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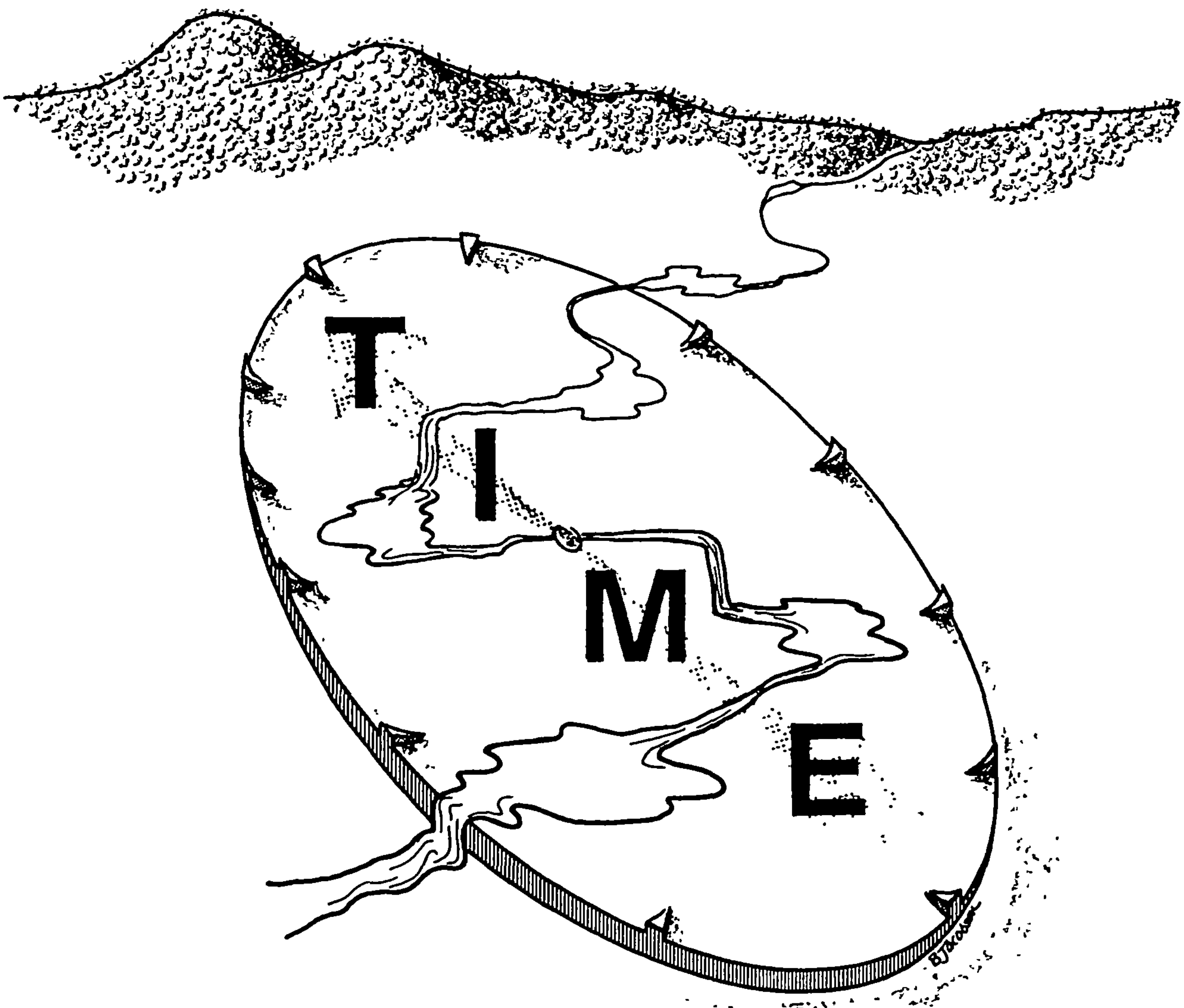
THE CONCEPT OF TIME



Aquatic Effects Research Program

THE CONCEPT OF TIME

TEMPORAL INTEGRATED MONITORING OF ECOSYSTEMS (TIME)

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THE CONCEPT OF TIME
TEMPORAL INTEGRATED MONITORING OF ECOSYSTEMS (TIME)

BY

K.W. THORNTON[1], F.E. PAYNE[1], J. FORD[2], AND D.H. LANDERS[3]

1.1 TIME

The Temporal Integrated Monitoring of Ecosystems (TIME) project is a proposed long-term monitoring program to assess the future affects of acidic deposition on aquatic ecosystems. The TIME project is intended to address the following questions:

- What are the early and on-going regional trends in surface water acidification or recovery?
- What are the relationships between the observed patterns and trends in surface water chemistry and regional patterns and trends in atmospheric deposition?
- Do these observed patterns and trends correspond with model forecasts of future regional patterns in surface water chemistry (e.g., the EPA Direct/Delayed Response Project)?

The TIME project currently is in the conceptual design phase. The purpose of this document is to:

- Describe the current concept of the TIME project and its relation to the EPA Aquatic Effects Research Project (AERP) and National Acid Precipitation Assessment Program (NAPAP);
- Discuss on-going and proposed analyses to improve and refine the Concept for preparation of a Research Plan;

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- o Discuss the possible options and alternatives for aquatic monitoring programs;
- o Describe the general TIME frame proposed for each region of concern; and
- o Elicit comments and constructive criticism of the proposed Concept of TIME.

1.2 IMPORTANCE

Long-term monitoring is absolutely essential to determine if additional aquatic systems will become acidic or will recover in the future. Evaluating the effectiveness of any mandated emission control procedures must be based on high quality, long-term records. Long-term, with respect to acidic deposition, is measured in decades, not 2-4 years. Verifying model forecasts of future surface water acidification or recovery can be accomplished only through comparisons with long-term records of surface water chemistry. It is not possible to corroborate long-term forecasts without having concommitant long-term data (Simons and Lam 1980). Likens (1983) stressed the importance of long-term monitoring in understanding and detecting subtle environmental changes that may be occurring and are difficult or impossible to detect from short-term or fragmented records. Establishing long-term, high quality monitoring programs may represent the highest priority in environmental research (Likens 1983).

In hearings before the U.S. House of Representatives Subcommittee on Natural Resources, Agriculture Research and Environment (GPO, 1985), it was noted that, in general, long-term monitoring programs in the U.S. are an ad hoc collection of diverse public and private programs, many of which suffer from:

- o Design and operation inadequacies;
- o Parochialism in purpose and approach;
- o Lack of comparable data from one system to another; and, above all,
- o Lack of coordination.

In spite of the fact that environmental monitoring is essential to the implementation of all major environmental statutes and is critical for the detection of future environmental crises, consistent, reliable data to support environmental policy-making in this country still do not exist (GPO, 1985). A major problem in assessing the effects of acidic deposition on aquatic systems has been the lack of long-term records (NRC 1986).

The purpose of the TIME project is to design and implement, through NAPAP, a coordinated long-term monitoring effort that will obviate many of the criticisms associated with environmental monitoring programs.

2.0 NAPAP AND AERP

2.1 NAPAP

The Acid Precipitation Act of 1980 (PL 96-294) established an Interagency Task Force to develop and implement a comprehensive National Acid Precipitation Assessment Program (NAPAP). The purpose of NAPAP is to increase our understanding of the causes and effects of acidic deposition on the environment. The activities of various federal agencies engaged in acid deposition research are collectively funded through this Program. The U.S. Environmental Protection Agency (EPA) is one of the federal entities cooperating through NAPAP and is the agency responsible for Task Group 6 - Aquatic Effects. The major EPA program in Task Group 6 is the Aquatic Effects Research Program (AERP).

2.2 AERP

The AERP is focusing on four primary policy questions:

- What is the extent and magnitude of past damage attributable to acidic deposition?;
- What damage is expected in the future under various deposition scenarios?;
- What is the target loading of sulfate below which damage would not be expected?; and
- What is the rate of recovery if sulfate deposition decreases?

To provide answers to these four policy questions, the AERP has focused on biologically relevant changes in chemistry resulting from long-term and short-term (i.e. episodic) acidification. The component projects, either ongoing or planned, within AERP that are addressing these policy questions are the National Surface Water Survey (NSWS), the Direct/Delayed Response Project (DDRP), the Watershed Manipulation Project (WMP), the Episodic Response Project (ERP), and the TIME project. These projects are addressing four major elements of the policy and assessment questions:

- Quantification of the chemical status and extent of surface waters at risk (NSWS,ERP);

- o Prediction of the future chemical and biological changes within aquatic ecosystems (DDRP);
- o Confirmation of these predictions and development of an improved understanding of controlling mechanisms (WMP, ERP); and
- o Corroboration or verification of these results and findings through long-term monitoring (TIME).

2.2.1 Program Approach

The NSWS, DDRP, WMP, ERP, and TIME collectively comprise the Regionalized Integrative Studies (RIS). Each project in the hierarchy builds on the findings of the previous projects (Figure 2.1). The RIS approach has a broad scale perspective with emphasis on identifying and characterizing regional patterns in surface waters. Acidic deposition occurs at regional and national scales but regional and subregional differences in aquatic resources are critical to understanding the effects of acidic deposition on these resources. The AERP is targeted to define the subpopulations of aquatic resources at risk as a result of acidic deposition within subregions. This approach allows a large number of systems to be described and subsequently classified at regional scales. The resulting classification, then, permits successively smaller subsets of systems to be selected for study. This also permits extrapolation of in-depth, process-oriented research to better understand broad-scale regional patterns. Site-specific, process-oriented research is essential and is used to guide the broader-scale research program and to develop hypotheses for testing on these scales. The mechanisms observed in lakes and streams typical of a regional population can then be extrapolated with quantifiable/known confidence to a regional or national scale.

Initial RIS activities used a large scale classification study (NSWS) to identify regional patterns and characteristics of surface water chemistry. Subsequently, more detailed characterization and process-oriented research on selected systems at the subpopulation levels will provide an understanding of underlying mechanisms responsible for the regionally observed patterns and effects.

2.2.2 NSWS

The NSWS represents the foundation of the AERP and has two major components - the National Lake Survey (NLS) and the National Stream Survey (NSS). The NSWS will be described briefly because of its importance in

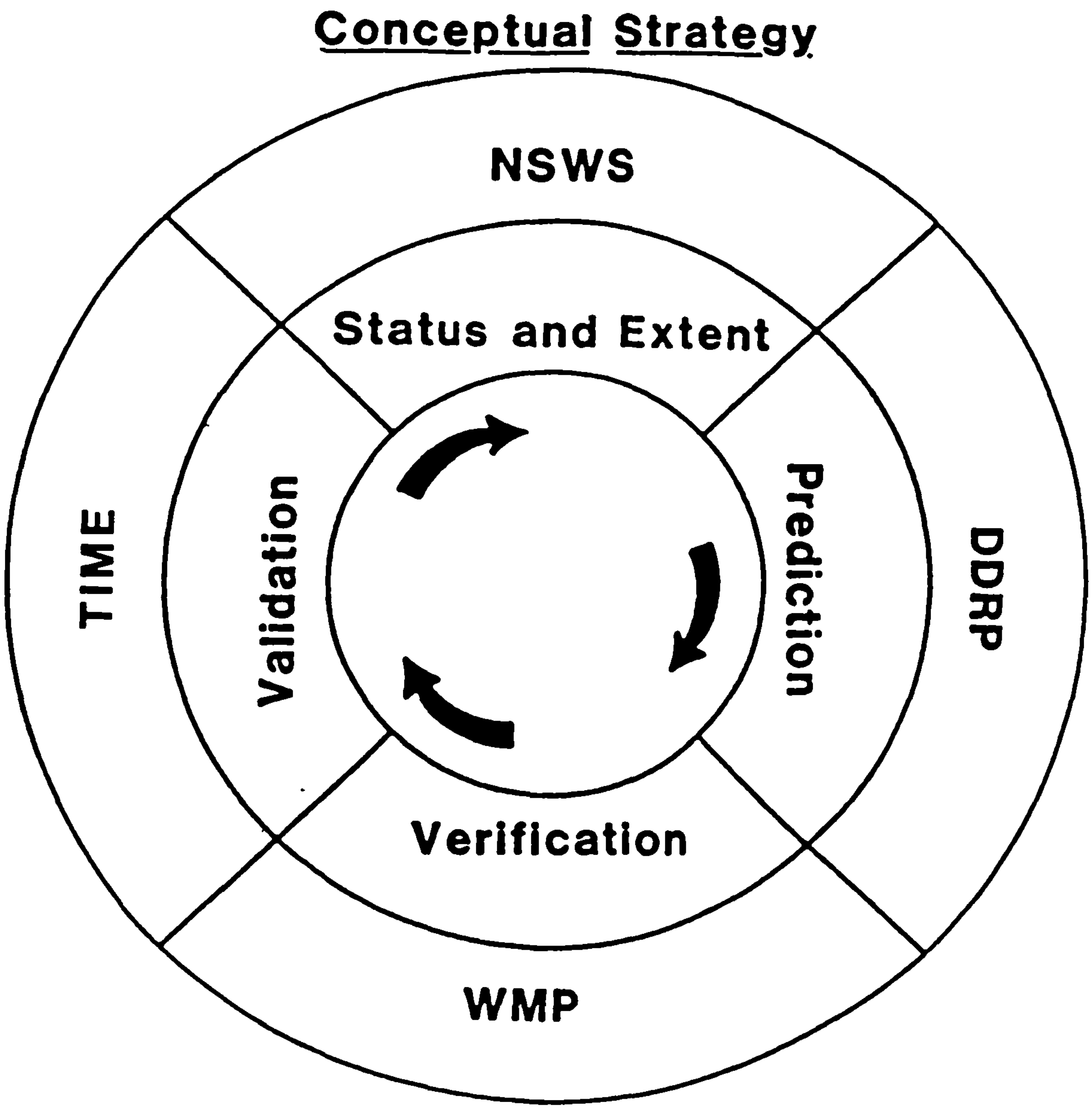


Figure 2.1. Conceptual strategy of Regionalized Integrative Studies within the Aquatic Effects Research Program.

understanding several design aspects of the TIME project and several issues related to long-term monitoring, in general.

2.2.2.1 NLS

The NLS is a two-phased project. Phase I consisted of fall index sampling in lakes in the Eastern U.S. during 1984 and Western lakes in 1985 (Figure 2.2); Phase II consisted of seasonal sampling (i.e., spring, summer and fall) in Northeastern lakes during 1986 (Linthurst et al. 1986, Landers et al. 1987, Thornton et al. 1986).

2.2.2.2 NSS

The NSS also consisted of two components: A Pilot Survey conducted during the spring and summer of 1985; and the NSS-Phase I conducted during the spring of 1986 in the Eastern U.S. (Figure 2.2), (Messer et al. 1986). Index sampling also was used in the NSS.

2.2.2.3 Design Considerations

The NSWS incorporated several factors important in the design of a long-term monitoring program. These factors were:

- A statistical frame with probability samples that permitted regional population estimates of the status and extent of various surface water chemistry attributes;
- An index sampling approach for surface water chemistry;
- A standardized sampling and analysis protocol; and
- Extensive QA/QC on sample collection, chemical analysis, data management, and statistical analysis.

2.2.2.4 Statistical Frame

The NSWS was designed within a statistical frame with probability sampling. Each lake or stream sample was selected with a known inclusion probability or probability of being selected from the regional target population. This probability is used to assign a weight to the physical or chemical attribute measured in the lake or stream sample. Calculations can then be made to estimate population means, medians, variances, or other descriptive statistics for the population. The important consideration is that the lake or stream sample can be statistically related

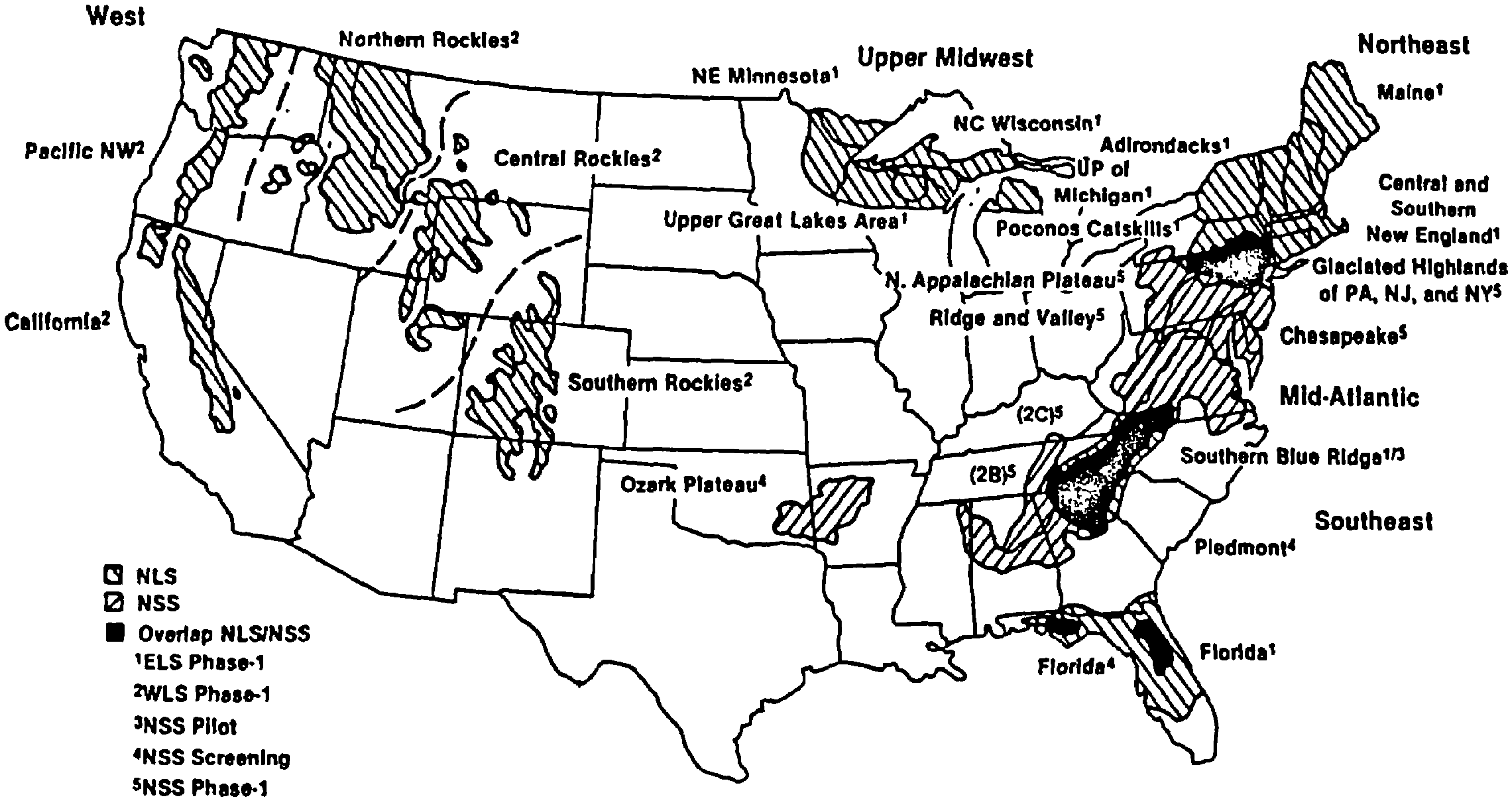


Figure 2.2. Regions and subregions of the United States used to define target populations for the National Surface Water Survey.

back to the target population and the proportion of the population represented by those lake or stream attributes can be estimated.

2.2.2.5 Index Sample

It is obvious that one sample, from one location, at one time of the day, in a specific season of a particular year, cannot characterize the complex chemical dynamics of a lake or stream. Such a sample is justified only in the sense that it is an index to the essential characteristics of the system (Linthurst et al 1986). Even if two or three samples were taken, these samples would still serve only as indices because understanding the dynamics of a single system requires much more detailed study (Linthurst et al 1986). The NSWS was designed to describe the characteristics of populations of lakes and streams and estimate among lake/stream differences in water chemistry rather than within lake/stream differences. The index concept is appropriate for these types of comparisons.

2.2.2.6 Standardized Protocol

Standardized sampling procedures and analytical methods were used throughout the NSWS. One of the major problems encountered in many earlier studies was the use of different procedures and methods, which significantly reduced or eliminated comparisons among data and studies. Data comparability is important for regional studies but critical for long-term monitoring to detect subtle trends in aquatic systems.

2.2.2.7 QA/QC

Quality assurance and quality control were an integral part of the NSWS. QA/QC procedures were implemented prior to sample collection in the field and followed throughout the program from field sampling and processing of samples to laboratory spikes and splits to data validation and verification. Data of known quality are important for any long-term monitoring program.

2.4 OTHER AERP ELEMENTS

Other AERP projects also are integrated with the TIME project, in addition to the NSWS. Verification of the DDRP forecasts can occur only by collecting data through TIME. The WMP and ERP process-oriented studies provide insight into the causal mechanisms that might control changes in the regional patterns observed in aquatic systems through TIME. TIME provides a regional perspective for site-specific studies and permits a better understanding of the relation between the specific site attributes and the characteristics and possible response of other sites in the region.

3.0 THE CONCEPT OF TIME

3.1 BACKGROUND

In 1982, EPA initiated a program for long-term chemical monitoring of surface waters under NAPAP. The EPA long-term monitoring (LTM) program was initially designed to detect and measure chemical trends in low ANC surface waters across atmospheric deposition gradients. In July 1982, the Aquatic Effects Task Group (TG-E) organized an ad hoc committee to develop the framework for a national network and a standardized sampling and analysis chemical monitoring protocol to guide the LTM Program. In January 1983, a draft protocol was prepared and subsequently used as a provisional guide for the Program. After extensive peer review, this document was revised and approved as the basis for the EPA Program. All EPA-supported cooperators were required to follow these standardized protocols. However, some exceptions were made to allow continuity with historical precedents, and QA/QC procedures were not finally standardized until 1985. By 1985, EPA was supporting the monitoring of 121 lakes and reservoirs and 23 streams in 11 states.

The NSWS, initiated in 1984, was designed in a statistical frame with probability samples that permitted population estimates of the status and extent of various surface water chemical attributes. Standardized sampling and analysis protocols were an integral part of the NSWS program including extensive QA/QC on sample collection, chemical analysis, data management, and statistical analysis. Because the LTM program was initiated prior to the NSWS, the LTM was unable to address some of the systematic problems associated with long-term monitoring programs. Several of these systematic problems, therefore, were associated with the LTM program.

Primarily, the LTM lakes and streams were chosen with an unknown probability from an unknown population so quantifying regional trends is difficult. Further, the sampling and analysis and QA/QC protocols were not totally standardized among monitoring projects. Because of these concerns, the continuing need for monitoring data to assess changes in surface water quality, and the acquisition of an extensive regional surface water data base through the NSWS, a re-evaluation of the scope and design of regional-scale, long-term monitoring has been undertaken. The previous LTM program was concluded in 1987. The LTM data, however, are being extensively analyzed and compared with the NSWS data for TIME planning purposes. Several of these analyses are discussed in the next chapter, 4.0 PREVIOUS AND ON-GOING ANALYSES. Several of the LTM sites will probably be incorporated in the TIME Project following characterization of these sites with respect to specific regional subpopulations of interest.

To provide a regional-scale assessment of the effects of acidic deposition on aquatic ecosystems, a long-term monitoring program needs to incorporate representative site selection, measurement of biologically relevant chemical variables, standardized analytical methods and quality assurance protocols, and a sampling scheme that permits long-term changes in chemical response to be differentiated from episodic changes and short-term daily, monthly, or annual periodicities. The monitoring program must be predicated on a clear set of goals and objectives.

3.2 GOALS

The TIME Project has as its goals to:

- Estimate the regional proportion and subpopulation physiochemical characteristics of lakes and streams that exhibit early and on-going trends of surface water acidification or recovery;
- Compare patterns and trends in observed surface water chemistry to forecasts made using empirical or process-oriented procedures; and
- Determine the relationships between patterns and trends in atmospheric deposition and trends in surface water chemistry for defined subpopulations of aquatic resources in areas particularly susceptible to acidification or recovery.

3.3 OBJECTIVES

In order to achieve these goals, the TIME project has the following objectives:

- Provide an early and ongoing indication of regional trends in surface water acidification or recovery, using the most appropriate techniques to detect such trends;
- Quantify, with known certainty, for defined subpopulations of lakes and streams;
    - The rate at which changes in relevant chemistry are occurring;

- The subpopulation characteristics of the affected lakes and/or streams; and
- The regional or subregional extent of these systems.

o Compare trends in local and regional atmospheric deposition with regional trends in surface water chemistry.

3.4 HIERARCHICAL DESIGN

To achieve the TIME objectives, it is proposed the TIME project be designed within an integrated, hierarchical frame. This hierarchical frame would be sufficiently flexible to accommodate investigations ranging from broad spatial pattern identification for regional trend detection to specific process-oriented research to identify causal mechanisms. This hierarchy or tiered approach is illustrated in Figure 3-1.

3.4.1 Regional Tier (Tier 1)

The purpose of this level is to describe broad regional patterns and trends in ecosystem attributes such as water chemistry. A statistical frame with probability samples might represent the design for this tier. In the base or bottom tier, there might be a large number of regionally distributed ecosystems that could be sampled during an index period. This tier would include some ecosystems that might serve as early indicators (i.e., rapid response systems) of increased acidification or recovery and ecosystems that reflect the subregional characteristics or range in characteristics of ecosystems in the regional target population. These two categories of ecosystems are probably not equivalent because the most appropriate early indicator systems are probably atypical of many ecosystems in the subregion.

3.4.2 Seasonal Tier (Tier 2)

The second tier of the hierarchy could include a smaller number of ecosystems in each region to be sampled seasonally in lakes or bi-monthly in streams to identify seasonal patterns or trends. Ecosystems with similar attributes could be paired or triplicated. If similar changes occur in both or all three systems, the significance attributed to the change, and the confidence in subsequent decisions, might be greater than if changes were observed in only one ecosystem. The seasonal samples also could be used to "calibrate" the index samples monitored in the regional tier. This could allow the validity of the more extensive index samples to be assessed

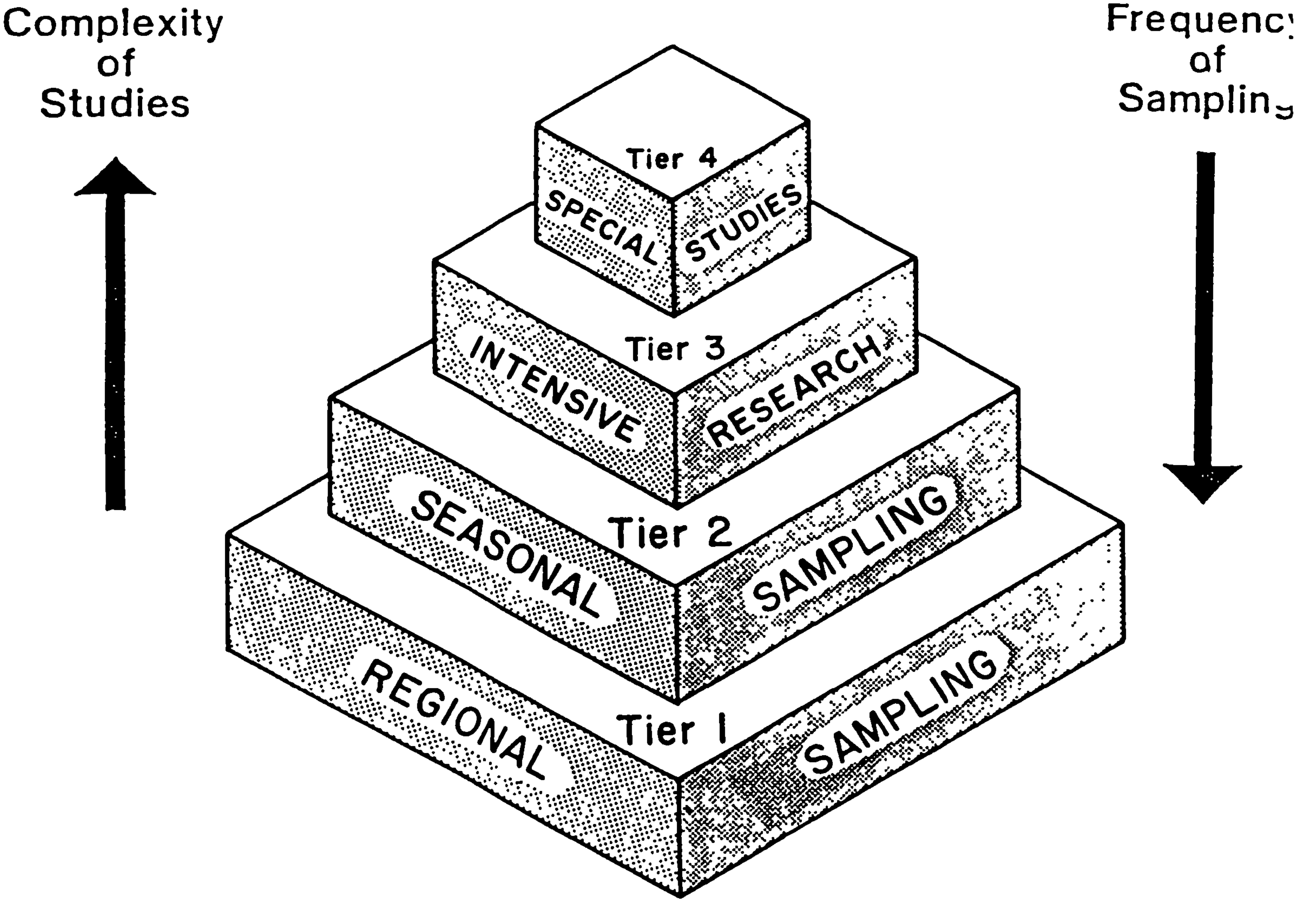


Figure 3.1. **Hierarchical approach for TIME with increased complexity of studies and decreased number of sites as one moves up the hierarchy.**

on an on-going, annual basis. It could also permit more detail for systems of particular interest such as those that indicate early recovery or increased acidification.

3.4.3 Research Tier (Tier 3)

The third tier would integrate process-oriented study sites or intensively monitored sites such as the WMP, Regional Episodic and Acid Manipulation (REAM), Forest Effects Program study sites, Long-term Ecological Reserve (LTER), USGS Hydrologic Benchmark sites, soils monitoring activities, or other similar sites with the TIME sampling regime. Hypotheses about causal mechanisms or processes controlling surface water acidification can be tested in this tier. These sites also provide information on short frequency occurrences such as storm events and can improve the understanding of why various changes in site specific and regional patterns might be occurring.

3.4.4 Special Studies Tier (Tier 4)

The fourth and final tier represents special studies. This tier would investigate specific patterns of change noted within and among subpopulations or regions. For example, resurveying NLS lakes and NSS streams could provide excellent corroboration of any trends indicated in the TIME systems at the subpopulation or regional level. The probability sampling frame and population estimates have been established for the NLS and NSS. Such resurveys could determine if there has been a statistically significant change in surface water chemistry within the subregions or regions.

3.4.5 Adaptive Frame

TIME is envisioned as an evolving project with a flexible, adaptive frame. As our understanding of acidic deposition effects increases, new questions and hypotheses will arise that might require monitoring revisions or adaptations. The hierarchical structure or frame provides this flexibility while retaining long-term continuity among sites in the lower tiers.

The TIME project is presently in the conceptual/ preliminary design phase. The goals and objectives of the TIME project, listed at the beginning of this section, have been defined and will continue to guide the design. Two workshops were conducted in 1986, one of which was a NAPAP Interagency Watershed

Coordination Workshop, to discuss various considerations for an integrated monitoring program for both lakes and streams in regions potentially susceptible to atmospheric deposition. An hierarchical approach was agreed to be a useful approach for long-term monitoring if at least the bottom three tiers were implemented.

A number of issues were identified during the workshops and during the preliminary conceptual phases of TIME that are important in designing an efficacious long-term monitoring program. Several studies have been completed or are on-going to address these issues. These are discussed in the next chapter.

4.0 PREVIOUS AND ON-GOING ANALYSES

4.1 OVERVIEW OF ISSUES AND QUESTIONS

There are a number of issues and questions that must be addressed in designing a long-term monitoring project. In TIME, the following five major categories of issues have been identified:

- o Statistical frame/Site selection;
- o Regional estimates and trend detection;
- o Appropriate biological/chemical measurements;
- o Data analysis and interpretation of QA/QC data and the formulation of appropriate QA/QC protocols; and
- o Reporting.

Examples of issues that have been considered under these five major categories are listed in Table 4.1.

A number of analyses have been, or are being, performed to address these issues. For example, data from EPA's Long-Term Monitoring (LTM) program has been and is being used to identify characteristics of the LTM sites, estimate the components of variance in selected chemical constituents through an analysis of variance, and estimate the number of lakes and samples required to detect differences in constituent concentrations and/or trends in constituent concentrations.

Other analyses being performed include:

- o Model-based population extrapolation procedures (Section 4.3);
- o Reviews and evaluations of possible biological indicators and indices for detecting trends in acidification or recovery of aquatic systems (Section 4.4);
- o Evaluation of biologically relevant chemical constituents, rates of change, and constituent concentrations (Section 4.5);
- o Comparison of fall index samples with other seasons (Section 4.6.1);
- o Trend detection analyses for individual aquatic systems and the effect of constituent variability on trend detection (Section 4.7);
- o Specific trend detection (Section 4.7);

Table 4.1. **Examples of issues being addressed during the designed of the TIME project.**

A. Statistical Frame/Site Selection

- o Appropriate regions, subregions, and subpopulations for sampling.
- o The need and/or desirability to redefine regions.
- o Prioritizing regions.
- o Population inference.
- o Stream sampling design for regions outside those sampled in National Stream Survey.
- o Desired confidence levels and estimates of precision for constituents and regional population projections.
- o Required number of sites, samples, and frequency to achieve the desired confidence and precision.
- o Constituents to monitor and constituent variability.
- o Information gained from a fall index sample versus index samples from other seasons.
- o Characterization of streams based on two spring samples.
- o Procedure for selecting regionally representative lakes and streams.
- o Evaluation of data from special sites for possible site inclusion in TIME.
- o Multivariate exploratory procedures to identify unique subpopulations of systems.

B. Regional Estimation and Trend Detection

- o Extrapolation procedures for non-randomly selected aquatic systems (i.e., those outside the NSWS frame).
- o Monitoring duration required to detect a trend in a constituent at a given confidence and precision level.
- o Expected annual rates of change for ANC, pH, and SO_4.
- o Relation between number of lakes, among lake variance and the required time to detect trends in ANC, pH, and SO_4.
- o Number of samples needed to describe subpopulation versus subregional characteristics.
- o Trend detection at individual sites.
- o Regional trend detection procedures.
- o Influence of less than detection limit data on trend analyses.

Table 4.1. Continued.

C. Appropriate Biological/Chemical Measurements
- o Aquatic Organisms or associations of organisms that indicate acidification and/or recovery.
- o Relationships between chemical constituent concentrations or rate of change and biological effects.

D. QA/QC Data
- o Formulating rapid QA/QC feedback loops to cooperators.
- o QA/QC assessment of centralized vs satellite laboratories.
- o Procedures for transition of laboratories.
- o QA/QC evaluation procedures for data outside TIME.
- o Inclusion procedures for historical data.

E. Reporting
- o Types of reports.
- o Format of reports.
- o Frequency of reports.

- Estimates of duration to detect trends (Section 4.7);
- Regional trend detection analyses (Section 4.8);
- Multivariate analyses to identify characteristic subpopulations of lakes and streams in various regions (Section 4.9);
- The influence of less than detection limit data on trend detection and statistical procedures for using censored data (Section 4.10);
- Analysis and interpretation of QA/QC data collected during the NSWS and proposed QA/QC procedures for TIME (Section 4.11); and
- Deposition network evaluation (Section 4.13).

Each of the previous and on-going analyses will be discussed briefly below. The data source, analyses, and results will be presented for each topic. The emphasis is on the interpretation of these results and the implications for the design of the TIME project.

4.2 LTM ANALYSES

Analyses have been conducted on the LTM data sets to:

- Assess the quality of the data;
- Determine seasonal and annual variation;
- Evaluate the efficiency of the monitoring design;
- Describe the relationship of LTM lakes to the population of NSWS lakes;
- Estimate the number of lakes to be sampled in the TIME Project;
- Examine data for temporal trends; and
- Evaluate sources of variability.

Lake monitoring sites for EPA's LTM Program were selected in areas where annual wet sulfate deposition ranged from 0-10, 10-20, and 20-30 kg/ha and average volume-weighted precipitation pH ranged from about 5.5 to 4.3. Specific site selection criteria for LTM sites included:

- ANC < 200 ueq/L^{-1};
- No recent land use changes or prospects of future changes;
- Absence of local atmospheric pollutant sources;

- o Accessibility;
- o No recent history of forest fires or logging in the watershed; and
- o No chemical manipulation of lake or watershed.

Lakes were selected for monitoring in the following areas:

- o The Adirondack Mountains in New York;
- o Vermont;
- o Maine;
- o The Upper Midwest (i.e., Minnesota, Wisconsin, and Michigan);
- o The Southern Appalachians (TVA reservoirs in the Southern Blue Ridge Province of North Carolina, Tennessee, and Georgia); and
- o The Rocky Mountains.

4.2.1 Data Quality

Through an analysis of quality assurance samples, Newell et al. (1987) estimated the quality of the LTM data, including precision and accuracy for selected constituents. The available audit data indicated a relative overall bias of 0.3% ±38.4% but were too variable to estimate between-laboratory bias. Blank and duplicate data were insufficient to estimate possible contamination or precision. LTM cooperators, however, did comply with EPA guidelines on the number of blanks and duplicate samples. Analysis of the QA data did indicate three important considerations for future long-term monitoring programs. First, a more rigorous QA/QC program could identify and quantify inter-laboratory bias, and would enable smaller confidence bounds to be placed about the data collected. Such a program should require an increased number of blank and duplicate samples and include periodic analyses of stable audit samples so that inter-laboratory bias could be assessed. Second, future QA/QC designs should include minimum numbers of blank and duplicate samples, so that the number of samples collected will be large enough to permit estimates of precision with known confidence. Third, to insure that accuracy is maintained over time, an audit system should be designed that is capable of detecting changes in bias from one year to the next, as well as detecting bias among laboratories at any point in time.

4.2.2 Comparison of LTM Lakes to the NLS Population

Analyses performed by Newell et al. (1987) to compare LTM lakes to the ELS-Phase I lakes included cumulative distribution frequency curves and trilinear plots (Figures 4.1 and 4.2, respectively).

Generally, LTM lakes occupied the lower portion of the ANC cumulative frequency distribution for ELS lakes (Figure 4.1) in the various ELS subregions. The trilinear diagrams indicated the occurrence of many sulfate dominated lakes in the LTM population. Cumulative frequency distribution curves indicated sulfate was moderately higher and dissolved organic carbon was lower in the LTM lakes than the median values in ELS lakes.

Although the LTM lakes represented low ANC systems, three problems precluded their use for regional extrapolation or estimation. First, the lakes in the LTM program were not chosen from a defined population, so the inclusion probability for the LTM lakes is unknown. Second, although one could argue that LTM samples were chosen from lakes with ANC <200 ueq/l and thus represent the population of low ANC lakes, the strict statistical representation cannot be quantified. Third, LTM lakes were clustered within subregions and, therefore, may not exhibit spatial variability found across the subregion.

Based on their physical-chemical characteristics with respect to the ELS lakes, the LTM lakes might represent rapid response lakes. Rapid response lakes might provide an early indication of increased surface water acidification or recovery in the subregion or region. This is an important class of lakes to incorporate in TIME. As will be discussed later, the strict statistical representation of rapid response lakes in the population is not critical in the current concept of TIME. Further analyses are being conducted to characterize rapid response and LTM systems.

4.2.3 Regional Sample Size

Newell et al. (1987) and Payne et al. (1987) estimated the number of lakes (i.e., samples) in a subregion to detect a given change in the subregional mean concentration for selected constituents. In the Northeast, Newell et al. (1987) estimated from 13 to 88 lakes per state were required to detect a 10 ueq/l change in ANC (mean lake ANC concentrations $\leq$ 10 ueq/l) and from 5 to 64 lakes per state to detect a 10 ueq/l change in ANC (mean lake concentrations 20 < ANC $\leq$ 100 ueq/l). The number of lakes estimated to detect a 0.20 change in pH or 10% change in sulfate was similar to the ANC estimates. As the change to be detected

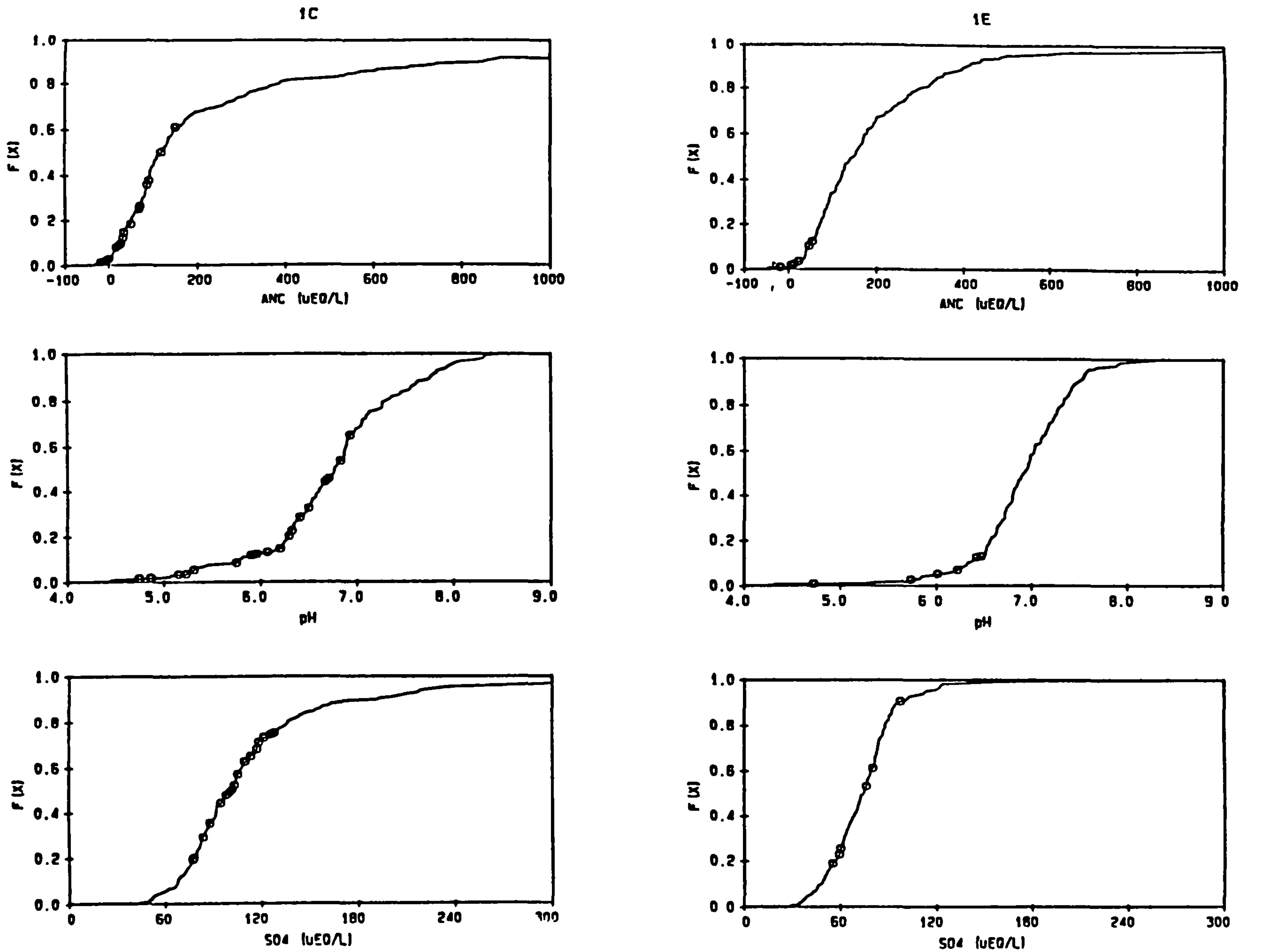


Figure 4.1. Example output of cumulative distribution frequency curves (F(X)) for ANC, pH, and SO_4^{-2} from the ELS data for Central New England (1C) and Maine (1E). LTM lakes in these subregions are indicated as open circles.

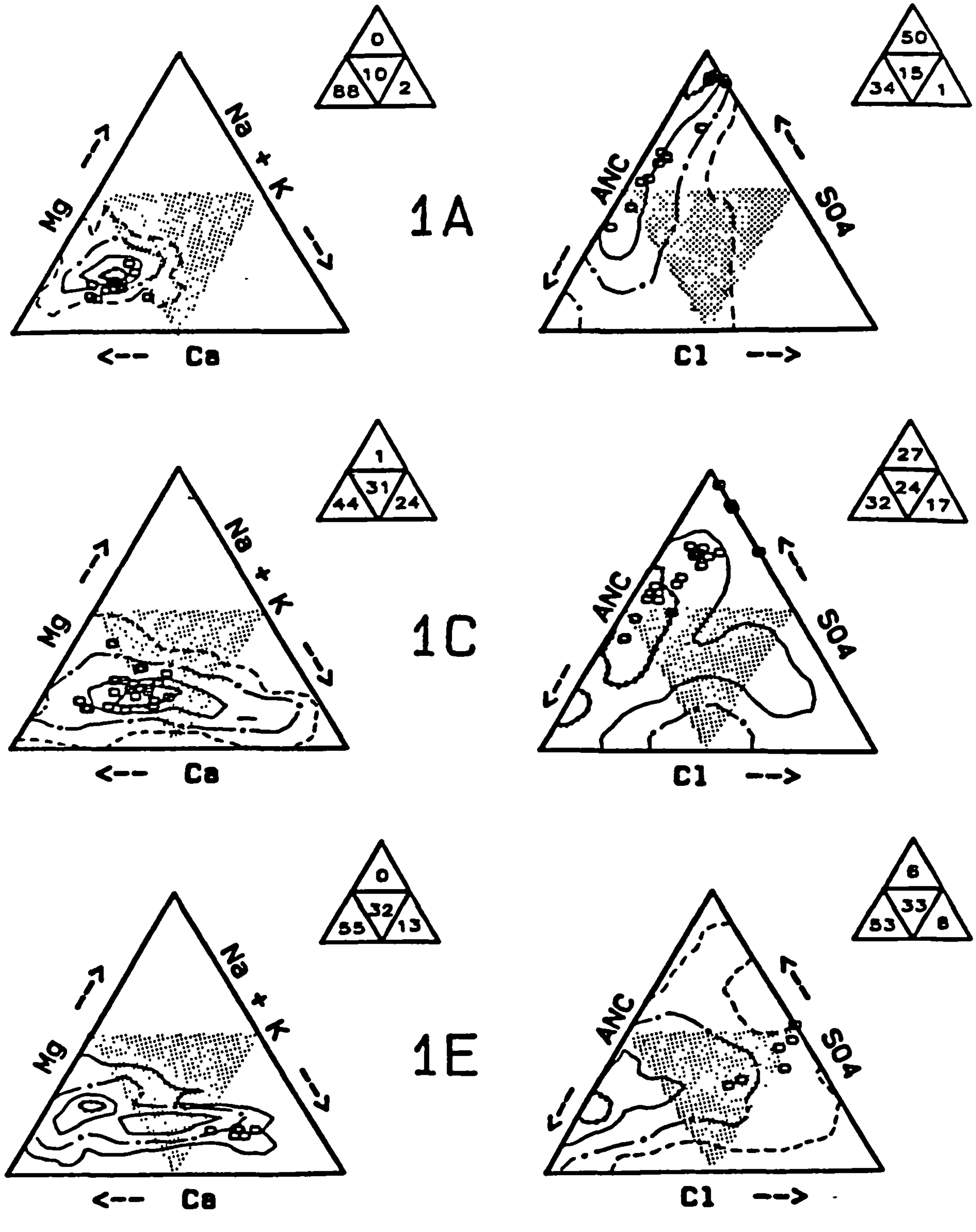


Figure 4.2. Example of trilinear diagram output. Trilinear diagrams for anions and cations for the Adirondacks (1A), Central New England (1C), and Maine (1E). Open circles represent LTM lakes, while dashed and dotted lines indicate percentiles of the ELS population density. The smaller triangles to the right of the trilinears indicate the percent of the ELS population found in each of the subtriangles (—•— 80th; — 50th; • — • 20th; - - - 5th).

became larger, the estimated number of lakes to be sampled decreased. The above estimates were calculated with an and level of 0.10.

In the Upper Midwest, estimates of lakes to be sampled to detect a 10 ueq/l change ranged from 20 to 412 lakes per state (mean lake concentrations $\leq$20 ueq/l) and from 30 to 78 lakes per state (mean lake concentrations 20 < ANC $\leq$ 100 ueq/l). As above, lake estimates were similar for SO_4 and pH and decreased as the desired change to be detected increased. The and levels used in these estimates were 0.10.

Payne et al. (1987) estimated lake sample sizes for the Upper Midwest region and the Adirondack subregion, rather than by states. Estimates of the number of lakes to detect a 10 ueq/l ANC change with mean ANC concentrations $\leq$ 20 ueq/l was 10 for the Upper Midwest and 24 for the Adirondacks at an level of 0.10. The estimated number of lakes in the Upper Midwest for lakes with mean ANC concentration 20 < ANC $\leq$ 100 uq/l was 30 and 83 for the Adirondacks at level of 0.10.

Although Newell et al. (1987) and Payne et al. (1987) used different techniques, the results are not grossly different. About 30-100 lakes should allow detection of changes if they occur in nearly all subregions. Variance estimates are expected to decrease in the TIME project.

4.2.4 Sources of Variability

It was recognized that variability associated with the LTM data sets could be contributed by a variety of sources. Both Newell et al. (1987) and Payne et al. (1987) used nested analysis of variance methods to partition the total variance into the variance components explained by each source. The results of these analyses are presented in Table 4.2 and 4.3. In general, among-lake variance was the largest single component of constituent variability, generally explaining greater than 80% of the variability.

Although Newell et al. (1987) and Payne et al. (1987) analyzed the data in slightly different ways, both investigators determined spatial variability generally accounted for 70 percent of the variance in ANC, pH, and SO_4 compared with temporal variability (i.e., among seasons and among years). This implies it might be more important to have more lakes to detect regional changes than a few lakes with more samples throughout the year.

Table 4.2. **Percentage of variability contributed by lake, year, and seasonal effects (Newell et al., 1987).**

	Lakes	Year	Seas(Year)[1]	Lake by Year	Lake by Seas(Year)
ANC					
NY	88.39	1.08	3.93	0.98	5.63
VT	86.65	0.86	4.55	1.65	6.29
ME	92.36	1.09	2.10	2.07	2.39
UPMW	89.70	5.12	2.02	0.35	2.80
MN	83.00	2.43	2.74	6.82	5.01
MI	90.59	1.99	1.30	1.61	4.51
WI	57.95	19.49	7.92	3.98	10.66
SBR	95.07	3.66	0.64	0	1.43
pH					
NY	86.93	1.44	6.36	0.95	4.34
VT	86.66	1.16	4.96	1.15	6.07
ME	96.30	1.23	1.35	0.38	0.74
UPMW	93.80	5.62	4.86	0	0
MN	72.98	2.69	7.86	3.93	12.54
MI	98.10	2.08	0.23	0	1.04
WI	77.39	8.85	3.18	4.72	5.86
SBR	45.00	15.57	4.07	14.75	20.62
SO_4^{-2}					
NY	82.16	1.29	6.00	3.54	7.01
VT	57.54	10.69	12.39	6.56	12.83
ME	96.26	0.35	1.37	1.04	.097
UPMW	87.49	3.51	2.46	4.87	1.67
MN	69.48	15.45	4.21	7.67	3.18
MI	91.89	4.42	1.75	0.71	1.24
WI	86.78	10.03	1.46	0	3.66
SBR	93.56	1.15	1.70	1.58	2.01

[1] Seas(Year) refers to a nested effect of season within each year.

Table 4.3. The percent of the total variance contributed by the various sources or components (Payne et al., 1987).

I. H^+

% of Variance

Source of Variation	Upper Midwest <20 ueq/l	Upper Midwest 20<ANC≤100 ueq/l	Adirondacks <20 ueq/l	Adirondacks 20<ANC≤100 ueq/l
Investigator	0.0	0.0	--	--
Subregions	59.1	17.7	--	--
Year	2.0	0.5	0.0	0.0
Season	0.0	25.9	2.6	5.4
Lakes	37.6	12.0	78.4	67.3
Error	1.3	44.0	18.9	27.3

II. ANC

% of Variance

Source of Variation	Upper Midwest <20 ueq/l	Upper Midwest 20<ANC≤100 ueq/l	Adirondacks <20 ueq/l	Adirondacks 20<ANC≤100 ueq/l
Investigator	0.0	0.0	--	--
Subregions	41.1	43.2	--	--
Year	1.3	6.6	0.3	0.0
Season	12.3	4.7	19.1	23.4
Lakes	27.4	6.7	38.1	46.0
Error	18.0	38.9	42.5	30.6

III. SO_4

% of Variance

Source of Variation	Upper Midwest <20 ueq/l	Upper Midwest 20<ANC≤100 ueq/l	Adirondacks <20 ueq/l	Adirondacks 20<ANC≤100 ueq/l
Investigator	4.8	0.0	--	--
Subregions	9.6	70.8	--	--
Year	2.7	1.4	4.4	11.9
Season	0.0	0.0	0.0	2.1
Lakes	80.7	17.8	86.7	57.8
Error	2.2	10.0	8.9	28.2

4.3 MODEL BASED EXTRAPOLATION STUDIES

One of the issues being considered in TIME is the appropriate statistical frame. The statistical frame needs to incorporate regionally representative lakes including rapid response and special interest systems so that regional trends can be detected, if regional changes are occurring. Regional estimates can be obtained using either a design-based or a model-based approach.

Regional population estimates, using a design-based approach, are based on a set of regionally representative probability samples collected within a statistical sampling frame (i.e., statistical design or design-based). Because the inclusion probability for each lake and stream is known, these sample systems can be weighted to provide unbiased regional estimates. This approach was successfully used in the NSWS.

Regional population estimates also can be provided for non-randomly selected lakes and streams using a model based approach. A model based approach relates non-randomly selected systems with a subpopulation of randomly selected systems assuming these systems have similar system characteristics and attributes. The model-based approach assumes the statistical frame relating the probability sample to the target population is an adequate model for relating non-random systems to the target population. This approach, for example, might be used to relate results from the LTM lakes to the subregional or regional target population.

The general form of a model-based prediction equation might be:

$$\underline{y} = g(\underline{x})$$

With the probability or design-based analysis, y is determined directly. With the model-based analyses, the relationship between the x's (the vector of attributes that help to predict y) and the y's (the attributes of interest) is determined. Then y is predicted by substituting x's for the systems not randomly sampled and distributions are generated.

Both design-based (direct estimates) and model-based (indirect estimates) approaches to determine population estimates with the ELS-Phase II data are being investigated (Overton, personal communication). For the ELS-Phase II sample, direct estimates gave better precision than originally thought and a relatively small sample size per region (i.e., 50 to 100 lakes) could be used to provide estimates with acceptable precision. Both approaches are being considered for inclusion in TIME.

4.4 ROLE OF BIOLOGICAL DATA

Biological indicators or indices may be able to provide early indications of the onset of acidification or recovery processes of aquatic systems. Reorganization of biological communities begins early in the acidification process and can actually precede the subtle changes in surface water chemistry involved with acidification or recovery. Observed biological changes are the clearest signal that changes in chemical parameters are biologically significant.

Several literature reviews to determine the usefulness of various organismal groups as early warning indicators have been initiated. These reviews will be followed by a workshop to resolve divergent views and come to a state-of-the-art evaluation of possible useful approaches for integrating cost effective biological information into long-term monitoring program.

Indices are being investigated for all resources (lakes and streams) and regimes. The range of organisms being considered include phytoplankton, periphyton, zooplankton, benthic invertebrates, and fish. Different approaches may be utilized in different areas depending upon the nature and composition of the local communities. The focus will be on indices that can be demonstrated to complement and or extend information already contributed by the chemical monitoring program.

4.5 BIOLOGICALLY RELEVANT CHEMISTRY

Efforts relating changes in water chemistry to the biological community have been restricted primarily to fish (Haines and Baker 1986). The reasons for the emphasis on fish are:

- General ecological processes and functions appear to be relatively robust, with significant ecosystem impacts only at acidity levels above those that affect major fish species (Altshuller and Linthurst 1984; Schindler et al. 1985);
- Effects of acidification on fish, for the most part, appear to be direct rather than mediated through changes in food availability or quality (Rosseland 1985; Baker 1986);

- o The number of studies directed at quantifying the dose response for affects of acidification is substantially greater for fish than other aquatic organisms (Haines and Baker 1986); and
- o Effects on fish and declines in the fishery resource can more readily be expressed in terms directly relevant to public interest and resource utilization.

The key chemical variables that influence fish response to acidification are pH, inorganic aluminum and calcium (Altshuller and Linthurst 1984). Because lake pH and levels of inorganic aluminum and calcium are often highly correlated within any given region, estimates of effects may be reasonably predicted by pH. The most data, and most reliable estimates, are available for populations of fish in lakes, and for four species in particular: brook trout, lake trout, white sucker, and brown bullhead (Baker and Harvey 1984).

Although studies relating changes in water chemistry to the biological community have been primarily concerned with fish, the literature review and workshop discussed in Section 4.4 will expand the consideration to other organisms. These reviews will be used, in part, to define the chemical variables that should be included in the TIME project.

4.6 CALIBRATION OF INDEX SAMPLES

4.6.1 Lakes

During the NLS, lakes were sampled once during fall overturn. The assumption was that within lake and among lake variability would be minimized during this period of time. Fall overturn was selected because it is a relatively stable period and is a broader, more predictable period than spring ice-out.

Newell et al. (1987) investigated the spring to fall relationships for the primary variables, ANC, pH, SO_4 and Ca using LTM data to determine if fall samples might serve as predictors of lake chemistry in other seasons of the year. General linear models were used to investigate the relationship. The results are presented in Table 4.4. In general, coefficients of multiple determination were high ($R^2 > 0.8$). Although a strong relationship between spring and fall samples was generally observed, the analyses in Table 4.4 do not indicate how well fall data reflects spring chemistry (Newell et al. 1987). When spring to fall relationships are parallel from one year to the next, fall values alone may be used to indicate long term trends. If

Table 4.4. Characteristics for spring to fall relationships of ANC, pH, SO_4^{-2}, and Ca (Newell et al, 1987).

	ANC				pH				SO_4^{-2}				Ca			
	R^2	n	Slope	IV	R^2	n	Slope	IV	R^2	n	Slope	IV	R^2	n	Slope	IV
NY	0.90	66	m<1	yr	0.92	64	m=1	yr	0.83	66	m<1	yr	0.91	66	m<1	yr
VT	0.85	91	m<1		0.79	98	m<1	yr	0.55	90	m<1	yr	0.93	89	a	yr
ME	0.97	12	m<1		0.95	12	m=1		0.97	11	m>1		0.89	12	m=1	
MN	1.00	20	b	yr	0.88	23	m=1		0.90	23	m=1	yr	0.92	23	m=1	yr
MI	0.97	32	m<1	yr	0.97	36	m<1	yr	0.96	36	m<1	yr	0.98	35	c	yr
WI	0.54	27	m=1		0.87	29	m<1	yr	0.84	26	m=1		0.98	28	m>1	yr
SBR	0.95	23	m=1		0.17[d]	23	m<1		0.88	23	m=1		0.97	22	m=1	

Legend:

R^2 = the coefficient of determination for the model.
n = the sample size used in the model.
IV = the indicator variable used in the model.
m = the slope as determined by the model.

[a] slope not different from 1 for one year and less than 1 for all others.
[b] slope varies from <1 to >1 across years.
[c] slope >1 two out of three years, and not different from 1 in the remaining year.
[d] p = 0.292

the slopes are different, however, as they were for Ca in Vermont (VT) and Michigan (MI), then trends in fall values might not be good predictors of trends occurring among spring values.

Preliminary analyses also have been conducted using the ELS-Phase II data. Seasonal Phase II population distributions were compared to the Phase I population distributions for various constituents. The estimated population distributions for lakes with ANC < 400 ueq/l in the Fall of 1984 (Phase I) and the Fall of 1986 (Phase II) are shown in Figure 4.3. The estimated population distributions for these same lakes in the Fall of 1984 and the spring of 1986 are shown in Figure 4.4. The consistency of the Fall index over a two-year period and the relationship of Fall to Spring suggest that using fall index chemistry to monitor and detect seasonal and annual trends is feasible.

4.6.2 Streams

As in the NLS-Phase I, the National Stream Survey (NSS) relied on samples taken during an appropriate season from a regionally representative sample of water bodies to provide an "index" of the chemical characteristics of the regional population. The choice of the index sampling period was a compromise between minimizing season chemical variability and maximizing the expected probability of sampling during chemical conditions potentially limiting for aquatic organisms.

Ford et al. (1986) summarized the results of four recent studies of seasonal and short term variability in six second and third order streams in the Catskill Mountains of New York (Murdoch, 1986), the Laurel Hills of Pennsylvania (Witt and Barker, 1986), the Southern Blue Ridge Province of North Carolina and Tennessee (Olem, 1986) and the Ouachita Mountains of Arkansas (Nix et al. 1986). Minimum flow-weighted pH values and concentrations of base cations and ANC occurred during the spring at most sites. Therefore, spring appeared to be the most appropriate index sampling period because streamwater ANC was typically low and life stages of aquatic biota, sensitive to low pH, were likely to be present. The index sampling period for NSS was chosen as the time period following snowmelt or winter rains but prior to leaf out. A further restriction was to avoid sampling within 24 hours of a significant rain event.

A comparison of year to year data is not available, but Figure 4.5 illustrates comparisons of estimated population distributions of pH and ANC from three spring and one summer sampling intervals used in the NSS - Pilot Study in the

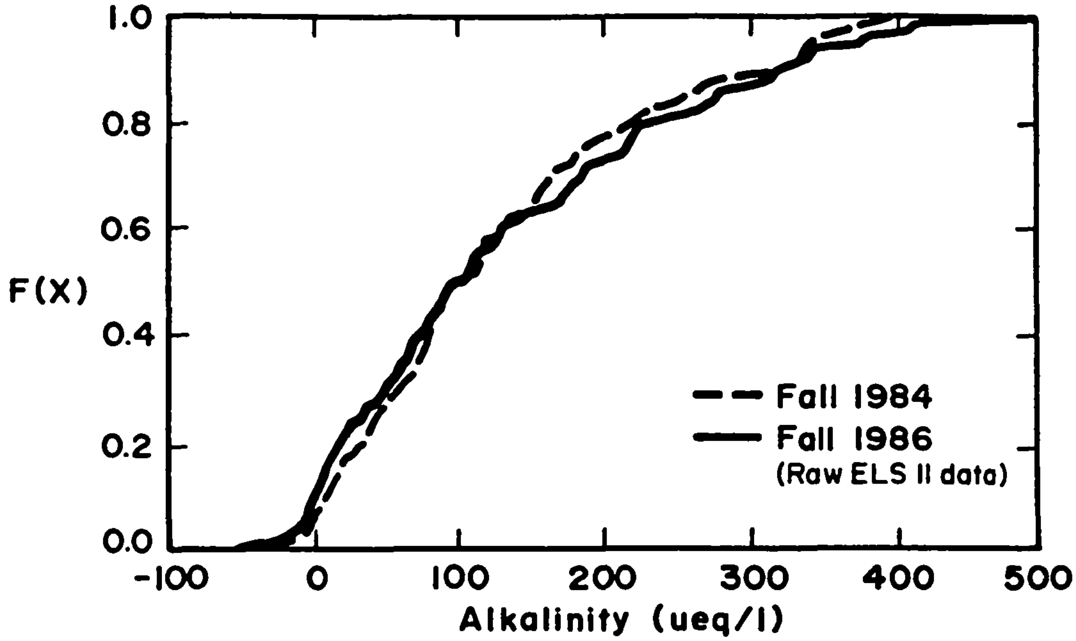


Figure 4.3. Estimated population distributions of alkalinity for lakes with ANC <400 ueq/l in the fall of 1984 and 1986.

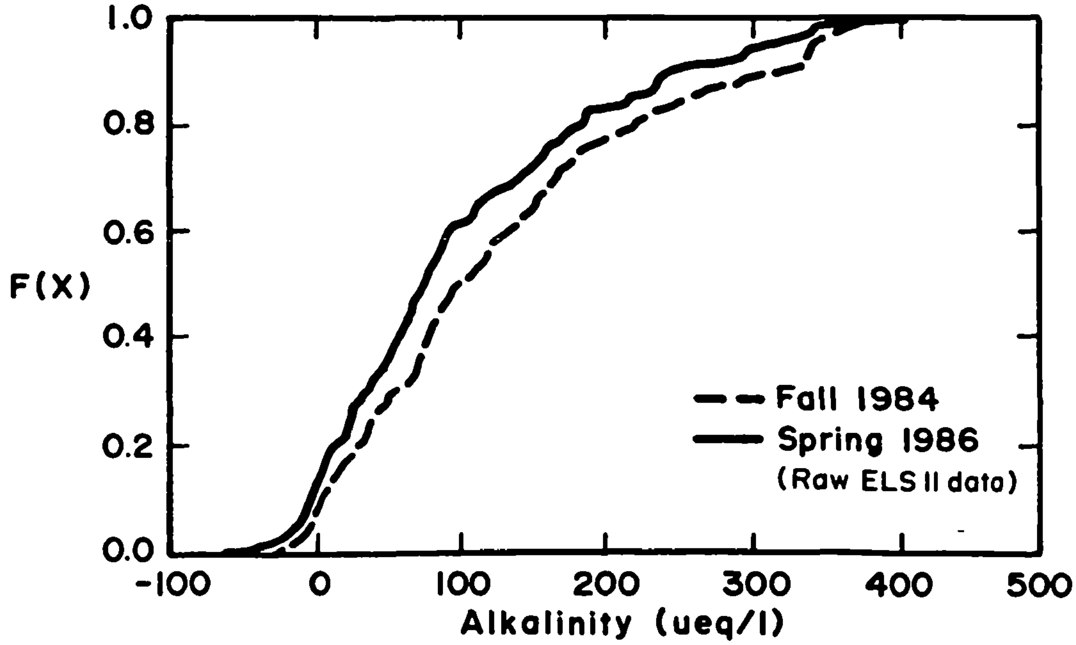


Figure 4.4. Estimated population distributions of alkalinity for lakes with ANC <400 ueq/l in the fall of 1984 and spring of 1986.

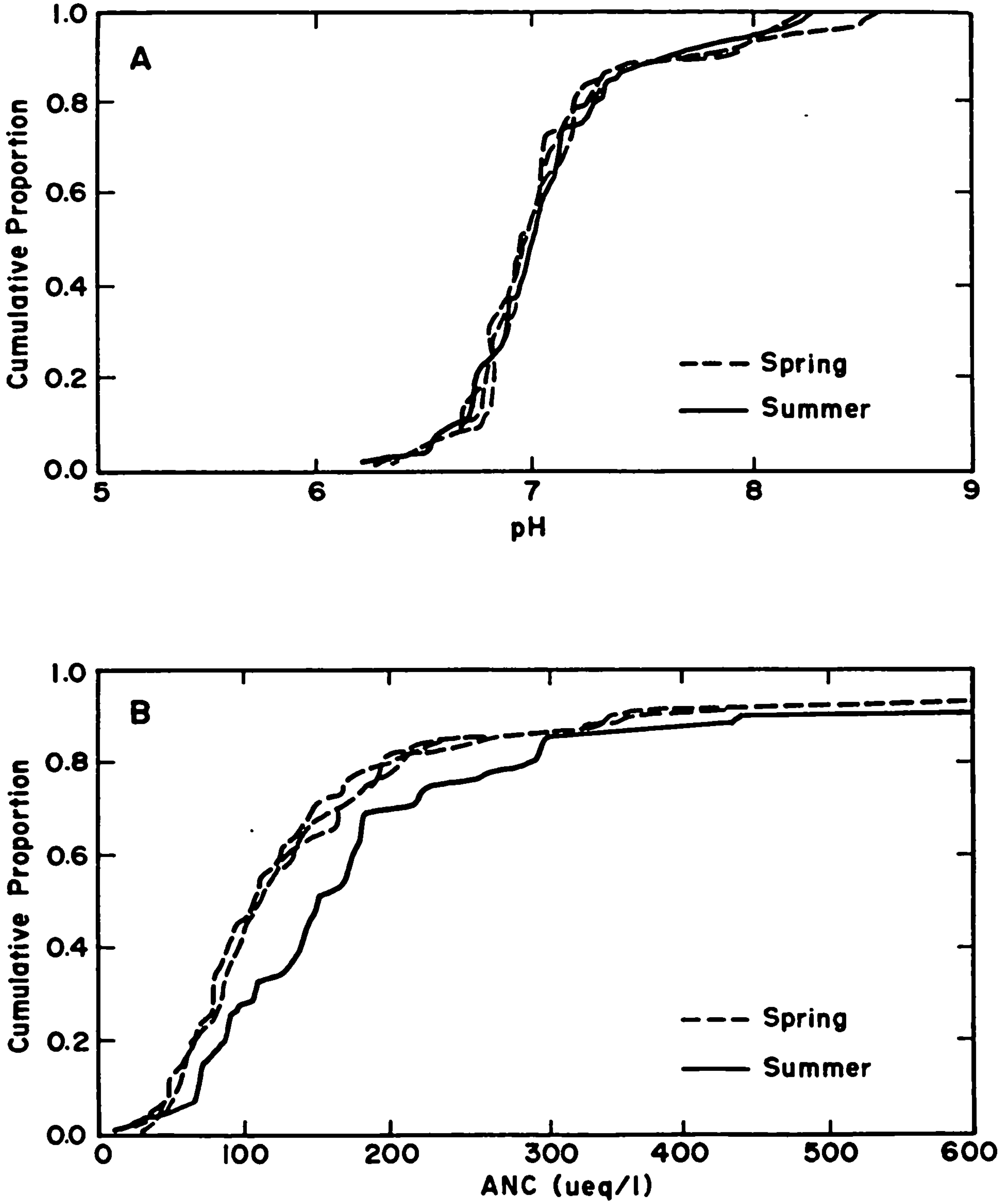


Figure 4.5. Comparison of estimated population distributions for pH (A), and ANC (B), based on length of stream reaches, from the three spring and one summer sampling intervals in the Southern Blue Ridge Subregion (Kauffmann, unpublished data).

Southern Blue Ridge Subregion (Kaufmann, unpublished data). In this subregion, there was little difference in population distributions taken approximately three weeks apart between March 15 and May 15. Preliminary results indicate that a spring sampling index is appropriate for estimating population distributions. Additional analysis regarding the feasibility of spring sampling are ongoing.

Based on the NSS - Pilot Survey, streams were sampled twice in the base flow period as opposed to three times in the NSS. There was little difference in population distributions for important variables during the spring sampling window. Currently the NSS scientists are analyzing among season and within season variability to assess and re-evaluate the utility of the spring baseflow chemical index in:

- o Evaluating chemical conditions most limiting to aquatic organisms;
- o Predicting chemical conditions at different times of the year; and
- o Representing the variation of chemistry within the spring chemistry.

Historical data from special interest sites are being used for the above analyses.

A number of other analyses are currently being conducted. The NSS scientists are analyzing historical data from special interest sites and selected NSS sites revisited in 1987 to assess the year to year stability of the spring index sample. This analysis is especially important to the NSS because sample year 1986 was a drought year in many regions of the Southeast. Hydrologic data (i.e., flows and precipitation) are being examined to refine knowledge of regional patterns in seasonal flow such as elevated spring flow, summer low flow and seasonal frequency-duration analyses of stormflow. This information will be used in the design of the stream monitoring program.

4.7 TREND DETECTION - INDIVIDUAL SYSTEMS

Loftis and Ward (1987a) examined trend detection procedures using quarterly and annual samples assuming linear trends, normal distributions and independent samples. Using LTM data for five lake regions and one stream region, they determined a range of standard deviations appropriate for ANC, pH, and SO_4 values in the eastern United States.

Approximate cumulative changes in mean ANC, SO_4, and pH, which would be detectable at a significance level of $\alpha = 0.2$ and power of $\beta = 0.2$ for each region and for several group sizes and length of record, were determined from generic curves as illustrated in Figure 4.6. Figure 4.6 presents the change detectable for ANC as a function of sample size and a wide range of standard deviations, which might be appropriate for each variable.

Using regional standard deviations and the curves presented in Figure 4.6 the detectable change in a given constituent versus the number of independent samples can be estimated (e.g., Table 4.5) For example, the regional standard deviation for ANC in Region 1A was 25.7. This regional standard deviation lies between curves c and d in Figure 4.6. For one lake and 5 samples (annually, quarterly, etc.) it would take a change of approximately 110 ueq/l to be detectable. However, if 5 samples were collected from 4 lakes then the standard deviation of the sample mean, x, over n lakes would be σ^2/n or, in our example, 25.7/ 4 = 12.85. This regional standard deviation now lies between curves d and e and the detectable change would be approximately 55 ueq/l. A number of similar curves were generated by Loftis and Ward (1987a) for ANC, pH and SO_4 and can be found in their report.

The results indicate that changes can be detected sooner and with fewer samples as the number of lakes sampled increases. In addition, change could be detected earlier if more samples are collected per year. However, it is important to remember these analyses were conducted under the assumptions of linear trends, normal distributions and independent samples. Seasonality and autocorrelation were not considered in these initial analyses. Therefore the time to detect change may increase.

Analyses on trend detection in lake water quality also were performed by Loftis et al. (1987b). Using a range of statistical characteristics for selected LTM lakes and Twin Lakes in Colorado (long-term data provided by U.S. Bureau of Reclamation), they compared alternative trend detection techniques considering the effects of seasonal variation, non-normality, and serial correlation.

Seasonal variation in Adirondack and Vermont Lake pH, ANC, and SO_4 values ranged from minimal seasonal differences to the case where the maximum quarterly mean and/or standard deviation was two to five times the minimum quarterly mean/standard deviation. Because of the small record length, no attempt was made to show seasonality was statistically significant. However, all three variables showed obvious seasonality in at least one region and ANC was seasonally more variable than sulfate.

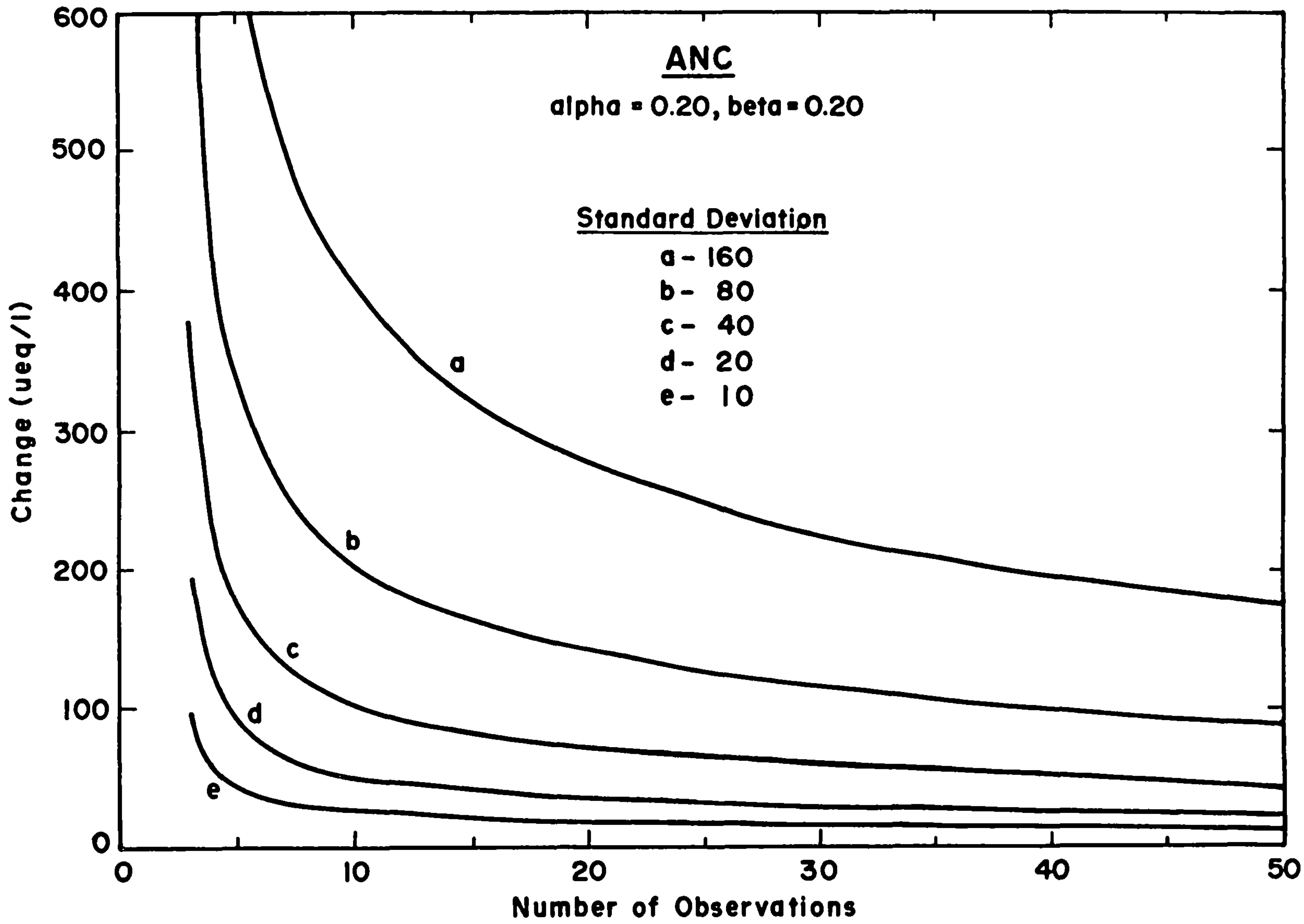


Figure 4.6 **Detectable change in ANC vs number of equally spaced sampled assuming a linear trend. Curves labeled a,b,c,d,e correspond to standard deviations (Loftis and Ward, 1987a).**

Table 4.5. Detectable changes in ANC (ueq/l) vs number of independent samples, assuming a linear trend. Significance level = 20%; power = 80% (Ward and Loftis, 1987a).

Region (Std. Dev.)	No. in Group	Number of Samples 5	10	20	30	40
NLS 1A	1	110	70	45	38	32
(25.7)	4	55	33	22	18	15
	16	27	17	10	8	6
	64	12	8	5	4	3
NLS 1C	1	80	45	30	25	22
(17.7)	4	40	24	17	12	10
	16	20	12	8	7	6
	64	10	6	4	3	3
NLS 3A	1	110	70	45	38	32
(26.5)	4	55	33	22	18	15
	16	27	17	13	9	7
	64	12	8	5	4	3
NLS 1E	1	32	20	12	9	8
(7.1)	4	17	10	6	4	3
	16	8	4	3	2	2
	64	<8	<4	<3	<2	<2
NLS 2	1	100	60	40	35	30
(22.4)	4	50	31	21	18	15
	16	23	16	12	9	7
	64	11	8	5	4	3
STREAMS	1	170	105	68	57	48
(39.8)	4	95	51	33	28	26
	16	42	27	18	15	12
	64	20	12	9	8	7

Most of the records studied by Loftis et al. (1987b) appeared to be normally distributed and, in general, log transformations or removal of quarterly means did not increase or decreased the number of data records that appeared to be normal. However, Loftis et al. (1987b) warn against assuming normality for TIME monitoring.

Loftis et al. (1987b) also investigated autocorrelation of ANC, pH, and sulfate values in several lakes. They found significant seasonal and serial autocorrelation for all three constituents.

Although Loftis et al. (1987b) did not attempt to analyze LTM data records for trend, they did set a range of trend magnitudes (i.e., 0.2%, to 2.0% of the standard deviation per quarter) based on U.S. Geological Survey benchmark streams (NRC, 1986) and long-term forecasts of lake quality using the MAGIC model. These trend magnitudes were then used in Monte Carlo simulations under a large array of alternative conditions.

The trend testing procedures used by Ward and Loftis (1987b) included:

- Seasonal Kendall-tau with correction for serial dependence (Hirsch and Slack, 1984)
- Kendall-tau with quarterly means removed (Snedecor and Cochran, 1980).
- Analysis of covariance for simulataneous estimation of quarterly means and trends, assuming normal distribution.
- Modified t test procedure assuming normal distribution.
- Analysis of covariance using ranks of data.
- Modified t test procedure using ranks.

Preliminary examination of the results indicated an analysis of covariance on ranks was the best procedure when the errors were normally distributed. For larger data records, the seasonal Kendall-tau test performance was similar to the analysis of covariance on the ranked data and, in about 7 percent of the simulations, had greater power than the analysis of covariance in ranked data. The above results should be considered preliminary since additional checks and analyses are on-going.

Miah (personnel communication) is investigating the use of Bayesian approaches to characterize system error and to detect trends. In this approach, characteristics of the system error are used to detect a significant change in SO_4, ANC, or pH lake values over time.

The methods Miah is using (posterior trend probability and regional trend analyses) are useful in a long term monitoring program where historical data over a long period of time is not available and the research objectives are to estimate regional and subregional trends by measuring a limited number of lake samples from a regionally representative number of lakes. Another advantage of the proposed technique is that it provides a means of relating the trend phenomena by using a quadratic regional trend with other external factors such as atmospheric deposition.

Payne et al. (1987) conducted preliminary trend detection analyses and slope estimations with the Seasonal Kendall-tau (Hirsch et al. 1982; Smith et al. 1982) in the LTM data set for the Upper Midwest. These analyses were conducted both on individual lakes and combined lakes in a given season. In general, very few trends ($P \leq .20$) were observed for individual lakes but, when lakes were combined, trends became more apparent. Table 4.6 shows the trend detection results and slope estimates for combined lakes. For lakes with ANC $\leq$20 ueq/l, trends were detected in the spring, summer and fall for ANC and SO_4. For lakes with $20 < \text{ANC} \leq 100$ ueq/l, trends for ANC and SO_4 were observed in the summer and SO_4 trends also were observed in the fall and spring. No trends were observed for hydrogen ion.

Payne et al. (1987) estimated the duration of monitoring required to detect changes in the Upper Midwest. Based on the Seasonal Kendall-tau results (Table 4.6) slopes were estimated for significant ANC and SO_4 trends. The slope estimators for ANC ranged from 1.002 to 2.810 ueq/l/yr (ANC $\leq$ 20) depending upon the season considered. The estimated time to detect a 10 ueq/l ANC change ranged from 4 to 10 years. The slope estimators for SO_4 (ANC $\leq$ 20 ueq/l) ranged from -1.873 to -3.954 ueq/l/yr, depending on the season and the estimated time to detect a 10 ueq/l SO_4 change ranged from 3 to 6 years.

Data, used in the above analyses, represented 15 lakes with varying lengths of records, up to seven years. These results are preliminary. More accurate estimated will be provided once serial correlation is investigated and 95% confidence bonds are established. However, if changes in deposition occur, trends appear to be detectable within reasonable period of time.

Table 4.6. Seasonal Kendall tau results from LTM lakes in the Upper Midwest stratified by ANC categories (Payne et al. 1987).

ANC (ueq/l)

	ANC ≤20				20<ANC≤100		
	Fall	Spring	Summer		Fall	Spring	Summer
Probability	0.154	0.113	<0.001	Probability	0.845	0.518	0.043
Slope	1.002	2.512	2.810	Slope	-0.383	-0.675	1.877
Trend	*	*	*	Trend			*

SO_4 (ueq/l)

	ANC ≤20				20<ANC≤100		
	Fall	Spring	Summer		Fall	Spring	Summer
Probability	<0.0001	0.087	0.0006	Probability	0.190	0.114	0.003
Slope	-3.954	-1.873	-3.438	Slope	-1.457	-2.081	-2.160
Trend	*	*	*	Trend	*	*	*

* Significant

4.8 REGIONAL TREND DETECTION

Preliminary analyses to detect regional trends is on-going. During the June 1987 Data Analysis Workshop, Overton discussed regional trend detection. Using the 1984 NSWS data as a reference frame, a description of change can be based on comparisons to this reference. A change on a regional basis could be determined by using either a paired comparison or a repeated measures test on individual lakes. A chi-square test could be used to determine if the distributions were different or if the medians were different. Figure 4.7 and 4.8 are examples of a generic plot comparing data collected at two different time periods (e.g., 1984 and 1986). If there has been no change in the parameter distribution, the points should cluster around the main diagonal, which represents a 1:1 slope (Figure 4.7). If a change in the parameter distribution has occurred, then a shift in the points above or below the diagonal would be observed (Figure 4.8).

Further refinements in these analyses could include testing for changes in distributions above and below the median or above and below quartiles. Comparisons can also be made between distributions of slopes, ranks, or sign and the percent of the population that showed a change.

4.9 EXPLORATORY ANALYSES

Multivariate exploratory analyses have been used to delineate subpopulations of lakes or streams of interest in various regions and subregions. Cluster analyses, for example, were used to identify subpopulations of lakes and their characteristics during the ELS-Phase II design. These analyses were important in developing appropriate criteria for stratifying the population of lakes prior to the random selection process.

Multivariate analyses of NSS stream chemistry are being used to identify acid mine drainage impacts on streams. These analyses also are being used to classify NSS sample stream and aid in the selection of study sites for AERP, ERP, and TIME projects. In conjunction with the multivariate analyses, ion-ratios, field reconnaissance, aerial photos and maps are being used.

4.10 LESS THAN DETECTION LIMIT DATA

Magoun and Malcolm (1987) investigated techniques to analyze samples that contain below detection limit data or samples that are censored. The techniques used were grouped into three basic categories:

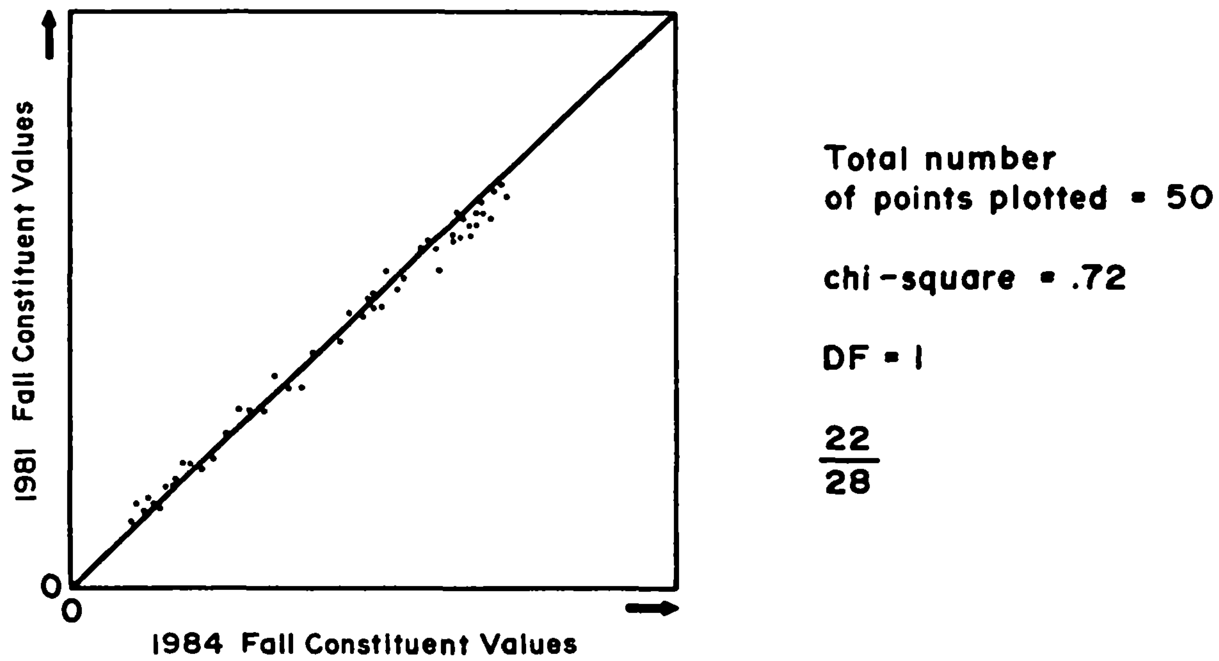


Figure 4.7. An example of a paired comparison plot showing no significant differences (Overton, 1987).

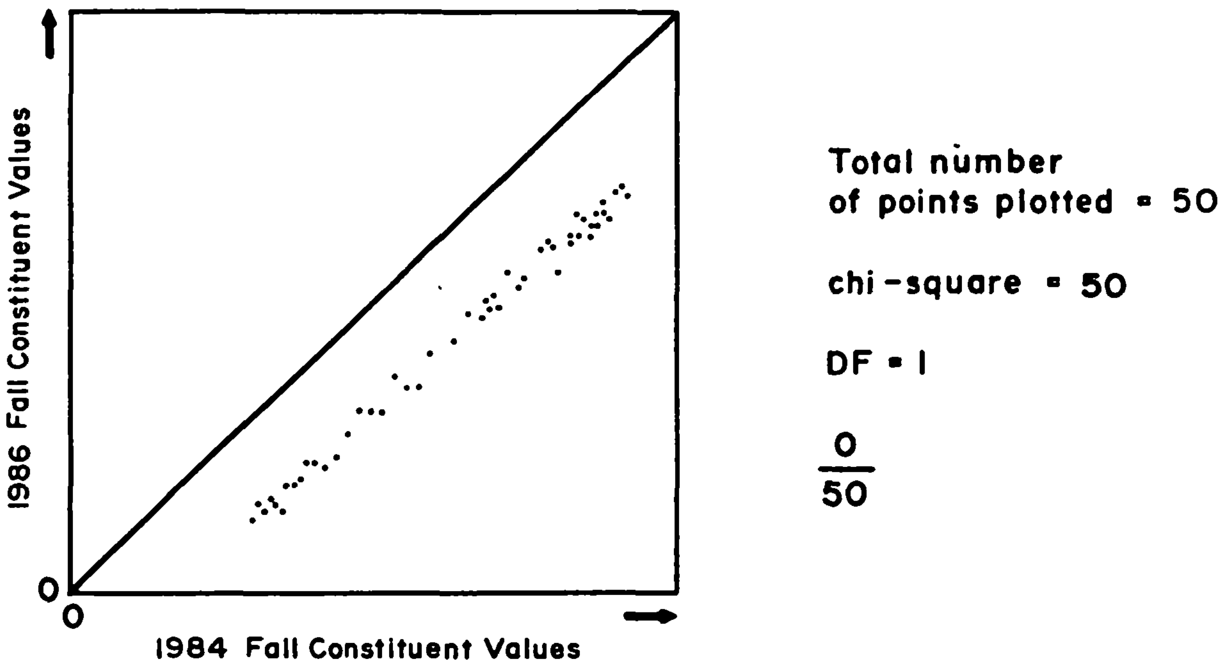


Figure 4.8. An example of a paired comparison plot showing significant differences (Overton, 1987).

- o Subjective analyses;
- o Data removal; and
- o Statistical estimation.

Subjective analytical procedures are convenient but biased. Data removal techniques result in the loss of valid data when the measured values are less than or equal to the maximum detection limit value.

Magoun and Malcolm (1987) recommended the maximum likelihood technique for the less than detection limit data. Maximum likelihood estimators are statistically based and all the data are used in the estimation procedure. Although not necessarily unbiased, the maximum likelihood have properties of asympotically efficiency, squared-error consistency, and invariance. All are highly desirable properties when unbiased estimators cannot be obtained. This procedure will be further evaluated for use in the TIME project.

4.11 QA/QC INTERPRETATION

The QA/QC interpretation of NSWS data is on going. Activities related to the development of a QA plan for TIME; based on these results, are presented below.

4.11.1 Overview of QA/QC Data Analyses

At the present time, QA data from NSWS are being analyzed for precision, accuracy, interlaboratory bias, and system detectability in order to determine the range of values expected for various analytes measured using similar methodologies in TIME. Also, the QA procedures that were the most useful in the NSWS (i.e., provided the most information) are being determined with reference to quality control, evaluation of system performance, and planning for future studies.

A QA workshop is planned for early November 1987. The goal of the workshop is to obtain a sufficient review of past QA experience to develop a QA plan for TIME that will be rigorous but flexible.

4.11.2 Measurement Uncertainty (System Precision)

Mericus et al. (1986) investigated the nature of measurement uncertainty in the ELS-I duplicate sample data and presented a means of estimating and expressing precision as a continuous linear function. Because uncertainty is described as a continuous function, an estimate of the expected precision is available for observations throughout the range of analyte concentrations. In addition, each precision estimate reflects the true nature of the analyte concentration to precision response relationship. Expected precision for the TIME project might be estimated from these relationships and concentrations measured in the NSWS or from other records.

4.12 COLLATION OF CANDIDATE SITES

There are at least three sources from which candidate sites will be identified: the NSWS; meetings with local experts; and surveys. A task has been initiated to identify sites at which aquatic monitoring has been and is continuing to be conducted as well as other sites with high quality data in the geographic areas of interest. A previous NAPAP watershed survey identified over 700 watersheds where some type of monitoring and/or research activity was occurring. This survey is now being expanded to include monitoring of aquatic systems by federal, state, local and private agencies or organizations. The results of these surveys will be used to develop a candidate list of sites that might be included in TIME.

4.13 DEPOSITION NETWORK EVALUATION

There is concern that the density of the current deposition network may be not adequate to provide data suitable for relating increased acidification or recovery of lakes and streams with changes in deposition. The density of the deposition network is generally sparse compared with precipitation monitoring stations. The location of NADP/NTN sites will be compared with the location of TIME sites, once the TIME sites are selected, to determine if the distribution is satisfactory to correlate trends between atmospheric deposition and surface water quality. A similar analysis will be conducted for precipitation monitoring stations. Of particular concern is the elevation of precipitation collectors in relation to the watershed elevation. Differences in elevation between the lake/stream and precipitation collector can confound correlation and regression analyses between precipitation inputs and system responses.

4.14 ALTERNATIVES AND OPTIONS

The studies reported above, workshop discussions and coordination activities have identified numerous alternatives and options for designing a long-term program. The next section list many of these alternatives and discusses these advantages and disadvantages.

5.0 ALTERNATIVES AND OPTIONS

5.1 MONITORING APPROACHES

Designing a long-term monitoring project is a fluid process. The design must reflect the project objectives, regional geography, climate, resource characteristics, and other factors. There are no standard designs suitable for all situations. Various alternatives for designing a long-term monitoring program were identified during workshops, previous and on-going analyses, and the preparation of the conceptual plan.

Six general alternative categories have been identified. These categories and several specific approaches in each category are listed in Table 5.1. Each alternative has advantages and disadvantages with respect to:

- The TIME objectives;
- Precision and confidence in the alternative; and
- Relative cost.

The advantages, disadvantages, relative precision, and relative cost of each alternative are listed in Tables 5.2 - 5.5 and discussed briefly in this chapter.

The design of a flexible, evolving long-term monitoring program should incorporate those alternatives best suited for a particular region or subregion. A uniform design across all the regions of concern is not a pre-requisite for the TIME Project. The goal is to provide an adequate design that will achieve the TIME objectives in each region and subregion.

5.2 ALTERNATIVES

5.2.1 Population Inference

Three alternative approaches might be considered for making inferences about trends in the regional population or extrapolating from the sampled lakes and streams to the target population. These alternatives include a model-based, design-based or combined approach for obtaining regional estimates.

5.2.1.1 Model-based Approach

The model-based approach was discussed in Section 4.3. The advantages and disadvantages of this approach are listed in Table 5.2. A model-based approach

Table 5.1 Alternative Categories of TIME.

A. POPULATION INFERENCE

1. Model-based Regional Estimation
2. Design-based Regional Estimation
3. Combined Approach

B. SITE TYPE

1. Rapid Response
2. Cross-Sectional
3. Special Interest
4. Holotype
5. Cluster

C. SAMPLING SCHEMES

1. Fixed Sites
2. Fixed + Random Selection Annually
3. Re-Survey

D. MONITORING PROTOCOL

1. Index Sampling
2. Seasonal Sampling
3. Continuous Sampling
4. Single Station/System
5. Multiple Stations/System
6. Limited Chemical Parameters
7. Phase I Chemical Parameters
8. Biologically Relevant Chemical Parameters
9. Biological Parameters/ Indices
10. Other Parameters - Soils, Veget., etc.

E. DATA MANAGEMENT AND ANALYSIS

1. STORET
2. Standard Data Mgt System
3. Customized Data Mgt.
4. Descriptive Statistics
5. Multivariate Statistics
6. Indiv. Sys. Trend Detection
7. Regional Trend Detection
8. Early Indication Analyses
9. Laboratory Reporting
10. User Distribution and Access

F. LOGISTICS

1. Contracts
2. Field Sampling
3. Laboratory Analyses
4. QA/QC
5. Database Mgmt

Table 5.2. Alternative approaches for population inference in Tier 1 - Regional Sampling.

A. MODEL-BASED SAMPLING

Advantages	Disadvantages
1. Permits detection of regional patterns and processes.	1. Distribution of lakes/streams has to be similar to the distribution obtained through probability sample (Phase I).
2. Permits the inclusion of special interest and early warning lakes	2. Data bases for a particular subregion or resource type might not exist to characterize subpopulation of interest.
3. Can include non-randomly selected systems.	3. Might exclude systems exhibiting the fastest response to acidic deposition.
4. Permits regional estimates of various population attributes.	4. Special interest and early warning lakes may be monitored using different field and analytical techniques.
5. Can be used to estimate portion of population exhibiting change.	5. Existing data from special interest and early warning lakes may be of unknown quality.
6. Precision and confidence in population estimates can be calculated for any region, subregion, or subpopulation.	

B. DESIGNED-BASED

Advantages	Disadvantages
1. Permits regional estimates of various population attributes	1. Special interest lakes will likely not be randomly selected for inclusion in the program.
2. Can be used to estimate proportion of population exhibiting change.	2. Might exclude systems exhibiting the fastest response to acidic deposition.
3. Can use existing NSWS frame for regional estimation.	3. The Phase II lakes might not represent the target population of interest.
4. Various criteria can be used to stratify the population of lakes prior to sampling.	4. There might be insufficient information to characterize or identify the appropriate subpopulation for long-term monitoring.
5. Precision and confidence in population estimates can be calculated for any region, subregion, or subpopulation.	5. To attain a desired precision and confidence level might require too large a sample or have different precision estimates for subpopulations.
6. Trends associated with individual lakes can be related directly to regional proportions.	6. Increased costs and logistical problems.

Table 5.2. Continued.

C. COMBINED APPROACH

Advantages	Disadvantages
1. Permits regional estimate of various population attributes. 2. Can use existing NSWS frame to estimate regional proportion of population exhibiting change. 3. Permits detection of regional patterns and processes. 4. Permits inclusion of special interest and rapid response systems. 5. Various criteria can be used to stratify the population of systems prior to sampling. 6. Precision and confidence in population estimates can be calculated for any region, subregion, or subpopulation. 7. Precision and confidence in population estimates can be calculated for any region, subregion, or subpopulation.	1. Limit special interest systems for inclusion in the program. 2. Might limit systems exhibiting the fastest response to acidic deposition. 3. The Phase II lakes might not represent the target population of interest. 4. To attain a desired precision and confidence level might require too large a sample or have different precision estimates for subpopulations. 5. Distribution of special interest lakes/streams has to be similar to the distribution obtained through the probability sample. 6. Data bases for a particular subregion might not exist to characterize subpopulation of interest. 7. Different field and analytical techniques might result in data of unknown quality. 8. Cost and logistic problems might be excessive.

Table 5.3. Alternative approaches to site types.

A. RAPID RESPONSE SYSTEMS

Advantages	Disadvantages
1. Provides early indication of increased acidification/ recovery.	1. Presumes characteristics of fast response systems known. Important subpopulations might be missed.
2. Regional estimates possible through model based approach.	2. Limited number of systems, low precision/confidence estimates.
3. Limited number of systems, more measurements/better QA/QC possible.	3. Regional coverage inadequate for all subpopulations, subregions, so lower confidence in regional patterns.
4. Any subpopulation of interest can be used to stratify prior to sampling.	4. Stratification by other factors, e.g., deposition might not be practical due to low number of systems in some areas.
5. Minimal cost.	

B. CROSS SECTIONAL

Advantages	Disadvantages
1. Permits regional, subregional subpopulation estimates.	1. Regional patterns/changes may not be applicable to individual lakes.
2. Permits testing (e.g., paired comparisons or repeated measure test) to determine if distribution is changing.	2. Autocorrelation among measurement error could be a problem.
3. A statistical frame for selecting lakes/streams is already in place.	3. Greater number of systems required to represent various subpopulations.
4. Good regional coverage, high confidence in regional patterns.	4. Greater cost associated with more sites.

C. SPECIAL INTEREST

Advantages	Disadvantages
1. Significant information already available.	1. Quality of historical records. may not be documented.
2. Can be identified in any region or subregion even if no other class of site occurs in the subregion.	2. Limited number of systems, low precision/confidence estimates.
3. Permits testing of ancillary hypotheses.	3. Different analytical methods probably used.
4. Lower costs and logistical problems.	4. QA/QC might be unknown.
	5. Inclusion probability unknown.

Table 5.3. Continued.

D. HOLOTYPIC

Advantages	Disadvantages
1. Permits specification of lake types of interest.	1. Presumes characteristics of interest are known.
2. Can provide early indication of increased acidification/recovery.	2. Limited number of sites for regional estimation.
3. Reduces number of lakes required to characterize various subpopulation responses.	3. Holotype response might not represent subpopulation response.
4. Minimal cost.	4. Confirmation of holotypic nature of sample site is expensive and time consuming.
	5. Reduces precision because of small sample size.

E. CLUSTER

Advantages	Disadvantages
1. Concentrate efforts around few calibrated watersheds with satellite waterbodies sampled less intensively.	1. Difficult to detect regional trends.
2. Can compare sites in different regions.	2. Presumes the type of system around which the cluster is developed is representative of subpopulation.
3. Reduced number of systems required to detect subpopulation changes.	3. Limited number of systems for regional estimation.
4. Lower costs than cross-sectional monitoring.	4. Reduces precision because of small sample size.
5. Estimates of system variances.	5. Extensive regional distribution of rapid response systems unlikely.

Table 5.4. Alternative approaches for sampling schemes.

A. FIXED SITES

Advantages	Disadvantages
1. Continuous reference frame for trend detection. 2. Permanent installation of equipment 3. Increases logistical efficiency. 4. Data analyses procedures standardized. 5. Cost-effective, budget can be estimated accurately.	1. Some unique/important resources might never be sampled. 2. Might be biased by ease of access, logistics or other factors. 3. Rapid response sites might not be included. 4. Decreased flexibility in modifying monitoring program.

B. FIXED PLUS RANDOM SELECTION ANNUALLY

Advantages	Disadvantages
1. Continuous reference frame for trend detection at fixed sites. 2. Permanent installation of equipment for some sites. 3. Potential reduction in annual costs per sampling effort. 4. Eventually obtain information on all sites in the target population.	1. Reduction in data available per lake/stream. 2. Comparisons between fixed sites and randomly selected sites tenuous. 3. Potential increase in costs because of increased logistical difficulties. 4. Decreased logistical efficiency. 5. Increased QA/QC difficulties. 6. Requires annual site selection.

C. RE-SURVEY

Advantages	Disadvantages
1. Reduction in number of sites monitored annually. 2. Reduction in annual costs. 3. Reduction in annual logistics. 4. Continuous reference frame for trend detection.	1. Presumes representative sites to detect change are selected. 2. Periodic substantial cost increases to resurvey when changes are detected. 3. Increases logistical difficulties during re-survey. 4. Trend detection based on limited temporal data.

Table 5.5. Alternative approaches for monitoring protocol.

A. SAMPLING INTERVAL

Advantages	Disadvantages
1. Index Sampling o Permits adequate characterization of regions, subregions, and subpopulations based on one sample per year during fall overturn in lakes, two samples per year during the spring in streams. o Permits comparisons among systems and over time. o Reduction in costs. o Reduction in human resources demands (i.e., person hours).	1. Index Sampling o Presumes index is a reference condition of lakes/streams in other places and other times. o Presumes fall overturn is the "best" time to index lakes. o Presumes spring is "best" time to index streams.
2. Seasonal Sampling o Permits adequate seasonal characterization of regions, subregions, and subpopulations. o Potential to reference conditions of lakes/streams in other places. o Potential to reduce the time necessary to detect a change. o Permits characterization of seasonal conditions and to calibrate assumptions of index sampling.	2. Seasonal Sampling o Reduction in coverage of regions, subregions, and subpopulations. o Potential to significantly increase costs if tradeoff between number of samples/year and monitoring duration is not realistic. o Inaccessibility of regions (i.e., the West) during late fall, winter, and spring.
3. Continuous Monitoring o Increased resolution in characterizing lake/stream on a site specific basis. o Potential to increase resolution in characterizing lake/stream on regional, subregional, and subpopulation basis. o Episodic monitoring possible.	3. Continuous Monitoring o Reduction in number of lakes and streams monitored. o Increased cost. o Potential to increase complexity of data analyses without concurrent gain in information. o Increased human resource demands (i.e., person hours).

Table 5.5. Continued.

B. NUMBER OF SITES

Advantages	Disadvantages
1. Single Station/System o Reduction in analytical cost o Increase efficiency of human resource utilization. o Index general characteristics of lakes and streams.	1. Single Station/System o Presumes limnetic spatial variation insignificant. o Does not permit examination of patterns within lakes/streams.
2. Multiple Stations/System o Permits evaluation of within and among system variability. o Increases precision of estimates.	2. Multiple Stations/System o Increases demands on human resources. o Increases analytical costs. o Increased complexity of data analysis. o Information gains may not be necessary to meet TIME objectives.

C. MONITORING VARIABLES

Advantages	Disadvantages
1. Limited Chemical Parameters o Eliminates contractual laboratory expenses. o Reduces field time. o Reduces time committed to data analyses.	1. Limited Chemical Parameters o Significantly reduces information. o Reduces ability to address cause and effect relationships. o Increases subjectivity of impacts of acidic deposition. o Reduces QA/QC checks and balances.
2. Phase I Chemical Parameters o Permits cohesiveness between TIME and NSWS. o Variables are related to atmospheric deposition, and surface water chemistry. o Increase number of variables to permit QA/QC checks and balances. o Certain variables are biologically relevant.	2. Phase I Chemical Parameters o Increases costs. o Increases field time. o Requires analytical laboratories. o Presumes all appropriate variables have been identified.
3. Biologically Relevant Chemicals Parameters o Relate directly to underlying goals of TIME. o Reduces analytical costs. o Reduces costs.	3. Biologically Relevant Chemicals Parameters o Presumes all important biologically relevant chemicals are known. o QA/QC variables may not be adequate for QA needs. o Assumes parameters exert comparable affect in all regions.

Table 5.5. Continued.

Advantages	Disadvantages
4. Biological Parameters/Indices o May permit detection of subtle shifts in biological community structure before chemical changes are detected. o Permits concommittent comparisons between biology and chemistry o May reduce time to detect recovery or acidification.	4. Biological Parameters/Indices o Increases human resource requirements (i.e., specific technical expertise). o Increases costs o Presumes appropriate biological organisms for monitoring are known. o Presumes organisms can be collected with a known precision and confidence level. o Presumes potential biological interactions (i.e., differences in competition and predation) can be accounted for over a regional distribution of lakes.
5. Other Parameters - Soils, Vegetation, etc. o Increases understanding of patterns and processes. o Provides linkages between atmospheric, watershed, water quality. o Provides ecosystem understanding.	5. Other Parameters - Soils, Vegetation, etc. o Few sites can be supported. o Substantial resource commitments on a site specific basis.

relates non-randomly selected systems to a sample of randomly selected systems with similar characteristics and attributes. This approach assumes the statistical frame relating probability samples to the target population is an adequate model to relate the non-randomly selected systems to the target population.

5.2.1.2 Design-based Approach

The design-based (Probability Sampling) approach also was discussed in Section 4.3. Its advantages and disadvantages are listed in Table 5.2. Regional population estimates using a design-based approach are based on probability samples (i.e., lakes or streams) collected within a statistical sampling frame. Because the inclusion probability for each lake or stream is known, these sample systems can be weighted to provide unbiased regional estimates. This was the approach used in the NSWS to provide regional estimates.

5.2.1.3 Combined Approach

The design and model-based approaches also can be combined to provide greater precision about the estimates. Various subregions or subpopulations might have different sample numbers, which influence the precision of the estimate. For some of these subregions, the model-based approach might provide more precise estimates while the design-based approach might be more precise in other subregions. Therefore, greater precision about the regional estimates can be obtained by combining both approaches. The advantages and disadvantages of the combined approach are listed in Table 5.2.

5.2.2 Site Type

Several types of sites or site combinations could be incorporated in a long-term monitoring program. Several of these alternative site types are assessed in Table 5.3.

5.2.2.1 Rapid Response Sites

Rapid response sites are systems expected to respond rapidly to acidic deposition. This rapid response might be exhibited through changes in surface water chemistry, aquatic biota or other indicators such as increased seasonal variance. These sites would be considered to be the most sensitive (i.e., exhibiting the fastest change) sites in a region.

5.2.2.2 Cross-Sectional Sites

Cross-sectional sites represent the range or cross-section of the site types in the region such as drainage lakes, seepage lakes, clearwater systems, darkwater systems, shallow lakes, etc. The sites would range from those sites expected to respond rapidly to acidic deposition to sites with higher ANC and other attributes expected to delay the response to acidic deposition. The range of site types and attributes included in the NSWS represents the category of cross-sectional sites.

5.2.2.3 Special Interest Sites

Special interest sites generally are considered to be sites that were not included in the NSWS but have special or unique attributes of interest. These special attributes might be a long monitoring record, sites known to respond rapidly to acidic deposition, good biological data on fish or other biota, or other important characteristics. The inclusion probability or regional representation is generally assumed to be unknown for special interest sites.

5.2.2.4 Holotypes

Holotypic sites are sites selected to represent a particular subpopulation or type of site. The subpopulation of lakes or streams might be perched lake (seepage) systems, small headwater mountain streams, or a category of systems identified through various exploratory analyses (i.e., cluster analysis). One or two sites considered typical of sites in the subpopulation might be selected for monitoring with any changes observed in these sites viewed as typical responses expected for other sites in this subpopulation. The holotypic site is analogous to a holotypic biological species but not with the implicit definition that it is the "type species" against which other sites are to be compared.

5.2.2.5 Cluster Sites

The cluster site concept has a main site that is "typical" and several peripheral or satellite sites in the area. The main site might be considered a holotypic site while the peripheral sites provide an indication of variability in system response within the area or subregion. The peripheral sites could be sampled on a less frequent basis.

5.2.3 Sampling Schemes

Three alternatives for sampling schemes include: sampling a fixed number of sites during each sampling period; sampling a smaller number of sites and supplementing sampling with randomly selected sites; and re-surveying lakes/streams in the region. The advantages and disadvantages of each approach are listed in Table 5.3.

5.2.3.1 Fixed Sites

A fixed number of sites could be selected to achieve a desired precision and confidence level in each region with each site sampled during each sampling period. Sampling a fixed number of sites provides continuity in the data and minimizes logistical problems. This represents the typical approach to monitoring.

5.2.3.2 Fixed + Randomly Selected Sites

In this approach, a fixed number of sites (generally a smaller number than above) are sampled during each sampling period to maintain continuity in the monitoring program. Additional sites are randomly selected from the target population for sampling on an annual or biannual basis. The sample selection can be stratified to ensure good cross-sectional representation of system types in the population. This approach provides an on-going continuous record on some sites and, eventually, some information on all sites of interest in the region. Some of the randomly selected sites might provide an earlier indication of regional change than the fixed sites.

5.2.3.3 Re-Survey

A small number of sites expected to exhibit rapid change, because of acidic deposition, might be monitored in this approach. Sampling other sites or a re-survey of sites might occur only when a change is indicated in the rapid response sites or at some fixed interval such as every five to ten years. This approach is compatible with either of the two approaches discussed above. This approach can indicate regional changes that might be occurring but at minimal cost on an annual basis.

5.2.4 Monitoring Protocol

There are at least three considerations for the monitoring protocol, and each consideration includes a number of alternatives or options. These three considerations are the sampling interval, number of stations/site, and monitoring variables. These alternative approaches are compared in Table 5.5. The number of samples to be collected at a station is part of the QA/QC program and is not discussed here.

5.2.4.1 Sampling Interval

There are several alternative sampling concepts ranging from an index concept (See Section 2.2.2.5 - Index Sample) to continuous monitoring. An index sample is collected on an infrequent but systematic interval (e.g., once per year in lakes or 2 samples/year in streams) during a critical period (e.g., fall overturn in lakes, spring elevated flow in streams) that serves as an index or indicator of the essential characteristics of the system. The index concept was used in the NSWS. Seasonal samples are collected once during each season in lakes or bimonthly in streams to characterize seasonal patterns occurring in these systems. This approach was followed in the ELS - Phase II. Continuous sampling might be monthly sampling in lakes and monthly or biweekly sampling in streams to characterize the seasonal dynamics in these systems.

5.2.4.2 Number of Stations

The number of stations per site or system depends on the program emphasis. Evaluating changes in patterns among lakes or streams might be achieved by sampling only one station per site. This station could indicate or index the general lake or stream characteristics. This approach was used in the NSWS. Evaluating changes in patterns both within the system and among systems requires multiple stations per system.

5.2.4.3 Monitoring Variables

The monitoring variables can vary widely both in the number of different variables and the type of variables. Some monitoring programs focus on in situ variables that can be continuously monitored such as pH, conductivity and temperature. The variables monitored in the NSWS are shown in Table 5.6. These variables were selected because of the relation between atmospheric deposition and

Table 5.6. Variables monitored in the NSWS and Phase II of the ELS.

In Situ
- pH
- Conductance
- Lake Temperature
- Secchi Disc Transparency

Field Laboratory
- Laboratory pH, closed system
- Dissolved Inorganic Carbon, closed system
- True Color
- Turbidity

Analytical Laboratory
- pH, air-equilabrated
- pH, open system
- Acid Neutralizing Capacity (ANC)
- Extractable Aluminum
- Total Aluminum
- Calcium
- Chloride
- Dissolved Inorganic Carbon, air equilabrated
- Dissolved Inorganic Carbon, initial ANC
- Dissolved Organic Carbon
- Fluoride, total dissolved
- Iron
- Potassium

Analytical Laboratory (Cont.)
- Magnesium
- Manganese
- Sodium
- Ammonium
- Nitrate
- Phosphorus
- Silica
- Sulfate
- Conductance

Additional Parameters Monitored in Phase II
- Acidity
- Inorganic Monomeric Aluminum
- Total Nitrogen
- Chlorophyll a

surface water chemistry, QA/QC checks and balances, and the relevance of certain constituent concentrations to biological effects. Biologically relevant chemical parameters such as calcium, pH, inorganic monomeric aluminum and dissolved organic carbon, for example, have been identified through laboratory and field bioassays as being important in biotic responses, particularly fish, to acidic deposition. The biotic response represents the integrated effect of surface water chemistry on biological organisms. Monitoring biological parameters or indices, therefore, might provide earlier indications of biotic effects than monitoring the change in chemical parameters. Monitoring watershed variables such as soil, vegetation, or other factors also might contribute to achieving the TIME objectives and aid in regional interpretation of results.

5.3 OTHER TOPICS

Data management and analysis and logistics are important considerations in the design and implementation of a long-term monitoring program. As indicated in Chapter 4.0, PREVIOUS AND ON-GOING ANALYSES, studies have or will be initiated to address the topics listed in Table 5.1 under each of these categories. The Draft Research Plan scheduled for May 1988 will discuss each of these topics in detail.

6.0 PROPOSED TIME FRAME

6.1 GENERAL CONSIDERATIONS

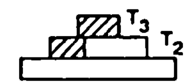
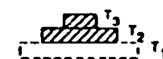
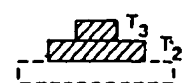
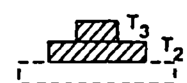
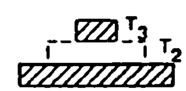
The design of any project or program must be predicated on the objectives. The TIME objectives focus on the subregion and regional scales. The regions of concern, however, span broad geographic boundaries from the East to the West, Upper Midwest to the Southeast with very different deposition patterns, climate, geology, soils, and aquatic resources. As discussed in the previous chapter, however, there are a number of alternative approaches that can be incorporated in the TIME design to accommodate these regional differences, provide the flexibility to achieve the TIME objectives and adaptable to address future environmental concerns.

Several factors to consider in the selection and integration of appropriate regional alternatives include:

- o Regional characteristics (e.g., climate, topography, soils, geology, etc.);
- o Proposed resources for monitoring (e.g., drainage lakes, seepage lakes, streams, etc.);
- o Anticipated change in the resource quality under current level of deposition;
- o Differences in the primary regional concerns; and
- o Anticipated changes in future deposition rates.

The general design frame proposed for each region that incorporates these factors is discussed below and summarized in Figure 6.1. This general design frame:

- o Satisfies the TIME objectives;
- o Provides a flexible, adaptive frame that can be readily modified to incorporate other tiers, options, or other components such as watershed soils, forests, etc.;
- o Recognizes and incorporates the unique characteristics and concerns of each region; and
- o Provides a cost effective approach for achieving the TIME objectives.

REGION/SUBREGION OF INTEREST	PROPOSED RESOURCE FOR MONITORING	ANTICIPATED CHANGE IN RESOURCE QUALITY - CURRENT DEPOSITION	PRIMARY REGIONAL CONCERNS	GENERAL DESIGN FRAME	ANTICIPATED FUTURE CHANGE IN DEPOSITION
NE Adirondacks Poconos/Catskills S New England C New England Maine	Lakes	↓ ↓ ↓ ↓ ↓	- Expect decrease in SO_4 - Expect increase in NO_3 - NO_3 "breakthrough" may be of concern - Need more deposition monitoring sites - Subregional emphasis important - DDRP forecasts available	 T_3 T_2 T_1	↓ ⬇ ⬇ ↓ —
Mid-Atlantic N Appalachians Valley and Ridge Chesapeake Area*	Streams	↓ ↓ ↓	- Presently receiving some of the highest deposition in the U S. - Coastal and inland streams of concern - DDRP forecasts available - Some systems in SO_4 steady state - NO_3 appears to be a developing concern - SO_4 concentration increase expected even if deposition decreases - Select 2 subregions to study the year to year variability in the T_1 and relationship to T_2* - SO_4 breakthrough is perhaps <u>now</u> beginning	 T_3 T_2 T_1 } 2 Sub-Regions*	↓ ↓ ↓
Southeast S Appalachians* Piedmont Blue Ridge Ouachitas	Streams	⬇ ⬇ ⬇ ⬇		 T_3 T_2 T_1 } 5 Remaining Subregions	⬆ ⬆ ⬆ ⬆
Florida	Lakes	⬇ (?)	- Projected increase in emissions - down wind are highest in U S. - Panhandle lakes are most sensitive - Primarily seepage lakes	 T_3 T_2 T_1	⬆
Upper Midwest	Lakes	⬇	- Seepage lakes dominate - Declines in SO_4 expected - Large lake chemistry changes not expected - East-West S deposition gradient exists	 T_3 T_2 T_1	⬇
West S Rockies Sierras Cascades	Lakes	↓ ↓ —	- Logistics prohibit probability and wide spread seasonal sampling - Changes in deposition possible - If lakes receive increased deposition they will acidify quickly - NO_3 is a developing problem	 T_3 T_2 T_1	⬆ (?) ⬆ (?) —

KEY

Hatched box: Rapid Response & Special Interest Systems (not necessarily Probability Sample)	⬇, ↓ Decrease/Deterioration (large, small)
Open box: Regional Probability Sample	⬆, ↑ Increase/Improvement (large, small)

Figure 6.1. Proposed general design frame for the TIME project.

6.2 GENERAL TIME DESIGN

The general TIME design frame will be discussed for five regions: the Northeast, Mid-Atlantic/Southeast, Florida, Upper Midwest and the West.

6.2.1 Northeast

6.2.1.1 Subregions

Subregions of interest in the Northeast include the Adirondacks, Poconos/Catskills, Southern New England, Central New England, and Maine. These subregions correspond with the subregional designations used in the ELS-Phase I and II. Lakes represent the proposed resource for monitoring in this region.

6.2.1.2 Potential Deposition Effects

Lake watersheds in the Northeast are assumed to be near sulfate steady-state (Rochelle and Church 1987). Under current levels of deposition, lake quality might continue to deteriorate but at a relatively slow rate. The Northeast has received considerable attention with respect to the current levels of deposition and proposed reductions in deposition on aquatic systems. Future sulfate deposition rates are anticipated to decrease because of possible emission control strategies.

6.2.1.3 Regional Concerns

Although sulfate deposition is anticipated to decrease, nitrate might become a concern in surface water acidification. There is some indication nitrate saturation might be occurring in some Northeastern watersheds, resulting in increased acid loading to surface waters (Driscoll, personal communication). DDRP forecasts for future changes in the Northeast will be available in late 1988 and will indicate whether additional lakes might become acidic within the next 50 years and their relative location. Lakes that are currently acidic also might recover if acidic deposition decreases.

6.2.1.4 General Design

A regional probability sampling approach is proposed for the regional tier (Tier 1) and seasonal tier (Tier 2) in the Northeast. The ELS-Phase II statistical frame permits regional estimates and provides broad spatial coverage of lakes across the deposition gradient that exists in the Northeast. The ELS-Phase II lakes were sampled with consistent, comparable methods and known QA/QC in the fall of 1984 and the spring, summer, and fall of 1986. The ELS-Phase II lakes (or a specific subset) are proposed as the Tier 1 lakes with a fall index sampling approach on an annual basis.

A subset of these Tier 1 lakes are proposed as probability samples for Tier 2 or seasonal sampling. These Tier 2 lakes should be supplemented by non-randomly selecting special interest and/or rapid response lakes. The Tier 2 lakes would be sampled during winter, spring overturn, summer and fall overturn.

The selection of Tier 3 lakes, with possible supplemental sampling and funding, will be coordinated with existing research sites (i.e., WMP site) and/or intensively monitored systems.

Chemical variables measured in the Tier 1 and 2 samples would include those variables measured in the ELS-Phase II Survey (Table 5.6). The use of various biotic measurements or indices are currently being evaluated and will be summarized in the Research Plan.

6.2.1.5 Rationale

A probability frame currently exists for the Northeast with regional estimates for two years of fall index samples and a year of seasonal samples. The power of this statistical frame in describing regional patterns in surface water chemistry was exemplified through analysis of both the ELS-Phase I and II Survey data. This frame can be used effectively for evaluating regional trends in lake quality. Emission control strategies and target loading scenarios have focused on deposition reductions in the Northeast. Evaluating the efficacy of these strategies, if implemented, can be effectively accomplished through regional and subregional estimates of changes in lake quality. The spatial coverage of the ELS-Phase II lakes will permit precise subregional estimates based on the Tier 1 index samples. Specific inclusion of special interest or rapid response systems can provide an early indication of changes that might be occurring in the region and subregions. These rapid response systems are most appropriately associated with Tier 2 to account for seasonal differences.

6.2.2 Mid-Atlantic and Southeast

6.2.2.1 Subregions

Subregions of interest in the Mid-Atlantic region include the Northern Appalachians, Valley and Ridge, and Chesapeake Area. Subregions of interest in the Southeast include the Southern Appalachians, Piedmont, Blue Ridge and Ouachita Mountains. These subregions correspond with the subregional designations used in the NSS-Phase I. Streams represent the proposed resource for monitoring in these regions.

6.2.2.2 Potential Deposition Effects

The Mid-Atlantic region is currently receiving some of the highest deposition in the U.S. Stream watersheds in this region appear to be in transition with some watersheds at or near sulfate steady-state and others retaining sulfate (Rochelle and Church 1987). Future sulfate deposition rates in this region are anticipated to decrease.

The Southeast generally has lower precipitation sulfate concentrations but wet deposition rates are nearly comparable to the Northeast because of higher precipitation inputs. Watersheds in the Southeast are generally retaining sulfate but there is concern about the time to sulfate steady-state (Rochelle and Church 1987). Future deposition in the Southeast is anticipated to increase as the Southeast becomes more industrialized.

6.2.2.3 Regional Concerns

Nitrate concentrations in Mid-Atlantic streams also appear to be increasing and there is concern that nitrate saturation might be occurring now in some watersheds (Corbeti and Lynch 1987, Helvey and Edwards 1987). Acidic stream reaches currently exist in the Mid-Atlantic region. DDRP forecasts for future changes in Mid-Atlantic stream chemistry will be available in 1989 and will indicate if additional stream reaches might become acidic over the next 50 years. Currently acidic stream reaches might recover if acidic deposition rates decrease.

Stream watersheds in the Southeast are currently retaining sulfate but there is indication that sulfate is replacing bicarbonate as the dominant ion in high elevation southeastern streams (Waide and Swank 1987). Preliminary DDRP forecasts indicated a significant potential for southeastern streams to become acidic in the next 50 years at current levels of deposition (Church et al. In preparation). DDRP forecasts for the Southern Blue Ridge Province will be available in late 1988 and will indicate the number of stream reaches that might become acidic within the next 50 years. If deposition increases, the potential number of acidic streams also would be expected to increase.

6.2.2.4 General Design

A regional probability sampling approach is proposed for two subregions: the Chesapeake Area of the Mid-Atlantic and the Southern Appalachians in the Southeast. These two subregions bound the geographic extent of these two regions. Streams will be selected from the NSS frame for the regional tier, Tier 1, in these two regions. A subset of streams from Tier 1 will be selected for Tier 2 seasonal sampling and supplemented with special interest streams or streams expected to exhibit a rapid response to acidic deposition. The probability samples selected from the NSS frame will permit the use of design-based approaches for regional trend estimation. An index approach similar to the 1986 NSS sampling protocol is proposed for Tier 1 streams with bimonthly sampling proposed for Tier 2 streams.

The general design for the remaining five southeastern subregions is to sample on a bimonthly basis only a select number of special interest streams or streams anticipated to respond rapidly to deposition (i.e., Tier 2 streams). There would be no streams selected for Tier 1 in these five subregions. If the Tier 2 streams or these rapid response streams indicate regional or subregional changes are occurring, a regional or sub-regional re-survey could be conducted within the NSS frame.

Each of the Tier 2 streams would be gaged. Flow measurements also will be made at the time of sampling in each of the Tier 1 streams. Chemical variables in Tier 1 and 2 samples would include those variables measured in the NSS-Phase I. The use of various biotic measurements or indices are currently being evaluated and will be summarized in the Research Plan.

The selection of Tier 3 streams, with possible supplemental sampling and funding, will be coordinated with existing research sites and/or intensively monitored systems.

6.2.2.5 Rationale

A probability frame is proposed for one subregion in the Mid-Atlantic and one subregion in the Southeast to bound this geographic area and provide regional estimates of changes that might be occurring in stream quality. Specific inclusion of special interest or rapid response systems can provide an early indication of changes that might be occurring in these regions. These rapid response systems are most appropriately associated with Tier 2 to account for seasonal differences.

An early indication of changes that might be occurring in the region could be used to trigger a re-survey. This re-survey would be based, in part, on an early indication of change and, in part, on the detection of regional trends based on the probability samples of two of the seven subregions.

6.2.3 Florida

6.2.3.1 Potential Deposition Effects

Current levels of deposition in Florida are relatively high but the projected increases in emissions down-wind are the highest in the U.S. Future deposition, as with the Southeast region, is anticipated to increase.

6.2.3.2 Regional Concerns

Florida currently has the highest proportion of acidic lakes in the U.S. Many of these systems are seepage lakes that are particularly susceptible to acidic deposition. The Panhandle subregion and Northern Florida ridge area are two areas that have a relatively large number of seepage lakes.

6.2.3.3 General Design

Lakes represent the proposed resource for monitoring in Florida. A select number of special interest lakes and lakes anticipated to be rapid response systems are proposed for seasonal sampling (i.e., Tier 2). There would be no lakes selected for Tier 1. If the Tier 2 lakes indicate a regional change is occurring in the lake systems, a regional re-survey could be conducted within the ELS-I frame. Re-surveys also might be conducted at a fixed interval such as every 10 years.

Chemical variables in Tier 2 samples would include those measured in the ELS-Phase II (Table 5.6). The use of various biotic measurements or indices are currently being evaluated and will be summarized in the Research Plan.

The selection of Tier 3 lakes, with possible supplemental sampling and funding, will be coordinated with existing research sites and/or intensively monitored systems.

6.2.3.4 Rationale

Although Florida has the greatest proportion of acidic lakes, the susceptible lakes are generally restricted to a relatively small geographic area in northern Florida. For this area, a cost-effective monitoring approach is to conduct seasonal sampling on a limited number of special interest lakes with a relatively long period of record and/or lakes expected to respond rapidly. Many of the potentially susceptible lakes are seepage systems. When a response is identified in these select lakes, a re-survey of ELS-I lakes can be used to evaluate regional trends that might be occurring.

6.2.4 Upper Midwest

6.2.4.1 Potential Deposition Effects

Current levels of deposition in the Upper Midwest are slowly decreasing. Emission reductions have been proposed or promulgated by the States of Minnesota and Wisconsin, which should reduce emissions further. The highest wet sulfate deposition rates in this region occur over the upper peninsula of Michigan with a distinct East-West gradient in deposition. Future deposition rates in this region are anticipated to decrease.

6.2.4.2 Regional Concerns

The Upper Midwest is dominated by seepage lakes that are potentially susceptible to acidic deposition. Acidic lakes were measured in this region during the ELS-Phase I and there is a concern additional lakes might become acidic in the future. If deposition decreases, however, recovery of currently acidic lakes might occur. Monitoring this recovery rate is an important element of a monitoring program in this region.

6.2.4.3 General Design

Lakes represent the proposed resource for monitoring in the Upper Midwest. A select number of special interest lakes and lakes anticipated to be rapid response systems are proposed for seasonal sampling (i.e., Tier 2). There would be no lakes selected for Tier 1. If the Tier 2 lakes indicate a regional change is occurring in the lake systems, a regional re-survey could be conducted within the ELS-I frame. Re-surveys also could be conducted at some fixed interval.

The selection of Tier 3 lakes, with possible supplemental sampling and funding, will be coordinated with existing research sites and/or intensively monitored systems.

Chemical variables in Tier 2 samples would include those measured in the ELS - Phase II (Table 5.6). The use of various biotic measurements or indices are currently being evaluated and will be summarized in the Research Plan.

6.2.4.4 Rationale

The proportion of acidic lakes in the Upper Midwest is relatively small and there is a trend for slowly decreasing deposition rates in the region. The majority of the lakes are seepage systems that might be expected to respond relatively slowly to deposition. A cost-effective monitoring approach for this region also is to conduct seasonal sampling on a limited number of special interest lakes with historical records and/or rapid response lakes. A re-survey of the region using the ELS-I frame can be conducted when a response is detected in these early indicator lakes.

6.2.5 West

6.2.5.1 Subregions

Subregions of interest in the West are the Southern Rockies, the Sierras, and the Cascades. These are three of five subregions surveyed in the 1985 Western Lake Survey (WLS) - Phase I. Lakes represent the proposed resource for monitoring in this region.

6.2.5.2 Potential Deposition Effects

Current sulfate deposition is low in the West and there is little anticipated change in the resource quality at current deposition rates. Deposition in the West, however, could increase dramatically with proposed mining and smelting activities and increased industrialization. There is an increasing concern about deposition in the Sierras and Southern Rockies.

6.2.5.3 Regional Concerns

Acidic episodes have been measured in lakes associated with summer storms in the Sierras (Melack et al. 1987). Nitrate deposition also is a growing concern in the Sierras. The high elevation western lakes have exceedingly low conductivities and ANC concentrations and might be expected to become acidic quickly if deposition increased. Many of the western lakes are located in wilderness areas and are considered unique aquatic resources.

6.2.5.4 General Design

A select number of special interest lakes and lakes expected to be rapid response systems are proposed for annual sampling in Tier 1. The index sampling approach would be used in these Tier 1 lakes. If the Tier 1 lakes indicate a change in resource quality might be occurring, a resurvey could be conducted within the WLS frame. Because of the potential susceptibility of these high elevation lakes, a resurvey every 10 years might be warranted. There would be no lakes selected for seasonal or Tier 2 sampling because of access problems during the late fall, winter and spring. A selection procedure similar to that for other regions would be proposed for Tier 3 lakes where seasonal sampling would occur.

Chemical variables in Tier 2 samples would include those measured in the ELS-Phase II (Table 5.6). The use of various biotic measurements or indices are currently being evaluated and will be summarized in the Research Plan.

6.2.5.5 Rationale

Western lakes are expected to become acidic quickly if deposition increases so rapid response lakes or lakes of special interest that might provide an early warning of increased acidification are particularly appropriate. Because many of the lakes are remote and difficult, if not impossible, to sample, a probability sampling frame is not feasible. In general, seasonal sampling also is not feasible. These lakes are difficult to reach in the spring during snowmelt. Early fall snowstorms and inclement weather make fall sampling treacherous. Summer sampling is logistically feasible and can provide an index of lake quality for trend detection and was, therefore, selected as appropriate for Western lakes.

6.3 PROPOSED TIME FRAME

The proposed TIME frame is provided to stimulate discussion. While there are certain objectives that must be satisfied in the TIME project, there might be alternative designs that also satisfy the TIME objectives but are more compatible with on-going monitoring programs conducted by other federal or state agencies. Review comments will be considered and evaluated from inclusion in the TIME Research Plan.

7.0 SITE SELECTION

7.1 OVERVIEW

Three types of sites will be selected for the TIME project:

- o Probability samples;
- o Rapid-response sites; and
- o Special interest sites.

This chapter outlines the steps involved in the site selection process, and sets forth preliminary criteria to be used in selecting each of the three classes of sites. The steps are illustrated in Figure 7.1.

7.2 GENERALIZED SITE SELECTION PROCESS

7.2.1 Define Inclusion Criteria

This step identifies the desired target populations for each class, and may apply to any level of the classification process (e.g., individual sites, subpopulations, subregions, regions, national distribution). Inclusion criteria will vary for each of the three classes of sites but might include:

- o Regions in which changes in sulfate are likely to occur in the near future;
- o Sites sampled in the NSWS for lakes and streams;
- o ANC levels;
- o Bedrock/surficial geology;
- o Soil depth; and/or
- o Special interest sites.

7.2.2 Classify/Stratify the Array of Potential Sites Into Categories By Geographical Region

This process will vary for each of the three site types. The purpose of this activity is to ensure good coverage of the range of issues that are being addressed. It will also serve as an aid to hypothesis testing in each category of sites. Sample categories are lakes/streams, ANC classes, ranges of sulfate deposition, groups of sites defined by cluster analyses or other statistical procedures, etc.

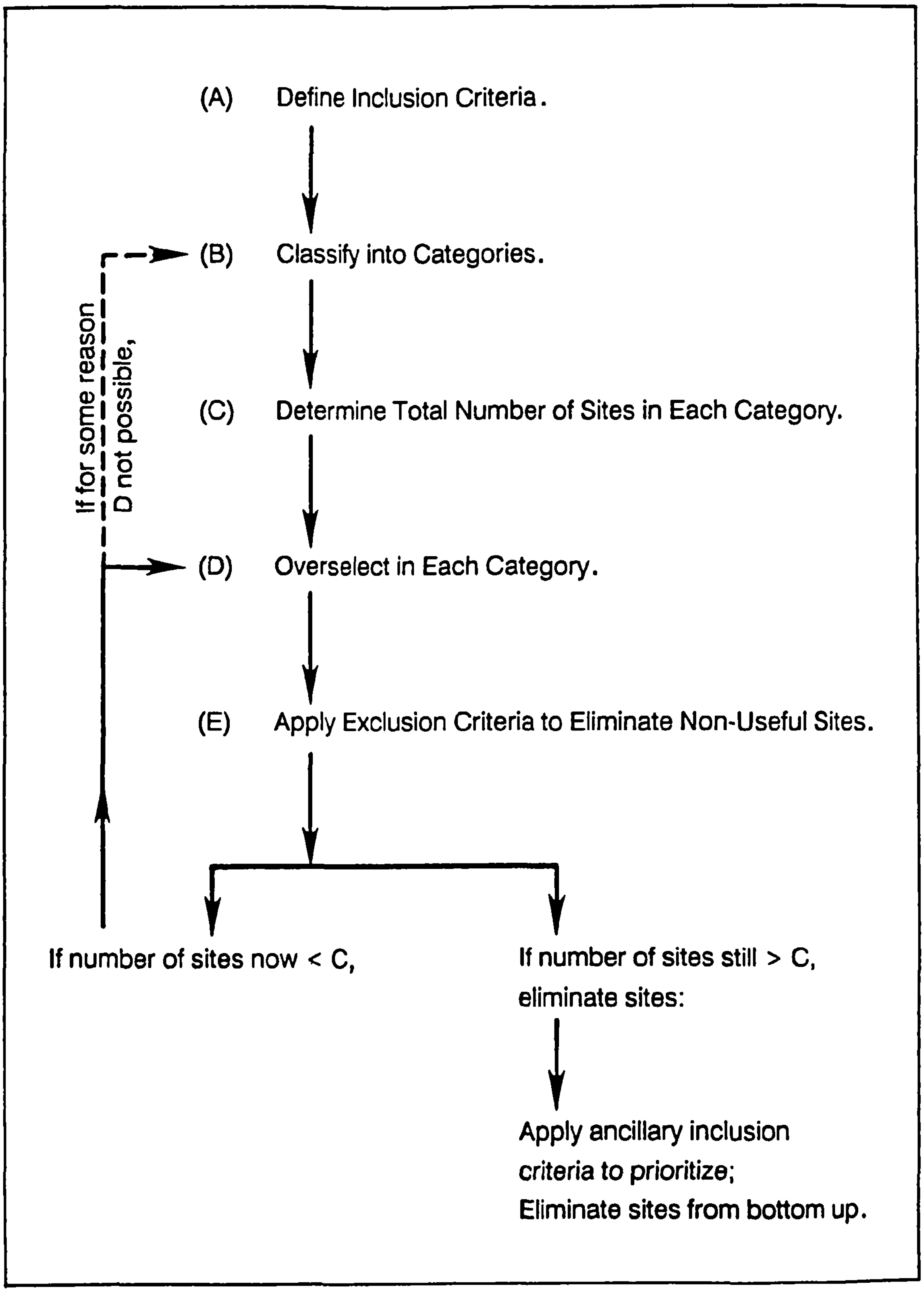


Figure 7.1. Overview of the site selection process.

7.2.3 Define the Desired Total Number of Sites in Each Category

The desired number of sites in each category will be estimated using standard statistical sampling formula. Desired precision and confidence levels will be specified for each category.

7.2.4 Select the Appropriate Number of Sites in Each Category

Initial site selection will be random for the probability samples, and non-random (i.e., hand-picked) for rapid-response and special interest sites. Overselection will be necessary for probability samples, because inclusion of some sites might not be appropriate even though they belong to the target populations (see Section 7.2.5 below). Over-selection also will probably occur for at least some categories of special interest and rapid-response sites because more sites will be identified than can be accommodated (as defined in Section 7.2.3).

7.2.5 Define and Apply Exclusion Criteria

There might be site characteristics that will compromise the usefulness of individual sites even though they belong to the target population. The application of exclusion criteria will eliminate some sites from further consideration. Each individual site identified for sampling must be evaluated against the list of exclusion criteria generated for that class of sites. There may be compelling reasons why individual exclusion criteria are not considered for rapid-response or special-interest sites, but if a site in either of these two classes violates several criteria, it should be eliminated from further consideration.

7.2.6 Compare the Number of Sites Remaining in Each Unit to the Desired Number of Sites in Each Unit and Adjust as Necessary

If there are too few sites, more sites should be selected, if possible (i.e. Section 7.2.4). If this is not possible, then Sections 7.2.2 and 7.2.3 need to be re-evaluated and adjusted, if necessary, (i.e., Section 7.2.2) until a balanced selection is achieved.

If there are too many sites in the unit, some sites will be eliminated. The first step in this process should be to prioritize remaining sites by applying ancillary inclusion criteria such as proximity to other types of studies, inclusion in existing monitoring programs, etc. These inclusion criteria will be specific to the class of site being selected. Once the list of sites has been prioritized by these ancillary inclusion criteria, sites can be eliminated from the lowest priority upwards until the correct number is achieved.

7.3 SITE SELECTION CRITERIA: PROBABILITY SAMPLES

7.3.1 Tier 1

7.3.1.1 Examples of Inclusion Criteria

7.3.1.1.1 Regional Distribution - Only regions in which: Changes in sulfate deposition are likely to occur in the near future; and Annual probability sampling is logistically feasible are included in the probability sample. Currently, this restricts the probability sample to 2 of the 4 NSWS regions (Northeast and Mid-Atlantic/Southeast).

7.3.1.1.2 Phase I - All sites in the probability sample will be drawn from the sampled NSWS sites (i.e., all sites sampled in Phase I lakes and streams). One consequence of this approach is that regions without a NSWS statistical frame cannot be included in the probability sample. This means, for example, that streams can only potentially be selected in two regions (Northeast and Mid-Atlantic/Southeast). This, however, is consistent with Inclusion Criteria, Section 7.3.1.1.1, which only requires probability sampling in these two regions.

A second consequence of this approach is that hand-picked (rapid-response and special-interest) sites will not be used in the probability sample. In regions without a proposed TIME probability sample (the Upper Midwest and the West) it might be possible to create regional approximations using a model-based approach.

7.3.1.1.3 ANC Levels - Because the goal of the TIME project is to track acidification and recovery, ANC should neither be very high nor very low (i.e., approximately -10 to 100 ueq/l). In either situation, substantial buffering against changes in pH can occur (carbonate/bicarbonate buffering at high ANC, buffering by aluminum and organic complexes at very low ANC). Desirable ranges of ANC will be specified. ANC is of interest as a surrogate for sensitivity and for stratifying sampling.

7.3.1.2 Classification

Classification procedures will be conducted on a regional level. Statistical techniques such as multivariate techniques (e.g., cluster analyses) will be used for this classification. Because streams have actually been sampled only in the Southeast and Mid-Atlantic, classification (Section 7.2.2) can only be achieved for these streams. A statistical frame exists for the Northeast streams but they have not been sampled. Classification for the probability sample will include consideration of deposition gradients in order to help ensure that, if deposition-related patterns of acidification and recovery occur, they will be detected.

7.3.1.3 Define the Desired Number of Sites in Each Category

This activity will take advantage of ELS-Phase II analyses where available (i.e., the Northeast) as well as results from the several analyses of the LTM data set that have been made (Newell 1987; Payne et al. 1987; Loftis and Ward, 1987a, 1987b; Overton 1987)

7.3.1.4 Site Selection

Sites will be (over) selected using random selection techniques applied to the categories defined in Section 7.2.4.

7.3.1.5 Exclusion Criteria

7.3.1.5.1 Present or Likely Future Disturbance - Because the purpose of the TIME project is to monitor changes in surface water resources due to atmospheric deposition, it is important that other confounding factors that could induce chemical and/or biological change be avoided as much as possible.

7.3.1.5.2 Access Problems - If there are physical or administrative (e.g., inaccessibility, ownership, etc.) obstacles that constrain sampling on a regular schedule, these should be weighed against the overall desirability of sampling that particular site. Maximum allowable sample holding times will be defined as part of this exclusion criteria.

7.3.1.5.3 Catchment Size - Maximum catchment size or catchment/surface water area ratio will be defined for both lakes and streams, as appropriate.

7.3.1.6 Adjustment of Number of Sites

This process should follow that outlined in Section 7.2.6.

For the probability sample, ancillary inclusion criteria should include:

- Proximity to existing deposition stations, hydrometeorological stations, or other monitored watersheds;

- o Inclusion in an existing program (e.g., LTM, state monitoring programs, etc);
- o Availability of other historical data (e.g., paleolimnological analyses);
- o Availability of other types of data (e.g., hydrological regime, vegetation and soils mapping, studies of soil and in-lake processes relevant to surface water acidification and recovery); and
- o The existence of continuous discharge stations, or automated event sampling stations (streams or inlets to lakes).

7.3.2 Tier 2

A subset of Tier 1 probability sites will be chosen for Tier 2 probability sampling in each region in order to examine seasonal properties of the index concept. The site selection process for this activity will follow that for Tier 1 and will be based on desired precision and accuracy and available resources.

7.4 SITE SELECTION CRITERIA: RAPID-RESPONSE SITES

7.4.1 Overview

Rapid-response sites are primarily identified for Tier 2, because a seasonal sampling schedule might be able to shorten the time frame within which trends can be detected. Because seasonal sampling will include samples in the index period (fall for lakes, spring for streams), there will be Tier 1 data available for most rapid-response sites. These will not be used as probability samples, however, unless these sites are coincidentally identified during the Tier 1 probability sample site selection process. Exceptions to this generalization occur in the West, where seasonal sampling is not possible for many subregions.

7.4.2 Inclusion Criteria

Inclusion criteria include:

- o Bedrock surficial geology;
- o ANC range;
- o Quantified response to both acid and base additions;
- o First-order stream or headwater lake (if a drainage lake);
- o (Lake) surface area;
- o Catchment area;

- o Overlap with DDRP systems for rapid response;
- o Soil depth; and/or
- o Length and quality of historical record.

Rapid-response sites will be identified for all regions (Northeast, Southeast, Upper Midwest, and West), and will form the backbone of the monitoring program in regions in which probability samples will not be taken (the Upper Midwest and West, as well as the Florida subregion of the Southeast).

7.4.3 Classification

Units of interest will include hydrological regimes, lithology, and current or anticipated sulfate deposition range (Upper Midwest, Southern Rockies). For example, although all rapid response sites will be located on highly sensitive bedrock/surficial geology, it might be appropriate to select sites on different substrates and/or with different hydrological characteristics within any one region and deposition range. This activity is an important component of hypothesis testing.

7.4.4 Define the Desired Total Number of Sites in Each Unit

Good replication within units will be necessary to make strong tests of alternate hypotheses.

7.4.5 Site Identification

Site selection for rapid-response sites will be done in close association with local scientists who have been involved in similar activities in the past. Local resources will include individuals in state agencies as well as LTM cooperators and other appropriate personnel in the public and private sectors. In this phase, candidate lists will be developed for each region, which will later be shortened. In this phase, however, the number of good rapid-response sites that can be used to test particular hypotheses will be maximized.

7.4.6 Exclusion Criteria

The exclusion criteria will be the same as those listed in Section 7.3.1.5. In addition, no rapid-response sites will be identified in subregions in which current deposition levels are low and changes in deposition have not occurred and are not expected (e.g., the Northern and Central Rockies, the Ouachita Mountains).

7.4.7 Adjustments of Number of Sites

This process should follow that outlined in Section 7.2.6. For the rapid-response sites, ancillary inclusion criteria should be as in Section 7.3.1.6.

- o Proximity to existing deposition stations, hydrometeorology stations, or other monitored watershed;
- o Inclusion in existing monitoring programs (e.g., LTM, state monitoring programs, etc.;
- o Availability of other historical data (e.g., paleolimnological analyses);
- o Availability of other types of data (e.g., hydrological regime, vegetation and soils mapping, studies of soils and in-lake processes relevant to surface water acidification and recovery); and
- o The existence of continuous discharge stations, or automated event sampling stations (streams or inlets to lakes).

7.5 SITE SELECTION CRITERIA: SPECIAL-INTEREST SITES

7.5.1 Overview

Special-interest sites are primarily identified for Tiers 2 and 3. These include sites for which there is significant information already available, or significant ancillary information from other sources that will become available. Most special-interest sites will also be the object of studies outside EPA's TIME project.

7.5.2 Inclusion Criteria

Inclusion criteria include:

- o Inclusion in other existing programs (e.g., LTM, other agency programs, state monitoring programs);
- o Length and quality of historical records (including paleolimnological analyses);
- o Extent and quality of independently funded ancillary studies (especially hydrology, vegetation and soils mapping, and studies of soil processes and in-lake processes relevant to lake acidification and recovery). Sites that already have continuous discharge monitoring, or that have

automated event sampling (streams or inlets to lakes) are of particular interest;

- o Usefulness for hypothesis testing. These need not be rapid-response sites, but could be added for testing hypothesis generated during the rapid-response site selection process. An example of such sites might be those with high nitrate loadings over a range of current or anticipated sulfate deposition loadings;
- o Availability of cost-sharing or in-kind services; and
- o Special-interest sites may be identified in any region or subregion, even if no other class of site (probability or rapid-response sites) occurs for this subregion. For example, special-interest sites might occur in the Northern or Central Rockies or the Ouachita Mountains or may be streams in areas other than the Southeast or lakes or reservoirs in subregions of the Southeast other than Florida.

7.5.3 Classification

Units of interest are ANC classes, bedrock/surficial geology, hydrological regime, current or anticipated sulfate deposition range.

7.5.4 Define the Desired Number of Sites in Each Unit

Aside from considerations of hypothesis testing, this will depend on budget constraints and the availability of cost-sharing or in-kind services for particular sites.

7.5.5 Site Identification

Site identification for special-interest sites will be done in close association with other programs, agencies, LTM cooperators, and others who have been involved in similar activities in the past. As with rapid-response sites, candidate lists will be developed for each region, which will be shortened later.

7.5.6 Exclusion Criteria

As in Section 7.3.1.5. and 7.4.6.

7.5.7 Adjustment of Number of Sites

This process should follow that outlined in Section 7.2.6. For the special-interest sites, ancillary criteria should include:

- ANC class;
- Relationship to deposition gradient; and
- Proximity to existing deposition stations, hydrometeorological stations, or other monitored catchments.

8.0 TIMELINE/TIME PROJECT AND REPORT FORMATS

8.1 TIMELINE

In order to coordinate the TIME project and to ensure tasks are completed in a timely fashion, Project Manager Workbench (PMW) was used to establish timelines through a Gantt chart (Table 8.1) and to determine the critical path using the Critical Path Network. The Gantt chart (Table 8.1) reflects the monthly schedule.

8.2 TIME PROJECT REPORT FORMATS

Two tentative report formats are presented. One format is for annual reports and the other biennial reports.

8.2.1 Annual Reports

The annual report is scheduled to appear approximately six months after sampling is completed for the year. In the report, a standard set of analyses will appear in an appropriate format. The focus will be on "highlights" of what was observed during the previous year. Analytes of interest in major policy issues will be analyzed with verified (peer reviewed) data from Tiers 1 and 2.

8.2.1.1 Tier 1

Each sample variable will be discussed by region and cumulative frequency distributions (CFD) will be presented for about six key variables. Comparisons will be made between present CFD and previous CFD. Additional comparisons may be made by pair wise and/or repeated measure tests. Shifts in overall distributions as well as shifts in specific parts of the distributions will be investigated. Bivariate comparisons (i.e., ANC vs. SO_4) have been considered but are as yet undefined.

8.2.1.2 Tier 2

This section of the report will present the data gathered by region, by variable and by lake. An example of the type of presentation envisioned is illustrated in Figure 8.1. Subregional averages and confidence limits will be calculated and presented in a modified form of Figure 8.1. Some narrative will be provided, and

Table 8.1. Gantt Chart reflecting monthly schedule for TIME.

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PROJECT: TIME PROJECT FILE: TIME2

TIME PROJECT	Da	Who
CONCEPTUAL PLAN		
CRITICAL PATH ANALYSIS	13	FP MM
ASSESSMENT MATRICES LTM	65	JL RW
EXAM TREND ANALSIS RPT	1	KT
ENVIRON CONCERNS-EPA HQ	2	KT DL
REDEFINE REGIONS	10	AK
PRIORITIZE REGIONS?	4	DL JF
DRAFT CONCEPTUAL PLAN	35	FP KT
LTM COOPERATOR MEETING	9	DL KT
MONITORING FRAME		
STREAM SAMPLING DESIGN	3	PK DL
? FOR MONITORING NETWORKS	4	DL KT
BIOLOGY		
DEVELOP BIO. STRATEGY	3	JF
BIO LIT. REVIEWS	67	JF X
BIOLOGY WORKSHOP	12	B JF
FINAL CONCEPTUAL PLAN		
FINAL CONCEPTUAL PLAN	25	FP KT
RESEARCH PLAN		
DESIGN ELEMENTS		
CRITERIA ID PARAMETERS	3	KT JF
RAPID RESPON & REG CHAR	4	KT SO
DATA ANALYSIS WORKSHOP	11	JF KT
REAL CHANGES SO4,ANC,PH	1	KT
REGION & SUBPOP VAR ESI	5	X
AUTOCORRELATION (FALL)	8	JB AN
EVALUATE SITE COVERAGE	6	SO AK
CLUSTER ANALYSIS	5	JB
ALT. CLUSTER ANALYSIS	5	JB
PLOT CSU CURVES BY %SO4	3	JL RW
ASSESSMENT MATRICES OTHER	14	JL RW
DDRP SEN ANALY. (RAPID)	6	KT JF
REGIONALY REPRES CRITERIA	10	AN JB
RAPID RESPONSE CRITERIA	11	AN JF
CHANGES FROM DDRP OUTPUTS	3	KT
COOR RTP (HYDROMET/DEP)	3	KT JF
COMPONENETS (FOREST/SOIL)	6	KT JF
MOD. NSWS DESIGN (T I,II)	7	DL JF
STREAM ANALYSES	8	PK KT
ASSESS REG DIF/SAMPL DES	8	AN MM
INTEGRATION W/ AGENCIES	10	JF
LOGISTICS		
COOP VS CENTRAL SAMP SYS	4	DL JE
ANALY LAB STRATEGY	7	DL JF
MEET WITH STATES	16	DL JF
QA PLANNING		
PRECISION VS CONCENTRAT	10	JP
VARIABLE VARIANCES	10	JP
SYSTEM BIAS	10	MO
EVALUATE QA FEEDBACK LOOP	3	JP
QA WORKSHOP	21	JP MM

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Table 8.1. Continued.

PROJECT: TIME PROJECT

FILE: TIME2

TIME PROJECT	Du	Who	1987 Dec	1988 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1989 Jan	Feb	Mar	Apr	May	Jun
DATA MANAGEMENT																					
IDENTIFY DBM ADVISORS	3	JB																			
CRITERIA DATA INCLUSION	5	AN MM																			
DATA BASE SPECIAL SITES	4	AN																			
FIRST DRAFTS																					
D SITE SELECT. CRITERIA	8	JF KT																			
DRAFT DQO DOCUMENT	30	KT MM																			
DQO INTERNAL REVIEW	10	DL JF																			
REVISE DRAFT DQOS	6	MM KT																			
SUBMIT DQOS TO HQ	5	DL X	•••																		
STRATIFY BY GEOLOGY?	6	AN PK																			
ANC RELAT IN SE STREAMS	3	PK																			
F. SITE SELECT. CRITERIA	21	AN KT	•••																		
DEFINE LAKES OUTSIDE NSWS	5	DL JF		.•••••																	
FINAL DQO DOCUMENT	20	MM KT	C••••••																		
IDENTIFY CHEM PARAMETERS	7	JF JE			.••																
IDENTIFY BIO. PARAMETERS	7	JF B			.••																
ROUGH DRAFT RESEARCH PLAN	15	FP KT	•••••••																		
COORDINATE W/DDRP,WMP,ERP	7	JF DL			.••••••••••																
D1 QA PLAN	20	JP MM			.C••••																
DEFINE QA OBJ.- CHEM.	10	MM JP			••••																
DEFINE QA OBJ.-BIO	8	MM B			••••																
METHODS MEET CHEM QA OBJ.	6	X MM				•															
METHODS MEET BIO. QA OBJ	6	B JF				•															
CHANGES ANALY. METHODS	10	AN MM				•••••															
PROC FOR LOSS OF COOP.	4	JP MM				•••••															
INTEREST & AVAIL. OF COOP	15	JF DL	•••••••••																		
D1 SITE SELECTION PLAN	16	AN JF			.C••••																
PLAN AERIAL RECON. TR 1	5	DL JF					.•••••														
GIS HYDROMET/DEP/WSHED	4	AN MM				.••															
QA OF DATA OUTSIDE TIME	5	MM				••••															
ID REPORT CONTENTS/FORMAT	6	DL JF		.•••••																	
D1 DATA ANALYSIS PLAN	20	JL RW			.C••••																
HIRE DBM CONSULTANT	6	JB DL		.•••••																	
D1 DATA MANAGEMENT PLAN	25	JB X			.•••••																
D1 RESEARCH PLAN	10	FP KT				.C•															
SUBMIT RESEAR. PLAN TO HQ	6	DL X				C••••															
DRAFTS FOR INTERNAL REVIEW																					
D2 QA PLAN	15	JP MM				•••••															
D2 SITE SELECTION PLAN	15	AN JF				•••••															
D2 DATA ANALYSIS PLAN	10	JL RW				•••••															
D2 DATA MANAGEMENT PLAN	15	JB X				•••••															
D1 ANALY. METHODS MANUAL	14	MS JP				••••															
D1 FIELD MANUAL	10	JR				••••															
D2 RESEARCH PLAN	6	FP KT					.C•														
COORDINATE W/AERP PROJ.	9	DL JF					••••••••••••••														
CONT. STRM MONITORING?	6	AN PK				••••••															
DRAFTS FOR PEER REVIEW																					
D3 QA PLAN	10	JP MM					C•••														
D3 SITE SELECTION PLAN	10	AN JF					C•••														
D3 RESEARCH PLAN	7	FP KT					C•••														

Table 8.1. · Continued.

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PROJECT: TIME PROJECT FILE: TIME2

TIME PROJECT	Du	Who	1987 Dec	1988 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1989 Jan	Feb	Mar	Apr	May	Jun
D3 DATA ANALYSIS PLAN	7	JL RW					C•••														
D3 DATA MANAGEMENT PLAN	8	JB X					C•••														
D2 ANALY METHODS MANUAL	10	JP MS					••••														
D2 FIELD MANUAL	5	JR					••••														
PEER REVIEW																					
REVIEW DRAFTS	10	X						.C••••													
PEER REVIEW	5	X							.C•												
PEER REVIEW REPORT	7	X							C••												
PREPARE FINAL DRAFTS																					
FINAL QA PLAN	15	JP MM								.•••••											
FINAL SITE SELECTION PLAN	20	AN JF								.C••••											
FINAL RESEARCH PLAN	8	FP KT								.•••••											
FINAL DATA ANALYSIS PLAN	8	JL RW								.•••••											
FINAL DATA MANAGEMENT	15	JB X								.•••••											
FINAL ANALY. METHODS MAN.	10	JP MS								.•••••											
FINAL FIELD MANUAL	10	JR								.•••••											
IMPLEMENTATION																					
DRAFT SAMPLING SCHEDULE	15	AN MM									.C••••••••										
SITE EVALUATIONS	40	X						.••••••••••••••••••••••••													
FINAL SAMPLING SCHEDULE	15	AN MM											.C••••								
FUND COOPERATORS	20	DL MM											.••••••••••••••,								
TRAIN COOPERATORS	10	JR															.•••••				
SAMPLE COLLECTION	0	X															.C				

Region 2
ANC (ueq/l)

LAKE	GRAPH	SIGNIFICANT TREND		
			* Statistical Test 1	Statistical Test 2
2A1 - ___		P ≤	____	____
2B1 - ___		P ≤	____	____
2C1 - ___		P ≤	____	____
2D1 - ___		P ≤	____	____
etc.		P ≤	____	____

* e.g. Seasonal Kendall tau

Figure 8-1. A sample format for presenting data generated in Tier 2.

part of this narrative will focus on rapid-response sites and continued evaluation of fall and spring index samples, if appropriate.

8.2.1.3 Tier 3

The preliminary plan for Tier 3 is to present a 1 to 2 page narrative of activities, and findings of each cooperator or intensive site. This summary will be based only on written material contractually required from the funded principal investigator. This section of the annual report, which may represent diverse types of information (soil, forests, etc.), will be customized rather than follow a specified format.

8.2.1.4 Tier 4

This section of the annual report will concentrate on what was done that previous year, what has been resolved and what is being proposed as special studies.

8.2.1.5 QA/QC Results

This section will address the analytical DQO's.

8.2.1.6 Extended Analysis of Previous QA/QC Results

The QA/QC results discussed in this section will be concerned with how the extended analysis of previous QA/QC results impact previous annual report results. This section is a trade-off between the desirability of getting the annual report out in a timely manner and allowing adequate time to complete the analyses of the QA/QC results. The annual reports will deal only with verified data but not necessarily validated data.

8.2.2 Biennial Reports

This report, which will appear every two years, is not well defined at this time. Major elements will be concerned with verified and validated data, interpretative data analyses, responses to policy maker's feedback on annual reports, and the effect of system error on observed and reported trends.

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