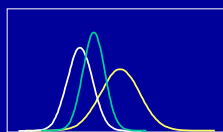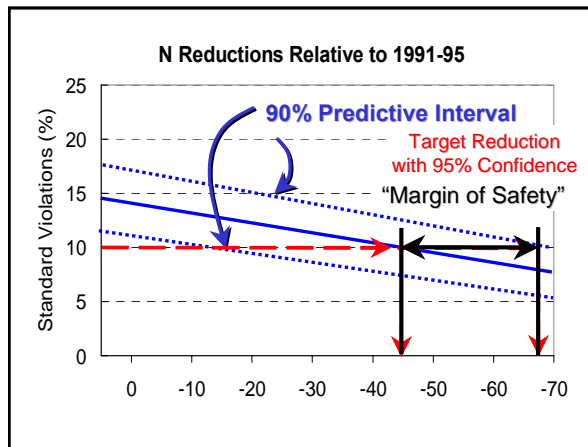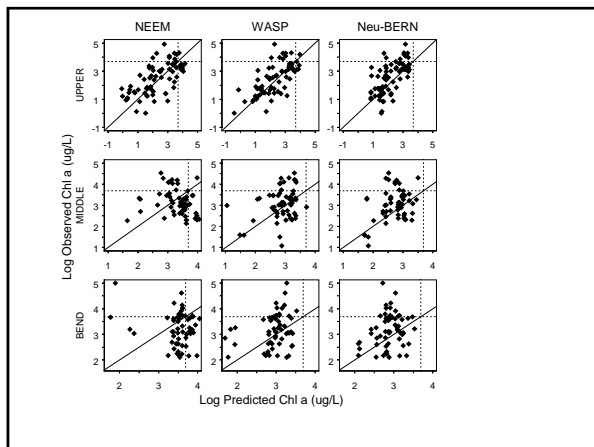# Adaptive Implementation Modeling and Monitoring for TMDL Refinement

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Project Objectives

• **Develop an adaptive implementation modeling and monitoring strategy (AIMMS) for TMDL improvement.**

• **Apply and evaluate AIMMS on the Neuse Estuary TMDL in North Carolina.**

NEEM   WASP   Neu-BERN

Log Observed Chl a (ug/L)

UPPER

MIDDLE

BEND

Log Predicted Chl a (ug/L)

N Reductions Relative to 1991-95

Standard Violations (%)

90% Predictive Interval

Target Reduction with 95% Confidence

"Margin of Safety"

We need predictions to guide TMDL decision making, so what should we do?
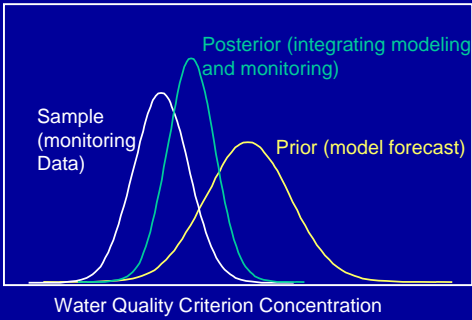
Adaptive Implementation

We can "learn while doing;" that is, we can observe how the real system (the actual waterbody) responds, and then use that information to augment and improve the prediction for the modeled system.

How might we conduct adaptive implementation?

• *Step 1:* To define the allowable pollutant load (the TMDL), a water quality model is applied; the forecast from this model provides the initial estimate of how the waterbody will respond to the pollutant load reductions required in the TMDL.

• *Step 2:* After the TMDL is implemented (i.e., nonpoint & point source pollution controls in place), a *properly-designed* monitoring & research program is established; this program can be focused on assessment of particular pollutant controls and/or on overall waterbody compliance with standards.

• *Step 3:* The pre-implementation model forecast (from step 1) is combined with the post-implementation monitoring (from step 2); this provides the best overall estimate of TMDL success and provides the basis for any necessary revisions to the TMDL.

Adaptive Implementation: Bayesian Analysis

Posterior (integrating modeling and monitoring)

Sample (monitoring Data)

Prior (model forecast)
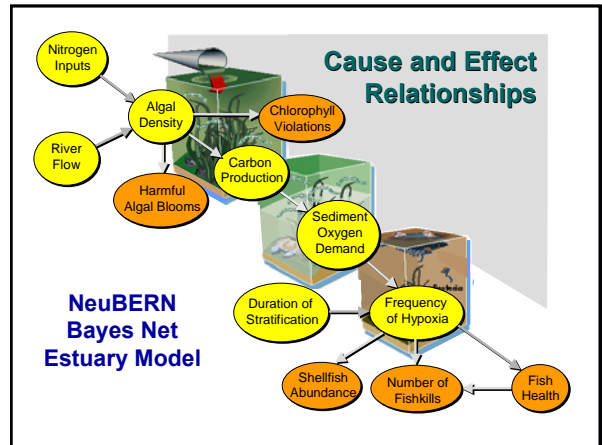
Water Quality Criterion Concentration

Post (TMDL) Implementation Questions

• Has compliance with the water quality standard been achieved?

• If compliance has not been achieved, what pollutant reduction actions did not respond as predicted?
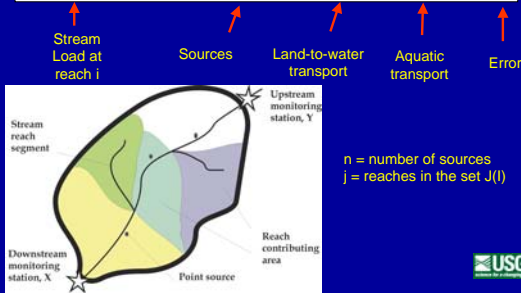

Determining the specific aspects (Who does what? Where?) of the TMDL implementation plan, and designing the post-implementation monitoring, are important decisions:

• Should TMDL implementation be focused on the most cost-effective pollutant reduction strategies?

• Should implementation be directed toward activities that provide learning opportunities?

Cause and Effect Relationships

NeuBERN Bayes Net Estuary Model

Nitrogen Inputs · Algal Density · Chlorophyll Violations · River Flow · Carbon Production · Harmful Algal Blooms · Sediment Oxygen Demand · Duration of Stratification · Frequency of Hypoxia · Shellfish Abundance · Number of Fishkills · Fish Health

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Neuse SPARROW Model

$$\text{TN Load}_i = \sum_{j \in J(i)} \sum_{n=1}^{N} \beta_n S_{n,j} \exp(-\alpha' Z_j) H^r_{i,j} H^S_{i,j}\ \varepsilon_i$$

Stream Load at reach i — Sources — Land-to-water transport — Aquatic transport — Error

n = number of sources
j = reaches in the set J(I)

Upstream monitoring station, Y · Stream reach segment · Reach contributing area · Downstream monitoring station, X · Point source

USGS

Tasks Completed or Underway

• NeuBERN and SPARROW models have been linked within a Bayesian framework (WinBUGS)

• NeuBERN is being re-specified to add more mechanism.

• SPARROW has been re-calibrated to address spatial correlation and improve parameter estimators.

Issues to Address in Year 2

• Model time step

• Representing land use (pollutant load) change in SPARROW

• Addressing lags in system response – use of observational data

• Role of stakeholders

• Monitoring program design (sensitivity analysis)

Expected Outcomes

• Re-assessment of the Neuse nitrogen TMDL

• Development of guidelines and procedures for adaptive implementation of TMDLs

• Determination of effective roles for stakeholders