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AN INFORMATION SYSTEM FOR THE MANAGEMENT OF LAKE ONTARIO

by

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FOREWORD

One of the major tasks before us as we move into the end of the present century is bridging the gap that persists between the generation of new knowledge at a rate unmatched in human history and the effective application of this knowledge to pressing social and environmental problems. As population grows, industry and agriculture expand and resource consumption increases, the residuals of production and consumption place ever greater stresses on the physical environment. Nowhere is this more evident than in the Great Lakes Basin.

We in North America have reached that point at which environmental quality has taken its place in the arena of public issues. Citizens are now applying pressures on their governments as a means of defending certain values that had lesser priority in earlier days. While recognizing that a beginning has been made, the facts of the matter are that we are not managing well our natural resources and that progress will continue to be slow and halting unless the requisite political will for some fundamental changes emerges.

There are a number of common factors that account for our inability to respond more effectively to the challenges to managing not only our water and land resources, but other social problems as well. A listing of a few of the more significant factors affecting resource management include: the diffused public interest; differing views about national priorities; inadequate legislation and enforcement; special interest politics; fragmentation of responsibilities within and among governments; and organizational jealousies. These elements operate individually and jointly in ways that seriously impede public programs that are designed to yield effective management of our resources.

There is, however, a more fundamental contributive factor and that is our failure to modernize the institutional structure. The institutional problem is defined as that of determining what kinds of government organizations are needed and how these organizations should be related to each other in order to achieve the most effective management of the natural resources of the Great Lakes Basin at the lowest possible economic, political and social costs. There is, of course, an existing institutional apparatus involving all levels of government in both Canada and the United States. This present structure, however, is not the product of any United States - Canadian long-term plan for the Great Lakes Basin. On the contrary, the present mix of governmental departments, agencies, boards and commissions simply evolved over the years at a rate and to an extent that were determined by the changing limits of political feasibility in each country.

For the past two years, the Water Resources and Marine Sciences Center at Cornell University has been engaged in a series of studies of the institutional problems in the Great Lakes Basin. Perhaps the most important conclusion of our studies is that the present institutional structure for resource management in the Great Lakes Basin is inadequate and is in need of fundamental revision.

The Cornell project focusing on the institutional problems of the Great Lakes consisted of three related yet distinct research efforts.

The first commenced in early 1971 when a group of twenty graduate students representing a wide range of disciplines investigated the water and related land management problems of the Lake Ontario Basin. The approach of this graduate seminar was to attempt a comprehensive, multiple resource-use investigation which included an examination of the social, economic and political factors peculiar to the Lake Ontario Basin. The objective of the group was to consider the need for, and the formulation of an improved management scheme for Lake Ontario. A background report (350 pages) was prepared and a summary report, The Management of Lake Ontario - A Preliminary Report Proposing an International Management Organization was distributed to the Governors and Provincial Ministers Conference on Great Lakes Environmental Problems at Mackinac Island, Michigan in July 1971.

The summary report concluded, among other things, that the improved management of Lake Ontario (and by extension, all of the Great Lakes) would require either a substantial strengthening of the International Joint Commission or the establishment of an altogether new binational agency to supplant the former in the Great Lakes Basin. The report recommended a joint Canadian - United States study in this matter and, as an interim action, a reference to the International Joint Commission authorizing the Commission to establish on a trial basis a management office with rather extensive coordinative responsibilities for the water and related land resources of the lower lakes region.

The graduate student group sought, in effect, a strengthened binational apparatus, preferably one based on the existing International Joint Commission, authorized to carry out a surveillance and mediation function in the lower lakes.

Canada and the United States.

The third phase of the Cornell research effort on the Great Lakes Basin consisted of an attempt to develop further the idea of a binational management office with wide coordinative responsibilities for the Lake Erie and Ontario Basins. Concurrently with the Canada - United States University Seminar (December 1971 - June 1972), a second graduate student group at Cornell University investigated, under the guidance of Professors Leonard B. Dworsky, C. Donald Gates and David J. Allee, selected elements of a hypothetical joint management office. As part of this effort, ten graduate students completed seven theses for advanced degrees, together with three research papers on some facet of a joint regional management office.

The type of joint office conceptualized is one designed to carry out a coordinative role in the management of a wide range of resource-use problems. The list of such problems used in the investigation included: water quality; municipal/industrial water supply; agricultural water supply; lake level control; hydropower; flood control; navigation; shoreline erosion; fish and wildlife protection; water-based recreation; solid waste disposal; air quality; economic development; agriculture and transportation.

In our attempt to simulate a Great Lakes operations office jointly established and operated by Canada and the United States, we endeavored to examine a selected number of those problems which both the designers of such an office as well as those who are ultimately charged with its direction would be obliged to address.

An obvious initial consideration, for example, would be the structure and functions of a modified joint agency. This topic is dealt with in Natural Resources Management in the Great Lakes Basin by James A. Burkholder. A primary task of an operations office would be the collection, interpretation and dissemination of data and information pertaining to the Basin. This important area is treated in An Information System for the Management of Lake Ontario by Dale Reynolds. The role of public participation in the activities of the proposed Basin operations office is examined in detail in Public Participation in Water and Land Management by Arvid L. Thomsen. Demographic trends and problems are traced on a national scale and then examined with respect to the Lake Ontario Basin as a case study in Toward a National Population Redistribution Policy: Some Policy Issues by Lawrence W. Saunders. The problems of

Surveillance is defined in this instance as essentially an information collection, data interpretation and dissemination role. It is an activity concerned with problem definition. Surveillance includes a continuing responsibility to be aware of problems and alert to future developments. Mediation, on the other hand, encompasses the development of joint programs to attack common problems. It involves also the promulgation of regulations, schedules and uniform standards, along with appropriate means to secure implementation of those regulatory mechanisms.

While some consideration might be given to assigning a joint agency a third function - that of control, particularly in the cases of water pollution or air pollution control, that does not appear to be a feasible direction in which to proceed, at least at the present time. The governments will be better able to determine their positions with respect to vesting a joint body with an effective control function once the Great Lakes Water Quality Agreement signed by Prime Minister Trudeau and President Nixon in April 1972 has had time to operate and be evaluated.

The second phase of the Cornell project began in late 1971. In order to further test the tentative findings of the graduate student group and also to encourage a binational focus on the problem, plans were laid for a six-month seminar comprised of interested faculty from universities in Canada and the United States.

A Canada- United States University Seminar was formed by various faculty from some twenty universities and colleges in Canada and the United States. The Seminar met in three formal sessions during the period December 1971 - June 1972. Using the information and data assembled by the Cornell graduate student group as a starting point, the Canada - United States University Seminar took up the question of improving the two countries' capabilities for managing the water and related land resources of the Great Lakes. A principal objective of the faculty group was to produce a report which would promote discussion in both countries on the problems of the Great Lakes. Another purpose was to set forth in general terms the available alternatives for improving the management of the water and related land resources of the Great Lakes Basin.

A final report of the Canada - United States University Seminar has been written and the findings (1) indicate that there is a need for a modified international arrangement to cope more effectively with the existing and emerging resource-use problems affecting the Great Lakes Basin, and (2) present three alternative institutional approaches as possible guides for further discussion and debate in water quality management of a lake basin are considered in Opportunities for Water Quality Management: A Case Study of the Lake Erie Basin by Ralph P. Meckel. Special problems of environmental quality management along an international boundary are the subject of Environmental Management of the Great Lakes International Boundary Areas: A Case Study of the Niagara Urban Region by Donald R. Kisicki. The opportunities and problems associated with Federal and state grants for wastewater treatment facilities are discussed in two case studies in Cost Sharing in Water Pollution Abatement Facilities - Some Economic and Political Consequences by James M. Foster. Land use management as an integral part of the overall planning process is the subject of a paper Land Management in the Lake Ontario Basin by James M. Wolf. In his paper entitled Management of the Biological Resources of the Lake Ontario Basin, Douglas M. Carlson provides a comprehensive survey of the biota of the lake basin as well as an assessment of present conservation management practices. Finally, in his paper Management of Water Supply, Navigation, and Power Programs, Martin J. Murphy focuses on those water uses in the Lake Ontario Basin and the potential role of a joint operations office with respect to municipal water supply, navigation and hydropower in a new institutional framework.

These papers, of which this by Dale Reynolds is one, are offered with the hope that they will contribute usefully to the improved management of the Great Lakes of Canada and the United States.

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Biographical Sketch

The author was born in Carnegie, Oklahoma on September 20, 1944. He attended public schools there and was graduated from the University of Oklahoma in June, 1967 with a degree of Bachelor of Science in Civil Engineering.

Since graduation, he has been employed by the Tulsa District of the U. S. Army Corps of Engineers. Upon completion of the one year rotational training program, he was assigned to the Hydraulics Branch, where he has been involved in hydrologic engineering studies.

The author was selected for the Corps' Planning Fellowship Program in 1971 and has attended Cornell University on this program since September, 1971.

He is an associate member of the American Society of Civil Engineers.

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INTRODUCTION

The uniqueness and the importance of the Great Lakes region has been stated many times and yet it cannot be overemphasized. The size of the area, in terms of both geographical area and population, and the economic significance to both the American and Canadian economies have made the efficient management of the Great Lakes a matter of great importance to both countries. Many efforts have been directed toward improving the management of the lakes. At the present time the United States and the Canadian governments have granted to the International Joint Commission (IJC) new authority to control water quality in the lakes. While this is a step in the right direction, a number of groups and individuals believe that the desirable ultimate goal is an organization which has responsibility for a significantly improved and expanded program of water and related land resources management for the area.

In 1970, the Cornell Water Resources and Marine Sciences Center initiated a study for the purpose of contributing to the general search on the part of both countries for the improved management of the Great Lakes. The study isolated Lake Ontario in order to keep the effort within manageable bounds. The purpose of the study was to determine whether there existed viable water resource management institutional forms which could be identified or if an improved management scheme should and could be constructed for that particular lake basin.

The principal conclusion of the study was that some form of an international institution must be established to provide those services needed to plan, develop, and maintain effective long-term management of Lake Ontario. This institution could be established within the existing framework of the IJC or it could be established as a new international body under a new treaty. The study proposes that an experimental international organization should be created for the management of Lake Ontario and tested over a three year period. If it proved effective, it could be made a permanent device and extended to cover Lakes Superior, Huron, and Erie.

As a part of the continuing study effort, a new group is currently in the process of expanding on the original study. This study effort accepts the basic premise that an Experimental Operations Office should be established for the management of Lake Ontario. Its purpose is to develop the organizational structure for such an office and to examine in more detail the functions and responsibilities of the office in a number of important problem areas. This report is a part of that effort and is concerned with the development of a management information system as a basis for the management tasks to be performed.

It should be apparent that the very complex task facing the Experimental Operations Office will require a large information base on which to make plans and decisions. The information base must be not only comprehensive but efficient and relatively easy to use. Everyone is aware of the data explosion in the last few decades in all areas of human endeavor, and the overwhelming volume of data which will undoubtedly continue to be generated in the future. In the field of water resources, we have only scratched the surface, in many respects, in defining and obtaining information needed for management purposes. And yet this relatively small amount of data is so large in absolute terms that it has overwhelmed our ability to devise systems for efficiently and effectively handling and using it.

Much work has been done on the mechanics of collecting, storing, and retrieving data with a great emphasis on the invaluable use of the computer. Unfortunately less attention has been devoted to the "software" aspects of information--that is, the development of information systems for specific purposes based on the needs and capabilities of the users.

This report will not deal with the mechanical details of data handling. It will be concerned with developing an information system which is effectively and efficiently responsive to the needs of the users, considering the purposes to be served and the types and amounts of information required to serve these purposes. The study is developed in three basic parts. The first part will be concerned with a general analysis of information needs for the Experimental Operations Office, considering the purposes and objectives of the office, the boundary of the office, and the problem areas to be managed by the office. The second part will deal with the theory of information and information systems in general, to provide a theoretical background. The third part will consist of an analytical framework for an information system, followed by case studies of two particular areas, namely an economic base study and water quality control. The framework attempts to provide a logical procedure for identifying information users, needs, sources, and implications for the nature of the information system and provides a basis for the case studies. The case studies illustrate this procedure in a detailed manner.

The information system being considered here will not only serve the Experimental Operations Office in carrying out its management and planning tasks, it will also serve as a means to carry out the much needed task of providing coordination of information collection, storage, and dissemination among all parties in Canada and the United States concerned with water resources. There have been attempts at data coordination, especially among agencies on the United States side, and also between Canada and the United States. These attempts have had limited success, and then only in rather limited areas where the need for such coordination has been most evident and immediate. There is still a great deal of duplication and inefficient use of all kinds of information.

Establishing an international planning and management office for Lake Ontario will involve many formidable obstacles, primarily political ones. Information coordination and exchange is one area where one of the greatest needs and the least controversy are involved. Possibly this will be the primary initial goal of the Experimental Operations Office with other responsibilities evolving as the office becomes established and accepted. While recognizing the urgent need for joint planning and management of water resources in the Great Lakes area, the need for an information system for information exchange, along with its more immediate feasibility from a practical viewpoint, might lead to the establishment of an information system itself as a separate entity or as a part of the IJC. It would become a part of the management and planning office when the office is established. So, although this report deals with the information system as a part of the Experimental Operations Office, the discussion could be applied to an information system as a separate, first-phase organization, by considering surveillance, or collection and interpretation of information, only in all the problem areas.

Chapter 1

THE EXPERIMENTAL OPERATIONS OFFICE

Purposes and Objectives

The Cornell study group, in the report The Management of Lake Ontario, recommended the establishment of an experimental international institution for the management of Lake Ontario.[1] This experimental office, which is called the Experimental Operations Office in this study, has as its purpose demonstrating the feasability of such an office to provide the comprehensive management of a common international resource, namely Lake Ontatio. If the office proves effective, it could be expanded to include the other Great Lakes common to Canada and the United States.

The study identified and examined 14 problem areas of significance in the management of the lake (excluding Government Problems). These problem areas are listed in table 1. In analyzing existing institutions for water management, the Cornell study developed criteria of evaluation and postulated management functions to be administered by any management institution. The full range of management functions was separated into three categories. They are:

1. Surveillance
2. Mediation
3. Control

Table 1

Problem Areas Separated According to Task Levels

Problem Areas	SURVEILLANCE (Information collection and reporting)	MEDIATION (Development of joint programs, standards, time schedules)	CONTROL (Control authority, standards, time schedules and surveillance)
WATER QUALITY	X	X	X
MUNICIPAL/INDUSTRIAL WATER SUPPLY	X		
AGRICULTURAL (IRRIGATION) WATER SUPPLY	X		
LAKE LEVEL CONTROL a/	X	X	X
HYDROPOWER	X	X	X
FLOOD CONTROL	X	X	X
NAVIGATION	X	X	
FISH AND WILDLIFE PROTECTION	X	X	X
WATER-BASED RECREATION	X		
SOLID WASTE DISPOSAL b/	X	X	
AIR QUALITY	X	X	X
ECONOMIC DEVELOPMENT	X		
AGRICULTURE	X		
TRANSPORTATION	X		

Source: The Management of Lake Ontario (Ref. 1)

Notes: a/- Lake level control is closely related to three other problem areas, specifically: hydropower, flood control and navigation.

b/- Shoreline and other dumpings by industry and municipalities.

These functions are defined in the report as follows:[2]

Surveillance. This is essentially an information gathering, data interpretation and dissemination role. It is a function concerned with problem definition. It includes a continuing responsibility to be aware of problems and alert to developments.

Mediation. This includes the surveillance function plus a more active role concerned with the development of joint programs to attack common problems. It also includes the promulgation of regulations, standards and compliance schedules, along with appropriate means (e.g., direct or indirect use of the sanctional authority of the governments involved) to give adequate effect to such regulatory mechanisms. It is generally an active role in which mediation, coordination, and other means of resolution of conflict are needed.

Control. This includes the surveillance and mediation functions as well as an oversight or control function. The organization may well exercise sanctional powers granted to it by its treaty or other basic legal mandate. The function is initiatory in nature. It includes the power to make decisions and the means of carrying them out on a non-ad referendum basis. The organization may initiate conference hearings and civil court actions when appropriate.

Based on the nature of the problem area (i.e., is it of local, state, federal or international interest?) and the form of institution needed to carry out the management functions, a matrix was developed which suggests the management function to be carried out in each problem area. This matrix is shown in table 1.

The information required for each problem area will depend to a large extent on the purpose to be served by the information--that is, the management function. The surveillance function is concerned primarily with monitoring of existing conditions, and also with coordinating existing information collection activities and providing a central repository for information needed by anyone concerned with water resources in the Lake Ontario area. The control function, on the other hand, will require the most detailed, comprehensive information concerning not only existing conditions but such factors as costs and benefits of the various alternative means of control and predictive models of the effects of various actions. The control function will require more information of the types needed to determine policies and establish objectives. Because of this relationship between information needs and management function, the information needs for the different problem areas are discussed below under the general headings of the different management functions.

Boundary of the Region

One of the difficulties facing any form of regional authority is the determination of the proper areal scale of operation. In the field of water resources management, the drainage basin of a river or lake has been generally accepted as the natural scale, due to the physical nature of the issue. However, there have been doubts expressed by some that this "natural resource region" approach is not entirely valid in our present society.[3] The objections are that the drainage basin will not coincide with political, economic, social, and cultural regions and that these factors may be of more importance than the physical factor, when any type of comprehensive planning is strived for.

This report cannot attempt to address such complex factors and accepts the popular idea that the drainage basin is a logical boundary for a management office, at least as a starting point. Actually the area of concern will depend on the particular problem area being dealt with. The drainage basin is taken to be the envelope boundary for all problem areas, although some problems such as air quality and economic development could easily involve areas outside the drainage basin.

Within this outer boundary, the area of concern for each problem should be limited as much as possible while still being large enough to allow the management office to meet its goals. Obviously the tasks facing this office will be overwhelming enough without attempting to collect superfluous data and involve itself in unnecessary problems.

Defining the boundary for each problem has to be a somewhat flexible task--the boundary must be defined initially so that information can be collected; but after this information is collected, the problem can be better understood and the boundary can then be redefined. Also, the degree of detail of information available may directly affect the boundary. For example, if certain economic information is available only at the county level, then it would be pointless to define the boundary of concern for this problem to include a part of a county.

To facilitate the collection of information for the management office, the boundaries for each problem area are discussed below. As stated above, this is an evolving task. Also, it is recognized that these boundaries are somewhat arbitrary and there might be disagreement about them even as a first step. Before an actual management office developed its information system, much more attention and expertise would have to be applied to defining boundaries than this report is capable of with the time and resource limitations. The problem areas would fall into the following different boundary definitions.

Drainage Basins

The physical nature of water--quantity and quality of the entire drainage basin surface water and ground water--is the major characteristic of the problem areas of water quality, municipal and industrial water supply, flood control, and agricultural water supply. Solid waste disposal is somewhat more ambiguous but might also be included here since seepage into the ground water and streams could directly affect water quality. Fish and wildlife protection would be concerned with the lake and all of the tributaries so this would be, in effect, the entire drainage basin. The drainage basin is shown in figure 1.

Modified Drainage Basin

The problem area of economic development is ambiguous. As a first step, the boundary would include essentially the drainage basin. However, due to the non-precise nature of the problem, the boundary could be altered with considerable discretion. Economic data can be collected and handled much more efficiently on a county basis so the boundary would follow county lines while staying as close as possible to the drainage basin line. Transportation is an undefined problem area, geographically, but would be related to economic development as would agriculture, so these two problem areas would also be included.

The Lake Area and Shoreline

The problems of lake level control, hydropower, and navigation are all directly related. Control of hydropower and navigation activities is concerned with maintaining optimum water surface elevations and therefore only with the lake area itself. However, these problems cannot be separated from the problem of lake level control to prevent detrimental effects to shore property. Water-based recreation must also be considered with these other problems since the lake level directly affects recreation in a number of ways including aesthetics, swimming beaches, boat ramps,

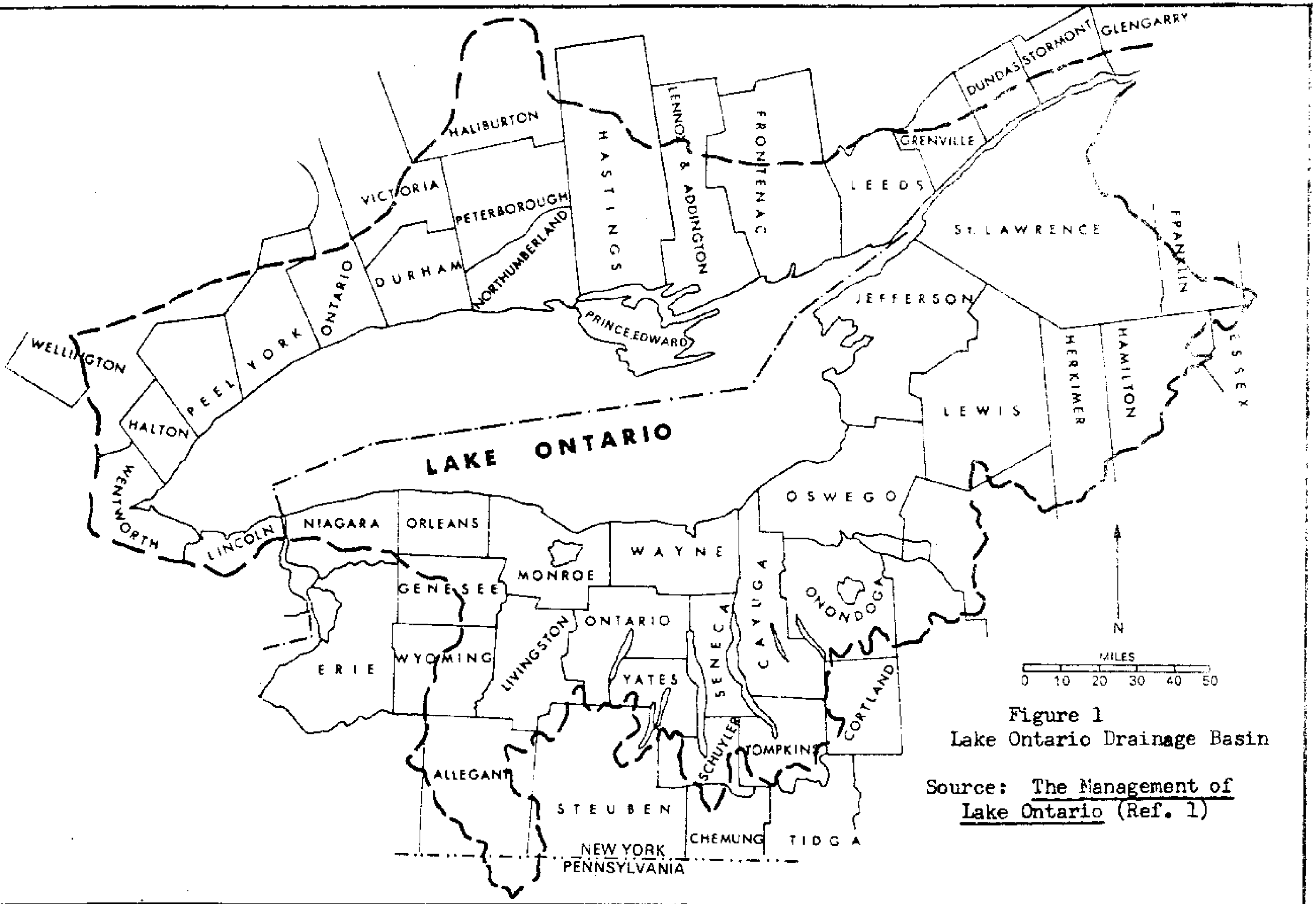

Figure 1
Lake Ontario Drainage Basin

Source: <u>The Management of Lake Ontario</u> (Ref. 1) and marinas. Water-based recreation might be considered to include activities on all of the tributaries as well, but as a first step it would seem prudent to limit the problems as much as possible and include only those activities related to the lake itself.

Air Quality Control Regions

Air quality control is one problem area where considerable attention has been given to defining the problem area geographically. The 1967 amendment to the U.S. Clean Air Act of 1963 directed the Secretary of the Department of Health, Education, and Welfare to "...designate Air Quality Control Regions (throughout the country) based on jurisdictional boundaries, urban-industrial concentration, and other factors, including atmospheric areas, necessary to provide adequate implementation of air quality standards."[4] It would be logical for the management office to use these regions for defining the boundary for air quality.

Problem Areas

In the Lake Ontario Management report, 14 problem areas were identified as being of current importance in the comprehensive management of Lake Ontario. It was recommended that the Experimental Operations Office ultimately include all of these areas in its management functions. It was recognized that the problem areas vary in degree of urgency and also in degree of interest at the international level.

For these reasons, the management function to be carried out varies among the problem areas.

In developing an information system, the information needs must be carefully determined by considering the purposes to be served by the information in order that all necessary information will be obtained, but just as importantly, unnecessary information will not be needlessly collected. Although large gaps exist in certain areas, generally speaking, the amount of information available in the water resource field far exceeds our ability to effectively handle all of it. To avoid unnecessary costs, all information must be collected for a specific, defined purpose.

Before starting to collect data in any field, careful consideration must be given to the management function to be performed, the objectives of the function, the information needed to meet these objectives, and the available sources of the information. In the case studies performed in later chapters, this is done in detail for selected problem areas considered to be of immediate and major interest. An attempt is made below to perform this analysis in a general way for all the problem areas.

Certain of the problem areas within each function are similar in nature and require essentially the same kinds of information or are so interrelated that they should be considered together. Implicit in the objectives for all program areas is the interpretation and dissemination of information to other users outside the office.

Surveillance Function

Municipal and Industrial Water Supply and Agricultural Water Supply (Irrigation). The objectives of the management office are to predict shortages of supply, in quantity or quality, to meet requirements. Information needed includes:

-- Use inventory and projection of requirements, based on population and economic data.

-- Hydrologic data on supplies: runoff, lake volumes, ground water, precipitation and evaporation.

-- Existing water quality and existing and projected water quality requirements.

Water-Based Recreation. The objectives of the management office are to project the demands for recreation and the adequacy of facilities for water-based recreation to handle the demands. The Great Lakes Basin Framework Study identifies ten recreation activities that are water oriented.[5] Land-based water-oriented activities are those that normally occur on the land but are enhanced by water and include beach swimming, picnicking, camping, nature trails, hiking and sight-seeing. Water surface activities are those that are water-dependent, and include boating, water-skiing, canoeing, and sailing. Fishing is not included since it falls in another problem area, fish and wildlife protection. In their study, the degree of visitor participation in each activity was derived from data developed by the Bureau of Outdoor Recreation, population data of the Bureau of Census, and data published in the Outdoor Recreation Resource Review Commission Study Report No. 19.

There are many factors which affect the demand for recreational facilities. These include, but are not limited to, age, population, educational level, income, employment, health, sex ratio, leisure time, and mobility.[6] Projections of any type are necessarily risky and recreation demand is possibily one of the more difficult since little has been done in this field and it involves complex socio-economic factors. An example of one such study is Outdoor Recreation: Projection for 1970-1985 by Kalter and Gosse.[7]

Information on the supply of recreational resources available in the area was obtained largely from the inventory data of the 1964 Nationwide Plan for Outdoor Recreation prepared by the Bureau of Outdoor Recreation, and a 1969 update of this inventory by the states. Information on private recreational enterprises was obtained from inventories by the National Association of Soil and Water Conservation Districts.[8]

Economic Development, Agriculture, and Transportation. These three areas are all essentially concerned with economic development. The objectives of the management office are to monitor activities in this area and to determine their effects on the water and related land resource. This area is considered in more detail in one of the case studies to be developed in a later chapter and so it will not be elaborated on at this point.

It should be pointed out that an economic data base is a foundation for dealing with all of the problem areas. Despite the increased importance of non-economic objectives such as aesthetics and preservation of the environment, water resources management today is still concerned primarily with evaluating the economic costs and benefits concerned with an activity. Even in these areas which cannot be quantified with dollar values, economic data is essential to project demands and to compare cost-effectiveness for different means of achieving specified goals.

Economic data includes such things as:

-- Population: characteristics and trends (income, employment, mobility, etc.)

-- Natural Resources: inventory of land use, water, minerals, fish and wildlife.

-- Man-Made Resources: inventory of land use, industrial and commercial development, public works (transportation, dams, etc.)

-- Structure of Economy: manufacturing, natural resource extraction, services, and agriculture.

-- Social and Cultural: amenities, leisure time, attitudes toward economic development.

Mediation Function

The only problem area to be considered under this function is solid waste disposal. The objectives of the management office are to establish joint standards, regulations, and programs for solid waste disposal. To accomplish these objectives, the most pressing need for information is research on the effects of solid wastes on the total environment and on more satisfactory methods of disposal.

Most solid waste disposal is in sanitary landfills, with an increasing amount of incineration. The problems associated with landfills include the increasing difficulty of obtaining adequate land at a reasonable distance to the large urban areas in order to keep transportation costs acceptable. Many of the larger cities in the United States currently using landfill have only a few years of land capability left and do not know at this time where the next facility will be located. Incineration is more costly than landfill and adds to the air pollution problem.

The obvious effects of solid wastes include the aesthetics problem, air pollution caused by incineration, use of land for landfills, and pollution of streams and groundwaters due to seepage through landfills. Data does not exist to establish relationships between solid wastes and disease.[9] Opposition to landfills near populated areas often lead to alternative locations along shorelines or other undeveloped areas which are unpopulated but hold potential for recreation and other uses. In the Great Lakes area, high quality or potential high quality shorelines of inland lakes, streams, and the Great Lakes are being used too often for disposal of solid wastes.[10]

Besides research needs on effects of disposal, information is needed on the availability of landfill sites, inventory and projection of waste sources and means of disposal, and costs of the different means of disposal.

In the United States, the National Survey of Community Solid Wastes Practices (1967-1970) documented existing operational and fiscal conditions in community solid waste management at one point in time. This was conducted by the Office of Solid Waste Management Programs of the Environmental Protection Agency. Demand for information from this survey indicates the need for a system for continuously collecting and disseminating technical data. The feasibility of establishing a National Solid Waste Data Network is currently being studied. This system would provide design and planning data to persons concerned with solid waste management from residential, commercial and industrial sources.[11]

<u>Control Function</u>

<u>Water Quality</u>. Water quality is one of the most visible problems in the Great Lakes area and could very well be the focal point around which a comprehensive management organization could be developed. This problem area will be elaborated on in one of the case studies to be done in a later chapter. The purpose of the management office is to control the amount of pollutants entering the water and protect its quality for other specific uses. There is a growing concern among society to maintain "clean" water as a desirable goal in itself.

The International Lake Erie and Lake Ontario-Saint Lawrence River Water Pollution Boards, in a 1969 Report to the International Joint Commission, judged the overall quality of water in Lake Ontario to be good, with the state of eutrophication being between oligotrophic and mesotrophic. However, there are local problems in nearshore waters for particular areas.[12]

Some of the types of information needed include:

-- Research on effects of water quality levels on the total environment as a basis for standards.

-- Monitoring of relevant water quality parameters.

-- Assimilative capacities of lakes and streams.

-- Municipal and industrial waste discharge inventory and characterization of wastes.

-- Costs of wastewater treatment to achieve various discharge levels.

-- Social values and goals.

Lake Level Control, Hydropower, Flood Control, and Navigation. These problems areas are all essentially concerned with the control of lake levels to produce the most benefits among the often competing water uses. The primary effects of lake level fluctuations are on shore property, navigation, and hydropower. Within the last several decades, three cycles of serious water level and flow conditions have been experienced on the Great Lakes and their outflow rivers--the low waters of the thirties, and the high water of the early fifties, the extreme low water culminating in 1964 and again, high water levels in the past on Lakes Superior and Erie.[13] These fluctuations had devastating impacts on water users of the Great Lakes Basins. However, they did not stem the expanding use of water for all purposes. This expanded usage led to increased demands by citizens of both Canada and the United States for government regulation of lake levels and produced a climate conducive to cooperative international control. This led to establishment of the International Great Lakes Levels Board in the IJC.

On October 7, 1964, the governments of the United States and Canada requested the IJC to investigate the desirability and feasibility of furthur regulation of lake levels to produce a more beneficial range of stage for improving:

(a) domestic water supply and sanitation,
(b) navigation,
(c) water for power and industry
(d) flood control
(e) agriculture
(f) fish and wildlife
(g) recreation, and
(h) other benefical public purposes.

If the study finds that further regulation is desirable, it is to estimate the costs of the needed control measures and appraise the value of these measures. Also, criteria will be developed to provide for consideration of ecological, sociological and aesthetic aspects.

This assessment involves a colossal amount of data assembly and analysis and could provide one of the most comprehensive information bases for the Experimental Operations

Office in any of the problem areas of concern. Besides basic hydrologic data on lake levels and flows, information on costs of alternative control methods, water withdrawal estimates, effects of variation in lake levels and shore property interests, effects on navigation and recreational boating, and on hydropower generation have been obtained or estimated for present and future conditions.

As a result of problems caused by high lake levels in 1952 and by the imminent power and navigation development in the Saint Lawrence River, it was realized that independent development of basic data was illogical and agreement on hydrologic and hydraulic factors was mandatory. In 1953, the Corps of Engineers and its Canadian Federal Agencies counterparts formed the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data. This Committee advises agencies of the United States and Canada responsible for collecting and compiling such data.

<u>Fish and Wildlife Protection</u>. Fish and wildlife protection is concerned primarily with fish, both commercial and sport, since they are so directly a part of the water environment. The use of water and the related land also has direct impact on waterfowl. Part of the problem is due to the fact that fish and wildlife in general have not had a vocal constituency in the past. There are some exceptions, such as commercial fishermen and sportsmen but these represent limited aspects of the overall problem. This situation is changing due to the increasing social concern over environmental protection.

One of the most positive steps taken toward international cooperation in this area was the establishment of the Great Lakes Fishery Commission by a treaty in 1955. But in the words of Harold C. Frick, "...although the Commission has been an instrument of international cooperation in formulating and pursuing common objectives, such as lamprey control, only a little has been accomplished so far in coordinating and rationalizing the management of the Great Lakes Fisheries."[14]

Some of the types of information needed are:

- -- Inventories: species and populations.
- -- Environmental survey: breeding and nesting grounds, and food supplies.
- -- Levels and projections of demand: hunting and fishing (sports and commercial).
- -- Research on effects of water pollution and other human activities such as filling of marshes.
- -- Social values and goals, on preservation per se.

Air Quality. Air pollution is one of the major undesirable by-products of industrialization and of urbanization. Urbanization appears to be the more important factor since the immediate concern is with local concentrations of air pollutants. The higher quality of life demanded by people also worsens the problem due to more automobiles and more electrical and industrial production. The heavy population and urbanization in certain areas around Lake Ontario have created serious air quality problems.

The three major sources of air pollutants, in order of decreasing importance, are automobiles, industry, and electric power plants. They contribute respectively, 60%, 17%, and 14% to national air pollutant emissions, in terms of weight.[15] The large contribution of the automobile makes regional control programs difficult since pollution control devices usually involve factory installation and would have to be a part of a nation-wide program.

The five most common primary pollutants in tons emitted are carbon monoxide, sulfur oxides, hydrocarbons, nitrogen oxides, and particulates. Reactions in the atmosphere may produce secondary pollutants, commonly known as photochemical smog. Contaminants must often be detected and measured at concentrations in the range of parts per million or less. The analytical chemistry involved produces a real challenge. Much scientific research is needed on the effects of the various pollutants, alone and in combinations, on the various receptors, including not only humans but vegetation, materials, and animals. Research is needed to predict movements of pollutants through the atmosphere. Also, there is a great need for research into means of controlling air pollution through cleaning emissions and basic changes in the processes producing the pollution.

Other basic data needs include:

-- monitoring of ambient air quality and of point sources;

-- an inventory of sources of air born wastes, including amounts and types of wastes, and means of control;

- -- meteorologic data to determine assimilative capacity of the atmosphere and the potential for air pollution episodes;
- -- information on social values and goals associated with "clean" air; and
- -- information on the costs of achieving certain ambient air quality levels.

Summary of Information Needs

The foregoing attempts to indicate informational needs of the Experimental Operations Office have been necessarily general and sketchy due to the scope of the management problem facing the office. To develop an information base in any one problem area would require an expertise in the problem area, familiarity with organizations and agencies in the area that could serve as information sources and information users, and an expertise in the field of information science.

In developing a comprehensive information system, priorities and the relative importance of various types of information should be established. This can be accomplished only by considering the number and importance of the problem areas for which this information is to be used. In table 2, an attempt has been made, first to identify the basic types of information and, secondly, to indicate the

Table 2

Summary of Basic Types of Data and Problem Areas
Where the Data is of Primary Importance

Basic Data	SURVEILLANCE						MEDIA.	CONTROL						
	M & I W.S.	Agric W.S.	W.B. Recreat.	Econ Devel	Agric	Transp	Solid Waste Disp.	Water Qual.	Lake Levels	Hydro-Power	Flood Control	Navig.	Fish & WL Prot.	Air Qual.
Water Quality Data	X	X	X	X				X				X	X	
Hydrologic Data	X	X	X	X			X	X	X	X	X	X	X	
Land Use Data		X	X	X	X		X	X	X		X	X	X	X
Econ. & Demo. Data	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fish & W.L. Data			X					X	X				X	
Air Quality Data				X			X							X
Social & Cultural (values, goals)			X	X			X	X	X				X	X
Research (to est. cause-effect rel.)		X	X	X			X	X					X	X

problem areas where this information has primary importance. Obviously, neither task is clear-cut or definite. However, the objective here is not to develop absolute guidelines but rather to suggest the manner in which the task should be approached. A logical extension would be to further delineate the types of information in more detail. The management function to be performed in each area will serve mainly to determine the detail and amount of information needed but will have little effect on the general types of information needed for each problem.

The priorities assigned to the different kinds of information will depend on the priorities of the problem areas which use the information. These priorities are determined by the management function assigned to each problem area. Those problems requiring control are the highest priority problems, demanding immediate action at the international level. The surveillance function implies a lower priority, with mediation falling between surveillance and control.

Major Information Sources

Some of the major sources of the basic data are listed below. These are only the major sources and the list is far from comprehensive. To develop a comprehensive list of basic data and other information sources would be a major task in developing an information system. The major sources below provide a starting point. These major sources should be aware of other lesser-known sources of local information and could be valuable in helping the information system designer locate additional data sources. Some of the major sources are:

Water Quality Data. United States Environmental Protection Agency, STORET system; New York State Department of Environmental Conservation; United States Geological Survey, Office of Water Data Coordination; and Ontario Ministry of the Environment.

Hydrologic Data. International Joint Commission, Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data. Most data collected by Corps of Engineers, United States Geologic Survey, and Canadian counterparts, but coordinated through the Coordinating Committee.

Land Use Data. New York State Office of Planning Services, Land Use and Natural Resources Inventory operated by Cornell University. Data available in computerized output or map form. The Canada Land Inventory, Department of Forestry and Rural Development.

Economic and Demographic. United States and Canadian Census Bureaus; U.S. Office of Business Economics and the Economic Research Service (together, the OBERS program); New York State Office of Planning Services; Ontario Department of Treasury and Economics; various federal, state, and provincial agencies in particular fields such as agriculture and labor.

Fish and Wildlife Data. Great Lakes Fisheries Commission; U.S. Department of the Interior, Fish and Wildlife

Service and Bureau of Sport Fisheries and Wildlife; Fisheries Research Board of Canada; New York State Department of Environmental Conservation; Ontario Department of Lands and Forests.

Air Quality. United States Environmental Protection Agency, STORET system; New York State Department of Environmental Conservation; Ontario Department of Energy and Resources Management, Air Management Branch; International Joint Commission, Air Pollution Advisory Board.

Social and Cultural. This information will be the most difficult to obtain. Certain types of social and cultural characteristics can be obtained from census material, but this category of information was added separately to include the more abstract type of information concerning social attitudes, values, and goals. Policy statements of legislative acts such as the National Environmental Policy Act are one source of such information. Other sources might include public hearings, reports and brochures of citizen and special interest groups, content analysis of mass media, surveys, and communication with local levels of government which are supposedly "closer" to the people. Such efforts are not currently made on any large scale, systemmatic basis. The difficulty of handling such information, which is difficult if not impossible to quantify, will present a real challenge to an information system and will possibly require some real innovation.

Basic Research. The Great Lakes Study Group is an informal international organization representing United States and Canadian agencies and institutions engaged in basic and applied research and engineering investigations related to the Great Lakes. The United States co-chairman of the Great Lakes Study Group organized a Federal Inter-Agency Committee on Great Lakes Research which keeps Federal agencies at the working level aware of research in the area. The International Association for Great Lakes Research is a formal organization concerned with coordinating all aspects of Great Lakes research and disseminating research information. Membership includes engineers, economists, sociologists, political scientists, legal experts, regional planners, and psychologists, as well as those in the natural sciences.[16]

An important source of information about water resources research in general is the Office of Water Resources Research of the U.S. Department of the Interior. This office publishes annual catalogs and semimonthly journals of abstracts of research projects. Services include a computerized system of abstract retrieval based on key word descriptors, with a number of remote terminals throughout the country.[17]

Perspective on Information Problems for Water Resource Management[18]

This chapter has discussed in a general, theoretical way the needs for information for water resource management.

In order to add a practical perspective, some of the general problems encountered in systematic studies of water problems must be considered.

The importance of water, affecting as it does almost every human activity, has led to systematic studies including most major activities and intellectual disciplines. While the need for comprehensive scope and global perspective is real, these qualities can "lead to formidable practical problems such as incomplete or grossly inadequate data to support such ambitious analyses, insufficient sensitivity to interactions among factors, and uncritical extrapolations of purely fortuitous historical trends into the nebulous future." The most ambitious studies are nearly indistinguishable from master plans for national economic growth.[19]

An example of the problems encountered is provided by the national assessments of the nation's water resources by the Water Resources Council. The first assessment has been completed and published and plans are underway for the second assessment.[20] The first assessment has been criticized for principal deficiencies of "insufficient data (especially on water quality and water use), inadequate analysis of interactions among factors (e.g. regional ambitions for water-related economic growth as opposed to balanced national economic growth or national economic efficiency), marked oversimplification of dynamic factors (such as population growth, demographic shifts, the direction and pace of technological development), and insensitive techniques (based on simple extrapolations of recent historical trends) for projecting future water requirements."[21]

Plans were begun immediately for the second assessment. The initial plans were very comprehensive and called for two layers of analysis: a hydrologic layer and a superimposed economic-demographic layer. The hydrologic layer called for a complete quantity-quality model of all the nation's water. A number of hydrologists have inquired where all the data for this expensive hydrologic model would come from. The quality of the nation's waters is not well documented--there are great gaps in the data base and much of the available data (such as BOD measurements) are notoriously erratic. Water quantity data is more complete but not adequate for the model. Especially in the arid West, data on groundwater, an important source, is not adequate.

The economic-demographic analysis also presents problems. The data was to be supplied by the Office of Business Economics (OBE) and the Economic Research Service (ERS), which together are called the OBERS system, an important data source for water management activities. The problems with this data are familiar ones--inadequate data, controversial (many would say "mistaken") methods of analysis, and insufficient sensitivity to the dynamic factors involved. Much of the difficulty lies in projection of demographic data. Population growth and distribution are sensitive to a variety of governmental policies, as well as technological and social developments. The lack of explicit and consistent governmental policies in such areas as population growth and distribution, economic growth, and agricultural production complicates the problem. To help solve these problems, many models and studies produce a range of answers based on varying assumptions of the complex policy and technological factors.

The complex problems just described imply that information needs are not rigid and well defined. The information system must be flexible enough to adjust to the needs of new methods and techniques as these are developed. Also, the system can contribute to the decision-making process by pointing out the limitations in quantity and quality of information and thus affect the choice of models by which decisions are made. The information system should maintain an awareness of the kinds of information and methods of use which are ideally desirable but the actual operation must be tempered by the practical limitations of availability and use.

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Chapter 2

INFORMATION AND INFORMATION SYSTEMS

Definition of Information

The state of the art in contemporary literature about information is such that at this time, an encompassing definition of information does not exist. However, a workable definition is provided by Rosove who states that "information is an aggregate of facts so organized or a datum so utilized as to be knowledge or intelligence. Information is meaningful data, whereas data, as such, have no intrinsic meaning or significance."[1]

Yovits and Ernst state that "the general definition of information proposed is 'Information is data of value in decision-making'. Data on the other hand, are transformations of observable action. Data are measurements that have been made on physical quantities. It is important to note, as has already been stressed, that the distinction between information, data, and observables is inherently involved in the decision-making process and therefore, must involve a transformation into observable actions"[2]

The important concept of information is that it is data which is used in a meaningful way for some specified human purpose or objective. The aquisition and handling of data involves effort and thus cost so any data aquired must be done so with an objective in mind. Before use, this data must be processed into information. This distinction between data and information emphasizes an important aspect of information which will be stressed later in connection with information systems. This aspect is that information is oriented toward the use of the data rather than the mechanics of data collection and storage as such.

The Role of Information

The twentieth century is characterized by many distinctive features but it seems likely to earn special designation for the importance of information in virtually every important aspect of society. Many observers, taking a long view, regard the modern epoch as the Age of Information.[3]

The reason information plays such a vital role is because of the rapidly changing nature of our society. The exponential growth of technology is self evident. In addition to this, or possibly because of it, all aspects of our society, including political and social values, are also in a state of rapid flux. A changing society must put a relatively strong accent on information and knowledge to attempt to offset the unfamiliarity and uncertainty that change implies.[4] Traditional ways (beliefs, institutions, procedures, and attitudes) may be adequate for dealing with the existent and known that characterize a stable society, but a changing society must anticipate changes based on available information.

In addition to being needed in a changing society, information has helped shape it. The information revolution, as a by-product of the industrial revolution, has called the attention of decision-makers to many problems such as the deprivations of certain groups, by accumulating descriptions and analyses of their plight. Information has influenced public policy making in other ways. In the federal government, there has been a significant shift, since about 1900, in leadership from the legislative to the executive branch. One of the factors that made this shift possible is the executive's advantage in information resources through executive agencies. The executive branch now largely initiates programs and Congress ratifies, delays, amends, or vetoes.[5]

There are three consequences that result from the changing nature of society, with respect to information and knowledge.[6] First, existing knowledge has to be examined for its meaning in the context of new questions. This is the synthetic aspect of knowledge. Secondly, the new questions that arise will not necessarily respect the traditional lines of established disciplines. Many of the problems we face today require interdisciplinary approaches and thus emphasize the exchange of information among all disciplines. In the water resources field, we can no longer limit ourselves to the economic concern of the traditional program purposes such as flood control and navigation. We cannot avoid becoming involved in political problems and administrative problems of management institutions and social values concerning the goals of water resources management. The third consequence is the need for institutionalization of the knowledge transfer function to insure the most effective use of knowledge to solve our social problems. This consequence addresses itself to the problem of information systems, to provide for effective use of information.

A changing society emphasizes the importance of decision-making relative to other social functions such as production.[7] The process of decision-making implies a situation which in some way is new and the consequences of alternative action unknown. If the situation is commonplace, procedures and routines will have been developed to cope with it in a manner which does not involve decision-making in the generally accepted meaning of the term. The action to be taken will follow directly from the statement of the problem, based on the known effects of the action.

The nature of an "affluent society" also has implications on the role of information. In a production oriented society, according to economic theory, resources will be allocated most efficiently by the free market, guided by Adam Smith's "invisible hand". But in a society which has achieved this affluence, there is increasing demand for services to improve the quality of life beyond material satisfaction. As the desired quality of life increases, the demanded services fall more and more in the realm of public goods. This is evidenced today in water resources by the increasing demand for clean water as a goal in itself, not just for economic reasons, for protecting and preserving the environment, and for recreational facilities. When government provision and control of these services is necessary, the guiding "hand" is all too visible and must be based on adequate scientific and social knowledge.

Information is power. This is well understood not only by governments which often distort or suppress information for political control, but also by private corporations who jealously guard trade secrets and information, and even by government agencies who have been known to become involved in "bureaucratic wrangles". Lasswell's generalization rates thoughtful consideration: "If our knowledge of past politics is a valid basis for inference, it indicates that whoever controls information (enlightenment) is likely to control public order."[8]

Information Systems

An information system, as defined by Rosove, is "the formal or rationally planned means whereby (users) receive and transmit information."[9] It is more than a data processing system, although this may be an important aspect of an information system. But information specialists are often concerned more with hardware systems than they are with actually capturing and providing data really needed and wanted.[10]

The main concept of an information system is that it must be user oriented. In the area of urban planning, there has been considerable experience with data banks, most of which has been disappointing.[11] Data were included in the system because they were available, because they were presently used, because people said they needed them, or all of these. The key criteria--organizational decision and operations requirements and their information needs--simply were not included. The failure to define the data base adequately led to the creation of a data wasteland which was not used.

This fault seems to exist in many, if not most, informations systems. Too little attention has been given to the need to provide information in those forms and formats in which it is needed by its users.

The Organization for Economic Cooperation and Development (OECD) has developed a report on <u>Information for a Changing Society</u> which addresses the problem of information use.[12] Certain themes run throughout this report: (i) various types of information are needed for decision-makers at all levels throughout society; (ii) information must be appropriately packaged and interpreted for each specific community of users; and (iii) quality of information--that is, its reliability and credibility--is more important than access to great masses of raw data.[13]

There may appear to be nothing profound or new about these ideas. But this approach does differ greatly from the usual approach to information systems, where the emphasis is primarily on accessibility to great masses of information and on the technology of manipulating such masses, with little or no thought given to the quality of the data or its evaluation and interpretation of different user communities.[14]

This emphasis on users of the information brings out an important organizational point. An organization is composed of different users of information. All aspects of management, from high-level policy decisions down to routine day-to-day operation, depend on information flows. The information system is analogous to the central nervous system in an organism that coordinates and controls the various components and forms a whole. The information system is an integral part of all the management activities and cannot be considered as a separate organizational unit which only provides input. The design of the system cannot be relegated to a certain group such as a data processing section or to information specialist consultants but must be an integral part of organizational design, involving the highest levels of management and planning. The information system, being such an integral part of the organization, may very well be one of the most important determinants of the organizational structure and functioning. Social institutions and organizations receive, process, and disseminate information much as the human brain or the computer, and may be regarded as information-processing systems, at least with respect to some crucial functions. The study of these entities as such has led to new understanding of their structures.[15]

One aspect of organizations which can be greatly affected by the information system is the degree to which control is centralized. In the past, as organizations have grown large, the trend has been toward decentralization. However, this has been a mixed blessing and has led to duplication of jobs and functions and the establishment of local goals that may conflict with the organization as a whole. Problems of information have been created by its dispersion in many separate files and the delay in its processing and transmittal to the higher levels of decision-makers. A centralized computer information system can correct many of these problems. The centralization of information may or may not lead to centralization of control. This is a moot question; the important thing is that it can streamline operations and give the organization a new coherence and sense of unity.[16]

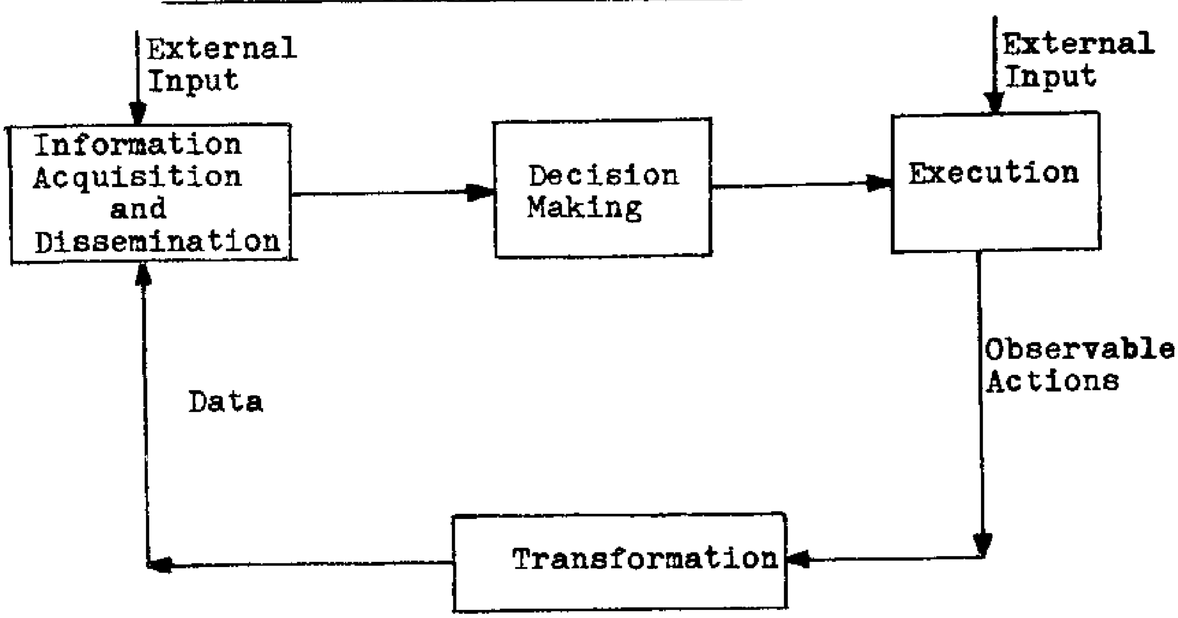
Information systems can be conveniently broken down into two aspects--the "hardware" and the "software". "Software" is a term about which there is no consensus on meaning. It is often used to refer exclusively to standard computer programs provided by computer manufactures. A more general definition would be everything about the system which is not "hardware". This report will be concerned with the "software" of information systems, in this more general context. The focus will be on information needed, sources of this information, identifying the users of the information, and developing an analytical framework for its use.

Generalized Information System Model

Yovits and Ernst have proposed a model of information systems which has general applicability.[17] They suggest that this model applies to any situation involving the flow of information, from the management of a complex organization to the simple switching on or off of a thermostat-furnace system. The four essential functions include: information acquisition and dissemination (IAD), decision-making (DM), execution (E), and transformation (T). The system is shown in figure 2. The model applies even when decisions are irrational, or without logical or analytical bases.

Figure 2

Generalized Information System Model



The DM function is the key consideration in the entire information flow process. It may be an individual or an organization, a man-machine, or machine system. The DM is responsible for generation of observable actions. Without the generation of observable action, the system has little or no physical meaning, and would have little point for existence. The observable actions are measurable, physical quantities other than information.

The feedback loop is a significant point. It always exist but often is not explicit and is not adequately considered in most presently designed "information systems". The closed loop is accomplished by the transformation of observable actions into data by measuring devices. It is important to note that the observable actions are physical in nature but are not information and cannot be utilized for decision-making without first being transformed into information. This distinction may be obvious but it is not trivial and is important to the structure.

Information supplied to the DM from the IAD is of three basic types. There is information from the feedback loop obtained by the transformation of observables into information. There is also information from the external environment over which the decision-maker has no control. Thirdly, there is fundamental information that the decision-maker may use such as tables, mathematical and physical constants, and lawful relations.

The DM function operates by the use of a predictive model which it believes will transform the information received into the appropriate observable action. The predictive model may be accurate or incorrect, logical or illogical. Part of the purpose of the feedback is to determine the accuracy of its model. The DM may alter its actions based on the predictive model as further information becomes available from external sources or from the transformation of resulting observable action. Also, the DM may develop new predictive models as further information becomes available.

The DM disseminates courses of action (results of decisions) communicated to the E function which transforms decisions into observable action. Perturbations from the external environment enter into the execution function and are mainly responsible for the inherent uncertainty of transforming information into action.

The IAD function, or more accurately, information acquisition, storage, and dissemination, is frequently referred to as an information system. However, this is only a component of the total closed system as shown in figure 2. The IAD collects the three basic types of information supplied to the DM as discussed previously. It stores a data base and, moreover, operates on the data and stores it in different ways. Some of the typical and most important operations performed on the data include:

a. restructuring
b. filtering or weighting
c. selection and rejection
d. analyzing
e. sequencing or ordering

f. prediction

g. display

Finally, the IAD disseminates data for use by the decision-maker. This dissemination may be passive or there may be active interaction between the DM and the IAD.

Developing an Information System

In the development of a large scale information system, there are five sequential stages or phases which must be considered.[18] These stages are:

Phase I - Requirements

Phase II - Design

Phase III - Production

Phase IV - Installation

Phase V - Operations

This report will be concerned primarily with Phases I and II--requirements and design, since these are concerned primarily with "software".

Requirements Phase

The requirements phase is concerned with determining what the system is to do, as opposed to the design phase which is concerned with how it is to do it.

In determining what a system is to do, the following types of questions arise: "Why is the system needed? What is its purpose or purposes? What is it expected to do? What problems is it supposed to solve? Who are the system users? What are their objectives? What preliminary qualitative and quantitative requirements for the system can be inferred from the users' objectives?"[19]

The primary objective of the requirements phase is to identify the users and their objectives and determine how the information system can help them meet these objectives. This sets the goals to be accomplished by the design phase.

Design Phase

The major objectives of an information system are to bring "relevant data in usable form to the right user at the right time."[20] In carrying out the design phase, the elements of the system must be identified and characterized. The relationships between these elements are as important as the elements themselves and must be considered in the system design.

Some of the important elements of an information system are as follows:[21]

- Data
- Personnel
- Display
- Equipment (i.e., input, output, transmission, processing, and storage)
- Retrieval
- Programming

Data. Data is obviously the most basic consideration of an information system. There are several important attributes of data to be considered, including its relevance for a particular task or tasks, degree of specificity (i.e., amount of aggregation), sources, destinations, and the amount of processing. The processing of data may involve simple logical examination, such as sorting and validating, some type of mathematical analysis, or simply passing it through with little change.

Personnel. People are an integral part of an information system. They not only use outputs from the system but are components themselves and often supply information input to the system. Human actions which are a part of an information system include--monitoring, comparing, assessing, predicting, deciding, commanding, informing, requesting, and complying. These actions form the operating procedures and range from the specification of the format of any communication to the operation of equipment.

Display. All parts of an information system involve output, but display is usually interpreted as the communication of data to people by machines. The display element is the major interface between the user and the rest of the system.

Some of the important aspects of display are:

(1) Degree of aggregation of data. This relates to the degree of specificity of the data. Aggregation is the accumulation of data items of the same level of specificity. Generally, the higher-echelon users will require more aggregation. Decision-making and planning at higher levels generally cover broad areas of interest and involve larger

amounts of information which must be summarized to avoid data "overload".

(2) Coding. This attribute of display is concerned with the particular form in which data is to be presented to people. The spectrum of modality used varies from visual at one end, which includes such things as graphs or pictoral forms (maps), to straight English narrative at the other end. Tabular formats would fall in between these two.

Much data can be coded in several different forms. Depending on the use of the data, more information can be derived from the data in one form than in another. Coding is an important consideration not only to the user of the data but also to the "hardware" designers since the characteristics will be partly determined by the display requirements.

(3) Initiation or Access. Some mechanism or criteria must be devised to cause the display of data to the right user at the right time. Much information will be called for at irregular or infrequent intervals and may be displayed only when specifically requested. On the other hand, certain types of information may be required at regular intervals in an unvarying format. An automatic control mechanism can be devised which will produce the required display of data addressed to the specific users automatically. In between these two extremes may lie situations that require a certain display of information that can be triggered whenever a cueing event occurs. For example, in a water quality monitoring program, if a parameter being stored drops below the minimum desired

level, an alarm might be produced, possibly along with information on other factors known to affect this parameter.

Equipment. Since this report is concerned primarily with the "software" aspects of information systems, little will be said about system equipment. In almost any large scale system, the digital computer is the central part of the system. An information system, as defined above, does not require machinery such as a computer to be classified as an information system. But from a practical point of view, the huge amounts of data generated and required in any field as broad as water resources management requires the storage capacity and the speed of operation which are the two outstanding features of the digital computer. Of equal importance is the capability of the computer to be programmed to perform routine evaluation and analyses of the data.

The equipment element can be regarded as two major units--the computer unit and the communication unit. The communication unit includes all hardware for sensing, inputting, outputting, and actual data transmission. The advent of remote terminals has revolutionized communication, making access for input and output to a central computer available over distances of hundreds or thousands of miles, instantly, as easily as dialing a long distance telephone call. In water quality monitoring, data can be collected in the field by automatic monitors, transmitted to a central station, coded, verified, stored, processed, and displayed, all automatically, without human intervention.[22]

Retrieval. Retrieval of information is a critical element of the information system. The technical aspects of computer retrieval are well studied and will not be covered here. Retrieval is basically just another part of programming which is discussed below and retrieval has been discussed somewhat in connection with other elements discussed above. One aspect that should be mentioned is that an indexing scheme is needed so that a human operator can readily perceive the structure and contents of the system data.

Programming. Programming is simply the means by which man communicates directly with the computer. While this is a part of the "software" aspects of information systems, it is of a technical nature and has received a great deal of attention. The state of the art has been raised to a high level by specialists in the field. In keeping with the overall theme of this report it will simply be stated that this programming must be performed with the user in mind and close cooperation between programmers and users must be maintained. The goals and objectives must be determined by the information user, with the programmer being responsible for determining and pointing out the capabilities and limitations of his art.

Other Aspects of Information Systems

The preceeding discussion in this chapter might seem to give the impression that all of the problems of decision-making would disappear if only an information system centered around a computerized data processing center existed to supply decision-makers with adequate information. While this report is definitely concerned with emphasizing the importance of information in decision-making, it must be recognized that information and knowledge are not synonomous. Rather than over-emphasize the role of information, a good information system must recognize its own limitations and contribute what it can in other aspects of the decision-making process.

Oettinger has attempted to explain the role of computers in decision-making by categorizing the tasks performed by decision-makers.[23] Descriptions of these categories are somewhat involved and are not necessary for this discussion. For these different tasks, the usefulness of the computer varies from unquestionable predominance to marginal. For at least one category, he states that "the necessary things get done simply because the official system is usually by-passed, machines and all." There have been a number of observations made on this problem including Dearden's that "many managers today are making decisions using less than one-tenth of the information that would be available to them without a computer."[24] Vannevar Bush has stated that "The investigator is staggered by....findings and conclusions.... many of which he cannot find time to grasp, much less to remember", and he did not say staggered by the papers and the reports....most of which he cannot find.[25] Perhaps the problem is best summarized by Tukey who states that "The unhandleable part (of information)--in people's minds, rough notes and conversation--which is often of greater importance, still escapes all tools of information pursuit except human memory."[26]

To address this problem, Oettinger suggests that a fresh approach is needed in using computers for such unhandleable information as the understanding and judgement of individuals. One such use of the computer might be to maintain detailed, accurate, and up-to-date organization charts to enable the sources of such information (that is individuals) to be easily found.

Handling non-quantifiable information such as narrative statements and social ideas is another challenge for an information system. Systems are in operation for written documents using abstracts and search routines based on key word descriptors.[27] An example of a proposed information system for other types of non-quantifiable information is An Information System for Improving the Evaluation of Non-Marketed Outputs.[28] While concentrating on evaluating environmental impacts, it provides a framework for evaluating other noncommensurate benefits. Basically, the system consists of two major information displays in the form of matrices with accompanying narratives. The first matrix is the Environmental Impact matrix which relates classes of project effects to a series of alternative designs. The cells of the matrix will consist of a positive or negative sign or a zero, to indicate positive, negative, or neutral effect. The Public-Participation Display relates project impacts to user groups. The cells of this matrix will also consist of a positive or negative sign or a zero, to indicate the evaluation of each user group.

This example is mentioned to emphasize the fact that an information system is not merely a computerized data bank. This example is a rather simple but innovative way of handling, summarizing, and displaying certain types of non-quantifiable information. As such, it fits the earlier definition of an information system as a formal or rationally planned means whereby (users) receive and transmit information. The design and operation of information systems would appear to demand more innovative ideas and less technical complexity.

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Chapter 3

AN ANALYTICAL FRAMEWORK FOR AN INFORMATION SYSTEM

Purpose of the Framework

A number of important points and considerations about information and information systems have been stated in the previous chapters. The purpose of this chapter is to formally recognize these considerations and develop a framework to provide a logical, orderly manner in which to approach the problems of defining information needs and uses and developing a system to satisfy them.

The important consideration in developing an information system is that it must be designed for the users. This may seem to be so obvious that it is almost trivial. But as stated before, there is often a tendency to lose sight of this point when system designers become engrossed in the technical complexities of computer hardware and techniques for storage and retrieval of large amounts of data. A related consideration which is not so obvious is that the information system may itself change the information needs of the users. The capability of the computer to handle vast amounts of data may allow the use of new models and problem solving techniques which were not previously feasible. These new techniques may require new types of data or much more detailed data than previously used.

The following steps are proposed as the basis of the framework and are discussed in the following sections:

(1) Define the problem area (e.g. water quality control, navigation).

(2) Determine the objectives of the Experimental Operations Office in the particular problem area.

(3) Determine the uses of the information (including users outside the office).

(4) Identify types and formats of information needed by users.

(5) Identify sources of information.

(6) Determine implications of the above steps for the information system.

Definition of the Problem

The ultimate goal of any governmental organization is to satisfy a need of society to the maximum extent possible, given the limitation imposed by other conflicting needs. The conflict between social needs may be direct, as between the use of water for water supply and the use for sewage disposal. Or, on the other hand, the conflict may exist at a more abstract level such as the conflict between the need for strong government control to achieve certain goals, as opposed to the needs of society for individual freedom and self-determination. At any rate, this conflict is what gives rise to social problems including those related to water resource management.

In defining specific problem areas, the process must begin by first considering some of the basic goals of society; then deducing more specific objectives of water resources management; and finally determining specific objectives for each of the problem areas of water resources management. Identification of the problems in a general context must be based on the desires of the people, as expressed directly by them, or through their elected representatives. The definition of the problem should include the limitations imposed on control agencies by competing uses of the water, limitations in power due to conflicting social goals, and competition for financial resources due to other social programs.

The role of the water resources planner is twofold--first, he must take the expressed desires of the people and translate them into specific concerns; secondly, by informing the public of existing and potential situations, he plays an important role in defining and making the public aware of real and potential problems. The current concern over water pollution, for example, is due largely to the changing values of society. But just as importantly, water resources agencies have stimulated interest by creating an awareness of the seriousness of the problem through the collection and dissemination of information on water quality conditions and effects.

Defining the geographical boundaries of the problem has been discussed in the previous chapter. Basically, the concern is in having a boundary large enough to encompass as many of the externalities as is practical, while still keeping the area limited enough so the administrative and political aspects do not become impractical. Considerable judgement is usually involved and the particular boundaries of concern may be established somewhat arbitrarily.

Objectives of the Experimental Operations Office

The objectives of the office in each problem area have been discussed previously and can be broadly categorized by the management functions. The three management functions suggested by the Cornell study group were surveillance, mediation, and control.[1] The criteria used to determine the function for each problem area include the degree of urgency of the problem and the degree of interest at the international level.

The management functions imply a priority of attention and thus of information needs. The effect on information needs will be primarily in terms of the detail and urgency of information needed rather than of type. The control function is concerned with those problems which are of greatest urgency at the international level. To carry out the control function will require the most detailed information identifying the problem in very specific geographical and functional terms, as well as detailed information about the costs and effects of alternative means of control. The surveillance function, on the other hand, is concerned with identifying existing or potential long range problems in broad terms and requires less detailed information. Some of these problems may be urgent at a lower level and the control function will be exercised by agencies below the international level.

Besides internal management objectives, the office has the more general objectives of coordinating planning and management by other agencies and also involving all interested participants in the policy and decision-making processes, especially the general public. These objectives have a bearing on the information system by emphasizing the need for lines of communication to collect and disseminate information to all interested participants.

Uses of the Information

One of the main purposes of the information system of the Experimental Operations Office is to coordinate information exchange among all interested parties, so the users will not be confined to those within the office. Identifying all of the specific users of water resource information would be a complex but needed function of the information system. An attempt has been made here to categorize the users by the primary use for which they need information. This suggested categorization includes:

(1) Research. The purpose of research is to gain an understanding of often complex physical and social phenomena. Only by this understanding can existing and potential problems be fully identified and defined. By studying correlations among different parameters, relationships and models of the phenomena can be developed. Simulation models are necessary tools of decision-makers and provide the means to evaluate the effects of projected, natural, and man-made activities.

(2) Regulation and Operations. This task is interpreted to mean the short range day-to-day activities of water resource agencies such as enforcement of water quality standards and operation of control works such as treatment plants or flow augmentation facilities. This would also include any monitoring activities to obtain basic physical and biological data.

(3) Planning. Planning is a long range activity and is concerned with identifying problems and developing programs to cope with these problems. This function might be considered a coordination of the other functions, as well as a separate function itself. Using the objectives and guidelines established by policy-making, planning develops specific programs for managing problems. These programs ultimately result in regulation and operation by some agency. In developing these programs, the planning function uses results from the research function and guides the research into the areas of greatest need.

(4) Policy-Making. The task of policy-making is to determine the goals and objectives of water resource management in broad terms. In a democracy such as ours, the ultimate responsibility for setting policies rests with the public and is expressed directly by the people as well as through their elected representatives. The legislation establishing any public agency will set the policy goals, often in broad terms, and the policy-makers in the agency then interpret these goals in terms of more specific objectives. However, this interpretation must be accomplished with input from the public and from other public agencies. The value of an effective public participation program has been recognized only relatively recently but is becoming a well established idea in principle.

The Canada-United States University Seminar on the management of the Eastern Great Lakes has examined a number of alternative institutional arrangements for integrated management of the water and land resources. An arrangement has yet to be agreed upon but the alternative proposals all have certain provisions in common. These provisions are:

-- Joint agency

-- Initiatory authority under guidelines

-- Joint Budget

-- Program responsiveness

-- Joint planning

-- Joint information collection and analysis

-- Public reporting

Consideration of some of these characteristics can illustrate some of the ways in which information would be used within the Experimental Operations Office itself. Joint information collection and analysis is of course discussed throughout this report. Public reporting has been discussed elsewhere.

Initiatory authority under guidelines. This authority stresses the function of identifying problems of concern to the people in the region and initiating programs to solve these problems. This is an important change from the present situation where the International Joint Commission must wait for a reference from one or both countries before acting on a problem. But this authority carries with it the responsibility of collecting and interpreting information from the public to identify social issues. This task has not been accepted as a normal role of state governments as much as it has been by the federal government and hopefully will be by the international management agency.[2] Information derived from the surveillance of different aspects of water and water use must be interpreted and disseminated to identify potential problems and to point out early danger signs.

Program responsiveness. Once a program has been established, it must be responsive to changing conditions and unexpected circumstances. Information on all aspects of the effectiveness of the program must be collected and interpreted. This illustrates the importance of the feedback mechanism in the information system model described in

Chapter 2. In order for the program to respond to changing or unexpected conditions, there must be a continual measurement of its effectiveness, by whatever criteria are applicable. The ultimate criterion is the ability of the program to solve or alleviate problems of concern to people in the region. Information must be obtained from the public to determine any changes in social objectives and to measure the effectiveness of the program in meeting these objectives.

If the objectives of the program do not change, the effectiveness will depend on how closely the physical, social, and economic models represent reality. Using the terminology of the information system model, the observable actions produced by the decision-makers must be transformed into data, fed back into the system along with perturbations from the external environment, and used to adjust or revise the models used by the decision-makers.

Joint planning. The role of planning is to translate purpose to action. Ideally, the characteristics of the planning process include (a) the coordinated collection of all possible facts on the problem or issues; (b) the analysis of these facts in an objective setting; (c) the development of alternative solutions as guides to decision-making bodies in determining courses of action; and (d) the appraisal of results in implementing the plan and the initiation of review, modification, and updating of the plan to meet future developments.[3]

The first two steps have obvious importance to the information system; in fact, they are two of the more important functions of the system--collection of facts and the analysis and interpretation of these facts. The third step involves the actual use of the information to develop courses of action to solve problems. Basically the planning function uses information gained from measurement of past and present conditions with predictive models to project future conditions under different courses of action. The last step is related to program effectiveness, to provide a basis for response. Use of information for this purpose has been previously discussed.

Types and Formats of Information

The types of information needed for each of the problem areas will have to be determined, based on a knowledge of the physical, social, and economic phenomena involved. Some of the basic formats in which the information may be obtained and used are listed below. This listing represents a heirarchy of synthesis and aggregation. At each successive level, detail is sacrificed over the preceding level in order to gain an ability to see a larger picture. This loss of data detail can result in a gain in information content, due to an increase in the ability of the user to use the results. A possible categorization of formats might include:

(1) Basic Data. Tables of basic data output generally are of limited usefulness, except as input to further interpretation. The major problems of water resource management involve complex physical, social, and economic phenomena and thus large quantities of data. Some degree of aggregation and interpretation is usually necessary before this data is meaningful for decision-making and planning. For certain situations such as the daily operation of a treatment plant, the scope of concern and the time period may be small enough that the basic data can be used to direct control operations. Also, examination of basic data may be useful to spot possible errors and unusual trends and patterns that might not be revealed in the usual evaluation procedures.

(2) Numerical and Graphical Analyses. This would include standard numerical characterizations such as mathematical and statistical evaluation of means, maximums, minimums, etc. This might also include simple graphing and mapping of the basic data to show time or geographical distributions. As the number of basic data items becomes larger, such interpretation becomes necessary to allow the data to be comprehended. This is a first step toward converting the data into information.

(3) Relationships of Variables. As the phenomena being studied become more complex, more variables are introduced. The empirical relationships between variables must be determined to develop models to simulate responses of

the physical, social, or economic system being studied. As discussed in Chapter 2, the models used by the decision-making function are an important part of any information system. Reducing a large number of observations into one or a few mathematical relationships represents a high degree of aggregation and possibly considerable judgement since the relationship will not usually describe all of the events accurately. However, the form of the information is very useful for many purposes such as estimating the effects of natural or man-made activities.

(4) Non-Quantifiable. To the technically oriented, mathematical descriptions are the most effective means of transferring information, when such means are applicable. However, all information is not quantifiable and there are many non-technical people directly involved in water resources planning and policy making. Those involved at the higher levels of decision-making do not have the time or often the ability to pour over detailed statistics, graphs, etc., and often must rely on narrative or oral reports of subordinates, possibly backed up by simple graphs and statistics. This format can represent the highest aggregation of information but may be less precise and objective than the other formats. Even for the technical person, engineering reports do not consist only of tables of numbers or graphs, but are largely narrative. This format of information is the most difficult to handle in a computer-oriented information system since the computer is geared to numerical data processing.

Sources of Information

This is closely related to the task of identifying the users. In many cases the users will also be sources and vice versa. This two-way relationship between the office and the user/source should be fostered to provide incentives for the free exchange of information. Practically all public agencies at least give lip-service to cooperation with other agencies. But to be realistic, these agencies should not be expected to devote their limited resources to providing information to the office unless they expect to gain by their cooperation by receiving needed information in return.

As stated earlier, searching out all of the potential users/sources will be a difficult but needed task. The dynamic nature of our society in general and of water resource problems in particular, stresses the need for establishing lines of communication with users/sources to allow a contin ous exchange of up-to-date information. One of the real problems of information exchange today is the different formats in which information is used by the different users. In areas directly related to water resources, the Experimental Operations Office could have as one of its major tasks, the standardization of information formats to facilitate information exchange. In other areas, such as social and economic information, the office should add its voice to the others calling for standardizing information, and use what influence it has to accomplish this.

Implications for the Information System

Based on the above considerations, certain implications for the information system can be drawn. As a first step in doing this, the users of information should be related to the formats of information. This is done in table 3 which shows the primary formats of information input and output for each of the basic users.

Table 3

Relationships of Uses and Formats of Information

Uses	Primary Formats	
	Output from System to Use	Input from Use to System
Research	Basic and analyzed data	Relationships and models
Regulations and Operations	All formats (primarily basic and interpreted data)	Activity (transformed to basic data)
Planning	Relationships and models; interpreted data; narrative reports	Reports of proposed action
Policy Making	Narrative statements and reports; highly interpreted data	Narrative reports and statements (guides for plan.)

One of the first implications regarding the nature of the information system can be drawn from the above table by considering the primary functions of the office, as related to the "uses". The first two formats of information discussed above, that is basic data and basic analysis involve data and procedures of a "programmed" nature. That is, the procedures for collection and handling are of a routine, repetitive nature. This feature plus the fact that the information is generally of a quantitative, numerical nature implies that this type of information lends itself readily to the popular "data bank" approach which emphasizes computerized techniques for collection, storage, and retrieval of large quantities of data.

On the other hand, the last two information formats, relationships of variables and non-quantifiable, are generally of a "non-programmed" nature. Such information is not produced on a routine basis but is largely the result of research efforts, planning studies, etc., and is produced on an ad hoc basis as needs are recognized and resources are obtained. The real function of an information system for these kinds of information is establishing lines of communication with groups producing such information and maintaining an awareness of what information is being constantly produced. The computer can still be a valuable tool for dealing with such information, but its role is not as clearly-defined or all-important as with routine numerical data. An example of a computerized system for dealing with such information is the Water Resources Scientific Information Exchange program of the United States Department of the Interior. This system stores abstracts of scientific literature, research reports, and engineering reports related to water resources. Key words or descriptors related to a particular user's interest are entered in the computer and a search routine produces a printout of references with abstracts which contain these descriptors. The difficulty of producing a relevant list of abstracts while at the same time not overwhelming the user with irrelevant material can be easily perceived. Possibly of more importance is the problem of obtaining all up-to-date information from the innumerable possible sources of such information. The interdisciplinary nature of water resources planning requires information from a wide range of disciplines in the social and physical sciences and complicates the problem of maintaining up-to-date information from all possible sources.

The broad scope of problems facing the Experimental Operations Office will force the office to be concerned primarily with higher level planning and policy making. Even for the problem areas falling under the control function, much of the more detailed planning and operations will undoubtedly be delegated out to other agencies at the national, state, or local level. Therefore, according to table 3, the information system will involve a heavy emphasis on the "un-programmed" types of information. The implication of this is that the system must not be approached with the emphasis on establishing a large data bank of raw data but rather with the emphasis on the software aspects of information use. These aspects include the problems of establishing procedures for handling non-quantifiable information; establishing lines of communication to obtain and disseminate non-routinely produced information from diverse sources; an awareness of new techniques and methodologies requiring and resulting from new kinds of information; the flexibility to deal with new kinds of information; and close coordination with the users and producers of new information.

Obtaining information from the public and disseminating information to the public to induce public participation will be a vital task of the management organization. It could also be one of the more challenging tasks of the information system because of the diversity of interested participants and the different kinds of information transmitted. Some of the mechanisms for disseminating information might include public notices, newsletters, news media, a speakers bureau, or published agency reports. Techniques for information collection include surveys by polling and interviewing, public hearings, public inquiries, and special task forces. Dialogue or two-way communication can include informal contacts, workshops, group advocates, advisory committees, formal meetings, and informal meetings.[4]

A successful public participation program will require as a starting base, a thorough identification of potential participants; careful selection of the types and formats of information required by the different types of participants from the office, and by the office from the participants; and selection of the proper mechanism for information transmittal. The availability of additional information such as agency reports should be stressed in the standard means of communication such as newsletters.

An examination of the sources of information reveals that in many areas (such as the following case studies of an economic data base and water quality control) fairly comprehensive and sophisticated information systems are presently in existence or are being developed. When this situation exists, there would be little point to duplicating these efforts. Besides the obvious waste of resources and effort, it is conceivable that the operators of these other systems would be less than enthusiastic about cooperating in an effort which could seriously undermine their systems. When such systems exist, they should be used as much as possible and duplicated as little as is necessary. None of these systems are international in scope. The function of the information system of the Experimental Operations Office should be to coordinate these systems and fill in any gaps in geographical or functional coverage.

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Chapter 4

ECONOMIC DATA BASE

Purposes of Economic Information

The purposes to be served by economic information are twofold. These two purposes are interrelated and the distinction may be somewhat vague but it is felt that the distinction is real enough and significant enough to be examined. In the first place, one of the problem areas of concern to the Experimental Operations Office is the problem area of economic development. The function of the office is surveillance of economic development, especially as related to water resources, and the objective is to monitor parameters of economic development and determine the role of water resources in economic development.

The second purpose of economic information is the development of an economic data base to be used for the management of all of the problem areas. This aspect will be concerned more with basic economic data, to project demand functions for water for the various uses, and calculate the benefits and costs of various management activities and programs. There has been much concern recently about the nonquantifiable benefits (and social costs) of water resources planning, such as environmental protection. However, water resources projects are still evaluated primarily on the basis of economic benefits and costs. Even when social objectives override purely economic ones, economics plays an important role in determining how these objectives are to be obtained.

The two categories of concern in economic information for water resources planning might be distinguished by the following questions. The first purpose is concerned with--what is the role of water resources development in economic development? With respect to the second purpose, the question is, what is the role of economic data in water resources planning?

The Role of Water Resources in Economic Regional Development

Allee has stated, "Sweeping generalizations about the crucial role of water resources in regional development and thus the need for planning for its development are common. But they sometimes seem at variance with what little we know about economic development".[1] Many public decision-makers look upon water resources development as a means of stimulating regional economic growth. However, there are great deficiencies in available knowledge about the relationships between water resources and regional and national economies. Because of gaps in data and the lack of fully developed analytical tools, the influence of water development cannot, at this time, be traced in precise quantitative terms through our complex economic system.[2]

Allee goes on to point out that water resources are important and possibly crucial as limiting factors to economic growth, but their role in inducing economic growth is less clear. Water resources are only one aspect of a broad class of investments known as social overhead capital (SOC). SOC includes such social investments as roads, dams, schools, and police and fire protection. The effects of all SOC are difficult to evaluate precisely. Economic growth is a function of both SOC and directly productive activities (DPA) which are generally private investments over which governments have little direct control.

As economic development takes place and grows in a region, activities related to the exploitation of natural resources such as water diminish in relative importance. Obviously, the importance of water depends on the particular region and its economy. In the development of agricultural economies in arid regions of the West, water is of utmost importance. But this does not contradict the point that water is important primarily as a limiting factor. Generally speaking, water alone does not appear to offer enough to attract industrial uses, and even for the exploitation of immobile resources such as agriculture and recreation it is only one of many important factors.[3] The growth of demand for services, which reduce the resource content in consumption, is an important consideration. There is a strong suspicion that the effects of water resource development on stimulating regional development have been overstated.[4] As Gemmell has stated "Too often the planning for economic development of the region has been centered on the development of its water resources when the converse should have been true."[5] This is especially true in a region such as the Great Lakes region which has a large, well-established economy.

What implications does this have for an information system for water resource management, in the area of economic development? An institution concerned primarily with the water resource will have little control over many important factors affecting economic growth; therefore, the management function is limited to surveillance. Water resource development is only a part of an overall policy. Planning for water resources must be done in a framework of policy which considers highways, airports, rapid transit, vocational schools, job retraining, land use control, etc., if there is to be any hope of meeting growth objectives.[6] Lines of communication must be established with other agencies more concerned with economic development as such, and information on their policies must be obtained to determine their effects on water resources management. Also, since water resources is one factor in economic growth, information on availability and cost of water must be supplied to these agencies to help them formulate their policies. Much research is needed in the field of economic development and any such coordination can be done only in a rough manner but this should not keep the attempt from being made.

The Role of Economics in Water Resources Planning

Economics has always played a major role in water resource management and it continues to do so. Benefit-cost analysis has historically been the major criteria for justification of projects. However, in recent years, economists have begun to raise questions and doubts about some of the basic assumptions and conceptions on which benefit-cost analyses have been made and the economic implications of present criteria.

Water resource management is concerned with the field of welfare economics, which is that part of economics concerned with the evaluation of the social desirability of alternative economic states.[7] The objective is not, as in private investment, to maximize profits, or even necessarily to recover financial costs but rather to maximize social welfare. There is probably little disagreement with this goal, but the difficulty of translating it into specific objectives and actions is apparent. To achieve this maximum social welfare, the net social benefits, i.e., the difference between streams of discounted social benefits and discounted social costs, should be maximized. The term "social" implies not only financial benefits and costs but social goals such as redistribution of income or protection of the environment. Much research is needed on ways to deal with such social goals.

One frequently adopted social welfare function assumes that the gross benefits of a project can be measured by summing the amounts the project's beneficiaries would be willing to pay for the services if the project is built. The "consumers' surplus" is the aggregate "willingness to pay" minus consumers' cost. Measurement of consumers surplus requires that a demand function be derived, showing the relationship of price of water versus the amount demanded. Some economists recommend more sophisticated means of measuring consumers' surplus, but there appear to be enough practical difficulties associated with even the simpler concepts.[8]

Economists have been concerned with the fact that projections of resource use, including water, have often been made on the basis of the quantity of the resource required to meet some projected level of final output. This quantity needed is based on relationships currently existing between the input and output with a possible adjustment for expected trends. Basically, this approach assumes that the projected amount will be used regardless of the cost of supplying it. But if projections of demand are to be used as a basis for water resource management, functions which relate demand to cost are essential. When satisfactory market conditions exist for a good, demand functions can be derived by statistical demand analysis, an advanced field of econometrics. But much work remains to be done when the outputs are essentially non-priced such as water-based recreation, or when the prices which do exist are distorted by such factors as government subsidies, as in the case of irrigation water in Western regions. An interesting example of the methodology of deriving demand functions in such cases is provided by Ruttan in The Economic Demand for Irrigated Acreage.[9]

Another important economic concept which is too often over-looked is that of opportunity costs. The important concept in the use of a resource such as water is not the monetary cost of purchasing or developing the resource, but the social opportunity cost. This basically is the value of the output sacrificed by not using the resource in the most productive alternative use. This implies that all alternative uses of the water must be evaluated when a specific action is considered.

Besides the conceptual considerations just discussed, economics plays an important part in water resources planning by projecting future economic conditions of the region. The development of a region involves other social and cultural factors but the primary factor is the economic one. An understanding of economic principles and relationships is necessary to make or understand projections of population, industrial development, and other factors bearing on water-services demand. And, as discussed in the previous section, it is necessary to understand the effects that water-services can have on economic growth.

Types of Economic Information Needed

As discussed in the preceeding section, economic information is needed to determine demand functions for water resources and related land uses, and thus evaluate benefits, and also to determine costs of supplying the water. Many of the more sophisticated models needed to describe water demand for specific uses are either non-existent or are not widely established and accepted. The information system will have to be flexible enough to add the information required by the models as the need develops. The cost of supply is composed of two parts--the financial costs of developing the resource and the social opportunity cost. The financial costs of developing the resources require detailed studies for each of the problem areas. The opportunity costs, on the other hand, are dependent on benefits from the other uses and thus are functions of the overall demand for the water resource. The main objectives of the economic information base then, are first to inventory the available water and related resources, and secondly, to examine those factors bearing on present and projected demand.

Demographic and Economic Base Studies

Demographic and economic base studies of a region are vital to many areas of planning and policy making other than water resources planning. Scores of federal, state, provincial, and local agencies are engaged in such studies.

These agencies have the financial and manpower resources to conduct such comprehensive studies and can provide the Experimental Operations Office with much of the information needed. The task of the office will then be primarily to search out such sources, acquire the necessary information, and store it in a proper format for use by the office.

An example of the kinds of economic data needed in an economic base study for a water resource planning agency is provided in table 4. This outline was prepared by the Erie-Niagara Basin Regional Water Resources Planning and Development Board, in cooperation with the New York State Water Resources Commission.[10]

Water Service Demand Studies[11]

In addition to the economic base studies, which are general studies describing the present and future economic environment of the region, water service demand studies are required. These studies are more specific for water resources. These demand studies are necessary as a basis for estimating benefits from water resources development. Much of this information is not readily available and will have to be developed by the Experimental Operations Office itself or through reasearch projects sponsored by the office.

For industrial use, descriptive inventories of regional industrial water use are needed for the region. These inventories should include water usage classified by

Table 4

Example of Economic Base Study Information

Inventory of Resources for the Economic Area and Subareas

1. People
   a. Numbers and growth (decline) trends since 1900
   b. Age-Sex distribution
   c. Social and economic characteristics
   d. Mobility trends - net migration movements
2. Natural Resources of the Area and Subareas
   a. Air
   b. Water
   c. Minerals
   d. Forests
   e. Soils types
   f. Weather, terrain, geography, etc.
   g. Fish and wildlife
3. Man-made Assets
   a. Business and industrial plants
   b. Residential complex
   c. Public works, e.g. parks, dams, roads, airports
   d. Transportation facilities - public and private
   e. Cultural centers
   f. Medical institutions
   g. Educational system
   h. Governments and private institutions for dependents

The Basin Economic Base

1. Structure
   a. Manufacturing, trade service, construction, transportation, finance, utilities, government
   b. Agriculture
   c. Identification of "export" industries
   d. Inter-industry ties
2. Geographic Distribution of Economic Activity
   a. County-by-county study of employment centers
   b. Development and mapping of future land use pattern
3. Performance of Area and Subarea Economies
   a. Employment and Unemployment
      1. Comparisons - Nation, State, Region
   b. Personal Income - Totals and Per Capita
      1. Level, distribution and origin
      2. Comparisons - Nation, State, Region
   c. Growth Trend Analyses of Employment and Income
      1. Comparisons - Nation, State, Region
   d. Study of Value Added by Manufacture Statistics
      1. Trend in totals
      2. Productivity per worker (two or three digit Standard Industrial Classification grouping)

Table 4 (continued)

Example of Economic Base Study Information

The Basin Economic Base (continued)

3. Performance of Area and Subarea Economies (continued)
   e. Performance of Non-manufacturing Sectors
      1. Agriculture
      2. Trade
      3. Services
      4. Utilities
      5. Transportation
      6. Government
      7. Contract Construction
      8. Finance, Real Estate, Insurance
   f. Sensitivity of Area and Subarea Economies to Cyclical Swings of Business
   g. Net Social Benefits Accruing to Area and Subareas
   h. Amenities available in the Area

Projections

1. Employment to 2020 by County, Subarea and Area
   a. By Sector and Industry (two or three digit Standard Industrial Classification groupings)
   b. Based on:
      1. Trend Analyses
      2. Shift patterns
      3. Industry studies
      4. Inter-industry relationships
      5. "Export" - "Service" Ratios
      6. Location Quotients
      7. Field studies in Area
      8. Comparisons with Labor Force Projections and Assumptions re: Unemployment Levels
2. Population
   a. By County, Subarea and Area to 2020
   b. Based on projections of birth, death and migration rates
   c. Tempered by projections of employment opportunities
3. Industries of the Future

Source: Plan of Cooperative Study for Comprehensive Water Resources Development (Ref. 10) quantity and quality of industrial withdrawal, consumption, recirculation, and return flow. Further classification should include type of industry, size, technology, climate, cost of water quantity and quality, and type of usage. In addition to these descriptive inventories, analytical studies are necessary to estimate future demands. These studies should include the sensitivity of locational decisions to water availability and cost, technical substitution possibilities, price elasticities of water, and probable impact of future technology.

Descriptive inventories of residential use should include quantity and quality of residential water withdrawal, recirculation, and discharge, classified by community population size and density, disposable personal income, the price of water services, climate, and other significant variables. Research on residential water use has been conducted by the John Hopkins University.[12] Analytical studies should consider the sensitivity of migration patterns to water availability and cost, and price and income elasticities of residential demand for water services, as well as future technological impacts.

Agricultural use studies should include descriptive inventories of use classified by purpose of use, source of supply, cost of water, type and value of agricultural output produced, amounts and costs of other inputs used (labor, capital, materials), crop yields, etc. Agricultural production functions should be developed which will reveal the marginal physical product of water in agricultural production. These functions would facilitate studies of the elasticity of substitution of other inputs for water. The impact of future technology on these elasticities should be examined. Estimates of future demands for agricultural products are also needed.

Water-based recreational demand is growing rapidly as the population increases and has available more disposable personal income and leisure time. Inventories of the present use of recreational resources should be conducted, classified by type and extent of use, user cost including distance traveled, length of stay, and by the quantity and quality of water required. A great deal of research remains to be done in the analysis of recreational data. Surprisingly little is known about the relationships between public recreation and demand, disposable personal income, income distributions, amount of leisure time, costs of recreational services, the types of recreation chosen, etc. Water-based recreation demand functions need to be developed to relate regional demand to the relevant variables.

Similar descriptive and analytical studies are needed for all other water uses, including flood control, navigation, hydropower, and fish and wildlife.

Sources of Economic and Demographic Data

The importance of adequate demographic information was recognized even at the time the United States Constitution was written. The first article of the Constitution adopted in 1787 provided for a population census or "Enumeration" to be conducted every ten years. Over the decades, the scope of census activities has grown to include many facets of the nation's life. Today, the statistical system of the federal government involves a vast machinery for collection and dissemination of all kinds of demographic and economic data.[13]

<u>United States-Federal</u>

In the United States federal government, the statistical information responsibilities are not centralized but are divided among agencies according to their subject matter fields. To coordinate the various efforts and improve the statistical program as a whole, the Office of Statistical Standards, Bureau of the Budget, was established as the central coordinating agency. A large proportion of the statistical activities of the federal government are accounted for by general-purpose statistical agencies, the most important of which is the Bureau of the Census. The purpose of these agencies is to collect, compile, and publish general-purpose statistics. The other general-purpose statistical agencies are more specific in scope and include the Bureau of Labor Statistics, Statistical Reporting Service of the Department of Agriculture, National Center for Health Statistics, and the National Center for Educational Statistics. Because of its resources of equipment and skills, the Bureau of the Census performs services for these other agencies, including data collection.[14]

Other important types of agencies involved in statistical information include the analytic and research agencies and the administrative and regulatory agencies. The analytic and research agencies' primary role is the extensive analysis or interpretation of data from other sources. These include such agencies as the Council of Economic Advisors and the Office of Business Economics. Most administrative and regulatory agencies collect some statistical information in the course of their operations. Much of this information is of limited general interest and is used primarily for administration of the agency, but much important information of general inte est is also generated as a by-product of operating responsibilities. One of the main objectives of the Office of Statistical Standards is to increase the availability and usefulness of this type of information.[15]

The Bureau of the Census collects the following kinds of information: population, housing, agriculture, business (retail, wholesale, and services trades), manufactures, mineral industries, transportation, and governments (state and local units). This information is collected at five year intervals (10 years for population and housing), with sample surveys at more frequent intervals--monthly, quarterly, or annually.[16]

Before 1960, the Census Bureau was primarily a production agency--the product being a set of printed volumes summarizing the results of each census. Its mission was accomplished when the publications were printed and there was little consideration given to access and use of the vast amount of data not published. Since 1960, the trend has been toward the Bureau as a service agency. There has been a growing community of users whose needs were not met by the published reports. Information is often needed in more detail, in special tabulations and categories, or in machine-readable form, suitable for efficient analysis to their own specifications.[17]

The 1960 census was the first wholly computerized census operation. Basic record tapes were created containing information about each household, and summary tapes were prepared from the basic tapes. Users quickly took advantage of the possibilities and purchased many data products and services such as special tabulations and matching studies of the basic record tapes. The Bureau is now giving emphasis to developing its role as a data deliverer as well as a fact finder.[18]

There are two important references which the potential user of census data should be aware of. The Census Bureau Programs and Publications[19] is a comprehensive review of the statistical programs of the Census Bureau and of the reports issued by the Bureau. The geographic areas covered and principal subjects are shown for most of the publications. The Guide to Census Bureau Data Files and Special Tabulations[20] outlines the programs and activities of the Census Bureau and describes the data files and special tabulations which are not published. Information is provided on how these materials may be obtained, geographic areas for which statistics are available, and includes descriptions of other unpublished materials such as computer programs.

The non-published data is available in the form of computer punchcards and tapes. This data may be obtained and analyzed by the user or the Bureau will process the information in the form desired, at the expense of the user. Safeguards are provided to protect confidential data and make identification of individual persons, enterprises, farms, etc., impossible without written authorization of the person or legal representative of the person or unit involved. For special services, the user pays only the actual cost of the service and not for collection of the data. However, the Bureau will undertake special surveys to collect data on a reimbursable basis under certain conditions, one of which is that the Bureau must determine that there is a public interest in the survey results.

The Bureau of the Census and the other federal general-purpose statistical agencies basically only collect and compile data. At the state level, there are data collection activities, but the federal statistical services provide the bulk of economic and social data. This fact is plainly evident from the sources cited in various state economic studies and planning reports. The basic data provided is compiled and analyzed on a regional basis by a number of state agencies.

New York State

In New York State, the Office of Statistical Coordination of the New York State Division of the Budget publishes an annual New York State Statistical Yearbook.[21] This yearbook is designed to serve as a single comprehensive source of statistical data about New York State and also identifies the major sources of such data, with information about their regularly published statistical series. The following agencies are sources of information needed to establish an economic data base for water resources planning:

(1) Department of Agriculture and Markets. Published and unpublished statistics on agricultural activities.

(2) Department of Commerce. Collects and publishes economic, population, and related data from a variety of sources.

(3) Department of Labor. A major source of statistics on employment and unemployment.

(4) Office of Planning Services. This is the state's central long-range planning agency. It produces no regular statistical series but has the responsibility for making population projections. It also makes important economic studies of the state's economic regions.

(5) Department of Transportation. This agency is concerned with the development and operation of such transportation facilities as highways, mass transit systems, marine and aviation facilities, and the state's waterways. It annually updates an inventory of traffic volume and physical

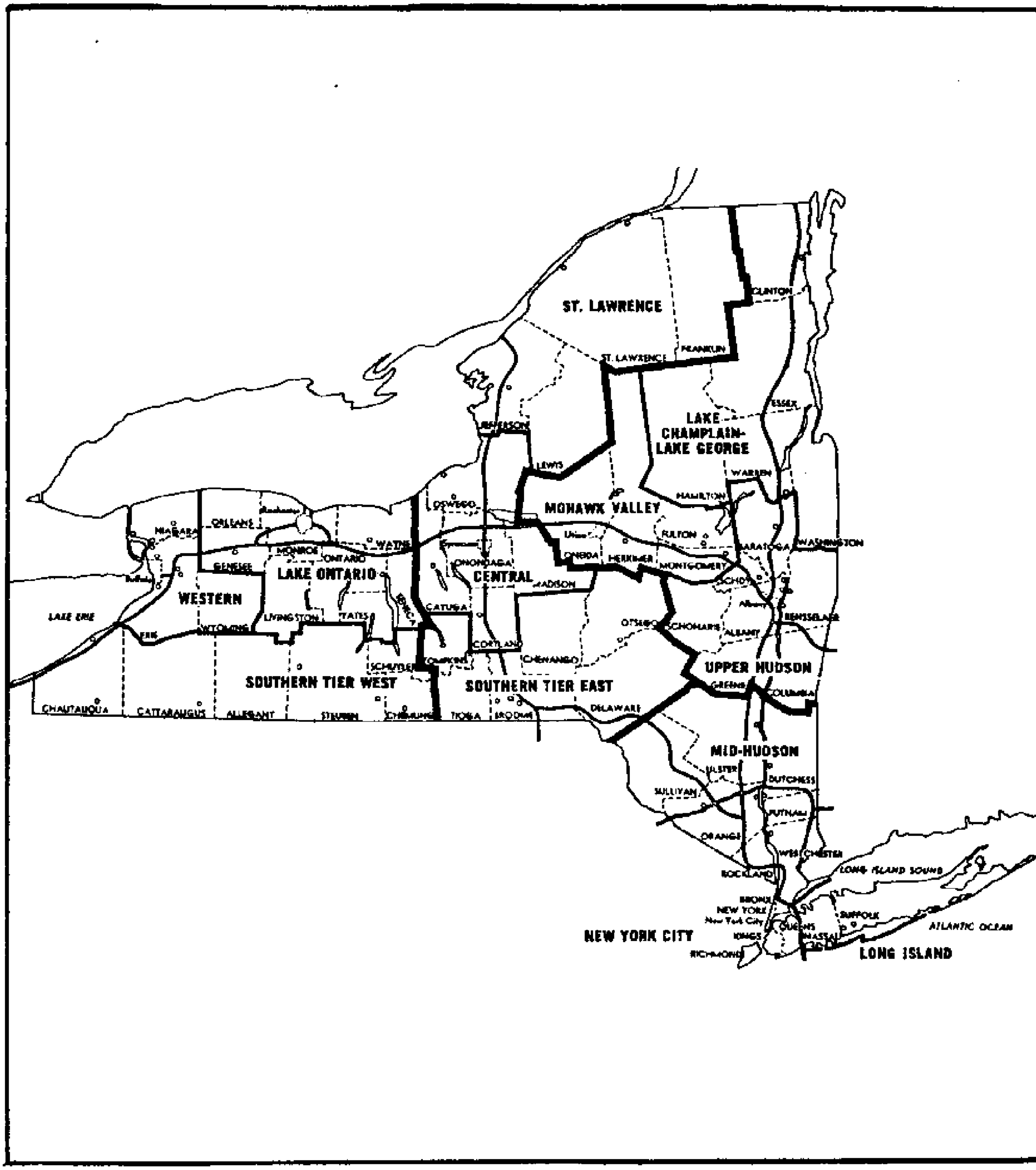
condition data for the 13,000 miles of the state highway system.

As stated above, the Office of Planning Services (formerly the Office of Planning Coordination) is the state's central long-term planning agency. As such, it is a valuable source of information for any planning agency, providing special compilations, analyses, and projections of the basic economic and related data provided by such sources as the Census Bureau. It is responsible for formulating a comprehensive plan to guide the economic, social, and physical development of New York State, and has produced the New York State Development Plan - 1[22] which proposes 1990 distribution of land uses, population or settlement densities, and transportation corridors. The agency also coordinates and assists planning by the various state agencies; coordinates state planning with that of local, federal, or private groups; conducts research to provide uniform information and projections; and administers technical and financial assistance for local planning.

The Office of Planning Services has prepared a series of regional economic studies for the economic planning and development regions of New York State (see figure 3). These studies are published in two phases. Phase I includes basic inventories and analyses of past and present situations. Its purpose is to place in perspective the demographic, economic, and public financial factors affecting the development of the region and is designed to help

Figure 3
New York State Comprehensive
Planning and Development Regions

Source: Demographic Projections for New York State Counties to 2020 A.D., (Ref. 41)



orient state and regional planners toward the requirements of the area. Information is provided on a regional, county, and smaller area basis. The information includes a broad overlook of the region, its topographic features, problems and developments in agriculture; changes in population, its distribution and social influence (education, marital status, etc.); the economic structure, as reflected in the labor force, industry and occupational distribution and the level and change in income; economic activity in manufacturing, trade and service; the financial structure and problems; and recent changes in population and employment and some problems and strengths of the individual counties.[23] Phase II consists of analyses and projections. It describes present trends in demographic, economic, and public finance factors which affect the region's development and analyzes how government planning might affect the economic trends. One such report, the Central New York Regional Economic Study, is based largely on a survey of manufacturing firms asking opinions about such factors as water, and the firm's plans for expanding or relocating.[24]

Another series of reports produced by the office is the Community Profile Series, also for each planning region of the state. These publications are computer printed rankings in 15 categories concerning size, wealth, and urbanization of each city and town in New York State, showing how each community ranks in relation to its county, its region, and the state. These publications are the first to result from the Planning and Environmental Data System being developed by the New York State Office of Planning Services to provide uniform data for all planners in the state. The categories in these reports include: total population, land area, property value, property tax, median family income, per capita property value, per capita property tax, percent of family income over $2000, percent of family income over $4000, population density, property value per acre, property tax per acre, percent of sound housing, educational level in median years, and population mobility.[25]

Another important information service in New York State is the Land Use and Natural Resources (LUNR) Inventory. This program was developed by the Cornell University Center for Aerial Photographic Studies under contract to the New York State Office of Planning Coordination (now Services). The initial data were obtained from aerial photographs of New York State, specially flown for the purpose, with other information obtained from secondary sources, mostly in published form, maps, etc. Information contained in the inventory consists of 14 main categories (see table 5). The data consists of three types of measurements--area (in hectares), point data (counting of facilities), and linear data (miles of shoreline or streams).

The information was mapped on USGS 7½' maps and overlays produced on transparent film. These overlays can be obtained by the user and used with the easily obtained

Table 5

New York State LUNR Inventory Categories

ACTIVE AGRICULTURAL AREAS
Orchards
Vineyards
Horticulture or Floriculture
High Intensity Cropland
Cropland and Cropland Pasture
Pasture
Specialty farms

INACTIVE AREAS
Inactive Agricultural Areas
Urban inactive Areas
Under construction (non-agr.)

FOREST LAND
Forest Brushland
Forest Lands
Plantations

WATER RESOURCES
Natural Ponds and Lakes
Artificial Ponds
Streams and Rivers
Marshes, shrubwetlands and bogs
Wooded Wetlands
Marine (Salt) Wetlands
Marine Lakes, Rivers & Seas (embayments and sounds)
Hudson River (N.Y. City to Mohawk River)

RESIDENTIAL LAND USE
High Density
Medium Density
Low Density
Strip Development
Rural Hamlet
Farm Labor Camp
Rural Estate

COTTAGES AND VACATION HOMES
Shoreline Development

COMMERCIAL AREAS
Central Business Sections
Shopping Centers
Resorts
Strip Development

INDUSTRIAL AREAS
Light Mfg. and Industrial Parks
Heavy Manufacturing

OUTDOOR RECREATION
Outdoor Recreation Land Use

EXTRACTIVE INDUSTRY (Mining)

Open Mining
Stone quarries
Sand and Gravel Pits
Other open mining

Underground Mining
Underground mining

PUBLIC AND SEMI-PUBLIC
Public and Semi-Public Land Use

TRANSPORTATION, COMMUNICATIONS AND UTILITIES
Highways
Railway
Airport
Barge Canals
Port or Dock Facilities
Shipyards and Dry Docks
Locks and Water Control Structures
Pumping Stations, gas & oil, electric, etc.

NON PRODUCTIVE LAND
Sand
Exposed rock cliff, slopes and slide areas

Source: The New York State Land Use and Natural Resources Inventory (Ref. 26) quadrangle maps. In addition, the information has been stored in computer form to facilitate handling and processing. The smallest geographical area for which information can be obtained is the Universal Transverse Mercator (UTM) Grid Cells, which are identified by the Southwest coordinates of each cell. One cell represents a square kilometer in area (or 247.1 acres). The state of New York (50,000 square miles) is divided into approximately 140,000 such UTM grid cells.

Land use information, consisting of 129 data items for each of the 140,000 cells is stored on one IBM 2316 disk and additional information on soils, economic viability of farms, geology and depth-to-bedrock are contained on a second disk. Space is available for another 200 items and the storage can be expanded to accomodate additional items per cell. Updating of information can be accomplished without destroying the old data, by using the additional storage space. In this way, comparisons can be made to analyze land use changes. Original plans anticipated a 5-or 10-year updating cycle.

Computer output can be obtained for any study area, in tabular or graphical display, after the study area is defined by coordinates. The DATALIST program (tabular output) lists the requested data for each cell and aggregates for the study area. The PLANMAP output (graphical display) provides summary information and displays information in a graphic manner to highlight patterns and geographic interrelationships of data visually. However, this output contains less detail than is available from DATALIST.[26]

It was stated earlier that long-range planning for water resources development must take place within a framework of the anticipated future economic and social environment of the region. These anticipated conditions must be based not only on past trends and projections of growth and development, but must also take into account government plans and activities which attempt to influence the economic and social development. Besides being influenced by development, the possible role of water in directing development must be explored and defined when possible.

Planning for future development in New York State has come a long way since it was introduced as an essential policy of state government in 1961. The Office of Planning Services has recently published the <u>New York State Development Plan - 1</u>, the first phase of a comprehensive statewide plan, which deals with patterns of land use and settlement for a population of 23 million, forecast for around 1990. This plan provides for the first time a common framework of developmental objectives for all planning efforts in the state. This phase of the plan deals with physical development aspects because these could be accomplished first. Two forthcoming phases will have in turn an economic and a social emphasis. However, the interdependencies of these three aspects require that they be integrated to a certain extent in every stage of the work.[27]

Planning activities at the state level are directed at functional planning, which views government activities as an interrelated system of "functional" programs. The state's concerns have been classified into ten broad functional areas such as economic development, natural resources, human resources, etc. All government activities influence patterns of land use and settlement. The direct influence of such projects as roads, parks, water systems, and public roads is small in volume compared with private activities but important in their indirect influence on private decisions about location and land use. At present, the state's powers to affect actions of other governments, private groups and individuals, and state government itself, fall into five broad categories. These categories are: coordination, land use controls, location of public facilities, advice and education, and fiscal incentives. These first three categories have obvious implications for a comprehensive water and related land management office. Close coordination with the state, involving both input and output of information about goals and activities is a practical necessity.[28]

The first phase of the State Development Plan contains information on goals to be followed for important aspects of the physical environment; practical objectives to be achieved in pursuit of these goals; and the resulting statewide settlement, land use and transportation patterns proposed for 1990, which if achieved, would fulfill those objectives. A number of action steps are suggested for consideration by the Governor and the Legislature. The plan deals only in the broadest terms, because the infinitely detailed working out of the plan's objectives must be done on a regional and local basis. Much detailed work has been done by localities but vastly more remains to be done. Until now, localities could not relate to more than their own territorial horizons. The plan provides for the first time a common structure, a framework of objectives for the entire state.[29]

<u>Canadian-Federal</u>

In Canada, a situation similar to that in the United States exists with respect to economic and demographic information. The Dominion Bureau of Statistics conducts a decennial census of population and housing and also collects basic data on agriculture, manufacturing, wholesale and retail trade, etc. The users of socio-economic data in Canada have been confronted with the same type of problems which have been previously discussed with respect to the federal statistical services of the United States government. The inadequacies of former methods of compilation and dissemination of information have been increasingly apparent and have forced the Bureau to shift more to a user service orientation.

One of the major problems is that the rapid advance in data processing technology and statistical methodology together with the expansion of statistical needs of data users has rendered former methods of collecting, organizing, and disseminating data inefficient and obsolete. Means of more convenient manipulation and integration of data currently being gathered at great cost are needed to allow complete utilization. A second, and related, major problem is that governmental collection and development of information is conducted on an "ad hoc" basis. Much data is collected by agencies in the course of their normal activities. Too often, this data is used only for the particular agencies' operational responsibilities, with little attempt at inter-agency coordination. Little attempt is made to determine if the data needed already exists; if another agency needs data which could be easily collected, with little additional effort during a proposed survey; or if methods, procedures, and coding can be standardized with those used elsewhere.

In response to these problems, the Dominion Bureau of Statistics has under development a computerized system for providing census data for large urban areas on a user-specified basis. This system is the Geographically Referenced Data Storage and Retrieval System (GRDSR), commonly called Geocoding. The system basically provides data on large urban centers to be quickly and inexpensively selected and aggregated for areas specified by the user, as opposed to present standards, such as enumeration areas, census tracts, and municipalities. Eventually, diverse socio-economic statistics from other surveys could become available on a similar basis, with cross-tabulations in a variety of combinations. Recognizing the importance of Geocoding for urban analysis and policy planning, the Ontario government formed a team comprised of members of the Department of Treasury and Economics and the Department of Highways to investigate the possibility of applying Geocoding techniques to projects in Ontario.[30]

The Canada Land Inventory is a comprehensive survey of land capability and use for various purposes, being undertaken as a cooperative federal-provincial program under the Agricultural Rehabilitation and Development Act (ARDA).[31] This inventory defines the land capability for agriculture, forestry, recreation, and wildlife management. Present land use information is broadly classified with the most important aspect considered to be the breakdown between lands that are intensively cultivated and those that are in less intensive use, such as pasture. In addition, the program will attempt to assess social and economic factors relative to land use. Statistical data are available from the Dominion Bureau of Statistics on most of the important socio-economic factors. Much of this information is available on computer tapes and can be readily utilized by a computer system. Such data include: type of farming, economic classification of farms, age of operators, size of farms, capital investment in farms, and population characteristics.

Information from the inventory is presently available mostly in map form. The computer has been utilized in storing, analyzing, and presenting data as tables or maps. However, it appears that the computerized part of the program output has not yet been as fully developed as the New York LUNR system in certain aspects such as the handling and aggregation of data on a small-scale grid system.

Ontario

At the provincial level, the Ontario Department of Treasury and Economics is a major source of economic information. Provincial agencies collect and compile data in various fields, using the Dominion Bureau of Statistics as a major data base. Information in specific areas such as agriculture and transportation is handled through the respective provincial agencies, such as the Department of Agriculture and Food and the Department of Transportation.

The Department of Treasury and Economics includes an Economic and Statistical Services Division. The Ontario Statistical Centre is a part of this division. The Centre prepares a bimonthly Ontario Economic Review which presents current information on economic activity in Ontario, as well as articles of interest. In addition, the Ontario Statistical Review is published as an annual reference supplementing the Ontario Economic Review. Its two basic objectives are to provide an historical perspective for the economic indicators in the Economic Review and to bring together a wide range of information relating to Ontario's economy.

The Regional Development Branch in the Ontario Department of Treasury and Economics plays a major role in guiding and coordinating planning and decision-making at all levels as they affect the overall development of the Ontario region. It is similar in many respects to the New York State Office of Planning Services, in that it attempts to provide a framework of future goals and objectives of the region, to guide activities at all levels of government and private enterprise. The Regional Development Branch has published a number of Design for Development reports which deal with regional development in Ontario. The regional development program is described in Design for Development in Ontario: The Initiation of a Regional Planning Program.[32]

The Regional Planning Program is based on the fundamental principle of parliamentary democracy and involves the people in all phases of specific policy development. It is also based on a second fundamental principle of coordination among the three levels of government and private enterprise.[33] As such, the program is a major source of information on social goals and policies regarding future regional development. The necessity of cooperation and information exchange between the Regional Development Branch and the Experimental Operations Office should not need elaboration.

The Regional Development Program recognizes three major trends which create problems and with which the program must cope. These three trends are: the increasing tendency of populations to concentrate in certain urban areas; the tendency towards unstructured sprawl in these areas; and the sometimes unwise use of the physical setting--the land, water, air, and other natural resources.[34] To project future trends, two basic approaches were recognized. The first approach is to use mathematical models of input and output. Such models are being prepared by the Economic Analysis Branch, but the lack of refinement of data needs necessitated reliance on the second approach, that of studying past trends. To carry out these studies, 63 indicators of change were examined for the census years of 1951-1966, or any more recent years for which data could be obtained. Not all required data was available and due to the lack of resources for collecting new data, the indicators were selected partially on the basis of available data.[35]

The Department of Treasury and Economics has divided Ontario into ten Economic Regions. The regions bordering Lake Ontario include the Niagara, Central Ontario (Toronto-centered Region), Lake Ontario, and Eastern Ontario Regions. (see figure 4). A series of descriptive and analytical studies of each region has been prepared. These surveys are intended to provide detailed background for understanding the past location of economic activity in Ontario, and to indicate the contribution of each region to the economic life of the Province. A wide range of information, ranging from physical environment to economic characteristics, has been included, and change over time has been indicated where data are available.[36]

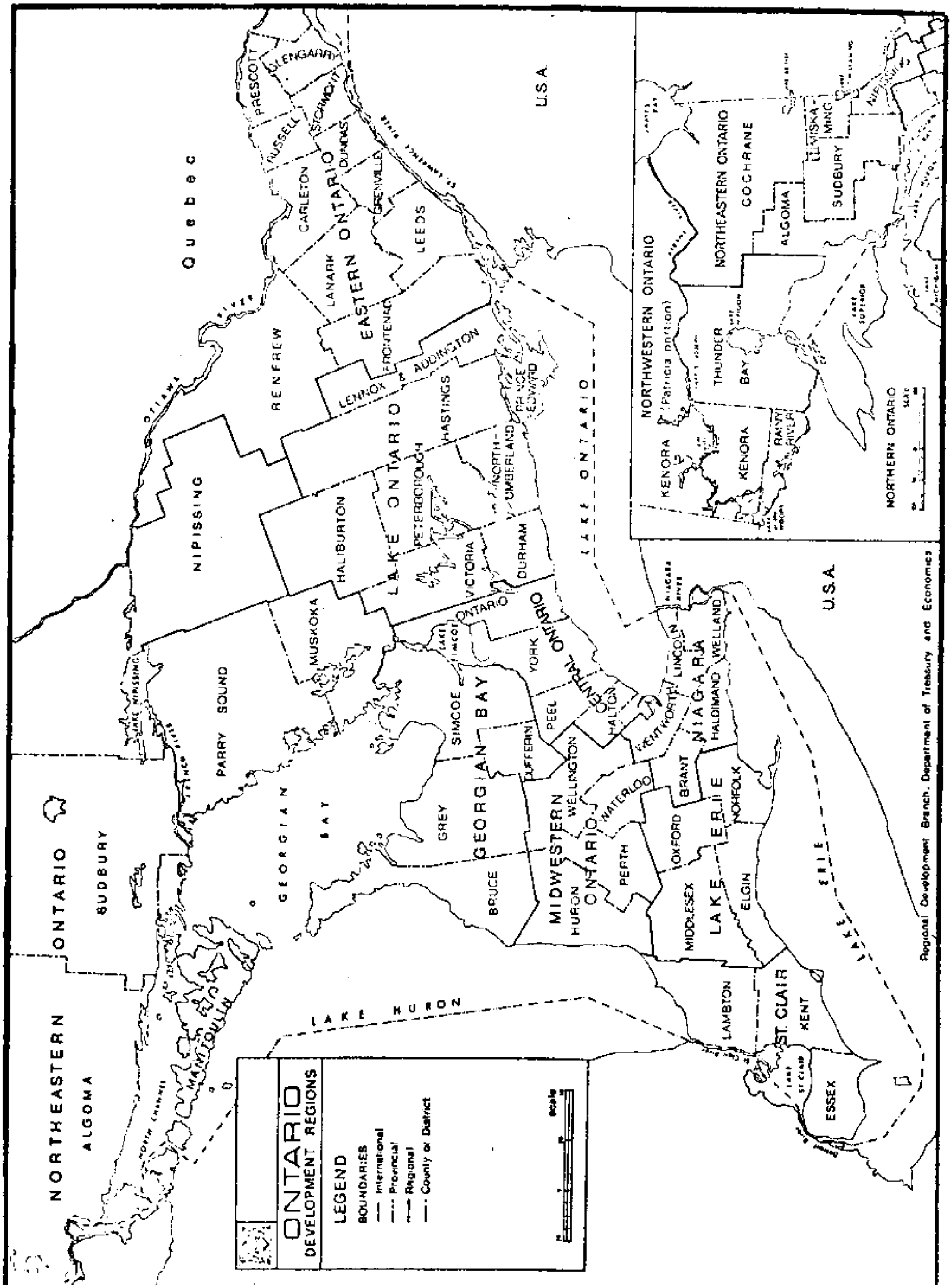


Figure 4: Ontario Development Regions

Use of Economic Data

In previous sections, needs for economic data and its usage in a general way have been discussed. This discussion has been conceptual in tone and focused largely on research needs to develop theoretical models for deriving demand functions and evaluating benefits in an economically desirable way. The need for developing and using conceptually "correct" methods and information is very real. There has been considerable criticism, by economists and others of the practical applications of economic information and methods used by water resources planners. However, the development and management of our water resources demands immediate action, and when the desired sophisticated models are not available or useable, or when adequate information does not exist, this cannot be allowed to stop all activity. One of the distinctive characteristics of decision-making is that it often must be done with inadequate information or predictive models. In fact, if such information is available, the problem becomes deterministic and could hardly be called decision-making.

This section includes some practical examples of how economic information is used. The specific uses are furnished only as examples and it is realized that the methods of use will change as more sophisticated predictive models and techniques are developed.

The problem, as stated before, is that of determining present and projected demands. Actually, the term "requirements" would more aptly describe present procedures, since demand has an economic implication of demand functions which generally do not exist. Also, present and future requirements are essentially aspects of the same problem; that is, estimating requirements over time. The present situation is merely one point in time, although, obviously the point of foremost importance.

A program of national economic analysis and projection for use by water resource agencies in the United States has been instituted under the aegis of the United States Water Resources Council and performed by the Office of Business Economics of the United States Department of Commerce and the Economic Research Service of the United States Department of Agriculture. This program is referred to as the OBERS program. These projections are made on the basis of past trends, with reasoned modifications. An important point is that government actions, possibly stemming from these projections, can affect future conditions and possibly cause the projections to be in error. When revealed problems are eliminated, such errors are welcomed.[37]

The methodology used in such projections is beyond the scope of this report. Some of the important variables are:

-- Population

-- Personal Income

-- Agricultural Output

-- Labor Force

-- Gross Product by Industry

-- Employment by Selected Industries

These studies have been conducted on economic areas delineated by OBERS. Basically, projections are made on a national basis and then successively disaggregated into regions and then, economic areas. The economic areas are composed of blocks of several whole counties. The problem encountered in using OBERS projections is that the data may have to be further disaggregated for more detailed information and then possibly reaggregated for different planning areas of the water resource agency.

The degree of aggregation or disaggregation is one of the primary considerations in the use of economic data. The degree of detail required will have to be evaluated on a problem by problem basis. Generally, economic projections on a county basis would appear to be adequate for long range planning. The county is the smallest unit for which current economic information is readily available except in metropolitan areas. In these areas, as discussed previously, computer procedures, such as Geocoding in Canada, are being developed to provide data by user-specified small areas. The uncertainity and impreciseness of future projections would probably not warrant any more detail than the county level. The regional economic studies conducted by the New York State Office of Planning Services make certain projections on a county basis. Such projections include population, labor force, employment by industry group, employment by occupational group, and family and per capita income.[38]

The following examples are included to show specifically how the economic and demographic data base is used for particular problem areas. Such analyses would have to be performed for all of the problem areas to determine what information is needed, and in what form.[39]

Municipal water demand. The general method used in projecting demands for municipal water is quite simple. It consists of multiplying the projected population by the projected use rate in gallons per capita per day (gpcd). The crux of the problem is, first, in disaggregating population predictions to smaller units such as counties or stream reaches (20 to 50 miles), and, secondly, to estimate trends in per capita rates of use. Some populations may have be projected on a city (SMSA) basis.

Some of the variables which might affect future per capita use rates are: (1) the general state of the economy, (2) standard of living of the population served, (3) rank (with respect to size) of population served, (4) climate, (5) price of water, and (6) extent of metering. The economic base study should provide information on the general state of the economy and certain factors of the standard of living, such as personal income. Evaluation of these factors in historic data, along with projections of these factors for the future should serve as guides for demand forecasts. Population data also has a bearing on the per capita use rate, as indicated by the variable "rank of population". It has been observed that, for example, large city demands are greater, per capita, than that of a small town. Other effects may be involved (it may be that the growth of a city is coincidental with an expanding economy) and should be separated out. Population density effect on water demand may also be considered in this factor or examined separately.

Industrial water demand. There are two basic methods used to project industrial water demand. One method requires industrial projections of employment in an industry and uses a water-use factor of gallons per employee day (gped), based on historical use records. The other method uses industrial projections in terms of units of production, with a use factor based on gallons per unit of production (gpup), also based on past records.

As with municipal demand projections, industrial projections will have to be disaggregated, if not available, for smaller areas. Generally, a county level would be adequate and some such projections may be available from local and state planning groups.

In addition, a problem arises from the fact that data on past industrial water usage is rather scant. The Census Bureau conducts a Census of Industrial Water Use. The published data are on too broad a scale for use, but the Bureau has been contracted to compile the data in more detail. Data on water use can be furnished by Standard Industrial Classification (SIC) number, for counties where disclosure regulations permit, and at least for multicounty planning areas.[40]

Projections of industrial water use are probably the most difficult part of the study, due to the rapid technological changes in industrial processes that can occur. Some of the important variables which can affect future water use are: (1) product manufactured, (2) manufacturing process, (3) amount of production, (4) rate of production, (5) cost of water supply, and (6) cost of waste water disposal.

Water quality control. The purpose of the economic base study, regarding water quality, is to project the waste water volume and character. These are functions of the water supply demand which, as just discussed, is a function of population and industrial growth projections. The percentage of municipal demand which is discharged to streams as waste water flow is not expected to vary appreciably in the near future. Therefore, return flows will be obtained by applying present return flow percentages to projected municipal demands. The quality of future return flows is not expected to differ greatly from present quality.

Projecting industrial return flows is more difficult and encounters the same type of problems as projecting industrial demand. Rapid technological changes cannot be foreseen. Reclaiming of wastes and recycling of water will probably increase as water quality control efforts are increased. Also, information on return flows is often not readily available or it varies widely. For example, plants producing identical products have been observed to have widely differing water use patterns and return flow quality, due partly to such factors as different operating practices, availability of water, and geographical location. Some present return flow data can be obtained from the Bureau of Census, and a number of studies have been made for specific industries. The programs of water quality control agencies in the United States and Canada should be able to provide waste characteristics of certain industries.

Water-based recreation. The demand for recreation is computed for each activity by applying a participation rate to the effective population to get an activity occassion. Conversion standards are then applied to express acreage requirements per 1000 population and use per acre per year, so that both supply and demand can be converted to recreation days. The participation rates are made up of two components: (1) existing use of facilities and (2) latent or unexpressed demand.

Use data for existing facilities is available but often unreliable for major facilities and meager for minor ones. Latent demand is not directly measurable but methods of estimating it have been devised using factors such as population change, mobility, income, and leisure time. The economic data base provides the basic data for computing existing and projected demand.

The geographical relationship of the population to the facilities is of major importance. Present procedures call for overlaying two circles on each Standard Metropolitan

Statistical Area (SMSA), one at 40 miles radius and the other at 125 miles. These correspond to the average travel distance for a day's outing and weekend use, respectively. Studies have shown that 60 percent of the demand will occur in the 40 mile circle, 30 percent in the 125 mile circle, and 10 percent occurs as long duration trips beyond 125 miles. To apportion demand to the various plan areas falling within the zone of influence of the various SMSA's, the proportion of the circles falling within the plan area boundary is used, lacking more sophisticated techniques.

To help visualize the problems arising from differences in supplies and demands of water quantity and quality, locational maps, backed up by more detailed information in tabular form, can be very useful. The location of all municipalities plus other government installations having water supplies can be plotted on a map showing the hydrologic system so that the geographical relationships of supplies and demands can be seen. USGS maps of underground aquifers can be used to indicate the probable yield of groundwater supplies. Heavy water using industries will also be plotted. Tables for industrial information should show water use by SIC numbers by counties, and by county totals and planning area totals. Plotting of information for water-based recreation has been discussed previously.

Interpretation of Economic Information

Some of the problems of interpreting the available economic information have been discussed in this chapter and in Chapter 2 (see "Perspective on Information Problems"). This recapitulation suggests more precise guidelines for the information system to use in its interpretation function.

It has been pointed out that much information is available from various sources, notably the Census Bureaus of both countries. However, this information has been collected for general use by many diverse users. Before it can be useful to any one agency, careful consideration must be given to interpretation and evaluation.

One of the first problems is the deficiency of available data. In spite of the tremendous amounts of information gathered, the wide range of interests preclude the general purpose data collection agencies meeting the needs of every specific user, such as a water resource agency. The information system must identify the information needed specifically for water resources planning and management and assume the responsibility for its collection. Some of these types of information have been identified in the previous section "Water Service Demand Studies". Even when the desired types of information are available, deficiencies in the detail of the data often exist. Census Bureaus in both countries have recently made efforts to provide information in more detail than has been previously available but disclosure regulations may present a problem when great detail is required. Projections of economic information, such as those by the Office of Business Economics and Economic Research Service (OBERS) program use methods which are not capable of providing sufficient detail. It is readily conceded that the more specific projections are, the less accuracy can be expected; but attempts should be made to develop methods for more detailed projections. Possibly a range of expected conditions would be more valuable than one dubious projection.

Much of the information available and needed by the Experimental Operations Office has been analyzed to some extent. The methods of analysis used are sometimes controversial. The value of this information must be determined by economists, planners, and others who are capable of examining the methods and assumptions used in the analysis. Again, the projection of economic and demographic data presents real problems. Even without considering the problems of detail discussed above, projections of a more general nature are often doubtful because of a lack of consideration of the dynamic factors involved. Often simple extrapolation of past trends is used. While such unknowns as governmental policies and technological and social developments are difficult to include, some consideration should be given to them. Here again, possibly a range of projections should be produced based on varying assumptions associated with individual factors.

Proper interpretation of available information considering questions such as those just discussed must be done by the users of the information who should have the expertise required for such interpretation and evaluation. This again emphasizes the need for direct involvement of the users in the design and operation of the information system.

Implications for the Information System

From this chapter on economic information, a number of considerations stand out that have implications for the information system of the Experimental Operations Office. Some of these implications are as follows.

The following tasks are being performed by agencies with the required resources and will not be major tasks for the office:

(1) Raw data collection and storage.

(2) General analysis of data, including aggregation and disaggregation, relationships among variables, projections of economic activities, and plans for desired economic development.

(3) Development of user-oriented computerized services for specific analyses.

The office will be concerned with the following:

(1) Filling important gaps in basic data related to water resources.

(2) Obtaining information from existing sources and further analyzing as necessary for use.

(3) Coordination with other information and planning agencies, such as specifying needed information not being gathered, providing specific information on water resources, and insuring that water resource management fits into policy frameworks to guide and control economic development and growth.

(4) Providing a "referral" service for other water resource agencies by informing them of sources of economic information, the types of information available, formats, and means of obtaining it.

(5) Performing, sponsoring, and collecting research to apply economic concepts to water resources, such as deriving demand functions, measuring benefits, and developing models of economic growth which show the role of water resources.

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Chapter 5

WATER QUALITY CONTROL

The Water Quality Control Problem

The problem of water quality has always been of concern to man, since water is one of the most essential, life-sustaining natural resources. But only in the last relatively few years has this concern began to increase, at an accelerating pace, until today, water quality in particular, and environmental quality in general, have become problems of major social concern. Part of this concern is due to a visible deterioration in water quality in many areas. But of equal importance are two other factors--the first being the change in social values resulting in an increasing demand for "clean" water as a general principle of protecting the environment and increasing the quality of life. Secondly, more information is being constantly accumulated that points out some of the more subtle effects of water quality and increases everyones awareness of the problem.

Water quality problems are created by our growing population and its concentration in urban areas and by our industrialization. Our higher standard of living increases the amount of industrialization, and the technology of manufacturing of many new products and processes produces a large amount of water-born wastes. The complexity of products and wastes creates severe challanges for water quality control and introduce new chemicals everyday, most of which have not been studied adequately to enable prediction of effects on water quality.[1]

The two areas in the United States where water quality problems are most severe are in the Northeastern United States and the Great Lakes.[2] The problems in the Great Lakes area were recognized as early as 1912, when the International Joint Commission undertook an extensive, five-year, bacteriological examination of the four international lakes. The survey disclosed "a situation along the frontier which is generally chaotic, everywhere perilous, and in some cases disgraceful...." A treaty was drafted to carry out the recommendations of the International Joint Commission but it was not approved and no real definitive action has been taken to date.[3]

A report of the International Joint Commission in 1970 found that the waters of Lake Erie, Lake Ontario, and the international section of the Saint Lawrence River are being seriously polluted on both sides of the boundary to the detriment of both countries and to an extent which is causing injury to health and property on the other side of the boundary. The report concluded that contaminants originating in one country do move across the boundary and degrade the quality of the water in the other country. The polluted waters are lakewide in extent.[4]

Water Quality Control Goals and Objectives

Sub-Group No. 1 of the Canada-United States Working Group on Great Lakes Pollution has outlined the goals of water quality control, by concluding that "programs for the protection of Great Lakes water quality should continue to give increasing emphasis to the protection of ecosystems in the Great Lakes; programs should be designed to maintain existing levels of water quality where these are high, and enhance the quality of water where existing conditions are unsatisfactory. In this way, the waters of the Great Lakes system will be preserved for the largest number of future beneficial uses."[5]

Water quality standards are a means of expressing the desired quality of water by numerical specifications of a number of relevant parameters. These standards are based on social objectives and, theoretically at least, represent a weighing of benefits versus costs of achieving different levels of water quality. Standards cannot be directly established on economic grounds because all of the benefits of water quality improvement cannot be computed. The public, Congress, and many public officials have expressed an urgent desire to improve water quality and so standards have been set based on some, usually vague, consideration of damage costs versus costs of quality improvement.[6] The benefits and costs are not necessarily economic or quantifiable and often involve considerable value judgement. Protection of public health was the first social objective to be considered. Aesthetics became associated with health and such words as "pure, wholesome, and potable" appeared in public health laws.[7] The next objective of water quality control involved the protection of beneficial uses not directly involving public health. This objective might be thought of as primarily involving economic efficiency and is concerned with protecting beneficial uses such as industrial and agricultural water supply.

At the present time, a totally new social objective has been added to the two described above. This objective is concerned with maintaining or providing "clean" or "pure" water per se, in order to protect and preserve the natural environment. This is an interest partly for aesthetic reasons but also because it is felt that man is only one part of the ecosphere and cannot disrupt the functioning of nature too drastically or he will endanger his own survival.

The International Joint Commission report has recommended the adoption of five "general objectives" and nine "specific objectives" to maintain the minumum quality of water in the lower Great Lakes. The general objectives are as follow:[8]

> The receiving waters of Lake Erie, Lake Ontario, the International Section of the Saint Lawrence River and the Connecting Channels of the Great

Lakes at all places and at all times should be:

(a) Free from substances attributable to municipal, industrial, or other discharges that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life or waterfowl.

(b) Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges in amounts sufficient to be unsightly or deleterious.

(c) Free from materials attributable to municipal, industrial or other discharges producing color, odor or other conditions in such a degree as to create a nuisance.

(d) Free from substances attributable to municipal, industrial, or other discharges in concentrations that are toxic or harmful to human, animal or aquatic life.

(e) Free from nutrients derived from municipal, industrial and agricultural sources in concentrations that create nuisance growths of aquatic weeds and algae.

Furthermore, no substances should be introduced into these waters unless reasonable efforts have been made to ensure that it will not lead to the violation of any of the foregoing objectives. Ontario and all states have compatible general standards.

In addition to these objectives, the Commission states that it "does not condone degradation of waters which now have a quality superior to that envisaged by the Objectives." Ontario and all states have similar non-degradation statements or similar requirements for specified waters, included in their standards. The specific objectives recommended are discussed below.[9]

Information Needs for Water Quality Control

After the social goals (and objectives) of water quality control are established, these must be translated into more specific standards which can be expressed by quantifiable, measurable parameters. To establish these standards, there must be some weighing and balancing of the costs against the benefits from various levels of improvement of water quality. The costs of water quality control, theoretically at least, can be calculated. Estimates have been made of the costs of meeting certain standards (for example, see The Cost of Clean Water reports by the Federal Water Pollution Control Agency).[10] Most studies in the past have been concerned with the costs of treatment but a report has been recently released which makes an attempt to assess the comprehensive economic impact of water pollution control efforts. This report includes the costs in terms of the closing of hundreds of factories, possible unemployment of thousands of workers, pushing of prices and imports up, and forcing the nation's production down.[11]

Evaluating benefits, however, run into two major obstacles. The first of these is our limited knowledge of the effects of water quality. One of the foremost issues relating to water quality standards is the lack of adequate knowledge concerning many of the quality characteristics of a physical, chemical, or biological nature demanded by aquatic life, industrial process, or other use.[12] The drastic effects such as massive fish kills are easily recognized but quite often the true cause of such events cannot be defined even in extensive retrospective studies. There is also the challenge of detecting, understanding, and then preventing the more subtle, long-term effects of pollution. Such effects are illustrated by the accumulation of such substances as mercury and pesticides in animals which has recently come to light. The other major problem is that many effects, even if understood, seem to defy quantification, such as aesthetic enjoyment and preserving the functioning of natural ecosystems.

However, there is almost universal agreement that some action must be taken to improve the quality of the water so it is necessary to substitute judgement and intuition for lacking knowledge. All standards which are set for water quality includes some balancing of benefits and costs by a mixture of knowledge and judgement. Most of the controversy in the field involves the use of value judgements of benefits. A good example of this is the Congressional Bill proposed by Senator Muskie which would prohibit the discharge of any pollutants by the year 1985. The costs of meeting this requirement would be enormous. One rough estimate of the costs involved places them at $2.34 trillion dollars for the nation.[13] This bill is not as stringent as many people have assumed but still the proponents of such a measure are apparently assuming that the non-measurable benefits would be very large.

Most water quality control programs now include water quality standards as the basic legal tool. These standards set desirable and permissible threshold limits on individual substances and characteristics in the receiving stream. They may also include criteria such as non-degradation of existing water quality and requirements of specified treatment levels such as secondary treatment.

The most pressing need for information is in the field of basic research to establish criteria and then standards for water quality. After standards have been set, an extensive stream monitoring system is needed to identify violations. Stream monitoring is also required to establish water quality baselines and trends. Assessment of changes in water quality are the most effective means of evaluating the effectiveness of water quality management programs.

In addition to stream monitoring, individual waste discharges must be inventoried and monitored. This is necessary to enable treatment plant operators to maintain optimum treatment efficiencies, to maintain a current knowledge of wastes entering each water body, and to assess the individual effects of each waste source on the waters into which wastes are discharged. Often in conjunction with stream standards are other requirements such as a uniform degree of treatment. Also, when stream standards are not being met, corrective actions by control agencies must be based on considerations of the quantity and quality of individual dischargers and their costs of waste treatment and other means of waste discharge reduction.

To project future water quality control needs, the economic base study projects industrial activity and disaggregates this information into small planning areas for types of industries. (see page 116 of Chapter 4.) Information on the quantity and characteristics of present waste discharges, by specific types of industries, are needed to estimate the water quality control problems of the future. Studies based on monitoring programs can help furnish this type of information.

Types of Information Needed

The types of information needed for control of water quality include: (1) criteria by which the quality relative to use can be judged, (2) monitoring of existing water quality based on the parameters included in the criteria and standards, (3) inventory of waste discharges, including quantity and quality of individual waste discharges, and (4) economic information on costs of waste discharge reduction for individual sources.

The setting of standards is primarily a problem of basic research, including both scientific and socio-economic considerations. The International Joint Commission recommended specific objectives for the lower Great Lakes. These do not apply in areas of proximity to outfalls where mixing zones must be studied. It is stated in the report that these parameters are intentionally limited to those believed to be most meaningful in relation to International Joint Commission responsibilities. These objectives are designed to protect the international waters for the most restrictive use in each case. Parameters 1 through 9 are those for which objectives have been established. Parameters 10 through 17 are additional parameters which should be considered for joint United States-Canadian standards. These specific objectives are:[14]

(1) Coliform Group. The geometric means of not less than five samples taken over not more than a 30-day period shall not exceed 1,000/100 ml total coliforms, nor 200/100 ml fecal coliforms in local waters.

(2) Dissolved Oxygen. In the connecting channels and in the upper waters of the (Lower) Lakes not less than 6.0 mg/l at any time; in the hypolimnetic water not less than the concentrations necessary for the support of fish life, particulary cold water species.

(3) Total Dissolved Solids. Less than 200 mg/l in Lake Erie, Lake Ontario, and the International Section of the Saint Lawrence River; in the Saint Marys River, pending

the results of a study of the Upper Great Lakes, a level of total dissolved solids not exceeding that of 1970; and in the other connecting channels a level consistent with maintaining the levels of total dissolved solids in Lake Erie and Lake Ontario less than 200 mg/l.

(4) Temperature. No change which would adversely affect any local or general use of these waters. (The problem here is in defining the temperature change that would have adverse affects. Much research is needed into this complex problem.)

(5) Taste and Odor. No objectionable taste or odor. Phenols desirably absent but not to exceed a monthly average of 0.001 mg/l. Other taste and odor producing substances absent.

(6) pH. No change from the present range of levels, 6.7 to 8.5.

(7) Iron. Less than 0.3 mg/l.

(8) Phosphorus. Concentrations limited to the extent necessary to prevent nuisance growths of algae, weeds, and slimes which are or may become injurious to any beneficial water use. Phosphorus loadings to Lake Erie and Lake Ontario (in grams total phosphorus per square meter of lake surface per year) have been defined to meet the objective.

(9) Radioactivity. Elimination of radioactive materials to the extent necessary to prevent harmful effects on health. Pending the adoption of more stringent limits,

in no event is gross beta activity to exceed 1,000 pCi/l, Radium-226 not to exceed 3 pCi/l, and Strontium-90 not to exceed 10 pCi/l.

The remaining parameters are those for which objectives have not been set, but which should be considered in joint standards:

(10) Metals (other than iron).

(11) Pesticides.

(12) Ammonia Nitrogen.

(13) Oil

(14) Methylene blue active substances (MBAS).

(15) Chloride.

(16) Sulfate

(17) Fluoride.

Monitoring of water quality represents the greatest problem in basic data collection and handling for water quality control. The Lake Ontario basin contains more than 28,000 miles of rivers and streams and 449,300 acres of rivers, lakes, and embayments, on the United States side alone. In addition, Lake Ontario itself has a surface area of 7,340 square miles.[15] Obviously, there is no limit to the amount of data which could be accumulated over time on all of these streams and lakes. To make the most effective use of limited resources, careful consideration must be given to the number and location of stations, sampling frequencies, and parameters measured, to maintain the best coverage possible for control purposes and water quality baseline studies.

A sample of polluted water can contain many chemical and biological constituents. Some of these are valuable indicators of water quality while others serve only as troublesome interferences in other analyses. The first consideration for monitoring is to select those parameters required to characterize the sample, considering the past history of the water body and the planned or desired uses. The Environmental Protection Agency's computerized storage and retrieval system, STORET, for water quality data can list 425 water quality parameters but only a limited number are required or possible at any single sampling station.[16] Decisions regarding which parameters to omit are just as important as which ones to include. Unnecessary determinations not only add nothing of value but waste valuable time and resources which could be used for more frequent analyses or important characteristics.

The parameters used to characterize water quality are of two main types--basic water quality characteristics and specific waste constituents. The specific constituents are those chemical substances which in themselves are undesirable or at least potentially so. Water quality characteristics are not undesirable constituents but indicate effects on the quality in various ways and include such things as biological oxygen demand, temperature, and alkalinity. For example, biological oxygen demand is important as an indicator of the amount of dissolved oxygen that will be used while the waste is being degraded. Certain coliform organisms are measured as surrogates for the pathogenic organisms which are hazardous to health.

For the purposes of enforcing standards, the extreme values are of greater concern than averages. To guarantee full compliance would require continuous sampling and analysis of all of the indices of quality. Since the cost of this at all stations would be prohibitive, practical sampling frequencies should be based on the following:[17]

-- the particular index of quality requiring the most frequent evaluation;
-- the importance of the water uses being protected at the location and the impact of a violation on these uses;
-- the potential for brief violations to occur.

Many of the parameters of water quality can vary greatly over a relatively short time period such as the diurnal variation of dissolved oxygen or sudden industrial spills and accidental discharges. The need for in situ, automatic, continuous monitoring is apparent. Since the basic goal is the control of water quality rather than merely measurement, the use of monitoring equipment to sound an alarm or even to automatically initiate action by control mechanisms should be an essential part of the monitoring concept. Another great need for continuous data is research to determine relationships between various parameters to evaluate the efforts of control activities.

There are a number of limitations on automatic monitors which limit their use at the present time. One concern is the cost. Not only do the instruments themselves cost money but they require routine maintenance by generally higher salaried personnel than are required for manual sample collection. The number of parameters presently measurable by such means is rather limited. Also, a vast amount of data is generated, some of which may not be necessary, and which may require more elaborate and expensive data handling procedures. Nevertheless, the prospect of keeping a continuous check on the pulse of a stream is an attractive prospect and has created a growing interest.

An example of an automated system of monitoring is the Ohio River Valley Water Sanitation Commission system installed in 1960. The system consists of 14 field stations, a central receiving station, and a data processing system. All field stations are equiped with transmitters for telemetering data to headquarters on leased teletype-grade lines. Each field station has multiple analyzer units which use sensors for measuring these water quality characteristics: pH, oxidation-reduction potential (ORP), chloride, dissolved oxygen, conductivity, temperature, and solar radiation. Not all measurements are made at each station. ORP is included at some stations on an experimental basis to determine any correlation between the state of oxidation or reduction and quality conditions.

ORSANCO headquarters automatically interrogates once each hour and receives data on conditions as they are being measured at that moment. Data is automatically punched on paper tape for use by the computer.[18]

Current Activities in Information and Data Collection

Stream Monitoring

Activities in collecting and disseminating information for the water quality problem have been directed primarily toward stream monitoring of water quality parameters. There are a number of agencies involved in this basic data collection and there have been efforts made to coordinate the collection and dissemination of the data to interested parties. Unfortunately, these efforts have been generally made for only one side or the other of the lake with little effort at international coordination for the entire Lake Ontario basin.

Most of the attempts at data coordination are concerned with state and federal agencies. But a significant amount of information is collected at the local level. Most municipal water treatment facilities and many waste water treatment plants routinely monitor the quality of water received and discharged, and could provide a source of considerable information. Other local or private sources, such as university research programs should also be considered as a source of water quality data. An information system for water quality control should consider these sources, even though it may be difficult to locate the sources and develop an efficient procedure for routinely obtaining the data. The quality of the data may often be questionable and the formats in which it is stored and reported may not be standardized.

United States-Federal. More than a dozen federal agencies in the United States are involved in the direct acquisition of water quality data. In 1964, United States Bureau of the Budget Circular A-67 called upon the Department of the Interior to coordinate water data acquisition activities of federal agencies. To carry out this coordination, the Office of Water Data Coordination was established within the Interior Department's Geological Survey. Certain state agencies, municipal agencies, and private organizations also participate in the program. No effort was made by the office to contact all non-federal agencies. An attempt was made to contact those agencies most active in water-data acquisition in their state, thus obtaining extensive, although not necessarily complete coverage. Some of the agencies contacted indicated they would be willing to participate but were unable to do so at present because of manpower limitations.[19]

The Office of Water Data Coordination does not collect or store the actual data--this must be obtained from the reporting agencies. One of the responsibilities of the office is to maintain a Catalog of Information on Water Data. One section of this catalog is the Index to Water

Quality Section. The catalog is a file of information about water data acquisition activities. This information is available on media suitable for data processing, supplemented by microforms and station-location maps. The Index to Water Quality Section contains: (1) identification and location of stations, (2) major types of data collected, (3) period of record of collection, (4) frequency of data collection, (5) in what form the data are stored, and (6) agencies reporting the data.

The Budget Circular also contains guidelines for developing a national network to acquire water data. In the field of water quality, plans for integrated state-federal water quality monitoring systems for a number of Environmental Protection Agency regions have been developed and are being implemented.[20] The nation-wide water quality surveillance system will use existing programs of the EPA, state pollution control agencies, and other federal water data collection agencies, principally the United States Geological Survey. To coordinate and evaluate water quality data, the EPA has developed its STORET (acronym for STOrage and RETrieval) system. This system, with a central computer in Washington, D. C., provides a central repository for all water quality and related data collected by EPA. The system is still being developed and several federal and state agencies are currently supplying and receiving data. The data collected are entered in the central computer on a daily and weekly basis by remote terminals in all EPA regions. The remote terminals can also be used to obtain timely information from the central computer.

The data stored in the STORET system includes water quality data, municipal and industrial waste facility inventory, water quality standards compliance, fish kill, oil spill, construction cost, and other related data. This large data base can be drawn on for raw data in printed form. Data can also be retrieved in statistically analyzed form. Calculations can be provided of monthly and annual averages and trends, comparisons between results at different sampling stations, and correlations between such different water quality parameters as dissolved oxygen, waste load, and temperature. Also available are other types of analyses such as comparison of water quality to federal-state standards and digital plotting of data and maps. The parameters measured at long term water quality stations by the Environmental Protection Agency in the Lake Ontario basin are shown in table 6.

One of the main purposes of STORET is to provide for an exchange of data but the availability of sensitive data may be restricted to a single user. STORET began as a computer-oriented system for storage and retrieval of raw water quality data and has evolved to include other data and processing capabilities. It will continue to grow as required to allow it to fulfill its role as a responsive management information system. A variety of output formats

Table 6

Water Quality Parameters Measured by the Environmental Protection Agency (Lake Ontario Basin Office)

<u>Chemistry</u>

1. Water Temperature
2. pH
3. Specific Conductance
4. Alkalinity
5. Turbidity
6. Dissolved Oxygen
7. BOD*
8. COD
9. $N-NH_3$
10. $N-NO_3$
11. N-Organic
12. Phosphates
13. Solids
14. Chlorides
15. Sulfates
16. SiO_2
17. Magnesium
18. Iron*
19. Calcium

* Not measured at all stations

<u>Biology</u>

Benthic Fauna
Phytoplankton
Chlorophyll

<u>Microbiology</u>

Coliform
Fecal Strep
Fecal Coliform

<u>Special</u> - Federal Water Quality Monitoring Network Station

Pesticides
Toxic Metals
Trace elements
Radioactivity
Potassium
Sodium

Source: Letter of January 24, 1972, from R.L. Flint, Jr., Environmental Protection Agency, to Dr. Anando Rao.

will eventually be offered for the raw data and statistical summaries using printers, magnetic tape, X-Y plotters, and cathode ray tubes.[21]

New York State. The New York State Department of Environmental Conservation operates a water quality surveillance program which appears to be a well designed, progressive program and could provide the major source of water quality data on the United States side of Lake Ontario. The major objective is to evaluate the water pollution abatement activities and determine their effects upon the water quality. To meet this objective the program is designed to:

-- Acquire, evaluate, and disseminate information on the quality of water for and from the varied local, state, inter-state, and federal agencies together with educational, commercial, industrial, and individual entities.

-- Determine the long term trend and variation of water quality.

-- Provide a rapid intelligence system for the preservation of the waters and the protection of the water users, including compliance with water quality standards.[22]

The program has four components: manual surveillance, automatic surveillance, aerial surveillance, and public surveillance. The stations for manual surveillance were selected to represent the general quality of the water in a given drainage basin and to indicate the effects upon this quality from upstream waste discharges. Manual surveillance is currently conducted at approximately 200 surface water sampling stations of which about 80 are operated by other agencies, municipalities, and industries. Only two of the stations are in Lake Ontario, but there is a large number in the drainage basin. Sampling frequency was initially set at an arbitrary frequency of one sample per month. This frequency was then varied depending upon the location. A sampling frequency of two times per month is generally used below major sources of pollution where gross pollution problems were found to exist. Several stations located on lakes are sampled only two or four times per year. Selected stations are sampled at other frequencies for microscopic organisms, phenols, radioactivity, oil, fluorides, heavy metals, pesticides, and toxic materials. The parameters measured are shown in table 7.

The automatic surveillance component of the program is intended to quickly detect undesirable conditions and act to eliminate them; to verify and provide a basis for improvement of stream survey evaluations and predictive models; and to show water quality trends for program management and public information purposes. The criteria established for locating the automatic monitors are:

-- The water quality and/or quantity at the site fluctuates rapidly.

Table 7

Water Quality Parameters Measured by New York State
Department of Environmental Conservation
(Manual Surveillance)

The chemical, bacteriological and physical parameters which are routinely measured at the water quality surveillance sampling stations are:

ABS (total apparent)	mg/l	Manganese as Mn	mg/l
Air Temperature *	Deg. C	Magnesium as Mg	mg/l
Alkalinity (Bi-Carb.)		Nitrates as N	mg/l
as $CaCO_3$	mg/l	Nitrites as N	mg/l
Alkalinity (Carb.) as		Nitrogen (organic as N)	mg/l
$CaCO_3$	mg/l	pH (at collection) *	
Ammonia as N	mg/l	pH (Laboratory) *	
BOD (5 day) *	mg/l	Phenols *	mg/l
Calcium as Ca	mg/l	Phosphates as PO_4	mg/l
Carbon Dioxide *	mg/l	Potassium as K	mg/l
Chloride as Cl-	mg/l	Residue on Evap. (Fixed)	mg/l
COD (Dichromate)	mg/l	Residue on Evap. (Total)	mg/l
Coliform (MPN or MF)	per 100 ml	Sodium as Na	mg/l
Color *		Sulfates as SO_4	mg/l
Conductivity	umhos	Suspended Solids (Fixed)	mg/l
Dissolved Oxygen *	mg/l	Suspended Solids (Total)	mg/l
Flow *	cfs	Total Plate Count *	per 100 ml
Fluorides as Fl- *	mg/l	Turbidity *	Jcu
Hardness as $CaCO_3$	mg/l	Water Temperature *	Deg. C
Iron as Fe-	mg/l		

* These parameters were not measured at all stations on a routine basis.
In addition to the above parameters, microscopic analysis (standard units) are performed on some samples collected at a limited number of stations.

Source: Water Quality Surveillance in New York State, (Ref. 22)

-- Site is in an area where there is a high potential for accidental spills of various wastes.

-- The site allows continuous evaluation of response of the stream system.[23]

The major automatic monitors measure the following water and air parameters: hydrogen ion concentration (pH), dissolved chloride concentration, dissolved oxygen concentration, dissolved fluoride concentration, conductivity, water temperature, turbidity, water stage height, solar radiation intensity, and air temperature. The minor monitors are essentially the same as the major monitors except that they measure less than the ten parameters listed above and do not have their own shelter. Satellite monitors are small, compact, and battery powered and transmit the data via radio to the major monitor. They measure only a small number of parameters and are used when it is impractical to install a major monitor or to measure certain parameters at the site of a major monitor. The Department of Environmental Conservation has proposed a total of 36 major monitors, 4 minor monitors, and 83 satellite monitors by 1976. None of these are in Lake Ontario.

Aerial surveillance is used on a limited scale. The two forms of aerial surveillance are aerial photography and remote sensing. Aerial photography uses both true color and false color infrared film and often can produce more information than can be contained in numerical measurements.

The true color film can show the presence of deleterious materials such as color, suspended and floating solids and oils. False color infrared film can indicate the presence of aquatic vegetation and algae. Remote sensing includes quantitative airborne thermal imaging and radiometry to detect temperature characteristics of the water, and ultraviolet scanning to detect oil. Numerical and pictorial data are obtained.

Of necessity, the formal water quality surveillance program cannot adequately cover all the waters in the state subject to pollution. To enlist the aid of the public, a "Water Watchers" program was established. Anyone interested in pollution control is requested to take note of and report any unusual events occurring in the waters. A telephone is available in the Water Quality Surveillance Section for reporting of events by calling collect. Besides providing information of water quality conditions, this program will hopefully form a basis for active public participation in the fight against water pollution.

Canada. In Canada, the agency primarily responsible for water pollution control is the newly created Office of Water Management, in the Ontario Ministry of the Environment. This office was formerly the Ontario Water Resources Commission. A routine monitoring program was begun in 1964 and by 1970 had expanded to include sampling at 650 locations on 137 rivers and at 2,000 locations on the Great Lakes and connecting channels. Automated collection (remote monitoring) was conducted at two locations but neither of these was in the Lake Ontario basin. Annual publications of collected data are released to interested parties.[24]

The bulk of computer processing is done on a computer located at the Ontario Department of Highways. The design of a Water Quality Information System was completed in 1970. Storage and retrieval segments of the Water Quality Monitoring system has been implemented and programs are being written and tested to process water quality data gathered from survey work on the Great Lakes.[25]

Lake Surveys

The information sources cited so far have been concerned primarily with monitoring of water quality in streams. There are several additional information sources which are concerned with water quality in Lake Ontario itself. Data collection in the lake has been mainly done for research purposes, whereas stream monitoring is usually concerned more with locating and controlling pollution sources.

One source of such information is the United States National Oceanic and Atmospheric Administration of the Department of Commerce. This administration absorbed the United States Lake Survey from the Army Corps of Engineers in 1970. Data have been obtained in the past from periodic surveys conducted by research vessels, but studies are underway to establish continuous monitoring stations. Projects have been started to compile available data pertaining to chemical and physical properties of the water, evaluate the data, and collect supplementary data where serious data deficiencies exist. The assembled data are placed on cards in a standardized format for computer processing, handling, and correlation. Research projects are coordinated with the Environmental Protection Agency and Canadian agencies.[26]

The Great Lakes Research Division of the University of Michigan has two well equipped research vessels with which it conducts research on the Great Lakes. Research activities include the collection of water quality data. Thus far research has been confined to Lakes Michigan, Huron, and Superior because of staff and facilities limitations. Theoretically though, the division is interested in all of the Great Lakes and might be a means of obtaining additional data on Lake Ontario, through research grants, if such data are needed.[27]

The Canada Centre for Inland Waters is the major federal interdisciplinary water resources research institute in Canada. The Centre's initial programs have been directed toward research in the Great Lakes and it has available a research vessel. A full year of chemical monitor data was accumulated for Lake Ontario for monthly cruises starting in April, 1969 and ending in March, 1970. After cruises, preliminary charts of surface distribution of temperature, dissolved oxygen content, conductivity, and turbidity are made up and distributed to interested individuals and agencies. The regular full chemistry monitor cruises include analyses for ortho-phosphate, soluble reactive silica, nitrate + nitrite, ammonia, total alkalinity, specific conductance, turbidity, dissolved oxygen, pH, total phosphate, total organic nitrogen, and 20 other specific metals and elements including mercury. Most of these analyses were conducted on only a limited number of samples.[28] Computer programs are being developed to facilitate retrieval and analysis of cruise data and the data is in a form available for retrieval, sorting, and statistical testing by a variety of computer programs.[29]

Inventory of Waste Discharges and Facilities

In addition to water quality data, detailed knowledge of waste sources, treatment and discharges is also necessary to develop and implement programs for water quality control. Reasonably good information is available about municipal sewage and waste water contributions. On a national scale, the EPA completed the processing and analysis of data on municipal waste facilities during 1969 and has published the inventory. Because of the need for timely and accurate data, procedures have been developed for bringing this inventory up to date and keeping it current.[30] Information contained in the inventory includes the location of the facility, place (stream, lake, land, etc.) of waste water discharge, population served, daily flow, type of treatment, population equivalent of BOD (for untreated and discharged water), treatment needs, and remarks.[31]

Unfortunately, there has not been any such nationwide inventory of industrial waste sources published. Plans have been made by the Environmental Protection Agency to initiate an inventory of industrial manufacturing and processing plants. Initially, this will be an in-house effort and will eventually be expanded to a joint EPA-state cooperative project. The EPA STORET system will be used to store and evaluate the data and make it readily available to all users. Some information on industrial waste facilities is available from STORET now.

In Canada, the Ministry of the Environment, in carrying out its industrial pollution control program, regularly surveys all sources of industrial pollution and prepares reports describing the quantity and quality of the discharges. The status of pollution control at each industry is assessed and appropriate remedial measures are recommended where required to bring effluent quality in line with the government objectives. Problems associated with discharges of industrial wastes to municipal sewers are also investigated.

The office also has the task of reviewing engineering plans from industry where the effluent from the proposed treatment works is to be discharged into a water course, and issues certificates of approval. Because of this regulatory function, the emphasis of survey activities has shifted. Since a growing percentage of waste discharges programs have been reviewed and approved, there are less in-depth surveys required to identify problems. Pollution problems are now identified and corrected before they are created and there is an increasing emphasis on routine surveillance visits and unannounced spot checks to insure that treatment plants are operated as approved.[32]

Fortunately, there is available a considerable amount of information about pollution of Lake Ontario and Lake Erie. In 1960, the Congress of the United States appropriated funds to launch a comprehensive pollution study of the Great Lakes. Actual studies of Lake Erie began in 1963, and of Lake Ontario and the international section of the Saint Lawrence River in 1964. The research and technical data work was begun by the Department of Health, Education, and Welfare and after reorganization, continued by the Department of the Interior. These departments were responsible for water pollution control activities before the creation of the Environmental Protection Agency.

These studies were used in preparing the report Pollution of Lake Erie, Lake Ontario, and the International Section of the Saint Lawrence River by the International Joint Commission in 1969. In Canada, studies of the lower Great Lakes for this report began in 1964, after water pollution became a matter of reference to the IJC by the two governments. The Department of National Health and Welfare, the Department of Energy, Mines and Resources, the Fisheries Research Board of Canada, and the Ontario Water Resources Commission all initiated programs to develop data on which to base recommendations for the necessary remedial action on the two lakes.[33]

One of the important results of these studies is the identification and characterization of sources of wastes being discharged into Lake Ontario and the Saint Lawrence River. Of primary importance here are industrial and municipal wastes. Other sources studied include shipping, dredging, sediment accumulations, and atmospheric sources.

Figure 5 shows the location of major municipal, industrial and tributary waste loadings to Lake Ontario and the Saint Lawrence River. The list of municipal and industrial dischargers and the characteristics of their wastes is too long to be reproduced here. But examples of the information available are shown in tables 8 and 9. The major pollutants of municipal wastes are biochemical oxygen demand, chlorides, phosphorus, and nitrogen. The municipal loadings include waste waters from both domestic populations and industries connected to municipal sewerage systems. About one third of the industries in the Lake Ontario basin are connected to municipal sewerage systems.

The characteristics of industrial wastes are quite varied. Those most commonly measured include biochemical oxygen demand (BOD_5), total and suspended solids, total nitrogen, total phosphorus, and chlorides. Other important parameters peculiar to specific industries may include acids, alkalis, oil, phenols, cyanide, and iron. Pesticides and herbicides and other synthetic organic chemi-

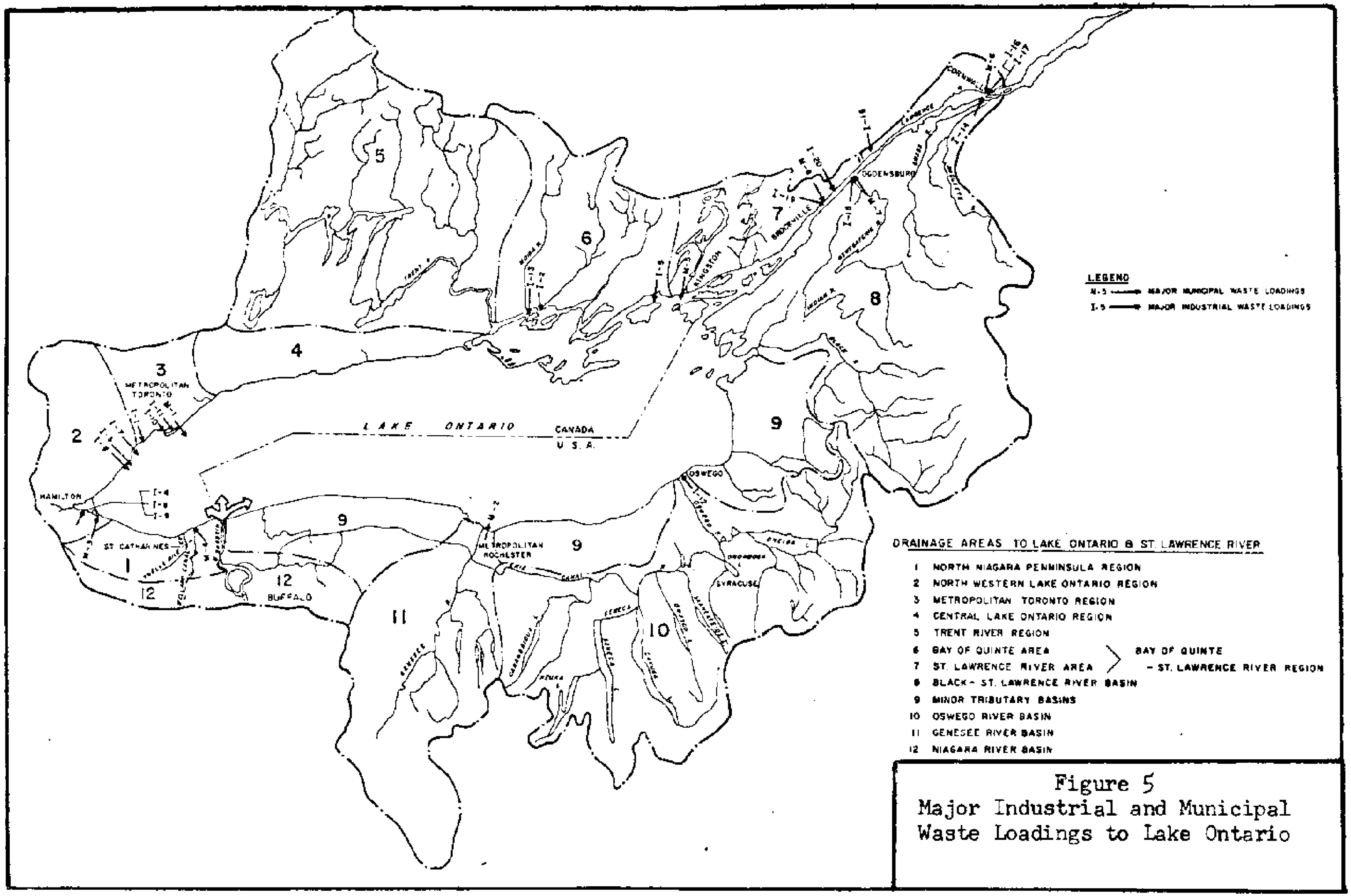


Figure 5
Major Industrial and Municipal
Waste Loadings to Lake Ontario

Source: Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River (Ref. 33)

Table 8

Example of Municipal Waste Discharge Information in the Lake Ontario Area
1966-1967 (short tons/year)

Municipalities Lake Ontario	Map index	Existing treatment	Sewage flow (mgd)	Population served with sewers (thousands)	BOD_5	Solids Total	Solids Susp.	Total nitrogen (N)	Total phosphorus (P)	Chlorides
Ontario										
North Niagara Peninsula Region										
Niagara-on-the-lake	M-1	Lagoon	0.2	2.9	2	167	5	3	2	21
St. Catharines -Port Weller	M-2	Primary	6.5	65.0	937	7,770	1,410	453	89	1,100
- Port Dalhousie	M-3	Primary	3.0	30.0	372	3,160	372	138	36	509
Beamsville	M-4	Secondary	0.3	3.8	15	372	25	16	5	55
N. Grimsby										
- Grimsby Beach	M-5	Secondary	-	0.5	4	52	4	5	1	7
- Grimsby Biggar	M-6	Lagoon	0.1	0.5	3	140	5	3	1	13
Northwestern Lake Ontario										
Hamilton	M-7	Primary	36.1	283	3,360	38,900	3,950	1,060	193	6,520
Burlington										
- Skyway	M-8	Secondary	3.9	(	50	3,960	35	86	40	776
- Drury Lane	M-9	Secondary	1.5	(65.4	15	2.160	22	46	20	268
- Elizabeth Gdns.	M-10	Secondary	0.8	(	20	700	15	25	11	144

Source: Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence (Ref. 33)

Table 9

Examples of Industrial Waste Discharge Information in the Lake Ontario Area
1966-1967 (short tons/year)

Principal discharges

Industries Lake Ontario	Map index	Existing treatment	Flow (mgd)	BOD_5	Solids Total	Solids Susp.	Total nitrogen (N)	Total phosphorus (P)	Chlorides
Ontario									
North Niagara Peninsula Region									
Louth Twp.									
- Culverhouse Canning Ltd.	1-1	None	0.1	91	167	16	1	-	-
Saltfleet Twp.									
- E.D. Smith & Sons	1-2	Screening, Aerated Lagoon	0.2	15	70	7	1	-	-

Other discharges

Industries	Total Iron	Dissol. Iron	Sulphate	Sulphite	Ether Solubles	COD	Cyanide	Phenols	Others
Lake Ontario									
Steel Co. Canada Ltd. (Parkdale)	12		42		1	10		0	Chromium 19 Alk. 42 ($CaCO_3$)
Steel Co. Canada Ltd. (#2 Rod Mill)	150	1	314		16	3,000			
Firestone Tire & Rubber	1								
Domtar Chemicals Ltd.					1	27		2	Alk. 4 ($CaCO_3$)

Source: Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence (Ref. 33) cals are also of increasing concern. There is also a problem of waste heat due to power generation.

The oxygen demanding wastes are degraded by natural biological activity in the lake and streams but many of the substances and nutrients are not degraded and produce a lasting effect on the lake. Several indicators of water quality were studied in the lake, to indicate the zones of influence of the pollution loads. Isopleths were constructed of total phosphorus, soluble ortho-phosphate, ammonia, chlorides, conductivity, and coliforms.

Interpretation of Water Quality Information

As the amount of data collected on water quality increases, especially as continuous monitoring becomes more prevalent, methods for interpreting and analyzing the data will become more critical. As in many other fields, the electronic computer has become an invaluable tool. The vast amounts of data generated can be stored much more efficiently, but possibly more important, routines can be developed to retrieve the data in analyzed form for use by decision-makers.

The ORSANCO monitoring system provides an example of the problems of data interpretation. With 14 automatic field monitors, the amount of data collected is so great that manual processing becomes physically and economically impossible. To summarize manually the data collected during one year, showing daily averages, maximums and minimums for all quality characteristics at all stations would require 150 man-years. The system can produce more than 650,000 items of data per year, but something less than this is actually received due to technical difficulties and erroneous items. If these were corrected, the amount of data to be processed would increase 15-25% over that now received.[34]

The first task in the processing of the data is editing and validating. This is necessary because of the possibility of instrument error or equipment malfunction. A number of tests have been established for validating the data and can be performed by the computer. About 99% of the decisions on acceptance or rejection of data are made automatically. The remaining 1% must rest on personal judgement.[35]

To facilitate retrieval of monitoring information, the stations must be indexed on a geographical location basis. The STORET system uses a hydrologic index and geographical coordinates (latitude-longitude).[36] The hydrologic index locates a station on a defined river system and thus allows sorting and retrieval of data records in relation to direction and level of stream flow. Hydrologically indexed data is retrieved by specifying the beginning and ending indexes of the stream to be studied. Retrieval of information in hydrologic order can be useful, for example, in tracing a contaminant downstream. Geographical coordinates can be used for large open bodies of water and locations which cannot be readily associated with points on a stream. Other advantages are that it avoids the complex river-mile-index coding and provides a rapid and familiar method of defining station locations. Data is retrieved for this method by giving the coordinates of the vertices of the polygon or polygons.

The computer can handle and deal with the tremendous number of individual data items but the human mind cannot comprehend this data without methods of interpretation and aggregation. There are a number of ways in which water quality data are currently interpreted and evaluated. Standard mathematical characterization of the data include such calculations as summaries of average, maximum, and minimum values of a certain parameter over time, and statistical evaluations include such things as frequencies of occurence of values and percent of time certain values are exceeded. These types of interpretation basically relate quality conditions to time.

Graphical displays of data are valuable in relating quality conditions to time and especially in exploring geographical relationships. Geographical relationships are especially valuable in water quality control due to the movement of pollutants by river flow. The ORSANCO staff uses an interesting graph called a qualigram which shows quality data plotted in terms of frequency of occurrence and geographical location. An example of a qualigram is shown in figure 6. This device provides a means of weighing actual stream conditions against an established objective for it shows at a glance the percent of time the objective is met. Also by overlaying graphs for different years, conditions over time can be determined, allowing an evaluation of progress being made by control programs.[37] The STORET system is capable of digital plotting of data and maps.[38]

Both the ORSANCO staff and the New York Department of Environmental Conservation have shown interest in index numbers as a means of a quick reference system of water quality status. An index number represents the composite influence of various parameters weighted according to their importance. Such indices should be devised so that parameters well above requirements cannot override deficiencies of other parameters.[39, 40]

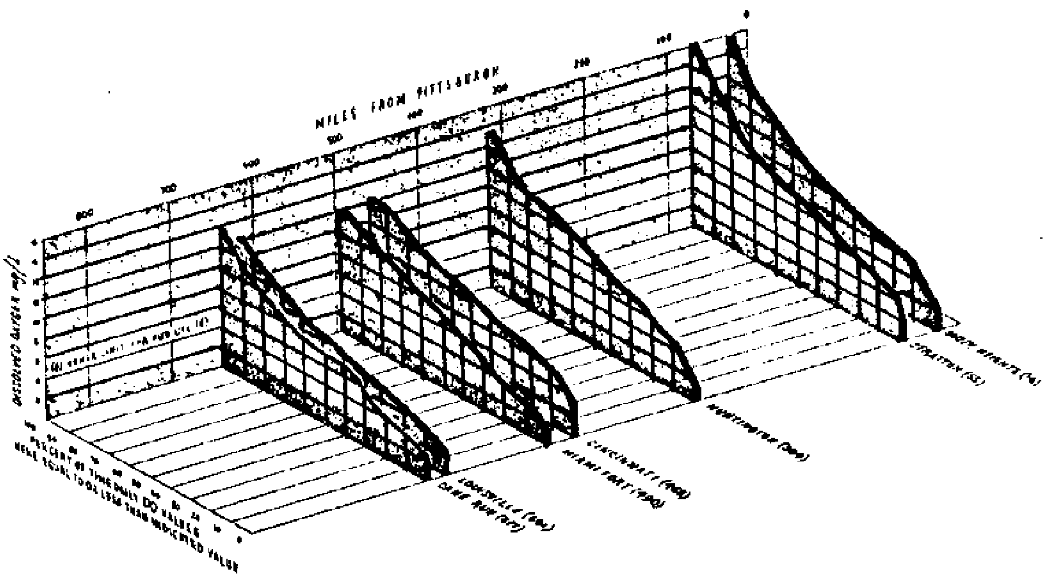
Interpretation, including data presentation, is a vital part of assessing water quality conditions. It is in this aspect of effort that the federal agencies concerned with water quality surveillance have been lagging. Examples of data presentation are shown in figures 7 and 8. Supplementary narrative information should accompany each visual presentation. Simple assemblies of data suggest an unrealistic static condition by indicating only the current levels of water quality. Interpretive reports should offer not only this data but also delineate various factors and interrelationships that influence water quality over an entire stream system, a section of stream, or at any given

Figure 6
Examples: Water Quality Data Presentation

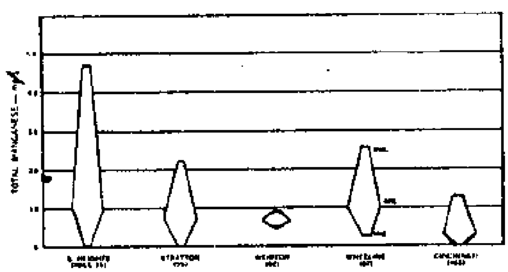
Source: <u>Assessment of the Adequacy of Water Supplies - Water Quality Aspects</u>, (Ref. 41)

<u>Illustrative Examples: Data as Presented by</u>

<u>Ohio River Valley Water Sanitation Commission</u>



DISSOLVED-OXYGEN QUALIGRAMS
(Period of record — 1964-65 except for Miami Fort, June 1964-May 1966, and Cane Run, July 1965-June 1966)



MANGANESE RANGES 1963-65

Graphs taken from <u>Eighteenth Yearbook 1966</u>,

Ohio River Valley Water Sanitation Commission.

Figure 7
Examples: Water Quality Data Presentation

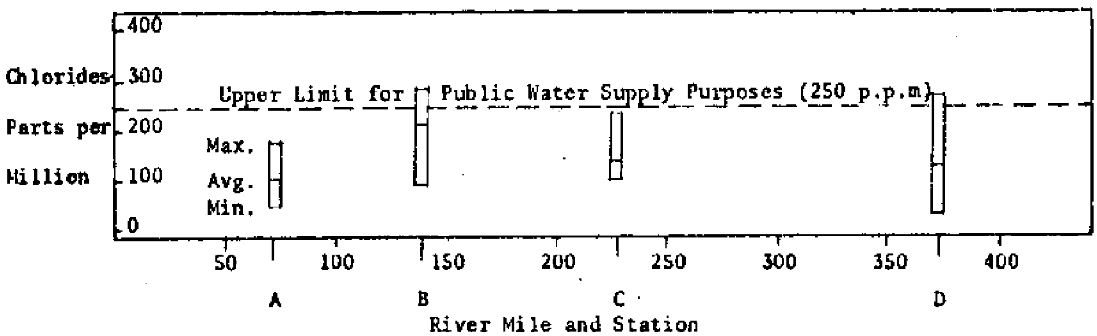
Source: Assessment of the Adequacy of Water Supplies - Water Quality Aspects, (Ref. 41)

1. Tabular Presentation of Polluting Substances.

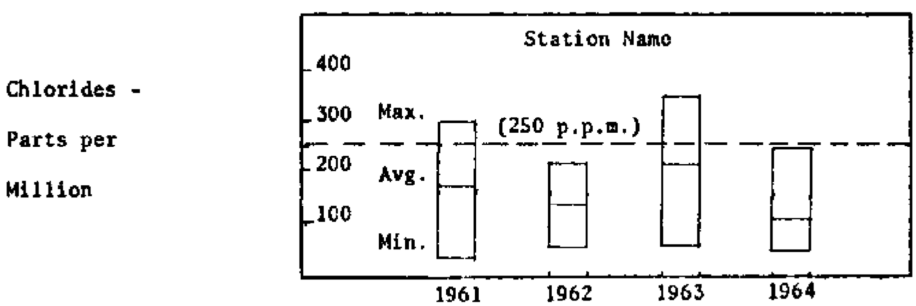
Chlorides - Parts per Million.

Station	Range		Average	
	Minimum	Maximum	Monthly	Annual
Name and River Mile Ditto				

2. Graphical Presentation of Polluting Substances by Station and River Mile.



3. Graphical Presentation of Polluting Substances by Station-Year.



location. This should provide a basis for estimating future conditions resulting from such matters as population and industrial growth, waste abatement, or future resource developmental programs. Interpretation should be based on the particular region's established and expected water uses. The water quality parameters of importance will be those which normally affect the principal water uses.[41]

Water quality surveillance programs and waste discharge inventories are objective, desirable methods for assessing the quality of water. However, it must be recognized that data deficiencies and the difficulty of quantitatively defining all pollution problems may require supplementary methods of assessment. Narrative summaries, backed up where feasible by tables and charts can fill gaps left by other methods by allowing subjective expressions for local areas by expert field personnel of various agencies. This method could include information on such indicators as agency appropriations, expenditures, administrative and regulatory action, enforcement conferences, and hearings. It can also include information on problems not adequately covered by other methods, such as fish kills, heat, aquatic plant growth, and underground pollution.[42]

In spite of the large quantities of water quality data existing in various locations, it is still difficult to gain an understanding of the nature and extent of the water quality problem. This is due largely to the physical complexity of the problem as well as lack of interpretation and reporting.

The variability of many characteristics require continuous monitoring; but the cost of continuous monitoring precludes its extensive use. Also, the geographical variability should require many more station locations than are presently used. The lack of adequate data is a serious problem in assessing existing or past conditions.

The lack of knowledge of industrial wastes is another serious information deficiency. Only by understanding the causes of the water quality problem can effective solutions be hoped for.

In assessing water quality, especially for the benefit of the public, the available data must be compared with some standard to give meaning to the data. State and federal stream standards are obvious and logical standards of comparison. But this comparison can present problems. For example, which of the many characteristics are most important, how often are the standards violated, by how much are the standards violated, and at how many points on the stream are the standards violated?

One approach might be to use the index number idea discussed previously to weight the various characteristics of water quality according to their importance for the water use. Measurements of all the characteristics at one location at a particular time could be combined into one index number. A frequency curve of index numbers similar to a flow duration curve could be drawn at each station and criteria developed to classify the water quality at the station.

The criteria should take into account both magnitude and frequency of occurence of the index numbers and would depend on the use of the water. It might be allowable, for example, for some uses to have low quality water at infrequent intervals, but for other uses even infrequent low quality conditions might be unacceptable. The criteria could be used to classify the water as simply low, medium, or high or a numerical rating scale might be used. A map showing the classified quality of streams and water bodies could be developed and when overlayed with a map showing water requirements, could identify problem areas.

As discussed in the framework for developing an information system (Chapter 3), certain uses of information such as public information, policy-making, and to a certain extent, planning, may require information in a highly interpreted, narrative format. This narrative may be supplemented by easily understood figures, numbers, and pictoral presentations. Ease of understanding is an important consideration and, especially in the case of public information, attracting the interest of the user of the information. The information presented should include an assessment of water quality conditions, trends, results of programs, and options for the future.

A good example of the type of public reporting needed is the article of the National Geographic on the restoration of the Williamette River in Oregon.[43] With attractive, impressive pictures and a well-written text, this type of article can attract the reader's interest and inform him in an interesting, enjoyable, and thorough (for his purposes) manner. As opposed to the more technical reports of many water agencies, this type of reporting may present less data but more information--in the sense that information is data that is meaningful to the user.

Implications for the Information System

There are a number of agencies and groups collecting basic water quality data in the Lake Ontario region. Several of these are relatively comprehensive and well organized systems, including such things as automatic monitoring and computerized storage and retrieval. One of the first tasks of the information system is to assess the existing information for such factors as its quality, availability, comprehensiveness, and suitability for the office's purposes. Lines of communication for transferral of such routine, technical information should be relatively easy to establish, possibly by remote computer terminals.

However, due to the scope of the surveillance problem, there is practically no limit to the amount of data which could be collected on the many miles of streams and lakes. There will probably be gaps in coverage which the office will fill in by collecting the data or sponsoring such collection by others. This is especially true in the lake area itself. Other types of information such as industrial waste inventories are not as readily available and may have to be collected by the information system of the office. Even when information is collected by the office it may be desirable to use an existing system (or systems) such as the Environmental Protection Agency's STORET for storage and processing of the data. This could help to avoid the need for a large, costly computer operation for the information system.

The causes of water quality control problems are generally local in nature. Control functions are decentralized, both by geography and authority. Also, problems requiring immediate action, such as standards violations, fish kills, and accidental spills of toxic materials, can occur very quickly. All of these factors emphasize the need for a communication network to rapidly receive information from many sources, interpret it, and disseminate it to many users. Procedures will have to be established well in advance of any crisis situations and means of rapid communication such as the telephone, teletypes, and remote computer terminals will have to be used.

The large quantities of basic data collected, the complexity of using all this data to assess and control water quality, and the many different users involved, require that interpretation and reporting of information be a vital task of the information system. Uses of the information will vary from scientific research which requires detailed, technical data, to public information which will require highly aggregated, summarized, and interpreted information. A wide range of methods of interpretation and reporting will be required to satisfy the variety of users.

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Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The need for an international management organization for the Great Lakes area, with an appropriate degree of comprehensiveness in the beginning, is not yet recognized or acknowledged by leaders of the two countries. Given the importance of the region to both the United States and Canada, and the importance of the water resource to the region, such an organization seems inevitable at some point in the future. This study initiates a practical approach toward such an organization and shows how the task of information management, as part of an Experimental Operations Office for Lake Ontario, can be effected. However, the findings and conclusions of this study are not dependent on the exact nature of the management organization. It is suggested that even the International Joint Commission with its limited powers could be given the responsibility of developing a broader information system, beyond that authorized for water pollution, for its own use as well as the use of the public, other decision-makers, and water resource planning and management agencies in the region. The major conclusions regarding the information system are listed and discussed below.

(1) An information system is needed to move toward comprehensive planning and management. The interdisciplinary nature of water resources planning and management requires a tremendous amount of information from many diverse fields of human knowledge. The information requirements range from abstract, philosophical knowledge of human values and ideals to the most technical knowledge of complex physical and biological phenomena. In many, if not most, areas, the information available is superficial and the need for additional information is very real. But even the amount of information currently existing is so large and diffuse that it has overwhelmed our ability to deal with it effectively and make the most use of it to solve our problems. Because of the amount of information needed, a high priority must be given to developing an effective system for dealing with it.

(2) An information system is not merely a data bank. Fascination with computerized techniques for storing and retrieving large amounts of data must not obscure the other aspects of the information system. The "data bank" approach has proven to be a failure in other areas due to a lack of consideration of the organizational and decision-making needs for information. The needs of the users must be the guiding consideration. Interpretation and reporting methods are vital and must be carefully developed for all of the different users. Limitations of the computer in handling nonquantifiable information and converting data into knowledge

must be recognized. Fresh approaches to the use of the computer must be explored--for example, maintaining up-to-date information on organizations and their interests and personnel so sources of non-quantifiable information, such as reports and people, can be easily located. Establishing lines of communication for collecting and disseminating information is a basic function of the system.

(3) The information system is an integral part of the organization. This is a corollary of the previous conclusion. In analyzing the needs of the users, an analysis of the entire decision-making process is necessary. The system should not be considered as only a tool to supply information which is currently used. Capabilities for handling more detailed information or new kinds of information may affect the basic techniques and methods by which decisions are made. The system should be concerned with communication between organizational units and is analogous to the nervous system of an organism. All aspects of management, from high-level policy decisions down to routine day-to-day operation, depend on information flows. Being such an integral part of the organization, the information system may be an important determinant of the structural design and functioning of the organization. The design and operation of the system should involve all levels of decision-makers.

(4) There currently exists a large amount of information about the region. Due to the diversity of information needed, the sources of such information are many and diverse.

Lack of coordination among the sources has led to a wide variation in the quality of the information and the formats in which it is available. Much of the information is not readily available, having been collected for specific uses with little or no thought given to dissemination to other users. However, there are a number of information systems in operation or being developed. These are of limited scope dealing with specific areas such as water quality, water quantity, and economic-demographic data--and they are not international.

(5) The management agency will be largely concerned with "non-programmed" information. The needs for basic data certainly should not be minimized. However, it must be recognized that the management organization will be largely concerned with broad-scale planning and management, and the coordination of more detailed work done by less comprehensive organizations. The organization might be analogous to the director of an organization who deals mostly with summarized information and reports of his subordinates. The office will be concerned with setting policies to guide water resource management for the area. Much of the information it deals with will be of the non-quantifiable type which is less easily handled by the computer.

(6) An important task is providing service to other users outside the management office. It is not suggested, nor would it be feasible, that a comprehensive, international management agency would replace all other national,

state, and local water resource agencies. These agencies would continue to play a vital role and their successful operation would be necessary for the Experimental Operations Office to carry out its purpose. Therefore, the office should be vitally concerned with providing information to these other users either by supplying the information directly, or by providing a "directory" service to allow these users to easily find the information wherever it is stored. By coordinating information exchange, much duplication and overlapping of information collection should be avoided, allowing more efficient operation. The large number of users emphasizes the importance of interpretation and reporting for the different types of users.

Recommendations

It is recommended that an information system be developed as a part of the Experimental Operations Office for comprehensive management of Lake Ontario. An information system should be an important part of any comprehensive management organization for Lake Ontario or for the entire Great Lakes. In the event such an organization is not established in the near future, it is further recommended that such a system be established as a part of the International Joint Commission to contribute not only to its functions but to meet the needs of other regional water resource planning and management agencies. Initially, the main function of the system in such a case would be the coordination of information collection and dissemination, with less emphasis on the actual collection and storage of large quantities of data. The following specific recommendations are made regarding the organization and functions of the information system.

The detailed structure of the organization of the information system is beyond the scope of this report. However, certain characteristics can be derived from the preceeding conclusions. In the first place, the staffing of the system should involve highly competent professionals from both countries. These professionals should not be limited to computer or information specialists but should involve planners familiar with the broad range of problems of water resources management and the techniques and methods used to solve these problems.

The information system would undoubtedly involve some computer equipment. The nature of the equipment could not be specified without detailed studies of storage requirements and equipment costs. But it should not be assumed that a large computer for storage of all information is necessary. Linkages to existing systems such as the Environmental Protection Agency's STORET by remote terminals should be thoroughly explored. The use of existing systems could not only save money but could produce more cooperation and better coordination with these other sources.

The primary functions of the information system should include the following:

(1) Assessment of information needs. The first step is to assess the ways in which existing information can be used most effectively. Secondly, the staff of the system should be aware of new or more desirable models and techniques and the needs for new or more detailed information. The first step is concerned with meeting immediate problems in the best way possible; the second is concerned with developing more theoretically "correct" information and methods for dealing with future problems.

(2) Assessment of existing information, including the types of information available, availability, formats, and quality.

(3) Establishing lines of communication with sources and users. Some types of information, such as water quality data, can be collected and disseminated in a routine manner. For other types of non-quantifiable information which is not routinely produced, the problem lies in searching out the diverse sources and maintaining an up-to-date awareness of what information is available. Similarly, the information system must disseminate and publicize the availability of its information to a wide variety of users.

(4) Standardization of information and information systems. The system could play a key role in standardizing methods of measurement and collection; formats for recording information; computer programs for storing, retrieving, and interpreting information; computer equipment to possibly allow more direct linkages between the various

sources and users; and any other factors which would facilitate the exchange of compatible information. Because of the key role that information plays, its exchange and standardization could also lead to standardization of methods and techniques used in planning and management.

(5) Storage of some information. Computer storage space costs money. Because of this, information should not be collected and stored without carefully considering the need and any alternatives to actual collection and storage. If the information is already stored elsewhere, consideration should be given to obtaining the information as needed without storage in the system. However, if the information is frequently used, is not in the desired format, or in the desired interpreted form, then storage in the system may be feasible or even necessary. The gains in efficiency through more direct access must be balanced against the extra costs of duplication of storage.

(6) Information collection. While much information is being collected by various sources, there are undoubtedly many gaps in coverage which need to be filled. By identifying these deficiencies, it might be possible to stimulate the interest of other agencies, especially those primarily concerned with basic data collection, and induce them to fill in these gaps. If not, the office itself will undoubtedly have to collect some basic information, either directly or by grants to other agencies and universities. Besides basic data collection, the information system could play

a key role in identifying research needs and sponsoring research on the air, land, and water resources.

(7) Interpretation and reporting. The goal of the information system is to provide the right information, in the right form, at the right time, to the right user. Once the information needed is identified and collected, the problem becomes that of interpretation and reporting. The wide range of potential users both inside and outside of the office will require a range of degree of interpretation and of reporting techniques. Obviously, the methods used should be designed for each type of user.

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