Water Quality Monitoring

to support

Nutrient TMDLs Development

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NJ Department of Environmental Protection
Division of Watershed Management

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Presentation Overview

- Nutrient enrichment and excessive plant growth
- NJ Surface Water Quality Standards for Nutrients
  - Numeric and Narrative criteria
- Overview of nutrient impairment in New Jersey
- TMDLs approach
  - complex vs. simple water quality modeling
- Water Quality Data for Nutrient TMDLs development
- Sources of Water Quality Data
- Monitoring Plans for TMDLs development- Case Study
- Conclusion/Questions

Indicators of Excessive Productivity

- Significant attached algae (Periphyton)
- Significant rooted plants (Macrophytes)
- Significant free floating algae (Phytoplankton)
  - Significant water column Chlorophyll-a
- Significant Diurnal Dissolved Oxygen Swings
  - Dissolved oxygen instream standard violations (4 mg/l FW2-NT, 5 mg/l FW2-TM, 7mg/l FW2-TP)
- Excessive loading of silt, organic matter, and nutrients

Factors Impacting Excessive Productivity

- Nutrient availability- phosphorus, nitrogen, silica
- Solar radiation
- Water temperature
- Water clarity- turbidity, secchi depth
- Stream substrate (e.g., rock prevents rooted macrophytes, but provides a good medium for Periphyton growth)
- Geometry of waterbody- surface area, depth, volume
- Flow, velocity and depth

Phosphorus Criteria

- Streams:

  TP ¡ 0.1 mg/l **unless** it can be demonstrated that TP is not a limiting nutrient **<u>and</u>**

  TP will not otherwise render the waters unsuitable for designated uses

- Lakes, Ponds Reservoirs (and their tributaries & intakes)

  TP ¡ 0.05 mg/l

  Except where watershed or site-specific criteria are developed

Nutrient Requirements by Plant and Algae

- The Limiting Nutrient is the nutrient that will run out before other nutrients
- Algal cells require nitrogen and phosphorus in relatively fixed proportions
  - if there is less available phosphorus relative to stoichiometric requirements, then phosphorus is the limiting nutrient
- Available nitrogen (TIN)
  - TIN = NO_2 + NO_3 + NH_3
- Available phosphorus DRP or TOP
  - DRP = Dissolved Reactive Phosphorus
  - TOP = Total Ortho-Phosphorus

- TIN/TOP >> 10 Phosphorus limited, 10 to 20 range suggested by EPA (nutrient criteria guidance)

- TIN/TOP << 10 Nitrogen limited

- Phosphorus Evaluation Study uses a TIN/TOP < 5 to indicate phosphorus limitation is very unlikely

Are the Designated Uses Rendered Unsuitable Due to Phosphorus

(Phosphorus Evaluation Study- exit ramp)

- **Dissolved oxygen**
  - Does diurnal DO violate criteria?
- **Are algal densities excessive?**
  - Phytoplankton concentration:

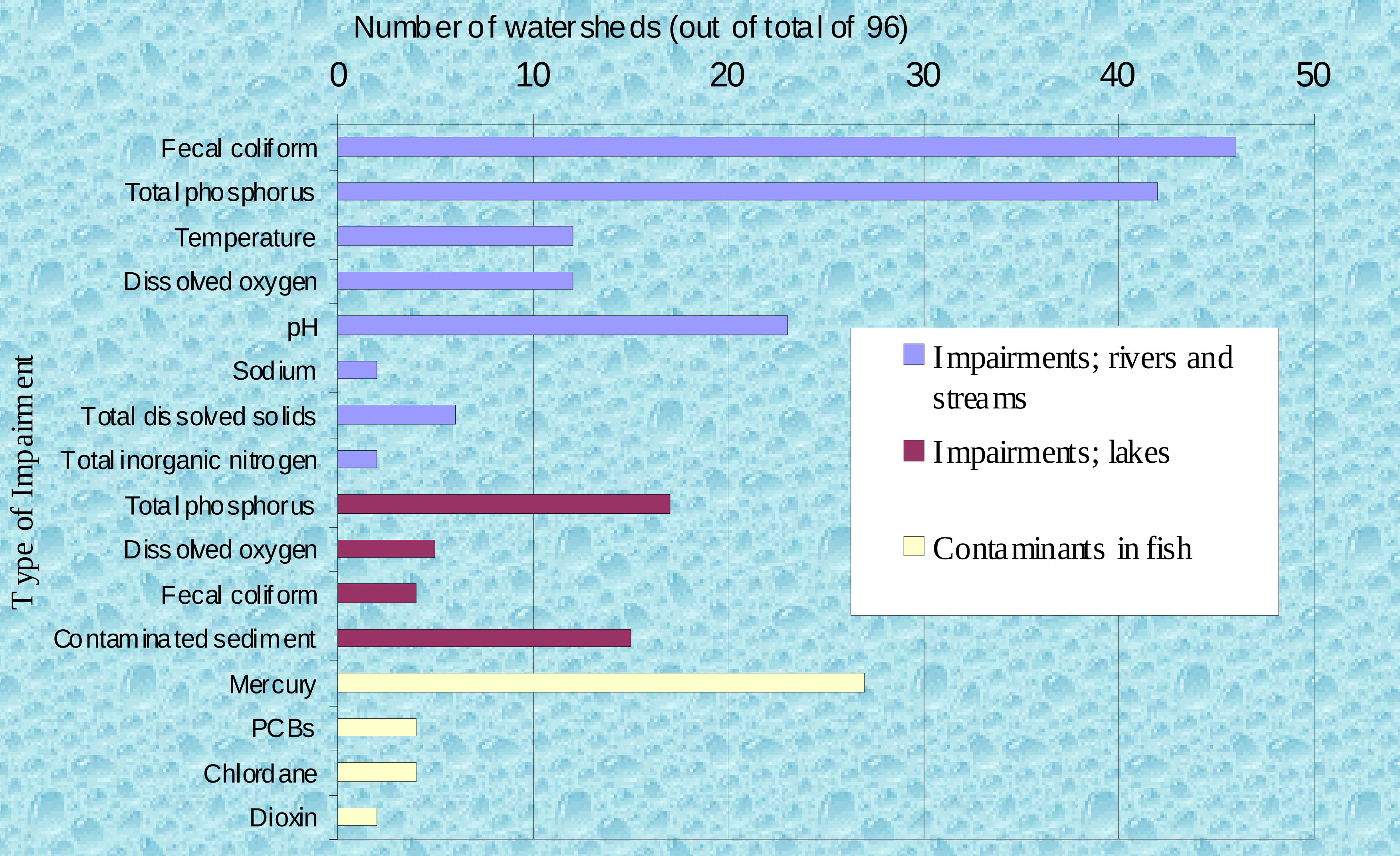
    24 µg/l chl-a seasonal mean, OR

    32 µg/l chl-a 2-week mean
  - Periphyton density:

    150 mg/m² chl-a seasonal mean, OR

    200 mg/m² chl-a single sample event

Impairments in Watersheds (1998 303(d) List)



Nutrient TMDLs Development

- A wide range of water quality models were used statewide to develop Nutrient TMDLs
- Water Quality Data requirements is depended on model selection
- Water Quality Models may require extensive set of data
- Most, if not all, complex (detailed) water quality models require additional data beyond the data collected under routine monitoring and data collection programs

Stream and Lake Phosphorus TMDLs So far:

- Completed:
  - 25 stream phosphorus TMDLs
  - 43 lake phosphorus TMDLs
- Complete by Summer 2006:
  - 55 phosphorus impaired waterbodies within the Passaic and Raritan Basins (WMAs 3,4,6,8,9,and 10) Omni Env.
- Complete by Summer 2008
  - Nutrient TMDLs for the NY/NJ Harbor Estuary. Addressing lower Passaic and Raritan Rivers, Hackensack and Rahway Rivers and Newark Bay… HydroQual
- Additional water quality sampling was conducted in 2004-5 for Rancocas and Pennsauken CK for purpose of developing TP TMDLs

Water Quality Models for TMDLs

- Watershed Models (pollutant load):

  Used to estimate pollutant load to a waterbody

  ex. GWLF, loading using export coefficients
- Waterbody models (pollutant response):

  Used to predict the pollutant concentrations in the waterbody as a function of incoming loads

  ex. WASP, HSPF
- Water Quality models:
  - Mechanistic (physical) Models: model the underlying processes that affect the pollutant concentration in the waterbody
  - Statistical (empirical) Models: Use statistical techniques to discern relationships underlying measured data

Water Quality Models for TMDLs

- Model selection is based in part on:
  - What is the nature of the source - PS, NPS, both, unknown?
  - What is the geographic extent of the TMDL? Accuracy required?
  - Are the stretches of waterbody segments continuous, or discontinuous?
  - Time and Resource considerations
  - One or more TMDLs per parameter per area?
  - Data needs?

Overview of Data Collected for Nutrient TMDL Study

- Flow Conditions
  - low flows, high flows, and ambient flows
- Nutrient Chemistry
  - in-situ and laboratory analysis
- Biology
  - aqueous and biomass
- Dissolved Oxygen
  - grab and diurnal

Water Quality Parameters List

(Freshwater)

- Flow
- Temperature
- pH & Diurnal pH
- Dissolved Oxygen (DO) & Diurnal Dissolved Oxygen
- Ammonia
- Kjeldahl Nitrogen (TKN)
- Nitrate + Nitrite
- Total & Dissolved Reactive Phosphorus
- Silica
- Chlorophyll-a (Phytoplankton & Periphyton)
- CBOD5
- Total Suspended Solids (TSS)
- Total Dissolved Solids (TDS)
- Total Organic Carbon (TOC)
- Sediment Oxygen Demand (SOD)
- Iron
- Secchi Transparency
- Turbidity
- Alkalinity

Water Quality Data Sources

- Ambient Surface Water Monitoring Network (NJDEP/USGS)
- Diurnal dissolved oxygen data collected by NJDEP and USGS
- Ambient Biomonitoring Network
- Phosphorus Evaluation Studies
- Point Source Loading and Attenuation Study
- NY-NJ Harbor Estuary Program & Delaware Estuary Program
- Clean Lakes Program (eutrophication study)
- Data submission by stakeholder

Developing Lake Nutrient TMDL using Reckhow Model

- Empirical models used to relate annual phosphorus load to steady-state in-lake concentration
- Equations derived from simplified mass balances fitted to large datasets of actual lake measurements
- Resulting regressions applied to lakes that fit within range of morphology, hydrology and loading of lakes in model database

Developing Lake Nutrient TMDL using Reckhow Model – data requirements

- Total inflow or outflow (Q) and Lake surface area (As)
  - total inflow from historic study
  - surface area from lakes GIS coverage
- Quantification of current total phosphorus loading to the lake
  - Mass Loading from runoff using loading coefficients (Unit Areal Load)

$$L = (\text{loading per unit area})\ (\text{area})$$

- Detention time (DT) and mean depth (Dm) to check the applicability of the model.
- Total phosphorus data for model validation

Developing Stream Nutrient TMDL using Flow-Integrated Reduction of Exceedances (FIRE)

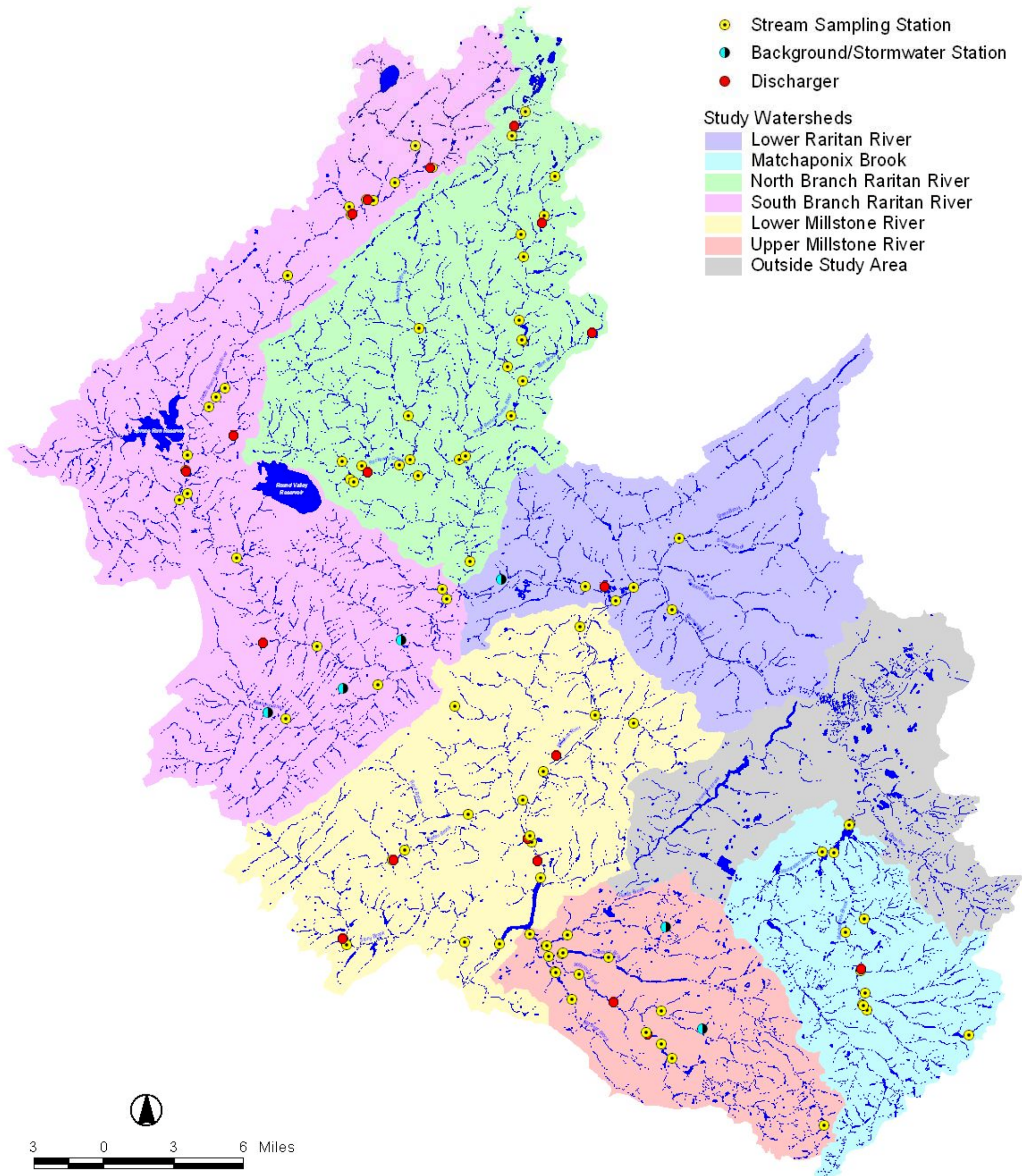
- Has successfully been applied to 25 total phosphorus TMDLs
- TMDL target over a range of flows
- Percent reduction of existing loadings to attain the water quality standard (TMDL)
- Explicit margin of safety (based on statistical uncertainty)
- Only flow and total phosphorus concentrations needed to run FIRE

Case Study

Raritan River Basin Nutrient TMDL Study

- Raritan River Basin
  - Over 80 wastewater treatment plant
  - Highly varying land uses generate nonpoint source loads
- Streams “Impaired” for Phosphorus and other parameters (temperature, pH, TSS)
  - TMDLs Required
- Must Determine Targets / Endpoints
  - Where is phosphorus causing impairment?
  - What phosphorus reductions would fix the problem?
  - What other measure would address the problem?
  - What is natural condition?

Raritan River Basin Nutrient TMDL Study



Raritan River Basin Nutrient TMDL Study

- Identify nutrient impairments, critical locations, and water quality targets for a watershed-based nutrient TMDL;
- Nutrient source assessment- identify &estimate sources;
- Develop, calibrate, and verify watershed models to relate nutrient sources to water quality targets at critical locations;
- Establish scientifically-defensible load allocation; and
- Provide the basis for TMDL development of other conventional pollutant impairments as enabled through the monitoring and modeling work for the nutrient TMDLs

Raritan River Basin Nutrient TMDL Extensive Monitoring Program in 2004

- Monitoring Objectives
  - **Identify nutrient impairments and critical locations**
    - Diurnal DO, pH, temperature
    - Phytoplankton (chl-a)
    - Periphyton (chl-a)
  - **Assess nature and cause of other conventional impairments (DO, pH, TSS, temperature)**
    - Ambient stream data under variety of flows
    - Stormwater data to characterize nonpoint sources
    - STP effluent data to characterize point sources
  - **Develop, calibrate and verify watershed models**
    - Algae, Phytoplankton, Periphyton,
    - Diurnal DO/pH/temperature/DO saturation
    - Stream Chemistry samples- pH, temperature, DO, alkalinity, CBOD5, P-series, N-series, iron, TDS, TSS, TOC, turbidity

Raritan River Basin Nutrient TMDL Monitoring Parameters

- In Situ
  - pH, temperature, dissolved oxygen, flow (stream and STP)
  - Diurnal meters @ 41 stream and lake locations
- Laboratory
  - P-series, N-series, TDS, TSS, alkalinity, $CBOD_5$ (stream and STP)
  - Chlorophyll-a (Phytoplankton and Periphyton), iron, and turbidity (stream only)

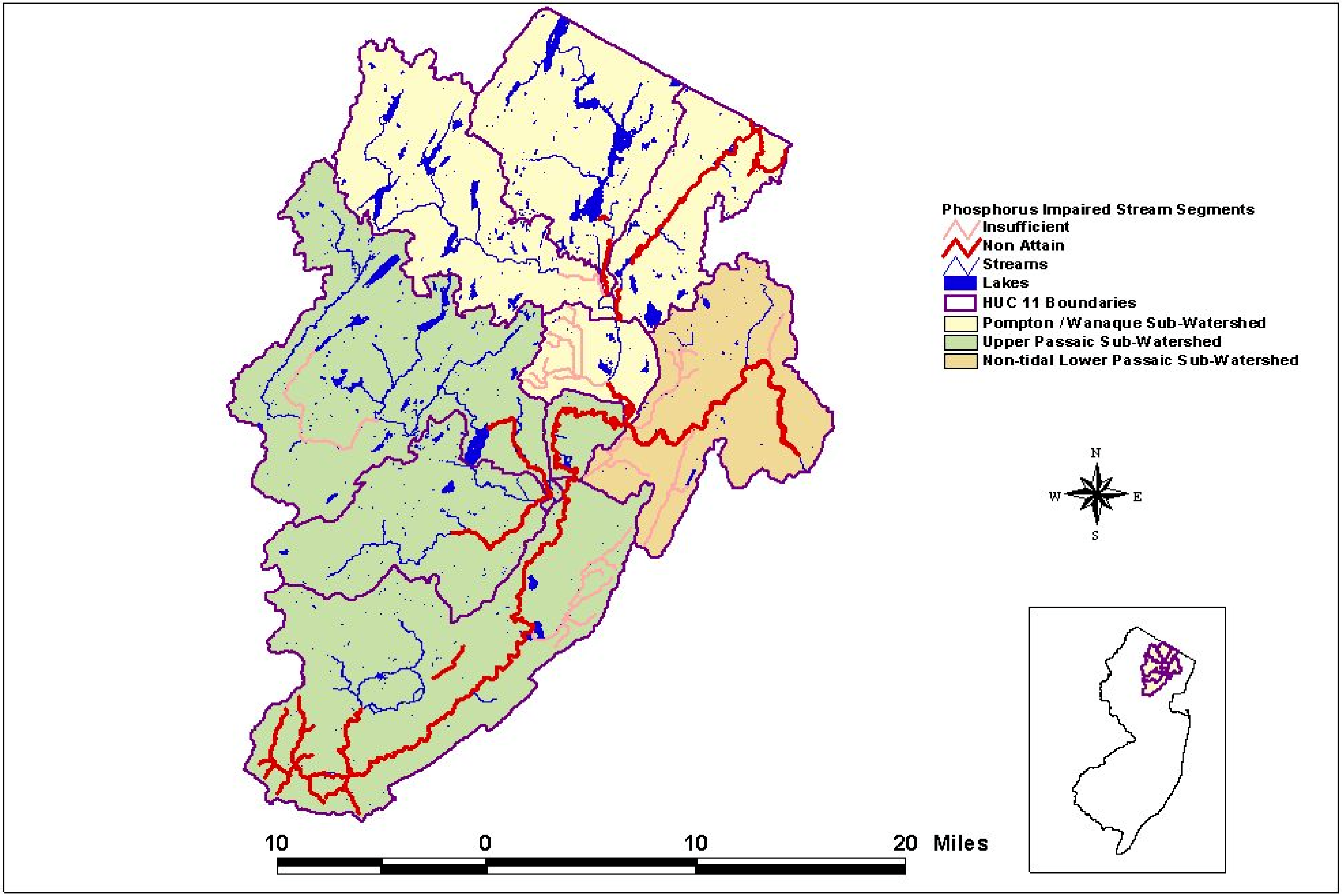
Raritan River Basin Nutrient TMDL Monitoring Networks

- Streams and “in-line” Lakes
  - 32 Stream Stations
  - 9 Lake Inlet Stations
  - 9 Lake Stations
  - 9 Lake Outlet Stations
  - 6 Tributary Stations
  - 9 Baseflow Stations
- 6 Stormwater Stations
- 13 STP Stations
  - all major municipal DSWs and selected minor

Raritan River Basin Nutrient TMDL Stream Monitoring Events

- 3 Low-flow Events (2 days each) @ 77 stations (including 12 STPs)
- 3 High-flow Events (2 days each) @ 69 stations (including 13 STPs)
- 8 Ambient Events @ 41 stations
- 3 Diurnal Events @ 41 stations
- 3 Stormwater Events @ 6 stations

Passaic River TMDL Subbasin Delineations
Phosphorus Impaired Stream Segments



Passaic River Basin Sampling Plan

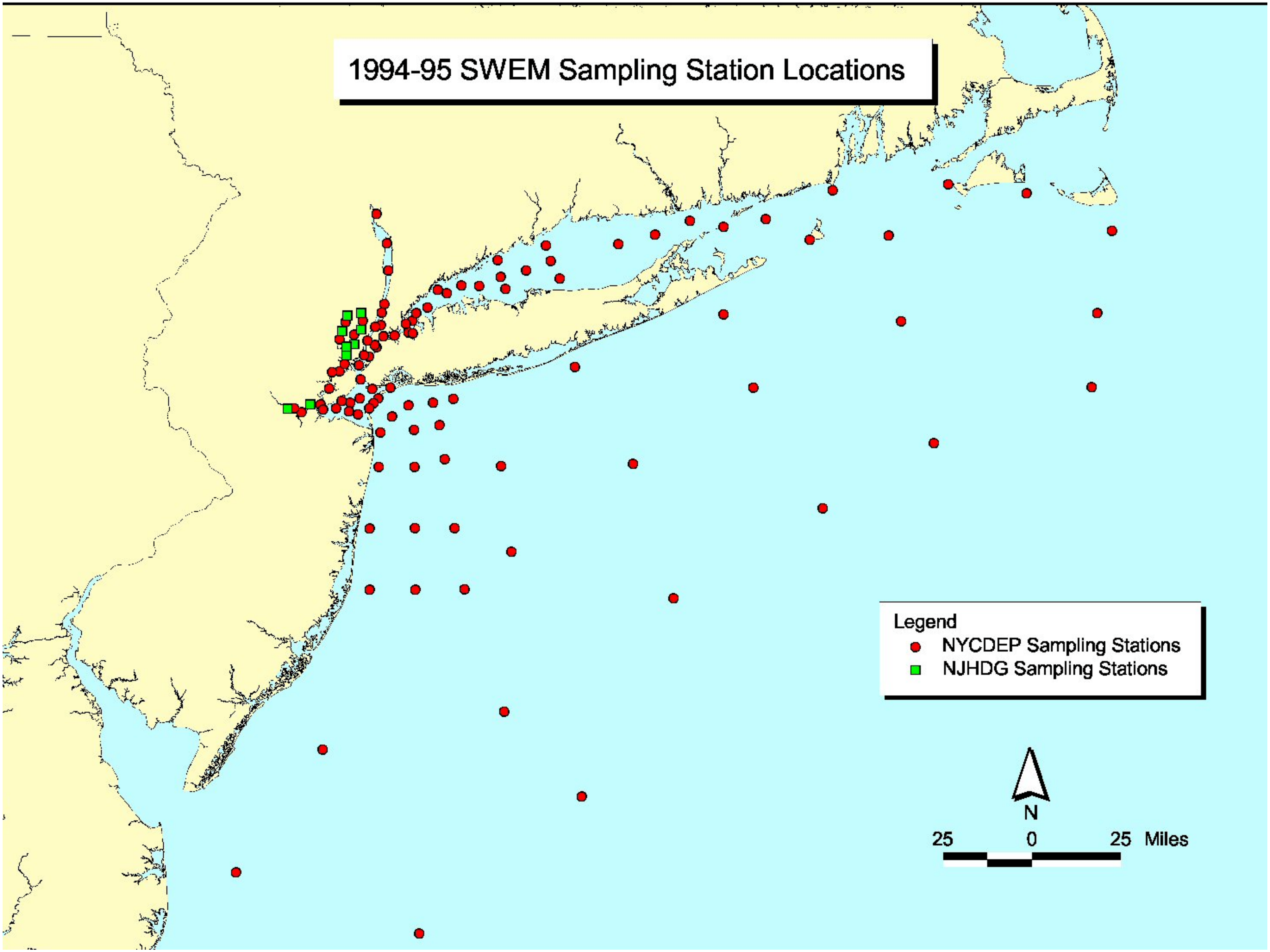
- 6 Characterization Monitoring Locations
  - 20 events
  - weekly sampling
- 30 Stream Monitoring Locations
  - 3 two-day events for model calibration (low flow)
  - 3 two-day events for model calibration (high flow)
- 24 STP Monitoring Locations
  - 6 events (24-hour composites) for model calibration
- 20 Diurnal Dissolved Oxygen Monitoring Locations
  - 3 two-day, low flow events
- 8 Baseflow / Reference Monitoring Locations
  - 3 one-day dry weather events
- 20 Biomass Monitoring Locations
  - 4 one-day events
- 8 Stormwater Monitoring Locations
  - 3 storm events
  - 4 samples/storm/location

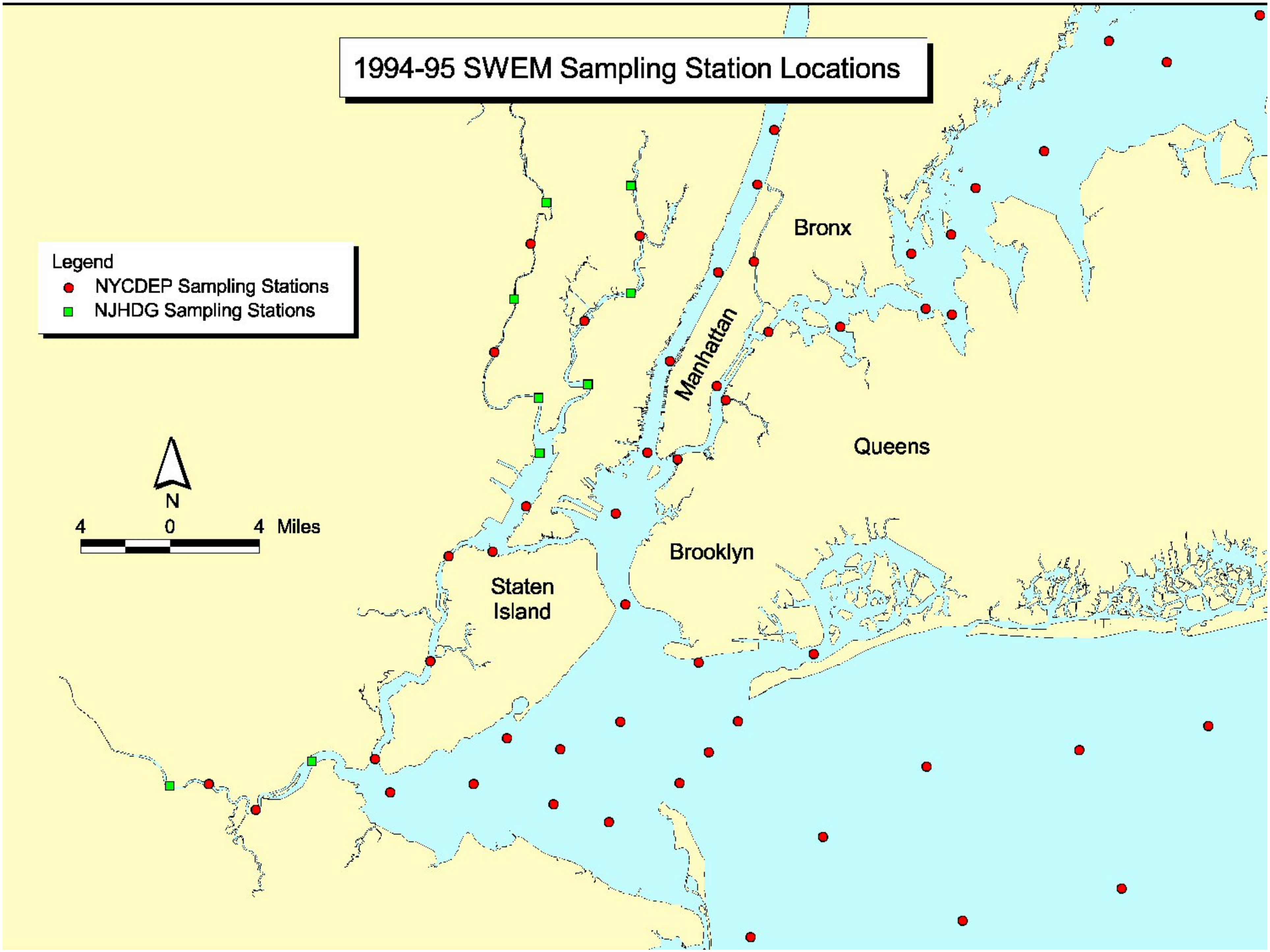
NY/NJ Harbor Estuary
Extent of Data Used for Nutrient TMDL

- 1994-95 NYCDEP Synoptic Sampling for SWEM
- 1994-95 New Jersey Harbor Dischargers Group
- 1994-95 NYCDEP Harbor Survey
- 1994-95 CTDEP Routine Monitoring
- 1993-94 Interstate Sanitation Commission/HEP
- 1988-89 LISS/NYCDEP Monitoring
- 1988-1994 Studies Conducted in NJ Waters

1994-95 NYCDEP Synoptic Sampling for SWEM

- Physical Oceanography
- Ambient Water Quality
- Sediment Surveys
- Water Column Primary Productivity
- Point Source Monitoring
- Atmospheric Deposition


1994-95 SWEM Sampling Station Locations
Legend
NYCDEP Sampling Stations
NJHDG Sampling Stations
N
25
0
25
Miles


1994-95 SWEM Sampling Station Locations
Legend
NYCDEP Sampling Stations
NJHDG Sampling Stations
N
4 0 4 Miles
Bronx
Manhattan
Queens
Brooklyn
Staten Island

Conclusions

- Routine Monitoring Programs may not fulfill all data needs for detailed TMDL modeling effort; however, more TMDLs are developed nationwide using simple methodology and using only data collected under routine monitoring networks
- Good Coordination between Monitoring and TMDL Programs is essential for optimal use of data
- Diurnal dissolved oxygen data is proof to be one of the most important parameters in evaluating nutrient impairments when sampled in the right time

Conclusions

- Chlorophyll-a (Phytoplankton & Periphyton) data could be misleading- sampling is highly depended on flow conditions not just season
- Field notes at the time of sampling is proof to be very valuable when assessing data
- Stream Survey is critical component of a successful TMDL study

Questions?