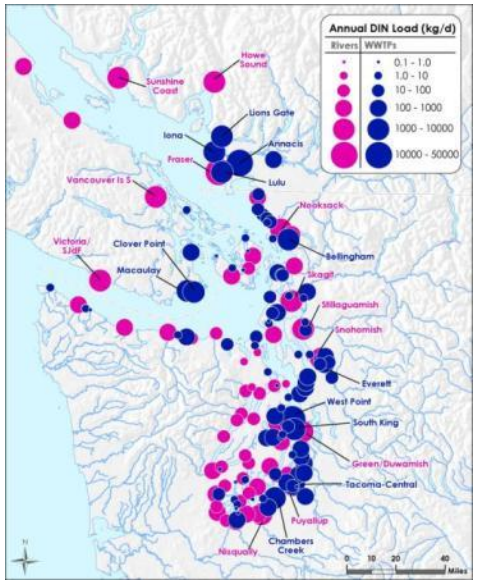
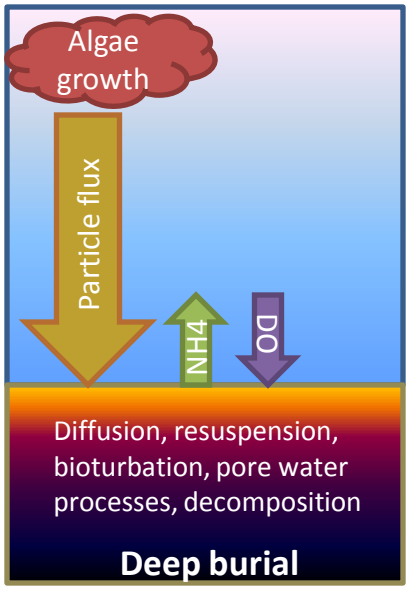
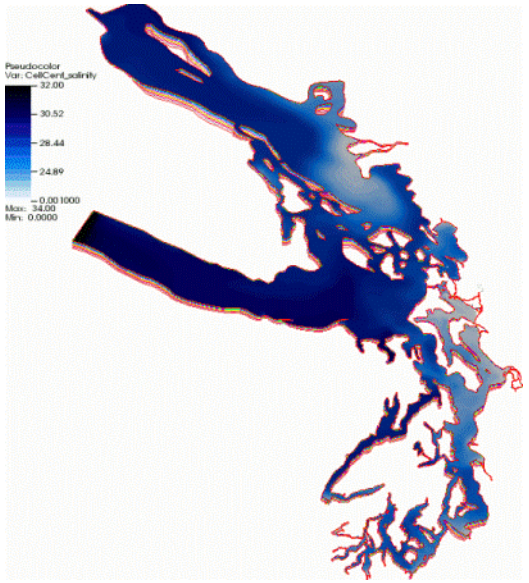
Briefing for advisory group:

Sediment-Water Interactions for Salish Sea Dissolved Oxygen Modeling (QAPP)

Mindy Roberts and Greg Pelletier
(Dept. of Ecology)
Tarang Khangaonkar and Wen Long (PNNL)



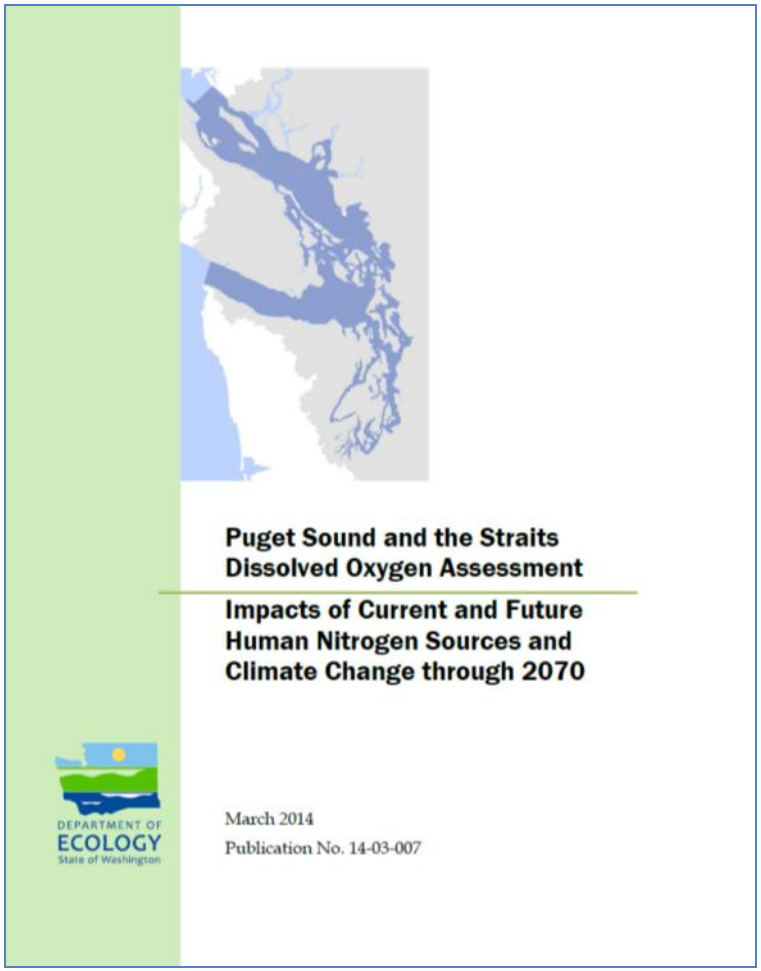


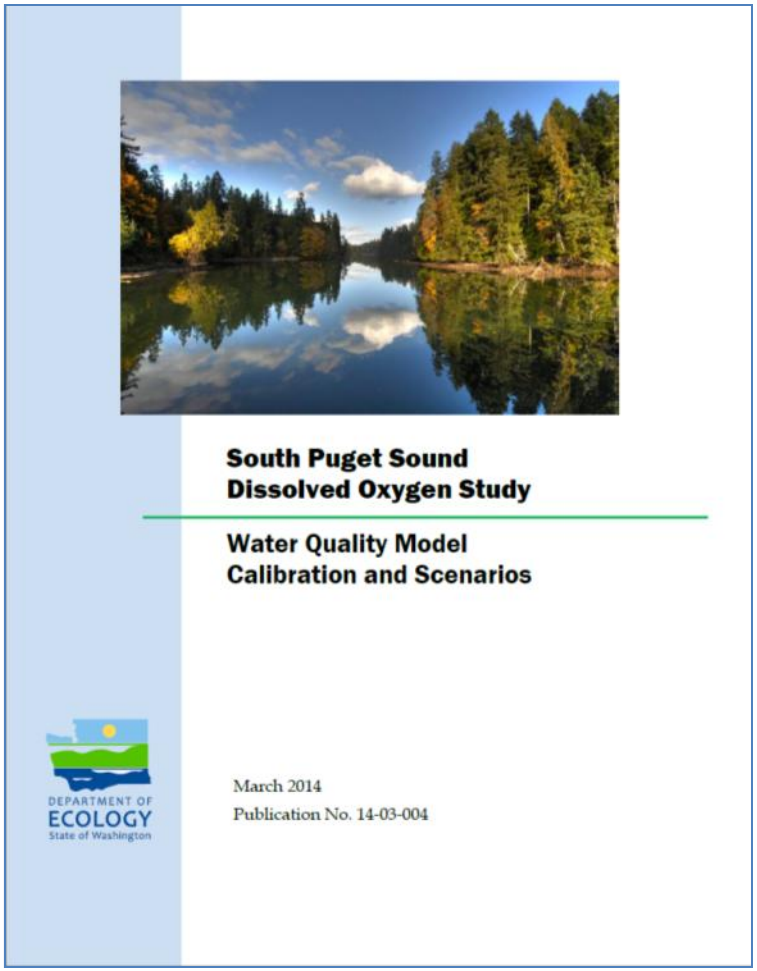


Overview

- General background and purpose – Mindy
- Overview of existing Salish Sea model – Tarang
- Proposed sediment diagenesis model setup and testing – Greg
- Proposed sediment diagenesis model calibration – Wen
- Schedule – Mindy
- Questions – All

Recent reports evaluate oxygen impacts from human activities





October 15, 2013 briefing on both

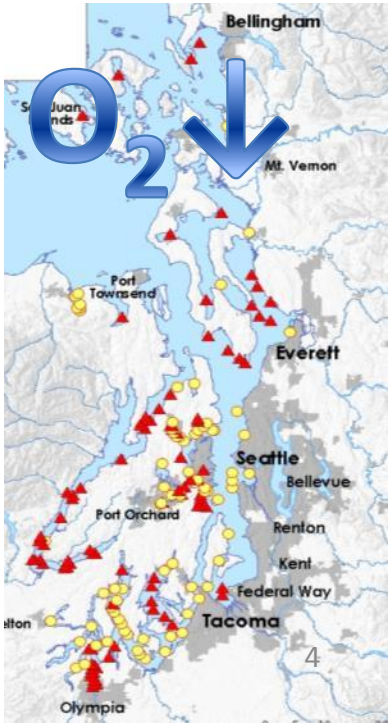
We measure low dissolved oxygen. Are human activities contributing?

- Human activities add nitrogen through wastewater, manure, fertilizer, etc.
- Nitrogen fuels algae blooms in Puget Sound
- As algae decomposes, it draws down oxygen
- Fish, and other aquatic life, need oxygen to breathe

➢ *Same questions as in Chesapeake Bay, Long Island Sound, Gulf of Mexico*

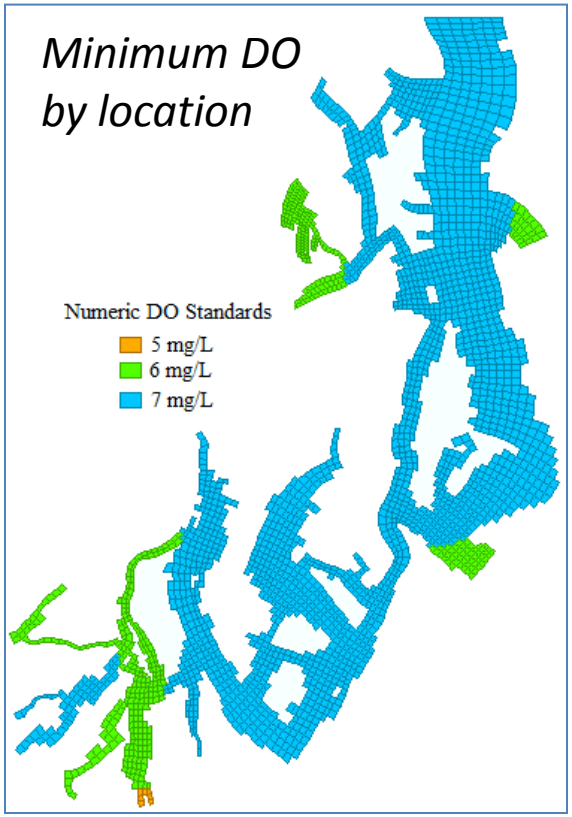
+N

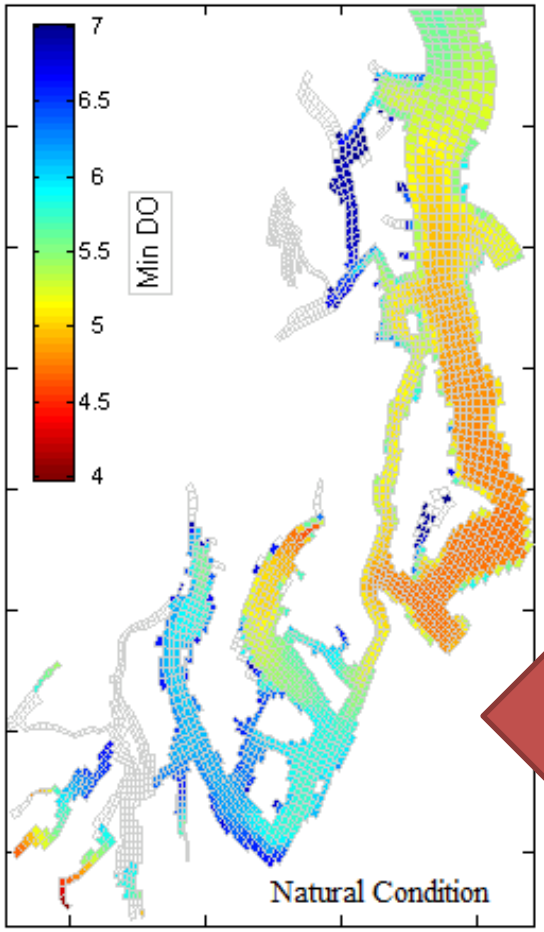
→algae



Water Quality Standards for dissolved oxygen in Puget Sound

- Oxygen > 7 mg/L (varies by location)





- If naturally < 7 mg/L, total human impact cannot cause oxygen to decline more than **0.2 mg/L**

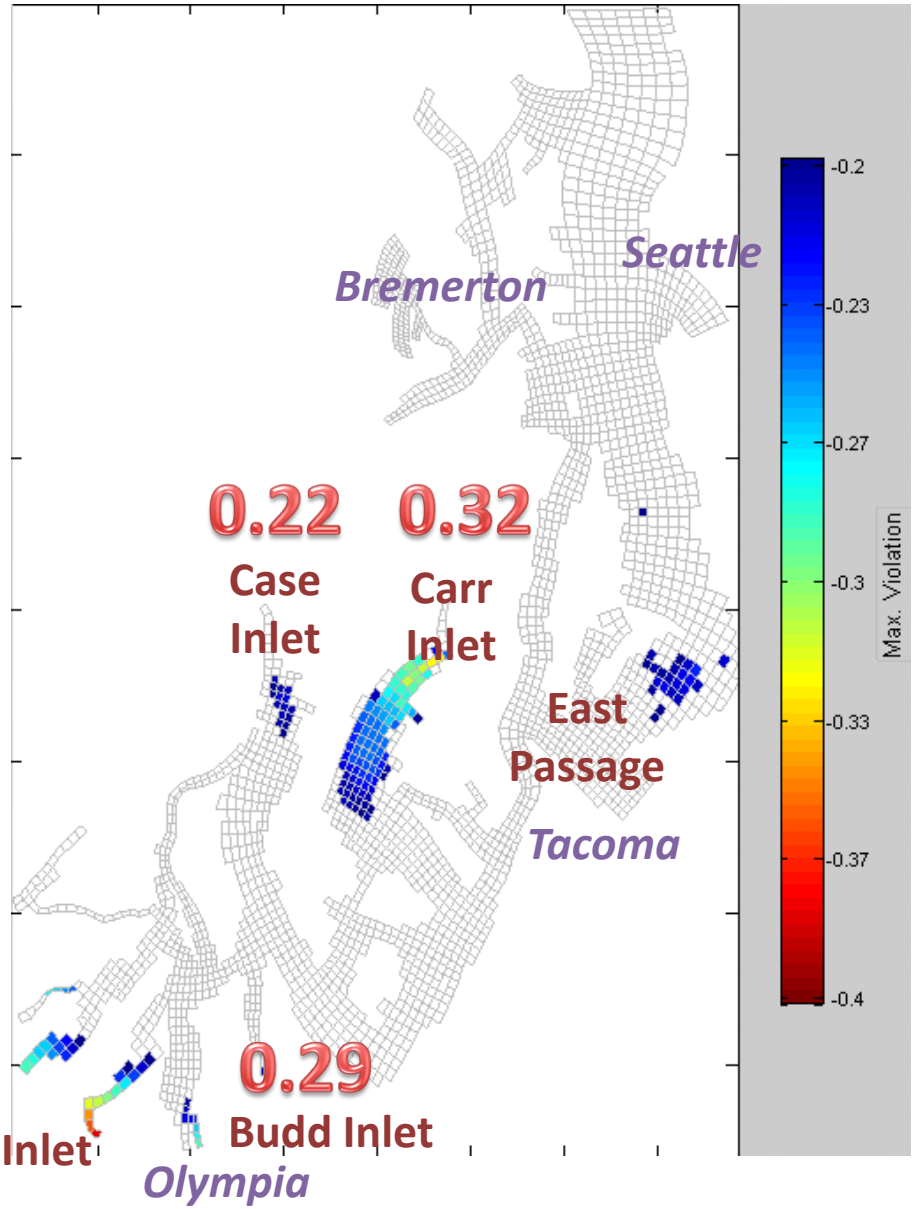
DO is naturally lower than the numeric criteria

What are the key questions?

- How much low oxygen is natural or due to the ocean and how much is human?
  - *Need sophisticated computer models to distinguish*
- How much reduction is needed to meet water quality standards?
  - *Cannot be determined yet with the existing models – Salish Sea or South/Central Puget Sound*

South (and Central) Puget Sound findings: Current human sources cause oxygen to decline as much as 0.4 mg/L

- Wastewater discharges to marine waters have bigger influence than river sources
- South Sound depletions influenced by a combination of:
  - South Sound sources
  - Central Sound sources
  - Other external human sources (North Sound and beyond?)



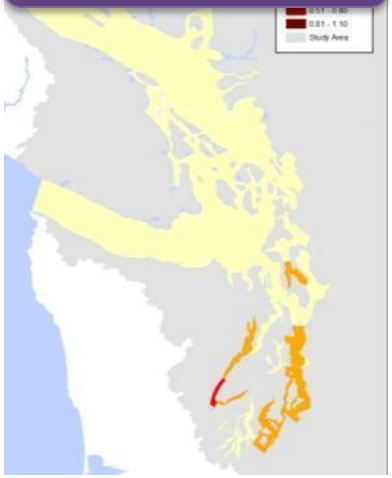
(does not include the effect of the Capitol Lake dam on Budd Inlet)

Future population growth will increase oxygen impacts; ocean trends would make it worse

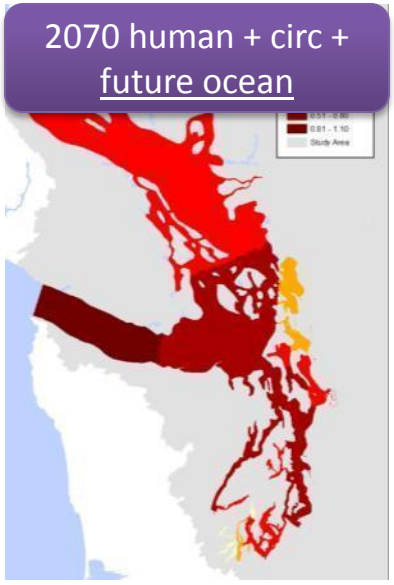
Current human sources, circulation, ocean conditions, air temperature

2070 human

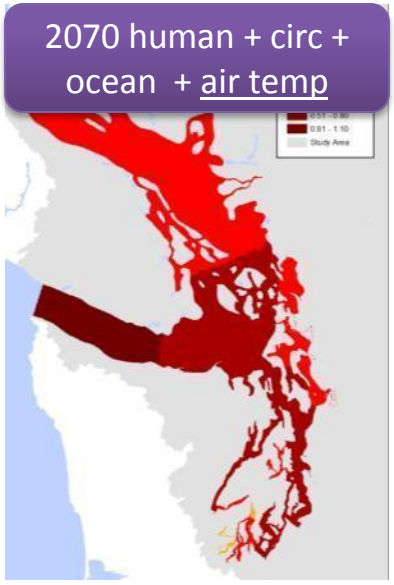
2070 human + future circulation



2070 human + circ + future ocean



2070 human + circ + ocean + air temp



Average depletion
(mg/L of oxygen decline compared with current conditions)

- 0.00 – 0.10
- 0.11 – 0.20
- 0.21 – 0.50
- 0.51 – 0.80
- 0.81 – 1.10

Relative impacts on dissolved oxygen

Increased air temperature

Changes in circulation due to changes in freshwater inflows

Increased wastewater from future population

Sediment-water exchanges

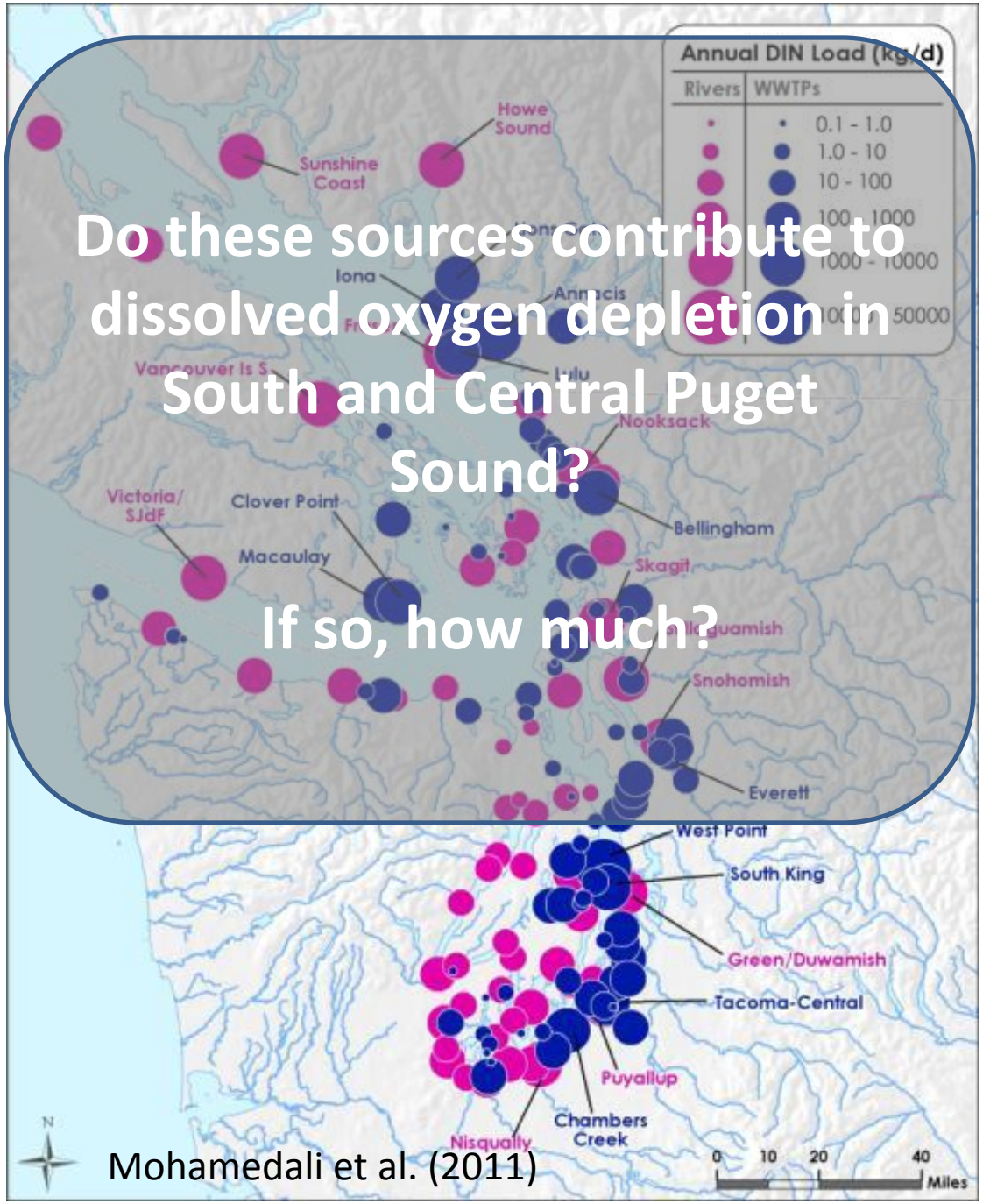
Pacific Ocean trends

Higher river nitrogen concentrations from land cover change

… more study needed.

Local sources of nitrogen *(US and Canada)*

- Pacific Ocean is the largest source of nitrogen
- Sediment-water exchanges highly influential

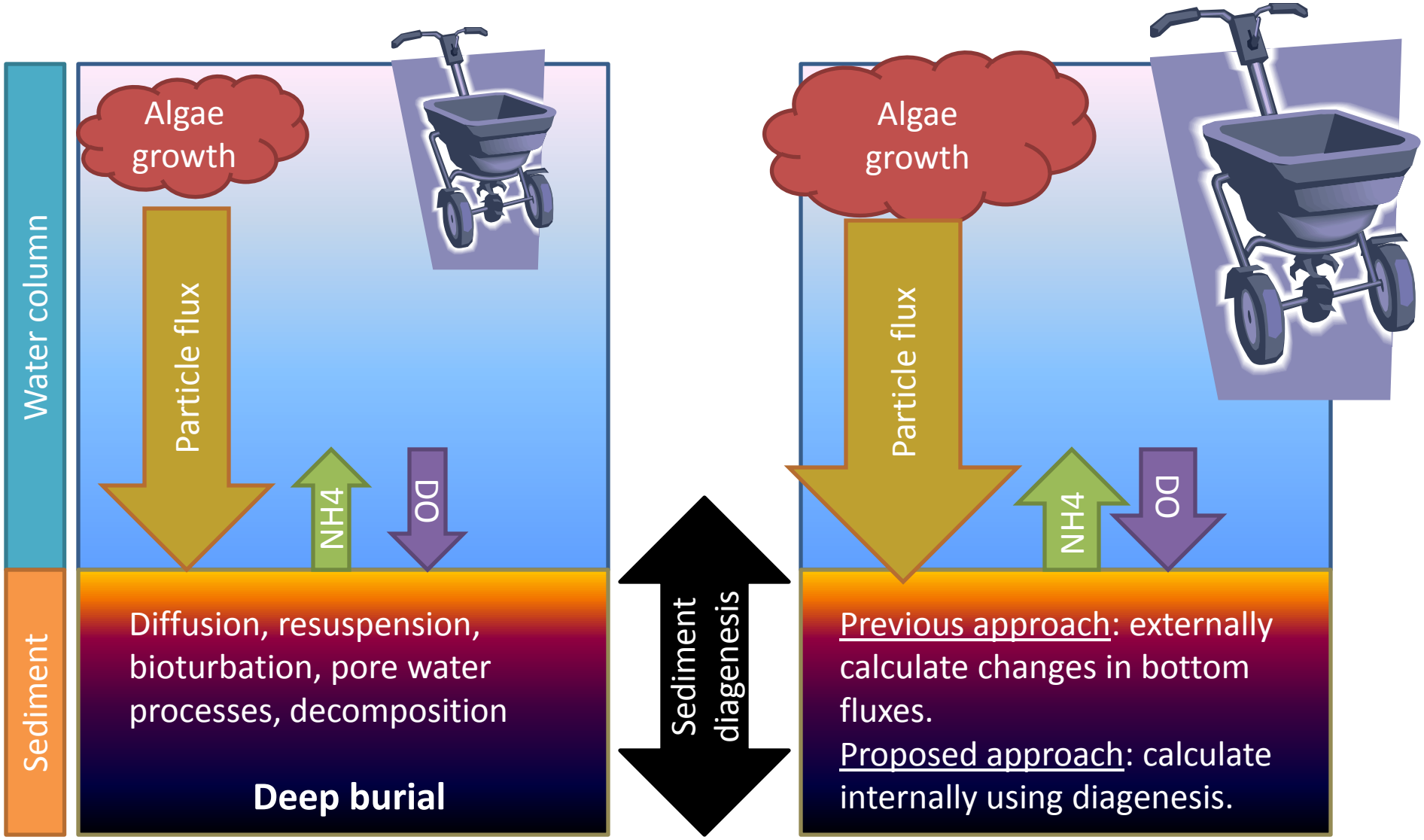


Do these sources contribute to dissolved oxygen depletion in South and Central Puget Sound?

If so, how much?

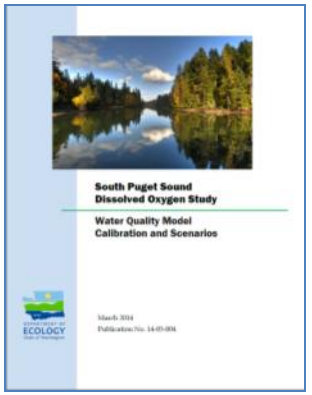
Mohamedali et al. (2011)

What is sediment diagenesis?



Purpose of adding sediment diagenesis to Salish Sea model

- Develop water column and sediment boundary conditions for the South and Central Puget Sound model
- Calculate relative influences of local human nutrient sources and the Pacific Ocean on low concentrations of dissolved oxygen
- *Plan to evaluate similar questions related to acidification … stay tuned!*



Salish Sea Model (SSM)

for the simulation of

Hydrodynamics and Biogeochemical Processes

Tarang Khangaonkar

- slides for inclusion in the

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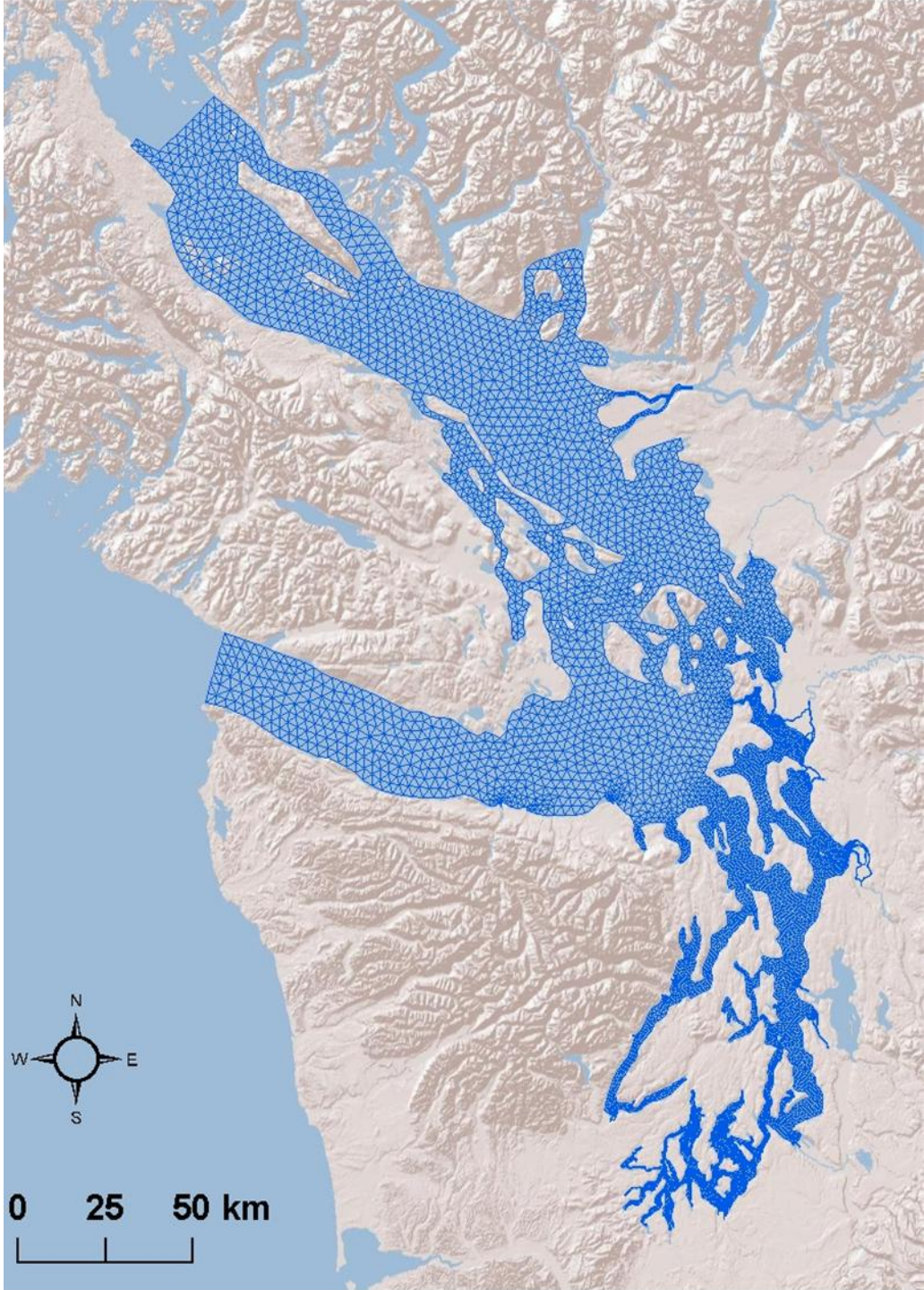
6/23/2014

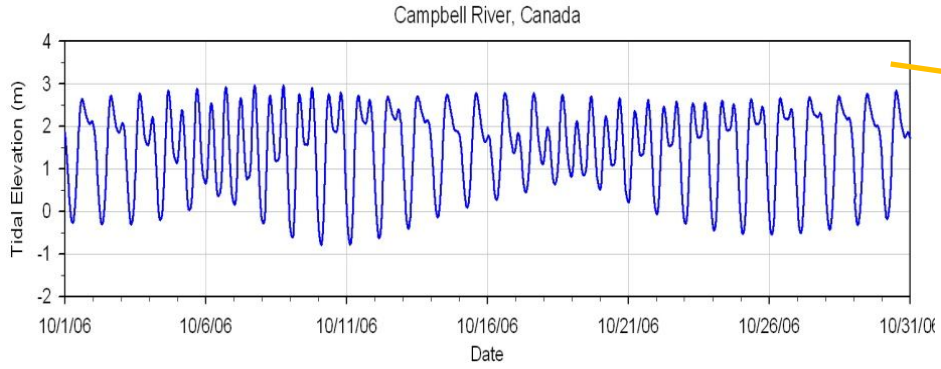
NEP Project (EPA / Ecology - 2008)

- Evaluate the effects of current and potential future nutrient loads on dissolved oxygen (DO) levels in Puget Sound
  - Development of a 3-D Hydrodynamic Model of Puget Sound
  - Development of an associated Water Quality and DO Model
- Models
  - Hydrodynamics
    - FVCOM (Chen et al 2003)
  - Water Quality
    - CE-QUAL-ICM (Cerco et al. 1995)



Open boundaries – Tides, Salinity and Temperature

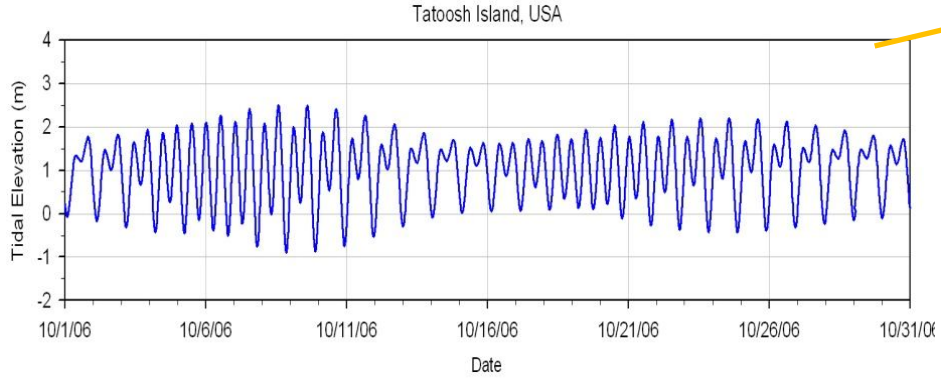
Year 2006

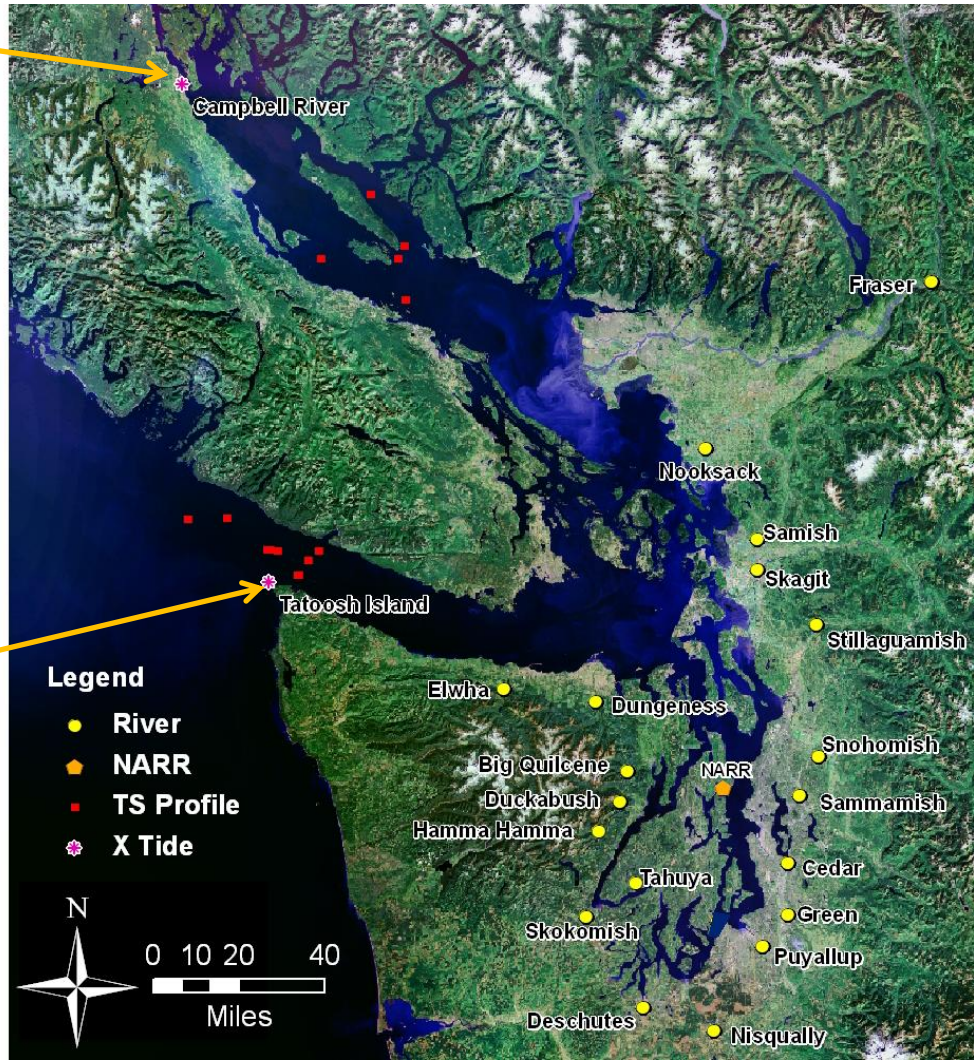


Tidal Elevations – Xtide

Harmonic tide predictor

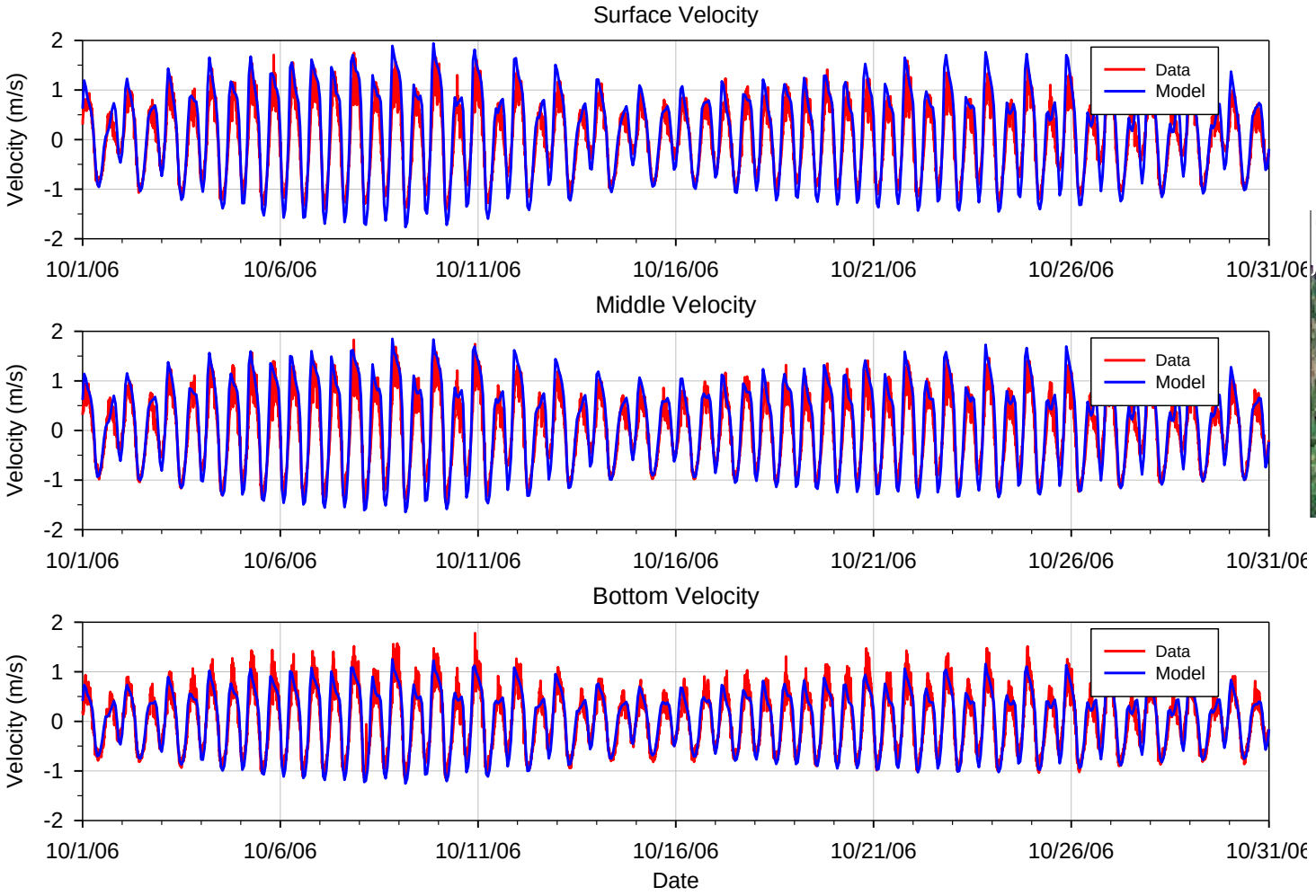
(Flater 1996)

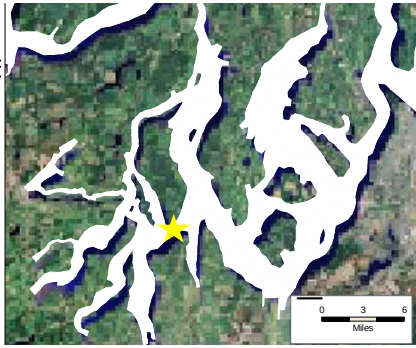




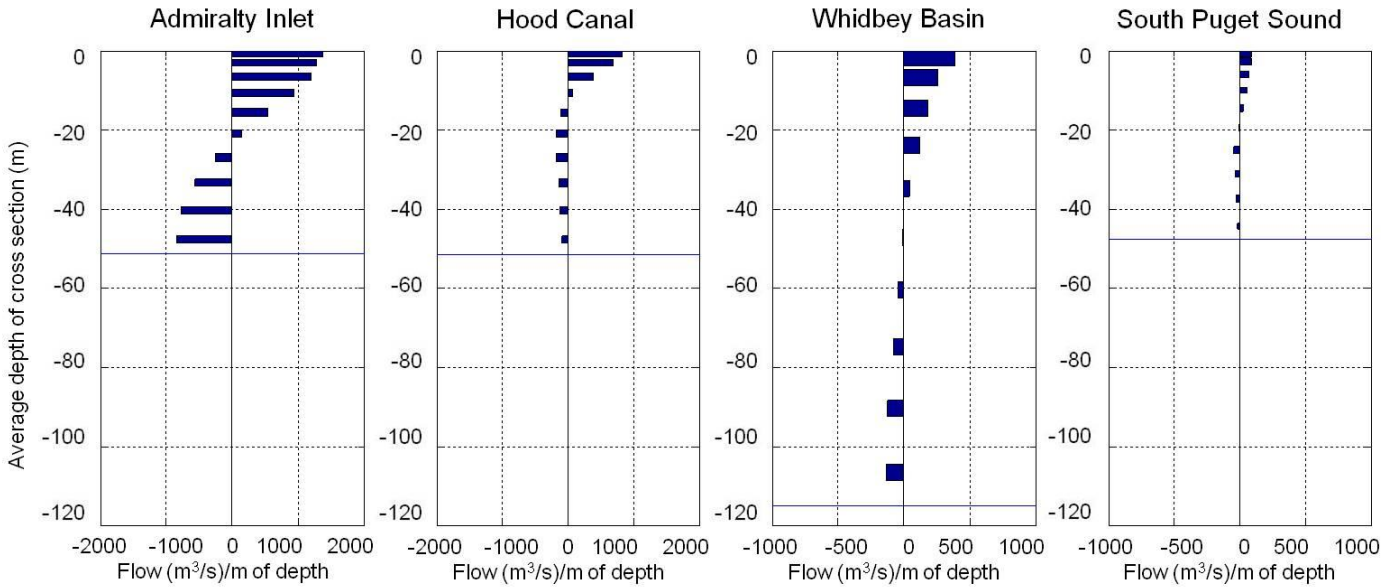
Calibration: Velocity

Dana Passage (example)



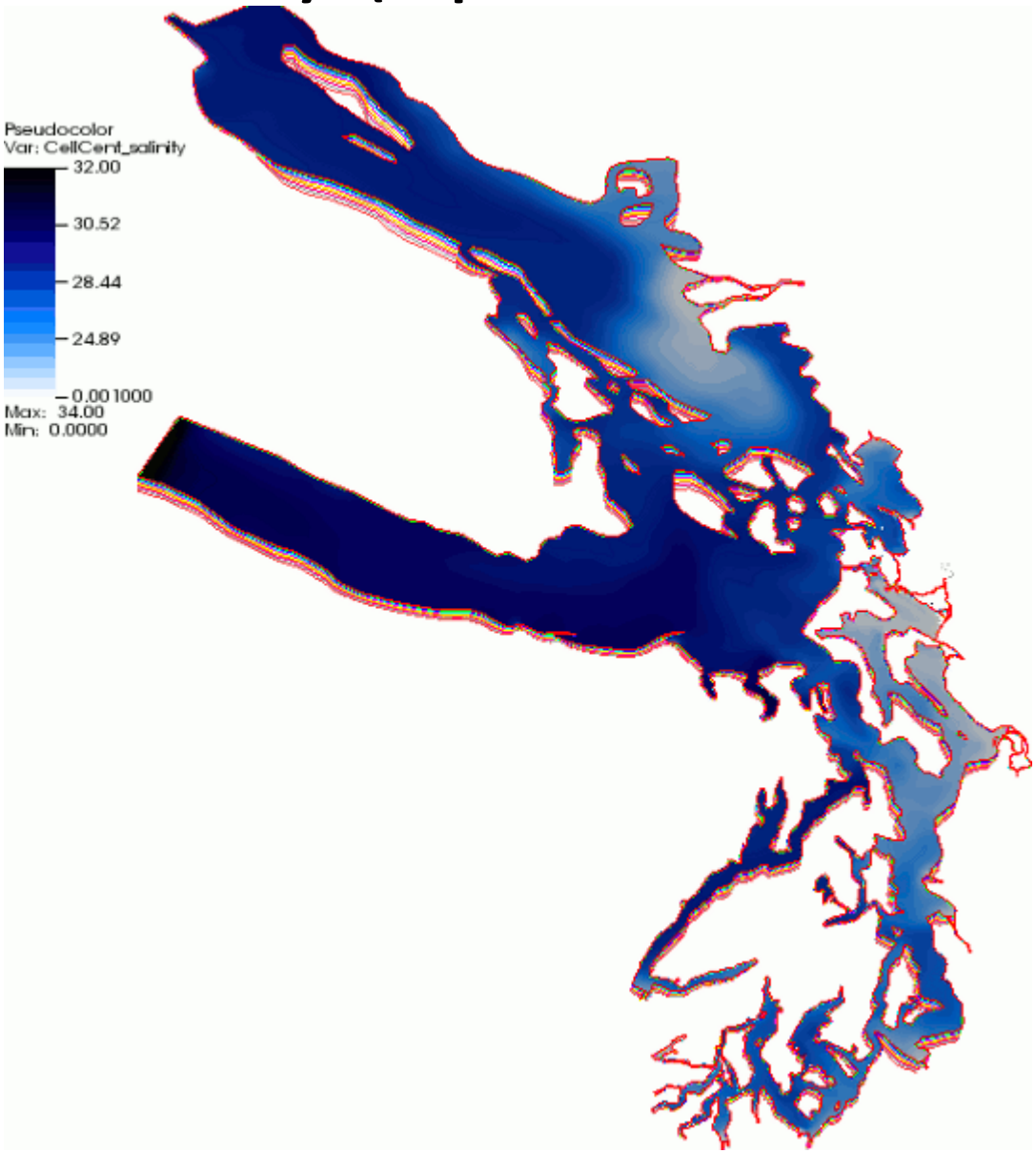


Year 2006 Mean Annual Flow



Subbasin and reach	**Mean annual tidal inflow** (m^3/s)	**Station name**	**Residence time** (days)
Strait of Juan de Fuca	129,300	Pillar Point	61
Admiralty Inlet to Puget Sound	17,117	Admiralty Inlet	160
Main Basin – Puget Sound	12,051	Jefferson Point	257
Whidbey Basin (inflow through Possession Sound)	6,111	Saratoga Passage	228
Hood Canal (inflow over the sill)	5,066	Eldon Point	282
South Puget Sound (inflow over Tacoma Narrows sill)	814	Devils Head	292

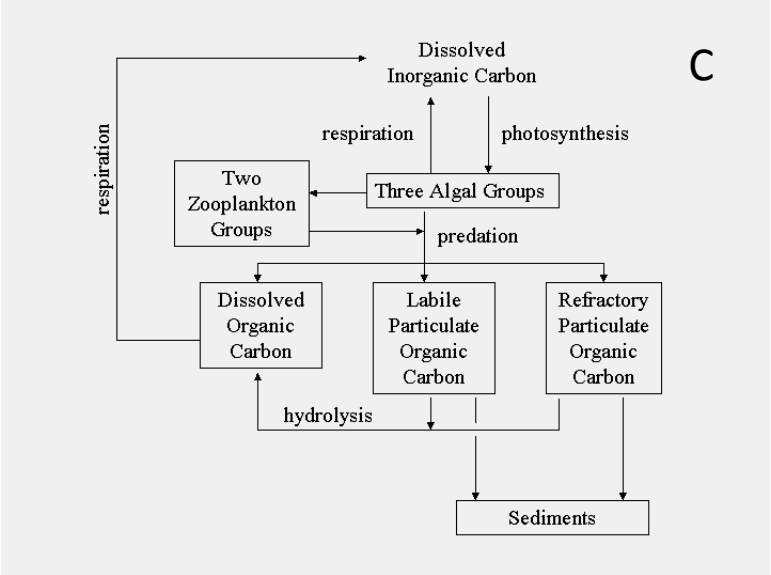
Surface Salinity (April 2006 conditions)

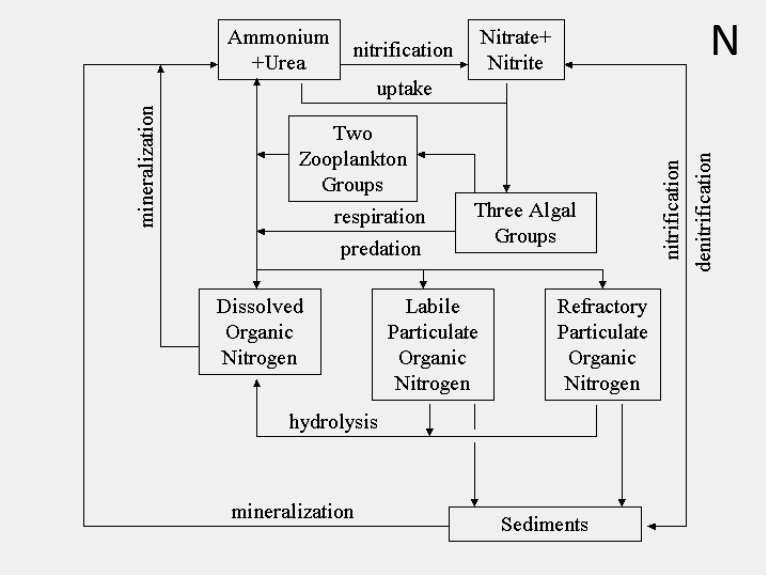


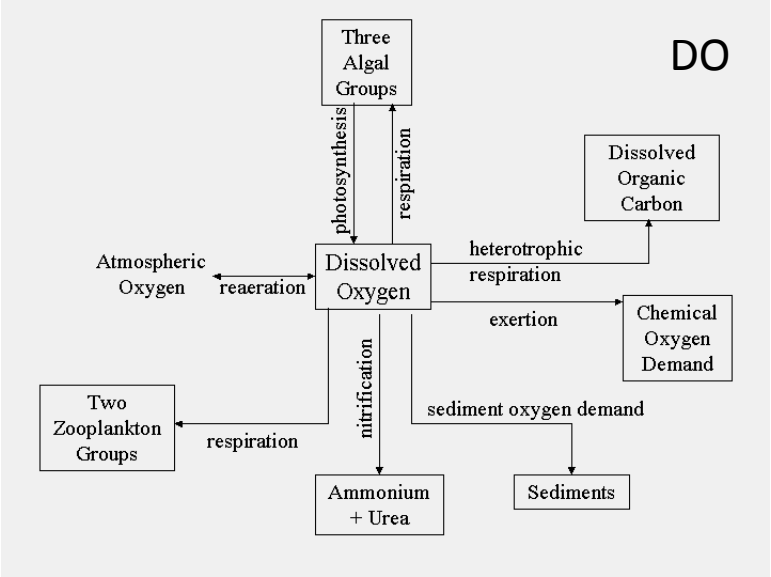
Biogeochemical model of Salish Sea

CE-QUAL-ICM

- Eutrophication model (Cerco and Cole, 1994)
- 32 water quality state variables
- Aquatic vegetation
- Predictive sub-model to calculated interactive fluxes between sediment and water columns
- Parallelized operation



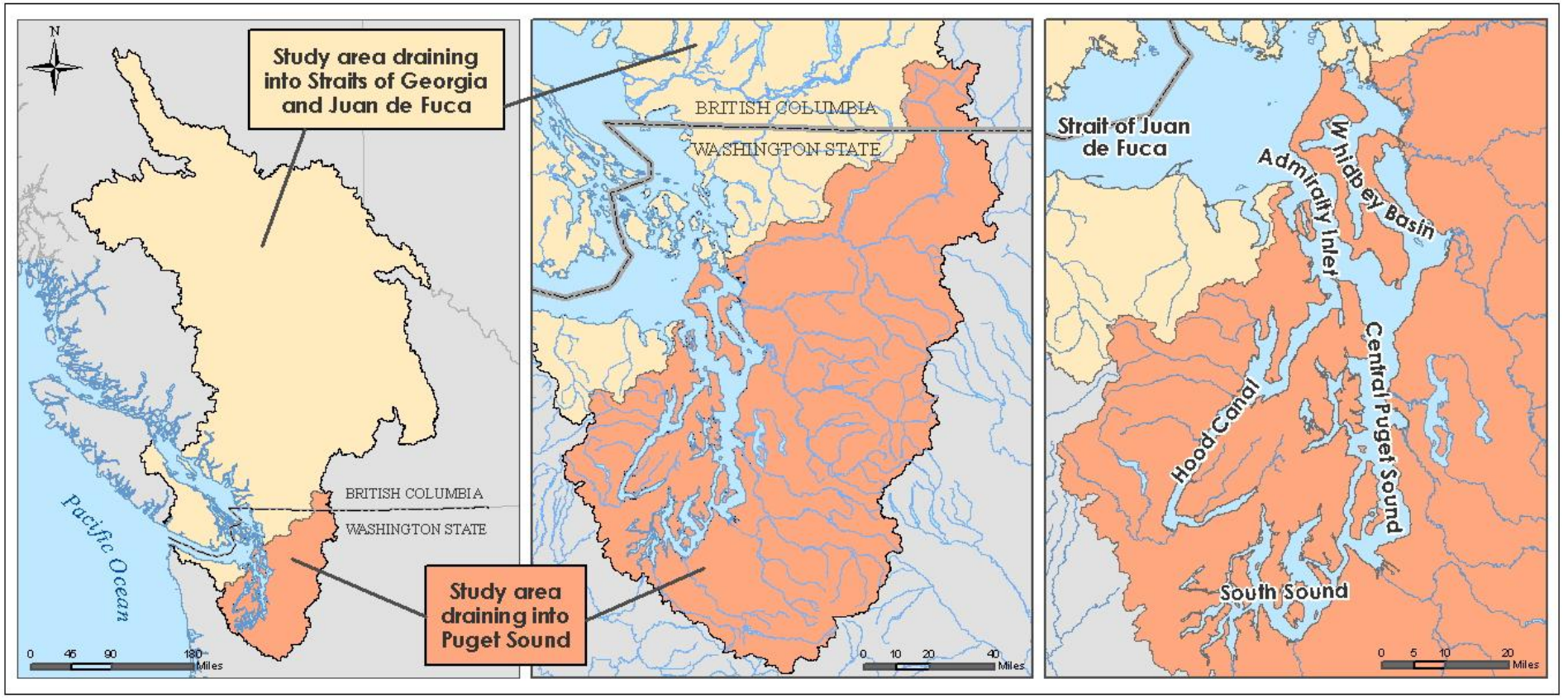




Carbon, Algae, Nitrogen and DO cycles in CE-QUAL-ICM

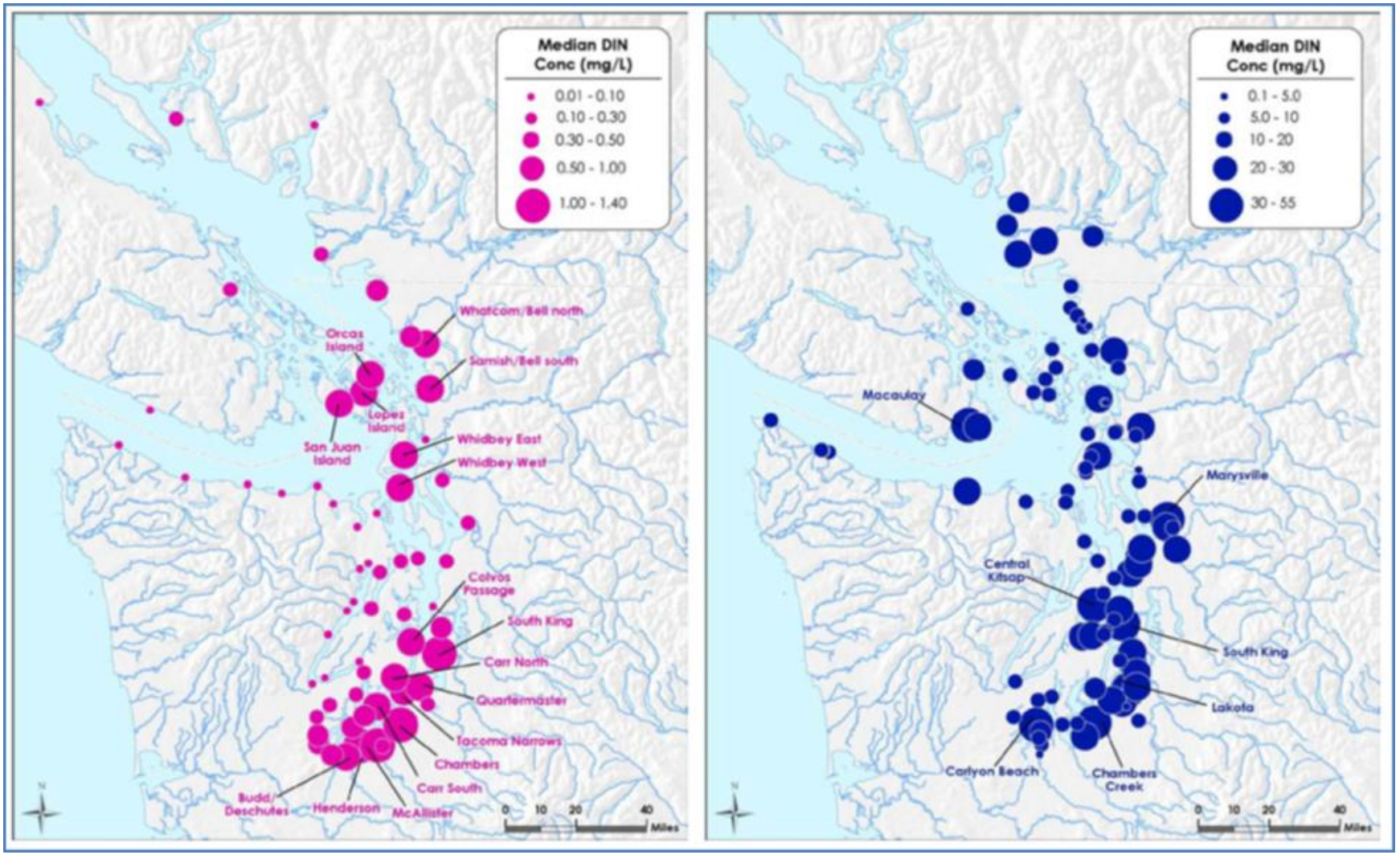
Nutrient Loads to Puget Sound

Rivers, Streams, Outfalls (Industrial and WWTP)



[Mohamedali et al 2013. Puget Sound Dissolved Oxygen Model Nutrient Load Summary for 1999–2008]

River and Point Source Loads in SSM

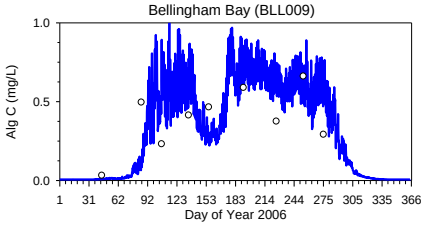


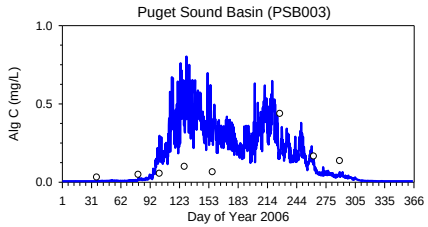
River and watershed loads

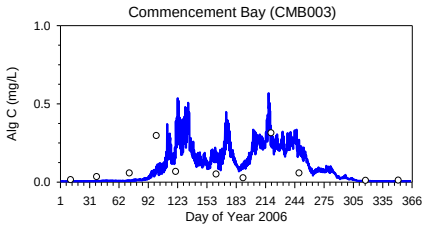
WWTP Outfalls
(point source loads)

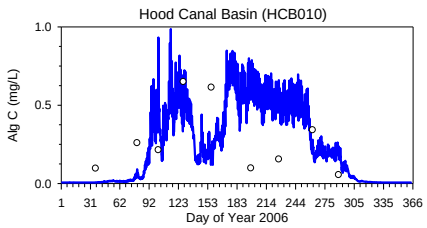
Simulated Surface Constituents (2006)

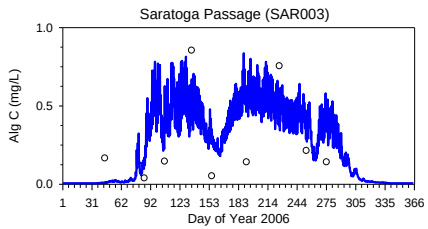
Algae



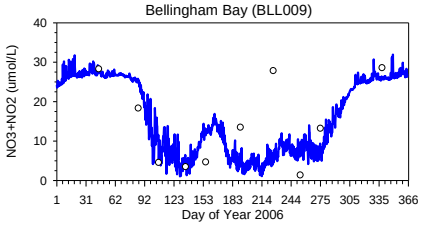


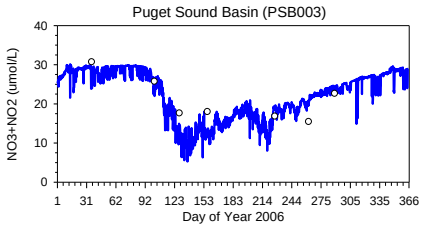


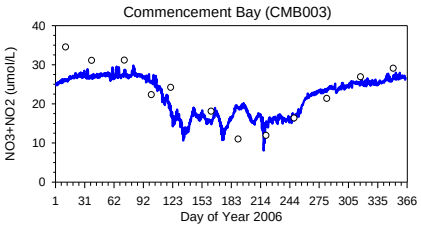


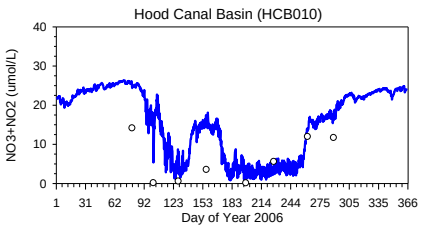


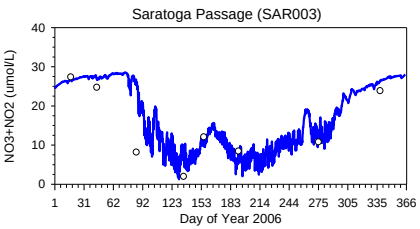
NO3+NO2



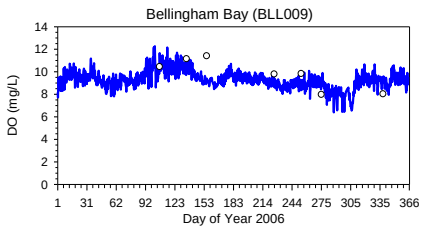


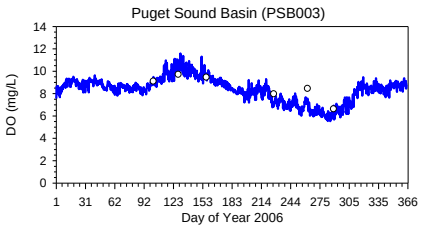


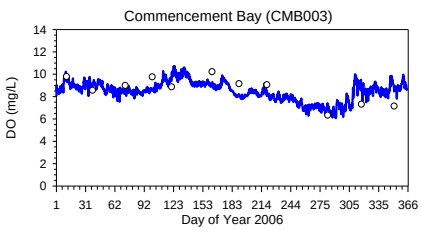


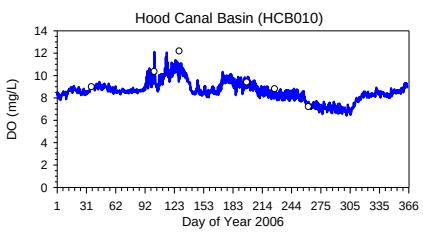


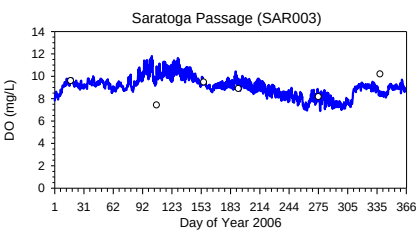
DO











Sediment flux loads – specified values

Existing setup in Salish Sea Model

Benthic Sediment Fluxes (5-cm depth)

Nutrients and Dissolved Oxygen

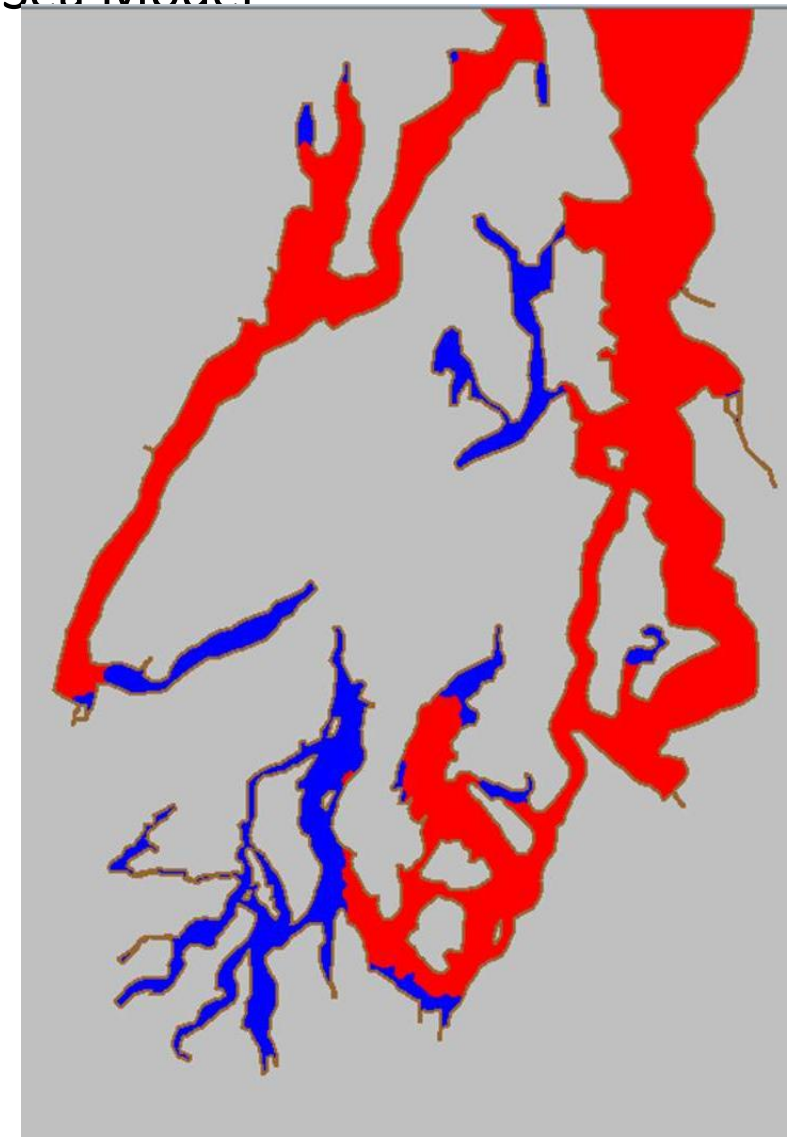
Constituent	Nitrate (NO_3+NO_2)	Ammonium (NH_4)	Phosphate (PO_4)	Dissolved Oxygen
Benthic Flux ($g\ m^{-2}\ d^{-1}$)	-0.011	0.064	0.02	-0.1[a] -2.0[b]
Range ($g\ m^{-2}\ d^{-1}$)	-0.004 to -0.016	0.03 to 0.12	0.0 to 0.05	-0.24 to -1.71

[a] Value specified in most of Salish Sea domain, [b] Value specified in selected shallow regions of Puget Sound known for low values of near bed DO

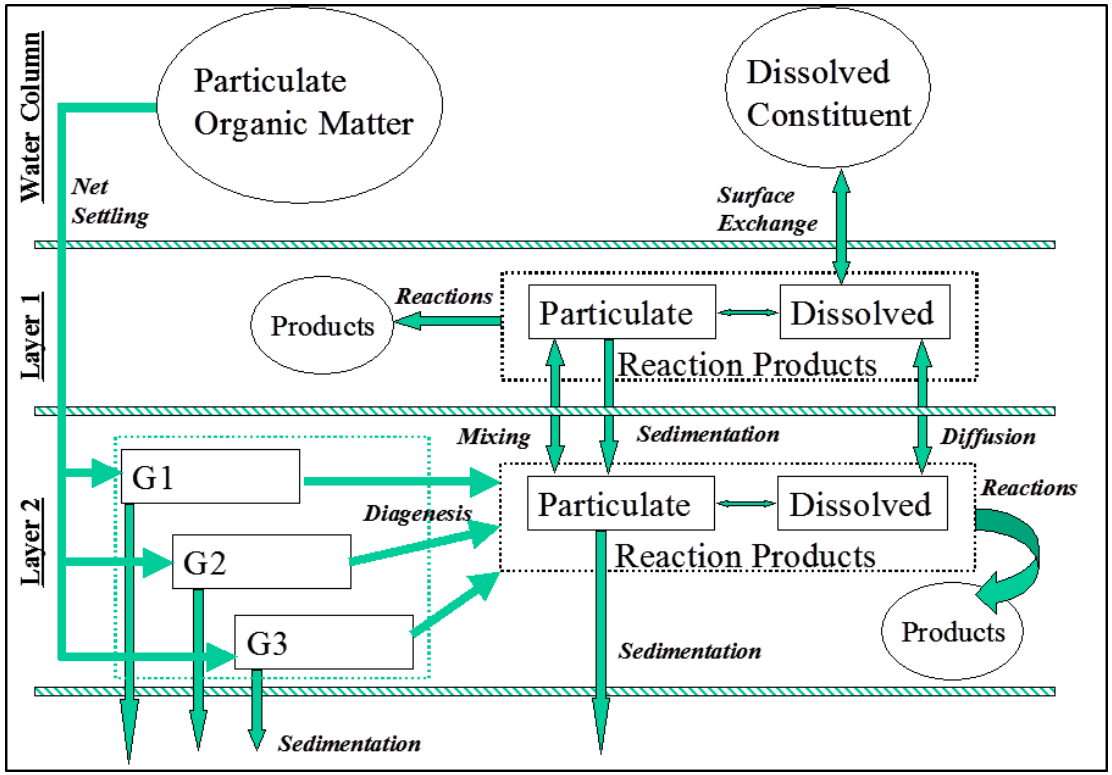
To be replaced by

Internally Computed Fluxes

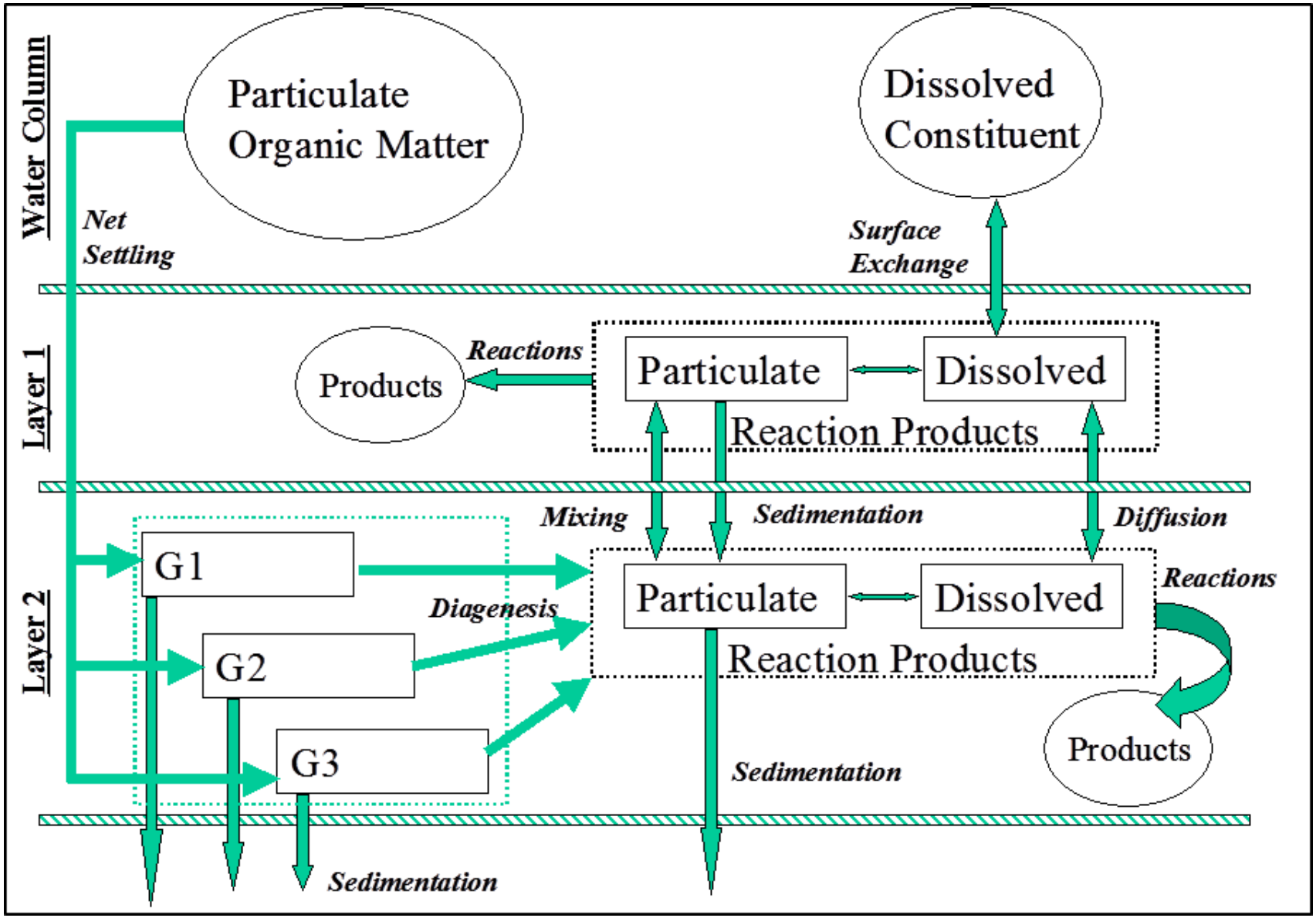
Sediment Diagenesis Flux Model



Model Setup and Testing
Greg Pelletier (Ecology)



Basic structure of sediment flux model



Inputs to the sediment flux model

- Settling of particulate organic C and N from the water into the sediment (phytoplankton and detritus)
- Concentrations of water quality variables in the water overlying the sediment (DO, temperature, salinity, ammonium, nitrate+nitrite, DOC)

Outputs from the sediment flux model

- Sediment water fluxes of DO (SOD), ammonium, nitrate, DOC, sulfide
- Pore water concentrations of solutes (ammonium, nitrate, DOC, sulfide)
- Particulate organic C and N concentrations in the sediment
- Thickness of the aerobic layer of the sediment

Implementing the sediment flux model

- Subroutine originally written in Fortran written by Hydroqual (Fitzpatrick, Cerco, DiToro) for Chesapeake Bay model
- CE-QUAL-ICM and WASP use nearly identical subroutines.
- Standalone Excel/VBA and Fortran versions will be used as QA check. Standalone version by Dr. James Martin was extensively tested by EPA for WASP
- Conduct QA tests to compare results of Subroutine with Standalone version

QA tests of the sediment flux model

- Steady-state solution of constant deposition and constant overlying water quality
- Time-variable solution of
  - assumed initial conditions, constant deposition, and constant overlying WQ
  - assumed initial conditions, constant deposition, and time-varying overlying WQ
  - steady-state initial conditions, constant deposition, and constant overlying WQ
  - steady-state initial conditions, constant deposition, and time-varying overlying WQ
- One-year simulation of linked model at one or more locations comparing SFM with standalone

FVCOM-ICM Sediment Diagenesis Model Validation and Calibration

Wen Long (PNNL)

1. Validate with analytical solution
2. Validate with Excel VBA code
3. Calibrate with available data
4. **Calibrate Puget Sound**

Calibrate Puget Sound Model

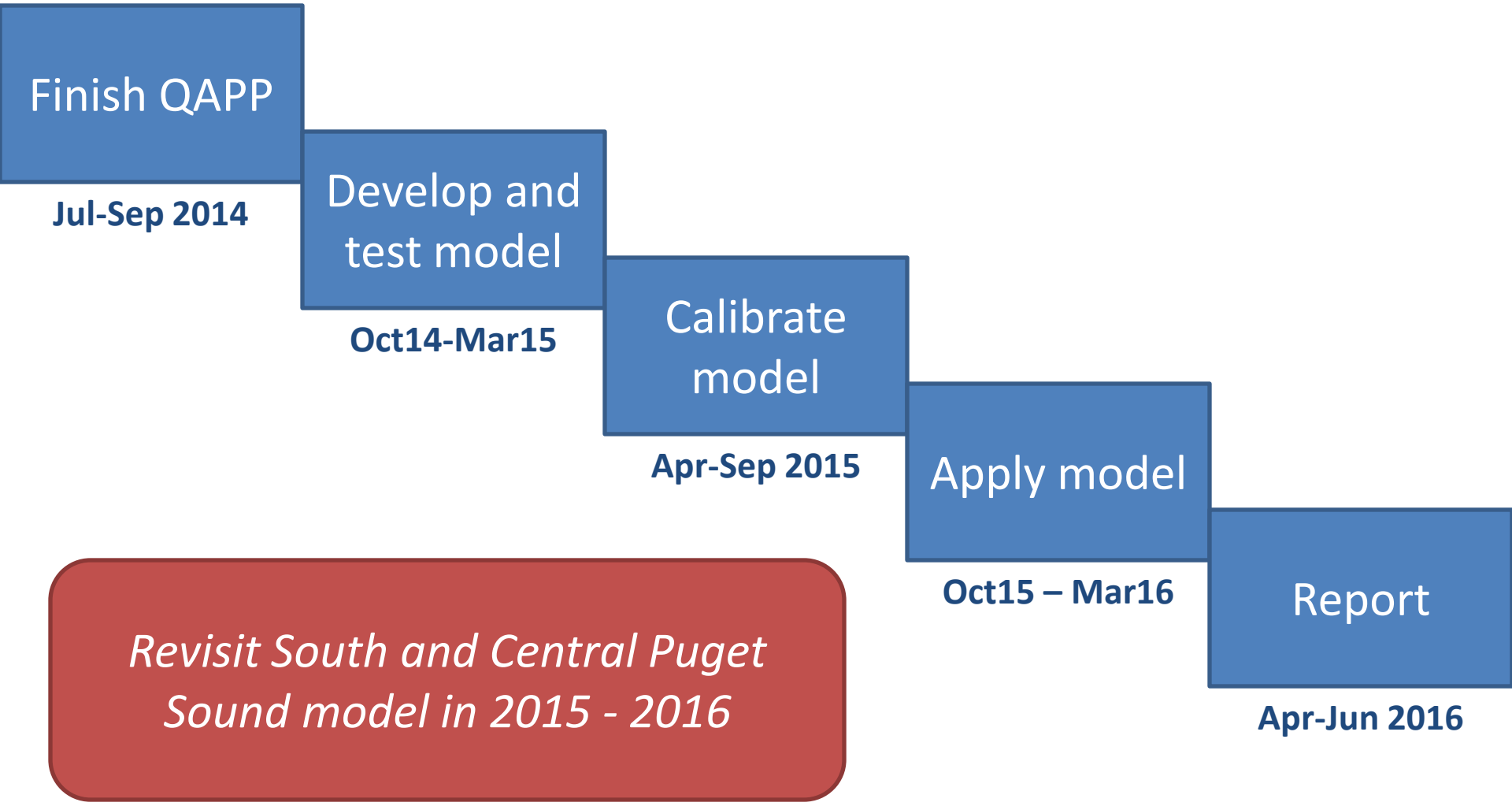
- Calibration would be based on simulation of Puget Sound with 2006-2007.

- Recalibrate NH4, NO3, PO4 and DO simulation based on water column profile measurements. Phytoplankton parameters may also be re-calibrated as needed

- Tuning parameters: solids concentration, and burial velocity from data, 3G classes, settling velocity, reaction rates, diffusion rates, mass transfer rates, thickness, partitioning constants, particle mixing half-sat

Project Components and Schedule

Mindy Roberts (ECY)



Comments on QAPP
Andrew Kolosseus (ECY)

- Email to Andrew.Kolosseus@ecy.wa.gov by July 23, 2013
- For more information:
  - http://www.ecy.wa.gov/programs/wq/PugetSound/DOModel.html
  - http://www.ecy.wa.gov/puget_sound/dissolved_oxygen_study.html
- Thank you!