A Regional Salinity Perspective on the San Joaquin Valley with an Emphasis on Dairy Contributions

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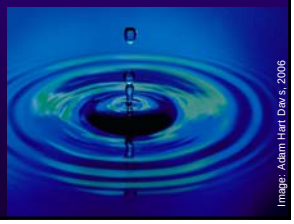

Image: Adam Hart Davis, 2006

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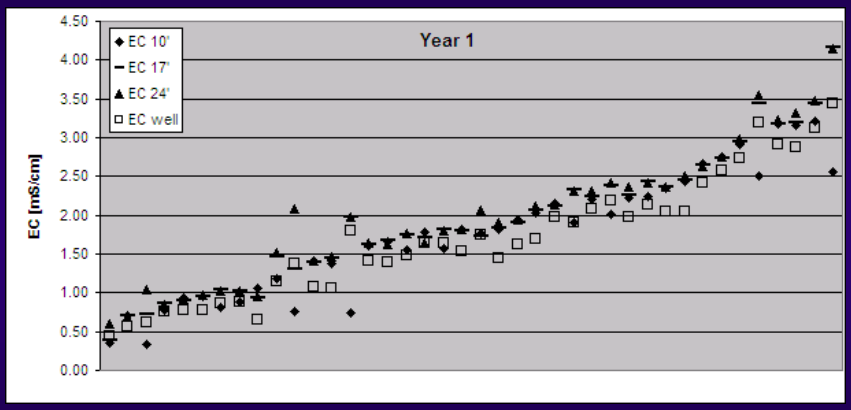
- University of California Salinity & Drainage Program

Outline

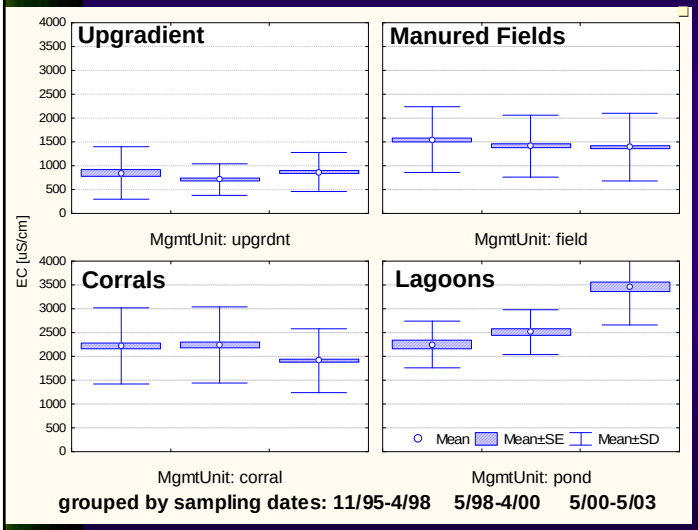
- Salinity in shallow groundwater underneath dairies
  - By source
  - By region
- Salinity in non-dairy shallow groundwater
- Mass balance approach to salinity from dairies
  - Farm scale
  - Regional scale
- Long-term groundwater transport of salinity

Salinity in Dairy Water Table Monitoring Wells, Eastern SJV



From: Harter and Talozi, 2004, Ground Water Monitoring and Remediation 24(4):97-105

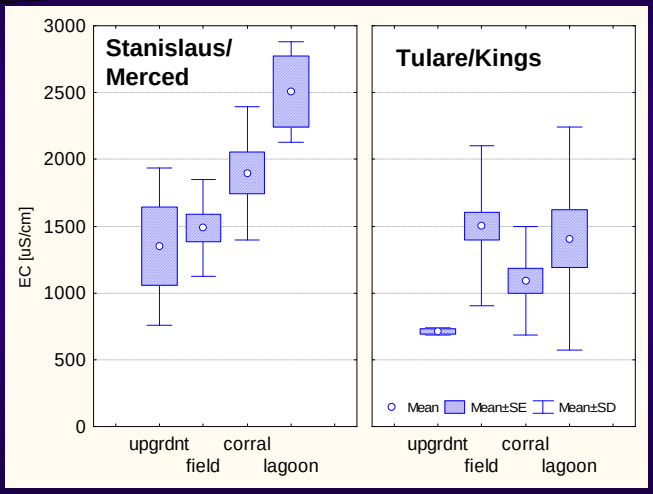
Salinity in Dairy Groundwater



Case Study Northern SJV (Turlock/ Modesto Area):

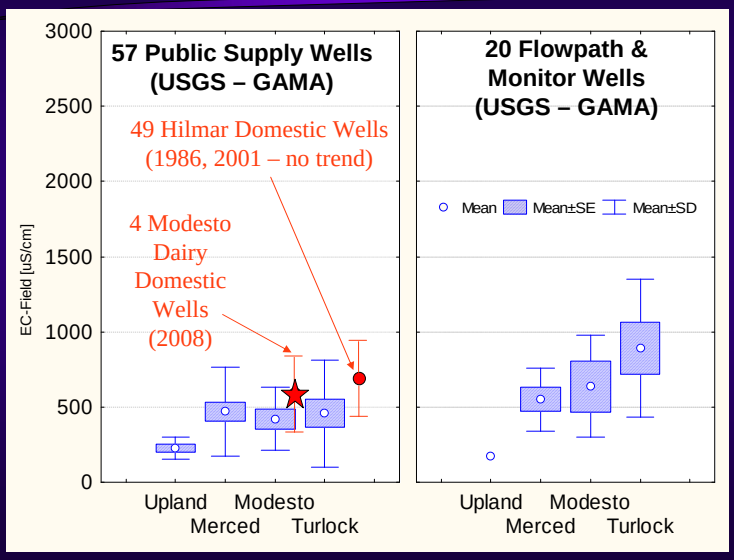
- Water-Table < 10 ft depth
- Sandy soils
- Low irrigation efficiency
- 40+ wells until 2000
- 70+ wells after 04/2000
- 5 dairies
- Sampled 6-8 weekly

Salinity in Dairy Groundwater: eastern SJV vs. Tulare Basin



averaged over 2 sampling events in water table monitoring wells: 01/2008 and 04/2008
14 wells on 2 dairies in Stanislaus/Merced
33 wells on 5 dairies in Tulare/Kings

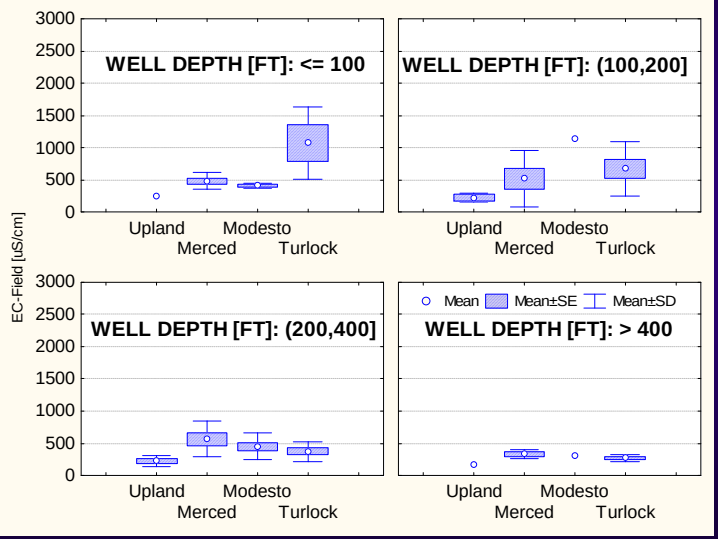
Salinity in Other Wells Eastern SJV



Original data from Table 1 and 4 in:

Landon and Belitz, 2008. Ground-Water Quality Data in the Central Eastside San Joaquin Basin 2006: Results from the California GAMA Program, USGS Data Series 325.

Salinity by Well Depth Eastern SJV



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Salinity by Well Depth, Northeast Modesto

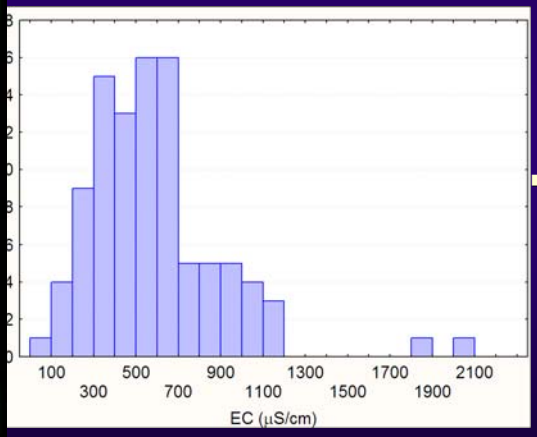
5. Summary of well characteristics and water chemistry field measurements of depth categories for monitoring wells sampled from October through November of 2003 004, for the public-supply well sampled from October 2003 through June 2005, and for surface-water sites sampled in February and June 2005, in Modesto, eastern San uin Valley, California.

s reported as ranges with median values in parentheses unless specified otherwise. $CaCO_3$, calcium carbonate; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; ublic supply well; na, not applicable]

Site type or pth category	Depth to top of screened interval (screen length) (meter)	Water-level elevation at time of sampling (meter)	Number of wells/samples	Temperature, °C	Specific conductance, µS/cm @ 25°C	Dissolved oxygen, mg/L	pH, standard units	Alkalinity, dissolved, mg/L as $CaCO_3$
ce-water chemistry								
basin	surface sample	surface sample	3	12–13 (13)	54–463 (59)	4.9–10.2 (8.4)	7.0–7.6 (7.0)	17–110 (22)
d-water chemistry								
riable	8.5–11.7 (1.5)	18.9–21.8 (20.5)	9/9	19.8–23.2 (22.4)	529–1060 (886)	1.8–6.6 (4.8)	6.8–7.4 (7.1)	208–477 (418)
w	29.0–35.1 (1.5)	18.8–19.8 (19.2)	3/3	20.3–21.0 (20.8)	704–1080 (784)	3.6–5.0 (3.9)	7.1–7.4 (7.4)	285–384 (298)
ate	50.6–65.5 (1.5)	16.1–19.8 (17.5)	7/7	20.6–22.4 (21.6)	288–492 (334)	3.4–5.4 (5.0)	7.4–7.8 (7.6)	110–187 (133)
	100.0–105.8 (1.5)	16.6–17.6 (17.1)	4/4	22.7–23.0 (23.0)	175–329 (20	2.2–3.0 (2.7)	7.4–8.1 (8.1)	79–139 (84)
	27.7 (91.4)	na	1/4	19.4–21.2 (20.2)	414–667 (500)	4.4–5.1 (4.6)	7.1–7.5 (7.4)	171–288 (204)

From: Jurgens et al., 2008, Hydrogeology, Water Chemistry, and Factors Affecting the Transport of Contaminants in the Zone of Contribution of a Public-Supply Well in Modesto, Eastern San Joaquin Valley, California ; USGS Scientific Investigations Report 2008-5156.

Salinity in Domestic Wells



- Tulare/Kings Co Dairies, 5 wells, 2 dates in 2008
  - Range: 500–600 µS/cm
  - Mean: 530 µS/cm
- Tulare/Kings Co GAMA, 98 wells, 1 date in 2006:
  - Range: 100 – 1,100 µS/cm
  - Mean: 590 µS/cm
  - StD: 320 µS/cm

Salinity Input from Dairy Farms: Field Mass Balance

	Annual Crop N Uptake, kg ha^{-1} yr^{-1}				
	300	400	500	600	700
N excretion, kg/ha/year	540-990	720-1320	900-1650	1080-1980	1260-2310
Salt excretion, kg/ha/year	690-1260	910-1680	1140-2100	1370-2520	1600-2940
Lactating plus Dry Cows equivalent head/ha	3.5 – 6.5	4.7 - 8.6	5.9-10.8	7.0 - 12.9	8.2 – 15.1

Land application of [Na, K, Cl] salts as function of crop uptake, for agronomic rates of manure application. Total salts is 50%-100% higher than above. Some goes to crop uptake. (UC Committee of Consultants Report, UC ANR Communications, 2007; http://anrcatalog.ucdavis.edu/DairyCattle/9004.aspx).

Dairy Manure Annual Salt Loading to Groundwater

Irrigation Water Source	Salt Input, kg ha^{-1}		Annual Salt Loading kg ha^{-1}
	Winter Forage	Summer Corn	
East Side Sources	86	310	404
Wastewater + East Side	1356	2284	3615
West Side Sources	828	2983	3794
Wastewater + West Side	2000	4792	6452

Computed using “Watsuit” Model. Crop uptake is considered. Agronomic manure application rates. Scenario: Annual Summer Corn/Winter Forage Double Cropping with 250 and 150 lbs per acre of N inputs, respectively; annual water inputs are rainfall 12 inches ((30.48 cm), winter irrigation 10 inches (25.4 cm), and summer irrigation 36 inches (91.44 cm); and leaching fraction is 0.3. (UC Committee of Consultants Report, UC ANR Communications, 2007; http://anrcatalog.ucdavis.edu/DairyCattle/9004.aspx).

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130 – 220 µS/cm

1,200 – 1,900 µS/cm

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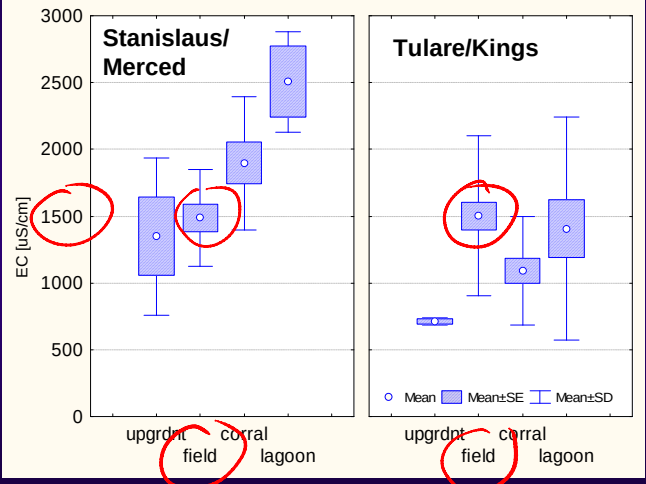
Salinity in Dairy Groundwater: eastern SJV vs. Tulare Basin



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Dairies Salinity Inputs to SJV roundwater – Regional Mass Balance

- Dairy salt cycle: feed – cow - manure – land application – crop/grdwater – feed
- Low import rates of feed into the valley => no significant net salt import
- Recent trend of using distillers grains (from ethanol production) => some increase in net salt import to SJV

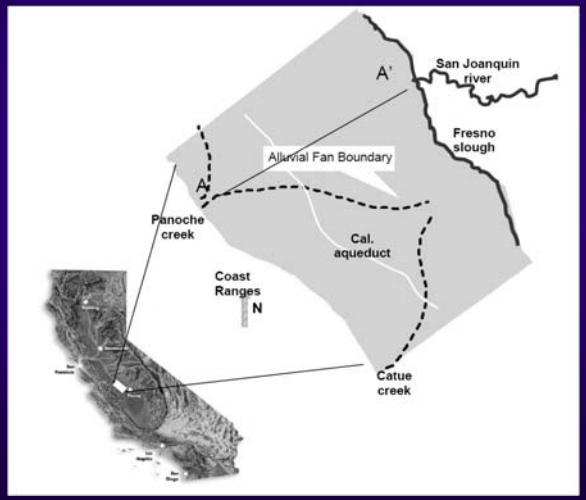
Dairies Salinity Inputs to SJV roundwater – Regional Mass Balance

- Within SJV:
  - Diffuse feed production
  - vs. concentrated land application
  - => redistribution and localized land application of salts
- Increased number of dairies in SJV:
  - Conversion from food & fiber production to forage production
  - => reduction of net EXPORTS of salts from SJV

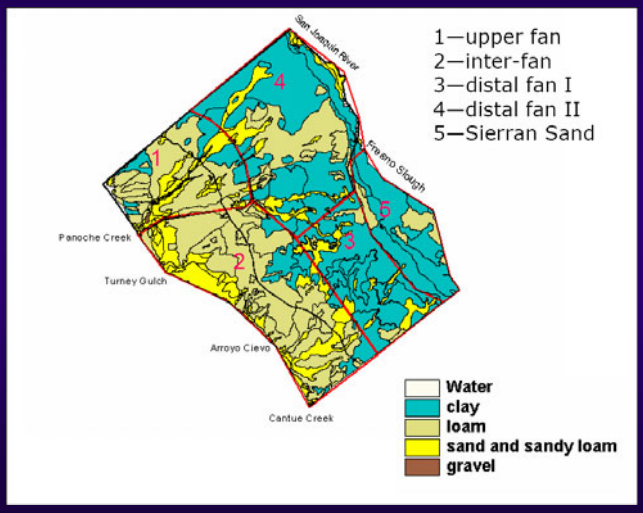
Long-Term Deep Groundwater Salinization: Risk of Preferential Flow

- Belitz and Phillips (WRR, 1995)
  - modeling study of Western SJV
  - salt front moves downward at ~ 1 ft/year
  - 500 years to 500′ depth.
- Jurgens et al. (USGS, 2008)
  - Natural tracer study in Eastern SJV (Modesto)
  - Mean age:
    - @100′: 30 – 40 years
    - @350′: several hundred years

Long-Term Deep Groundwater Salinization: Risk of Preferential Flow



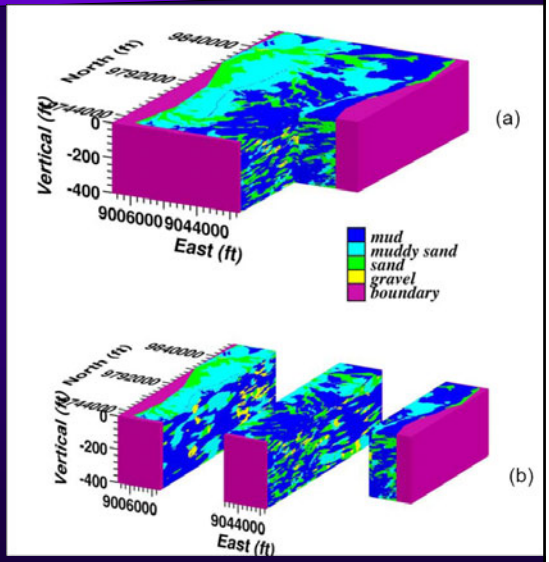
Taking into Account Aquifer Heterogeneity at Multiple Scales



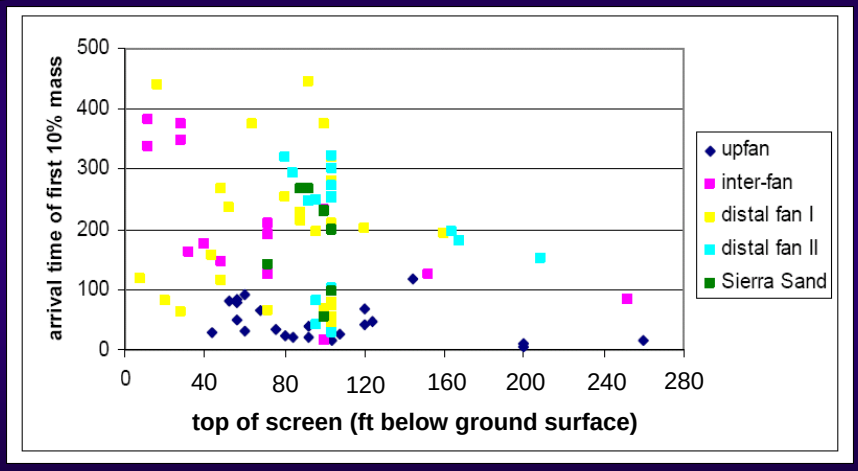
Conceptual Aquifer Model

- Groundwater Model:
- 101 layers
- 259x222 cells per layer
- cell size:
  - 490 ft wide
  - 4 ft thick
- 5.8 million cells
- Steady state

From: Hua Zhang, Master's Thesis, UC Davis, 2005



Arrival Time of Salt in Production Wells



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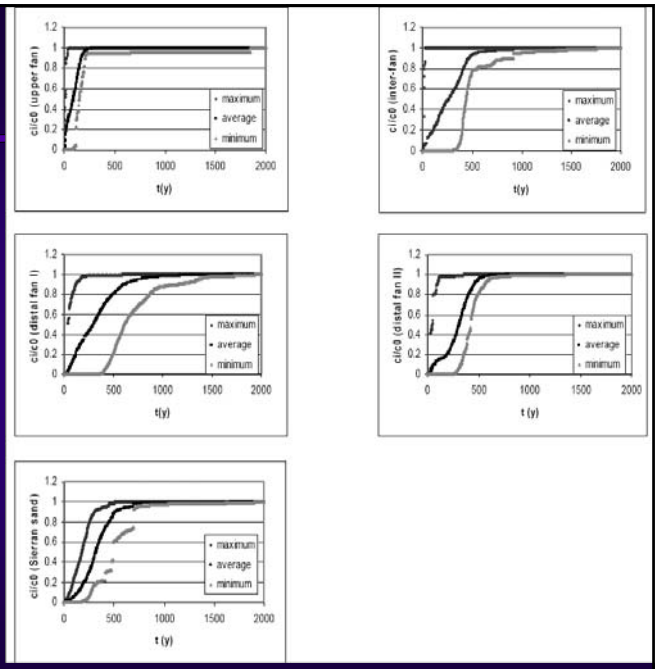
Salt Breakthrough in Deep Production Wells



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Conclusion

- Manure land application salinity in recharge (1,500 μS/cm) is 2x – 4x above typical recharge from field crop
- Manure lagoons have highest salinity in recharge (2,000 – 4,000 μS/cm)
- Some improvements expected from WDR
  - Reduced/more diffuse land application in the most impacted areas (shallow water table, eastern SJV)
  - Lagoon liner requirements
- Major impacts to deep aquifer are on the centuries scale
- Preferential flow & well leakage will drive salinity downwards more quickly than expected