Balancing Future Growth and Nitrogen Discharge Limitations: Wastewater Master Planning for the City of Raleigh
Wastewater Treatment Master Plan: Development

- Background
- Methodology
- System-Wide Flow Alternatives
- Treatment Process Options
- Recommended Wastewater Treatment Solution
Existing Wastewater System

- CORPUD provides sanitary sewer service to 195,000 customers and a service population of 570,000 people.
- Wastewater collection system consists of 2,500 miles of pipeline and 114 pump stations.
- CORPUD owns and operates three WWTPs:
  - Neuse River RRF (75 mgd)
  - Smith Creek WWTP (3 mgd)
  - Little Creek WWTP (2.2 mgd)
Key Planning Drivers

Capacity

AA flows are expected to double from 48 mgd in 2015 to more than 92 mgd by 2040 to meet the growing service area.

Sustainability

CORPUD has a long term vision to be a leader in the use of wastewater as a beneficial resource.

Regulatory

- TN load limit of 784,847 lb/yr
- Average effluent total nitrogen concentration less than 3 mg/L will be required
- Existing nitrogen regulations will play a critical role in future wastewater treatment.

Drivers will shape the landscape of future wastewater treatment in CORPUD service area.
Nitrogen Limitations

The graph shows the total nitrogen discharge and allocation from the Neuse River RRF from 1995 to 2040. The current nitrogen allocation is 687,373 lbs/yr. The projected TN loading surpasses current TN allocation in 2033, with a loading of 821,441 lbs/yr. By 2034, the projected TN loading is projected to surpass the current TN allocation with a loading of 801,108 lbs/yr.
Methodology: Determination of System-Wide Treatment Solution

Treatment Process Options

- Conventional
- MABR
- MBR

System-Wide Flow Alternatives

- Baseline
- Alt 1
- Alt 3

Final Selection

System-Wide Wastewater Treatment Solution
System-Wide Flow Alternatives: Expand Existing or Build New?

Baseline

Alternative 1

Alternative 3
Baseline
Alternative 1

Smith Creek WWTP (Expansion to 6 MGD)

Little Creek WWTP (2.2 MGD)

Neuse River RRF (Expansion to 105 MGD)

Existing Plant

Proposed Plant
Alternative 3
Treatment Process Options: Conventional or Innovative Treatment?

Key criteria in screening process options was ability to achieve low total nitrogen concentrations in plant effluent and potential for water reuse.
Treatment Process Options: Conventional or Innovative Treatment?

Existing Facilities
- MABR

New Facilities
- MBR
System-Wide Wastewater Treatment Solution: Present Worth Cost Analysis

<table>
<thead>
<tr>
<th>BASELINE</th>
<th>ALTERNATIVE 1</th>
<th>ALTERNATIVE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>$1,258 M</td>
<td>$1,212 M</td>
</tr>
</tbody>
</table>

- Alternative 1 only includes upgrades to existing treatment facilities.
- Baseline and Alternative 1 include an additional expansion at the Neuse River RRF that is not required in Alternative 3 over planning horizon.
- Alternative 3 includes the construction of two plants and upgrades at the existing plants.

### Present Value Costs (Million $)

<table>
<thead>
<tr>
<th>Gravity Sewer</th>
<th>O&amp;M</th>
<th>Pump Station/Force Main</th>
<th>Treatment</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>$43</td>
<td></td>
<td>$180</td>
<td>$498</td>
<td></td>
</tr>
<tr>
<td>$44</td>
<td></td>
<td>$241</td>
<td>$406</td>
<td>$44</td>
</tr>
<tr>
<td>$44</td>
<td></td>
<td>$44</td>
<td>$600</td>
<td>$44</td>
</tr>
<tr>
<td>$537</td>
<td></td>
<td>$521</td>
<td>$559</td>
<td>$559</td>
</tr>
<tr>
<td>$1,000</td>
<td></td>
<td>$1,200</td>
<td>$1,400</td>
<td>$1,400</td>
</tr>
</tbody>
</table>
System-Wide Wastewater Treatment Solution: Envision Sustainability Analysis

Quality of Life
Fewer plants = reduced impacts to surrounding community.

Leadership
More plants = more opportunities for water reuse and collaboration with stakeholders.

Resource Allocation
Fewer plants = reduced materials. More plants = more opportunities for reuse.

Natural World
Fewer plants = reduced impacts on habitats, greenfields, etc.

Climate & Risk
More plants = more resiliency and opportunities for reuse. Fewer plants = longer force mains and potential for methane emissions.
**System-Wide Wastewater Treatment Solution: Resiliency Analysis**

- Alternative 1
- Alternative 3
- Baseline

- **EXTENDED DROUGHT**
- **INCREASED STORMS**
- **ECONOMIC BOOM TIME**
- **ECONOMIC BUST TIME**
- **HIGH ENERGY PRICES**
- **SYSTEM VULNERABILITY**
- **TN LOAD REDUCED**
- **INTERLOCAL AGREEMENTS**
- **EMERGING CONTAMINANT TREATMENT**
- **BIOSOLIDS MANAGEMENT**
Regional Partnership Evaluation
Recommended Wastewater Treatment Solution: Alternative 1

- Consists of upgrades and expansions at the Neuse River RRF.
- Recommended due to its cost and simpler environmental permitting process.
- Allows CORPUD to consolidate their wastewater treatment and operations at one primary facility.
Recommended Wastewater Treatment Solution: Alternative 1

**Year 2033**
- Avg Daily Flow = 80% of the 90-MGD RRF
- Submit evaluation of future ww needs

**Year 2031**
- Avg Daily Flow = 90% of the 75-MGD RRF
- Start 90-mgd expansion

**Year 2037**
- Avg Daily Flow = 90% of the 90-MGD RRF
- Start 105-mgd expansion

- 105 mgd Design & Permitting
- 105 mgd Construction
- 136,985 lb TN/year increase
- 105 mgd expansion timeline

- 90 mgd Design & Permitting
- 90 mgd Construction
- 134,534 lb TN/year increase
- 90 mgd expansion timeline

- Year 2026
  - Avg Daily Flow = 80% of the 75-MGD RRF
  - Submit evaluation of future ww needs

- Year 2029
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 90-mgd expansion

- Year 2030
  - Avg Daily Flow = 80% of the 75-MGD RRF
  - Start 90-mgd expansion

- Year 2032
  - Avg Daily Flow = 80% of the 90-MGD RRF
  - Start 90-mgd expansion

- Year 2033
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 105-mgd expansion

- Year 2034
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 105-mgd expansion

- Year 2035
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 105-mgd expansion

- Year 2036
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 105-mgd expansion

- Year 2037
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 105-mgd expansion

- Year 2038
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 105-mgd expansion

- Year 2039
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 105-mgd expansion

- Year 2040
  - Avg Daily Flow = 90% of the 90-MGD RRF
  - Start 105-mgd expansion
Wastewater Treatment Master Plan: Implementation

- 15 NCAC 02B.0234 Update
- NC House Bill 812
- Nutrient Trading Alternatives
- Modified Nutrient Offset Program
TIME TO SAY GOODBYE
\[ \sum_{i=1}^{n} (x_i - \bar{x})^2 = \sum_{i=1}^{n} x_i^2 - n \bar{x}^2 \]

\[ Q = \sum_{i=1}^{n} (y_i - b \bar{x} - a)^2 \]

\[ y = bx + a \]

\[ \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i ; \]

\[ y = a^x \]

\[ x + y = 3 \]

\[ \frac{a^x}{b^y} = \frac{a^3}{b^6} \]

\[ a^2 + b^2 = x \]

\[ Q = (y_1 - bx_1 - a)^2 + (y_2 - bx_2 - a)^2 + \ldots + (y_n - bx_n - a)^2 \]

\[ \sin A = \frac{1}{2} \]

\[ k = \pm \frac{1}{3} + kb \]

\[ \tan 2\alpha = \frac{1}{3} \]

\[ 2\pi + \alpha = y \]
Nitrogen Credits per the Neuse Rules

\[ TN = 1.0 \text{ MGD} \times 3.0 \text{ mg/L} \times 8.34 \left( \frac{\text{lb/MG}}{\text{mg/L}} \right) \times 365 \text{ day/year} \times 30 \text{ years} \times 42.68 \] \[ TN = 11,700,000 \]

1.0 MGD = $11.7 M Just for nitrogen credits

Assume ballpark $17/gal for construction cost, land, etc. which adds an additional $17,000,000.
Offset Credit Management in Jordan Lake

- Mitigation Services Cost over 30 years based on:
  - Nitrogen at 3 mg/L and $132/lb
  - Phosphorus at 0.18 mg/L and $343/lb
- Restoration Cost based on $40,000 lb/ac
- Acres based on 75 lbs/ac/yr

<table>
<thead>
<tr>
<th>MGD Systems</th>
<th>Lbs P</th>
<th>Lbs N</th>
<th>Acres Required</th>
<th>Mitigation Services Cost</th>
<th>Restoration Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>3,300</td>
<td>54,800</td>
<td>775</td>
<td>$250,965,000</td>
<td>$30,987,000</td>
</tr>
<tr>
<td>8</td>
<td>4,400</td>
<td>73,100</td>
<td>1033</td>
<td>$334,752,000</td>
<td>$41,334,000</td>
</tr>
<tr>
<td>10</td>
<td>5,500</td>
<td>91,400</td>
<td>1292</td>
<td>$418,539,000</td>
<td>$51,680,000</td>
</tr>
<tr>
<td>12</td>
<td>6,600</td>
<td>109,600</td>
<td>1549</td>
<td>$501,930,000</td>
<td>$61,974,000</td>
</tr>
<tr>
<td>14</td>
<td>7,700</td>
<td>127,900</td>
<td>1808</td>
<td>$585,717,000</td>
<td>$72,320,000</td>
</tr>
<tr>
<td>16</td>
<td>8,800</td>
<td>146,200</td>
<td>2067</td>
<td>$669,504,000</td>
<td>$82,667,000</td>
</tr>
<tr>
<td>18</td>
<td>9,900</td>
<td>164,400</td>
<td>2324</td>
<td>$752,895,000</td>
<td>$92,960,000</td>
</tr>
<tr>
<td>20</td>
<td>11,000</td>
<td>182,700</td>
<td>2583</td>
<td>$836,682,000</td>
<td>$103,307,000</td>
</tr>
<tr>
<td>26</td>
<td>14,300</td>
<td>237,500</td>
<td>3357</td>
<td>$1,087,647,000</td>
<td>$134,294,000</td>
</tr>
</tbody>
</table>
Nutrient Offset Credits on Existing CORPUD Property
Treatment vs. Offsets

Primary vs. Secondary vs. Tertiary

- Primary: Sand & Grit Removal, Coarse Debris Screen, Wastewater
- Secondary: Primary Clarification, Aeration, Solids, Sludge, Activated Sludge
- Tertiary: Clarification, Disinfection, Nutrient Removal, Effluent

Nutrient removal and effluent at the end of the process.
Nutrient Offsets
The Next Generation
Boldly go where no man has gone before..................
Riparian Buffers
Advantages

- Less costly compared to mitigation services
- Known end product
- Known cost
- Ability to negotiate agreements
- Ability to spread cost over several years
- Mitigation experts ensuring permanent credits
Riparian Buffer vs. Other Nitrogen Reduction Measures

**FIGURE 1. Average Cost of Selected Nitrogen Reduction Measures**

Dollars per pound of annual nitrogen reduction

- Stormwater: 500+
- WWTP: 92.40
- Agriculture: 47.40
- New practices: 47.40
- Stormwater treatment development
- WWTP upgrades (high)
- WWTP upgrades (low)
- Native grasses (low)
- Algal turf scrubbing
- Cover crops
- Land retirement
- Conservation tillage
- Grassed ditches
- Forest buffers
- Restored or constructed

Note: Cost estimates do not take into account the baseline or minimum practices that agriculture will have to implement prior to selling credits. Depending on which practices farmers implement first, the costs of agricultural nutrient reduction measures may be higher or lower. Costs represent the costs of achieving the nitrogen reduction only. Actual credit prices under a nutrient trading program will be affected by market dynamics of supply and demand.

# Neuse Mitigation Strategies

<table>
<thead>
<tr>
<th>Mitigation Services</th>
<th>$63,259,000</th>
<th>$6,643,000</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS Private Mitigation Bank</td>
<td>$44,282,000</td>
<td>$6,643,000</td>
<td>-30%</td>
</tr>
<tr>
<td>HUC Legislation H812</td>
<td>$26,570,000</td>
<td>$6,643,000</td>
<td>-40%</td>
</tr>
<tr>
<td>1.1 Ratio (Rules)</td>
<td>$13,285,000</td>
<td>$6,643,000</td>
<td>-50%</td>
</tr>
</tbody>
</table>

Savings by potential future regulatory actions for 49,405 lbs nitrogen
Map 1: Neuse River Basin - Current Service Areas
Map 2: Neuse River Basin - Expanded Service Areas
Balancing Future Growth and Nitrogen Discharge Limitations: Wastewater Master Planning for the City of Raleigh

Steve Tedder  
Regulatory Consultant, Tedderfarm Consulting  
tedderfarmconsulting@gmail.com

Susan D. Auten, P.E.  
Civil Engineer, Black & Veatch  
AutenS@bv.com