



CASA & Clean Water SoCal Present Nutrient Management  
Research in Southern California

# Lessons from Other Watersheds: Modeling Nutrient Impacts in Long Island and the Salish Sea

David L. Clark, PE, WEF Fellow



May 18, 2026



# Lessons from Other Watersheds: Modeling Nutrient Impacts in Long Island and the Salish Sea

**1** Salish Sea and Puget Sound

**2** Long Island Sound





# Puget Sound Nutrient Management

70 Wastewater Utilities

58 Marine Dischargers

- Nutrients
- Wet Weather Compliance
- Toxics

- Dissolved Oxygen Standards
- Endangered Species (ESA)
- Stormwater Management
- Reuse (Nutrient Diversion, Water Supply)
- Climate Resiliency (Seismic, Sea Level)
- Environmental Justice

# The Salish Sea in Washington State and British Columbia



## Puget Sound

- 58 Marine Wastewater Point Source Discharges
  - ~70 Watershed Discharges from WWTPs

# Washington Department of Ecology on Puget Sound

- Wastewater 69% Nitrogen Loadings

## Excess nutrients are a problem

The diagram on the left illustrates the eutrophication process. It starts with 'nitrogen loading' from the surface, which leads to 'nitrogen-rich surface water layers fuel algal blooms'. This results in an 'algae bloom' where 'algal cells die and decompose'. The decomposition process 'lowers dissolved oxygen concentrations in bottom waters', leading to 'low dissolved oxygen' that 'stresses marine organisms'. The map on the right shows 'Low dissolved oxygen (2014 water quality assessment)' with a color-coded legend for 'Very Low', 'Low', and 'Moderate' oxygen levels across the Puget Sound region.

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State of Washington

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## Sources of Nutrients in the Greater Puget Sound

The pie chart shows the distribution of nutrient sources. 69% of the total regional nitrogen load from human sources is attributed to 'WWTPs discharging to Puget Sound', while 31% is attributed to 'Watershed Sources'. The text 'Total regional nitrogen load from human sources' is positioned below the chart.

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State of Washington

What we learned from Bounding Scenarios Report (2019):

- Confirmed human sources of nutrients exacerbate low DO
- WWTP discharges contribute to low DO
- Watershed nutrient loads also contribute to low DO

15

## Eutrophication Indicators

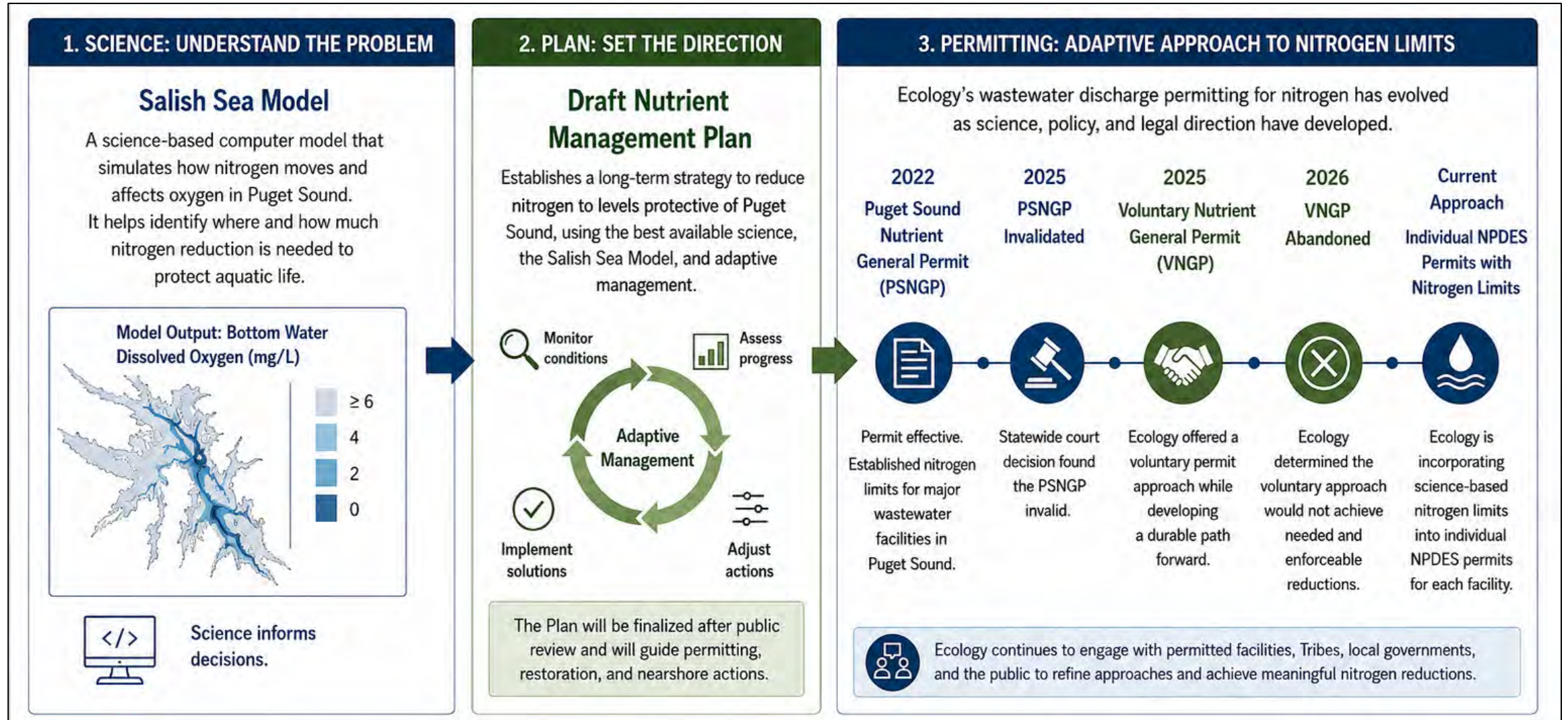
The four photographs illustrate different indicators of eutrophication: 'Overabundance of jellyfish' (a large jellyfish), 'Algal bloom' (aerial view of a large orange-brown bloom), 'Nuisance macroalgae' (a rocky shore covered in green algae), and a red water bloom (a large body of water with a thick red layer on the surface).

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State of Washington

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Eleanor Ott, Ecology Water Quality Program. PNCWA Spring Summit – Nutrient Workshop. April 15, 2026

# Ecology's Approach to Modeling, Nutrient Management Planning, and Discharge Permitting



# Puget Sound Nutrient General Permit (PSNGP)

- Effective January 1, 2022
  - Expiration December 31, 2026
- Narrative Effluent Limits
  - Nitrogen Loading “Action Levels”
    - Nitrogen Optimization Plan Specified as Narrative Effluent Limit
      - Optimize treatment performance to stay below the action level. Submit Optimization Report annually per the requirements in S4.C

Issuance Date: December 1, 2021  
Effective Date: January 1, 2022  
Expiration Date: December 31, 2026


**PUGET SOUND NUTRIENT GENERAL PERMIT**


A NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM  
AND STATE WASTE DISCHARGE GENERAL PERMIT

State of Washington  
Department of Ecology  
Olympia, Washington

In compliance with the provisions of  
The State of Washington Water Pollution Control Law  
Chapter 90.48 Revised Code of Washington  
and  
The Federal Water Pollution Control Act  
(The Clean Water Act)  
Title 33 United States Code, Section 1251 et seq.

Until this permit expires, is modified or revoked, Permittees that have properly obtained coverage under this general permit are authorized to discharge nutrients in accordance with the conditions, which follow.

 DEPARTMENT OF  
ECOLOGY  
State of Washington

  
Vincent McGowan, P.E.  
Water Quality Program Manager  
Washington State Department of Ecology

# S4.E. NUTRIENT REDUCTION EVALUATION (NRE) - 1

Due December 31, 2025

- All Known, Available and Reasonable Methods of Prevention, Control and Treatment
  - AKART Analysis
    - An alternative representing the greatest TIN reduction that is reasonably feasible on an annual basis
      - Site-specific main stream treatment plant upgrades, the applicability of side stream treatment opportunities, alternative effluent management options (e.g., disposal to ground, reclaimed water beneficial uses), the viability of satellite treatment, and other nutrient reduction opportunities

## S4.E. NUTRIENT REDUCTION EVALUATION (NRE) - 2

- a. Wastewater Characterization
- b. Treatment Technology Analysis
- c. Economic Analysis

Capital, O&M Costs, 20-Year NPV

Appendix C Office of Management and Budget Circular No. A-945

[https://www.whitehouse.gov/wp-content/uploads/2020/12/2020\\_Appendix-C.pdf](https://www.whitehouse.gov/wp-content/uploads/2020/12/2020_Appendix-C.pdf)

- d. Environmental Justice (EJ) Review

Selection of the most reasonable treatment alternative based on the AKART assessment; and the selected alternative for achieving an effluent concentration of 3 mg/L TIN (or equivalent load reduction) based on an April – October seasonal average.

Include an **affordability assessment** to identify how much overburdened communities identified in S4.E.5.d.i can afford to pay for the wastewater utility

# PSNGP Nutrient Reduction Evaluation

- Achieve Effluent Concentration of 3 mg/L TIN
  - Seasonal Basis April – October
    - Or Equivalent Load Reduction
- EPA. Life Cycle and Cost Assessments of Nutrient Removal Technologies in Wastewater Treatment Plants
  - Level 4 Treatment

**Table ES-1. Target Effluent Nutrient Concentrations by Level**

Level	Total Nitrogen, mg/L	Total Phosphorus, mg/L
1	no target specified	no target specified
2	8	1
3	4-8	0.1-0.3
4	3	0.1
5	<2	<0.02

“First, clear trade-offs in cost and potential environmental impact were demonstrated between treatment level configurations. This suggests that careful consideration should be given to the benefits from lower nutrient levels compared to the potential environmental and economic costs associated with treatment processes used to achieve those levels.” (EPA)

[life-cycle-nutrient-removal-2023-update.pdf \(epa.gov\)](#)

# Pollution Control Hearings Board (PCHB) Invalidated Puget Sound Nutrient General Permit (PSNGP), February 28, 2025

## General Permit Invalidated

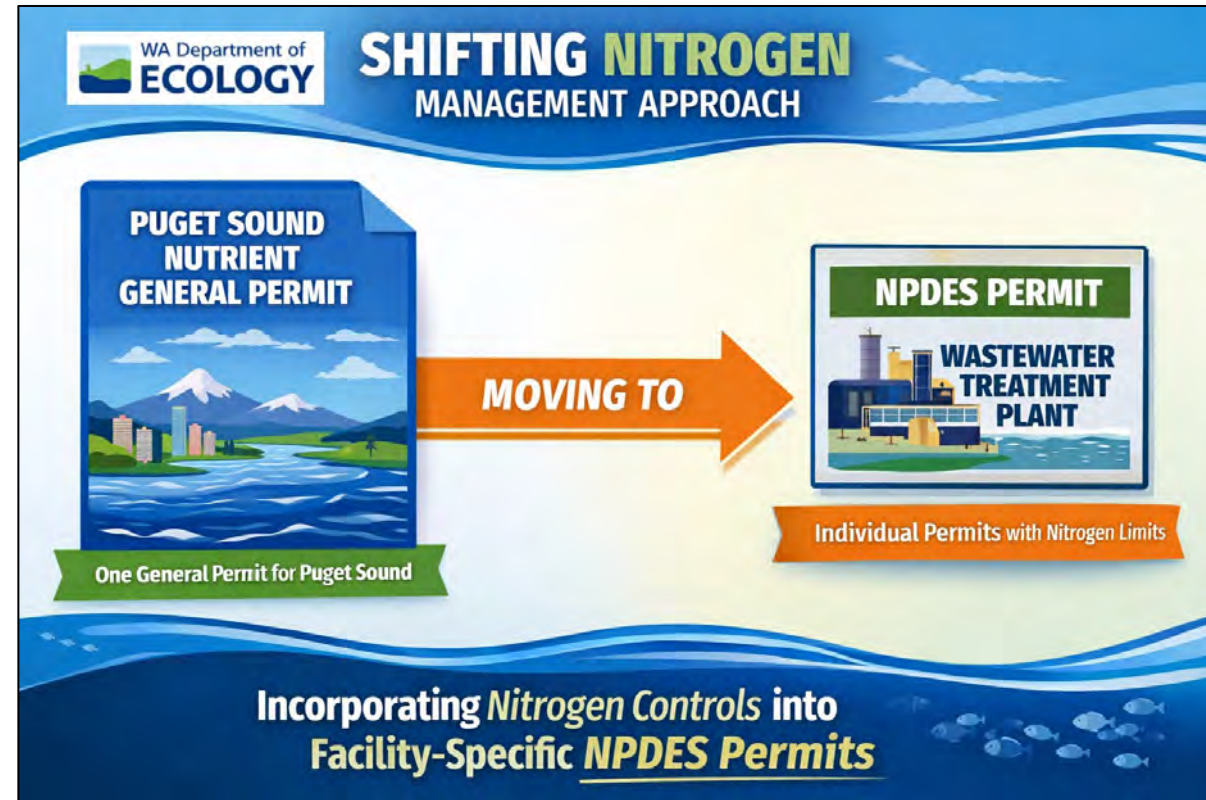
- Unlawful for Ecology to require coverage under both an individual and general permit for the same discharge

*“Pursuant to WAC 371-08-540(2), the Board INVALIDATES the PSGNP insofar as it is mandatory for already-permitted dischargers and REMANDS the permit to Ecology for further actions consistent with the law and this decision. SO ORDERED this day, February 28, 2025.”*

1	POLLUTION CONTROL HEARINGS BOARD STATE OF WASHINGTON	
2	PUGET SOUNDKEEPER ALLIANCE, KING COUNTY, CITY OF TACOMA, WASHINGTON ENVIRONMENTAL COUNCIL, SUQUAMISH TRIBE, CITY OF EVERETT, CITY OF BREMERTON, BIRCH BAY WATER AND SEWER DISTRICT, ALDERWOOD WATER & WASTEWATER DISTRICT, PIERCE COUNTY, and CITY OF EDMONDS,	PCHB No. 21-082c
3		ORDER GRANTING PERMITTEES' JOINT MOTION FOR PARTIAL SUMMARY JUDGMENT ON THRESHOLD ISSUES
4		
5		
6		
7		
8		
9	Appellants,	
10	v.	
11	STATE OF WASHINGTON, DEPARTMENT OF ECOLOGY,	
12	Respondent.	
13	I. INTRODUCTION	
14	On December 22, 28, 29, and 30, 2021, the Pollution Control Hearings Board (Board)	
15	received 10 separate appeals (P21-082, P21-083, P21-085, P21-087, P21-088, P21-090, P21-091,	
16	P21-092, P21-093, P21-094) challenging the Puget Sound Nutrient General Permit (PSNGP), a	
17	National Pollutant Discharge Elimination Systems (NPDES) and State Waste Discharge General	
18	Permit that was issued on December 1, 2021, by the Department of Ecology (Ecology).	
19	Environmental group and tribal appellants in this case are Puget Soundkeeper Alliance	
20	(Soundkeeper), Washington Environmental Council (WEC), and the Suquamish Tribe. Municipal	
21	appellants are King and Pierce Counties; the cities of Tacoma, Everett, Bremerton, and Edmonds;	
	ORDER GRANTING PERMITTEES' JOINT MOTION FOR PARTIAL SUMMARY JUDGMENT PCHB No. 21-082c	
	1	

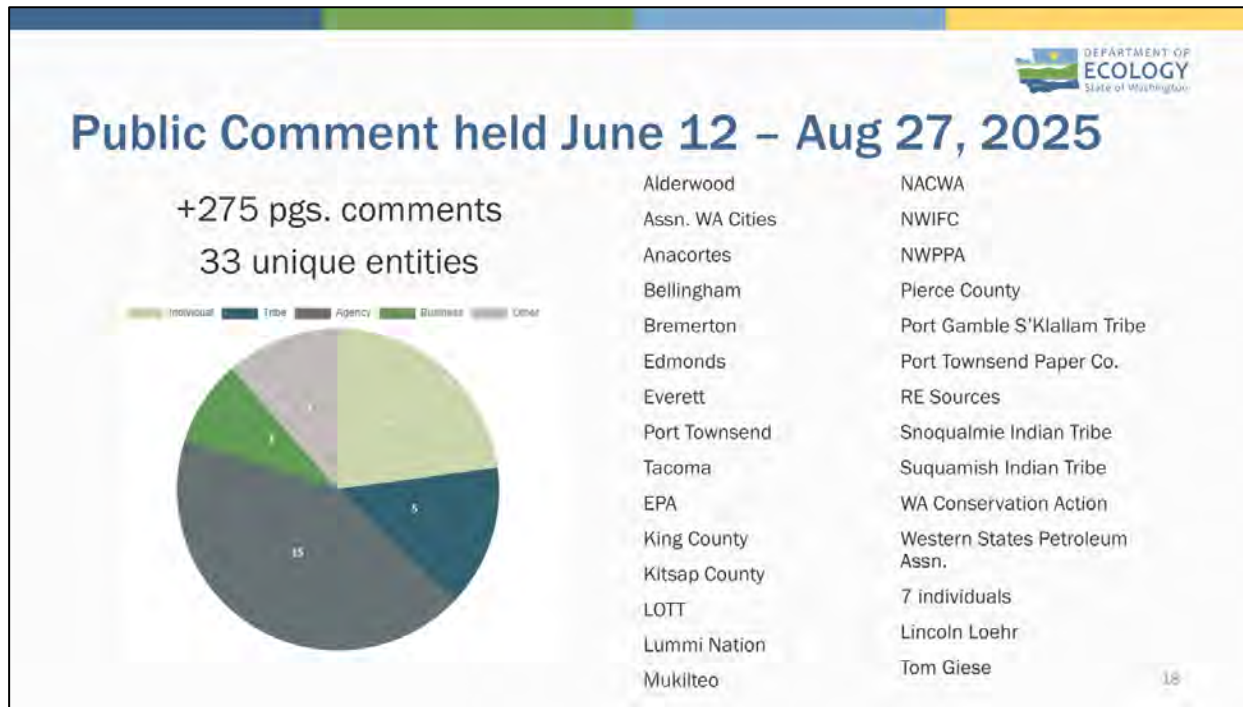
# 2026 Ecology's *Evolving Approach* to Nitrogen Discharge Permitting

- Puget Sound Nutrient General Permit (PSNGP) Invalidated
- Voluntary PSNGP Permit Development Discontinued
- Pending Nitrogen Requirements in Individual NPDES Permits
  - **May 15, 2026 Entity Draft Permit Review Comments**



# Ecology's Nutrient Reduction Plan

- Advance Restoration Plan in Lieu of TMDL
  - Parallel TMDL Litigation
- 2025 Review Draft NMP



# Northwest Environmental Advocates (NWEA) v. EPA and Intervenors King County and City of Tacoma

- Federal District Court for Western Washington
- NWEA Contended EPA Must Prepare Puget Sound TMDL
- **April 3, 2026 Court Ruling**
  - **Court Denies NWEA Plaintiff's Motion**

*“Given the ongoing Nutrient Reduction Plan together with the submitted Budd Inlet TMDLs, this Court finds that the State has not clearly and unambiguously decided not to submit Puget Sound dissolved oxygen TMDLs.”*

**LAWSUIT FILED IN FEDERAL DISTRICT COURT**

**NWEA vs. EPA**

**NORTHWEST ENVIRONMENTAL ADVOCATES**

**WASHINGTON DEPT. OF ECOLOGY**

No TMDL for Puget Sound  
Constructive Non-Submission

**EPA**

**EPA Must Act!**

**MOVE TO A TMDL ?**  
TOTAL MAXIMUM DAILY LOAD

**RULING PENDING**

~~EPA Could be Required to Prepare TMDL Puget Sound~~

# Puget Sound Nutrient General Permit (PSNGP)

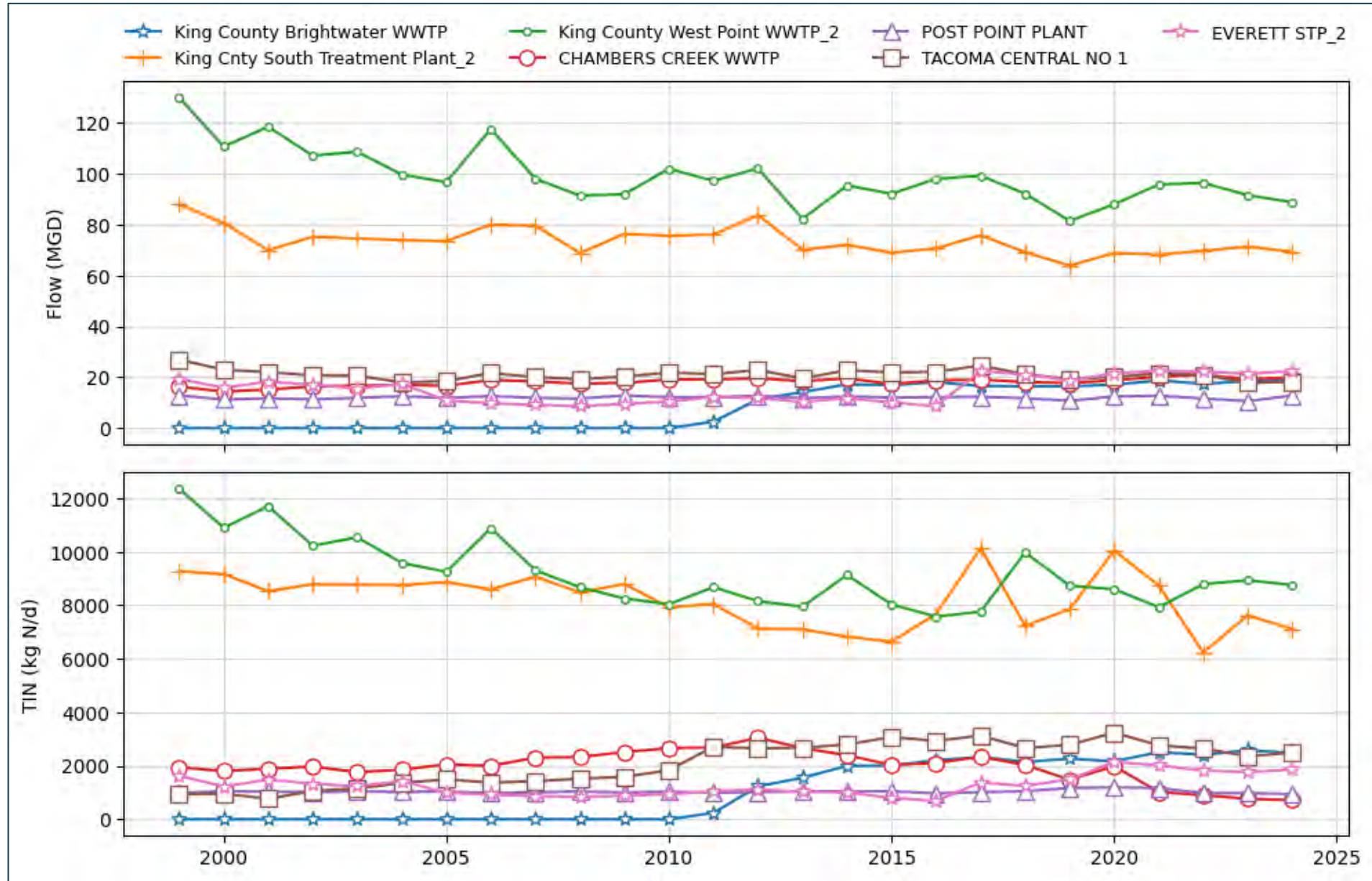
## Dominant WWTPs with Total Inorganic Nitrogen

### *Nitrogen Action Levels: Annual Mass Loadings*

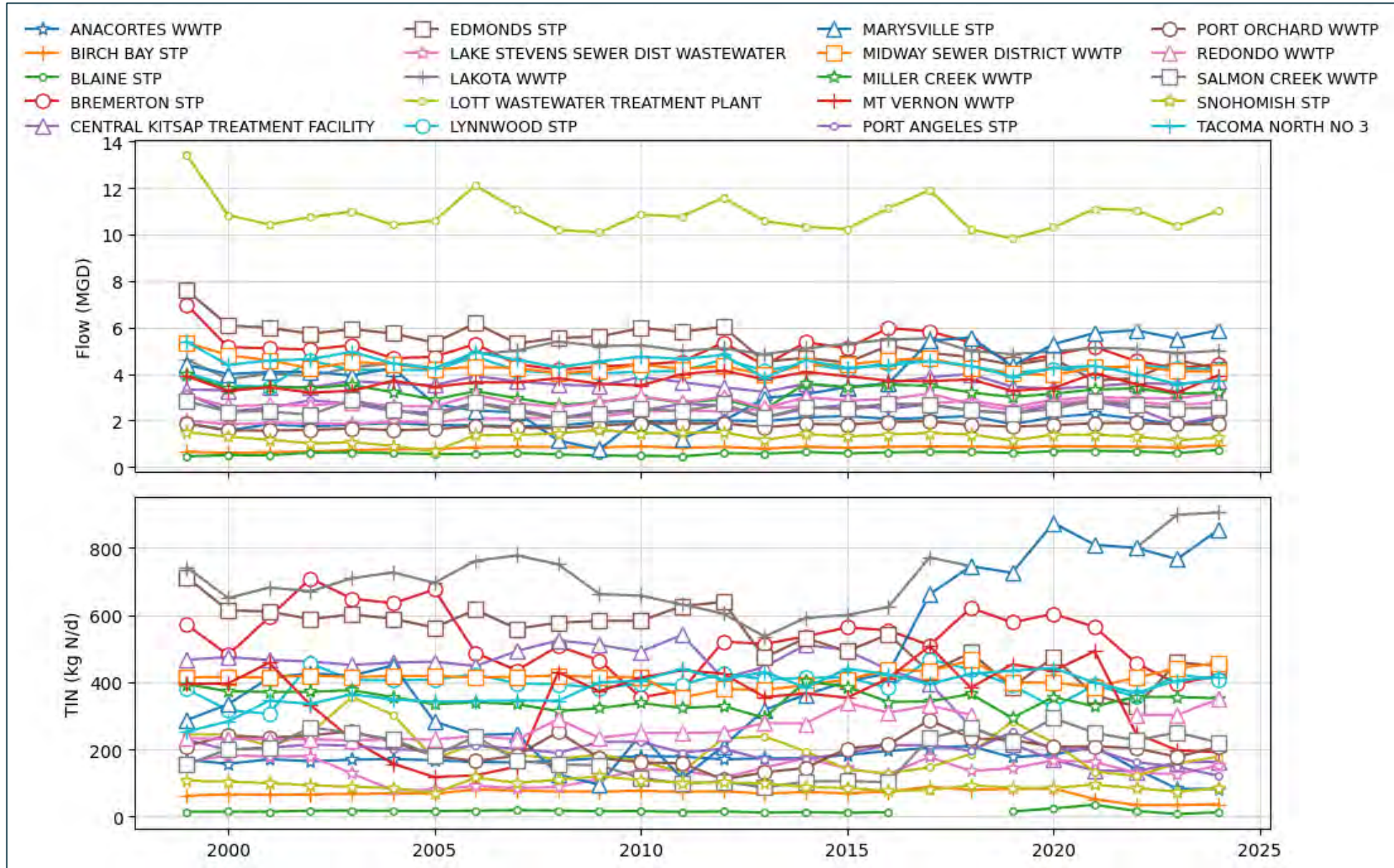
**Table 5. Dominant WWTPs and Total Inorganic Nitrogen Action Levels**

Wastewater Treatment Plant	Individual NPDES Permit Number	Action Level, TIN lbs/year	Outfall Number
Everett STP	WA0024490	1,530,000	100/015
King County Brightwater WWTP <sup>1</sup>	WA0032247	1,810,000	001
King County South WWTP <sup>1</sup>	WA0029581	7,340,000	001
King County West Point WWTP <sup>1</sup>	WA0029181	6,670,000	001
Pierce County Chambers Creek Regional WWTP	WA0039624	1,880,000	001
Post Point WWTP (Bellingham STP)	WA0023744	993,000	001
Tacoma Central No. 1 WWTP <sup>4</sup>	WA0037087	2,410,000	001

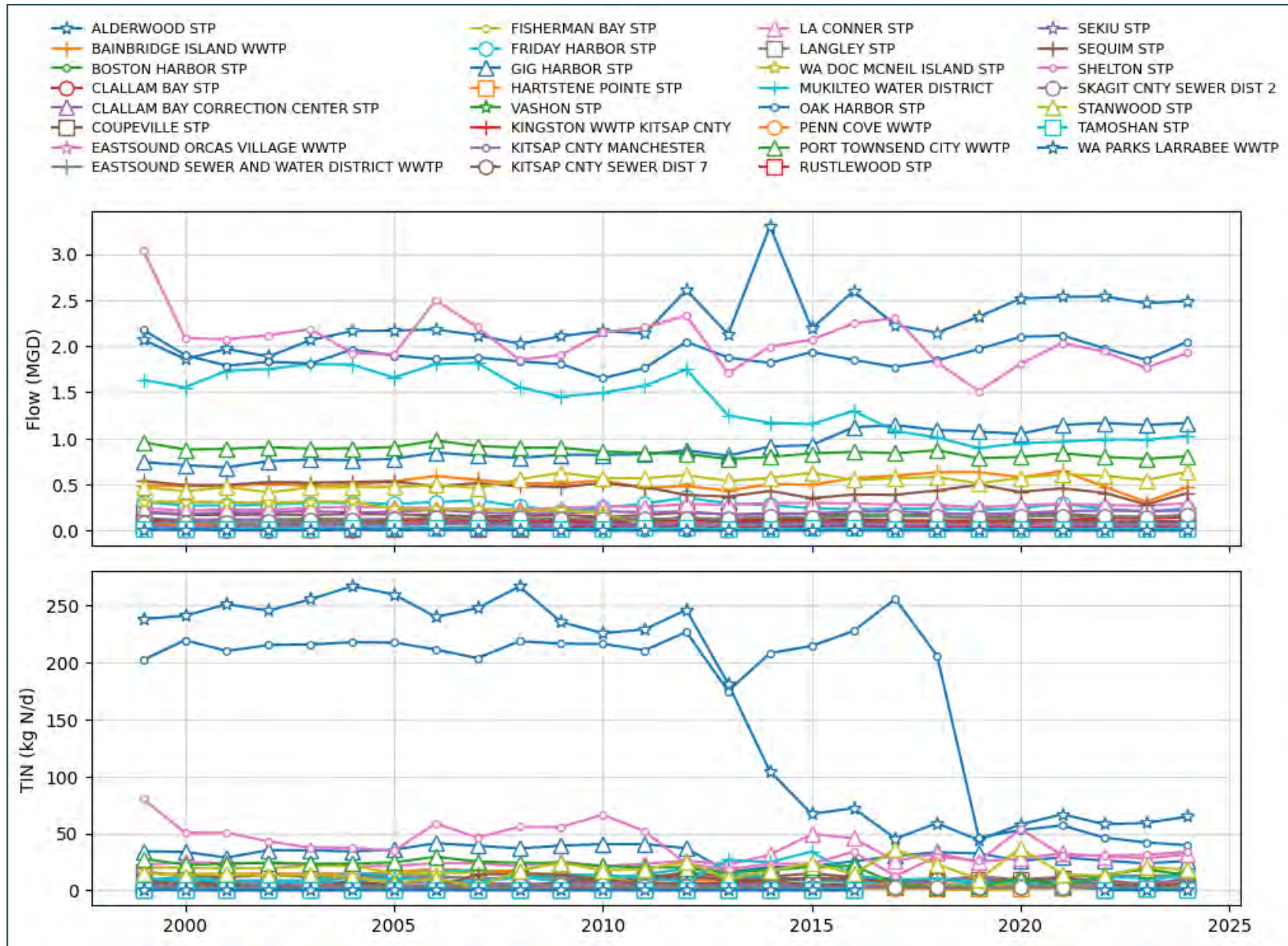
# Nitrogen Loadings for Dominant Dischargers, 1999 - 2024



# Nitrogen Loadings for Moderate Dischargers, 1999 - 2024

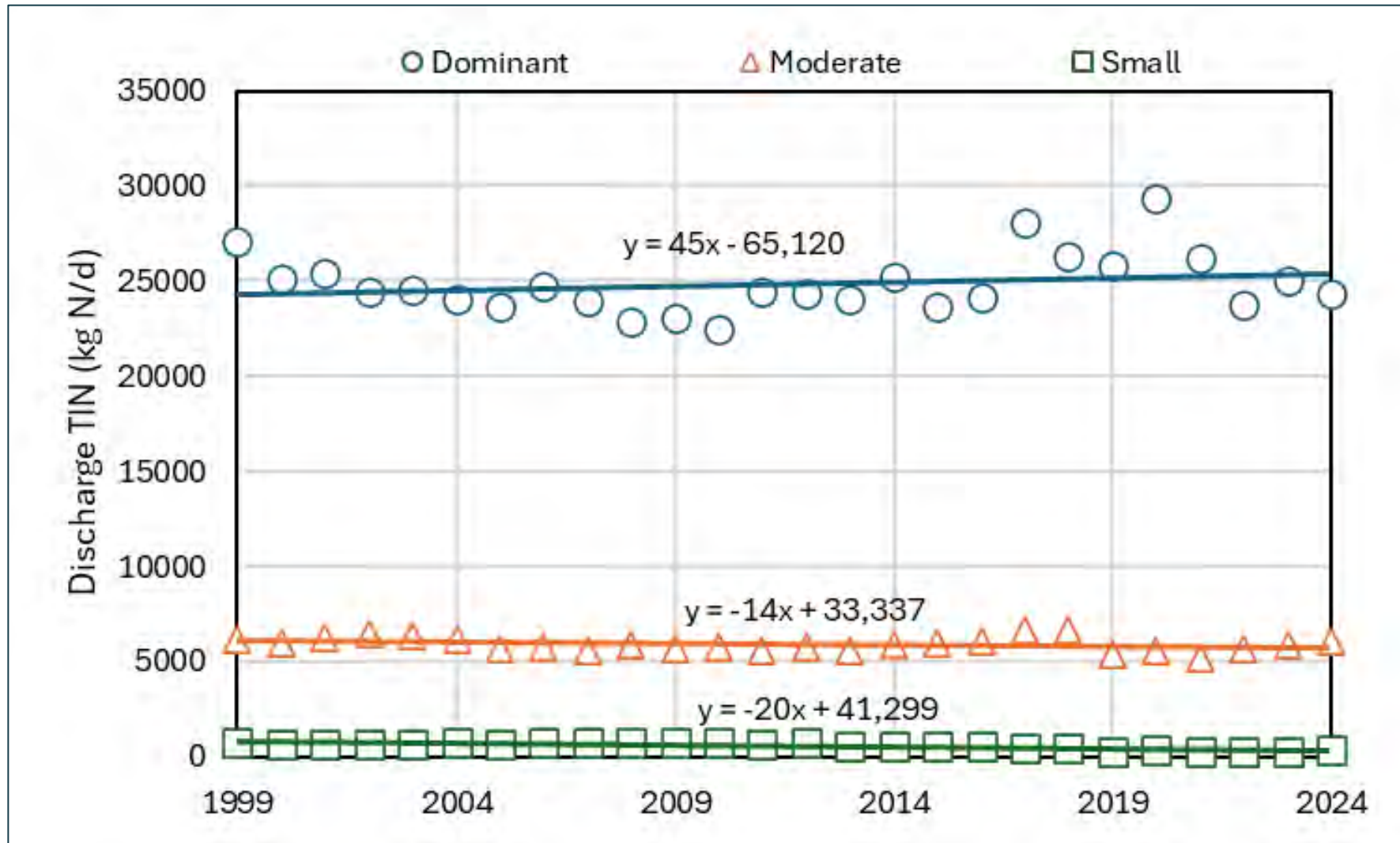


# Nitrogen Loadings for Small Dischargers, 1999 - 2024



# Nitrogen Loading Trends in Dominant, Moderate, and Small Dischargers

Total N Loading Increased ~0.3% Annually 1999 - 2024



A scenic photograph of a sunset over a large body of water, likely Puget Sound. The sun is low on the horizon, creating a bright orange and yellow glow that reflects on the water's surface. In the foreground, a long bridge spans across the water. The background features dark, silhouetted mountains under a cloudy sky. The overall mood is serene and natural.

# Low dissolved oxygen occurs naturally in Puget Sound

**PNCWA 2024. Tracking Puget Sound Nutrient Loading Trends and Water Quality Response. David L. Clark, HDR and Joel E. Baker, University of Washington Puget Sound Institute.**

# Ocean Conditions Strongly Influence Puget Sound Water Quality

- Upwelled ocean water entering Puget Sound is depleted in dissolved oxygen
- 88% of nitrogen entering Puget Sound comes from ocean sources

Seattle



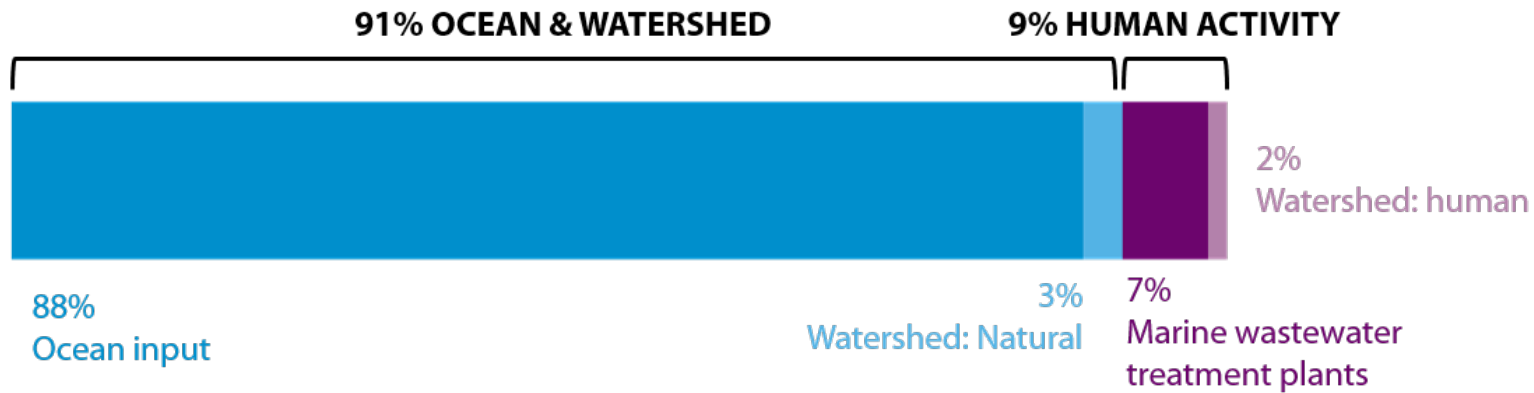
# Climate Change

- Dissolved oxygen in ocean water entering Puget Sound has decreased ~20% over 40 years ([Pierce et al., 2012](#))
- How will shifts in upwelling and stratification change the availability of ocean nutrients?
- Warming waters hold less oxygen and increase how much marine life needs

Seattle

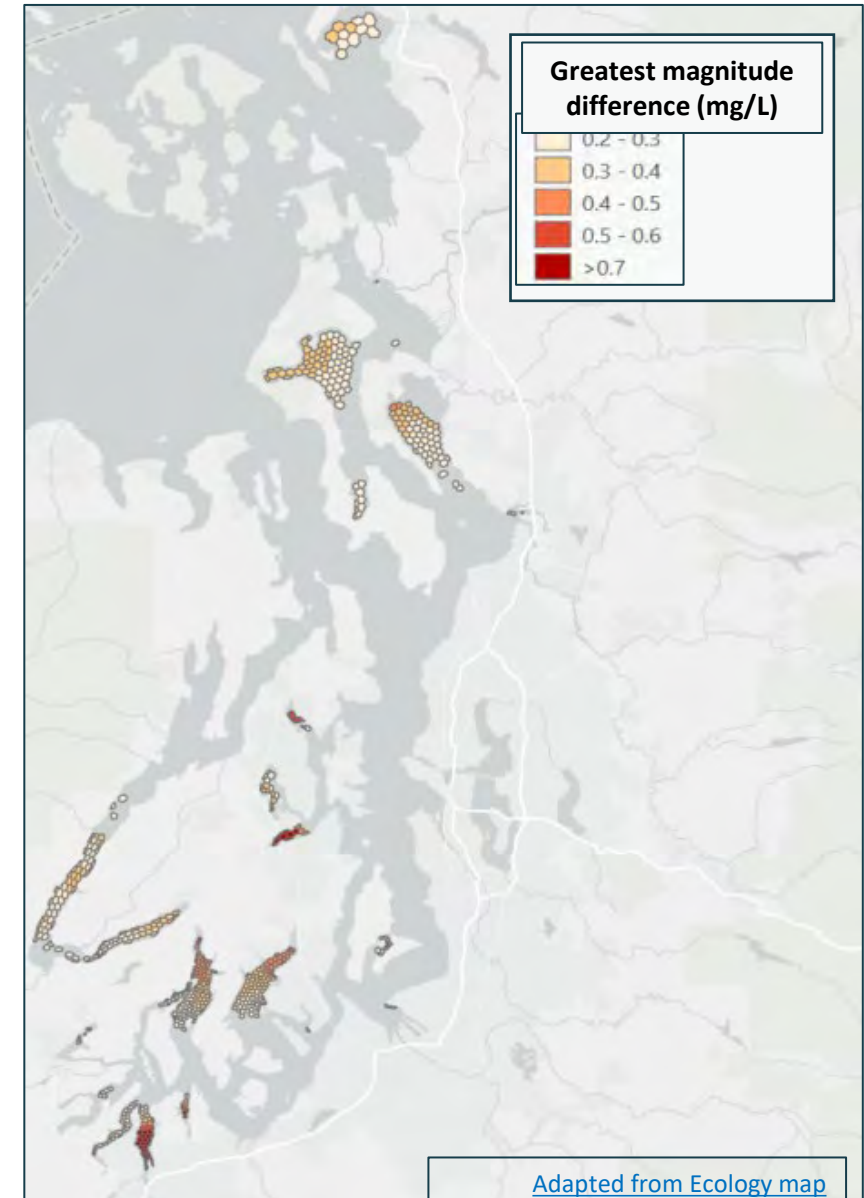


# Human activities contribute 9% of nitrogen



Modeling suggests human activities may further decrease dissolved oxygen in:

- Shallow embayments with long residence times
- Parts of Hood Canal, which is deep and fjord-like

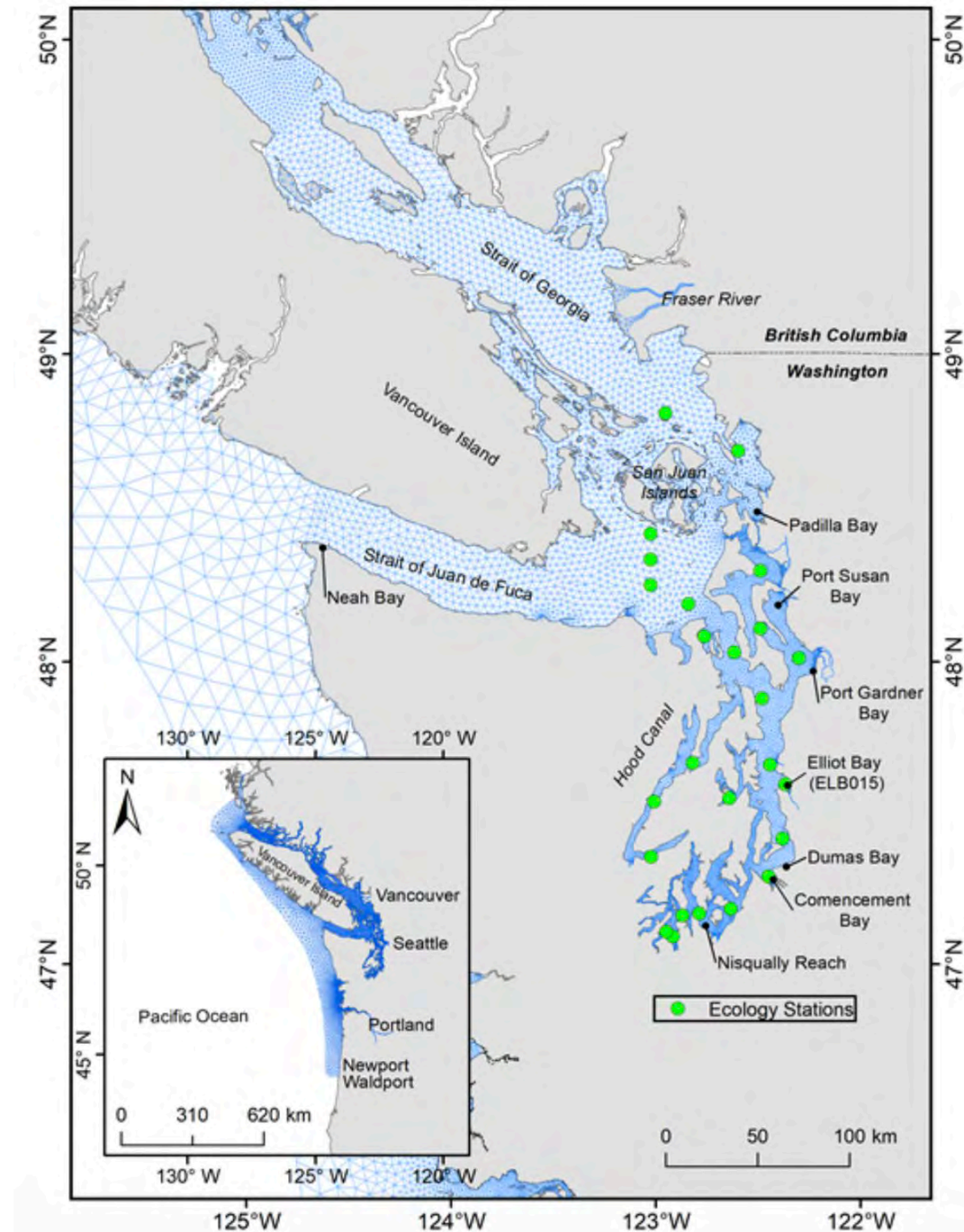


WEFTEC 2025. Tracking Puget Sound Nutrient Loading Trends and Water Quality Response.  
David L. Clark, HDR and Joel E. Baker, University of Washington Puget Sound Institute

[Adapted from Ecology map](#)

# Salish Sea Model

- Predicts hydrodynamics and water quality for over 16K model cells, with 10 layers each
- Model version aligned with [Ahmed et al. \(2021\)](#)
- Analysis based on 2014 predictions
- Nearshore masked

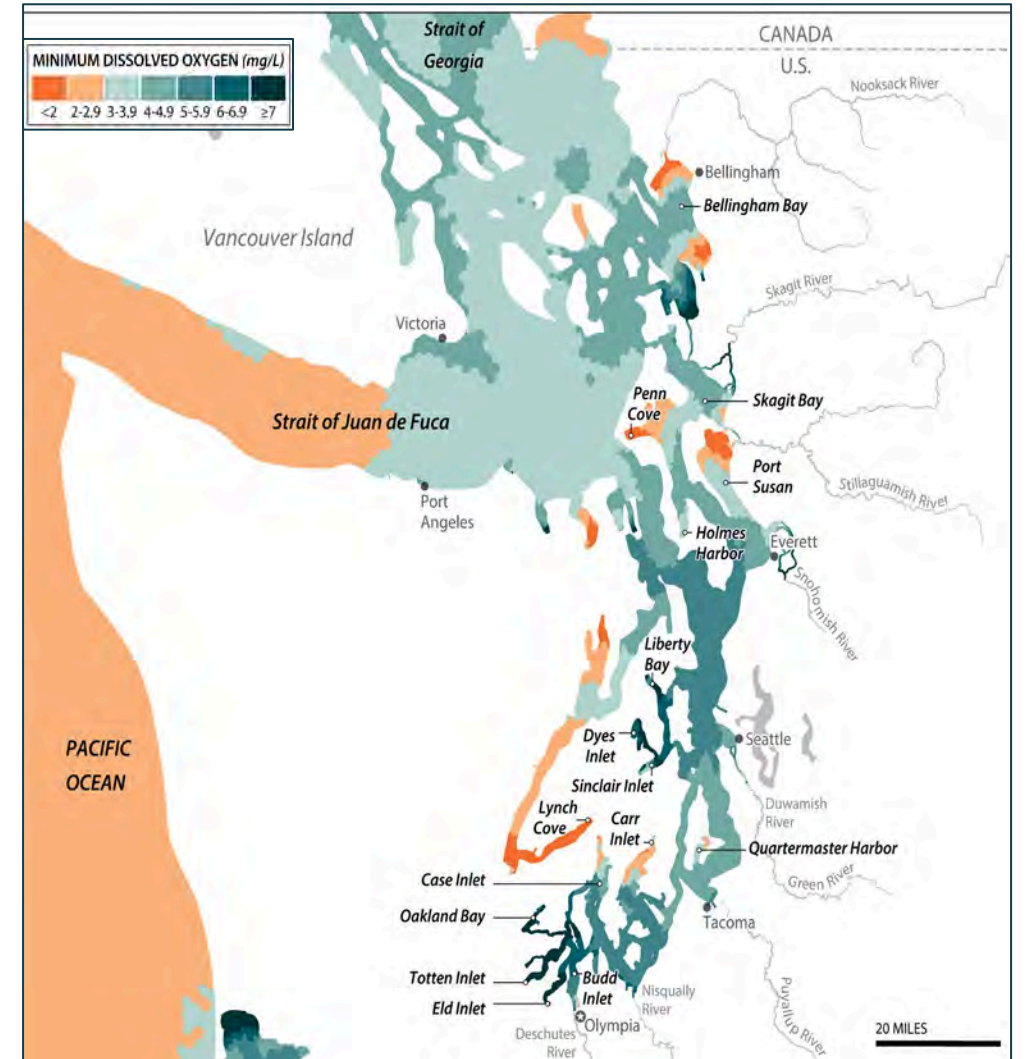


# Model Uncertainty

## Domain-wide error results across all versions:

- < 1 mg/L DO RMSE
- Similar for temperature < 1 degree C, salinity < 1.2 PPT, and tides < 6% relative RMSE
- Single year calibration runs for 2006, 2008 and 2014

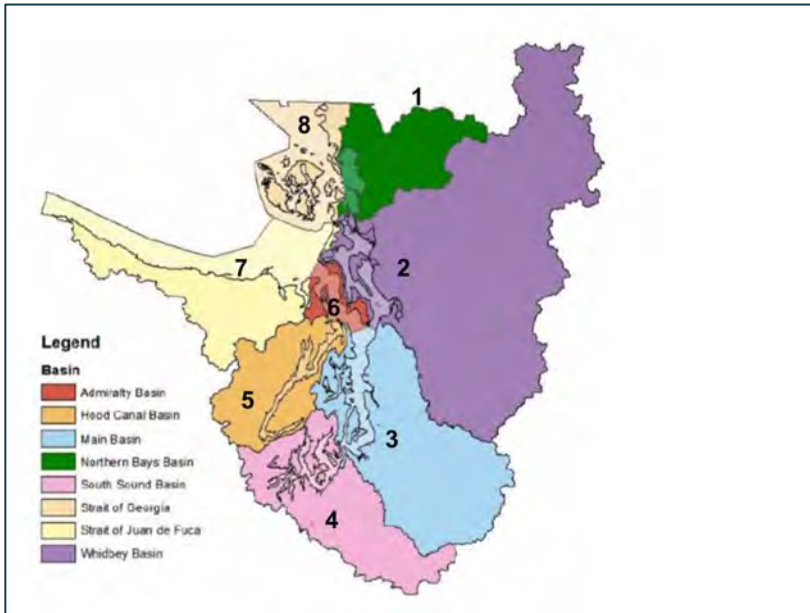
PNCWA 2024. Tracking Puget Sound Nutrient Loading Trends and Water Quality Response. David L. Clark, HDR and Joel E. Baker, University of Washington Puget Sound Institute.



# Salish Sea Model Optimization Scenarios Phase 2 Update “Refined WWTP Frameworks”

**WWTP TIN Reduction 67% to 74%**

Basin	Basin #
Northern Bays	1
Whidbey	2
Main	3
South Sound	4
Hood Canal	5
Admiralty	6
SJF - US	7
SOG - US	8



- Seasonal BNR levels coupled with Basins:
  - BNR 8 (Cool = Nov-Mar), BNR 5 or 8 (Warm = Apr-Jun), BNR 3 or 5 (Hot = Jul-Sep)
  - Opt2\_8: Very small: existing, Basins 5-8: existing, Sinclair: 3/3/3, Main Basin Dominants w/o West Point: 8/3/3, **All others: 8/5/3**

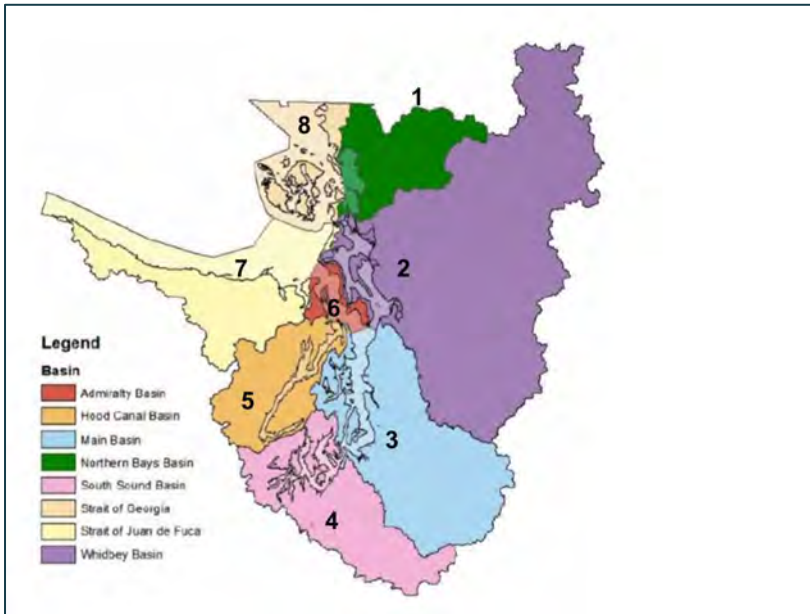
# Assessing Impacts of Nitrogen Loadings on Puget Sound Water Quality - 2

## Salish Sea Model Simulations of Dissolved Oxygen

Basin	Basin #
Northern Bays	1
Whidbey	2
Main	3
South Sound	4
Hood Canal	5
Admiralty	6
SJF - US	7
SOG - US	8

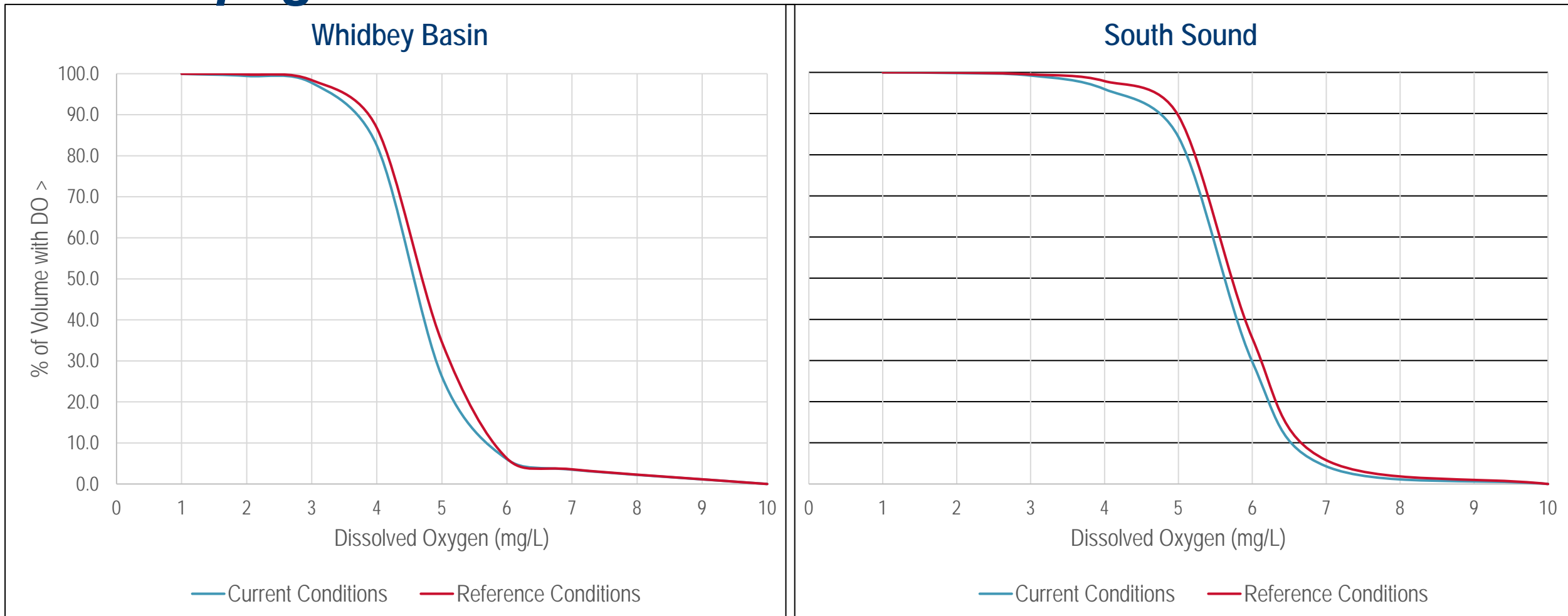
- Whidbey Basin (#2)

- Penn Cove and Port Susan waters have the greatest sustained periods of calculated hypoxia (<2 mg/L)
- Eliminating nitrogen loads from all 16 WWTPs:
  - Reduced non-compliance from 174 to 139 days per year
  - Changed the corresponding magnitude and persistence of non-compliance throughout the year
  - Maximum non-compliant volume reduced from ~3% to ~1%



# Volume Weighted D.O. Current v. Reference Conditions

*Area between the line is the currently modeled impact of anthropogenic nutrients*



# Puget Sound Nutrient Management Assessment and Lessons Learned

- Continuing Disagreement on Water Quality Assessment
- Over-emphasis on Discharge Permitting
  - Nutrient General Permit Invalidated ---> Voluntary General Permit Abandoned ---> 58 Individual NPDES Permits
- Restrictive Ecology Interpretation of Natural Conditions D.O. Standard
  - Cumulative Anthropogenic Depression of 0.2 mg/L Dissolved Oxygen
- Ecology Led Nutrient Workgroup and Advisory Committee
  - Ineffective Facilitation, Lack of Consensus, Distrust
- Ecology's Late Introduction of Nutrient Reduction Plan
  - Garbled Translation of Limits: Total Inorganic Nitrogen v. Total Nitrogen (TN)
  - Limit of Technology Treatment TIN 3 mg/L at Outset
- Ineffective Discharger Communication and Collaboration



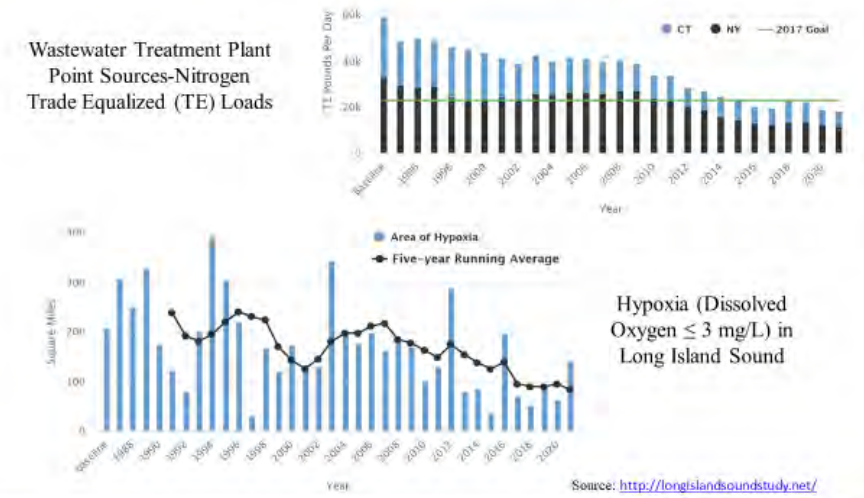


## Long Island Sound

- 2000 Nitrogen TMDL
- Substantial Wastewater Nitrogen Reduction
- Challenges Remain
- Wet Weather Compliance Challenges, LTCP Update, Use Attainability Analysis (UAA)



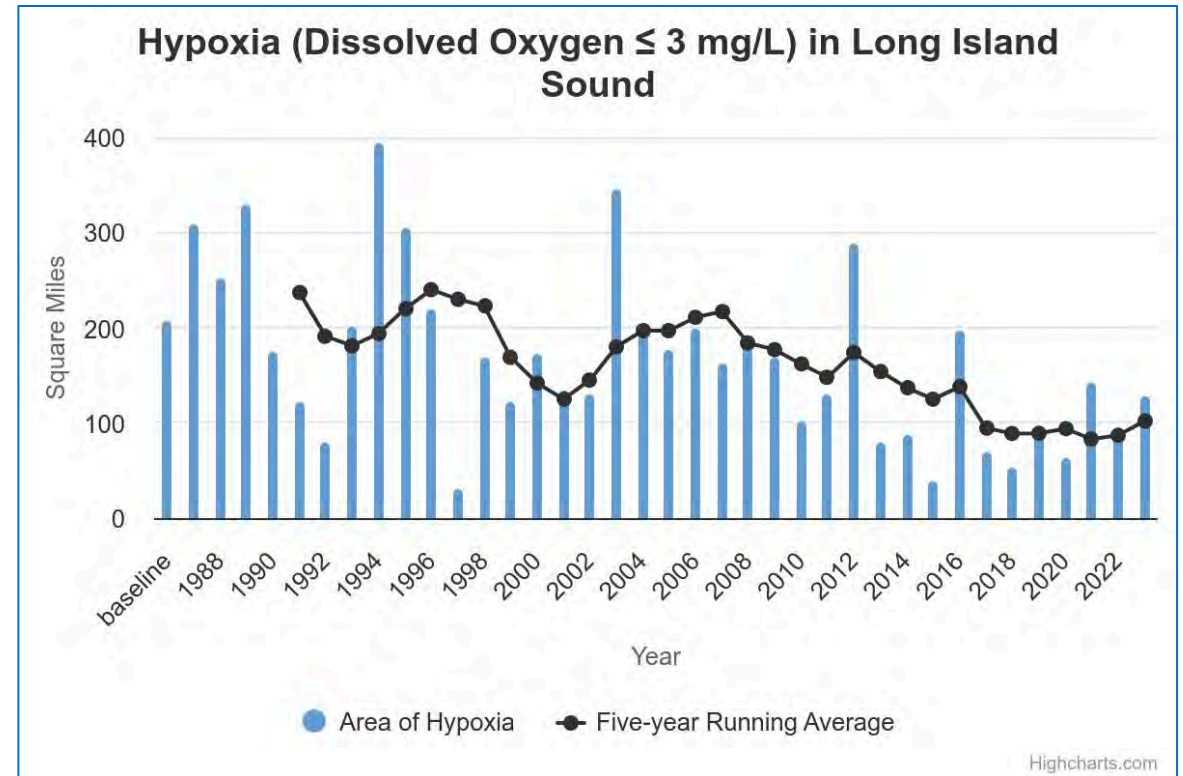
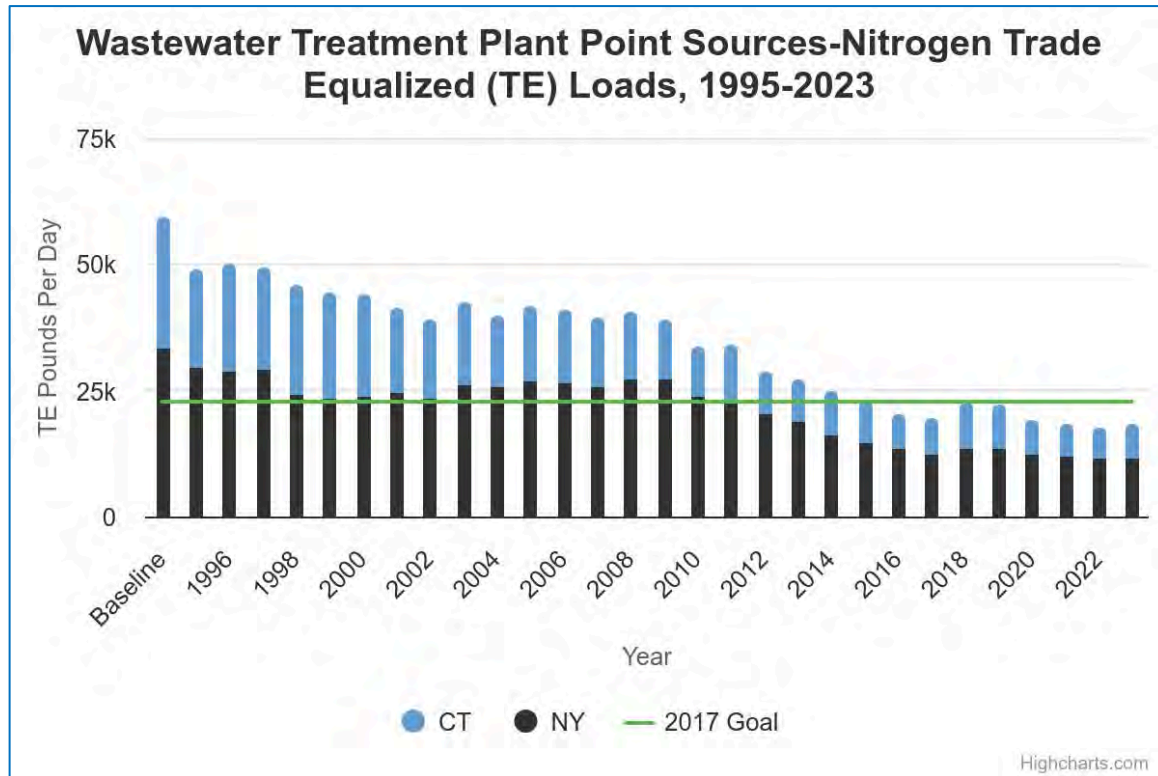
There has been progress...



# Long Island Sound Update

- 2000 Nitrogen TMDL
  - Multiple States involved NY, CT (MA, NJ)
  - To address western LIS low DO levels (hypoxia)
  - Main sources: WWTPs, CSOs, NPS/SW, atmospheric deposition
    - Over 100 WWTPs in NY/CT
  - Required 58.5% nitrogen reduction
  - Majority of reductions achieved 2015-2020
- Challenges still remain
  - NYCDEP has spent >\$1B upgrading four East River WRRFs to meet TMDL reductions
  - Hypoxic area still exists although smaller
- Next generation nitrogen reduction efforts
  - NYSDEC Long Island Nitrogen Action Plan (LINAP)
  - CTDEEP 2<sup>nd</sup> Generation Nitrogen Strategy
  - Focus on embayments, groundwater/septic

# Long Island Sound Wastewater Nitrogen Loadings v. Hypoxia (Sq Miles <3 mg/L)

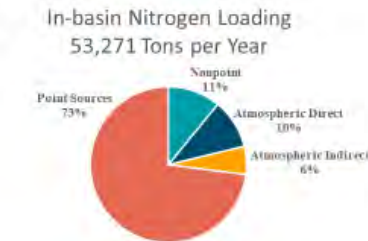
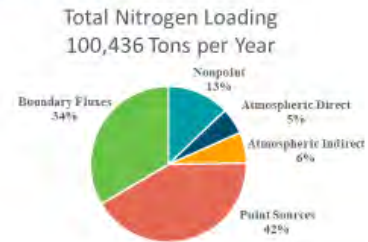


# Long Island Sound

## NYC Challenges- Long Island Sound Nitrogen



- To achieve water quality standards for DO, in 2001, the USEPA approved the 2000 LIS TMDL
- The TMDL required NY and CT to achieve 58.5% nitrogen reduction target



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## NYC Challenges- Long Island Sound Nitrogen Biological Nutrient Removal Projects

- DEP has spent >\$1B upgrading its Upper East River WRRFs to enhance biological nutrient removal to meet 2000 LIS TMDL goals



Construction costs to upgrade Upper East River Wastewater Recovery Facilities (WRRFs) for step-feed biological nutrient removal (BNR)

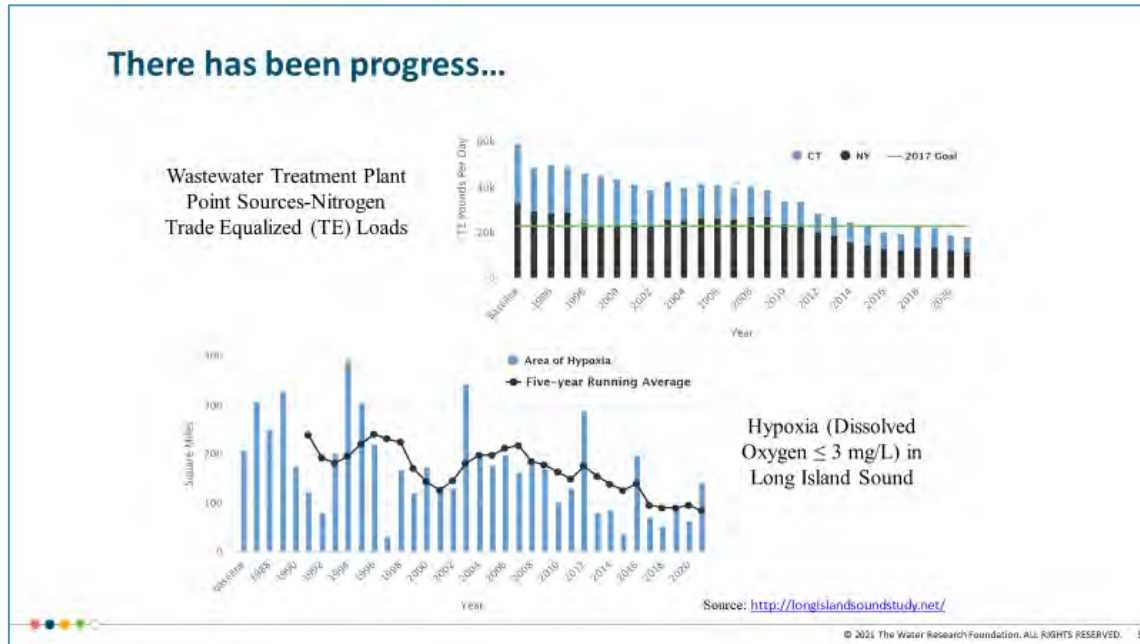
WRRF Facility	Total Cost	BNR Cost
1. Wards Island	\$439M	\$389M
2. Hunts Point	\$497M	\$273M
3. Tottam Island	\$444M	\$203M
4. Bowery Bay	\$354M	\$160M
<b>Total</b>	<b>\$1,734M</b>	<b>\$1,025M</b>

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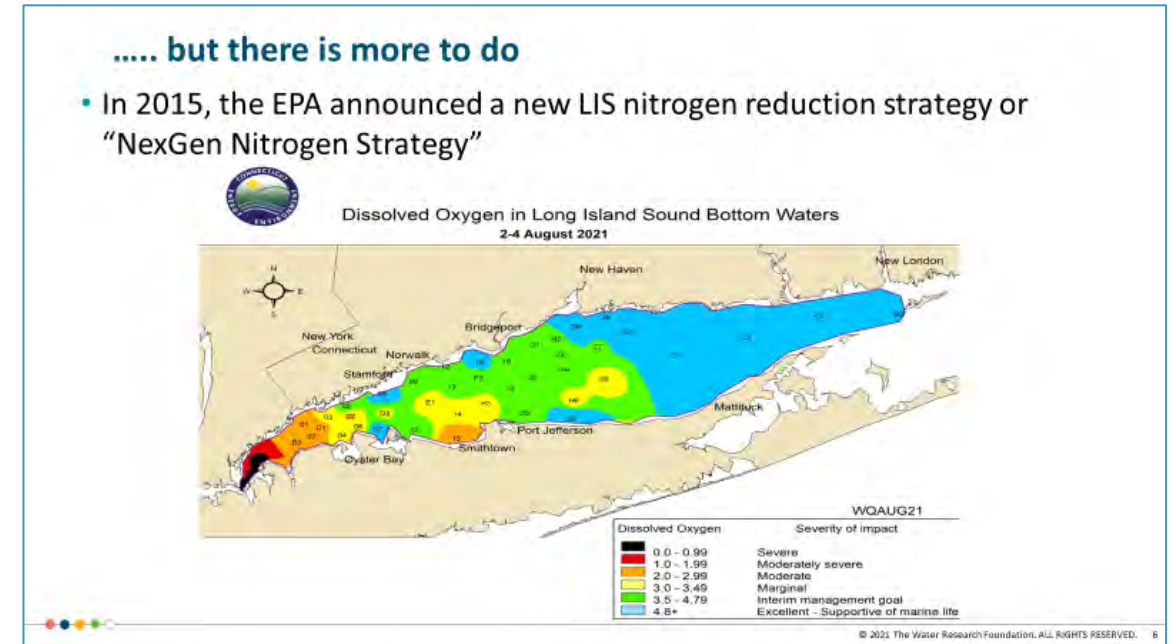
- Pinar Balci, Assistant Commissioner, NYC Department of Environmental Protection (NYCDEP)
  - New York Water Week, March 22, 2023
  - NYCDEP's Collaborations with Water Research Foundation (WRF) and Long Island Sound Study with EPA and Stakeholders

# Progress...but there is more to do

- Pinar Balci, Assistant Commissioner, NYC Department of Environmental Protection (NYCDEP)



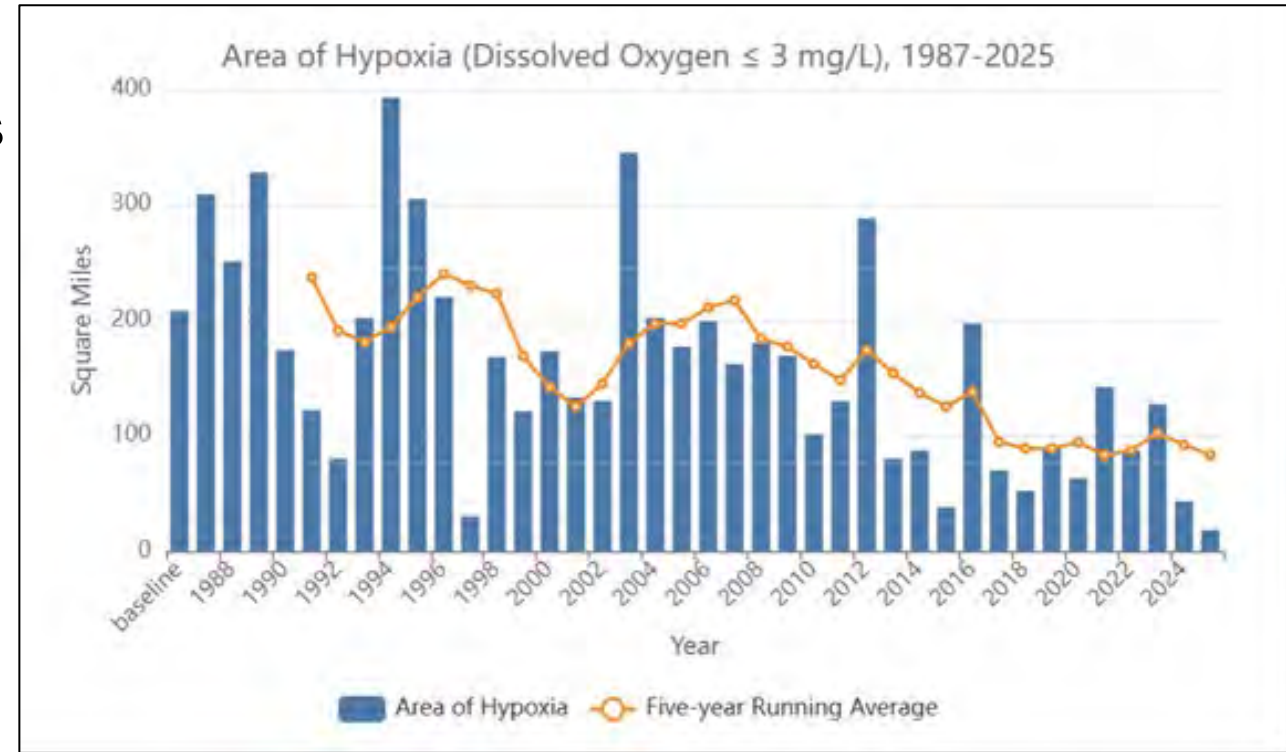
- 2000 TMDL Goals
- NYCDEP \$1B WRRF Upgrades
- 4 East River WRRFs



- 2015 EPA “NexGen Nitrogen Strategy”

# Continuing Reduction in LIS Area of Hypoxia

- 2025 Smallest Hypoxic Area on Record
- Implement Incremental Nutrient Reductions and Track Water Quality Changes
  - Monitoring is Essential
- Shift in Focus to NonPoint Sources
  - e.g. Septic Systems, Sewering, etc.
  - Bioextraction Using Sugar Kelp
    - Targets WQ Improvements in Embayments v. Open Waters of LIS



# Long Island Sound Modeling Project

## 2026 Simulation of 3 Management Scenarios:

### 1. Pre-development

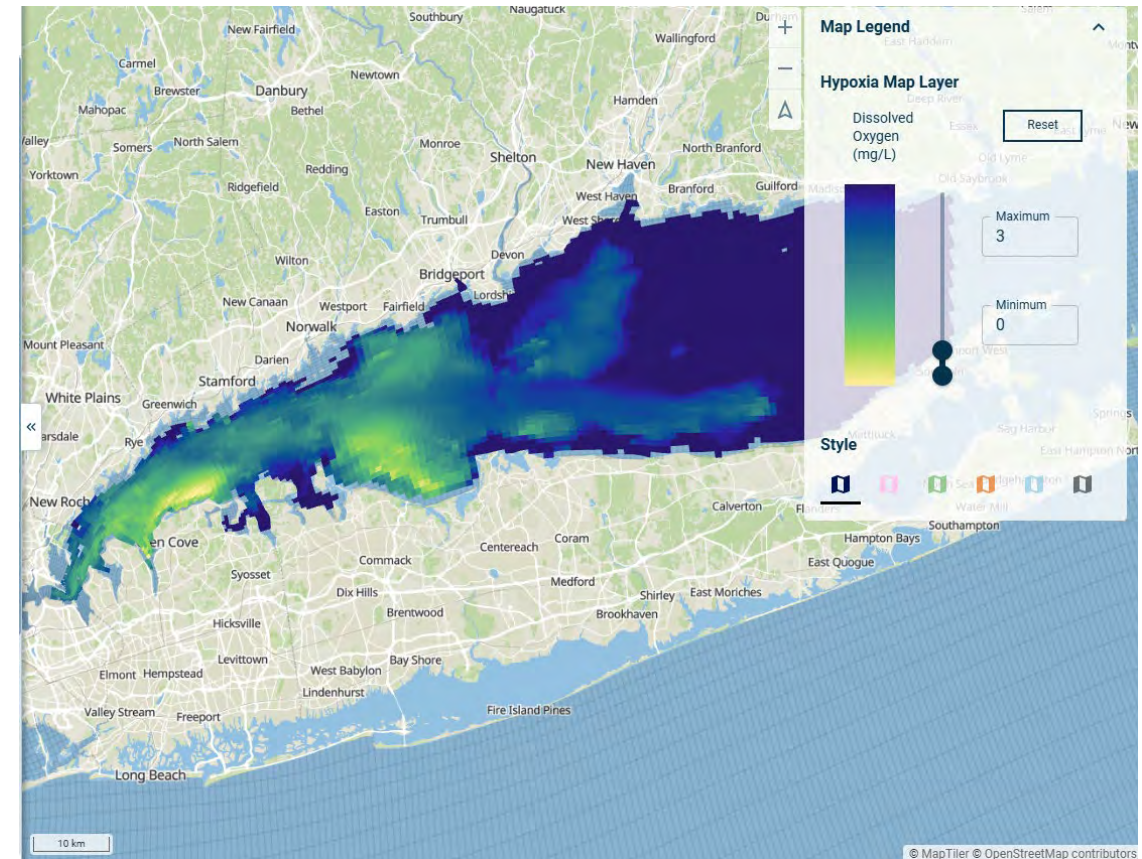
- Non-anthropogenic, No Humans, Pre-colonial, CTRL Case

### 2. Post-development

- Current Conditions with Planned Projects and Reductions
  - May Establish Better Baseline Than CTRL Case

### 3. Post-development with Nutrient Bioextraction

- e.g. Grow Seaweed for Nutrient Uptake, Harvest and Removal
  - Targets WQ Improvements in Embayments v. Open Waters of LIS





CASA & Clean Water SoCal Present Nutrient Management  
Research in Southern California

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