Assessing Salinization Across the South Platte River Basin

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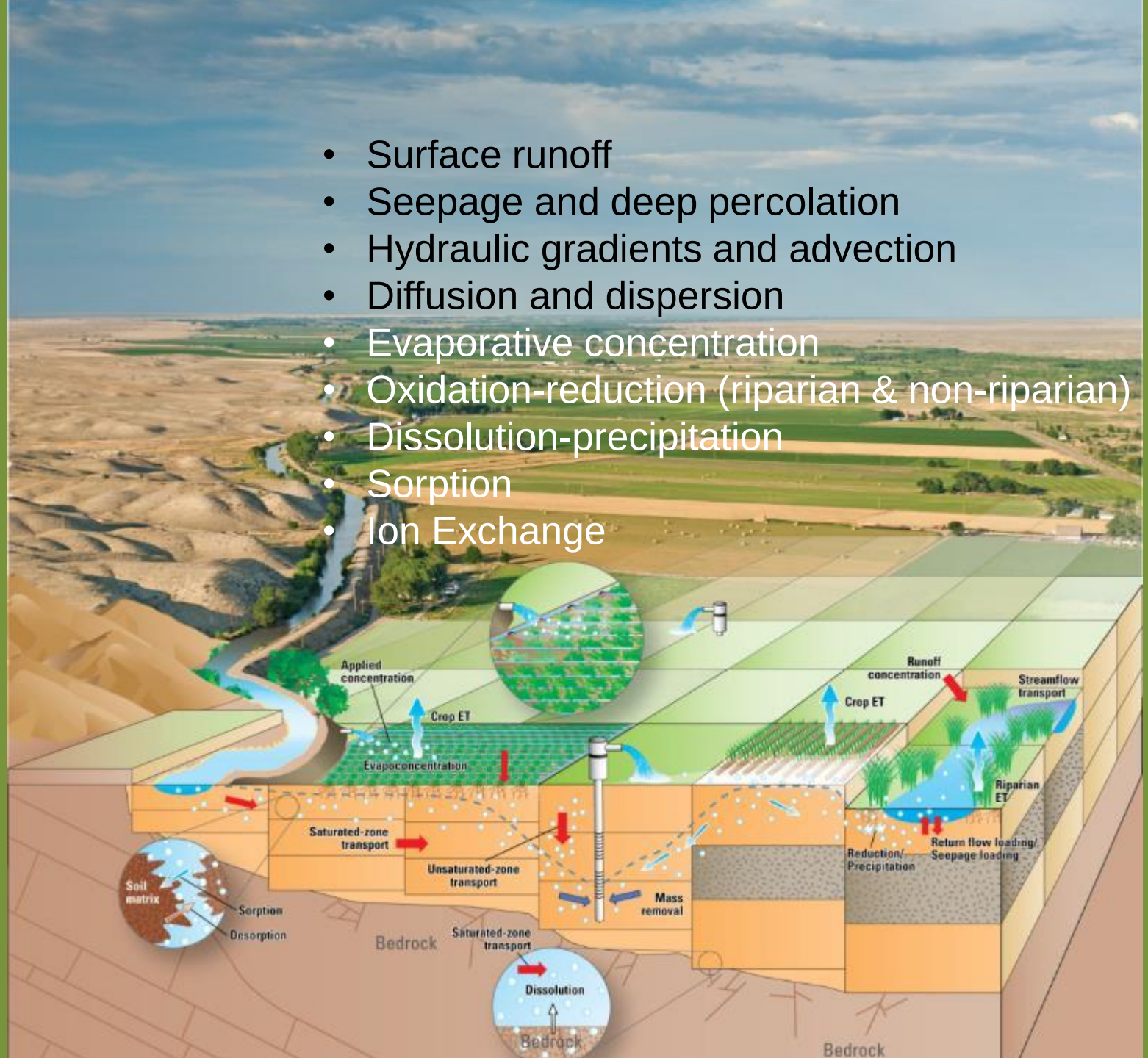
Lower South Platte Water Symposium
23 January 2025

Colorado State University

Return Flow and Solute Transport Processes in an Irrigated Stream-Aquifer System

- Surface runoff
- Seepage and deep percolation
- Hydraulic gradients and advection
- Diffusion and dispersion
- Evaporative concentration
- Oxidation-reduction (riparian & non-riparian)
- Dissolution-precipitation
- Sorption
- Ion Exchange



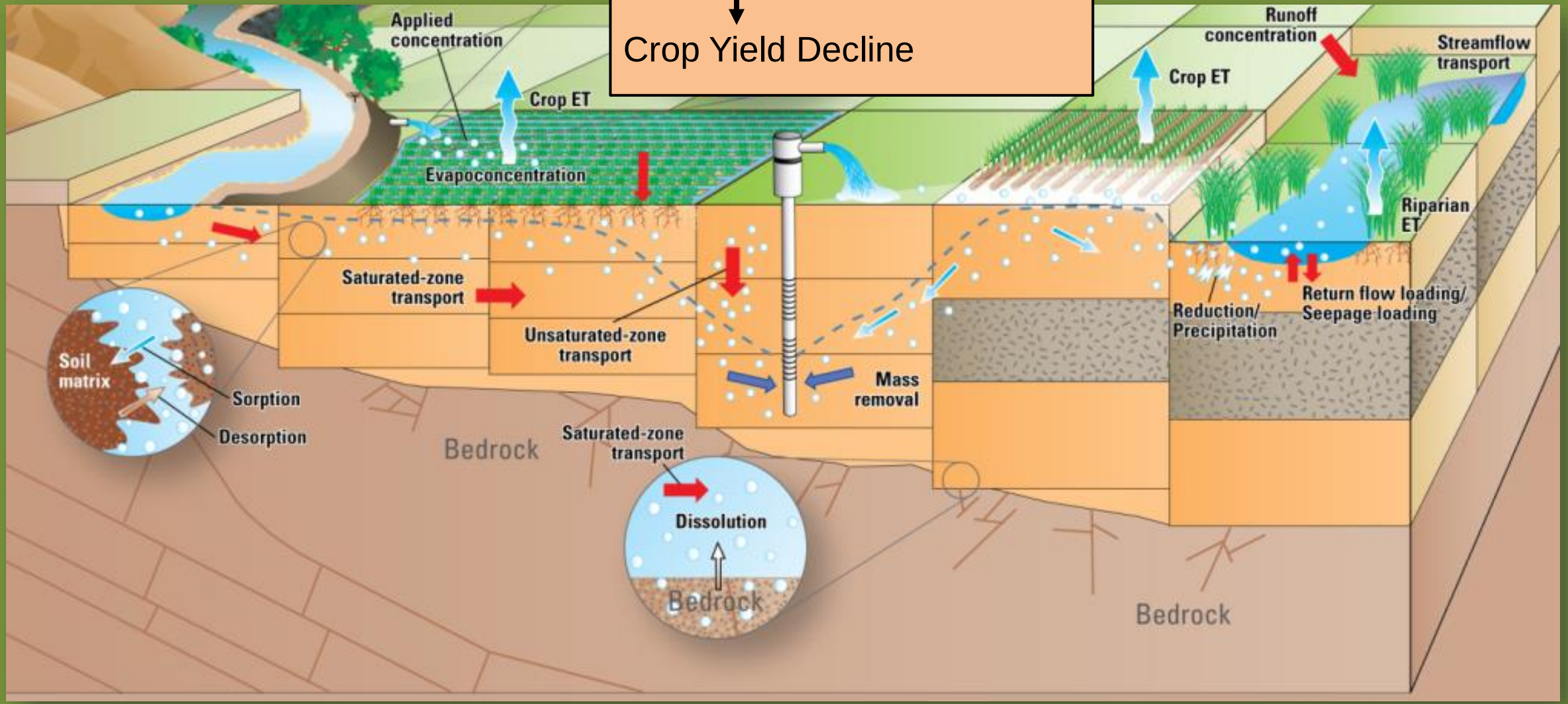
Salt Accumulation

↓

Water and Land Degradation

↓

Crop Yield Decline



Growing Concern about Salinization of Water and Land Resources in the South Platte River Basin

Anecdotal Evidence
Intermittent and Limited Data

BASINWIDE ISSUES OF CONCERN

- spatial and temporal patterns of salinity in streams, groundwater, soils
- impacts of soil salinity on crop productivity
- implications of dissolved salts/trace elements in streams to water supply and aquatic life in the stream network
- effects of expanding sprinkler irrigation and selected curtailment of well pumping on shallow groundwater and soil salinity
- long-term impact of recharge ponds for well augmentation on subsurface and surface water salinity
- potential of alternative water and land management strategies to lower salinity
- economic costs and benefits of salinity management

CSU SPRB SALINITY PROJECT

A systematic study to define, in collaboration with stakeholders, the problem of water and land salinization in Colorado's South Platte River Basin (SPRB), forming a sound basis for a search for effective solutions.

Stage 1

Problem Characterization

Phase 1: Data collection for salinity description & assessment

Phase 2: Extended data collection, identification of impacts, sources, controlling factors

Stage 2

Search for Solutions

FUNDING

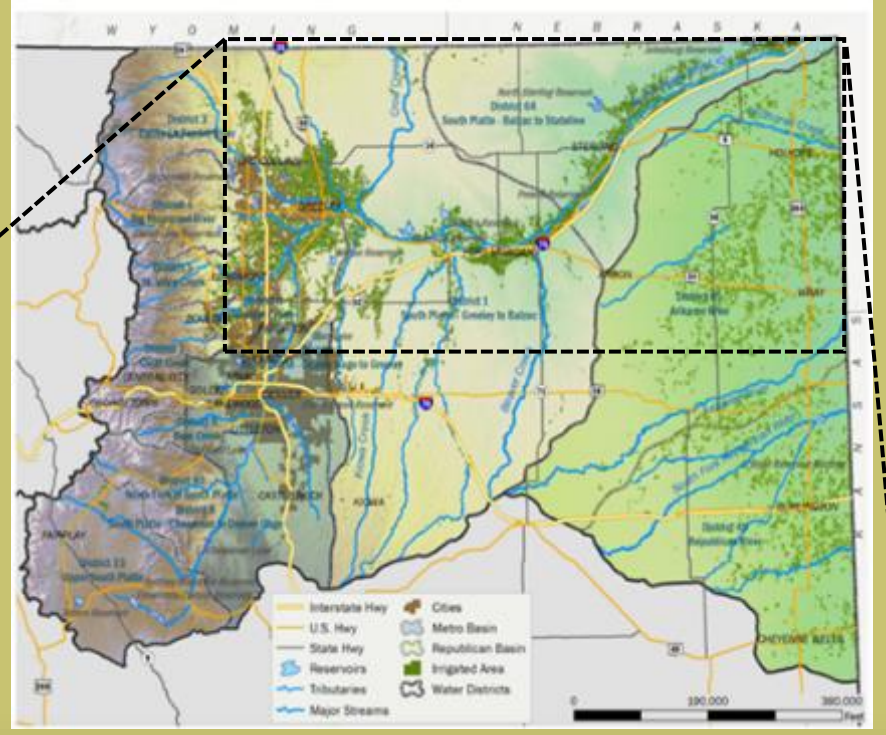
- Colorado Agricultural Experiment Station
- Colorado Water Conservation Board
- USDA NIFA
- CO Corn
- Northern Water
- South Metro Water Supply
- Denver Water
- Borland Endownment
- Colorado Water Center

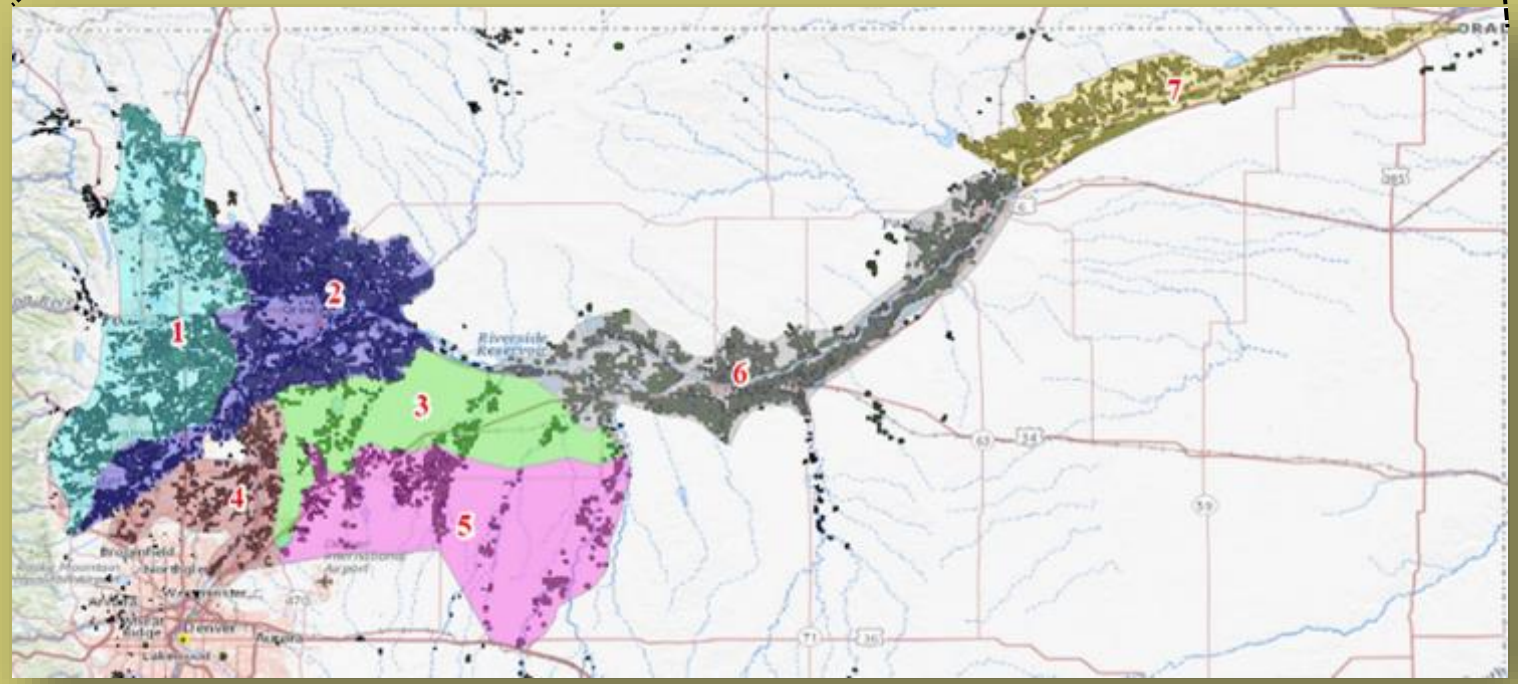
Field Monitoring Summary

- 27 field sites (confirmed and pending)
- Other field sites under consideration

Seven study regions

designated based upon location along stream network, soils, subsurface geology.



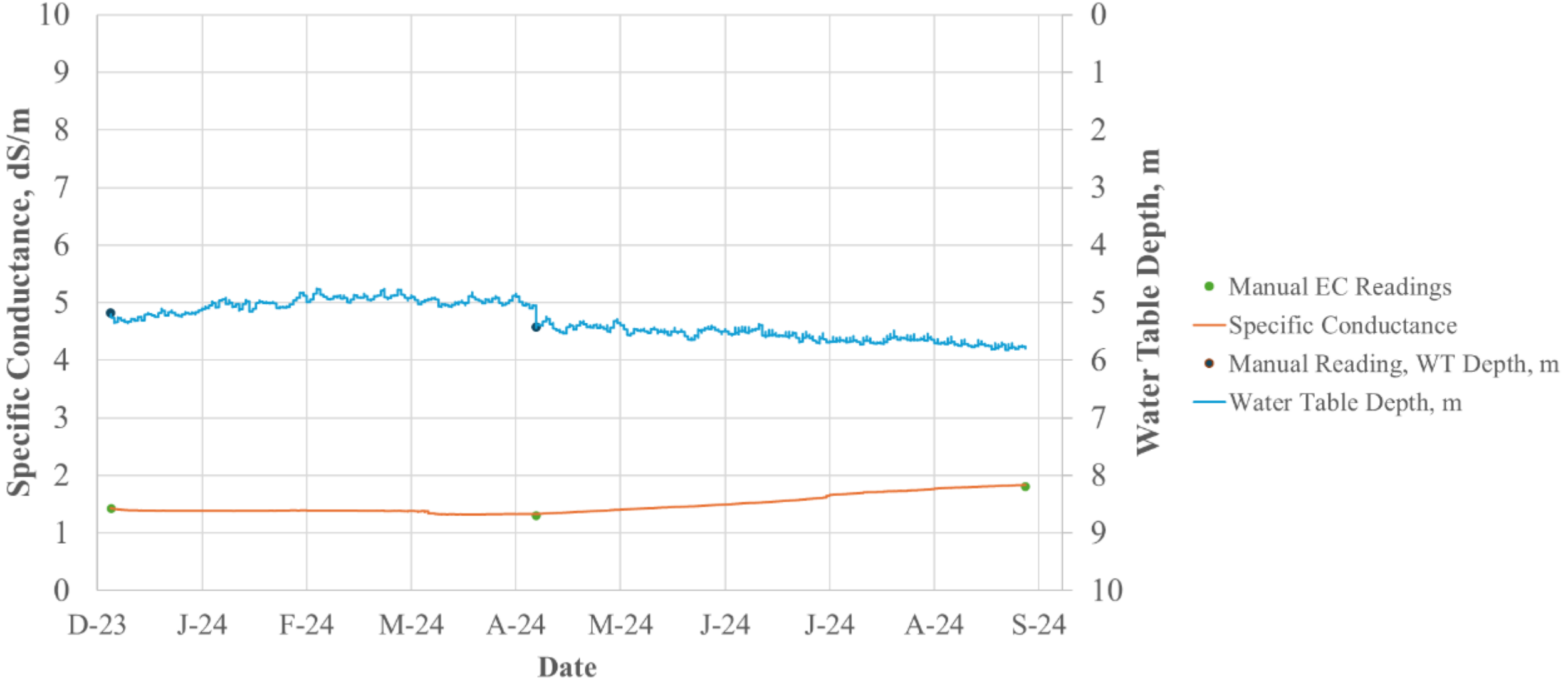


South Platte River Basin
Salinity Field Monitoring Sites
January 2025

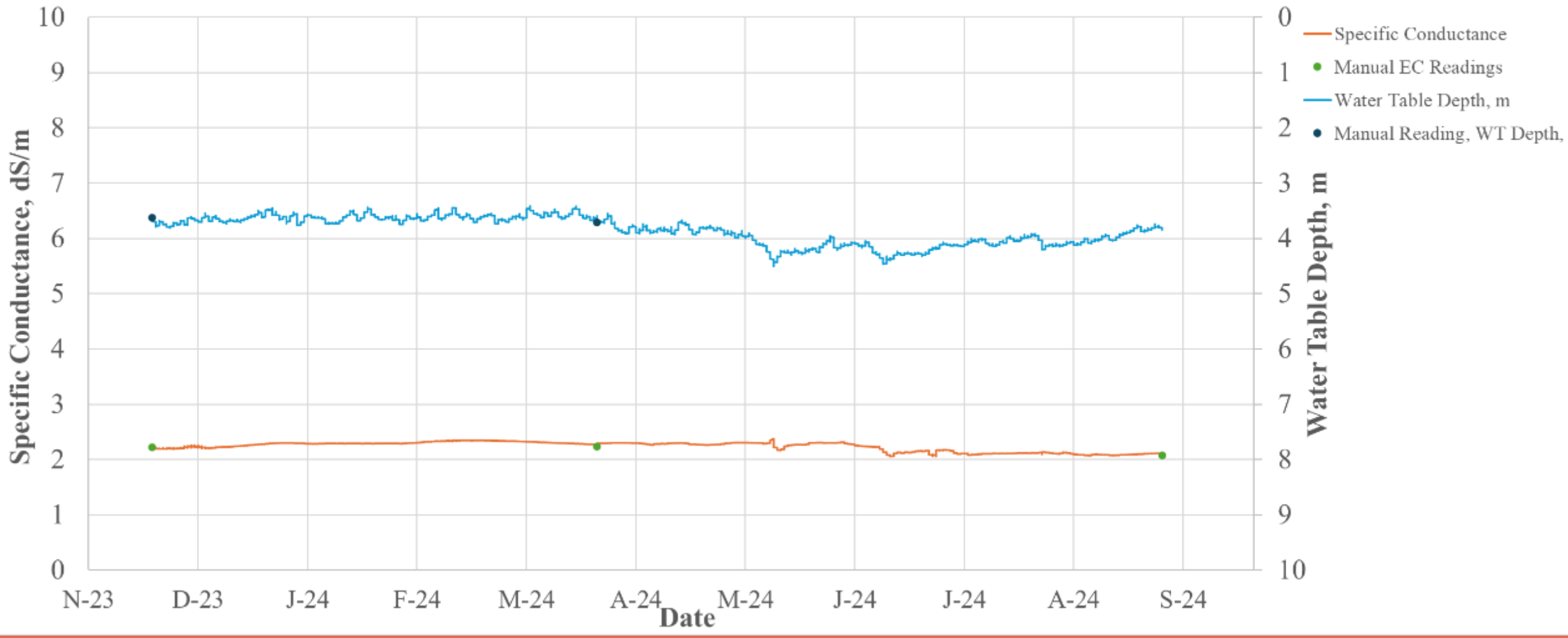
Groundwater Level and Salinity

- 25 wells with continuous water table and EC loggers
- 18 wells with water quality samples (major ions, TDS, pH)

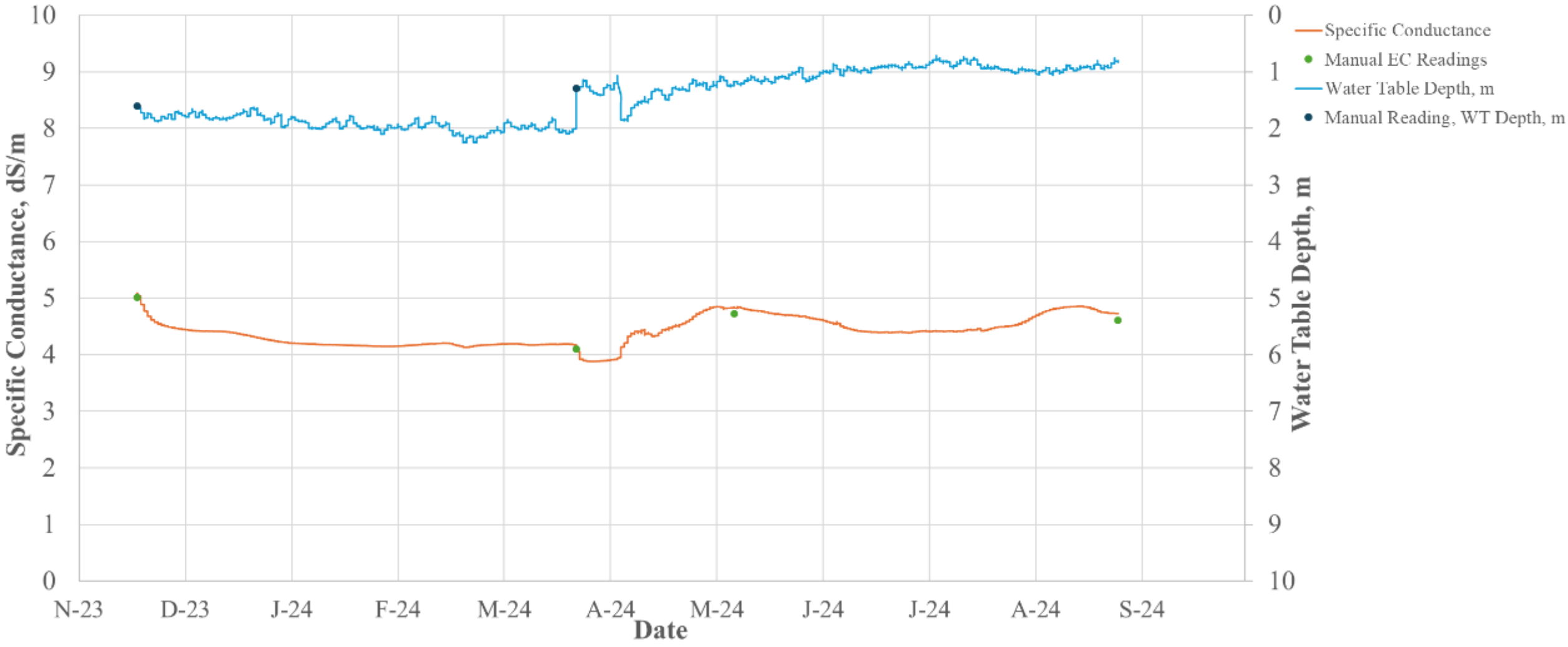
Region 2
Example Groundwater Monitoring Well Data



Region 6
Example Groundwater Monitoring Well Data



Region 7
Example Groundwater Monitoring Well Data

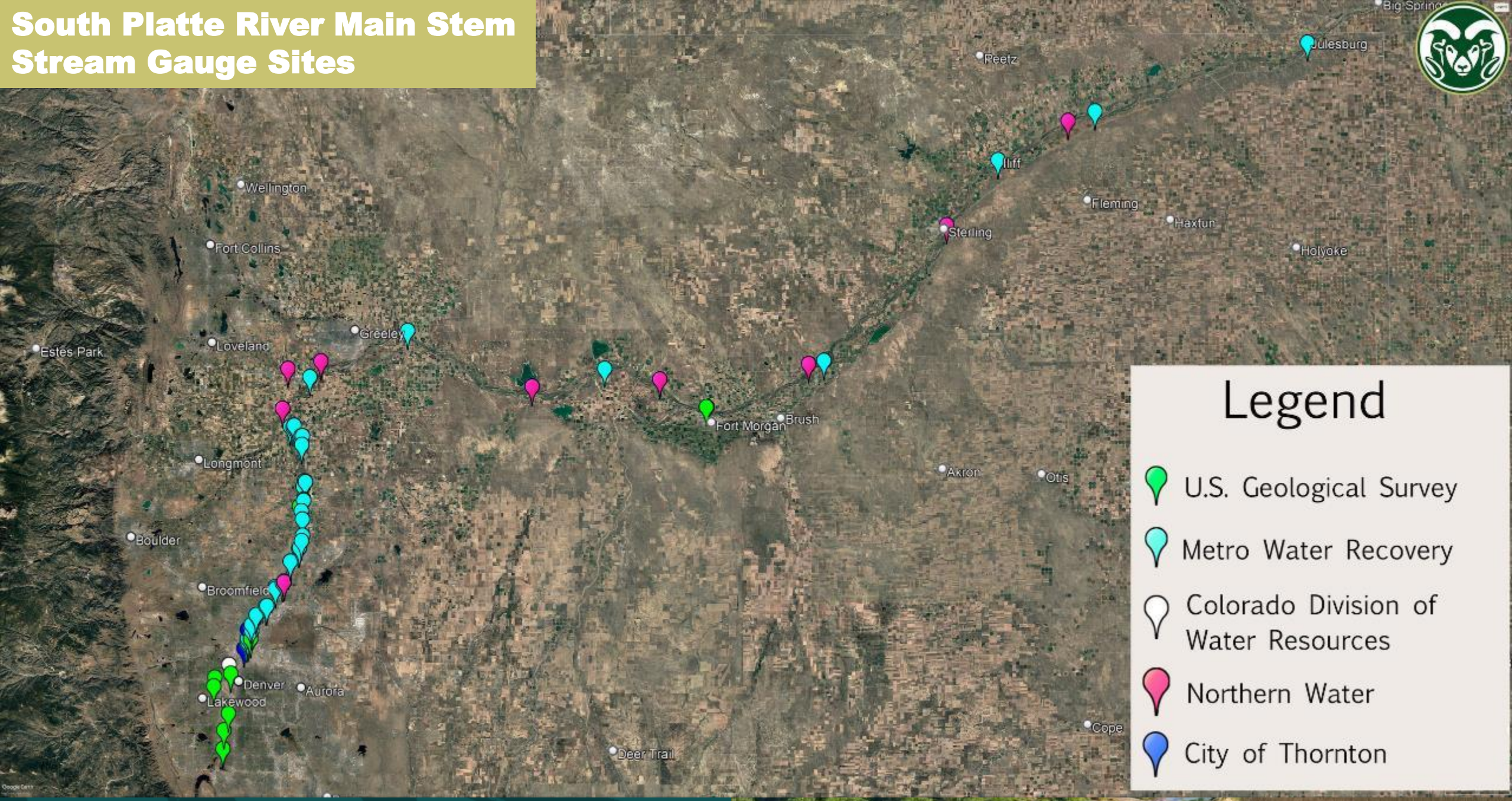


Site	Average Depth to Groundwater (GW) (m)	Average GW EC (dS/m)
R2-1	8.5	3.2
R2-2	3.5	2.1
R2-3	8.7	
R2-4A	5.3	1.4
R2-4B	5.3	1.5
R6-1	11.4	2.0
R6-2	3.2	7.0
R6-3	3.4	2.0
R6-4	3.9	2.2
R6-5A	1.6	4.6
R6-5B	9.5	
R6-6		4.5
R6-7	5.2	2.4
R6-8	1.4	6.2
R7-1	4.2	3.9
R7-2	1.5	4.4
R7-3	3.1	2.6
R7-4	2.5	2.5
R7-5	4.4	2.1
R7-6	2.8	4.9
R7-7	1.7	

Surface Water Salinity

- Identified existing salinity monitoring sites contributed by multiple agencies
- Preparing metadata summary
- Evaluating need for new sites

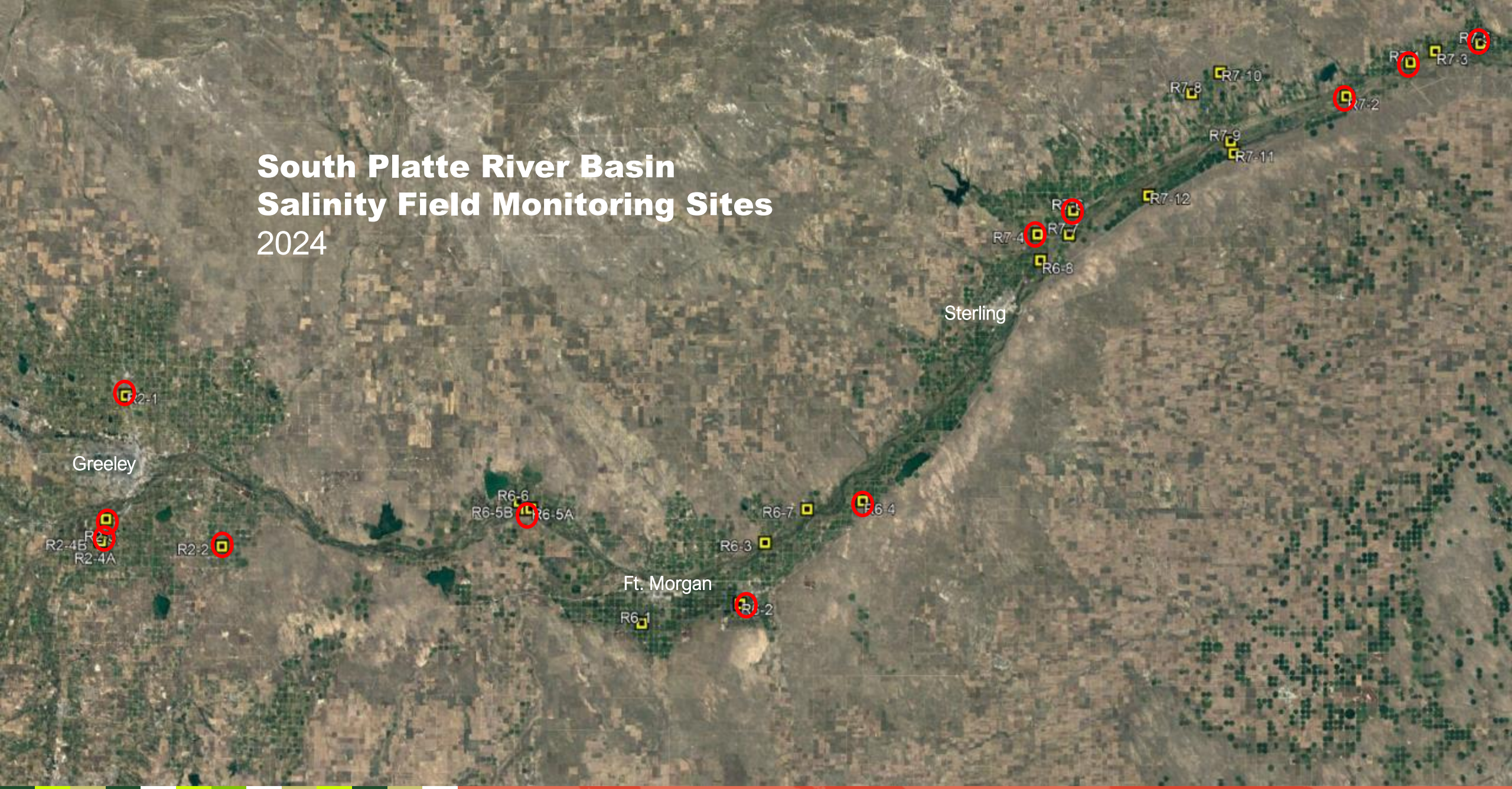
South Platte River Main Stem Stream Gauge Sites



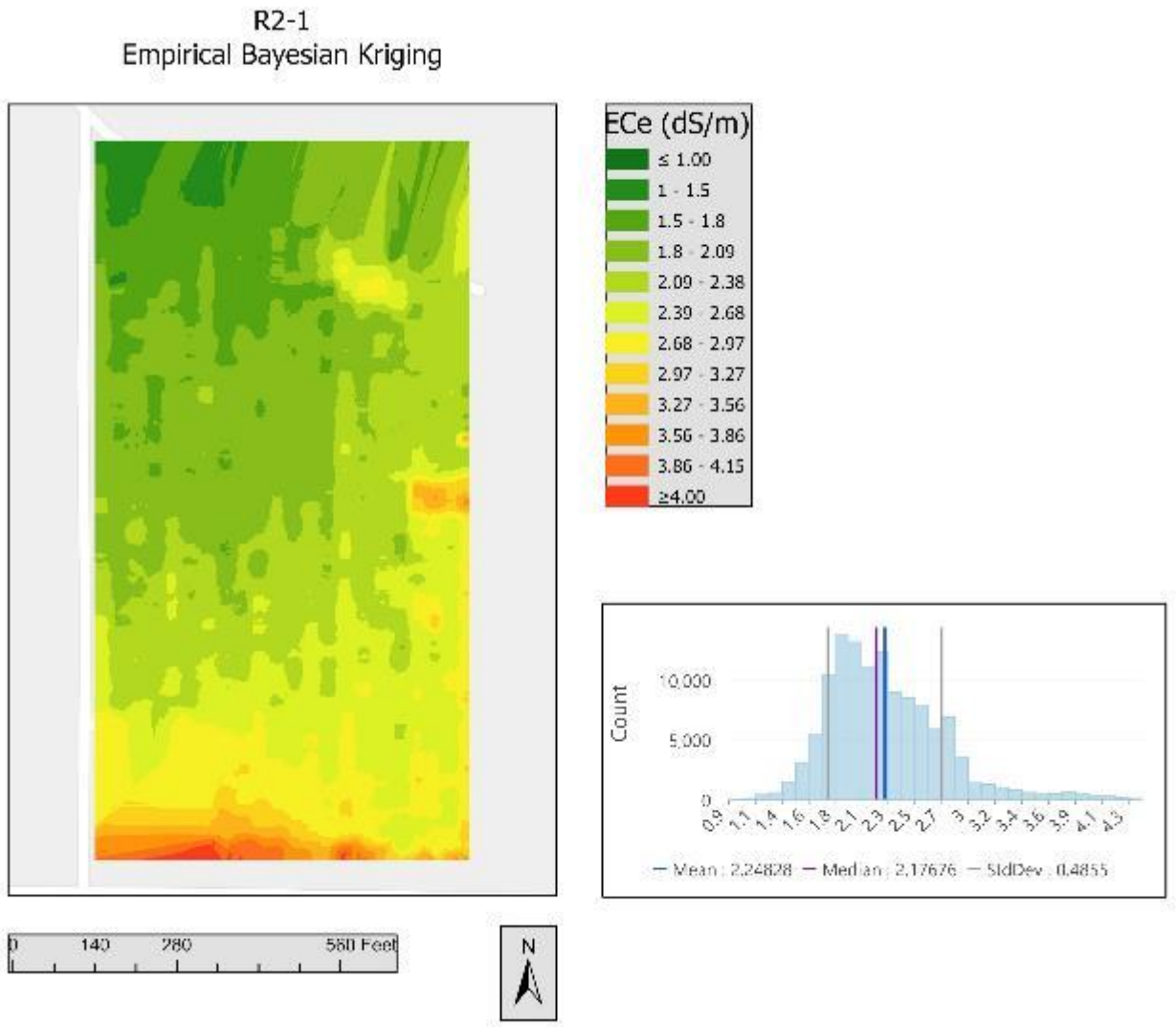
Soil Salinity

- 13 fields surveyed with electromagnetic induction probes
- Calibrated with lab soil salinity, soil water content, soil texture, soil temperature

EM38-MK2 Survey


South Platte River Basin
Salinity Field Monitoring Sites
2024
Greeley
Ft. Morgan
Sterling
R2-1
R2-4B
R2-4A
R2-2
R6-6
R6-5B
R6-5A
R6-7
R6-4
R6-3
R6-2
R6-1
R7-10
R7-8
R7-2
R7-3
R7-9
R7-11
R7-12
R7-4
R6-8

Region 2
Example Soil Salinity (EC_e) Data

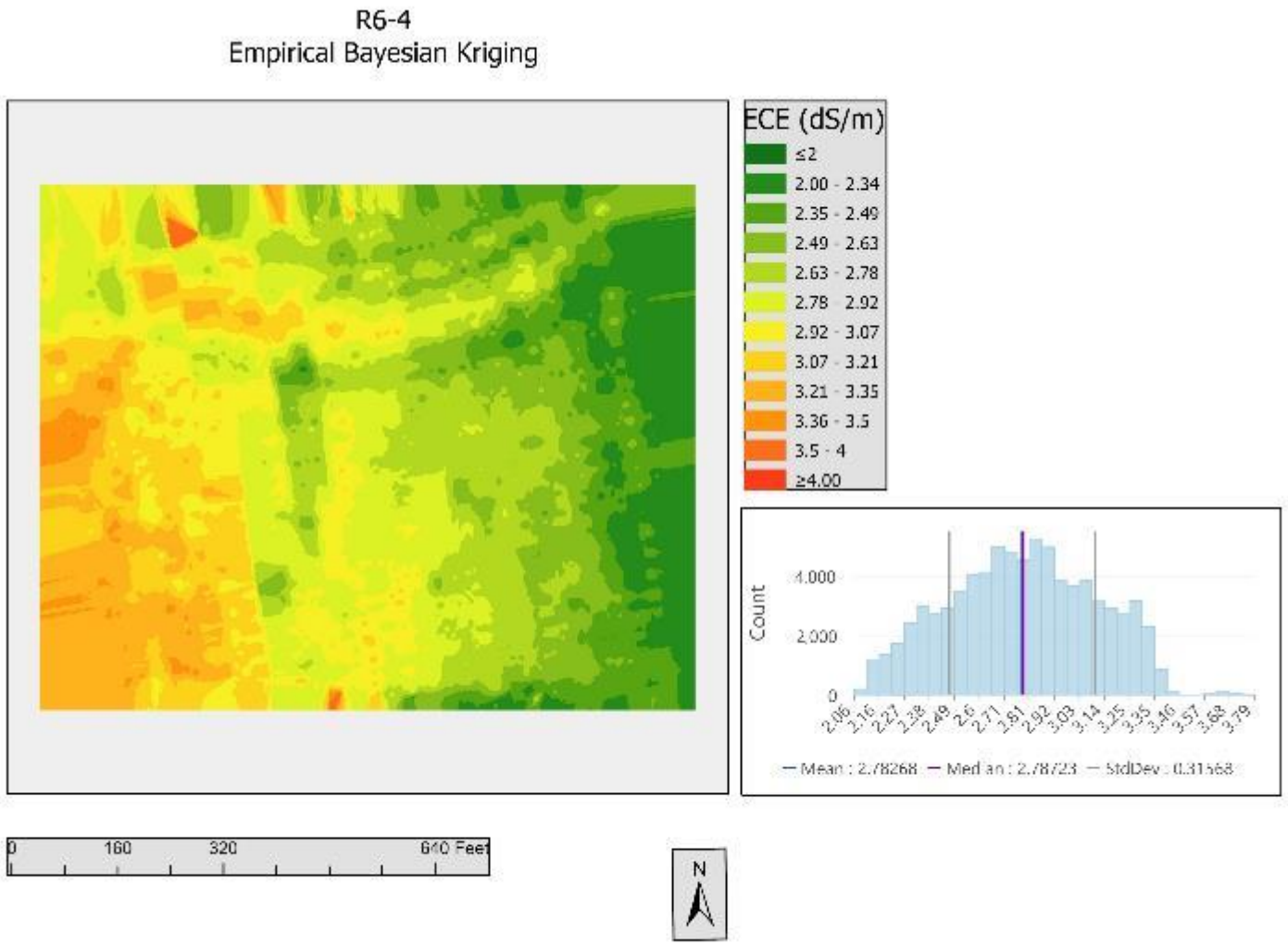


Average EC_e 2.3 dS/m
(Onion Threshold 1.2 dS/m)

99.7% Greater than Threshold

Groundwater:
Average Depth 8.5 m
Average EC 3.2 dS/m

Region 6
Example Soil Salinity (EC_e) Data

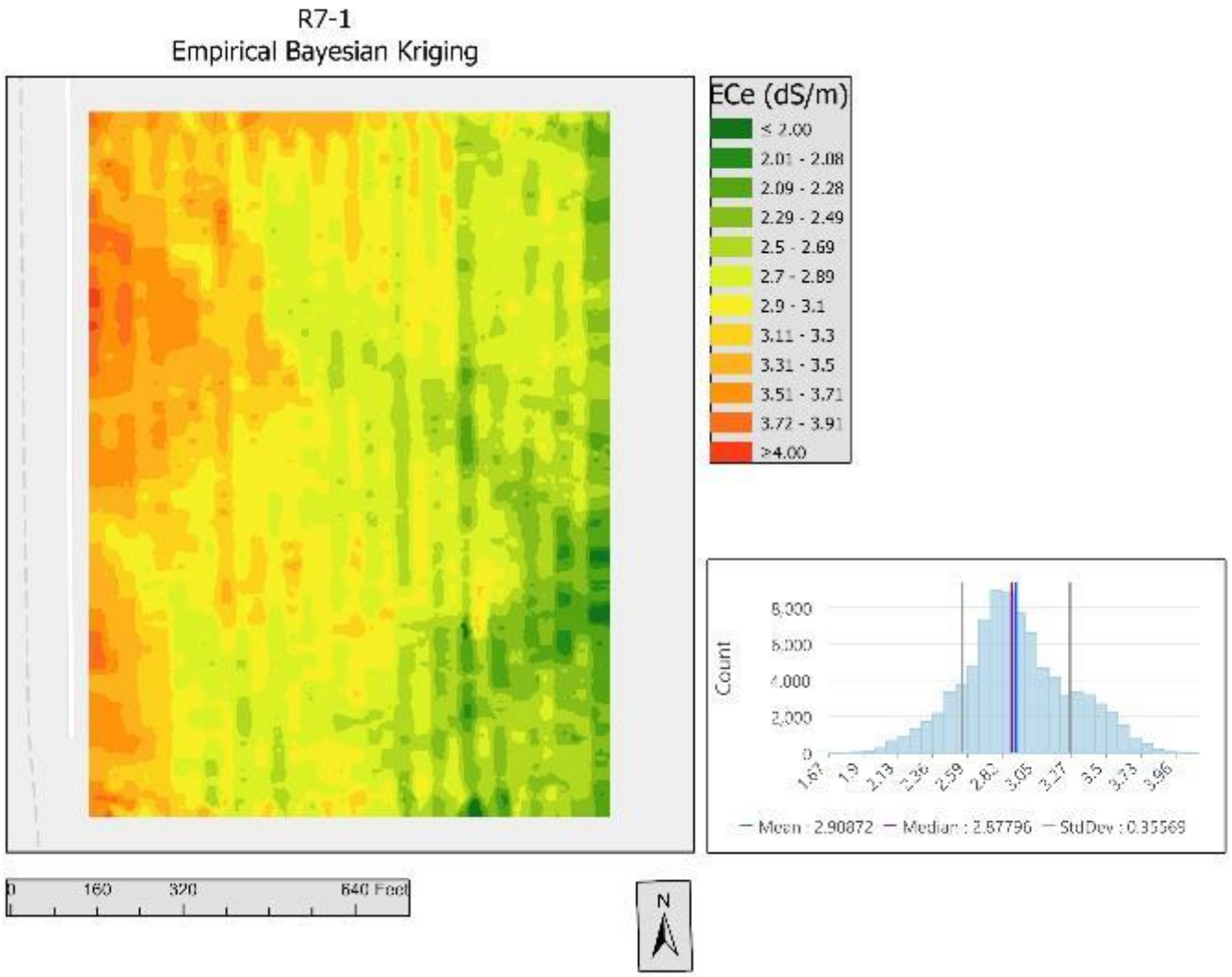


Average EC_e 2.8 dS/m
(Alfalfa Threshold 2 dS/m)

100% Greater than Threshold

Groundwater:
Average Depth 3.9 m
Average EC 2.2 dS/m

Region 7
Example Soil Salinity (EC_e) Data



Average EC_e 2.9 dS/m (Soy Beans Threshold 5 dS/m)

0% Greater than Threshold

Groundwater:
Average Depth 4.2 m
Average EC 3.9 dS/m

Summary

Site	Crop	Crop Salinity Threshold (dS/m)	EM38-MK2 Survey Completed	Dominant soil texture	Average EC_e (dS/m)	Percentage of EC_e Above Threshold	Average Depth to Groundwater (GW) (m)	Average GW EC (dS/m)
R2-1	onion	1.2	Yes	Silt Loam	2.3	99.7	8.5	3.2
R2-2	alfalfa	2.0	Yes	Clay Loam			3.5	2.1
R2-3	cabbage	1.8	Yes	Sandy Loam	1.2	0.4	8.7	
R2-4A	corn	1.7		Sandy Loam			5.3	1.4
R2-4B	corn	1.7		Sandy Loam			5.3	1.5
R6-1	corn	1.7		Sandy Loam			8.8	
R6-2	alfalfa	2.0	Yes	Sand / Sandy Loam	4.2	99.9	3.2	7.0
R6-3	corn	1.7	Yes	Clay Loam	1.8	57	3.4	2.0
R6-4	alfalfa	2.0	Yes	Clay Loam / Sandy Loam	2.8	100	3.9	2.2
R6-5A	alfalfa	2.0		Sandy Loam			3.0	4.6
R6-5B	alfalfa/corn	2.0	Yes	Sandy Loam	2.2	57	2.9	
R6-6	corn	1.7		Clay Loam				
R6-7	corn	1.7		Clay Loam				
R6-8	corn	1.7		Clay Loam				
R7-1	soy beans	5.0	Yes	Sandy Loam / Silt Loam	2.9	0	4.2	3.9
R7-2	grass hay		Yes	Silty Clay Loam / Sandy Loam	2.3		1.5	4.4
R7-3	alfalfa	2.0		Sandy Loam / Silt Loam			3.1	2.6
R7-4			Yes	Loam	3		2.5	2.5
R7-5	alfalfa	2.0	Yes	Silt Loam	2.1	45	4.4	2.1
R7-6	alfalfa	2.0	Yes	Clay Loam			2.8	4.9

Remote Sensing

- Satellite imagery
- Unmanned aerial systems

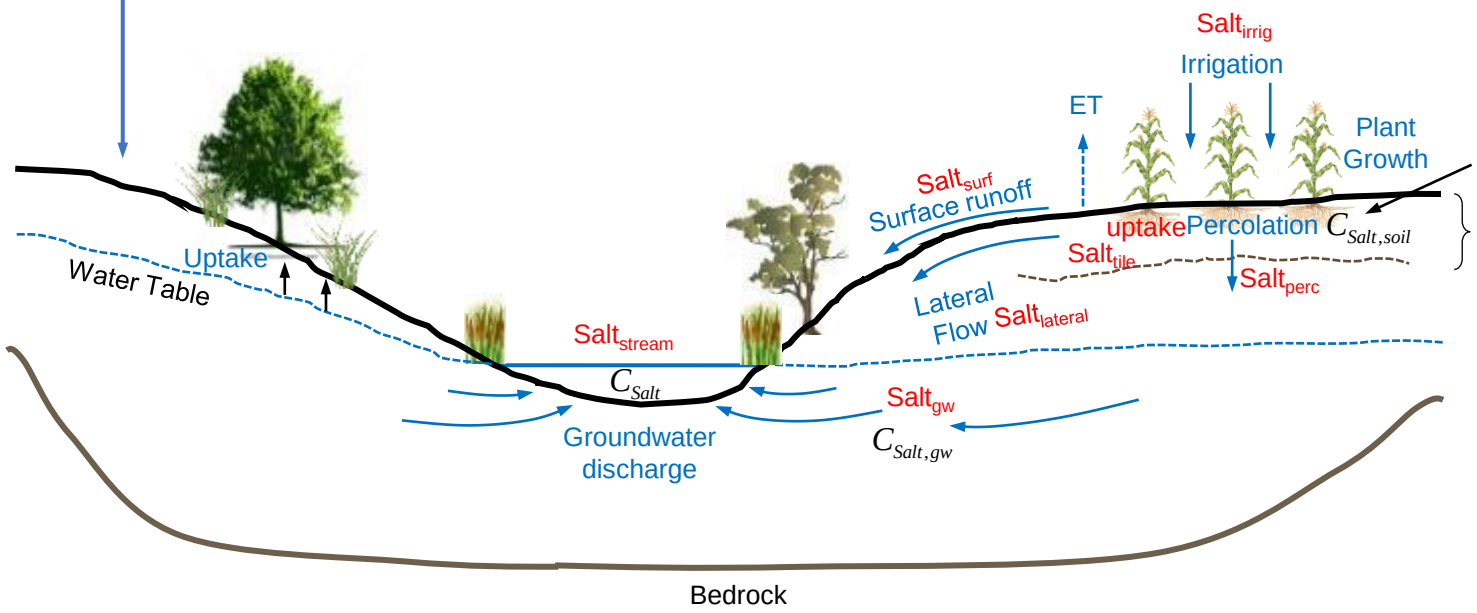
Modeling

Assessing, Forecasting, and Planning for Mitigation of Salt Pollution in Semi-Arid Irrigated Regions

Modeling with SWAT+

External Loadings

1. **Atmospheric Deposition** (rainfall)
2. **Road Salt** (winter weather)
3. **Point Sources** (e.g. WWTP, industry)



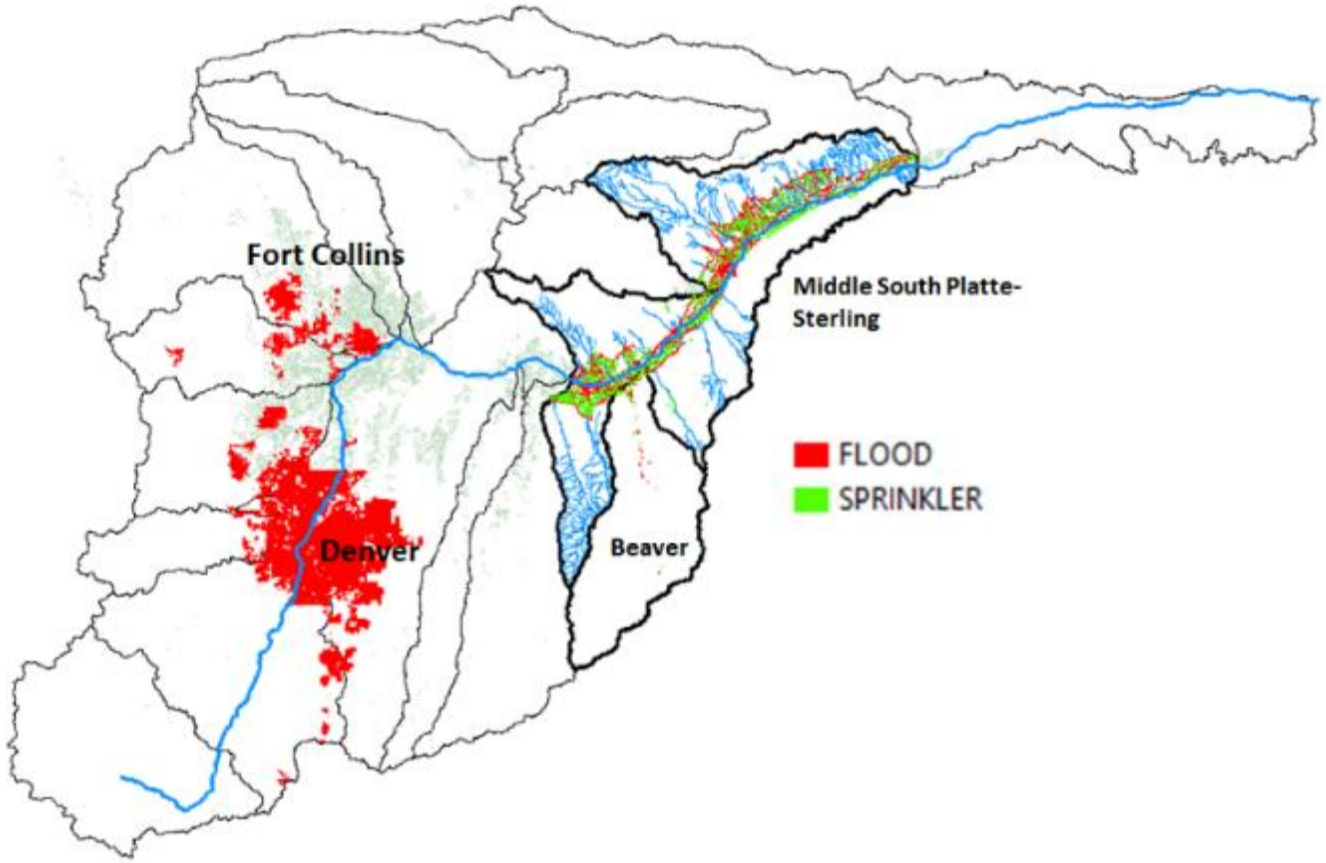
Salinity stress on crop growth

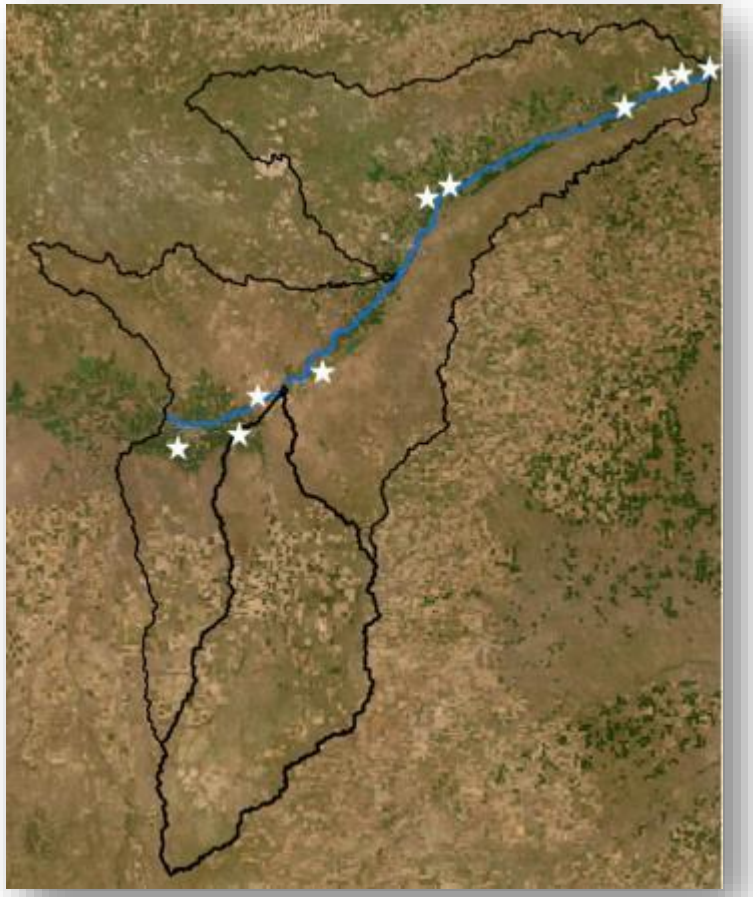
- Precipitation-Dissolution
- Complexation
- Cation Exchange

Salt = SO_4, Ca, Mg, Na, K, Cl, CO_3, HCO_3

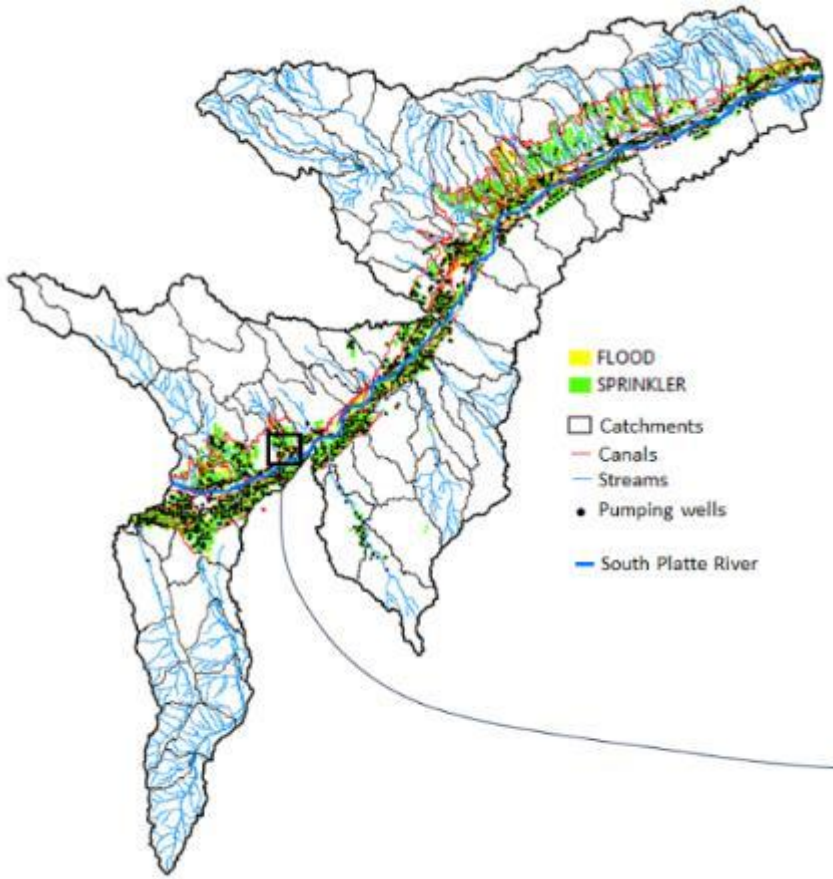
Also: salt mass and concentration in reservoirs/ponds/wetlands

Assessing, Forecasting, and Planning for Mitigation of Salt Pollution in Semi-Arid Irrigated Regions

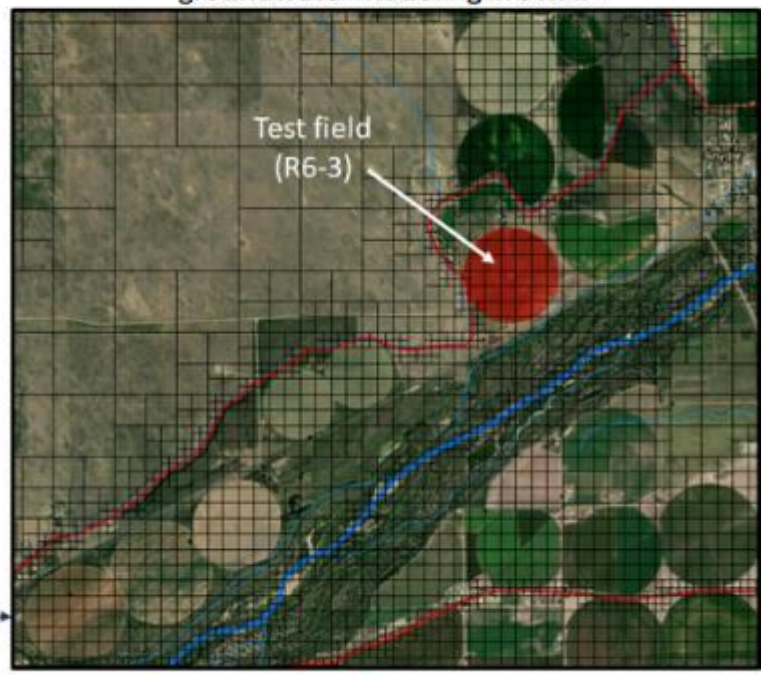




Assessing, Forecasting, and Planning for Mitigation of Salt Pollution in Semi-Arid Irrigated Regions



Unstructured Grid used for groundwater modeling in SWAT+



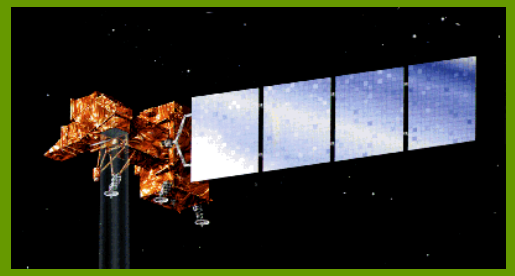
- Unstructured grid
- Simulate canal diversions, recharge ponds, fields, groundwater, groundwater-river exchange (flow, salt ions)
- Test model against streamflow, groundwater levels, groundwater return flows, soil salinity, groundwater salt concentrations, salt ion mass loadings to the South Platte River.

WATER & LAND MANAGEMENT BMPS

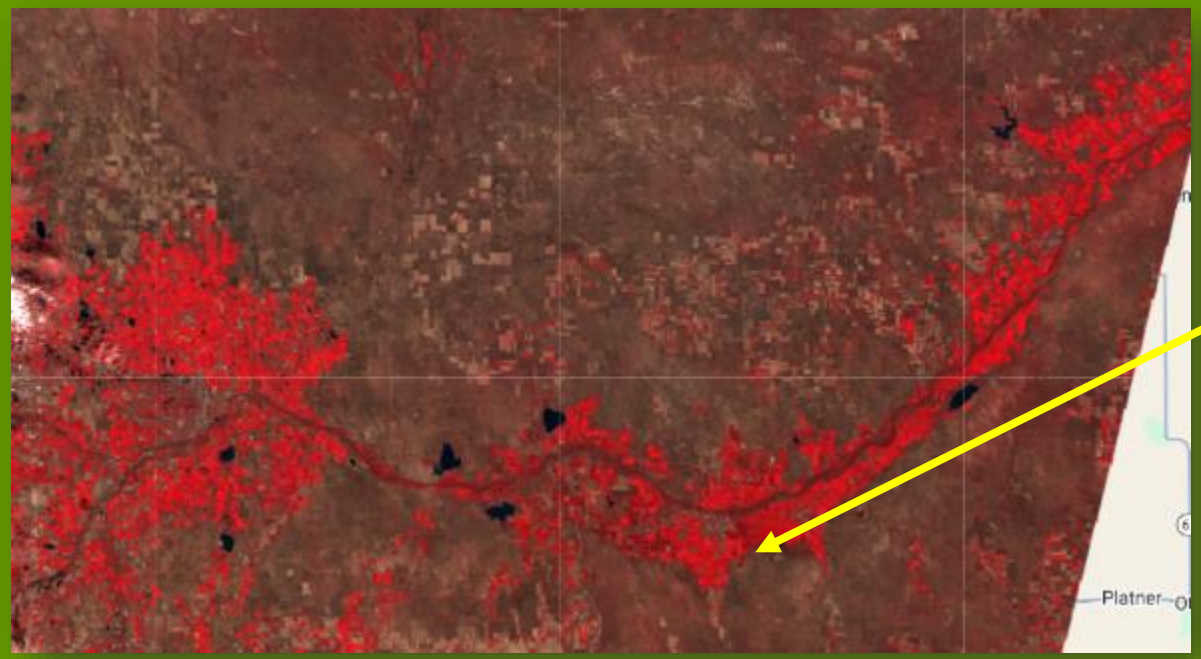
- Reduce excess irrigation applications
- Control canal seepage
- Insure adequate leaching under sprinkler irrigation
- Strategically locate recharge ponds and augmentation wells
- Lower excess fertilizer and manure applications
- Enhance treatment of urban effluent discharge
- Refine control of urban road salt runoff

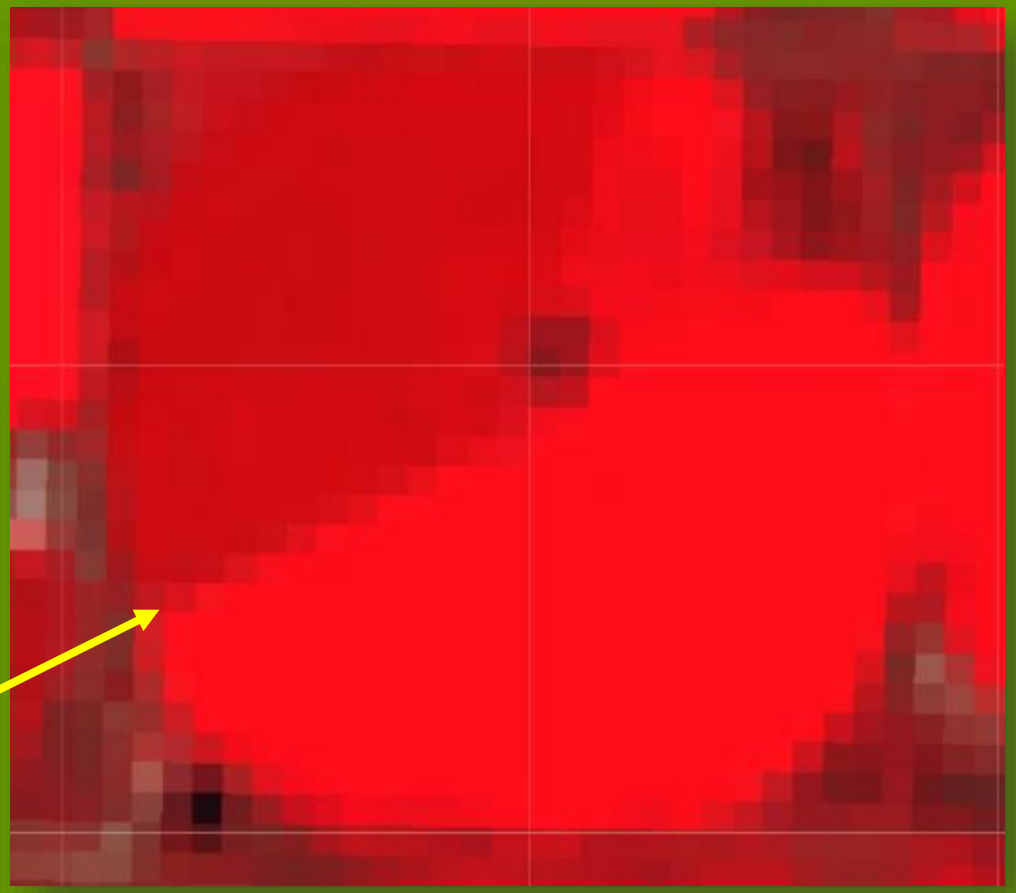

Questions &
Comments

Landsat-9: 30 m pixel spatial resolution



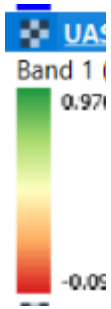
15 Aug 2024



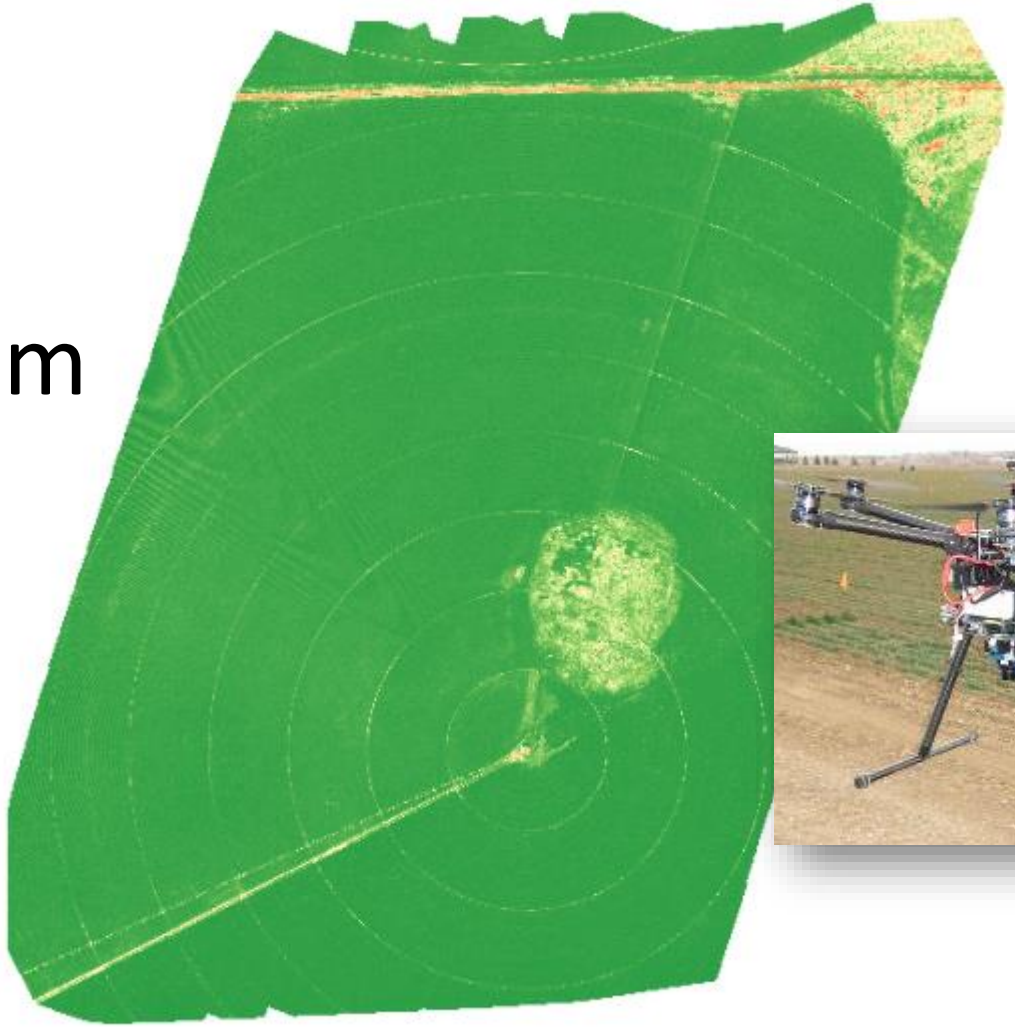


USDA-ARS: UAS - NDVI and Thermal Imagery

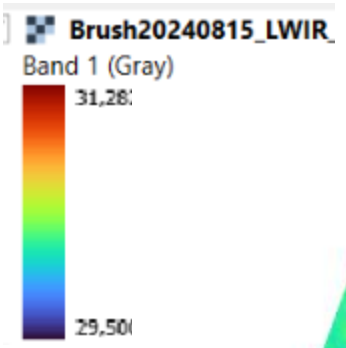
NDVI



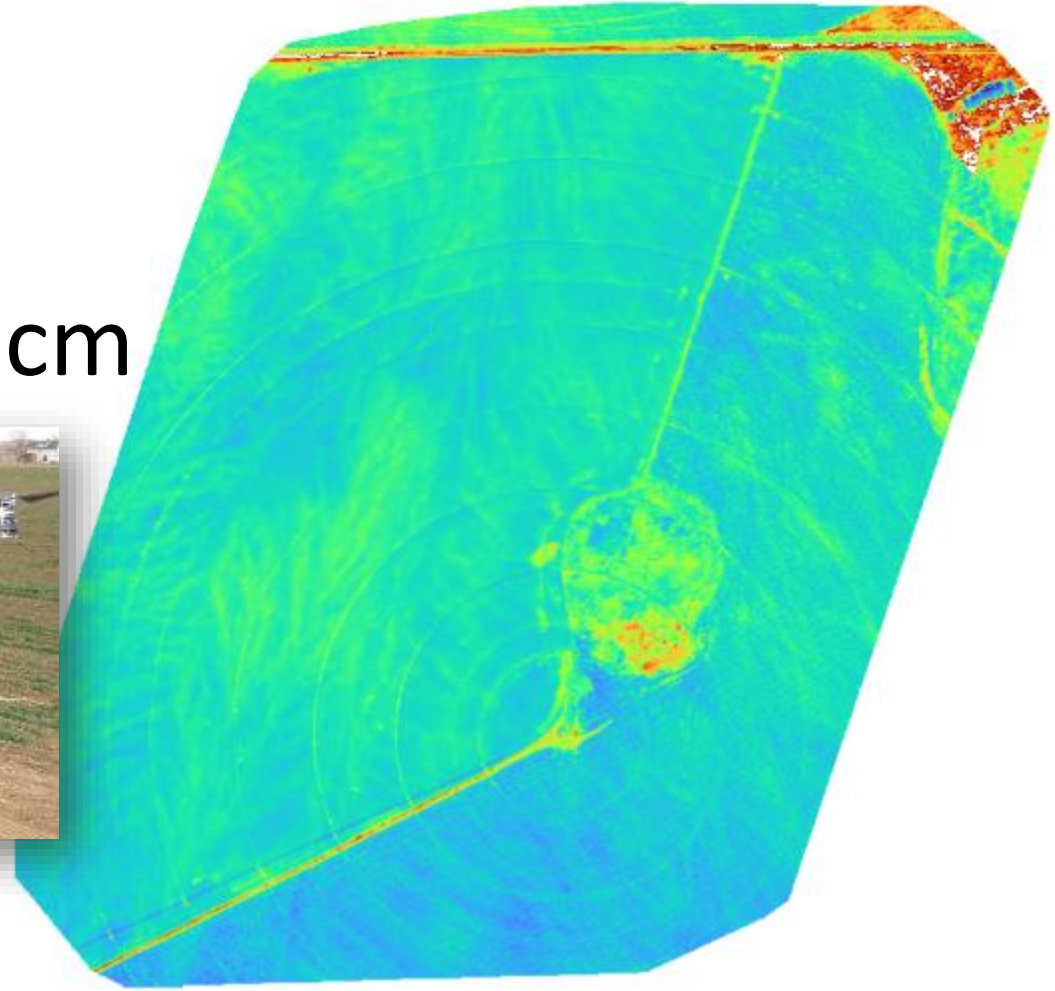
5 cm



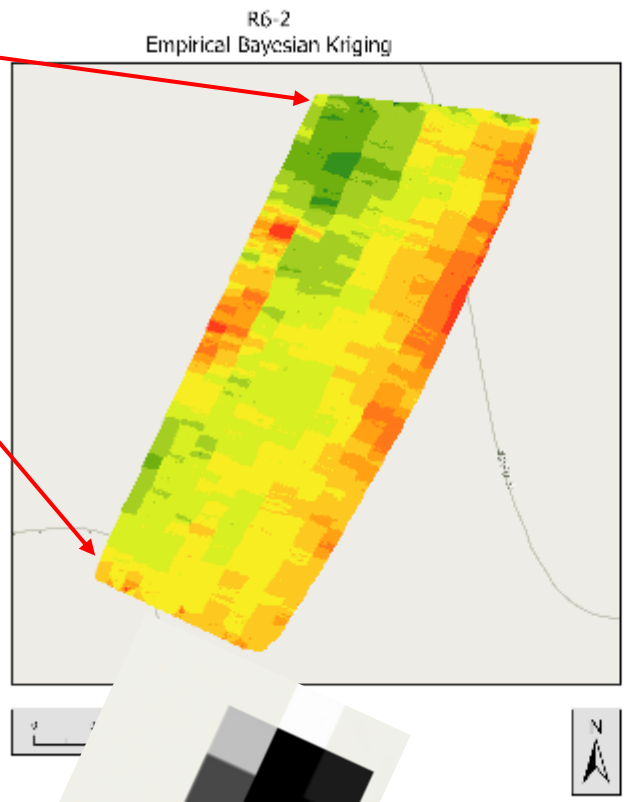
Temperature, °C

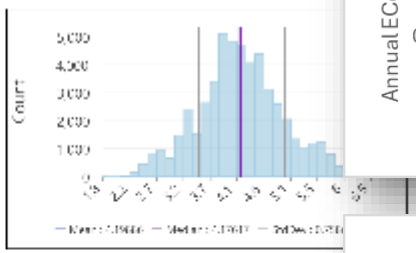


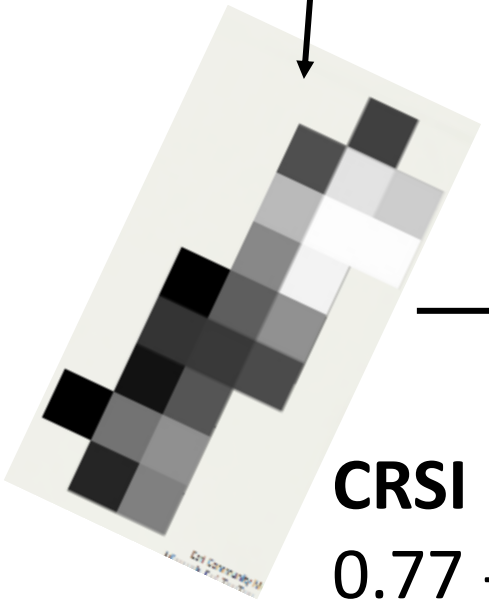
30 cm

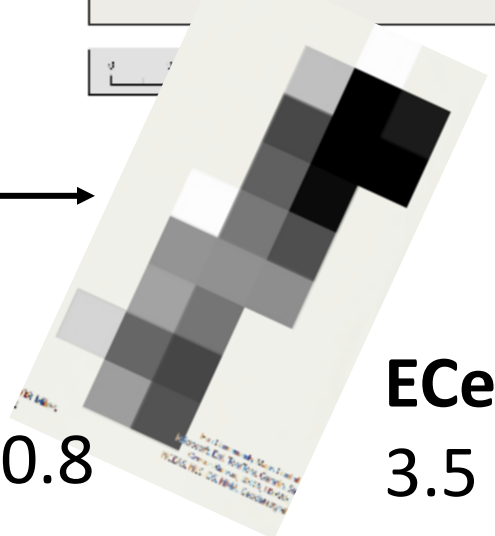


Calibrating RS-based ECe models with EM38-ECe



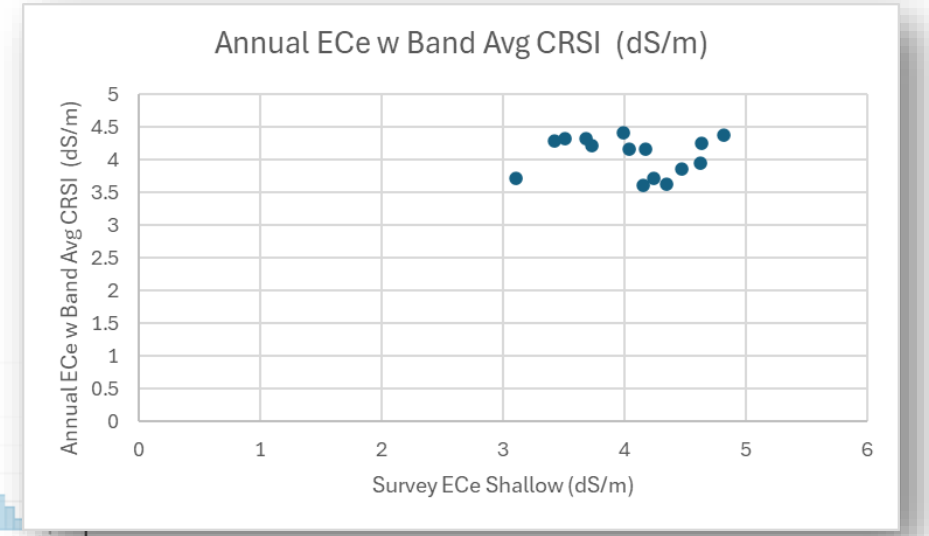


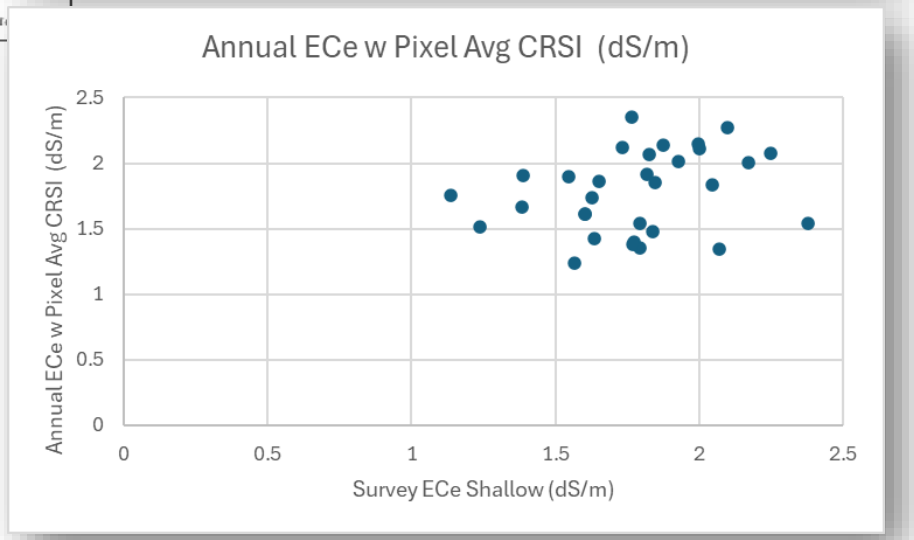




CRSI
0.77 - 0.8

ECe
3.5 - 4.5

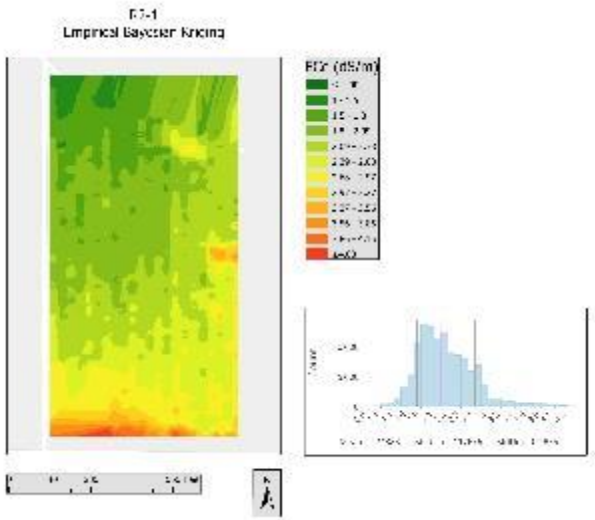


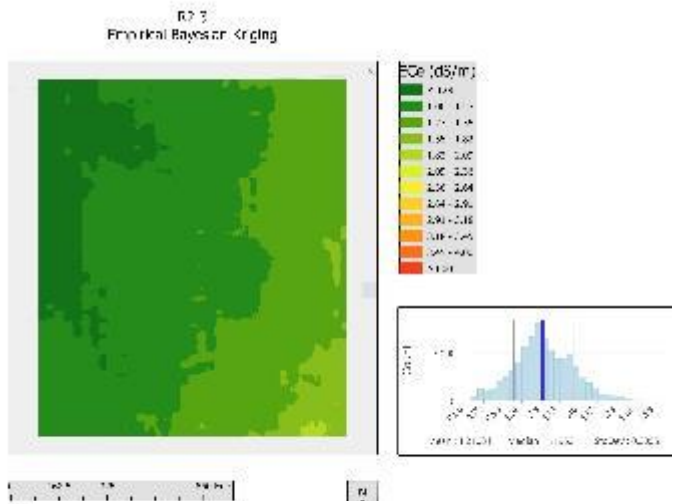


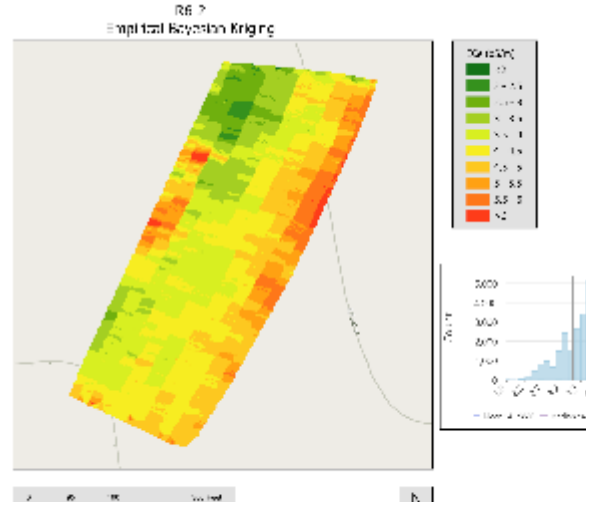

Peetz
Pawnee National Grassland
Wellington
Fort Collins
Fleming
Haxtun
Sterling
Holyoke
Merino
Greeley
Loveland
Fort Morgan
Brush
Longmont
Akron
Otis
Yuma
Eckley
Wray
Boulder
Broomfield
Denver
Aurora
Lakewood
Idalia
Joes
Kirk

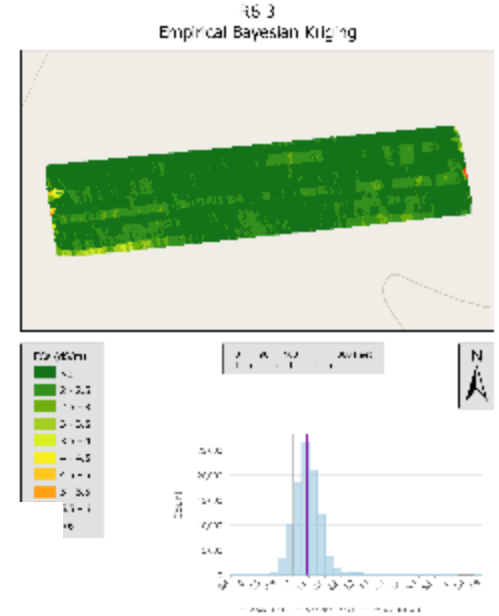
Soil electrical conductivity surveys

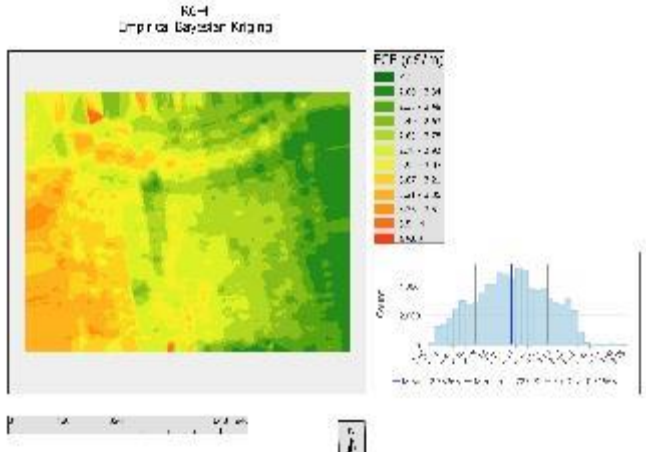
- Geonics EM38-MK2 electromagnetic induction meter with GPS and field computer – soil apparent electrical conductivity (EC_a) measurements at 0 – 0.75 m and 0 – 1.5 m depths
- EM38-MK2 walked near the ground along transects across each field (~ 10,000+ EC_a readings per field)
- Electromagnetic Sampling Analysis and Prediction model (ESAP, ver. 2.35) used to identify 6 or 12 soil sampling locations using EC_a survey data
- Soil samples collected (0 – 1.5 m), air dried, and sent to Ward Labs for saturated paste extract (EC_e) analyses
- Regression (calibration) equation derived and used to convert EC_a readings to estimated EC_e values
- EC_e maps generated in ArcGIS (ESRI, Inc.) using kriging

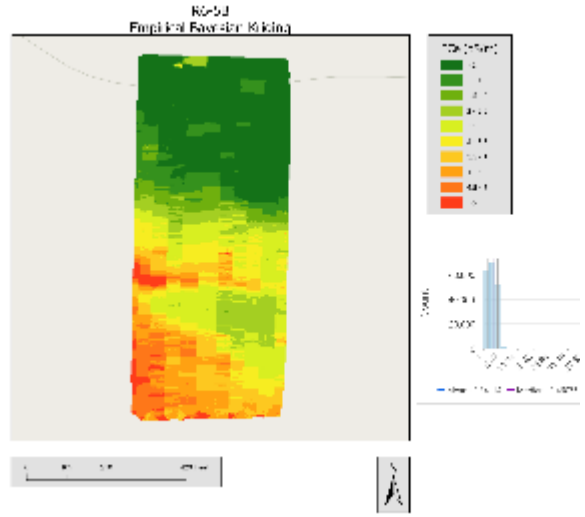

KZ-1
Empirical Bayesian Kriging
ECe (dS/m)

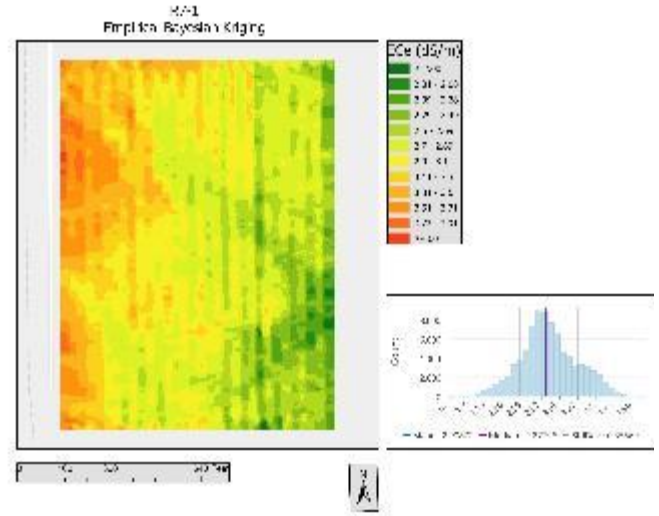

KZ-3
Empirical Bayesian Kriging
ECe (dS/m)

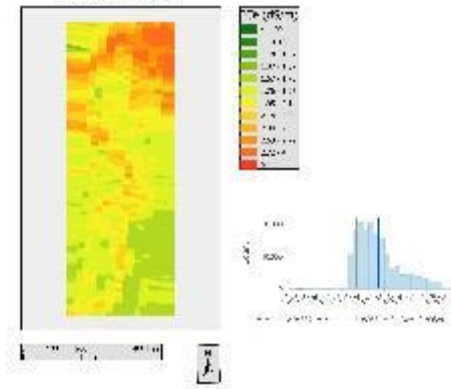

KS-2
Empirical Bayesian Kriging

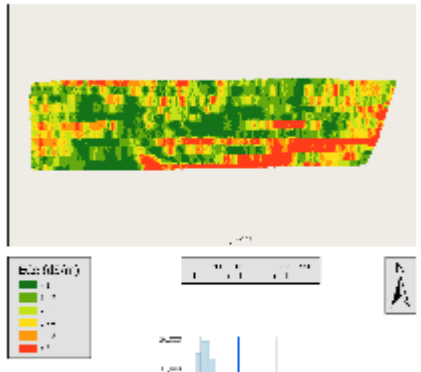

KS-3
Empirical Bayesian Kriging

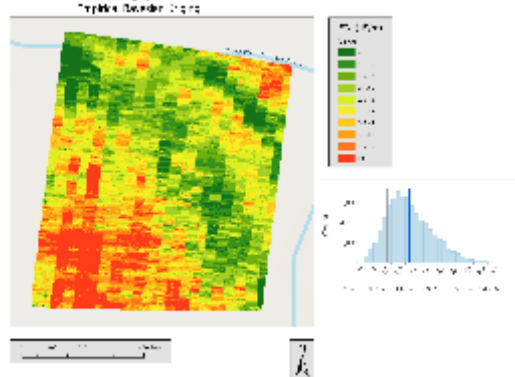

KZ-4
Empirical Bayesian Kriging
ECe (dS/m)


KZ-5
Empirical Bayesian Kriging


KZ-1
Empirical Bayesian Kriging
ECe (dS/m)


KS-1
Empirical Bayesian Kriging


KZ-2
Empirical Bayesian Kriging


KZ-1
Empirical Bayesian Kriging