PROCEEDINGS OF THE

ECOLOGICAL QUALITY ASSURANCE WORKSHOP

Sponsored by

U.S. Environmental Protection Agency
Corvallis, Oregon

NAPAP

FOREST RESPONSE PROGRAM

QUALITY ASSURANCE PROJECT

EPA United States Environmental Protection Agency

United States Department of Agriculture — — Forest Service

PROCEEDINGS OF THE

ECOLOGICAL QUALITY ASSURANCE WORKSHOP

Sponsored by

U.S. Environmental Protection Agency
Corvallis, Oregon

Organized by

Forest Response Program
QA Staff

March 29-31, 1988

Denver, Colorado

Table of Contents

Preface

The scientific community is increasingly called upon to address ecosystem responses to a myriad of human activities at local, regional, and even global levels. In the decade of the 1990's and beyond, a clearer understanding of such ecosystem responses will be fundamental to emerging policy issues. Monitoring and research within ecosystems is seen, therefore, as a major scientific need for the period ahead, and Quality Assurance (QA) procedures will need to accompany these developments.

As a preparatory step, the QA staff of the Forest Response Program under the National Acid Precipitation Assessment Program (NAPAP) organized a workshop to discuss the role of QA in ecological science. The workshop was held on March 29-31, 1988 in Denver, CO; the purpose was to:

1) strengthen interaction between the various QA programs by exchanging information on QA activities in a number of different monitoring and research areas, including water, soil, vegetation, and atmospheric sciences, and to strengthen interaction between the various QA programs;

2) provide a forum for discussing topics of general concern to QA implementation in monitoring and research programs; and

3) establish some guidelines for the extension of QA specifically into terrestrial/ecological research in the decade ahead.

In order to fulfill the first objective, day one of the workshop was dedicated to exchanging information about the QA programs represented, to foster discussion about the issues at hand, and to fulfill the first objective. A representative of each program or organization presented an overview of their activities, innovations, and difficulties. Section 4 contains an agenda, and a list of participants and groups represented.

The second and third day of the workshop focused on specific aspects of QA implementation, including: the adaptation of traditional QA to ecological research, comparability studies, and collection and evaluation of quality control data. For each of the three sessions, a discussion leader presented an issues paper prepared and distributed in advance of the workshop to stimulate discussion. These papers are presented in Section 2 of the proceedings, as modified after the workshop.

At the conclusion of the workshop, the workshop participants attempted to summarize the main issues discussed during the three sessions and identify conclusions. The outcome is presented in Section 3 of these proceedings.

One group consensus was to begin planning for an international symposium in 1989 to further define the role of QA in ecological research programs in the 1990's. Representatives from other agencies and governments have expressed interest in assisting with the arrangements for such a symposium.

Reaction to this workshop and future meetings was very positive. There was consensus that this workshop fulfilled its objectives and similar workshops or meetings are needed in the future. The U.S. EPA's Environmental Research Laboratory in Corvallis and the Forest Response Program plan to actively participate. We wish to thank the other participants for their efforts, particularly the authors of the three issues papers and our colleagues from Canada for their participation.

Section 1

OVERVIEW OF THE QUALITY ASSURANCE PROGRAMS REPRESENTED

About 40 people attended the workshop from across the U.S. and Canada. They represented QA interests among twenty-one federal, state, provincial, corporate and consulting organizations that expressed high interest in the workshop. Introductory remarks from spokespersons for sixteen organizations provided these highlights:

- **U.S. EPA and U.S. Forest Service, Forest Response Program (NAPAP),**
  Corvallis, Oregon - Susan Medlarz
  - In 1986, began implementing QA within this multi-agency program of research on air pollution and forest effects across the U.S.
  - Developed and applied a QA program to a highly diverse program focused on ecological research.

- **Great Lakes Survey**
  Burlington, Ontario, Canada - Keijo Aspila
  - Conducts inter-laboratory comparison studies.
  - Services seven major monitoring programs which employ over 400 laboratories.

- **Canadian Territories Sample Exchange**
  Sault Ste. Marie, Ontario, Canada - Ian Morrison
  - Conducts inter-laboratory comparison studies.
  - Uses round-robin tests for forest soil and plant tissues.

- **International Soil Sample Exchange**
  Las Vegas, Nevada - Craig Palmer
  - Undertakes comparability studies of the U.S. EPA Direct/Delayed Research Program (DDRP) soil survey analytical data and compares to standard soil survey information.
  - Approach is inter-laboratory soil sample exchanges.

- **National Acid Deposition Network/National Trends Network**
  Ft. Collins, Colorado - Dave Bigelow
  - Network designed to collect wet deposition samples at about 200 meteorological stations across the U.S.
  - Precipitation chemistry determined in laboratories from weekly samples.
  - QA/QC activities include guidelines for standard procedures at sites and in the laboratory.

- **National Surface Water Survey**
  Las Vegas, Nevada - Mark Silverstein
  - Undertook sampling of 1800 lakes and 450 streams in the NE U.S. and 750 lakes in the Western U.S.
  - Implemented QA procedures for lake water sampling methods, and sample tracking and analysis at eight contract laboratories.

- **U.S. EPA, Direct-Delayed Response Program**
  Las Vegas, Nevada - Lou Blume
  - Over 2200 soil samples were collected for the DDRP for the required chemical and physical analysis.
  - Analytical work was coordinated by QA staff through technical caucus approach.

- **U.S. EPA, Watershed Manipulation Program**
  Corvallis, Oregon - Heather Erickson
  - Program will test three hydrologic models from DDRP through manipulation experiments in paired catchments.
  - Goals of QA program, though still in the implementation phase, are to improve research results by establishing Data Quality Objectives (DQOs) for field research, standard support laboratory procedures, and inter-laboratory comparison studies.

- **U.S. EPA, QA Management Staff**
  Washington, D.C. - Linda Kirkland
  - Involved in developing QA policy for the U.S. EPA following the initiation of a EPA agency-wide QA program in 1984.
  - Strong emphasis on development of Data Quality Objectives for environmental monitoring and research.

- **U.S. EPA, Environmental Research Laboratory**
  Corvallis, Oregon - Deborah Coffey
  - Research program broadly-based across ecological issues (e.g., effects of UV-B, toxicants, GEMS, and human development on forests, crops, and wetlands).
  - Found QA to be most effective with top management support and when it is involved before, during, and after data collection.

- **U.S. EPA, Environmental Monitoring Systems Laboratory,**
  Research Triangle Park, NC - Bill Mitchell
  - Provide the materials, procedures, and QA services needed to document/assess the quality associated with the environmental monitoring of air, hazardous waste, and wet and dry deposition.
  - Philosophy is to combine R & D with simple common sense QA procedures relative to the critical measurements.

- **U.S. Geological Survey**
  Arvada, Colorado - Vic Janzer
  - Employs a staff of 120, the USGS processes 50,000 water samples/year from across all 50 states.
  - The QA unit is responsible for maintaining commitments from top to all field sampling people to achieve high data quality.

- **W.S. Flemming and Associates**
  Albany, NY - Jim Healy
  - Provides management, QA, and data management for the Mountain Cloud Chemistry Program.
  - At nine eastern U.S. and Canadian mountain sites measures physical, chemical, and general meteorological characteristics of clouds and atmospheric inputs to remote forest locations.

- **Research Triangle Institute**
  Research Triangle Park, NC - Jerry Koenig
  - A not-for-profit research organization of 1200 persons in engineering, math, survey, social, and environmental research projects focused on physical, chemical, and biological issues.
  - The QA staff developed a process for setting DQO's and applied it to their research projects.

- **Technology Resources, Inc.**
  Washington, DC - Jerry Filbin
  - A consulting firm specializing in environmental survey and monitoring projects (e.g., Maryland Synoptic Stream Chemistry Survey).
  - Developed a computer program, QCIC, to standardize and automate routine management and examination of analytical chemistry data.

- **Weyerhaeuser Testing Center**
  Tacoma, Washington - Kari Doxsee
  - A laboratory for analyzing samples from wood products, soils, plant tissues, fuels, and a broad array of environmental projects.
  - Uses standard QA/QC practices to produce quality data in a non-threatening manner which fits the needs of clients.

Five additional organizations expressed high interest in the workshop. Unfortunately, their representatives were unable to attend because of scheduling conflicts. These were:

- **U.S.D.I. National Park Service**, - Darcy Rutkowski
- **U.S. EPA, GLP Program** - John McCann
- **Research Evaluation Associates**, - Richard Trowp
- **Desert Research Institute,** - John Watson
- **Wildlife International**, - Hank Krueger

Section 2

QUALITY ASSURANCE ISSUES

2.1.1 Adapting Quality Assurance to Ecological Research

Paper by:

I. K. Morrison, Canadian Forestry Service, Sault Ste. Marie, Ontario, Canada

Introduction

Quality assurance (QA) and quality control (QC) are common to a wide range of pursuits from manufacturing to monitoring to research. In manufacturing, emphasis is placed on process and product quality control, with exacting requirements for accuracy and precision. This is especially the case when mass producing a product.

Environmental monitoring adapted many industrial QC concepts for mass collection of data (over time and/or space). Features of both situations generally include: (1) thoughtful objective setting, (2) establishment of measurable markers, (3) careful selection and thorough and lucid documentation of methods, (4) faithful attention to detail in implementation, (5) rigorous auditing, and (6) timely feedback leading to any required corrective action. The system organizing these activities was named "QA". The most recent challenge is the adaptation of QA to research, specifically ecological research. This paper addresses the issues at stake in making such an adaption.

Ecological research studies the relationship of living organisms or groups (populations or communities) of organisms to their environment. Processes within the scope of ecology vary widely in space and time, from small process occurring over short time intervals to processes involving major segments of the ecosphere and occurring over extended time periods. The "ecology" we presumably must address from a QA perspective is the latter, as it frequently involves large numbers of individuals, and continuity often must be maintained over long periods of time. This represents special challenges to QA.

Challenges

All research, ecological or otherwise, must conform to acceptable standards. This discussion is based on the special obstacles to environmental problem-solving which result from studying processes at the ecosystem level. Specifically, these are: (1) the evolution of issues and re-ordering of objectives over the time scale of research, (2) constraints on design, particularly on experimentation, (3) the need for comparability, (4) the need for continuity, (5) the availability of research techniques, and (6) natural variability.

Evolving Issues - A number of environmental issues have surfaced over the past decade, evoking scientific (and popular) concern. These issues have pointed out general deficiencies in our current knowledge of ecological processes, particularly how such processes inter-relate. In addition, issues frequently evolve over the time scale necessary for environmental research. For example, the (purported) impact of regional air pollutants was initially concerned mainly with "acid rain". Later, the issue was taken to include both "acid rain" and other air pollutants (chiefly ozone). Now, it is focused on "forest decline" in general, possibly occurring in response to a mix of stress-inducing factors including, but not limited to, the above pollutants. These other stress factors include: (1) climatic stresses (chiefly winter damage, late or early frost damage, and summer drought), (2) insect or disease attack, and (3) poor management.

In general, however, tree health and tree growth are the central issues with respect to effects of air pollutants or any other stress-inducing factor on forest ecosystems. Thus, to reach an ultimate resolution, forest growth reduction (or stimulation) and causal relationships need to be unequivocally demonstrated. Furthermore, forestry values at risk are primarily economic; these need to be in readily convertible to units of timber measure.

Design Constraints - Various research methods are employed in ecological research: experimentation, correlation, surveys, and monitoring. In most research, traditional factorial experimentation does not usually pose major problems. Hypotheses can be framed and tested, treatments can be applied and adequately replicated, and the research can proceed. However, some ecological research does face unique space and/or time problems. For example, the relationship of any type of forest to any one or combination of air pollutants could presumably be characterized by a dose-response relationship. But mature forests tend not to lend themselves to direct factorial experimentation without either being unacceptably artificial or unacceptably confounded. Also, comparing or contrasting processes in similar forests in zones of different pollutant loading tends to be confounded by differences in climate, geology, and soils. Though variation can often be statistically accounted for by study design and by replication on a smaller scale, the costs of replicating whole-ecosystem studies is often a major consideration. Finally, pollutant loadings (in eastern North America) tend to vary along the same gradient as climate.

Need for Comparability - If research activities forming part of an integrated program are carried out at different locations and by different personnel, some basis of comparison must be included. This implies a need for at least minimum standardization. Areas where some degree of standardization has been achieved or where standardization could be considered included: (1) assessments of tree health, (2) measurements of forest or tree growth, (3) various climatic measurements, (4) sampling and chemical analysis of foliar tissues, and (5) soils descriptions, sampling, and analysis.

Need for Continuity - Fixed reference points are necessary if research or monitoring is extended over long time periods as in 'baseline' or 'set-the-clock' type studies. However, changes in technology over time should be considered. While methodologies or equipment can be resurrected, there is often a reluctance on the part of scientists to accept obsolete methods or old data, which can cast some doubt on the utility of studies. Maintenance of samples and standards over time may help, though there are considerations of long term stability.

Availability of Techniques - Despite the advance of technology over the past several decades, there does not appear to have been a commensurately large increase in the number of techniques or tools available to the field-ecologist for efficient, accurate and precise measurements (e.g., forest productivity). Physiological measures such as CO_2 or H_2O exchange offer possibilities, though currently they tend to fall within the domain of research, and some standardization is in place.

Chemical analysis of plant parts attracts interest. In forestry, most plant analysis for diagnostic use involves the determination of total concentrations (usually w/w) of various macro-elements (N, P, K, Ca, Mg, S), micro-elements (Fe, Mn, B, Zn, Cu, Mo, Cl), or other inorganic elements (e.g. Na, Al, Ni, Cd, Pb, etc.) in dried foliage. However, buds, bark, inner bark, xylem sap, and fine roots have all been used. The object is usually to relate internal concentration to some external (environmental) variable. Various interpretive techniques have been advanced, including the establishment of 'critical levels', the use of various ratios and proportions, limiting factors analysis, vector analysis, and DRIS (diagnosis and recommendation integrated system). Foliage analysis derives its predictive ability from the goodness of correlation between analytical results and environmental measurements. Even when standardized, the necessary empirical relationships have not always been apparent.

Soils analysis, as currently used in forestry, is largely borrowed from agricultural usage. Like foliage analysis, soils tests presumably derive their predictive ability from the goodness of correlation of analytical results with some measure of tree response. Unlike foliage analysis (in which total concentrations are usually determined), most soils tests extract particular fractions, often purported to be 'available' or 'exchangeable' forms. Empirical relationships are often species-specific and for regional application. Only in a few instances have empirical relationships been derived for natural trees.

Natural Variability - Variability is usually controlled experimentally or is accommodated statistically by replication or stratification. The approach is normally dictated by the study objective. Ecology tends to focus at the population, community, or ecosystem level, or, for practical purposes, on trees, stands of trees, forest types, forest associations, etc. On soils, the focus is frequently at the series level or higher. Studies therefore tend to be concerned with stand-to-stand, species-to-species, forest type-to-forest type differences. This leaves the variability to be accounted for at the within-tree, tree-to-tree or plot-to-plot levels.

For growth studies, tree dimensions of interest generally include diameter at breast height (DBH), total height, form class, etc. Individual tree growth is usually estimated in terms of diameter or height increment, or change of form class. Stand dimensions are normally expressed in terms of stemwood volume (total or merchantable) or in terms of dry weight (biomass or phytomass). Stand growth on a per area basis is usually expressed in terms of mean annual increment (MAI), net periodic or current annual increment, gross periodic or current annual increment, or (in ecological terms) net primary production. Conventions exist for all of these. If data are available, the number of trees or plots necessary to bring standard errors within acceptable limits can be readily calculated.

Sampling, on the other hand, is not well-standardized even though it generally outweighs analytical error. In addition to stand-to-stand and species-to-species variation, there is within-tree and between-tree variation to be taken into account. The main sources of within-tree variation (which may vary among elements) include: (1) position in the crown, (2) variation through the season, (3) difference of needle age for conifers, and (4) sun versus shade leaves for hardwoods. Aspect may also be important. Most authorities tend to favor sampling during periods when concentrations are stable (generally late in the growing season but prior to leaf coloration for hardwoods, or during the dormant season for conifers). However, some have suggested sampling during the period of leaf expansion when plants are physiologically more active (but, this presents some practical difficulties). Within tree variation generally lends itself to stratification. Some between-tree variation may be eliminated by stratification (e.g., restricting sampling to trees of certain sizes or crown classes). At present, however, accommodating for between-tree variation is mainly approached through replication. Again, if data are available, the number of samples needed to bring the standard error to within acceptable limits (generally for the most variable parameter) can be calculated. However, precisely sampling a required large numbers of large trees can be a significant problem.

Soils properties, including physical and chemical properties, vary both horizontally and vertically, and to some extent, temporally (in response to processes such as microbial activity, tree uptake, leaching, etc). Vertical and temporal variability can be reduced, somewhat, through stratified sampling and standardization of technique; horizontal variation can be reduced somewhat by replication. Again, the required number of samples can be calculated, but may be prohibitively large. For other sampling (e.g., litter, precipitation, throughfall, or leachate), locating sites is usually study-specific and the number of collectors can be calculated as above.

Summary

The aforementioned subjects (the evolution of issues, design constraints, etc.) are some of the obstacles to solving environmental problems through ecological research. All have data quality implications; data quality would be improved through better issues identification, better study designs, more precise and accurate methods, continuity and comparability, and accommodating natural variability. The task before us is to adapt existing QA concepts to ecological research to promote these concepts.

2.1.2 Workshop Discussions

Dr. Ian Morrison presented his paper to set the stage for the first discussion session. Based upon his long experience and lucid thinking in forest ecology research, Dr. Morrison's talk stimulated the group to rethink some important basic QA issues as a prelude to reviewing QA applications to ecological research.

For example, what is the basic definition of QA? It is not in the common reference lexicons. Without getting out the text books, these thoughts emerged at the workshop:

- QA is a system whereby we define in a general way how to quantify what we are interested in.
- It is: a) what we do to be sure what we do is technically sound and legally defensible; b) up front rules or procedures to follow in monitoring; c) in research, not a system which drives methodology -- rather some research must come first to lay the foundation for QA; and d) set forth in a QA plan and in research the plan keeps changing (i.e., QA evolves).
- Quality data requires documentation of what was done; thus, the philosophy of QA is partly dependent upon documentation of each data collection step.
- Conventionally, we thought QA began with taking and handling a sample; Canadians developed the idea of starting with work plan development and following through to and including the scientific report. This concept is called quality management (QM) in science.
- More definitions of QA and associated terms are presented in Robarge's paper (Section 2.2.1).

Also, what is quality?

- We judge quality by the lack of quality or departure from a norm or defects that will or will not be tolerated.
- A value judgement that QA does not define, but rather depends upon others to establish first (i.e., a kind of model).

Where does QA fit in science?

- Basically, QA is a component of science.
- Science has to be allowed to proceed.

- The value of QA activities are to ensure that: a) a scientist can defend his/her work through a system of documenting and correcting errors; and b) what the scientist does meets the needs of the policy-maker.

QA has a narrow task and a broad task as reflected in the activities described in a and b above.

- Through early involvement at the planning phase QA can guide the data quality objectives (DQOs).

- In research, QA involvement depends on the research to be undertaken -- in leading edge research, QA people are often following the advice of the scientist.

- An effective QA program is dependent upon good communications among key managers, scientists, technicians, and QA personnel.

Levels of QA implementation - Quality Management vs. Quality Assurance vs. Quality Control?

- There are these three levels at which data quality can be managed. The appropriateness and utility of each needs to be considered as new programs or projects are established. The activities associated with each were discussed.

- Quality Management: (1) focuses on ensuring data meets the needs of the users and that the policy questions driving the program are clearly formulated, (2) is a system which provides oversight and leaves the participating scientists to determine how QA and QC will be addressed.

- The role of Quality Assurance is following the development of succinct policy goals and ensuring data is collected in a sound manner. QA activities have developed largely from other disciplines (e.g. chemistry and air monitoring) so its adaptation to ecological research is developing without guidance. Checks on many ecological variables are not available; they are being developed to check the process but this is still an imperfect system. QA in ecological fields faces cross-media complexities. To provide continuity for long-term ecological research one should bank samples (e.g. tissue, aqueous, soils, remotely sensed imagery) so future comparisons are possible when methods have been refined. New vs. old data must be assessed to minimize loss of current activities.

- Quality Control is the nuts and bolts of quantifying the precision and accuracy at the project level.

2.2.1 Comparability Studies

Paper by:

Wayne P. Robarge, N.C. State University, Department of Soil Science, Raleigh, NC

Introduction

This issues paper focuses on: (1) defining comparability and models, (2) some examples of how comparability studies can be implemented, (3) the use of comparability studies, and (4) questions for discussion on the need for comparability studies in ecological research. Please note the distinction between the term "comparability" and the subject area of the discussion group ("comparability studies in ecological research"). This paper is not intended to be a detailed document on how to carry out comparability studies among analytical laboratories. Such information is readily available in published books and the peer reviewed literature. Rather, this document and the workshop were intended to develop a better understanding of how to design, implement, and use results from comparability studies in ecological research to improve the data quality. Therefore, the terms and definitions cited in this document serve only as a basis for further discussion.

COMPARABILITY AND DEVELOPING MODELS

Comparability is one of five data quality indicators required in the EPA's interim guidelines for preparing quality assurance project plans. Comparability can be defined as the confidence with which one data set can be compared to another. A data set can refer to small sets of data generated by a single technician comparing two analytical techniques, or to an extensive database covering several disciplines that serves as a baseline to measure long-term changes in an ecosystem. Regardless of the scale at which the comparisons are made, they will require establishment of suitable confidence limits prior to acquisition of the data. This is most effectively accomplished through the use of a model.

A model is an idealized representation of an often complex reality. Models attempt to bring together, among other things, prior knowledge, hypotheses, and assumptions concerning the phenomena or the system under investigation. Development of a correct model (or models) leads to the quality of data that will be necessary to provide the information required. This in turn can be used to develop a set of data quality objectives for the proposed project.

This approach does not have analytical methodology as its central focus. Rather, selecting a particular analytical technique and associated QA follows from: (1) a detailed consideration of the problems to be solved, and (2) a conscientious decision regarding the quality of data required to reach a satisfactory solution. Comparability then is not an addition to an experimental plan, but an integral part of the planned research. It requires input from both the project leader and the agency receiving the final data set. These two groups need to decide on the quality of collected data required for their particular needs. Topics that need to be addressed concerning comparability among data sets are covered below.

IMPLEMENTATION OF COMPARABILITY STUDIES

Stating a given confidence level for a particular data set implies knowledge of the precision, accuracy (bias), and representativeness of the data. The following is a listing of the general ways in which this information is obtained. This listing, however, should only be used as an example of ways to implement comparability studies. It is important to the success of this workshop to not allow the terminology and concepts often associated with analytical chemical methodology from dominating our discussions regarding ways to implement comparability studies in ecological research.

Sampling Design - The importance of sampling is well understood by most researchers and is the subject of numerous monographs. Perhaps of most concern to QA are what populations are actually being sampled in ecological studies and what assumptions can be made regarding population distributions. Random sampling is usually the answer to such questions, but the basis for this is more from statistical concepts underlying the experimental design than an appreciation for the distribution of the samples. Many parameters are spatially and temporally related in ecological systems, thus strict adherence to random sampling may lead to sampling numbers larger than necessary in order to obtain a valid conclusion. Alternative sampling strategies are available but require a least some information about the parameter of interest before they can be applied successfully.

Reference Sample Exchanges - A reference material is a substance that has been characterized sufficiently well so that its composition or related physical property has a certified value of known accuracy. The chief role of reference samples is to evaluate the accuracy of calibration standards for a particular analytical instrument or complete measurement process. Note that this does not necessarily mean that actual sample accuracy can be measured using a reference material. The latter can only be approximated when the matrices of the reference material and samples are similar. The obvious drawback to the use of reference materials is the lack of suitable, stable substances that match all possible sample populations likely to be encountered in ecological research. As the similarity in matrices diminishes, the role of a reference material in assessing comparability is reduced.

Audit/Exchange Samples - Sample exchanges of non-certified material that approximates the matrix of the sample population provides a means of determining relative accuracy in a data set. Such estimates may be methodology dependent and may yield results with substantial unknown bias that could limit comparisons between data sets. Many measurements made in ecological research are related to specific biological processes. In other words, they only have meaning when combined with another data set. Audit or exchange samples, therefore, provide more useful information regarding precision within a given data set than yielding estimates of accuracy or bias.

QC Check Samples - Also known as in-house controls, these samples are necessary for monitoring quality control and estimating precision within a data set. Their use, however, is limited to methodologies where repeated measurements can be made from sample matrices whose composition for the parameter of interest does not change markedly as a function of time. For biological or physio-chemical processes that are changing with time, use of in-house controls will not be possible or will be restricted to portions of a methodology which are relatively independent of time.

Methodology Comparisons - Adopting a set of methods as standard operating procedures is a necessary step in developing a QA plan and is fundamental to providing estimates of precision and bias in a data set. Selection of a particular method is a function of the data output desired and its cost. When suitable reference materials are present, comparison of methods is straightforward. Lack of a suitable reference material dictates the use of other approaches, such as: (1) the use of spiked samples and surrogates, (2) analysis of analogous reference materials, or (3) a comparison of the selected methodology to a method that is accepted as a standard but is too expensive to perform on a routine basis. All three of these approaches are capable of estimating quality providing the assumptions involved with each are satisfied for any given situation.

Use of methodology comparisons in ecological research, however, may suffer the same limitations as outlined for audit and exchange samples. Many methods in ecological research are designed as an attempt to quantify different biological or physical processes which are essentially in a constant state of change. The method being attempted is based to some degree on physical, chemical, or biological principles, but there is no way to determine what is the right answer. For example, measuring dry deposition to a forest canopy produces an estimate which is based on current technology and an understanding of deposition processes. Attempting to assign accuracy and precision estimates to such methods will require a different approach than that used with common analytical procedures.

Equipment Comparisons - Equipment comparison between analytical instrumentation assumes that the same sample matrix can be introduced into each instrument being tested. If this condition is met, then such comparisons provide estimates of bias in the data set introduced by the use of a given instrument. Such comparisons are definitely in order for contributing to the comparability of a data set.

The application of equipment comparisons to non-analytical instrumentation, such as exposure chambers (e.g. CSTRs vs. Open-Tops vs. field studies) poses a different set of questions. It might be argued that such a comparison is not valid and should not be addressed under the category of quality control. This argument might be valid if the treatments used in these chamber studies produced a response that followed a continuous function and was unique upon exposure to the test substance. This is generally not the case. Also, documentation of a response within a controlled chamber does not constitute a direct link to similar processes occurring in the field. If the effect of a given substance is a function of several environmental variables, then the response to different concentrations of this substance in the environment will follow a response surface and not a simple function. Thus, the location of a damage response on the response surface is observed in the field versus observations of damage in controlled chambers is a measure of bias in the data generated from such experiments.

Comparison between non-analytical instrumentation also serves to delineate problems with treatment precision within a given design, and how this may influence interpretation of the results. Unlike analytical instrumentation, where the x-variable can generally be assumed to be error-free, there may be a substantial amount of uncertainty in the actual treatment concentrations present during an experiment. Failure to account for the uncertainty in the x-axis may result in a bias in the final interpretation of the data and the type of response function assumed to be present. Comparison with chambers specifically designed to control precision of the treatment concentration would be one way to determine the presence of such bias in the data set.

USE OF COMPARABILITY STUDIES

Because of the way comparability is defined, it is necessary to speak of the use of comparability studies at two different levels. On the one hand, output from a comparability study could be used to address selected topics for a specific data set produced by a particular project. The rate of output would essentially match that of the main project. To a large extent this is the manner in which most comparability studies are currently defined and executed. As pointed out above, however, comparability should be considered an integral part of the development of a model for a given research project. It would follow then, that questions raised by addressing the comparability of the projected data set will require solutions before a project can be successfully carried out. Such questions may be beyond the scope of the planned project(s) and require separate investigations to arrive at a satisfactory answer. The output from these comparability studies would be used to plan future research projects.

COMPARABILITY IN MONITORING

Following are topics that should be addressed to show comparability of data sets from different monitoring programs:

(1) how sampling stations or sites in each network are sited. Ideally, each network has the same probability of collecting a representative sample (for example, sites are selected to detect maximum values or values representative of an area or volume?);

(2) how the same variables (analytes) measured in each program are reported in the same units and corrected to the same standard conditions. If not, provide a mathematical or gravimetric relation between variables;

(3) how procedures and methods for collection and analysis of any particular observable phenomenon are the same among networks. If not, provide a mathematical relation;

(4) how data quality is established and how there will be sufficient documentation of audits and DQOs to determine data adequacy;

(5) how, in terms of accuracy and precision, data for one observable phenomenon, measured by one method or equivalent methods, can be combined or compared in a statistically defensible manner among programs.

2.2.2 Workshop Discussions

Discussions centered around Dr. Wayne Robarge's paper and presentation on comparability studies generated the most controversy and disagreement. Interestingly, it was not the thoroughly prepared overview of implementing comparability in ecological research that was the concern, but the semantics of this aspect of data quality. Several questions were presented for discussion. Following is a summary of the participants response.

Is it possible to draw a distinction between comparability and comparability studies?

- The consensus was no. Comparability is one of several quality descriptors applied to a body of numerical information.

- Comparability studies are the means of determining the information necessary to state the degree of confidence with which one data set can be compared to another.

- Even identifying how comparable different data sets are that use the same methodology is difficult. We are just beginning to identify the components that contribute to variability when different methodologies are used.

What is the difference between comparability studies and calibration studies?

- This was not resolved.

PROGRAM	METHOD	
	SAME METHOD	DIFFERENT METHODS
WITHIN	1*	2
BETWEEN	3	4

*Complexity increases from 1 to 4

Can comparability studies be defined as a separate entity from a research program?

- No. This type of study is only pertinent when defined within the scope of all data quality descriptors for that research.

Does reference to comparability studies in ecological research really imply the need for the development of better or alternative methodologies to study ecological processes?

- o Selecting a specific methodology to be used in a research project is then reflected in the body of numerical information to be produced. Comparability studies allow for the determination of overall error variance in the method selected. If this error variance exceeds the data quality objectives set for the research program, then these objectives need to be re-evaluated or a different methodology selected.

- o Comparability studies in ecological research reflect the heterogeneity of methods in ecological research. They are very important indicators that no one method has proven itself above all others in certain fields. Also, comparability studies help to determine which methods are better.

Is there too much emphasis on numerical accuracy in ecological research?

- o The participants agreed that the answer to this question directly depends on the data quality objectives set for a given research project. It is more than likely that too much emphasis is being given to numerical accuracy for many methods currently used in ecological studies, especially those comparing data sets from different ecosystems or regions of the country.

- o More emphasis should be placed on using comparable interpretations of such data sets, rather than the data itself.

Does ecological research require the development of a different set of quality assurance and quality control criteria (i.e. different from those developed for monitoring and analytical chemistry)?

- o No. The QA/QC criteria for a given research project is a direct function of the specific data quality objectives for the variables of concern. The biggest difference is the basis of QA for research on relative vs. absolute accuracy. Knowledge about accuracy for many variables exists only as estimates for research. Whereas in monitoring programs, specific accuracy on monitoring is available.

- o For both research and monitoring programs, data quality objectives must be based on cost-effective considerations established with realistic needs of the problem and the capability of the measurement process.

- Data quality objectives should not be confused with accuracy and precision limits set for individual analytical techniques.

Does the propagation of error set finite limits on the quality of data that can be produced with the current experimental designs used for research projects?

- This question pertains more to the representativeness of a body of numerical information and was not addressed during the workshop. It does, however, pertain to the capability of a particular measurement process to produce data of sufficient quality to solve the problem at hand.

What role should models or modeling play in setting quality assurance guidelines in ecological research?

- Simulation models should be used whenever data bases already exist that are applicable to the questions at hand. Such models could be very useful in setting priority areas within a research project requiring comparability studies.

Is the quality assurance data being generated really being used by funding agencies?

- Yes. However, it is apparent that in the future more emphasis should be given at the data quality management level in establishing well defined data quality objectives for ecological research, especially for programs dealing with long term ecological monitoring. These objectives are the basis for implementing QA/QC programs. The resulting QA/QC program should provide direct feedback in terms of the quality of data being produced and whether such data will be useful in solving the problems to be addressed.

2.3.1 Quality Control Data

Paper by:

John K. Taylor, Gaithersburg, MD

Introduction

Almost everyone will agree that data which is used for decisions must be of sufficient accuracy for the specific application. Otherwise, the decisions based on its use can have limited, if any, value. Yet, the absolute accuracy of data can never be known. The only thing that can be known is a reasonable estimate of the limits of its inaccuracy. Modern measurement practices, based on sound quality assurance concepts, can provide a statistical basis for the assignment of limits of uncertainty. The following discussion reviews the techniques that have been found to be most useful for providing a statistical basis for the evaluation of data quality.

Reliable data must be produced by an analytical system in a state of statistical control. The analytical system, in its broadest concept, includes the sampling system, the measurement process, the calibration process, and the data handling procedures. The sampling system includes the sampling operations, the transport and storage of samples, and any sub-sampling operations that are required. The system must provide reproducible samples that do not undergo any changes compromising their use.

The measurement process must be capable of meeting the data quality objectives with respect to its accuracy, selectivity, and sensitivity. Measurements must be operated in a state of statistical control, which means it must be stabilized and its output statistically definable. The calibration system must be adequate and operate in a state of statistical control.

Appropriate quality control procedures should be developed and applied to attain and maintain statistical control of the above operations. Quality assessment techniques are applied to verify statistical control and to evaluate the quality of the various outputs. The remaining discussion deals with several aspects of the use of quality assessment samples (often called quality control samples) to evaluate analytical operations and the data produced by them.

EVALUATION SAMPLES

Evaluation samples describe any material used in the evaluation of an analytical system and its data outputs. Regardless of the kinds of samples used, they must be of unquestionable integrity. This includes their homogeneity in every case and the accuracy of their characterization when used for accuracy evaluation. Samples should be available in sufficient quantity, including periodic re-evaluations and/or analyses at the conclusion of the measurement program. It is of utmost importance that evaluation samples have as close a correspondence as possible to natural samples, since the data will be used to evaluate the performance of the analytical system when measuring natural samples.

Variability Samples - Samples may be measured to evaluate the attainment and maintenance of statistical control and the variability of the measurement process. Analysis can include replicate measurement of some natural samples as well as samples especially introduced into the measurement program to evaluate these parameters. Natural samples have the advantage that they truly represent the natural samples, but they can introduce uncertainties due to homogeneity considerations. Samples of known composition may be used to evaluate variability as well as accuracy, but this may consume larger quantities of such samples than may be desirable. Replicate measurements of natural samples are superior evaluators of precision, but such measurements can be used only for precision. Accuracy estimates must be made using other techniques.

Accuracy Samples - Samples of known composition must be used to evaluate accuracy. Examples of such samples are, in order of reliability:

1) Reference Materials- samples of matrix and analyte level closely analogous to natural samples. They need to be stable and homogeneous, with thoroughly characterized analyte levels. In some cases, it may be difficult to meet these needs.

2) Spikes/Surrogates- natural matrix samples spiked with analyte of interest or a surrogate at appropriate levels. The main objection is the question of analogy to naturally incorporated analyte. Alternately, a benign matrix (e.g. distilled water) spiked as above may be useful, but only for truly matrix-independent methodology.

3) Independent Measurement- not truly a sample, this involves the comparison measurement of a sufficient number of natural samples by a second reference technique.

Blanks - Blanks are a special class of evaluation samples. Sampling blanks of various kinds are used to verify that sample contamination is insignificant or to quantitatively evaluate its magnitude. Blanks are also used to evaluate artifactual contributions of the analytical process resulting from the use of reagents, solvents, and chemical operations. When used for yes/no decisions, the number of blanks required can be smaller than when quantitative estimates are of concern. Indiscriminate and arbitrary schedules for blanks can be counterproductive, since their measurement can be of little value and consume valuable resources that may be better diverted to measurement of natural samples.

Instrument Response Samples - Special samples may be used to monitor certain aspects of the outputs of instruments such as response factors, for example. These should not be confused with other kinds of quality assessment samples that are designed to monitor the total output of the analytical process.

Synthesized evaluation samples may appear to have some advantage when they can be more accurately compounded than analyzed. However, homogeneity considerations and questions of analogy can override this apparent advantage. It is virtually impossible to homogenize spiked solid samples; they may need to be individually prepared and used in their entirety. The accuracy attained in preparing evaluation samples cannot be assumed, but must be experimentally demonstrated. Ordinarily, the accuracy of certified values should exceed that required for the data by a factor of 3 or greater.

Another kind of evaluation sample, not often considered as such, is a calibration evaluation sample. There are two types of calibration samples: those to evaluate maintenance of calibration, and those to verify that the production of calibration samples is reproducible. The first consists of remeasuring an intermediate calibration point at selected intervals during the measurement program. The second consists of a simple analysis of variance in which samples are prepared and measured in replicate to estimate both precision of their measurement and precision of their production. The accuracy of calibration is evaluated on the basis of analysis of all sources of bias in their preparation and the precision with which they can be prepared.

When using reference materials, the overall evaluation of the calibration process is involved in the overall evaluation of accuracy. If biases are found, the first place to look to identify their cause is in the calibration process. And finally, the appropriateness of the calibration procedure used must be verified initially and throughout a measurement program.

Accuracy can be evaluated using a reference laboratory to measure a sufficient number of split samples. The participating laboratories evaluate their own precision and measure a few reference samples, but the bulk of the accuracy assessment is based on comparison of results with those of the reference laboratory.

CONTROL CHARTS

The results of evaluation sample measurements are best interpreted by use of control charts. In doing so, a single measurement at any time is related to a body of control data and becomes meaningful. Otherwise, a number of replicate measurements must be made each time an evaluation is undertaken. The accumulation of control data via control charts increases the degrees of freedom for the statistical estimates and minimizes the amount of effort to assure measurement quality. Control charts also can be very useful for the evaluation of the precision and bias of the measurement process.

FREQUENCY OF QA SAMPLE MEASUREMENT

The frequency of QA sample measurement will depend on the stability of the analytical system, the criticality of the data, and the risk associated with being out-of-control. In principle, all data during the interval from last known "in control" to first known "out of control" is suspect and may need to be discarded. Such situations should be avoided to minimize the resulting loss of data and programmatic costs.

For a well understood and stable system, devotion of 5 to 10 percent of the total effort to quality assessment may be sufficient and is not a large cost. For small operations, as much as 50 percent QA may be required. For very critical data, the ratio may be as high as 95 percent QA to 5 percent natural samples.

Some steps in the measurement program may be adjusted to minimize the amount of overall evaluation (i.e., the QA samples). Readjustment of calibration intervals may be an example of this. Careful attention to blank control, sample preparation steps, and chemical processing are other areas for better control. Anything that can be done to improve quality control generally will minimize the QA effort.

SOURCE OF CONTROL

The bulk of quality control and quality assessment must be done at the laboratory, and even at the bench level. Checks are required at the supervisory level, but less frequently. Checks need to be made at higher levels as is necessary, but are generally needed at a decreasing frequency as the level of analysis is removed from the source of data production. A monitoring director far removed from the scene of action can only evaluate what was done; the bench can evaluate what is being done. Each level must engender the respect and earn the trust of every higher level.

This can only happen when there is a mutual understanding of the goals and delegated responsibility for the quality at each level.

Every time that a sample is handled, there is a chance for contamination or loss. This increases the need for all kinds of blanks and check samples. Accordingly, sample handling should be minimized as possible.

DATA CONTROL

Data control consists largely of minimizing random errors, to the point of virtual elimination. Such errors are different from measurement errors and may be called by the undignified title of "blunders". Blunders have a better chance of elimination than any other kinds of error and are best identified and controlled by inspection.

UNCERTAINTY EVALUATION

Uncertainty around measured values is estimated based on measurements of materials assumed to be similar to natural samples. A further assumption is that the analytical system is in statistical control at all times. The estimation process is as follows:

1) Measure a reference sample.
2) Use a t-test to decide significant differences.

2a) If insignificant, conclude that measurement is unbiased. Assign limits of uncertainty based on the confidence interval for the mean.
2b) If significant, conclude that the measurement is biased. Try to identify the cause(s) of bias. Eliminate source(s) of bias as possible. Correct data only if validity of correction process can be proved.

In either case, the decision relates to a particular test which generally will need to be reproducible. Good measurement practice dictates that an analytical system should be continually monitored to verify decisions and evaluate quantitative relationships. The control chart approach is an excellent way to accomplish both objectives. The central line of the control chart becomes the best estimate of the limiting mean of the measurement process and for evaluation of bias. The control limits become the best estimate of the precision of measurement.

MEASUREMENTS USING EMPIRICAL METHODS

In some measurement programs, the value of a parameter is defined empirically by the method of measurement. In such cases, the accuracy is synonymous with the precision of measurement. However, one cannot discount that both observer and instrument bias can enter measurement data. Collaborative testing programs can identify such problems when the programs are properly designed and executed. It may be possible to develop a "standard test instrument". Collaborative tests of any parameter involving unstable test samples (ozone for example) may require that all participants assemble in the same area and measure a local, homogeneous sample (even the same sample if possible) to minimize the effect of sample uncertainty.

DATA QUALITY OBJECTIVES

DQOs should reflect realistic estimates of tolerable uncertainty about measurement data as related to a specific use. They should not be based on the perceived capability of the measurement system. Once known, the requisite capability of the analytical system can be estimated and the requirements for total limits of uncertainty, U_m, can be established. Clearly, U_m must be less than the DQOs to provide useful data.

Ideally, the ratio of DQO to U_m should be $\geq$ 10.
Practically, the ratio of DQO to U_m should be $\geq$ 3.

While U_m includes components due to sample and measurement, we will confine the following remarks to measurement. However, the basic concepts are applicable to all aspects of the analytical system.

Let: U_m = CI + bias (CI = confidence interval)

where:

CI = t s / n (n = n-size, s = std. dev., t = t-value)
bias = experimental bias + judgmental bias

Experimental bias is evaluated as mentioned above. It should represent the average of at least 7 independent estimates of the bias (e.g., x $\pm$ Certified Value). Judgmental bias is based on a bias budget that reflects contributions from the "lack of control" of known sources of bias for which quantitative relationships are known, and best estimates of limits from unevaluated sources. In setting limits, and especially in correcting data, all of the above must be documented and the original uncorrected data should be accessible so that revisions can be made as appropriate. The following "Good Data Analysis Practices" are recommended for consideration in this regard:

1. Bias identification is diagnostic but not a calibration process.

2. Bias identification is not bias evaluation but only a yes-no decision. Bias evaluation is a quantitative process and requires extensive quantitative measurement.

3. Never correct for a bias without understanding its origin.

4. Evaluation of bias over the entire measurement range (at least at 3 levels such as low, intermediate, and high) is necessary though not sufficient to understand the nature of existing bias and can be helpful to indicate ways to eliminate bias.

5. Ideally, eliminate bias at its source.

6. Development and consideration of a bias budget is a helpful first step in the elimination of bias.

7. In most cases, reference materials should be considered as diagnostic tools, and not as calibration items, in most cases.

8. Data evaluation is an on-going process that must be pursued systematically and consistently. Any procedure that is implemented should be reviewed for its utility and revised as necessary to be most effective. The measurement of control samples is costly and must be cost-effective.

9. Involvement of all levels of analytical input is needed to develop and implement a cost-effective data evaluation program. Quality assurance requirements that are imposed from "on high" can be misunderstood and meet with resistance. And sometimes they are not credible. Feed-back and the mutual development of remedial actions is necessary for realistic operation of a reliable analytical system.

10. Without statistical control, measurement data has no logical significance.

MANAGEMENT OF A QA PROGRAM

The quality assurance aspects of all measurement programs are essentially the same. Only the details differ, and these should be developed specifically for each program if they are to be of optimum value. When designing and managing a quality assurance program for a research or monitoring project, special emphasis should be given to such matters as:

1) The amount of effort devoted to quality assessment.
2) The kind of quality assessment samples to be measured.
3) The frequency of measurement of QA samples.
4) The amount of effort that should be carried on as part of a contract laboratory's internal program.
5) The amount of effort that,should be done using externally supplied materials and monitored externally.
6) How internal and external QA programs are to be coordinated.

The preceding discussion provides general guidance for considering these important matters. However, specific answers need to be developed, based on the precise nature of a given project. The following set of questions are presented for consideration by QA management when designing a program for a specific project.

1) What are the accuracy requirements for the data?
2) What kind of QA samples will be most effective for the research or monitoring that is contemplated?
3) What is the prior experience in use of QA samples for the project planned or for projects of a similar nature?
4) What is the relative reliability of natural matrix and synthetic QA samples?
5) What is the level of QA understanding of participants?
6) What role will blanks play?
7) What is the source of QA samples?
8) What are the accuracy requirements for the QA samples?
9) What will be done to establish the credibility of each QA sample used?
10) If QA samples are to be produced by a supplier, what will be the specifications that the samples must meet and how will compliance be evaluated?
11) What will be the feed-back loop for evaluation of the effectiveness of an initially implemented QA sample program?
12) What will be the relative frequencies of bench or laboratory QA samples?
13) Should a reference laboratory be used as an adjunct to, or in place of, some of the QA sample program?
14) How will each laboratory establish and monitor its establishment of statistical control?
15) What procedure will be used to establish initial competence in the methodology that is to be used?
16) What corrective actions should be taken in the event of unsatisfactory results on QA samples?
17) In the case of a long term project, would periodic meetings of participants be helpful in solving problems, improving accuracy, and promoting continuity of effort?

REFERENCE

The following reference by the present author discusses several of the above matters in more detail. Discussions of allied topics related to QA matters are also included.

John. K. Taylor "Quality Assurance of Chemical Measurements", Lewis Publishers, Inc. P.O.Drawer 519, Chelsea, MI 48118 (1987).

2.3.2 Workshop Discussions

A review of the subject of quality control data was lead by Dr. John Taylor. His expertise in this area and the thorough discussion provided in his issues paper initiated active discussion. Unlike the previous two areas addressed in the workshop, adapting QA to ecological research and comparability studies, the collection and evaluation of QC data has long standing historical precedent. The points raised and discussed by the participants are given below.

What determines the level of quality control data needed?

- Depends primarily on the intended use of the data.

What is the risk associated with being "out-of-control"?

- The measurement process used is the primary determinant; if one is dealing with a good measurement process then the level of QA needed drops as low as 5 percent of the effort is devoted to evaluating data quality (e.g. through quality control checks). If, however, the measurement process is poorly defined (or if it is a small operation) then as much as 20 percent (sometimes even up to 50 percent) of the effort will need to be spent on defining error and evaluating data quality.

What is the purpose of defining accuracy, a standard component of data quality objectives, in ecological research?

- Defining accuracy means that the true value of a variable can be identified. This is not possible in ecological research. The closest one can get is the identification of relative bias or by assigning limits of "uncertainty" to the data sets.

Quality control checks at the routine level are more important than periodic checks, such as are provided through audit or audit samples.

What is the definition and importance of bias in the analytical process?

- Bias is an error source which can be caused by a process, an operator, and/or a design. One of the most frequent mistakes made when dealing with QC data is the tendency to correct for bias without understanding the cause or origin of the bias.

- Bias needs to be evaluated across the whole range of the measurement process, this is important to identify the cause of bias in a process.

Some defining of QC samples was discussed.

- o Evaluation samples include every QA sample which is developed for a specific purpose; the strategy was identified in advance.

- o Variability samples are natural replicates.

- o Accuracy samples include: reference materials, spikes, blanks, and independent laboratory reanalysis.

What is an effective way to evaluate what type of QC data is needed in a measurement process?

- o All sources of error need to be identified. Determine which of those are controlled and which are uncontrolled.

What are the aspects of QC data which need to be considered when establishing an ecologically based research program?

- o Managers need to define what level of effort should be devoted to QA/QC by clearly identifying the goals of the program.

- o The type of QC checks needed can be evaluated, then the number of samples will be dependent upon size and complexity.

- o Internal and external QC should be coordinated to minimize the cost and to maximize the benefit.

Statistical control is often underemphasized in QA/QC programs.

- o One of the primary functions of QC data is to attain and maintain statistical control, which includes the measurement process, the sampling system, the calibration process, and the data custody and management.

- o All portions of the QA process need to focus on statistical control.

Section 3

Conclusions and Future Challenges

The workshop provided a unique opportunity to exchange ideas and expertise gathered in a wide variety of programs addressing QA implementation in ecological research and environmental monitoring. Consensus was reached in several areas. The involvement of quality assurance staff needs to be expanded to manage data quality to ensure these goals are realistic and achievable. Most programs that require data quality to be defined, overlook the importance of also clearly defining programmatic objectives. If QA is to be effective, both concerning cost and effort, then QA needs to be incorporated when programs are initiated.

General agreement leads to defining the components of QA as Quality Management, Quality Assurance, and Quality Control. These definitions are specific to the implementation of QA in ecological programs. Ecological research can be divided into two general areas: (a) monitoring and analysis of data, and (b) process oriented research. QA in environmental monitoring and data analysis is well established. We are in the process of expanding QA principles to apply to process-oriented research. It is important to include managing data quality in program administration and especially during its establishment. Also, the research team needs to be a part of the process that develops QC and to define areas of error and to determine if QA/QC activities are quantitative or qualitative.

The process of adapting QA to ecological science is just being established. The workshop participants identified five important activities in ecological QA implementation: documenting procedures, establishing inter-laboratory sample exchanges, developing methods to archive samples, conducting comparability studies, and, lastly, jointly training all of the project personnel who collect data.

QA has become increasingly complex. During the early years of this century QA became an important consideration in the industrial process. Then it was expanded to environmental monitoring and now to ecological research.

< 1950	1970 - 1980	1980 +
manufacturing	monitoring	research
organism	populations	ecoregions
single	several populations	multiples....
media, stresses, disciplines		
local	international	global

This has lead to expanding the definition and role of QA. New and not widely accepted are the ideas of expanding QA to be more innovative, to be responsive to public issues, and to ensure that policy makers' needs are clearly identified. To be effective QA needs to lose its negative association by gaining distance from its enforcement origins and becoming more innovative and flexible.

3.2 Workshop Critique

The following provides an overview of the recommendations which came from the Workshop:

1. Expand the involvement of QA to include management in addition to QA and QC, i.e. Quality Management or QM.

2. Define and/or explain the terminology under Quality Management, Quality Assurance, and Quality Control sufficiently to ensure they become a part of the scientific process.

3. Emphasize the need for a clear definition of the product required by management. Communication between quality assurance staff and program management must be a part of this task.

4. The general guidelines for conducting QA in ecological research include:

- document procedures
- foster opportunities for joint training
- establish inter-laboratory exchanges
- develop mechanisms for sample banking
- conduct comparability studies

5. Cooperate with the scientific community openly, thereby encouraging QA/QC by the scientists themselves. This will: (a) ensure their contribution, and (b) better identify important aspects of QA/QC.

6. QA needs to be a part of program and project conceptualization. Impetus to ensure QA is initiated early must come from managers of scientific programs, i.e. QM.

There were several areas where no consensus was reached. For example, a definition of data comparability was not reached though many aspects of collecting and analyzing QC data were discussed. Further discussions concerning adapting QA to ecological research were not definitive and need to be expanded.

3.3 Future Plans

It was the general recommendation of the participants that QA personnel hold annual workshops. The sponsorship could rotate to minimize the effort to any specific group. Workshop effectiveness would be enhanced by establishing small working groups to address priority issues within the areas of ecological monitoring and experimentation. The working groups should meet or have conference-call discussions early and then workshop time to respond to preliminary recommendations of the smaller groups.

Section 4

4.1 Workshop Agenda

NATIONAL
ECOLOGICAL QUALITY ASSURANCE WORKSHOP
March 29-31, 1988

Holiday Inn Downtown- Mariner
Denver, CO

Monday, March 28th (Glenarm Place)

7:00pm - 10:00pm Reception

Tuesday, March 29th (Cripple Creek Room)

9:00am Introductory Remarks, John Bailey

9:15 Program Overviews (15 minute presentations)
- Forest Response Program, Susan Medlarz
- Great Lakes Survey, Keijo Aspila
- Canadian Terr. Sample Exchange, Ian Morrison
- International Soil Sample Exchange, Craig Palmer

10:30 Break

10:45 Program Overviews (continued)
- NADP, Dave Bigelow
- Direct-Delayed Response Program, Lou Blume
- Watershed Manipulation Program, Heather Erickson
- Mountain Cloud Chemistry, Jim Healy
- Surface Water Surveys, Mark Silverstein

12:00 Lunch

2:00 Resume Program Overviews, Bob Mickler
- USEPA, QA Management Staff, Linda Kirkland
- USEPA ERL-Corvallis QA Program, Deborah Coffey
- USEPA EMSL-RTP QA Program, Bill Mitchell
- US Geologic Survey QA Programs, Vic Janzer
- USDI National Park Service, Darcy Rutkowski
- USFS Rocky Mtn. Station, Claudia Regan

3:30 Break

3:50 Program Overviews (continued, 10 minutes each)
- Research Triangle Institute, Jerry Koenig
- Research Evaluation Associates, Richard Trowp
- Desert Research Institute, John Watson
- Technology Resources, Inc., Jerry Filbin
- Weyerhaeuser Testing Center, Kari Doxsee

4:40 Adjourn for the day

NATIONAL ECOLOGICAL QA WORKSHOP (continued)
March 29-31, 1988

Wednesday, March 30th

8:30am Session 1: Adapting QA to Ecological Research
Discussion Leader: Ian Morrison
Facilitator: Steve Cline

12:00 Lunch

1:30 Session 2: Comparability Studies
Discussion Leader: Wayne Robarge
Facilitator: Bill Burkman

5:00 Adjourn for the day

(morning and afternoon break)

Thursday, March 31st

8:30am Session 3: Quality Control Data
Discussion Leader: John Taylor
Facilitator: Steve Byrne

12:00 Lunch

1:30 Future Challenges in Ecological QA, Jack Winjum

3:30 Adjourn

(morning break)

4.2 List of Attendees

*Paul A. Addison
Government of Canada
Canadian Forestry Service
Ottawa, Ontario, Canada
K1A 1G5
613/997-1107

Keijo I. Aspila
National Water Research Institute
867 Lakeshore Road
Burlington, Ontario L7R 4A6
Canada
416/336-4638

John Bailey
Corvallis Environmental Research Lab
200 SW 35th Street
Corvallis, OR 97333
503/420-4772

Cathy Banic
Environmental Applic. Group, Ltd.
6126 Yonge Street, 2nd floor
Willowdale, Ontario M2M 3W7
416/224-0701

Dave Bigelow
Grasslands Laboratory
Colorado State University
Fort Collins, CO 80521
303/491-5574

Louis J. Blume
U.S. EPA
Environmental Monitoring Systems Lab.
P.O. Box 93478
Las Vegas, NV 89193-3478
702/798-2213

Bill Burkman
Corvallis Environmental Research Lab
c/o USDA Forest Service, NEFES
370 Reed Road
Broomall, PA 19008
215/690-3122

Gerald Byers
Lockheed EMSCO
1050 East Flamingo Road
Las Vegas, NV 89119
702/734-3327

Steve Byrne
Corvallis Environmental Research Lab
c/o NCSU AIR Program
1509 Varsity Drive
Raleigh, NC 27606
919/737-3520

Steve Cline
Corvallis Environmental Research Lab
200 SW 35th Street
Corvallis, OR 97333
503/757-4724

Deborah Coffey
Northrop Services, Inc.
200 SW 35th Street
Corvallis, OR 97333
503/757-4666 ext. 323

A. Scott Denning
NPS/ NREL
Colorado State University
Fort Collins, Co 80523
303/491-1970

Kari Doxsee
Weyerhaeuser Company
WTC 2F25
Tacoma, WA 98477
206/924-6452

Heather Erickson
Corvallis Environmental Research Lab
200 Southwest 35th Street
Corvallis, OR 97333
503/757-4666 ext. 349

Jerry Filbin
Technical Resources, Inc.
3202 Monroe St.
Rockville, MD 20852
301/231-5250

Don Hart
Beak Consultants
14 Abacus Road
Brampton, Ontario, Canada
416/458-4044

Jim Healey
W. S. Fleming & Assoc., Inc.
55 Colvin Avenue
Albany, NY 12206
518/458-2249

*Dan Heggen
Exposure Assessment Res. Div.
EMSL-Las Vegas
P.O. Box 93478
Las Vegas, NV 89193-3478
FTS 545-2278

Victor Janzer
U.S. Geological Service
5293 Ward Road
Arvada, CO 80002
303/236-3612

Linda Kirkland
U.S. Environmental Protection Agency
RD-680
401 M. St., S.W.
Washington, DC 20460
202/382-5763

Donald E. King
Ontario Ministry of Environment
P.O. Box 213
Rexdale, Ontario, Canada
M9W 5L1
416/235-5838

Jerry Koenig
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709
919/541-6934

*Hank Kruegar, Director
Terrestrial Ecology Div.
Wildlife International Ltd.
305 Commerce Dr.
Easton, MD 21601
301/822-8600

John Lawrence
National Water Research Institute
867 Lakeshore Road
Burlington, Ontario, Canada
L7R 4A6
416/336-4638

Bernard Malo
U.S. Geological Survey, WRD
416 National Center
Reston, VA 22092

*John A. McCann
Environmental Protection Agency (EN-342)
401 M. St., S.W.
Washington, DC 20460
202/382-7830

Susan Medlarz
Corvallis Environmental Research Lab
c/o USDA Forest Service, NEFES
370 Reed Road
Broomall, PA 19008
215/690-3105

Bob Mickler
Corvallis Environmental Research Lab
c/o USDA Forest Service, SEFES
Forestry Sciences Lab., Box 12254
Research Triangle Park, NC 27709
919/549-4022

William J. Mitchell
U.S. EPA
Env. Monitoring Systems Lab., MD 77B
Research Triangle Park, NC 27711
919/541-2769

Ian K. Morrison
Canadian Forestry Service
Great Lakes Forestry Centre
P.O. Box 490
Sault Ste Marie, Ontario, Canada
P6A 5M7
705/949-9461

Marilyn Morrison
Corvallis Environmental Research Lab
200 SW 35th Street
Corvallis, OR 97333
503/757-4666 ext. 443

Craig J. Palmer
UNLV Environmental Research Center
4505 South Maryland Parkway
Las Vegas, NV 89154
702/739-3382

Claudia Regan
USFS/ Rocky Mtn. Exp. Station
240 W Prospect
Ft. Collins, CO 80526
FTS: 323-1274

Wayne Robarge
NCSU/Soil Science Department
3406 Williams Hall
Raleigh, NC 27695
919/737-2636

Beth Rochette
Dept of Geological Science
Environmental Science Lab
University of Maine
Orono, ME 04469
207/581-3287

Jane Rothert
Illinois State Water Survey
2204 Griffith Drive
Champaign, IL 61820
217/333-7942

LeRoy Schroder
U.S. Geological Survey
P.O. Box 25046, MS 407
Lakewood, CO 80225
303/236-3605

Randolph B. See
U.S. Geological Survey, MS-401
5293 Ward Road
Arvada. CO 80002

*William J. Shampine
U.S. Geological Survey, MS-401
Denver Federal Center
Denver, CO 80225-0046

Mark Silverstein
Lockheed EMSCO
1050 E. Flamingo Road
Las Vegas, NV 89119
702/734-3291

*Bob Stottlemeyer
Michigan Tech. University
Department of Biological Sciences
Houghton, MI 49931
906/487-2478

John K. Taylor
Quality Assurance Consultant
12816 Tern Drive
Gaithersburg, MD 20878
301/948-9861

*Richard Trowp
Research and Evaluation Assoc., Inc.
727 Eastown Drive
Suite 200A
Chapel Hill, NC 27514

*John Watson
Desert Research Institute
P.O. Box 60220
Reno, NV 89506
702/972-1676

Jack K. Winjum
U.S. EPA
Corvallis Environmental Research Lab
200 SW 35th Street
Corvallis, OR 97333
503/757-4324

* denotes invited but unable to attend