Paleohydrology Workshop

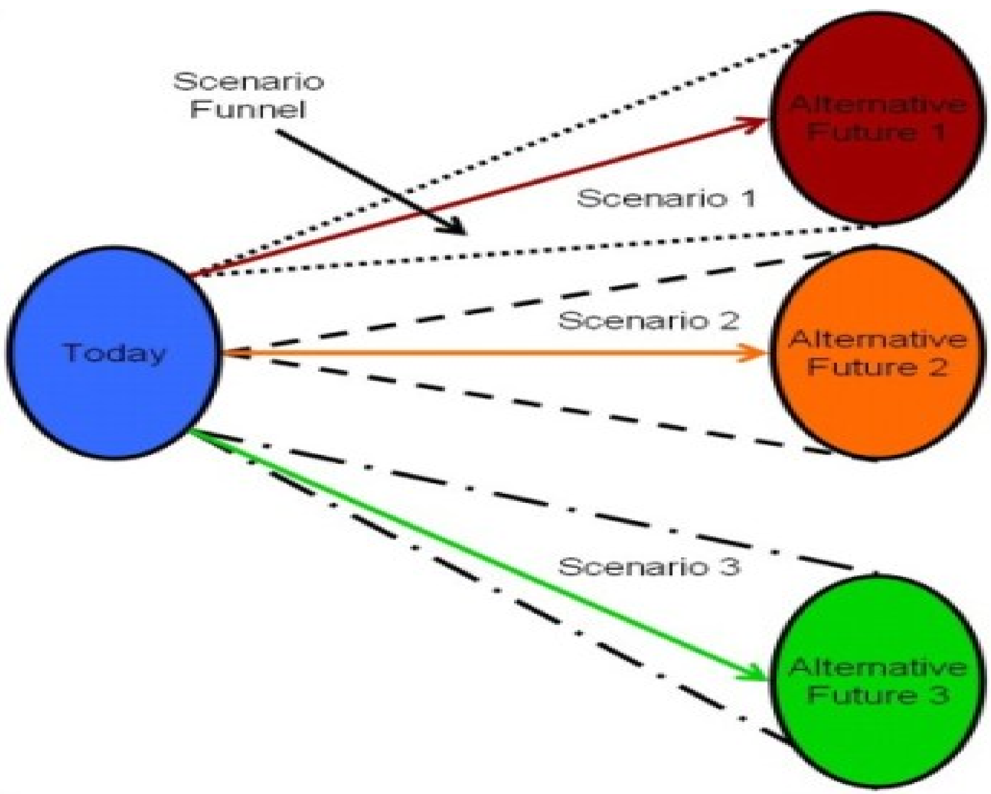
Decision Center for a Desert City & Decision Theater, Arizona State University
September 11, 2009

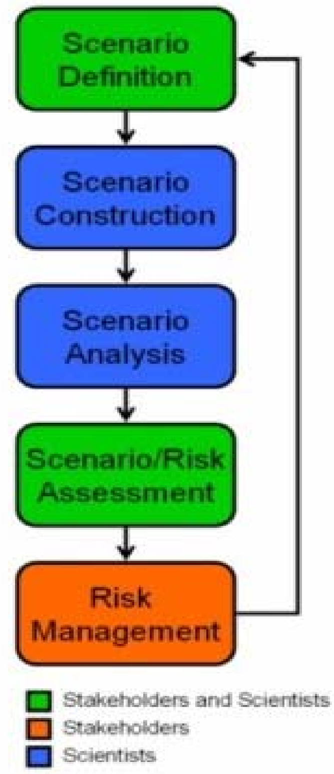
Scenarios as Tools for Planning

- Overview – *Kathy Jacobs (U of AZ)*
- Use of Tree Ring Reconstructions for Scenario Development – *Katie Hirschboeck (U of AZ)*

Scenario Overview and Discussion (see http://www.sahra.arizona.edu/scenarios/)

"A scenario is a coherent, internally consistent and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold." IPCC





Draft 2005 TAMA Water Budget

Tucson AMA
GWMC Format

DRAFT, SUBJECT TO REVISION

		1998	2005	2025
MUNICIPAL (includes exempt wells)				
DEMAND		160,500	194,500	247,100
SUPPLY	Groundwater	150,800	97,500	63,000
	CAP (direct use; credit recovery; repleni	200	83,400	146,400
	Effluent	9,500	13,300	37,700
INCIDENTAL RECHARGE		56,100	14,000	13,100
INDUSTRIAL				
DEMAND		57,500	54,200	75,400
SUPPLY	Groundwater	56,800	52,500	70,700
	CAP (direct use & credit recovery)	0	200	0
	Other surface water	0	400	
	Effluent	700	1,100	4,700
INCIDENTAL RECHARGE		6,900	5,700	7,600
AGRICULTURAL				
DEMAND		94,800	94,100	57,200
SUPPLY	Groundwater	70,900	66,700	44,200
	Groundwater (*in lieu*)	22,900	16,400	10,000
	CAP (direct use; no *in lieu*)	0	11,000	0
	Effluent	1,000	0	3,000
INCIDENTAL RECHARGE		19,000	18,800	8,700
INDIAN				
DEMAND		100	14,200	16,000
SUPPLY	Groundwater	100	800	200
	CAP (direct use; no *in lieu*)	0	13,400	15,800
	Effluent	0	0	0
INCIDENTAL RECHARGE		0	2,800	3,200
OTHER				
DEMAND	Riparian	3,700	3,700	3,700
SUPPLY	Cuts to the aquifer	2,300	15,300	45,200
	Net natural recharge	62,000	62,000	62,000
OVERDRAFT				
TOTAL		**158,900**	**119,000**	**52,000**
ADDITIONAL RECHARGE FOR FUTURE USE*				
OTHER	Net aritificial recharge	22,700	102,900	13,500

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Tucson Water Long Range Planning Area

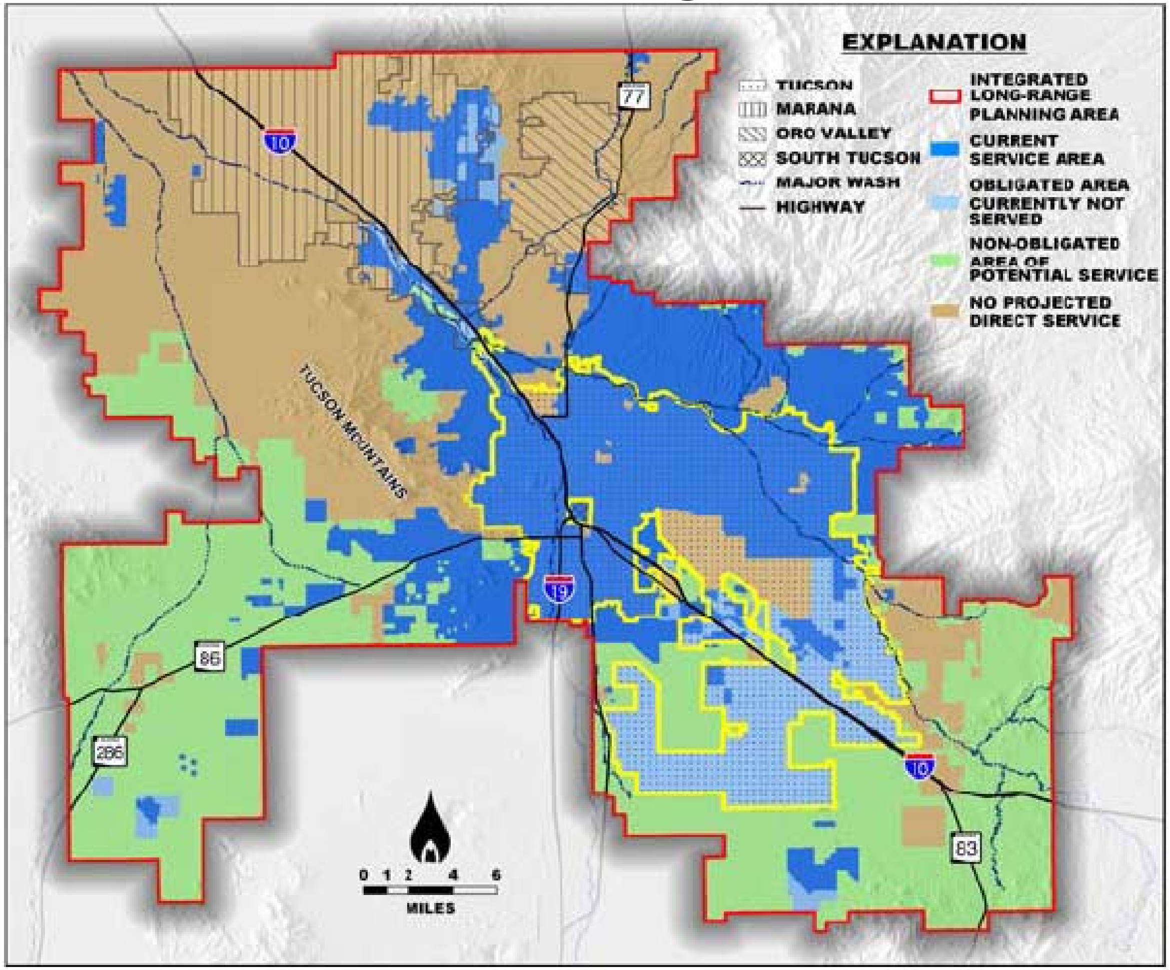


Figure ES-1: Long Range Planning Area.

Tucson Water Long Range Plan

POPULATION PROJECTIONS

Revised projections were used to develop population estimates for Tucson Water's Obligated Area and its Potential Service Area; these projections are graphically shown on Figure ES-2. The Obligated Area population is estimated to increase from 638,936 in 2000 to approximately 990,000 in 2030 and to just over 1.1 million by 2050. The Potential Service Area population is estimated to be about 1.1 million in 2030 and almost 1.3 million in 2050.

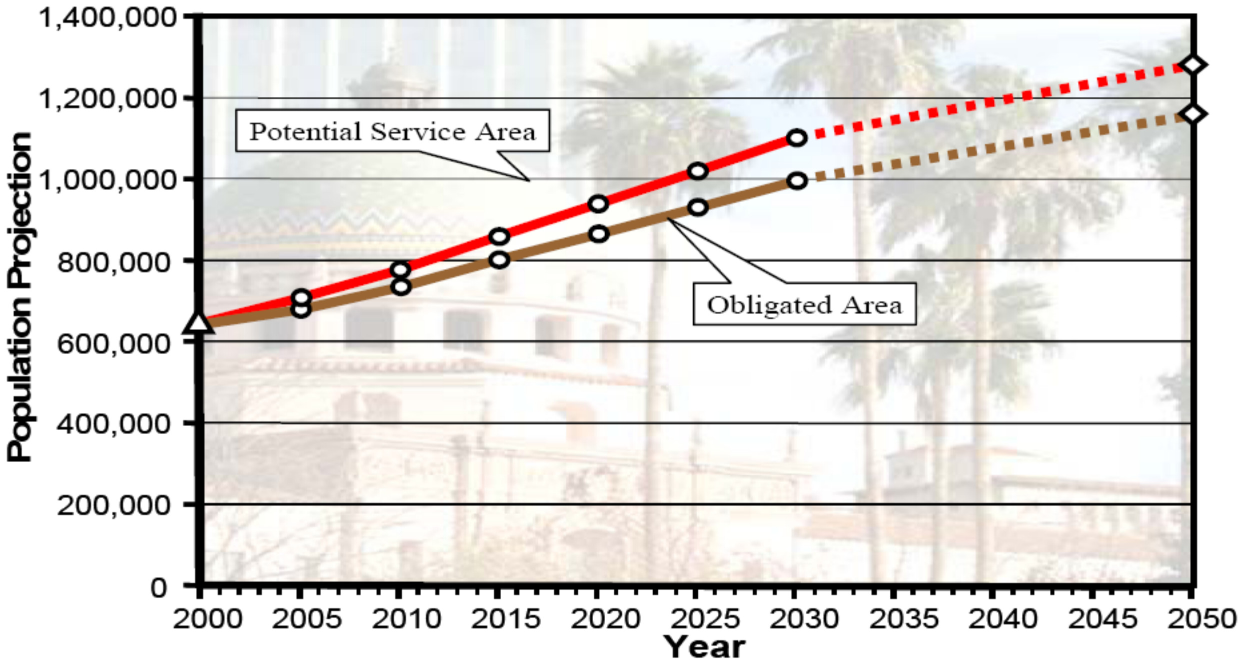


Figure ES-2: Population Projections.

Tucson Water recommends that the resource planning priority be placed on developing additional renewable resources such as the City's effluent supplies, additional imported supplies or a combination of both. In this manner, new growth after 2032 would become more hydrologically sustainable and the City's AWS designation could be extended well beyond 2050. Of the four future scenarios analyzed, *Scenario A* delays the need to develop or acquire additional renewable supplies furthest into the future and maximizes planning flexibility to deal with future uncertainties.

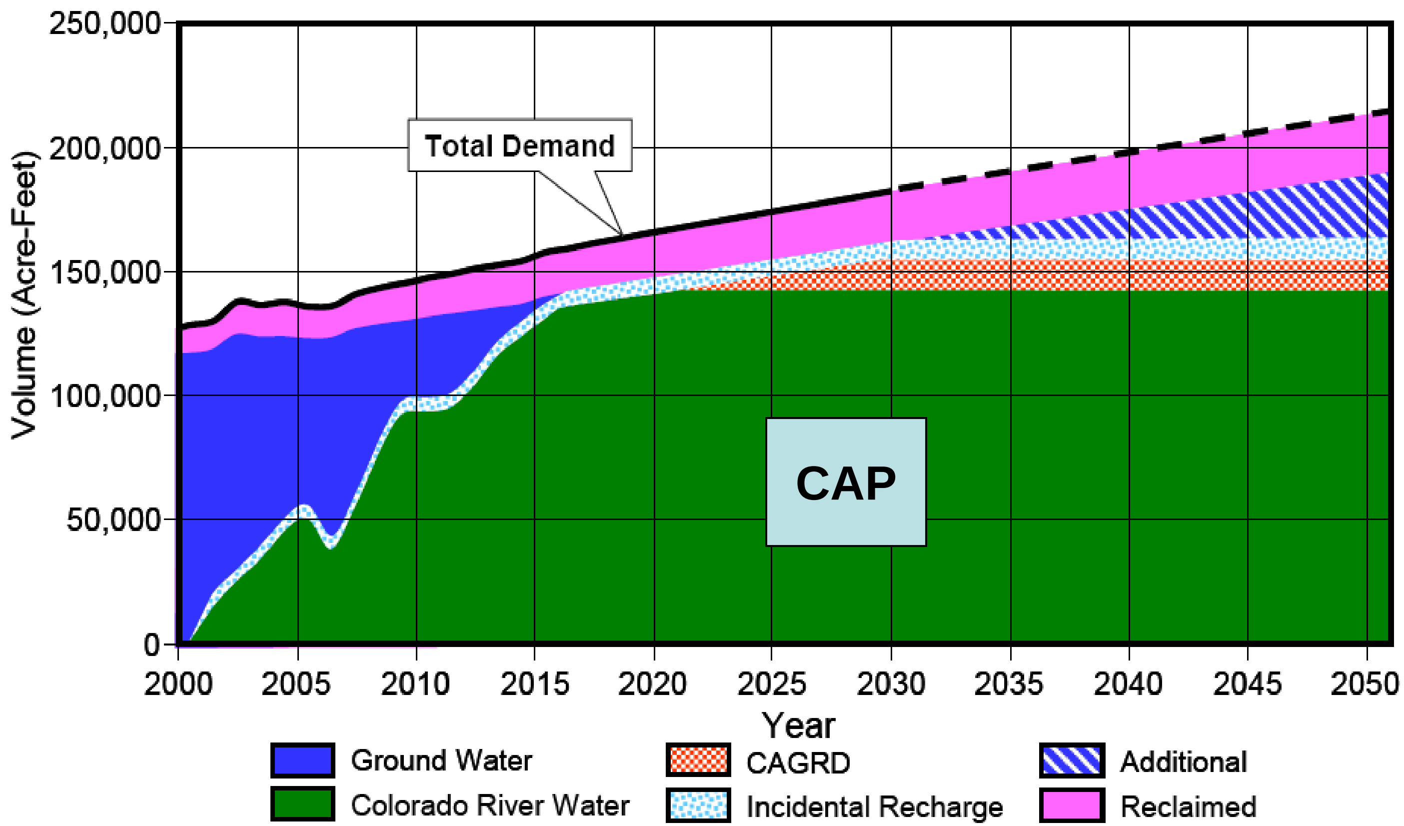
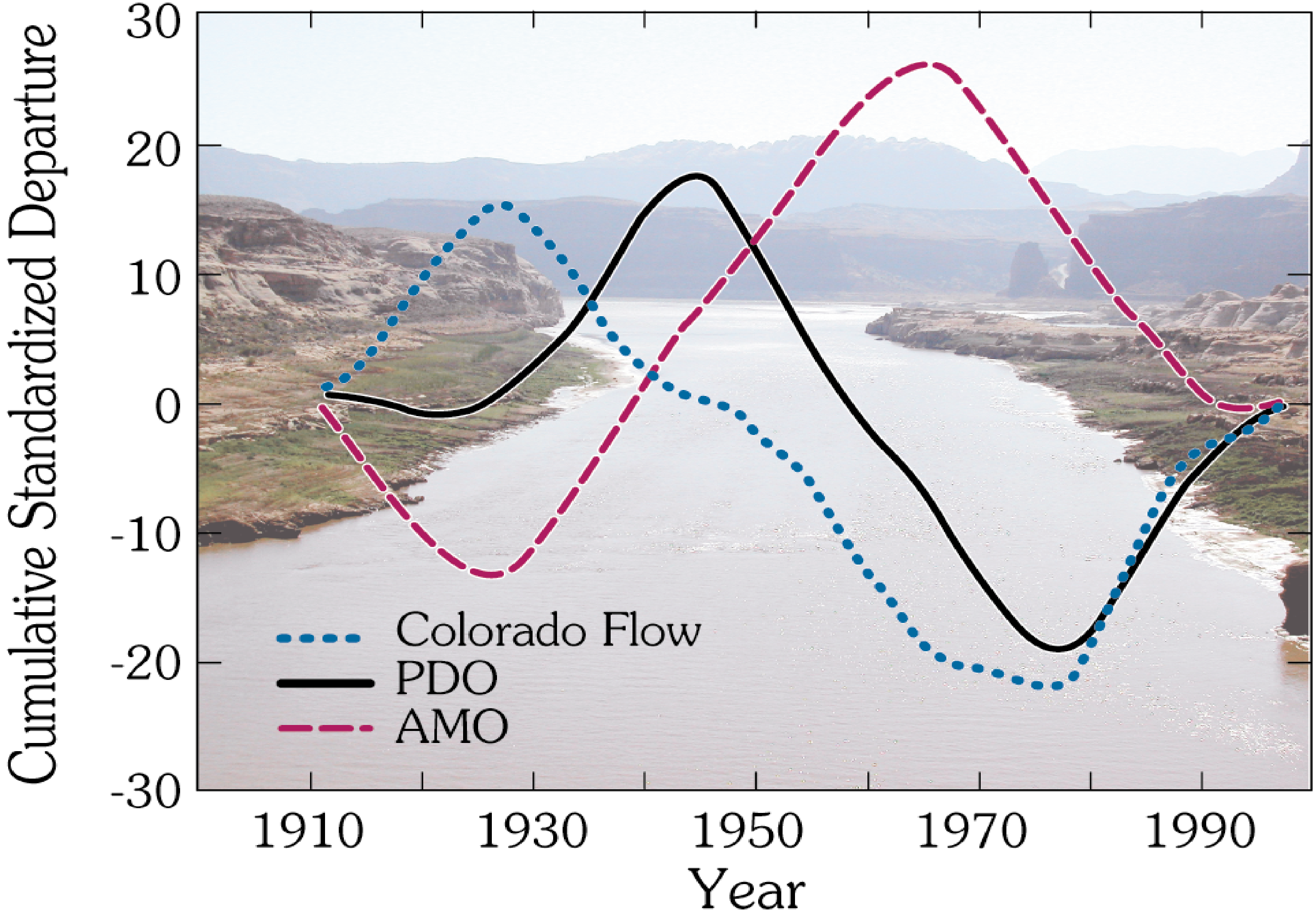


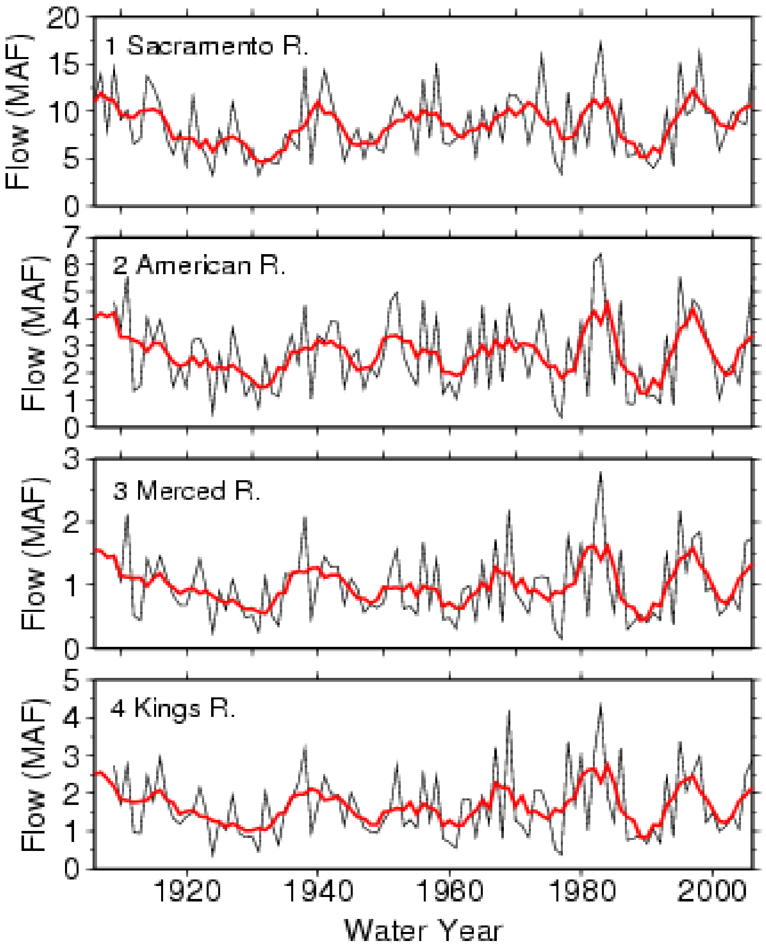
Figure ES-5: Scenario A, Projected Demand and Water Resource Utilization: 2000-2050.

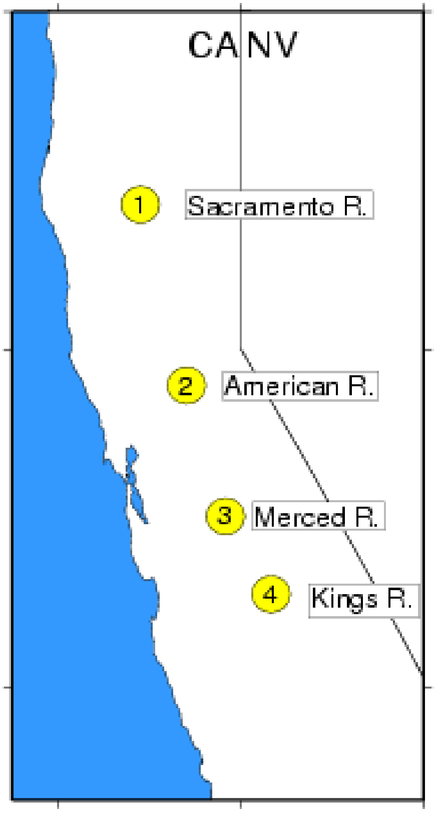
Separating Variability from Trends – a critical part of projections



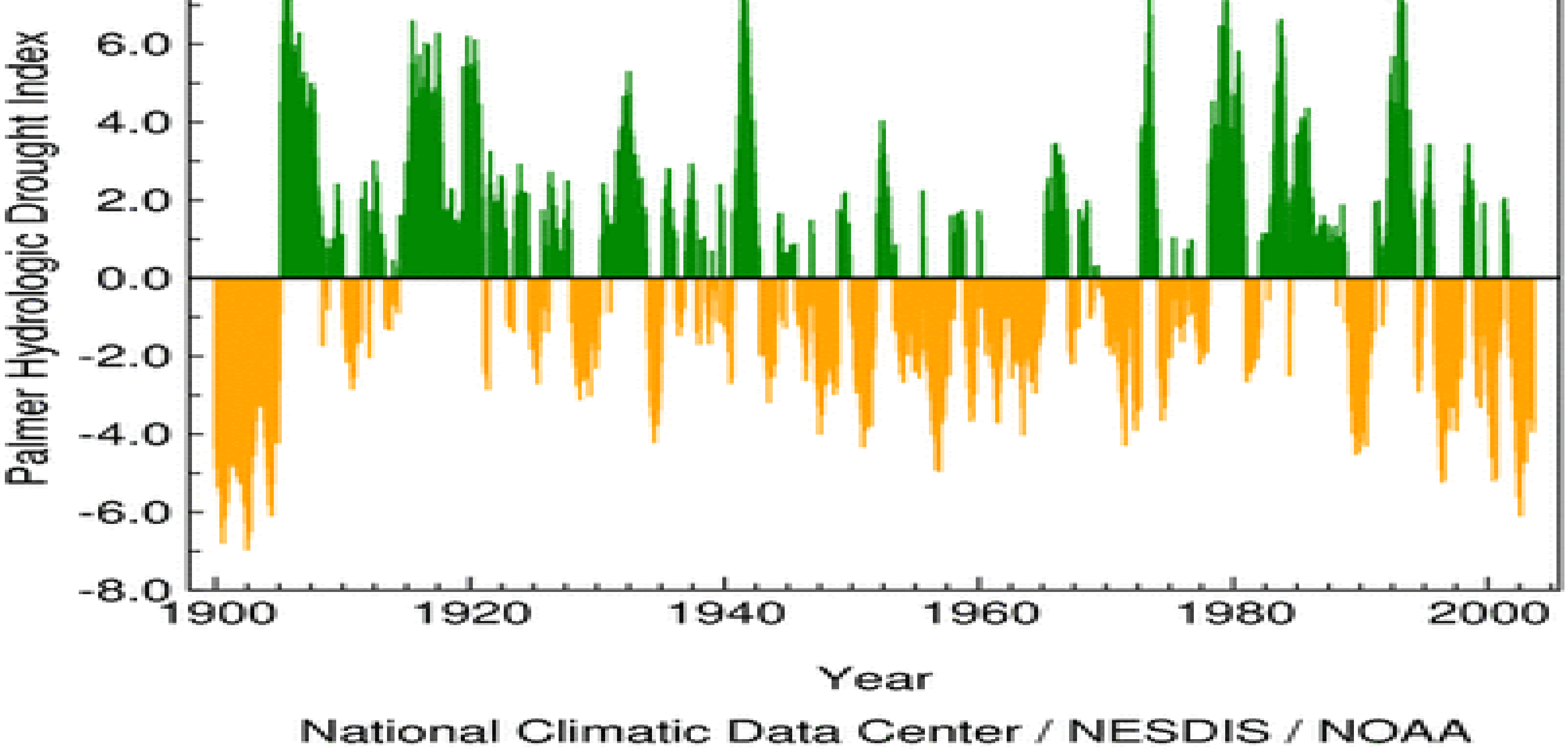
McCabe, Betancourt & Hidalgo.
JAWRA

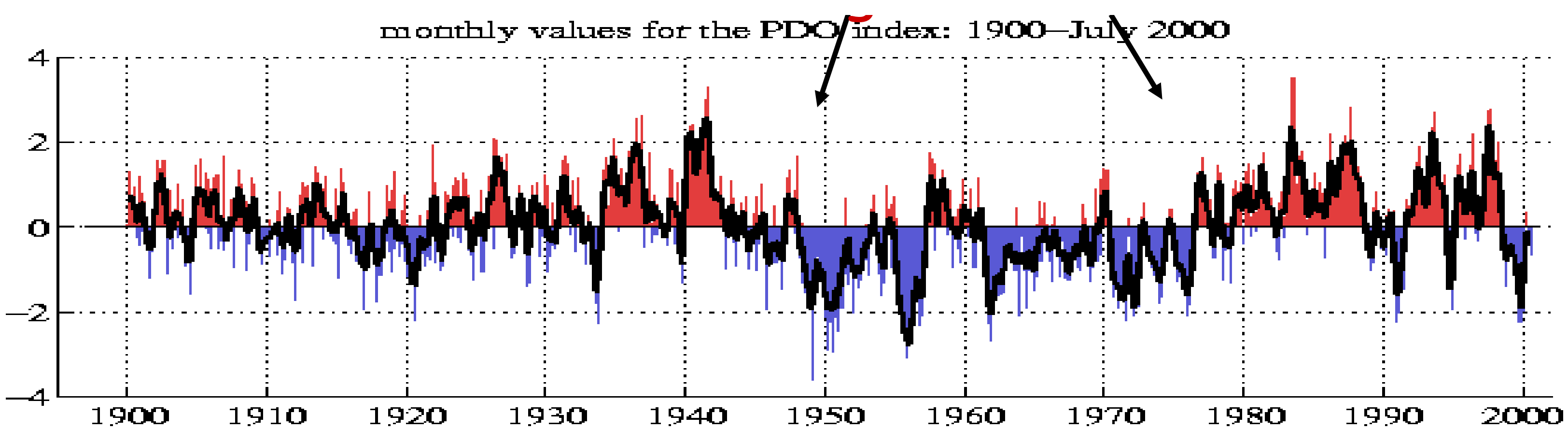
Interannual and Decadal Variability





Annual flow in four major California rivers show superposition of interannual variability (ENSO-like), partly decadal-scale variability, possibly longer-term variability (Andy Wood)

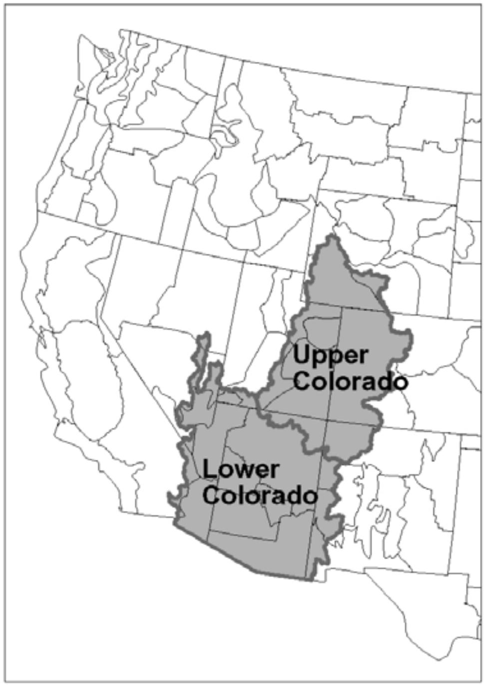


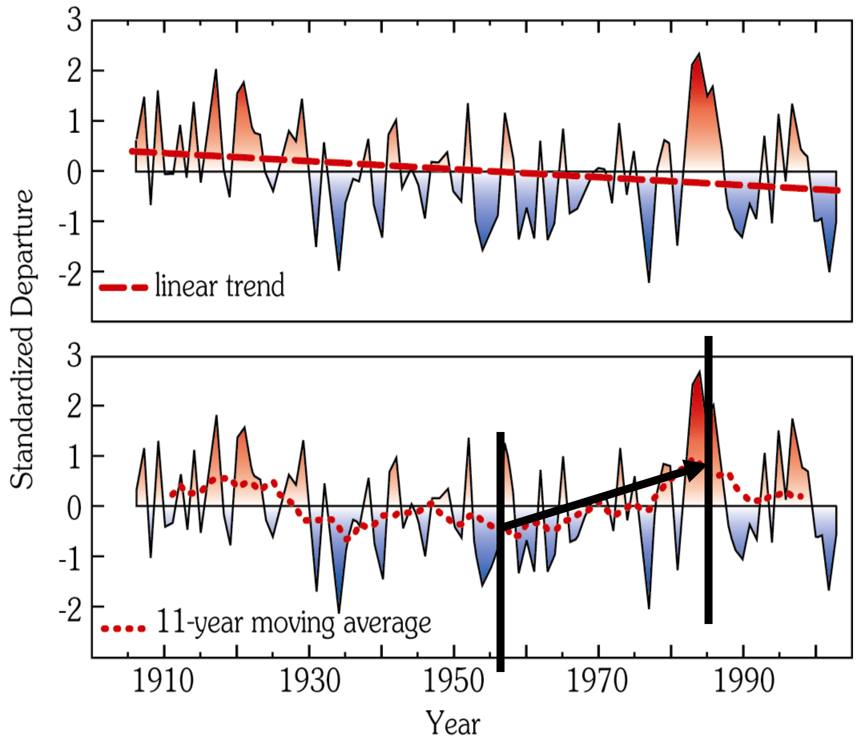


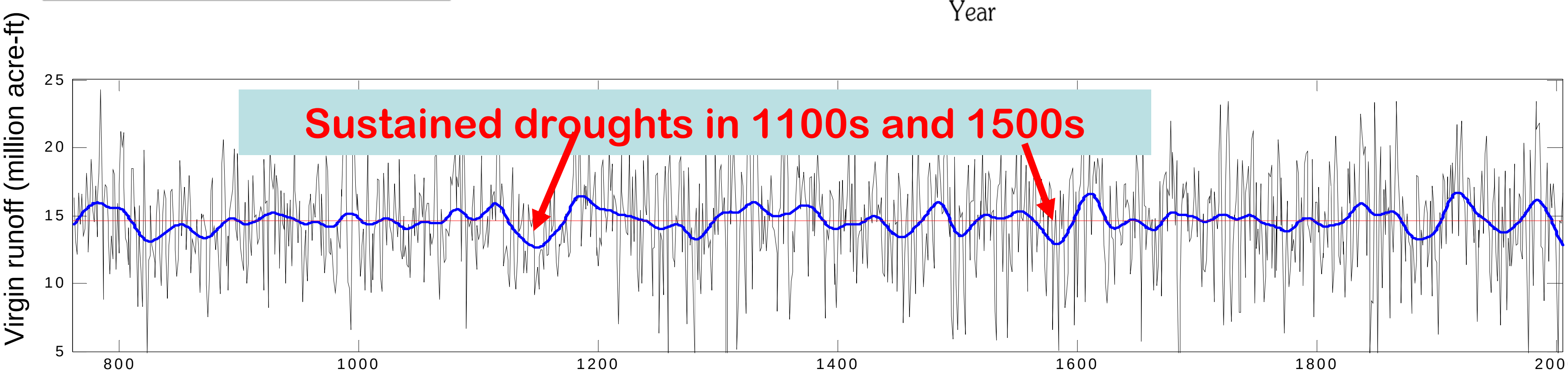
Courtesy of Nate Mantua

Developing a Longer-term Perspective

McCabe, G.J., Betancourt, J.L. and Hidalgo, H. in review.







Data from Meko et al., Geophysical Res.

USE OF TREE-RING RECONSTRUCTIONS FOR SCENARIO DEVELOPMENT

Improved Tools for Drought Planning and Management

A Framework for Generating Exploratory Scenarios of Drought Conditions Using Tree-Ring Information

"EXPLORATORY SCENARIOS describe the future according to known processes of change and extrapolations from the past by incrementally progressing through time."
SAHRA Scenario Development Group

This site provides a compilation of information to aid in the construction of exploratory scenarios of drought conditions in the Southwest through the use of tree-ring based streamflow reconstructions of the Salt-Verde-Tonto and Upper Colorado river basins.

The Laboratory of Tree-Ring Research The University of Arizona | Decision Theater Arizona State University | East Valley Water Forum | Arizona Water Institute

http://fp.arizona.edu/kkh/awi/awi.htm

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University of Arizona
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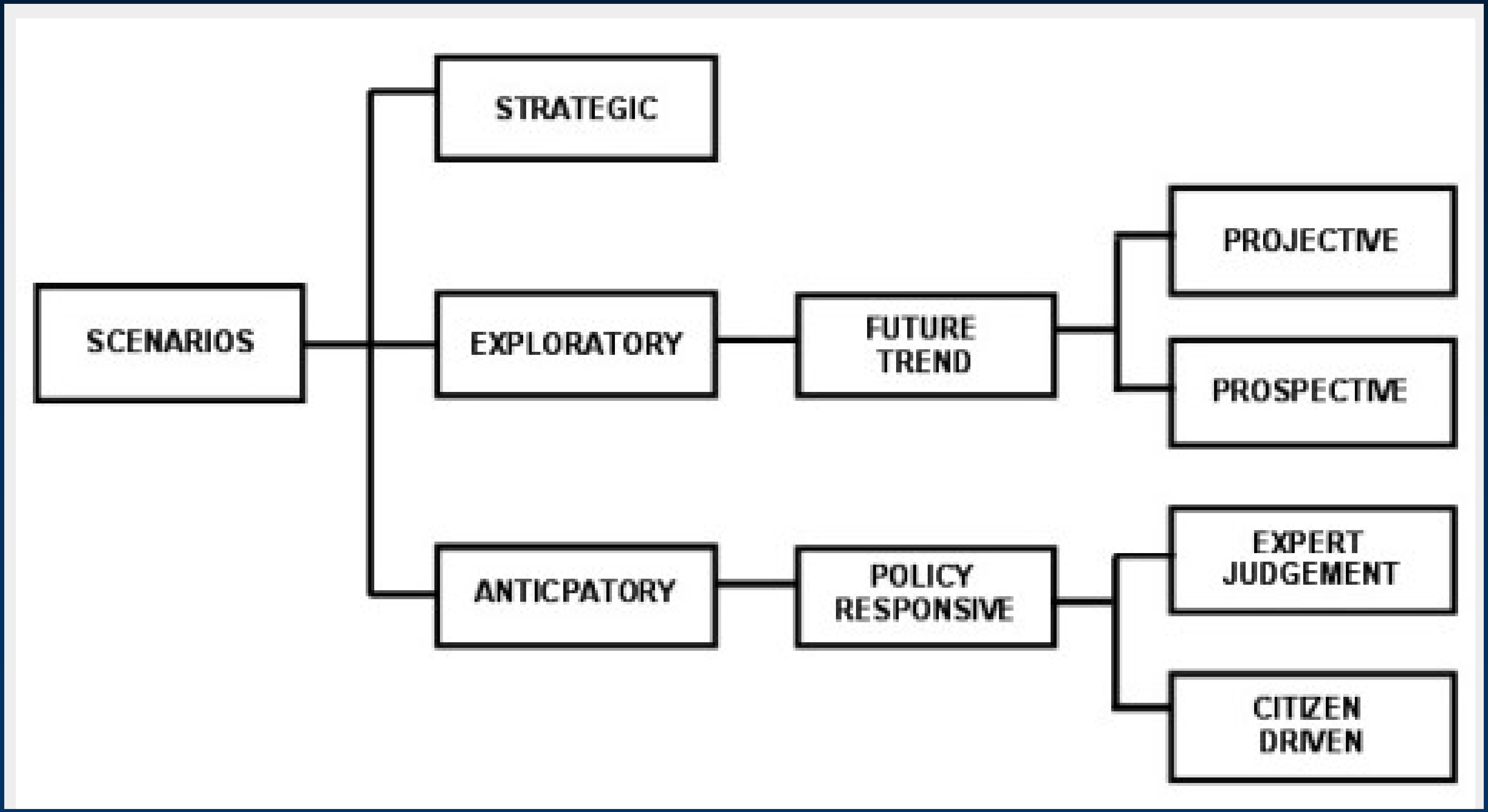
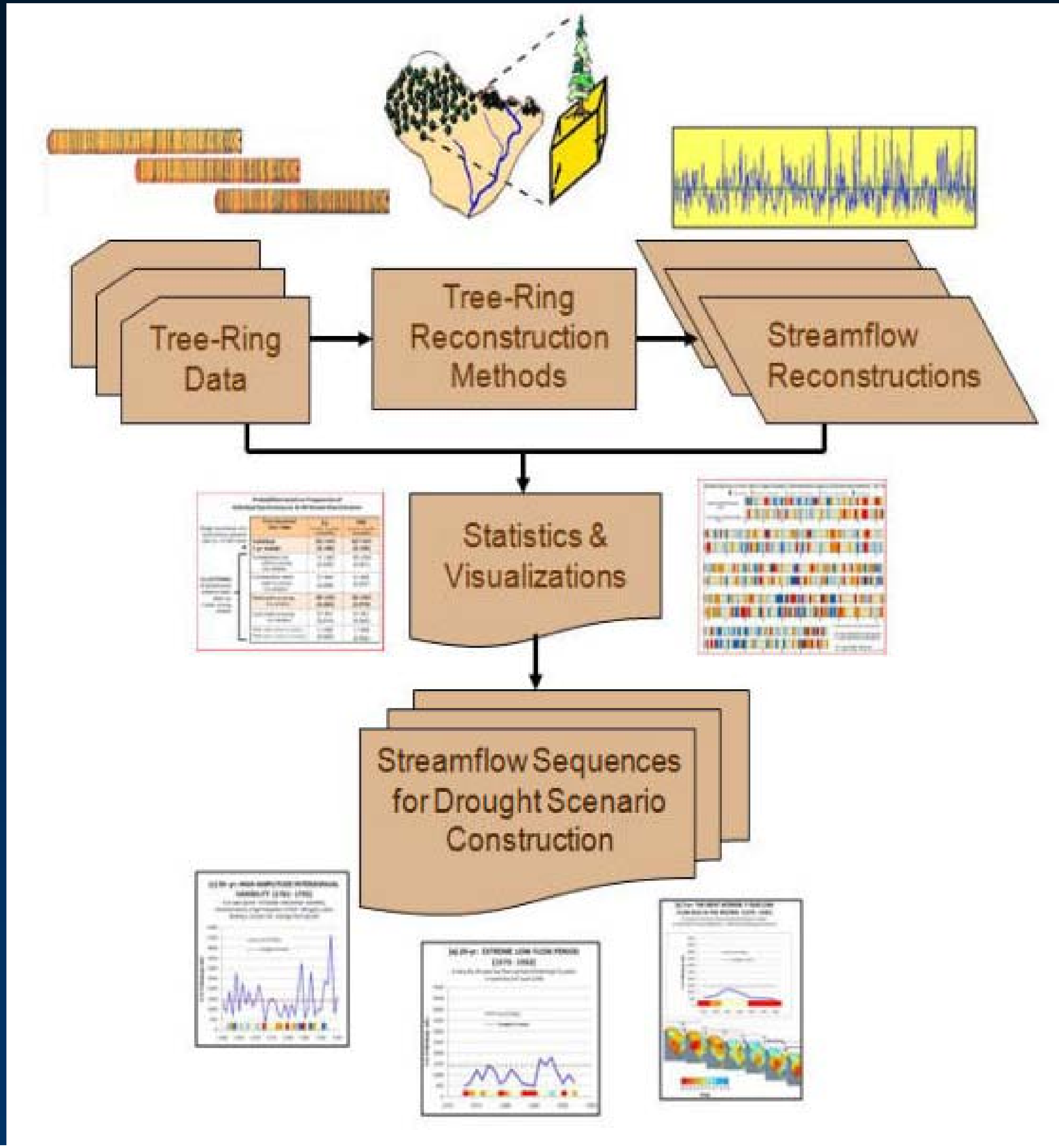
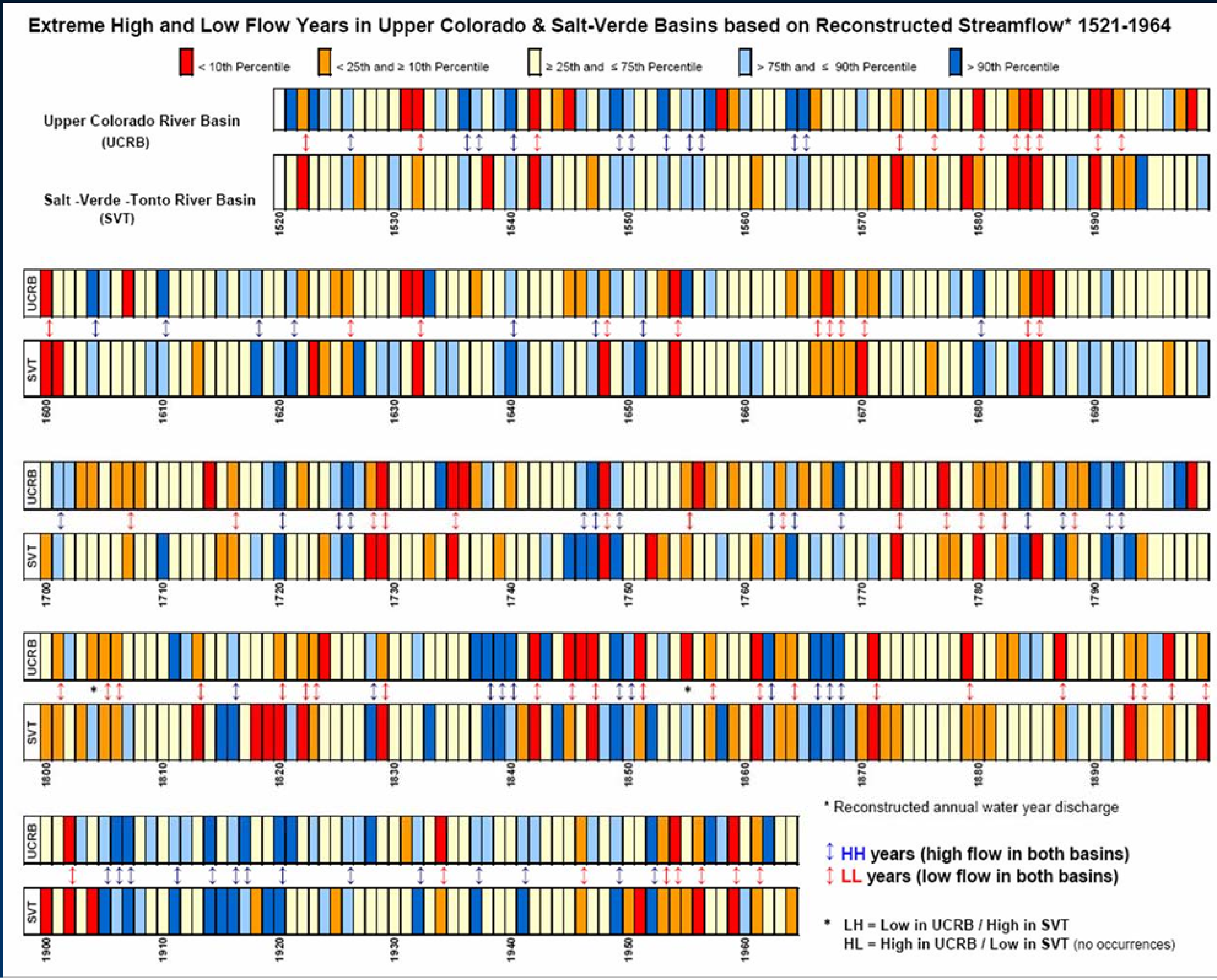
TYPES OF SCENARIOS

from the SAHRA Scenario Group

http://www.sahra.arizona.edu/scenarios




Tree-Ring Data
Tree-Ring Reconstruction Methods
Streamflow Reconstructions
Statistics & Visualizations
Streamflow Sequences for Drought Scenario Construction

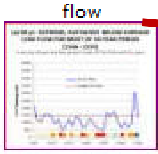
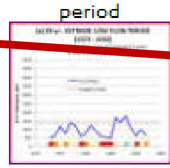
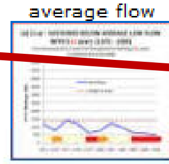
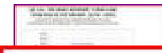

Extreme High and Low Flow Years in Upper Colorado & Salt-Verde Basins based on Reconstructed Streamflow* 1521-1964
< 10th Percentile
< 25th and ≥ 10th Percentile
≥ 25th and ≤ 75th Percentile
> 75th and ≤ 90th Percentile
> 90th Percentile
Upper Colorado River Basin (UCRB)
Salt -Verde -Tonto River Basin (SVT)
UCRB
SVT
* Reconstructed annual water year discharge
HH years (high flow in both basins)
LL years (low flow in both basins)
* LH = Low in UCRB / High in SVT
HL = High in UCRB / Low in SVT (no occurrences)

Suggested Uses of the Streamflow Sequences in Exploratory Scenarios

PROJECTIVE SCENARIOS, - the sequences can be used individually or in combination to **project** streamflow behavior that ***has been experienced in the past*** **onto the future** to represent severe or moderate drought conditions, future episodes of high amplitude streamflow variability, or "best case scenario" wet episodes.

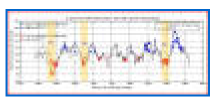
PROSPECTIVE SCENARIOS - specific sequences can be identified that represent the most probable type of streamflow behavior associated with different climate model projections. These **specially tagged sequences can then be combined, extended, or statistically amplified** to construct new streamflow sequences for proposed future climate regimes.

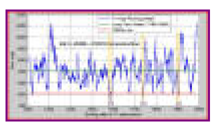
Driest periods (extreme low magnitude flows)	30-yr-a Extreme sustained low flow 	11-yr-a Sustained below average flow 	7-yr-a Most extreme 7-yr low flow run in record 
Continuous runs of low flow years	30-yr-f Sustained below average low flow 	11-yr-b Nearly continuous below average flow 	7-yr-b Most extreme continuously dry sequence 
Low flow periods with intervening high flow for recovery	30-yr-d 6-year low flow run broken by wet year 	7-yr-d Extremely dry run with intervening H year 	

	30-Year Sequences	20-Year Sequences	11-Year Sequences	7-Year Sequences
1500s	30-yr-a (1566-1595) Extreme sustained low flow 	20-yr-a (1573-1592) Extreme low flow period 	11-yr-a (1575-1585) Sustained below average flow 	7-yr-a (1579-1585) Most extreme 7-year low flow run in record 
1600s	30-yr-b (1657-1686) Clustered run of low flow years during low-to-average period 	20-yr-b (1660-1679) Clustered run of flow years during below average period 	-------------	

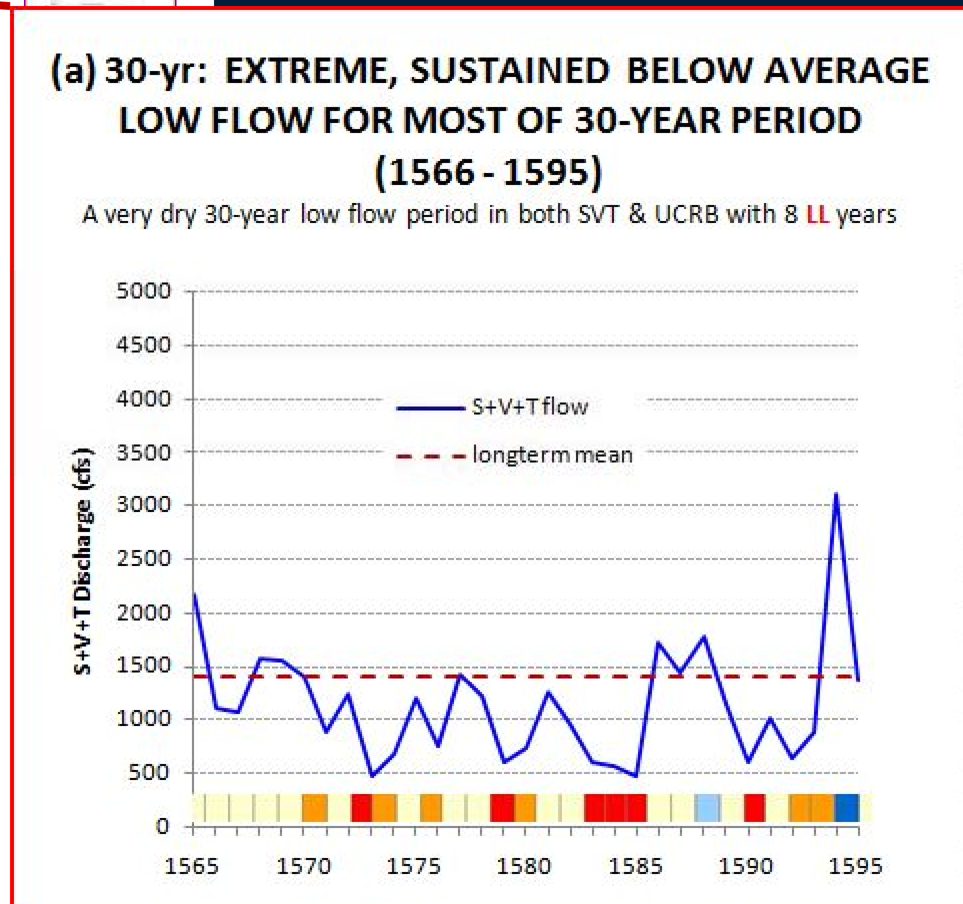
Filtered Time Series Plots Showing Selected

30-Year Sequences 

20-Year Sequences 

11-Year Sequences 

7-Year Sequences 



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7-YR SCENARIO SEQUENCES

RECONSTRUCTED FLOW TIME SERIES (1521-1964)

(Rank 1 = driest year, 444 = wettest year)

- ≤ 10th Percentile
- ≤ 25th and > 10th Percentile
- > 25th and < 75th Percentile
- ≥ 75th and < 90th Percentile
- ≥ 90th Percentile

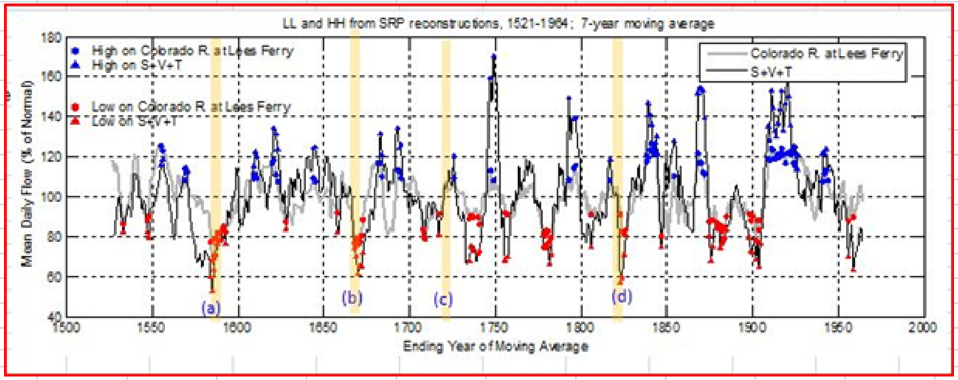
* Reconstructed annual water year discharge

HH years (high flow in both basins)

LL years (low flow in both basins)

LH = Low in UCRB / High in SVT

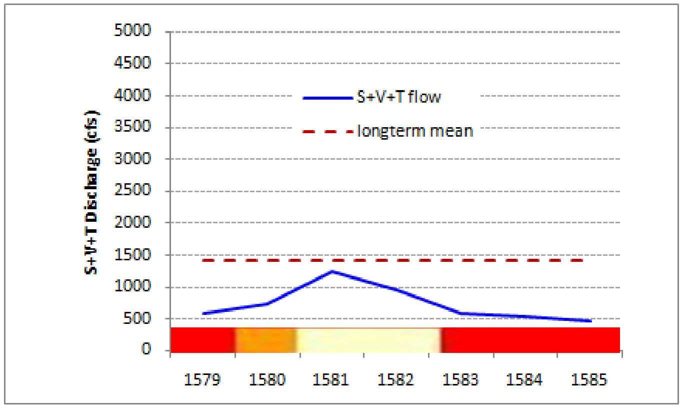
HL = High in UCRB / Low in SVT *(none)*



UPPER COLORADO RIVER BASIN					SALT-VERDE-TONTO RIVER BASIN			
water yr	Qnt	UCRB Q (cfs)	rank ↑		water yr	Qnt	SVT Q (cfs)	rank ↑
1565		26280	406	HH	1565		2179	392
1566		15991	104		1566		1100	170
1567		17352	143		1567		1077	162
1568		19239	198		1568		1569	294
1569		21609	271		1569		1554	292
1570		24332	358		1570		1411	252
1571		18799	190		1571		873	109
1572		20631	242		1572		1240	208
1573		15898	101	LL	1573		466	16
1574		16327	112		1574		674	58
1575		20038	215		1575		1207	198
1576		15029	85	LL	1576		754	80
1577		25409	386		1577		1430	259
1578		23285	327		1578		1226	205
1579		18461	179		1579		591	37
1580		7319	10	LL	1580		738	74
1581		16871	129		1581		1256	213
1582		20256	227		1582		959	126
1583		14073	68	LL	1583		588	36
1584		5479	6	LL	1584		552	29
1585		10259	23	LL	1585		471	17
1586		22235	292		1586		1718	325
1587		19312	201		1587		1442	262
1588		20397	233		1588		1788	337
1589		20364	230		1589		1142	186
1590		9866	18	LL	1590		597	40

(a) 7-yr: THE MOST EXTREME 7-YEAR LOW FLOW RUN IN THE RECORD (1579 - 1585)

A very dry 7-year low flow period containing 4 LL years in both the SVT and UCRB and 4 ≤ 10th Percentile years in the SVT



30-yr Scenario Sequences | 20-yr Scenario Sequences | 11-yr Scenario Sequences | 7-yr Scenario Sequences | LL HH Extreme Yrs Both Basi

Web-based “course” by UA’s Roger Caldwell:

“Anticipating the Future”

http://cals.arizona.edu/futures/

- Represent Events by Simple Curves
- Question Assumptions
- Watch for Groupthink and Fixed Mindsets
- Expect Both Surprises & ‘Expected Results’
- Several Solutions are Likely