WATER BALANCE, SALT LOADING AND SALINITY CONTROL NEEDS OF RED BLUFF RESERVOIR, TEXAS

A Reconnaissance Report

Submitted to

The Pecos River Compact Commission

Prepared By

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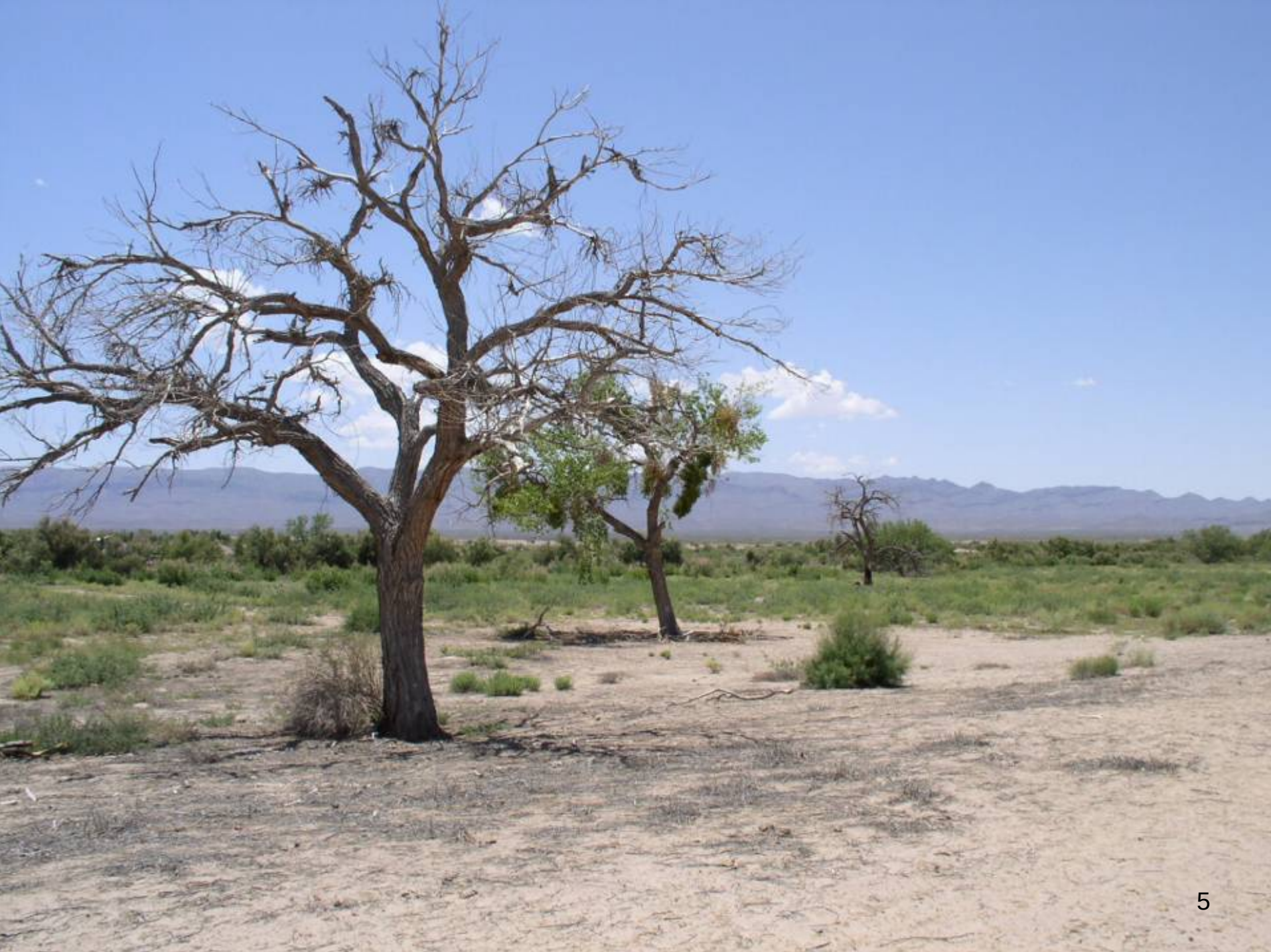
Why Do We Worry About Salinity of the Pecos River

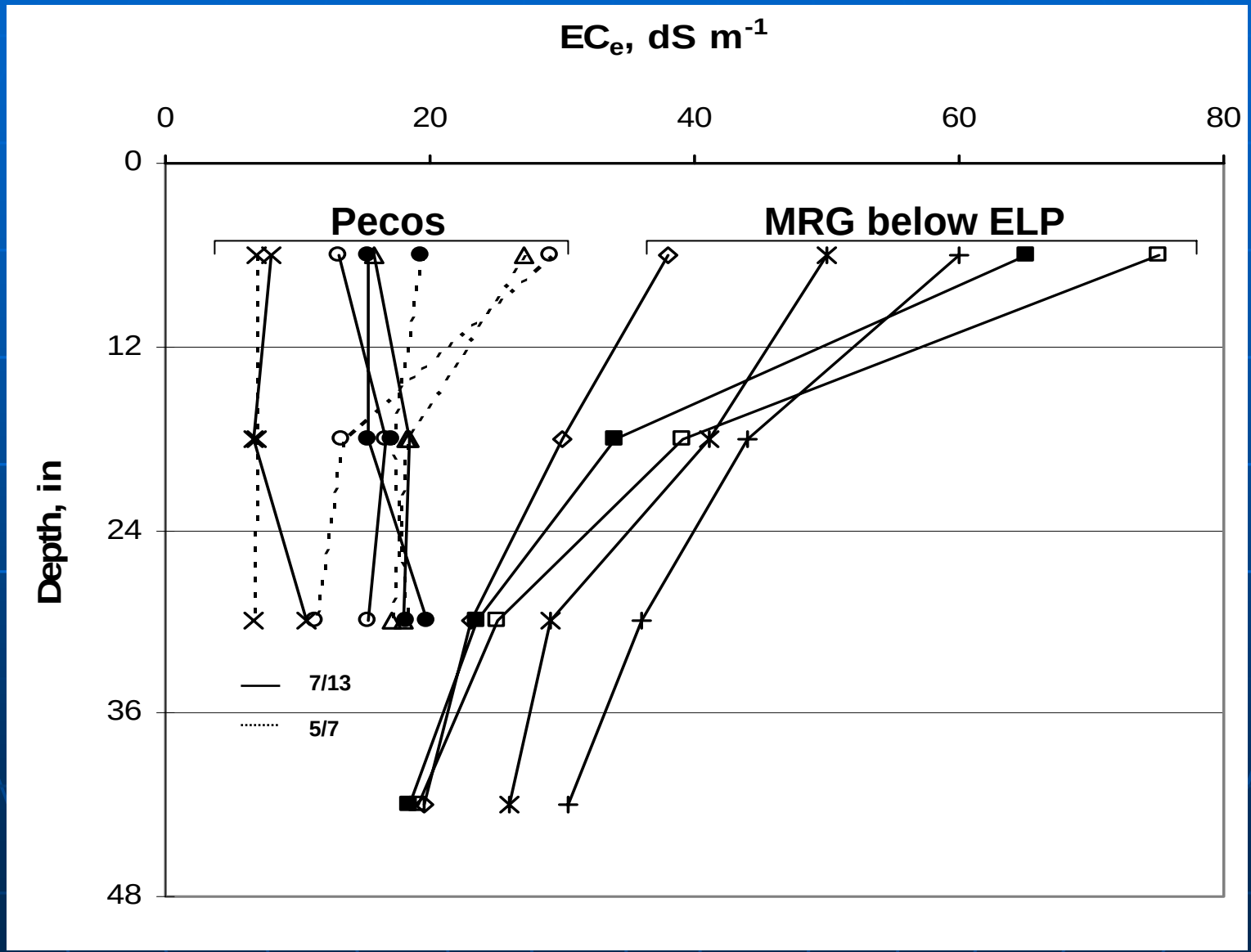
1. Lower economic values

2. Reduce biodiversity

   - Aquatic species (TC EQ)
   - Bank vegetation (TCE, Ft. Stockton)



Soil Salinity of River Bank



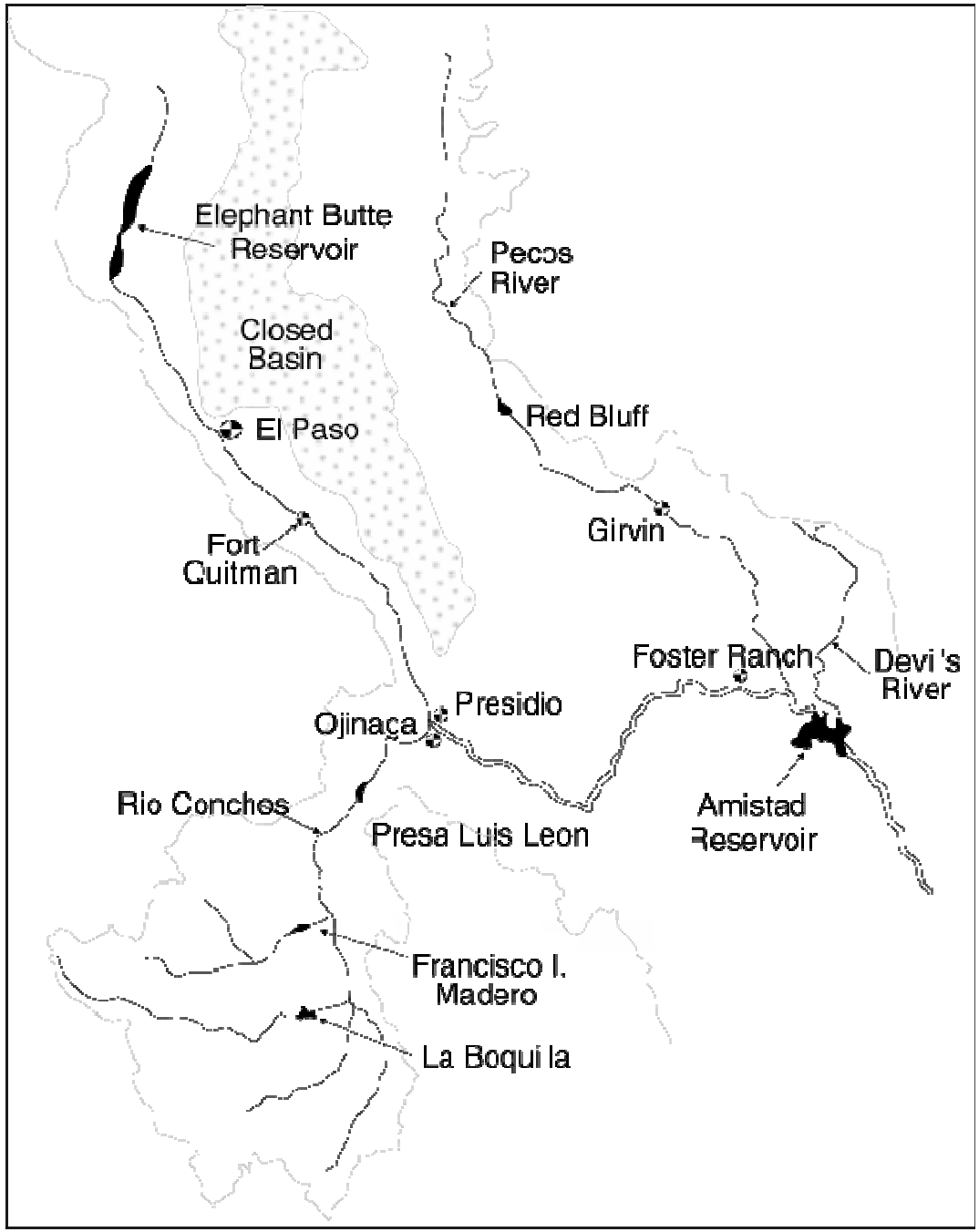
Why Do We Worry About Salinity of the Pecos River (cont'd)

3. Making Amistad Reservoir salty

- Salinity near 1,000 mg L^{-1}, the drinking water standard.
- Pecos contribution: 26% of the salts, 9% in flow (33% if ignore salts in fresh water)

Impact on Amistad International Reservoir

Storage Capacity = 6 billion m^3 (5.0 MAF)


Elephant Butte
Reservoir
Pecos
River
Closed
Basin
El Paso
Red Bluff
Girvin
Fort
Quitman
Foster Ranch
Devi's
River
Presidio
Ojinaga
Rio Conchos
Presa Luis Leon
Amistad
Reservoir
Francisco I.
Madero
La Boquilla

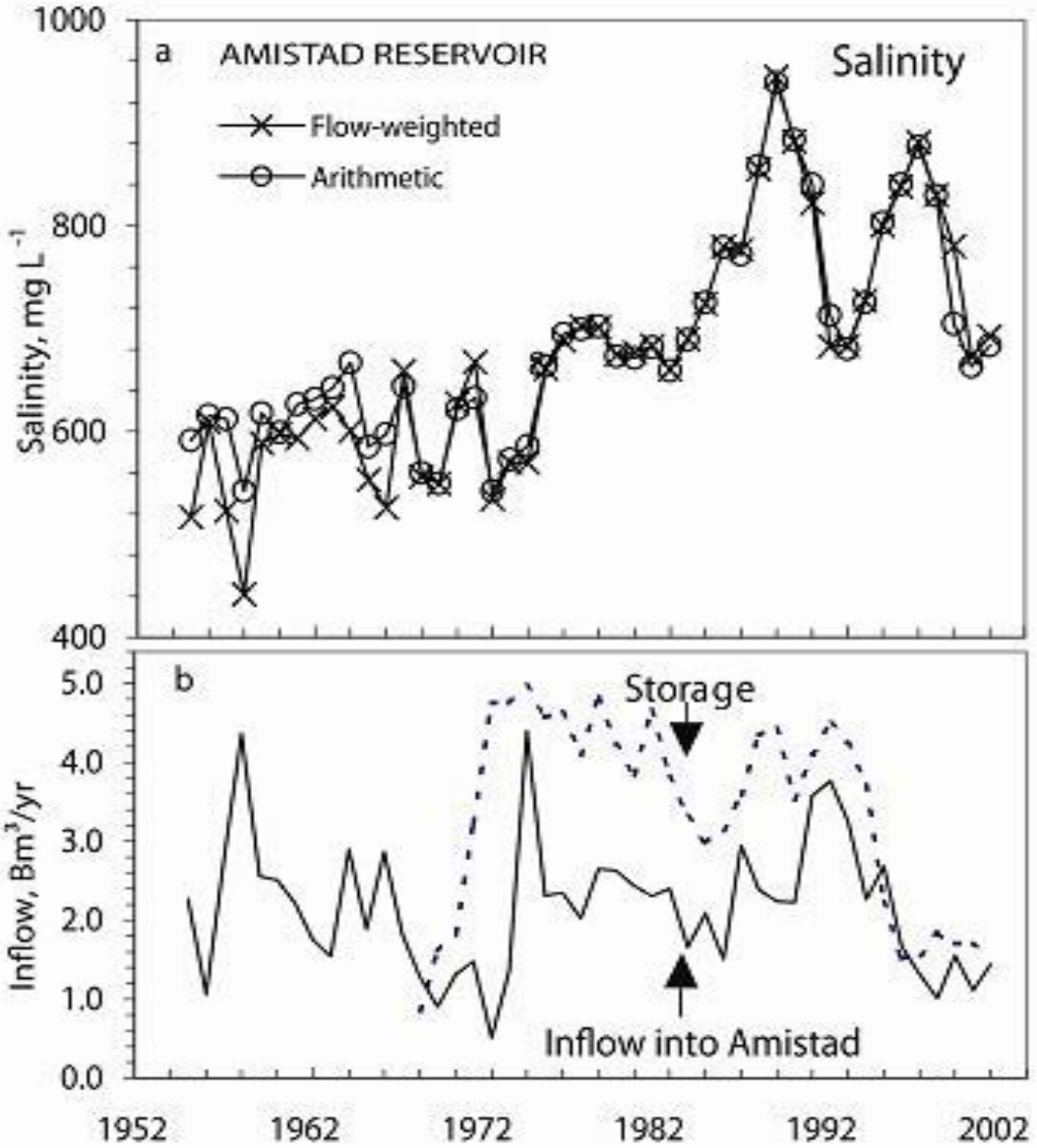


Fig. 4 Changes in salinity, inflow into and storage at Amistad Reservoir.

Amistad International Reservoir

Salinity fluctuation: reached 1,000 mg L^{-1} in Feb. 1988.

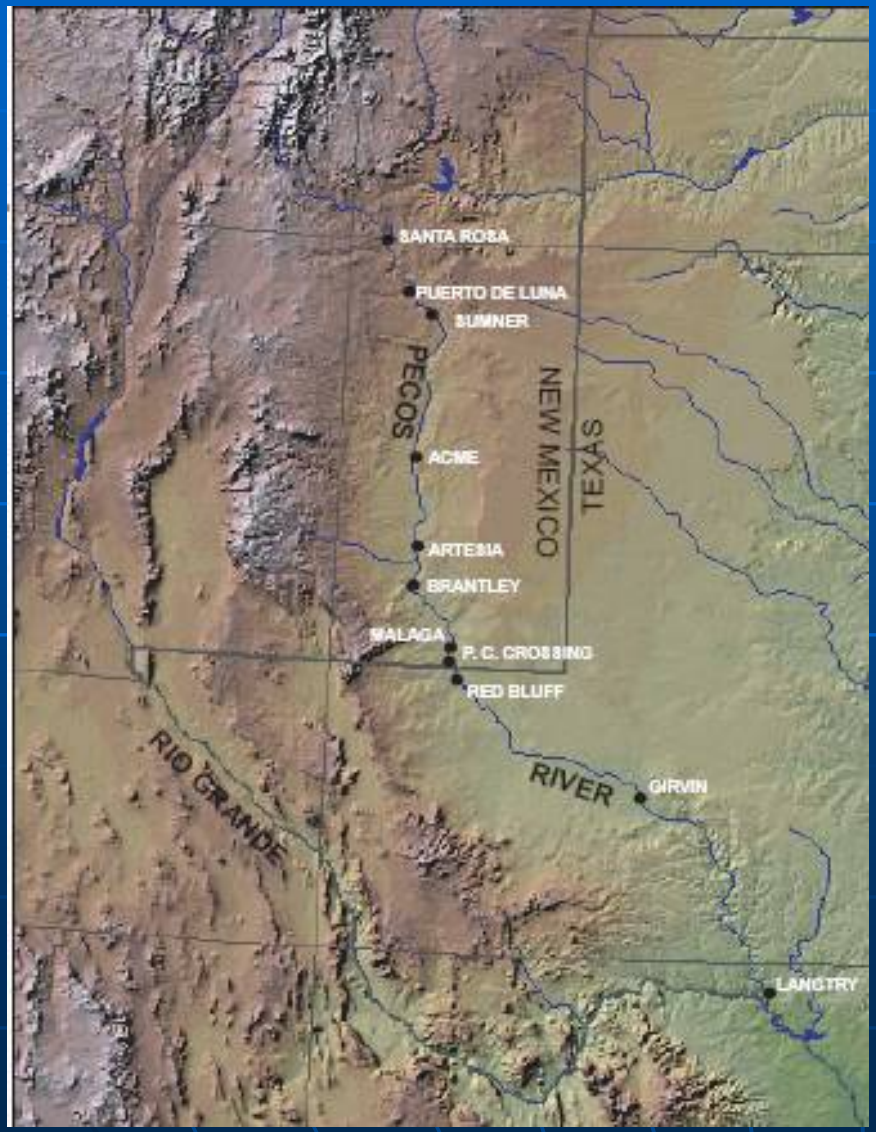
The Pecos River, Sleeping Cell

1. Amistad
- Average storage: 3 billion m^3 (2.4 MAF)
- Salt storage: 2.4 million tons

2. Salt flushing from the Pecos
- Flood of 1941
- Flow: 1.6 billion m^3 (1.3 MAF)
- Concentration: 3,000 ppm at Langtry

- Salt loading: 5 million tons (1941)
- Salt loading: 3 million tons (1942)

The Permian Basin



Once under the ocean and drying left evaporites: gypsum, halite and epsomite.

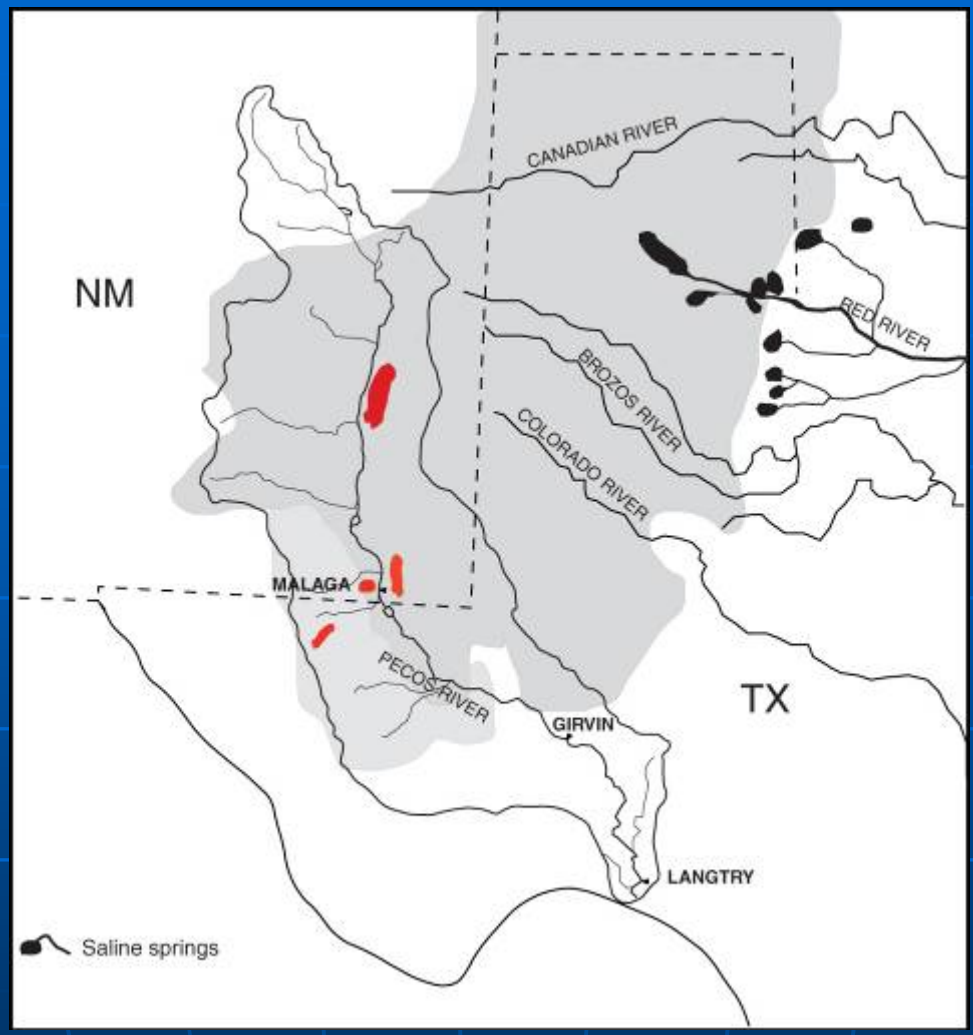


Fig. 2 Permian evaporite deposite of west Texas and southeastern New Mexico and the river basins affected by salt dissolution.

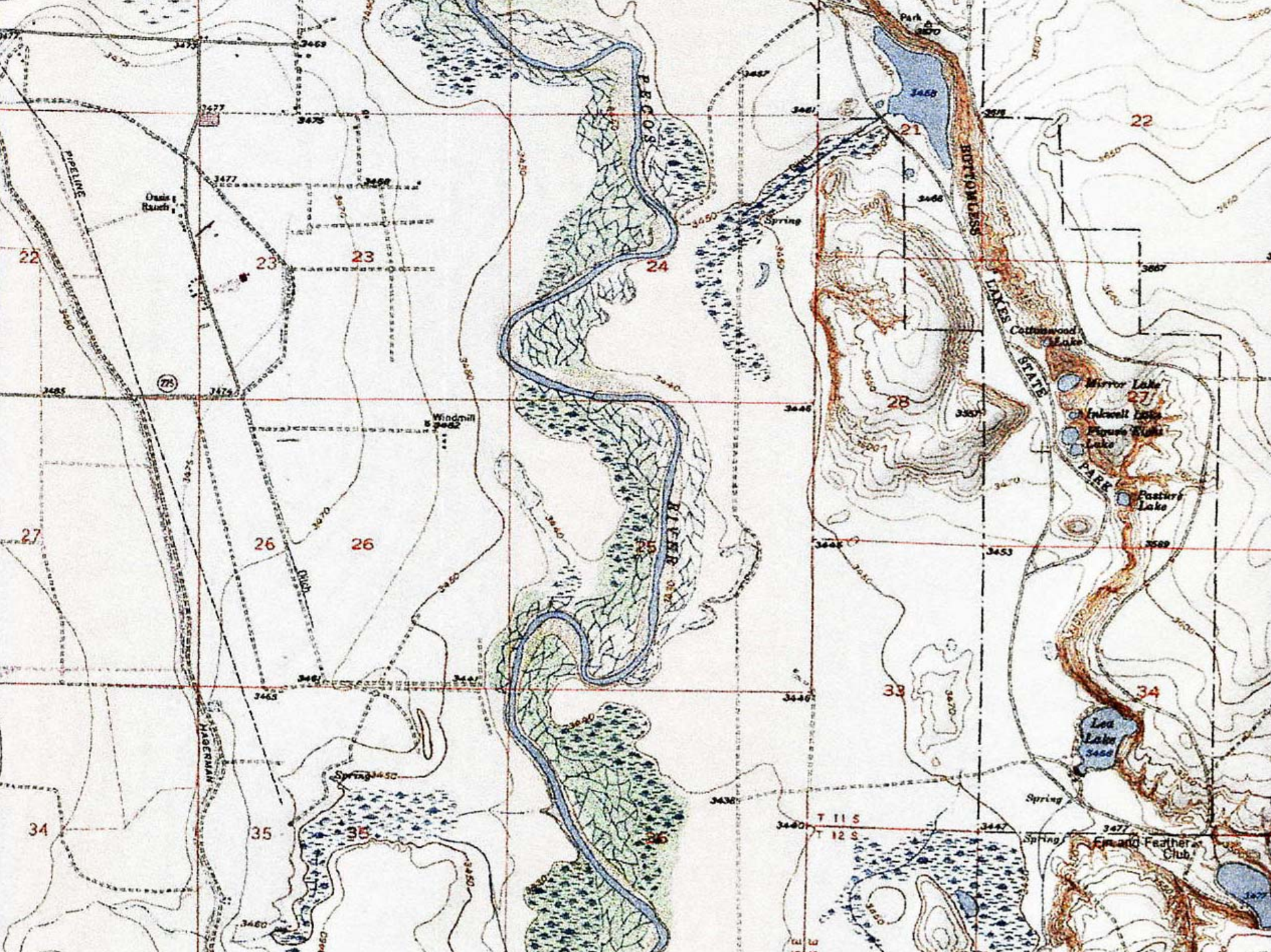
Table 1. Flow, annual mean salinity, dissolution concentration, and salt load of the Pecos River averaged over 1959 - 2002 (USGS Data).

Gauging Stations	Annual Flow	Annual[1-] Salinity	Salt Load	Load[2-] Changes	Loading Contribution[3-]	
					Girvin	Langtry
	M m^3/y	mg/L^{-1}	1000 ton/y		%	%
Santa Rosa	87	675	59	+ 59	7	7
P. Luna	168	1527	257	+ 198	25	23
Sumner	162	1494	242	- 15	-	-
Acme	138	1722	238	- 4	-	2
Artesia	159	3171	504	+ 266	34	30
Brantley	130	3176	413	- 91	-	-
Malaga	80	4111	329	- 84	-	-
P. C. Crossing	81	7128	577	+ 248	32	28
Red Bluff	84	7028	590	+ 13	-	-
Girvin	29	12849	373	- 217	-	-
Langtry	234	1995	467	+ 94	-	10

[1-] Annual flow-weighted mean salinity by Eq (8).

[2-] The positive values indicate a gain in salt load.

[3-] Percentage of the positive salt loading total above Girvin (784,000 tons/year) and that of the total above Langtry (878,000 tons/year).

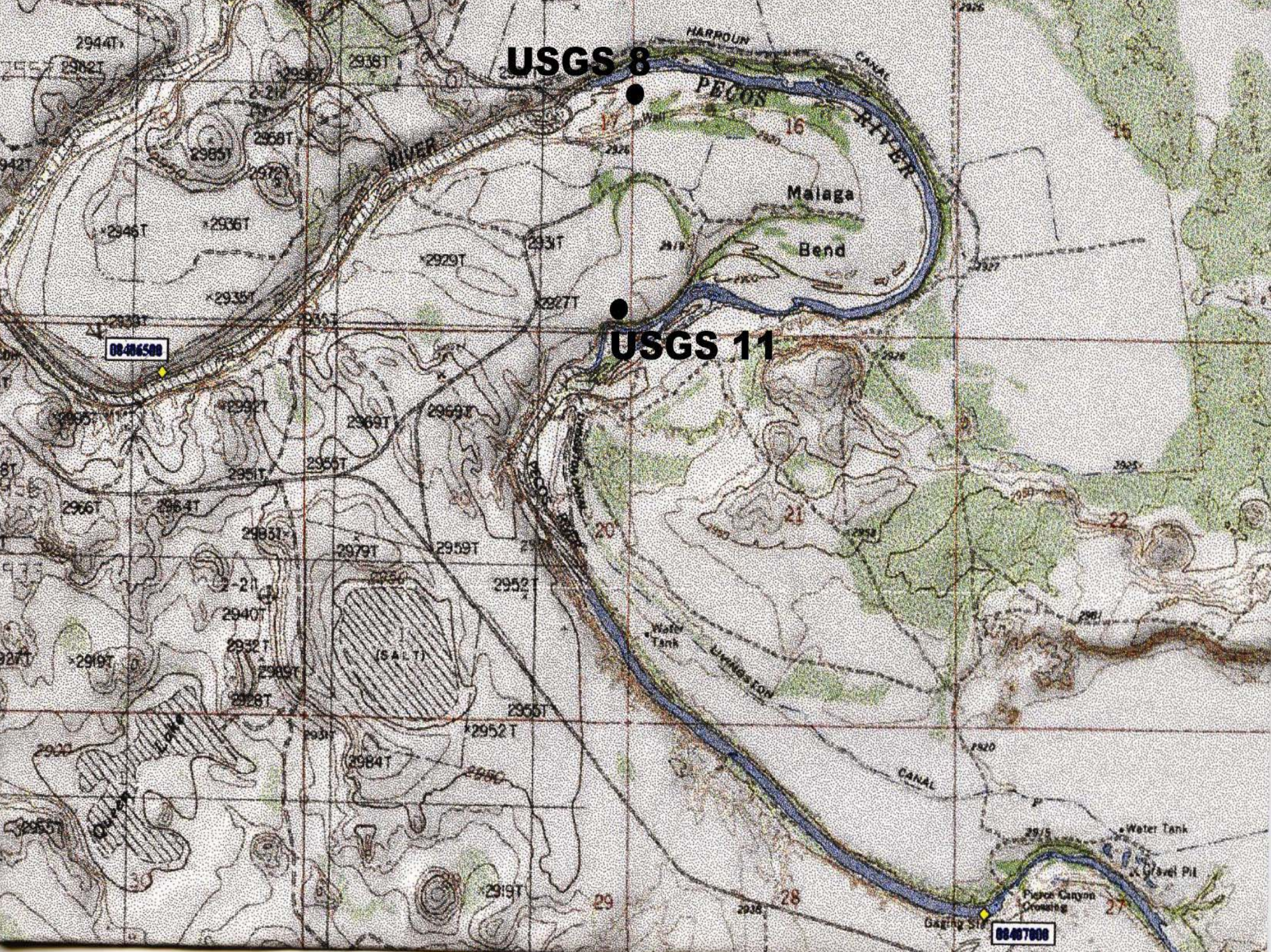

PECOS RIVER
BOTTOMLESS LAKES STATE PARK
PIPELINE
Oasis Ranch
Windmill
Spring
Cottonwood Lake
Mirror Lake
Pasture Lake
Lea Lake
Fin and Feather Club
HAGERMAN
T 11 S
T 12 S
22
23
24
21
28
27
26
25
33
34
35
36


a


b


c


d


USGS 8
USGS 11
PECOS RIVER
HARPOUN CANAL
Malaga Bend
08406500
08407000
CANAL
Water Tank
Pierce Canyon Crossing
Gaging Sta
Gravel Pit
(SALT)

Saline Seepage at Malaga Bend

Type: NaCl

Concentration: 340,000 mg L^{-1}

(360,000 mg L^{-1} SL of halite)

Discharge Rate:

USGS estimate of 0.44 cfs

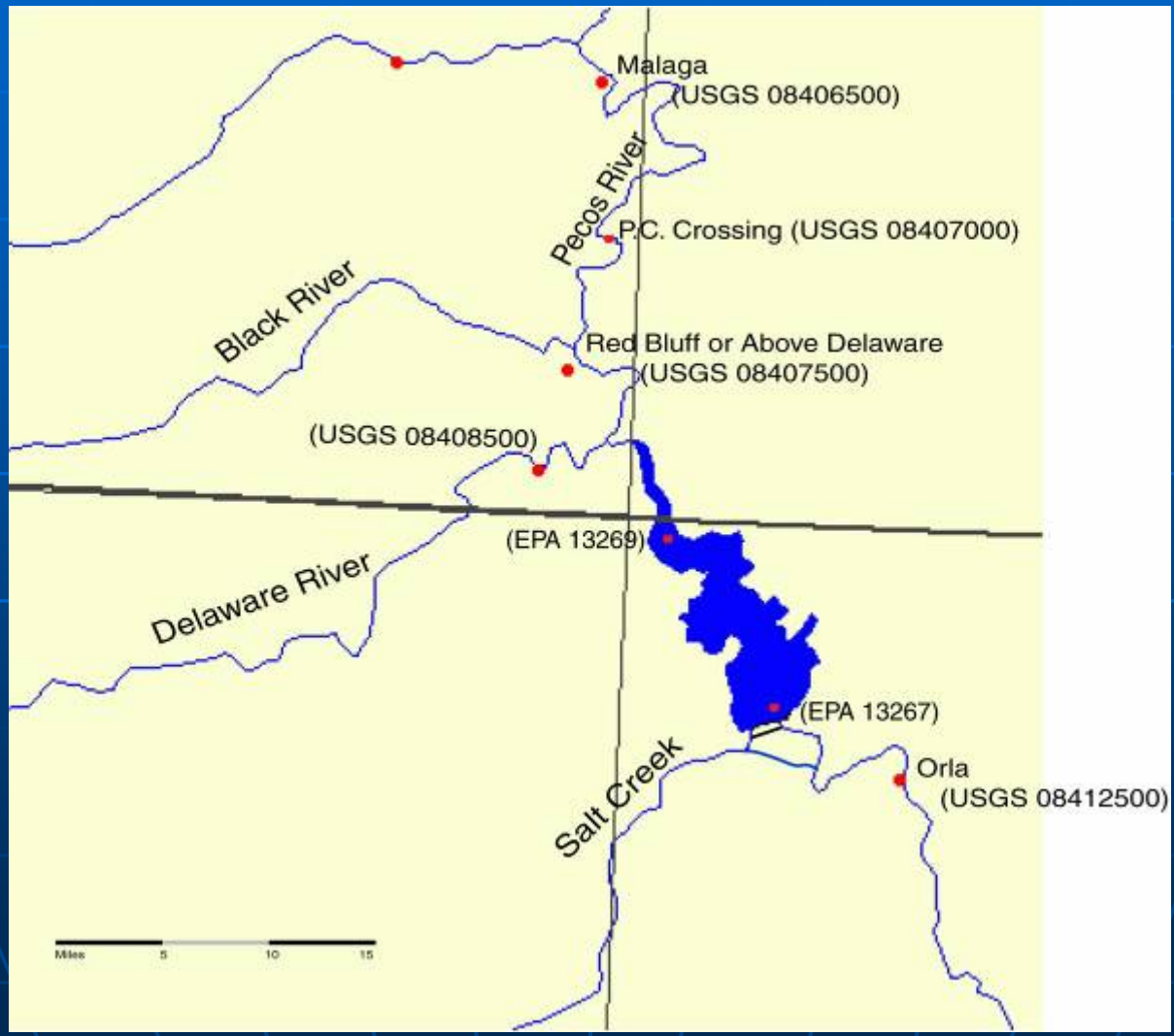
Quantity: 140,000 – 200,000 tons/y


Halite Crystal
1 cm

Specific Objectives of Red Bluff Study

1. Determine reservoir water balance so as to evaluate water losses.
2. Salt loading trends of the past several decades.
3. Impact of salt loading on monthly salinity of the reservoir or outflow.

Data Sources



Water Balance

Measured

Daily flow ⟶ monthly flow

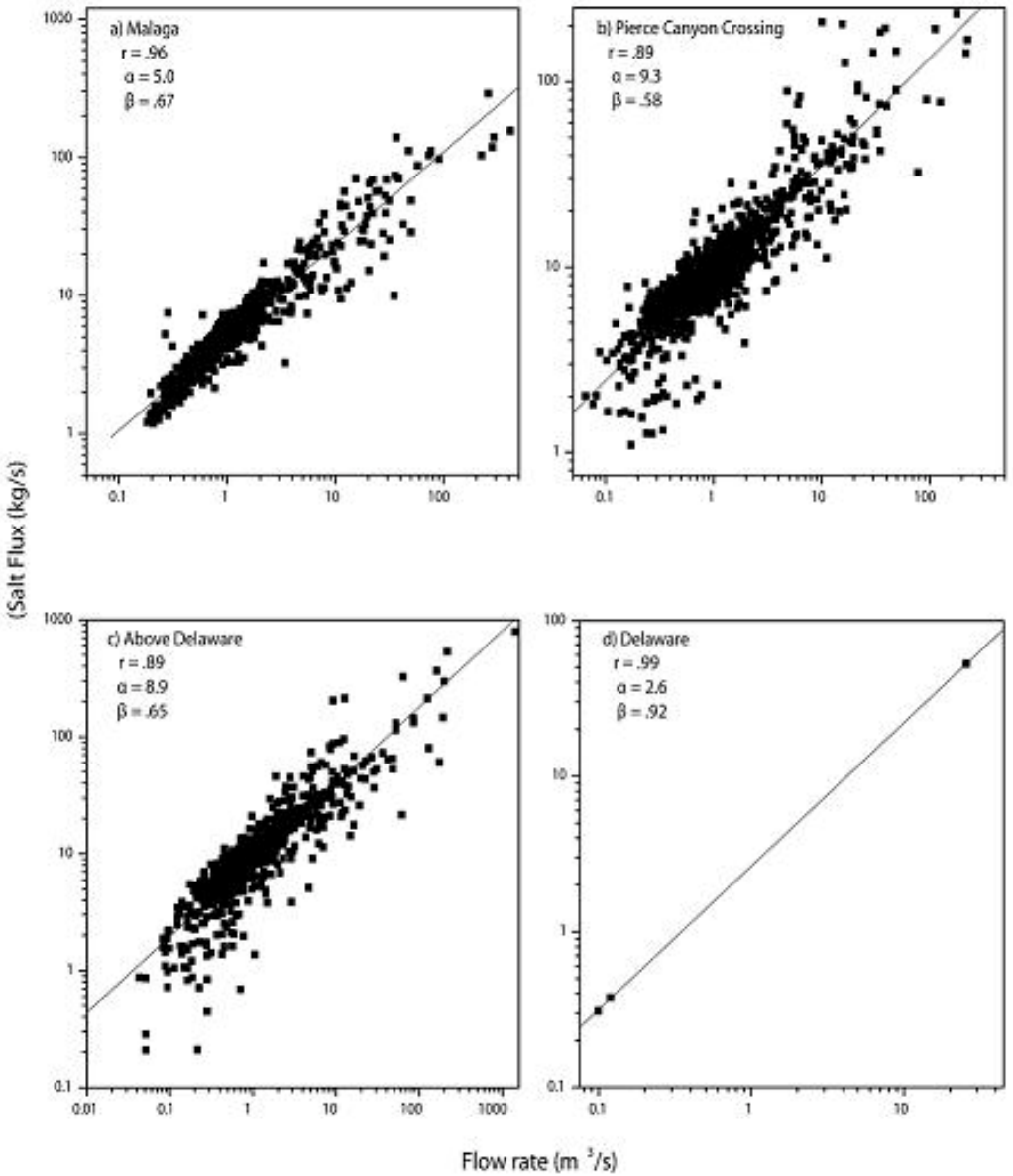
Inflow = the Pecos + the Delaware

Outflow = District Data

Evaporation = 0.7 x E_{PAN} x Area

Area = f (storage)

Percolation = In – Out – Evap + Rain – storage gain



A-I The historical relationship between salt flux and momentary flow rate at the time of water sampling.

Data Processing

$$C_i q_i = \alpha q_i^{\ \beta}$$

$$C_A = \sum C_m Q_m / \sum Q_m$$

$$C_A = \frac{\sum (C_i q_i)}{\sum q_i} \left[\frac{q_m}{\sum q_i / n} \right]^{\beta - 1}$$

Estimate of Reservoir Salinity

Equalized by mixing with reservoir storage

1. Complete Mixing

$$C_j = \frac{C_{j-1}S_{j-1} + C_{INj}Q_{INj} - C_{j-1}QP_j}{S_{j-1} + Q_{INj} - QP_j}$$

2. Evaporative Concentration

$$C_{OUTj} = dA_jC_j / (dA_j - E_j + R_j)$$

Results

Let us deal with units first

Volume:

1 million m^3 .....810 AF

Flow:

1 m^3/s.....35.3 cfs

Salinity:

1 dS m^{-1} = 1 mmho/cm

= 650 ~ 700 mg L^{-1} (ppm)

= 0.88 ~ 0.95 t/acre-ft.

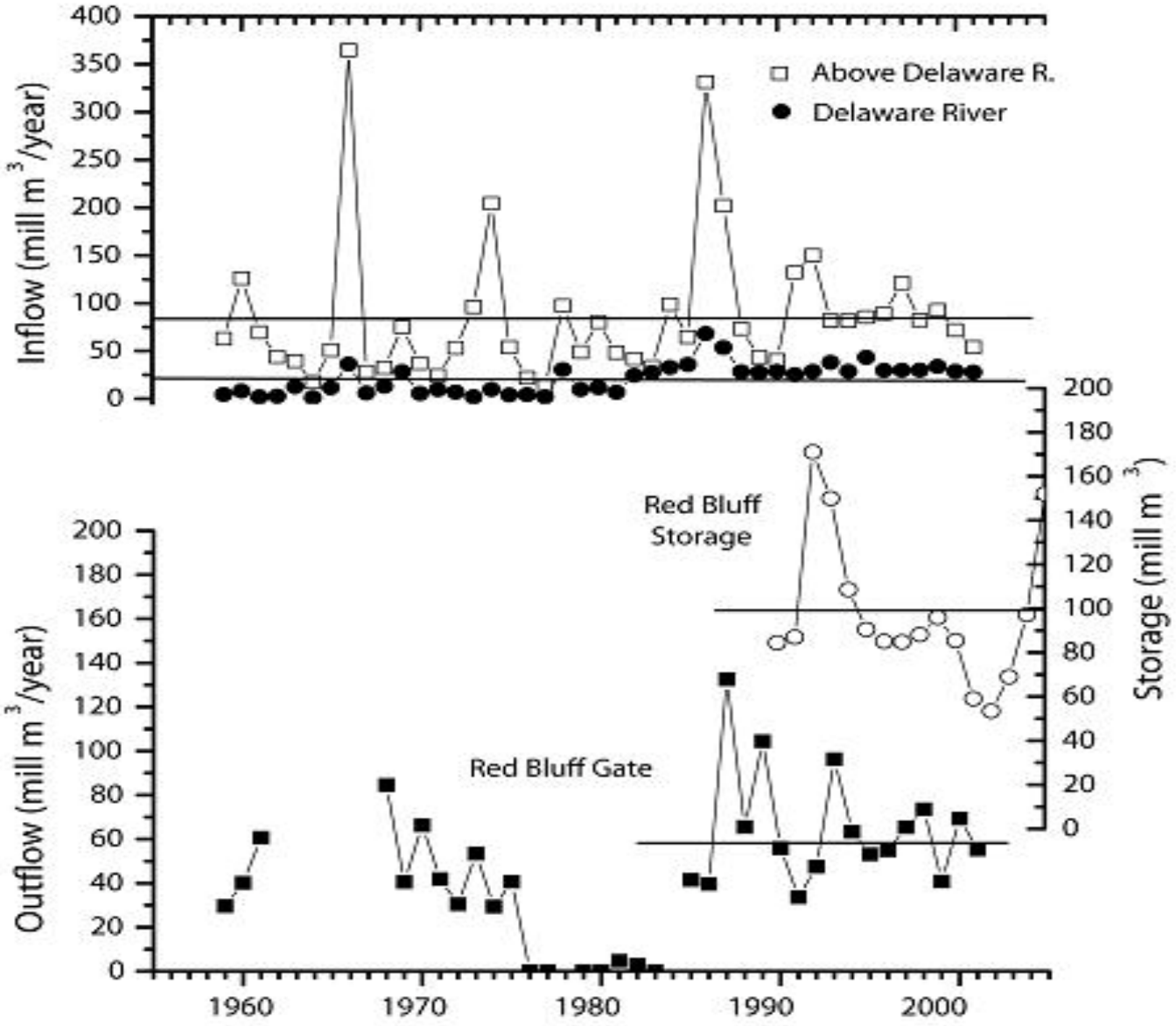


Fig. 6 The annual inflow, the storage, and the outflow from Red Bluff Reservoir (original data from USGS).

Table 4. The annual inflow, annual outflow, reservoir storage, surface area, rainfall, evaporation and percolation losses.

	Inflow		Outflow	Storage		Surf Area	Rainfall	E_{VAP}	Evap	Percol Loss
Year	Above DWR	DWR	Red Bluff	Red Bluff		Red Bluff	Red Bluff	Red Bluff	Red Bluff	Red Bluff
	Mm^3/y		Mm^3/y	Mm^3		km^2	Mm^3	cm/y	Mm^3	Mm^3
1990	(40)[1] -	29	56	_[2] -	84[3] -	15	3.7	130	19	-
1991	132	25	34	87	147	15	6.8	210	32	36
1992	150	29	47	171	186	26	13.5	170	45	61
1993	82	37	96	150	124	24	10.4	226	54	42
1994	82	29	63	109	100	18	4.4	236	43	32
1995	85	43	53	90	90	16	3.8	205	32	58
1996	89	30	55	85	98	15	7.0	218	32	37
1997	121	30	65	85	114	15	4.0	195	29	37
1998	82	30	73	88	85	15	4.7	230	35	38
1999	93	34	41	96	107	16	3.2	191	31	35
2000	72	29	69	85	80	15	3.4	196	29	32
2001	54	28	55	59	47	11	1.6	161	18	44
Avg.	**95**	**31**	**59**	**100**		**17**	**5.7**	**204**	**35**	**41**

[1] - Incomplete data.

[2] - Average storage for 1991 - 2001.

[3] - End of year storage.

Water Balance

	1959 - 01	1991 - 01
Inflow (Mm^3/y)		
The Pecos	84	95
The DWR	21	31
Total	105	126
Outflow (Mm^3/y)		
Gate	-	59
Losses (Mm^3/y)		
Evap	-	35
Percolation	-	41 (37)[1] -
Total	-	76 (72)[1] -

[1] - Ignoring two high percolation years.

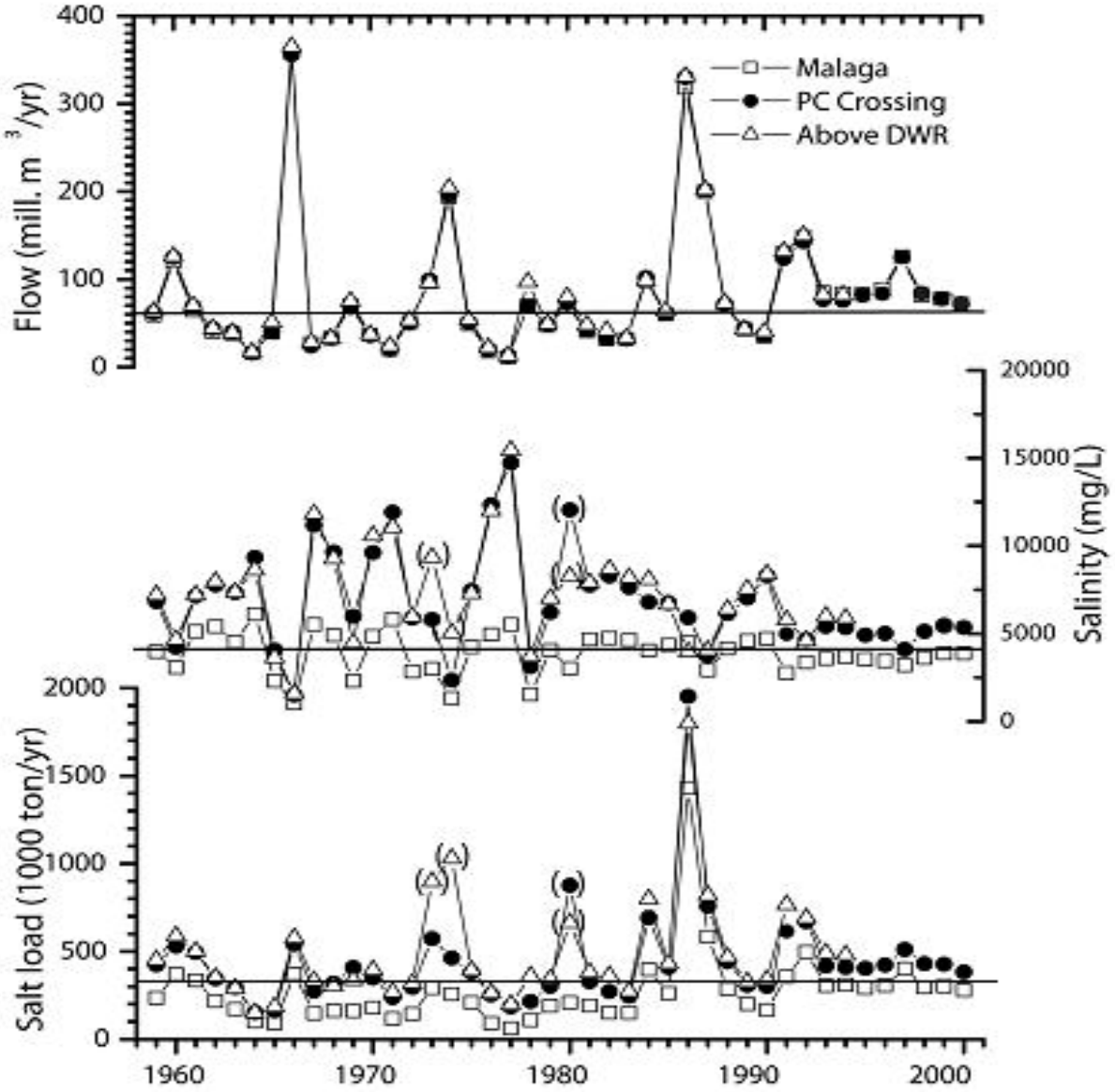


Fig. 7 The inflow, the salinity, and the salt load recorded at Malaga, P.C. Crossing, and Above Delaware River (DWR). The data in parenthesis are not credible.

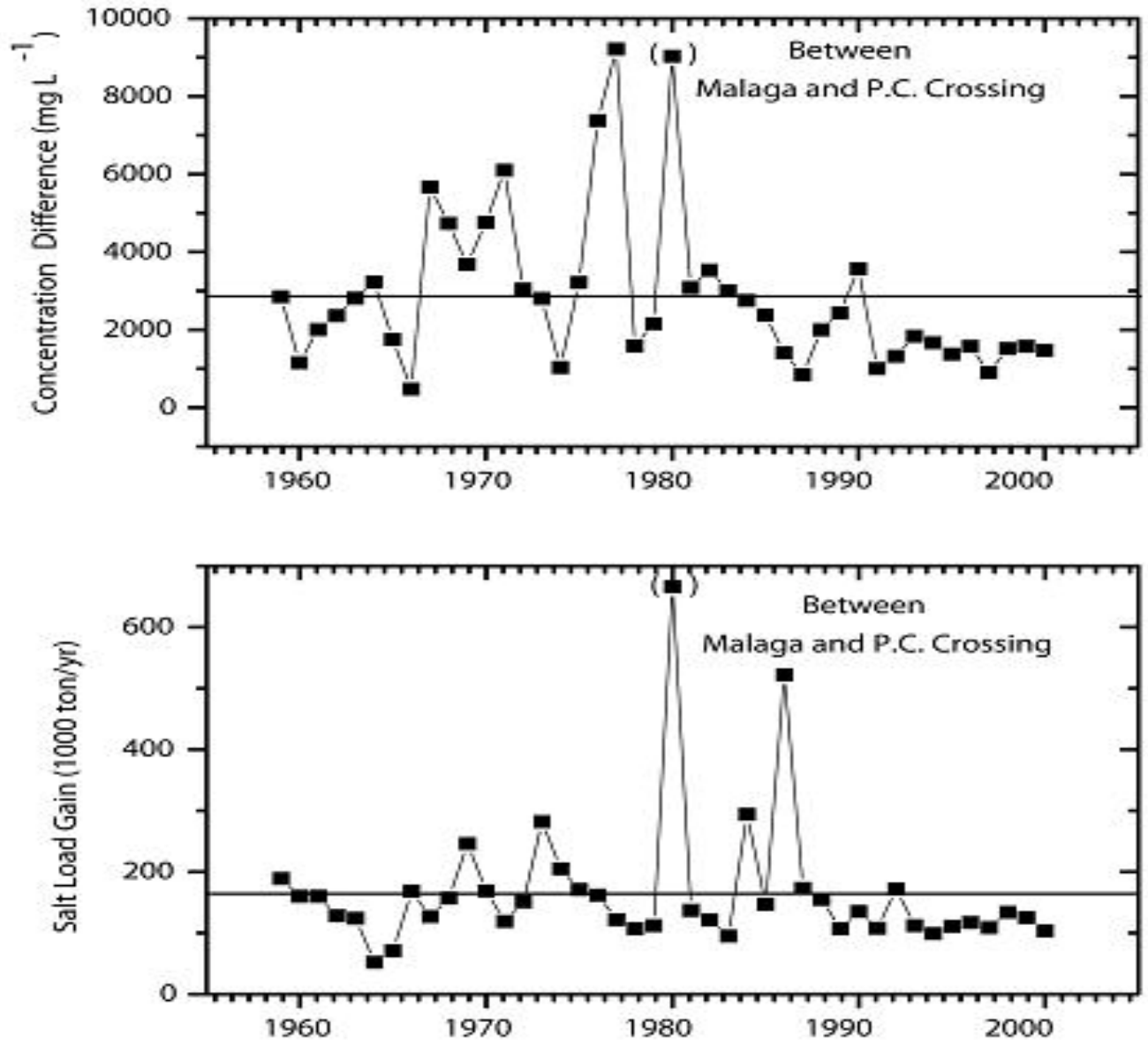


Fig. 8 Differences in salinity and salt load between Malaga and P.C. Crossing. Data in parenthesis not credible.

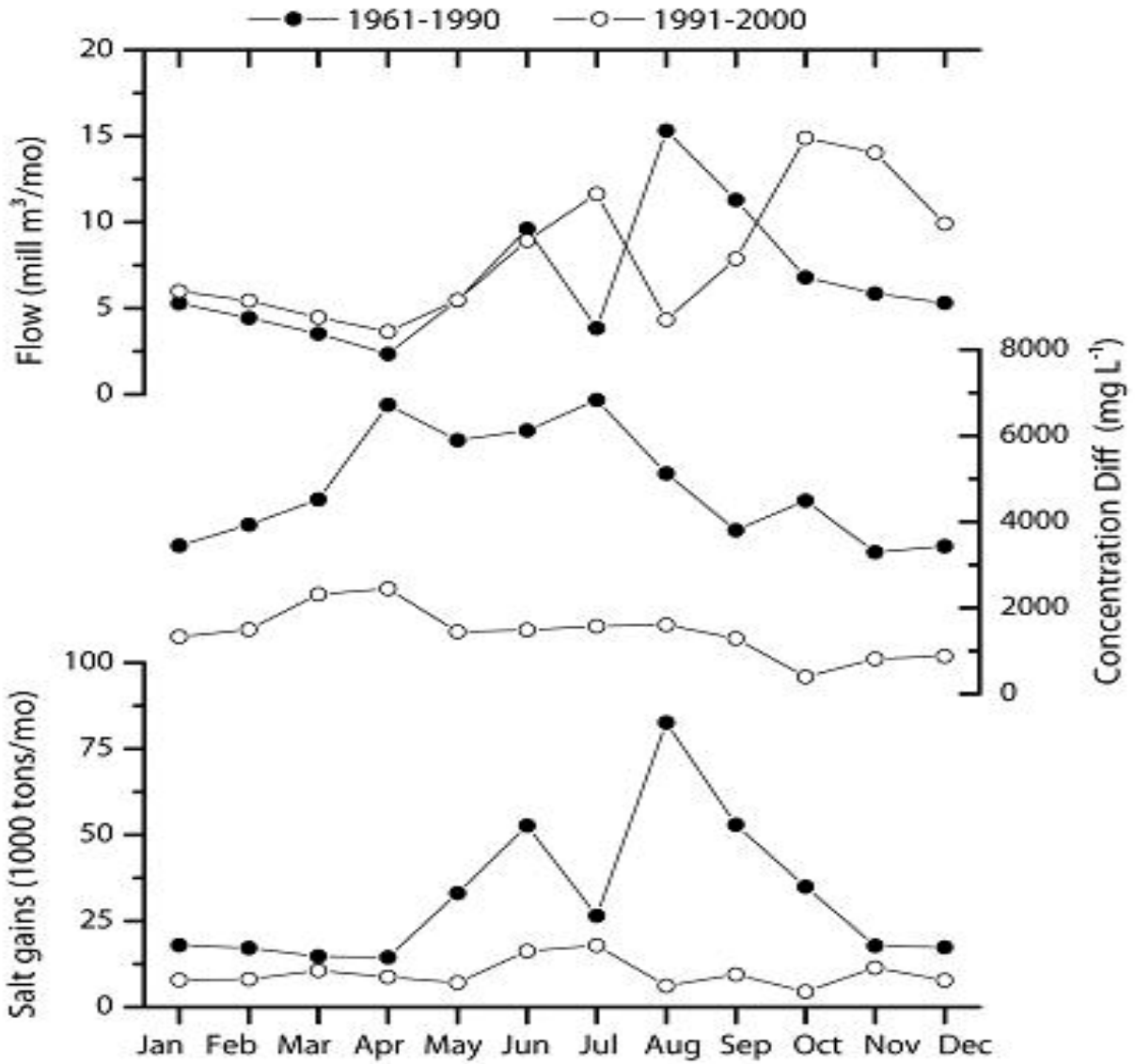


Fig. 9 Seasonal changes in averaged flow at Pierce Canyon Crossing and Above Delaware, concentration differences and salt gains between Malaga and Above Delaware for the past four decades. The data in parenthesis are not credible.

Salt Balance

	1959 - 2001			1991 - 2001		
	Flow	Salinity	Load	Flow	Salinity	Load
	Mm^3/y	mg/L	1000 t/y	Mm^3/y	mg/L	1000 t/y
Inflow						
The Pecos	84	7028	590	95	5080[2]-	483
The DWR	21	2677[1]-	56	31	2572	80
Composite (USGS)	105	6160	646	126	4470	563
(EPA)	-	-	-	-	5495[3]-	
Reservoir Storage				storage		
EPA data	-	-	-	-3.6 (Subtotal)	-	24[4]- (587)
Outflow						
Gauged (Dist./EPA)	-	-	-	59	6150[3]-	363
Percolation (EPA)			-	41 (Subtotal)	5310	218 (581)

[1]- Estimated by using the salinity and flow relationship.

[2]- This concentration is at P.C. Crossing, and probably lower than those at the station below (Above DWR).

[3]- Arithmetic means.

[4]- An estimate based on EPA data. Salinity at the beginning and ending was reported to be 6480 and 6640 mg L^{-1}, respectively.

Simulation of Reservoir Outflow Salinity (d = 0.8 m)

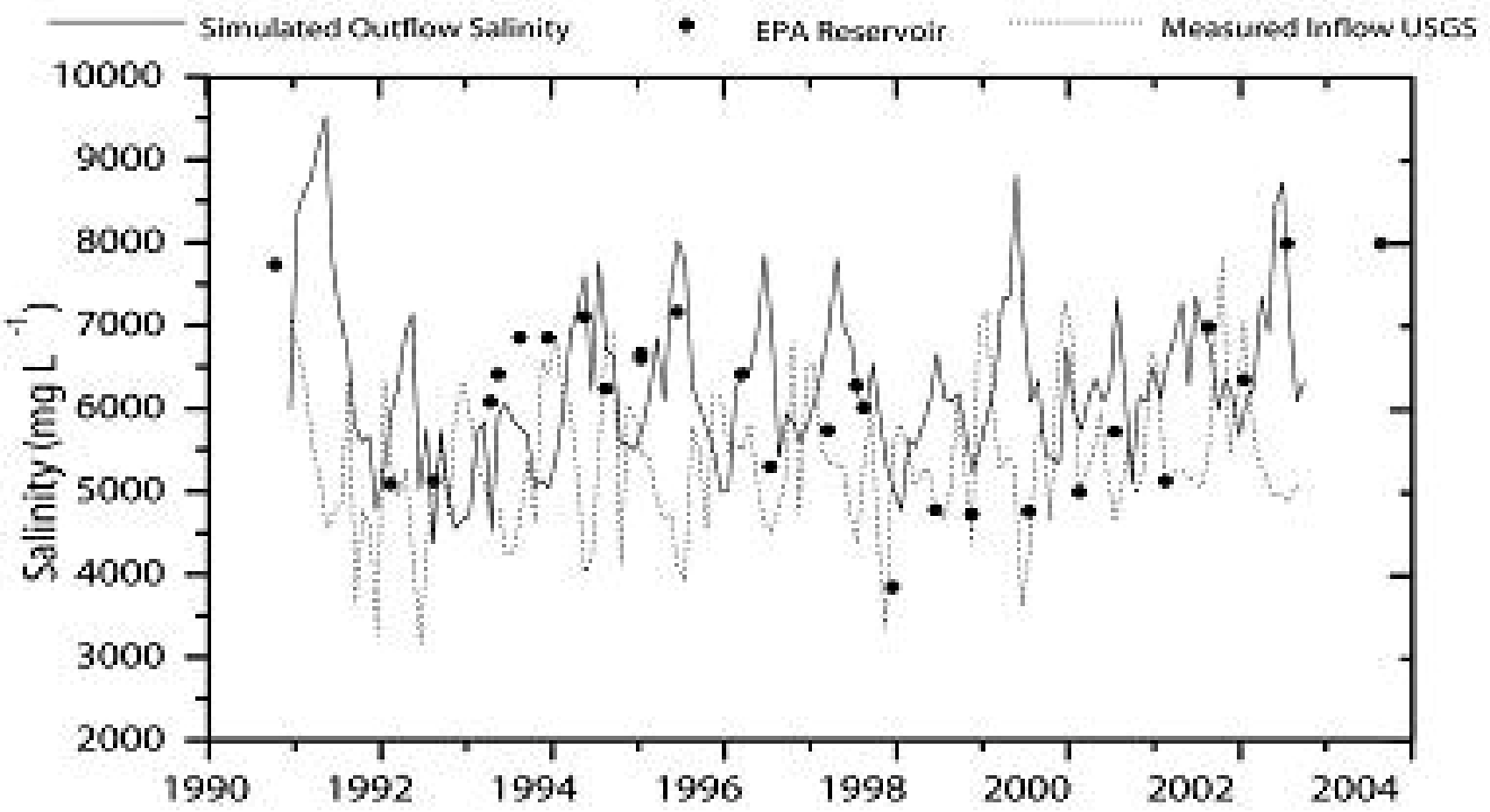


Fig. 10 Simulated reservoir outflow salinity, measured reservoir salinity by EPA, and measured inflow salinity by USGS.

A Tentative Target Salinity for Red Bluff Release (Suggestion)

1. Go back to the salt level of 1937 – 1940: 4710 mg L^{-1} (current 6150 mg L^{-1})

2. Attainable through brine intrusion control at Malaga Bend

No Control	6150 mg L^{-1}
100,000 t/y	5350 mg L^{-1}
200,000 t/y	4400 mg L^{-1}

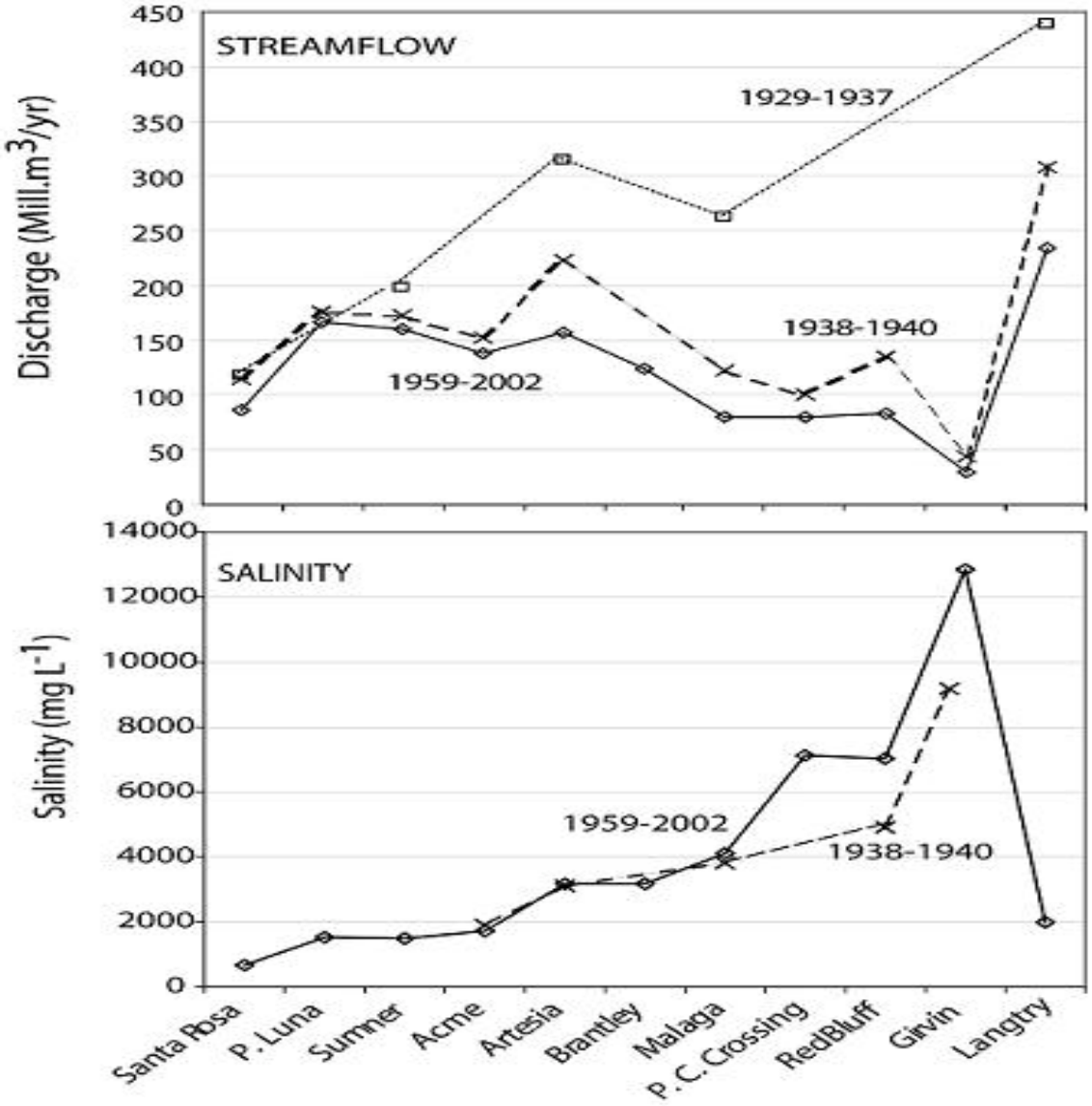


Fig. 3 Flow of the Pecos River at selected gauging stations; dotted line 1929 - 1937, dashed line 1938-1940, solid line 1959-2002. Salinity data prior to 1937 are not available.

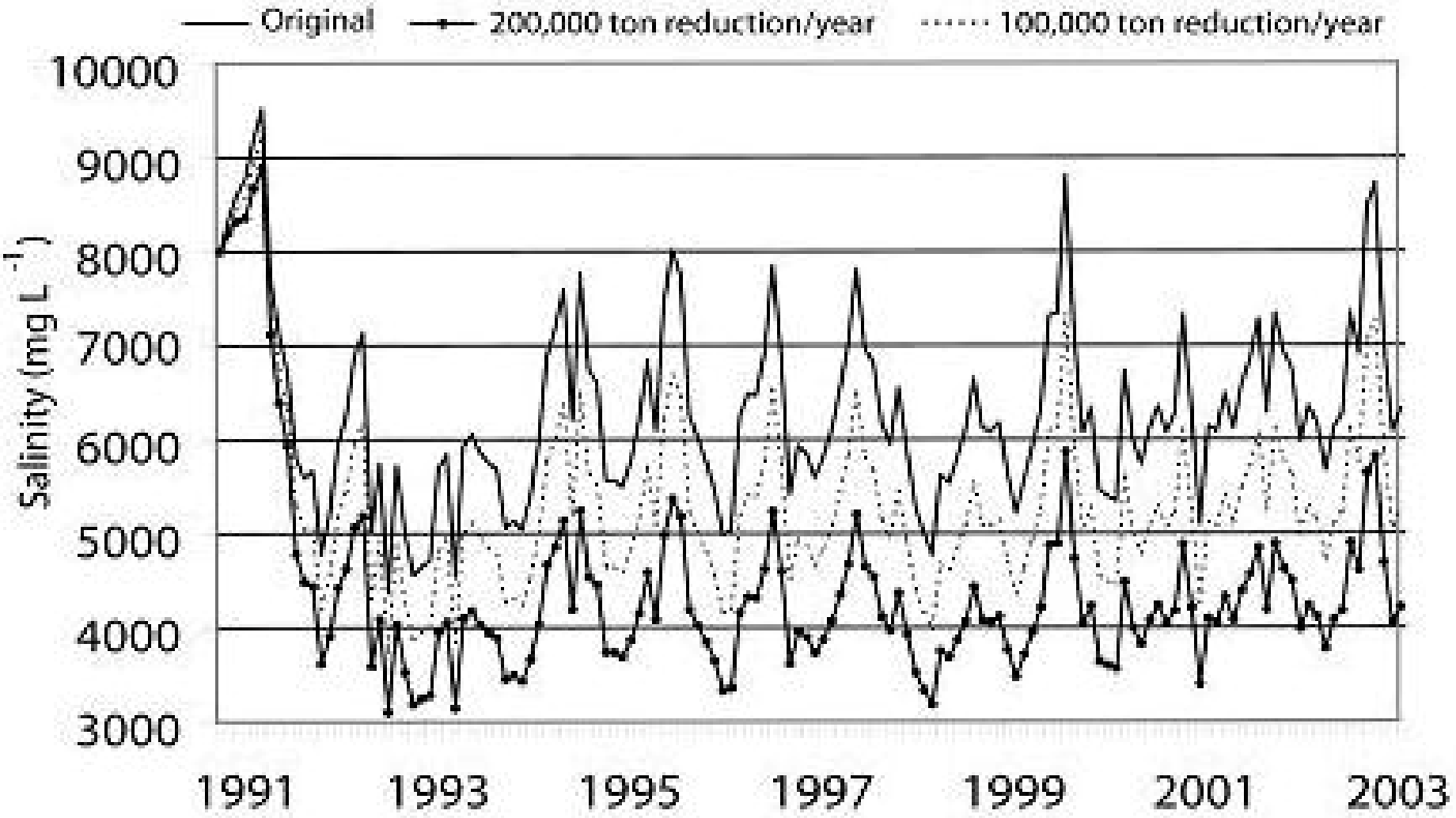


Fig. 11 The simulated outflow salinity and the projected salinity of the outflow when the salt load is assumed to be reduced in 200 and 100 thousand tons/y.

Making the Long Story Short

1. There are several reasons why we need to lower salinity of Red Bluff Release (biodiversity, sustainability of irrigated farming, and salt loading control to Amistad)

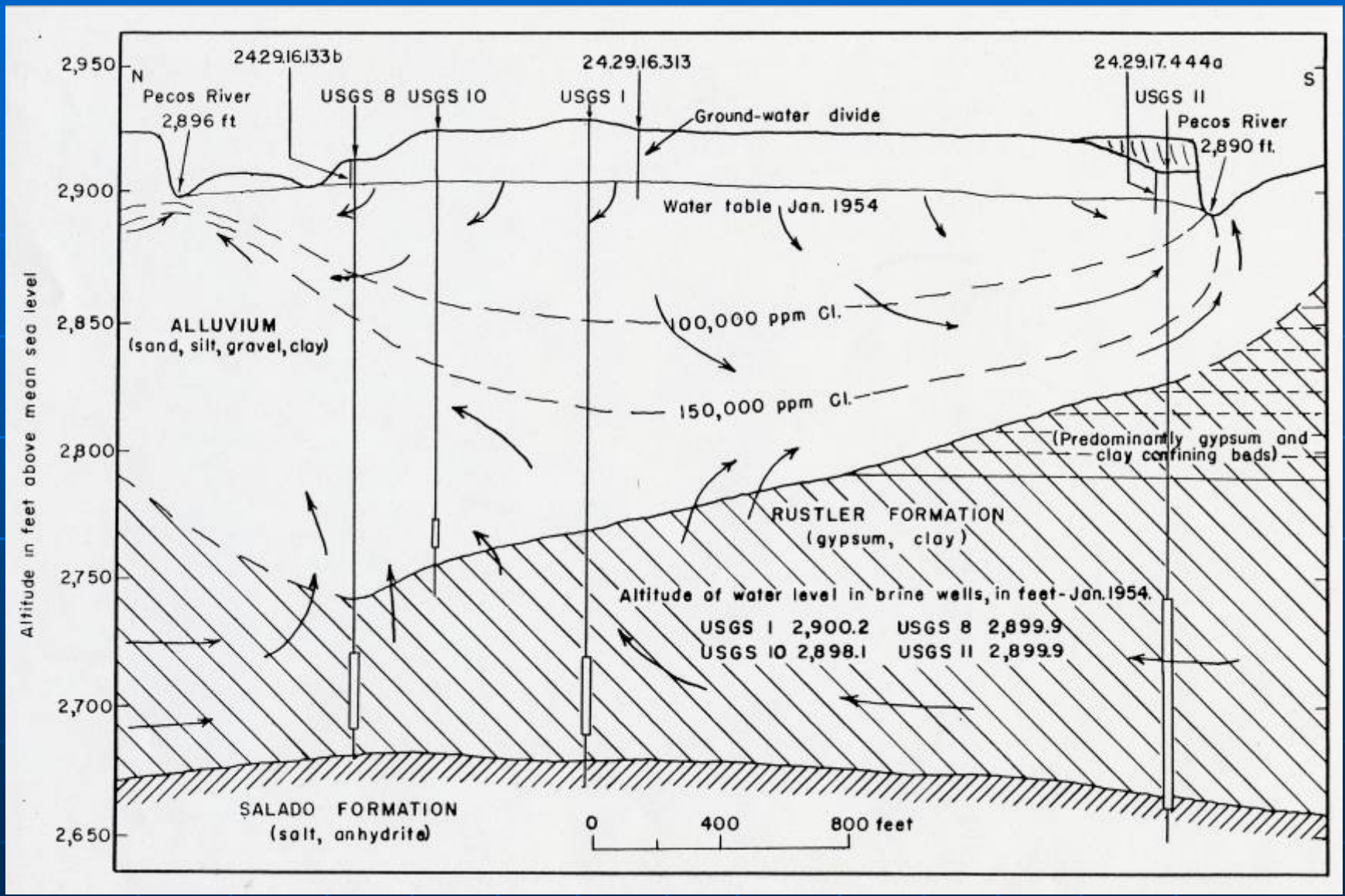
2. Brine intrusion control at Malaga Bend can bring salinity down to the level existed for the era of 1937 – 1940.

Potential Options for Reducing Salinity

1. Salinity control near Roswell
   - Pumping ground water into the Rio Grande near Acme
   - Replacement of wetland with aquaculture/salt generation

Unlikely options due to competing interests.

2. Salinity Control at Malaga Bend

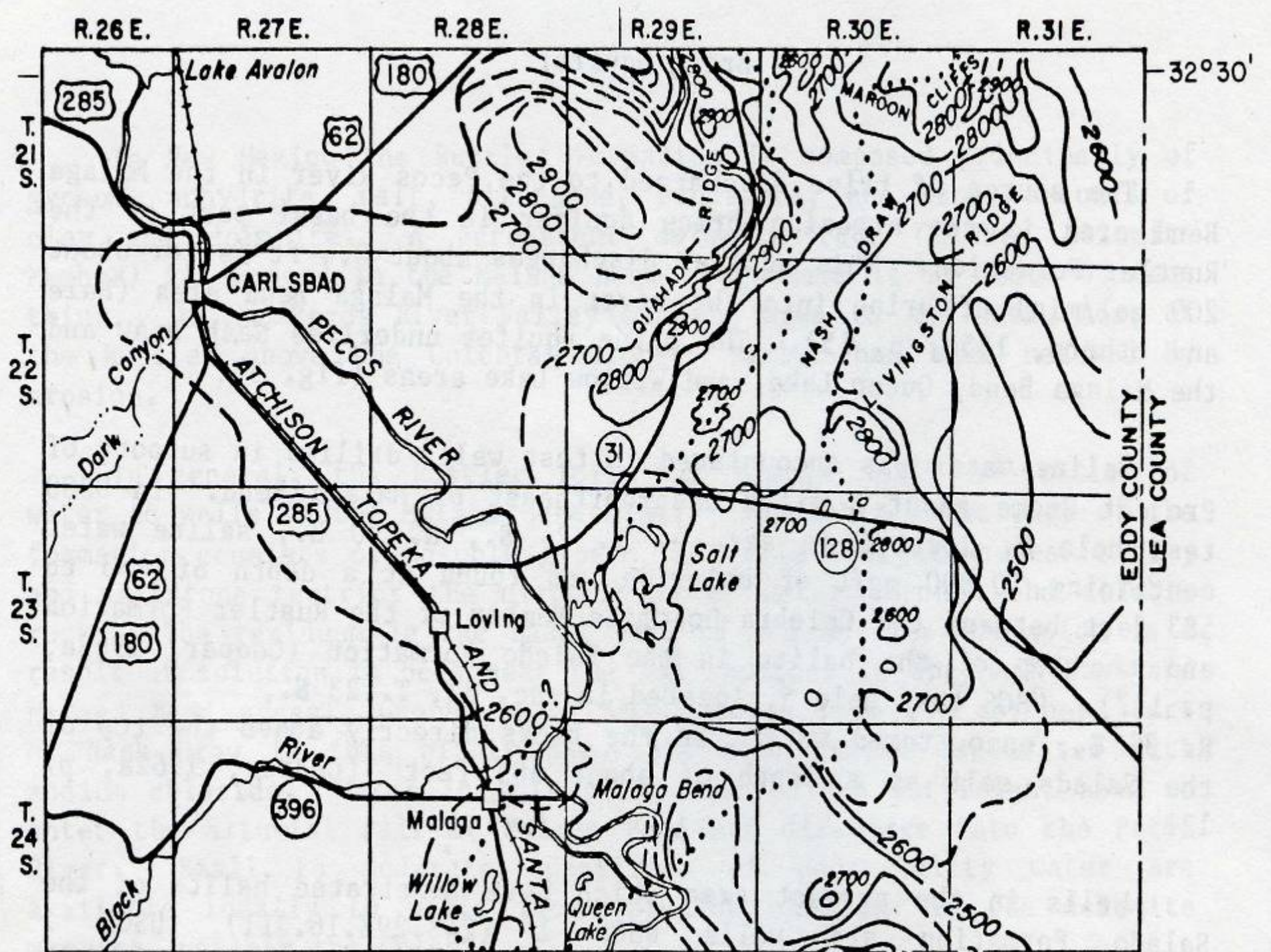


Easy to pump, but....

Salt Production (sweet dream)

2. Salinity Control at Malaga Bend (cont'd)

- Pumping at 0.44 cfs may not correct salt flushing during flood events
- Another option: Water infiltration control
  - Bear Grass Draw north of Nash Draw is considered an infiltration basin.
  - Another entry is west of the Pecos through a sinkhole.
  - Complication over mining rights.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R.27 E.
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R.29 E.
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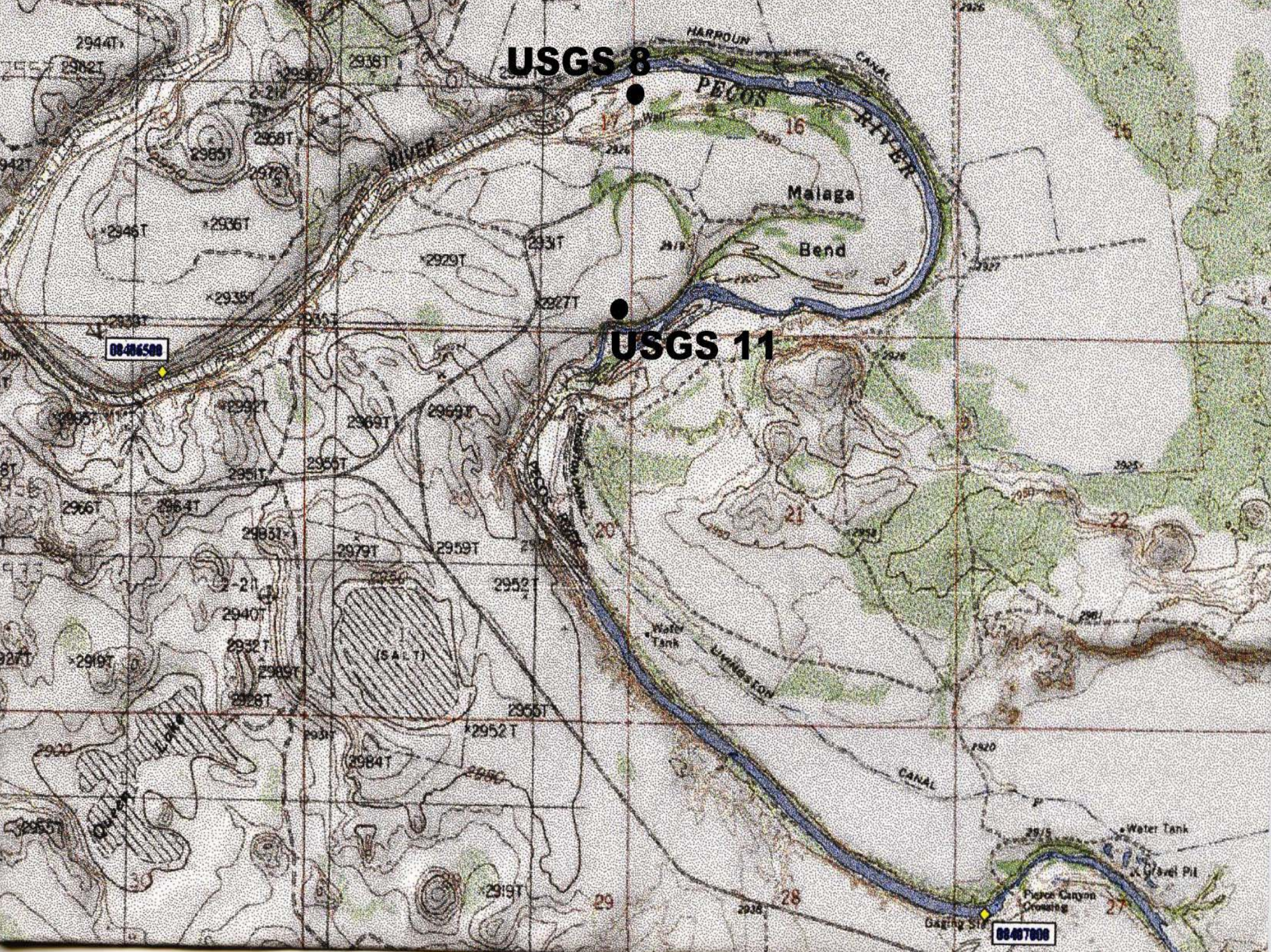
R.31 E.
32°30'
T. 21 S.
T. 22 S.
T. 23 S.
T. 24 S.
Lake Avalon
285
180
62
CARLSBAD
PECOS RIVER
ATCHISON TOPEKA AND SANTA FE
Dark Canyon
Loving
Malaga
Malaga Bend
Willow Lake
Queen Lake
Salt Lake
Black River
396
31
128
QUAHADA RIDGE
MAROON CLIFFS
NASH DRAW
LIVINGSTON RIDGE
EDDY COUNTY
LEA COUNTY
2900
2800
2700
2600
2500


USGS 8
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08406500
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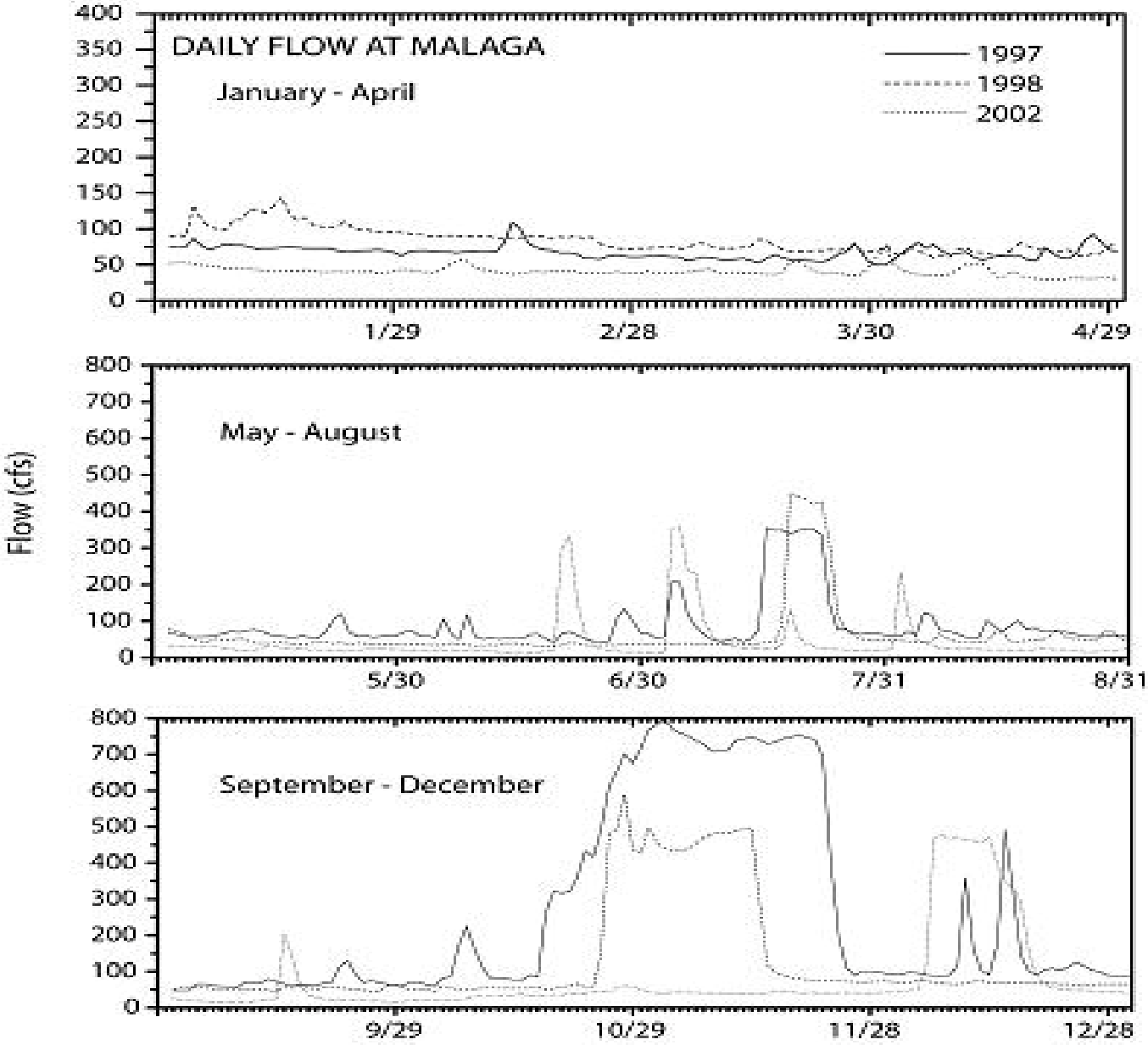

Fig. 14 Examples of daily flow at Malaga: 1997, 1998, 2002.

3. Seepage Control at All Reservoirs

- McMillan Dam was bleached in 1990, due to sedimentation and sinkhole development
- Avalon and Red Bluff: also leaking
- Brantley is a good replacement

Closing Note
Save this spot for me for fishing