SBX2 1 Nitrate in Drinking Water:
UC Davis “N Tracking Analysis” to Estimate Potential Groundwater N Loading

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All technical details are documented in Viers et al. (2012), http://groundwaternitrate.ucdavis.edu/files/139110.pdf
Purpose and Expected Outcome

SBX2 1 (Perata, 2008) – Water Code Section 83002.5: “To **improve** understanding of the causes of groundwater contamination […], the State Water Resources Control Board […] shall develop pilot projects in the Tulare Lake Basin and the Salinas Valley that **focus on nitrate contamination** and do all of the following:

(a) (1) […] utilizing existing data […] along with the collection of new information as needed […]:

- (A) **Identify sources, by category of discharger,** of groundwater contamination due to nitrates in the pilot project basins.
- (B) **Estimate proportionate contributions to groundwater** contamination by source and category of discharger.

*(emphasis added for clarity)*
Data Elements 1 – N Leaching Estimation

1. Some N Leaching to groundwater was estimated using literature-derived or permit-specified leaching values (spatial scale identified in parentheses):
   - Lawns (available maps of urban area boundaries)
   - Golf courses (parcels in DWR landuse survey)
   - Urban wastewater system leaching (available maps of urban area boundaries)
   - Wastewater treatment plants, food processors (location from discharge permit records)
   - Septic systems (estimated density/location based on US census, 1990)
   - Dairy lagoons and corrals (digitized/mapped from aerial photos)
   - Alfalfa (leguminous crop) (parcels in DWR landuse survey)

2. Farmland N leaching to groundwater (except alfalfa) was estimated by N mass balance (by individual parcels in DWR landuse survey):

   \[ N \text{ leached to groundwater} = \]
   \[ N \text{ inputs to farmland } MINUS \ N \text{ outputs from farmland root zone} \]
   \[ (\text{that is: } N \text{ outputs other than } N \text{ leached to groundwater}) \]
Data Elements 2 – Potential Farmland N Inputs

- Synthetic fertilizer N
- Wastewater treatment plant / food processor effluent N
- Biosolids N
- Dairy manure N (on dairy-farm or exported)
- Atmospheric deposition N
- Irrigation water N
Data Elements 3: Potential Farmland N Outputs

- Atmospheric losses N (ammonia volatilization, denitrification)
- Harvested N
- Surface runoff N
- *Groundwater leaching N (estimated)*
- *Storage changes in perennial crops/root zone N*: we assumed to be negligible due to long-term averaging of N fluxes, recycling of plant residues, and lack of significant, wide-spread build-up of organic matter across the project area soils over the past decades.
Explaining the Mass Balance Approach to Estimate N Leaching to Groundwater

Mass balance requires that:

<table>
<thead>
<tr>
<th>Synthetic fertilizer N</th>
<th>Atmospheric losses N</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Wastewater effluent N</td>
<td>+ Harvested N</td>
</tr>
<tr>
<td>+ Biosolids N</td>
<td>+ Surface runoff N</td>
</tr>
<tr>
<td>+ Dairy manure N</td>
<td>+ Leaching N to groundwater</td>
</tr>
<tr>
<td>+ Atmospheric deposition N</td>
<td>+ Storage Change in N in root zone</td>
</tr>
<tr>
<td>+ Irrigation water N</td>
<td>[Mathematical Equation]</td>
</tr>
</tbody>
</table>

[Add any additional explanations or diagrams here]
Explaining the Mass Balance Approach to Estimate N Leaching to Groundwater

After setting “storage change in N” to zero and rearranging the mass balance equation, we obtain the following formula to estimate N leaching to groundwater:

\[
\text{Leaching N to groundwater} = \text{Synthetic fertilizer N} + \text{Wastewater effluent N} + \text{Biosolids N} + \text{Dairy manure N} + \text{Atmospheric deposition N} + \text{Irrigation water N}
\]

\[- \text{Atmospheric losses N} + \text{Harvested N} + \text{Surface runoff N}\]
Spatial Scale: Resolution of Available Data

- Many different spatial scales – examples:
  - Aerial N deposition: modeled for California at a model grid resolution scale of several miles
  - Wastewater treatment plant: very specific N data, local maps
  - Nitrate in irrigation water: average (one number) for each groundwater sub-basin
  - N application and N harvest: by crop type (58 crop types; no distinction by soil, farm, ownership, irrigation type, location etc.)
  - Atmospheric losses of N from root zone: 10% of total N application (uniform across study area)
  - Landuse
    - DWR landuse maps: high resolution (landuse parcels, meter scale accuracy)
    - County Agricultural Commissioner reports: county total landuse acreages
Spatial Scale: Assessment/Analysis

• N Mass Balance / Estimation of Nitrate Loading to Groundwater was performed at 4 different scales (resolution):
  o 50 m x 50 m grid cells for spatial mapping (“pixels”)
  o Discharger category totals and averages
  o County totals and averages (Fresno, Kern, Kings, Monterey, Tulare)
  o Study area totals and averages (Tulare Lake Basin & Salinas Valley)
The next slide shows, in map form, the mass balance procedure used to estimate groundwater N loading. Please note that

• Storage change of N in the root zone is assumed to zero.
• The atmospheric loss N output is assumed to be 10% of all N inputs. Hence, it is accounted for by multiplying the sum of all N inputs with 0.9 before subtracting the two other outputs (harvest and runoff).
• The spatial resolution of the maps is 50 m x 50 m pixels (about 1 acre). The mass balance was computed separately for each pixel.

The second slide (after the next) shows the mass balance equation at a different spatial (resolution) scale: The pie-chart represents N fluxes aggregated over the entire study area.

• Left half = N inputs
• Right half = N outputs
Total Nitrogen Inputs: 420,000 tons N/yr

- Irrigation water
- Atmosphere
- Synthetic Fertilizer
- Biosolids
- Effluent
- Poultry, Swine
- Dairy Manure

Total Nitrogen Outputs: 420,000 tons N/yr

- Atmosphere
- Runoff
- Leaching to Groundwater
- Harvest

Scale: Study Area

Nitrogen Inputs:
- Irrigation water
- Synthetic Fertilizer
- Biosolids
- Effluent
- Poultry, Swine
- Dairy Manure
- Atmosphere

Nitrogen Outputs:
- Irrigation water
- Synthetic Fertilizer
- Biosolids
- Effluent
- Poultry, Swine
- Dairy Manure
- Atmosphere
- Runoff
- Leaching to Groundwater
- Harvest
Temporal Resolution

• Annual nitrogen fluxes, which are averaged over five-year periods:
  o 1943-1947 => “1945” period
  o 1958-1962 => “1960” period
  o 1973-1977 => “1975” period
  o 1988-1992 => “1990” period
  o 2003-2007 => “2005” period
The next slide shows, in map form, the temporal evolution of N leaching to groundwater. The spatial resolution of these maps is 50 m x 50 m pixels (about 1 acre).

The second slide (after the next) shows the temporal evolution of four elements of the mass balance equation in aggregated form for the entire study area:

- Synthetic N inputs
- Dairy manure N inputs
- Harvested N outputs

- *also shown:* Total acreage harvested
Cropland Area

tons N/yr

study area scale

Cropland Area (without Alfalfa)

- Synthetic Fertilizer + Manure
- Synthetic Fertilizer
- Harvest
- Manure


0 0 0

440,000 330,000 220,000 110,000

4M ac 3M ac 2M ac 1M ac

ac
Reporting Mechanisms

• All data collected from existing sources
Benefits

• Provides scientifically best estimate of “proportionate contribution to groundwater contamination by source and by discharger category” (SBX2 1), GIVEN available data, funding, and scope/purpose of the study

• Identifies long-term trends

• Provides overall magnitude of N fluxes at crop category / county / study area level

• Shows patterns of spatial distribution of potential groundwater nitrate loading
Challenges in Applying the Approach to Field / Farm / Township Scale

• Estimates are uncertain for a specific field/farm due to variability in soils/irrigation/farm practices (no available data)

• Atmospheric losses (volatilization, denitrification) variable, few specific measurements available (here: 10% of total land applied nitrogen, appropriate at county scale)

• Harvested N based on reported county average crop yields per acre (county ag commissioner) and USDA estimates of moisture and nitrogen content per yield unit. No crop/farm/field specific data available.

• Synthetic fertilizer N use based on crop-specific surveys by USDA, UC Davis. No crop/farm/field specific data available.

• Short-term N storage changes in the root-zone and in perennials not included.