Groundwater Nitrate Removal Capacity of Riparian Zones in Suburbanizing and Agricultural Watersheds in RI

TK Watson¹, DQ Kellogg¹, K Addy, AJ Gold¹, MH Stolt¹, PM Groffman²

¹ University of Rhode Island
² Cary Institute of Ecosystem Studies
Riparian areas can function as ground water denitrification “hot spots” on the landscape.

**Microbial Denitrification**

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

- Anaerobic
- Needs electron donor (usually organic carbon)

**In riparian zones:**
- Water tables approach soil surface \(\rightarrow\) anaerobic conditions
- Subsurface carbon enrichment
  - organic soils
  - buried horizons, reflecting fluvial processes

Diagram:
- Fertilizers
  - Animal Waste
  - Human Waste

\(\text{Atmospheric} \quad \text{N}_2\)

\(\text{Upland} \quad \text{NO}_3^-\text{-N} \quad \text{NH}_3^-\text{-N} \quad \text{NO}_x\)

\(\nabla \quad \text{Denitrification} \quad \text{N}_2, \text{N}_2\text{O}\)

\(\text{Stream} \quad \text{NO}_3^-\text{-N} \quad \text{Completing the cycle}\)
Research Question:
Does watershed disturbance related to suburbanization or agriculture alter riparian ground water denitrification capacity as compared to undisturbed watersheds?
Potential stream responses to suburbanization:

- Culverts → flow restrictions at stream crossings
- Peak flows higher and faster during storms
- Stream channel enlargement by incision and downcutting
- Sediment deposition
  - mineral or organic debris, i.e. yard wastes
- Braiding
Potential water table responses to suburbanization:

**Lowered water tables**
- Reduced ground water recharge
- Stream incision

**Raised water tables**
- Stream crossing flow restrictions
Potential stream and water table responses to agriculture

Possible sedimentation, depending on management

![Image of a person collecting water samples near a stream with a silt containment fence marked.](image-url)
Possible sedimentation, depending on management
Water tables influenced by irrigation and/or subsurface drainage

Potential stream and water table responses to agriculture

Silt containment fence
Riparian Site Selection

3 sites with watersheds dominated by “Ag”
- ≤ 5% impervious cover
- ≥ 22% agriculture
- irrigation from adjacent high volume wells

3 sites with watersheds dominated by unsewered “Suburban”
- ≥ 35% impervious cover
- ≤ 3% agriculture

3 sites with watersheds dominated by “Forest”
- < 3% impervious cover
- 0% agriculture
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Common features:
- Hydric soils
- Low gradient
- Alluvial or outwash material
- 1st, 2nd, or 3rd order streams
- Forested riparian vegetation
APPROACH

Assess the potential for riparian ground water denitrification in developed watersheds by examining:

- Water table dynamics
- Soil morphology
- In situ denitrification capacity
Water Table Monitoring

- Water table wells at each site
- Monthly sampling over 20 months

Noted stream channel enlargement
- Incisement
- Braiding
Soil Morphology

Used high volume pumps to lower the water table in soil pits to identify:

- Signs of disturbance
- Buried organically-enriched layers

Buried organic layers at an “Ag” site
In situ denitrification capacity

- 3 “shallow” mini-piezometers (50-90 cm depth)
- 3 “deep” mini-piezometers (150-200 cm depth)
In situ denitrification capacity

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**Ambient sampling of mini-piezometers:**

- dissolved oxygen
- dissolved organic carbon
- NO$_3$-N
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- dissolved oxygen
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*Push-pull in situ denitrification capacity assessment*
**Push-Pull Method**  
(Addy et al., 2002)

1. Pump groundwater
2. Amend with $^{15}\text{NO}_3^-$ and Br$^-$
3. Lower DO to ambient levels
4. Push (inject) into well
5. Incubate
6. Pull (pump) from well
7. Analyze samples for $^{15}\text{N}_2$ and $^{15}\text{N}_2\text{O}$, the products of microbial denitrification
RESULTS: Mean Annual Water Table Depth vs. Dominant Watershed Land Use

- Agriculture
- Suburban
- Forest

$p < 0.05$
<table>
<thead>
<tr>
<th>Summer Water Table Depths (cm)</th>
<th>Lower (25%) Quartile</th>
<th>Upper (75%) Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>19</td>
<td>48</td>
</tr>
<tr>
<td>Suburban</td>
<td>10</td>
<td>62</td>
</tr>
<tr>
<td>Forest</td>
<td>26</td>
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Our “Ag” sites had high volume irrigation wells in the adjacent upland that contributed to lower riparian water tables.
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• Our “Ag” sites had high volume irrigation wells in the adjacent upland that contributed to lower riparian water tables.

• Incisement or braiding was noted at all “Suburban” sites and one “Ag” site.
RESULTS: Ground Water Denitrification Capacity vs. Dominant Watershed Land Use

Cumulative Measurements (%)

Ground-water Denitrification Capacity (μg N/kg soil/day)

- Agriculture (n = 15)
- Suburban (n = 15)
- Forest (n = 27)
RESULTS: Ground Water Denitrification Capacity vs. Dominant Watershed Land Use

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High variability in denitrification capacity among "suburban" sites

"Suburban" site with the highest denitrification capacity:

Possible carbon sources:

- Many buried organic layers and lenses
- Buried partially decomposed grasses

Ambient water table depth
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Ambient water table depth

Plastic found at 60 cm depth → deposition occurred since WWII
Denitrification capacity did not correlate with
- Dissolved oxygen
- Dissolved organic carbon
- Soil organic matter
- Ambient nitrate concentrations
Streams in developed watersheds are dynamic and display an array of depositional patterns.

– Culverts contribute to complexity and variability of riparian structure in urbanizing watersheds.
Increased velocity associated with storm flows can carry large loads which may be deposited onto riparian zones. **Organic debris** → may contribute labile carbon. **Mineral sediment** → may create deep zones that lack substantial labile carbon pools.
Summary

- Array of disturbances restricts our ability to relate ground-water denitrification capacity to generalized watershed characteristics.

- In developed watersheds, forested riparian ecosystems may not reflect the riparian N sink functions observed in forested watersheds.
How can stream restoration alter/enhance riparian functions in developed watersheds?
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“Shopping Cart Island”