

# Bounding Scenario Results from Salish Sea Model, Vol 1:

## DO Improvements in Greater Puget Sound from Biological Nutrient Removal at WWTPs

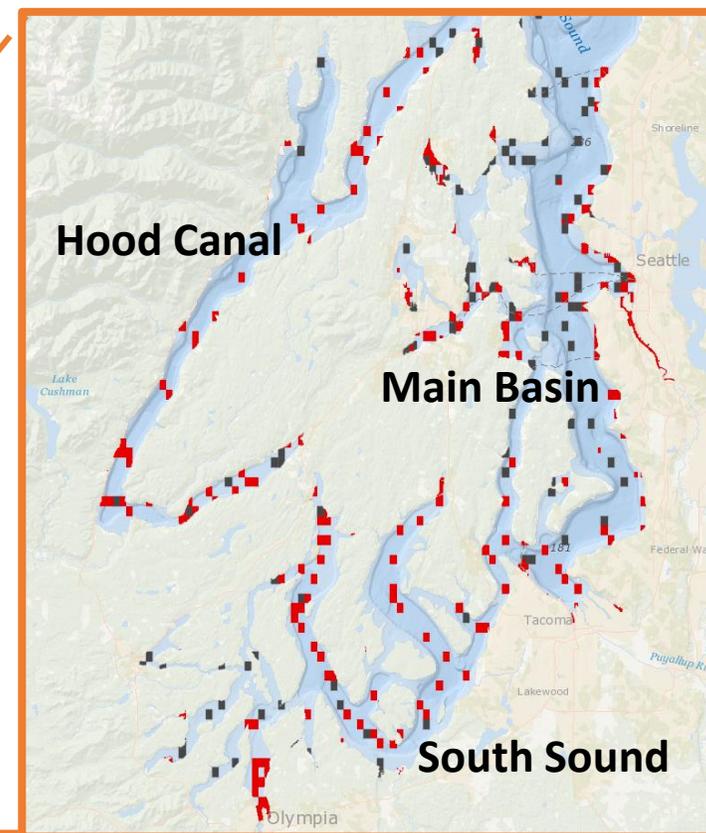
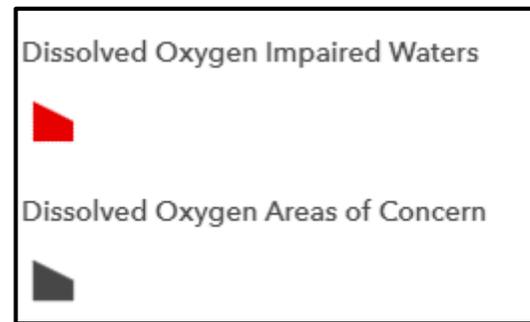
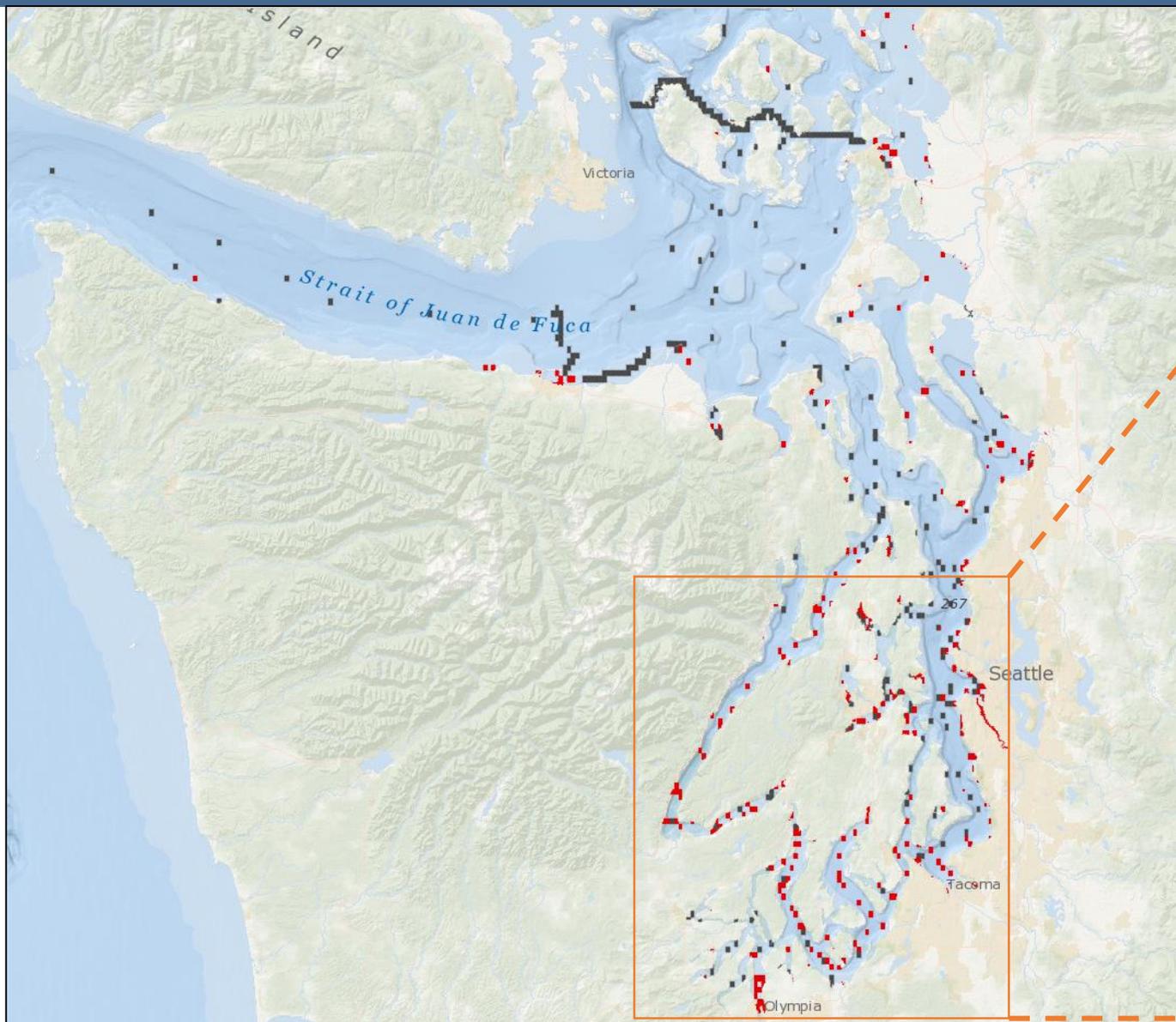
Puget Sound Nutrient Source Reduction Project

Puget Sound Nutrient Forum  
February 6, 2019

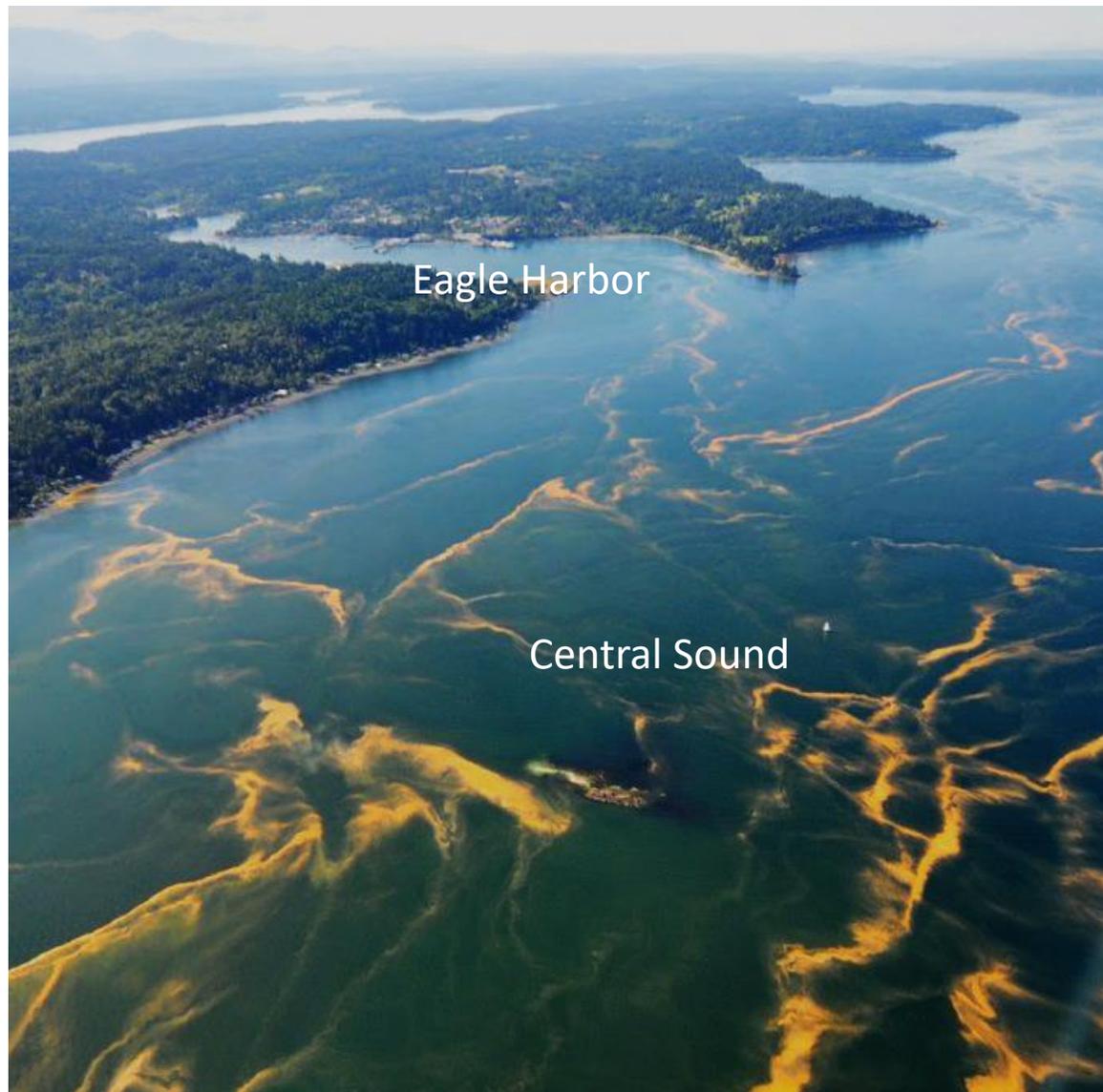


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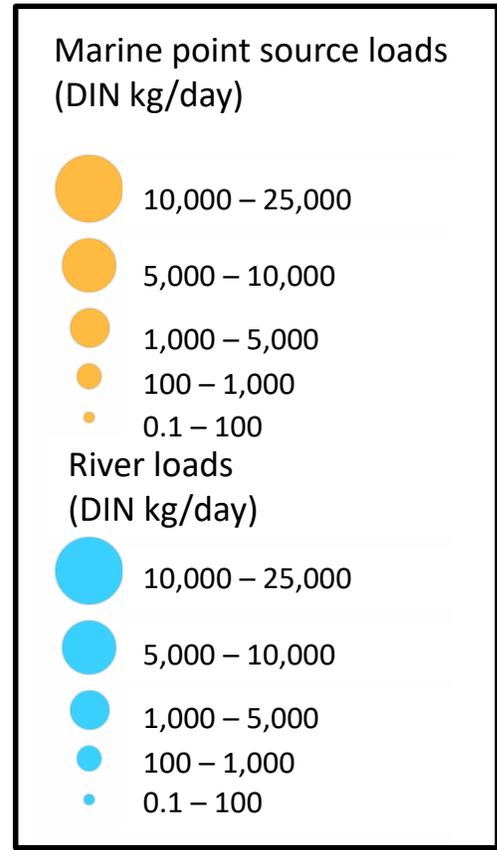
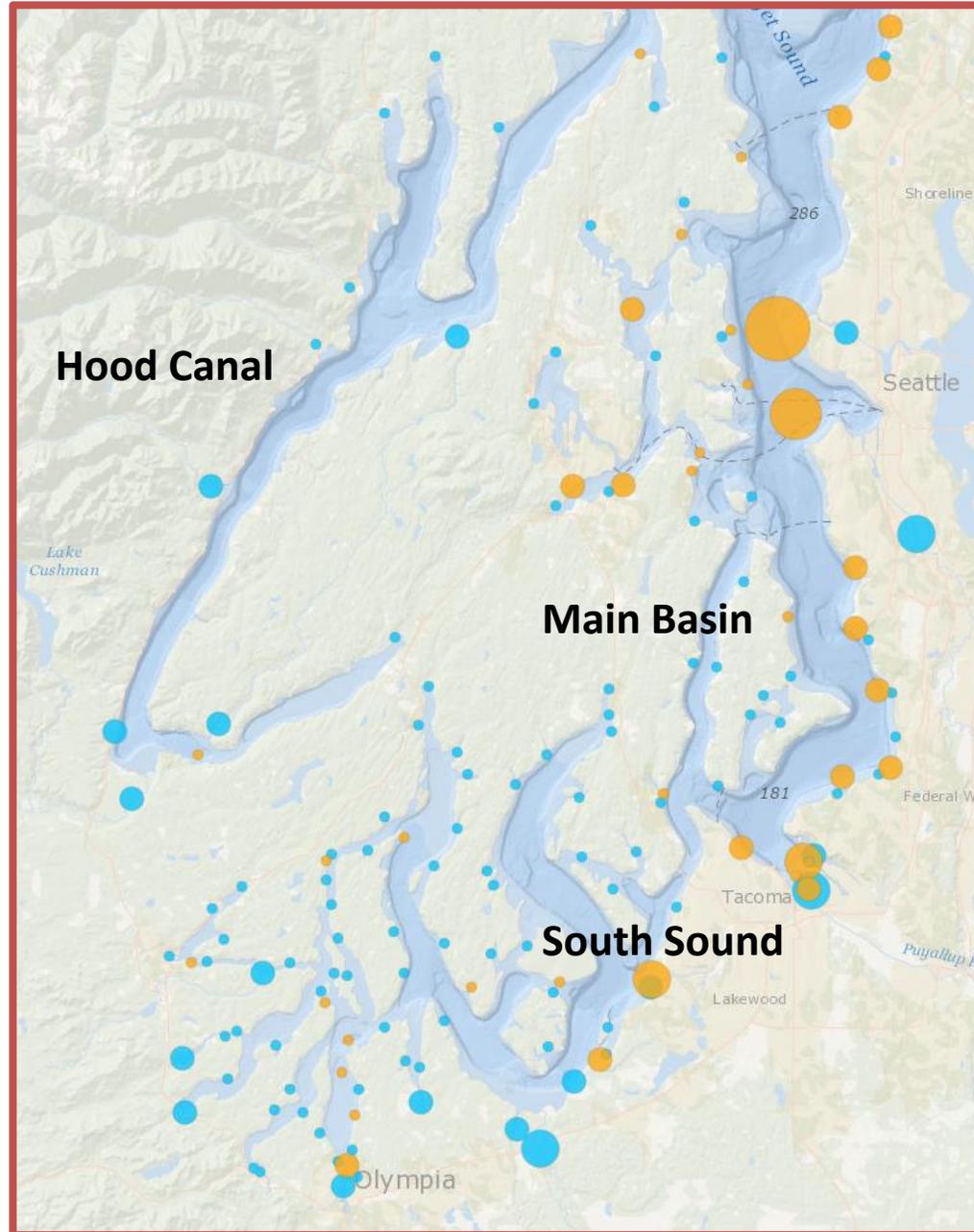
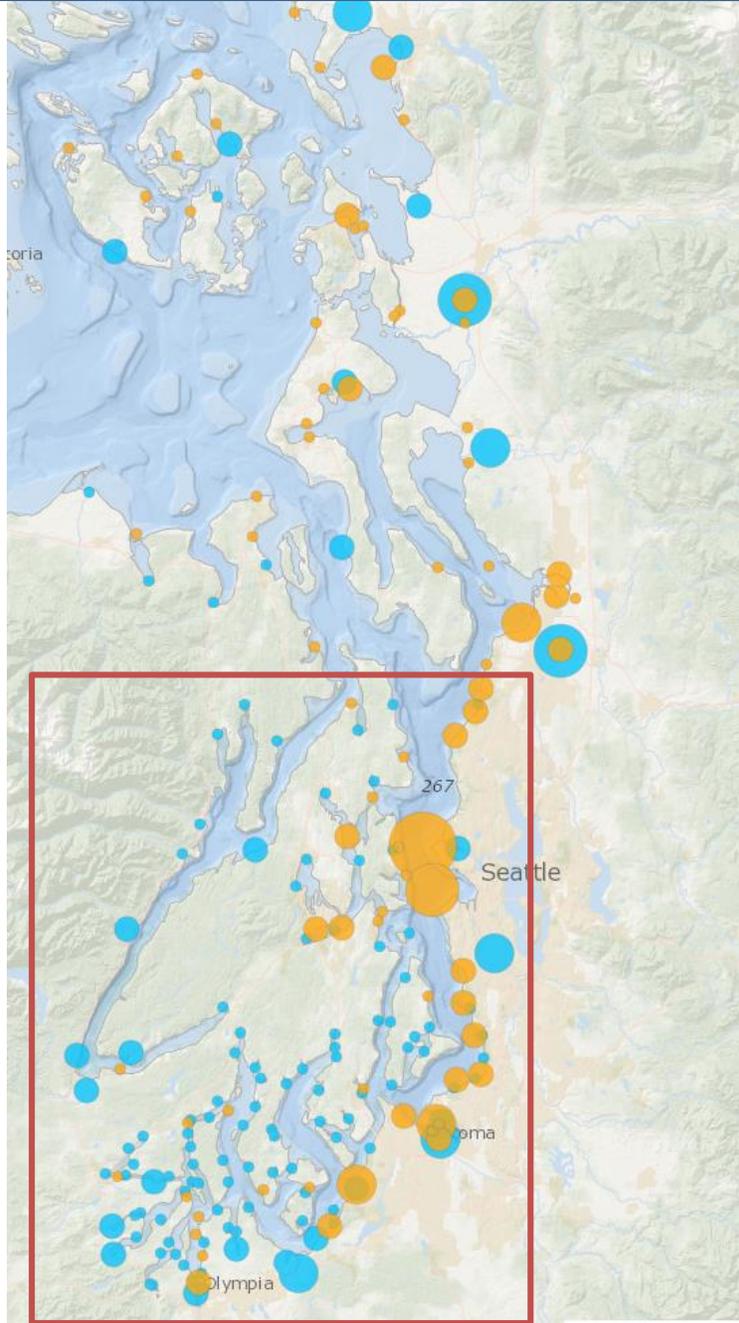
# Oxygen levels are low



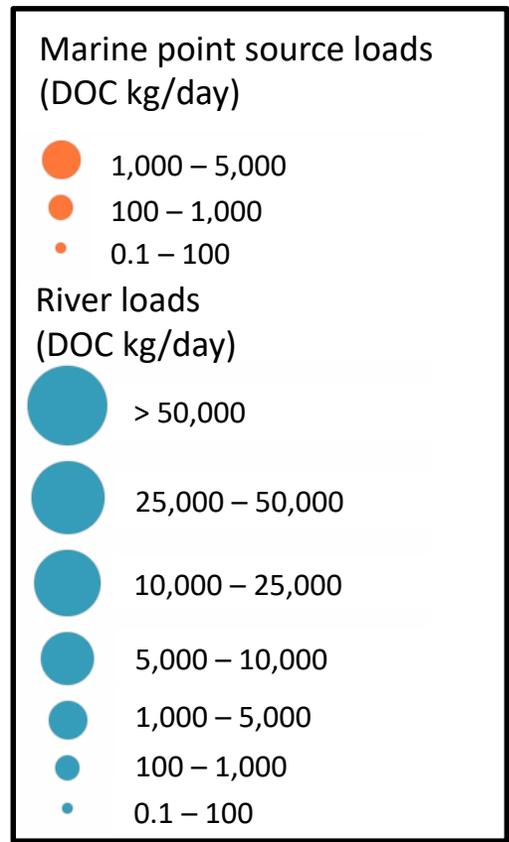
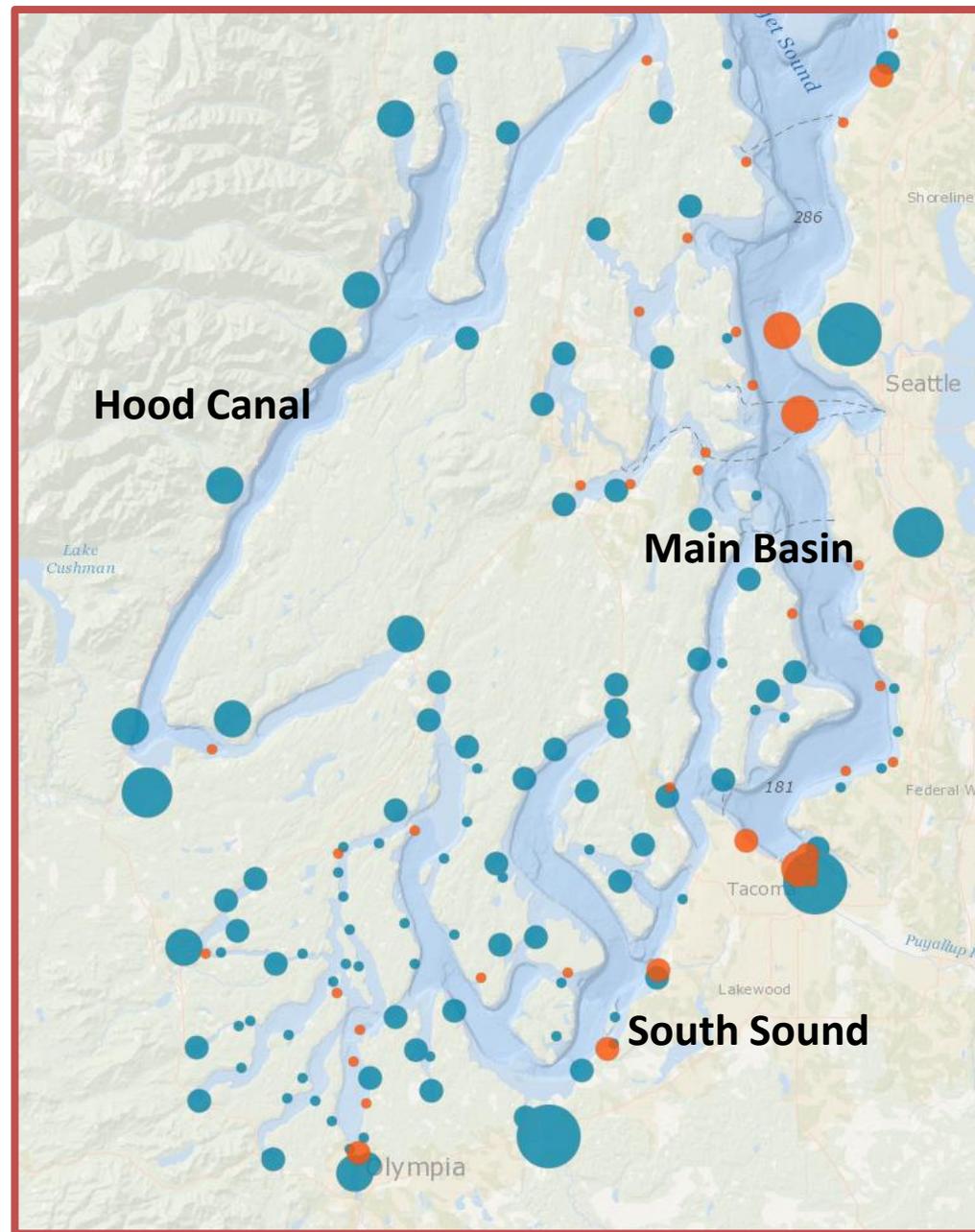
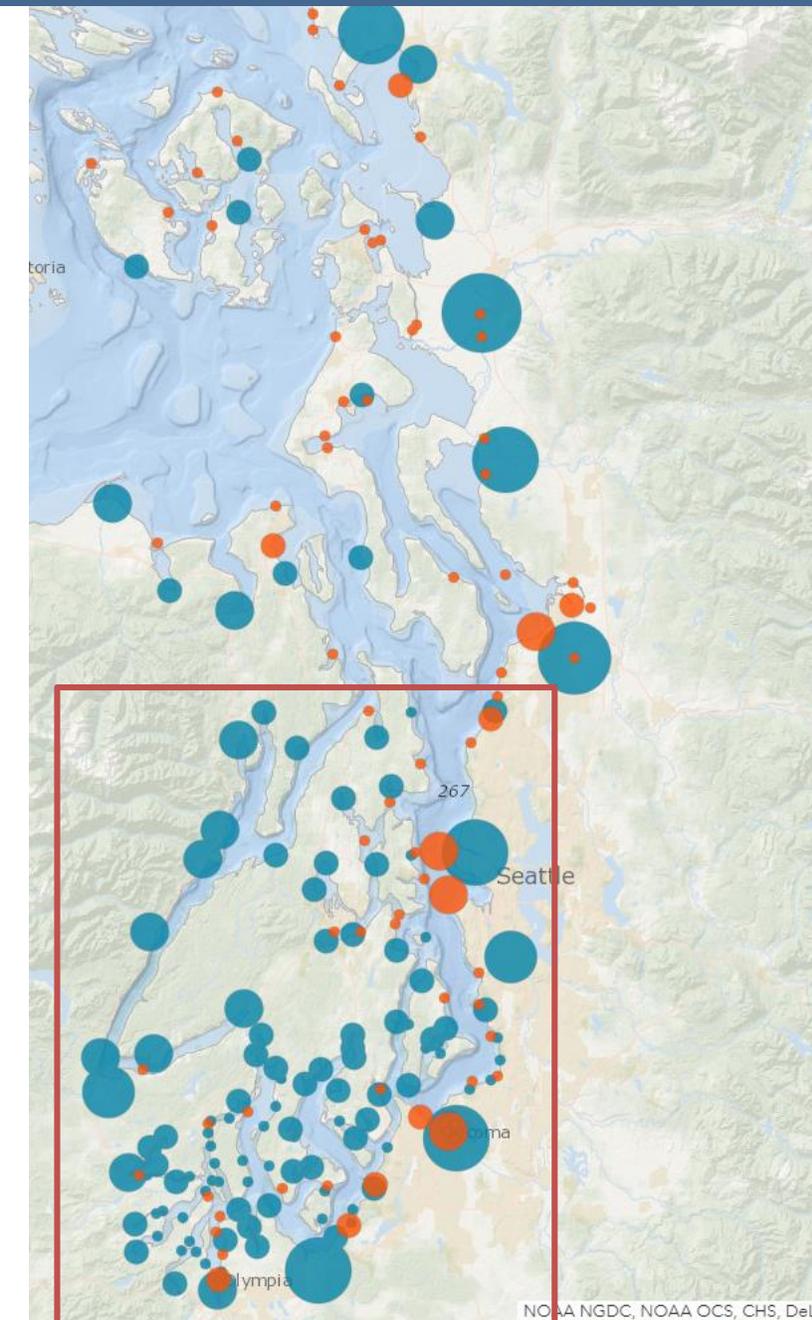
# Algal blooms



# United States Nitrogen Loading 2006

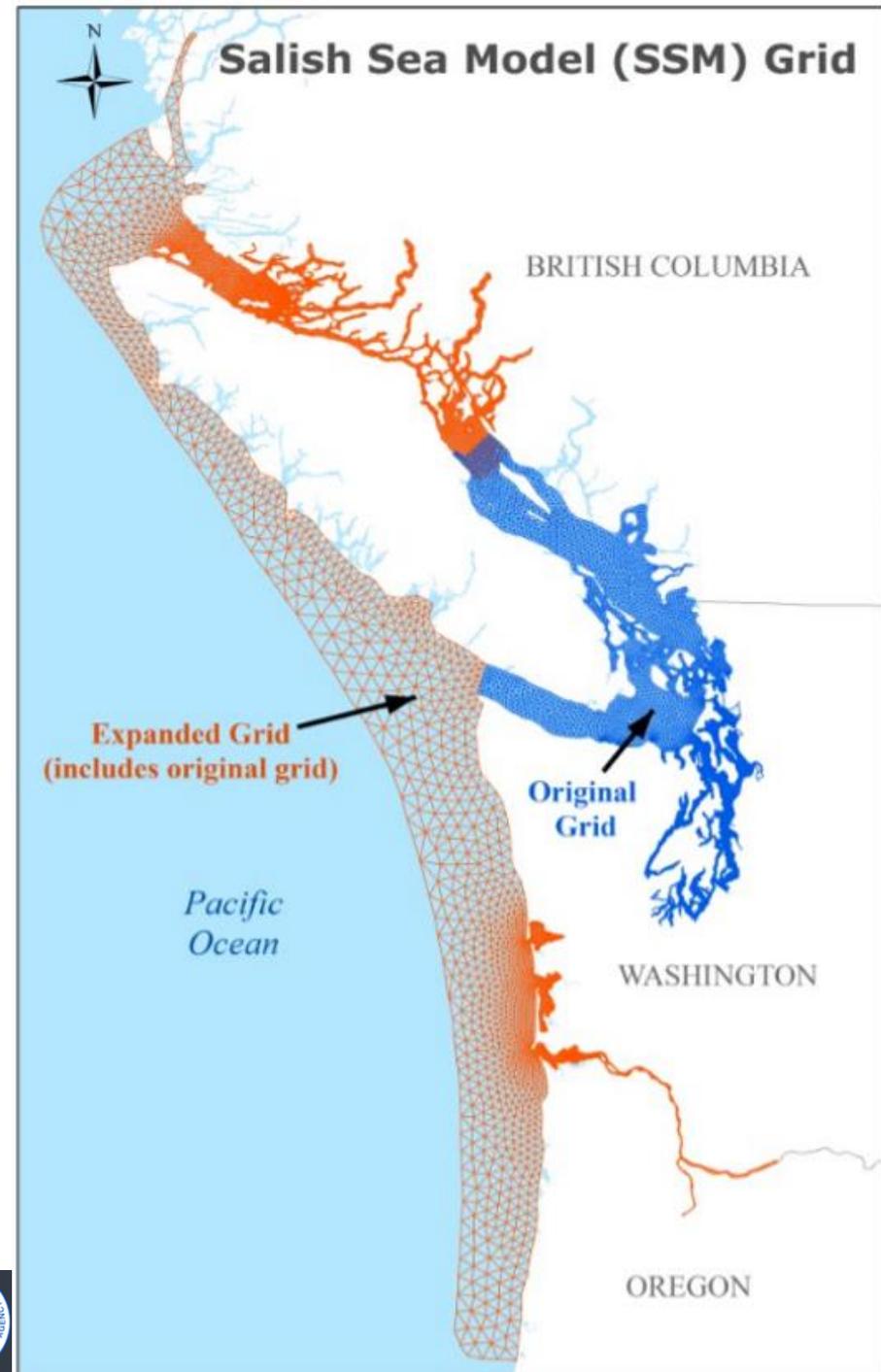


# United States Organic Carbon Loading 2006



# Salish Sea Model

- State of the science model.
- Thoroughly peer reviewed.



FVCOM



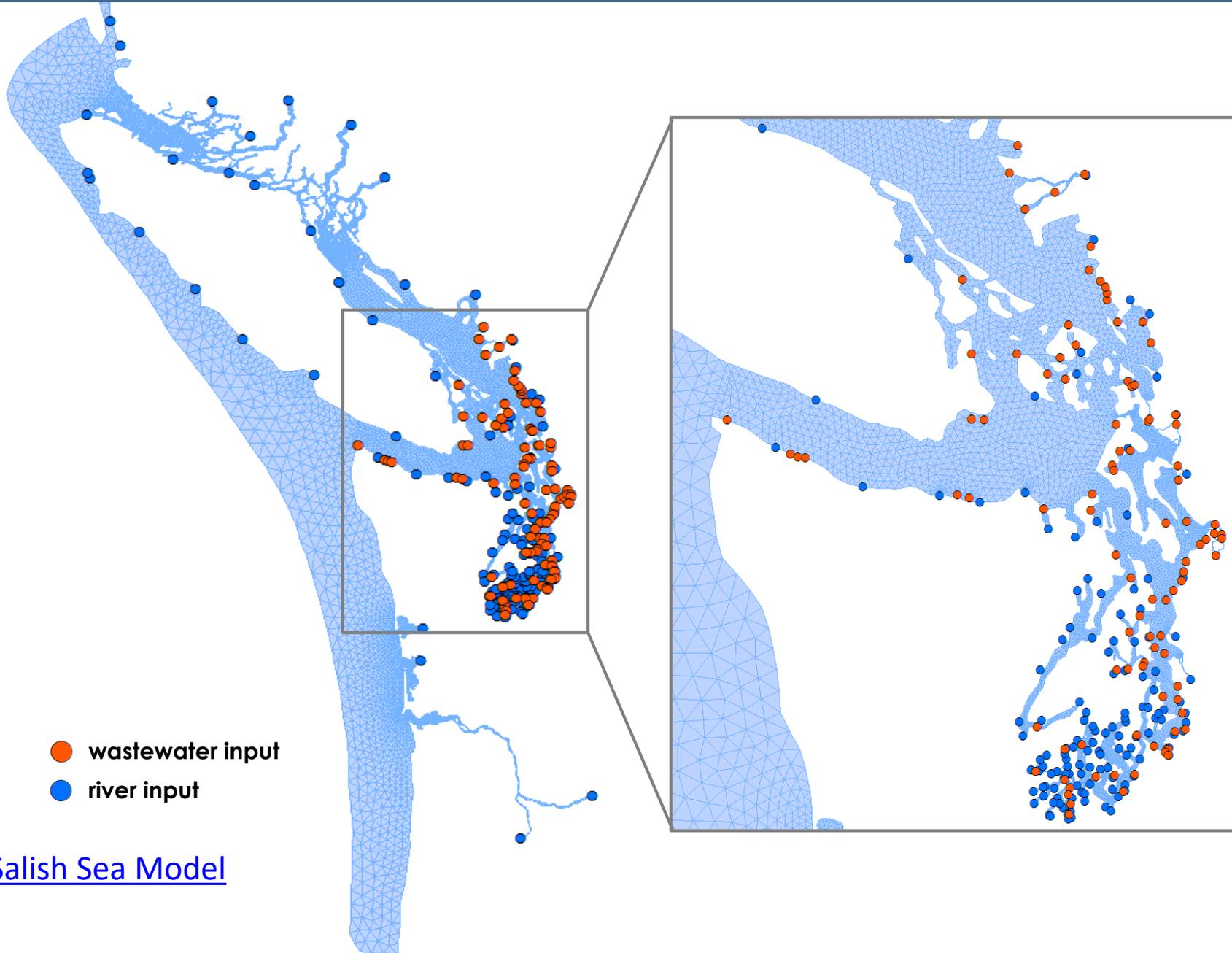
[CE-QUAL-ICM water quality model](#)



Developed by: PNNL in collaboration with WA ECY,  
funded by EPA



# Salish Sea Model



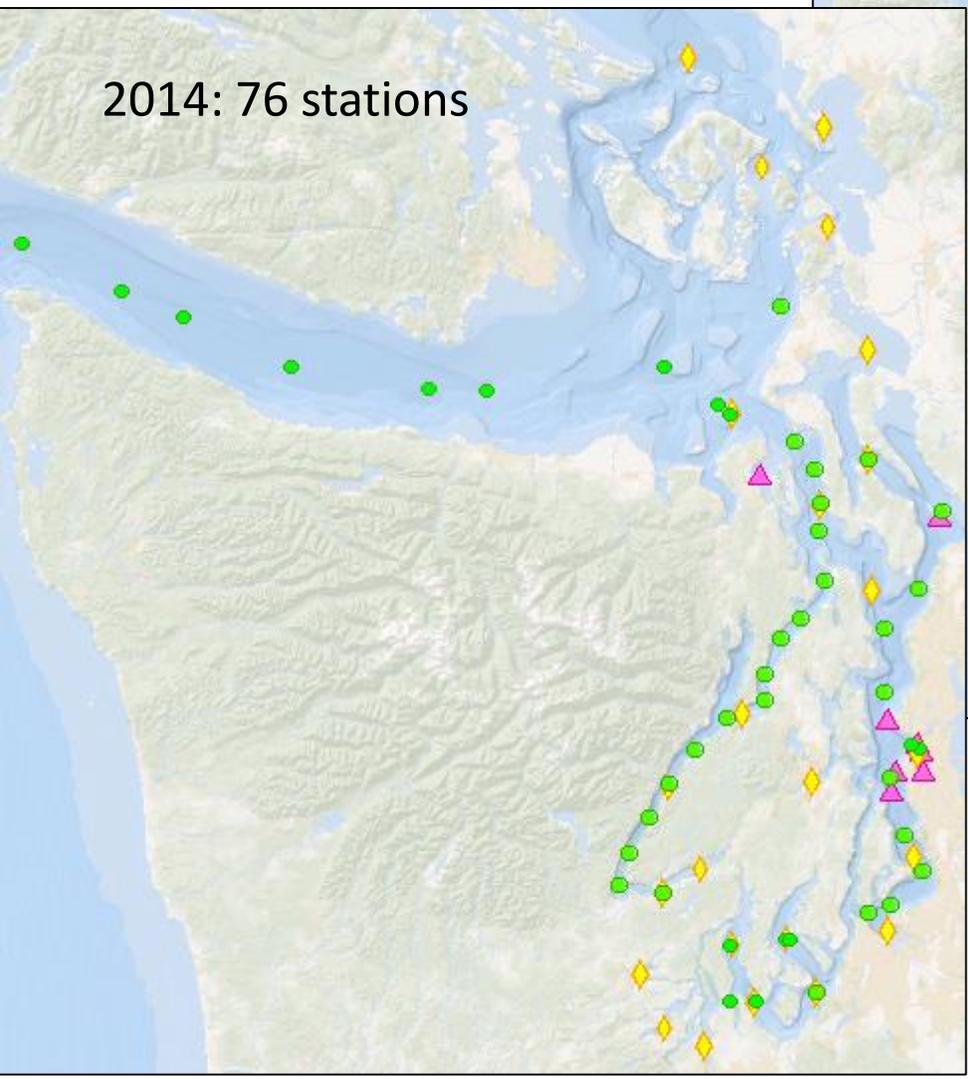
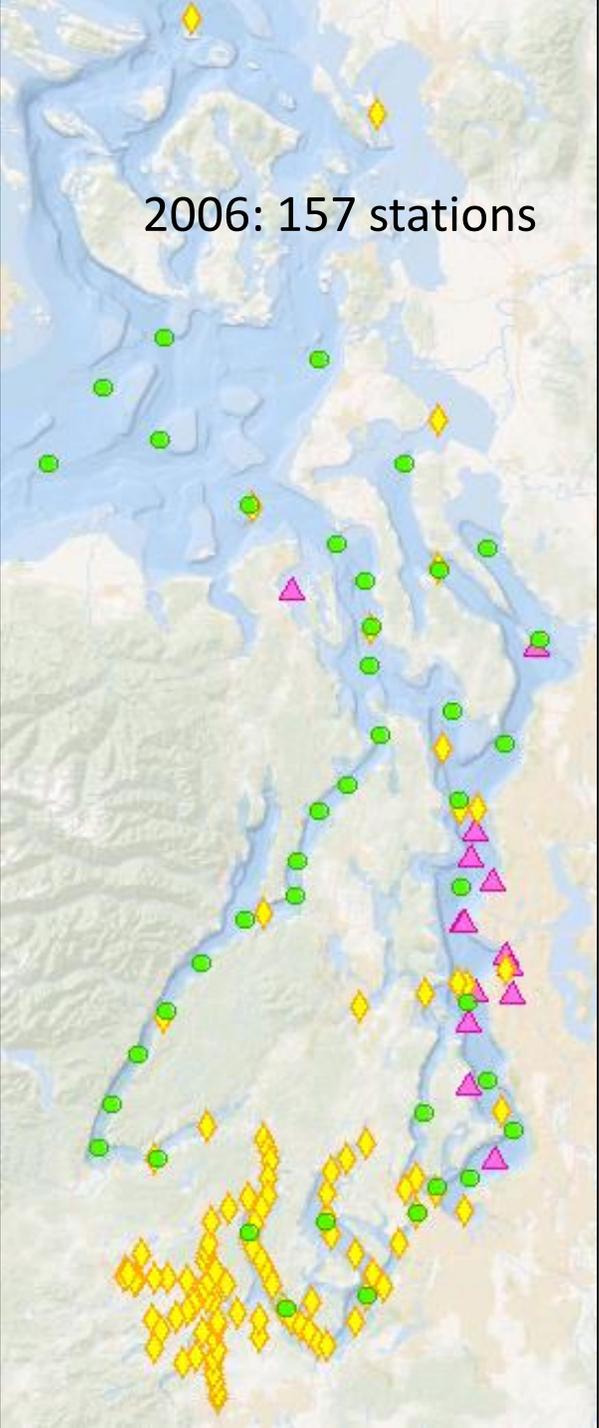
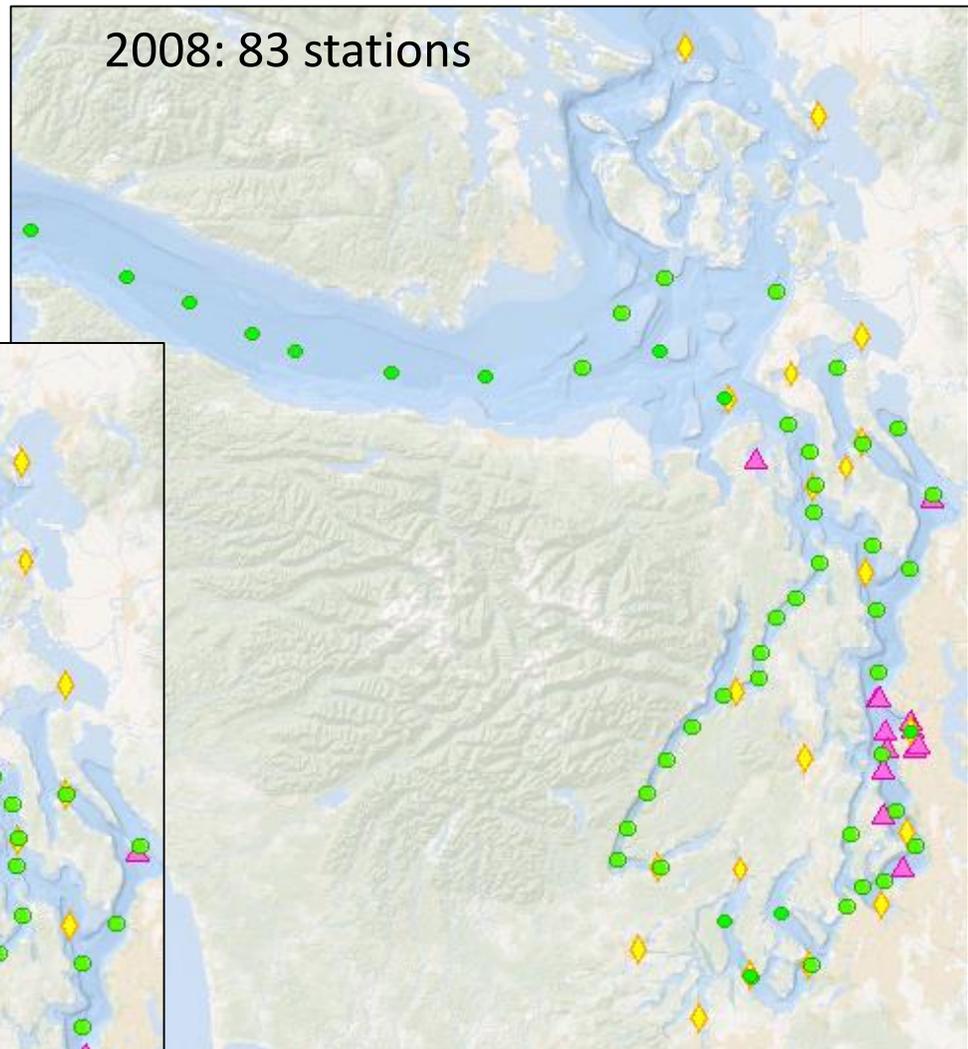
## 161 river and streams

- Rivers and streams entering Puget Sound, the Straits and the Pacific Ocean

## 99 point sources

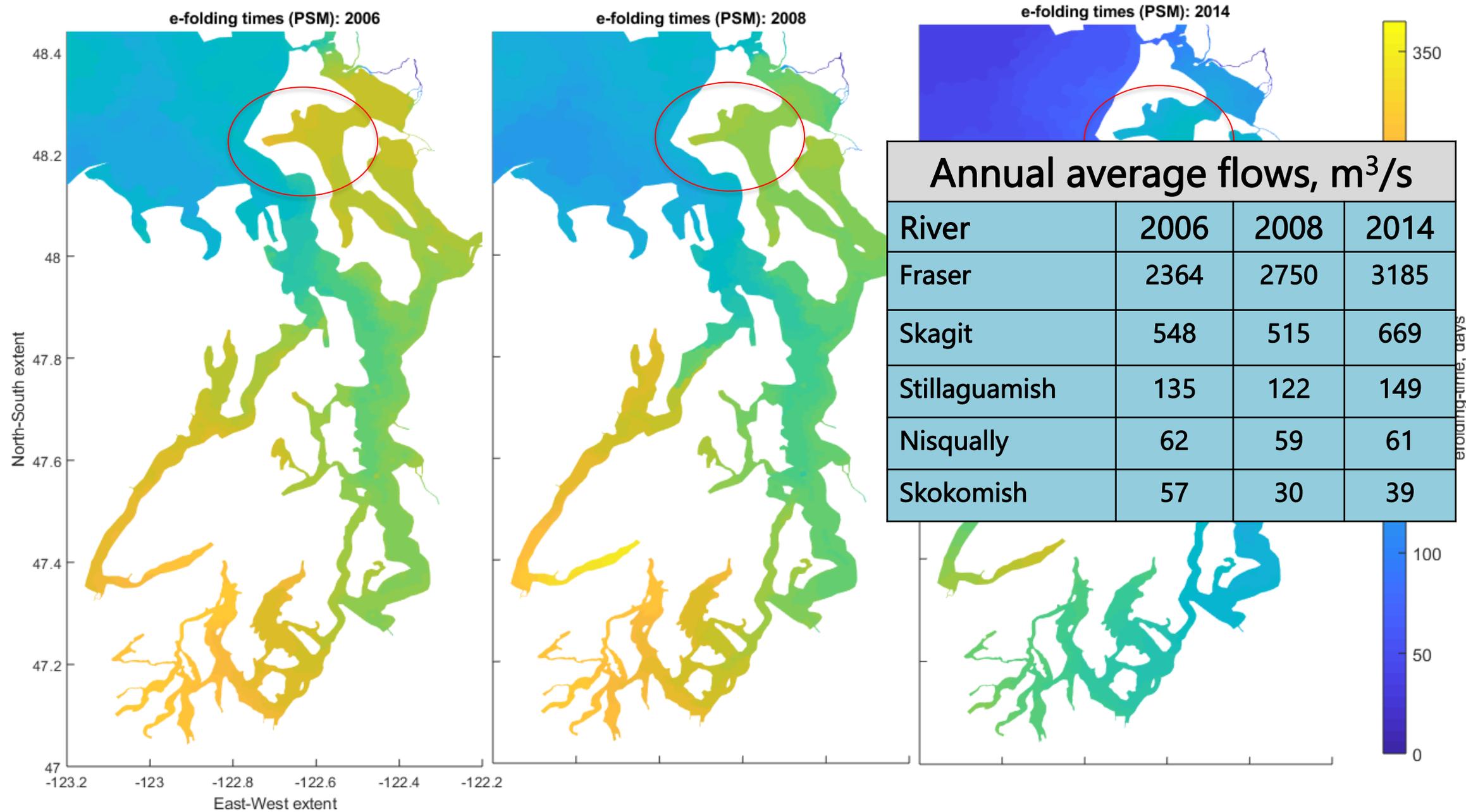
- All facilities with marine outfalls
- 78 U.S. WWTPs
- 9 Canadian WWTPs
- 10 industrial facilities

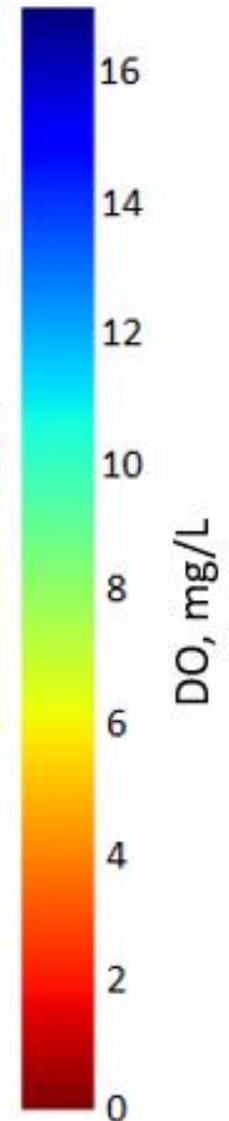
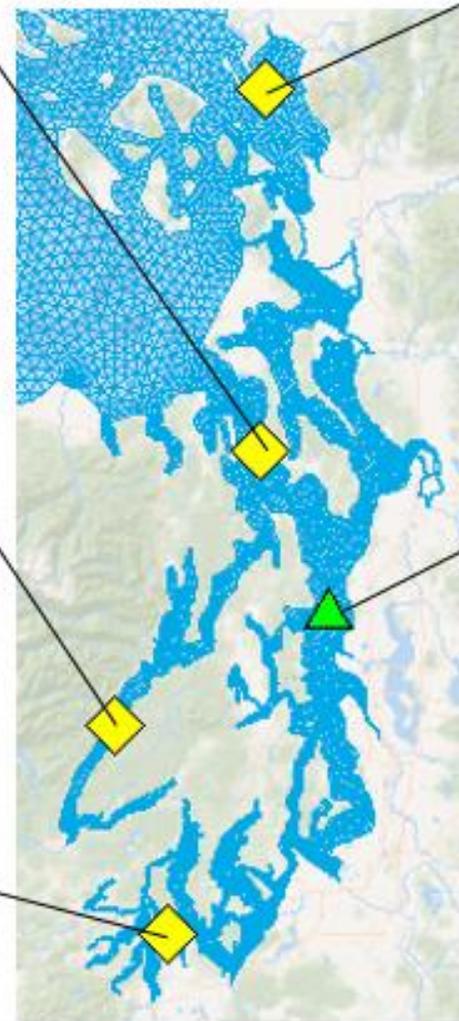
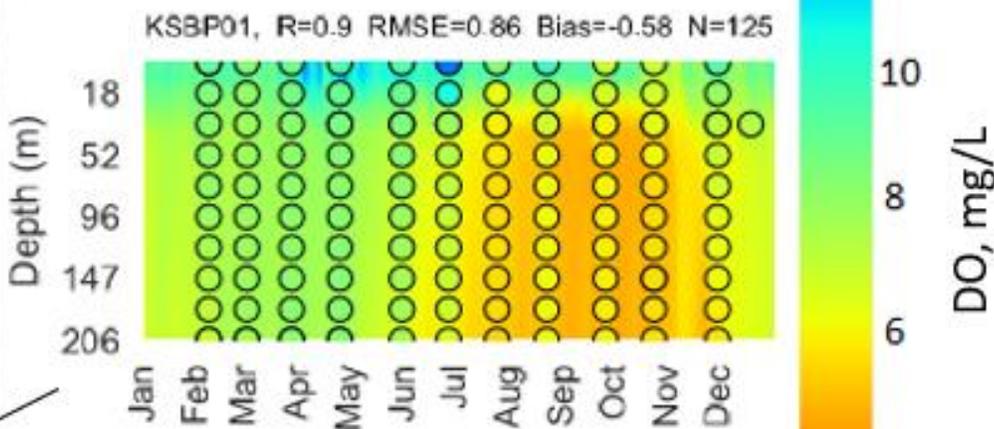
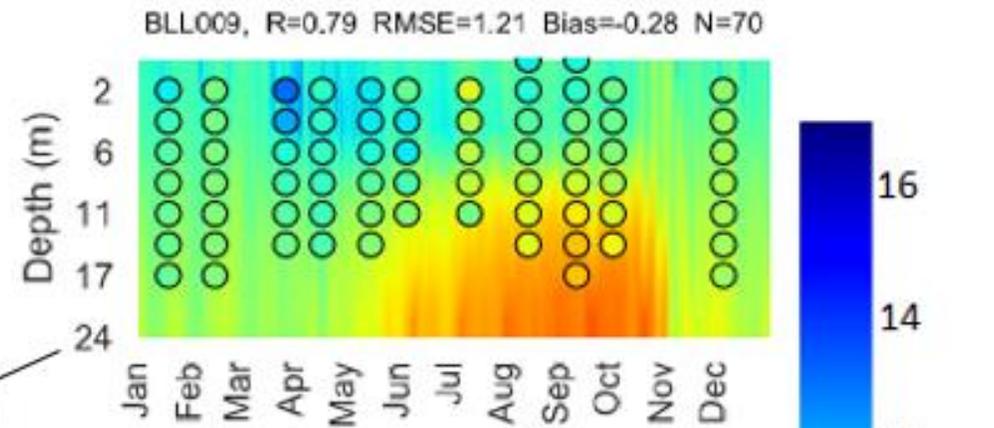
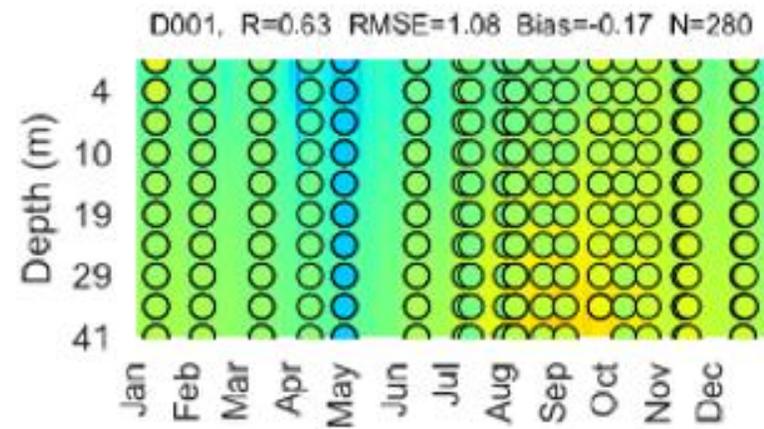
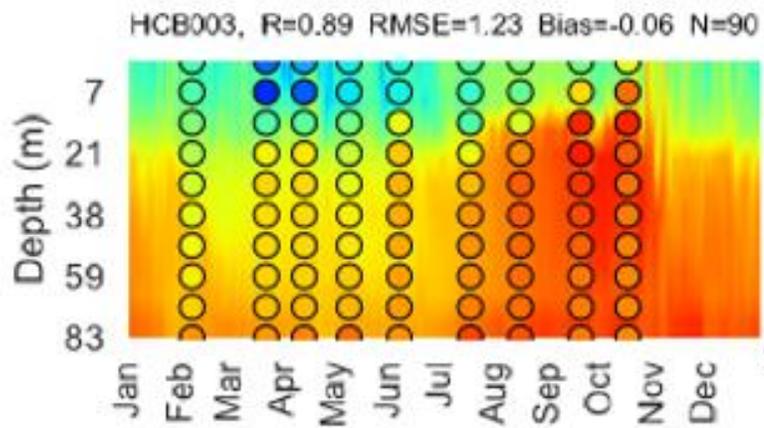
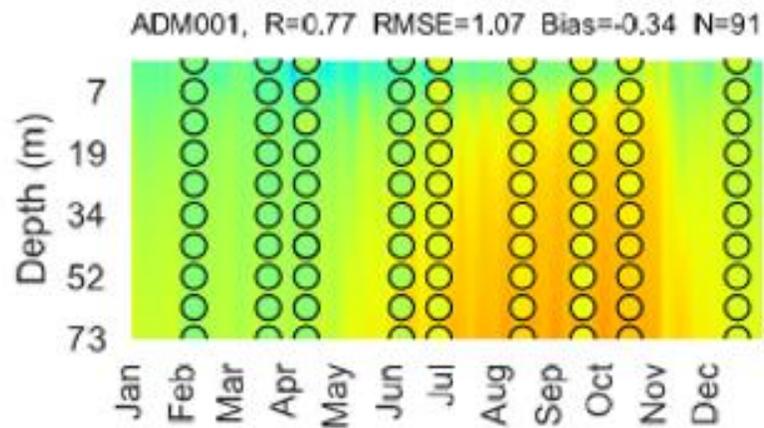
# Stations where model performance was evaluated for water quality



- NOAA\_UW
- ▲ King County
- ◆ Ecology

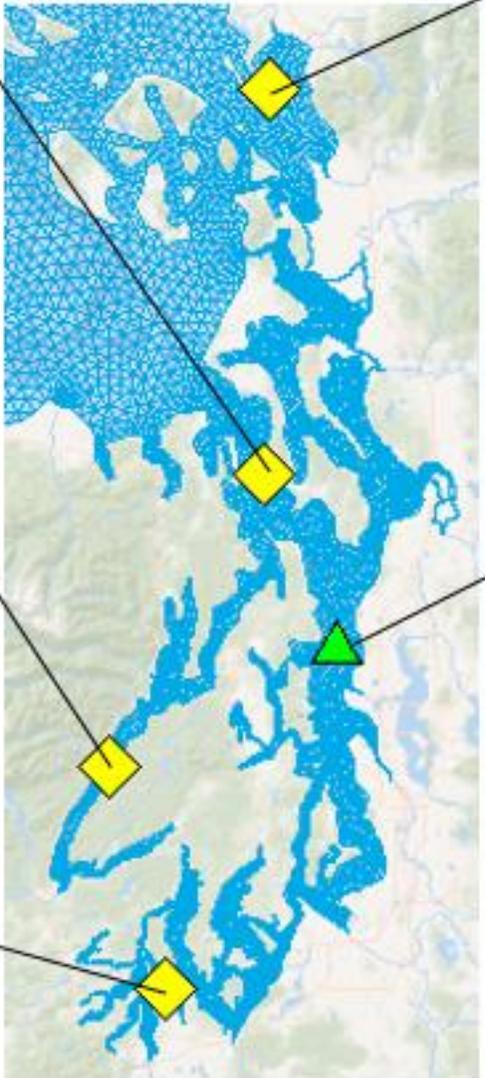
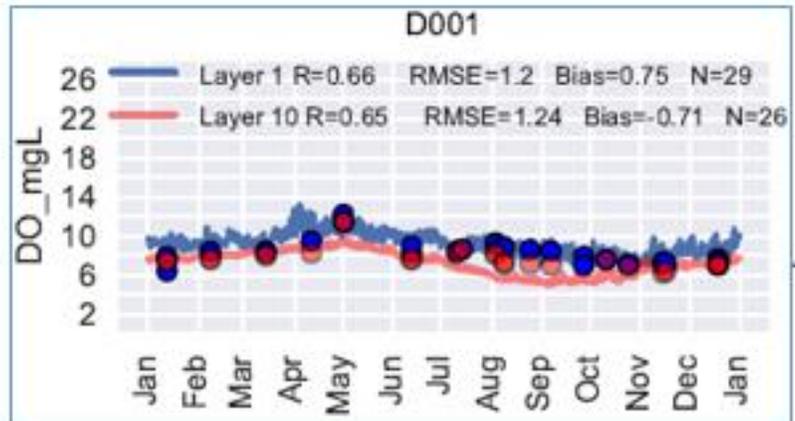
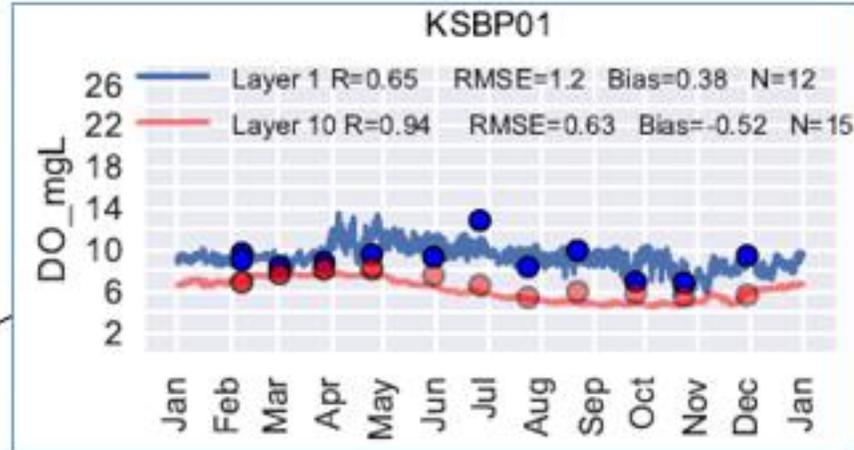
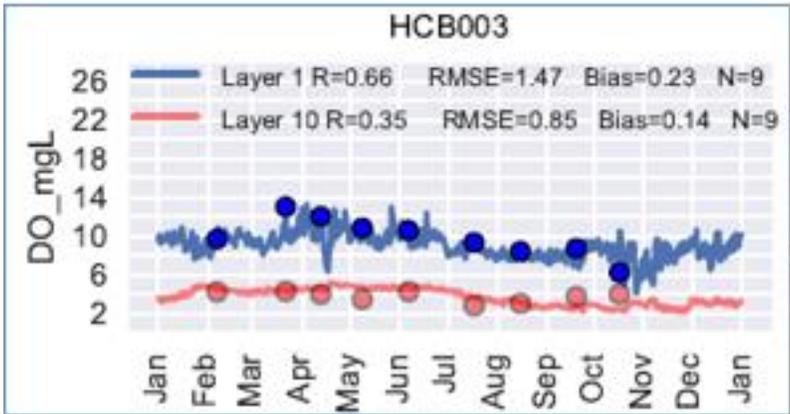
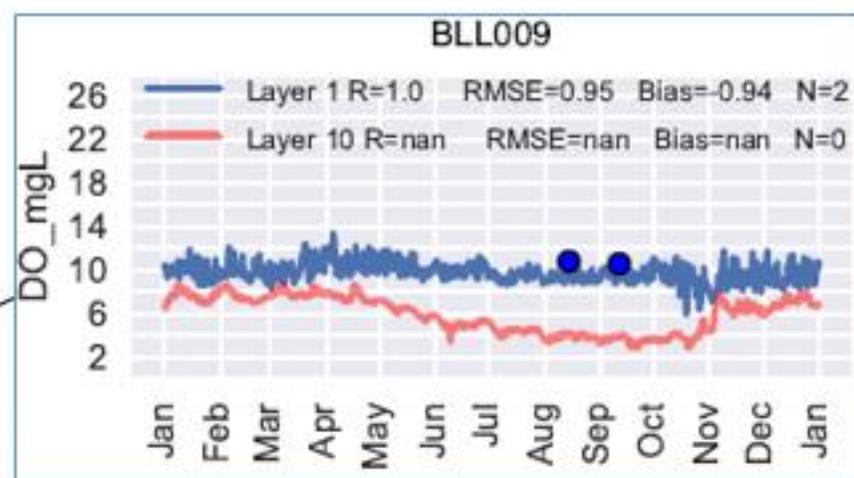
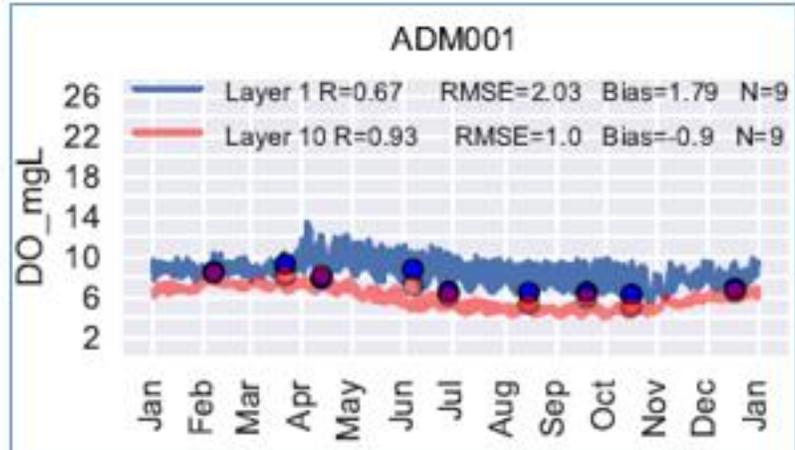
# Characteristics of three years modeled





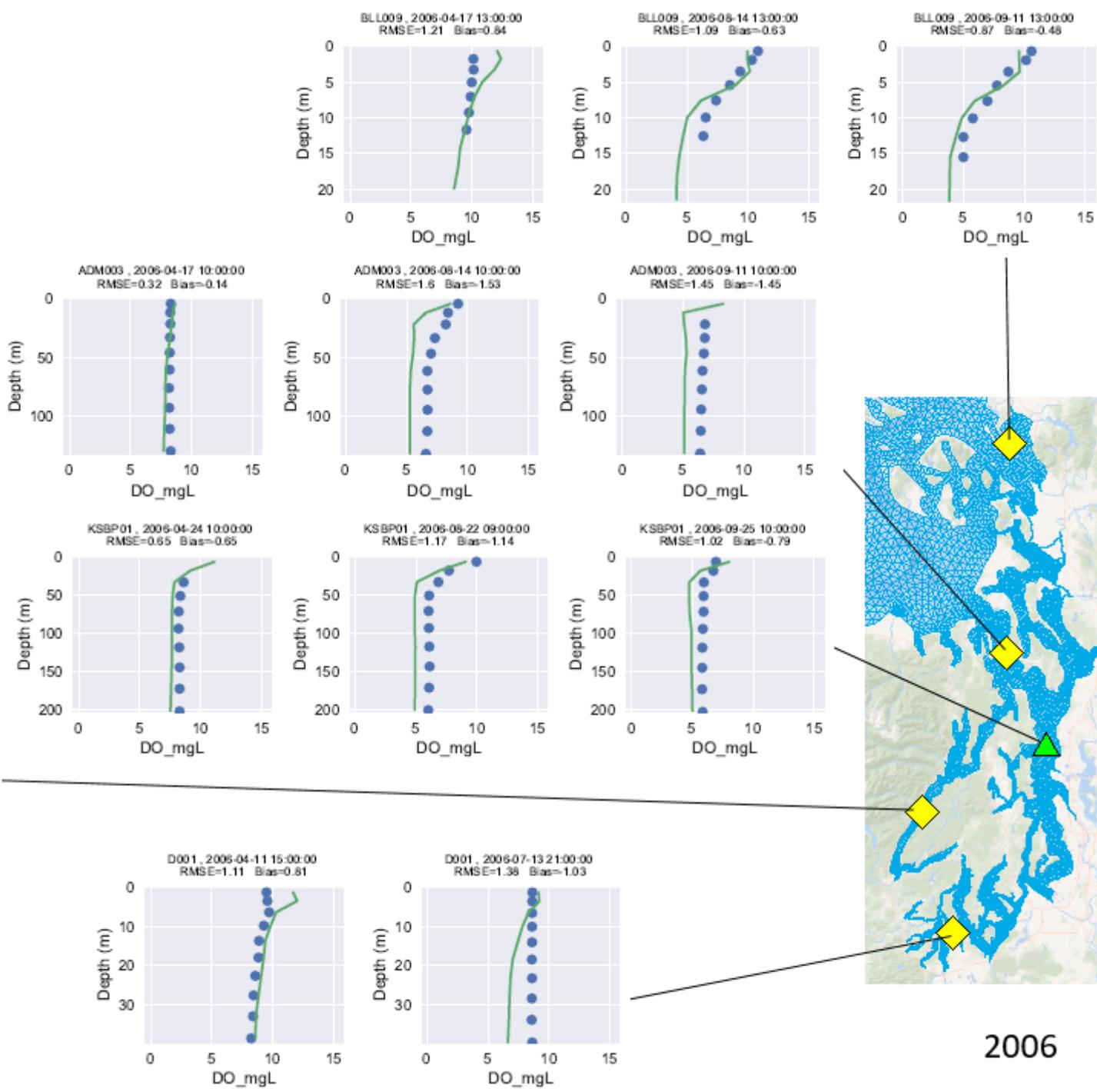
2006

Model performance (time-depth):  
Dissolved Oxygen



Model performance (time-series):  
Dissolved Oxygen  
2006

# DO profiles at selected stations: 2006

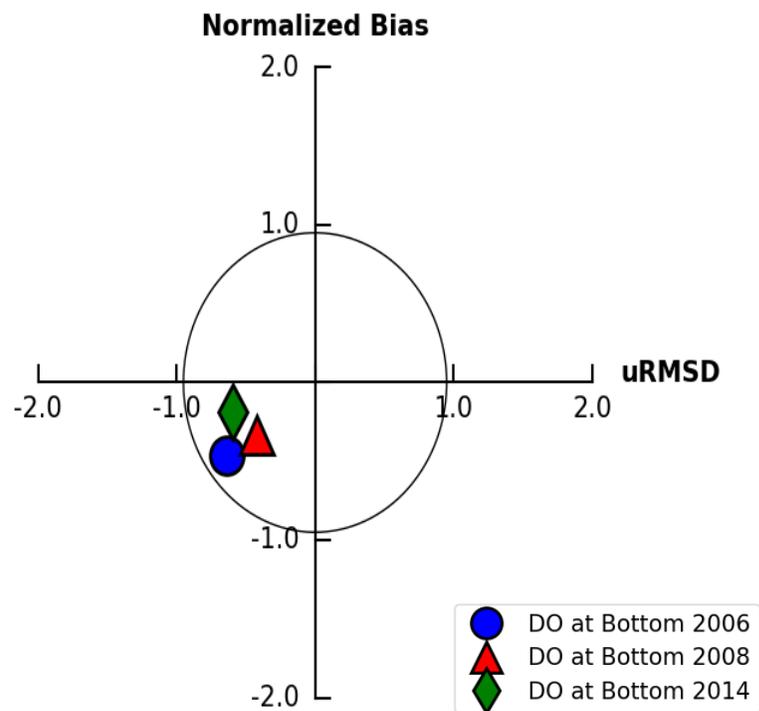


2006

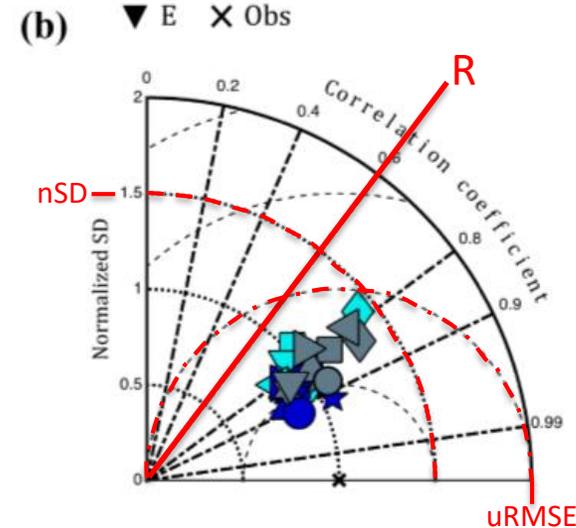
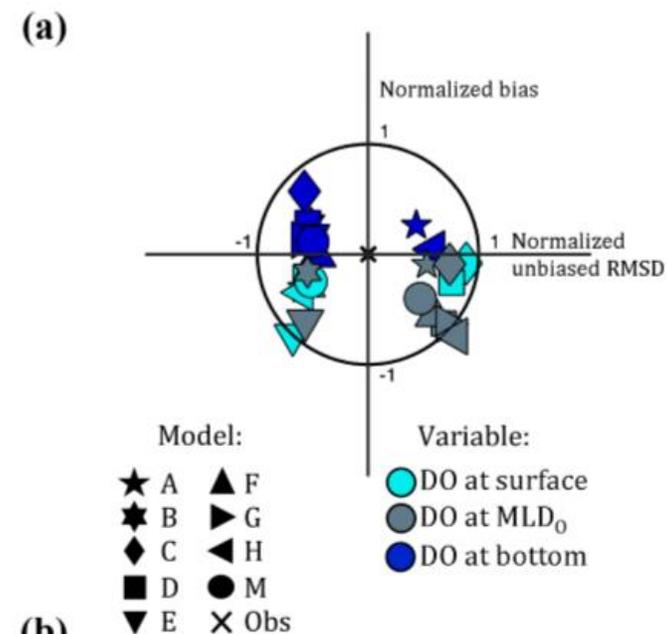
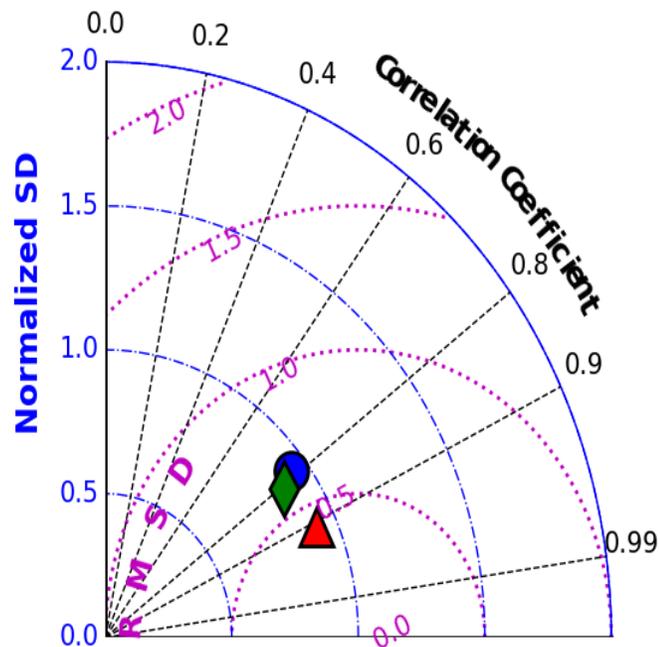
## Model Performance for Dissolved Oxygen:

<b>Dissolved Oxygen, mg/L</b>				
<b>Model Run</b>	<b>R</b>	<b>RMSE</b>	<b>Bias</b>	<b>n</b>
2008 PSM (Bianucci et al. 2018)	0.80	1.8	-1.56	66538
2014 SSM (Khangaonkar et al. 2018)	0.83	0.99	-0.24	26082
2008 SSM	0.85	0.98	-0.53	66931
2006 SSM	0.80	1.09	-0.57	135115
2014 SSM	0.81	0.96	-0.34	87725

# Uncertainty of predicted DO is well within acceptable range



**Salish Sea Model**



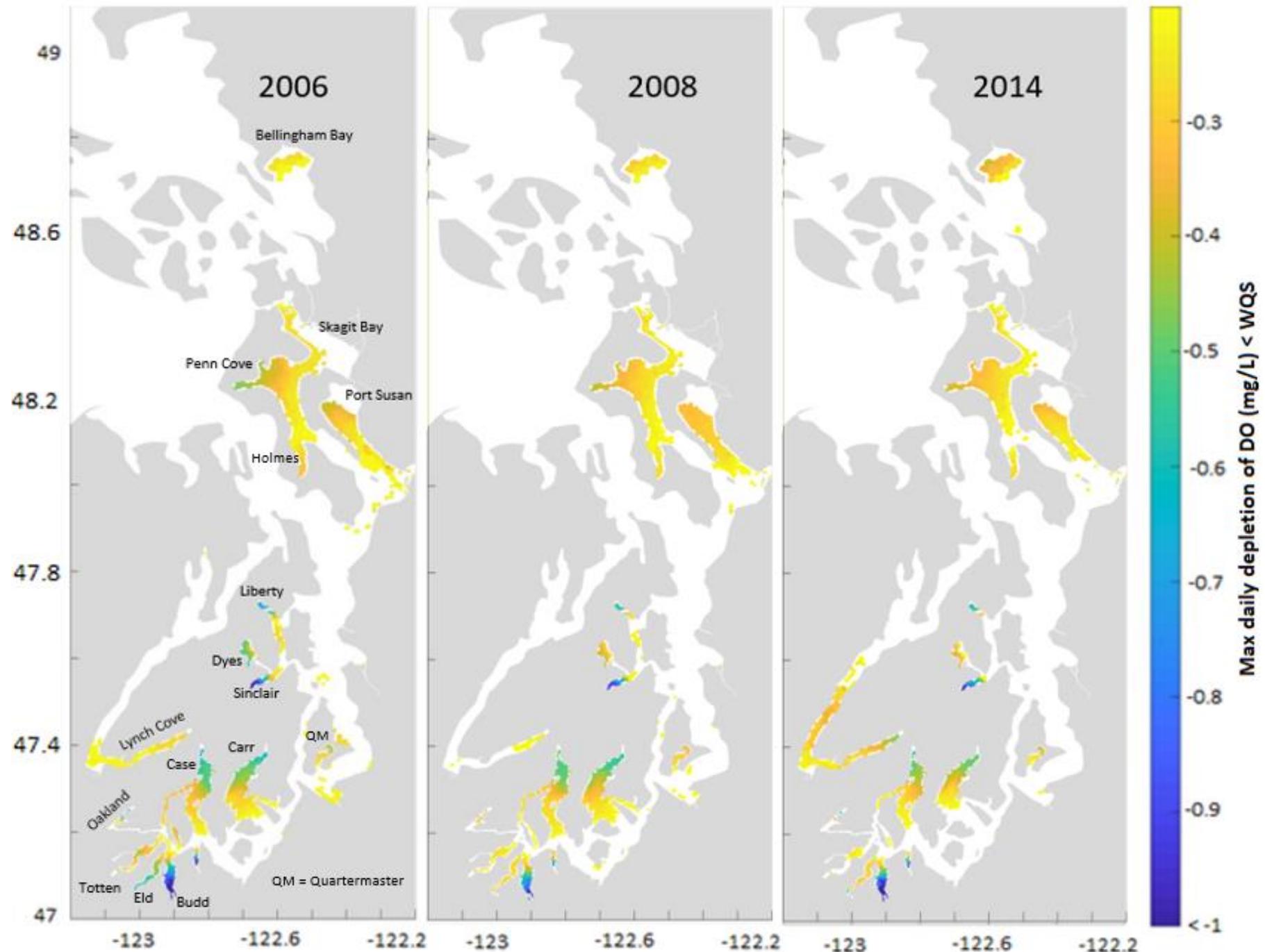
**Chesapeake Bay Model**

\* Cerco and Noel. 2013. Twenty-one-year simulation of Chesapeake Bay Water Quality Using the CE-QUAL-ICM Eutrophication Model. JAWRA. Vol 40. Issue 5. pp:1119-1133

\*\* Irby et al. 2016. Challenges associated with modeling low-oxygen waters in Chesapeake Bay: a multiple model comparison. Biogeosciences. 13, 2011–2028.

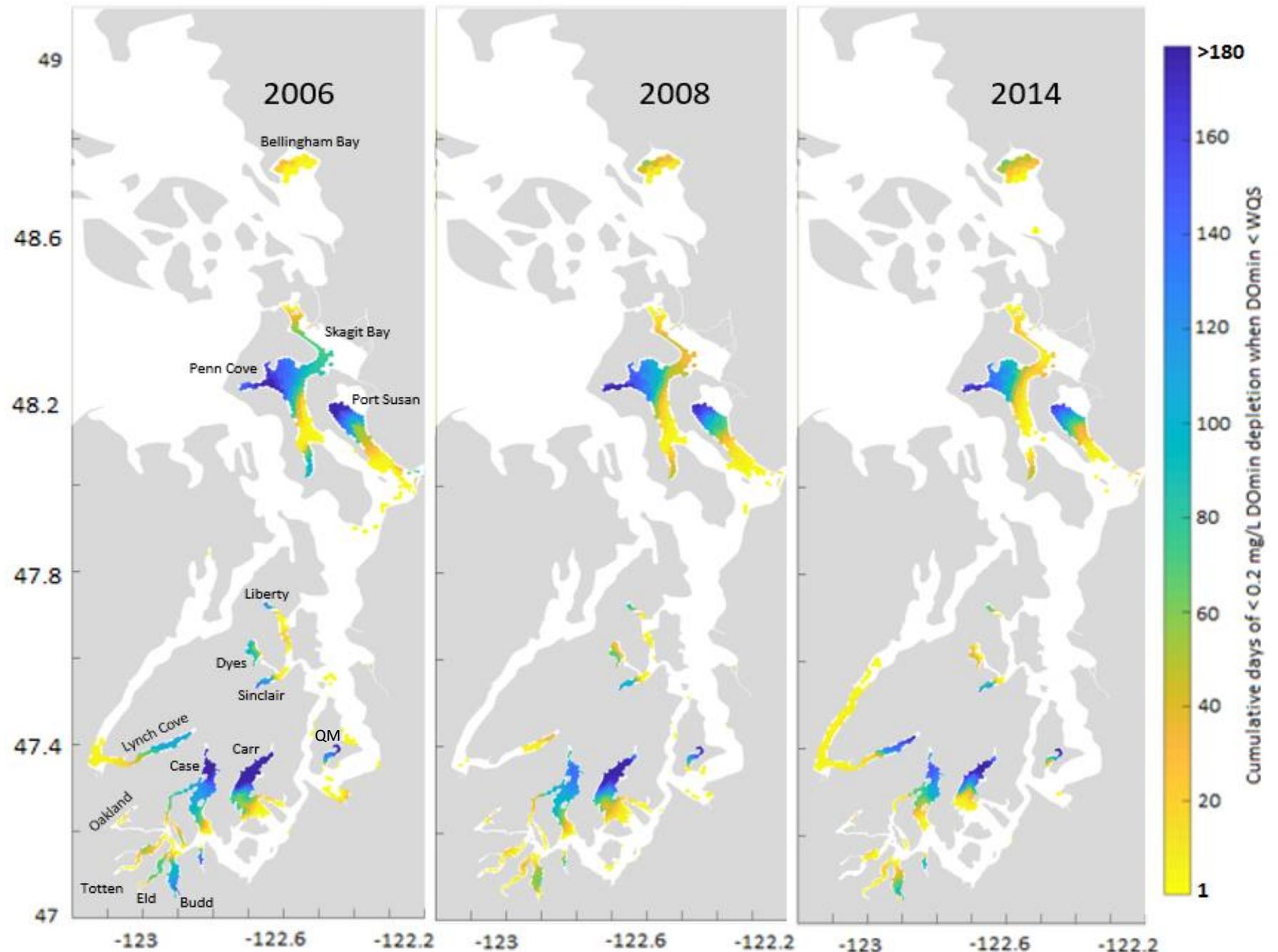
**Maximum depletions below dissolved oxygen standards in Washington's portion of the Salish Sea are also localized in shallow embayments.**

Predicted dissolved oxygen depletions in Budd Inlet are the highest for the years modeled.



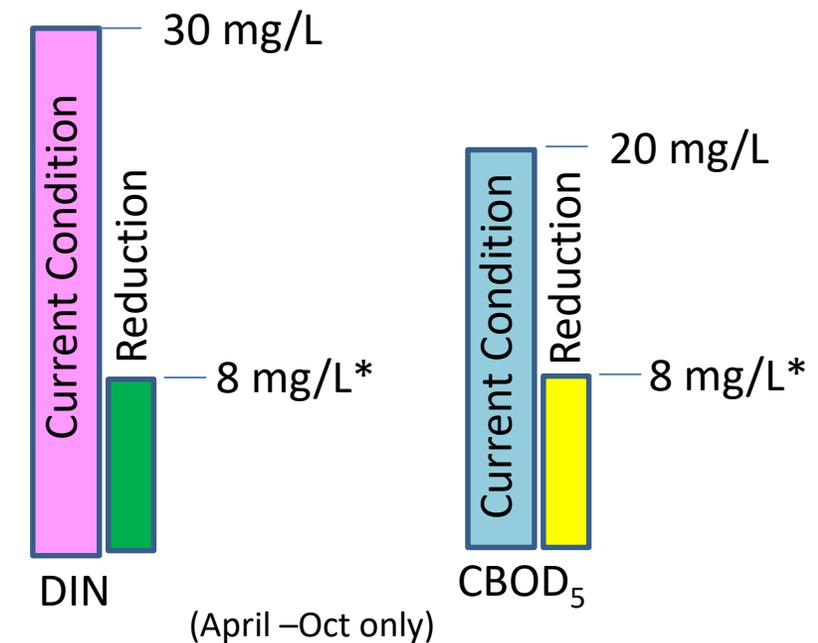
# Embayments with poor flushing exhibit higher number of cumulative noncompliance days of the marine water quality standard.

Carr Inlet and Quartermaster Harbor exhibit the highest number of cumulative exceedance days during the years modeled.



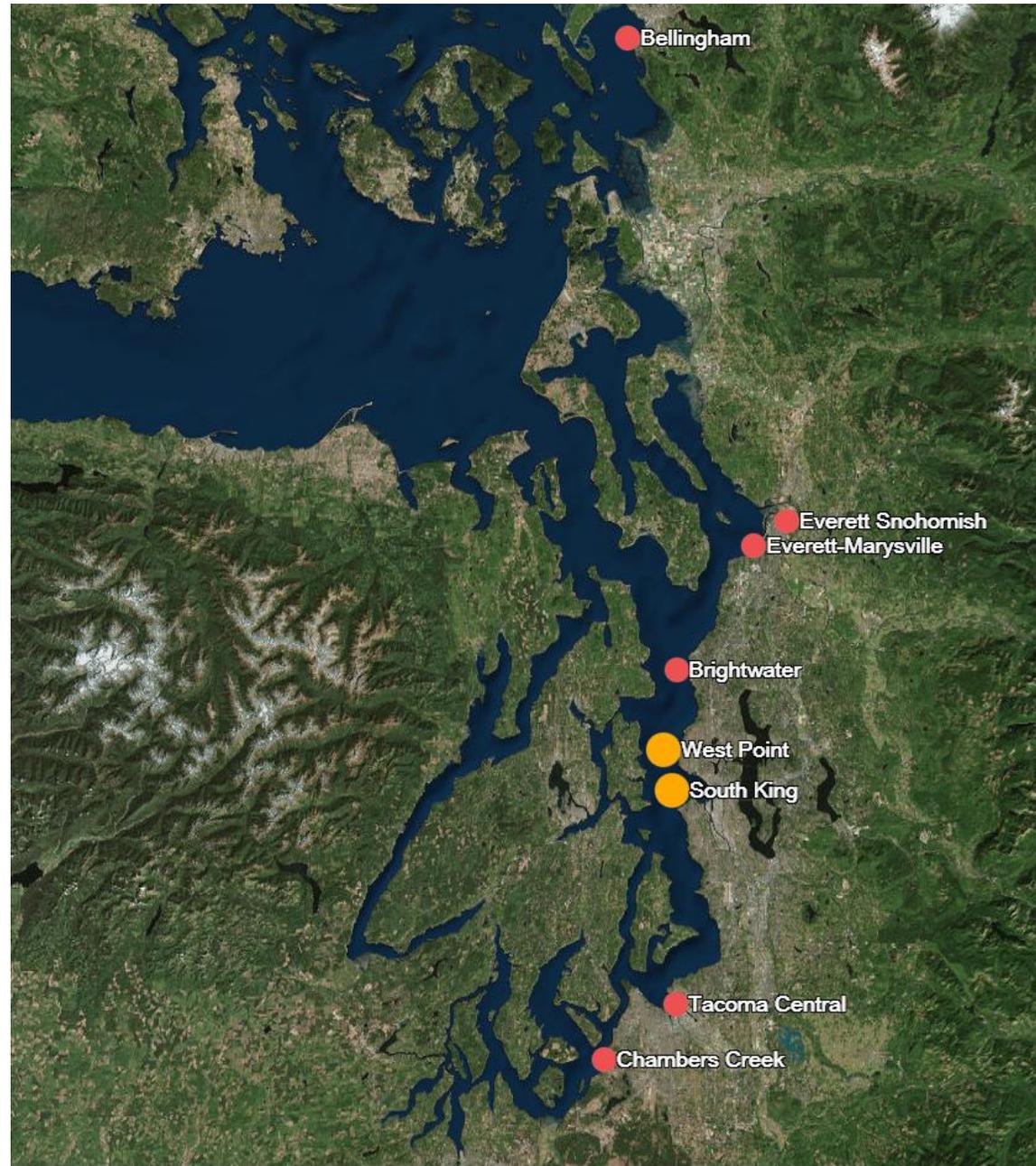
# Bounding Scenarios

- 1 Impact of rivers on dissolved oxygen.
- 2 Impact of municipal WWTPs on dissolved oxygen.
- 3 Impact of reduced nitrogen and carbon at all WWTPs.
- 4 Impact of reduced nitrogen and carbon at medium to large sized WWTPs.
- 5 Impact of reduced nitrogen and carbon at large WWTPs.

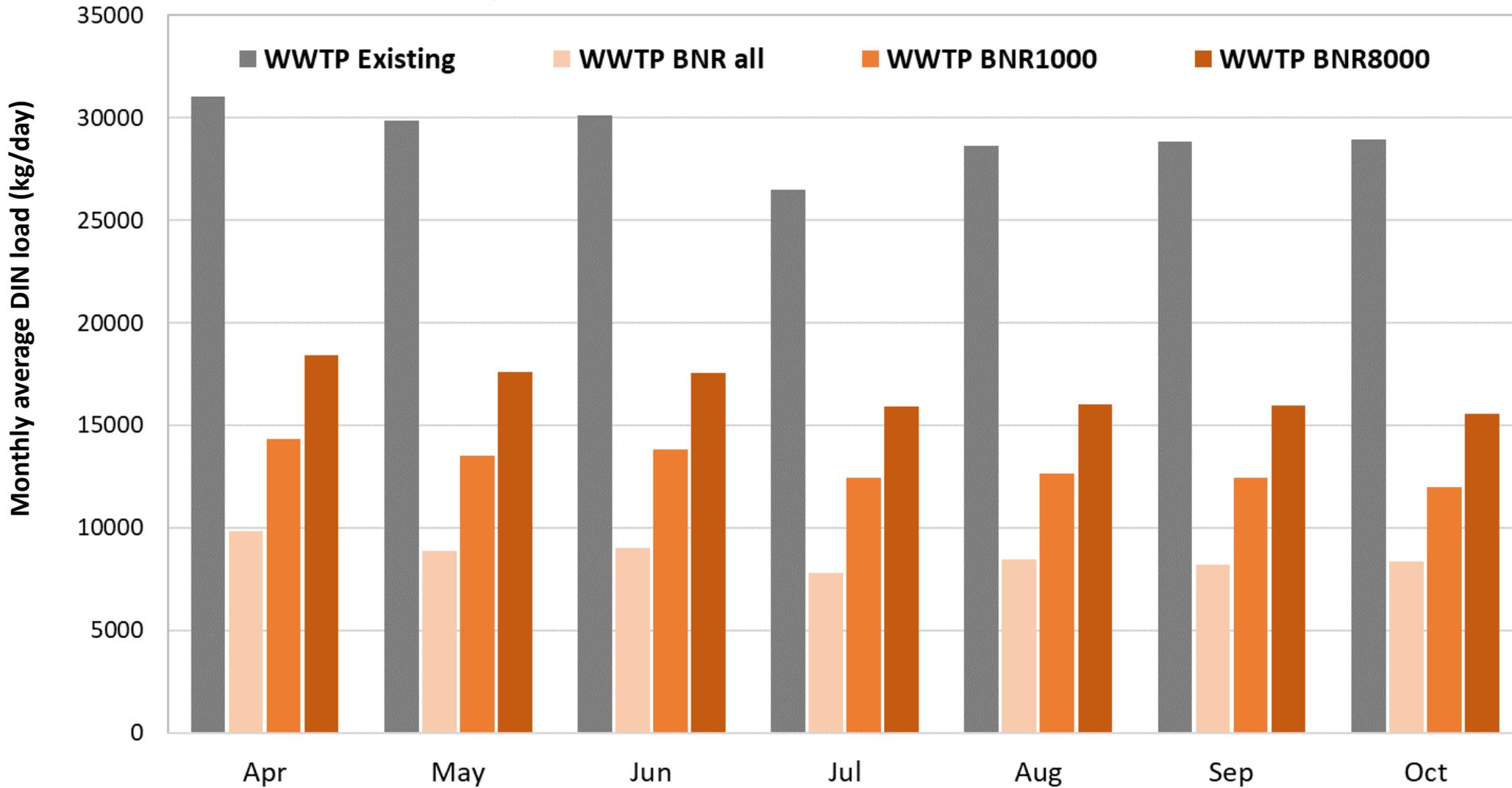


\* TetraTech 2011. Technical and Economic Evaluation of Nitrogen and Phosphorus Removal at Municipal Wastewater Treatment Facilities in Washington State. Ecology Publication Number 11-10-060

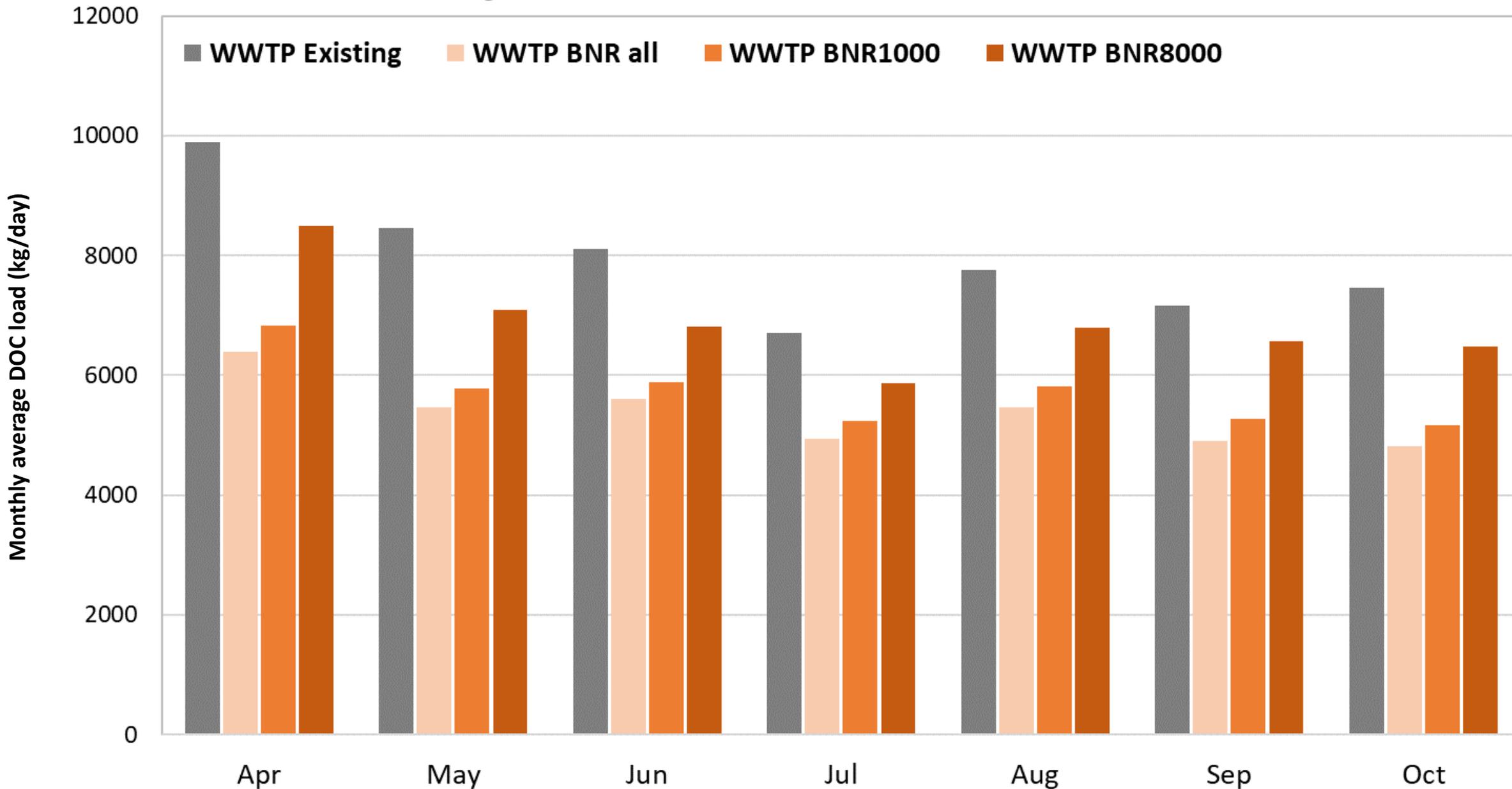
# Midsized and Large Wastewater Treatment Plants



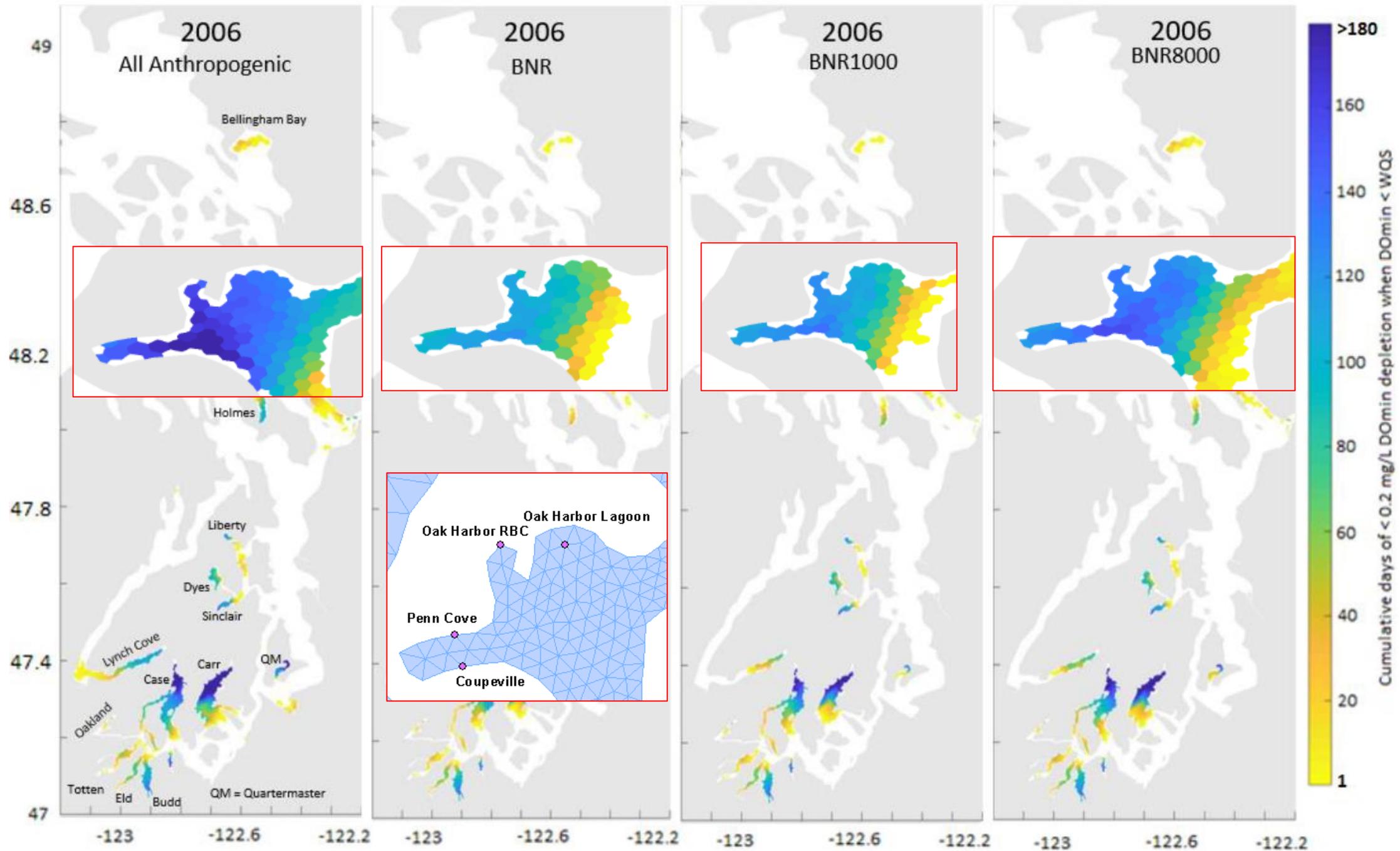
## 2008 Puget Sound WWTP DIN loads - BNR Scenarios



## 2008 Puget Sound WWTP DOC loads - BNR Scenarios



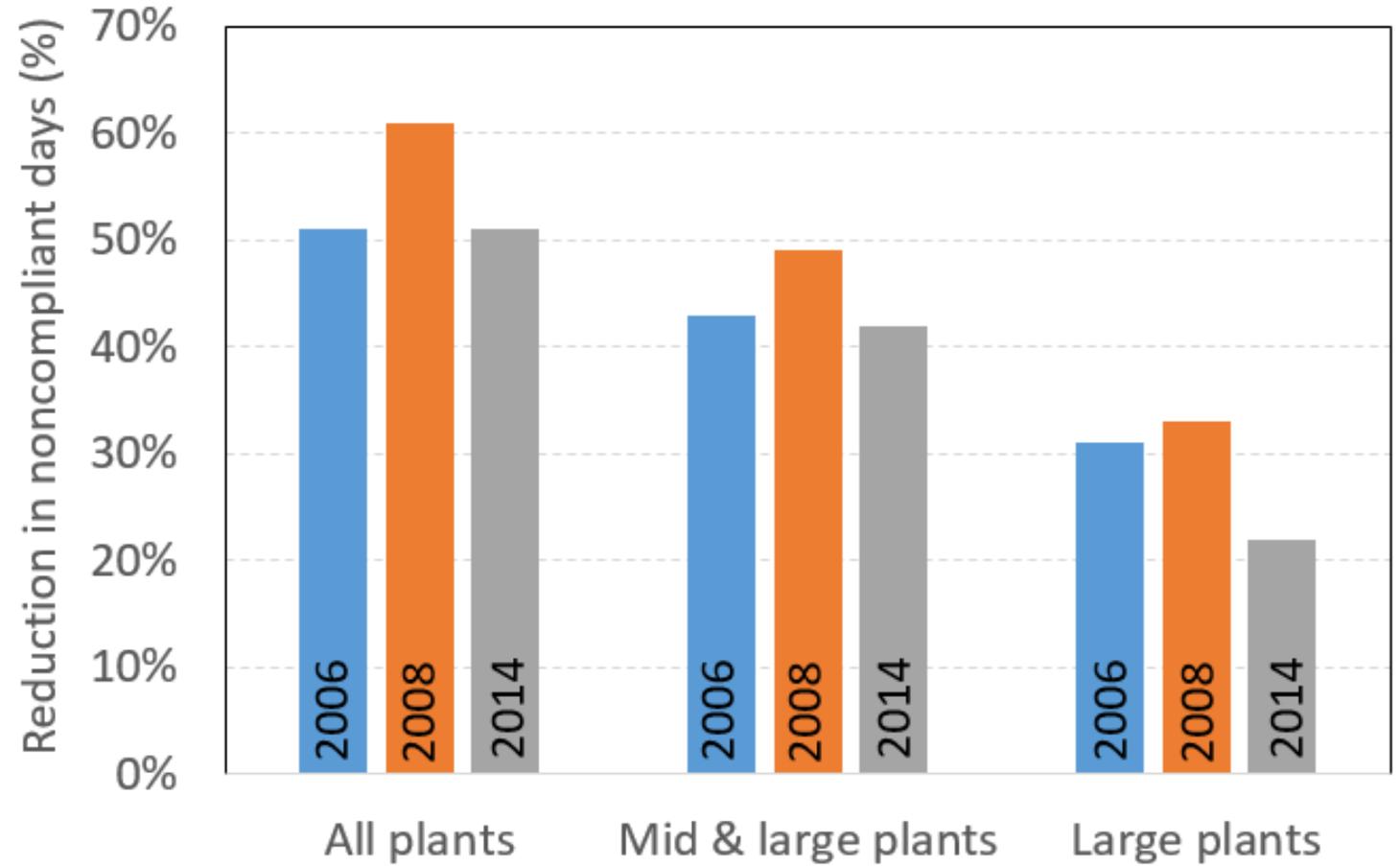
# BNR reduces the number of days when DO depletions are below the Standards



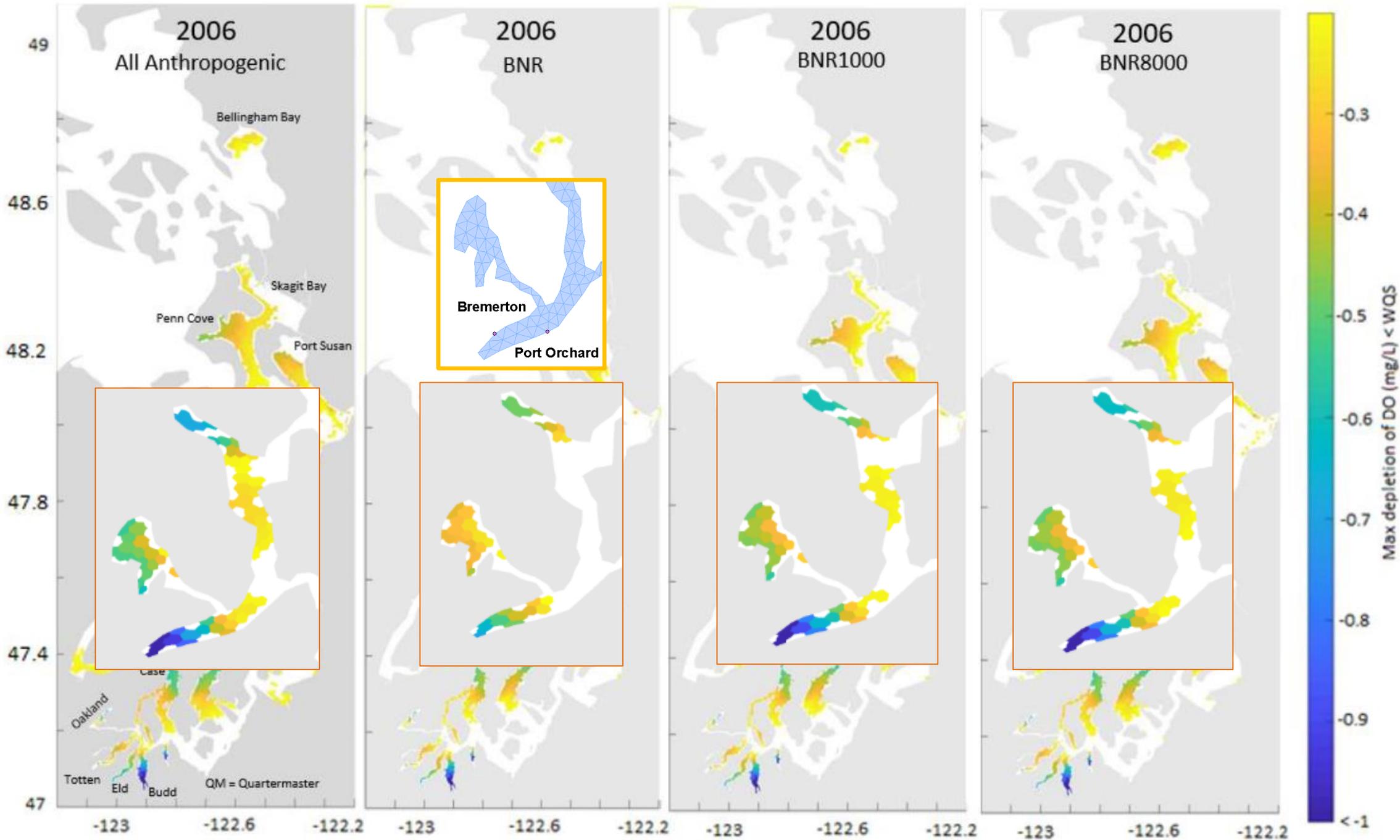
BNR improves the number of non-compliant **days**



Improvement in non-compliant days with BNR



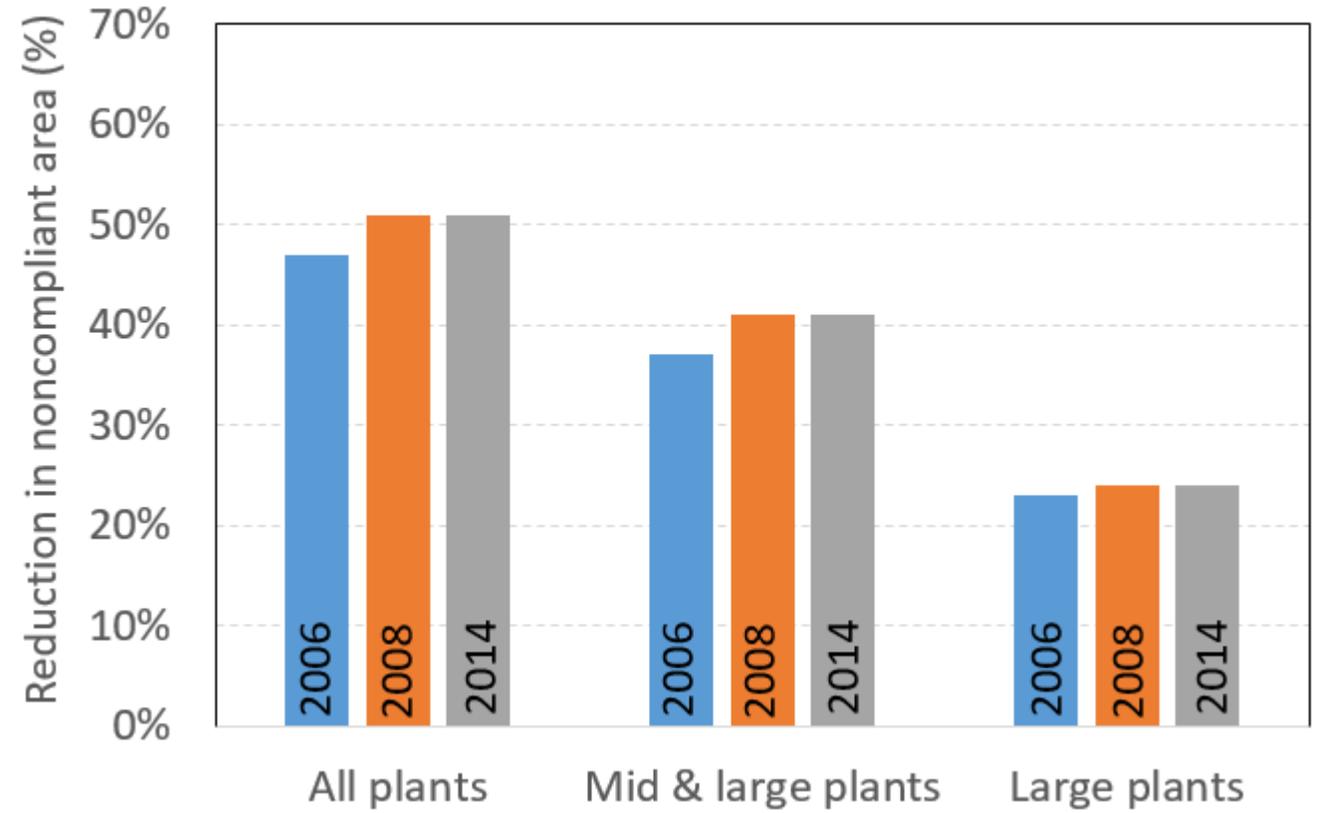
BNR reduces the magnitude of maximum DO depletions below the Standards



BNR improves the extent of non-compliant **area**



Improvement in non-compliant area with BNR



# Conclusions & Next Steps

- Multiple years modeled show that status quo DO levels are below standards in many areas of Greater Puget Sound where circulation is poor
- BNR at WWTPs improves DO in terms of magnitude, duration and spatial extent by 20 to 50 percent with highest improvement when BNR is implemented at all WWTPs. Note the nearfield and farfield impacts of BNR!!
- Additional reductions in watershed nutrients are needed to fully comply with DO standards in the greater Puget Sound. This would be included in phase 2:
  - look at various reductions at the mouths of rivers (watersheds) in combination with BNR at WWTPs to develop a set of anthropogenic loadings that improves DO levels to DO standards
- Look at future growth impacts on DO depletions in Puget Sound

# Questions?

1. Bounding Scenario Report: <https://fortress.wa.gov/ecy/publications/SummaryPages/1903001.html>
2. Ecology webpage for the Salish Sea Model: <https://ecology.wa.gov/Research-Data/Data-resources/Models-spreadsheets/Modeling-the-environment/Salish-Sea-modeling> (includes links to all model related publications)
3. Pacific Northwest National Laboratory webpage for the Salish Sea Model: <https://salish-sea.pnnl.gov/>
4. Reducing nutrients in Puget Sound: <https://ecology.wa.gov/Water-Shorelines/Puget-Sound/Helping-Puget-Sound/Reducing-Puget-Sound-nutrients>
5. Nitrogen in Puget Sound - A Story Map: <https://waecy.maps.arcgis.com/apps/MapSeries/index.html?appid=907dd54271f44aa0b1f08efd7efc4e30>

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