DRAFT Technical Memorandum

Soil Salinity Monitoring Report 2012

SAN JOAQUIN RIVER RESTORATION PROGRAM

August 2013

Table of Contents

Tables

Appendices

Attachments

List of Abbreviations and Acronyms

%	percent
BGS	below ground surface
CCID	Central California Irrigation District
Cl	clay loam
dS/m	decisiemens per meter
ECe	electrical conductivity of the soil saturation extract
EM	electromagnetic soil conductivity
EMh	horizontal position
EMv	vertical EM signal
FAO	Food and Agriculture Organization
Fsl	fine sandy loam
GPS	global positioning system
Gr sand	gravelly sand
GW	groundwater
Hsl	heavy sandy loam
in	inch
Lfs	loamy fine sand
Lt	light
Lt cl	light clay loam
Lt loam	light loam
Lt sil	light silt loam
meq	milliequivalents
meq/L	miliequivalents/liter
mS/m	microSiemens per meter
QA/QC	quality assurance/quality control
SAR	Sodium Adsorption Ratio
Sicl	silty clay loam
SJRRP	San Joaquin River Restoration Program
Sl	sandy loam
USDA	U.S. Department of Agriculture
Wave	weighted average ECe with gypsum adjustments if needed

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1.0 Introduction

The baseline soil salinity monitoring program is a supporting investigation for the San Joaquin River Restoration Program (SJRRP) Seepage Management Plan (Reclamation 2010). The primary purpose of the soil salinity evaluation is to determine baseline conditions and evaluate soil salinity trends over time. Other parameters evaluated include:

- Water table depth
- Capillary fringe thickness
- Presence and depth of soil mottling and gleying
- Soil moisture levels
- Soil temperature
- U.S. Department of Agriculture (USDA) soil texture
- Soil reaction
- Saturation percentage
- Qualitative soil lime content
- Root abundance and depth
- Sodium adsorption ratio (selected samples)
- Soil gypsum content (selected samples)
- Crop yield potential
- Crop type and condition

Sixteen baseline soil salinity sites were established in the spring of 2012. These sites complement the existing 101 sites established in the spring of 2010 and 2011. Most of the 2010 and 2011 sites were reevaluated for soil salinity in 2012 to determine if soil salinity had changed since the advent of SJRRP Interim Flows. The following sites were not reevaluated: 3, 18, 22, 25, 26, 27, and 28. These sites were not resampled, usually because access permission could not be obtained. An additional seven sites (L and DF series) specifically located by a landowner were sampled throughout the 2010 and 2011 growing season to determine seasonal soil salinity trends associated with drip and gravity irrigation and were sampled in spring 2012. All of the existing sites are scheduled to be resampled in the spring of 2013. Winter of 2011/2012 was much dryer than normal. Dry conditions persisted into early March. Conditions were too dry for leaching of salts and in some fields too dry for reliable electromagnetic soil conductivity (EM38) surveys.

Nearly all of the sites were evaluated using soil samples and EM38 measurements. Three sites, 114, 115, and 117, were only evaluated with the EM38.

2.0 Methodology

Soil sampling was typically done by a two or three man crew under the direction of a soil scientist. An EM38 survey was conducted within a 100-foot radius of the initial selected site. At least 12 paired EM measurements were made. The EM38 in the horizontal position (EMh) generally measures the bulk soil electrical conductivity to a depth of about 30 inches, while the vertical EM signal (EMv) generally reflects the bulk electrical conductivity of the 0–60-inch soil depth. Both readings can be used to estimate the soil salinity of the 0–36-inch soil zone (Rhoades, et al. 1989). The number of measurements can be increased if the survey area has variable readings. The EM readings were averaged and adjusted for soil temperature. The final central boring soil sampling site was placed directly under a pair of EM measurements. EM measurements at the sampling site were generally well within the range of readings measured surrounding the site. Sites with unusually high or low EM readings were usually not chosen for central boring sites. because these sites did not appear to represent the average condition for which the borings were intended to represent. Advantages of the EM38 include the following:

- It can provide many real-time soil salinity measurements.
- The instrument measures the bulk soil electrical conductivity of an area about 6 feet long, 5 feet deep, and about 2.5 feet wide.
- The EM survey provides real-time information on soil salinity levels, salt distribution in the profile, and spatial variation of soil salinity within an area surrounding the boring site.

The soil scientist hand augured the central boring and collected soil samples at 0–12 inches, 12–30 inches, and 30–60 inches. In a few cases (see Appendix A for sampling intervals), the soils could not be sampled to the full 60 inches due to hardpan layers or, most commonly, the presence of unstable saturated soils. The soil was examined and a soil profile log was prepared using the USDA soil textural system and nomenclature. Special attention was given to the depth of mottling, and/or gleying, capillary fringe thickness, and the depth to shallow groundwater.

A separate multi-increment spatial composite soil sample of surface soil (0–1 foot) was collected from an area within a 100-foot radius of the central boring. These samples contained between 15 and 30 increments. These samples were collected with a 1-inch-diameter Dakota probe or, in some cases, an Oakfield probe. Baseline soil samples in field crops and row crops were collected in a stratified random manner to ensure that the top, sides, bed shoulders, and furrows were represented in the composite surface soil samples. Orchard and vineyard areas were carefully sampled to avoid underground plastic pipe manifolds and trench backfill; and to make sure that the spatial composite soil samples included increments collected from near the emitter, near the center of the tree rows, and areas near the edge of the tree canopy. In some cases soil sampling procedures were customized for each orchard or vineyard, depending on the type of irrigation system used. Replicate soil salinity samples were also collected from the area within a 100-foot radius around some of the boring sites. A 0–12 inch soil sample was also collected from the central site. This sample was mainly used for EM meter calibration. The multi-increment surface soil composite samples were used for most evaluations, including establishing baseline soil salinity values and estimating crop yield potential.

Soil samples were sent to the Fruitgrower's Laboratory in Santa Paula, California, for analysis. A screenable testing procedure was used. If the electrical conductivity of the soil saturation extract (ECe) exceeded 3 decisiemens per meter (dS/m) or the pH paste was 8.5 or higher, a Sodium Adsorption Ratio (SAR) analysis was requested. If the SAR testing found saturation extract calcium concentrations over 20 miliequivalents/liter (meq/L), then calcium was determined on a 1–5 soil per water extract. These data were used to estimate the soil gypsum content.

Quality assurance/Quality control (QA/QC) of laboratory salinity data was provided by the SJRRP office. All laboratory data presented in this report met or exceeded SJRRP acceptance criteria.

Soil salinity, soil reaction, sodicity, and soil gypsum content data are presented in Appendix A. Copies of the soil boring logs for sites evaluated in 2012 are attached to this report as Appendix B. A set of drawings showing the locations of the soil sampling sites is attached as Appendix C. A list of abbreviations used on the soil logs is presented as Appendix D. Global Positioning System (GPS) coordinates for all baseline soil salinity sites are presented in Appendix E.

Attachment 1 includes comparison graphics of soil salinity data from 2010, 2011, and 2012.

3.0 Field Quality Assurance/Quality Control Evaluations

Field evaluation of soil sampling procedures and sampling errors was evaluated by the field soil samplers. Please refer to the 2010 and 2011 baseline soil salinity reports presented in the *2011 Annual Technical Report, Appendix A, Report 5* (SJJRP 2011) for extensive data on field soil sample replicates and EM38 replicate surveys. Since the sampling techniques proved to be reliable in 2010 and 2011, only limited additional field replicate samples were taken in 2012. The results of these replicate sampling operations are presented in Table 1.

Table 1. Soil Samples, Field Replicates of Multi-Increment Spatial Composite Samples (ECe)

Sample Site	Initial Result	Replicate Result	Relative Percent Difference
14-12 0-12 30x	6.10	7.15	16.9
52-12 0-12 30x	1.66	1.76	5.8
82-12 0-12 30x	1.16	0.97	18.0
95-12 0-12 20x	0.39	0.48	20.4
Df-2 0-12 30x	2.45	2.59	5.6
101-12 0-12 30x	4.85*	3.25	39.5

Note:
*Contained residual gypsum
Key:
ECe = electrical conductivity of the soil saturation extract

Based on field replicate sample data, it is proposed that sites with salinity level changes of over 20 percent have probably increased or decreased in soil salinity over time. Changes of less than 20 percent may be due to random spatial soil salinity variation, sampling error, or laboratory error. Summary tables presented below consider soil salinity stable if the most recent soil ECe level is between 80 and 120 percent of the original baseline ECe.

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4.0 Results

A comparison of surface soil salinity data at sites sampled in the spring of 2010 and 2011 with salinity data collected in the spring of 2012 is presented in Tables 2 and 3. Nearly all sites were resampled in 2012. The survey area was affected by events that could have changed soil salinity levels. The dry winter limited leaching incidental to rainfall and limited flows and associated seepage most of the spring, especially in Reaches 3 and 4. The river flows associated with the SJRRP have the potential to affect soil salinity in the following manner:

- Raise the level and duration of shallow groundwater levels into the root zone and increase upflux of water and salts
- Reduce the salinity of irrigation water diverted at the Mendota Pool and Sack Dam
- Increase irrigation water soil salinity levels in areas where drain water or groundwater from drain sumps or groundwater pumps is mixed with irrigation water

Table 2. Soil Salinity Trend Analysis Summary, 0–12 Inch Spatial Composite Samples 2010 Sites vs. 2012 Sites

Site	2010 Ece (dS/m)	2012 Ece (dS/m)	Change Direction	Percent of 2010 Baseline
1	0.99	2.47	Increase	249
2	4.72	6.43	Increase	136
4	1.80	4.56	Increase	253
5	4.36	8.11	Increase	186
6	1.49	1.43	Decrease	96
7	1.77	1.74	Decrease	98
8	0.96	0.64	Decrease	67
9	0.98	1.12	Increase	114
10	1.50	0.55	Decrease	37
11	1.23	0.97	Decrease	79
12	4.89	5.22	Increase	107
13	7.21	5.71	Decrease	79
14	2.78	6.62	Increase	238
15	0.81	1.04	Increase	128
16	2.69	3.11	Increase	116
17	8.35	15.8	Increase	189
19	1.54	2.38	Increase	155

Table 2. Soil Salinity Trend Analysis Summary, 0–12 Inch Spatial Composite Samples 2010 Sites vs. 2012 Sites (contd.)

Site	2010 Ece (dS/m)	2012 Ece (dS/m)	Change Direction	Percent of 2010 Baseline
20	1.62	1.65	Increase	102
21	2.09	1.62	Decrease	78
23	0.69	1.01	Increase	146
24	1.47	2.03	Increase	138
25	1.39	2.01	Increase	145
29	2.25	2.01	Decrease	89
30	1.88	2.31	Increase	123
31	2.90	3.05	Increase	105
32	1.70	1.26	Decrease	74
33	1.16	4.15*	Increase	358
34	1.32	1.40	Increase	106
35	1.51	2.38	Increase	158
36	1.94	1.72	Decrease	89
37	1.72	0.76	Decrease	44
38	1.79	1.41	Decrease	79
39	1.89	1.69	Decrease	89
40	1.88	4.16	Increase	221
41	2.37	1.01	Decrease	43
42	1.82	3.41	Increase	188
43	1.18	2.17	Increase	184
44	1.80	4.03*	Increase	223
45	0.95	2.53	Increase	266
46	0.95	1.80	Increase	189
47	1.09	1.36	Increase	125
48	0.99	1.65	Increase	167
49	1.10	2.05	Increase	186
50	4.95	6.59*	Increase	133
51	3.39	4.82	Increase	142
52	2.24	1.71	Decrease	76
53	0.94	2.05	Increase	218
54	1.53	1.46	Decrease	95
55	0.87	1.51	Increase	174
56	1.37	4.21*	Increase	307
57	1.31	1.31	Stable	100
58	1.10	1.16	Increase	105
59	1.16	1.57	Increase	135
60	7.83	13.2*	Increase	169

Table 2. Soil Salinity Trend Analysis Summary, 0–12 Inch Spatial Composite Samples 2010 Sites vs. 2012 Sites (contd.)

Site	2010 Ece (dS/m)	2012 Ece (dS/m)	Change Direction	Percent of 2010 Baseline
61	16.0	21.4*	Increase	134
62	6.25	8.83*	Increase	141
63	2.04	1.17	Decrease	57
64	0.83	0.99	Increase	119
65	0.59	0.90	Increase	153
66	0.79	0.96	Increase	122
67	0.57	0.71	Increase	125
69	0.77	1.57	Increase	204
70	1.43	6.27*	Increase	438
71	1.26	1.18	Decrease	94
73	0.87	1.39	Increase	160
74	1.54	2.24	Increase	145
75	3.13	5.13*	Increase	164
76	11.3	7.19	Decrease	64
79	7.13	13.7*	Increase	192
2010	All sites	Average	Increase	143

Key:
Ece = electrical conductivity of the saturated soil extract
dS/m = decisiemens per meter

Table 3. Soil Salinity Trend Analysis Summary, 0–12 Inch Spatial Composite Samples 2011 Sites vs. 2012 Sites

Site	2011 ECe (dS/m)	2012 ECe (dS/m)	Change direction	Percent of 2011 baseline
80	1.27	3.22*	Increase	253
81	1.04	2.19	Increase	201
821	1.18	1.07	Decrease	91
83	1.11	1.89	Increase	170
84	8.43	16.9	Increase	200
85	1.01	2.56	Increase	253
86	0.92	0.96	Increase	104
87	1.12	0.98	Decrease	88
88	0.80	0.94	Increase	118
89	0.46	1.73	Increase	376
90	5.53	8.76*	Increase	158
91	6.26	8.79	Increase	140
93	1.07	2.36	Increase	221
94	1.07	1.16	Increase	103
95	0.26	0.44	Increase	169

Table 3. Soil Salinity Trend Analysis Summary, 0–12 Inch Spatial Composite Samples 2011 Sites vs. 2012 Sites (contd.)

Site	2011 ECe (dS/m)	2012 ECe (dS/m)	Change direction	Percent of 2011 baseline
96	0.68	0.76	Increase	112
97	3.46	7.02*	Increase	203
99	0.72	1.03	Increase	143
100	1.48	1.51	Increase	102
101	2.08	4.05*	Increase	195
Df1	2.13	1.79	Decrease	84
Df2	2.44	2.52	Increase	103
L21	1.85	2.23	Increase	121
L26	1.55	1.99	Increase	128
L28	1.70	1.51	Decrease	89
L48	1.31	1.93	Increase	147
L66/68	0.47	1.02	Increase	217
2011	All sites	Average	Increase	159
2010 2011	All sites	Average	Increase	148

Key:
Ece = electrical conductivity of the soil saturation extract
dS/m = decisiemens per meter

Overall surface soil salinity trends determined on Table 4 are based on the change direction data presented in Tables 2 and 3. Sites with ECe values below 1 on both years were tallied separately since these ECe levels are favorable for all crops. Sites with changes of less than 20 percent were considered stable based on sampling and laboratory error determinations. It should be noted that surface soil salinity rose in Reach 4b on the southwest side of the San Joaquin River. This stretch of river has not yet received SJRRP Interim Flows. Salinity trends at these Reach 4b sites are listed separately below. No SJRRP Interim Flows were released into Reach 4 during 2012.

Table 4. Surface Soil Salinity Trend Summary 2010, 2011, and 2012

Trend	All Sites	SW Reach 4B sites
Increasing	54	12
Decreasing	13	2
Stable	16	2
Sites with ECe less than 1 dS/m	10	0

Key:
Ece = electrical conductivity of the soil saturation extract
dS/m = decisiemens per meter
SW =South West

4.1 EM38 Salinity Surveys

These surveys were generally conducted in a circular area within a 100-foot radius of the central boring site. At least 12 pairs of EM measurements were collected at each site in a stratified random manner (see description in Section 2.0, Methodology for further description of the method). The EMh reading measures soil salinity in roughly the top 30 inches of soil while the EMv reading measures soil salinity in the top 60 inches of soil. The EMh signal is strongest near the soil surface while the maximum EMv signal comes from about 16 inches below the soil surface. The EMh signal strength is sometimes considered a good representation of soil salinity for plant growth and salt tolerance evaluations since the signal strength from different soil depth intervals tends to follow plant water uptake patterns. Both the EMh and EMv readings can be used to estimate bulk soil salinity levels in the 0–36 inch depth zone (Rhoades et al. 1989). The signal data can be used to estimate bulk soil electrical conductivity; however, it is difficult to predict soil saturation extract salinity values from EM data. Soil texture, temperature, and soil moisture content, as well as soil salinity levels, affect the EM signal data. All EM38 measurements collected at the sites were adjusted for soil temperature, and then averaged. Classic statistical methods were used to determine the 95 percent confidence range. The percentage of inverted soil salinity readings is also listed since an increase in the percentage of inverted soil salinity profiles is judged an important indication of declining land productivity, which is symptomatic of shallow groundwater and poor drainage conditions. During the dry winter of 2011 through 2012, 27 of the sites were judged to be too dry for reliable EM38 surveys. One criteria used in selecting the initial sites was optimum soil moisture conditions (near field capacity). Subsequent sampling of the same sites is done regardless of soil moisture conditions, due to time constraints and access permission time windows. Survey data from these dry sites are omitted from the following tables.

4.2 EM 38 Data at New Baseline Sites

Table 5 presents a summary of EM38 data at the new baseline sites established during the spring of 2012. All data are corrected to a standard temperature of 25 degrees Celsius. Soils at Sites 102 through 106 were too dry for reliable EM38 surveys.

Table 5. EM38 Data Summary of New Baseline Sites 2012, Corrected to 25 Degrees Celsius

Site	Number of Observations	EMh mS/m	EMh 95 Percent Confidence Interval	EMv mS/m	EMv 95 Percent Confidence Interval	Percent Inverted Profiles
107	16	32.0	27.4 – 36.6	51.9	44.7 – 59.1	00
108	15	48	44.9 – 51.1	70.9	66.6 – 75.2	00
109	14	38	34 – 42	60.9	55.7 – 66.1	00
110	16	90.1	78.4 – 101.8	99.3	89 – 109.6	6
111	15	211.2	187.2 – 235.2	264.9	238.9 – 290.9	00
112	16	128.2	116.1 – 140.3	210.6	189.4 – 231.8	12.5
113	12	112.2	103 – 121.4	158.9	149 – 168.8	00
114	15	57.2	54.6 – 59.8	82.9	77.8 – 88	00
115	16	54.2	49.9 – 58.5	88	79.6 – 96.4	00
116	18	61.4	56.5 – 66.3	53.7	48.1 – 59.3	56
117	14	5.2	4.7 – 5.7	5.4	4.9 – 5.9	43

Key:
mS/m = microsiemens per meter
EMh = horizontal position
EMv = vertical EM signal

A comparison of baseline EM38 data collected in 2010 and 2011 to EM data collected in 2012 at the same sites is presented in Table 6. The data have been adjusted to a standard soil temperature of 25 degrees Celsius. Soil textural conditions and soil moisture conditions were similar for both years at 63 sites.

The EMh reading generally indicates soil electrical conductivity at the 0–30-inch depth. The EMh signal return is strongest near the soil surface and decreases with depth (Geonics 1998). The EMh signal provides meaningful information since it tends to emulate crop water uptake patterns. However, the EMh signal can underestimate soil salinity if dry saline surface soils are present. This is generally not the case during late winter and early spring in the survey area.

Table 6. EMh Trends 2010 Through 2012 at Selected Sites, Corrected to 25 Degrees Celsius

Site	Average 2010 EMh (mS/m)	Average 2012 EMh (mS/m)	General Trend	Percent of 2010	Significant at 95 percent?
10	16.1	13.2	Decrease	82	Yes
15	61.1	77.3	Increase	127	Yes
19	30.4	36.5	Increase	120	No
20	49.6	49.5	Decrease	100	No
21	19.6	33.8	Increase	172	Yes
30	36.2	34.5	Decrease	95	No
32	70.3	56.1	Decrease	80	Yes
33	39.7	81.2	Increase	205	Yes
37	40.1	36.8	Decrease	92	No
38	53.7	43.3	Decrease	81	Yes
39	49.8	61.6	Increase	124	Yes
40	59.7	58.5	Decrease	98	No
41	49.8	51.5	Increase	103	No
42	39.9	50.4	Increase	126	Yes
43	49.0	63.5	Increase	130	Yes
44	42.9	58.6	Increase	137	Yes
45	57.5	77.5	Increase	135	No
46	68.1	76.2	Increase	112	No
47	60.3	54.0	Decrease	90	Yes
48	43.1	36.1	Decrease	84	Yes
49	62.0	70.0	Increase	113	Yes
50	88.3	103.9	Increase	118	No
51	122.5	110.2	Decrease	90	No
52	91.4	72.2	Decrease	79	Yes
53	58.4	80.4	Increase	138	Yes
54	49.1	55.7	Increase	113	Yes
55	25.4	34.2	Increase	135	Yes
56	38.4	48.5	Increase	126	No
57	34.5	41.7	Increase	121	Yes
58	51.5	48.9	Decrease	95	No
59	45.2	36.6	Decrease	81	Yes
60	42.1	52	Increase	124	Yes
61	107.2	131.1	Increase	122	No
62	42.7	70.8	Increase	166	Yes
63	79.2	59.6	Decrease	75	Yes
64	64.8	66.5	Increase	103	No
66	34.1	32.7	Decrease	96	No
67	40.1	36.6	Decrease	91	No
68	31.4	67.1	Increase	214	Yes
69	64.8	56.9	Decrease	88	Yes
70	98.8	125.5	Increase	127	Yes
71	56.7	37.6	Decrease	66	Yes
72	150.4	172.8	Increase	115	No
73	120.2	104.9	Decrease	87	No
74	62.1	47.9	Decrease	77	Yes

Table 6. EMh Trends 2010 Through 2012 At Selected Sites, Corrected to 25 Degrees Celsius (contd.)

Site	Average 2010 EMh (mS/m)	Average 2012 EMh (mS/m)	General Trend	Percent of 2010	Significant at 95 percent?
75	63.1	84.4	Increase	134	No
76	52.6	58.9	Increase	112	No
77	38.6	98.0	Increase	254	Yes
78	55.0	72.6	Increase	132	Yes
79	91.5	74.5	Decrease	81	Yes
84	82.4	103.8	Increase	126	Yes
85	37.4	31.3	Decrease	84	No
86	51.7	54.7	Increase	106	No
89	40.3	39.9	Decrease	99	No
90	139.3	128.8	Decrease	92	No
91	191.5	192.3	Increase	100	No
92	89.3	105.9	Increase	119	Yes
93	88.5	79.3	Decrease	90	No
94	92.2	98.8	Increase	107	No
96	9.8	15.8	Increase	161	Yes
97	65.1	50.0	Decrease	77	Yes
98	73.1	71.1	Decrease	97	No
99	47.3	45.5	Decrease	96	No
1001	35.2	37.7	Increase	107	No
101	79.5	76.9	Decrease	97	No

Key:
mS/m = microsiemens per meter
EMh = horizontal position
EMv = vertical EM signal

Table 7. EMh Trend Summary

Trend Analysis 95 Percent Confidence Level	2010–2012 Sites	2011–2012 Sites	All Sites
Increases	18	3	21
Decreases	12	1	13
No significant change	20	11	31
Average percent of baseline EMh value	115	104	113

Key:
EMh = horizontal position

The data indicates an increase in bulk soil salinity in the top 30 inches of soil (active root zone). However, the data also indicate that bulk soil salinity was more stable between 2011 and 2012. Areas in Reach 4b near the Eastside Bypass generally remained saline. These lands contain native salts. Soil reclamation of these lands is inhibited by high groundwater levels. Bulk soil salinity also increased somewhat in the portion of Reach 4b southwest of the river reach where no SJRRP Interim Flows have yet to be released. No SJRRP Interim Flows were released into Reach 4 during 2012.

4.3 EMv Trends 2010–2012 at Selected Sites

The EMv reading generally measures bulk soil electrical conductivity in the 0–60-inch zone. The signal returns are low at the soil surface and peak at about 16 inches (Geonics 1998). The signal gradually decreases below a depth of 16 inches. The EMv signal best represents subsoil and substrata soil salinity conditions. The presence of wet and saturated layers in the top 5 feet of soil can increase the EMv value and lead to an overestimation of soil salinity. The EMv trends between 2010 and 2012 at available sites and EMv trends between 2011 and 2012 at other available sites are presented in Tables 8 and 9. Table 10 presents a summary of the trends in EMv. Overall the bulk soil salinity in the top 5 feet of soil appears to have remained fairly stable.

Table 8. EMv Trends 2010–2012 at Selected Sites

Site	EMv 2010 (mS/m)	EMv 2012 (mS/m)	Change Direction	Percent of 2010	Significant at 95 Percent?
10	16.8	16.7	Decrease	99	No
15	72.8	72.4	Decrease	99	No
19	35.4	55.1	Increase	156	Yes
20	59.9	73.0	Increase	122	Yes
21	32.7	50.4	Increase	154	Yes
30	44.4	39.1	Decrease	88	No
32	99.2	70.8	Decrease	71	Yes
33	57.6	93.5	Increase	162	Yes
37	66.1	55.9	Decrease	85	Yes
38	81.9	56.8	Decrease	69	Yes
39	69.8	79.3	Increase	114	Yes
40	91.1	85.0	Decrease	93	No
41	86.8	73.9	Decrease	85	No
42	67.3	66.4	Decrease	99	No
43	74.7	84.3	Increase	113	No
44	66.9	79.0	Increase	118	No
45	66.7	96.3	Increase	144	Yes
46	90.2	101	Increase	112	No
47	84.9	74.0	Decrease	87	Yes
48	61.8	54.6	Decrease	88	Yes
49	91.7	96.5	Increase	105	No
50	136.2	144.3	Increase	106	No
51	162.2	161.5	Decrease	100	No
52	125.7	106.0	Decrease	84	Yes
53	95.2	111.8	Increase	117	Yes
54	78.9	76.3	Decrease	97	No
55	36.5	47.9	Increase	131	Yes
56	39.1	63.1	Increase	161	Yes
57	42.3	44.5	Increase	105	No
58	68.3	70.0	Increase	102	No
59	60.4	48.4	Decrease	80	Yes
60	49.9	44	Decrease	88	No
61	130.2	110	Decrease	84	Yes
62	53.5	64.9	Increase	121	Yes

Table 8. EMv Trends 2010 – 2012 at Selected Sites (contd.)

Site	EMv 2010 (mS/m)	EMv 2012 (mS/m)	Change Direction	Percent of 2010	Significant at 95 Percent?
63	101.7	87.1	Decrease	86	Yes
64	81.7	79.2	Decrease	97	No
66	49.8	41.4	Decrease	83	Yes
67	61.8	50.1	Decrease	81	Yes
68	51.9	84.4	Increase	163	Yes
69	80.7	62.7	Decrease	78	Yes
70	135.3	144	Increase	106	No
71	78.2	43.1	Decrease	55	Yes
72	177.2	184.9	Increase	104	No
73	169.5	130.4	Decrease	77	Yes
74	83.4	68.8	Decrease	82	Yes
75	98.1	103.7	Increase	106	No
76	43.2	38.9	Decrease	90	No
77	67.8	131.7	Increase	194	Yes
78	74.5	86.6	Increase	116	Yes
79	91.6	76.6	Decrease	84	Yes

Key:
mS/m = microsiemens per meter
EMv = vertical EM signal

Table 9. EMv Trends 2011–2012 at Selected Sites

Site	EMv 2011 (ms/m)	EMv 2012 (ms/m)	Change Direction	Percent of 2010	Significant at 95 Percent?
84	90.3	111.2	Increase	123	Yes
85	49.5	40.2	Decrease	81	Yes
86	72.2	76.4	Increase	106	No
89	67.0	61.6	Decrease	92	No
90	160.4	147.8	Decrease	92	No
91	232.6	255.2	Increase	110	Yes
92	118.9	139.9	Increase	118	Yes
93	123.9	115.7	Decrease	93	No
94	118.6	126.1	Increase	106	No
96	12.5	16.9	Increase	135	No
97	77.7	54.6	Decrease	70	Yes
98	91.1	84.7	Decrease	93	No
99	67.6	57.4	Decrease	85	Yes
100	41.4	51.1	Increase	123	Yes
101	104.3	108.1	Increase	104	No

Key:
mS/m = microsiemens per meter
EMv = vertical EM signal

Table 10. EMv Trend Summary

Trend Analysis 95 Percent Confidence Level	2010–2012	2011–2012	All Sites
Increases	12	4	16
Decreases	16	3	19
Stable	21	8	29
Percent of baseline EMv value	105	102	104

Key
% = percent
EMv = vertical EM signal

4.4 Change in Percentage of Inverted Salinity Profiles at Selected Sites 2010–2012

The presence of inverted soil salinity profiles (surface soil salinity higher than subsoil salinity) is an indicator of adverse soil salinity conditions that are often related to a shallow stagnant water table. A significant increase in the percentage of inverted soil salinity profiles near the salinity sites is a cause for concern. Table 11 presents a summary of inverted salinity profile trends from 2010, 2011, and 2012 at sites affected by excess salts. Table 12 presents a summary of the direction change of the salinity trends for all sites for the period between 2010 and 2012.

Table 11. Inverted Soil Salinity Profile Trends 2010–2012 at Selected Sites

Site	2010 Inverted Profile (percent)	2011 Inverted Profile (percent)	2012 Inverted Profile (percent)	Trend and Change Direction	Percent of Baseline Year
13	82	ND	60	Decrease	73
14	17	ND	27	Increase	159
16	8	ND	Too dry	No trend	-
17	76	69	83	No trend	109
50	8	ND	40	Increase	500
51	0	ND	67	Increase	Over 1000
56	43	67	86	Increase	200
60	0	31	73	Increase	Over 1000
61	15	19	88	Increase	587
62	0	19	60	Increase	Over 1000
70	8	ND	13	Increase	163
72	17	ND	77	Increase	453
75	0	ND	0	No trend	-
76	78	36	62	No trend	79
78	Too dry	7	13	Increase	186
79	44	50	57	Increase	130

Table 11. Inverted Soil Salinity Profile Trends 2010–2012 at Selected Sites (contd.)

Site	2010 Inverted Profile (percent)	2011 Inverted Profile (percent)	2012 Inverted Profile (percent)	Trend and Change Direction	Percent of Baseline Year
84	ND	35	50	Increase	143
90	ND	31	21	Decrease	68
91	ND	8	0	Decrease	-
97	ND	8	36	Increase	450
98	ND	0	6	Increase	-
99	0	0	0	No trend	-
100	ND	7	0	Decrease	-
101	ND	0	0	No trend	-

Key:
% = percent
ND = no data

Table 12. Inverted Salinity Profile Summary

Direction Change	Number of Events that Occurred
Increases	14
Decreases	4
Stable	6

On sites with elevated soil salinity levels it appears that the percentage of inverted soil salinity profiles, has increased from 2010 or 2011 levels. Sites 17, 50, 51, 56, 60, 61, 62, 72, and 97 appear to have a large increase in inverted soil salinity profiles indicating possible adverse effects related to upflux of salts associated with shallow groundwater.

4.5 Soil Moisture Observations

Table 13 summarizes soil moisture observations found in spring 2012 at sites where shallow groundwater was encountered. Most of the sites listed are soil sampling sites. However, some of the sites listed are unsampled exploratory borings evaluated during seepage hotline call response investigations, flow bench soil evaluations, or geophysical investigations. In some cases, field soil moisture observations were adjusted based on gravimetric soil moisture data from the laboratory. Field observations of capillary fringe thickness have proven to be challenging. Capillary fringe soil moisture evaluations have proven to be especially difficult in fine-textured soils due to the limited macropore space. Field observations are more reliable in medium- and coarse-textured soils. The depth-to-capillary-fringe data listed below should be considered as estimates.

Table 13. Soil Moisture Factors

Site	Date	Substrata Texture USDA	Depth to Mottling (in)	Depth to Capillary Fringe (in)	Depth to Water Table (in)	Capillary Fringe Thickness (in)
1	4/18/12	Sand	20	55	58	3
39	3/22/12	Loam	52	52	55	3
40	3/28/12	Sicl	51	28	54	26
41	4/4/12	Fsl	44	37	47	10
42	4/4/12	Loam	44	30	54	24
43	4/4/12	Loam	49	49	56	7
44	4/4/12	Lt cl	36	52	59	7
45	4/5/12	Loam	42	38	58	20
46	4/5/12	Loam	37	37	61	24
47	4/5/12	Loam	60	18	62	44
50	4/5/12	Fsl	30	24	56	32
51	3/28/12	Lt sil	33	39	49	10
52	3/28/12	Lt loam	26	40	47	7
53	3/28/12	Lt loam	26	35	64	29
54	4/4/12	Loam	24	43	55	12
55	4/4/12	Lfs	28	18	41	23
57	4/19/12	Fsl	39	116	131	15
61	4/17/12	Loam	None	14	41	27
62	4/17/12	Loam	18	27	37	10
64	3/22/12	Loam	60	30	64	34
70	3/22/12	Hsl	37	37	44	7
74	4/5/12	Fsl	31	40	61	21
79	3/13/12	Sl	None	30	34	4
84	4/17/12	Loam	None	16	35	19
89	3/23/12	Loam	None	30	55	24
90	3/23/12	Fsl	38	30	41	11
91	3/23/12	Sl	28	28	40	12
101	4/4/12	Lt loam	20	50	56	6
104	1/31/12	Gr sand	48	116	124	8
107	3/21/12	Scl	60	71	100	29
108	3/21/12	Loam	62	91	98	7
109	3/21/12	Clay	45	30	69	39
110	3/23/12	Hsl	40	18	29	11
111	3/27/12	Loam	36	50	56	6
112	2/27/12	Sil	20	62	64	2

Table 13. Soil Moisture Factors (contd.)

Site	Date	Substrata Texture USDA	Depth to Mottling (in)	Depth to Capillary Fringe (in)	Depth to Water Table (in)	Capillary Fringe Thickness (in)
113	3/27/12	Lt loam	52	45	63	18
114	3/27/12	Fsl	34	100	121	21
117	4/25/12	Sand	34	116	120	4
Df2	4/10/12	Sand	22	44	55	13
Pzr2b-3	3/6/12	Gr sand	68	132	144	12
Pzr2b-4	3/6/12	Ls	52	90	98	8
Pzr2b-5	3/6/12	Lt sil	68	84	116	32
Sam 5	4/25/12	Sand	35	128	135	9
Willis 1	6/7/12	Fsl	46	106	136	30
Ref1	6/12/12	Sicl	39	80	96	16
Ref2	6/12/12	Cl	61	101	106	5
Ref3	6/12/12	Loam	40	89	101	12
Ref4	6/12/12	Sand	42	75	87	12

Key:
Cl = clay loam
Fsl = fine sandy loam
Gr sand = gravelly sand
Hsl = heavy sand loam
in = inch
Lfs = loamy fine sand
Lt = light
Lt cl = light clay loam
Lt loam = light loam
Lt sil = light silty loam
Sicl = Silty clay loam
Sl = sandy loam
USDA = U.S. Department of Agriculture

A statistical summary of capillary fringe thickness at boring sites examined in 2012 is presented in Table 14. These data represent the full capillary fringe interval. The anoxic portion of the capillary fringe is assumed to be the lower half of the full capillary fringe zone. The upper portion of the capillary fringe is assumed to contain sufficient air for plant root development and water uptake (Sands 2009).

Table 14. Capillary Fringe Summary Statistics

Average Thickness	95 Percent Confidence Interval	Range
16.2 inches	13.2–19.2 inches	2–44 inches

5.0 Discussion

Examination of EM38 data and soil samples collected in 2010, 2011, and 2012 indicates increasing surface soil salinity conditions in the SJRRP study area. Salinity of subsoils and substrata have also increased slightly. Surface soils at most sites appear to be more saline in 2012 than in 2010. Possible reasons for this increase include the following:

- The dry winter of 2011–2012 did not provide sufficient rainfall for leaching surface soils. Rainfall is nearly pure water and effectively leaches salts.
- In some areas plants transpire shallow groundwater and pull salts upward within the groundwater.
- The salinity of the Sacramento-San Joaquin Delta water increased relative to 2010 and 2011. This is the primary source of irrigation water for most lands west of the San Joaquin River in the Central California Irrigation District (CCID), San Luis Canal Company, and the Columbia Canal Company east of the San Joaquin River.
- Some sites were affected by shallow groundwater even in areas with no river flows, such as Reach 4, where no SJRRP Interim Flows were released in 2012.
- Groundwater rises incidental to high flood release flows during the early summer of 2011 appear to have brought salts into surface soils at some sites (e.g., Site 56).
- Incomplete leaching near the edges of the dripline in drip and micro sprinkler irrigated orchards.
- In some areas drain effluent from new drains was mixed with irrigation water, thus increasing the salinity of the irrigation water.

5.1 Crop Yield Estimates at Selected Sites

Soil salinity is elevated at some sites. Sites presented in Table 15 below all had elevated soil salinity levels in 2010, 2011, and/or 2012, or in multiple years. Estimated crop yield reductions for these sites based on 2012 salinity and springtime groundwater levels are listed below. Field observations seem to suggest that pistachios are more salt tolerant than the crop salt tolerance tables indicate. For example, Sites 84-11 data suggest a yield potential of 33 percent; however, the trees appeared fairly healthy in most areas. It’s possible that the trees are only using water from a small less-saline area surrounding the micro-sprinkler. Since the emphasis of the sampling program is to determine salinity changes over time, the entire orchard floor is included in the spatial composite surface soil samples used for this crop yield evaluation. Since most of the grain fields are cut for dairy silage, the salt tolerance data for forage wheat are used rather than grain yield data.

Most soil salinity sampling borings were only excavated to a depth of 5 feet. If the groundwater level was listed as over 5 feet, a yield potential of 100 percent for anoxic conditions was assumed. This assumption may not be valid in some orchards or vineyards with water tables between 5 and 7 feet.

Table 15. Crop Yield Potential at Selected Sites

Site	Depth to GW (feet BGS)	Wave ECe (dS/m)*	Crop (2012)	Yield potential Anoxic Factors (percent)	Relative Yield Salinity (percent)	Estimated Yield Potential (percent)
2	Over 5 feet	4.57	Wheat	100	100	100
4	Over 5 feet	4.39	Wheat	100	100	100
5	Over 5 feet	7.91	Wheat	100	91	91
12	Over 5feet	4.37	Wheat	100	100	100
13	Over 5feet	5.56	Pistachio	100	90	90
14	Over 5 feet	5.69	Pistachio	100	89	89
16	Over 5 feet	3.92	Corn	100	73	73
17	Over 5 feet	9.88*	Palms	100	79	79
31	Over 5 feet	3.03	Pistachio	100	100	100
32	Over 5 feet	2.94	Almonds	100	73	73
42	5.5	3.07	Tomatoes	100	94	94
44	5.8	2.91	Tomatoes	100	95	95
45	5.4	3.19	Cotton	100	100	100
50	5.5	4.86*	Cotton	100	100	100
51	4.7	6.50	Tomatoes	96	60	58
53	Over 5 feet	5.66	Alfalfa	100	73	73
56	Over 5 feet	2.26*	Almonds	100	86	86
57	11.4	2.67*	Almonds	100	78	78
60	Over 5 feet	8.67*	Pistachios	100	67	67
61	4.2	15.5	Pistachios	85	16	14
62	3.8	5.75*	Pistachios	81	89	72
70	3.8	5.61*	Grain	95	96	91
73	Over 5	2.44	Almonds	100	82	82
75	Over 5	4.23*	Alfalfa	100	84	84
76	Over 5	7.25	Pistachios	100	77	77
77	Over 5	3.98	Grapes	100	76	76
79	2.8	9.95	Grain	87	86	75
82	Over 5	3.21	Almonds	100	68	68

Table 15. Crop Yield Potential at Selected Sites (contd.)

Site	Depth to GW (feet BGS)	Wave ECe (dS/m)*	Crop (2012)	Yield potential Anoxic Factors (percent)	Relative Yield Salinity (percent)	Estimated Yield Potential (percent)
84	3.5	11.7*	Pistachios	75	44	33
90	3.4	6.69*	Grain	94	94	88
91	3.4	12.56*	Alfalfa	94	77	28
93	Over 5	5.85	Alfalfa	100	72	72
97	Over 5	4.53*	Almonds	100	43	43
99	Over 5	2.75	Almonds	100	76	76
101	5.2	3.57*	Cotton	96	100	96
102	Over 10	3.98*	Grapes	100	77	77
103	11.0	2.23	Grapes	100	93	93
104	10.3	2.53*	Grapes	100	90	90
105	Over 11.8	2.48	Grapes	100	90	90
106	Over 5	3.47	Almonds	100	63	63
110	2.5	4.91	Wheat	80	99	79
111	5.4	18.2*	Milo	100	0	0
112	6.4	9.12	Cotton	100	93	93
113	6.0	20.5*	Cotton	100	33	33
116	Over 10	3.18*	Almonds	100	68	68

Note
*with gypsum adjustment
Key:
% = Percent
BGS = below ground surface
dS/m = decisiemens per meter
ECe = electrical conductivity of the soil saturation extract
GW = groundwater
Wave = weighted average ECe with gypsum adjustments if needed

5.2 Soil Salinity Yield Potential

For this report, yield potential is determined by first estimating the yield loss due to soil saturation (anoxic conditions) then estimating the relative yield loss due to salinity. For example, if the yield loss due to saturation is 10 percent and the salinity relative yield potential is 20 percent, then the total yield loss estimate would be 100 – 10 = 90 percent; (90) (.20) = 18 percent; 90 – 18 = a total yield potential of 72 percent.

Yield potentials are based on the salinity of the water used by plants. Since plants use most of their water from the top portion of the root zone, the following weighting methods were used to estimate soil salinity levels based on water uptake by plants. For the soil samples collected on 1-foot intervals (L and DF series), the soil salinity is weighted at 40, 30, 20, and 10 percent per foot on the top 4 feet of soil. Salinity yield potential calculations for all other sites are listed in Tables 16 and 17.

Table 16. Inverted Salinity Sites

Depth Designation	Weighting of Depth Interval	Depth Weighted per Inch	Weight of Zone Percent
0–12	67 percent	5.6	76
12–30	33 percent	1.8	24
30–60	0 percent	0	0

Table 17. Regular and Uniform Soil Profiles

Depth Designation	Weighting of Depth Interval	Depth Weighted per Inch	Weight of Zone Percent
0–12	33.3 percent	2.78	49
12–30	33.3 percent	1.85	32
30–60	33.3 percent	1.11	19

5.3 Crop Salt Tolerance Data

Soil salinity levels can be compared to crop salt tolerance tables to estimate relative yield reductions. Crop salt tolerance data used in this report are from the Food and Agriculture Organization (FAO) Annex 1 (FAO 2002) to Handbook 29 (FAO 1985). The annex to Handbook 29 reproduces data from Maas and Grattan published in 1999. In some cases, only qualitative crop salt tolerance data are available. In these cases the midpoint of the qualitative range on the graph was used to estimate relative yield. Field observations suggest that pistachios are salt tolerant. A review of recent Internet sites and research papers indicates that pistachios are more salt tolerant than the Maas and Grattan data set (1999) indicates. Salt tolerance data for pistachios are based on recent information published by University of California experts (Ferguson 2002, 2011).

A listing of relative yields at successively higher ECe levels for crops commonly grown in the SJRRP damage assessment area are listed in Table 18.

Table 18. Yield Potential of Selected Crops[1]

Crop	Relative Yield Percent[3] ECe dS/m Threshold	Yield Decrease (percent) Per EC unit Over the Threshold Value	ECe 2	ECe 3	ECe 4
Alfalfa	2	7.3	100	93	85
Tomatoes	2.5	9.9	100	95	85
Field beans[1]	1	19	81	62	42
Corn	1.7	12	96	84	72
Almonds	1.5	19	90	71	52
Pistachios	4.2	7.4	100	100	100
Lima beans*[2]	4.5	7.7	100	100	100
Cantaloupes	1	8.4	92	83	75
Pomegranates*	2.3	10.3	100	93	82
Forage wheat	4.5	2.6	100	100	100
Cotton	7.7	5.2	100	100	100
Grapes	1.5	9.6	95	86	76

Notes:

* Only qualitative data was available. Salt tolerance was estimated from Figure A1-1 of Annex 1, FAO paper 29.

[1] United Nations Food and Agriculture Organization, Irrigation and Drainage paper #29; Annex 1 (FAO 2002)

[2] Lima beans are more tolerant than field beans;

[3] ECe values above 3 may require a soil gypsum content adjustment to determine yield decreases.

Key:

dSm = decisiemens per meter

ECe = electrical conductivity of the soil saturation extract

5.4 Depth to Shallow Groundwater

The effect of saturated soil conditions on crops is hard to determine. The type of crop, time of year, oxygen content of the water, and the salinity of the groundwater all affect yield potential. Observations and landowner information in the survey area indicate that water table depths shallower than about 20 inches will prevent cultivation and harvesting of crops. The University of California Almond Production Manual (Micke 1996) suggests that almond rooting depths in well-drained soil can be deeper than 9 feet and that a rising water table during the growing season can damage root systems, which in turn would reduce crop yield. The U.S. Department of the Interior, Bureau of Reclamation, Drainage Manual (Reclamation 1993) contains a graph (page 139) showing approximate yield potential for deep- and shallow- rooted crops at varying water table depths. This graph is used to estimate damages from anoxic conditions in this report.

5.5 Soil Gypsum Content and Effects on Prediction of Crop Yield Potential

Limited soil testing in the fall of 2010 suggested that some soils in the lower Reach 4a area with an ECe over about 4dS/m contain natural or applied gypsum. Saline lands in Reach 2b appeared to have a different ECe/gypsum level relationship. Gypsum and sulfur are periodically applied to surface soils on some lands. Sulfur reacts with soluble calcium dissolved from lime calcium carbonate in the soil to form gypsum. Since gypsum is a sparingly soluble salt, relatively more gypsum is dissolved in the saturation extract than is dissolved in the soil water. Therefore, FAO Annex 1(FAO 2002) and most other salt tolerance data sources (Maas 1993) recommend subtracting a value of 2 dS/m from the saturation extract ECe value when gypsum is present before using salt tolerance data to estimate yield potential. Based on soil monitoring data from SJRRP soils, it is proposed to subtract an ECe value of one unit (1 dS/m) when 0.1–2 milliequivalents (meq)/100 grams of residual gypsum is present and 2dS/m when over 2 meq/100 grams of gypsum is present. The ECe of the soil layers containing gypsum should be adjusted before averaging soil ECe values with the other soil depth zones.

Many soils in Reaches 4a, 4b, and 2b with an ECe over 3 and more than 20 meq/liter of calcium in the saturation extract were tested for calcium in a 1–5 soil/water extract. If significantly more calcium was dissolved in the 1–5 extract on a dry soil weight basis, then the soils were assumed to contain residual gypsum. Additional soil testing for gypsum content is planned for future soil sampling events. Soils with an Ece over 3 and more than 15 meq of calcium in the saturation extract will be tested to estimate the gypsum content.

5.6 Root Zone Depth Observations

Soil logs completed in 2011 and 2012 contained notes on root zone depth. The presence and abundance of roots were noted on some of the soil logs. Hand-augur borings provide limited information on root zone depth since the small diameter of the boring may miss some of the coarser roots. Roots were commonly observed above a depth of about 3 to 4 feet. Crops with roots observed at depths deeper than 5 feet included alfalfa, grapes, almonds, and walnuts. One grower reported that he observed roots of 1-year-old almond trees to a depth of 6.5 feet in a large gas line trench excavated through his orchard.

The FAO Soils Bulletin 42 (FAO 1979) reports:

> *While a rooting depth of 150cm (5 feet) is ideal in a well drained friable soil, experience has shown that many irrigated annual and perennial crops produce excellent yields with a well drained effective root zone depth of 90 cm (3 feet)*

5.7 Irrigation System Types and Crop Type Factors

Drip irrigated fields are more difficult to obtain representative samples than gravity irrigated fields (Hanson 2006). Soil salinity patterns, buried infrastructure, and in some cases wire trellises and/or metal stakes were present in some tracts. Backfill from trenching and pits associated with tree planting is also present on some of the tree row berms. EM surveys and surface soil sampling patterns took these issues into account. Drip-irrigated tomatoes and melon fields were sampled with half the sites in the furrows and half of the sites near the shoulder of the crop beds. Sometimes these zones were sampled separately to determine soil salinity patterns. EM38 surveys in orchards and vineyards were also conducted to measure salinity in various positions relative to the tree and drip emitter locations. Growers tend to schedule drip irrigations based on crop water use, and little leaching of salts takes place during the growing season. Leaching that does occur is confined to areas near the drip emitters. Salts tend to accumulate near the soil surface at the margins of the areas wetted by the drippers or micro-sprinklers (FAO 1985). Drip-irrigated sites are sometimes leached during the off season by winter rains and /or gravity or sprinkler irrigation methods. Soil samples at saline drip-irrigated orchard sites were collected both in the tree row near the emitters and in interow areas to determine soil salinity levels that the tree roots are exposed to. A summary of soil sampling to determine soil salinity variation due to irrigation system uniformity is presented in Table 19.

Table 19. Soil Salinity Spatial Variation in Drip Irrigated Orchards

Site	Depth (ins)	Number of Increments in composite	Tree Row ECe (dS/m)	Interow ECe (dS/m)	Average ECe (dS/m)
60-11	0-12	15	3.30	3.11	3.21
61-11	0-12	15	10.5	12.0	11.25
84-11	0-12	15	9.73	7.13	8.43
62-11	0-12	15	6.97	5.14	6.06
1-12	0-12	12	2.71	2.23	2.47

Key:
dS/m = decisiemens per meter
ECe = electrical conductivity of the soil saturation extract
ins =Inches

5.8 Determination of Long-Term Soil Salinity Trends

Long-term springtime soil salinity trends will be determined based primarily on the 0- to 12-inch spatial composite surface soil samples and the EM38 signal data that is adjusted for soil temperature. Typically, the 95 percent confidence level is used to evaluate significant soil salinity trends, but the 70 percent confidence range and/or other ranges can also be determined.

Soil salinity levels in the March-through-April period will be used for this comparison. This time period is critical since it is usually the lowest soil salinity level of the season and is the salinity level present just before planting. Crop germination and emergence is a critical time period for crops (Maas 1993). Winter rains and in some cases pre-irrigation have leached the soils and tend to even out soil salinity levels. Soils typically are near field capacity and are relatively easy to sample in the March-through-April period. EM38 measurements are also easiest to interpret when the soil is near field capacity and surface soils are moist.

5.9 Seasonal Soil Salinity Variation

Soil salinity levels later in the growing season tend to change in response to irrigation and drying cycles due to crop water use (FAO 1985). Salinity micro-variation patterns in soils also become more pronounced later in the crop season. Seasonal soil salinity is normally highest following crop moisture extraction after the last irrigation event. Table 20 presents surface soil salinity information from the DF and L series samples collected at the same location on different dates throughout the year. Soil samples were collected from the side (shoulder) of the beds at nearly the same location (within 2 meters of each other) in fields that were drip irrigated. A subsurface drain system was installed on part of the area in late 2010.

Table 20. Seasonal Soil Salinity Variation in Surface Soils 0-12 Inches

Site	ECe dS/m 7/15/2010	ECe dS/m 9/16/2010	ECe dS/m 2-15-2011	ECe dS/m 4-14-2011	ECe dS/m 4-10-2012	Average ECe dS/m 2010/2011/2012
Df1	1.46	3.34	1.40	1.55	1.79	1.91
Df2	1.60	3.42	1.60	2.04	2.52	2.24
L21	3.64	1.92	1.30	2.23	2.23	2.26
L26	5.83	2.79	0.90	2.15	1.99	2.73
L28	1.90	2.04	0.60	0.48	1.51	1.31
L48	4.75	5.57	N/A	1.06	1.93	3.33
L50	1.52	3.21	N/A	1.15	Ns	1.96
L68	3.24	4.41	1.60	0.72	1.02	2.20

Key:
N/A = not available
dS/m = decisiemens per meter
ECe = electrical conductivity of the soil saturation extract

6.0 Recommendations

1. All sites should be resampled during the spring of 2013 and at 5-year intervals thereafter.

2. Soil sampling methods to predict salinity damages on drip- and micro-sprinkler irrigated orchards and field crops should be evaluated. Possibly the central boring could be placed within a few feet of the drip emitter or micro-sprinkler to better estimate the salinity of the soil in the most active rooting zone or a separate multi-increment composite soil sample could be collected within the wetted perimeter of the dripper or micro-sprinkler.

3. The EM38 meter data should only be used on fields that have recently been irrigated. If the field is too dry to obtain a Dakota or Oakfield probe core, then it is certainly too dry for EM38 evaluations. The EM38 performs best at or near field capacity. This moisture level occurs approximately 1 day following an irrigation event in sandy soils and about 2 days following irrigation on medium- and fine- textured soils. ECe can be estimated for dryer soils but the accuracy and reliability is much lower than for soils near field capacity.

4. Continue to use a capillary fringe (anoxic portion) adjustment of 0.5 foot for sandy soils (including sands, gravelly sands, and loamy sands) and a 1.0-foot adjustment for all soils heavier than loamy sand, including loamy fine sands.

5. Soil salinity of entire fields can be mapped using the EM38. This can be done by walking or by mechanized methods. A grid or transect survey with calibration soil samples collected at 10 to12 selected sites in each field is recommended. Most agricultural universities, including Fresno State, now have mobile equipment to conduct these types of surveys.

6. A literature search should be conducted to obtain existing information on, capillary fringe issues relating to use of water from the zone and the zones effect on crop production. Upon completion of the literature search, in-place monitoring of seasonal water table depths and capillary fringe thickness may be an appropriate research project to support the SJRRP Seepage Management Program. Tensiometers, transiometers, watermark sensors, or other appropriate instrumentation could be used in conjunction with a monitoring well. These sites would need to be set up in a field to be most useful. The following hypothesis should be tested:

    a. Capillary fringe zones should be thinnest when groundwater is in or near the crop root zone in the summer time when plants are rapidly transpiring water.

   b. Although the lower portion of the capillary fringe may be anoxic the upper portion should contain some air. The air percentage should increase gradually as distance from the free water surface increases.

   c. Capillary fringe zones should be thicker when water tables are well below the root zone.

   d. Water tables and capillary fringe zones should be shallowest just after pre-irrigation. Capillary fringe zones should be relatively thick following pre-irrigation and before crop emergence.

7. Obtain land owner soil salinity data from current and past years and compare ECe values with current values at the SJRRP sites.

8. Revise the screenable testing criteria to test for gypsum if the saturation extract calcium content exceeds 15 meq/100 grams rather than the 2012 criteria of 20 meq/100 grams.

7.0 References

Ayers, R.S., and D.W. Westcot. 1985. Water Quality for Agriculture. Food and Agriculture Organization Irrigation and Drainage Paper 29, Revision 1.

Ferguson L., Sanden B., S. Grattan, et al. 2002. Potential for using blended drainage water for irrigating west side San Joaquin Valley Pistachios.

Ferguson, L.H., J. A. Poss, S.R. Grattan, C.M. Grieve, D. Wang, C. Wilson, T.J. Donovan, and C.T. Chao. 2002. Pistachio rootstocks influence scion growth and ion relations under salinity and boron stress. Ferguson L. H., H. Reyes, B. Sanden, S. Grattan, C. Wilson, and Seydi. 2011. California Pistachio Orchards, Early Rootstock Trials, updated 2011.

Food and Agriculture Organization. 2002. Annex 1: Crop Salt Tolerance Data, to FAO 29. Adapted from Maas and Grattan 1999 crop salt tolerance data sets.

Food and Agriculture Organization. 1985. Annex 1: Crop Salt Tolerance Data, to FAO 29. Adapted from Maas and Grattan 1999 crop salt tolerance data sets.

_____. 1979. FAO Soils Bulletin 42. Soil Survey Investigations for Irrigation.

_____. 1985. FAO Soils Bulletin 42. Soil Survey Investigations for Irrigation.

Geonics. 1998. EM 38 Ground Conductivity Meter, Dual Output Version, Operating Manual. Geonics Limited 1-1998.

Hanson, B., S. Grattan, and A. Fulton. 2006. Controlling Soil Salinity. Department of Land, Air, and Water Resources, UC Davis. UC Publication 3375. Agriculture Salinity and Drainage Review.

Maas, E.V. 1993. Testing Crops for Soil Salinity Tolerance. Proceedings Workshop on Adaptation of Plants to Soil Stresses, p 234-247. *In* J. W. Maranville, B.V. Baligar, R. R. Duncan, J. M. Yohe (eds.) Intsormil. Publication number 94-2. University of Nebraska, Lincoln, Nebraska. August.

Maas, E.V. and S.R. Grattan. 1999. Crop yields as affected by salinity. *In* Agricultural Drainage. Chapter 3, pp55-108 Agronomy monograph #38 American Society of Agronomy. Madison, Wisconsin.

Micke. 1996. University of California Almond Production Manual. Publication 3364.

Rhoades, J.D., N.A. Manteghi, P.J. Shouse; and W.L. Alves. 1989. New calibrations and formulations, Soil Science Society of America, 53:433-439

San Joaquin River Restoration Program. 2011a. Soil Salinity Monitoring Report. Appendix A, Section 5 of 2011 final Annual Technical Report.

Sands, Gary. 2009. University of Minnesota Extension Publication Series W-07644, Agricultural Drainage. Soil Water Concepts 2001. Reviewed 2009.

U.S. Department of the Interior, Bureau of Reclamation. 1993. Drainage Manual, 1993 edition.

_____. 2010. Seepage Management Plan.

_____. 2012. Seepage Management Plan, August 31, 2012.