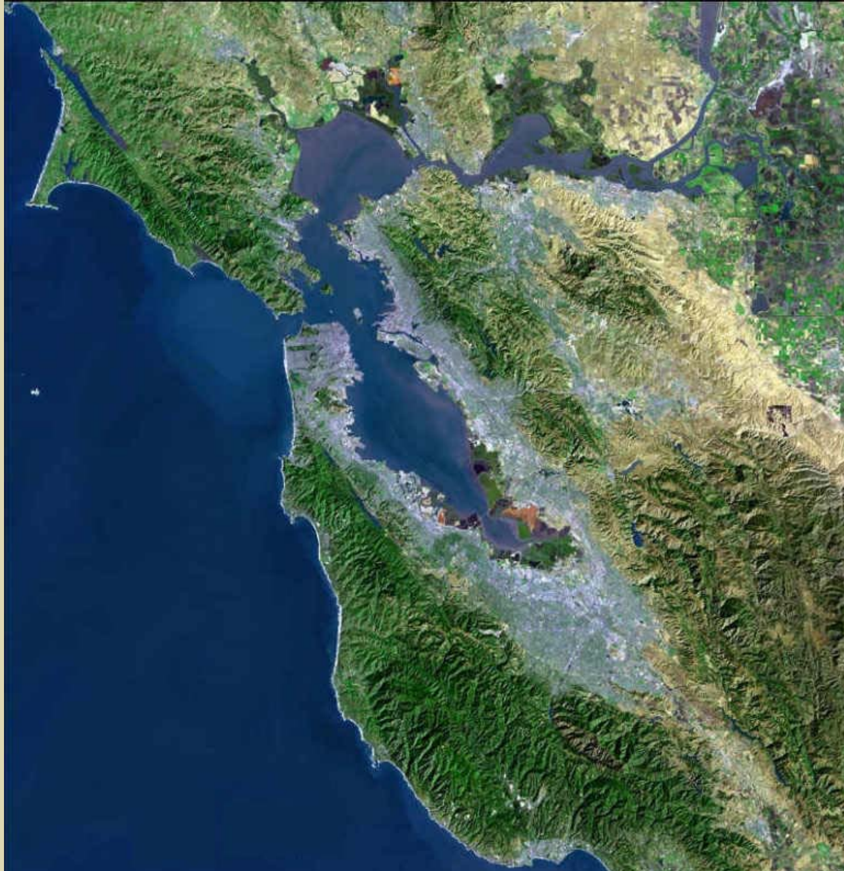


HDR

Bay Area Clean Water Agencies
A Joint Powers Public Agency
Leading the Way to Protect our Bay

# NUTRIENTS: IMPLICATIONS FOR BAY AREA AGENCIES



***David L. Clark***
***dclark@hdrinc.com***

***January 26, 2012***

# Overview

- Wastewater Treatment Technology Issues
  - Limits of Treatment Technology
- Sustainability and Watershed Management
  - Costs of Treatment and Measures of Sustainability
  - Quantification of Point and Nonpoint Sources
- Nutrient Criteria Implementation
  - Regulatory Solutions
  - Balancing and Adaptive Management
- Nutrient Discharge Permitting
  - Distinguish Nutrients from Toxics
  - Variability and Averaging Periods
  - Watershed Scale v. Mixing Zone
  - Nutrient Speciation and Bioavailability

# Wastewater Treatment Technology Issues

# Numeric Nutrient Endpoints and Limits of Wastewater Treatment Technology[1]

| Parameter | Typical Municipal Raw Wastewater, mg/l | Secondary Effluent (No Nutrient Removal), mg/l | Advanced Wastewater Treatment | | | San Francisco Bay Ambient, mg/l [2] |
|---|---|---|---|---|---|---|
| | | | Typical Advanced Treatment Nutrient Removal (BNR), mg/l | Enhanced Nutrient Removal (ENR), mg/l | Limits of Treatment Technology, mg/l | |
| Total Nitrogen | 25 to 35 | 20 to 30 | 10 | 4 to 6 | 3 to 4 | *0.300 to 1.40* |
| ***Reference Wastewater Treatment Facilities*** | | | | | | |
| <u>**Chesapeake Bay**</u> | | | | | | |
| **Virginia (Current)** | | | | 3 to 18 | | |
| **Virginia (EPA TMDL, 2025)** | | | | | 3 to 4 | |
| <u>**Puget Sound**</u> | | | | | | |
| **LOTT Budd Inlet Plant** | | | | | TIN 2 mg/l (TN ~4) | |

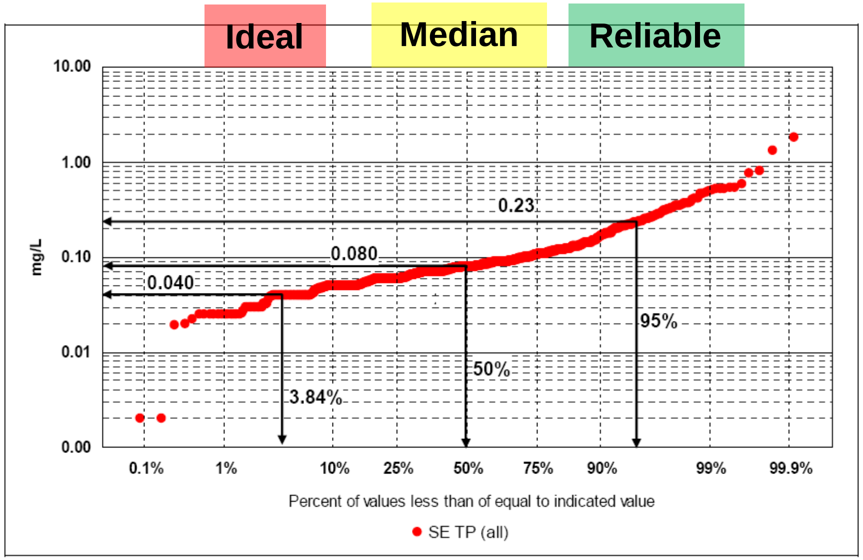
[1] *Ignoring Considerations of Variability and Reliability of Wastewater Treatment Performance*

[2] State of California, The Resources Agency, Department of Water Resources Division of Environmental Services, "Water Quality Conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays during 2009," December 2010

# Water Quality and Advanced Wastewater Treatment

- Numeric Nutrient Endpoints Based on Natural Conditions May Be Very Low Concentrations
  - Lower Than Treatment Technologies Are Capable of Achieving If Applied "End-of-Pipe"
- Effectiveness of Advanced Treatment for Nutrient Removal
  - Variability in Treatment Performance
  - Reliability
  - Effluent Speciation
    - Bioavailability
- Translation to Discharge Permits
  - 303(d) Impairment Listings and TMDLs
  - Direct Application to Discharge Permits

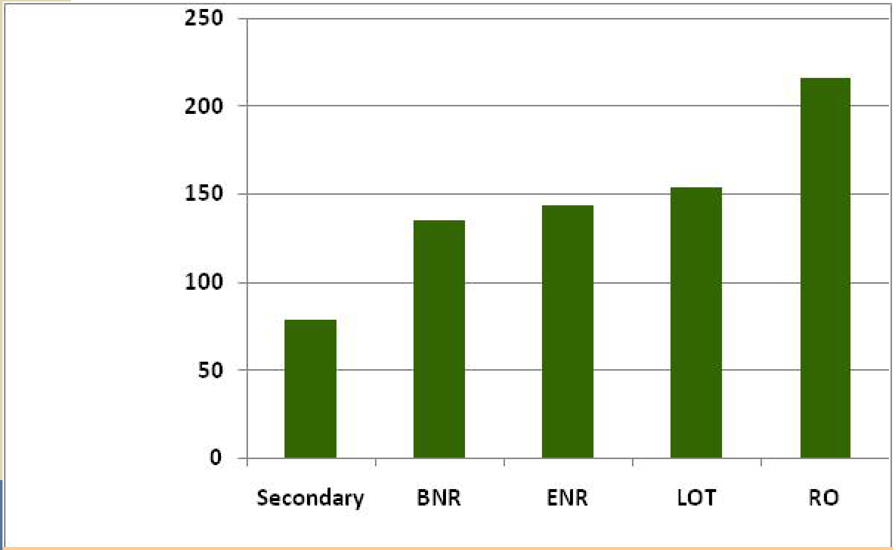
***Technology Performance Statistics***



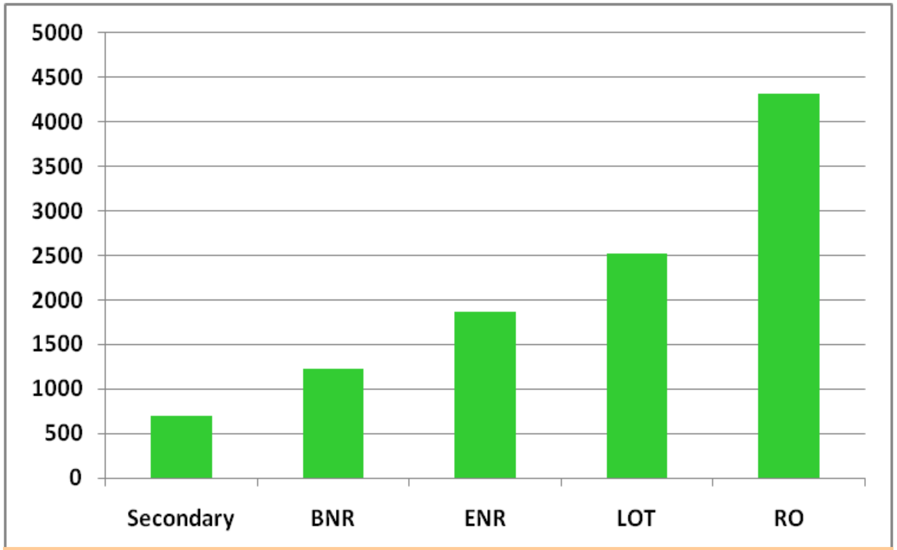

Neethling, JB; Stensel, H.D.; Parker, D.S.; Bott, C.B.; Murthy, S.; Pramanik, A.; Clark, D. (2009) What is the Limit of Technology (LOT)? A Rational and Quantitative Approach. *Proceedings of the WEF Nutrient Removal Conference*, Washington DC, Water Environment Federation, Alexandria, Virginia.

# Sustainability and Watershed Management

# Treatment Costs Escalate Substantially Approaching Technology Limits




**Estimated Capital Costs for 10 mgd Capacity (Million $)**

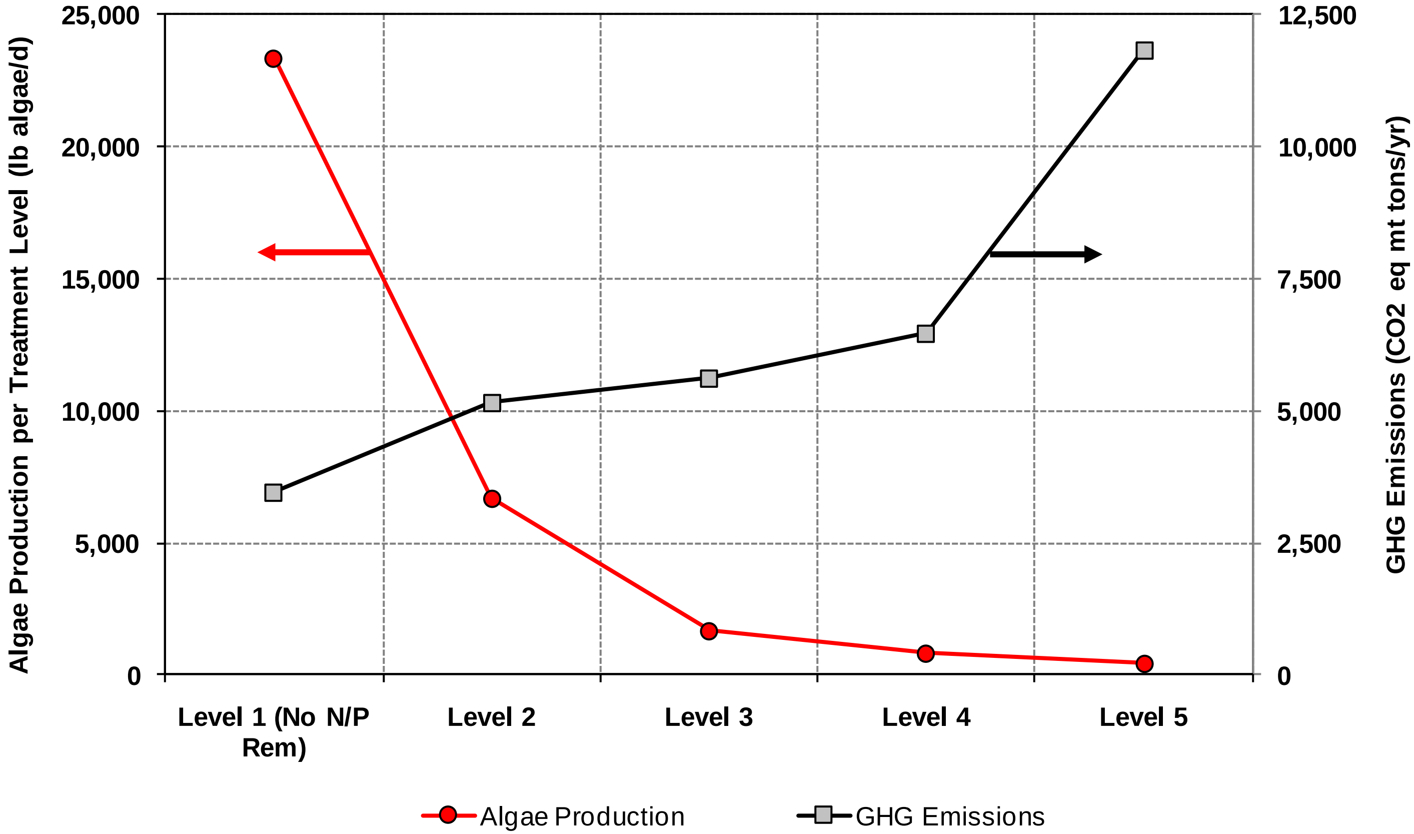



**Estimated O&M Costs for 10 mgd Capacity ($1,000/yr/10 MG Treated)**

**Water Environment Research Foundation (WERF) "*Striking the Balance Between Wastewater Treatment Nutrient Removal and Sustainability*" November 2010**

1. *Secondary Treatment (No nutrient removal)*
2. *Biological Nutrient Removal (BNR) TP 1 mg/L TN 8 mg/L*
3. *Enhanced Nutrient Removal (ENR) TP 0.1-0.3 mg/L TN 4-8 mg/L*
4. *Limit of Treatment Technology (LOT) TP <0.1 mg/L TN 3 mg/L*
5. *Reverse Osmosis (RO) TP <0.01 mg/L TN 1 mg/L*

# Algal Production Potential v. Greenhouse Gas Production

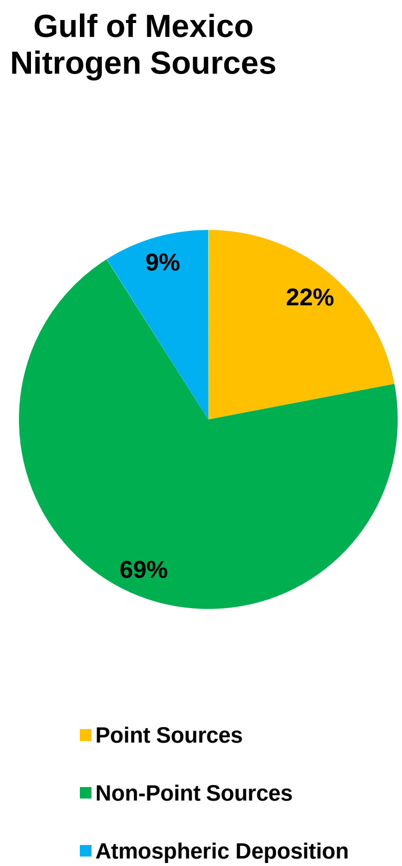


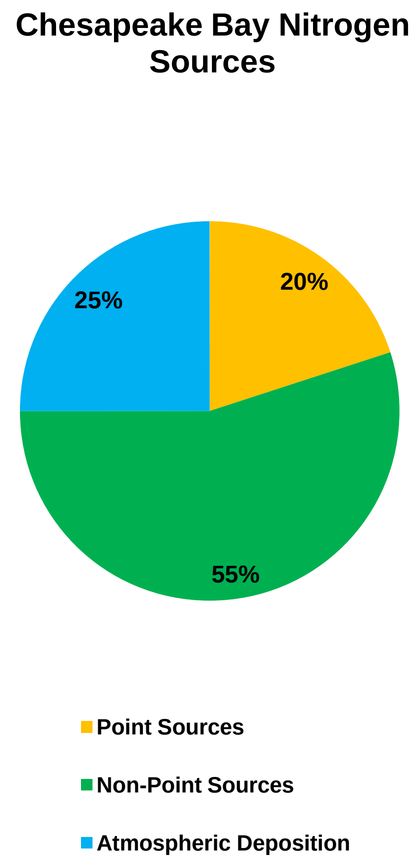

**Water Environment Research Foundation (WERF) "*Striking the Balance Between Wastewater Treatment Nutrient Removal and Sustainability*" November 2010**

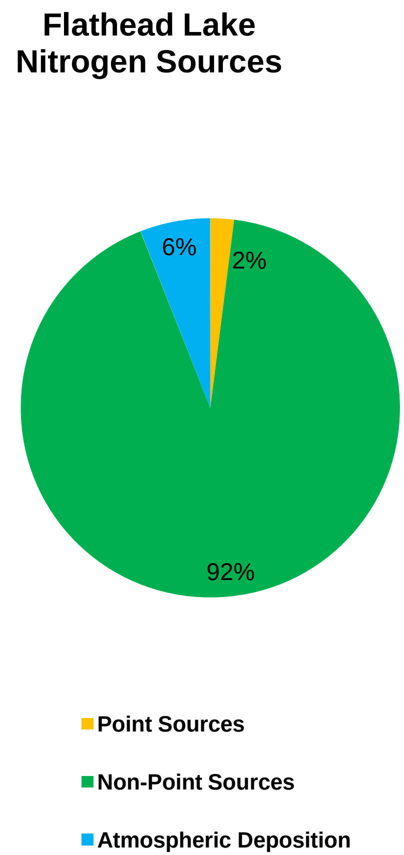
1. *Secondary Treatment (No nutrient removal)*
2. *Biological Nutrient Removal (BNR) TP 1 mg/L TN 8 mg/L*
3. *Enhanced Nutrient Removal (ENR) TP 0.1-0.3 mg/L TN 4-8 mg/L*
4. *Limit of Treatment Technology (LOT) TP <0.1 mg/L TN 3 mg/L*
5. *Reverse Osmosis (RO) TP <0.02 mg/L TN 2 mg/L*

# Nonpoint Source Nutrient Loadings Dominate Many Watersheds

**Nitrogen Loading Summaries for Gulf of Mexico, Chesapeake Bay, and Flathead Lake**




***Watershed Loading Analysis Establishes a Foundation for Successful Nutrient Management Plans***

# Nutrient Criteria Implementation

# *Potential Solutions* -- Water Quality Variances, Treatment Technology Standards, Affordability Tests

## Key Issues

- Permit Requirements Below the Capabilities of Wastewater Treatment Technology
- Reconciliation with Water Quality Standards
- Attainable Effluent Limits

## *Case Study Examples*

- *Wisconsin Dual Legislation*
  - *Numeric Nutrient Criteria*
  - *Treatment Technology Standard*
    - *Adaptive Management*
- *Colorado Regulation #31 and #85*
  - *Numeric Nutrient Criteria*
  - *Treatment Technology Standard*
    - *Adaptive Management*
- *Montana Senate Bill 95 and Senate Bill 367*
  - *Affordability Test (1% MHI)*
  - *Limit of Technology*
  - *Treatment Technology Std (TP 1 mg/L, TN 10 mg/L*

# Wisconsin

- Midwest Environmental Advocates Notice of Intent to Sue EPA Nov 23, 2009
  - Failure to Perform its Non-discretionary Duty to Promulgate Numeric Nutrient Criteria
- 2010 Rulemaking
  - Phosphorus Criteria for Streams
    - Streams 0.075 mg/L
    - Large Rivers 0.100 mg/L
  - Chapter NR217 Effluent Standards and Limitations for Phosphorus
    - Implementation by Adaptive Management
      - Watershed Adaptive Management Option
      - NPS + Stormwater

- Numerical Effluent Limitations
  - 1st Permit
    - TP 1 mg/L
      - Rolling 12 Mo. Ave
  - 2nd Permit
    - TP <0.6 mg/L
      - 6-Mo. Ave
  - 3rd Permit
    - TP <0.5 mg/L
      - 6-Mo. Ave
    - Adaptive Watershed Plan
  - Water Quality Based Effluent Limitations (WQBELs)

# Colorado

- Initial Nutrient Criteria for Rivers and Streams – February 9, 2010
  - Selecting Numeric Nutrient Criteria That Allow 5% Decrease in Biological Condition
    - Multi Metric Macroinvertebrate Index
- Regulation #31 Basic Standards and Methodologies for Surface Water
  - New Section 31.17 Nutrient Interim Values
    - After May 31, 2017 and Prior to May 31, 2022

- Regulation #85 – Nutrients Management Control Regulation
  - **Establishes Numerical Effluent Limitations**
    - **Existing Plants**
    - **First Level BNR (3-stage)**
      - **TP 1 mg/L**
      - **TIN 10 mg/L**
    - **New Plants**
    - **Enhanced BNR (4 & 5-stage)**
      - **TP 0.7 mg/L**
      - **TIN 7 mg/L**
  - **Running Annual Median**

| Rivers and Streams | Cold Water | Warm Water |
|---|---|---|
| Chl a $mg/m^2$ | 150 | 150 |
| TP, ug/L | 110 | 160 |
| TIN, ug/L | 400 | 2,000 |

# Montana

- Benthic Algae 150 mg Chla/m$^2$ Considered Nuisance Threshold by Public
  – Rarely Occurs in Western Montana Reference Streams
  – Harm-to-Use Threshold for Salmonid Streams
    - Salmonid Growth Enhanced by Productivity Up to 150 mg Chla/m$^2$
      - DO Problems Begin at Higher Levels

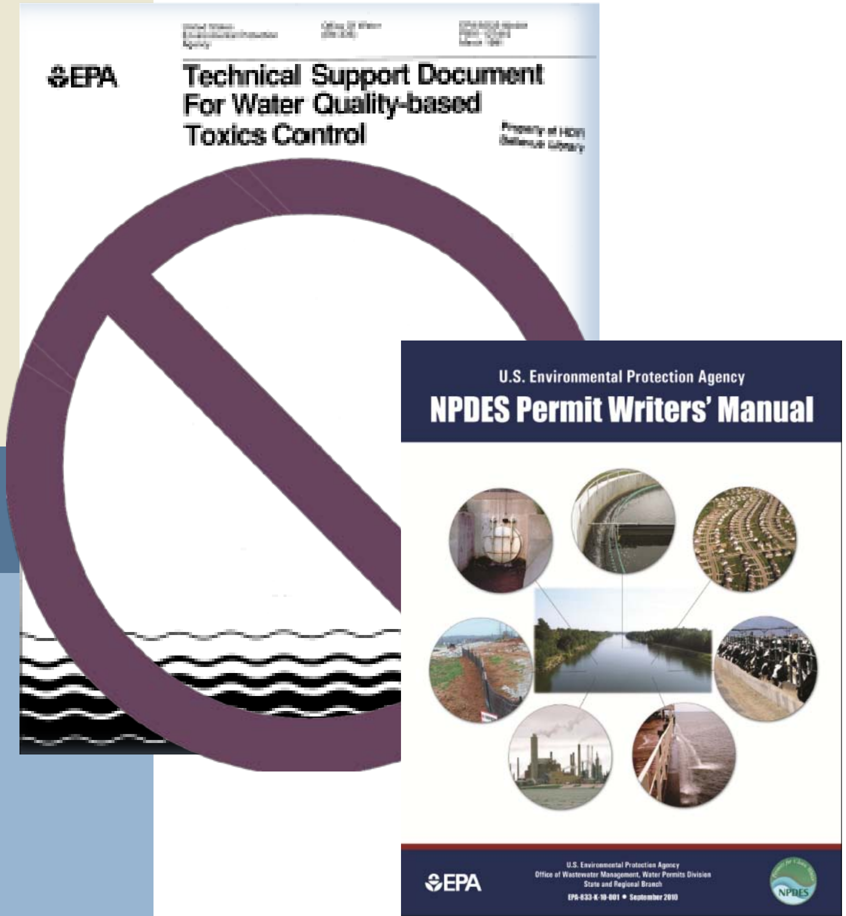
F 150 mg/m$^2$ Chla

D 1,250 mg/m$^2$ Chla

- 2009 Senate Bill 95 Variance
  – Temporary Nutrient Standards
  – Economic Hardship
    - Substantial and Widespread
    - Targeted 1% Median Household Income
  – Limits of Technology
- 2011 Senate Bill 367
  – Nutrient Standards Variances
    - Individual, General, Alternative
  – Numerical Effluent Limitations
    - TP 1 mg/L TN 10 mg/L (Q>1 mgd)
    - TP 2 mg/L TN 15 mg/L (Q<1 mgd)
    - Lagoons (Maintain Performance)
  – Monthly Average Limits

# Nutrient Discharge Permitting

# Appropriate Discharge Permit Guidance for Nutrients




- Translation of Numeric Nutrient Endpoints to NPDES Permit Limits
  - Critical Interpretation of Water Quality
  - Existing Permit Writer Guidance Focused on Toxics
- Appropriate Averaging Periods
- Variability in Low Nutrient Plant Performance
- Effluent Speciation and Bioavailability

*Over-specifying effluent discharge permit limits will not enhance water quality protection, but may result in noncompliance*

# Nutrients Differ From Toxics

## Nutrients

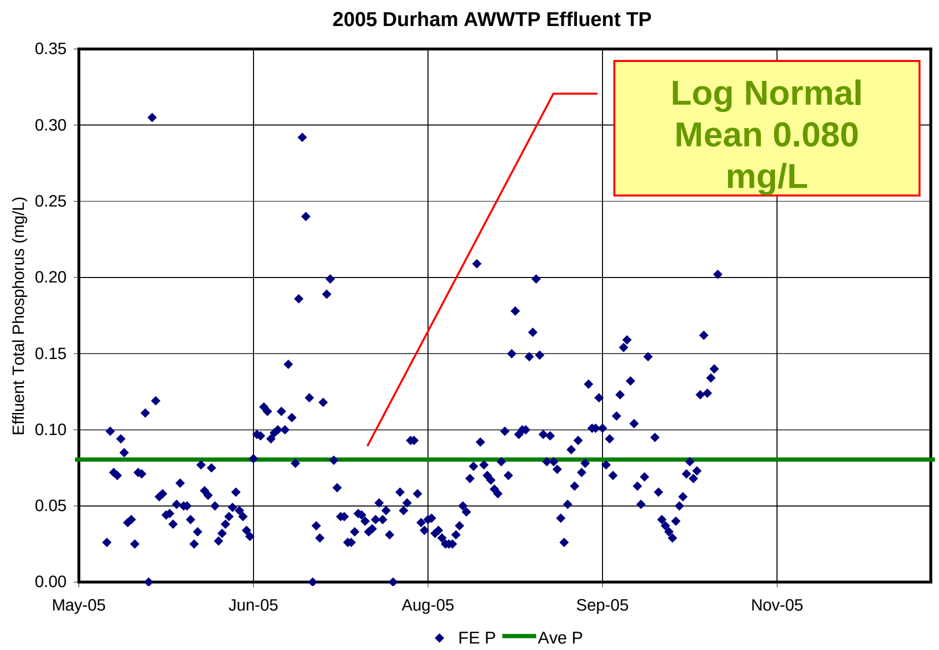
- No Immediate Impact
  - Aside from Ammonia
- Watershed Scale Impacts
  - Nutrient Enrichment Leads to Aquatic Growth
- Algal Response Over Longer Periods
  - Longer Averaging Period Appropriate for Nutrients
  - Seasonal or Annual Averages Appropriate
- Treatment Technology
  - Variability at Low Levels in the Best Technologies

## Toxics

- Acute and Chronic Impacts on Aquatic Life
  - Ammonia, Chlorine, Metals, Organics
- Near-field (mixing zone) and Far-field (watershed) Impacts
- Long Term Response
  - Average Limits
- Short Term Response
  - Maximum Limits Required
- Treatment Technology
  - Available Technology to Prevent Excursions

# Improved Nutrient Permitting will Recognize Daily Treatment Process Variability at Low Effluent Levels

- Daily Process Performance Varies Even in Excellent Treatment Plants
- Feasible Compliance with Long Averaging Periods
  - Median or Average Basis
  - Annual or Seasonal
- Maximum Daily or Weekly Limits May Result in Noncompliance




*Clean Water Services of Washington County, OR (CWS) Durham Plant Effluent Phosphorus, mg/L*

# Permit Structure – Long Term Seasonal Averages and Seasonal Mass Limits

## Key Issues

- Translation of TMDL Requirements to Effluent Discharge Permits
- Appropriate Averaging Periods for Nutrient Limits
- Maximum Day and Maximum Week Dilemmas
- Effluent Mixing Zones
- Permit Requirements Below the Capabilities of Wastewater Treatment Technology
- Novel NPDES Permit Approaches

## *Case Study Examples*

- *Chesapeake Bay TMDL*
  - *Jim Hanlon, EPA Office of Wastewater, Memo on Annual Averaging*
    - *Nitrogen and Phosphorus*
- *Tualatin River – Clean Water Services*
  - *Seasonal Median TP Concentration*
- *Las Vegas Wash – City Las Vegas, CCSD, Henderson*
  - *Seasonal Mass TP Loading Shared Between 3 Dischargers*
- *Spokane River DO TMDL*
  - *Seasonal Mass Loading Limits for Phosphorus, NH3N, CBOD*
    - *Coeur d'Alene (Region 10 EPA)*
    - *Spokane County (Washington Ecology)*

# NPDES Permitting Regulations

- 40 CFR 122.45(d) requires that all permit limits be expressed as average monthly limits and average weekly limits for publicly owned treatment works (POTWs) and as both average monthly limits and maximum daily limits for all others, unless "impracticable."

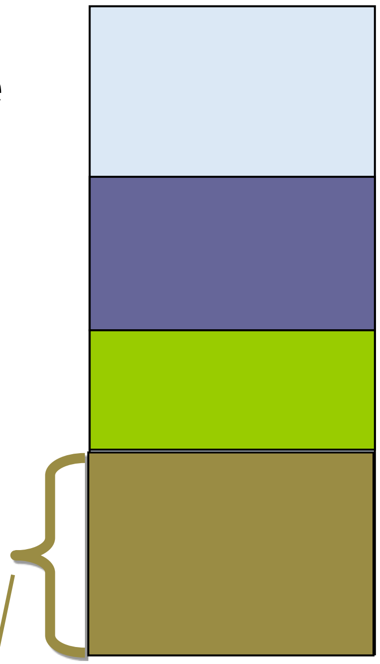
***Maximum monthly, weekly, and daily limits likely to be exceeded by even the best designed and operated low nutrient treatment facilities***

***Effluent N and P concentration is highly variable for even the best designed and operated low nutrient treatment facilities***

***Individual permit writers in every nutrient limited watershed must interpret these NPDES regulations and the definition of "<u>impracticable</u>" with limited guidance***

# Advanced Nutrient Removal Treatment

*Reduced Concentration* | *Altered Speciation* | *Reduced Bioavailability*



| Nitrogen Species | Nutrient Removal Effluent |
| --- | --- |
| Nitrite + Nitrate | ~0.5 – 3 mg/L |
| Ammonia | ~0.1-0.5 mg/L |
| Particulate Organic Nitrogen | ~0.01-1.0 mg/L |
| Dissolved Organic Nitrogen | ~0.5-2 mg/L |

*Inert DON and Bioavailable DON*

David Sedlak, University of California, Berkeley

WERF
Water Environment Research Foundation
*Collaboration. Innovation. Results.*

# Permit Structure – Nutrient Speciation and Bioavailability

## Key Issues

- Low N and P Effluent Speciation
  - Refractory N and P
    - Not Biodegradable
    - Bioavailability?
  - Effluent Limits Based on Total or Inorganic N and P?
    - Inorganic Limits Avoid Refractory Constituents

## *Case Study Examples*

- *Onondaga Lake TMDL, Syracuse, NY*
  - *Onondaga County (NYDEC)*
- *Spokane River DO TMDL*
  - *Spokane County (Washington Ecology)*
  - *Coeur d'Alene (Region 10 EPA)*

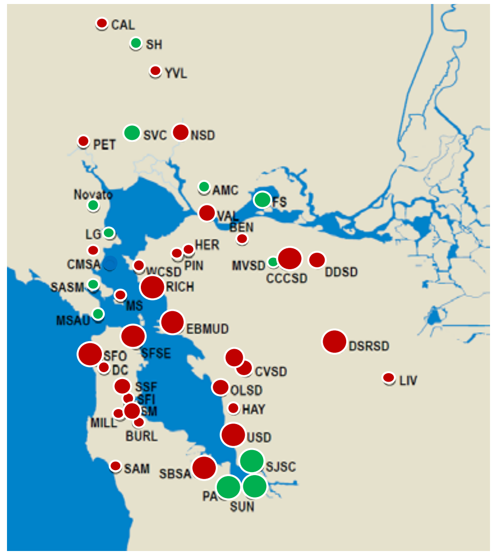
**S1.B.a Alternate effluent limits for oxygen consuming pollutants demonstrated to be equivalent to DO TMDL baseline effluent limits in S1.A (option 1)**

| Parameter | Seasonal Limit Applies March 1 to October 31 See notes f and g | |
|---|---|---|
| Carbonaceous Biochemical Oxygen Demand (5-day) ($CBOD_5$) | 133.4 pounds/day (lbs/day) average | |
| Total Phosphorus (as P) March 1 to Oct. 31 | 3.34 lbs/day average | |
| Total Ammonia (as $NH_3$-N) | **Seasonal Limit** | **Maximum Daily Limit** |
| For "season" of March 1 to March 31 | 1067.5 lbs/day average | 16 mg/L |
| For "season" of April 1 to May 31 | 66.7 lbs/day average | 16 mg/L |
| For "season" of June 1 to Sept. 30 | 16.7 lbs/day average | 8 mg/L |
| For "season" of Oct. 1 to Oct. 31 | 66.7 lbs/day average | 16 mg/L |
| **Parameter** | **Average Monthly [a]** | **Average Weekly [b]** |

| | |
|---|---|
| g | Future adjustments to the final effluent based on demonstrated pollutant equivalencies or non bioavailable P will be implemented as major permit modifications requiring public notice and comment. |

# Keys to Appropriate NPDES Permitting of Low Effluent Nutrient Discharges

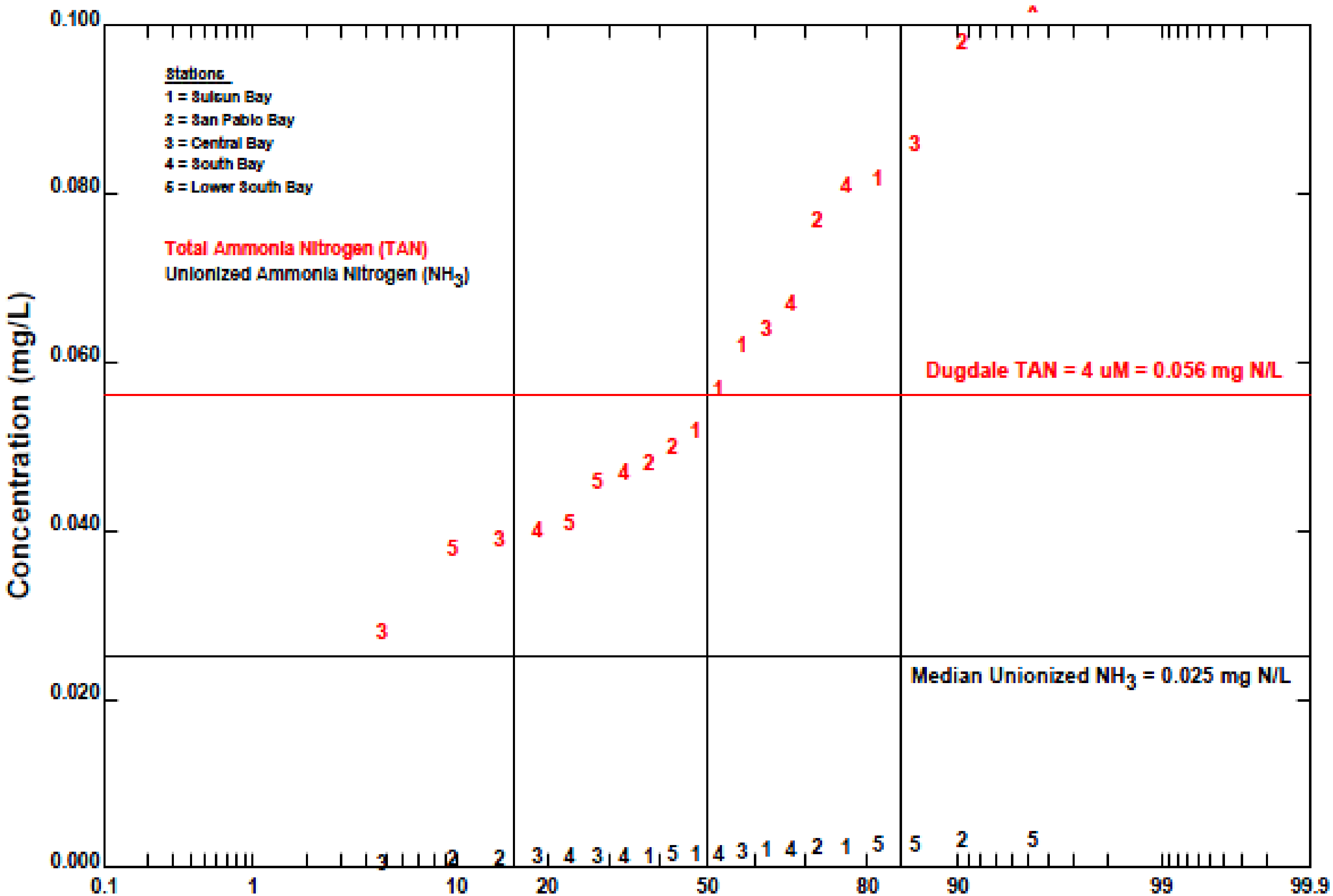
- Receiving Water Quality
  - Appropriate Averaging Periods
  - Far-field Watershed v. Near-field Mixing Zone
- Treatment Technology Issues
  - Variability in Effluent Performance
  - Reliability
  - Speciation and Bioavailability
- Permit Structures for Successful Compliance and Watershed Management
  - Consider Reuse, Offsets and Trading



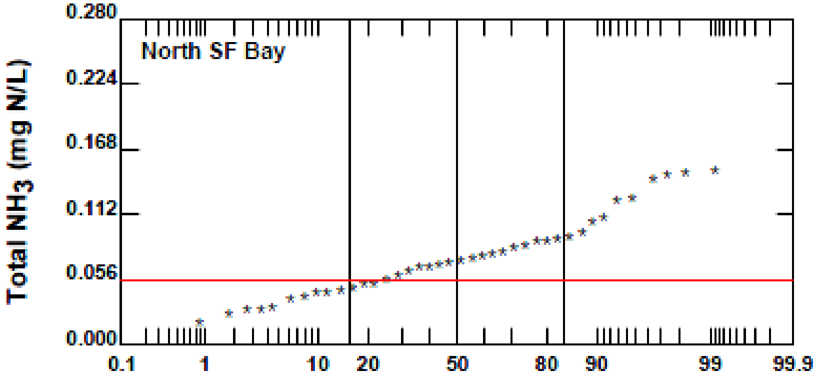

| Flow (mgd) | Ammonia Removal | Secondary Treatment |
|---|---|---|
| >20 | | |
| 10-20 | | |
| <10 | | |

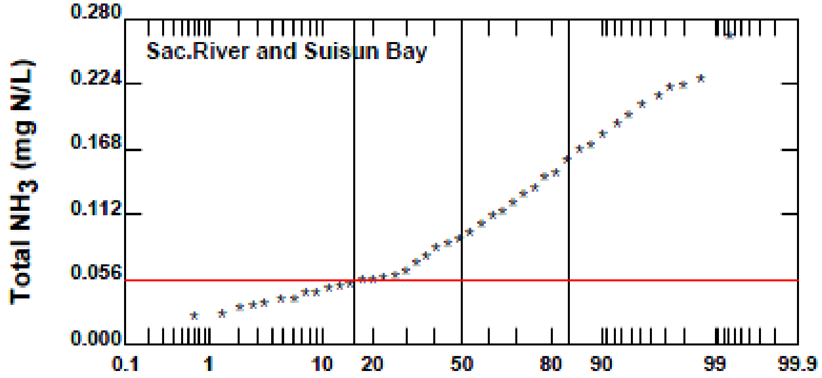
# Q & A

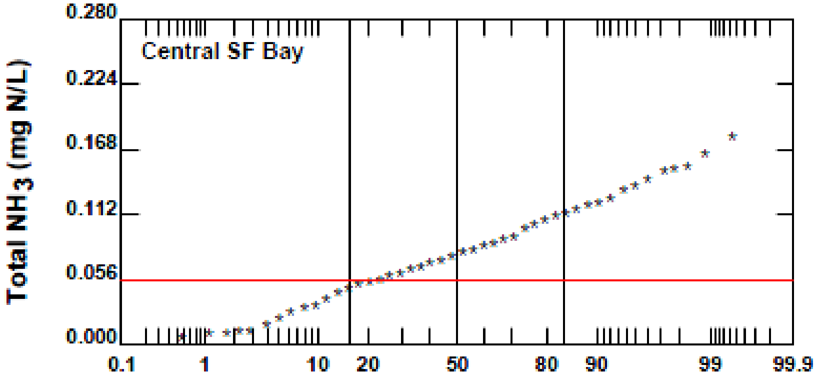
# Where are we now?- RMP data

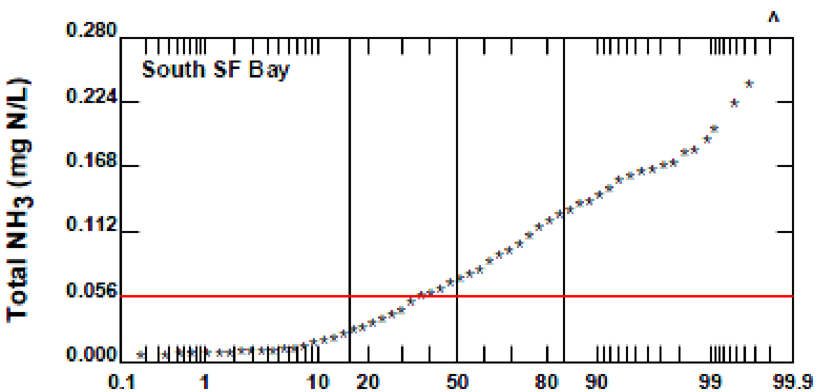


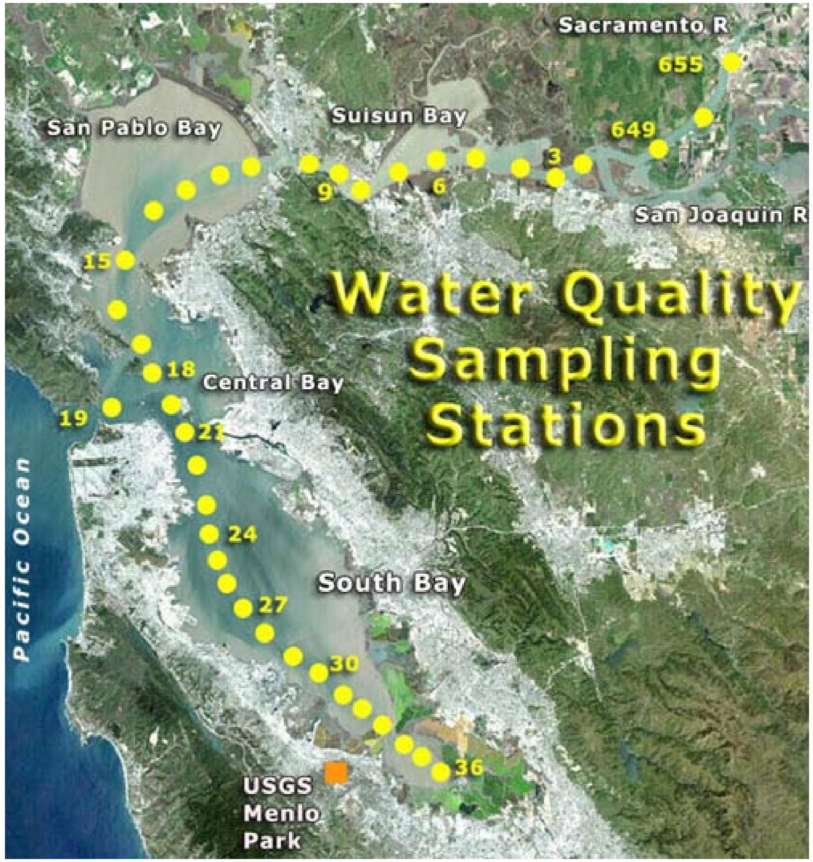
# Where are we now?- USGS data




BACY

# Chesapeake Bay Average Annual Limits

***Daily Maximum, Weekly Average and Monthly Average Limits Not Mandatory***

- Guidance from EPA Headquarters Office of Wastewater Management
- Annual Permit Limits for Nitrogen and Phosphorus for Permits Designed to Protect Chesapeake Bay
  - *"…permit limits expressed as an annual limit are appropriate and that it is reasonable in this case to conclude that it is* *<u>"impracticable"</u>* *to express permit effluent limits as daily maximum, weekly average, or monthly average effluent limitations*."

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 3 2004

OFFICE OF WATER

**MEMORANDUM**

**SUBJECT:** **Annual Permit Limits for Nitrogen and Phosphorus for Permits Designed to Protect Chesapeake Bay and its tidal tributaries from Excess Nutrient Loading under the National Pollutant Discharge Elimination System**

**FROM:** James A. Hanlon, Director
Office of Wastewater Management

**TO:** Jon Capacasa, Director
Water Permits Division, EPA Region

Rebecca Hanmer, Director
Chesapeake Bay Program Office

This memo responds to your proposal to use National Pollutant Discharge Elimination System (NPDES) permit effluent limits for nitrogen and phosphorus expressed as an annual limit in lieu of daily maximum, weekly average, or monthly average effluent limitations, for the protection of Chesapeake Bay and its tidal tributaries from excess nutrient loading. Based on the information provided by your staff and for the reasons and under the circumstances outlined herein, I concur that permit limits expressed as an annual limit are appropriate and that it is reasonable in this case to conclude that it is "impracticable" to express permit effluent limitations as daily maximum, weekly average, or monthly average effluent limitations. This memo describes the scientific and policy rationales that support this approach.

EPA Region 3 has developed recommended water quality criteria for certain parameters designed to protect water quality in Chesapeake Bay and its tidal tributaries.[1] The main cause of water quality impairment for these parameters in the main stem of the Bay is loading of nutrients, specifically nitrogen and phosphorus, from point and nonpoint sources throughout the entire Chesapeake Bay watershed. The States are in the

[1] See EPA's Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll for the Chesapeake Bay and Its Tidal Tributaries, April 2003. "Chesapeake Bay and its tidal tributaries" is the portion of the Chesapeake Bay watershed subject to the ebb and flow of ocean tides. This area encompasses all of the mainstem Bay and the area north and east to the fall line. The fall line is a physical barrier on the Bay's larger tributaries marked by waterfalls and rapids.

Internet Address (URL) • http://www.epa.gov
Recycled/Recyclable • Printed with Vegetable Oil Based Inks on Recycled Paper (Minimum 30% Postconsumer)

**Jim Hanlon, Office of Wastewater Management, March 3, 2004**

# Permit Structure – Effluent Limits

## Mass and Concentration

- Long Averaging Periods Preferred
- Maximum monthly, weekly, and daily limits likely to be exceeded by even the best designed and operated low nutrient treatment facilities

Individual permit writers in every nutrient limited watershed must interpret these NPDES regulations and the definition of “impracticable” with limited guidance

## Mass Only

- Mass Limits Provide Greater Flexibility
  - Supports Effluent Reuse
  - Supports Trading/Water Quality Off-sets

# Variety of Successful Permit Structures Nationally for Nutrients

| Location | Total Phosphorus Limits | Comments |
|---|---|---|
| Clean Water Services of Washington County, OR | 0.100 mg/l | Monthly Median, May 1 to Oct 31<br>Watershed Permit |
| Las Vegas, Clark County, Henderson, NV | 334 lbs/day<br>(130/174/30 lbs/day) | Mar 1 to Oct 31<br>Cooperative Agreement to Share for Flexibility |
| Alexandria, VA | 0.18 mg/l and 37 kg/day<br>0.27 mg/l and 55 kg/day | Monthly Average<br>Weekly Average |

- Concentration Only, Mass Only, Both
  - Seasonal Limits
  - Mean or Median
  - Shared Capacity

# Case Study Example: *Spokane River Dischargers (Washington Ecology, Idaho DEQ, EPA Region 10)*

**Dissolved Oxygen TMDL**

- Very Restrictive
  - Cumulative Anthropogenic D.O. Depression <0.2 mg/L
- TMDL Scenario
  - TP 0.042 mg/L

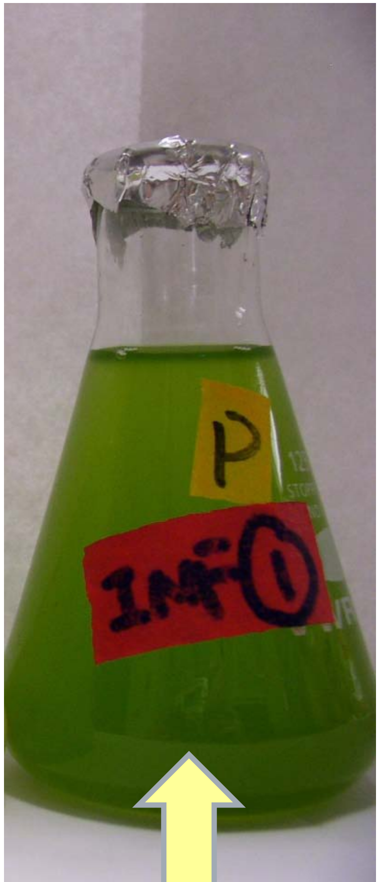
**Draft NPDES Permit**

- Seasonal Mass Loading Limits
  - TP, CBOD, $NH_3N$
    - Compliance Based on Season

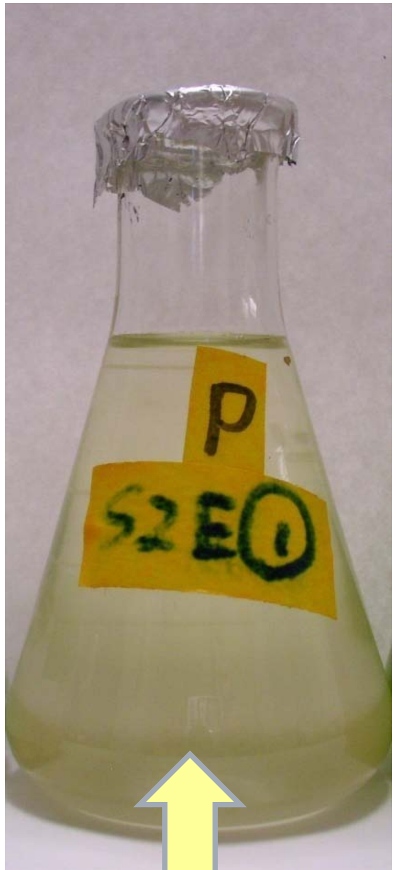
**S1.B.a Alternate effluent limits for oxygen consuming pollutants demonstrated to be equivalent to DO TMDL baseline effluent limits in S1.A (option 1)**

| Parameter | Seasonal Limit Applies March 1 to October 31 See notes f and g | |
|---|---|---|
| Carbonaceous Biochemical Oxygen Demand (5-day) ($CBOD_5$) | 133.4 pounds/day (lbs/day) average | |
| Total Phosphorus (as P) March 1 to Oct. 31 | 3.34 lbs/day average | |
| Total Ammonia (as $NH_3$-N) | **Seasonal Limit** | **Maximum Daily Limit** |
| For "season" of March 1 to March 31 | 1067.5 lbs/day average | 16 mg/L |
| For "season" of April 1 to May 31 | 66.7 lbs/day average | 16 mg/L |
| For "season" of June 1 to Sept. 30 | 16.7 lbs/day average | 8 mg/L |
| For "season" of Oct. 1 to Oct. 31 | 66.7 lbs/day average | 16 mg/L |
| **Parameter** | **Average Monthly [a]** | **Average Weekly [b]** |
| Carbonaceous Biochemical Oxygen Demand (5-day) ($CBOD_5$), November 1 through February 29 | 2.0 milligrams/liter (mg/L) 133 pounds/day (lbs/day) | --- |

# Bioassay Methods Used to Measure Bioavailability of Phosphorus




**Secondary Effluent BAP**




**Alum/settled Effluent BAP**


**Alum/Filtered Effluent BAP**

**Michael T. Brett & Bo Li, University of Washington libo@u.washington.edu**

# Biodegradability vs Bioavailability
# WWTP ←→ Water Quality

**Treatment Plant**

Technology Base

How much can WW biology remove?

i.e. What is LOT?

?

**Water Quality**

Ecosytem Base

How much can ecosystem use for growth?

i.e. What WQ Impact?

# Conceptual Model for Dissolved Organic Nitrogen (DON) Fractions

Hydrophobic

**Inert DON**
**30-50%**

XAD Adsorbed

Hydrophilic

**BioAvailable DON**
**50-70%**

XAD Effluent

David Sedlak, University of California, Berkeley

WERF
Water Environment Research Foundation
*Collaboration. Innovation. Results.*