Developing Water Quality Objectives for Salinity Diversions to Agriculture using Steady-state and Transient Models

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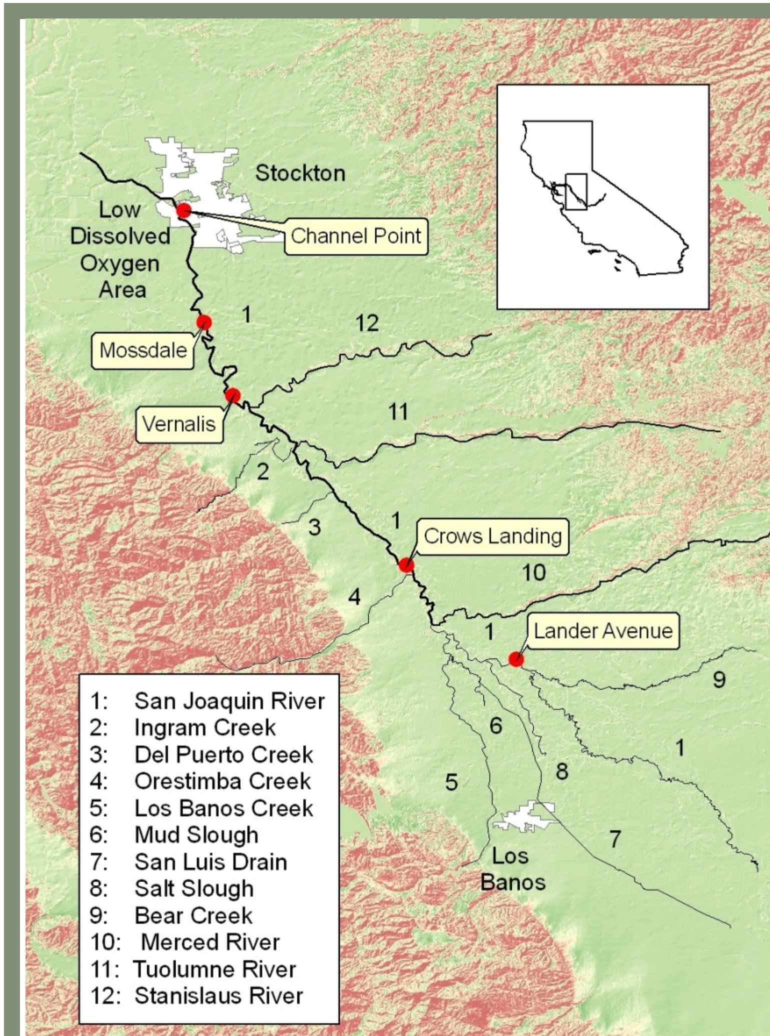
April 11, 2016

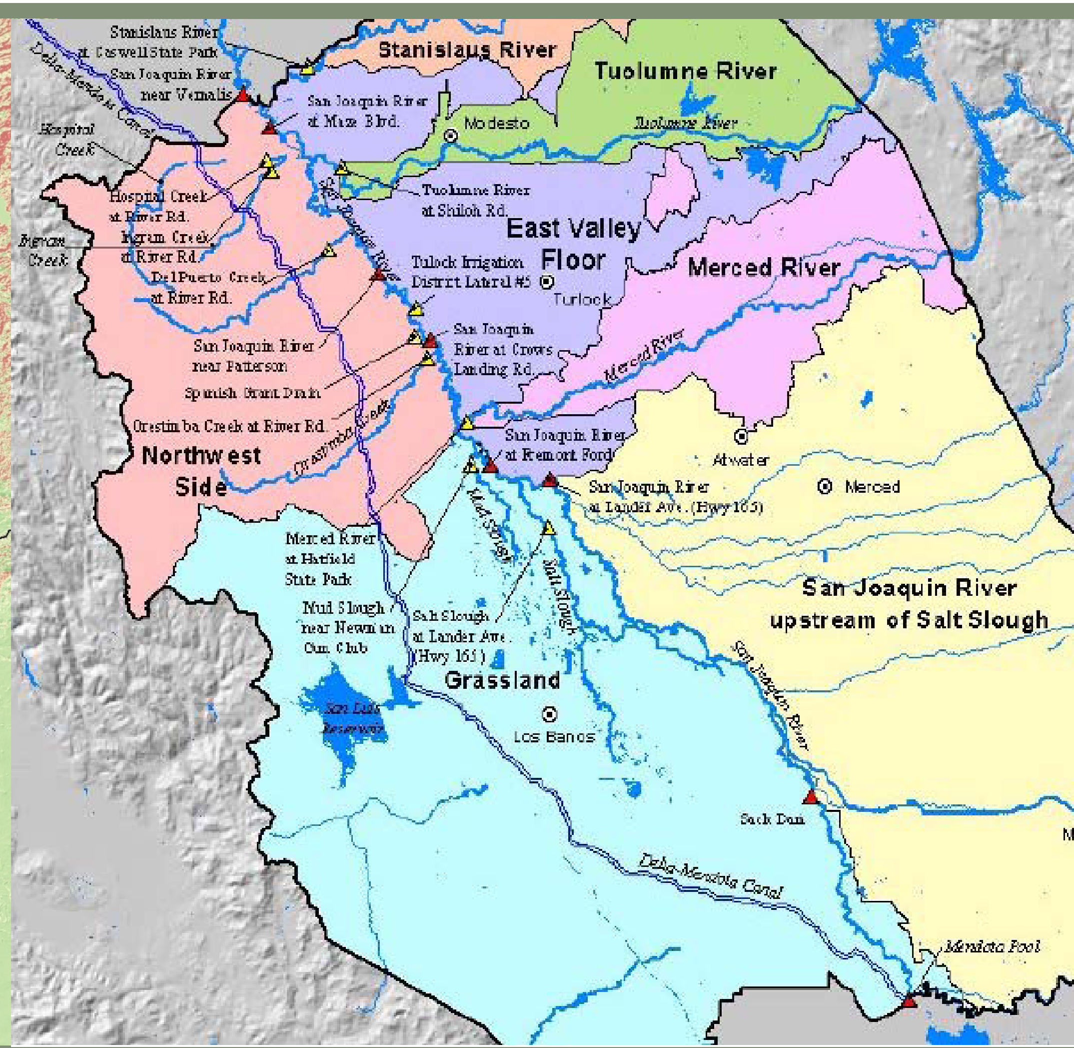
Salinity regulation in the San Joaquin Basin

- The Central Valley Regional Board adopted a stakeholder-centric approach to salinity planning and regulation – CVSALTS.

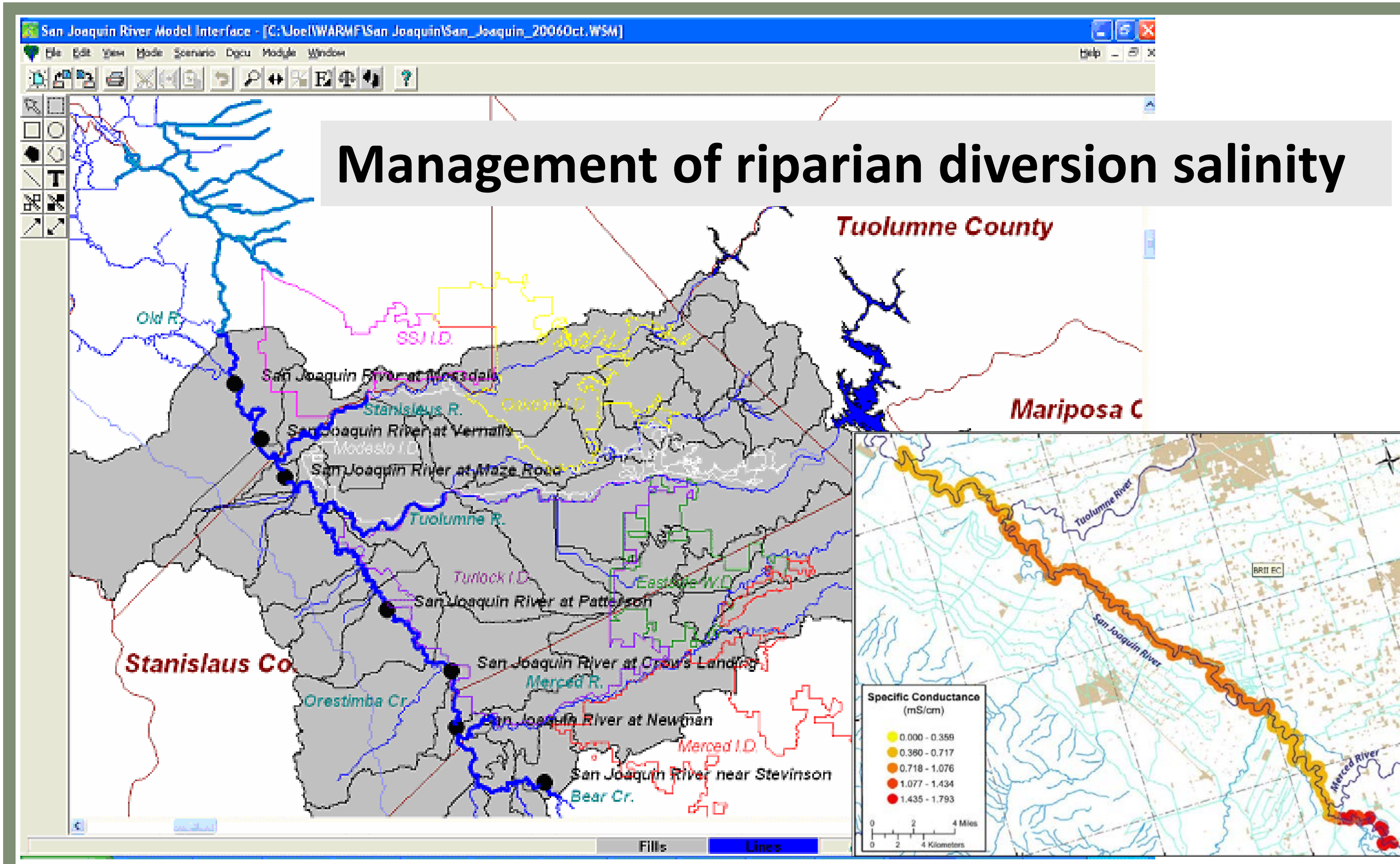
  Tasked with rewriting the Basin Plan for water quality
- Basin Plan includes provision for real-time salinity management
- Requires dischargers (otherwise subject to WDR's) to adopt a "Board approved" real-time salinity management program
- Program includes continuous monitoring, data access and sharing, modeling and real-time decision support
- Reliance on sensor networks and the development of a stakeholder supported sensor web.
- Need to develop protective water quality (salinity) objectives for irrigation diversions from the San Joaquin River

Monitoring return flow and salinity to the SJR

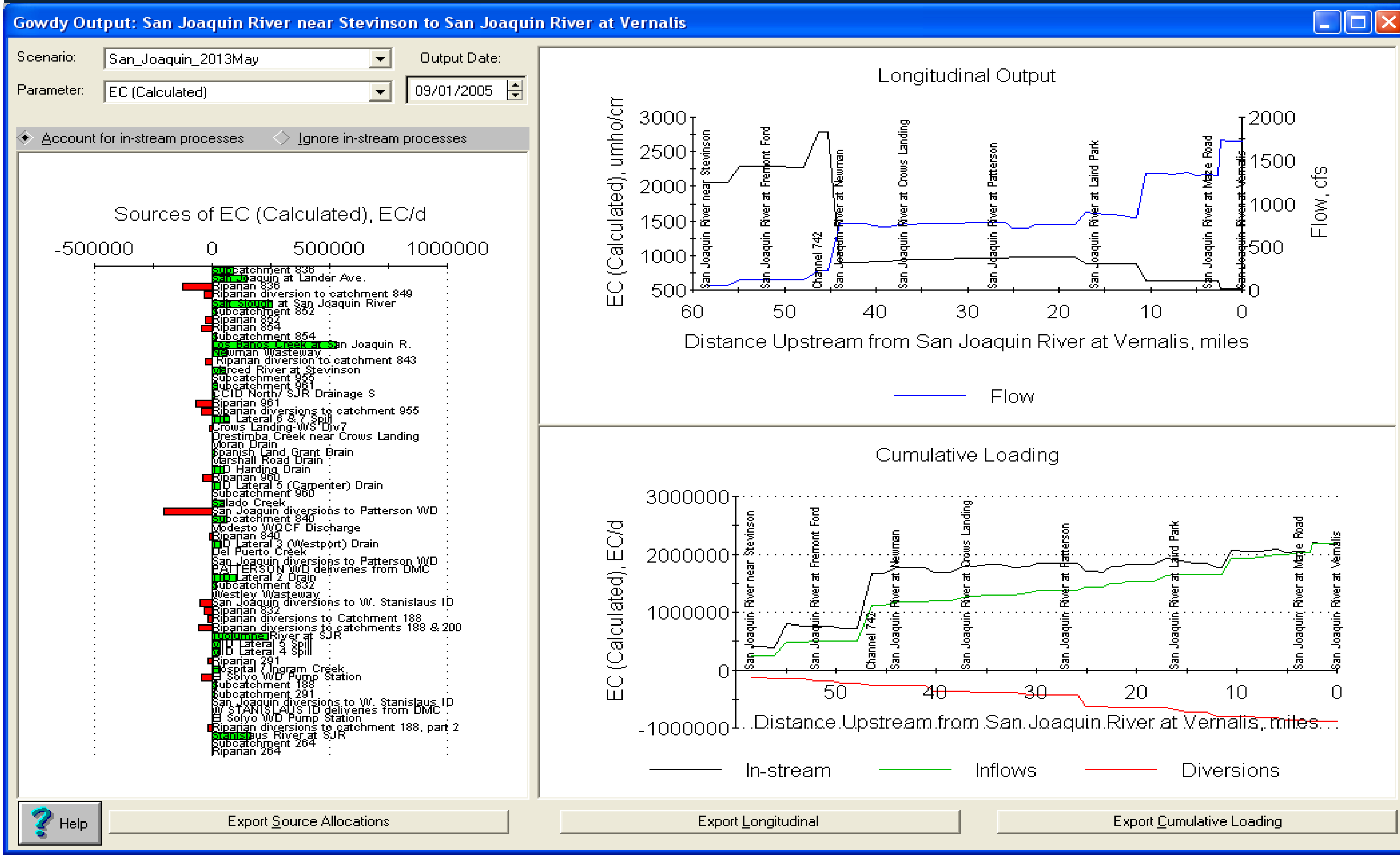




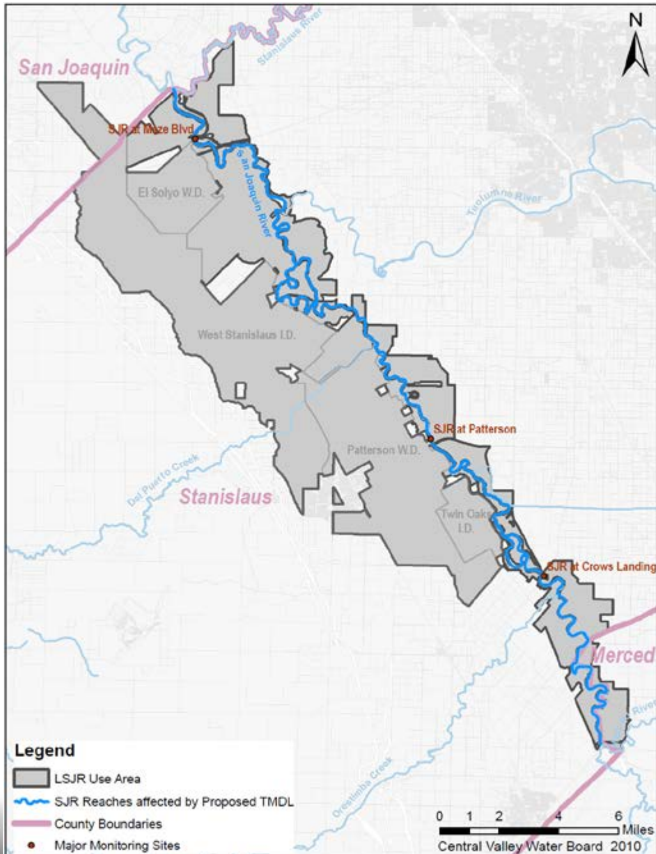
Management of riparian diversion salinity

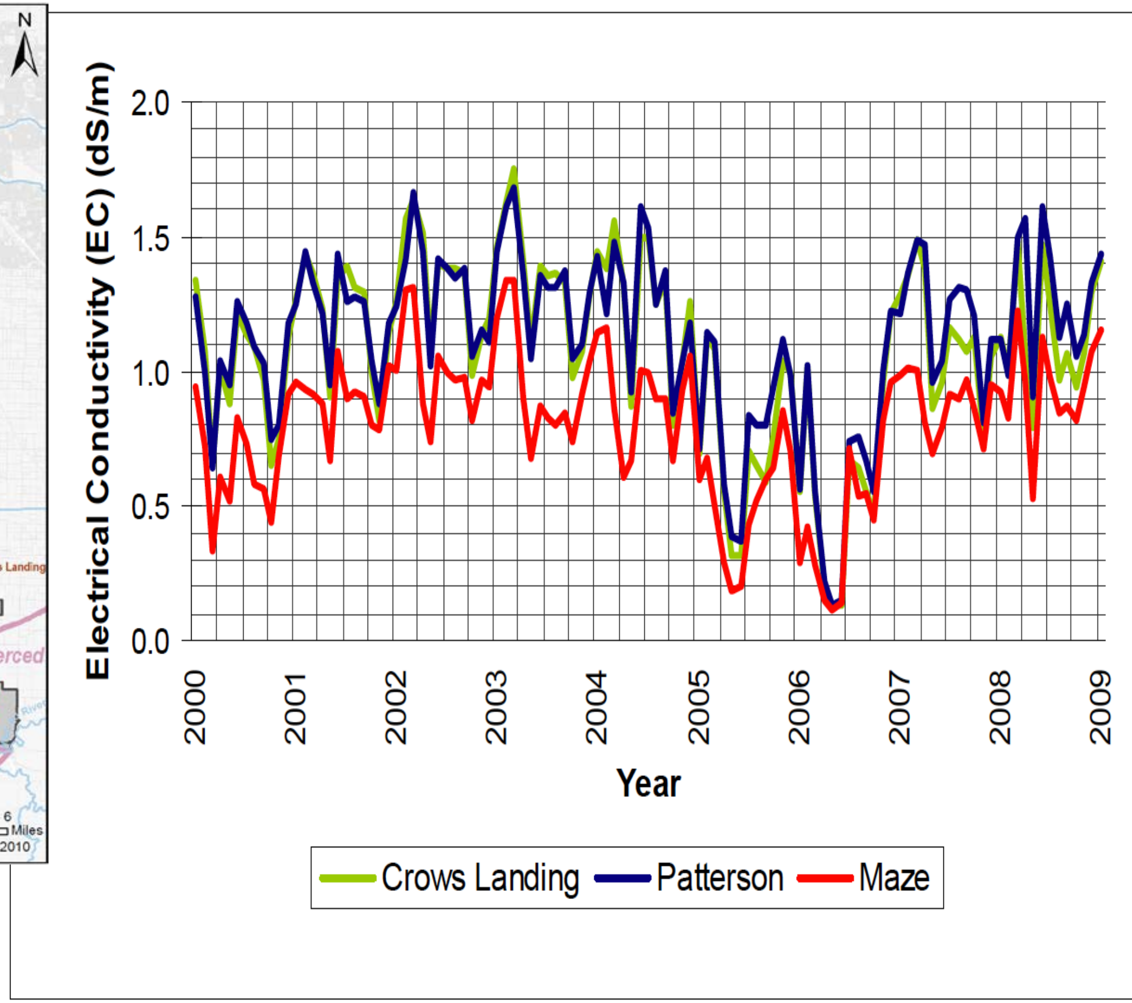


HYDROECOLOGICAL ENGINEERING ADVANCED DECISION SUPPORT (HEADS)



Comparison of EC at three SJR monitoring stations





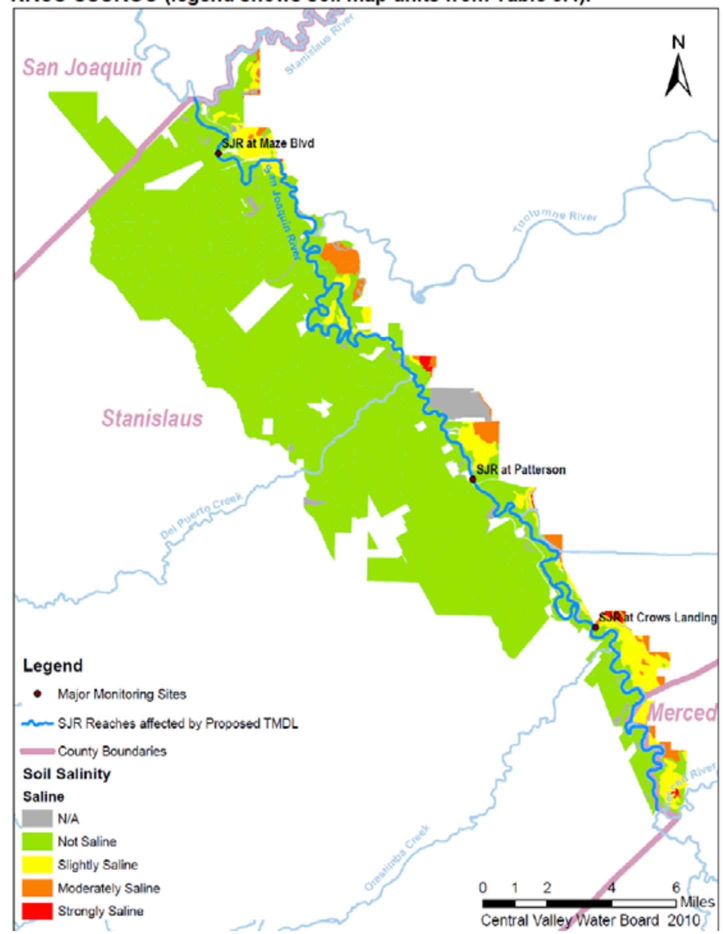
Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta, Hoffman, 2010

Criteria affecting water quality for crop production

- Salinity
  - Osmotic stress on plants
- Sodicity
  - Loss of soil permeability
- Toxicity
  - Direct toxic effect on plants

Units of Measure for Electrical Conductivity
1 dS/m = 1,000 µS/cm = 1 mmho/cm
1 dS/m ≈ 640 mg/l or 640 ppm total dissolved solids

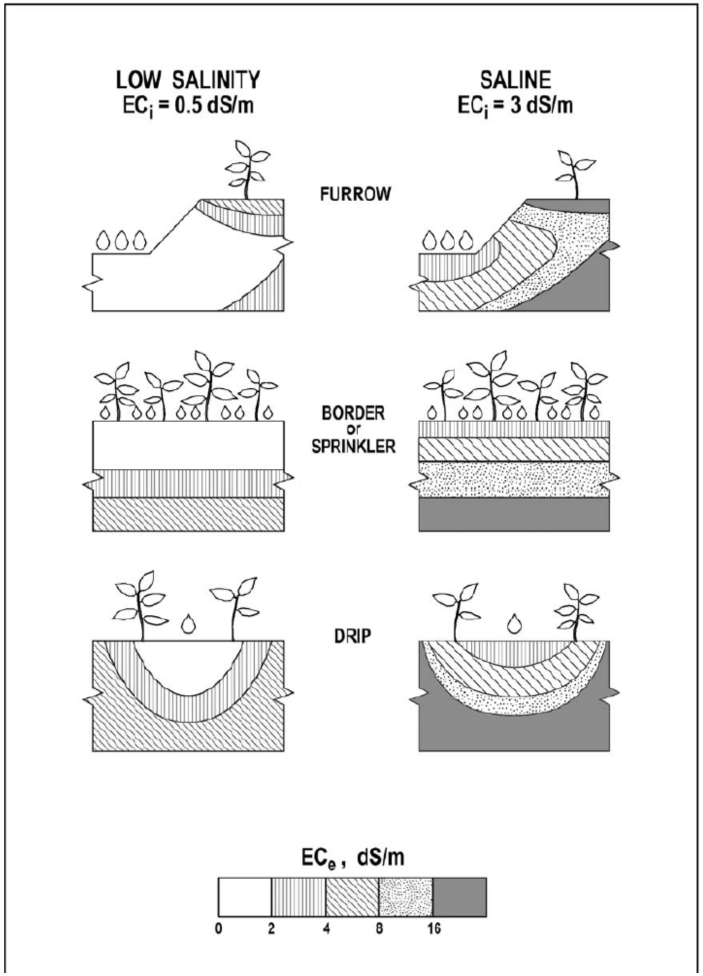
Figure 3.7a. Location of saline soils in the LSJR using GIS data from the NRCS-SSURGO (legend shows soil map units from Table 3.4).



Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta, Hoffman, 2010.

Factors affecting salinity objectives for irrigated agriculture

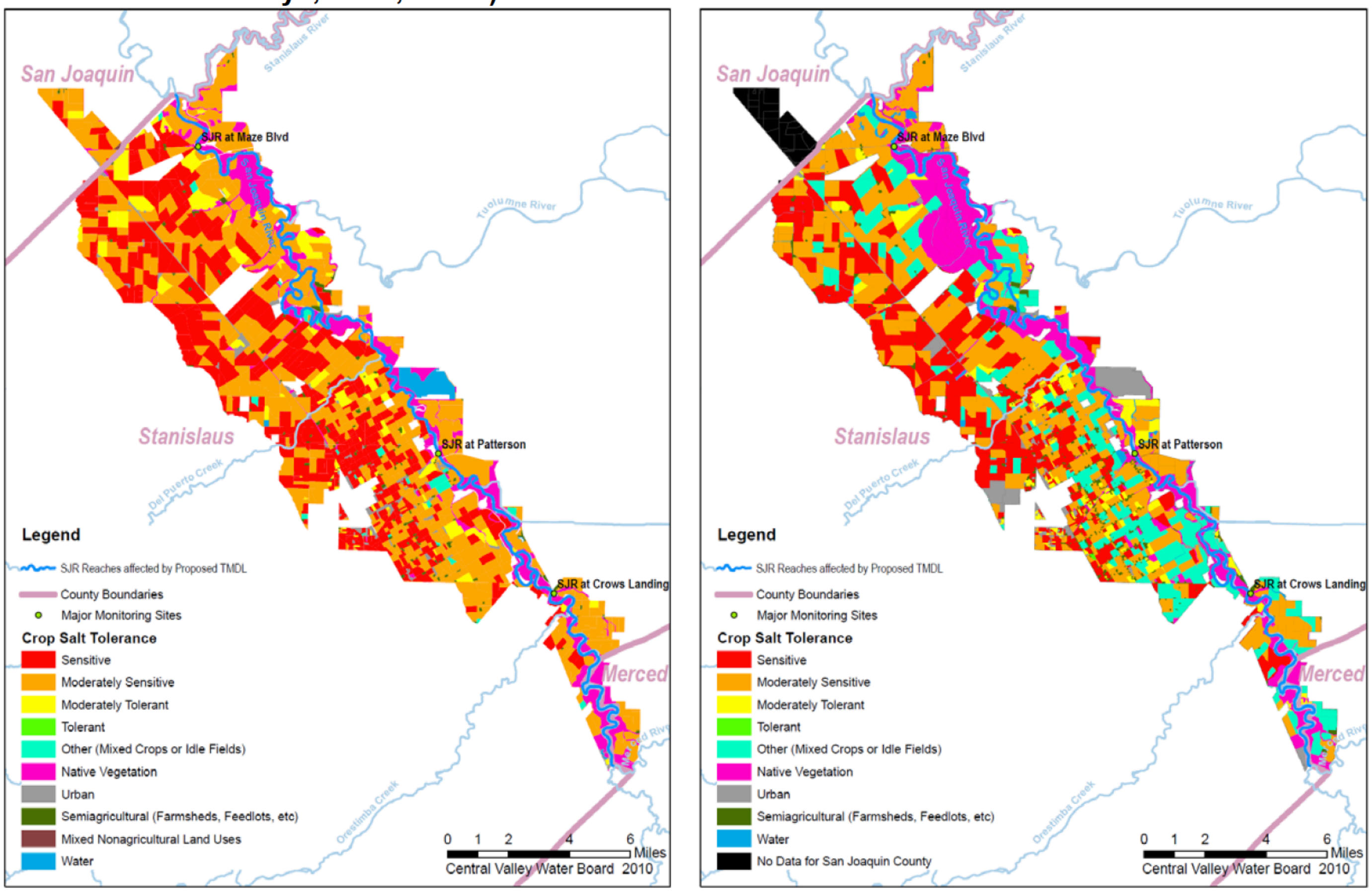
- Season-long crop salt tolerance
- Crop salt tolerance at various growth stages
- Preferential (bypass) flow of applied water
- Effective rainfall
- Irrigation method
- Crop water uptake distribution
- Climate
- Salt precipitation / dissolution
- Shallow groundwater
- Leaching fraction



Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta, Hoffman, 2010.

Comparison of crop salt tolerance 1990's vs 2000's

Figure 3.4. Distribution of crops in the LSJR Irrigation Use Area for the 1990s and 2000s based on salt tolerance (from DWR land use surveys; DWR, 2009a).



Crop Salt Tolerance in 1990s DWR Land Use Survey

Crop Salt Tolerance in 2000s DWR Land Use Survey

CWQRCB. LSJR Salt Tolerance Report, 2016.

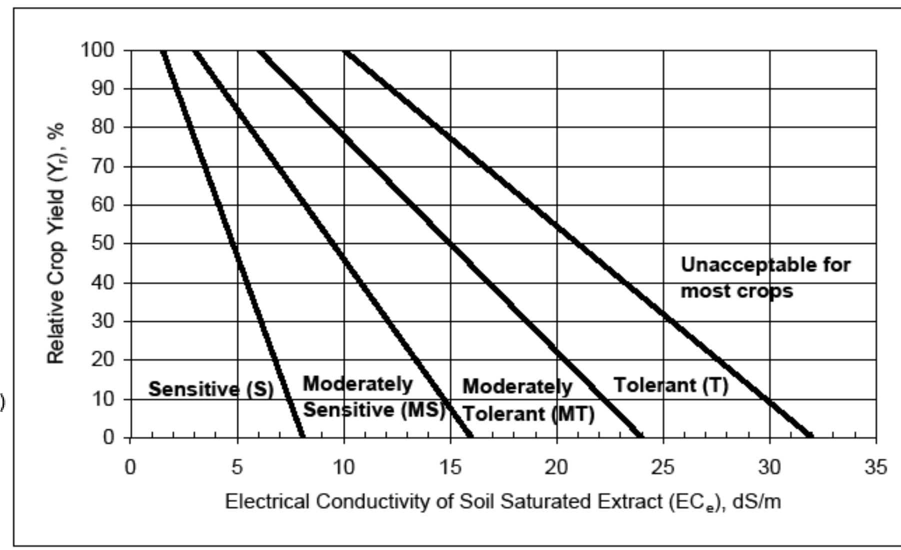
Seasonal salt tolerance by crop type

$$Y_r = 100 - b\,(EC_e - a)$$

Common Name	Botanical Name	Tolerance based on	Threshold* ECe, dS/m	Slope* % per dS/m	Relative Tolerance **
Alfalfa	Medicago sativa	Shoot DW	2.0	7.3	MS
Almond	Prunus duclis	Shoot growth	1.5	19	S
Asparagus	Asparagus officinalis	Spear yield	4.1	2.0	T
Bean	Phaseolus vulgaris	Seed yield	1.0	19	S
Corn	Zea mays	Ear FW Shoot DW	1.7 1.8	12 7.4	MS MS
Grape	Vitus vinifera	Shoot growth	1.5	9.6	MS
Oat	Avena sativa	Grain yield Straw DW	--- ---	--- ---	T T
Safflower	Carthamus tinctorius	Seed yield	---	---	MT
Tomato	Lycopersicon lycopersicum	Fruit yield	2.5	9.9	MS
Walnut	Juglans	foliar injury	---	---	S
Wheat	Triticum aestivum	Grain yield Shoot DW	6.0 4.5	7.1 2.6	MT MT

Values of threshold = (a) and slope = (b) in above equation

Relative salt tolerance ratings: (S) sensitive, (MS) moderately sensitive, (MT) moderately tolerant, and (T)



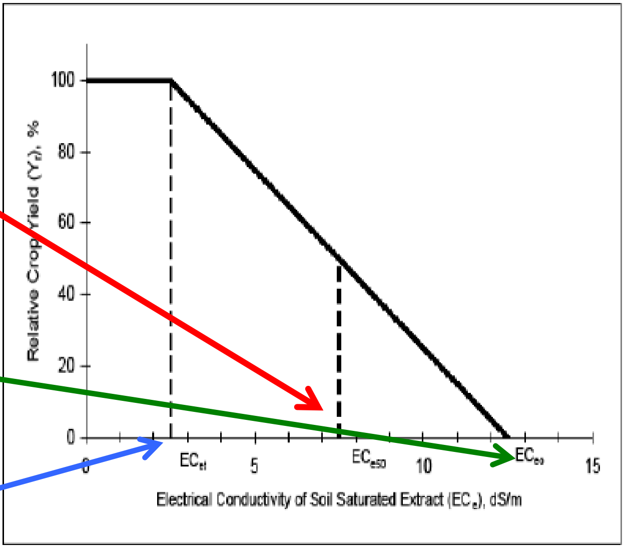
Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta, Hoffman, 2010

Steady-state models for soil salinity management

- **Bernstein (1964)**: $L_r = EC_i / EC_{e50}$
  (consistently overestimates L_r)

- **Bernstein and Francois (1973b) & van Schilfgaarde (1974)**: $L_r = EC_i / (2^*EC_{e0})$
  (consistently underestimates L_r)

- **Rhoades (1974):** $L_r = EC_i / (5^*EC_{et} – Ec_i)$
  (reasonable at low L_r, overestimates severely at high L_r)



- **Rhoades and Merrill (1976):** $L_r = EC_i / EC_e$ 40-30-20-10
  (large swings between over/underestimating L_r)

- **Hoffman and van Genuchten (1983)**:
  (correlates best with measured L_r - underestimates at high L_r)

$$C/C_a = 1/L + (\delta/Z \times L) \times \ln [L + (1 – L) \times \exp(–Z/\delta)] – 1.73$$

C = salt conc. of soil saturated extract

Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta, Hoffman, 2010

Forage grasses

Crop	Experimental Results L_r	Experimental Results EC_i	L_r Prediction Using EC_{e50}	$2EC_{e0}$	$5EC_{et}-EC_i$	40-30-20-10	Exp.
Alfalfa	0.20	2.0	0.18	0.05	0.15	0.16	0.13
Alfalfa	0.32	4.0	0.36	0.11	0.36	0.52	0.22
Alfalfa	0.06	1.0	0.11	0.03	0.11	0.09	0.09
Alfalfa	0.15	2.0	0.23	0.06	0.25	0.31	0.17
Barley	0.13	2.2	0.17	0.05	0.08	0.02	0.07
Cowpea	0.17	2.2	0.31	0.09	0.38	0.45	0.22
Fescue	0.10	2.0	0.17	0.05	0.17	0.17	0.13
Fescue	0.25	4.0	0.25	0.07	0.40	0.58	0.23
Oat	0.17	2.2	0.31	0.0	0.25	0.22	0.18
Sudan Grass	0.16	2.0	0.14	0.04	0.19	0.17	0.13
Sudan Grass	0.31	4.0	0.28	0.08	0.49	0.58	0.23

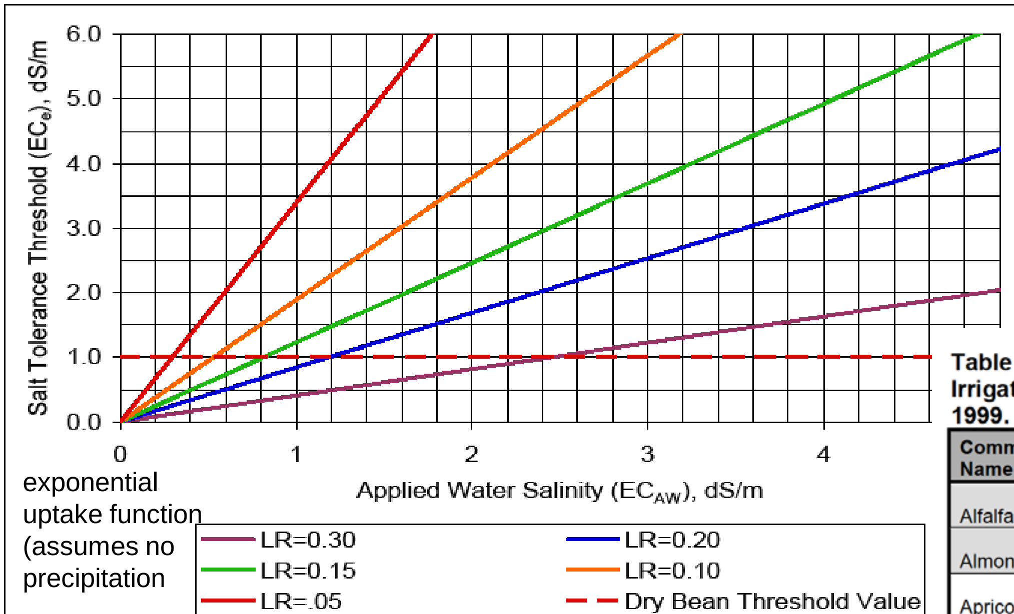
Cereals

Crop	Experimental Results L_r	Experimental Results EC_i	L_r Prediction Using EC_{e50}	$2EC_{e0}$	$5EC_{et}-EC_i$	40-30-20-10	Exp.
Barley	0.10	2.2	0.12	0.04	0.06	0.01	0.05
Oat	0.10	2.2	0.18	0.06	0.11	0.04	0.09
Sorghum	0.08	2.2	0.22	0.08	0.07	0.01	0.06
Wheat	0.07	1.4	0.11	0.03	0.05	0.03	0.04
Wheat	0.08	2.2	0.17	0.05	0.08	0.01	0.07

Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta, Hoffman, 2010

Graphical solution of model exponential uptake function

Dry bean response at various leaching rates

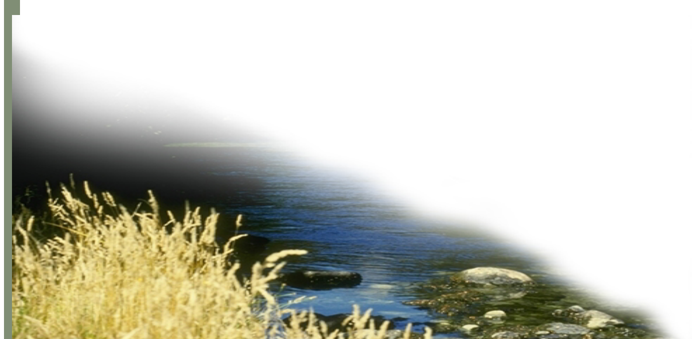


exponential uptake function (assumes no precipitation

Table 3.1. Crop salt tolerance coefficients for important crops in the LSJR Irrigation Use Area based on Maas and Hoffman (1977); Maas and Grattan, 1999.

Common Name	Botanical Name	Tolerance based on	Threshold* ECe, dS/m	Slope* % per dS/m	Relative Tolerance**
Alfalfa	*Medicago sativa*	Shoot (dry weight)	2.0	7.3	MS
Almond	*Prunus duclis*	Shoot growth	1.5	19	S
Apricot	*Prunus armeniaca*	Shoot growth	1.6	24	S
Bean (Dry)	*Phaseolus vulgaris*	Seed yield	1.0	19	S
Cabbage	*Brassica oleracea*	Head (fresh weight)	1.8	9.7	MS
Castor Bean	*Ricinus communis*	---	---	---	MS
Celery	*Apium graveolens*	Petiole (fresh weight)	1.8	6.2	MS
Grape	*Vitus vinifera*	Shoot growth	1.5	9.6	MS
Sudan Grass	*Sorghum sudanense*	Shoot (dry weight)	2.8	4.3	MT
Walnut	*Juglans*	Foliar injury	---	---	S

* Values of threshold = (a) and slope = (b) for Equation 3.1
** Relative salt tolerance ratings noted as (S) sensitive, (MS) moderately sensitive, (MT) moderately tolerant, and (T) tolerant, see Fig. 3.2.



Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta, Hoffman, 2010

Factors affecting performance of existing transient models

- Appropriate water uptake function
- Feedback mechanism for soil-water status, plant growth & transpiration
- Allows additional water uptake from non-stressed region of root zone.
- Accounts for salt precipitation/dissolution
- Can be compared to field experimental data

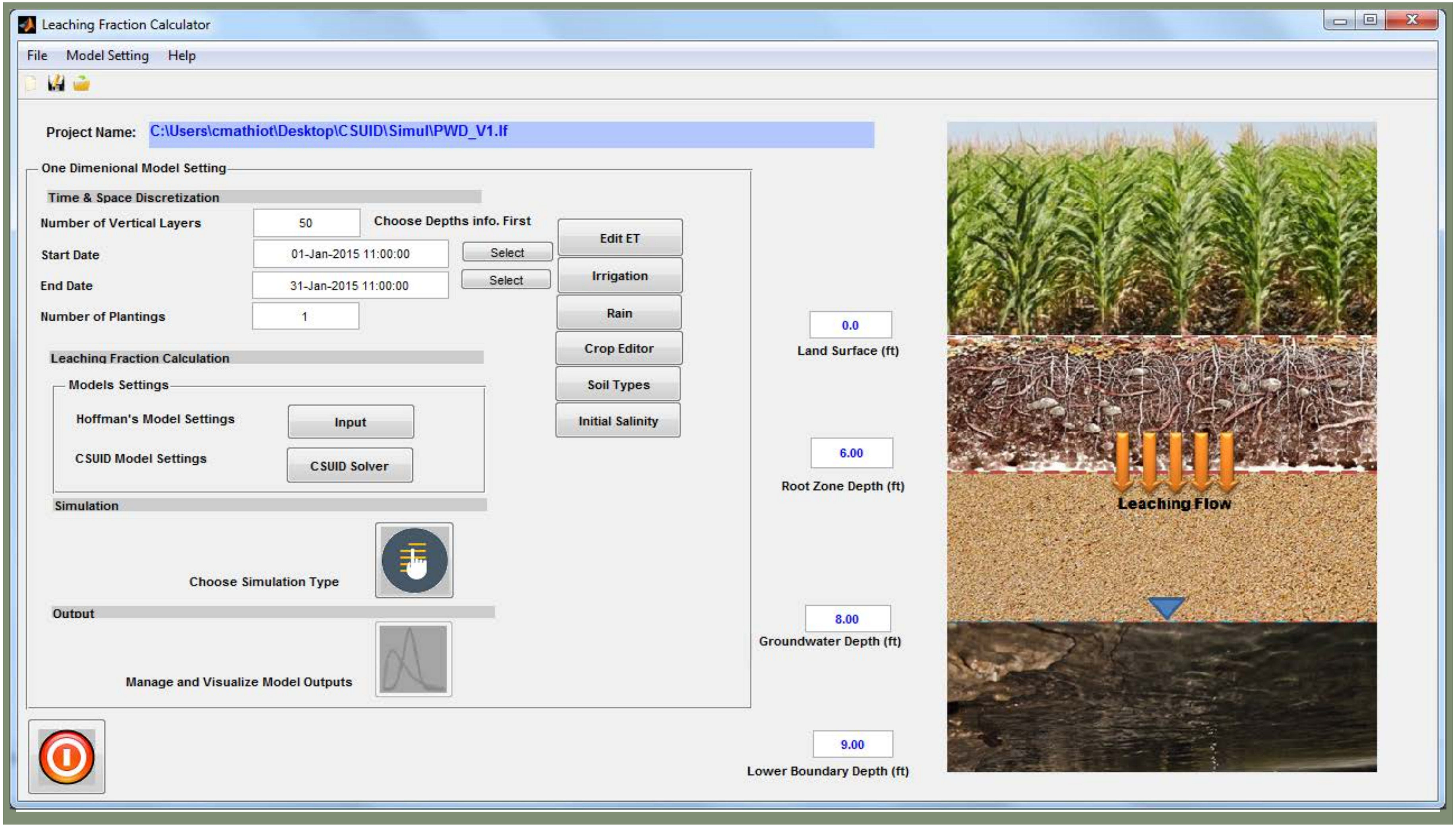
- Grattan – modified 40-30-20-10
- Corwin - TETrans
- Simunek - UNSATCHEM
- Letey – ENVIRO-GRO

Factor	Grattan	Corwin	Simunek	Letey
Water uptake function	Yes	Yes	Yes	Yes
Feedback mechanism	No	Yes	No	Yes
Water uptake based on stress	No	Yes	No	Yes
Salt precipitation / dissolution	No	No	Yes	No
Field tested	No	Yes	Yes	Yes

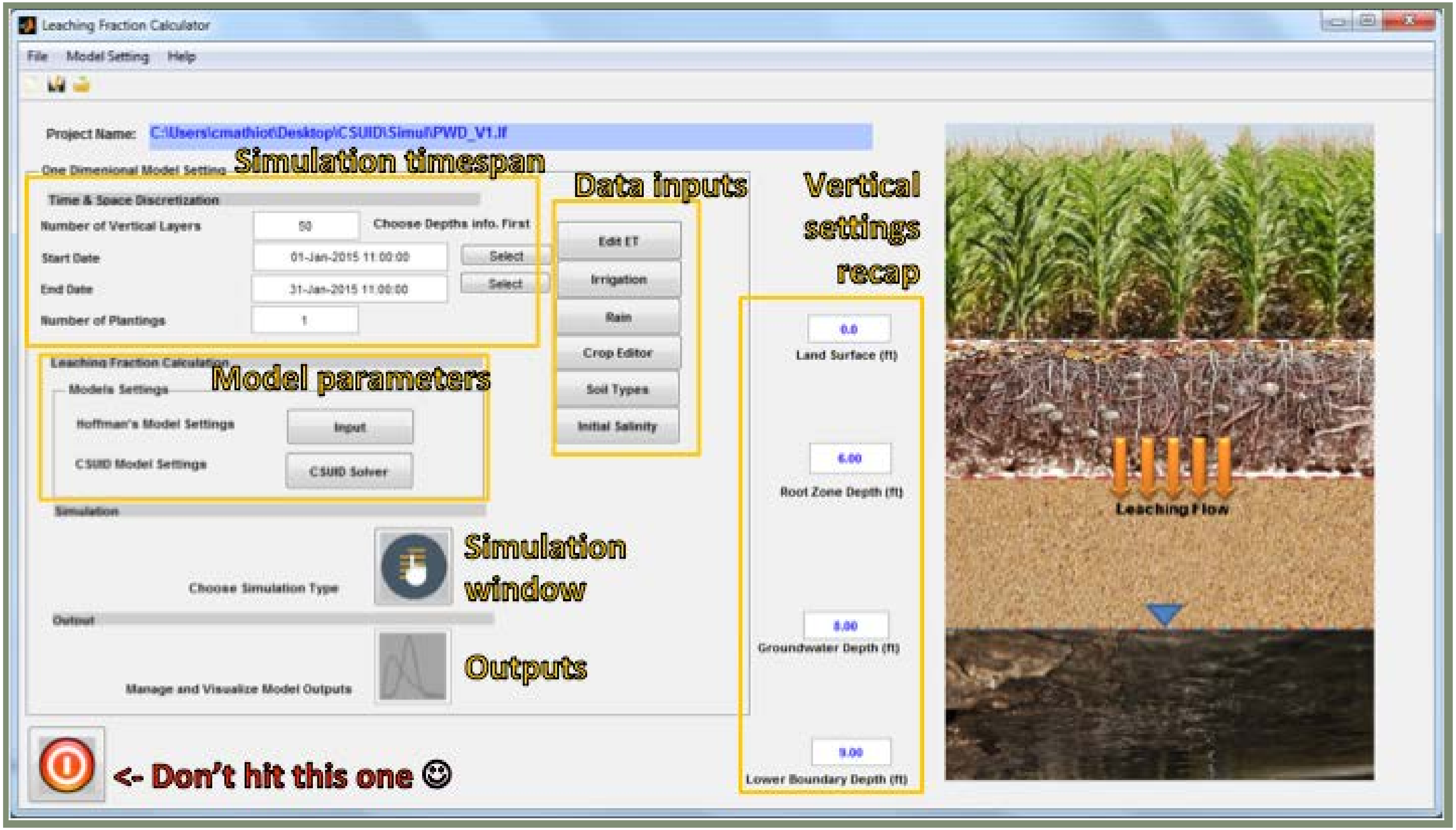
Limitations of existing transient hydrosalinity models

- Poor or non-existent documentation
- Developed and more appropriate for use by the research community
- Poorly designed or non-existent graphical user interfaces
- Few are validated with field data
- Very few being used for day-to-day salinity management
- Difficult to make direct comparisons with more widely accepted steady-state models (Hoffman model)

Graphical user interface for CSUID/Hoffman model

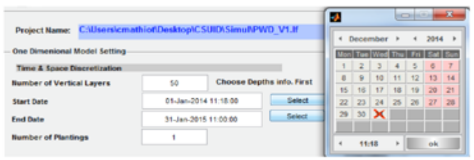


Organization of the CSUID/Hoffman model GUI



Data input screens in CSUID/Hoffman GUI

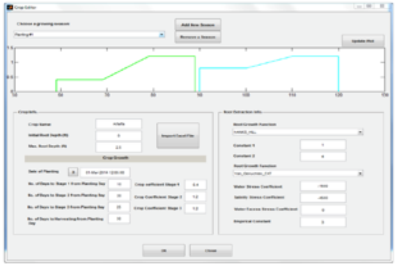
Simulation timespan



- Select Start and End dates

NB: Simulation duration is only slightly influenced by timespan (small timespan </=> short simulation)

Crop Editor



- Enter crop parameters (growth coefficients, key dates)
- If multiple cuts/harvest (e.g. alfalfa), add 'Growing seasons', with different coefficients

/!\ The 'Date of planting' must be between the Start and End date of the simulation /!\

Input format

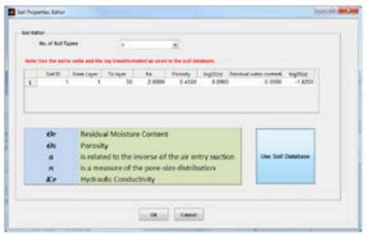
	A	B	C
1	Simulation Date	ET (in/day)	
2	0	0.06	
3	1	0.06	
4	2	0.05	
5	3	0.06	
6	4	0.06	
7	5	0.04	
8	6	0.04	
9	7	0.05	
10	8	0.06	
11	9	0.06	
12	10	0.04	
13	11	0.07	

For ET, Irrigation, Rain, Temperature and Radiation:

- Prepare Excel files following the example of the input window
- Check if properly loaded with 'Plot data' button

Graphical solution of model exponential uptake function

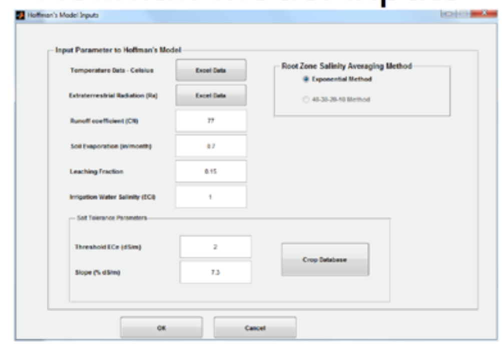
Soil Editor



Soil database 'Rosetta table'

- Match soil types and corresponding soil layers (if heterogeneous soil)
- Use 'Rosetta table' to find coefficients

Hoffman model inputs



- Import temperature and radiation formatted excel sheets
- Set targeted Leaching Fraction (default at 15%)
- Select Salt tolerance parameters (with database)

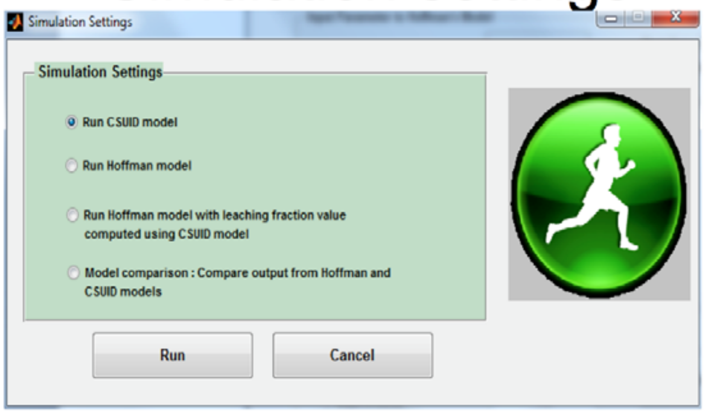
Initial conditions

- Set initial soil salinity
- Set ECe/Ecsw ratio condition

For valid comparisons between crop yields computed using either the CSUID or Hoffman models, there is a need to reconcile calculations of root zone salinity. Most crop yield models base their calculation on the soil root zone salinity extract (ECe), while the CSUID model computes salinity of the liquid phase to produce ECsw. In order to be able to make direct comparisons between the two model outputs - ECsw was converted to ECe using the standard conversion of ECsw = 0.5 ECe. To account for variations in the conversion ratio – two additional fixed conversions of ECe = 1.5 ECsw and ECe = 2.5 ECsw were created and added to the user interface.

Graphical solution of model exponential uptake function

Simulation settings



- Run CSUID model
- Run Hoffman model
- Run Hoffman model without setting the value a priori
- Automated comparison of CSUID simulations with various ECw values

- CSUID model currently limited to 2 year simulation (730 days)
- Hoffman spreadsheet model requires trial and error solution – model develops response surface automatically
- Can select leaching fractions to input into the Hoffman model or use those calculated by CSUID.
- Can adjust EC_e / $EC_{(s)w}$ ratio
- Output graphics customized to allow direct comparison of outputs from CSUID and Hoffman models

Output for Hoffman model from CSUID GUI interface

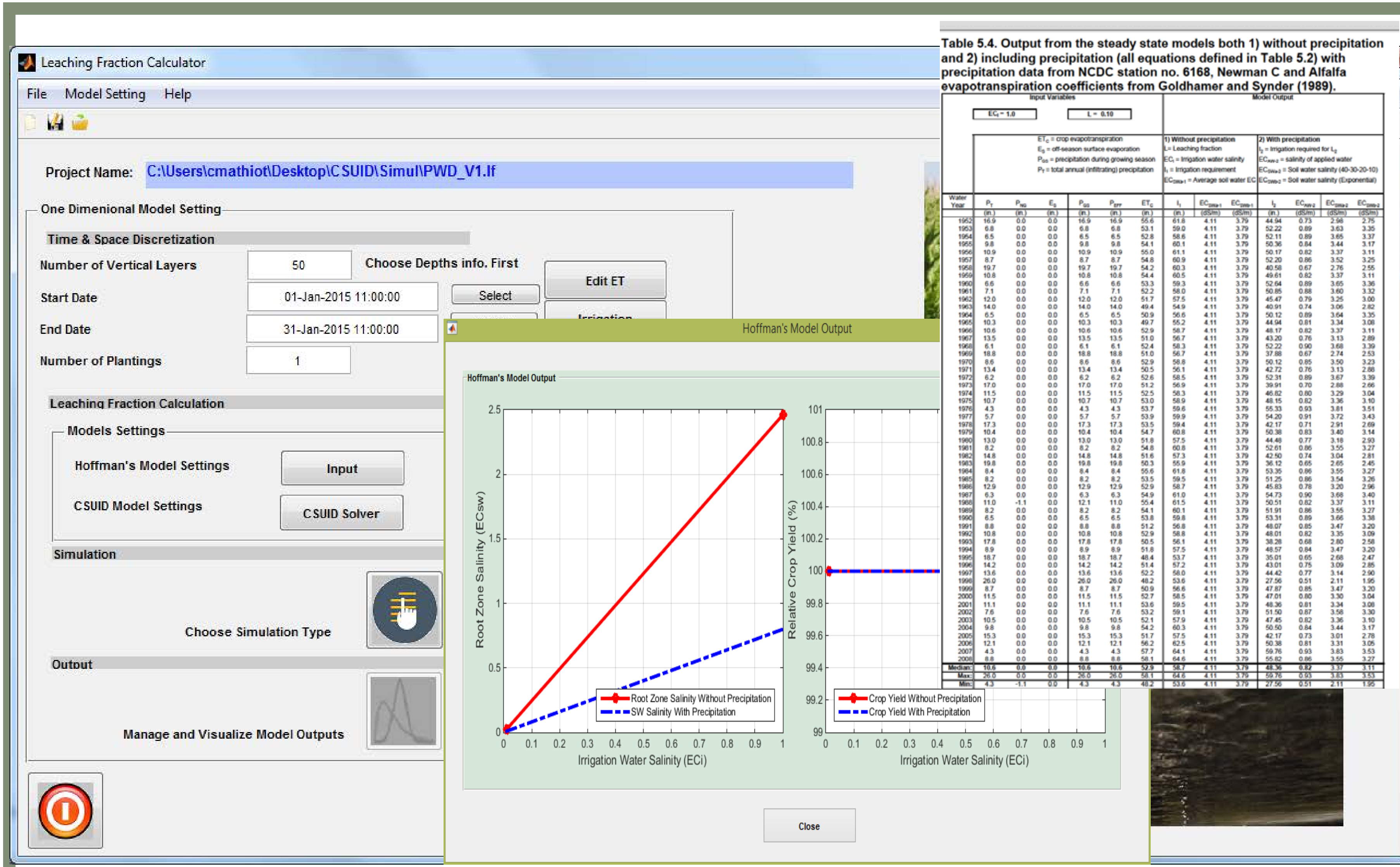


Table 5.4. Output from the steady state models both 1) without precipitation and 2) including precipitation (all equations defined in Table 5.2) with precipitation data from NCDC station no. 6168, Newman C and Alfalfa evapotranspiration coefficients from Goldhamer and Synder (1989).

Input Variables: EC_i = 1.0; L = 0.10

ET_C = crop evapotranspiration
E_S = off-season surface evaporation
P_{GS} = precipitation during growing season
P_T = total annual (infiltrating) precipitation

Model Output

1) Without precipitation
L= Leaching fraction
EC_i = Irrigation water salinity
I_1 = Irrigation requirement
EC_{SWa-1} = Average soil water EC

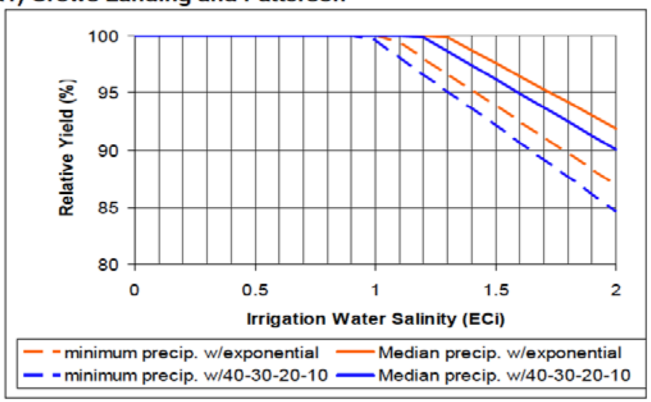
2) With precipitation
I_2 = Irrigation required for L_2
EC_{AW-2} = salinity of applied water
EC_{SWa-2} = Soil water salinity (40-30-20-10)
EC_{SWe-2} = Soil water salinity (Exponential)

Water Year	P_T (in.)	P_{NG} (in.)	E_S (in.)	P_{GS} (in.)	P_{EFF} (in.)	ET_C (in.)	I_1 (in.)	EC_{SWa-1} (dS/m)	EC_{SWe-1} (dS/m)	I_2 (in.)	EC_{AW-2} (dS/m)	EC_{SWa-2} (dS/m)	EC_{SWe-2} (dS/m)
1952	16.9	0.0	0.0	16.9	16.9	55.6	61.8	4.11	3.79	44.94	0.73	2.98	2.75
1953	6.8	0.0	0.0	6.8	6.8	53.1	59.0	4.11	3.79	52.22	0.89	3.63	3.35
1954	6.5	0.0	0.0	6.5	6.5	52.8	58.6	4.11	3.79	52.11	0.89	3.65	3.37
1955	9.8	0.0	0.0	9.8	9.8	54.1	60.1	4.11	3.79	50.36	0.84	3.44	3.17
1956	10.9	0.0	0.0	10.9	10.9	55.0	61.1	4.11	3.79	50.17	0.82	3.37	3.11
1957	8.7	0.0	0.0	8.7	8.7	54.8	60.9	4.11	3.79	52.20	0.86	3.52	3.25
1958	19.7	0.0	0.0	19.7	19.7	54.2	60.3	4.11	3.79	40.58	0.67	2.76	2.55
1959	10.8	0.0	0.0	10.8	10.8	54.4	60.5	4.11	3.79	49.61	0.82	3.37	3.11
1960	6.6	0.0	0.0	6.6	6.6	53.3	59.3	4.11	3.79	52.64	0.89	3.65	3.36
1961	7.1	0.0	0.0	7.1	7.1	52.2	58.0	4.11	3.79	50.85	0.88	3.60	3.32
1962	12.0	0.0	0.0	12.0	12.0	51.7	57.5	4.11	3.79	45.47	0.79	3.25	3.00
1963	14.0	0.0	0.0	14.0	14.0	49.4	54.9	4.11	3.79	40.91	0.74	3.06	2.82
1964	6.5	0.0	0.0	6.5	6.5	50.9	56.6	4.11	3.79	50.12	0.89	3.64	3.35
1965	10.3	0.0	0.0	10.3	10.3	49.7	55.2	4.11	3.79	44.94	0.81	3.34	3.08
1966	10.6	0.0	0.0	10.6	10.6	52.9	58.7	4.11	3.79	48.17	0.82	3.37	3.11
1967	13.5	0.0	0.0	13.5	13.5	51.0	56.7	4.11	3.79	43.20	0.76	3.13	2.89
1968	6.1	0.0	0.0	6.1	6.1	52.4	58.3	4.11	3.79	52.22	0.90	3.68	3.39
1969	18.8	0.0	0.0	18.8	18.8	51.0	56.7	4.11	3.79	37.88	0.67	2.74	2.53
1970	8.6	0.0	0.0	8.6	8.6	52.9	58.8	4.11	3.79	50.12	0.85	3.50	3.23
1971	13.4	0.0	0.0	13.4	13.4	50.5	56.1	4.11	3.79	42.72	0.76	3.13	2.88
1972	6.2	0.0	0.0	6.2	6.2	52.6	58.5	4.11	3.79	52.31	0.89	3.67	3.39
1973	17.0	0.0	0.0	17.0	17.0	51.2	56.9	4.11	3.79	39.91	0.70	2.88	2.66
1974	11.5	0.0	0.0	11.5	11.5	52.5	58.3	4.11	3.79	46.82	0.80	3.29	3.04
1975	10.7	0.0	0.0	10.7	10.7	53.0	58.9	4.11	3.79	48.15	0.82	3.36	3.10
1976	4.3	0.0	0.0	4.3	4.3	53.7	59.6	4.11	3.79	55.33	0.93	3.81	3.51
1977	5.7	0.0	0.0	5.7	5.7	53.9	59.9	4.11	3.79	54.20	0.91	3.72	3.43
1978	17.3	0.0	0.0	17.3	17.3	53.5	59.4	4.11	3.79	42.17	0.71	2.91	2.69
1979	10.4	0.0	0.0	10.4	10.4	54.7	60.8	4.11	3.79	50.38	0.83	3.40	3.14
1980	13.0	0.0	0.0	13.0	13.0	51.8	57.5	4.11	3.79	44.48	0.77	3.18	2.93
1981	8.2	0.0	0.0	8.2	8.2	54.8	60.8	4.11	3.79	52.61	0.86	3.55	3.27
1982	14.8	0.0	0.0	14.8	14.8	51.6	57.3	4.11	3.79	42.50	0.74	3.04	2.81
1983	19.8	0.0	0.0	19.8	19.8	50.3	55.9	4.11	3.79	36.12	0.65	2.65	2.45
1984	8.4	0.0	0.0	8.4	8.4	55.6	61.8	4.11	3.79	53.35	0.86	3.55	3.27
1985	8.2	0.0	0.0	8.2	8.2	53.5	59.5	4.11	3.79	51.25	0.86	3.54	3.26
1986	12.9	0.0	0.0	12.9	12.9	52.9	58.7	4.11	3.79	45.83	0.78	3.20	2.96
1987	6.3	0.0	0.0	6.3	6.3	54.9	61.0	4.11	3.79	54.73	0.90	3.68	3.40
1988	11.0	-1.1	0.0	12.1	11.0	55.4	61.5	4.11	3.79	50.51	0.82	3.37	3.11
1989	8.2	0.0	0.0	8.2	8.2	54.1	60.1	4.11	3.79	51.91	0.86	3.55	3.27
1990	6.5	0.0	0.0	6.5	6.5	53.8	59.8	4.11	3.79	53.31	0.89	3.66	3.38
1991	8.8	0.0	0.0	8.8	8.8	51.2	56.8	4.11	3.79	48.07	0.85	3.47	3.20
1992	10.8	0.0	0.0	10.8	10.8	52.9	58.8	4.11	3.79	48.01	0.82	3.35	3.09
1993	17.8	0.0	0.0	17.8	17.8	50.5	56.1	4.11	3.79	38.28	0.68	2.80	2.58
1994	8.9	0.0	0.0	8.9	8.9	51.8	57.5	4.11	3.79	48.57	0.84	3.47	3.20
1995	18.7	0.0	0.0	18.7	18.7	48.4	53.7	4.11	3.79	35.01	0.65	2.68	2.47
1996	14.2	0.0	0.0	14.2	14.2	51.4	57.2	4.11	3.79	43.01	0.75	3.09	2.85
1997	13.6	0.0	0.0	13.6	13.6	52.2	58.0	4.11	3.79	44.42	0.77	3.14	2.90
1998	26.0	0.0	0.0	26.0	26.0	48.2	53.6	4.11	3.79	27.56	0.51	2.11	1.95
1999	8.7	0.0	0.0	8.7	8.7	50.9	56.6	4.11	3.79	47.87	0.85	3.47	3.20
2000	11.5	0.0	0.0	11.5	11.5	52.7	58.5	4.11	3.79	47.01	0.80	3.30	3.04
2001	11.1	0.0	0.0	11.1	11.1	53.6	59.5	4.11	3.79	48.36	0.81	3.34	3.08
2002	7.6	0.0	0.0	7.6	7.6	53.2	59.1	4.11	3.79	51.50	0.87	3.58	3.30
2003	10.5	0.0	0.0	10.5	10.5	52.1	57.9	4.11	3.79	47.45	0.82	3.36	3.10
2004	9.8	0.0	0.0	9.8	9.8	54.2	60.3	4.11	3.79	50.50	0.84	3.44	3.17
2005	15.3	0.0	0.0	15.3	15.3	51.7	57.5	4.11	3.79	42.17	0.73	3.01	2.78
2006	12.1	0.0	0.0	12.1	12.1	56.2	62.5	4.11	3.79	50.38	0.81	3.31	3.05
2007	4.3	0.0	0.0	4.3	4.3	57.7	64.1	4.11	3.79	59.76	0.93	3.83	3.53
2008	8.8	0.0	0.0	8.8	8.8	58.1	64.6	4.11	3.79	55.82	0.86	3.55	3.27
Median:	10.6	0.0	0.0	10.6	10.6	52.9	58.7	4.11	3.79	48.36	0.82	3.37	3.11
Max:	26.0	0.0	0.0	26.0	26.0	58.1	64.6	4.11	3.79	59.76	0.93	3.83	3.53
Min:	4.3	-1.1	0.0	4.3	4.3	48.2	53.6	4.11	3.79	27.56	0.51	2.11	1.95

Effect of leaching rate and rainfall on yield response

Figure 5.13a. Relative alfalfa yield (percent) as a function of irrigation water salinity (EC_i) with L=0.10 assuming median precipitation (solid lines) and minimum precipitation (dashed lines) from NCDC station no. 6168, Newman C (for Crows Landing and Patterson) and NCDC station no. 5738, Modesto C (for Maze) for water years 1952 through 2008.

a1) Crows Landing and Patterson



a2) Maze

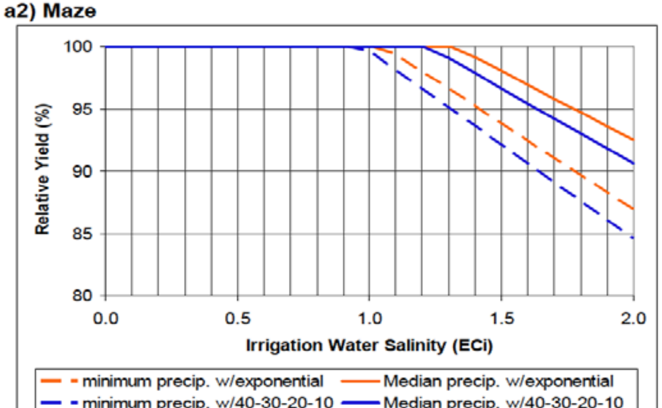
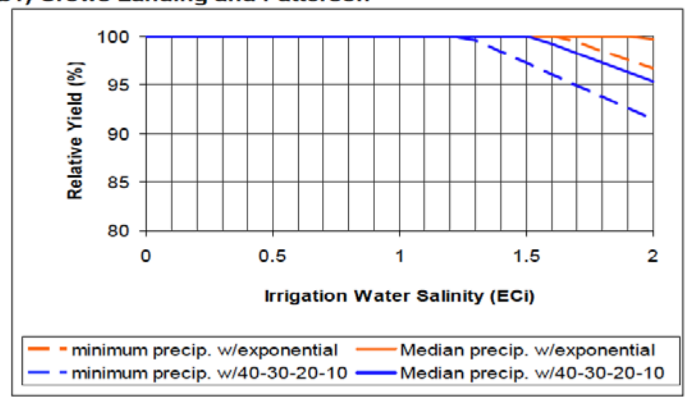
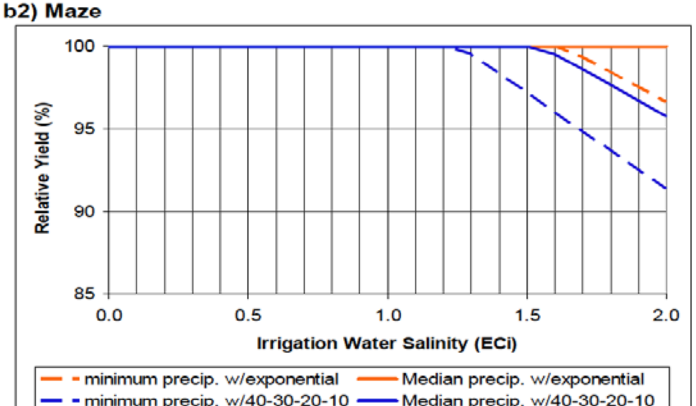


Figure 5.13b. Relative alfalfa yield (percent) as a function of irrigation water salinity (EC_i) with L=0.15 assuming median precipitation (solid lines) and minimum precipitation (dashed lines) from NCDC station no. 6168, Newman C (for Crows Landing and Patterson) and NCDC station no. 5738, Modesto C (for Maze) for water years 1952 through 2008.

b1) Crows Landing and Patterson



b2) Maze



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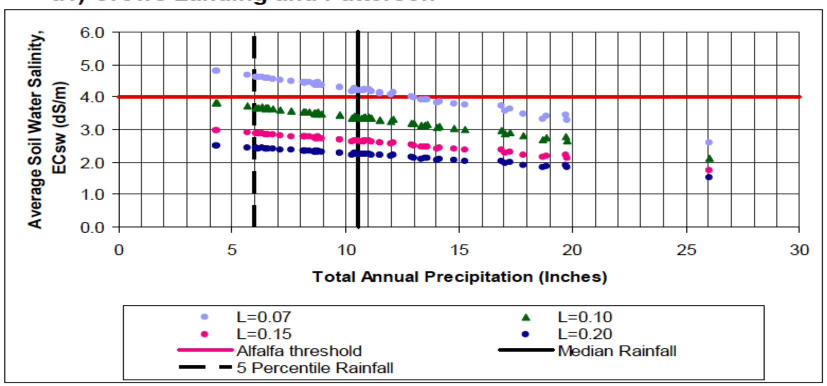
EARTH SCIENCES DIVISION

HYDROECOLOGICAL ENGINEERING
ADVANCED DECISION SUPPORT (HEADS)

Soil water salinity vs total annual rainfall by root zone uptake function

Figure 5.11a. Average soil water salinity (EC_{sw}) vs. total annual rainfall for alfalfa with leaching fractions ranging from 0.07 to 0.20 and irrigation water (EC_i) = 1.0 dS/m using the 40-30-20-10 crop water uptake function from NCDC station no. 6168, Newman C (for Crows Landing and Patterson) and NCDC station no. 5738, Modesto C (for Maze) for the water years 1952 through 2008.

a1) Crows Landing and Patterson



a2) Maze

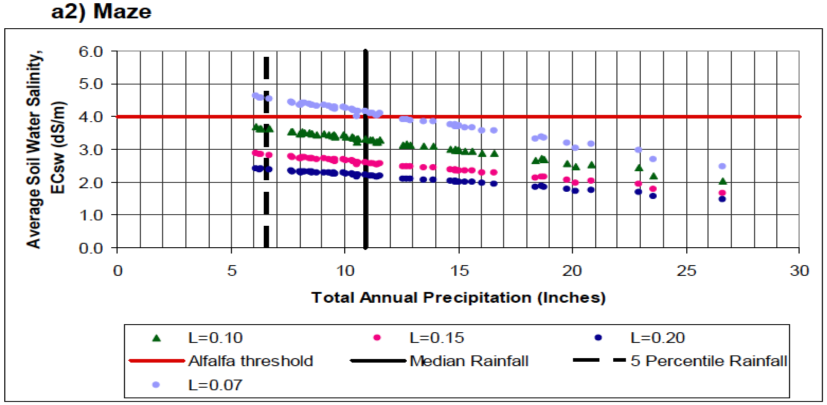
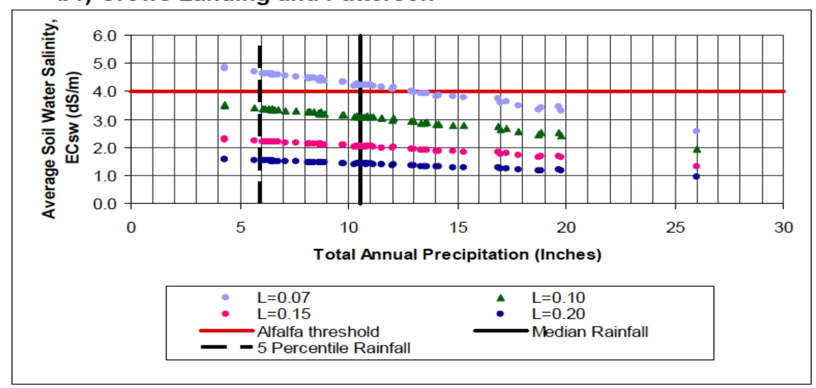
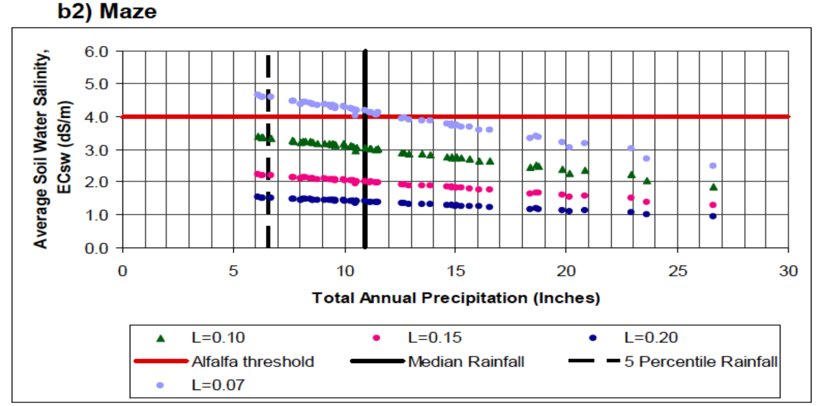


Figure 5.11b. Average soil water salinity (EC_{sw}) vs. total annual rainfall for alfalfa with leaching fractions ranging from 0.07 to 0.20 and irrigation water (EC_i) = 1.0 dS/m using the exponential crop water uptake function* from NCDC station no. 6168, Newman C (for Crows Landing and Patterson) and NCDC station no. 5738, Modesto C (for Maze) for the water years 1952 through 2008.

b1) Crows Landing and Patterson



b2) Maze



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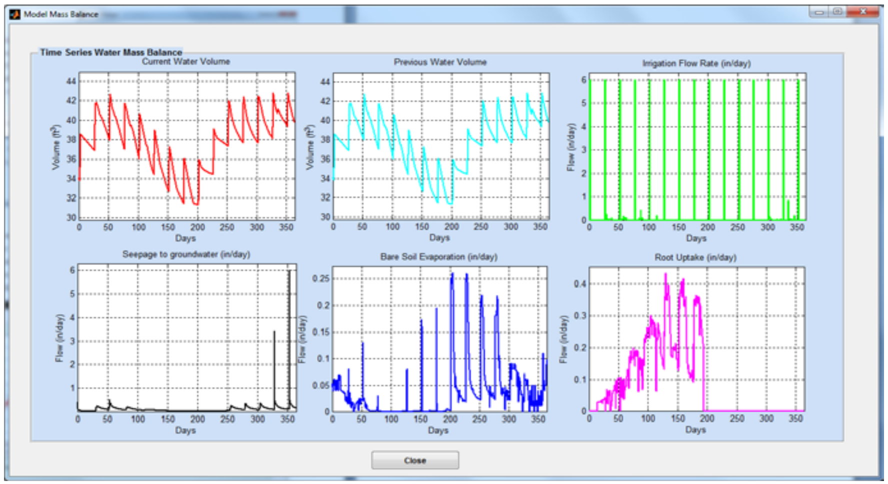
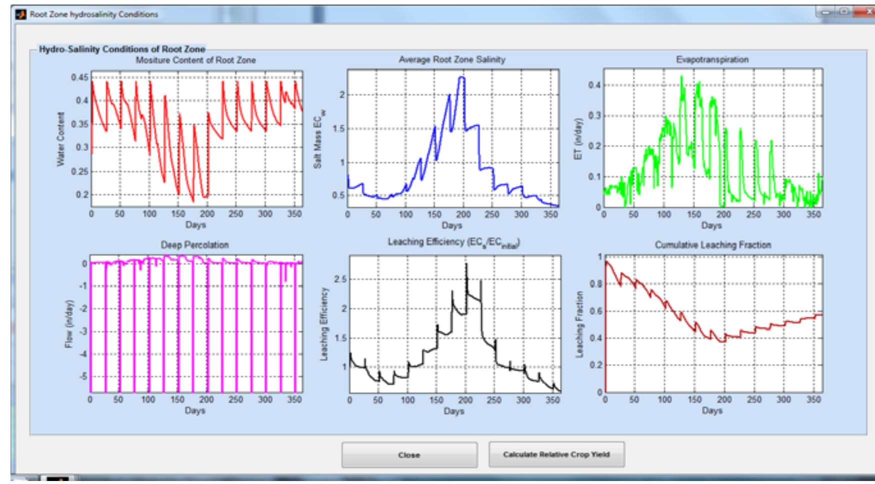
CSUID GUI flow, EC and salt load model outputs

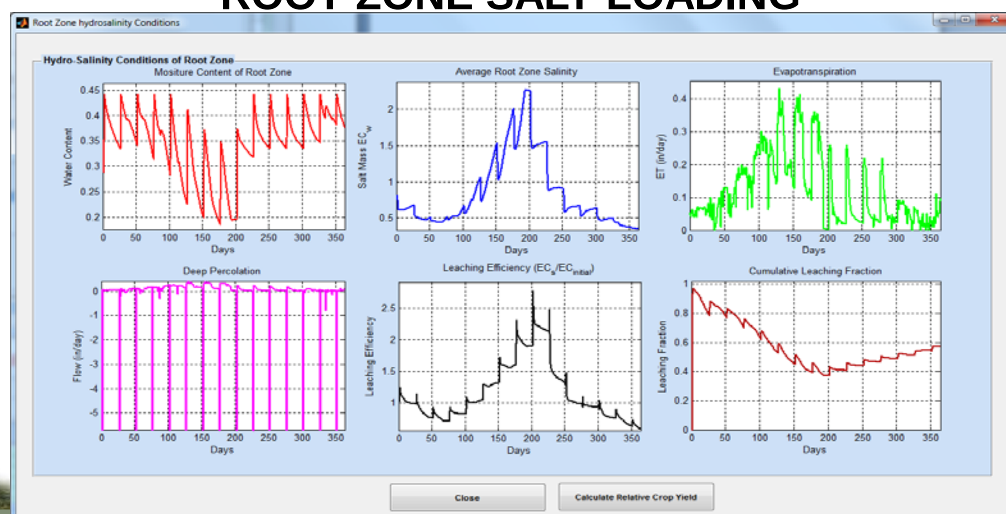
ROOT ZONE WATER BALANCE



ROOT ZONE EC



ROOT ZONE SALT LOADING



Summary and Conclusions

- Real-time water quality (salinity) management will require better understanding of appropriate crop leaching rates for various irrigation application water salinities
- Steady-state models have been used successfully for planning studies but have limitations as decision support systems at the watershed level
- Existing transient salinity models have limited utility given their lack of documentation, graphical user interfaces and limited visualization
- The CSUID-Hoffman model addresses these deficiencies –provides greater decision support capability.
- Model currently being applied to investigate long-term yield declines in alfalfa and Jose tall wheat grass in Panoche Water District