Water Resources and Ecosystem Stability in the Changing Climates of the North American Deserts

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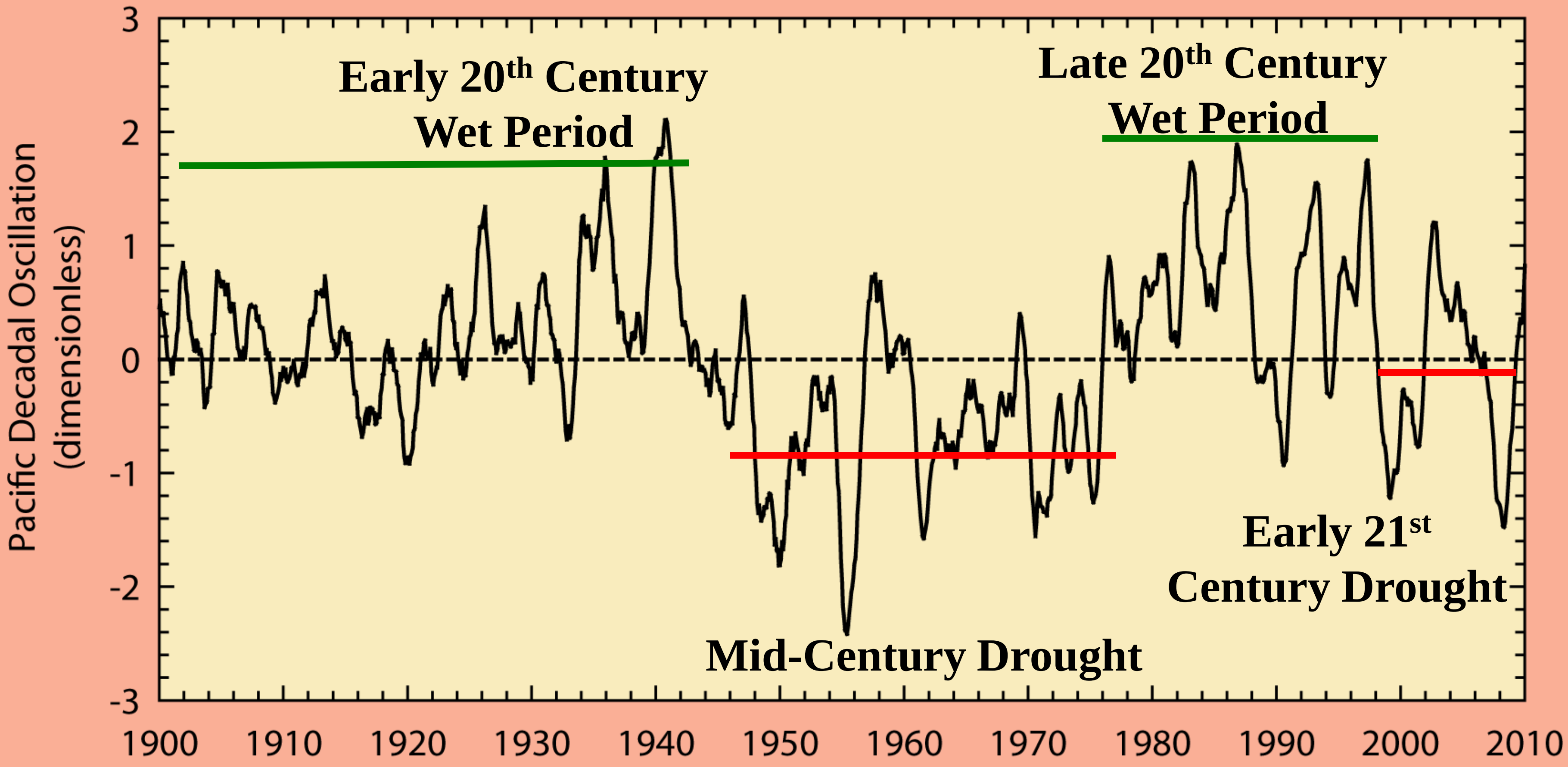
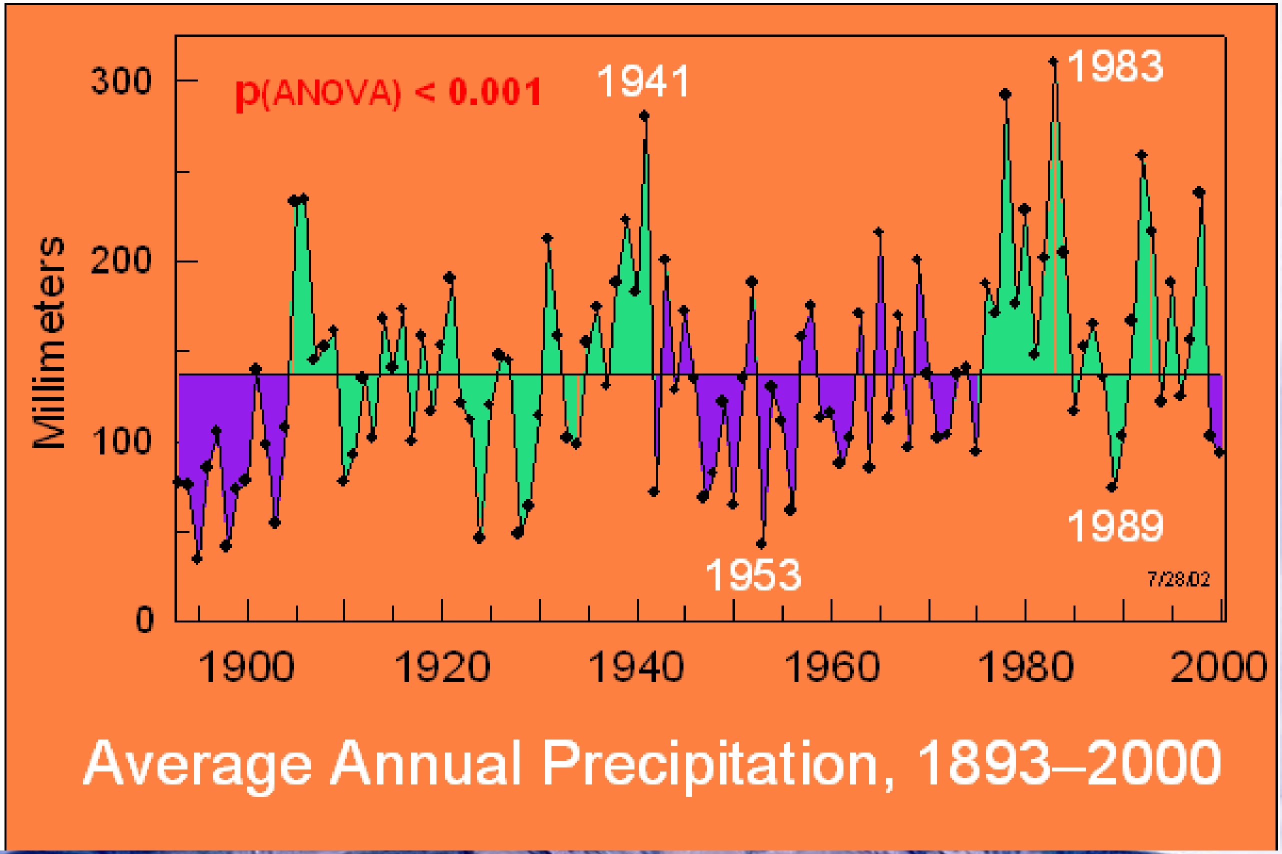
Pacific Decadal Oscillation (smoothed)



ANNUAL PRECIPITATION OF THE MOJAVE DESERT (1893-2000)



Important droughts: 1890s-1904, late 1920s to mid-1930s, mid-century drought, 1989-1990, current

Important wet periods: 1905-1920, late 1930s-1941, late 1970s to mid 1980s, 1991-1993

Source: Hereford et al. (2002), Hereford et al. (2006)

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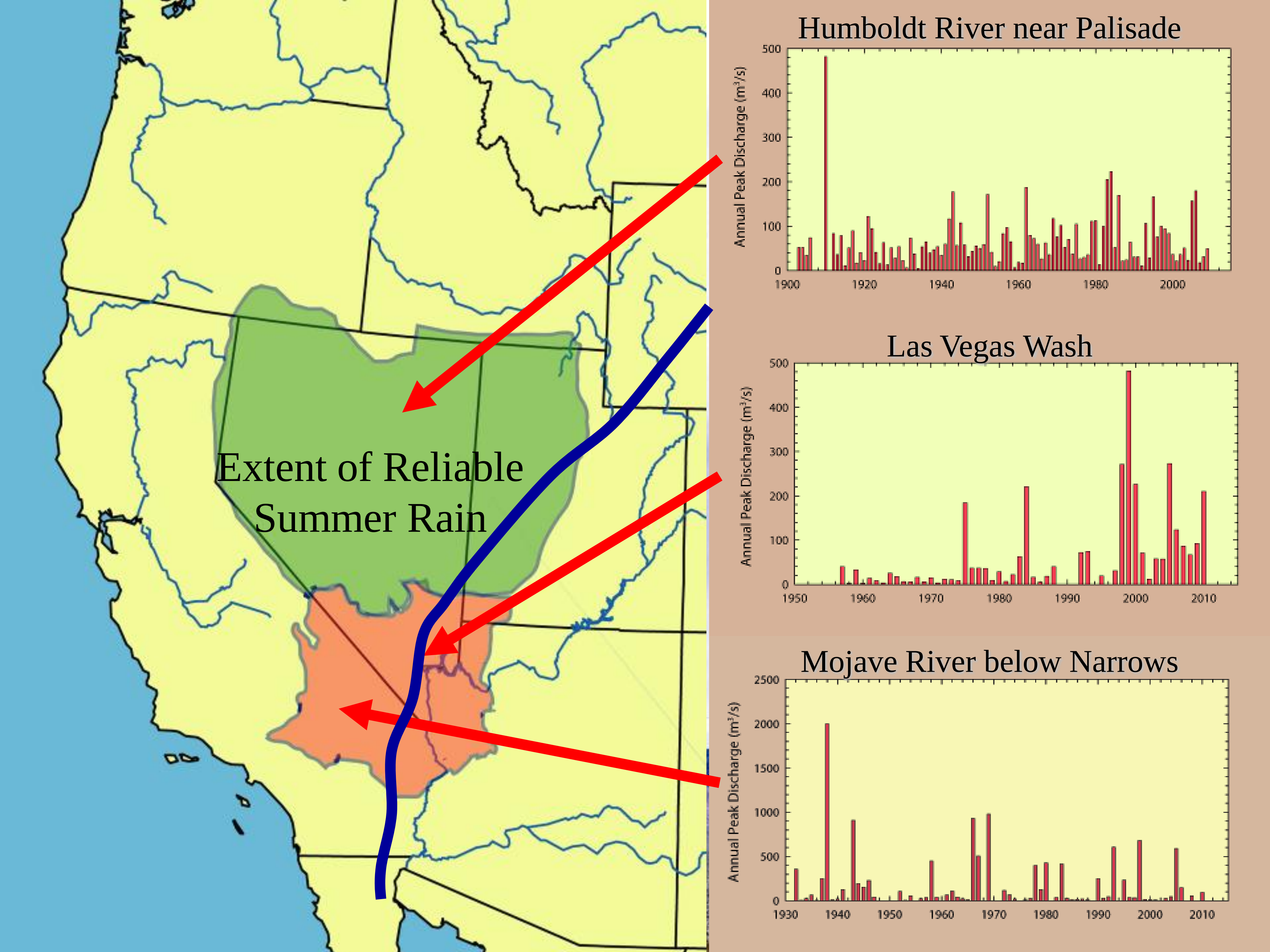
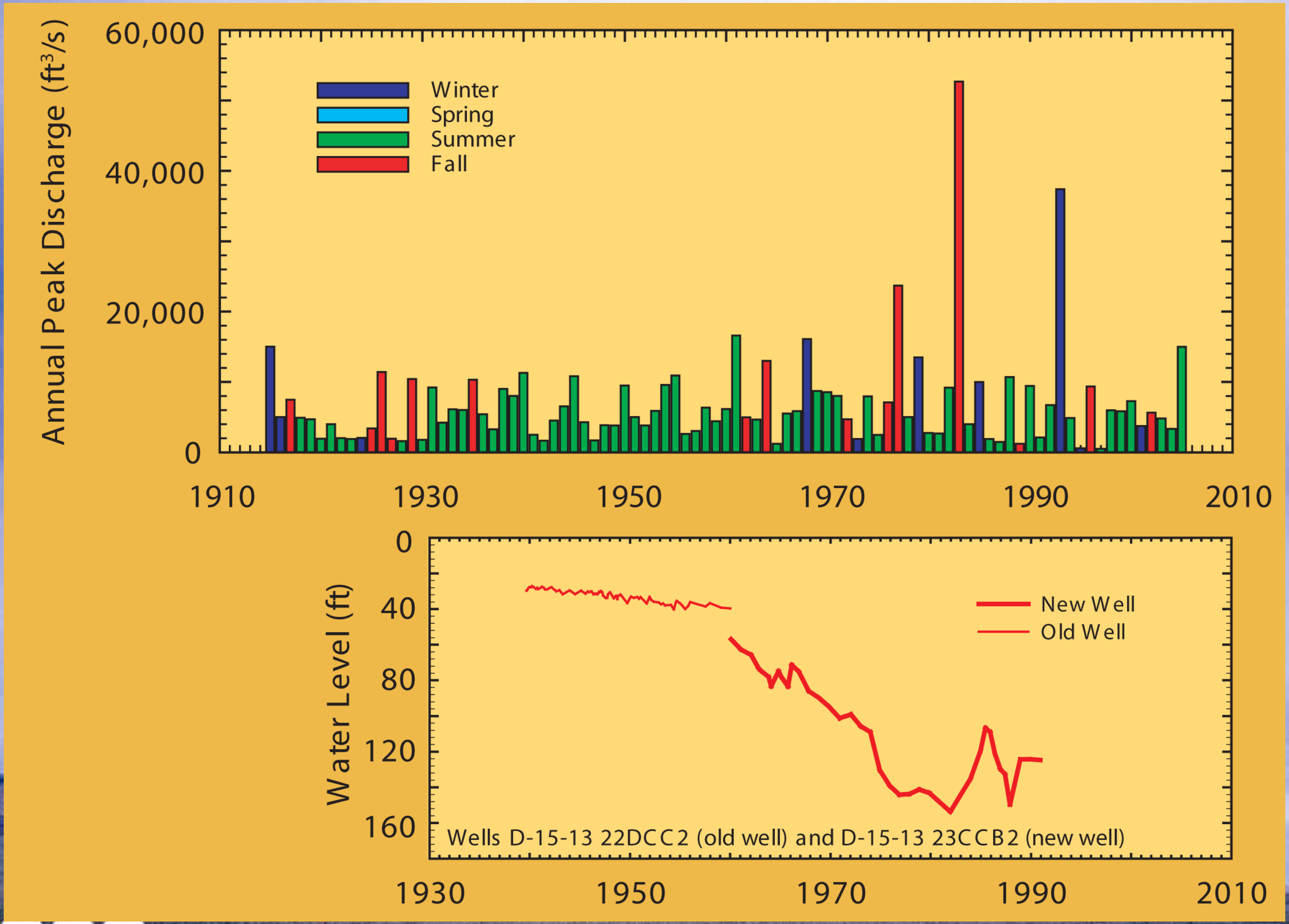
THREE TYPES OF WATER RESOURCES

- Inter-basin transfers, particularly involving the Colorado River
- Surface water
- Groundwater
- All are inter-related
- All are to at least some degree affected by climatic change

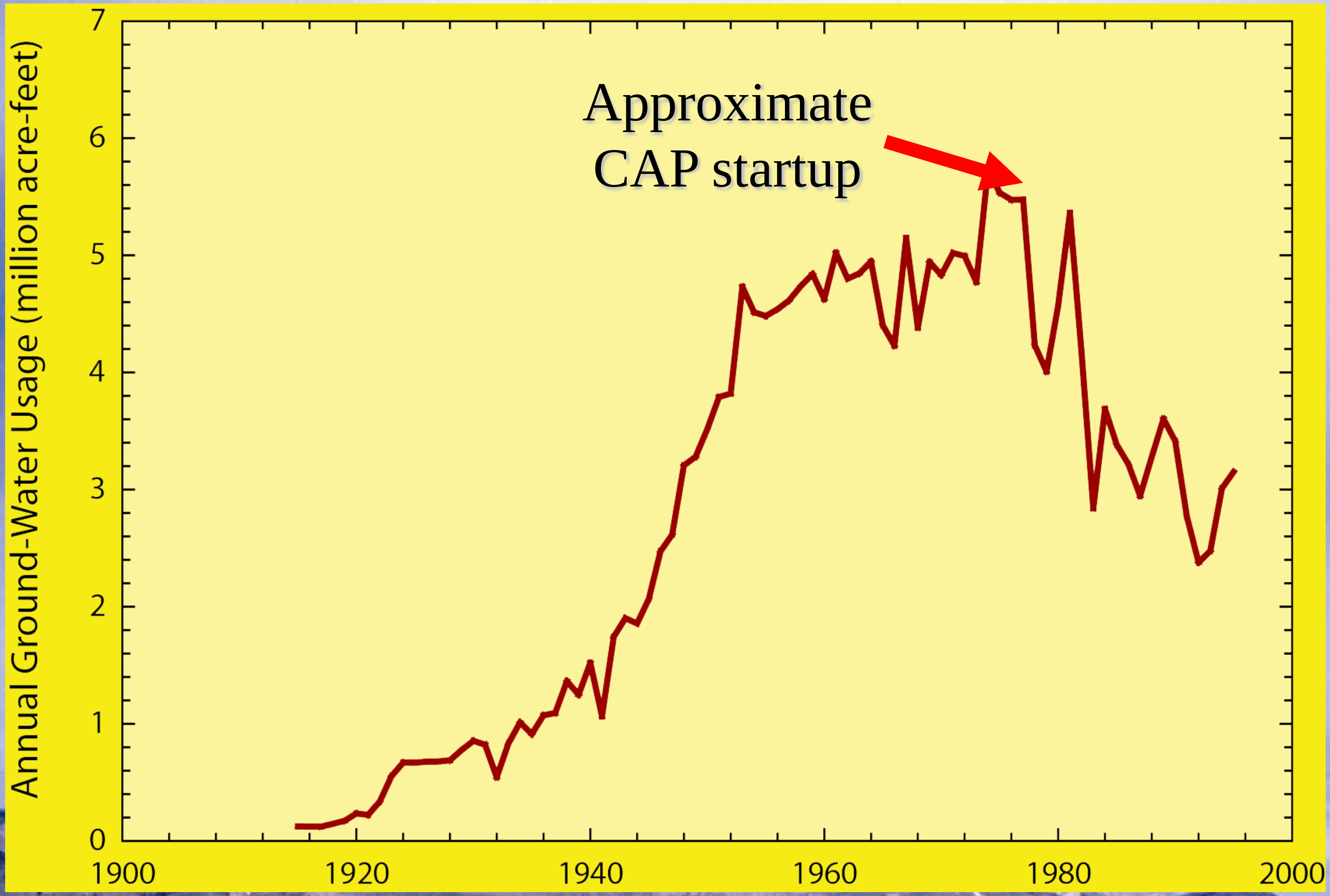


Extent of Reliable Summer Rain
Humboldt River near Palisade
Annual Peak Discharge (m3/s)
0 100 200 300 400 500
1900 1920 1940 1960 1980 2000
Las Vegas Wash
Annual Peak Discharge (m3/s)
0 100 200 300 400 500
1950 1960 1970 1980 1990 2000 2010
Mojave River below Narrows
Annual Peak Discharge (m3/s)
0 500 1000 1500 2000 2500
1930 1940 1950 1960 1970 1980 1990 2000 2010

SANTA CRUZ RIVER AT TUCSON



GROUND-WATER USE IN ARIZONA



Anning and Duet (1990), updated by Mark Anderson, unpublished data

Transmission of Climate Signals through Groundwater Systems

Changes in flow from climate change could be seen rapidly in surface runoff, but timing of changes in groundwater systems is highly dependent on factors including

- Changes in near-surface evapotranspiration
- Time for changes in recharge to move through the unsaturated zone
- Propagation of changes through the saturated zone to areas of groundwater discharge

Source: S.A. Leake, USGS, unpublished data

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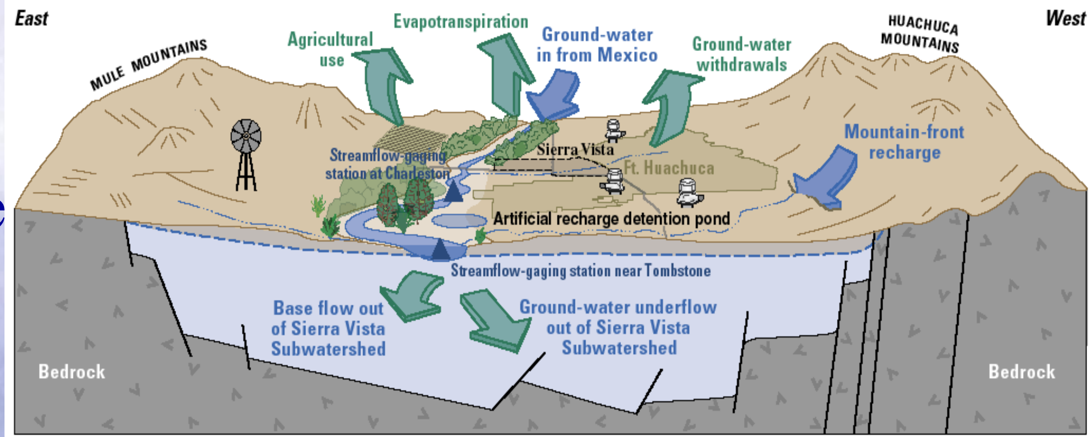
Transmission of Climate Signals through Groundwater System– San Pedro model (2006)

– Recharge at periphery
– Discharge occurs in riparian system
– Test - increased recharge by 25 percent, tracked changes in outflow through time
– Analysis considers only saturated GW flow



Simulated annual water budget for a ground-water-flow model — Values are in acre-feet per year

GROUND-WATER INFLOW

	Estimated range	2002 Estimates	2011 Projections
—Natural recharge	11,200–16,000	15,000	15,000
—Underflow from Mexico	3,000–3,400	3,000	3,000
—Total		18,000	18,000

GROUND-WATER OUTFLOW

	Estimated range	2002 Estimates	2011 Projections
—San Pedro base flow	3,250–6,290	3,250	3,250
—Net ground-water withdrawals		16,500	18,600
—Riparian and wetland evapotranspiration	6,230–7,700	7,700	7,700
—Ground-water underflow at Tombstone streamflow-gaging station	300–440	440	440
—Total		27,900	30,000

ANNUAL STORAGE CHANGE (no management measures)

—2002 Estimated	–9,900
—2011 Projected	–12,000

Source: S.A. Leake, USGS, unpublished data

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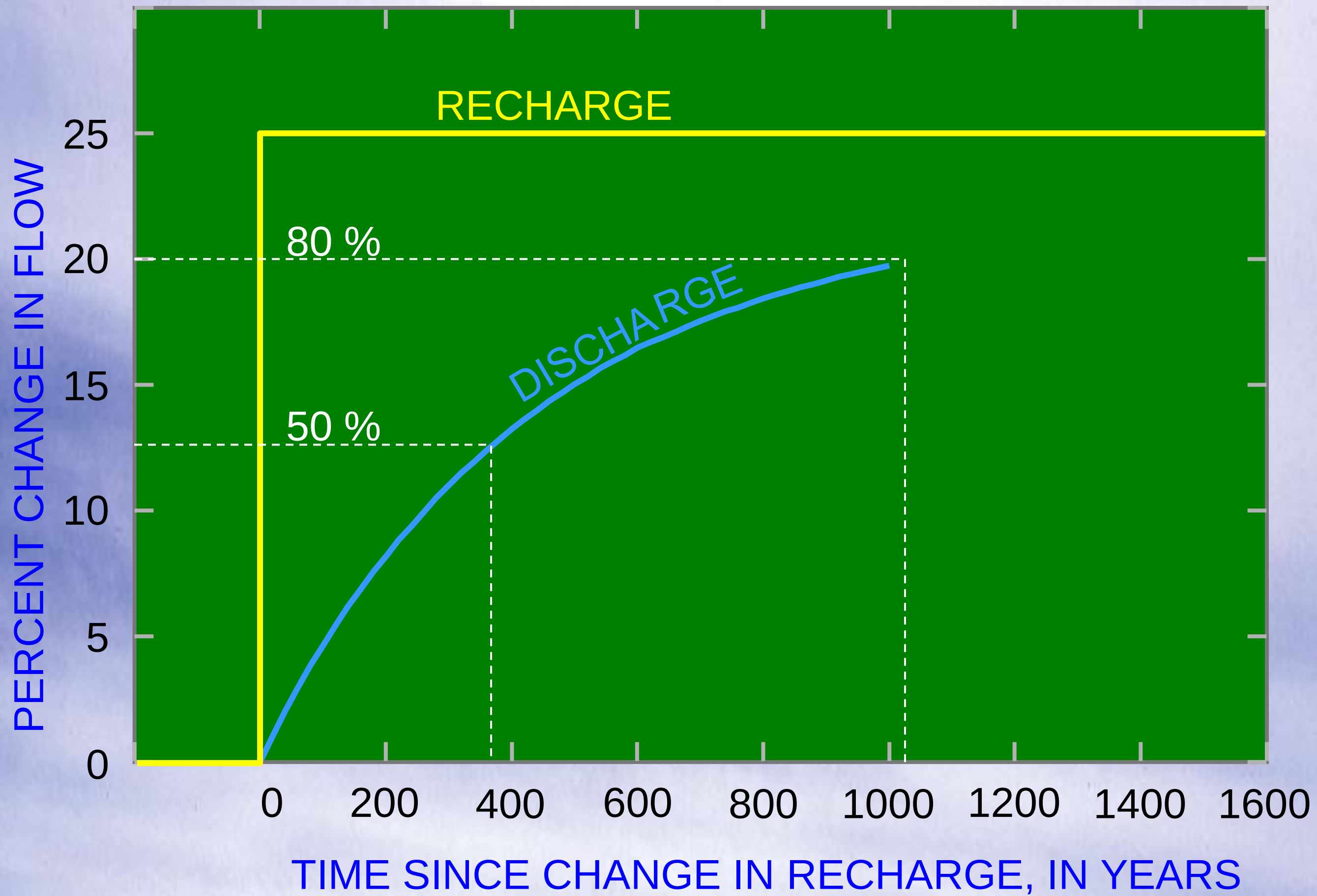

Transmission of Climate Signals through Groundwater—San Pedro Results

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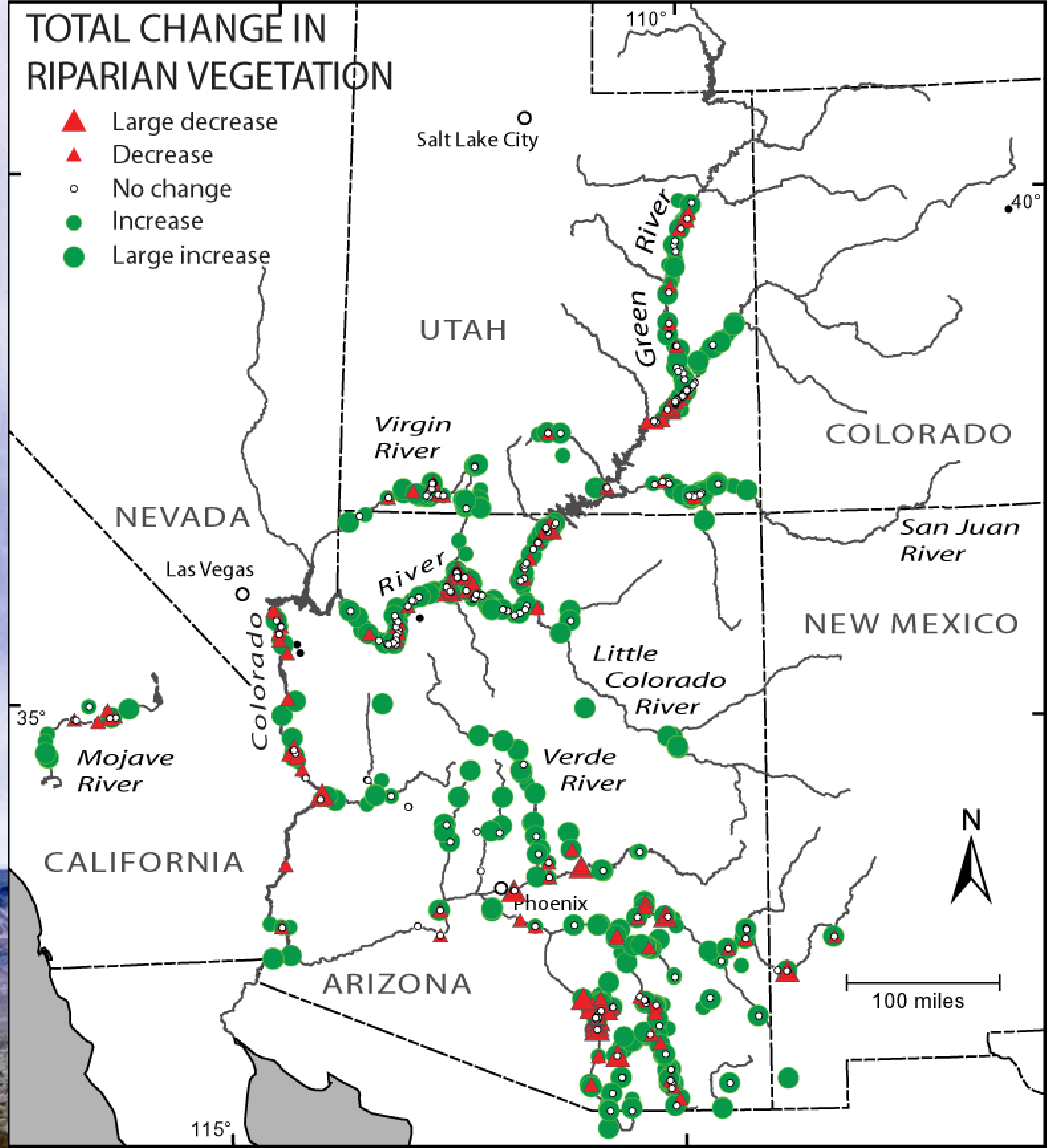
Source: S.A. Leake, USGS, unpublished data

Desert Springs

We don't know a whole lot about the hydrology of mountain springs or its relation to climate change.

CHANGE IN RIPARIAN VEGETATION

Evaluated with about 2000 repeat photographs, 1871-2000



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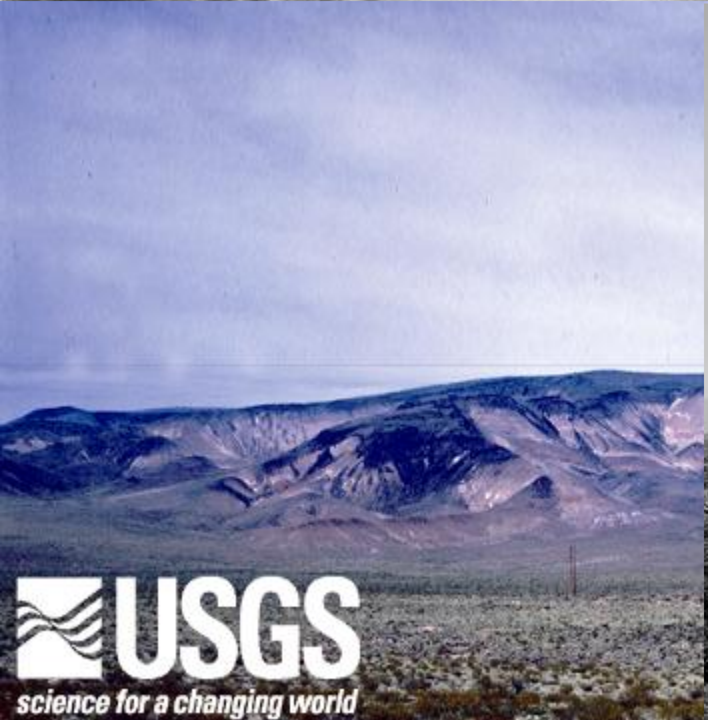
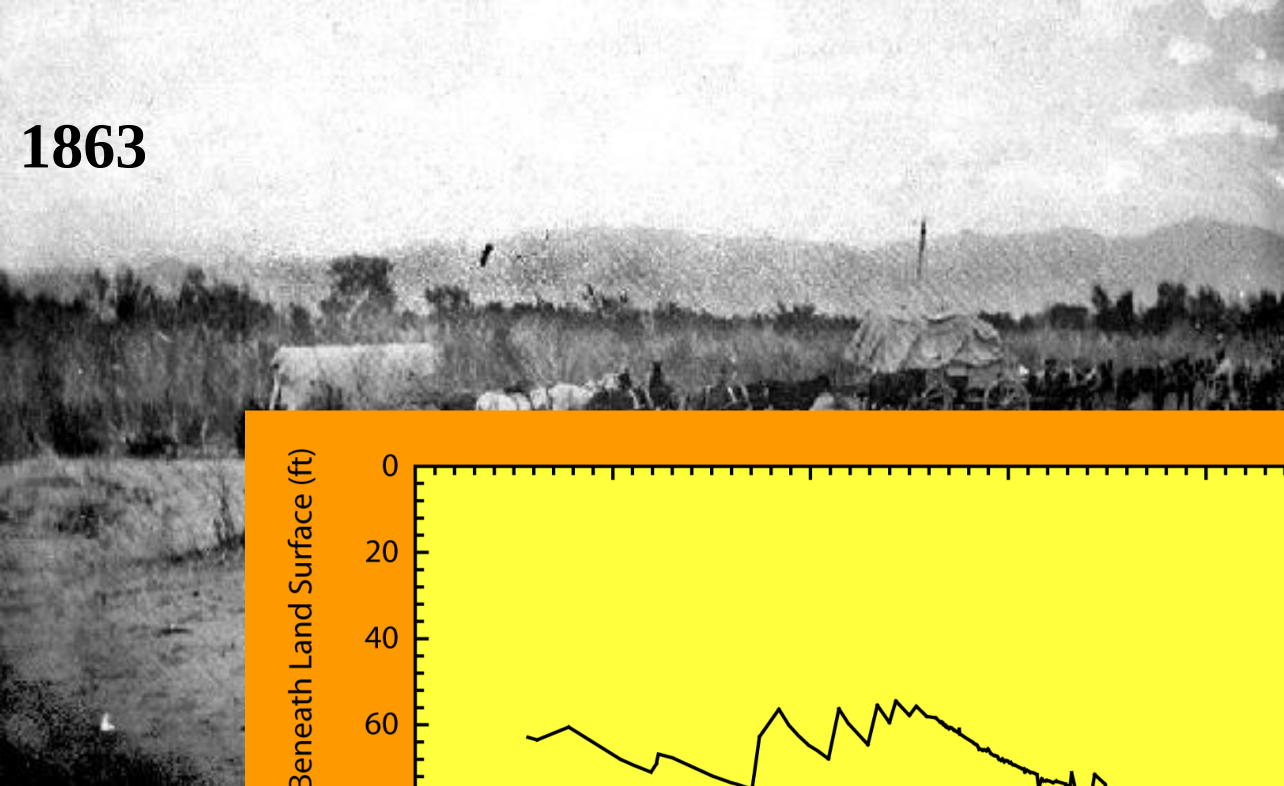
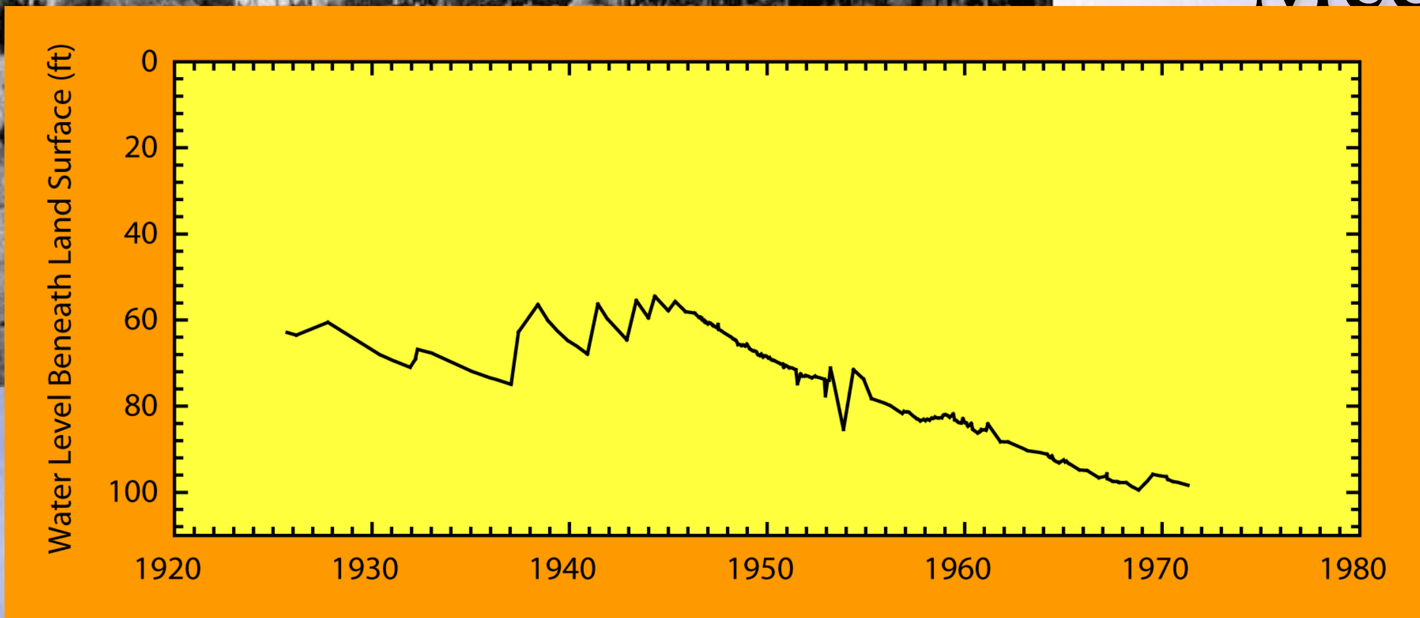
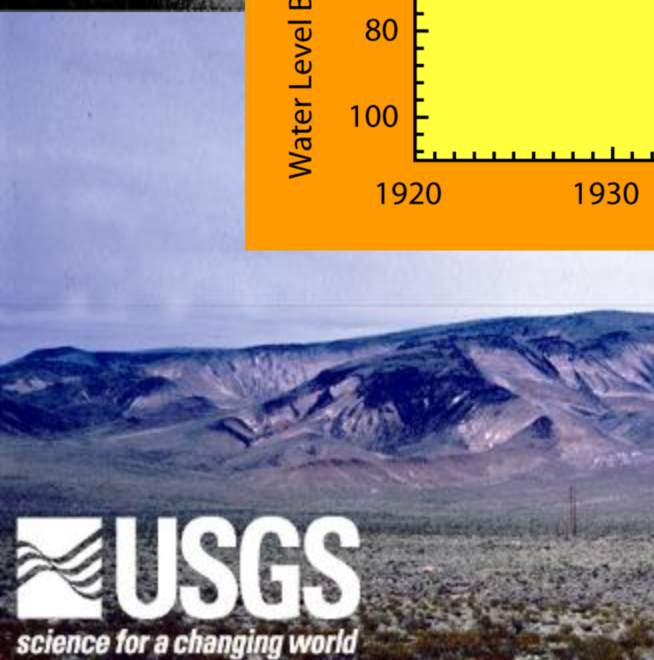
Mojave River Upstream of Lower Narrows

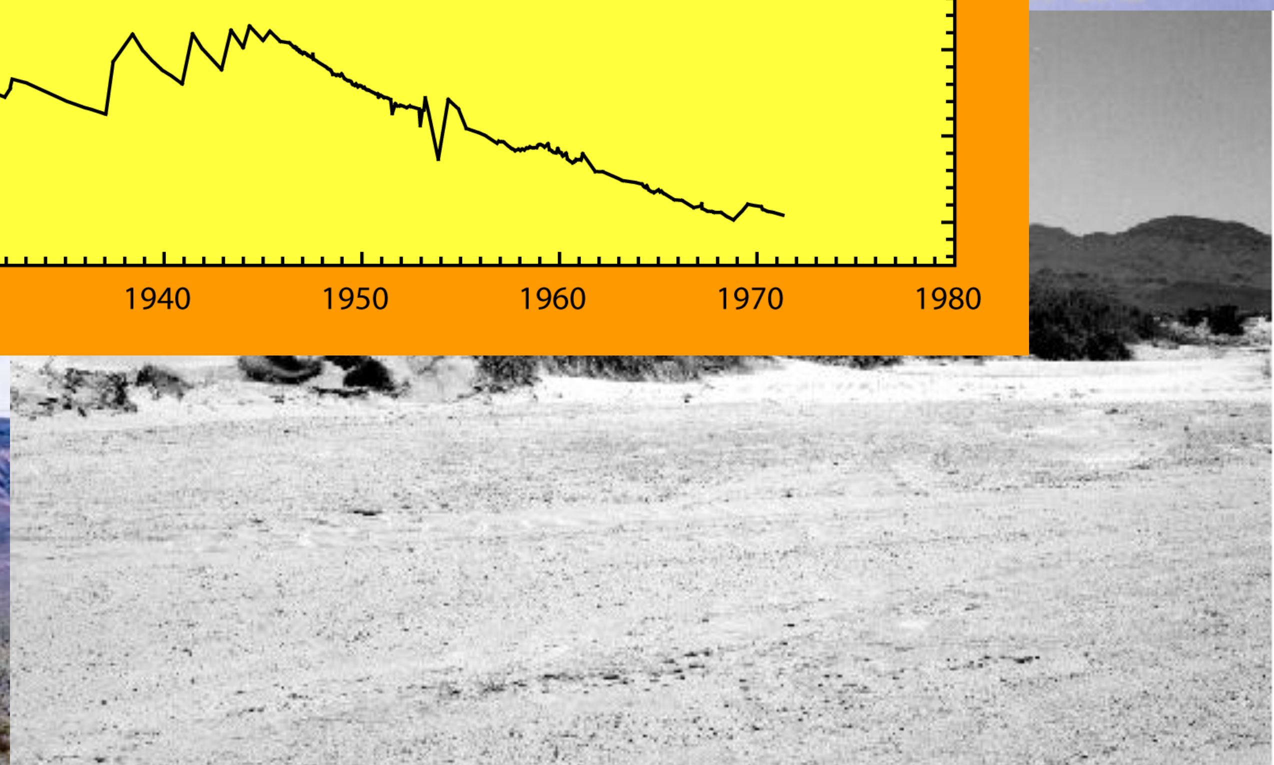


Mojave River Meeting
the
ads









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WHY HAVE INCREASES OCCURRED?

- Two 20th century wet periods of increased winter rainfall and floods beneficial to woody riparian vegetation.
- Higher winter and nighttime temperatures have increased the growing season period.

WHY HAVE DECREASES OCCURRED?

- Excessively pumped groundwater.
- Surface-water diversion and excessive groundwater use.
- Bank protection and excessive groundwater use.
- Reservoirs.

WHAT DOES THE FUTURE HOLD?

- Assuming that winter drought is prevalent in the coming decades, groundwater recharge, particularly in alluvial aquifers far from mountain fronts, appears certain to decline but effects won’t be felt for centuries.
- Native riparian species are likely to be decimated, particularly if groundwater use is excessive in alluvial aquifers.
- Non-native species may profit if summer floods increase.

DESERT PLANTS

- Some have taken Vasek's (1980) work on *Larrea* clones to suggest that life spans of Mojave Desert perennials is inordinately long (11,000 years). Actually, the plants must be younger than 8,000 years.
- Bowers *et al.* (1995) document longevity for common Mojave Desert perennials.
- Current efforts use repeat photography and permanent vegetation plots.

SKIDOO TOWNSITE, Death Valley NP

1916

1999

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Species	Years	Number
Artemisia filicifolia	31	1
Atriplex canescens	108	10
Atriplex confertifolia	108	5
Ceratoides lanata	105	4
Chrysothamnus nauseosus	104	1
Chrysothamnus viridiflorus	80	11
Coleogyne ramosissima	128	79
Ephedra torreyana	128	31
Ephedra viridis	127	1
Juniperus osteosperma	128	4
Quercus turbinella	128	3
Rhus aromatica	128	7
Sarcobatus vermiculatus	105	4
Shepherdia rotundifolia	128	2

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MAXIMUM LONGEVITY

MORTALITY AND RECRUITMENT RATES

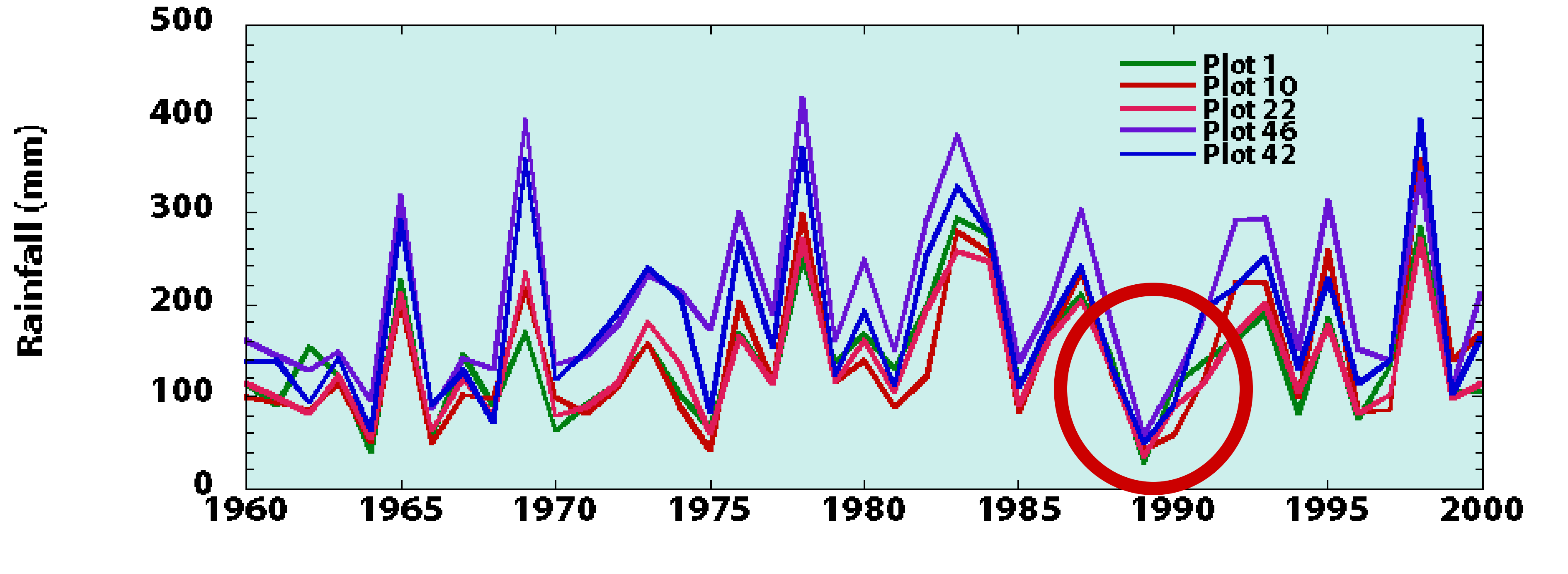
SPECIES	MORTALITY (%/century)	RECRUITMENT (%/century)	% CHANGE
Larrea tridentata[2]	1	7	+5.9
Ambrosia dumosa[2]	43	28	-21.7
Ephedra sp.[2]	17	22	+6.8
Ephedra torreyana [1]	14	17	+4.4
Atriplex canescens[2]	89	92	+38.9
Coleogyne ramosissima [1]	9	15	+9.6
Yucca angustissima[2]	55	58	+9.1
Lycium andersonii[2]	13	14	+1.1
Pleuraphis rigida[2]	32	25	-9.5

[1] From Webb et al. (2004).
[2] From Bowers et al. (1995).

NEVADA TEST SITE

- Perennial vegetation was measured in 1963, 1975, 2000-2002, and 2005 using line intercepts following Beatley.
- The combined data are imperfect but highly useful in showing the trajectory of long-term changes.

NTS CLIMATE, 1960-2000



Four high wet periods, two major droughts, increased growing season.

STRONG POSITIVE RESPONSE

Larrea tridentata

(n = 32 plots)

	Percent Change		
	1963-1975	1975-2002	1963-2002
Cover	47	31	90
Biomass	57	66	156

Ephedra nevadensis

(n = 28 plots)

	Percent Change		
	1963-1975	1975-2002	1963-2002
Cover	42	53	118
Biomass	70	84	219

Creosote bush and Mormon tea increased dramatically between 1963 and 2002 with little mortality or recruitment. Few individuals of either species died in 1989. Most existing individuals increased in size.

Plot 2 (1964)

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Plot 2 (2000)

LARGE, FLUCTUATING RESPONSE

Achnatherum speciosum
(n = 10 plots)

	Percent Change		
	1963-1975	1975-2002	1963-2002
Cover	528	-43	66
Biomass	713	-6	191

Ambrosia dumosa
(n = 23 plots)

	Percent Change		
	1963-1975	1975-2002	1963-2002
Cover	37	133	246
Biomass	48	129	357

C3 perennial grasses increased in the wet winter years of the 1970s-80s, only to die off during the 1989 drought. Grasses rebounded 1992-1995. Few grass clumps persisted 1963-2002.

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HIGH DROUGHT-RELATED MORTALITY

Grayia spinosa

(n = 30 plots)

	Percent Change		
	1963-1975	1975-2002	1963-2002
Cover	56	-77	-73
Biomass	74	-75	-68

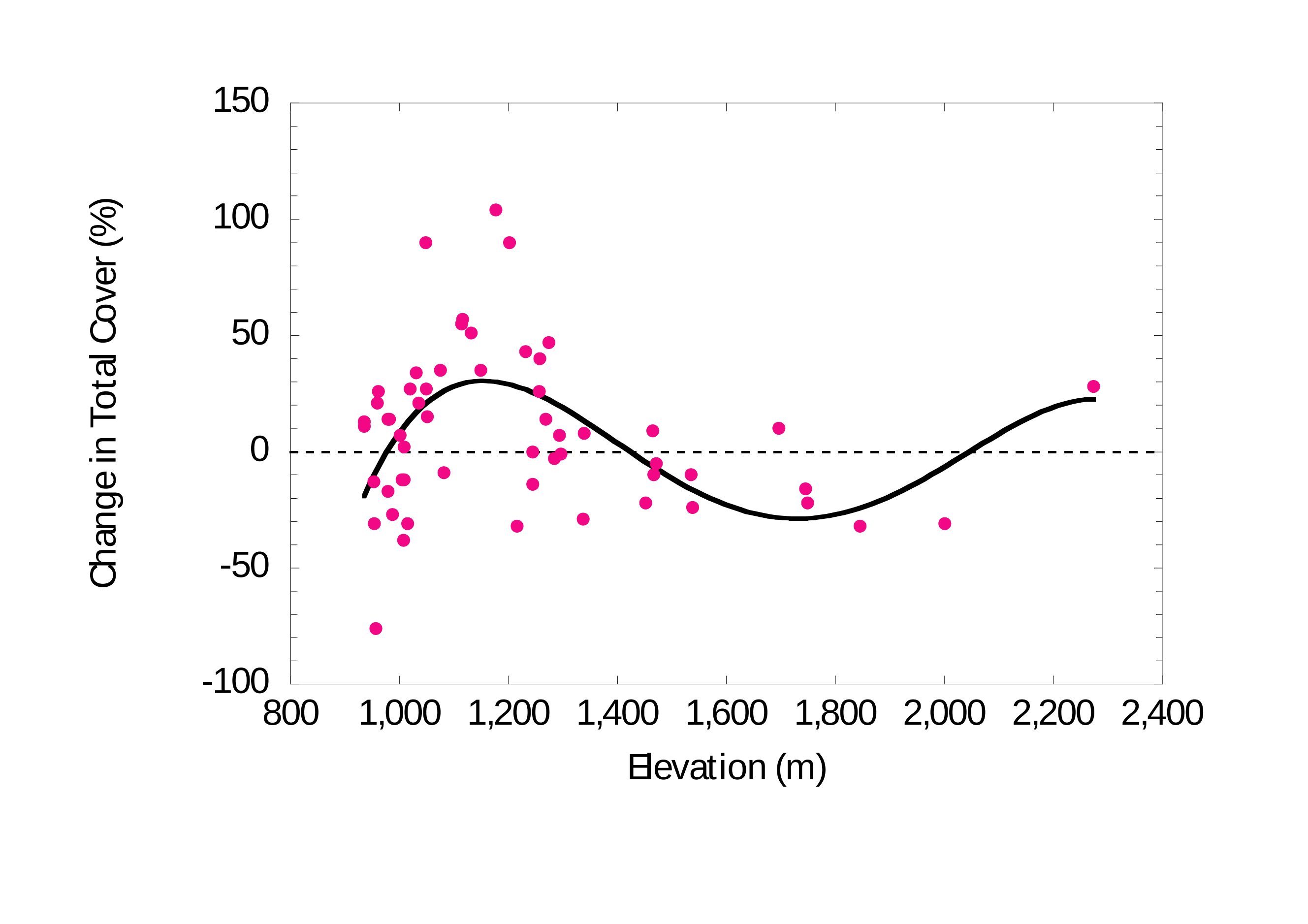
Atriplex confertifolia

(n = 9 plots)

	Percent Change		
	1963-1975	1975-2002	1963-2002
Cover	39	-47	-32
Biomass	98	-56	-23

Spiny hopsage increased from 1963-1975 then decreased on every plot that it was present in 1963 and 1975. Shadscale is less common but also decreased.

LONG-TERM (1963-2003) CHANGE IN UNDISTURBED PERENNIAL VEGETATION



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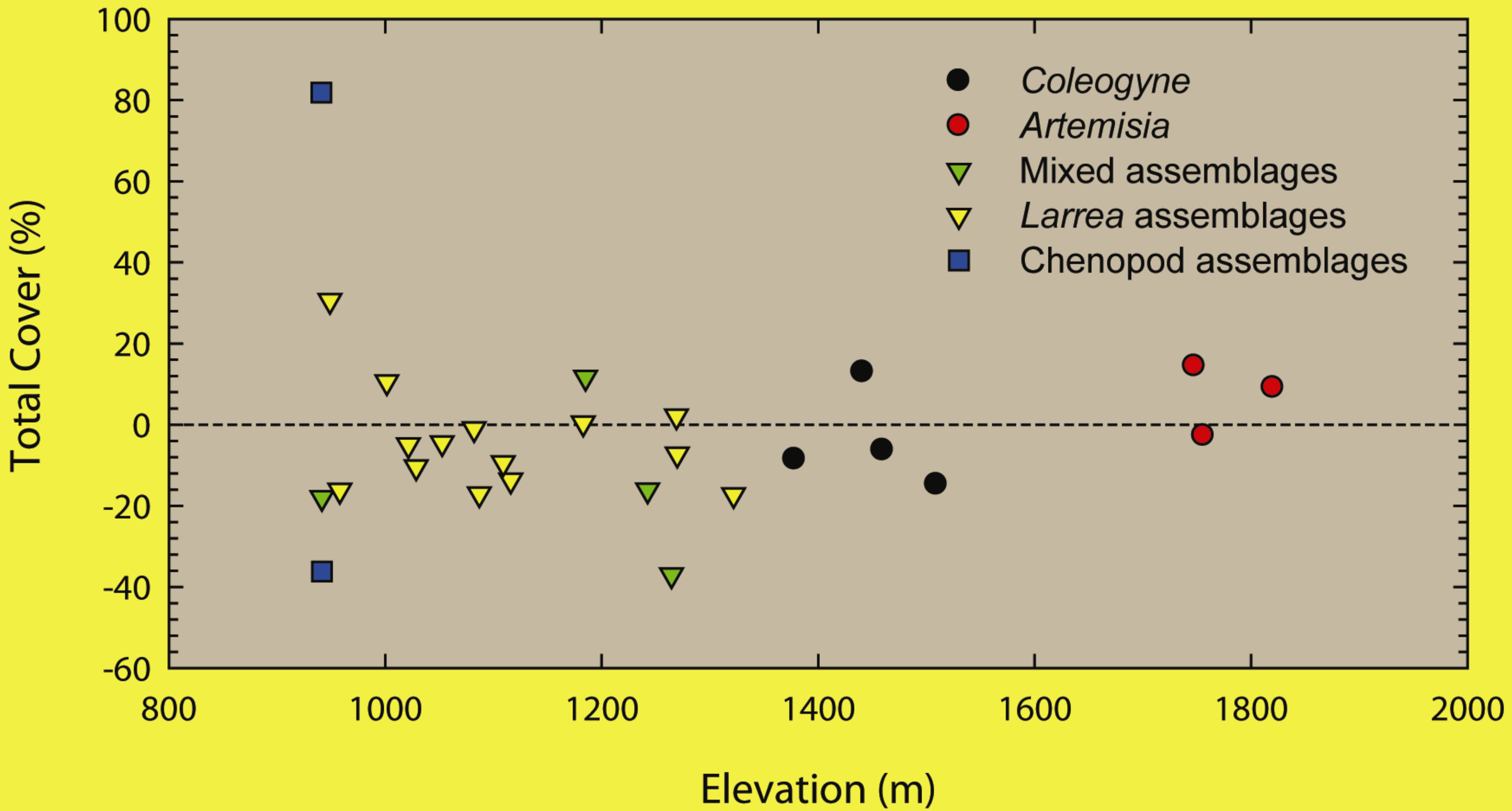
SEVERE DROUGHT, 2002-2004

- Depending upon where you are in the Southwest, drought has been severe in the early 21st century.
- On the Nevada Test Site and the Mojave Desert, the most severe year was 2002.
- Unlike 1989-1991, summer rainfall was significant.
- “Not all droughts are created equal.”

NET CHANGE, 2001-2005



WHAT DOES THE FUTURE HOLD?

- Fluctuations in plant size for dominants (e.g., *Larrea*, *Coleogyne*, *Artemisia*) is to be expected, but widespread mortality is not.
- Increased summer rainfall could spur some species (e.g., *Larrea*).
- The 1989-1991 drought decimated chenopod populations, changing vegetation distributions at the alliance/association level.
- Boom-bust cycles of desert plants, especially perennial grasses, is to be expected in the future.