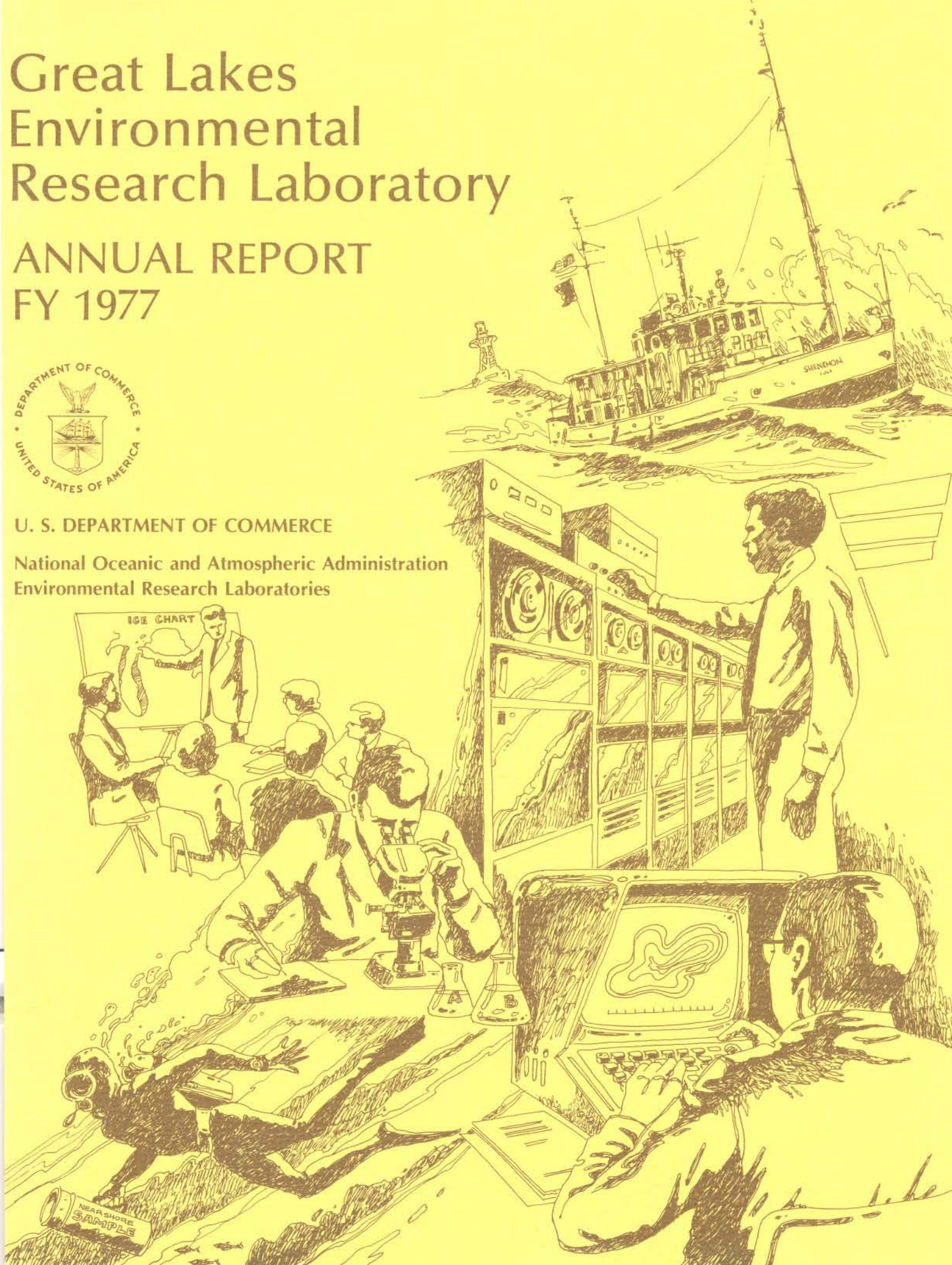
Great Lakes Environmental Research Laboratory

ANNUAL REPORT FY 1977

U. S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
Environmental Research Laboratories



GREAT LAKES

ENVIRONMENTAL RESEARCH LABORATORY

ANNUAL REPORT FY 1977

October 1977

Eugene J. Aubert, Director

U. S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
Environmental Research Laboratories
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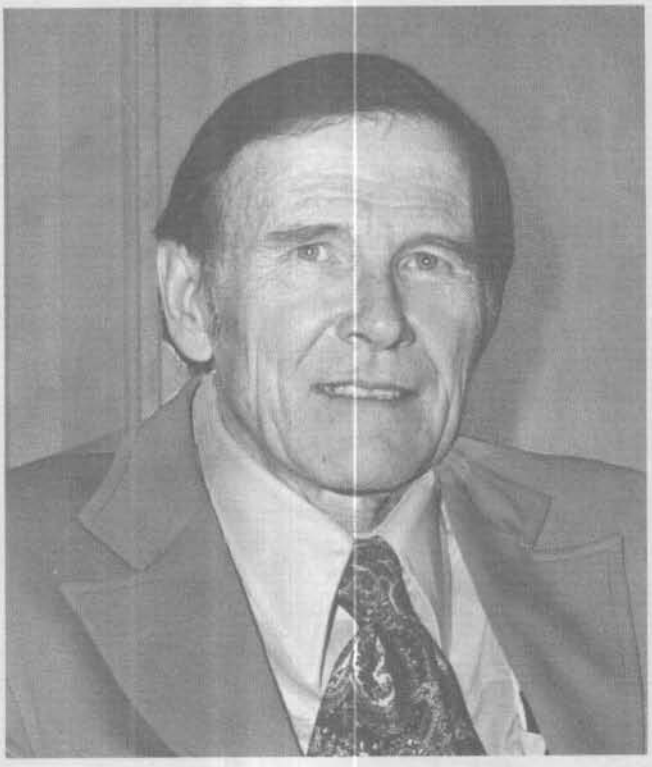
PREFACE



GLERL Director—Eugene J. Aubert.

(Photograph by R. L. Chambers.)

The Great Lakes Environmental Research Laboratory (GLERL) has completed its third year of operation in Ann Arbor. Our mission at GLERL is to conduct research directed toward understanding the environmental processes and solving problems in resource management and environmental services in the Great Lakes and their watersheds. The environmental information developed is made available to NOAA, other government agencies, private organizations, and individual citizens to aid them in their environmental services, plans, and operations.

Understanding the complex lake-land-atmosphere system of the Great Lakes region and the many interactions that influence our lives in this region requires a team of scientists with many different backgrounds working together on field, laboratory, and analytic investigations into the limnological, hydrological, and meteorological properties of the Lakes, their basins, and the overlying atmosphere. The ultimate goal of the GLERL program is to understand the lake-land-atmosphere system to the extent that environmental simulation and prediction models can be built to provide sufficient information on Great Lakes processes and phenomena to support enlightened use of the region's resources and activities.

This *Annual Report* is intended to inform the Great Lakes community of GLERL's capabilities, program, significant results, and plans for the future. It is also intended to encourage an exchange of information between the laboratory staff and those in need of environmental information for operational, planning, or management activities.

Examples of some of the major problem areas that the GLERL program addresses are lake water levels and connecting channel flow prediction—critical to erosion control, transportation, recreation, and power generation; lake ice prediction—critical to lake transportation and shoreline structure design and protection; lake circulation—critical to ecosystems analysis and an understanding of the transport and dispersion of pollutants; surface waves and oscillations—critical to lake transportation, boating, and the control of shore erosion and flooding; and the dynamics of certain chemical and biological properties—critical to an understanding of man-induced changes in the Great Lakes ecosystem and to water quality, water supply, and fisheries management.

The GLERL staff has been and is working with Great Lakes regulatory and management agencies, in both Canada and the United States, to provide them with the research products, data, and expertise they need. GLERL staff serve as officers, board members, or committee members of such organizations as the International Joint Commission (IJC), the Great Lakes Basin Commission, and the International Association for Great Lakes Research (IAGLR), among others. These activities serve to provide an outlet for GLERL products and a means of identifying environmental problems requiring further study.

Other outlets for GLERL products include requests from private organizations and individual citizens. The scientific community is informed of the products through journal articles, NOAA Technical Reports and Memoranda, and presentations at society meetings. The location of GLERL in Ann Arbor with the University of Michigan provides for graduate student participation in GLERL projects. Visiting scientists have in the past participated in GLERL research studies; this activity is continuing.

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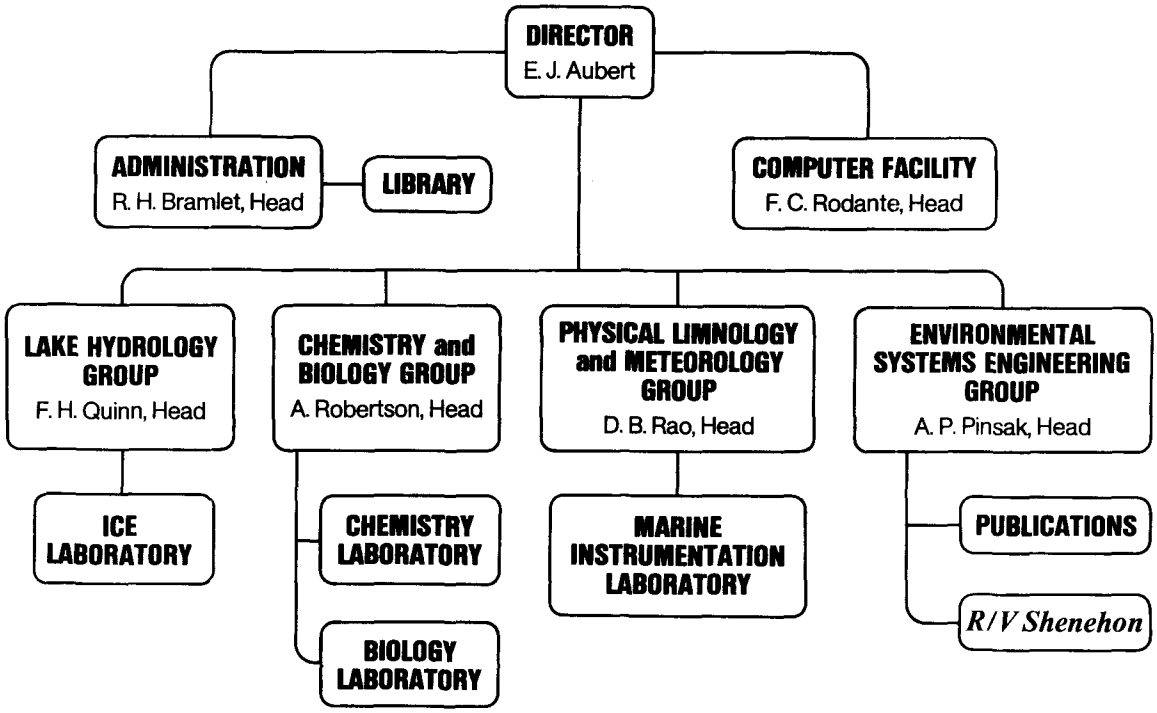
GLERL ORGANIZATION CHART



HIGHLIGHTS

The laboratory has completed its third year of operations in Ann Arbor. There has been a major increase in the laboratory facilities in the past year, providing better support for field operations. Activities have also increased markedly in interagency and international involvement and in advisory services.

The GLERL organization chart shows that process research is aligned in four primary discipline areas. Problem-oriented multidisciplinary research is conducted with staff from more than one group.

The GLERL in-house research program is supplemented by research grants and contracts with private institutions and other agencies. Likewise, GLERL receives some 5 percent of its fiscal support through interagency agreements with other government organizations. A major GLERL product is the publication of our research results and their presentation and discussion at scientific and user meetings. During FY 1977, 35 papers authored by GLERL staff and 11 papers by GLERL contractors were published, and 23 papers were presented by GLERL staff at meetings.

Highlights of accomplishments during FY 1977 are as follows:

Research

- Ecological modeling work included the application to Lake Ontario of a model designed to simulate seasonal changes in several types of plankton and chemicals in the upper and lower lake waters. Special emphasis was given to the study of exchange of materials between the sediment and lower waters. The model will permit the examination of whole ecosystem properties difficult to investigate experimentally on a large lake such as Ontario.
- Analysis of data collected in 1976 in the nearshore zone of Lake Michigan off the mouth of the Grand River indicated that spring runoff (March/April) accounts for about 30 percent of the annual total nutrient, trace metal, and suspended matter loadings and that these large inputs result in biostimulation in the nearshore area.
- Analysis of the whitings in Lake Michigan continued, with emphasis on the kinetics of this autogenic calcite ($CaCO_3$). The kinetics are important because of the particles' inherent light scattering properties, which will affect phytoplankton growth and, thereby, the entire ecosystem. Also, the $CaCO_3$ crystals adsorb nutrients (particularly phosphorus) along with vitamins and other organics and transport these to the bottom through precipitation.
- Work on the IFYGL energy budget program was completed. Data input and analyses of the energy budget terms provided by 26 United States and Canadian investigators were evaluated and synthesized into an annual budget. Results showed that the heating of Lake Ontario from April to August 1972 was dominated by the net radiation, the cooling in October by evaporation, and the cooling from November 1972 to February 1973 by sensible heat flux and evaporation.
- A numerical model of Lake St. Clair simulating transport and diffusion of water quality variables was developed and tested as an aid in defining natural distribution and variability in that lake and as a tool in evaluating impacts of inputs and management strategies.
- A mathematical model was developed to predict the effect of waste abatement programs and human development of the drainage basin on Great Lakes phosphorus levels. In addition to phosphorus, this model predicts several parameters directly reflecting a lake's trophic state. This model is useful for planning purposes to compare the effect of various treatment strategies on Great Lakes' phosphorus concentrations and eutrophication. It was used to prepare testimony for hearings held by the State of Michigan on the effects of a limitation of phosphorus in detergents upon the water quality of Lakes Erie, Michigan, and Huron.
- A mathematical hydrologic response model was developed and used to simulate the lake levels and flows that would have occurred naturally from 1860 to 1975 to test the effect of lake regulation at the Soo on water levels in the upper lakes. Comparisons between the simulated and recorded levels showed an average rise of 17 cm in Lake Superior due to lake regulation.
- A study of the optical properties of Great Lakes ice was conducted to better understand the impact of ice type and snow covers on solar radiation transmission through ice and on the reflectance of radiation.
- Studies on the IFYGL water movements tasks were completed. The long-term, large-scale current properties of Lake Ontario showed a one-cell cyclonic gyre during the warm season, but a two-cell counterrotating circulation also occurs. The current power spectra show that inertial and near inertial Poincaré waves predominate in mid-lake, while longer period topographic and Kelvin waves predominate within 12 km of shore.
- The results of the analysis of currents measured during the winter of 1974-75 in Lake Huron were published. This study, a part of the IJC Upper Lakes Reference Study, showed that, during winter, Lake

Huron was characterized by cyclonic circulation similar to what is now thought to characterize the summer circulation. The winter currents were more intense and penetrated to deeper water depths as was also noted in Lake Ontario.

- Surface wave studies using Waverider data from IFYGL and from Lake Michigan in 1976 to better understand the temporal spectral growth and nonlinear characteristics of wind-generated surface waves show a shift to lower frequencies of the wave spectra during development.

- A theoretical computer model was developed to simulate the intensity of storm surges on Lake Erie caused by lake-wide wind forcing. With routine National Weather Service wind forecasts for Lake Erie, water levels can be forecast up to 36 hours in advance.

IFYGL

The IFYGL Project Office continued as a part of the GLERL program. The NOAA role as U.S. lead agency required continued management activity to insure the satisfactory documentation of this multiagency program as it nears completion. The following are the major accomplishments:

- The IFYGL archive is complete.
- The 78 U.S. analysis tasks have been completed.
- Over 320 articles on IFYGL results have been published.
- The 12 chapters of a book, *IFYGL–The International Field Year for the Great Lakes*, summarizing and synthesizing the major research segments are in various stages of completion.
- An IFYGL symposium was held as a part of the International Limnological Society meetings in Copenhagen, Denmark, in August. Eight IFYGL papers were presented and will appear in the Proceedings.
- The IFYGL Wrap-Up Workshop was held in Ontario, Canada, with 66 of the key participants in attendance. The program accomplishments were reviewed and future objectives for Great Lakes research were identified. The conclusions were that IFYGL successfully met its objectives, the IFYGL archive will be valuable as a research data source for years to come, and IFYGL established working relationships between United States and Canadian scientists that will improve Great Lakes research programs in the future.
- Water circulation and ecosystem modeling have been improved.

International and Interagency Activities

The annual IAGLR meeting was cohosted by GLERL and the University of Michigan in May 1977.

GLERL staff participated in the review and updating of the Great Lakes Water Quality Agreement between the United States and Canada.

GLERL staff are also actively involved in the Great Lakes Basin Commission program as Alternate Department of Commerce Commissioners and as working members of the Great Lakes Plan Committee, Priorities Committee, Coastal Zone Management Committee, and the Standing Committee on Research and Development.

In their capacity as members of the Interagency Technical Advisory Group of the Lake Erie Wastewater Management Study, GLERL staff evaluated the impact of phosphorus loading on Lake Erie for comparison with other impact assessments.

GLERL staff are active in several capacities on the Great Lakes-St. Lawrence Seaway Navigation Season Extension. Areas of involvement include planning for an assessment of the environmental impact of the extension and chairing of the Ice Information Work Group.

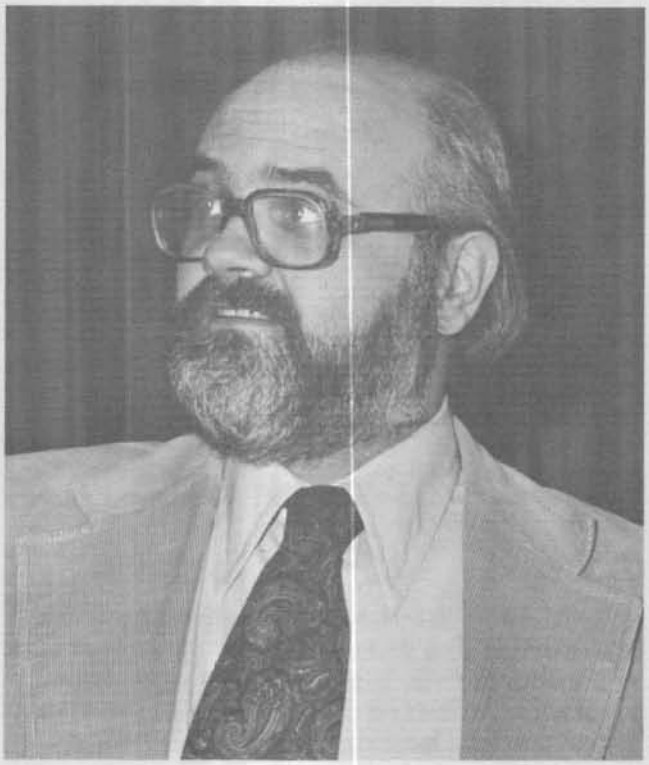
Advisory Services

During FY 1977, 650 requests for information, data, or reports were received from various user groups and answered as a part of the GLERL advisory service activity; 400 recipients are on the mailing list for GLERL publications. Additionally, support has been given to the Great Lakes Sea Grant colleges in carrying out their advisory service activities.

Facilities

- The total space of the laboratory's temporary quarters was increased by almost 50 percent with the leasing of an additional building. This provided the necessary space for the marine instrumentation laboratory to have a staging, machinery, electronics, and storage area and also will provide space for the installation of the new ice laboratory.
- The *R/V Shenehon* was modified by replacing the forward mast with a hydraulic articulated crane. This crane increases the ship's capability to deploy and retrieve heavy equipment, such as instrumented buoys and towers.
- A mobile chemistry laboratory was developed for on-site analysis of water samples during field programs where analysis is time-critical and samples cannot be returned to the laboratory at GLERL.

CHEMISTRY AND BIOLOGY



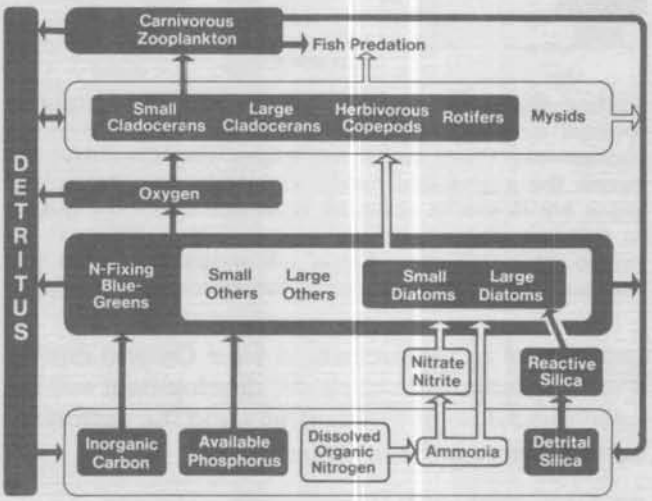
Chemistry and Biology Group Head—Andrew Robertson.
(Photograph by R. L. Chambers.)

The work in chemistry and aquatic biology is concentrated in three principal task areas: ecosystems modeling, plankton studies, and water chemistry studies. The program is aimed at understanding the existing lake conditions, recognizing the trends that have occurred, and developing the capability to predict the course of events given alternative approaches to the management of the Lakes. In this respect, the program will provide information pertinent to a large number of problem areas relative to the use, protection, and conservation of the Great Lakes.

Ecosystems Modeling

A series of models is being developed at several levels of complexity to simulate realistically the fluctuations in amounts of carbon and other ecologically meaningful components of the Great Lakes ecosystems. Once components are identified and interrelationships are defined, available data, including the IFYGL data base, will be used to test, tune, and verify the models. In the process, research areas requiring further effort will be identified.

A model of the upper and lower waters of Lake Ontario, designed to simulate seasonal changes in five types of phytoplankton, six types of zooplankton, detrital carbon and silica, organic nitrogen, ammonia, nitrate, available phosphorus, soluble reactive silica, dissolved oxygen, and the carbonate system, was calibrated to the IFYGL data. The dynamics of phosphorus, nitrogen, carbon, silica, oxygen, and benthic invertebrates were also simulated for the shallow sediment zone of Lake Ontario

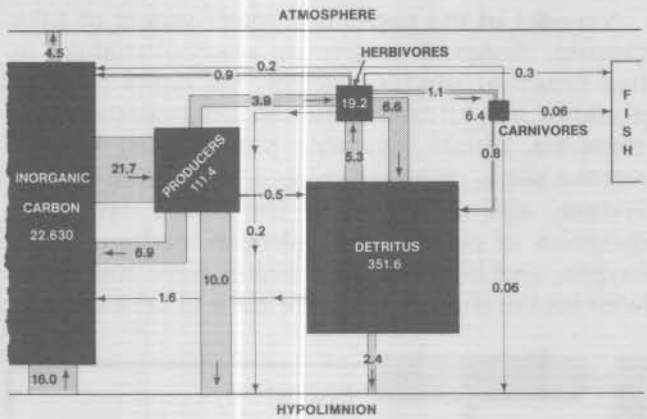


Schematic diagram of the Lake Ontario ecosystem model. Arrows indicate transfer pathways of biological and chemical processes (e.g., production, consumption, respiration). Models such as this can be used to simulate and predict the concentrations of several biological and chemical properties in the Great Lakes.

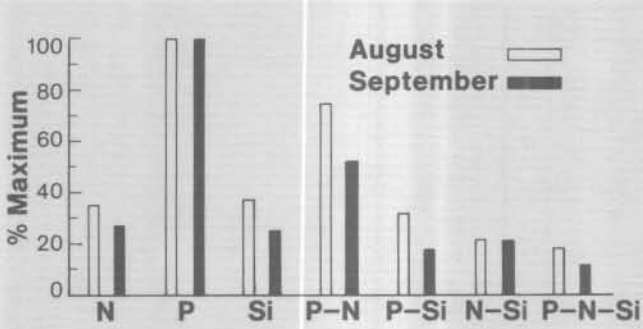
with special emphasis on the exchange of material between the sediment and lower waters.

The model is being used in a number of ways. One investigation involves aggregating the output from several model compartments and averaging over time to produce carbon flow diagrams similar to those used in experimental and theoretical ecology. In these diagrams the size of the boxes represents the amount of carbon in each compartment or trophic level and the size of the pipes represents the flow between boxes. By generating these flow diagrams from model output during various seasons, we can begin to examine whole ecosystem properties quite difficult to investigate experimentally on such a large system as Lake Ontario.

Additional work in our ecological modeling program includes calibration and testing of the model in three physical regimes: 1) multilayer lake-averaged one-dimensional, 2) two-dimensional transect, and 3) three-dimensional. We will also use the model to examine specific biological and chemical processes



Carbon flow diagram. This represents model output as annual average epilimnetic carbon concentrations (boxes—mg C/m³) and flows (pipes—mg C/m³/day) between the aggregated model compartments. Boxes and pipes are drawn to scale. By representing model output in this way, the major pathways of carbon flow can be traced. This leads to a better understanding of the system and can assist in designing future research projects.



Phytoplankton growth as stimulated by various nutrients. Phosphorus, nitrate-nitrogen, and silica were added to the water at an offshore station in Lake Michigan, 15 km west of Grand Haven, Michigan. The radiocarbon technique was used to measure photosynthesis. These results show that phosphorus is the primary nutrient limiting phytoplankton growth.

and control of productivity in Lake Ontario during IFYGL. Specific areas of model development will involve simulation of fish dynamics and the sediment-water column exchange process.

Plankton Studies

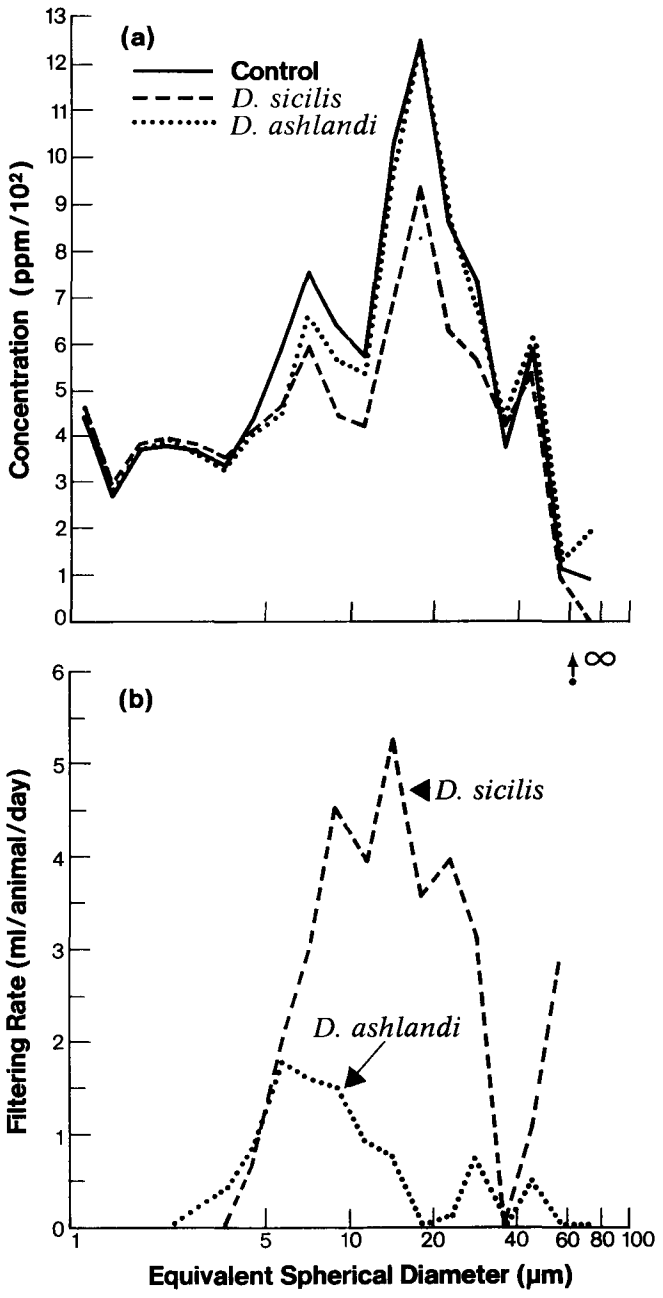
An understanding of the Great Lakes ecology and successful ecological modeling requires detailed knowledge of plankton dynamics because plankton constitute a significant component of the food chain. Until recently, models of plankton biomass dynamics treated phytoplankton as a whole; this held true for zooplankton, as well. For many problems of water quality management, however, information is required on particular groups or species of phytoplankton rather than just total phytoplankton biomass. In addition, the kinds of zooplankton present may represent the available food and affect fisheries. The ultimate goal of this work is to build a realistic dynamic model of seasonal succession for plankton.

Studies on phytoplankton succession and nutrient competition at an offshore station in southern Lake Michigan from May through October 1976 and in August 1977 show relatively distinct patterns in species succession, significant seasonal variations in rates of phytoplankton production, and weekly fluctuations in important nutrient concentrations. Diatom populations of *Diatoma*, *Asterionella*, *Fragilaria*, and *Cyclotella* develop individual maxima from May through late summer. Green and blue-green algae develop relatively large populations, partially displacing diatoms during summer and fall. Nutrient limitation studies and variations in nutrient concentrations show that phosphorus limits phytoplankton growth, that silica is reduced to limiting levels at certain times, and that variations in the ratio of silica to phosphorus may trigger shifts in diatom species succession. Studies on dissolved carbon dioxide and nitrate-nitrogen indicate that these nutrients do not regulate phytoplankton succession or production.

Immediate plans for 1978 include further data analysis of physical, chemical, and biological variability during 1976 at the offshore station, the completion of a detailed phytoplankton species cycle, and an analysis of species successional patterns and growth rates in relation to variations in nutrient concentration.

To predict the dynamics of growth and death of various kinds of phytoplankton and zooplankton, it is necessary to predict feeding rates of different zooplankton on different kinds of phytoplankton. Toward this goal, we are measuring size-selective feeding rates for Lake Michigan seston (phytoplankton and other particulate materials) by different species of *Diaptomus*, the dominant genus of herbivorous copepods in the Great Lakes. Copepods as well as other grazers are generally believed to select phytoplankton and other seston largely on the basis of size.

Much of our effort during the past year has been spent on evaluation of an electronic particle counter that will make the rapid analyses of particle-size spectra in lake water required for grazing studies. Although care must be used in interpreting the results from the particle-size analyzer, it appears to give satisfactory results.



Concentration and filtering rates. (a) Concentration of particulate material in control (lake water only) and experimental (lake water with zooplankton) bottles of Lake Michigan water after 24 hours of feeding. (b) Filtering rates calculated from data in (a). These results show that *D. sicilis* prefers larger particles than *D. ashlandi*. Experiment was performed 23 June 1977.

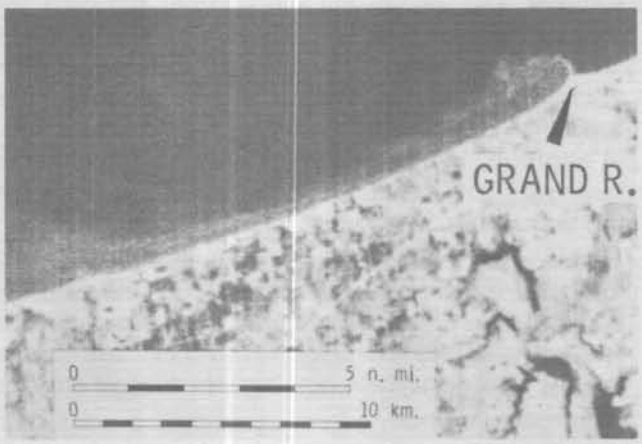
Using the particle-size analyzer, we have examined grazing over a broad range of particle size for the four common species of Lake Michigan *Diaptomus*. Results so far indicate that the larger species, *D. sicilis* and *D. oregonensis*, "select" larger particles, and that the smaller species, *D. ashlandi* and *D. minutus*, select smaller particles. Such grazing experiments have been carried out on copepods during spring, summer, and fall. During late summer and early fall, grazing rates are very low. This appears to be correlated with the abundance of large filamentous blue-green algae and diatoms that may be too long to be handled by the feeding appendages of the copepods; in addition, blue-green algae may be unpalatable. Low grazing rates of these algae may, in part, explain the dominance of these forms during summer.

Next year, studies will be conducted in an attempt to establish correlations between food selection and the structure of the feeding appendages. Further studies to define the selection process and the response of zooplankton feeding rate to algal concentration are planned.

Water Chemistry Studies

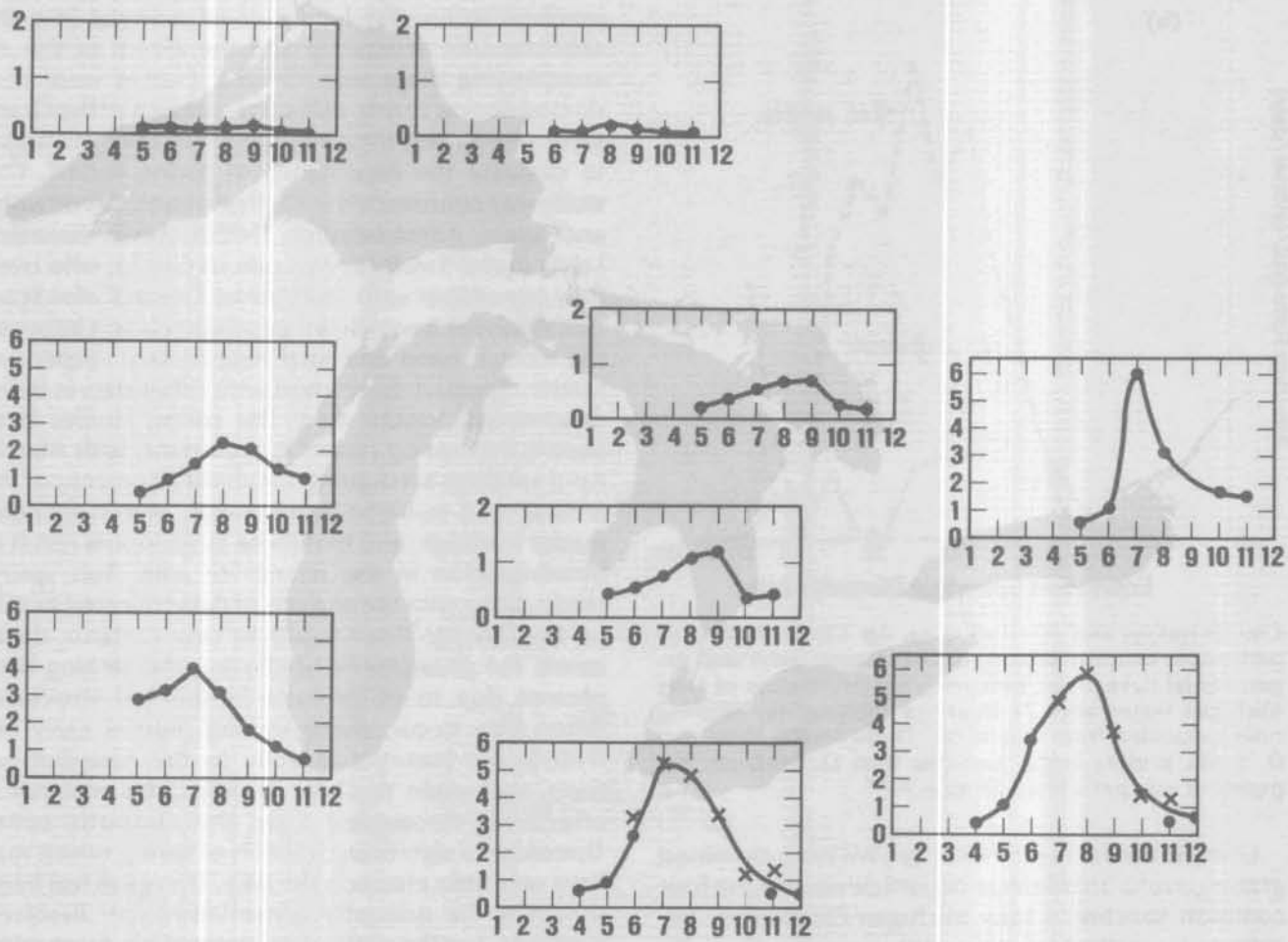
Data analysis has concentrated on samples collected in the nearshore zone of Lake Michigan. Our major objective is to decipher transport mechanisms involved in moving land-derived material into the offshore lake ecosystem and the extent of the accompanying diagenesis. Several cruises were conducted during spring 1976 off the mouth of the Grand River (the largest river emptying into Lake Michigan) to evaluate the importance of spring runoff. This study was coordinated with the National Aeronautics and Space Administration (NASA) Lewis Research Laboratories Satellite Applications Group, who overflew our cruises with an airborne Ocean Color Scanner. Analyses have shown good correlation between the 632-nm band and total near-surface suspended matter. Spectral correlation with other data is being determined. Results from the spring studies have shown that spring runoff is important, with March-April loadings accounting for about 30 percent of the annual total nutrient, trace metal, and suspended matter loadings, and that these large inputs result in biostimulation in the nearshore area. This spring study, along with the analysis of data collected in 1972 off the Oswego River mouth in Lake Ontario, documents the phenomena of floating and sinking river plumes due to differences in thermal structure. When they occur, these sinking plumes carry the river-borne material directly to the near-bottom zone, and when the lake stratifies, this material is effectively decoupled from the euphotic zone. Therefore, a significant fraction of spring runoff may have very little effect on the lake. Transport has been shown to be primarily conservative for dissolved materials, but the particulate material has three components. One fraction (presumably the smallest particles) appears to mix conservatively; a second frac-

tion settles to the thermocline and travels along this maximum density gradient; and a third fraction flocculates, forming a zone at the sediment water interface from a few centimeters to several meters thick.



Landsat Color Scanner image of the Grand River plume. Flocculent material and other suspended matter make the plume visible from the air before dispersing and settling in the lake. On this day, 28 April 1976, winds were holding the plume near the Michigan shoreline.

Another area of emphasis during the past year has been the inorganic carbon cycle in the Great Lakes. Satellite imagery has shown progressive buildup of whitings, which we have shown to be autogenic $CaCO_3$ crystal growth. Analysis of 1965–1975 data files covering cruises on all of the Lakes gave us an indication of the extent of potential $CaCO_3$ formation. The kinetics of particle formation in the Lakes is important because of the particles' inherent light scattering properties, which will affect phytoplankton growth and thereby the entire ecosystem, as well as the documented ability of $CaCO_3$ crystals to adsorb nutrients (particularly phosphorus) along with vitamins and other organics and transport these to the bottom through precipitation. Field work this year concentrated on quantifying the $CaCO_3$ formation and its temporal variation. Future studies will involve the amount of nutrient complexing and the effect of particles on the light climate.



Monthly rates of $[Ca^{++}]$ $[CO_3^{=}]$to K_{sp} (solubility product) for selected regions of the Great Lakes: east Superior (1968), west Superior (1969), north Michigan (1970), south Michigan (1975), north and south Huron (1966), east Erie [1965 (×) and 1967 (•)], west Erie [1965 (×) and 1967 (•)], Ontario (1971). A ratio of 1.0 equals saturation.

ENVIRONMENTAL SYSTEMS ENGINEERING

Environmental Systems Engineering Group Head—Arthur P. Pinsak.

(Photograph by R. L. Chambers.)

The work of the Environmental Systems Engineering Group includes projects on environmental engineering models and applications and GLERL environmental information services. Objectives in environmental engineering models and applications projects are to develop, test, and apply improved simulation and prediction models and other tools as a basis for rational decisions in development and use of Great Lakes natural resources.

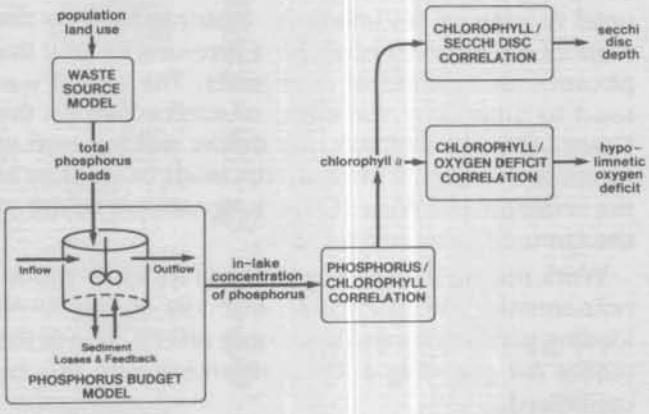
Current Great Lakes issues and environmental information requirements are determined in large part through participation of GLERL staff on various interagency, State-Federal, and international boards, commissions, committees, and work groups. Environmental information services involve continuing identification of new users and their needs, dissemination of GLERL products and other environmental information, and response to environmental information requests.

The combination of environmental engineering models and applications and environmental information services provides an information system and expertise to assist in the solution of Great Lakes issues and problems. Such involvement establishes a direct two-way channel for our scientific expertise and tools, ascertains research needs pertinent to our program planning, and identifies substantive areas for GLERL participation in interagency research.

Environmental Engineering Models and Applications

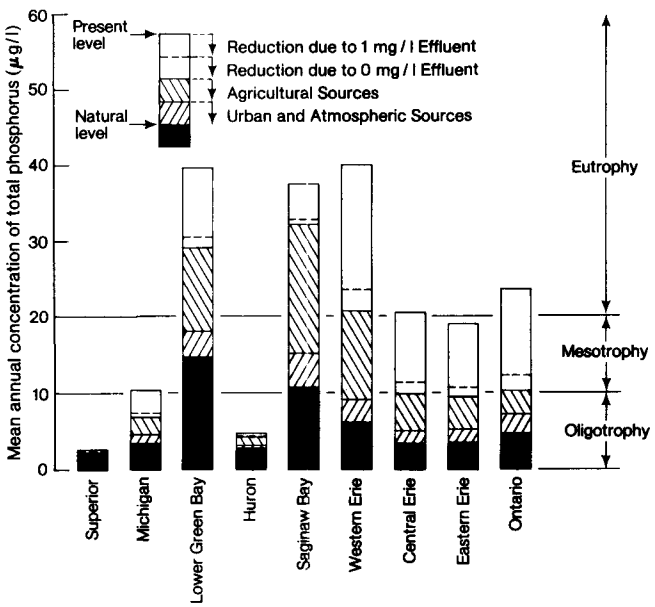
Eutrophication, the overstimulation of aquatic plants by increased nutrient inputs, is a critical water quality problem in the Great Lakes. This overstimulation results in such undesirable characteristics as decreased water transparency and the reduction of oxygen to levels below those necessary for the survival of many aquatic organisms. The key nutrient causing eutrophication, and the one most easily controlled, is phosphorus. In fact, present efforts to reverse the trend toward eutrophication in the Great Lakes have focused on phosphorus control. To facilitate effective management decisions in this area, the Environmental Systems Engineering Group developed a mathematical model designed to predict the effect of waste abatement programs and human development of the drainage basin on phosphorus concentrations in the Great Lakes.

While the original model dealt strictly with phosphorus, the model has been extended over the past year to predict several variables that more directly reflect a lake's trophic state. The approach consists of a number of submodels and correlations that form a causal chain starting with human development of the drainage basin and ending with such measures of



Schematic diagram of the Great Lakes phosphorus model developed by GLERL. With this model, scientists can predict the impact of human development on Great Lakes water quality. This information can be used by governmental and planning agencies in their decision making.

eutrophication as chlorophyll *a*, water clarity, and hypolimnetic dissolved oxygen. Other developments include a more realistic treatment of sediment-water phosphorus exchange. The major conclusion of this analysis is that, while much of the system would respond significantly under the present program of point source control, localized areas such as Saginaw Bay, Western Lake Erie, and Green Bay would also require reduction of diffuse sources to reach acceptable levels.



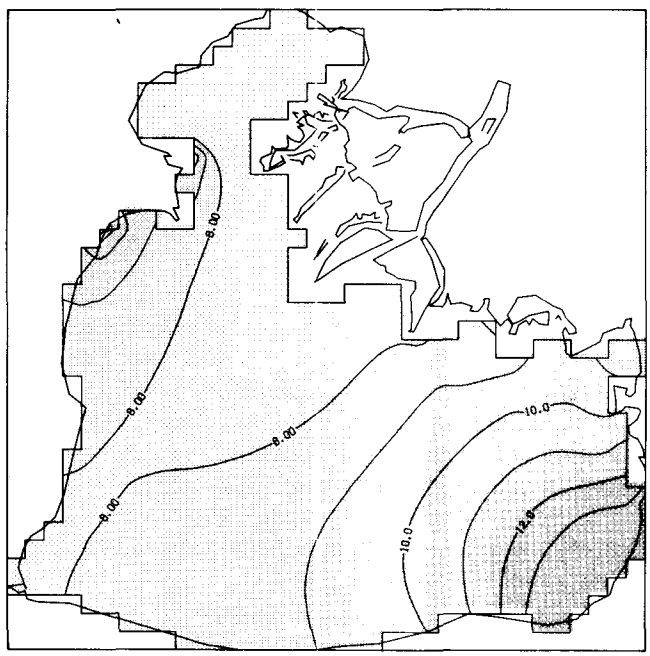
Total phosphorus concentrations resulting from various treatment schemes for the Great Lakes as calculated by the phosphorus model.

The model is also proving useful in a number of actual management contexts. For example, it was used to prepare testimony for hearings held by the State of Michigan to consider a proposal to limit the phosphorus content of detergents. The model was used to determine the effect of such a ban on the Great Lakes. In addition, the model will be used to estimate acceptable phosphorus loads in support of the renegotiated Water Quality Agreement between the United States and Canada.

Work during the coming year will focus on model refinements, with particular emphasis on improved loading predictions and nearshore effects. Use of the model for planning and management will also be continued.

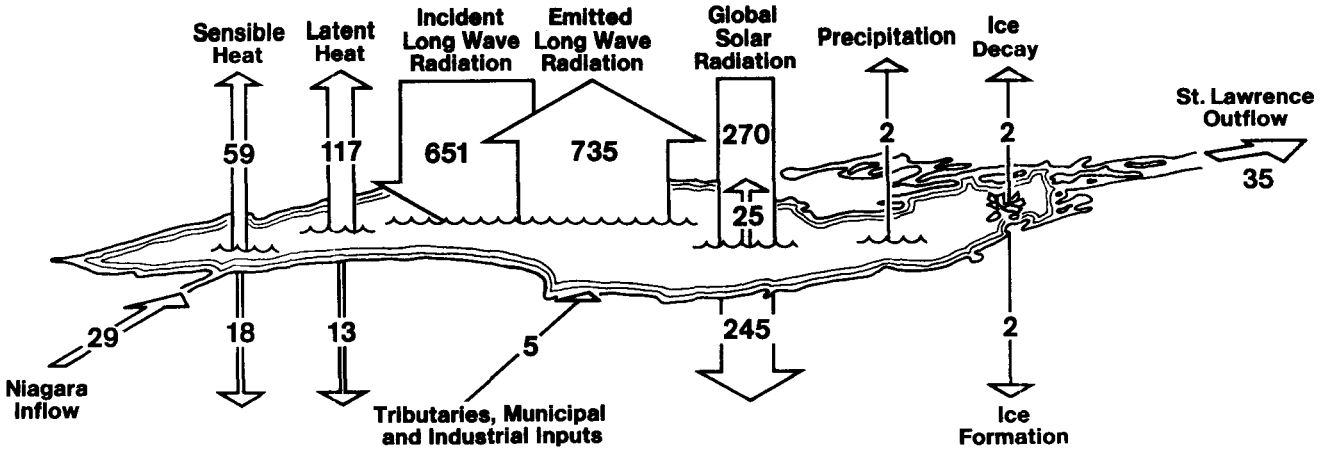
Based on discrete observations combined with hydraulic transient flow models, loadings of dissolved constituents in the St. Clair and Detroit Rivers are providing input to the IJC Reference concerning pollution of the upper Great Lakes. These estimates are also of interest to the Michigan Department of Natural Resources in their operational programs. Averaging times are extremely critical in developing estimates of river loadings to the downstream lakes and the flow model provides the time resolution necessary to reflect short-term changes in water composition.

A numerical model of Lake St. Clair simulating transport and diffusion of water quality variables was developed and tested as an aid in defining natural distribution and variability in that lake and as a tool in evaluating impacts of inputs and management strategies. A significant portion of the population of metropolitan Detroit live along this international water body and contribute to this major problem area in the lower Great Lakes. Loads to Lake St. Clair from the St. Clair River and from peripheral tributaries and outfalls, of interest to both United States and Canadian managers, do not mix homogeneously in the lake, but rather have varying impacts on the Detroit River related to short-term changes in circulation.



Lake St. Clair water quality model applied to chloride. Mathematical models can be used to simulate transport, diffusion, and significance of material entering the Lakes. Distribution patterns, such as shown in this graphical computer display of chloride (in mg/l) in Lake St. Clair, are then verified with observed data.

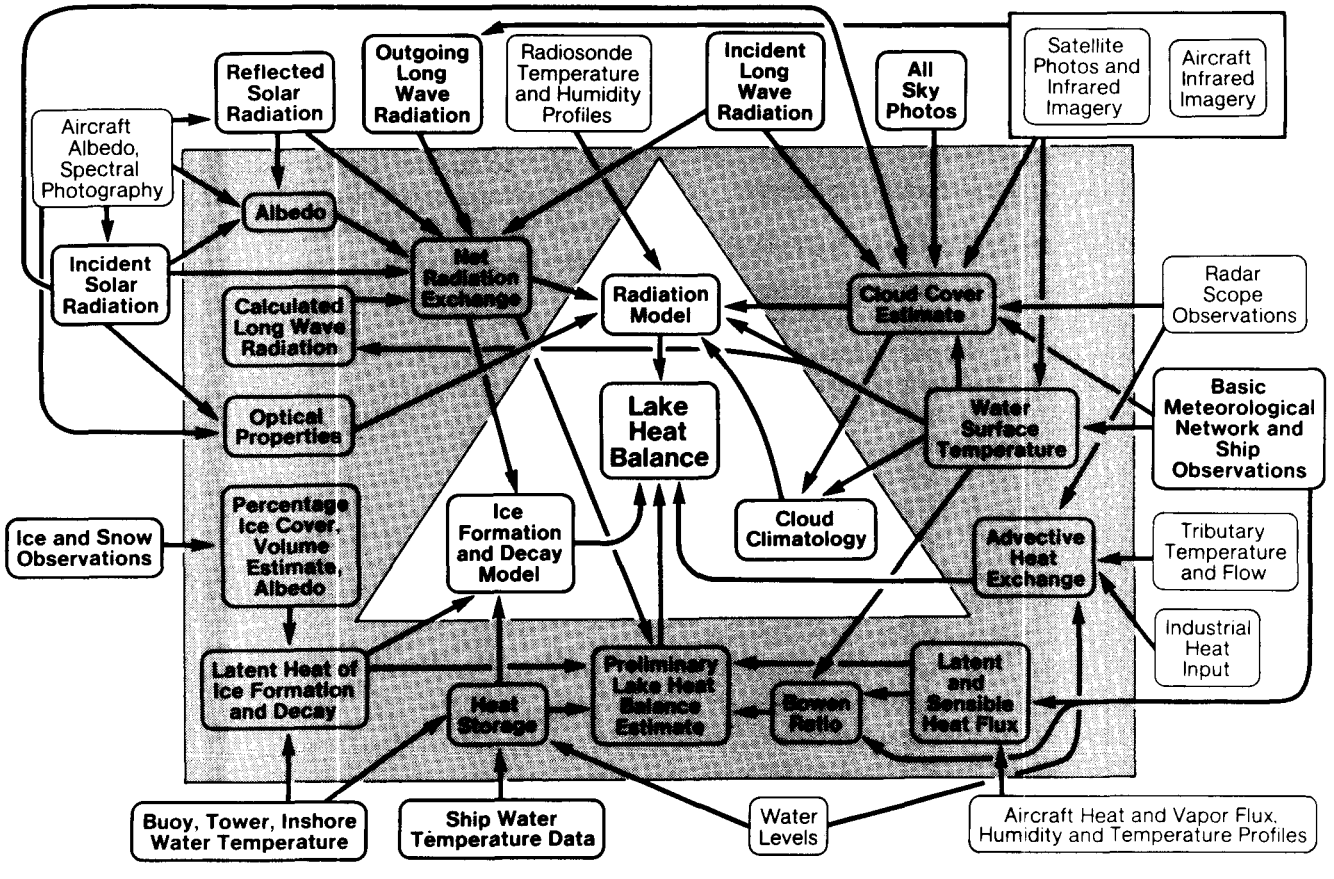
This water quality model was adapted to Lake Ontario and tested against the observed distribution of mirex in the bottom sediments of that lake and, using sources in the Niagara and Oswego Rivers, was able to duplicate the observed distribution patterns. Al-



Average annual fluxes of energy balance components (calories/cm²/day) contributing to heating and cooling of Lake Ontario during IFYGL (April 1972–March 1973). Ice formation and decay terms are based on a 15-week period. Average over-lake cloud cover for the year is 71 percent.

though the elements of the problem in Lake Ontario had already been defined, the data set provided a good basis for verification of this model approach and the potential for application to other generically similar problems in the Great Lakes.

One of the core IFYGL programs was the development of an energy budget for Lake Ontario. Twenty-six United States and Canadian investigations were directly involved in providing data inputs and analyses of each of the energy balance terms. Results



Lake Ontario heat balance. Many of the IFYGL tasks contributed to final calculations of the lake heat balance. Synthesis tasks are within the triangle and analysis tasks within the rectangle. Basic data are outside (primary data in bold type and secondary in light).

of these investigations were evaluated and synthesized during FY 1977 into an annual budget. A numerical radiation model and a two-dimensional heat conduction model developed by contractors were used to define radiation terms and to make lake-scale estimates of heat used in ice formation and decay. The generally applied method of partitioning evaporative and sensible heat was evaluated and the problems associated with application to a large dimictic lake were clarified. Application of the Bowen Ratio is tenuous during the lake heating cycle from March through August, but fortunately, this phase accounts for only a very small percentage of the annual net evaporation. Results of this energy balance program will provide input to ice forecasts and estimates of evaporation, water balance, climatic effects, and dissipation of heat as these relate to navigation, power generation, lake regulation, weather characteristics, and projected trends of municipal-industrial stress. A summary of the energy budget research, along with other IFYGL programs, will be published during FY 1978 in a book entitled *IFYGL–The International Field Year for the Great Lakes*.

The atlas of Lake Ontario physical variables is nearing completion. Maps depicting distributions of atmospheric and water variables have been completed as have tabular summaries of the data. A large number of scientists have contributed to the information processing that will be drawn together to serve as a reference document to scientists, engineers, and resource planners and managers.

Environmental Information Services

One of the major missions of the GLERL program is to provide environmental information to individuals and organizations involved in operational, planning, or management activities that impact upon, or are impacted by, the environment in the Great Lakes. To this end, an advisory service activity was established within the Environmental Systems Engineering Group to provide a focus within GLERL for communication with the users of GLERL data, information, and publications. The GLERL mailing list presently includes 400 recipients who desire and regularly receive 1 or more of the 6 types of GLERL publications.

During FY 1977, GLERL handled 650 requests for information, data, or reports. Requests come from a broad spectrum of users, including universities, Federal and State agencies, private organizations, regional planning groups, and individual citizens. Every request cannot be filled with an item from the shelf; many require some degree of analysis, an opinion, or computer runs with or without some minor programming changes. Examples are Federal and State agencies who request runs of our hydraulic response models for specific time periods for a connecting channel such as the Detroit River, agencies or private companies involved with transportation in the Lakes that request information on existing ice conditions for prediction models or ice climatology for planning or research purposes, secondary schools that need material for environmentally-oriented course work, or university libraries that require publications on Great Lake limnology.

In support of NOAA's Office of Ecology and Environmental Conservation, 22 Draft Environmental Impact Statements pertinent to the Great Lakes or the Great Lakes Basin were reviewed and commented upon during 1977.

Determination of the need for Great Lakes environmental information and interactions takes many forms. In addition to the inquiries and requests handled by the laboratory, many GLERL scientists are involved in interagency and international meetings, symposia, and workshops where information exchange takes place. The scientists also serve as consultants; committee, board, and commission members; and officers in Great Lakes organizations and as working members of interagency special study or work groups.

Future plans call for continued contact with other Federal, regional, State, and local organizations to increase awareness of the GLERL mission and program and to further define problems in the Great Lakes requiring input of environmental information. This will help in the evolution of the GLERL program to meet these needs.

LAKE HYDROLOGY

Lake Hydrology Group Head—Frank H. Quinn.
(Photograph by R. L. Chambers.)

The emphases of the Lake Hydrology Group are on the hydrologic cycle, including channel hydraulics, and on ice research. The objectives of the hydrologic work are to develop improved methods of prediction and simulation of lake levels, connecting channel flows, and flow in tributary streams and to improve understanding of the hydrologic processes. The objectives of the ice work are to improve the prediction of freezeup, breakup, areal extent, and thickness of ice in the Great Lakes and their bays, harbors, and channels and to improve understanding of the natural variability and optical properties of ice cover. The work involves an integrated program of data collection, data base development, analysis, prediction model development and testing, and advisory service.

Prediction and simulation information on lake levels and flows is necessary for water resource planning and management and for the solution of problems in water supply, water quality, shore erosion, hydropower, navigation, recreation, and flooding. Primary users of hydrologic information are the Corps of Engineers, the Great Lakes shipping industry, the Environmental Protection Agency (EPA), recreational boating enthusiasts, the power utilities, the Great Lakes States, and the general public.

The amount, type, and extent of ice on the Great Lakes is of interest to all those who use the Lakes in winter, but especially to those who navigate them. Prediction information on Great Lakes ice is of value to winter navigation, shoreline engineering, hydropower generation, water supply management, and waste disposal. Primary users of ice information are the Corps of Engineers, the U.S. Coast Guard, the National Weather Service, the St. Lawrence Seaway Development Corporation, the Great Lakes shipping industry, shoreline property owners and the general public.

Hydrology

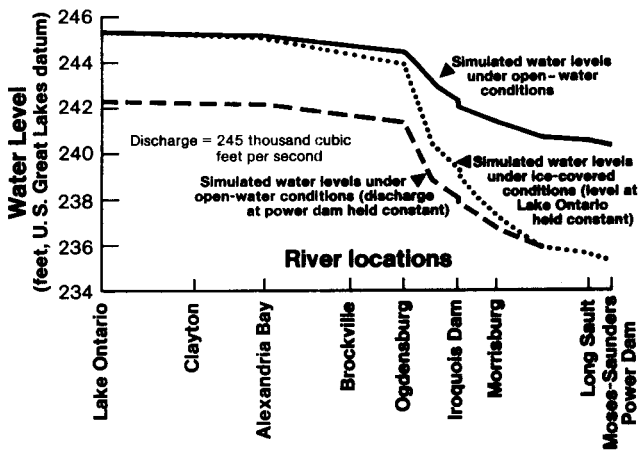
During FY 1977, emphasis was placed on modeling and simulation studies. The first of these studies was to determine the historical effect of Lake Superior regulation on the water levels and flows of the upper Great Lakes. A mathematical hydrologic response model was developed to represent the natural regime of Lake Superior as it existed between 1860 and 1887. The model was used to simulate the Lake Superior lake levels and outflows that would have occurred from 1860 to 1975 under natural conditions. Comparisons between the simulated, natural, and recorded levels showed an average rise of 17 cm due to regulation. The simulated outflows for the period 1937–1975 were run through GLERL's Great Lakes Hydrologic Response Model to analyze the effects of regulation on Lakes Michigan-Huron, St. Clair, and Erie. The results showed no long-term bias due to regulation.

The locks and compensating works at Sault Ste. Marie, Michigan. The locks allow ships to pass between Lake Superior and the lower lakes. The compensating works, constructed between 1901 and 1921, help regulate water levels in Lake Superior.

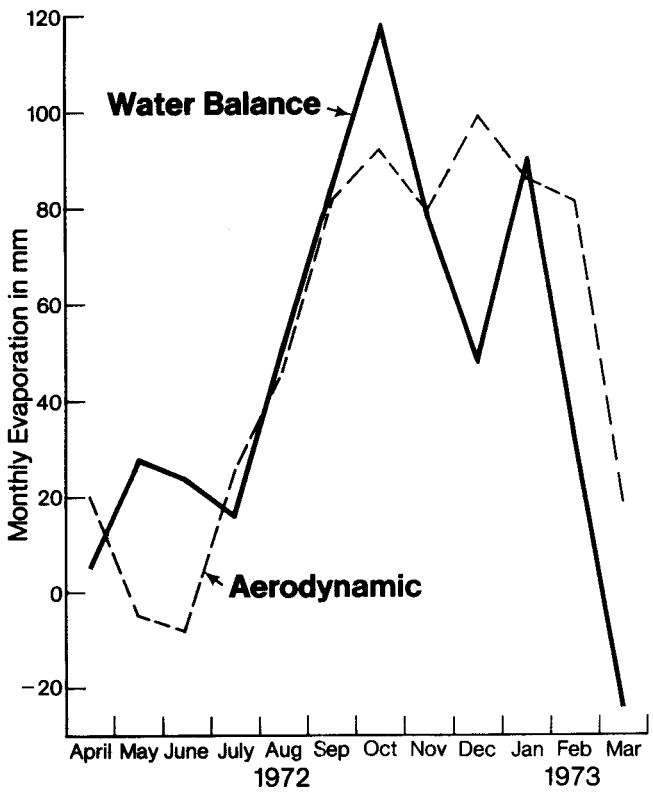
Two conceptual watershed models, the National Weather Service Hydrologic (NWSH) and the Corps of Engineers Streamflow Synthesis and Reservoir Regulation (SSARR), were adapted for use in the Great Lakes Basin. The models were evaluated for accuracy in simulating volumetric runoff and as a potential tool for predicting regional runoff into the Great Lakes. Two pilot projects were conducted. The models were initially evaluated on a single watershed, the Genesee River Basin in western New York. The SSARR model was selected and further tested on a large area with multiple watersheds constituting the southeastern Lake Michigan Basin. More extensive application of the models is planned for FY 1978.

In July 1977, a study was begun to develop a hydraulic transient model of the St. Lawrence River. Initiated by request of the Corps of Engineers, the model divides the St. Lawrence River, from Lake Ontario to the Moses-Saunders Power Dam, near Cornwall, Ontario, into 30 reaches and provides information on flows and corresponding stages in each reach. Primary use of the model during winter is for analysis of ice-related problems. The model will provide information on the effects of different ice conditions on flows and water levels in the seaway and examine the effects of hanging ice dams. Projected uses of the model include determining the effects of extending the navigation season on water levels in Lake Ontario.

On the IFYGL evaporation synthesis program, final evaporation estimates have been received from the



Effects of ice cover on water levels in the St. Lawrence River. The solid line indicates simulated water levels assuming open-water conditions. The dotted line indicates simulated water levels assuming the same water level at Lake Ontario as in the above case and 1-ft ice cover on the river. The dashed line indicates the water level of Lake Ontario under open-water conditions that would deliver the same volume of water past the Moses-Saunders Dam as the above lake level with a 1-ft ice cover.



Monthly evaporation estimates for Lake Ontario. These curves compare two methods used to estimate Lake Ontario evaporation during IFYGL.

supporting IFYGL panels. Work is proceeding on the final intercomparisons and analyses of the terrestrial water balance, energy balance, evaporation pan technique, aerodynamic procedures, and atmospheric water balance tasks. The final synthesis and recommended values for Lake Ontario evaporation will be completed in FY 1978.

Ice

The amount of radiation penetrating ice or a combined ice and snow cover is often critical to the survival of plants and animals in both large and small freshwater lakes. But the nature and magnitude of radiation penetration through ice is only partially understood. A major effort during FY 1977 was directed toward the study of the optical properties of ice. The first measurements of radiation transmittance through ice on the Great Lakes in the 400–700 nm range were completed. Data were gathered on the variation of radiation transmittance due to solar altitudes, cloud types and amounts, and different types and thicknesses of ice and snow. Naturally snow-free and snow-covered ice surfaces as well as artificially cleared (of snow) ice surfaces were examined.

Several factors were found to affect radiation transmittance. When total sky cover changed from clear to cloudy, radiation transmittance was significantly affected; variations of nearly 20 percent were observed on one occasion. On the other hand, varying visual appearance of the ice surface did not necessarily indicate significant changes in radiation transmittance.

Results of calculations from a simple two-layer model show that even a thin snow cover overlying an ice layer exerts a profound effect on the overall transmittance and reflectance of the combination; this was verified by field data. The model also shows that ice layers with high reflectance exert some influence on the overall transmittance and reflectance if the upper layer (of snow, frost, etc.) has a reasonably low reflectance and high transmittance.

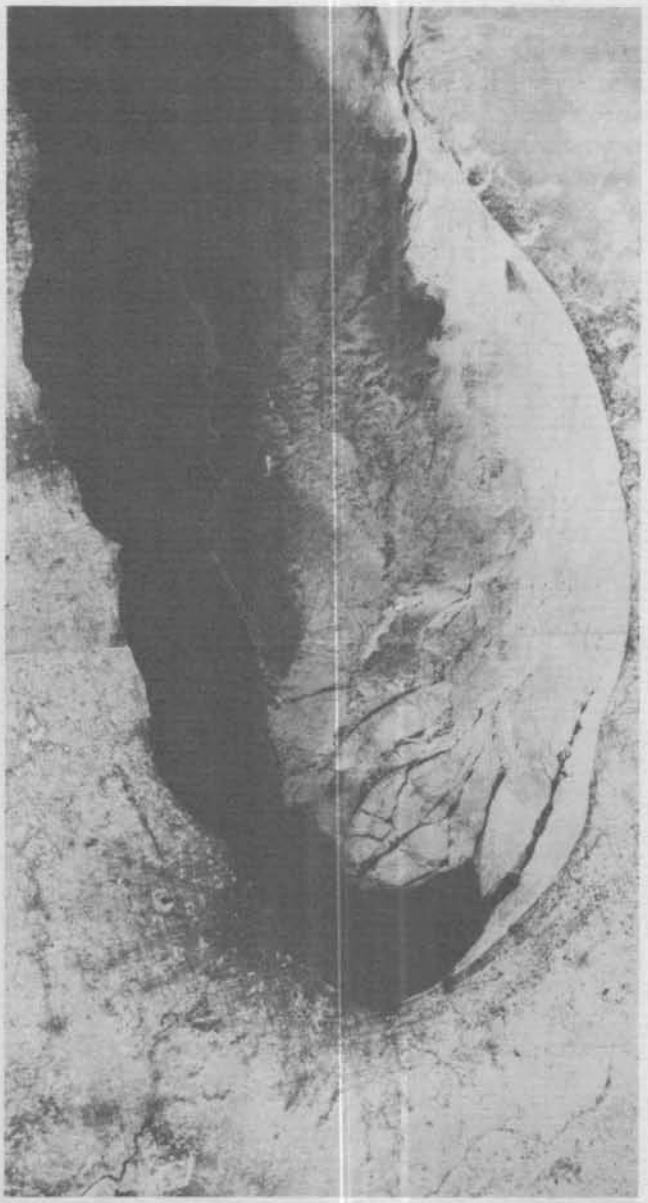
This study has provided significant new information on the penetration of photosynthetically active radiation through certain ice and snow covers common to the Great Lakes region.

Investigations are continuing on day-to-day changes in ice albedo and extension of the observations of irradiance at various water depths below ice. The spectral reflectivity of ice in the 300–1100 nm range will also be examined. Two spectroradiometers were recently acquired for that purpose and will be used for initial data collection during the 1977-78 winter season.

A pilot study to archive areal ice-cover data for the Great Lakes in a digital format was initiated. Data from ice charts depicting ice concentration, distribution, and age for Lake Superior during past winters are currently being abstracted and stored on computer tapes. In the coming year, computer programs to analyze this data will be developed to update ice-cover climatology of the Great Lakes and to make the ice-cover data base more useful for researchers and engineers, in both the public and private domains.

The 1976-77 ice cycle on the Great Lakes was documented through the collection of visual aerial ice reconnaissance, ice charts, side looking airborne radar imagery, and satellite imagery. This information will be used to update current ice-cover climatology and to distribute as part of the ice advisory services. This past winter was noteworthy in that ice covers

Computer produced ice chart of Lake Superior for 15 January 1976. This was generated after data from a visual reconnaissance ice chart was entered into the computer. Once hundreds of such charts are in memory, statistical analyses and calculations can be performed for scientific purposes, such as development of an ice climatology.



Satellite photograph of ice on southern Lake Michigan. This image, taken from LANDSAT on 10 February 1977, shows the ice concentrated on the eastern shore of the lake, where it has been driven by the prevailing winds.

formed early and were unusually extensive. One indication of the winter's severity was the unusually extensive ice cover in southern Lake Michigan in February 1977.

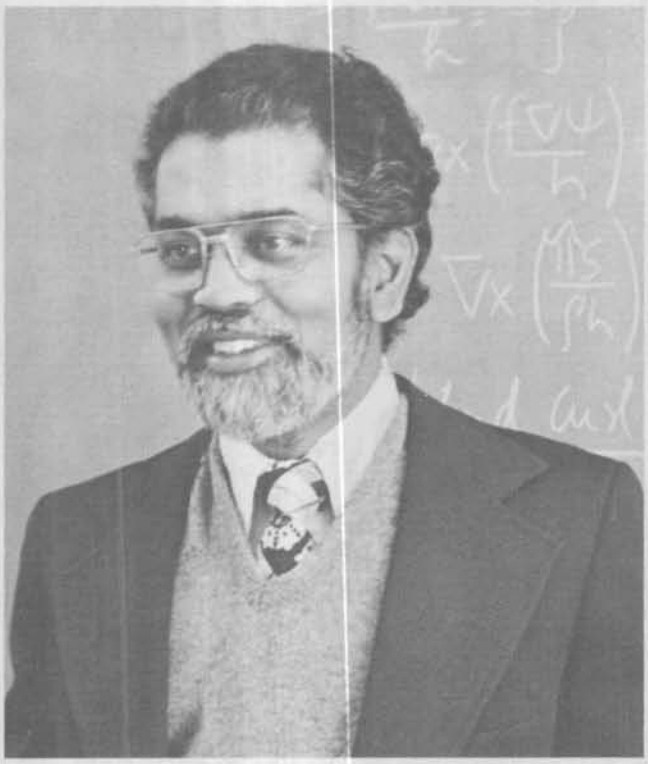
A better understanding of ice transport in the Great Lakes has been gained by formulating a one-dimensional model. Plans for the coming year include a determination of the best representation of the internal stress of ice, an analysis of the effect of waves on ice transport, and an examination of thermodynamic effects on ice transport. Currently this study is focused on Lake Erie, but with some modification it could be applied to other Great Lakes.

Ice-thickness data collected from 24 bay, harbor, and river sites on the Great Lakes were correlated with freezing degree-day accumulations to develop regression equations to predict ice thickness. Data bases at individual sites ranged from three to eight winters in length.

Scientist launching an expendable bathythermograph (XBT). These probes transmit the water temperatures as they fall from the surface to the bottom.

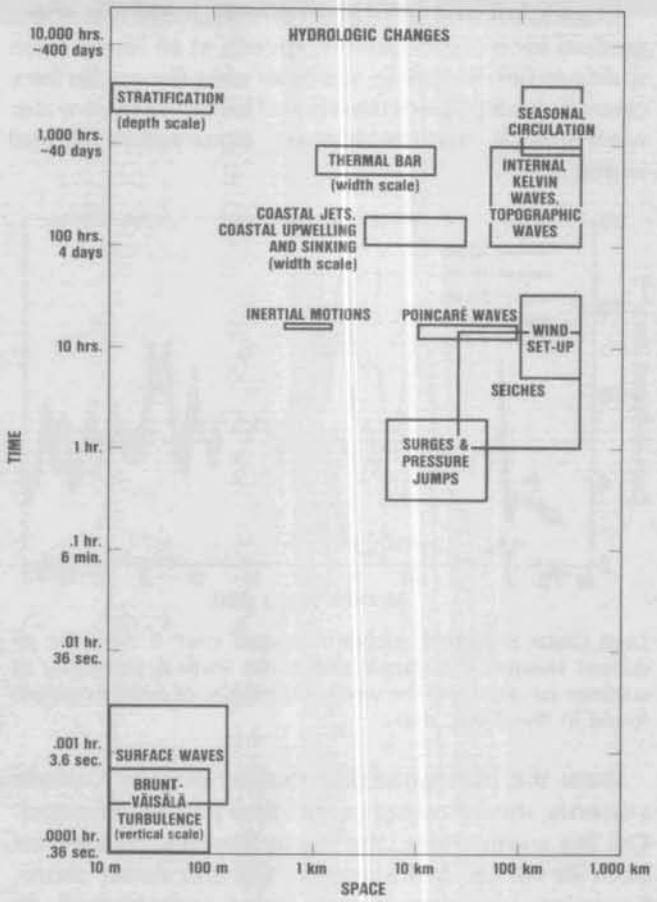
Bathythermograph data collected on Lake Superior over a four-winter period were used to calculate winter heat storage and its temporal variation. By the use of a technique developed to describe the change in heat storage for a given winter, a relationship between the date of fall overturn and maximum ice extent on Lake Superior for a given winter was developed. Commencing in August 1976, additional data on water temperatures during late summer and fall have been gathered. After an adequate data base has been established, this data will be used to study the feasibility of developing a technique for long-range forecasting of the date of initial ice formation.

PHYSICAL LIMNOLOGY AND METEOROLOGY



Physical Limnology and Meteorology Group Head—Desiraju B. Rao.

(Photograph by P. W. Sloss.)



Scales of physical lake phenomena. This chart indicates the time and space scales of known physical phenomena. To be accurate, circulation models must faithfully simulate as many of these phenomena as possible.

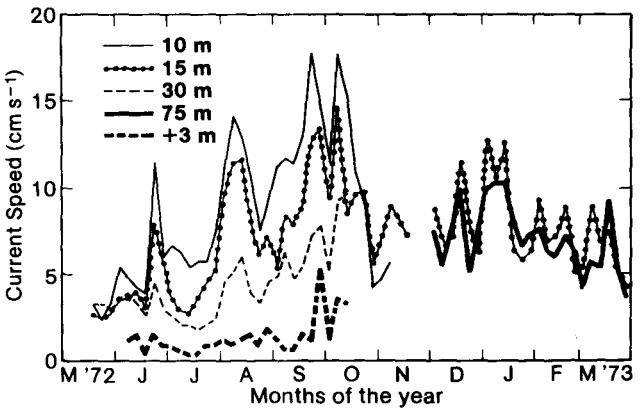
The work in physical limnology and meteorology is in two projects: (1) water movements and temperature and (2) surface waves and oscillations. The purpose of each project is to improve understanding of the dynamic processes and to better predict currents, temperatures, wind waves, and other environmental variables. Circulation, transport, and diffusion must be understood in order to predict the chemical and biological properties of the lake environment that are important in diverse user activities, such as waste management, power generation, fisheries management, and water supply planning. Waves and oscillations present potential hazards important to shoreline property owners, navigation, commercial and sport fishing activities, recreational boating, beach erosion, coastal zone management activities, ship design, etc.

The phenomena that need to be studied vary from annual and seasonal to hours and seconds in time scales and from the length of a lake to only a few meters in space scales. Of importance are a set of lake phenomena with common and scientific names: seasonal circulation, internal Kelvin and Poincaré waves, topographic waves, coastal jets, upwelling and downwelling, thermal bar, and seasonal stratification—all phenomena for investigation in the water movements and temperature project; and wind set-ups, seiches, storm surges, and surface waves—all phenomena for investigation in the surface wave and oscillation project. The studies are diverse in nature, including observational programs, data analyses, numerical simulations, and theoretical studies.

Water Movements and Temperatures

Long-term, large-scale current studies of Lake Ontario were completed and documented in FY 1977 as part of the IFYGL Project. The data revealed that in winter, when the lake was unstratified, currents had similar speeds at all depths. In summer, on the other hand, when the lake was stratified, speeds decreased rapidly with depth. The changeover from stratified to unstratified occurred near the end of October.

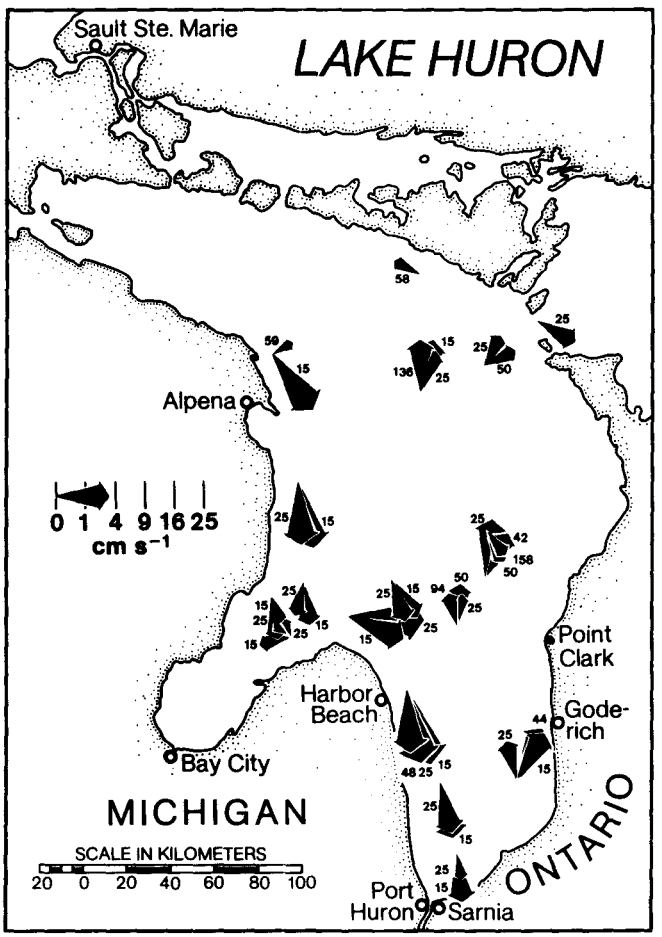
In addition to stratification effects, there was also a gradual increase in current speeds at all levels from spring to fall. In spring, warm air over the cooler lake caused atmospheric stability and lessened over-water wind speeds. Just the opposite occurred in fall and winter.



Lake Ontario current speeds averaged over 5 days for all current meters. This graph shows the vertical variability of summer currents and the vertical similarity of winter currents found in the IFYGL data.

From the horizontal distribution of Lake Ontario currents, the following overall flow pattern emerged. Off the south shore, the mean flow was to the east both in winter and summer. Off the north shore, however, the pattern was more complicated. In summer the eastern two-thirds of the north shore had a westward mean flow, while the western one-third had an eastward flow. Where these two flows met, the currents turned southwest. In winter, with more variable winds and very little thermal current, the northwestern clockwise flow expanded and contracted from month-to-month. At one extreme, the entire mean flow was counterclockwise.

Analyses of mean current patterns observed in Lake Huron during winter 1974-75 were completed and published. This study, a part of the IJC Upper Lakes Reference Study, showed that during winter Lake Huron was characterized by cyclonic circulation similar to what is now thought to characterize summer circulation. Winter currents were more intense and penetrated deeper in contrast to summer currents, which were more often confined to surface layers. This behavior is similar to what was found in the IFYGL current data from Lake Ontario. The cyclonic flow observed in the homogeneous (winter) water mass raises fundamental questions about the nature of lake circulation phenomena. Processes suggested as causes of one-cell cyclonic flow patterns have in past studies depended on the existence of density stratification. Winter studies in both Lakes Ontario and Huron reveal a need for re-examination of these phenomena.



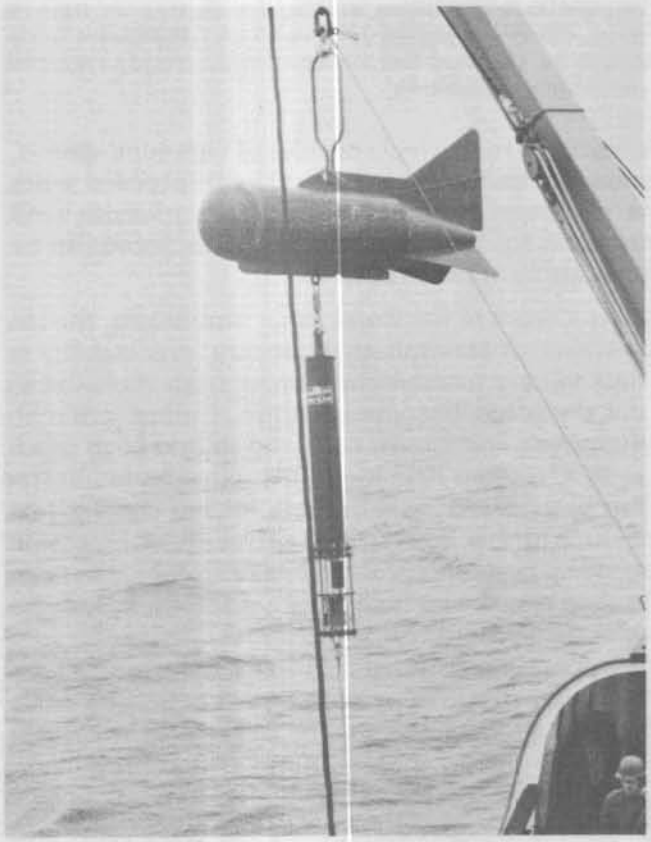
Resultant current flows observed in Lake Huron during winter 1974-75. The depth of each measurement level is indicated beside the seasonal vector resultant.

In a previous study, long-period waves of undetermined origin were found in the Straits of Mackinac during summer and fall 1974. The waves appeared to be independent oscillations of both the Lake Michigan and Huron Basins, but a longer period of data was required for identification of these waves. Hence, two recording current meters were set in the straits in October 1975 and retrieved in May 1977. Records of 15-months duration were obtained and are being examined to determine the nature of these newly-found lake basin oscillations.

In May 1976, a comprehensive field experiment was undertaken to study current and temperature distributions in the southern basin of Lake Michigan. Experiments in other lakes had shown that lake currents were strongest in the first 10–15 km offshore. To study the characteristics of these coastal jets, their longshore variations, and the role of long internal

waves propagating along the coastline in nearshore dynamics, pairs of stations at 7.5 and 15 km offshore were set at intervals of 30 km along the east coast of southern Lake Michigan. A cross section extending from Racine, Wisconsin, to Holland, Michigan, was instrumented to study the matching of coastal flow with the interior circulation and near-inertial period internal waves on the thermocline. The University of Wisconsin-Milwaukee and the University of Wisconsin-Madison participated in this study. The field portion of the program was completed in November 1976. The data have been processed and edited and some analysis has been started.

An array of current meters with integral temperature sensors was deployed in Green Bay in May 1977 and retrieved 5 months later. The purposes of this study were to quantify water mass exchange rates between the bay and Lake Michigan and to determine patterns of water movement within the bay itself. Green Bay has experienced water quality degradation due to continuing large inputs of contaminants about its perimeter. Determination of its flushing rate and water movement characteristics is essential for eventual improvement.



Deployment of a current meter. When current data at various depths are needed, strings of such meters are suspended in a column.

(Photograph by J. H. Saylor.)

A seven-layer numerical model of circulation patterns and thermal distributions in Lake Ontario has been developed and tested. Tuned realistically with IFYGL data, the model produced results generally similar to those observed. Two episodical simulations, one for July and the other for December, were carried out with hourly meteorological forcing obtained from IFYGL data. The time-dependent results differed strikingly from the mean states. Detailed comparisons, made with coastal-chain measurements as well as other IFYGL data, indicated satisfactory general agreements. However, it was found that the model response was faster than that observed in the lake.

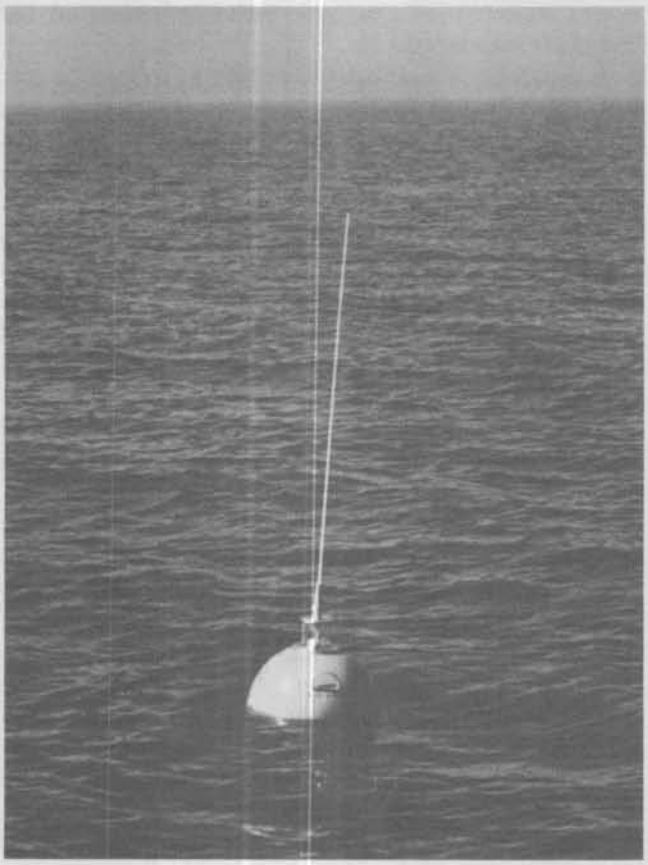
A three-dimensional circulation model with increased resolution of the coastal zone has been shown to reproduce the summer circulation of Lake Ontario better than existing models. In addition, it has been shown that a similar model can be used to understand the circulation of Lake Kinneret, the former Sea of Galilee. Long-term simulations of Lakes Ontario and Michigan have also been done and progress made toward applying the results to chemical-biological models.

Plans for next year include continuing analyses of currents in Lakes Huron, Ontario, and Michigan, including comparisons of their similarities and differences.

Surface Waves and Oscillations

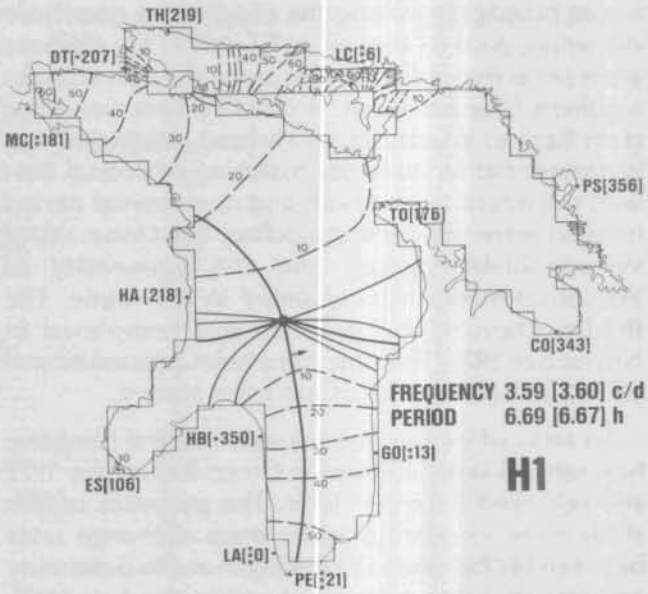
Results of an extensive study of temporal spectral growth and nonlinear characteristics of wind-generated surface waves in Lake Ontario showed that spectral growth prevailed most often during periods of increasing wind speeds. The higher order wave-wave and multiwave interactions are generally most intense near the peak-energy frequency of the unispectrum. Thus, the exchange of energy within the unispectral peak is of predominant importance. Furthermore, from examining the temporal growth of bispectral and trispectral components, it has been clearly demonstrated that the peak-energy frequency transfers more energy to the lower frequency components than to the higher frequency components.

The field measurement program in Lake Michigan this past year consisted of four Waveriders located 20 km offshore from Milwaukee, Wisconsin, and 10 and 20 km offshore from Muskegon, Michigan. An instrument tower was installed 2 km offshore from Muskegon, Michigan, in 16 m of water. Sensors placed on the tower included two for wind speed,



Wave measuring buoy. Data on wave heights are transmitted to a shore station, where they are recorded as functions of time.

(Photograph by R. J. Robbins.)



The longest period seiche of the main Lake Huron Basin. Calculated phase distribution relative to LA (Lakeport, Michigan) is shown by solid lines in increments of 30°, with the 0° line labeled by an arrow indicating the direction of propagation. Calculated amplitude distribution relative to a maximum of 100 is indicated by dashed lines. Observed phases relative to LA, amplitudes (indicated by the number of asterisks), frequency, and period are in brackets.

two for air temperature, one for wind direction, and one for surface water temperature. An array of four wave staffs was used to measure wave heights in order to compute directional wave spectra. The data were telemetered to shore and recorded on a recording and processing system designed by GLERL's marine instrument laboratory.

A cooperative program between GLERL and Atlantic Oceanographic and Meteorological Laboratories (AOML) was initiated to combine *in situ* wave gage data with remote sensing measurements from aircraft during the fall storm of 20–21 November 1977. The program will provide both temporal and spatial wave data for a comprehensive surface wave study. Next year, plans are to analyze the directional wave spectra from the tower data and the measurements made during the GLERL-AOML cooperative program.

Lake Erie storm surges caused by lake-wide wind forcing were simulated by a computer model. From wind data recorded hourly at United States and Canadian weather stations around Lake Erie, large-scale water level fluctuations of the lake can now be simulated. For several episodes of high wind speeds, model output agreed very well with recorded water levels. When routine National Weather Service wind forecasts for Lake Erie are used, water levels can be forecast 36 hours in advance.

As a result of the storm surge simulations, the importance of atmospheric boundary layer stability in determining momentum transfer from the wind to the water has become apparent. During stable atmospheric conditions, when the air may be as much as 20° C warmer than the water, momentum transfer can be reduced by half. Plans for the coming year include further investigation of this effect, extension of storm surge simulations to Lake Huron, and cooperation with the National Weather Service to evaluate operational storm surge forecasts.

The two-dimensional seiche characteristics of Lake Huron have been computed with the adjoining water bodies—Saginaw Bay, Georgian Bay, and the North Channel—taken into account. Theoretical computations of the periods and structures of several seiche modes agreed well when compared with those deduced from spectral analyses of water level data. The Physical Limnology and Meteorology Group has now computed the two-dimensional seiche characteristics for all the Great Lakes.

INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES (IFYGL)

IFYGL is a multiagency, joint United States-Canadian program of environmental and water resource research addressing Lake Ontario and its drainage basin. The central objective is to improve knowledge, information, and simulation models of the environment to provide a scientific basis for improved management of Great Lakes water-related activities. The data collection program was initiated in 1972 and the analysis and reporting phase will be completed in mid-1978.

U.S. IFYGL Coordinator—C. Frederick Jenkins.

(Photograph by R. L. Chambers.)

NOAA is the U.S. lead agency and GLERL exercises management responsibility. IFYGL work cuts across all disciplines at GLERL and constitutes a major part of the effort.

There have been a number of significant accomplishments to date on the IFYGL Program. Some of these are:

- Completion of archives at the National Climatic Center, Asheville, North Carolina, and at the Canada Centre for Inland Waters, Burlington, Ontario, Canada, containing data collected by United States and Canadian scientists. These data are available to interested users.
- Completion of the 78 U.S. analysis tasks.

- Publication of 320 articles and reports on the IFYGL results.
- Presentation of a set of eight papers at an IFYGL Symposium held in Copenhagen, Denmark, in August 1977 as part of the International Limnological Society triannual meeting.
- Improved knowledge of the temporal and spatial distribution and variability of physical, chemical, and biological properties.
- Development and testing of numerical models to simulate and predict physical, chemical, and biological processes and phenomena related to water quality, water quantity, water circulation, and living resources in Lake Ontario.
- Preparation of the first 4 of a set of 12 international Summary Scientific Report volumes to be published in 1978 summarizing the IFYGL work.

The program remains on schedule for completion in 1977, except for publication of a book, *IFYGL–The International Field Year for the Great Lakes*, containing the Summary Scientific Reports. An IFYGL Wrap-Up Workshop was held in October 1977 in Ontario, Canada, with 66 of the key participants in attendance. The program accomplishments were reviewed and future objectives for Great Lakes research were identified. The conclusions were that IFYGL successfully met its objectives, that the IFYGL archive will be valuable as a research data source for years to come, and that IFYGL established working relationships between United States and Canadian scientists that will improve Great Lakes research programs in the future.

IFYGL reports were regularly distributed to 450 institutions or individuals in the United States and to 250 in Canada.

INTERNATIONAL AND INTERAGENCY ACTIVITIES

The GLERL program includes support activities for and participation in the work of many other agencies, in both the United States and Canada. This is one of the mechanisms whereby our research product is used; in addition, we obtain information on requirements for environmental information to support planning and management activities. This user need information is helpful in shaping the future GLERL research program.

International Joint Commission (IJC)

GLERL participates in many of the activities of the IJC. Various staff are involved in committee and subcommittee work. These include work on the Research Advisory Board that provides the IJC with information on the state-of-the-art in Great Lakes research and recommends research programs. Also included is participation on the Scientific Basis for Water Quality Criteria Committee, the Upper Lakes Reference Group, the Pollution From Land Use Activities Reference Group, the Surveillance Subcommittee of the Water Quality Board, the Environmental Mapping Task Force, and the Federal Support Committee to the U.S. Cochairman of the Water Quality Board. The Scientific Basis for Water Quality Criteria Committee provides advice on the water quality objectives for pollutants in the Great Lakes; the Pollution From Land Use Activities Reference Group is assessing the significance and sources of pollution from land drainage to the Great Lakes and will develop recommendations on remedial measures. The Surveillance Subcommittee provides an annual assessment of the environmental quality of the Lakes, defines problem areas, and coordinates the surveillance activities of the many different agencies. The Environmental Mapping Task Force conducted a workshop and prepared a report including recommendations for mapping the Great Lakes.

GLERL staff participated in the review and updating of the Great Lakes Water Quality Agreement between the United States and Canada. This agreement will be administered by the IJC.

Great Lakes Basin Commission

GLERL staff are involved in the Great Lakes Basin Commission as Alternate Department of Commerce Commissioners, members of the Great Lakes Basin Plan Committee (formerly the Comprehensive Coordinated Joint Plan Committee), the Priorities Committee, the Coastal Zone Management Committee, the Standing Committee on Research and Development, and as participants in the Maumee River Basin Level B Study. The Great Lakes Basin Plan Committee has responsibility for developing an approach to identifying and coordinating water and related structural and non-structural near- and mid-term programs designed to enhance the economic, environmental, and societal aspects of the Great Lakes Basin. A major effort has been development of a process to analyze effects of plans at all levels and to include public participation in the process.

The Priorities Committee develops guidelines and criteria for establishing priorities of the Federal or federally supported Great Lakes Basin water resources initiatives for consideration by the National Water Resources Council; the Coastal Zone Management Committee coordinates, exchanges, and develops information pertinent to the Coastal Zone Management activities of the Great Lakes States; the Standing Committee on Research and Development assists Priorities Committee and Great Lakes Basin Plan Committee activities and develops improved research coordination, particularly for the Great Lakes portion of the basin. GLERL participation in the Maumee River Basin Study consisted of development and review of a Proposed Level B Plan which, after approval, completed the study.

Winter Navigation Program

GLERL is working in support of the Corps of Engineers in a multiagency program to examine the feasibility of extending the navigation season throughout the Great Lakes system. The Ice Information Work Group is chaired by a GLERL staff member. Also, GLERL has membership on the Winter Navigation Working Committee and the Steering Committee of the Environmental Planning Task Force, and represents NOAA in the Environmental Evaluation Work Group. The laboratory provides data on the physical and structural character of lake ice; on ice formation, growth, and decay; and on the effects of winter navigation on shore properties. In addition, a marine environmental service is provided to shippers during the extended season.

A report by the Winter Navigation Program was submitted to Congress in late 1976. Legislation passed Congress in 1976 to extend the program through June 1979. The emphasis of the extended demonstration program will be on the St. Lawrence River.

The International Coordinating Committee on Great Lakes Hydraulic and Hydrologic Data

Because much of the Great Lakes data base is used internationally, Canadian and United States users of hydraulic and hydrologic data formed a Coordinating Committee in 1953. The objectives of this committee are to reach agreement upon hydraulic and hydrologic data and related physical data concerning the Great Lakes; to assist agencies in pursuing studies requiring international data; to provide basic data to anyone with a recognized need; to reach agreement on methods and procedures for measuring, collecting, and storing pertinent data; and to publish coordinated data. GLERL participates on the River Flow Subcommittee with a charge to coordinate tributary stream inflow to the Great Lakes system, to coordinate studies of flow in the connecting channels and the St. Lawrence River, and to establish procedures for updating and disseminating river flow data.

Great Lakes Basin Hydromet Network Work Group Study

The Great Lakes Basin Hydromet Network Work Group, with membership from NOAA, the U.S. Geological Survey, and the Corps of Engineers, was formed to determine specific alternatives with timeframes and cost estimates for implementing, improving, and expanding U.S. Great Lakes Basin hydrologic monitoring. GLERL is one of the NOAA members of this work group, the aim of which is to improve lake level forecasts.

Lake Erie Wastewater Management Study

The Lake Erie Wastewater Management Study is a multiyear U.S. Army Corps of Engineers program to design and develop a demonstration wastewater management program for the rehabilitation and environmental repair of Lake Erie. GLERL staff participate on the Interagency Technical Advisory Group and have also, based on phosphorus loadings supplied by the Corps of Engineers, evaluated the impact of these loadings on Lake Erie for comparison with other impact assessments.

International Association for Great Lakes Research (IAGLR)

Members of GLERL actively participate in the activities of IAGLR. They hold membership on the Publications Committee (Chairperson) and the Board of Directors, and A. Robertson of the GLERL staff is serving this year as President of the Association.

GLERL and the University of Michigan served as cohosts of the 20th Conference on Great Lakes Research in May 1977. There were over 200 papers and 500 attendees at this meeting. Many of the GLERL staff contributed their efforts toward making this a successful conference.

FACILITIES

GLERL's laboratory and support facilities are an integral part of its research program. These are housed in three leased buildings in Ann Arbor, with a total space of about 19,000 square feet, and in a 10,000 square foot warehouse and dock facility in Monroe.

Chemistry Laboratory

During the past year, chemistry laboratory work has concentrated on the analysis of nutrient and chlorophyll samples from the nearshore environment of Lake Michigan. In conjunction with nutrients, techniques have been adapted for the analysis of organic carbon and carbonates in water and sediments. Dissolved and particulate humic acids, important as complexing agents for trace metals and organics, have also been quantitatively analyzed. The distribution and diagenesis of saturated hydrocarbons in the nearshore zone have been studied; this work will be extended in the near future to include aromatic materials by the use of gas and liquid chromatography. Also in the immediate future, we will be adapting a graphite furnace to our atomic absorption spectrophotometer, enabling us to analyze low levels of dissolved trace metals in water.

Technician using the AutoAnalyzer II. This instrument is being used to measure total nitrogen and phosphorus concentrations in lake samples.

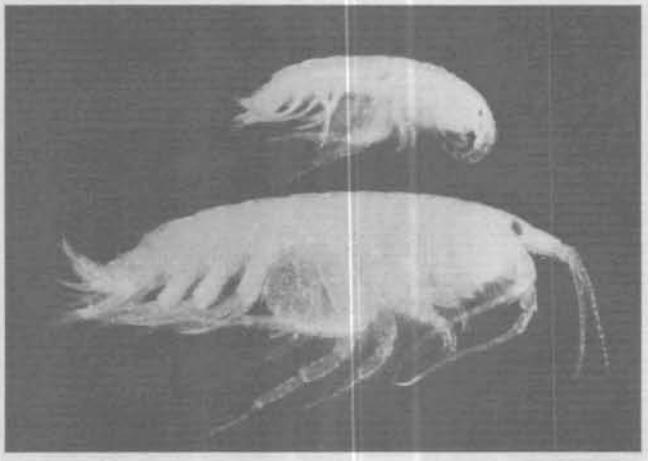
(Photograph by P. W. Sloss.)

Biology Laboratory

The biology laboratory is equipped to carry out a variety of experimental studies involving benthos, zooplankton, and phytoplankton. Studies measuring nutrient uptake with radioactive isotopes have been conducted with the aid of a liquid scintillation counter, and the effects of zooplankton feeding on particle size distributions have been monitored with a Coulter Counter. Controlled environment chambers allow the culturing of various kinds of plankton. An inverted microscope is used to obtain species counts for algae and conventional microscopes are used to identify and count zooplankton and benthos.

Scientists counting benthic organisms. Densities in a bottom sample indicate the degree of water quality.

(Photograph by C. F. Jenkins.)



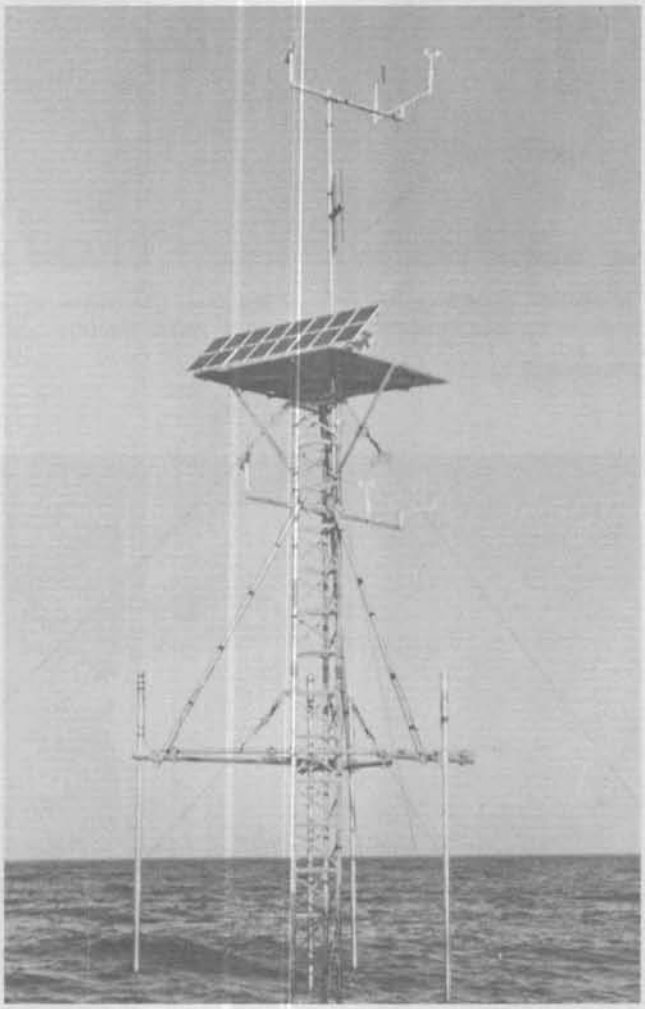
Juvenile and adult *Ponteporeia offinis* (9X). This species, one of the most widely distributed benthic organisms in the Great Lakes, is an important food source for many types of fish.

Marine Instrumentation Laboratory

The marine instrumentation laboratory has recently moved into new quarters with 5800 square feet

of office and laboratory space. This new facility allows consolidation of GLERL's instrumentation engineering, maintenance, staging, and storage operations in the Ann Arbor area, thereby greatly improving support to GLERL field observation programs. Some of the accomplishments in FY 1977 are:

- Installation of a complete operational wave direction and amplitude measurement system powered by solar energy on a tower in Lake Michigan. The information gathered includes four wave staff signals, two wind speed signals, one wind direction signal, three temperature signals, one solar input signal, and one storage battery condition signal.
- Deployment of four Waveriders in Lake Michigan. Using data telemetered to shore, GLERL routinely advises the marine forecast section of the National Weather Service in Chicago of wave conditions.
- Development and implementation of a general purpose programmable data acquisition and data reduction micro-computer system with a Zilog 8-bit central processing unit. This system is being used with our vector averaging current meters and surface wave measurement systems.
- Construction of the Chapelsky-Vanderploeg-Soo plankton trap and testing in the University of Michigan fluid mechanics laboratory test tank.
- Completion of a temperature-controlled water circulation unit to work with radiocarbon uptake incubators.



Instrumented wave tower. Wind speed and direction, air and water temperatures, and water level are measured simultaneously. Radioed to a shore station and recorded as a function of time, these data can be used to determine relationships between waves and meteorological variables. The tower operates on solar power.

(Photograph by P. W. Sloss.)

Shore station at Muskegon, Michigan. The two instruments to the left receive and record data transmitted from the instrumented wave tower. (See left.) The two instruments to the right receive and record data transmitted from wave measuring buoys.

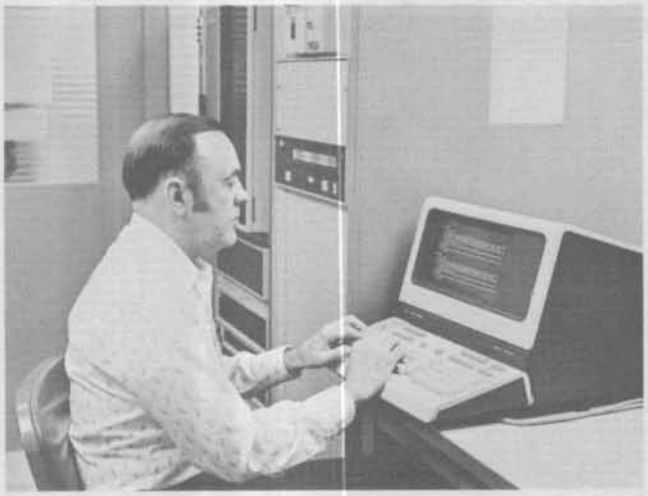
(Photograph by P. W. Sloss.)

Computer Laboratory

During the year the GLERL computer laboratory and its staff have contributed greatly to GLERL projects in the following activities: data management, analysis, modeling, and evaluation. The programming activities are accomplished via remote batch processing through a UNITECH (UT-1) Remote Communications Processor connected to a CDC 6600 computer located at the Environmental Research Laboratories in Boulder, Colorado. A Tektronix 4014-1 Graphical Display Terminal is also connected to the CDC 6600 to assist project scientists in the analysis of data and to provide them with the capability of graphical displays of their data.

A Hewlett-Packard 9603A Scientific Measurement and Control System allows GLERL to process and edit existing raw data records from a variety of field data

collection instruments and to develop a laboratory real-time interactive data acquisition system.



The computer laboratory. The Hewlett-Packard Scientific Measurement and Control System is in the background. (Photograph by P. W. Sloss.)

Ice Laboratory

A new ice laboratory has been ordered and will be installed in Ann Arbor in early 1978. The laboratory will be used for such diverse applications as measuring the dielectric properties of ice samples for inter-remote sensing and for environmentally calibrating delicate optical sensors. The laboratory has two compartments. The larger compartment is a workroom kept at +20° F. The smaller compartment, kept at −20° F, is primarily an ice storage room, but it can also be used for ice crystal growth experiments.

R/V Shenehon

Many of GLERL's field experiments use the *R/V Shenehon*, a converted T-boat, length—65.5 feet, beam—17.7 feet, and draft—6.5 feet, which is operated by GLERL. The vessel has a 600-nautical-mile range, with a cruising speed of 10 knots, and is fully complemented with navigational, communication, depth sounding, and water and sediment sampling equipment. Forward and aft winches handle both hydrographic wire and multiconductor electric cable. The 120 square foot laboratory facilitates the conduct of onsite chemical and biological analyses. Specially developed plankton traps for grazing experiments, *in situ* chemical probes, and incubation chambers for culture and radioactive isotope uptake experiments are used in biological and chemical experiments.

The forward mast was removed this past year and was replaced with a hydraulic articulated crane. This crane, with a 1630-pound lifting capacity at 21-foot extension, increases the ship's capability to deploy and retrieve heavy equipment, such as instrumented buoys and towers.

Placement of buoys with the *R/V Shenehon*. The crane, added this past year, greatly facilitates such operations. (Photograph by R. L. Chambers.)

During 1977, the *R/V Shenehon* operated in southern Lake Michigan out of the Port of Grand Haven in direct or logistical support of six GLERL projects:

- The ship was used to deploy and service telemetering accelerometer type wave buoys as part of a program to study the processes of fetch-limited surface waves in southern Lake Michigan.
- During the entire open-water season, open-lake water samples were used to document differences in food selectivity by individual zooplankton species and to determine the effect of grazing by the entire zooplankton community on the summer succession of phytoplankton species. *In situ* primary production, chemical, and nutrient analyses are being used to investigate phytoplankton nutrient competition.
- Chemical constituents, particulate material, nutrients, and trace metals were measured off the mouth of the Grand River to quantify and characterize transport, deposition, and impact of material being discharged into Lake Michigan.
- Sediment cores and bottom water samples were taken by divers for extraction of invertebrates being identified in an investigation of the time-spatial distribution of these organisms and their relationship to water depth, particle size, and organic carbon.
- Sediment traps built at the laboratory were deployed at multiple depths at nine stations off the mouth of the Grand River; these were retrieved each month and sediment extracted for analysis in a project to classify various organic and inorganic elements

with respect to sediment grain-size and distance from source.

- Meteorological observations and solar radiation were continuously recorded aboard ship in support of each of the sampling programs.

These various field investigations have provided essential support to laboratory programs concerned with determining natural distribution and variability of lake characteristics and defining physical, chemical, and biological processes and interrelationships and sediment-water and air-water exchanges; all are essential inputs to numerical simulation of the natural system and to forecasts of time and space scales of interest to users.

Library and Information Services

The GLERL library supports the laboratory's programs through the facilities of a small, growing collection of periodicals, technical reports, books, and reference materials. Currently, these materials are being augmented by materials obtained from a recently dissolved NOAA library. Future plans call for participation in the on-line cataloging system of the Ohio College Library Center (OCLC). OCLC is designed to reduce duplication of effort by sharing original cataloging among cooperating libraries. The large bibliographic data bases within the OCLC system also facilitate interlibrary loans.

Supplementary materials required by individual laboratory researchers are obtained by purchase or interlibrary loan. Regular trips are made to local academic and research libraries to obtain materials. In addition, an on-line search service has been instituted, providing ready reference to the computerized bibliographic data bases of NOAA's Oceanic and Atmospheric Scientific Information Service (OASIS). OASIS is an information retrieval system that uses computerized sources to provide reference to the technical literature and to research in the environmental sciences and marine resources.

Publications Section

Publications are a major GLERL product and dissemination of information provides a critical communications link. During the past year the publications section has processed, edited, and typed 37 manuscripts in various formats as prescribed for publication in professional journals and NOAA reports.

A list of GLERL publications is sent to the mailing list every 6 months and requests are filled until supplies are exhausted.

An IBM Mag Card II Selectric Typewriter facilitates review, editing, and formatting to various publishers' specifications. All graphics and photo services are procured under contract to the laboratory.

CONTRACTS AND GRANTS DURING FY 1977

Principal Investigator	Institution	Title
H. E. Allen	Illinois Institute of Technology	Trace Metal Species
J. R. Bennett	Massachusetts Institute of Technology	Circulation of Lake Ontario
G. E. Birchfield	Northwestern	Coastal Circulation of Lake Ontario
R. P. Canale	University of Michigan	Phytoplankton Nitrogen Utilization
C. W. Chen	Tetra Tech, Inc.	Water Quality Ecological Model for Lake Ontario
G. T. Csanady	Woods Hole Oceanographic Institution	Coastal Circulation
K. E. Damann	State University of New York (Buffalo)	Dynamics of Lake Michigan Plankton
J. E. Gannon	University of Michigan	Role of Predacious Rotifers
T. Green	University of Wisconsin (Madison)	Current Measurements in the Coastal Zone of Eastern Lake Michigan
D. D. Houghton	University of Wisconsin (Madison)	Dispersion of Pollutants
S. J. Jacobs	University of Michigan	Parametric Model for Wave Prediction
G. F. Lee	University of Texas (Dallas)	Biological Characteristics of the Nearshore Waters of Lake Michigan
C. H. Mortimer	University of Wisconsin (Milwaukee)	Currents and Oscillations of the Offshore Waters of Lake Michigan
C. H. Mortimer	University of Wisconsin (Milwaukee)	Whole Basin Inertial Oscillations
R. R. Rumer	University of Delaware	Effects of Wind and Waves on Ice Transport
J. T. Scott	State University of New York (Albany)	Climatology Circulation Patterns
F. Sciremammano	Stockton State College	Lake Ontario Water Supplies
E. F. Stoermer	University of Michigan	Algal Populations
R. A. Sweeney	State University of New York (Buffalo)	Copepod Life History

STAFF AS OF 30 SEPTEMBER 1977

	Full Time Permanent	Commissioned Officers	Temporary or Part Time
Office of Director	4	0	3
Physical Limnology and Meteorology Group	17	0	2
Chemistry and Biology Group	11	0	3
Lake Hydrology Group	9	1	0
Environmental Systems Engineering Group	6	1	3
Computer Systems	5	0	0
Total	52	2	11

PUBLICATIONS

A 6-months listing of our available publications can be obtained from

Writer-Editor
Great Lakes Environmental Research Laboratory
2300 Washtenaw Avenue
Ann Arbor, Michigan 48104

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†Not affiliated with this laboratory.
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*No longer affiliated with this laboratory.
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Scientist addressing an in-house seminar. GLERL staff speak at conferences, in-house seminars, and other meetings where scientists or laymen gather to discuss the environment of the Great Lakes.

(Photograph by P. W. Sloss.)

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†Not affiliated with this laboratory.
*No longer affiliated with this laboratory.

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