South Puget Sound Dissolved Oxygen Study

Circulation Modeling Status

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May 20, 2009 Briefing for Advisory Committee
What we cover

1. Project overview
2. Data report status
3. Hydrodynamic model and report development
4. Upcoming steps
   – Water quality model development
   – Scenarios
   – Advisory Committee
   – Final report
Model status

• Much progress

• Circulation model is not quite calibrated
  – Exchange through the Tacoma Narrows is problematic

• Developing tools for assessing influence of Central Puget Sound (and South Sound) sources

• No absolute answers today
1. What is the combined effect of human nutrient contributions from nonpoint and point sources on DO?

2. Are Central Puget Sound sources contributing to South Sound problems?
Project components

- Data collection
- Circulation model
- Water quality model
- Scenarios
- Reports
  - Data (done)
  - Circulation (pending)
  - Water quality (winter)
River and stream concentrations

Nearly all <1 mg/L DIN
Median 21.8 mg/L DIN
Nutrient sources

**South Puget Sound (south of Tacoma Narrows)**

- **Annual**
  - WWTPs: 52%
  - Rivers: 48%

- **Sept 2007**
  - WWTPs: 80%
  - Rivers: 20%

**South and Central Puget Sound (south of Edmonds)**

- **Annual**
  - WWTPs: 79%
  - Rivers: 21%

- **Sept 2007**
  - WWTPs: 92%
  - Rivers: 8%
SEPTEMBER 2007
Dissolved Inorganic Nitrogen Loads

<table>
<thead>
<tr>
<th>Wastewater Treatment Plant Inputs (kg/d)</th>
<th>Tributary Inputs (kg/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>○ zero load/no data</td>
<td>○ zero load/no data</td>
</tr>
<tr>
<td>● 0.1 - 1.0</td>
<td>● 0.1 - 1.0</td>
</tr>
<tr>
<td>● 1.1 - 10</td>
<td>● 1.1 - 10</td>
</tr>
<tr>
<td>● 10.1 - 100</td>
<td>● 10.1 - 100</td>
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<tr>
<td>● 100.1 - 1000</td>
<td>● 100.1 - 1000</td>
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<tr>
<td>● &gt; 1000</td>
<td></td>
</tr>
</tbody>
</table>
**Rivers** (includes upstream septic systems, WWTPs, stormwater, groundwater, atmospheric deposition, other point and nonpoint sources, and other natural sources). The 710 kg/day accounts for about 85% of the watershed.

**Atmospheric Deposition** (directly on South Puget Sound)

**Sediment**

**Locally Significant**

**WWTPs** (discharging directly into South Puget Sound)

**Annual**
Rivers (including upstream septs, WWTPs, stormwater, groundwater, atmospheric deposition, and other point and nonpoint sources). The 710 kg/day accounts for about 85% of the watershed.

Atmospheric Deposition (directly on South Puget Sound)

To the rest of Puget Sound and the Pacific Ocean

WWTPs (discharging directly into South Puget Sound)

Large seasonal source (recycling?)

Model-derived value (dilution?)

*The atmospheric deposition load is an annual average
Circulation model development

• Build grid
  – Horizontal grid cells
  – Vertical layers

• Boundary conditions
  – Northern boundary water surface, temp, salinity
  – River flows, temperature (zero salinity)
  – WWTPs added for tracers
  – Meteorology

• Initial conditions (inside the model domain)
Circulation model development

- Calibration and confirmation
  - Water surface elevations
    - PSTides
    - NOAA tide gauge
  - Surface and near-bottom temperature and salinity
    - Geographic differences
    - Time series
  - Profiles of temperature and salinity
  - Current velocities
3-D Circulation Model

- 2623 grid cells
- 500 m X 500 m (nominal)
- Up to 17 layers

Bathymetry source: Finlayson (2005)
Northern boundary conditions

Water surface elevations:
PSTides
- Specialized tidal model
- Detailed predictions not available from other sources
- Selected segment closest to the northern (Edmonds) boundary
Northern boundary conditions

Temperature and salinity

- Monthly marine data (King County DNR)
- Interpolated between monthly visits
- Considered other sources
  - Princeton Ocean Model
  - ORCA (Hood Canal)
  - Would need assumptions
River Inflows

Measured flows at USGS stations
Extrapolate to subwatersheds using tributary area and precipitation factor

• Interactive tool for exploring data:
ftp://www.ecy.wa.gov/Sackmann/psdom_2009_q1.html
River temperature (salinity = 0)

- Cedar River (USGS) data for year round daily values
- ECY ambient monthly grabs
Meteorology

- SeaTac and McChord, assigned to SPS, CPS
  - Wind, precipitation
- UW solar radiation data
Initial conditions

- June 2006 marine data assigned to each of three regions
Calibration and confirmation: water surface elevations from PSTides

- Tuning parameters:
  - Grid element volumes
  - Bottom friction
- Revised bathymetry to match chart volumes:
  - Tacoma Narrows
  - Budd Inlet
  - Hammersley Inlet
  - Pickering Passage
Water surface elevations

- Commencement Bay (top) represented well, with low RMSE (9 cm)

- Carr Inlet (west of Tacoma Narrows) has high RMSE (25 cm)
  - Affected by Tacoma Narrows
Calibration and confirmation: surface and near-bottom temperature and salinity

*DRAFT RESULTS*(earlier model run)

- September 2006 data
- September 2006 model

Results are good if the colors are alike
Calibration and confirmation: surface and near-bottom temperature and salinity

*Draft Results* (earlier model run)

- September 2006 data
- September 2006 model

Results are good if the colors are alike
Calibration and confirmation: surface and near-bottom temperature and salinity

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Calibration and confirmation: surface and near-bottom temperature and salinity

*Draft Results* (earlier model run)

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Results are good if the colors are alike

Salinity (psu)
Calibration and confirmation: surface/bottom temperature and salinity time series

### Alki West

<table>
<thead>
<tr>
<th>Salinity (psu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AlkW(67,141)</td>
</tr>
</tbody>
</table>

- **Observed.mdb: (KT)**
- **Observed.mdb: (KB)**
- **c_SPSEEdmonds.17b_AA_3.mdb: (KT)**
- **c_SPSEEdmonds.17b_AA_3.mdb: (14)**

**Results are good if dots plot on lines**

### Central Carr Inlet

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS71 (Central Carr Inlet)</td>
</tr>
</tbody>
</table>

- **Observed.mdb: (KT)**
- **Observed.mdb: (KB)**
- **c_SPSEEdmonds.17b_AA_3.mdb: (KT)**
- **c_SPSEEdmonds.17b_AA_3.mdb: (12)**
Calibration and confirmation: surface/bottom temperature and salinity time series

<table>
<thead>
<tr>
<th>Salinity (psu)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>South of Key Peninsula</strong></td>
<td><strong>Central Budd Inlet</strong></td>
</tr>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
</tr>
<tr>
<td>SS38</td>
<td>SS58</td>
</tr>
</tbody>
</table>

Results are good if dots plot on lines
Calibration and confirmation: temperature and salinity profiles

<table>
<thead>
<tr>
<th></th>
<th>Salinity (psu)</th>
<th>Temperature (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tacoma Narrows</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image1" alt="Salinity Profile" /></td>
<td><img src="image2" alt="Temperature Profile" /></td>
</tr>
<tr>
<td>North of Ketron</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image3" alt="Salinity Profile" /></td>
<td><img src="image4" alt="Temperature Profile" /></td>
</tr>
</tbody>
</table>
Calibration and confirmation: current velocities

- 2007 transects
- Fall 2007 for two weeks
  - Budd Inlet
  - Case Inlet
  - Carr Inlet
- Fall 2006 at Pickering Passage
Calibration and confirmation: Carr Inlet current velocities

- Data (west)
- Model (west)
Calibration and confirmation status and goals

• Water surface elevations must be well described throughout the model domain (RMSE < 10 cm)
  – Lowest error: Central Puget Sound
  – Highest error: Oakland Bay (needs work)

• Surface and near-bottom salinity and temperature must capture geographic and spatial variability
  – Salinity good; temperature needs work
Calibration and confirmation status and goals

• Profiles must capture geographic and temporal variation
  – Salinity OK; temperature needs work

• Current velocities must match phasing (timing) and amplitudes
  – Needs work

• Close, but not quite a calibrated model
Example future model output (not final yet)
Example dye releases
Can we rule in or rule out Central Puget Sound sources?

• Circulation model?
  – Maybe, but answer could very well be in a gray area (not black or white)

• Water quality model
  – Beginning development now
  – Later 2009 for indications of area of influence
Next steps
Water quality model development

• Builds from the circulation model
• Developing boundary conditions
  – Rivers and wastewater treatment plants
  – Northern boundary (nutrient and DO profiles)
• Compare against measured data
  – Calibration and confirmation
• Scenarios
Apply model to various what-if scenarios

- Input Data
- Model Development
- What-if Scenarios

What if nitrogen loads decrease?

Will South Sound DO levels...
... improve markedly?
... remain low?
Project milestones

• Draft circulation model report June 2009
• Water quality model development Ongoing
• Water quality model report Dec 2009
• Scenarios Ongoing
• Final project report June 2010

• NEP funding overview (model audits, scenarios)

• June 2010: How much of an effect are human nutrient sources having on South Puget Sound?
Questions?
If needed for questions
WWTP DIN concentrations

Conc (mg/L)

South Sound
HARSTENE
RUSTLEWOOD
CARLYON
BOSTON HARBOR
TAMOSHAN
SEASHORE
LOTT
FORT LEWIS
CHAMBERS
GIG HARBOR
TACOMA NORTH
TACOMA CENTRAL
SIMPSON
LAKOTA
REDONDO
MIDWAY
MILLER
SOUTH KING
SALMON
VASHON
WESTPOINT
KINGSTON
MANCHESTER
BAINBRIDGE
PORT ORCHARD
BREMERTON
CENTRAL KIT
SUQUAMISH

Comm Bay

South Central

North Central

Sinclair Dyes
Sediment DIN flux

- World Flux Database
  - Mean: 0.040 g-N/m$^2$-d (NH4)
- Chesapeake Bay
  - Mean: 0.064 g-N/m$^2$-d (DIN)
- Budd Inlet Scientific Study
Sediment flux estimates

• Budd Inlet
  – 1998 Budd Inlet Scientific Study (annual and seasonal)
    • Annual: 326 metric tons-N/yr or 890 kg-N/d
    • Late summer: 2400 kg-N/d
  – Present study
    • Late summer: 1100 kg-N/d (Budd Inlet)
    • WWTPs: 2800 kg-N/d (South Sound)
    • Tribs: 2700 kg-N/d (South Sound)

– Sediments are an important nutrient reservoir
Sediment flux locations
Sediment oxygen demand

- 9/10/2007
- 9/24/2007
- 10/22/2007

Mean: 0.7 g $\text{O}_2$/m$^2$-d
Sediment DIN loads

9/10/2007

9/24/2007

10/22/2007

Mean: 0.052 g - N/m²