ANALYSIS OF WATER AND WATER-RELATED RESEARCH REQUIREMENTS IN THE GREAT LAKES REGION

June 1968

This report is prepared for the Director, Office of Water Resource Research, Department of the Interior, Washington, D.C., in compliance with Contract 14-01-0001-1571.

Council on Economic Growth, Technology, and Public Policy of the Committee on Institutional Cooperation

Sponsorship and Authorship. The work reported herein was conducted by the Council on Economic Growth, Technology, and Public Policy of the Committee on Institutional Cooperation for the Office of Water Resource Research, Department of the Interior, under Contract 14-01-0001-1571 with The University of Michigan. This report is being published by The University of Michigan in compliance with this contract. It was derived from the deliberations and written contributions of the individual investigators listed and the Project Steering Committee. The responsibility for the preparation of the report rests entirely with the Project Steering Committee.

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ABSTRACT

Investigators interested in water and water-related research in the Great Lakes region have considered applicable research requirements and methodologies, with special emphasis on the applications of systems analysis and modeling. Representatives of many disciplines, from major midwestern universities, water resources centers, and federal agencies, met in two working conferences and on numerous other occasions to discuss a framework for research activities which appear necessary to comprehensive water management and related development in the Great Lakes system. Under the auspices of the Committee on Institutional Cooperation (CIC), the research requirements have been appraised on a region-wide scale, and this, with an appropriate mechanism for coordination, could promote a unique research collaboration among disciplines and among universities.

This report indicates the focus placed by researchers of many disciplines upon a systems analysis model of the Great Lakes. Early in the study it was determined that a water-quantity model of the entire system is necessary and feasible. Attempts at a water-quality model for the Great Lakes region on a subregional, subsystem basis, with subregional groupings anticipated as available data and systems technology permit, are also presented. The need for a regional economic-growth model, water-related information systems, and a gaming-simulation model for research on relevant institutions is described. The research efforts to supplement and support the water-quantity and water-quality subsystems are specified, and priorities among these are suggested. The appendixes to the report contain papers contributed to the study, proceedings of the working conferences, names of conference participants, a listing of responses by conference participants and their colleagues to a questionnaire on research activities needed in the Great Lakes region, and other supplementary materials.

CONTENTS

ILLUSTRATIONS

1
INTRODUCTION

The water-resource problems of the Great Lakes region* are large, diverse, and urgent. Under this contract, the Council on Economic Growth, Technology, and Public Policy of the Committee on Institutional Cooperation sought to provide program managers of the Office of Water Resource Research, Department of the Interior, with the guidance essential to effectively executing the water-resources research and training program authorized by the Water Resource Research Act of 1964 as amended. A report identifying water and water-related research requirements in the Great Lakes region and specifying desirable priorities and schedules for such research was to be the vehicle for this guidance.

The procedure followed in preparing the report was to hold two working conferences of people knowledgeable and experienced in work concerned with the Great Lakes region and to have a project staff compile the report from the activities and discussions of the two conferences.

The first working conference was held at Alpine Valley, Elkhorn, Wisconsin, from 10 through 15 September 1967. Its purpose was to consider the feasibility of developing comprehensive research projects using systems analysis techniques to solve problems affecting the Great Lakes region. Some of the problem areas in which systems analysis could be appropriately used were to be identified, as were the fundamental investigations required to support these efforts. The second working conference was held in Ann Arbor, Michigan, on 30 and 31 October 1967 to consider the personnel needs and priorities associated with the investigations identified during the first working conference.

A steering committee met periodically before and during both major conferences to plan and evaluate the working groups and discussions of the conferences. This committee was the main policy-making body for this program and was vested with the responsibility for general guidance of the work throughout the contract period. The membership of the steering committee was kept flexible in order to accommodate particular interests and capabilities brought out during the working conferences.

2
SUMMARY AND CONCLUSIONS

In the light of the previously documented seriousness of water-related problems in the Great Lakes region, this multidisciplinary, collaborative effort explored research topics and methodologies

*"Region" here refers to the influenced service area and is not limited to the watershed *per se*.

which appear necessary and appropriate for universities and other concerned organizations and groups with a research perspective which can be focused on this region. The major findings which emerged from the conferences and small group work sessions over a period of six months may be summarized as follows:

(1) Subsystem modeling and related water-resources research should proceed as soon as is practicable in each geographic sector of the Great Lakes region with the long-range objective of obtaining a region-wide comprehensive model, even though such a model is not feasible at this time.

(2) Systems analysis research in at least three aspects, (a) a water-quantity and lake-level model, (b) a water-quality model, and (c) an economic-growth model, is needed for water resources management in this region. The relative difficulty involved in each of the proposed models clearly emerged during this study, and past and present efforts were determined to be inadequate in terms of the innovative experimentation necessary.

(3) Data storage and information retrieval should be coordinated, with all public and nonpublic agencies involved in water and water-related research activities in this region cooperating, to promote operational and research efficiency and as a basis for planning on a region-wide scale.

(4) Analysis and evaluation of the effectiveness of institutions responsible for water-management decisions are required. Criteria for appraisal and recommendations with regional perspectives need to be established for improved water-resource decision making.

(5) Pioneering research is called for on the socioeconomic ramifications of water-management decisions at the various governmental and private levels.

(6) Increased collection and analysis of data in physical, chemical, biological, and social areas is recommended.

(7) A mechanism to coordinate water-resources research among academic institutions in this region and between them and relevant federal and state agencies is needed.

3
RESULTS TO BE ACHIEVED FROM A REGIONAL ANALYSIS OF GREAT LAKES WATER RESEARCH

Until now, research related to water resources in the Great Lakes region has been approached primarily by several disciplines working independently, with little collaboration among the region's universities. Any effective procedures for interuniversity cooperation which are developed for this region may be transferable to other regions. A regional analysis should also provide guidance for planners and enable researchers to see their individual contributions in the context of development and management of the entire region. It should suggest valuable means of communication among relevant private and public (community, state, national, and international) bodies.

3.1. GUIDANCE FOR PROGRAM PLANNERS AND MANAGERS

A comprehensive systems analysis model must explicitly treat and interrelate many diverse variables. There is no one goal taking precedence over all other considerations for the Great Lakes region, but, instead, a mixture of important objectives which must be taken into account. Some of these objectives are complementary, but some are incompatible. Models which consider the many feedbacks and time-dependent factors involved would allow a planner to investigate and compare the effects of alternative policies, which is especially important in the Great Lakes region where many different policies already interact. Such a model would also allow planners and administrators to observe the behavior of the system over a period of time when subject to their policies and water-use projections. If the water-use projections are developed endogenously, then the planner can use the model to test the sensitivity of the assumed relationship between water use and other variables. A gaming-simulation or role-playing model would allow a planner to be an intimate part of the model himself, to make dynamic decisions and react to the impacts these have upon the system, and to see the alternative decisions available to him.

3.2. A FULLER CONTEXT TO WHICH RESEARCHERS MAY RELATE THEIR WORK

A comprehensive systems analysis framework would enable researchers in various disciplines to see where their work fits into the overall system and the kinds of results necessary in terms of information needed by the model. It could point up cases where only slight modification to research in progress would make this work useful to the model. The system-wide analysis should also indicate the weakest areas of the model, allowing researchers to give these areas highest priority. As results are obtained the model could be reformulated and refined. Thus, the areas requiring greatest effort would always be kept prominently before researchers and those who fund research.

3.3. VALUABLE COMMUNICATION AMONG INDIVIDUAL RESEARCHERS AND GROUPS WORKING IN THIS AREA

Since a multidiscipline approach involving information and data exchanges uncommon to a region of this size will be required to develop a comprehensive systems model of the Great Lakes region, this will serve to open communications between researchers in various disciplines. It should also open channels of communication between individuals and groups concerned with the Great Lakes region because of the broad and diverse cooperation that will be necessary.

One requirement of a comprehensive systems analysis model is for consistent and uniform presentation of data. Extensive communication among those working on each research project in the system will be essential to obtain and report data in this manner. This, in turn, can lead to the establishment of means for effectively disseminating information to planners and policy makers as well as researchers.

4
SUMMARY OF THE TWO WORKING CONFERENCES

Two major "study sessions" or working conferences were carried out as recommended in this contract. Knowledgeable investigators from the CIC universities and from state water resources centers and additional systems designers from private industry and nonprofit organizations attended these conferences. Papers were presented by these participants and by representatives of selected federal agencies. High-level personnel from the Office of Water Resource Research of the Department of the Interior, the Water Resources Council, and the Great Lakes Basin Commission were present at both working conferences. Appendixes A and B are detailed accounts of the conferences which are summarized here.

4.1. THE FIRST WORKING CONFERENCE

This five-day study session held at Alpine Valley, Wisconsin, succeeded in bringing together researchers and program managers concerned with water problems of the Great Lakes region. After it was decided that water-quality research could best be implemented on a subregional basis, the necessary and feasible research projects in modeling and systems analysis were discussed. Steps were also taken to begin design of a water-quantity model for the entire Great Lakes System.

Multidisciplinary work groups at this conference set about identifying particular areas for water-resources research. Presentations from federal agencies detailed data collection, analysis, and dissemination capabilities and current programs in the Great Lakes basin. It was generally agreed that the Lake Michigan basin should serve as one major focus for research efforts. The need to design the relevant subsystem models in a way consistent with the eventual evolution of a total system model was emphasized. The potential research projects identified at this first conference were placed in two broad categories for consideration, physical-biological research and institutional-socioeconomic research, with understandable overlap in many cases. Once major areas of research had been considered, the task of examining specific research requirements for the Great Lakes basin remained for the second working conference.

4.2. THE SECOND WORKING CONFERENCE

One of the highlights of the two-day session in Ann Arbor was the decision to focus on the physical, economic, political, and biological relationships and possible tradeoffs between wastewater treatment and raw water treatment in a given sector of a subregion under study. This research program would involve (1) the necessity to enlist several CIC universities for each subregion, i.e., southern Lake Michigan, western Lake Superior, or the southern half of Lake Erie, (2) the all-important consideration of present and future water-supply requirements and associated costs, (3) the cooperation of industrial and municipal interests, and (4) the collaboration of natural scientists, social scientists, engineers, systems analysts, and other specialists in an effort of mutual concern.

A regional economic-growth model, gaming simulation as a research and learning tool, refinement of the water-quantity and water-quality models, and associated requirements for institutional-social research were major topics of discussion at this conference. A paper on the state of the art in system model building was presented (see Appendix C). The purpose and structure of nine system models and results using them were reviewed. Eight of these models are mathematical models evaluated by computer, while one is a gaming-simulation model in which players are used in roles to approximate actual conditions. Some examples of the types of subsystem models that have been constructed were also presented. This review was concluded with a statement on the characteristics required of a model for the Great Lakes region and a suggested approach for formulating such a model.

Near the end of the second working conference it was urged that the research capabilities of the institutions and agencies represented be itemized. An outgrowth of this evaluation was an inventory of projects and a statement of major proposals deemed important for a systematic management strategy in the Great Lakes region. Appendixes D through G are research design papers put into their present form at a drafting session held in Milwaukee, Wisconsin, 17 November 1967. Investigators interested specifically in institutional and social systems research met in Madison, Wisconsin, on 15 March 1968. In collaboration with investigators who had attended earlier sessions, Norman Wengert, Professor of Political Science, Wayne State University, and Keith Warner, Professor of Rural Sociology, University of Wisconsin, contributed substantially to these deliberations on socio-political research requirements (see sections 5.4 and 5.5).

5
MAJOR WATER SUBSYSTEMS AND ASSOCIATED SOCIOECONOMIC AND INSTITUTIONAL RESEARCH

The physical system under consideration is composed of the area covered by the Great Lakes and their contiguous, contributing subwatershed areas. The surface drainage area is well defined and serves as a convenient starting point for such study. This physical system was approached as two subsystems. A model of one of these, the water-quantity subsystem, was determined to be feasible for immediate preliminary design and construction on a region-wide scale. Modeling of the water-quality subsystem was determined to be feasible for one or more subregions within the Great Lakes region. It was further judged that both subsystem models, whether formulated on a region-wide basis or subregionally, would have political and social characteristics that should be considered for research.

While separating the quantity and quality modeling efforts is helpful, it was recognized that there are important linkages between the two subsystems. A better understanding of these might be obtained by studying an element such as chloride over a period of time for the entire Great Lakes system. This type of study could provide information about such things as the flushing rates and the direction of movement through the system by the element being studied.

5.1. THE WATER-QUANTITY SUBSYSTEM*

The variation in levels of the Great Lakes affects shoreline interests, navigation interests, and hydropower interests. At present, two of the lakes, Superior and Ontario, are regulated by controlling the outflow according to rule curves developed by the U. S. Army Corps of Engineers and modified many times since they were first developed. While reducing high lake levels and increasing low levels is certainly one step in regulation, a foot reduction in high levels should not be considered to have the same associated values as a foot increase in low levels. Economic data should be used to properly weigh the two alternatives against each other so that operating rules minimizing losses or maximizing benefits can be determined.

Several new techniques generally summarized under the name systems analysis are presently feasible and ideally suited for developing and exploring new methodologies for optimal control of lake levels. It is proposed to investigate the applicability and limitations of these techniques in determining optimal operating policies for the Great Lakes system. In cooperation with this investigation, it is proposed to evaluate the effects of (1) land management on runoff, (2) precipitation increases, and (3) evaporation reduction (cf. Figure 1). To determine the difference between present day operating rules and any new ones derived in the study it will be necessary to construct a mathematical simulation model of the Great Lakes which will permit testing of these alternatives. This will be done in close cooperation with the U. S. Army Corps of Engineers which is presently in charge of regulating the Great Lakes.

5.2. THE WATER-QUALITY SUBSYSTEM**

The difficulties of developing an effective water-quality model for the Great Lakes region are considerable; however, the successful application of systems analysis in several complex problem areas during recent years justifies undertaking this major effort. The methodology for handling broad environmental studies by this means is presently under development, with much of the technology adapted from uses of systems analysis in industrial, health, defense, and space research programs. Recent studies have designed water-quality models for rivers and estuaries to assist in the selection of operating policies for such systems, and, although lake problems are different from those of rivers, the methodologies for analyzing both kinds of system are likely to be complementary.

*This section constitutes a summary of Appendix E.

**This section constitutes a summary of Appendix F.

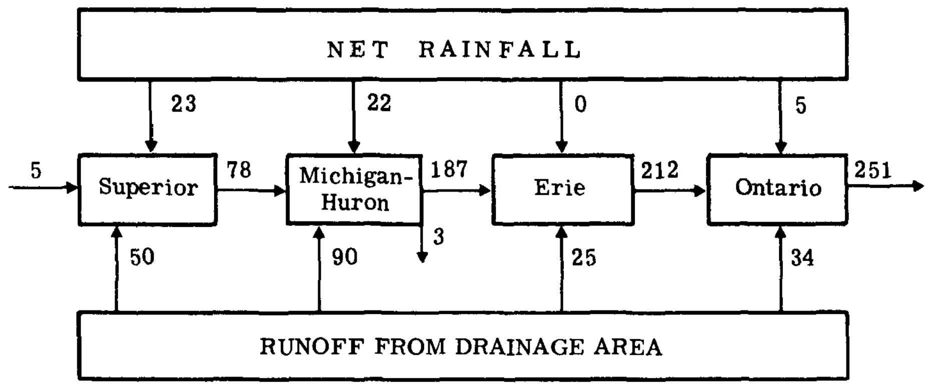

FIGURE 1. "BLACK BOX" MODEL OF AVERAGE INPUTS AND OUTPUTS OF THE GREAT LAKES SYSTEM. The data are from the U. S. Lake Survey and are in thousands of cubic feet per second. These averages are for the period 1950 to 1960 and are based on keeping the lakes level.

Because of the complex nature of the numerous elements involved, it will be useful to approach the water-quality subsystem from several points of view. It was determined to try two approaches, a lake model and a sublake model, initially. The lake-modeling approach is designed to quantify the relationship among local areas lake by lake. The sublake approach seeks to describe the nature and alternative courses of action within a localized sector, taking into account the effect of neighboring sectors. The two approaches are not separate and distinct, and results with the sublake model will allow refinement of the lake model; since the two models will thus be complementary, they must be developed simultaneously.

The lake model is to describe the water quality by subregions within each of the Great Lakes as a function of water use requirements and the quality of water put into the lake, whether by natural runoff or return from some use. Each subregion is to be chosen so as to be relatively homogeneous in its properties, to receive local inputs, and to provide local withdrawal. Figure 2 presents, as an example, the initial subdivided model of Lake Michigan. This type of subdivision seems applicable for spring, summer, and fall, though in winter many of these boundaries tend to disappear. Information on the physical nature of currents in each lake and the physical, chemical, and biological transformations that accompany the currents in each subregion of the lake must be collected. Also, the transfer functions which apply to the exchange of water and material between subregions must be determined.

The sublake model will not only complement the lake-modeling effort, but also an economic-growth model. The sublake model is indicated as a local sector in Figure 3, which shows the spatial relationships between the local lake sectors and associated water uses (see Appendix F for definitions of the symbols used). The uses may be such as for municipal or industrial water supply or for recreational purposes. The location, amount, and quality of water put into and withdrawn from each of the sectors must be determined. For some uses it will be possible to employ controls on the water quality before or after the water is used, while other uses will allow no control measures.

Obviously, information must be exchanged between the two modeling efforts. The sublake model must use the transfer functions between lake subregions and within each subregion as determined from the lake model. The lake model will require the location, amount, and quality of influent and effluent water for each subregion as determined from the sublake model. It will be necessary to identify the water uses in each sector along with the water-quality limits associated with each use. After these limits have been established for each quality parameter, studies must be conducted to determine the methods of water and waste treatment, management, enforcement, etc. that may be employed to control the level of water quality within the limits for the local sector. The lake model will then integrate these sublake models to determine their interdependence and effect on the entire lake. The costs and benefits associated with controlling the level of water quality in selected local sectors, not only the direct costs and benefits normally identified but also those social values which are usually not estimated, should be studied and evaluated. With a comprehensive assessment of the resources available, the use demands, ideal and practical institutional and

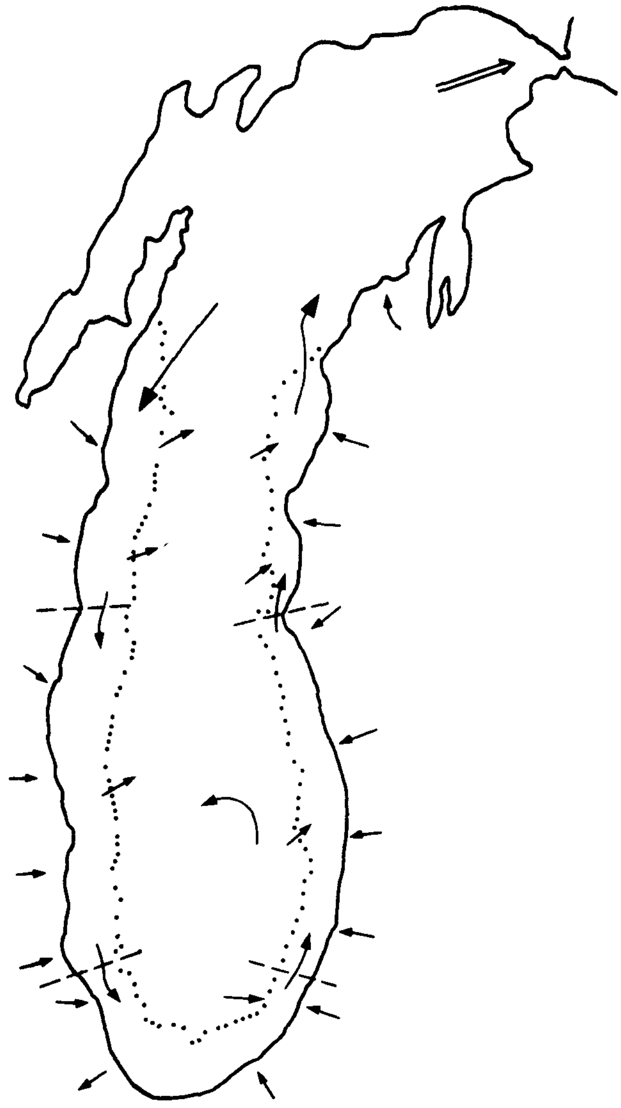

FIGURE 2. INITIAL SUBDIVIDED MODEL OF LAKE MICHIGAN. Inputs, withdrawals, and internal transfers under mean conditions are indicated. The internal boundaries change seasonally and are long-term averages from observations.

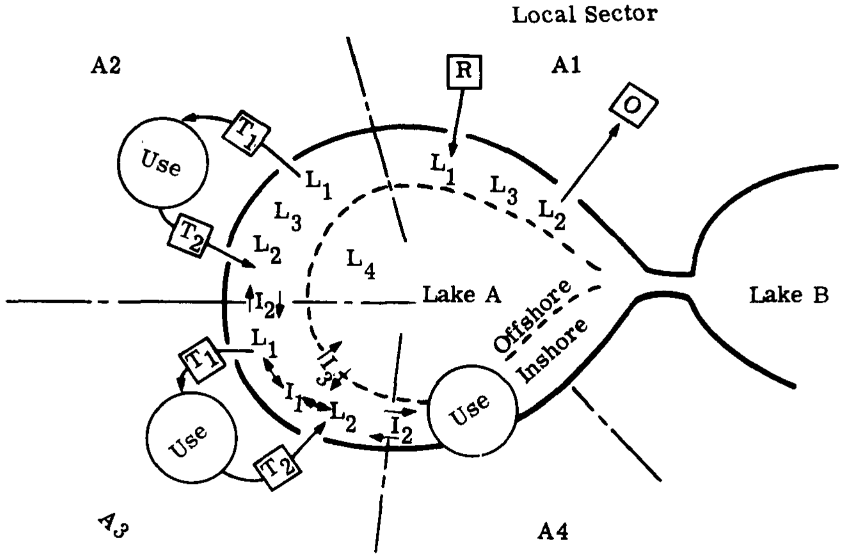

FIGURE 3. SPATIAL RELATIONSHIPS BETWEEN LOCAL LAKE SECTORS AND ASSOCIATED WATER USES

legal constraints, and the interactions of the system components, alternative procedures for controlling water quality to meet selected social goals may be suggested.

It was decided that the major initial effort on the water-quality subsystem would be directed toward Lake Michigan because of the urgency and magnitude of the problems involved, the relative isolation of this lake from the other lakes, and the interest of available personnel. It is anticipated that other individuals and universities will develop the interest necessary to become involved in the study of the other lakes.

5.3. A REGIONAL ECONOMIC AND DEMOGRAPHIC GROWTH MODEL

While the study of difficult questions such as water quality may require first attempts on a subregional or local scale, there is strong evidence that final results must be viewed in a broader context such as that of an overall regional economic-growth model. Such a model can serve to unite local problem areas and to provide an appropriate framework for judging the impact of alternative public actions. It is the essence of the joint effort of the CIC for improving Great Lakes management that decisions made in a local framework will tend to be less optimum than those made on a regional basis, and a regional economic-growth model is necessary for providing the regional viewpoint.

In relation to the particular water-quality model sketched above, a regional economic-growth model can serve many purposes. By incorporating the local water-quality sector in the growth model, it will be possible to judge not only the feedback from the economy to water, but also the feedback from water to the economy. It is widely agreed that sound economic projections are needed as a basis for Great Lakes' management, but no one has constructed a model showing the feedback from the costs for various lake levels and water qualities to the region's economic growth. Yet, this information would be of major importance in gaining the perspective needed for influencing economic growth in the region. Moreover, while the water-quality link between lakes may be small, the alternative uses of the lakes should be tied to a model of the region's economic growth. It would be incorrect, for instance, to consider the recreational benefits of water-quality management in one local area independently of the total benefits from water-quality management within the area and within the lake system as a whole. It is only possible to judge all of the alternative uses of the lakes within the broad framework of projected population and economic activity.

A regional economic-growth model would also have several uses not directly connected with the water-quality model. It should be useful in establishing the overall framework for the water-quantity model, especially if the feedback between the water quantity and the economy is found to be significant. More importantly, the model should be helpful in making explicit the interdependences for economic growth that exist among such policy areas as water-resource management and urban and transportation development.

While the construction of such a model has not gone far enough to permit a statement of its form, there has been enough consideration to identify some problem areas. For one thing, it is usually accepted that a general regional economic model considering all relevant questions is an impossibility. Decisions must be made on exactly which questions this model will answer. Also, as has been indicated, the Great Lakes region is indeed a combination of a large number of subregions. Since it is again generally agreed that there are no "all-purpose" regions, determining the appropriate subregions for consideration may be difficult. Furthermore, the Great Lakes region constitutes such a large part of the national economy that national economic projections can not be regarded as external to this area of investigation. It will be necessary to specify more completely the effects of economic growth in the Great Lakes region upon the national economy and subsequently back upon the region itself.

Though the economic-growth model will obviously be a large undertaking, it is necessary if the various CIC research efforts are to have a "specific orientation towards enhancing the means and capacity for influencing the direction of the regional change." This model investigation is now being considered under a separate CIC research project.

5.4. STUDIES OF SOCIAL FACTORS

Issues of water quantity, quality, and use ultimately must be resolved by reference to the interests and actions of people. It is people's use of water resources that is the fundamental basis of society's concern with the quantity and quality of these resources; water performs essential and important functions for people, and the interests, actions, and distributions of people are important determinants of water quantity and quality. Broadly defined, social factors may be studied by political scientists, economists, legal scholars, and social psychologists as well as by sociologists. Each discipline will bring somewhat different perspectives and emphases to these studies, and these must eventually be integrated as research findings are applied to the solution of practical problems. This section is intended to suggest some particular areas for needed research by sociologists, political scientists, and others. The next section, on institutional studies, provides a framework for integrating diverse social science studies by focusing on water resource institutions.

First, research to facilitate orderly setting of goals and establishing of priorities for water resources in the context of society is needed. Although it is not the proper function of the social sciences to establish goals and values, systematic study can help to determine the consequences of attaining or failing to attain alternative goals and the relationships of decisional processes to end results. This information can provide the basis for a more rational selection of goals and priorities.

Research on the social consequences of policies, programs, and technological developments related to water resources is also necessary. The effects of such factors on patterns of community growth and concentration of population, location of industry (and therefore employment), recreational facilities (especially as metropolitan population pressures increase), and other social programs (e.g., by preempting tax dollars) are representative of such consequences. Studies in this area might include determination of (1) what the specific social and political consequences of particular water policies, programs, and developments are, (2) the extent to which these consequences were anticipated and intended, (3) organizational means of assuring greater agreement between actual and intended consequences, and (4) means for more accurately predicting the consequences of alternative programs and developments.

Conversely, social changes that have consequences for water resources should also be investigated. Population growth, redistribution, and concentration; changes in the amount of leisure time available and in recreational patterns; developments in the location and operation of agriculture and industry; establishment of voluntary associations interested in promoting conservation of resources; transportation changes that make the population more mobile; and advances in communication on social problems (e.g. health, discrimination, and pollution) through mass media are just some of the social changes having important consequences for water resources.

The nature and degree of social organization related to water resources in such areas as the Great Lakes region is yet another topic meriting investigation. Such relevant questions as the following might be raised: (1) In what way and to what extent can social systems analysis be applied to the entire region and/or to its parts? (2) How extensively are the people of the region organized with reference to water resources? (3) Which organizations are more interested and more powerful in water resource decisions? (4) What are alternatively useful ways of studying parts of society relevant to particular programs and policies, e.g., community power structure, organizational sets? (5) What are the region's peculiar problems of coordination (or rivalry) among institutions and agencies concerned with water resources?

Allied with this research would be that on the advantages and disadvantages of alternative forms of organization and decision making. For example, what are the merits of multiple-purpose agencies or projects relative to multiple agencies or projects with a single purpose? What are the merits of vesting the authority and responsibility for decisions in units at the local level rather than the state or interstate level? What are the advantages and disadvantages of coalitions between public and private organizations to deal with water resources as opposed to public organizations alone for this purpose?

The organizational patterns and performance of water-resources agencies should be examined and evaluated. How do the organizational patterns of these agencies influence their performance? For example, how are administrators and other staff members evaluated and rewarded for their work, and, in turn, how does this influence the content and implementation of policies and programs and the enforcement of laws? There seems to be a tendency in such agencies to neglect social goals in favor of economic or physical goals, and it should be determined to what extent this is true. If it is true, what could be done to facilitate the accomplishment of social goals related to water resources?

Finally, studies of the beliefs, values, and actions of people in relation to water resources and agencies dealing with these resources are needed. There are several ways such information could be useful. For example, public organizations relying upon laws relating to water pollution and enforcement agencies with relatively small staffs cannot observe each citizen and enforce such laws on an individual basis. There must be some acceptance, internalization, and self-enforcement of the norms by the people. Then, how do people come to accept the norms and guide themselves? What programs for this are effective? How long does it take to change the values and attitudes of people in such matters? Or, the problem may concern voting a bond for some water facility. How can we predict behavior on the basis of beliefs and values and, thereby, predict the success or failure of such bonding attempts? What motivates people to support or reject policies and programs for water resources, and how much of this motivation involves factors only indirectly related to the resources themselves?

There are, in sum, two major kinds of work to be done by sociology and some of the other social sciences in relation to water resources. One is to apply accumulated theory and research findings to particular water resource problems, while the other is to develop basic knowledge about those aspects of society important to the quality, quantity, and use of water. The preceding suggestions for research constitute a "first view" of useful work to be done. As more study is given to such areas, new perspectives will emerge, and focal points will become sharper; consequently, what research is necessary will have to be redefined.

5.5. STUDIES OF INSTITUTIONS

During the considerations of a systems analysis approach to research on the Great Lakes, discussion frequently turned to "institutional constraints." There was general recognition that no matter how "right" a physical and economic solution might be, there were often institutional obstacles to its adoption and that research on such institutional problems is urgently needed.

The terms "institutions" and "institutional systems" are here used to designate a web of poorly defined interdependences among law, agency operations, and public finance as these activate and constrain federal, state, and local governments in formulating and implementing water policies and programs. The relationship of research on these to systems analysis of Great Lakes water resources is by no means clear. While it may be said that social, economic, legal, and political forces do interact to constitute a type of institutional system or systems which may determine whether actions indicated by physical and economic considerations will be taken, it is apparent that these interactions are not readily amenable to quantitative systems analysis. Limitations of systems analysis in studying institutions have been identified by Professor Donald Michael:*

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* Program Director, Center for Research on the Utilization of Scientific Knowledge, and Professor of Psychology and Natural Resources, The University of Michigan. The points listed here are paraphrased from a personal memorandum to Spenser W. Havlick, 17 November 1967.

(1) Setting Goals. The systems approach does not resolve the prior problem of choosing among goals. In the human sphere, particularly the political sphere, goals are not only difficult to set, they are difficult to maintain. In fact, there is often a question of reestablishing goals when feedback from the environment requires changes in the original goals. If goals are not sensitive to environmental data, the response from the system tends to be out of phase with a set of goals or priorities which were previously in effect.

(2) Interdependency of Goals and "Means". Our political process always involves compromises on goals and on the means for attaining them. A critical aspect of our approach to life is often to eschew goals and make the means ends in themselves. As a consequence, neither system boundaries nor subsystem relationships can be clearly differentiated. Also contradictions and ambiguities in the "system"—conditions which the systems approach is designed to eliminate—are inherent in the political-biosphere ecology the program is designed to examine. Revealing these ambiguities and contradictions and their political utility would be very informative for bio-ecologists, political ecologists, and systems designers.

(3) Values That Are Not Quantifiable. The problems of goal setting, interdependences of goals and means, and system ambiguity all converge on and may be symbolized by the problem of how to incorporate aesthetic considerations into the systems models. Although aesthetic factors are not quantifiable, they are nevertheless central to the political and biological interplay involved here.

Acknowledging these limitations, we nevertheless believe that institutional research in the Great Lakes region can profit from a systems approach. Thinking in terms of systems and general systems theory can aid in relating a variety of pertinent factors, such as the physical and economic imperatives in a specific situation and the institutional systems which may be involved in their accomplishment. More specifically, a systems approach can serve to

(1) Alert us to the extent of interdependences

(2) Alert us to unintended as well as intended and unanticipated as well as anticipated consequences and side effects

(3) Alert us to direct or indirect alternatives for changing the system when we may be blocked from changing certain variables

(4) Constrain us to search for new and more powerful variables than the numerous traditional and easily measured ones that often have relatively little relation to decisions or actions on water resources

A systems approach in considering water and related resources in the Great Lakes region will emphasize that there are institutional values important for reasons other than water-related considerations and that these must therefore be balanced against specific water-related benefits and costs associated with alternative institutional arrangements. Research in this area, then, must involve not only water agencies, but the whole range of institutions affecting decisions on water policy and management. Institutions directly concerned with water resources are not separable from the entire spectrum of institutions relied upon to achieve a wide range of social purposes. Particularly in the humid eastern portion of the country, specific water agencies must be considered only a small part of the total institutional environment significant in water-resource problems.

Within this frame of reference, several areas of institutional research emerge as important:

(1) Analysis of the institutional systems through which water policies and programs are formed and implemented. Studies of specific agencies should document differences and relationships among their objectives, legal authority, financing methods, and staff needs. In short, this research should illuminate these agencies' capacity to deal with problems of the Great Lakes, the clientele they serve, and the influences to which they respond and the interactions among agencies required in attacking the region's water-resources problems.

(2) Identification and analysis of the institutional implications of interaction between water-centered decisions and related environmental factors, e.g., land use, industrial development, suburbanization, recreation, and transportation.

(3) Studies of indirect factors affecting water-related decisions, such as the operations of realtors, organized industrial and conservation interests, engineering consulting firms, and news media.

(4) Studies to develop ways of identifying the "community of interests" which institutional arrangements should serve by water resource decisions. Research is needed on the decision structures required by specific water problems and on identifying the beneficiaries, cost sources, and principal participants associated with specific actions.

(5) Studies to illuminate different perceptions of the nature and seriousness of water-related problems so that "political demand," as distinguished from "economic demand," may be better expressed. Such studies can also guide the design of institutional arrangements to properly articulate these value judgments along with other factors with which they must interact.

(6) Analysis of the relative roles of the professions and politics in water policies and programs. There is general agreement that fundamental water decisions today involve balancing conflicting social values and that these decisions must ultimately be made through political processes. Studies that will clarify the need and methods of maintaining clear channels of political responsibility should be encouraged. Analyses of existing independent water agencies to determine the extent and significance of political responsiveness to them would throw light on the kinds of institutional adjustments which would promote more responsible political action.

(7) Analysis of emergency legal-institutional problems associated with enforcing water regulations under current federal law. For example, enforcement patterns between state agencies and

public (municipal) corporations are fairly well established, but those for private corporations, an area of considerable importance in the immediate future, are less well developed.

Research in these seven general areas obviously calls upon the energies and competence of a variety of disciplines and professions. In addition to a basic understanding of the technical parameters involved in problems of water use, there is a need for high-quality research in economics, sociology, political science, and law. Much basic legal research related to water use in the Midwest has already been done, yet there is still considerable room for new contributions from the legal profession. Special attention has been given in the preceding section to the needs for sociological research on water-related problems, and it is also contemplated that many of the above areas of institutional studies should invite contributions from sociologists.

In addition to the important contributions that independent research in any of these general areas can make to better understanding of the institutional problems associated with water resources in the Great Lakes region, specific case studies, properly selected, can provide an appropriate vehicle for probing these questions in depth and showing how they interact to form a total institutional environment. This approach should identify a relatively discrete decision structure; for instance, studies might concentrate on water supply and waste discharge functions. Decision units in such an area would normally be defined by some relatively homogeneous group of urban jurisdictions tributary to a lake. For Lake Michigan, the subregional water-quality models proposed in this report could further aid in delineating a decision structure in terms of the physical and economic parameters of water supply and waste discharge actions. In such a context, several of the above general research questions could be examined with the possibility of more immediate results.

Case studies of this kind are also amenable to experimental heuristic or gaming simulation of institutional behavior. The relative roles of institutions involved in water-use decisions, their response to alternative solutions which might be proposed, and the legal or fiscal constraints they might encounter are all important in developing a simulation model of institutional behavior. Heuristic or gaming simulation lends itself to the immediate exploration of institutional behavior in a theoretical and highly abstract way. This approach may quite soon provide some tentative and contingent guidelines for institutional design. It would permit the introduction of improved physical-economic information as the more sophisticated models become operative and thus, in turn, enhance the possibility of developing a more sophisticated gaming model. The possibility of such a gaming project is described in greater detail in Appendix G.

5.6. DATA REQUIREMENTS

There exists the need to examine the present status of and future requirements for collection, storage, and retrieval of water and water-related data on the Great Lakes region so that water information programs will be able to fulfill the needs of research, planning, and management programs in the region (cf. Appendix D). Such an examination has two particularly important aspects within the systems analysis and modeling framework proposed for research in this region. First, present data-collection sources, the types of data collected, and the form in which they are available must be identified. Then, present and future data needs should be clarified, the present supply of data evaluated for its adequacy for future research and information programs, and proposals for making the necessary data available outlined.

An accurate description of the data requirements for the proposed modeling effort will remain unknown until the models are designed. Nevertheless, during this designing, a major effort will be necessary to compile a detailed list of the data sources in subject areas expected to support the models developed. Because of the comprehensive nature of the modeling effort, a broad set of information areas must be evaluated to determine the characteristics of completed data-collection programs and those in progress and the availability of data from these programs. The following may be cited as only a few of the diverse types of data that will be required: inlake subsystem models will need water-chemistry, plankton, and current data; economic subsystem models will need data on water supply costs, sewage treatment costs, and recreation demands; and sociopolitical subsystem models will need data on the political structure, specific governmental units, and special interest groups in the area.

A system for collecting and using the diverse kinds of data and information required in the program should be developed in three separate parts: (1) a system for handling selected basic data, (2) a system for referencing data banks available on file, and (3) a system for processing abstracts and texts containing analyzed data and information pertinent to the modeling of the Great Lakes region. The Departments of Agriculture, Commerce, and the Interior are developing federal information systems along these lines and it would be possible, through planning coordinated with both federal and state agencies, to create a unique collection of basic data for the topics and region under study. Any integration of such multisource data into a system which will identify major data sources, be coordinated with state and national data storage and retrieval systems, and fill the unique data needs dictated by the models developed obviously requires detailed planning and design.

5.7. SURVEY OF NEEDED RESEARCH PROJECTS IN THE GREAT LAKES REGION

In addition to the discussions of research efforts indicated in sections 4 and 5, the CIC staff provided an opportunity for conference participants and their colleagues to suggest what degree of personal priority they would assign to the research activities suggested at the working conferences and drafting sessions and in recommendations sent to staff headquarters in Ann Arbor. Immediately after the second working conference in Ann Arbor, an "Inventory of Needed Research Activities in the Great Lakes Region" was mailed to investigators who attended the conferences. This inventory, in the form of a multiple-choice questionnaire, was intended to obtain the personal preference of those responding for several water-related research activities, so the results of this informal preference tally should not be construed as a group sanction of any particular research project. The responses are tabulated in Appendix H.

5.8. A MECHANISM FOR THE COORDINATION OF WATER-RELATED RESEARCH BY UNIVERSITIES IN THE GREAT LAKES REGION

A regional water and water-related research effort of the scope and complexity described in this report should have continuing guidance and coordination. Therefore, it is suggested that a University Water Resources Research Group, which would replace the steering committee now constituted and responsible for this report, be established. This consideration of the research competence and appropriate organization to further develop, manage, and execute the research design proposed here has been requested by the sponsor of this project

The principal role of universities in an area such as this is to perform high-quality fundamental research relevant to the problems and applicable to policy formulation, planning, and program development by governmental agencies. These research efforts should be free of the constraints that are by definition imposed upon planners and program managers, but, on the other hand, the research community must appreciate that the fruits of research may only be accepted and applied to the extent that these constraints will allow. The fundamental division of effort between the research community and the agencies responsible for policies, plans, and programs is recognizable at the federal level where the Office of Water Resource Research is constituted as an agency responsible for relations between the Department of the Interior and the research community and is separate from policy, planning, and program agencies like the Department's Federal Water Pollution Control Administration or the U. S. Army Corps of Engineers. In the same sense, the Office of Water Resource Research is distinct from, although obviously associated with, the Water Resources Council, which exercises centralized supervision over the several river basin commissions. We believe the university research community should, in the same manner, be separate from the operating agencies of the several states and the federal government in this region. This is not to say that research relevant to the problems faced by the operating agencies is not of paramount importance to this research community, which should maintain working liaison with state agencies and with federal agencies through the Great Lakes Basin Commission. The research programs should support the Commission and its constituent agencies as they study problems of water and related land resources as necessary for the preparation of comprehensive and coordinated plans.

The university research community in the Great Lakes region is broader than that represented by the CIC universities alone. Other U. S. and Canadian educational institutions in this region also have substantial research competence. It is therefore suggested that the CIC or another existing regional consortium serve as the coordinating vehicle for all of the academic research community in the region by sponsoring a University Water Resources Research Group consisting of at least the following members:

(1) Directors of the water-resources research centers in the several Great Lakes states

(2) Representatives from the CIC universities which either do not have water-resources centers or are not land-grant institutions, i.e., the University of Chicago, Indiana University, the University of Iowa, The University of Michigan, and Northwestern University.

(3) Members-at-large from other major universities in the region, including at least one Canadian representative, with these members-at-large to be selected by the sponsoring consortium

(4) The chairman of the Great Lakes Basin Commission or his designate

Should the industrial community develop a grouping similar to the suggested academic group, it would then be appropriate to invite the chairman of such a group to sit with the university group. This group should select a chairman and a small executive committee to conduct business between meetings of the full group, and limited staff assistance should be provided. Public and private funds could be solicited to underwrite costs of the group's operation. This proposed organization would be built around existing institutions such as the CIC and the several water-resources research centers already existing at the land-grant universities, and it is deemed the better part of wisdom to build on such existing institutional structures. By including the directors of the water-resources research centers, the group would have channels of communication to all universities, public and private, within the nine-state region; the research center directors could acquaint competent investigators in any of these institutions with research programs encouraged by the group.

The broad mission of the University Water Resources Research Group would be to encourage, guide, and coordinate academic research activity in the Great Lakes region in support of policy-makers, planners, and program managers in the responsible governmental agencies. The governmental structure in the United States portion of this region is, of course, formalized in the Great Lakes Basin Commission. The universities should not presume to preempt or duplicate the activities of the governmental agencies, but, rather, should relate their work to significant problems while maintaining accepted academic research freedom. In addition, the following specific activities are suggested for the University Water Resources Research Group:

(1) Maintaining an overview of relevant and desirable areas for research – an extension of the comprehensive research design developed in this report

(2) Encouraging the development of research proposals consistent with (1) above and particularly on an interuniversity basis

(3) Reviewing and endorsing interuniversity research proposals consistent with (1) above at the request of those making the proposal

(4) Assisting in obtaining the approval of public and private funding agencies for proposals

(5) Serving as a general channel of communication among the region's universities and between these and public and quasi-public bodies

(6) Maintaining immediate liaison with the Great Lakes Basin Commission, the principal agency for coordinating plans for the development of water and water-related resources in the region. (The chairman of the Commission or his designate has been suggested as a member of the group.)

(7) Cooperating with the International Association of Great Lakes Research on symposia devoted to Great Lakes investigations. This will allow researchers to review the progress and results of CIC projects on a sustaining critical basis.

(8) Serving on request as a consultative body, or in arranging balanced advisory teams for specific tasks, or in making recommendations to public or private bodies seeking qualified professional talent for either permanent or consulting services

(9) Sponsoring conferences to present problems and challenges of at least 20 years from the present, which, in the minds of CIC investigators and public agency personnel, need to be anticipated and appraised. Anticipating changes which are expected in the Great Lakes region will permit research activities to be geared to meeting needs before crises or irreversible developments arise.

(10) Making recommendations concerning water resources research policies on a consensus basis, through the CIC, to appropriate bodies

Appendix A
A REPORT ON THE FIRST WORKING CONFERENCE: CONSIDERATION OF GREAT LAKES SYSTEMS RESEARCH

10 - 15 September 1967

Alpine Valley, Elkhorn, Wisconsin

A.1. INTRODUCTION

This report is an overview of the events of the First Working Conference, which considered Great Lakes systems models and related research. It was held 10-15 September 1967, at Alpine Valley, Elkhorn, Wisconsin.

The agenda and timetable of events are listed in Section A.2. Section A.3 presents major portions or highlights of presented papers, special work group discussions, and plenary session summaries. In Section A.4, general conclusions of the week are given in addition, to a "laundry list" of projects which emerged as appropriate targets for research by a consortium of CIC member universities. It is emphasized that this latter list is a beginning inventory of opportunities which need attention. Additional listings of projects and names of accompanying investigators were welcomed.

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A.2. THE CONFERENCE TIMETABLE

Sunday, September 10

3:30 p.m.	Arrival of conference participants
5:30 p.m.	Steering Committee and CIC staff gathering
6:30 p.m.	Dinner and keynote address by Dr. Henry P. Caulfield, Executive Director, Water Resources Council
9:30 p.m.	Steering Committee and staff meeting

Monday, September 11

8:45 a.m.	Presentation of conference format and program task, Professor William C. Ackermann, Conference Chairman
10:00 a.m.	Coffee pause
10:15 a.m.	Open discussion Informal comments solicited from Dr. Roland Renne, Director, Office of Water Resources Research, and Harry Steele, Water Resources Council
12:00	Lunch
1:15 p.m.	Problem and subsystem consideration in work groups selected by discipline, with the following membership under the following "subsystem" titles:

Physical-Biological Subsystems	Economic-Demographic Subsystems	Social-Institutional Subsystems
Rohlich, Chmn.	Milliman, Chmn.	Duke, Chmn.
Deininger	Afriat	Smith
Ayers	Holt	Hines
Dambach	Wright	Luken
Mortimer	Hamilton	Flinn
Walton	Koenig	Ray
Meredith (staff)	Ben-David	Havlick (staff)
Kerrigan (staff)	Brown (staff)	
	Drake (staff)	

The following were at liberty to visit among the three groups:

Ackermann
Renne
Caulfield
Steele
Misener

3:30 p.m.	Coffee pause
3:45 p.m.	The three groups reassembled and then later reported in plenary session
4:30 p.m.	Issues of primary importance were reported by group leaders Professors Gerard Rohlich, University of Wisconsin, Jerome Milliman, Indiana University, and Richard Duke, Michigan State University
5:15 p.m.	Open discussion and questions
6:30 p.m.	Dinner, followed by observations and comments by Dr. Roland Renne, USDI, and Dr. Henry Caulfield and Harry Steele, Water Resources Council
8:30 p.m.	Open discussion focused on conference objectives and problem identification
10:30 p.m.	Steering Committee and staff meeting

Tuesday, September 12

8:30 a.m.	Overview of comprehensive regional systems modeling for water resources management, Professor J. W. Milliman, Indiana University, presiding
9:00 a.m.	Presentation by Henry R. Hamilton, Battelle Memorial Institute-Columbus Laboratories: "The Susquehanna Experience"
10:00 a.m.	Discussion
10:15 a.m.	Coffee pause
10:45 a.m.	Presentation by Rolf A. Deininger, School of Public Health, University of Michigan: "Physical Modeling of the Great Lakes System"
11:30 a.m.	Discussion
12:00 noon	Lunch
1:15 p.m.	Presentation by Charles Holt, University of Wisconsin: "Economic-Demographic Subsystem Modeling"
2:00 p.m.	Comments by Professors Sydney Afriat, Purdue University, and Colin Wright, Northwestern University
3:00 p.m.	Coffee pause

3:15 p.m. Open discussion

5:00 p.m. Adjournment

10:00 p.m. Steering Committee and staff meeting

Wednesday, September 13

9:00 a.m. Consideration of social subsystems including institutional arrangements in Great Lakes region, Gerard Rohlich, moderator for the day

9:15 a.m. Panel discussion headed by Dean Stephen Smith, University of Wisconsin School of Natural Resources
Other panel participants:
Fox
Havlick
Hines

10:30 a.m. Coffee pause

10:45 a.m. Discussion and questions re social subsystems

12:00 noon Lunch and Steering Committee-staff meeting

1:30 p.m. Open discussion and assessment of progress. Five multidisciplinary groups were formed to consider geographical and problem-oriented research possibilities. Group members:

Social Goals and Values	Quantitative	Quality	Economic	Legal-Institutional
Brown	Afriat	Ayers	Graham	Ackermann
Drake	Deininger	Ben-David	Hamilton	Clevenger
Duke	Drescher	Dambach	Kerrigan	Havlick
Flinn	Meredith	Heavenrich	Milliman	Hines
Koenig	Walton	Holt	Steele	Ray
Smith		Mortimer		Runge
Wright				

3:45 p.m. Discussions in interdisciplinary groups led by moderators: Ayers, Duke, Hines, Milliman, and Walton

4:30 p.m. Free time

6:30 p.m. Dinner

8:00 p.m. Remarks by Gov. Mathew E. Welsh, Chairman, International Joint Commission, U. S. Section

9:30 p.m. Discussion and questions

Thursday, September 14

9:00 a.m. Presentation of reports from the five multidisciplinary work groups

10:30 a.m. Coffee pause

10:45 a.m. Continuation of reports and discussion after each

12:00 noon Lunch

1:00 p.m. Remarks by Hon. Raymond F. Clevenger, Great Lakes Basin Commission

1:45 p.m. Questions

2:00 p.m.	Series of presentations on existing data sources for Great Lakes Research Robert E. Graham, Department of Commerce
2:40 p.m.	William Drescher, U. S. Geological Survey
3:00 p.m.	Coffee pause
3:15 p.m.	H. F. Lawhead, U. S. Army Corps of Engineers
3:45 p.m.	B. G. DeCooke, U. S. Lake Survey
4:10 p.m.	Phillip L. Taylor, Federal Water Pollution Control Administration
4:30 p.m.	Discussion
5:00 p.m.	Free time
6:30 p.m.	Dinner
8:00 p.m.	Informal discussions

Friday, September 15

9:30 a.m.	Plenary session, William Ackermann presiding Review of reports from problem-centered multidisciplinary work groups
10:30 a.m.	Comments by Dr. James T. Wilson, Chairman of the Project Steering Committee
11:30 a.m.	Discussion; summary of the conference results Adjournment for general participants
12:00 noon	Lunch
1:15 p.m.	Steering Committee-staff meeting
3:00 p.m.	Adjournment for Steering Committee and staff

A.3. ABSTRACTED HIGHLIGHTS OF THE CONFERENCE

Inasmuch as the major objectives in this section are to illustrate the evolution of thinking and present highlights of the group effort, the names of individuals making specific remarks have not been included. Abstractions of many remarks have been made from tape recordings and notes assembled by the CIC staff. Due apologies are made because more complete renditions of the discussions and presentations were deemed inappropriate in this summary.

10 September 1967 — Evening Session

The formal program of the conference began with a keynote address by Dr. Henry P. Caulfield, Executive Director of the Water Resources Council. A useful history of federal involvement in water-management activities set the stage for a discussion of present and future expectations in water-planning activities by the governmental organizations which now exist. For the sociologists, economists, engineers, biologists, and systems analysts who were not intimately familiar with the posture of the federal establishment in water-related research, the remarks provided a necessary and enlightening beginning for the week's deliberations.

The administrative operation of the Water Resources Council was detailed in terms of membership, responsibilities, and ongoing functions. It was pointed out by the speaker that from his vantage point the will of both the Congress and the Executive Branch regarding overall management functions in natural resources is coordination of water- and related land-resources matters as provided by the Water Resources Planning Act of 1965. Those functions are:

(a) To maintain a continuing study and to prepare biennially a national assessment of the adequacy of water supplies.

(b) To appraise the adequacy of administrative and statutory means for coordination and implementation of the water- and related land-resources policies and programs of the several federal agencies and to make recommendations to the President with respect to federal policies and programs.

(c) To establish, after appropriate outside consultation and with the approval of the President, principles, standards, and procedures for federal participation in the preparation of comprehensive regional or river-basin plans and for the formulation and evaluation of federal water- and related land-resources projects.

(d) To coordinate schedules, budgets, and programs of federal agencies in comprehensive interagency regional or river-basin planning.

(e) To carry out Council responsibilities with regard to the creation, operation, and termination of federal-state river basin commissions.

(f) To receive and review comprehensive regional and river-basin plans and transmit them, together with Council recommendations, to the President for consideration and transmittal to the Congress.

(g) To assist the states financially in developing and participating in the development of comprehensive water- and related land-resources plans.

To perform these functions the Council has been organized as set forth in its Rules and Regulations. Certain highlights are significant for your understanding of this new institution.

First, the organization is designed to assure that Council members themselves, who in effect constitute a Cabinet Committee, "will meet at least quarterly and consider and decide major matters . . . "

Second, the organization provides for Representatives of Council members together with the Executive Director to "take action when necessary and appropriate and, after consideration, submit recommendations to Council members on matters requiring their action." The Executive Director is chairman of meetings of Council Representatives, and they are held at least biweekly. Decisions at this level are by unanimous agreement of the Representatives and the Executive Director. Thus all unresolved matters automatically go to the Council members for decision.

Third, the organization includes provision at headquarters for administrative, technical, and consultative committees. Three administrative committees—for policy, planning, and state grants—have been established. Each is chaired by the appropriate Assistant Director of the staff. The Council's technical committees, so far, are the old technical subcommittees of the Inter-Agency Committee on Water Resources, popularly known as "Icewater," that was abolished in April 1966. By consultative committees, the Council means committees of persons from outside the Federal Government. To date, the Council has not given consideration to establishment of any consultative committees.

"Icewater" field committees also came under the aegis of the Council in April 1966. It is now expected that these committees will continue to function until, as in New England, the Pacific Northwest, and the Great Lakes they are superseded by Title II river basin commissions.

At this point the discussion began to zero in on the replacement of interagency committees. Then a special reference is made to the River Basin Commission arrangement with the Great Lakes Basin Commission (GLBC), held up as a case in point:

> We have, as you know, established the Great Lakes Basin Commission. The functions of a river basin commission are what you need to be concerned about here. Let's get to the structure now and functions later. What we have here applies to the Great Lakes Basin Commission, the chairman being appointed by the President. Now he is not just a chairman of a commission; he is the coordinating officer for the federal member, with the additional functions of the chairman of the commission. This is not an unimportant role. In consultation with the Vice Chairman, he picks the time and place of meetings, sets deadlines of submission of annual and other reports, establishes subcommittees, and so forth. With the concurrence of the Vice Chairman, he appoints commission technical staff. He himself is responsible for the use and expenditure of funds of the commission, so that the chairman has some powers of consultation. The two of them have definite power of respective appointment of personnel. I might say, however, that the details of the chairman's functions that are not indicated in the by-laws can be circumvented by agreement of the commission.
>
> The River Basin Commission members are, of course, the eight states in the Great Lakes region; and the federal members are, I believe, from nine departments including the Justice Department, which was added because of the litigation or the degree of legal action that has taken place in this basin. The United States section of the International Joint Commission could be a member, but this was decided against for two reasons. One, because the United States section of the IJC is made up of three people who could not possibly divide themselves for actually attending meetings of all the commissions. That's a bureaucratic reason.
>
> The second reason is probably more important. We had to consider the role of the GLBC as opposed to the role of the IJC. The IJC is supposed to be an advisory body, not a negotiating body between American and Canadian members, considering problems without respect to nationality. If the same people were members of both commissions and participated in making IJC policy, their membership in the GLBC would in a sense be prejudicial in making their decisions in the IJC. We therefore decided (Governor Welsh was particularly influential here) against having IJC membership on the GLBC. The IJC considered this question also.

Four functions of the Great Lakes Basin Commission seemed to stand out in the presentation. First, the Commission is to be the principal agency for coordinating all water planning in the region. This coordination function included "water- and land-resources planning" at all levels of government. It remains an open question how far down the ladder this in fact can go and how involved private industry can be.

A second function is to prepare and keep up to date a comprehensive, coordinated joint plan for water and related land resources in the region. The language in Title II of the Water Resources Planning Act suggests that the plan include federal, state, interstate, local and <u>nongovernmental</u> resources development.

A third function, although not stressed, deals with recommendations of long-range schedules of priorities for the collection and analysis of basic data. Equally important is a fourth function, which encourages the Commission to support and "undertake such studies of water and land resources problems . . . as are necessary" for comprehensive river-basin planning and management.

Most of the above points are fairly obvious if one is at all familiar with Senate Document No. 97 and the Federal philosophy in this field. Dr. Caulfield gave due emphasis to the objective of economic development, but he went beyond that consideration to stress the social and amenity objectives which are awkward to deal with in economic analyses. The example of preserving wild rivers in their natural state for the purpose of open space and natural beauty was used.

> At the time this was put in Document 97 it was a brand new idea. Now we have Scenic Rivers Bills, etc., and it is accepted almost as "old hat." Well-being of people is a general term which has social significance, and as indicated here it is very difficult at times to spell out more precisely in a general way, applying all over the country, exactly what one would mean by well-being. It certainly is a reminder to indicate that people, after all, are what we are concerned about here in connection with the use of resources, in many instances. However, in a group like this I should remind you that this also means particular policies which the Federal Government has adopted which are believed to be of social importance, and are matters of law.

The final thrust of Dr. Caulfield's remarks concerned challenges and opportunities which are in need of serious consideration.

> Procedures for getting the principles of welfare economics into planning have not yet been developed adequately to get such procedures into use by people actually employed in the work. In the Delaware Study in some rough way Marshallian considerations were incorporated in what that study thought was a "Marshall Plan." The Delaware Study people were conscious of this in time, but their procedures were very crude indeed compared to what might have been rigorous procedures leading to an optimum solution. As you know, we take into consideration the constraints of social goals (which are intangibles and include any kind, even, shall we say, a wild river) when we are thinking of modifying an efficiency model. However, there has been no project formulated in the United States that has ever actually done this. This is an important point. You may know that we have developed a joint Army and Interior project on the Upper Missouri which originally had eleven alternatives and came down to, in the public sense, five meaningful alternatives. But it certainly did not start out as an efficiency model in such a way that you could indicate the development suggestions by means of the constraints on the model . . .
>
> Now as far as I am aware, there has never been a model rigorously developed for a river basin or ever practically carried out. The hard work on the Harvard and Lehigh River models fell short [sic] as many of you know, and you can understand that one can't take the approach, "Well, this just takes a few more of us bright fellows and it will get done." But I need not labor that point; I'm sure you're all aware of this. So a real research function exists, real things aren't known and real inventions are needed in this field. It is in these inventions in river basin planning, where systems analysis can work, that we are looking forward to, and the possibility of your making a real contribution to this phase. This is a unique situation in the Great Lakes, not quite the same thing as in the Missouri Basin.
>
> Now I want to call your attention beyond these two areas into specific areas of research. One is on economic matters. Those of you who know more about this than I can carry on from here, but I will remind you that there may be something substantial here. Senator Nelson has introduced a bill — S2123 — for investigating alewife and other fish in this area, and so there may be something more going on than just what we are talking about. I need not mention to those from Wisconsin that we're concerned with the eutrophication problem. The area that I would think of first is cost sharing research. This is of more general interest. I think our friend over here from the University of Indiana knows more about that than we do, but I haven't seen any research paper on it yet.
>
> Then the next question is the whole problem of flood-plain management. The flood-plain management problem includes the problem of cost sharing of flood protection, flood insurance, and flood-plain use regulation. These are areas of needed research. Those of you who are hydrologists may know that the task force of flood-control policy singled out flood-frequency problems, methods of determination of uniform methods of determining flood frequency. This

is a very difficult problem. We have had our Hydrology Committee working on it, through outside consultants. This is an area in which (if we are going to really go ahead on any kind of flood insurance, let alone do a good job with flood protection) we certainly need to have much better methods or the best methods as the basis of determination of calculation of damage and risk.

I hope I have given you some kind of a conception of the government and other ongoing activity on the one hand and our interest in research on the other hand, and I hope, if your group decides to go forward, there can be a marriage between these efforts in such a way that neither member of the marriage is stifled by the association with the other, and that something fruitful can come from the marriage.

Monday, 11 September 1967

Moderator-for-the-day Professor William C. Ackermann led off with the basic challenge that the conference was intended to "advance the state of the art as a multidisciplinary group." It was made clear that no constraints should exist on areas and approaches to be considered. Definitions were offered about the tasks at hand, the concept of the model, and the system and subsystems under discussion. A problem-oriented approach was emphasized.

Whether the development of a model for the entire Great Lakes drainage basin was realistic came up as a serious question. The Canadian experience illustrated how the Lake Ontario basin has been "divided" seven ways for planning purposes (water, quasi-political, economics, terrain, population, industrial, and "potential for development"). Then a caution was issued about the "falsity of boundaries." The 1967 National Assessment by the Water Resources Council is a first attempt to overcome particular boundaries. In fact a considerable effort seems needed in correcting the distortions created by economic and physical externalities (economies and diseconomies) in the system.

Another tack was taken by the question "What are the problems we want to solve?" Official objectives (via Senate Document No. 97) are stated as economic development, recreation, flood protection, etc. Problems specific to the Great Lakes are the difficulties with "pollution, alewives, lake levels, hydro-power capacities, recreation development, soil erosion, water supply, wildlife considerations, massive urban proliferation, maintenance of wild areas, waste disposal procedures and ineffective institutional arrangements."

At one point a participant expressed his surprise about the magnitude of the CIC contract. It was suggested then that the ultimate goal of this experiment in systems models was "to produce a proposal, not a result." The notion of a problem basis with a geographical subsystem for each major problem began to gain support. Several participants suggested a "blue sky" approach; others favored a research design which could produce results with high practical utility in terms of current organizational problems. Still other questions raised were to whom the research is to be directed, how much money is available, and "will the people with the money have to define the problem."

After some confusion at this point, a suggestion was made that a basic set of interrelationships could be put together rather as a farmer integrates and manages his unit of the landscape. The farmer interfaces the market conditions with his environmental capabilities and manages the farm as a relatively simply system. Of course the analogy is weakened when one considers the complexity of even one of the Great Lakes' basins. It was agreed that the model of a municipal or metropolitan operation might make a better analog: the elements have to be identified and a time scale has to be agreed upon.

Before the three subsystems groups (physical-biological, economic, and social) went into work sessions, a series of questions which expressed the interests and concerns of many conferees was propounded. The questions listed below serve as illustrations:

---- If our mission is to lay out a regional research design or proposal instead of solving local problems per se, don't we have to look at the interrelationships between all three basins (Upper Mississippi, Ohio, and Great Lakes)?

---- What was the Susquehanna experience?

---- At what points does the water sector actually feed back on the economic sector as a whole?

---- Is some research needed on what the social goals really are?

---- Is the pollution problem in the Great Lakes so long term and subtle that we would have trouble identifying action proposals?

---- Wouldn't it be a good idea to try to study feedback from the water sector in terms of <u>critical point identification</u>?

---- Is there really a public demand for pollution abatement?

---- Is there really a water shortage in the Great Lakes basin?

---- What are the marginal products vis á vis tradeoffs between navigation and power?

---- What are the restraints from the Supreme Court "diversion" activity?

---- How much social value and economic value is placed on different levels of pollution?

****

Reports of the three groups are paraphrased below in a condensed form.

Professor Rohlich's report on the physical-biological subsystems began the afternoon session. Attention was directed principally to water pollution and lake levels.

It was indicated that lake-level investigation lends itself very well to systems analysis. Some question exists about whether the total lake-level picture is truly a system. Is it worth while to go into more sophisticated models of lake levels at the present time? Can existing works be better used? Could Lake Superior be used as an upstream regulatory body? Models can be built to answer these last two questions and others.

The eutrophic problem was a critical issue. Factors which affect the metabolism of the lakes were discussed, and it was agreed that we need more research on indices of eutrophication, better monitoring or eutrophication, and research on sediment-water interfaces. The ground-water "basin" needs to be established and compared with the surface-drainage area. Improvement of tributary water quality was discussed in terms of total lake quality. More needs to be known about coastal and offshore waters in terms of "mechanisms of exchange."

Availability and retrieval of data at the present time needs study. How little data can we get along with to do the necessary modeling?

Questions raised as a result of the group's report included one concerning a possible benefit-cost analysis of the U. S. Army Corps of Engineers' dredging and disposal operations. Other statements indicated that very little relationship exists between lake levels and pollution. Also it was pointed out that eutrophication and pollution are not synonymous.

Professor Milliman's report from the economic-demographic subsystems group was next.

> Do we need a large complex economic model of economic growth of the Great Lakes region, perhaps in a systems sense, to answer the kinds of questions that we are dealing with; and when will we know if that kind of economic model is justified? A large complex economic model could be used to generate possible growth patterns and factors that condition economic growth in the area and to generate an idea of demands of the economy (under various assumptions) to deal with the various kinds of water and water-related problems. In addition, that model could show strong feedback between changes in water costs and the economy; and perhaps it would show if there is any feedback and how the economy would be influenced by various changes in water costs . . . . If changes in water costs do not directly and greatly affect economic growth, then it is fairly doubtful on this basis alone that a large complex economic model (very difficult to construct) would be justified. We don't know the answer to that, but we suggest as a strategy that some preliminary research needs to be done to find out. As a starter some likely critical points, in terms of both products and spatial configurations should be picked out, where we think that the water-economy feedback might be evident. If the preliminary research strategy shows that strong feedback does exist, then the case for a complex economic systems model depicting economic growth, within which you look at other factors affecting economic growth as well as water, might be strong.

You could take some simple, straightforward projections of economic activity and from them see the demands for water. The field of recreation was mentioned. What changes in water costs will affect "sensitive" industries? "We feel very strongly that additional work needs to be done on price policy, on financing and on allocation . . . . We need to know the efficiency implications of putting water into one use as opposed to another . . ." Could we not build a simple model to monitor the economic effects that changes in the water-quality regulations will bring about, at least at a few critical points, to give us a handle on economic effects of changes in water-quality management?

The message from this group to the CIC is that the complex systems approach perhaps can be justified in examining the water sector, but only after the initial models and research have been undertaken. Also, the group agreed that the CIC can take the leadership to begin the very, very difficult task of doing some quantitative research on social goals and values.

Professor Duke reported for the social-institutional subsystems group.

Three considerations were presented as a prelude to the main points of the report: (a) "There is relatively slow growth in water technology in terms of the problems which are evident; (b) with the greatest supply of fresh water in the world, people are going to congregate in megalopolitan regions on a scale that society has not encountered before; and (c) water as a free good is going to become increasingly scarce ". . . which will call for more political demands for water policy, for further managerial intervention, for further planning of water usage, and for reduction of such negative externalities as shipping your sewage down to the next lake." The discussion centered on a review of present and future organizations including the Great Lakes Basin Commission and the need some day for an effective international organization, which will ultimately be required.

Perhaps more limnological data are needed before institutional arrangements can be devised. Are the localized pollution problems really a concern for the entire Great Lakes system? If not, what subsystems should be identified and what linkages built?

Public involvement in the water-planning process was discussed. The examples of Texas, Illinois, and California were given. In the Great Lakes region some experimentation could be done with "anticipation of problems" in addition to the traditional approach of planning to resolve problems. Some research is needed in organizational effectiveness in local and regional water-management bodies. "The theory of planned social intervention and planned social change is akin to the notion of strategic theory, and this has been . . . very badly developed in the social sciences. The other kind of model (naturalistic theory) has been very good; but it does not help us to be good change agents and perhaps an elaboration of that would be helpful."

As an appendix to the social subsystem report, the "annotated outline" prepared by Lyle E. Craine, Spenser W. Havlick, and Ralph A. Luken, which was discussed in the social-institutional subsystems group, is included here.

An "Annotated Outline" of the Social Subsystem in the Great Lakes Region

The destiny of the Great Lakes region depends in part on its ability to utilize its resources for regional development. The available water resource is one key ingredient for development. Water of the Great Lakes Basin, to greater or lesser extent, constitutes a physical system. However, decisions regarding water use and development involve interaction with other systems. For the purpose of this conference we are conceiving the entire Great Lakes Regional System as being composed of three functional subsystems: physical, economic-demographic, and social.

Our outline focuses on the social subsystem. This system is less precise then the others and has been given relatively less attention by systems analysts. We suggest that social subsystems be delineated by the interdependencies of social change agents. These agents of social change are often, but not always, identifiable organizational entities. They are the formal and informal mechanisms of social interchange which articulate the collective needs of the region and mobilize resources for meeting these needs.

In order to provide a basis for discussion, we raise several questions in outline form which seem germane to the consideration of the role of social systems to water resources of the Great Lakes. In this exploratory approach we propose to raise and briefly comment on a succession of questions. We anticipate several answers to our questions, many of which will differ from our answers.

I. What is a system?

A system is a set of objects, together with relationships between the objects and between the attributes [1].

Subsystems are primary divisions of a system.
Objects are parts of components (physical or abstract) of the system.
Attributes are properties of the objects. For example, stars have temperature, velocity, etc.
Relationships are the interdependencies which tie the system together. Any set of objects has relationships. The question is, which are the relevant relationships?

Whether a set of relationships is a system or subsystem depends on the complexity of the problem and the objectives of systems analysis.

II. What do we mean by systems analysis?

Two possible definitions are:

A. Systems analysis is a strategy for problem solving. In this situation it has been defined as an effort "to make comparisons systematically and in quantitative terms and to use a logical sequence of steps which can be retraced and verified by others" [2].

B. Systems analysis aids in defining the relevant components of any system and the relevant linkages or interdependencies among the components (objects). The approach is more descriptive than the problem-oriented approach. In many cases, a systems approach may be as important as a method of defining the relevant problem as it is a process of problem solving. It is broader gauged research in that it deals with quantitative and qualitative factors.

III. What is regional development?

A. What is a region?

We suggest one set of criteria for defining a region. These criteria are geographic (the physical environment), an awareness of regional problems and opportunities, and an anticipated capacity to solve these problems [3].

B. What is development?

Economists distinguish between economic growth and development for a region. Economic growth is usually defined as a change in real per capita income as a result of capital investments. Economic development is both a change in real per capita income and a change in technical and institutional arrangements which generate income [4].

C. What is the role of the social subsystem in this process?

In the ultimate analysis evidence suggests that whatever gets accomplished does so as a result of the social subsystem. Social interaction emerges in decisions to locate industry, to develop recreation facilities, to modify zoning regulations, or to dredge harbors. One possible interpretation is that the social subsystem generates support for the particular objectives of regional development and mobilizes resources for achieving these objectives.

IV. What is the Great Lakes Region?

One possibility is the region described by hydrologic boundaries. We question whether the hydrological region is the relevant region for problem solving and planning in the Great Lakes area. Very few aspects of water management require a Great Lakes management program. Problems of pollution abatement, flood control, and provision of water-recreation facilities can be solved on subregional bases. For example, pollution abatement does not require a Great Lakes solution, but rather programs in specific independent areas, such as southern Lake Michigan, Detroit River, and eastern Lake Erie.

V. What is the social subsystem of the Great Lakes region?

The social subsystem comprises all components which engage in social interaction for resolving water-management problems or which utilize water for promoting regional development. Social interaction is defined as the "process in which individuals (organizations) relate to their own minds or the minds of others—the process, that is, in which individuals take account of their own or their fellows' motives, needs, desires, means and ends, knowledge, and the like" [5]. Social organization exists to the extent that actors engaged in social interaction make some effort to restrict entrance into or withdrawal from participation by present actors.

VI. What are the components or who are the social change agents in the Great Lakes Region?

Some of the components are:

(1) Formal political organizations—national, international, state, county governments
(2) Formal administrative agencies—U. S. Army Corps of Engineers, Water Resources Councils, F.W.P.C.A., U. S. Geological Survey, Great Lakes Basin Planning Commissions, state water agencies
(3) Formal private organizations—industries
(4) Planning bodies
(5) Interest groups

VII. What is the role of research in analyzing the social subsystem?

Perhaps the most important role is identification of linkages or interdependencies among the components, individually and collectively as they respond to challenges. For example, what are the linkages among the formal political organizations in the region and the Federal Government for pollution abatement; which are strong and activated frequently, and which can be controlled indirectly by policy guides instead of administrative decisions?

A. What are linkages among change agents in the region?
B. What are the linkages between the Great Lakes and other regions?

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[1] These definitions are taken from A. B. Hall and R. E. Fagen, General Systems Yearbook Vol. 1, 1956.

[2] E. S. Quade, Military Analysis (Santa Monica, Calif., The Rand Corporation, 1965), p. 2.

[3] 'Design For a Worldwide Study of Regional Development," (Washington, D. C., Resources For the Future, 1966), p. 4.

[4] This distinction is taken from Charles Kindleberger, Economic Development, 2nd ed., New York: McGraw-Hill, 1965, p. 3.

[5] Guy E. Swanson, "On Explanations of Social Interaction," Sociometry, (June 1965), p. 102.

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On Monday evening, Dr. Roland Renne presented his hopes and expectations about the conference and an overview from the Office of Water Resources Research (OWRR).

What with 26 federal agencies dealing with water resources in some way, OWRR sees its role as "extramural." A "relevancy test" has been developed as a result of about three years of experience (700 projects under way). It is applied by the water-resource center directors. For example, you in the Great Lakes know what the problems are and we are trying to stimulate research projects which "fit" the problems.

The CIC proposal appealed to us very much not only because of the approach and the significance of the problem but also because of the powerhouse that is represented by the eleven universities here in the Midwest that are involved. In Washington it is pointed out that one of the areas of greatest Congressional concern is the pollution of the Great Lakes (particularly

Lake Erie). We are asked what we expect to get from our investment in water-resources research.

By dependence only on mission-oriented agencies, many significant projects may be missed. Thus the OWRR brings together through competition the best competence in the country to discharge water-resources research; 107 universities are in the program.

The type of research that will come out of your deliberations will probably be considered under Title II. It now has 31 projects operating in FY 1968 out of 255 submitted projects asking $29 million versus $2 million appropriation available. Many of the systems analysis projects were disappointing. Shortage of time may have been a factor. Many of the projects were naive and exploratory. They fell short in terms of depth and were not related to specific major problems. The projects are due on 15 November 1967 for FY 1969. We don't know how much money will be available but we want to explore longer range planning horizons.

We're in the market for good projects in systems analysis of a set of problems that need further examination and study and more research, like the Great Lakes region. We're certainly interested in getting further work done that will reveal these areas, and we think that this $27,000 is a good investment in terms of getting from you more specific, detailed projects that we'll be very much interested in helping to support. Now of course the relevance of this type of work to the problems that are significant up in this area will have national significance; they will certainly fulfill the purpose of the Water Resources Research Act in trying to provide a more adequate supply of water both in quantity and quality for the United States and its growing needs, which purpose was written into the Act. But in addition, your work should be very helpful to the planning programs of this region; and while we are not interested solely in funding research that will be of benefit to the Water Resources Council (although it is important), we feel that in our overall program there should be projects of this kind that will be of primary interest and relevant to the planning problems of the area. So the usefulness of the results, if they are good in the case of water resources planning, will help develop a ready, good, and highly desirable market for further research along these lines. How we can weld together more effectively the research work we are doing with the planning needs of the Council is a very important matter.

The amount of money available for this undertaking might be about 10% at the outside limit ($400,000 or $500,000) if a $4 million appropriation is available for FY 1969. The Budget Bureau has emphasized Category Six in the 10-year program—"Research for Water Planning" (about 20%). One-fifth of our allotment projects are in the water-resources planning area, which is very encouraging.

In the matching fund projects the proportion is 30-32%. In Title II we've put 76% of FY 1968 money on research related to water-research planning (of a $10.1 million program). After these short-term projects (9-24 months) bear specific fruit, we hope to go up on the Hill and show what early efforts have yielded in order to obtain additional help.

Dr. Renne in his closing remarks offers an inspiring challenge:

Looking down the road it appears individual projects are not currently being made for ten years, but I'm sure, if this group comes up with a solid program of research needs and can develop the necessary projects that will stand up under our evaluation process, there isn't any reason why this office along with other agencies of the Federal Government can't take a more active role in helping to finance these for the next 5 to 10 years and get the kind of information and facts that we need for much more effective planning in water-resources development.

Mr. Harry Steele of the Water Resources Council noted the hard work that had preceded the present priority for research in the water-planning area. It was made clear that "extramural" research was going up and that "in-house" research is going down. Nevertheless, a strong in-house capacity is required to translate research results into action programs in the planning community, and this is the big gap.

Then a summary was given about the national water assessment presently under way. A hope was expressed that the figures in the Great Lakes Basin, for example, can be tested in order to improve the national ability to translate the economic projections into water requirements "realistically and more accurately." The present data are poor, e.g., current data on water use for the 1967 assessment. Better techniques for obtaining such data can improve the quality and reliability of the statistics.

Tuesday, 12 September 1967

Moderator-for-the-day Professor J. W. Milliman opened with comments about the inadequacy of the benefit-cost analysis for dealing with larger systems, particularly in river-basin planning. There is a need to fit public-investment decision making into schemes of regional growth models and models of regional economics. Then, within that framework, benefit-cost analysis does make some sense.

I started out making my living as an economist using the tools of benefit-cost analysis in the design and analysis of projects. Over the years I have become impressed with inadequacy of benefit-cost analysis for dealing with larger systems and with problems inherent in systems of public investment, particularly in the case of river-basin planning. I feel more and more strongly that the tools of benefit-cost analysis are not adequate until we have public-investment decision making fitted into schemes of regional growth models and models of regional economy; and once within that framework benefit-cost analysis does make sense. Prior to that, for the larger more basic questions of development and growth we need to explore much more thoroughly the questions of regional growth models and regional economics.

River-basin planning and regional economics developed in the economic literature more or less as two separate animals. River-basin planning in the economic literature (in the 1930's with the Tennessee Valley Authority, Columbia River Basin Project, Colorado River Project) should have showed that these regional problems would have been a source of theoretical inspiration for regional economics. The fact of the matter seems to be that river-basin planning at least until recently has not been responsible for new developments in regional economic theory. Nor has river-basin planning achieved its earlier promise of being truly regional in character. The best survey of regional economics [John R. Meier, Amer. Econ. Review, March 1965], however, did not include a single reference to river-basin planning. In river-basin planning we believe that there are no generally accepted procedures for forecasting in the planning process (regional forecasting, regional planning); however, both factors should be mutually supporting and proceed in a joint fashion. Initial planning guidelines must be established, then a preliminary forecast model be constructed.

Preliminary projections then will reveal a need for additional information about additional variables, which in turn will modify the planning assumptions. The refinement of plans and forecasts usually begins from nature, and as a process it is continually winnowing and expanding. Because of this we are now coming more and more to believe that it is desirable to construct a projection model in mathematical form which can be manipulated on a computer in order to illustrate the effects of alternative assumptions about goals, plans, and projections. Mathematical formulation serves to make alternative assumptions explicit and provide a systematic framework for quantitative analysis. In this sort of framework, the technique of computer simulation seems particularly well suited for the iteration of planning and projection.

The model is not a device for producing single-valued projections or not even for producing optimal solutions. It may, more importantly, be a means of facilitating understanding of complicated systems of relationships that are relative to policy making. An important existing illustration of regional model building by simulation technique is perhaps the Harvard model and the successor Lehigh model. The Hawaii planning model appears to be the most flexible tool but is still in need of vast improvement. It has an unusual feature: unlike any other model, when it grinds out projections of likely future income and employment under alternative public investment assumptions, it does distribute income by income class. It gives us a feeling for income redistributional consequences of various kinds of public policy measures. It's one of the first to get at some of the social questions more directly and explicitly within the model. Another feature of the Hawaii planning model is that it is kept as a planning tool and is continually revised, updated, and rerun in light of new information and new policies, etc. The model is used as a planning tool not to grind out single-valued projections which you are stuck with but continually gives revised projections in light of new technical information. This gives a feeling for policy.

Turning to a river-basin model based upon simulation, we can look at the Harvard and Lehigh models, which start out with an attempt to specify optimal design in optimizing operating procedures. These operating procedures are based on linear programming techniques. The programming techniques necessarily require simplification of the original problem. They use target outputs and benefit functions (highly restricted and simplified), and a rigid system of priorities had to be imposed. In many cases operating procedures for the facilities were fixed, and there are many sorts of dynamic feedback that necessarily had to be omitted. The Lehigh model simulates mean monthly flows and 3-hour flow at flood peaks measured at 6 reservoirs and 9 hydroelectric power plants. With systems design there is an associated unique operating policy and a schedule of priorities for the use of minimum flow. Economic benefit functions were associated with targets for water supply, flood control, recreation, and power. These economic benefit functions were used to evaluate the results and point toward optimal designs and optimal operating procedures. A regional economist using this model doesn't have much work to do. The economic projections and economic benefit functions which were developed outside the model were merely specified exogenously, and the simulation was largely engineering and hydrologic with predetermined economic benefit functions, predetermined targets, and economic projections.

There are differences of philosophy regarding river-basin planning and simulation vis á vis the Susquehanna model and the Lehigh model. The use of optimizing and programming techniques may limit the researcher in the complexities of the problem he can tackle. The mathematics for programming under many complex situations simply does not exist. There are an extremely large number of basic difficulties of public policy in attempting to specify a social welfare function.

For a large region (the kind that really makes sense to plan for), there are many publics; there are conflicts between these publics. These conflicts are not easily resolved. It's difficult to know what a social welfare function might look like. It may be impossible to construct a meaningful social welfare function in many cases. For this region, simulation which does not require an optimizing solution is a useful technique. Another major philosophical point is the relation of regional model building and river-basin planning. The two strands of analysis in regional economic growth, river works construction and river works planning, are part or should be viewed as part of the same general system. Regional economic analysis and river basins should take account of the effects of the economy upon the water and possible feedback from the water sector upon the economy. It is incorrect to plunge into river-basin planning, certainly on any large scale, by designing optimum management systems for the water variables without first having a general regional economic model of the basin which includes the water sector.

A general regional economic model can be fairly complex and sophisticated if necessary, or fairly crude and highly simplified. But even when the feedback is not strong from the water sector back upon the economy, we need to start from the framework of a general economic model, crude or sophisticated, and have this model include a water sector, in order to engage in a kind of river-basin planning that ties the hydrology and the water variables to the economic and social systems that we really want to make it a part of. Also, we must make public investments in the water sphere congruent with other important kinds of public investment variables with which we must deal, and which we must make more sensible in a planning spirit.

And it is in this spirit that I believe the planning organization might view the guidelines offered by the Lehigh simulation model. You may include some skepticism, or at least worry about optimizing procedures for design and optimizing operations of those design variables after they are placed within the larger framework of regional economic growth and regional economic systems. Ron Hamilton, manager of the Susquehanna model, took a group of in-house professionals and outside academic consultants and managed to produce a simulation model which is in some respects unique. The simulation involved for the first time an economic model that has direct ties with a demographic sector (economic sector with direct interdependent ties between them). All other large regional models have computed the supply of labor independently, by standard demographic techniques. Here the two sectors are brought together ad hoc and sort of rationalized. This model does have, however crudely, the economic and demographic sectors. Then you grind up assumptions about age groups, migration rates, etc., directly tied to the economic sector. It is also a river-basin model which generates demands upon the water within the model, directly related to economic activity. The demands upon the water are not computed once the economic projections are done.

[In the original Proceedings report, Rolf Deininger's paper, "Systems Analysis of the Great Lakes Area — The Physical Subsystems," was reproduced in its entirety. The reader is referred to the updated version, Appendix E.] Professor Deininger summarized his remarks by indicating that a complete modeling of water quantity and quality of the Great Lakes region is a desirable undertaking. Based on currently available knowledge, the water-quality modeling will present difficulties due to the fact that the technological relations are not known very well. The modeling of the water quantity seems to hold more promise and is the area where systems analysis can contribute immediately.

The following list of questions and summary remarks (in the order they were raised) indicates the sort of thinking that characterized the afternoon proceedings.

---- Has anyone analyzed major economic implications of regulating the levels of Lake Superior or the other lakes?

---- Do we know enough about the lake processes to model Great Lakes water quality?

---- What about ground-water boundaries and influences?

---- What data are really significant in terms of our objectives?

---- Where shall the emphasis of new data collection be put?

---- What shall our priorities be for research proposals?

---- Not enough data are available on coastal currents, stratification, and the nutrient budget of the lakes.

---- Modeling should be tried to compare demographic influences on nutrient levels in the lakes.

---- Lake-level problems are an appropriate target for systems analysis.

---- What is lacking in lake-level regulations is a sound management strategy.

---- The quality dimension deserves a high priority for physical and biological research.

---- Some crude model building should be attempted by use of nutrient parameters.

---- A critical area for analysis is the southern end of Lake Michigan.

---- We need both optimizing models and simulation models to do our job.

---- Optimizing models are used for making the search more efficient.

---- Nonlinear systems have greater sensitivity in certain regions, but this approach is very difficult to devise. We go into this with extreme humility.

---- There are optimum levels of pollution vis ā vis utilities versus cost.

---- Consider water demand as a function of the price people are willing to pay for it.

---- Water law in the Great Lakes raises questions amenable to research.

---- Development of "social indicators" may be a new area of discourse.

---- The demand for cleaning up Lake Erie may come from nonusers who express a need even though they have no direct economic or geographical contact.

---- We're concentrating almost too much on water and neglecting land-related problems.

---- A "water-use" orientation will be helpful for focusing on research proposals.

---- The real problem is what do we want to use the Great Lakes for.

Wednesday, 13 September 1967

Moderator-for-the-day Professor Gerard Rohlich turned the floor over to Dean Stephen Smith, who headed a panel discussion, "Institutional Systems for Water Resources Management of the Great Lakes." The remarks summarized below include those of the other panel members (I. F. Fox, N. W. Hines, and S. W. Havlick).

Questions were raised about the way situations of public conflict are resolved into operative decisions, how various interests of a region are represented in institutions, and how information can be generated to provide a basis for public action. Data are needed on existing patterns of interest and influence in the Great Lakes. Private interests, for example, are very strong and often have very different objectives (vis ā vis public interests) as to what should be done.

Environmental corridors* which tend to be concentrated around water resources are in need of investigation in terms of legal, political, ecological, and social constraints. Pollution of shore lines and urban areas needs to be recognized as a significant organizational and jurisdictional problem. There are public and private, written and unwritten arrangements operating through law, public policies, and administrative devices.

Work needs to be done on how a public agency can be motivated to generate information on the range of choices and alternative strategies of managing a part of the environment. How are the potentially vast number of choices sifted down to an appropriate number for public consideration and who, in the final analysis, makes the decisions?

In order for practical research projects to result it was urged that focus be directed to specific problem areas. Effects of various decisions would be fed back to the institutions involved. Areas

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*Areas in urban or rural areas that provide quality opportunities for persons in contiguous land units. A corridor may contain scenic open space or structures of visual quality, for example.

of present and expected external diseconomies should help establish research priorities. It was argued that poor water-management decisions were not the result of apathy but rather "a matter of not knowing what the real alternatives are for the water decision-makers to examine."

We should be mindful of how lawyers approach the problems; often the point where the critical decisions are being made is influenced by lawyers or by individuals influenced by lawyers who are client oriented. Important differences were stressed between "legal structure" and unwritten performance which through custom becomes common usage.

It was mentioned that pollution-abatement agencies should consider the Ontario Water Resources Commission arrangement and the relevant applications of the Genossenschaften activities of the Ruhr Valley in West Germany. The current study of "Institutional Design for Water Quality Management" in the Wisconsin River basin was discussed. A major difficulty is our lack of precision in quantifying the benefits from improvements in water quality; e.g., for each increase in oxygen in parts per million, what are the incremental costs and benefits?

The suggestion that certain problem areas in the region be specific research targets came up again as it had in previous days and as it did throughout the rest of the week. Work can hardly be done on all of them at once, so some priority needs to be established in light of payoffs. The development of a research strategy seems called for here instead of prescription in any detail of an "optimum" solution to specific problems.

Special efforts seem needed to determine what institutions are effective and why, who the clientele are for various possible research activities, and who the beneficiaries are of pollution control and abatement.

At one point in the open discussion, considerable attention was given to flow of information between the private and public sector in water-management decisions. Part of the difficulty in achieving desirable programs for environmental enhancement is that of defining the range of choice. It was often mentioned that, with market mechanisms as they are, strong economic motivation exists for investors and private entrepreneurs to propose only particular courses of action. Even certain public agencies have shown partiality to structural measures as solutions to water problems which were brought to particular agencies for resolution. The need in almost every case is to explore a wide range of options designed to solve particular problems. Incentives must be provided, and before additional governmental apparatus is erected, simpler pathways toward solution of subsystem or subregion problems need testing.

The following summary, presented in outline form, is extracted from a discussion agenda by Smith and Fox. It covers the principal remarks of the Wednesday session.

I. Social Systems

A. Systems which structure private and public action.

B. Systems which establish working rules for private action, e.g., market mechanisms, water rights.

C. Systems which make decisions for taking action (public and private).

D. Informal processes of behavior concerned with definite courses of action.

II. Research Orientation

A. Orient research around defined problems—existent and prospective. (The patterns established by Lakes Erie, Michigan, and Superior give us limnological and institutional planning opportunities of the past, present and future.)

B. Identify the decision processes, formal and informal, relevant to the defined problem—understand the processes of behavioral response.

C. Understand system and intersystem interaction, which is a part of pluralistic adjustment—guard against unrealistic comprehensiveness on the one hand and excessive judgments on the other.

D. Identify, and quantify where possible, effects of system performance—also express it in gross and net monetary terms if this can be done.

E. Develop performance criteria.

1. Test effects of selecting alternative ranges of criteria.

2. Examine systems for determining criteria, e.g., generating information, achieving consensus, implementing capability.

III. Research Task

A. Define problems, e.g., pollution, commercial and sport fisheries, transportation, lake levels.

B. Define primary systems as they relate to the problem. Define secondary and tertiary systems as they relate to the problem, including feedback relationships.

C. Develop models of systems to test hypotheses and develop insight.

D. Relate performance to criteria.

E. Develop policy judgments for decision units such as IJC, states, Great Lakes Basin Commission, FPCA, Water Resources Council, operating agencies.

Thursday, 14 September 1967, and Friday, 15 September 1967

Reports on Thursday and Friday of work groups and subsequent discussions are presented in Section A.4 of this report. The summary nature of the final day and a half permits a logical division of the proceedings in this manner. Presentations and questions on Thursday afternoon were hosted by Dr. Wilson.

Mr. Raymond Clevenger, Chairman of the Great Lakes Basin Commission, brought to the conferees fresh information and insights regarding the operation of the Commission. The remarks were especially instructive inasmuch as several efforts of the CIC and the Commission may provide reciprocal benefits.

The existence of the GLBC is a demonstration of Congressional intent for a single agency to be charged with the responsibility for the formulation of a single, comprehensive plan for the basin. The Commission's efforts will continue only as long as a majority of the eight participating states want it to continue.

Funding and staffing of the Commission was discussed. States contribute 50%, and the Federal contribution is 50% (amounting to $300,000-$500,000 per year). Major challenges will be to (1) decrease the "perception of the problem" time lag, (2) formulate a comprehensive plan (within 2 to 3 years), (3) obtain a legitimate expression of the particular problems to be solved, and (4) provide for a closer dialogue at the technical level (between universities and agencies), which should expedite and integrate the participation in the work that needs to be done.

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After Mr. Clevenger's remarks, the representatives of federal agencies (see Section A.1) gave data papers on respective retrieval procedures, difficulties presently faced, and programs or expectations in the near future. All of the discussions concerned the Great Lakes region. Many of the points may have specific value to particular CIC researchers in the immediate future. Individuals who desire verbatim copies of the agency presentations are asked to correspond directly with the CIC staff based in Ann Arbor, where the substantial "permanent appendix" of these and other conference papers is maintained.

A.4. CONCLUSIONS AND CONFERENCE SUMMARY

Condensed reports of the work groups on Thursday and Friday have been incorporated into this section. The reader will discover a slightly elaborated "laundry list" of problems which are framed as possibilities for research among the CIC member universities. More important, however, is a presentation of specific researchable projects which emerged as reasonable targets for the investment of scholarly energy and federal monies. It was anticipated that, by the end of October 1967, some effort would be directed to the preparation of firm proposals (with names of investigators, techniques, target problems, etc.) by interested conference participants or academic colleagues.

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Eventually specific research project proposals will be written by the respective project leaders or principal investigators. Nevertheless an identification of useful systems studies and other Great Lakes research which comprise specific problems is a present goal. Consensus was reached that the Lake Michigan basin will be a primary target for research, with special emphasis on the southern portion of the lake and its environs. International impediments, although not serious, discouraged immediate consideration at critical subregions of the St. Mary's River, the Detroit River, and the Niagara River.

The idea that the southern portion of Lake Michigan be given hard scrutiny in terms of researchable projects should not be construed as a sign to discourage CIC universities from other research efforts in other problem-ridden subregions. Problems in need of attention, data availability, interest among a large number of institutions, and several probable researchers who indicated a personal commitment to the Lake Michigan region were leading factors in the consideration of that sector of the Great Lakes basin. Extreme care should be taken to design the subsystem models as part of an overall strategy because eventually a model of the entire basin will probably be feasible when the data and modeling tools are improved. In the summary reports, several of the work groups included diagrams and outline models to symbolize some problem-solving approaches. Two are given here.

The subgroup on legal and social institutions (Professor Hines) came up with Figure A-1. It was suggested that institutional problems occur on least at two levels: (1) policy establishment by the institutions involved in the political process, and (2) operating efficiency at the level of the action agency. It was agreed that the first step would be to identify the public and private agencies having some impact on the management of the region's water resources, and begin with a familiarization of their rules, processes, and actions.

A schematic model from the Ayer's "quality" group looked something like Figure A-2. To utilize this model, the following tasks are indicated:

<u>Task #1.</u> Define the inputs, outputs, and state-of-the-art controls.

<u>Task #2.</u> (a) Develop transfer functions between input, controls, and input pollution.

(b) Develop transfer functions between the elements of pollution and the general pollution level and controls.

(c) Develop relation between pollution level and effects.

Potential research projects which gained recognition in the final days of the conference are clustered into two broad areas — the institutional-socioeconomic and the physical-biological — with understandable overlap in many instances. <u>The lists which follow are not intended to be exhaustive.</u> There is the implicit hope that it may suggest refinements of these and other projects which can be accommodated under the auspices of the CIC institutions.

<u>Institutional and Socioeconomic Research Acitivities and Topics</u>

1. An analysis of the way water-management decisions are made in the (Lake Michigan) region and what techniques can be applied to assist the decision-making machinery in producing and selecting from a wider range of alternative programs of resource management.

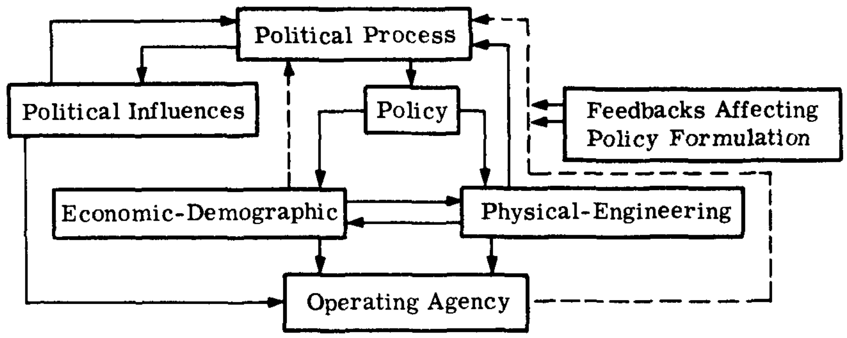

FIGURE A-1. A PROBLEM-SOLVING APPROACH

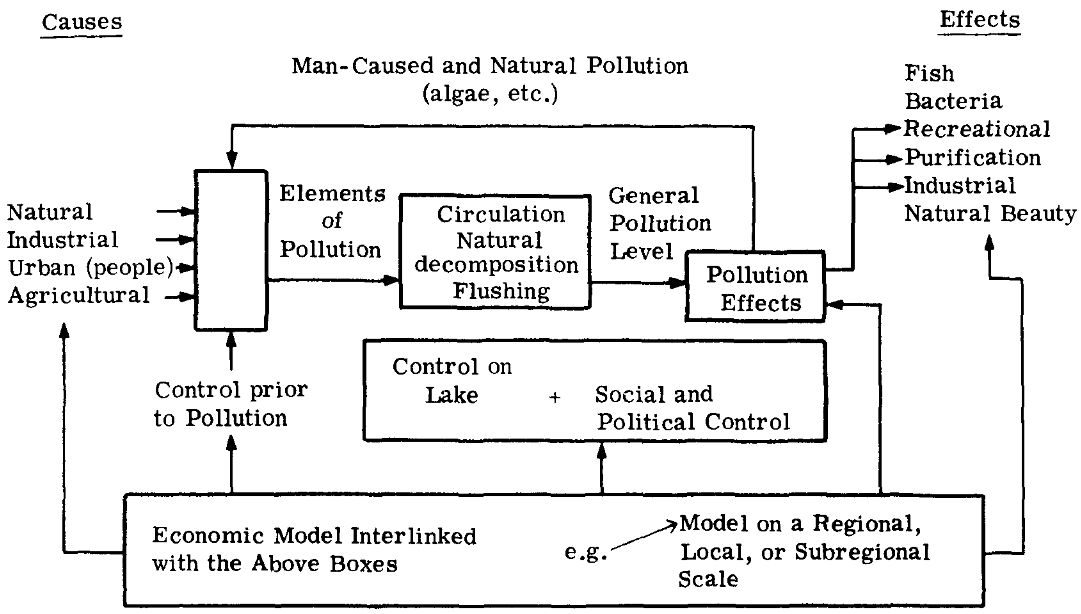

FIGURE A-2. AYER'S SCHEMATIC MODEL

2. An analysis of the flow of information for planning and policy activities between and among the private and public sectors of the subregion.

3. An identification of water-management influences and influential factors as a part of the regional or subregional political power structure.

4. Operational efficiency and effectiveness at various levels of water-related organizations.

5. How individuals, groups, organizations, and other public agencies express themselves in the process of arriving at a consensus about what should be done with the available water resources.

6. What media and vehicles can be applied most effectively (and how) in water-related information dissemination.

7. An evaluation of the prospect that traditional lines of authority and influence may be rerouted from Congressional delegations to regional agencies of national and international stature, particularly by state and metropolitan governments.

8. How values are expressed through our present institutions, including the International Joint Commission and the Great Lakes Basin Commission.

9. How an organization such as the Great Lakes Basin Commission needs to be assessed for its strengths and weaknesses in terms of reflecting social values, resource planning program strategies, etc.

10. A study of conflict situations among competing uses of Lake Michigan with respect to tradeoffs between (a) recreation and waste disposal (pollution), (b) commercial fishing and pollution, (c) one form of recreation versus an incompatible form of recreation (power boats vs. duck hunters or canoeists), and (d) power and maximum shoreline use and development.

11. Design of a feasibility study to determine an approach to a Lake Michigan model which can eventually be plugged into a Great Lakes regional model.

12. The social (as well as economic) implications of water-resource management and development in this subregion.

13. How frequently water management and development decisions are made by persons or organizations not directly involved as beneficiaries and/or contributors to the project cost.

14. How to monitor at a few critical points economic effects of changes in water quality as a result of putting water-quality standards into effect.

15. What social change can be brought about through planned intervention in conjunction with water-resource projects.

16. Determine the process of problem definition within watersheds, major lake basins, and the entire Great Lakes region and the priorities of the problems.

17. What heuristic research techniques may be applied to the decision-making performance of operating agencies.

18. Determine the process by which public opinion on water-resource questions is formed.

19. How a concern for the environment is formed among individuals or groups, how it is measured, how it is expressed, and how the governmental sector incorporates this concern into political and social action.

Physical-Biological Research Activities and Topics

1. Develop a quantitative model of the Great Lakes system with special attention directed to lake levels and to associated flows and losses including augmentation and diversions resulting from structural works.

2. Develop a water-quality model of Lake Michigan (or others) and its contiguous drainage basin in terms of nutrient budget, rate, and effects of fertilization.

3. Study the effect of evapo-transpiration rates, ground-water gains and losses, and the necessary degree of accuracy required for these and other variables in a quantitative model.

4. Establish relationships between various pollution levels and their effects in biological as well as economic terms.

5. Define inputs, outputs and state-of-the-art controls with respect to a cause-and-effect pollution model.

6. Develop transfer functions between input, controls, and input pollution, and also between elements of pollution and the general pollution level and controls presently in use in the Lake Michigan situation.

7. Relate physical observations of lake levels to resultant values (and to beneficiaries).

8. Determine the output from simulation or any physical model can be used most effectively, with the eventuality that value judgments will need to be made which force numerical rating techniques.

9. Study irrigation opportunities in the region and the consumptive implications.

10. Determine spatial requirements for recreation developments.

11. Consider physical, biological (as well as legal and economic) effects of further diversion or diversions of Lakes Michigan-Huron water.

12. Predict future water-supply needs and expected levels of pollution.

13. Determine the status and future of eutrophication in Lake Michigan.

14. Determine the effects and mechanics of coastal and offshore interchanges and mechanics.

15. Collect more data on pelagic and benthic conditions in Lake Michigan.

16. What simplified water-quality models can be applied to the entire Great Lakes system.

Priorities of research in the physical-biological area emphasizes the question of institutional arrangements and the way decisions are made. "There are some techniques that could be applied to this problem which would make sense to the researcher. I think that as a matter of strategy in writing our proposal, we might make sure that we don't stay with generalities. We keep falling into the traps of economic and engineering approaches that we know how to do pretty well."

There is a growing consensus, and it is highly critical, that we need to do some first-rate research on legal, social, and institutional problems. In writing this report we want to go farther than just calling for more research. We need to be explicit in suggesting case studies. We want to be explicit in suggesting particular kinds of institutions to look at. More important, we need to stress in some detail the kind of analytical techniques and tools that are available. There has been reputable, scholarly work that has been done in some other fields that are now beginning to grow. The question of nonmarket decision-making studies on power structures, etc., hasn't been applied to water organizations.

> The problem is getting enough "meat" here to entice some research in this field, and to entice the kind of scholars involved. It would be a good strategy since the present steering committee does not have the kind of competence on it to "flesh this out." Someone should give some examples of research approaches. The examples of scholarly techniques should be listed and how they can be applied to some given kinds of institutions and organizations.

In conclusion, emphasis was placed on generating research projects that would involve cooperation between schools, agencies, and the respective research personnel. If the areas of research are extensive enough to give an appropriate problem base, an advance will have been made in the state of the art and a regional service can be rendered with wider national and international application. In order to sustain a degree of cooperation, coordination, and informational feedback, some thought needs to be given about periodic appraisals and conferences by the steering committee and project leaders. Some effort should also be made to involve additional colleagues and agencies to achieve a more comprehensive dimension to the Great Lakes research effort.

Edmund Burke once said, "Those who would carry on the great public schemes must be proof against the most fatiguing delays, the most mortifying disappointments, the most shocking insults and, worst of all, the presumptuous judgment of the ignorant upon their designs." Even though this quotation was never used or suggested at the conference it may serve to dramatize the immensity of the challenge for which the stage has been set and at the same time remind the university scholar and resource administrator that answers are needed that will have consequences (whether we intend them or not) for the megalopolis of the Great Lakes well into the 21st century.

Grateful acknowledgment is expressed to Alice Bond, Pat Nemacheck, Marilyn Schmits, Herbert Heavenrich, and James Kerrigan for their help with the conference proceedings.

Appendix B
A REPORT ON THE SECOND WORKING CONFERENCE:
CONSIDERATION OF GREAT LAKES SYSTEMS RESEARCH

30, 31 October 1967

The University of Michigan
Ann Arbor, Michigan

B.1. INTRODUCTION

The Second Working Conference, held on 30 and 31 October 1967, in Ann Arbor, Michigan, was designed to advance the concepts of systems analysis and related water-research efforts in the Great Lakes region. The session was designed to serve as a follow-up of the First Working Conference at Alpine Valley, Wisconsin, 10-15 September 1967.

This appendix is a summary of the Ann Arbor meeting. Section B.2 compresses an annotated agenda. Section B.3 traces the discussion and thought during the plenary sessions. Section B.4 is a summary and a look toward the final report.

Participants in the Ann Arbor Working Conference are listed below. The double asterisk (**) indicates Project Steering Committee chaired by Professor Ackermann, and the single asterisk (*) indicates staff member of the Council on Economic Growth, Technology, and Public Policy of the CIC directed by Professor Carlisle P. Runge.

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B.2. THE CONFERENCE TIMETABLE AND ANNOTATIONS

Sunday, October 29

9:00 p.m. Steering Committee and CIC staff meeting

Monday, October 30

9:00 a.m. Opening remarks by Professor William C. Ackermann: a review of the charge spelled out in the OWRR contract and a discussion of tasks which need consideration

9:15 a.m.	The Alpine Valley Report summary and review by Professor Spenser W. Havlick

The reporting procedure was described with a listing of researchable projects. Three general conclusions were reported:

(1) A system-wide quantity model can be designed.
(2) A crude beginning can be made on a quality model for a subregion, e.g., southern Lake Michigan or Lake Erie and western Lake Superior.
(3) Arrangements with other organizations, including the Great Lakes Basin Commission, need to be considered and related to (1) and (2).

The report was received without objections.

9:35 a.m.	Dale Meredith presented a report which reviewed systems engineering, modeling, and gaming in water-resources research. This was the result of a literature search of major efforts in water-resource modeling and systems analysis.
10:00 a.m.	Coffee break
10:30 a.m.	General discussion on water-quantity model
12:15 a.m.	Luncheon
2:00 p.m.	General discussion on water-quantity model (continued)
3:45 p.m.	Coffee break
4:15 p.m.	Remarks by E. D. Eaton, Associate Director, Office of Water Resources Research, U. S. Department of the Interior
5:30 p.m.	Discussion
6:00 p.m.	Dinner
9:00 p.m.	Steering Committee and CIC staff meeting

Tuesday, October 31

8:45 a.m.	General discussion on a water-quality model
10:15 a.m.	Coffee break
10:45 a.m.	Discussion on research strategy
12:30 p.m.	Lunch
1:45 p.m.	Quality-model considerations
2:30 p.m.	Individual commitments of research interest
4:00 p.m.	Adjournment

B.3. HIGHLIGHTS OF THE CONFERENCE

The Second Working Conference on Great Lakes systems research began with a statement of purpose by Professor Ackermann. The group was charged with considering the feasibility of a systems model for the Great Lakes region. The obligation to prepare a final report may require a total of three meetings, but the task for October meeting included making a judgment on the feasibility of various models and exploring what university personnel and facilities are interested and available.

An abstract of the Alpine Valley meeting was presented as a review for participants who were at the first conference and as an introduction for the Ann Arbor conferees who had not been present at Alpine Valley. It was suggested that Professor Havlick's report on the proceedings (after condensation) be included as Appendix A to the final report. Mr. Meredith's "Survey of Systems Modeling" will also be attached to the final report as Appendix C. Therefore an elaboration of these two papers is not provided here.

The discussion reviewed and picked up the considerations which were left unresolved at the meeting at Alpine Valley.

Liaison with the Canadian counterpart of the CIC and appropriate governmental units needs to be established.

The water-quantity model, which is under the guidance of Professor Deininger, was discussed in considerable detail. A two-year project is anticipated for the preliminary model of lake stage and water quantity. Dr. Deininger was invited to proceed with the proposal formulation.

The work under way and anticipated in Ohio was reported by George Hanna. The remarks indicated primary research interest in water recreation and biological areas of the Great Lakes basin with special focus on Lake Erie as the target subregion.

Professor Duke called attention to the gaming-simulation research capabilities of the METRO model which was discussed in Mr. Meredith's paper. The simulation of the METRO model should be recognized as an educational device to sensitize decision-makers to effects of decisions, whereas mathematical models running on a computer are usually more helpful as predictive tools for water and land management. Interest was generated in the capabilities of the gaming research for looking at what Dr. Craine called "the knotty institutional and organizational questions" of the southern Lake Michigan subregion.

A suggestion was made that the CIC staff investigate the research capabilities and efforts of some of the more sophisticated regional planning commissions, particularly those of southeastern Wisconsin, northeastern Illinois, and southeastern Michigan.

Then the discussion returned to the quantity model. Ways of dealing with chlorides and other conservative elements were mentioned. The difficulty of estimating evaporation and ground-water inputs and losses was emphasized. Whether or not the quantity model would "drive" a water-quality model was a point raised by Professor Gemmell. This ultimately launched a mild controversy about the reasonableness of the kind of model that should come first, how the needs of a second-, third-, and fourth-generation model could best be met, and where the early payoffs might be expected.

Before the coffee break, a "roll call" of back home interest was requested. Several participants felt that after the Ann Arbor meeting they would be in a better position to obtain reactions about possible research interests and about who might be available during the next academic year. The majority of responses showed an interest in research related to the water-quality model. It was here that the first serious suggestions of interuniversity collaboration were indicated. It was suggested that specific research projects be sent to Ann Arbor for compilation.

Mr. Eaton's observations and comments concluded the formal session of the first day. The message which was extracted from a recent paper given at a Symposium on Water Resources Research restated the general challenge of transferring research results to practice; of identifying the multitude of physical, social, and economic interactions; and of improving the decision-making mix of water-resources management through methods of systems analysis, with special emphasis on a development of planning methods in metropolitan situations.

Informal discussions proceeded into the evening.

On Tuesday, 31 October 1967, significant progress was initiated by Professor Rohlich's suggestion of a water-quality model which articulates the possible tradeoff between waste-water treatment methods or costs and raw-water treatment costs. The analysis would focus on the intermediate uses which could be made of the receiving water under alternative degrees of waste treatment and treatment for water supply. Interest and approval were immediate on the part of the participants. An array of reasons were offered which supported a water-quality model whose major emphases were on water-supply costs and efficiencies which would accrue from various water-management practices. The research design calls upon the talents of the engineers, the economists, the biologists and limnologists, the sociologists, and the lawyers.

The same analysis was thought to be appropriate for "microsystem" studies for various municipal operations for water supply, and for industrial water users. Furthermore, several subregions could be studied simultaneously throughout the region. After the costs associated with water supply have been investigated, other water uses and water-quality needs could be studied. This of course would increase the list of parameters under consideration over time and presumably sophisticate our understanding of water quality in each of the Great Lakes.

Researchers interested in the current relationships between municipalities, states, and other units of decision-making would have a major task, according to Dean Stephen Smith. The interdependencies which are in need of identification would be a major research activity.

Even though work is slated to begin on a southern Lake Michigan model, Robert Ball and Dr. John Ayers urged that both the total system and the subsystem could proceed at the same time. William Drake felt that a modification of the METRO model could start in a relatively crude way as well.

Consensus was reached that an analysis begin with single urban and/or industrial units or sub-subsystems. Suggestions which marked forward steps in the discussion included the following:

1. Values of water supply in the Great Lakes need to be established.

2. What economic data can be obtained on the costs of water and waste treatment which are attributable to eutrophication?

3. The "faraway" goal of water-quality management can best be approached through submodel systems which can be plugged together ultimately for planning and operational reasons in a region as complex and extensive as the Great Lakes.

4. An assessment of research interests and availabilities indicated where active research is presently in operation or anticipated. A linkage of these operations appears to be the unique experiment in systems research which OWRR might be willing to support.

The Ann Arbor conference adjourned with the understanding that the participants from member CIC institutions and representatives of state water-resources centers identify how their inputs might best be fit into the water-quality and water-quantity models and other related Great Lakes research activities.

B.4. SUMMARY AND FUTURE PLANS

Several CIC staff meetings have taken place as follow-up activities growing out of the Ann Arbor working conference. Major energies have been directed to the preparation of the final report on terms established by the Office of Water Resources Research. A report of events which have taken place since the Ann Arbor meeting will be reported to a gathering of the Water Resources Steering Committee on December 6 and 7, 1967, scheduled at Des Plaines, Illinois.

However, it is appropriate to include here two interim efforts which may give the reader a clue about the direction which is being taken as a result of the Ann Arbor deliberations. The first is a suggested format for the final report. The combined efforts of Messrs. Meredith, Kerrigan, Runge, and Havlick have produced these suggestions.

A. Suggested Format

Report of a Consideration of a Comprehensive Systems Analysis Model of the Great Lakes Region

1. Introduction
    1.1. Agreement between CIC and OWRR
    1.2. Steering Committee and staff
2. Results to be achieved from macroscale and subsystem analysis
    2.1. Guidance for planners
    2.2. Enable researchers to relate their efforts in advancing the entire system
    2.3. Provide a valuable means of communication
3. Summary of Working Conferences
    3.1. Procedure of research design
    3.2. Abstracts of First and Second Working Conferences
    3.3. Major water subsystems considered

B. An Overview and a Preliminary Sketch of a Water-Quality Model

Systems Analysis Model of the Great Lakes Region

One approach to developing a system for study and analysis of the Great Lakes region and its associated problems would be to construct a diagram within which the major elements and sub-elements were organized. During the Alpine Valley conference a generalized scheme (Figure B-1) was suggested to identify the major elements and to illustrate their general interrelationships.

Social Values and Goals. The foundation of the schematic is the box, "Social Values and Goals" shown in Figure B-1. Social values, as used in the scheme, represent the values used in developing objectives in the planning and legislative processes. Among those values are respect for personal and public property rights, the market system, distributive equity, preservation of unique natural environments and historic monuments, as well as aesthetic values.

In the past only benefits and costs that could be measured by the market system or the "shadow" benefits and costs that could be generated were used in quantifying the values associated with a program or project under consideration for government support. Other intangible values, which were often major elements in the decision process, were set through fixed constraints or direct assignments. Several programs are under way to develop methods by which some of those intangible values can be structured into some quantifying system.

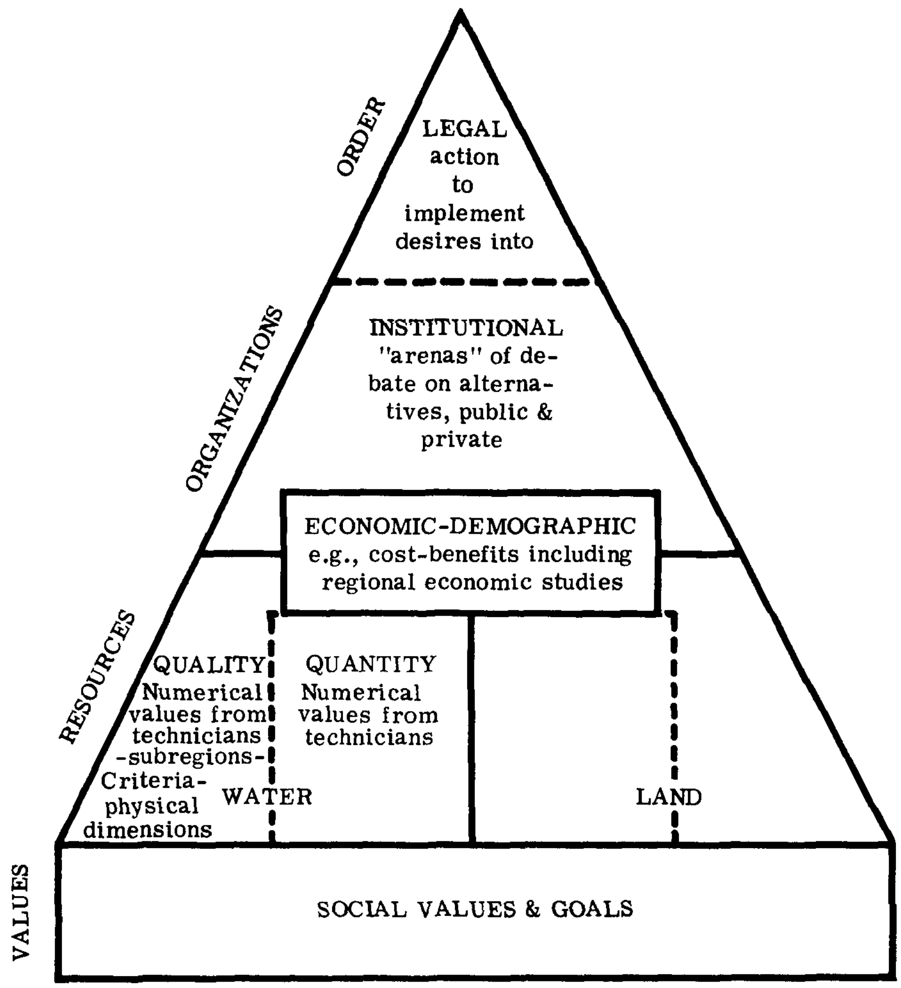

FIGURE B-1. SCHEMATIC FOR REGIONAL ANALYSIS

Fundamental studies will be required to take advantage of the work now under way, to develop new approaches and to make recommendations that may be incorporated into the planning process for the Great Lakes.

Resources. The water resources of the Great Lakes region among the greatest on earth; the land surrounding these mighty lakes help provide the great strength of both the United States and Canada. In Figure B-1 the resources for the region are separated into two categories: land and water. Land includes any physical resource that is not directly attributed to the water resources of the Great Lakes basin. The water sector is divided into the use and value areas of water quantity and water quality.

It can be shown that there is a relatively minor interrelationship between the quantity and quality aspects of the water resources in the basin. That is quite different from the relationships found in a river system where the stream flow has a major influence on the degree of water quality.

Because of the nature of the water-quantity system, it is best analyzed on a multilake or total basin basis. The quantities of water in surplus and in demand in connected lakes will require a total system management scheme if optimal operating procedures are to be developed. The U. S. Corps of Engineers is currently studying the question of lake-level regulation for the basin. To complement that study, the CIC universities are developing a number of optimizing schemes that may be useful.

On the other hand, the water-quality problems facing the basin may better be viewed as local problems from the physical standpoint. It is the opinion of many that generally there is a weak correlation between the water quality of connected lakes within the Great Lakes system. The major effect is localized along the inshore waters. It is primarily the shore waters that receive urban waste and drainage while being used as water-supply sources.

Economic-Demographic Development. The component of Figure B-1 titled "Economic-Demographic" includes the general system where the economy of the region is modeled and where projections of development are made and analyzed. A strong interacting element to the economy will be the demographic characteristics of the region. Both the population and economy will depend upon the social values selected for the region and the land and water resources available for allocation for use and for preservation.

This component in the overall structure will act as the accounting system to determine whether the resources are being allocated in the best manner and conform to the social values and goals identified for the basin.

Institutional. The organizational framework under which the region is operated and governed is the next component, titled "Institutional" in Figure B-1. Within the region two countries, eight states, one province, and several hundred local governments have responsibilities associated with the Great Lakes. The interrelationships between formal governmental units will shape the policies controlling the management of the region's resources. In addition, the commercial, industrial, labor, and recreational associations will influence the system within their respective areas of interest. Studies are needed to identify the current status of those interactions and to detail alterations that will enhance the present system.

Legal. In every workable framework there must be a system of rules that establishes rights duties. The component labeled "Legal" will cover the system of laws and rules governing the overall system. Supporting studies will be required in this area.

Water-Quality Model. During the Ann Arbor meeting a number of suggestions were made as to how a water-quality model might be approached. A few of these ideas were combined into a unified scheme, a discussion of which, with illustrations, is presented in Appendix F, Section F.2.

It was suggested that a first-cut water-quality model should define the municipal use of lake water. This would include the costs associated with treating lake water to meet given drinking water quality standards and the costs associated with treating the municipal wastes before they are discharged into the lake. It would be useful to determine the cost of waste treatment that would meet given effluent standards or water-quality levels.

Similar studies could be conducted to define the cost and direct benefits associated with treating or controlling the influent and effluent waters associated with other use sectors, such as urban runoff, industrial use, thermoelectric power generation, fishing, and recreation.

The difficulties of establishing the relationships between the degree of water quality in the various parts of the lake and the influx of degrading and enrichment materials are fully appreciated. However, as more information is gained in this area it should be incorporated into a useful model.

Appendix C
WATER SYSTEMS MODELING

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C.1. INTRODUCTION

A model is a formalization of the relationship which may be seen as existing among data, and a system is a set of objects, together with relationships between the objects and between the properties of the objects.

Simulation as used here means a particular type of model which pictures the functioning of complex, dynamic systems as they change in time.

To be acceptably accurate, quantitative behavior models of a system the size of the Great Lakes area system must inevitably be complex, yet must be feasible to operate. These requirements were not compatible until high-speed computers were available.

The ideal model would specify completely the properties of the processes that occur in all relevant components of a system. Our knowledge and techniques do not permit more than a rough approximation to this ideal.

A review of the state of the art in system model building that would be applicable to a Great Lakes area system model is presented. This is followed by some alternative approaches to the development of a Great Lakes area systems model itself. The author leaned heavily upon material from a forthcoming book, Systems Simulation for Regional Analysis: An Application to River Basin Planning [1] for parts of this paper.

C.2. STATE OF THE ART IN SYSTEM MODEL BUILDING

Sections C.3 and C.4 review the state of the art in system model building as it would influence building a model of the Great Lakes area system. Two schools of endeavor working on modeling techniques may be distinguished and will be discussed as follows:

(a) Complete system modeling, i.e., modeling of the entire system.

(b) Subsystem modeling, i.e., complete specification or complete modeling of each subsystem or each element in the system.

C.3. COMPLETE SYSTEM MODELS

The state of the art in building complete system models for economic study can possibly be best illustrated by describing some of the more important models which have been developed in the last few years. This survey is not complete either in terms of coverage or depth, but does show what can and has been done in model building for complex systems.

The models discussed are: (a) the New York Metropolitan Region Study, by the Graduate School of Public Administration, Harvard University, for the Regional Plan Association; (b) the Upper Midwest Economic Study, jointly undertaken by the Upper Midwest Research and Development Council and the University of Minnesota; (c) the Ohio River Basin Study, by Arthur D. Little for the U. S. Army Corps of Engineers; (d) the California Development Model, for the State of California; (e) the Oahu, Hawaii, Model, for the State of Hawaii; (f) the Lehigh Basin Simulation Model, by the Harvard Water Program, Harvard University; (g) the Susquehanna River Basin Model, by Battelle Memorial Institute; (h) a Regional Economic Simulation Model, by the Southeastern Wisconsin Regional Planning Commission; and (i) the METRO Model, developed for the Tri-County Regional Planning Commission, Lansing, Michigan.

A 1965 survey by Abt Associates, Inc. [2] includes descriptive typologies of over 50 representative current social, political, and economic models, computer simulations, and human player games. The Abt study includes a brief summary of the staffing, time, and money requirements for some of these model projects.

C.3.1. THE NEW YORK METROPOLITAN REGION STUDY [3, 4]

This study analyzed the major economic and demographic features of the New York Metropolitan region, a 22-county expanse covering 7000 square miles (in parts of three states), and made projections for 1965, 1975, and 1985.

The model makes two independent projections of population and the labor force. Taking into account birth rates, deaths, and migration by age groups, population projections were first made by standard demographic techniques. Employment and population projections were then derived from a separate model of economic activity. The two projections were reconciled by allowing the economic projections to stand and increasing the in-migration in the demographic model.

The complete model contains 47 linear equations for 47 variables and is designed to forecast employment, output, and value added for 43 industrial groups for the years 1965, 1975, and 1985. In addition to the outputs of 43 industries, it generates estimates of disposable personal income, total population, and employment for domestic servants and government employees.

The projection model was designed to utilize data and special projections made before the study, so that there was little opportunity to have the special projections fitted into the overall model before they were made.

The employment in national industries in the region was assumed to be some constant "share" of the projected total employment in the United States by industry for 1965, 1975, and 1985. These derived employment demands for the national industries was then used to derive an input-output matrix for the region. Total employment was derived by use of multipliers in the matrix, based upon assumed local input demands, local consumption patterns, and local labor-force participation rates. Then the output and employment for each industry and estimates of disposable personal income and total population were derived from the total employment.

National coefficients were used for the purchase of interindustry inputs for the local market for the input-output framework. Consumption purchases from each of the 43 industry sectors were computed by a simple linear consumption function based upon population and disposable personal income. Government expenditures were treated as a linear function of population with government purchases from each local market industry considered to be a fixed percentage of total government expenditure in the region. Disposable personal income was taken as a direct function of total employment, and total population was derived from total employment by a single parameter.

C.3.2. THE UPPER MIDWEST ECONOMIC STUDY [5]

The Upper Midwest regional study was designed to develop basic data for 1960 and to make projections of employment, income, population, and migration for 1975 for the region of the Ninth Federal Reserve District. This region includes Montana, North Dakota, South Dakota, Minnesota, 26 counties in northwestern Wisconsin, and the Upper Peninsula of Michigan.

The research team assumed that extensive region-wide policies could be implemented on the basis that component states have shared many similar growth experiences, with employment closely tied to the processing of natural resources.

The formal model is of the interregional multiplier type designed to provide estimates of income and employment under various independent assumptions about population increase, migration, and unemployment. There are no feedback relationships between the demographic and employment-and-income sectors. The basic set of projections for 1975 are labeled as "neutral" projections and are (a) that the National Planning Association projections for regions outside the Upper Midwest will be realized; (b) that the 1960 shares of the regional and national markets will remain the same for the Upper Midwest sectors; (c) that labor productivity will increase at nationally projected rates in the Upper Midwest sectors; (d) that income will increase at nationally projected rates in the Upper Midwest sectors; and (e) that the labor force will increase at the same rate as total employment in each Upper Midwest state.

The model concentrates upon interregional trade flows to specific regions instead of interindustry sales to specific industries. The assumed size and stability of the flow coefficients governing trade flows to the various regions are now important rather than the size and stability of interindustry coefficients needed in the New York model.

Thirty-eight income-generating sectors plus exogenous estimates for agricultural and military income are used in the model. Sales for each of the 38 sectors are computed for each of 15 regions (the 6 states and 9 regions encompassing the rest of the world). Income for each state and for each income-generating sector is derived from total sales by a parameter specifying the proportion of sales accruing as income payments. There were 690 equations, 921 variables, and 2784 parameters in the model. Total state incomes expressed as direct functions of demands by external regions were derived by a greatly simplified model containing only 6 equations. The expanded model was then used to derive employment and income for each of the employment sectors from the total state incomes.

C.3.3. THE OHIO RIVER BASIN STUDY [6]

The Ohio River Basin model was to provide guidelines and data to the U. S. Army Corps of Engineers and to public agencies interested in various kinds of water-resource-related investments in the region. The study concentrated on developing equilibrium estimates of the supply of and demand for labor by decades over a 50-year period for the entire Ohio River Basin, which covers parts of 10 states and 400 counties. The county was used as the basic political unit for purposes of data sources, so that the region boundaries would coincide with the drainage-basin boundaries as closely as possible. Difficult constraints upon data availability resulted because of the size of the area and the use of the county as the basic unit.

The supply of and demand for labor were projected separately and then reconciled by averaging the two sets of projections for each preceding projection year and checking back to make all the numbers consistent with the averaged projections. The supply of labor was determined by assumption made concerning labor-force participation rates and unemployment rates of the population estimates from a demographic model based upon cohort-survival techniques involving estimates of birth, deaths, and migration.

The demand for labor was based upon a modified input-output model by use of 29 separate sectors (27 major industry groups, 1 government sector and 1 nonclassified sector). The total output in the basin was taken as the sum of demands for each industrial sector; the demands were derived from the final demands for consumption, investment, government, defense, and net exports, and for interindustry demand. A set of simultaneous linear equations describing the demand sectors was then solved for the total demand for labor. The estimates for investment, government expenditures, defense expenditures, and net exports in the basin were derived exogenously from national projections.

The modified input-output model used only 81 interindustry coefficients instead of the 729 required by a full 27-industry matrix. The use of 81 coefficients allowed for substitution among inputs within each subtotal as long as the sum of inputs remained a fixed proportion of total output. Also, national coefficients were used at the regional level.

Separate projections were made for 19 subareas in the basin by fitting least-squares regression equations to each subarea's share of total employment for each of the employment sectors determined from historical observations. The effect on growth implied by historical trends was damped by employment of time lag. Thus the projections did not take into account internal factors influencing subarea growth because they were not made independently of the projections for the entire basin.

The model assumes that water will be available at all times in sufficient quantities and qualities to support the project economy.

C.3.4. THE CALIFORNIA DEVELOPMENT MODEL [7-9]

The purpose of the California Development model was to forecast personal income and employment on a quarterly basis by major industry groups for the State of California to 1975. The Phase II model discussed here projected personal income and employment for 59 industry sectors by quarters for the period 1963 through 1975.

Multiple regression for income and employment for each of the sectors were derived from a sample of 52 quarterly observations for the period 1950 to 1963. Wages and salaries served as proxy variables for output.

Export demands, interindustry demands, and local final demands are the demand sectors used. The national economic projections by the National Planning Association are used to determine exports for 7 categories. The interindustry and local final demands are then developed endogenously from the exports.

This is a one-region model. It depicts California and the rest of the world without feedback from California to the rest of the world. The state economic growth is generated by exports to the rest of the world. The model contains 130 equations, is linear in variables and coefficients, and is largely recursive. Thus, the structural relations are expressed in lags which are unidirectional with respect to time.

The sensitivity of the model to important assumptions and the meaning of forecast results beyond 1964 have not been explained.

C.3.5. THE OAHU, HAWAII, PLANNING MODEL [10, 11]

This study began in 1963 to develop a model for economic planning and growth for the island of Oahu, Hawaii. The first phase of the program was completed in 1965, and it was decided to extend the model to the entire State of Hawaii. There are no major structural differences between the Oahu model and the extended model.

The model projects economic growth and the types and levels of certain kinds of exogenous spending necessary to achieve four planning goals. Specified in quantitative terms, these goals were related to desired levels of population, to the shape of income distribution, to external payments outside the island, and to budgets of state and local government agencies. No discussion is provided on the derivation of the planning goals themselves, but the state report indicates that primary attention was given to the achievement of certain levels of population in 1985 and the ability of the economy to produce a sufficient number of jobs. The exogenous spending which is considered to be driving the local economy are Federal defense expenditures, tourist expenditures, research and development expenditures, and investment (public and private). A household sector plus 16 industry sectors which included a service sector and state and local expenditures, but excluded public investment, are considered to represent the local economy.

Exports to the rest of the world are given a rather minor role. Exports of sugar and pineapples were determined outside the model based upon trend projections over the past two decades, and the values of other exports are determined within the model under the assumption that given proportions of total outputs would be exported. Coefficients for most of the equations were determined on the basis of time-series estimates.

Total population was derived from a sum of total employment adjusted by coefficients measuring labor-force participation rates and unemployment. This population is then compared with side assumptions and calculations dealing with demographic factors such as birth rates, deaths, and net migration.

Plans are to keep the model in operation and to revise and keep it up to date in terms of new information.

C.3.6. THE LEHIGH BASIN SIMULATION MODEL [12-14]

The Lehigh model is a river-basin model which emphasizes the river and its hydrology and relies upon simulation techniques. The model is an outgrowth of an earlier study of the Harvard water program.

The earlier study involved a hypothetical river system involving 12 design variables consisting of reservoirs, power plants, irrigation works, target outputs for irrigation water and hydroelectric power, and specified allocations of reservoir capacity for active, dead, and flood storage. Fixed operating procedures, in conjunction with predetermined benefit and loss functions, were used to generate outputs and the resulting net benefits by routing hydrological data through the reservoirs, power plants, and irrigation systems for various periods of stream flows.

The simulation of a simplified river basin on a digital computer and the development of mathematical models for programming river systems were the major contributions of this study.

The Lehigh Basin study extends the methodology developed in the earlier Harvard study to a real situation—that of the Lehigh River Basin in Pennsylvania. The simulation analysis utilizes long synthetic stream-flow traces derived by statistical analysis of the historical record to trace the behavior of the system over time, given a certain set of priorities for flow use and a set of targets for outputs. Economic benefit functions associated with the target for water supply, flood control, recreation, and power (the only four purposes studied) are composed of benefits which result when the system exactly meets a predetermined target, and also of losses associated with being below or above the target in any time period.

The study attempted to specify optimal design and optimizing procedures despite the emphasis on simulation. The optimizing procedures are based in large part on linear programming techniques and specified objective functions. The target outputs and benefit functions were highly restricted and simplified, a rigid system of priorities was imposed, operation procedures for facilities were fixed, and many sorts of dynamic feedback were omitted.

The Lehigh model is one of hydrology and engineering design which takes the economy of the region as given. The compiled or binary object program for the simulation model uses almost all of the memory locations of an IBM 7094 computer.

C.3.7. THE SUSQUEHANNA BASIN STUDY [15]

The Susquehanna model is a dynamic, mathematical model of the economy of the Susquehanna River Basin. The basin is first divided into economic regions which are modeled separately but in like manner. The economic regions are then divided into sectors. Each sector is then further divided into subsectors. The sectors are demographic, employment, water, and income. An electric-power sector was used in the first version of the study but was not illustrated in the final report. The income sector does not feed back on the economy; it only computes a version of "per capita income" based on wages, salaries, and selected transfer payments. The demographic, employment, and water sectors are tied together in each subregional model. The demographic and employment sectors are separate from one subregion to the next but are tied together within each subregion. The water sector in a subregion is dependent on the water sectors in the other subregions upstream.

The model is modular, such that the sectors are connected by simple relationships; thus one sector can be changed without extensive modification of another.

The demographic sector is composed of three factors—births, deaths, and migration. The two major ties between this and the employment sector are migration and the labor-force participation rates. Migration occurs when the subregional unemployment rate differs from an assumed, long-run national rate and this alters the age-class structure of the population.

The employment sector consists of export industries, business-serving industries, and household-serving industries. The market demand for exports, operating through export industry employment, "drives" the model. The export industries' growth is determined by the relative attractiveness of the subregion to industry in relation to other areas and the demand for goods in relevant market areas that can be supplied economically from the subregion. The attractiveness is determined by a relative cost concept involving transportation and labor. The market demand for exports is specified to the model. Thus the model computes employment, given the export demand.

The water sector is to simulate conditions relating to water quality and quantity. Based on a lack of evidence of a basinwide water-problem, potential feedback on economic growth caused by investments in flood control, irrigation, power, or navigation were considered to be minimal or nonexistent. The hydrological model used considered only low flows at "critical points" in the basin. The water sector did not feed back to the demographic sector, and the only feedback to employment is through river works construction and the recreation subsector.

C.3.8. A REGIONAL ECONOMIC SIMULATION MODEL (SEWRPC) [16]

The Southeastern Wisconsin Regional Planning Commission is interested in providing a series of forecasts of future regional population and employment levels that are sensitive to alternative public and private development policies, to 1990, for seven counties in southeastern Wisconsin.

This is a dynamic input-output feedback simulation model with investment being the dynamic force in operation. The model is organized into a number of sectors that are interconnected by an input-output matrix.

The flow relationships between respective sectors of the economy are mathematically expressed as a series of balance equations. One balance equation is required for each industry in the model. This balance equation relates the output of the sector to the current purchases and capital investment of the other regional sectors. There are 32 sectors at the regional level (30 industries, regional household, and government). In addition, each of the regional sectors has an input-output and investment relationship with each of the 9 sectors at the national level (6 industries, national household, federal government, and foreign purchases). This results in 1312 input-output coefficients and the same number of investment coefficients. Many of these coefficients are zero.

National household, federal government, and foreign purchases are forecast outside the model. In addition, internal resource coefficients relating material purchases, capital spending, employment, and wages in each industry and the input-output coefficients relating sales and purchases in each industry are needed before the model can be operated. Sampling of individual firms, state corporate tax records, state industrial employment and payroll records, and household survey data were used to estimate the coefficients.

Government investment is a programmed exogenous variable since one of the primary purposes of the model is to determine the effects of public works investment spending on the regional economy. Investment is the dynamic force in the model operation and allows the balance equations to be solved sequentially using the investment lag to generate a synthetic series of employment forecasts with time.

In forecast runs, the present input-output matrix is assumed to remain constant over time. The productivity is assigned an annual rate of increase based on recent historical trends. Employment forecasts are obtained and used to estimate population and land requirements.

The model has no internal water sector.

C.3.9. THE METRO MODEL [17]

The METRO model represents a different type of study than those presented above. The other models are all in the form of mathematical equations and relations to be solved by a computer. The METRO model cannot be solved by computer alone, but is a gaming-simulation involving the participation of people to take care of the relationships which cannot be expressed in mathematical terms with definite coefficients. The people participating then become a part of the model.

In the METRO game simulation, there is created a miniature world that represents the typical metropolitan area, problems and all. The METRO model is designed to demonstrate to decision-makers the effects of a series of individual decisions on the metropolitan growth pattern. It does this by using a simulated, abstracted environment, with a reduced time span and dynamic interplay of current decisions with fixed policies. In addition it illustrates the kinds of data available to decision-makers and informs the decision-makers about the techniques that are available to evaluate the implement decisions.

The METRO model deals with ideal types of governments, budgets, issues, and policies, all abstracted from Lansing, Michigan, socioeconomic, demographic, and political data for the period 1960-1965. There are three basic firms in the model: a large, heavy-industrial manufacturing firm that is tied to the fluctuations of the national economy and has primarily blue-collar workers; a large, slow-growing, and highly stable firm of clerical and white-collar workers; and a high-growth, technologically oriented firm whose major product is innovation and which hires administrative, professional, and technical personnel. There are 5 household types in the region which are correlated with consumption patterns, residential mobility, and voter responses on political candidates and issues by multiple regression from historical data.

The number of people involved is large (for the Lansing model about 20 plus operating staff). The present model has two types of teams, a team of people representing an areal unit and a team of people representing particular roles. The areal teams are central city, suburbs, and urban townships. The roles are politicians, planners, school people, and land people, with one judge. The game starts at 1963 and goes from there. It takes about 90 minutes to simulate 1 year.

The relationships are dynamic, requiring heavy emphasis to be placed upon proper analysis of previous results. The controlling rules in the simulation are fairly complex, and the players can at best only approximate these relationships. The extent to which they analyze previous results will affect their success in the future.

C.4. SUBSYSTEM MODELS

The ideal model would specify completely the properties of the processes that occur in all the relevant components of a system. Subsystem modeling can be thought of as modeling certain parts of the system before a trial at model the entire system. Here the division of subsystem models is between those which are not water centered and those which are water centered.

C.4.1. NONWATER-CENTERED SUBSYSTEM MODELS

The work has ranged from the modeling of individual household units to the modeling of the national economy and population in a highly aggregative fashion.

The reference for microanalysis might well be the work by Orcutt et al. [18], in which individual household units are simulated. This is a disaggregation that is almost impossible to try to work with as a component of a larger system model, especially if that system were very large (such as the Great Lakes area).

Forrester [19] treats the central framework underlying industrial activity. The approach he presents is one of building models of companies and industries to determine how information and policy create the character of the organization.

Isard [20] sets forth the techniques of regional analysis which have been proved to have at least some validity. The virtues and limitations of the techniques are presented to allow the worker to judge the applicability of the technique for a particular regional situation. Techniques are presented for population projection, migration estimation, regional income estimation and social accounting, interregional flow analysis and balance of payments statements, regional cycle and multiplier analysis, industrial location analysis, interregional and regional input-output analysis, industrial complex analysis, interregional linear programming, and gravity, potential, and spatial interaction models.

A computerized model has been operated for assessing indirect impacts of water-resource projects [21]. The strategy of the model is to compare the most efficient locational solution under the existing conditions with the most efficient solution under the new conditions, as altered by the investment program for water-resource projects. The locational efficiency is measured by average delivered cost of the commodity. The difference in efficiency between the actual location patterns before and after the water-resource investment is assumed to be measured by the difference in efficiency between the most efficient solution with and without the investment. The working model is highly idealized. It is for a single industry with a standardized product and no cross-hauling or overlapping market areas.

C.4.1. WATER-CENTERED SUBSYSTEM MODELS

Amorocho and Hart [22] have presented a general survey of contemporary methodologies in hydrologic research. This account gives a clear exposition of systems analysis and synthesis as applied to both linear and nonlinear systems. Perhaps the most widely known nonlinear modeling of basin behavior for use with a digital computer is that developed by Crawford and Linsley [23]. This model aims at representing the entire land phase of the hydrologic cycle for basins 10 to 90 square miles. The model uses a period of the record to determine the parameters for the watershed (soil-moisture storage, stream-flow recession constants, ground-water discharge constants, infiltration capacity, etc.). Then, from daily evapotranspiration and hourly precipitation data, the model produces hourly stream-flow.

Orlob and Woods [24] have outlined a general hydrologic model and presented two deterministic, dynamic models for simulation of the operation of irrigation systems which determine, at any desired point within the system, the proportion of water which has been in prior contact with the surface of an irrigation plot.

To indicate the fact that operations research could be used in water-quality management, several simple models were developed at Harvard [25]. These included a queueing model for pollution transport in streams, a model to minimize economic risk in sanitary engineering design, and a model for determining optimal sizes of water-treatment plants. These are simple models to be used in optimizing procedures, are restrictive in application, and are similar to the subsystem models discussed in the other Harvard Water Program publications [12, 13].

The Aerojet-General Corporation [26] made a systems study for waste management in California. This report outlined the structure of waste-management systems and indicated some of the governmental functions and organization required to implement the systems approach to waste management. The study was aimed at minimizing the cost of waste disposal by "acceptable" procedures. A lot of effort went into indicating the cost of various units in waste disposal and the various alternatives. A more detailed analysis was made of the Sacramento area.

Bramhall and Mills [27] have presented a computer program the data for which are taken beginning at the head of a stream and proceeding down to its mouth, calculating at each specified station the stream-flow, the dissolved-oxygen level (DO) and the biochemical oxygen-demand level (BOD). The DO and BOD are computed by the Streeter-Phelps equation. As each tributary to the stream is reached, the program begins at the tributary head and follows it down to the confluence, performing the same calculations. The model is deterministic, to minimize the cost of meeting predetermined standards of DO and BOD.

If the DO falls below or the BOD above the predetermined standards, the wastes at the source of pollution immediately above the violation are treated to a level sufficient to eliminate the violation. After the entire system has been treated where necessary, the stream-flow is augmented at a station predetermined to be a potential damsite. At this higher flow level, all downstream stations are re-evaluated and treatment levels are correspondingly reduced. Flow augmentation proceeds in this manner by 5% increments until all violations are eliminated without treatment.

At each flow level the annual dollar cost of waste treatment and the annual dollar cost of storage to augment flow are computed and the minimum cost can be determined.

The 86-mile stretch of the Delaware Estuary between Trenton, New Jersey, and Liston Bay, Delaware, has been modeled by the Federal Water Pollution Control Administration [28]. The economic and demographic sectors of the model were of the trend projection type and are not discussed here. The concern here is with the water-quality model of the estuary. The estuary is responsive to an approximate and semidiurnal lunar tide.

Eight municipal waste-water treatment plants are assumed to be the waste sources. DO, alkalinity, coliform bacteria, chlorides, water temperature, and nitrogen constituents were the water-quality parameters monitored by weekly sampling runs during 1964. The first four parameters are the primary indicators illustrated. The study stops at the bay and is a one-dimensioned, deterministic system.

The basic quality system considered is for the DO and is composed of two subsystems, one for BOD and one for DO.

The estuary is divided into 30 sections, and a linear differential equation is used to represent the mass balance for the BOD in each sector. A similar equation is used for DO. This results in 2 series of 30 simultaneous equations each. The first solution is made on the assumption that the equations do not vary with time. This assumption allows the utilization of matrix manipulation techniques to obtain a set of transfer functions from the coefficients of the equations. This set of transfer functions details the transformation from a waste-load input in any section to the stream-quality output in any other section. The total effect at any section is then formed by summing for that section the effects caused by inputs anywhere in the estuary.

The solution of the equations for the time-varying situation were then solved, and the model was verified with past data which were not under steady-state conditions.

The cause-and-effect relationships for nonconservative variables such as bacteria concentrations are obtained by solving only those equations used for the BOD, with the proper decay rates for these variables. The decay mechanism is then eliminated in the BOD equations and used with such conservative variables as alkalinity—pH and chlorides.

Loucks [29] has formulated deterministic and stochastic linear programming models to determine reservoir releases and allocations of water to meet some management objective; maximization of total expected net benefits, minimization of total expected net losses, or minimization of total expected deviation from each use "target."

These are examples of the kind of subsystem models that have been developed.

C.5. GREAT LAKES AREA SYSTEMS MODEL SYNTHESIS

This section discusses some of the important concepts to be kept in mind while the model is developed, and then suggests some alternative approaches.

C.5.1. MODEL CHARACTERISTICS

A model is designed to answer specific questions. The questions to be answered determine the completeness required in the model. The types of system behavior anticipated are important in the selection of the factors to be included in the model.

A model is an abstraction from the real world and not an exact duplication. Models are neither true nor false. The value of a model is determined by the contribution it makes to our understanding of the system it represents.

The ideal model would specify completely the properties of the processes that occur in all the relevant components of the system. The specification would be given in terms of physical parameters and would involve all behavior relationships within the system.

The first major task is, then, to define the questions we want to ask and then see if we can develop one model that will answer them or whether we need several models. Two purposes for which the model might be designed are (1) forecasting the future of the system, and (2) evaluating the impact of alternative policies on the system [30]. Let us first look at how we might approach the problem of developing a complete system model to answer our questions.

C.5.2. COMPLETE SYSTEM MODEL

After we have the questions we want to ask the model, we must then define the boundaries of our model to correspond to boundaries of the real system so that these questions can be answered. One of the first characteristics that is noticed of the Great Lakes area is that it is an open system. No matter how we define the boundaries of the system it still exchanges materials, energies, and information with its surrounding area. The model will require the analysis of a large, complex system involving feedback, nonlinearities and lag structures.

The next step is to make a "rough cut" of the model to determine the areas needing further research. This could be followed by data gathering and further analysis so as to refine the model.

Two avenues are open for the model development. One approach would be for a complete mathematical formulation so that the desired answers to our questions could be obtained by computer calculations. This is the approach used in the Susquehanna study. The other approach would be a gaming-simulation study similar to the METRO project in which players are involved to serve as the "equations" which define the relationships we are unable to put into mathematical form or to which we are unable to assign parametric values. Both approaches have merit.

The complete computer model would allow a sensitivity study of various variables but would be difficult to formulate in terms of the decisions that must be made by people in the actual system.

The gaming-simulation permits the use of greater realism in the analysis and evaluation of a given set of policies in that the test environment can contain all of the characteristics that seem to be important to the systems functioning. It puts people into the model who can, by using creative abilities, design decision rules that help to advance the defined goals of the system and who can provide reactions to the model builder regarding the realism of the simulation. It is more flexible than real-world tests or all-computer simulation because we can more easily change either the computer or player parts. It is expensive because of the long time required to make a run and the number of participants involved. This often precludes sensitivity testing of results.

C.5.3. SUBSYSTEM MODELS

Subsystem models can be viewed as either subregion models or sector models. A complete system model could be developed by developing models for each of the subregions in the Great Lakes area and then tying the subregion models together. These subregion models could be developed by different researchers as long as there was enough communication between them to include the factors necessary to make the ties. This approach would allow certain "critical" areas such as the area of lower Lake Michigan to be modeled before the entire Great Lakes area was modeled.

A complete system model could also be developed by developing subsystem models for each of the sectors in the area. Many states are now involved in developing a systems model of their water sectors. These "water models" might be evaluated and an effort made toward tying these together to form a larger subsystem model of the Great Lakes area. This is an example of what might be done in the other sectors as well. It has already been agreed that the water-quantity sector can be readily modeled and offers an opportunity for quick results in terms of an operating model (see Appendix E). The important point in the development of the individual sector models is that there should be enough flexibility to tie them all together or at least be able to use them together to answer the questions we desire of the comprehensive model.

C.6. SUMMARY AND CONCLUSIONS

Some contemporary attempts at developing models, for both systems and subsystems, are reviewed.

A systems model of the Great Lakes area can be developed. The degree of refinement required in the model will be determined by the questions the model is to answer, and the degree of refinement will determine the amount of time and effort that must be expended in developing the model.

Two basic approaches seem to be available for a complete system model: (1) complete computer simulation and (2) a gaming-simulation. Either approach could be formulated by working with subsystem models which will be tied together, although the complete computer simulation seems to lend itself more favorably to this procedure.

The method to follow in developing a Great Lakes system model may be as follows:

(1) Define questions to be answered by the model.

(2) Make a "rough cut" of the model and determine the relevant subsystems to be included.

(3) Examine the subsystems to determine the areas of the model which are well defined and those which are least well defined.

(4) Give highest priority for research to those areas of greatest weakness in the model.

(5) Maintain a series of working conferences which meet periodically to keep the focus on the overall model and its development. This step is important in that it enables the researchers in the various disciplines to see where their work fits into the model and also to see the kinds of results they need to make their work compatible with the information needed by the model.

It might be desirable to proceed with modeling of the well-defined subsystems simultaneously with step (4) in order to have part of the system model working as soon as possible.

The above procedure could be used for either a model of the entire Great Lakes area or for a subregion.

The model could be modular, so that different sectors could proceed at different rates of development (e.g., the water levels in the lake could be modeled before the model to evaluate the effects of these levels is completed). The critical factor is that the various models must eventually be compatible.

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Appendix D
A PRELIMINARY DESCRIPTION OF WATER-RELATED INFORMATION SYSTEMS FOR THE GREAT LAKES REGION

Thomas E. Borton and William D. Drake
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D.1. PURPOSE

To conduct a feasibility study for a coordinated information system to supply data requirements of the various systems models under way or proposed for the Great Lakes system, and to prepare a proposed basic design for the structuring and implementation of such a system. This will include a statement of the needs, criteria, and guidelines for the long-range programming for the proposed system.

D.2. STATEMENT OF THE PROBLEM

There is growing concern among various specialists about the current condition of the Great Lakes. Speculations are that intensive management and control programs will be required if deteriorating conditions are to be stopped or reversed. Various research teams are proposing a set of linked systems modeling studies which will utilize simulation as a research tool in conjunction with the study of the Great Lakes. While conceptually these will consist of a set of linked models, they will be pursued by separate teams of individuals.

Models such as these are prodigious consumers of data and, as they become increasingly sophisticated, the need for a thorough rationalization of data requirements and sources becomes increasingly important. It is clear, then, that CIC universities involved in this research program will be collecting data on both primary and secondary source levels for utilization in their own particular systems modeling efforts. A thorough and coordinated understanding of available data, its sources, its limitations, and the needs and characteristics for potential additional data, will be of value to these research efforts and to other present or potential operating programs oriented towards the Great Lakes problems.

D.3. RESEARCH PROPOSAL

In order that the fullest possible level of coordination and compatibility of these CIC systems modeling efforts can be maintained, a clear need is present to provide a parallel and continuing examination of data types and forms used in these research programs which would lead to a more standardized methodology in data collection and handling. This would be aimed at increasing the potential effective utilization of data on an interstudy basis and would eventually increase the likelihood of a compatibility and comparability of the resulting systems models.

This proposal is to identify and clarify the data requirements for the specific set of systems models which are being developed that pertain to the Great Lakes quality and quantity conditions that may be used for management and control procedures in the Great Lakes basin.

Several steps are proposed to examine the feasibility of data systems to accomplish the operationalization of such systems models:

1. The identification of the characteristics of data collected and used for the systems models which are proposed for the Great Lakes area.
2. The definition of already available data bases (present programs, the types of quantity of data, and the forms of storage of this data, etc.).
3. A review of the characteristics of proposed or operating information systems.
4. A review of the feasibility of an organized data program for use with these models and a suggested structure for such a system. The study should follow an information requirements approach as the focus for the research effort concentrating on the specific requirements of the models being proposed by the several studies conducted under CIC's coordination.

D.4. RESEARCH PLANS

The identification of the characteristics of data collected and used for the systems models which are proposed for the Great Lakes area. Systems models referred to in this proposal are in embryonic form. They will change in complexity and style as the researchers learn more about the Lakes and as more information becomes available as input to the models. The research teams preparing the systems models will recognize basic needs in the type and form of data for their own particular research program. However, factors such as time and proximity normally will prevent an effective common effort at coordinating data collection and maintenance programs among these teams. For this reason, one of the primary objectives of this proposal is the identification of common properties in data used for present or proposed systems modeling programs through discussions with the research teams and the maintenance of a continuing liaison with these various projects.

The definition of already available data bases. The investigation will identify present data collection sources, the types of data collected, and the form in which it is available. This proposed research acknowledges the significant quantity of data generated in the normal course of activities of various individuals, firms, and agencies, but which is nevertheless not available to the researchers because of conditions of: lack of awareness of need for the data, its format or style, level of detail, and numerous other barriers of this type. For this reason, the study will be oriented toward the purpose and activities of various Great Lakes oriented organizations, with a particular emphasis toward rationalizing these considerations of the barriers to data utilization.

A review of the characteristics of proposed or operating information systems. There are two aspects to this portion of the research. First is the review of experiences in certain other information system design and implementation programs. This entails the selection of several most relevant examples and studying the experience of procedures and problems experienced in these cases. Second is the evaluation of the already functioning data supply programs which are relevant to the Great Lakes research program in terms of their adequacy for future developments for research, planning, and management programs for water resources. From this evaluation, recommendations will be made for the improved compatibility and coordination among agencies collecting and disseminating water and water related data important to the Lakes systems modeling research.

Review of the feasibility of an organized data program for use with these systems models and a proposed structure for such a data system. The ultimate aim of the research is to propose a feasible scope and design for an information support system for the present and future research, planning, and management programs for the Great Lakes area. This involves a number of aspects.

1. The investigation of organizational arrangements to implement and utilize improved information programs.
2. The exploration of the application of new information-gathering, -handling and -dissemination technologies which can assist in both research and decision-making. This phase would include the investigation of the use of remote sensing devices, high-speed computers and electronic display hardware. An example of the use of new technology is embodied in a computer software system being developed at The University of Michigan which stores, retrieves, manipulates, and displays mapped regions in a variety of ways. It is designed to be used in an on-line or remote terminal interactive mode, provide rapid feedback in graphic form, and allow exploration of many planning alternatives. Designers may examine arbitrary areas of interest, address complex multiple questions about the area to the system, and perform mathematical analyses of the area.
3. Propose improvements for the "quality" (timing, sequencing, feedback) of information for research.
4. Provide plans for a system which will enable more efficient use of the limited number of highly trained professionals available to agencies through the alleviating of much of the effort they must expend upon locating, recording, transferring, and collating data records in order to carry out their analyses and decision-making requirements.
5. Design and establish procedures to demonstrate the utilization of expanded water information programs to decision-makers and government agency personnel.

Appendix E
PRELIMINARY RESEARCH DESIGN OF THE WATER-QUANTITY SUBSYSTEM OF THE GREAT LAKES

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E.1. STATEMENT OF THE PROBLEM

The Great Lakes region comprises an area of roughly 300,000 square miles with a total population of 28 million, which in the next 50 years is expected to grow to close to 60 million with a five-fold increase in water demand. Although in the northern part of the region there is an abundant supply of good-quality water in the interior basins, the southern half of the region is meeting part of its demands already from the Great Lakes and will do so increasingly. The major problems in water-resource management will become more serious, one related to water quantity and one related to water quality. This research design will deal mainly with the problem of water quantity and its management over time and space, particularly the questions of water supply and lake-level control. The hydrologic subsystem of the Great Lakes area consists of five interconnected lakes. In order of decreasing lake elevations these are Lake Superior, Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario. The total drainage and water area is about 295,000 square miles, of which about 95,000 square miles are water surface. Of the total area, roughly 60% is under the jurisdiction of the United States, the remaining 40% is under Canada.

The principal source of water supply to the Great Lakes area is the precipitation over its water and land area. The average precipitation is about 31 inches per year, about two-thirds of which is returned to the atmosphere by evaporation and transpiration. The average net annual supply is therefore about 7×10^{12} cubic feet, or 5×10^{13} gallons. The amount of ground water entering or leaving the Great Lakes area is considered to be insignificant. The only additional source of water supply is from the Long Lake and Ogoki diversions, and this water enters the system via Lake Superior.

Considering one lake alone, a mass balance equation may be written as follows:

$$S = I - O + R + P - E \pm D$$

where S = change in lake storage
I = inflow from upper lake
O = outflow to lower lake
R = runoff from the drainage area
P = precipitation on the lake surface
E = evaporation from the lake
D = diversion in or out of lake

Figure E-1 is a flow chart of the average inputs and outputs of the system of lakes, based on data from the U. S. Lake Survey. These average inputs and outputs, for the period of 1950 to 1960, assume that the lakes have a constant level and indicate the relative magnitudes of the flows.

If these flows occurred continuously over time, the levels of the Great Lakes would actually stay constant and there would not be any problem with the hydrologic system. However, the very fact that the supply varies introduces a variation in the lake levels which is undesirable to almost all users. Excluding any water-quality considerations, three major water-use categories can be identified which relate closely to the lake levels and volume of water stored. These are: (1) riparian or shoreline interests, (2) navigation interests, and (3) power interests.

The shore property owners have an interest in reducing the high lake levels both in magnitude and duration, since they will cause erosion and damage buildings and lands. Similarly, low levels will expose land areas normally under water, which may look objectionable from an aesthetic point of view, and which may make it difficult to launch small boats. Most significant in economic terms is probably the damage due to erosion and wind action at high lake levels.

The navigation interests require high minimum levels on the lakes to support greater draft for the ships and also high minimum flows in the connecting channels. According to the U. S. Army Corps of Engineers studies, high levels and high flow velocities in the channels are of less importance.

The power interests are generally seeking higher lake levels to provide more head at their turbines and an equalizing in the outflow to increase their firm power capacity.

Summarizing, then: with the exception of power interests which seek high lake levels, all other interests are best served if the lake-level variation and the outflow variations are reduced and maintained close to their long-term average.

At the present time two of the lakes are regulated: Lake Superior and Lake Ontario. Lake Superior, the uppermost of the Great Lakes, has been regulated since 1921 when the natural river bed of the St. Mary's River was dammed and the outflow controlled by a number of gates. At the same time a lock system was installed to permit the movement of ships to and from Lake Superior. At the present time, Lake Superior is regulated according to the "modified rule of 1949." This rule curve was developed over the years by the Corps of Engineers and is a modification of some earlier rule curves. It provides for lowering the maximum stages and raising the minimum stages by regulating the outflow.

Lake Ontario has been regulated since 1960 in accordance with 1956 orders of the International Joint Commission (IJC). Again, these orders essentially provided fixed rule curves with the aim

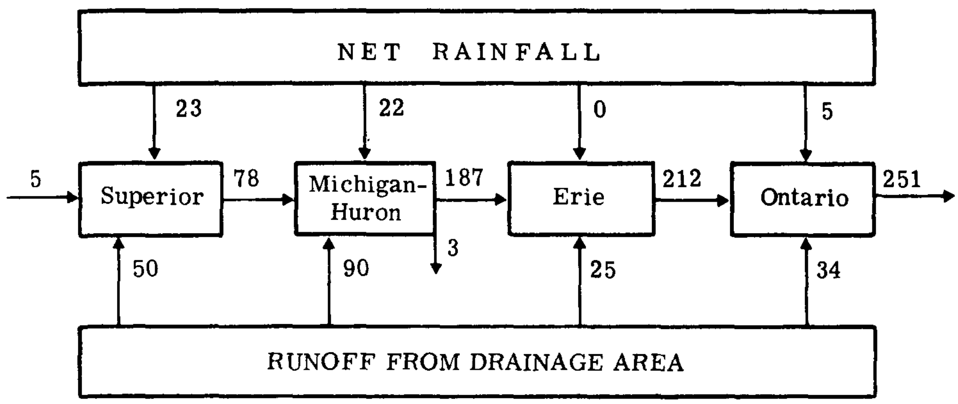

FIGURE E-1. INPUT AND OUTPUT MODEL. ×1000 cubic feet per second.

of lowering high stages and raising low stages. The rule curves were originally developed in 1958 by the Corps of Engineers; in a Corps report in 1965 it is stated that they had undergone three revisions in three years. This points up the need for continuous revision of these regulations to adapt to changing needs and also raises the question whether these rigid rule curves should not be replaced by a more dynamic decision process.

In 1965 the Corps of Engineers published a report on the regulation of all the Great Lakes in which, for the first time, the rule curves vary depending on the antecedent rainfall and net water supply to the basin. These plans, which include regulation of Lakes Michigan-Huron, and Erie, were developed considering U. S. interests alone and are presently under study by Canadian authorities.

It appears that there is a definite need for mathematical modeling of the water quantity and lake levels. The regulation rules should be determined for the total system, and not just for regulating one lake alone. For example, Lake Superior could be operated as a "reservoir" to help improve the levels of Lake Michigan-Huron. In the model one would have to weigh the damages due to low lake levels on Superior versus the benefits to be derived from increasing the lake levels of Lake Michigan-Huron.

Similarly, although reducing high lake levels and increasing low levels is a step in the right direction, a "foot" of low-level regulation should have a value different from a "foot" of high-level regulation, and these should be properly weighed against each other.

The objectives of this proposed research are to explore and develop new methods for optimal lake-level control. In this respect several new techniques generically summarized under the name of "systems analysis" are ideally suited. Specifically, it is proposed to investigate the applicability and limitations of the use of linear, nonlinear and stochastic programming for the determination of optimal operating policies and regulating structures of the Great Lakes system. The research will proceed along two major areas of models: deterministic models and stochastic models. Both types should add to our understanding of the lake-level control problems.

E.2. RESEARCH PLAN

The research leading to an improved method for lake-level regulation will proceed in the following three phases:

(1) Collection and analysis of the hydrologic and economic data.
(2) Formulation of deterministic and stochastic models.
(3) Verification of the proposed models by simulation of the system.

E.2.1. COLLECTION OF DATA

The first phase of the study will be a collection and critical review of all the data available at present regarding the hydrologic and economic systems, as related to lake levels, of the Great Lakes. Some preliminary review of the hydrologic data obtained from the Lake Survey of the Corps of Engineers is in process. Data on the net basin supplies to all of the Great Lakes have been obtained on IBM cards and are currently being analyzed for their statistical properties. Further data will be gathered on observed lake levels, rainfall, evaporation, and transpiration. Many of these data are available from the offices of the Corps of Engineers, the U. S. Geological Survey, the Weather Bureau, and state agencies. In order to establish benefit-and-loss functions for varying lake elevations, considerable data collection activities are necessary. At the present time the Lake Level Board is conducting a study on these aspects, and it is proposed not to duplicate this study but to use its data.

E.2.2. FORMULATION OF MATHEMATICAL MODELS

The mathematical models and techniques which will be explored in this study can be divided into two classes: deterministic and stochastic models. In the first category, models will be established beginning first with one lake and then expanding to the entire chain of lakes. For example, in the absence of economic data, criteria for lake-level regulation could be: (a) to minimize the square of the deviations from a proposed rule curve; (b) to minimize the sum of the absolute deviations from a preselected level; or (c) to find rule curves which minimize the maximum absolute deviation. If economic data are available, then one would wish to find operating rules which would minimize the total losses or maximize the net benefits. These models will be studied under present limitations by existing engineering works and then under conditions with these restraints removed.

Once these deterministic models have been explored to the fullest extent, a refinement to stochastic and chance-constrained models will take place. The amount of water supply in any one month to any one lake is a function of the previous month's rainfall, temperature, and lake level. Operating policies will therefore be established which will be optimal taking into consideration the hydrologic events of the past and the predicted supplies of the future. Typical of these types of models are, for example, the models Loucks has developed for the regulation of the Finger Lakes in New York. The Markow chain model, where the inflow each month is dependent only on the previous month's inflow, is a step in the right direction; however, the Great Lakes have more than one significant lag period and the several lakes have to be accounted for at the same time. It is therefore planned to extend this method and also to explore the use of some recent developments in the area of chance-constrained programming.

E.2.3. VERIFICATION OF THE PROPOSED MODELS

In order to establish the significance and the benefits to be derived from integrated lake-level control rules, it will be necessary to establish the difference between present-day operating rules and any new ones derived in the study. To accomplish this, it will be necessary to construct a mathematical simulation model of the Great Lakes which will permit a testing of these alternatives. This latter part will be executed in close cooperation with the U. S. Army Corps of Engineers which is now charged with the responsibility of regulating the Great Lakes. There is a possibility of using their regulation model and extending it where appropriate.

E.2.4. HYDRO-METEOROLOGICAL MANAGEMENT

Another aspect of water-quality modeling is evaluation of management practices which can change runoff from the drainage area, precipitation on the lakes and in the drainage area, lake evaporation, and diversions. These management possibilities as well as the purely engineering regulatory works need to be tested. For example, runoff from tributary drainage areas is not necessarily fixed, but may be subject to increase, decrease, or change in timing, depending upon land management practices.

Weather modification is receiving considerable attention, and it may become feasible to increase precipitation in the relatively near future. Such increases directly on the lake surfaces and in the form of increased land runoff can be evaluated in the water-quantity model.

Lake evaporation through the use of monomolecular film is now feasible for small ponds and lakes. An evaluation of these and other techniques for suppressing evaporation should be tested for their effects on lake levels and discharges as well as their economic consequences.

It is considered likely that numerous proposals for diversions into and out of the Great Lakes will be made in the interests of water supply and waste disposal. The water-quantity model will be well suited to test the physical and economic consequences of such proposals.

Finally, it should be pointed out that water-quality models are highly dependent upon a workable quantity model in matters of flushing rates and residence times of nutrients and pollutants.

Appendix F
PRELIMINARY RESEARCH DESIGN FOR THE WATER-QUALITY SUBSYSTEM OF THE GREAT LAKES REGION

A. The Proposition for a Lake Model

John C. Ayers
The University of Michigan

The lake model envisioned for the Great Lakes region divides each lake internally into a series of subregions. Each subregion is chosen to be relatively homogeneous in its properties. Successive summations of the inputs, outputs, and transfers of the subregions define water quality within each subregion, provide a mean level of water quality in the lake, and at the outlet give a level of water quality that serves as one of the inputs into the next lake.

The objective of the model is to describe water quality by subregions within all the lakes of the Great Lakes system as a function of population size and industrial activity and of the level of control imposed upon the sources of pollution input.

Steps in developing the model:

(1) Pollution inputs will have to be defined by location, types, and amounts. Location is defined as being the points of direct discharge into the lake. Type means identified by origin, e.g., industrial, municipal, or agricultural; and identified by inorganic nutrient contents, contents of conservative (nonbiological) inorganic compounds, and contents of organic compounds. Amount is defined as weight per unit volume. All the above should be determined as a function of population size and as a function of industrial activity in order that they may be meaningfully related to historical trends and to projections from the economic growth model.

(2) The best possible determination of present and past water-use (volume) demands and water-quality demands by subregions will be needed as functions of population size and industrial activity in order, again, that they may be related to projections from the economic growth model.

[Note: The assembly of the data listed in steps (1) and (2) should be coordinated with FWPCA, state, and all other data-gathering activities.]

(3) Information on the physical nature of lake currents in each lake and each subregion of each lake must be collected and organized for use in the model.

(4) The present information about physical, chemical, and biological transformations that accompany the currents in each subregion of each lake must be collected and organized for use in the model.

(5) An abstract model, which divides the lake into subregions that are reasonably homogeneous, must be formulated for each lake.

(6) Transfer functions that apply to the exchange of water and material between subregions must be determined for each subregion of each lake.

(7) The biological and/or chemical transformations which describe the water quality in parameters which are critical at water-intake points must be established as a function of inputs and withdrawals within the subregion and exchanges between subregions.

(8) The mean water quality at the lake outlet, which is one of the inputs into the next lake or the St. Lawrence River, can be determined by combining the model components developed in steps (1) through (7).

Figure F-1 presents, as an example, the initial subdivided model of Lake Michigan. This type of subdivision seems to be applicable in spring, summer, and fall; in winter these divisions tend to disappear.

Similar subdivided models of the other Great Lakes can be made from existing knowledge.

B. The Proposition for a Sublake Model

James E. Kerrigan
University of Wisconsin

The modeling of the water-quality aspects of the Great Lakes will necessarily take more than one form. Because of the complex nature of the numerous elements involved within the system, it will be useful to approach the water-quality system from several points of view. The previously lake-model approach described above is designed to quantify the interrelationships between local areas lake by lake. The sublake approach seeks to describe the nature and alternative courses of action that may take place within a localized region or local sector, taking into account the effect of neighboring sectors. By narrowing the scope of the physical region under investigation, it will permit a closer investigation of the parameters identifying water quality and the environmental factors which influence their occurrence. Also, it will permit manageable studies to be undertaken that will indicate possible methods for treating or controlling the levels of water quality within the local sector for specified uses.

The role of the sublake model will be to complement the other modeling undertaken to describe and identify the water-quality system, as well as the overall modeling that will be pursued under the framework of the study, such as the regional economic-demographic growth model. Within this context the sublake model will seek to satisfy a series of specific objectives which are uniquely suited to its design.

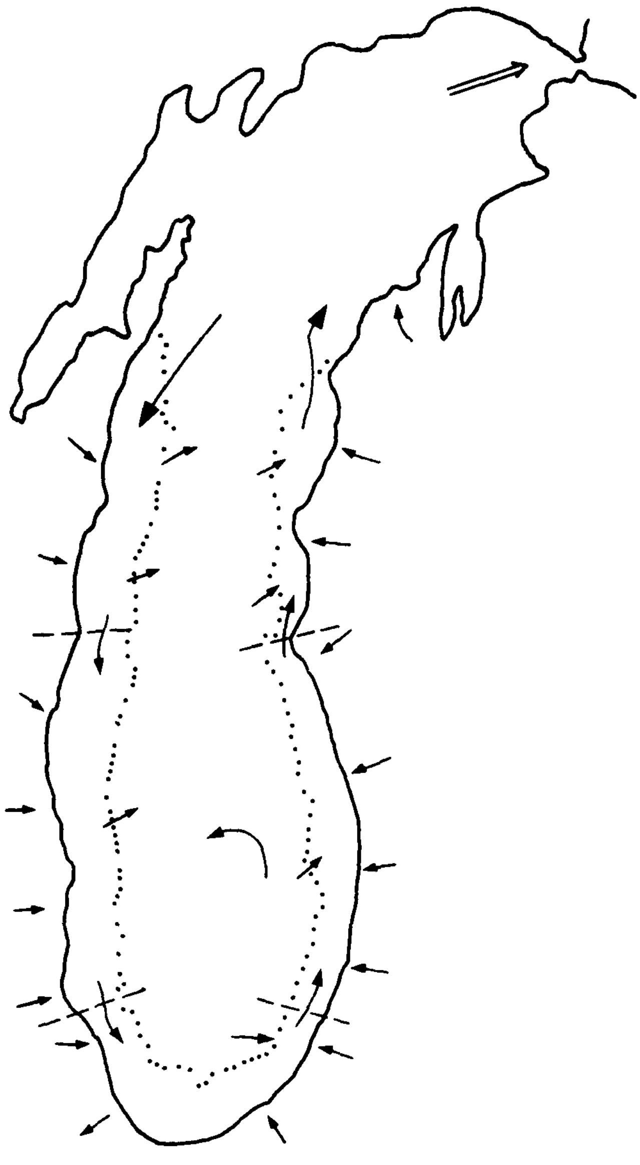

FIGURE F-1. INITIAL SUBDIVIDED MODEL OF LAKE MICHIGAN. Dotted lines indicate conceptual boundaries. Dashed lines indicate hypothetical subregions.

The objectives of the lake model include the following points:

(1) To test and evaluate alternative methods and levels of control, including budget constraints and enforcement costs. Among the alternatives are:

  (a) Effluent fees and subsidies
  (b) Water-quality standards (local, state, regional, national)
  (c) Information dissemination

(2) To provide realistic inputs representative of the local sectors into the lake model.

(3) To simulate or stimulate a control system capable of achieving and maintaining the results of a perfectly competitive market.

The first task of the sublake model will be to identify the system. A simplified free-body diagram, shown in Figure F-2, could be used as a basis for the system. The free-body diagram may be converted into the block diagram (Figure F-3) to show the general network of the sublake model. Figure F-4 illustrates the modular arrangement that could be used to build the sublake model to represent the interaction between uses within a sector, adjoining local sectors, and inshore and offshore water zones.

In these figures, the following symbols are used:

A1, A2, A3, A4 = the local sectors
B = benefits
C = costs
D = the sediment that forms at the bottom of the lake
I = the exchange of the substance or energy between the points within local sectors and between the surrounding areas of the lake
I_1 = the interaction between L_1 and L_2
I_2 = the interaction between the inshore water of adjoining local sectors
I_3 = the relationships between the water quality of the inshore and offshore water zones
i (subscript) = specific use parameter
j (subscript) = water-quality parameter
k (subscript) = local sector parameter
L = the degree of water quality for a given parameter in the lake
L_1 = the characteristics of the lake water at the point where the water is collected for a particular use
L_2 = the quality of the water following use
(Note: for some uses, L_1 and L_2 would be the same)

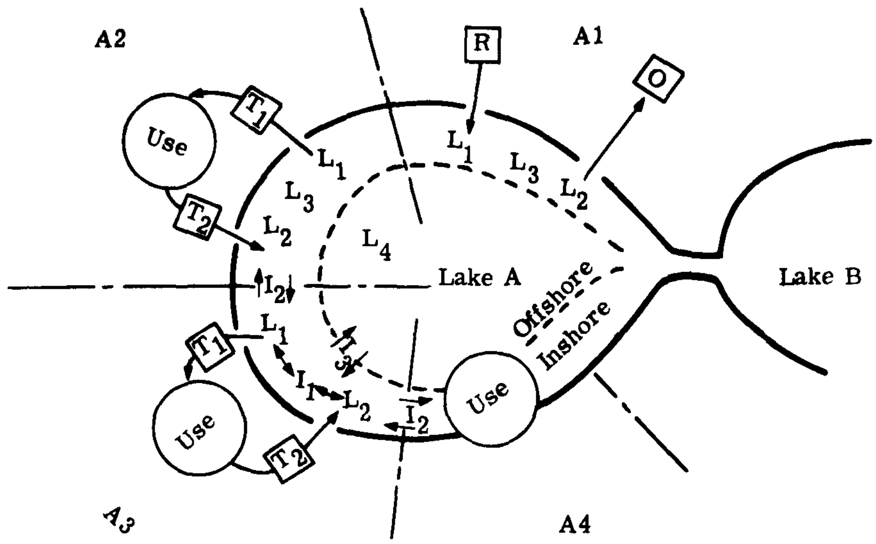

FIGURE F-2. FREE-BODY DIAGRAM OF SUBLAKE MODEL

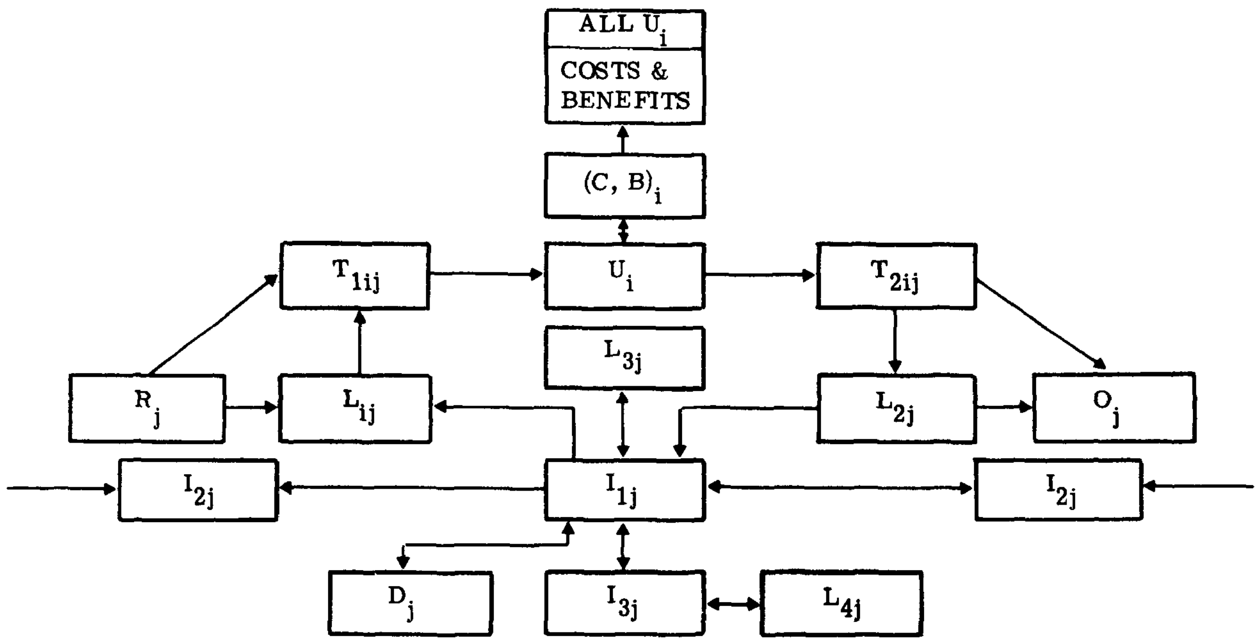

FIGURE F-3. BLOCK DIAGRAM OF SUBLAKE MODEL

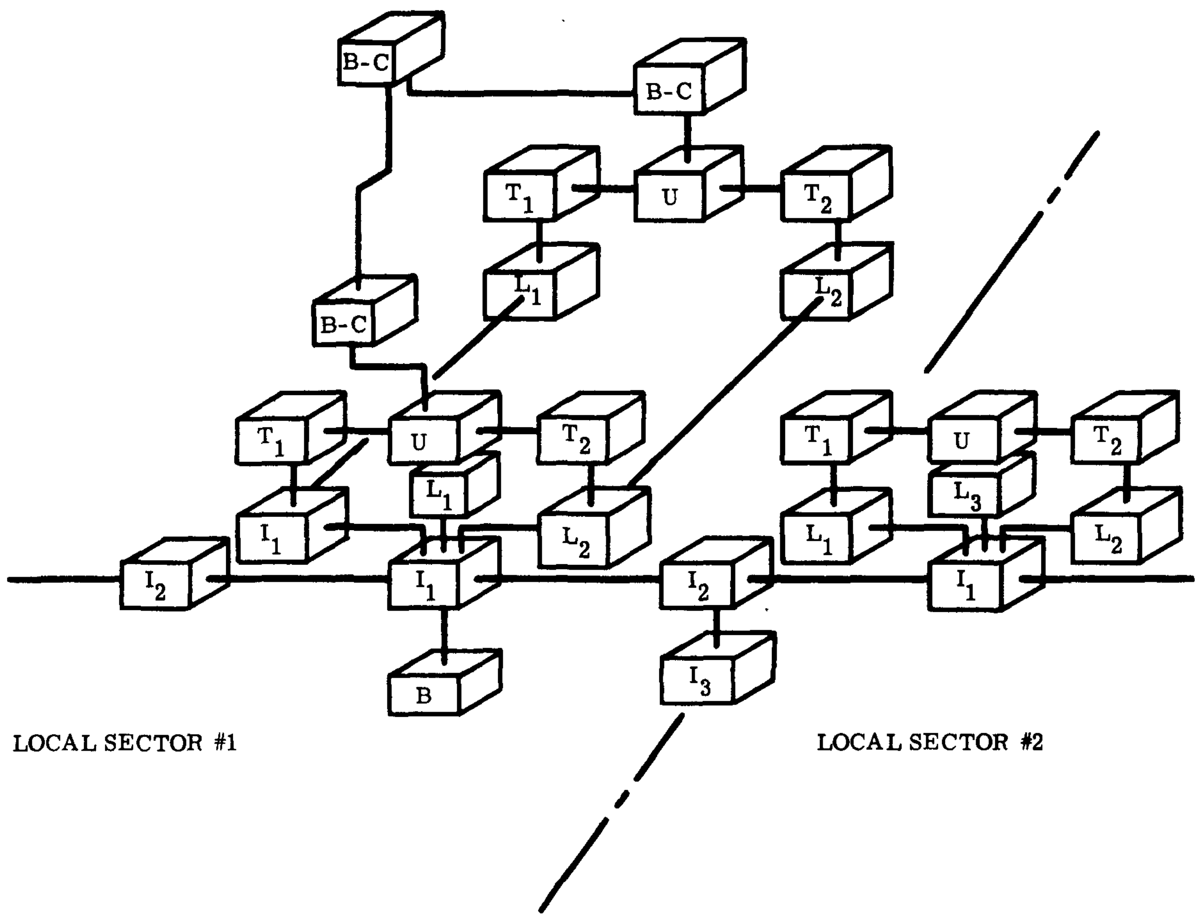

FIGURE F-4. MODULAR ARRANGEMENT FOR SUBLAKE MODEL

L_3 = the mean concentration of a given substance or physical state for the local sector

L_4 = the interaction between the inshore water zones of the local sectors

O = the diversion of water from the lake to a neighboring watershed

R = the characteristics of water discharging into the lake sector and not previously collected from the lake

T_1 = the treatment, management, or enforcement controls on influent water

T_2 = the controls on the effluent side of the specific use

U = use, and associated benefits and costs attributed to such use

Explanations of the complexities of some of the factors identified in these figures are given below.

D. Sediments tend to concentrate, stabilize, and exchange and release nutrients and other substances under various environmental conditions. An understanding of the interactions between the sediments and the overlying lake water will be required for the model.

i, j. The model is based on the identification of degree of water quality based on a specific use. Some of the major uses and quality parameters are listed below.

USES (i)

Commercial fishing	Irrigation
Cooling water	Recreation
Domestic waste carrier	Swimming
Domestic water supplies	Wading
Industrial waste carrier	Fishing
Industrial water supplies	Boating
	Sightseeing

WATER-QUALITY PARAMETERS (j)

Bacteriological indicator tests (coliform, enterococci, etc.)	Phenols
	Phosphorous compounds
Carbon dioxide	Plankton (number, diversity)
Color	Toxic substances
Dissolved oxygen	Suspended solids
Dissolved solids	Tastes
Hardness	Temperature
Nitrogen compounds	Toxic substances
Odor	Turbidity
Organic material	

L. It is well recognized that the water quality varies greatly in large lakes such as the Great Lakes. The variation is caused in part by the natural environment and physical configuration of the lakes, the lake currents, and localized shoreland uses. During the spring, summer, and fall seasons, a natural barrier develops between the inshore and offshore waters. The separation breaks down in the winter season, thus permitting a greater interchange of shore and deeper waters.

As shown in Figure F-2, the lake is divided into inshore and offshore water zones and boundary lines are used to separate "local sectors." Local sectors are areas in which strong water-quality interrelationships exist and have weak interaction with neighboring sectors.

R. Examples of water-discharge characteristics would be rural and urban runoff, discharges of used cooling water obtained from ground water, and ground water entering the lake from the adjoining land.

T_1, T_2. The water-flow pattern between the lake and the water-use zones is generally cyclic. Two situations can exist within a local sector where the water is not cycled and their influence on the system can be significant. (1) Lake water can be diverted from the lake for some use outside the original watershed, as in the case of the Chicago diversion for stream-flow augmentation. The lake water is used to improve the quality of the river system that drains away from the lake without affecting the quality of the lake water. An alternative in improving the quality of the river water may be to discharge the treated municipal waste into the lake. (2) The other case involves the influx of great quantities of pollutants and nutrients from the inflow of urban and agriculture drainage.

U. Figure F-2 indicates the spatial relationships between the local lake sectors and associated water uses. The uses may be municipal or industrial water supply, thermoelectric power generation, cooling water, recreation, commercial fishing, or irrigation, to mention only a few. For some uses it will be possible to employ management or treatment controls before and after the water is used, whereas other uses will permit only one, and possibly no control measure on the influent or effluent stream. For in-lake recreation uses, such as swimming, water quality control measures may be unavailable. However, the degree of water quality required for this use is high.

In Figure F-5, the I_m box may be defined as a time-dependent relationship which describes the material balance for a specific constituent by

$$\frac{dM_i}{dt} = \Sigma F_i$$

where M is the mass of the substance stored in the L_k element, t is the time, and F represents the mass rate of flow of the substance. The rate could be determined by

$$F_{ki} = \bar{v}_k A_k (V_k M_i) = \bar{v}_k A_k C_{ki}$$

where $\bar{v}_k$ is the mean current in the kth local sector, A_k is the effective cross-sectional area in the kth sector, V_k is the volume in the local sector, and M_i is the mass of the substance in a specific use. The concentration of the substance, C_{ki}, would be

$$C_{ki} = V_k M_i$$

In developing a useful scheme for selecting the kinds of control that may be used to manage the quality of the water within a local sector, it will be necessary to identify the water uses in the

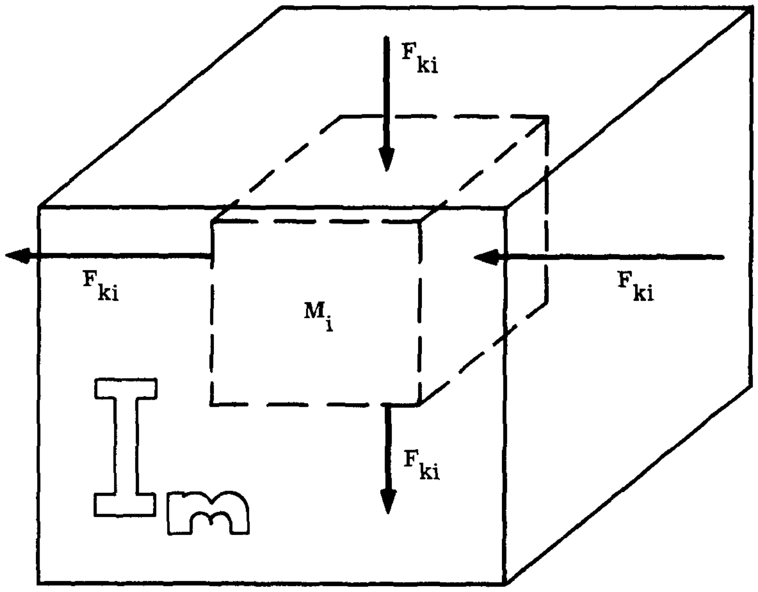

FIGURE F-5. TIME-DEPENDENT RELATIONSHIPS FOR SUBLAKE MODEL sector along with the limiting levels of water quality associated with each. After the limits have been established for each parameter, studies must be conducted to determine the types of water and waste-treatment methods, management-control measures, enforcement schemes, etc., that may be employed to control the level of water quality within the limited range. As a rough-cut model, it would be desirable to define the controls suitable to the municipal use of lake water. This would include the urban runoff and diversion for stream-flow augmentation. A series of investigations into the cost and benefits associated with controlling the level of water quality in selected local sectors should be undertaken. The objectives of such studies would be to evaluate the direct costs and benefits which are normally identified, as well as to make professional estimates of those social values which usually escape quantification. With the comprehensive assessment of the resources available, the use demands, ideal and practical institutional and legal constraints, and the interaction of the components of the system, alternative control schemes will be suggested to control and manage the water-quality scheme to meet selected social values.

Appendix G
PRELIMINARY RESEARCH DESIGN FOR THE GAMING SIMULATION

Richard D. Duke
The University of Michigan

The purpose of the envisioned gaming-simulation model is to design a heuristic micro-environment, replicating in its salient aspects key policy problems of water-basin planning and control. Objectives of this approach are listed below.

(1) It would clarify the technical problems of researchers for politically oriented decision-makers.

(2) On the other hand, it would clarify the political problems of decision-makers for technically minded research workers. (Too often technical advice that is given to politicians and administrators falls on deaf ears because they are unable to see the political relevance of the researchers' recommendations: (a) because politicians are not conversant with the technical rationale, and (b) because researchers are not attuned to the needs of politicians and give data and indicators that miss the real needs of decision-makers.)

(3) It would allow researchers to quickly and efficiently evaluate alternative models of politics, economics, and water resources but with a knowledge of policy.

(4) It would allow researchers to project alternatives for the future of the basin by using several different policy assumptions.

(5) It would allow key decision-makers to experiment with alternative innovations and to see their long-run impact on a basin, but in a risk-free setting.

(6) It would allow the linking together of families of models in one package so that researchers and decision-makers alike could see the entire universe in the reduced time span.

(7) It would train future professionals, both researchers and administrators, in the policy problems of water resources.

(8) It would allow key federal personnel to plan and evaluate alternative decisions altering their roles and relations within the game. Thus they could see the impact of various decisions on a future water-resource system.

One game that might be devised would be a free-wheeling structure that mimics international relations. This could point up problems and mechanisms of cooperation, conflict, and competition in a water-resource basin context. Issues would be developed for decision-makers to respond to ("polluters versus users" "up and down" stream sources and uses, multiple-use conflicts with varying quality and quantity criteria, etc.) Within such a game, each participating unit (city or other government) would have several roles, played by individuals, that might be considered to be typical for water-resource problems. These might include such roles as politicians representing constituencies at different levels of government; businessmen who are involved in water problems like use and consumption; technical specialists and administrators; health experts; economists; water engineers; government administrators; and, finally, representatives of the mass media. In addition, there would be computer simulation of population, influential natural events, firms, households, agencies, and water quantity and quality.

Critical problems of research supporting such a game are to determine what the power structure is, what characterizes its key positions and what the linkages between them is; and also what key organizations exist (with what power) and what their linkages are. This is essentially unresearched for large basins. Also, basic research is required on public opinion formation about water resources issues, the role of the mass media, and the relation between economic and political models of water resources.

The research design would include the identification of major social and political institutions (e.g., municipalities, townships, counties, states, private users) in the Great Lakes region, and their representation in modular form. These modules could be combined appropriately to represent the existing decision-making organizations in a particular water- and land-use area. A hypothetical water- and land-use area is shown in sector A of Figure G-1. After institutional constraints have been identified, possible alternatives to existing conditions would be formulated. Experiments could then be run to evaluate these various alternative institutional forms.

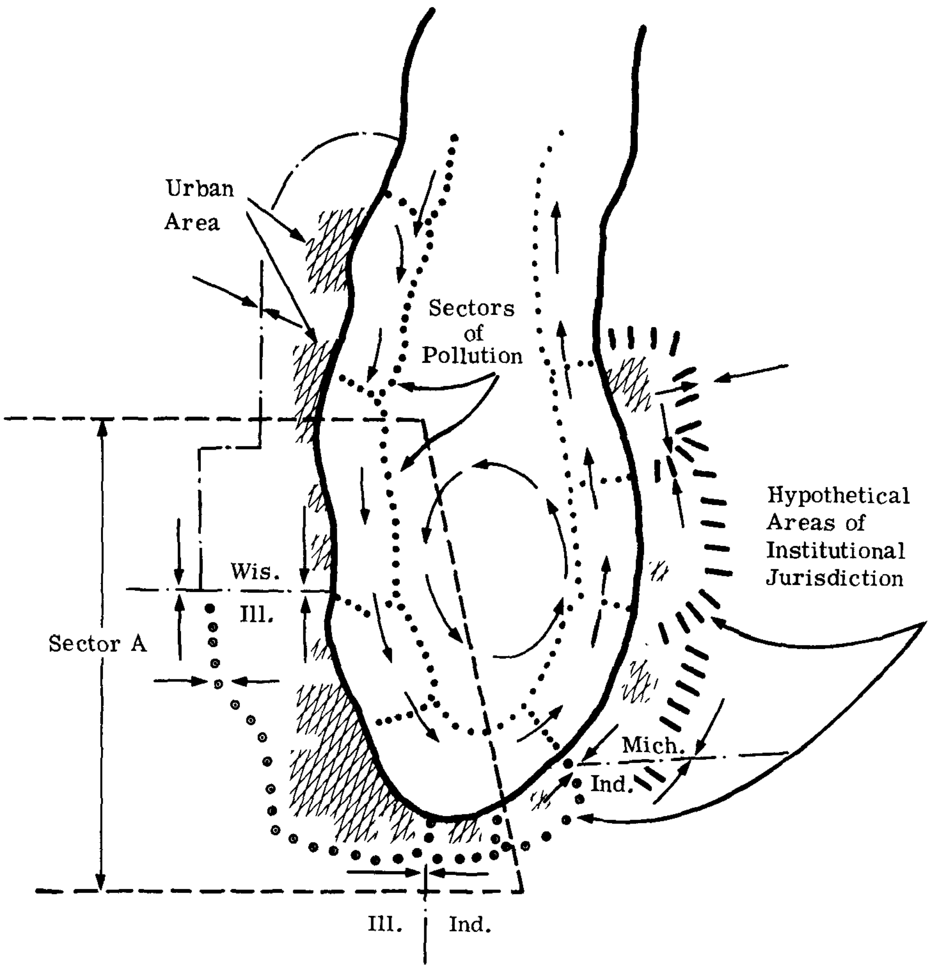

FIGURE G-1. SIMPLIFIED MODEL OF A SUBREGION. Sector A represents a hypothetical water- and land-use area that could serve as a sample area for modeling. The interaction between the water-quality modeling and the gaming-simulation model can be visualized from the figure. Pairs of facing arrows indicate interrelationship. Directional arrows show hypothetical current patterns.

Appendix H
AN INVENTORY OF NEEDED RESEARCH ACTIVITIES IN THE GREAT LAKES REGION

Compiled by
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The University of Michigan

As an indication of personal interest and, in an effort to obtain an indication of the personal interest of others, an informal survey was made of faculty at Water Resources Centers and participating universities. The objective of the survey was to provide an opportunity for investigators at earlier CIC gatherings to indicate their personal research preferences as shown below.

Basically two categories of research activities were identifed by participants in the working conferences. (Specific suggestions for interuniversity research projects which came from investigators were kept on file by the CIC staff.) Within these categories, "institutional and socioeconomic research activities" and "physical-biological research activities," items were arranged randomly in a questionnaire which was sent to investigators.

Part of the questionnaire asked the respondent to indicate, which projects, in his judgment, were in need of "immediate research attention" or "research attention very soon." The respondent was also given options to mark projects which needed research effort "ultimately" or "no attention at all." A space following each potential research activity permitted persons to register their names as an indication of personal interest.

Of the working conference investigators, 70% completed the questionnaire. Persons who indicated personal interest included many conference participants and their colleagues in CIC universities, and researchers in cooperating institutions including Cornell, Indiana, and Ohio Water Resources Centers.

The results of this modest inventory do not lend themselves readily to statistical analysis because of the variables which may have influenced respondents and because of their individual biases. Nevertheless, the replies concerning the areas where research attention was desirable "immediately" or "very soon" seemed of enough interest to merit publication.

QUESTIONNAIRE

In the randomly arranged list below, the number in the left column refers to the number of "early attention votes" which were cast for each research activity. Evidence was obtained that multi-university interest exists in each of the projects listed. Considerable overlap is found between several projects in the two categories. In both categories it is of interest to note that the research activities which received the highest number of "votes" are essentially the same research projects which have been stressed in this report.

The categories of research activities are arranged for cursory observation, with projects which received the highest number of "votes" listed first; but undue weight should not be placed on the number of indications of interest ("votes") attached to each potential project. This tabulation includes responses received before December 12, 1967.

Indications of Interest	Category of Institutional and Socioeconomic Research Activities
17	Collection of economic data on water and waste treatment costs as related to eutrophication.
16	An analysis of how water management decisions are made in the (Lake Michigan) region and what techniques can be applied to assist the decision-making machinery in producing and selecting from a wider range of alternative programs of resource management.
16	Construction of a regional economic growth model for the Lake Michigan subregion.
15	Conflict situations among competing uses of Lake Michigan are in special need of study. Tradeoffs, if any, need to be understood between (1) recreation and waste disposal (pollution); (2) commercial fishing, and pollution; (3) one form of recreation versus an incompatible form of recreation (power boats vs. duck hunters or canoeists); and (4) power and maximum shoreline use and development.
15	How does the price of water affect its recreational, domestic, and industrial uses?
13	How does the political process affect decisions relevant to water-resource usages in Lake Michigan or the Great Lakes system?
13	A feasibility study designed to determine an approach to a Lake Michigan model which can eventually be plugged into a Great Lakes regional model.
13	An analysis of the flow of information for planning and policy activities between and among the private and public sectors of a subregion.
13	How do individuals, groups, organizations, and other public sectors express themselves in the process of arriving at a consensus on what should be done with the available water resources?
13	How are values expressed through our present institutions, including the International Joint Commission and the Great Lakes Basin Commission?
12	What does the law say, and, what is the actual application in water resources?
12	What are the social implications (as well as economic) of water-resource management and development in this subregion?
11	Data storage and retrieval system from the water-research activities in the Great Lakes basin.
11	What are the organizations in the Great Lakes area?

Indications of Interest	Category of Institutional and Socioeconomic Research Activities (Cont.)
11	How does a concern for the environment form among individuals or groups, how is it measured, how is it expressed, and how does the governmental sector incorporate this concern into political and social action?
11	Identification of data-collection sources, the types of data collected, and the form of available data.
11	What is the process by which public opinion on water-resource questions is formed?
11	Monitoring of economic effects of changes in water quality at a few critical points as a result of putting water-quality standards into effect.
11	How are social values for different goods and services (from the water) related to different uses in different parts of the basin?
11	What is the process of problem definition within watersheds, major lake basins, and the entire Great Lakes region? What are the priorities?
11	An institutional arrangement such as the Great Lakes Basin Commission needs to be assessed for its strengths and weaknesses in terms of reflecting social values, resource-planning program strategies, etc.
11	In light of the externalities in the Lake Michigan situation, how can the differences and impacts between social values and economic values be determined?
10	An identification of water-management influences and influentials as a part of the regional or subregional political power structure.
✓ 10	How can the generation and presentation of information for making public decisions be improved?
9	A determination of operational efficiency and effectiveness at various levels, in water-related organizations.
9	What is the capability to implement decisions after consensus on water-resource developments or -management schemes?
8	What heuristic research techniques may be applied to the decision-making performance of operating agencies?
8	Attitude survey of water-using or water-polluting industries.
8	How frequently are water-management and -development decisions made by persons or organizations not directly involved as beneficiaries and/or contributors to the project cost?
7	What media and "vehicles" can be applied most effectively (and how) in water-related information dissemination?
7	What about new institutional structures?
7	An evaluation of the prospect that traditional lines of authority and influence may be rerouted from Congressional delegations to regional agencies of national and international stature, particularly by state and metropolitan governments.
7	What social change can be brought about through planned intervention in conjunction with water-resource projects?
6	Role-playing type of simulation.

Indications of Interest	Category of Institutional and Socioeconomic Research Activities (Concl.)
6	Production of documentary film on Great Lakes basin problems.
4	While the subsystem is under study, the effects of the study or the "client" need to be identified and separated from any changes in behavior, etc., that would have proceeded in the absence of an investigation. Thus the need for monitoring and evaluation in this area.
4	Time lag from occurrence of actual problem to perception of the problem.
	Category of Physical-Biological Research Activities
13	Water-quality model of Lake Michigan or others and its contiguous drainage basin in terms of nutrient budget, rate, and effects of fertilization.
13	Relationships need to be established between various pollution levels and their effects in biological as well as economic terms.
12	An investigation of transfer functions between input controls and input pollution; they also need to be developed between elements of pollution and the general pollution level and controls presently in use in the Lake Michigan situation.
12	The effects and mechanics of coastal and offshore interchanges and mixing.
11	A determination of the status and future of eutrophication in Lake Michigan.
11	What are significant parameters and methods of measuring water quality, sedimentation, and oxygen demand?
11	Quantitative model of the Great Lakes system with special attention directed to lake levels, associated flow, and losses including augmentation and diversions resulting from structural work.
11	The definition of inputs, outputs, and "state-of-the-art" controls on a cause-and-effect pollution model.
11	What simplified models can be applied to the entire Great Lakes system in areas of water quality?
11	Improved indices and monitoring techniques for eutrophication.
10	Future water-supply needs and expected levels of pollution.
10	A study on pelagic and benthic conditions in Lake Michigan or other Great Lakes.
10	How pollutants modify water quality.
10	Sport and commercial fishery resources.
9	A sediment-water interface study.
9	Is improvement in waste-treatment processing gaining on the increased pollution added by increased population?
8	Retention times in the Great Lakes.
8	How can the output from simulation or any physical model be used most effectively with the eventuality that value judgments will need to be made which force numerical rating techniques.

Indications of Interest	Category of Physical-Biological Research Activities (Concl.)
7	Precipitation-evaporation on lake surfaces of the Great Lakes.
7	Physical, biological (legal and economic), effects of further diversion or diversions of Lake Michigan-Huron water.
7	Spatial requirements for recreation developments.
7	The effect of evapotranspiration rates, ground-water gains and losses, and the necessary degree of accuracy required for these and other variables in a quantitative model.
7	Regulation of lakes with and without existing structures.
7	Physical observations of lake levels need to be related to resultant values (and to beneficiaries).
6	What engineering structures are needed to better regulate the system, what are the benefits, and to whom do they accrue?
5	Systemswide model of quality using a conservative element (e.g., chloride).
4	Irrigation opportunities in the region and the consumptive implications.