Lake Jessamine
Sediment Inactivation Project

Final Results
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General Overview of Lake Jessamine

- NE Lobe
- SW Lobe
- South Lobe
- East Lobe
- Central Lobe
Probing Locations for Water and Muck Depths in Lake Jessamine (March 29, 2011)
Water Depth Contours (ft) for Lake Jessamine on March 29, 2011
Muck Depth Contours (ft) in Lake Jessamine on March 29, 2011
Trends in Chlorophyll-a Concentrations in Lake Jessamine from 2000-2013

- chlorophyll-a is a photosynthetic pigment
- indicator of algal biomass
Lake Trophic State Classifications

Oligotrophic Lake
- Low in nutrients
- Few algae grow
- No algal blooms
- Water is very clear
- Support very few plants and fish
- About 12% of Florida lakes
- Water clarity > 12 feet
- Chlorophyll < 3 micrograms/liter
- Total P < 15 micrograms/liter

Mesotrophic Lake
- Moderate in nutrients
- Moderate algal production
- Periodic algal blooms
- Slightly green water
- Support moderate amounts of plants and fish
- About 31% of Florida lakes
- Water clarity 8 – 12 feet
- Chlorophyll 3 - 7 micrograms/liter
- Total P 15 to 25 micrograms/liter
Lake Trophic State Classifications – cont.

Eutrophic Lake
- High in nutrients
- High level of algal production
- Frequent algal blooms
- Green water with poor visibility
- May have large amount of plants
- About 41% of Florida lakes
- Water clarity 3 - 8 feet
- Chlorophyll 7 to 40 micrograms/liter
- Total P 25 to 100 micrograms/liter

Hyper-eutrophic Lake
- Very high in nutrients
- Extremely high algal production
- Virtually constant algal blooms
- Most biologically productive lakes
- Support large amounts of plants and fish
- About 16% of Florida lakes
- Water clarity < 3 feet
- Chlorophyll > 40 micrograms/liter
- Total P > 100 micrograms/liter
Trends in TSI Values in Lake Jessamine from 2000-2013

- Middle Lobe:
  - TSI values from 2000 to 2013
  - Trends indicate a significant increase in eutrophic conditions
  - Statistical analysis: $p = 0.0001$, slope = 0.7227

- Northeast Lobe:
  - TSI values from 2000 to 2013
  - Trends indicate a slight decrease in eutrophic conditions
  - Statistical analysis: $p = 0.0048$, slope = -0.3644

- Southwest Lobe:
  - TSI values from 2000 to 2013
  - Trends indicate a significant increase in eutrophic conditions
  - Statistical analysis: $p = 0.0043$, slope = 0.7917
Mean Monthly Concentrations of Total Phosphorus in Lake Jessamine from 1989-2009
Hydrologic Budget Components

- Precipitation
- Interconnected Lake Inflows
- Evaporation
- Runoff
- Groundwater Seepage
- Deep Recharge
- Outflow

\[ \pm \Delta \text{Storage} \]
Summary of Mean Annual Hydrologic Inputs and Losses to Lake Jessamine
Nutrient Budget Components

Bulk Precipitation

Interconnected Lake Inflow

Runoff

Sedimentation

Internal Recycling

Groundwater Seepage

Deep Groundwater

Outflow
Summary of Mean Annual Mass Inputs and Losses of Total Phosphorus to Lake Jessamine

- Lake Jessamine is a P limited lake
- P inputs must be controlled to improve water quality
Locations of Sediment Monitoring Sites in Lake Jessamine
Photographs of Typical Sandy Sediments Collected in Lake Jessamine During December 2010
Photographs of Typical Sandy and Organic Muck Sediments Collected in Lake Jessamine During December 2010

- Thick unconsolidated organic muck
- Unconsolidated organic muck over brown sand
- Thin layer of unconsolidated organic muck over sand
Typical Zonation in a Lake

- **Pelagic Zone (Open water)**
- **Littoral Zone**

**Epilimnion**
- Photic zone

**Hypolimnion**
- Poor circulation
- Anoxic

**Photosynthesis > Respiration**

~1% of surface light

**Lakes are sinks for nutrients**
- Organic matter accumulates in the bottom of lakes and undergoes decomposition
  - Nutrients are released during the decomposition
Phosphorus Bonding in Sediments

- P in lake sediments is generally bound in associations with:
  - Saloid
    - Consists of soluble P in pore water and easily exchangeable P
  - Iron and manganese
    - Direct inorganic precipitates (ex. FePO₄) and adsorption onto Fe/Mn oxides
    - Stability depends on redox potential
      - Bond with P is strong under oxidized conditions
      - Bond breaks apart under reduced conditions
  - Calcium
    - Primarily as inorganic precipitates
    - Becomes more significant at higher pH
    - Stability depends on pH
  - Aluminum
    - Direct inorganic precipitates (ex. AlPO₄) and adsorption onto metal oxides
    - Stability depends on pH
  - Organic matter
    - Fresh matter – decomposes relatively quickly
    - Recalcitrant matter – decomposes very slowly
- Significance depends on geology of the watershed and lake
P Fractionation of Sediments

- **Saloid** – soluble + easily exchangeable P
- **Fe Bound** – sediment P bound with Fe
- **Al Bound** – sediment P bound with Al
- **Ca Bound** – sediment P bound with Ca
- **Organic Bound** – P associated with organic matter

- Available for release
  - Σ(Saloid + Fe Bound) is referred to as “Total available P”

- Unavailable for release
Inactivant Dose Determination

- Based on available P in sediments
- The 0-10 cm layer of the sediments is sectioned off and speciated for available P using a modification of the Chang and Jackson technique
- Sufficient inactivant is added to bind all available P in the top 10 cm
- Alum dose determined by:
  \[ \text{Alum dose} = \text{total available P} \times \text{Al:P ratio} \]
- Al:P ratio usually between 5-10

<table>
<thead>
<tr>
<th>Element</th>
<th>Electronegativity (Pauling Scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>1.8</td>
</tr>
<tr>
<td>Al</td>
<td>1.6</td>
</tr>
<tr>
<td>Ca</td>
<td>1.3</td>
</tr>
<tr>
<td>La</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Modified Chang and Jackson Speciation Procedure for Evaluating Sediment P Bonding

1. **Wet Sediment**
   - 2N NH₄Cl (30 minutes)
   - Result: Saloid-Bound Phosphorus
     - Potentially available

2. **Residue**
   - 0.5 N NH₄F (1 hour)
   - Result: Aluminum-Bound Phosphorus
     - Unavailable

3. **Residue**
   - 0.1 N NaOH (17 hours)
   - Result: Iron-Bound Phosphorus
     - Potentially available
Isopleths of Total Available Phosphorus in the Top 10 cm of Sediments in Lake Jessamine

- sum of saloid + iron bound P

Internal Recycling = 139 kg total P/yr
  = 43% of total inputs

Groundwater Seepage = 36 kg total P/yr
  = 10% of total inputs

Combined inputs = 49%
Application Map Indicating the Fraction of Total Alum to be Applied to the Identified Zones
# Applied Chemical Quantities for Lake Jessamine Sediment Inactivation

<table>
<thead>
<tr>
<th>Zone</th>
<th>Fraction of Total</th>
<th>Alum (gallons)</th>
<th>Sodium Aluminate (gallons)</th>
<th>Gallons per Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Alum</td>
</tr>
<tr>
<td>1</td>
<td>0.24</td>
<td>45,027</td>
<td>11,436</td>
<td>15,009</td>
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<tr>
<td>2</td>
<td>0.48</td>
<td>91,280</td>
<td>23,182</td>
<td>30,427</td>
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<tr>
<td>3</td>
<td>0.22</td>
<td>41,545</td>
<td>10,551</td>
<td>13,848</td>
</tr>
<tr>
<td>4</td>
<td>0.04</td>
<td>6,993</td>
<td>1,776</td>
<td>2,331</td>
</tr>
<tr>
<td>5</td>
<td>0.02</td>
<td>4,155</td>
<td>1,055</td>
<td>1,385</td>
</tr>
<tr>
<td>TOTAL:</td>
<td></td>
<td>189,000</td>
<td>48,000</td>
<td>63,000</td>
</tr>
</tbody>
</table>
Application Boat and Tanker Barge Used for Alum Application in Lake Jessamine
Comparison of Pre- and Post-Treatment Concentrations of Total Nitrogen in Lake Jessamine
Comparison of Pre- and Post-Treatment Concentrations of Total Phosphorus in Lake Jessamine
Secchi Disk

- The depth at which a 20 cm disk can be viewed
  - A measure of water column transparency
  - An estimate of algal biomass in the water
  - Depth of the photic zone

Father Pietro Secchi
Scientific advisor to the Pope
(1818-1878)
Comparison of Pre- and Post-Treatment Secchi Disk Depths in Lake Jessamine
Summary of Mean General Characteristics of Pre- and Post-Treatment Sediment Core Samples Collected in Lake Jessamine During December 2010 and September 2013

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Mean Value By Sediment Collection Date¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>December 2010</td>
</tr>
<tr>
<td>pH</td>
<td>s.u.</td>
<td>6.41</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>%</td>
<td>51.2</td>
</tr>
<tr>
<td>Organic Content</td>
<td>%</td>
<td>5.4</td>
</tr>
<tr>
<td>Density (wet)</td>
<td>g/cm³</td>
<td>1.57</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>μg/cm³</td>
<td>1,653</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>μg/cm³</td>
<td>119</td>
</tr>
</tbody>
</table>

¹. Reflects geometric mean values
Statistical Summary of Pre- and Post-Treatment Values of pH, and Moisture Content in the Top 10 cm of Lake Jessamine Sediments
Statistical Summary of Pre- and Post-Treatment Values of Organic Content and Wet Density in the Top 10 cm of Lake Jessamine Sediments
Statistical Summary of Pre- and Post-Treatment Values of Total Nitrogen and Total Phosphorus in the Top 10 cm of Lake Jessamine Sediments
Statistical Summary of Pre- and Post-Treatment Values of Sediment Phosphorus Speciation in Lake Jessamine Sediments

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saloid Bound P (µg/cm³)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Iron Bound P (µg/cm³)</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Aluminum P (µg/cm³)</td>
<td>140</td>
<td>160</td>
</tr>
<tr>
<td>Total Available P (µg/cm³)</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

![Box plots showing pre and post treatment values for saloid, iron, aluminum, and total available phosphorus](chart.png)
Summary of Mean Pre- and Post-Treatment Phosphorus Speciation in Sediment Core Samples Collected in Lake Jessamine

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Mean Value by Sediment Collection Date</th>
<th>Change in Concentration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre- (12/10)</td>
<td>Post- (9/13)</td>
</tr>
<tr>
<td>Saloid-Bound P</td>
<td>μg/cm³</td>
<td>0.41</td>
<td>0.05</td>
</tr>
<tr>
<td>Fe-Bound P</td>
<td>μg/cm³</td>
<td>49</td>
<td>7</td>
</tr>
<tr>
<td>Total Available P</td>
<td>μg/cm³</td>
<td>50</td>
<td>7</td>
</tr>
<tr>
<td>% of Total Sediment P</td>
<td>%</td>
<td>42</td>
<td>6</td>
</tr>
<tr>
<td>Al-Bound P</td>
<td>μg/cm³</td>
<td>31</td>
<td>53</td>
</tr>
</tbody>
</table>

1. Reflects geometric mean values
Mean Monthly Concentrations of Total Phosphorus in Lake Jessamine from 1989-2009

The alum treatment will reduce P concentrations the most during dry season conditions.
Summary

- **Lake Jessamine is a phosphorus limited lake**
  - Largest P loading is contributed by internal recycling (43% of total)

- **Sediment inactivation conducted in Lake Jessamine in 3 separate applications**
  - 189,000 gallons of alum
  - 48,000 gallons of sodium aluminate

- **Treatment was successful in reducing available P in Lake Jessamine while increasing unavailable P bonding**
  - Available P reduced by 86%
  - Aluminum bound P increased by 74%
Questions?