Development of Nutrient Criteria to Support Recreational Uses of Texas Reservoirs

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Sampling Design Workshop

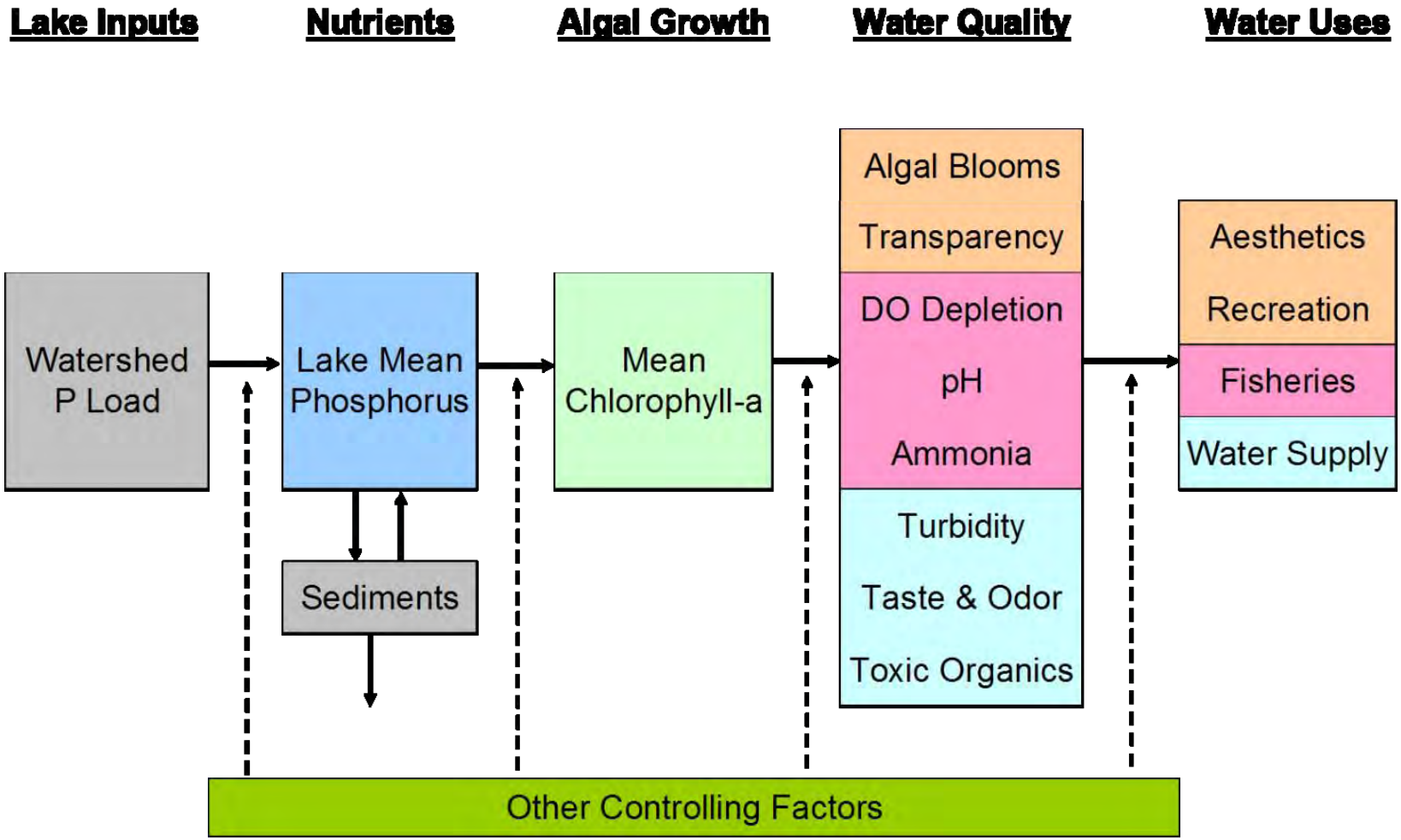
Austin

May 15-16, 2003

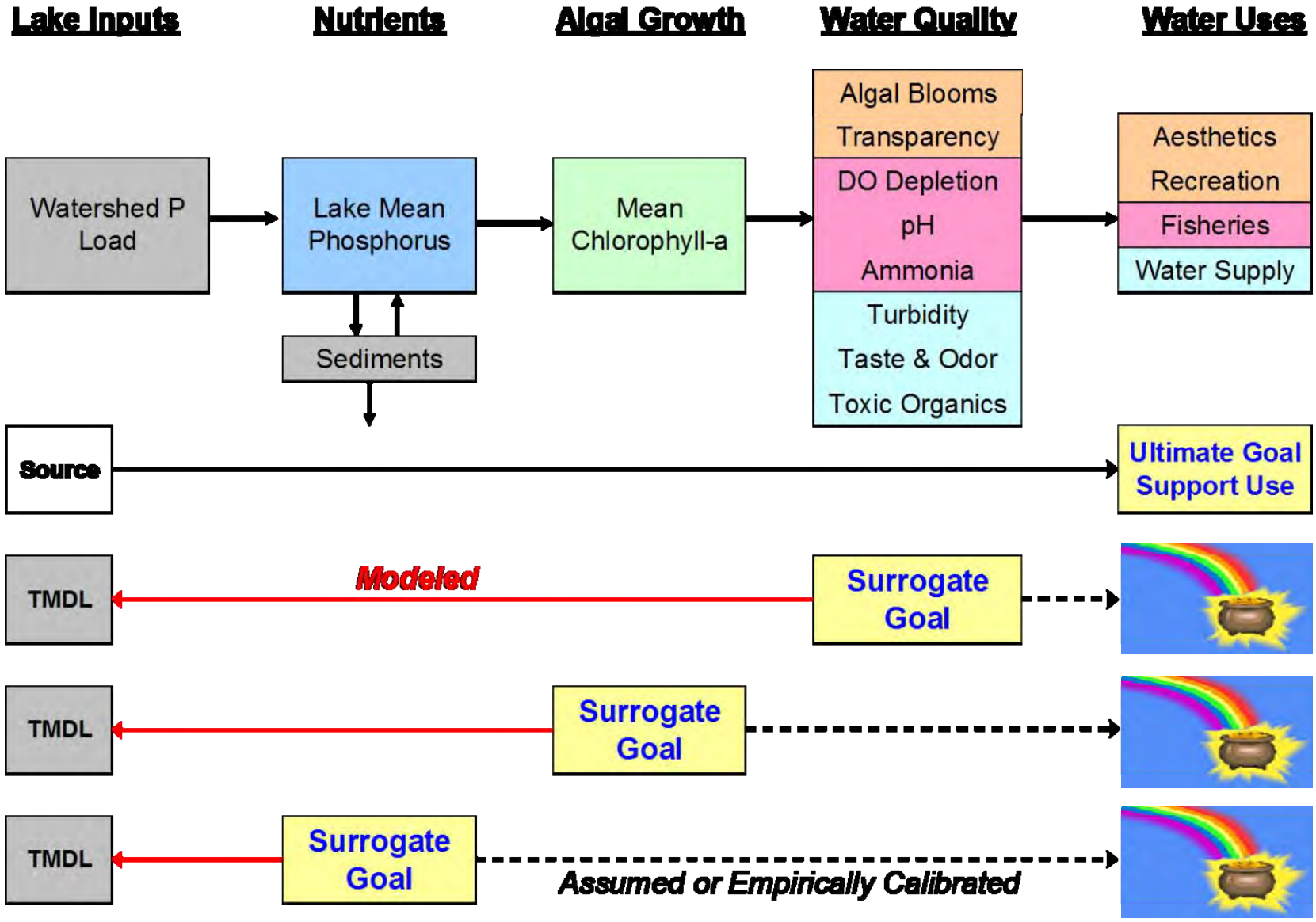
Topics

- Conceptual Model
- Case Studies
- Historical Data from Study Reservoirs
- Design of User Surveys
- Analysis of User Survey Data

Causal Pathways Linking P Loads to Water Uses



Conceptual Model for Lake Phosphorus TMDLs



Chlorophyll-a Nuisance Values for South African Impoundments

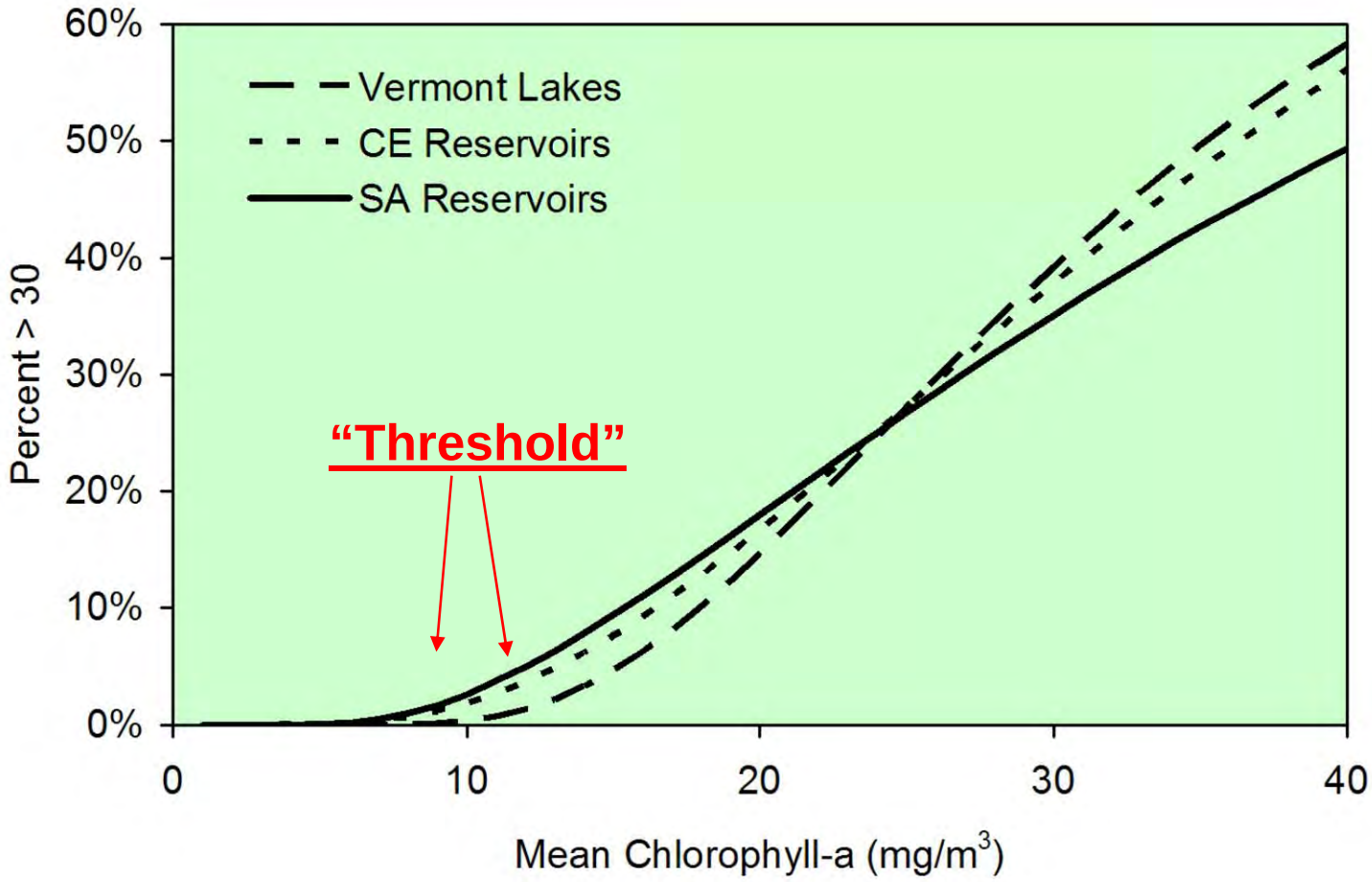
Instantaneous Chl-a (ppb)	Nuisance Value (Use Impact)
<10	No Problems Encountered
10-20	Algal Scums Evident
20-30	Nuisance Conditions
> 30	Severe Nuisance Conditions

Based upon simultaneous water quality sampling & user surveys

Walmsley, R., "A Chlorophyll-a Trophic State Classification System for South African Reservoirs", J. Environ. Qual., 1984

Statistical Basis for Mean Chlorophyll-a Criteria

Frequency of Severe Nuisance Blooms vs. Mean Chl-a



Based upon Log-Normal Frequency Distribution Models Calibrated to Various Datasets
Walker, W., "Statistical Bases for Mean Chlorophyll-a Criteria", Lake & Reservoir Mgt, 1985

Topics

- Conceptual Model
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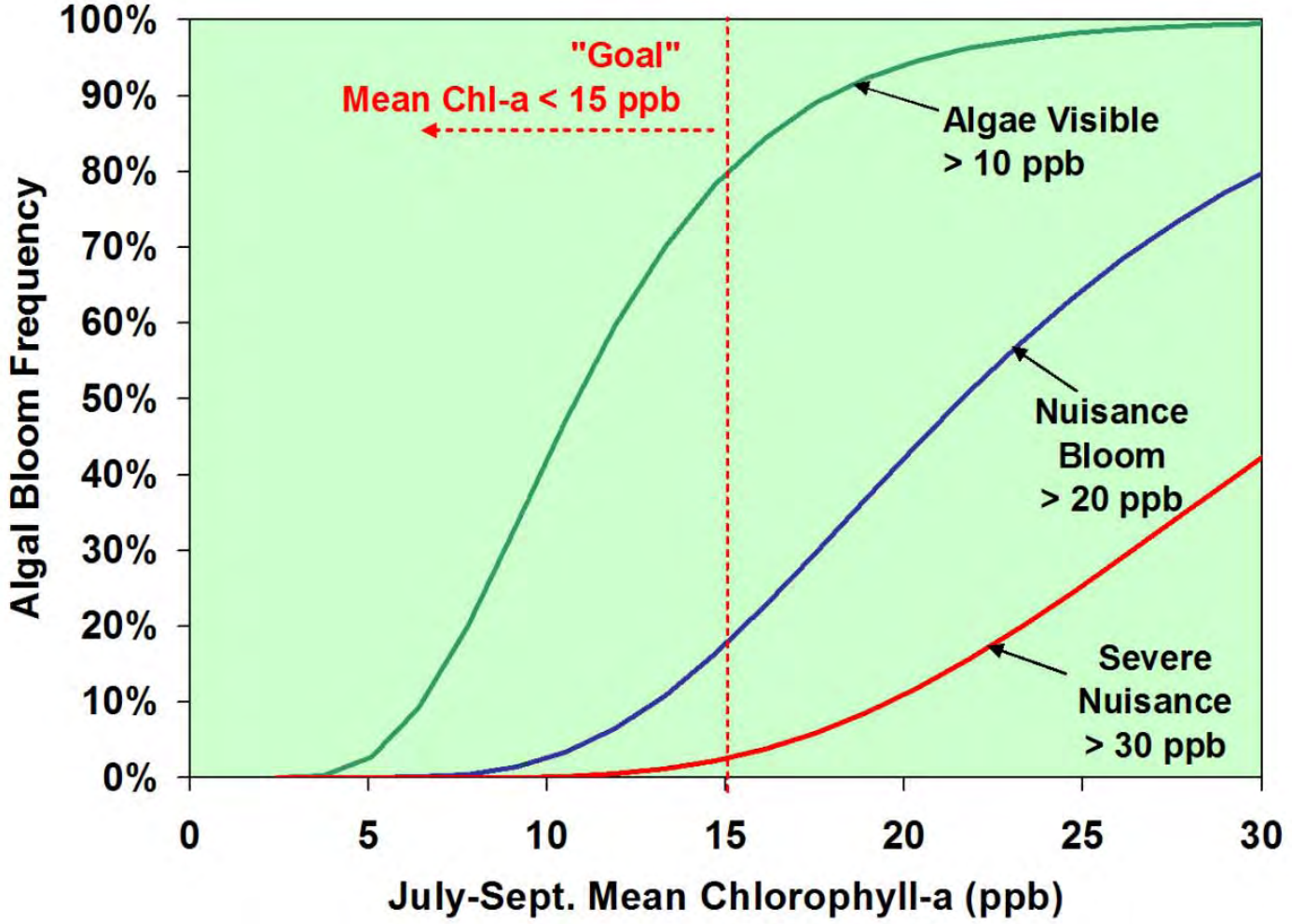
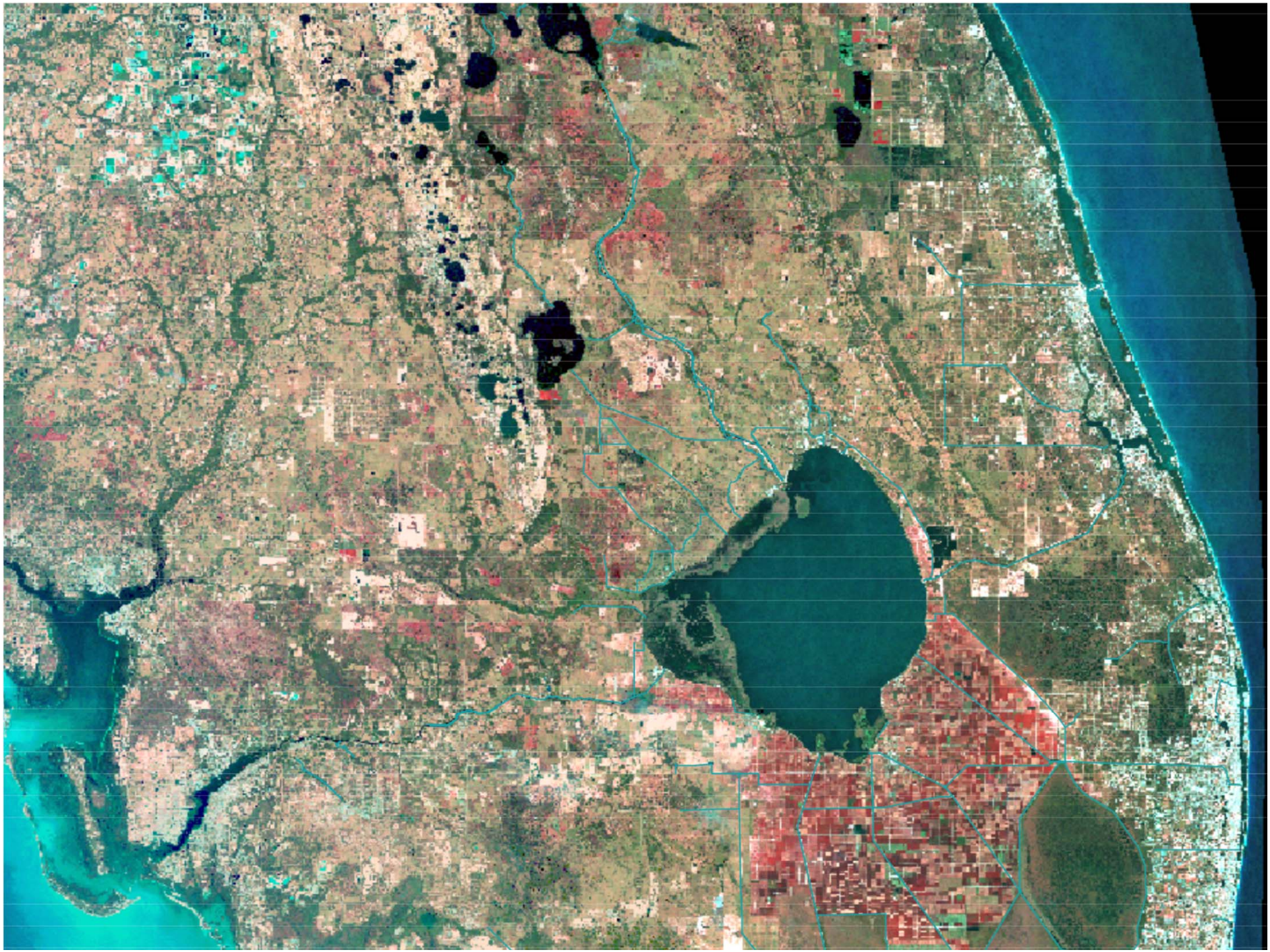
- Design of User Surveys
- Analysis of User Survey Data

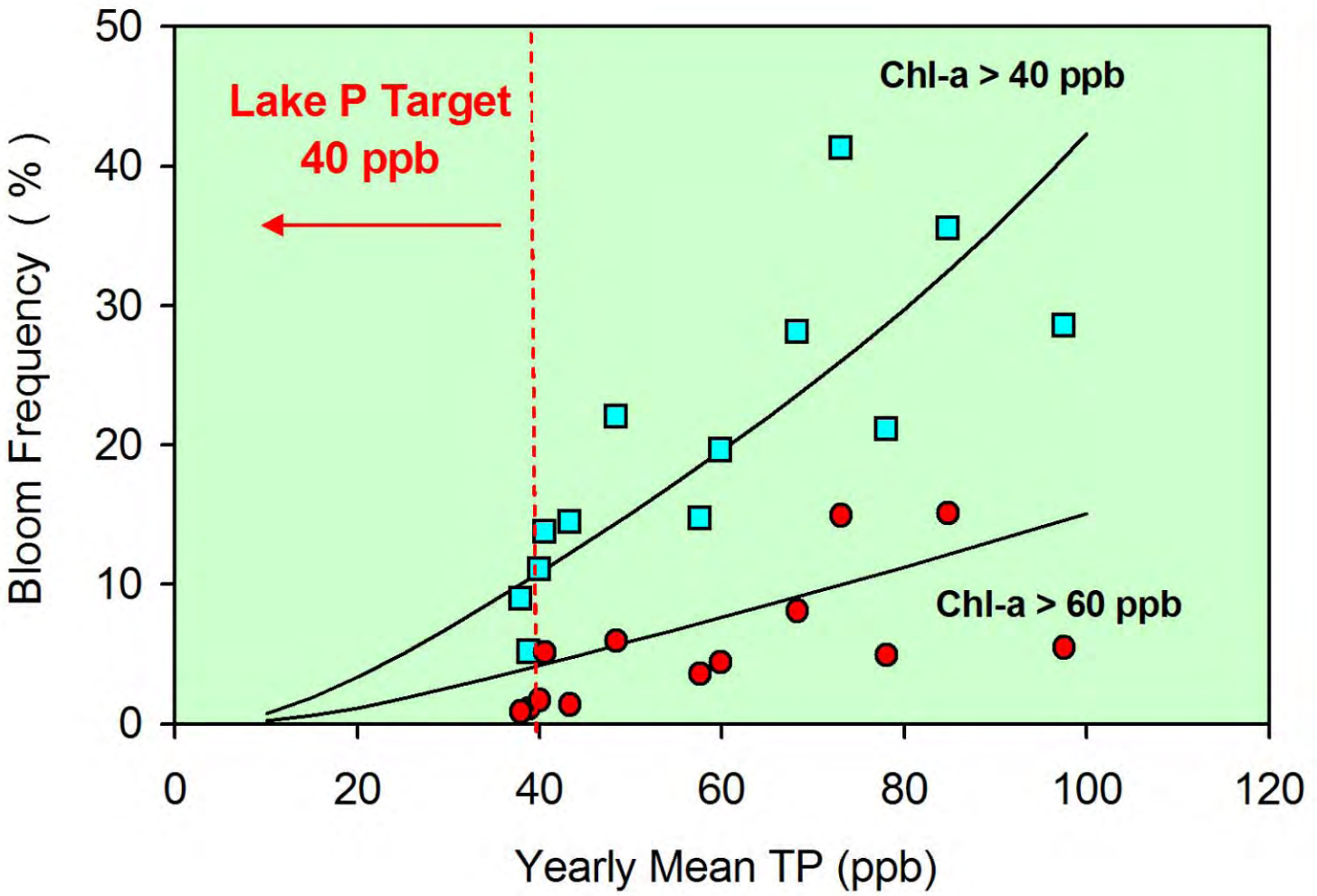
Algal Bloom Frequencies vs. Mean Chlorophyll-a
Cherry Creek Reservoir, Colorado



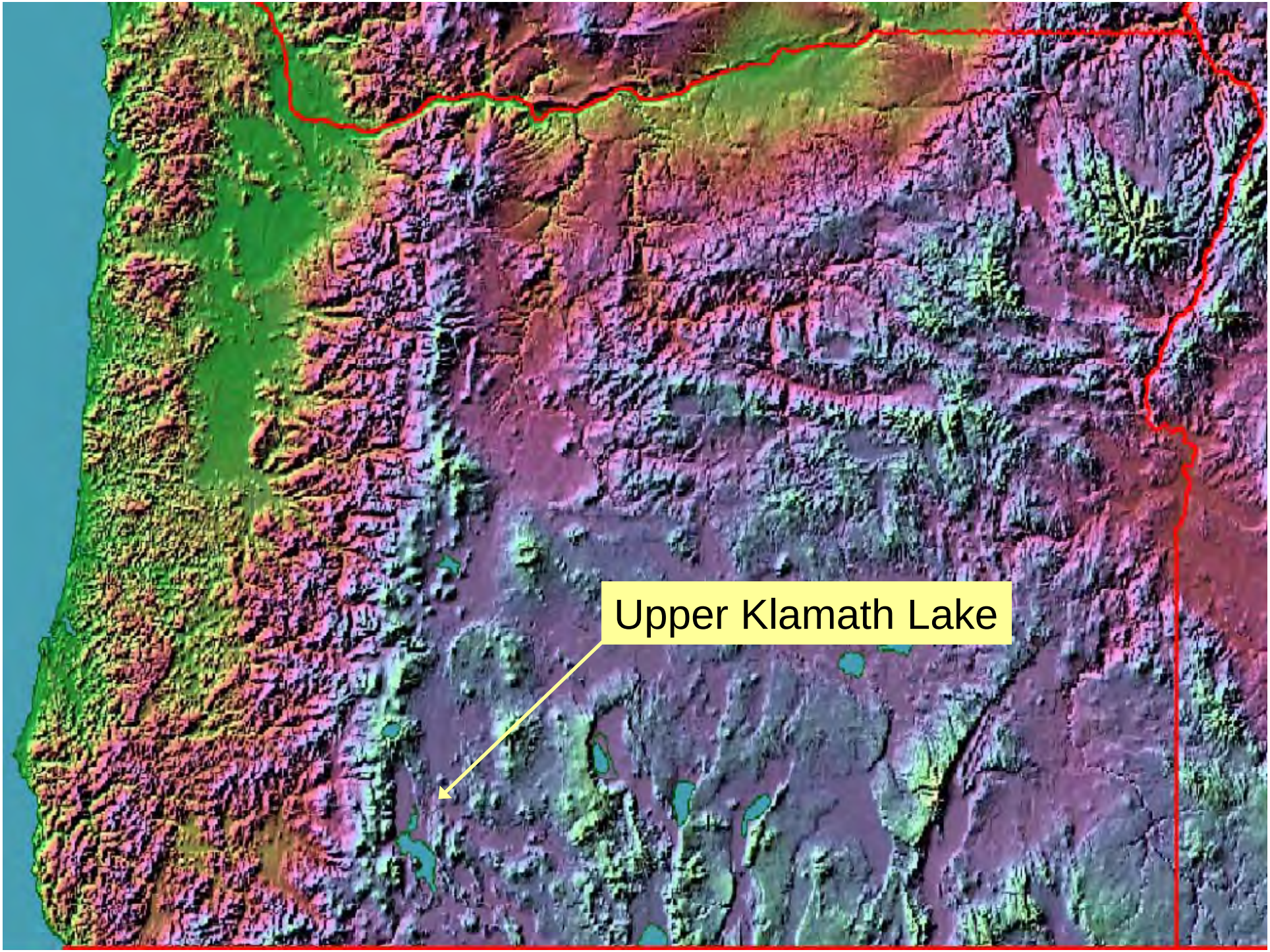
Y Axis: **Percent of Days in July - September with Chl-a Exceeding 10, 20, or 30 ppb**



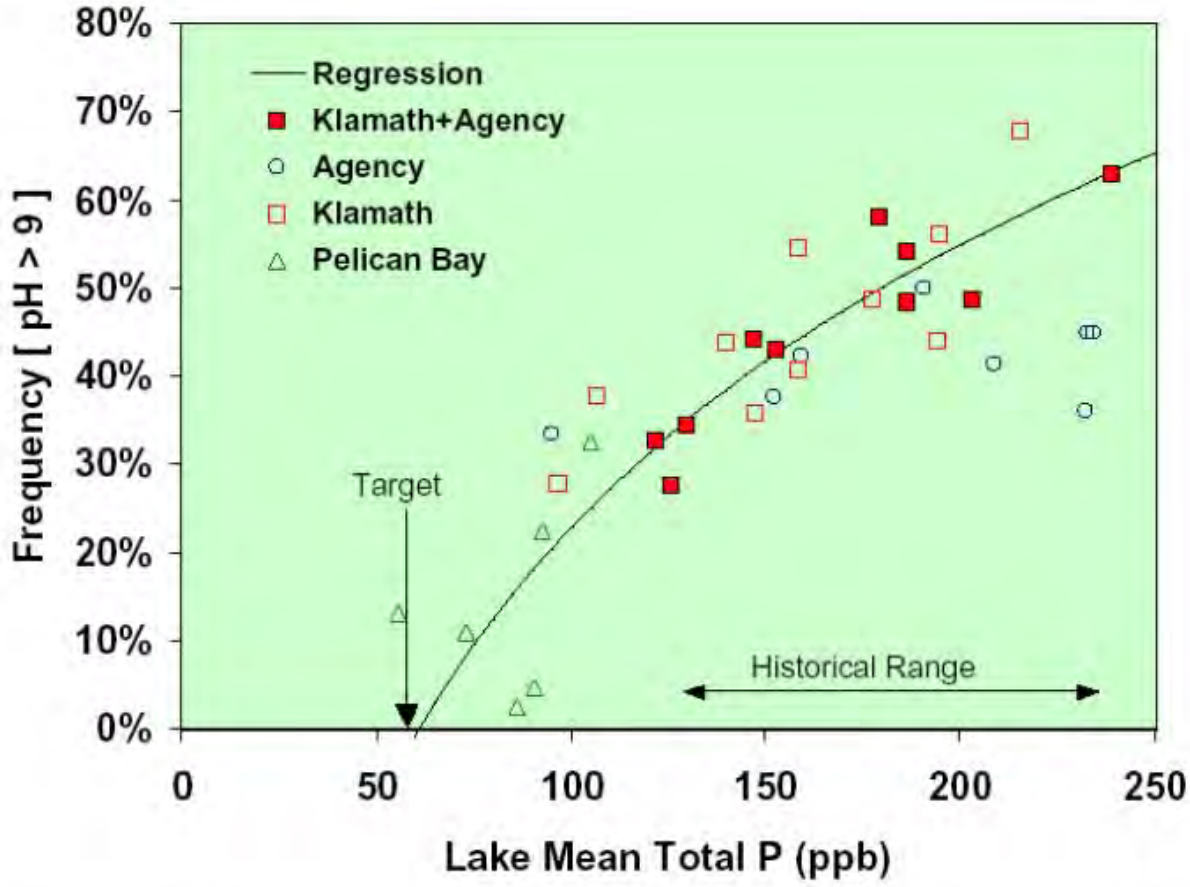
Near-Shore Bloom Frequencies vs. Pelagic Mean TP
Lake Okeechobee, Florida



Havens & Walker, Lake & Reservoir Mgt, 2002


Upper Klamath Lake

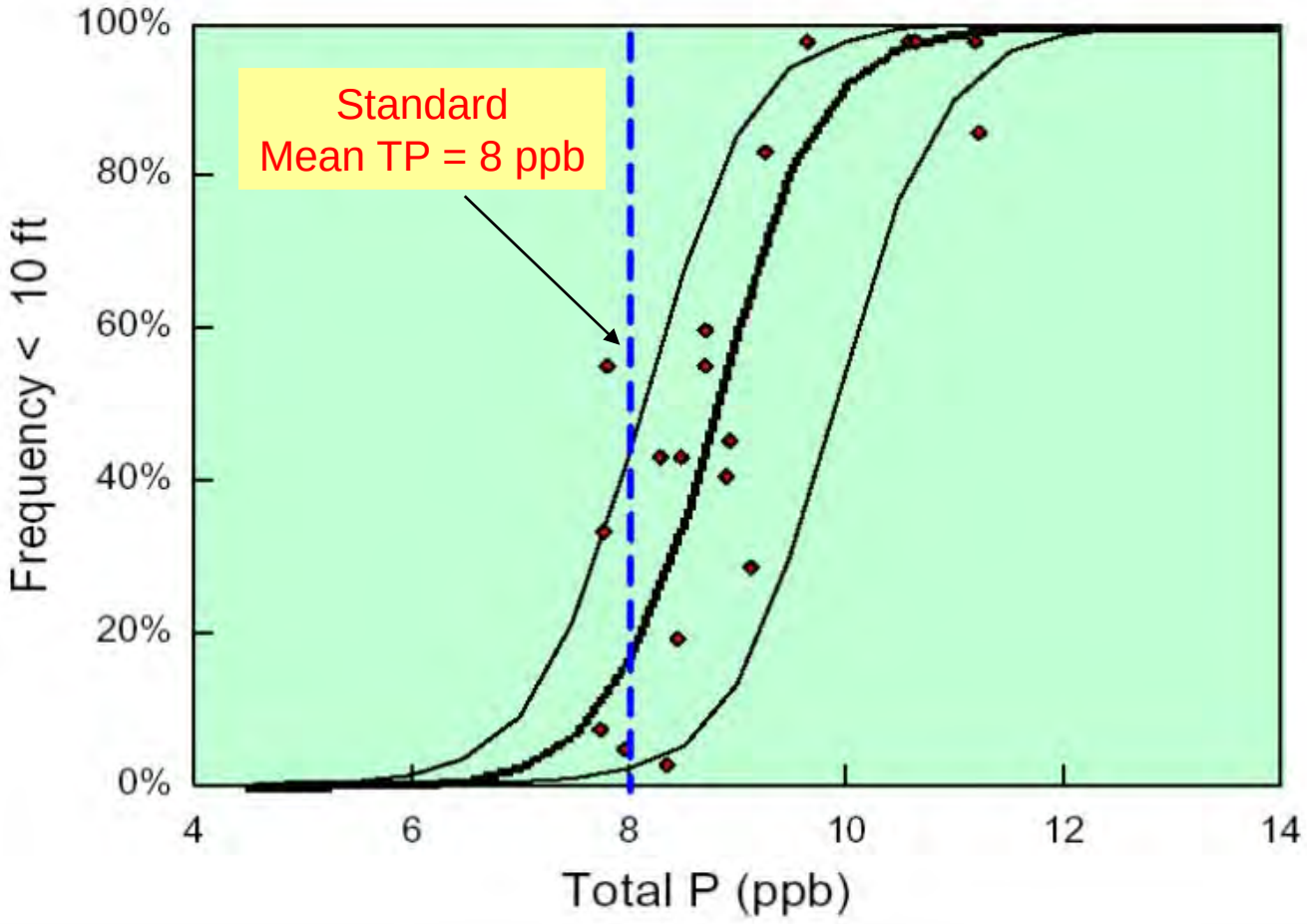
Derivation of P Target for Compliance with pH Standard
Upper Klamath Lake, Oregon



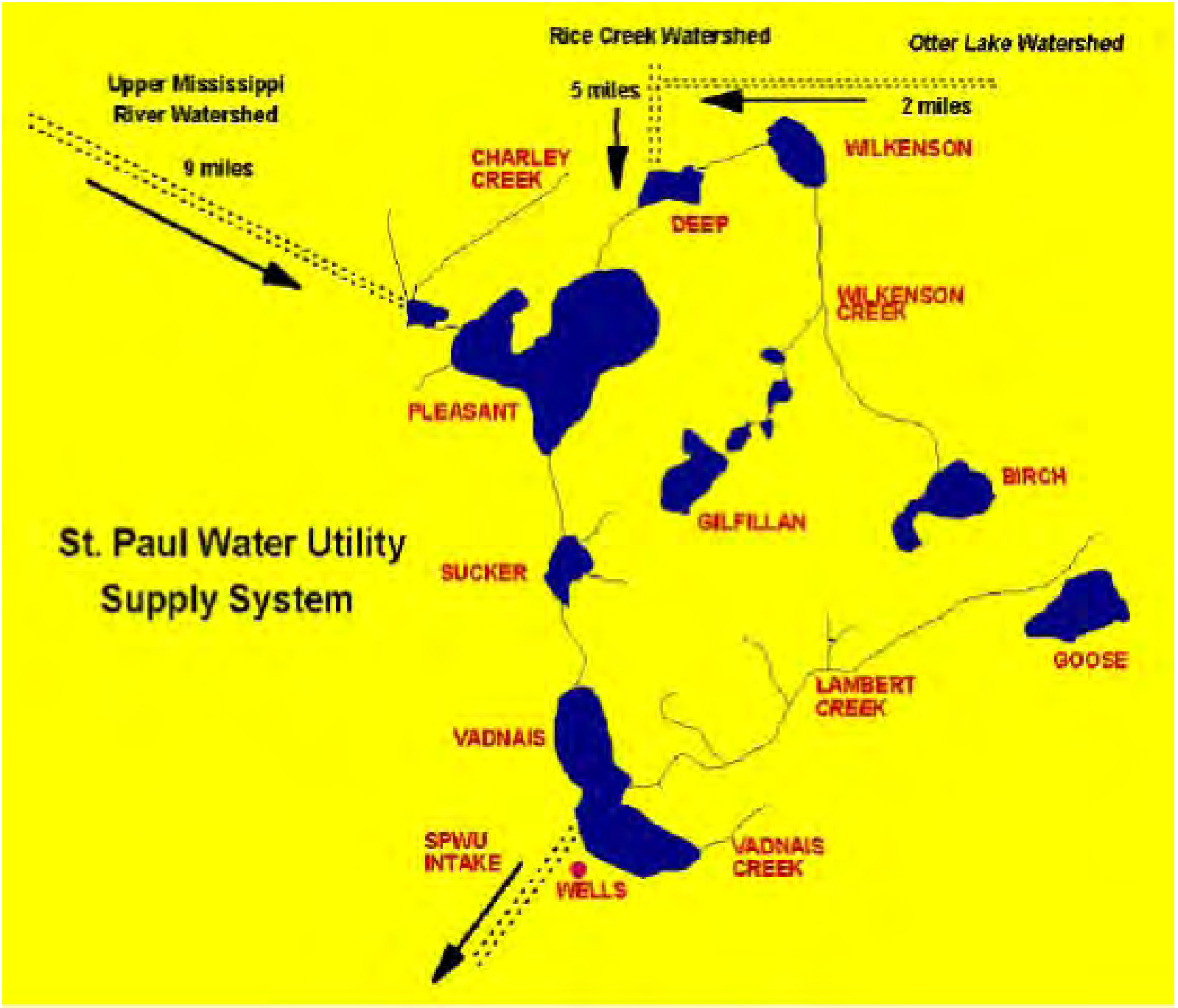
Yearly Means by Lake Region, April-October
Frequency = % of Measurements (All Stations & Depths) Exceeding pH 9


Lake Standard = 8 ppb
DUNES
Deer Lake
Mud Lake
BEAR
SLEEPING
Loon Lake
R 15 W
R 15 W
LAKE
Little Platte Lake
PERE MARQUETTE
Platte
Birch Point
Long Lake
Lake
Platte
Elland Lake
Rush Lake
ELEVATION 193
BENZONIA

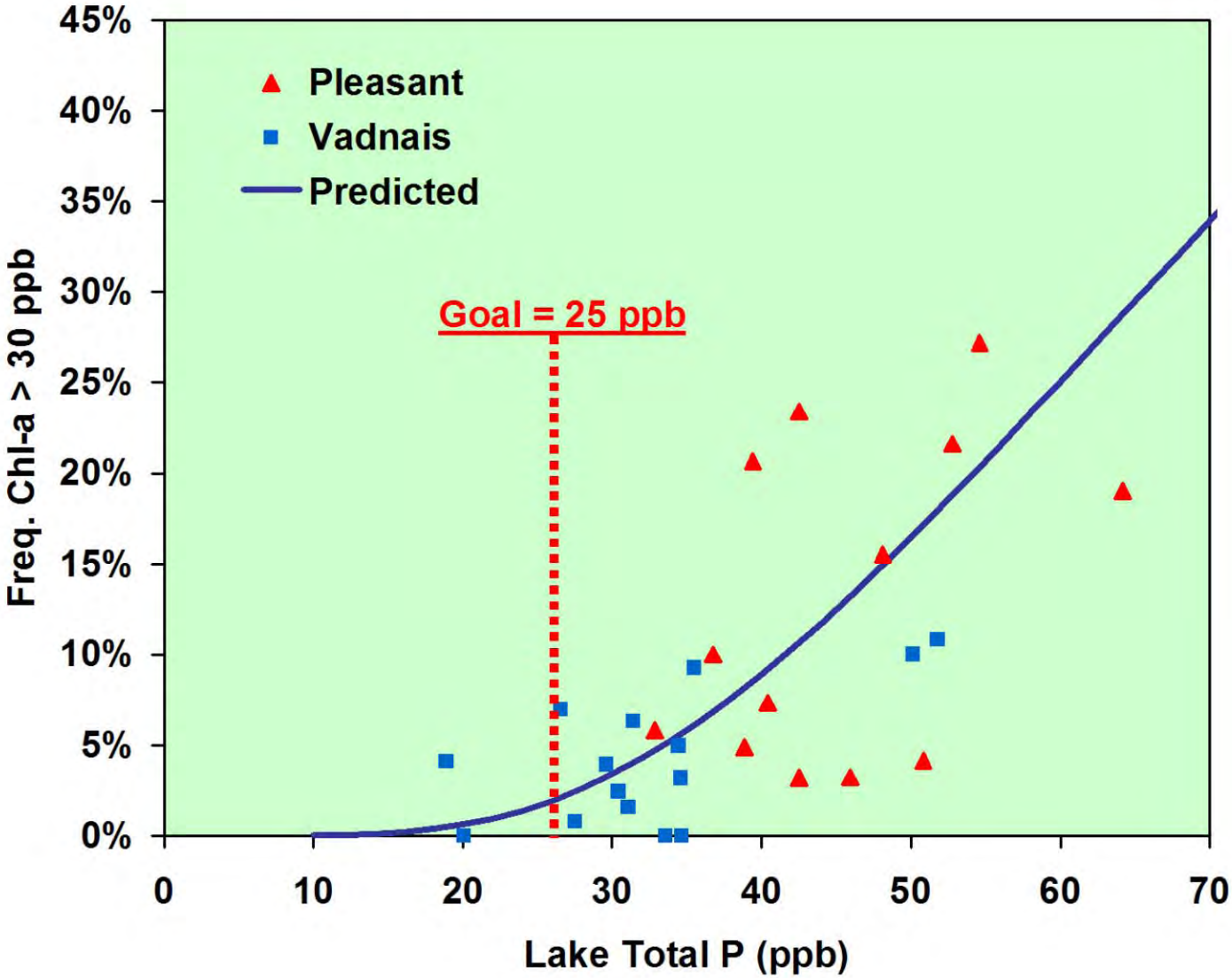
Total P Standard Based upon Transparency
Platte Lake, Michigan



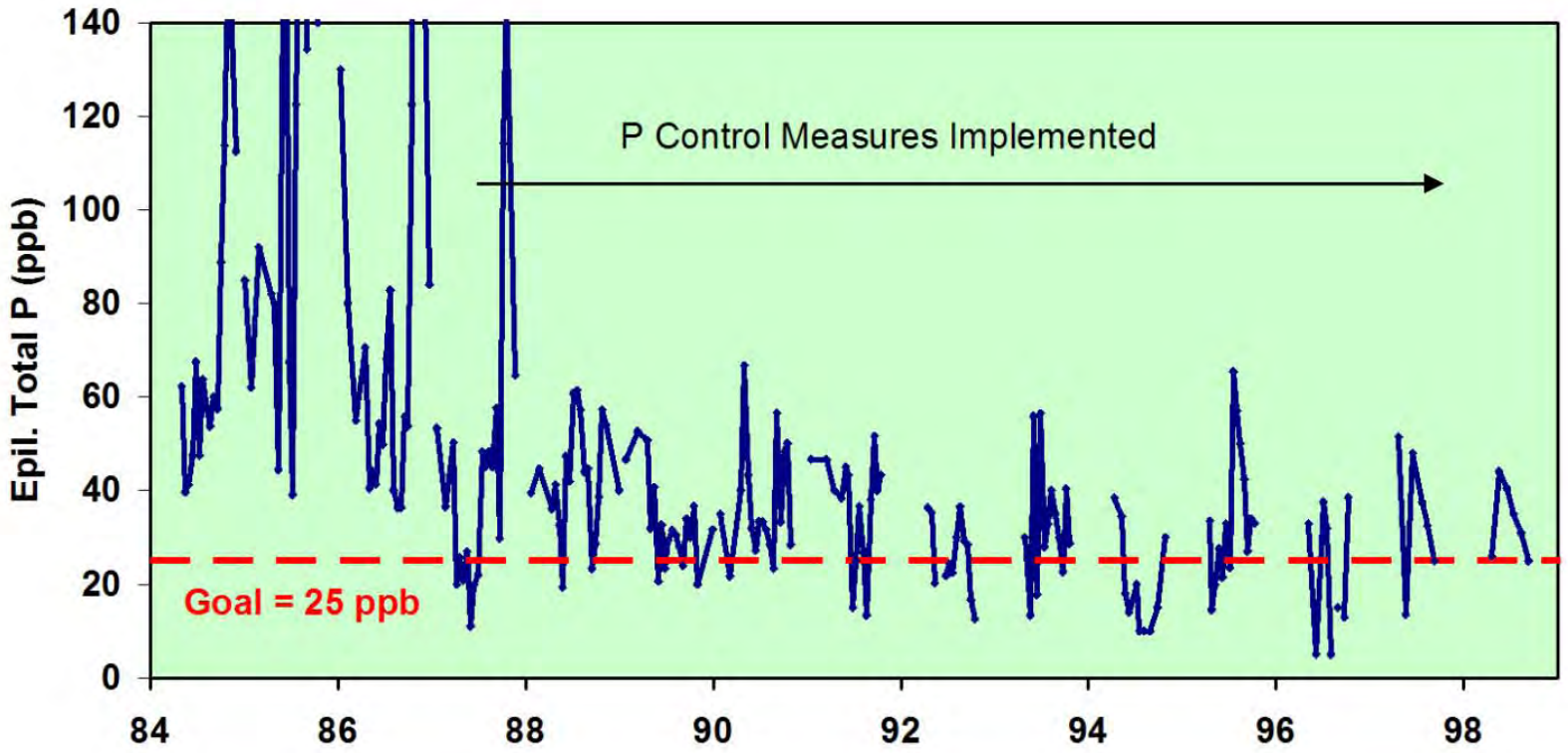
Y-Axis = Frequency of Secchi Depths < 10 feet


Rice Creek Watershed
Otter Lake Watershed
Upper Mississippi
River Watershed
5 miles
2 miles
9 miles
CHARLEY
CREEK
WILKENSON
DEEP
WILKENSON
CREEK
PLEASANT
BIRCH
GILFILLAN
St. Paul Water Utility
Supply System
SUCKER
GOOSE
LAMBERT
CREEK
VADNAIS
SPWU
INTAKE
VADNAIS
CREEK
WELLS

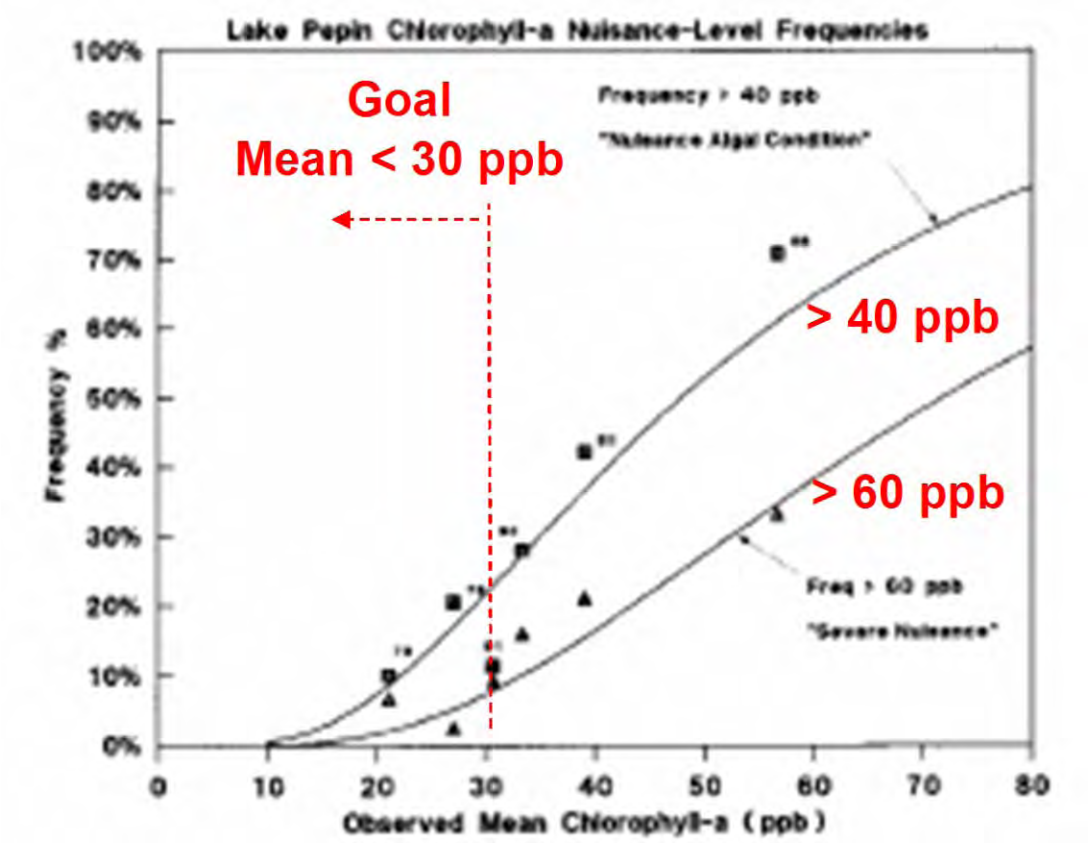
Algal Bloom Frequency vs. Total Phosphorus
St. Paul Water Supply



Progress Towards Achieving Total P Goal for Vadnais Lake



Development of a Chlorophyll-a Goal for Lake Pepin, Minnesota



Algal Bloom Frequencies vs. Mean Chl-a in Different Years

Heiskary & Walker, "Establishing a Chlorophyll-a Goal for a Run-of-the River Reservoir" Lake & Reservoir Management, 1995

Topics

- Conceptual Model
- Case Studies
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- Design of User Surveys
- Analysis of User Survey Data

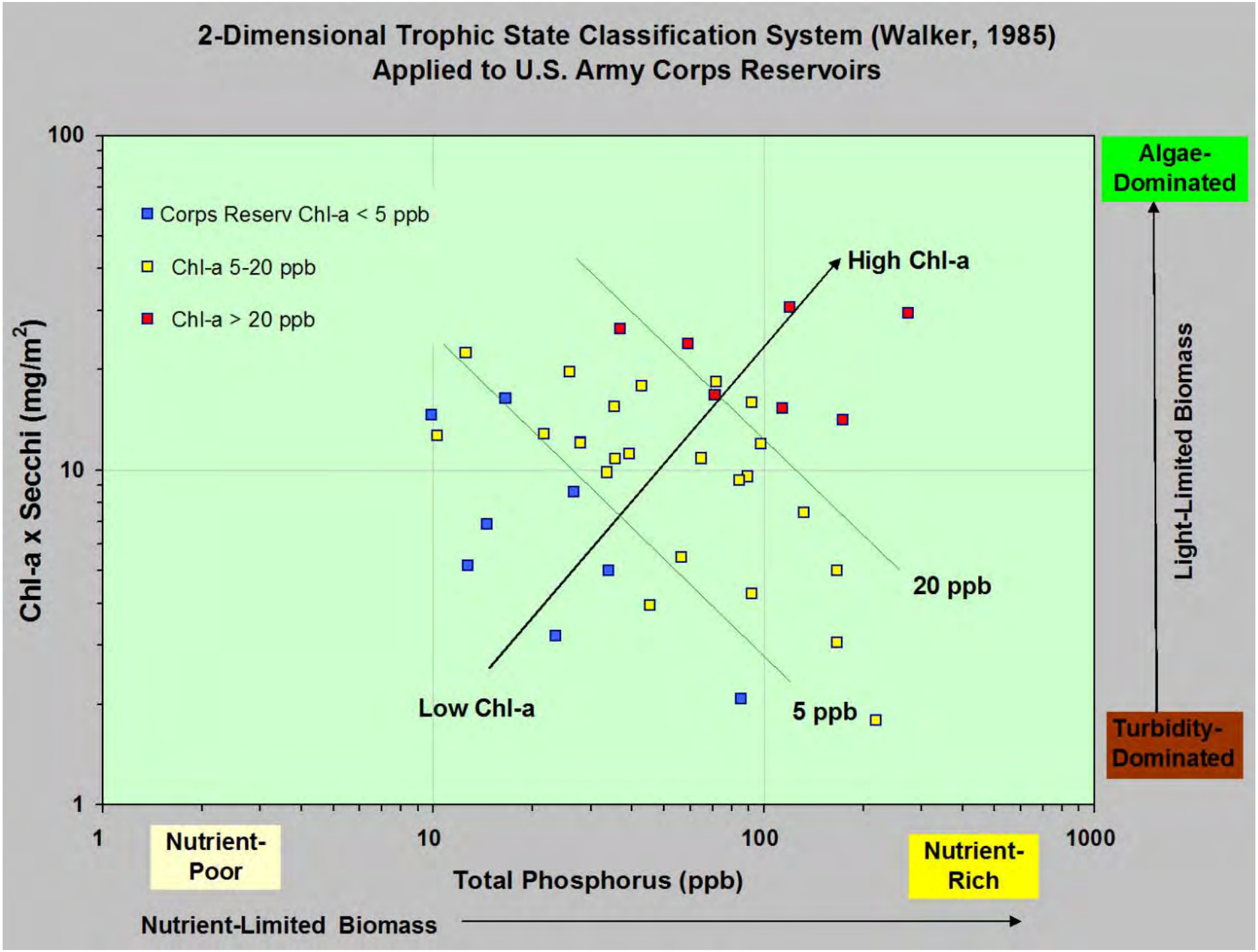
D R A F T

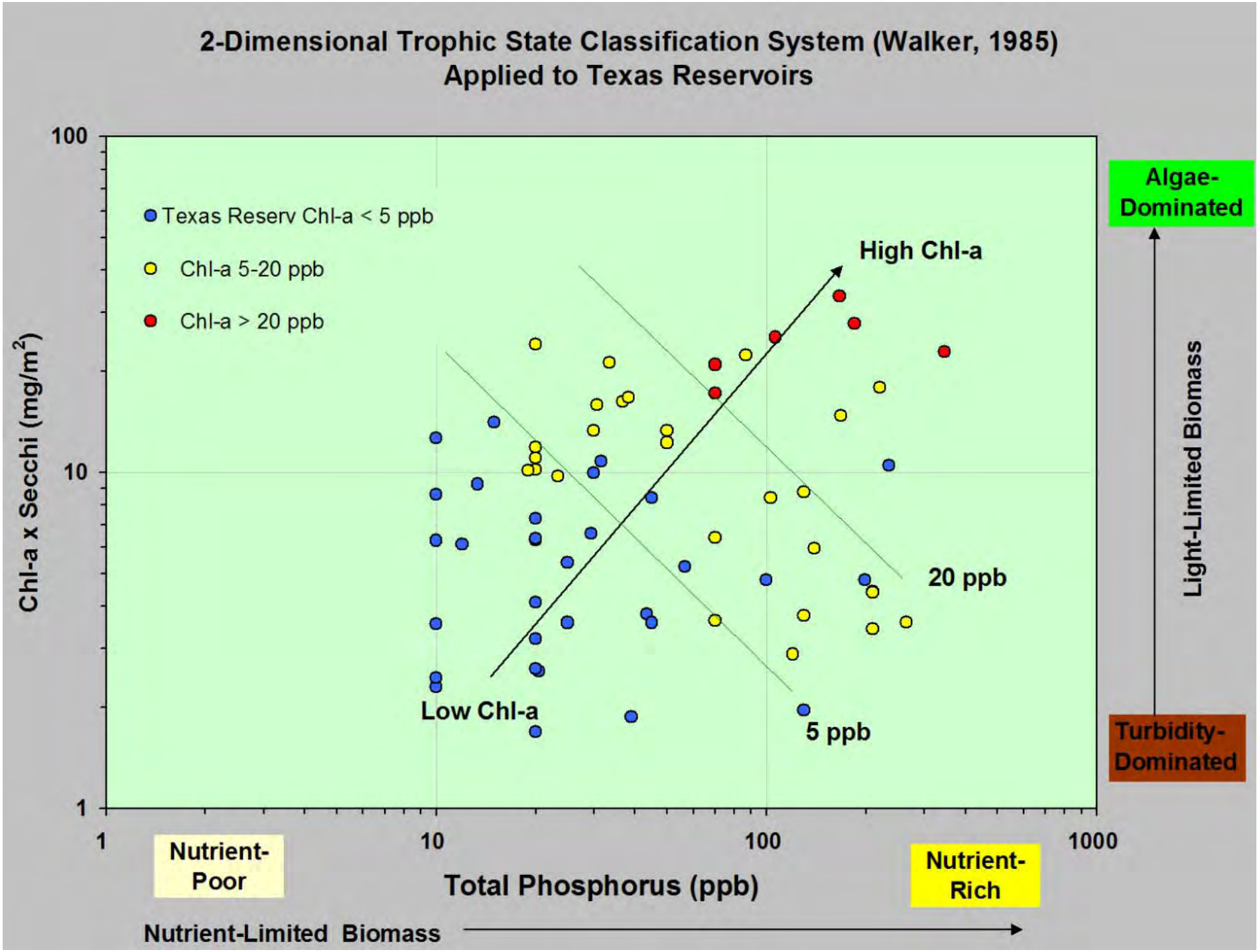
Summary of Historical Monitoring Data from Study Reservoirs

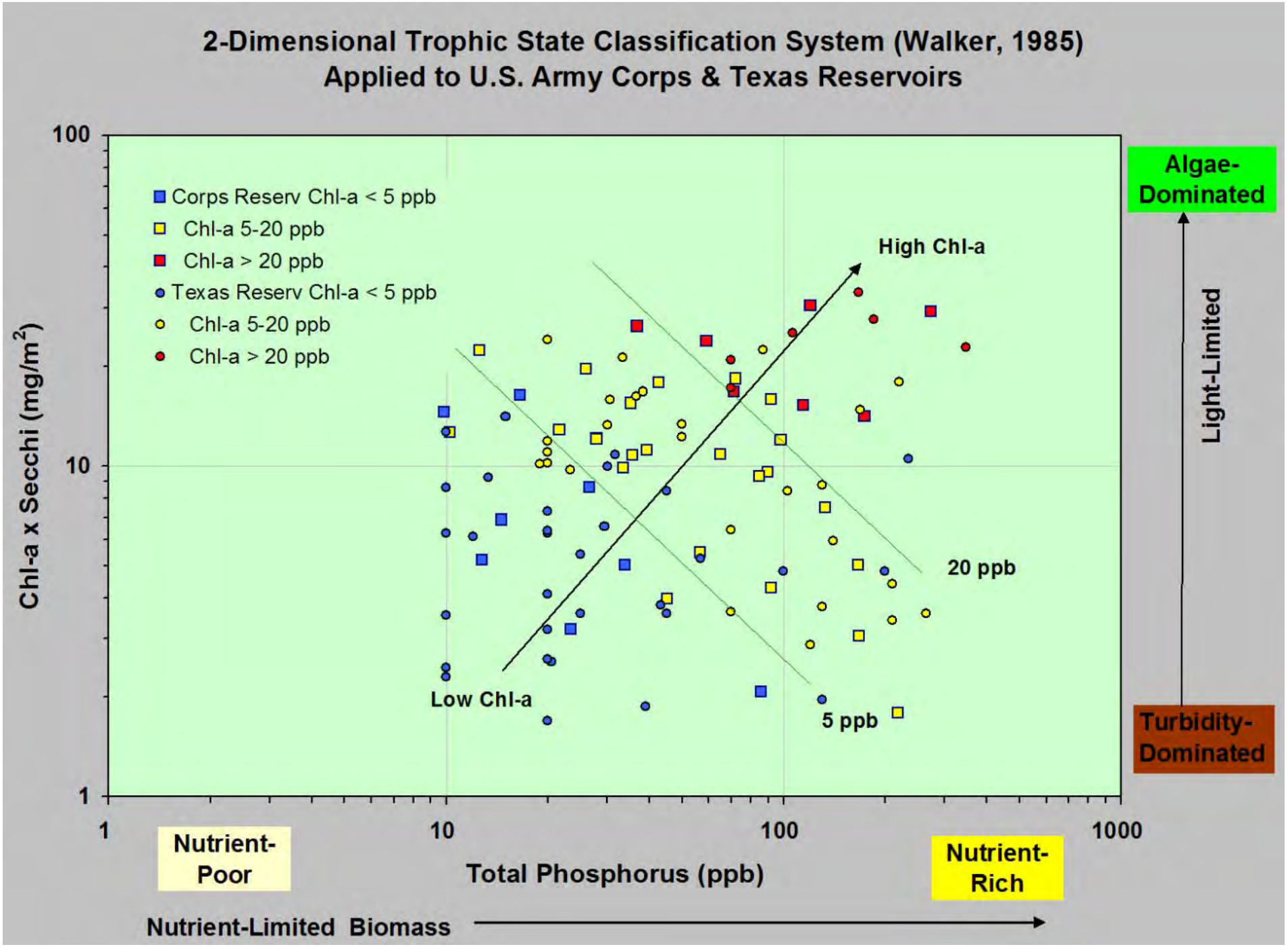
		Chlorophyll-a Samples			TP	Chl-a	Phaeo	Secchi
Reservoir	Ref	First	Last	Count	ppb	ppb	ppb	m
LAKE FORK	R	1990	2001	38	41	12.4	4.0	1.5
LIVINGSTON		1990	2000	39	151	21.9	3.6	0.9
BRIDGEPORT	R	1990	2001	24	31	5.8	0.1	1.6
CEDAR		1990	1994	6	74	15.1	5.6	0.7
HOUSTON		1990	2001	14	243	10.1	6.7	0.5
GRANGER		1990	1999	11	30	2.7	5.2	0.5
GEORGETOWN	R	1990	1998	12	20	1.8	1.3	2.3
TRAVIS	R	1990	2001	28	53	3.5	1.6	3.9
CANYON	R	1992	2001	27	45	2.3	2.0	3.5

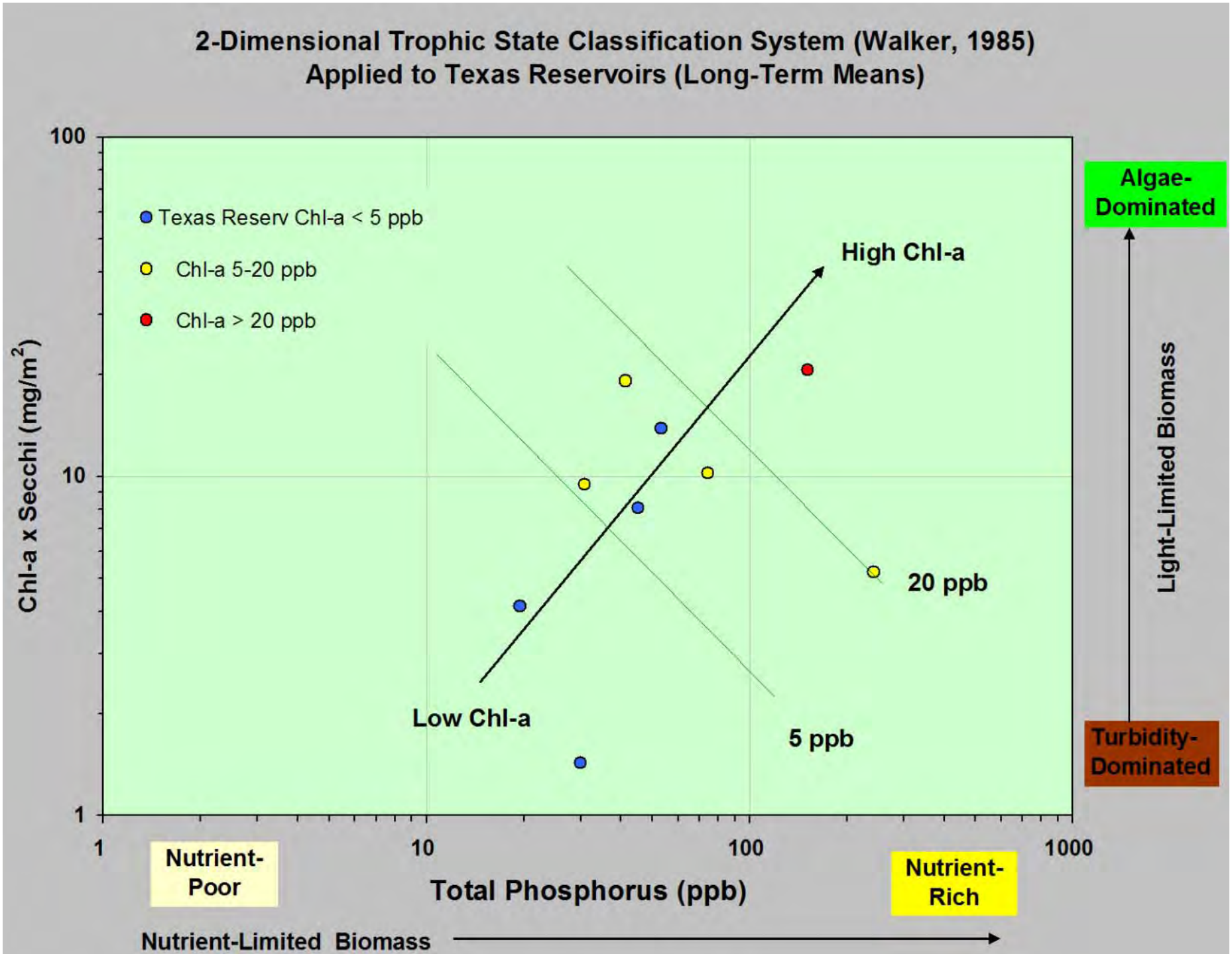
Ref = Reference Lake (State/USGS Study)

Samples <= 5 meters, May-September, 1990-2001

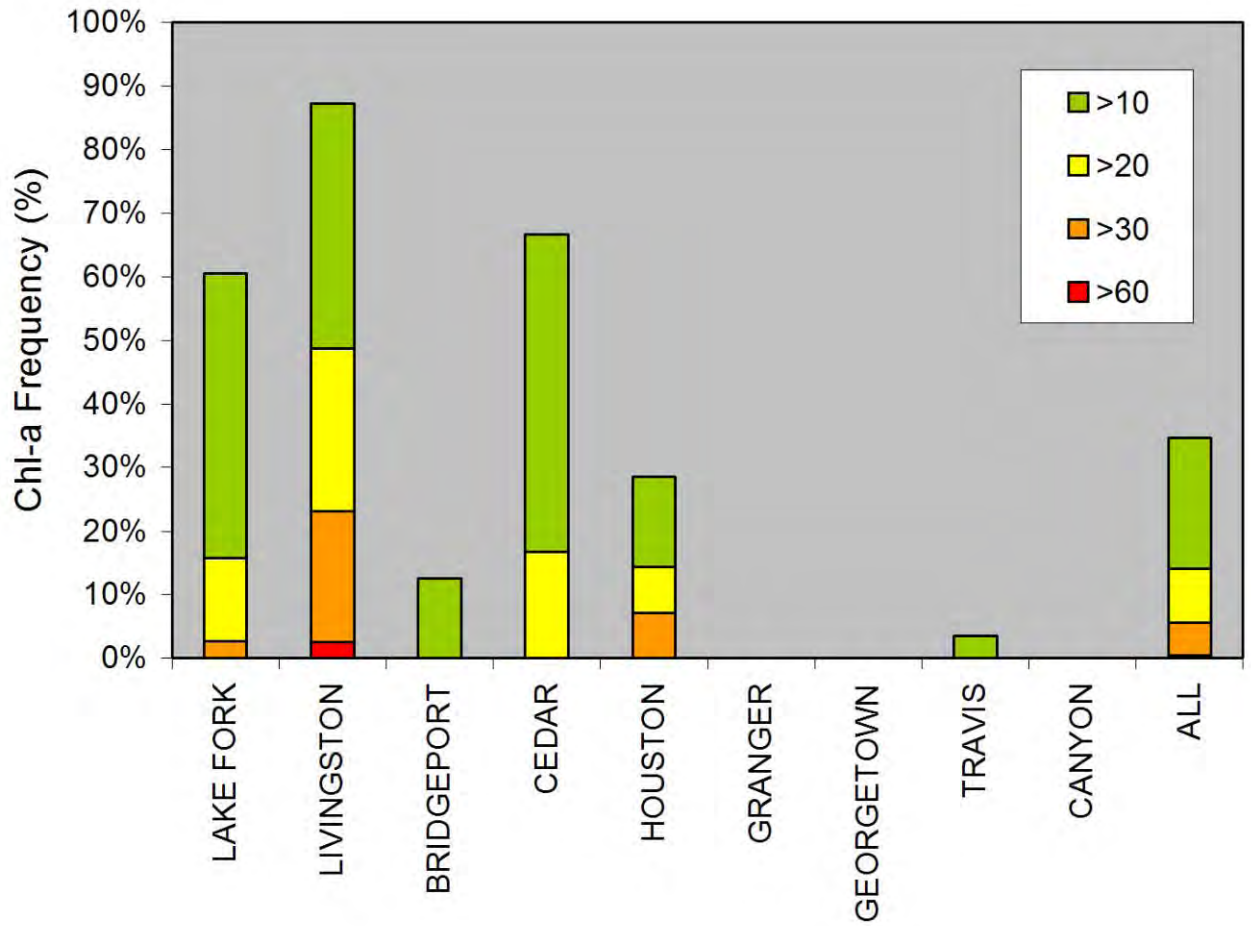

2-Dimensional Trophic State Classification System (Walker, 1985)
Applied to U.S. Army Corps Reservoirs
Corps Reserv Chl-a < 5 ppb
Chl-a 5-20 ppb
Chl-a > 20 ppb
High Chl-a
Low Chl-a
20 ppb
5 ppb
Algae-Dominated
Turbidity-Dominated
Light-Limited Biomass
Chl-a x Secchi (mg/m2)
100
10
1
1
10
100
1000
Nutrient-Poor
Nutrient-Rich
Total Phosphorus (ppb)
Nutrient-Limited Biomass


2-Dimensional Trophic State Classification System (Walker, 1985)
Applied to Texas Reservoirs
Texas Reserv Chl-a < 5 ppb
Chl-a 5-20 ppb
Chl-a > 20 ppb
High Chl-a
20 ppb
5 ppb
Low Chl-a
Algae-Dominated
Light-Limited Biomass
Turbidity-Dominated
Chl-a x Secchi (mg/m2)
100
10
1
1
10
100
1000
Nutrient-Poor
Total Phosphorus (ppb)
Nutrient-Rich
Nutrient-Limited Biomass


2-Dimensional Trophic State Classification System (Walker, 1985)
Applied to U.S. Army Corps & Texas Reservoirs
Corps Reserv Chl-a < 5 ppb
Chl-a 5-20 ppb
Chl-a > 20 ppb
Texas Reserv Chl-a < 5 ppb
Chl-a 5-20 ppb
Chl-a > 20 ppb
High Chl-a
Low Chl-a
20 ppb
5 ppb
Algae-Dominated
Light-Limited
Turbidity-Dominated
Chl-a x Secchi (mg/m2)
100
10
1
1
10
100
1000
Nutrient-Poor
Total Phosphorus (ppb)
Nutrient-Rich
Nutrient-Limited Biomass


2-Dimensional Trophic State Classification System (Walker, 1985)
Applied to Texas Reservoirs (Long-Term Means)
Texas Reserv Chl-a < 5 ppb
Chl-a 5-20 ppb
Chl-a > 20 ppb
High Chl-a
Low Chl-a
20 ppb
5 ppb
Chl-a x Secchi (mg/m2)
100
10
1
1
10
100
1000
Total Phosphorus (ppb)
Nutrient-Poor
Nutrient-Rich
Nutrient-Limited Biomass
Algae-Dominated
Light-Limited Biomass
Turbidity-Dominated

Algal Bloom Frequencies in Study Reservoirs



Walmsley (1983) Classifications based upon Instantaneous Chlorophyll-a (ppb)

>10 **Algae Visible**

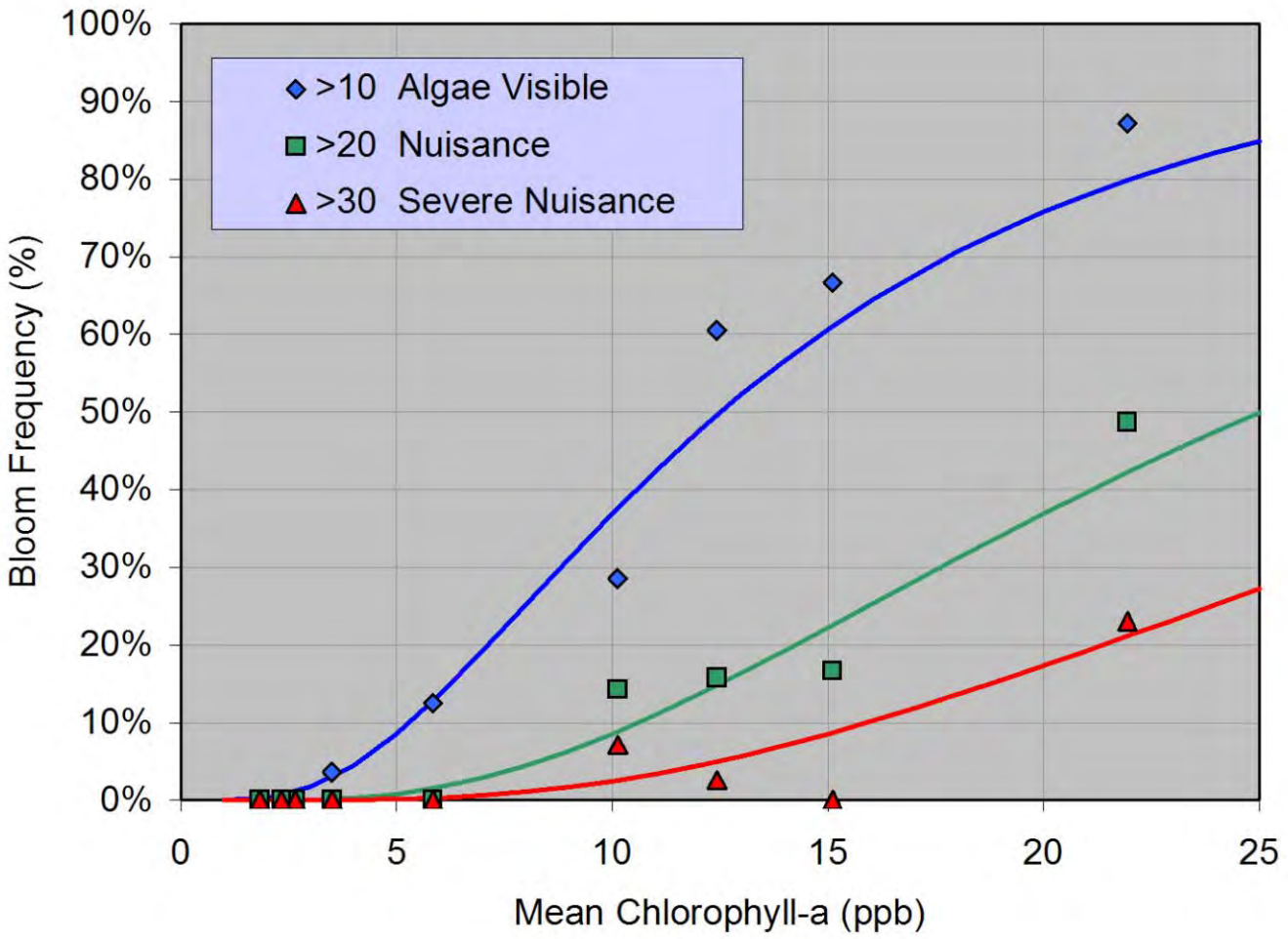
>20 **Nuisance**

>30 **Severe Nuisance**

>60 **[Even Worse]**

1990-2001, May-September

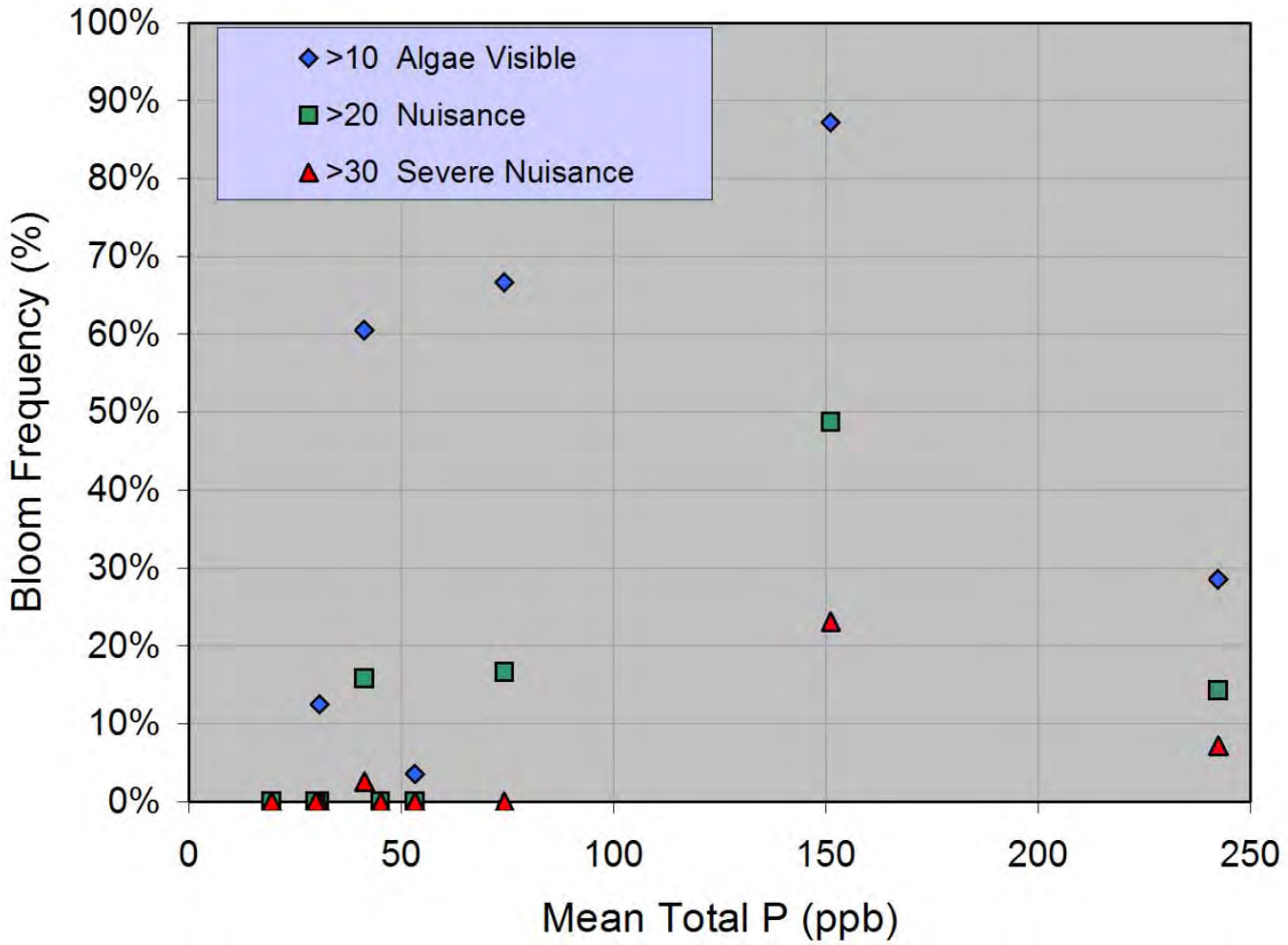
Bloom Frequency vs. Mean Chl-a in Study Reservoirs



Symbols = Observed Values for Study Reservoirs **1990-2001, May-September**

Lines = Predicted from Log-Normal Distribution **CV = 0.67 (Walker, 1985)**

Bloom Frequency vs. Mean Total P in Study Reservoirs



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Minnesota & Vermont User Survey Form

A. Please circle the one number that best describes the physical condition of the water today:

1. Crystal clear water.
2. Not suite crystal clear, a little algae present/visible
3. Definite algal green, yellow, or brown color apparent.
4. High algal levels with limited clarity and/or mild odor apparent.
5. Severely high algal levels with one or more of the following: massive floating scums on surface or washed up on shore, strong foul odor, or fish kill

B. Please circle the one number that best describes your opinion on how suitable the water is for recreation and aesthetic enjoyment today:

1. Beautiful, could not be any nicer.
2. Very minor aesthetic problems; excellent for swimming, boating, enjoyment.
3. Swimming and aesthetic enjoyment slightly impaired because of algal levels.
4. Desire to swim and level of enjoyment of the water substantially reduced because of algal levels (would not swim, but boating is okay).
5. Swimming and aesthetic enjoyment of the water nearly impossible because of algal levels.

Lower Charles River User Survey

Location: _____
Surveyor: _____
Data Collector: _____
Date: _____ Time: _____

Aesthetics

A. Please circle the one number that best describes the color of the water today:

1. Clear or blue
2. Yellow or brown
3. More brown than green
4. More green than brown
5. Green

B. Please circle the one number that best describes the amount of particles or algae present in the water today:

1. Very little or none
2. Some present
3. Substantial amount present
4. Overwhelming amount present

C. Please circle the one number that best describes the odor of the water today:

1. No odor
2. Mild odor
3. Strong odor

Type of odor detected: sewage, fish, musty, sulfur, other: _____

Lower Charles River User Survey

Location: _____
Surveyor: _____
Data Collector: _____
Date: _____ Time: _____

Recreation Use

D. Based ONLY on the aesthetic condition of the water today, please circle the one number that best corresponds to your level of enjoyment for swimming today (ignoring any previous impressions and assuming that there are no health risks):

1. Excellent for swimming; very minor or no aesthetic problems
2. Swimming enjoyment slightly impaired due to aesthetic problems; would still swim
3. Swimming enjoyment substantially reduced due to aesthetic problems; would not swim
4. Swimming enjoyment nearly impossible due to aesthetic problems

E. Based ONLY on the aesthetic condition of the water today, please circle the one number that best corresponds your level of enjoyment for boating today (ignoring any previous impressions and assuming that there are no health risks):

1. Excellent for boating; very minor or no aesthetic problems
2. Boating enjoyment slightly impaired due to aesthetic problems
3. Boating enjoyment substantially reduced due to aesthetic problems
4. Boating enjoyment nearly impossible due to aesthetic problems

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LAKE AND RESERVOIR MANAGEMENT, 1988 4(1): 1–9

Developing Phosphorus Criteria for Minnesota Lakes

Steven A. Heiskary
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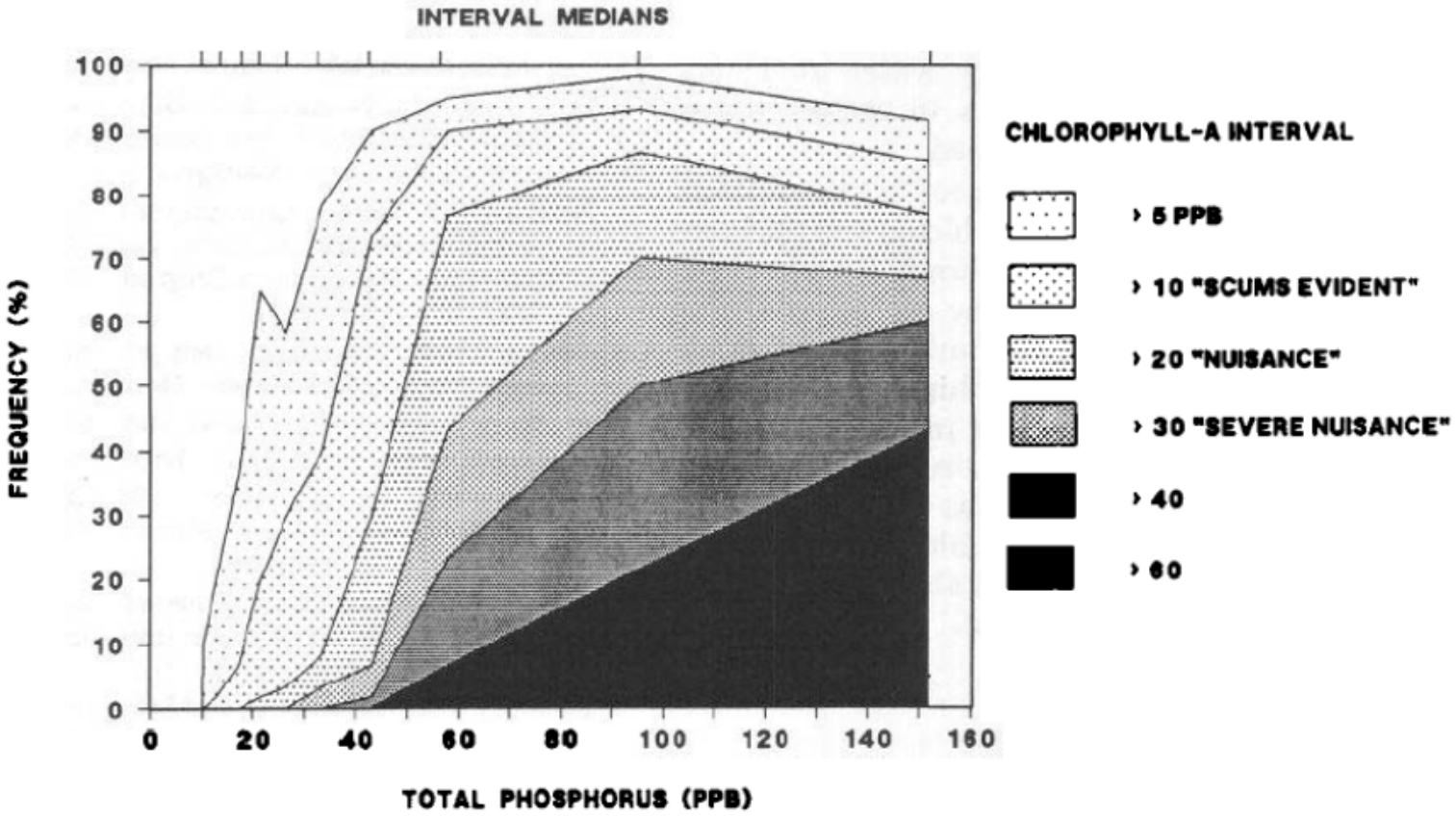
William W. Walker, Jr.
Environmental Engineer, Concord, Massachusetts

Table 1.—Aesthetic or use impairment classification systems based upon chlorophyll-a or transparency.

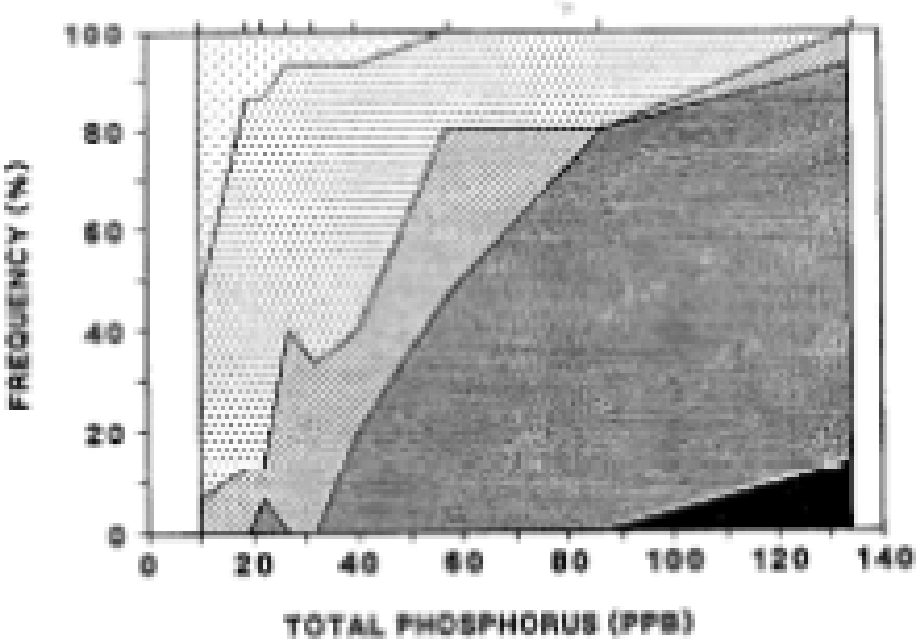
AUTHOR/ LOCATION	CHL-A (PPB)	SECCHI DEPTH (M)	RATING
Walmsley (1984) South African Reservoir	0–10		No Problems
	10–20		Scums Evident
	20–30		Nuisance
	> 30		Severe Nuisance
Burden et al. (1985) Louisiana	14 (a)	1.2	Excellent to Good
	30 (a)	0.8	Good to Acceptable
	32 (a)	0.7	Acceptable to Marginal
Barica (1975) Canadian Prairie Ponds	0–25	> 1	Clear, No Blooms
	25–100	.4–1	Moderate Blooms
	100–200	< .4	Dense Colonies & Scums
McGhee (1983) North Carolina	> 15		Unsuitable for Trout
	> 40 (b)		Severe Nuisance
Lillie and Mason (1983) Wisconsin	< 1	> 6	Excellent
	1–5	3–6	Very Good
	5–10	2–3	Good
	10–15	1.5–2	Fair
	15–30	1–1.5	Poor
	> 30	< 1	Very Poor
Effler et al. (1984) New York		> 1.2	State Standard for Beaches
MDPH (1969) Massachusetts		> 1.2	State Standard for Beaches

[a] Class means.
[b] North Carolina standard.

Bloom Frequency vs. Total P



Physical Appearance vs. Total P



PHYSICAL APPEARANCE

1 = CRYSTAL CLEAR

2 = SOME ALGAE

3 = DEFINITE ALGAE

4 = HIGH ALGAE

5 = SEVERE ALGAE

MPCA STAFF SURVEY

INTERVAL MEDIANS

Physical Appearance vs. TP, Chl-a, & Secchi

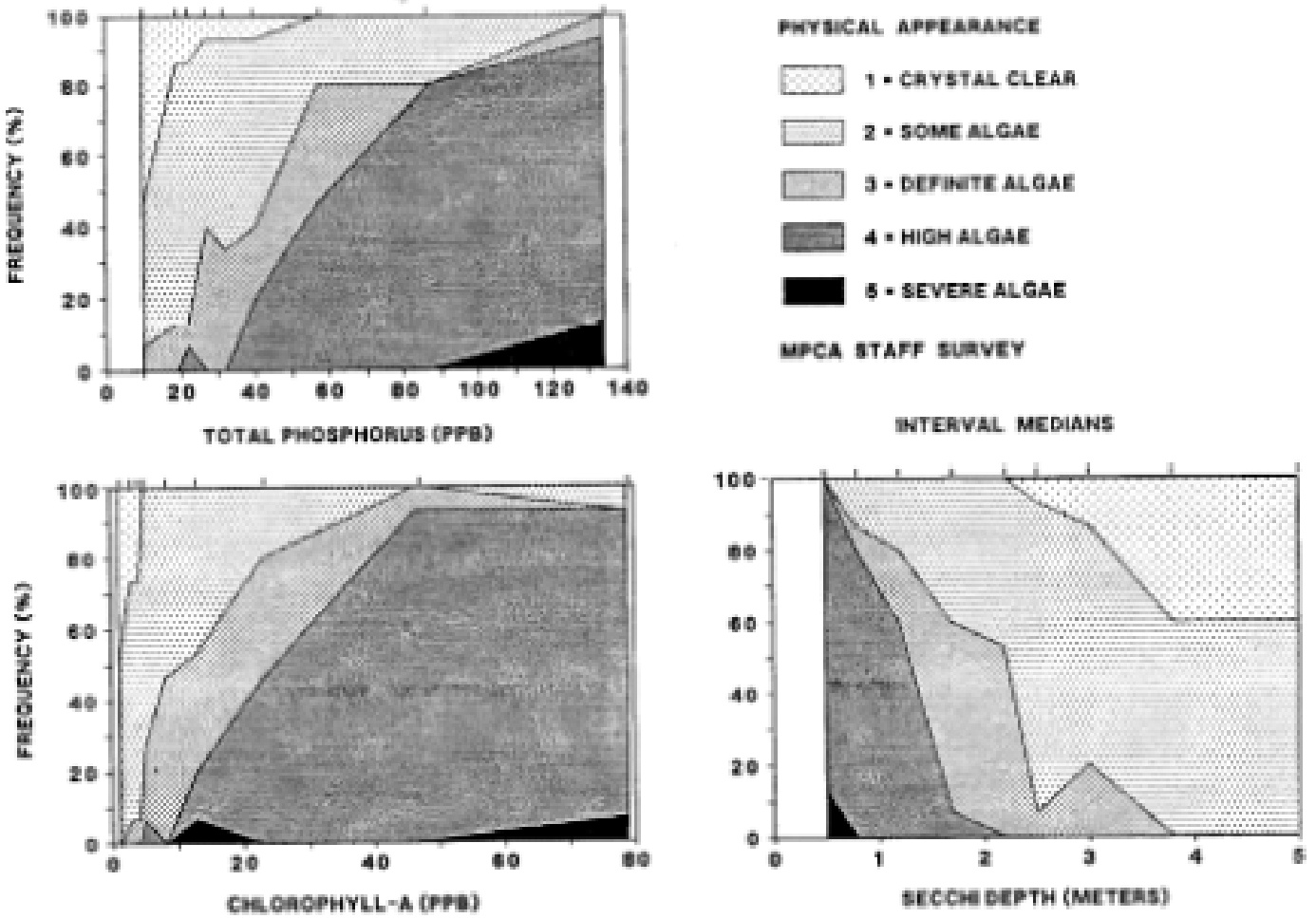


Figure 4.–Physical appearance ratings vs. lake water quality measurements.

Recreation Potential vs. TP, Chl-a, & Secchi

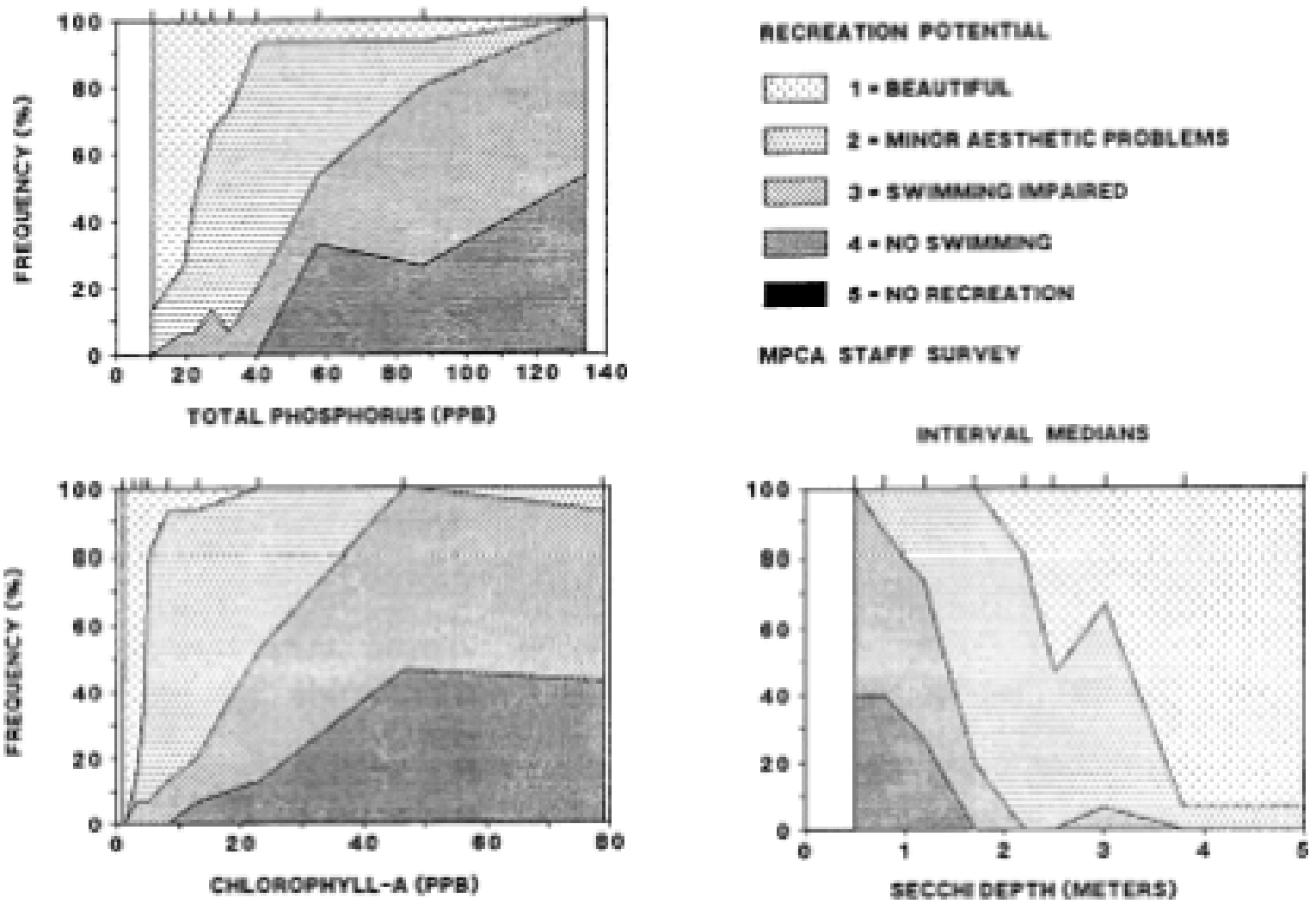
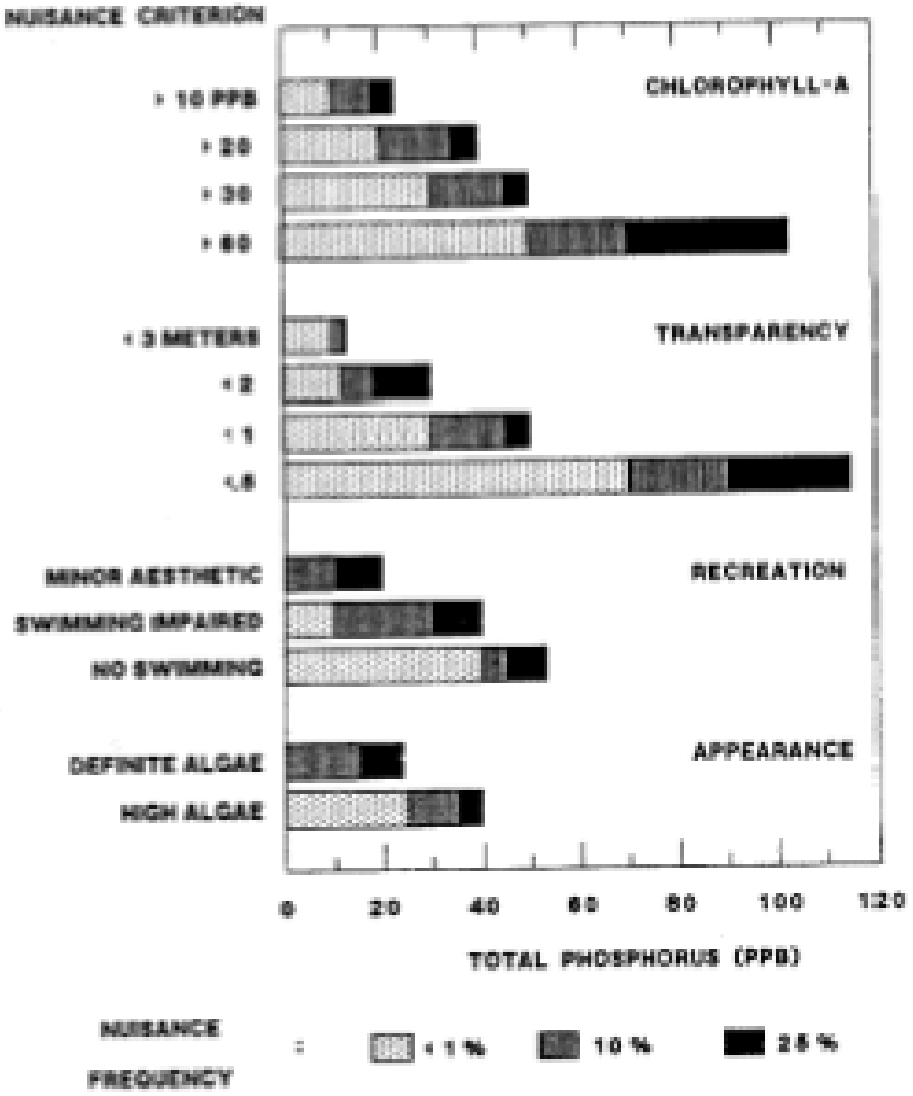
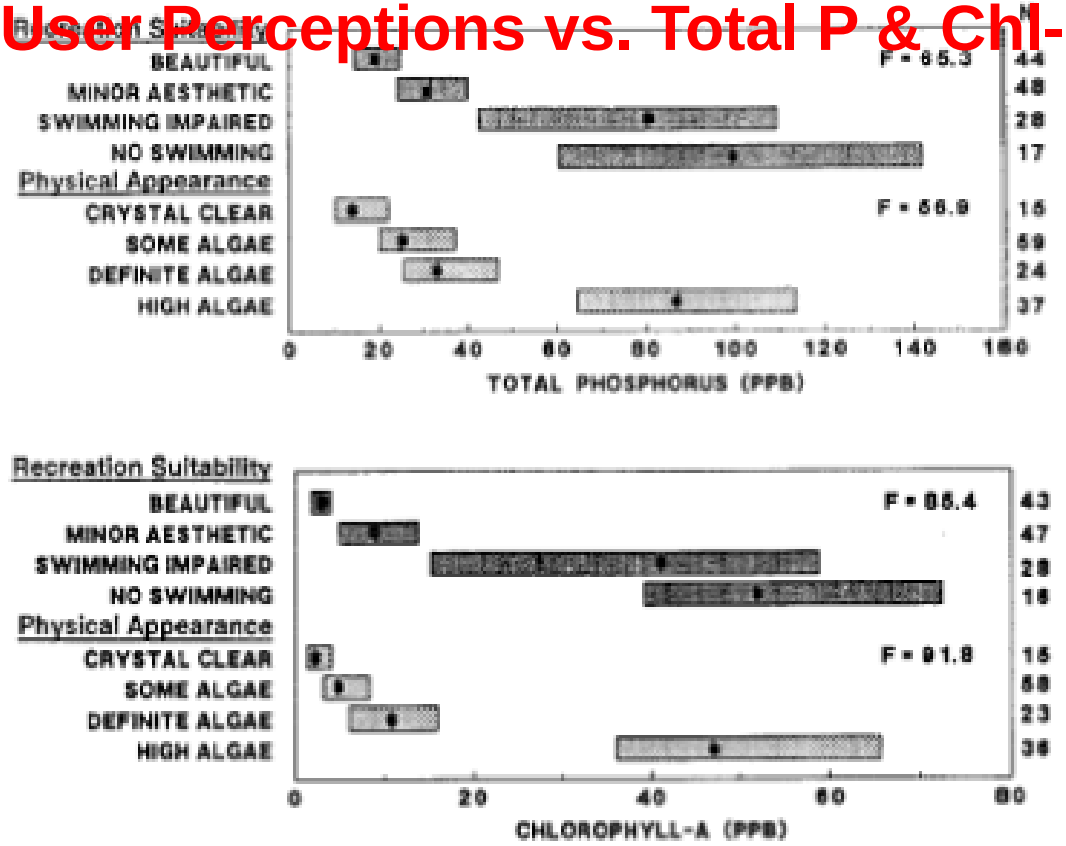


Figure 5.—Recreation potential ratings vs. lake water quality measurements.

Impairment Indices vs. TP



User Perceptions vs. Total P & Chl-a



Inter-Quartile Ranges of Data in Each Rating Category
Heiskary & Walker, “Development of Phosphorus Criteria for Minnesota Lakes”, Lake & Reservoir Management, 1985.

LAKE AND RESERVOIR MANAGEMENT, 1990 6(1): 109-118

Analysis and Applications of Lake User Survey Data

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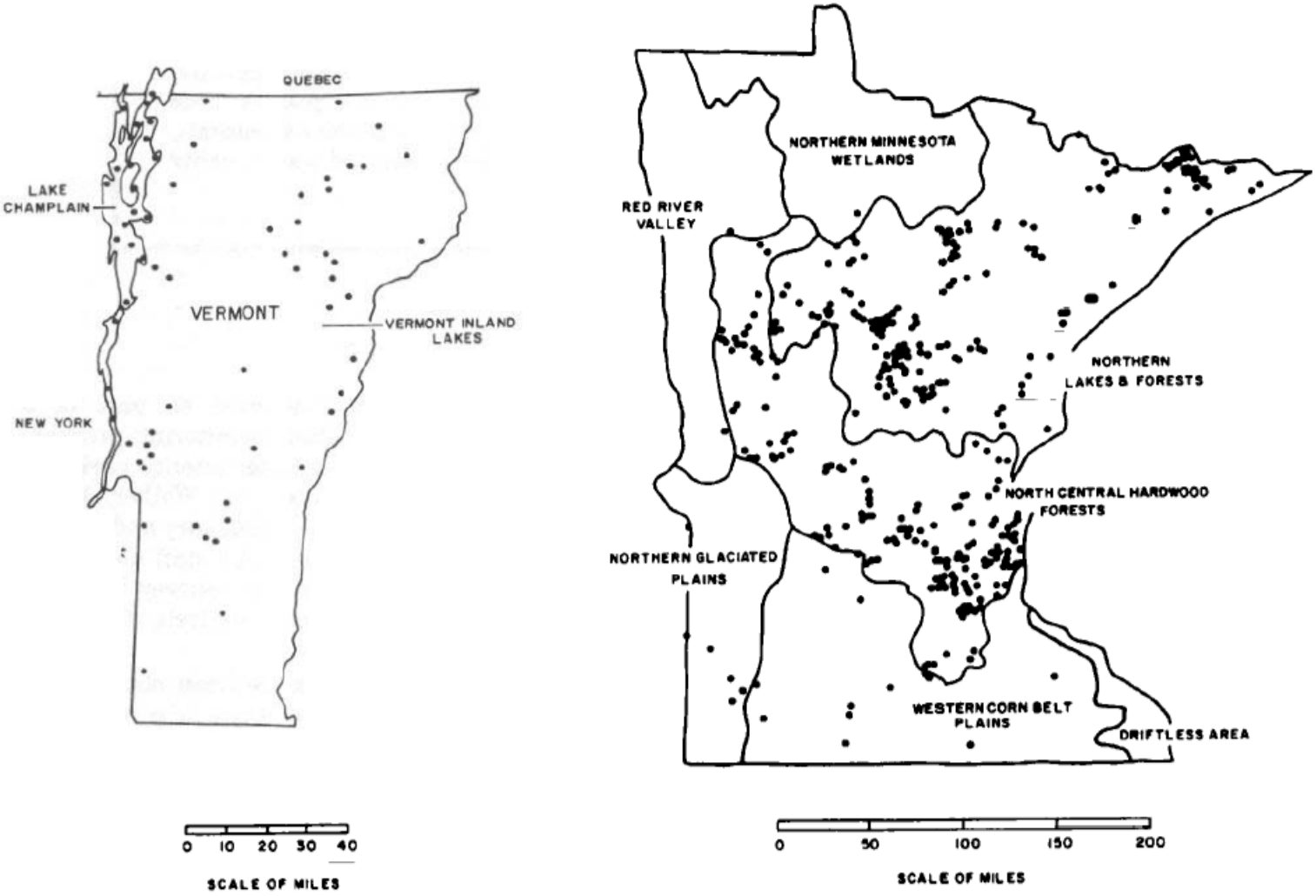
Regional Distribution of Study Lakes



Transparency vs. Recreation Potential & Region

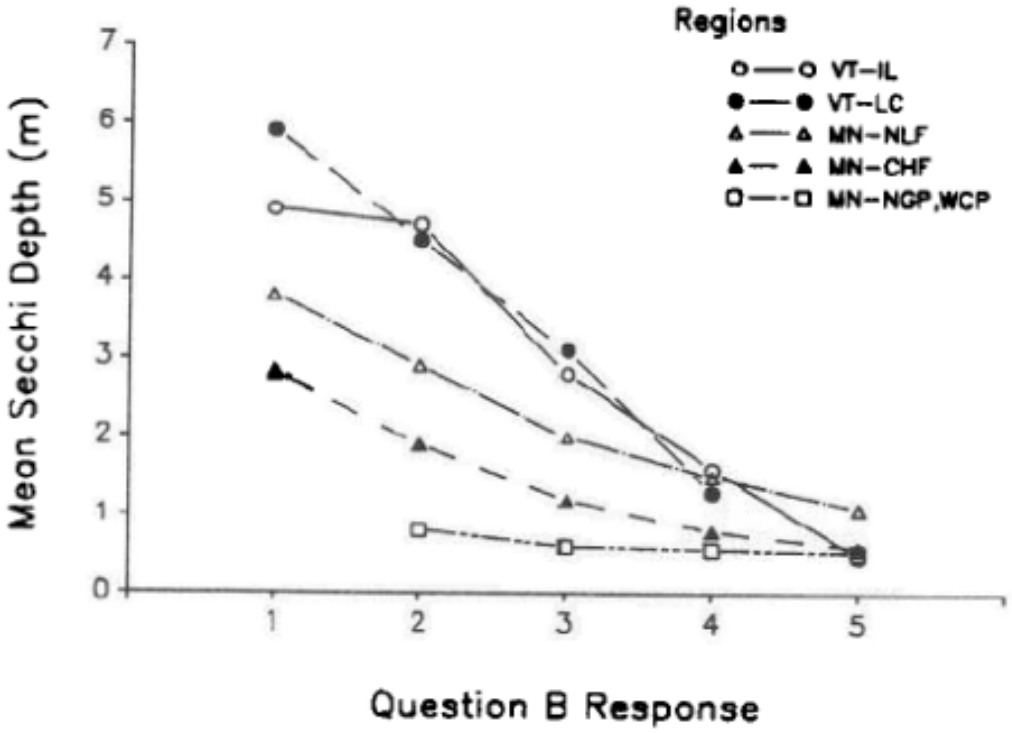


Figure 2.—Geometric mean Secchi depth plotted vs. user survey response category for lake regions in Vermont and Minnesota. See Table 2 for region definitions.

Criteria for Support of Recreational Use Based upon User-Survey Results Minnesota Lakes

1. **Fully supporting:** Lakes fully supporting their uses should exhibit "impaired swimming" conditions (survey response B3) at less than a 10 percent frequency and should exhibit "high algal levels" (survey response A4) at less than a 10 percent frequency.

2. **Fully supporting—threatened:** These lakes may exhibit "impaired swimming" conditions at a frequency of 11-25 percent and "high algal levels" at a frequency of 11-25 percent.

3. **Partial support—impaired:** These lakes may exhibit "impaired swimming" at a 26-50 percent frequency and "no swimming" (survey response B4) at less than a 10 percent frequency. In terms of physical conditions, these lakes may exhibit "high algal levels" at a 26-50 percent frequency.

4. **Non-support—impaired:** These lakes will exhibit "no swimming" conditions with greater than 25 percent frequency and "no recreation possible" (survey response B5) on occasion. In terms of physical condition, these lakes will exhibit "high algal levels" with greater than 50 percent frequency.

Recreation Potential vs. Total P
Vermont Lakes

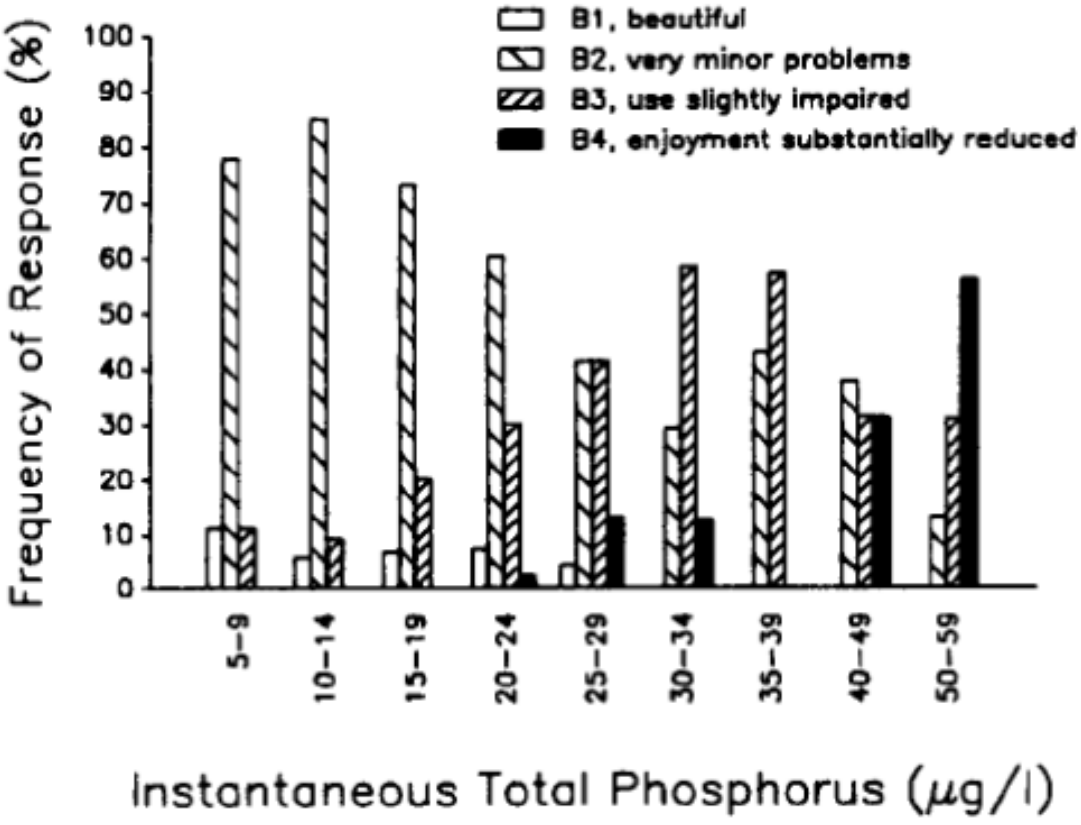


Figure 4.—Relationship between user survey response and total phosphorus concentration in Lake Champlain.

Recreation Potential vs. Chlorophyll-a
Vermont Lakes

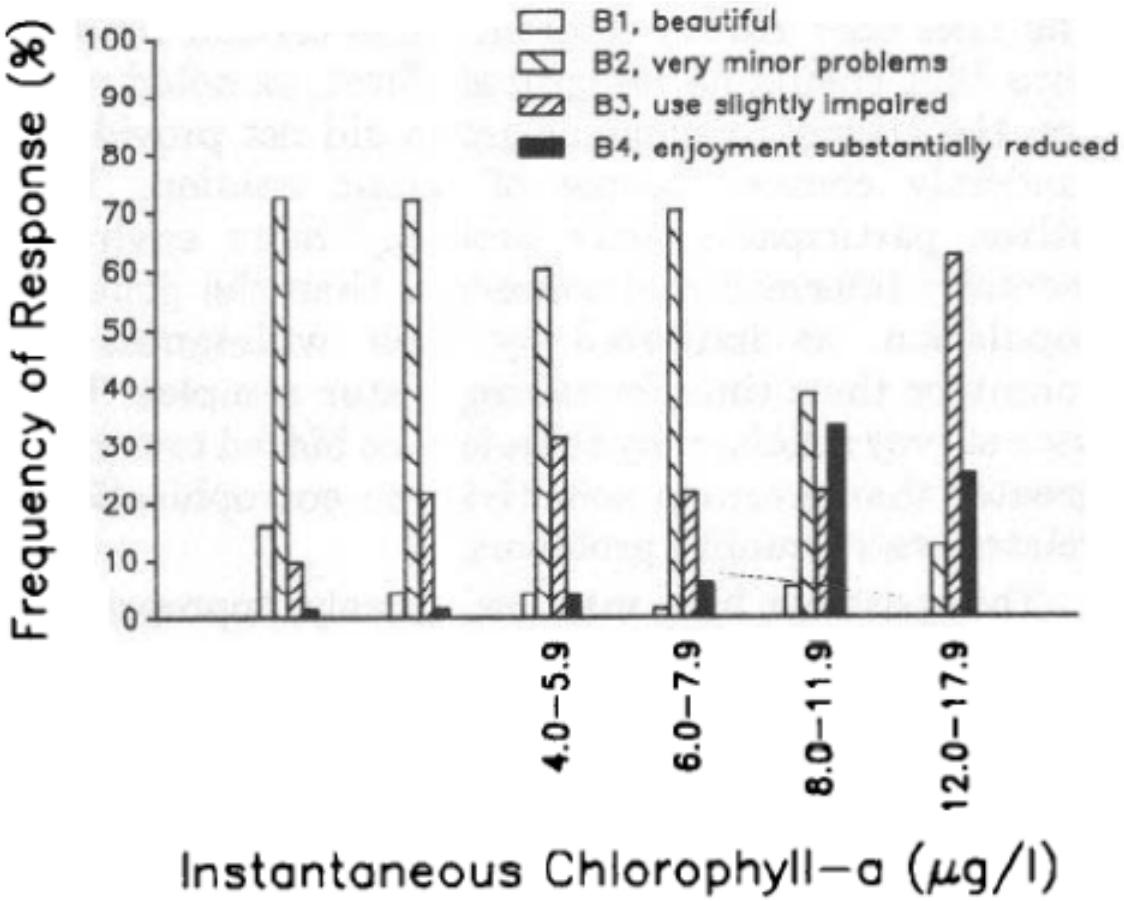


Figure 5.—Relationship between user survey response and chlorophyll *a* concentration in Lake Champlain.

Regional Variations in Transparency Criteria Based upon User Perception

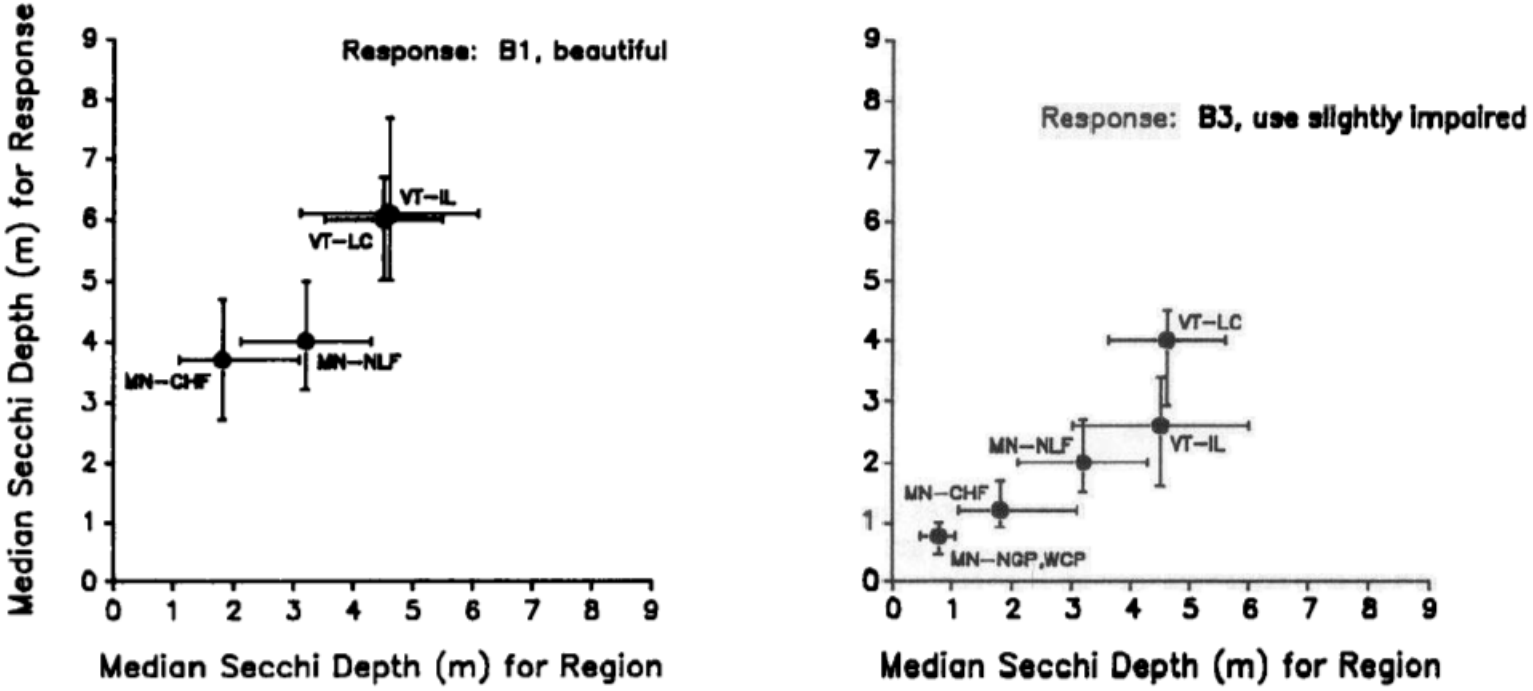


Figure 3.—Median Secchi depths for four user survey response categories plotted vs. the median Secchi depths for each lake ecoregion. Error bars represent interquartile ranges. See Table 2 for region definitions.