R6 Air Program-Sponsored Lake Monitoring

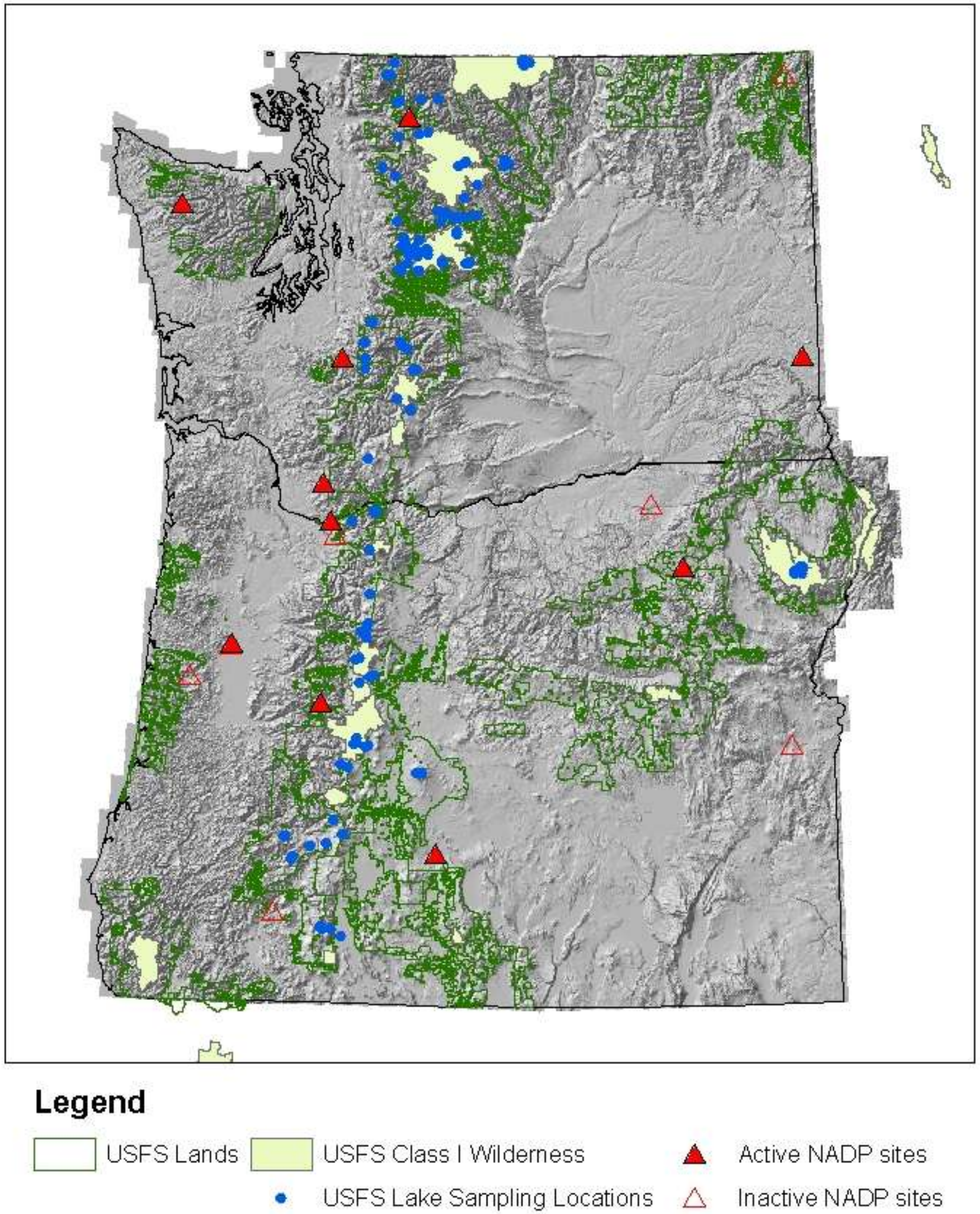
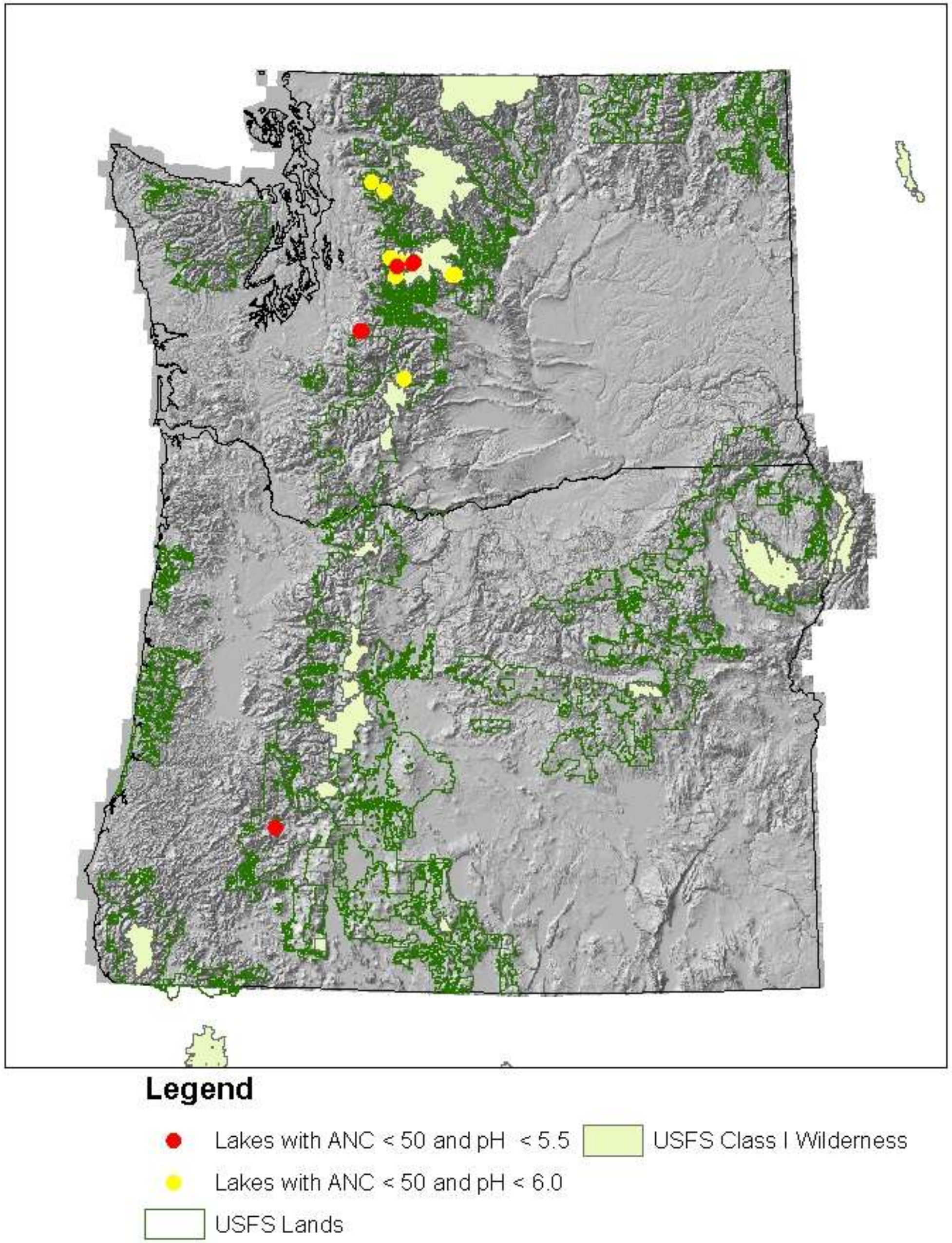


Fig. 1. NADP Monitoring Sites and Lake Sampling Locations in WA and OR


Legend
Lakes with ANC < 50 and pH < 5.5
USFS Class I Wilderness
Lakes with ANC < 50 and pH < 6.0
USFS Lands

United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-299
May 1992

Guidelines for Evaluating Air Pollution Impacts on Class I Wilderness Areas in the Pacific Northwest

Janice Peterson, Daniel Schmoldt, David Peterson,
Joseph Eilers, Richard Fisher, and Robert Bachman

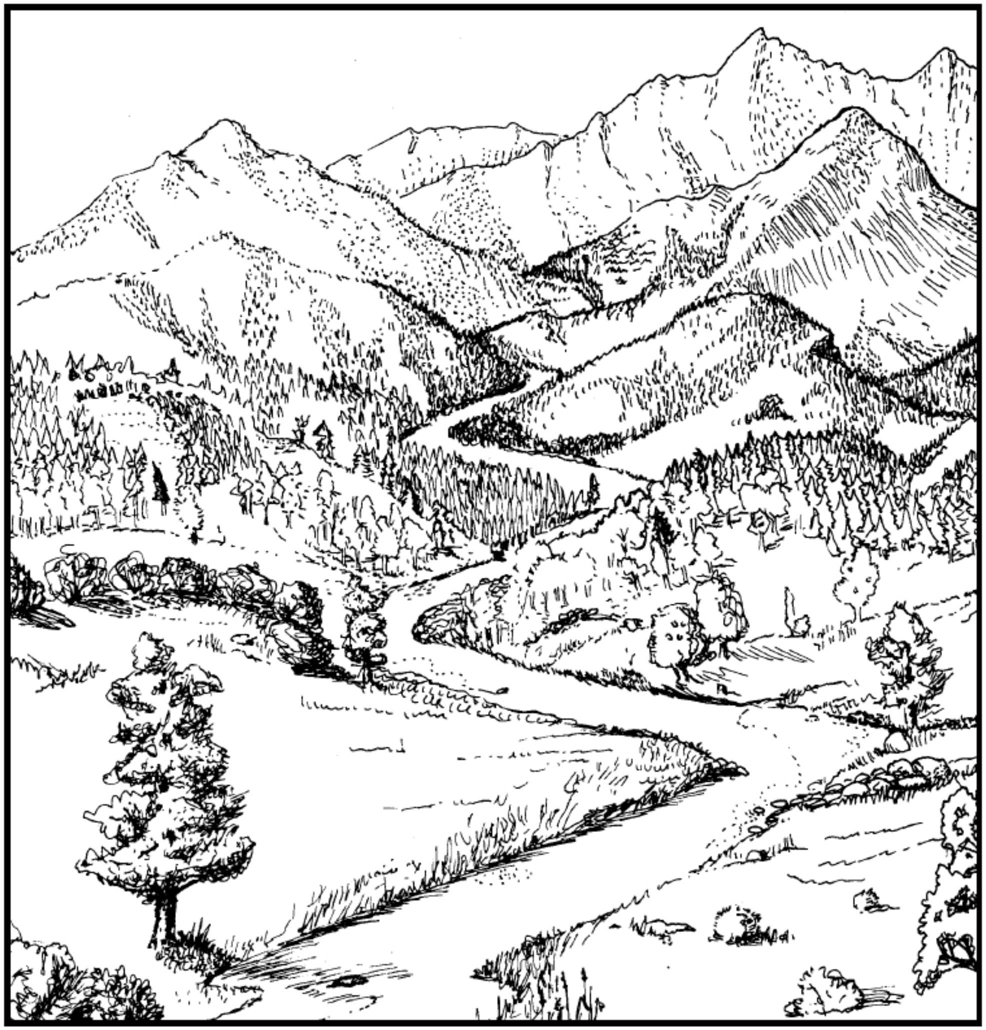


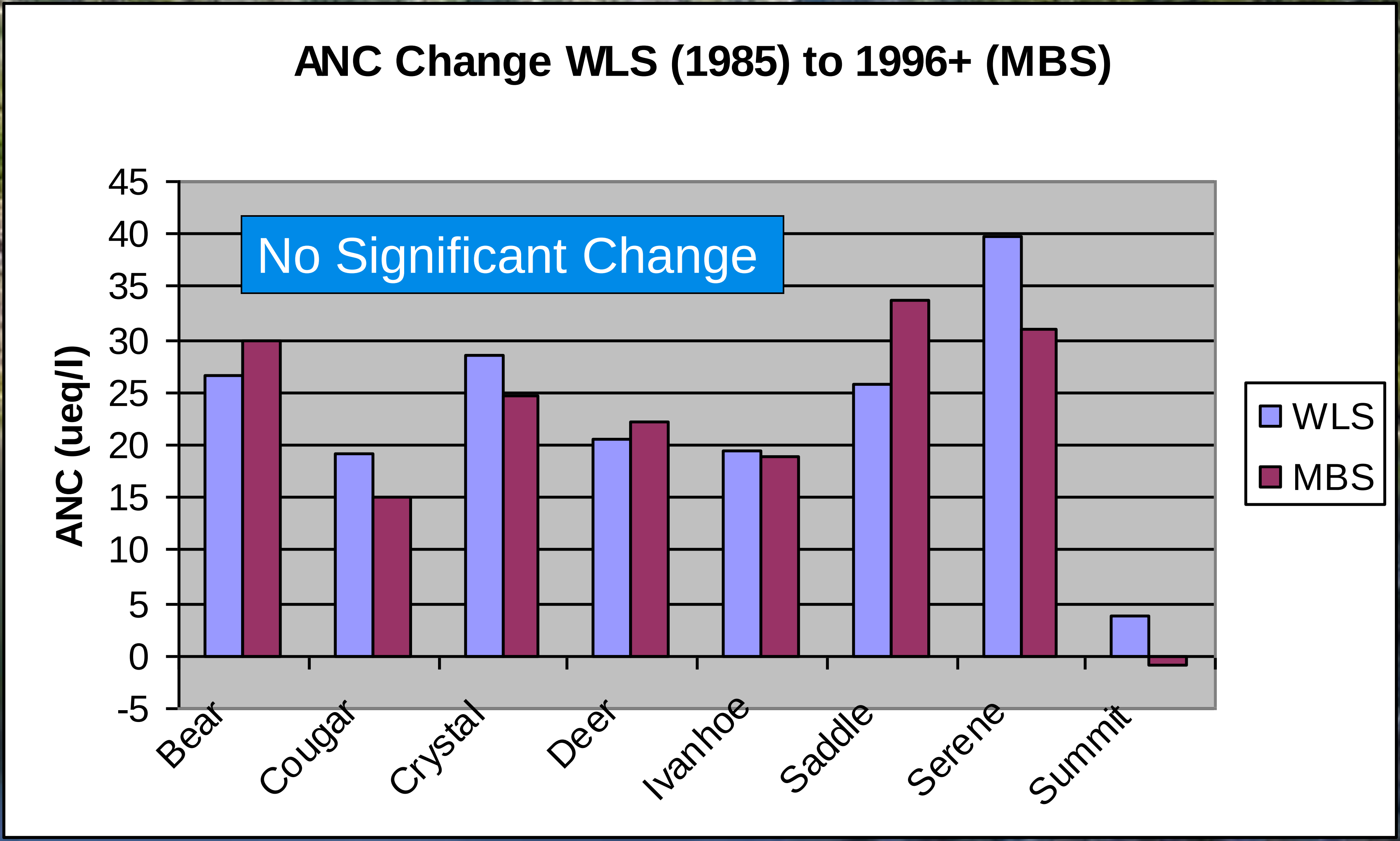
Table 10—Condition class definitions identified for sensitive indicators of aquatic resources [a,b]

Indicator	Initial condition	No significant deterioration	Significant deterioration	Severe deterioration
ANC (μeq L^{-1}):[c]				
Lakes		< 20%	> 20%	≤ 0 μeq L^{-1}
Streams	ANC < 25	No change	Any change	Any change
	ANC 25-100	< 25%	15-25 μeq L^{-1}	< 15 μeq L^{-1}
	ANC > 100	< 50%	15-25 μeq L^{-1}	< 15 μeq L^{-1}
pH:[c]				
Lakes		> 6.0	5.3-6.0	< 5.3
Streams	pH ≤ 6.3	> 6.3	6.0-6.3	< 6.0
	pH > 6.3	Δ< 0.2	Δ 0.2-0.5	Δ> 0.5
Total aluminum (μg L^{-1})[d]		< 30	30-50	> 50
Sulfate (μeq L^{-1})[d]		< 5	5-10	> 10
Nitrate (μeq L^{-1})[d]		< 1	1-3	> 3
Ammonium (μeq L^{-1})[d]		< 1	1-3	> 3
Total phosphorus (μg L^{-1})[d]		< 5	5-10	> 10
Secchi disk transparency (m)[c]		< 20%	20-30%	> 30%
Dissolved oxygen (mg L^{-1})[c,e]		< 1	1-4	> 4

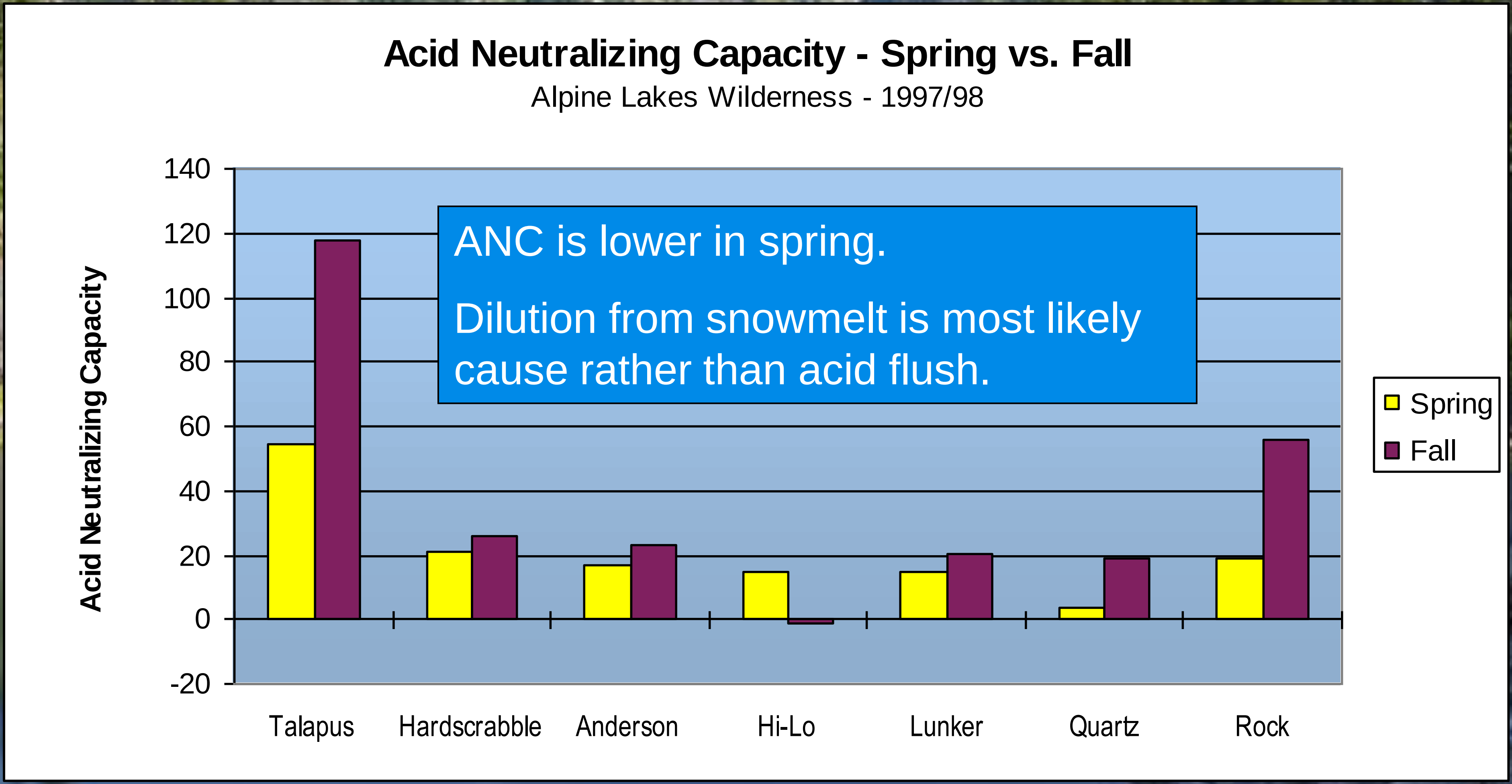
MBS Lake Monitoring Goals
(circa 1996)

1. Resample WLS lakes with ANC<50
2. Look for episodic acidification using paired spring/fall sampling
3. Single sample of “all” reasonably accessible lakes in C1 wildernesses
4. Long-term trends monitoring

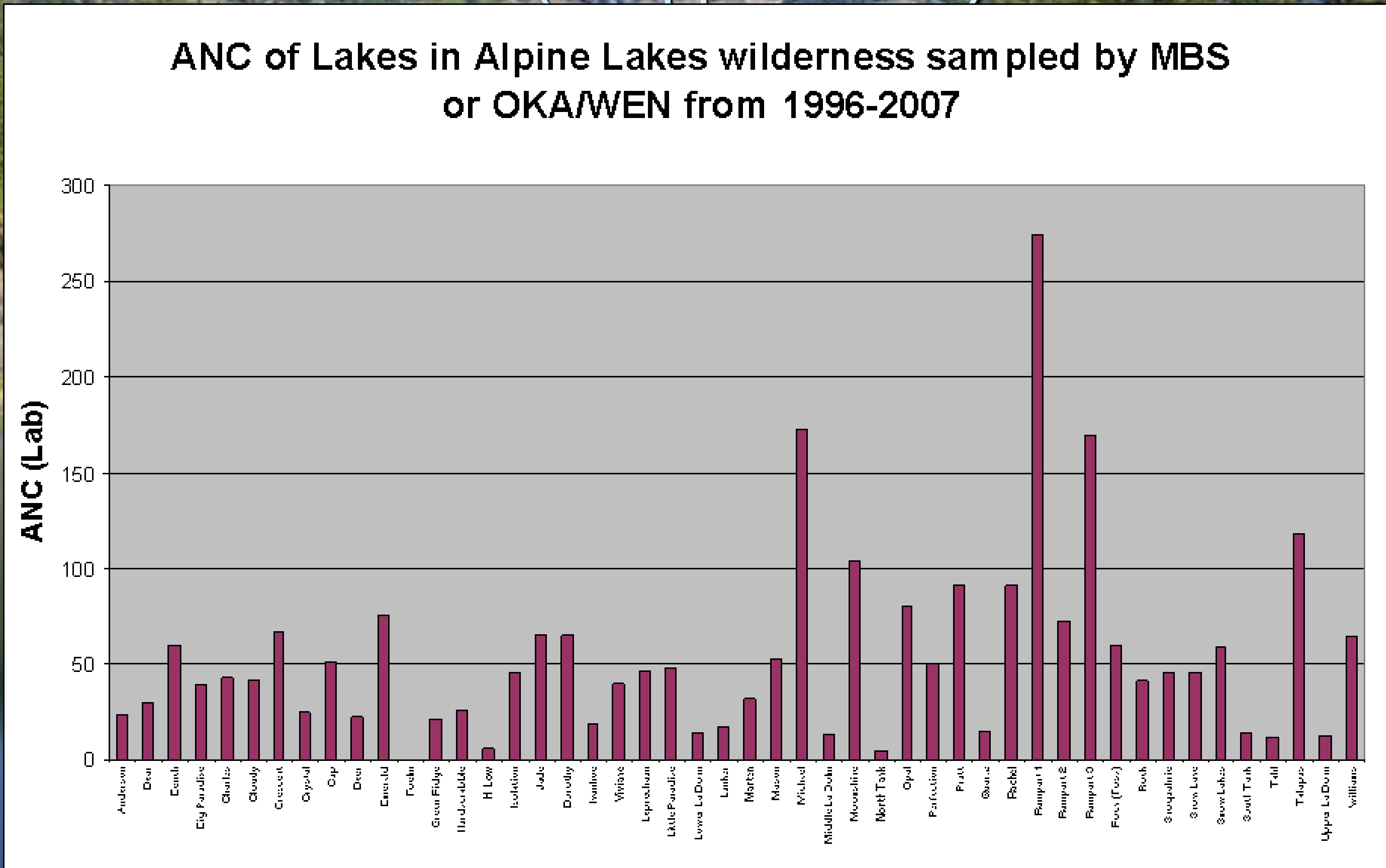
Results: Task 1



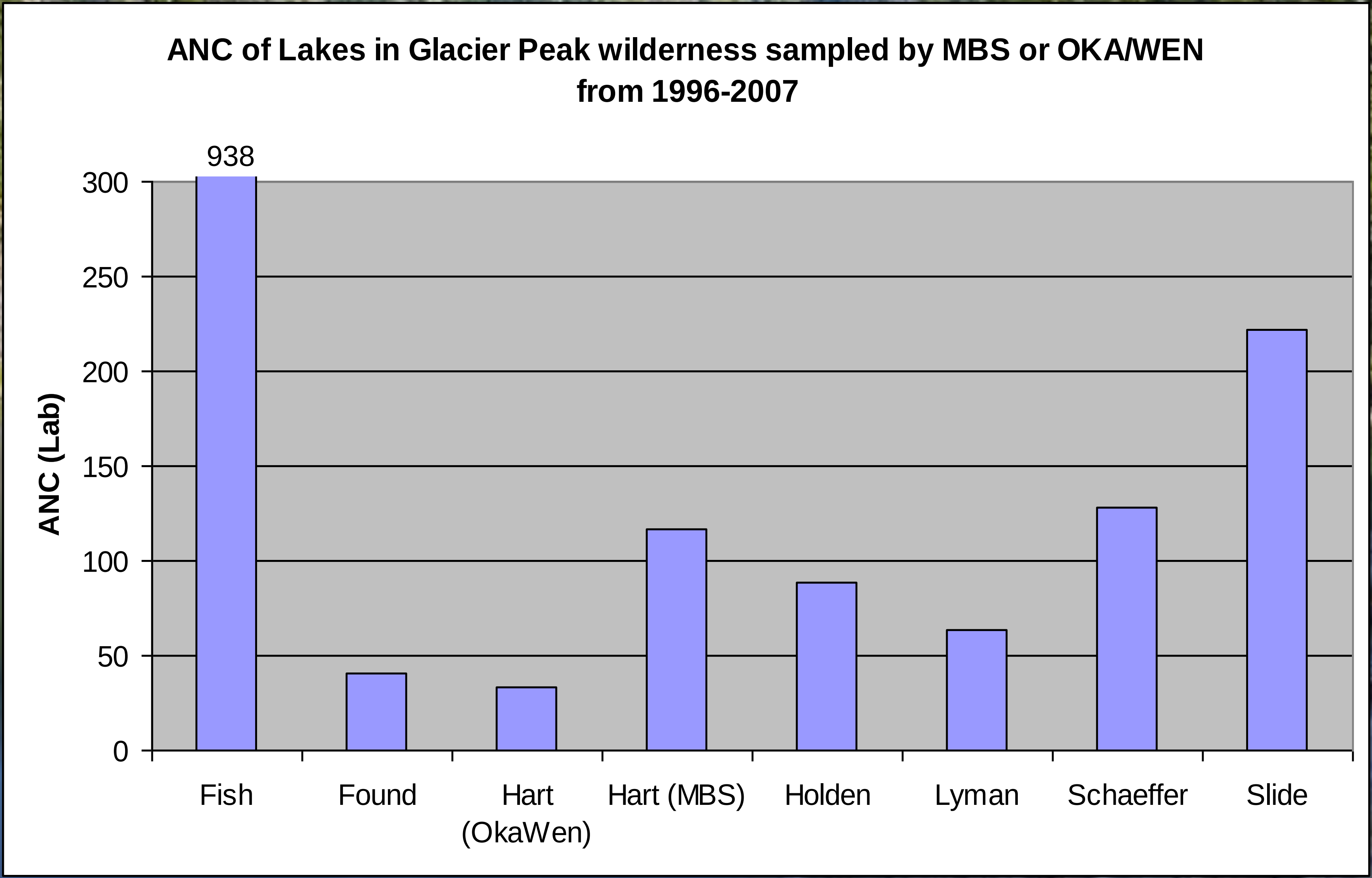
Results: Task 2



48 Lakes Sampled in Alpine Lakes Wilderness (of approx. 332) or 7%



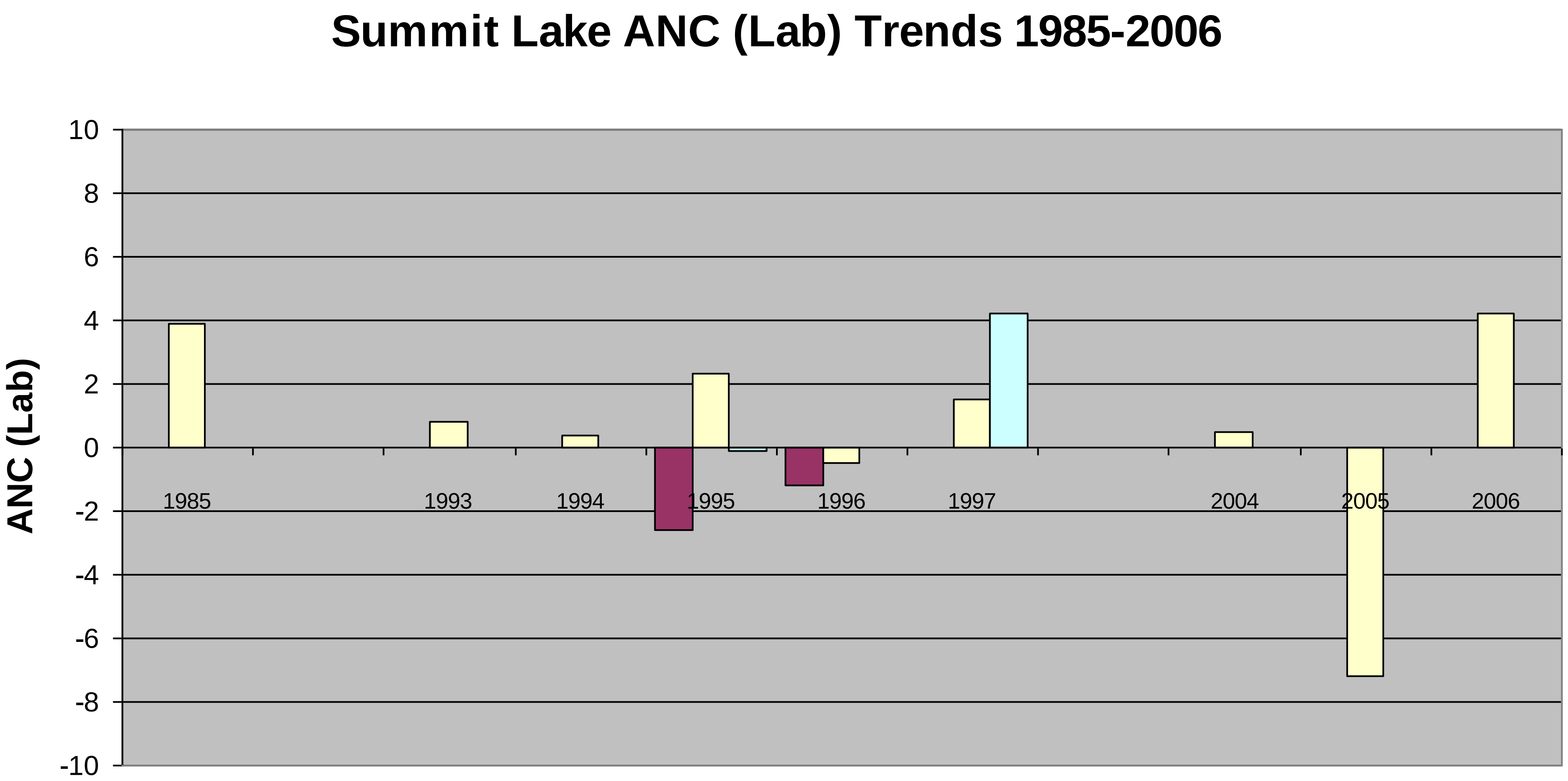
8 Lakes Sampled in Glacier Peak Wilderness (of approx. 107) or 13 %



Range of Chemistry MBS lakes

Dissolved Ca (mg/L)	0.025 - 9.524
Dissolved Cl (mg/L)	0.035 – 1.057
Conductivity (uS/cm)	1.82 – 187
Dissolved K (mg/L)	0 – 0.817
Dissolved Mg (mg/L)	0.006 - 0.624
Dissolved Na (mg/L)	0.09 – 1.298
Dissolved F (mg/L)	0 – 0.077
NH4 (mg/L)	0 – 0.057
NO3 (mg/L)	0 – 0.401
SO4 (mg/L)	0.092 – 7.766
SO4 (ueq/L)	1.92 – 161.8

Long Term Trends Monitoring
-Summit Lake-



Long-term monitoring, critical loads estimation (Eilers)

- Four extremely dilute lakes in R6 sampled (2004-2008)
  - Vertical profile (temp., pH, conductivity, DO, depth, ORP)
  - Major ions (Ca, Mg, Na, K, Cl, NO3, So4, HCO3, pH)
  - Nutrients (TKN, NO3, NH3, Si, TP, PO4)
  - Zooplankton, phytoplankton, bathymetry, sediment cores
  - CE-QUAL-W2

4-Lakes long-term study

1. Characterized the present condition of the lakes through lake sampling,
2. Defined the historical conditions of the lakes through use of paleolimnology, and
3. Simulated future response of the lakes to changing atmospheric conditions with hydrodynamic modeling.

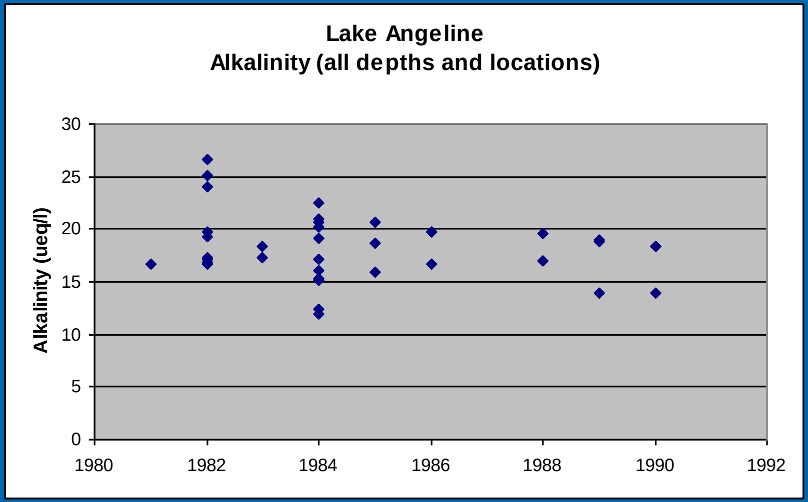
Notasha, Scout, Summit, Foehn Study Conclusions

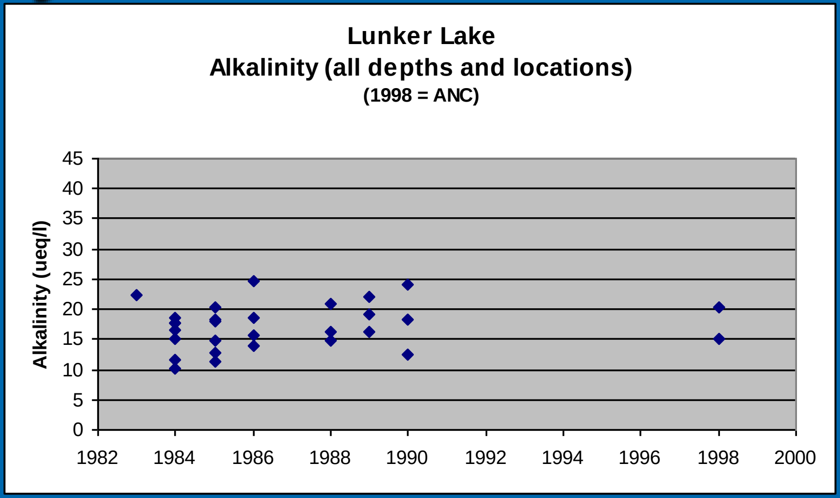
- Notasha, Scout, and Summit: 300% increase in S and N would be required before resulting in a change in pH.
- Foehn: 100% increase in S and N before a change in pH.
- Recommendations
  - Need measured deposition
  - Detailed study of a single system

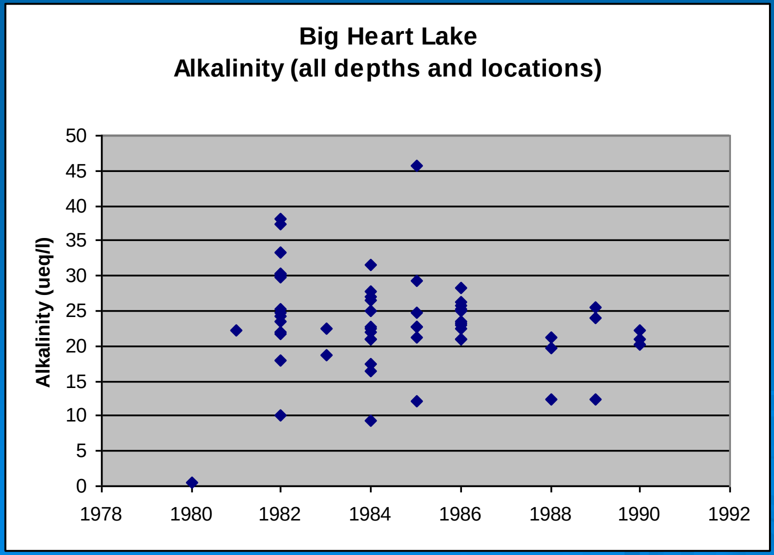
Determining critical N loads to subalpine lakes in the PNW

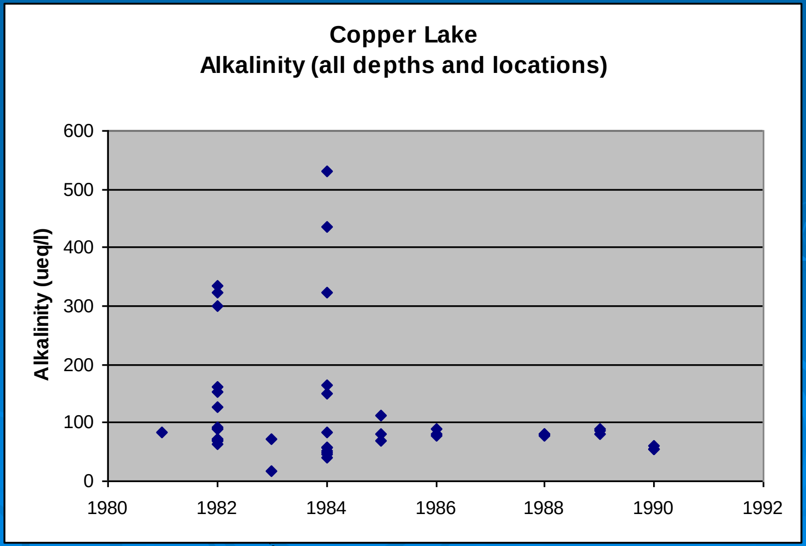
- Two lakes studied
  - Dorothy
  - Cora
- Findings:
  - lakes were phosphorus limited; not nitrogen limited
  - Seston C:N:P ratios could be useful for predicting nutrient limitation

Long-term monitoring Alkalinity/ANC

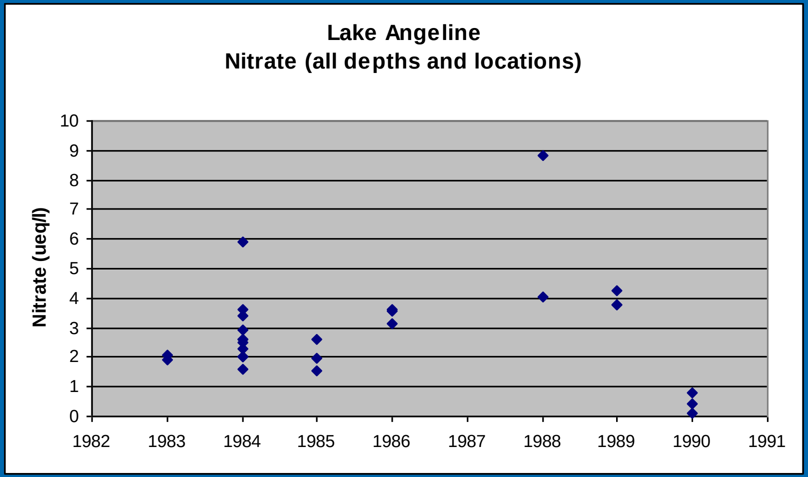


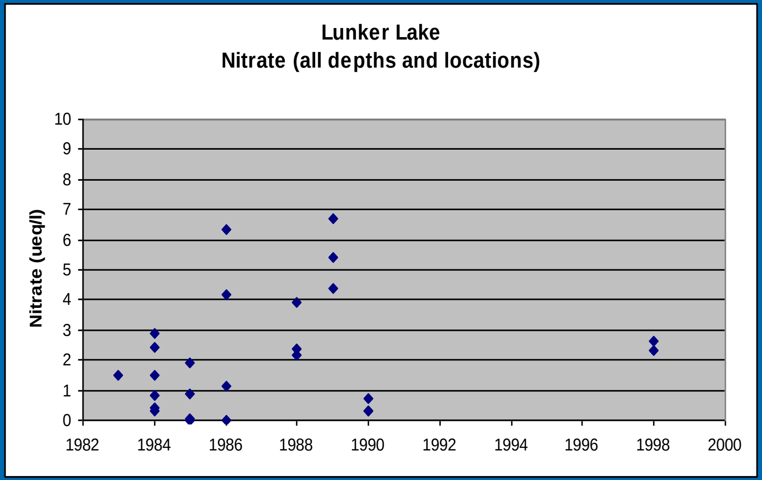


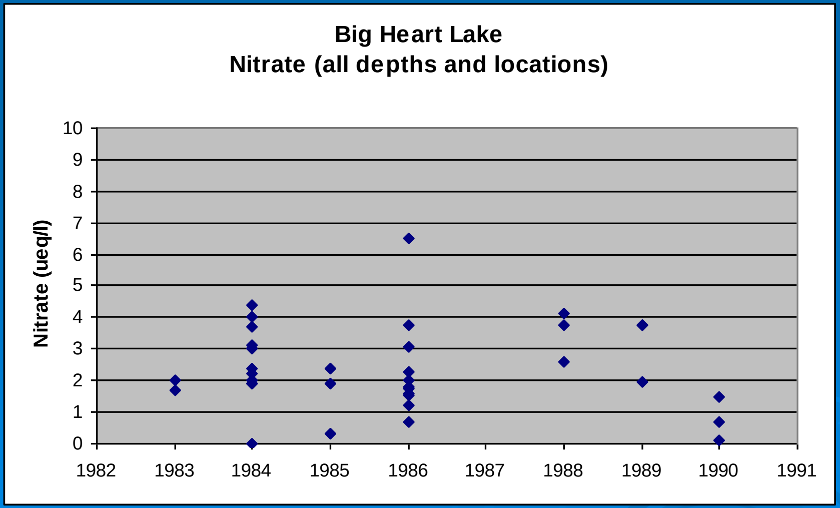


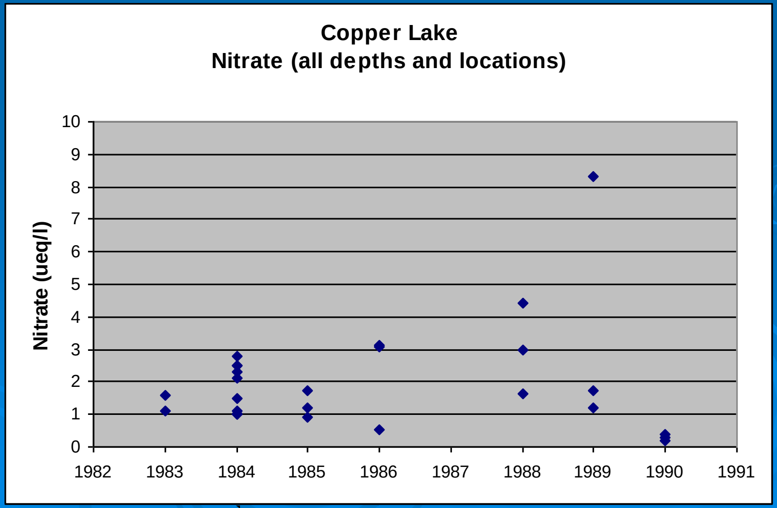


Long-term monitoring
Nitrate

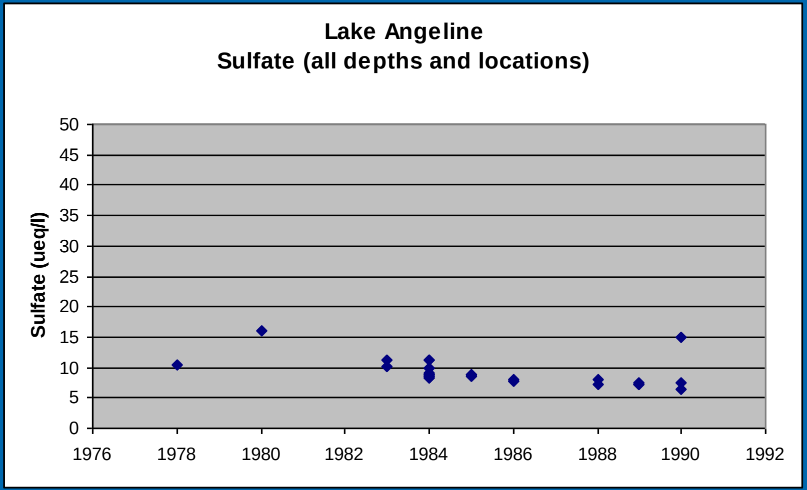


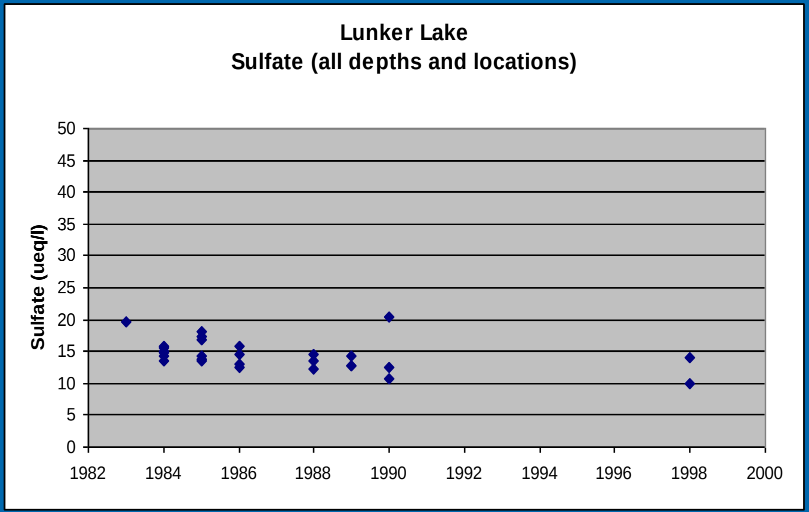


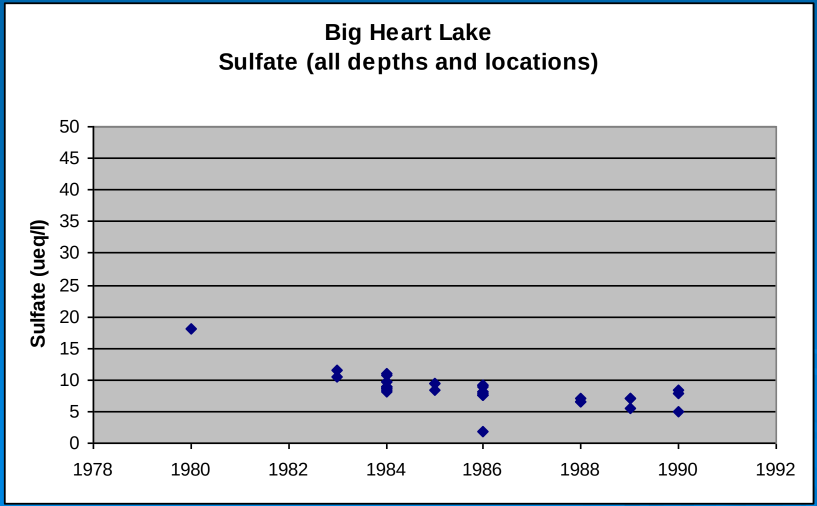


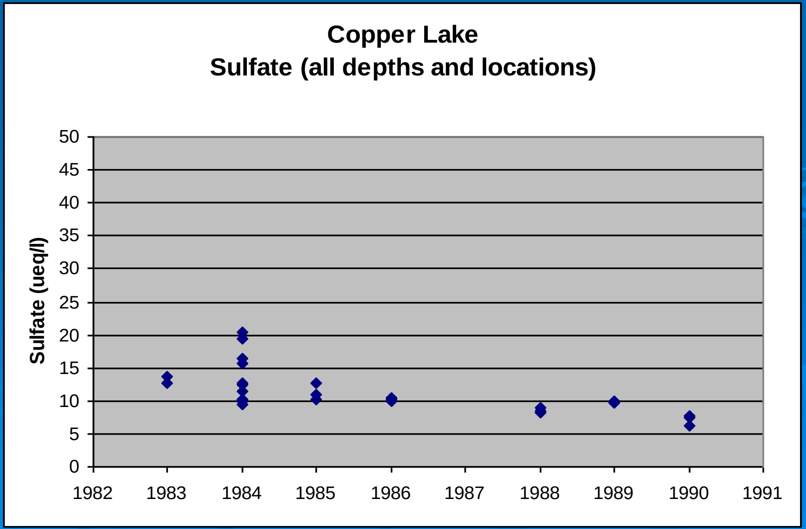


Long-term monitoring Sulfate

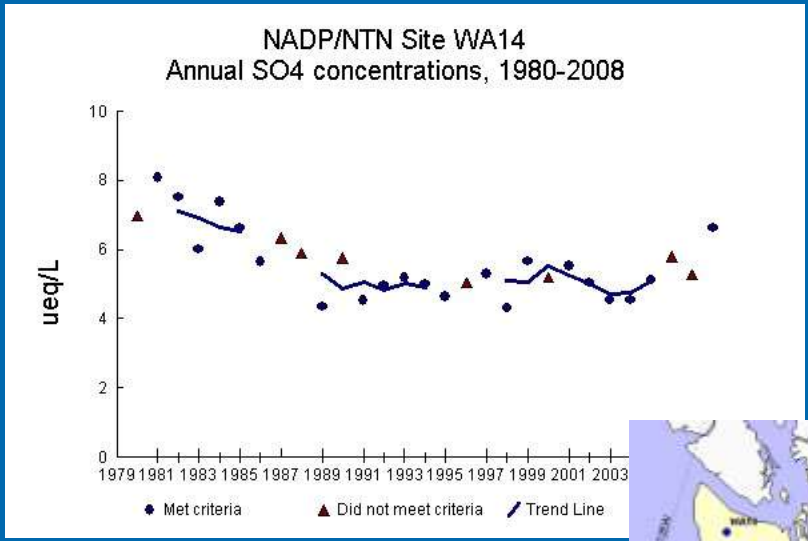


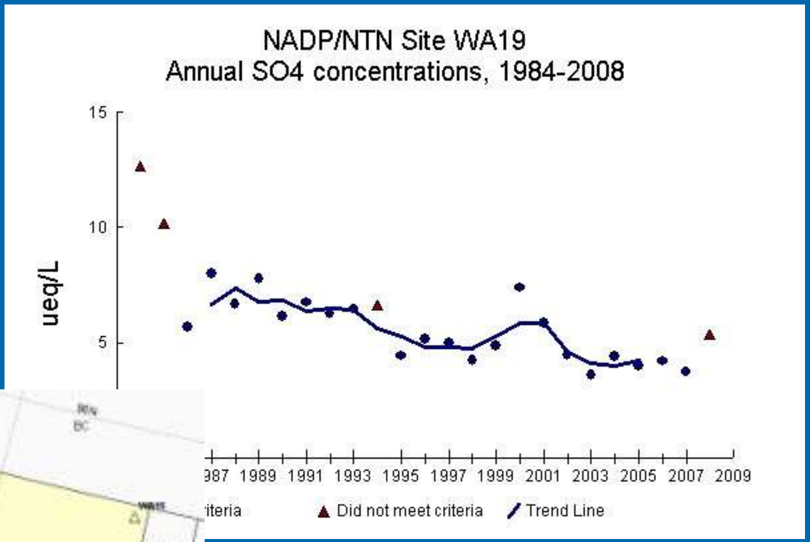


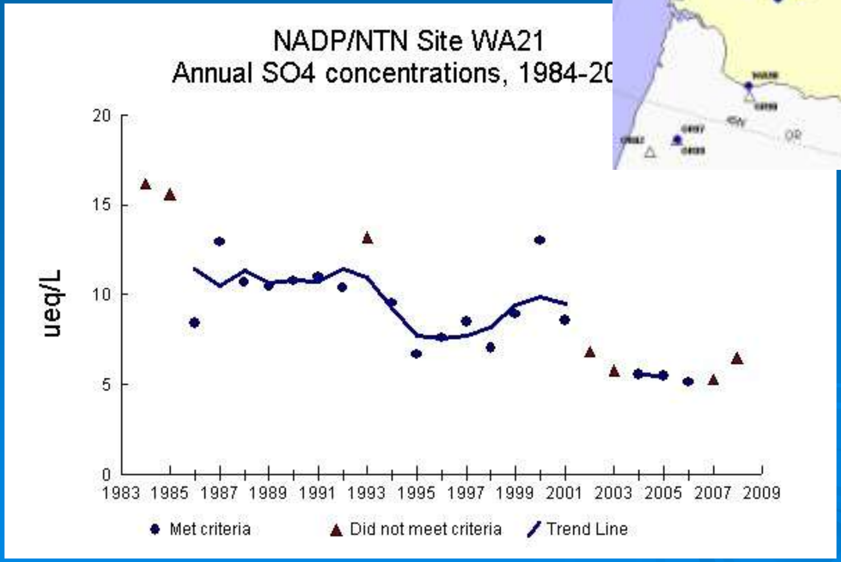


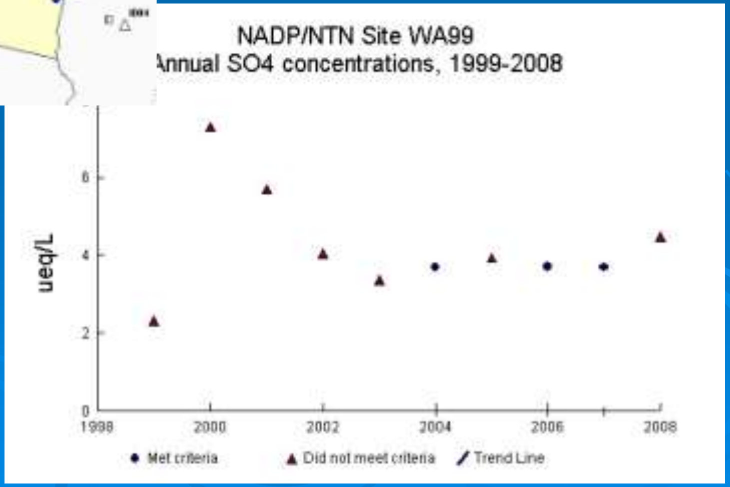


NADP/NTN SO4 trends in WA

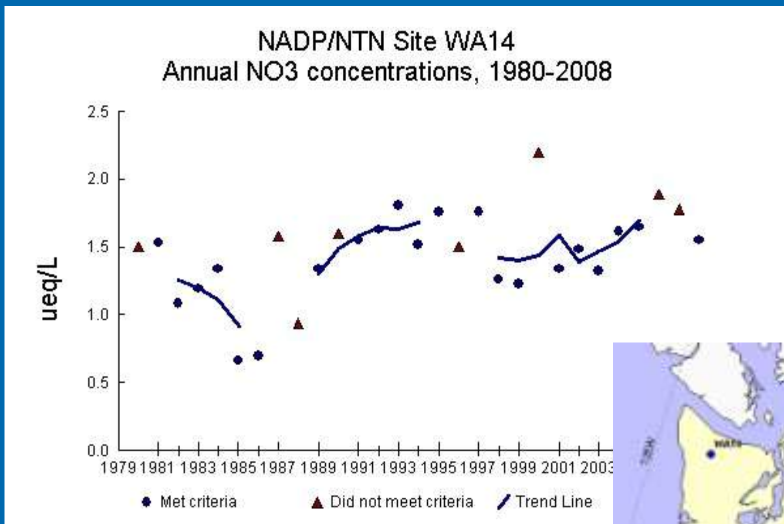


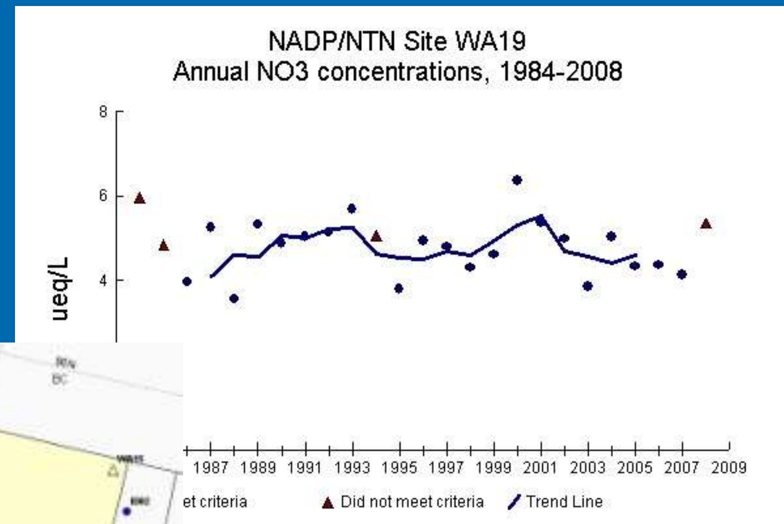


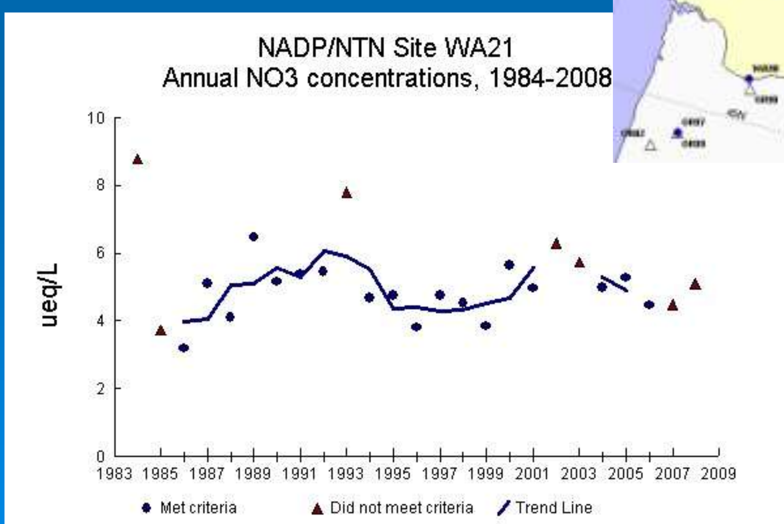


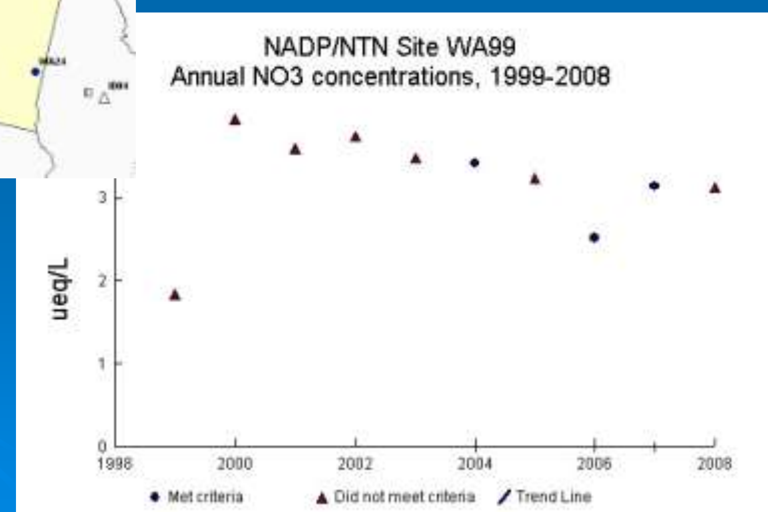


NADP/NTN trends in NO3 in WA









Conclusions from Past Monitoring *-tentative-*

- Lakes in areas of R6 have extremely low buffering capacity – sensitive to acidification.
- Lake chemistry is mostly stable or improving
  - No noticeable change since WLS
- Acidification is not occurring
  - S deposition and concentration in lakes is decreasing slightly
- N deposition is increasing slightly
  - Lakes not N limited

R6 Lake Program

1. How do we best summarize existing lake sampling information?
2. How can we use what we know about our lakes to best protect them?
3. Design and prioritize future lake efforts.

R6 Lake Program

- Future Program
  - What should our future program look like?
  - What air quality-related issues are threatening alpine lakes?
  - Do we need to establish a long-term chemistry sampling program? Toward what end?
  - How and when to make use of modeling?
  - Can we forget about acidification? Nitrification?
  - Are most lakes P limited and can we predict this?
  - Should we be looking for toxic chemicals or mercury?
  - Is the potential impact of climate change something we know how to measure/track/quantify at this point?

R6 Lake Program

- Strengths
  - Lots of lakes sampled
  - Long term cooperation with aquatics program
  - Some long term lakes sampled by contractor
  - Much high quality work by Eilers
- Weaknesses
  - Shifting issues
  - Little documentation