# Is Scientific Knowledge Sufficient for Environmental Decision Making?

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## Is Scientific Knowledge Sufficient for Environmental Decision Making?

*There is almost always enough scientific knowledge to make an informed decision*.

## ***When*** **is Scientific Knowledge Sufficient for Environmental Decision Making?**

*It depends…*

*on the amount of scientific uncertainty and the attitude toward risk.*

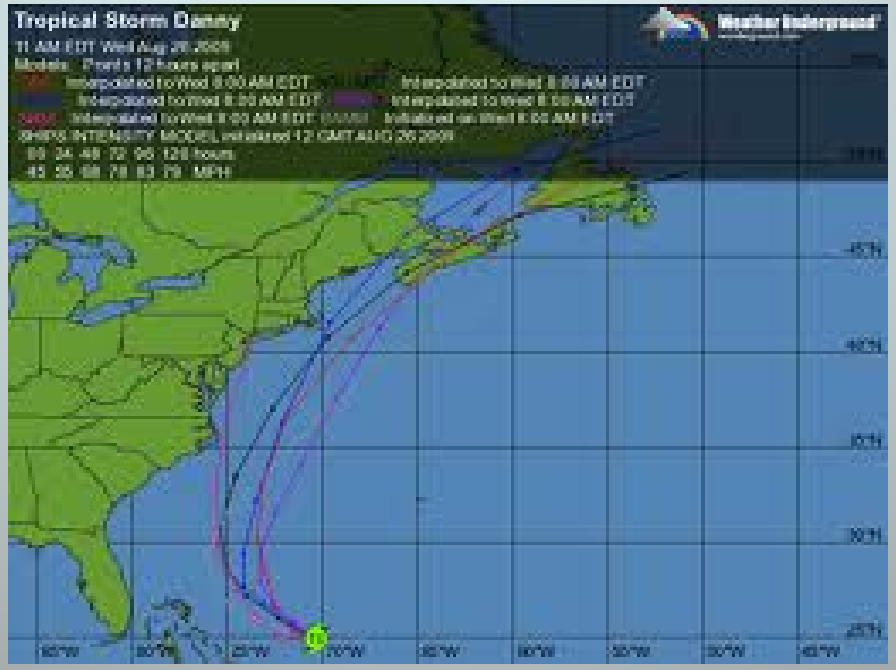
How do/should we make decisions when knowledge is uncertain?

How can knowledge of scientific uncertainty improve decision making?

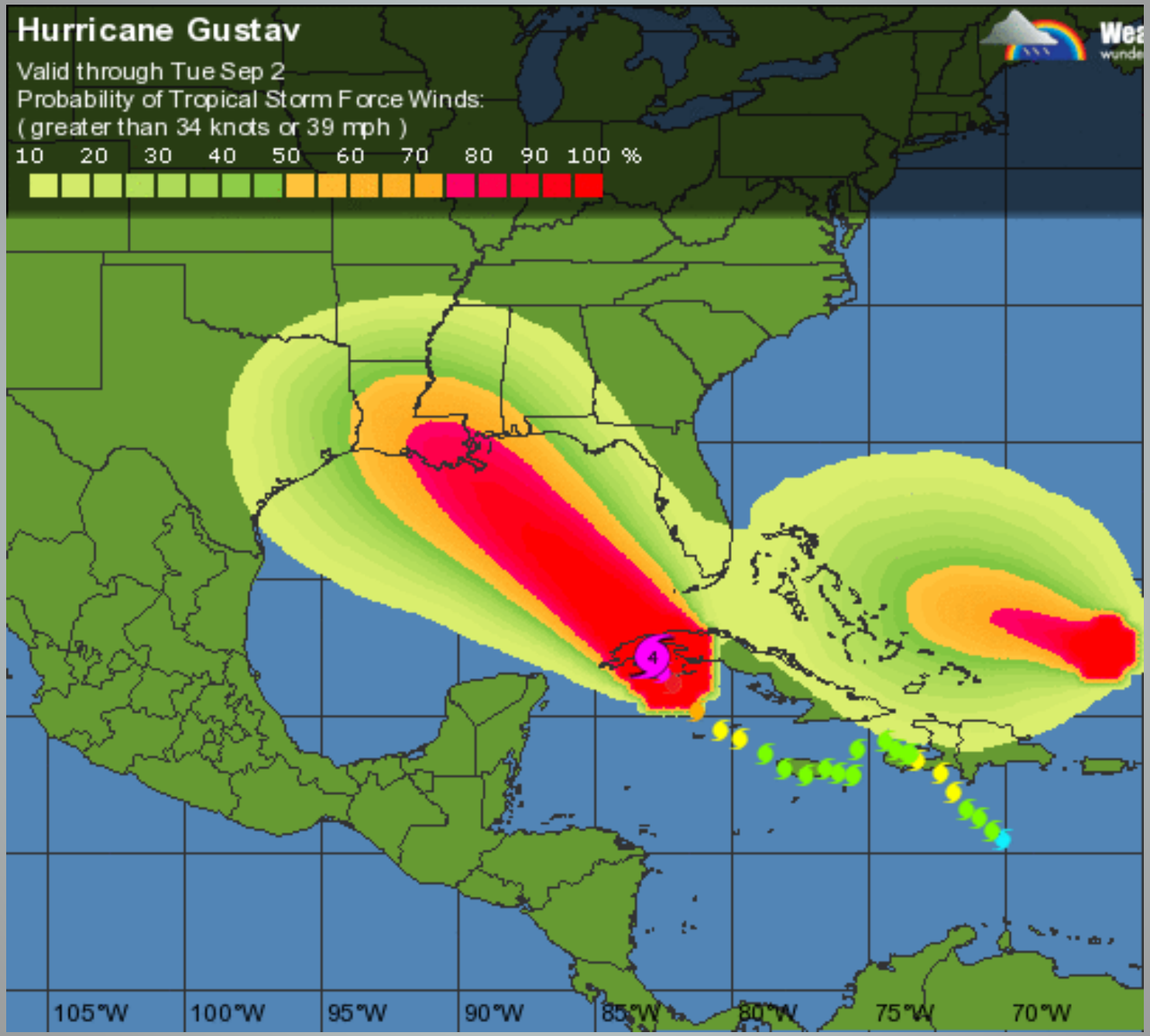

How do you want it – the crystal mumbo-jumbo or statistical probability?


REORGANIZE
NO
TOMORROW
SIT ON IT
YES
TODAY
PASS THE BUCK
MAYBE


A. BACALL
"We're expecting stocks to rally but we don't know which ones and when."


Tropical Storm Danny
Weather Underground


8 DAY OUTLOOK
FOX 8 NEWS
TUE WED THU FRI SAT SUN MON TUE
49 46 58 73 75 73 70 70
35 34 48 53 55 53 55
Much Warmer
80% 70% 40% 50%
FOX8.com


Hurricane Gustav
Valid through Tue Sep 2
Probability of Tropical Storm Force Winds:
( greater than 34 knots or 39 mph )
10 20 30 40 50 60 70 80 90 100 %
105°W
100°W
95°W
90°W
85°W
80°W
75°W
70°W

# Two essential elements that inform decision making:

- Probability model – this characterizes (scientific) knowledge; for example, this represents the prediction from a water quality model. Since it is probabilistic, it must include uncertainty analysis.

- Utility function – this characterizes the values of the decision makers (or stakeholders).

In theory, the *optimal* decision is found by integrating the probability model with the utility function.

This integration weights the utility (value) function by the probability of various outcomes.

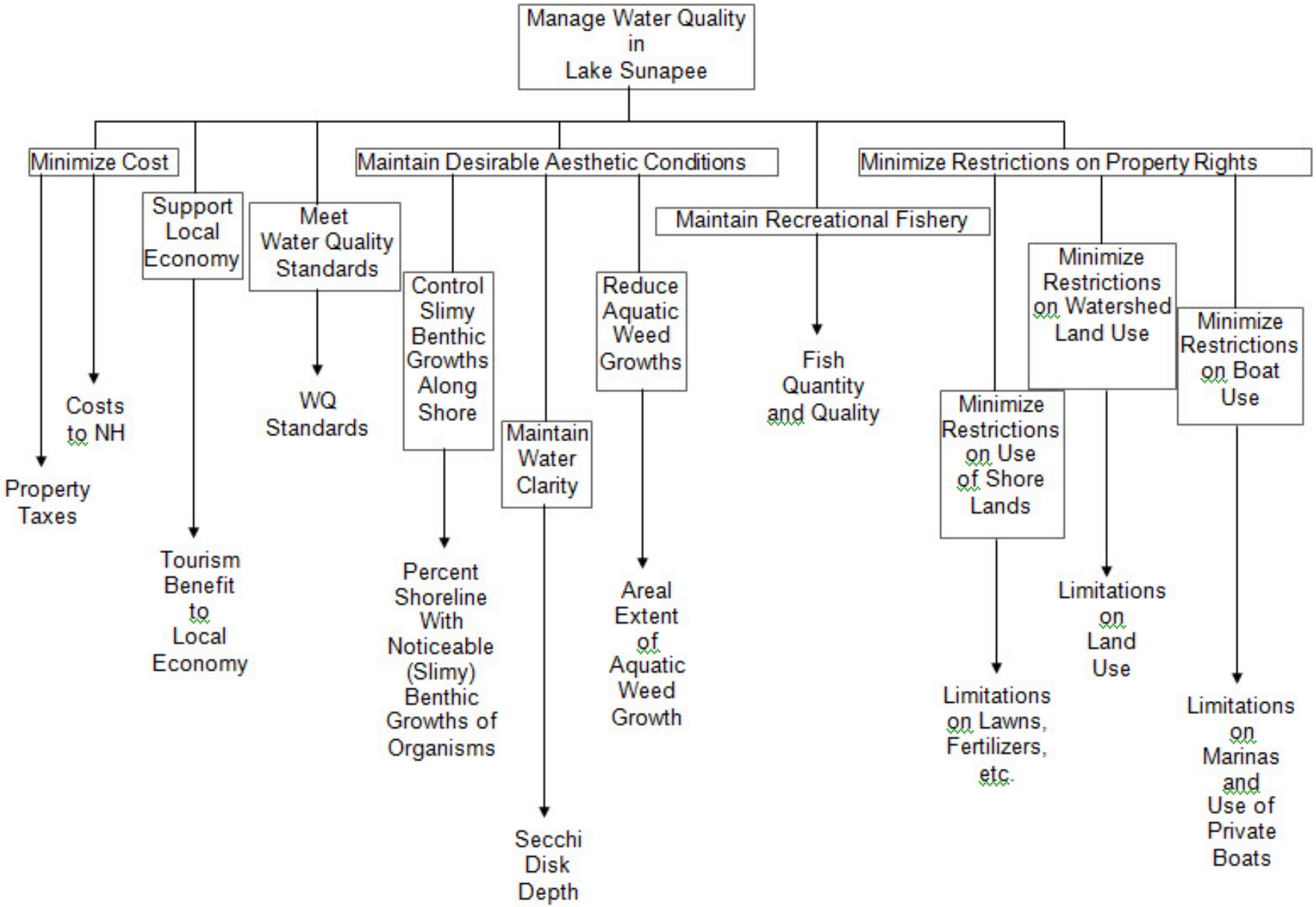
This allows a risk-averse decision maker (through the utility function) to hedge against large losses.

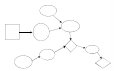
Only when the uncertainty in the scientific assessment (e.g., a WQ model) is determined, can the decision maker explicitly consider attitude toward risk.

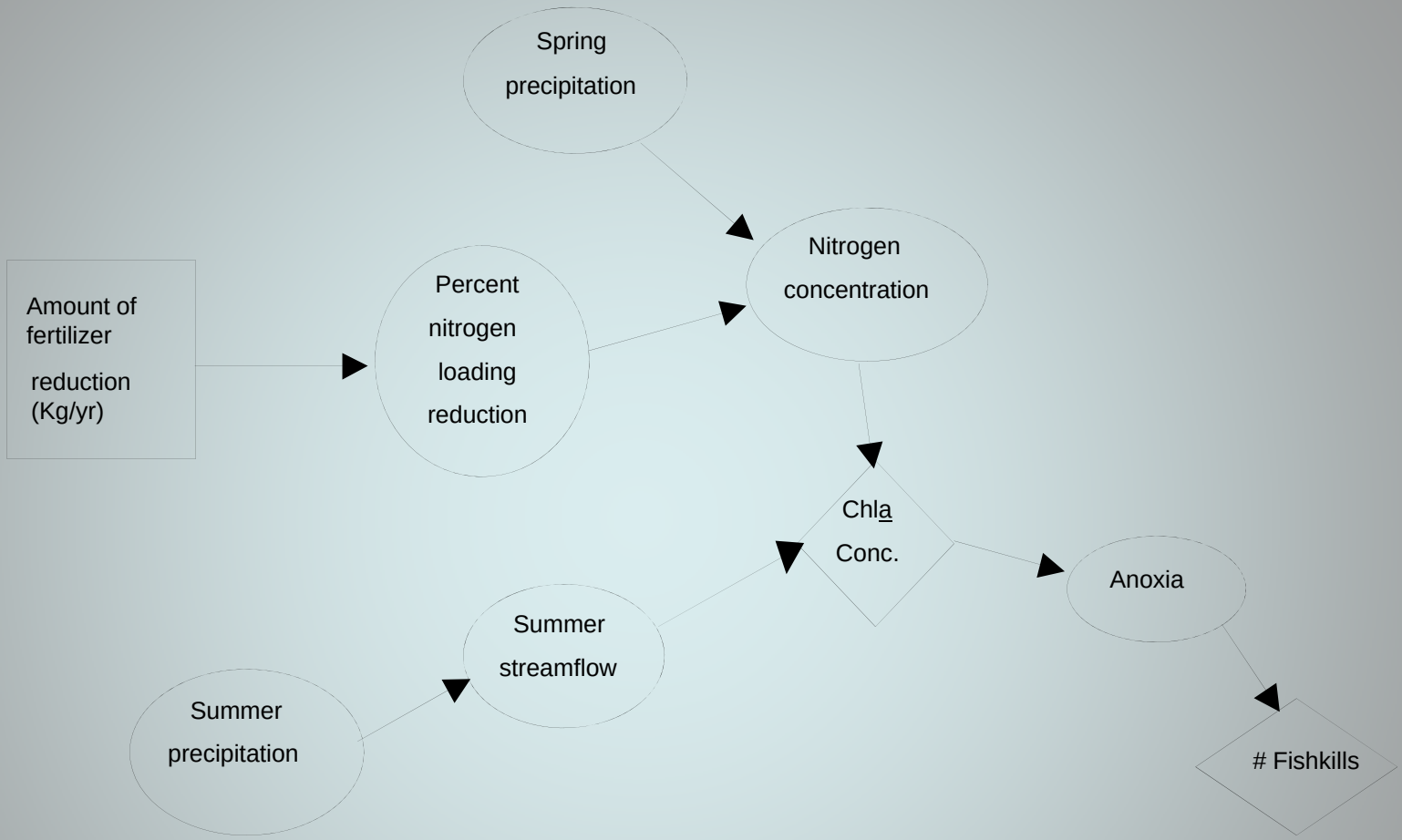
# Decisions Involving Many Issues: Lake Sunapee Eutrophication

Most interesting decisions involve multiple objectives and multiple endpoints or multiple outcomes of interest, such as overall costs, distribution of costs, environmental impacts, human health impacts, etc.

To address these decisions, we first need to identify all objectives relevant to the decision, and the measures of effectiveness (or “attributes”) that indicate the degree to which each objective is achieved by a proposed management action.


Manage Water Quality in Lake Sunapee
Minimize Cost
Property Taxes
Costs to NH
Support Local Economy
Tourism Benefit to Local Economy
Meet Water Quality Standards
WQ Standards
Maintain Desirable Aesthetic Conditions
Control Slimy Benthic Growths Along Shore
Percent Shoreline With Noticeable (Slimy) Benthic Growths of Organisms
Maintain Water Clarity
Secchi Disk Depth
Reduce Aquatic Weed Growths
Areal Extent of Aquatic Weed Growth
Maintain Recreational Fishery
Fish Quantity and Quality
Minimize Restrictions on Property Rights
Minimize Restrictions on Use of Shore Lands
Limitations on Lawns, Fertilizers, etc.
Minimize Restrictions on Watershed Land Use
Limitations on Land Use
Minimize Restrictions on Boat Use
Limitations on Marinas and Use of Private Boats

| | Attributes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Management Options** | Property Taxes | Costs to State of NH | Tourism Benefit to Local Economy | WQ Standards | Percent Shoreline With Noticeable Bottom Algal Growths | Secchi Disk Depth | Areal Extent of Aquatic Weed Growth | Fish Quantity and Quality | Limitations on Lawns, Fertilizers, etc. | Limitations on Land Use | Limitations on Marinas and Use of Private Boats |
| Require Agricultural BMPs | | | | | | | | | | | |
| Require Cluster Housing | | | | | | | | | | | |
| Limit Impervious Area | | | | | | | | | | | |
| Limit Shoreland Lawn Area | | | | | | | | | | | |
| Restrict Shoreland Fertilizer Application | | | |  | | | | | | | |
| Limit Marina Activity | | | | | | | | | | | |
| Extend Sewer Connections | | | | | | | | | | | |
| Implement Stormwater Management Programs | | | | | | | | | | | |


Spring precipitation
Amount of fertilizer reduction (Kg/yr)
Percent nitrogen loading reduction
Nitrogen concentration
Chla Conc.
Anoxia
Summer streamflow
Summer precipitation
# Fishkills

| | Attributes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Management Options** | Property Taxes | Costs to State of NH | Tourism Benefit to Local Economy | WQ Standards | Percent Shoreline With Noticeable Bottom Algal Growths | Secchi Disk Depth | Areal Extent of Aquatic Weed Growth | Fish Quantity and Quality | Limitations on Lawns, Fertilizers, etc. | Limitations on Land Use | Limitations on Marinas and Use of Private Boats |
| Require Agricultural BMPs | | | | | | | | | | | |
| Require Cluster Housing | | | | | | | | | | | |
| Limit Impervious Area | | | | | | | | | | | |
| Limit Shoreland Lawn Area | | | | | | | | | | | |
| Restrict Shoreland Fertilizer Application | | | |  | | | | | | | |
| Limit Marina Activity | | | | | | | | | | | |
| Extend Sewer Connections | | | | | | | | | | | |
| Implement Stormwater Management Programs | | | | | | | | | | | |

# What will decision analysis achieve?

A decision analytic framework facilitates focus on basic objectives, on measures to assess attainment of objectives, and on the evaluation of management options with awareness of uncertainty.

In many cases, decision analysis should not be expected to provide the optimal management solution. Rather, the decision analytic process should help decision makers reach decisions themselves by clarifying issues and focusing attention on key factors affecting the decision.

# Research & Application Challenges

How can we quantify prediction uncertainty for complex models?

How can we present uncertain science to decision makers and stakeholders so that they make better decisions than they would in the absence of knowledge of uncertainty?

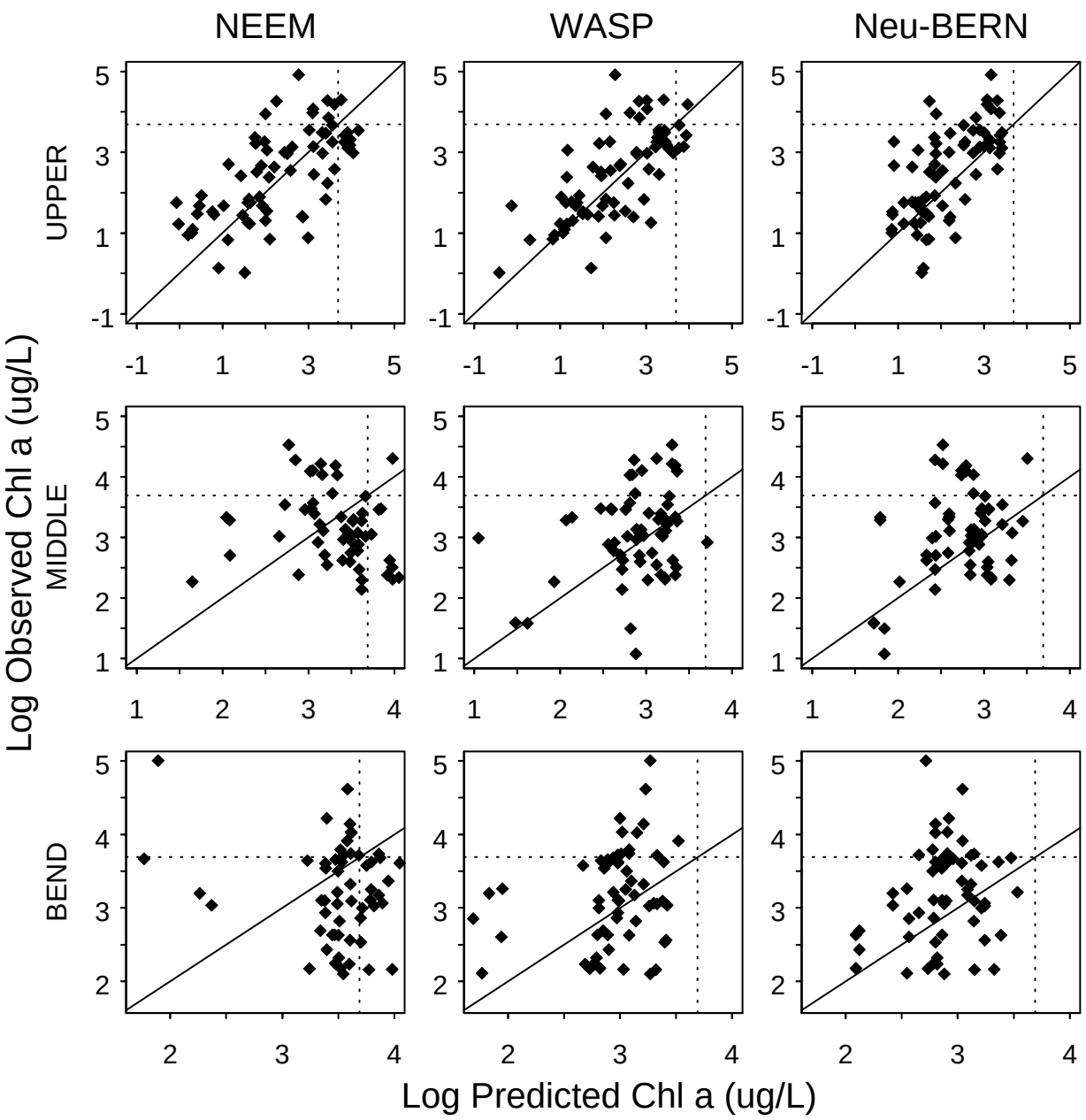
"There's a 50% chance of rain, so I only watered half the lawn."

# Neuse Estuary TMDL

- **Sum of allowable loads to meet State water quality standards**
  - **Wasteload allocations from point sources**
  - **Load allocations from nonpoint sources and natural background**
- **Margin of safety (MOS)**

# Three Different Models were Applied

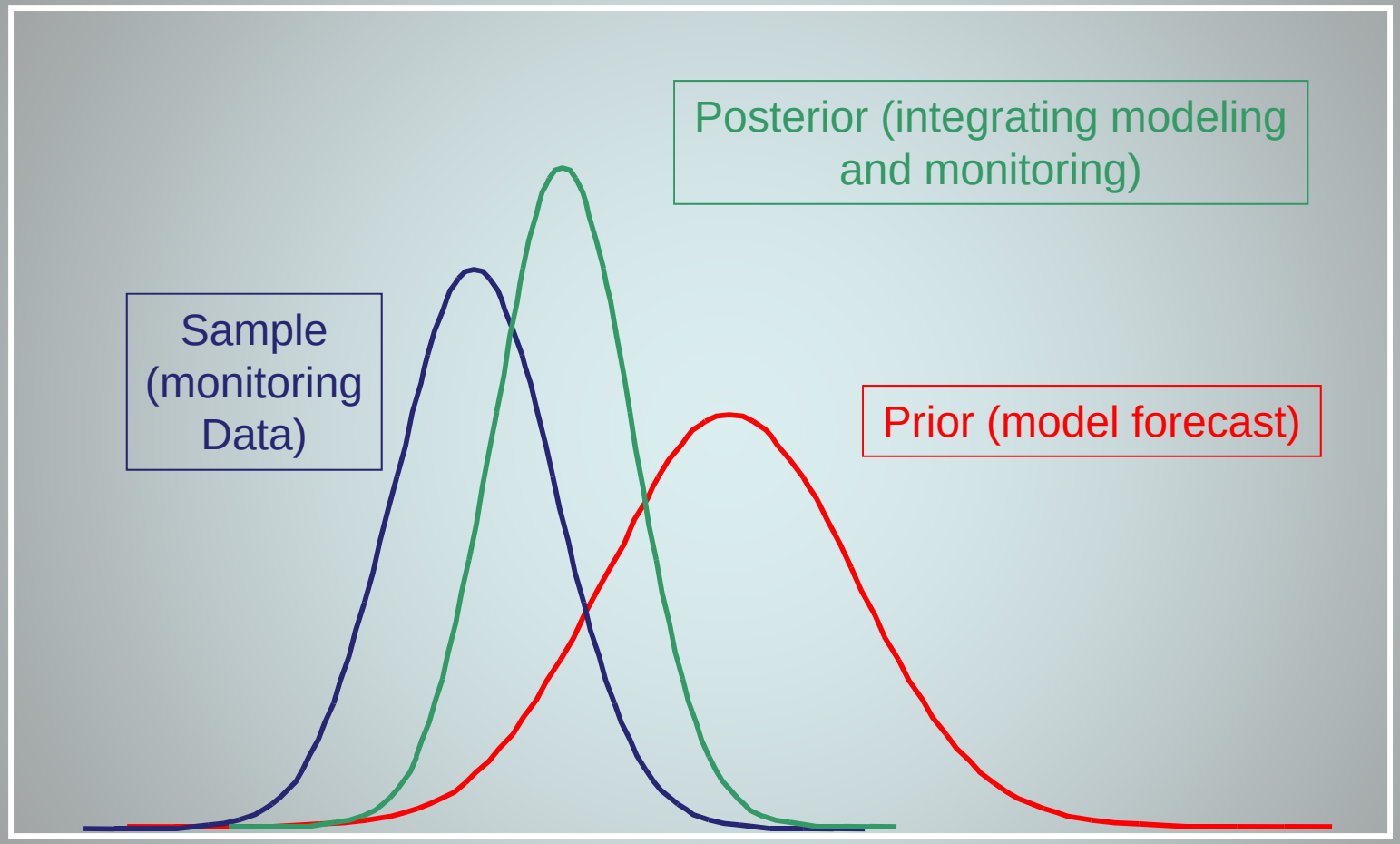
- CE-QUAL-W2 (NEEM; 2-dimensional)
- EFDC-WASP (3-dimensional)
- A Probability Network Model (Neu-BERN)


NEEM
WASP
Neu-BERN
UPPER
MIDDLE
BEND
Log Observed Chl a (ug/L)
Log Predicted Chl a (ug/L)

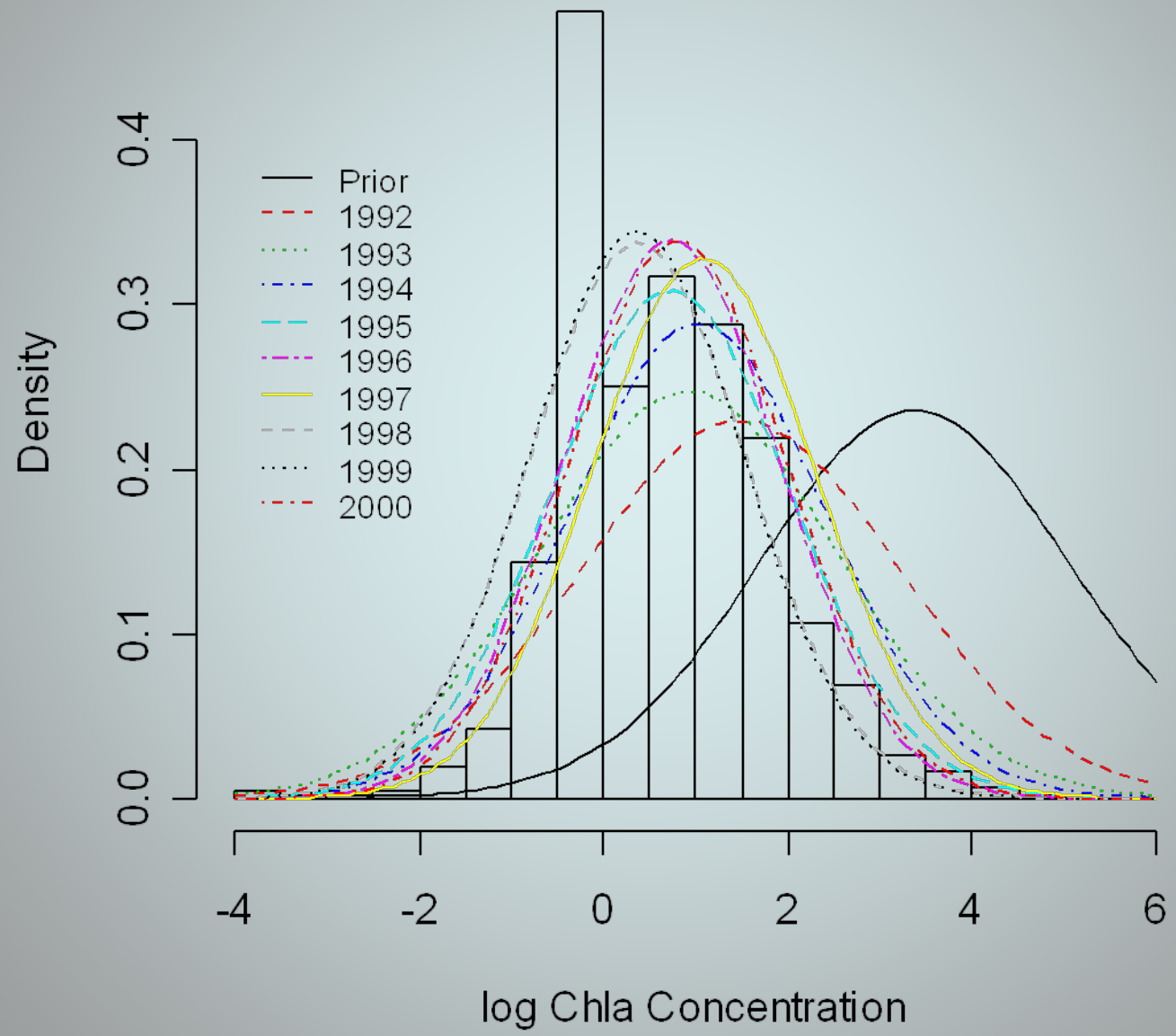
## *Given the uncertainty, how do we decide?*

**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.**

# Adaptive Implementation: Bayesian Analysis



# Neuse Estuary Chlorophyll a



# 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?**

# What do we do if the initial post-implementation assessment still indicates noncompliance?

- Improve the model using the new post-implementation data.

- Continue with another round of pollutant load reductions, guided by the improved model.

# A Recommendation for Improvements in the TMDL Implementation Process

Allow two forms of TMDL implementation:

- Standard (or conventional)
- Adaptive

Standard implementation (SI) of a TMDL should occur when the level of certainty regarding causes, remedies, and water body condition is high, or when the costs of making an error in the face of uncertainty are deemed acceptable.

Adaptive Implementation (AI) should occur where uncertainty is substantial and the costs of error are deemed significant.

# How can we make adaptive implementation work?

• An organization is needed with the commitment of resources to the learning process.

• There needs to be an initial implementation plan, a funding strategy to support the commitment of follow-on monitoring and modeling, and support for continuing stakeholder involvement that will achieve agreement on modifications to the implementation plan over time.

• When there are point sources of pollutants, attention may need to be paid to possible accommodations for AI in the NPDES permitting process given that AI may result in modification to the TMDL or the WLA over time.

**In summary, adaptive implementation begins with installation of certain controls that serve to move the watershed in the direction of reducing pollutant loads, while also providing information on their effectiveness in influencing water quality at different geographic and time scales.**

- With the new knowledge, the original watershed and water quality analyses and models can be revised.

- This will allow updating of the estimates of current and future pollutant loads and the resulting water quality in the impaired water body as a result of revised control strategies (based on the revised model).

"In the beginning there were only probabilities."

Martin Rees

“There are no certainties in life; there are only probabilities.”

Jack Ryan (*The Sum of All Fears* – Tom Clancy)