Predicting Changes in Nitrogen Flux Due to Truckee River Restoration with Hydrologic Simulation Program-Fortran (HSPF)

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Outline

- Introduction
- Background
- HSPF Modeling
- Results
- Summary
- Conclusion

Excavated wetlands at McCarran Ranch
Introduction

• Increased urbanization affects habitat and water quality

• Purpose of study:
  – Simulate restoration on the lower Truckee River to assess changes in nitrogen flux due to restoration

• Developed 2004 HSPF Model
McCarran Ranch Study Area

Truckee River basin (courtesy USGS)

McCarran Ranch area
Restoration

- Restoration conducted worldwide to:
  - Repair habitat
  - Create more natural flow conditions
  - Provide flood protection

Restoration at McCarran Ranch
(Photo courtesy of Louis Provencher, The Nature Conservancy)
Restoration on Truckee River

- McCarran Ranch through October, 2003
  - Reconnect river to floodplain
  - Rearing ponds for threatened species
  - Create in-river habitat
  - Improve water quality

Leopard frog rearing ponds
Nitrogen

Nitrogen is a nutrient of concern because:

– Limiting nutrient on lower Truckee River
– Excessive plant growth leads to dissolved oxygen swings
– Nitrogen TMDL at Lockwood
  • Total Maximum Daily Load (TMDL) = 454 kg d\(^{-1}\) (1000 lb d\(^{-1}\))

Railroad bridge – end of Reach 311
Nitrogen

• Sources of nitrogen inputs:
  – Agricultural or urban runoff (non-point sources)
  – Municipal or industrial discharges (point-sources)
    • TMWRF – Truckee Meadows Water Reclamation Facility

Irrigation return flow
Assimilative Capacity

- Ability of the Truckee River to assimilate nitrogen loads
- Study focused on nitrogen uptake by algae

Riffles at McCarran Ranch
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Beginning of McCarran Ranch reach
HSPF

- HSPF – Hydrologic Simulation Program – Fortran
- Previous applications on Truckee River
  - USGS flow routing model (Berris, 1997)
  - Temperature/dissolved solids model (Taylor, 1998)
- Cities of Reno and Sparks chose HSPF as their long-term management tool
  - Truckee River HSPF - TRHSPF
    - Enhanced periphyton and water quality routines
2004 HSPF Model Development

- Model extent – 15 km (9.5 mi)
- Boundaries
  - Upstream - Lockwood (Reach 307)
  - Downstream - Tracy (Reach 315)
2004 HSPF Model Development

Photo courtesy of City of Reno
# 2004 Input Data

<table>
<thead>
<tr>
<th>Meteorology</th>
<th>Flow</th>
<th>Nutrient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature (H)</td>
<td>USGS Vista Gage (H)</td>
<td>Nitrate (D)</td>
</tr>
<tr>
<td>Dewpoint temperature (H)</td>
<td>Murphy Ditch (D)</td>
<td>Nitrate (D)</td>
</tr>
<tr>
<td>Wind speed (H)</td>
<td>- Measured diversion flow</td>
<td>Total ammonia (D)</td>
</tr>
<tr>
<td>Cloud cover (H)</td>
<td>- Estimated return flow</td>
<td>Orthophosphate (D)</td>
</tr>
<tr>
<td>Solar radiation (H)</td>
<td></td>
<td>Organic reactive phosphorous (D)</td>
</tr>
<tr>
<td>Precipitation (H)</td>
<td></td>
<td>Total inorganic carbon (H)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbon dioxide (H)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total dissolved solids (D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dissolved oxygen (H)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water temperature (H)</td>
</tr>
</tbody>
</table>

* National Climatic Data Center – Reno Airport weather station

* USGS Water Resources

**Federal Watermaster

* TMWRF

H = Hourly input

D = Daily input
Model Calibration

- Input 2004 data
- Input calibration parameters
  - Initially set at TRHSPF 2000-2002 model
  - Only adjusted values in Reaches 411 and 412
- Calibration locations
  - Patrick: mid-restoration
  - Tracy: end of model
- Calibrated constituents:
  - Flow
  - Total dissolved solids
  - Water temperature
  - Dissolved oxygen
  - Inorganic nitrogen species - nitrate (NO$_3^-$), nitrite (NO$_2^-$), total ammonia (NH$_3$ + NH$_4^+$ = TAM)
Scenarios

- Restoration to date – Scenario 1
  - Restored geometry
  - Riffles
Scenarios

- Pre-restoration – Baseline
- Changed to pre-restoration values:
  - River geometry (FTABLES)
  - FRRIF
Scenarios

• Scenario 2
  – Additional riffles in McCarran Ranch reaches

• Scenario 3
  – Additional riffles in entire modeled lower Truckee River
Scenarios

• Scenario 4
  – Additional shading at McCarran Ranch reaches

• Scenario 5
  – Additional planned restoration at McCarran Ranch by The Nature Conservancy
Outline

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Calibration Results

- Parameters changed:
  - Fraction of reach composed of riffles (FRRIF)
  - Shade factor (CFSAEX)
Calibration Results at Tracy

Flow

RMSE = 29 ft³ s⁻¹, R² = 0.98

Water Temperature

RMSE = 0.98 °C, R² = 0.98

Dissolved Oxygen

RMSE = 1.25 mg l⁻¹, R² = 0.69

Nitrate

RMSE = 0.127 mg L⁻¹, R² = 0.40

Nitrite

RMSE = 0.0078 mg L⁻¹, R² = 0.84

Total Ammonia

RMSE = 0.037 mg L⁻¹, R² = 0.03
Scenario Modeling Results

- All scenarios resulted in increased uptake of dissolved inorganic nitrogen (DIN)
  
  $$\text{DIN} = \text{NO}_3^-, \text{NO}_2^-, \text{total ammonia (TAM)}$$

- Species of inorganic nitrogen assimilated by algae varies with each scenario
Scenario Modeling Results

**Scenario 2 - Nitrogen output at Tracy**

$\Delta$ DIN = 53 kg

**Scenario Modeling Results**
Scenario 3

Scenario 3 - Nitrogen output at Tracy

$\Delta \text{DIN} = 173 \text{ kg}$
Scenario 4

\[ \Delta \text{DIN} = 84 \text{ kg} \]
Scenario 5

\[ \Delta \text{DIN} = 63 \text{ kg} \]
Threshold?

- Algal biomass affects type of nitrogen species removed

<table>
<thead>
<tr>
<th>Scenario</th>
<th>$\text{NO}_3^-$</th>
<th>$\text{NO}_2^-$</th>
<th>TAM</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-133 (-294)</td>
<td>+1 (+2)</td>
<td>+212 (+469)</td>
<td>+80 (+177)</td>
</tr>
<tr>
<td>2</td>
<td>+31 (+68)</td>
<td>-9 (-20)</td>
<td>+32 (+70)</td>
<td>+53 (+117)</td>
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<td>3</td>
<td>+799 (+1762)</td>
<td>-40 (-88)</td>
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<td>4</td>
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<td>+362 (+797)</td>
<td>+84 (+37)</td>
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<td>5</td>
<td>+59 (+130)</td>
<td>-9 (-20)</td>
<td>+13 (+30)</td>
<td>+63 (+139)</td>
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</table>

Nitrogen (kg d$^{-1}$ (lb d$^{-1}$)) uptake over the baseline for model year 2004
Effect on Dissolved Oxygen

Dissolved Oxygen minimum

Baseline | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4

Dissolved oxygen concentration (mg L⁻¹)

1/2 2/2 3/2 4/2 5/2 6/2 7/2 8/2 9/2 10/2 11/2 12/2
Summary

- Restoration effective at increasing nitrogen uptake
- Type of restoration will determine species of nitrogen used
  - Shading increases uptake of TAM
  - Significant increase in riffles increases uptake of NO$_3^-$
- Large flows lead to scour events that decrease assimilative capacity
  - Flow management tied to restoration for better results
- Uptake based on algal dynamics
- Assumptions
Next Steps

- Model assimilative capacity
  - Change incoming nitrogen loads
- Nitrogen budget
  - Determine how much nitrogen actually removed from river
- Denitrification
  - Determine significance on Truckee River
Acknowledgements

- Funding provided by cities of Reno and Sparks
- Dr. Laurel Saito, Advisor
- The Nature Conservancy

Surveying cross sections with Cities of Reno/Sparks
## Calibration Results

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>RMSE</th>
<th>% Bias</th>
<th>N</th>
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<tbody>
<tr>
<td><strong>Patrick – mid restoration</strong></td>
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<tr>
<td>Temperature</td>
<td>°C</td>
<td>0.64</td>
<td>0.69</td>
<td>8394</td>
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<tr>
<td>Dissolved oxygen</td>
<td>mg L⁻¹</td>
<td>1.06</td>
<td>-0.74</td>
<td>8394</td>
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<tr>
<td><strong>Tracy/Clark – downstream boundary</strong></td>
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<tr>
<td>Flow</td>
<td>ft³ s⁻¹</td>
<td>29.34</td>
<td>-1.3</td>
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<tr>
<td>TDS</td>
<td>mg L⁻¹</td>
<td>19.60</td>
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<tr>
<td>Temperature</td>
<td>°C</td>
<td>0.98</td>
<td>1.15</td>
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<tr>
<td>Dissolved oxygen</td>
<td>mg L⁻¹</td>
<td>1.25</td>
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<tr>
<td>NO₃⁻</td>
<td>mg L⁻¹</td>
<td>0.127</td>
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<tr>
<td>NO₂⁻</td>
<td>mg L⁻¹</td>
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<tr>
<td>TAM</td>
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<td>PO₄²⁻</td>
<td>mg L⁻¹</td>
<td>0.031</td>
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</table>

RMSE = root mean squared error
Scenario 3 - Nitrogen output at Tracy

Load (kgs)

Nitrate
Nitrite
Total ammonia
Nitrate preference fact