Nitrate Pilot Projects
SBX2 1

State Water Board Meeting
June 21, 2011
Item #6

Erik Ekdahl, PG
GAMA Program
State Water Resources Control Board
Presentation Overview

- SBX2 1 Background
- Preliminary Findings – UC Davis
Why SBX2 1?

- Nitrate is a known groundwater issue
- Central Valley and Central Coast hit hard
- Communities reliant on groundwater with no alternative water supply vulnerable
SBX2 1 Background

- (2009) Water Code Section 83002.5:

  Water Boards required, in consultation with other agencies, to develop **Nitrate Pilot Projects** in Tulare Lake Basin and Salinas Valley
SBX2 1- Nitrate PilotProjects

- Requirements of SBX2 1
  - Identify the sources and causes of groundwater nitrate contamination
  - Identify potential nitrate source reduction, remediation, and treatment solutions
  - Identify funding options to:
    - Clean up existing contamination
    - Treat groundwater
    - Ensure that all communities have clean sources of drinking water
SBX2 1- Nitrate Pilot Projects (cont)

- State Water Board to:
  - Create Interagency Task Force (ITF)
  - Oversee Pilot Projects
  - Report key findings and recommendations to the Legislature
SBX2 1- Nitrate Pilot Projects (cont)

- UC Davis under Contract to perform Nitrate Pilot Project Studies in Tulare Basin and Salinas Valley
Thomas Harter Ph.D.,
UC Davis
SB X2-1
Nitrate in Groundwater
Report to the Legislature

OVERVIEW AND KEY OUTCOMES

Thomas Harter
University of California Davis - SBX2-1 Team

State Water Resource Control Board - June 21, 2011
UCD Project Team Leaders

- Thomas Harter (PI), Subsurface Hydrology
- Jeannie Darby, Water Treatment
- Graham Fogg, Subsurface Hydrology
- Richard Howitt, Agricultural Economics
- Katrina Jessoe, Water Quality Economics
- Jay Lund, Water Resources Management
- Jim Quinn, Spatial Data Mgmt. in Environmental Policy
- Stu Pettygrove, Soils and Nutrient Management
- Tom Tomich, Agricultural Sustainability Institute
- Joshua Viers, Spatial Data Management in Environmental Sciences

FUNDING PROVIDED BY:
- Proposition 84 / SB X 2-1 => CDPH => SWRCB
UCD Project Team

- Aaron King
- Allan Hollander
- Alison McNally
- Anna Fryjoff-Hung
- Cathryn Lawrence
- Daniel Liptzin
- Dylan Boyle
- Elena Lopez
- Giorgos Kourakos

- Holly Canada
- Josue Medellin-Azuara
- Kristin Dzurella
- Kristin Honeycutt
- Mimi Jenkins
- Nate Roth
- Todd Rosenstock
- Vivian Jensen

- ...many undergraduate students....
Timeline

• Data collection and analysis – 2\textsuperscript{nd} Quarter 2011
• Economic and policy analysis – 3\textsuperscript{rd} Quarter 2011
  – 2\textsuperscript{nd} ITF Meeting – May 3, 2011
• Draft report – September 2011
  – 3\textsuperscript{rd} ITF Meeting – October 2011
• Final report – December 2011
• SWRCB Report to Legislature – April 2012
• Directed follow-up studies – April 2013
Motivation

- Nitrate most common groundwater pollutant
- Tulare Lake Basin and Salinas Valley among most affected groundwater basins in CA
- Domestic well water typically untreated / unknown quality
- High nitrate costly to treat for small / disadvantaged communities

How can this be best fixed?
Project Area
Landuse

Study_Areas
Native Vegetation
Barren
Riparian Vegetation
Water Surface
Urban
Citrus and Subtropical
Deciduous Fruits and Nuts
Field Crops
Grain, Rice, and Hay
Idle
Pasture
Alfalfa
Semiagricultural and Incidental to Agriculture
Truck, Nursery, and Berry Crops
Vineyards

0  20  40  60 Mi
0  30  60  90 Km

2010
Key Study Outcomes: Assessment

N Loading / Sources
Nitrate distribution in groundwater / spatial and temporal trends
Key Study Outcomes: Actions

N Loading Reduction Options / Source Control
Key Study Outcomes: Actions

Remediation of groundwater
Key Study Outcomes: Actions

N treatment options
Key Study Outcomes: Costs
Key Study Outcomes: Funding

FUNDING OPTIONS
Framework for Funding and Regulatory Options

N Loading Reductions

Porter-Cologne

Decade(s) later

Groundwater Remediation

Treatment / Alternative Supply
N Loading: Fertilizer

- **Time Frame(s):**
  - 2000-2010

- **Methods:**
  - Land Use Estimates (CAML 2.0)
    - Farmland Mapping Monitoring Program
    - DWR by county (date varies)
    - Cropland Data Layer from National Agricultural Statistics Service (2009)
    - CDF Multisource Land Cover (2002)

- **Results:**

<table>
<thead>
<tr>
<th>Study Basin</th>
<th>Potential N Load Leached (Mg/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinas Valley</td>
<td>9,688</td>
</tr>
<tr>
<td>Tulare Lake Basin</td>
<td>84,775</td>
</tr>
</tbody>
</table>
Fertilizer Loading Reduction Necessary to ~ Meet MCL
N Loading: Animal Farming (Dairies)

Dairy N loading to land application: 114,000 Mg/yr
Dairy N loading directly via corrals and lagoons: 2,000 – 10,000 Mg/yr (Preliminary)
<table>
<thead>
<tr>
<th>Metric Tons (Mg) of N Applied Annually in facility discharge</th>
<th>WWTP (90%)</th>
<th>WWTP (est. 100%)</th>
<th>FP (reported)</th>
<th>FP (est. max)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>By County</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresno</td>
<td>2,344</td>
<td>2,604</td>
<td>303</td>
<td>674</td>
</tr>
<tr>
<td>Kern</td>
<td>913</td>
<td>1,014</td>
<td>455</td>
<td>1,010</td>
</tr>
<tr>
<td>Kings</td>
<td>121</td>
<td>134</td>
<td>167</td>
<td>372</td>
</tr>
<tr>
<td>Tulare</td>
<td>1,583</td>
<td>1,759</td>
<td>91</td>
<td>203</td>
</tr>
<tr>
<td>Monterey</td>
<td>313</td>
<td>348</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td><strong>Basin</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLB</td>
<td>4,961</td>
<td>5,511</td>
<td>1,016</td>
<td>2,259</td>
</tr>
<tr>
<td>SVB</td>
<td>313</td>
<td>348</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,274</strong></td>
<td><strong>5,859</strong></td>
<td><strong>1,031</strong></td>
<td><strong>2,292</strong></td>
</tr>
</tbody>
</table>

These are preliminary estimates and do NOT include applied solids.
Current Groundwater Quality: Highest NO3 per Land Section

2005 - 2010
Maximum in Section
Nitrate as Nitrate (ppm)
- 1 or less
- 1.1 - 15.0
- 15.1 - 22.5
- 22.6 - 45.0
- 45.1 - 90.0
- over 90

Sources: CDPH, USGS, SWRCB, DWR, Private, Counties
Date: April 27, 2011 DRAFT
Projection: NAD 1983 California Teale Albers
Current Groundwater Quality:
Highest NO3 per Land Section & per Dairy
Current Nitrate in Wells with Depth Information

Bakersfield

Fresno

Salinas
Current Nitrate in Wells with Depth Information
## Nitrate in Wells: Long-Term Trends

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean Change [mg/L/yr]</th>
<th>Conf. Interval -95%</th>
<th>Conf. Interval +95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tulare Lake Basin (Tulare County) Public Supply Wells, 1970s-current&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.27 (0.41)</td>
<td>0.17 (0.22)</td>
<td>0.36 (0.59)</td>
</tr>
<tr>
<td>Salinas Valley Public Supply Wells, 1970s-current&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.53</td>
<td>0.31</td>
<td>0.77</td>
</tr>
<tr>
<td>Salinas Valley Dedicated Monitoring Wells, 1990-current</td>
<td>2.04</td>
<td>1.25</td>
<td>2.82</td>
</tr>
</tbody>
</table>

<sup>1</sup> underlying data: all public water supply well data
Raw Water Nitrate Levels Exceeding the MCL (45 mg/L as nitrate) and Consideration of Co-contaminants
Raw Water Nitrate Levels Exceeding the MCL (45 mg/L as nitrate) and Consideration of Co-contaminants

[Map showing distribution of nitrate levels across California, with annotations for different concentration levels and a legend for interpreting the symbols on the map.]
Raw Water Nitrate Levels Exceeding the MCL (45 mg/L as nitrate) and Consideration of Co-contaminants
Community Water Systems

SV: ~295,000 people

TLB: ~2,100,000 people

Water System Boundaries and Size:
- Yellow: 0 - 3,300 people
- Orange: 3,301 - 10,000 people
- Dark brown: 10,001 - 100,000 people
- Red: 100,000+ people
Household Self-Supplied Systems

SV: ~32,000 people

TLB: ~300,000 people

Source: 1990 Census
DATE: May 3, 2011 DRAFT
Projection: NAD 1983 California Teale Albers
Disadvantaged Communities

Source: 2000 Census
DATE: May 3, 2011 DRAFT
Projection: NAD 1983 California Teale Albers
Alternative Water Supply Options

- **Improve Existing Source**
  - Blending
  - Drill Deeper or New Well
  - Community Treatment
  - Household Treatment
  - Centralized Management of POU/POE

- **Create Alternative Supplies**
  - Switch to Treated Surface Water
  - Consolidation
  - Trucked Water
  - Bottled Water

- **Relocate Households**

**Ancillary Activities:**
+ Well Water Quality Testing
* Dual System
System Distribution by Population Served

<table>
<thead>
<tr>
<th>System Size (Population)</th>
<th>Population Served</th>
<th>% of Total Population on CWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Large (100,000+)</td>
<td>1,230,047</td>
<td>52%</td>
</tr>
<tr>
<td>Large (10,001 - 100,000)</td>
<td>860,892</td>
<td>37%</td>
</tr>
<tr>
<td>Medium (3,301 - 10,000)</td>
<td>155,497</td>
<td>7%</td>
</tr>
<tr>
<td>Small (501 - 3,300)</td>
<td>68,246</td>
<td>3%</td>
</tr>
<tr>
<td>Very Small (25 - 500)</td>
<td>32,852</td>
<td>1%</td>
</tr>
</tbody>
</table>
Piped Connection to an Existing System

The Minimum Distance from a Small System to a Larger System [Source: PICME 2010]

- Number of Systems
- Distance (miles)

<table>
<thead>
<tr>
<th>Distance Range</th>
<th>Number of Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1.25</td>
<td>108</td>
</tr>
<tr>
<td>1.25 - 2.5</td>
<td>44</td>
</tr>
<tr>
<td>2.5 - 3.75</td>
<td>52</td>
</tr>
<tr>
<td>3.75 - 5.0</td>
<td>52</td>
</tr>
<tr>
<td>5.0 - 6.25</td>
<td>27</td>
</tr>
<tr>
<td>6.25 - 12.5</td>
<td>56</td>
</tr>
<tr>
<td>12.5 - 25</td>
<td>18</td>
</tr>
<tr>
<td>25 - 28.75</td>
<td>3</td>
</tr>
</tbody>
</table>

(<10,000 ppl) to (>10,000 ppl)
• Ion Exchange
  – Nitrate displaces chloride on anion exchange resin
  – Resin recharge with brine solution
  – Limitations: sulfate, resin fouling, disposal

• Reverse Osmosis
  – Water molecules pushed through membrane
  – Contaminants left behind
  – Limitations: membrane fouling, pretreatment, disposal

• Electrodialysis
  – Electric current governs ion movement
  – Anion and cation exchange membranes
  – Limitations: operationally complex, disposal
• Biological Denitrification
  – Bacteria transform nitrate to nitrogen gas
  – Anoxic conditions
  – Requires electron donor (substrate)
  – Limitations: lack of U.S. full scale systems, substrate requirement, post-treatment (filtration, disinfection)

• Chemical Denitrification
  – Metals reduce nitrate to ammonia (typically)
  – Zero-valent iron (ZVI)
  – Catalytic denitrification
  – Limitations: pilot studies only, reduction to ammonia, dependence on temperature and pH
From CDPH Emergency Regulations, as of December 21, 2010,

“…a public water system may be permitted to use point-of-use treatment devices (POUs) in lieu of centralized treatment for compliance with one or more maximum contaminant levels… if;

1. the water system serves fewer than 200 service connections,
2. the water system meets the requirements of this Article,
3. the water system has demonstrated to the Department that centralized treatment, for the contaminants of concern, is not economically feasible within three years of the water system’s submittal of its application for a permit amendment to use POUs, … no longer than three years or until funding for the total cost of constructing a project for centralized treatment or access to an alternative source of water is available, whichever occurs first…”
Systems Treating or Blending to Address High Nitrate Levels

Stats on treating/blending systems mapped – (wells (depth), population, average influent and effluent nitrate concentration, nitrate, arsenic, sulfate, hardness… Time series?)
### Systems Treating or Blending to Address High Nitrate Levels

<table>
<thead>
<tr>
<th>Type</th>
<th>Population Range (Total)</th>
<th>Max</th>
<th>Min</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ion Exchange</td>
<td>25 – 133,750 (261,200)</td>
<td>71</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Reverse Osmosis</td>
<td>45 – 6,585 (6,760)</td>
<td>75</td>
<td>24</td>
<td>41</td>
</tr>
<tr>
<td>Blending</td>
<td>45 – 25,500 (83,475)</td>
<td>64</td>
<td>3</td>
<td>32</td>
</tr>
</tbody>
</table>
## Example Costs for Alternative Supply Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Example</th>
<th>Est. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Providing POU systems with Maintenance for <strong>Three Years</strong> for Potable Uses Only</td>
<td>A 1,000 person community</td>
<td>$ 200,000</td>
</tr>
<tr>
<td>Providing Bottled Water for <strong>One Year</strong> for Potable Uses Only</td>
<td>A 1,000 person community</td>
<td>$ 400,000</td>
</tr>
<tr>
<td>New 1,400 ft Well</td>
<td>Ducor Community Services District (Population: 600)</td>
<td>$ 700,000</td>
</tr>
<tr>
<td>New 700 ft Well + Pump + Tank + Distribution System</td>
<td>Plainview Mutual Water Company (Population: 800)</td>
<td>$ 2,500,000</td>
</tr>
<tr>
<td>Consolidation</td>
<td>Several Small Communities North of Lamont to the East Niles Community Service District</td>
<td>$ 6,500,000</td>
</tr>
</tbody>
</table>
## Costs by Technology

<table>
<thead>
<tr>
<th>Type</th>
<th>Annualized Capital Cost ($/kgal)</th>
<th>Annual O &amp; M Cost ($/kgal)</th>
<th>Total Annualized Cost ($/kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IX – Literature</td>
<td>0.08 – 0.80</td>
<td>0.15 – 1.25</td>
<td>0.34 – 2.04</td>
</tr>
<tr>
<td>IX – Survey</td>
<td>0.06 – 0.94</td>
<td>0.12 – 2.63</td>
<td>0.41 – 2.73</td>
</tr>
<tr>
<td>RO – Literature</td>
<td>0.81 – 4.40</td>
<td>1.22 – 2.00</td>
<td>2.32 – 5.86</td>
</tr>
<tr>
<td>RO – Survey</td>
<td>0.19 – 3.16</td>
<td>1.15 – 16.16</td>
<td>1.35 – 19.16</td>
</tr>
<tr>
<td>BD</td>
<td>0.47 – 0.83</td>
<td>0.30 – 0.94</td>
<td>0.92 – 1.56</td>
</tr>
</tbody>
</table>

### Treatment costs are unique to individual systems based on:

- system size
- co-contaminants
- location
- treatment type
- blending options
- nitrate level
- disposal options
- seasonal variation
- others…

### Technologies

- **Ion Exchange (IX)**
  - Pro: Generally the least expensive
  - Con: Brine disposal

- **Reverse Osmosis (RO)**
  - Pro: Wide treatment capabilities
  - Con: More expensive

- **Biological Denitrification (BD)**
  - Pro: Long term sustainability
  - Con: Limited application
• Sustainability and sufficiency of main sources unclear

• No/limited funds for Ag investment targeting nutrient mgt/NO$_3$ reduction

• Ag water use efficiency funds to fund NO$_3$ loading reduction?

• Many smaller sources of grant $ for drinking/wastewater for small communities and DACs, BUT: scattered, difficult to access

• Nitrate drinking water contamination investment needed statewide, based only on 2010-11 fundable list > $4/person for capital costs only

• No funds for community water supply regionalization feasibility studies and planning
Regulatory Instruments: Analytical Criteria

• **Cost-effectiveness**
  – Abatement (nitrate reduction) costs to meet a nitrate standard
  – How can a standard be achieved at the least cost?

• **Administrative costs**
  – Bulk of these costs are monitoring and enforcement
  – Costs vary depending on the unit of regulation – few industries or many individuals
  – Future work could quantitatively compare these instruments

• **Information Requirements**
  – What information is needed to implement these regulatory tools?

• **Revenue Raising**
  – Regulatory instruments and funding options overlap
  – Is a regulatory instrument also a source of funding?
Regulatory Instruments Considered

- **Technology mandate (non-market instrument)**
  - Example: Management practices for pesticides

- **Performance standard (non-market instrument)**
  - Example: The dairy regulatory program nutrient management plan, which requires the ratio of N applied to N harvested to be less than 1.65

- **Cap and trade (market-based instrument)**
  - Example: Sulfur dioxide markets in the U.S. to address acid rain; AB 32
  - Overall, a 10% reduction in fertilizer use (5% reduction ha A and 15% ha B)

- **Fee (market-based instrument)**
  - Example: Mill tax; tax on fertilizer that induces a 10% reduction in fertilizer use
  - With C&T choose a quantity (market determines price) and with a fee choose a price (market determines quantity)
Regulatory Instruments Considered

- Information disclosure
  - Example: Consumer confidence reports on drinking water quality (SDWA)

- Liability rules
  - Example: Superfund

- Payment for water quality
  - Analogous to payment for ecosystem services
  - Public pays farmers to not release nitrates or farmer pays gov’t to release nitrate
  - Example: Drinking water in NYC; Perrier and Evian; REDD

- Redesignation of beneficial use
  - Example: Change beneficial use from drinking to another standard
What can be regulated?

• Fertilizer use
  – Regulation on input
  – Advantages: Low administrative costs; low information requirements
  – Disadvantages: Regulating input rather than “pollutant” (i.e. gasoline tax rather than a tax on emissions)

• Nitrate leachate concentration within recharge area of drinking water source
  – Regulation on actual pollutant flux into groundwater recharge area
  – Advantages: Regulate the pollutant of interest; achieve policy objective
  – Disadvantages: High administrative costs (non-uniform mixing); high information requirements; uncertainty in assessing recharge area for specific source

• Other ideas?
  – Nitrate emissions concentration – concentration of nitrate emissions released into source (not account for non-uniform mixing)
  – Nitrate emissions volume – volume of nitrate emissions released into source
Funding Options: Water Fees

- Fixed monthly fee on drinking water for CA residents
- Volumetric fee on drinking water for CA residents
  - Option: Fee for “high quantity” consumers
- Tax on irrigated water
- Fixed fee on agricultural water
- Fertilizer or nitrate tax
- Groundwater pumping fee
- Fee on bottled water (similar to recycling fee)
Funding Options: Other Fees

- Fertilizer tax
- Nitrate emissions tax
- N leachate tax
- Food tax
- Agricultural property tax
- Auctioned fertilizer or nitrate permits (cap and trade)
- Septic tank discharge
- Waste water discharge
- State water bonds
Nitrate problem will likely worsen and not improve for several decades.

Largest regional sources are agricultural fertilizers and animal wastes; other sources are locally relevant.

Nitrogen loading reductions possible, but will take decades to benefit drinking water sources.

Short-term solutions are blending, treatment, and alternative water supplies.

Treatment is unaffordable for most small communities.

Promising funding options, incentives, and regulatory tools are identified.

Incoherence and inaccessibility of data prohibit better and continuous assessment.