Establishing and Implementing Lake-specific Water Quality Targets in TMDLs in Connecticut

October 2, 2024
EPA Region 10 Nutrient Seminar

Connecticut Department of Energy and Environmental Protection

Presentation Topics

- Review of CT WQS Provisions pertaining to Lakes and Nutrients
- Proposed Weight of Evidence Approach for WQ Target derivation
- Development of Improved Implementation Approach

CT Water Quality Standards

Applicable CT Narrative Criteria & Standards

- Narrative Nutrient Criteria (22a-426-9 Table 1)
- The loading of nutrients, principally phosphorus and nitrogen, to any surface water body shall not exceed that which supports maintenance or attainment of designated uses

Natural Conditions (22a-426-4(A)(4))

- WQ Criteria do not apply to environmental conditions brought about by natural causes or conditions

Applicable CT Narrative Criteria & Standards

- Natural (22a-426-1(47)
- Means the biological, chemical and physical conditions and communities that occur within the environment which are unaffected or minimally affected by human influences.

Requirement to Control Nutrients

- Requires controls such as BMPs or permit limits for point and nonpoint sources of nutrients (22a-426-4(a)(11)) and indicates BMPs etc. for NPS nutrient sources are preferred over use of biocides to address altered trophic state in lakes. (22a-426-4(a)(12))

Applicable Lake Narrative Criteria & Standards

Lakes (22a-426-6)

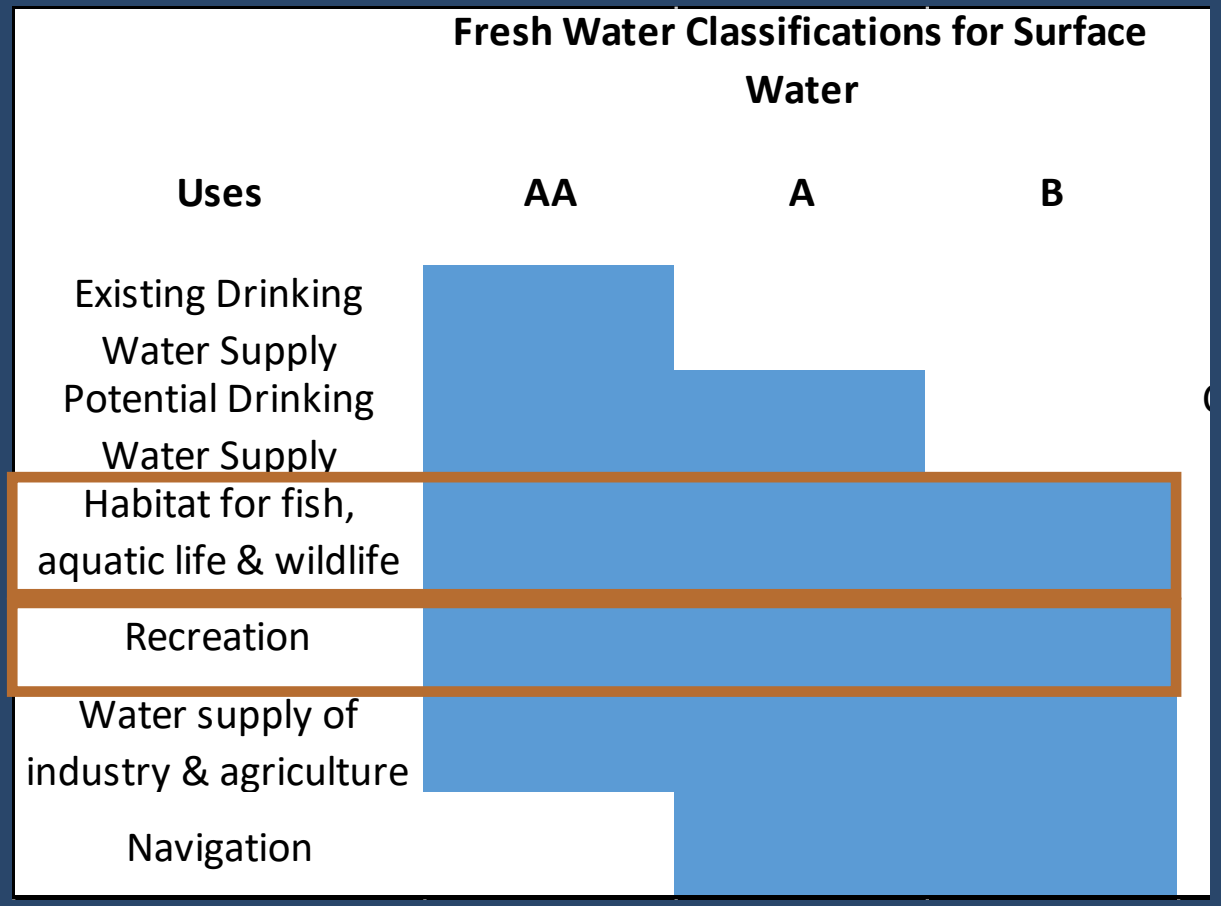
- Identifies the Natural Trophic State of the lake as the WQ Goal
- Identifies nutrient levels associated with various trophic states (not criteria)
- Provides consideration to adjust trophic state evaluation based on macrophyte coverage

Trophic State	Parameter	Range
Oligotrophic	Total Phosphorus	0-10 µg/l
	Total Nitrogen	0-200 µg/l
	Chlorophyll-*a*	0-2 µg/l
	Secchi Disk	6 + meters
Mesotrophic	Total Phosphorus	10-30 µg/l
	Total Nitrogen	200-600 µg/l
	Chlorophyll-*a*	2-15 µg/l
	Secchi Disk	2-6 meters
Eutrophic	Total Phosphorus	30-50 µg/l
	Total Nitrogen	600-1000 µg/l
	Chlorophyll-*a*	15-30- µg/l
	Secchi Disk	1-2 meters
Highly Eutrophic	Total Phosphorus	50 + µg/l
	Total Nitrogen	1000 + µg/l
	Chlorophyll-*a*	30 + µg/l
	Secchi Disk	0-1 meters

CT Water Quality Classifications

CT Water Quality Classifications are based on Designated Uses

Based on assessment data, Aquatic Life Uses and Recreation are most commonly affected uses in impaired lakes



Procedure to Set Lake-Specific Nutrient Criteria

Set Trophic Level Boundaries

- Evaluate Current Trophic State
- Predicted Status based on natural conditions

Model Expected Trophic Conditions

- Weight of Evidence Approach
- Landscape condition models to predict in lake Chlorophyll A
- Lake-specific studies if available

Translate Chl A to Lake-specific nutrient criteria

- Watershed Model (LLRM or HSPF)
- Water Quality Model (BathTub, potentially WASP)

Example: Bantam Lake

- CT's largest natural lake
- Important public resource for swimming, water skiing, fishing, boating, other recreation
- Affected by nuisance aquatic vegetation
- Summer algal blooms beginning in July or August
- Bottom phosphorus concentration increase as dissolved oxygen decreases

Photo from Bantam Lake Protective Association
http://bantamlakect.com/aboutus.html

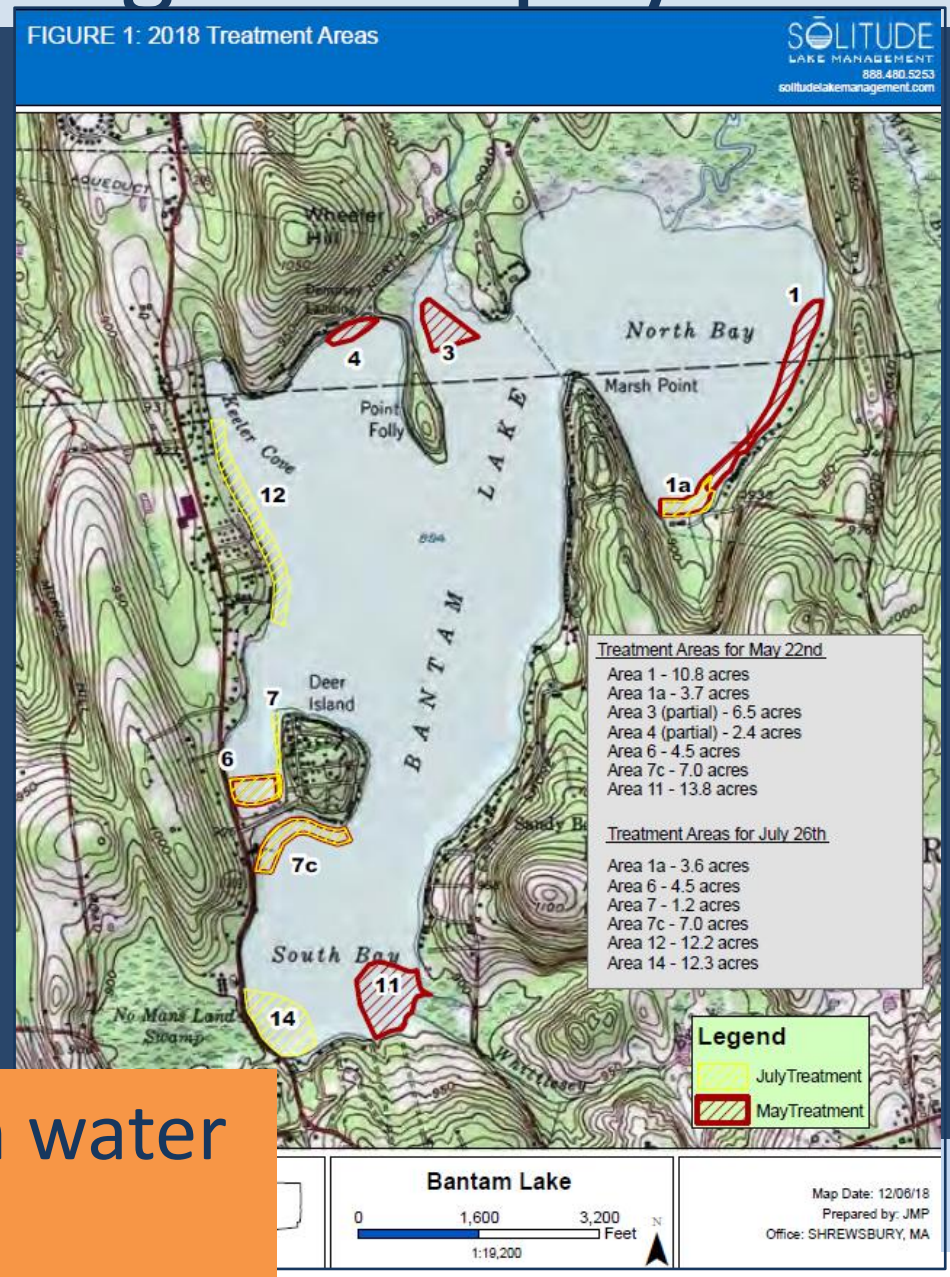
Current Trophic Level: Water Chemistry

	EPA		CT	CT	CT	CT
	Chl A (ug/l)		Chl A (ug/l)	TN (ug/l)	TP (ug/l)	Secchi (m)
# Samples	4		4	150	182	132
Range	27 to 48		27 to 48	175 to 1630	8 to 78	0.85 to 4.20
Average	37		37	513.8	23.7	2.1
Oligotrophic	0-2		0-2	0-200	0-10	6+
Mesotrophic	2-7		2-15	200-600	10-30	2-6
Eutrophic	7-30		15-30	600-1000	30-50	1-2
Hypereutrophic	>30		>30	>1000	>50	0-1

Current Trophic Status:	Upper Mesotrophic/Eutrophic (CTDEEP)
Data:	April - Oct (2007-2018)

Current Trophic Level: Considering Macrophytes

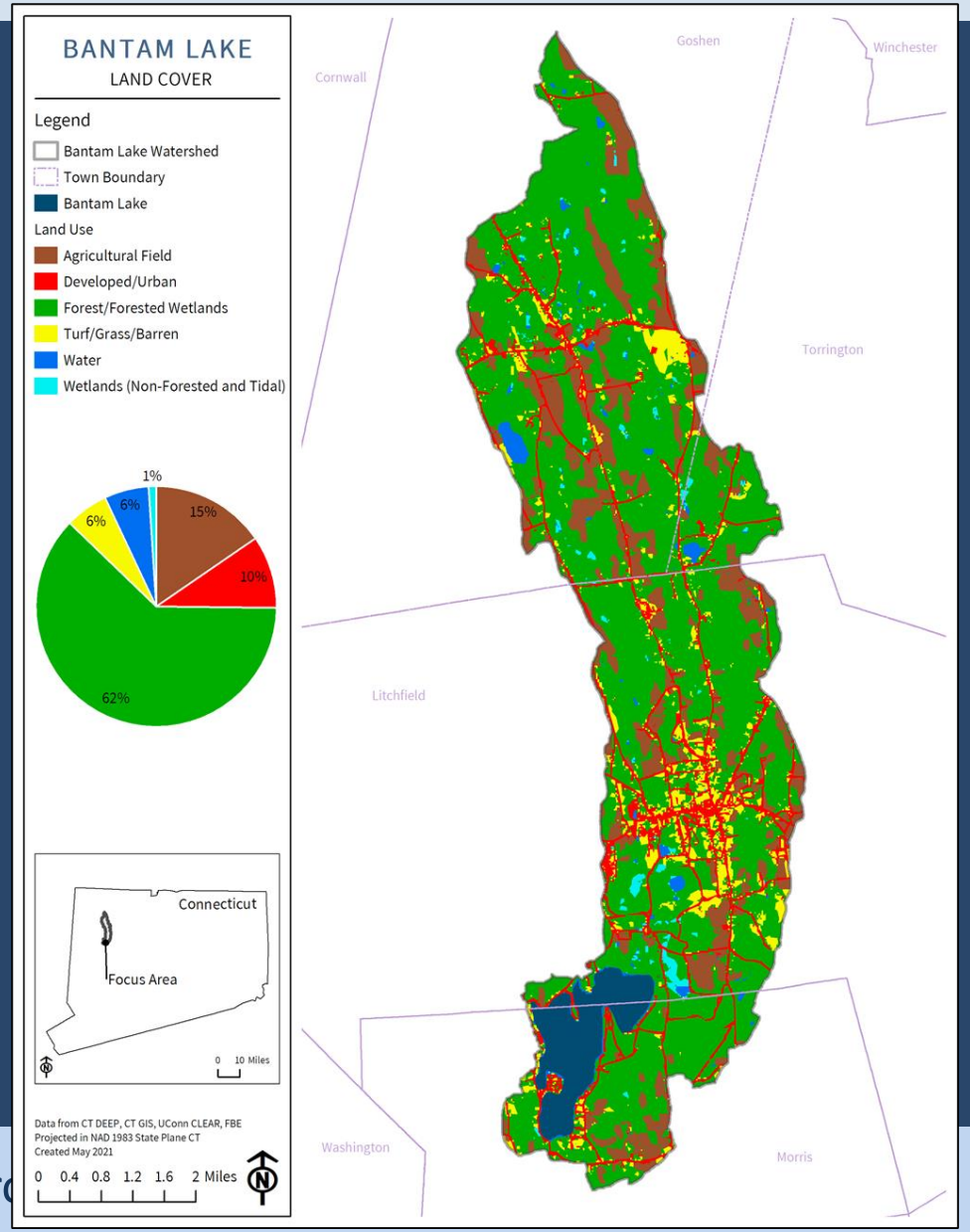
- CT WQS:
- 75%-100% coverage: Highly Eutrophic
- 30% - 75%
  - Change oligotrophic to mesotrophic
  - Change Mesotrophic or Eutrophic to Eutrophic
- Macrophyte coverage in Bantam Lake is approximately 30% (assuming no herbicide treatment)



Bantam Lake is currently eutrophic based on water chemistry and macrophyte coverage

Predictive Models for Trophic State

- Looked for models that relate landscape characteristics to lake trophic status (Chlorophyll A)
- Selected Models
  - Landscape-based Taylor approach
  - Hollister (EPA)
  - New England Lake & Pond Model (TNC)



Developing a Reference Data Set for Lakes

- Currently using 2007 & 2012 National Lakes Assessment Reference Lakes for Region 1
- In future, will incorporate 2017 data set
- Based on Eco Regions Used for National Aquatic Resource Surveys
- Reference conditions for NLA based on
  - Least disturbed condition defined as best available chemical, physical and biological habitat conditions given current landscape
  - This is consistent with CT WQS “natural” which is minimally affected
- Focus on Chlorophyll A for Trophic Evaluation

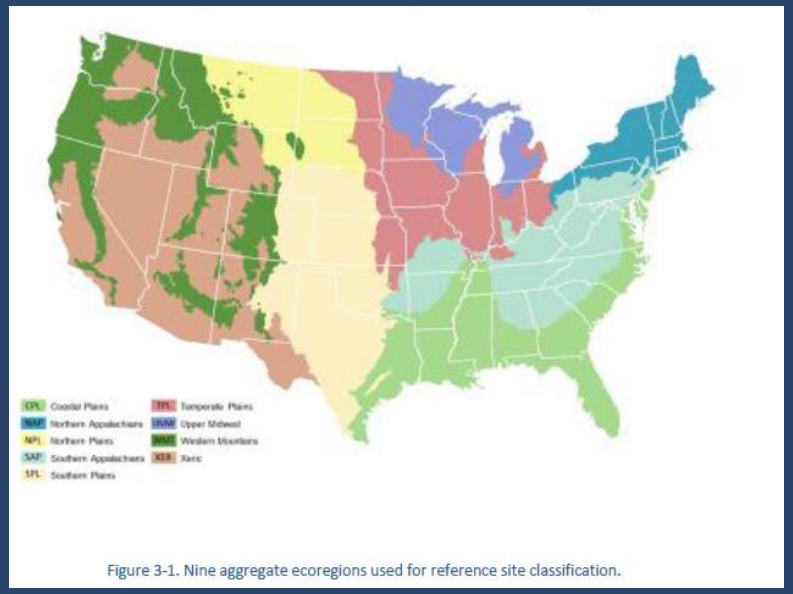
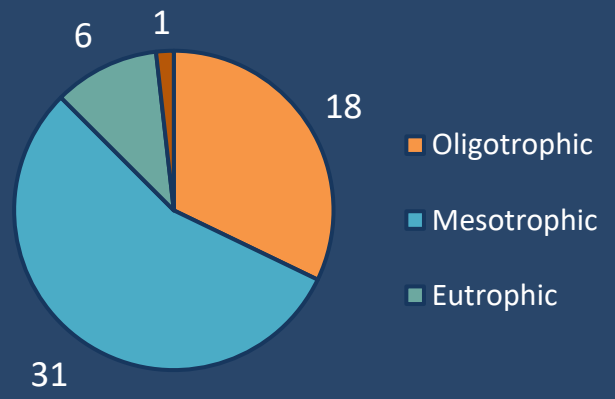
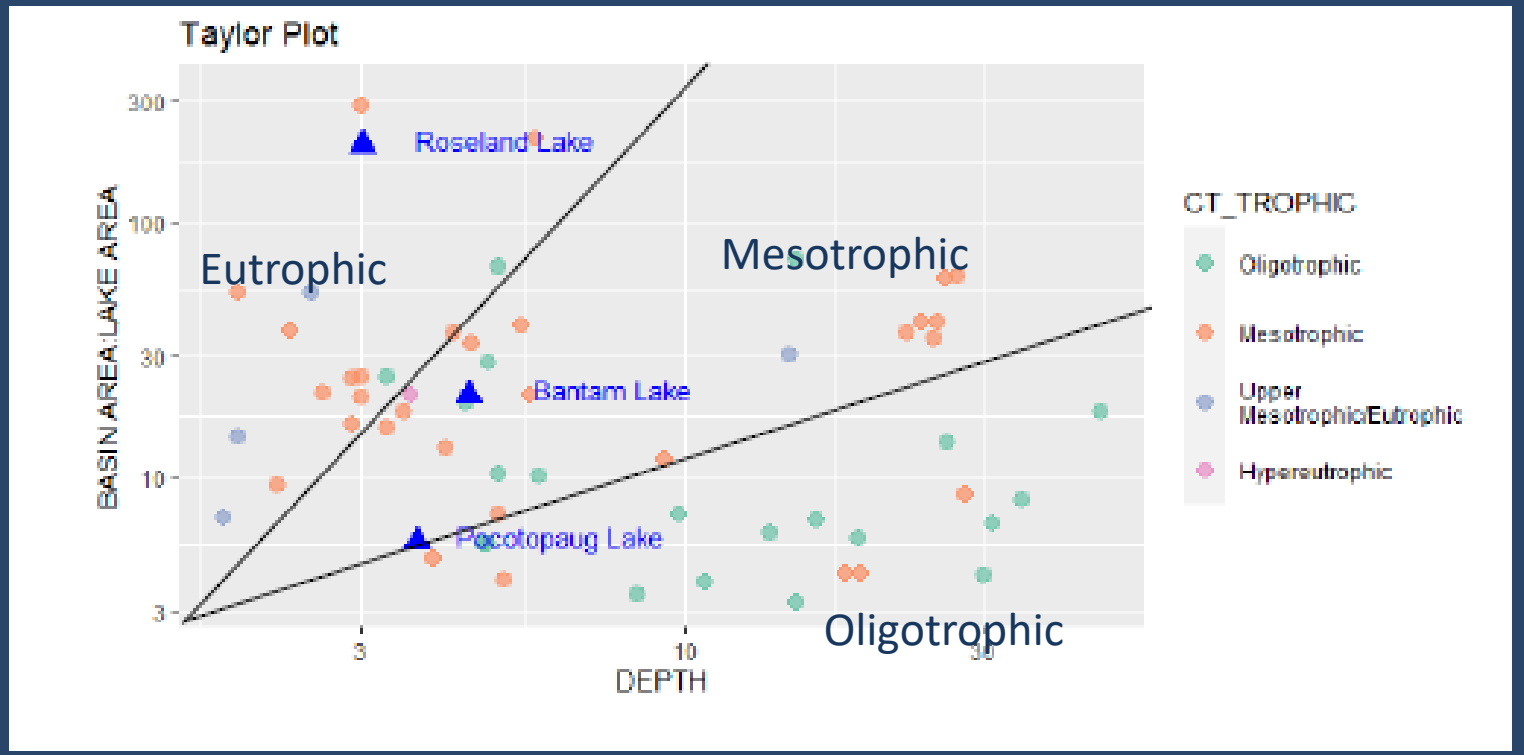


Figure 3-1. Nine aggregate ecoregions used for reference site classification.



Landscape Model: Taylor Approach

- Used Reference Data Set of New England lakes that meet designated uses
- Based on landscape relationships in common mass balance equation predicting TP concentrations in lakes
  - Based on watershed area, surface area, and mean depth
  - Commonly used in limnology



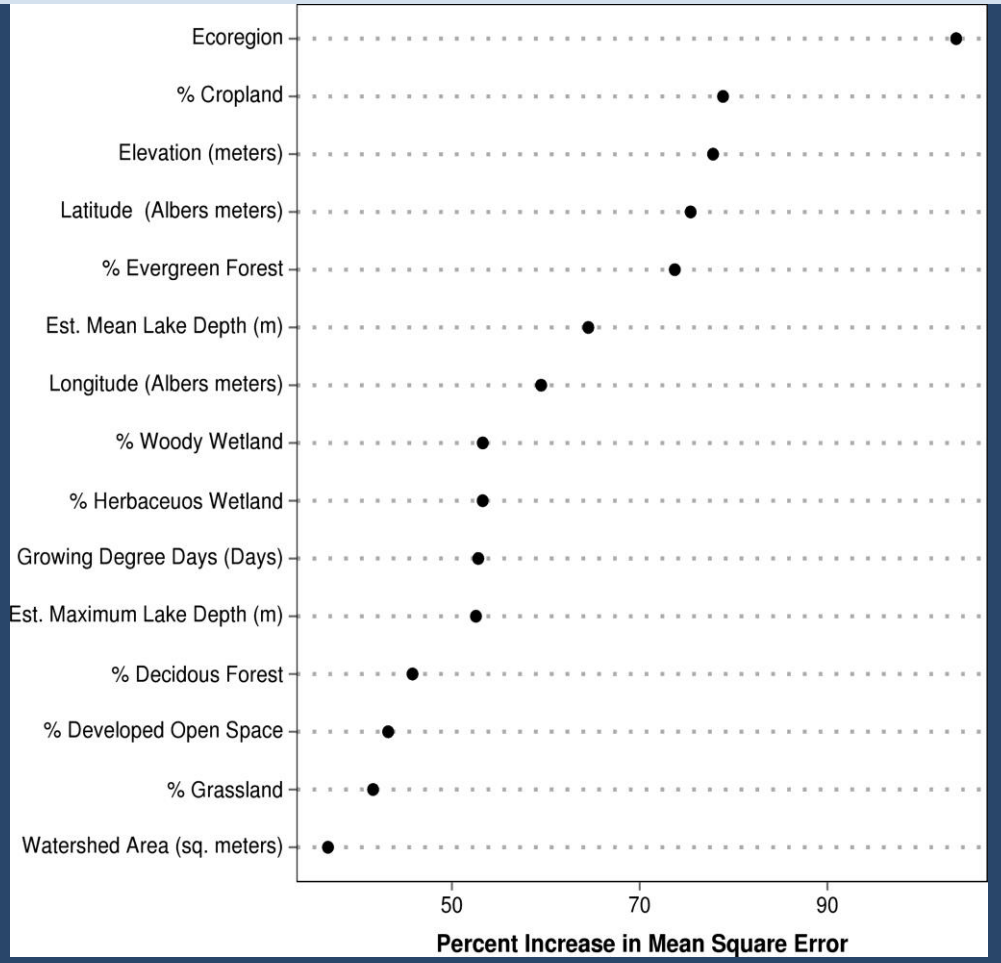
Approach Developed by Robert Taylor, 1988

Taylor, Robert (1979) Connecticut Lakes Management Program Efforts published in Connecticut Institute of Water Resources Special Report 30 Proceedings: Lake Management Conference.

Taylor Landscape Evaluation for Bantam: Upper Mesotrophic

Landscape Model: EPA Hollister Model

- Model Developed by Hollister et al, EPA Narragansett Lab
- Model based on nutrients & landscape variables
- Error rate 36.1% based on random forest modeling
- Results accessed through TNC Lake Report

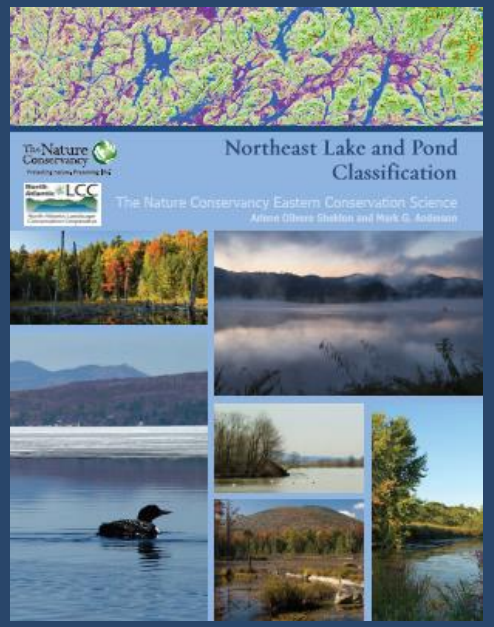


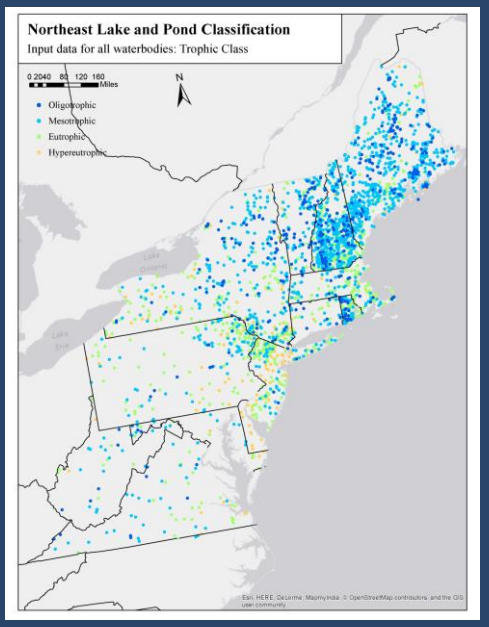
Hollister, J. W., Milstead, W. B., and Kreakie, B. J. (2016). Modeling lake trophic state: a random forest approach.

Hollister Model Results for Bantam Lake: Mesotrophic

Landscape Model: TNC NE Lake & Pond Model

- EPA Trophic Classifications
- Random Forest Model
- Trophic Model Error Rate 23.59%





Olivero-Sheldon, A. and M.G. Anderson. (2016). Northeast Lake and Pond Classification. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA

Modeled Probabilities:

	PROB_OLIG	PROB_MESO	PROB_EU	PROB_HYP
Bantam	0.457000	0.286000	0.210000	0.047000
Roseland	0.139000	0.278000	0.545000	0.038000
Pocotopaug	0.169000	0.393000	0.175000	0.263000

TNC Model Results for Bantam: Oligotrophic - Mesotrophic

Lake-Specific Studies

Bantam Lake Study

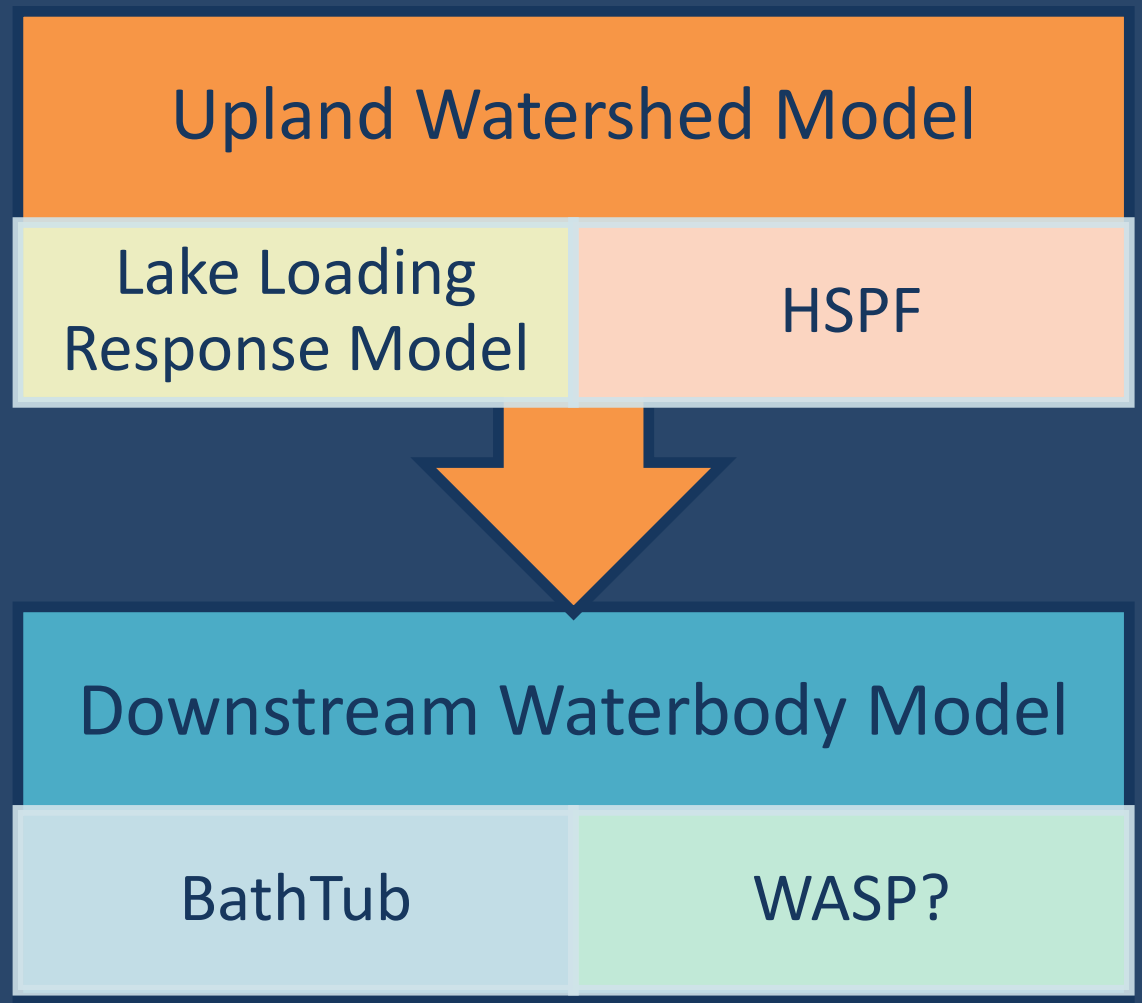
- Using sediment cores, evaluated:
  - diatom relative abundance
  - mean diatom size
  - Predicted trophic status
- Examined historical record for WQ data

Core depth (cm)	Age	Trophic score	Trophic status
0–0.5	1991	213	Eutrophic
1–1.5	1989	202	Eutrophic
2.5–3	1987	222	Eutrophic
4.5–5	1984	188	Eutrophic
7–8	1980	196	Eutrophic
9–10	1975	na	na
13–14	1964	200	Eutrophic
18–19	1946	35	Mesotrophic
20–21	1938	4	Mesotrophic
24–25	1926	− 43	Mesotrophic
30–32	1910	na	na
34–36	1898	− 108	Oligo/Early Meso
36–38	1889	na	na
40–42	1857	− 136	Oligo/Early Meso

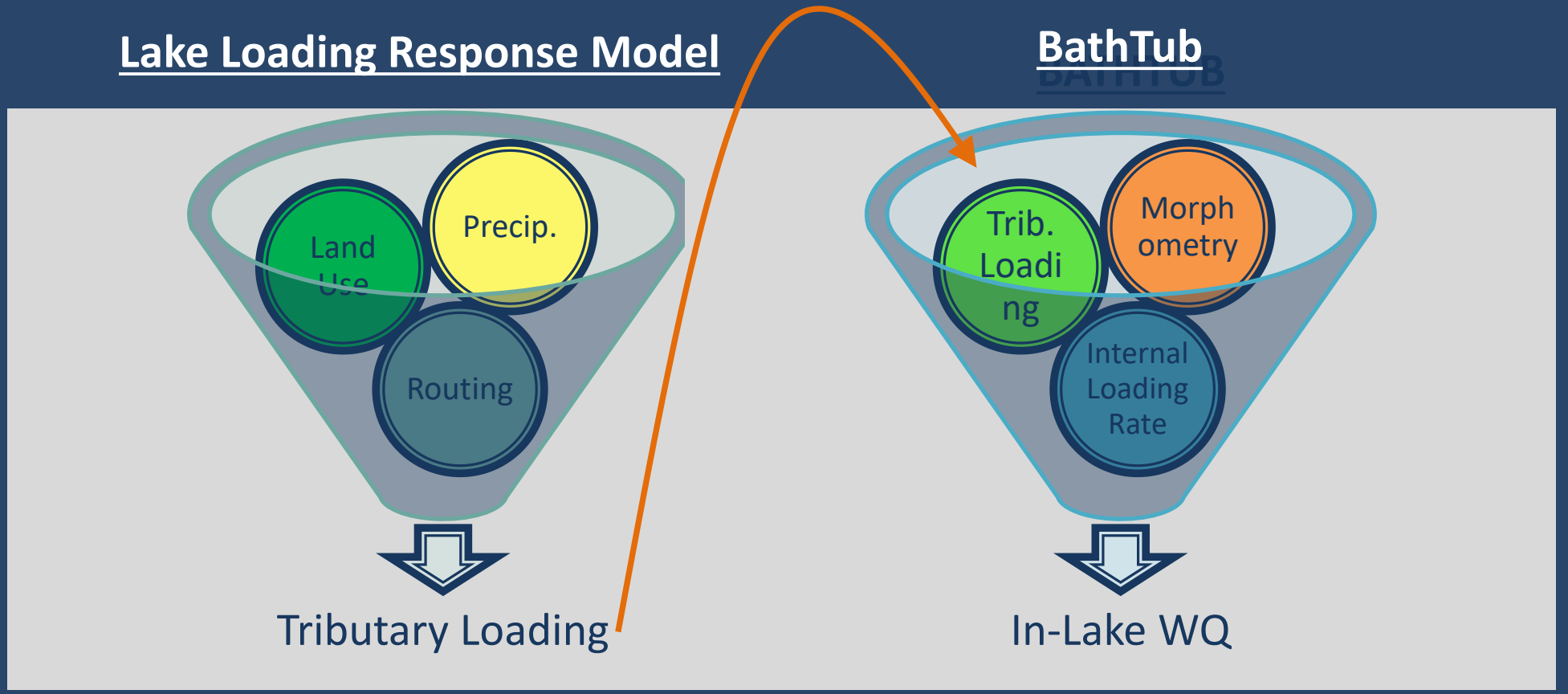
Based on historical record, Bantam Lake was Mesotrophic, with a strong shift to eutrophy in mid 1960s

Watershed Modeling Approach To Set Lake-specific Nutrient Targets

- Objective:
  - Develop a watershed scale approach
  - Evaluate nutrient related environmental conditions and sources
  - Nitrogen & Phosphorus
  - Point and Nonpoint Sources
  - Nutrient effects in
    - freshwater watersheds & associated embayments
    - Lakes
  - Restoration and Protection
  - Used to model in lake Water Quality based on Natural Conditions



Modeling Overview



In the future, we may use a HSPF, for upland contributions and are evaluating WASP for In-Lake water quality modeling

Converting Loading into In Lake Concentrations

- Use relationships between watershed loading and in lake concentrations from modeling report to translate updated load into in lake concentrations

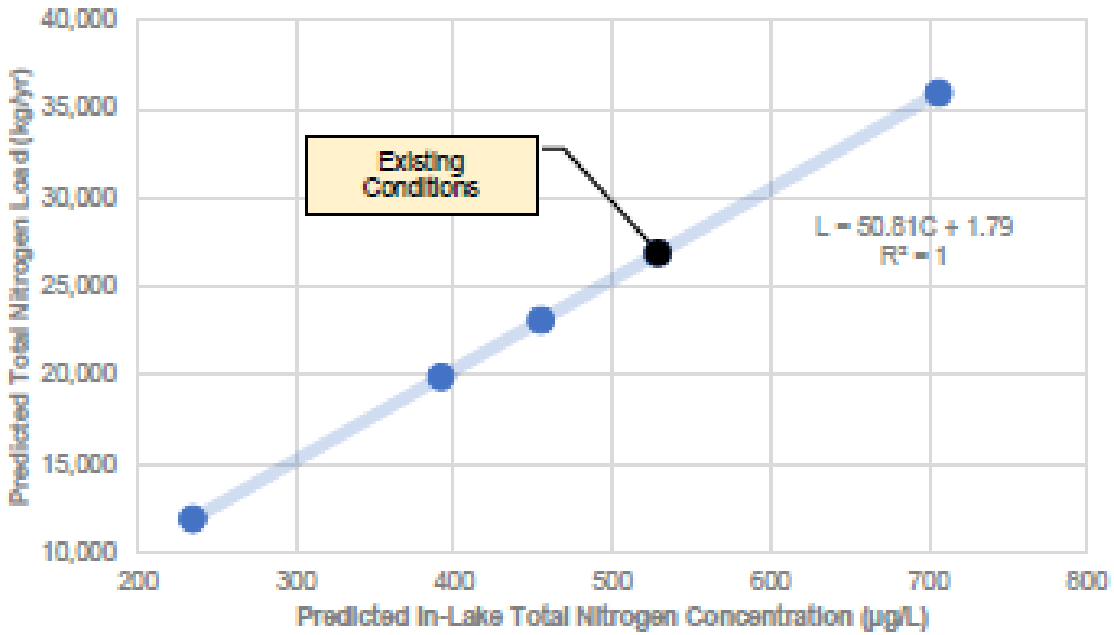


Figure 6-2: Predicted relationship between total nitrogen loading and resulting average in-lake total nitrogen concentration in the upper mixed layer (0-3 m) during the averaging period.

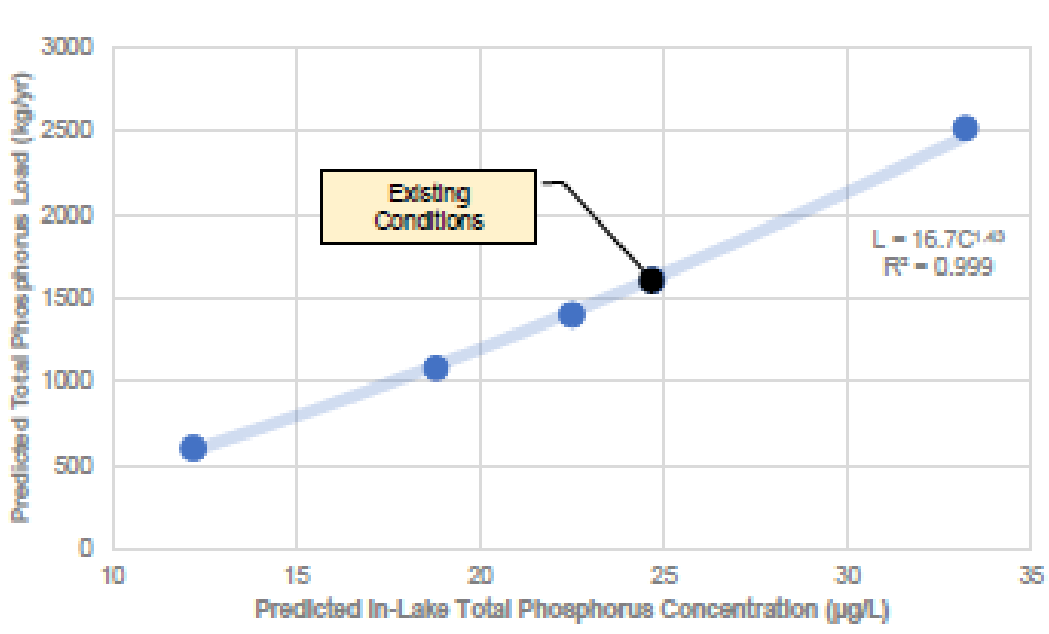
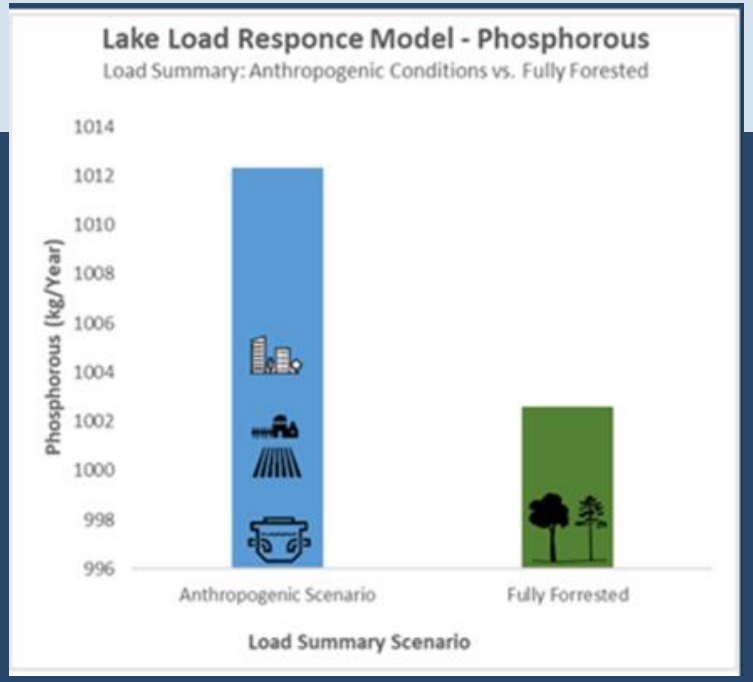


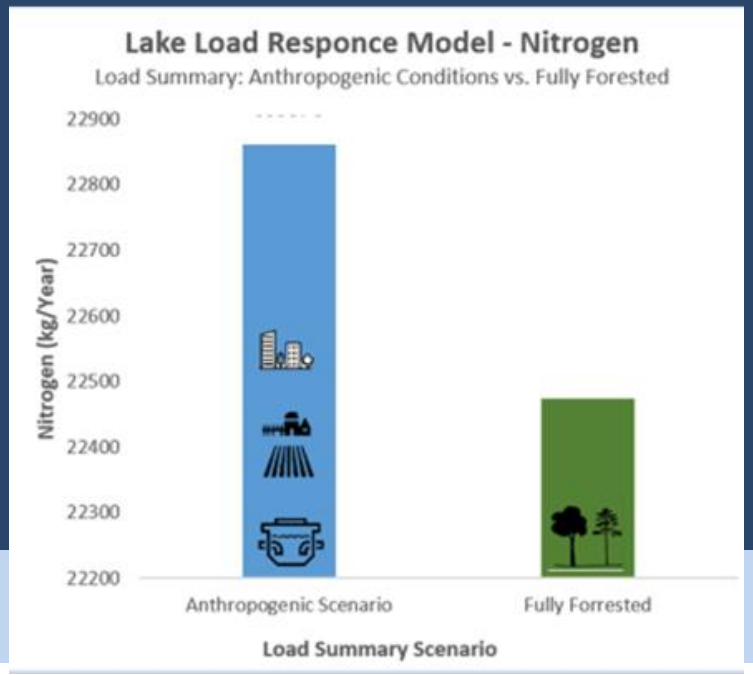
Figure 6-1: Predicted relationship between total phosphorus loading and resulting average in-lake total phosphorus concentration in the upper mixed layer (0-3 m) during the averaging period.

Model Natural Conditions

- Use calibrated LLRM/BathTub models for target lake
- Set Landcover = All Forest Cover
- Remove anthropogenic sources such as discharges, septic systems, etc.
- Run models to identify Chlorophyl A in the lake under natural conditions

Chlorophyll A ug/L	Modeled Current In Lake Concentration	Modeled Natural In Lake Concentration	Mesotrophic
Total Phosphorus	24.7	11.5	10-30
Total Nitrogen	528.6	281	200-600





Weight of Evidence Evaluation: Bantam Lake

Weight of Evidence Evaiuation	EPA Chl A Targets (ppb)	0-2	2-7	7-30	>30
Bantam Lake	CT Chl A Targets (ppb)	0-2	2-15	15-30	>30
	CT Total Phosphorus (ppb)	0-10	10-30	30-50	>50
	CT Total Nitrogen (ppb)	0-200	200-600	600-1000	>1000
	CT Secchi Disk (m)	6+	2-6	1-2	0-1

Line of Evidence	**Confidence**	**Oligotrophic**	**Mesotrophic**	**Eutrophic**	**Highly Eutrophic**
Current Trophic Level	High			★	
Taylor Landscape Analysis	Medium		★		
EPA Hollister Model	Medium		★		
New England Lake & Pond Model	Medium	0.457 ★	0.286	0.21	0.047
Fully Forested Model			★		
Lake Specific Studies			★		

Recommendation

- Water Quality Goal: Mid Mesotrophic
- TP = 20 ug/l
- TN = 400 ug/l

Implementation

Lake Project Overview

Program Development

- Develops an approach to evaluate and manage nutrient loads to CT Lakes and Impoundments
- Streamline plan development activities
- Facilitate community engagement and implementation

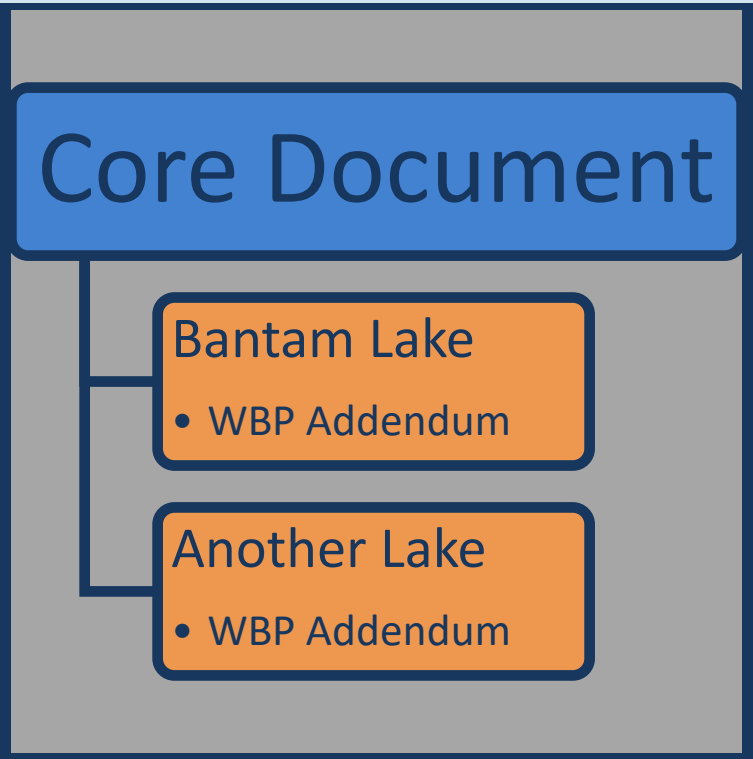
TMDL

- Evaluate watershed and water quality
- Set lake-specific water quality goals
- Provide technical support for implementation activities
- Reduce Harmful Algal Blooms where possible

Watershed Based Plan

- Identify specific problem areas for potential BMPs
- Provide education and information to communities
- Creates a flexible plan that will support achieving water quality goals for lake

New Work Flow for Development of WQ Plans



Integrates Project Elements across all related documents

Core Document

- Contains general information on required elements for TMDLs and Watershed Based Plans
- Includes reference & resource materials to assist implementation

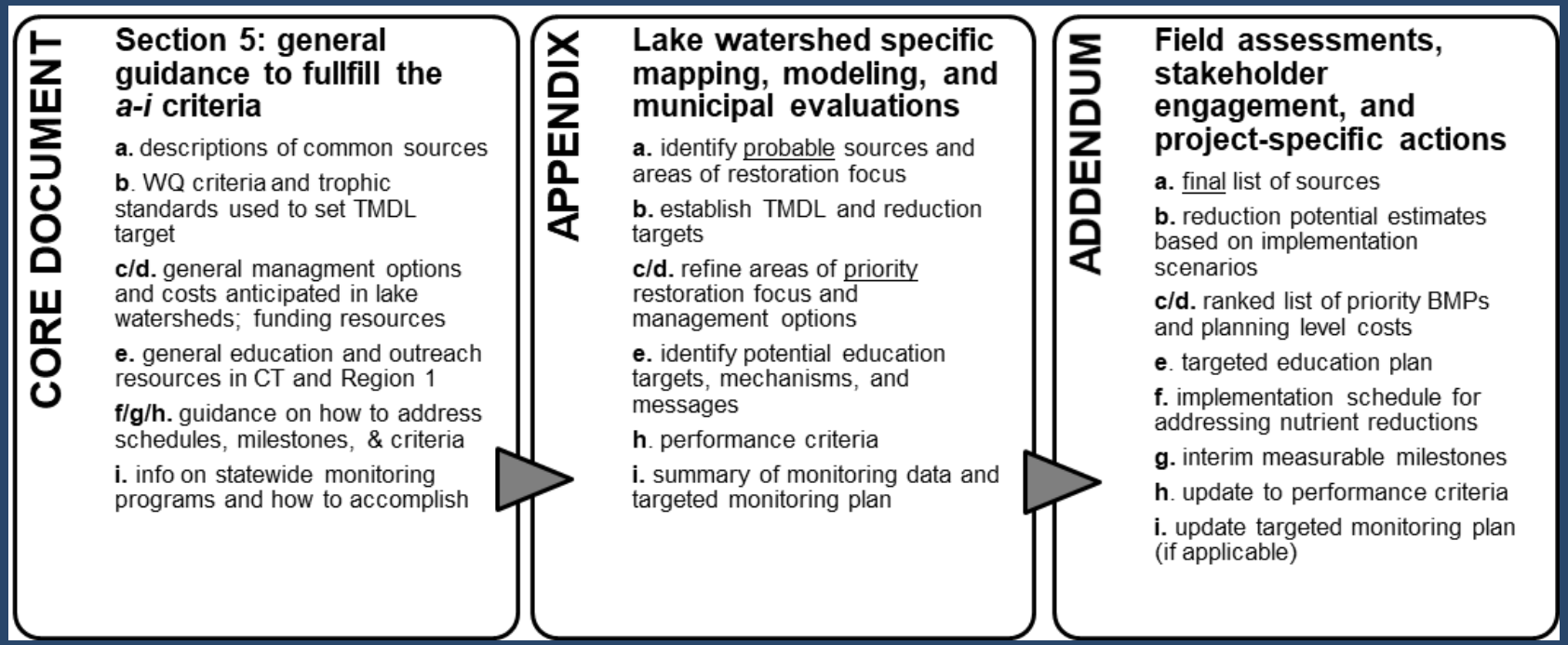
TMDL Appendices

- Watershed Specific Appendices consistent with TMDL requirements, documents lake-specific Water Quality Criteria

WBP Addendums

- Developing Watershed-Based Plan Addendum Template to streamline process
- Include 9-element components not fully covered in Core document or TMDL Appendix
- Focus on Implementation Activities

Distribution of NPS 9 Elements throughout documents



- Reduce repetitive analysis and presentation
- Provide more consistency between setting and implementing goals
- Allows Watershed Plan to provide more focus on implementation

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CTDEEP Project Web Page: Bantam Lake Watershed Projects