ESM 202
Modeling Biogeochemistry to Inform Policy Decisions

Problem Statement
- DO levels are low during certain times of the year
- Excessive algal growth
- Hypoxia (e.g. Gulf of Mexico)
- Toxic levels of NH₃
- WQ Objectives exceeded
  - Define objectives/criteria
  - Define protocol for monitoring

Define Conceptual Model
- What compartments will be considered?
- What processes are important?
- What are some of the interactions between different chemicals?
- How do biota affect the processes?
**Types of Models**

- **Mass Balance & Steady State Conditions**
  - Determine water balance for period of interest
  - Determine N&P fluxes into waterbody
    - Point Sources (average discharge flux = conc x flow)
    - Export from Non-Point Sources (average contribution)
      - Agriculture
      - Atmospheric Deposition
      - Urban runoff (lawns, golf courses, parks)
      - Septic Systems
      - Groundwater
      - Livestock
  - Calculate concentrations (mass chemical/volume water)
  - Estimate rate(s) of transformation

- **Dynamic Models**
  - Water flow driven by meteorology
  - Determine variable N&P fluxes to watershed
    - Non-Point Sources (atmos dep, ag, urban, septs, …)
    - Determine N&P assimilation in watershed
    - Calculate export of N&P in runoff & GW
  - Determine variable N&P fluxes into waterbody
    - Point Sources (can consider daily variation)
    - Non-Point Sources (runoff, GW)
    - Estimate rate of transformation in stream/lake
    - Calculate concentrations in stream/lake

**Local Hydrologic Model**

- **Hydrology in a Catchment**

**Sources of Nutrients**

- Atmospheric Deposition
- Fertilizer application
- Septic systems
- Groundwater irrigation
- Livestock & manure
- Treated wastewater
Watershed Processes

Dry deposition of nitrate
Dry deposition of ammonia
Wet deposition of nitrate
Wet deposition of ammonia
Throughfall (chemical not taken up by canopy)

\[ \text{NH}_4^+ \rightarrow \text{NO}_3^- \]

Shallow infiltration
Deep infiltration
Weathering releases P, N, Ca, ...

Microbial decomposition

\[ \text{CO}_2 \rightarrow \text{HCO}_3^- \]

\[ \text{O}_2 \rightarrow \text{HCO}_3^- \]

Export of NO\textsubscript{3}^- & DON in runoff, P in sediments

Export of N, P
Alk, Ca in GW

Fertilizer application
\[ \text{NH}_4\text{NO}_3/\text{PO}_4/\text{K} \]

Increased Export of NO\textsubscript{3}, DON, P
Increased Export of N, P in GW

Case Study
Santa Clara River

Impairment due to high DIN

Los Angeles Regional Water Quality Control Board
Watersheds, Lakes, and Rivers

Legend
Region 4
Boundaries
Lakes
Rivers

Santa Clara River Watershed
Ventura County
Los Angeles County

Santa Clara River

California

Pacific Ocean

Los Angeles

Ventura

Palm Desert

US-101

Los Angeles County Water

Santa Clara River

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Impairment due to high DIN
Nitrate + Nitrite

"Not to exceed 10 mg/L nitrogen as nitrate-nitrogen plus nitrite-nitrogen, 45 mg/L as nitrate, 10 mg/L as nitrate-nitrogen, or 1 mg/L as nitrite-nitrogen"

\[
\text{NO}_2^- \rightarrow \text{NO}_3^-
\]

\[
\frac{\text{MW}_{\text{NO}_2^-}}{\text{MW}_N} = \frac{62}{14} = 4.43
\]

10 mg/L as NO$_3$-N = 45 mg/L as NO$_3$-

**Ammonia CCC**

Table of observed pH data

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Reach 8</th>
<th>Reach 7 above Valencia</th>
<th>Reach 7 below Valencia</th>
<th>Reach 7 at County Line</th>
<th>Reach 3 above Santa Paula</th>
<th>Reach 3 at Santa Paula</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 percentile</td>
<td>7.16</td>
<td>7.69</td>
<td>7.78</td>
<td>7.78</td>
<td>7.81</td>
<td>8.00</td>
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<tr>
<td>90 percentile</td>
<td>7.53</td>
<td>7.80</td>
<td>7.84</td>
<td>7.90</td>
<td>8.00</td>
<td>8.00</td>
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<tr>
<td>Mean</td>
<td>7.31</td>
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<td>7.81</td>
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<td>7.95</td>
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<td>Std. deviation</td>
<td>0.22</td>
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<td>0.32</td>
<td>0.26</td>
<td>0.29</td>
<td>0.31</td>
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<tr>
<td>CV*</td>
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<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Statistics of observed temperature data (in °C)

<table>
<thead>
<tr>
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<th>Reach 8</th>
<th>Reach 7 above Valencia</th>
<th>Reach 7 below Valencia</th>
<th>Reach 7 at County Line</th>
<th>Reach 3 above Santa Paula</th>
<th>Reach 3 at Santa Paula</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 percentile</td>
<td>19.95</td>
<td>19.33</td>
<td>20.20</td>
<td>20.20</td>
<td>20.00</td>
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<td>19.22</td>
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<td>Std. deviation</td>
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<td>3.97</td>
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<tr>
<td>CV*</td>
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<td>0.22</td>
<td>0.22</td>
<td>0.32</td>
<td>0.14</td>
<td>0.17</td>
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</tbody>
</table>

Historical Water Quality

**SCR Reach 7 below Valencia WWTP**

- Observed data
- Simulation
- Numerical Target

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**SCR Reach 7 below Valencia WWTP**

- Observed data
- Numerical Target
**Historical Water Quality**

- Watershed delineation

---

**Watershed Model**

- Define watershed
- Load watershed characteristics
- Load meteorology
- Load PS and NPS data
- Calibrate Hydrology
- Calibrate Water Quality
- Determine sensitivity to key parameters
- Use it for decision support
**Soil Types**

Land Use Map, Data from 2002

**Daily Precipitation**

Santa Clarita, CA

**Point Sources**

PS Flow: Temporal pattern

Flow = 4.00E-05x - 0.997

PS Concentration: Temporal pattern

**Septic Systems**

Table 1: Septic Systems, Flow, and Loading

<table>
<thead>
<tr>
<th>Subregion</th>
<th>People</th>
<th>Flow, m^3/d</th>
<th>( \text{NH}_4)-N, kg/d</th>
<th>PO4-P, kg/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mint Canyon Creek</td>
<td>463</td>
<td>131</td>
<td>4.21</td>
<td>0.79</td>
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<td>Santa Clara River Reach 9</td>
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<td>27.83</td>
<td>5.22</td>
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<td>364</td>
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<tr>
<td>Santa Clara River abv. Sespe Ck</td>
<td>526</td>
<td>149</td>
<td>4.78</td>
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<tr>
<td>Sespe Creek</td>
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<td>1.49</td>
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<td>19</td>
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<td>0.11</td>
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<tr>
<td>Brown Barranca / Long Canyon</td>
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<td>0.6</td>
<td>0.02</td>
<td>0.003</td>
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<tr>
<td>TOTAL WATERSHED</td>
<td>7484</td>
<td>2166</td>
<td>69.30</td>
<td>12.99</td>
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</tbody>
</table>

**Fertilizer**

Table 1: Monthly Land Application of Nitrate, kg/d as N

<table>
<thead>
<tr>
<th>Region</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
<tr>
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<td>0</td>
<td>32</td>
<td>32</td>
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<td>795</td>
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Average Daily Land Application of Nitrate, kg/d as N
Sources of Nutrients

Number of times lawn fertilized

Chesapeake Bay survey (1999) by Center for Watershed Protection

Timing of Residential Fertilization

Chesapeake Bay survey (1999) by Center for Watershed Protection

Calibration: Hydrology

SCR Reach 7 below Valencia WWTP

Model Calibration

In-stream Flow
Interpretation of Results

Sources of Nutrients

Upper SCR

Fertilization
Atmospheric Deposition
Well Pumping Irrigation
Direct Point Sources
Groundwater Discharges
Diversions
Septic Systems

Loading, kg/d

Sources of Nutrients

Lower SCR

Fertilization
Atmospheric Deposition
Well Pumping Irrigation
Direct Point Sources
Groundwater Discharges
Recharge/Irrigation

Linking Sources to Water Quality

Ammonia

Santa Clara River Watershed

Nitrate

Linking Sources to Water Quality

Santa Clara River Watershed

Nitrite

Linking Sources to Water Quality

Point
Non-Point

Upstream/GW

Point
Non-Point
Sources of Nutrients

Reach 7 below Valencia: Source Contributions

Nitrate + Nitrite (mg N/L)

PS contribution
NPS contribution
GW contribution
Atmospheric contribution

Evaluating Alternatives

New NDN

NH₃/NH₄⁺ + NO₃⁻ + N₂(g)

Evaluating Alternatives

Policy Options

- Implement NDN in WWTPs in SCR
  - Major reduction of ammonia & nitrite
  - Slight increase in nitrate
  - Within SCR assimilation capacity
  - Well-within drinking water MCL
  - $5-10 million in WWTP upgrades
- Reduce NPS
  - 20% reduction of ag fertilizer in 7 years
  - Stormwater monitoring
  - Education campaign
- Tradable Permits?
- Monitoring Program for success of implementation