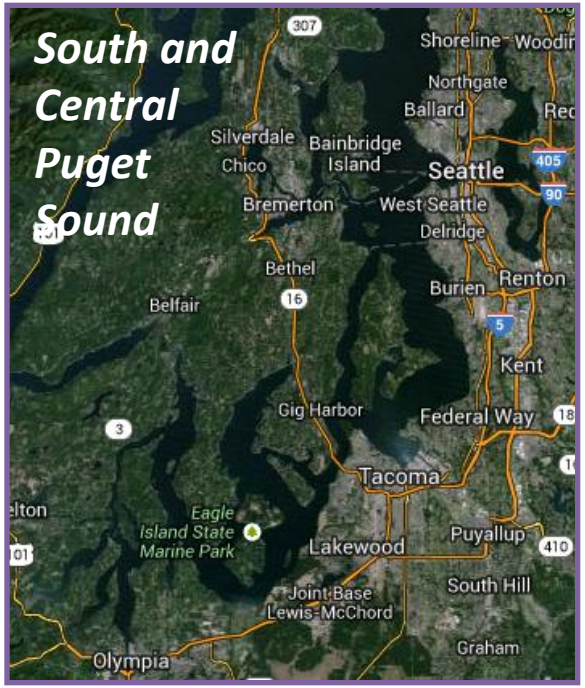
Dissolved Oxygen Modeling Results for South Puget Sound and the Salish Sea*

*(*Puget Sound, Strait of Juan de Fuca, Strait of Georgia of US and Canada)*

Briefing for Advisory Committees



Mindy Roberts

Anise Ahmed

Greg Pelletier

October 15, 2013

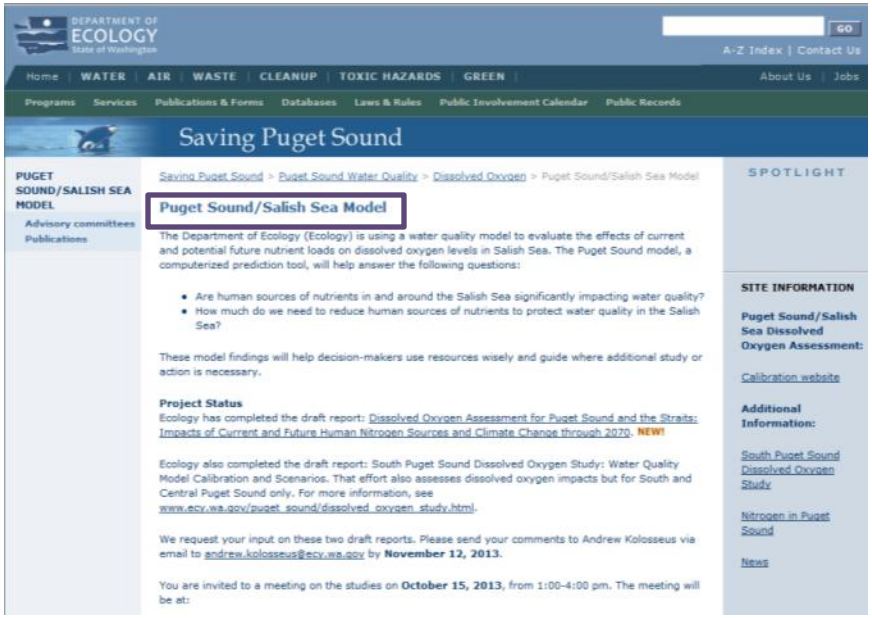
Summary

- Draft Reports: Send comments to Andrew.Kolosseus@ecy.wa.gov by November 12
- While the studies provide a great deal of information, more research and certainty is needed before effective actions can be specified
- Next steps: improving models (2015)
- *We will continue coordinating with you on study findings and future steps*

Project Component	South and Central Puget Sound	Salish Sea (Puget Sound and the Straits)
Circulation model development and calibration	(external rev. 12/09)	Yang et al. (2010)
Nutrient loading estimates from watershed inflows* and wastewater treatment plants**	Mohamedali et al. (2011a)	Mohamedali et al. (2011b)
Water quality model development and calibration	**Today**	Khangaonkar et al. (2012)
Water quality scenarios	**Today**	**Today**

* Includes all upstream sources, both natural and human, such as septic systems and runoff from developed lands.
** Discharging to marine waters; those discharging upstream are part of the watershed inflow load estimates.

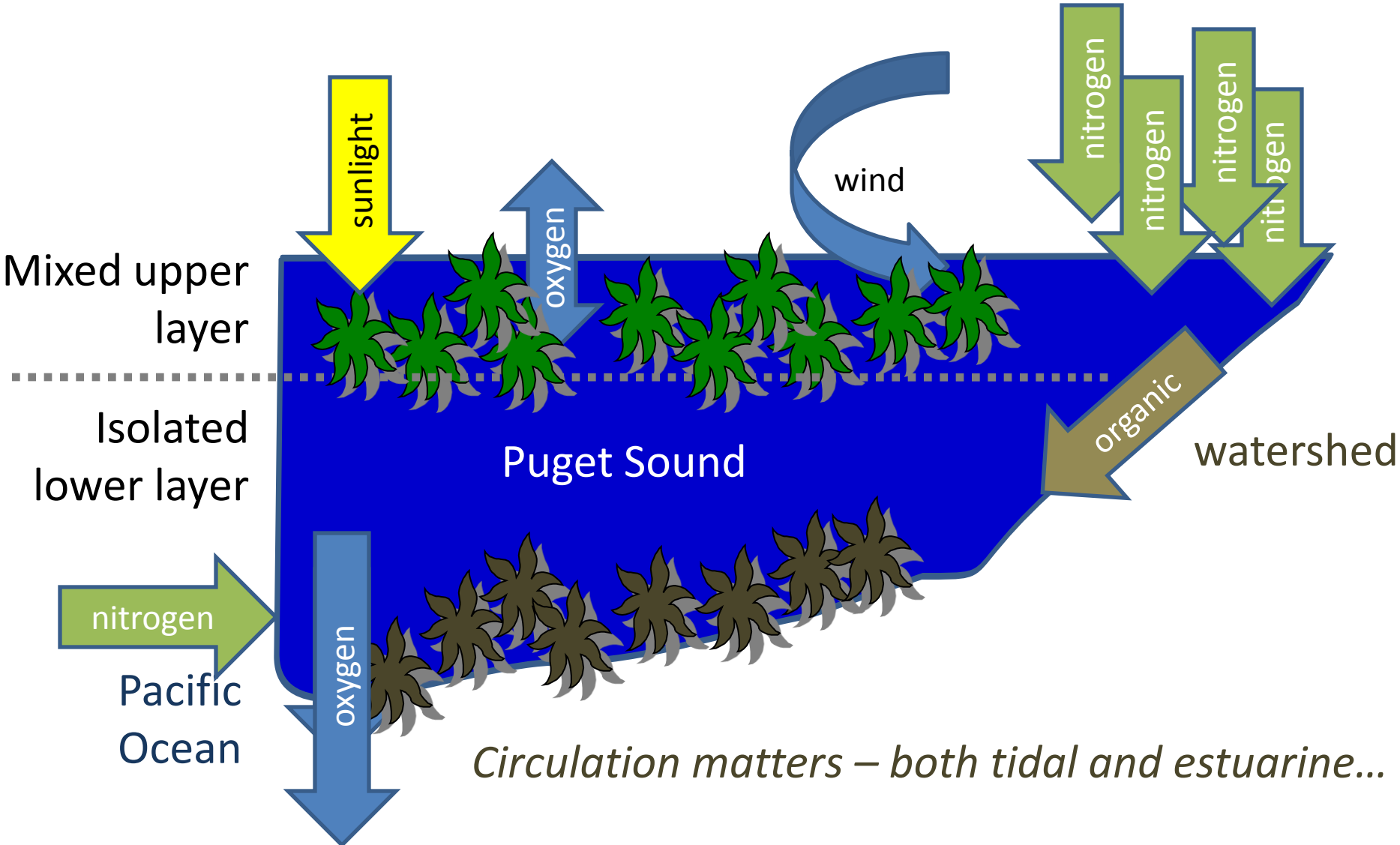
Web sites – information portals



www.ecy.wa.gov/puget_sound/dissolved_oxygen_study.html

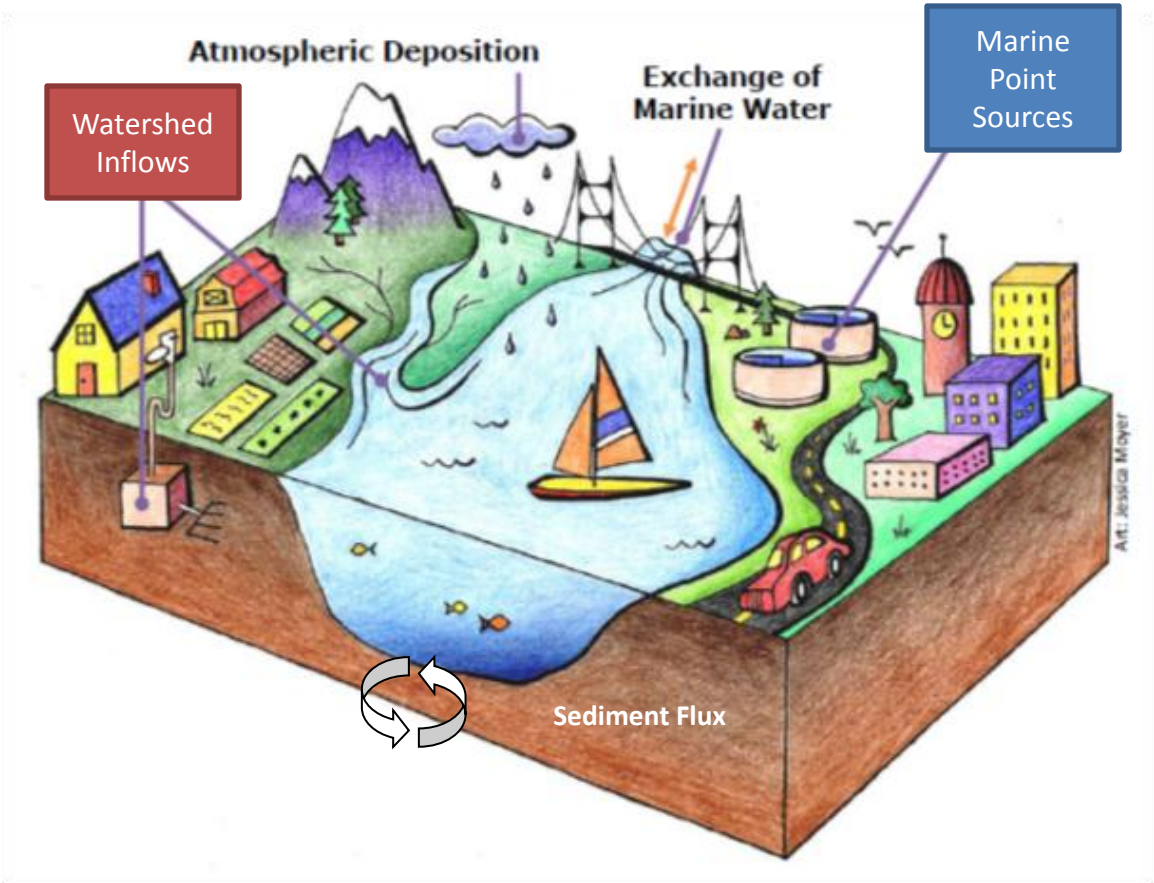
www.ecy.wa.gov/programs/wq/PugetSound/DOModel.html

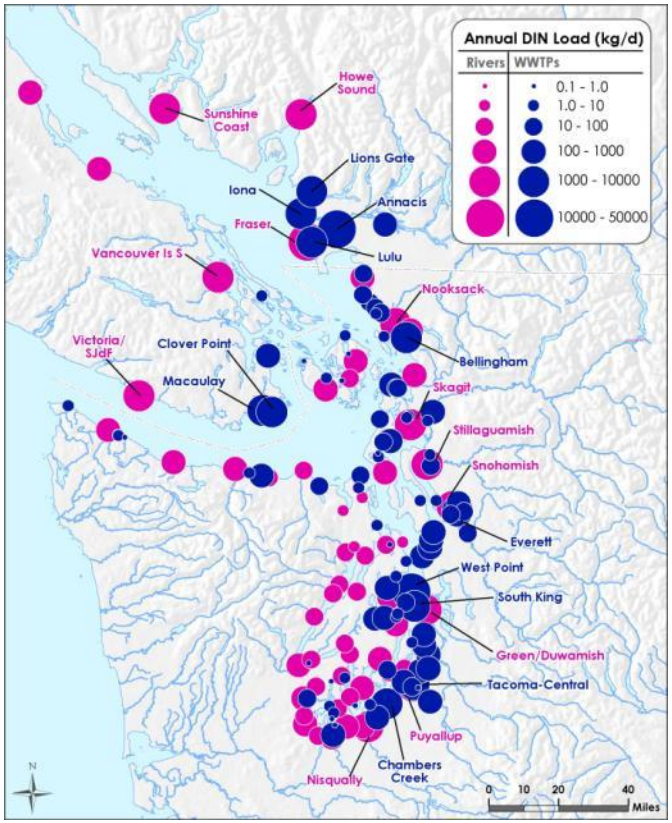
Why reduce nutrients when we care about dissolved oxygen?

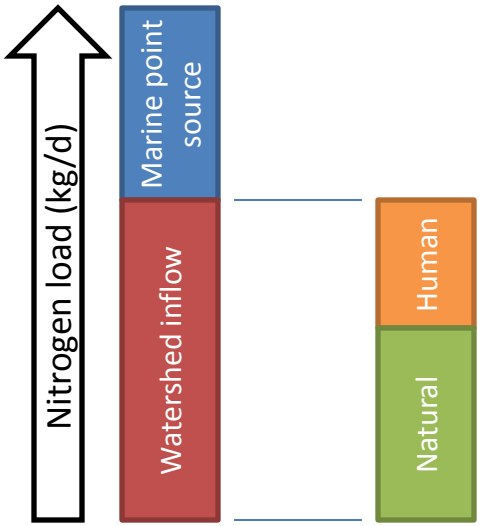


Circulation matters – both tidal and estuarine…

What are the sources of nitrogen?

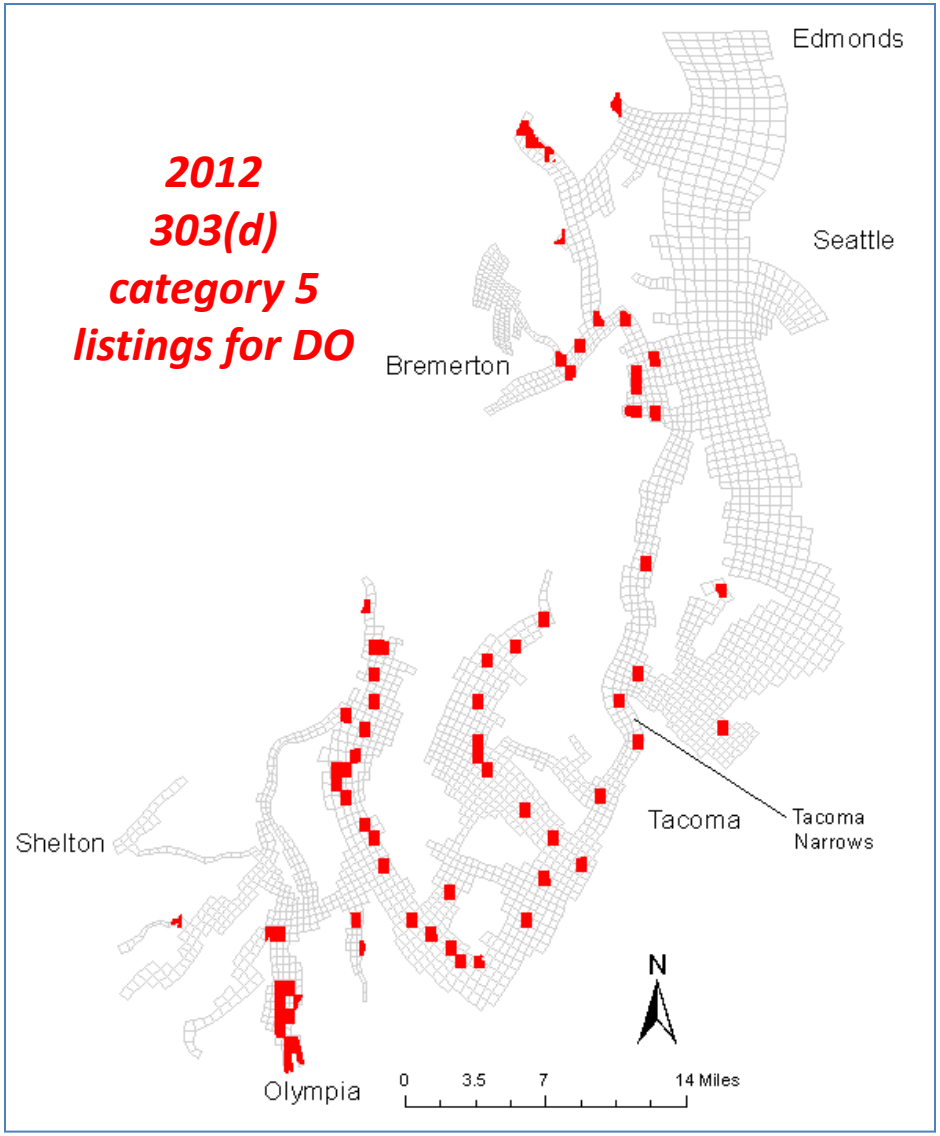


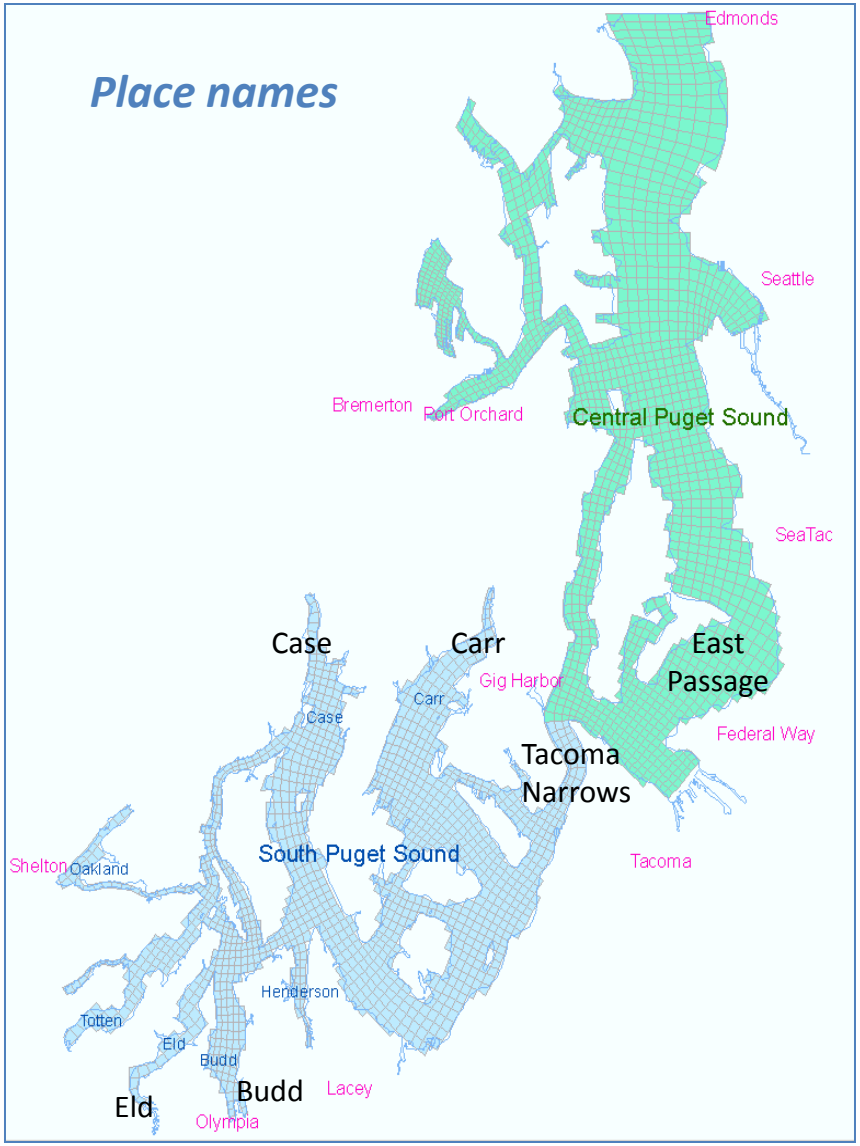




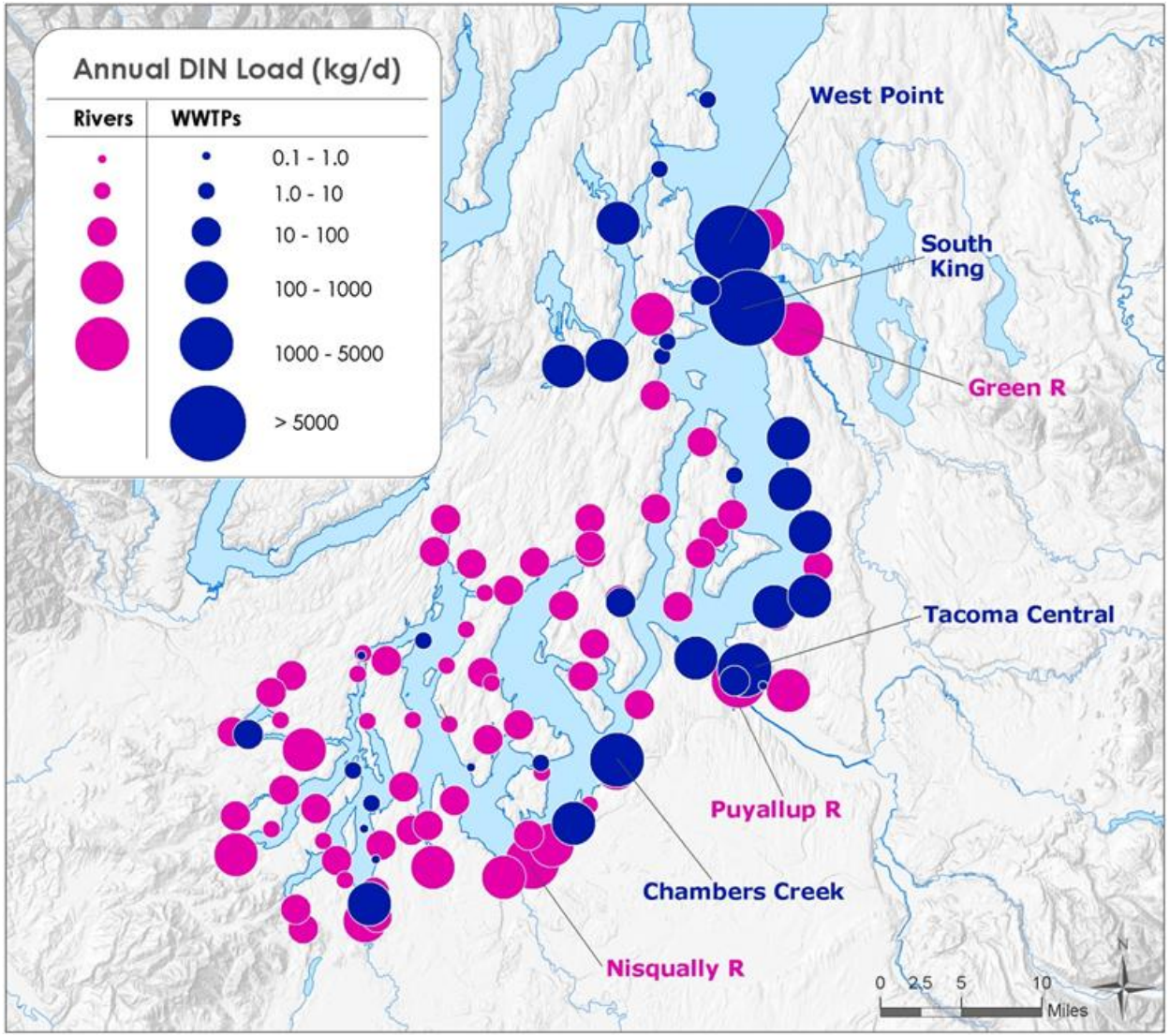
Dissolved inorganic nitrogen (DIN) = nitrate + nitrite + ammonium

1. South Sound calibration and scenarios



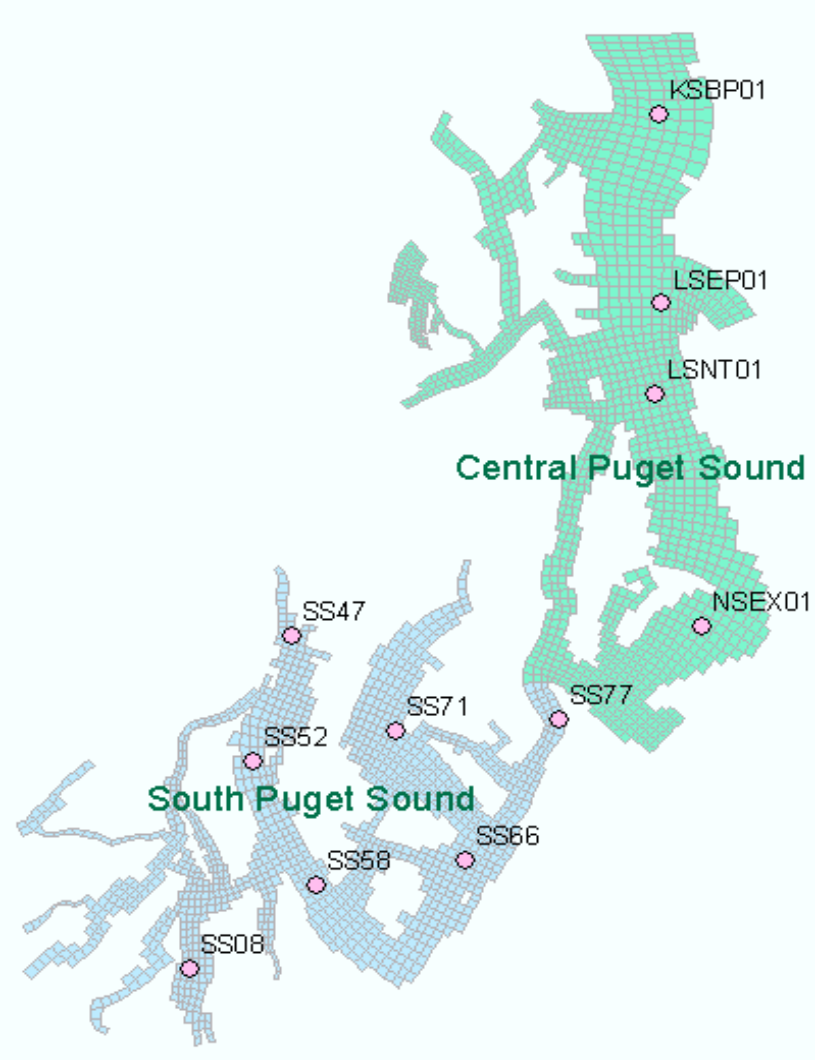


Sources of Nitrogen loading to South and Central Puget Sound

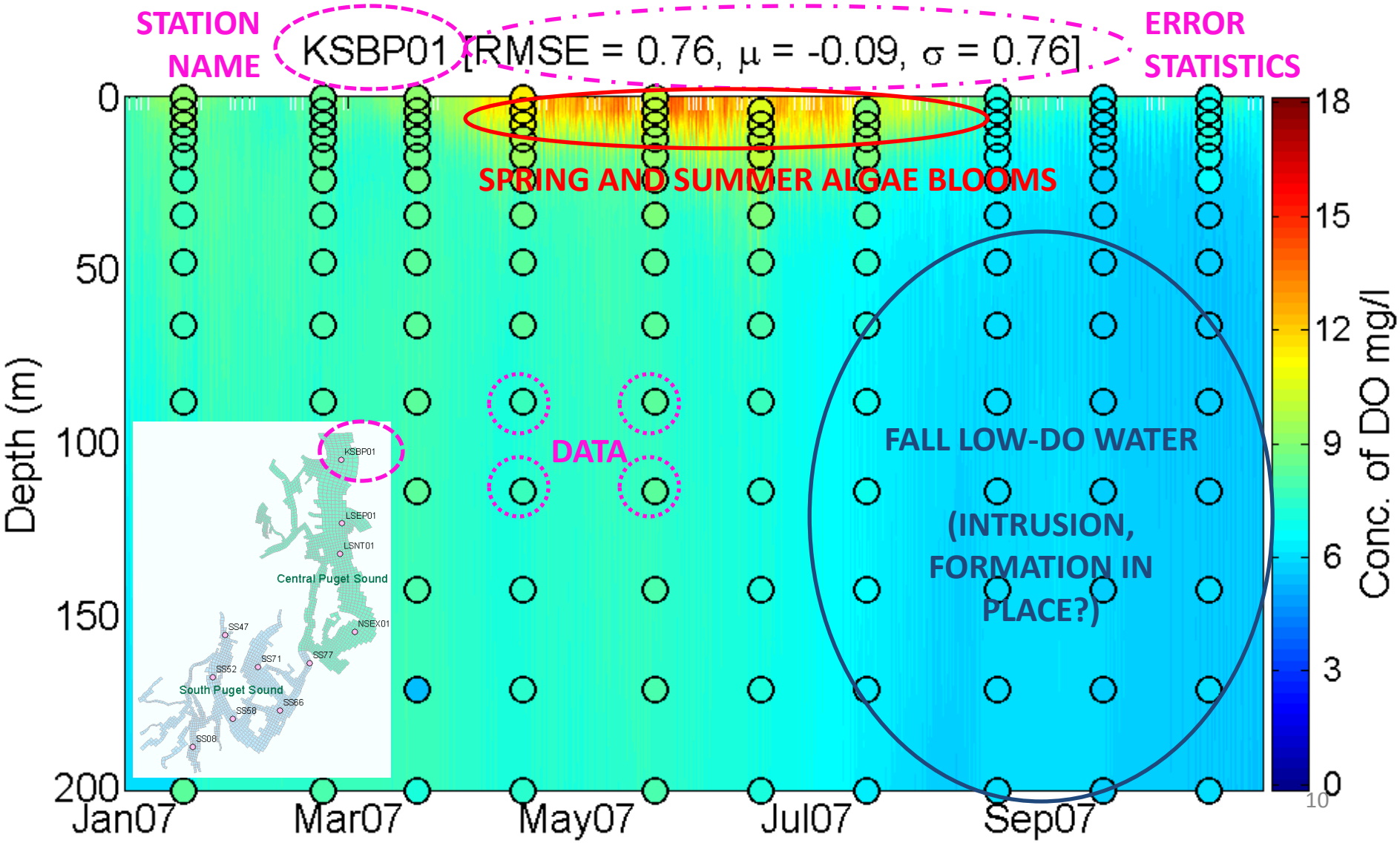


Calibration process

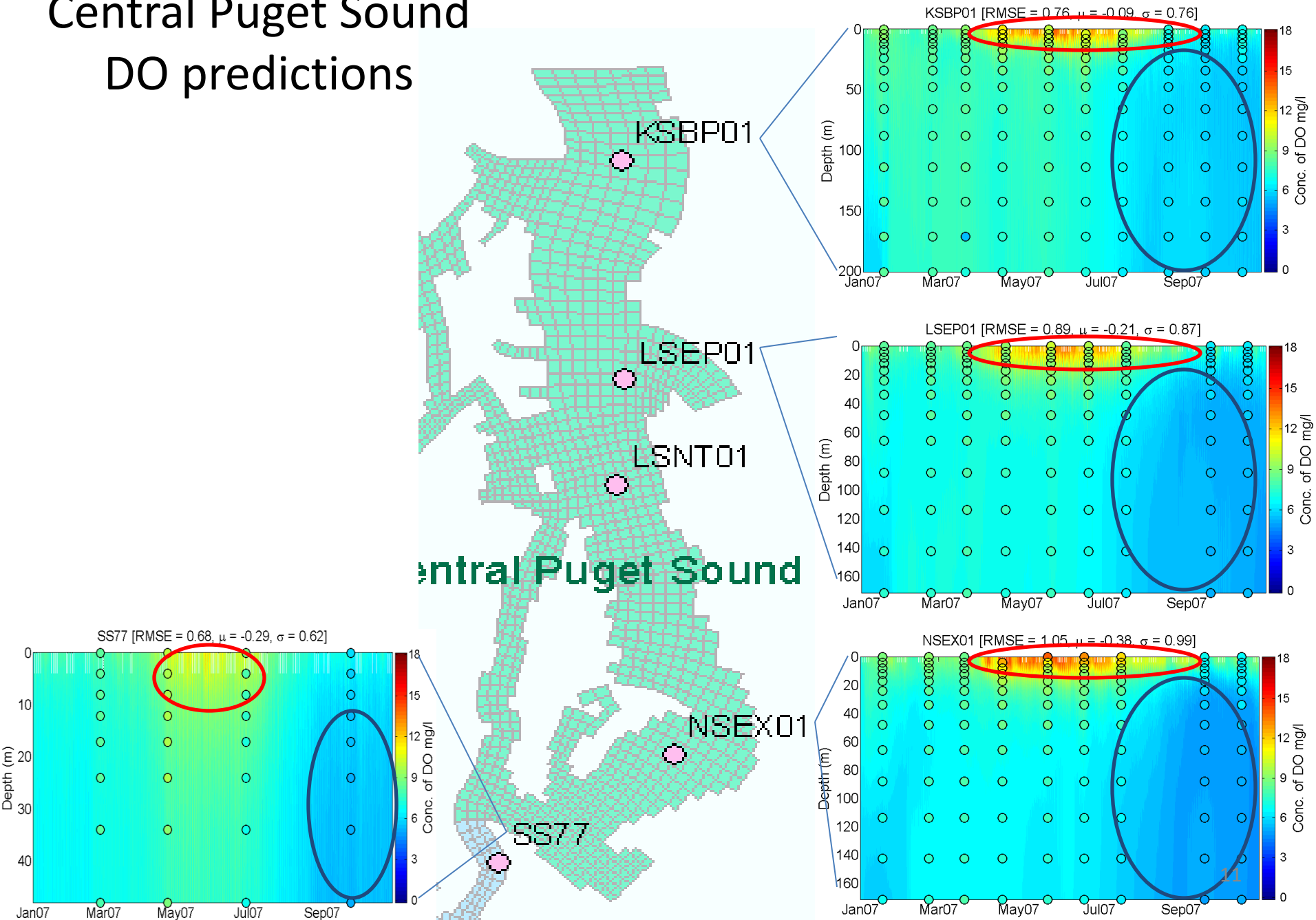
- Calibrate circulation model
- Begin with Budd Inlet WQ model parameters
- Batches of 50-70 runs varying algal kinetics and other key parameters
- Error statistics – best fit to measured data
- Adjust next parameter, batches of 50-70 runs
- Repeat … 1190 runs
- *@ 10 days each = 33 years…*



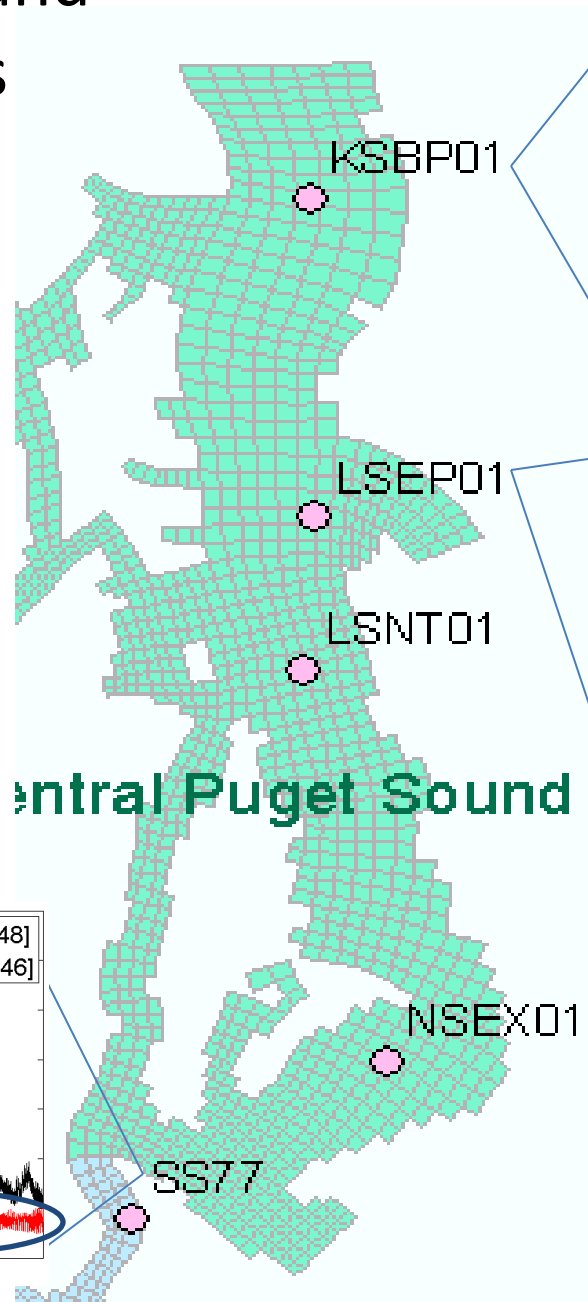
DO predictions good (north end of Central PS)

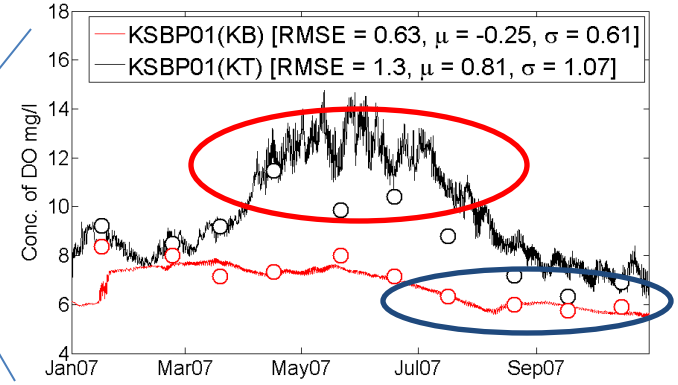


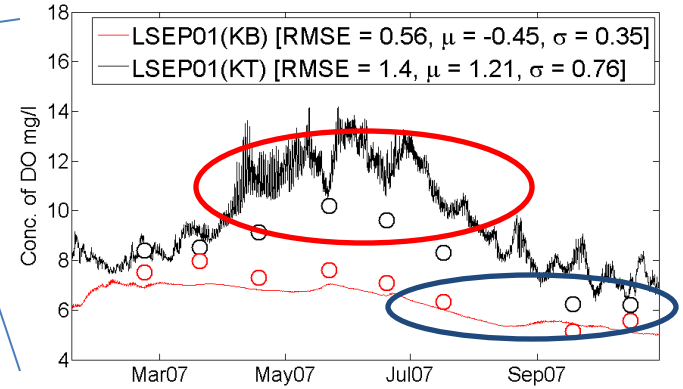
Central Puget Sound DO predictions

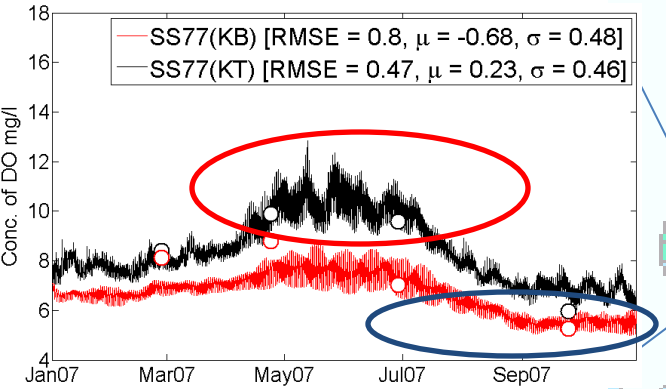


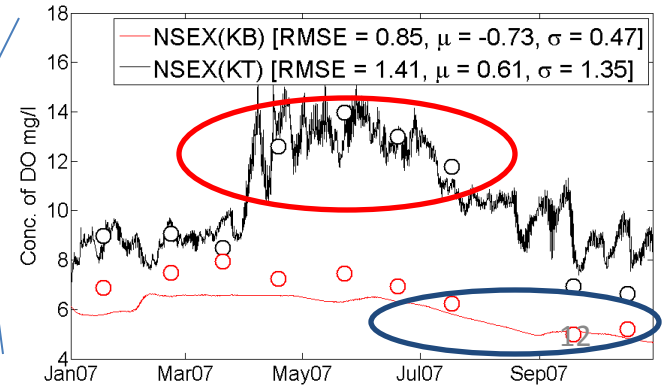
Central Puget Sound DO predictions



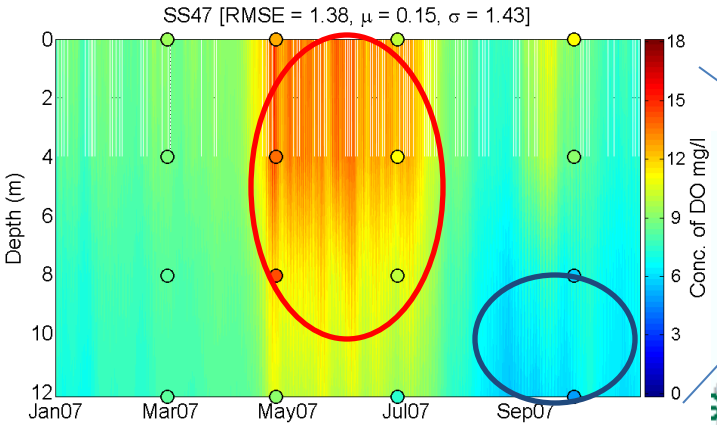


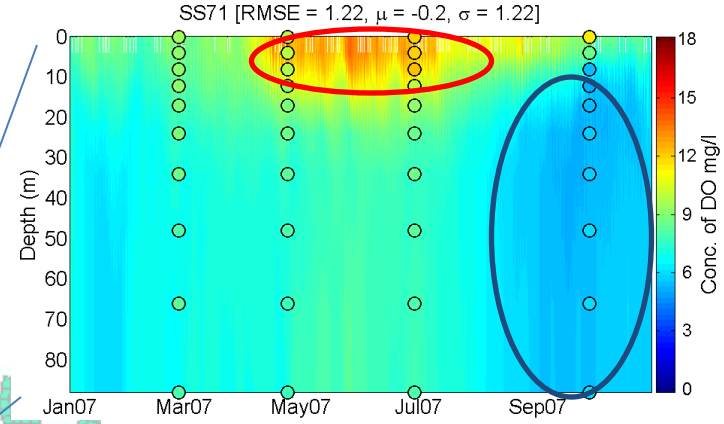


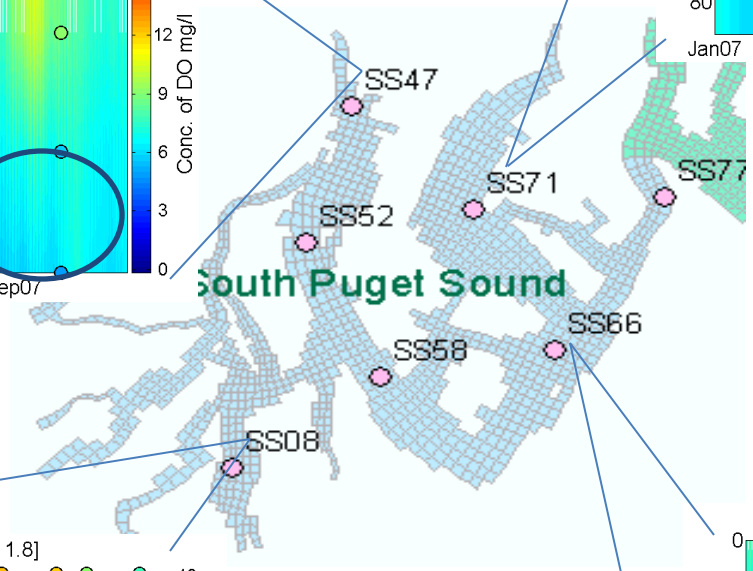


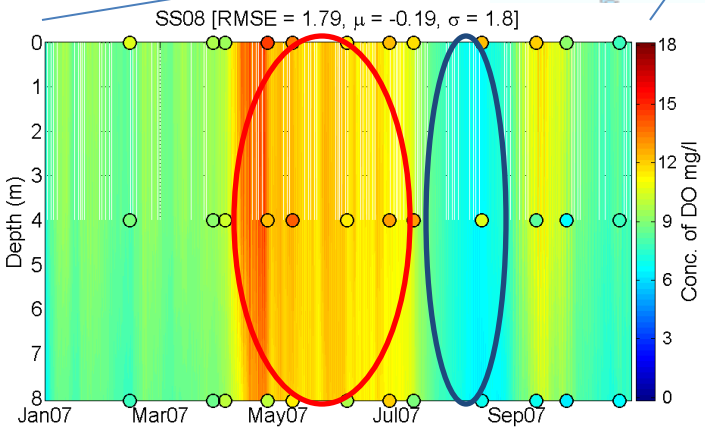


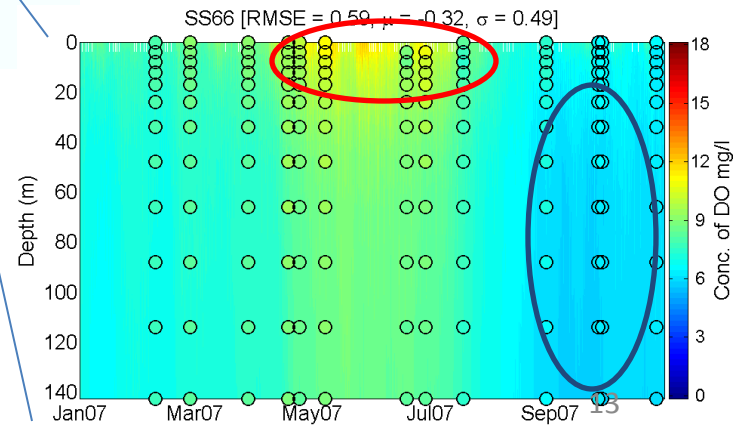
South Puget Sound DO predictions



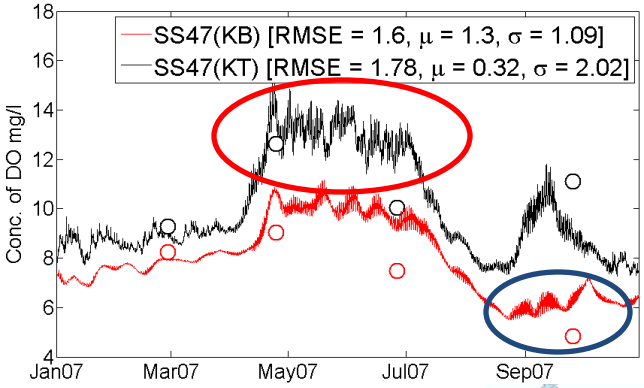


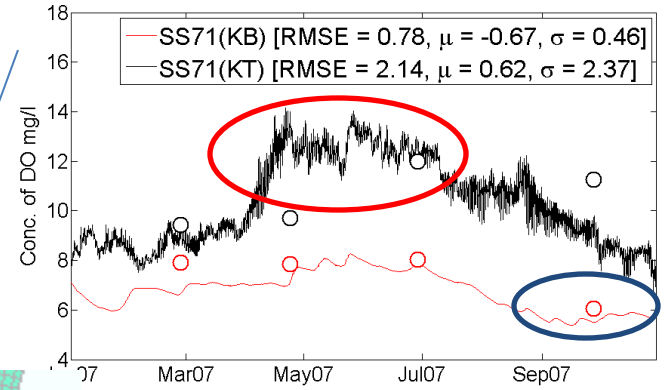


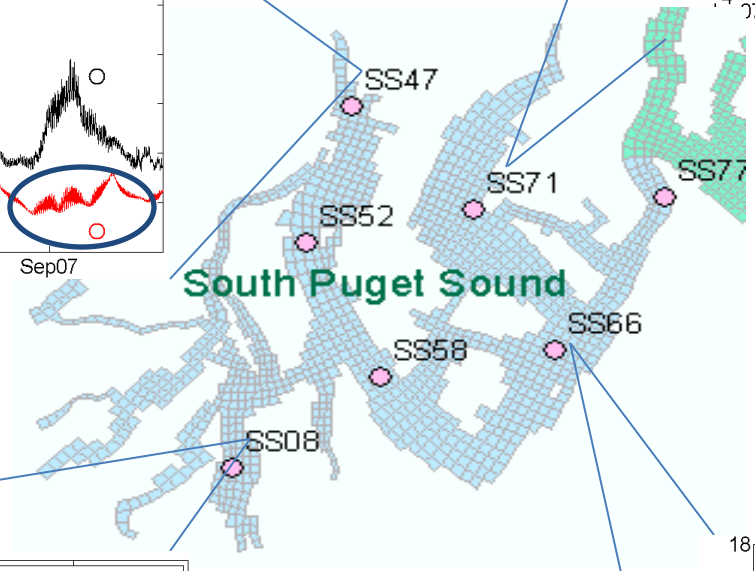


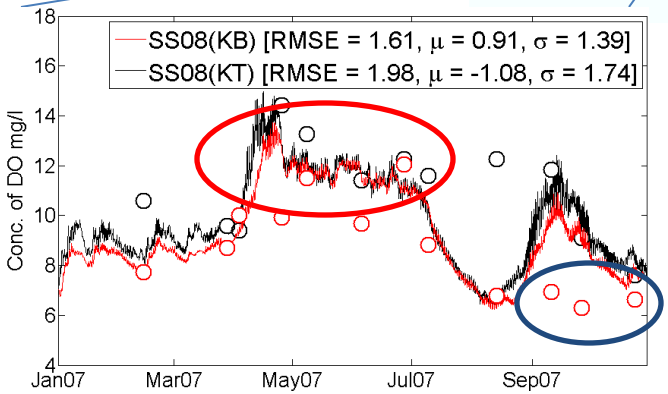


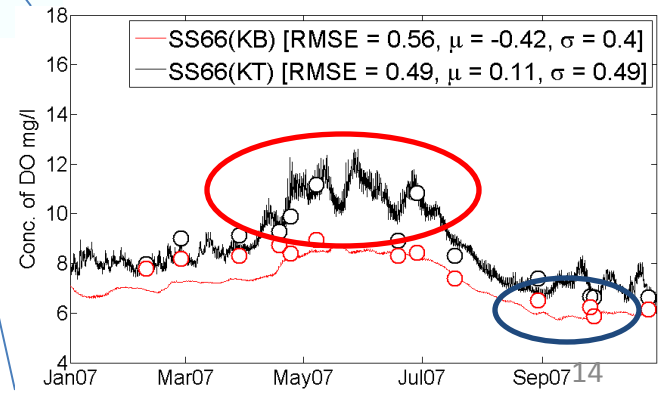
South Puget Sound DO predictions





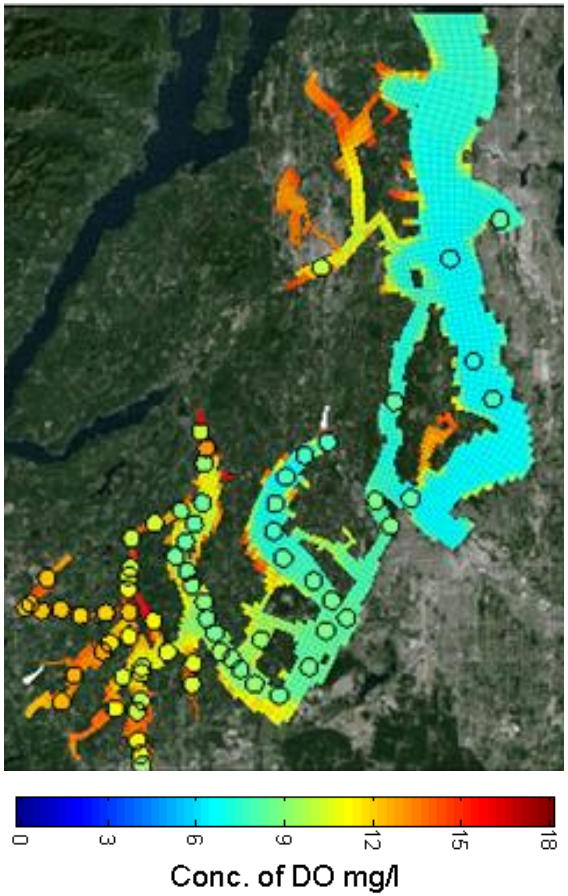




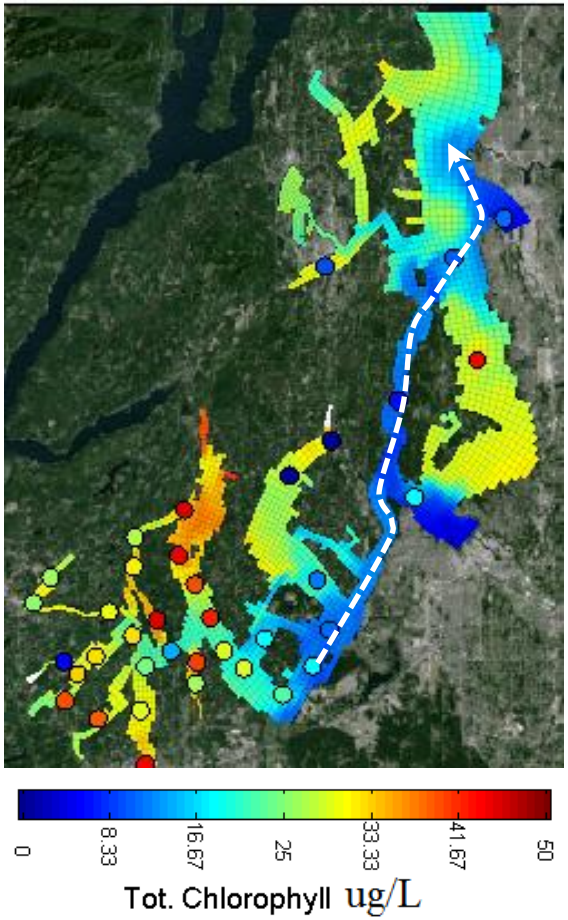


April 2007

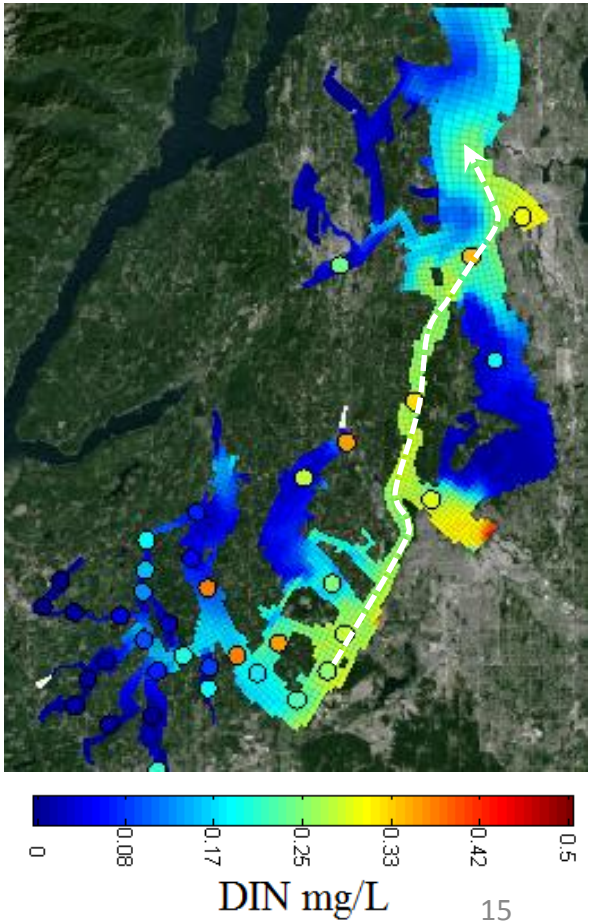
Bottom Dissolved Oxygen



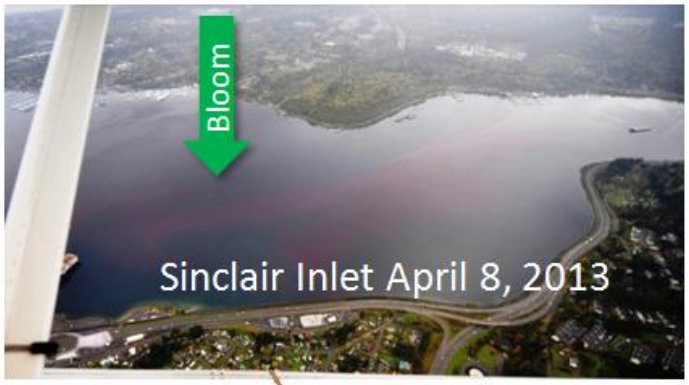
Surface Chlorophyll

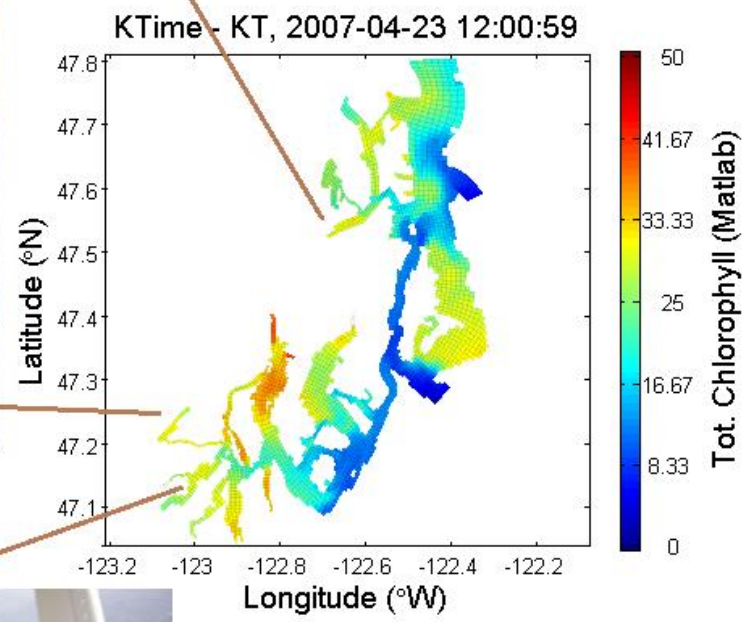


Surface Dissolved Inorganic Nitrogen

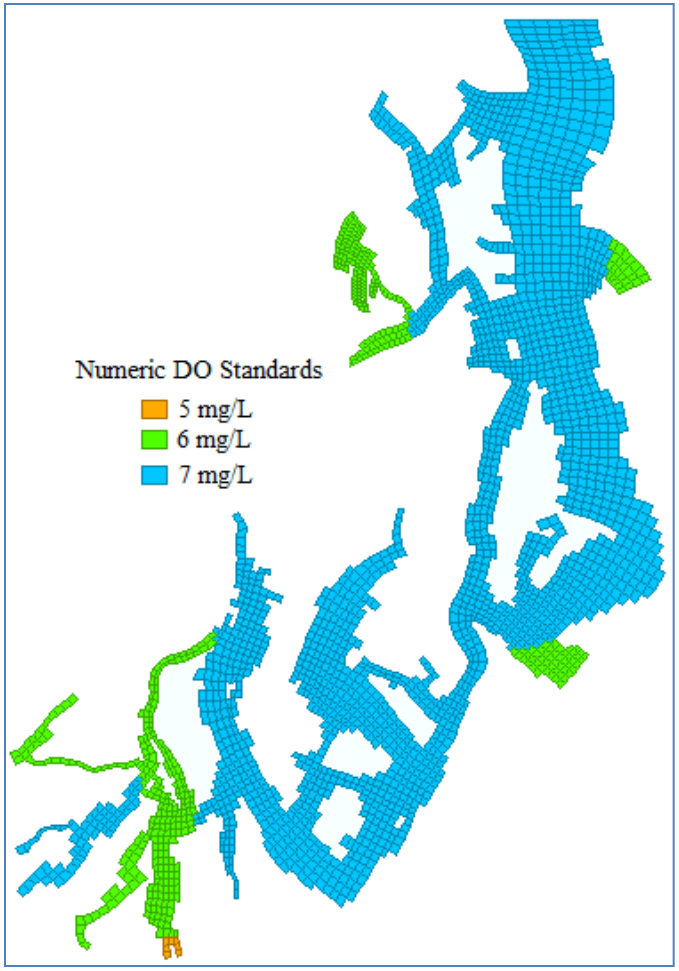


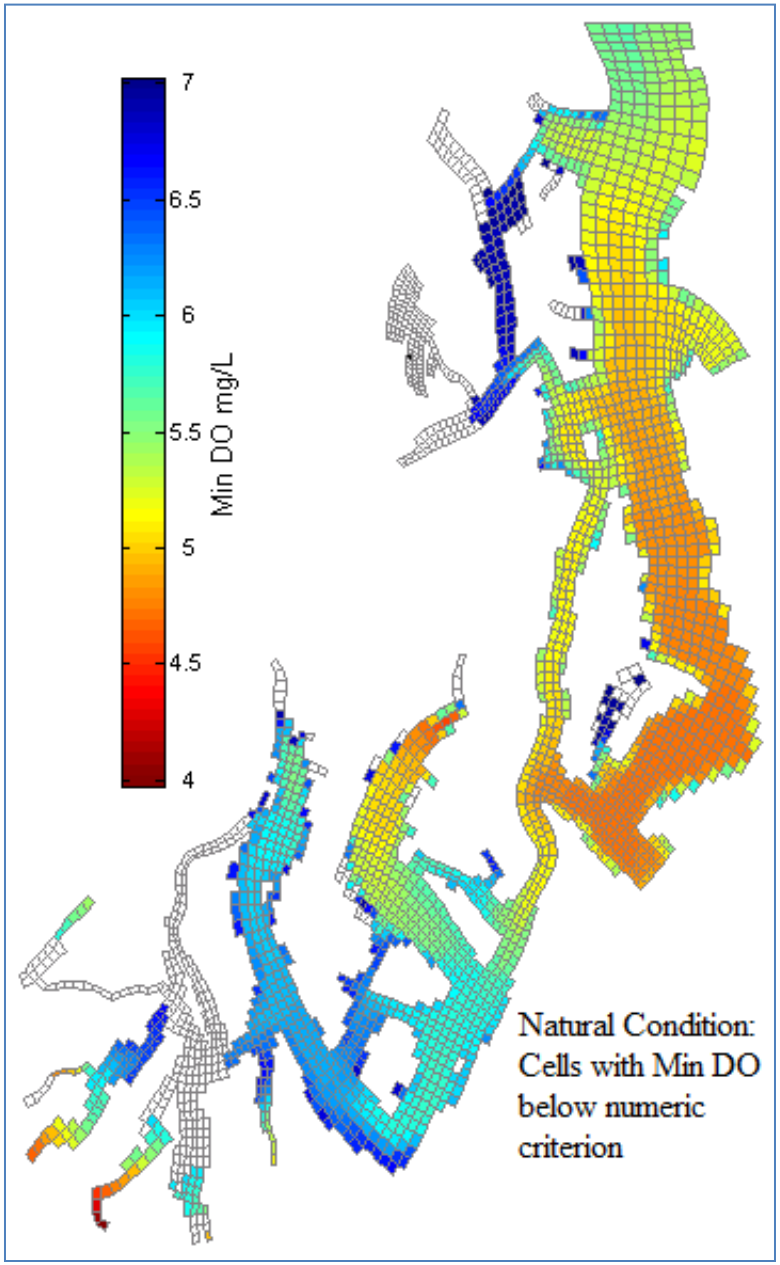
Eyes over Puget Sound (April 2013)





Scenario Results – minimum DO under natural conditions

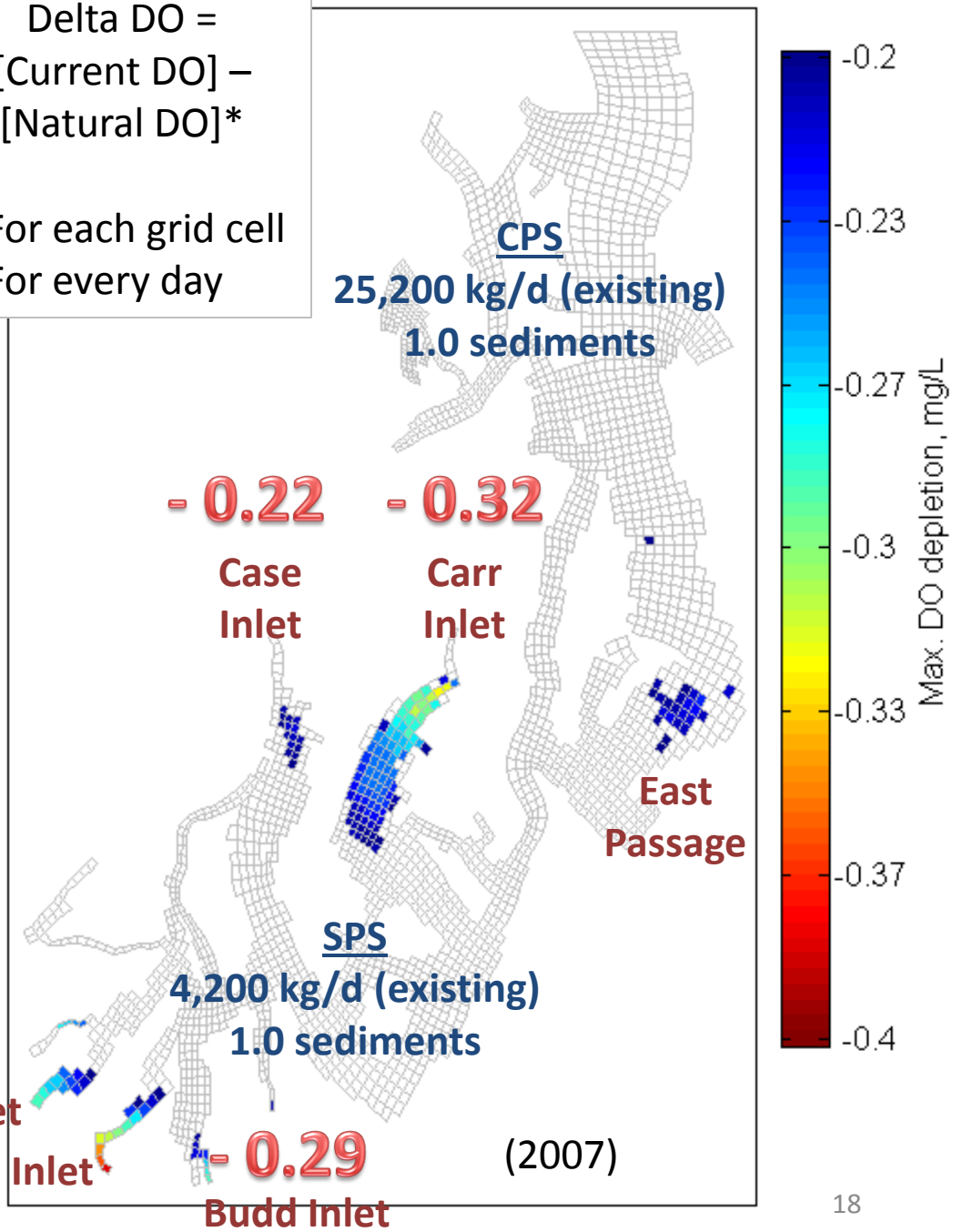




Scenario Results – current human sources in South and Central Puget Sound and external anthropogenic sources cause depletions up to 0.4 mg/L in limited areas

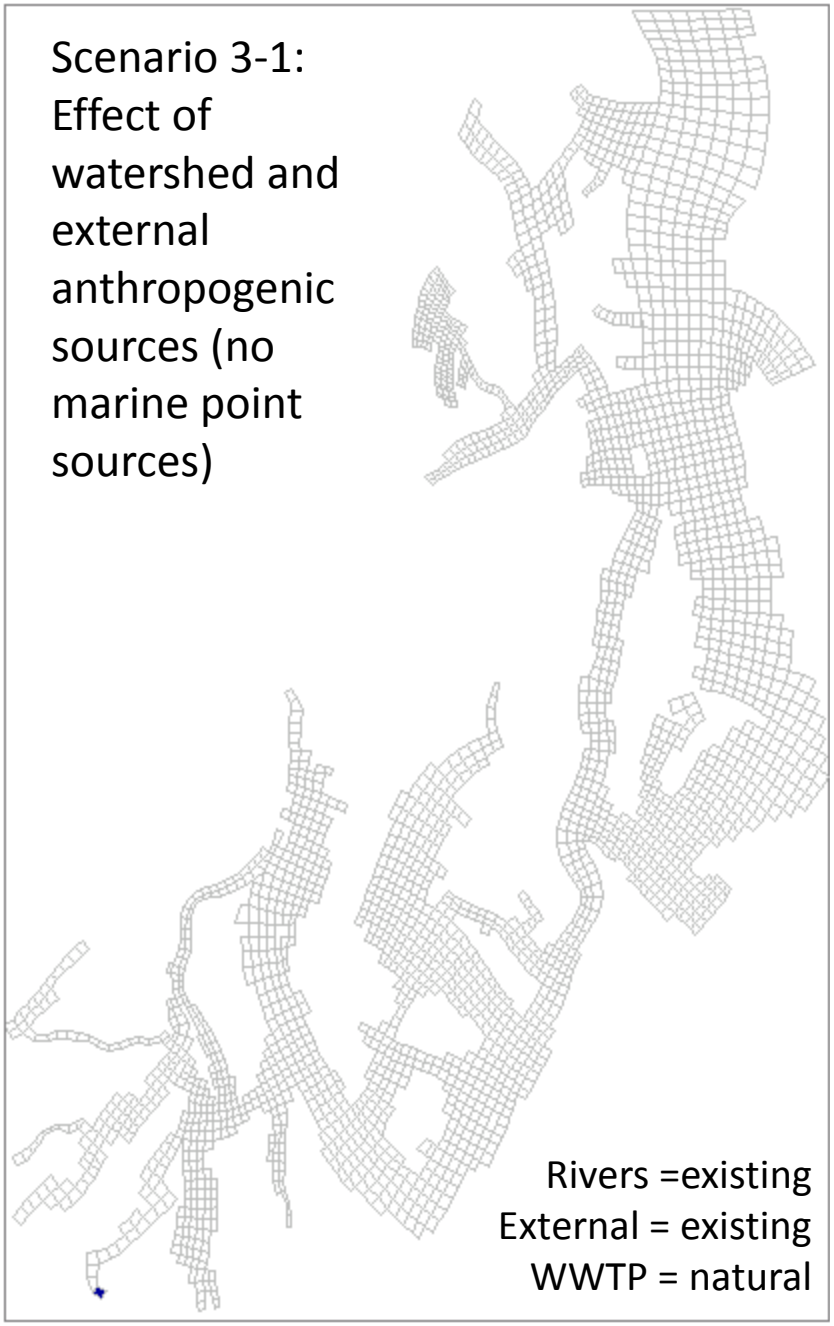
Delta DO = [Current DO] – [Natural DO]*

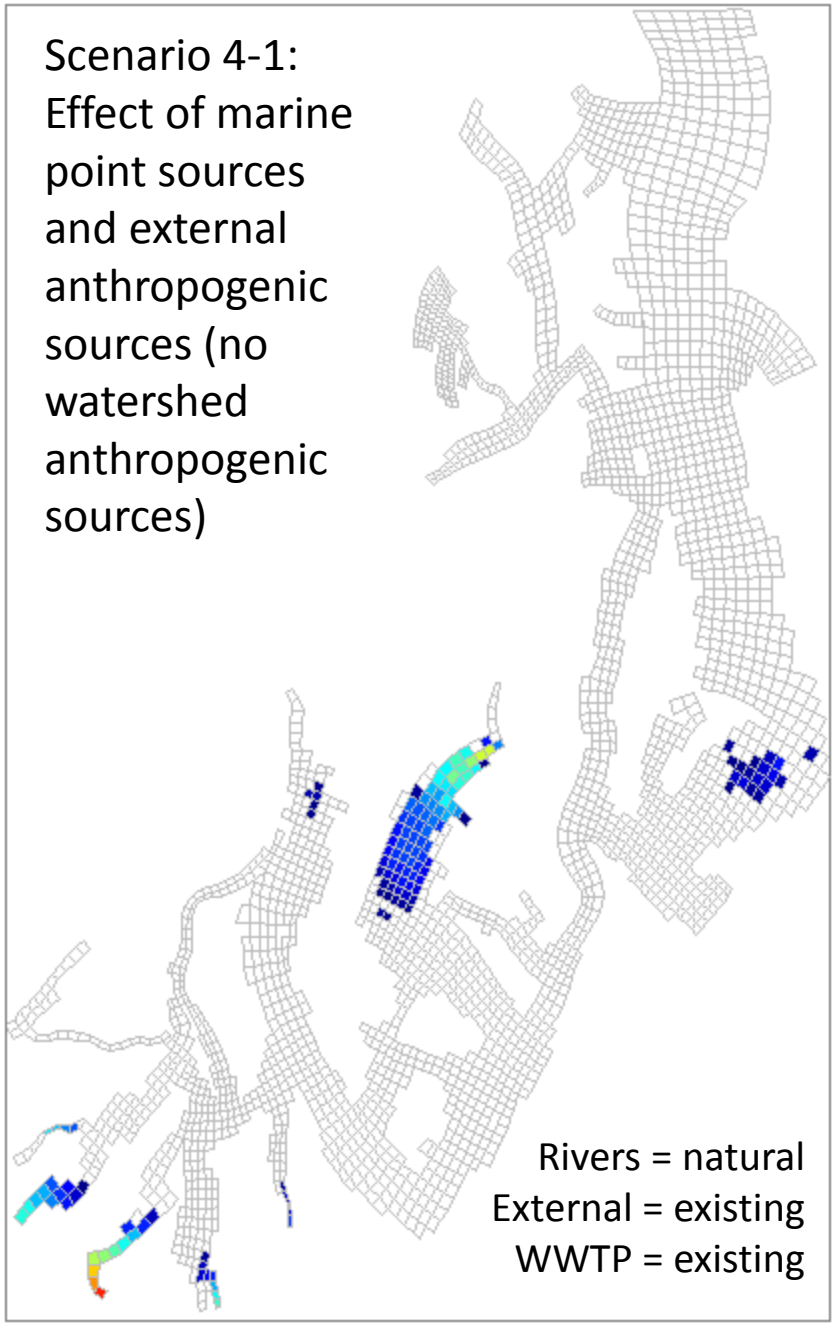
- For each grid cell
- For every day

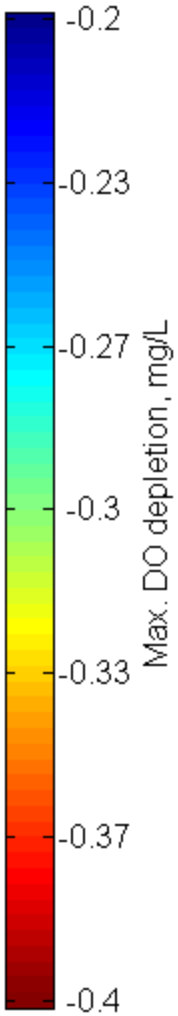


* When natural is below standard else compare with standard

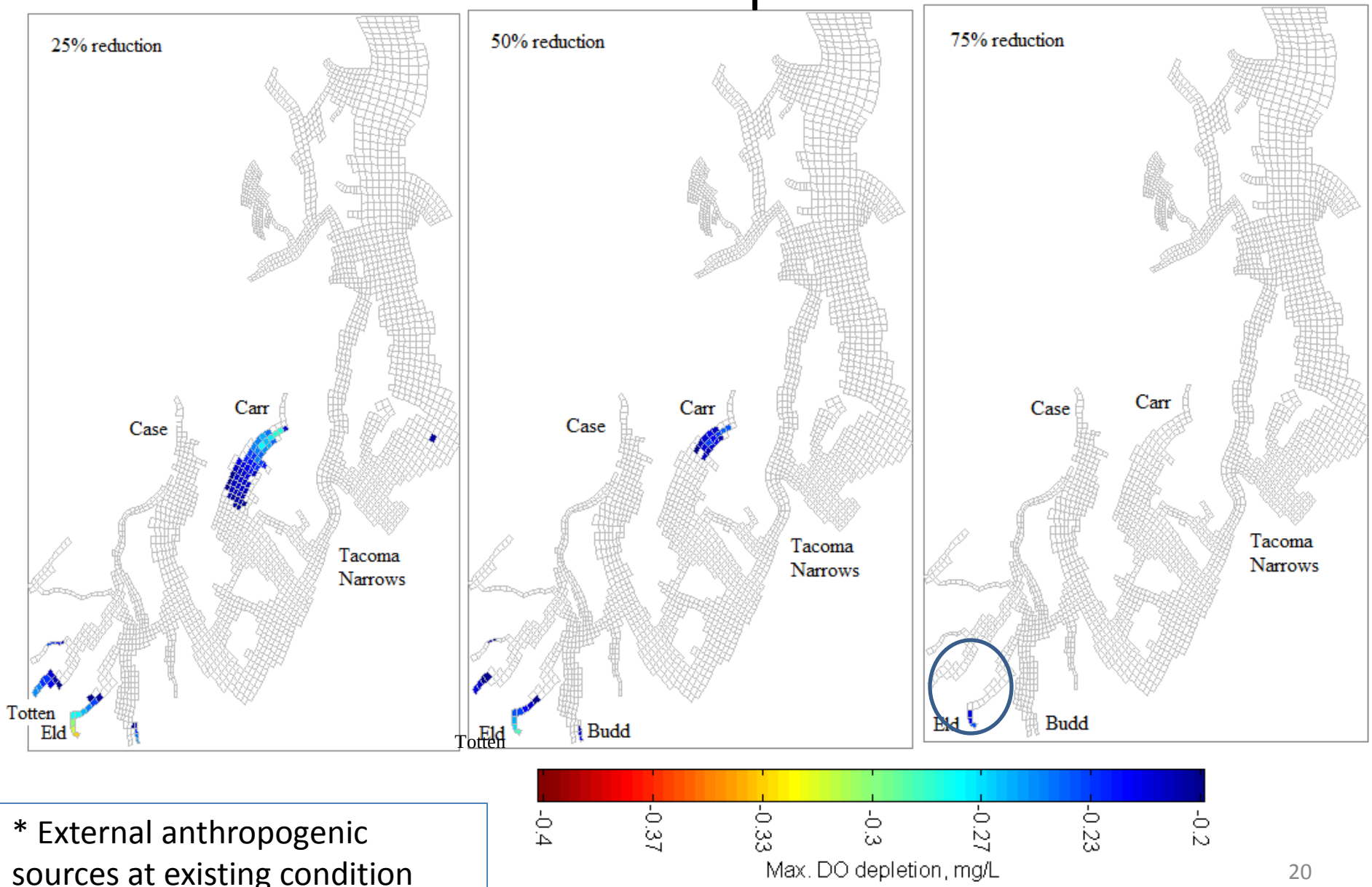
Marine point sources have greater influence than watershed sources





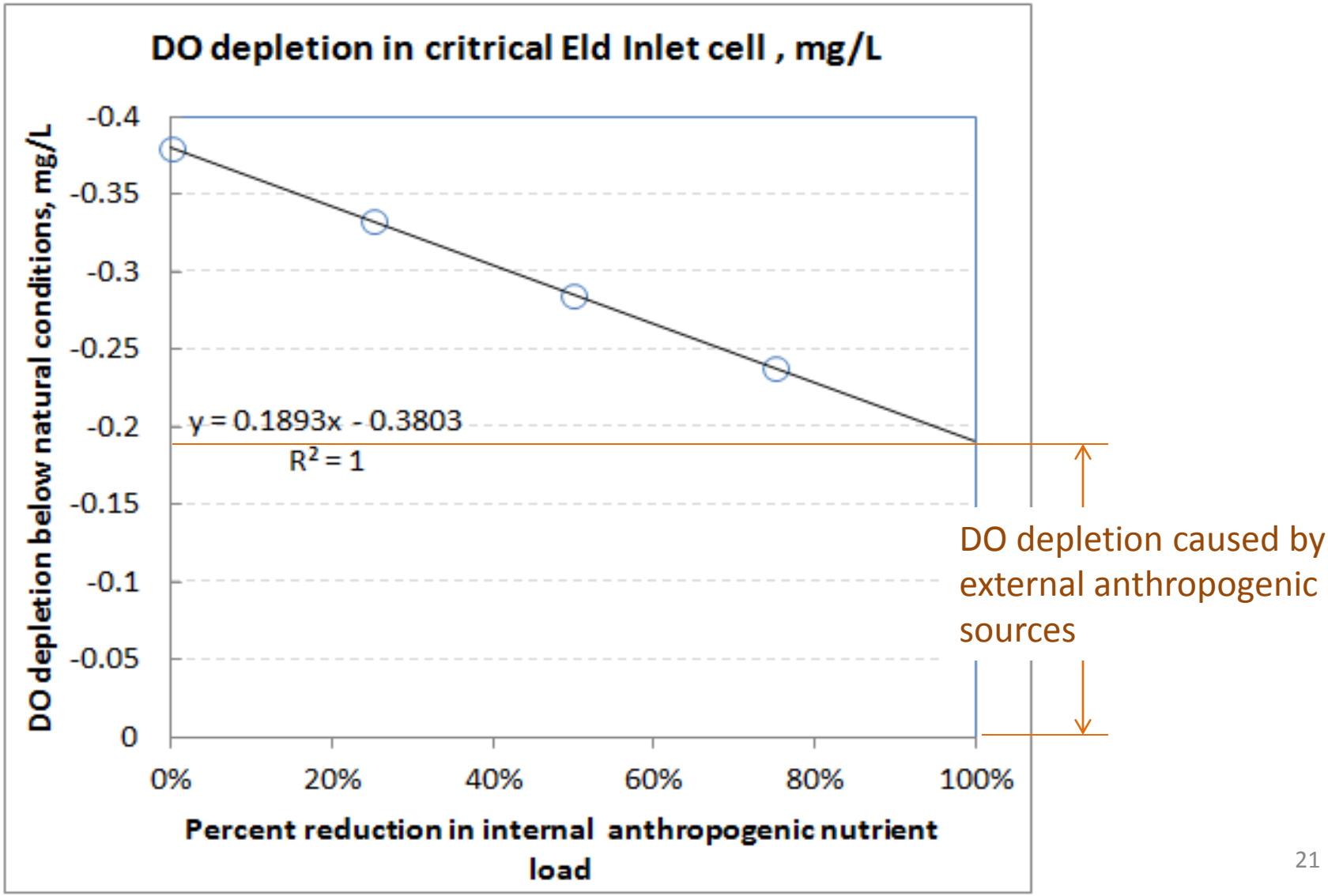


Reducing within-domain* human sources would decrease depletions

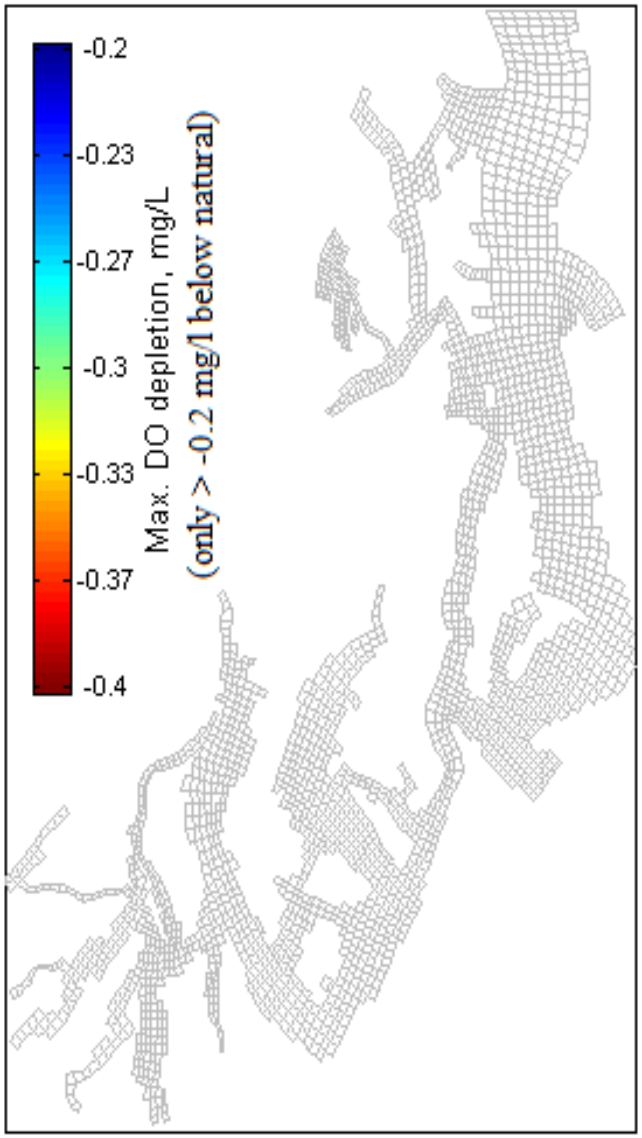


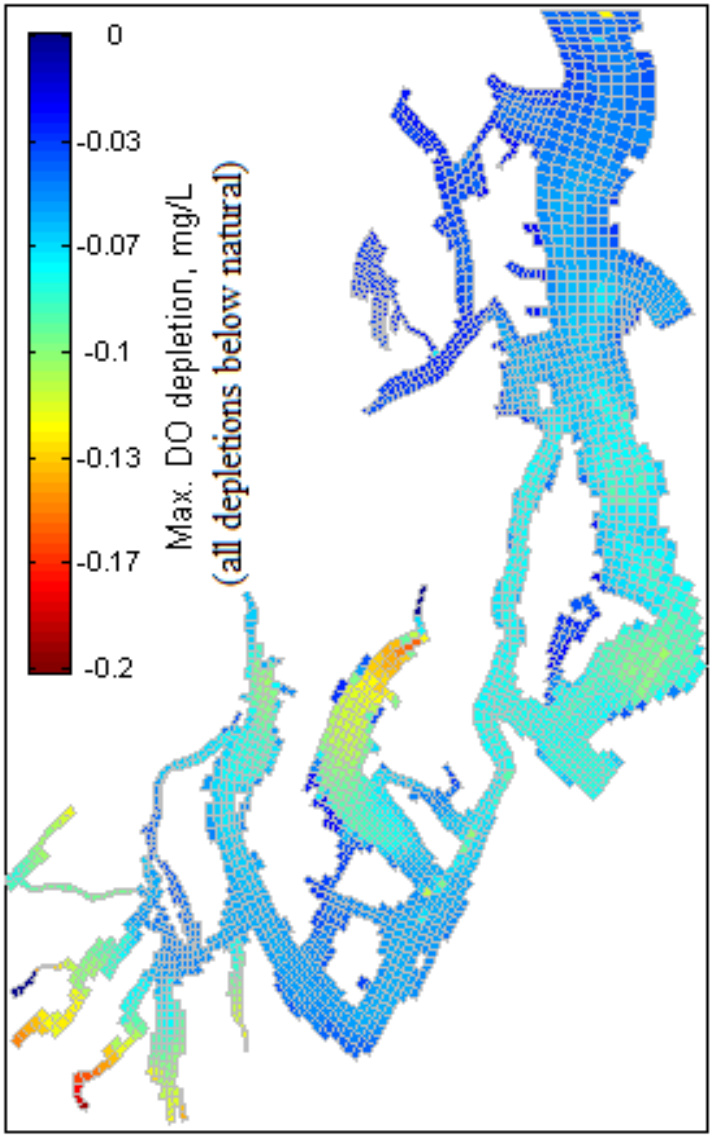
* External anthropogenic sources at existing condition

DO depletion from external anthropogenic sources

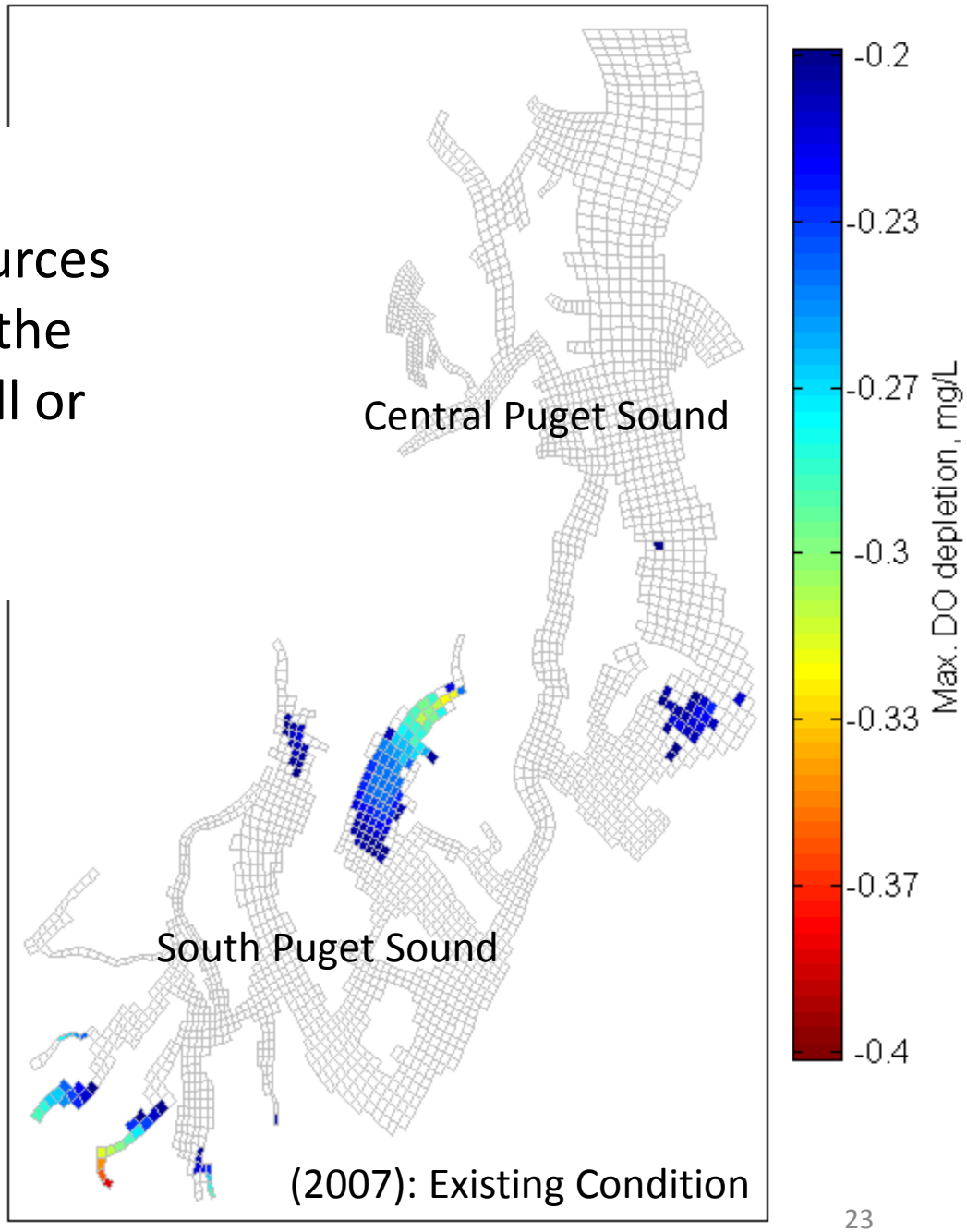


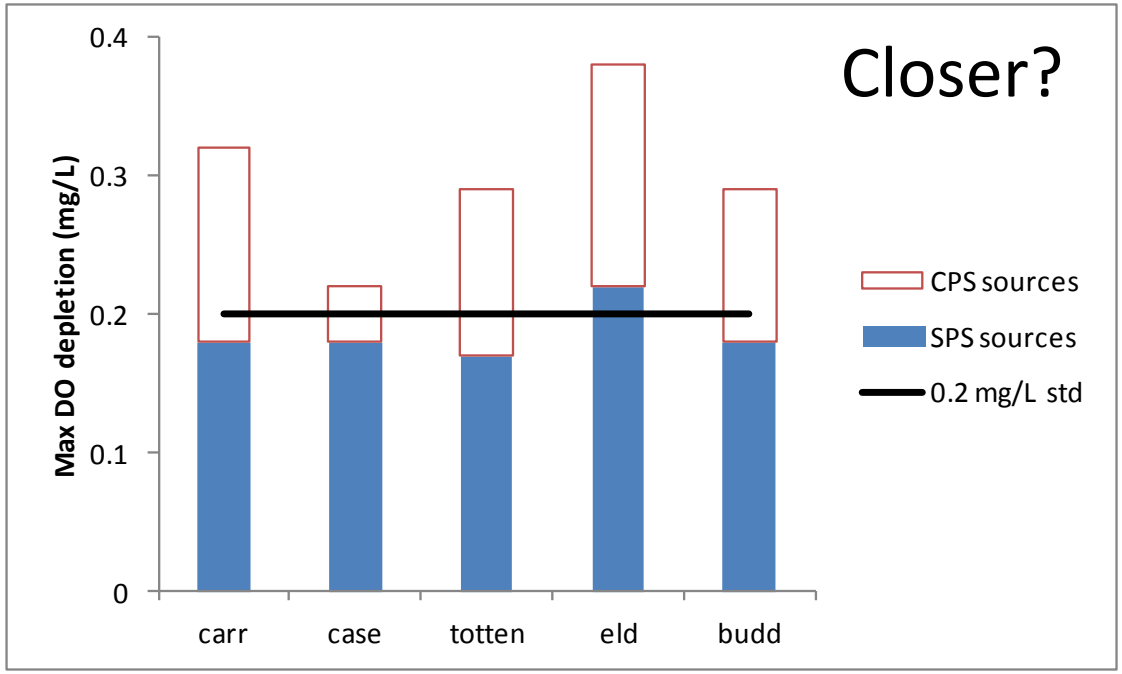
DO depletion from external anthropogenic sources (continued)





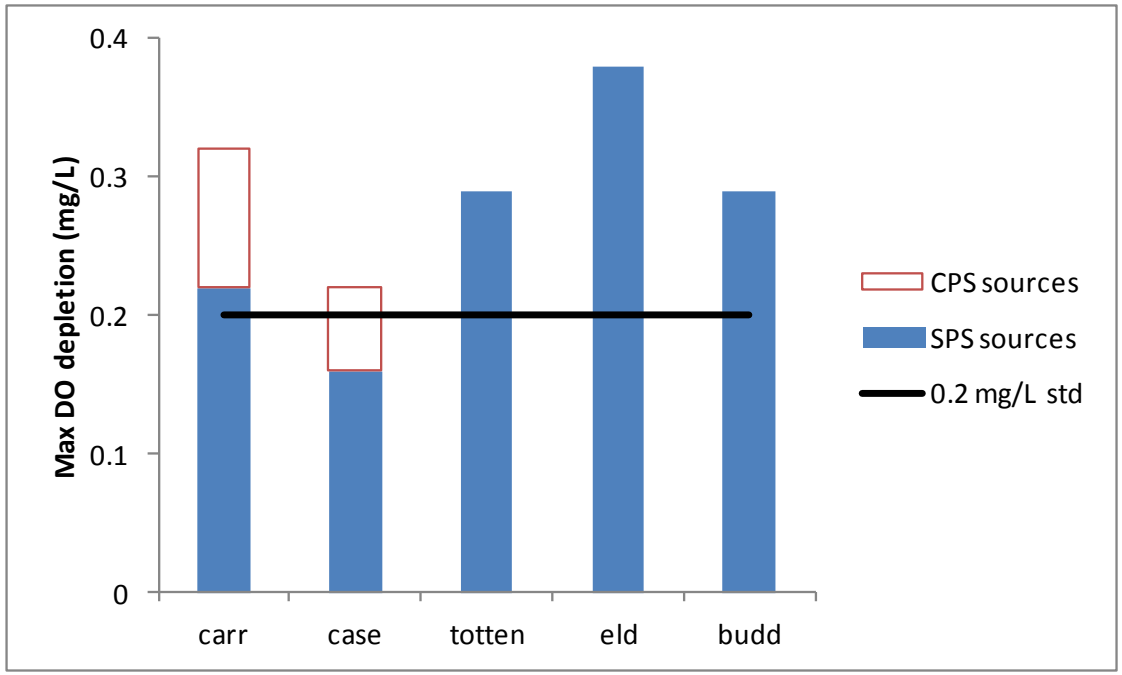
Influence of Central Sound sources depends on how we handle the sediment scalars – apply to all or none of South Sound?





If CPS sources reach SPS
(adjust sediments throughout)

We have not determined fraction of Central Sound nutrients that enter South Sound



If CPS sources *do not* reach SPS,
(adjust sediments in CPS only)

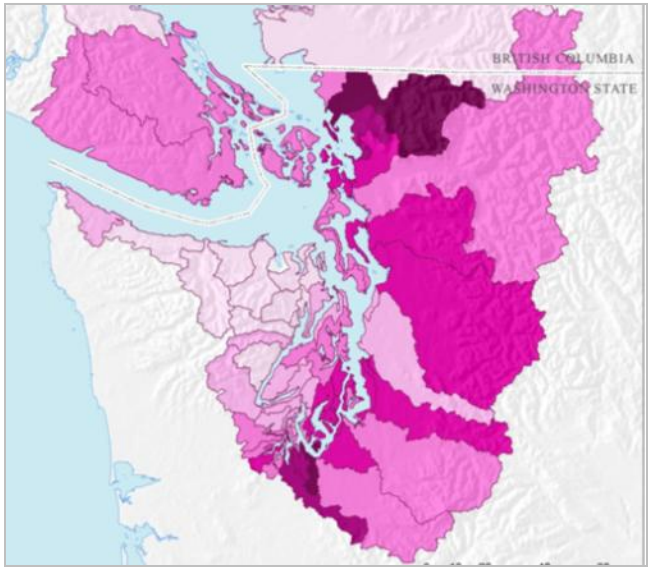
What are the relative impacts of current human sources in South and Central Puget Sound?

- Current sources cause 0.2-0.4 mg/L depletions in Carr, Case, finger inlets, East Passage of CPS
- More impact from marine point sources than watershed inflow human sources
- Reducing within-domain inputs results in lower depletions and extent of area >0.2 mg/L
- How we handle sediments influences the results

SPS Questions?

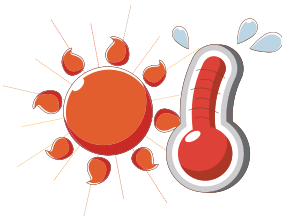
2. Salish Sea* scenarios

(*Puget Sound, Strait of Juan de Fuca, Strait of Georgia)

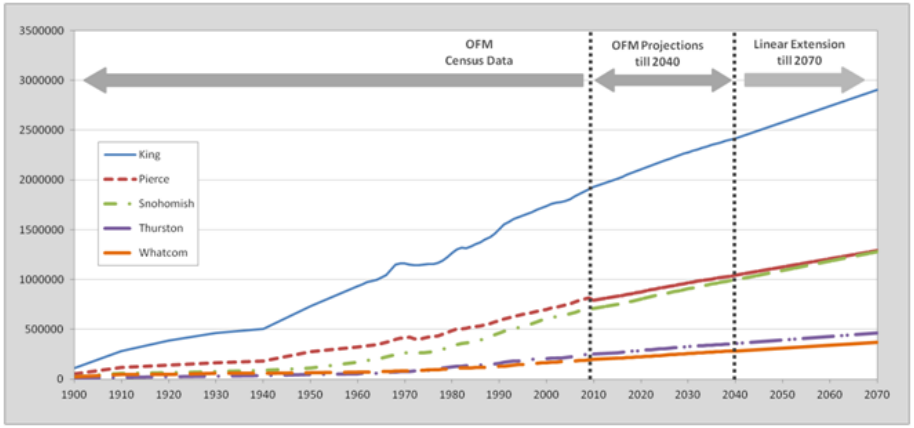


Factors:

- Population (now + growth)
- Land cover change
- Climate change
- Pacific Ocean conditions



Faster decline near Strait of Juan de Fuca (Station P4)



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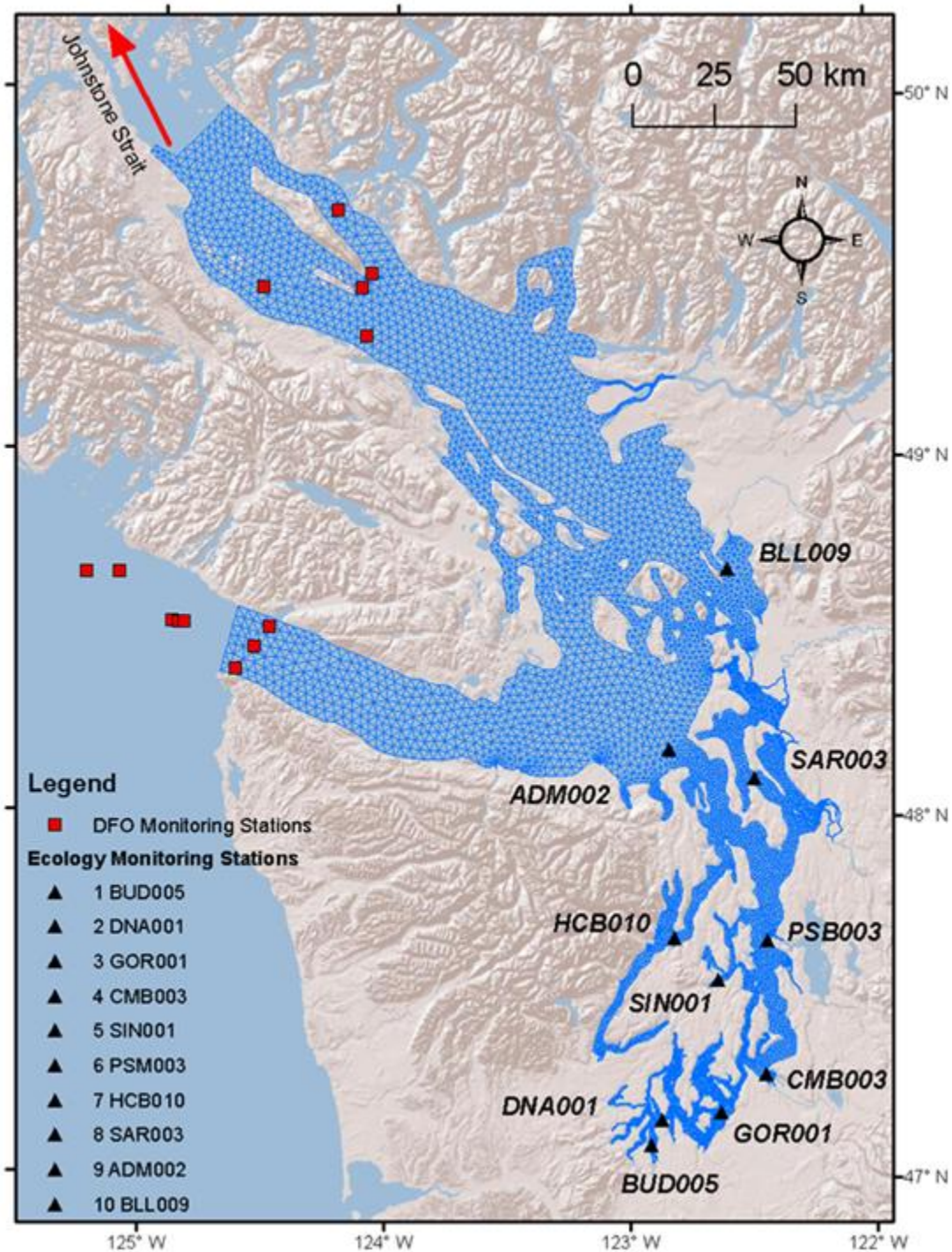


Approach:

Apply calibrated model to *(A) Current and (B) Future Scenarios*

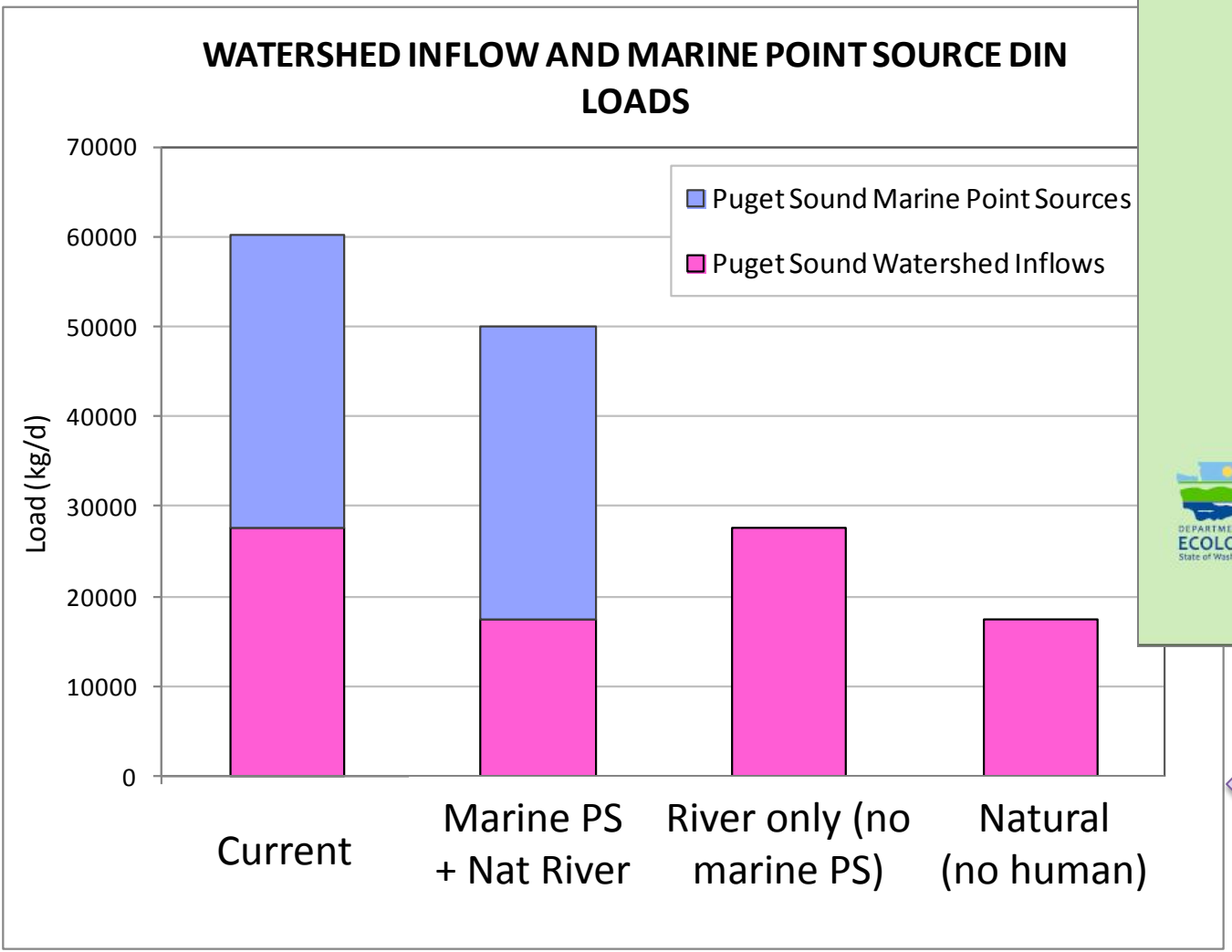
Compare DO with natural conditions from 2006

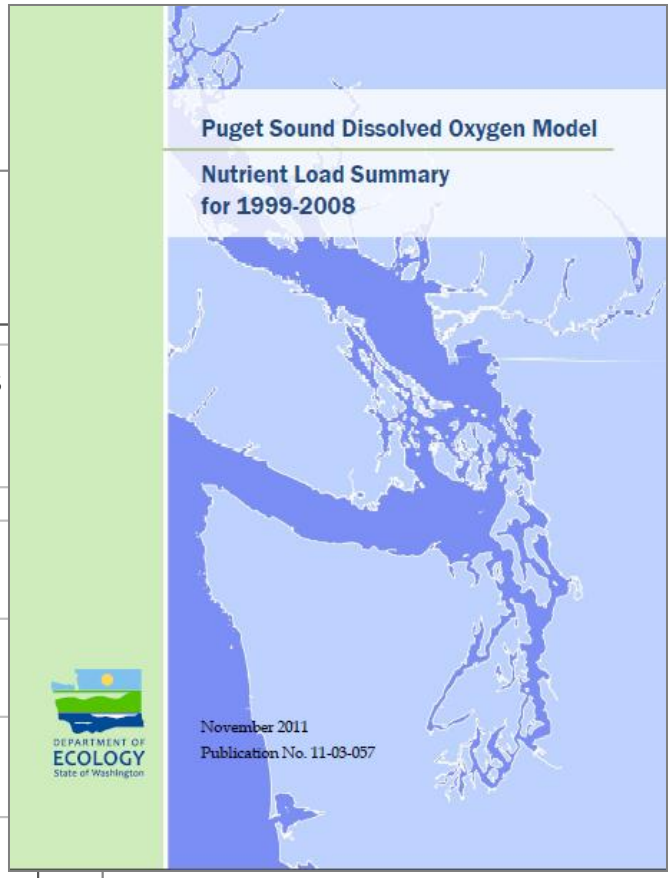
10 layers for vertical resolution

Source: Khangaonkar et al. (2012)

(A) Current scenarios – total loads to Salish Sea

See loading report (Mohamedali et al., 2011) for details:

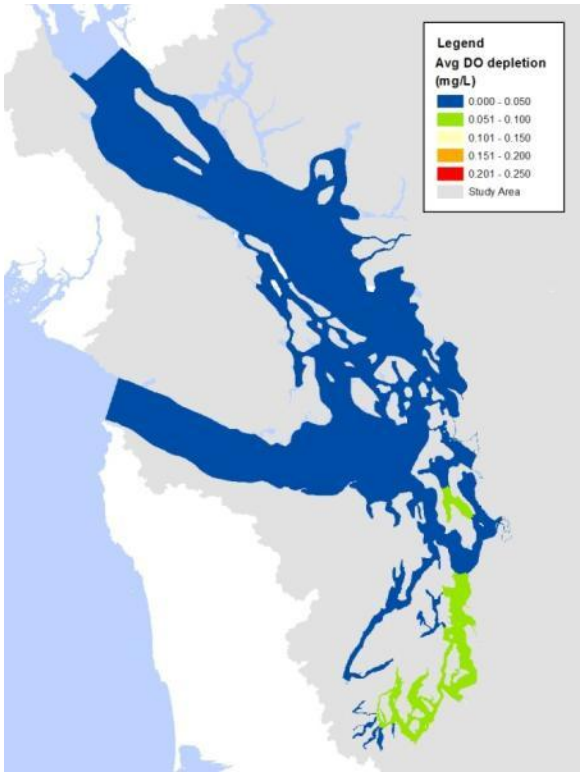




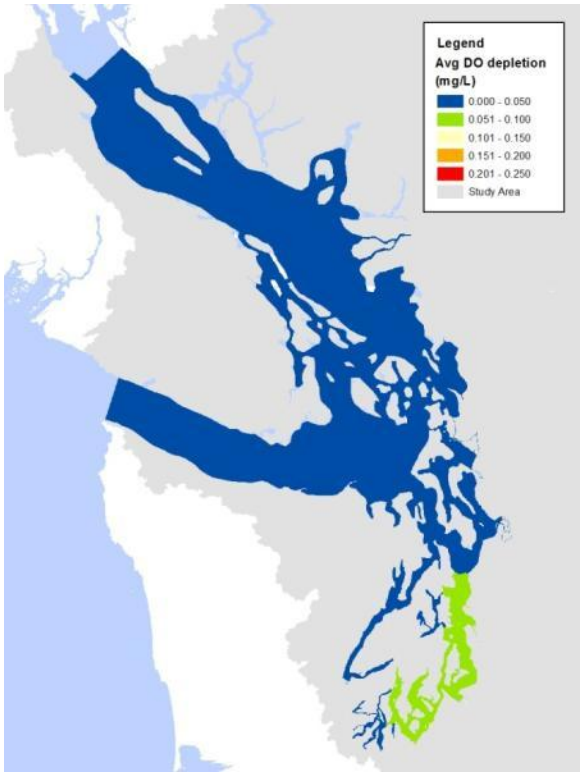
Example for just Puget Sound

Current average regional DO depletion

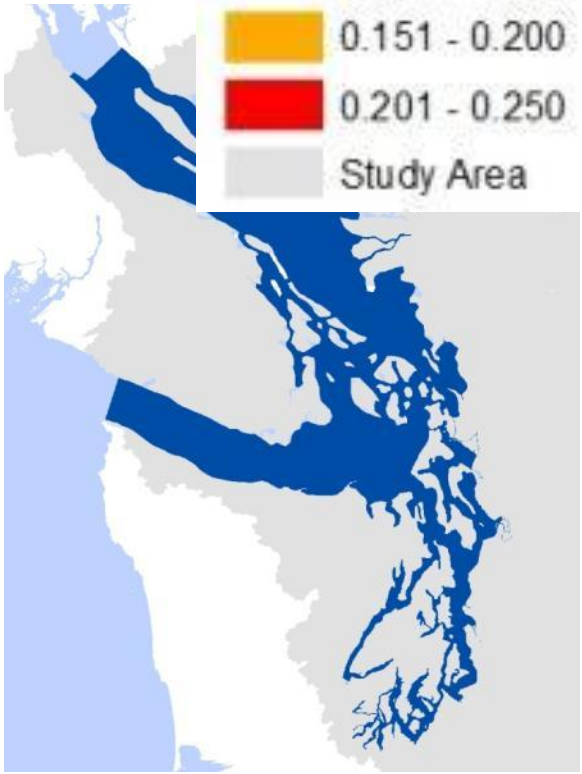
- *Greatest impacts in South Puget Sound, southern Central Sound*
- *Marine point sources have greater impact on DO than human sources in watershed inflows*



Marine point sources + watershed sources



Marine point sources only



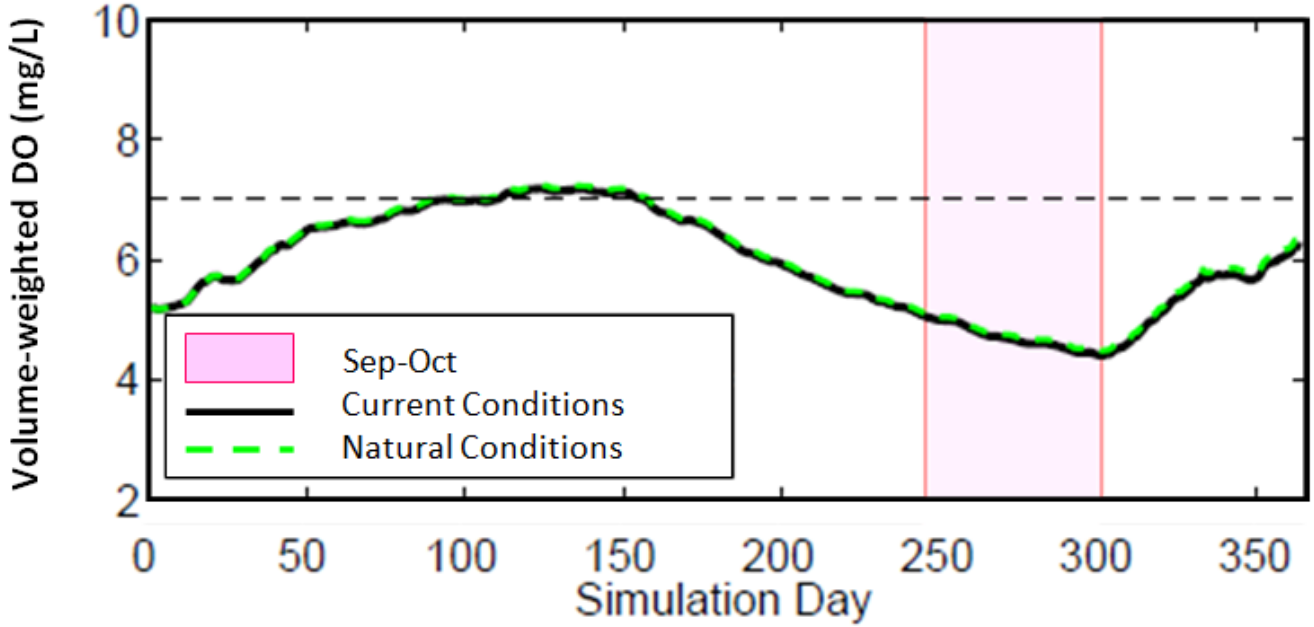
Watershed sources only

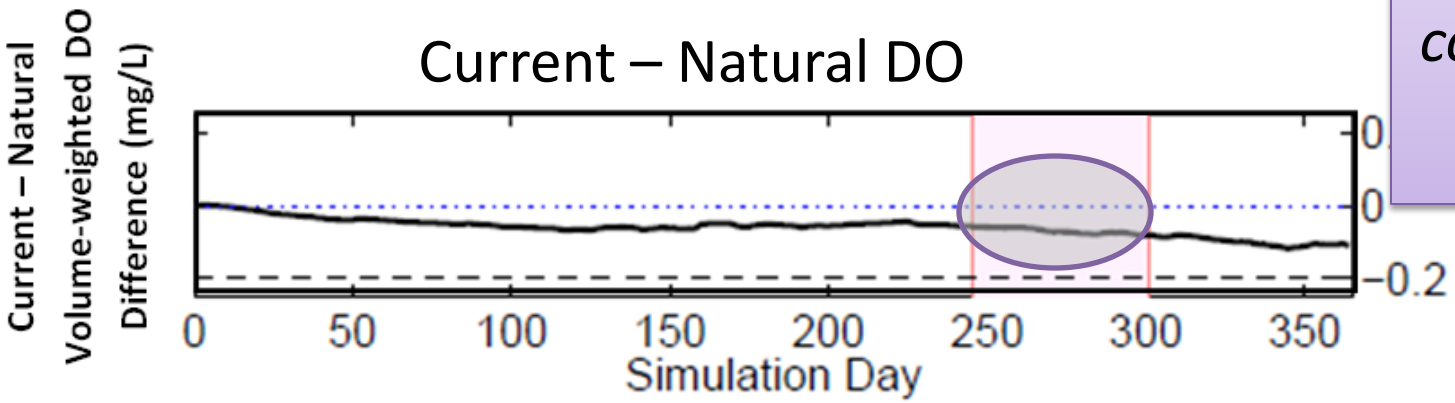
Legend

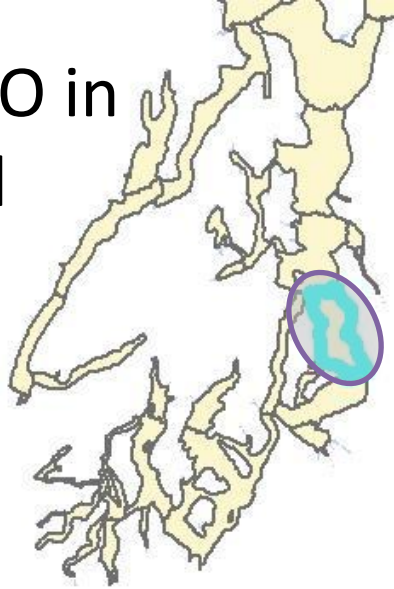
Avg DO depletion (mg/L)

- 0.000 - 0.050
- 0.051 - 0.100
- 0.101 - 0.150
- 0.151 - 0.200
- 0.201 - 0.250
- Study Area

Human nutrients *decrease* minimum DO in deeper waters of Central Puget Sound

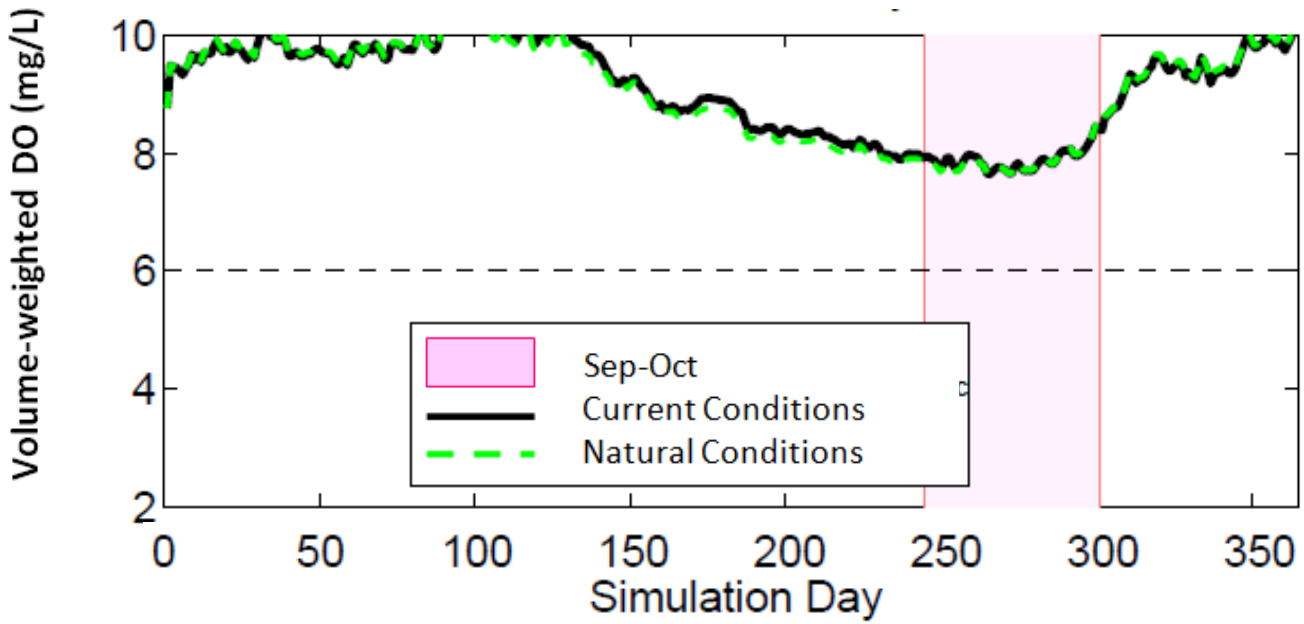


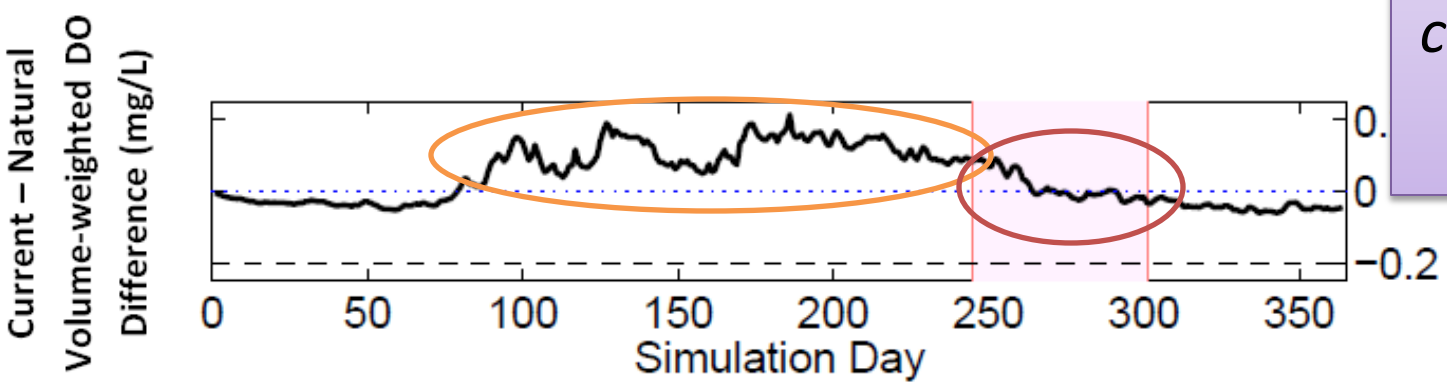




Average regional and seasonal DO depletion – *compare across scenarios*

Human nutrients can *increase* minimum DO in Oakland Bay

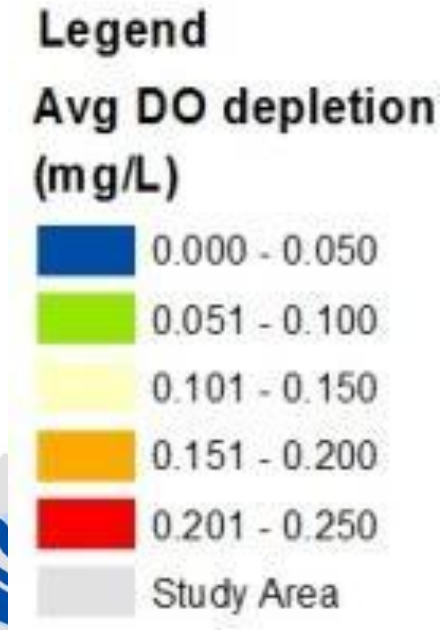


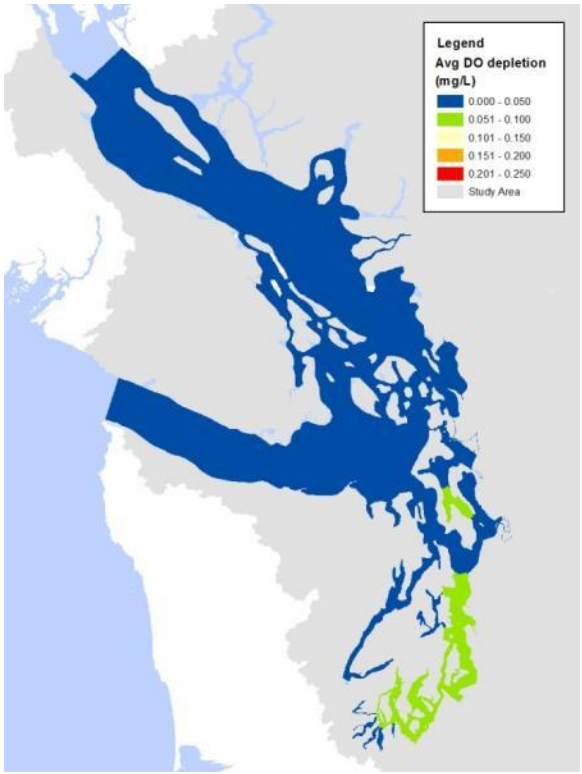


Average regional and seasonal DO depletion – *compare across scenarios*

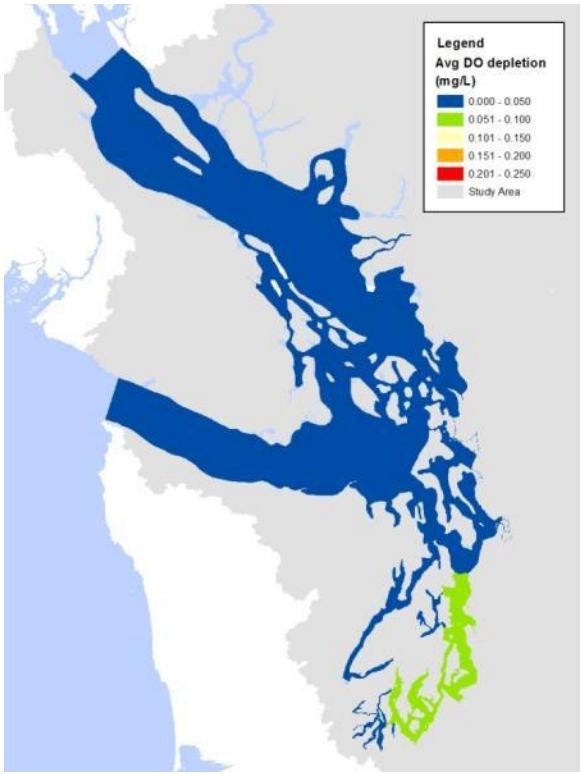
Current average regional DO depletion

- *Not directly applicable to water quality standards*
- *Size of regions varies considerably*

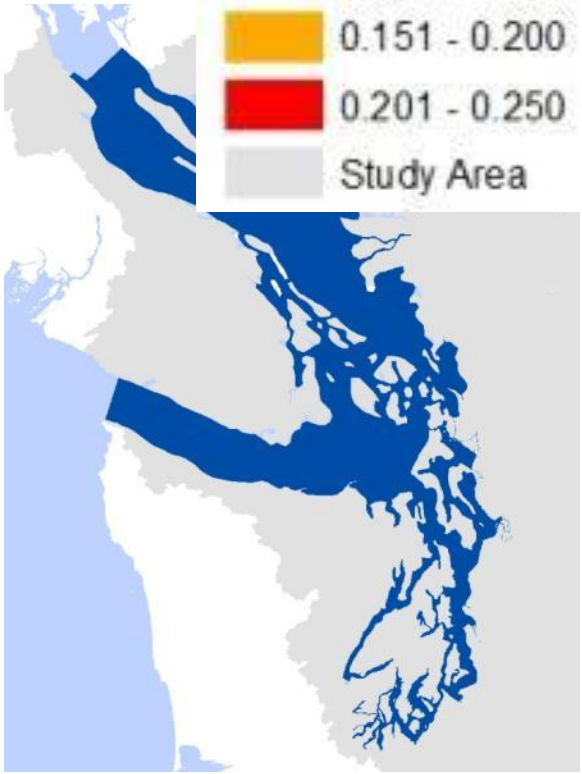




Marine point sources + watershed sources

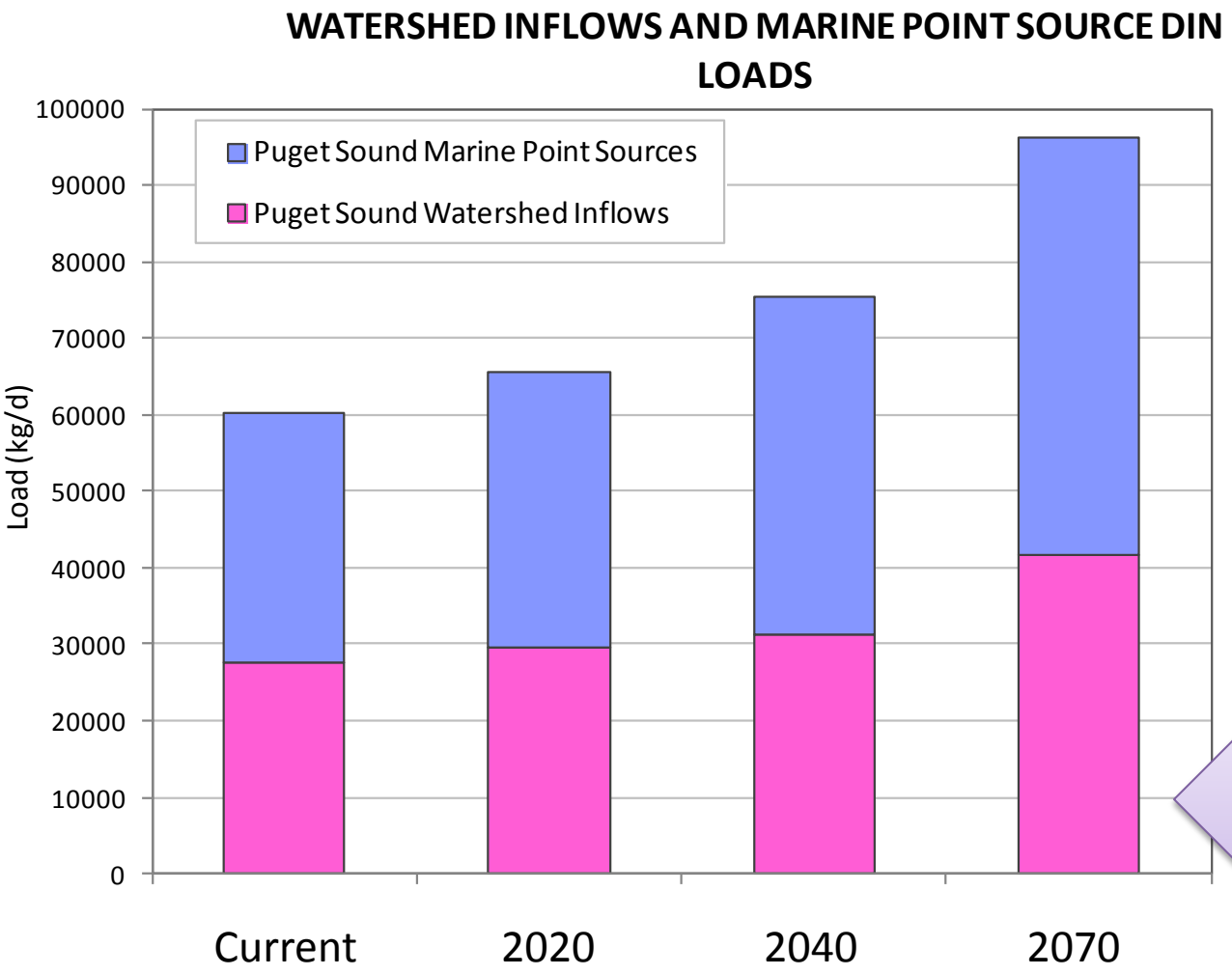


Marine point sources only



Watershed sources only

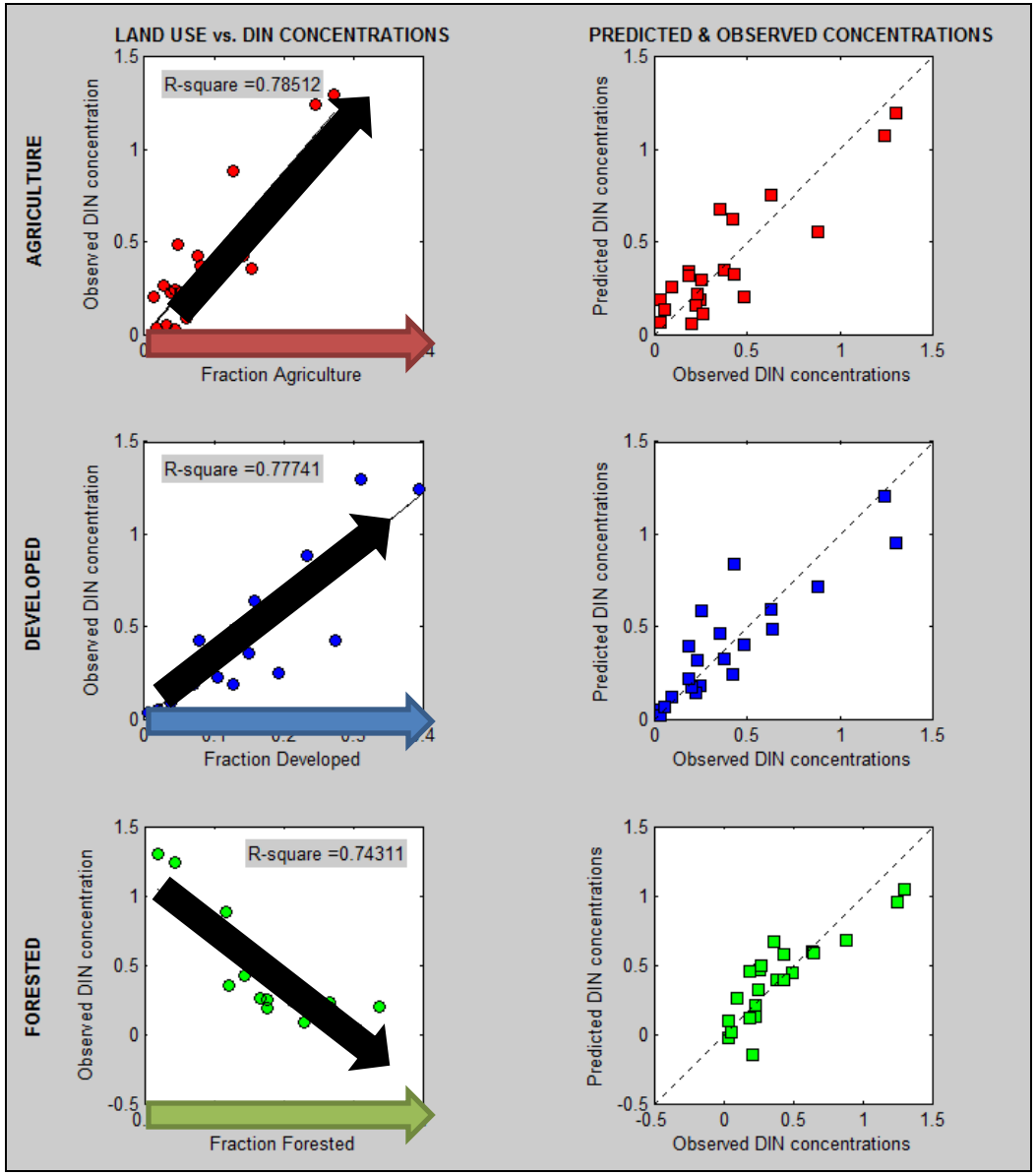
(B) Future scenarios – total loads to Salish Sea



See Methods, Scenario Comparisons sections in this report for details … very detailed

Example for just Puget Sound

Predicting future river concentrations – *highlights*



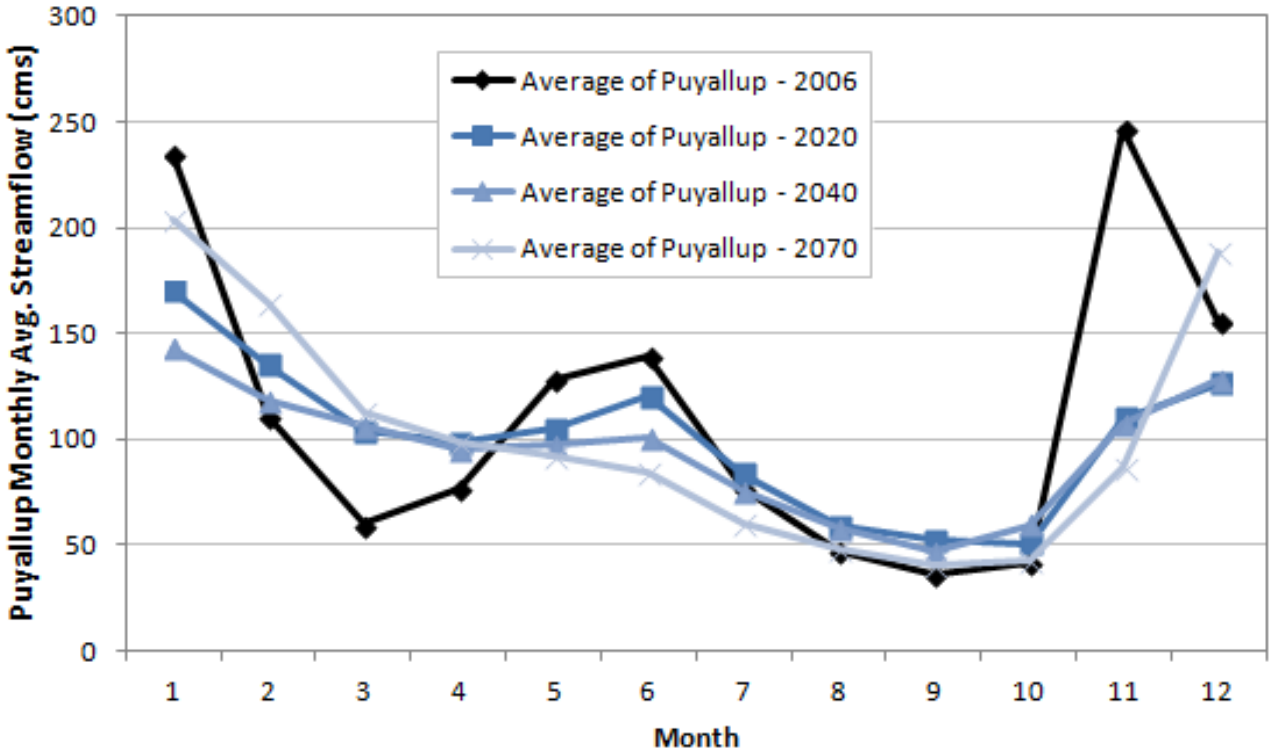
River DIN increases with:

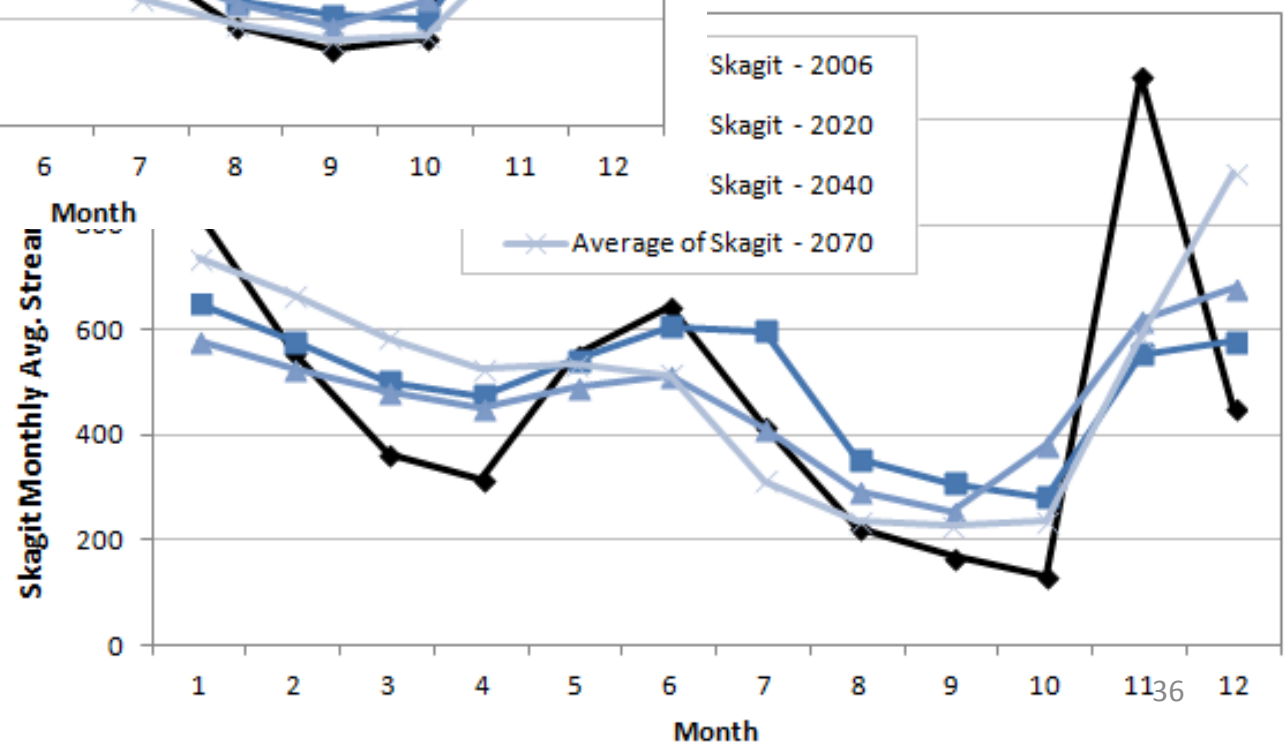
- Higher %agriculture
- Higher %developed
- Lower %forested

➢ *All will change in the future…*

Use today's relationships with future land cover (OSU Alternative Futures) to predict future DIN concentrations

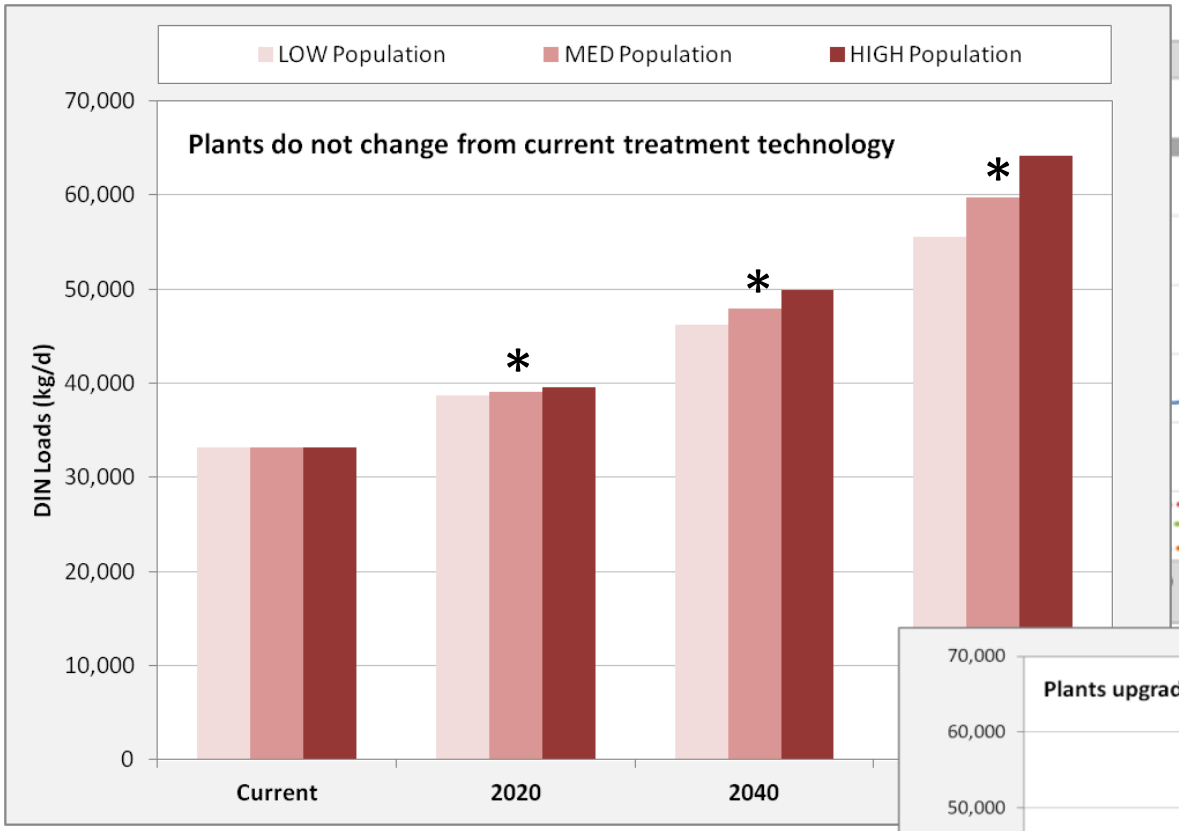
Predicting future river flows – *highlights*

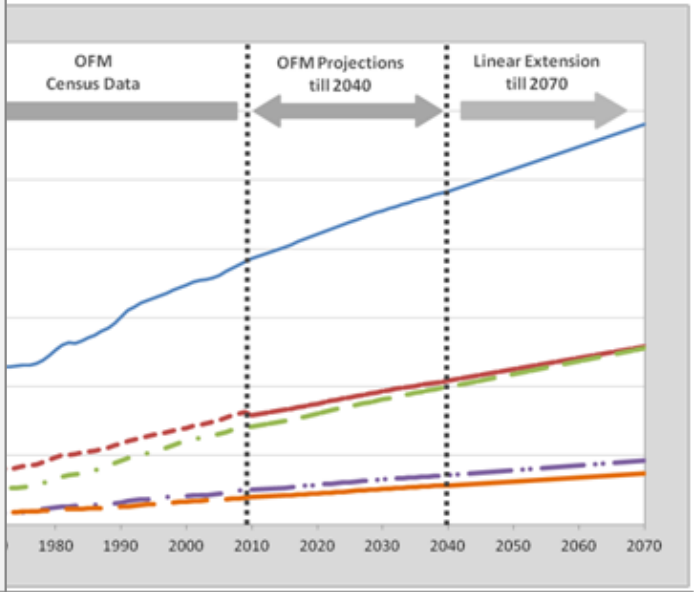


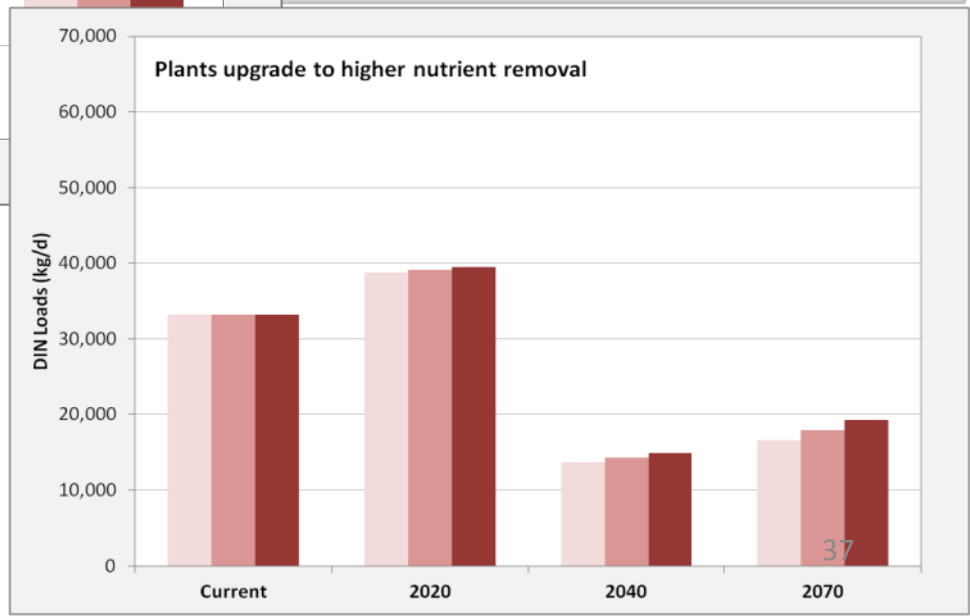


Future river flows provided by Alan Hamlet, formerly of UW Climate Impacts Group

Predicting future marine point sources – *highlights*







* Loading scenarios evaluated with water quality model

Data presented are for all US WWTPs discharging to Puget Sound and the Straits

Setting up future scenarios

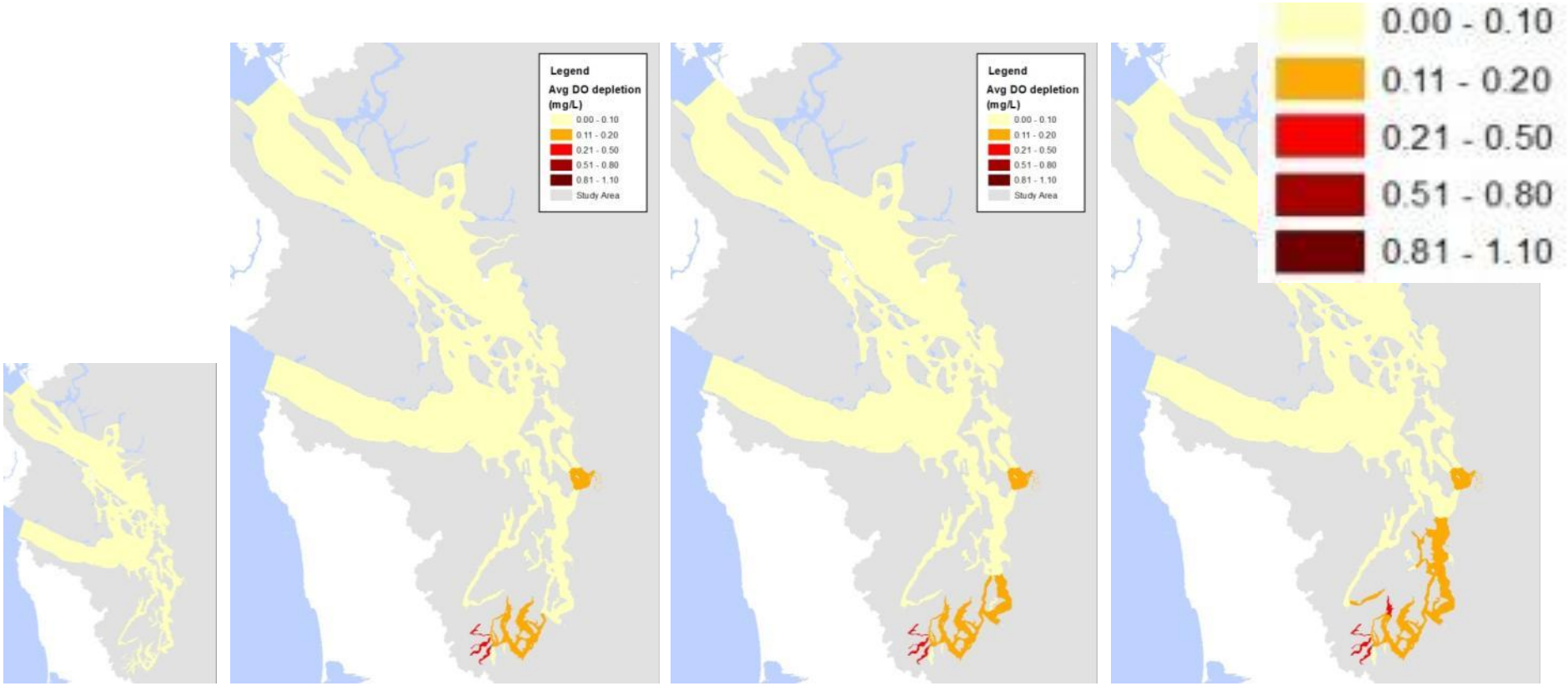
Future loads

Future loads + future circulation

Future loads + future circulation + future ocean conditions

Future loads + future circulation + future ocean conditions + future air temperature

Average regional DO impacts due to future human loads (Runs 29-31)



current

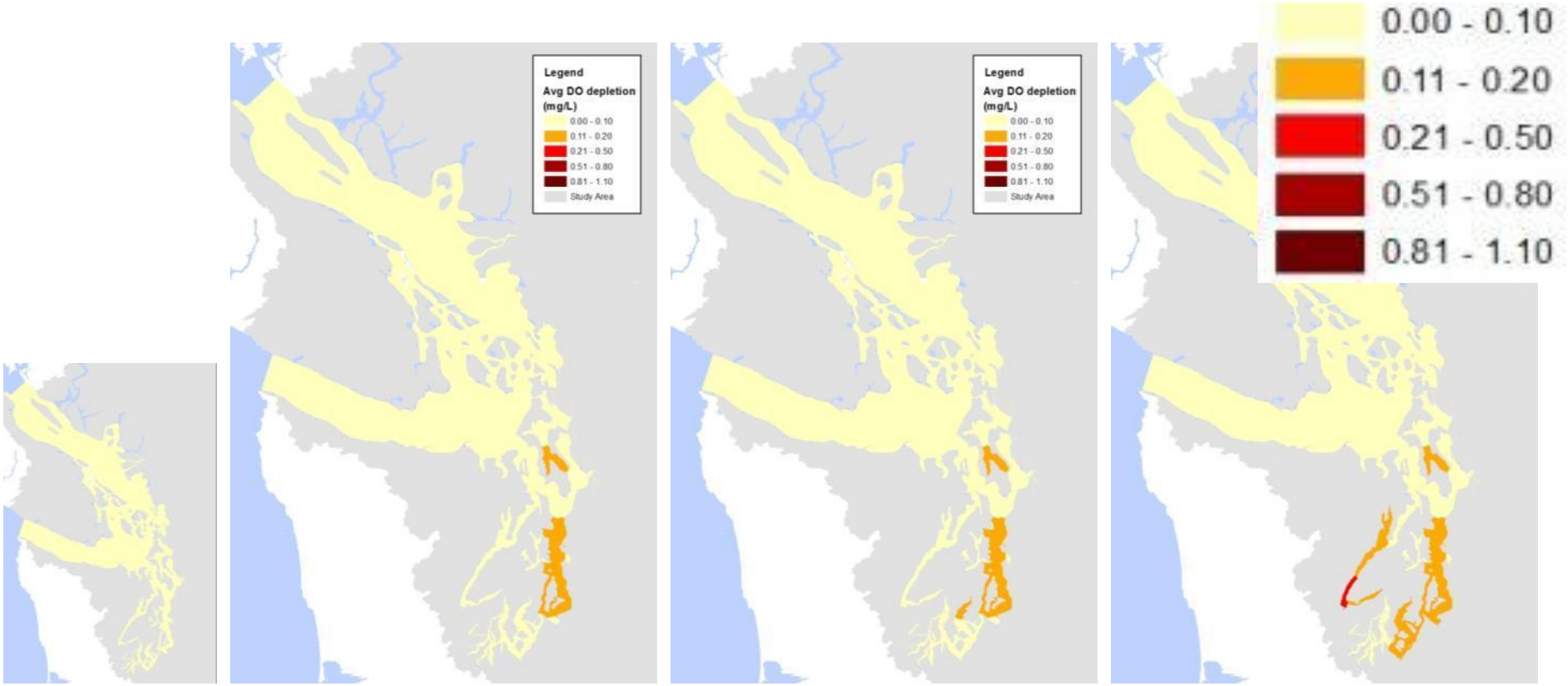
2020 loads, current circ, current ocean

2040 loads, current circ, current ocean

2070 loads, current circ, current ocean

Run # refers to calibration website naming convention:
https://fortress.wa.gov/ecy/spsdos/salish_sea/index.html

Average regional DO impacts due to future human loads and future circulation (Runs 26-28)



current

2020 loads, future circ, current ocean

2040 loads, future circ, current ocean

2070 loads, future circ, current ocean

Run # refers to calibration website naming convention:
https://fortress.wa.gov/ecy/spsdos/salish_sea/index.html

Future scenarios – ocean circulation patterns

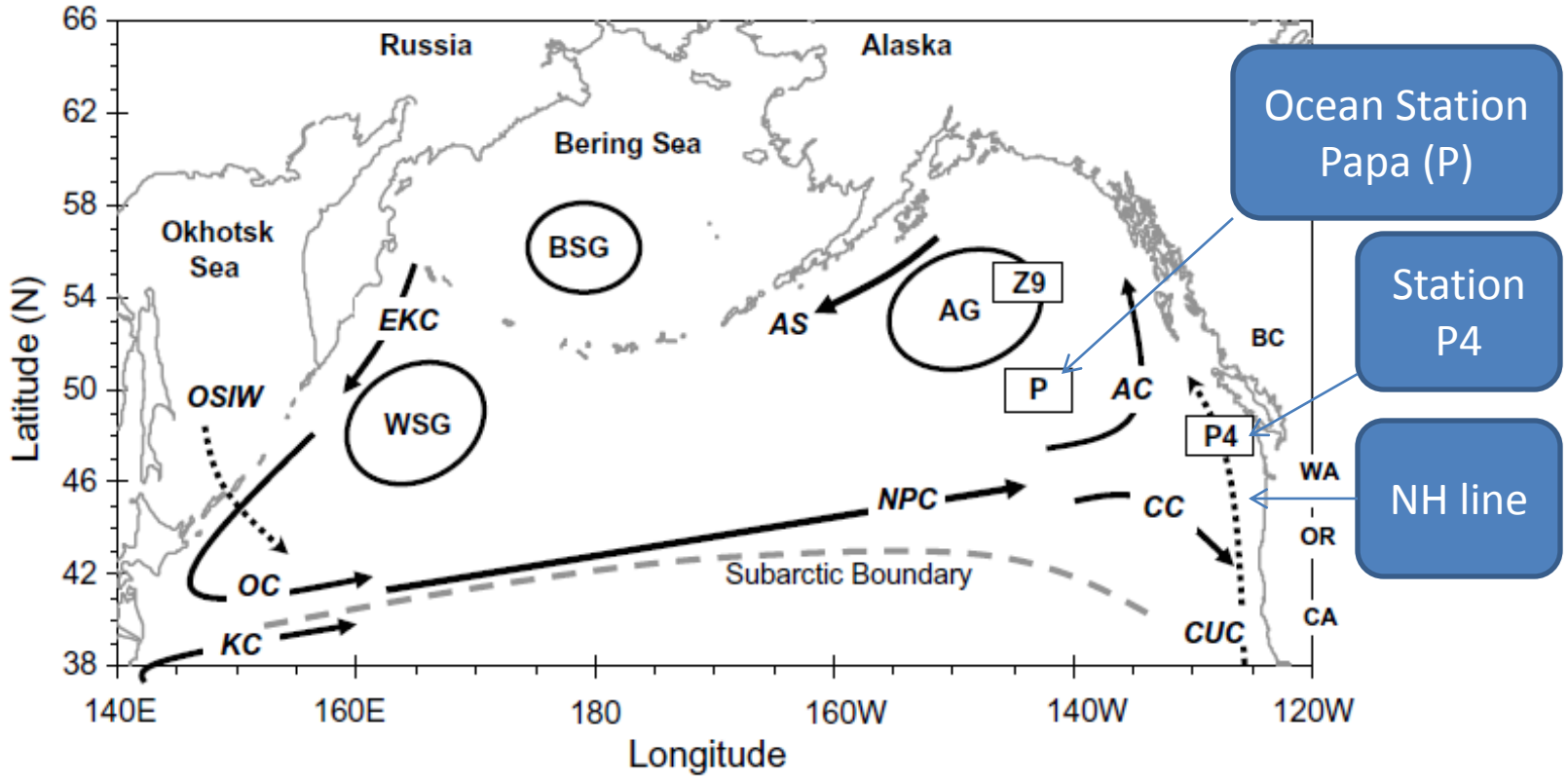


Fig. 1. Map of the North Pacific Ocean showing major currents (EKC, East Kamchatka Current; OSIW, Okhotsk Sea Intermediate Water; OC, Oyashio Current; KC, Kuroshio Current; NPC, North Pacific Current; CC, California Current; CUC, California Undercurrent; AC, Alaska Current; AS, Alaska Stream) and gyres (BSG, Bering Sea gyre, WSG, Western Subarctic gyre; AG, Alaska gyre). Also identified are Ocean Station P (P) at 50°N, 145°W, station P4 at 48.66°N, 126.67°W, British Columbia (BC), Washington (WA), Oregon (OR) and California (CA).

F.A. Whitney et al. / Progress in Oceanography 75 (2007) 179–199

Future Scenarios – Pacific Ocean DO is declining (50-yr trend) – 2070??

Station P:
-0.033 mg/L per yr
(-1 umol/kg-yr)

Station P4:
-0.040 mg/L-yr
(-1.22 umol/kg-yr)

NH Line:
-0.023 mg/L-yr
(- 0.7 umol/kg-yr)

2070: -1.47 mg/L
low end

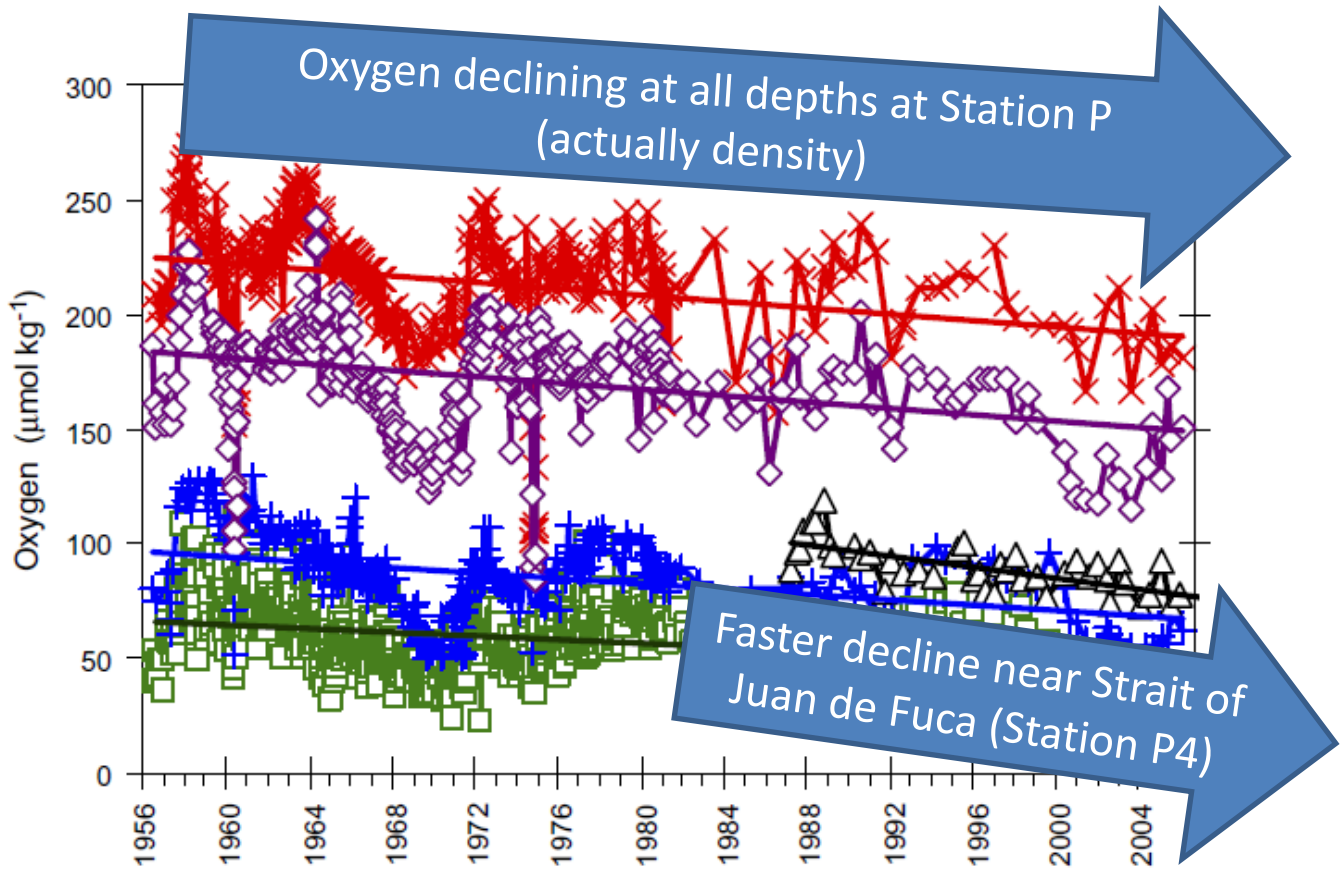
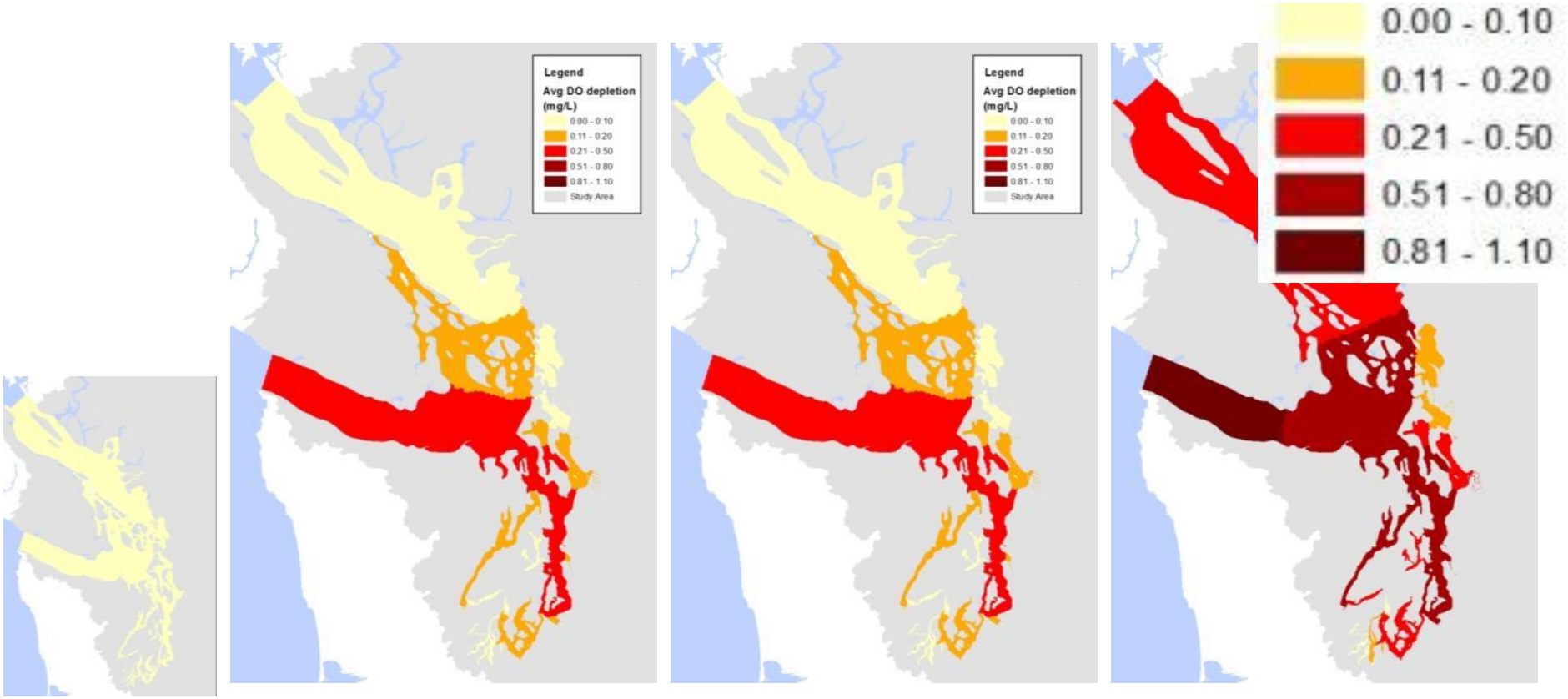


Fig. 4. Temperature and oxygen trends at Ocean Station P on the 26.5 (×), 26.7 (◇), 26.9 (+) and 27.0 (□) isopycnal surfaces and at station P4 (△) on the 26.7 surface. T and oxygen trends from linear regressions are provided in Table 1. Depth ranges (average and standard deviation) are 140 ± 15 m, 168 ± 17 m, 278 ± 27 m and 370 ± 44 m on the 26.5, 26.7, 26.9 and 27.0 isopycnals, respectively. P4 is warming at 0.0084 °C y^{-1}, with O_2 declining at 1.22 µmol kg^{-1} y^{-1}. Two mesoscale eddies are labelled 1 and 2.

F.A. Whitney et al. / Progress in Oceanography 75 (2007) 179–199

Average regional DO impacts due to future human loads, circ, and ocean (Runs 32-34)



current

2020 loads, future ocean, future circ

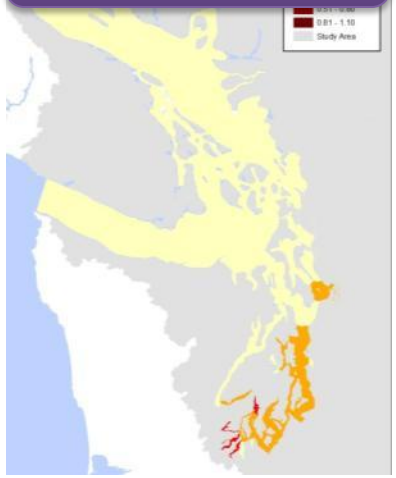
2040 loads, future ocean, future circ

2070 loads, future ocean, future circ

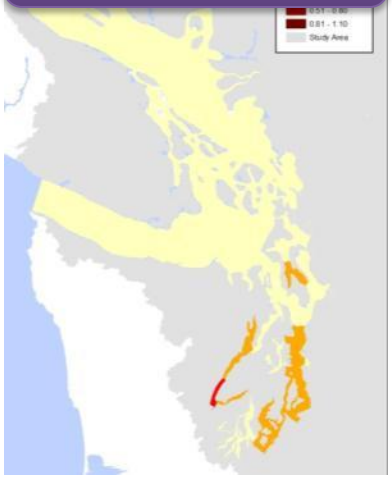
Salish Sea findings: Future population growth will increase oxygen impacts; ocean may make it worse

Current human sources, circulation, ocean conditions, air temperature

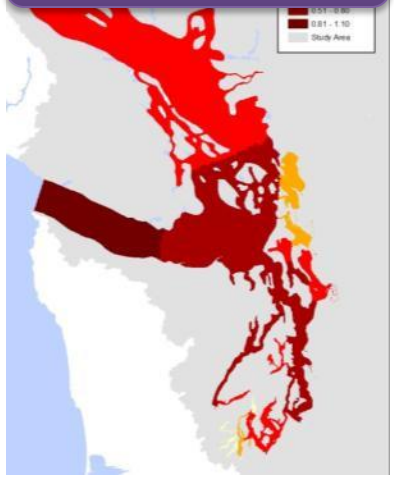
2070 human



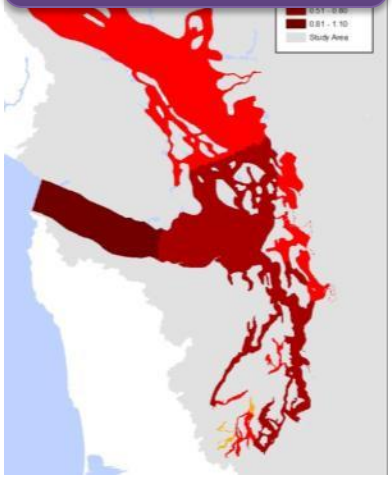
2070 human + future circulation



2070 human + circ + future ocean



2070 human + circ + ocean + air temp



LEGEND

(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

Puget Sound – Salish Sea model performance and application

- What are the relative impacts of current human sources on dissolved oxygen?
  - South Sound and southern Central Sound show greatest impacts from human sources (consistent with SPS model)
  - Marine point sources > human sources within watershed inflows
  - Current sources decrease average regional DO by up to 0.1 mg/L (*not directly applicable to stds*)

Puget Sound – Salish Sea model performance and application

- Future human sources through 2070?
  - DO declines more with increasing loads, but effects vary by location
  - Changes in circulation could mitigate impacts in some regions but could worsen others
- Future ocean conditions and climate?
  - If ocean trends continue, future ocean conditions would cause greater impacts than local humans
  - Increasing air temperature would also worsen dissolved oxygen
  - *Future ocean conditions are highly uncertain…*

Influence

HIGHER LOWER

Uncertainty

HIGHER

LOWER

Future ocean conditions

Future marine community shifts

Future climate
(air temperature, precipitation, hydrology)

Future sediment-water exchanges

Future watershed concentrations
(land cover)

Future watershed inflows

Future marine point source concentrations

Future marine point source flows

Current sediment-water exchanges

Current ocean conditions

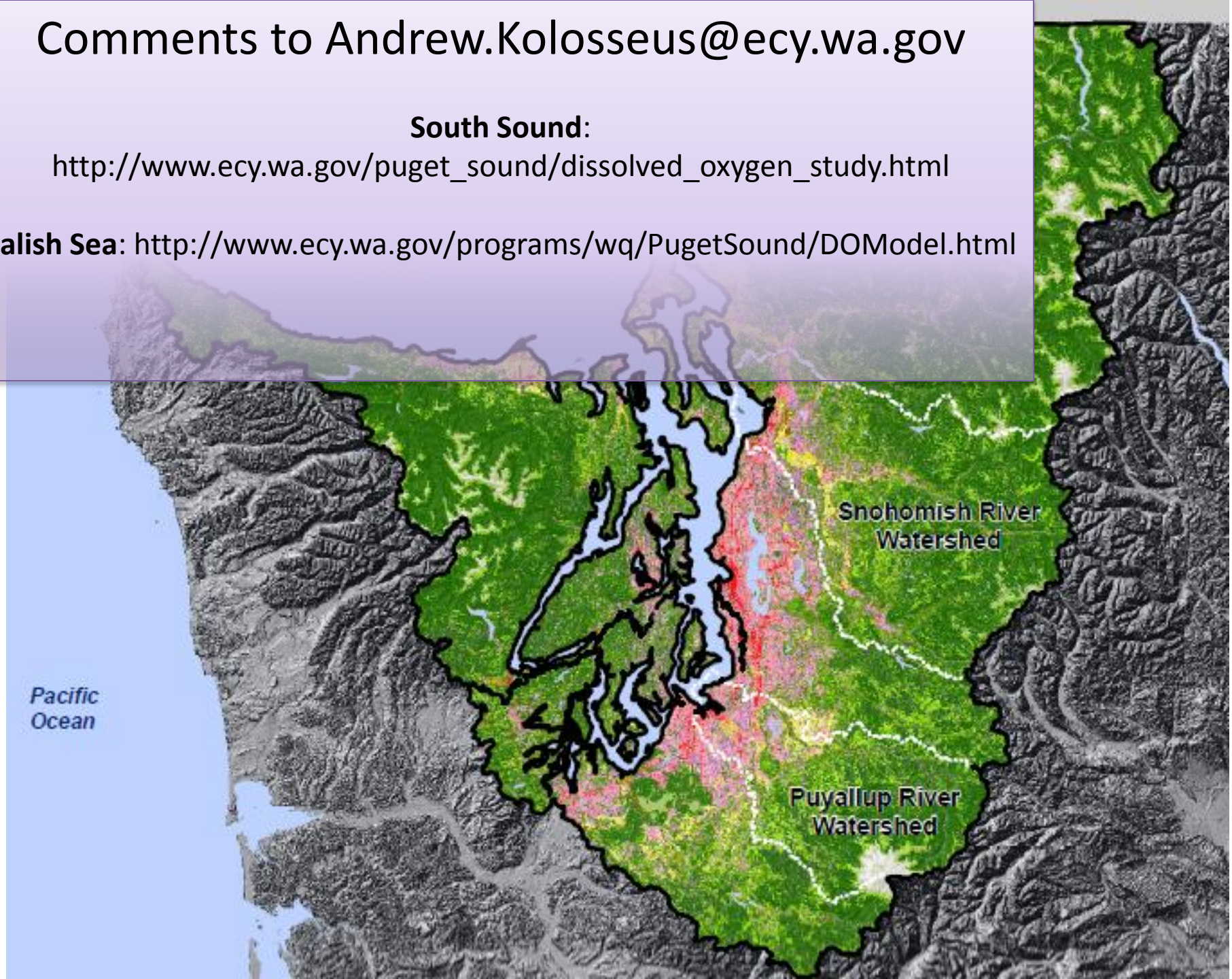
Current watershed inflows

Current marine point sources

South Puget Sound and Salish Sea models – next steps

- November 12 – external review comments due on each report to Andrew Kolosseus
- Publish reports in January (+ SPS circulation)
- Update Salish Sea model with linked sediment-water exchanges (funded through 2015)
- Use updated Salish Sea model to refine South Sound predictions

Comments to Andrew.Kolosseus@ecy.wa.gov

South Sound:
http://www.ecy.wa.gov/puget_sound/dissolved_oxygen_study.html

Salish Sea: http://www.ecy.wa.gov/programs/wq/PugetSound/DOModel.html