Lake Okeechobee Sediment Management

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Greater Everglades Ecosystem Restoration Conference 2010
Outline

• Background
• Sediment characteristics
  – Physical
  – Chemical
• Sediment management
  – What is it important to address the sediment load?
  – How to deal with the sediments while minimizing adverse impacts?
  – What do you do with the sediments once they are removed?
  – What have we done so far?
• Sediment management challenges
  – Removal
  – Handling
• Addressing the challenges
Background

- Substantial deposits of Phosphorus (P) enriched sediments across the lake bed are a direct consequence of sediment-laden, nutrient-rich watershed runoff.
- Varying depths of “mud” sediments (predominantly <50 µm-sized particles) cover a very large area (>50%) of the lake bed:
  - About ~200 million m³ distributed over >80,000 hectares by some estimates.
- Mud sediment depths range from 1-2 cm to >50-60 cm.
Mud Thickness

- Mud thickness maps suggest declines in mean mud depths were accompanied by modest changes in the distribution of mud over 20 years.
- Decline in depth between 1998 and 2006, and the emergence of some new mud zones also suggest some modest transport.
- 2004/05 hurricanes caused significant resuspension, mixing, and relocation.

Internal P Loading

- Mud sediments serve as a significant source of internal P loading.
- Majority of the P is confined to the upper layers (top 10–12 cm):
  - 1988 estimate: 28,600 metric tons of P associated with the upper layers
  - Recent estimates: 57,000 metric tons
- Total P is about 33% higher in the upper layers (0–10 cm) compared to the next sediment layer (10–20 cm).
- Approximately 60 to 65% of the total P is confined to the upper 30 cm.
Internal P-loading

• P transport from sediments to the overlying water column is primarily due to diffusion and resuspension
  – Resuspension is primarily wind driven; rapid and transient
  – Diffusion is a more steady and constant process

• Net direction of transport:
  – Particulate P tends to move from water column to sediment bed
  – Dissolved reactive P flux is from sediment to the water column
### Sediment Characteristics

- **Physical characteristics**

<table>
<thead>
<tr>
<th>Physical Property</th>
<th>Average</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids Content (%)</td>
<td>45.7</td>
<td>74</td>
<td>18</td>
</tr>
<tr>
<td>~200 Sieve (%)</td>
<td>30.3</td>
<td>86.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Organic Content (%)</td>
<td>15.0</td>
<td>43.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.4</td>
<td>2.6</td>
<td>1.91</td>
</tr>
</tbody>
</table>

#### Atterberg Limits

<table>
<thead>
<tr>
<th>Physical Property</th>
<th>Average</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasticity Index</td>
<td>NP</td>
<td>4</td>
<td>NP</td>
</tr>
<tr>
<td>Liquid Limit</td>
<td>51</td>
<td>112</td>
<td>26</td>
</tr>
<tr>
<td>Plastic Limit</td>
<td>NP</td>
<td>25</td>
<td>NP</td>
</tr>
</tbody>
</table>

Eagle Bay Island Habitat Enhancement Dredging Design Evaluation Project, BCI 2007
Sediment Characteristics

- **Physical characteristics**
  - Relatively high solids content
  - Low to modest organic content
  - High proportion of sand and silty sand
  - Predominantly non-plastic (lack of clay)
    - Higher PI (>4) means more slowly the sediment will dewater and more poorly it will consolidate
  - Low specific gravity
    - Lower the specific gravity, more organic material is present and the more compressible it is likely to be
    - Mineral soil particles range from 2.6 to 2.8
    - Organic particles ranges from 1.2 to 1.7
  - Relatively short settling times
    - Within 24–36 hrs 30 to 40% solids settle out
Sediment Characteristics

- **Chemical characteristics**
  - Rich in P and N
    - 635 mg/Kg of total phosphorus
    - 5,779 mg/Kg of total nitrogen
  - No significant hits for priority pollutants metals, PAHs, PCBs, and organochlorine pesticides
  - A few samples exceeded the Florida Soil Cleanup Target Level (SCTL) for arsenic
    - Residential construction limits exceeded in 15 out of 27 samples
    - Commercial construction limits exceeded in 2 out of 27 samples
    - SPLP leaching tests indicate that arsenic is bound to the sediments and will not leach to the groundwater or diffuse into the surface waters
Sediment Management

• Why is it important to address the sediment load?
  – Internal P loading almost equal to external P loading
  – Re-suspended sediments not only add P to the water column but also increase turbidity and impact light penetration
  – Addressing the sediment load will
    • Reduce internal P loading to the water column
    • Increase light penetration depth – SAV enhancement
    • Significantly increase in-lake P assimilative capacity – TMDL relief
    • Deliver relatively “cleaner” water to ECP STA’s, ROG solutions

Lake Okeechobee will not achieve true and complete restoration until the internal loading is addressed
Sediment Management

- How to deal with the sediments while minimizing adverse impacts?

**In-Situ Treatment**
- Chemical Treatment?
- Capping?
- Which chemical?
- What dosage?
- How often?
- Chemical toxicity issues
- Easy availability?
- Permittability
- Cost

**Dredging**
- Dredging Technology?
- Duration of Dredging?
- In-lake water quality impacts
- CDF effluent quality
- Sloughing
- Low depths
- Distance from shore
- How often?
- Permittability
- Cost
Sediment Management

• What do you do with the sediments once they are removed?
  – Sediment volume (mud and sand)
  – Transport
  – Handling
  – Cost
Sediment Management

• *What have we done so far?*
  - Numerous sediment characterization studies going back to 1988
    • Physical and chemical characterization
    • Mud layer mapping
    • Sediment transport modeling
  - Lake O Sediment Feasibility Study
    • Pilot Dredging Study
    • Beneficial Reuse Evaluation
  - Muck Scrapping and Tilling/Disking
  - Eagle Bay Habitat Enhancement Project
Thirty-six potential management options to stabilize or remove sediments were initially screened on the basis of:

- Effectiveness
- Implementability
- Risk
- Reliability
- Applicability to Lake Okeechobee

Three alternatives were retained for full-scale evaluation:

- No action
- Chemical treatment using aluminum sulfate (alum) and sodium aluminate
- Dredging
<table>
<thead>
<tr>
<th>Strategy</th>
<th>Benefit</th>
<th>Cost (2001 Dollars)</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No in-lake action (assumes TMDL is met by 2015)</td>
<td>Goal reached in 50 to 70 years</td>
<td>No in-lake costs</td>
<td>Recommended course of action</td>
</tr>
<tr>
<td>Alum addition</td>
<td>Goal reached in 20 years</td>
<td>$500 Million over 3 years</td>
<td>Re-evaluate if the lake does not respond to external load reductions. Repeat every 15 years</td>
</tr>
<tr>
<td>Whole lake dredging</td>
<td>Goal reached in 50 to 70 years</td>
<td>$3 Billion over 15 years</td>
<td>Not effective</td>
</tr>
</tbody>
</table>
Lake O Pilot Dredging Study

• Demonstrate effectiveness of an innovative sediment dredging technology in removing the phosphorus-laden, fluid mud layer from the bottom of Lake Okeechobee in an environmentally sensitive manner

• Pilot Dredge Site
  – 5 miles SW of Port Mayaca
  – Area of study site - 425 ft x 425 ft
  – Mud thickness - approximately >12 in
Lake O Pilot Dredging Study

- An innovative dredge head based on the SEDCUT technology was designed and field-tested in the lake.
- Dredge head was designed to selectively target the fluid mud layers and remove them almost in situ with minimal addition of ambient water.
- Dredged material was transported by barge to a confined disposal facility.
- Following settling, the supernatant was separated and chemically treated to reduce TP concentrations to below 40 ppb.
SEDCUT Dredge Head
Partially Submerged Dredge Head Mounted on Dredge Barge
Dredge Barge Pulled by Winch System
Dredge Slurry Pumped Via Floating Pipe to Tank Barge
End-of-Pipe Slurry Samples Collected at Tank Barge
Water Quality Samples being Collected at the “Dredge Sample Location”
Confined Disposal Facility, East Cell
Water Treatment Compound in the Background
Test Results

- Total sediment slurry removed: 4,000 cy
- Total P in slurry removed: ~ 5 metric tons
- No significant water quality impacts
- Water treatment with both technologies yielded concentrations of total P <40 ppb
- Treated water was shown to be “lake ready” (met Lake O operating permit parameters)
Lake O Pilot Dredging Study Conclusions

- Customized SEDCUT dredge head was successful in selectively dredging the upper layers of the mud sediments.
- Technology maximized sediment removal (high solids content).
- Dredging was accomplished with minimal adverse water quality impacts.
- Despite the high solids content achieved, dredging would still generate a large volume of water that would require processing.
Lake O Beneficial Reuse Evaluation

• Evaluated beneficial reuse options
  – Brick manufacture
  – Soil blending for landfill cover
  – Highway road fill
  – Agriculture top soil
  – Beach re-nourishment
  – Habitat enhancements
  – In-lake islands and near shore marshes

• Recommended large CDF areas along the lake and land application/top soil
Muck Scrapping and Tilling/Disking

- SFWMD and FFWCC took advantage of the extremely low lake levels in 2007 and 2008 and implemented several in-lake restoration projects
- Muck Scrapping and Tilling/Disking/Plowing addressed the exposed sediments
Muck Scrapping

- Muck scrapping involved removal of accumulated organic materials from exposed near-shore areas of the lake.
- Fish and wildlife habitat within the scraped areas were enhanced due to the removal of cattails and associated organic sediments.
- Approximately 1,500 ac were scrapped resulting in removal of about 1.0 million cy of organic material at a cost of about $2.3 million.
- Estimated 67 metric tons of P was removed.

HDR
Muck Scrapping Locations

- Eagle Bay Marsh
  "Outside the Lake"

- Eagle Bay Island
  "Inside the Lake"

- North West Marsh

- Harney Pond

- Fisheating Bay

- South Bay
Muck Scrapping
Muck Scrapping
Tilling/Disking Demonstration Project

- Tilling/Disking involved mechanical flipping of the thick layer of consolidated muck beneath the underlying sand layer.
- 40 ac project site located was located to the southwest of Indian Prairie Canal on the northwest shore of the lake.
- Soil inversion on this parcel, using two established tilling techniques (Baker and moldboard plows), was shown to be a highly effective means for reducing flux of nutrients from enriched surface sediments to the overlying water column, based on laboratory incubations of pre- and post-tilled soils.
Tilling/Disking Demonstration Project
Tilling/Disking
Tilling/Disking
Eagle Bay Habitat Enhancement Project

- Evaluated feasibility of dredging a 4.6 m² area located to the southeast of Eagle Bay Island
- Average muck thickness = 0.4 ft
- Total volume removed = 3.3 million cy
  - Muck = 1.8 million cy
  - 3 to 4 inches of sand layer overcut = 1.5 million cy
- Would remove as much as 5,000 metric tons of N and 550 metric tons of P
Eagle Bay Habitat Enhancement Project

- Recommended hydraulic dredging and transfer to an upland disposal site
- Dewatering and treatment of return water would be required
- Did not address sloughing issue
- Planning level project cost estimates range from $12 to 21/cy for a total project cost of $22 to $38 million
  - Does not include cost of land acquisition or transport/truckling of dewatered material from the disposal site
EBHH Project Conceptual Design

Hydraulic Suction Dredge

Eagle Bay - Lake Sediment

Dredged Sediment

Flocculant Addition

Alum Addition

Polishing Pond

Return Water
Sediment Management Challenges

• Volume of material
  – Removal with minimal adverse environmental impacts
  – Handling

• Nature of material
  – Fluid mud nature
  – High P content

• Geophysical properties of the lake
  – Shallow water depths
  – Large expanse
  – Sandy bottom
  – Lack of infrastructure
Sediment Management Challenges ....

- Return water quality
  - Meet 40 ppb TP concentration
  - Meet Turbidity limits
  - Meet all Lake O Operating Permit limitations

- Technology
  - Surgical Dredging
  - Chemical Treatment

- Cost
  - Multi-year/decade commitment
  - Process may have to be repeated every 15 to 20 years
Out of the box thinking is required….

- In-lake compartmentalization
- Deep well injection
  - In-lake
  - Off-shore
- New dredging and chemical treatment technologies
- Treat/Trap sediments in the inflows to the lake
Conclusions

- Sediments in the lake are not going anywhere anytime soon; need to do something sooner than later ...
- Internal loading needs to be addressed with the same urgency as the external loading
- By increasing the lake’s assimilative capacity, sediment removal can provide significant relief for the Lake O TMDL
- Multiple sediment management options may have to be simultaneously resorted to
- May not have to remove the entire 200 million m$^3$ of sediments to get measureable relief
- Lake Okeechobee and by extension the Everglades will not achieve true and complete restoration until the internal loading is addressed
Acknowledgement

This presentation would not have been possible without the help and support of Dave Unsell and his group of dedicated professionals at the SFWMD’s Lake Okeechobee Division.
Questions?

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