SBX2 1 (2008, Perata)

UC Davis Report to State Water Board
for its Report to the Legislature

ADDRESSING NITRATE IN CALIFORNIA'S DRINKING WATER,

TULARE LAKE BASIN AND SALINAS VALLEY

Public Release

March 13, 2012

Thomas Harter & Jay Lund, *Principal Investigators*

Jeannie Darby, Graham Fogg, Richard Howitt, Katrina Jessoe, Jim Quinn, Stu Pettygrove, Joshua Viers, *Co-Investigators*

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Watershed Science Center
University of California, Davis
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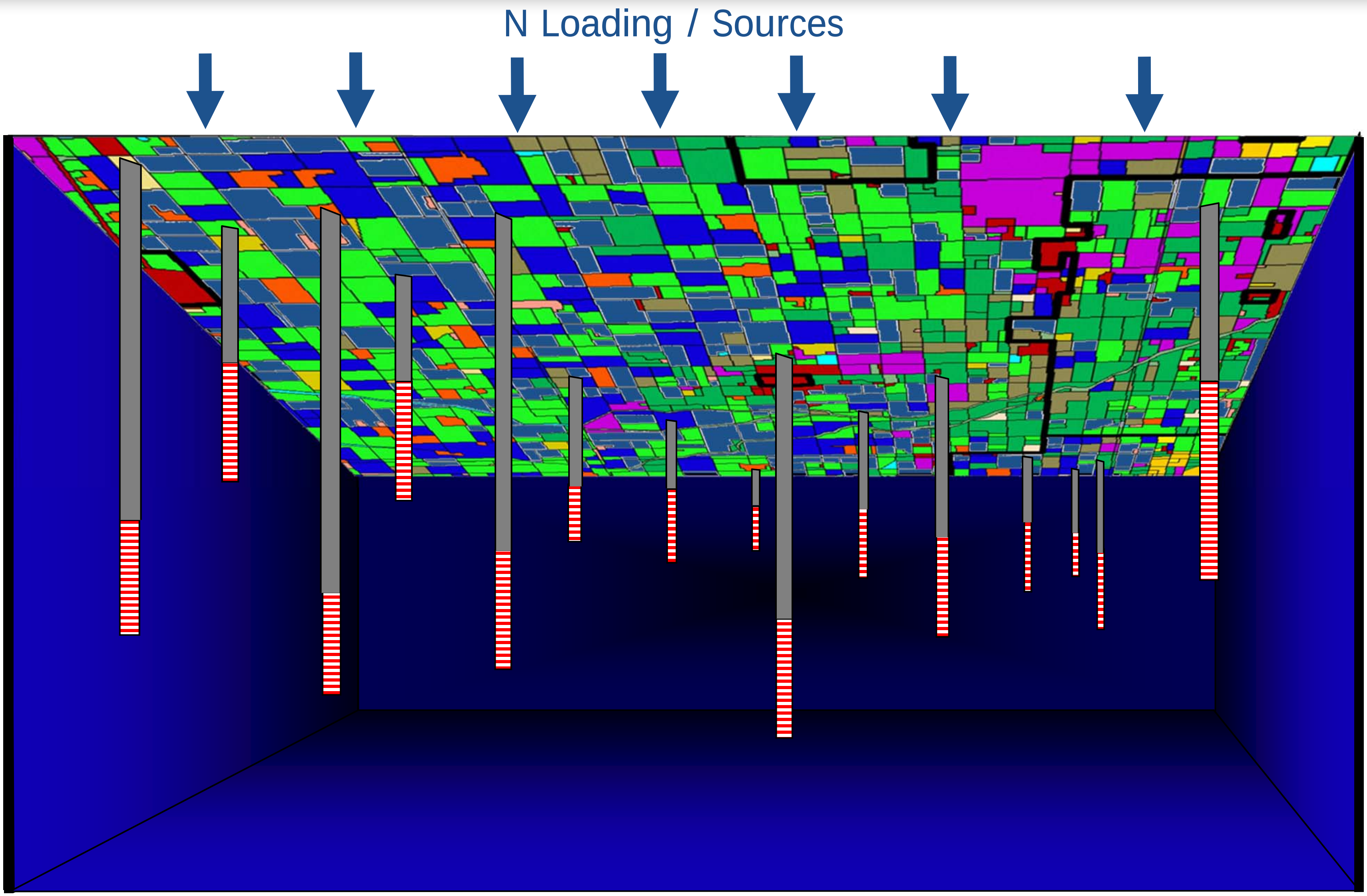
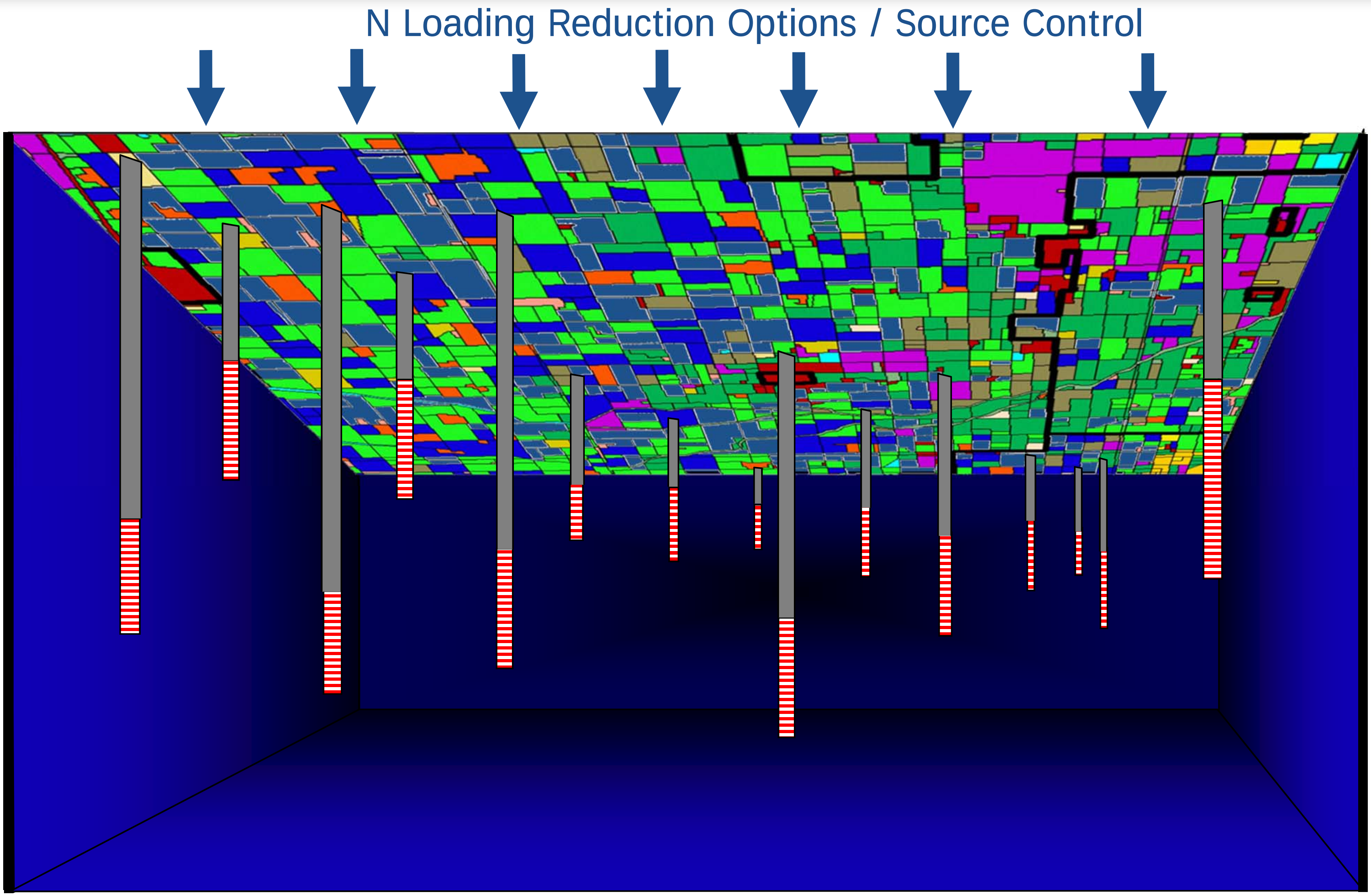
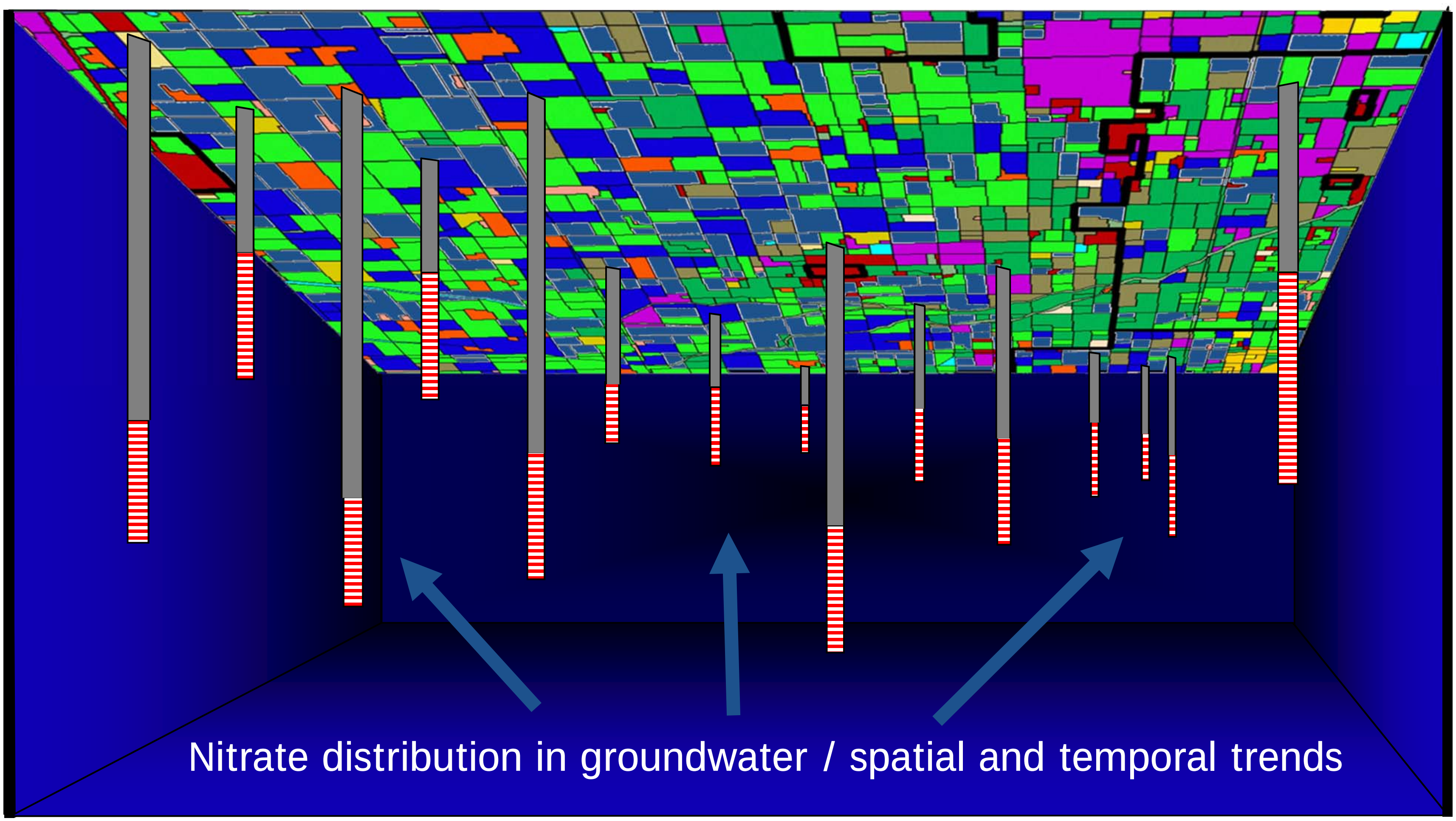
#1: Sources of Nitrate



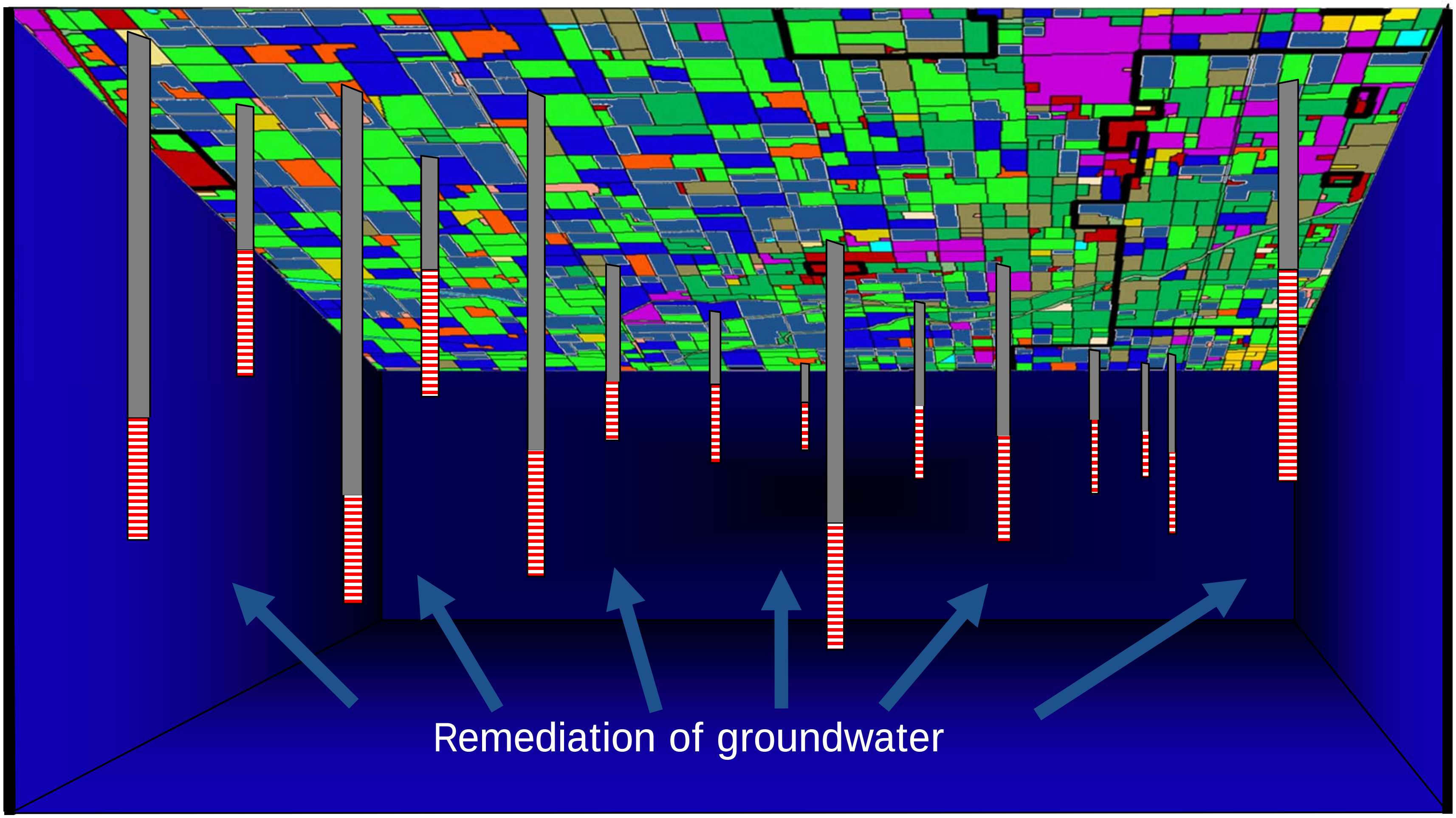
#2: Nitrate Source Reduction



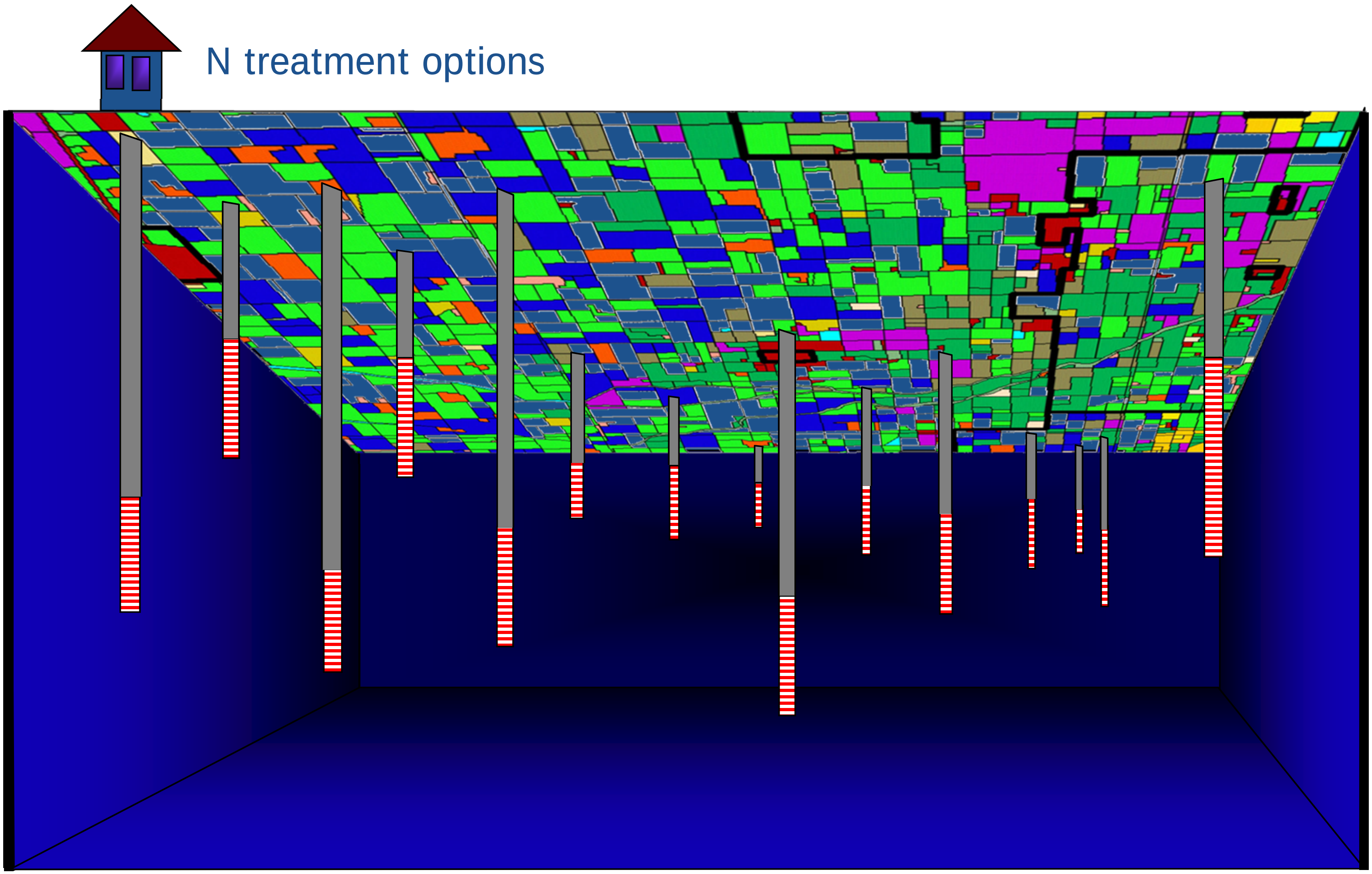
#3: Groundwater Nitrate



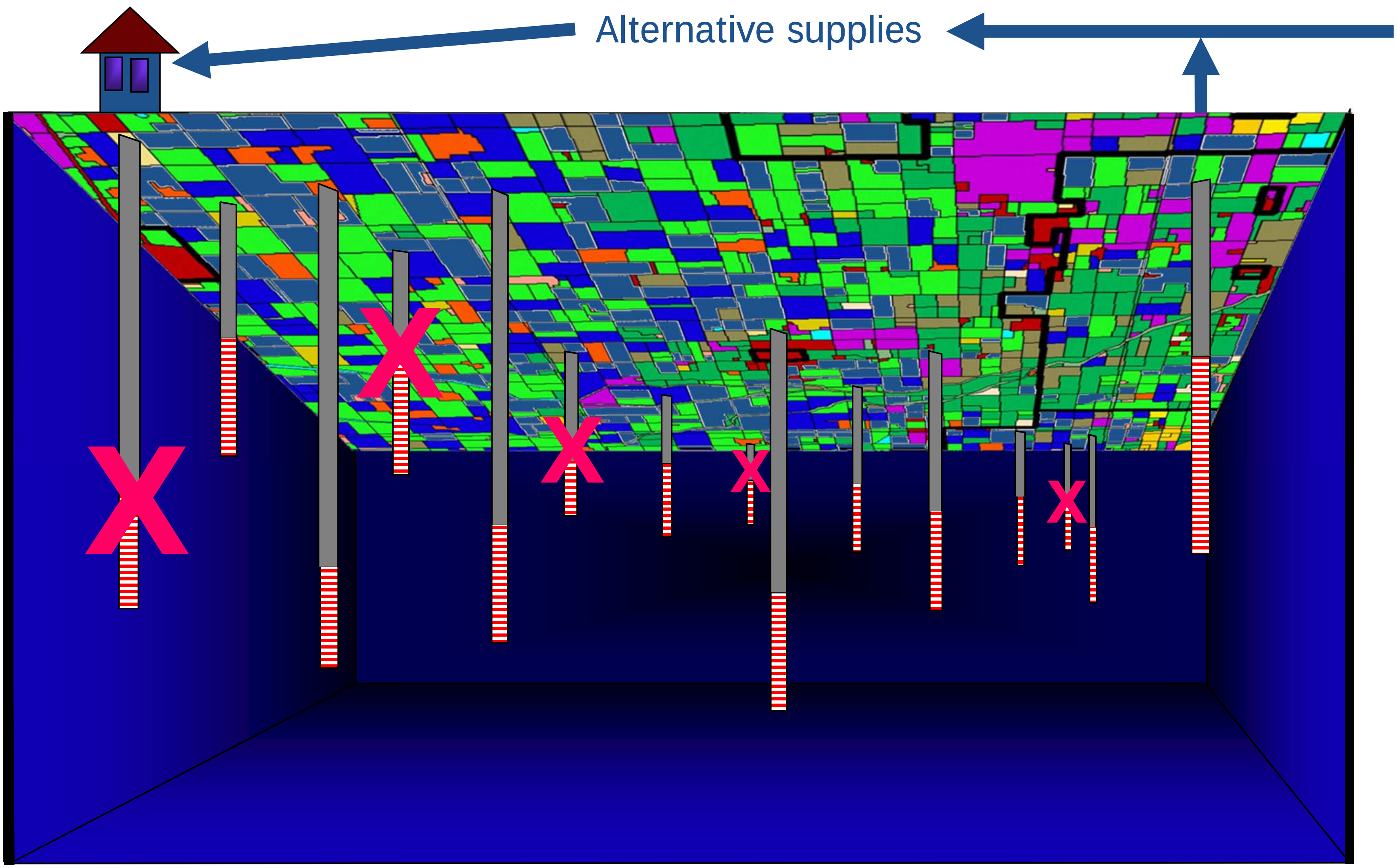
#4: Groundwater Remediation



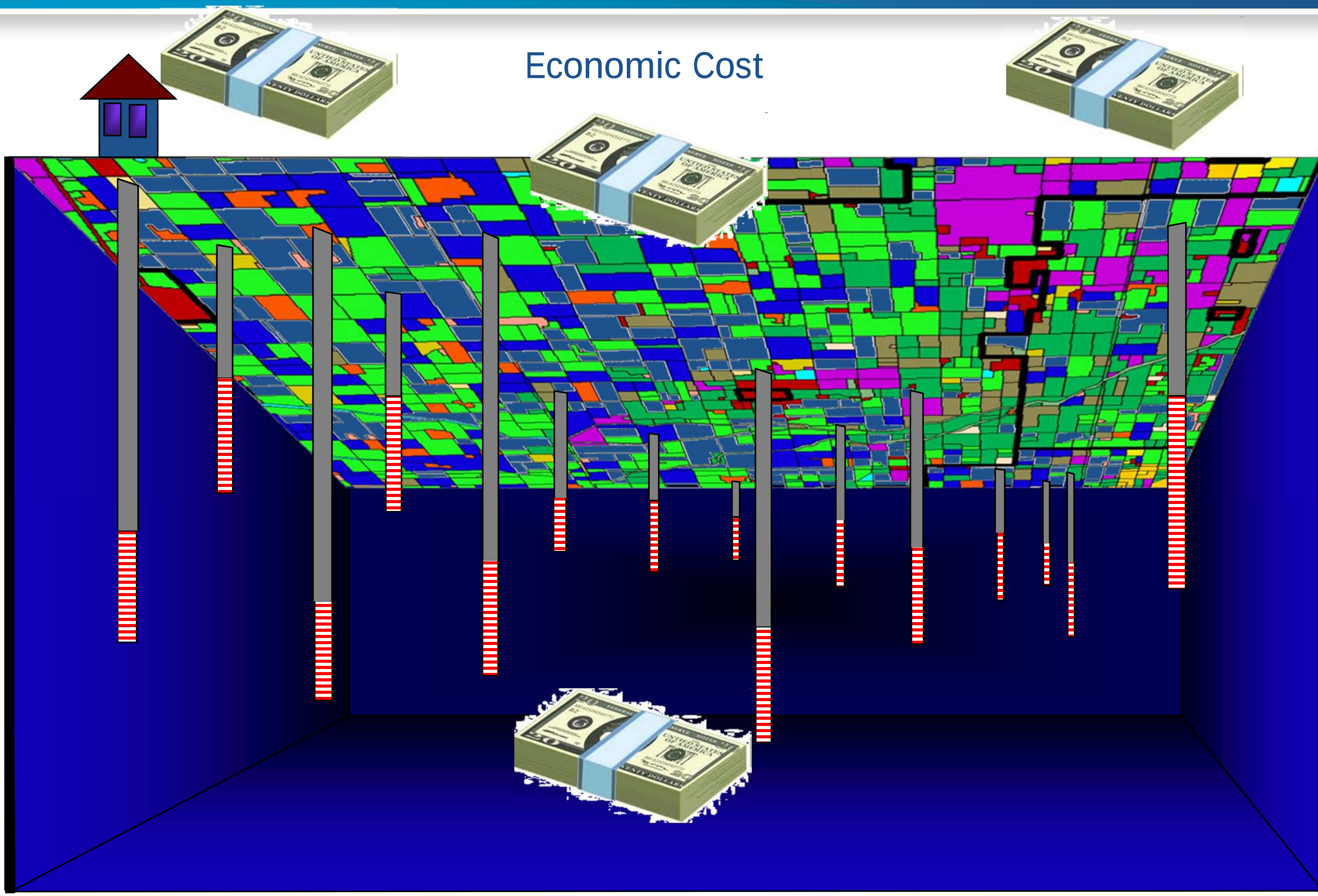
#5: Drinking Water Treatment



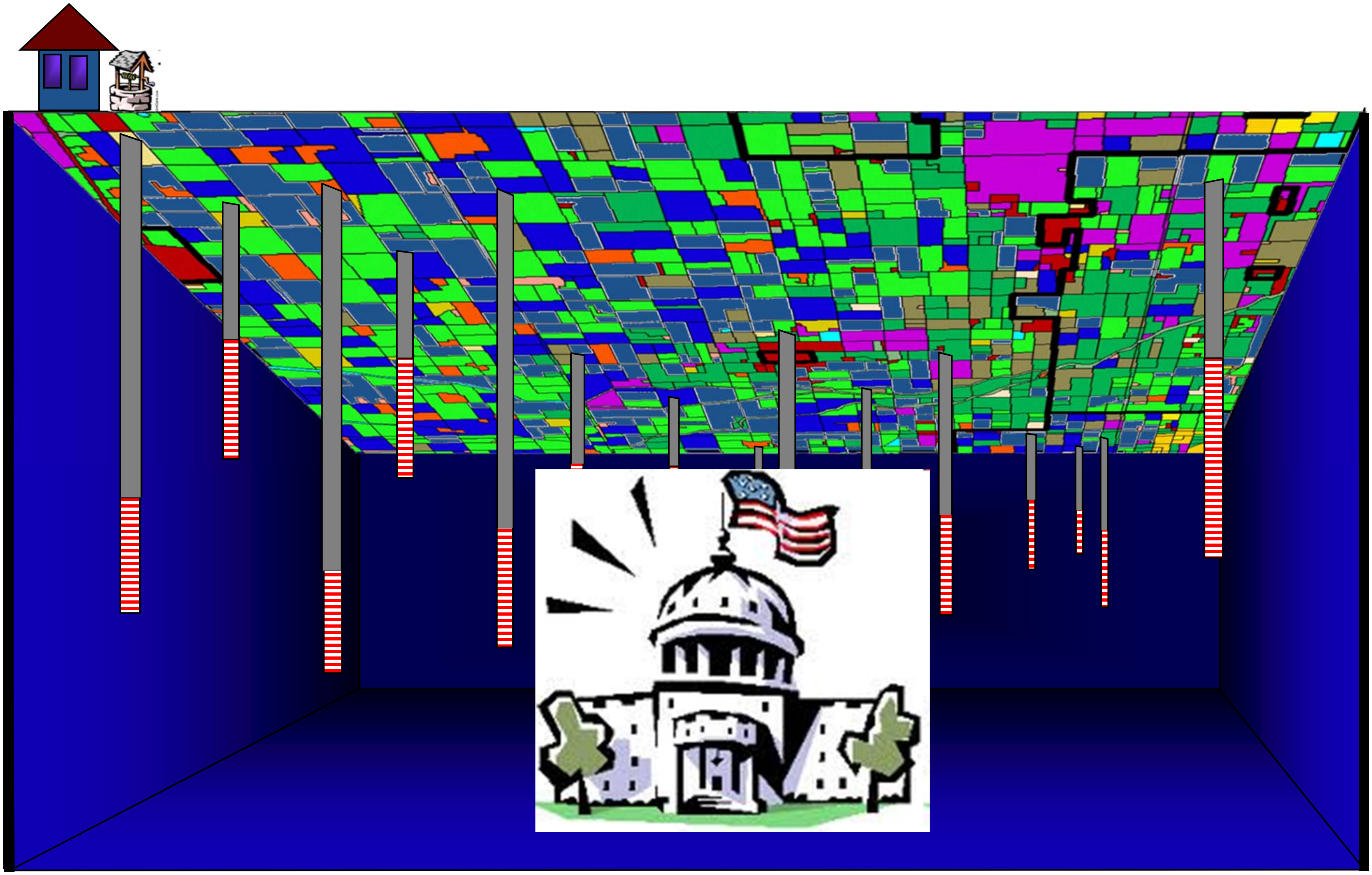
#6: Alternative Supplies



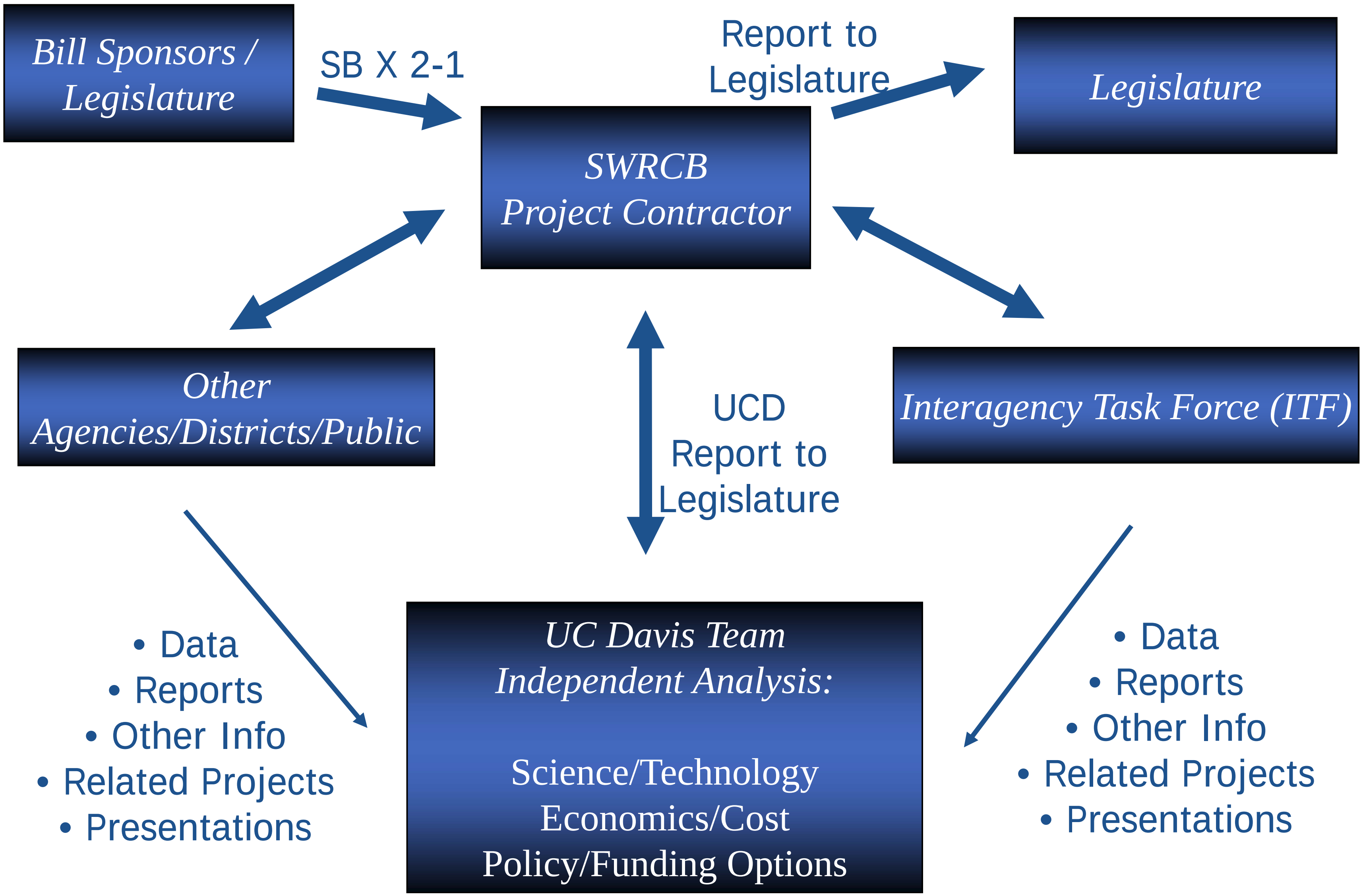
#7: Costs of Actions



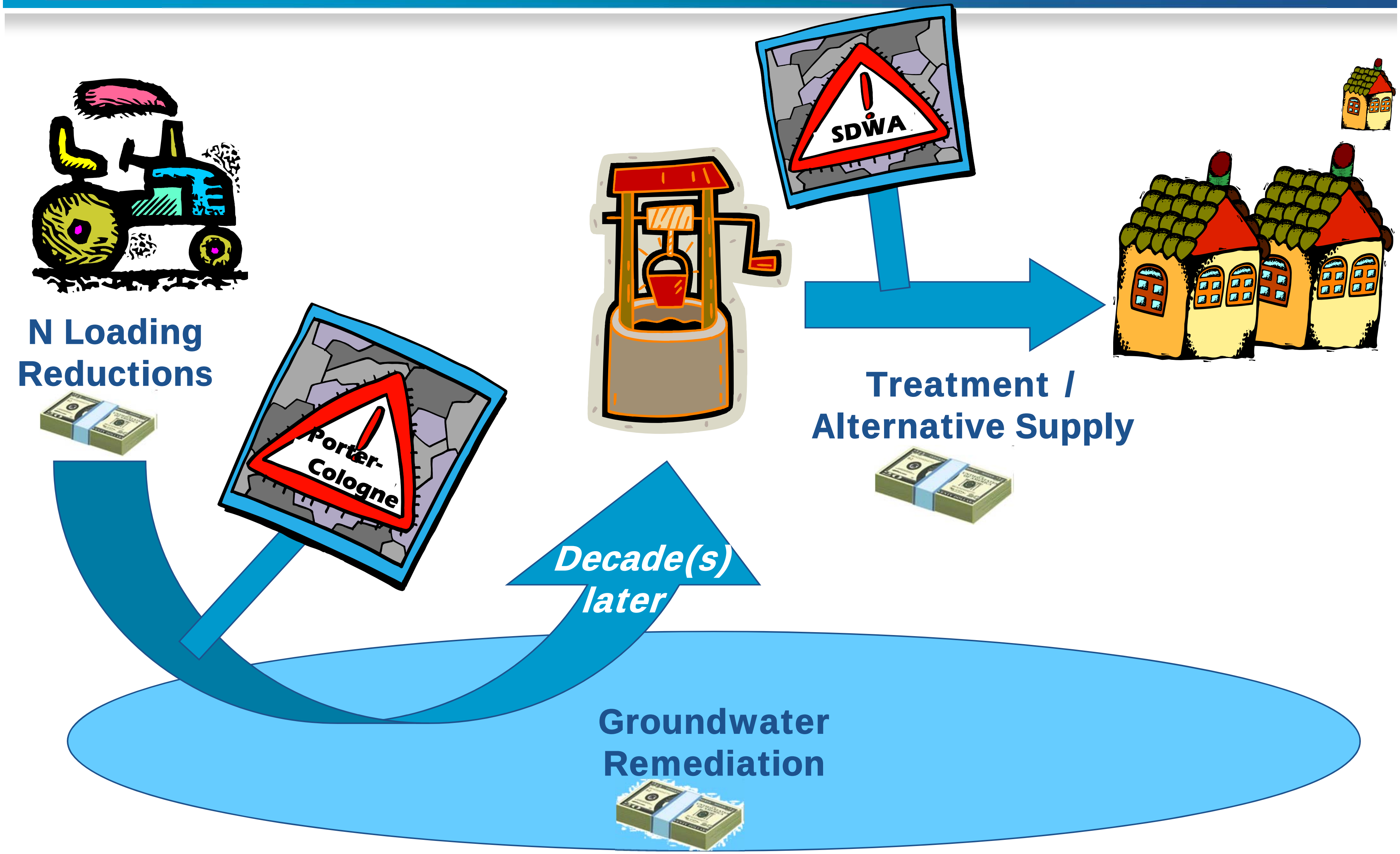
#8: Funding and Policy



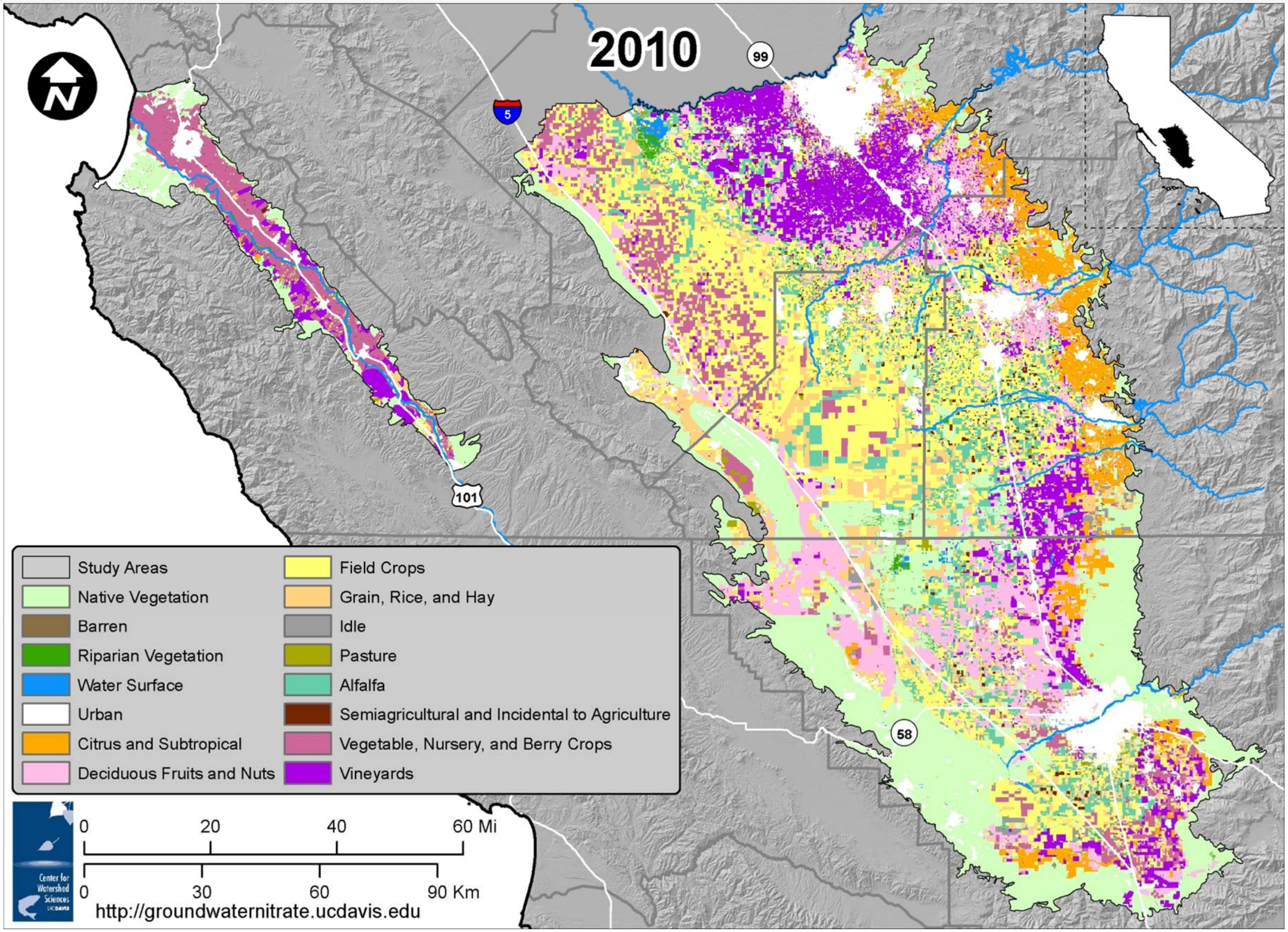
UC Davis Role



Funding and Regulatory Framework

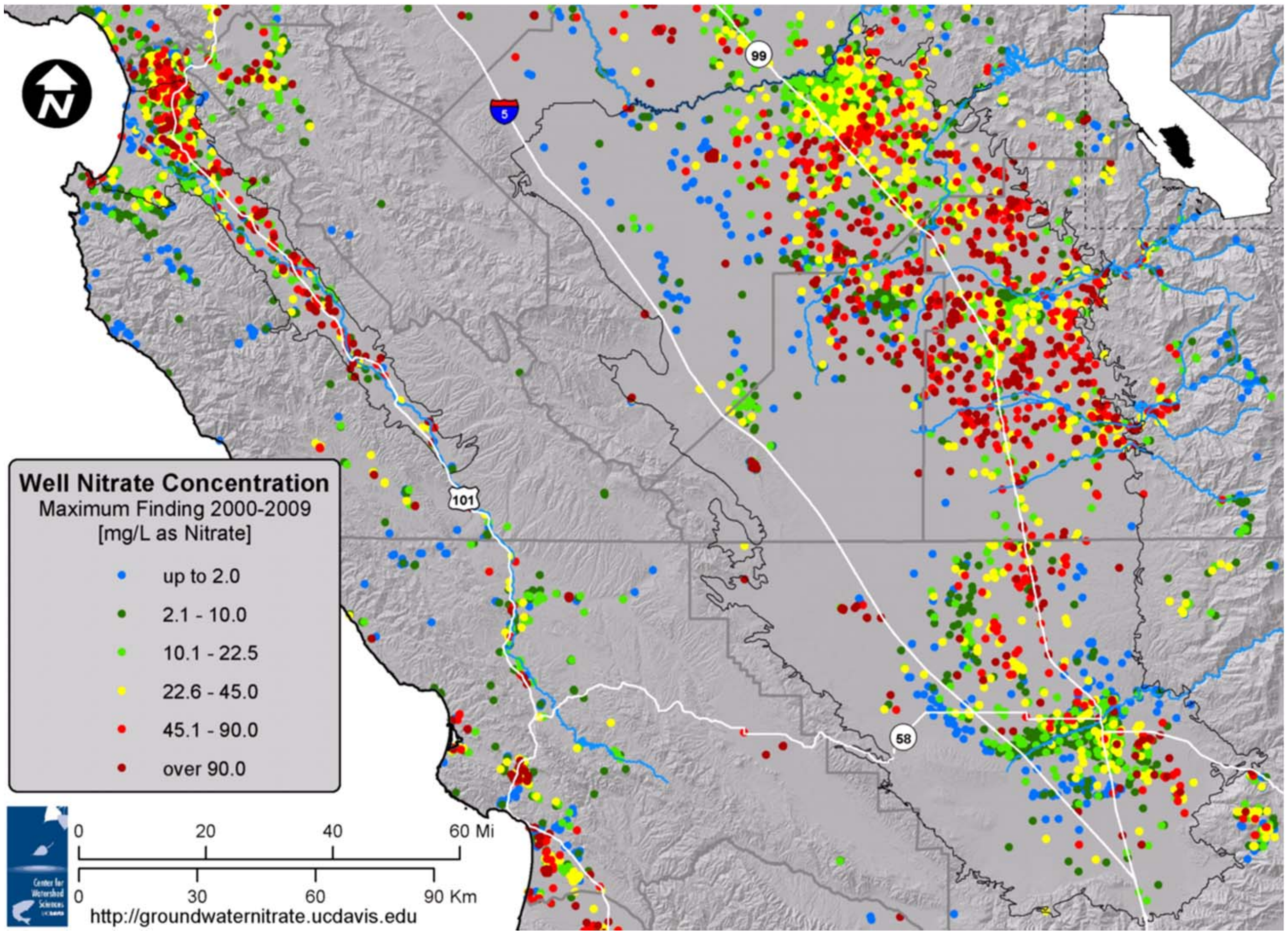


Nitrate Contamination Study Area



KEY FINDINGS

Nitrate Contamination Will Persist



- **Nitrate contamination will worsen for years/decades**
- **Direct remediation of groundwater is extremely costly**

RED: ABOVE THE NITRATE MCL (45 mg/L)
DARK RED: ABOVE TWICE THE NITRATE MCL (90 mg/L)

Cost of Safe Drinking Water: $20 - $36 Million / Year (Study Area)

- **Most cost-effective drinking water supply actions:**
  - **Blending**
  - **Treatment (community, point-of-use)**
  - **Consolidation/regionalization**
  - **Other alternative supplies**

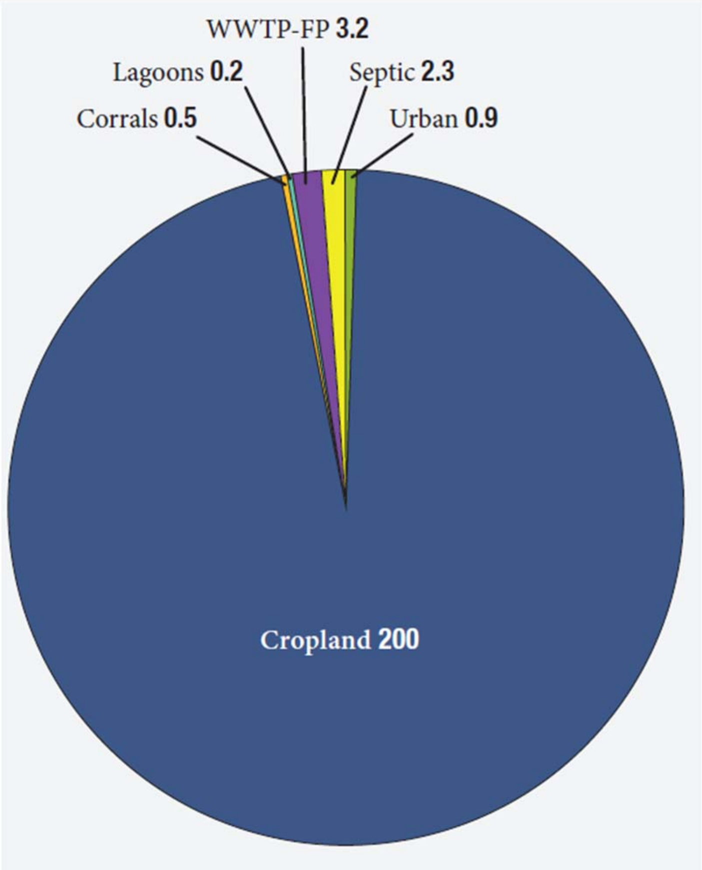
- **Affordability difficult for small communities**

- **Most promising revenue source:**
  - **Fee on nitrogen fertilizer use**
  - **Fee on water use**
  - **Local compensation under Section 13304 of CA Water Code**

http://www.frugalbits.com/food-drink/say-no-to-bottled-water-and-yes-to-charity-wate/

http://www.middlebrookhealth.org/Summer%20Safety.html

Largest Nitrate Source: Cropland

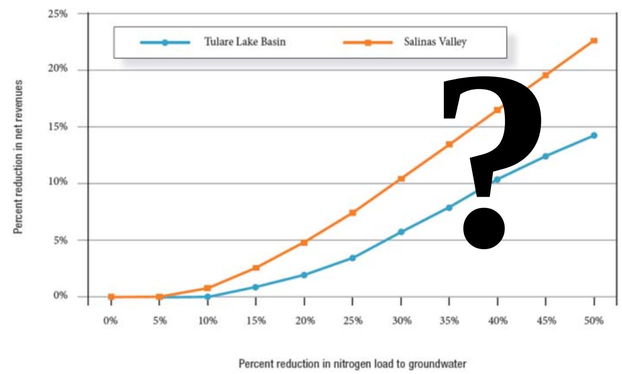


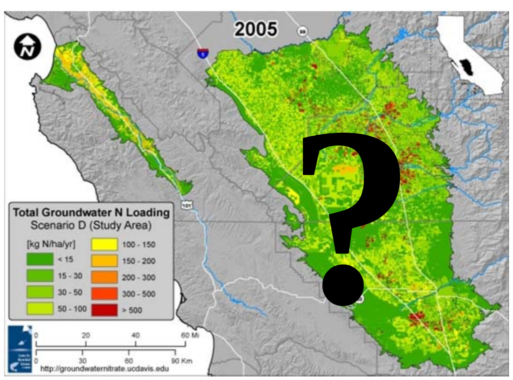
- Nitrate loading reductions are possible

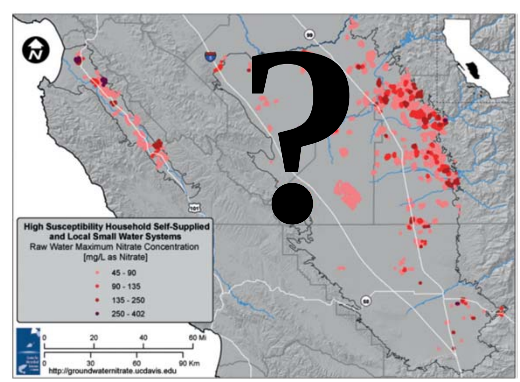
- Largest cropland nitrogen sources:
  - Synthetic fertilizer
  - Animal manure

Data for Assessing Public Exposure and Nitrate Sources

- More consistent, accessible data needed for efficient implementation
- Agencies not organized to gather data or make effective use of data





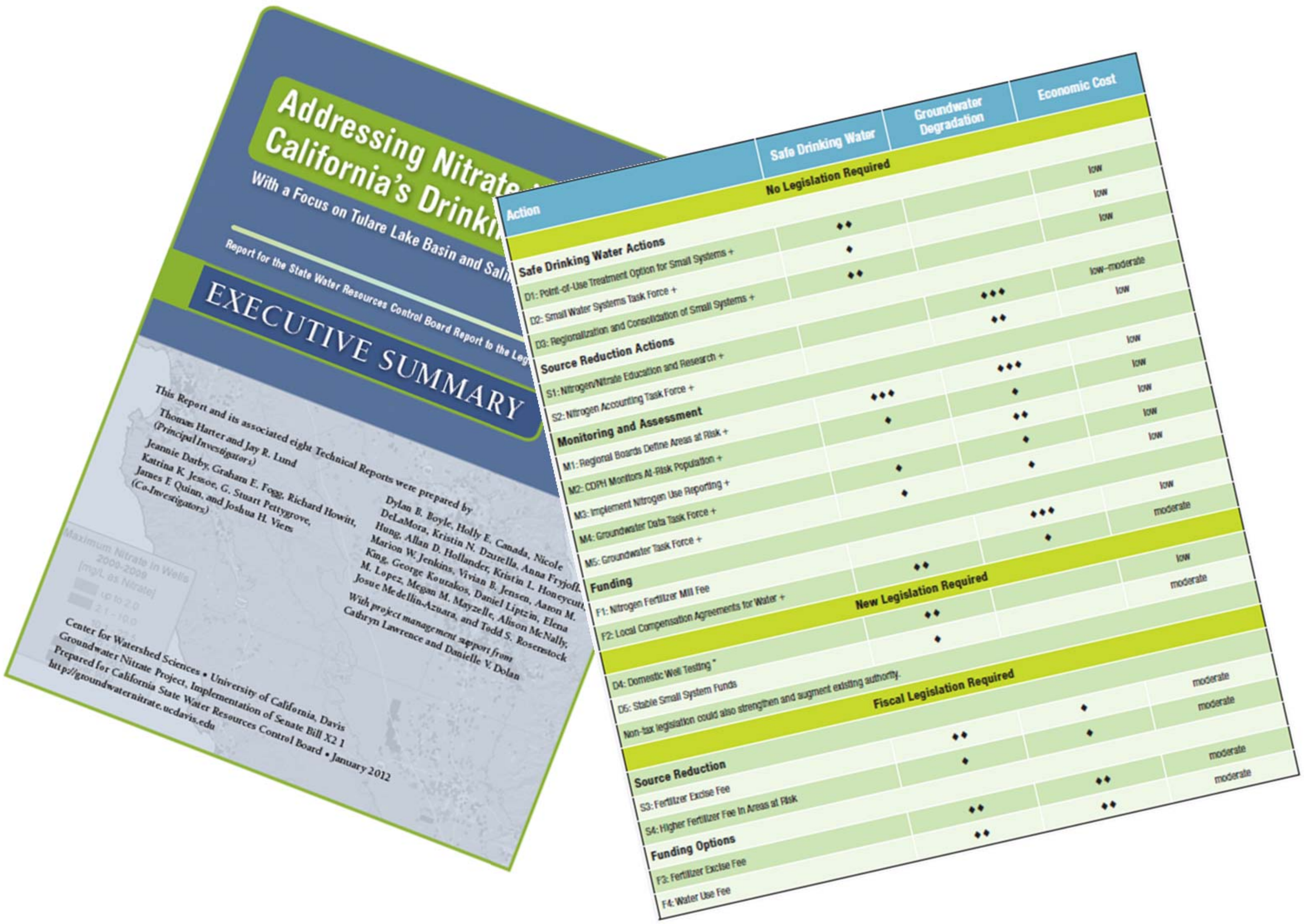


Key Take Home Messages

- Safe drinking water is the most pressing issue
    - Challenges: organization and funding
- Nitrate loading can be reduced, long-term
    - Challenges: training, research, investment, compliance, and funding
- State needs to collect and organize data to allow for better assessment
    - Challenges: institutional silos, organization, privacy issues/data security, and funding

Promising Actions

- See back page of the "Executive Summary"



Action	Safe Drinking Water	Groundwater Degradation	Economic Cost
No Legislation Required			
Safe Drinking Water Actions			
D1: Point-of-Use Treatment Option for Small Systems +	◆◆		low
D2: Small Water Systems Task Force +	◆		low
D3: Regionalization and Consolidation of Small Systems +	◆◆		low
Source Reduction Actions			
S1: Nitrogen/Nitrate Education and Research +		◆◆◆	low–moderate
S2: Nitrogen Accounting Task Force +		◆◆	low
Monitoring and Assessment			
M1: Regional Boards Define Areas at Risk +	◆◆◆	◆◆◆	low
M2: CDPH Monitors At-Risk Population +	◆	◆	low
M3: Implement Nitrogen Use Reporting +		◆◆	low
M4: Groundwater Data Task Force +	◆	◆	low
M5: Groundwater Task Force +	◆	◆	low
Funding			
F1: Nitrogen Fertilizer Mill Fee		◆◆◆	low
F2: Local Compensation Agreements for Water +	◆◆	◆	moderate
New Legislation Required			
D4: Domestic Well Testing *	◆◆		low
D5: Stable Small System Funds	◆		moderate
Non-tax legislation could also strengthen and augment existing authority.			
Fiscal Legislation Required			
Source Reduction			
S3: Fertilizer Excise Fee	◆◆	◆	moderate
S4: Higher Fertilizer Fee in Areas at Risk	◆	◆	moderate
Funding Options			
F3: Fertilizer Excise Fee	◆◆	◆◆	moderate
F4: Water Use Fee	◆◆	◆◆	moderate

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Researchers

Center for Watershed Sciences
University of California, Davis
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SBX2 1

Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 2: LANDUSE & POTENTIAL GROUNDWATER LOADING

Public Release of the UC Davis Study

March 13, 2012

Thomas Harter, Anna Fryjoff-Hung, Allan Hollander,
Vivian Jensen, Aaron King, Dan Liptzin, Elena M. Lopez,
Alison McNally, Josue Medellin-Azuara, Stu Pettygrove,
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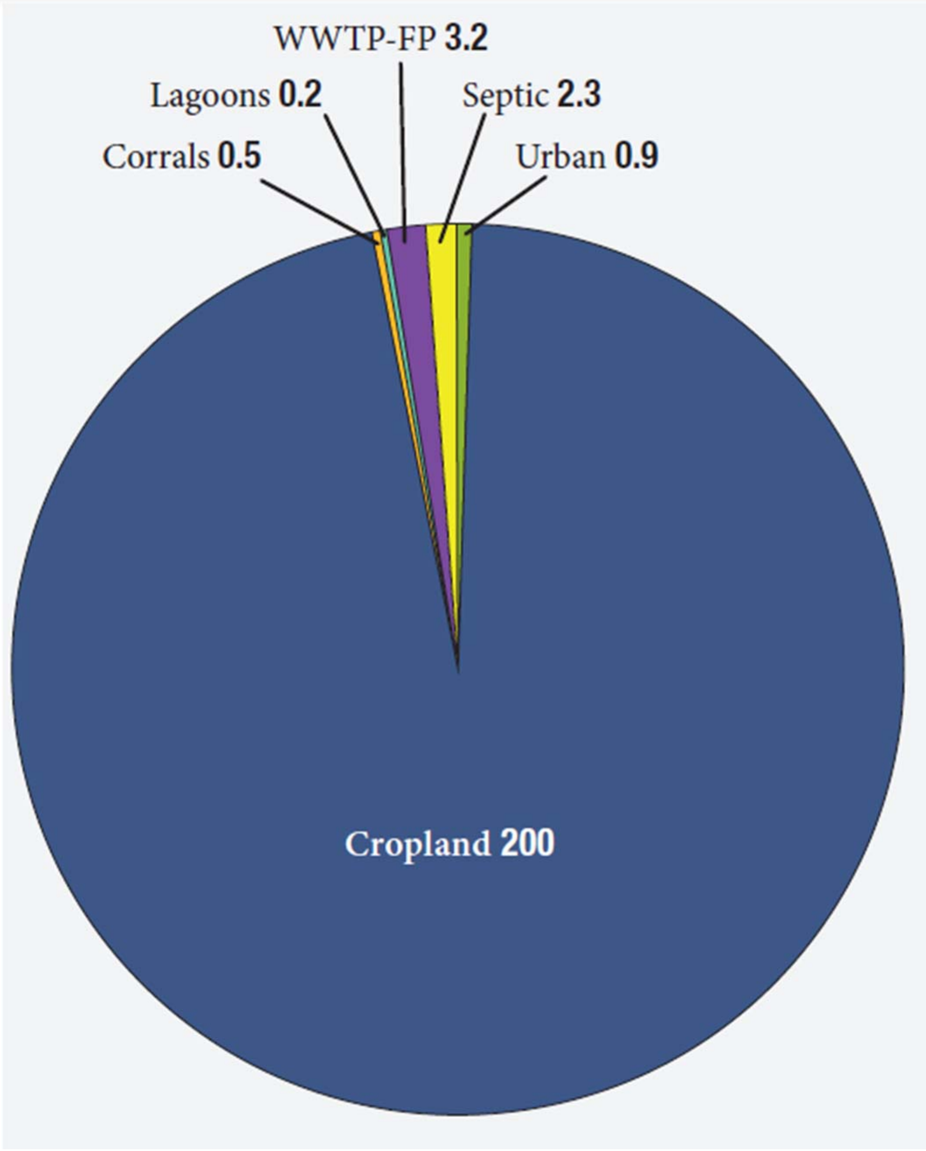
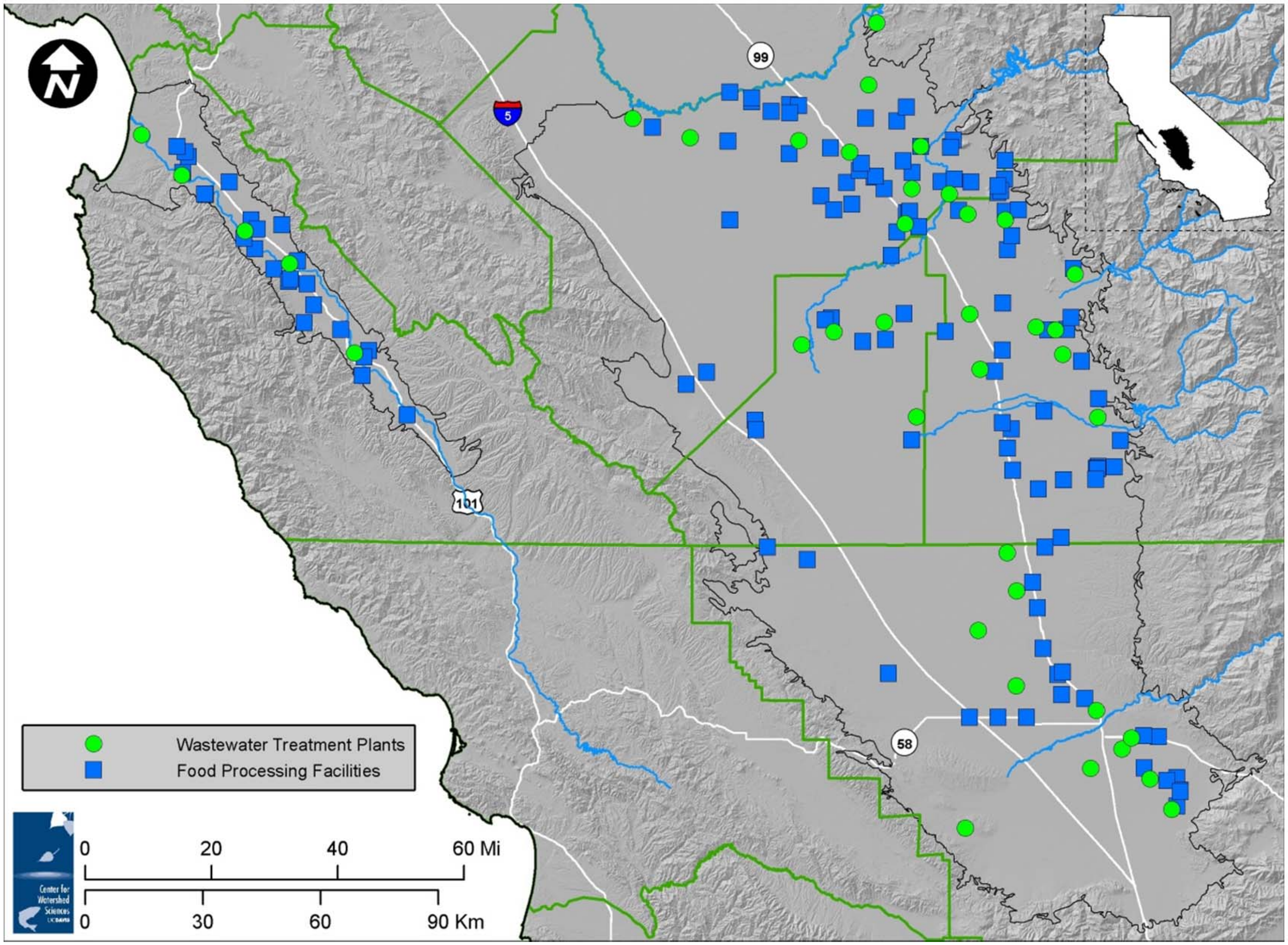
Sources of Groundwater Nitrate

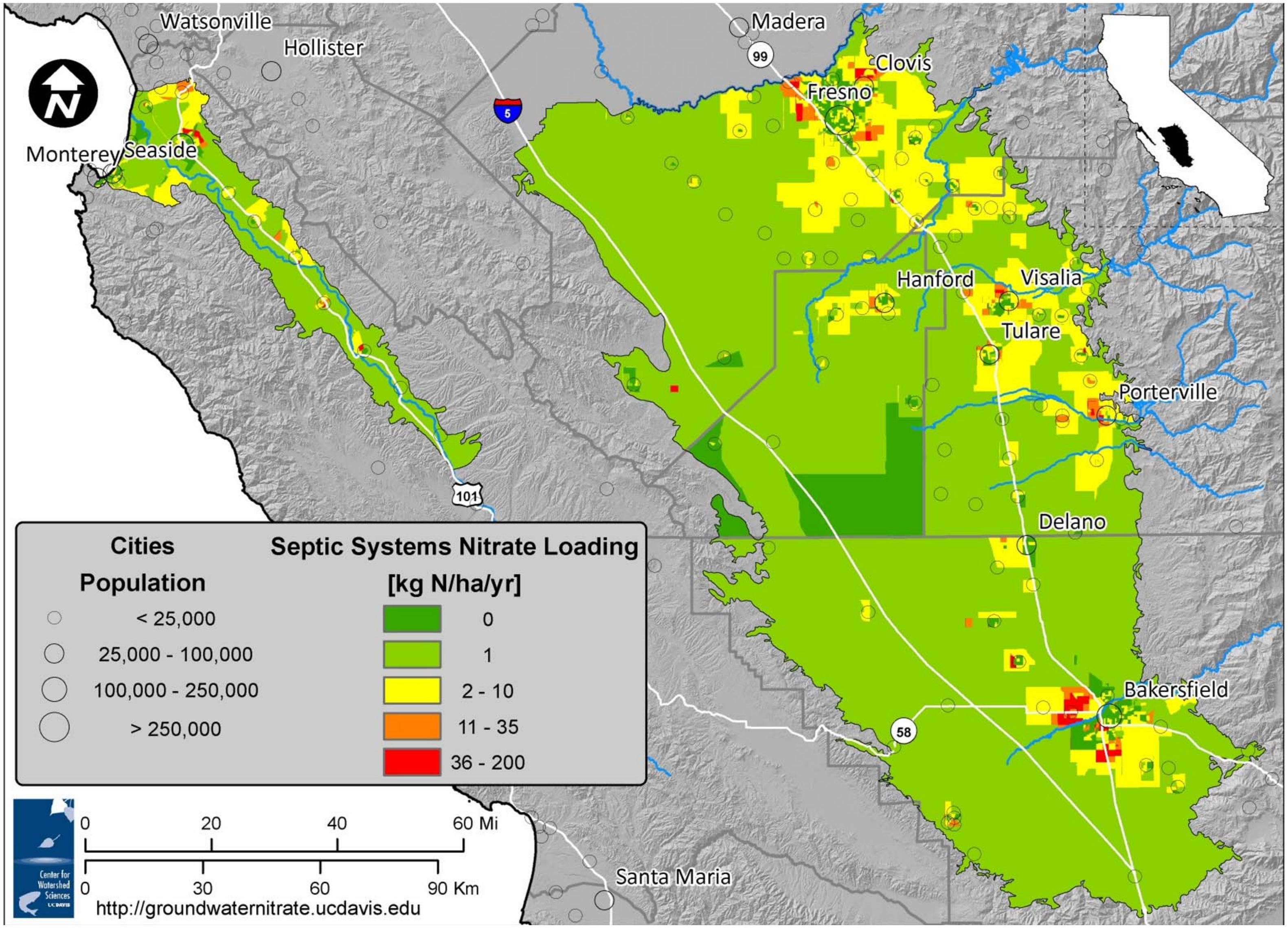


Gg N/yr

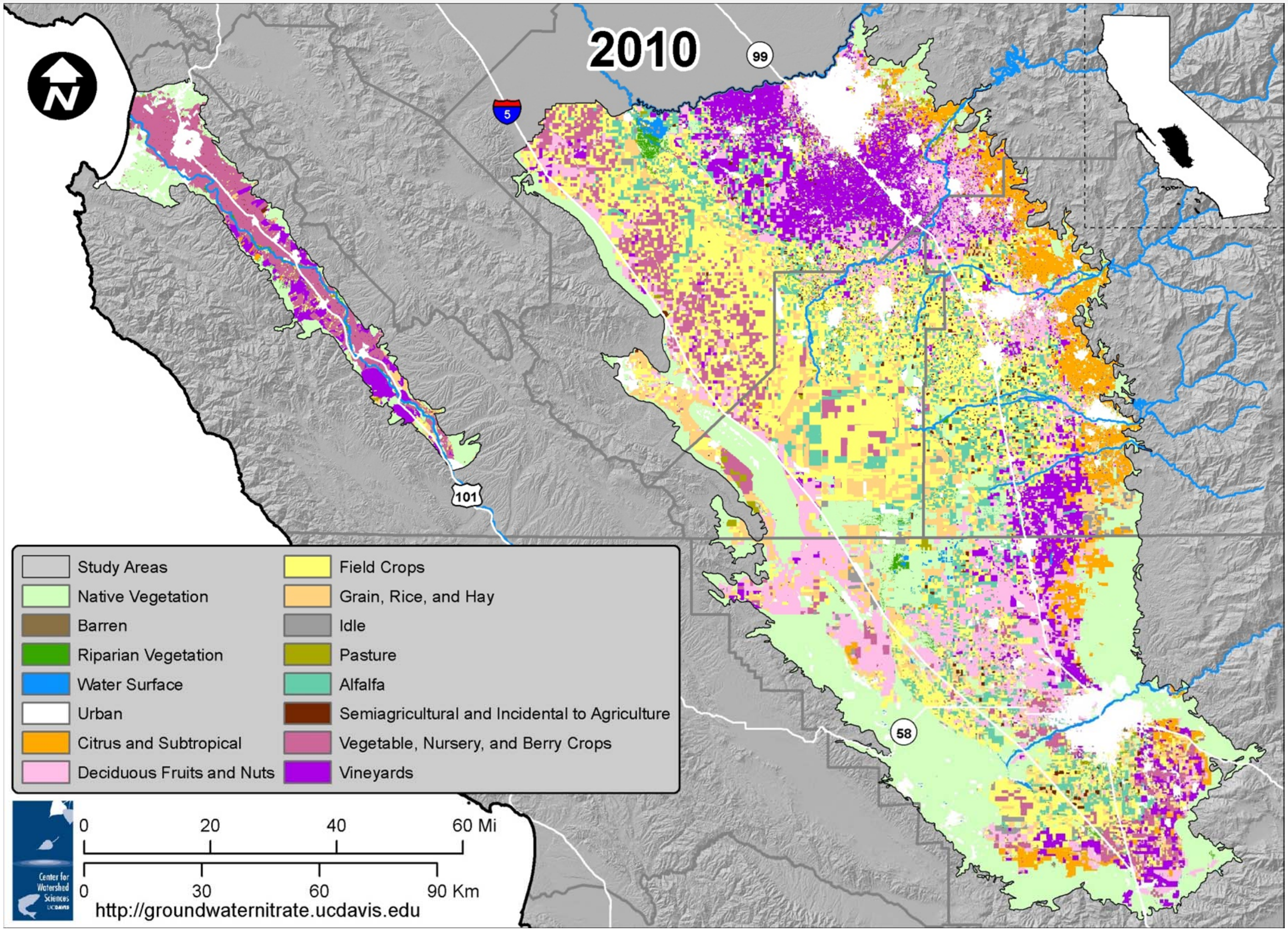
Wastewater Treatment Plants and Food Processors

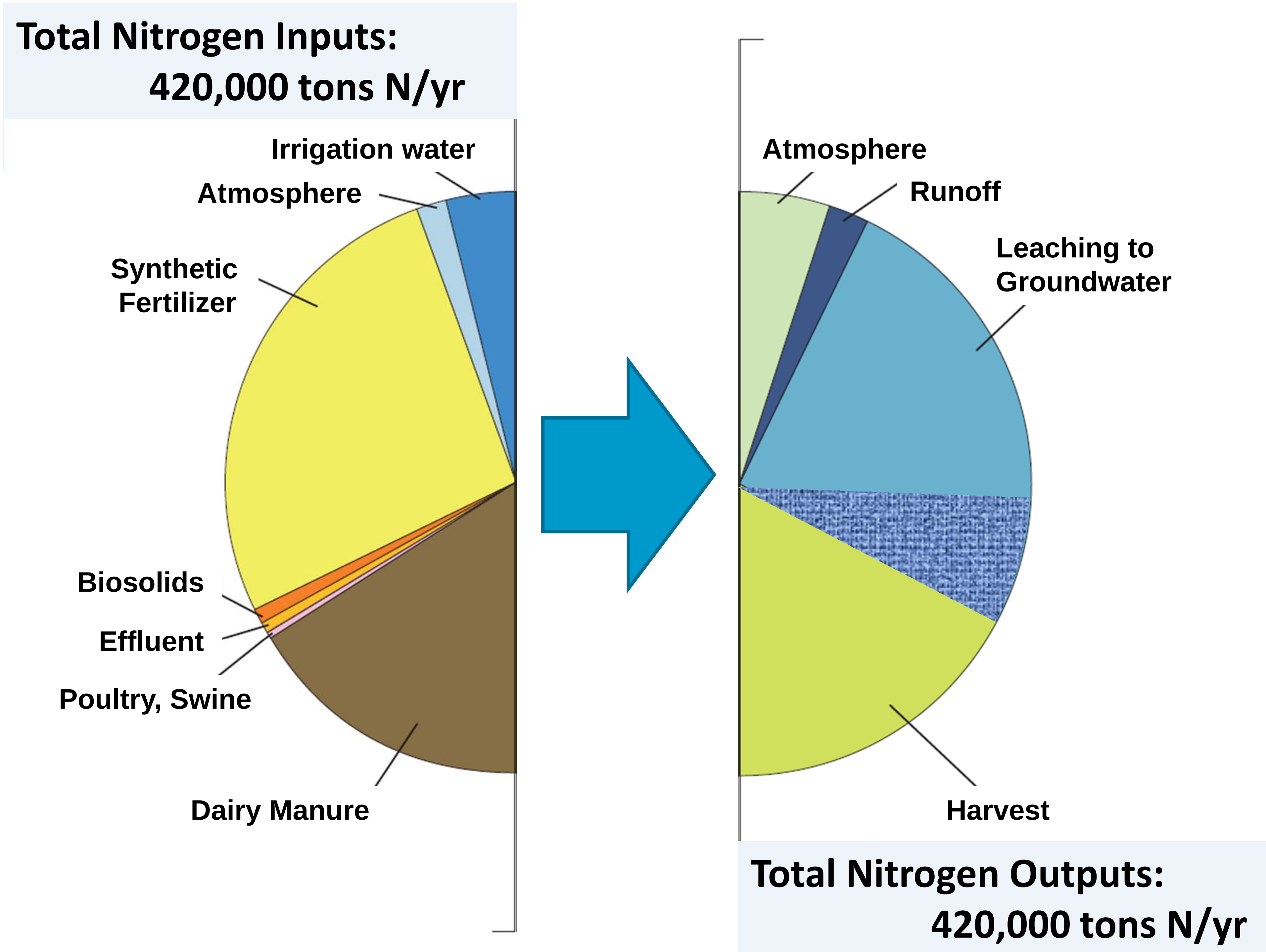


Septic Systems

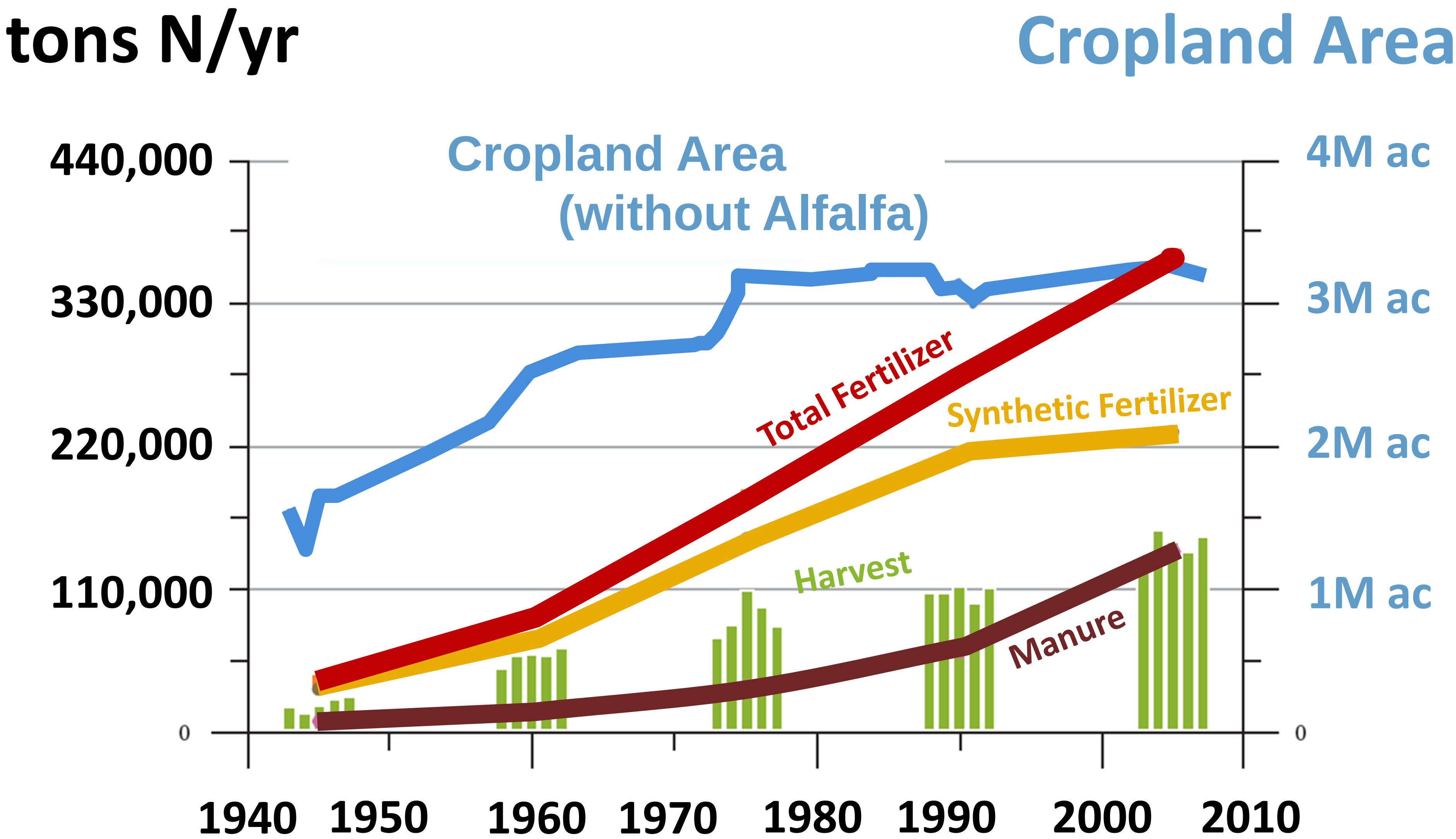


Agricultural Sources

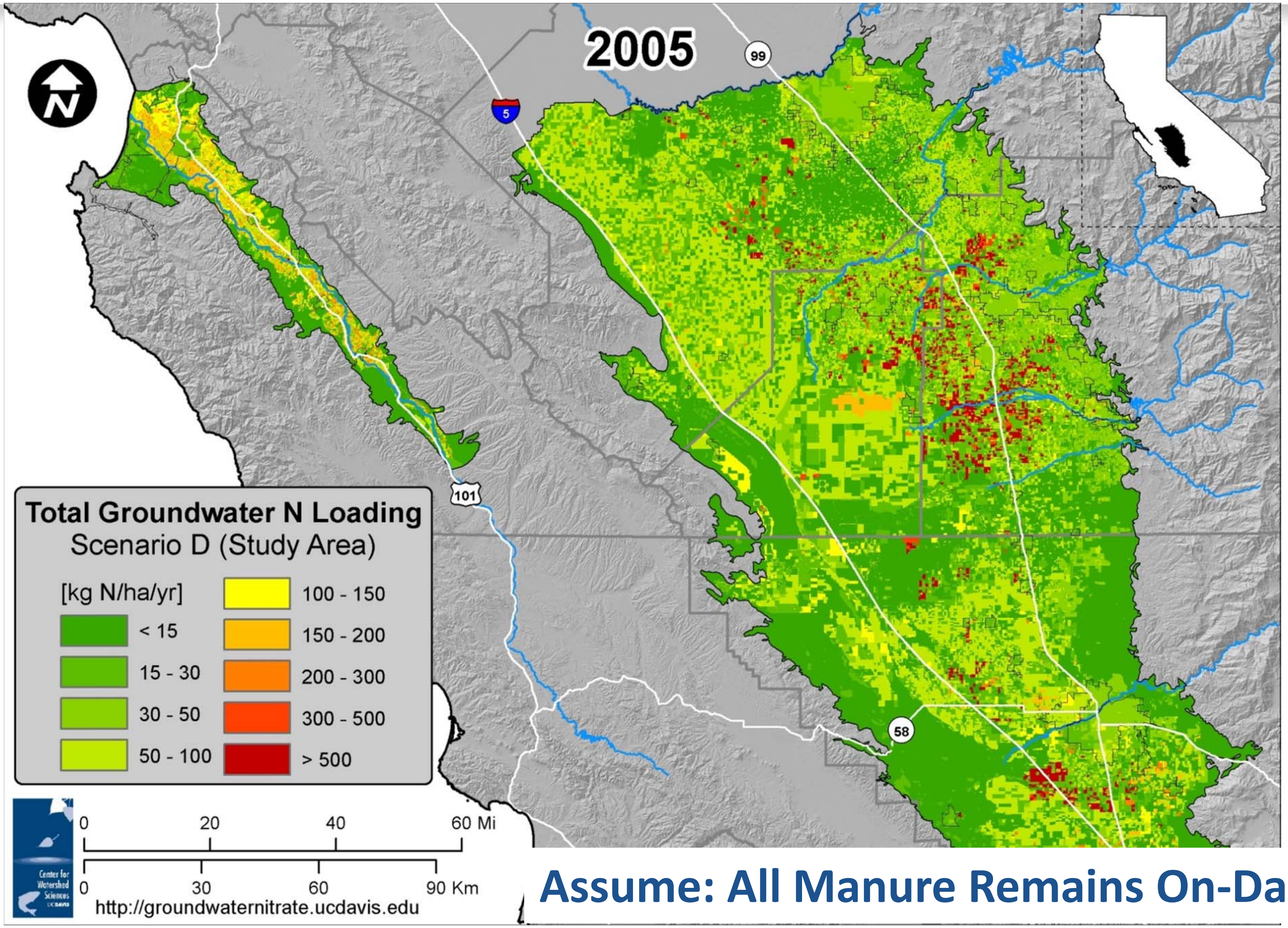



Total Nitrogen Inputs:
420,000 tons N/yr
Irrigation water
Atmosphere
Synthetic Fertilizer
Biosolids
Effluent
Poultry, Swine
Dairy Manure
Atmosphere
Runoff
Leaching to Groundwater
Harvest
Total Nitrogen Outputs:
420,000 tons N/yr

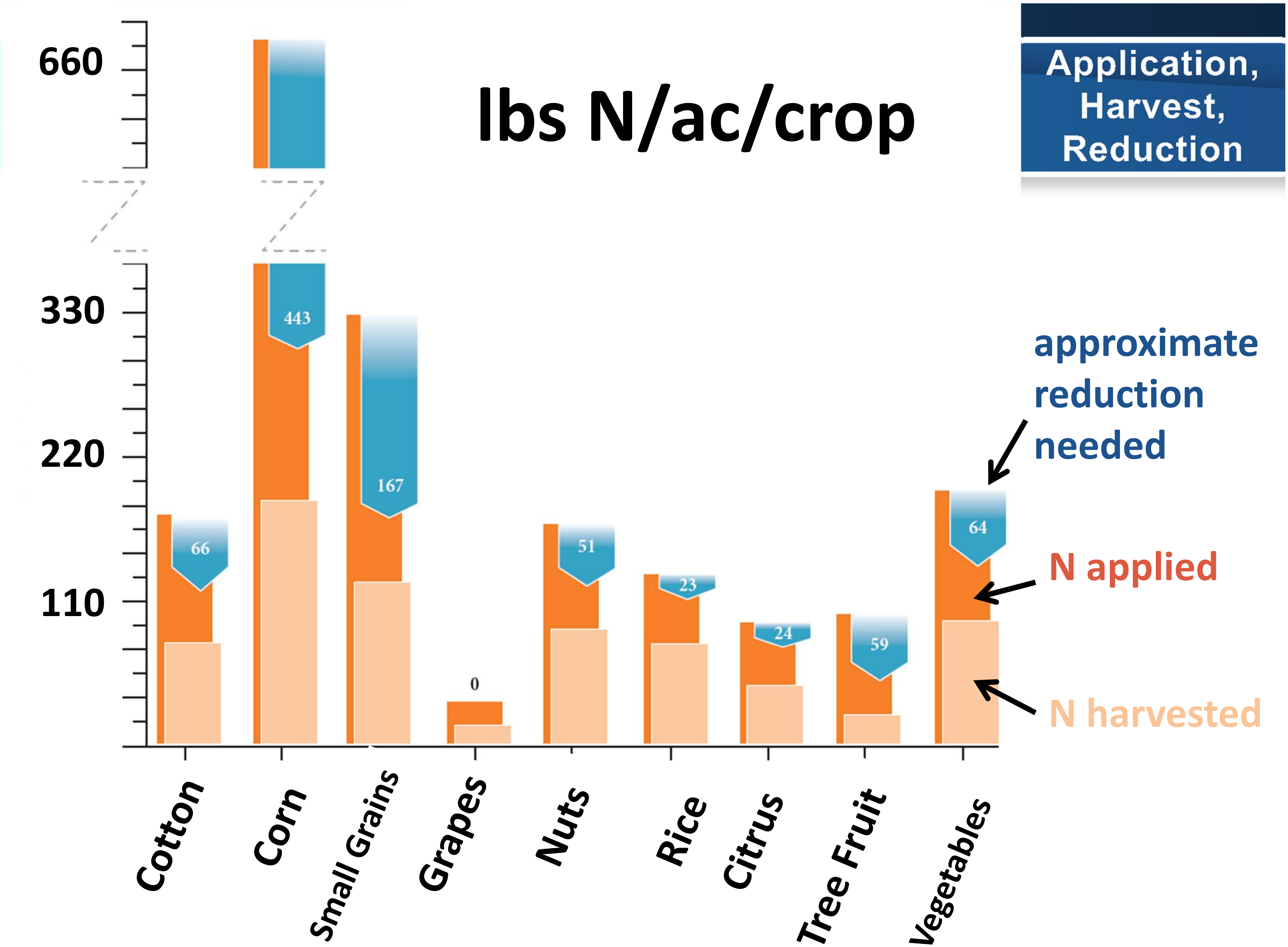
Historic Nitrogen Fluxes



Estimated Groundwater Nitrate Loading



Assume: All Manure Remains On-Dairy



lbs N/ac/crop
Application, Harvest, Reduction
660
330
220
110
443
167
66
0
51
23
24
59
64
approximate reduction needed
N applied
N harvested
Cotton
Corn
Small Grains
Grapes
Nuts
Rice
Citrus
Tree Fruit
Vegetables

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Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 3: NITRATE SOURCE REDUCTION

Public Release of the UC Davis Study

March 13, 2012

Kristin Dzurella, Thomas Harter, Vivian Jensen, Aaron King, Josue Medellin-Azuara, Stuart Pettygrove

Center for Watershed Sciences
University of California, Davis
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thharter@ucdavis.edu

Agricultural Source Reduction

Increase crop N-use efficiency -- Decrease deep percolation

Basic Components	Management Measures	50 Practices
Improve irrigation and drainage systems	✓ Perform system evaluation and monitoring	3
	✓ Improve Irrigation scheduling	4
	✓ Improve irrigation system design and operation	13
	✓ Other irrigation infrastructure improvements	2
Improve fertilizer and manure use	✓ Improve rate, timing, and placement	15
Change crop rotation	✓ Modify crop rotation or grow cover crops	4
Improve storage and handling	✓ Avoid fertilizer material and manure spills during transport, storage and application	9

FINDINGS: Cropland Source Reduction

- Recommended practices can increase N in the harvested crop to **~60-80%** of N inputs
  - Current averages as low as ~30-40%
- Some practices are already in use:
  - Rate of adoption, regional impact unknown
- Suite of practices will be the most effective:
  - Tailored to specific soils and crops
- Barriers to expanded adoption:
  - Logistics, education, costs

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- Suite of practices will be the most effective:
  - Tailored to specific soils and crops
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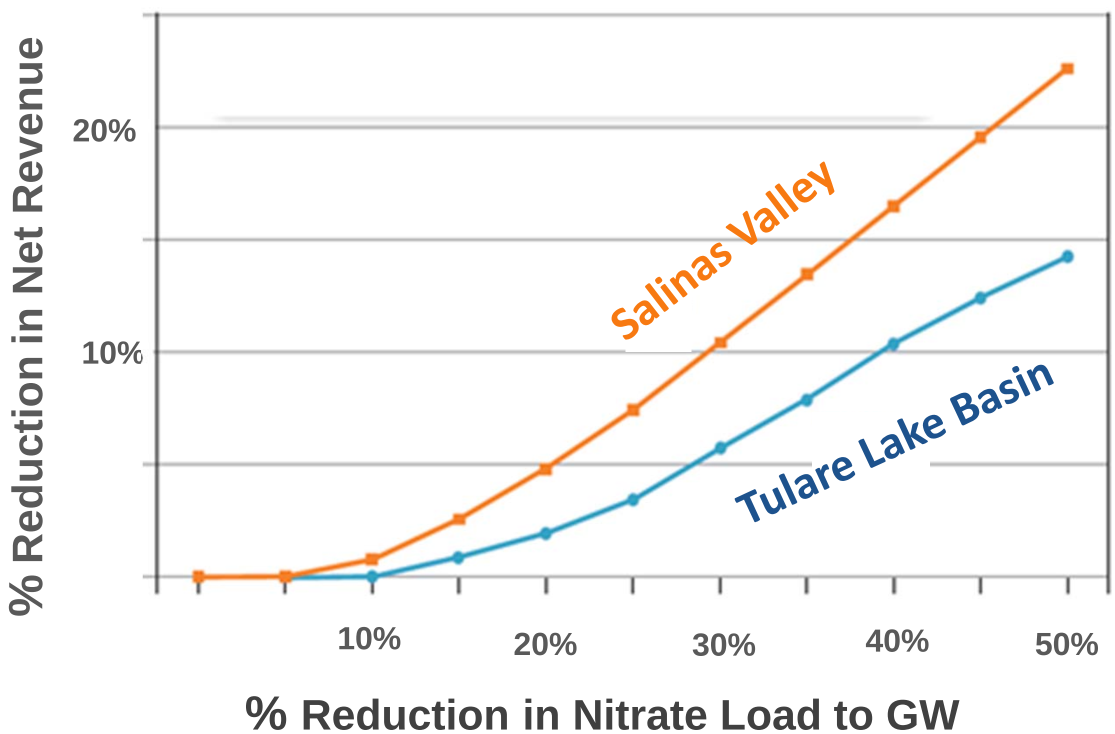
Economics of Source Reduction

- Cost of improving crop N use efficiency is uncertain but likely low for small improvements.
- Load reductions of half or more may come at a significant cost, potential reduction in irrigated crop area.



Cropland Source Reduction

PROMISING ACTIONS

- Expand efforts to promote adoption of N-efficient practices:
  - Grower education
  - Adaptive research

- Support development of N accounting methods:
  - Grower evaluation of improvements in crop N-use efficiency
- Fine-tune nitrate leaching risk assessment methods:
  - Identify associated monitoring requirements

Cropland Source Reduction
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- Fine-tune nitrate leaching risk assessment methods:
  - Identify associated monitoring requirements

FINDINGS: Livestock Operations

Dairy manure now regulated.
To comply dairies are:

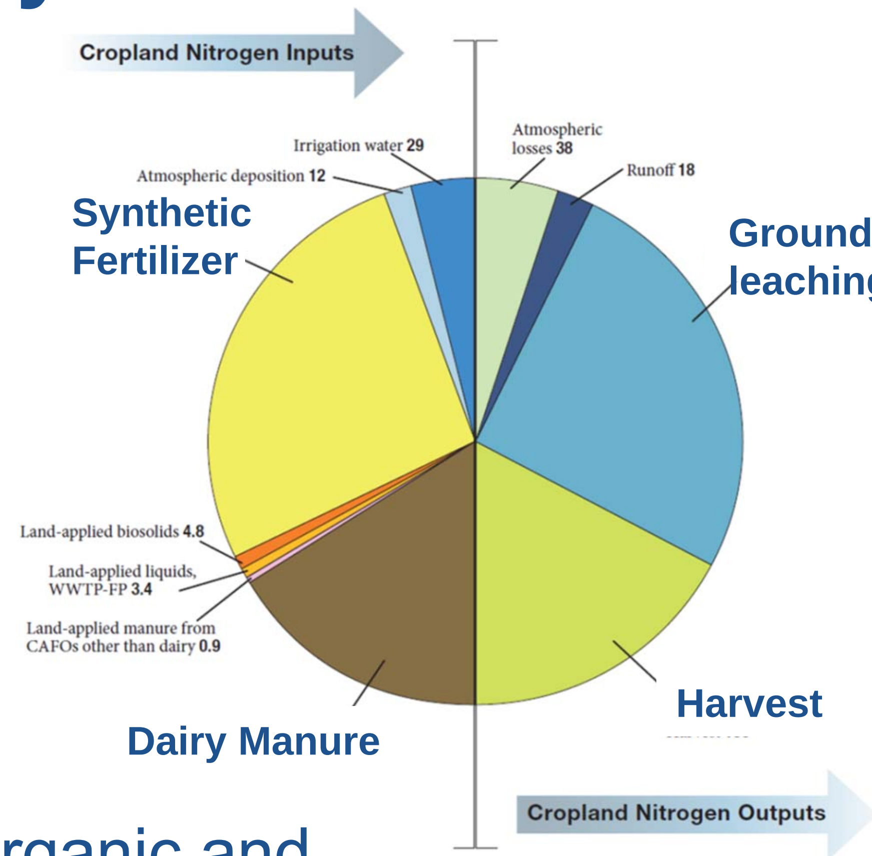
- Improving infrastructure
  - lagoon water handling

- Exporting excess manure off-farm:
  - Receiving farms likely not reducing N fertilizer applications accordingly

PROMISING ACTIONS: Livestock

Reduce, Reuse, Recycle

- Develop methods for better determining fertilizer value
- Alternative Forms:
  - Heat treatment
  - Pelleting
  - Compost
- Guidance in co-managing organic and conventional N sources



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Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 4: GROUNDWATER QUALITY

Public Release of the UC Davis Study

March 13, 2012

Dylan Boyle, Aaron King, Giorgos Kourakos, Graham Fogg, Thomas Harter

Center for Watershed Sciences
University of California, Davis
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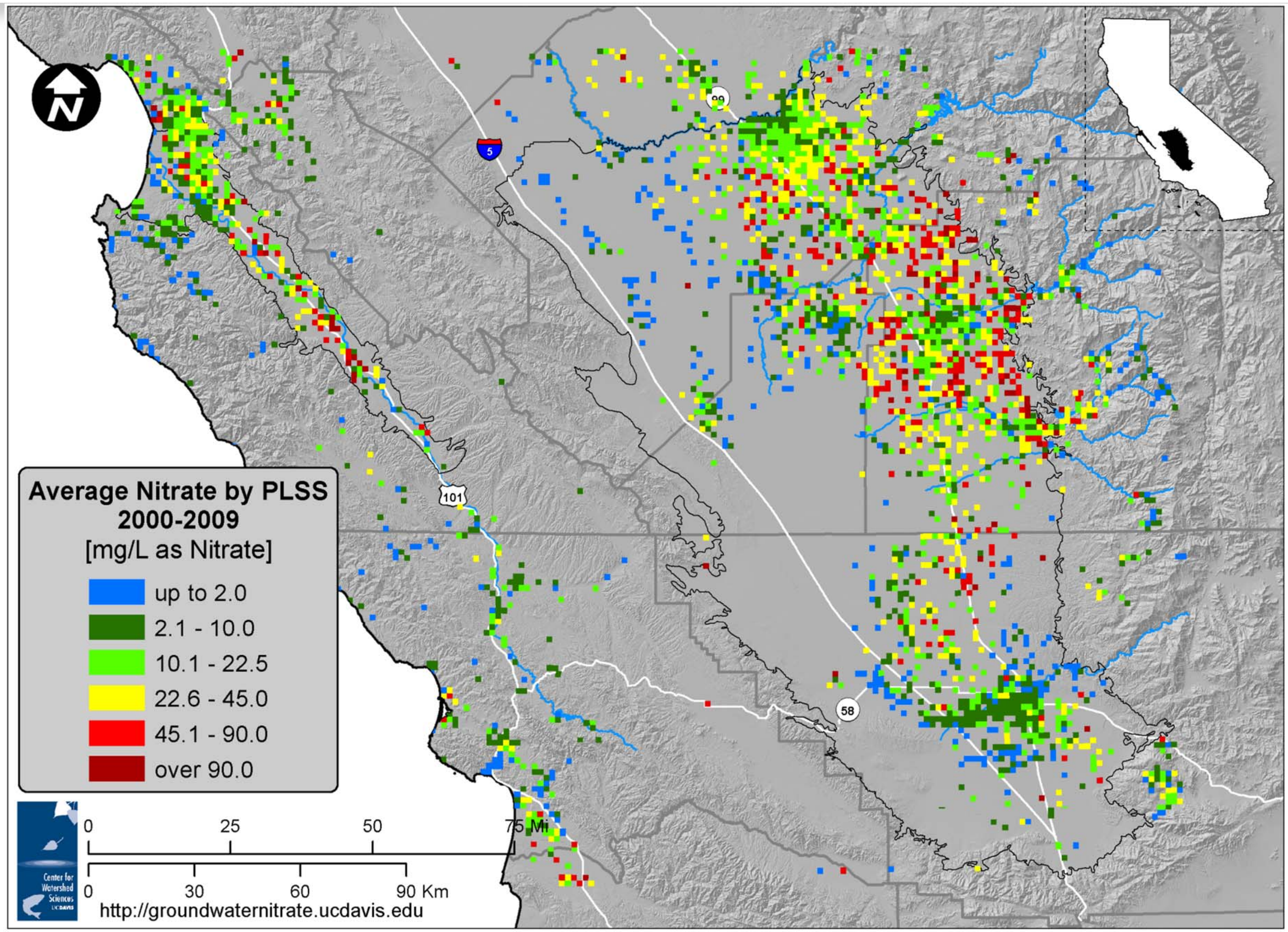
thharter@ucdavis.edu

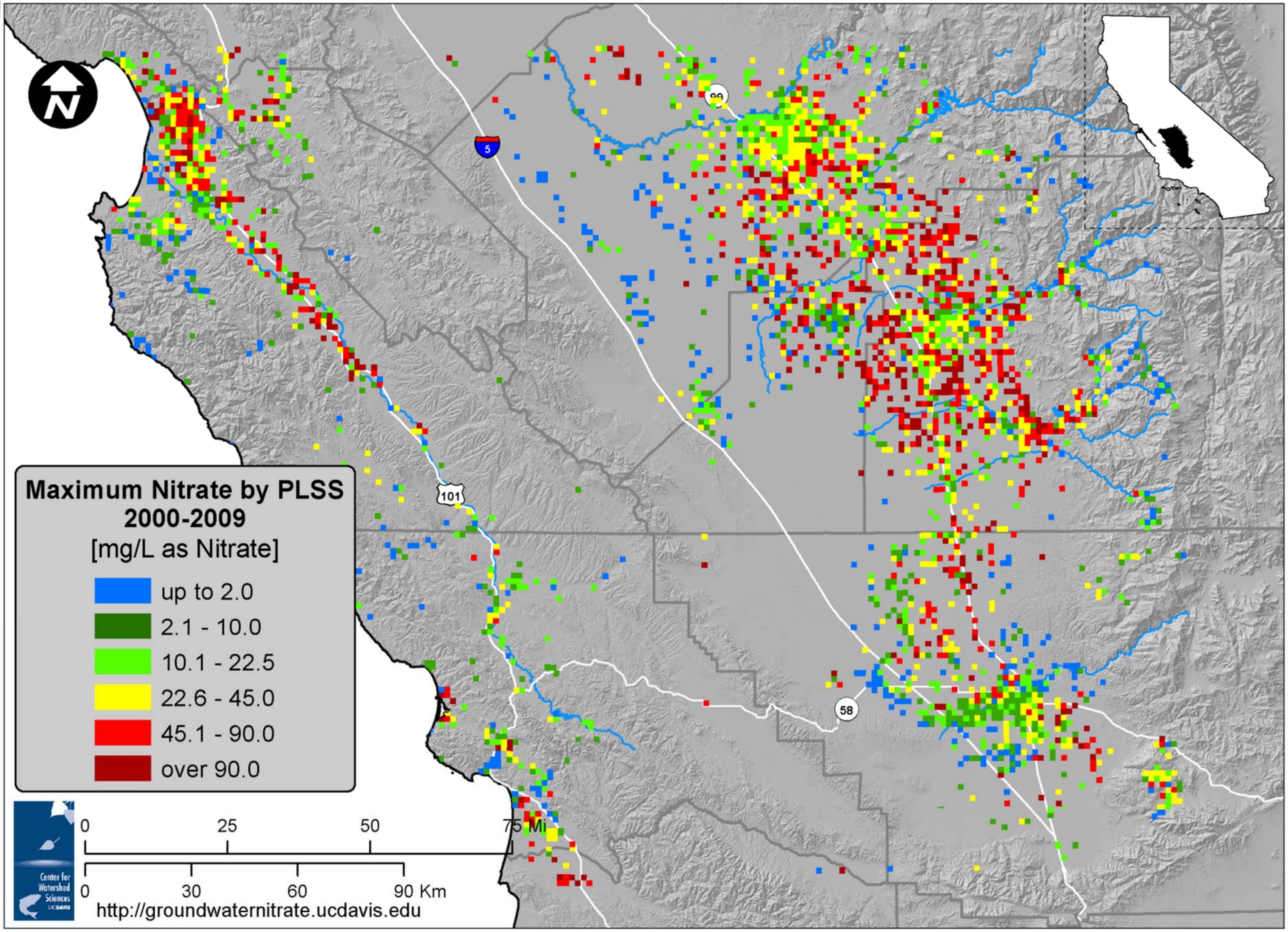
Key Findings

- Widespread nitrate contamination
  - Eastern TLB and Salinas Valley most affected
- Lack of long-term historic water quality datasets
  - Majority of data 2000→present.
- Future: nitrate expected to increase in many areas

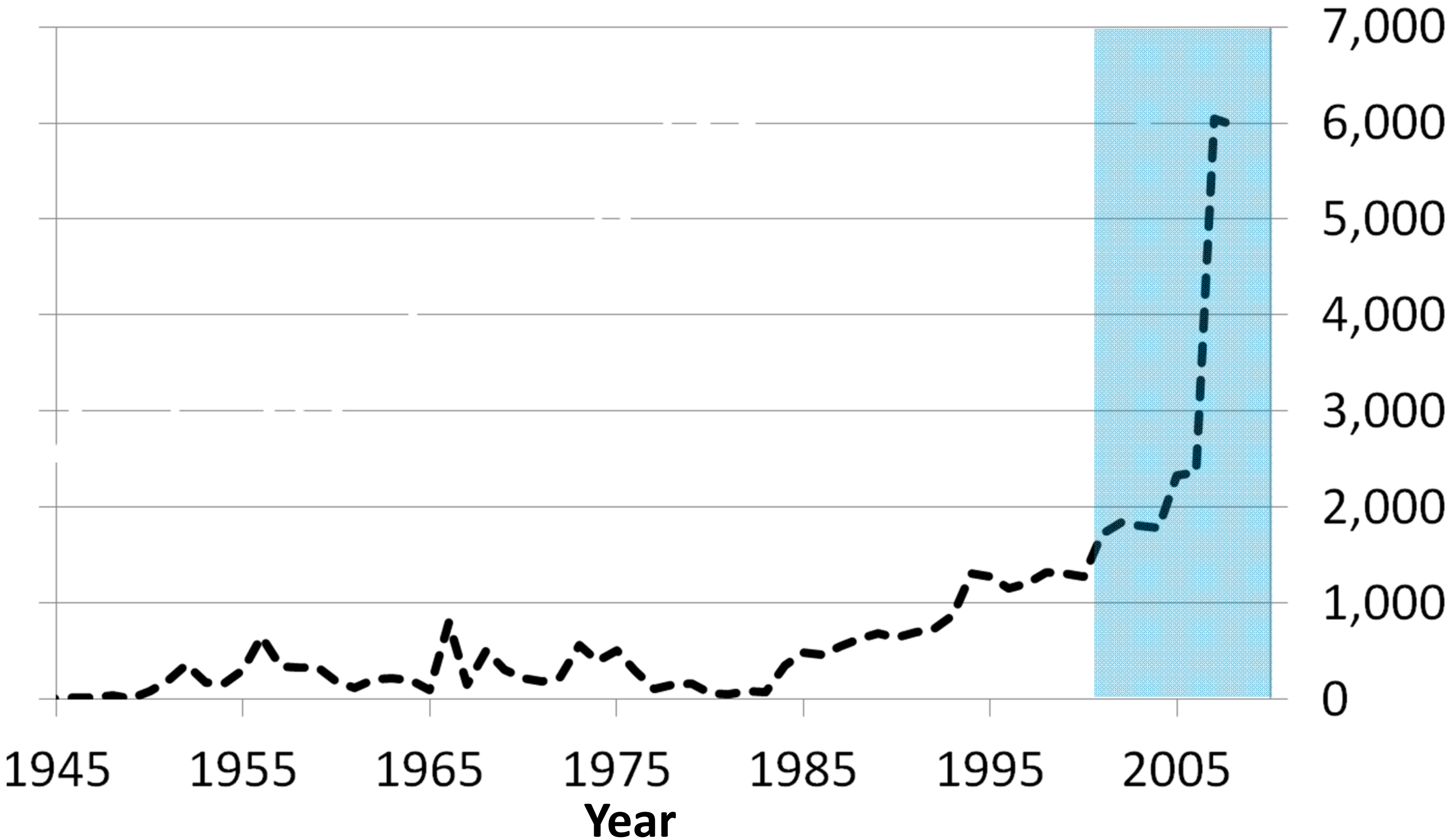
Average Nitrate Concentrations by Section



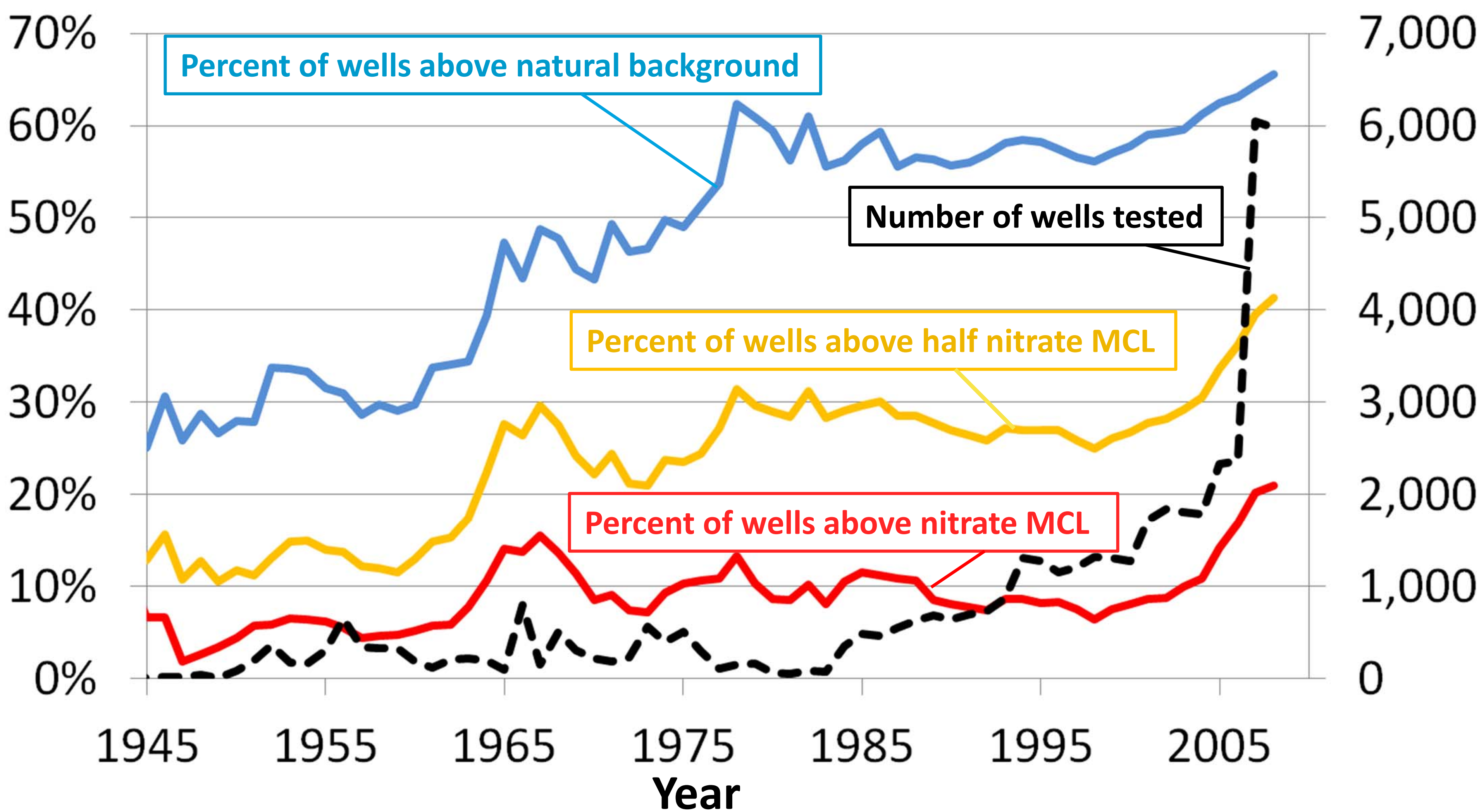
Maximum Nitrate Concentrations by Section



Number of Wells Sampled
CASTING Database

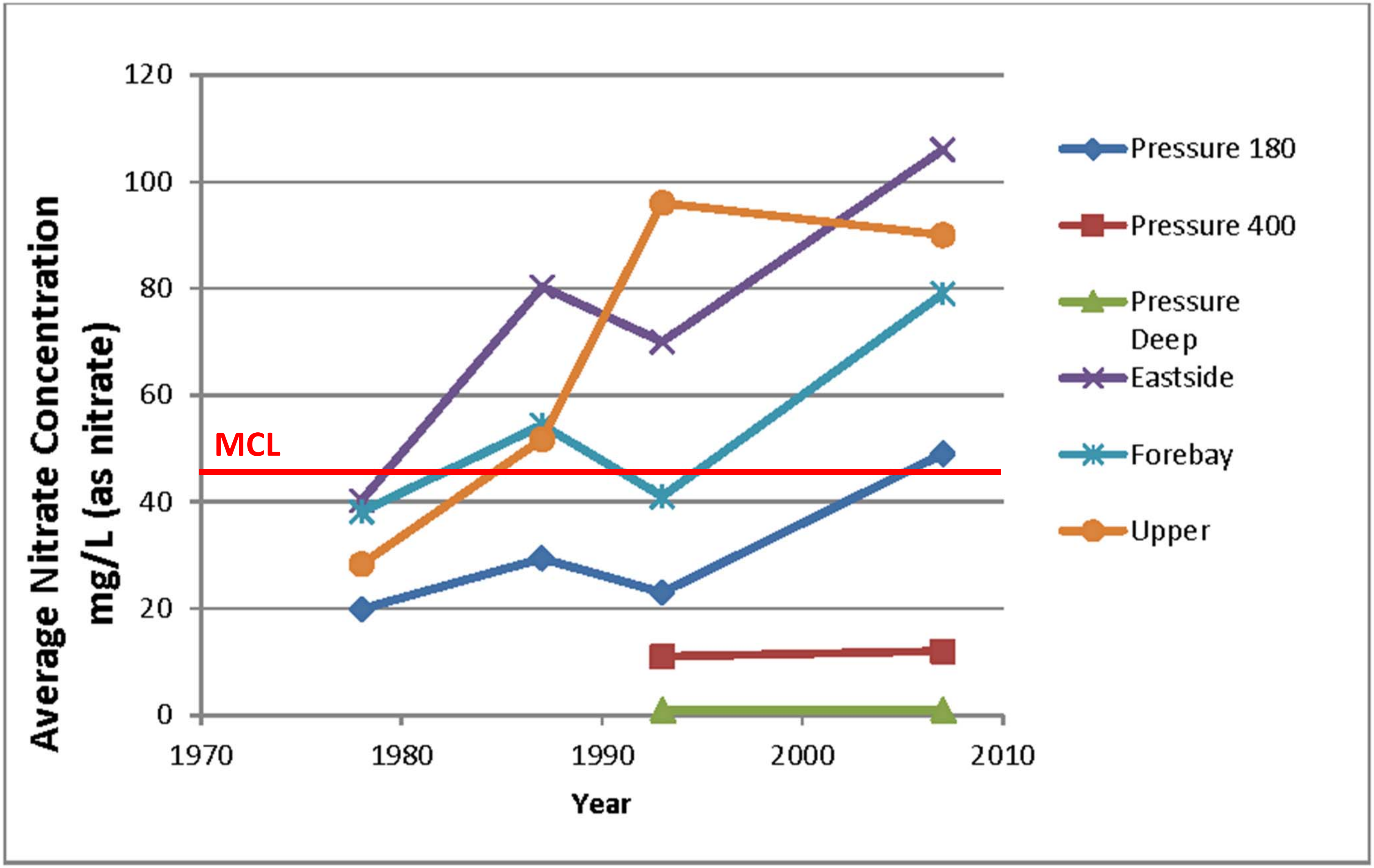


Historic Nitrate Trends, TLB: Exceedance Rate



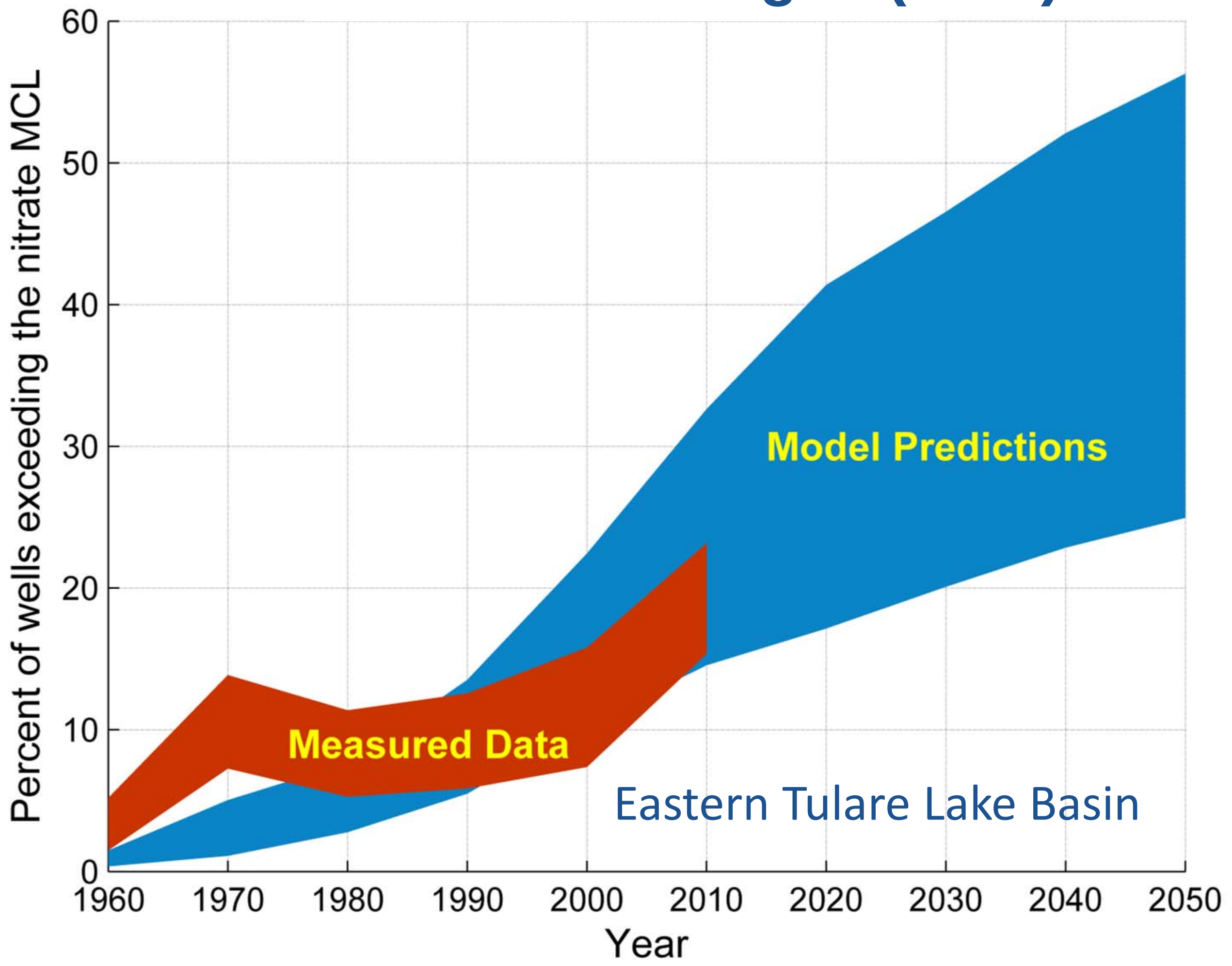
Nitrate Trends, Salinas Valley

(MCWRA Published Regional Well Network Data)



Predictions Using Groundwater Nitrate Loading

Exceedance Probability, Nitrate above 45 mg/L (MCL)



SBX2 1

Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 5: GROUNDWATER REMEDIATION

Public Release of the UC Davis Study

March 13, 2012

Aaron King, Graham Fogg, Vivian Jensen, Thomas Harter

Center for Watershed Sciences
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Contact: amking@ucdavis.edu
thharter@ucdavis.edu

Key Findings

- Basin-wide conventional remediation is not feasible
  - Expensive (>$14-30 billion) (volume: 35-88 million acre feet)
  - Technically infeasible – time, inefficiency
- Local remediation is appropriate
  - Clean up of nitrate hot spots with plume-scale remediation methods
    - In situ (e.g. Permeable Reactive Barriers)
    - Ex situ (e.g. Pump and Treat)
- Basin-wide groundwater quality management needed
  - Source reduction
  - Regional adoption of Pump and Fertilize
  - Recharge with higher quality water

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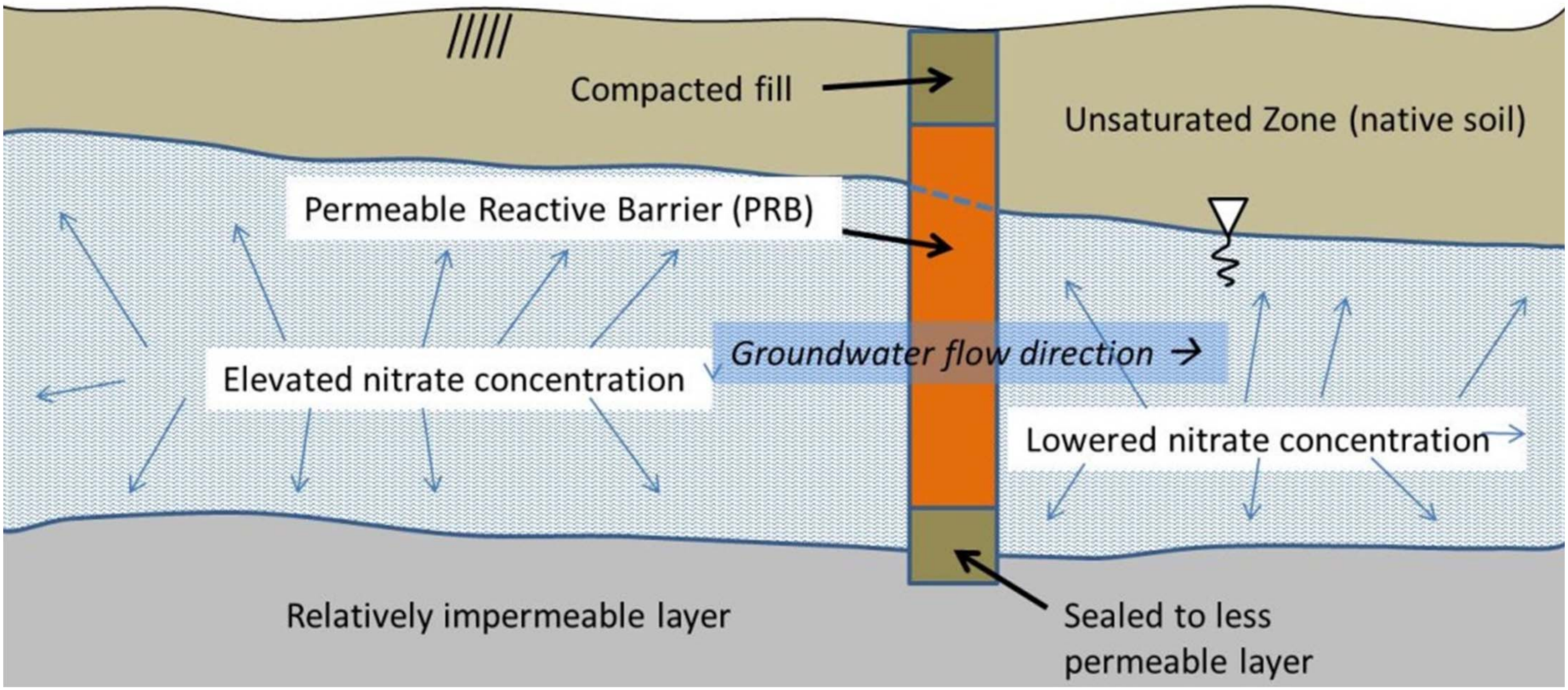
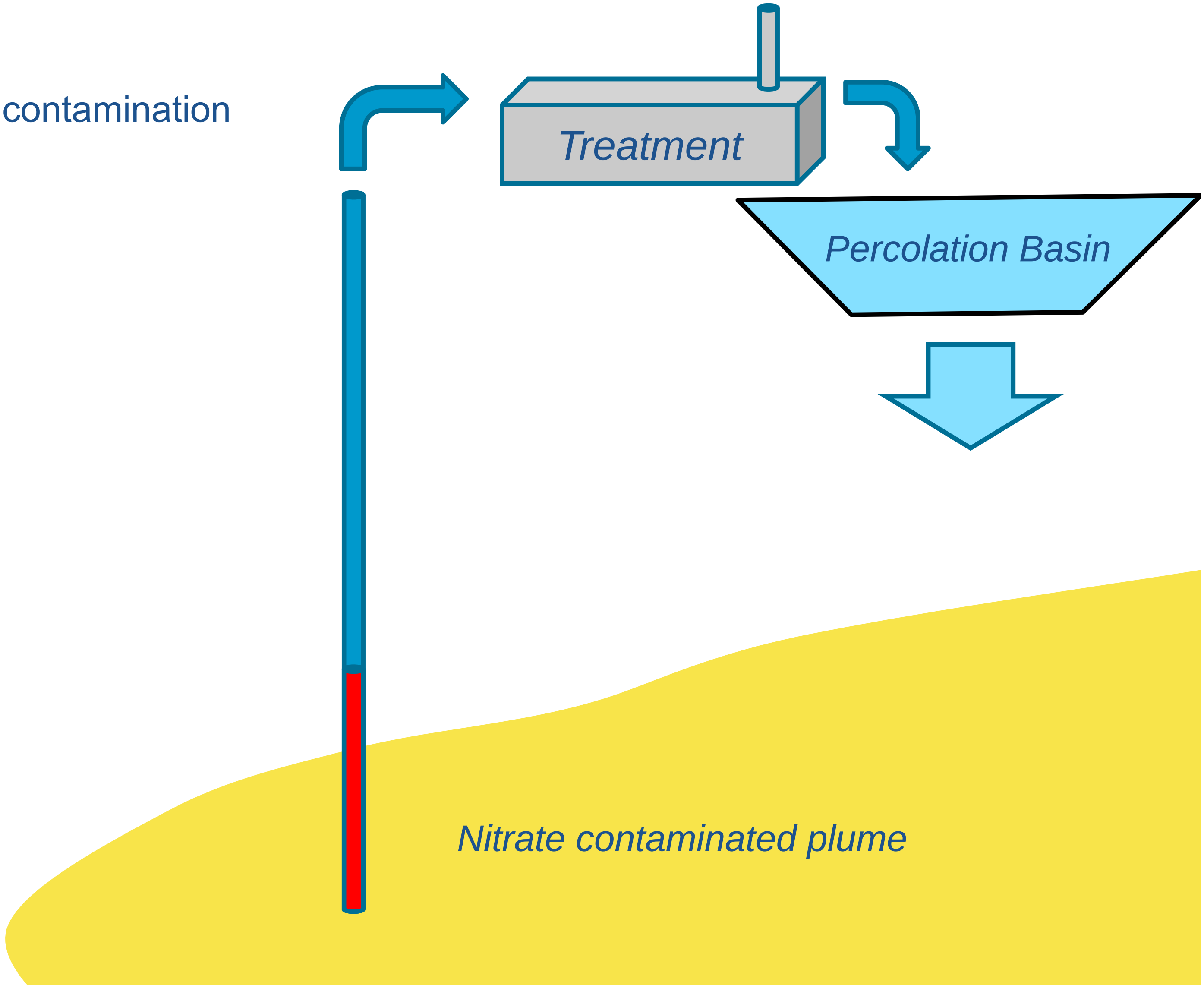
Local-Scale Remediation Options

- Permeable Reactive Barriers
  - Maximum cost-effective depth 50-100 feet
  - Enhance denitrification to protect specific wells
  - Intercept high nitrate subsurface flows
  - High capital cost, very low O&M cost



Local-Scale Remediation Options

- Pump and Treat
  - Can target deeper contamination
  - High Capital cost
  - High O&M cost



Pump and Fertilize (PAF)

- Current irrigation pumping captures more than current recharge
- Crops remove nitrogen from irrigation water
- N in irrigation water
  - Consider in fertilizer calculations
  - 32,000 short tons ($30 M fertilizer value)
  - Potential for 15% reduction in applied synthetic fertilizer
- Implementation
  1. Education and outreach
     - Monitoring of well nitrate costs $150 per well per year
  2. Regional groundwater quality management modeling
  3. Redistribution of irrigation pumping to shallower depths

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- Current irrigation pumping captures more than current recharge
- Crops remove nitrogen from irrigation water
- N in irrigation water
  - Consider in fertilizer calculations
  - 32,000 short tons ($30 M fertilizer value)
  - Potential for 15% reduction in applied synthetic fertilizer
- Implementation
  1. Education and outreach
     - Monitoring of well nitrate costs $150 per well per year
  2. Regional groundwater quality management modeling
  3. Redistribution of irrigation pumping to shallower depths

Groundwater Quality Management

- Any remediation requires source reduction
- Increase fraction of high quality recharge
  - Groundwater banking
  - River recharge management
- Preferential pumping
  - High N → irrigation (pump and fertilize)
  - Low N → drinking water
- New groundwater management paradigms
  - Basin-wide strategies
  - Joint management water quantity and quality

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- Near-term solutions to supply safe water now

SBX2 1

Addressing Nitrate in California's Drinking Water

TECHNICAL REPORTS 6 & 7: DRINKING WATER TREATMENT & ALTERNATIVE WATER SUPPLY

Public Release of the UC Davis Study

March 13, 2012

Kristin Honeycutt, Vivian Jensen, Holly Canada, Jeannie Darby, Mimi Jenkins, Jay Lund

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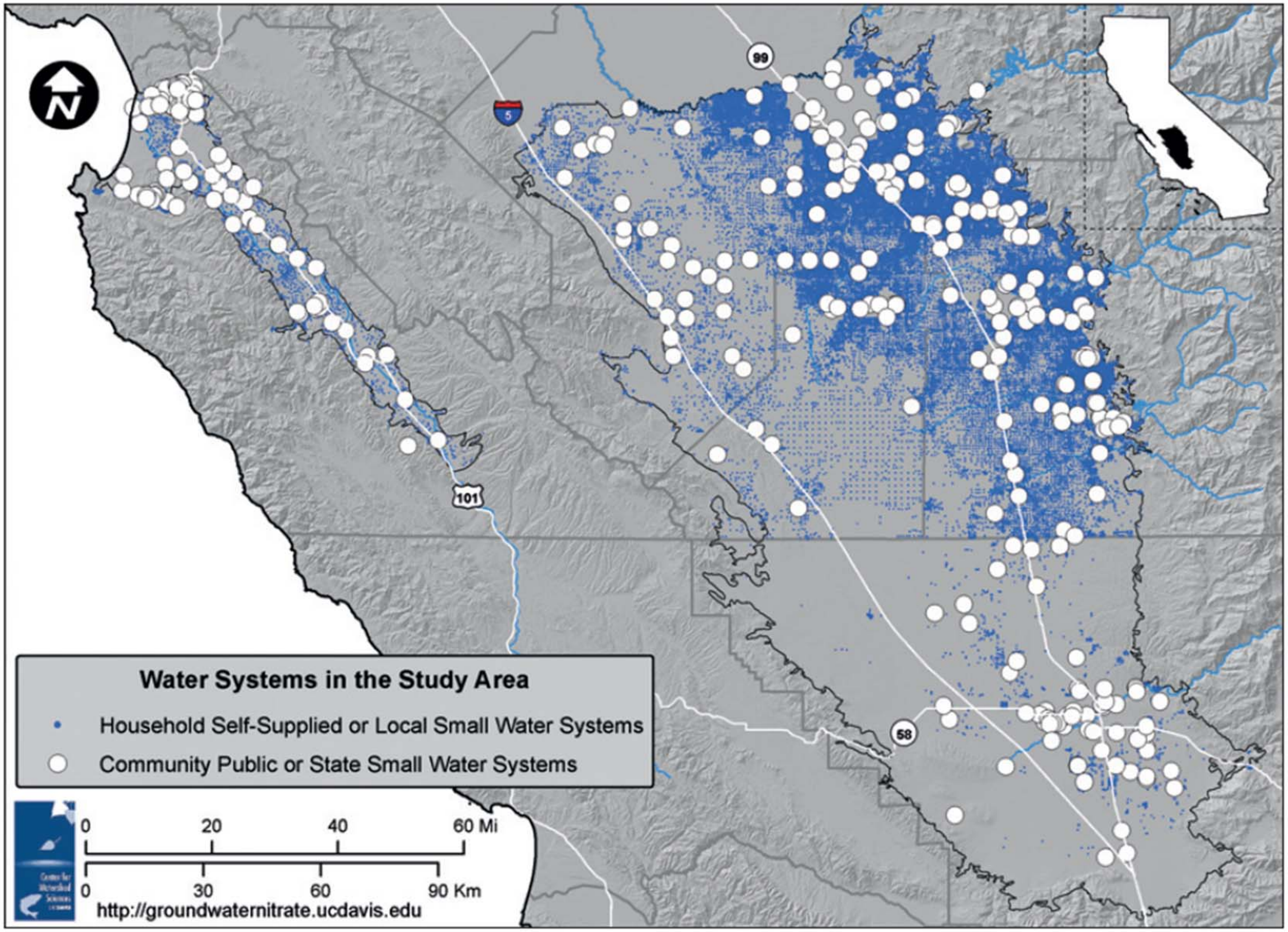
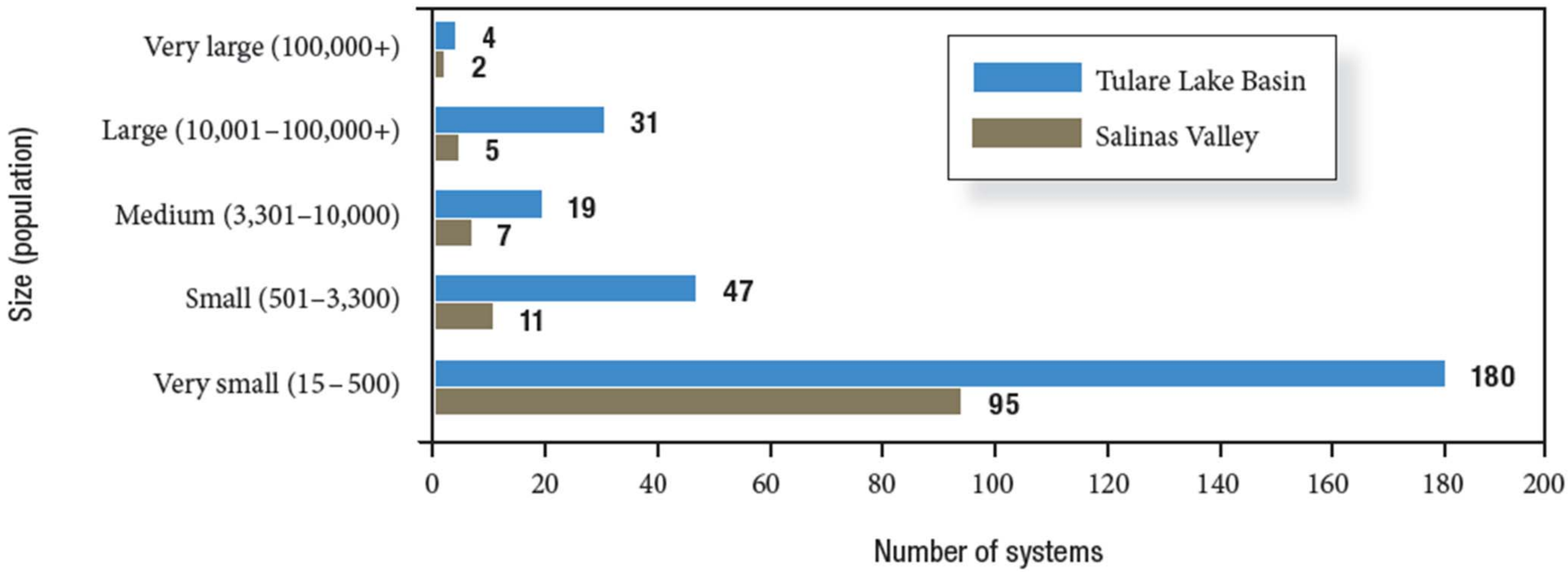
All Water Systems



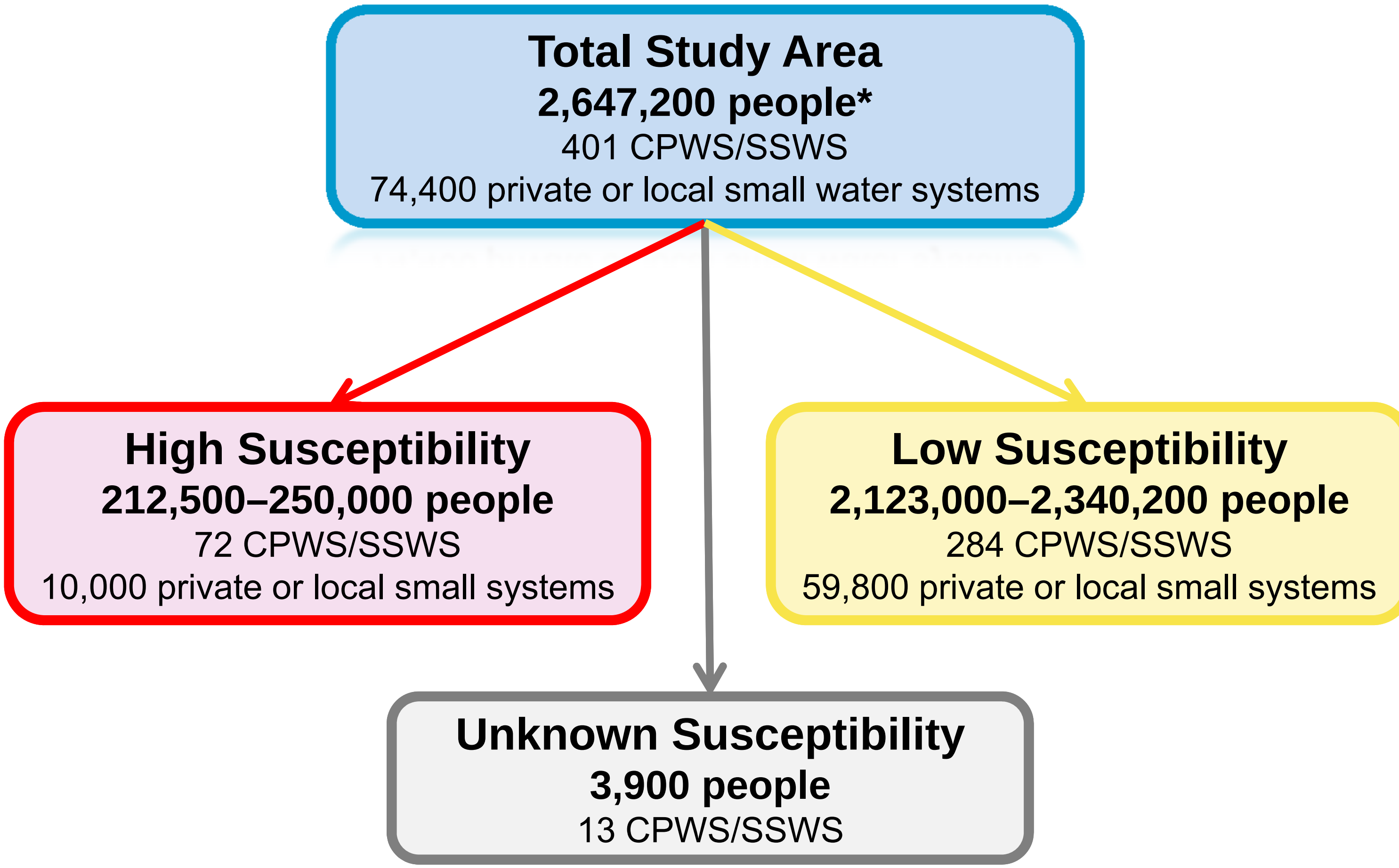
Estimated locations of the area's roughly 400 regulated community public and state-documented state small water systems and of 74,000 unregulated self-supplied water systems. Source: Honeycutt et al. 2012; CDPH PICME 2010.

Community Public & State Small Water Systems



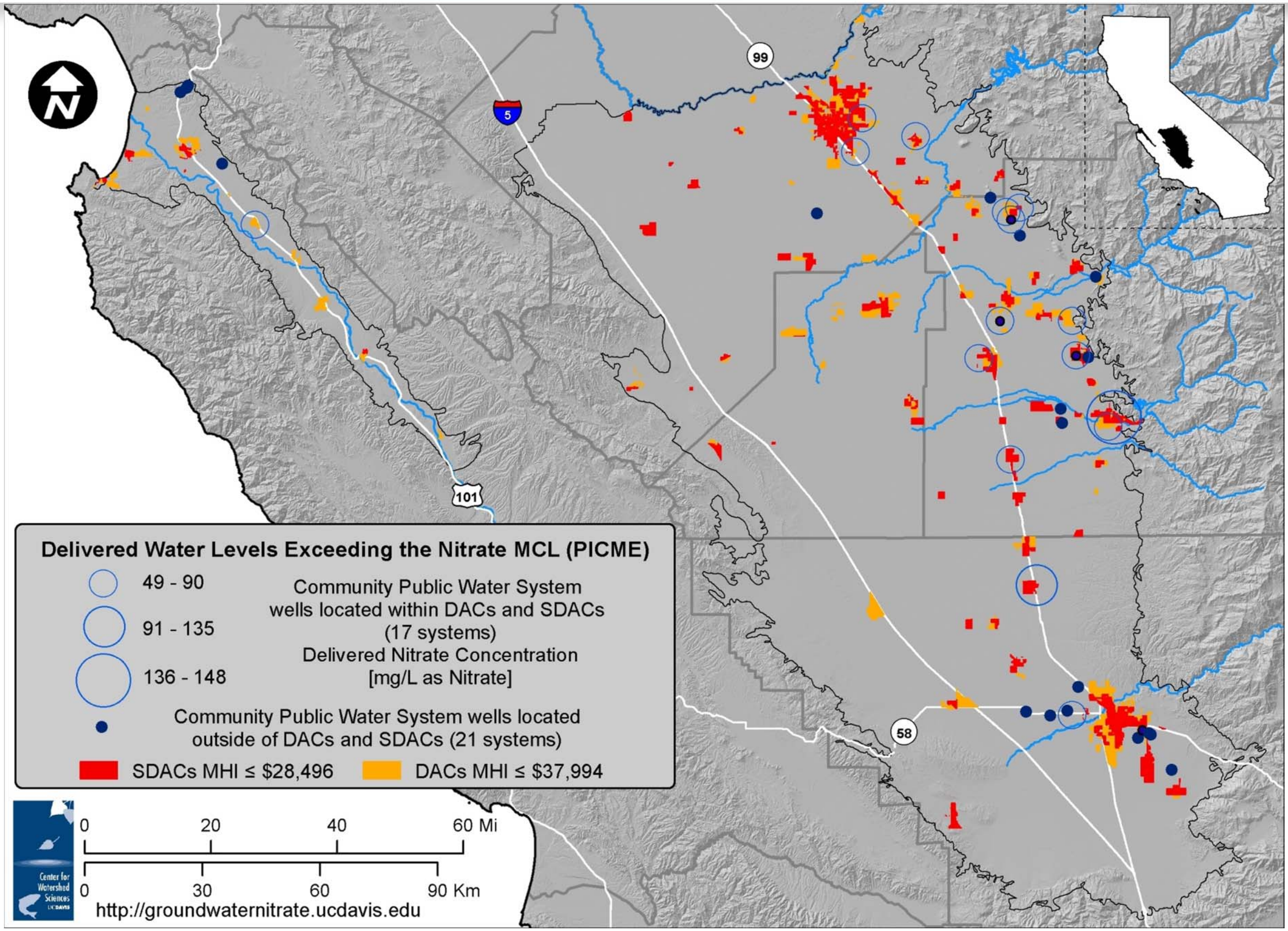
Community public and state-documented state small water systems of the Tulare Lake Basin and Salinas Valley. Source: CDPH 2010.

Susceptible Population



**Total study area population includes population served by surface water systems which is not susceptible to groundwater nitrate contamination and is not included in the subsequent susceptibility classifications.*

DACs and Delivered Water Quality



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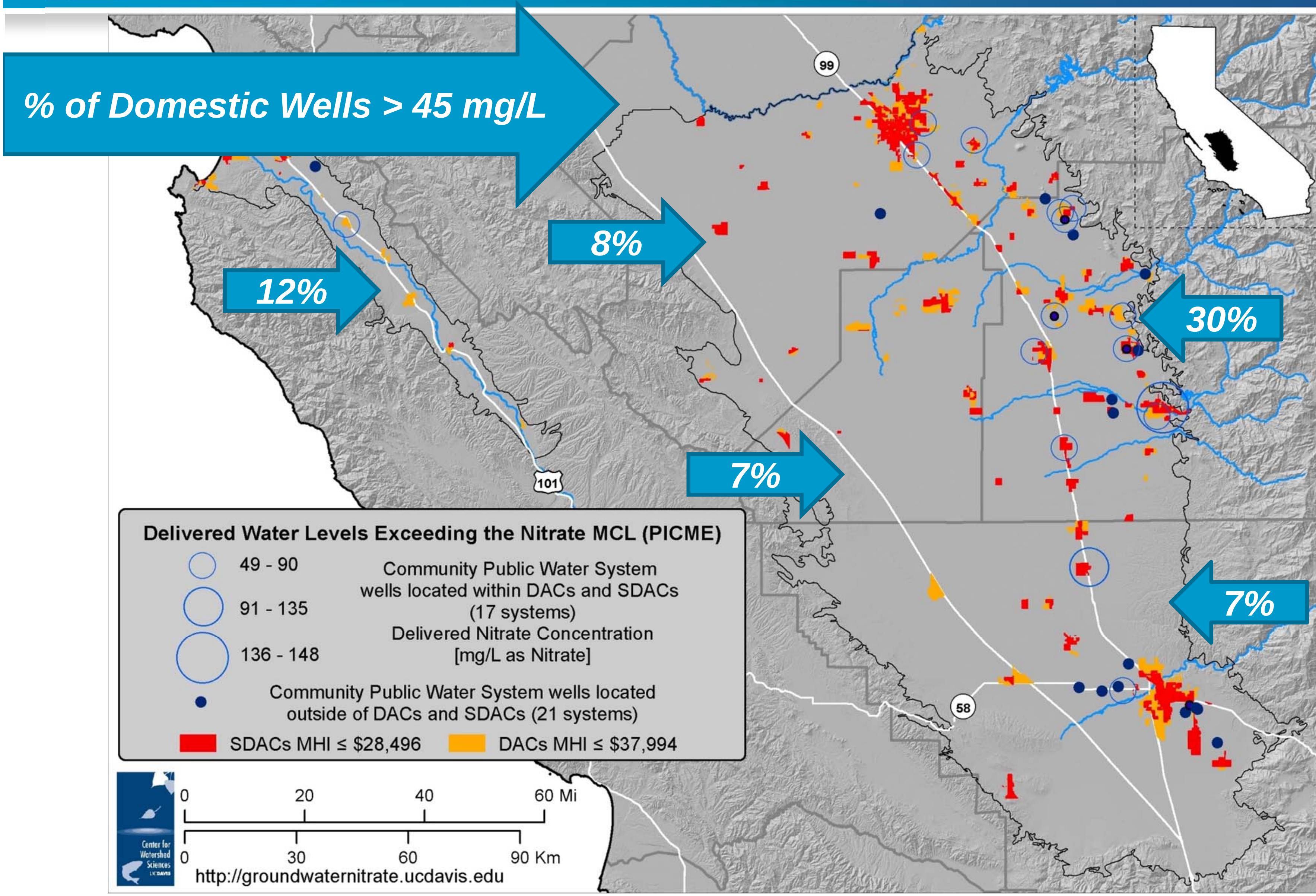


Alternative Water Supply Options

Improve Existing Source

- Deeper Well or New Well
- Blending
- Treatment

Use Alternative Supply

- Surface Water
- Connection to Another System
- Regionalization and Consolidation
- Trucked Water and Bottled Water

Treatment Options

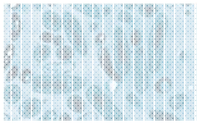

Source: Siemens


Source: Dow Chemical


Source: PC Cell

<u>REMOVAL TECHNOLOGIES</u> – Disposal concern

- Ion Exchange
  - Nitrate displaces chloride on resin, resin recharge with brine solution.
- Reverse Osmosis
  - Water molecules pushed through membrane, contaminants left behind.
- Electrodialysis
  - Electric current governs ion movement through membranes.


Source: AnoxKaldnes


Source: Hepure Technologies

<u>REDUCTION TECHNOLOGIES</u> – Limited full-scale application to date

- Biological Denitrification
  - Bacteria transform nitrate to nitrogen gas.
- Chemical Denitrification
  - Metals reduce nitrate to ammonia (typically).

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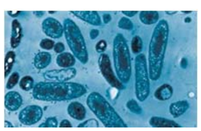
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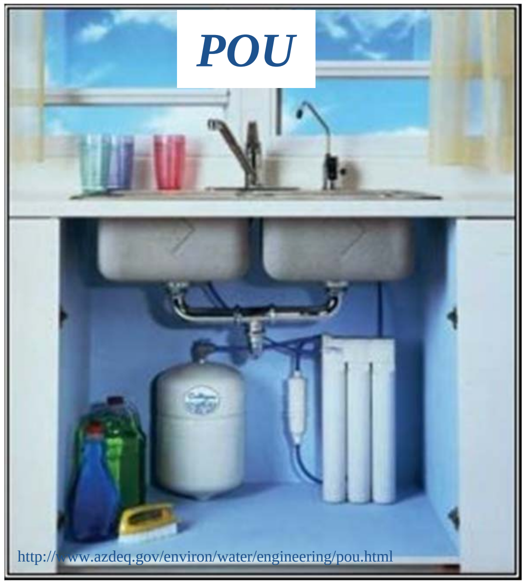
POU/POE



- Point-of-Use (POU)
  - Under the sink, treatment of only potable water
- Point-of-Entry (POE)
  - Household treatment, treatment of all water
- CDPH regulations limit POU treatment for water systems
- Primary option for household self-supply treatment

Costs for Alternative Supply Options

Option	Estimated Annual Cost Range ($/year)	
	Self-Supplied Household	Small Water System (1,000 households)
Improve Existing Water Source		
Blending	N/A	$85,000–$150,000
Drill deeper well	$860–$3,300	$80,000–$100,000
Drill a new well	$2,100–$3,100	$40,000–$290,000
Community supply treatment	N/A	$135,000–$1,090,000
Household supply treatment (POU)	$250–$360	$223,000
Alternative Supplies		
Piped connection to an existing system	$52,400–$185,500	$59,700–$192,800
Trucked water	$950	$350,000
Bottled water	$1,339	$1.34 M
Relocate households	$15,090	$15.1 M
Ancillary Activities		
Well water quality testing	$15–$50	N/A
Dual distribution system	$575–$1,580	$260,000–$900,000

Estimated Annualized Basin Wide Costs

Alternative Supply Costs for CPWS/SSWS (220,000 people)

- Short-term Solutions: **$13 - $17 million/year** (includes POU and new well)
- Long-term Solutions: **$34 million/year** (excludes POU and new well)

Alternative Supply Costs for Households (34,000 people)

- POU: $2.5 million/year

Alternative Supply Costs for TOTAL Susceptible Population (254,000)

- Short-term Solutions: $20 million/year
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Major Findings

- 254,000 people susceptible or potentially susceptible.
- Individual engineering and financial analyses for each system.
  - Not one solution for all, but necessary technology is available.
- Significant potential for consolidating small systems.
- Multiple contaminant removal technologies promising.
- Obstacles and hurdles do exist.
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Major Findings

- **Promising Options for Community Public Water Systems**
  - Consolidate
  - Ion exchange
  - New well
  - Blending

- **Promising Options for Self-Supplied Households**
  - Point-of-Use
  - New well

- **Overall Cost = $20 - $36 million/year**
  - $80 - $142 / year per SUSCEPTIBLE PERSON
  - $5 - $9 / year per IRRIGATED ACRE
  - $100 - $180 / year per TON OF FERTILIZER NITROGEN
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Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 8: REGULATORY & FUNDING OPTIONS

Public Release of the UC Davis Study

March 13, 2012

Holly Canada, Thomas Harter, Kristin Honeycutt,
Katrina Jessoe, Mimi Jenkins, Jay Lund

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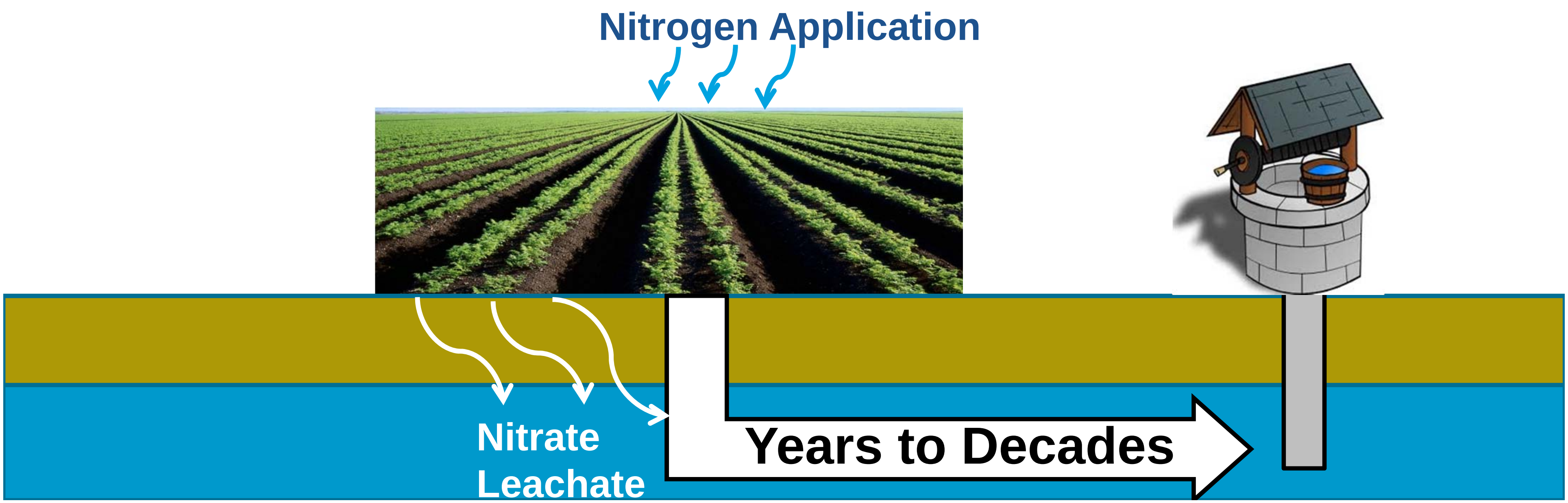
Major Findings: Current Regulatory Programs

- **Regulations have been insufficient to control groundwater nitrate contamination.**
- **Drinking water source quality will improve only after many years of nitrate source reductions.**

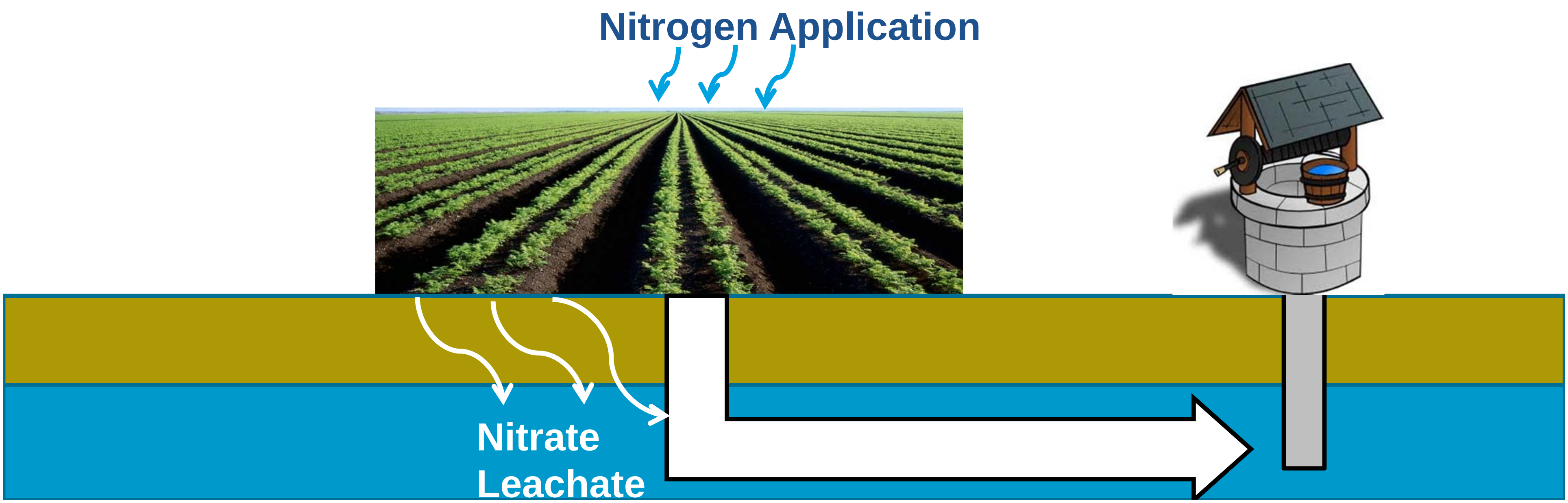


Regulatory Options Considered

- Technology Mandate
- Performance Standard
- Fee
- Cap and Trade
- Information Disclosure
- Liability Rules
- Negotiation or Payment for Service
- De-designation of Beneficial Use

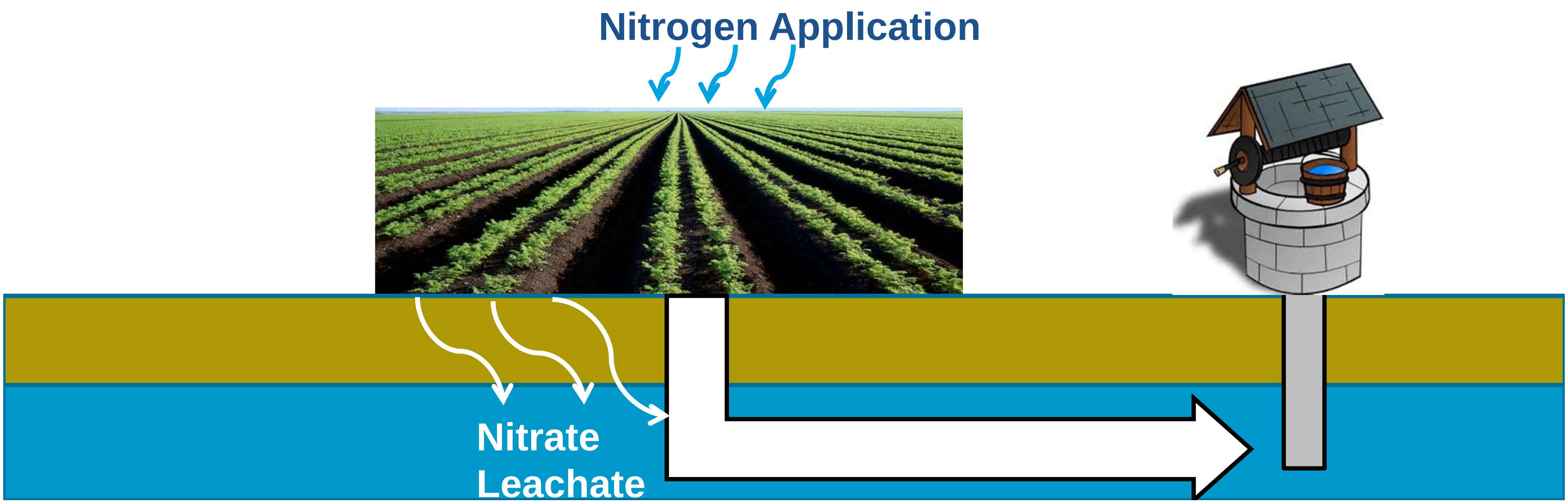
Ways to regulate nitrate?

- Technology Mandate
- Performance Standard
- Fee
- Cap and Trade



Regulating Nitrogen Application Preferred

Regulated Entity	Abatement Costs (costs to reduce loading to achieve a nitrate standard)	Monitoring / Enforcement Costs	Information Requirements	Revenue Raising
Nitrate Leachate	Lower – regulate pollutant	High	High	Maybe
Nitrogen Application	Higher – regulate input	Low	Low	Maybe



Promising Regulatory Options

1. Nitrate dischargers pay for the additional drinking water costs - authorized under Section 13304 of CA Water Code.

2. Regulate nitrogen use rather than nitrate leachate.

3. Consider market-based instruments for long-term regulation.

4. Learn from successful Department of Pesticide Regulation programs.

Chronic Funding Problems

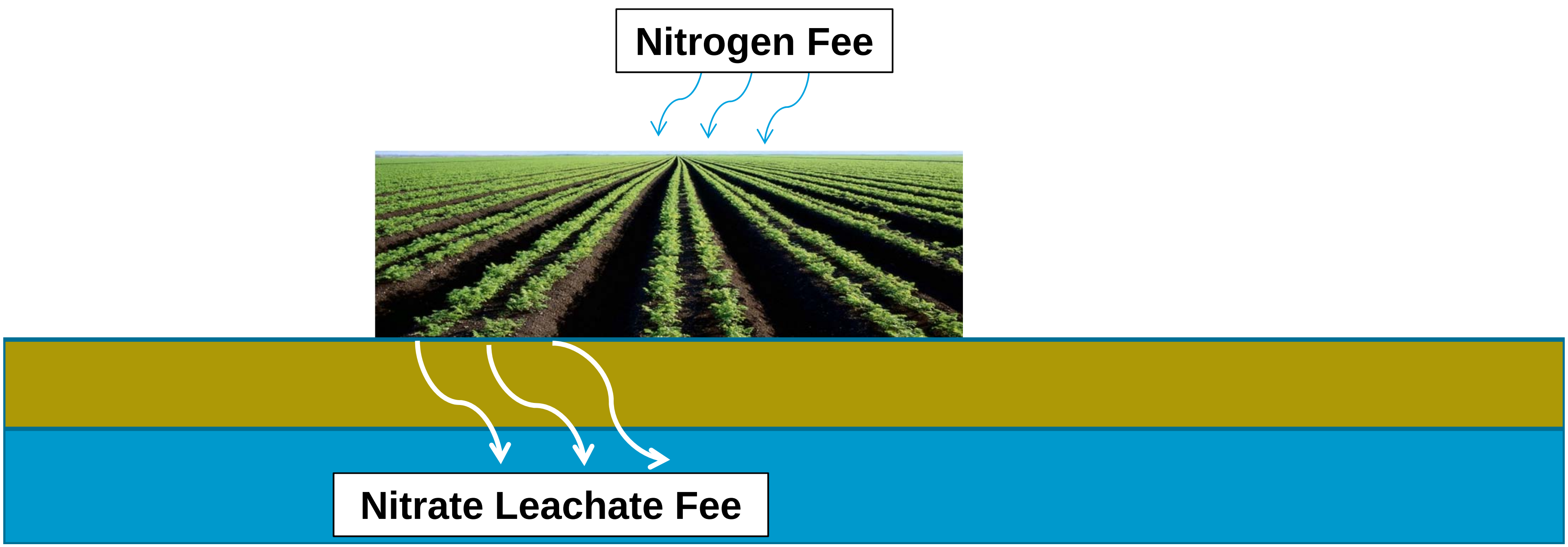
1. Small, rural communities
2. Communities are spread-out

higher infrastructure costs
= higher household costs

3. Lack economies of scale
4. Less Technical, Managerial, Financial (TMF) resources

difficulty with:
- loans
- funding applications
- operation & maintenance

Funding Options



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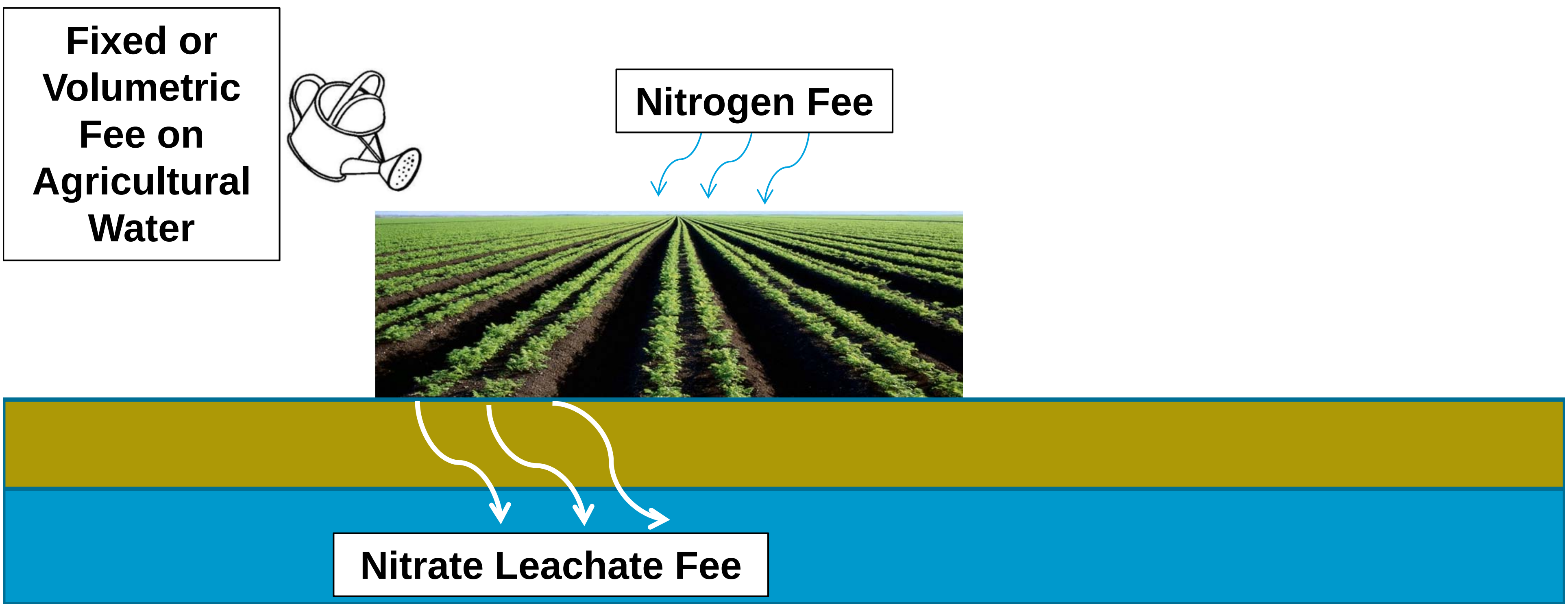

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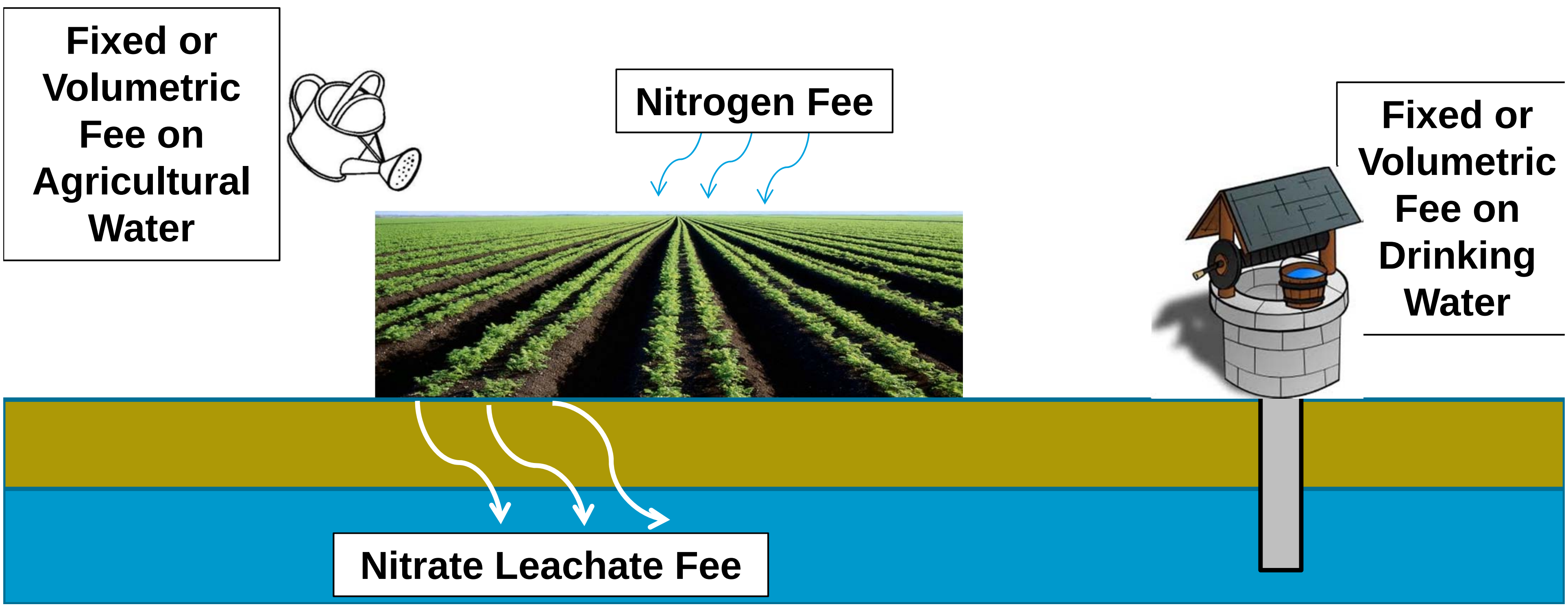

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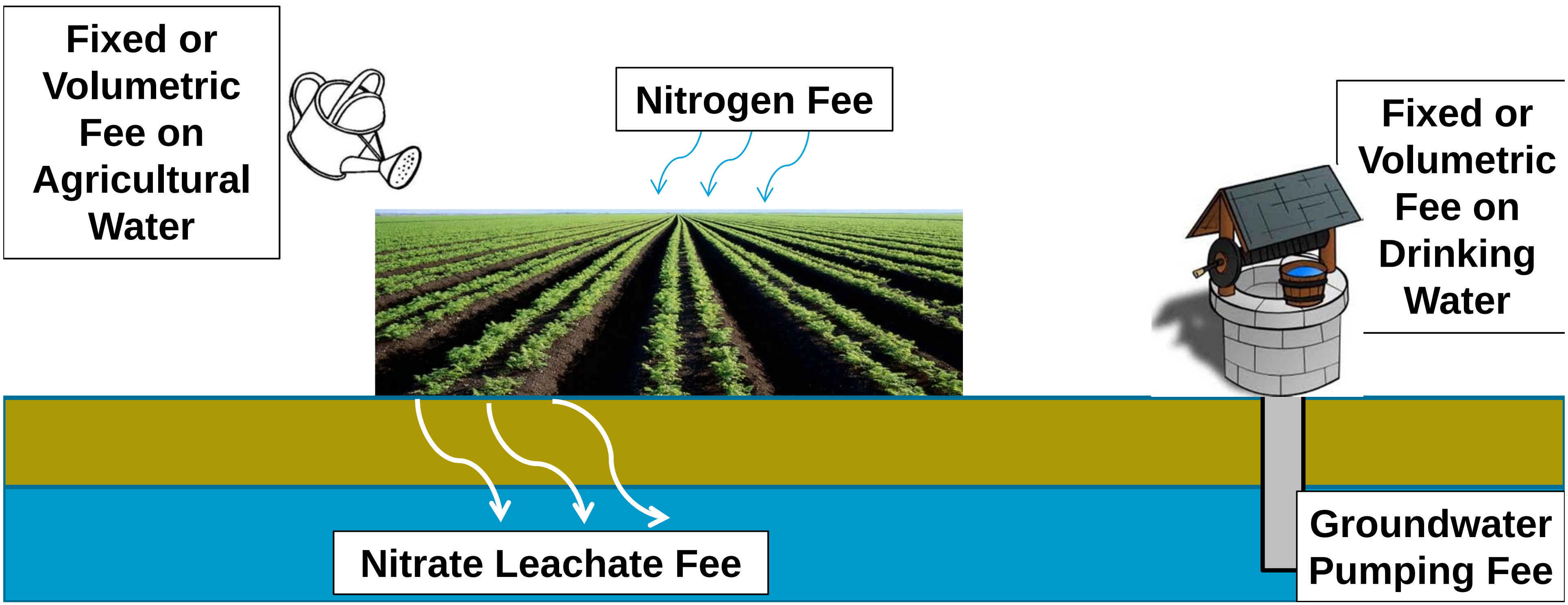

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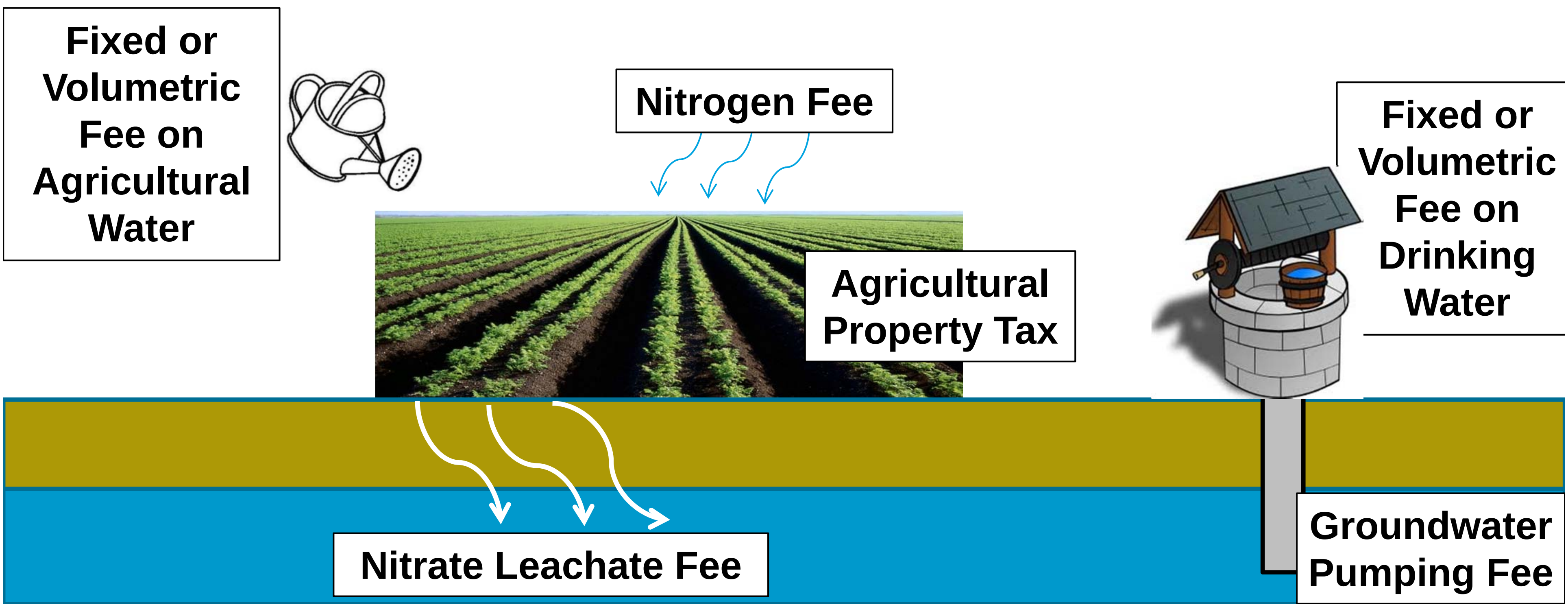

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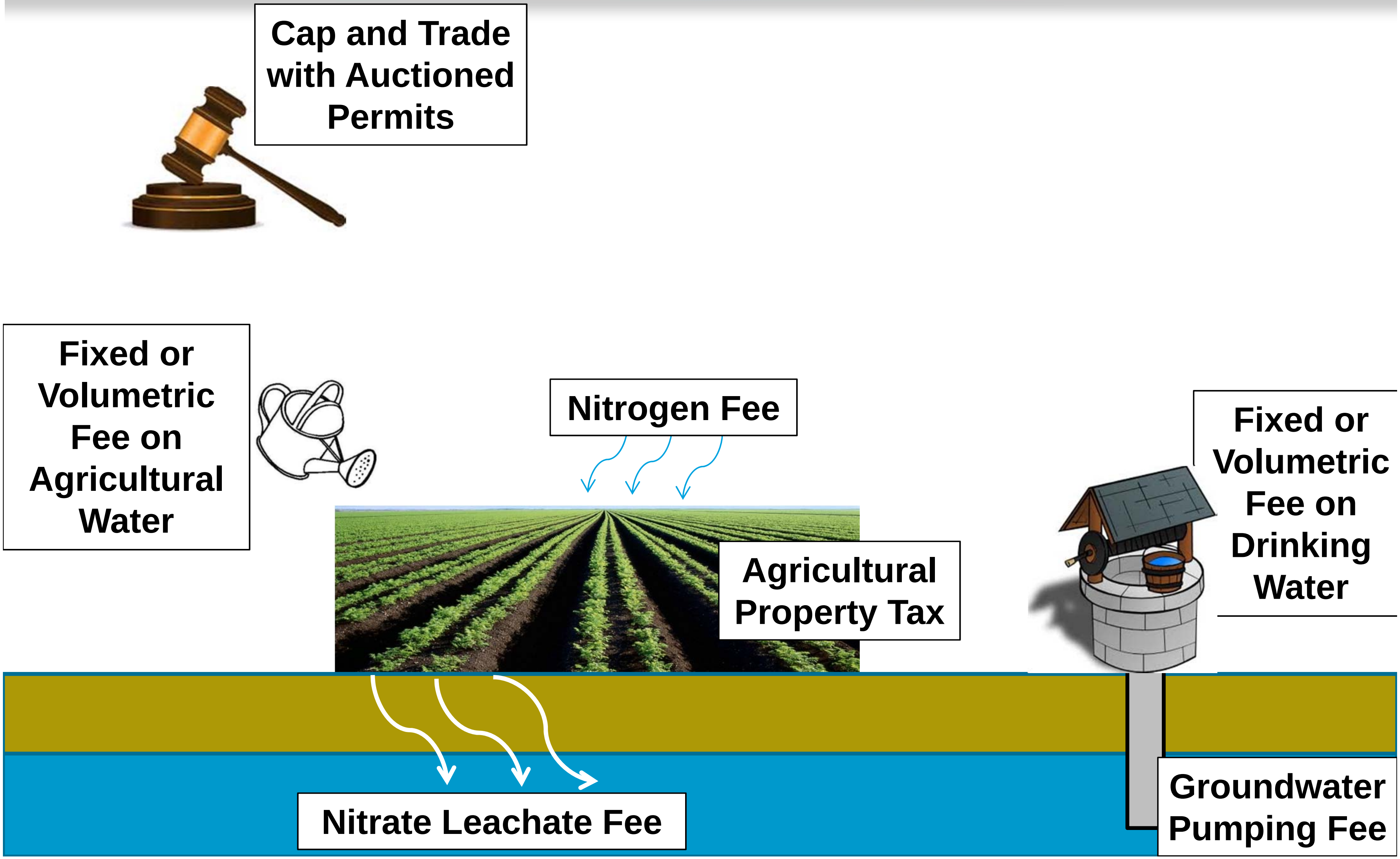

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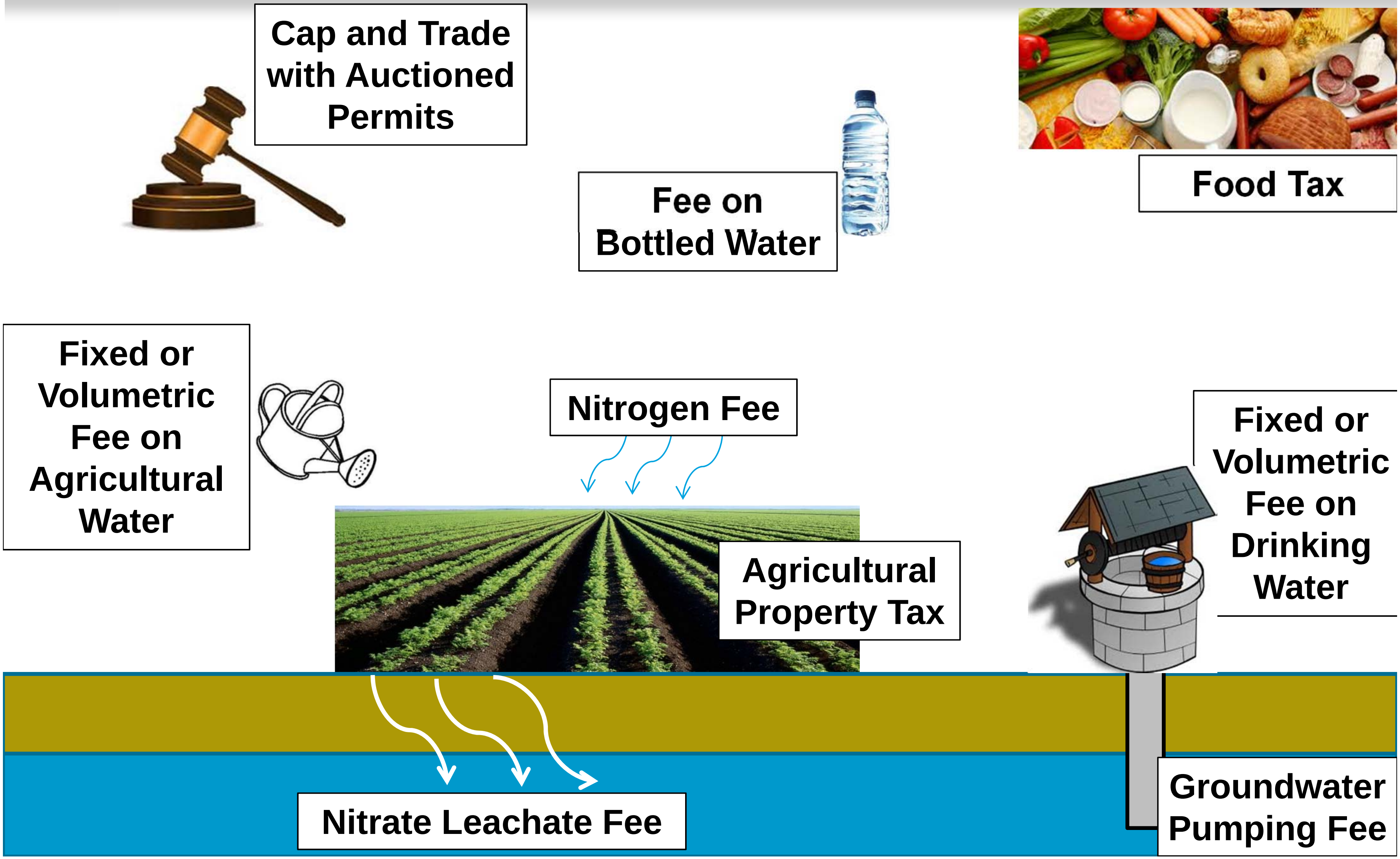

Promising Funding Options for Affected Communities

1. Where appropriate, combine funding programs.

2. Fund long-term drinking water solutions, particularly regionalization of small systems.

3. Increase financial assistance to small systems.

4. Create state funding programs for domestic well owners and for small water systems.

Promising Statewide Funding Options

1. **Increase CDFA's mill assessment rate on nitrogen fertilizer sales to its full authorized amount.**
   - Raises additional $1 Million / year statewide.

2. **Introduce a statewide nitrogen fertilizer sales fee, perhaps equivalent to sales tax.**
   - Could generate $28 Million / year in study area.

3. **Consider a more comprehensive statewide water use fee.**

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UC Davis Report to State Water Board
for its Report to the Legislature

ADDRESSING NITRATE IN CALIFORNIA'S DRINKING WATER,

TULARE LAKE BASIN AND SALINAS VALLEY

Public Release

March 13, 2012

Thomas Harter & Jay Lund, *Principal Investigators*

Jeannie Darby, Graham Fogg, Richard Howitt, Katrina Jessoe, Jim Quinn, Stu Pettygrove, Joshua Viers, *Co-Investigators*

Aaron King, Allan Hollander, Alison McNally, Anna Fryjoff-Hung, Cathryn Lawrence, Daniel Liptzin, Danielle Dolan, Dylan Boyle, Elena Lopez, Giorgos Kourakos, Holly Canada, Josue Medellin-Azuara, Kristin Dzurella, Kristin Honeycutt, Megan Mayzelle, Mimi Jenkins, Nicole de la Mora, Todd Rosenstock, Vivian Jensen, *Researchers*

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