



# Groundwater Workshop

JANUARY 24, 2023





# Chris Lee

SOLANO COUNTY WATER AGENCY

# Groundwater Workshop

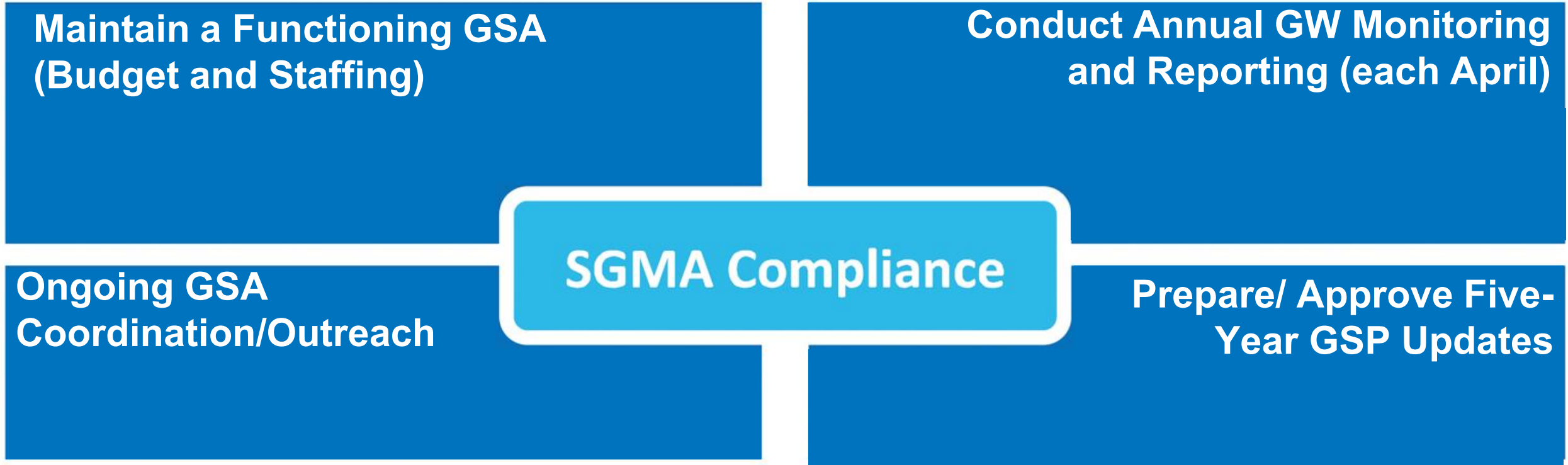
January 24, 2023

## Welcome to the Solano Subbasin



Chris Lee  
Solano County Water Agency/Solano Groundwater Sustainability Agency

# California SGMA Requirements



# Solano Subbasin is Comprised of Multiple GSAs

- Groundwater Sustainability Plan (Plan Area)
- Find out if you are located in the Solano Subbasin: [solanogsp.com/solano-subbasin/](http://solanogsp.com/solano-subbasin/)

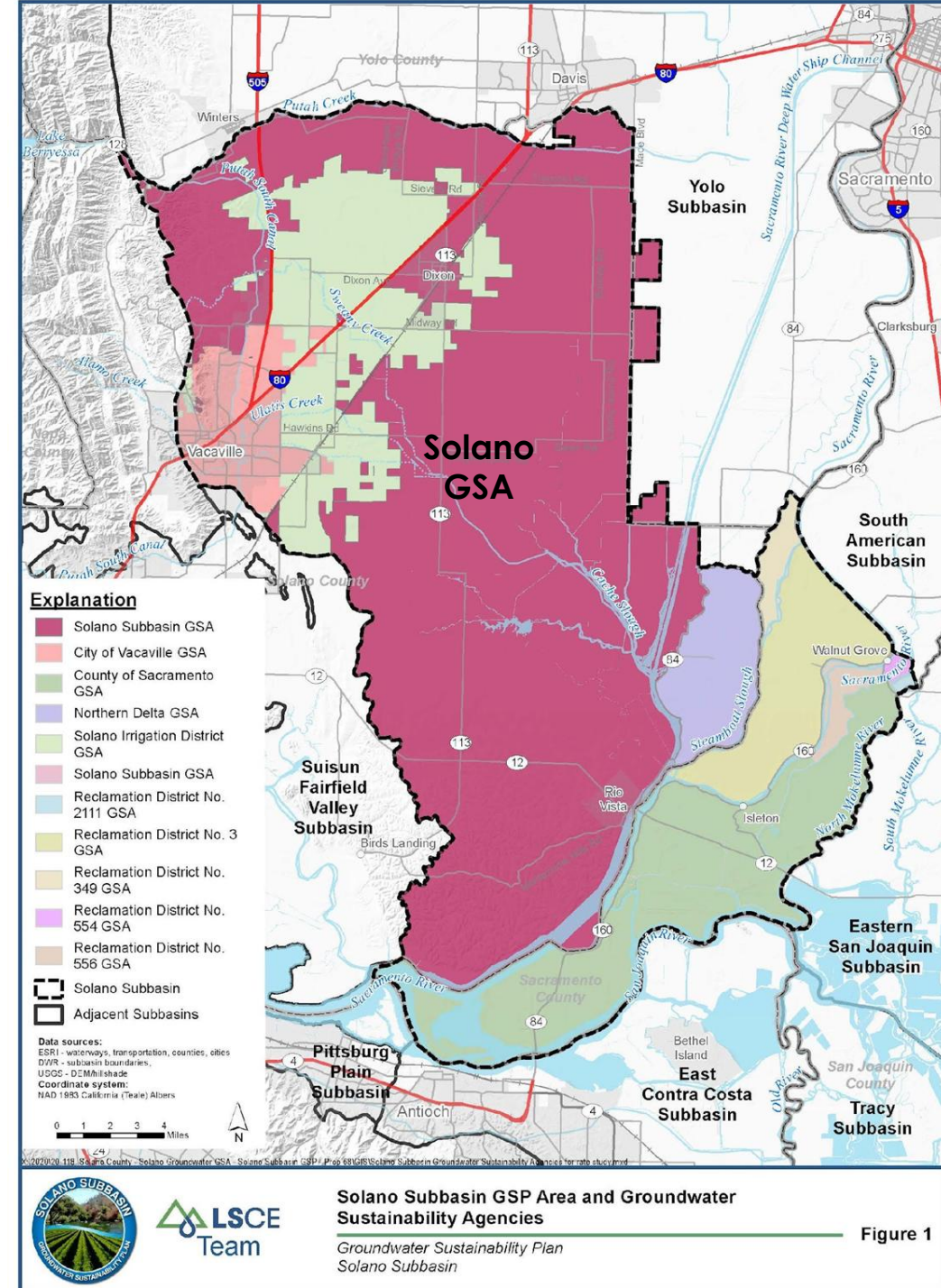


Figure 1

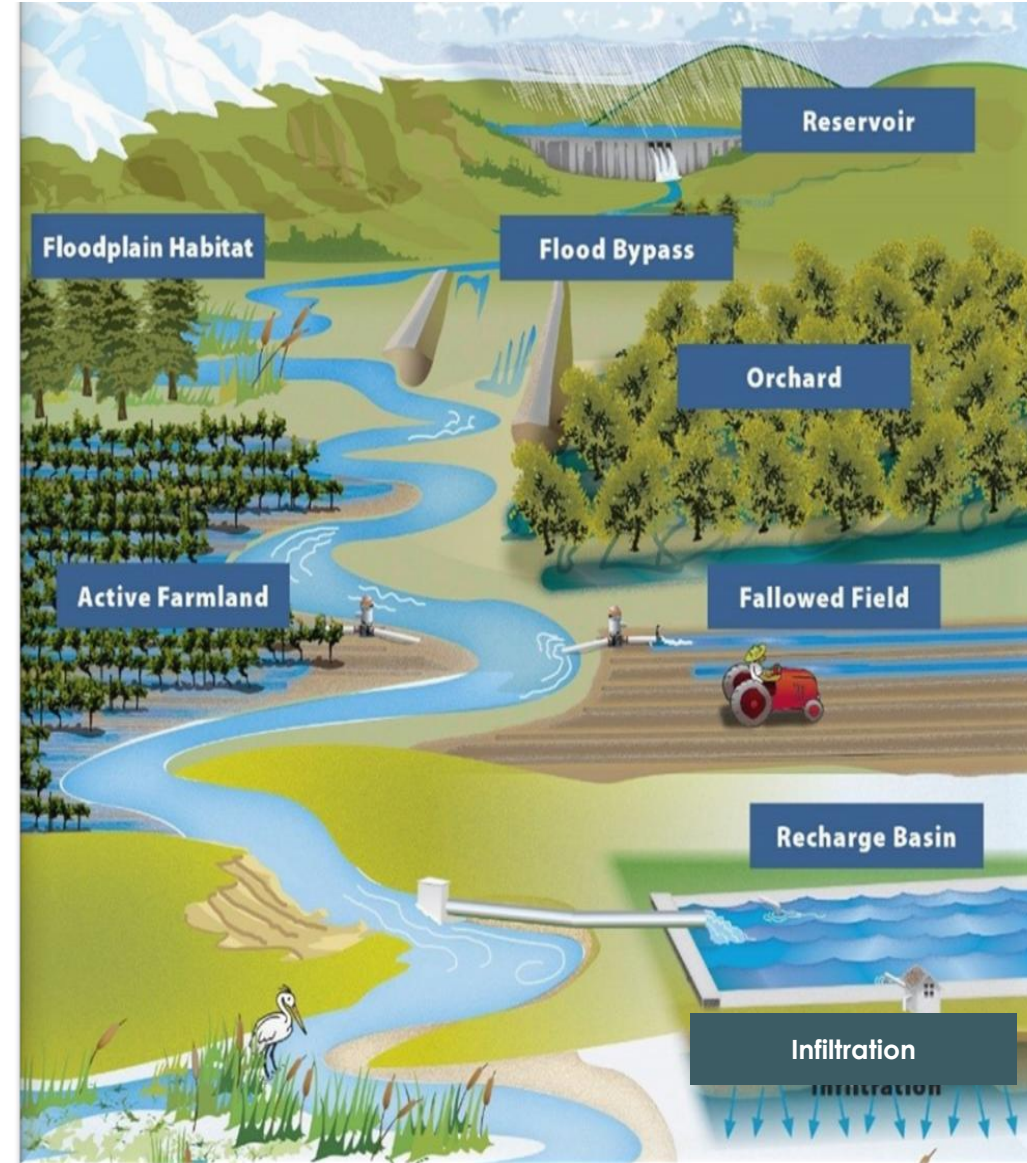
# Solano Collaborative



**Independent Reclamation District (RD) GSAs; RD 3, RD 349, RD 555, RD 556, RD 2111, RD 317**

# GSP Implementation: Ongoing Activities

- Annual Reports and Five-Year Updates
- Tracking Groundwater Conditions
- Projects and Management Actions
- Outreach
- Grant Opportunities



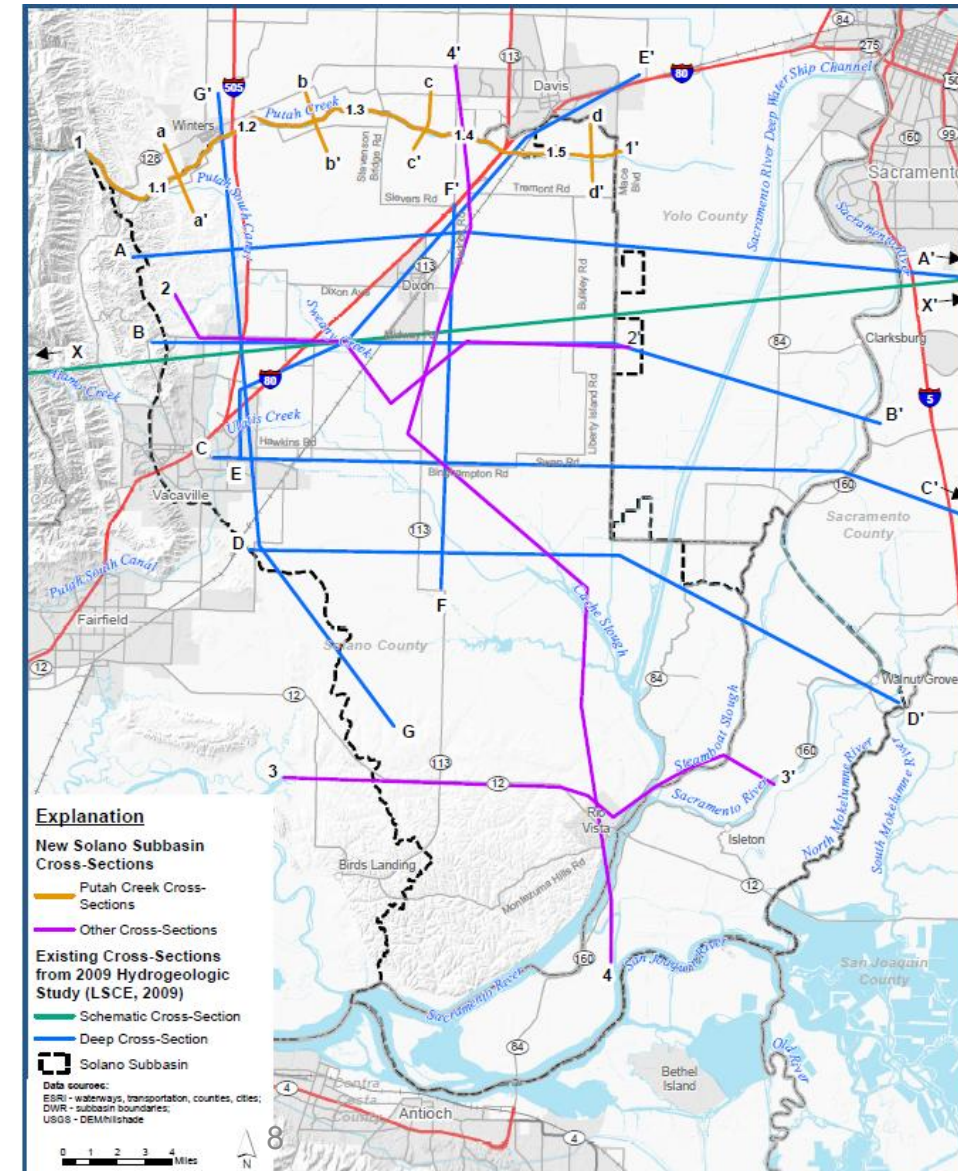
# Hydrogeologic Conceptual Model



## § 354.14. Hydrogeologic Conceptual Model

Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.

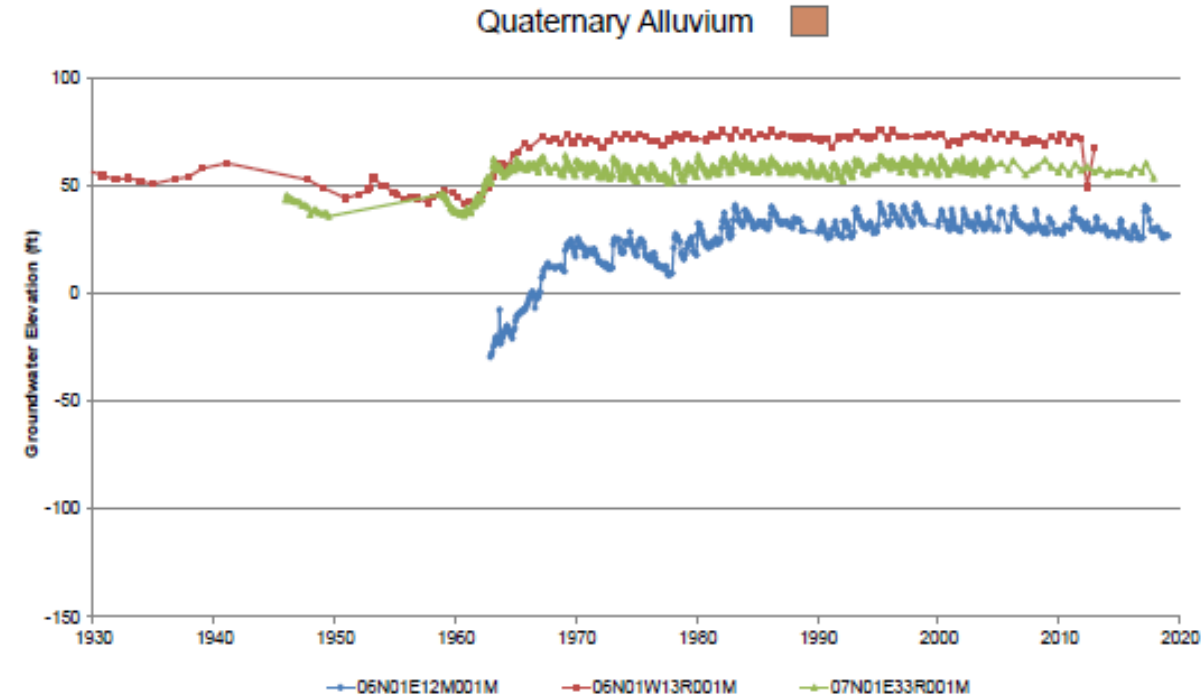
- **Geologic Cross Sections (Key Component of HCM)**
  - 7 prior cross sections focused on deeper conditions
  - 8 new cross sections to enhance HCM
    - 5 shallow sections along Putah Creek
    - 3 across northern and southern areas of Subbasin
- **Lithologic & Geophysical Logs: Characterize Subsurface Sediments to Depths >2500 Ft**



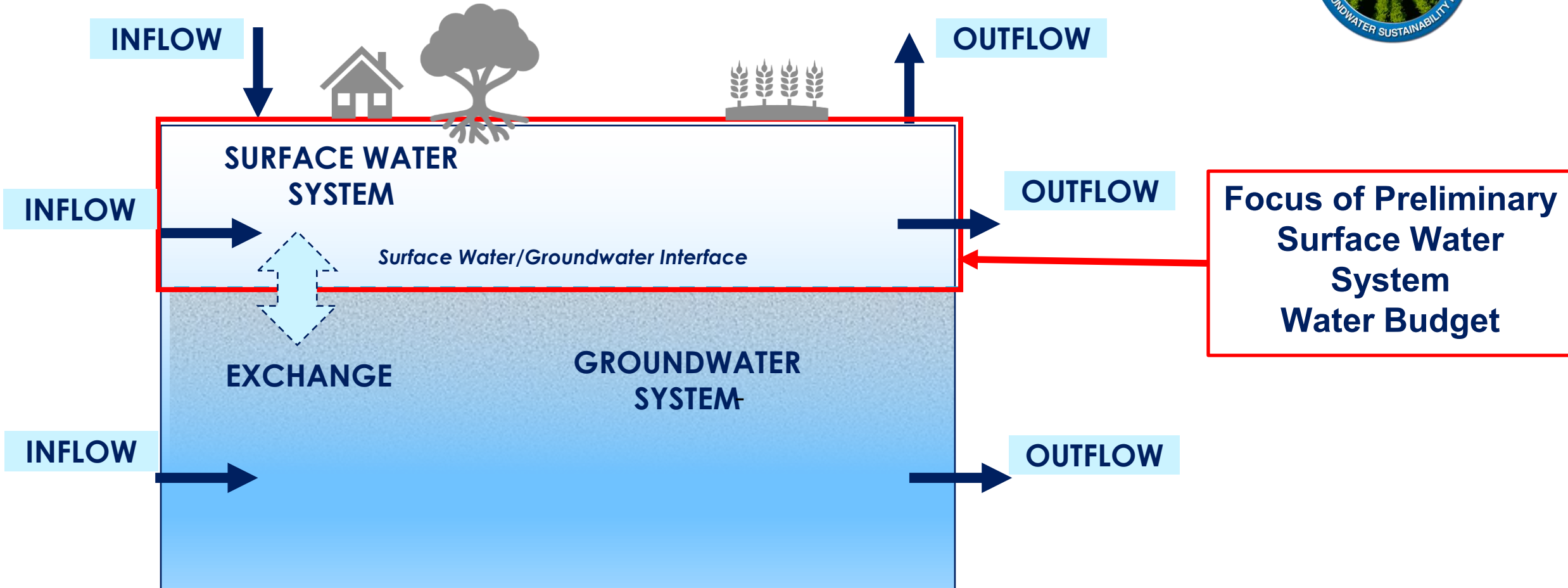


# HCM and Groundwater Conditions

- Previous Hydrogeologic Studies
- Numerous Figures/Maps
- Groundwater Data and Analyses (historical by aquifer/depth zone)
  - GW levels (hydrographs; contours)
  - GW quality (key constituents: TDS; nitrate; boron; arsenic; chromium 6)

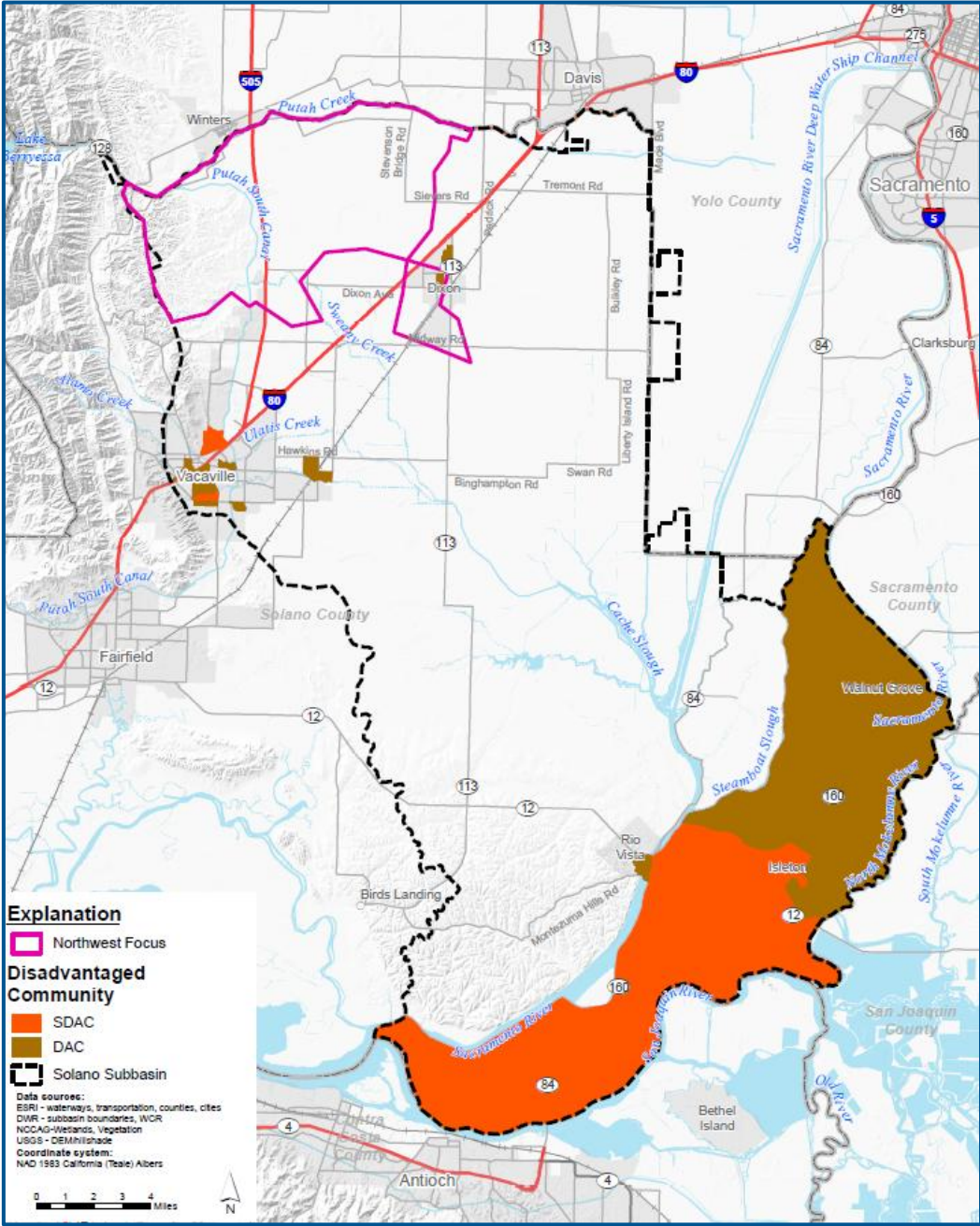


# Water Budget Schematic: Preliminary Surface Water System Water Budget



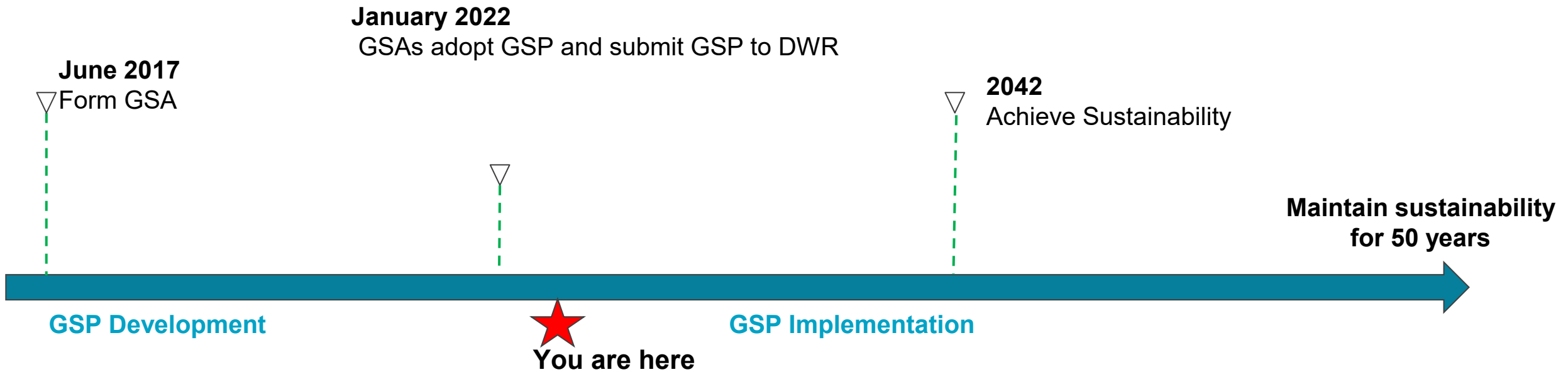


# Northwest Focus Area



# Solano Subbasin – Long-Term Funding Strategy

## SGMA Timeline



Occurring throughout:

- Outreach & Engagement
- Monitoring & Adaptive Management
- Annual reports and 5-year updates

# Upcoming Grant Funding Opportunities

<b>Example:</b>	<b>Department of Water Resources SGMA Implementation – Round 2 Funding Cycle</b>
<b>Purpose:</b>	<b>To provide funding support for implementation activities including annual reports, five-year updates, projects, and management actions</b>
<b>Timeline:</b>	<b>Grant application will be submitted in approx. Fall/Winter 2022</b>
<b>GSA Charges:</b>	<b>Will be adjusted accordingly based on future grant funding</b>

# Proposition 68 Grant Application

Grant Funding Requests			
Project Title	Cost	Component Ranking	Comments
Component 1- Grant Administration	\$391,000	5	Currently assumes maximum allowable at 10%
Component 2- GSP Monitoring and Data Management Enhancements	\$970,000	2	
Task 1: Monitoring Enhancements and Addressing Monitoring Data Gaps	\$340,000		
Task 2: Data Management System Enhancements	\$250,000		
Task 3: Interconnected Surface Water (ISW) and Groundwater Dependent Ecosystems (GDEs) and Putah Creek Projects	\$380,000		
Component 3- Supporting Groundwater Use Management Actions	\$1,075,000	3	
Task 1: Improving Understanding of Basin Water Use	\$375,000		
Task 2: Local Water Conservation and Management	\$400,000		
Task 3: Groundwater Management Policy- Positioning for the Future	\$300,000		
Component 4- Water Supply Replenishment and Reliability Projects	\$900,000	4	
Task 1- Recharge Study – Targeted Augmentation	\$600,000		
Task 2- Localized Groundwater Conditions Evaluation (near Lake Solano)	\$150,000		
Task 3- City of Vacaville Recycled Water Planning	\$150,000		
Component 5- GSP Implementation, Outreach, and Compliance Activities	\$965,000	1	
Task 1- Prepare Annual Reports	\$400,000		Annual reports WY 2022-2025
Task 2- Modify GSP in Response to DWR Determination	\$15,000		
Task 3- Five-Year GSP Update	\$325,000		Due January 2027, grant funding expires April 2026; approx. 50% of total cost included
Task 4- Stakeholder Engagement and Community Outreach	\$225,000		
Total Funds Requested	\$4,301,000		

# Multiple ways to stay involved



## Ongoing outreach via:

- Website: [SolanoGSP.com](http://SolanoGSP.com)
- Newsletters
- Press Releases
- Town Halls
- Events in partnership with RCDs
- Individual GSA Board meetings

## Work with beneficial user groups includes:

- Projects and Management Actions
- Inter-basin Coordination
- Intra-basin Coordination
- Tribes
- Disadvantaged Communities



**THANK YOU**



# Vicki Kretsinger Grabert

LUHDORFF & SCALMANINI CONSULTING ENGINEERS



**SACRAMENTO VALLEY WATERSHEDS:  
REGIONAL COLLABORATIVE APPROACHES TO MAINTAINING  
AND IMPROVING GROUNDWATER QUALITY**

January 24, 2023

Vicki Kretsinger Grabert, Lohdorff & Scalmanini, Consulting Engineers

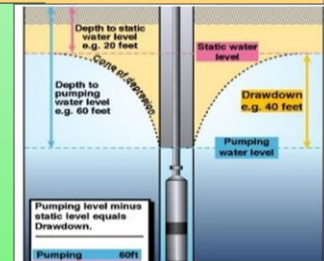
# OVERVIEW

- Nitrate in Groundwater: Occurrence in Sacramento River Watershed
- SVWQC Irrigated Lands Regulatory Program: GAR Update and AGLAND Domestic Wells' Results
- Central Valley BPA: Nitrate Control Program
- Sustainable Groundwater Management Act



BPA Management Zone (MZ)

SGMA Groundwater Sustainability Plans



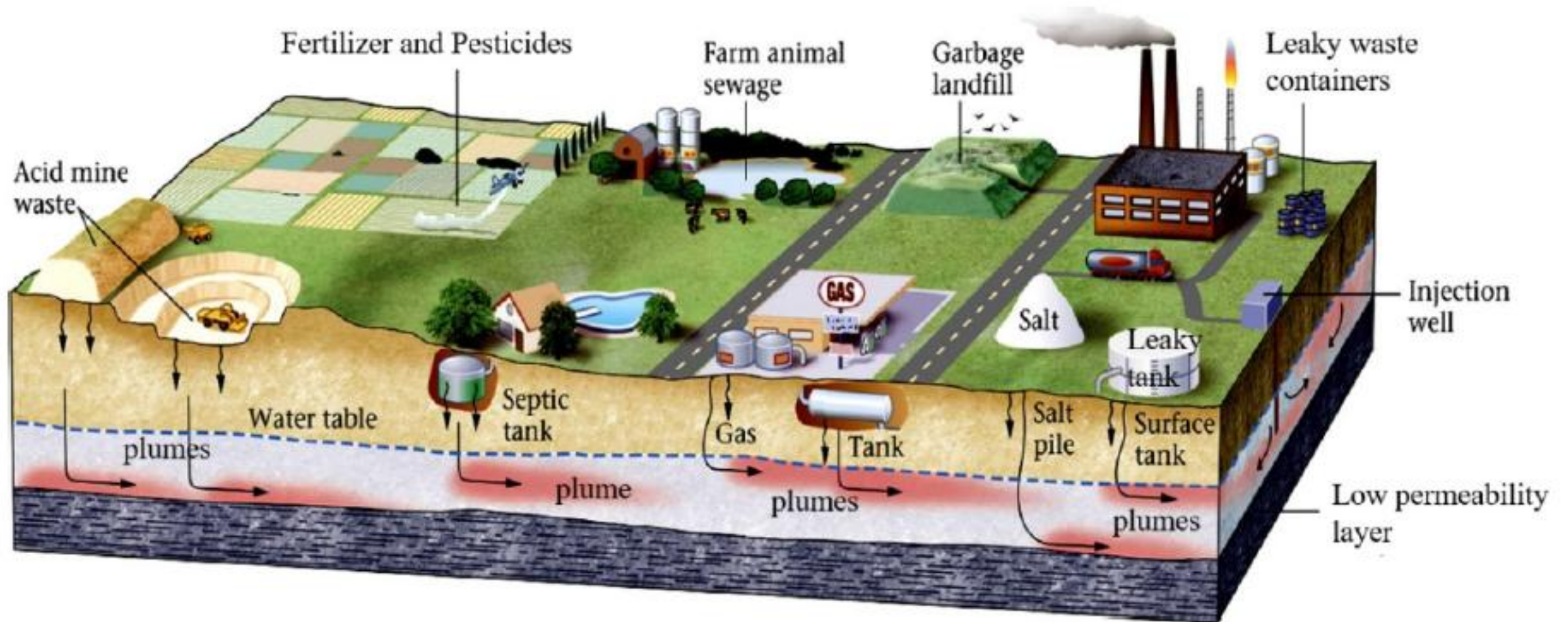
Irrigated Lands Regulatory Program Coalition (GQMP/MPEP)

# NITRATE: A VERY COMMON CHEMICAL

## ■ What is Nitrate?

- Contaminant that can make drinking water unsafe for drinking when above a certain level
- You can not see, smell, or taste Nitrate in water
- You can not boil Nitrate out of water
- Chemical found in most fertilizers, manure, and septic tanks
- Rain or irrigation water can carry Nitrate down through the soil and into groundwater

# CHEMICAL CONSTITUENTS (INCLUDING NITRATE): HUMAN LAND USES



• Adapted from Marshak, 2005 in Poeter, et al., 2020

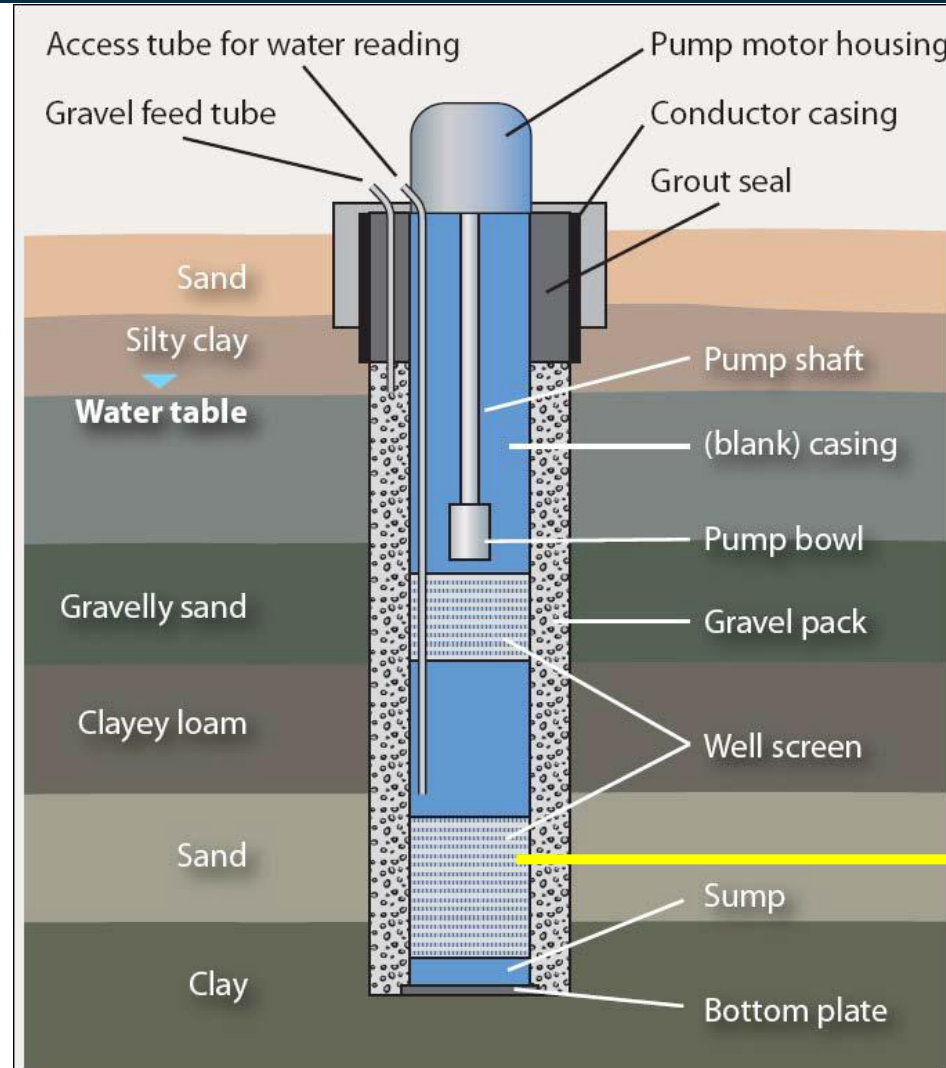
# WHY DO WE CARE ABOUT NITRATE?

- When is Nitrate Unsafe?
  - Government set a legal limit on the amount of Nitrate in water used for drinking
  - Drinking water limit is 10 milligrams per liter Nitrate as nitrogen (US EPA and California state regulatory requirement; Maximum Contaminant Level [MCL])



# HOW DO NITRATE AND OTHER CHEMICALS GET INTO WELL WATER?

- How does Nitrate get into your well water?
  - Groundwater is produced from water-bearing deposits beneath the land surface
  - All wells need to have good integrity and be protected from land surface activities
  - Proper well construction helps reduce contaminants from being introduced at the land surface



Typical Well Structure

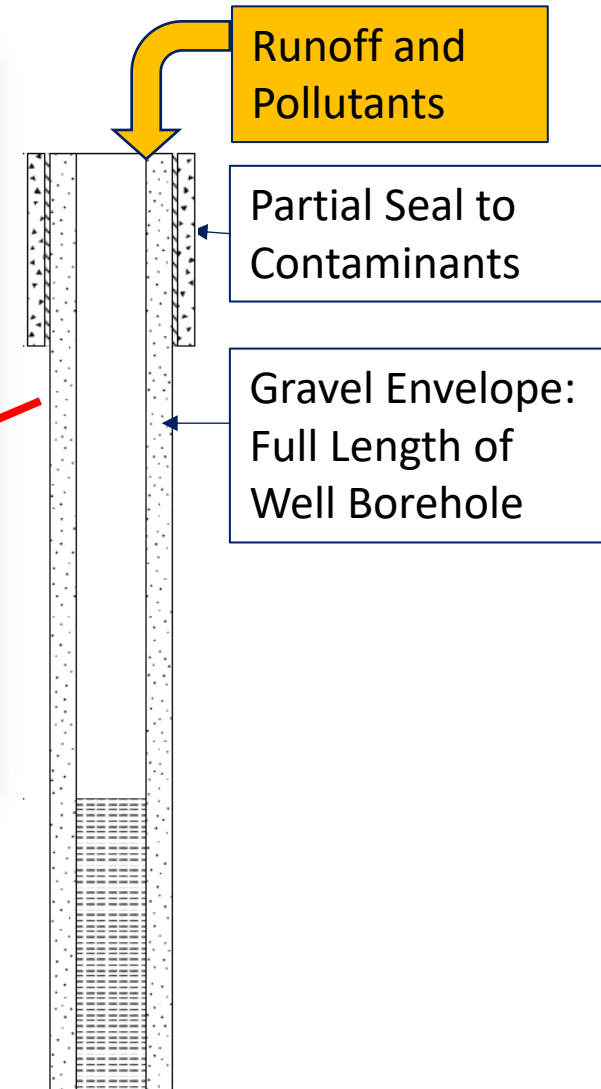
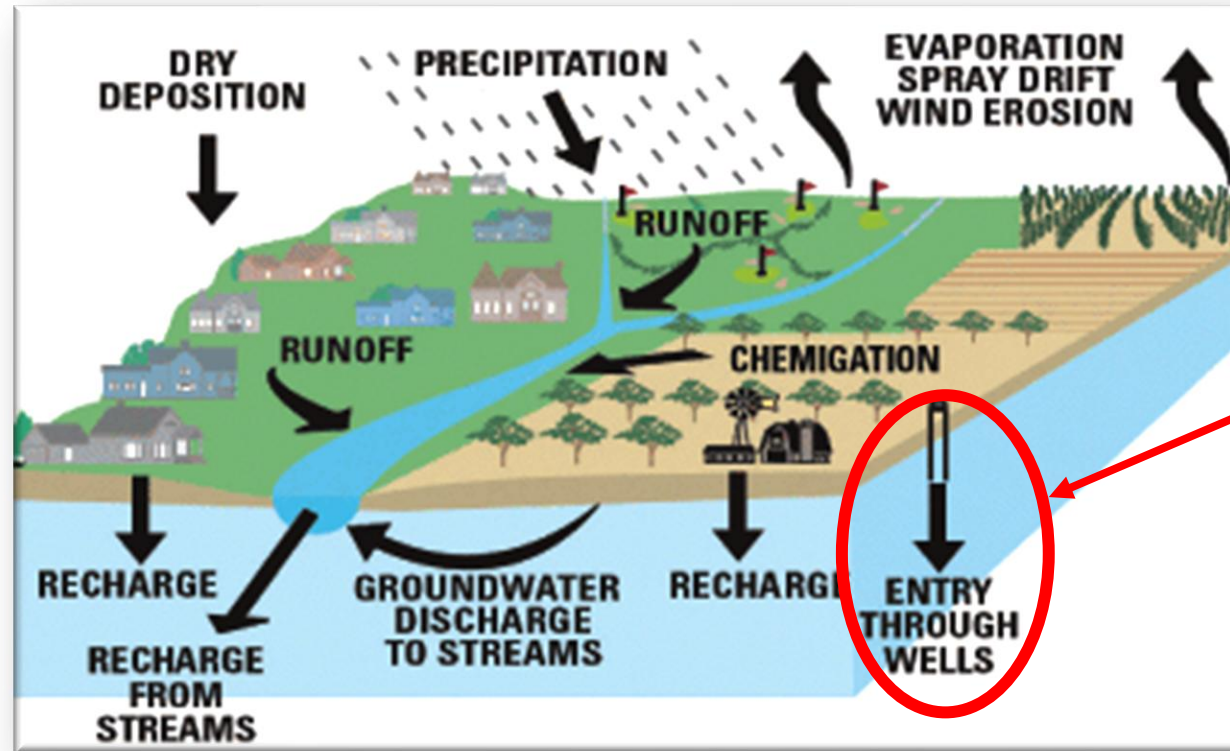
Well Screen



# NITRATE AT THE LAND SURFACE MAY AFFECT GROUNDWATER

## Sources of Nitrate Near Well:

- Entrance to well near land surface

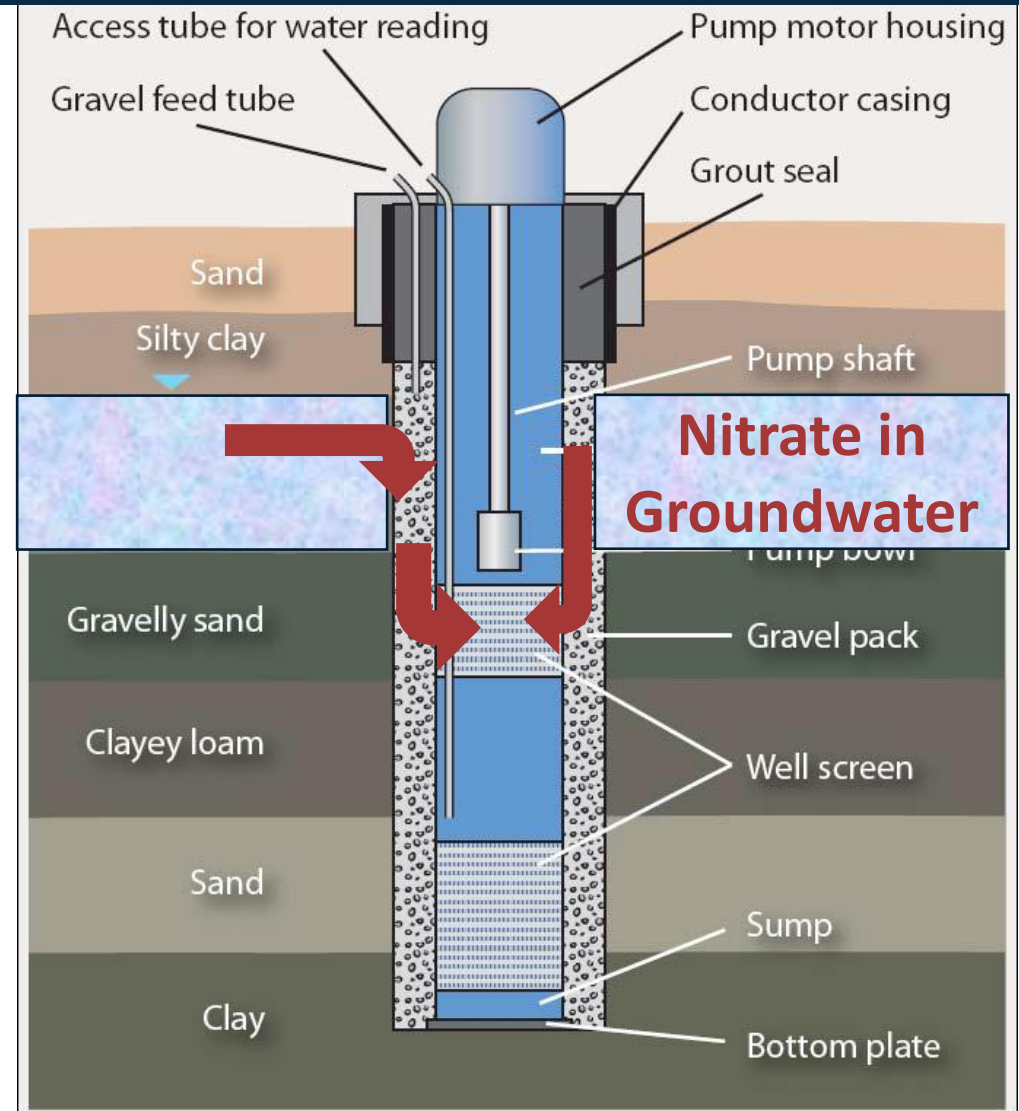


USGS, C.E. Thodal et al.. 2008. Fact Sheet 2009-3093  
Modified from Gilliom and others, 2006

# NITRATE IN GROUNDWATER MAY ENTER THE WELL

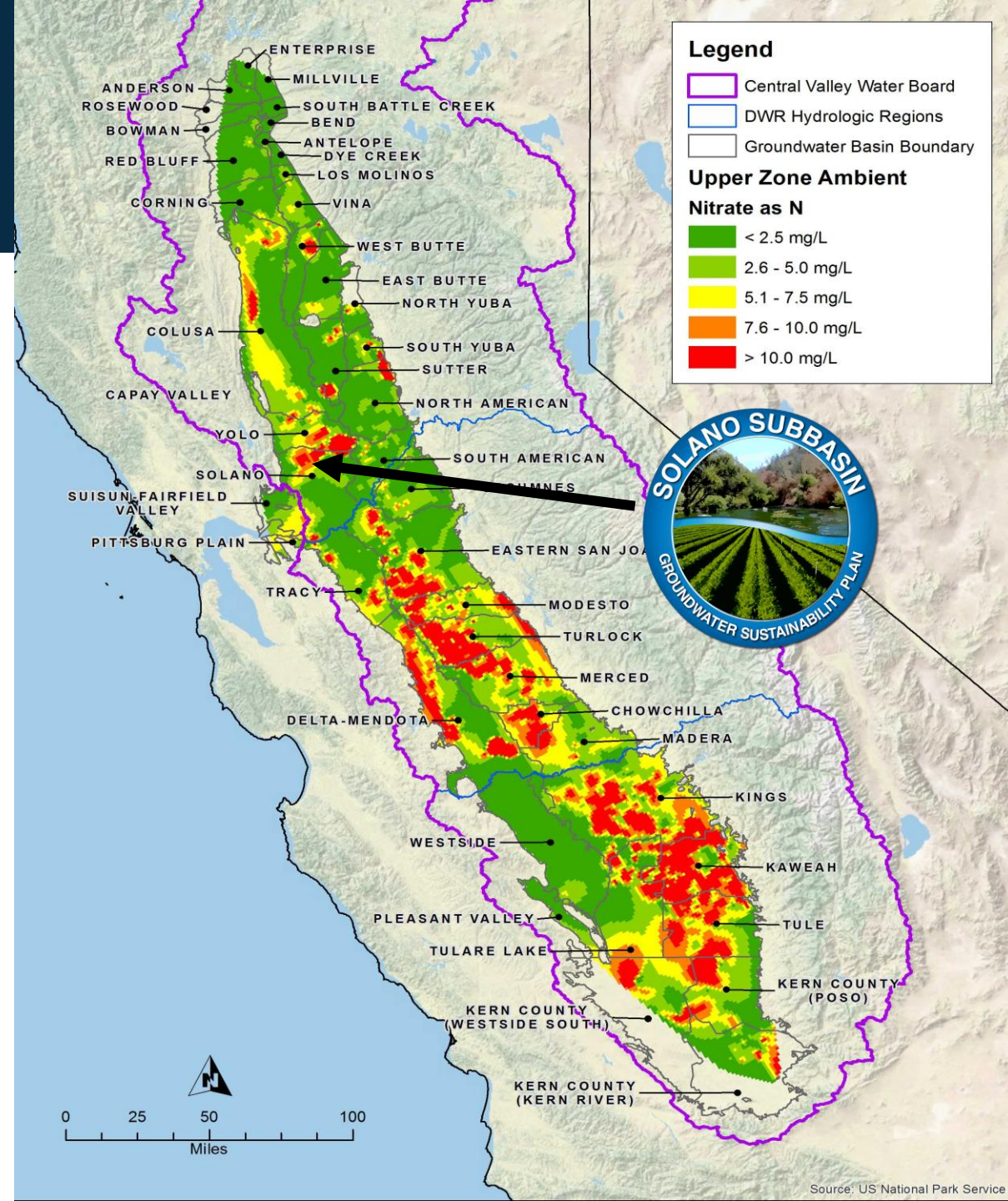
## Movement into Well Structure:

- Shallow Groundwater with Nitrate in Vicinity of Well May Move into Well



# CENTRAL VALLEY AND NITRATE IN GROUNDWATER

- Legacy and existing conditions
- Direct impacts to drinking water supplies
- Significant economic costs, including treatment or alternate supply
- Diverse sources of nitrate to be managed



# WHY DO WE CARE ABOUT NITRATE IN GROUNDWATER?

Drinking water obtained from groundwater that enters our homes through a private domestic well may require action if impacted by Nitrate.

## ■ Public Supply Wells

- Public Supply Wells are tested regularly
- Public Supply Wells can have treatment to make sure the water is safe for drinking or cooking before it reaches homes



## ■ Private Domestic Wells

- The well owner must test the water to determine if it is impacted by Nitrate
- If impacted, the well owner should take action to address the Nitrate before water is used for drinking or cooking

VS.



# SVWQC Irrigated Lands Regulatory Program

Groundwater Quality

# ILRP REQUIREMENTS: GROUNDWATER QUALITY ASSESSMENT REPORT UPDATE

- One of the key objectives of the GAR:
  - “Provide an assessment of all readily available, applicable and relevant data.... to determine the high and low vulnerability areas where *discharges from irrigated lands may result in groundwater quality degradation.*”
- Additionally, as part of data review and analysis:
  - “Determine where known groundwater quality impacts exist for which irrigated agricultural operations are a potential contributor or where *conditions make groundwater more vulnerable to impacts from irrigated agricultural activities.*”



## 2022 Groundwater Quality Assessment Report 5-Year Update

PREPARED FOR

Sacramento Valley Water  
Quality Coalition

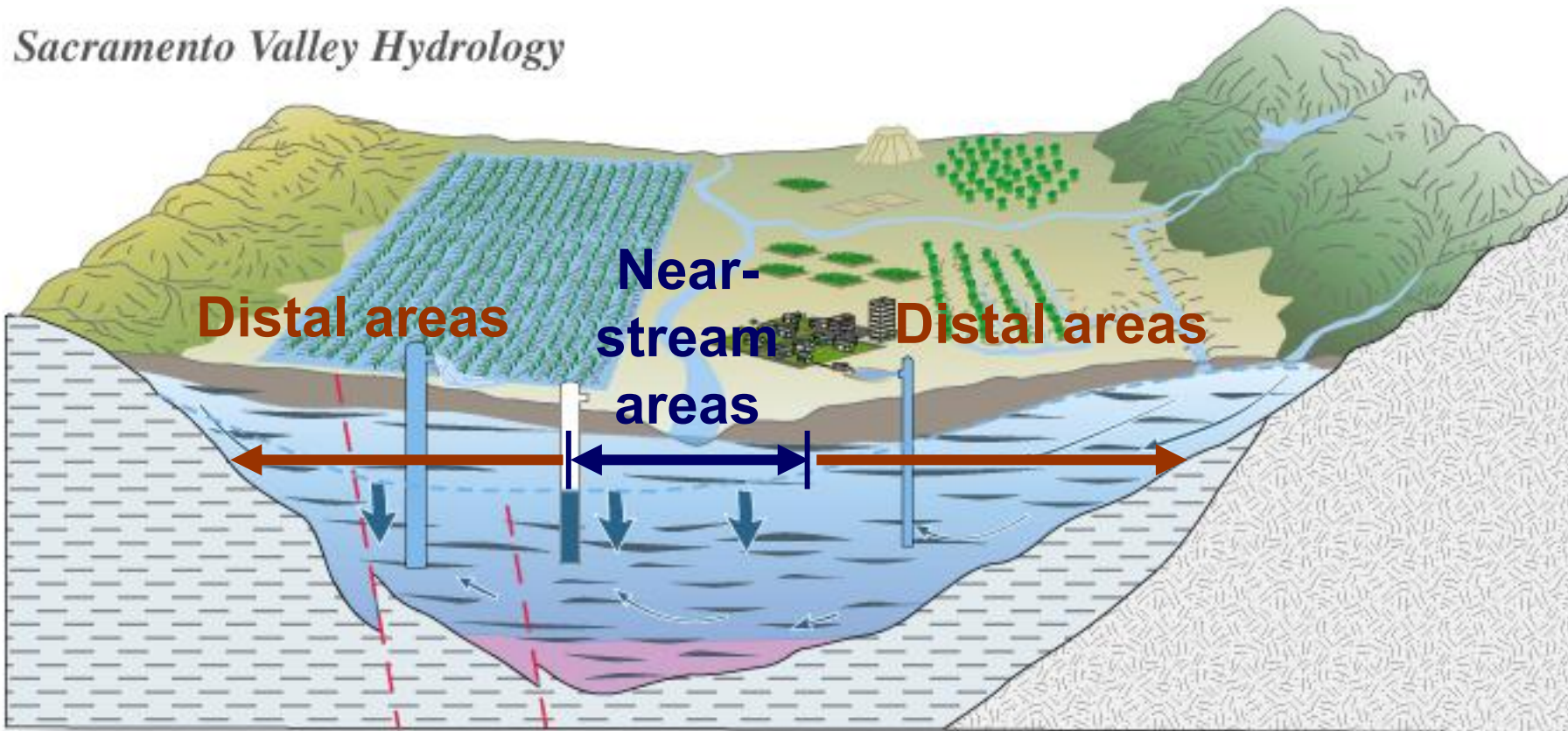


PREPARED BY



September 2022

# CONCEPTS RELATING TO GROUNDWATER VULNERABILITY



Graphic modified from USGS

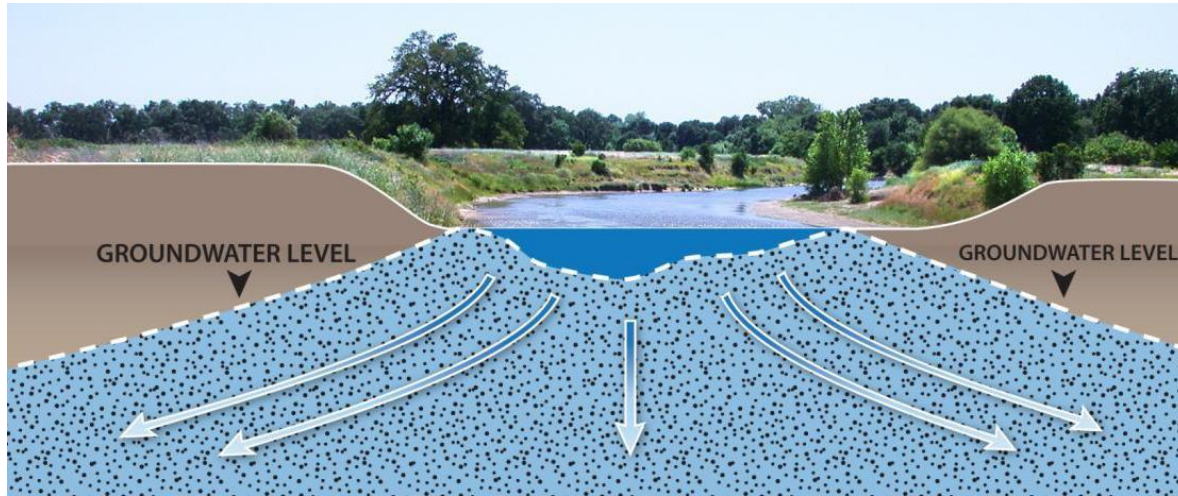
## Near-Stream Areas

- **Shallow GW**
- **High SW/GW exchange**
- **Low NO<sub>3</sub>**
- **Low vulnerability to impairment**

## Distal Areas

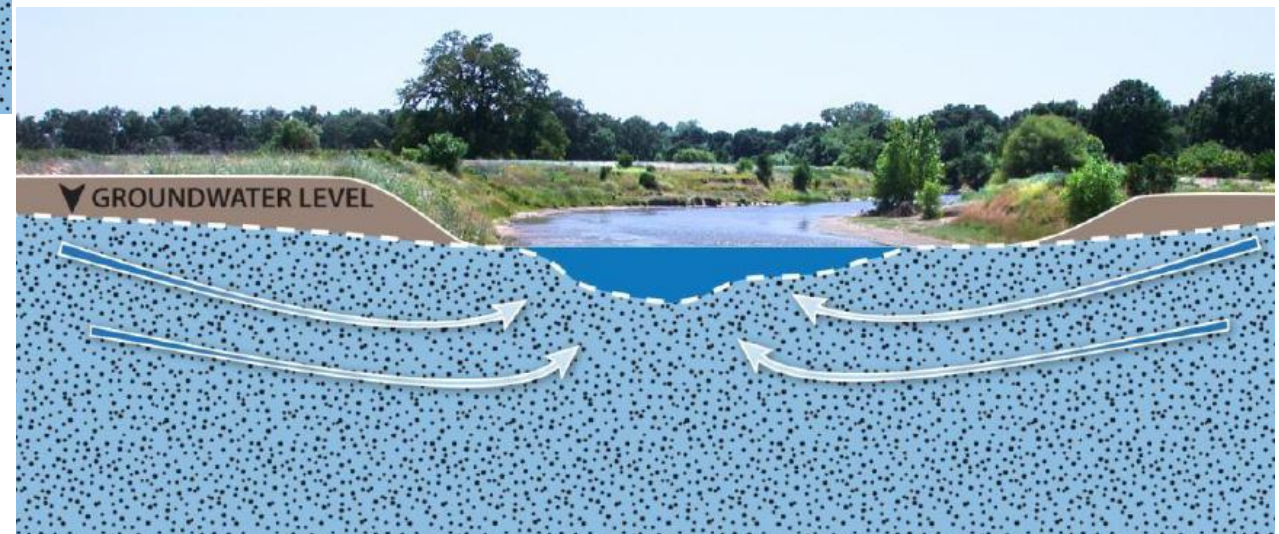
- **Deeper GW**
- **Greater influence by sediment character**
- **Potential vulnerability to impairment, depending conditions**

# NEAR-STREAM AREA SW-GW INTERCONNECTIONS



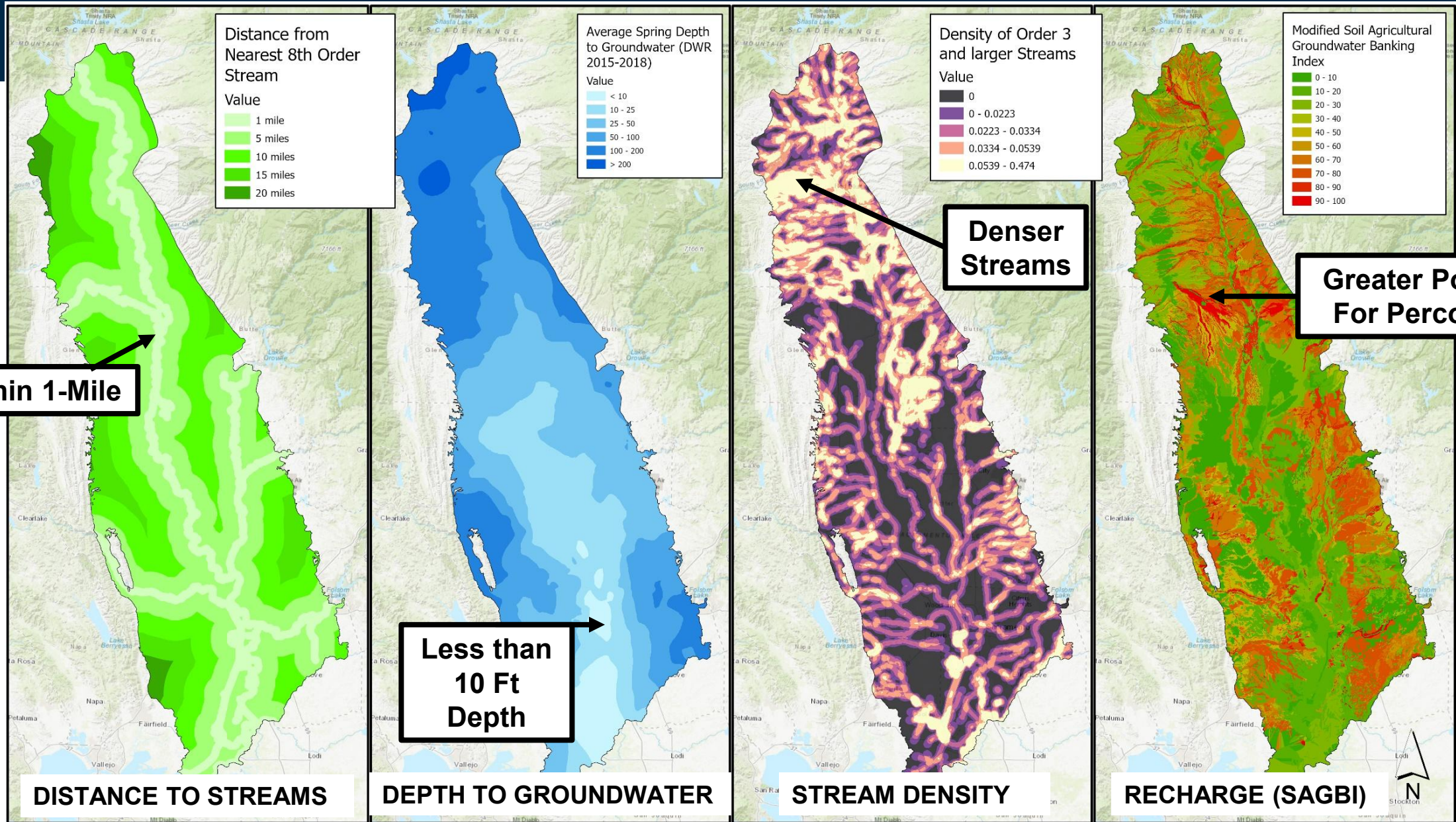
High recharge volume; low  $\text{NO}_3$  in GW

High GW discharge; low  $\text{NO}_3$  in GW



Graphic source: TNC

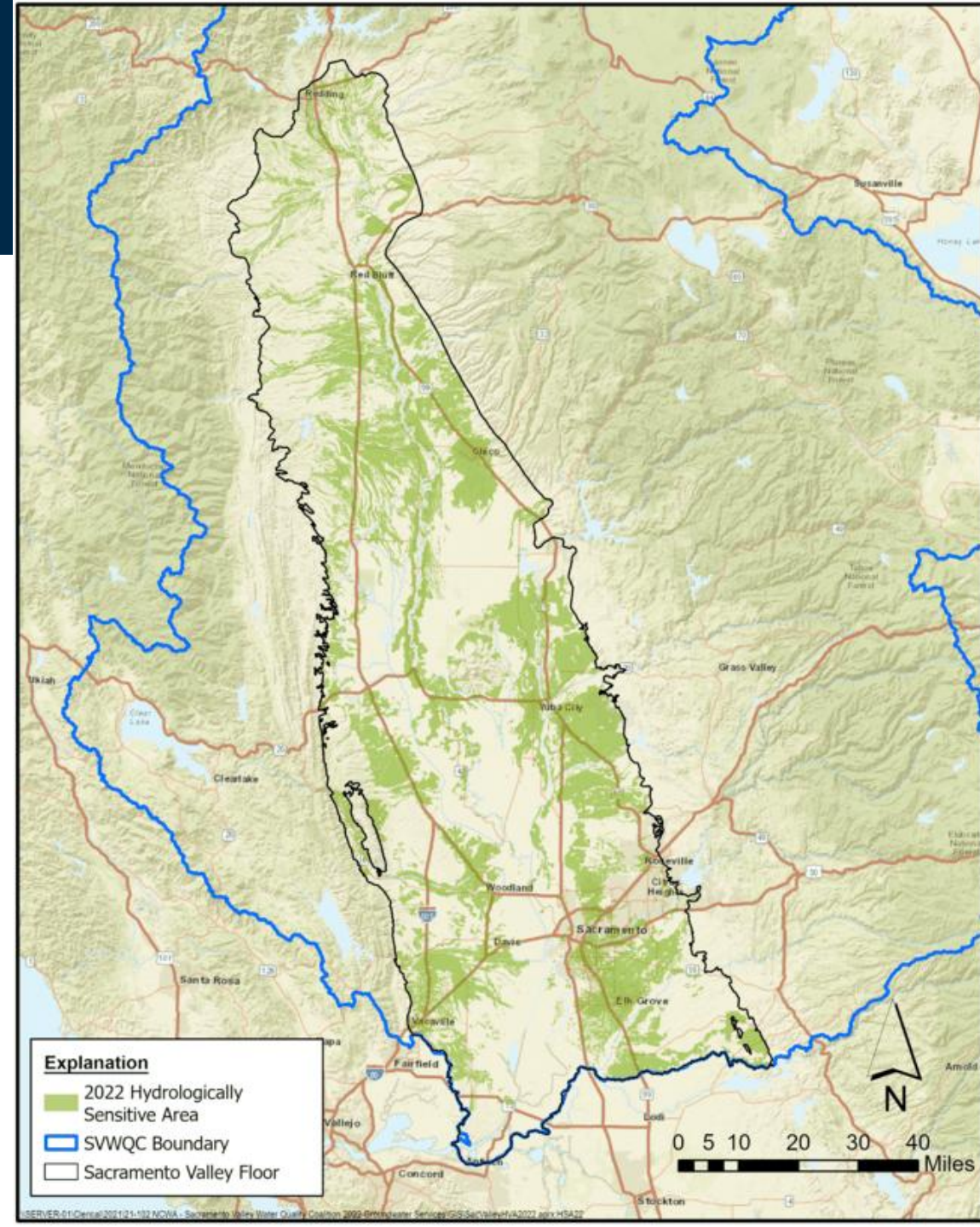
# INPUT VARIABLES TO MAP HYDROGEOLOGIC SENSITIVITY



# HYDROGEOLOGICALLY SENSITIVE AREAS

Hydrogeologically Sensitive Areas (HSA) defined based on physical characteristics:

- **1,478,472 acres** in the Sacramento Valley
- Not evaluated outside of Sacramento Valley

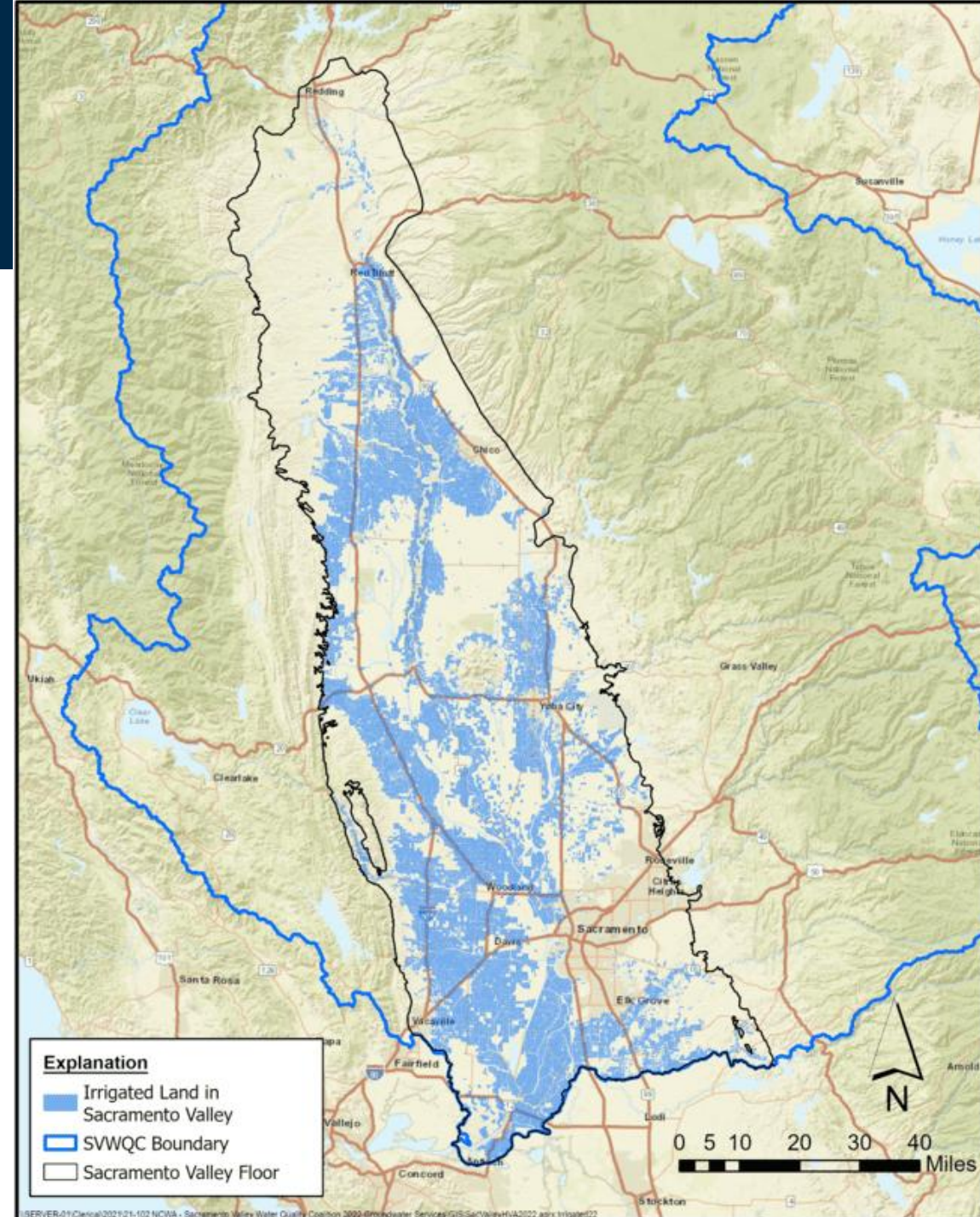


# IRRIGATED LANDS

Irrigated Lands as defined by:

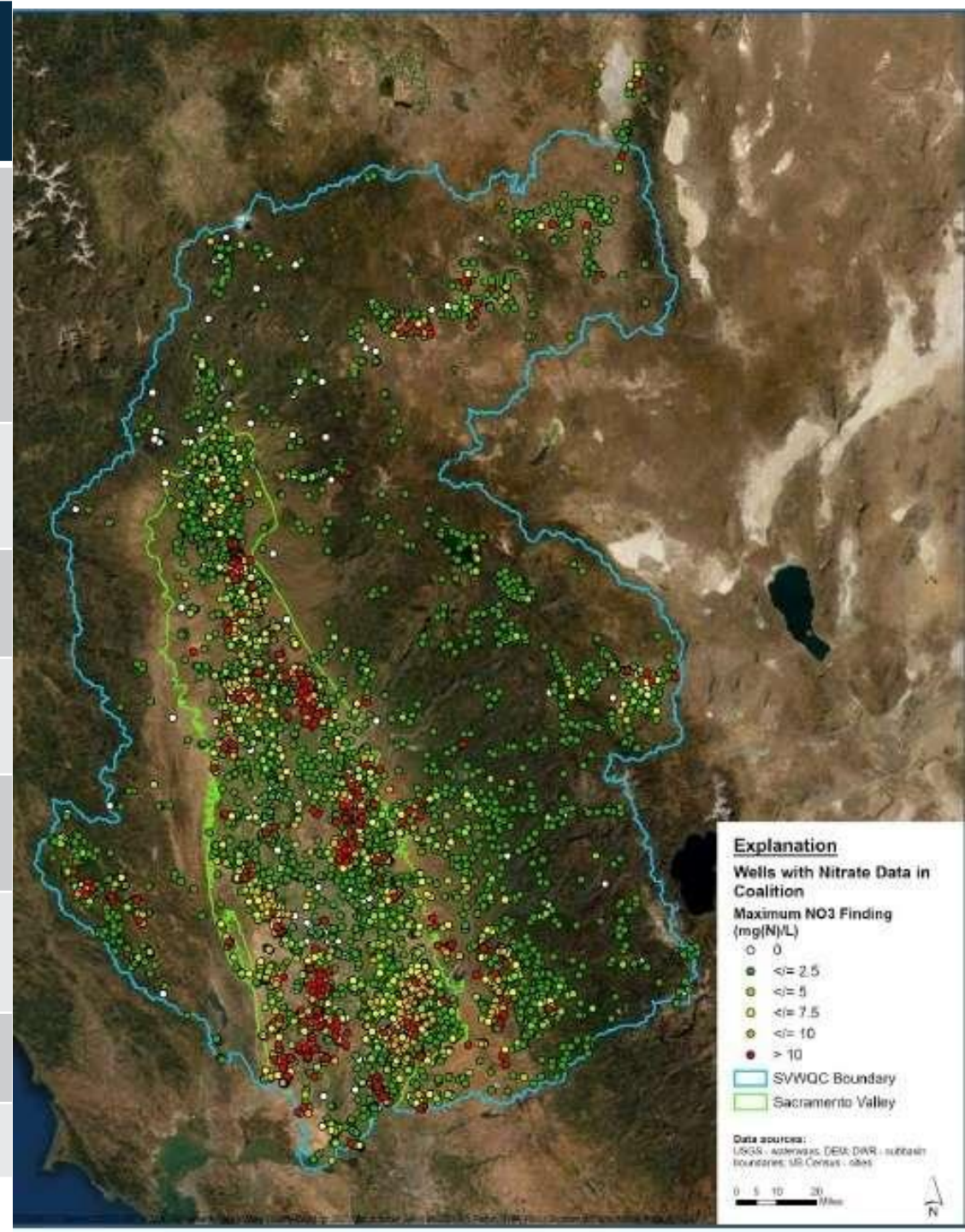
- LandIQ 2018 landuse (DWR)
- CropScape 2020 landuse (NRCS)

**Total Irrigated Acres = 1,331,666**



# Nitrate Data Sources in the Sacramento Valley

Data Source	Count of Wells in Sac Valley	Count of Wells in Sac Valley with Depth Data	Count of Nitrate Samples in Sac Valley	Count of Wells in Coalition	Count of Nitrate Samples in Coalition
State Board-DDW	1,844	606	40,326	3,170	56,855
State Board-GAMA	264	0	488	749	1,378
DWR	1,547	331	5,413	2,229	7,252
USGS	1,600	1,299	3,037	2,107	3,934
Special Studies	62	0	65	62	65
ILRP	22	18	40	30	53
<b>Total</b>	<b>5,339</b>	<b>2,254</b>	<b>49,369</b>	<b>8,347</b>	<b>69,537</b>

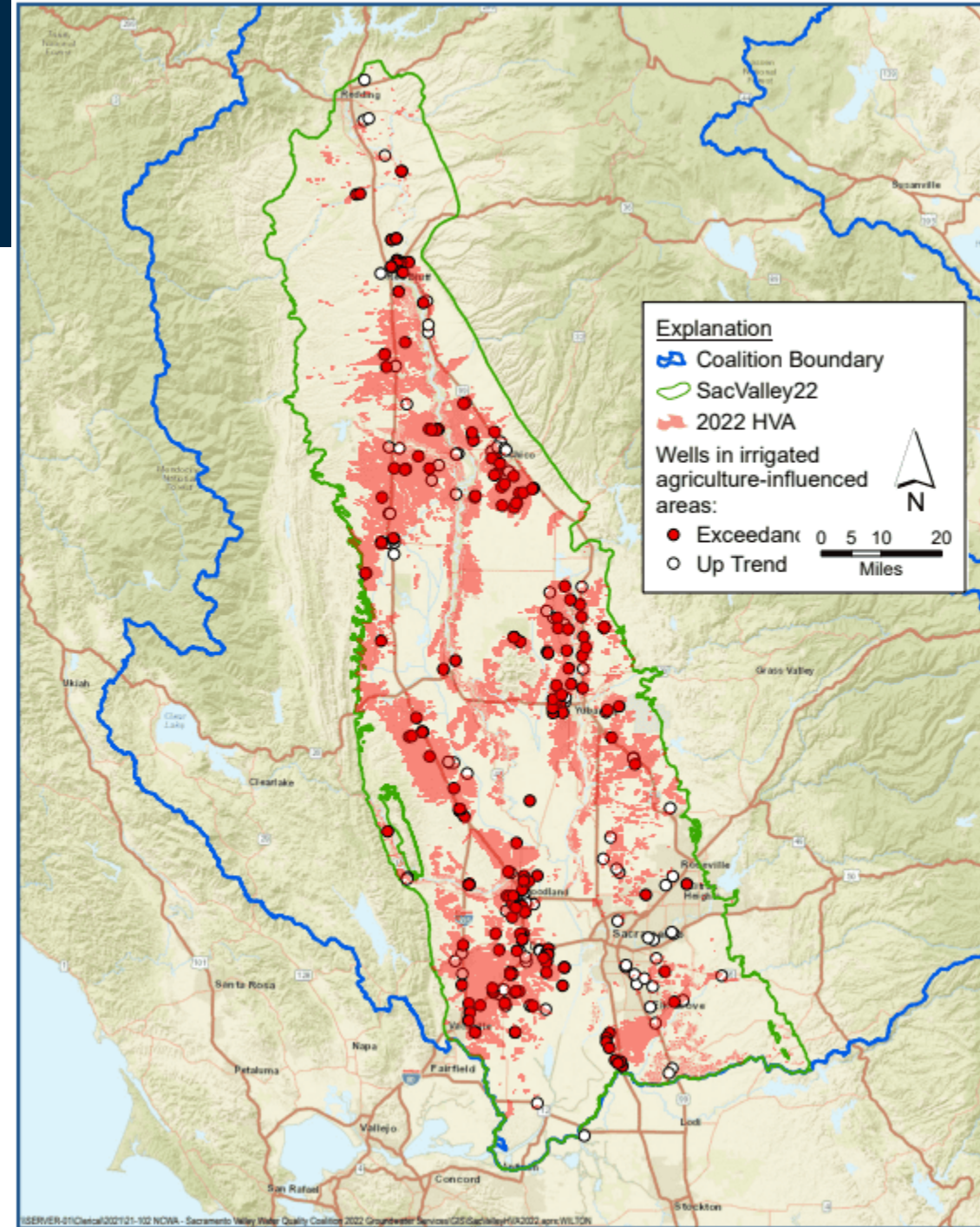


# 2022 HVA

## Hydrogeologic Vulnerability Area (HVA):

All Irrigated HSA lands in Sacramento Valley that encompass Nitrate exceedances and wells with increasing Nitrate trends.

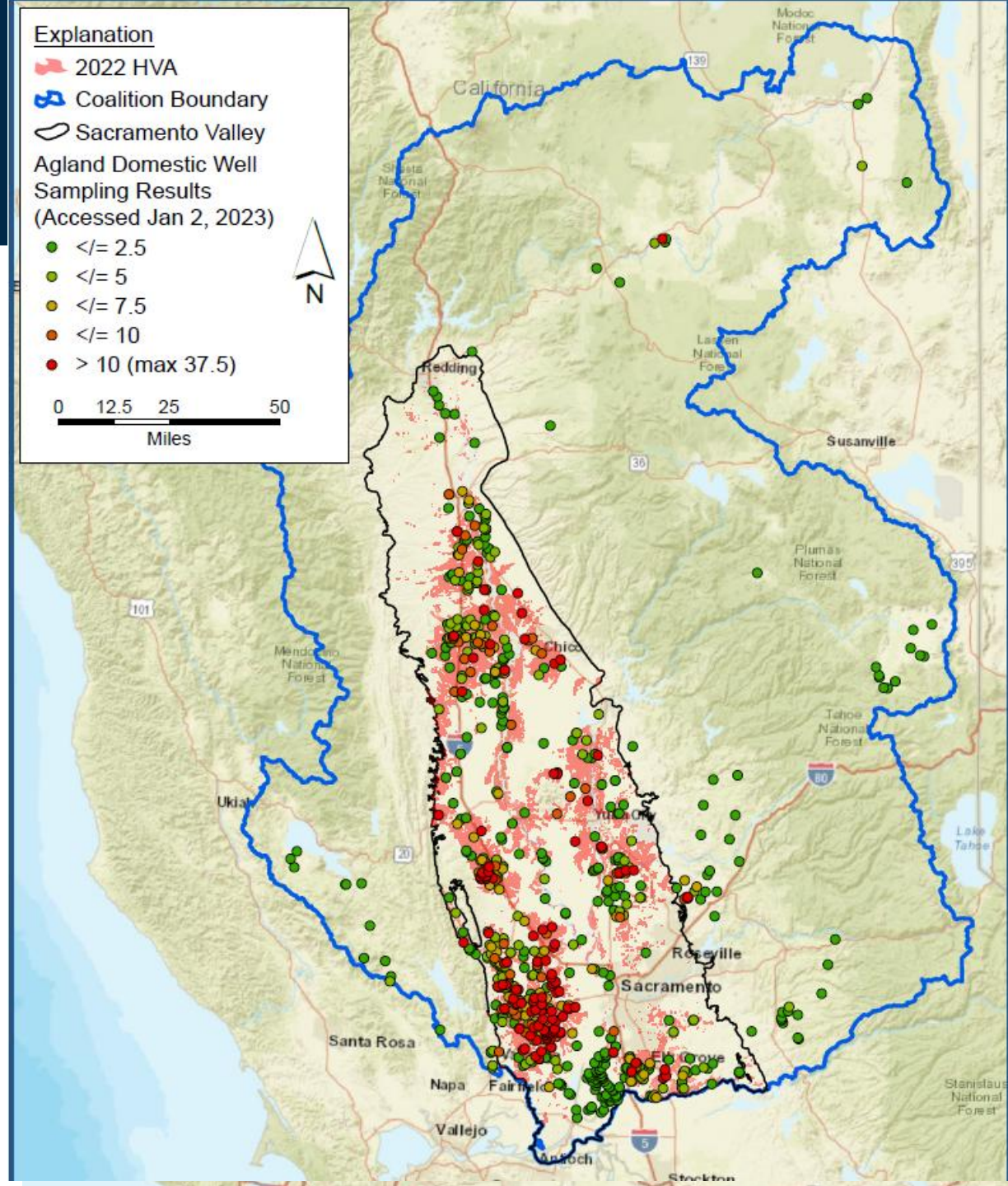
Land in 2022 HVA	Acres
Irrigated	598,262
Irrigated and Enrolled	468,342
Irrigated and Not Enrolled	129,920
Enrolled Not Irrigated (buffer area)	2,667
<b>All HVA Acres</b>	<b>600,929</b>



# 2022 DRINKING WATER WELL TESTS (RESULTS AS OF 1/7/23)

## ■ ILRP Drinking Water Well Testing Program

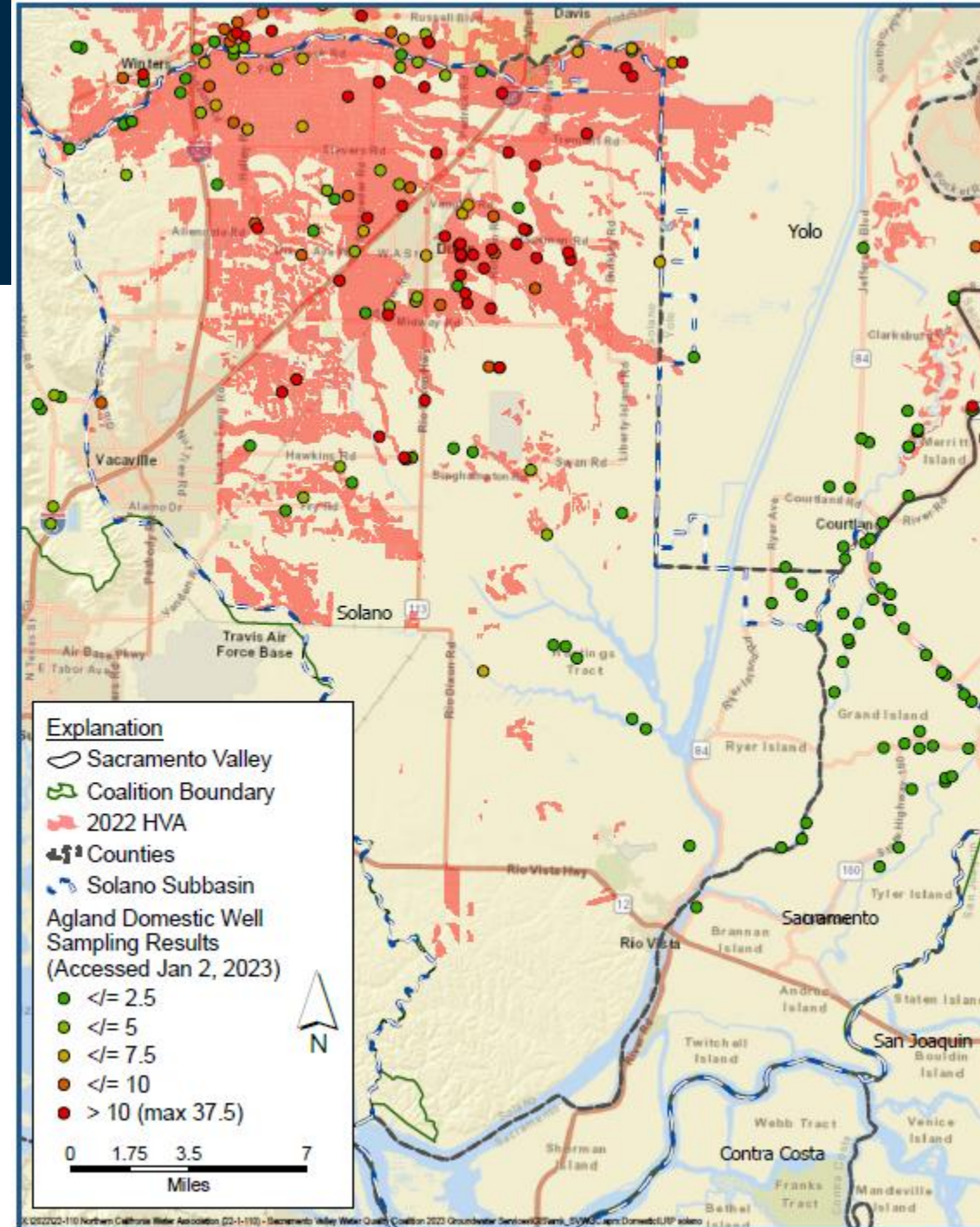
- Nitrate testing required of individual landowners for domestic wells by end of 2022
- **Total number of drinking water wells tested to date ~817; 738 in Sacto. Valley**
  - 17% of well tests in the Valley exceed  $\text{NO}_3$  MCL
- **122 nitrate exceedances to date**
  - 96% of wells with exceedances within 0.5 mile of HVA



# SOLANO SUBBASIN NITRATE WELL TESTS

Nitrate Domestic Well Tests in Solano Subbasin as of January 7, 2023

- **147** Domestic Wells tested for Nitrate per ILRP requirement
- **40** Domestic Wells that exceed the Nitrate MCL (27% of tests)
- **39** wells located within 0.5 miles of HVA



# Central Valley Basin Plan Amendment

Nitrate Control Program

# SNMP/BASIN PLAN AMENDMENT GOALS

## 1. Ensure safe drinking water supplies

- Short-term and long-term solutions

## 2. Reduce salt and nitrate loadings to not cause or contribute to exceedances of water quality objectives

- Short-term and long-term solutions

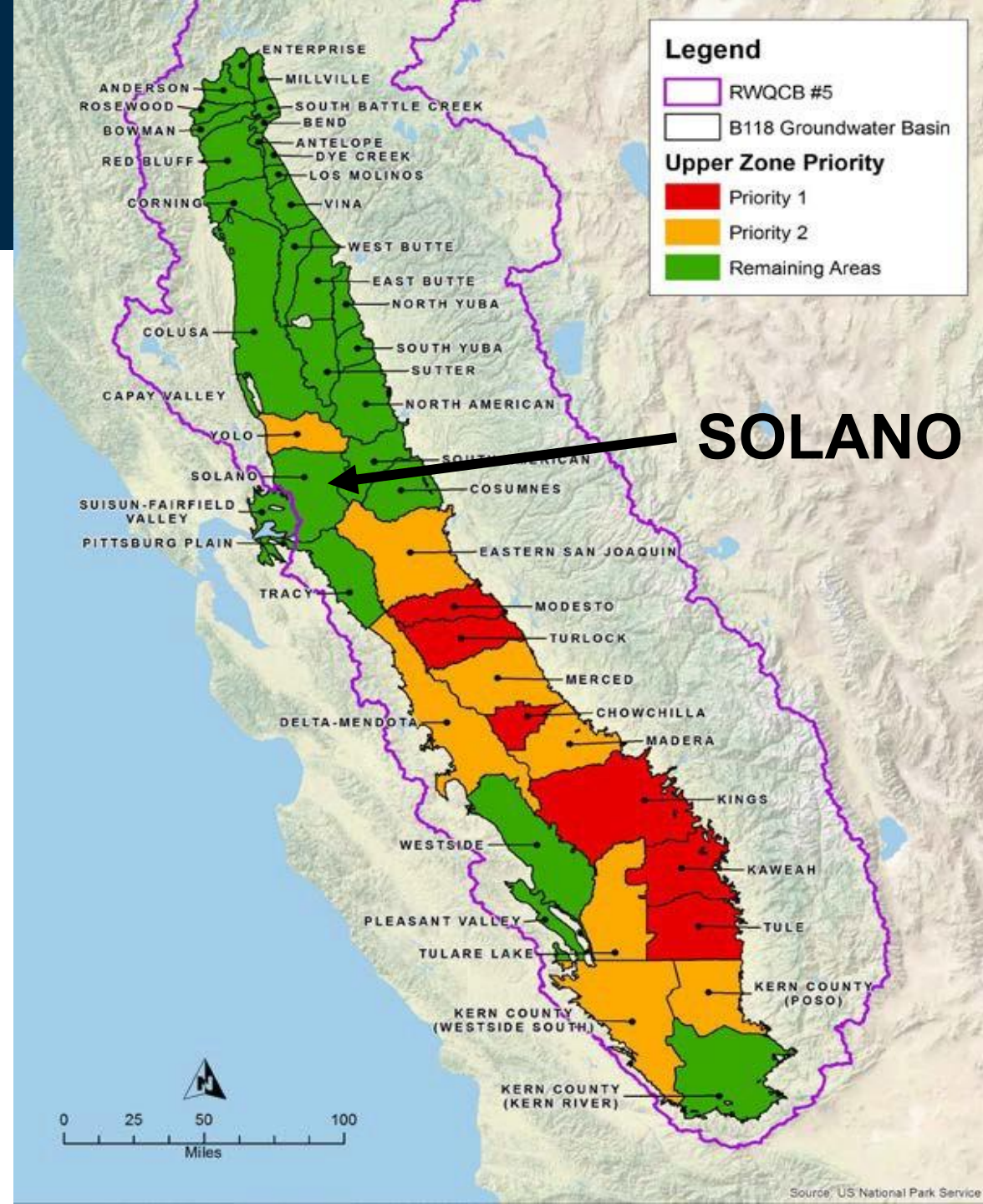
## 3. Implement long-term managed aquifer restoration programs

- Where reasonable, feasible and practicable



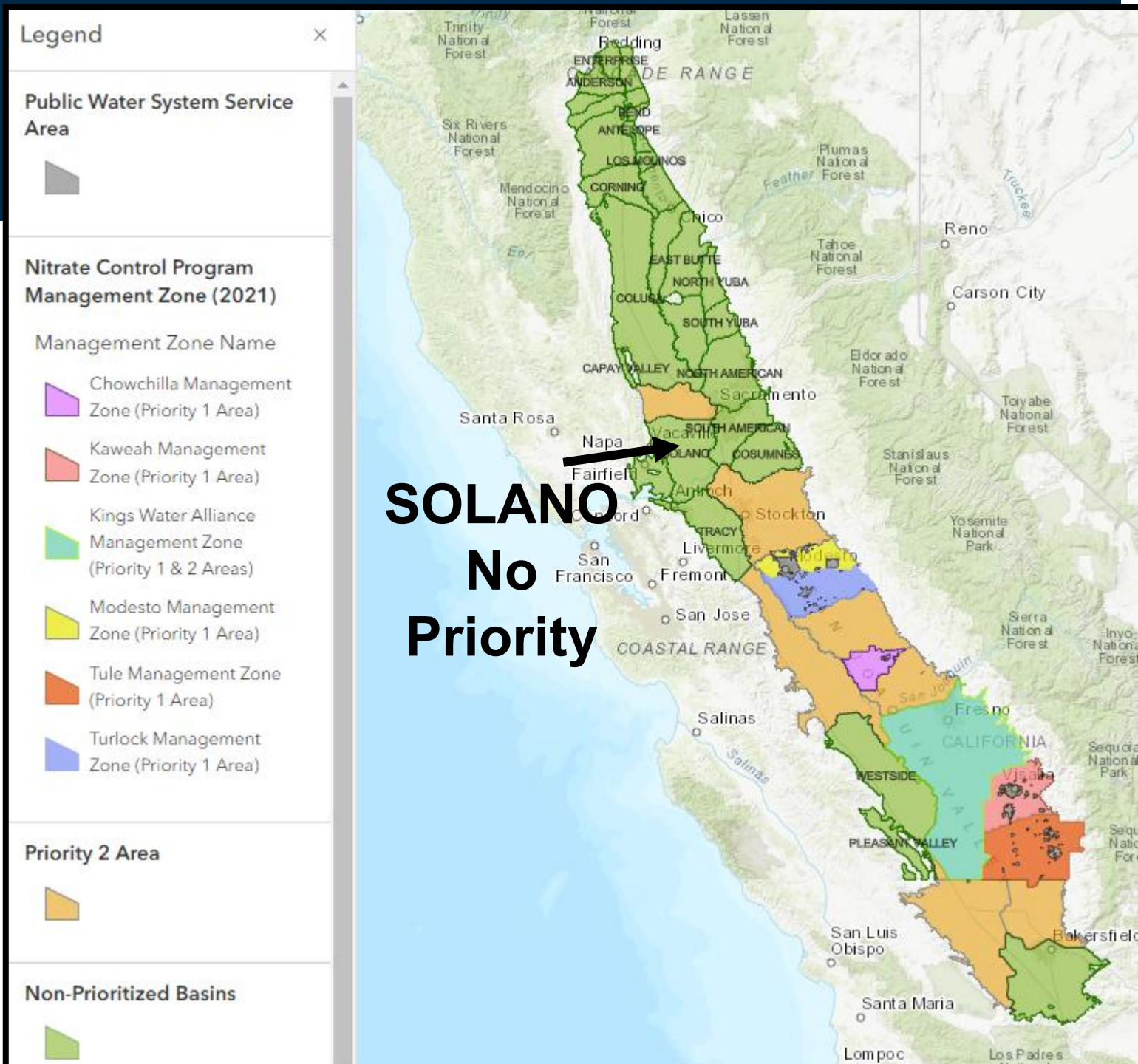
# NITRATE CONTROL PROGRAM IMPLEMENTATION

- **Priority 1 Area (Red)**
  - Notice to Comply within one year of Basin Plan amendments becoming effective
- **Priority 2 Area (Orange)**
  - Notice to Comply within 2-4 years of Basin Plan amendments becoming effective
- **Remaining Areas (Green)**
  - Implementation to be phased in at a later date

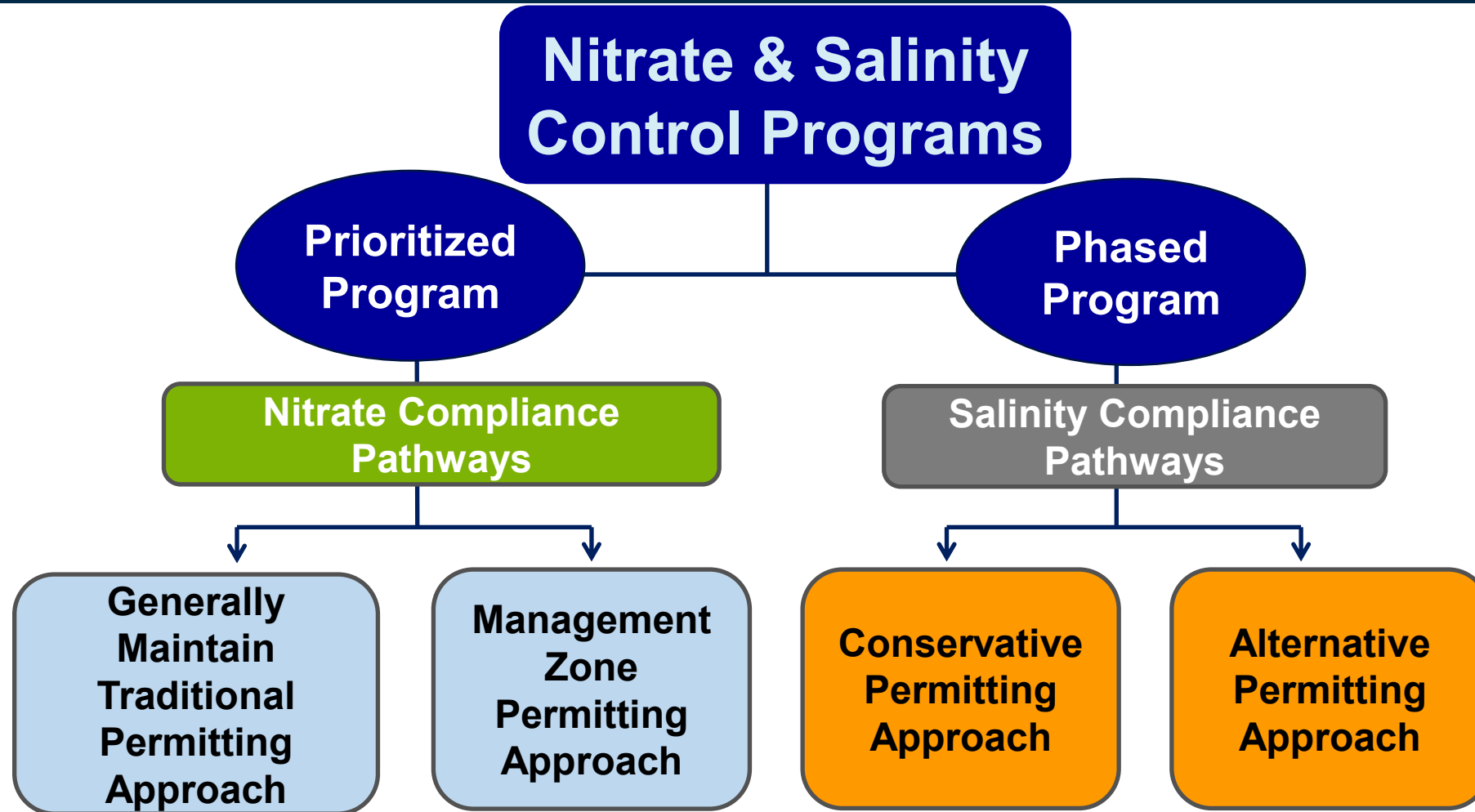


# STARTED IN 2020 WITH PRIORITY 1 BASINS

DWR No.	Groundwater Basin
5-22.11	Kaweah
5-22.03	Turlock
5-22.05	Chowchilla
5-22.13	Tule
5-22.02	Modesto
5-22.08	Kings

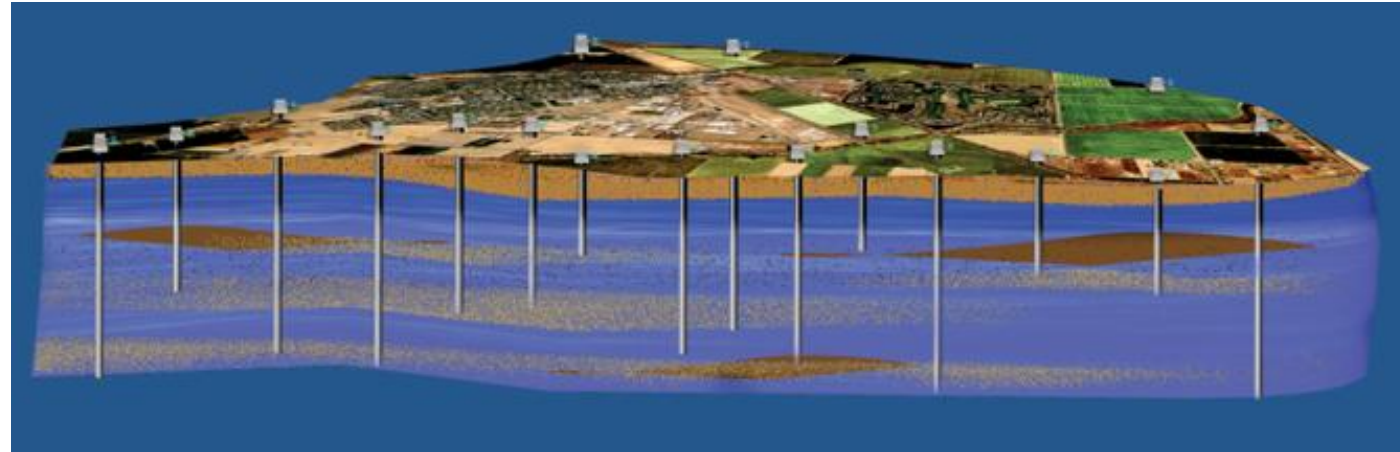


# FUTURE CHOICES TO ADDRESS SALT & NITRATE ISSUES



# WHAT IS A MANAGEMENT ZONE?

- Regulatory construct in BPA
- Defined area; discrete regulatory compliance unit for nitrates in groundwater (Nitrate Control Program)
- Dischargers in MZ cooperate to implement Early Action Plan to address nitrate in groundwater



- Nearer term – Early Action Plan to address wells with nitrate-impaired groundwater (i.e., interim clean water supplies)
- Longer term – Implement Plan for maintaining/improving GW quality and reducing salt and nitrate impacts, and restoration where practical/feasible

# MANAGEMENT ZONE IMPLEMENTATION PLANS (MZIPS)

**Nitrate Control Program is unlike anything tackled in California before and currently involves 6 MZs:**

- Assessing nitrate in GW across **~2,644,000** acres
- Addressing nitrate contamination in **~9,000** wells and an affected population of **~86,000**
- Working with all sectors of dischargers (ag, dairy, wastewater facilities, food processors, wine industry, poultry, rural residential septic systems, and others)
- Developing nitrate loading estimates
- Developing an understanding of nitrogen reduction efforts
- Determining long-term solutions for clean water for communities and private wells



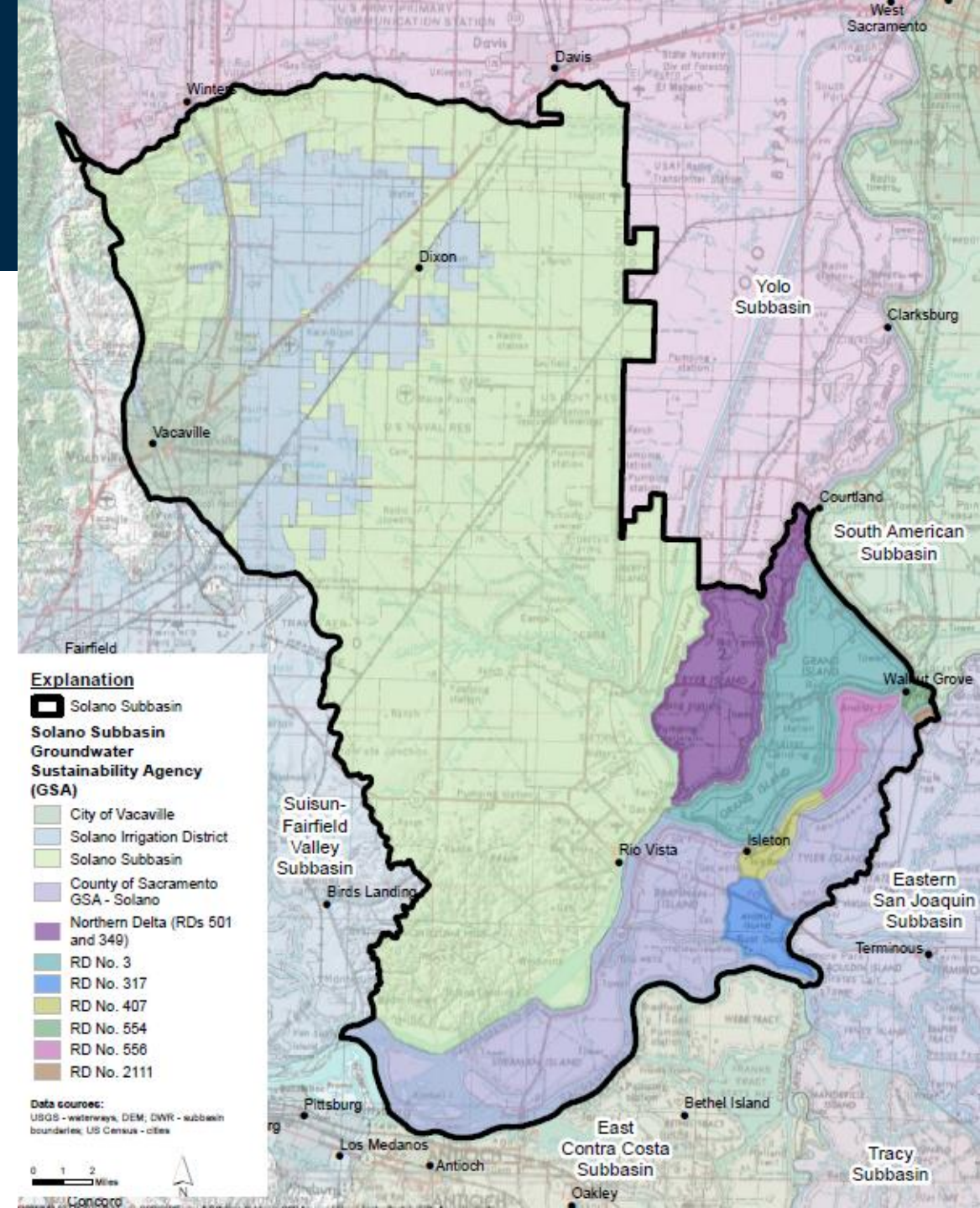
# Sustainable Groundwater Management Act

Solano Subbasin

# GSP IMPLEMENTATION

## Solano Subbasin

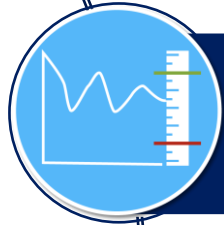
- Groundwater Sustainability Plan (Plan Area)
- GSP Submitted to DWR January 2022
- GSP Implementation
  - Monitoring
  - Annual Report
  - Projects/Management Actions (like Recharge Projects)



# SOLANO SUBBASIN GROUNDWATER SUSTAINABILITY PLAN



Describe the Basin Conditions



Define Basin Sustainability



Develop Projects/Management Actions & Implementation Plan



Develop & Adopt GSP

# SGMA: GROUNDWATER CONDITIONS – QUALITY

## § 354.16. Groundwater Conditions

Each Plan shall provide a description of **current and historical groundwater conditions in the basin**, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:

- (d) **Groundwater quality issues** that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes.

# SGMA AND PROTECTING GROUNDWATER QUALITY

## Avoid significant and unreasonable degradation of groundwater quality

- Consider local, state, and federal water quality standards applicable to the basin
- GSAs not responsible for regulatory programs enforced by other agencies
- GSAs are responsible for groundwater quality conditions affected by sustainability projects

## SOLANO SUBBASIN GROUNDWATER SUSTAINABILITY PLAN

November 30, 2021  
Volume 1 - Main Report



SACRAMENTO  
COUNTY

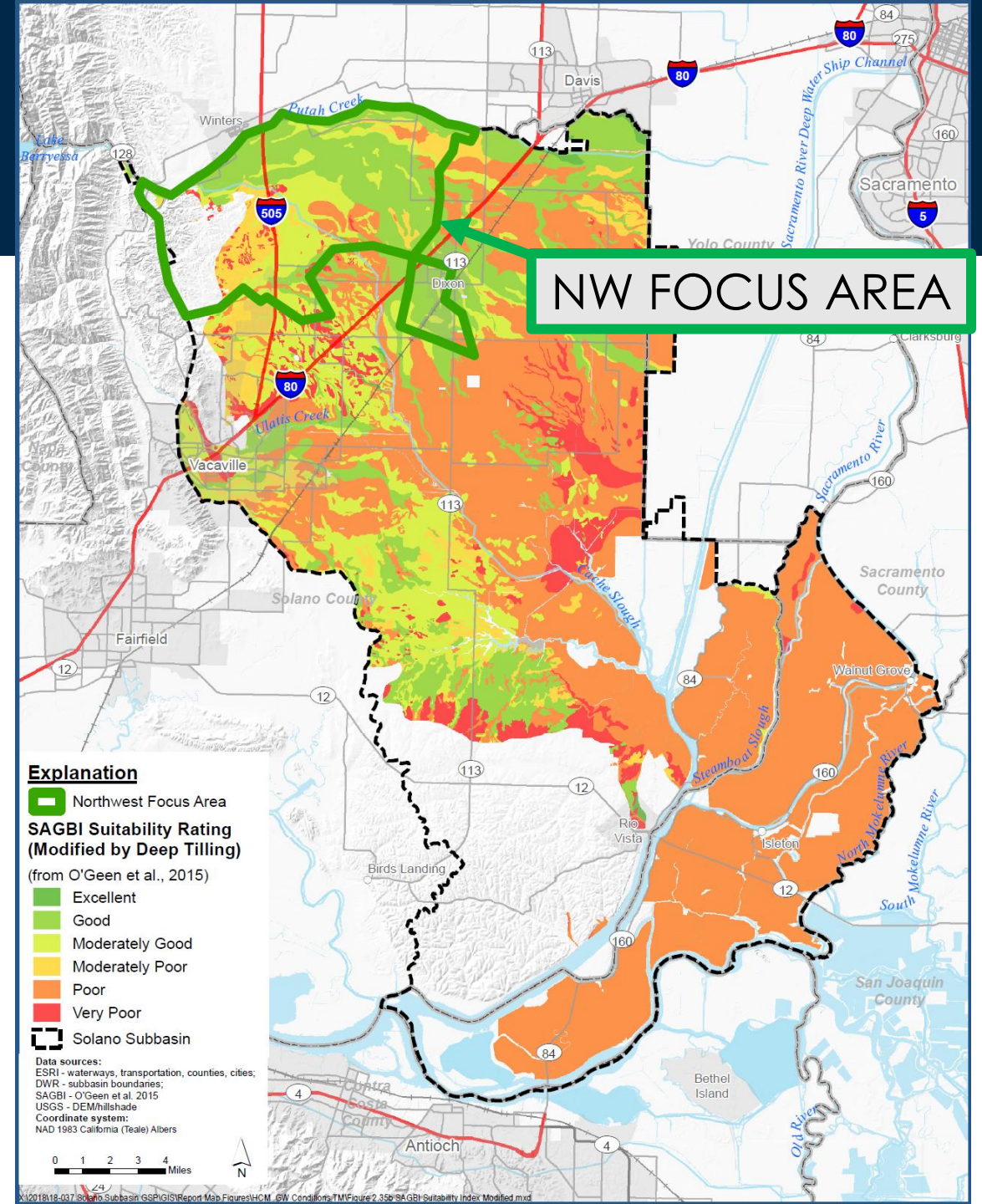
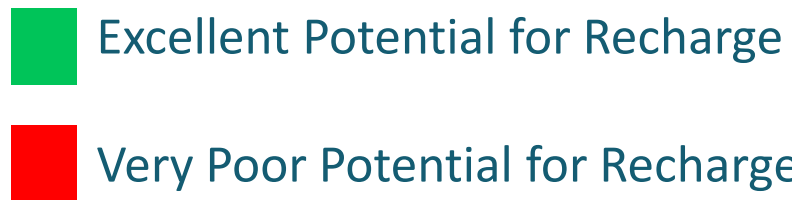




# POTENTIAL GROUNDWATER RECHARGE AREAS

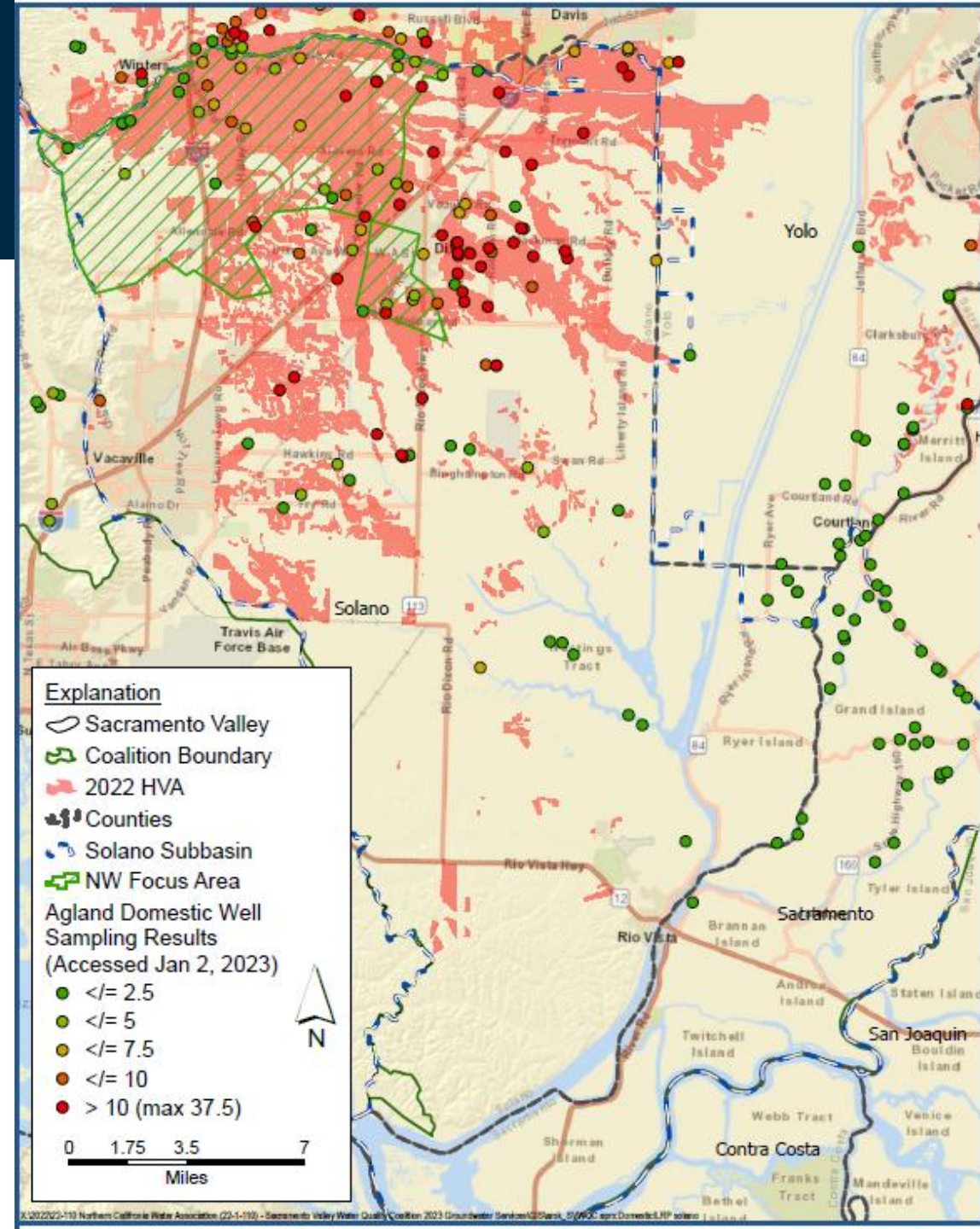
Preliminary identification of recharge locations based on:

- Soil properties
- Hydrogeology
- Conveyance
- Areas of interest generally excellent recharge potential



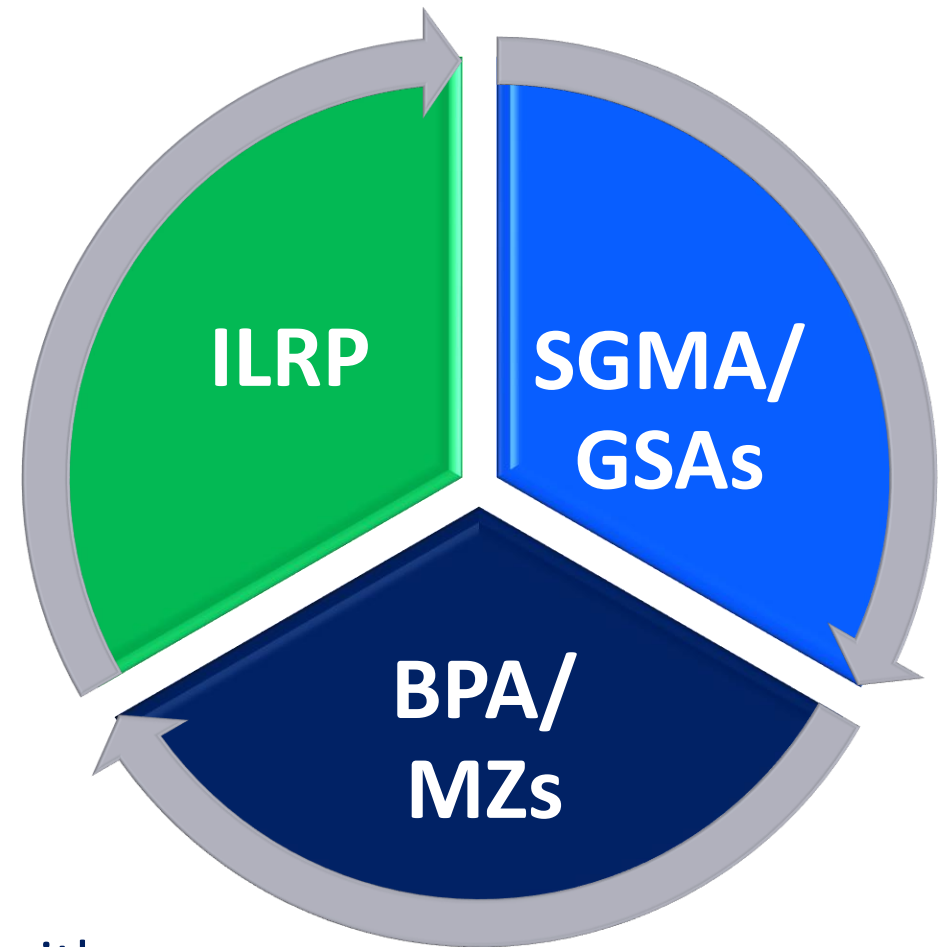
# RECHARGE PROJECT CONSIDERATIONS

- Assess effect of recharge on GW quality
- Regional Board recognizes salt and nitrate in vadose zone
  - Potential for short-term WQ degradation near recharge sites
- Enhanced natural recharge and/or intentional recharge may increase nitrate and/or salt concentrations initially
  - Long-term quantity and quality recharge benefits likely outweigh initial effects



# GROUNDWATER QUALITY AND PROGRAM SYNERGIES

- GW quality characterization & GW quality trend **monitoring** (ILRP)
- Surveillance and **monitoring** program (BPA/MZs)
- GW conditions/conceptualization (SGMA)
  - Inform management strategies
  - Sustainability indicator (quality and quantity) **monitoring**
- Coordination between Groundwater Sustainability Agencies (GSAs) and MZs
  - Maintain local flexibility
  - Coordinate **monitoring**
  - Coordinate SGMA management actions/projects with salt and nitrate management strategies





**THANK YOU**



# Dr. Helen E. Dahlke

UNIVERSITY OF CALIFORNIA, DAVIS

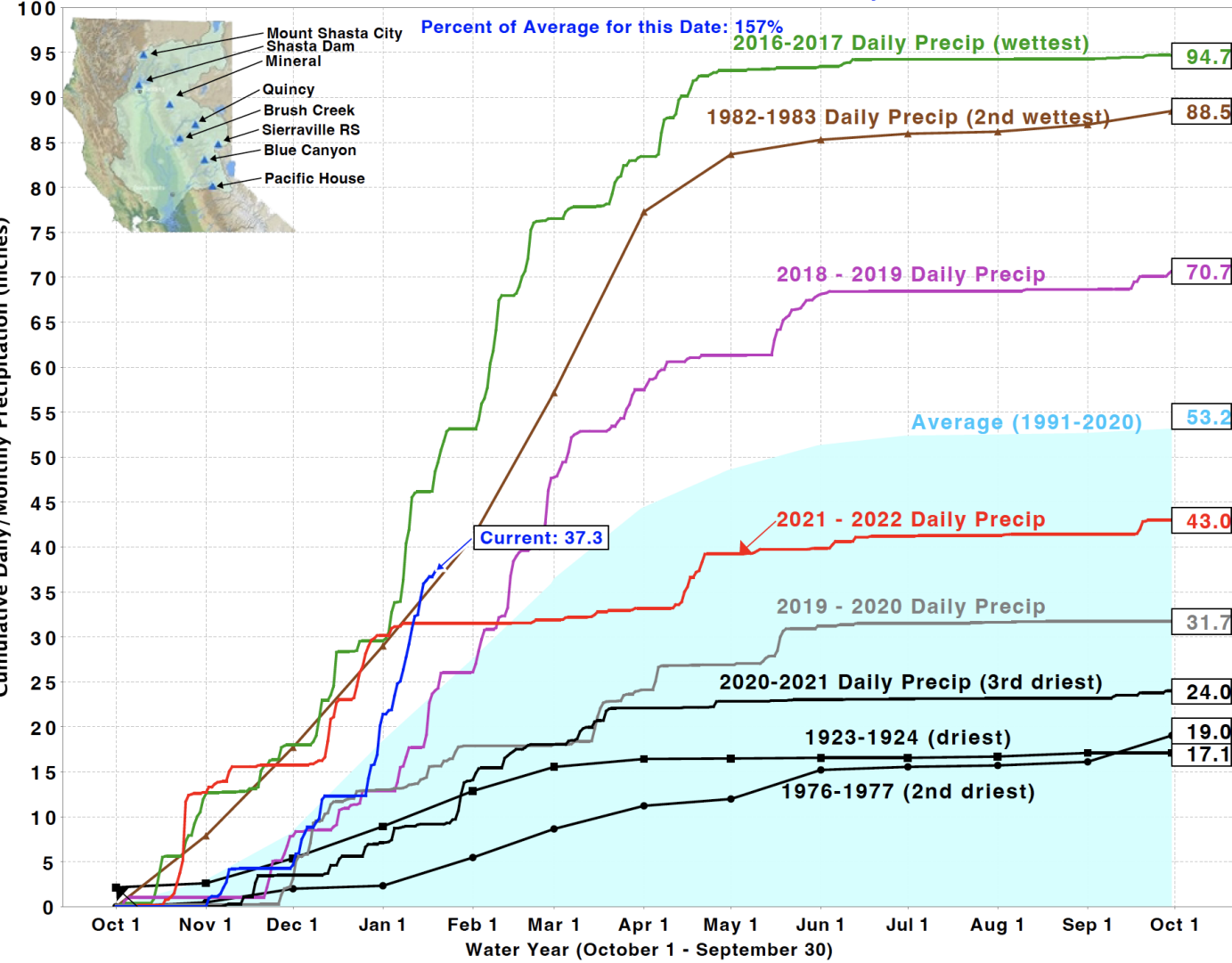


# Nitrogen fate during agricultural managed aquifer recharge: Linking plant response, hydrologic, and geochemical processes

Helen E. Dahlke, Elad Levintal, Nick Murphy, Yonatan Ganot, Spencer Jordan, Thomas Harter  
University of California, Davis - [hdahlke@ucdavis.edu](mailto:hdahlke@ucdavis.edu)

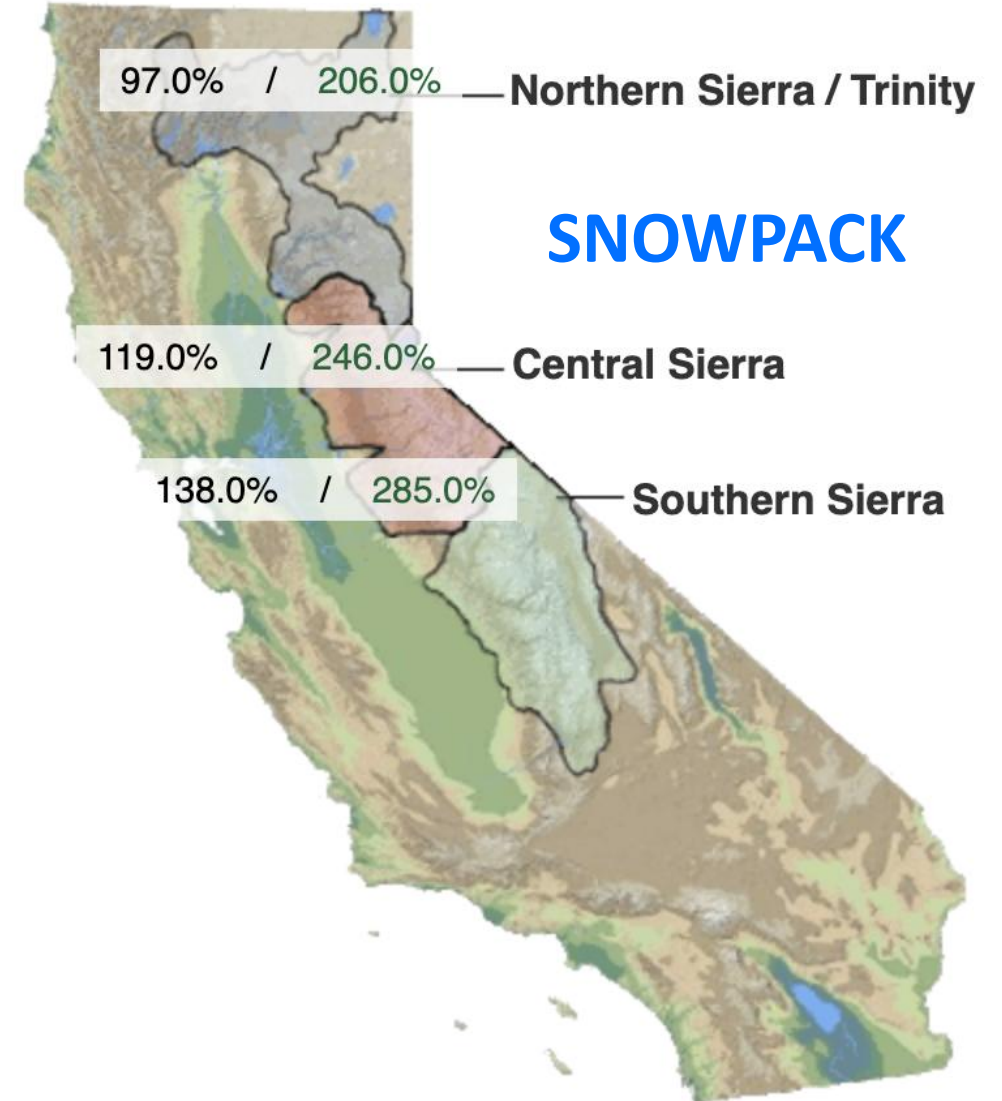
# Current surface water & groundwater situation

Northern Sierra Precipitation: 8-Station Index, January 19, 2023

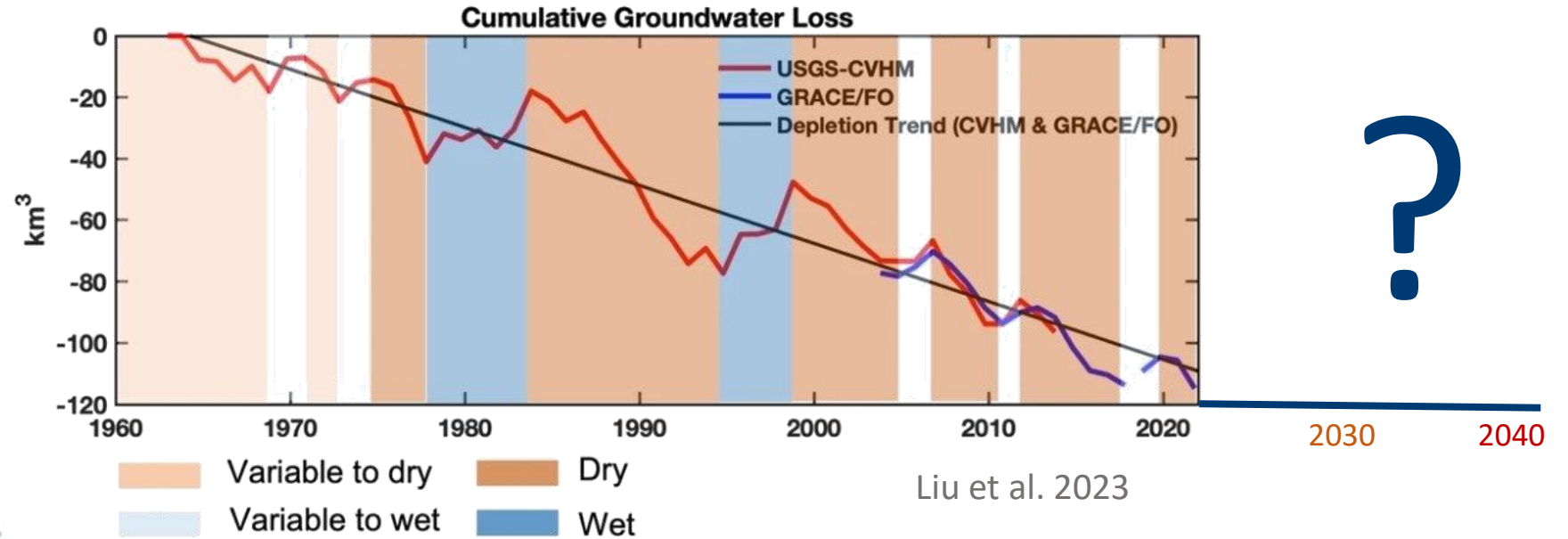
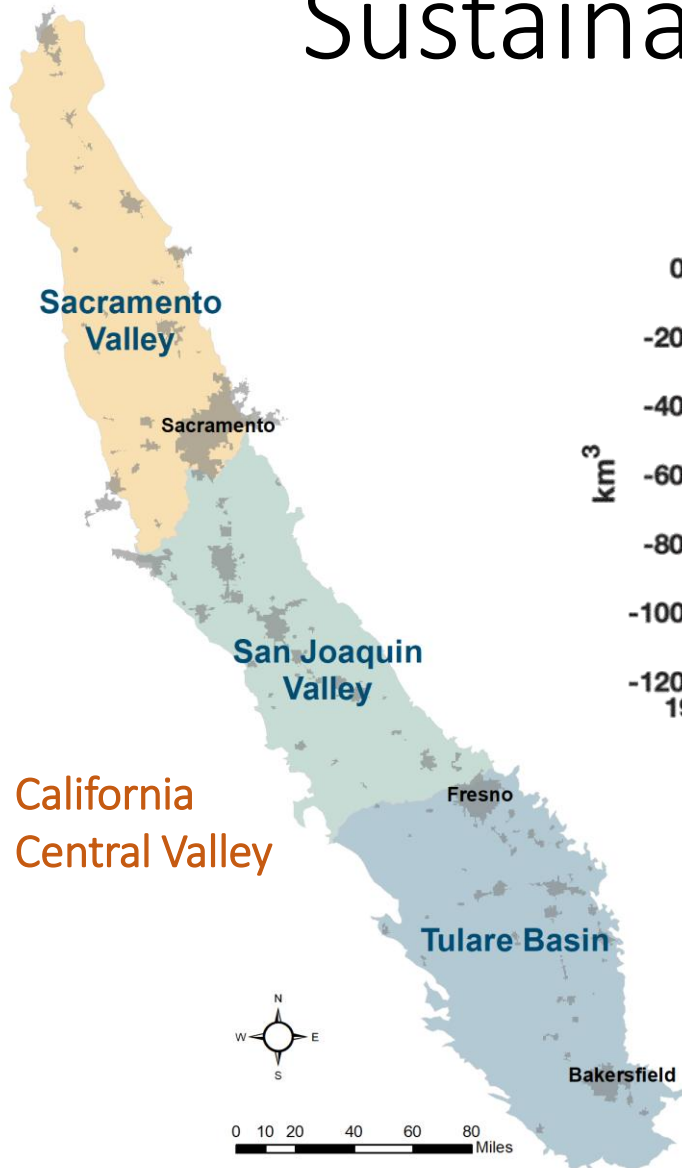


Data For: 15-Jan-2023

% Apr 1 Avg. / % Normal for this Date



# Sustainable groundwater management



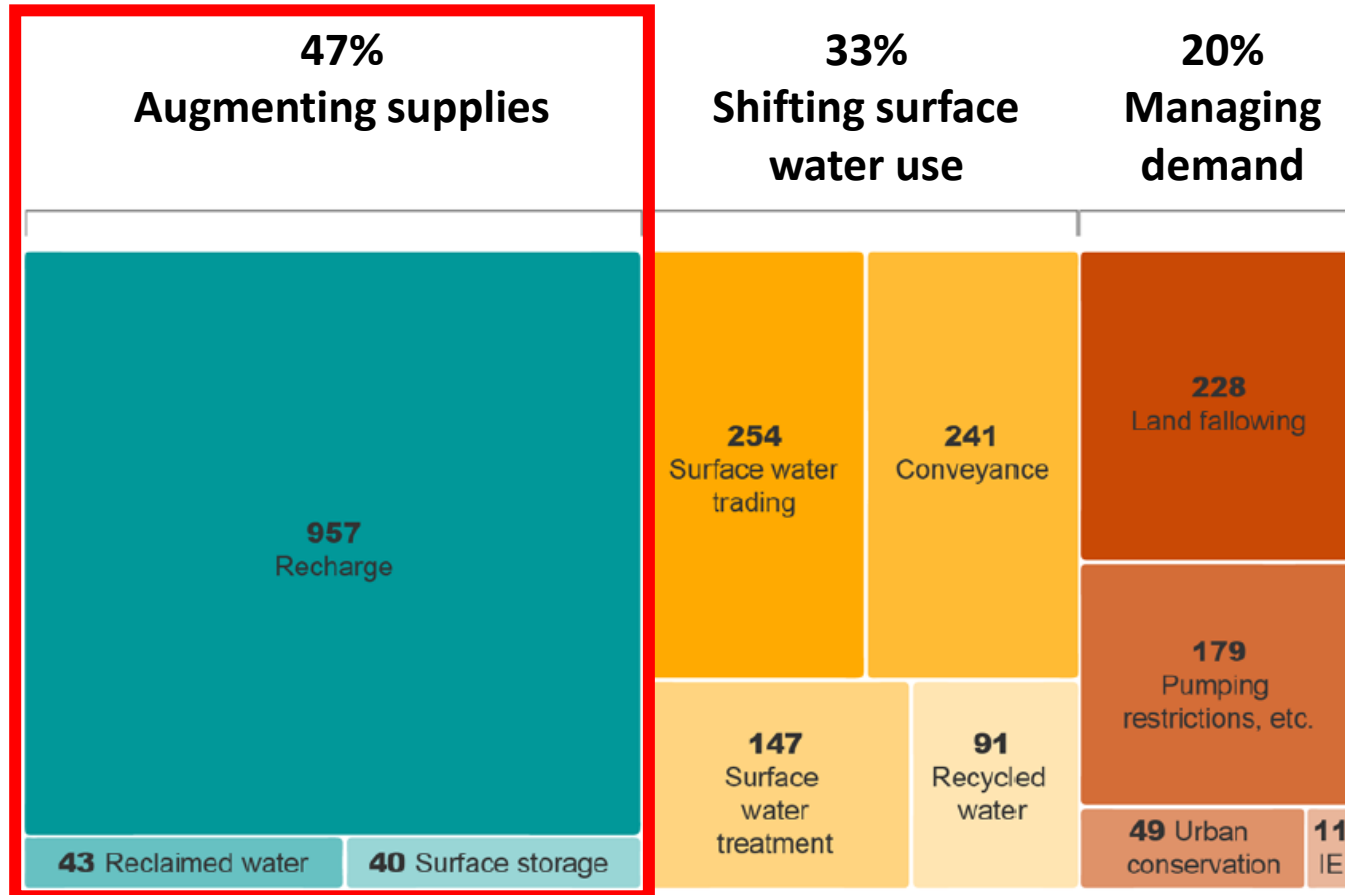
## Undesirable results of groundwater overdraft



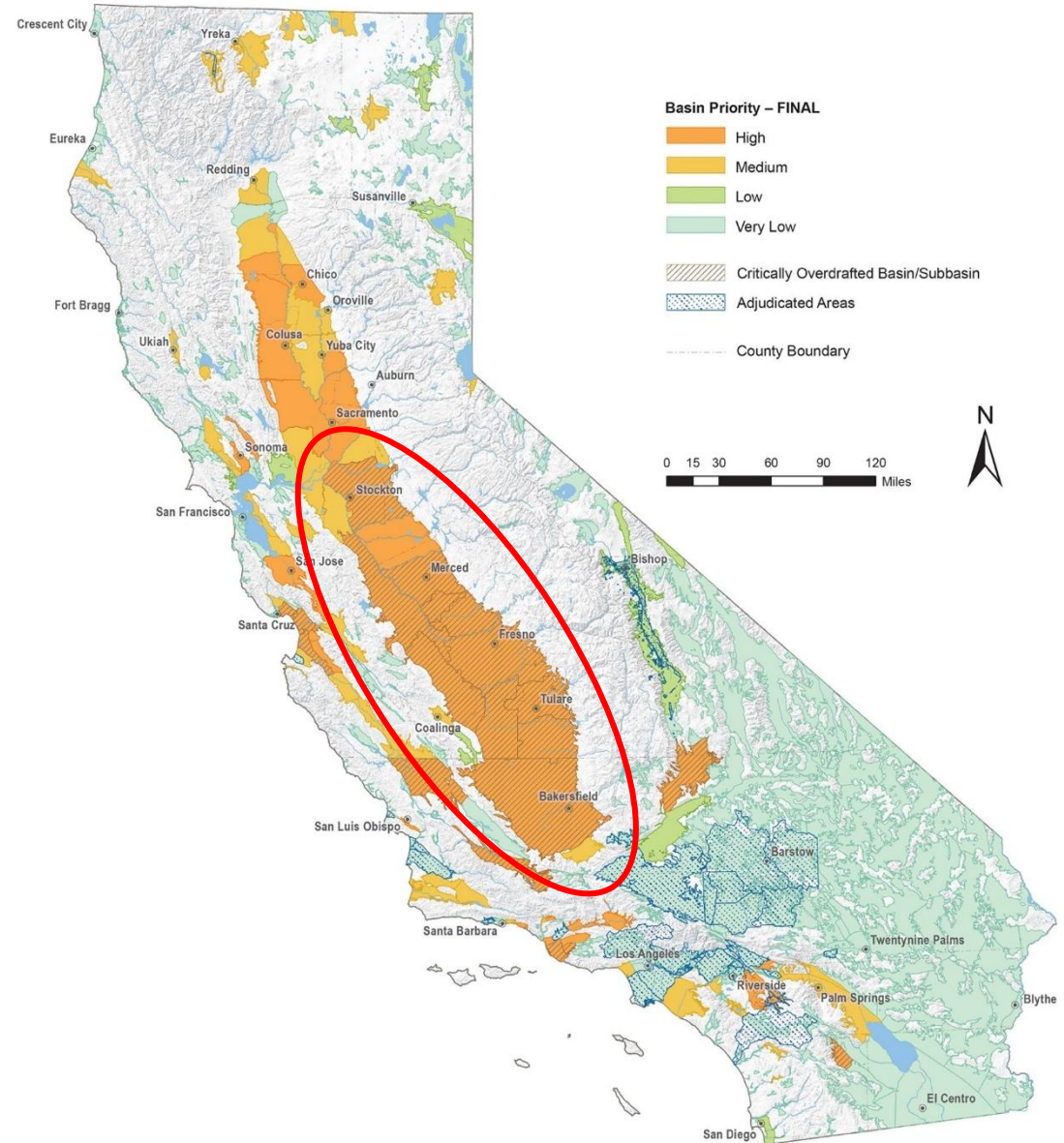
A wide, flat agricultural field, likely a rice paddy, stretches to the horizon under a dramatic sunset sky. The sun is low on the horizon, casting a golden glow across the clouds and the field. The sky is filled with large, dark blue and grey clouds, some of which are illuminated from below by the setting sun, creating a mix of blue, grey, and yellow tones. The field in the foreground is dark and appears to be recently tilled, with rows of furrows leading towards the horizon. In the distance, there are some faint outlines of buildings and utility poles. The overall mood is serene and contemplative.

How do we remedy groundwater  
overdraft of 2-4 MAF per year?

# Current plans to address groundwater overdraft



Total amount: 2,241 taf/y



# Capture high-magnitude flows

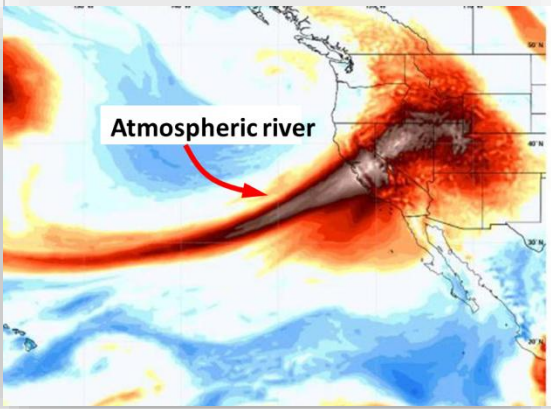
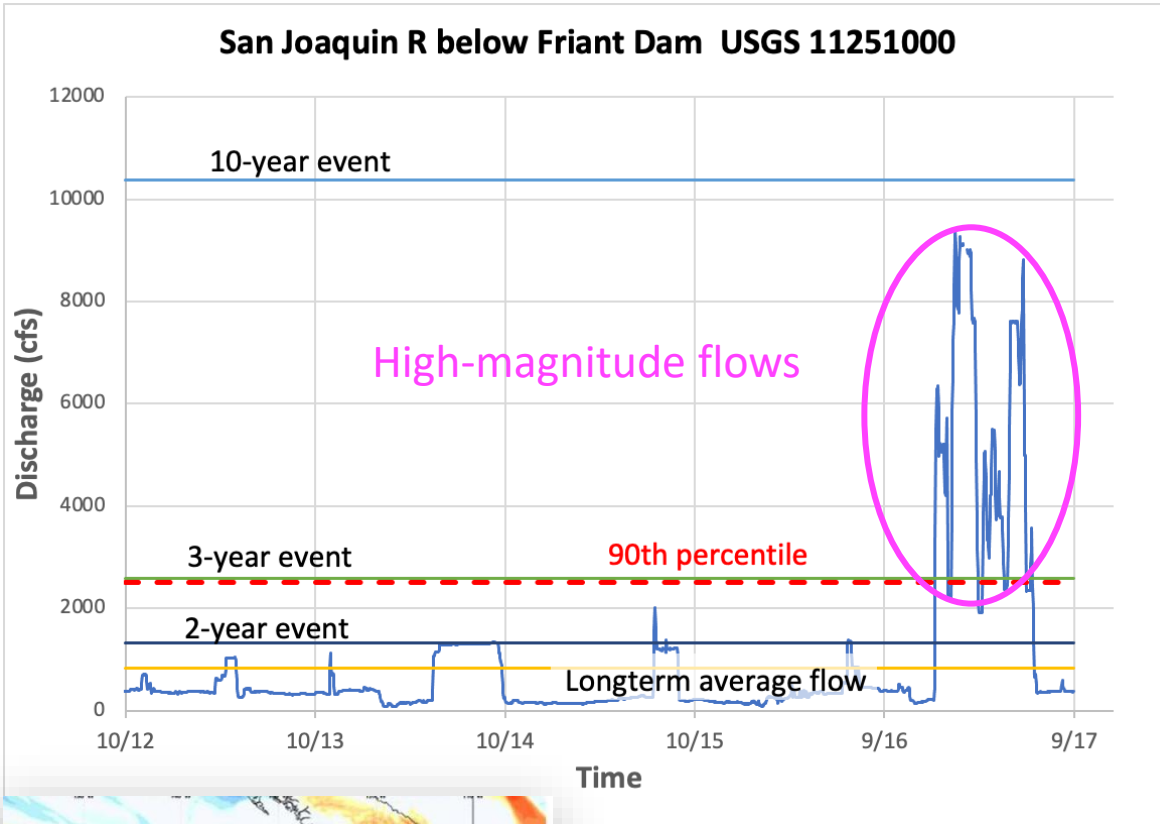


Photo credit: Sustainable Conservation



How do we capture large amounts of water in a short time?

# California Flood-MAR program

waterboards.ca.gov/waterrights/water\_issues/programs/applications/...  
CA.GOV | Home | Share: | About Us | Contact Us | Subscribe | Settings  
CALIFORNIA WATER BOARDS State Water Resources Control Board  
Board Programs Drinking Water Water Quality Water Rights Notices Water Boards Search  
Home | Waterrights | Water Issues | Programs | Applications | Groundwater Recharge | Streamlined Permits

## Streamlined Processing for Standard Groundwater Recharge Water Rights



**QUICK LINKS**

- Home
- Application Types
- FAQs
- Fact Sheets
- Groundwater Recharge Applications
- SGMA Home

The state legislature enacted the Sustainable Groundwater management Act (SGMA) to address widespread overdraft and other undesirable results caused by groundwater conditions in California’s groundwater basins. SGMA requires local agencies in high and medium priority basins to develop plans that achieve sustainability in the basin within 20 years of implementation. Groundwater recharge is likely to be an important part of achieving sustainability in groundwater basins, but local agencies may lack the water rights to divert and use that water later. The streamlined permitting process for diversion of high flows to underground storage was developed, in part, to assist local agencies to obtain necessary water rights. Those water rights will, in turn, help Groundwater Sustainability Agencies (GSAs) reach their sustainability goals more quickly.

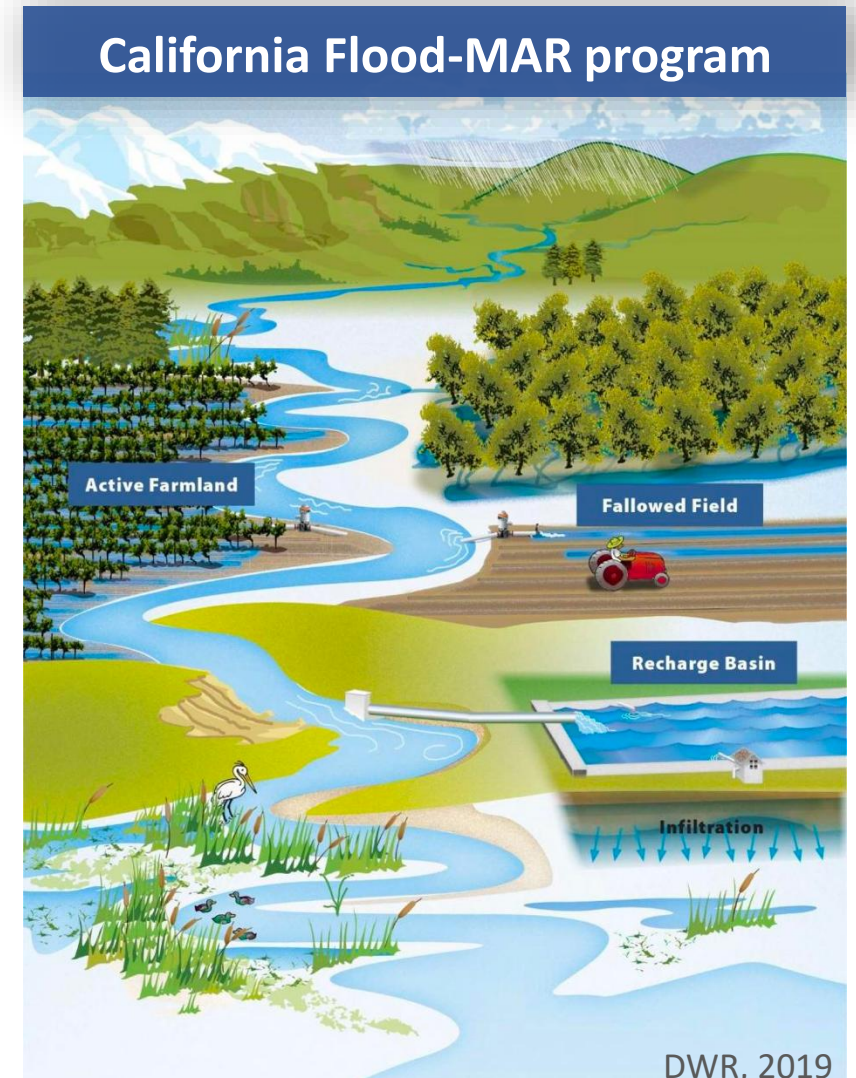




Photo credit: PPIC

Don Cameron, General Manager, Terranova Ranch

## Bio-physical factors

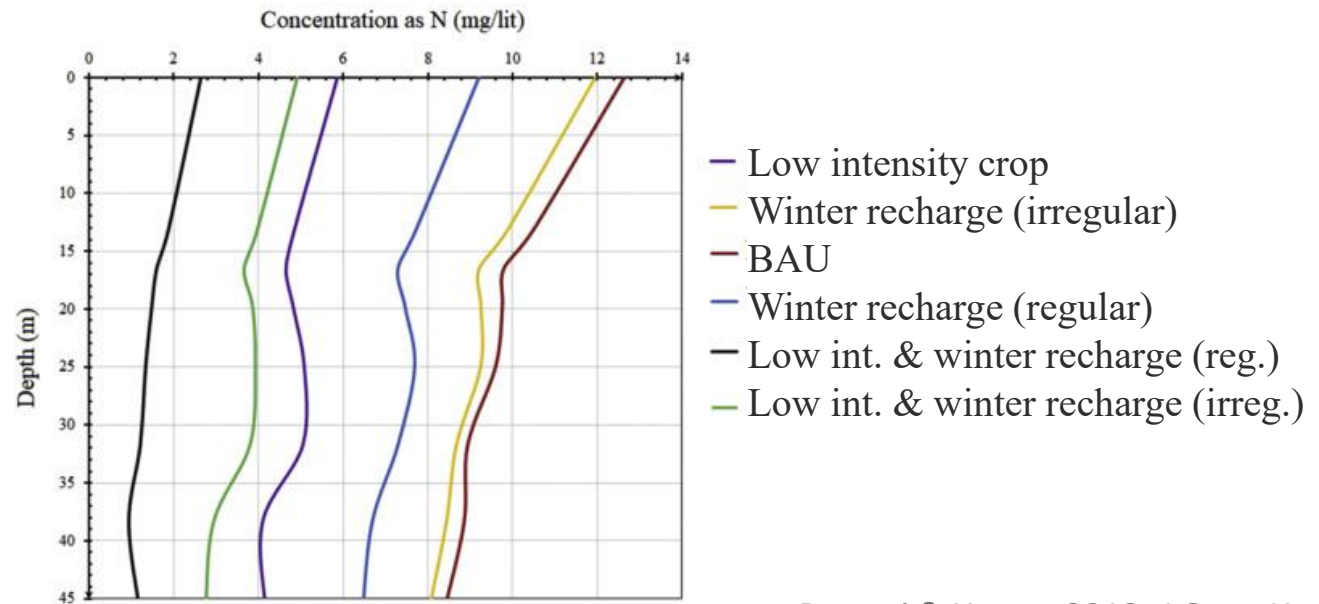
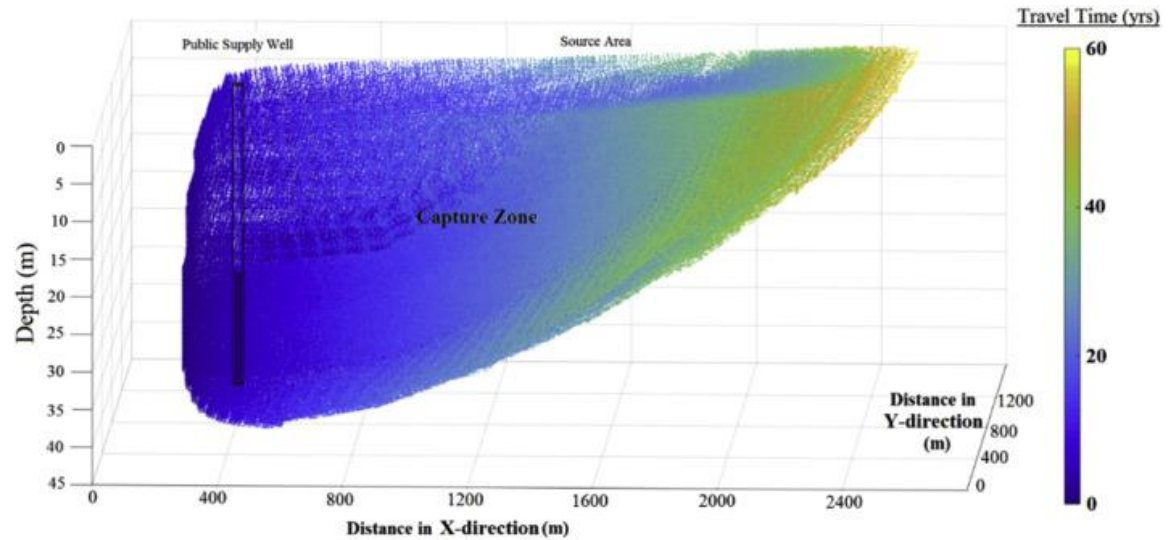
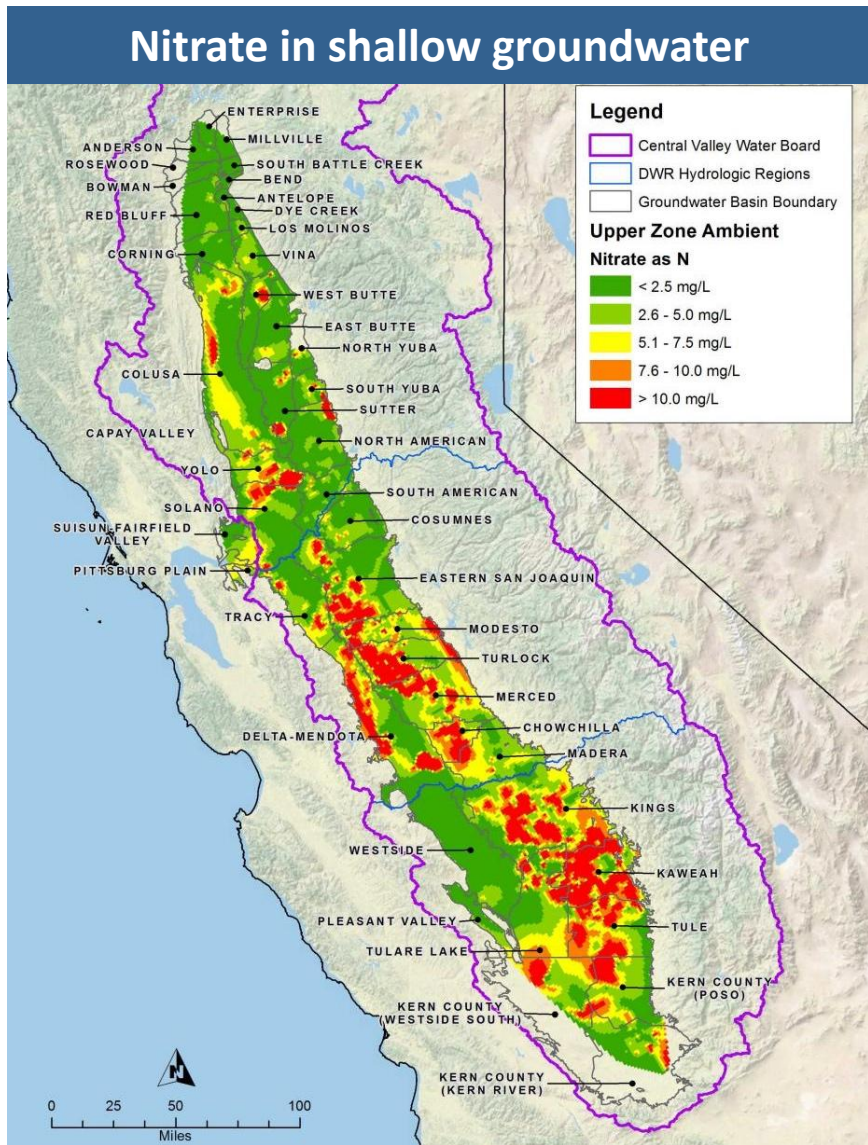
- Crop tolerance
- Soil suitability
- Water availability
- Hydrogeology
- Conveyance capacity

## Institutional factors

- Cost & incentives
- Water rights
- Permits
- Shared governance
- Ecosystem services and benefits



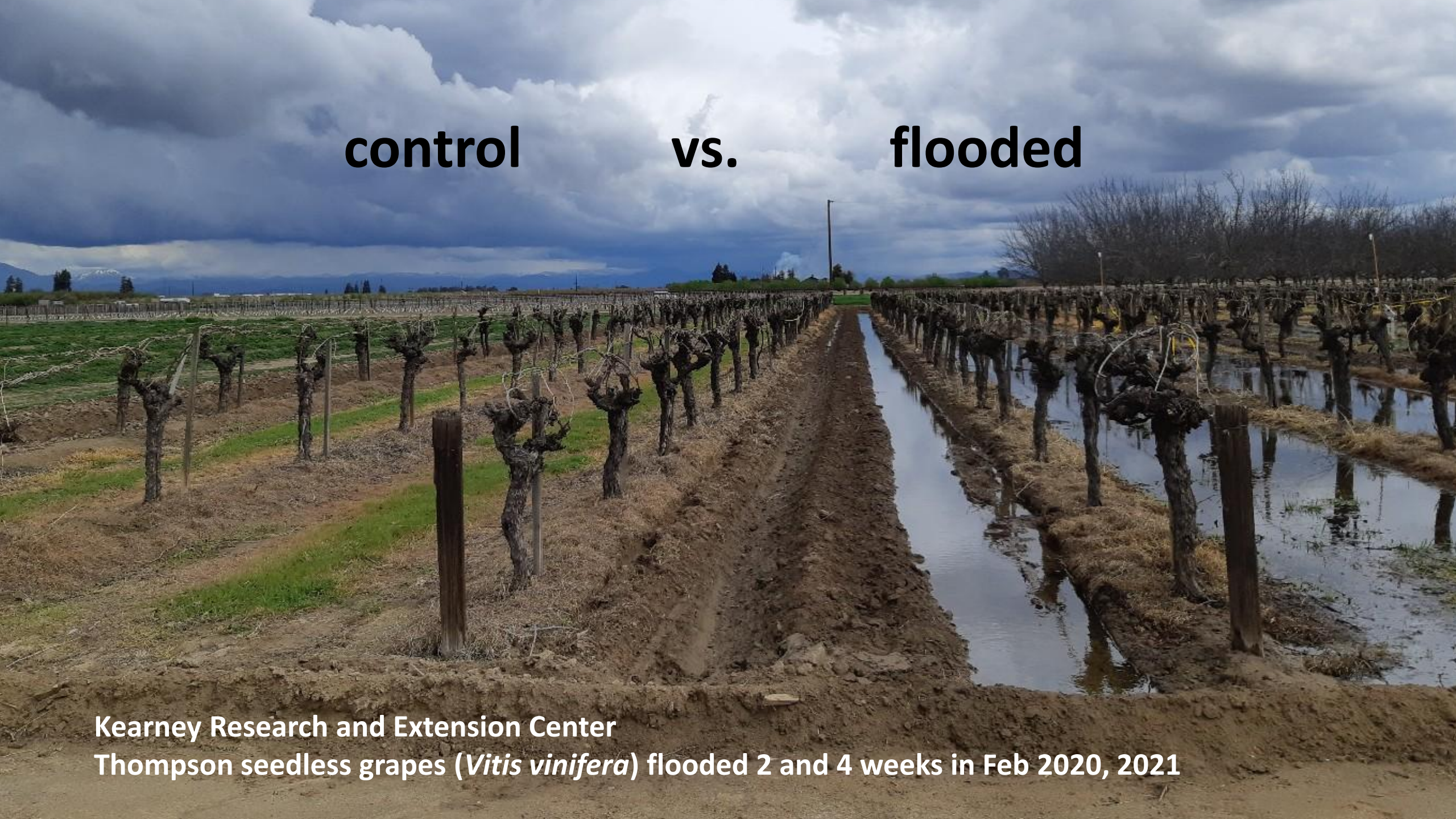
# Risk of groundwater contamination



**control**

**vs.**

**flooded**

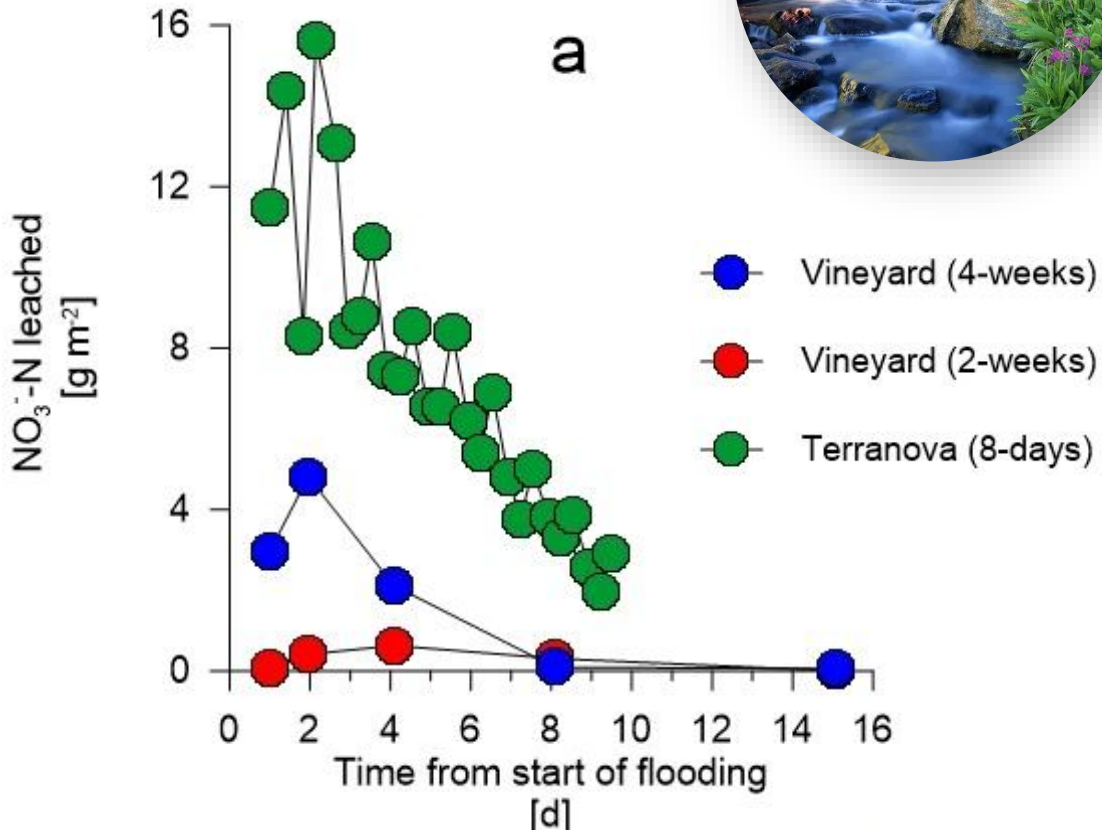


**Kearney Research and Extension Center**

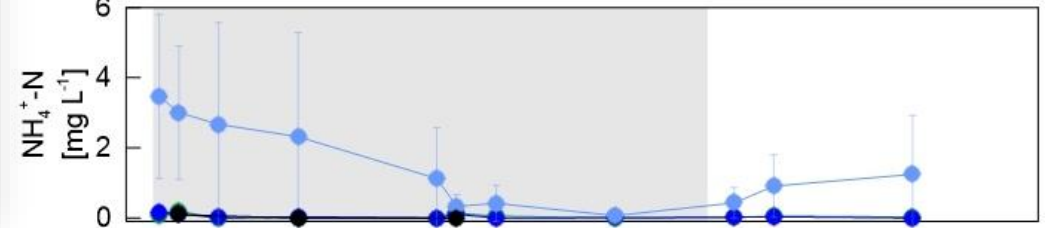
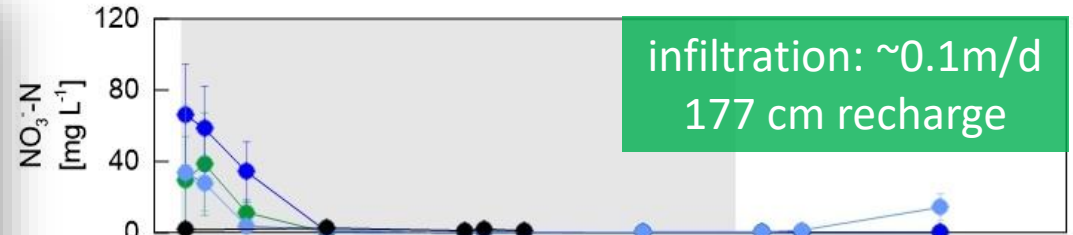
**Thompson seedless grapes (*Vitis vinifera*) flooded 2 and 4 weeks in Feb 2020, 2021**

# Site-specific nitrogen management

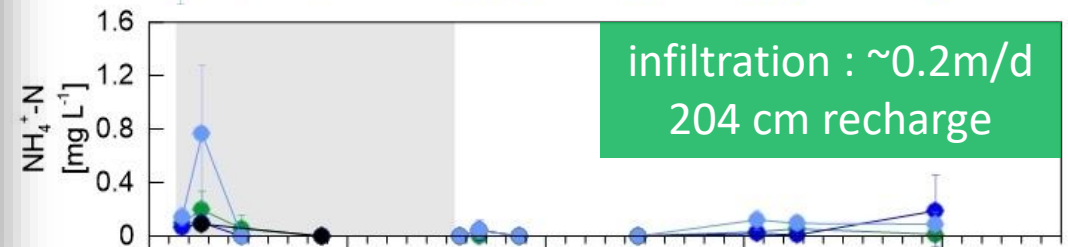
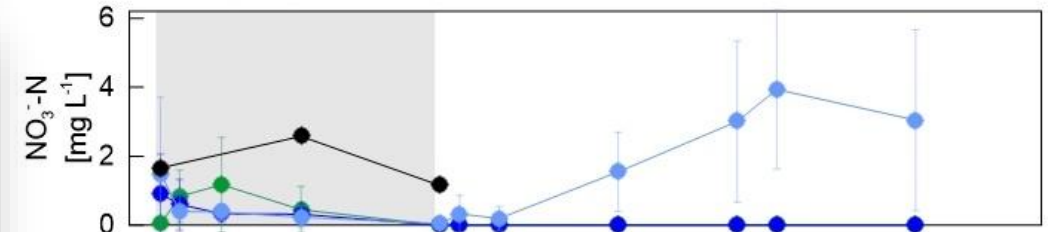
Low N source water



4-week flooded



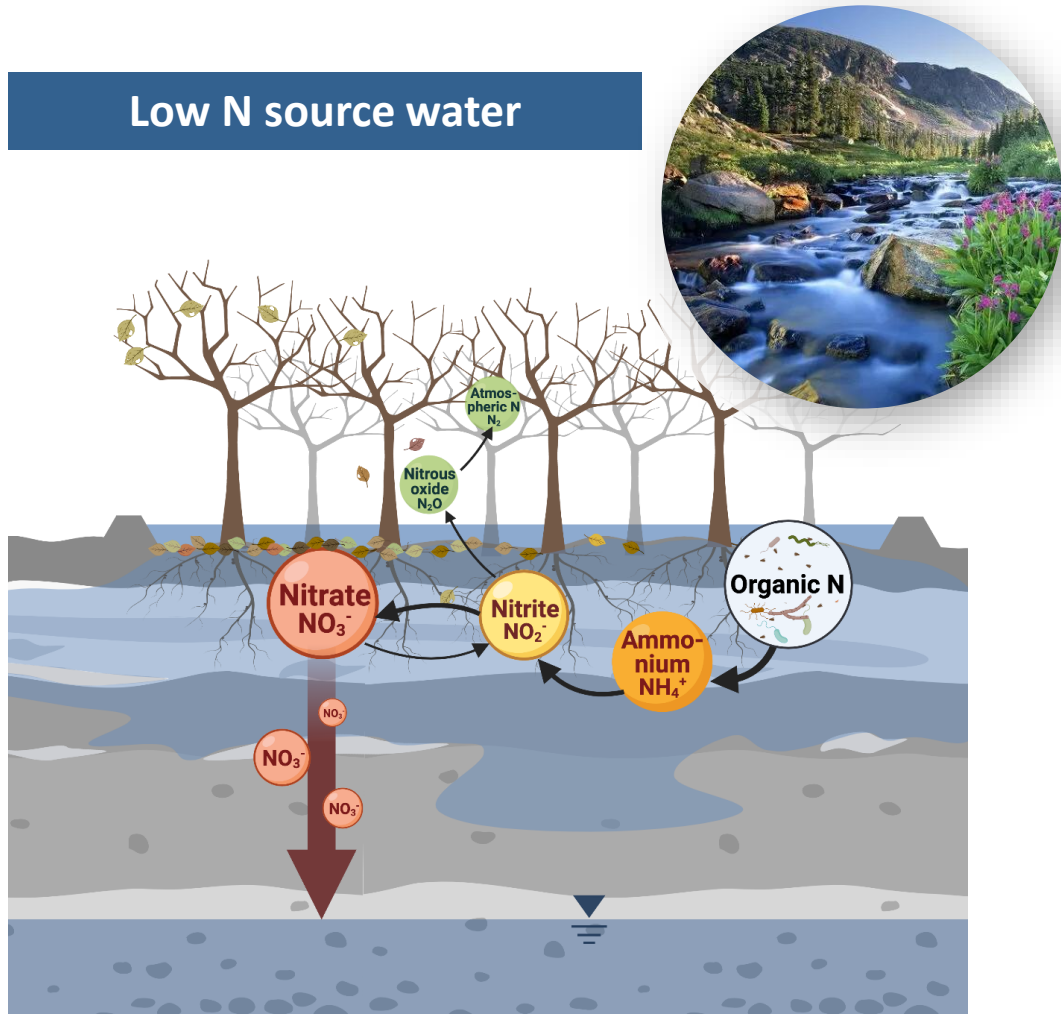
2-week flooded



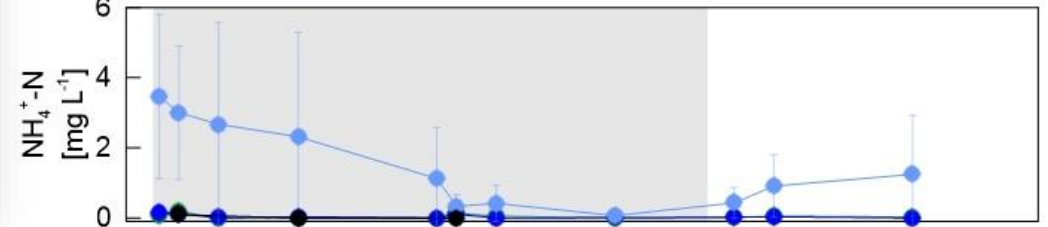
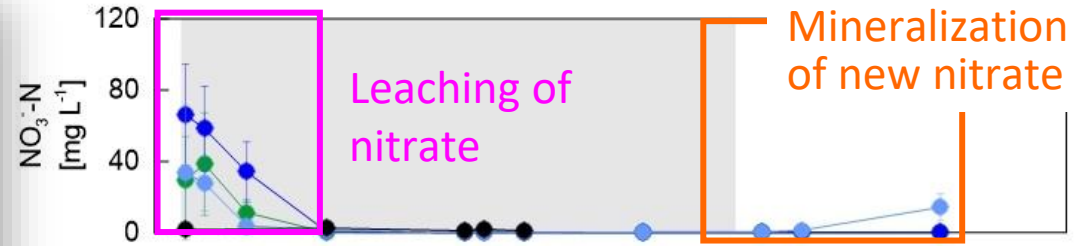
Time

0.2m 1m  
0.6m Ponding water

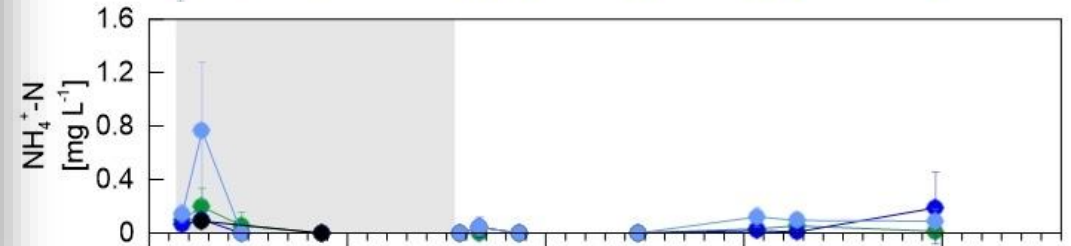
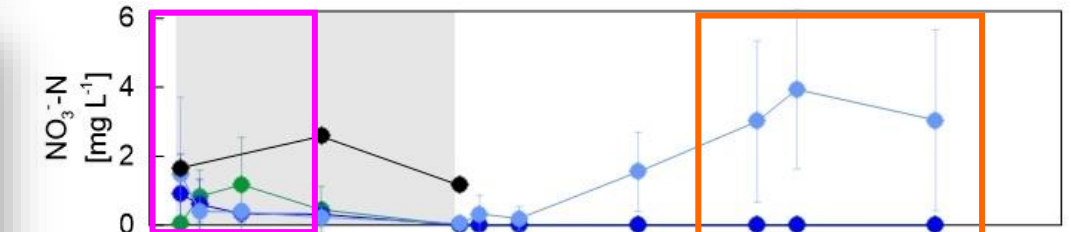
# Site-specific nitrogen management



4-week flooded



2-week flooded

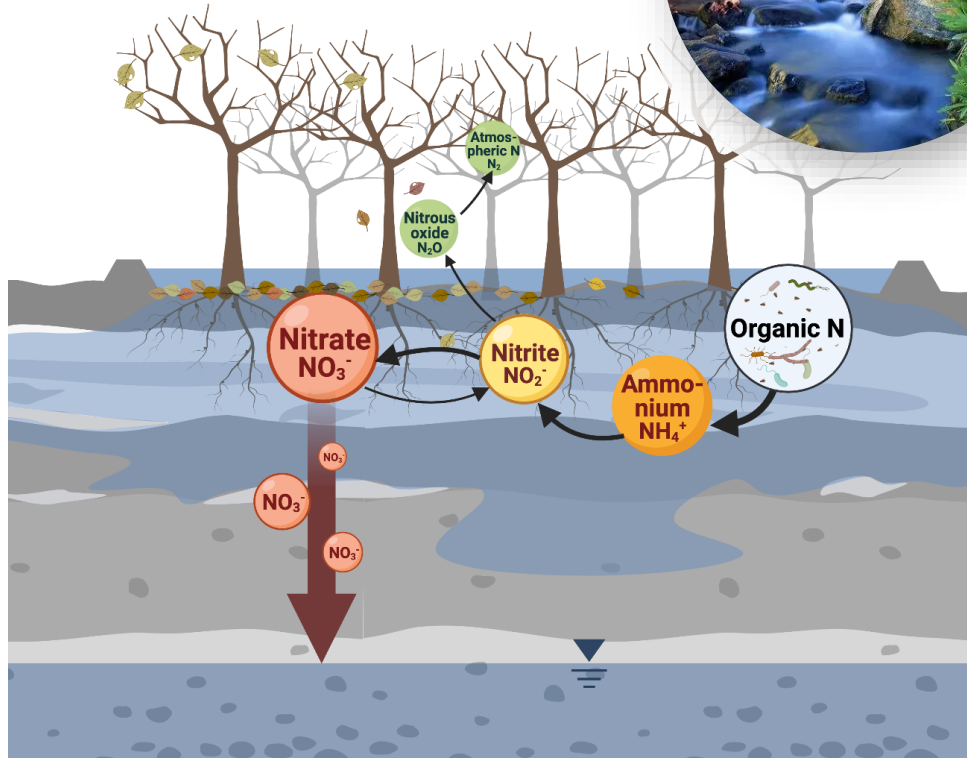


Time



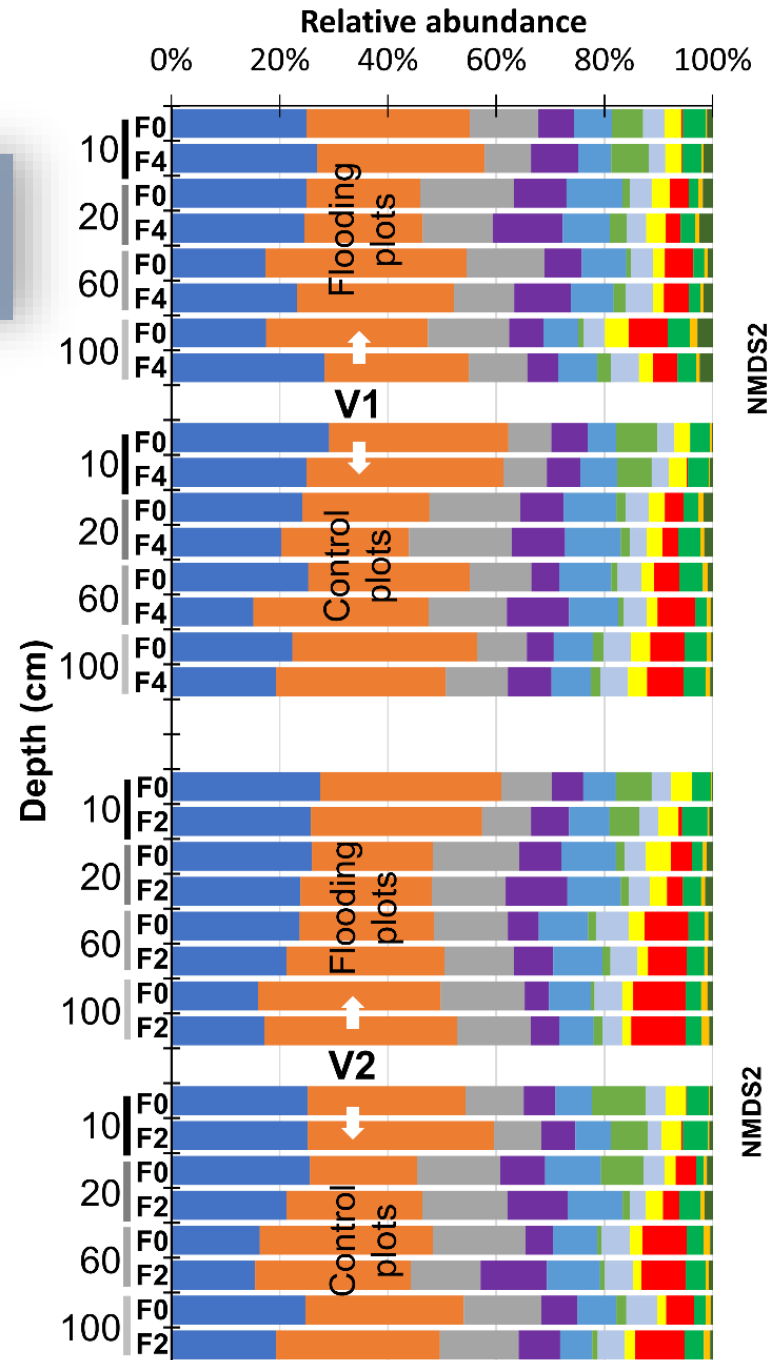
# Nitrogen cycling processes

Low N source water

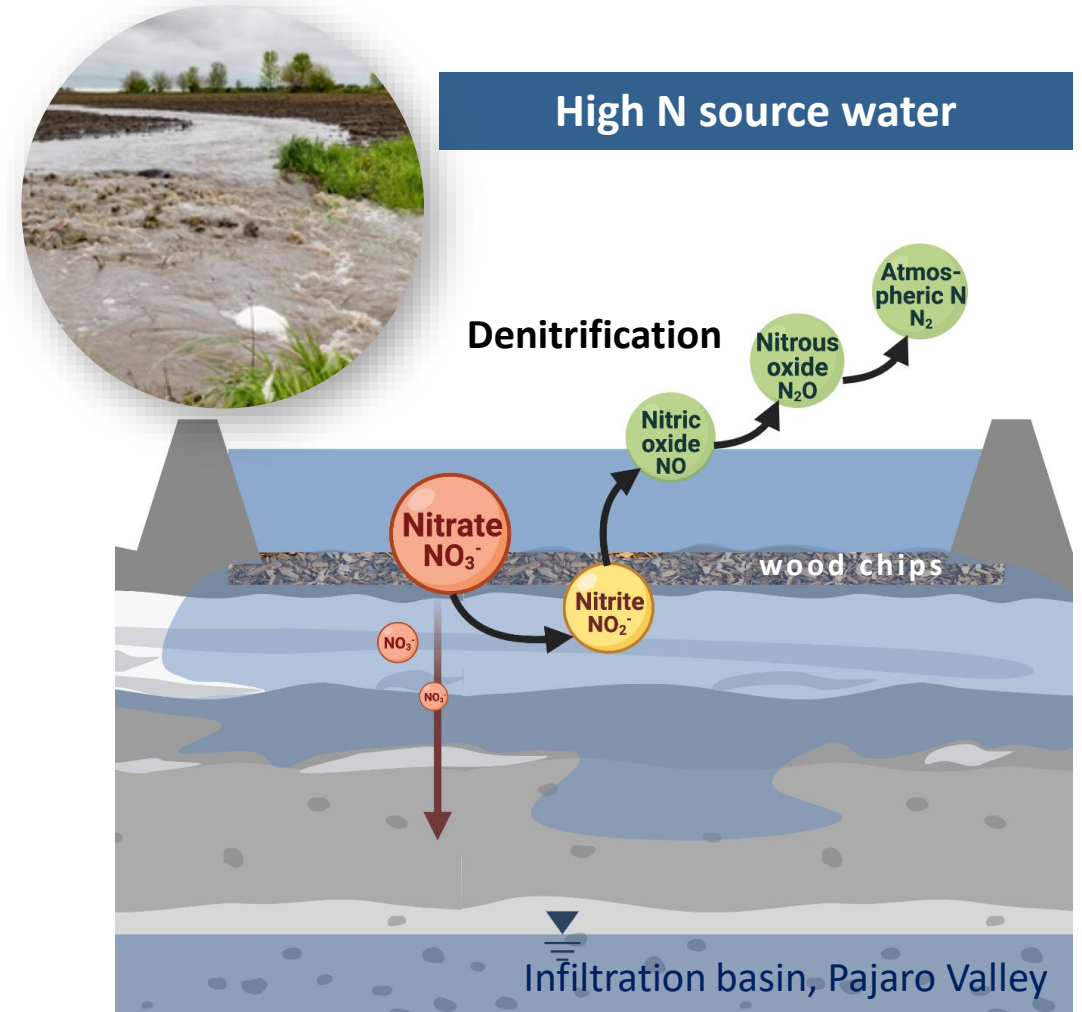
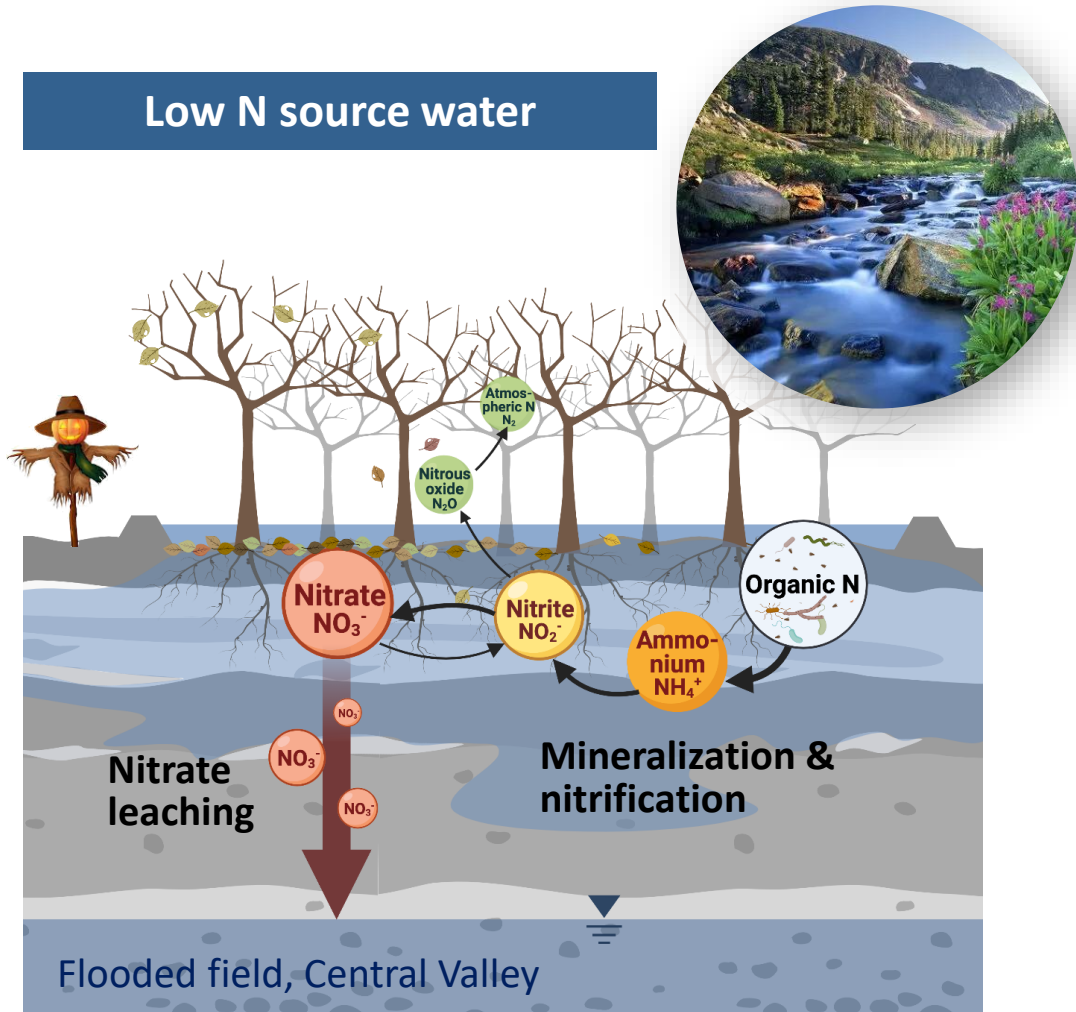


Soil microbial communities

- Proteobacteria
- Firmicutes
- Planctomycetota
- Crenarchaeota
- Actinobacteriota
- Chloroflexi
- Verrucomicrobiota
- Nitrospirota
- Acidobacteriota
- Bacteroidota
- Methylomirabilota
- Desulfobacterota



# Site-specific nitrogen management



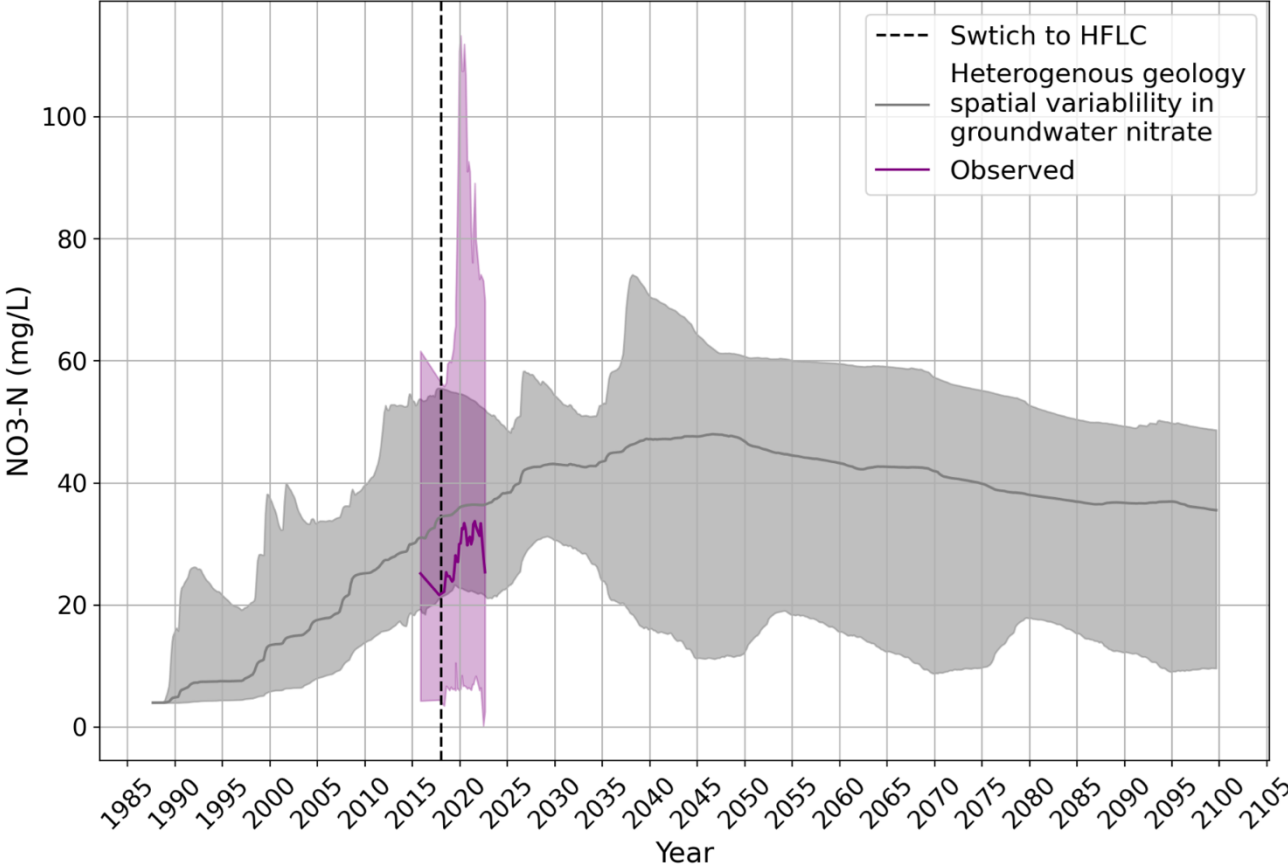


Effect of Ag-MAR on groundwater nitrate?

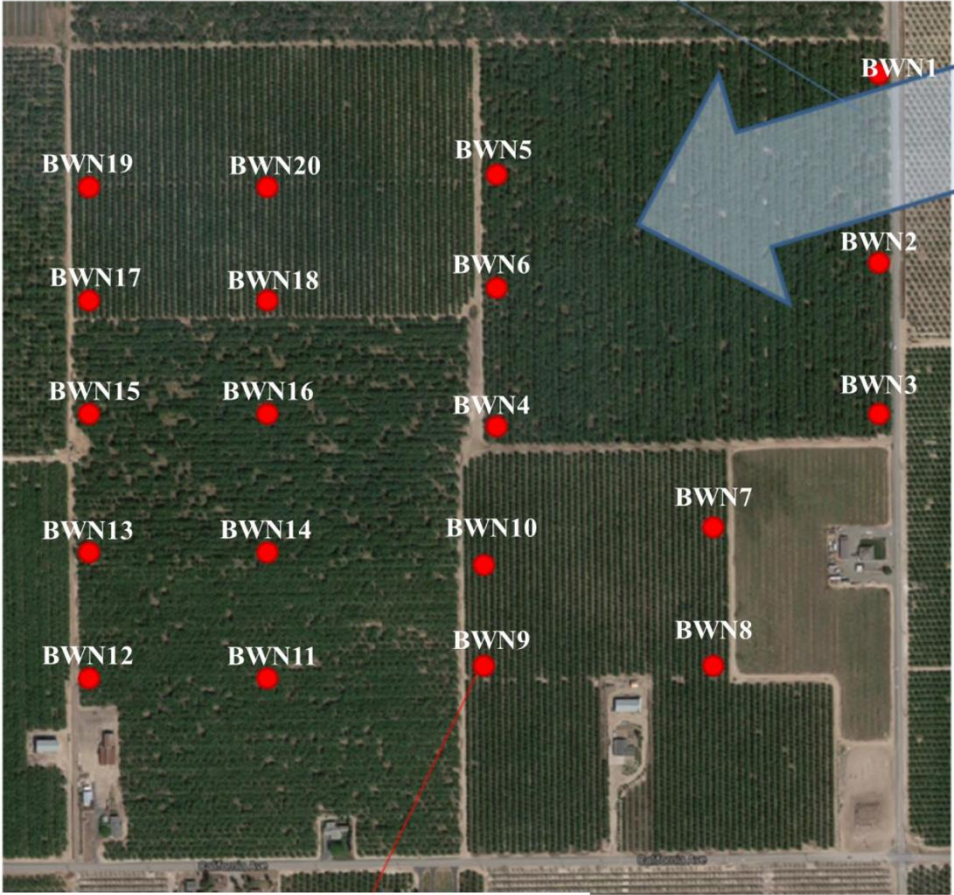
# MODFLOW Modeling of Orchard Groundwater

## Almond orchard - Modesto

MODFLOW Modeled and Observed Groundwater NO3-N Concentrations Across Orchard



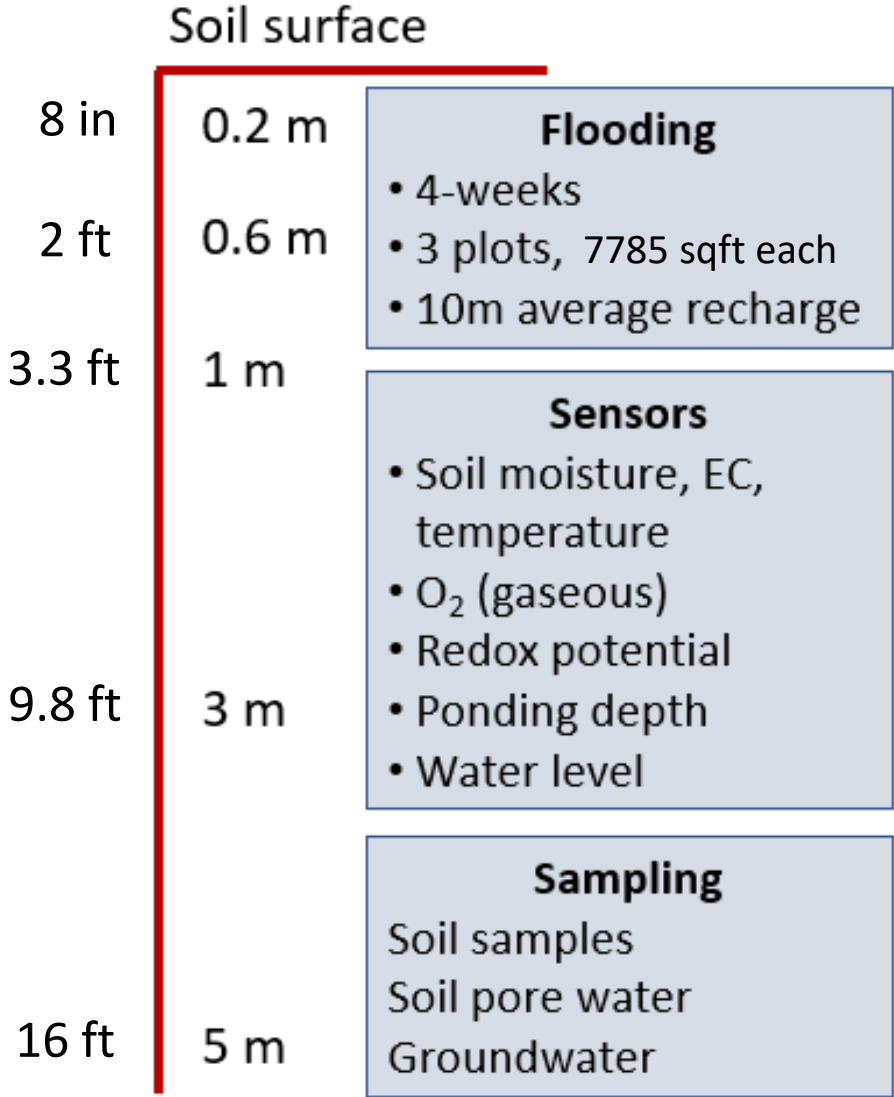
- Even with High Frequency Low Concentration fertilization, model predicts ~30 years to see NO<sub>3</sub><sup>-</sup>-N reduction in Groundwater!!



Soil coring site ●

# Nitrate leaching risk

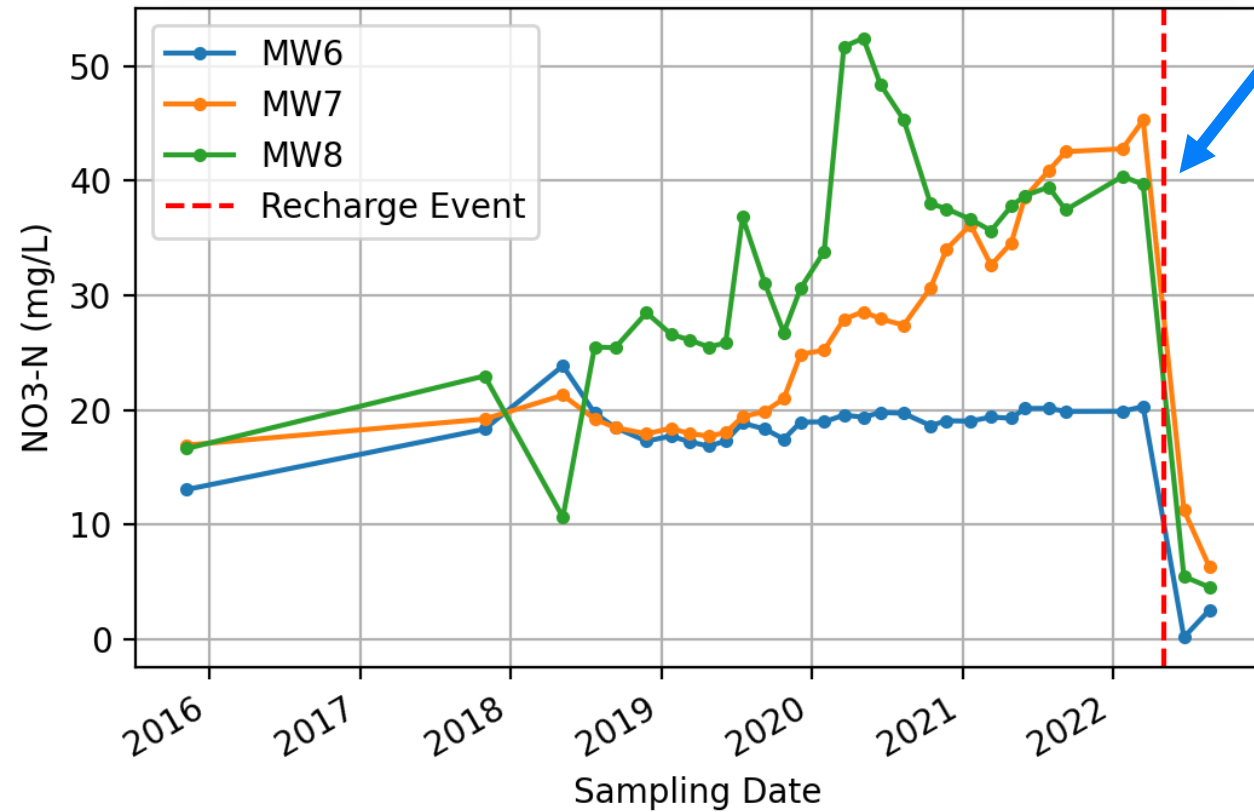
## Almond orchard - Modesto



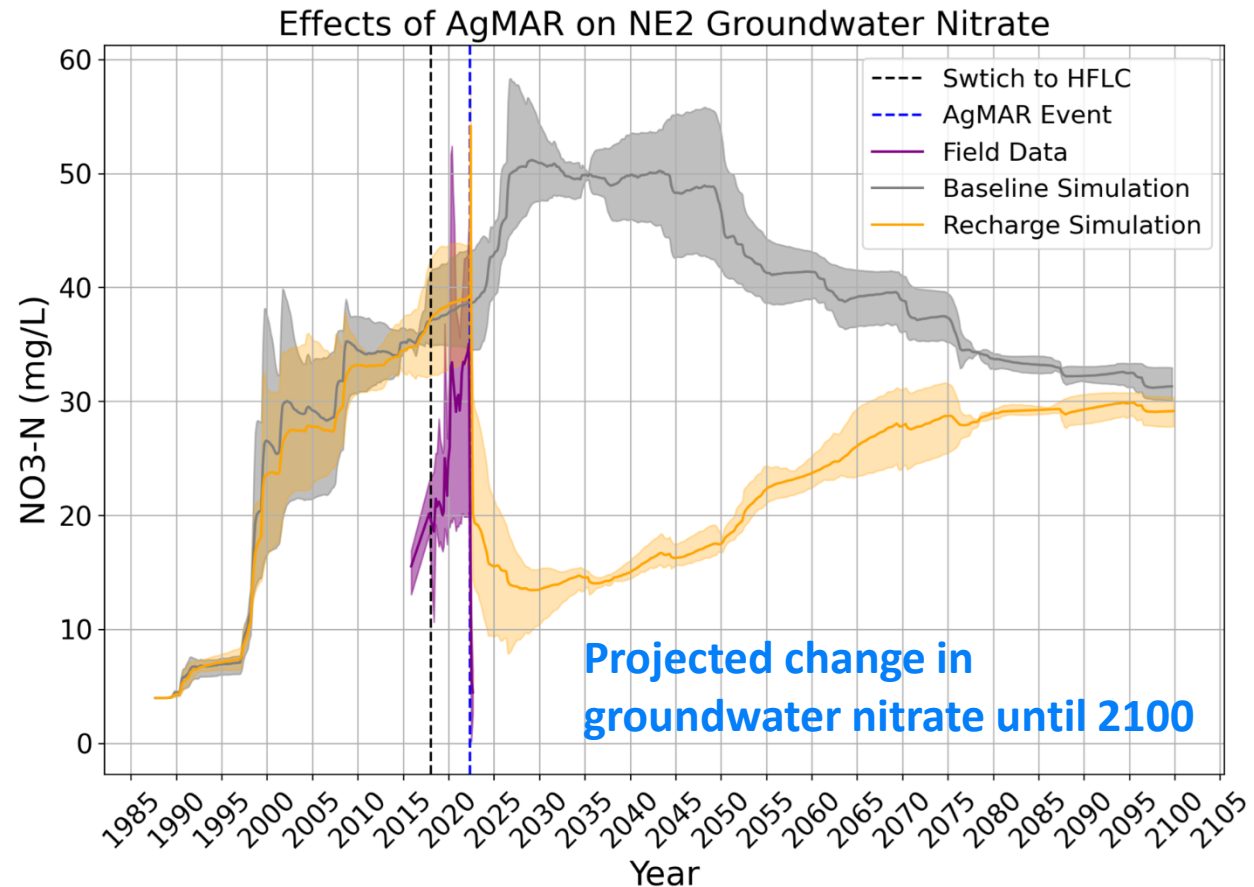
Groundwater table at 21 ft

# Effect of Ag-MAR on groundwater nitrate

Ambient groundwater nitrate concentrations



Recharge effect on ambient groundwater nitrate concentration



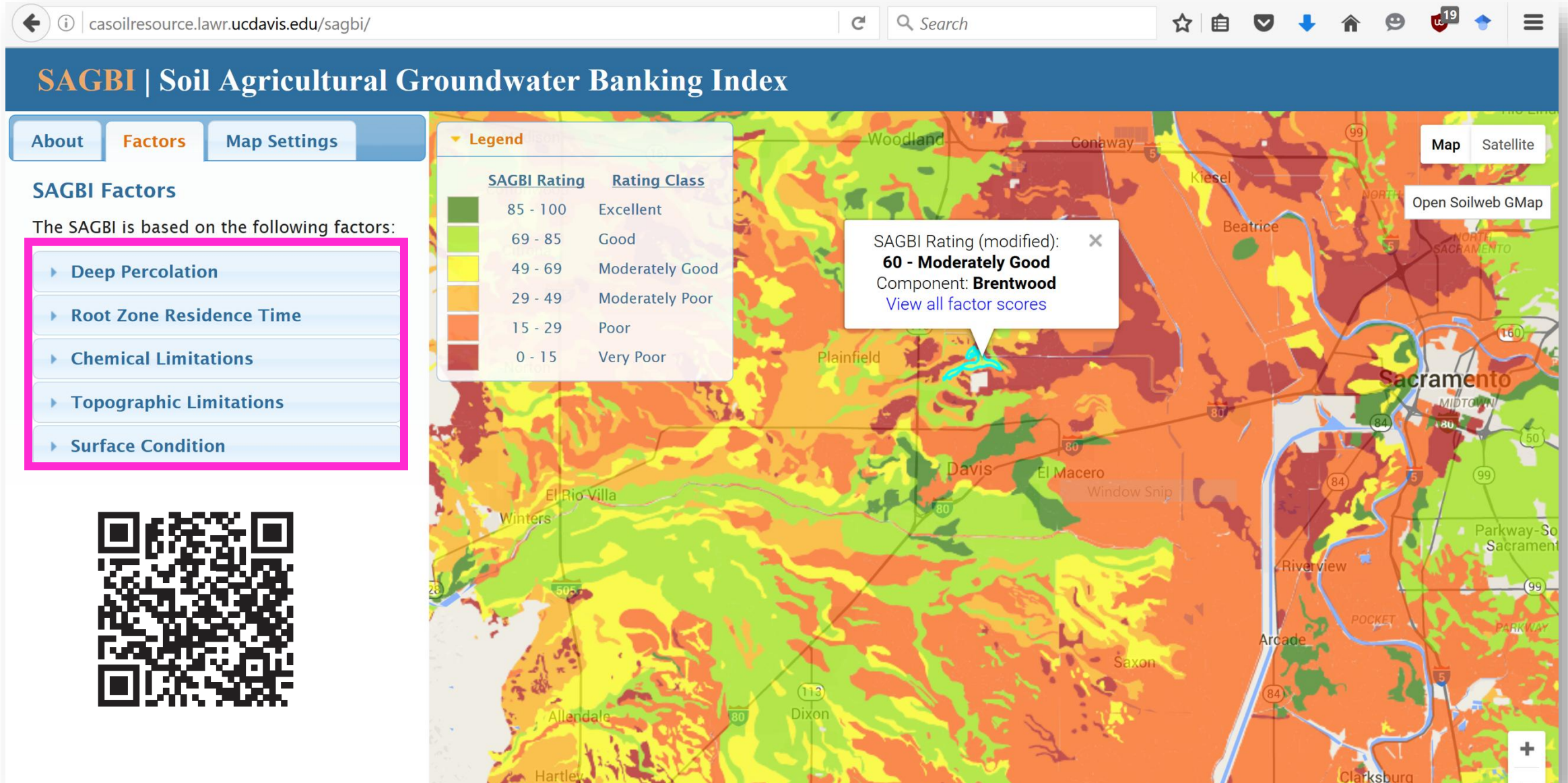
Projected change in groundwater nitrate until 2100

A sunset over a body of water with a forest in the background and some structures in the distance. The sky is filled with soft, golden light, and the water reflects the colors of the setting sun. The foreground shows a dark, rocky shoreline.

# DECISION SUPPORT TOOLS

How to site the best Ag-MAR locations?

# Decision support



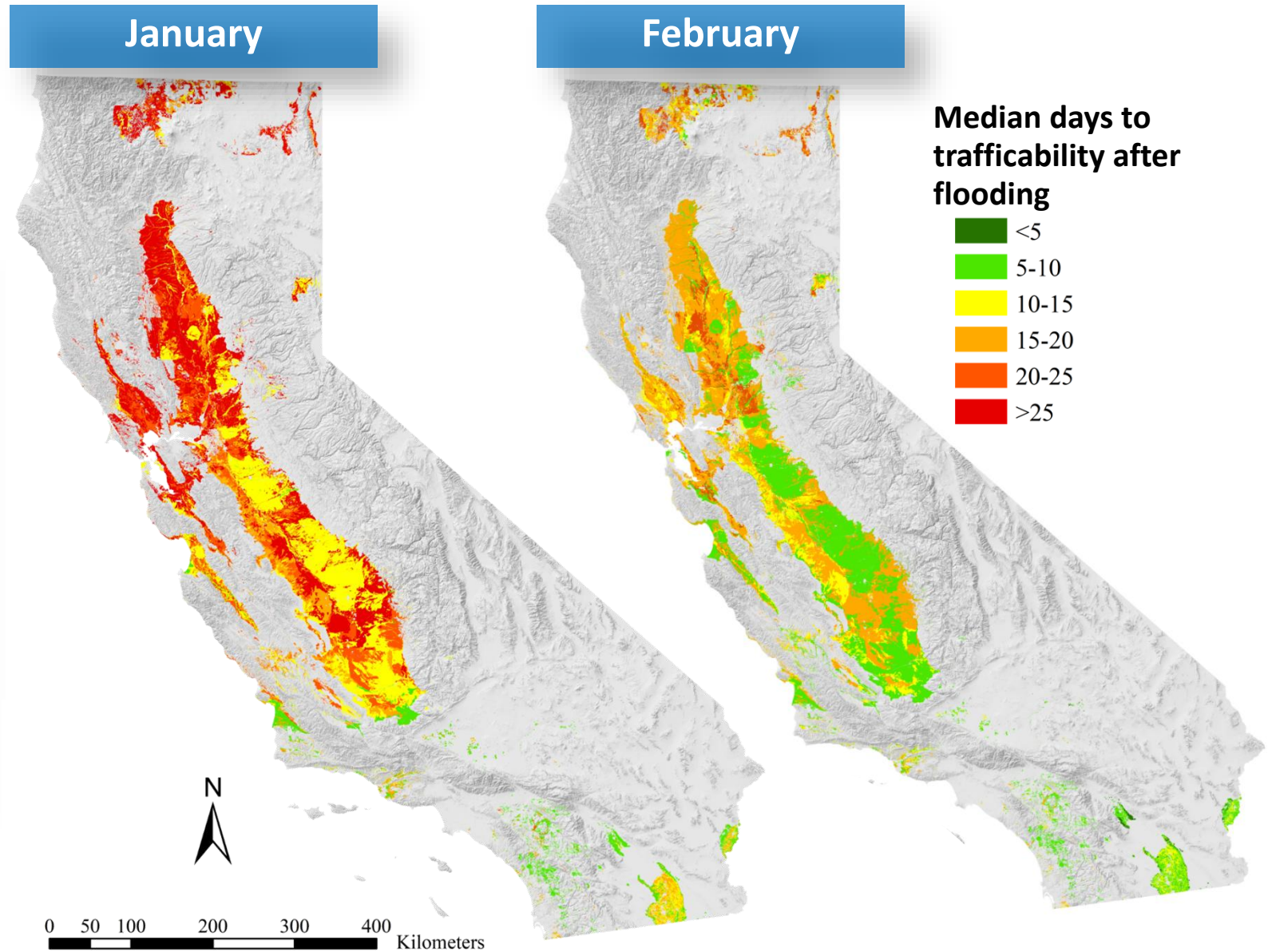
# Soil-crop relationships

Crop	SAGBI rating	Soil texture	Infiltration rate (in/hr)	Water applied (ft)	Deep percolation (%)	Yield - compared to control (%)
<b>Almond</b>	Excellent	Dune land	13	2.1	99	125
<b>Alfalfa</b>	Good	Stoner gravelly coarse loam	3.9	28	99	90
<b>Almond</b>	Moderately good	Dinuba fine sandy loam	2.7	2	87	99
<b>Tomato</b>	Moderately poor	Traver fine sandy loam	0.24	1.95	85	125
<b>Almond</b>	Moderately poor	Tehama silt loam*	0.25	0.4	77	-
<b>Grape</b>	Poor	Hanford sandy loam*	0.32	6.7	98	88
<b>Grape</b>	Poor	Hanford fine sandy loam*	0.16	5.8	95	60

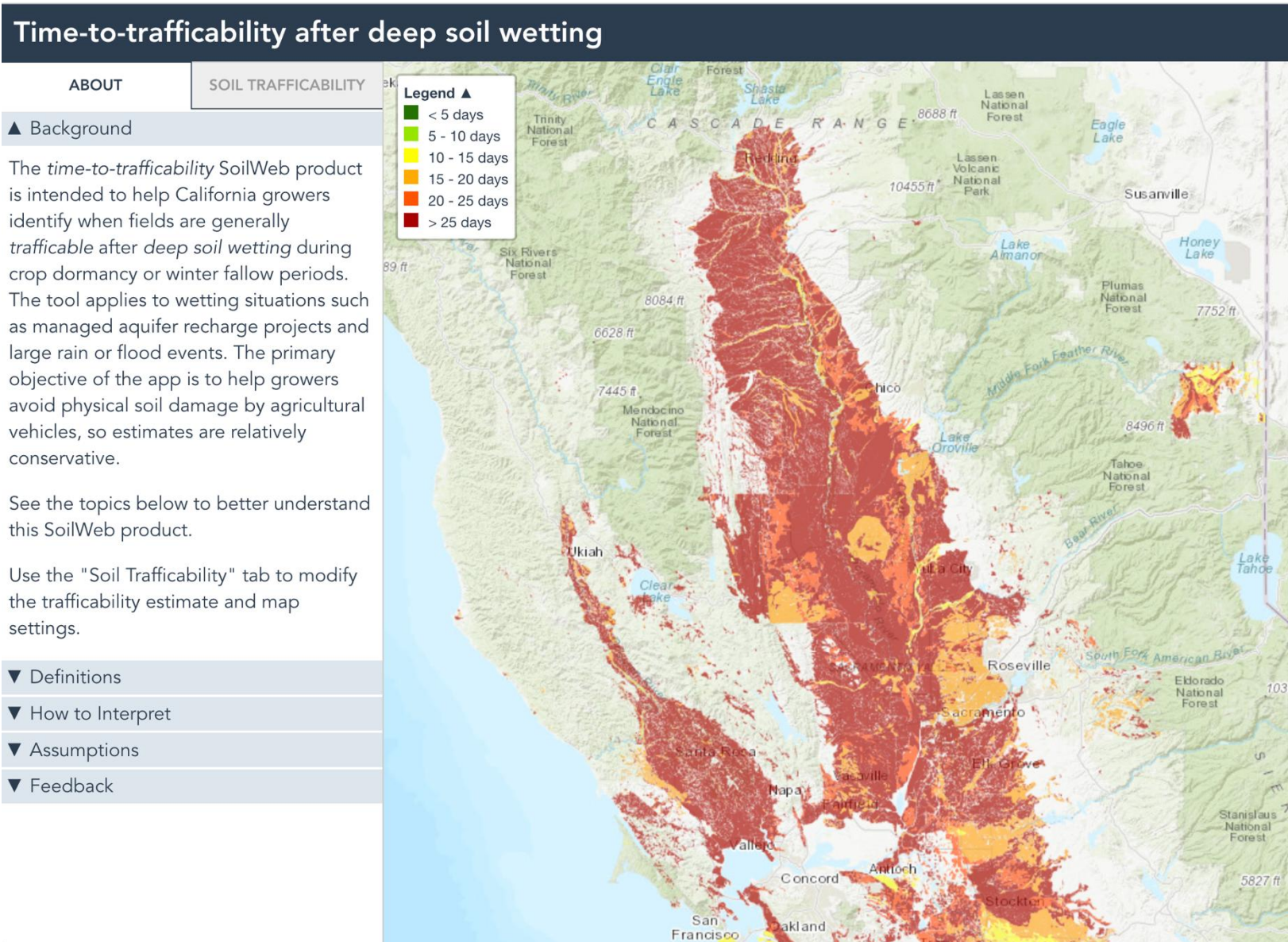
\* Soil with hardpan

# Soil trafficability after deep wetting

Trafficability and risk of soil compaction



# Soil trafficability after deep wetting



<https://soilmap2-1.lawr.ucdavis.edu/soil-trafficability/>

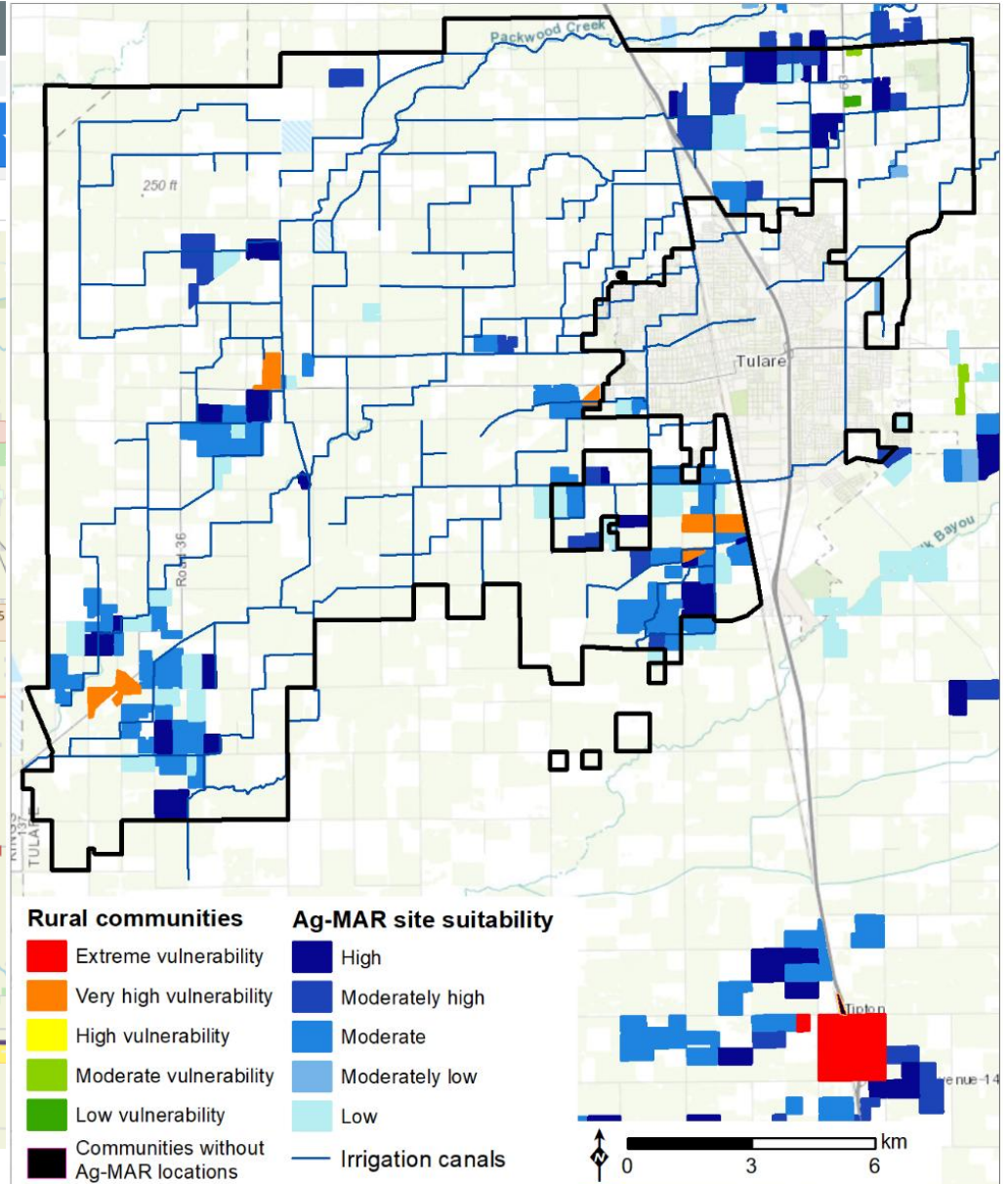
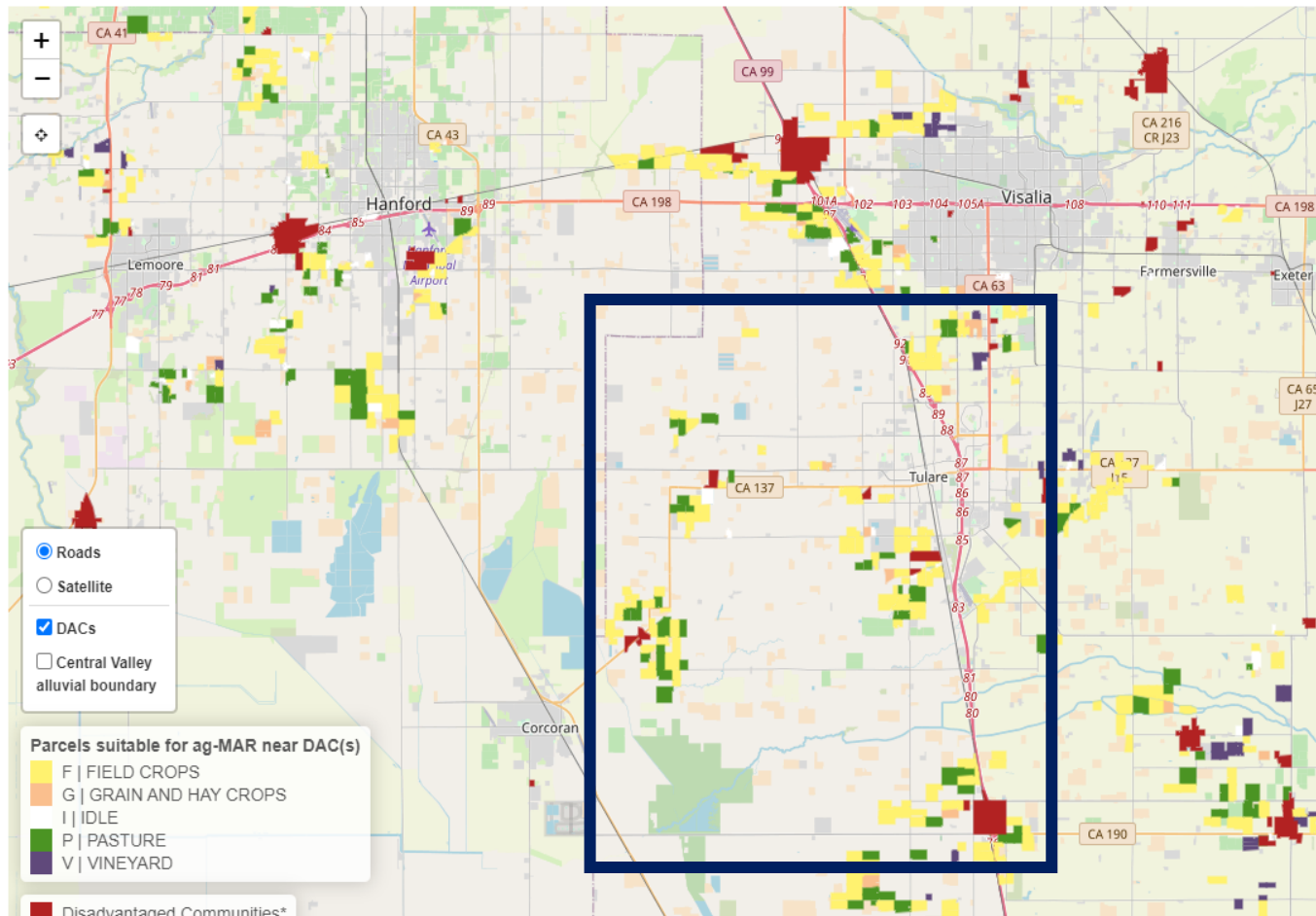


# Targeted recharge near vulnerable communities

<https://agra.ucdavis.edu>

Agricultural Groundwater Recharge Assessment (AGRA) Final Results Suitable Ag-MAR Locations DAC Vulnerability to Groundwater Shortages

Suitable parcels for ag-MAR that can benefit community water supplies



# Why should I consider Ag-MAR

- Increased groundwater storage for next drought
- Fill up soil profile prior to growing season
- Frequency of wet years is decreasing (every 5-7 years)
- Additional moisture stimulate mineralization (natural production of nitrate in soils)
- Recharge with low nitrogen source water does dilute elevated groundwater nitrate concentrations
- Management of soil salinity



Thank you!

Many **THANKS** to my students, postdocs and collaborators!

Don Cameron, Nick Blom, Cristina Prieto Garcia, Elad Levintal, Yonatan Ganot, Nick Murphy, Shulamit Shroder, Yara Pasner, Matt Fidelibus, Nick Clark, Astrid Volder, Roger Duncan



# References

- Levintal, E., Kniffin, M.L., Ganot, Y., Marwaha, N., Murphy, N.P., and H.E. Dahlke. 2022. Agricultural managed aquifer recharge (Ag-MAR) – a method for sustainable groundwater management: A review. *Critical Reviews in Environmental Science and Technology*. <https://doi.org/10.1080/10643389.2022.2050160>
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- Dahlke, H.E., Brown, A.G., Orloff, S., Putnam, D., A. O’Geen. 2018. Managed winter flooding of alfalfa recharges groundwater with minimal crop damage. *California Agriculture*, <https://doi.org/10.3733/ca.2018a0001>
- Kocis, T.N. and H.E. Dahlke. 2017. Availability of high-magnitude streamflow for groundwater banking in the Central Valley, California. *Environmental Research Letters*, <https://doi.org/10.1088/1748-9326/aa7b1b>.
- O’Geen et al. 2015. A Soil Survey Decision Support Tool for Groundwater Banking in Agricultural Landscapes, California *Agriculture Journal*, <https://doi.org/10.3733/ca.v069n02p75>



Carolyn M. Jones

NATURAL RESOURCE CONSERVATION SERVICES



United States Department of Agriculture

# Natural Resources Conservation Service

Carolyn M. Jones, PE  
Bay/Delta Team Agricultural Engineer  
Vacaville (CA) Service Center

Irrigated Lands Regulatory Program  
Well Decommissioning with NRCS  
January 24, 2023



Natural  
Resources  
Conservation  
Service

[nrcs.usda.gov/](https://nrcs.usda.gov/)

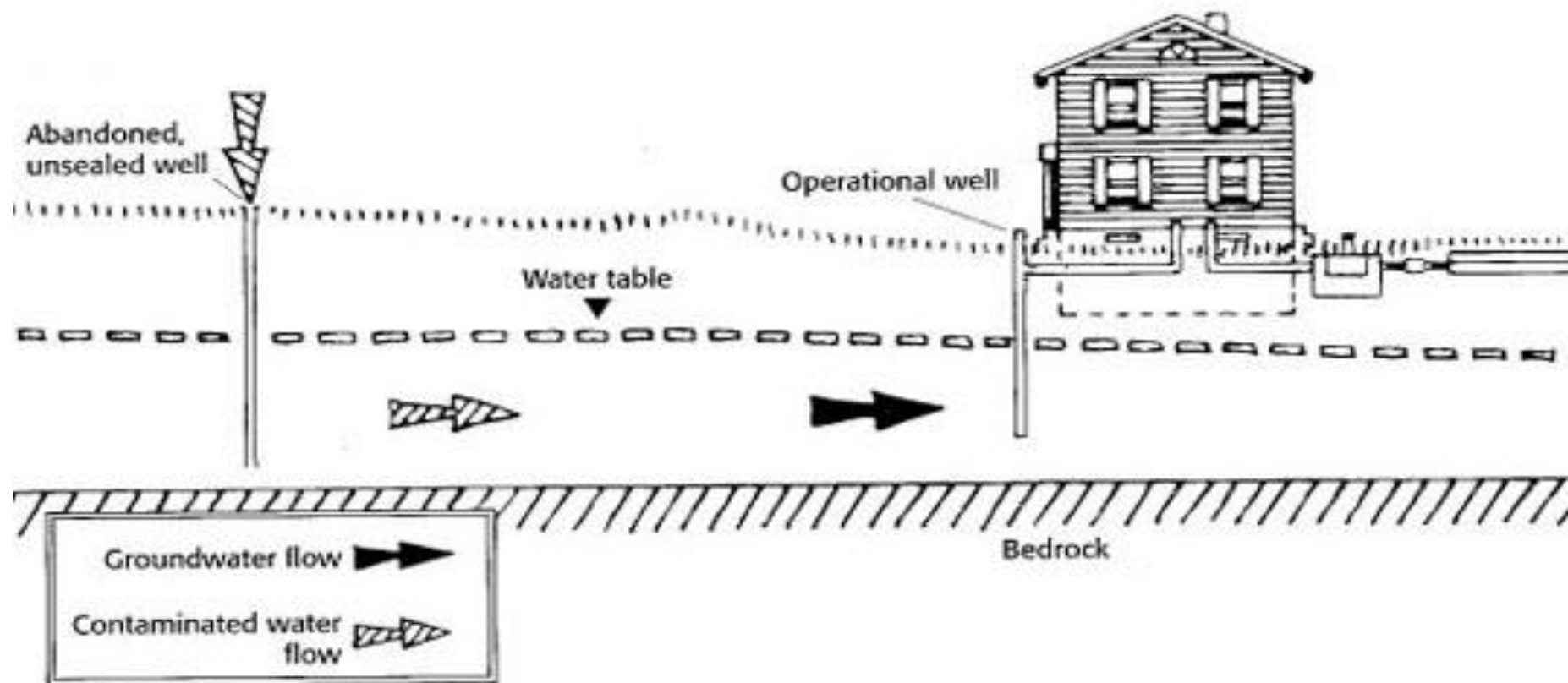
A photograph of two men in a field. The man on the left is wearing a blue cap and a plaid shirt, looking towards the man on the right. The man on the right is wearing a dark cap, sunglasses, and a maroon shirt, holding a blue bag and looking at a plant sample. The background is a lush green field with a body of water in the distance.

NRCS provides one-on-one, personalized technical assistance for voluntary conservation

NRCS helps people make investments in their operations and local communities to address resource concerns

NRCS generates, manages and shares the data, technology, and standards to help producers make informed decisions

# Why protect a wellhead or decommission an abandoned well?



# Wellhead Protection

## Step by Step Instructions

The Farm Evaluation has 4 components:

- Section 1: Whole Farm Evaluation
- Section 2: Irrigation Well Information
- Section 3: Sediment & Erosion Control Practices
- Section 4: Farm Map(s)

*Step 2: Section 2:* Complete the Wellhead Protection Practices table and/or Abandoned Well Practices table for all irrigation and abandoned wells on your property. Give each well a unique identifier (Well ID) and list them in the first column of the table. Complete the table by marking which Wellhead Protection Practices or Abandoned Well Practices apply to each of your wells. Mark the location of all in-use wells (irrigation and drinking water supply wells), abandoned wells, and off farm surface water discharge points on a Farm Map. Wells should be marked with the Well ID noted on the Farm Evaluation. Keep the map in your files (do not return to the Coalition). The map(s) with well identifiers must be produced if you have a Regional Water Board compliance inspection. *If your land does not contain irrigation wells or abandoned wells, check the appropriate box above the Wellhead Protection Practices table and/or the Abandoned Well Practices Table.*

## Section 2 – Irrigation Well and Abandoned Well Information

Member Name: \_\_\_\_\_ Coalition Member ID#: \_\_\_\_\_

- Irrigation Wells:** Create a unique Well ID for each irrigation well. For each well, fill in the table below with the Well ID and mark an "X" under the practices that apply to the individual well. Mark the location of your wells on the provided Farm Map(s) or your own farm map using the unique Well ID.

<input type="checkbox"/> Check this box if you have no irrigation wells on your parcel(s).						
Well ID (A unique name of your choice)	Wellhead Protection Practices					
	Ground Sloped Away from Wellhead	Standing water avoided around wellhead	Good Housekeeping Practices*	Air Gap (for non-pressurized systems)	Backflow Preventive / Check Valve	Cement Pad

\*Good housekeeping practices include keeping the area surrounding the wellhead clean of trash, debris and any empty containers.

Comments: \_\_\_\_\_

- Abandoned Wells:** Create a unique Well ID for each abandoned well. Mark the location of your wells on the provided Farm Map(s) or your own farm map using the unique Well ID. Indicate the year the well was abandoned (write "UNK" if the year is unknown; approximation is okay) and mark how the well was destroyed with an "X" under the appropriate practice.

<input type="checkbox"/> Check this box if you have no abandoned wells on your parcel(s)				
Well ID (A unique name of your choice)	Abandoned Well Practices			
	If abandoned, year abandoned	Destroyed – certified by county	Destroyed by licensed professional	Destroyed - Unknown method

Comments: \_\_\_\_\_

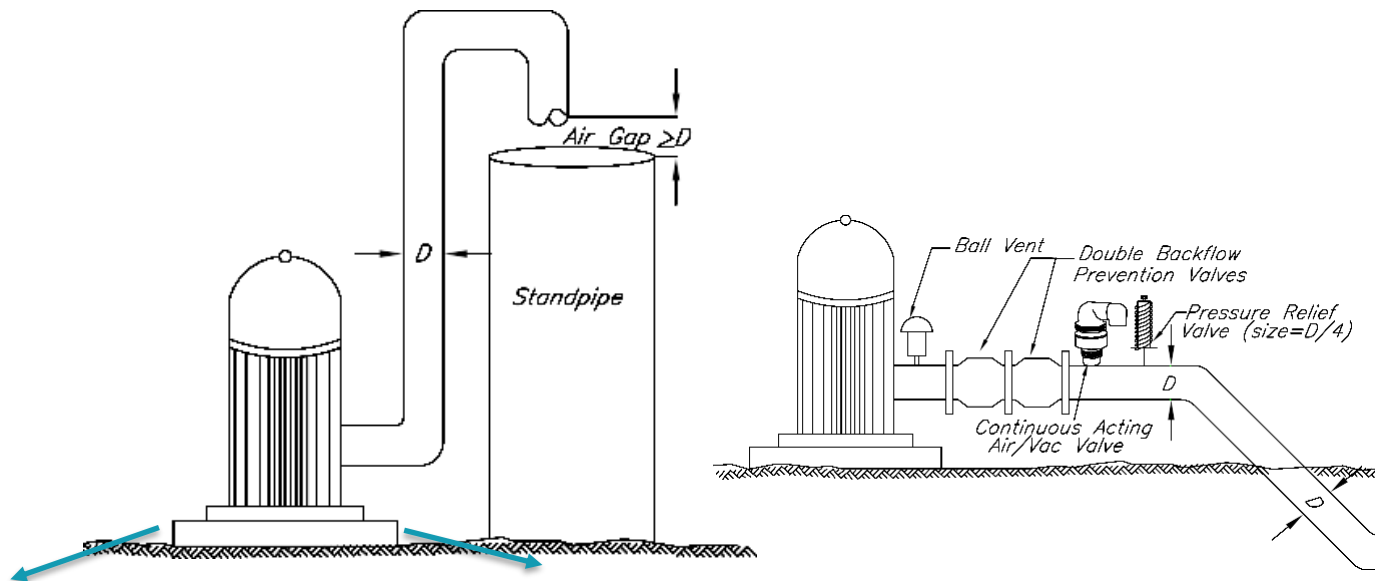


# Wellhead Protection



Well ID (A unique name of your choice)	Wellhead Protection Practices					
	Ground Sloped Away from Wellhead	Standing water avoided around wellhead	Good Housekeeping Practices*	Air Gap (for non-pressurized systems)	Backflow Preventive / Check Valve	Concrete <del>Cement</del> Pad

\*Good housekeeping practices include keeping the area surrounding the wellhead clean of trash, debris and any empty containers.



Well ID (A unique name of your choice)	Abandoned Well Practices			
	If abandoned, year abandoned	Destroyed – certified by county	Destroyed by licensed professional	Destroyed - Unknown method

## Solano County Specifics

Solano County Code has adopted CA DWR Bulletin 74-81 "Water Well Standards: State of California" with the addition of county-specific requirements for Chapter 13.10-14 (d) Drilling Waste and (e) Mud pits and 13.10-19 Inspections)



# Abandoned Wells



What's considered  
"abandoned"?

A well is considered "abandoned" or permanently inactive if it has not been used for one year unless the owner demonstrates intention to use the well again.



# Why decommission my abandoned well?

“Baby Jessica”, October 1987, Midland TX



Cary Grant remembered, Mark and Giffie, Alaska's whales



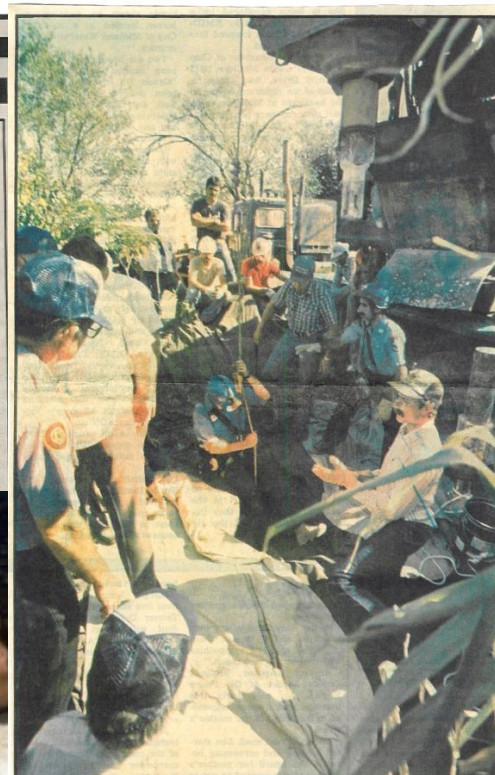
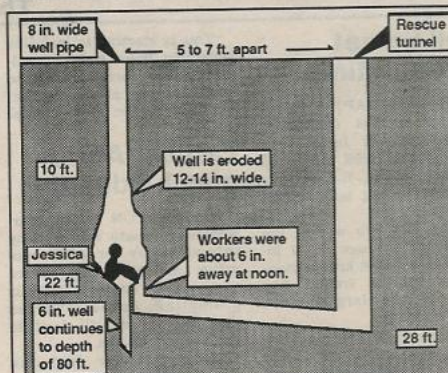
## THE RESCUE EFFORT

FROM 1A

JESSICA TRAPPED

### creams

... of a nearby phone. Sprague and husband Ray, ... have lived at 3311 Tanner ... five for 20 years. The grandparents of 14 children and parents of five voiced willingness to do whatever they could to help. A portion of their rear fence is uprooted to make room for an air compressor that delivered warm air to the trapped Jessica who was in a chamber thinner than the shaft about 12 to 14 inches in diameter, White said. Photographers and children climbed on ladders and peered over the fence for a glimpse of



Volunteer caver Bill Bentley is lowered into the rescue hole.

The Oklahoman/Mark Rogers



# Well Decommissioning (351)

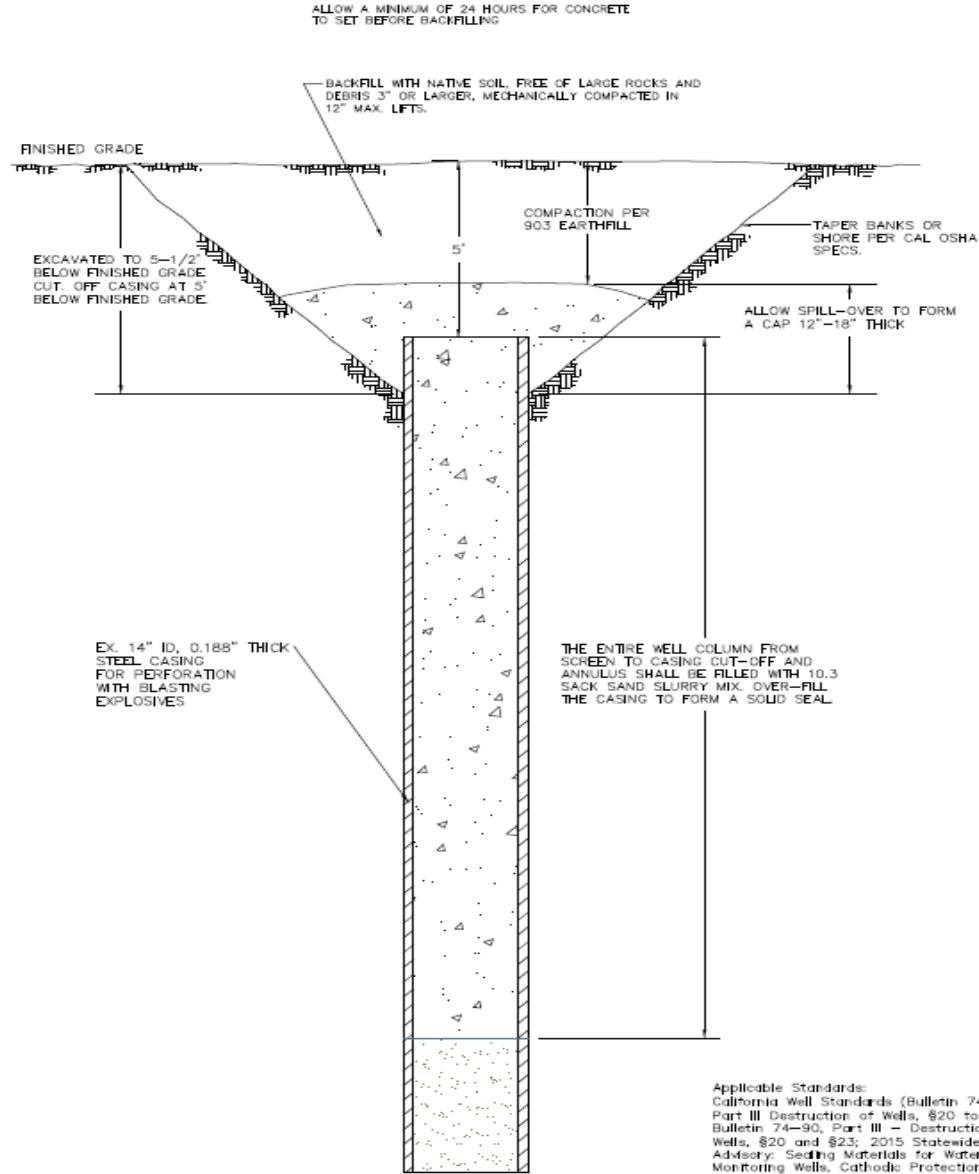


- **Definition** – The sealing and permanent closure of an inactive, abandoned, or unusable water or monitoring well.
- **Purposes** – Protect ground water from surface water contamination. Protect the aquifer water quality. Restore the natural hydrogeologic conditions.
- **Procedure** as outlined in the NRCS Conservation Practice Standard (CPS) 351
  - Data Collection
  - Permitting, Applications, & Bids
  - NRCS Implementation Requirements (IR) Development
    - Requires approval by NRCS State Conservation Engineer
  - Well Preparation
  - Disinfection
  - Casing Removal/Perforation/Blasting/Grouting
  - Sealing Material
  - Fill (plugging) Material
  - Surface Seal (mushroom cap)
  - Surface Soil Backfilling
  - Final Reporting

## Solano County Specifics

Solano County Code has adopted CA DWR Bulletin 74-81 "Water Well Standards: State of California" with the addition of county-specific requirements for Chapter 13.10-14 (d) Drilling Waste and (e) Mud pits and 13.10-19 Inspections)





Applicable Standards:  
 California Well Standards (Bulletin 74-81, Part III Destruction of Wells, §20 to §23; Bulletin 74-90, Part III - Destruction of Wells, §20 and §23; 2015 Statewide Advisory: Sealing Materials for Water Wells, Monitoring Wells, Cathodic Protection Wells, and Geothermal Heat Exchange Wells)  
 Solano County Code Chapter 13.10 (including, but not limited to, Chapter 13.10-14 (d) Drilling Waste and (e) Mud pits and 13.10-19 Inspections) and NRCS Well Decommissioning (351).



# Example from 2022 – preparation, grout and charge placement:



## Example from 2022 – grout and charge placement completion:



# Example from 2022 – final concrete “mushroom cap” and finished site:



# NRCS Well Decommissioning Assistance



## • Tentative Payment Rates FY 2023

- Drilled Well > 300 FT (\$17.75/FT)
- Drilled Well < 300 FT (\$34.23/FT)
- Shallow Well > 20 FT (\$708.73/CY)
- Shallow Well < 20 FT (\$626.31 /CY)

## • NRCS Financial Assistance Programs for Well Decommissioning include:

- Environmental Quality Incentives Program (EQIP)
- Agricultural Conservation Easement Program (ACEP) - Wetland Reserve Enhancement (WRE) Program
- Wetland Reserve Enhancement Program (WRP)

## Caveats

- Payment rates are higher for Historically Underserved (HU) producers and those in identified Source Water Protection zones
- Payment rates shown are tentative for FY 2023 and are subject to change
- Final payment amounts will be based on the well decommissioning completion report submitted to the County and NRCS



# Other NRCS Assistance



- **Slow It**

- Provide a rougher, more vegetated surface that slows down water flow.

- **Spread It**

- Prevent flow accumulation by widening the flow path.

- **Sink It**

- Create a soil surface that allows water infiltration into unconfined shallow and/or deep aquifers.

- **Store It**

- Create a healthy, biologically active soil profile with organic matter that acts more as a sponge.

- **NRCS' Field Office Technical Guide (eFOTG)**

- <https://efotg.sc.egov.usda.gov/#/state/CA/documents/section=4>

## How?

By slowing, spreading, sinking, and storing rainwater on your field(s), availability of early season soil water can be increased and recharge of groundwater and reliance on pumped groundwater can be reduced.



# Slow It, Spread it, Sink It, and Store It



- **Conservation Cover (327)**
  - Definition – Establishing and maintaining permanent vegetative cover.
  - Applicable purposes include – Reduce sheet, rill, and wind erosion and sedimentation. Reduce ground and surface water quality degradation by nutrients and surface water quality by sediment. Improve soil health.
- **Cover Crop (340)**
  - Definition – Crops including grasses, legumes, and forbs for seasonal cover and other conservation purposes.
  - Applicable purposes include – Reduce erosion from wind and water. Increase soil organic matter content. Capture and recycle or redistribute nutrients in the soil profile. Promote biological nitrogen fixation and reduce energy use. Manage soil moisture. Minimize and reduce soil compaction.
- **Residue and Tillage Management, No Till (329)**
  - Definition – Limiting soil disturbance to manage the amount, orientation, and distribution of crop and plant residue on the soil surface year-round.
  - Applicable purposes include – Reduce sheet, rill, and wind erosion and excessive sediment in surface waters. Maintain or increase soil health and organic matter content. Increase plant available moisture.
- **Residue and Tillage Management, Reduced Till (345)**
  - Definition – Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting. .
  - Applicable purposes include – Reduce sheet, rill, and wind erosion and excessive sediment in surface waters. Improve soil health and maintain or increase organic matter content.

## How?

These full- or partial-field practices reduce flow concentration and raindrop impact while enhancing nitrogen fixation and the soil microbiome. They can provide additional root penetrations that help to improve water infiltration while increasing the soil's ability to act as a sponge.



# Slow It



- **Field Border (386)**
  - Definition – A strip of permanent vegetation established at the edge or around the perimeter of a field.
  - Applicable purposes include – Reduce erosion from wind and water and reduce excessive sediment to surface waters. Reduce sedimentation offsite and protect water quality and nutrients in surface and ground waters.
- **Filter Strip (393)**
  - Definition - A strip or area of herbaceous vegetation that removes contaminants from overland flow.
  - Applicable purposes include - Reduce suspended solids and associated contaminants in runoff and excessive sediment in surface waters. Reduce dissolved contaminant loadings in runoff. Reduce suspended solids and associated contaminants in irrigation tailwater and excessive sediment in surface waters.
- **Grassed Waterway (412)**
  - Definition – A shaped or graded channel that is established with suitable vegetation to convey surface water at a non-erosive velocity using a broad and shallow cross section to a stable outlet.
  - Applicable purposes include - Convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding. Prevent gully formation. Protect/improve water quality.
- **Hedgerow Planting (422)**
  - Definition – Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose.
  - Applicable purposes include – To provide substrate for predaceous and beneficial invertebrates as a component of integrated pest management. To intercept airborne particulate matter. To reduce chemical drift and odor movement. To increase carbon storage in biomass and soils.
- **Mulching (484)**
  - Definition – Applying plant residues or other suitable materials to the land surface.
  - Applicable purposes include – Improve the efficiency of moisture management. Improve the efficient use of irrigation water. Reduce concentrated flow erosion. Reduce sheet, rill, and wind erosion. Maintain or increase organic matter content.

## How?

These practices  
can slow and  
filter water  
running on and  
off of fields.



# Spread It



- **Diversion (362)**
  - Definition – A channel generally constructed across the slope with a supporting ridge on the lower side.
  - Applicable purposes include – Break up concentrations of water on long slopes, on undulating land surfaces and on land that is generally considered too flat or irregular for terracing.
- **Waterspreading (640)**
  - Definition - A system of diverting or collecting runoff from natural watercourses and spreading the runoff over relatively flat areas.
  - Applicable purposes include - Reduce the potential for flooding and ponding. Reduce the potential for gully formation. Manage natural precipitation more efficiently. Facilitate ground water recovery.

## How?

NRCS practices can, on a case-by-case basis, be employed to spread out concentrated flows to increase infiltration and reduce the erosive power of water.



# Sink It – Interim Groundwater Practices

- **Groundwater Recharge Basin or Trench (815)**

- Definition – An off-channel impoundment with a permeable base underlain by an unconfined aquifer.
- Purpose – To recharge a specific aquifer to reduce the risk of natural resource degradation, or limitation to land use caused by groundwater depletion.

- **On-Farm Recharge (817)**

- Definition – The periodic application of surface or stormwater to cropland with connectivity to an unconfined aquifer.
- Purpose – To recharge a specific aquifer to reduce the risk of natural resource degradation, or limitation to land use caused by groundwater depletion.

## Caveat

As of FY 2022, these practices are limited for funding to pilot projects in **Madera, Merced, Tulare, and Kern** Counties and is expected to remain so until the evaluation period for the interim practices is complete.



# Store It



- **Soil Carbon Amendment (808)**

- Definition – Using carbon-based amendments to increase soil carbon and improve the physical, chemical, and biological properties of the soil.
- Applicable purposes include – Maintain, increase, or improve soil organic matter quantity and quality. Maintain or improve soil aggregate stability. Maintain or improve habitat for soil organisms. Improve plant productivity and health. Improve the efficient use of irrigation water.

## How?

The addition of soil carbon and organic matter can increase the ability of the soil to soak up and retain water, allowing it to percolate deeper into the soil profile after rainfall events.



## Other NRCS Practices

- **Microirrigation System (441)**
- **Irrigation Water Management (449)**
- **Nutrient Management (590)**
- **Pest Management Conservation System (595)**
- **Denitrifying Bioreactor (605)**

### How?

Many of NRCS' other available practices may be employed to assist with conserving irrigation water, managing nutrient and/or pesticide applications, and managing excess irrigation water and/or nitrogen applications.





United States Department of Agriculture

# Q&A will be at the end of the workshop.

Contact your local NRCS Office at

## Solano County:

Carolyn M. Jones, PE

Bay/Delta Team Agricultural Engineer

phone: (707) 448-0106 ext. 3

e-mail: [carolyn.jones@usda.gov](mailto:carolyn.jones@usda.gov)



Natural  
Resources  
Conservation  
Service

[nrcs.usda.gov/](https://nrcs.usda.gov/)



# Amy King

SOLANO RESOURCE CONSERVATION DISTRICT

# Soil amendments for nitrogen and water management: cover crops, compost and biochar



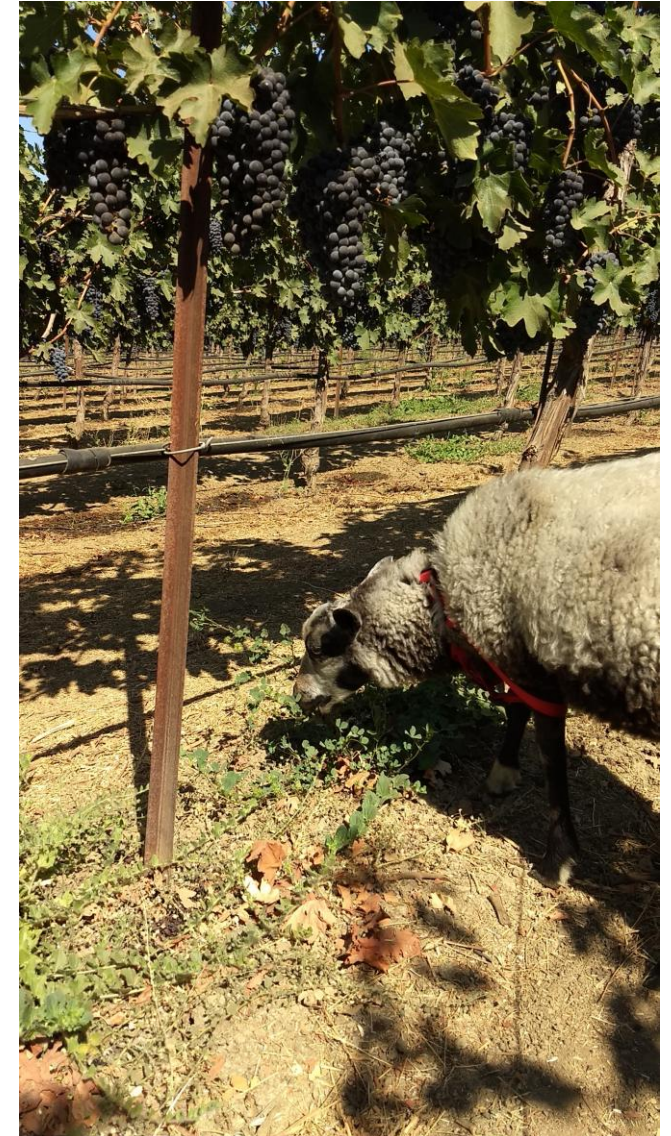
**SOLANO**  
Resource  
Conservation  
District

Amy King  
Watershed Project Manager  
Solano RCD

# Soil/water goals in an ag system:

- Provide sufficient water for the crop
- Minimize water use in the dry months
- Minimize standing water or flooding in the wet months
- Recharge groundwater/improve infiltration
- Minimize nutrient/contaminant loss to surface water and groundwater

All of these are improved with increased soil organic matter (carbon)



# Easiest ways to increase soil organic matter

- Cover crops (annual or perennial)
- Compost
- Weeds



## Other interesting ways to increase soil organic matter

- Biochar
- Minimize tillage
- Biosolids
- Trees



# Cover Crop Heebie Jeebies

Extra field ops/expense

One more thing to manage

Prevent spring soil heating and exacerbate frost

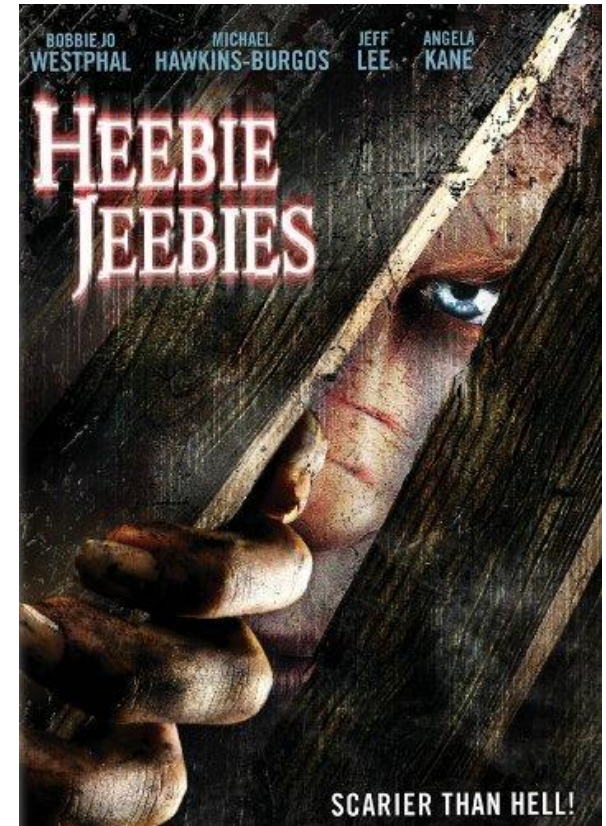
Keep ground too wet in the spring

Take available soil water from the primary crop

Make harvest difficult

Attract unwanted insects/pathogens

Attract rodents



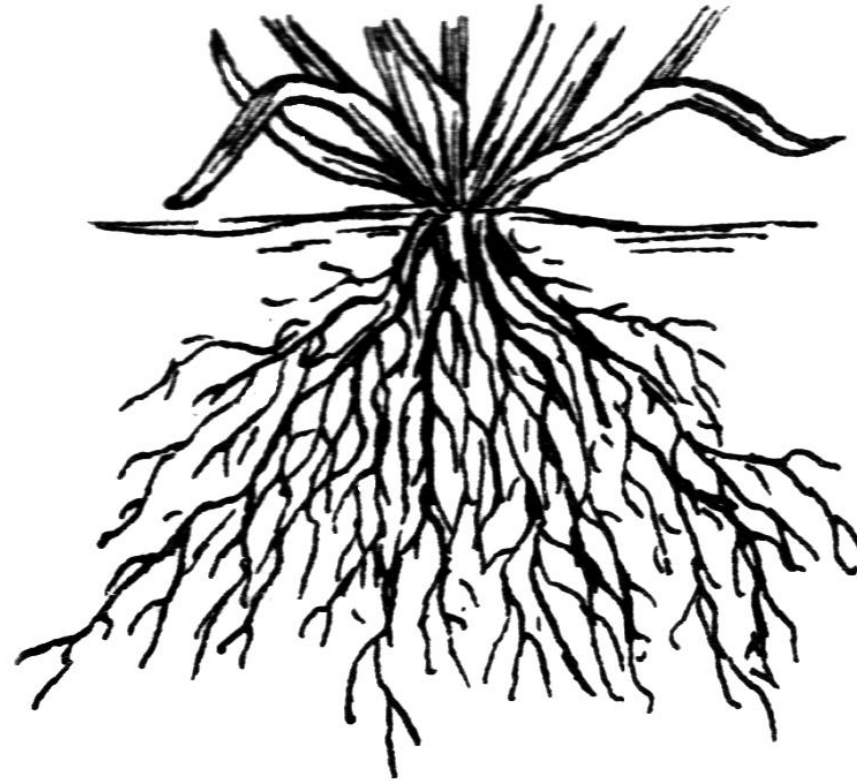
# But we love them anyway, because they.....

Contribute organic matter to the soil

Improve soil water holding capacity

Improve soil water infiltration

Reduce soil erosion

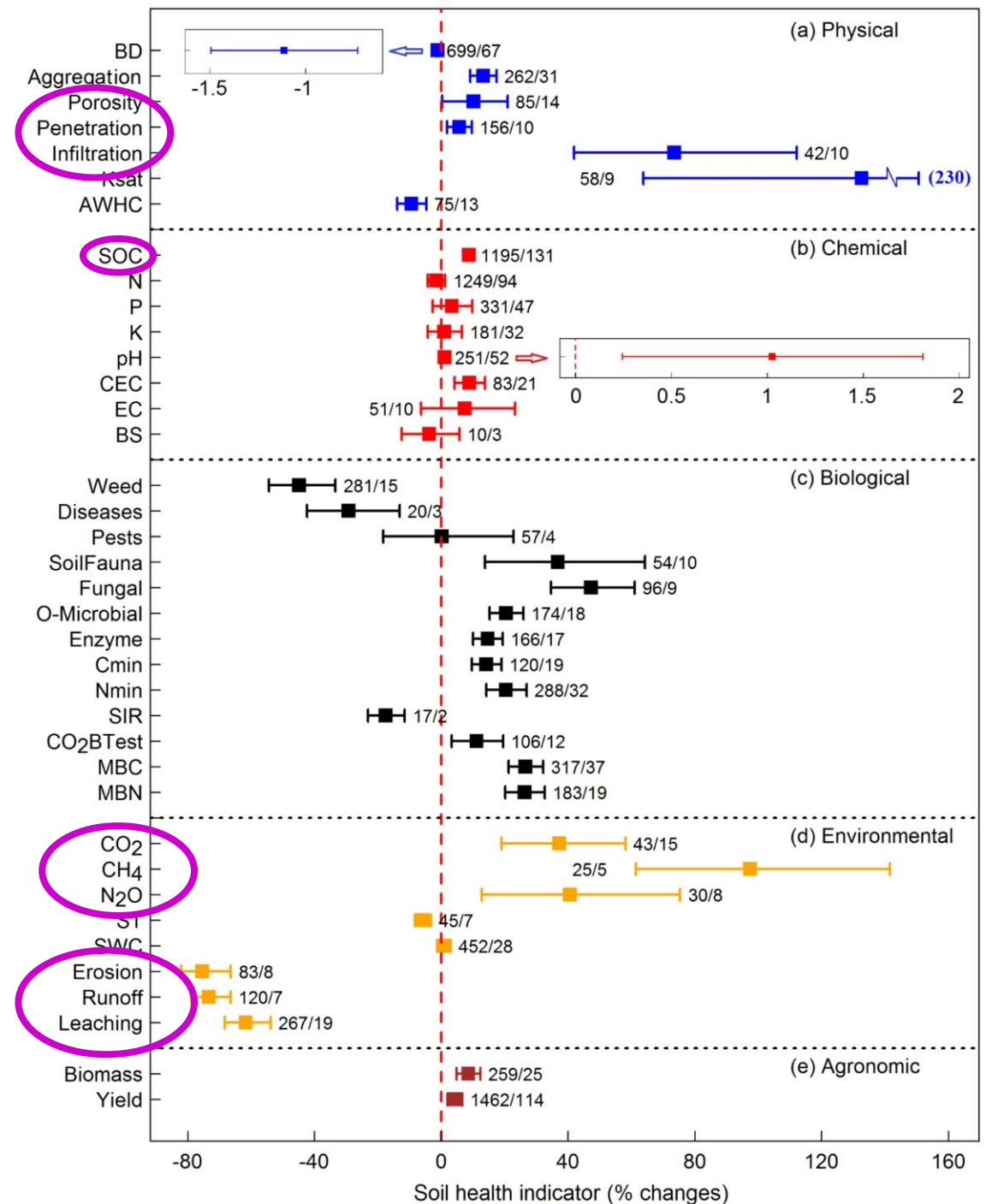


Contribute nitrogen and micronutrients to soils and crops

Shade out weeds

Take carbon out of the atmosphere and put it in the soil

A recent review of published studies on the effects of cover crops on soil health measures shows significant benefits in cover cropped systems



From: J Jian, B Lester, X Du, M Reiter, R Stewart. 2020. A calculator to quantify cover crop effects on soil health and productivity. Soil and Tillage Research 199: 104575.

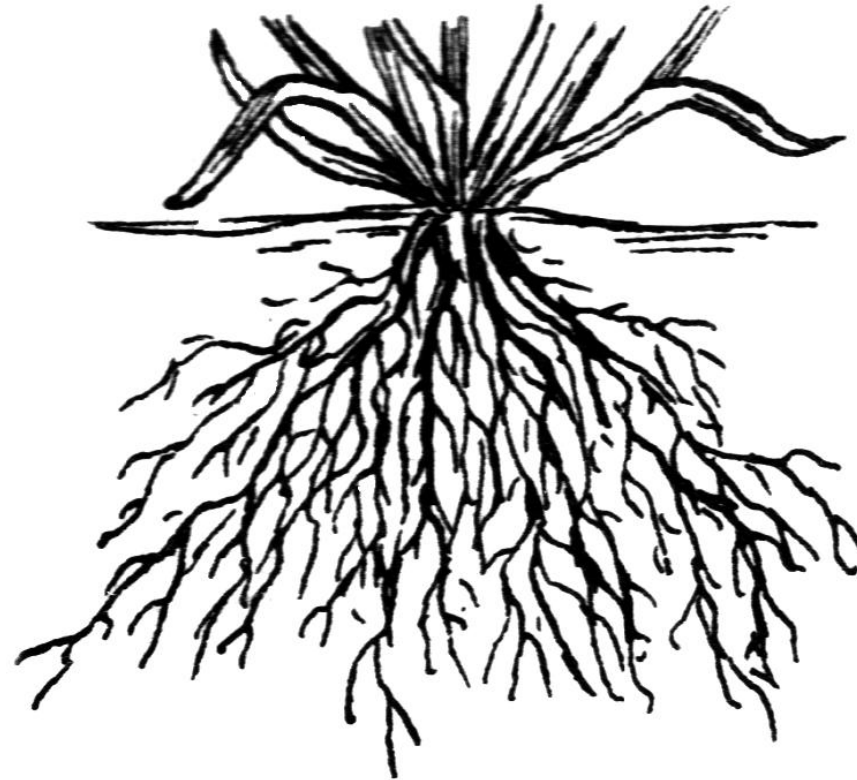
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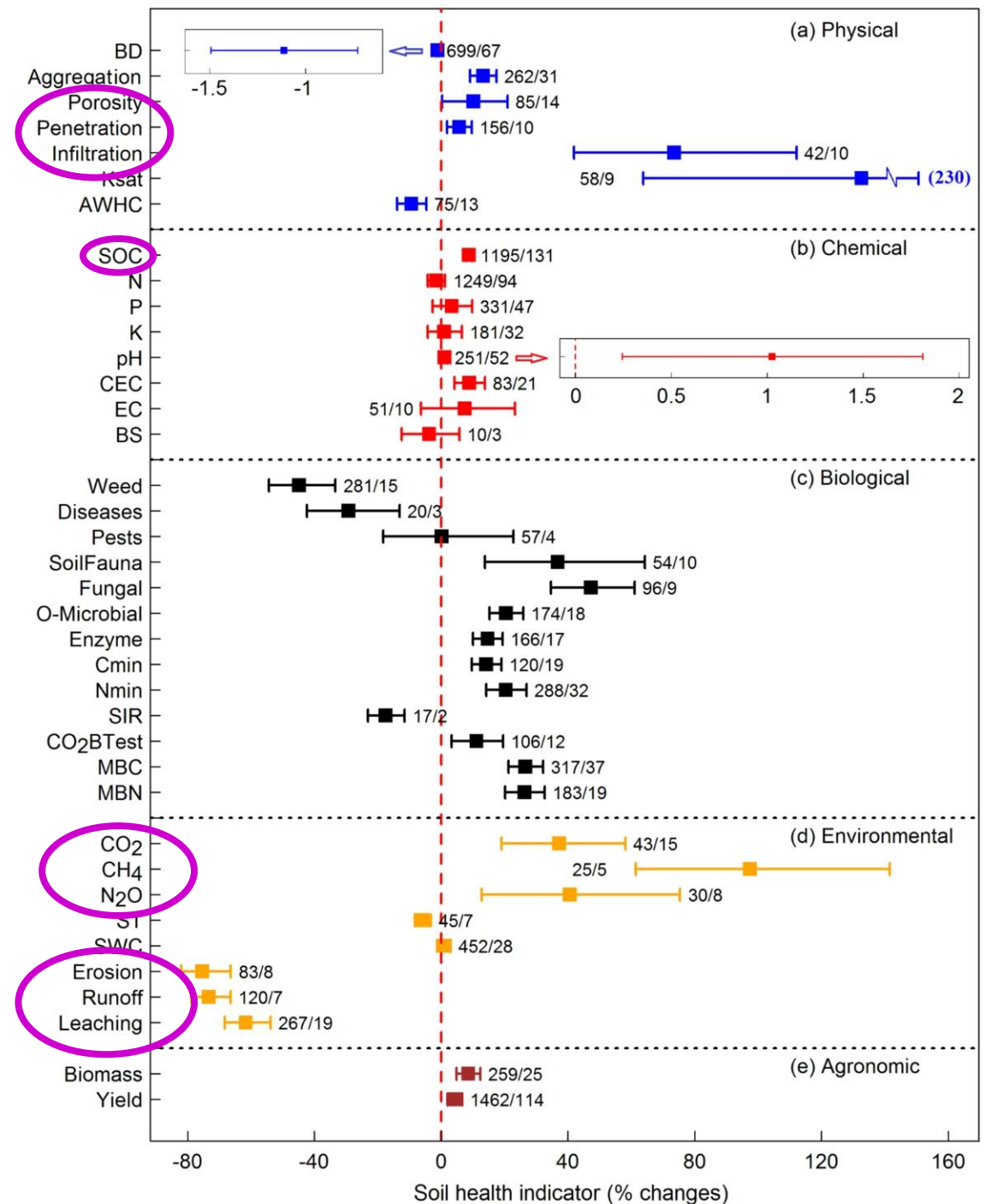


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From: J Jian, B Lester, X Du, M Reiter, R Stewart. 2020. A calculator to quantify cover crop effects on soil health and productivity. Soil and Tillage Research 199: 104575.

# Compost

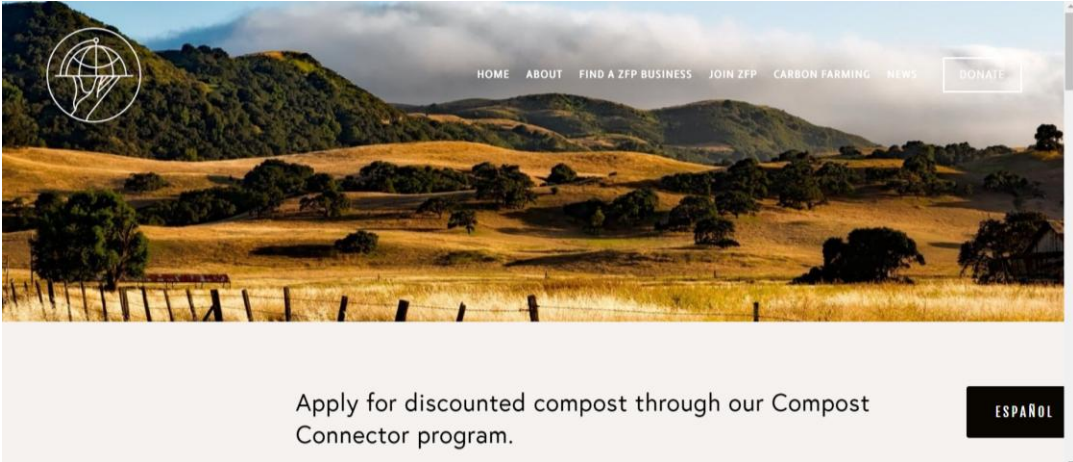
- Incorporated or surface-applied
- Variable in C:N ratio, contaminant levels, nutrient content and moisture content
- Increases soil organic matter, water holding capacity, nutrient availability



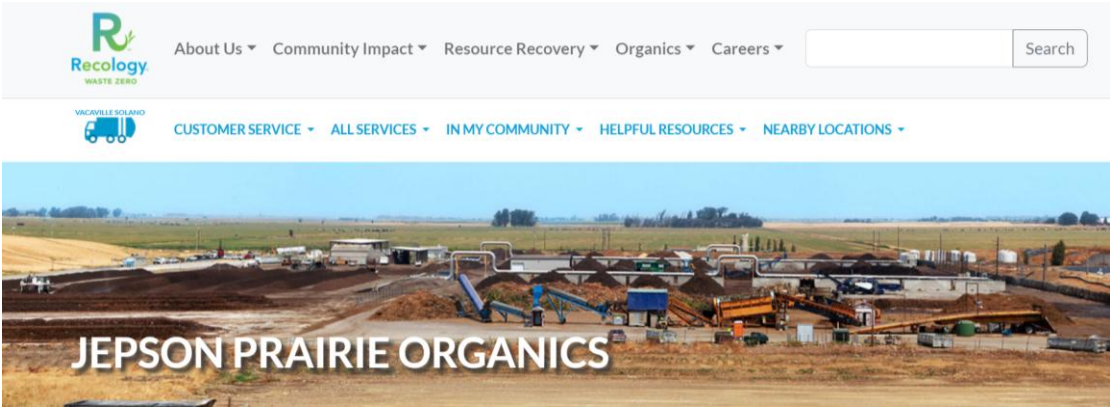
Photo: Ramon Barreiro

# If you are looking for compost....

Zero Foodprint's Compost Connector program



Compost facility at Hay Road landfill



Also available at Napa Recycling and Waste Services, other Central Valley locations

# If you are **STILL** looking for compost....

*(We may be able to help you get some!)*

1. SB 1383 mandates that jurisdictions collecting curbside green waste (cities and counties) must make finished compost available, free of charge, to their residents. The amounts required are based on population, and meeting those requirements will require moving some of that compost out to farms.
2. State funding focused on healthy soils/regenerative agriculture is providing major financial incentives to apply compost on farms and ranches.



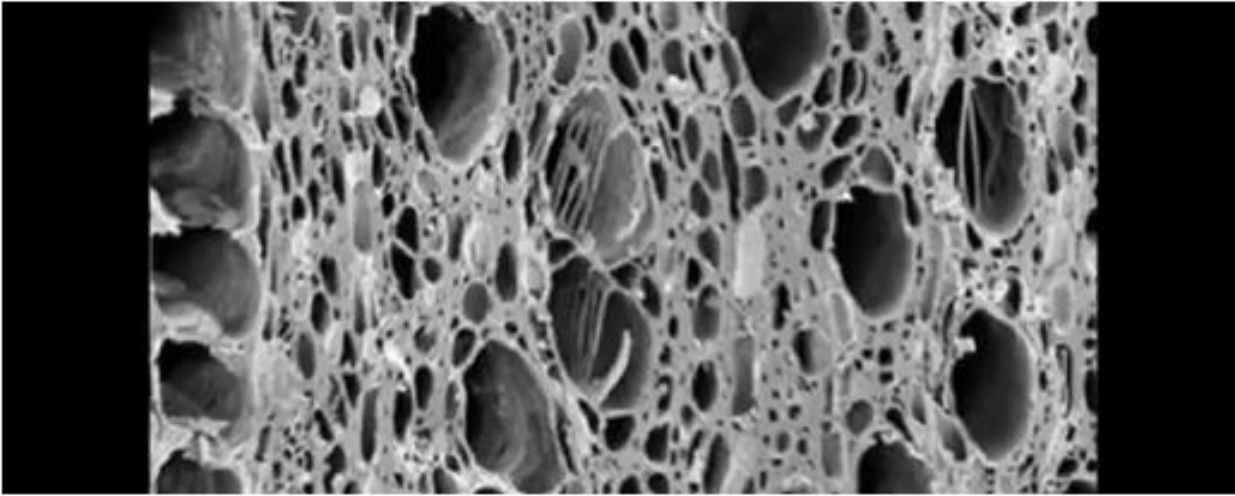
*(ask for Amy or Kevin)*

# Biochar

- Created by incinerating organic material (wood) at very high temps in low/no oxygen (pyrolysis)
- Leaves a carbon skeleton (charcoal) with exceptionally high surface area for adsorbing water and nutrients

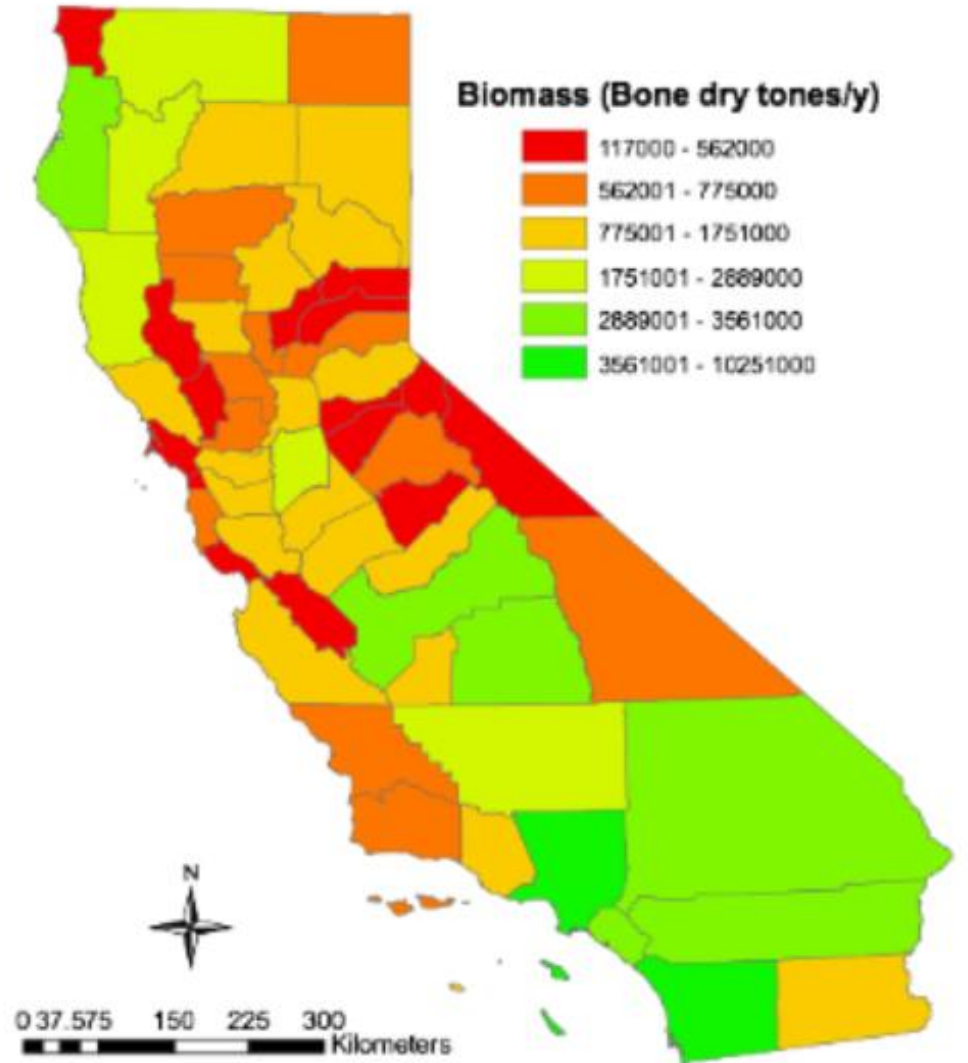


Photo: K.salo.85



From: acarbons.com

- Increases soil water holding capacity
- Filters contaminants from soil
- Sequesters carbon by growing plants and then burying their carbon in a very stable form (100s – 1000s of years) in the soil



**Figure 3.** Amount of biomass produced annually in counties in the state of California, US (Commission, 2007).

**Table 1. List of active biochar producers in California.**

Biochar producers, City	Year started	Products	Commercial product	Focus application sector	Main feedstock	Status
Genesis industries, Redondo Beach	2011	Reactors, biochar	Biochar and bio-stimulants	Farming and gardening	Nutshells, urban green waste	Phase 2
Pacific biochar, Santa Rosa	2014	Biochar	BlackLite	Agriculture	Woody residues	Phase 3
Biorobotech, Redwood City	2012	Reactors, biochar	Soil mix pro	Organic waste management	Biosolids, manure, green waste	Phase 2
Carbo culture, Woodside	2017	Biochar (green landscaping)	Carbon services	Climate & soil, landscaping	Forestry waste	Phase 1
Full circle biochar, San Francisco (bio365 LLC)	2007	Biochar	BioCore and BioCharge	Agriculture	Wood waste from timber industry	Phase 1
Blue sky biochar, Thousand Oaks	2010	Biochar	SEEK fertilizer	Agriculture	Pine, bamboo	Phase 2
Cool planet energy systems, Camarillo	2009	Biochar	CoolTerra	Agriculture	Farm residues	Phase 2
Energy Anew IMC, San Rafael	2005	Biochar (solar-powered)	Biocharm	Vegetables, flowers, fruit trees	Wood chips	Phase 2
Interra energy, INC, San Diego	2009	Biochar, fuels, reactor	Interra Preta	Agriculture, biofuels	Trimmings, wood, timber & green waste	Phase 2
All power labs, Berkeley	2007	Reactors, biochar, blends	Chartainer, power pallet	Local carbon network	Woody residues	Phase 2
Phoenix energy, San Francisco	2006	Reactors, biochar	Reactor	Agriculture	Forest and woody residues	Phase 2
Tolero energy, LLC, Sacramento	2009	Reactors, biochar, fuels, activated carbons	Tolero fuel	Transportation, water treatment	Urban biomass residues	Phase 2

From: Thengane et al 2021. Market prospects for biochar production and application in California. Biofuels, Bioproducts and Biorefining.

**Table 2. Annual biochar production and application potential in different sectors of California.**

Biochar production		
Total biomass available (agriculture + forest)	52.26	Million BDT
Total accessible biomass available (agriculture + forest) <sup>20</sup>	23.52	Million BDT
Total biochar production (20% conversion)	4.70	Million BDT
Biochar application		
Agriculture and forestry		
Land covered by biochar application (1 BDT/acre)	4.70	Million acres
Time required to cover total agricultural land of state	5.38	Years
Time required to cover total forest land of state	7.02	Years
GHG reduction		
State total GHG annual emissions <sup>49</sup>	424.1	Million-ton CO <sub>2</sub> -e
State GHG annual emissions in agriculture sector <sup>49</sup>	32.23	Million-ton CO <sub>2</sub> -e
Biochar carbon sequestration potential (average biochar carbon content: 70%) <sup>35</sup>	12.08	Million-ton CO <sub>2</sub> -e
Soil N <sub>2</sub> O emission reduction (1 BDT/acre application) <sup>50</sup>	0.22	Million-ton CO <sub>2</sub> -e
Portion of total state GHG emissions in agriculture sector	38.16	%

Groundwater		
State annual water consumption in agriculture <sup>51</sup>	11.08	Trillion gallons
Water holding capacity increment (2% (w/w) biochar application) <sup>52</sup>	7275	Gallons/acre
Total increased water holding <sup>52</sup>	0.39	Trillion gallons
Portion of total water consumption in agriculture	3.54	%
Wastewater treatment		
State annual wastewater generation <sup>53</sup>	1.46	Trillion gallons
Portion of wastewater treated by biochar (0.51 kg/m <sup>3</sup> ) <sup>54</sup>	43.24	%
Livestock feed and manure management		
Livestock feed (1% biochar in daily feed w/w <sup>56</sup> ~ 0.39 million BDT biochar)		
Enteric fermentation (20% GHG reduction <sup>55</sup> )	2.27	Million-ton CO <sub>2</sub> -e
Manure management (13.6% w/w biochar in manure ~4.31 million BDT biochar)	11.07	Million-ton CO <sub>2</sub> -e
Portion of total state GHG emissions in agriculture sector	41.38	%

From: Thengane et al 2021. Market prospects for biochar production and application in California. Biofuels, Bioproducts and Biorefining.

# A word on trees:



- Can occupy farm edges, non-arable land, roadsides
- Create tremendous networks of sub-surface channels to improve soil water infiltration and groundwater recharge
- Pull CO<sub>2</sub> out of the air while so doing

# How can we help?



- Cover crops, compost, biochar
- Hedgerows, riparian forest, wildlife nesting boxes and perches
- Fencing and troughs to keep cattle off waterways
- Irrigation system evaluations
- Groundwater recharge basins
- Fire-safe land management
- Creek management and flood prevention
- Carbon farm plans

We can work with you to plan projects and find funds to implement them!

# To chat about water or dirt or plants, any time!

Amy King

Solano Resource Conservation District

Watershed Project Manager

530-848-3551

[Amy.King@solanorcd.org](mailto:Amy.King@solanorcd.org)

1170 N. Lincoln Street, Suite 110

Dixon, CA 95620





# Kevin Young-Lai

SOLANO RESOURCE CONSERVATION DISTRICT

# AG WATER EFFICIENCY PROGRAM



**Kevin Young-Lai**  
**Assistant Project Manager**  
**January 24, 2022**



# DRONES



# PLATFORMS



## Multi-rotor Copters

- ▶ Generally 18-25 minute flight time with
- ▶ Vertical take off and landing
- ▶ Typically < 2 pound payload
- ▶ Can cover > 50 acres per flight



## Fixed-Wing

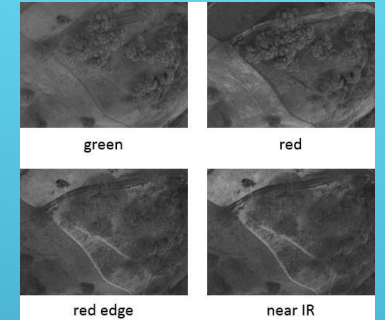
- ▶ Longer flight time (> 40 min)
- ▶ Moves faster and can cover > 100-300 acres per flight
- ▶ Typically can carry more payload
- ▶ Harder to replicate your flight plan

# PAYLOADS

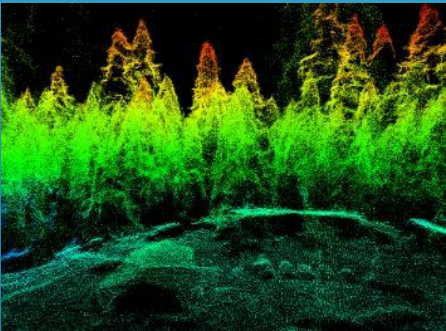
## RGB



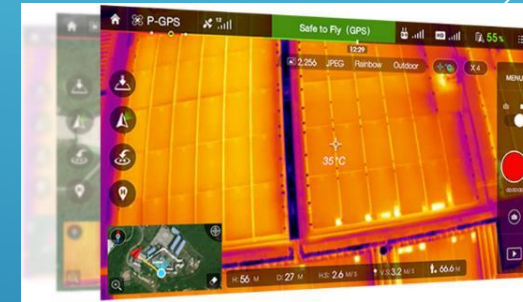
## Multispectral



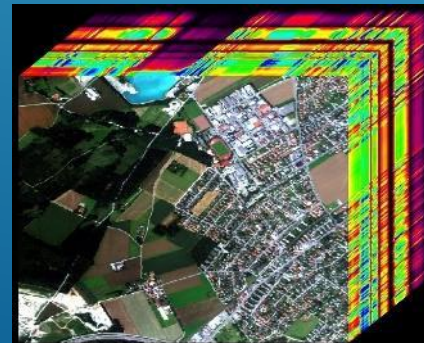
## LiDAR



## Thermal



## Hyperspectral



**WHAT KIND OF DRONE WORK DOES SRC D DO?**

The image features a solid blue background with a gradient from light blue at the top to a darker blue at the bottom. In the center, the text "WHAT KIND OF DRONE WORK DOES SRC D DO?" is written in a bold, white, sans-serif font. In the bottom right corner, there are several white, parallel diagonal lines that create a sense of motion or a graphic element.

# AERIAL PHOTOGRAPHY AND VIDEOGRAPHY



Glen Cove

**Mostly aerial  
photography  
and  
videography!**



Lake Dalwigk

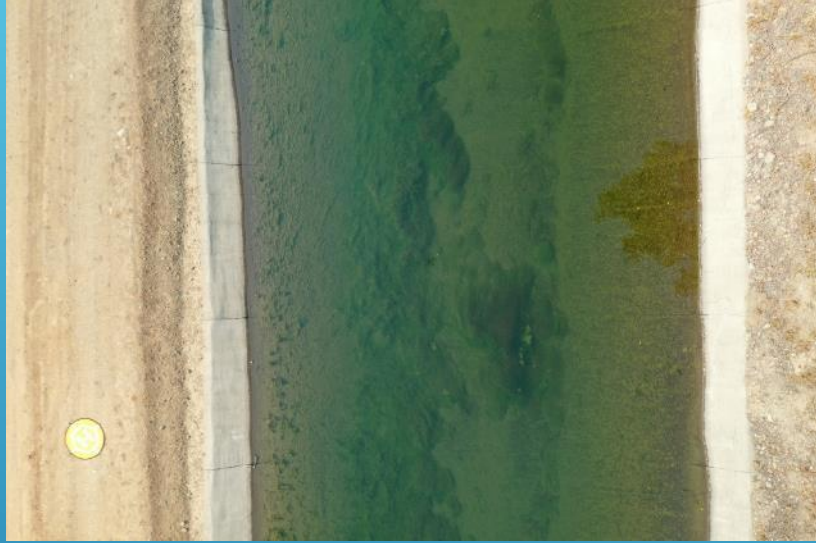


Pond C



Vallejo Waste Water Treatment Plant

# PHOTOGRAPHY MONITORING



**Algaecide monitoring**



**Flood monitoring**

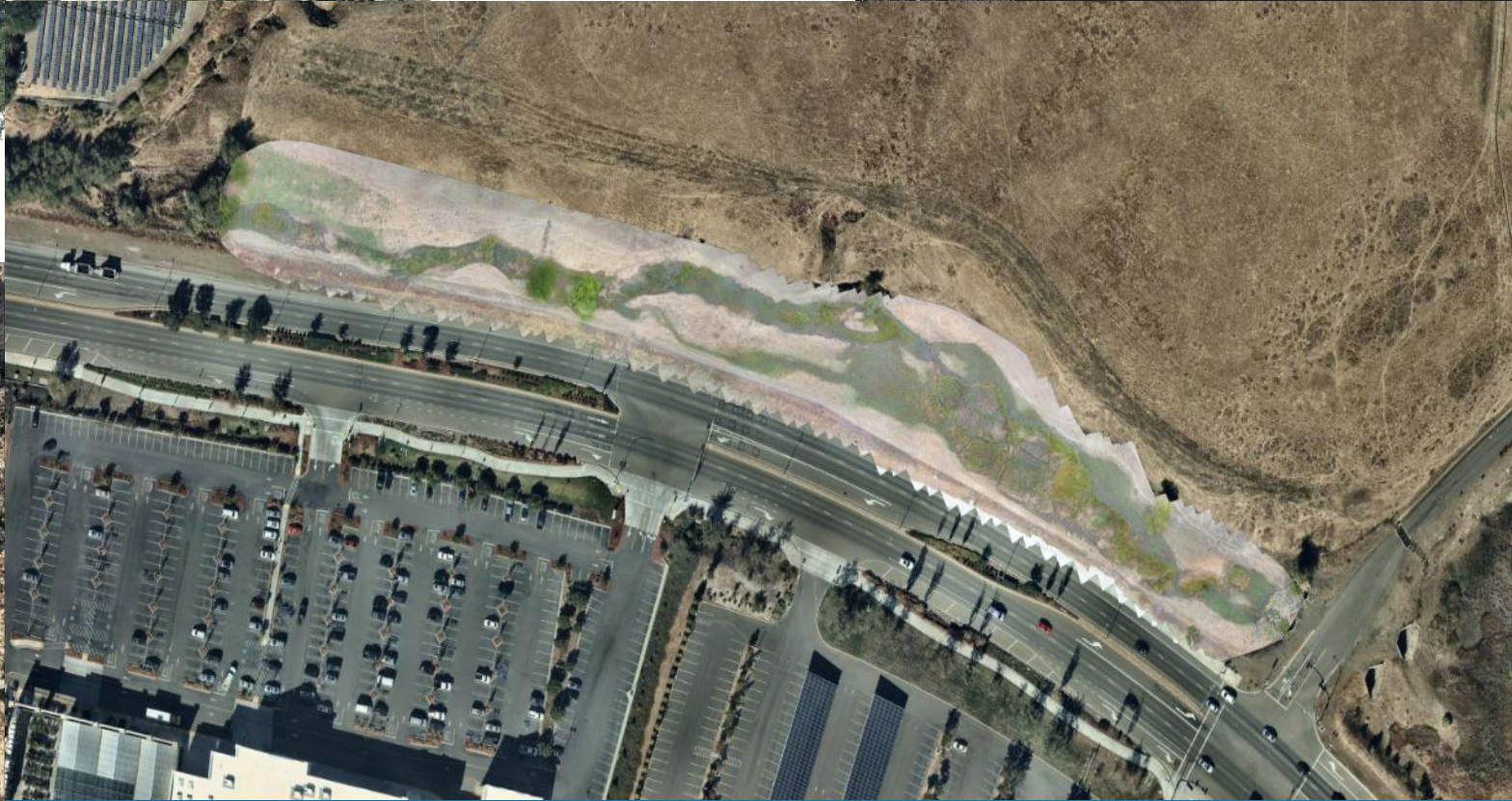
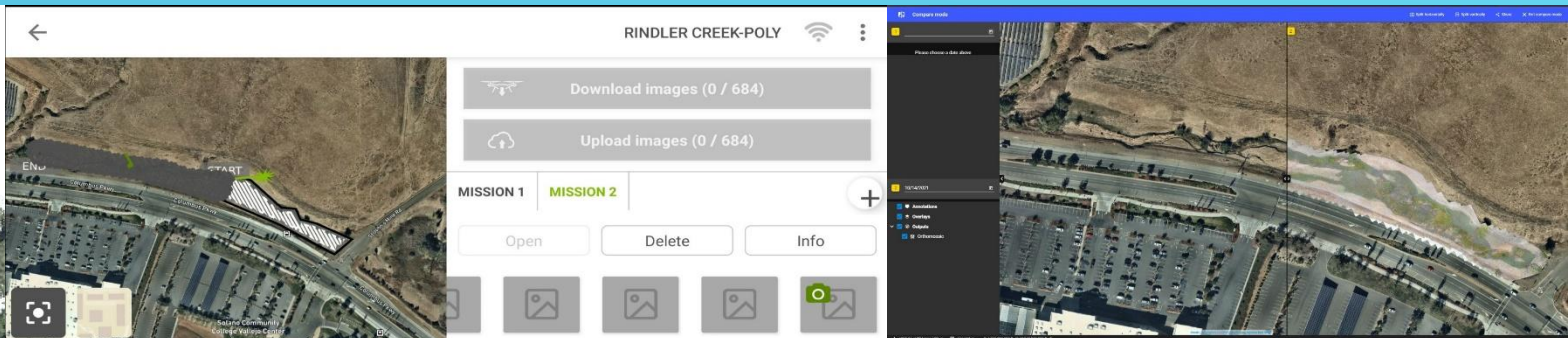
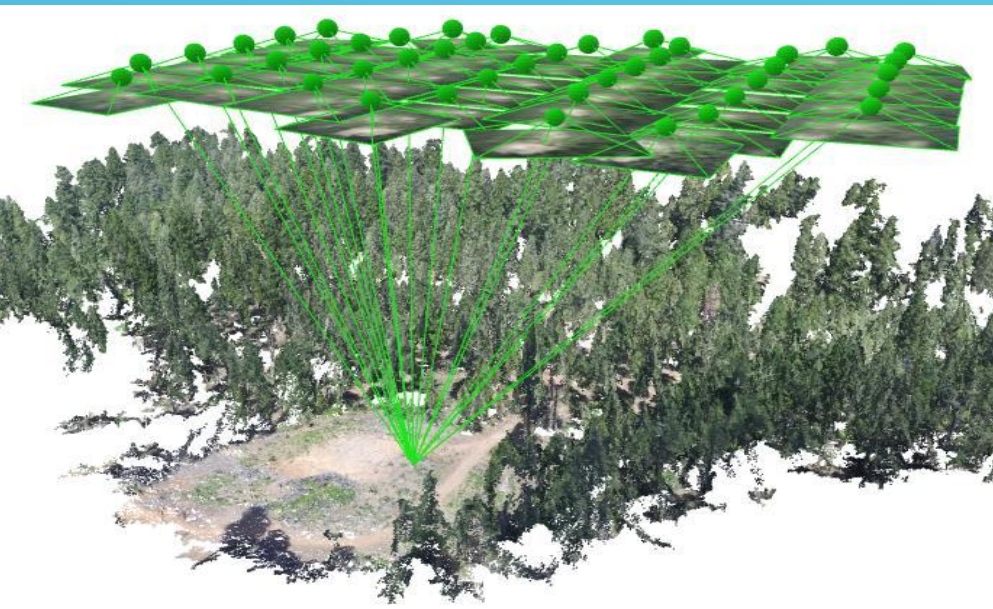


**Yolo Arundo monitoring**



**Yolo Arundo monitoring**

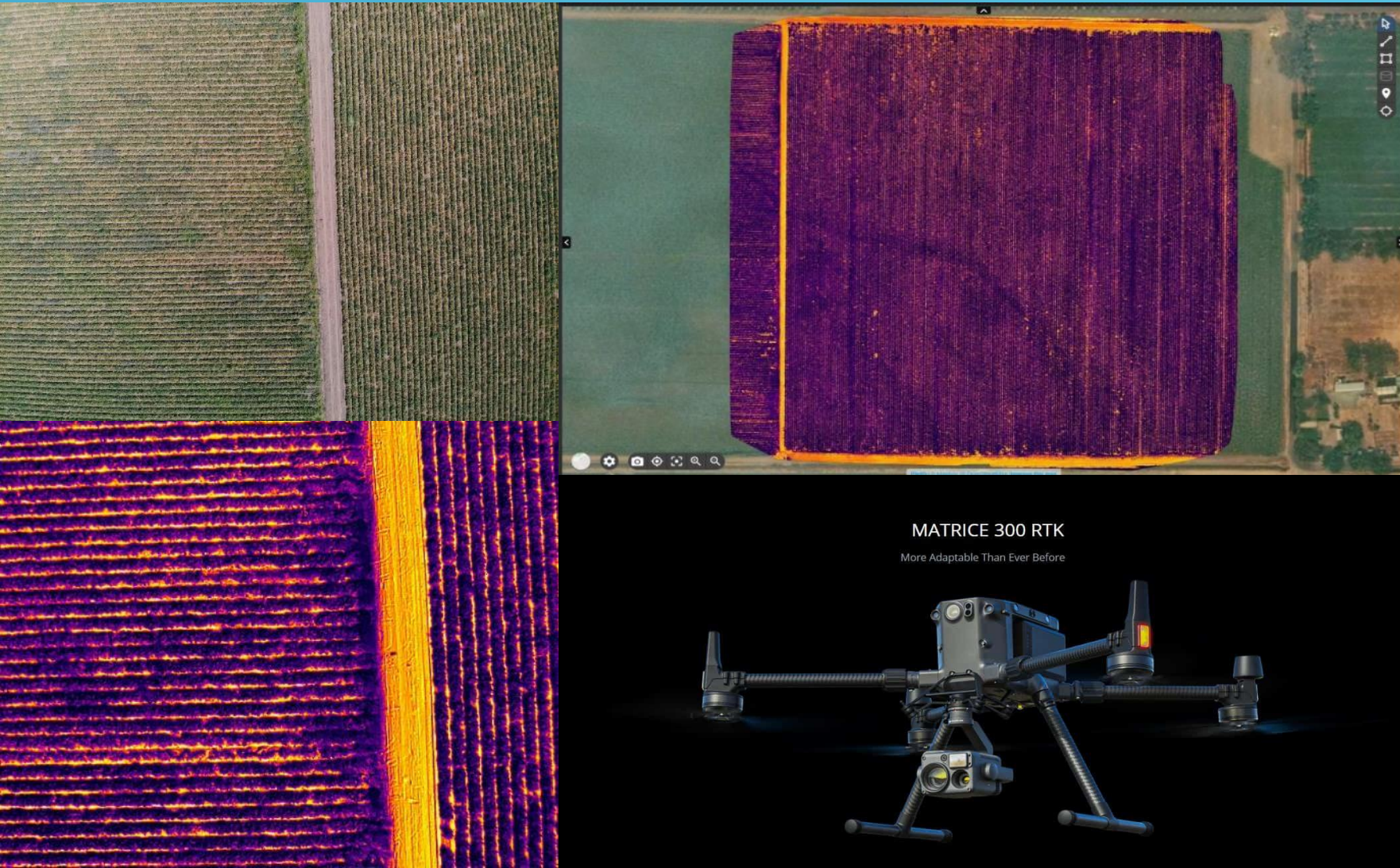
# PHOTOGRAMMETRY



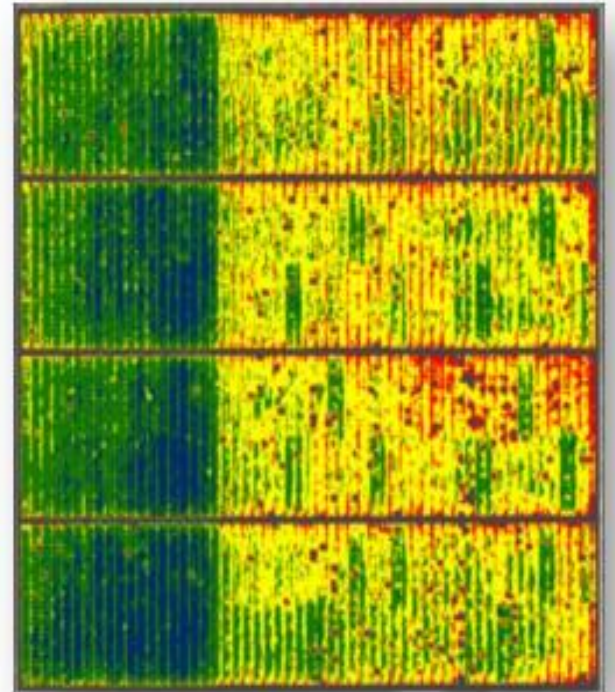
Post-Fire GPS Down Trees

Photogrammetry of Rindler Creek

# THERMAL IMAGERY- WATER USE EFFICIENCY



## Water Stress Level



# WHAT ARE MULTISPECTRAL/THERMAL IMAGES?

- ▶ Type of image that shows data at specific frequencies across the electromagnetic spectrum.
- ▶ Every surface reflects back some of the light that it receives.
- ▶ Objects that have different surface features reflect or absorb the sun's radiation in different ways.
- ▶ Perceived color of an object corresponds to the wavelength of the visible spectrum with the greatest reflectance.
- ▶ These wavelengths maybe separated by filters or by the use of instruments which are sensitive to particular wavelengths, including light from frequencies beyond our visible sight.

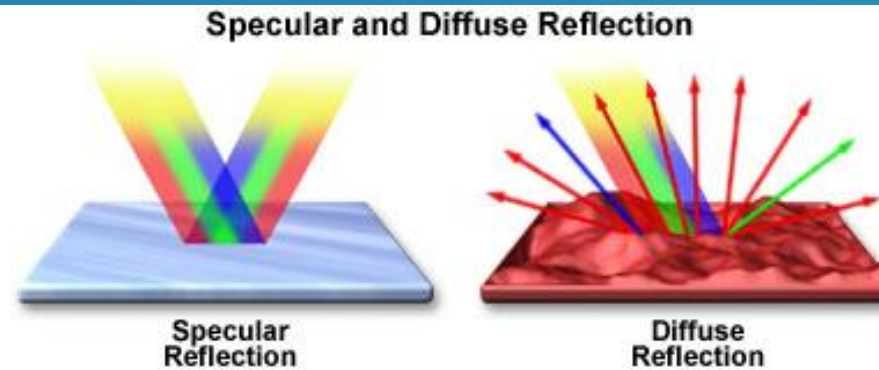
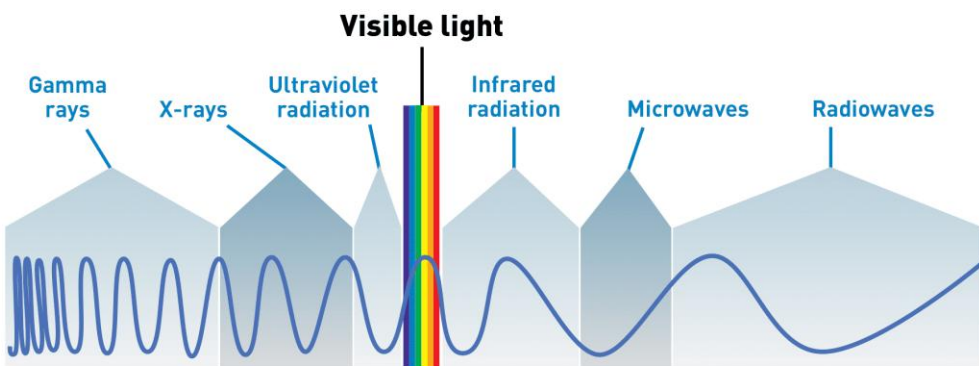
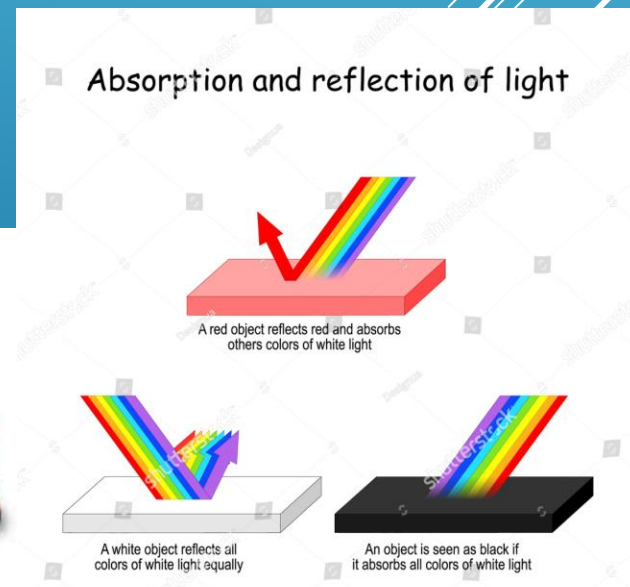
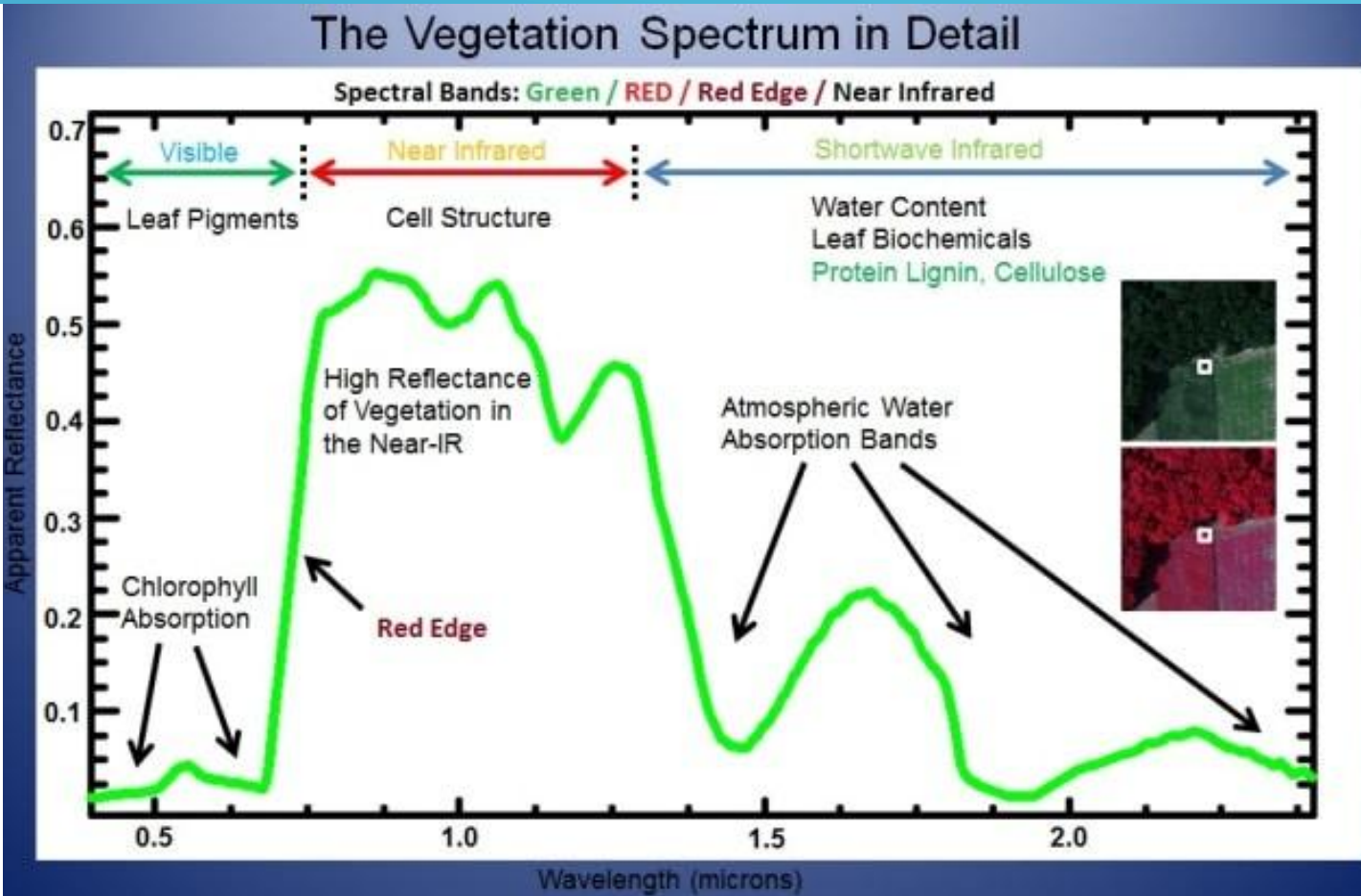
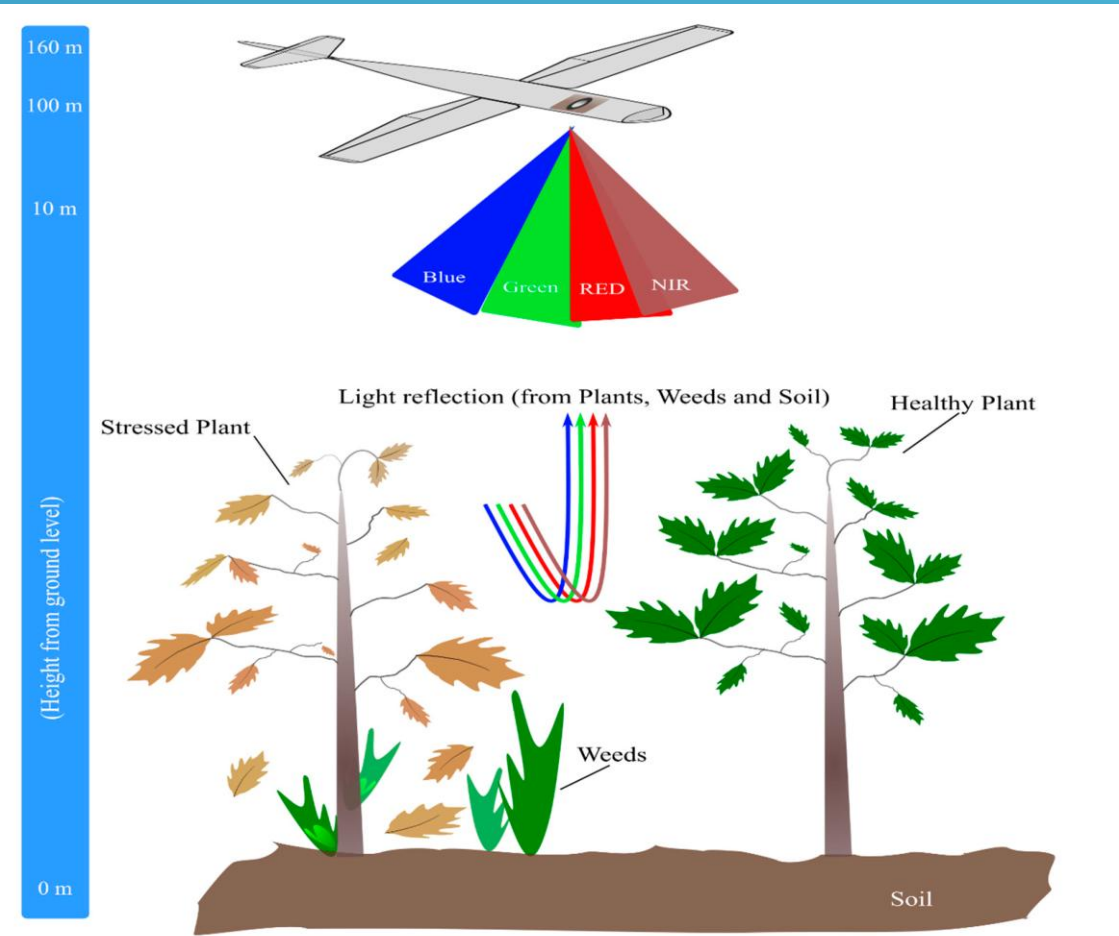


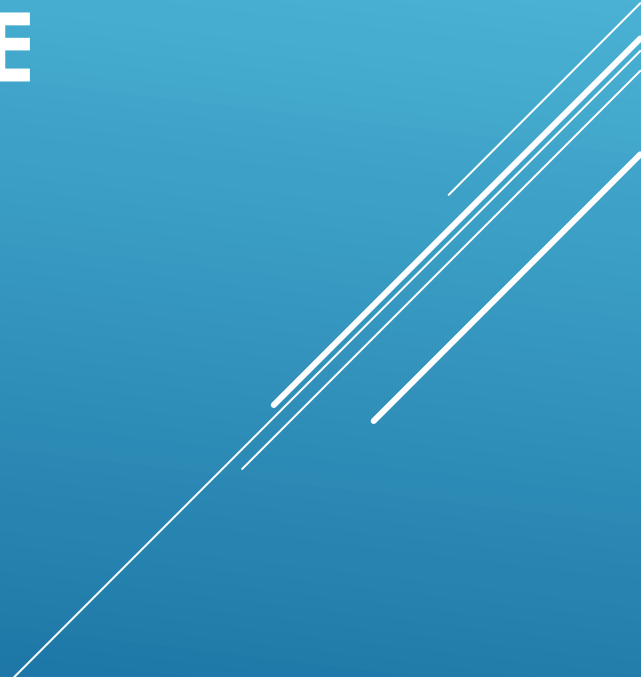
Figure 3



# VEGETATION SPECTRUM

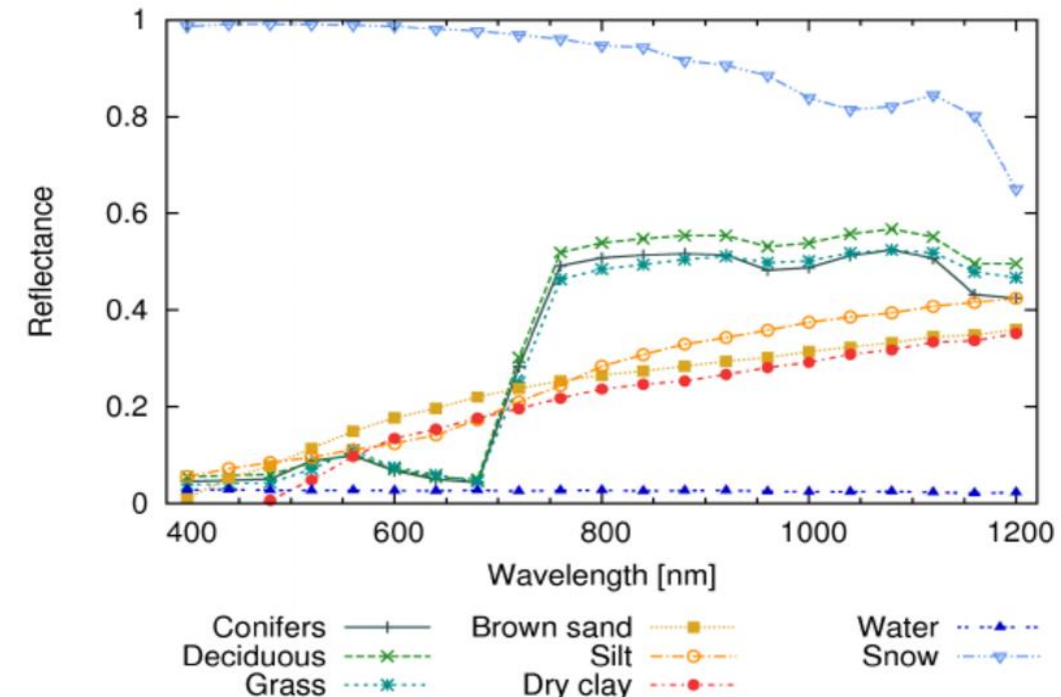
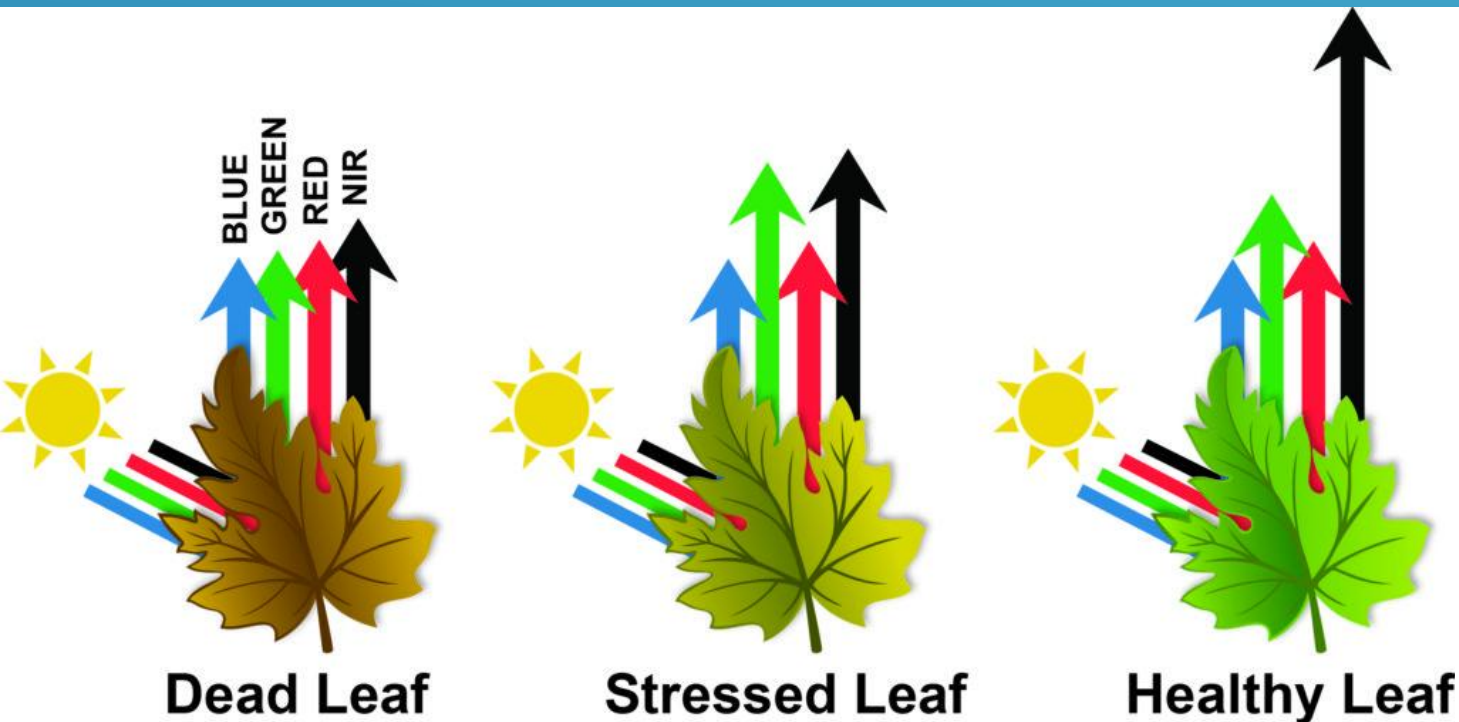


# SPECTRAL REFLECTANCE CURVE



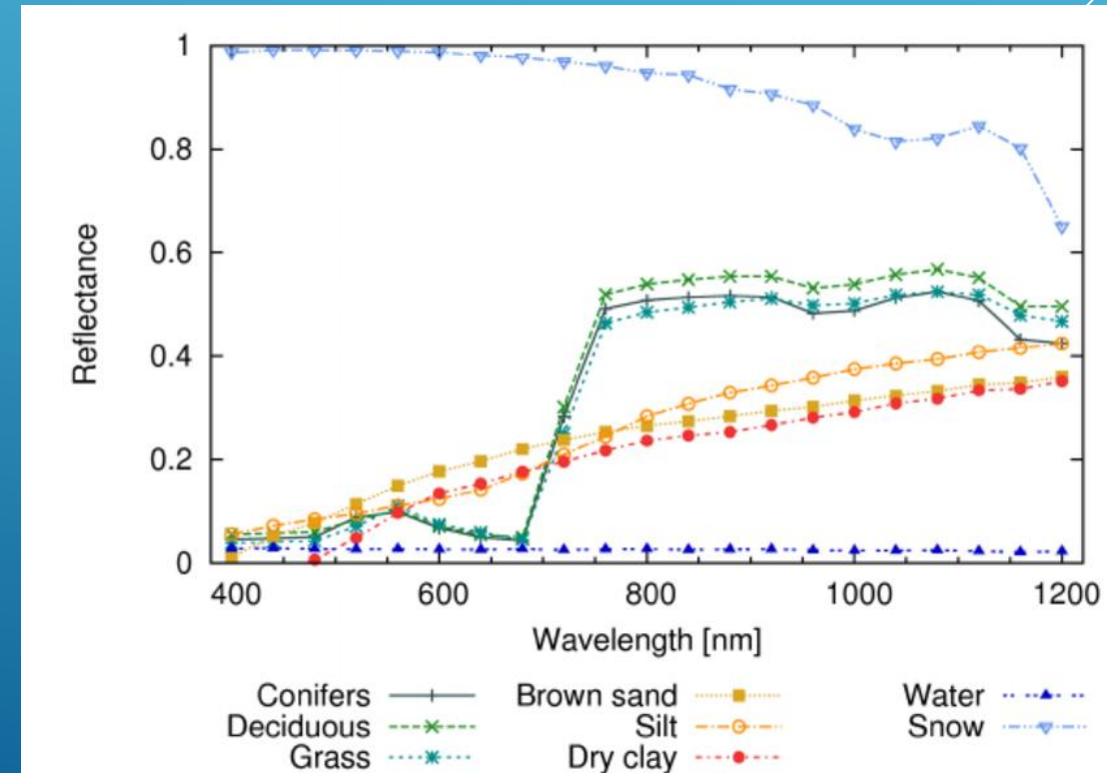
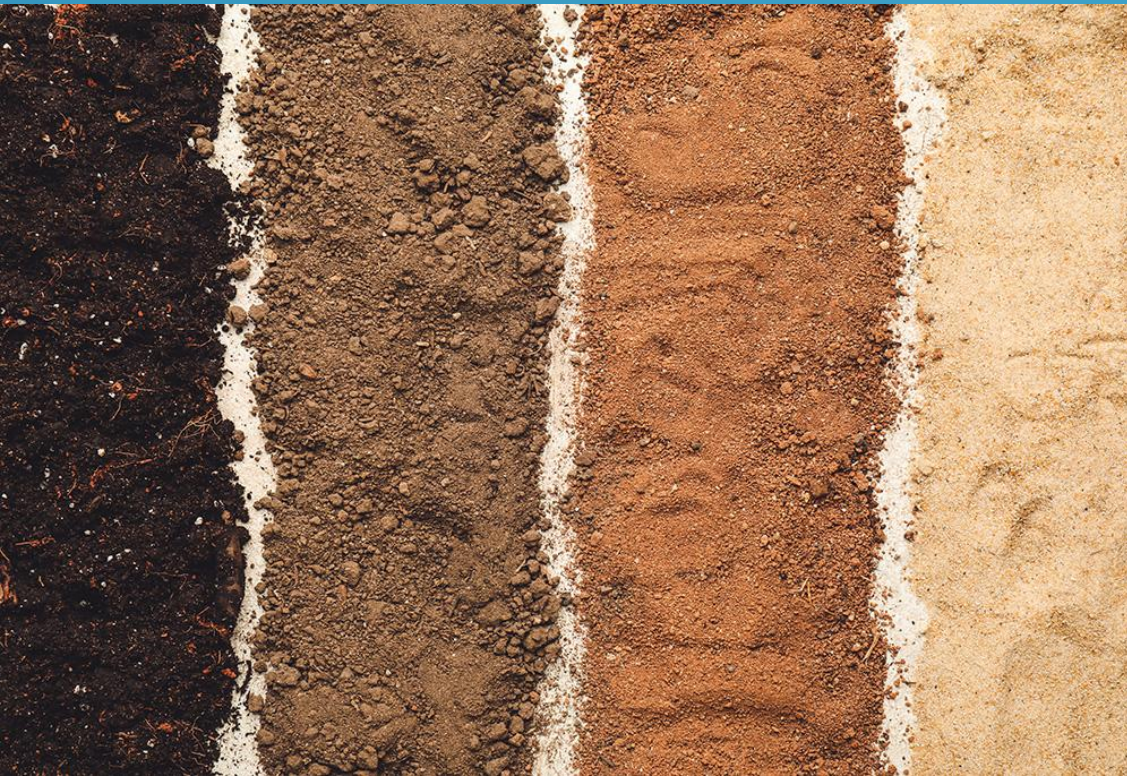
# VEGETATION CURVE

- ▶ Significant minimum of reflectance in the visible portion of the electromagnetic spectrum resulting from the pigments in plant leaves.
- ▶ Healthy vegetation will absorb in both the blue and red bands, giving rise to what is called the “green bump of healthy vegetation”.
- ▶ Reflectance increases dramatically in the near infrared. Stressed vegetation can also be detected because stressed vegetation has a significantly lower reflectance in the infrared.



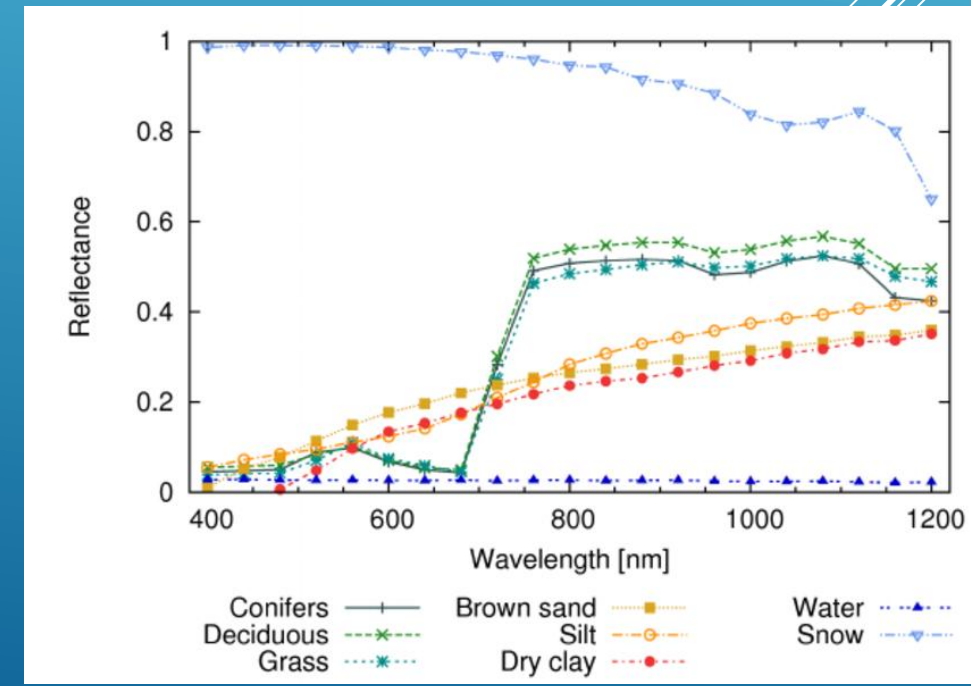
# SOIL CURVE

- ▶ Bare soil is considerably less variable.
- ▶ The reflectance curve is affected by moisture content, soil texture, surface roughness, presence of iron oxide and organic matter.
- ▶ These factors are less dominant than the absorbance features observed in vegetation reflectance.



# WATER CURVE

- ▶ The water curve is characterized by a high absorption at near infrared wavelengths range and beyond.
- ▶ Because of this absorption property, water bodies as well as features containing water can easily be detected, located and delineated with remote sensing data.
- ▶ Turbid water has a higher reflectance in the visible region than clear water.
- ▶ This is also true for waters containing high chlorophyll concentrations. These reflectance patterns are used to detect algae colonies.

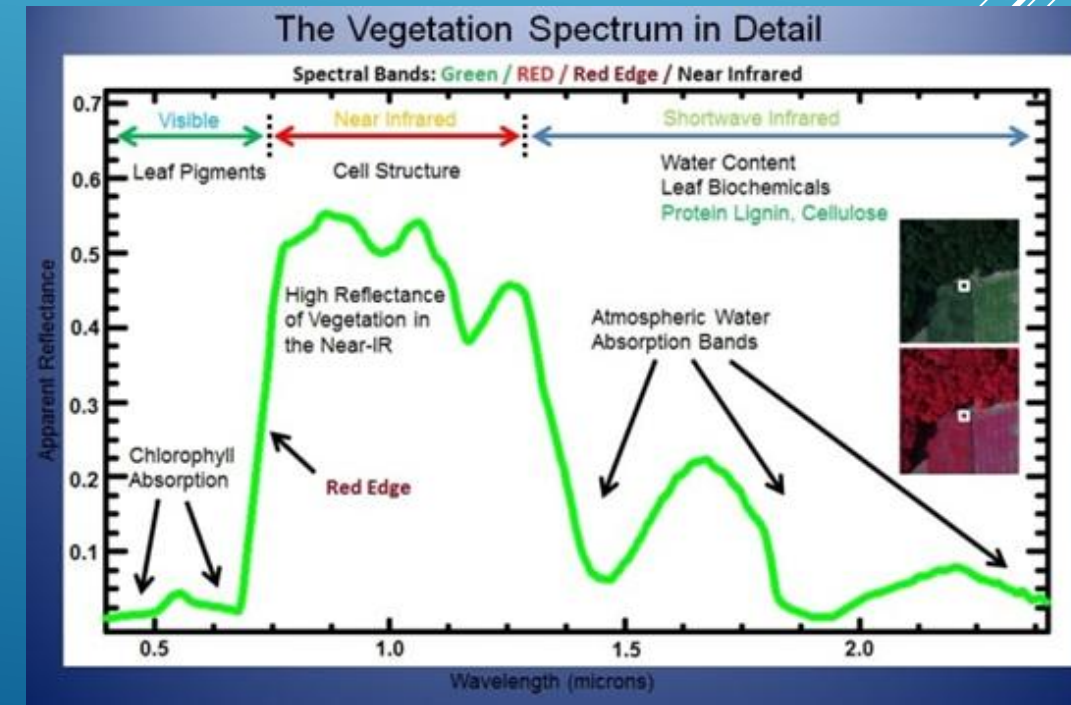
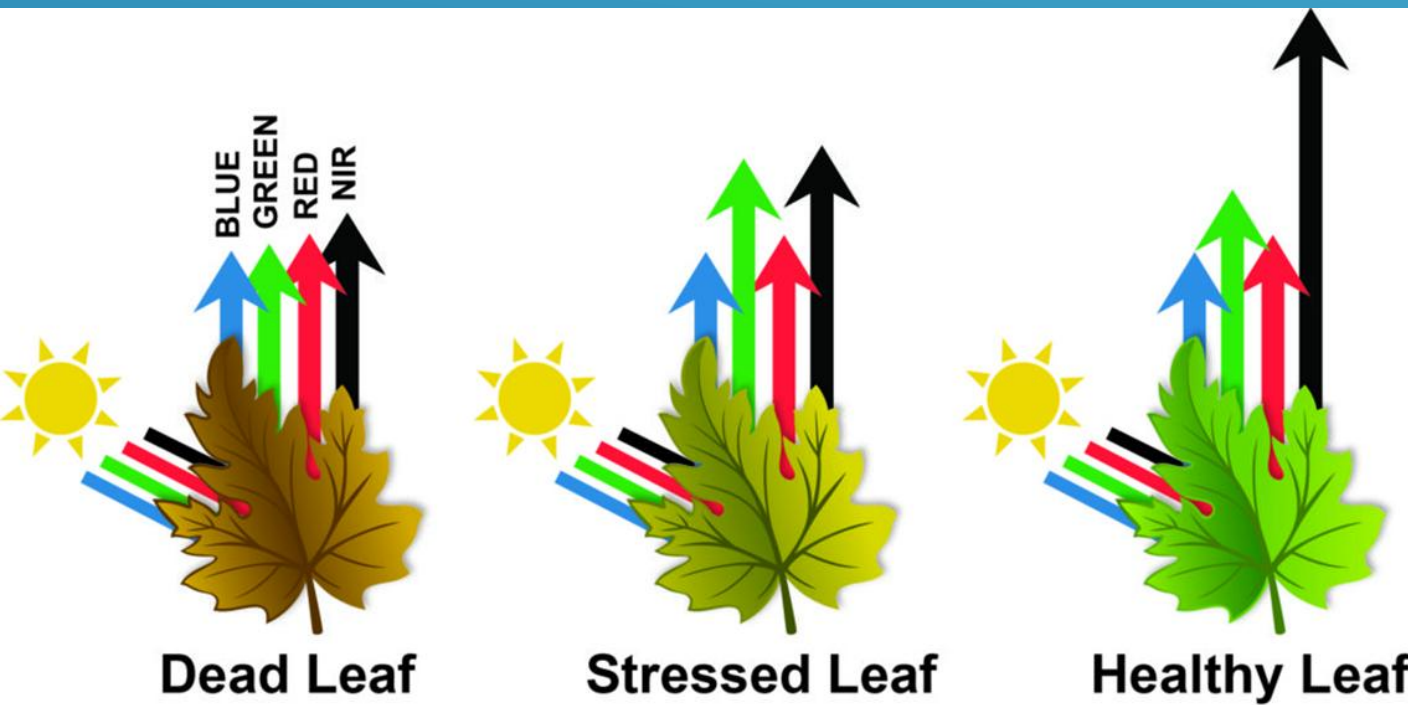


# MULTISPECTRAL VEGETATION BANDS



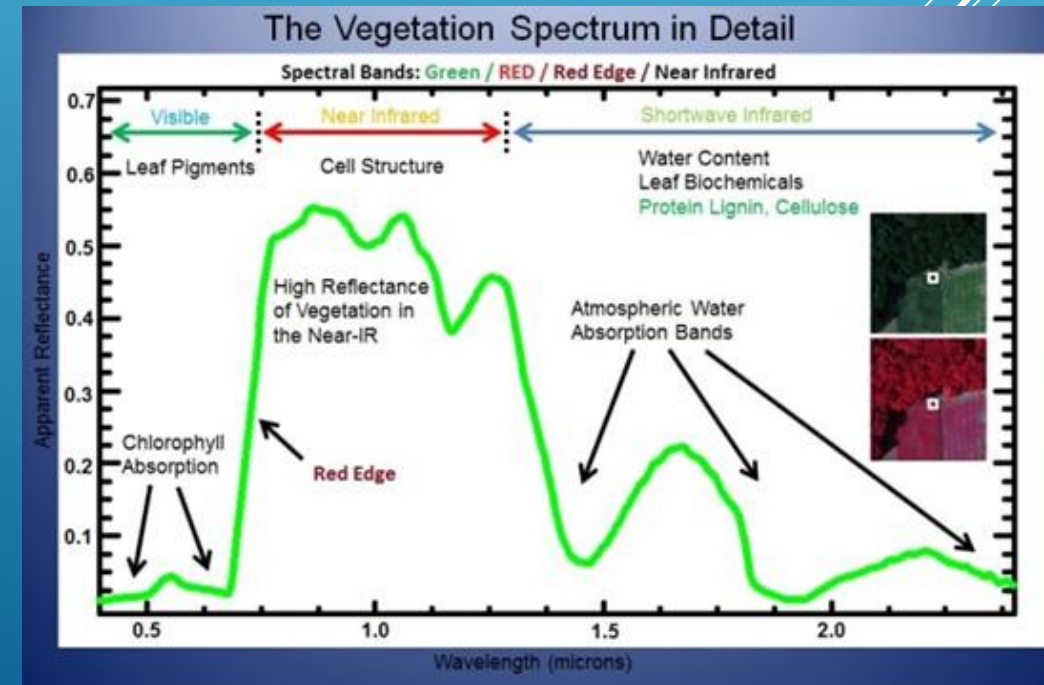
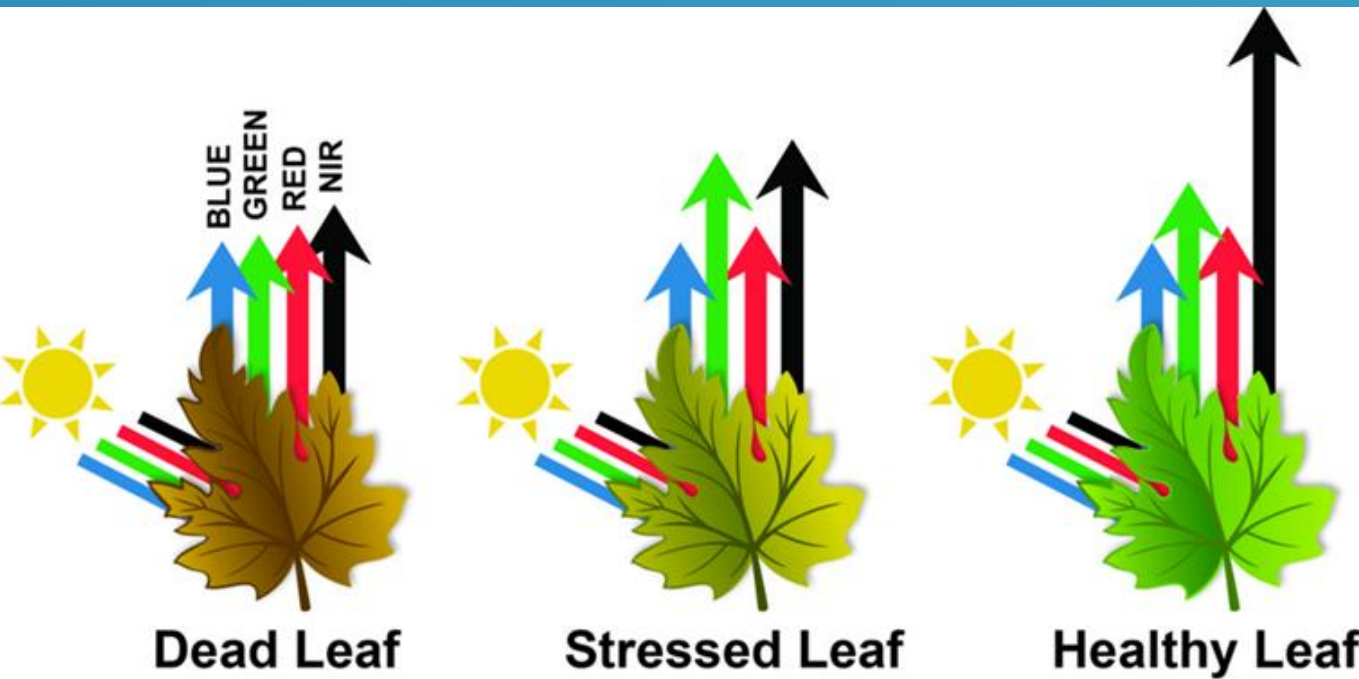
# GREEN BAND

- ▶ The reflectance curve of a healthy plant exhibits the greatest reflectance in a green waveband (in the range of 550 nm).
- ▶ Correlated with the amount of chlorophyll contained in the plant.
- ▶ The internal structure of healthy crops act as excellent diffuse reflectors of near-infrared wavelengths. Measuring and monitoring the near-IR reflectance is one way to determine how healthy (or unhealthy) vegetation may be.



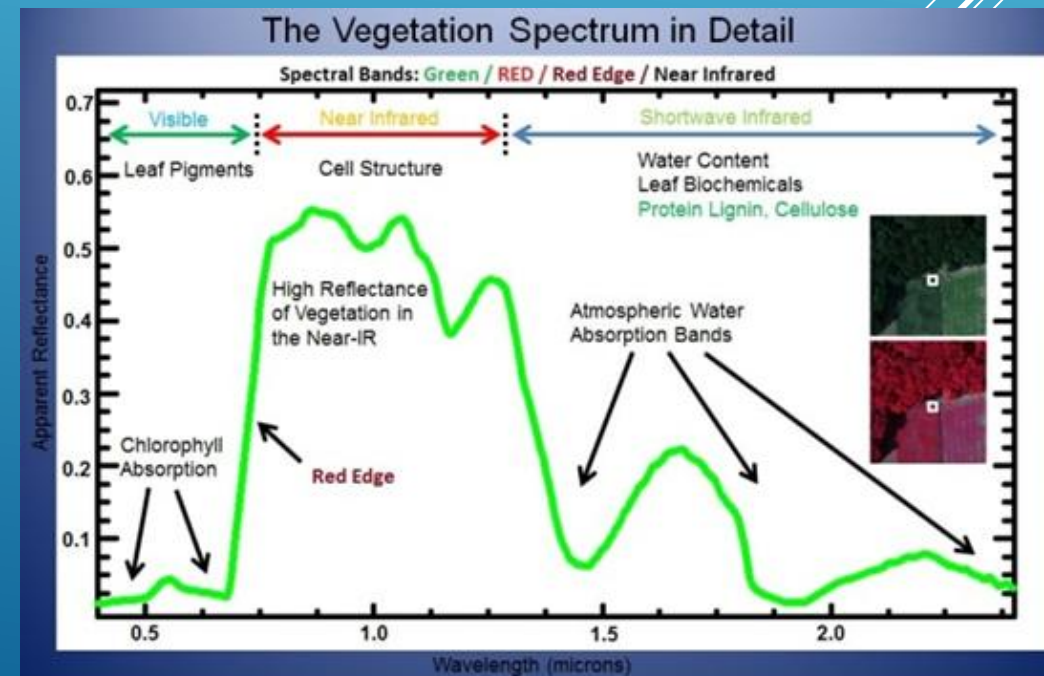
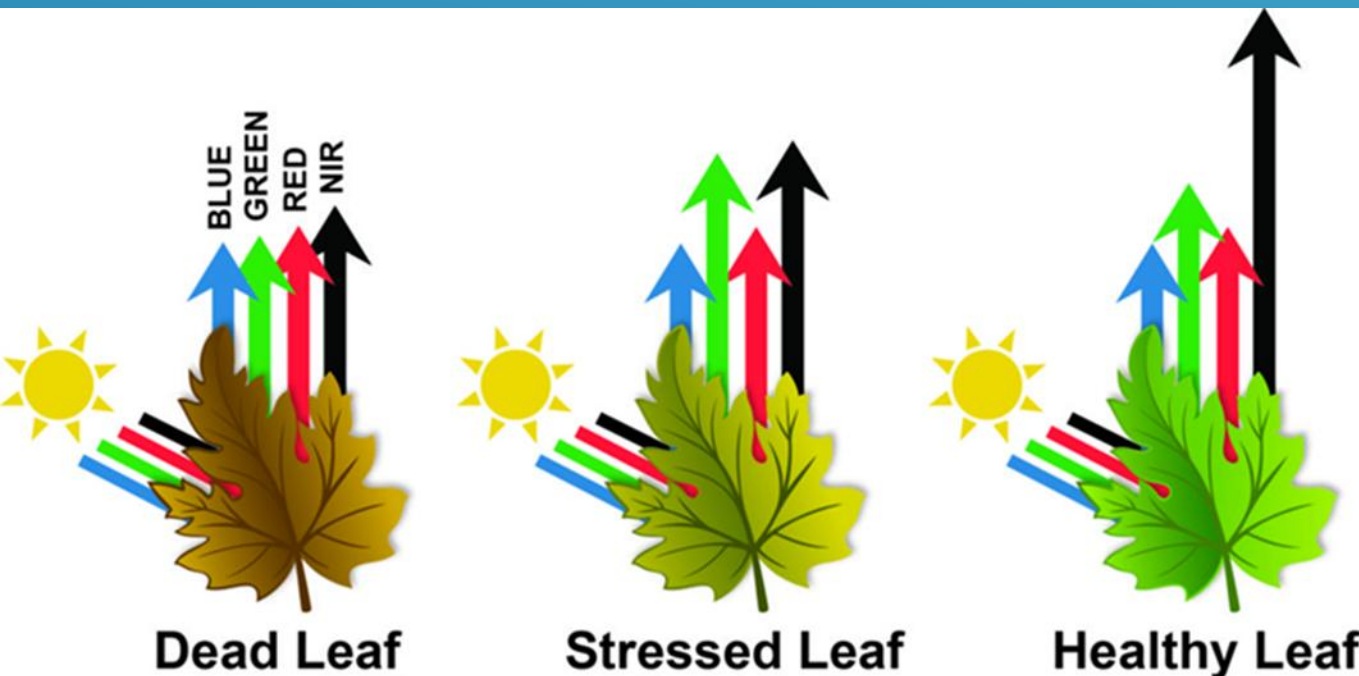
# RED BAND

- ▶ Corresponds to the reflected energy in the 600 – 700 nm spectral band.
- ▶ The strong chlorophyll absorption in this band results in a low reflectance.
- ▶ Reflectance varies significantly in relation to factors such as biomass, LAI (Leaf Area Index), soil history, crop type, humidity and plant stress.
- ▶ For most crops this band gives an excellent contrast between the plants and the soil



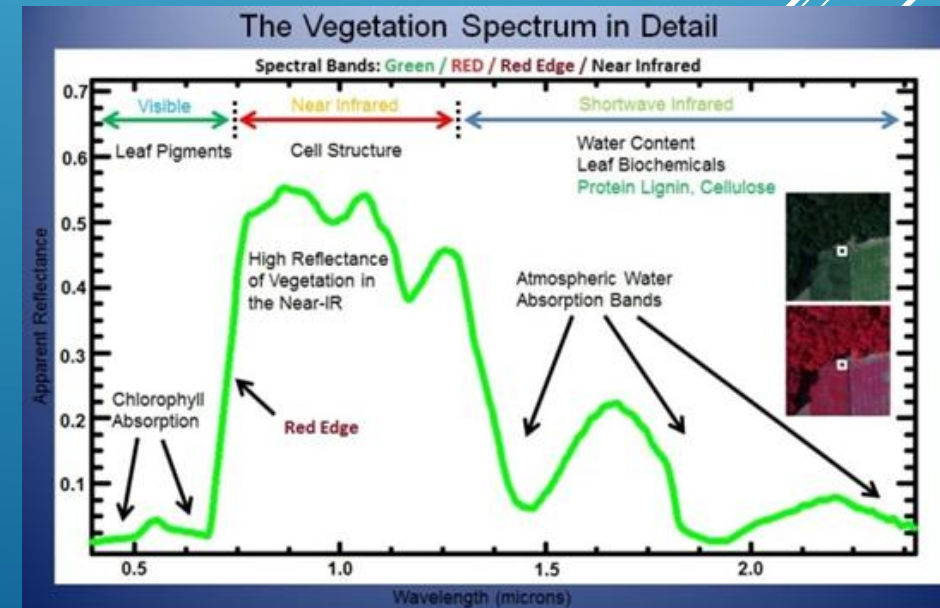
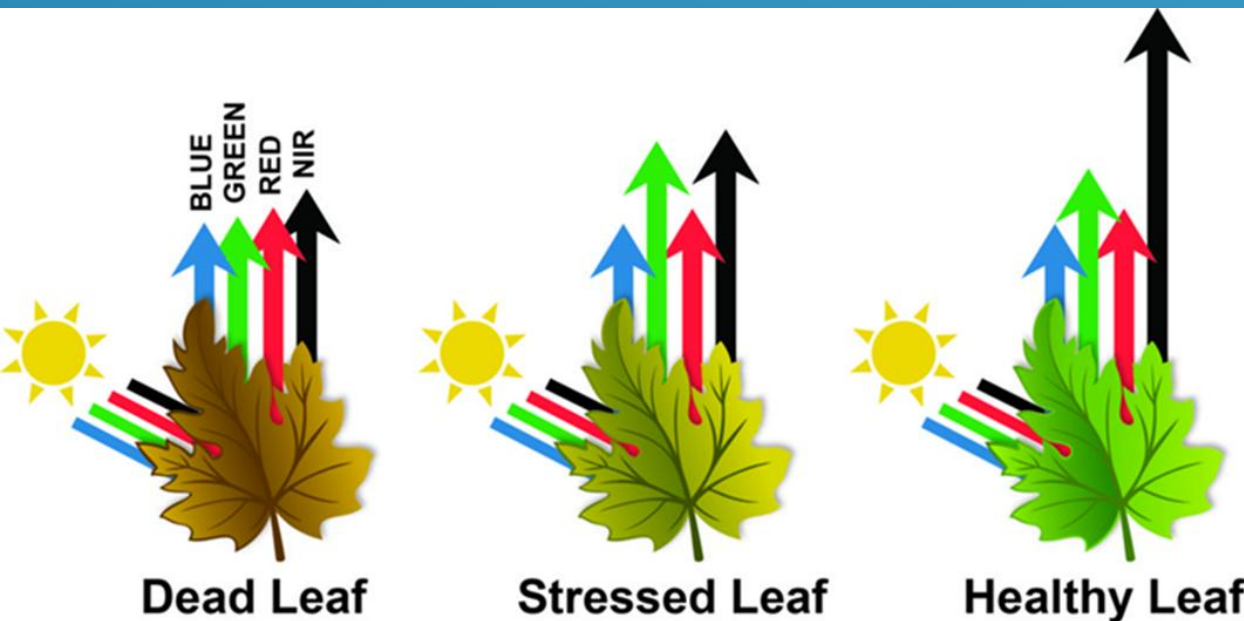
# RED EDGE BAND

- ▶ This a very narrow band (700 – 730 nm), which corresponds to the entry point of Near Infrared.
- ▶ It is the point of sudden change in reflectance, from strong absorption of Red to substantial reflection of Near Infrared.
- ▶ This band is very sensitive to plant stress and provides information on the chlorophyll.



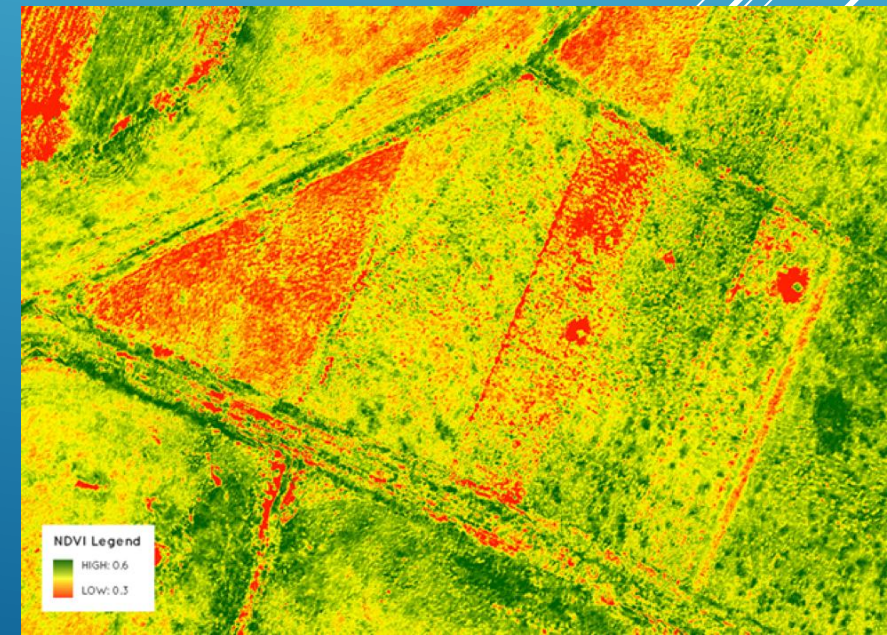
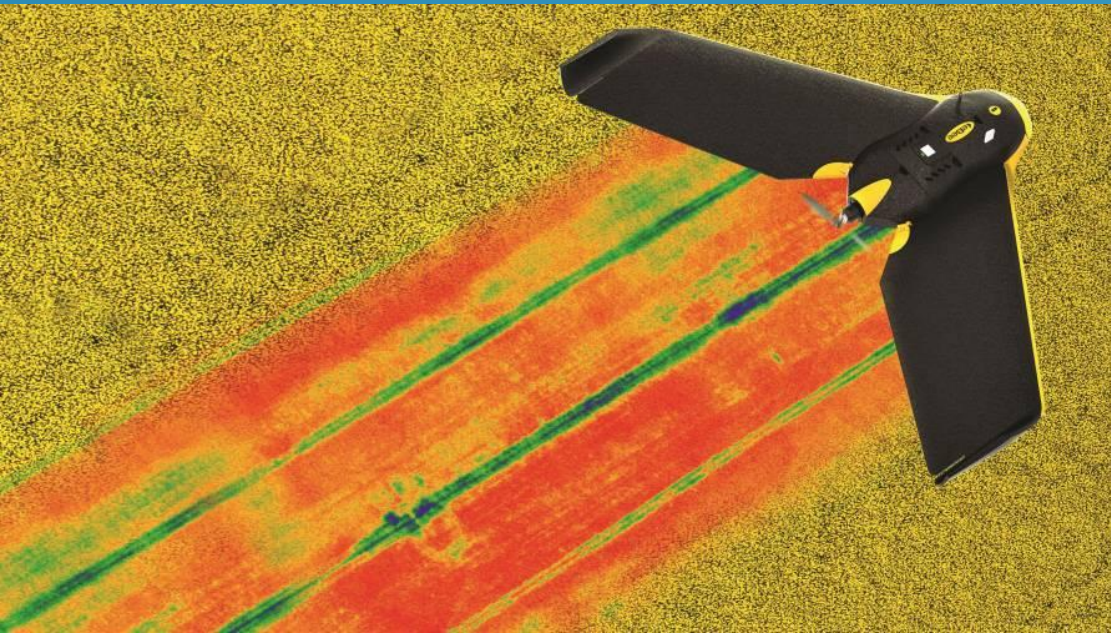
# NIR (NEAR-INFRARED) BANDS

- ▶ Corresponds to the wavelengths in the 700 nm to 1.3  $\mu\text{m}$  range.
- ▶ A very strong correlation between this reflectance and the level of chlorophyll in the plant.
  - ▶ Healthy vegetation absorbs blue and red-light energy to fuel photosynthesis and create chlorophyll.
  - ▶ A plant with more chlorophyll will reflect more near-infrared energy than an unhealthy plant.
  - ▶ A highly significant variation of the reflectance in this band is produced when a plant is under stress.
- ▶ NIR is sensitive to the leaf cellular structure and provides critical data to monitor changes in crop health.



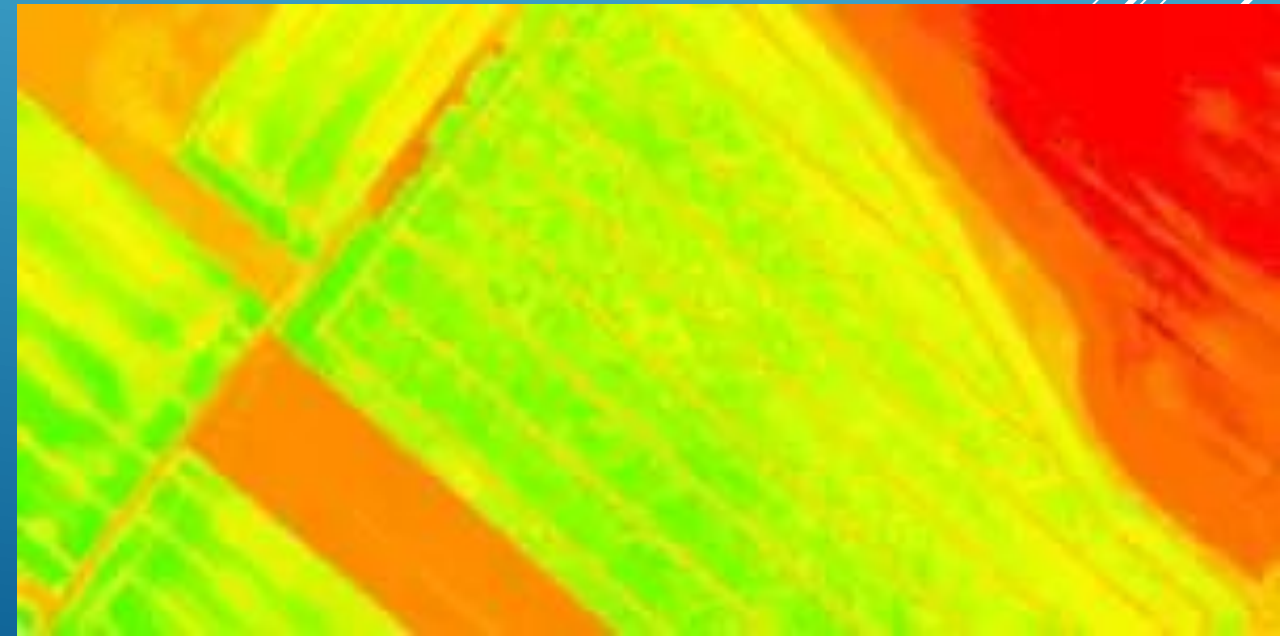
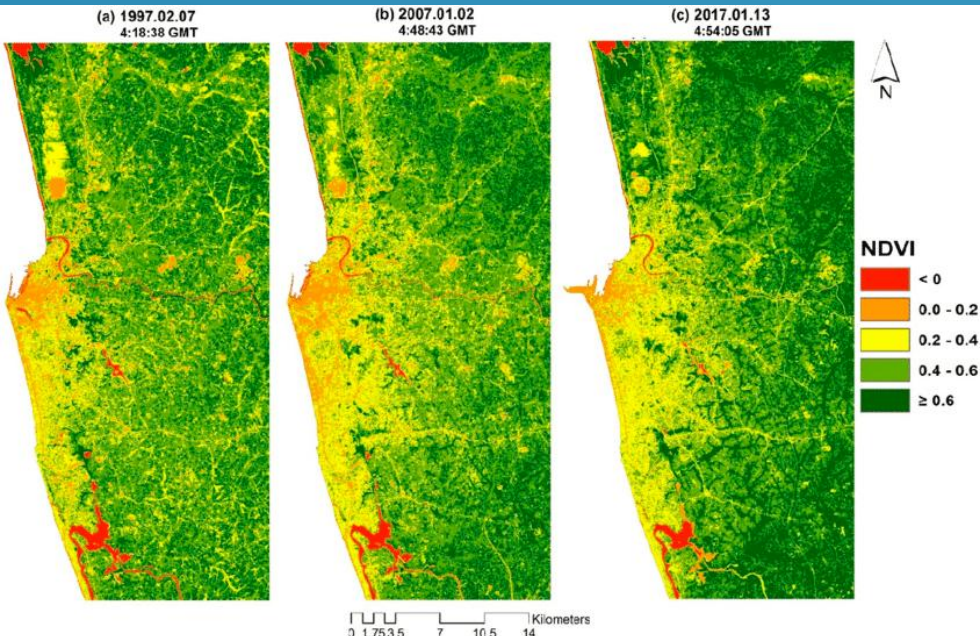
# VEGETATION INDICES

- ▶ Vegetation reflectance properties are used to derive vegetation indices (VIs).
- ▶ Analyze various ecologies.
- ▶ Constructed from reflectance measurements in two or more wavelengths to analyze specific characteristics of vegetation, such as total leaf area and water content.
- ▶ The most popular vegetation index is *NDVI* (Normalized Difference Vegetation Index).



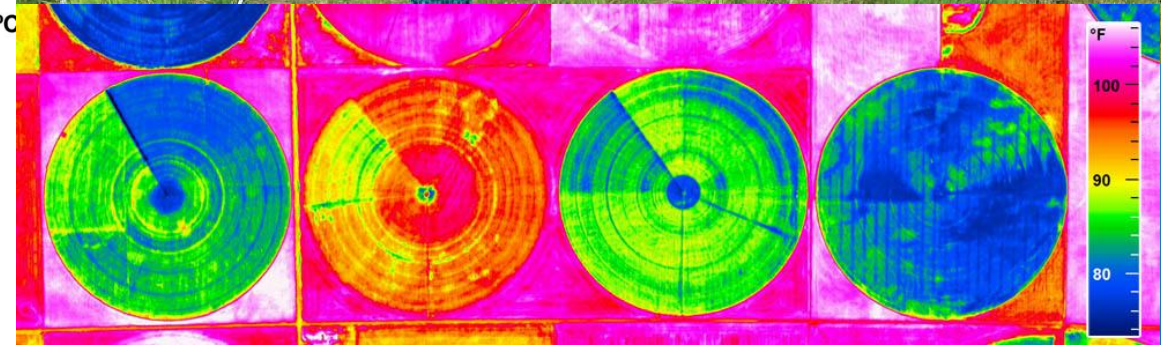
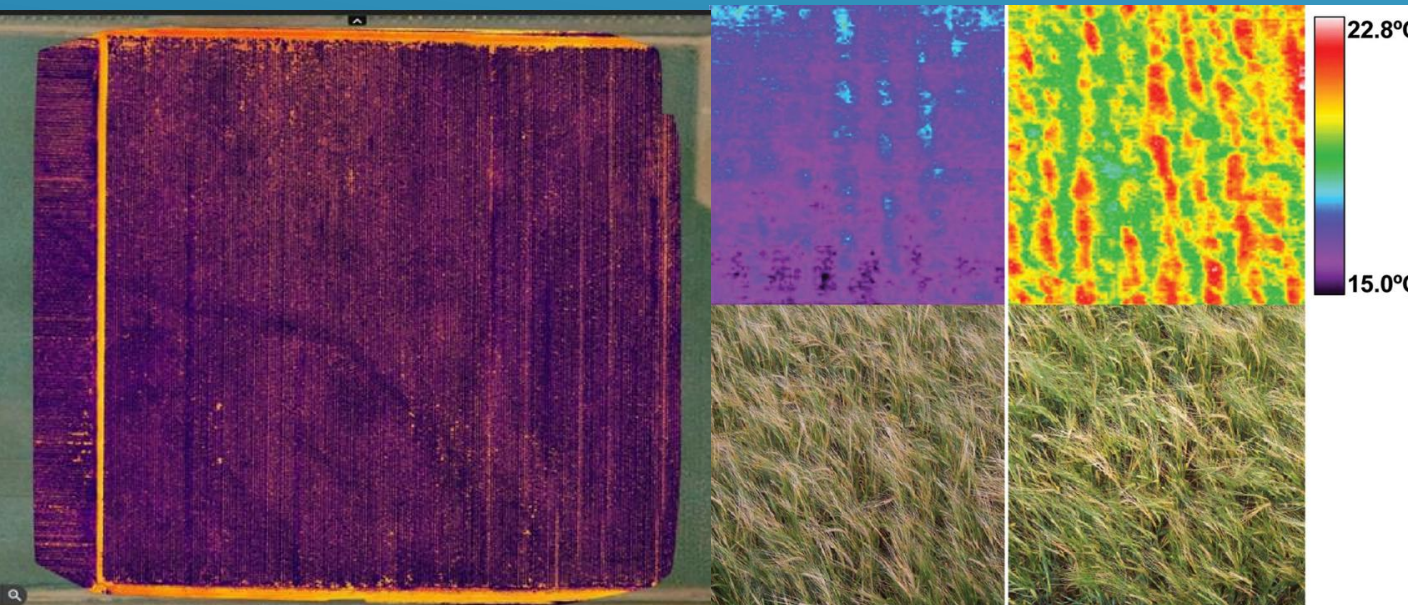
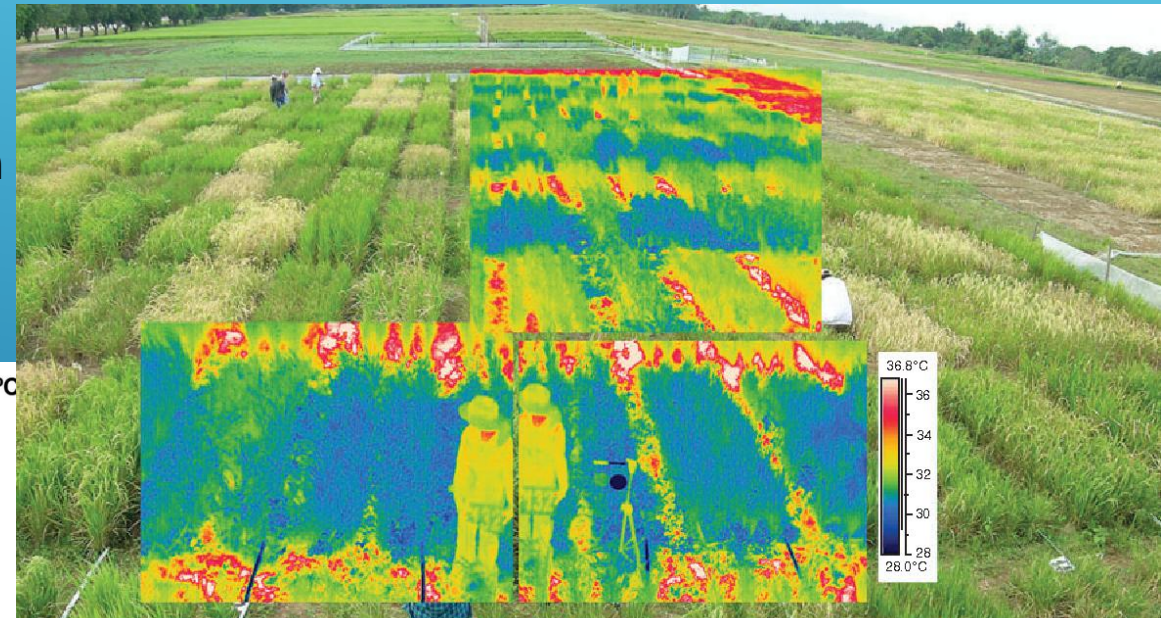
# NDVI VEGETATION INDEX

- ▶ Index of plant “greenness” or photosynthetic activity
- ▶ By taking the ratio of red and near infrared bands from a remotely sensed image (calculated on a per-pixel basis), an index of vegetation “greenness” can be defined.
- ▶ Various factors can affect NDVI values like plant photosynthetic activity, total plant cover, biomass, plant and soil moisture, and plant stress. Because of this, NDVI is correlated with both agricultural and ecosystem attributes
- ▶ Because it is a ratio of two bands, NDVI helps compensate for differences both in illumination within an image due to slope and aspect, and differences between images due things like time of day or season when the images were acquired.



# THERMAL INFRARED

- ▶ Thermal imagery captured from the air makes visible the heat emitted from objects on the ground, revealing temperature differences.
- ▶ Results can show:
  - ▶ Crop stress
  - ▶ Pinpoint common issues in irrigation systems
  - ▶ Optimize irrigation scheduling and system design for the terrain and soil conditions.



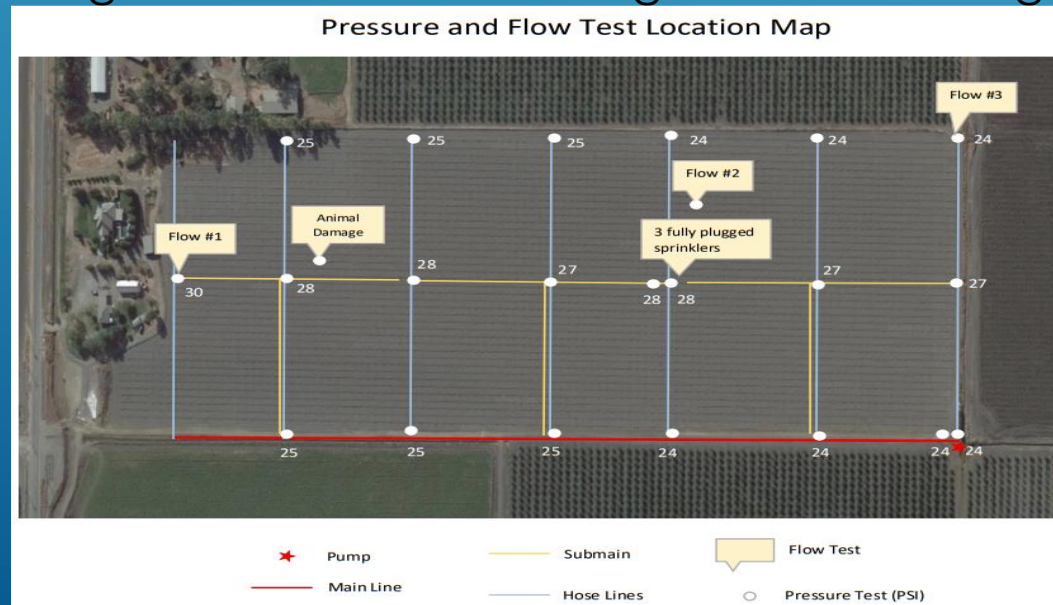
# AG WATER EFFICIENCY PROGRAM SERVICES

- Currently, SRCO is working with SCWA and SID on this program to offer various services for free.

- **Type of services offered:**

- General irrigation efficiency plans
- Assistance with monitoring equipment (weather stations, soil moisture sensors, etc.)
- Certification of Irrigation and Nitrogen

## Management Plans for the Irrigated Lands Program.



One of the key components of this report is the distribution uniformity (DU) rating, a measure of how evenly water is distributed throughout the irrigation system. The DU is calculated by comparing sprinkler or emitter flow rates collected in at least 3 different locations across the system. The closer the DU rating is to 100% equates to the higher the efficiency (uniformity) of the system.

This irrigation system's performance:

<b>Distribution Uniformity (global)</b> .....	<b>95%</b>
<b>Distribution Uniformity (flow)</b> .....	<b>93%</b>
<b>Application Rate</b> .....	<b>0.067 in/hr</b>

The global system DU of 95% is excellent for a micro sprinkler system. For all practical purposes, 100% is not possible; however, highly efficient micro systems typically have DUs above 92%. Global DU values are calculated through the use of an irrigation evaluation program while flow DU values are determined through the use of a low quarter formula located in the 'Application Rate and Flow DU' section of this report.

For this evaluation the MIL has identified several issues that include:

- Minor sprinkler plugging
- Slight pressures variability at manifold valve inlets
- Inaccurate pressure gauges at manifold valves

- Sprinklers close to minimum pressure recommended from manufacturer

### System Pressures

Balanced pressures are an incredibly important factor that determine flow rates at each sprinkler or emitter (unless pressure compensating or flow control devices are used). When

# PUMP EFFICIENCY TEST

## What is a pump test?

- A pump test measures various aspects of the pump's operation and provides an estimation of the overall efficiency of the pump and cost of running it under *test conditions*.

## Who does the pump testing?

- Currently, SRCD is working with a contractor to provide pump efficiency tests to landowners.

## Why should I do a pump test?

- Regular pump testing can identify problems before a breakdown occurs, energy bills climb, and increase water efficiency.

## How often should I test my pump and use the data from a pump test?

- A pump should be tested every 1-3 years depending on the annual usage and severity of operating conditions. While booster pumps being supplied with clean water should be tested once every 2-3 years.
- When comparing the results of the pump test and original pump's performance curve, it will show if a pump adjustment or repair is needed.

## How can I obtain a pump test?

- Please contact Kevin Young-Lai at Solano RCD in order to get scheduled for a pump test.




# TECHNICAL ASSISTANCE FOR PLANNING ON-FARM PRACTICES

Solano RCD staff can brainstorm with you about:

- Carbon farm planning
- Preventing soil erosion
- Applying for financial assistance programs to implement your ideas:
  - USDA NRCS
  - CDFA Healthy Soils
  - Other State/Federal funds
- Cover crops, hedgerows, windbreaks, wildlife habitat, pollinator projects, etc!

1170 N Lincoln, Suite 110  
Dixon, CA 95620  
(707) 678-1655 x 3  
FAX (707) 678-5001  
www.solanorcd.org



Conservation Plan

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**Date:** May 14, 2021  
**Name:** [REDACTED]  
**Address:** [REDACTED]  
**Contact:** [REDACTED]

**Resource concerns**

*Water conservation in vineyard alleys:* Landowner received a Healthy Soils grant to incorporate cover crops and mulch in vineyard operations. The perennial cover is difficult to establish, as the soil is extremely rocky and hard to prepare for seeding. Perhaps mulching the alleys would be more efficient?

*Rodent management:* Gophers are an issue and owl boxes are of interest to attract natural predators to the area.

*Sources for mulch:* Wood chips are always useful and sources for them would be helpful.

*Plants to avoid near winegrapes:* If native plants, or garden plants, are established in the vineyard area it would be good to avoid species that are known hosts for grapevine pests.

**This conservation plan will address the following topics in individual sections:**

1. Soils map and description
2. Options for vineyard alleys and sources for mulch
3. Owl box plans and recommendations
4. "Do not plant" list for grapevines

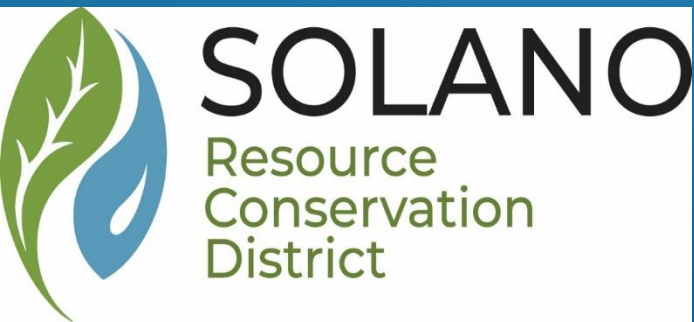
# PESTICIDE DISPOSAL PROGRAM



# PESTICIDE DISPOSAL PROGRAM

- **FREE** disposal of legacy pesticides/herbicides
  - Currently, we will work with you individually for disposal of such hazardous waste.
- First come first serve.
- Pilot program will end when grant funds are depleted, or on December 31<sup>st</sup>, 2023
- Pesticide disposal will be set up by appointment only.

Partners: Solano County Resource Management, Solano Ag Commissioner's Office, Dixon Resource Conservation District, and Cal Recycle.



# INFORMATION NEEDED FOR SIGN-UP?

- Name
- Contact information
  - Phone number
  - Email address
- List of what legacy pesticide you would like to have disposed of.
  - Pesticide/herbicide name
  - Quantity of the legacy pesticide

**Kevin Young-Lai's contact information:**

Solano Resource conservation District  
 1170 N. Lincoln Street Suite 110  
 Dixon, CA 95620  
 Office: (707) 678-1655 x 123





## AGRICULTURAL PESTICIDE INVENTORY FOR DISPOSAL

PRINT CLEARLY to avoid processing delays.

First Name: \_\_\_\_\_ Last Name: \_\_\_\_\_  
 Address: \_\_\_\_\_ City/Zip: \_\_\_\_\_  
 Home: \_\_\_\_\_ Mobile: \_\_\_\_\_ Email: \_\_\_\_\_

If multiple containers of the same product exist, you must list each container separately:

Product Name	Container Contents and Size		Container Condition (check one)	
List name on label and if label is removed, state "unknown"	List estimated remaining volume in qt. or gal.	List size in qt. or gal. as labeled, or estimate size if label is removed	Seal intact can be moved and transported safely	Pest. requires handling location due to deterioration, leaks
EXAMPLE: Diazinon 4 Spray	1 gallon	5 gallons	✓	

ACKNOWLEDGMENT: I, the undersigned, agree to hold the County of Solano and Solano Resource Conservation District harmless in my participation in the Pesticide Disposal Pilot Program and follow the U.S. Department of Transportation's rules related to the transport limits of hazardous waste as a small quantity generator.

\_\_\_\_\_  
Signature of Participant

\_\_\_\_\_  
Date







Q & A

QUESTIONS AND ANSWERS WITH THE PRESENTERS



Please take a few  
minutes to fill out the  
workshop evaluation.

Thank you for attending!