GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

ANNUAL REPORT FY 1979

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
Office of Research and Development
Environmental Research Laboratories

GREAT LAKES

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ANNUAL REPORT FY 1979

December 1979

Eugene J. Aubert, Director

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
Office of Research and Development
Environmental Research Laboratories
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PREFACE

The Great Lakes Environmental Research Laboratory (GLERL) has completed its fifth 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, universities, industries, 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 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 sufficiently precise information on Great Lakes processes and phenomena to support enlightened use of the region's resources.

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 and systems – critical to understanding and prediction of the natural ecosystem and human alterations in the 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, the Great Lakes Basin Commission, and the International Association for Great Lakes Research, 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 the opportunity for cooperative research programs and 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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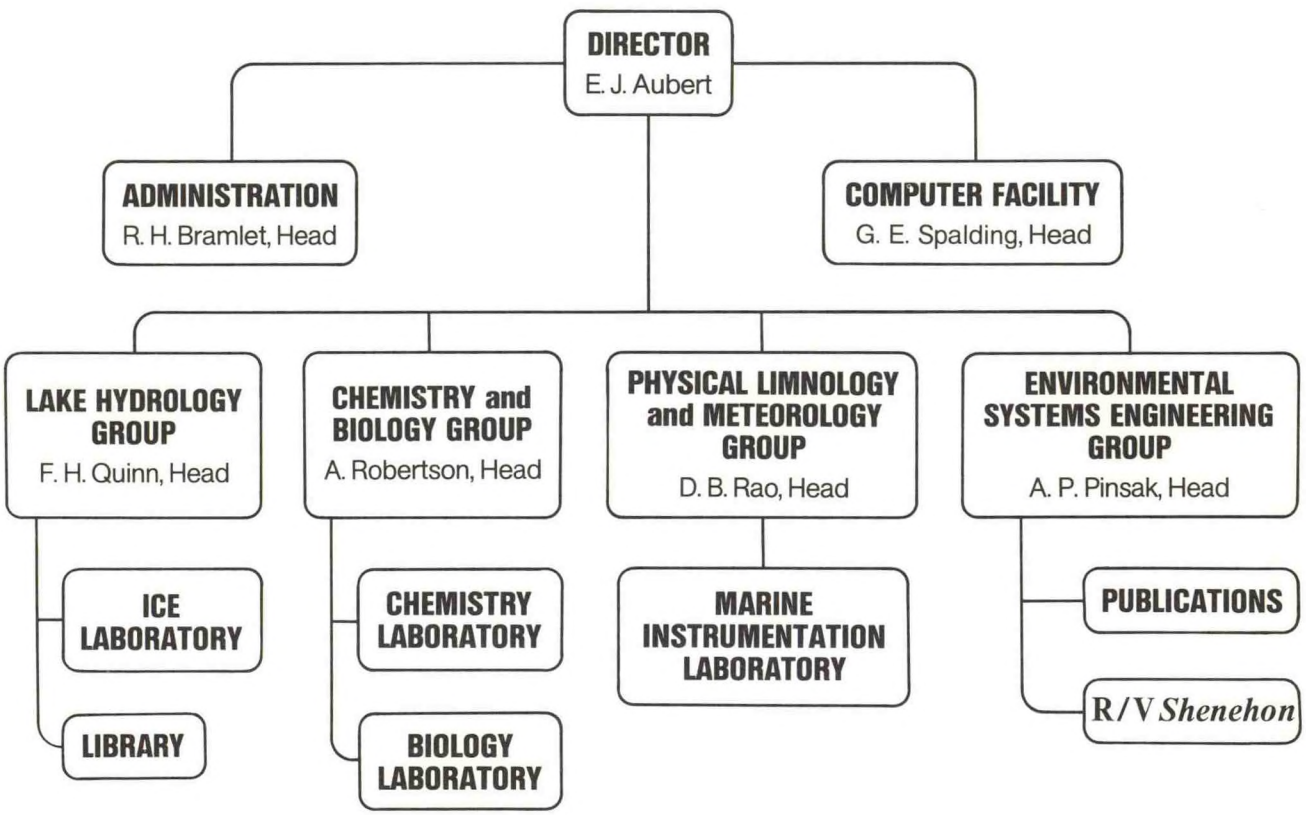
GLERL ORGANIZATION CHART



HIGHLIGHTS

For 5 years the laboratory has been involved in research on significant processes and problems in the Great Lakes Region. GLERL research is diversified in form. As is shown by the organization chart, process research is aligned in four primary discipline areas. But problem-oriented multidisciplinary research, using staff from more than one group, is also conducted. The in-house research program is supplemented by grants and contracts with private institutions. In turn, GLERL supports the efforts of other government agencies; this past year 13 percent of the laboratory budget came through interagency agreements. The dissemination of research results by publication or presentation and discussion at scientific and user meetings is a major GLERL product. During FY 1979, 40 papers authored by GLERL staff and 10 papers by contractors were published, and 40 papers prepared by GLERL staff were presented at meetings.

Research

Some changes and consolidations have occurred in the GLERL research program. Two new projects were initiated, one in particle dynamics and one in cycling of toxic organics. A cooperative program was also initiated by GLERL and the University of Michigan to build teams of scientists from these two organizations to work together on marine pollution problems in the Great Lakes. These changes reflect a trend at GLERL toward more problem-oriented research, particularly in the area of marine pollution.

Mathematical modeling continued at GLERL with activities in the following areas:

Multilayer ecological models were applied to study the vertical structure of physical, chemical, and biological properties in Lake Ontario; the seasonal aspects of this structure; and the expected ecosystem response to rapid variations in winds and surface water temperature. The large gradients of biological and chemical properties in the nearshore region during the spring-summer transition period were found to be controlled primarily by the interaction of biological and chemical processes occurring in the presence of vertical mixing.

The GLERL total phosphorus management model was used to estimate the loading restrictions necessary to meet water quality goals in the Great Lakes. These estimates were then used by the International Joint Commission in their determination of phosphorus loading criteria for the recently renegotiated Great Lakes Water Quality Agreement.

Another major development in the area of water quality management modeling was the laboratory's role (through publication and contracts) in introducing the concept of uncertainty analysis to lake trophic state predictions. A eutrophication model was applied to Saginaw Bay to test the sensitivity of the error in the prediction of eutrophication (phytoplankton concentration) to the errors in the initial state variables, the model coefficients, and nutrient loadings.

The models used to compute the Detroit River transient flow for hourly, daily, and monthly time scales were modified to incorporate wind stress effects previously neglected. The wind stress effects were found to be important for hourly and daily flow computations when wind speeds along the river exceeded 6 meters per second.

A two-dimensional cross-sectional model of water circulation was coupled to a chemical and ecological model for Lake Ontario, and the spring regime was simulated. The combined model successfully reproduced the observed large gradients of many chemical and ecological variables, such as particulate organic carbon and available phosphorus. Because the effects of large-scale hydrodynamic circulation were included, the model helped scientists understand why one-dimensional ecological models require unrealistically low sinking rates for particulate matter.

A Great Lakes spill model was developed in response to questions on the movement of oil and hazardous material spills resulting from accidents. The model, which can be operated from a portable (briefcase size) computer terminal or a teletype unit, predicts the drift of the spill given spill location and winds. The model was successfully applied to predict the drift of the abandoned ship *Labradoc* in April 1979.

The Lake Erie storm-surge forecast model developed by GLERL was implemented by the National Weather Service as the standard operational procedure starting in September 1979.

Experimental and theoretical research to better understand the physical, chemical, and biological processes operating in the lakes included a number of studies.

A program in marine pollution studies has been initiated in cooperation with the University of Michigan.

A new project has been established within the GLERL program to study the cycling of toxic organics in the Great Lakes. It initially focuses on two classes of toxic organic substances: polynuclear aromatic hydrocarbons (PAH's) and polychlorinated biphenyls (PCB's).

Process research underway, both in-house and in cooperation with the University of Michigan, includes studies on volatilization, photodecomposition, sorption onto particulates, and the transport and settling of suspended matter indigenous to the Great Lakes.

Nutrient studies have concentrated on understanding the environmental chemistry and transport mechanisms

of phosphorus in the Great Lakes. These studies involve the use of sediment traps in the lakes to provide data on the role of settling particulate material in the phosphorus regeneration in, or removal from, productive regions of a lake.

Phytoplankton studies this year have centered on the processes responsible for the seasonal distribution and diversity of plankton types in Lake Michigan. It was found that phytoplankton growth cannot be predicted simply from phosphorus concentrations and that silicon:phosphorus ratios have limited value for predicting the shift in species composition.

Zooplankton studies have centered on a Lake Michigan field program to evaluate and quantify the significance of predation of the freshwater shrimp *Mysis relicta* on zooplankton under varying conditions of species composition and abundance of zooplankton.

The draft final report was prepared for the study on consumptive uses of water in the Great Lakes from 1975 to 2035. This draft report has been submitted to the International Great Lakes Diversions and Consumptive Uses Study Board of the International Joint Commission. The study indicates that consumption in the Great Lakes will increase dramatically after the year 2000 owing to assumed continued growth of the region. Alternative assumptions have been made concerning the use of water by the municipal, manufacturing, and power sectors, and the resultant differences in consumption have been determined.

A study examining the overall Great Lakes precipitation climatology from 1900 to date was completed. A change in the precipitation regime found to occur in the mid-1930's increased the average annual precipitation by approximately 8 percent and the standard deviation by 40 percent. If the current precipitation regime persists, it will present many challenges for water resource managers and planners in the Great Lakes Basin. For example, under increased water supplies the current Great Lakes regulation plans may not perform within design specifications; they did not perform as well as expected during the 1968-73 high water supply period. This emphasizes the need for improved Great Lakes water supply forecasting techniques to take into account the probability of higher precipitation.

Another completed study involved the analysis of wind stress effects on the computed discharges of the Detroit River. Mathematical transient models are currently used to compute Detroit River flows for hourly, daily, and monthly time scales. These models previously neglected the effects of wind stress. The incorporation of wind stress into the models was found to be important for hourly and daily flow computations when wind speeds along the river were in excess of about 6 meters per second.

Two state-of-the-art scanning spectroradiometers have produced the first spectral ice and snow reflectance measurements on the Great Lakes. Optimum instrument configuration requires that incoming radiative flux be recorded simultaneously with flux reflected from the surface. Meaningful spectral reflectance data can thus be collected without regard to variability in cloud cover or solar altitude. The system is now capable of collecting extremely accurate data under all types of cloud conditions.

A new interdisciplinary project, particle dynamics, was initiated this year to study the movement of various types of particulate matter through the lake environment. This is important to studies of toxic organics and nutrients since these substances enter the lake attached to particulate matter. The pathways and ultimate fate of these pollutants in the lakes depend upon the particle movement.

A comprehensive field program to measure various physical, chemical, and biological properties of the lake was planned and launched during this fiscal year as a part of the Lake Erie surveillance program directed by the International Joint Commission and supported by the U.S. Environmental Protection Agency. This program was undertaken jointly by our laboratory and the Canada Centre for Inland Waters (Burlington, Ontario). Since the development and persistence of anoxia, lack of oxygen, depends on characteristics of circulation (and stratification), a prime objective is to measure the movement of water between the central basin and other basins of Lake Erie. GLERL's project is an attempt to quantify the water volume exchanges across the basins and also to examine the spatial and temporal variability of the basin-wide circulation with a total of 58 current meters on 28 moorings, and 5 thermistor chain moorings.

Analysis was completed on the data from the GLERL and Sea-Air Interaction Laboratory, Atlantic Oceanographic and Meteorological Laboratories, cooperative program in which an airborne laser profilometer was used to map waves during a fall storm in Lake Michigan.

Advisory Services

During FY 1979, 630 requests for information, data, or reports were received from various user groups and answered as a part of the GLERL advisory service activity. There were 22 Draft Environmental Impact Statements evaluated. The GLERL mailing list includes 441 recipients who have requested regular receipt of one or more of the 6 types of GLERL publications. Additionally, GLERL supports the Great Lakes Sea Grant Colleges in their advisory service activities.

International Field Year for the Great Lakes

This program has been completed except for publication of the final two reports. *The International Field Year for the Great Lakes (IFYGL) Data Catalog: United States Data Archive* was published in FY 1979. The *IFYGL Atlas – Lake Ontario Physical Properties* is in press. All but one chapter of the book *IFYGL – The International Field Year for the Great Lakes* have been prepared, reviewed, and are being edited.

International and Interagency Activities

GLERL staff members were active in several International Joint Commission boards and committees, including the Science Advisory Board, the Surveillance Subcommittee, the Aquatic Ecosystem Objectives Committee, the Task Force on Environmental Mapping, and the Consumptive Uses Subcommittee.

GLERL staff members participate in the Great Lakes Basin Commission program as Department of Commerce Alternate Commissioners and as working members of the Great Lakes Basin Plan Committee, Priorities Subcommittee, Coastal Zone Management Committee, the Standing Committee on Research and Development, and the Great Lakes Environmental Planning Committee.

In their capacity as members of the Interagency Technical Advisory Group of the Lake Erie Wastewater Management Study, GLERL staff reviewed study programs and recommendations.

GLERL staff participated on the International Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data and the Interagency Great Lakes Basin Hydromet Network Work Group.

GLERL staff were active in the Great Lakes-St. Lawrence Seaway Navigation Season Extension Program as members of the Winter Navigation Working Committee, the Ice Information Work Group, and the Environmental Evaluation Work Group.

Facilities

The chemistry laboratory program has involved analysis for trace organics in components of the lake ecosystem. A recently acquired Waters liquid chromatograph equipped with ultraviolet and fluorescent detectors has been used in this analysis. The nutrient cycling program continued. Experiments involving size and molecular weight separation were conducted with radio-labeled phosphorus-spiked water samples. Quantitative analysis of "cold" phosphorus was performed by spectrophotometry and by fluorometry.

The marine instrumentation laboratory used its recently developed micro-computer system to examine both serial and parallel data from deployed instruments within hours and days of collection to validate data integrity, decode data formats, and determine design faults. Applications included testing for the 58 current meters and 28 acoustic releases deployed in Lake Erie; data retrieval of the water temperature profile from the expendable bathythermograph data logger; development of an interactive current meter recording system; and the interface, modification, and verification of an Aanderaa tape playback interface unit.

The Hewlett-Packard 9815 computer was interfaced with EG&G spectroradiometers and programmed for simultaneous data logging and albedo calculations in support of the ice measurement program.

The R/V *Shenehon* successfully supported several water chemistry and biology experiments in Lake Michigan and physical limnology experiments in Lake Erie.

STAFF AS OF 30 SEPTEMBER 1979

	Full Time Permanent	Temporary or Part Time
Office of Director	9	0
Chemistry and Biology Group	11	4
Environmental Systems Engineering Group	4	4
Lake Hydrology Group	8	1
Physical Limnology and Meteorology Group	15	2
Total	47	11

Assel, R. A.	LH	Lawton, B. J.	LH
Aubert, E. J.	OD	Lee, J. P.	OD
Bell, G. L.	CB	Leshkevich, G. A.	LH
Bennett, J. R.	PLM	Liu, P. C.	PLM
Bermann, L. F.	CB	Malczyk, J. M.	CB
Bolsenga, S. J.	LH	McCormick, M. J.	CB
Booker, H. L.	PLM	Miller, G. S.	PLM
Bramlet, R. H.	OD	Muzzi, R. W.	PLM
Burns, W. R.	ESE	Nalepa, T. F.	CB
Carrick, B. J.	LH	Noble, P. E.	OD
Chambers, R. L.	CB	Norton, D. C.	LH
Chapra, S. C.	ESE	Parker, R. K.	OD
Congdon, S. W.	ESE	Pickett, R. L.	PLM
Del Proposto, D. J.	OD	Pinsak, A. P.	ESE
Derecki, J. A.	LH	Quigley, M. A.	CB
Doughty, B. C.	PLM	Quinn, F. H.	LH
Dungan, J. E.	PLM	Rao, D. B.	PLM
Eadie, B. J.	CB	Robertson, A.	CB
Field, L. P.	PLM	Royse, G. B.	PLM
Gardner, W. S.	CB	Saylor, J. H.	PLM
Grasso, J. O.	CB	Scavia, D.	CB
Grimes, J. E.	ESE	Schwab, D. J.	PLM
Grumblatt, J. L.	PLM	Slavens, D. R.	CB
Hodson, A. W.	OD	Soo, H. K.	PLM
Huang, J. C. K.	PLM	Tarapchak, S. J.	CB
Jenkins, C. F.	OD	Thompson, T. S.	ESE
Kelley, J. M.	ESE	Vanderploeg, H. A.	CB
Kelley, R. N	LH	White, B. J.	ESE
Kistler, R. D.	PLM	Willis, P. D.	OD

LH – Lake Hydrology Group
OD – Office of the Director
CB – Chemistry and Biology Group
PLM – Physical Limnology and Meteorology Group
ESE – Environmental Systems Engineering Group

CHEMISTRY AND BIOLOGY

The work in chemistry and aquatic biology is concentrated in three principal task areas: water chemistry, ecosystems modeling, and plankton 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.

This information is of immense value to water resource managers in the Great Lakes Basin as they make decisions affecting water quality, power generation, commercial fisheries, and recreational uses of the lakes. Numerical models of the ecosystem can be used to forecast future conditions, to predict the results of implementation of various possible strategies, and to better understand the dynamics of lake biological and chemical phenomena. The variety and distribution of plankton types affect water supply taste and odor and play an important role in the entire ecosystem as plankters are a vital part of the lake food web. Water chemistry studies, by describing the constituents of the water at various sites and changes with time and with variations in temperature, currents, and loading, are particularly important to water quality determinations. The current emphasis is on understanding the cycling of nutrients and toxic organic compounds within the ecosystem.

Water Chemistry

A new project was established this year. It is an expansion of studies in the cycling of organic materials into the area of toxic organics. The primary goal of the project is to produce a clearer understanding of the cycling of hydrophobic toxic organic compounds in the Great Lakes environment. GLERL scientists are employing a systems analysis approach that will ultimately enable one to simulate the location of selected contaminants, their expected residence time in any location or phase, how rapidly and into what they will decompose, and where they will finally reside.

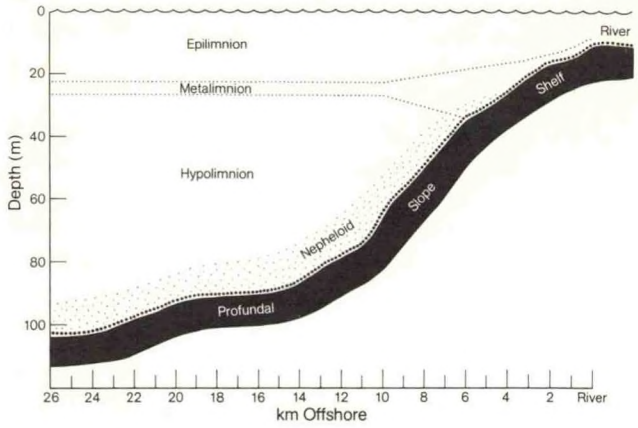
The planning for this project has included involvement of University of Michigan researchers under a formal cooperative research structure, as well as outside investigators and GLERL staff. A hierarchy of models will be used to monitor the progress of the research at different levels throughout the course of the program. These models will be continuously upgraded through the results of the process research experiments along with other information from the literature. Carrying out process research and modeling simultaneously will permit continual determination of the weakest or most sensitive areas in the systems approach and definition of the research necessary to address these specific problems.

In the next 1-3 years, effort will be concentrated on two classes of toxic organic substances, PAH's and PCB's. Process research underway, both in-house and in cooperation with the University of Michigan, includes studies on volatilization, photodecomposition, sorption onto particulates, and the transport and settling of suspended matter indigenous to the Great Lakes.

A principal objective of the nutrient cycling program is development of a greater understanding of the environmental chemistry and transport mechanisms of phosphorus in the Great Lakes. Phosphorus is known to limit photosynthetic production in epilimnetic waters, but potential availability of the nutrient from various phosphorus pools in the lakes is unclear. Phosphorus, in dissolved and sized-particulate fractions, is currently being studied to develop preliminary information about these pools and their changes with time and space in the lakes. These experiments will be continued in order to provide information on the relative importance of selected nonliving and living pools to phosphorus cycling in the lakes. Nutrient measurements (and chemical availability studies) of particulate material from sediment traps placed at three depths at various locations in Lake Michigan will provide information on the role of settling particulate material in the phosphorus regeneration in, and removal from, productive regions of the lake.

An understanding of the dynamics of materials movement is of extreme importance to the study of water chemistry because chemicals adhere to these materials. During the past year, much of the effort in this area has been directed toward analyzing data on the nepheloid layer, vertical flux, and distribution of total suspended matter in southern Lake Michigan. These data came from a 2-year sediment trap program and more than 35 cruises made from 1977 to 1979.

The benthic nepheloid layer is a region of highly turbid bottom water up to 10 meters thick, with particle concentrations two or more times those in the hypolimnion. The layer covers the southern Lake Michigan Basin; however, it is most highly developed at the base of the eastern slope, which is also the region of highest sediment accumulation. Particle flux profiles within the nepheloid layer increase exponentially toward the bottom, with a resuspension scale length of about 7 meters. A nearly ubiquitous background nepheloid system is generated and maintained by weak, but persistent, current and wave energy in the slope-basin region. Elevated concentrations of several chemical substances are associated with this region. Therefore, the role and contribution of



Schematic illustration of the distribution of particulate matter in southern Lake Michigan. Light transmission varies throughout the epilimnion and hypolimnion, but is generally high, reflecting small amounts of total suspended matter in the water. However, in the bottom few meters the total suspended matter increases by a factor of two to eight, with minimum to zero light transmission. This region of very high turbidity is called the nepheloid layer and plays an important role in the cycling of nutrients and toxic organics in the lakes.

the nepheloid layer to the cycling of polluting and enriching substances should be considered in any systems approach to Great Lakes ecology.

Data from sediment traps placed below the thermocline but above the influence of resuspended sediment have shown the same accumulation rates as lead-210 dating of adjacent sediments. This fact will permit calculation of the mass flux of nutrients, metals, and trace organics into the hypolimnion and aid in evaluating decomposition rates associated with the sedimentary environment.

Plans for next field season are to place these upper sediment traps throughout Lake Michigan and (in cooperation with several outside investigators) to estimate mass fluxes of several polluting and enriching compounds to the entire lake system. This information will be valuable to various GLERL modeling programs.

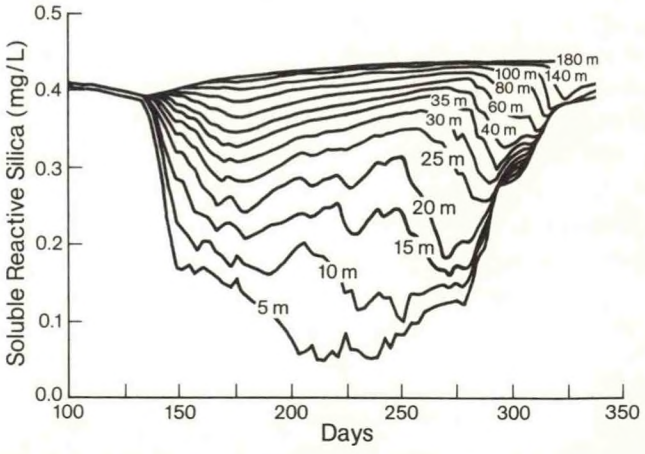
To determine the effect of sedimented matter on the nearshore benthic community, the Chemistry and Biology Group conducted laboratory experiments to measure the oxygen uptake rate of the bottom sediments and to partition the rate into its biological and chemical components. Such measurements give a relative idea of community function and the important pathways of materials flow through the benthic system. Most of the oxygen uptake resulted from the respiration of bacteria in mineralizing the sedimented material. Maximum rates were recorded in spring, corresponding to the time of greatest input of the material into the sediment.

In a study to define the role of nearshore sediments in the cycling of nutrients, the release of phosphorus, silica, and ammonia was measured. The concentration of these nutrients in water overlying incubated sediment cores was significantly higher than background levels, indicating net flux out of the sediments. The activities of benthic animals appear to be the main stimulus for this release.

Ecosystems Modeling

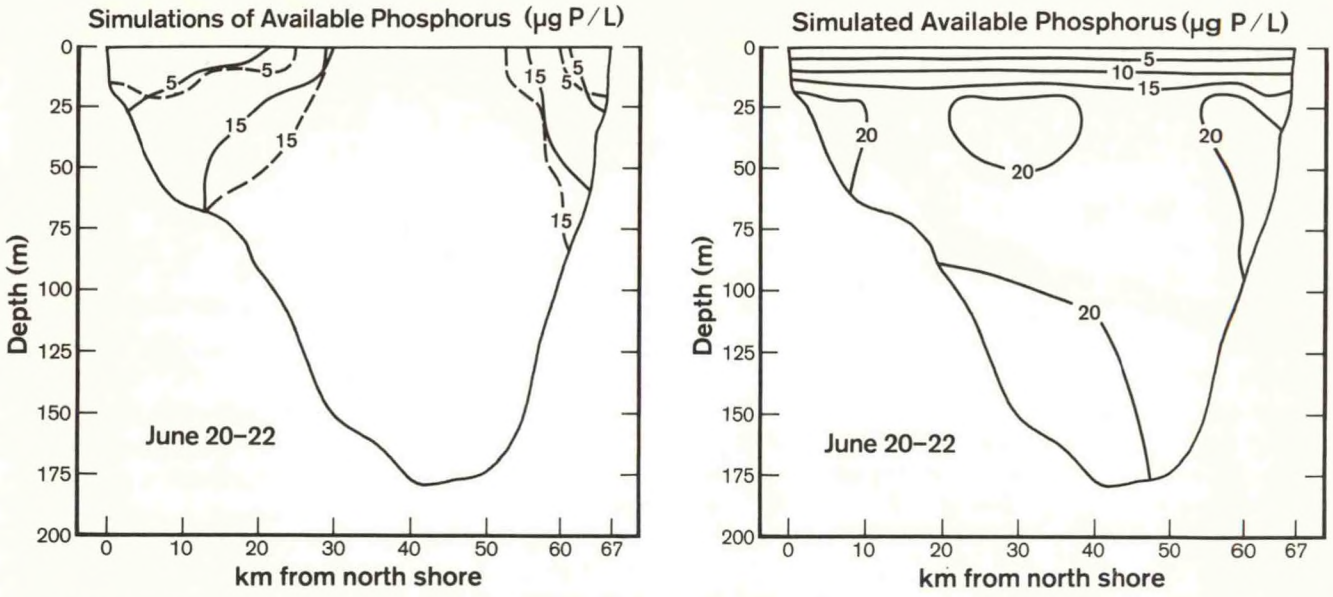
The numerical models formulated under this project aid in detailed examination of the interaction of the biological, chemical, and physical processes in the Great Lakes.

This past year the modeling emphasis was on application and testing rather than development. Investigations have been made into the biological, chemical, and physical processes controlling ecological processes and properties in Lake Ontario and into use of the model for identifying research needs. In one application, a multilayered model was used to investigate the seasonal aspects of the vertical structure of properties in Lake Ontario and the expected ecosystem response to rapid variations in winds and surface water temperature.



A plot of soluble reactive silica (SRS) versus time. Each line represents a time trace of SRS concentration corresponding to particular depth intervals. The depth contours indicate regions of high diatom productivity because diatoms deplete SRS. The irregularity of the contours reflects the variable environmental conditions that affect diatom growth.

In a second application and test, a two-dimensional, north-south transect, hydrodynamic model was used to simulate observed properties in Lake Ontario during the spring-summer transition period. Results from numerical experiments with the model suggest that the large inshore-offshore gradients of biological and chemical properties are controlled by the interaction of *in situ*



Simulations of phosphorus available for phytoplankton growth under different hydrodynamic regimes. Left panel – broken lines represent normal hydrodynamic case; solid lines represent vertical mixing only (i.e., no currents). Right panel – simulation with no hydrodynamics. Biological and chemical processes, as well as sedimentation, are simulated in every case. These results demonstrate that vertical mixing, not larger scale currents, is the physical factor most influential in establishing the strong inshore-offshore gradients in spring.

processes and differences in vertical mixing on either side of the 4°C isotherm. Because of reversals in flow patterns, the effect of currents is to reduce concentration gradients, but the effect on overall distributions is minimal. Other analyses with this model resulted in a suggested explanation of differences among measured sinking rates, rates used in one-dimensional models, and rates used in two-dimensional models.

The original two-layer model, previously calibrated to the IFYGL data set, was used to examine ecosystem properties that are difficult to study experimentally – ecological efficiencies, community turnover rates, etc. It was also used as part of a larger study describing the general properties of the North American Great Lakes and the specific ecosystem dynamics of Lake Ontario.

Another task this year involved testing the sensitivity of the error in the prediction of eutrophication (phytoplankton concentration) to the errors in the initial state variables, the model coefficients, and nutrient loadings. The model used was developed under contract by the U.S. Environmental Protection Agency to assist in the management decision process. For this analysis, a statistical technique called the Kalman filter was implemented and tested in a number of ways to assure its applicability in this context. The Kalman filter estimates the propagation of errors from model inputs and coefficients through the model to the output or predictions. It can also use the model prediction (with its error quantified) and measurements (with their associated errors quantified) to produce best estimates of the predicted variables, as well as better estimates of the controlling parameters. This latter procedure will lead to smaller prediction errors and thus more confidence in model predictions. To date, this technique has been tested on several hypothetical and theoretical systems, as well as on Saginaw Bay, and the results indicate that, although the prediction errors can be quite large, methods of error reduction will be able to bring predictions within acceptable error limits.

Epilimnion turnover times (amount of time necessary to replace existing pool) in days as calculated from the Lake Ontario ecological model. In general, the shortest turnover times are in summer because production rates are closely controlled by temperature. One exception is the producer group (phytoplankton); scarce nutrient supplies in summer tend to reduce their turnover rate and thus lengthen the turnover time.

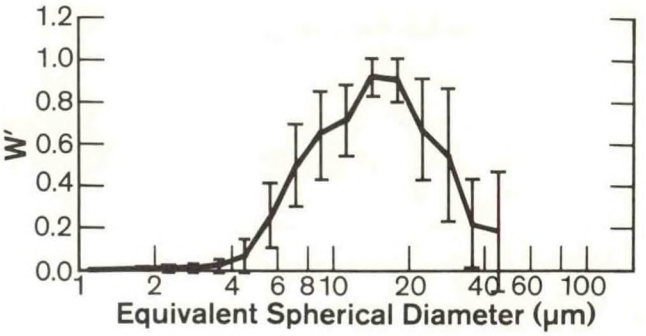
	Seasonal averages				
	Winter	Spring	Summer	Fall	Average for year
Producers	8.5	3.7	5.5	8.4	5.1
Herbivores ...	6.8	3.3	1.4	2.7	2.1
Carnivores ...	27.5	8.0	4.0	10.3	5.8
Detritus	312.8	48.5	21.1	90.7	44.5
Total Seston	311.3	14.1	15.5	62.3	22.5

Next year's work will include more detailed analysis of the vertical structure of properties in Lake Ontario, as well as a comparative study of these properties among the upper Great Lakes. The analysis of errors in the Saginaw Bay eutrophication model will be completed.

Plankton Studies

Plankton studies have concentrated on the processes responsible for the seasonal distribution and diversity of plankton types in Lake Michigan. In the last year, work on phytoplankton has focused on the effects of phosphorus concentration, phosphorus turnover rate, and silica concentration on primary productivity and chlorophyll production throughout the water column at an offshore station. These studies showed that phytoplankton growth cannot be predicted in a straightforward way from phosphorus concentrations because of luxury uptake of phosphorus by phytoplankton. Further, it was demonstrated that silica:phosphorus ratios have limited value for predicting the shift in species composition of the phytoplankton from diatoms to green and bluegreen algae. Analyses of autoradiographs of carbon-14 uptake by phytoplankton were started. These analyses will allow calculation of species-specific uptake rates of carbon, which are necessary to predict species growth rates. Next year, work on phytoplankton will emphasize the autoradiographic analyses and further analyses of factors affecting species composition and growth.

Grazing studies have focused on the process by which copepods of the genus *Diaptomus*, the most important group of herbivores in the Great Lakes, select seston (phytoplankton and other particulate material) of different sizes. These studies have demonstrated that each species appears to have an invariant pattern of selection of small and medium-sized particles when grazing in Lake Michigan water. This invariance led to the development of a



Mean selectivity coefficients (W') of feeding of *Diaptomus sicilis* on varied size food in Lake Michigan. W' is the conditional probability that a food of a particular size will be eaten if encountered.

feeding model that predicts amounts of different kinds of food that *Diaptomus* will eat under varying conditions of food supply. Feeding experiments with cultured species of phytoplankton were initiated to evaluate this feeding model. Next year, further experiments will be performed to evaluate the feeding model and to examine the mechanisms of large particle selection by *Diaptomus*.

The freshwater shrimp *Mysis relicta* is an important predator of zooplankton, and *Mysis*, in turn, is an important food for Great Lakes' fishes. Previous studies of *Mysis* predation have been limited to a few feeding experiments performed under artificial conditions in the laboratory. To evaluate and quantify the significance of *Mysis* predation on zooplankton, GLERL developed special gear and methods to examine their feeding *in situ*. During this year, *in situ* feeding experiments were performed in Lake Michigan from spring through fall under varying conditions of species composition and abundance of zooplankton. Next year, plans are to analyze the data obtained from these experiments.

ENVIRONMENTAL SYSTEMS ENGINEERING

The work of the Environmental Systems Engineering Group includes projects on environmental engineering models and applications and GLERL environmental information services. The objectives of the 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 to provide guidance in our program planning, and identifies substantive areas for GLERL participation in interagency research.

Environmental Information Services

The dissemination of the environmental information produced is vital to the accomplishment of the GLERL mission. The costs of scientific research cannot be justified if the results are not used. Thus, a principal GLERL activity is the maintenance of an advisory service as a means of providing scientific information in a form compatible with user needs.

This past year, as part of that service, GLERL provided research products in response to 630 documented requests. Of these, 30 percent came from agencies in various levels of government and 70 percent from private individuals or groups outside government. This is in addition to regular mailings to a list of 441 recipients who have indicated interest in receipt of a 6-month listing of available publications and of one or more of the 5 types of GLERL publications: chemistry and biology, environmental systems engineering, ice, lake hydrology, and physical limnology and meteorology. But publications are just one form of environmental information. Also included are predictions and simulations produced from environmental models, forecasts and forecast techniques, descriptive or analytical information on the present or past status of one or more limnological characteristic of a lake or of the system, and data bases.

Draft Environmental Impact Statements are reviewed and critiqued in support of NOAA's Office of Ecology and Environmental conservation. Intended to ensure that proposed activities in and around the lakes have been designed to have little or no long term adverse effects on the environment, the Draft Environmental Impact Statements are required by law to be submitted by the company or agency planning the activity for review by all interested or affected entities.

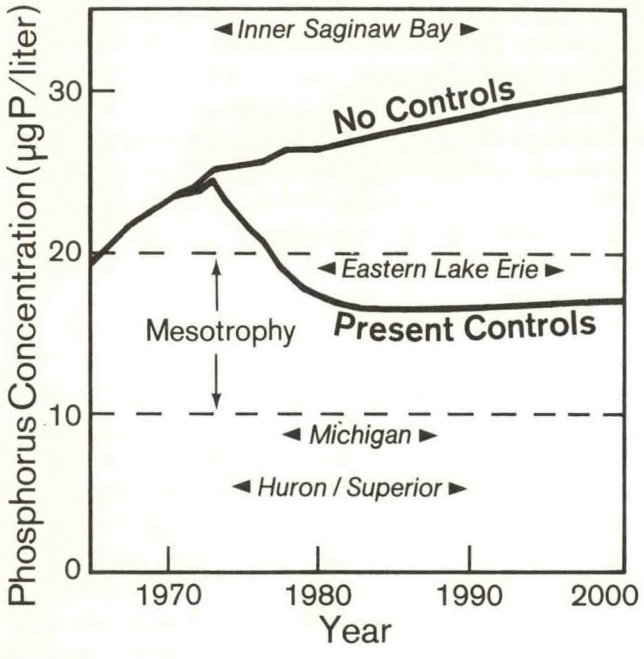
Not all potential users know of GLERL and the range of services and products available, so other responsibilities carried out under this project include identification of and communication with potential users, determination of user interests and needs, and liaison between the laboratory and users. Committee and board memberships and attendance at workshops, conferences, and other scientific gatherings are means of informing people about GLERL; certain special publications, such as the *Technical Plan* and this *Annual Report*, are others.

Environmental Engineering Models and Applications

By quantifying the various aspects of a system, environmental models allow managers to try out projected management alternatives or possible developmental scenarios quickly and without harmful effects. Models developed by the Environmental Systems Engineering Group have been used for guidance in real decision-making situations.

A mathematical model developed to predict long term trends of total phosphorus in the Great Lakes was used to analyze the effectiveness of phosphorus control measures that have been applied to Lake Ontario over the past decade. By predicting the effect of waste abatement programs and other human activities in the Great Lakes drainage basin on phosphorus concentrations in the lakes, the model can indicate the trophic state to be expected if given policies are adopted. The major conclusion of the Lake Ontario study was that detergent controls implemented in the early 1970's have resulted in a 30-percent decrease in the lake's phosphorus level. Conversely, the model was also used to predict that if controls had not been initiated, phosphorus concentration in the lake would have reached a condition similar to highly deteriorated Saginaw Bay by the year 2000. Other applications of the model in planning and management contexts included simulations done for the Great Lakes Environmental Planning Study and the renegotiation of the Great Lakes Water Quality Agreement.

In terms of research, two major areas were developed: error analysis and the application of phosphorus loading

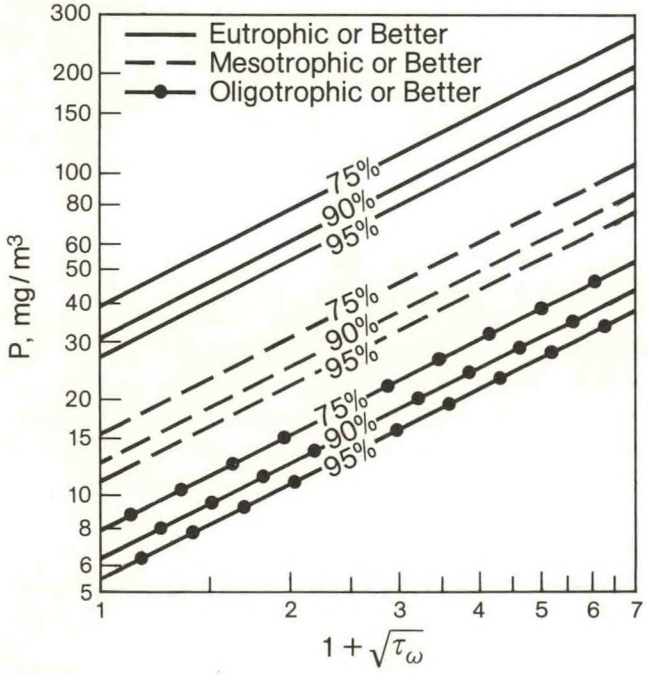


Effects of detergent controls and municipal waste treatment on the phosphorus concentration in Lake Ontario. Also shown are the projected levels given no controls. For purposes of comparison, phosphorus concentration levels are indicated for inner Saginaw Bay, eastern Lake Erie, Lake Michigan, and Lakes Huron and Superior.

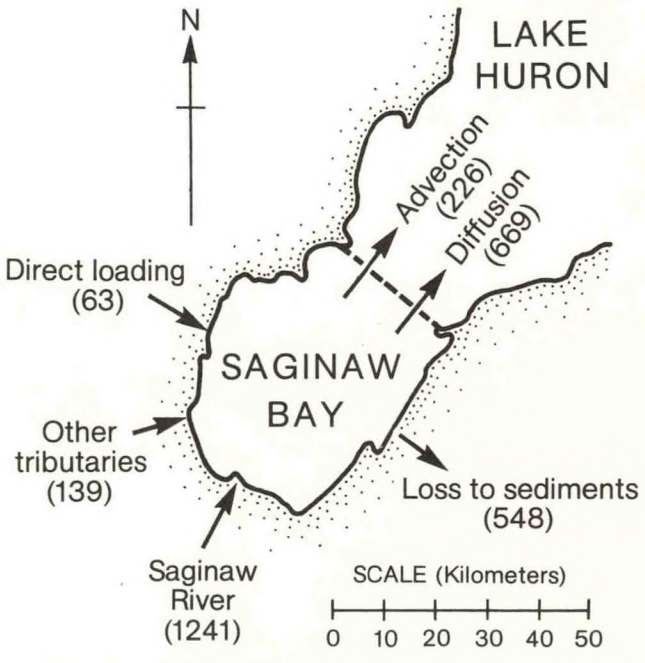
models to incompletely mixed systems. The former is an effort to present decision-makers with estimates of the uncertainty of model predictions. It was accomplished in part through a contract with Michigan State University. The latter is designed to provide forecasts of phosphorus levels in the embayments and nearshore areas of lakes, where environmental stresses and public use and awareness of the water bodies are most intense.

Under a contract with the U.S. Army Corps of Engineers, GLERL calculated present and projected consumptive use of water in the United States portion of the Great Lakes Basin to the year 2035 as part of a joint United States-Canadian project, the Great Lakes Diversions and Consumptive Uses Study directed by the International Joint Commission. Consumptive use of water, that is, the volume taken out of but not returned to a system, has a significant and growing effect on Great Lakes water levels.

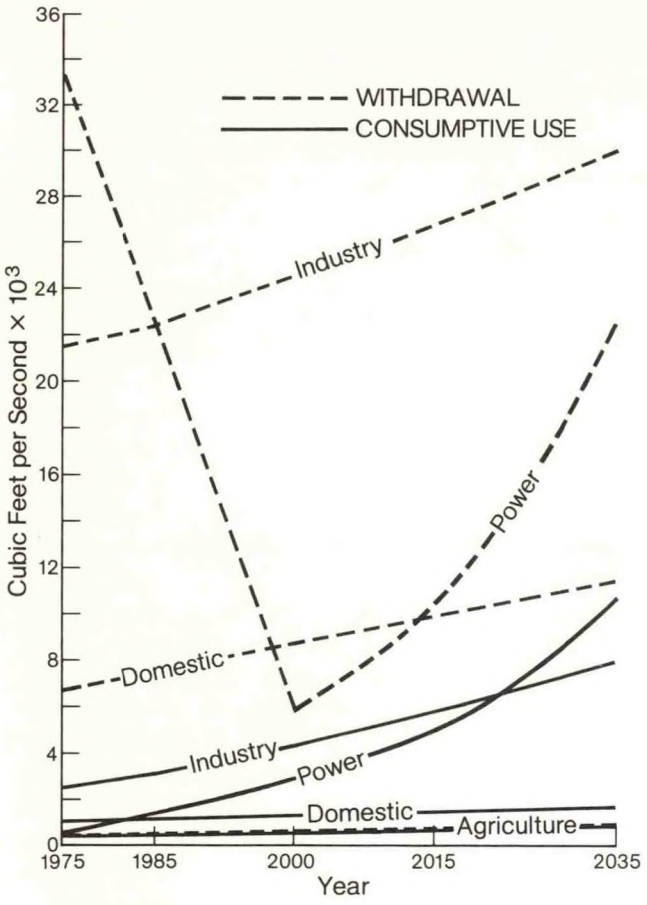
Consumptive water use in the Great Lakes Basin is expected to be five times greater in 2035 than it was in 1975. This is primarily due to the assumption that industries and power utilities will evolve to closed water-cycling systems because of government regulations protecting the environment. Consumptive use will increase from 7 percent of total withdrawal in 1975 to 32 percent



Probabilistic loading plot showing the logarithm of the predicted inflow concentration of phosphorus as a function of the water residence time. Percentages represent the certainty that the inflow concentration will achieve the expected trophic state.



Results of a total phosphorus budget model for Saginaw Bay. Such models are important for analyzing the nearshore areas of lakes, where environmental stresses and public awareness of the water bodies are most intense.



Estimated withdrawals and consumptive uses of Great Lakes water for the years 1975-2035 for four major activities. The large increase in consumptive use and the characteristics of the withdrawal curve for the power segment are due primarily to the projected evolution to closed cycle cooling because of environmental concerns.

in 2035. A major attraction of the Great Lakes area has been the abundant water supply, and the manufacturing sector has historically taken advantage of this benefit. Manufacturing consumed 54 percent of the 4300 cubic feet per second total in 1975, with municipal consumption at 17 percent and the power industry at 10 percent. These three sectors accounted for 81 percent of water consumed in 1975 and will increase to 92 percent of the much larger volume of water consumed in 2035. The compounded annual growth rate in total consumptive use will be 2.6 percent.

The great increase in projected consumptive use relative to withdrawals reflects the evolving environmental concerns. Existing legislation, environmental controls, economic considerations, and institutional constraints account for the significant projected increases in consumption by the power and manufacturing sectors. For economic and environmental reasons, these industries will be evolving to closed cycle cooling. In 1975 consumptive water use in the U.S. portion of the Great Lakes ranged from 0.1 percent to 1 percent of the average discharge in all lakes, except Michigan, which was 2.3 percent. Consumptive use in 2035 is projected to range from 0.6 percent to 1 percent of average discharge, except for Lake Erie at 4.2 percent and Lake Michigan at 10 percent. The increases in consumptive use are generally proportional to increasing water withdrawals, but the significant increases in Lakes Michigan and Erie reflect changing practices in the power and manufacturing sectors.

It is assumed that the source of abundant water afforded by the Great Lakes will continue to be a major factor in the economy of the region. Because of this abundant freshwater supply, conservation will not be as stringent as in other parts of the United States and will be predicated on environmental and economic considerations. Additionally, it is assumed that, despite short term trends of out-migration of people and industries, the basic need for water will dictate continued growth in productivity and population during the long term.

Compilation of the *IFYGL Atlas—Lake Ontario Physical Properties* was completed. This compilation in the form of maps, charts, and tables of data on the physical characteristics of Lake Ontario during the observational period from April 1972 to March 1973 will be a valuable tool for managers, engineers, scientists, students, and other individuals interested in resource development or impact on the lake of related developmental programs.

Work is planned next year on an atlas of man and the Great Lakes ecosystem that will initially focus on the eutrophication issue. Information will include natural and cultural nutrient sources, lake loads, lake-scale effects, and societal impacts.

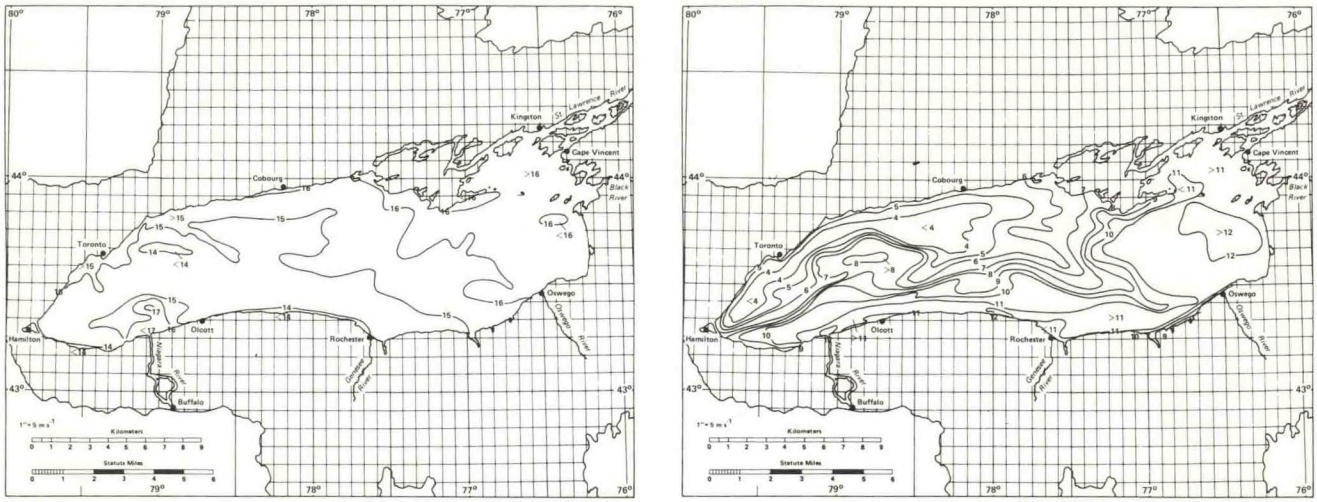
The phosphorus loading concept will be applied to incompletely mixed systems, such as estuaries, in which potential availability of phosphorus will be dynamically modeled and applied to actual water bodies.

Work will continue on application of uncertainty analyses to phosphorus model forecasts.

The Lake Ontario energy budget task will be completed with publication as an IFYGL Scientific Summary Report.

Work will continue on development of a model hierarchy to address water quality and use problems identified in the Great Lakes Basin Commission's Great Lakes Environmental Plan of Study.

The Great Lakes Diversions and Consumptive Uses Study will be integrated with its Canadian counterpart and presented to the public and the International Joint Commission.



Isotherm charts showing a radical change in Lake Ontario surface water temperatures between October 5 and 18, 1972, as a result of an outbreak of cold air across the lake. These figures are from the upcoming *IFYGL Atlas – Lake Ontario Physical Properties*.

LAKE HYDROLOGY

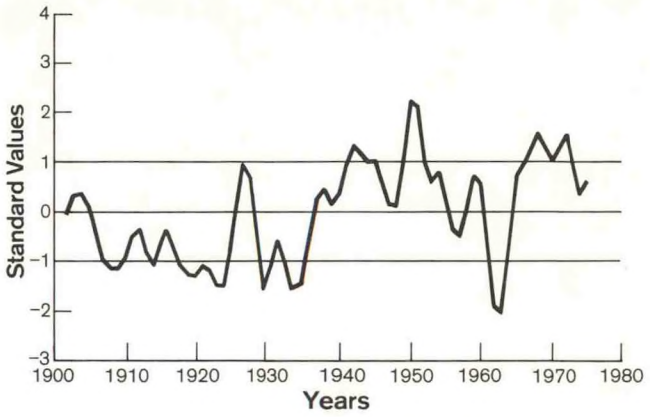
The emphases of the Lake Hydrology Group are on the hydrologic cycle, including channel hydraulics, and on ice research. The objectives of the hydrologic work are to develop improved methods of prediction and simulation of lake levels, connecting channel flows, and flow in tributary streams and to improve 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 U.S. Army Corps of Engineers, the Great Lakes shipping industry, the U.S. Environmental Protection Agency, 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 U.S. Army 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

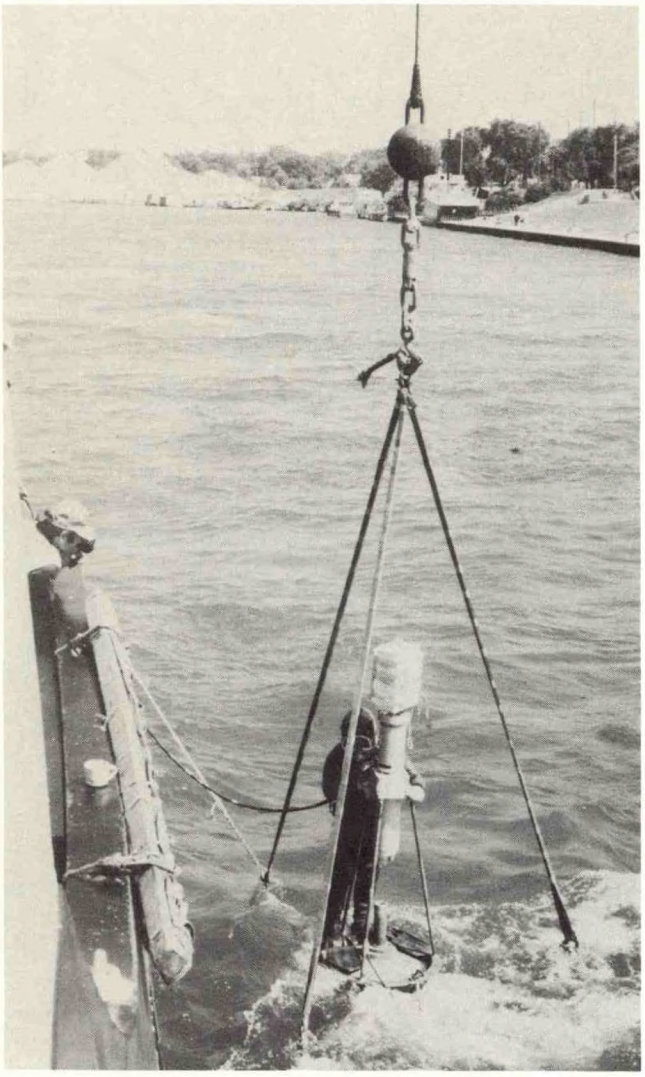
During this past year, a study was completed to examine the overall Great Lakes precipitation climatology from 1900 to date. A change in the precipitation regime found to occur in the mid-1930's increased the average annual precipitation by approximately 8 percent and the standard deviation by 40 percent. If the current precipitation regime persists, it will present many challenges for water resource managers and planners in the Great Lakes Basin. Continued high precipitation will stress the current Great Lakes regulation plans, which did not perform as well as expected during the 1968-73 high water supply period. This emphasizes the need for improved Great Lakes water supply forecasting techniques that take into account the probability of higher precipitation.



Great Lakes 5-year weighted standardized precipitation time series. The standardized value is the annual precipitation minus the mean annual precipitation divided by the standard deviation. Note the dry spell in the early 1960's and the wet spells around 1950 and the early 1970's.

Another completed study involved the analysis of wind stress effects on the computed discharges of the Detroit River. Mathematical transient models are currently used to compute Detroit River flows for hourly, daily, and monthly time scales. These models previously included the complete one-dimensional equations of continuity and motion, but neglected the effects of wind stress. The incorporation of wind stress in the models was found to be important for hourly and daily flow computations when wind velocities were in excess of about 6 meters per second. The inclusion of the wind stress terms in the mathematical models may also prove to be significant for some Lake St. Clair water balance studies.

Last summer, a unique field data collection program was initiated for continuous measurement of velocities in the St. Clair and Detroit Rivers. Velocity is measured with electromotive current meters, since seaweed and other floating debris quickly clog the moving vanes of mechanical meters and render them impractical for continuous operation. These measurements will be used to verify and improve the St. Clair and Detroit River transient models and to determine winter flows in the two rivers. The existing models are based on river flow measurements made periodically by the U.S. Army Corps of Engineers during the open water season. Winter ice conditions make standard velocity measurements extremely difficult and preclude them altogether during the ice-cover season. However, severe ice conditions and associated ice jamming in these rivers produce abnormal river profiles and large discrepancies in the winter flows simulated by the existing models.



Current meter and diver being lowered into the water from the U.S. Coast Guard ship *Bramble*. The diver will position the current meter and detach the cables used to lower it into the water.

The 2-year field program is divided into two phases. During the first phase, initiated last summer, two Marsh McBirney, model 585, electromotive current meters were deployed in the upper St. Clair River. The two current meters were installed outside the navigation channel, 50 and 70 meters from the U.S. shore in 15 meters of water, to provide an index of mean river velocity. The meters are connected by cables to a shore recording facility, which provides remote access to the current meter output. Because of extensive ice movement during winter, the cables along the river bank are protected against shore ice. After the first year of operation, the field program will be expanded to provide velocity measurements simultaneously in the St. Clair and Detroit Rivers.

Ice

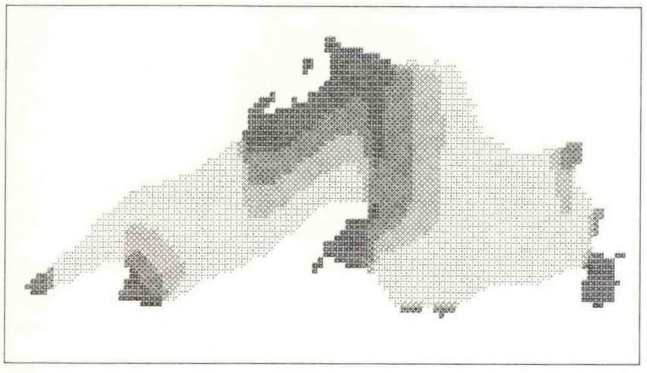
State-of-the-art scanning spectroradiometers have produced the first spectral ice and snow reflectance measurements on the Great Lakes. Hostile environment support systems have been fabricated for these instruments, which cover the 300-1100-nanometer range (10-nanometer bandpass slits). Optimum instrument configuration requires that incoming radiative flux be recorded simultaneously with flux reflected from the surface. Accurate spectral reflectance data can thus be collected without regard to variability in cloud cover or solar altitude. Simultaneous recording of upward and downward flux was achieved at the end of the 1978-79 season. The techniques, devices, and electronics employed had never before been used to measure spectral reflectances of ice, snow, or any other natural substance. The various ice types show significantly different spectral characteristics and the physical state of each ice type appears to exert a strong influence on the spectral signature. Data collection will continue over the next 4 years from sites in the upper Great Lakes. Data collection will concentrate on spectral definition of the various ice types (pancake, snow-ice, etc.).

The 1978-79 winter season produced a record ice cover on the Great Lakes: all five lakes were almost completely ice covered. The simultaneous occurrence of such extensive ice cover on all five lakes had not been

NOAA-5 image for February 17, 1979. On this date, all five Great Lakes were virtually frozen over.

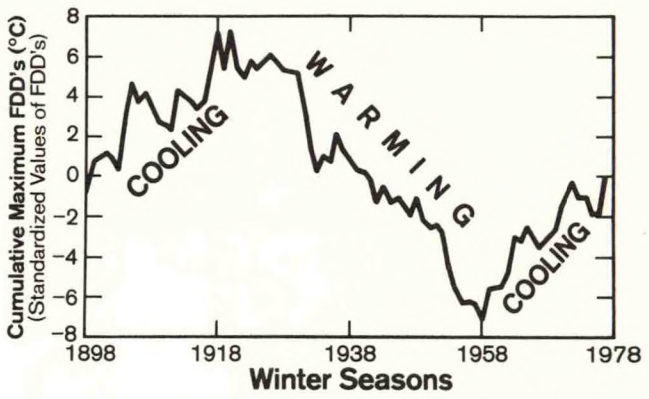
observed before, making this event particularly noteworthy. A multiagency report on the 1978-79 Great Lakes ice cycle is in preparation by authors from the National Weather Service, National Environmental Satellite Service, GLERL, and a contractor. Also a report describing the 1977-78 Great Lakes ice cycle was completed in 1979 and will be published early in 1980.

Historic ice charts for Lakes Superior and Michigan were digitized in 1979 and will be edited and analyzed for the development of a revised ice-cover climatology. In 1980 historic ice charts for Lakes Huron, Erie, St. Clair, and Ontario will be digitized.



Computer analysis of early season Lake Superior ice concentration data. The darker gray areas indicate higher ice concentrations. Ice charts such as these help identify patterns in ice-cover concentration and distribution over time.

Work on the establishment and analysis of an 80-winter freezing degree-day (FDD) data base from 25 locations on the shores of the Great Lakes was completed in 1979. A report defining a winter severity index for the Great Lakes based on the distribution of maximum FDD's at the 25 locations was also completed in 1979. The report identified trends in winter severity and the mild and severe winters in the Great Lakes Region during the period 1897-1977. This report and a data report giving seasonal values and normals of air temperature and



Average of cumulative normalized maximum freezing degree-day values for 25 stations. Note the following three trends in Great Lakes winters: (1) a cooling period from 1897 to 1918, (2) a warming period from 1920 to 1958, and (3) a second cooling period from 1958 to the present.

degree-days for the data base provide a valuable reference for evaluating climatic trends and relating them to ice-cover trends during the past 20 winters and, perhaps, by statistical inference during the past 80 winters.

A 4-year program to document heat storage in Lake Superior during the fall cooling period was completed in 1979. These data will be used to identify the bathymetric and fall seasonal characteristics of the water temperature decline in Lake Superior. This information will provide the necessary calibration and verification data for future development of a model of temperature decline and initial ice formation in Lake Superior.

GLERL has an extensive set of ice-cover data bases for the Great Lakes and has served as a major archive for this type of material since formation of the laboratory in 1974. To facilitate greater accessibility and distribution of these materials, the Lake Hydrology Group will transfer most of these data to World Data Center-A for Glaciology (snow and ice) located at the University of Colorado in Boulder, Colorado. This is one of three international data centers established to facilitate international exchange of data on all forms of snow and ice, and it serves as a national information archive and retrieval center for materials related to snow and ice research.

PHYSICAL LIMNOLOGY AND METEOROLOGY

The Physical Limnology and Meteorology Group studies the physical variables describing the lake environment and the way in which these variables change as a result of external forces. The relevant physical characteristics of the lakes are currents, temperature, and water level fluctuations, and the primary driving forces are the wind stress acting on the lake surface and the heat exchange between the lake and the atmosphere. The primary emphasis of the program is on developing and testing models that will improve the capability of predicting these variables. These prediction models will, in turn, permit estimates of chemical and biological properties of the lakes that are important in diverse user activities, such as waste disposal, power generation, fisheries management, and water supply planning. In addition, waves and other water level oscillations present potential hazards and may result in loss of lives and in damage to shoreline property, shipping, and recreational boating activities.

The phenomena that need to be modeled and predicted have time scales ranging from years to seconds and space scales from the length of the lake to a few meters. In view of this tremendous range in time and space scales, it is necessary to separate and group the various phenomena according to their scales in order to better understand and model them. Hence, the basic research program in the Physical Limnology and Meteorology Group has been arranged in two projects. Project (1), water movements and temperature, deals with lake circulation and thermal structure. This project encompasses studies dealing with lake-wide and nearshore circulation, seasonal changes in circulation, and upwelling and downwelling phenomena. Project (2), surface waves and oscillations, deals with wind generated waves, storm surges, seiches, and problems of overlake winds. The phenomena grouped in project (2) need real-time prediction capability in view of their importance as hazards.

A new interdisciplinary project, particle dynamics, was started during this year. The prime reason for initiating this project is the fact that toxic organic substances and nutrients enter the lake attached to particulate matter. Hence the pathways and ultimate fate of these pollutants in the lakes depend on the movement of various types of particulate matter through the lake environment.

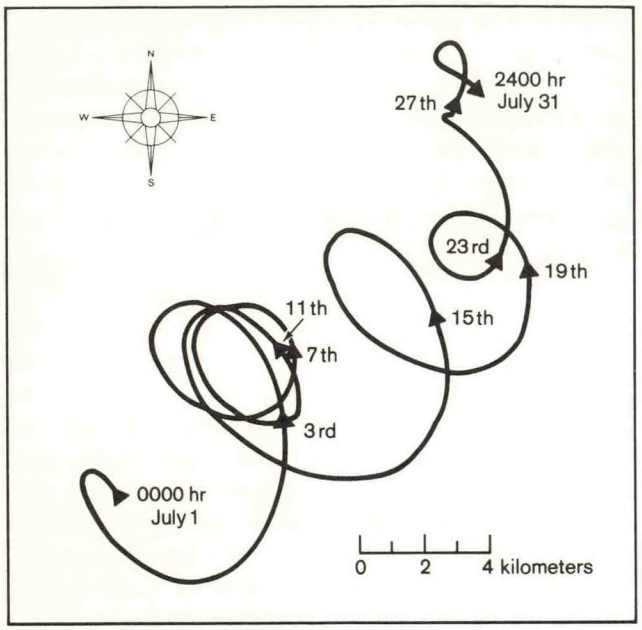
The basic approach used in studying the problems in all the above projects is a combination of experimental (laboratory and field), theoretical, and modeling methods. Experimental data provide information on what is happening in the lake. Theoretical studies attempt to use basic physical principles to explain the observed features. Modeling studies try to incorporate the important physical processes into governing mathematical equations and extrapolate the equation in time in order to develop predictions of the future state of the lake environment. Experimental data, in turn, help to validate the accuracy of these predictions.

Water Movements and Temperature

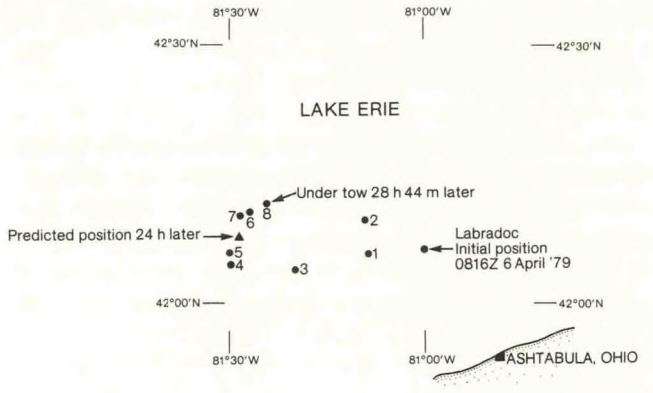
An array of current meters and temperature recorders was deployed in Green Bay, Wisconsin, in May 1977. Part of the array was retrieved in fall 1977, and the remainder in spring 1978. Data collected in the passages connecting Green Bay with Lake Michigan are being studied to determine the quantity and nature of water volume exchanges between the bay and the lake so that the pattern of the water quality degradation within the bay can be better understood and simulated. A determination of the bay's flushing rate and interior circulation is essential to the planning of water quality restoration. The Physical Limnology and Meteorology Group found an intense inflow of water into the bay from Lake Michigan in bottom waters of the Death's Door and Rock Island Passages. This wind-driven exchange is much larger than the flushing due to the tidal-like currents associated with long-period surface waves, and it accelerates the renewal of water in the northern half of the bay.

The Fox River discharges a heavy load of contaminants to the south end of the bay. Additionally, toxic materials are discharged along the west shore of the bay from the Menominee River. The latter discharge may pose a potential hazard to the potable water supply for the cities of Menominee, Michigan, and Marinette, Wisconsin, as their water intake is located close to the river mouth. A preliminary report analyzing data collected in this reach of the bay has been prepared for the U.S. Environmental Protection Agency. This preliminary analysis shows that the circulation is especially sensitive to wind forcing along the bay's principal axis, with currents in the shallow water along the shore flowing with the wind and return flow in the center of the bay against the wind. The current patterns observed with prevailing southwesterly winds put the water intake precariously downstream from the river mouth.

Coupling hydrodynamic models to ecosystem models is a complicated problem in view of the differences in the important space and time scales in each of the models. In order to understand the effects of physical variables, such as water movements and temperatures, on the ecosystem variables from a modeling point of view, GLERL coupled a two-dimensional cross-sectional model to a chemistry and ecology model for Lake Ontario and carried out a simulation for the spring regime. The combined model successfully reproduced the observed large gradients of many of the chemical and ecological variables, such as particulate organic carbon and available



Current track near the center of Lake Michigan during July 1976. This track traces the movement of a parcel of water during the month. As can be seen, loops occur every 4 days as the parcel drifts northeastward.



Comparison of GLERL's prediction of the drift of the ship *Labradoc* and the positions observed by the U.S. Coast Guard. A severe gale in April 1979 flooded the ship's hold and forced abandonment. A GLERL model correctly predicted that the ship would drift *with* the currents and *against* the wind.

phosphorus. By including the effects of the large-scale hydrodynamic circulation, GLERL scientists were able to use the model to explain why the one-dimensional ecological models require unrealistically low sinking rates for particulate matter.

The potential for accidents has increased in recent years with the increase in shipping on the Great Lakes. If an accident does happen, it is necessary to be able to answer questions regarding the spread of any oil spilled from the ship's fuel tanks, the drift of the cargo, and possibly the drift of the disabled or abandoned ship itself. In anticipation of these questions, a Great Lakes spill model was put together. Using available lake circulation and oil spill models, GLERL set up a computer program that is run by answering a series of questions. The program was designed for operation from either a portable (briefcase size) computer terminal or a teletype unit. Either device requires only a standard electrical outlet and a telephone to operate the model.

The program performed well when the ship *Labradoc* was abandoned on April 6, 1979, after being hit by gale force winds and high seas in Lake Erie. Surprisingly, the abandoned ship drifted westward into the gale force winds. The reason is that it was low in the water and entrained in a powerful offshore countercurrent. The model accurately predicted this direction of drift.

Eventually such spill programs should provide operational forecasts (or even hindcasts, e.g., determining where a particular spill originated) for any spill in the open waters of the Great Lakes.

In support of the Lake Erie surveillance program directed by the International Joint Commission and supported by the U.S. Environmental Protection Agency, a comprehensive field program to measure various physical, chemical, and biological properties of the lake was planned and launched during this fiscal year. This program was undertaken jointly by our laboratory, the U.S. Environmental Protection Agency, and the Canada Centre for Inland Waters (Burlington, Ontario).

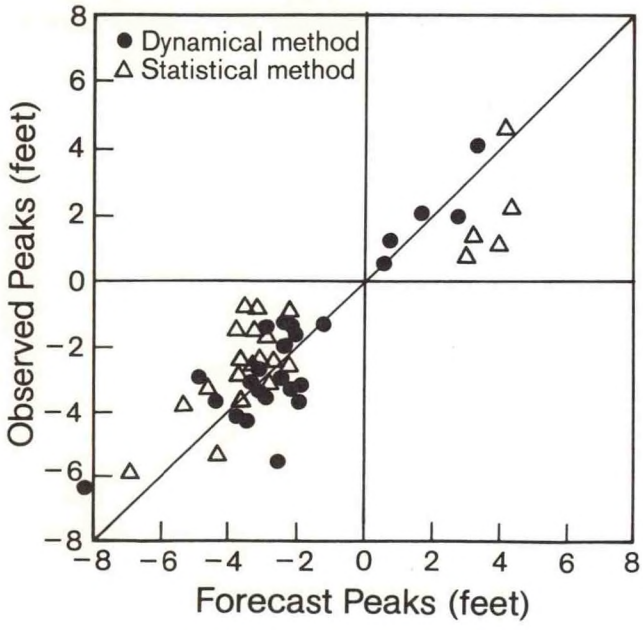
Because Lake Erie is the shallowest of the Great Lakes, it suffers most severely from pollution inputs. Even though the condition of Lake Erie improved in recent years because of conservation and cleanup efforts, an annual problem called anoxia—oxygen depletion of waters—plagues the lake. Its investigation is one of the focal points of this study. Because Lake Erie is so shallow, during the stratified season the thermocline in the central basin penetrates almost to the bottom, leaving a very thin hypolimnion. Biological processes, such as respiration by fish and decay of organic material sifting down from above, rapidly use up the limited supply of oxygen in the hypolimnion, while the thermocline inhibits fresh infusions of oxygen-bearing waters. This results in the loss of oxygen—or anoxia. The consequence of all these processes is to produce problems of taste and odor in municipal water supplies of cities like Cleveland, Ohio. The anoxia is mainly confined to the central basin of Lake Erie. Since the development and persistence of anoxia depends on characteristics of circulation (and stratification), a prime objective is to measure the movement

of water between the central basin and other basins of Lake Erie. GLERL's program is attempting to quantify the water volume exchanges across the basins and also to examine the spatial and temporal variability of the basin-wide circulation with a total of 58 current meters on 28 moorings, as well as 5 thermistor chains. A major part of the program effort in the next 2 years will be a detailed analysis of this Lake Erie data set.

Surface Waves and Oscillations

An important aspect of the study of wind generated waves is their spatial variability, which is produced by the effects of islands, curved coast lines, and changes in bottom topography, in addition to the changes in fetch (overwater travel distance of air). Such a study requires the use of a remote sensing technique to measure the waves over an entire lake, particularly during strong wind conditions. To investigate this problem, GLERL and the Sea-Air Interaction Laboratory carried out a cooperative program in which an airborne laser profilometer was used to map the waves during a fall storm in Lake Michigan. Ground truth to validate the airborne measurements was provided by two Waveriders deployed in the lake. The measurements were made during the passage of an intense frontal system on November 20-21, 1977. Waves were measured both ahead of and behind the front to include areas with different atmospheric stabilities. The analyses show that atmospheric stability plays a distinctive role in wave growth processes. Specifically, it is evident that the fetch required to generate a wave condition for an unstable atmosphere is shorter than that required to generate the same wave condition for a stable atmosphere. Therefore, an unstable atmosphere usually generates higher waves for the same wind speed. During growth, peak energy shifts to lower frequencies as we expected. Our analysis suggests this is due to nonlinear energy transfer. For larger fetch cases, however, the actual growth appears to be mixed, with phases of exponential growth and overshoot effects.

Analyses continued on data gathered from the solar powered research tower installed in Lake Michigan in July 1977. The tower, located 2 kilometers offshore from Muskegon, Michigan, in 16 meters of water, provided a stable platform for two levels of anemometers and air temperature sensors, a surface water temperature sensor, and an array of four wave staffs to measure meteorological and directional wave variables. Solar power was successfully used for tower instrumentation. The measurements comprise over 1300 well-documented hourly wind and wave data for further detailed studies. The results show that the triangular array of wave staffs provides reasonable wave direction information, although nearshore waves appear to have a larger onshore component of momentum than would be indicated by prevailing winds. Statistical distributions of wave slope and wave curvature have also been examined. We found that the probability distributions of the surface slopes are generally represented by a Gaussian curve.



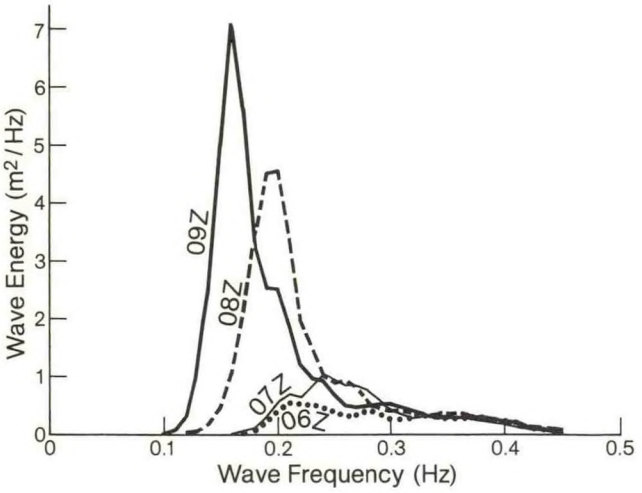
Comparison of observed and predicted lake storm surges at Toledo, Ohio. The new GLERL dynamical method is a considerable improvement on the older statistical method.

The field measurements of waves for 1979 were confined to Lake Erie. Three Waveriders were deployed, one to the east and one to the west of Kelleys Island (the island that divides the western basin from the main basin) and a third one near North Springfield, Pennsylvania. Airborne measurements on Lake Erie were taken jointly with the Sea-Air Interaction Laboratory during 1979.

In contrast to the wind-generated waves, which are of small spatial and temporal scale, storm surges represent a response of the whole lake to large-scale disturbances. Wind-induced storm surges on Lake Erie contribute to flooding and shoreline erosion. Low water levels on the upwind end of the lake can be a hazard to navigation. In an effort to provide the best possible storm-surge forecast guidance to local forecast offices, GLERL and the Techniques Development Laboratory have compared Lake Erie storm-surge forecasts produced by a dynamical method developed at GLERL and the National Weather Service operational-statistical method for several months in 1977 and 1978. The dynamical method is based on a finite difference model of Lake Erie and uses computer generated wind forecasts as input data. The statistical method consists of a set of regression equations

developed from observed data. Sea level pressure forecasts are input data to this method. Storm-surge forecasts are produced twice a day and extend to 36 or 48 hours. The dynamical method yielded much better forecasts at Buffalo, New York, and slightly better forecasts at Toledo, Ohio. Therefore, starting in September 1979, the dynamical forecast method replaced the statistical method for providing guidance storm-surge forecasts.

The National Weather Service also started issuing guidance forecasts for storm surges at Bay City, Michigan, in Saginaw Bay and Port Huron, Michigan, at the southern end of Lake Huron, again determined by statistical procedures. In view of the success of the dynamical procedure developed for Lake Erie, the dynamical model was modified for application to the above two points. The performance of the dynamical and statistical methods will be evaluated this year.



A growth episode of wave spectra from Lake Superior recorded on June 26, 1979, by NOAA buoy 45001. The significant wave heights grew from 0.9 meters at 06 z to 2.5 meters at 09 z during 8 meters per second south-southwest winds with stable atmosphere. It is well known that peak-energy frequency migrates continuously toward lower frequency during wave growth as is shown in this figure.

Research comparing various wave prediction models has progressed to the stage of testing several models against wave observations. The observations are from GLERL's tower in Lake Michigan and from the National Data Buoy Office operational buoy in Lake Superior.

Preliminary tests of a dynamical method of predicting the details of winds around the lakes were encouraging, and we are actively testing this model against observations. The model is driven by boundary conditions from a larger scale version developed by NOAA's Techniques Development Laboratory. At present, we are testing the model's ability to forecast the details of land winds and water levels around Lake Erie. In the future, we hope to extend our tests to overlake winds.

Particle Dynamics

This project, a cooperative venture with the faculty and scientific staff at the University of Michigan, was just started during this fiscal year. The GLERL-University of Michigan team has begun to define the research needs in this area and to prepare a program document. Meanwhile, the University of Michigan scientists have started work on two studies. One deals with the settling characteristics of different types of particulate matter in a laboratory, and the other attempts to characterize the nature of suspended sediments in the southern basin of Lake Michigan.

INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES (IFYGL)

The technical work on this multiagency, joint United States-Canadian program has been completed. During 1979 the *IFYGL Atlas—Lake Ontario Physical Properties* went through final editing; it is now in press. All but one chapter of the book *IFYGL—The International Field Year for the Great Lakes* have been prepared and reviewed and are being edited.

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

GLERL participates in many of the activities of the International Joint Commission. Various staff are involved in committee and subcommittee work. These include work on the Science Advisory Board that provides the International Joint Commission with information on the state of the art in Great Lakes research and recommends research programs. Also included is participation on the Consumptive Uses Subcommittee of the Diversions and Consumptive Uses Study Board, the Aquatic Ecosystem Objectives Committee of the Science Advisory Board, and 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 Diversions and Consumptive Uses Study Board will provide information to the International Joint Commission relevant to water supply and the Great Lakes Regulation Plan. 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.

Great Lakes Basin Commission

GLERL staff are involved in the Great Lakes Basin Commission as Alternate Department of Commerce Commissioners and as members of the Great Lakes Basin Plan Committee, the Priorities Committee, the Coastal Zone Management Committee, the Standing Committee on Research and Development, and the Great Lakes Environmental Planning 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. The Great Lakes Environmental Planning Study is analyzing the accumulative system effects of state pollution control plans on the water quality of the Great Lakes.

Winter Navigation Program

GLERL worked in support of the U.S. Army 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 was chaired by a GLERL staff member. Also, GLERL had membership on the Winter Navigation Working Committee and the Steering Committee of the Environmental Planning Task Force, and represented NOAA in the Environmental Evaluation Work Group. The laboratory provided 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 was provided to shippers during the extended season. The program was completed this past year.

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.

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 participated on the Interagency Technical Advisory Group in review of study programs and recommendations.

International Association for Great Lakes Research

Members of GLERL actively participate in the activities of the International Association for Great Lakes Research. They hold membership on the Publications Committee (Chairperson) and the Board of Directors.

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 U.S. Army Corps of Engineers, was formed to determine specific alternatives, with time-frames 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 and water resource management.

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, Michigan.

Marine Instrument Laboratory

The marine instrumentation laboratory staff selects, calibrates, repairs, and (when necessary) adapts or designs instruments to collect data in the lakes and their environs. They work closely with GLERL researchers to ensure that instruments are compatible with the purposes of the experiment.

In 1979 the micro-computer system for use in design and maintenance tasks became operational. It allows examination of both serial and parallel data presented by new and old instruments within hours and days. It validates data integrity, decodes data formats, and points to design faults, both on GLERL's part and on the manufacturers'. Some of the tasks aided by this flexible tool are as follows:

- Preparation of 58 vector-averaging current meters and 28 acoustical releases scheduled for deployment during the western Lake Erie current measurement program.
- Retrieval of the water temperature profile from the expendable bathythermograph data logger. It provided data printouts for the scientists immediately after their semimonthly cruises and gave GLERL personnel valuable feedback on operating characteristics of the data logger.
- Development of an interactive electromagnetic current meter recording system. The MFE 5000 terminal was chosen for use as a shore based recorder because of its communications capabilities. Marine instrumentation laboratory engineers, with the aid of the micro-computer system, defined and modified the MFE 5000 terminals to work with Prentice, model P113D, and Marsh McBirney, model 585, vector-averaging current meters so that the parameters and operating modes of the current meter could be sent and recorded data retrieved through the telephone at desired processing intervals.
- Interface, modification, and verification of an Aanderaa tape playback interface unit. When the manufacturer's equipment was generating a large amount of noise, marine instrumentation laboratory engineers (with the aid of pattern recognition and generation capability on the micro-computer system) modified the Aanderaa unit for proper operation.

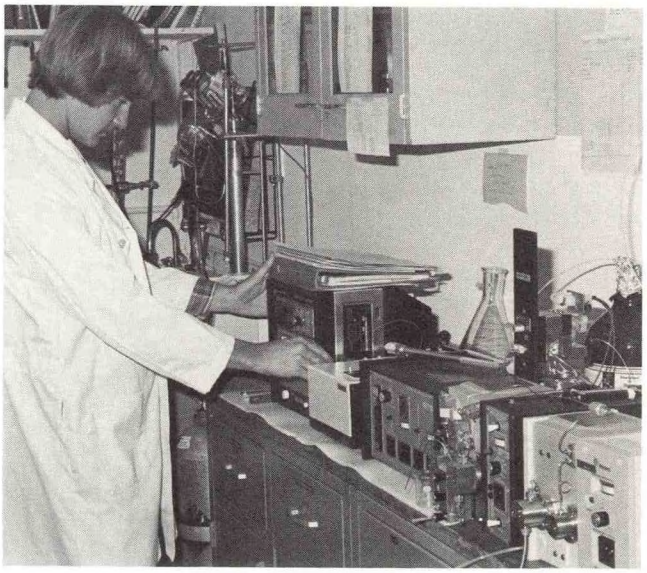
In support of the ice measurement program, marine instrumentation laboratory engineers successfully interfaced and programmed the Hewlett-Packard 9815 calculator with EG&G spectroradiometers for simultaneous data logging and albedo calculations.

The Chapelsky-Vanderploeg-Soo plankton traps worked successfully with the deck-top incubation tank on joint experimental cruises with University of Michigan scientists. The phytoplankton settling chambers are making it easier to prepare carbon-14 active slides for productivity studies.

The marine instrumentation laboratory, in conjunction with the computer laboratory, has made operational a real-time digital wave spectral processing and data transmission system. Field tests indicate that interference is too severe on the 27-megahertz band. On switching to 40-megahertz operation, scientists encountered problems owing to excess power requirements and logistics late in the season. Work is continuing on improvement of the radio link and retrieval of the signal from the radio receiver.

Chemistry Laboratory

The chemistry program this past year has included analysis for trace organics in components of the lake ecosystem. Polynuclear aromatic hydrocarbons are extracted from various ecological matrices by Soxhlet extraction and cleaned through chromatographic separation on Sephadex and silica. Separation and analysis are performed on a glass capillary Hewlett-Packard gas chromatograph and on our recently acquired Waters liquid chromatograph equipped with ultraviolet and fluorescent



Technician using the Waters liquid chromatograph. The chemistry laboratory has been using this new instrument to analyze sediment samples for trace organics.

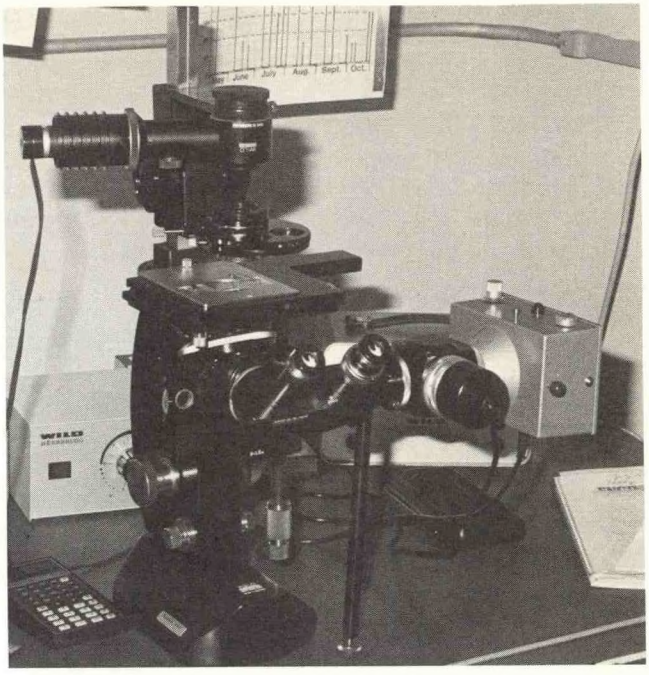
detectors. Yields are calculated by recovery of carbon-14 labeled spikes introduced into the original sample matrix. Initial results indicate that yields are averaging 80+ percent recovery and our quantitative precisions for selected compounds are around ± 15 percent.

The nutrient cycling program is still active within the laboratory. Experiments involving size and molecular weight separations are being conducted with radio-labeled phosphorus-spiked lake water samples. Quantitative analysis of the "cold" phosphorus is performed spectrophotometrically either on an autoanalyzer or manually. Pigments are analyzed both by spectrophotometry and by fluorometry.

Currently under development is an enzyme reduction technique for the analysis of phosphate-phosphorus that will be valuable in the partitioning of the phosphorus pool into its various components.

Biology Laboratory

The biology laboratory includes modern equipment and instrumentation. A multichannel Coulter Counter is routinely used to measure particle size selection and zooplankton grazing on natural lake algae and seston. An array of instruments, including a liquid scintillation spectrometer, is used to investigate nutrient uptake, growth rates, competition for nutrients by algae, and cycling rates of selected algal nutrients. Facilities also include a full complement of sampling gear and instrumentation, growth chambers, stereo and inverted microscopes, and cultured populations of phytoplankton and zooplankton species for model studies. A mobile trailer has been outfitted for lake-side investigations on the physiology and feeding rates of planktonic and benthic organisms.



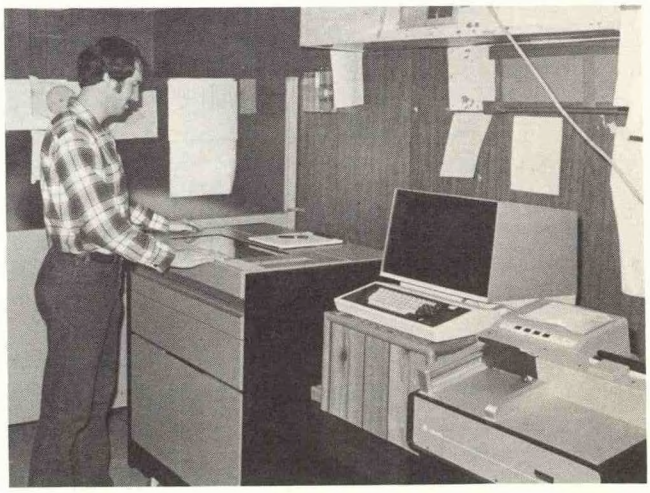
Inverted microscope in the biology laboratory. This inverted conventional microscope is used to observe and count particles settled out of a small sample of lake water.

Ice Laboratory

The ice laboratory makes it possible to extend the winter measurement season and to expand the capabilities for measurement of ice characteristics. The facility is composed of a work room and an ice storage room. The work room, held at +20°F, can be used to calibrate field instrumentation environmentally, as well as to conduct experiments on natural ice harvested earlier in the field. The interior walls are painted flat black to facilitate optical experiments, such as the measurement of spectral radiation transmission through ice slabs. Ancillary equipment includes a high-intensity light source, a mercury line source, and an optical bench. Adjacent to the work room is a smaller room held at −20°F for the storage of natural ice samples and the growth of ice crystals.

Computer Laboratory

The computer laboratory staff supports the work of GLERL scientists by writing, debugging, and testing programs to meet the scientists' specifications; advising scientists and technicians in the writing, adapting, and maintenance of FORTRAN programs; and creating retrieval subroutines to access field data. Programs are entered through a UNITECH (UT-1) remote communications processor connected to a CDC 6600 computer located at the Environmental Research Laboratories in Boulder. Recently, seven local telephone numbers were



Scientist checking the printer in the computer laboratory. The card reader and cathode ray tube are in the foreground.

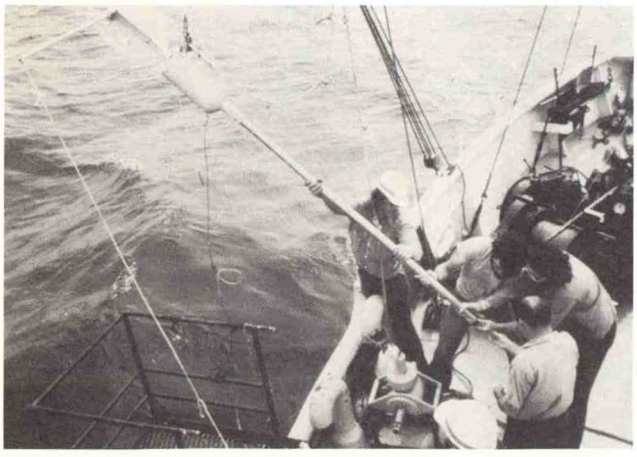
added to provide a link between Texas Instrument Silent 700, model 745, portable data terminals and the CDC 6600. This has provided interactive access and greater convenience for GLERL scientists.

A Tektronix 4014-1 graphical display terminal, also connected to the CDC 6600, is used for graphical display of data on a cathode ray tube. Hard copy of the display can be obtained in seconds and microfilm copy can be printed in Boulder and returned to GLERL by mail.

Before a data base can be created, much less analyzed, on the CDC 6600, the raw field data must be converted from analog to digital form and edited. The Hewlett-Packard 9603A scientific measurement and control system performs the above functions and, in so doing, serves as a link between instruments in the field and the more sophisticated computer hardware. An example is Lake Erie wave data, which are presently being telemetered and transmitted by land line directly to the Hewlett-Packard system.

R/V *Shenehon*

The primary platform used in support of open-lake field investigations is the *Shenehon*. The vessel is a converted T-boat 65.6 feet long, with a 6.5-foot mean draft, a 600-nautical-mile cruising range, and a 10-knot cruising speed. A hydraulic articulated crane with a 1630-pound lifting capacity at 21-foot extension can be used for deployment and retrieval of heavy instrument moorings, and winches handle wire and multiconductor cable for sample casts and *in situ* measurements of water variables. An on-board laboratory facilitates the conduct of onsite chemical and biological experiments.



Removing a sediment sample from the piston corer. In addition to lake bottom sediments, chemical and biological samples are collected by the R/V *Shenehon*. The ship is also used to deploy and retrieve instrument moorings.

During 1979 the ship was based at the U.S. Army Corps of Engineers yard at Grand Haven, Michigan. Space was also provided at that location for two laboratory trailers. During 1979 the range of ship operations was extensive as it provided support to tasks in the St. Clair River and Lake Erie in addition to those in Lake Michigan.

In support of continuing experiments in the Grand River plume and on its nearshore impacts in both time and space, the *Shenehon* was used to measure selected chemical components and physical characteristics. Nutrients, dissolved oxygen, water temperature, light transmittance, carbon dioxide, organic carbon, calcium carbonate, and chlorophyll were measured.

During summer and fall, the ship was used to collect data in support of the carbonate "whiting" project in offshore areas of southern Lake Michigan. Particulate inorganic carbon, water temperature, pH, alkalinity, total suspended material, and chlorophyll were measured at various water depths.

Biology experiments supported by the ship this past year included both planktonic and benthic studies. Plankton net tow, water samples, and temperature data were collected at regular intervals. These data are being used in studies of seasonal species-specific zooplankton grazing and nutrient uptake. Benthic meiofauna distribution, sediment particle size, and organic carbon content of surface sediments were observed *in situ* through use of SCUBA techniques. The purpose of these experiments is to determine seasonal variations in population and to relate distribution to those environmental variables crucial to the existence and well-being of the benthic meiofauna. Observations were also made on the lake bottom to evaluate the effects of benthos on sediment properties and nutrient exchange at the sediment-water interface. The ship was also used in a series of overnight cruises for a cooperative project with the University of Michigan: plankton traps were deployed to investigate *in situ* predation of zooplankton by *Mysis relicta* and to test the hypothesis that Cladocera avoid mysid predation by vertical light-related migration.

In physical characteristics studies, the *Shenehon* was used to install a meteorological spar buoy in western Lake Erie and to retrieve current meter moorings that had been deployed 6 months earlier as part of a contract with the U.S. Environmental Protection Agency to aid their Lake Erie monitoring program. Three Waverider buoys were also deployed and retrieved from Lake Erie. These provided observations for characterizing deep water waves and examining island effects on surface wave patterns.

The work in the St. Clair River was in support of diving operations and deployment of current meters. Flow measurements will be used in conjunction with the U.S. Army Corps of Engineers cross-sectional measurements in determination of the winter flow regime of that river.

The *Shenehon* also supported a cooperative GLERL-University of Michigan sediment dynamics project. This experiment was aimed at determination of sediment characteristics at the water interface and observations of the overlying nepheloid layer in a transect across the southern basin of Lake Michigan.

Library and Information Services

Laboratory programs are supported through the services and facilities of the GLERL library. The collection consists of research materials in climatology, hydrology, hydraulics, ice, limnology, mathematical modeling, meteorology, oceanography, sedimentation, wave motion, and their environmental impacts upon the Great Lakes Basin. During FY 1979 the library received over 260 current periodical and serial titles supplemented by data files, technical reports, and books. Library staff are responsible for acquisitions, interlibrary loans, translations, and literature searches.

NOAA's Computerized Information Retrieval Services and the Bibliographic Retrieval Service, Inc., message switching system permit information retrieval, literature searching, and interlibrary loans through direct, on-line communication. Participation in the National Journalink Union List facilitates the sharing of up-to-date periodical holdings between the GLERL library and other libraries.

Publications Section

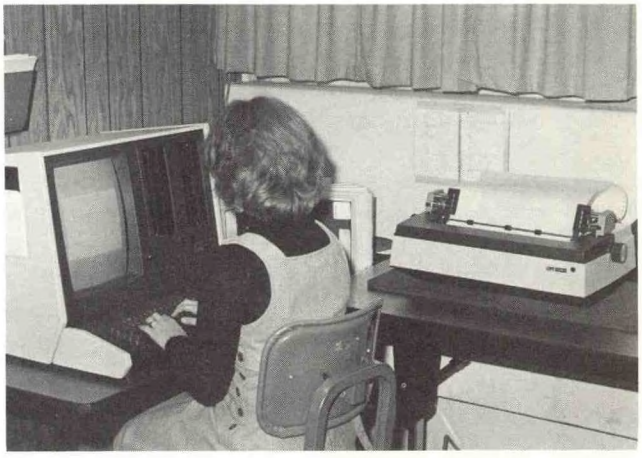
Publications are a major GLERL product and a critical part of our efforts to make research findings available to a broad spectrum of users for application to environmental problems and decisions.

The publications section has responsibility for the preparation of manuscripts, including editing, typing, proofing, procurement of graphics, and when appropriate, pasteup. Manuscripts are formatted according to the requirements of the publication form: articles and notes in professional journals, NOAA Technical Reports and Memoranda and Data Reports, or in-house reports. During the last fiscal year, 47 manuscripts were processed in the GLERL publications section.

A listing of GLERL publications is sent to the mailing list every 6 months, and requests are filled until supplies are exhausted. Of course, copies of publications are also available through the National Technical Information Service.

Capabilities were recently improved with acquisition of a CPT 8000 disktype word processing system. This is a software-oriented system with full page cathode ray tube display, a random access dual disk drive for input and storage, and a high-speed impact printer. Although the equipment has been in service for only a short time, it is expected to greatly improve efficiency.

Graphics and photographic services continue to be procured under contract.



Manuscript revision on the new CPT 8000 word processor in the publications section. This disktype machine has improved the efficiency of the publications process.

PUBLICATIONS

A 6-month listing of available publications can be obtained from
Advisory Service
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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†Not affiliated with this laboratory.

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CONTRACTS AND GRANTS DURING FY 1979

Principal Investigator	Institution	Title
A. M. Beeton	University of Michigan	A Cooperative Program in Great Lakes Long Term Effects Research
A. M. Beeton	University of Michigan	The Cycling of Toxic Organic Substances in the Great Lakes Ecosystem
J. A. Bowers	University of Michigan	*Mysis* Feeding Studies
E. F. Brater	University of Michigan	Estimating Runoff From Ungaged Drainage Basins
C. W. Chen	Tetra Tech, Inc.	Calibration of a Three-Dimensional Ecological Hydrodynamics Model for Lake Ontario
G. T. Csanady	Woods Hole Oceanographic Institution	Coastal Circulation
G. T. Csanady	Woods Hole Oceanographic Institution	Mass Exchange Mechanisms
B. H. DeWitt	Bernard DeWitt and Associates, Inc.	Summary of Great Lakes Weather and Ice Conditions
J. E. Gannon	University of Michigan	Role of Predacious Rotifiers
S. J. Jacobs	University of Michigan	A Parametric Model for Wave Prediction
S. S. Killham	University of Michigan	Species Specific Growth Rates of Phytoplankton
J. T. Lehman	University of Michigan	Formulation for Zooplankton in Lake Ecosystem Models
G. A. Meadows	University of Michigan	The Growth and Decay of the Coastal Boundary Layer
C. H. Mortimer	University of Wisconsin (Milwaukee)	Inertial Motion Examined by Episode in Large Stratified Lakes
C. H. Mortimer	University of Wisconsin (Milwaukee)	Coupling of Physical and Biological Dynamics in Large Lakes
R. H. Reckhow	Michigan State University	Use of Selected Lake Models for Policy Evaluation
C. P. Rice	University of Michigan	Studies in PCB's
R. R. Rumer	State University of New York (Buffalo)	Ice Transport by Wind and Waves in the Great Lakes
R. R. Rumer	State University of New York (Buffalo)	Internal Resistance of Lake Ice
R. A. Sweeney	State University of New York (Buffalo)	Copepod Life History