Linking field measurements and numerical modeling to understand fluvial transport processes and nitrate retention in the Suncook River, NH

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Nitrate Transport and Retention in Rivers

- Rivers can remove up to 80% of nitrogen inputs (Wollheim et al. 2013, WRR 47)
- Hot spots: Locations of increased uptake
- Hot moments: Times of increased uptake due to changes discharge or biogeochemistry
Nitrate Uptake in Rivers

Grab Samples (8/2001)

No uptake

With uptake

Figure adapted from: Stewart et al. 2011, WRR 47
Data Source: NH hydrography dataset, NH public roads, and NH political boundaries form NH Granit, http://www.granit.unh.edu/
Suncook River Hydrology


Bathymetry and Field Measurements

Tracer Studies: Lateral Mixing

Direction of Flow
Tracer Studies: Transient Storage

Time Since Release:
- 9 min
- 13 min
- 16 min
- 22 min
- 28 min
Transport Compared to Other NH Rivers

NH River Data: Smith. 2002, USGS
Nitrate Uptake from Field Measurements

- Use measured breakthrough curves to estimate transport
- Assume spatially uniform uptake rate constant, $k=1.3 \text{ day}^{-1}$ (Wollheim et al. 2014, Biogeochemistry)
- Assume constant nitrate loading
Linking measurements and hydraulic modeling

- Hydraulic modeling to explore the effect of nitrate transport on reach-scale retention
- Delft3D-Flow
  - 2D hydraulic model
  - Shallow water equations
  - Boundary Conditions
  - LiDAR Bathymetry
Depth Averaged Velocity

Reach 1
Q = 5.43 m³/s

Eddy Formation

Comparison cross section

Steady State Simulation

Comparison to Measurements
Reach 1
Q = 5.43 m³/s

<table>
<thead>
<tr>
<th>Distance from left bank (m)</th>
<th>Observed Depth</th>
<th>Predicted Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<tr>
<td>10</td>
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<tr>
<td>20</td>
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</table>

Steady State Simulation

Comparison to Observations
Breakthrough Curves

- Numerically simulate Rhodamine WT instantaneous release.
- Front Arrival Time Difference: 2.75 min
- Peak Arrival Time Difference: 4.25 min
Next Steps

- Simulate nitrate transport at multiple discharges.
- Compare spatially uniform and spatially variable uptake rate constant.
- Assume constant nitrate loading.
- Establish relationship between discharge and reach-scale nitrate retention during steady flow conditions.
- Explore nitrate retention during unsteady flow conditions.
- Estimate nitrate transport and seasonal averaged retention at the reach scale.

![2015 Summertime Hydrograph](image)
Conclusions

• Nitrate transport and retention may be influenced by geomorphology and discharge levels.

• Hydraulic models can be used to explore the effects of transport on reach-scale retention.

Thank you! Questions?
Additional Tracer Studies

- Discharge (m³/s)
- Rhodamine WT (mg/L)
- Time Since Release (min)

- Measured RWT
- Gaussian Curve
- Detention Time
- Peak Arrival
- Measured Discharge
- Reach Discharge

Graphs showing the relationship between discharge, rhodamine concentration, and time since release.
Step 1: Hydrodynamic Modeling

- Identify area of interest

  
  - Set up hydrodynamic model: Grid creation, interpolate bathymetry, set observation points.
  
    
    - Prepare boundary conditions and initial conditions
    
      
      - Calibrate and validate hydrodynamic model for steady conditions
      
        
        - Simulate low to moderate flows

  
  
  Hydrodynamic model results:
  Depth averaged velocity, water depth, etc.

Step 2: Water Quality Monitoring

- Set up water quality model (spatially uniform and varied nitrate uptake)

  
  - Input hydrodynamic model results
    
      
      - Set nutrient process parameters
      
        
        - Validate water quality model
        
          
          - Water quality model results:
            Nitrate retention and transport
Table ##: Summary of USGS gage recorded discharge, measured reach discharge, location, and date, time of tracer release, reach length, mass of tracer released, and fluorometer recording interval for the tracers studies conducted on the Suncook River from July to November 2015.

<table>
<thead>
<tr>
<th>USGS Gage Discharge (m³/s)</th>
<th>Reach Discharge (m³/s)</th>
<th>Location</th>
<th>Date</th>
<th>Time of release</th>
<th>Reach Length (m)</th>
<th>Mass Released (g)</th>
<th>Recording interval (s)</th>
<th>Mass Recovered</th>
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