The San Joaquin River Improvement Project (SJRIP) in California: long term reuse of saline drainage water for forage production and water quality improvement

Multi-State Salinity Coalition (MSSC) Annual Conference; Las Vegas, NV, Feb. 23-25, 2022

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Outline

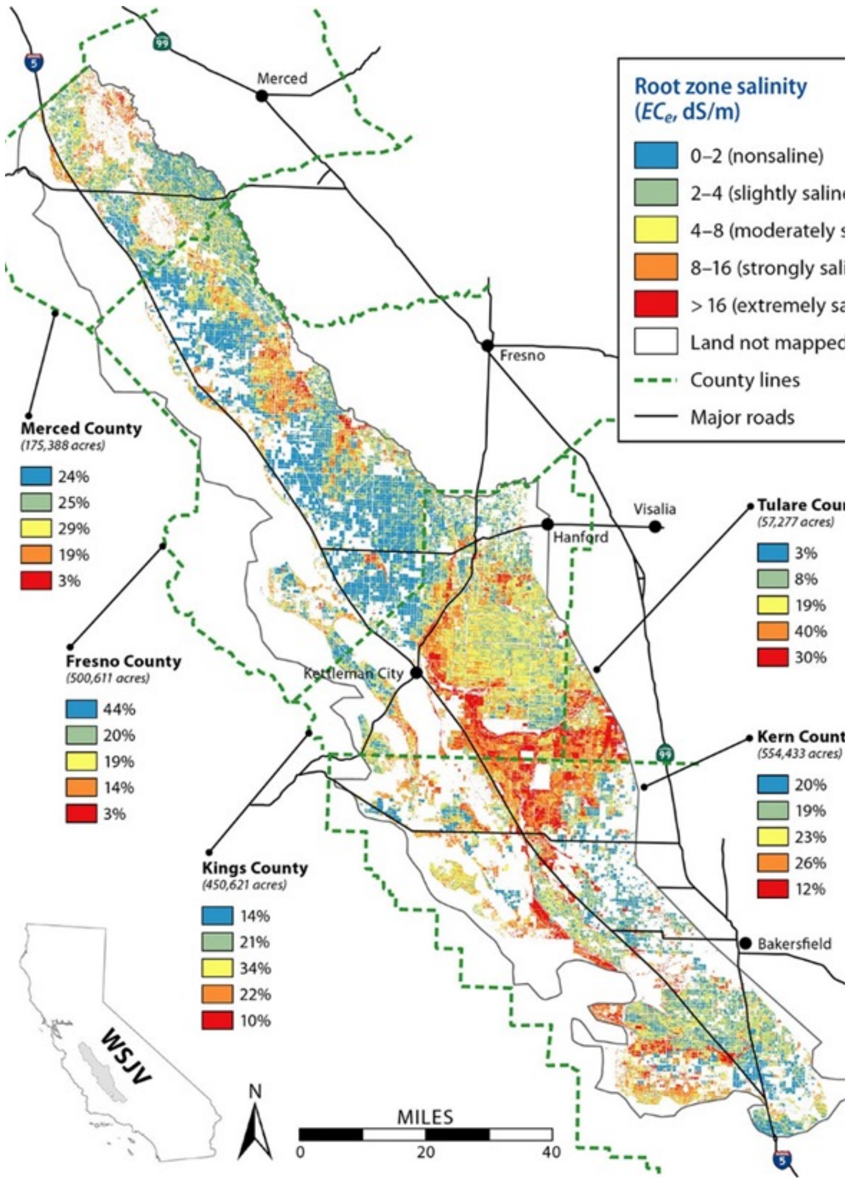
- **Grasslands Bypass Project and the SJRIP (San Joaquin River Improvement Project)**
  - history, organization
  - water quality objectives (WQO's)
  - short and long term objectives

- Research work
  - irrigation water salinity monitoring
  - EM38 soil surveys (salinity mapping)
  - [groundwater monitoring wells]
  - forage sampling (dry matter yield and toxic ion accumulation)
  - satellite / drone imagery analysis

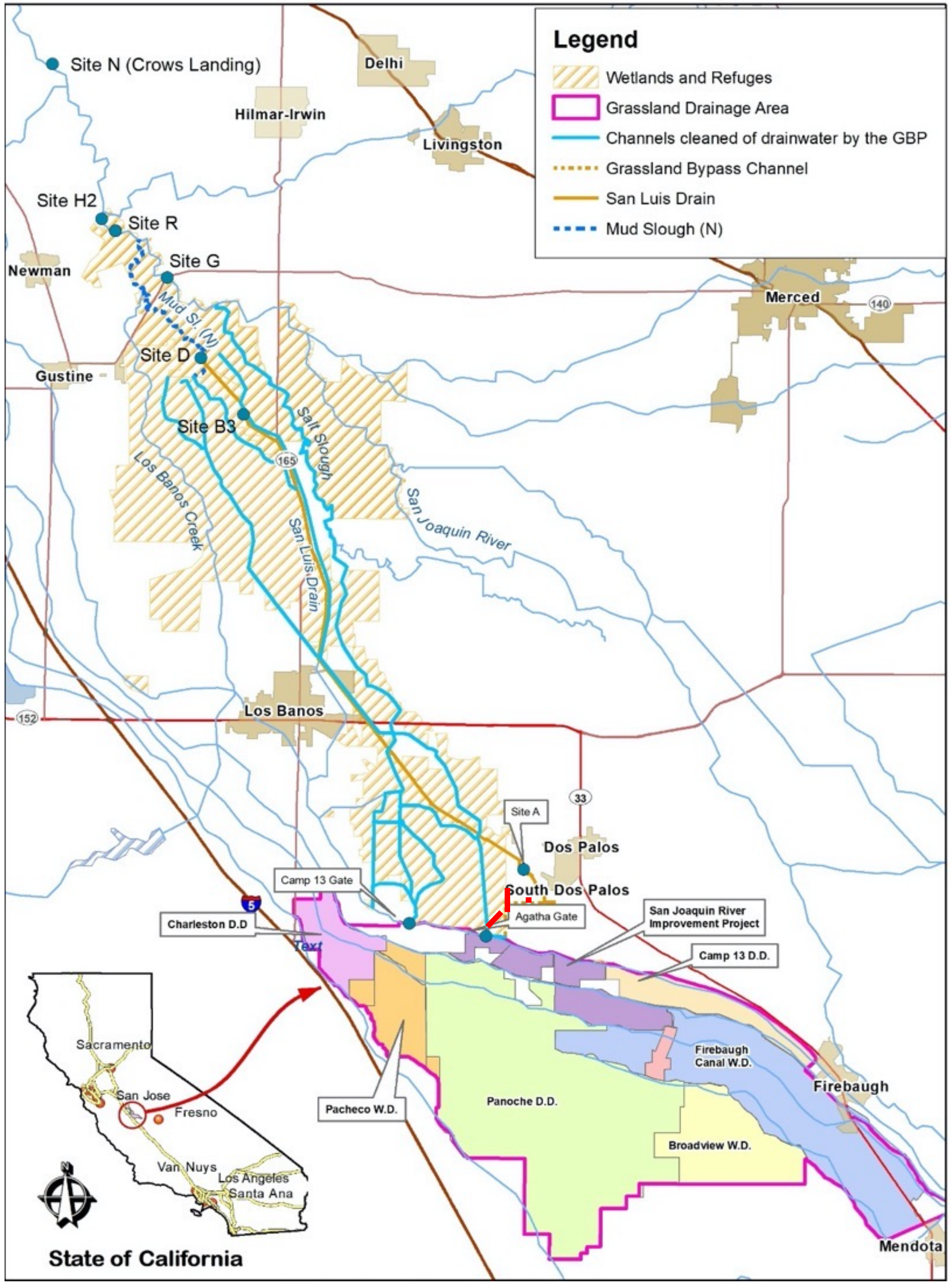
Western San Joaquin Valley (SJV) of California

Scudiero, Corwin et al. (2017, California Agriculture)

- **45% of the mapped farmland (315,654 ha) salt affected (i.e., EC_e > 4 dS/m)**
  - 30% of this salt-affected land was “strongly” or “extremely saline” (>8 or >16 dS/m)
  - *Remote sensing is a viable tool…..help landowners make decisions about land use and to help water districts and state agencies develop salinity mitigation strategies*
- **Irrigation water shortage** (drought, maintain environmental flows….).
  - High quality water (non-saline) water increasingly allocated to high value nut, fruit, and vegetable crops
  - Lower quality irrigation waters for forage crops



Remote-sensing estimations of root zone (0 to 4 feet) soil salinity for agricultural soils (orchards not included)



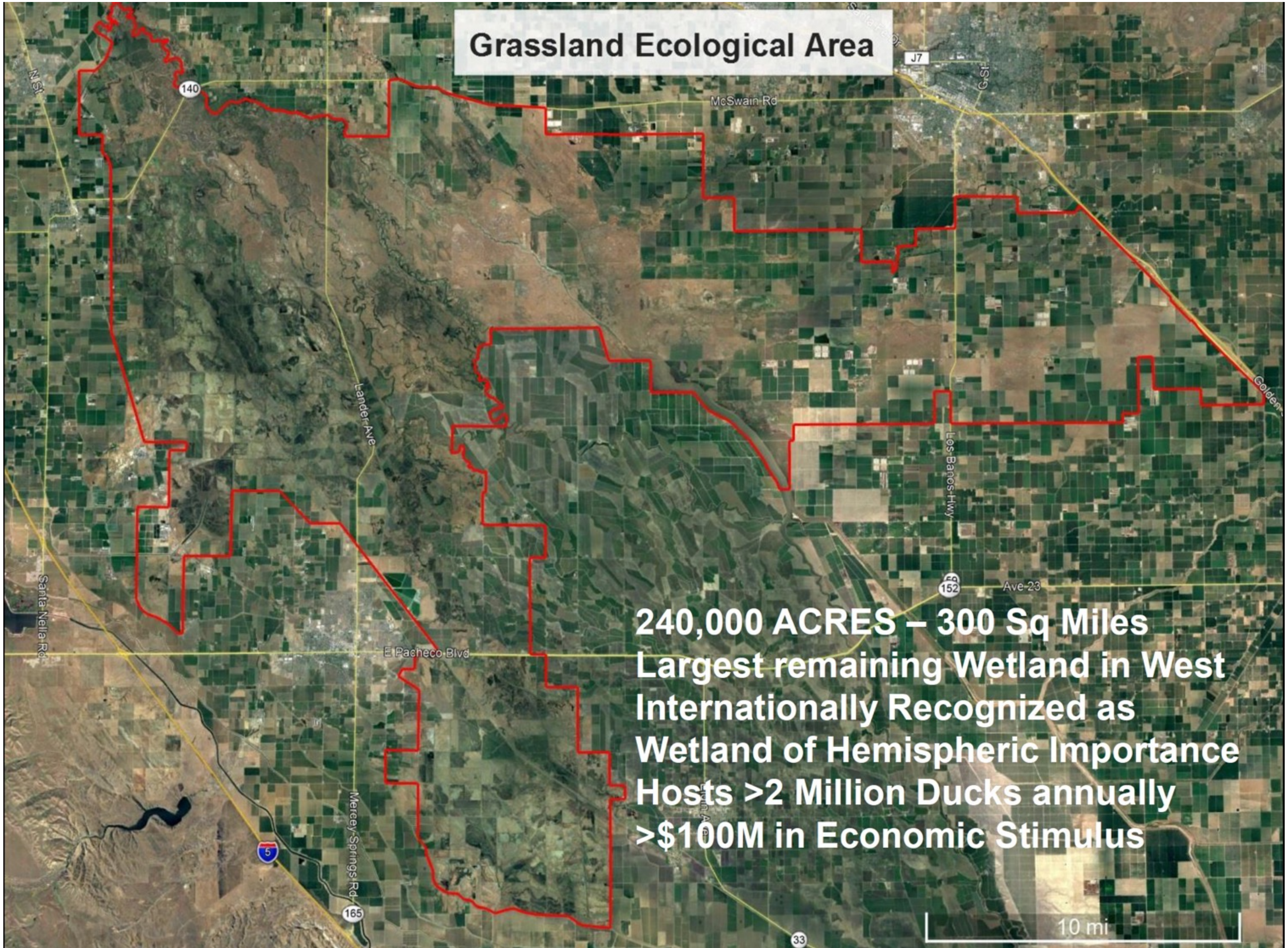
Grasslands Bypass project (GBP)

- Achieve LT sustainability of irrigated agriculture in Grasslands subarea (100 K acres) of the San Joaquin River Basin…. in response to a moratorium on selenium-contaminated tile drainage export from the Westlands Water District

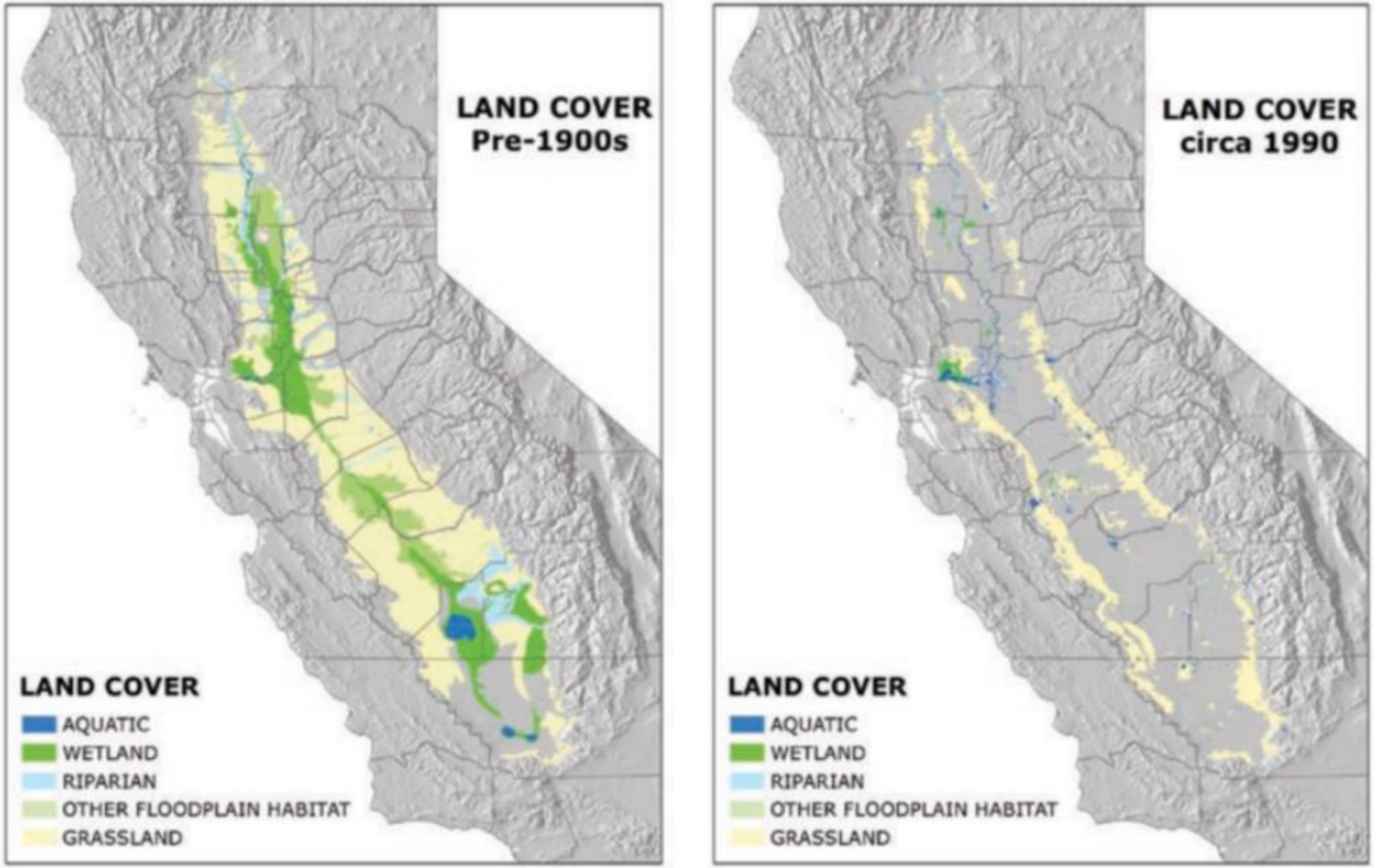
- Long history of drainage export to the SJ River through ~160 km of earthen channels running through seasonal waterfowl habitat— 160 private duck clubs, State and Federal wildlife refuges and cattle operations made use of agricultural return flows….. in spite of high Se in the water

- Replacement water supply was being sought from the Bureau of Reclamation for ~ 158,000 acres of seasonally managed wetlands (Grasslands Ecological Area)

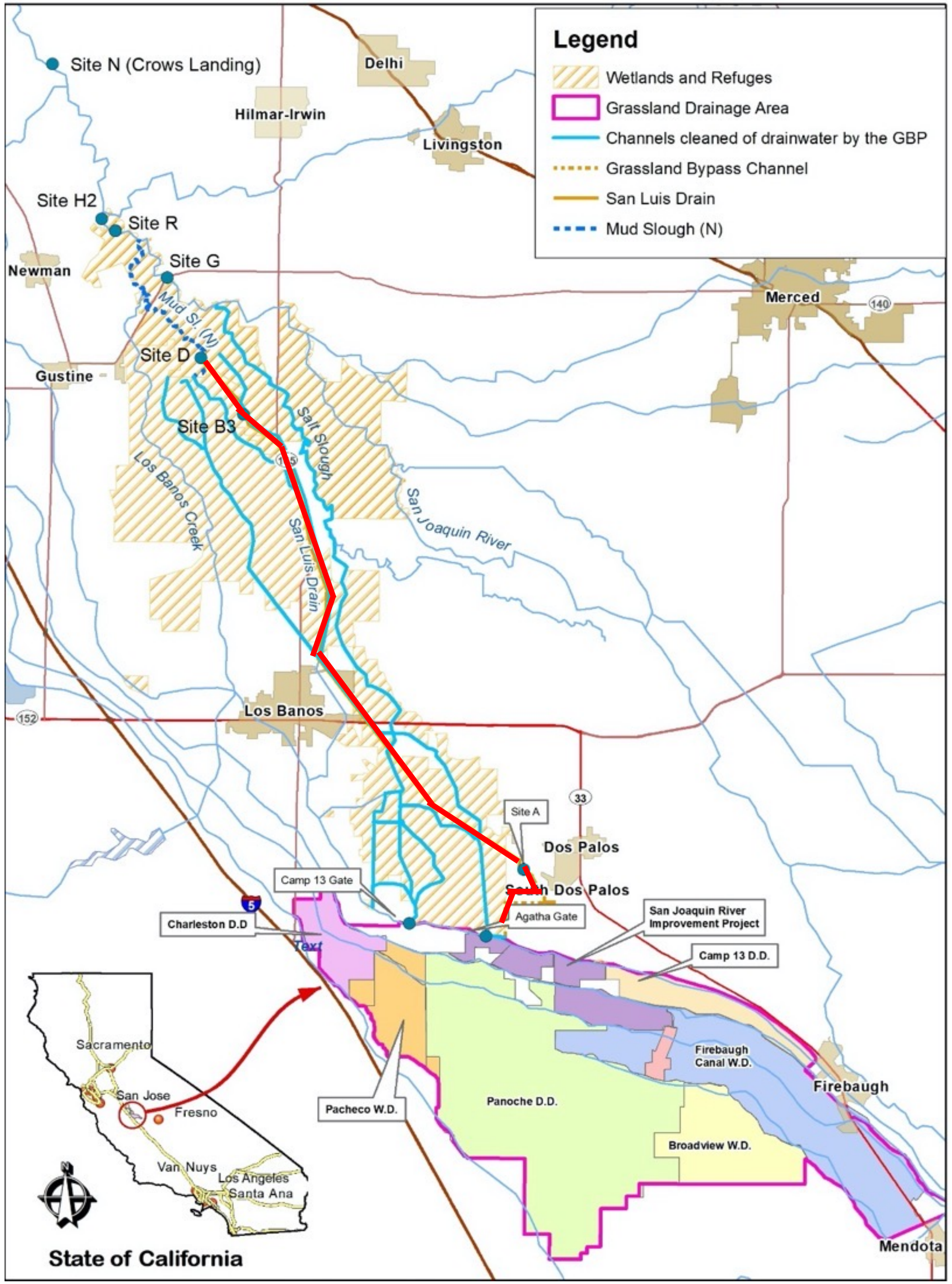
Map credit: Chris Linneman, Summers Engineering


Grassland Ecological Area
240,000 ACRES – 300 Sq Miles
Largest remaining Wetland in West
Internationally Recognized as
Wetland of Hemispheric Importance
Hosts >2 Million Ducks annually
>$100M in Economic Stimulus
McSwain Rd
Lander Ave
Los-Banos-Hwy
Ave 23
E Pacheco Blvd
Santa Nella Rd
Mercey Springs Rd
J7
140
152
165
5
33
10 mi

California has lost 95% of its interior freshwater wetlands!



Disappearance of Central Valley wetlands © Central Valley Historic Mapping Project, California State University, Chico, Geographic Information Center, 2003



Grasslands Bypass project (GBP)

- **Ag entities granted temporary use of northern 28-mile portion of federally-owned San Luis Drain……** closed earlier due to the Se hazard of Ag drainage water
- **Project goal: remove Se- contaminated drainage (> 2 ppb Se) from the wetland channels.**
- Ag-draining entities established a reuse facility on several hundred hectares of low value, salt impacted agricultural land. Expanded over the last 20 years to 6000+ acres. Land leased, infrastructure (conveyance, etc.), planting. First reuse in ~2001.

  ⇒ **SJRIP (San Joaquin River Improvement Project)**
- **Source control, improved irrigation efficiency in service area also key efforts to mitigate drainage problem**
- Regional water quality control board oversees. Must meet the water quality objectives and address wildlife concerns as mandated by the board

Slide credit: Chris Linneman, Summers Engineering

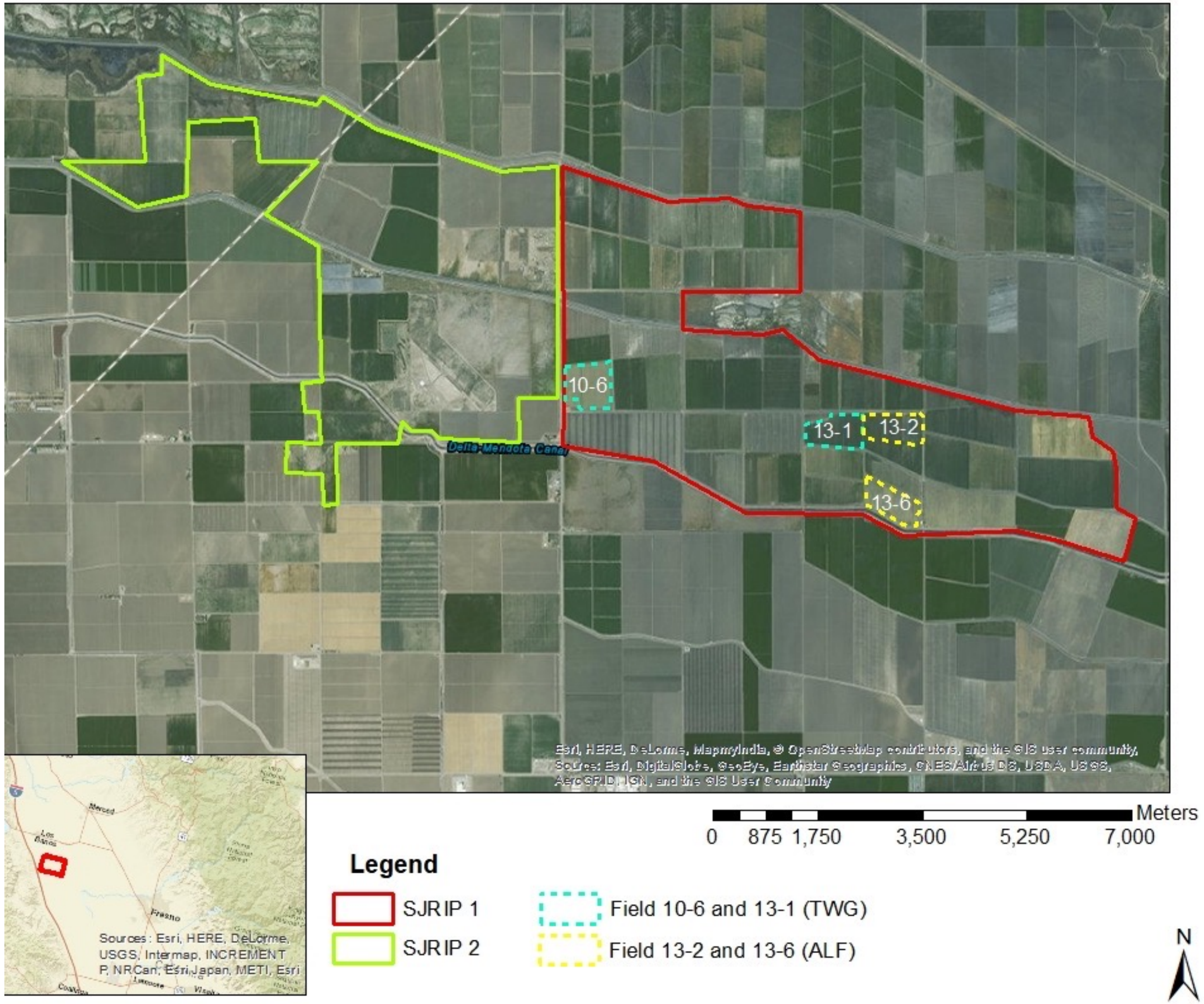
SJRIP (San Joaquin River Improvement Project)

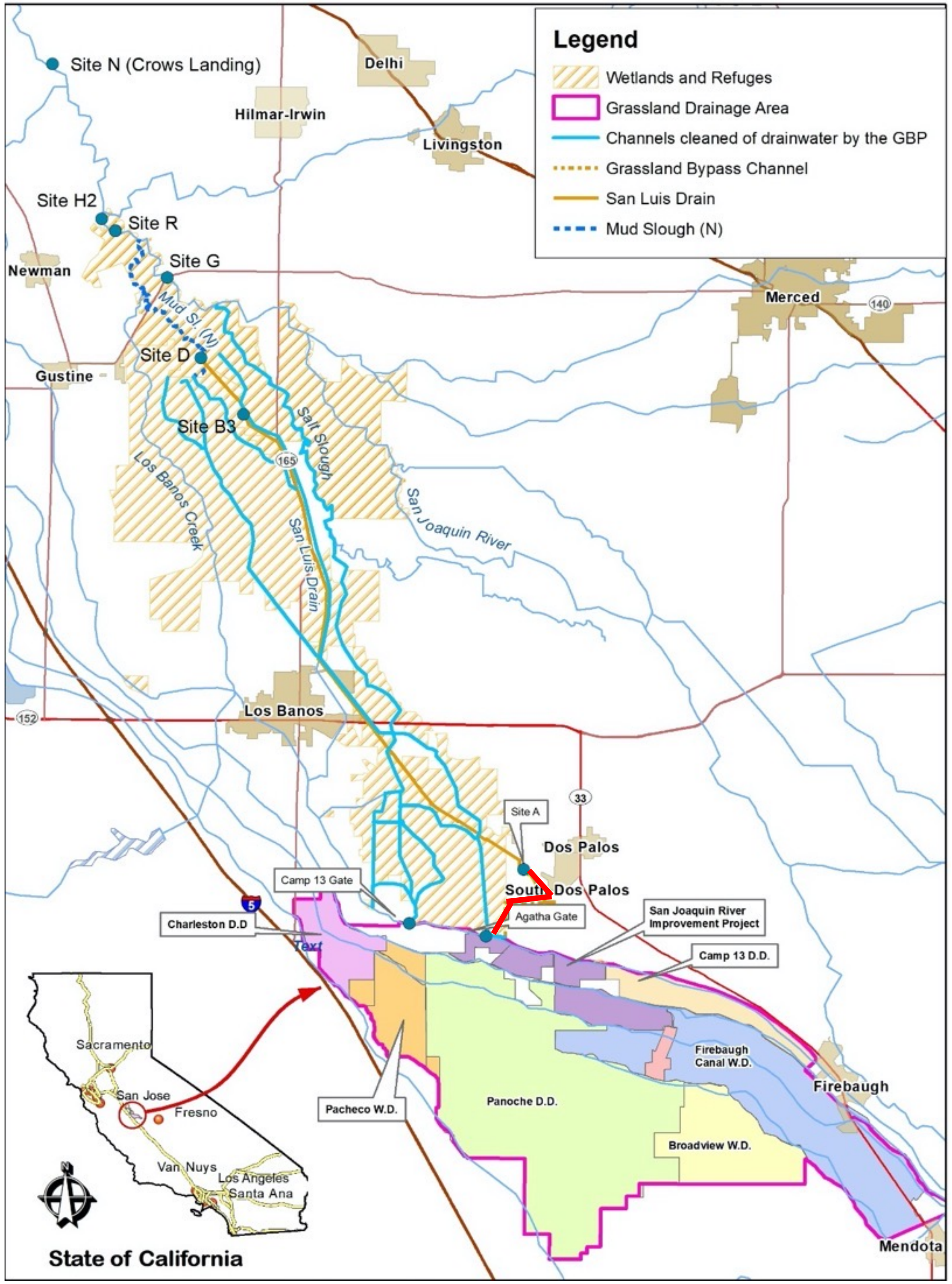
- 6000 acre re-use facility
  - ~28% tile-drained

- Receives saline drainage water from Grassland Drainage Area (~ 98,000 acres of highly productive farmland)

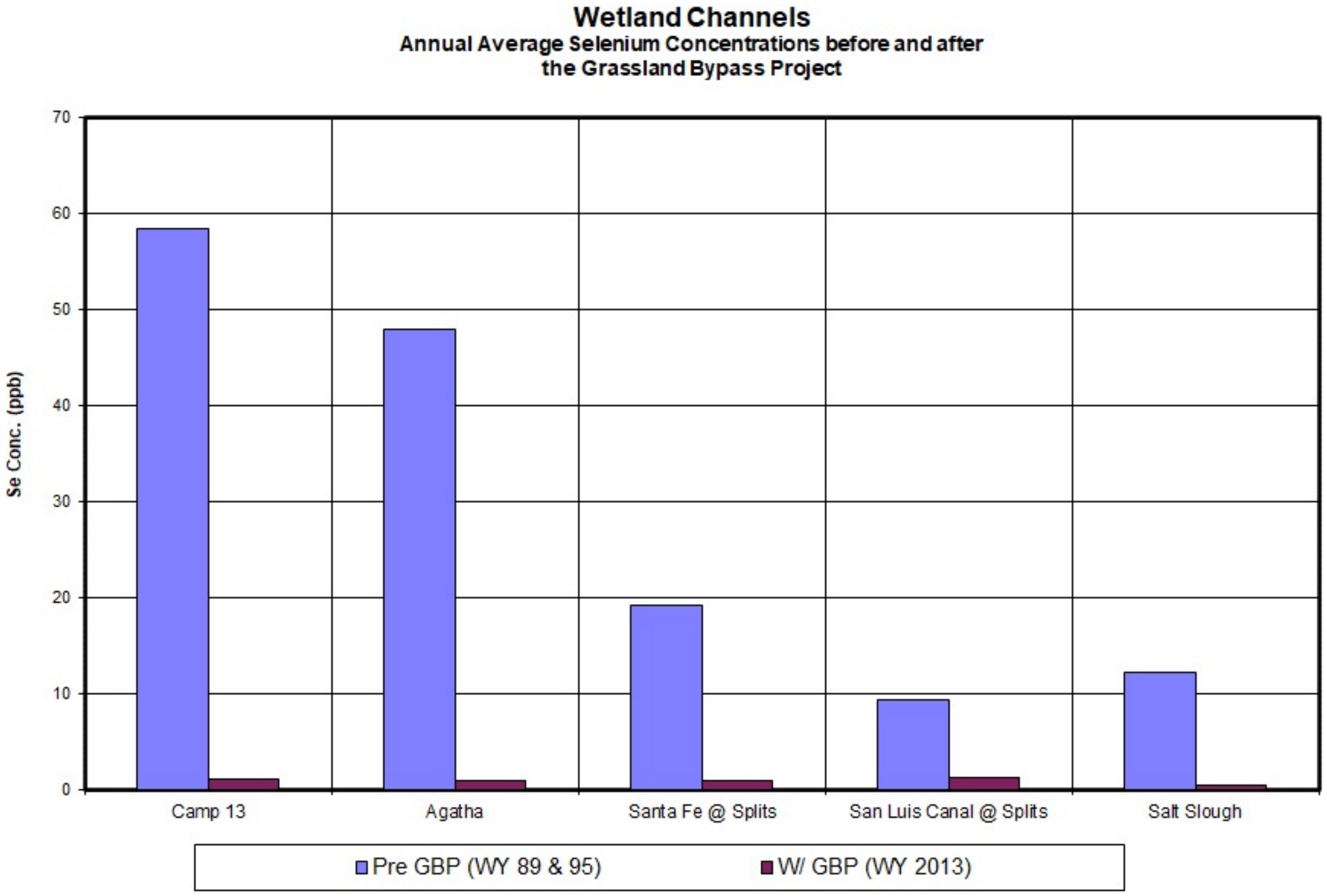
- Primarily salt tolerant forages
  - 'Jose' tall wheatgrass (*Thinopyrum ponticum)* (TWG) ~ 1520 ha
  - Alfalfa (ALF): most converted to TWG
  - Smaller acreage of pistachios for revenue gen.

- From 1998 to 2012, re-use achieved…
  - 82 % ↓ in drainage discharge to the SJ River
  - Selenium, salt and boron loading to the river ↓'d by 94%, 84%, and 74%, respectively

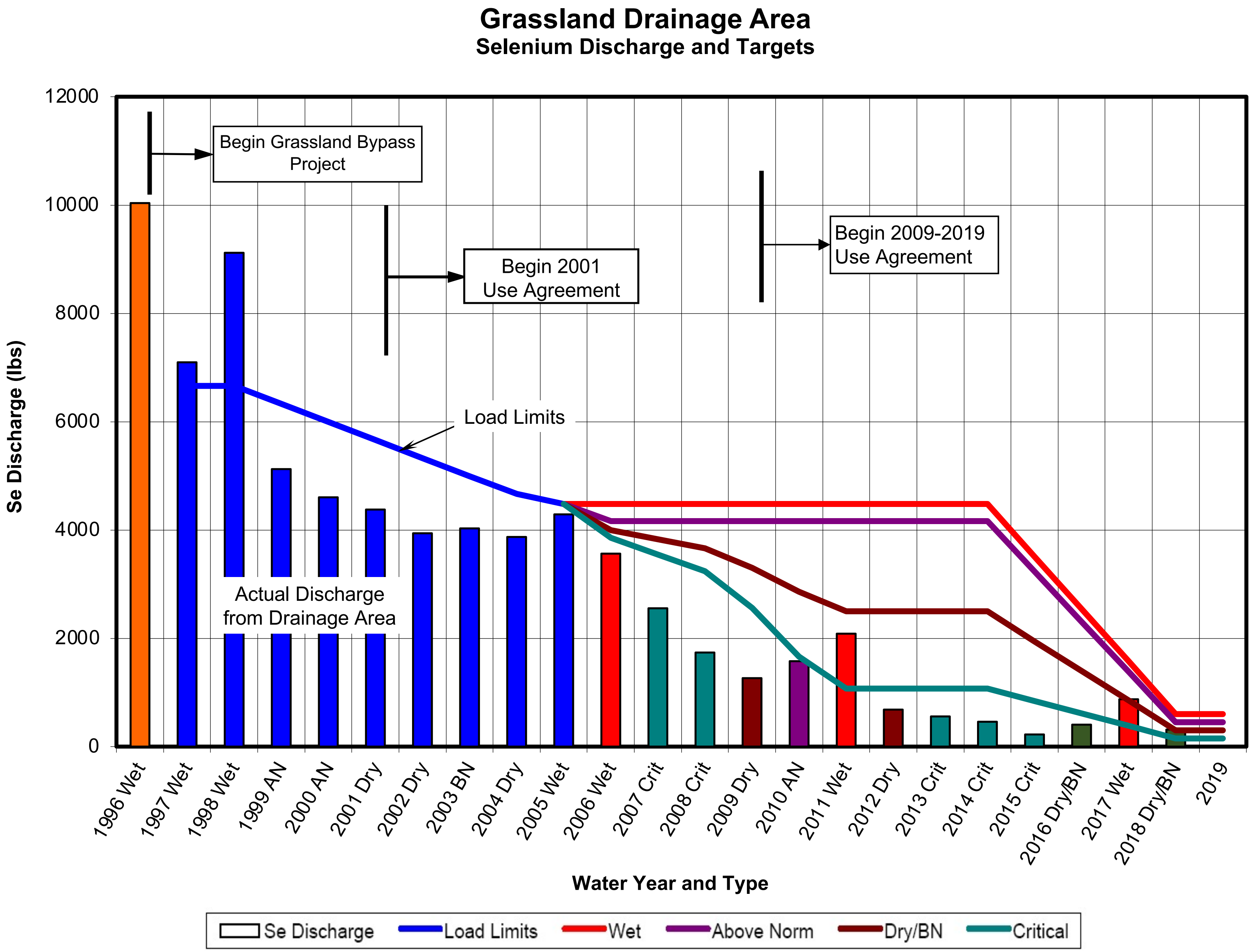




Grasslands Bypass Project



Slide credit: Chris Linneman, Summers Engineering

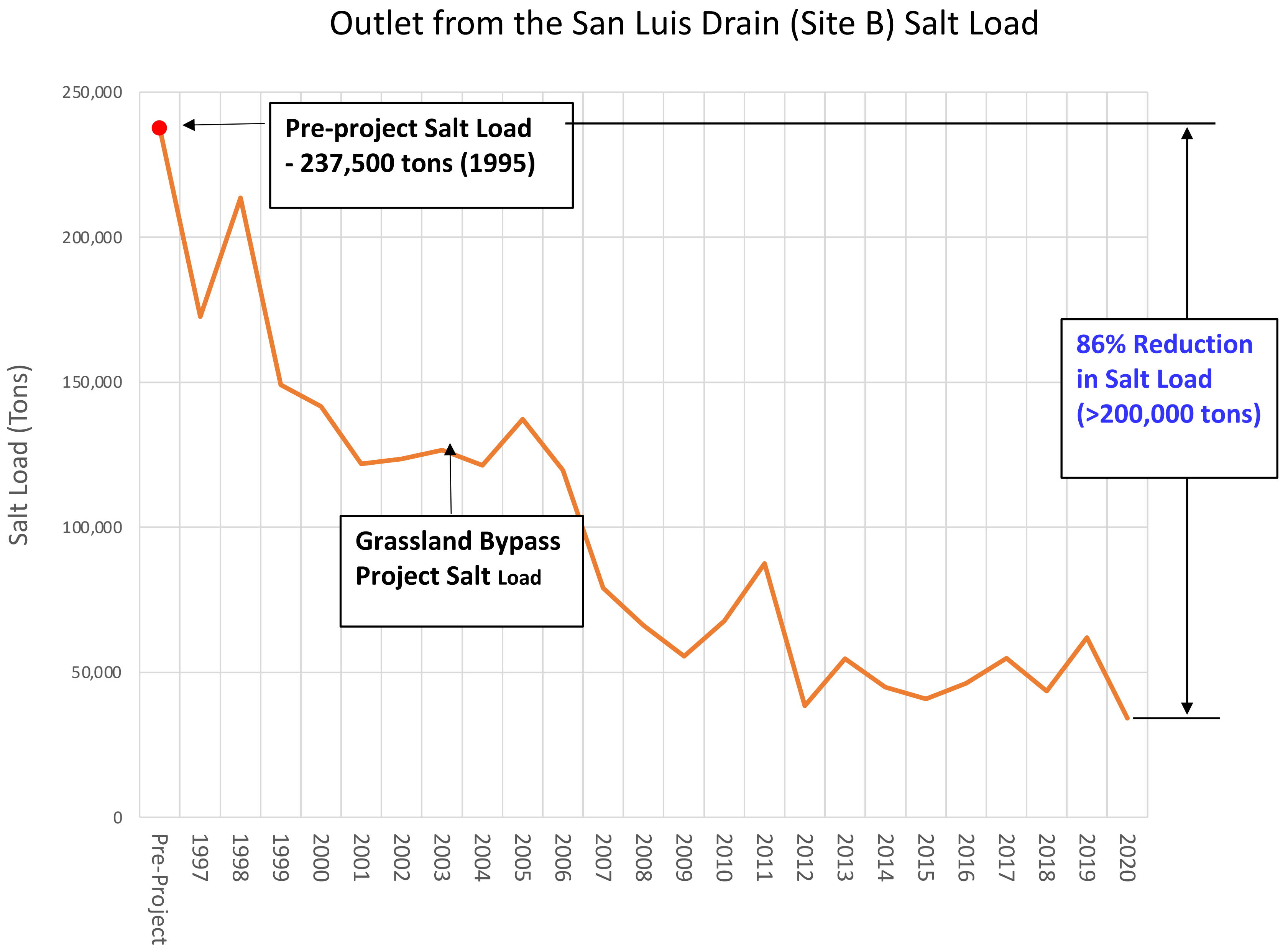


<u>Selenium</u> Discharge to San Joaquin River

- ~95% reduction in annual discharge from Grasslands area

<u>Slide credit</u>: Chris Linneman, Summers Engineering

Salt Discharge to San Joaquin River



Slide credit: Chris Linneman, Summers Engineering

Current Status

- Drainage reductions due to Westside Plan implementation
  - **source control, irrigation efficiency**
  - reuse – San Joaquin River Improvement Project (SJRIP)

- Since 2014, drainage during irrigation season has been managed without discharge into the San Luis Drain.

- All water discharged through the Grassland Bypass Project since that time has been storm-induced drainage from irrigated lands.

- Operation of the Grassland Bypass Project now focused on the objectives of the Long-Term Storm Water Management Plan

Slide credit: Chris Linneman, Summers Engineering

Long-Term Storm Water Management Plan Objectives

- minimize unmanaged ponding of water containing selenium that could impact wildlife within the GDA (grasslands drainage area)

- Protect downstream habitat and soil and water quality in the wetland areas and wildlife refuges.

- facilitate storm water management from irrigated lands that maintains the viability of agriculture.

- keep storm water drainage from breaking into irrigation water supply channels and causing damage.

- To <u>eliminate, to the extent feasible, storm water drainage discharged</u> from irrigated lands within the Grassland Drainage Area (GDA) <u>into wetland water supply conveyance</u> channels.

<u>Slide credit</u>: Chris Linneman, Summers Engineering

Storm Water Management Plan Tools

- Increase the size of the San Joaquin River Improvement Project to improve drainage management capabilities
  - ~260 acres currently in escrow.

- Construct a short-term storage basin to divert storm water flows
  - storage basin project currently in design phase. Construction expected to begin summer of 2022.

- Install SCADA systems to de-energize sumps remotely to reduce selenium concentrations in storm discharges
  - ~30% of the sumps can currently be de-energized remotely - full system operation expected by Spring of 2022.

<u>Slide credit</u>: Chris Linneman, Summers Engineering

Research at the SJRIP

Objectives

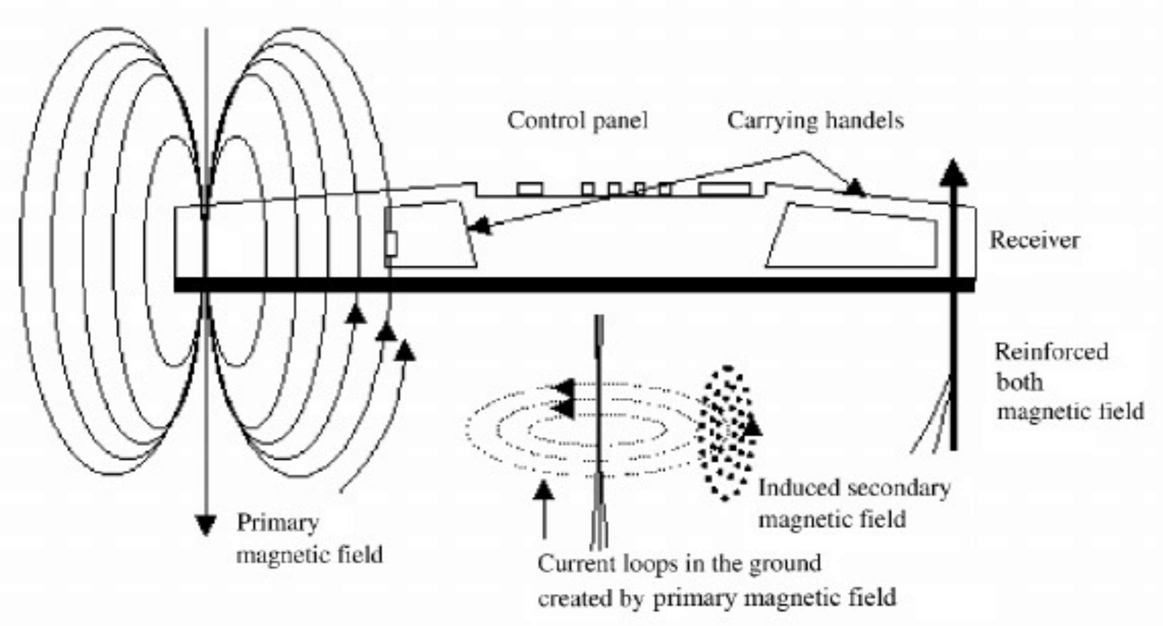
- **Conduct EM-38 soil surveys to assess** the spatial distribution of salinity within the four forage fields
- **Document irrigation water salinity** applied to each field
- Gather field-specific data to calibrate the Hydrus computer model to simulate 1-dimensional movement of water and salt and predict the outcome of long term irrigation with saline-sodic water on forage production
- **Develop GIS maps** depicting the spatial extent of salinity to help guide the management practices within SJRIP

Long term

- **Provide guidelines for saline water application and appropriate leaching requirements (LR)**
- Identify key factors to improve the long term sustainability of forage production in the SJRIP

EM-38

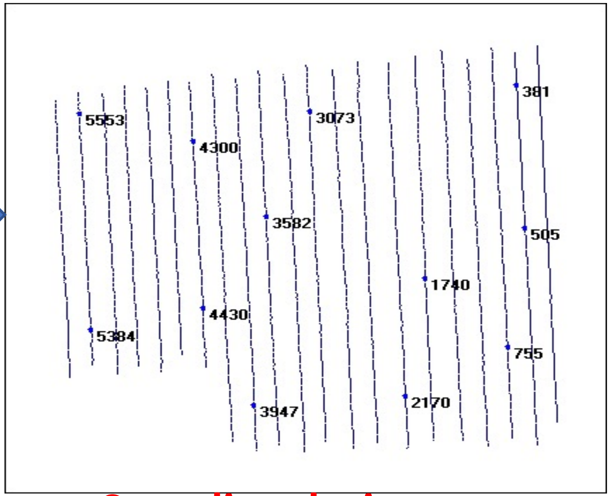
- Widely used by soil scientists
- **EM38-MK2** (Geonics limited, Canada)
- Two transmitter receiver coils, separation at 1 m and 0.5 m
  - **2 effective depth ranges (1.5 m & 0.75 m in vertical and horizontal dipole mode, referred as EMv and EMh respectively**



Steps involved in an EM-38 surveys

Conduct EM-38 Survey

ESAP -RSSD



Sampling design

Soil Sampling

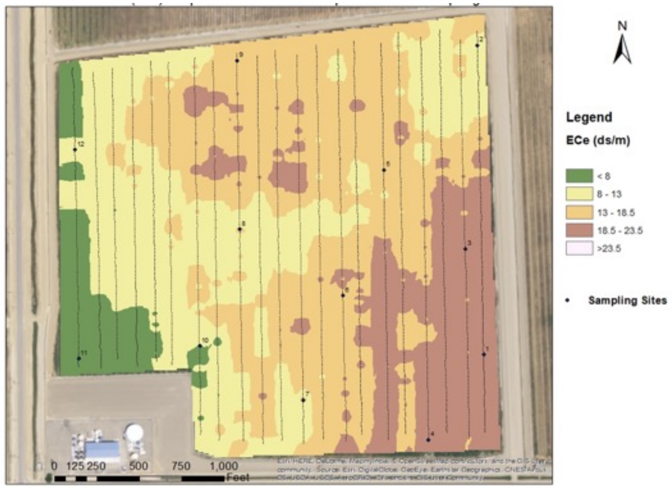
Lab Analysis

ESAP- Calibrate
- Spatial Stat analysis
- Calibration equation
- Good correlations (r2 values) obtained for ECa to ECe conversions

ECa to ECe conversion

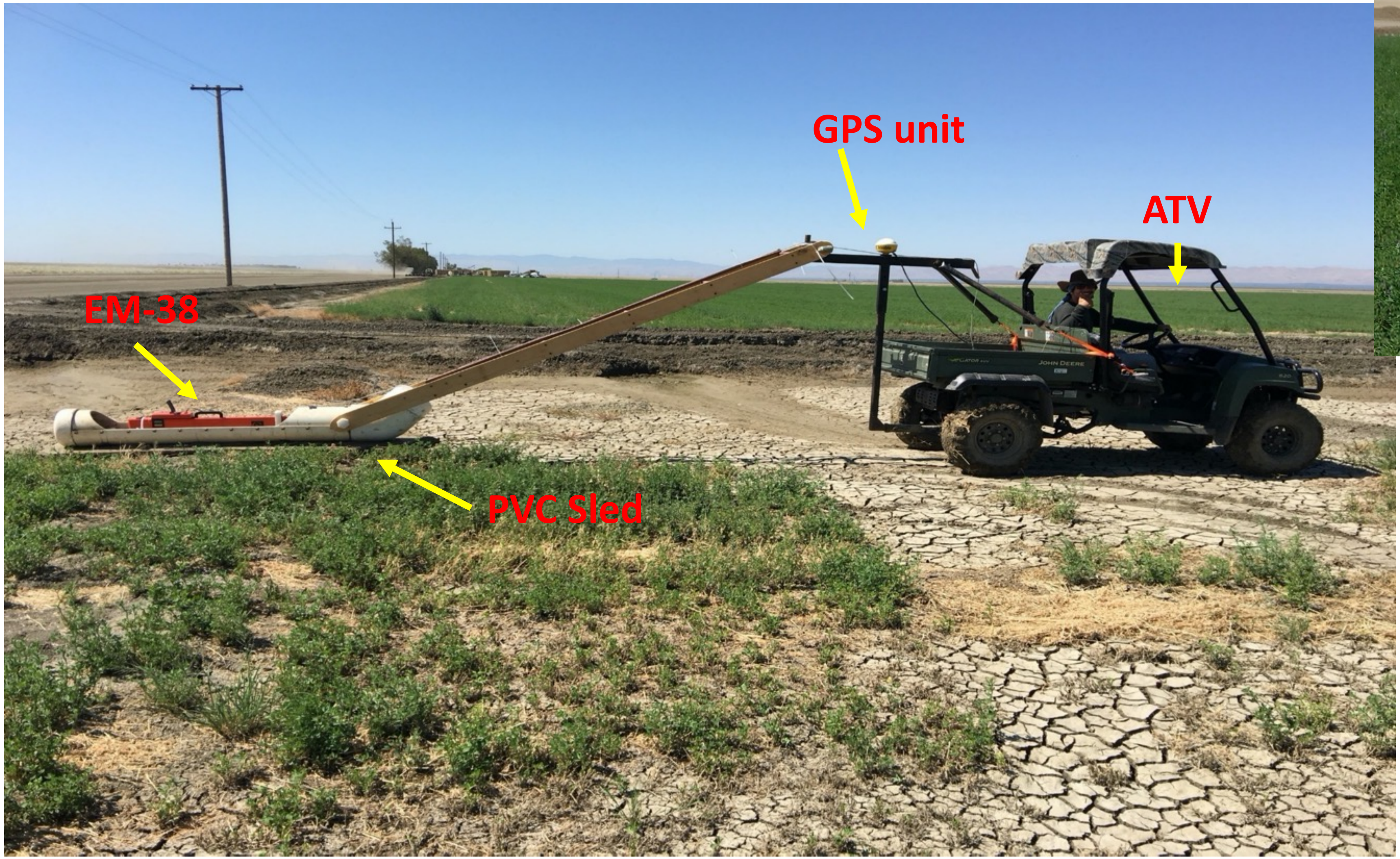
ln(ECe) = b0 + b1(z1) + b2(z2)

Salinity Map



CSUID model

Components




a
b
c
d

Quality Control Important for EM-38 data

- Correlation between EMv and EMh
  - High correlation (r >0.8): data are good
  - Low correlation: textural or moisture variability present
  - *Poor correlations observed during Fall seasons for Field 13-1.*

- DPPC (Dual Pathway Parallel Conductance) Model
  - developed by Rhoades et al. (1989).
  - relationship between bulk soil electrical conductivity (ECa), volumetric water content, and the electrical conductivity of the soil water (ECe).
  - **Check if the observed ECa data agrees with 'calculated ECa'**

- Calibration (EC_a to EC_e conversion)
  - r^2 values in acceptable range

Fields selected

Tall Wheatgrass (TWG)

(*Thinopyrum ponticum* var 'Jose')

- **Field 10-6 (36 ha)**
  - **clay to silty clay loam**
- **Field 13-1 (28 ha)**
  - **clay to clay loam**

(Field 13-1 drained; 10-6 not)

Alfalfa (ALF)

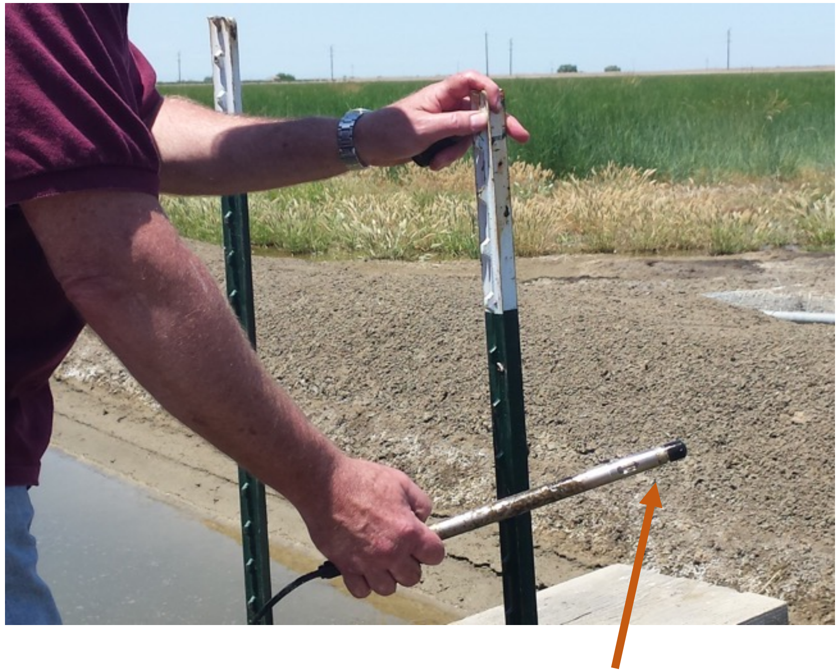
(*Medicago sativa*)

- **Fields 13-2 (30 ha)**
  - **clay to clay loam**
- **13-6 (30 ha)**
  - **clay**

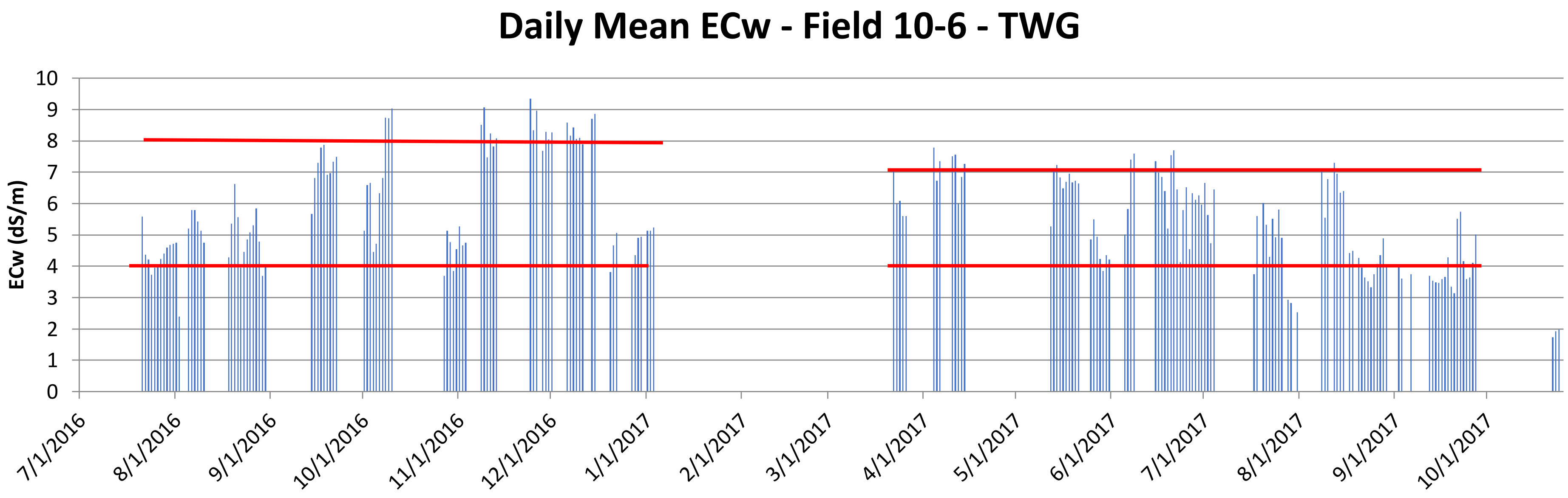
(Field 13-2 drained, 13-6 not)

Irrigation water salinity (real-time monitoring)

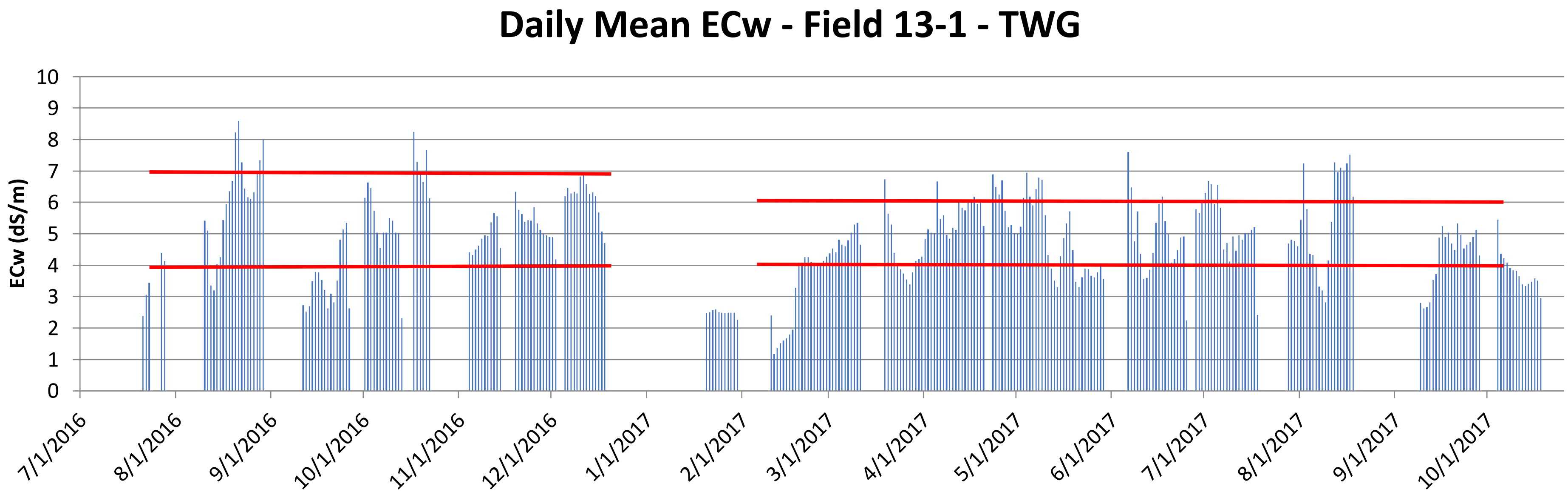
- *In-Situ* electrical conductivity (EC) sondes to provide frequent, real-time measurement of the salinity of applied irrigation water.
- Limited number of grab samples were also collected for salinity assessment and were sent to ‘Bryte’ lab for complete analysis of chemical constituents.



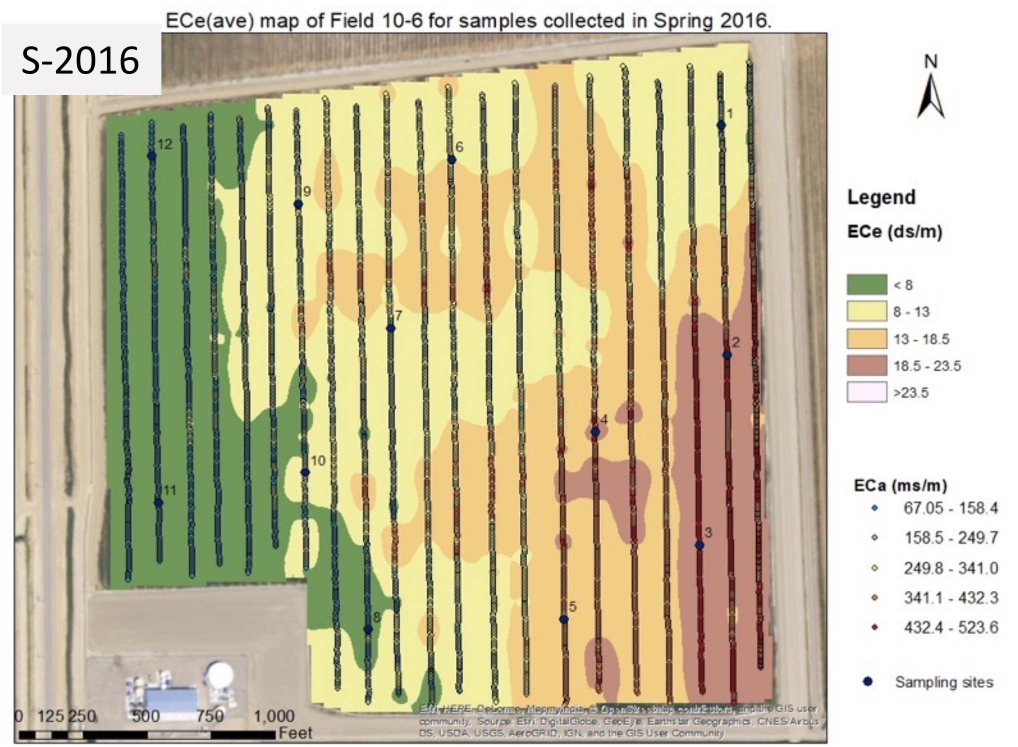
“Aquatroll 200” EC sonde

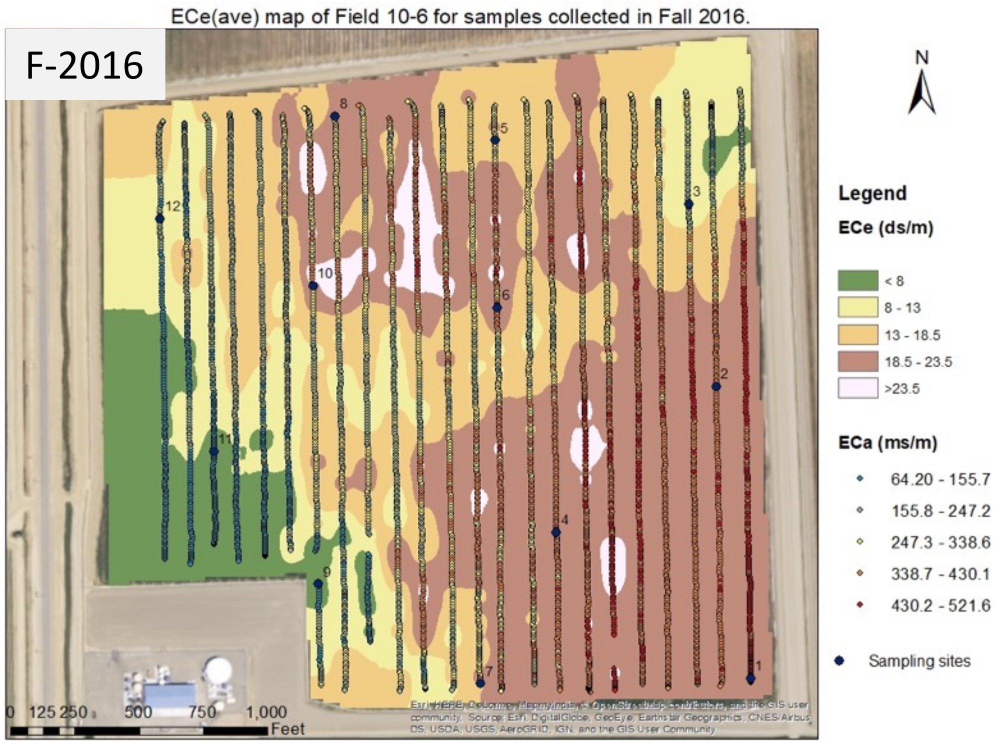


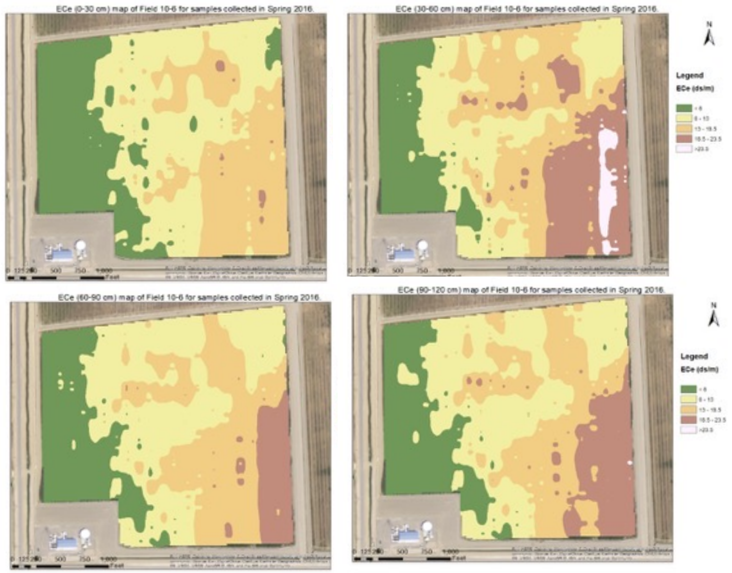
Irrigation water salinity

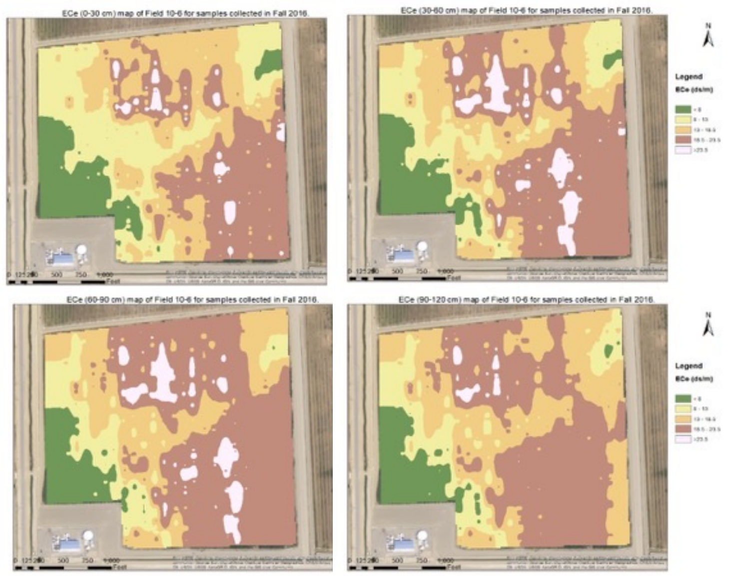


Field 10-6 (TWG) 2016

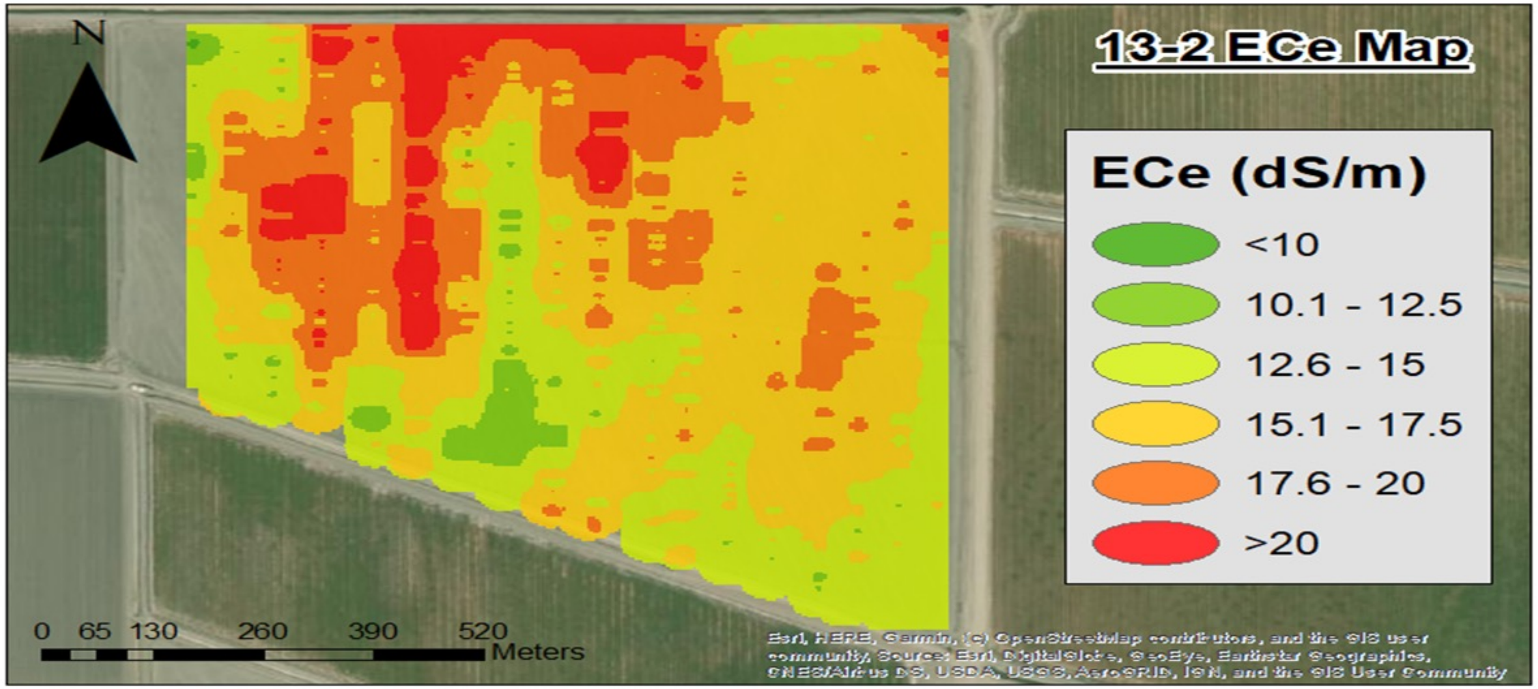


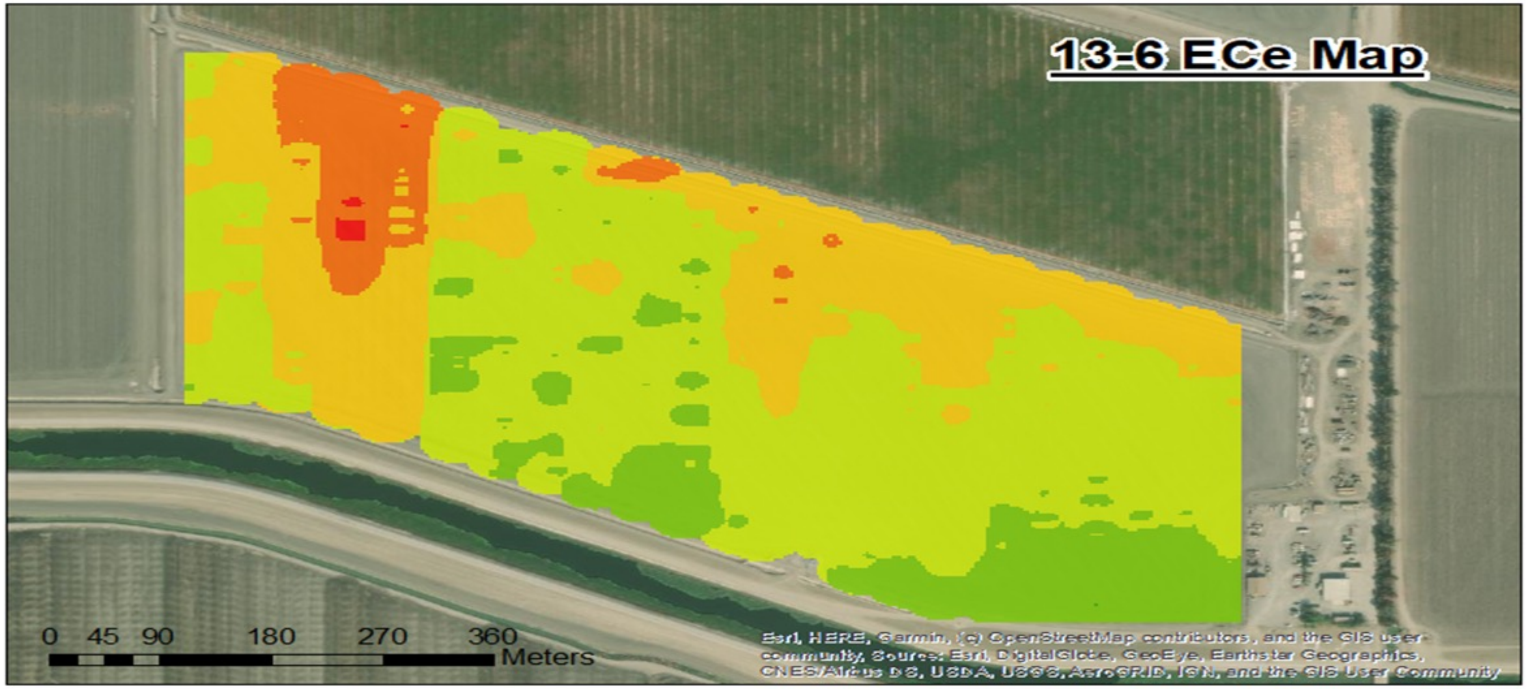






Soil salinity (ECe), 0-30, 30-60 (upper) 60-90, 90-120 (lower) cm soil depths for Fall and Spring seasons of 2016


N
13-2 ECe Map
ECe (dS/m)
<10
10.1 - 12.5
12.6 - 15
15.1 - 17.5
17.6 - 20
>20
0 65 130 260 390 520
Meters
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


13-6 ECe Map
0 45 90 180 270 360
Meters
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

2021 map

SJRIP Operation and Management

- Incoming drainage water this year (6,000 – 13,000 ppm TDS; 7 – 14 dS/m). Irrigate with 4.5 - 9.5 dS/m
- **Forage production ('Jose' tall wheatgrass) offsets ~25 – 30% of O&M costs ($4 M/ year)**
- Pistachio (small acreage) adds additional revenue. High profit potential if can achieve good yields
- Grants fund improvements, new plantings, etc.
- **$37 / acre charged to growers in water districts/ ag entities receiving drainage service**
- **Continually looking to ↑ revenue and ↓ costs,** incl. costs of pumping well water for blending.
  - tall wheatgrass is low maintenance (no fertilizer or pest management). $70 - $140 / ton. 1 - 3 cuts/year. Alfalfa 2X as profitable, but 3X cost.
  - monitoring costs: water samples monthly. Bird monitoring: May to July
- Critical water years, running short of drainage water to irrigate the forage fields.
  - 2021 (dry year): 0.13 to 3 ton/acre ~ amount of water applied.
- **Yield is not the primary objective…. it is elimination Se discharge into the SJ River. Adaptive management. 20 years of operation. Key piece of meeting the WQ objectives of the Grasslands Bypass project.**

Thank you

Questions?

Funding:
CA Department of Water Resources Proposition 204 Agricultural Drainage Program

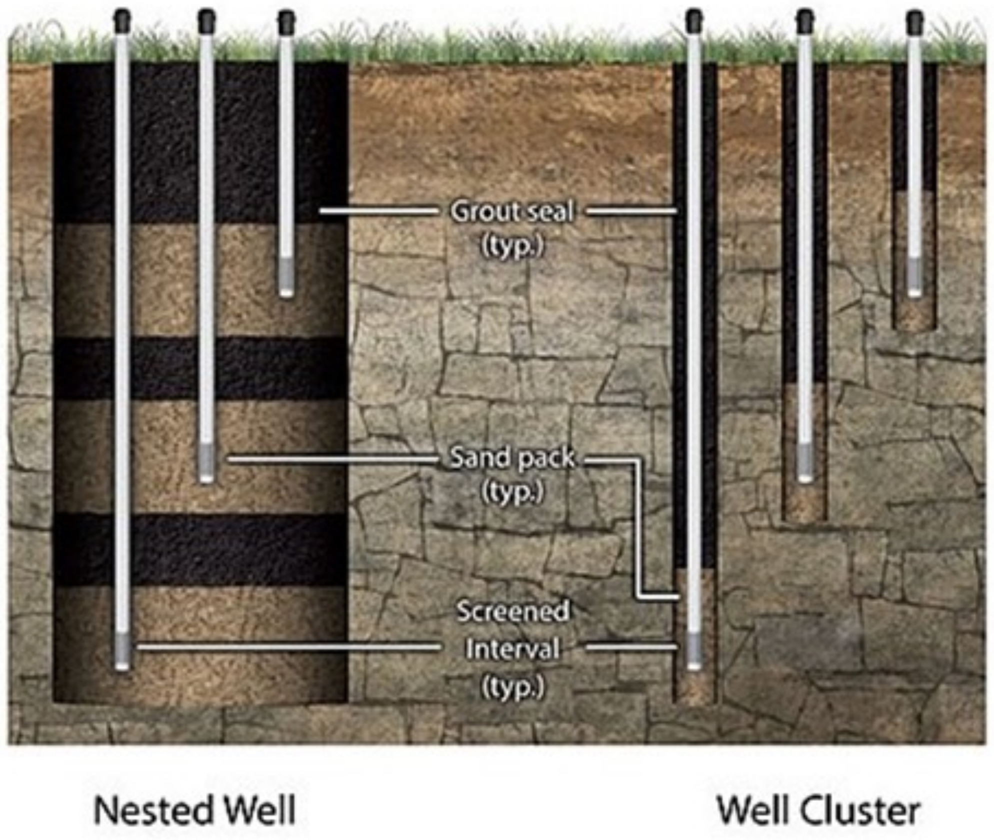
California State University ARI (Agricultural Research Institute)

Soil Salinity EC_e (ds/m): each sampled depth for all surveyed points in 'TWG' fields

Depth (cm)	Spring 2016		Fall 2016		Spring 2017		Fall 2017	
Field 10-6								
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
0-30	10.6	2.5- 23.3	15.5	3.3- 34.0	11.8	4.1- 19.0	14.6	3.3- 38.2
30-60	13.9	3.2- 27.3	17.0	1.7- 32.4	14.8	5.1- 23.9	16.5	5.8- 33.4
60-90	12.2	3.1- 23.3	18.1	1.4- 28.1	15. 6	5.6- 25.0	16.4	6.0- 28.8
90-120	12.7	3.0- 26.0	16.7	1.1- 27.0	15.2	5.7- 23.8	14.8	4.4- 27.5
Avg.	**12.5**	**3.10- 23.7**	**17.0**	**1.73- 30.6**	**14.4**	**5.16- 23.0**	**15.7**	**4.86- 31.6**
Field 13-1								
0-30	13.0	10.3- 17.3	12.6	6.8- 40.7	12.0	6.1- 17.7	13.4	9.5- 16.6
30-60	19.6	13.2- 33.3	17.0	9.1- 31.0	16.3	7.2- 25.1	19.6	14.2- 25.4
60-90	20.8	15.1- 31.4	17.5	11.4- 45.5	18.5	9.3- 27.1	20.3	14.9- 26.0
90-120	23.2	18.6- 29.8	19.2	8.2- 47.9	18.6	9.6- 26.4	21.0	16.1- 25.0
Avg.	**19.3**	**14.6- 27.2**	**16.6**	**8.8- 38.9**	**16.4**	**8.1- 23.8**	**18.6**	**13.7- 23.1**

Shallow Groundwater monitoring well

- sampling for depth and EC_{sw}



Nested shallow GW monitoring wells installed to extract water from:

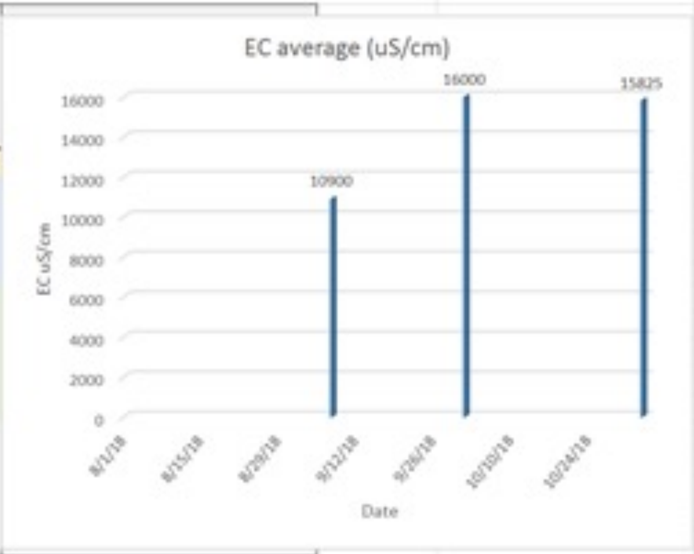
-- shallower (1.5 – 2.5 m) and

-- deeper (3.7 – 4.6 m) to assess deep percolation (leaching)

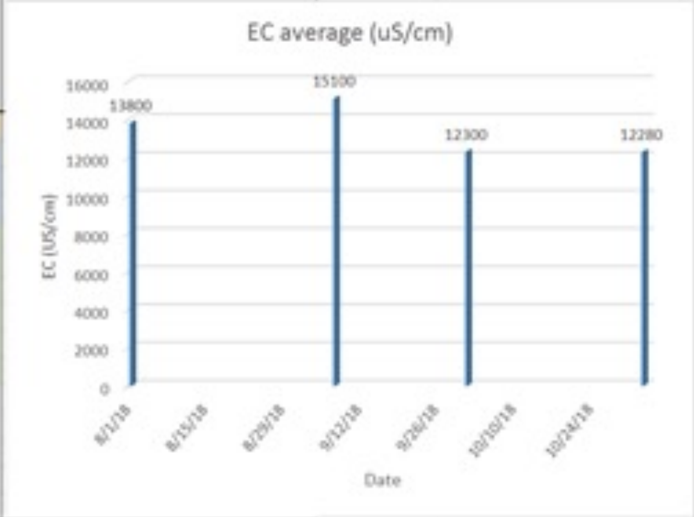
In two of the four fields, wells ended up in tight lenses… little groundwater can be extracted.

SJRIP Shallow GW monitoring wells-- *Field 10-6 (TWG)*

Date	Well	Stick-up Elevation (SUE) (ft)	Depth (ft.) before pumping (after subtracting SUE)	Depth (ft.) after pumping (after subtracting SUE)	Change in depth (ft)	Pumping time (min.)	EC (uS/cm)	EC average (uS/cm)
8/1/18	10 - 6 - 9	2.71	2.44	4.23	1.79	15	.	
9/7/18	10 - 6 -9	2.71	2.69	2.89	0.20	12	11600	
9/7/18	10 - 6 -9	2.71	2.69	2.89	0.20	12	11500	
9/7/18	10 - 6 -9	2.71	2.69	2.89	0.20	12	10400	
9/7/18	10 - 6 -9	2.71	2.69	2.89	0.20	12	10200	10900
10/1/18	10 - 6 -9	2.71	2.64	2.83	0.19	5	16100	
10/1/18	10 - 6 -9	2.71	2.64	2.83	0.19	5	16100	
10/1/18	10 - 6 -9	2.71	2.64	2.83	0.19	5	16000	
10/1/18	10 - 6 -9	2.71	2.64	2.83	0.19	5	16000	
10/1/18	10 - 6 -9	2.71	2.64	2.83	0.19	5	16000	16000
11/2/18	10/6/09	3.13					15800	
11/2/18	10/6/09	3.13					15900	
11/2/18	10/6/09	3.13					15800	
11/2/18	10/6/09	3.13	3.13			4	15800	15825



Date	Well	Stick-up Elevation (SUE) (ft)	Depth (ft.) before pumping (after subtracting SUE)	Depth (ft.) after pumping (after subtracting SUE)	Change in depth (ft)	Pumping time (min.)	EC (uS/cm)	EC average (uS/cm)
8/1/18	10 - 6 - 15	3.17	9.17	13.43	4.26	15	13800	13800
9/7/18	10 - 6 - 15	3.17	5.08	13.23	8.15	12	16300	
9/7/18	10 - 6 - 15	3.17	5.08	13.23	8.15	12	14700	
9/7/18	10 - 6 - 15	3.17	5.08	13.23	8.15	12	14200	15100
10/1/18	10 - 6 -15	3.17	7.41	13.33	5.92	3	12400	
10/1/18	10 - 6 -15	3.17	7.41	13.33	5.92	3	12200	
10/1/18	10 - 6 -15	3.17	7.41	13.33	5.92	3	12200	
10/1/18	10 - 6 -15	3.17	7.41	13.33	5.92	3	12300	
10/1/18	10 - 6 -15	3.17	7.41	13.33	5.92	3	12300	12300
11/2/18	10 -06-15	3.17	6.66	13.24	6.58	4	12300	
11/2/18	10 -06-15	3.17					12300	
11/2/18	10 -06-15	3.17					12300	
11/2/18	10 -06-15	3.17					12300	
11/2/18	10 -06-15	3.17					12200	12280



EC_{sw}- salinity of shallow groundwater (2 depth)

- -1.5– 2.5 m
- - 3.7 – 4.6 m

Next step- satellite or drone imagery (forage canopy reflectance)

- thermal, multispectral, RGB….

Imagery from drones being used to detect water stress in crops. Can it detect salinity stress?

Must control for other crop stress factors (drought, disease, pest, nutrient….)

Preliminary analysis of satellite (Sentinel II) images: poor correlations to soil salinity patterns from EM-38 surveys.
Other bands or drone imagery may have more promise