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Methods for Hoffman Modeling
Performed by Jim Brownell in July 2014
Central Valley Water Quality Control Board
Requested by the Lower San Joaquin River Committee
August 28, 2014 Committee Meeting

In all of the 2014 Hoffman Model runs for prediction of almond soil water salinity, the same model spreadsheets were used that were used by Central Valley Water Board staff for modeling runs reported in the March 2010 *Salt Tolerance of Crops in the Lower San Joaquin River (Stanislaus to Merced River Reaches* (Draft Report). The Draft Report spreadsheets are equivalent to the spreadsheets utilized by Dr. Glenn Hoffman for his report titled *Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta*, January 5, 2010, developed for Delta salinity modeling.

The modeling and cropping assumptions made for the 2014 modeling are presented in Sections 5.1.1 and 5.1.2 of the Draft Report. References for setting model crop coefficients and growth periods for estimating crop evapotranspiration requirements are presented in Section 5.1.3 of the Draft Report. Figure 5.5 presents the almond crop coefficients and growth periods that were used in the 2014 modeling.

Daily climate data for various model runs presented in the Draft Report were taken from two weather stations: NCDC station no. 6168 (Newman C) for Crows Landing/Patterson modeling and NCDC station no. 5738 (Modesto C) for Maze modeling. The Crows Landing/Patterson model results were more conservative than the Maze results. That is, the Draft Report modeling predicted higher soil water salinity values using Crows Landing/Patterson climate records when all other parameters such as leaching fraction and irrigation water salinity were held constant. Therefore, only Newman C daily climate data for the 2014 model runs were utilized.

The Central Valley Water Board received many comments on the Draft Report in support of using the exponential crop water use uptake pattern rather than the 40-30-20-10 pattern and the CV-SALTS Policy Committee has also recommended exponential over 40-30-20-10. Therefore, only the exponential pattern for the 2014 modeling was utilized.

Following the recommendations of the Lower San Joaquin River Committee, The following parameters were modeled: almond soil water salinity to determine the irrigation water salinity that would result using 15 percent leaching fraction, 95 percent crop yield, and the fifth percentile of total annual precipitation recorded since the 1952 water year. The Draft Report modeling climate record extended from the 1952 through 2008 water years. For the 2014 modeling runs, I used climate records from the 1952 through the 2013 water years from the NCDC station no. 6168 (Newman C).

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Attachment 1 presents a model output table for almond soil water salinity when the irrigation water EC is 1.55 S/cm and the leaching fraction is 15%. The far right column shows the soil water salinity for each water year between 1952 and 2013. At the bottom of that column, the soil water salinity results are presented for a year with median rainfall and for a year with 5th percentile rainfall. The 5th percentile value of 3.53 EC value is approximately the value predicted to result in a crop yield of 95%.

The top graph on Attachment 2 plots the resulting soil water salinity output table with irrigation water EC values between 0.5 and 2.0 S/cm are modeled, each at the same leaching fraction of 15%. The bottom graph plots the resulting crop yield against increasing irrigation water salinity.

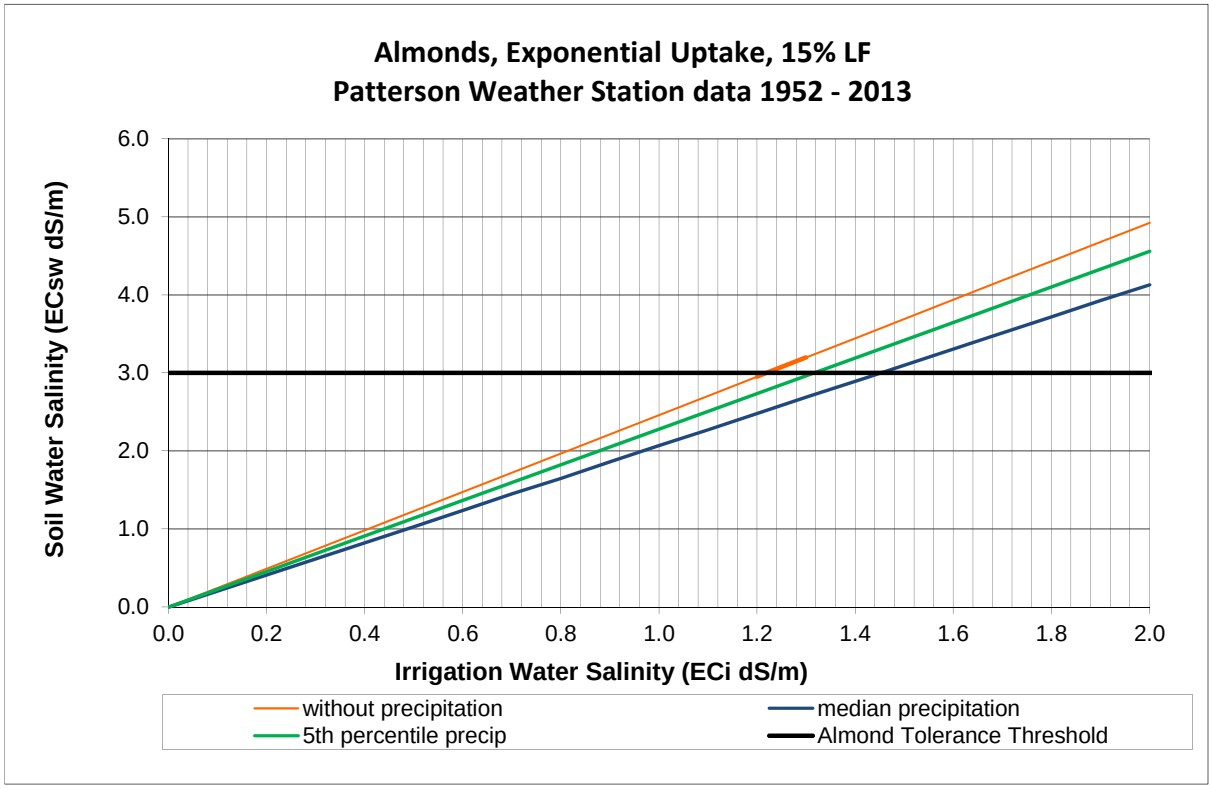
The top graph on Attachment 3 plots the resulting soil water salinity at a constant leaching fraction of 15% and irrigation water EC of 1.55 S/cm, but a changing total annual precipitation amount. The 95% crop yield threshold is placed on the graph to show that the threshold is reached when the annual rainfall drops to the 5% driest years if the leaching fraction is 15% and the EC of irrigation water is 1.55 S/cm. The bottom graph plots the results with irrigation water EC at 1.32 S/cm, leaching fraction of 15% and the 100 percent yield salinity threshold of 3.0 S/cm.

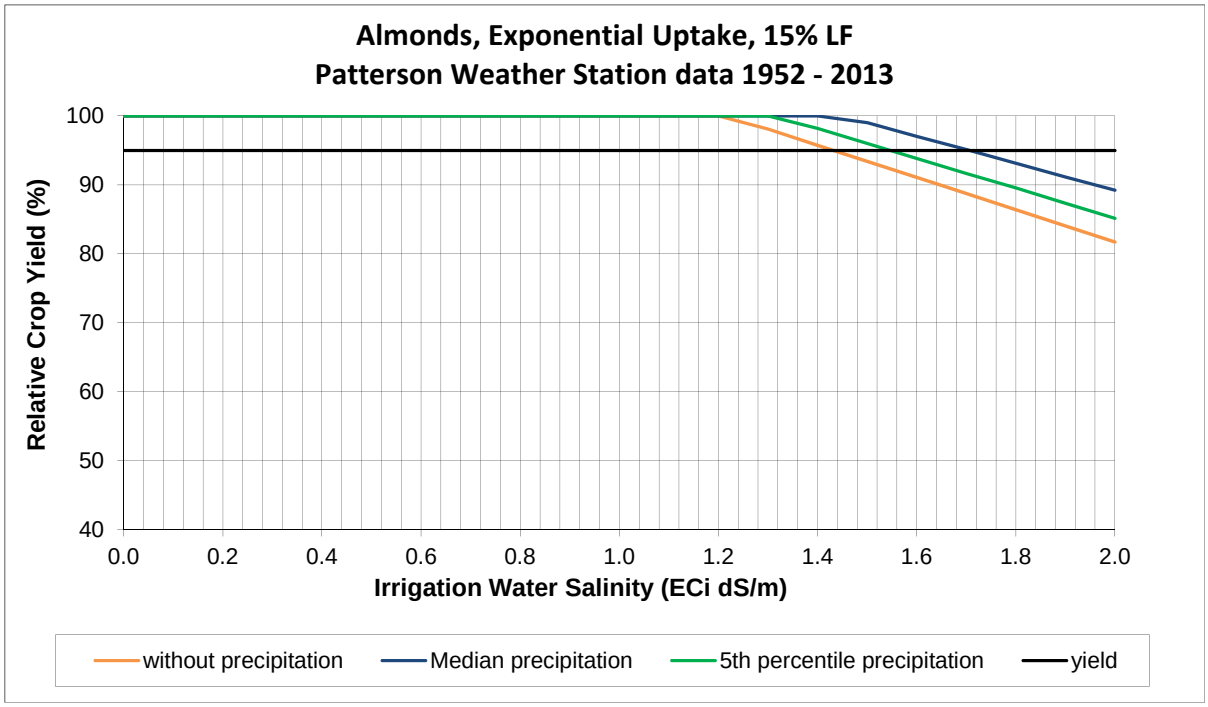
Attachment 4 presents modeling results and assumptions presented to the LSJRC on June 26, 2014.

Attachment 1

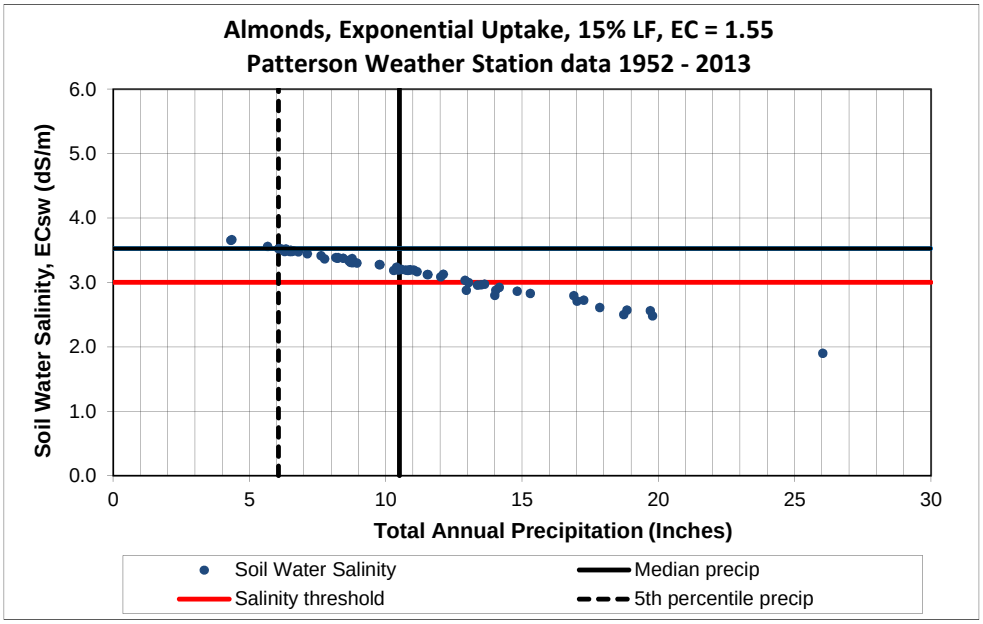
Input Variables							Model Output						
							EC_i = 1.54681						
							LF = 0.15						
	ET_C = crop evapotranspiration E_S = off-season surface evaporation P_{GS} = precipitation during growing season P_T = total annual (infiltrating) precipitation						1) without precipitation Assumes no precipitation LF_1 = leaching fraction EC_{i1} = irrigation water salinity I_1 = irrigation requirement[c] EC_{SW1} = Avg. soil water EC[d]			2) with precipitation Considers precipitation I_2 = irrigation req'd for LF_2[f] EC_{i2} = allowable irrig. EC[g]			
Water Year	P_T	P_{NG}	E_S	P_{GS}	P_{EFF}	ET_C	I_1	EC_{SWa-1}	EC_{SWb-1}	I_2	EC_{AW-2}	EC_{SWa-2}	EC_{SWb-2}
	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(in.)	(dS/m)	(dS/m)	(in.)	(dS/m)	(dS/m)	(dS/m)
1952	16.89	8.72	2.20932	8.17	14.68068	46.9106246	55.1889702	4.920809194	3.807845	40.5082852	1.13534974	3.6118366	2.79492955
1953	6.78	5.09	2.23233	1.69	4.547671	44.7044027	52.593415	4.920809194	3.807845	48.0457437	1.41306339	4.49531444	3.47858681
1954	6.51	2.69	2.20932	3.82	4.300685	44.3594237	52.1875572	4.920809194	3.807845	47.8868723	1.41934378	4.51529395	3.49404746
1955	9.75	6.15	2.20932	3.6	7.540685	45.9497133	54.0584862	4.920809194	3.807845	46.5178013	1.33104701	4.23439945	3.27668426
1956	10.89	8.09	2.20932	2.8	8.680685	46.2963069	54.4662435	4.920809194	3.807845	45.7855585	1.3002869	4.13654372	3.20096105
1957	8.68	2.85	2.23233	5.83	6.447671	45.9620112	54.0729544	4.920809194	3.807845	47.6252831	1.36237155	4.3340508	3.35379697
1958	19.69	6.92	2.20932	12.77	17.48068	45.512674	53.5443223	4.920809194	3.807845	36.0636374	1.04182361	3.31430618	2.56469307
1959	10.84	5.12	2.20932	5.72	8.630685	45.5745001	53.617059	4.920809194	3.807845	44.9863741	1.29782488	4.12871141	3.19490021
1960	6.61	5.29	2.20932	1.32	4.400685	44.969893	52.9057565	4.920809194	3.807845	48.5050716	1.41815048	4.51149776	3.49110987
1961	7.11	5.08	2.23233	2.03	4.877671	44.028935	51.7987471	4.920809194	3.807845	46.9210759	1.401157	4.45743719	3.44927645
1962	12	9.58	2.20932	2.42	9.790685	44.2538681	52.0633743	4.920809194	3.807845	42.2726893	1.25593065	3.9954352	3.09176775
1963	14.02	8.48	2.20932	5.54	11.81068	41.3296066	48.6230666	4.920809194	3.807845	36.8123817	1.17108836	3.72553027	2.88290855
1964	6.47	2.55	2.20932	3.92	4.260685	42.5748241	50.0880283	4.920809194	3.807845	45.8273434	1.41523591	4.50222579	3.48393498
1965	10.28	4.78	2.23233	5.5	8.047671	41.9786026	49.3865913	4.920809194	3.807845	41.3389201	1.29475671	4.11895076	3.18734718
1966	10.57	8.86	2.20932	1.71	8.360685	44.945123	52.8766153	4.920809194	3.807845	44.5159304	1.30223661	4.14274624	3.20576072
1967	13.48	7.94	2.20932	5.54	11.27068	43.226802	50.8550612	4.920809194	3.807845	39.5843763	1.20400342	3.83024144	2.96393668
1968	6.06	3.3	2.20932	2.76	3.850685	44.3120718	52.1318492	4.920809194	3.807845	48.2811642	1.4325596	4.55733684	3.5265813
1969	18.84	11.23	2.23233	7.61	16.60767	43.5097246	51.1879113	4.920809194	3.807845	34.58024	1.04495765	3.32427635	2.57240824
1970	8.64	5.19	2.20932	3.45	6.430685	44.4480073	52.2917733	4.920809194	3.807845	45.8610884	1.35659147	4.31566289	3.33956794
1971	13.36	7.84	2.20932	5.52	11.15068	42.6483332	50.1745097	4.920809194	3.807845	39.0238247	1.20305308	3.82721818	2.96159721
1972	6.16	5.56	2.20932	0.6	3.950685	44.5547545	52.4173583	4.920809194	3.807845	48.4666733	1.43023096	4.54992887	3.52084883
1973	17.01	11.18	2.23233	5.83	14.77767	43.6353519	51.3357081	4.920809194	3.807845	36.5580369	1.10154287	3.50428835	2.71170602
1974	11.53	5.46	2.20932	6.07	9.320685	44.1444595	51.9346583	4.920809194	3.807845	42.6139734	1.26920813	4.03767424	3.12445337
1975	10.73	5.72	2.20932	5.01	8.520685	44.9755119	52.9123669	4.920809194	3.807845	44.391682	1.29772451	4.12839209	3.19465311
1976	4.31	0.86	2.20932	3.45	2.100685	44.7450347	52.6412172	4.920809194	3.807845	50.5405323	1.4850873	4.72444083	3.65589055
1977	5.66	2.72	2.23233	2.94	3.427671	44.9955665	52.9359606	4.920809194	3.807845	49.5082894	1.44665581	4.6021805	3.56128244
1978	17.25	9.61	2.20932	7.64	15.04068	45.0319077	52.978715	4.920809194	3.807845	37.93803	1.1076727	3.52378889	2.72679603
1979	10.38	5.91	2.20932	4.47	8.170685	46.4518304	54.6492123	4.920809194	3.807845	46.4785274	1.31554754	4.1850917	3.23852869
1980	13.03	6.63	2.20932	6.4	10.82068	43.4361037	51.1012985	4.920809194	3.807845	40.2806135	1.21927659	3.87882929	3.00153518
1981	8.24	4.47	2.23233	3.77	6.007671	46.0953159	54.2297834	4.920809194	3.807845	48.2221121	1.37545521	4.37567326	3.38600547
1982	14.81	6.54	2.20932	8.27	12.60068	43.3499985	50.9999982	4.920809194	3.807845	38.3993132	1.16463917	3.70501373	2.86703235
1983	19.78	8.37	2.20932	11.41	17.57068	42.9837111	50.5690719	4.920809194	3.807845	32.998387	1.00935938	3.21102919	2.48477475
1984	8.42	6.56	2.20932	1.86	6.210685	46.8274038	55.0910633	4.920809194	3.807845	48.8803783	1.37243409	4.36606231	3.37856828
1985	8.22	4.8	2.23233	3.42	5.987671	45.1595287	53.1288573	4.920809194	3.807845	47.141186	1.37248664	4.36622946	3.37869762
1986	12.9	6.15	2.20932	6.75	10.69068	44.8472341	52.7614519	4.920809194	3.807845	42.070767	1.23339387	3.92373995	3.03628817
1987	6.32	3.63	2.20932	2.69	4.110685	46.4297955	54.6232888	4.920809194	3.807845	50.5126039	1.43040825	4.55049286	3.52128525
1988	11.017013	6.917013	2.20932	4.1	8.807698	46.4230699	54.6153764	4.920809194	3.807845	45.8076785	1.29736281	4.12724145	3.19376272
1989	8.15	4.74	2.23233	3.41	5.917671	45.7272624	53.7967793	4.920809194	3.807845	47.8791081	1.37666373	4.37951785	3.38898051
1990	**6.5**	**3.11**	**2.20932**	**3.39**	4.290685	45.5037845	53.5338642	4.920809194	3.807845	49.2431792	1.42283843	4.52641133	3.50265036
1991	8.77	2.31	2.20932	6.46	6.560685	42.684037	50.2165141	4.920809194	3.807845	43.6558292	1.34472591	4.27791553	3.3103581
1992	10.8	5.63	2.20932	5.17	8.590685	44.8405344	52.7535698	4.920809194	3.807845	44.1628849	1.2949222	4.11947724	3.18775458
1993	17.84	10.9	2.23233	6.94	15.60767	42.2682613	49.7273662	4.920809194	3.807845	34.119695	1.06132349	3.37634026	2.61269659
1994	8.93	4.44	2.20932	4.49	6.720685	43.2183636	50.8451337	4.920809194	3.807845	44.1244488	1.34235688	4.27037904	3.30452617
1995	18.72	9.71	2.20932	9.01	16.51068	40.9028277	48.1209738	4.920809194	3.807845	31.6102889	1.01608994	3.23244082	2.5013436
1996	14.15	7.66	2.20932	6.49	11.94068	43.905427	51.6534435	4.920809194	3.807845	39.7127586	1.18923825	3.7832697	2.92758877
1997	13.61	11.97	2.23233	1.64	11.37767	44.2044871	52.0052789	4.920809194	3.807845	40.6276077	1.20840333	3.84423869	2.97476811
1998	26.02	16.59	2.20932	9.43	23.81068	40.4260465	47.5600547	4.920809194	3.807845	23.7493698	0.77240991	2.45723261	1.90146808
1999	8.7	3.71	2.20932	4.99	6.490685	42.4876743	49.9854992	4.920809194	3.807845	43.4948143	1.3459581	4.28183544	3.31339142
2000	11.51	5.83	2.20932	5.68	9.300685	43.9027029	51.6502388	4.920809194	3.807845	42.3495538	1.26827841	4.03471656	3.12216465
2001	11.14	4.46	2.23233	6.68	8.907671	45.0462032	52.9955332	4.920809194	3.807845	44.0878619	1.28682019	4.09370268	3.16780958
2002	7.61	6.09	2.20932	1.52	5.400685	45.0023038	52.9438869	4.920809194	3.807845	47.5432019	1.38902704	4.41884869	3.4194157
2003	10.45	4.97	2.20932	5.48	8.240685	43.3956361	51.0536895	4.920809194	3.807845	42.8130046	1.29713945	4.12653089	3.19321287
2004	9.77	5.76	2.20932	4.01	7.560685	46.0418332	54.1668626	4.920809194	3.807845	46.6061777	1.33090758	4.2339559	3.27634103
2005	15.29	7.11	2.23233	8.18	13.05767	43.2947392	50.9349873	4.920809194	3.807845	37.8773161	1.15027343	3.65931269	2.83166773
2006	12.1	5.48	2.20932	6.62	9.890685	47.3294009	55.6816481	4.920809194	3.807845	45.7909632	1.27205471	4.04672994	3.1314609
2007	4.34	3.05	2.20932	1.29	2.130685	48.1548218	56.6527316	4.920809194	3.807845	54.5220466	1.48863899	4.73573967	3.66463387
2008	8.76	6.84	2.20932	1.92	6.550685	48.9043412	57.534519	4.920809194	3.807845	50.9838341	1.37069901	4.36054257	3.37429697
2009	**6.54**	**3.78**	**2.23233**	**2.76**	4.307671	42.5210511	50.024766	4.920809194	3.807845	45.7170947	1.41361665	4.49707451	3.4799488
2010	13.99	6.46	2.20932	7.53	11.78068	37.9015043	44.5900051	4.920809194	3.807845	32.8093202	1.13814555	3.62073079	2.8018121
2011	12.95	5.46	2.20932	7.49	10.74068	37.4408982	44.0481155	4.920809194	3.807845	33.3074306	1.16963914	3.72091992	2.87934096
2012	6.28	1.51	2.20932	4.77	4.070685	40.5813993	47.7428227	4.920809194	3.807845	43.6721378	1.41492837	4.50124741	3.48317789
2013	7.74	6.31	2.23233	1.43	5.507671	40.6549454	47.8293476	4.920809194	3.807845	42.3216763	1.36869443	4.35416548	3.36936221
Median:	**10.51**	5.74	2.20932	4.88	8.300685	44.4037155	52.2396653	4.920809194	**3.81**	44.1436668	1.29905589	4.13262756	**3.20**
5th Percentile	**6.065**											0.16017317	**3.53**

Attachment 2

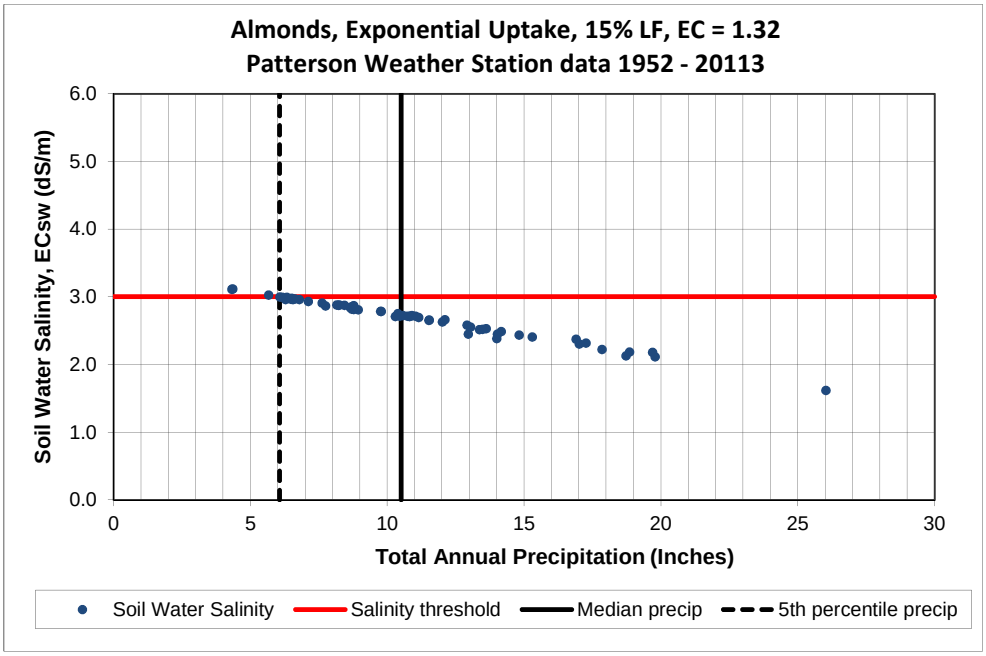




Attachment 3



This graph shows that a ECi of 1.55 returns the maximum ECsw at which crop yield is reduced by no more than 5% during a 5th percentile rainfall year.



This graph shows that a ECi of 1.31597 returns the maximum ECsw at which crop yield is not reduced during a year when rainfall is at the 5th percentile.

Attachment 4

Hoffman Modeling of Almond Salinity Requirements
LSJRC Meeting
June 26, 2014
Jim Brownell

Model Parameters:

1 Patterson Weather Station
data 01/01/52 thru 09/30/13
2 Median precipitation = 10.5 inches
2 5th percentile precipitation = 6.1 inches
3 15% leaching fraction

4 Exponential uptake
5 Crop soil water EC threshold = 3.0
6 95% crop yield protection
7 Bare soil ET = 0.7 inches/month
8 Runoff coefficient = 77
9 Growth stage crop coefficients:

B	Kc1 = 0.5
C	Kc2 = 0.9
E	Kc3 = 0.5

Growth stage dates:

A	15-Feb
B	15-Feb
C	1-Jun
D	1-Sep
E	10-Nov

S = (1000/CN) - 10 = 3.0

Extraterrestrial radiation (mm/day) at 37º latitude

Month	Ra
1	6.88
2	9.00
3	11.65
4	14.47
5	16.31
6	17.04
7	16.65
8	15.18
9	12.69
10	9.84
11	7.39
12	6.31

Results:

The ECsw value necessary to obtain a crop yield of 95% is 3.53
At the ECsw value of 3.53, the ECi value is 1.55
Therefore, the ECi needed to obtain 95% crop yield in a 5th percentile rainfall year of 6.1 inches is 1.55

Precipitation	Maximum ECi values	
	100% Crop Yield (ECsw = 3.00)	95% Crop Yield (ECsw = 3.53)
median	1.45	1.71
5th percentile	1.32	1.55