Development of Nutrient Criteria Through Use Impairment Survey Data

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Nutrient Criteria for....?

- EPA Recommends that Nutrient Criteria be Developed for:
  - Causal Variables:
    - Phosphorus and Nitrogen
  - Response Variables:
    - Water Clarity and Chlorophyll a

Options for Developing Nutrient Criteria

1) Existing Narrative Standard
2) Existing Guidance Value
3) Default 304(a) Criteria
4) Reference Condition or Reference Waterbody Approach
5) Combination of Options 1 to 4

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Existing Narrative Standard

- **Phosphorus and Nitrogen:**
  - **NY: "None in amounts that will result in growths of algae, weeds, and slimes that will impair the waters for their best usages"**
  - **ME: "There shall not be allowed any increase in trophic state from cultural activity"**
  - **MA: "no new or increased point source discharge of nutrients...to lakes and ponds.... Any existing point source discharge containing nutrients in concentrations which encourage eutrophication or growth of weeds or algae shall be provided with the highest and best practical treatment to remove such nutrients"**
  - **CT: "None other than of natural origin"**
- **Water Clarity:**
  - **No narrative standard exists**
- **Chlorophyll *a*:**
  - **No narrative standard exists**
- **Non- or Anti-Degradation laws exist in all states**

Existing Narrative Standard

- Advantages:
  - "Existing"- Does not need to be promulgated
  - "Narrative"- Provides flexibility in interpretation
  - "Standard"- Provides regulatory teeth for enforcement purposes
  - Can be linked to guidance value or numerical criteria as means of interpreting standard

Existing Narrative Standard

- Disadvantages:
  - Difficult to provide adequate enforcement
  - Does not provide numerical endpoint for mitigation or management
  - Does not reflect geographic differences (ecoregion) or differing lake uses
  - Appears to be inadequate to prevent nutrient over-enrichment

Existing Guidance Values or Water Quality Standards in New York State and Others

- **Phosphorus:**
  - NY: 20 µg/l to protect contact recreation (Class B and above)
  - NH: No discharge to lakes or tribs that would encourage eutrophication (11.5 µg/l)
  - RI: 25 µg/l unless natural conditions
  - VT: 10-54 µg/l in Champlain and Memphremagog; 1 µg/l increase in upland streams
- **Nitrate:**
  - NY: 10 mg/l standard to protect human health (Class A and above)
- **Ammonia:**
  - NY: 2 mg/l standard to protect human health, varying standards for un-ionized ammonia (NH_3) to protect aquatic life
- **Water Clarity:**
  - NY: 4 feet (1.2 meters) State Department of Health "guideline" for siting new beaches to protect bathing safety (Class B and above)
- **Chlorophyll *a*:**
  - NY: No guidance value exists

Existing Guidance Value(s)

- Advantages:
  - "Existing"- Does not need to be promulgated
  - Provides numerical endpoints for enforcement or management
  - Guidance values for phosphorus and clarity were developed in recognition of contact recreation

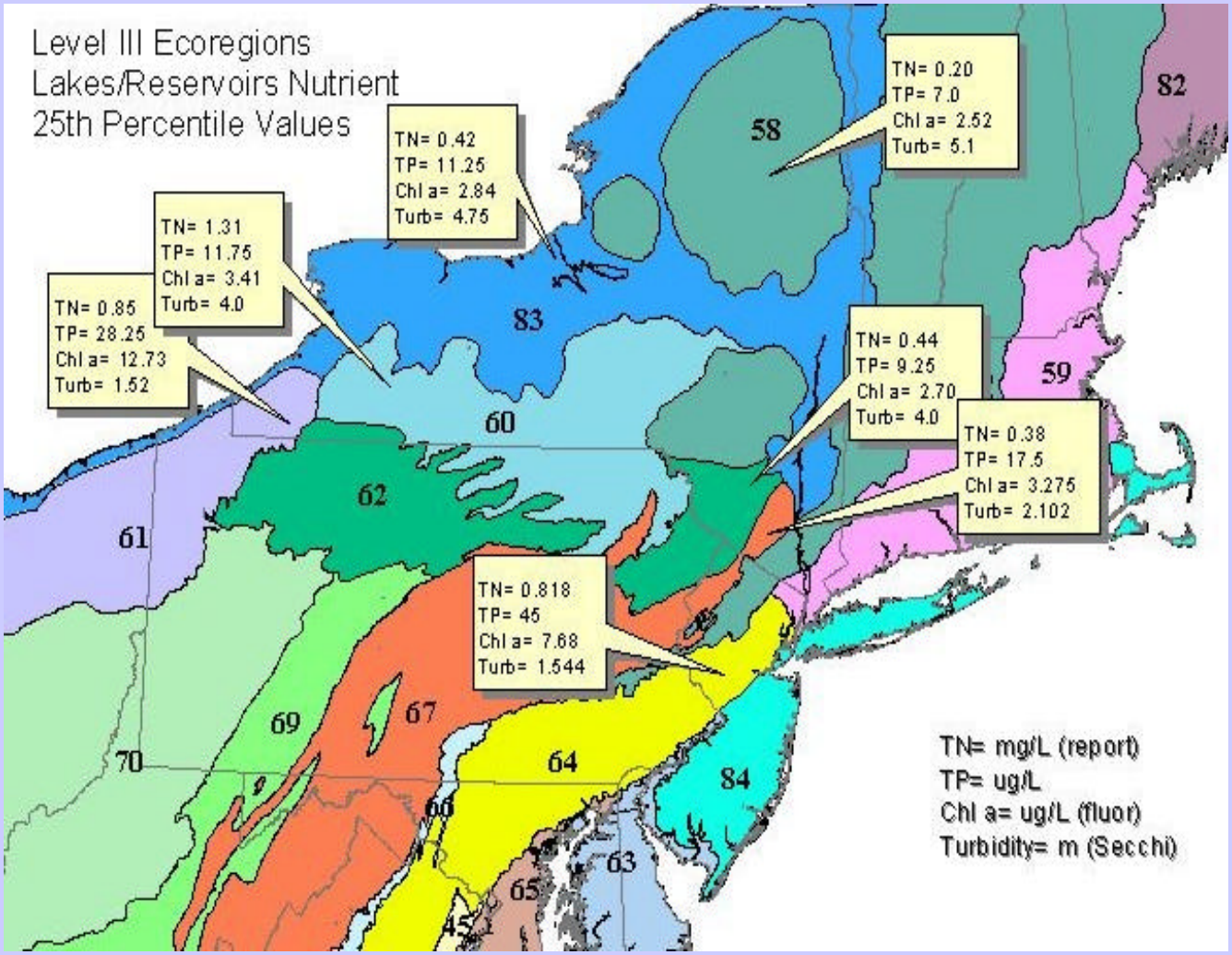
Existing Guidance Value(s)

- Disadvantages:
  - Confers potentially lower legal status than standard
  - Nitrogen and water clarity values do not protect most sensitive use (contact recreation or aesthetics)
  - Does not reflect geographic differences (ecoregion) or differing lake uses
  - Appears to be inadequate to prevent nutrient over-enrichment

Default 304(a) Criteria

- EPA Defines Default Criteria thru Nutrient Criteria Technical Guidance Manuals
- Criteria Are Eco-Region Based
- Generated from the 25th Percentile of Total Phosphorus, Total Nitrogen, Secchi Disk Transparency, and Chlorophyll *a* Readings Collected from 1990-1999

Default 304(a) Criteria



Default 304(a) Criteria

- Advantages:
  - Utilizes both large datasets and ecoregion approach
  - Criteria have already been developed
  - States can “delegate” promulgation to EPA
  - Provides numerical endpoints for enforcement or management
  - Protective of best uses in most ecoregions
  - Defined by EPA as “scientifically defensible”

Default 304(a) Criteria

- **Disadvantages:**
  - Overly restrictive in some ecoregions
  - Does not reflect differing lake uses or implicitly recognize need to base criteria on use impairment
  - Assumes ~75% of waterbodies violate criteria
  - Not recommended by EPA as sole approach to developing nutrient criteria

photo by Mike Burger

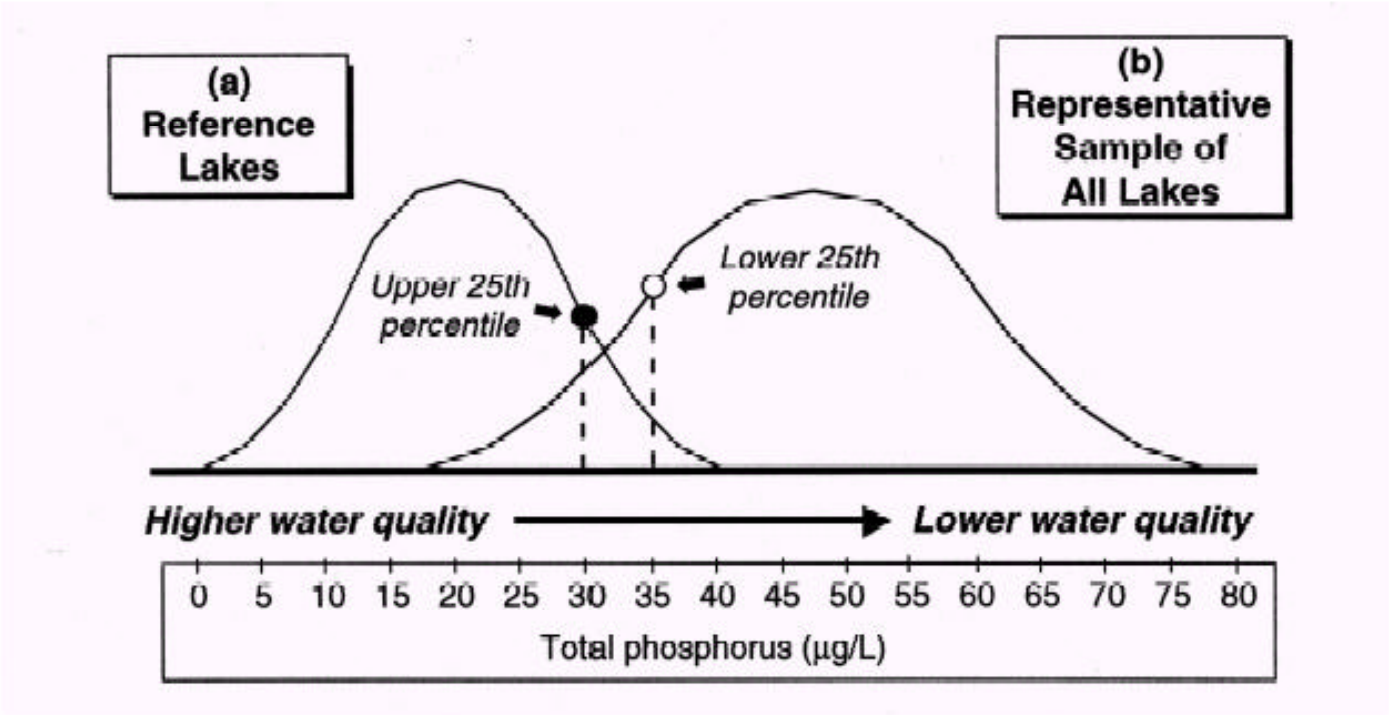
Alternative Approaches for Development of Draft Preliminary Nutrient Criteria- EPA Region 1 RTAG

- ***Statistical Approach*** *— based on Frequency Distributions and Selected Percentiles*
- ***Threshold Approach*** *— based on comparison to literature-derived nutrient thresholds for protection of designated uses*
- ***Use Impairment Approach****—based on comparison to 305(b) assessment of water uses*
- ***Multivariate Analysis*** *—discriminant analysis for potential sub-classification of waterbodies*
- ***Buffer Zone Land Use*** *—ID of reference lakes*

Reference Condition or Reference Waterbody Approach

- **Reference Condition Approach Recommended by EPA Identifies Reference Waterbodies that Correspond to "Unimpaired" or "Minimally Impaired" Conditions**
- **Criteria based on "representative statistic" (such as the upper 25th percentile or the lower 75th percentile) generated from reference waterbody dataset**

Reference Condition or Reference Waterbody Approach



Reference Condition or Reference Waterbody Approach

- "Use Impairment" surveys utilized in volunteer monitoring programs can identify reference conditions based on responses to survey questions
- Surveys originally developed by VT and MN, and are now utilized by most states in northeast and upper midwest with volunteer monitoring programs

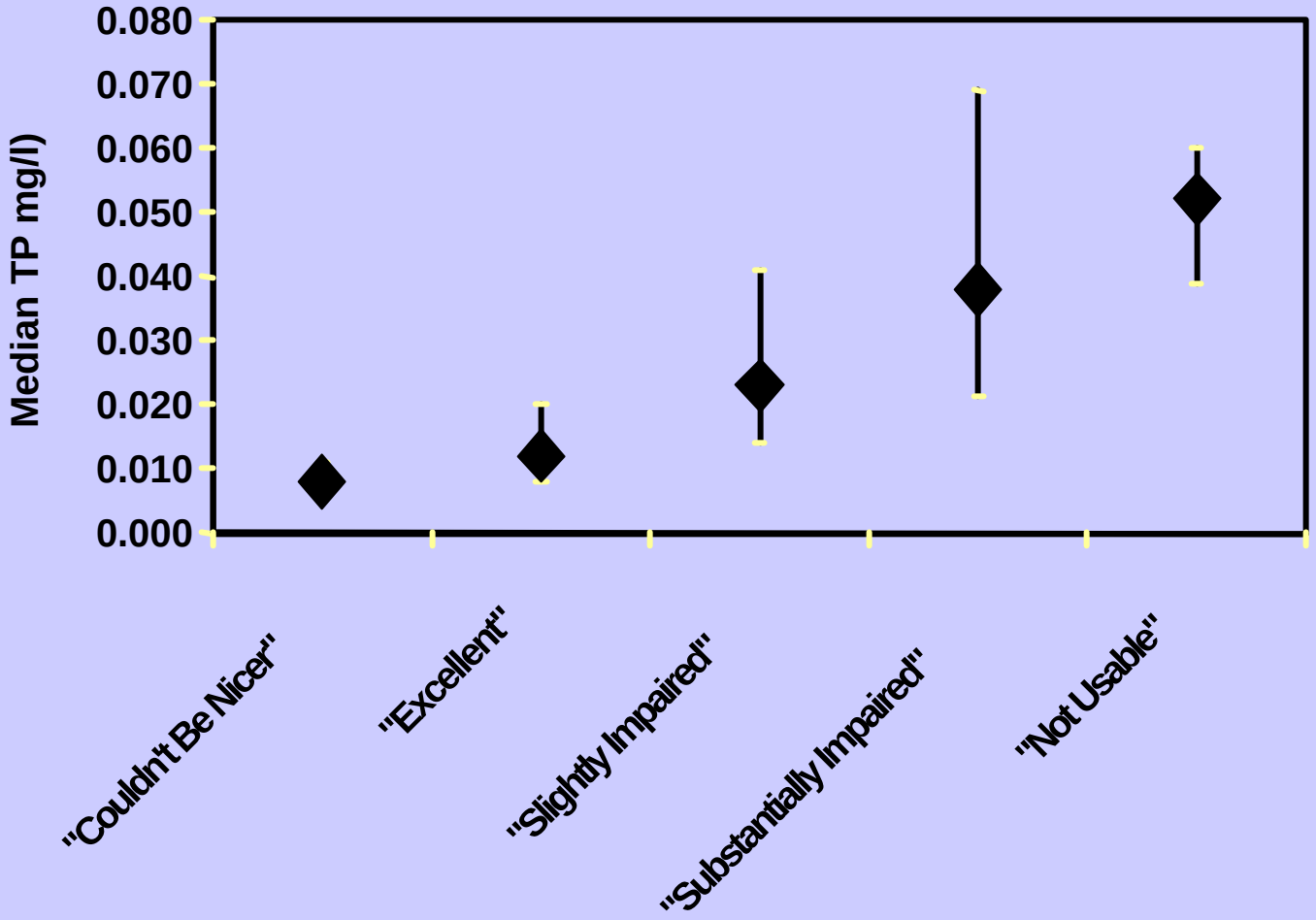
USE IMPAIRMENT SURVEY FORM

- **PLEASE CIRCLE THE <u>ONE</u> NUMBER THAT BEST DESCRIBES YOUR OPINION OF THE SUITABILITY OF THE LAKE FOR RECREATIONAL ENJOYMENT TODAY (QC):**
  1. **Beautiful, could not be nicer**
  2. **Very minor aesthetic problems- excellent for swimming, boating, and overall enjoyment**
  3. **Swimming and aesthetic enjoyment slightly impacted**
  4. **Desire to swim and enjoy the lake substantially reduced, although the lake still can be used**
  5. **Swimming and aesthetic enjoyment of the lake impossible**

USE IMPAIRMENT SURVEY FORM

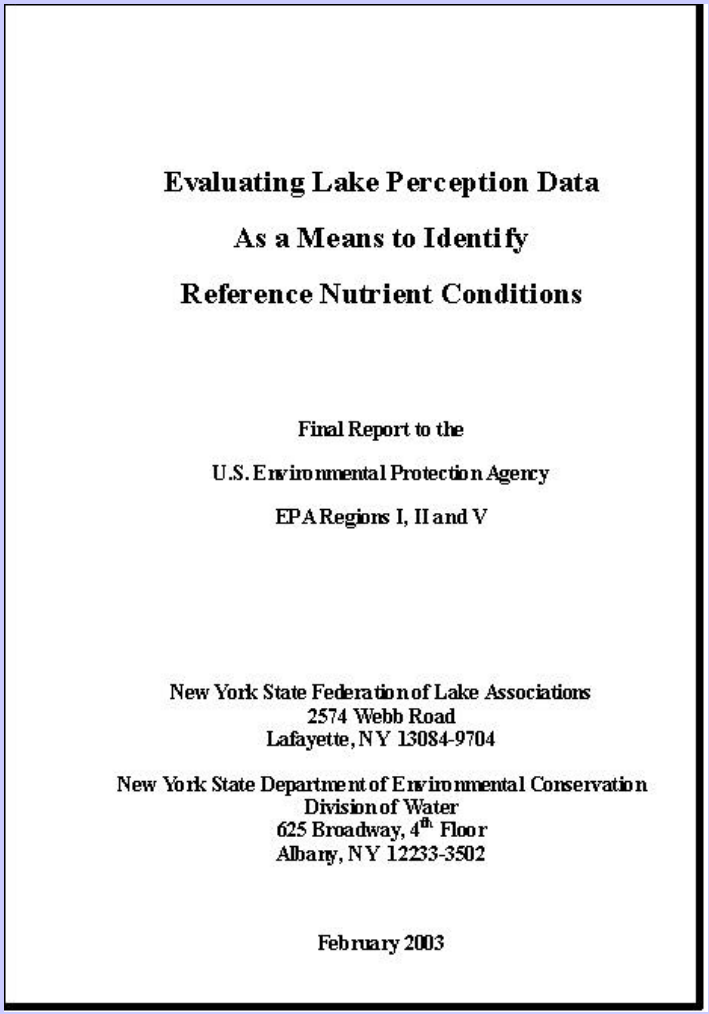
- **PLEASE CIRCLE THE ONE NUMBER THAT BEST DESCRIBES THE PHYSICAL CONDITION OF THE LAKE WATER TODAY:**
  1. **Crystal clear water**
  2. **Not quite crystal clear- a little algae visible**
  3. **Definite algae green-ness, yellowness, or brown-ness apparent**
  4. **High algae levels with limited clarity and/or mild odor present**
  5. **Severely high algae levels with one or more of the following: massive floating scums or streaks on lake or washed up on shore, strong foul odor, fish kills**

TOTAL PHOSPHORUS v. RECREATIONAL ASSESSMENT



Use Impairment Report

- Report Issued to EPA in February 2003 Evaluating Use of Lake Perception Data
- 307 Pages
- >700 Tables and Figures
- 7 Methods to Evaluate Use Impairment Data



Evaluating Lake Perception Data

As a Means to Identify

Reference Nutrient Conditions

Final Report to the

U.S. Environmental Protection Agency

EPA Regions I, II and V

New York State Federation of Lake Associations
2574 Webb Road
Lafayette, NY 13084-9704

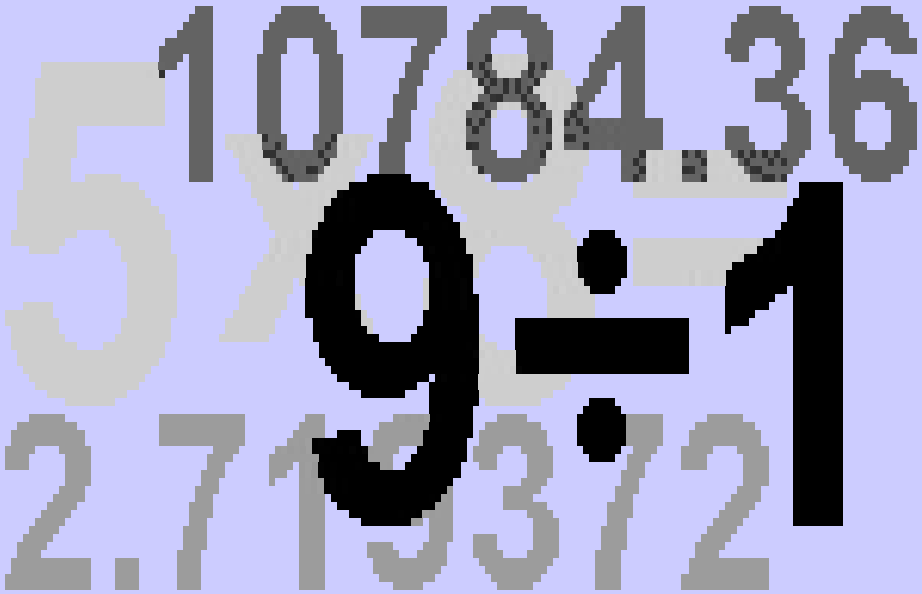
New York State Department of Environmental Conservation
Division of Water
625 Broadway, 4th Floor
Albany, NY 12233-3502

February 2003

STATE	TYPE	YEARS	# LAKES / SAMPLES	% LINKED w/ WQ DATA
NY	VT/NY	1992-99	~180/~3950	99 % Linked with Zsd 87 % Linked with TP 94 % Linked with Chl.a
ME	VT	1995-96	~135/~1950	100 % Linked with Zsd 0 % Linked with TP 0 % Linked with Chl.a
VT	VT	1987-91	~90/~2550	95 % Linked with Zsd 55 % Linked with TP 75 % Linked with Chl.a
NH	VT	1991-99	~60/~2500	98 % Linked with Zsd 0 % Linked with TP 80 % Linked with Chl.a
WI	VT	1986-99	~925/~57,000	100 % Linked with Zsd 6 % Linked with TP 0 % Linked with Chl.a
MN	VT	1990-99	~1215/~94,000	100 % Linked with Zsd 4 % Linked with TP <1 % Linked with Chl.a
IN	VT	1995-99	~125 /~3400	100 % Linked with Zsd 13 % Linked with TP 14 % Linked with Chl.a
OH	VT	1990-99	~120/~8400	100 % Linked with Zsd 0 % Linked with TP 0 % Linked with Chl.a
MI, MA*	NA	NA	NA	NA
PA, IL, IA, CT, NJ **	NA	NA	NA	NA

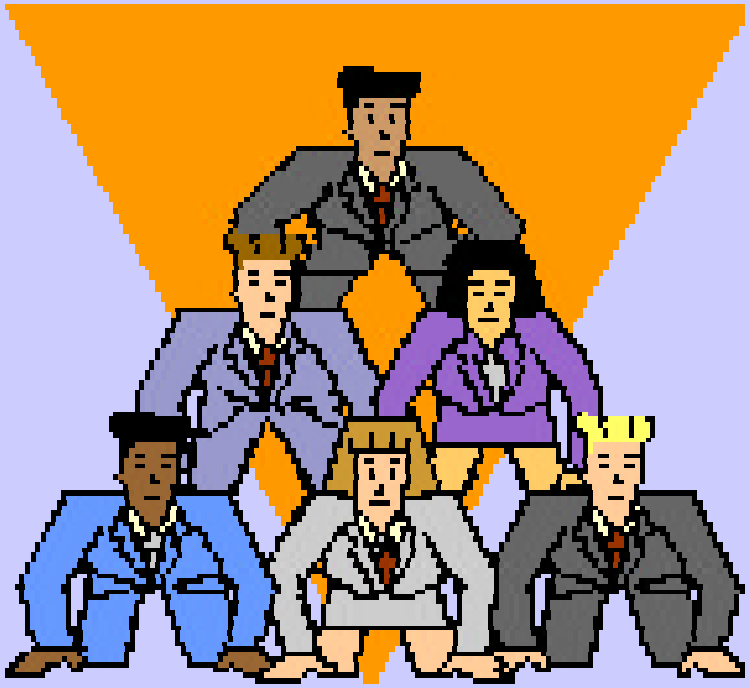
Reference Condition or Reference Waterbody Approach

- Criteria can be based on “representative statistic” (such as 75th percentile) generated from reference waterbody or reference condition dataset
- Reference waterbody dataset can be defined in multiple ways



HISTORICAL PRECEDENT?

- **Minnesota and Vermont have utilized use impairment data to establish nutrient criteria**
- **Lakes are defined as “fully supporting” if they exhibit “impaired swimming” (survey response #3) at a frequency of <10%**
- **Lakes are defined as “fully supporting but threatened” if they exhibit “impaired swimming” at a frequency of 11-25%**



Regional Nutrient Criteria in Lake Champlain: Origin of Ecoregional Criteria

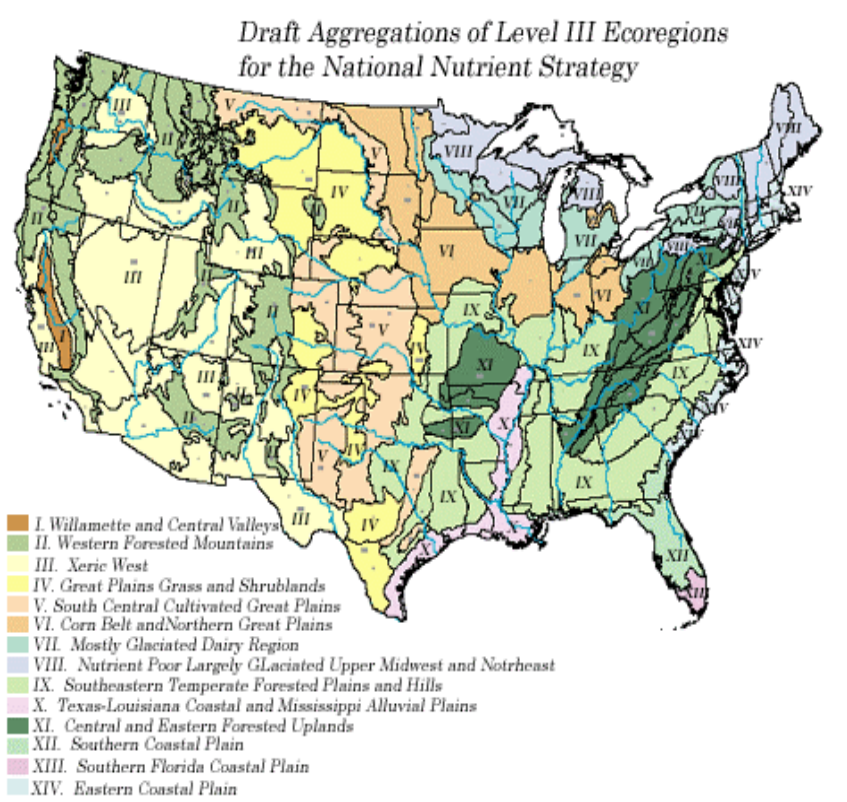
- Main Lake: 10 µg/l
- Northeast Arm: 14 µg/l
- Missisquoi Bay: 25 µg/l
- South Lake: 25-54 µg/l

Use Impairment vs. EPA Datasets

- Use Impairment datasets generated from water quality and perception data collected in volunteer monitoring programs
- EPA datasets generated from all data sources (including volunteer monitoring)
- Extrapolating results from Use Impairment datasets to EPA datasets requires similarities between the two datasets

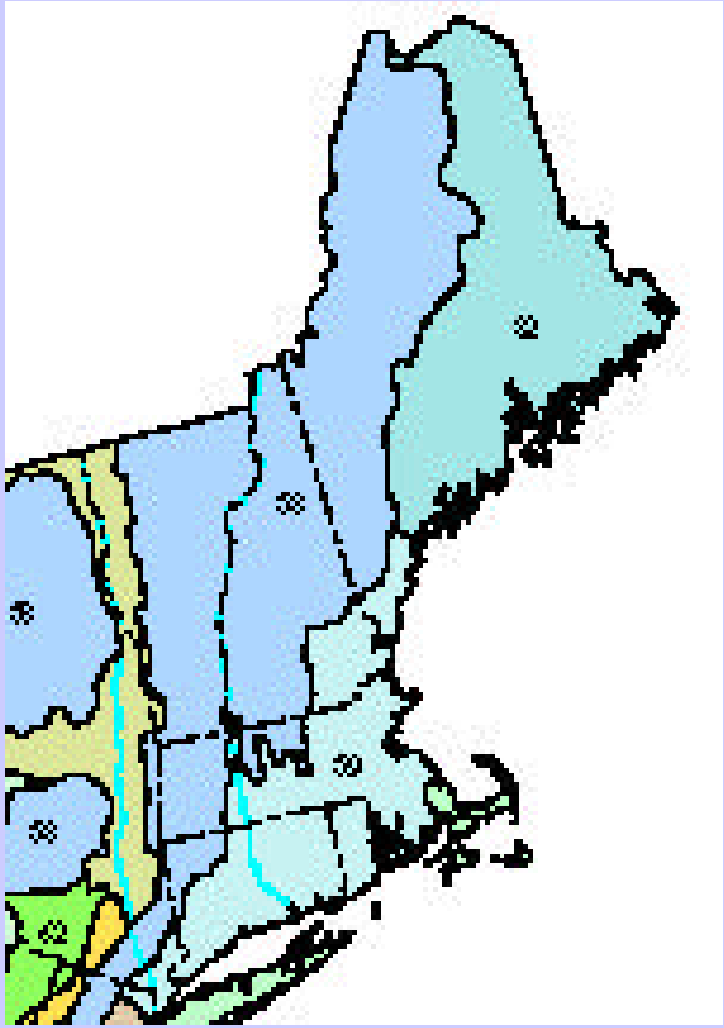
EPA Region I Ecoregions

- **<u>Ecoregion VII</u>- Mostly Glaciated Dairy Region**
- **<u>Ecoregion VIII</u>- Nutrient Poor Largely Glaciated Upper Midwest and Northeast**
- **<u>Ecoregion XIV</u>- Eastern Coastal Plain**

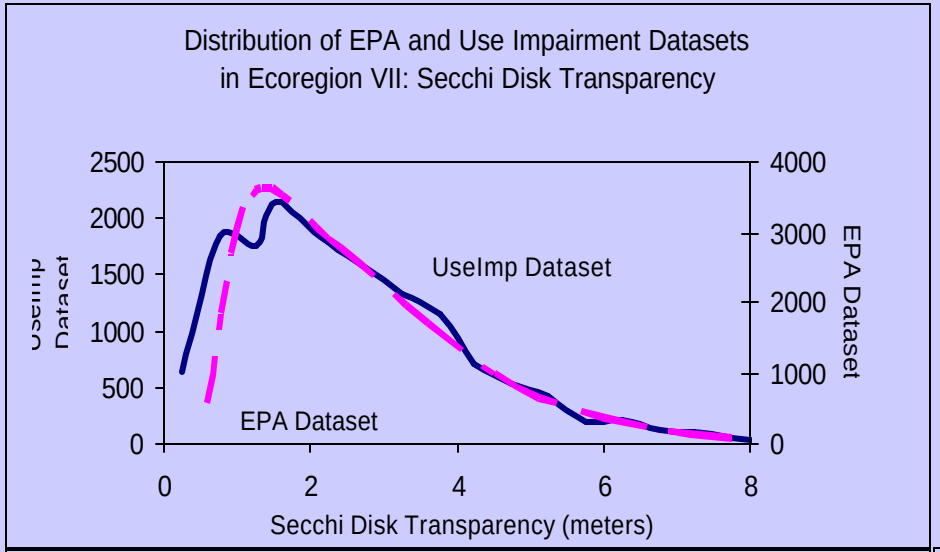


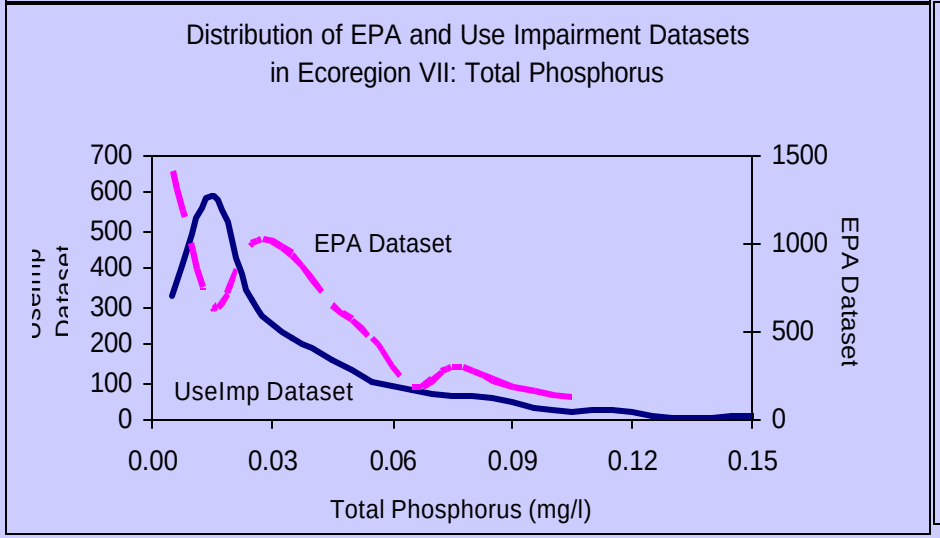
EPA Region I Sub-Ecoregions

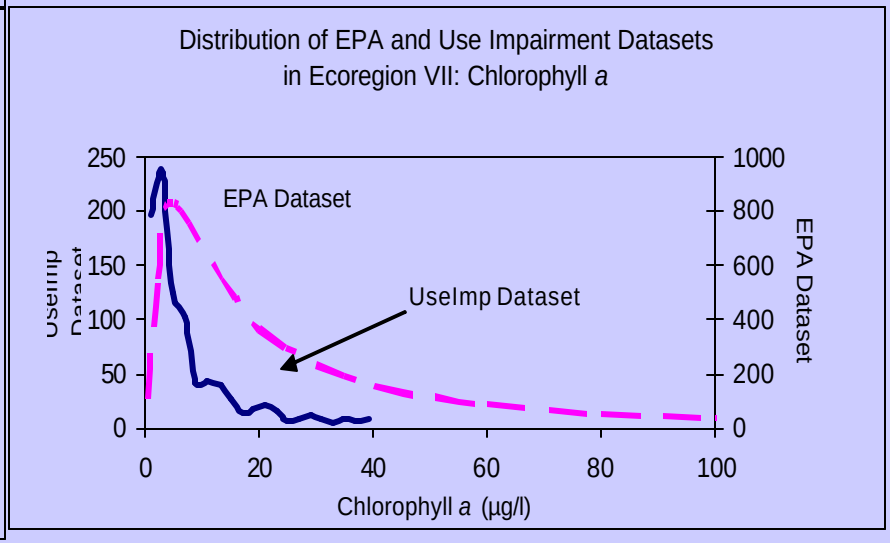
- **<u>Ecoregion 58</u>- Northeastern Highlands**
- **<u>Ecoregion 59</u>- Northeastern Coastal Zone**
- **<u>Ecoregion 82</u>- Laurentian Plains and Hills**
- **<u>Ecoregion 83</u>- Eastern Great Lakes and Hudson Lowlands**



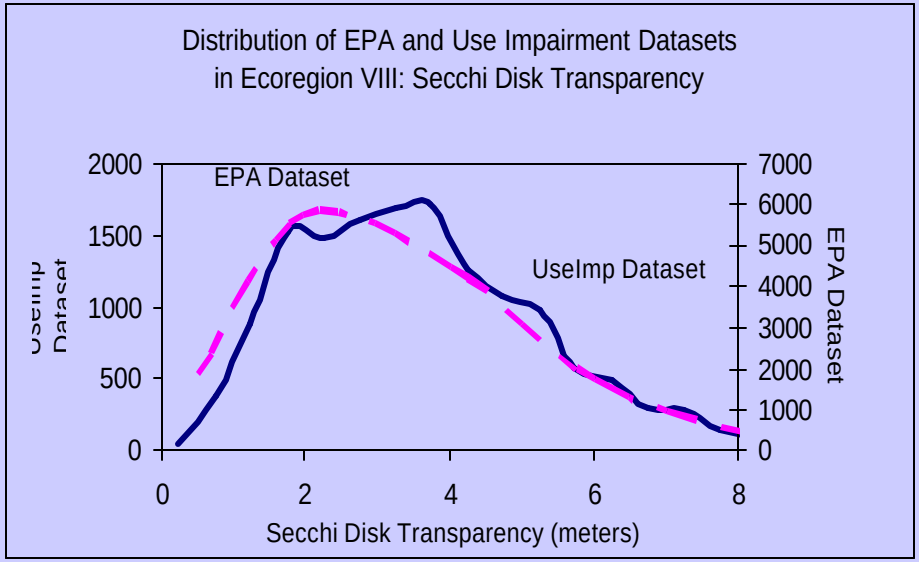
Ecoregion VII

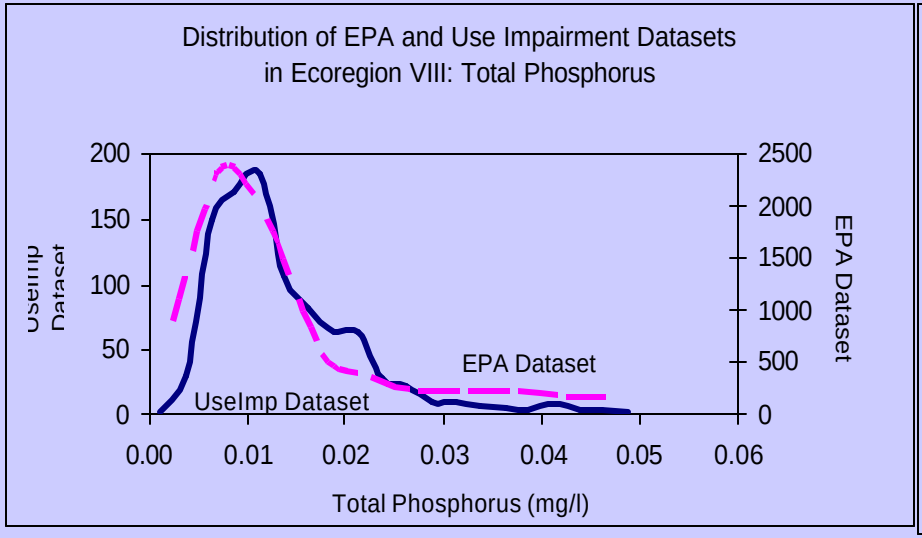


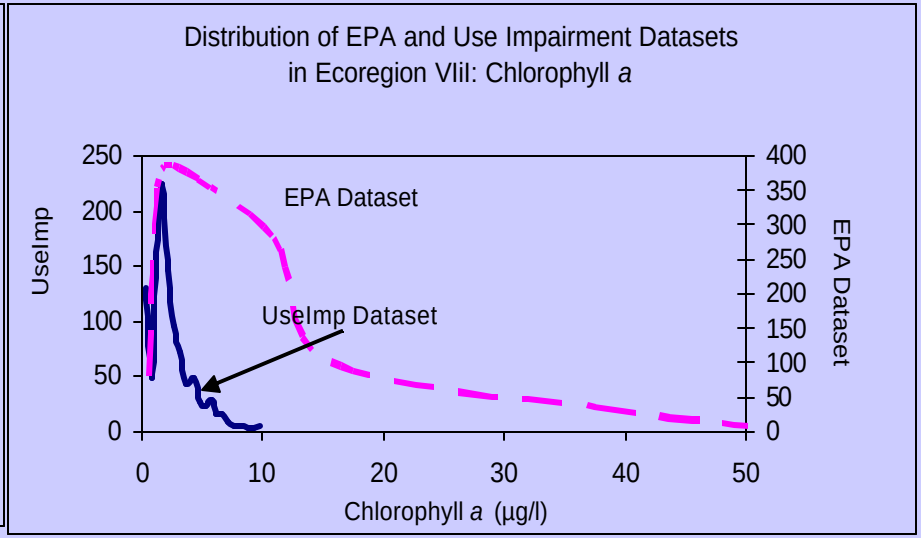




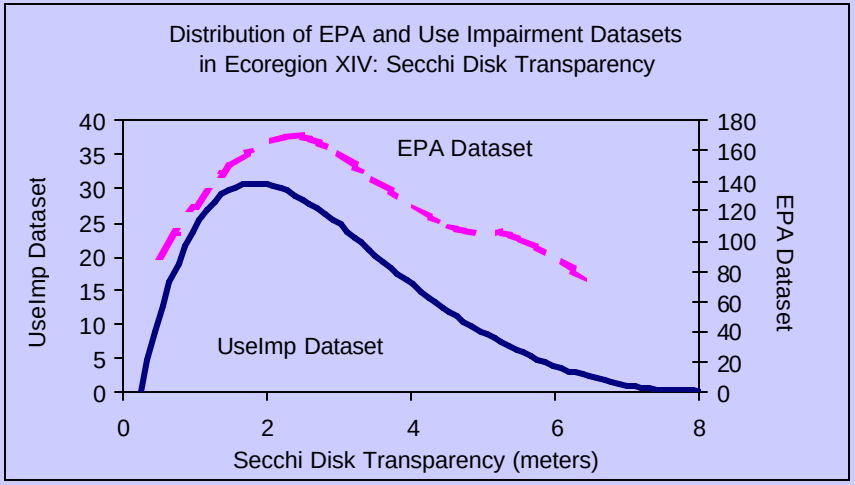
Ecoregion VIII

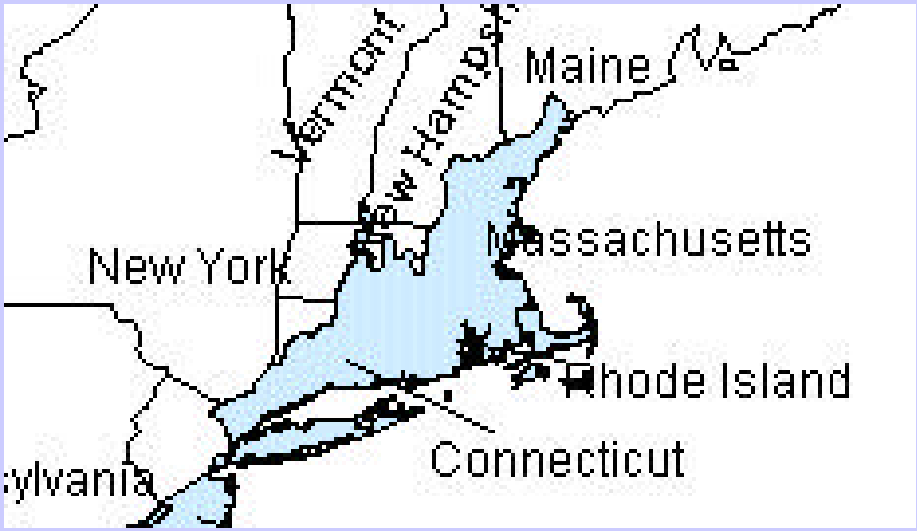


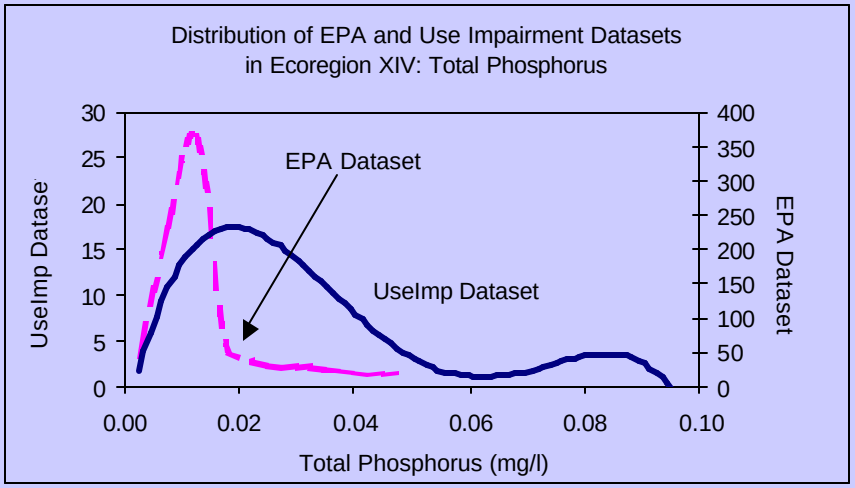


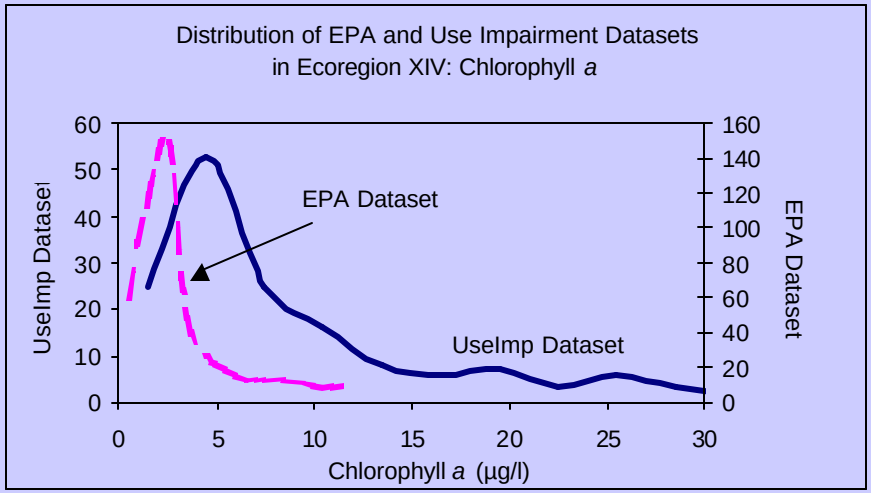


Ecoregion XIV

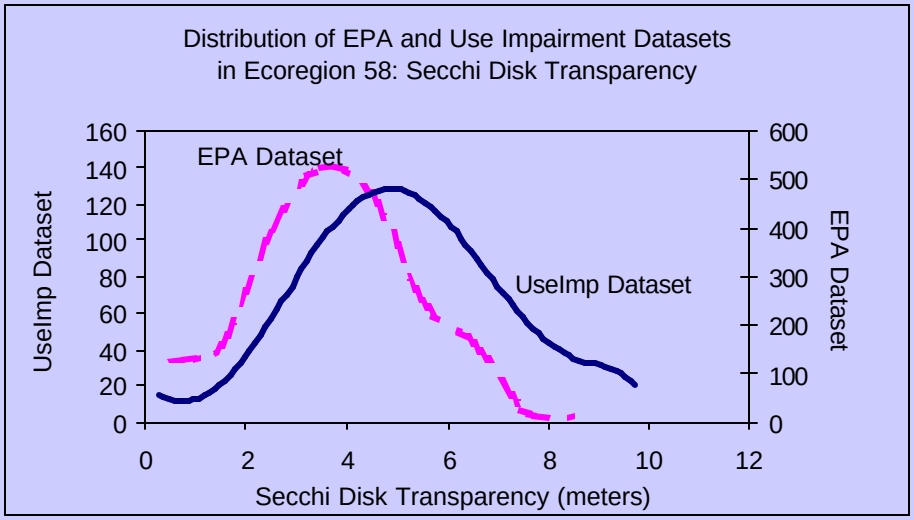


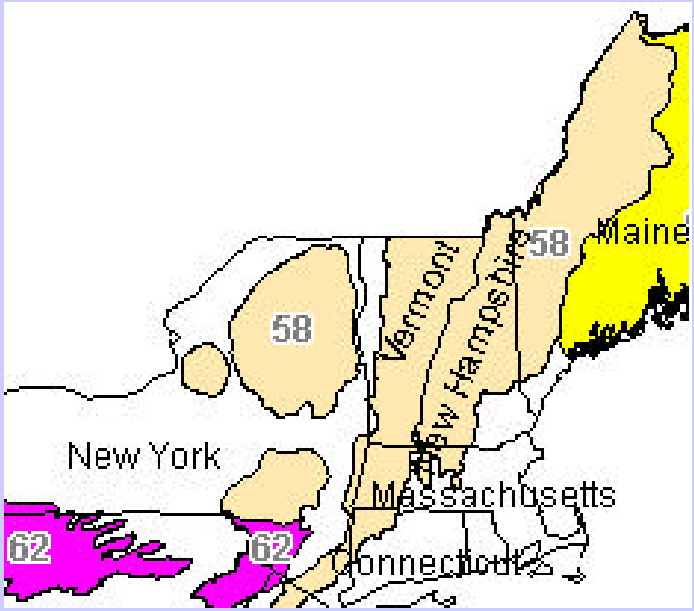


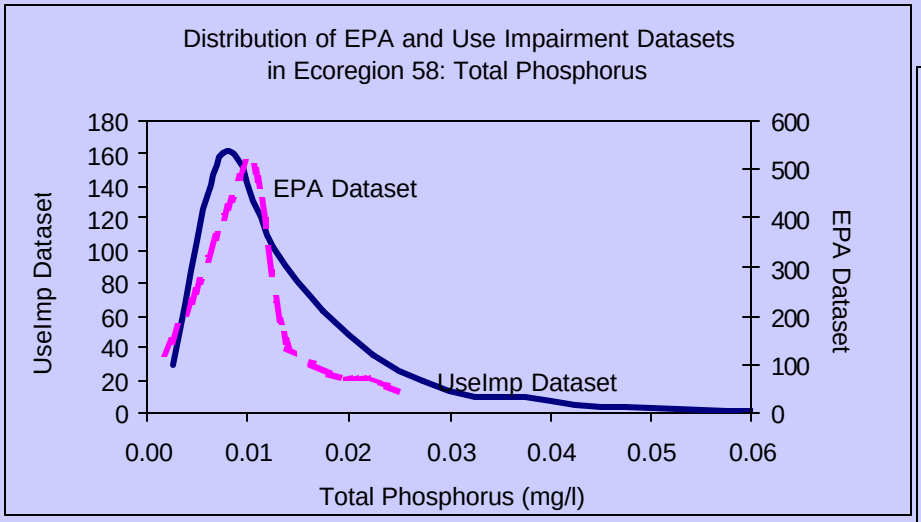


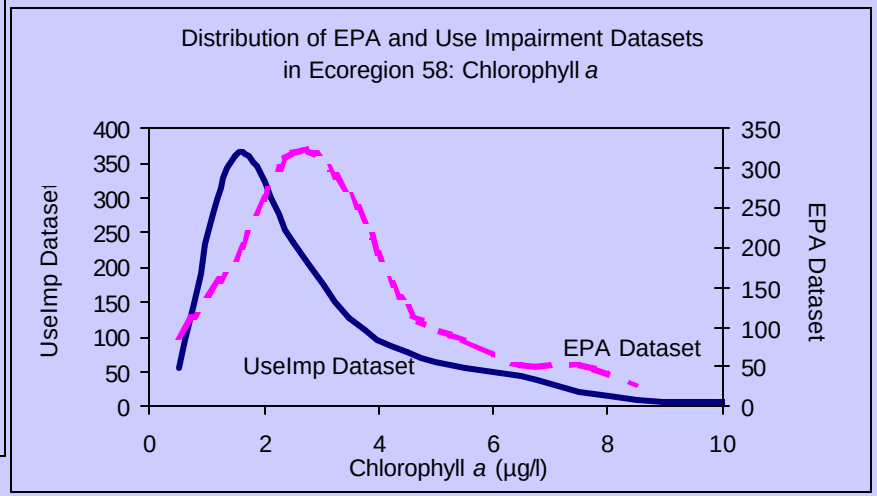


Ecoregion 58

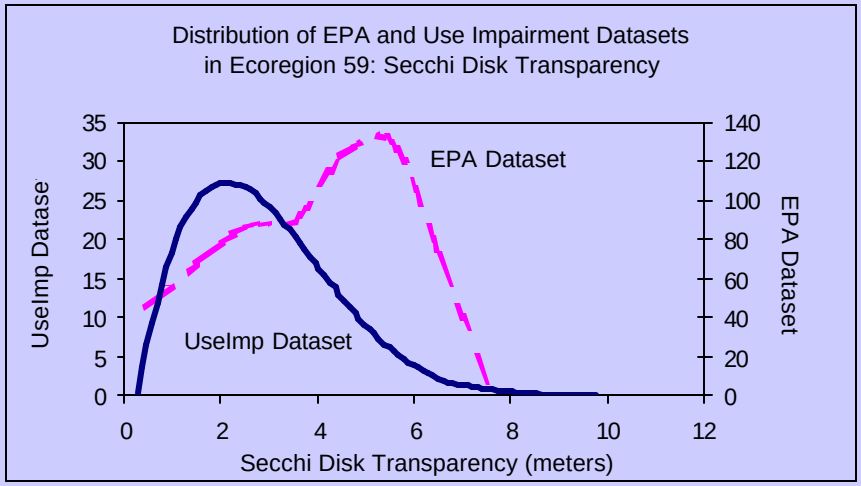


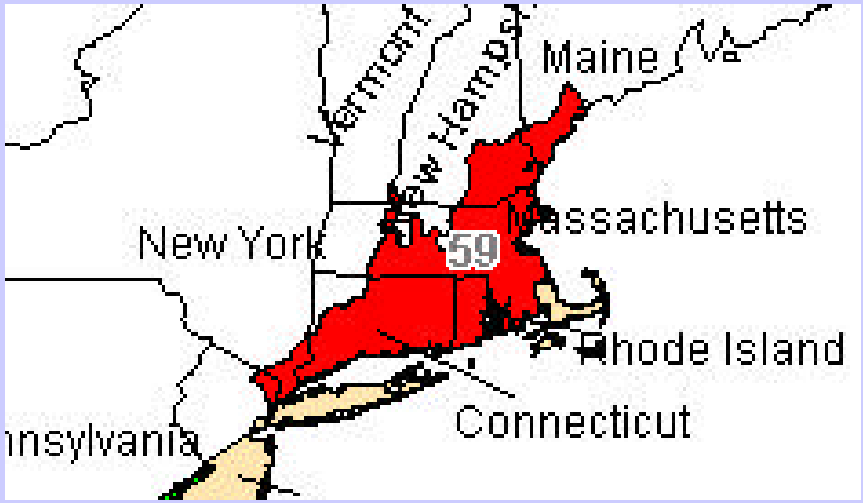


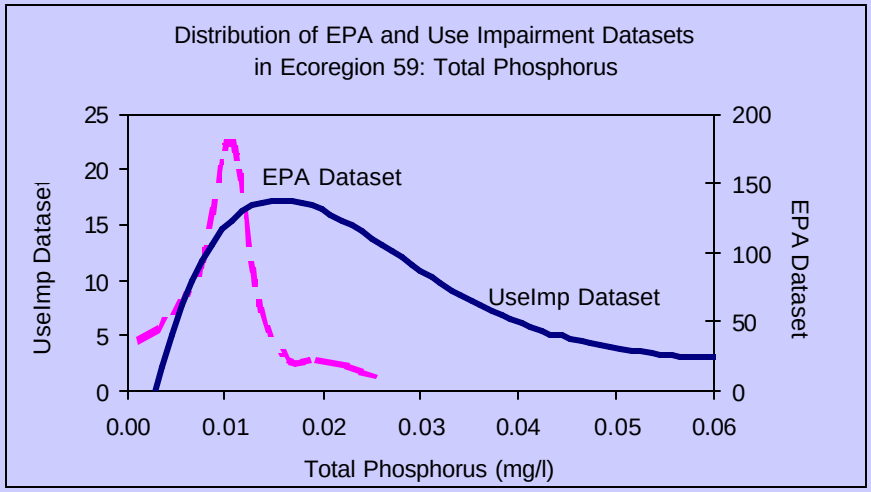


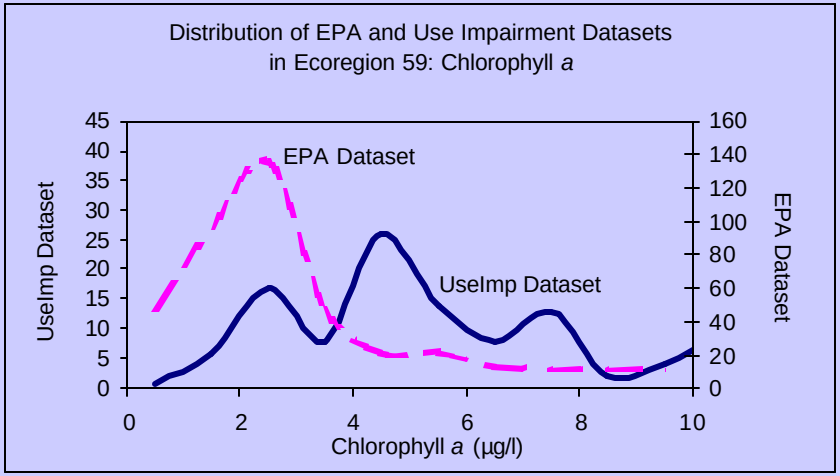


Ecoregion 59

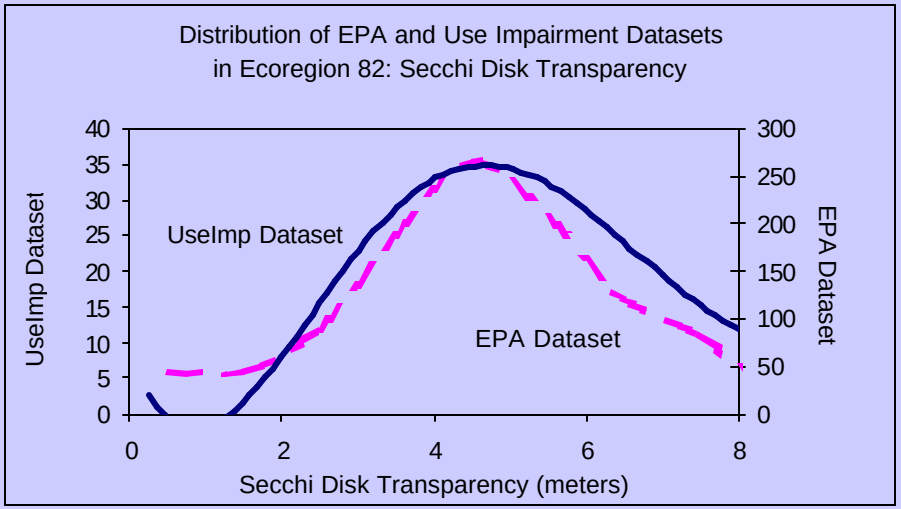


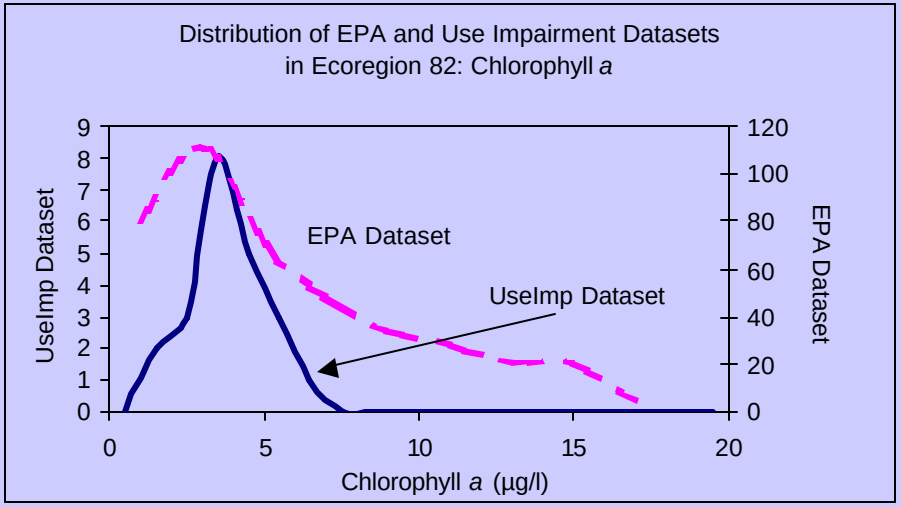


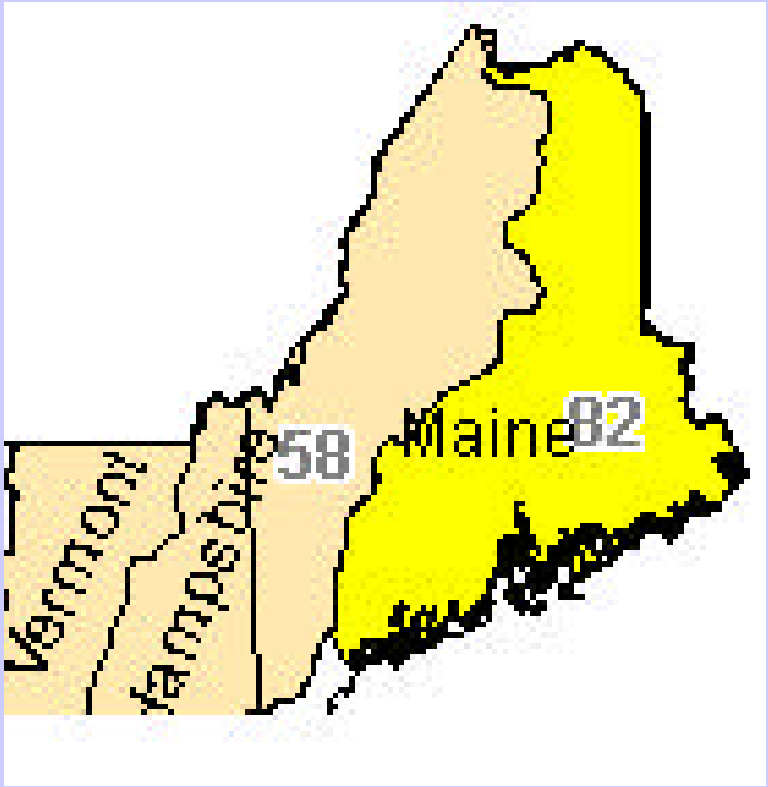




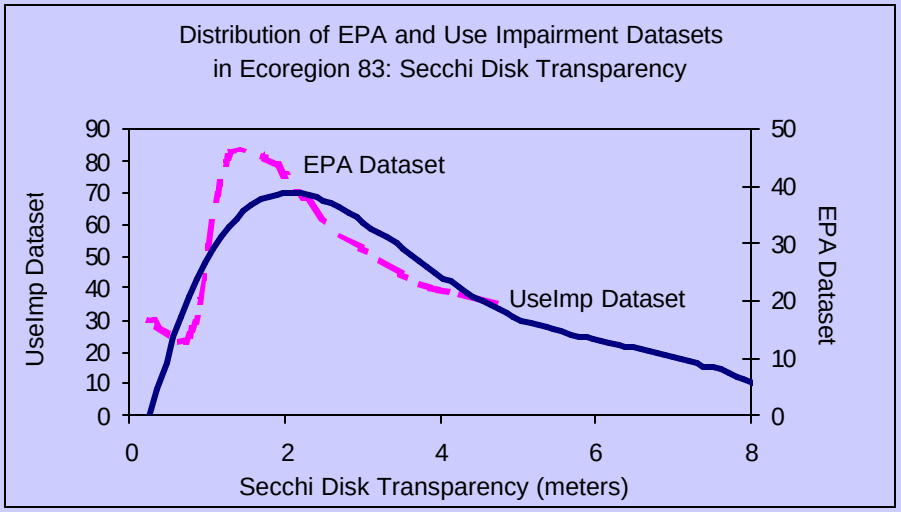
Ecoregion 82

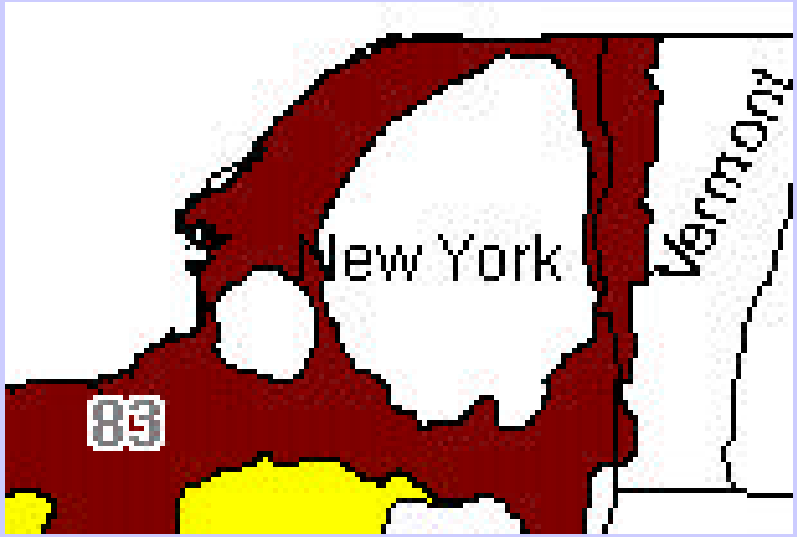


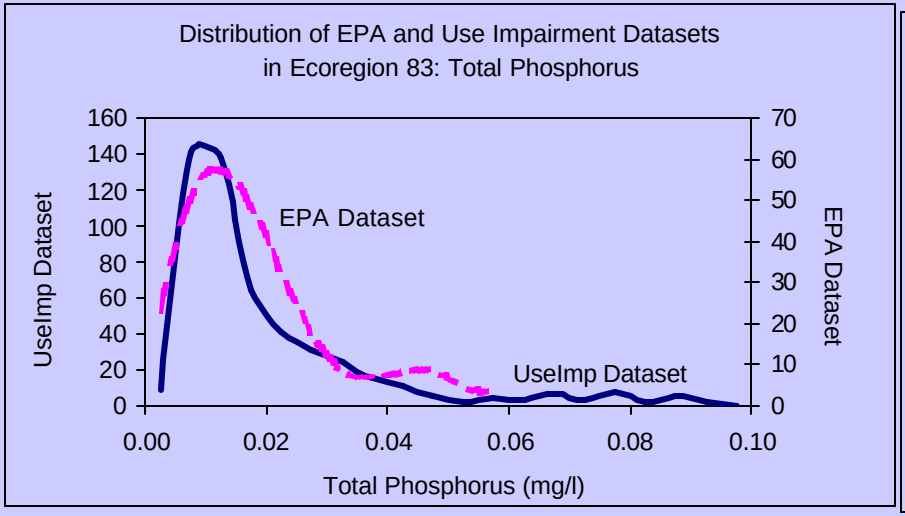


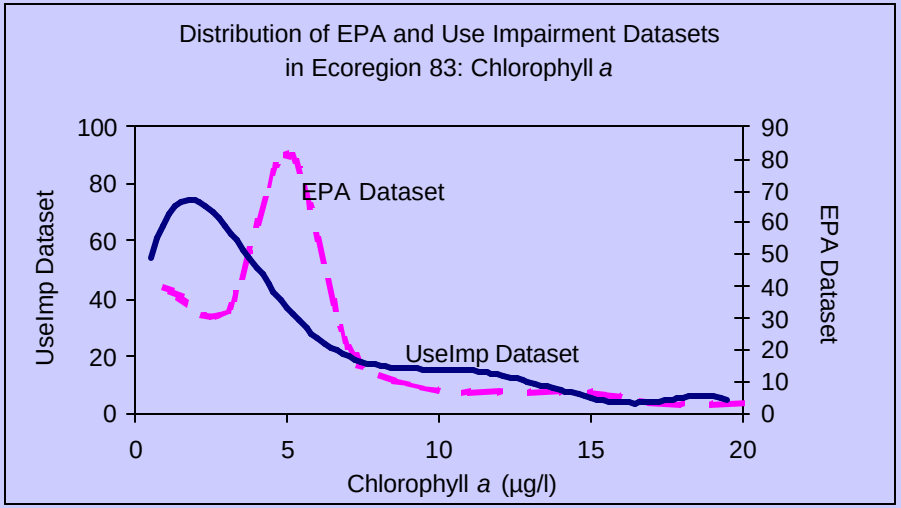


Ecoregion 83









Comparison of EPA and Use Impairment Datasets

- **For most ecoregions, largest datasets (EPA and Use Impairment) comprised of water clarity data**
- **Relatively high correlation for water clarity suggests perception "conclusions" in Use Impairment dataset can be extrapolated to EPA dataset**
- **Lower correlation for nutrients and chlorophyll *a* probably due to smaller datasets**

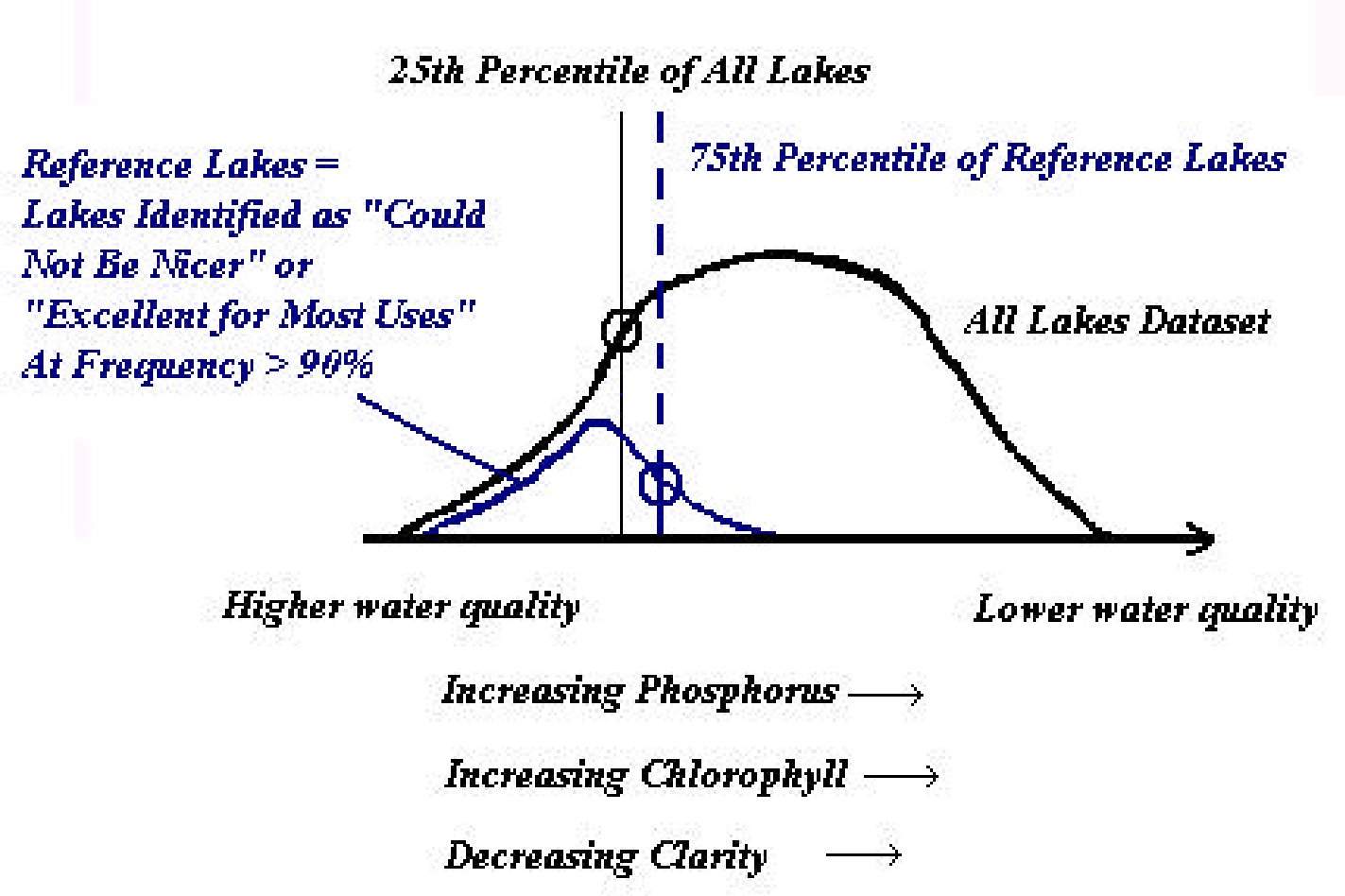
Reference Condition or Reference Waterbody Approach

- **Method A:**
  - **<u>Define reference waterbodies as those that are described as "fully supporting" recreational uses</u> ("impaired swimming" (Response 3 on the impairment survey) at a frequency of no greater than 10%)**
  - **Reference condition corresponds to the 75th percentile of the reference waterbodies**

Reference Condition or Reference Waterbody Approach

- **Method A:**
  - **“10%” frequency benchmarks are consistent with the suggested EPA CALM criteria used to evaluate attainment of water quality standards or supporting designated uses**
  - **“Fully supporting” waterbodies violate standards at a frequency of <10% using methodology adopted in MN**
  - **This may also satisfy EPA’s definition of “pristine” waters as identified as a standard for reference waterbodies (EPA Nutrient Criteria Technical Guidance Manual)**

Method A Schematic



Results from Method A:

Reference Lakes "Fully Supporting" = "Impaired" at Frequency <10%

<u>Ecoregion VII</u>

(35% Lakes Meet Criteria)

- **Secchi Disk = 2.2 meters (304a = 3.4 meters)**
- **Total Phosphorus = 22 µg/l (304a = 11 µg/l)**
- **Chlorophyll *a* = 4 µg/l (304a = 3 µg/l)**

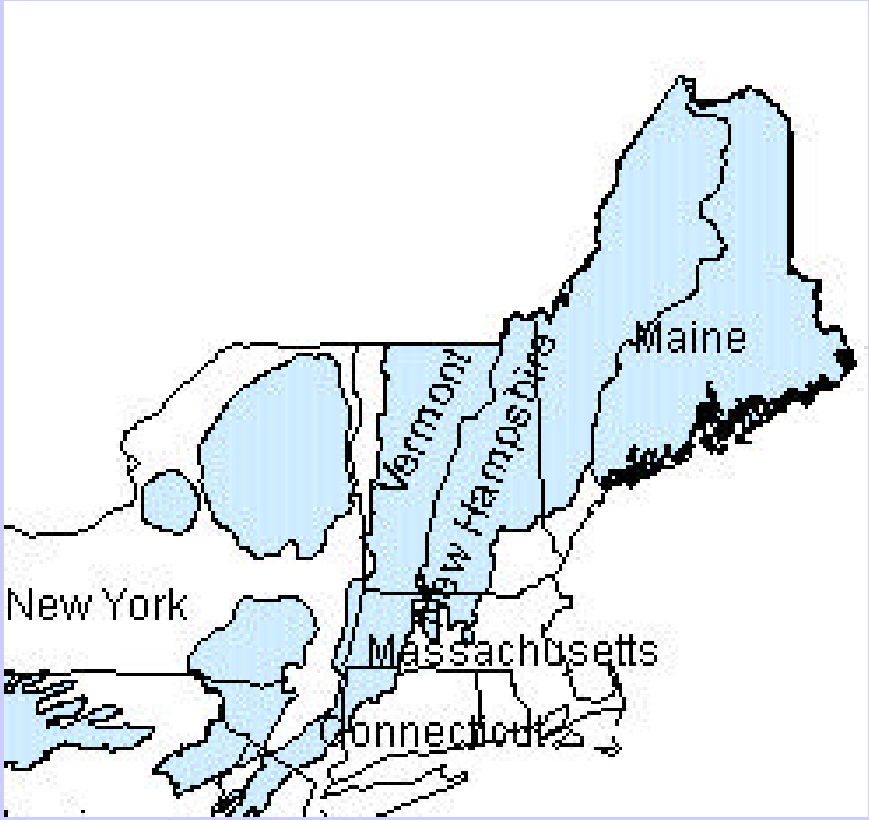
Results from Method A:

Reference Lakes "Fully Supporting" = "Impaired" at Frequency <10%

<u>Ecoregion VIII</u>

(62% Lakes Meet Criteria)

- **Secchi Disk = 2.9 meters (304a = 5.1 meters)**
- **Total Phosphorus = 15 µg/l (304a = 8 µg/l)**
- **Chlorophyll *a* = 4 µg/l (304a = 2 µg/l)**



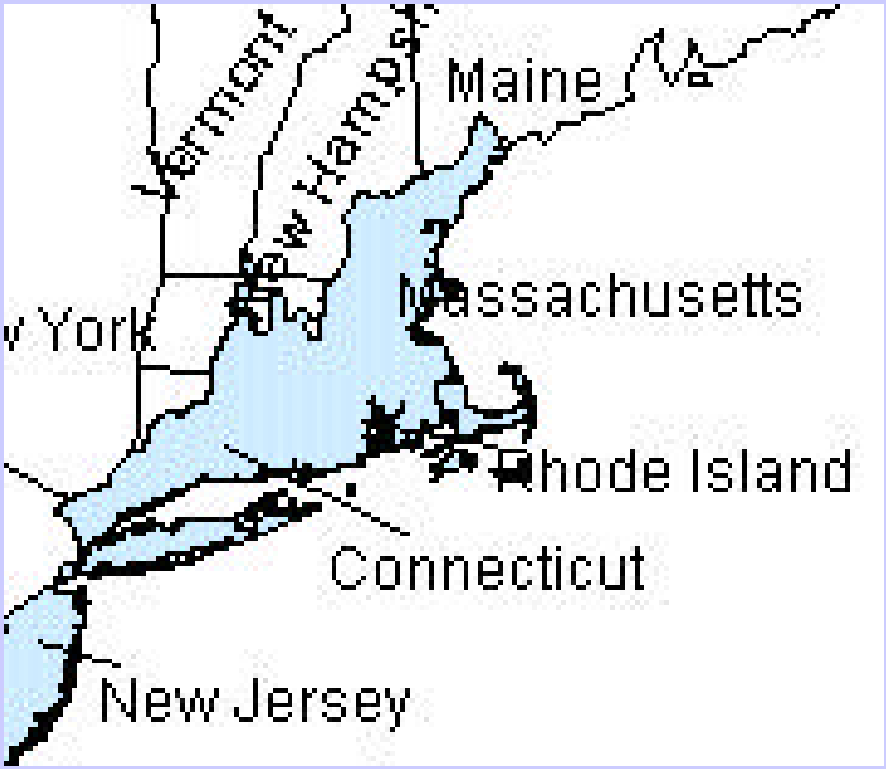
Results from Method A:

Reference Lakes "Fully Supporting" = "Impaired" at Frequency <10%

<u>Ecoregion XIV</u>

(37% Lakes Meet Criteria)

- **Secchi Disk = 3.4 meters (304a = 5.4 meters)**
- **Total Phosphorus = 23 µg/l (304a = 8 µg/l)**
- **Chlorophyll *a* = 5 µg/l (304a = 2 µg/l)**



Results from Method A:

Reference Lakes "Fully Supporting" = "Impaired" at Frequency <10%

Ecoregion	Zsd (m) Method A / 304a	TP (µg/l) Method A / 304a	Chl.a (µg/l) Method A / 304a
58 (67%)	4.2 / 5.4	12 / 7	4 / 2
59 (40%)	3.8 / 5.8	23 / 8	6 / 2
82 (69%)	4.1 / 6.4	NA / 9	4 / 3
83 (29%)	3.9 / 4.7	14 / 10	4 / 4

Reference Condition or Reference Waterbody Approach

- **Method B:**
  - **Define reference conditions by waterbodies that correspond to the most restrictive conditions that meet EPA's dataset criteria (>10% of ecoregion and > 10 waterbodies in dataset)**
  - **Reference condition corresponds to the 75th percentile of the reference dataset**

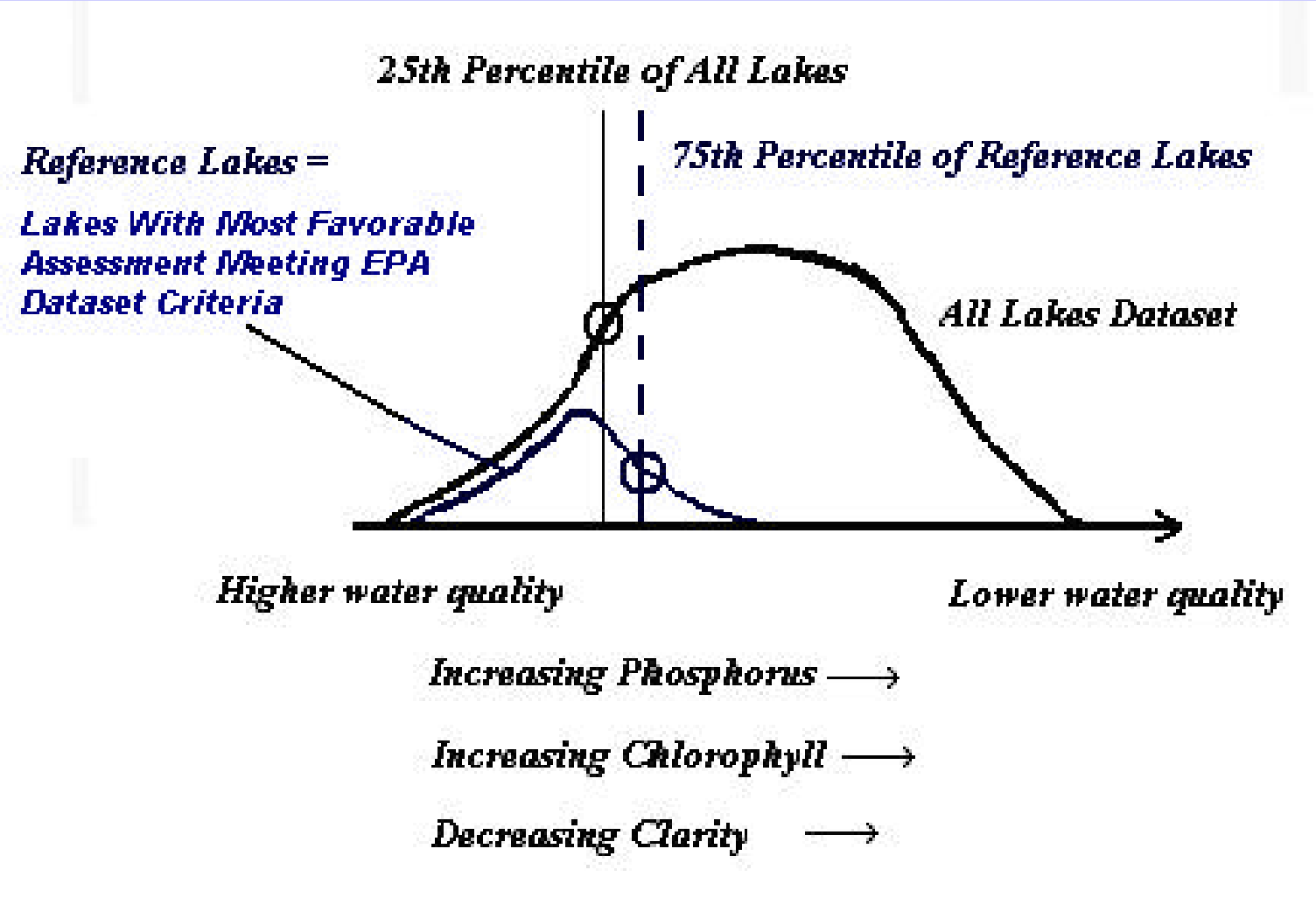
Reference Condition or Reference Waterbody Approach

- **Method B:**
  - **Consistent with EPA guidance instructing States and Tribes to "...use the most protective approach for… reference condition calculations" (EPA Nutrient Criteria Technical Guidance Manual)**

Most Restrictive Criteria

Ecoregion	Most Restrictive Criteria w/ > 10% of Database and > 10 Lakes
VII	“Unimpaired” >75% of samples
VIII	“Unimpaired” >90% of samples
XIV	“Minimally Impaired” (QB2) >90%
58	“Unimpaired” >90% of samples
59	“Minimally Impaired” (QB2) >90%
82	“Unimpaired” >90% of samples
83	“Minimally Impaired” (QB2) >90%

Method B Schematic



Results from Method B:

Reference Lakes Meet Most Protective Criteria

- **Ecoregion VII (10% of Lakes Meet Criteria)**
  - **Secchi Disk = 2.0 meters (304a = 3.4 meters)**
  - **Total Phosphorus = 22 µg/l (304a = 11 µg/l)**
  - **Chlorophyll *a* = 4 µg/l (304a = 3 µg/l)**
- **Ecoregion VIII (15% of Lakes Meet Criteria)**
  - **Secchi Disk = 3.4 meters (304a = 5.1 meters)**
  - **Total Phosphorus = 12 µg/l (304a = 8 µg/l)**
  - **Chlorophyll *a* = 3 µg/l (304a = 2 µg/l)**
- **Ecoregion XIV (37% of Samples Meet Criteria)**
  - **Secchi Disk = 3.4 meters (304a = 5.4 meters)**
  - **Total Phosphorus = 23 µg/l (304a = 8 µg/l)**
  - **Chlorophyll *a* = 5 µg/l (304a = 2 µg/l)**

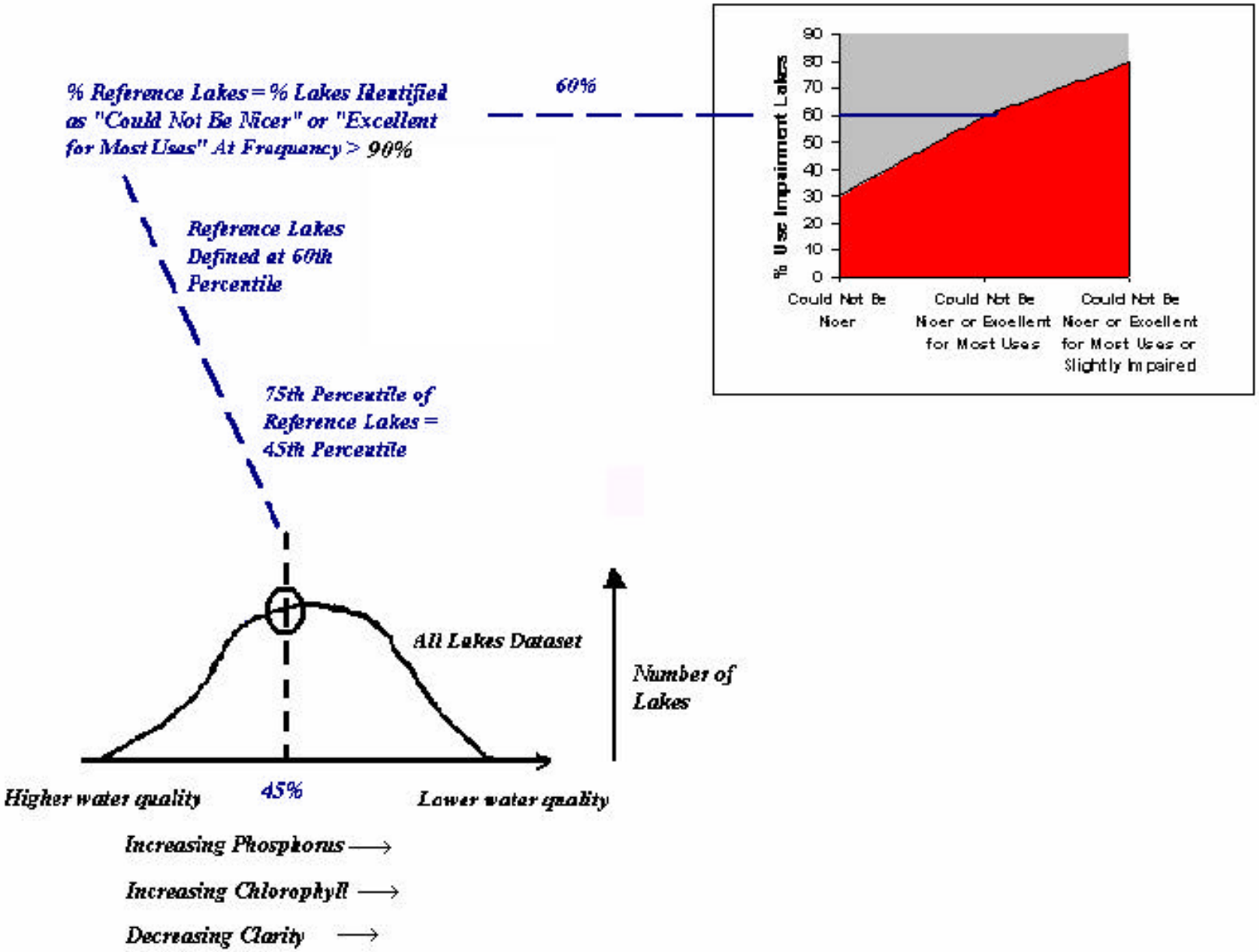
Results from Method B:
Reference Lake Meet Most Protective Criteria

Ecoregion	Zsd (m) Method B / 304a	TP (µg/l) Method B / 304a	Chl.a (µg/l) Method B / 304a
58 (16%)	4.6 / 5.4	9 / 7	3 / 2
59 (40%)	3.8 / 5.8	23 / 8	6 / 2
82 (14%)	4.4 / 6.4	NA / 9	4 / 3
83 (29%)	3.9 / 4.7	14 / 10	4 / 4

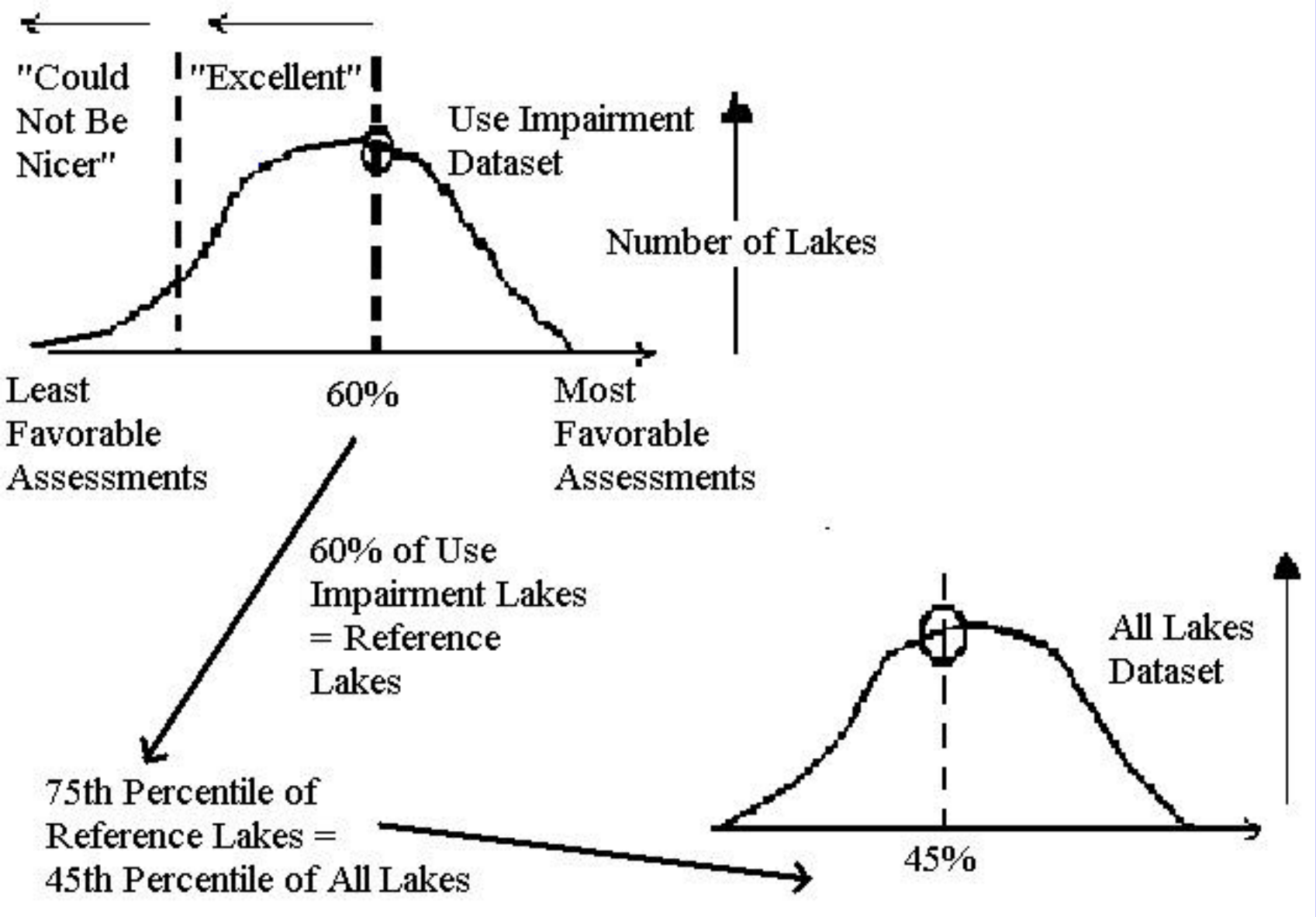
Reference Condition or Reference Waterbody Approach

- **Method C:**
  - **<u>Apply the % waterbodies that meet the Method 1 criteria in the use impairment dataset to the overall EPA nutrient dataset</u>**
    - **= % of lakes in the use impairment dataset that are described as "could not be nicer" or "very minor aesthetic problems, but excellent for ..most uses" (Response 1 or 2 on the impairment survey) at a frequency of no less than 90% of the recreational season (summer)**
  - **Reference condition corresponds to the 75th percentile of the reference waterbodies**

Method C Schematic



Method C Schematic



Results from Method C:

Reference Lakes "Fully Supporting" = "Excellent" or Better at Frequency > 90%

- **Ecoregion VII (35% of Lakes Meet Criteria)**
  - **Secchi Disk = 3.3 meters (304a = 3.4 meters)**
  - **Total Phosphorus = 10 µg/l (304a = 11 µg/l)**
  - **Chlorophyll *a* = 4 µg/l (304a = 3 µg/l)**
- **Ecoregion VIII (62% of Lakes Meet Criteria)**
  - **Secchi Disk = 3.9 meters (304a = 5.1 meters)**
  - **Total Phosphorus = 10 µg/l (304a = 8 µg/l)**
  - **Chlorophyll *a* = 3 µg/l (304a = 2 µg/l)**
- **Ecoregion XIV (37% of Lakes Meet Criteria)**
  - **Secchi Disk = 5.1 meters (304a = 5.4 meters)**
  - **Total Phosphorus = 9 µg/l (304a = 8 µg/l)**
  - **Chlorophyll *a* = 2 µg/l (304a = 2 µg/l)**

Results from Method C:

Reference Lakes "Fully Supporting" = "Excellent" or Better at Frequency > 90%

Ecoregion	Zsd (m) Method C / 304a	TP (µg/l) Method C / 304a	Chl.a (µg/l) Method C / 304a
58 (67%)	4.0 / 5.4	10 / 7	3 / 2
59 (40%)	5.5 / 5.8	9 / 8	2 / 2
82 (69%)	4.8 / 6.4	12 / 9	5 / 3
83 (29%)	5.0 / 4.7	9 / 10	3 / 4

Results from All Methods: Ecoregion VII

Method (%Lakes Meeting Criteria)	Zsd (m) Method / 304a	TP (µg/l) Method / 304a	Chl.a (µg/l) Method / 304a
A (35%)	2.2 / 3.4	22 / 11	4 / 3
B (10%)	2.8 / 3.4	22 / 11	4 / 3
C (35%)	3.3 / 3.4	10 / 11	4 / 3

Results from All Methods: Ecoregion VIII

Method (%Lakes Meeting Criteria)	Zsd (m) Method / 304a	TP (µg/l) Method / 304a	Chl.a (µg/l) Method / 304a
A (62%)	2.9 / 5.1	15 / 8	3 / 2
B (15%)	3.4 / 5.1	12 / 8	3 / 2
C (62%)	3.9 / 5.1	10 / 8	3 / 2

Results from All Methods: Ecoregion XIV

Method (%Lakes Meeting Criteria)	Zsd (m) Method / 304a	TP (µg/l) Method / 304a	Chl.a (µg/l) Method / 304a
A (37%)	3.4 / 5.4	23 / 8	5 / 2
B (37%)	3.4 / 5.4	23 / 8	5 / 2
C (37%)	5.1 / 5.4	9 / 8	2 / 2

Results from All Methods: Ecoregion 58

Method (%Lakes Meeting Criteria)	Zsd (m) Method / 304a	TP (µg/l) Method / 304a	Chl.a (µg/l) Method / 304a
A (67%)	4.2 / 5.4	12 / 7	4 / 2
B (16%)	4.6 / 5.4	9 / 7	3 / 2
C (67%)	4.0 / 5.4	10 / 7	3 / 2

Results from All Methods: Ecoregion 59

Method (%Lakes Meeting Criteria)	Zsd (m) Method / 304a	TP (µg/l) Method / 304a	Chl.a (µg/l) Method / 304a
A (40%)	3.8 / 5.8	23 / 8	6 / 2
B (40%)	3.8 / 5.8	23 / 8	6 / 2
C (40%)	5.5 / 5.8	9 / 8	2 / 2

Results from All Methods: Ecoregion 82

Method (%Lakes Meeting Criteria)	Zsd (m) Method / 304a	TP (µg/l) Method / 304a	Chl.a (µg/l) Method / 304a
A (69%)	4.1 / 6.4	NA / 9	4 / 3
B (14%)	4.4 / 6.4	NA / 9	4 / 3
C (69%)	4.8 / 6.4	12 / 9	5 / 3

Results from All Methods: Ecoregion 83

Method (%Lakes Meeting Criteria)	Zsd (m) Method / 304a	TP (µg/l) Method / 304a	Chl.a (µg/l) Method / 304a
A (29%)	3.9 / 4.7	14 / 10	4 / 4
B (29%)	3.9 / 4.7	14 / 10	4 / 4
C (29%)	5.0 / 4.7	9 / 10	3 / 4

Reference Condition or Reference Waterbody Approach

- Alternative Approaches:
  - Build criteria based on reference condition rather than reference waterbody
    - Reference conditions based on only “could not be nicer” or “excellent for most uses” samples
  - Build criteria based on allowing up to 25% frequency of impairment (rather than 10%)
    - Based on conservative side of “partially supporting” conditions in CALM

Reference Condition or Reference Waterbody Approach

- **Advantages:**
  - **Based on use impairment**
  - **Can take advantage of both use impairment datasets (to delineate break between reference and non-reference) and larger EPA datasets**
  - **Can get around relatively small datasets for some variables (causal or response)**

Reference Condition or Reference Waterbody Approach

- **Disadvantages:**
  - **May be difficult to explain to public**
  - **May be subject to non-representative datasets (in some ecoregions or states)**
  - **Results may be sensitive to “unreasonable” use impairment assessments**
  - **Not yet consistently adopted by EPA**

One Approach to Assigning Nutrient Criteria: Phosphorus in ER 83

- **Option 1: Narrative Standard**
  - **Non-numeric**
- **Option 2: Guidance Value**
  - **10-25 µg/l (VT- ranging from 10 µg/l @ Malletts Bay to 25 µg/l at Missisquoi Bay); most common in 14 µg/l**
- **Option 3: Default 304(a) Criteria**
  - **10 µg/l**
- **Option 4: Reference Conditions: Use Impairment Criteria**
  - **9-14 µg/l (average = 12 µg/l)**
- **Final Phosphorus Criteria = Average of Options 1-4**
  - **12 µg/l (or range of 9-25 µg/l)**

Additional Work to Be Done

- Use Impairment Survey report needs to be simplified and tailored for use in developing actual nutrient criteria, rather than evaluating all potential approaches
- Definition of “reference condition” (as related to use impairment) should be standardized
- Additional use impairment data needs to be collected in some ecoregions
- Use impairments driven by non-water quality factors (invasive weeds, user conflicts, poor weather, etc.) need to be figured into process