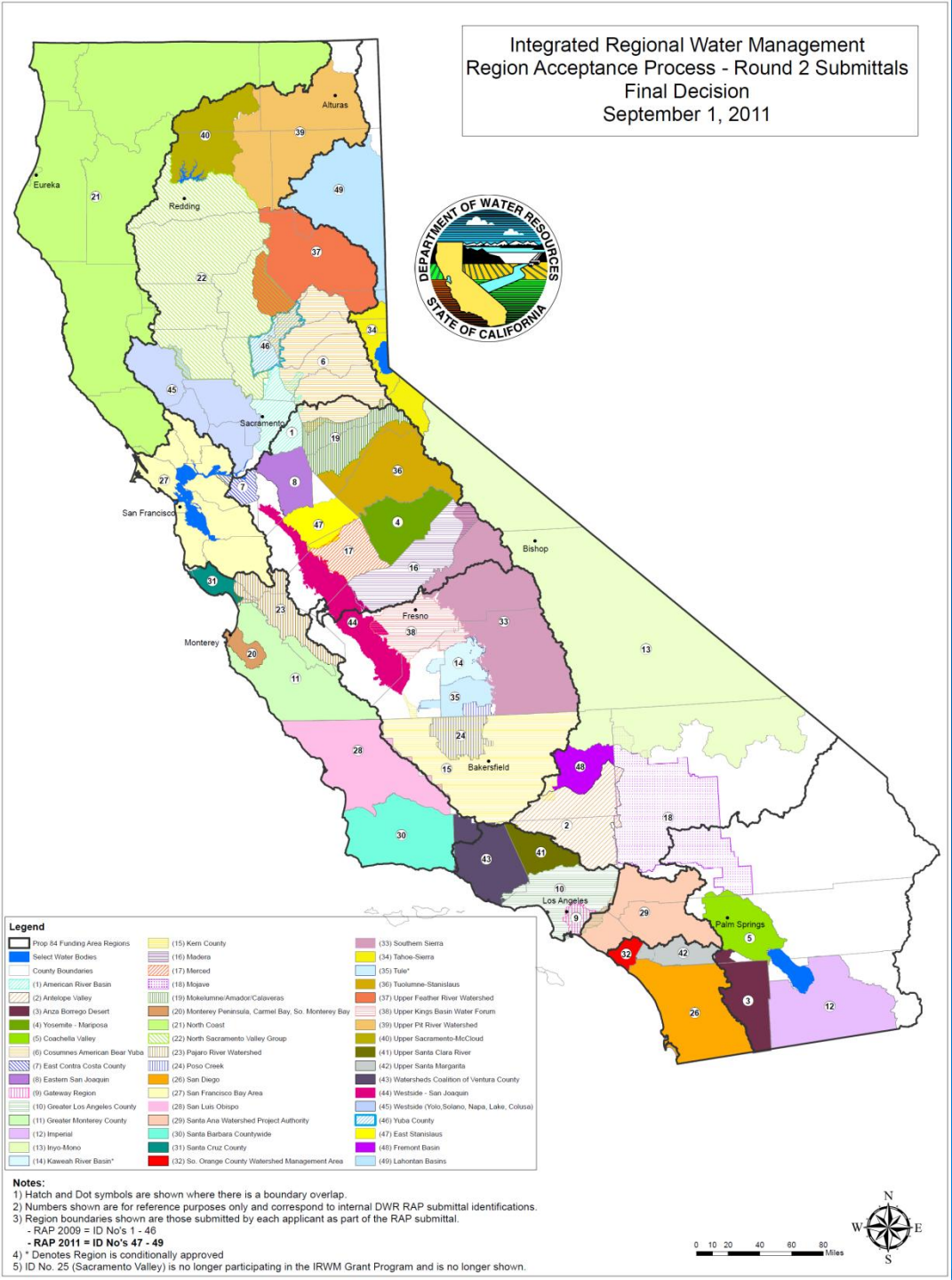
IRWM regions and process

- One operational scale for implementing system
- Usually not the only show in town – Regional Progress Reports, Basin Plans, Blueprint planning, regional health assessments, regional economic reports …

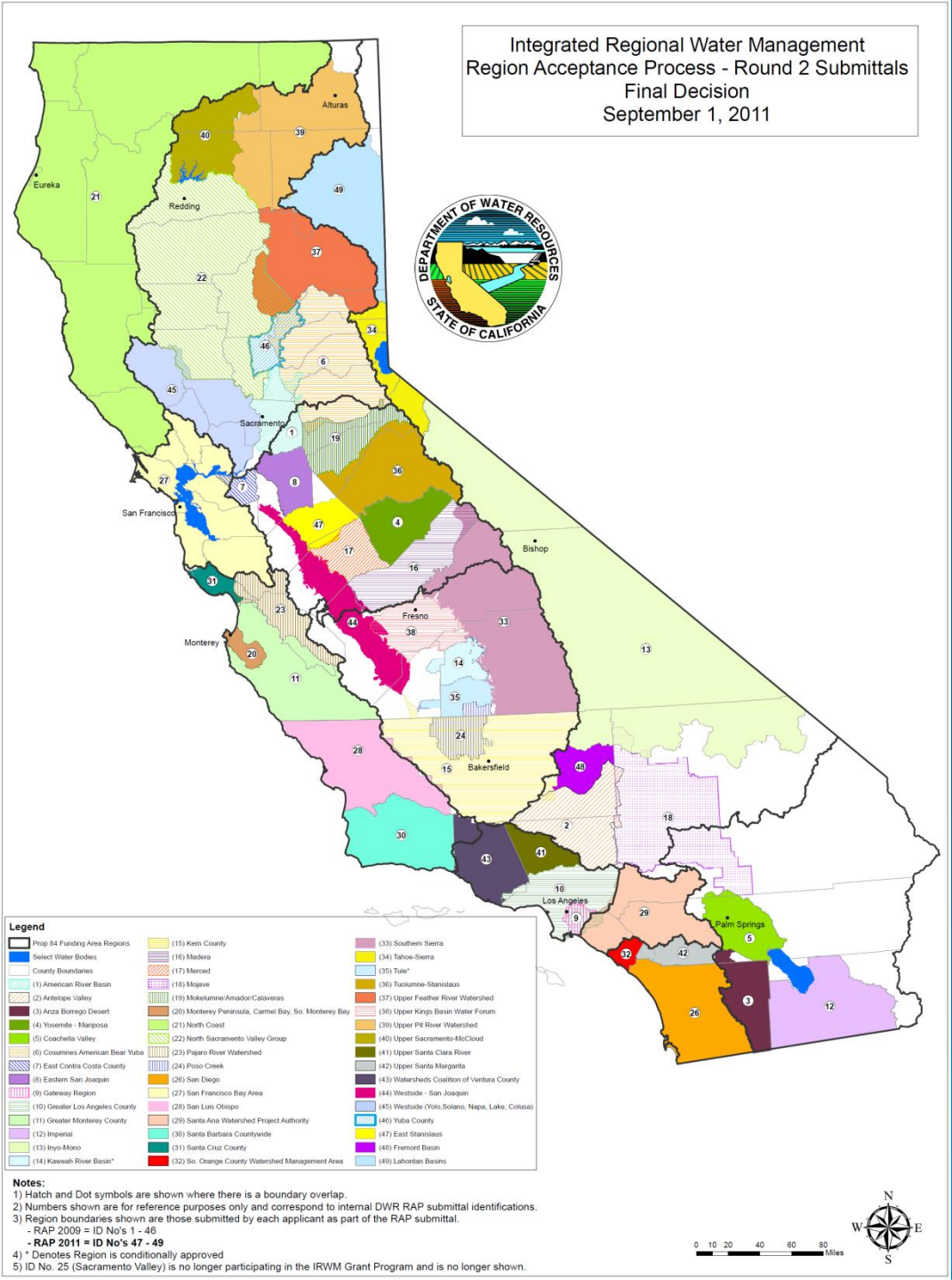
Phase II – Proof of Concept

1. Select region within California to test-implement the framework, including selection of goals & indicators, status and trends analysis, and reporting. Incorporate “water footprint” into analysis

2. Select sub-set of indicators for whole state, status and trends analysis, and reporting. Incorporate water and ecological footprint analyses into decision-support tool.



- A region could be an IRWM planning area, “Prop 84” region, county, land-use planning region, watershed, or river basin



a) the region represents a cross-section of the wide range of activities and natural conditions of California;

b) working with the region will assist with regional management needs and meet state-level/Water Plan management needs;

c) high-quality data is available for a cross-section of indicators; and

d) the region has the capacity and desire to engage with the project team.

Statewide Water Indicators (examples)

Number of basins with years-long aquifer declines (known as overdraft) or projected future declines

Projected likelihood of water shortages

Projected drought resilience

Projected flood resilience

Equitable decision-making process for water management, diversity of participating organizations

Water-miles, distance traveled by units of water used

Energy required per unit of clean water sourced, treated, delivered, used, and again treated

Phase II

Contact Information

Fraser Shilling: fmshilling@ucdavis.edu

Water Sustainability Indicator System – Discussion

Fraser Shilling
University of California Davis
fmshilling@ucdavis.edu

Sustainable Water Resources Roundtable
Tuesday, December 6, 2011
University of California, Davis

5 minutes overview/reminder

15 minute discussion of each of two topic areas

20 minute reporting back

Overview

- California water sustainability goals and objectives
- Methods
- Interface with IRWM
- Phase II – regional and statewide proof of concept

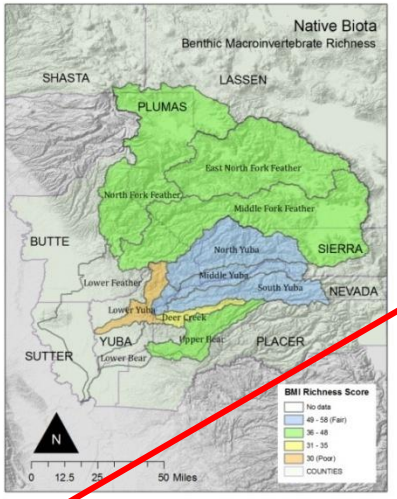
Proposed Sustainability Goals and Objectives
Goal 1: Manage and make decisions about water in a way that integrates water availability, environmental conditions, and community well-being for future generations.
Goal 2. Improve water supply reliability to meet human needs, reduce energy demand, and restore and maintain aquatic ecosystems and processes Objectives: Improve water use efficiency; Increase water recycling; and Increase water conservation.
Goal 3. Contribute to social and ecological beneficial uses and reduce impacts associated with inter-basin water transfers and to the Delta. Objectives: Improve regional water movement operations and efficiency; Investigate new water technologies.
Goal 4. Increase quantity, quality, and reliability of drinking water, irrigation water, and in-stream flows Objectives: Increase conjunctive management of new and recycled water from multiple sources.
Goal 5. Safeguard human and environmental health and secure California water supplies Objectives: Protect and restore surface water and groundwater quality; Protect the natural systems that maintain these services.
Goal 6. Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and processes Objectives: Practice, promote, improve, and expand environmental stewardship.
Goal 7. Integrate flood risk management with other water and land management and restoration activities.
Goal 8. Support decision-making, especially in light of uncertainties, that support integrated regional water management and flood and water resources management systems Objectives: Improve and expand monitoring, data management, and analysis.

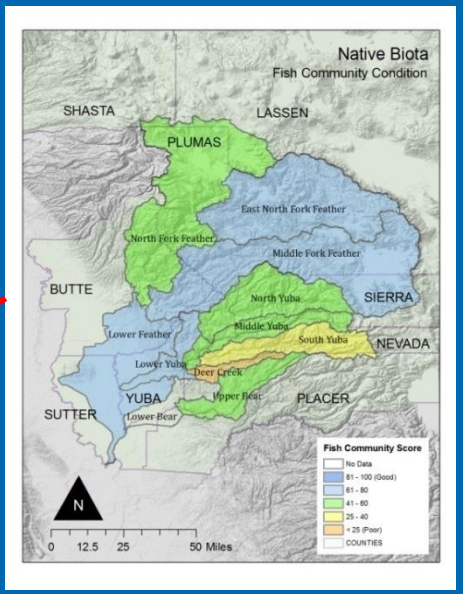
Measuring Performance

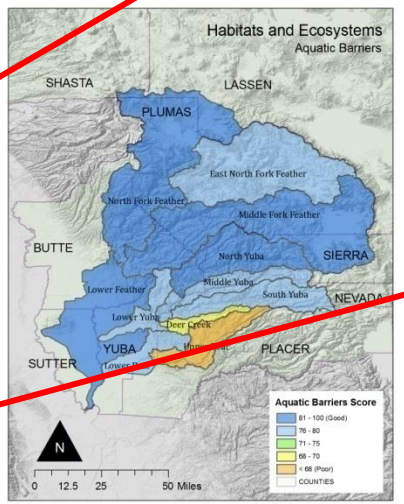
We are almost always measuring condition against some standard. It is unlikely that report cards and indicators would be useful without this comparison. This approach is called normalization or re-scaling. The specific approach used is “distance to target” and allows inter-indicator and inter-regional comparison.

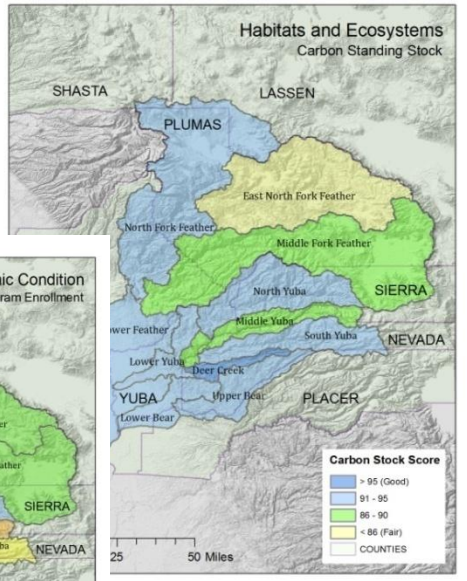
Web Report Cards within IRWM regions

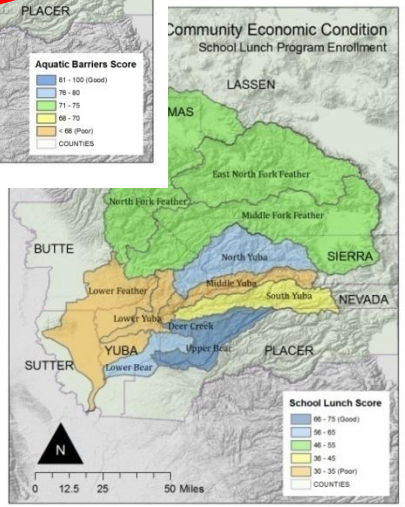
Goals	Measurable Objective	Condition	Trend	Confidence
Water quality and supply for natural and human communities	Water quality for aquatic health	51	↔	Medium-high
	Maintain natural stream flows	55	n/a	Medium
Protect and restore native animals and plants	Native birds	100	↔	Medium
	Native invertebrates	46	↔	High
	Native fish	49	↔	High
	Agricultural/urban development	90	n/a	Medium
Protect and enhance habitats, ecosystems, and watersheds	Protect aquatic connections	77	n/a	Medium-high
	Protect landscape connections	33	n/a	High
	Maintain natural production and nutrient cycles	82	↓	Medium
Maintain and restore natural disturbance	Restore natural fire regimes	9	↔	Medium
	Encourage natural flooding, while protecting people	50	n/a	Low
Improve social and economic conditions & benefits from healthy watersheds	Enhance wildlife-friendly agriculture	83	↑	Medium-high
	Improve community economic status	51	↓	High



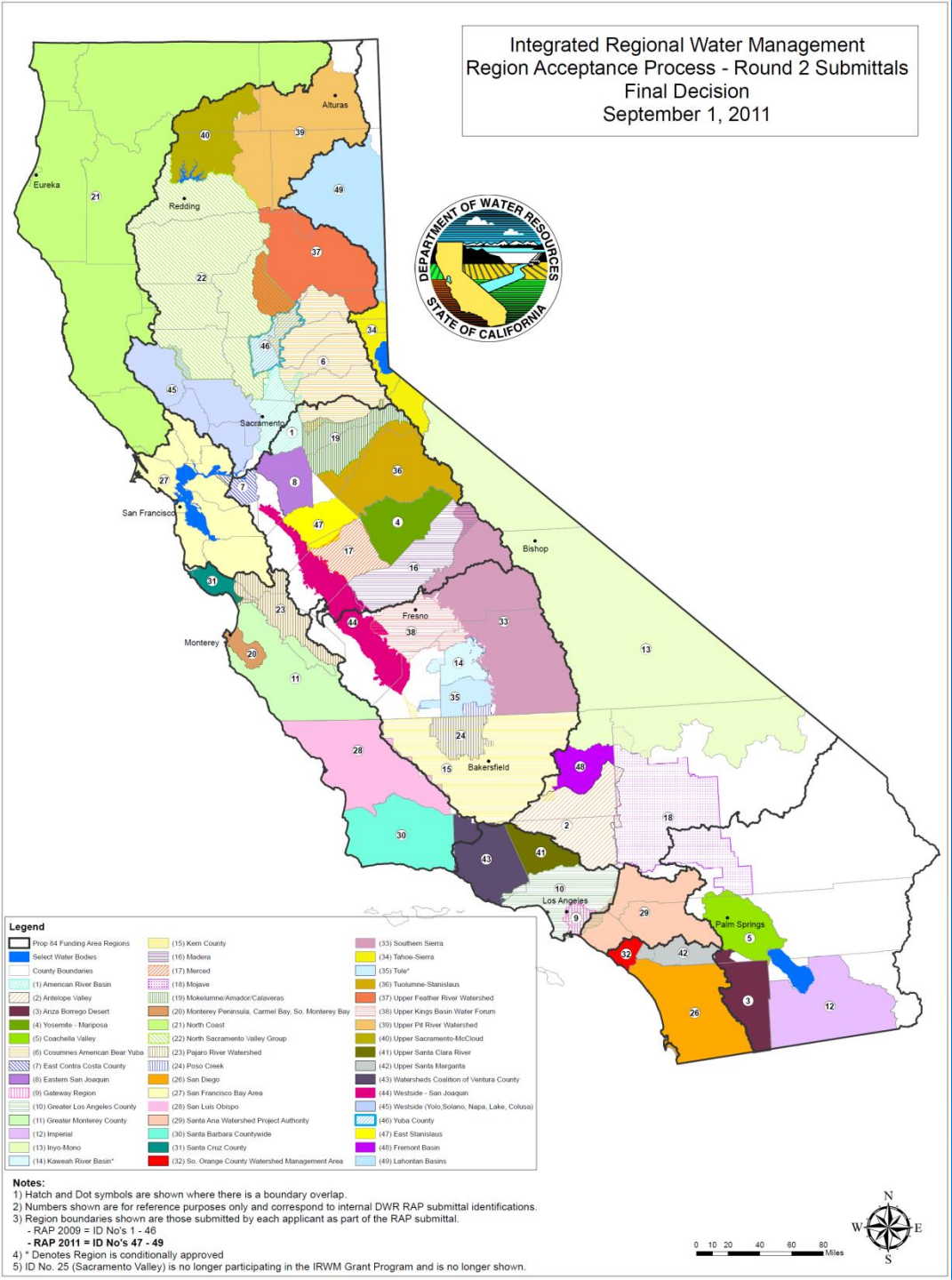








IRWM Nexus



Criteria for partner region

a) the region represents a cross-section of the wide range of activities and natural conditions of California;

b) working with the region will assist with regional management needs and meet state-level/Water Plan management needs;

c) high-quality data is available for a cross-section of indicators; and

d) the region has the capacity and desire to engage with the project team.

Statewide Water Indicators (examples)

Number of basins with years-long aquifer declines (known as overdraft) or projected future declines

Projected likelihood of water shortages

Projected drought resilience

Projected flood resilience

Equitable decision-making process for water management, diversity of participating organizations

Water-miles, distance traveled by units of water used

Energy required per unit of clean water sourced, treated, delivered, used, and again treated

Phase II – state scale

Questions for the Group

A. What barriers do you think are likely to exist that inhibit rollout and adoption of the indicators system at local, regional, state, and national scales?

B. How can the state and federal governments collaboratively help people get on-board and using such a system?

C. What can the state do to help make the system operational at the local and regional scales (including the Water Plan 2013 sustainability indicators project)?

Questions for the Group

We have developed several criteria to select a region:

a) the region represents a cross-section of the wide range of activities and natural conditions of California;
b) working with the region will assist with regional management needs and meet state-level/Water Plan management needs;
c) high-quality data is available for a cross-section of indicators; and
d) the region has the capacity and desire to engage with the project team.

A. Please provide feedback on these criteria.

B. Please also provide feedback on the appropriate size (e.g., IRWM region) and type (e.g., county, river basin) of region.

C. Given that all regions can't implement this Framework immediately, is there value in using a set of screening indicators aggregated across regions to the state scale?

Questions for the Group

A. What barriers do you think are likely to exist that inhibit rollout and adoption of the indicators system at local, regional, state, and national scales?

B. How can the state and federal governments collaboratively help people get on-board and using such a system?

C. What can the state do to help make the system operational at the local and regional scales (including the Water Plan 2013 sustainability indicators project)?

a) the region represents a cross-section of the wide range of activities and natural conditions of California;
b) working with the region will assist with regional management needs and meet state-level/Water Plan management needs;
c) high-quality data is available for a cross-section of indicators; and
d) the region has the capacity and desire to engage with the project team.

A. Please provide feedback on these criteria.

B. Please also provide feedback on the appropriate size (e.g., IRWM region) and type (e.g., county, river basin) of region.

C. Given that all regions can't implement this Framework immediately, is there value in using a set of screening indicators aggregated across regions to the state scale?