- 1991 – USGS begins National Water Quality Assessment Program
- 1999 – USGS publishes “The Quality of Our Nation’s Waters” with specific reference to nutrients and pesticides

Conclusion

- Differences in natural features and land management practices make some areas more vulnerable to contamination than other areas.

Significance

- Recognition of differences in vulnerability to contamination can help target resources for protection of groundwater at greatest risk. The most extensive control strategies should be on the more vulnerable settings.

Groundwater vulnerability separated into intrinsic and specific vulnerability.

- Intrinsic are factors over which farmer has no control, such as soil hydrological properties and hydrogeological factors. Each type of irrigation system and crop has an intrinsic vulnerability.
- Specific vulnerability is a function of management factors such as quantity, rate, timing, and methods of nitrogen and water application.

'ARISTOTLE.'

"It is the mark of an instructed mind to rest satisfied with the degree of precision which the nature of the subject permits, and not to seek an exactness where only an approximation of the truth is possible."

Aristotle

PURPOSE

To provide information for farmers to voluntarily target resources for management practices that will yield the greatest level of reduced nitrogen contamination potential for ground water by identifying the fields of highest intrinsic vulnerability.

This is not a new concept in California. I served on two committees that proposed using a hazard index based on the soil, crop, and irrigation systems. The most recent was the Nutrient Technical Advisory Committee (TAC) appointed by the State Water Resources Control Board (1994). The recommendations of TAC have never been implemented because a hazard rating for each crop and soil had to be established. We generally followed the guidelines proposed by TAC but did make some modification in detail.

What is Important in Protecting Groundwater

- Less NO_3 concentration or less total mass of NO_3 percolating beyond the root zone?
- Obvious answer is to have both.
- However, low concentration may not necessarily equate to low mass flow.

Consider Conservative Salt

$$C_d = C_i / LF$$

C_d is concentration of water leaving the root zone

C_i is concentration in irrigation water

LF is leaching fraction

$$LF = (AW-ET) / AW = DP / AW$$

AW is applied water that infiltrates the soil

DP is amount of deep percolation

$$C_d = C_i AW / DP$$

Increasing DP causes decreasing concentration

Relationship Between Fertilizer Application and Irrigation on N Concentration Below Root Zone

N Application kg/ha	Irrigation cm	N Conc. mg N/L	Calc. N Leached kg/ha
0	100	8.6	13.2
90	100	12.4	20.2
179	100	16.9	26.8
358	100	32.1	66.7
0	60	9.4	0.52
90	60	12.1	0.78
179	60	15.4	1.03
358	60	35.9	2.95
0	20	16.2	0.0
90	20	27.2	0.0
179	20	34.0	0.0
358	20	47.0	0.0

Extensive Investigation on NO_3 in Ag. Tile Drain in 1970s

- No correlation between NO_3 concentration and fertilizer application
- Correlation between mass of NO_3 and fertilizer application
- No correlation between NO_3 concentration and amount of drainage water
- Correlation between mass of NO_3 and amount of drainage water

Results of USGS measured NO_3 concentrations in domestic wells:

- NO_3 concentration not correlated with N-fertilizer application within a 0.25- and a 0.50-mile radius.
- No relationship between NO_3 concentration and soil permeability, hardpan percent, and clay percent.
- The lack of a relationship to soil properties in the counter balancing effect of reduced leaching fraction and increased denitrification. No measurement of mass flow.

Whether, from a groundwater quality perspective, it is better to have a high volume of leachate water with a low concentration of NO_3 or to have a smaller volume of leachate with a higher concentration can be debated.

A conclusion that is well supported by research findings and scientific principles is that the concentration is not a valid indicator of good versus bad agricultural management.

Nutrient TAC Report

- *http://www.swrcb.ca.gov/nps/docs/tac_nutrient.doc*
- **Recommended Hazard Index for:**
  - **Soils**
  - **Crops**
  - **Irrigation System**

Scale

- **Nutrient TAC Report**
  - **Scale for Soil of 1, 2, and 3**
- **After Analysis and Discussion**
  - **Scale for Soil of 1 through 5**

Soil Rating

The hazard rating for soils is 1 through 5.

- **Soils rated as 1 are those that have textural or profile characteristics that inhibit the flow of water and create an environment conducive to denitrification.**
- **Soils rated as 5 are those that have high water infiltration rates, high water transmission rates through the profile, and low denitrification potential.**
- **Soils rated 2, 3, or 4 are those with intermediate properties.**

Soil HI Examples

- **HANFORD SERIES**
  - Well drained
  - 60 inches of sandy loam or fine sandy loam
  - OM less than 1%
  - Moderately rapid permeability
  - No mottles or restrictive layers

HI = 5

Soil HI Examples

- **BRYMAN**
  - Well Drained Soil
  - (A) Loamy Sand, (B) Sandy Clay Loam
  - (C) Sand
  - Moderate Permeability

HI = 4

Soil HI Examples

- **YOLO**
  - Well Drained
  - Silt Loam
  - No Evidence of Mottles
  - Moderate Permeability

HI = 3

Soil HI Examples

- **CROPLEY**
  - Moderately Well Drained
  - Clay to Clay Loam
  - Light Mottles & Iron Deposits
  - Slow Permeability

HI = 2

Soil HI Examples

- **CASTRO**
  - Poorly Drained Soil
  - Strong Prominent Mottles
  - Clay
  - Slow to Very Slow Permeability
  - Lime Hardpan at 38 inches

HI = 1

Crop Rating

The hazard rating for crops is from 1 through 4. Factors considered in establishing the crop hazard rating include:

1. **Rooting depth**
2. **Ratio of N in crop tops to recommended N application**
3. **Fraction of the crop top N that is removed from the field with the marketable product**
4. **Magnitude of the peak N uptake rate**
5. **Whether the crop is harvested at a time when the N uptake rate is high**

A slightly different set of criteria was used for tree and vine crops.

Procedures

- Review of the Literature
- Giving a High, Medium or Low categorization of each factor for each crop
- Entering the Information in Spreadsheets

Procedures Cont.

- Give the Crop an Overall Hazard Index Rate
- Sent Information to Experts for Review
- Compiled the Opinions and Revised the Hazard Index Rating

Lets Now Look at Some Crops

- **Tree and Vine – Grapes**
  - **Low N Requirement**
  - **Deep Rooting**
  - **High Ratio 1**
  - **Medium Ratio 2**
  - **Small Leaf Deposits**

HI = 1

More Crops

- **Tree and Vine – Almonds**
  - **Higher N Recommendation**
  - **Deep Rooted**
  - **High Ratio 1**
  - **Low Ratio 2**
  - **Large leaf Deposits**

HI = 2

More Crops

- Vegetable - Lettuce
  - High N requirement
  - Shallow roots
  - Ratio 1 Medium
  - Ratio 2 Low
- Harvested During Peak N Uptake

HI = 4

More Crops

- **Field Crops - Alfalfa**
  - **No N Recommended**
  - **Deep Rooted**
  - **Ratio 1 High**
  - **Ratio 2 High**
- **Seed or Hay ??**

HI = 1

Irrigation System Rating

We accepted the rating system proposed by TAC for irrigation systems

1. **Micro-irrigation accompanied by fertigation**
2. **Micro-irrigation without fertigation**
3. **Sprinklers used for pre-irrigation or throughout the irrigation system**
4. **Surface irrigation systems throughout the season**

Integrated Hazard Index (HI)

- Multiply the soil, crop, and irrigation system hazard ratings
- Result is a number from 1 through 80
- We propose a HI of 1 through 20 is of minor concern
- A HI greater than 20 should receive careful management attention
- Equally, if not more, important than the numerical value of the HI are the factors that lead to the higher HI values. These provide management guidelines for reducing NO_3 transport to groundwater

Supporting Evidence for Hazard Index Concept

USGS measured NO3 in groundwater beneath three agricultural land-use settings in eastern San Joaquin Valley 1993-1995

Land use settings were:

- **Vineyards**
- **Almond Trees**
- **Crop Grouping of Corn, Alfalfa, Vegetables**

Soils

Vineyards and almonds on similar coarse-grained soils with rather rapid water transmission properties and low potential for denitrification

The three-crop setting on relatively fine-grained sediments with lower transmission properties and higher denitrification potential

Our Hazard Index

Soil hazard rating higher for vineyards and almonds than the three-crop lands.

Crop hazard higher for almonds than vineyards because of lower N application to vineyards.

The three-crop system consists of alfalfa (lowest) and vegetables (highest hazard) – cumulative effect unknown but expected to be intermediate

Results

- NO_3 concentration in wells highest in almonds, intermediate in three-crop area, and lowest in vineyard area.
- Concentrations of Cl and NO_3 were correlated in almond and vineyard settings indicating little denitrification.
- The EC and Cl concentration higher in three-crop area than other settings indicating a lower leaching fraction.
- NO_3 and Cl not correlated in three-crop system indicating denitrification. Dissolved oxygen lower in three-crop systems.

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http://www.lib.berkeley.edu/WRCA/WRC/wqp_hazard.html

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Water Quality Program - Nitrate Groundwater Pollution Hazard Index

Find Your Index Number

HI NO_3^- for Irrigated Agriculture in the Southwest

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How it Works: The index works with an overlay of soil, crop, and irrigation information. Based on the three components, an overall potential hazard number is assigned and management practices are suggested where necessary. If you don't know what soil type you have, try this online soil survey with detailed soil survey data for much of California, Arizona, and Nevada.

More Information:

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- Dynamics of Nitrogen Availability and Uptake (pdf, 124kb)
- Basic Factors Affecting N Transport through Soils (pdf, 107kb)
- Interpretation of Nitrate Groundwater Pollution Hazard Index Number (pdf, 42kb)
- Workshop Presentations:
  - Background Information and Supporting Evidence for the Hazard Index (pdf, 154kb)

Water Quality Program

- Water Issues Survey
- Watershed Management
- Nutrients & Pesticide Mgmt.
- Drinking Water & Human Health
- Water Cons. & Ag Water Mgmt.
- Water Policy & Econ.
- Animal Manure & Waste Mgmt.
- Nitrate Hazard Index

Done

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California Soil Resource Lab

Links Online Soil Survey People Projects Site Map Software

Online Soil Survey (D.E. Beaudette and A.T. O'Geen)

Submitted by dylan on Tue, 2005-05-31 17:37.

Location Query Results:

Zoom to Street Address:

Address:
City
State:
GO

Zoom to CA PLSS Grid:

Section Information

1/4 1/4 Section

Township / Range Information

T N R E Mt. Diablo, CA

GO

Zoom to Geographic Coordinates:

	Decimal Degrees	*Degrees Minutes Seconds*
Latitude:	° North	° ′ ″ North
Longitude:	° West	° ′ ″ West

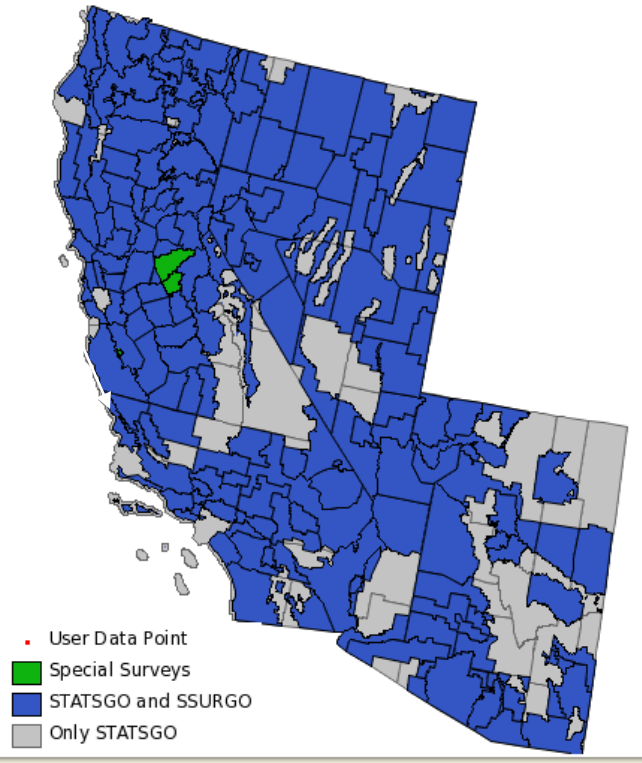
GO

Experimental Interfaces:

Pinnacles National Monument, CA
Google Earth Interface
Google Maps Interface
Static Map Interface
Text-based Interface Suitible for a braile console

Contact Us

Status Map



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Online Soil Survey (D.E. Beaudette and A.T. O'Geen)

Submitted by dylan on Tue, 2005-05-31 17:37.

Location Query Results:

Associated Survey Area: ca664

Go to this point!

Zoom to Street Address:

Address: 209 Surf Street

City Morro Bay

State: CA

GO

Zoom to CA PLSS Grid:

Section Information

1/4 1/4 Section

Township / Range Information

T N R E Mt. Diablo, CA

GO

Zoom to Geographic Coordinates:

	Decimal Degrees	*Degrees Minutes Seconds*
Latitude:	° North	° ′ ″ North
Longitude:	° West	° ′ ″ West

GO

Experimental Interfaces:

Pinnacles National Monument, CA

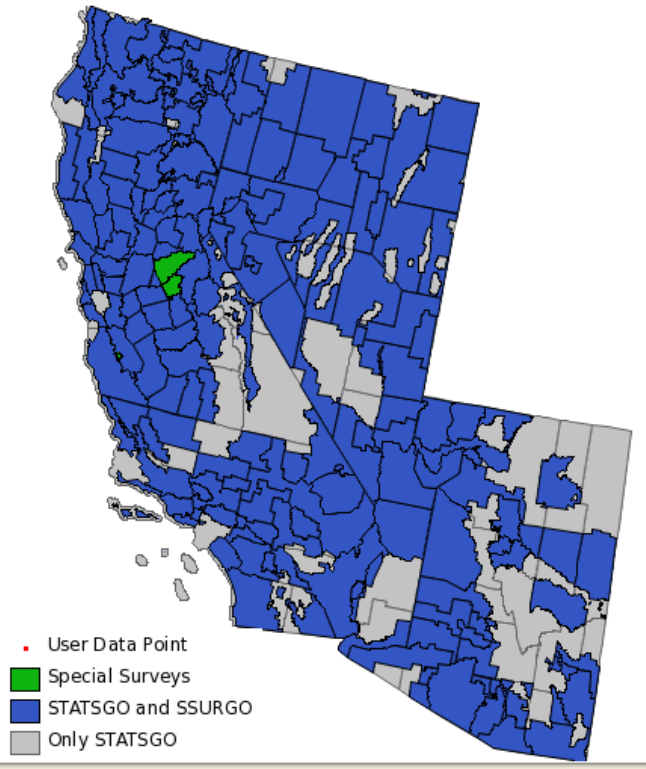
Google Earth Interface

Google Maps Interface

Static Map Interface

Text-based Interface Suitible for a braile console

Status Map



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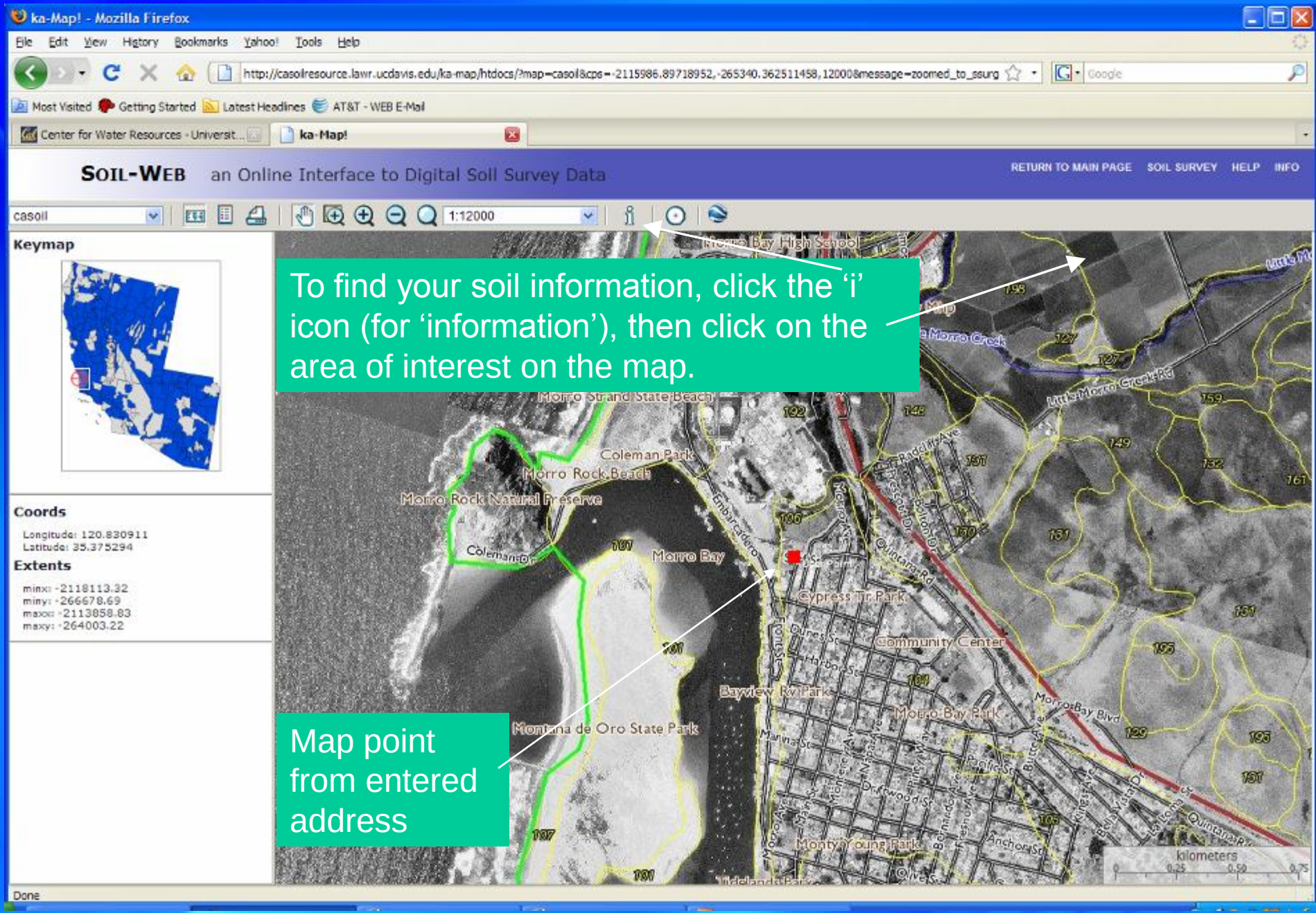
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SOIL-WEB an Online Interface to Digital Soil Survey Data
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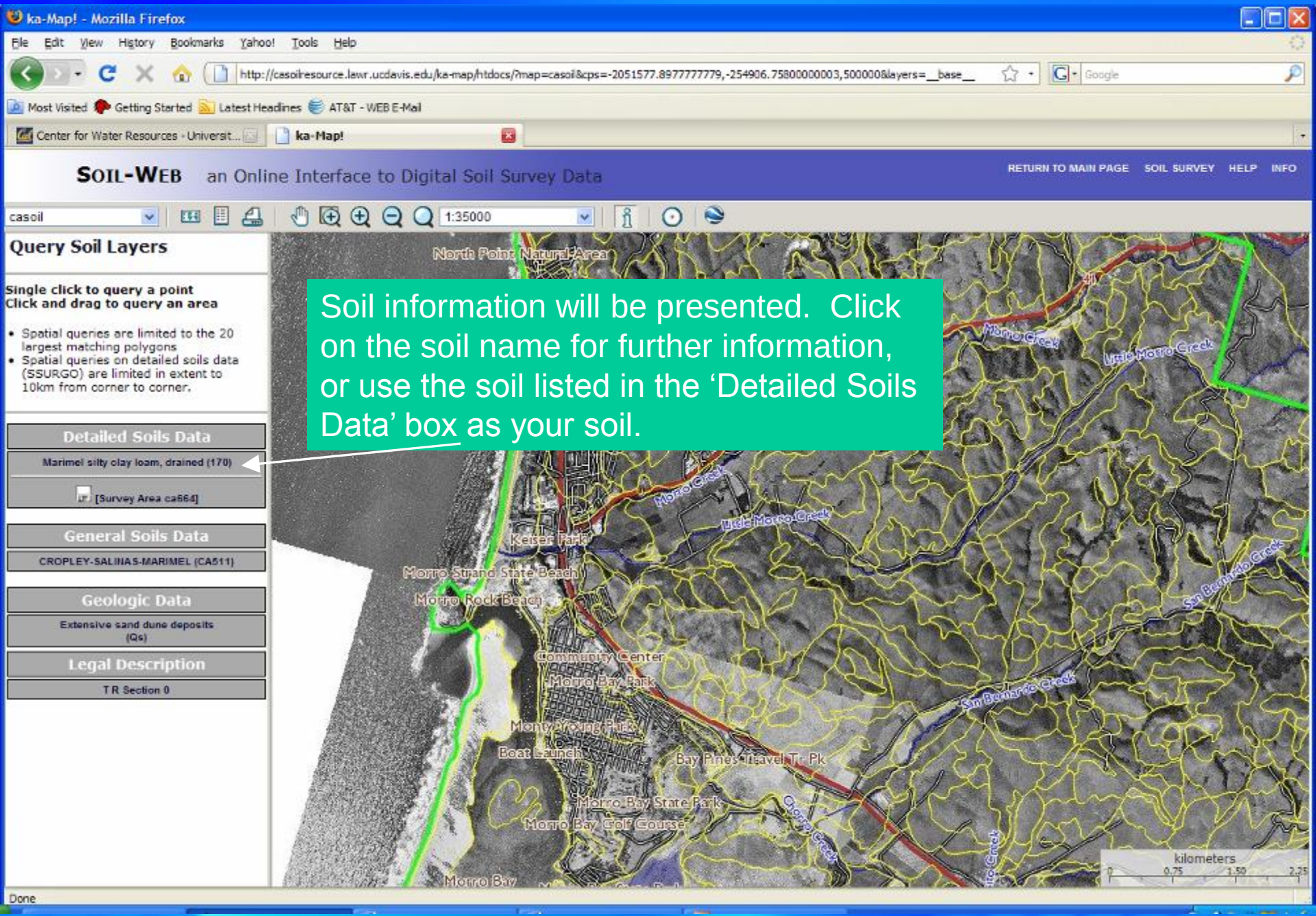
INFO
Keymap
Coords
Longitude: 120.830911
Latitude: 35.375294
Extents
minx: -2118113.32
miny: -266678.69
maxx: -2113858.83
maxy: -264003.22
To find your soil information, click the 'i' icon (for 'information'), then click on the area of interest on the map.
Map point from entered address
Morro Bay
Coleman Park
Morro Rock Beach
Morro Rock Natural Preserve
Morro Strand State Beach
Cypress Tr Park
Community Center
Bayview Rv Park
Morro Bay Park
Montana de Oro State Park
Monty Young Park
kilometers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casoil
1:35000
Query Soil Layers
Single click to query a point
Click and drag to query an area
Spatial queries are limited to the 20 largest matching polygons
Spatial queries on detailed soils data (SSURGO) are limited in extent to 10km from corner to corner.
Detailed Soils Data
Marimel silty clay loam, drained (170)
[Survey Area ca664]
General Soils Data
CROPLEY-SALINAS-MARIMEL (CA511)
Geologic Data
Extensive sand dune deposits (Qs)
Legal Description
TR Section 0
Soil information will be presented. Click on the soil name for further information, or use the soil listed in the 'Detailed Soils Data' box as your soil.
North Point Natural Area
Morro Creek
Little Morro Creek
Keiser Park
Morro Strand State Beach
Morro Rock Beach
Community Center
Morro Bay Park
Monty Young Park
Boat Launch
Bay Pines Travel Tr Pk
Morro Bay State Park
Morro Bay Golf Course
Morro Bay
San Bernardo Creek
kilometers
0 0.75 1.50 2.25
Done

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California Soil Resource L

Map Unit Composition

Map units consist of 1 or more soil types, commonly referred to as "components".

Component Name	% of Map Unit	Component Type	Horizon Data
Soil Type 1 **Marimel**	85	Major Soil Type	YES
Soil Type 2 **Camarillo loam**	3	Inclusion	None
Soil Type 3 **Cropley clay**	3	Inclusion	None
Soil Type 4 **Mocho**	3	Inclusion	Similar Data [4] *
Soil Type 5 **Unnamed**	2	Inclusion	None
Soil Type 6 **Salinas**	2	Inclusion	Similar Data [3] *
Soil Type 7 **Unnamed**	2	Inclusion	None

Note: links to horizon data marked with an * are approximate.

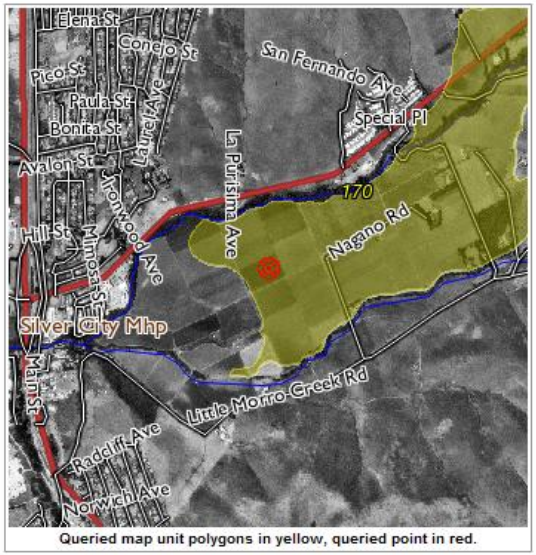
Map Unit Data *What is a Map Unit?*

Cartographic information about this map unit.

Map Unit Name:	Marimel silty clay loam, drained
Map Unit Type:	Consociation
Map Unit Symbol:	170
Map Unit Acres:	545 acres (2970ac. total in survey area)

Raw Map Unit Data

Raw Component Data (All Components)



Queried map unit polygons in yellow, queried point in red.

Map Unit Aggregated Data

Generalized soils information within this map unit.

Farmland Class:	Prime farmland if irrigated and drained
Available Water Storage (0-100cm):	17.41 cm
Max Flood Freq:	None
Drainage Class (Dominant Condition):	Well drained
Drainage Class (Wettest Component):	Well drained
Hydric Conditions:	Partially hydric
Min Water Table Depth:	n/a
Min Bedrock Depth:	n/a

Raw Aggregated Map Unit Data

Map Unit Notes

Miscellaneous notes recorded by NRCS staff about this map unit.

Adjacent Soil Polygons

Links to the soil polygons touching the currently selected polygon.

1 Psamments and Fluvents, occasionally flooded

Done

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Water Quality Program - Nitrate Groundwater Pollution Hazard Index

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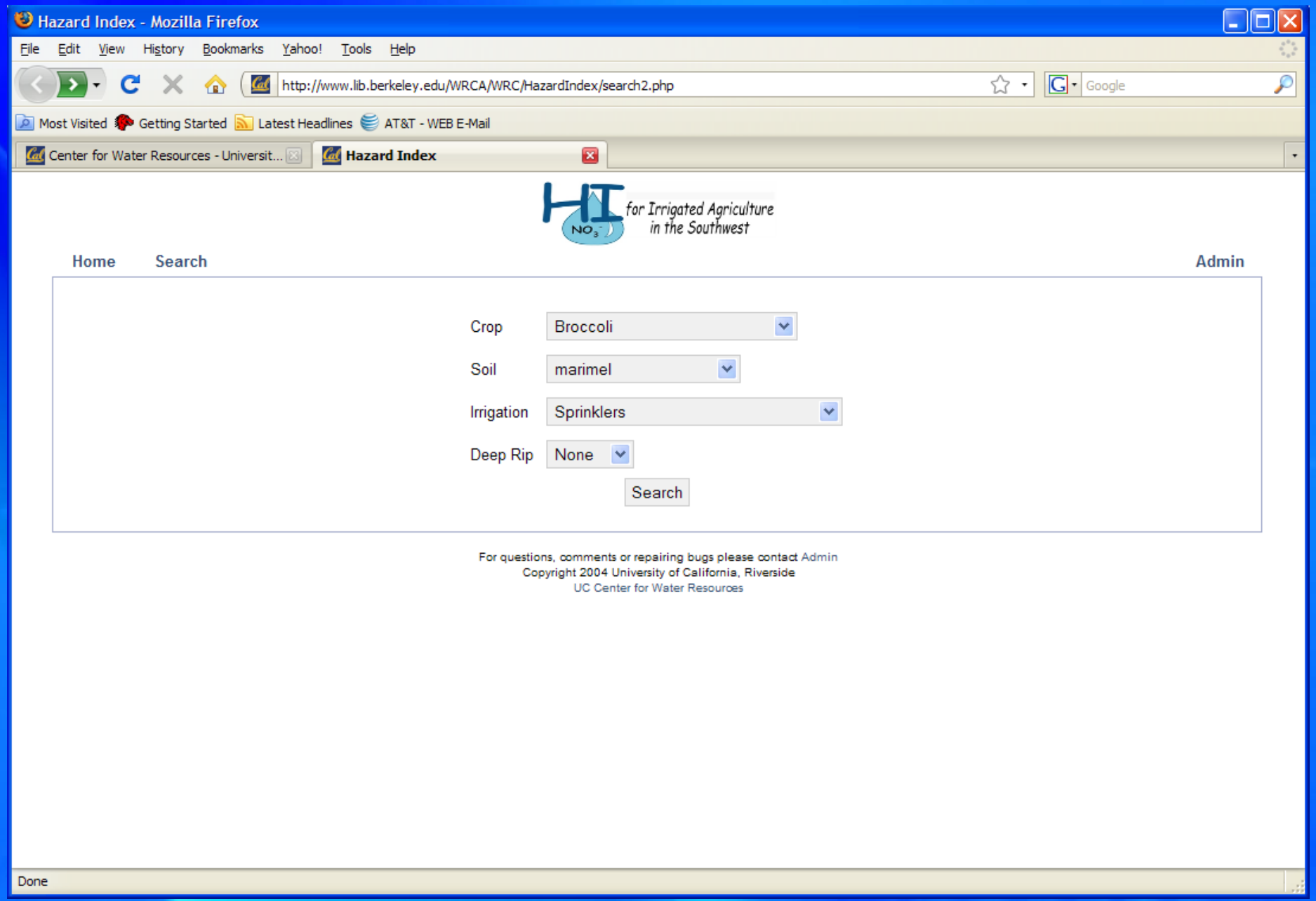
Nutrients & Pesticide Mgmt.
Drinking Water & Human Health
Water Cons. & Ag Water Mgmt.
Water Policy & Econ.
Animal Manure & Waste Mgmt.
Nitrate Hazard Index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Crop Broccoli
Soil marimel
Irrigation Sprinklers
Deep Rip None
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HI for Irrigated Agriculture in the Southwest

Your Hazard Index (HI) is 24.
Please see table below to assess your relative risk of contaminating groundwater.

An HI of 1 to 20 is of relatively minor concern. The grower should use sound management practices but extraordinary procedures are not required. However, an HI greater than 20 should receive careful attention.

As can be seen in the table on the right, agricultural fields with soils rated 4 or 5 often have HI's of greater than 20 and should be managed to reduce the risk of groundwater contamination. Soils rated 1 or 2 generally have HI's that range between 1 and 20 and can be cultivated with more latitude in the choice of crop and irrigation system.

To view other crops with your rating (4) click here.

Crop	Soil 1	2	3	4	5	Irrigation
1	1	2	3	4	5	1
1	2	4	6	8	10	2
1	3	6	9	12	15	3
1	4	8	12	16	20	4
2	2	4	6	8	10	1
2	4	8	12	16	20	2
2	6	12	18	24	30	3
2	8	16	24	32	40	4
3	3	6	9	12	15	1
3	6	12	18	24	30	2
3	9	18	27	36	45	3
3	12	24	36	48	60	4
4	4	8	12	16	20	1
4	8	16	24	32	40	2
4	12	24	36	48	60	3
4	16	32	48	64	80	4

The hazard rating for the production of Broccoli is high ('4') because
- nitrate is likely to quickly move beneath the shallow roots of this crop
- a low proportion of the N concentrated within plant tissues is removed during harvest, leaving most atop the soil in the crop residue. Here it can be mineralized and become available for subsequent crops or leaching

Click here for suggested practices to mitigate problematic crop characteristics.

Hazard rating for your soil type (Marimel): 2.

Click here for soil characteristics associated with this rating

Hazard rating for Sprinklers: 3.

Click here to see a description of this irrigation method.

For questions, comments or repairing bugs please contact Admin

Hazard Index - Mozilla Firefox

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http://www.lib.berkeley.edu/WRCA/WR

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Use the 'back' button on your browser to get back to the hazard rating page.

HI for Irrigated Agriculture in the Southwest

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Broccoli

High value crops, such as broccoli, tend to be over-fertilized by growers. Often the same yields can be realized with less added N than common knowledge dictates. To help you keep abreast of current recommended practices for the addition of N, some information resources are listed at the end of this page.

The amount of water applied during irrigation of crops with shallow roots must be carefully monitored. Otherwise soluble nitrate may be leached beneath the crops rooting zone prior to the time required for the crop to utilize the applied N for plant growth.

Significant amounts of N are taken up during the growth of broccoli. This leaves little behind in the soil to be leached. However, while N is removed from the soil during the growth of broccoli, it is redeposited on the soil surface after harvest in the form of plant residue. The nitrogen in this plant residue can be easily mineralized if left atop the soil and then leached. This suggests the use of cover crops to immobilize N during the rainy season. Successfully immobilizing N has the benefit of 'free' nitrogen added to your soil, which should reduce your fertilizer costs. At the beginning of each growing season, your soil can be tested to see how much nitrogen is available in it for use by your crop. Extension specialists in your state can direct you in how to have these tests done.

Done

HI for Irrigated Agriculture in the Southwest

Home Search Admin

Your soil type has a hazard rating of "2". These soils slow the leaching of nitrate to underlying groundwater, generally due to the presence of clay and silt, or a shallow restrictive layer (hardpan, duripan, or bedrock). Denitrification, in which bacteria convert nitrates to gaseous nitrogen, probably decreases the risk that excess N will move to the underlying aquifer.

Effect of irrigation method. Soils rated '2' generally have slow permeability due to their fine textures. Additions of irrigation water and fertilizer nitrogen tend to remain near the land surface and move to depth slowly. This allows some latitude in your choice of irrigation methods. Generally, any carefully managed and well-maintained irrigation system can be used on these soils with relatively low risk of polluting ground water as long as it is used in conjunction with a fertilizer-nitrogen application plan tailored to your crop. Denitrification can occur in these soils, which further reduces the risk of nitrates being transported to groundwater.

For an official description of your soil type, Marimel, **click here**.

HI for Irrigated Agriculture in the Southwest

Irrigating with sprinklers carries a hazard rating of "3". Sprinkler systems can be managed to produce uniform irrigation when carefully selected, installed, calibrated, and maintained. However, to do so requires considerable vigilance. Additionally, changes in environmental variables, such as wind speed and crop canopy characteristics, can greatly alter the pattern of water drop distribution, often requiring alterations to the timing and duration of irrigation. Crop canopy capture varies over the course of crop growth with larger plants capturing more water. Smaller and more frequent irrigations help deliver a spatially focused pulse of water – and fertilizer -- to the root zone. One benefit of sprinkler is that the amount of water applied can be controlled manually or electronically.

Effect of soil type: Sprinklers are appropriate for all soil types as long as the water application intensity is designed to be equal or less than the infiltration rate of the soil being irrigated.