Peer Review and Credibility in TVA Environmental Research and Development (1986)

Pages
51

Size
5 x 9

ISBN
0309310415

Committee on Peer Review Processes for TVA Environmental Research; Board on Environmental Studies and Toxicology; Commission on Physical Sciences, Mathematics, and Resources; National Research Council

PEER REVIEW AND CREDIBILITY IN TVA ENVIRONMENTAL RESEARCH AND DEVELOPMENT

Committee on Peer Review Processes
for TVA Environmental Research
Board on Environmental Studies and Toxicology
Commission on Physical Sciences, Mathematics, and Resources
National Research Council (U.S.)

NATIONAL ACADEMY PRESS
Washington, D.C. 1986

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Copies are available in limited supply from the Board on Environmental Studies and Toxicology, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418

Printed in the United States of America

8-11-87

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Preface

The Tennessee Valley Authority (TVA) asked the National Research Council to evaluate current peer review practices with respect to the environmental research and development activities conducted by the TVA. TVA management is concerned about the adequacy of these practices for a variety of reasons, including perceptions about the frequency of citation of research conducted at the TVA, the limited use by regulatory agencies of data generated from TVA's activities, and the need to maximize the quality and acceptibility of research conducted at the TVA on sensitive environmental issues. In carrying out the TVA's request, the National Research Council formed an ad hoc committee with members from a broad range of experiences and perspectives.

The committee began its evaluation by interviewing a selection of TVA managers and scientists concerned with environmental research and development, and by reviewing TVA's written material describing its research and development operations. The TVA staff members who participated in these discussions are listed in the Appendix.

We gratefully acknowledge the many members of the TVA staff who provided information and insight to the committee.

George M. Hidy
Chairman

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1
Introduction

In its request to the National Research Council to evaluate its current peer review practices in environmental research and development programs, the Tennessee Valley Authority (TVA) management asked the committee to consider the following:

- How can peer review be used to improve the acceptability of TVA environmental research and development within the scientific community?
- What processes could be used to review research plans, proposals, and results, taking into account the different focuses of the various units in TVA conducting environmental research and development?
- Could a peer review process be implemented that is flexible and practical enough to operate within the constraints of the TVA?
- What could be the process for deciding when and what type of peer review is needed, how reviewers are selected, and how reviewers' comments are handled?

The Tennessee Valley Authority broadly defines environmental research and development (TVA Code IX, Environmental Quality, 1981) as the "pursuit of new, innovative, or improved knowledge, methods, and/or technologies related to the identification and resolution of environmental issues in support of TVA energy, fertilizer, and resource development activities and programs. Environmental research and development (ER&D) activities include studies and investigations in the areas of environmental characteristics, measurement, monitoring, transport, transformation, effects, fate, and pollution control technology. Socioeconomic and

cost-benefit analyses will also be conducted as part of ER&D consideration." This definition is quite broad in scope, encompassing monitoring and experimental data compilation from operations, engineering research for emission control, and regulatory research relating to TVA policy development. To date, no organization-wide program for peer review has been implemented.

For the purpose of this study, the committee based its definition of peer review on the American Chemical Society and The Conservation Foundation's (1985) report entitled *Issues in Peer Review of the Scientific Basis for Regulatory Decisions*. Peer review is considered to be a critical scrutiny of research plans, results, and policy statements by independent technical experts to determine (1) the accuracy of technical data, (2) the validity of the technical interpretation, and (3) the relevance of the technical data and interpretation to policy decisions. In both the above-mentioned document and this report, a distinction is made among different types of peer review depending on the intended use of the information. Review for the acceptance of information within the standards of the relevant discipline, review so that information can be reused reliably, and review of scientific investigations conducted in support of policy development in the TVA all have different procedural requirements, as discussed later in this report.

Peer review is one of the processes used to establish the quality, and in turn the credibility, of a research and development program from its inception to its completion. By itself, peer review cannot ensure the quality of research. A peer review process must be viewed as one means for assuring high-quality research and must be used in conjunction with other measures to attract and maintain scientists who perform high-quality research, provide adequate facilities for research, and define an appropriate research program.

Peer review then is an element of a quality control and assurance program. Quality control is generally considered to be the internal process for monitoring the technical reliability of results. Quality assurance is an external process, and it includes peer review.

Using these terms of reference, the committee has briefly examined the TVA's infrastructure for review of the development of environmental research and development plans, the implementation of the research, and the research results.

The current review practices in the TVA were evaluated in the context of the organization's mission. The nature of the TVA

places unique requirements on the need for scientific credibility and for review of its scientific effort. The TVA obtains its research funds from several sources, including the generation of power, appropriations from Congress, and contracts with other organizations. Therefore, the need for public disclosure of research results must be viewed differently than the same need in the private sector, including investor-owned utilities, where peer review in privately held companies sometimes exists but is highly variable depending on the nature of the research and its influence on the company policy.

Peer review is an important step toward public acceptance and is well developed in a private, nonprofit organization related to the TVA, the Electric Power Research Institute. This organization is primarily a research-granting entity but has a broad-based, formal review process including internal and external mechanisms to evaluate research plans and contractor efforts. This process ensures that the member utilities as well as the research community have input into the research program and gives credibility to the research in the scientific community.

To provide a common starting point for discussions on environmental protection, the scientific basis for the policy in question must be accepted by scientists outside the organization. Peer review is an important tool available to the TVA management for reinforcing confidence in the credibility and quality of the TVA's scientific investigations. Viewed in this light, the peer review process within the TVA becomes a necessary ingredient in making those decisions that are based on the scientific evidence.

Peer review is an important, though not sufficient, requirement for establishing scientific credibility. The following chapter discusses in a general sense the elements needed for establishing and maintaining credibility at the levels of both the individual researcher and the organization conducting scientific research. Chapter 3 describes the organization for environmental research and development in the TVA and the practices currently used for peer review. The current practices are evaluated, and strategies for improving these practices, as well as strategies for improving the quality and hence the credibility of TVA's research as a whole, are recommended in Chapter 4.

2
Elements of Establishing Scientific Quality and Credibility

Scientific credibility of an organization is a direct result of the quality of the research activities and the professionalism of its scientists. If the research is truly of high quality, it ultimately will be credible when judged by the scientific community. Hence, the first step for establishing scientific credibility is to ensure that an organization's scientists perform high-quality research. Thus, it is appropriate to ask if there are clearly defined, objective criteria for making an assessment of the quality of an individual's, group's, or organization's research.

Asked offhand to evaluate a fellow scientist or scientific group, most scientists will have an immediate response about the quality of the individual's or group's scientific credentials or reputation, if part or all of the research overlaps the evaluator's area of expertise. The perception of the scientific credibility of a researcher or research group is based on reports of research results, critical review of that research, and the quality of other professional involvement. Less informed evaluations offered by others may be based simply on the reputation derived from communication with colleagues and possibly from observation of performance in a public setting such as research paper presentation, seminar, or even dialogue in an informal scientific discussion.

The quality of an organization's research is ultimately assessed through peer review of one form or another. When research results are presented at scientific meetings, the audience is in part a peer review body, and scientific judgments are made regarding the

research and its presentation. Similarly, reports published without external peer review undergo informal peer review when read by fellow scientists because the quality of the report is assessed by the reader.

The principal criterion of scientific credibility within most research units is the unit's publication rate in the refereed literature. It is simply a formalization of the processes mentioned above, with one notable exception; the peer review takes place before public disclosure. This offers several obvious advantages. First, flaws, omissions, and errors are pointed out to the researcher in advance. Second, revision can lead to a better product and enhancement of the researcher's reputation. Third, if the research is flawed to the degree that the results should not be published, the process is stopped short of public embarrassment.

Of course, it is possible that the peer reviewers selected do not have adequate knowledge of the subject and research methods with which to judge the work. It is possible to have inadequate reviews for well-conducted science and for poorly conducted science as well. In such cases, research results that should not be published could be accepted, and results that should be published could be rejected. Reviewers are not necessarily always objective, well-informed, or capable of evaluating truly innovative, high-quality research. Admittedly, the peer review system has its disadvantages, but it does provide a means of validating the quality of scientific research.

Peer review not only applies to publication of research results, but also happens throughout the research process. Research grant applications frequently undergo peer review. In many cases, the researcher must have already established credentials in a research area to obtain funding. For organizations such as the TVA, where internal funding for research is provided for under broad programmatic directives, this formal peer review process can be circumvented. However, maintenance of scientific credibility and enhancement of the publication process can result from peer review of project work plans and research programs. The rigor of such reviews and the attention paid to reviewers' recommendations become an integral part of scientific credibility.

In summary, an essential element of scientific quality is publication in the open literature. Peer review is a quality assurance procedure that enhances both scientific quality and credibility. If peer review is not formalized and incorporated in the research

process, it will occur informally after the results are published. Furthermore, the perception of the absence of peer review (or refusal to engage in peer review) will lead to a negative bias regarding scientific quality, deserved or not.

The following excerpts* from the American Chemical Society's and The Conservation Foundation's (1985) document *Issues in Peer Review of the Scientific Basis for Regulatory Decisions*, while focusing on the development of the technical basis for governmental policy decision, provide a succinct analysis of the concept of peer review and its importance in both the scientific and policy contexts.

> For the purpose of this document we consider peer review to be the critical scrutiny of a report or policy statement by independent technical experts to determine 1) the accuracy of technical data, 2) the validity of the technical interpretation, and 3) the relevance of the technical data and interpretation to a policy decision. Peer review is used at various stages of the policy-making process to reduce the chance of omission or mistaken application of key technical material.
>
> A distinction can be made among three types of peer review: 1) the peer review for minimum disciplinary acceptability of the information; 2) the peer review for disciplinary and interdisciplinary reuse of the information; and 3) the peer review for government policy purposes. This report deals only with the third kind of review. In this context, a distinction can be made between review of the data and review of the interpretation of the data.
>
> We assume policymakers will have, to a greater or lesser extent, strong technical expertise either on staff or as external consultants to make critical judgments about the scientific basis of a particular decision. We discuss peer review as a process eject review as a process that critiques the quality of the technical information that these government officials and consultants use and how they use it.
>
> We recognize that the quality of peer review in the technical literature varies markedly and that the purpose of such a review may vary substantially from one type of technical communication to another. The choices and mechanisms for peer review by the policymakers are quite dependent on the appropriateness of the peer review which has already been performed on the technical information available to them. Therefore, before discussing the potential uses and mechanisms of peer review for policy, it is worth considering the nature of peer review of technical communications.
>
> As performed by the technical community, peer review is the expert scrutiny of a technical report by professionals in the same

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field of expertise for independent confirmation that (1) the report is presented in a technically sound, understandable, and internally consistent manner; (2) the observations made were obtained by methods approved by the particular scientific discipline; and (3) the communication as a whole is a worthwhile contribution to the discipline. In their scrutiny of the work, peer reviewers are not acting as colleagues when providing rigorous criticism but rather are serving as independent professional doubters.

The original technical data are collected and stored in such places as laboratory and field notebooks, study files, and specimen storage vaults. When a portion of these data is reported in writing (e.g., a journal article) or a talk (e.g., a professional society meeting), it may be peer reviewed. If it is peer reviewed for the purpose of a particular communication, that review will be performed essentially to affirm that the data collection methods (e.g., experimental design, analytical techniques) were appropriate for the conclusions drawn. The reviewers will check that the data reported do support the interpretation and that the interpretation is discussed correctly in terms of findings already reported by other investigators. Advice is also offered as to whether this report is a worthwhile enough contribution to the field to warrant communication in the manner being considered.

This peer review which screens and improves presentation of new technical information is a critical process in the advancement of science. Information that has been peer reviewed is widely regarded as much more valuable than that which has not been peer reviewed. However, for understanding its value in establishing a scientific base for policy, it is also important to note the limitations of this type of peer review.

This type of peer review, in contrast with peer review for policy purposes, does not affirm that the data were reported completely—other data collected but not reported by the investigator might have changed the conclusions. It does not verify that the investigator reported accurately what was done—the techniques actually used might have been different and, in the unusual extreme, the data set itself might have been fabricated. This peer review assumes the basic scientific competence and integrity of the investigator. For a particularly significant policy decision, it is appropriate to subject the original data set to rigorous peer review or, if possible, repeat the key experiment.

This peer review for a technical communication does not affirm the interpretation of the investigator to be one with which most technical peers would agree. Rather, it states that the interpretation is consistent with the data and with other observations in the field. It states that the communication is judged to be a sound, useful contribution to the debate in the technical community.

This review does not affirm that the data were collected appropriately for any other use to which they may be put. The original reported data are peer reviewed again when other results and conclusions are drawn from them in subsequent communications. When the data in such a communication are used for conclusions

with respect to another technical discipline, they are peer reviewed by peers of the new discipline to assure that the interpretation is consistent with the data collection methods of that discipline and properly discussed in terms of other related work in that discipline.

Multidisciplinary review is often required for technical information useful to policymakers. Appropriate selection and use of information for risk assessments is one example. The technical peer review process is most difficult when evaluating information that is multidisciplinary. Each scientific discipline focuses on a distinct range of observations using its own methods and paradigms. Experts in one field may not be expert in a second. The choice of peers for data selection and peers for interpretation in the context of a multidisciplinary review needs to be made with care.

Central to any peer review process for policy is a sensitivity to the human factors. Technical reviewers may have personal and scientific biases. Some reviewers may be more competent or more conscientious in their review.

Special difficulties arise when the technical data are quite recent and have not been adequately peer reviewed within the discipline or when the investigator's interpretation of the data falls outside the current range of agreement of workers in a discipline.

Peer review of the technical information for a policy decision involves not only the question of whether data and interpretation in the technical communications have been peer reviewed appropriately within the original field of expertise reviewed but also whether they have been reviewed appropriately for the policy use intended. Peer review for policy includes reviewing the completeness of the information selection process.

Because of uncertainties inherent in new scientific information and possible limitations in the peer review process itself, when information that has been peer reviewed is communicated to policymakers it is especially important to express the range of uncertainty in the results as well as the range of agreement of experts in the field. Examination of this expression of ranges is also a part of policy peer review.

In summary, it is important to distinguish carefully the types of peer review to which technical information may be subject. The needs of policymakers differ from the needs of a technical discipline, and these differences need to be properly accommodated when establishing and using peer review panels. In particular, peer review for policy purposes may require that the accuracy and adequacy of the original technical data be thoroughly scrutinized, that their possible interpretations be examined from a variety of viewpoints, and that conflicting data and interpretations be examined and included in the information passed on to policymakers. This review process may need to be accomplished in the context of the policy under consideration. The thoroughness of the review will depend on the nature of the information and of the policy decision to be made.

Although the peer review process may have its flaws, the total process provides a mechanism for attaining scientific credibility and is the principal route for identifying and maintaining quality of individual research efforts and collectively for research organizations. To make this process effective, the quality of the research must be objectively and independently assessed by scientists external to the organization.

Another component of the quality of an organization's research is the credibility of its individual scientists. Thus, evaluation of the scientists themselves is important. Some criteria for objectively evaluating the scientific quality of an individual's product or output and the credibility of the individual are (1) numbers from the citation index, (2) professional and scientific society service (especially national offices and committee chairmanships), (3) rate and quality of peer-reviewed publications, (4) awards resulting from scientific endeavors, (5) editorships and memberships on editorial advisory boards of scientific journals, and (6) special and prestigious appointments such as fellowship status in professional societies and membership in organizations such as the National Academy of Sciences or the National Academy of Engineering.

The scientific credibility in the research community of an organization's research staff also relates to the educational status of the staff. The range of degrees (BA, BS, MS, Ph.D., D.Sc., etc.), the particular disciplines as they relate to the research being conducted, and the institutions from which the degrees have been conferred are, quite frankly, indicators of scientific credibility. If an organization is respected for the quality of its science, it will be competitive in attracting well-qualified researchers from prestigious schools. Related to this is the professional development through education of the research staff after employment. In part, this last category is reflected in the above-mentioned indices.

A final important point is that use of the peer review process and the criteria for evaluating credibility will not alter the basic competency of the scientists; it will merely provide the mechanism for objectively evaluating this competency. An evaluation mechanism is essential in providing a basis for rewarding the superior scientists as well as for developing and maintaining a credible research organization.

3
Description of the TVA's Environmental Research and Development Programs

STRUCTURE OF ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAMS IN THE TVA

Objectives and Potential Conflicts

In many respects the Tennessee Valley Authority (TVA) is unique among federal agencies. The federal government generally is organized according to major purpose or function, but the TVA is organized on a regional basis with a broad charter to promote the national defense and the physical, social, and economic development of the Tennessee River basin. Under the act creating the TVA, the Congress for the first time adopted a unified approach by vesting in a single federal agency responsibility for the conservation of natural resources and the agricultural and industrial growth of a geographic area.

The TVA is a multipurpose agency that by law has both social and commercial objectives. According to President Franklin D. Roosevelt, effective accomplishment of the goals established by the TVA Act called for the creation of a new type of federal agency—"A corporation clothed with the power of government but possessed of the flexibility and initiative of private enterprise" (U.S. Congress, House, 1933). The TVA is a wholly owned government corporation subject to the provisions of the Government Corporation Control Act, which provide for the submission of an

annual business-type budget to the President and the Congress and a commercial-type audit by the General Accounting Office. The corporation's commercial functions—generation and sale of electric power and development of fertilizers—are self-supporting and financed from revenues and the sale of bonds to the public, or currently, the Federal Financial Bank. The TVA's other programs for the development of agricultural, water, land, forest, economic, and community resources are financed by annual congressional appropriations.

In accordance with its original broad mandate, the TVA remains a multipurpose agency, but there is no question that the production and sale of power have become its dominant activity. The TVA today operates the nation's largest electric power system.

While the TVA has attempted to balance the region's needs for low-cost energy, a clean environment, and a sound economy, efforts to harmonize these competing and sometimes conflicting objectives have not always been successful and have caused bitter controversies. The TVA was criticized because of its refusal to comply with the 1970 Clean Air Act on the ground that the law did not apply to federal facilities (Mosher, 1983). It was argued that the techniques for cleaning stack gases from coal-fired plants were too costly and would increase power rates. In 1978 the TVA reversed its position and signed a court decree requiring TVA to comply with the Clean Air Act. The TVA's (1985a) annual report identifies as one of the "challenging and unresolved issues—how to meet future energy needs in an environmentally acceptable way." The TVA has renewed its commitments to environmental quality as a vital complement to economic growth and relies on its environmental research to help carry out this commitment.

Organization for Environmental Research and Development

The Tennessee Valley Authority operating divisions and staffs are grouped into three major program offices and two corporate support offices that report to a general manager and three-member board of directors (Figure 1). The term of a TVA director is nine years. The board has delegated responsibility for day-to-day administration to a general manager, and office heads report to

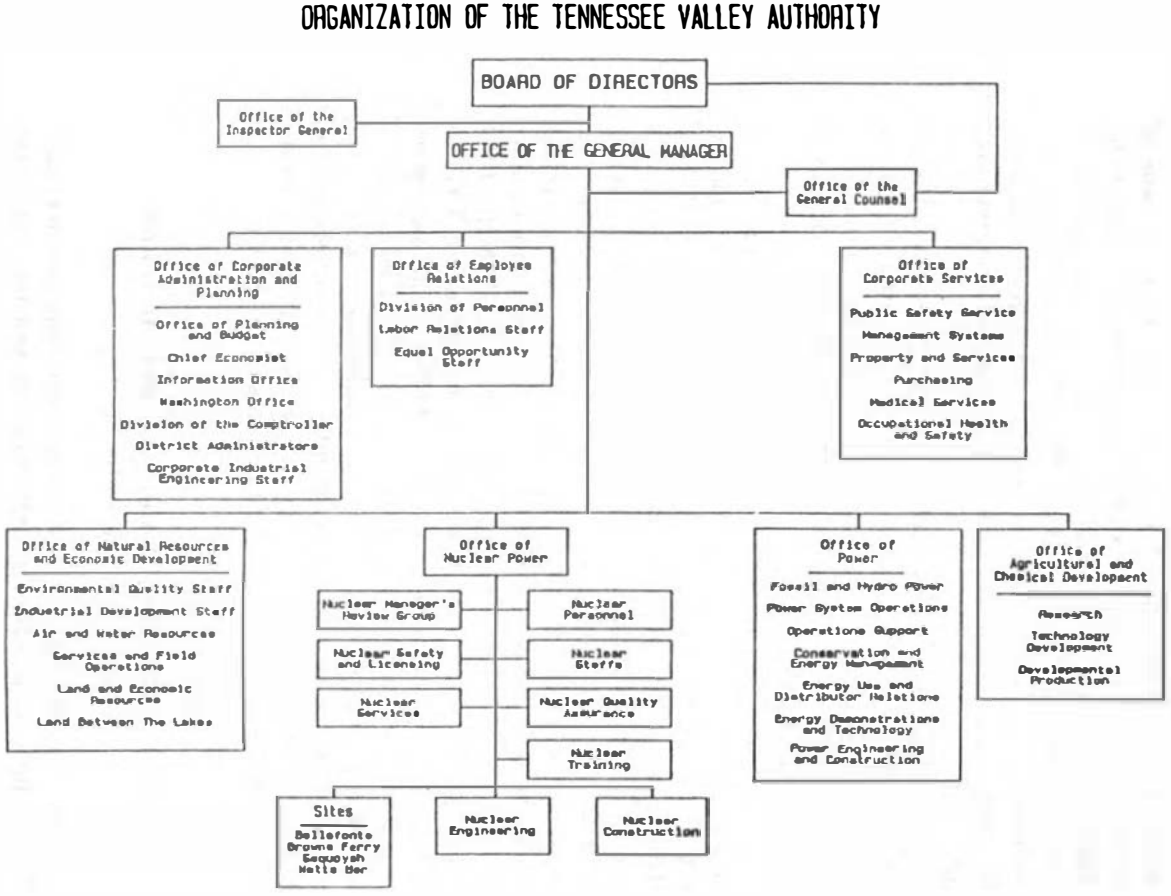

FIGURE 1 Organization of the Tennessee Valley Authority, July 1, 1986 (courtesy of TVA).

the board through the general manager. The general manager is appointed by the board.

At the corporate level, the Environmental Research and Development Section, a part of the Environmental Quality Staff in the Office of Natural Resources and Economic Development (ONRED), coordinates and provides overall direction for all TVA environmental research and development. It serves as a "coordination point to assist in avoiding duplication of environmental research and development efforts, in fully developing opportunities for multiple program benefits from integrating those efforts, and in ensuring the efficient use of TVA's technical capabilities" (TVA, 1983).

Within the TVA, the three offices that conduct the major share of environmental research and development are the Office of Power, the Office of Natural Resources and Economic Development, and the Office of Agricultural and Chemical Development (OACD). The Environmental Research and Development Committee, composed of representatives of those three offices as well as the Office of Corporate Planning and Administration, serves as an advisory group to the Environmental Quality Staff. The committee discusses issues related to the TVA's environmental research and development program, assists in the resolution of technical disputes on such issues, and facilitates interoffice coordination of environmental research and development activities in the TVA.

The Tennessee Valley Authority environmental research is funded by allocations from power revenues, by congressional appropriations, and by funds or reimbursements from other public or private organizations for TVA services provided under cooperative research agreements. Currently, approximately 1.3 percent of the total revenue (approximately $5 billion annually) from the generation of power is used for research on pollution control technologies and research and on the environmental effects of power generation. Of this amount, approximately 3 percent ($1.5 million dollars annually) is for environmental effects research.

IMPLEMENTATION OF ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAMS IN THE TVA

The principal use of environmental research and development in the TVA is to provide information on environmental issues in support of the various offices. Therefore, the first task to be confronted in the research process is the identification of the issues to be addressed. This task rests with the individual TVA offices with guidance from the Environmental Quality Staff. Guidance from the Environmental Quality Staff and in particular its subunit the Environmental Research and Development Staff is important because their aim is environmental protection while the aim of the various offices often is to achieve fiscal goals. Environmental issues will often result from impending legislation, litigation, or action by some constituency of significance to the TVA. Offices often raise issues in an attempt to find more cost-effective means of meeting a specific environmental guideline.

Once an issue has been raised, the next step in providing information is to establish a research plan. Once again the individual offices carry out this step in consultation with the Environmental Quality Staff. The Environmental Research and Development Committee, composed of representatives from each office, assists in establishing priorities and ensuring that there is no redundancy in the proposed research. The interoffice nature of this committee also helps to reduce the bias in the planning of the research because the participants come from offices with a diverse set of viewpoints. Projects within these research plans can also undergo external review, although this procedure varies from office to office. In certain instances, this outside review becomes formalized when an outside funding agency (e.g., EPRI, EPA, and commercial sources) supports the research either in part or in full. Recently, this outside funding of TVA research has been extended to the point that some units are highly dependent on these sources for maintenance of their operations.

After the research plan is established, the next step in the research process is the actual implementation of the project. Many of the projects are carried out using the personnel and facilities within the Office of Natural Resources and Economic Development. The other offices concerned with environmental research and development, including the Office of Power and OACD, can

avail themselves of the staff and facilities of ONRED, or they may in some instances do the work themselves or even contract it out. Again the involvement of the Environmental Research and Development Staff, the Environmental Research and Development Committee, and an outside review panel is important regardless of who carries out the work. This involvement is important to try to balance any potential bias associated with the research, to resolve any issues that might arise, and to lead to acceptance of the outcome of the research by those both inside and outside the TVA, particularly if the results will influence TVA policy.

The acquiring of data for TVA research projects often involves some type of monitoring or surveillance protocol, whether the project is a demonstration project, an environmental fate study, or pollution control research. This data-gathering process involves development and application of methodology such as properly measuring the pH of rainwater, the dissolved oxygen content of turbine discharges, or the concentration of polychlorinated biphenyls in fish. Finally, after the data have been gathered, a TVA report is issued with an interpretation of the data. Reports are transmitted to the Environmental Quality Staff so that they can be disseminated to the appropriate individuals in TVA, although the committee was advised that this routing does not always occur. These reports, particularly those published in peer-reviewed journals, then provide a basis for future decision-making on TVA policy. In some instances the data are presented at a national scientific meeting and/or published in a peer-reviewed journal.

CURRENT METHODS OF REVIEW

The practices for peer review currently used in various units of the three offices conducting environmental research and development in the TVA, the Office of Power, the Office of Natural Resources and Economic Development, and the Office of Agricultural and Chemical Development, are presented in the following sections. The descriptions given below are based on written material that the committee requested from the offices regarding their current practices and interviews with several managers and researchers (see the Appendix).

The review activities, including both internal review and external review, are discussed under three headings: formal written procedures, ad hoc policies, and advisory panels and consultants.

Under each heading, the practices of the three offices are described separately.

Formal Written Procedures

As a first level of evaluating current peer review practices, the committee examined the formal written procedures for various review activities. The practices followed by individual offices and their various units are as follows.

Office of Power

The Office of Power states that it has no formal written procedures for peer review of its environmental research activities. It stresses that the office conducts very little in-house environmental research. Instead, the environmentally related research is contracted to others, notably ONRED.

Office of Agricultural and Chemical Development

In contrast, OACD provides a detailed document, "The Planning and Decision-making Process for the National Fertilizer Development Program" (TVA, 1985a). This document details the procedures for strategic planning and allocation of resources as they pertain to program selection and review. However, this set of elaborate procedures relates principally to the improvement of fertilizers and the lowering of their costs to farmers. Environmental considerations related to fertilizer use are seen as part of the overall project and are directed at evaluating environmental impacts and determining measures necessary to control pollution generated by or associated with fertilizer use.

The program has a stated goal, and an associated strategy. A strategic plan is developed following identification of major issues with the aid of the public, industry, government, and the users via issue papers, discussion documents, and strategic plan documents.

As stated in the document outlining the planning and decision-making process (TVA, 1985b), it appears that considerable peer review is involved, including review of the outcome of the projects and review of the capabilities for carrying out proposed efforts. Identified issues are prioritized, and proposed projects require approval through a process involving advisory panels with representatives from universities, government agencies, the private

sector (industry), and specific foundations and institutes related to agricultural development. There is a program of periodic formal and informal reviews of program progress. Decisions are made on initiation or continuation (as appropriate) and termination of a project as a result of this review.

Each of the OACD branches has a specific written policy regarding dissemination of research findings. These policies are quoted below from the material received by the committee.

Chemical Research Branch. Research results are usually published in refereed journals. All reports intended for publication or external distribution are reviewed by the branch chief and other senior-level technical staff members as appropriate. Papers scheduled for presentation at external meetings or conferences must first be presented internally to an open forum of technical and administrative staff members to ensure technical accuracy, clarity of presentation, and appropriateness. All active research projects are to be reported internally on approximately a quarterly basis; these "progress reports" are technically reviewed by the appropriate senior project leader, the branch chief, and other senior-level technical staff as required. Projects dealing with nitrogen or phosphorus fertilizer research are reviewed by interested industry representatives at least biannually at a formally scheduled joint TVI/TVA Technology Transfer Workshop. During the life of a research project, one or more formally scheduled internal "Peer Reviews" may be called by the branch chief or division director. These reviews are interbranch or interdivision as necessary and allow technical staff across OACD the opportunity to formally evaluate and comment on the progress or direction of ongoing work.

Agricultural Research Branch. Completed research activities are reviewed orally in the branch reporting sessions and often in the sessions with outside experts (PPI, NFSA, TFI, USDA, etc.). Reporting on completed research also consists of internal written greenhouse, laboratory, and field reports. These reports are reviewed by the assistant to the chief, the branch editor, and at least one researcher who was not involved in the project before it is printed in final form for distribution.

Branch researchers are also encouraged to present the findings of their research orally before major national and regional scientific meetings in their field. Abstracts of these talks are edited through the regular branch internal review process (above) and through

the division and office approval route. In addition, an informal "dry run" of the oral presentations is held, and the presentations are critiqued for content, clarity, time, quality of slides, and conclusions. This dry run is held about a week prior to the meeting to allow time for any corrections needed on slides or in content.

Researchers are also encouraged to publish findings of significant completed research in scientific journals. These reports are edited and reviewed by the assistant to the chief, the branch editor, and at least one other branch researcher before it is submitted to the division and office management for approval. Once approved, the reports are sent to the appropriate scientific journal. All of the journals to which ARB papers are submitted are refereed journals, and all require review by at least three reviewers who are knowledgeable in the field.

Contractual research is reported on semiannually, and these reports are reviewed by the ARB project leaders. A final completion report is required for each project. In addition, most of these projects result in published papers in scientific journals. They are subject to the internal peer review system at the university and the external review system of the journal to which the paper is submitted.

Biomass Branch. Research papers scheduled for publication or presentation at external meetings must be cleared internally through the branch review committee which consists of technical staff members of various disciplines and the branch chief to ensure technical accuracy, clarity, and appropriateness of subject matter. Quarterly performance reports of research and reimbursable activities are submitted for review to the project managers and the branch chief. The research activities of the pilot plants and laboratory research activities are reviewed periodically by a peer review group consisting of private sector, government, and university participants. The peer reviews are internal and external and provide for input necessary for critical evaluation of program objectives. Results are published in refereed journals in some instances, but the more frequent route is presentations at professional meetings.

Office of Natural Resources and Economic Development

Within ONRED, the Air Quality Branch does not have formal written procedures. The Water Quality Branch also indicated it had none. The Fisheries and Aquatic Ecology Branch (in the

Division of Air and Water Resources) reported that neither formal nor written procedures exist. Rather, research needs are identified by individual researchers, programs, or organizations as related to specific problems facing the TVA. The Engineering Laboratory did not indicate formal written procedures. The Division of Land and Economic Resources reported the absence of written procedures related to peer review.

Ad hoc Policies

Office of Power

The Office of Power reports that it develops research programs and individual projects with ONRED and others in the TVA. Many of these projects involve funding from other organizations, among which are the Electric Power Research Institute and the Environmental Protection Agency. As a result, research plans and results are subject to these organizations' peer review processes. During the annual budget cycle, program plans and those projects funded solely by the Office of Power receive internal review. The purpose of this review is primarily to inform other TVA units and presumably outside organizations on the scope of activities rather than to technically review the project.

Office of Agricultural and Chemical Development

The Office of Agricultural and Chemical Development, in addition to its formalized review procedures for program development, conduct, and completion, also convenes outside review teams on an ad hoc basis for purpose of program review and for identification of research needs in specific areas. Subsequently, the appropriate roles for the office's units such as the National Fertilizer Development Center are identified. This center also has its own external industry review board.

Office of Natural Resources and Economic Development

Within ONRED, various ad hoc policies are used for internal as well as peer review. The Air Quality Branch has the following policy for the review of documents produced by staff members. All publications, whether to be submitted to a journal or published by the TVA or some other agency or group, must be reviewed by

a member of the performing section who is not an author. The reviewer is designated by the section supervisor. The manuscript must also be reviewed by a scientist, selected by the branch chief, from a different section who has some knowledge of the subject matter. Once branch review is complete, the manuscript is forwarded to the Information Office for approval. At this time the branch chief may request, at his or her discretion, additional review from one or more of the following organizations—Office of General Counsel, Environmental Quality Staff, the Office of Power's Energy Demonstration and Technology Division, and OACD. Individual authors may request additional peer review by scientists outside of the TVA. After the above review processes are complete, the manuscript is revised as necessary and may be printed as a TVA report or submitted to a journal for publication.

The ad hoc policies in the Water Quality Branch generally consist of seeking reviews internally from any part of the TVA that may have expertise to offer on proposals and reports, depending to a large extent on the complexity of the project. Internal groups include the Laboratory Branch, Fisheries and Aquatic Ecology Branch, Engineering Laboratory Branch, Air Quality Branch, National Fertilizer Development Center, Power, Data Services Branch, and Field Operations. Reviews and input are sought, as the Water Quality Branch deems appropriate, from external organizations, e.g., state agencies, the Environmental Protection Agency, the U.S. Geological Survey, Oak Ridge National Laboratory, the Fish and Wildlife Service, and various experts in their fields. A similar policy prevails in the Fisheries and Aquatic Ecology Branch, at least for review of proposals.

The Engineering Laboratory reviews reports by requiring that a control sheet be submitted with the report containing names for reviewers within and outside the branch. No indication was given if this included reviewers external to the TVA.

The Division of Land and Economic Resources stated that while obtaining internal and external comments on major program proposals and research activities is a standard practice of many of their programs, there is no explicit division policy requiring this to be done. However, the lack of written procedures or division policy regarding peer review does not necessarily keep programs from developing effective informal mechanisms for carrying out this important function. The view presented is that they recognize the importance of peer review in environmental research, and thus

seek advice as appropriate from many sources, including fellow scientists, universities, state agencies, and others.

Advisory Panels and Consultants

Office of Power

The Office of Power has a Research Review Committee drawn from senior division management that periodically meets to review its research program, funding levels, and results. The committee also serves as a forum for discussion of new research ideas. Committee representatives are appointed by the manager of Power and all are within the Office of Power. The Office of Power does not retain specific consultants for advice on environmental research matters. It does, however, make use of several regional universities, Oak Ridge National Laboratory, and Battelle Columbus Laboratories to review plans or provide advice on environmental research topics. This process is achieved through task order contracts.

Office of Agriculture and Chemical Development

The Office of Agriculture and Chemicals Development has an array of formal advisory boards and study panels. Detailed procedures and objectives for each were described in the written materials transmitted to the committee, though there was no information on the selection process or how the reviewers' performance is evaluated.

Office of Natural Resources and Economic Development

Within ONRED, the use of advisory panels is generally limited. Consultants to assist in research projects are more widely used. The Air Quality Branch periodically selects specific consultants to assist in research projects. Criteria for selection include specialized knowledge in their field and national or international recognition. Internal recommendation in the Air Quality Branch plays a role as well. Contractor performance is reviewed by the contract representative, program manager, and technical staff. A formal evaluation of consultant's performance is done by the contract representative at the end of the contract period or when the contract is submitted for renewal. The contractor's performance

on program objectives and deliverables (papers, reports, services, etc.) is evaluated at this time. The Water Quality Branch reports no current advisory panels but does use consultants for advice on research matters. Some of these individuals are former TVA employees who have taken academic positions. The selection process is stated to be on the basis of expertise in specific areas, reputation, personal knowledge, and recommendations from respected contacts. Performance is evaluated through standard contract evaluation forms required by the TVA Division of Personnel.

The Fisheries and Aquatic Ecology Branch has no advisory panel or committee. It reports use of consultants who are selected on the basis of expertise, current research interests, performance, and proximity. The performance of these consultants is evaluated informally through "discussions with staff," peer review conducted by outside funding agencies, and publication record in peer-reviewed journals.

The Engineering Laboratory made reference to contract work supported by the Electric Power Research Institute (EPRI). Review of this work is conducted by consultants selected by EPRI, the implication being that specific advisory panels and committees are absent. Consultants have often been requested to review projects of a sensitive nature or those in which the TVA apparently had limited experience. Criteria for selection of these consultants include prominence in their field and the individual's credentials.

The Division of Land and Economic Resources reports that none of its programs conducting environmental research have established research advisory panels or committees set up expressly for the purpose of giving advice and consent. There are a few individuals and groups that are apparently consulted frequently to obtain comments on ongoing and planned research activities. Other than a few organizations and individuals, the units of the division involved in environmental research do not obtain advice on research matters routinely from consultants.

Summary

Considerable variation exists across and within the TVA Offices of Agricultural and Chemical Development, Power, and Natural Resources and Economic Development with regard to peer review processes. The review procedures used by the three office are summarized in Table 1. It is apparent that extensive review,

TABLE 1 Summary of Review Procedures in Three Offices Conducting Environmental Research and Development in the TVA

	Office of Power	ONRED	OACD
Formal written procedure	No procedure.	No procedures in any branches.	Extensive procedure.
Ad hoc policies	Follows review procedures of external funding agencies; program plans and projects receive annual internal review.	No division-wide policy. Air Quality Branch--internal review by performing section, outside section and sometimes other units. Individual authors may request peer review. Water Quality Branch and Fisheries and and Aquatic Ecology Branch--internal review from various parts of TVA. Engineering Laboratory-requires control sheet submitted with names of reviewers.	Outside review teams.
Advisory panels and consultants	Research review committee.	Use of advisory panels limited in all branches. Consultants used to various degrees in all branches.	Advisory boards and study panels.

although mostly internal, is in practice in many of the branches conducting environmental research. Some branches do not have well-defined practices for either internal or external review.

Not all review processes are formalized in written protocols. Of the unwritten review procedures, the degree of formalization also varies. For specific research activities, routing sheets with mandatory review hierarchies take on the character of strict formalization in some units under ONRED. More commonly, this procedure is followed for review of the reporting process, written and oral, rather than for review of program development or proposal submission to external agencies.

The practice is highly variable particularly within the branches of ONRED. Discussions with managers and researchers have brought out varied opinions regarding the degree of rigor that

should be used for the review process. Yet they seemed in general to be favorably disposed to a meaningful and beneficial process that did not unnecessarily impede the research activities and overly burden the financial resources.

4
Analysis and Recommendations

STRENGTHS AND WEAKNESSES OF THE CURRENT SYSTEM

The mission of the TVA and the goals of environmental research and development conducted within the units of the TVA must be kept in mind in evaluating the strengths and weaknesses of the current system of peer review. Based upon information provided by these units, the goals of environmental research within the TVA are as follows:

- Identify and assess the magnitude and significance of current and potential environmental problems in the Tennessee Valley region.
- Develop sufficient understanding of the nature of current and potential environmental problems to permit scientifically sound engineering solutions to be identified and evaluated.
- Provide information to TVA management to assist in decision-making on TVA policy and on priorities for future research.

The various units involved with the environmental issues have additional specific objectives. For example, the Environmental Quality Staff has the additional objectives of (1) providing overall guidance for TVA environmental research and development and (2) determining and effecting compliance with TVA policy in the environmental area.

The strengths of the present peer review system are that in most units it is flexible, serves as one means of keeping colleagues cognizant of related research, serves to minimize duplicate investigations, and incurs minimal time and dollar costs. Most

manuscripts and some projects are given some form either internal or external review before publication (see Chapter 3). The current system in most units is largely ad hoc and very flexible, allowing for different degrees of review for data collection projects, limited-scope investigations, or research projects. In addition to peer review of proposals and projects by colleagues in the TVA and consultants, the Environmental Research and Development Coordinating Committee provides additional review of programs and projects. The Environmental Quality Staff provides an internal TVA review of the issues requiring research and of the adequacy of research programs for the resolution of individual issues. Where peer review has been used, it has facilitated the identification of problems prior to initiation of research and during the research process, and has improved the quality of the reporting of results.

The peer review of the identification of new issues for research, projects, and manuscripts in OACD appears to be very thorough. The peer review process within this office has clearly led to a high level of credibility of the scientists within these groups. However, it should be noted that the peer review process can be a liability if it becomes so extensive as to significantly reduce the amount of time that scientists are able to spend in actual research.

The apparent lack of a TVA-wide policy to employ peer review as a quality assurance component is perceived by this committee as a weakness of the environmental research program. The extent and nature of peer review varies greatly across the units within the TVA conducting environmental research and development and appears, superficially at least, to be roughly proportional to the extent to which individual units interact externally with individual scientists and scientific groups (e.g., Land Grant colleges, U.S. Fish and Wildlife Service, EPA, EPRI). Those units that have the least contact with outside scientists tend to make the least use of peer review. The extent of peer review in some branches is quite limited. In addition, peer review costs, with some exceptions, are not included in project budgets.

Another weakness of the current report review system is the tendency of the TVA to use its own scientists and a group of consultants drawn largely from local universities for peer review. This approach may be less effective in countering the "electric power utility" bias than would the use of external reviewers, of whom a majority are from outside the region.

This committee was informed that studies of limited objectives and scope (so-called "quick and dirty" studies) are frequently carried out to satisfy internal TVA needs. Periodic review, by an external peer panel consisting of individuals of broad experience and some with in-depth expertise in particular subdisciplines, could provide an effective evaluation of the merit of these limited scope studies as opposed to other approaches.

Environmental research and development funded by the TVA is conducted primarily to meet specific programmatic objectives. The lack of external peer review of projects may contribute to a perception by those outside of the TVA that a significant part of the environmental research carried out by the TVA is defensive research conducted primarily to defend against specific environmental requirements. This perception introduces a potential for bias in data collection and interpretation that needs to be countered with a strong peer review program.

Based on these general observations and on specific cases presented to the committee, we conclude that, with the exception of some units (e.g., OACD and the acid rain program), current peer review procedures do not appear to be adequate to ensure the quality of environmental research being carried out by the TVA. A more effective system for peer review could be one measure that would improve the acceptability of results of research conducted by the TVA.

RECOMMENDED PEER REVIEW STRATEGY

The Peer Review Concept

The peer review process is a major component in establishing scientific credibility in a research program. It provides one measure of insurance as to the perceived quality of an organization's research plans and results. The design of the long-range strategic plan, the detail of the experimental protocol, as well as the originality of the research, its significance to the discipline, the validity of the experimental data, the adequacy of supporting information, and the soundness and logic of interpretation of the research results, are all included in a comprehensive peer review process.

Detailed guidelines for the peer review process are not included within the scope of this report. Rather, a strategy is presented

that outlines the requirements for the process and the minimum framework that the committee believes is necessary for its effective operation. Detailed guidelines for the process should be developed within the TVA and should include, as a minimum, the level of review, e.g., number of internal and/or external reviewers (or the basis for determining the level of review) to be given to each activity and/or document, how reviewers are to be selected, and how review results are to be used. The costs associated with the process likewise are not included, although they are recognized as a factor in determining the degree of review to which any single document should be subjected.

The review process extends beyond the conventional technical review of an editorial board. The TVA is responsible for the statements and opinions publicly presented by its authors. The review process recommended here is in addition to the review performed by supervisors and managers as a part of their administrative and management responsibilities. It involves the review, to the extent necessary, needed by management to render approval.

The strategy recommended by the committee is for certain minimum procedures to ensure that programs and products meet the standards for quality. A uniform process is presented that establishes a senior advisory group, a coordinator or coordinators, and a structure within which the review process can be accomplished. This approach allows maximum flexibility to exert more extensive review in the event of data uncertainties, controversial technical or policy issues, or legal implications.

What Should Be Peer Reviewed?

The documents (or activities) that require review under this strategy include all program plans, experimental protocols, and research results. Table 2 enumerates the various planning documents and reports along with the recommended review process.

One issue that must be considered in initiating a review of a program or a report is the amount of time that will be involved in the process. Time (and money) lost in initiating a vital research program and delays in making policy decisions and implementing new technologies have to be offset and justified on the basis of sound decision-making and development of scientifically credible programs, data, and reports.

TABLE 2 Recommended Peer Review Strategy for Environmental Research and Development in the TVA

Research Activity	Method of Review
Plans	
Program/Plans/Strategy	Science Advisory Board
Work Plans/Proposals	Peer Review Coordinator
Protocols (Design, Sampling, Analysis, Data Processing, Methods for Interpretation)	Peer Review Coordinator
Reports	
Data Tabulations (Uninterpreted)	Audits, Standard Methods for Quality Control
Primary (Gray) Literature Data Reports (Interpreted) Progress Reports Final Reports (Project/Program) Conference Papers	Peer Review Coordinator
Secondary Literature Summary/Survey Reports, Reviews	Peer Review Coordinator
Journal Articles/Texts	Publisher's Editorial/Peer Review Board

Who Should Conduct Reviews?

The committee recommends the establishment of a standing scientific advisory board to advise the Board of Directors and the general manager on policy, science, and strategy matters as a major feature of the peer review strategy. The interdisciplinary Science Advisory Board would perform the essential role of recommending an overall direction for the TVA's environmental research program. In addition to the expertise and service that that group can provide, the establishment of such a board announces management's intent to enhance the credibility of the TVA's scientific product. A hierarchy of several interdisciplinary advisory panels could be established to operate beneath the standing advisory committee and to advise the TVA on various issues.

The designation of a peer review coordinator (or coordinators) is also recommended to objectively manage the review process.

This individual or group of individuals would establish the procedure for review and determine the reviewers or groups of reviewers on either a standing or ad hoc basis for the purpose of conducting the reviews. The coordinator would provide the reviewers with any necessary insight requiring their special attention and would negotiate settlement on any unresolved issues between author and reviewer.

The peer review coordinator(s) should be assigned at the appropriate organizational level to have:

- major program perspective or overview
- perspective to integrate, interrelate, and identify gaps and overlaps, redundancy, conflict, controversy, etc.
- command of management's attention
- the ability to assign review tasks, requirements, and schedules (in coordination with line management)
- control over resources to effectively administer external review (as required—postage, transportation, per diem, honoraria, etc.)
- policy insight and sensitivity
- authority to make decisions regarding the level of review required and the acceptability and conclusions of the review process

The coordinator(s) could, therefore, serve at the office level as deemed appropriate by management, with performance of the process being monitored by the general manager and the Board of Directors.

Panels can also be established to conduct the reviews and can be either standing or ad hoc, although ad hoc panels typically take longer to establish, assemble, organize, and inform.

How Should Reviewers Be Selected?

Reviewers should be chosen on the basis of their known expertise in the research field covered by the manuscript, report, or project. The ability of an individual to render an objective, critical, and timely review should also be considered in the selection of reviewers.

Membership on the TVA's Science Advisory Board should be reserved for internationally recognized scientists of the highest status. It is suggested that professional societies, appropriate

government agencies, and national-level interdisciplinary groups, such as the boards of the National Research Council, and other groups be solicited to assist in identifying nominees for board membership. The number of members and mix of technical skill appropriate for the board should be dictated by the consideration that all relevant disciplines be represented.

The individuals selected to serve as reviewers or review panel members should likewise be reputable scientists in their respective disciplines. They may be selected from qualified academic, industrial, and federal and state scientists. The peer review coordinator could, for example, assemble a data base of potential candidates with recommendations from the TVA's investigators, a science advisory board, and other scientists. Selection, however, should remain the responsibility of the coordinator. The coordinator should also maintain a record of the reviewer's performance with respect to the quality of the review(s) provided and his and her responsiveness in meeting the time requirements and objectives of the review.

For programs or program results that are particularly sensitive because of either technical or policy issues, a science advisory board can serve in helping to identify high-quality reviewers and, in some cases, to conduct certain aspects of the review themselves.

In the screening of reviewers, extreme care must be taken to avoid the selection of a reviewer with a real or apparent conflict of interest with the TVA, the author(s), or the subject matter of the review. In addition, care must be taken that the same peers and consultants are not repeatedly requested to perform reviews. There are distinct limitations in using only TVA colleagues and local consultants for peer review of the TVA's environmental research and development.

Appendix II of the ACS Style Guide (1986) contains ethical guidelines for authors and reviewers of scientific literature. Most of these guidelines are already subscribed to by the majority of experienced researchers. They should be of help, however, to every scientist in organizing his or her approach to the preparation and review of technical reports. The formal adoption of these procedures or of a set specifically designed to meet the TVA's needs is highly recommended.

How Should the Results of Peer Reviews Be Used?

The final decision to accept a program plan or adopt a multi-year strategy is the responsibility of the TVA's Board of Directors. Implementation of the strategy or plan is the responsibility of the general manager. Reviewers, including the science advisory board, serve in an advisory capacity, although it is recommended that a summary of their findings be made a part of the public record. The final decision to accept a proposal or protocol or to publish a report should be the responsibility of the appropriate peer review entity, i.e., the peer review coordinator(s) in conjunction with the appropriate line manager. Although decisions are nearly always based on reviewers' comments, the review entity has the responsibility to resolve issues and negotiate differences. It also retains the right to publish in the face of negative comments and reject the document in the face of positive comments. As noted above, the peer review coordinator(s) should be a senior management representative who has the appropriate authority to make those determinations. He or she should also be a scientist of stature.

Response in writing, particularly to the science advisory board, regarding final action or degree of implementation of their recommendations is likewise recommended. Written documentation of the review results should also be prepared and should include the rationale for the acceptance or rejection of the document. These findings provide positive feedback to investigators and management for their accomplishments and direction when incomplete or inaccurate results are reported.

ADDITIONAL RECOMMENDATIONS FOR IMPROVING SCIENTIFIC CREDIBILITY

Credibility is defined here as the acceptability of the outcome of the research by someone other than those responsible for doing it. In a very narrow sense this credibility could mean that those in the TVA accept the work of others in the TVA and stand behind that work. In a much broader sense it means that those outside of the TVA including peers (e.g., scientists outside of TVA and those in other power-producing industries), regulators (e.g., EPA), customers (e.g., electricity consumers, and, in the case of the TVA, Congress) as well as the general public accept the work. This credibility external to the TVA is particularly important in

that the TVA has conflicting goals, as discussed previously. In addition, there may be disagreements about the quality of the work between those inside and those outside of the TVA. Thus, credibility, both internal and external, comes from the scientific stature of the TVA scientists, which comes in turn from doing excellent work and then developing awareness of it in others both inside and outside of the TVA.

One of the best mechanisms for publicizing scientific work is through report writing. While publication as an internal TVA report may fulfill project requirements, an external publication in a peer-reviewed journal is more effective in publicizing the results. A publication that is frequently cited is even more advantageous. Therefore the goal in this area should not be simply to carry out good science but also to publish the work in a widely read, credible journal so that the work is used (and therefore accepted, cited, and made credible) by others and the credibility of the TVA scientists is enhanced.

The situation is similar for presentations. Presentations should be used as opportunities to present data before peers and to rapidly obtain their opinion. They also facilitate personal interaction between the TVA scientists and their peers and allow for timely discussion of research results. Presentations should not be used as a substitute for peer-reviewed publications, but as one of the steps in making those outside the TVA aware of the information. Presentations and unrefereed extended abstracts from meetings should not be used as substitutes for publishing in peer-reviewed journals. While presentation at local and regional scientific meetings is useful, it is more desirable to present at national meetings of the various societies representing the relevant disciplines. It is even more preferable when the presentations are invited because this indicates at least some degree of recognition of the work. Presentations should not be limited to scientific meetings but should also include university and industrial and general public information seminars. While these types of seminars are not as prestigious as scientific meetings, they are an effective way of "getting the word out" about the nature and competence of the research being conducted.

Another means of establishing credibility is through committee service by the TVA scientists. The effort expended on these committees is often time-consuming, so these assignments must be carefully reviewed before they are accepted. This review should

take into account the selection process by the organization establishing or convening the committee. If the aim is to serve on committees to enhance scientific credibility, service should be reserved for those committees for which the selection process is based on the individual's scientific reputation rather than on his or her affiliation with a particular organization. Another source of committee-type work that is often overlooked is serving on editorial review boards or as a referee for a specific journal.

An additional source of credibility is through awards given to TVA scientists. These can cover a broad spectrum ranging from awards administered by professional societies to awards given by local civic groups for some type of community service. They can contribute greatly to establishing the credibility of TVA scientists in the minds of those outside the TVA.

Some of these methods for establishing scientific credibility are already in place in the TVA. Policies and procedures are needed, however, to institutionalize these suggestions. Funds must be set aside to permit travel to present one's research, to attend committee meetings, and to cover page charges for publication in journals. Furthermore, the TVA should not merely encourage scientists to publish and present their research; they should reward them if they do. Publications, presentations, committee work, and awards should be made part of a merit system. This does not imply that these suggestions should be the only criteria for rewarding employees for their work, but they must play a significant role. The rewards could range from simple commendations, to financial awards, to promotions, to sabbatical leaves, and possibly to a science fellow program such as has been adopted by many industries. These rewards then provide the mechanism for attracting, nurturing, and keeping credible scientists.

Finally, records of the measures of the scientific credibility discussed above should be maintained so that the progress of individual scientists and of the agency as a whole can be evaluated.

5
Summary and Recommendations

The National Research Council organized, at the request of the Tennessee Valley Authority, an ad hoc committee to examine the TVA's current approach to peer review of its environmental research and to advise the TVA on how to enhance the scientific credibility of its environmental research through a process of peer review as well as through other means. For the purposes of this report, the committee adopted the following definition of peer review: the critical scrutiny of research plans, results, and policy statements by independent technical experts to determine (1) the accuracy of the technical data, (2) the validity of the technical interpretation, and (3) the relevance of the technical data and interpretation to a policy decision (American Chemical Society and The Conservation Foundation, 1985).

The peer review process serves as a major component in establishing the scientific quality of and hence credibility in a research program. It provides one measure of insurance as to the quality of research plans and results. Review of the design of the long-range research plan, the detail of the experimental protocol, as well as the originality of the research, its significance to the discipline, the validity of the experimental data, the adequacy of supporting information, and the soundness and logic of interpretation of the research results, are all included within the scope of a comprehensive peer review process.

Peer review is only one element, although an important one, in ensuring the scientific quality of an organization's research. High-quality research, in turn, leads to scientific credibility. A peer review process can help ensure that only high-quality research

plans and results are released to the public, but such a process must be used in conjunction with other means for maintaining and nurturing high-quality scientists. Other important areas for establishing credibility include publication of research results in journals, participation in scientific meetings, and service on scientific committees.

After discussion with several scientists in the TVA, the committee concluded that the processes for obtaining peer review of research plans and results vary widely throughout the various units conducting environmental research. In general, the scientists recognized the value of peer review and the need for objective assessment of their research. Some of the informal processes currently followed by some units in the TVA are effective. However, there is no written, agency-wide policy for obtaining peer review, leading to the perception outside of the TVA that its environmental research does not undergo peer review.

Because of the multiple roles that the TVA must fulfill in balancing its objectives as both a public utility and an organization dedicated to maintaining a clean environment, the types of environmental research conducted in the TVA also vary widely. Some research is conducted to provide a basis for formulating the TVA's environmental policy, some research is conducted at the request of other units for internal purposes, and some research is to support routine monitoring activities. A procedure or policy that is sufficiently flexible to be applied to this broad range of activities needs to be developed.

With these views in mind, the committee recommends the following:

- A policy outlining a minimum procedure for peer review should be developed and applied to all units conducting environmental research in the TVA. The procedures should allow for different peer review processes for different types of research activities and should be flexible enough to accommodate those sound practices currently being followed in many units conducting environmental research. A recommended review strategy for various research activities is described in Chapter 4. Detailed guidelines for peer review should be developed based on the recommended strategy.
- The Tennessee Valley Authority should establish a standing interdisciplinary board of nationally recognized experts to

oversee and provide guidance for the agency's environmental research program. The functions of the board would be to review the environmental research programs, to monitor the review process, to recommend external reviewers when appropriate, and to otherwise serve in an advisory capacity to the TVA in conducting its environmental research.

- An established scientist or group of scientists with senior-level management responsibilities in the TVA should be designated to coordinate the review process. Responsibilities would be to formulate guidelines for peer review procedures, to determine the extent to which a particular report or research plan should be subjected to internal or external review, to oversee the selection of reviewers, and to ensure that the reviewers' comments are adequately taken into account.

- The management of the TVA should encourage its scientists to publish their research results in the open literature and to disseminate their results through participation in scientific meetings. A merit system, based on measures such as citation indices, participation in scientific meetings, invitations to serve on committees, and so on, could be used to encourage scientists of the TVA to become more active outside of the agency and thus more familiar to outside scientists. Credibility of the agency will improve with increased recognition of its scientists. Records of the indices of scientific credibility should be maintained to objectively monitor the progress of the individual scientists and of the agency as a whole.

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Appendix: TVA Staff Participating in Discussions With the Committee

Roger Betson, Office of Natural Resources and Economic Development
Charles Bohac, Office of Natural Resources and Economic Development
Billy J. Bond, Office of Natural Resources and Economic Development
Patricia Brewer, Office of Power
Ralph Brooks, Office of Natural Resources and Economic Development
Robert Brooks, Jr., Office of Natural Resources and Economic Development
David Daugherty, Office of Power
E. Ely Driver, Office of Natural Resources and Economic Development
William Elder, Office of Power
Billy G. Isom, Office of Natural Resources and Economic Development
Myron Iwanski, Environmental Quality Staff
Robert Johnson, Environmental Quality Staff
James M. Kelly, Office of Natural Resources and Economic Development
James Morris, Office of Natural Resources and Economic Development
William M. Pearse, Office of Engineering
John Phillips, Office of Agricultural and Chemical Development
Alan Pulsipher, Corporate Administration and Planning
Martin Rivers, Environmental Quality Staff

Eugene Sample, Office of Agricultural and Chemical Development
Gary Scales, Office of Planning and Budget
Myra Soroczak, Office of Agricultural and Chemical Development
John Stewart, Corporate Administration and Planning