Arizona's Narrative Nutrient Standards Project

Lake Classification and Potential Numeric Targets

ADEQ Arizona Department of Environmental Quality

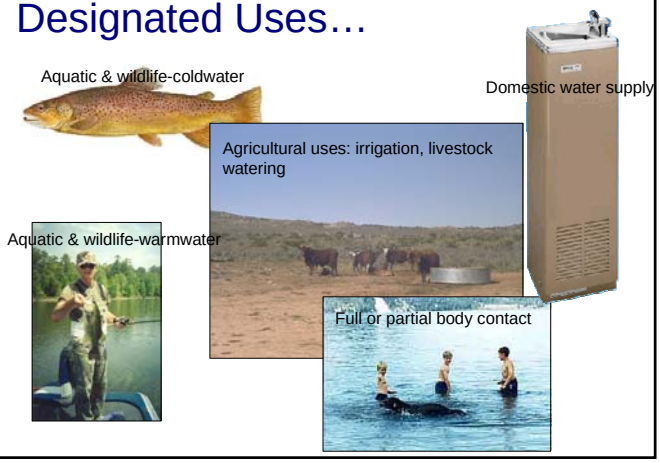
Public Meeting: April 29, 2005

Outline

- Background on USEPA's National Nutrient Strategy
- Overview of Arizona's approach for lakes and reservoirs
- Results: Statewide analysis of lake data
- Lake classification
- Potential numeric targets

Water Quality Standards

Designated Uses…



Nutrients most common cause of lake/reservoir impairment…

Figure 2. Leading Causes and Sources* of Impairment in Assessed Rivers, Lakes, and Estuaries

	Rivers and Streams	Lakes, Ponds, and Reservoirs	Estuaries
Causes	Pathogens (Bacteria)	Nutrients	Metals (Primarily mercury)
	Siltation (Sedimentation)	Metals (Primarily mercury)	Pesticides
	Habitat Alterations	Siltation (Sedimentation)	Oxygen-Depleting Substances
Sources	Agriculture	Agriculture	Municipal Point Sources
	Hydrologic Modifications	Hydrologic Modifications	Urban Runoff/Storm Sewers
	Habitat Modifications	Urban Runoff/Storm Sewers	Industrial Discharges

*Excluding unknown, natural, and "other" sources.

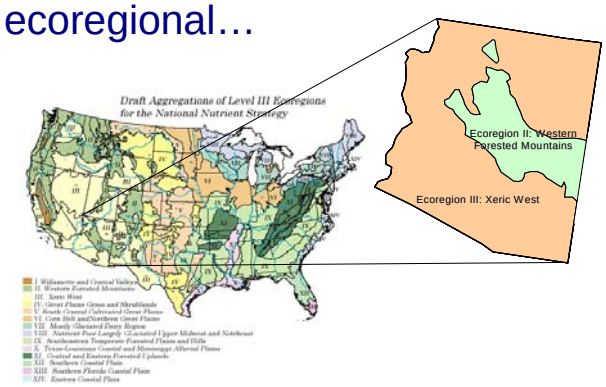
Problems with nutrients

- Undesirable algal/macrophyte growths
  - Unaesthetic
  - Toxic
  - Taste & odor problems
  - Low dissolved oxygen
  - Food quality impacts
  - Habitat degradation

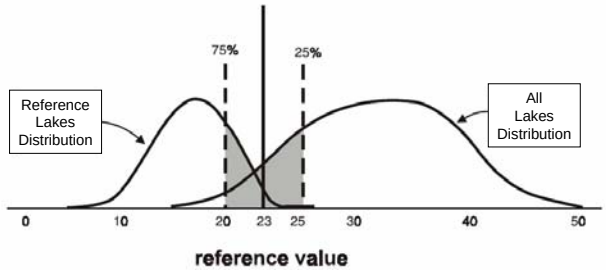
USEPA's National Nutrient Strategy

- As of 1995, most states did not have effective nutrient standards
- USEPA's National Strategy document published in 1998
- Technical guidance manuals published in 2000
- Nutrient criteria in 2001-2002
  - Causal variables: TN, TP
  - Response variables: Chlorophyll *a*, and Secchi depth
- States required to adopt standards in 2004-2007 timeframe

USEPA's default criteria are ecoregional…



Percentile-based approach



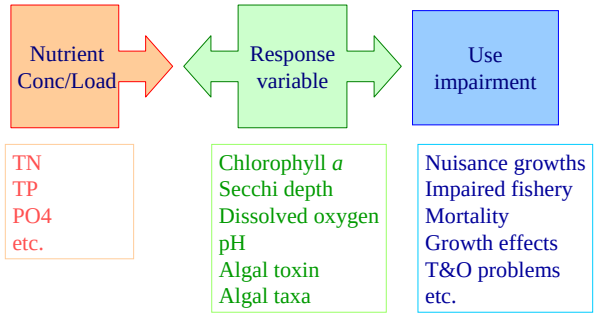
Default 304(a) Criteria

Parameter	Ecoregion II Western Forested Mountains	Ecoregion III Xeric West
Total phosphorus (μg/L)	9	17
Total nitrogen (mg/L)	0.10	0.40
Chlorophyll-*a* (μg/L)	1.9	3.4
Secchi depth (m)	4.5	2.7

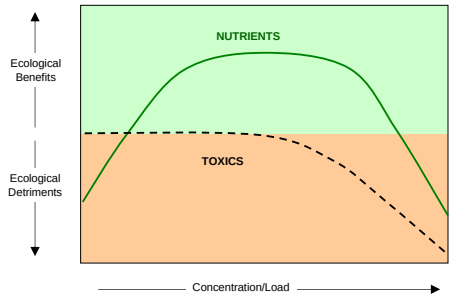
Arizona's existing nutrient criteria

- Narrative: "Navigable waters shall be free from pollutants in amounts or combinations that…cause the growth of algae or aquatic plants that inhibit or prohibit the habitation, growth, or propagation of other aquatic life or that impair recreational uses." [A.A.C. R18-11-108.A.6]
- Water body-specific criteria based on conditions observed in 1970s and 1980s.
  - Annual mean
  - 90th percentile
  - Single sample maximum
- *Implementation Guidelines for the Narrative Nutrient Standard* (1996)

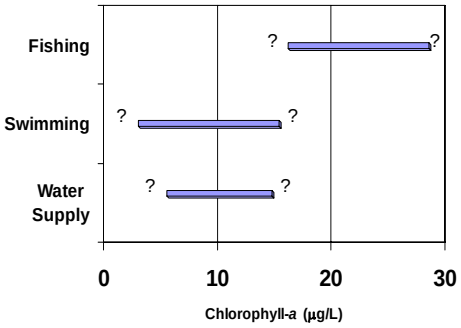
Really two connections to be made…



A different response curve from toxics

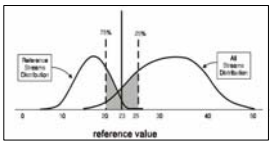


Uncertainty and Variability in Correct Targets

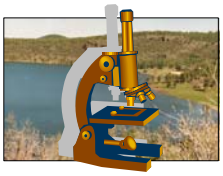


Arizona DEQ seeking a practical compromise between two approaches

Percentile-based approaches



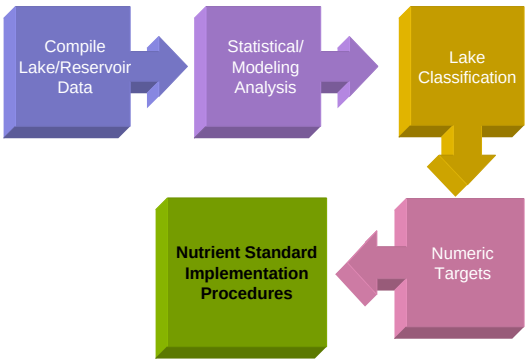
Detailed but resource-prohibitive studies of every water body



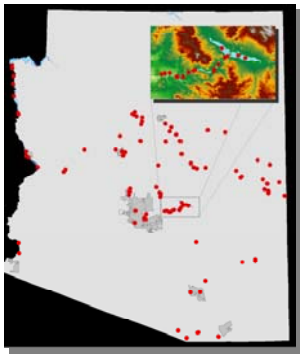
Narrative Nutrient Standards: Project Goals

- Develop flexible *narrative nutrient criteria* and *associated implementation procedures* for Arizona's lakes that will maintain a consistent, scientifically-based means of compliance assessment.
- Avoid "one-size fits all" numeric targets; i.e., consider how variability in lake/watershed characteristics affects trophic responses.
- Link criteria/numeric targets with designated uses.

Overview of Approach



Data Compilation

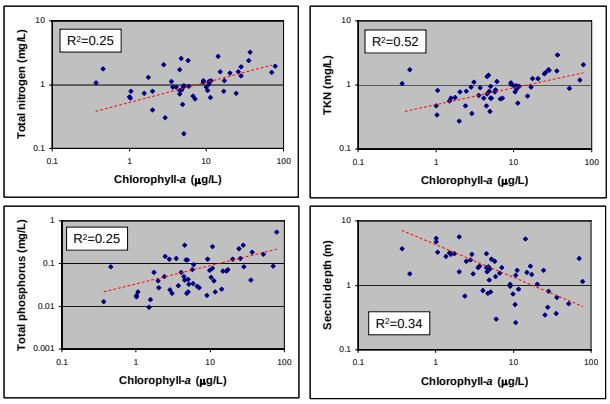


- **Water Quality Data**
  - **74 lakes/reservoirs**
  - **138 sampling sites**
  - **Multiple agencies**
- **Water Quality Data**
- **Lake Characteristics**
- **Watershed Characteristics (GIS)**

Statistical and Modeling Analysis: Basic Question

- What parameters control a water body's nutrient-related characteristics?
  - Water quality
  - Lake characteristics
  - Watershed characteristics
- What kinds of water bodies have similar nutrient/trophic responses?

Significant relations between nutrients and response variables

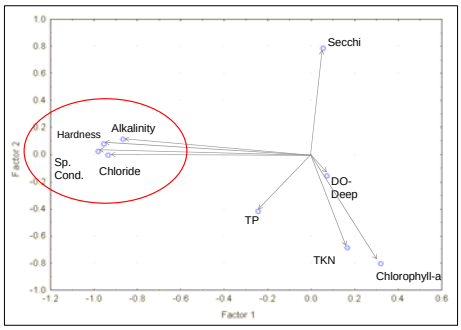


These relations used to developed Arizona trophic state indices

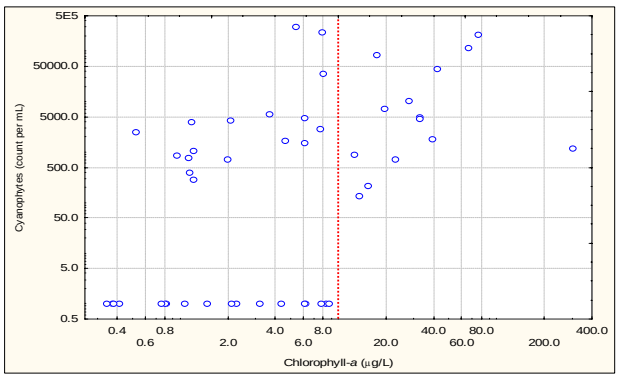
TSI	Trophic State	Chla (µg/L)	SD (m)		TP (µg/L)		TN (mg/L)		TKN (mg/L)
		AZ & Brez.	AZ	Brez.	AZ	Brez.	AZ	Brez.	AZ
<40	Ol			>2	<57	<23	<1.0	<0.45	<0.79
40-53	Me			3-2	57-78	23-46	1.0-1.3	0.45-0.87	0.79-1.0
53-60	Eutrophic	12-20	1.0-1.1	1.0-1.3	78-92	46-68	1.3-1.5	0.87-1.2	1.0-1.2
>60	Hypereutrophic	>20	<1.0	<1.0	>92	>68	>1.5	>1.2	>1.2

Arizona nutrient thresholds tend to be higher than other regions.

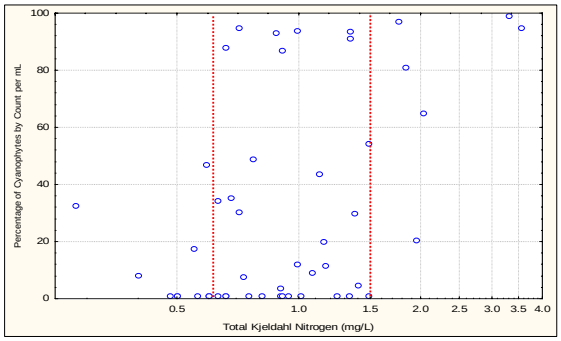
Most other water quality correlations not significant



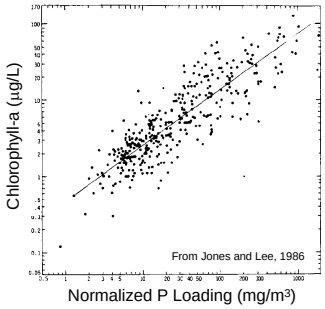
Cyanophytes v. Chlorophyll-*a*



% Cyanophytes v. TKN

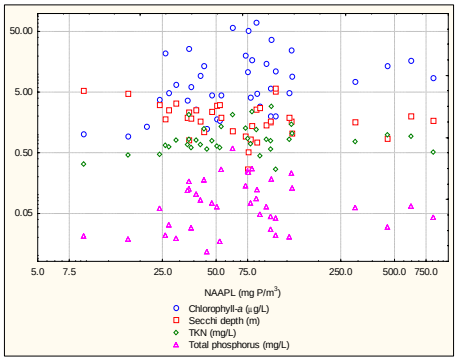


Vollenweider-OECD Model



- Annual phosphorus loading
- Hydraulic residence time
- Surface area
- Depth

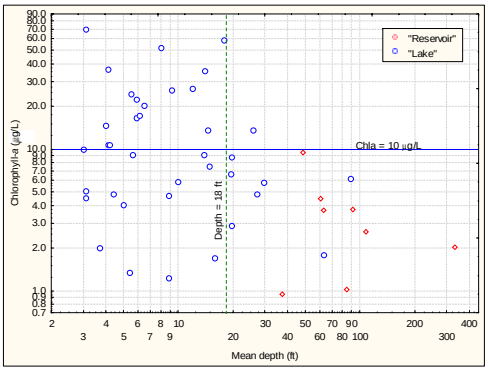
Robust relations not confirmed w/ Arizona data…



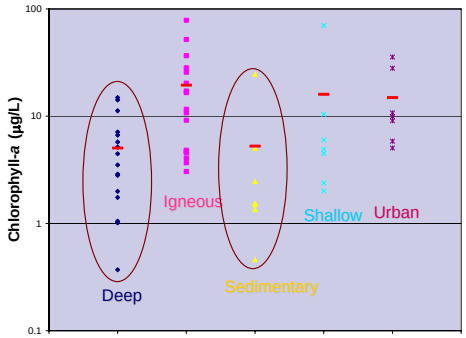
Important lake/watershed characteristics

- Soils associated with higher chlorophyll/ phosphorus concentrations
- Igneous lithologies
- Shallower lakes
- "Lakes" v. "reservoirs'

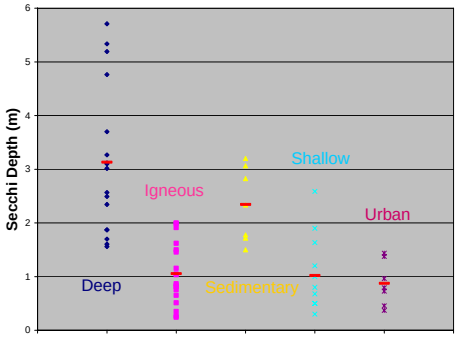
Chlorophyll-*a* v. Mean depth



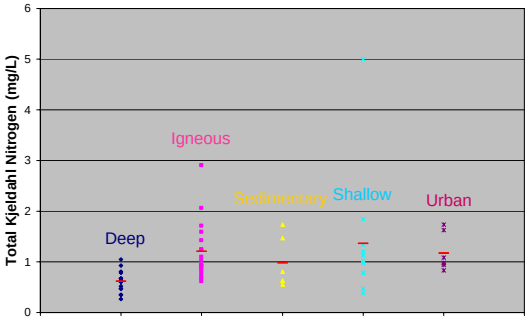
Deep lakes and sedimentary watersheds had lower chlorophyll-a…



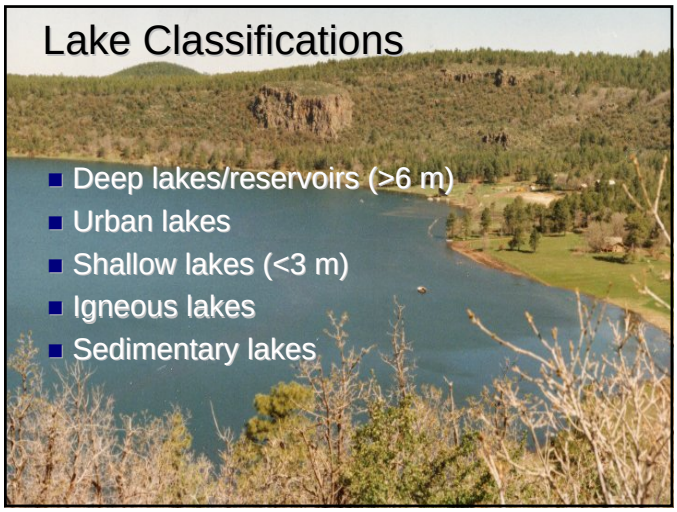
…and higher Secchi depth…



…and lower nutrient concentrations.



Lake Classifications



- Deep lakes/reservoirs (>6 m)
- Urban lakes
- Shallow lakes (<3 m)
- Igneous lakes
- Sedimentary lakes

Concept: Matrix of numeric water quality targets

Use	Chlorophyll-*a*	Secchi depth
A&Wc	?	?
A&Ww	?	?
Full Body Contact	?	?
Partial Body Contact	?	?
Drinking water	?	?

Ideally based on demonstrable, quantitative relations between water quality and designated use impairments.

Recreation/Aesthetic Uses

- User perception surveys (MN, VT)
- Academic/regulatory assessments
- Major conclusion: targets vary widely depending on historical lake quality and user expectations.

Example: Kansas v. Louisiana

Chlorophyll-*a* (µg/L)	*Kansas DHE Description (Carney, 1998)*
6-7	Algae begins to be noticeable.
9-10	Definite observable levels of algae.
12-15	Algae levels moderate. Swimming uses begin to be impaired.
15-20	Algae levels high. Contact recreation impaired.
20-25	No swimming due to concerns for human health.
30-80	Severe algal scums. Recreational/aesthetics severely impaired.

Example: Kansas v. Louisiana

Chlorophyll-*a* (µg/L)	*Lousiana "Lake Condition Index" (Burden et. al., 1985)*
0-15	Excellent to good
15-30	Good to acceptable.
>30	Acceptable to marginal

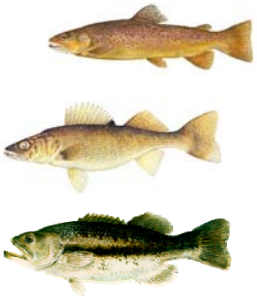
Minnesota: Regional Secchi depth targets vary between 1 m and 3 m, depending upon user perception. (Heiskary and Walker, 1988)

Human Health-Based Targets

- Cyanobacterial cells (World Health Org.)
  - 20,000/mL — Allergenic health effects
  - 100,000/mL — Moderate health effects
- Chlorophyll-*a*
  - 10 µg/L
  - 50 µg/L
  - (Pilotto *et. al.*, 1997)
  - 10-15 mg/L — Arizona study

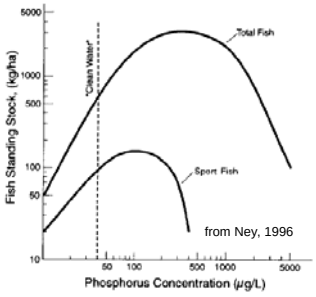
Fisheries/Aquatic Life Uses

- Coldwater
  - Trout, northern pike
- Coolwater
  - Walleye, striped bass
- Warmwater
  - Bass, sunfish, catfish



Fisheries v. trophic state

- Literature reveals positive correlations between fisheries and nutrients.
- Fisheries targets higher than aesthetic targets.
- Hypereutrophication can harm fisheries.



from Ney, 1996

Coldwater fisheries

- Chlorophyll-*a*
  - 1 μg/L (Peak abundance of trout in MN lakes; Schupp and Wilson, 1993)
  - 10 μg/L (Dillon and others 1975)
  - 15 μg/L (North Carolina standard for trout waters)
- Secchi depth
  - 1-4 m

Coolwater fisheries

- Few specific studies
- Chlorophyll-*a* concentrations of 7-15 μg/L are supportive.
  - Minnesota Lakes
  - Walleye in Lake Erie
  - Striped bass in Virginia
- Higher concentrations may also be supportive if DO does not become limiting.

Warmwater fisheries

- Many warmwater species not limited by hypolimnetic hypoxia.
- Positive correlations with chlorophyll-*a* up to 20-60 μg/L
- But, under hypereutrophic conditions
  - Game fish declines
  - Harmful algal blooms
  - Epilimnetic (diel) hypoxia
  - Fishing physically impaired by algae.

Warmwater fisheries

- Water quality targets very different from aesthetic targets.
  - Chlorophyll-*a* limits of 25-40 μg/L
  - Secchi depth >0.5-1.0 m

Water supply

- Cyanophyte toxins
  - Similar targets as with swimming uses
- Taste & odors
- Chlorophyll-*a* targets
  - 9-10 μg/L: Taste & odor problems can become noticeable
  - 15-20 μg/L: Water supply uses impaired (Carney, 1998)
  - >30 μg/L increases risk of health-related problems. (Heath et. al. 1988)
  - 20-50 μg/L : Microcystis blooms (Chorus and Bartram, 1999)

Selecting potential targets for Arizona's lakes and reservoirs

- Primarily based on response variables
  - Chlorophyll-*a*
  - Secchi depth
  - Cyanophyte count or proportion
- Associated nutrient targets derived from Arizona trophic state index

Selecting potential targets for Arizona's lakes and reservoirs

- Targets based on a combination of
  - Scientific lake/management categories
  - Water quality characteristics of lake categories
  - Realistic management objectives
- All water quality targets expressed as a range.

Recreational Uses

Lake Category	Chl-*a* (μg/L)	Secchi Depth (m)	Tot. Phos. (μg/L)	Tot. Nit. (mg/L)	TKN (mg/L)	Cyano-phytes (per mL)
Deep	10-15	1.5–2.5	70-90	1.2-1.4	1.0-1.1	20,000
Shallow	10-15	1.5-2.0	70-90	1.2-1.4	1.0-1.1	
Igneous	20-30	0.5-1.0	100-125	1.5-1.7	1.2-1.4	
Sedimentary	10-15	1.5-2.0	70-90	1.2-1.4	1.0-1.1	
Urban	20-30	0.5-1.0	100-125	1.5-1.7	1.2-1.4	

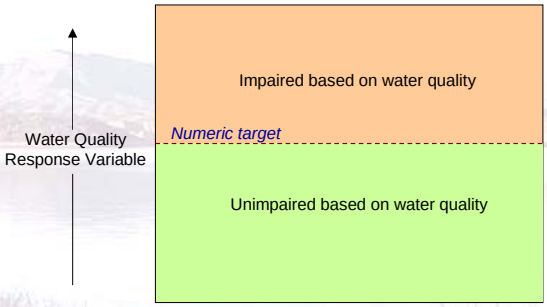
Aquatic Life/Fisheries Uses

Fishery Type	Chl-*a* (μg/L)	Secchi Depth (m)	Tot. Phos. (μg/L)	Tot. Nit. (mg/L)	TKN (mg/L)	Cyano-phytes (%)
Coldwater	5-15	1.5-2.0	50-90	1.0-1.4	0.7-1.1	<50
Coolwater	15-30	0.8-2.0	90-125	1.4-1.7	1.1-1.4	
Warmwater	25-40	0.8-1.0	115-140	1.6-1.8	1.3-1.6	
Urban	30-50	0.7-1.0	125-160	1.7-1.9	1.4-1.7	

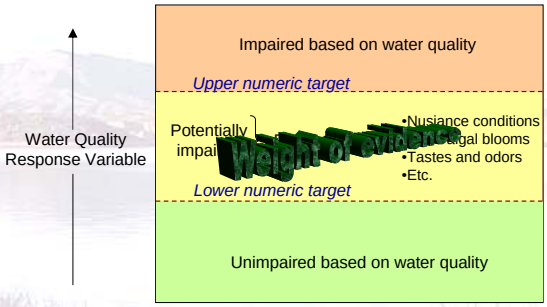
Domestic Water Supply Use

Chl-*a* (μg/L)	Secchi Depth (m)	Tot. Phos. (μg/L)	Tot. Nit. (mg/L)	TKN (mg/L)	Cyano-phytes (per mL)
10-20	1.0-1.5	70-100	1.2-1.5	1.0-1.2	20,000

Application of single pass/fail target



Arizona's proposed approach



Advantages of Arizona's Approach

- Targets based on both
  - Available scientific information on use attainment.
  - Unique characteristics of Arizona's water bodies.
- Also allows lake-specific information to be incorporated, where available.
- Avoid being locked into overly simplistic pass-fail criteria by
  - Expressing targets as a range
  - Using weight of evidence approach