

# Information Concerning Water Resources Research Center Projects, 1964-1974

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WATER RESOURCES RESEARCH CENTER  
UNIVERSITY OF MINNESOTA  
GRADUATE SCHOOL

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## FOREWORD

This Bulletin is published in furtherance of the purposes of the Water Resources Research Act of 1964. The purpose of the Act is to stimulate, sponsor, provide for, and supplement present programs for the conduct of research, investigations, experiments, and the training of scientists in the field of water and resources which affect water. The Act is promoting a more adequate national program of water resources research by furnishing financial assistance to non-federal research.

The Act provides for establishment of Water Resources Research Institutes or Centers at Universities throughout the Nation. On September 1, 1964, a Water Resources Research Center was established in the Graduate School as an interdisciplinary component of the University of Minnesota. The Center has the responsibility for unifying and stimulating University water resources research through the administration of funds covered in the Act and made available by other sources; coordinating University research with water resources programs of local, State and Federal agencies and private organizations throughout the State; and assisting in training additional scientists for work in the field of water resources through research.

This report is number 19 in a series of publications designed to present information bearing on water resources research in Minnesota and the results of some of the research sponsored by the Center. Information concerning completed projects, projects underway, and authorized projects funded during the period 1964-74 by the Water Resources Research Center through the Federal Office of Water Resources Research is summarized in this bulletin. Since 1964, thirty-nine projects have been completed; research results are described in 141 reports and 21 theses.

## INFORMATION CONCERNING WATER RESOURCES RESEARCH CENTER PROJECTS, 1964-74

### INTRODUCTION

The Water Resources Research Center was established in the Graduate School, University of Minnesota in September 1964 under the provisions of the Federal Water Resources Research Act of 1964 (Public Law 88-379 as amended by P.L. 89-404 and P.L. 92-175.) According to that Act, "It shall be the duty of each such institute to plan and conduct and/or arrange for a component or components of the college or university with which it is affiliated to conduct competent research, investigations, and experiments of either a basic or practical nature, or both, in relation to water resources and to provide for the training of scientists through such investigations, and experiments. Such research, investigations, experiments, and training may include, without being limited to, aspects of the hydrologic cycle; supply and demand for water; conservation and best use of available supplies of water; methods of increasing such supplies; and economic, legal, social, engineering, recreational, biological, geographic, ecological, and other aspects of water problems, and scientific information dissemination activities, including identifying, assembling, and interpreting the results of scientific and engineering research deemed potentially significant for solution of water resource problems, providing means for improved communication regarding such research results, including prototype operations, ascertaining the existing and potential effectiveness of such for aiding in the solution of practical problems, and for training qualified persons in the performance of such scientific information dissemination; having due regard to the varying conditions and needs of the respective States, to water research projects being conducted by agencies of the Federal and State Governments, the agricultural experiment stations, and others, and to avoidance of any undue displacement of scientists and engineers elsewhere engaged in water resources research. The annual programs submitted by the State institutes to the Secretary for approval shall include assurance satisfactory to the Secretary that such programs, were developed in close consultation and collaboration with leading water resources officials within the State to promote research, training, and other work meeting the needs of the State."

The Center's goals and objectives are as follows:

- \* Apply academic water resources research to the social and technical problems of the State and nation.
- \* Stimulate University of Minnesota and State and Private College water resources research through administration of funds associated with the Federal Water Resources Research Act of 1964.
- \* Coordinate Center research programs with programs of local, State and Federal agencies and private organizations throughout the State and Nation.

- \* Disseminate information concerning the Center's programs and the results of its research projects.
- \* Facilitate cross-disciplinary, multi-disciplinary and interdisciplinary water resources research collaboration.
- \* Strengthen water resources research programs of academic departments by referring sponsors of disciplinary research to academic departments, providing statistical and research design consultation assistance, making available research equipment, and helping move good research ideas into proposal form.
- \* Facilitate graduate and undergraduate water resources education programs by providing employment for students and stimulating educational offerings.

In general, the Center emphasizes multi-disciplinary applied research with statewide, multistate, and national implications. Research projects funded by the Center concern:

The character, occurrence, and movement of water resources; or the technology of water resources development and management including the physical, socio-economic, and institutional aspects of the technology. The following types of effort are not considered eligible for funding: equipment development projects which might be undertaken by equipment suppliers; activities that appeared to be predominantly data gathering, such as projects dealing with yields of water from different land areas, or dealing with water resources in a particular type of terrain; however, non-duplicative data collection which is an integral part of a well-planned research effort is eligible for consideration; and projects that constitute mere tabulations or analyses of data already existent without being an integral part of a research effort. Both basic and applied research is considered. Basic research is that type of research which is directed toward increase of knowledge in science. It is research where the primary aim of the investigator is a fuller knowledge or understanding of the subject under study, rather than as is the case with applied research, which is concerned with a practical application thereof.

Funding priorities are based on the results of regional water resources problem-research need workshop conferences and a statewide needed research priority questionnaire as described in the publication entitled "Water Resources Problems and Research Needs in Minnesota, 1974 - Guidelines for Research Programs," by W.C. Walton, Bulletin 68, Water Resources Research Center, which was published in 1974. High priority water resources research need topics are as follows:

- Methods for making beneficial use of waste heat from thermal power production in Minnesota
- Identification and evaluation of groundwater pollution caused by municipal and industrial waste discharges, urbanization, and agricultural practices; monitoring groundwater pollution in Minnesota; and identifying groundwater pollution hazard areas

- Management methods and techniques for protecting groundwater resources in Minnesota
- Improving the water resources planning process in Minnesota by integrating water resources planning with land-use planning; integrating water quality planning with total water resources planning; and more fully considering alternatives, environmental consequences, public interests, and priority setting
- Alternative solutions for small community waste disposal problems in Minnesota; income index-hardship cases involving pollution control policies
- Determining the optimum balance between preservation and protection of wetlands and drainage for agricultural practices in Minnesota; social and economic impacts of wetland drainage
- Ways and means for encouraging the private sector to preserve and protect wetlands in Minnesota; feasibility of providing tax (individual and county) incentives for wetland preservation
- Estimating the effects of future large groundwater withdrawals in the Minneapolis-St. Paul area on groundwater levels, streamflows, lake levels, and pollution hazards; social and economic impacts of withdrawals; design of computer hydrologic system model
- Projecting average annual flood damages with a vigorous floodplain zoning program involving both urban and rural lands in Minnesota; assisting the State in mapping flood plain areas and determining flood hazards; assisting local governmental entities in carrying out floodplain management programs
- Economic sanctions and incentives that could more effectively eliminate pollution in Minnesota
- Feasibility of wastewater land disposal systems in Minnesota; environmental impacts; recycling nutrients presently discharged into water bodies
- Determining the physical, social and economic impacts of alternative methods of taconite tailings disposal in Minnesota; environmental aspects of on-land disposal of taconite tailings; ecological and health hazards associated with taconite tailings disposal in Lake Superior
- Evaluating the water quality impacts associated with possible future copper-nickel mining and processing in Minnesota
- Estimating groundwater recharge under various watershed characteristics in Minnesota; dynamics of groundwater flow systems
- Institutional arrangements for improving the coordination of water resources agencies and programs in Minnesota; improving communication between professionals and professionals and professionals and citizens
- Reuse and sequential use of water in Minnesota; increasing the efficiency of water use

Many functions are carried out by the Center emphasizing the application of knowledge and the solutions of problems. The special ability of the Center to facilitate cross-disciplinary, multi-disciplinary and interdisciplinary research collaboration is regarded as one of the prime justifications for its existence. Several factors have contributed to the growing emphasis on multi-disciplinary research. The so-called knowledge explosion contributed to the fragmentation of disciplines into new and important specialties and to the emergence of new cross-disciplinary relationships. The

second major push toward inter-disciplinary collaboration has been the increased demand for applied knowledge to solve scientific, technical and social problems. Problem-solving cannot necessarily be restricted to disciplinary boundaries.

The nature of the Center's interdisciplinary involvement and the extent of interdisciplinary collaboration in the Center's programs can be described as follows. The Center involves faculty members from different disciplines; individuals tend to work independently on separate aspects of a larger problem. There is an overall, integrative design to the total enterprise, but substantial autonomy is granted each researcher in the design and direction of separate phases of the effort.

Center resources are distributed among the functions of research, public service, and instruction. Research and public service are the primary or predominant functions. Estimated distribution of resources among functions are: research - 93 percent, public service - 6 percent and instruction - 1 percent.

The Center does not perform research, it administers and facilitates research. The Center is administratively responsible for the research carried out under its sponsorship; the research is actually "produced" in various academic departments. The principal task is to coordinate efforts and ensure accountability to funding agencies. Research programs on the problems of water quantity and quality require competencies from several disciplines, and as problems shift over time, the specific professional talent, equipment and facilities required also change. As a result, the Center supports faculty members from several departments, all of whom maintain their principal identification with their departments. The task of maintaining and coordinating these complex interpersonal and organizational relationships is considerable. The Center facilitates research by referring sponsors of disciplinary research to departments, providing statistical and research design consultation assistance, making available research equipment, and helping move good research ideas into proposal form.

The Center is not involved in the administration of public service, it is involved in the performance and facilitation of public service. The Center publishes and distributes Bulletins, Information Circulars and a Newsletter and sponsors seminars and conferences. The primary purpose of the Center's public service is to disseminate information concerning the Center's programs and the results of its research projects. The Center facilitates public service by offering guidance and technical advice to agencies which provide direct delivery of public service like the Cooperative Extension Division.

The Center does not perform or administer instruction but it does facilitate instruction. The Center facilitates graduate and undergraduate education programs by providing employment for students.

The contract model adopted by the Federal government is largely responsible for the adaptive organizational structure of the Center. The Center

undergoes a continuous process of initiating and terminating projects; it has only a small managerial staff. The professional staff for research projects is drawn from the faculties of the University of Minnesota and State and Private Colleges. The Center has a small office of its own; it does not have a laboratory or library nor does it house any research equipment. Professional staff members do not have any long-term career identification with the Center. The Director, with the assistance of an Advisory Committee, is responsible for the effective operation of the Center. The organizational structure of the Center is designed to maintain flexibility in personnel commitments, space, equipment and other resources sufficient to make major changes in the tasks pursued as well as in the procedures followed. The desire to strengthen graduate education and research programs figures prominently in having the Center function as a unit of the Graduate School. The Center is effective in generating needed external income for graduate education and research. Some have likened the university to a federation, composed of departments, colleges, schools, institutes, and centers, each going its own way and following its own interests. Much of the strength of the University as well as such inefficiency and vulnerability result from this condition. The Center provides one means of preserving the strengths of this federated diversity among departments and individual faculty members while reducing the negative consequences through increased cross-departmental communication and coordination in the field of water resources. The Center has functioned with a part-time Director, Assistant Director, Research Accountant, and Property Accounting Officer and a full-time Secretary.

The principal mechanism utilized by the Center in coordinating its activities with other governmental agencies and the private sector is an Advisory Committee. Advisory Committee members are appointed by the Center Director in consultation with the Dean of the Graduate School. The Advisory Committee meets at least twice a year; rotation of some members occurs every three years to provide widespread representation. The Advisory Committee reviews the Center's programs and makes recommendations concerning activities and research needs and priorities; assists the Center in coordinating its programs with water resources programs of other organizations within the State; provides public liaison; and assists the Center in information dissemination. The roster of the Advisory Committee is given below.

University of Minnesota

A.G. Anderson	St. Anthony Falls Hydraulic Laboratory
D.A. Brown	Department of Geography
R.G. Bond	School of Public Health
M. Brodbeck	Graduate School
R.O. Megard	Dept. of Ecology and Behavioral Biology
L.P. Gerlach	Dept. of Anthropology
W. J. Heug, Jr.	Agricultural Experiment Station
C.L. Larson	Dept. of Agricultural Engineering
A.C. Mace	School of Forestry
W.J. Maier	Dept. of Civil and Mineral Engineering
W.P. Martin	Dept. of Soil Science
T.E. Straw	Div. of Science & Math (Morris)

W.R. Swain School of Medicine (Duluth)  
 M.S. Walton Minnesota Geological Survey  
 T.F. Waters Dept. of Entomology, Fisheries and Wildlife  
 H.E. Wright Limnological Research Center

State and Private Colleges

N. Baron Dept. of Geography, Winona State College  
 C.H. Fuchsman Center for Env. Studies, Bemidji State College  
 A.J. Hopwood Dept. of Biology, St. Cloud State College  
 J. Jack Dept. of Geography, Mankato State College  
 R.T. Moline Dept. of Geography, Gustavus Adolphus College  
 T. Surdy Dept. of Biology, Southwest Minnesota State College

State, Local and Federal Agencies

R.M. Dennistoun Minn. Dept. of Agriculture  
 F.H. Geisenhoff Minn. Dept. of Economic Development  
 G. Gere Minn. Dept. of Natural Resources  
 C.A. Johannes Minn. Pollution Control Agency  
 E.H. Ross Minn. Dept. of Health  
 J.E. Sizer Minn. State Planning Agency  
 E.M. Weiberg Minn. Water Resources Board  
 F. Lamm Metropolitan Council  
 L.L. Breimhurst Environmental Protection Agency  
 J.H. Strub National Weather Service  
 C.R. Collier U.S. Geological Survey  
 R.E. Cox U.S. Army Corps of Engineers  
 H.M. Major U.S. Soil Conservation Service  
 J. Scott U.S. Bureau of Sport Fisheries and Wildlife  
 C.A. Van Doren U.S. Agricultural Research Service

Interest Groups and Private Concerns

D. Asmussen Minn. Public Interest Research Group  
 D.W. Barr Consulting Hydraulic Engineer  
 R.A. Haik Attorney  
 H. Lykken Sierra Club  
 J.T. Shields Minn. Association of Commerce & Industry  
 P. Toren Izaak Walton League of America  
 M. Watson League of Women Voters

The Center maintains close liaison with the various Schools, Departments and Divisions of the University of Minnesota, State and private research firms and Consultants and voluntary organizations through its Advisory Committee and through its membership on the All-University Council on Environmental Quality and Advisory Committee, Center for Studies of the Physical Environment, Institute of Technology, at the University of Minnesota. The Center's activities have been made known to State Legislators through the Center Director's testimony before Senate and House Committees during each of the Legislative Sessions since 1964. The Center director has served as an Advisor to Committees of the Minnesota Senate and House of Representatives. The programs of the Center have been coordinated with the programs associated with Title III of the Water Resources Planning Act of 1965 through the Center's past membership on the Water Resources Coordinating Committee. That Committee assisted the State Planning

Agency in administering Title III funds and programs and it was composed of all State agencies with responsibilities in the water resources field. For several years, the Center Director served as the Chairman of the Water Resources Coordinating Committee.

Undue overlap and duplication is avoided through the facilities of the Water Resources Scientific Information Center, Office of Water Resources Research, and the Smithsonian Science Information Exchange. These organizations seek to disseminate scientific and technical information to the national water resources community through: Abstracting journal, Published indexes, Catalogs of active research projects, topical bibliographies, State-of-the-art reviews, and retrospective searching of information base. In addition, all research projects funded by the Center must be approved by Departmental Heads, Deans, the Office of Sponsored Programs-Graduate School Research Center, and the Business Office, University of Minnesota.

Water resources research is being conducted in Minnesota by 19 units of the University of Minnesota, 6 State Colleges, 3 Private Colleges, 4 Federal agencies, 5 State agencies, 1 Private organization and 6 Consultants. In 1972, 136 water resources research projects were being conducted involving 202 man-years of effort and a support volume of \$3.9 million. There are about 194 water resources research faculty at the University of Minnesota and State and Private Colleges in the State. State government contains at least 21 departments, agencies, boards, commissions, committees, etc. who use the results of water resources research as well as 30 Federal agencies, 5 International organizations, 5 regional organizations, 3 interstate organizations, numerous local governmental agencies, many special purpose districts, 49 Interest Groups, and the Legislature and Congress. At present, coordination of water resources research efforts in Minnesota and liaison between researchers and research users could stand improvement. Institutional arrangements could be devised to improve the coordination of water resources research efforts in the State. A potentially feasible arrangement is the combination of the centralized and decentralized approaches described below.

For administrative purposes, the State could be subdivided into 8 regions along Regional Development Commission and Metropolitan Council boundary lines. Water Resources Research Regional Councils (WRRRC) could be established in each region initially with headquarters at institutions and locations given below.

Region No.	Council Headquarters Institution	Council Headquarters Location	Regional Development Commission Areas Covered by Council Boundaries
1	University of Minnesota	Duluth	3
2	Bemidji State College	Bemidji	1, 2
3	University of Minnesota	Morris	4
4	St. Cloud State College	St. Cloud	5, 7
5	University of Minnesota	St. Paul	11
6	Winona State College	Winona	10
7	Gustavus Adolphus College	St. Peter	6E, 9
8	Southwest Minnesota State College	Marshall	6W, 8

The Water Resources Research Center (WRRC), University of Minnesota, could serve as permanent headquarters for the WRRRC for Region No. 5 and also as the permanent headquarters for a Water Resources Research State-wide Council (WRRSC).

Headquarters for WRRRC-1, 2, 3, 4, 6, 7, 8 could be rotated periodically among member educational institutions of Councils. Membership on WRRRCs' could consist of representatives from the University of Minnesota, State and Private Colleges; State, Federal and local governments; Private Organizations; and Interest Groups residing in each WRRRC. Membership on WRRSC could consist of the Chairman of WRRRCs'. The Chairmanships of WRRRCs' could be rotated periodically among member educational institutions of Councils. The Director, Water Resources Research Center, University of Minnesota could serve as Chairman of WRRSC.

At least initially no Legislative action or formal agreements between Institutions and Agencies is deemed necessary to establish WRRRCs' and WRRSC. The Councils could be developed and operated on an informal basis without written charters or establishment as corporate entities. Memorandums of Agreement could be executed as deemed necessary on an individual basis between researchers and funding agencies or between groups of researchers and funding agencies in the case of joint ventures. More formal institutional arrangements may be deemed necessary at some later date based on experience gained under informal arrangements.

WRRRCs' could establish and maintain liaison between water resources researchers, research funding agencies, and research users in regions; establish and maintain inventories of ongoing water resources research needs in regions; establish and maintain directories of water resources researchers in regions; assist water resources researchers in submitting research project proposals to funding agencies; provide material for Newsletter to be published and distributed by WRRSC through WRRC and otherwise facilitate water resources information dissemination in regions; facilitate cross-disciplinary, multi-disciplinary and inter-disciplinary water resources research collaboration in regions; facilitate graduate and undergraduate water resources education programs by stimulating educational offerings; and sponsor regional water resources research meetings.

WRRSC could assist WRRRCs' in their activities; prepare and submit to the Legislature through the Minnesota Resources Commission (MRC) an Annual Report summarizing ongoing water resources research in Minnesota and other information concerning WRRRCs' and WRRSC; offer assistance to MRC concerning State funding of water resources research projects; develop and maintain contact with funding agencies; participate in the Environmental Protection Agency's River Study Centers program; develop and maintain liaison with River Basin Commissions and OWRR Regional Organizations; establish and maintain, with the assistance of WRRRCs', a central clearing house for statewide research information; keep abreast of governmental plans, programs, and policy issues; translate water resources policy and management issues into compatible research designs; and publish and distribute a Newsletter through WRRC; and sponsor an annual Conference during which information concerning ongoing water resources research could be exchanged.

Information concerning completed projects, projects underway, and authorized projects funded during the period 1964-74 by the Water Resources Research Center through the Federal Office of Water Resources Research is summarized in this bulletin. Data on the costs of projects, man years of effort, publications resulting from projects, and research results are presented to partially inform the reader of the nature and magnitude of the Center's research program. Additional detailed information concerning projects can be obtained from the references listed at the end of this document.

The main thrust of the Center's program to date has been directed towards: determining groundwater contribution to streamflow and its relation to hydrologic basin characteristics; appraising the effect of potholes on groundwater resources; evaluating induced infiltration of water in streams; determining soil moisture movement induced by winter thermal gradients; establishing a practical baseline of water quality for Lake Superior through the use of the continuous plankton recorder technique; the analysis and interpretation of existing Federal, State, and local water resources legislation and court decisions and ways and means for improving water laws in Minnesota; ascertaining the physiological and ecological requirements of the algal species responsible for severe blooms on lakes scattered throughout the State to assist in controlling the excessive productivity of polluted lakes; determining methods for rainfall-runoff predictions which are based on the physical characteristics of ungauged small watersheds and rainfall characteristics; reconciling and integrating water quality management with the ecological and social-economic objectives of the total water resources of Minnesota; formulation of an economic optimizing model for water quality and sewage disposal on selected stretches of the Upper Mississippi River; investigation of programs that appear to have special merit relative to hydrologic analysis for determination of design floods and for design of spillways and related structures; investigation of soil dynamic changes when interacting with water to assist in solving water problems such as infiltration, water spreading and flow properties in soils; determination of runoff-time distribution for a variety of watershed sizes and slopes; determining the role of bottom sediments in the phosphorus cycle for lakes of different types to assist in devising corrective measures for overfertilized lakes; development of techniques that will pinpoint polluted areas in reaches of the Upper Mississippi River where algacides might be profitable administered to control pollution; investigation of mist irrigation as a method of reducing water stress in potato crop production and thereby reducing transpiration; investigation of the mechanics of soil moisture movement and retention to assist water resources developers and managers in estimating recharge to groundwater reservoirs and the effect of soil moisture movement on surface water runoff; study of citizens groups involved at the grass roots to improve the water resources environment in Minneapolis-St. Paul, Miami and environs, and two other metropolitan areas and environs in the USA; determining existing ecological conditions in the Mississippi River near Monticello, Minn. before operation of a large nuclear power plant and monitoring the environmental changes due to the thermal discharge from the power plant generator; improving water resources administration in

Minnesota; establishing a biological baseline for Lake Superior; methods for predicting runoff in small watersheds; mathematical simulation of a large watershed; finding a nutritional, medicinal or industrial use for unwanted aquatic plants; renovation of Lake Minnetonka; optimum level of hydrogeologic data; developing a water resources research plan for Minnesota; establishing water quality status and trends indices; developing a water information system for Minnesota; application of remote sensing techniques to water problems; role of surface runoff and groundwater flow in overfertilization of surface waters; perceptions concerning water resources and problems in Minnesota; area financing of water resources development; social and economic factors in the adoption by industry of water pollution control measures; forecasting floods; forest management alternatives; alternative water resources policies in Minnesota; use of wasted heat from power plants; role of scientist-technician in water policy decisions; pollutional eutrophication of lakes; bio-manipulation of lakes; and thermal pollution.

#### Annual Allotment Program

##### Completed Projects

OWRR Project No.: A-001-Minn

Project Title: The Effect of Pothole Drainage Upon Groundwater Resources

Principal Investigator: P.W. Manson, Department of Agricultural Engineering

Project Began: May 15, 1965      Project Completed: June 30, 1968

Cost of Project: \$44,002 federal funds

Man Years of Effort: 3.75

Publications Resulting from Project: (1) Manson, P.W., G.M. Schwartz, and E. R. Allred. 1968. Some Aspects of the Hydrology of Ponds and Small Lakes. Agr. Exper. Stat., Univ. of Minn., Tech. Bull. 257. 88 p., 55 fig., 40 tab., 14 ref. (2) Reinke, J.W. 1968. The Hydrology of a Typical Ice Block Galcial Lake. M.S. Thesis. Univ. of Minn. Dept. of Agric. Engr.

##### Research Results:

The relationship between drainage and groundwater resources in the vicinity of 69 potholes and small lakes located in 6 major geological environments in Minnesota was evaluated. The common pothole with a bed of impervious silt or clay soil sediments contributes little recharge to the groundwater reservoir according to field laboratory and office observations. At places where the bed of the pothole is pervious, the water surface of the pothole is generally an expression of the water table. The main controlling factor of the level of the water in potholes and small lakes is the relation between precipitation and evaporation. The results of the research indicate that the best method to recharge groundwater reservoirs is to induce infiltration of precipitation into the soil by proper landuse practices rather than to attempt to utilize potholes where much of the water is evaporated before it can reach the water table. Information generated by the project will assist those individuals and water resource agencies who are planning water conservation programs for small watersheds.

OWRR Project No.: A-004-Minn

Project Title: Factors Influencing Soil Freezing in Forests and the Importance of Their Effect on Runoff

Principal Investigator: D.B. Thorud, School of Forestry

Project Began: May 15, 1965      Project Completed: June 30, 1967

Cost of Project: \$11,793 federal funds

Man Years of Effort: 1.40

##### Publication Resulting from Project:

Thorud, D.B. and D.A. Anderson. 1969. Freezing in Forest Soil as Influenced by Soil Properties, Litter and Snow. Water Resources Research Center, Univ. of Minn. Bull. 10, 41 p., 20 fig., 16 tab., 19 ref.

##### Research Results:

Laboratory experiments and field studies were conducted to obtain knowledge concerning the forest-associated variables that control soil freezing. Soil texture variations have much less influence on frost penetration and therefore surface runoff than forest litter variations. The rate of frost penetration can be ranked from the most rapid to the slowest as follows: bare-oak-red-pine-white pine. Forest litter and snow cover appreciably affect soil freezing in that the litter and snow act as insulators. The results of the research will assist water resource agencies in making flood forecasts and planning water and land management practices.

OWRR Project No.: A-005-Minn

Project Title: Vertical migration of moisture in the soil induced by winter thermal gradients and its influence upon spring water resources

Principal Investigator: D.G. Baker, Department of Soil Science

Project Began: July 1, 1965      Project Completed: August 31, 1968

Cost of Project: \$8,997 federal funds, \$15,282 non-federal funds

Man Years of Effort: 1.64

##### Publication Resulting from Project:

Baker, D.G. 1971. Snow Cover and Winter Soil Temperatures at St. Paul, Minnesota, Water Resources Research Center, Univ. of Minn. Bull. 37, 24 p., 7 fig., 4 tab., 5 ref.

##### Research Results:

Climatological data of 30 or more years duration for Minnesota were analyzed to determine the vertical migration of moisture in the soil induced by winter thermal gradients and its influence on spring floods. Because snow cover proved to be the major factor determining the winter thermal regime of soils, the 8 winters (1961-62 through 1968-69) considered in

this study were categorized into 4 kinds based upon snow cover characteristics. They were (1) deep and persistent snow cover (2) deep but non-persistent snow cover with an ice layer, (3) an average snow cover and (4) a light and non-persistent snow cover or an "open" winter. It is believed that these 4 kinds of winters and particularly the extremes, 1 and 4, represented a range of conditions that ordinarily would be expected only in a 50-100 year period. A major conclusion obtained from this study was that there were in reality only 3 kinds of winters with respect to the OC isotherm configuration. Based upon the depth and persistence of the snow cover there were in effect 3 kinds of winters: one with deep persistent snow cover, one with very little snow cover (an "open" winter) and all other winters which fall within the two extremes. There was close agreement between the kinds of winters (based upon snow cover) and the following: the maximum depth to which the OC isotherm penetrated, the average rate of movement of the OC isotherm between Dec. 15 and Mar. 1, the minimum temperature at 1cm depth, and the depth in the soil at which the OC isotherm last occurred in late winter or early spring. In general the time of occurrence of the phenomena discussed could not be estimated by knowing the kind of winter. An exception appeared to be the time in late winter or early spring when the soil temperature at 1 and 5 cm depth remained above 0C. Under a normal sod cover the soil at St. Paul freezes to a depth of 114 cm. Upon thawing, which usually takes place from both top and bottom of the soil, there often remains for some time within the soil a frozen layer. This layer persisted longest at the mean depth of 63 cm and lasted some 13 days on the average after the surface had thawed. The presence of such a layer within the soil presents a very deceiving picture of the soil when viewed from the surface, and its presence prevents drainage of water within and on the soil. Flood hazards are greatly reduced after this frozen layer has disappeared. The periods of restricted water movement within the soil varied from 108-143 days and averaged 126 days. In order for a measurable vertical migration of soil moisture to occur under natural conditions, under the temperature conditions observed, the soil moisture content must be at field capacity or higher.

OWRR Project No.: A-006-Minn

Project Title: Water Adsorption and Its Interactions With Clay and Quartz

Principal Investigator: G. R. Blake, Department of Soil Science

Project Began: May 15, 1965      Project Completed: June 30, 1968

Cost of Project: \$43,007 federal funds

Man Years of Effort: 3.47

Publications Resulting From Project: (1) Blake, G.R. and J.B. Swan. 1967. New Dimensions for Soil and Water Conservation. Minn. Sci. Vol. 23, No. 3, p. 18-19, 2 fig. (2) Lin, Shen-Maw. 1967. Porosity and Pore Size Distribution of Soil Aggregates. M.S. Thesis, Dept. of Soil Science, Univ. of Minn. 51 p., 6 fig., 8 tab., 43 ref.

Research Results:

The behavior and characteristics of soil fabrics to water were studied in the laboratory to obtain a better understanding of the mechanics of soil moisture movement and retention. Moist soil aggregates increased in stability at intermediate water contents, then decreased as air dryness was

approached. Soil aggregate porosity was higher in loess soils than those in till soils. Virgin soil aggregate porosities were higher than those from cultivated fields. Information generated by the project on soil fabric, structure, formation and stabilization will assist scientists in controlling water in soils.

OWRR Project No.: A-007-Minn

Project Title: Studies on the Use of Planktonic Desmids as Indicators of the Trophic Status and Water Quality of Freshwater Lakes.

Principal Investigator: A.J. Brook, Department of Ecology and Behavioral Biology

Project Began: May 15, 1965      Project Completed: June 30, 1967

Cost of Project: \$9,442 federal funds

Man Years of Effort: 1.32

Publication Resulting from Project: Brook, A.J. 1968. The Phytoplankton of Minnesota Lakes. Water Resources Research Center, Univ. of Minn. Bull. 36.

Research Results:

From the results of this research, it has been shown that desmids (green algae) may prove to be valuable as indicators of the trophic status of lakes in Minnesota. Plankton collections were made from 150 lakes in different parts of the state; the lakes sampled being representative of a wide spectrum of chemical and overenrichment types. These range from the lakes in the northeast which are low in fertility to the artificially enriched lakes in the southwest. In the analysis of these collections, compound phytoplankton quotients were determined for each lake. Comparison of the quotients gives an indication of the relative fertility of the lakes. The algae studied indirectly or directly are sensitive to pollution, therefore desmids may serve as useful indicators of eutrophication and the results of the research will assist agencies in evaluating the water quality of lakes.

OWRR Project No.: A-008-Minn

Project Title: Water Quality, Organic Productivity, and the Distribution of Organisms in Minnesota Lakes

Principal Investigator: H.E. Wright, Limnological Research Center

Project Began: May 15, 1965      Project Completed: June 30, 1967

Cost of Project: \$33,379 federal funds

Man Years of Effort: 2.68

Publication Resulting from Project: Megard, R.O. 1967. Limnology Productivity and Carbonate Sedimentation of Minnesota Lakes. Limnological Research Center, Univ. of Minn. Interim Rep. No. 1, 69 p., 25 fig., 11 tab., 6 ref. and Megard, R.O. 1968. Planktonic Photosynthesis and the Environment of Calcium Carbonate Deposition in Lakes. Limnological Research Center, Univ. of Minn. 47 p., 6 fig., 6 tab., 33 ref.

Research Results:

The seasonal chemical changes and primary productivity of 14 selected lakes in various parts of Minnesota were studied for a period of 2 years using a fully equipped mobile limnological laboratory. Rates of photosynthesis and respiration by plankton were measured by the light-dark-bottle technique. Bio-assays were made to assess the interaction between biological activity and water chemistry. An analytical method was devised for comparing the fertility of lakes which is based on the premise that primary productivity integrates the physical variables on one hand and the biological variables on the other. This method will permit the prediction of the susceptibility of a lake to algal blooms and other recreationally undesirable features.

OWRR Project No.: A-009-Minn

Project Title: Groundwater Contribution to Streamflow and Its Relation to Hydrogeologic Basin Characteristics and Recharge Rates to Aquifers in Minnesota.

Principal Investigator: E.A. Ackroyd, Minnesota Geological Survey, School of Earth Sciences

Project Began: July 1, 1965      Project Completed: June 30, 1966

Cost of Project: \$6,964 federal funds

Man Years of Effort: 1.04

Publication Resulting From Project: Ackroyd, E.A., W.C. Walton and D.L. Hills. 1967. Groundwater Contribution to Streamflow and Its Relation to Hydrogeologic Basin Characteristics and Recharge Rates to Aquifers in Minnesota. Minn. Geol. Survey. Rept. of Invest. 6. 36 p., 13 fig., 6 tab., 17 ref.

Research Results:

Annual groundwater contributions to streamflow from 38 drainage basins in Minnesota were estimated by use of standard streamflow hydrograph separation methods. The general characteristics of the drainage basins were determined from published reports and maps. Relations between groundwater runoffs and basin characteristics such as geologic environment, precipitation and temperature, and percentage of lake and wetland cover were determined by statistical analysis. Groundwater runoff is least from glaciated basins with surface lakebed sediments or gray drift ground moraine immediately underlain by relatively impermeable bedrock. Groundwater runoff is greatest from glaciated basins with surface sand and gravel deposits immediately underlain by relatively impermeable bedrock and glaciated basins with thick surface loess deposits immediately underlain by permeable bedrock. In northern parts of the state annual groundwater runoff is greatly affected by the degree of lake and wetland cover. Lakes and wetlands act as natural reservoirs which sustain and regulate streamflow during rainless periods. Because many aquifers in Minnesota are deeply buried not all groundwater runoff can be diverted into cones of depression. The results of the research will assist federal and state agencies in evaluating groundwater discharge to streamflow.

OWRR Project No.: A-010-Minn

Project Title: Analysis of Factors Affecting Aquifer Test Results Under Induced Streambed Infiltration Conditions with Electric Analog Computers.

Principal Investigator: W. C. Walton, Graduate School

Project Began: May 15, 1965      Project Completed: June 30, 1966

Cost of Project: \$17,166 federal funds

Man Years of Effort: 1.17

Publication Resulting From Project: Walton, W.C. and E.A. Ackroyd. 1966. Effects of Induced Streambed Infiltration on Water Levels in Wells During Aquifer Tests. Water Resources Research Center, Univ. of Minn. Bull. 2, 43 p., 21 fig., 4 tab., 25 ref.

Research Results:

Electric analog computers were used to appraise the accuracy of estimated effects of streambed induced infiltration on ground water levels based on the image-well theory. Electric analog computers for two aquifer test sites for which field data are available were constructed. The analog computers consist of analog models and excitation-response apparatus. The analog models are regular arrays of resistors and capacitors and are scaled-down versions of aquifer stream situations. The excitation-response apparatus consists of a power supply, waveform generator, pulse generator and an oscilloscope. It is concluded that, during induced infiltration aquifer tests, the image-well theory closely describes drawdowns on the land sides of streams with a high degree of accuracy whether the cone of depression spreads beneath and beyond or only part way beneath the streambed. Drawdowns beneath or beyond the streambed and the streambed areas of infiltration based on the image-well theory are not those which are observed in the field. However, the streambed infiltration rates per foot of head loss based on hypothetical drawdowns beneath streambeds and streambed areas of infiltration computed with the image-well theory are not those which are observed in the field. However, the streambed infiltration rates per foot of head loss based on hypothetical drawdowns beneath streambeds and streambed areas of infiltration computed with the image-well theory seem to be empirically correct. The results of the research will assist agencies in estimating groundwater recharge.

OWRR Project No.: A-011-Minn

Project Title: A Study of the Open Water Distribution and Abundance of Net Plankton As an Index of Eutrophication in Lake Superior.

Principal Investigator: T.A. Olson, School of Public Health

Project Began: May 15, 1965      Project Completed: June 30, 1969

Cost of Project: \$40,793 federal funds

Man Years of Effort: 3.02

Publications Resulting from Project: Olson, T.A. and T.O. Odlaug. 1966. Limnological Observations on Western Lake Superior, Proc. Internat. Conf. on Great Lakes Res. Pub. No. 15. Great Lakes Res. Div., Univ. of Mich., p. 109-118.

Olson, T.A., T.O. Odlaug and W.R. Swain. 1966. The Continuous Plankton Recorder, A Review of the Literature. Water Resources Research Center. Univ. of Minn. Bull. 3, 221 p., 155 fig., 24 tab., 40 ref.

Swain, W.R., T.A. Olson and T.O. Odlaug. 1967. Studies of Chlorophyll and Carotenoid Pigments in Lake Superior Periphyton. Proc. 10th Conference on Great Lakes Res. p. 107-114.

Swain, W.R. 1969. Crustacea of Lake Superior, Michigan and Huron as Determined by the Continuous Plankton Recorder Technique. Thesis. School of Public Health, Univ. of Minn.

Parkos, W.G. 1969. Primary Productivity Studies With C-14 Along Shipping Routes in Lake Superior, Michigan, Huron and Erie. School of Public Health, Univ. of Minn.

Fox, J.L., T.O. Odlaug, and T.A. Olson. 1969. The Ecology of Periphyton in Western Lake Superior. Part I - Taxonomy and Distribution. Water Resources Research Center, Univ. of Minn. Bull. 14., 127 p., 87 fig., 24 tab., 79 ref.

Parkos, W.G., T.A. Olson and T.O. Odlaug. 1969. Water Quality Studies on the Great Lakes Based on Carbon Fourteen Measurements on Primary Productivity. Water Resources Research Center, Univ. of Minn. Bull. 17, 121 p., 38 fig., 35 tab., 72 ref.

Stokes, L.W., T.A. Olson and T.O. Odlaug. 1970. The Photosynthetic Pigment of Lake Superior Periphyton and Their Relation to Primary Productivity. Water Resources Research Center, Univ. of Minn. Bull. 18, 150 p., 110 fig., 26 tab., 168 ref.

#### Research Results:

The carbon-14 productivity method and Continuous Plankton Recorder (CPR) method, as used in investigations, have been shown to be effective methods for the study of fauna and flora of the Great Lakes basin. Lake Superior was found to be the least eutrophic lake of the 4 lakes sampled. Lake Huron, Michigan, and Erie, in that order were found to be more eutrophic, with Lake Erie being more than 4 times as productive as any of the other lakes sampled. The degree of eutrophication noted in the lakes sampled increased progressively as the more southerly latitudes were reached. The mean seasonal productivity of the lakes sampled increased progressively as surface water temperature increased, with the exception of Lake Michigan. In the latter case a longer sampling season, including the cold fall months was involved, and the mean temperature was lowered. The productivity rate on each of the lakes increased as the season advanced during the 1967 sampling period. A similar rate was observed only near the end of the 1968 summer period. The general data accumulated indicate that sharply delineated regions of high zooplankton concentrations occur, confirming the hypothesis of non-uniform dispersal of organisms. Differences in species composition and members of organisms were evident when samples from water masses of Lakes Superior, Huron, and Michigan were analyzed. Definitive seasonal differences in zooplankton were detected and a marked diurnal variation in species composition of the plankton has been noted also. Data collected from chemically polluted and enriched areas indicated that marked increase in zooplankton occurs in these regions as compared to lake areas that display a paucity of nutrients. Differences in primary phytoplankton production

occur in the water masses of the Great Lakes system. Lowest levels of productivity from the four great Lakes indicated a definitive increase in phytoplankton carbon fixation activity of the lower lakes. Especially marked rises in primary production were found in lower Lake Michigan and in Lake Erie -- both regions where a high level of enrichment of the waters has undoubtedly developed because of massed populations and industry.

OWRR Project No.: A-013-Minn

Project Title: Review and analysis of precipitation and runoff data from selected watersheds in Minnesota.

Principal Investigator: C. Edward Bowers, St. Anthony Falls Hydraulic Laboratory

Project Began: July 1, 1965      Project Completed: June 30, 1968

Cost of Project: \$23,013 federal funds

Man Years of Effort: 2.82

Publication Resulting from Project: Bowers, C.E. and A.F. Pabst. 1968. Review and Analysis of Rainfall and Runoff Data for Selected Watersheds in Minnesota. Univ. of Minn., St. Anthony Falls Hydraulic Laboratory, Project Rept. No. 97, 97 p., 64 fig., 14 tab., 10 ref.

#### Research Results:

The objective of this project was the analysis of rainfall and runoff data for selected watersheds in the State of Minnesota to assist in the evaluation of peak rates of runoff for design purposes. Five basins or watersheds throughout the State, ranging in size from 93.8 to 1360 sq. mi., were selected for study. Rainfall and runoff data for 51 summer flood events were assembled and analyzed. In addition, all annual flood events were subjected to a frequency analysis. Rainfall and runoff data for the 31 flood events were analyzed with the assistance of a "Unit Graph and Loss Rate Optimization Program" developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center. This program determines the best unit hydrograph and loss coefficients, within the limits of the mathematical model, to reproduce a number of flood hydrographs from specified rainfall events. The following observations resulted from the study: Storm characteristics, including pattern, location, time distribution and direction had a pronounced effect on the optimized variables as well as the shape of the unit hydrographs. It is possible that some of these effects may be more significant than the question of linearity of the runoff process which is currently receiving considerable attention in research efforts. Very good agreement was obtained between computed and observed flood hydrographs of specific events using the optimization program. The program was very useful in determining hourly loss rates, based on this particular mathematical model. Storms with average rainfall were quite high, ranging up to 1.5 inches in one hour. A loss-rate curve was computed for each watershed, based on average values of 5 variables optimized for each storm. The resulting curve provided a very interesting basis for numerical comparison of the basins or watersheds. The Corps of Engineers Optimization Program used in the study is recommended for further design and research

studies. Results of this study should assist designers and researchers who may have occasion to use the optimization program used in this study, provide data on hourly (basin wide) loss rates, based on the model used in the program, and provide some indication of the possible effect of storm characteristics on some of the variables associated with the runoff process.

OWRR Project No.: A-014-Minn

Project Title: Recharge from Induced Streambed Infiltration Under Varying Stream-State and Aquifer Water-Level Conditions.

Principal Investigator: W. C. Walton, Graduate School

Project Began: July 1, 1966      Project Completed: June 30, 1967

Cost of Project: \$11,034 Federal funds

Man Years of Effort: 0.98

Publication Resulting from Project: Walton, W.C., D.L. Hills and G.M. Grundeen. 1967. Recharge from Induced Streambed Infiltration Under Varying Groundwater-level and Stream-state Conditions. Water Resources Research Center, Univ. of Minn. Bull. 6, 43 p., 19 fig., 3 tab., 19 ref.

#### Research Results:

An Aquifer-stream system for which hydrogeologic data are available was studied using electric analog computers and analytical methods to gain insight into the magnitude of recharge by induced streambed infiltration under complex stream-state and groundwater level conditions. The profound influence of changes in stream state on recharge from induced streambed infiltration is illustrated by the results of the analytical studies. The results of the electric analog computer studies demonstrate that much greater drawdowns are computed for an aquifer-stream system when maximum infiltration conditions are taken into account than when maximum infiltration conditions are ignored. The electric analog computers consist of low impedance analog models and excitation-response apparatus. The analog models are regular arrays of resistors, capacitors, transistors, and diodes and are scaled-down versions of the aquifer-stream system. The excitation-response apparatus consists of two power supplies, a waveform generator, a pulse generator, two power amplifiers, and an oscilloscope. Analog model streambed elements were designed with resistors, transistors, and diodes to correctly simulate leakage through the streambed under maximum infiltration conditions. Streambeds must be simulated in mathematical and analog models in such a way that: 1) leakage of water through a streambed is directly proportional to the drawdown beneath the streambed until the water table declines below the streambed, thereafter, induced streambed infiltration remains constant provided the stream stage and temperature remains stationary; & 2) provided the water table remains below the streambed, leakage of water through a streambed is directly proportional the average depth of water in the stream and varies with stream-state changes and changes in the surface-water temperature. The results of the research will provide a better understanding of the role of streams in groundwater recharge.

OWRR Project No.: A-015-Minn

Project Title: Hydrologic and other Aspects of Water Laws in Minnesota

Principal Investigator: W.C. Walton, Graduate School

Project Began: July 1, 1967      Project Completed: June 30, 1969

Cost of Project: \$26,767 federal funds

Man Years of Effort: 2.01

Publications Resulting from Project: Walton, W.C., R.A. Haik, and D.L. Hills. 1968. Codified and Uncodified State Laws and Municipal Ordinances Bearing on Water and Related Land Resources in Minnesota. Water Resources Research Center, Univ. of Minn., Bull. No. 9, 640 p.

Haik, R.A., W.C. Walton, and D.L. Hills. 1969. Aspects of Water Resources Law in Minnesota. Water Resources Research Center. Univ. of Minn. Bull. No. 11, 143 p., 9 ref.

#### Research Results:

In Minnesota, the planning, development, and management of water and related land resources in the past has been largely the responsibility of local units of government such as counties, cities and villages. The confusion and often contrary decisions that result from this provincial approach are reflected in the general legislation applicable to local units of government and in the special legislation adopted at each legislative session to deal with specific local problems. There are several examples of the nullifying effect of existing water laws. Statements concerning mandatory coordination and cooperation of state, local, and federal agencies and other organizations such as commissions and compacts contained in the codified and uncodified state water laws, for the most part, are weak expressions describing piece-meal cooperation, often on a voluntary basis, between agencies and organizations. Responsibility for comprehensive coordination and cooperation within the water and related land resources development and management field is not centralized. There is not a single entity charged specifically with the responsibility of coordinating federal, state-interstate, local, and non-governmental activities pertaining to water and related land resources planning, development and management. The most ambitious attempt by the state legislature to require coordination has been the establishment of the Water Resources Board which was created with the declared power of resolving contradictions in the existing programs when applied in a specific proceeding and with the objective of establishing a forum where conflicting aspects of the public interest can be presented and considered, the inconsistencies resolved, and a controlling state water policy determined. The Water Resources Board has an excellent assignment, but there is no requirement imposed upon agencies to present problems to the Board. Thus, an excellent legislative objective is set forth in the state law, but by reason of the lack of any requirement to submit questions to the Board, there have been few, if any statewide water policies enunciated by the Water Resources Board since its creation in 1955. There is no evidence indicating that Minnesota's water laws have been a serious deterrent to the development of

the state. Furthermore, available information concerning the future (1969-2020) balance between water demands and needs and the availability of water and related land resources suggest that the efficient allocation of water resources between competitive users will not become crucial provided some changes are made in the present water permit system. The Department of Conservation has not developed and published rules, regulations and criteria for evaluating water permit application in accordance with the Administrative Procedure Code of the State although it has had the opportunity to do so since 1945 when the first code relating to promulgation of rules and regulations was established. Consideration should be given to legislative enactments which would require state and local agencies, charged with developing water policy through the issuance or denial or resource use permits, to develop and publish within a specified time rules, regulations, and criteria that form the basis of evaluating and processing a permit application. The general public and private interests should be given the opportunity to react to the merit of the rules, regulations, and criteria before they are adopted in accordance with the Administrative procedure Code of the state. Also, state and local agencies should be required to submit their proposed and existing rules, regulations, and criteria to some state agency for overall review and comment concerning such matters as conflicting aspects of public interest and relation to the whole water policy of the state. The objective would be to ascertain and resolve inconsistencies in rules, regulations, and criteria from a comprehensive viewpoint and enhance coordination of agencies. The water resources policy of the state consists not only of formal declarations and statements enunciated by the legislature, but also of the rules and regulations adopted by state and local agencies consistent with the law, and the actions of state and local agencies. The legislative formal declarations and statements are broad from a comprehensive viewpoint. Considerable latitude is given to state agencies to formulate policy through the adoption of detailed rules and regulations. Little has been done to eliminate conflicts between rules and regulations formulated by special interest state agencies nor to weld together legislative formal declaration and statements and state agency detailed rules and regulations into a unified state policy for water and related land resources development and management. From the standpoint of other states and the federal government, Minnesota's policy is undefined on a detailed comprehensive basis. The present legal classifications of waters, necessitated in part by the meagerness of knowledge concerning the interrelationship of waters in bygone days, is hydrologically unsound and in need of revision in light of present knowledge. Modification of obsolete classifications is a difficult task because of the predilection of the legal profession for precedent and tradition. There is need for courts to: Apply the same rule of law to all groundwater, rather than attempt to distinguish between supposedly different kinds of groundwater which do not exist in nature; and further, apply the same rule of law to surface water, recognizing the widespread interconnection between ground and surface water and the necessity of treating the common supply as a whole where such interconnection exists. The compilation of numerous legislative enactments bearing on water resources, compilation and discussion of the major court decisions in Minnesota concerned with legal water rights, discussion of pertinent aspects of states statutes, discussion of aspects of Federal statutes and Supreme Court decisions, and recommendations concerning ways and means for

improving water law should provide comprehensive background information required for effective future action in the important and increasingly complex field of water resources law in Minnesota.

OWRR Project No.: A-016-Minn

Project Title: Primary Productivity of Selected Minnesota Lakes

Principal Investigator: H.E. Wright, Limnological Research Center

Project Began: July 1, 1967      Project Completed: June 30, 1970

Cost of Project: \$33,580 federal funds

Man Years of Effort: 3.19

Publications Resulting from Project: Megard, R.O. 1968. Algae and Phosphorus in Lake Minnetonka. Limnological Research Center, Univ. of Minn. Interim Rept. No. 4. 26 p., 9 fig., 3 ref.

Megard, R.O. 1969. Algae and Phosphorus in Shagawa Lake, Minnesota. Limnological Research Center, Univ. of Minn. Interim Rept. No. 5. 36 p., 5 fig., 10 tab., 8 ref.

Megard, R.O. 1970. Lake Minnetonka: Nutrients, Nutrient Abatement, and the Photosynthetic System of the Phytoplankton. Limnological Research Center, Univ. of Minn. 210 p., 21 fig., 10 tab., 22 ref.

Research Results:

Chlorophyll analyses and photosynthesis experiments were performed during 1968 in Lake Minnetonka to measure the degree of eutrophication in basins. In terms of algal growth at depths where light is optimal, lower Lake Minnetonka ranks third among 15 lakes that have been studied in Minnesota. Photosynthesis beneath a unit of lake surface, however, is greater in Minnetonka than in the other lakes. It is estimated that the daily production of organic matter could be reduced more than 50% if the phosphorus concentration in surface waters could be reduced from 50 ug/L, which was the typical concentration, to 30 ug/L, which was the lowest concentration that was measured. Depth maps indicate that the basin is virtually the same in 1968 as it was in 1905. Sedimentation rates evidently have not accelerated significantly during the last 50 years and there is no limnological reason why the lake could not be rejuvenated. Population densities of planktonic algal, daily rates of photosynthesis, nutrient concentrations, and other limnological parameters were measured at 11 localities in Lake Minnetonka during 1968-70. Algal productivity is near an upper limit in some basins; the productivity in one basin is similar to that of unpolluted Lake Itasca. Maximum population densities of planktonic algae during summer in the lower lake are 2 or 3 times higher now than 30 years ago. Blue-green algae are now much more numerous than diatoms. Phosphorus alone limits the algae during the summer. Results of studies suggest that the initial management objective for most of the lake should be to prevent concentrations of total phosphorus from exceeding 45 mg/m<sup>3</sup> during mid-summer. The lower lake will improve to conditions prevailing in the summer of 1967

within 3-5 years after the flow of sewage stops and the phosphorus influx is reduced. A mathematical model developed enables lake productivity to be estimated much more efficiently than with other methods.

Photosynthesis in Lakes Shagawa, Clearwater, Trout, Kimball and Minnetonka was measured in 1967 by determining the oxygen produced by algae. The phytoplankton of Shagawa Lake was dominated by a blue-green algae in summer and a diatom in winter. Most algae were concentrated near the surface, in depths above 4 m, both in water and in spring. The average daily rate of photosynthetic carbon assimilation was 42 ugC/ug chlorophyll; this was also the rate at the same temperature in Lake Minnetonka. Average daily gross photosynthesis in Shagawa Lake was 2.02 gC/m<sup>2</sup>/dv. Photosynthesis in 3 other lakes in northeastern Minnesota ranged from 0.38 to 0.78 gC/m<sup>2</sup>/dv, but it was 3.10 gC/m<sup>2</sup>/dv in Lake Minnetonka, which is also enriched with sewage effluent. Experiments concerning different kinds of sewage effluent in algal growth indicated photosynthetic capacity was stimulated 40 % by 5% and 10% secondary sewage effluent but inhibited by 20% secondary effluent.

Lake Minnetonka, an intensively developed lake in the Minneapolis-St. Paul suburbs, has been subjected to severe eutrophication due to man's activities. For several years, lakeshore owners, municipalities discharging treated sewage into the lake, and special purpose districts searched for an optimum rehabilitation management program that would improve the recreational use of the lake. Before OWRR Project No.: A-016-Minn. was started on July 1, 1967, available information concerning the productivity of the lake was not sufficient to permit the prediction of the effects of selected management practices. The lake was studied by the Principal Investigator in cooperation with State agencies, municipalities, special purpose districts and several private engineering firms. It was demonstrated that phosphorus is the nutrient that limits algal growth during the summer, when very dense populations of nitrogen-fixing blue-green algae develop. A model of the photosynthetic system of the phyto-plankton was developed. Computations based on a materials balance indicated that the mean annual phosphorus content of the lake's largest basin should decrease from an existing 13 metric tons to a desirable 4 metric tons within 3 years if the phosphorus influx was reduced by stopping the influx of sewage. Based on the result of the research project, a comprehensive lake watershed management plan was prepared. Sewage effluents will be diverted from the lake within two years. The emphasis of OWRR Project No.: A-026-Minn., which started on July 1, 1971, was to monitor the effect of stopping the flow of sewage into the lakes and thereby measure the effectiveness of the management plan.

OWRR Project No.: A-017-Minn

Project Title: Effects of areal and time distribution of runoff supply on watershed hydrographs

Principal Investigator: C.L. Larson, Department of Agricultural Engineering

Project Began: July 1, 1967

Project Completed: June 30, 1970

Cost of Project: \$18,315 federal funds

Man Years of Effort: 1.88

Publications Resulting from Project: Wei, T.C. and Larson, C.L. 1971. Effects of Areal and Time Distribution of Rainfall on Small Watershed Runoff Hydrographs. Water Resources Research Center, Univ. of Minn. Bull. 30, 118 p., 31 fig., 28 tab., 71 ref.

Research Results:

A mathematical watershed model of 1,456 square miles was developed to route runoff through overland flow and through the channel system. Excess rainfall was used as input data and the flow was routed by the successive numerical solution of the kinematic wave equations to produce outflow hydrographs for elementary (first order) watersheds. These hydrographs were used as input to the channel system where the flow was routed by the successive numerical solution of the dynamic wave equations to yield the outflow hydrograph for the model watershed. Backwater effects were considered at most of the junctions of the model watershed. The model was used to study the effects of time distribution and areal distribution of rainfall, storm movement and watershed shape on the runoff hydrograph. In each study, attempts were made to find a relationship between an appropriate input parameter and a modification (peak flow) coefficient, to be used in adjusting the peak discharge estimated by conventional methods, which normally assume a stationary, constant intensity storm uniformly distributed over the watershed. The results of this study indicate that, in general, the selected factors have significant effects on peak discharge. The results of the research project are being used by the Principal Investigator and other hydrologists throughout the United States to develop new methods for peak streamflow determination for ungaged, small watersheds which will involve consideration of more watershed characteristics and avoid the use of the linearity assumption. The U.S. Soil Conservation Service in Minnesota has expressed great interest in the results of the research; and is revising its planning procedures in light of the new knowledge.

OWRR Project No.: A-018-Minn

Project Title: Methodology for Integrating Water Quality Management with Management of the Total Water Resources in Minnesota

Principal Investigator: C.P. Straub, School of Public Health

Project Began: July 1, 1967

Project Completed: June 30, 1970

Cost of Project: \$30,409 federal funds

Man Years of Effort: 3.55

Publications Resulting from Project: Gibson, U.P., Straub, C.P., and Bond, R.G. 1970. Integrating Water Quality Management into Total Water Resources Management in Minnesota. Water Resources Research Center, Univ. of Minn. Bull. 23. 376 p., 53 fig., 14 tab., 112 ref.

Research Results:

Water resources management is a governmental response to the growing need to maximize the productivity of hydrologic resources. Six characteristics of water resources are contributory factors to the need for governmental involvement in water resources management. Water quality management encompasses data collection, research and analysis, and technical engineering and policy measures. Regulation, effluent charges, and incentive payments should be considered in systems analysis. Water quality management should play the role of the integrator of the various aspects of water resources management. Seven criteria for water management institutions and the roles of different levels of government are proposed. The institutional approaches the four foreign countries and two regions in the United States and water resources management in Minnesota are described. Three alternatives are proposed for the achievement of integrated water resources management in Minnesota. Common to all proposals are increased public representation on the decision-making bodies of State and regional bodies and regional decentralization. Research needs are stressed. The study provides information upon which the reorganization of water resources management in Minnesota may be undertaken. The findings and recommendations of the study were useful to the 1971 State Legislature in its consideration of reorganization of water resources management in the State. The report may also be useful to other States undertaking similar reorganization of water resources management programs.

OWRR Project No.: A-019-Minn

Project Title: Economics of Water Quality Control in the Upper Mississippi River, Minnesota

Principal Investigator: J. J. Waelti, Department of Agricultural and Applied Economics

Project Began: July 1, 1968      Project Completed: June 30, 1971

Cost of Project: \$34,547 federal funds

Man Years of Effort: 3.18

Publications Resulting from Project: Lewis, R.C. 1970. The Marginal Costs of Alternative Levels of Water Quality in the Upper Mississippi River. Water Resources Research Center, Univ. of Minn. Bull. 25. 59 p., 12 fig., 6 tab., 37 ref.

Research Results:

Seven principal organic waste sources including 5 municipal sewage treatment plants, are present along the Mississippi River in the Minneapolis-St. Paul area with severe pollution. The Minnesota Pollution Control Agency and Sewer Service Board, Metropolitan Council are concerned with water quality programs in the area. Under present conditions, the treatment facilities are discharging more BOD into the river than the river can assimilate at the seven consecutive day summer low flow that occurs once in ten years. A mathematical model for combining the DO sag curve resulting from organic waste disposal in the river, with the cost of sewage treatment was devised

to estimate the least cost method of attaining alternative levels of DO. In order to achieve the current river standard of 3 mg/l with least increases in total annual treatment expenditures, percent BOD removed by the Mpls.-St. Paul Sanitary District plant needs to be increased from 48.8% to 87.6%; the BOD removal rate of 90% by So. St. Paul Plant needs to be maintained; and the Newport St. Paul Park and Cottage Grove plants need only primary treatment. With a cost minimizing management plan, the current river standard could be maintained for an additional annual expenditure of 4.8%. The research results have been made available to the Metropolitan Council and the Minnesota Pollution Control Agency.

OWRR Project No.: A-020-Minn.

Project Title: Evaluation of Selected Computer Programs in Hydrology

Principal Investigator: C.E. Bowers, St. Anthony Falls Hydraulic Laboratory

Project Began: July 1, 1968      Project Completed: June 30, 1971

Cost of Project: \$22,858 federal funds

Man Years of effort: 1.89

Publications Resulting from Project: Bowers, C.E., A.F. Pabst, and S.P. Larson. 1971. Computer Program for Statistical Analysis of Annual Flood Data by the Log-Pearson Type III Method. Water Resources Research Center, Univ. of Minn. Bull. 39. 26 p., 16 fig., 4 ref.

Bowers, C.E., A.F. Pabst, and S.P. Larson. 1971. St. Anthony Falls Hydraulic Laboratory. Project Report No. 124. 200 p.

Research Results:

The Federal Water Resources Council has recommended the adoption of the log-Pearson Type III method of establishing flood flow frequencies. The computer program developed in this study was written in Fortran IV language to facilitate log-Pearson Type III method computations. Annual floods are sorted in decreasing magnitude and then logarithms, mean, standard deviation and skewness of the logarithms are computed. The magnitude of the 100, 50, etc., year flood are determined with the aid of tables. The initial computer printout consists of sorted values of the floods; empirical values of recurrence interval and probability, and the logarithms of the floods. Application of the method to selected streams in the United States indicates that difficulties may be encountered when a given set of data contains one or more very low floods or outliers. The log-Pearson Type III distribution appears to have a substantial advantage over the Gumble and log-normal distributions that have been used for flood frequency analysis because it can be used for data having either a plus or a minus skewness. Also, it reduces to the log-normal distribution for zero skewness where the data fit this distribution. However, it will require a data screening procedure and sufficient use to indicate desirable restrictions on skewness values for short records and perhaps for various regions. The knowledge of the availability of computer programs covering a variety of topics in hydrology can lead to improved water resources management. As an example, the availability of flood frequency and water surface profile

computer programs are of paramount importance to a realistic flood plain mapping project. Flow simulation programs may be used to study the effects of alternate methods to reduce flooding losses, or improve water quality.

OWRR Project No.: A-021-Minn

Project Title: Water Resources Administration in Minnesota

Principal Investigator: W. C. Walton, Graduate School

Project Began: July 1, 1969      Project Completed: June 30, 1972

Man Years of Effort: 2.86

Publications Resulting from Project: Walton, W.C. and Hills, D.L. 1971. Water and Related Land Resources State Administration, Legislative Process and Policies in Minnesota, 1970. Water Resources Research Center, Univ. of Minn. Bull. 27, 344 p., 19 fig., 18 tab.

Walton, W.C. and D.L. Hills. 1971. International, Regional, Federal-State, Interstate and Federal Organizations with Water and Related Land Resources Programs in Minnesota, 1971. Water Resources Research Center, Univ. of Minn. Bull. 42. 262 p., 16 fig., 13 tab., 22 ref.

Walton, W.C. and D.L. Hills. 1971. Interest Groups With Water and Related Land Resources. Water Resources Research Center, Univ. of Minn. Bull. 45. 96 p.

Walton, W.C. and D.L. Hills. 1971. Water and Related Land Resources State Administration, Legislative Process and Policies in Minnesota, 1970. Bull. 27. 344 p., 19 fig., 18 tab.

#### Research Results:

In 1970, Minnesota's State government contained at least 46 departments, agencies, boards, commissions, committees, etc. with water and related land resources responsibilities. Expenditures by these organizations increased from \$5.7 million in 1950 to \$31.9 million in 1970. About 86% of expenditures were made by the Department of Conservation. Total State agency staff complements increased from 1,100 in 1960 to 1,400 in 1970. Prime responsibility for water and related land resources programs rested in 3 committees of the Senate and 2 committees in the House. The Governor's and Legislature's control of the State's administrative apparatus is hampered through fragmented organization. A recommended plan of reorganization centers on consolidation of major functions within a Department of Natural Resources. There is need for the Legislature to enunciate a comprehensive environmental policy for the State. There are 8 International, 5 regional, 3 interstate, and 4 Federal-State organizations with programs in the State. Federal responsibilities in water and related land resources planning, development and management in Minnesota are divided among 30 units in 8 executive departments and agencies; 6 independent agencies; 6 units in the executive office of the president; 9 other boards, committees, councils and commissions; and 1 quasi-official agency. In fiscal Year 1970, Federal Outlays for water and related land resources activities in the State totaled about \$75 million or 2.3 percent of total Federal outlays in Minnesota of about \$3.3 billion.

There were about 1,300 Federal employees residing in Minnesota in fiscal year 1970 with assignments pertaining to water and related land resources. In 1971, there were at least 49 Interest groups in Minnesota with major water and related land resources programs, 4 Leagues and Associations with minor water and related land resources programs, at least 80 organizations that tend to have a continuing interest in water and related land resources issues, and at least 150 National organizations concerned with water and related land resources programs which have or could have members in the State. Of the 53 Interest groups (49 Interest groups and 4 Leagues and Associations mentioned above), 40 were conservation-preservation oriented, 8 had the word environmental in their name, and 5 were development and management oriented. Taking into consideration multiple memberships, it is estimated that approximately 25,000 citizens in Minnesota were members of the 53 Interest groups in 1971. Membership in individual Interest groups ranged from 13 to 12,000. Expenditures in 1971 for water and related land resources programs of the 53 Interest groups probably totaled in excess of \$250,000. It is estimated that the number of water and related land resources Interest groups increased from about 16 in 1950 to 25 in 1960 to 33 in 1965 to 53 in 1971.

During past Legislative Sessions in Minnesota there have been numerous Committee hearings concerning water resources laws, administration and policies. In addition, two Governors appointed Committees to study the State's water resources statutes and government, and to make recommendations concerning needed changes. Prior to the start of OWRR Project No.: A-015-Minn. on July 1, 1967 and A-021-Minn. on July 1, 1969, the Legislature's and Governor's Committees were greatly hampered in their efforts because of the lack of comprehensive reports on water resources laws, State administration, Legislative process, and policies. Codified laws, uncodified Legislative enactments, and local laws bearing on water resources in Minnesota were collected, compiled and published. An analysis and interpretation was made of State and Federal statutes and court decisions and recommendations were made concerning ways and means for improving water resources laws. The Principal Investigator inventoried and appraised State water resources administration, Legislative process and policies as of December 1970. Recommendations were made concerning reorganization of State agencies and needed State policies. The information generated by the research has filled large gaps in the understanding of Minnesota's water resources laws and government and the need to improve laws. In 1970 and 1972, the Principal Investigator served as an adviser to Committees of the Minnesota Senate and House of Representatives and using the results of the research assisted the Committees in preparing reports on needed water resources legislation. The Citizens League, League of Minnesota Municipalities and numerous voluntary environmental organizations have sought the advice of the Principal Investigator in matters pertaining to water resources laws and government. Several recommendations resulting from the research were accepted by legislators and incorporated in bills introduced during the 1973 session of the Minnesota Legislature.

OWRR Project No.: A-022-Minn

Project Title: Zooplankton Biomass and Incipient Eutrophication in Lake Superior.

Principal Investigator: T.A. Olson, School of Public Health

Project Began: July 1, 1969      Project Completed: June 30, 1972

Cost of Project: \$25,545 federal funds

Man Years of Effort: 1.79

Publications Resulting from Project: Johnson, J.M., Odlaug, T.O., Olson, T.A. and Ruschmeyer, O.R. 1970. The Potential Productivity of Fresh Water Environments as Determined by an Algal Bioassay Technique. Water Resources Research Center, Univ. of Minn. Bull. 20. 79 p., 36 fig., 5 tab., 183 ref.

Swain, W.R., R.W. Magnusen, J.D. Johnson, T.A. Olson, & T.O. Odlaug. 1970. Vertical Migration of Zooplankton. Mimeographed Report. 57 p., 18 fig., 1 tab., 26 ref.

Conway, J.B., F.R. Schiebe, T.A. Olson and T.O. Odlaug. 1971. A Practical Evaluation of the Clarke-Bumpus Plankton Sampler and Suggestions for its Use. Univ. of Minn., School of Public Health, Limresta, Research Report No. 1. 28 p., 5 fig., 4 tab., 17 ref.

Adress, M., Nelson, R., Schlottman, L. and Parkos, W. 1971. A Study of the Potential of Periphyton Organisms as components of Lake Superior Plankton. Limresta, Research Report, No. 2. School of Public Health, Univ. of Minn.

Conway, J.B., O.R. Ruschmeyer, T.A. Olson and T.O. Odlaug. 1973. The Distribution, Composition and Biomass of the Crustacean Zooplankton Population in Western Lake Superior. Water Resources Research Center, Univ. of Minn. Bull. 63. 157 p., 44 fig., 26 tab., 54 ref.

#### Research Results:

Although data were collected for two years, 1970 and 1971, the major portion of this research was carried out the second year. This research took place in western Lake Superior and most of the data were collected at two stations, Larsmont and Stony Point, which were twenty miles northeast of Duluth. Each of these stations included two sites, one a half mile and the second two miles from shore. The other area where samples were collected was at the Little Marais and Sugar Loaf Cove stations, some 70 miles north of Duluth. The major purposes of this research were to study the productivity and the vertical, seasonal and horizontal distribution of the crustacean zooplankton population in western Lake Superior. A limited study of the biology of the copepod, Limnocalanus macrurus, was also conducted. Productivity at the Larsmont and Stony Point area averaged 323 crustaceans per 100 liters of water and 60 grams per square meter (based on a fifty meter water column). Productivity at the Little Marais and Sugar Loaf Cove area averaged 95 crustaceans per 100 liters and 37 grams per square meter. In general, productivity decreased as the depth increased from zero to 50 meters. If a thermocline was present, then both the total number of crustaceans and the biomass became relatively scarce below twenty meters. Cladocerans were most frequently found in the upper ten meters of the water column, whereas copepods were present at every level. Adult copepods were usually heavier than adult cladocerans and it was not unusual to find the mean weight of an organism at 50 meters ten or more times that of one at five meters. Productivity at the Larsmont and Stony Point area was bimodal during the sampling season; the first peak occurred in July and contained primarily copepods and the second, which was the seasonal maximum, occurred in September and contained both copepods and cladocerans. Surface water temperatures were also bimodal during the sampling season; the peak recorded

in July was thirteen degrees centigrade and sixteen degrees was reached in September. The cladoceran, Bosmina, became abundant after the water temperature reached five degrees in July. Another cladoceran, Daphnia, replaced Bosmina in September when the water temperature was above eleven degrees. Ephippia, the overwintering stage of Daphnia first appeared in late August. Three copepods, Diaptomus, Limnocalanus and Cyclops were present during most of the sampling season. Limnocalanus was present at all depths from June to early August, but was most numerous at ten meters. When the water temperature warmed above twelve degrees, the population shifted downward and was usually below the thermocline during the daylight hours. At this time, they were most abundant at 40 meters. The copepod, Epischura, was numerous in the upper layers after the water warmed above eleven degrees. Productivity differences were found between the various sites and stations. These differences point to the lack of homogeneity in the horizontal distribution of the crustacean zooplankton population and support the phenomenon of "zooplankton patchiness". Productivity levels at the Little Marais and Sugar Loaf Cove area were from one-third to two-thirds of those at Larsmont and Stony Point. The Larsmont station was slightly more productive than Stony Point. The Stony Point inshore site was slightly more productive than the offshore site. The period of maximum productivity occurred at the Larsmont inshore site and at both Stony Point sites in September. Maximum productivity was recorded at the Larsmont offshore site in July. A phytoplankton bloom was observed at the Stony Point station on July 20, 1971, but was not seen on the same day at the Larsmont station. Limnocalanus macrurus contributed the greatest percentage of the crustacean biomass (often more than 90 percent) at depths of 30, 40 and 50 meters in western Lake Superior. The male to female ratio established was 1:2. The mean lengths of mature males and females were 2.09 and 2.16 millimeters, respectively. The length-weight correlation was: Dry weight (mg/100) = 3.31 length (mm) - 2.95. Two cladocerans, new to Lake Superior, were identified. They were: Alona guttata Sars and Holopedium gibberum Zaddach. A base line has been established for zooplankton in Lake Superior which in future studies of this kind can be used as a reference point.

OWRR Project No.: A-023-Minn

Project Title: Predicting Peak Flow of Small Watersheds by Use of Channel Characteristics

Principal Investigator: C.L. Larson, Department of Agricultural Engineering

Project Began: July 1, 1970      Project Completed: June 30, 1972

Cost of Project: \$16,005 federal funds

Man Years of Effort: 1.53

Publications Resulting from Project: Rice, C.E. and Curtis L. Larson. 1972. Methods for Routing Hydrographs Through Open Channels. Water Resources Research Center, Univ. of Minn. Bull. 51. 121 p., 21 tab., 44 fig., 36 ref.

Larson, C.L., R.F. Gronwald and A.G. Pennell. 1972. Predicting Peak Flow of Small Watersheds by Use of Channel Characteristics. Water Resources Research Center, Univ. of Minn. Bull. 52. 100 p., 19 fig., 5 tab., 19 ref.

#### Research Results:

In this study a simulation model of an open channel system was used to evaluate some existing flood routing methods, observe the effect of different physical variables on flood wave movement, and to develop a simple routing method. The physical geometric, and hydraulic components of the model were patterned after real-life conditions common to southeastern Minnesota. The dynamic equations of unsteady flow were used to route flood hydrographs through the channel system and outflow hydrographs were generated to achieve the objectives listed above. The method of characteristics with a specified time interval was used to solve the unsteady flow equations. Two simple storage routing methods, the Method A and the Method B were developed and evaluated. Other simple routing methods evaluated include: the Miskingum, the Puls, and the Kinematic Wave. Complete methods evaluated were the Direct and the Explicit. The methods were the Direct and the Explicit. The methods were evaluated by comparing the results by the methods with the generated results. Comparisons were made on the accuracy of the predicted results, the complexity of the method, and the computation time required for a solution. In previous studies, a method was developed for predicting the effects of channel characteristics, including watershed size and shape on peak flow from small watersheds. The method was incomplete, however, since it lacked a working method of estimating the time parameter for ungaged watersheds. Therefore, the first objective of this study was to satisfy this need. The second objective was to test the over-all method as a means of predicting peak flow for small ungaged watersheds, given the runoff volume. The overall method begins with a hydrologic analysis of numerous rainfall-runoff events observed at selected experimental watersheds. This yields certain hydrologic parameters which can be evaluated only for gaged watersheds. Then, the physical characteristics of these watersheds, primarily the channel characteristics, are utilized to evaluate the same parameters by use of an hydraulic or flow approach. If this can be accomplished successfully, the same procedure can be applied to ungaged watersheds. The following conclusions can be made based on the results of the study: A new time parameter, time to 50% of equilibrium,  $T_{50}$ , was proposed. It can be evaluated hydrologically, i.e., from observed hydrographs in many but not all cases this is essential if it is to be used in peak flow predictions for other, ungaged watersheds. The combination of peak flow equation, the time parameter,  $T_{50}$ , and the relationship of  $C_p$ , the peak flow coefficient, to the ratio  $D/T_{50}$ , where D is the duration of rainfall excess, appears to provide a satisfactory but not highly accurate procedure for estimating peak runoff, given the volume of rainfall excess and its approximate time distribution.

It is expected that the results will partially fill the serious deficiency in methods for predicting peak flows for ungaged watersheds in the range from about 1 to 50 sp. mi., i.e., for hydrologic design of the numerous highway culverts, small bridges, erosion control structures and channel modifications installed each year. The results of the current study are only partial (as planned) since it deals only with the channel or routing phase of runoff. Predicting the input to the channel system (the runoff volume) is equally important and difficult. The results of the study on channel routing methods appear to be of immediate use to engineers involved

in design of watershed flood control projects and similar activities. The comparison of various routing methods will be helpful in choosing a method for a given problem situation by providing information on relative accuracy and cost. The new method of storage routing without fitted coefficients appears to be a significant improvement of existing methods for ungaged watersheds and, as such, is expected to be of considerable benefit.

OWRR Project No.: A-024-Minn

Project Title: Mathematical Simulation of a Large Watershed Using the Systems Approach to Quantity and Quality Analysis

Principal Investigators: C.C.S. Song and E. Bowers, St. Anthony Falls Hydraulic Laboratory, Department of Civil Engineering and Hydraulics

Project Began: July 1, 1970      Project Completed: June 30, 1973

Cost of Project: \$33,051 federal funds

Man Years of Effort: 2.77

Publications Resulting from Project: Song, C.S., A.F. Pabst, and C.E. Bowers. 1973. Simulation of the Quantity and Quality of Flow in a River Basin. St. Anthony Falls Hydraulic Laboratory, Univ. of Minn. Project Report No. 145. 34 p., 3 tab., 25 fig., 19 ref.

#### Research Results:

The objective of this study was the simulation of the quantity and quality of flow in a fairly large basin on a continuous synthesis basis. To accomplish this objective, an existing mathematical model was modified slightly and fitted to the 16,200 square mile Minnesota River Basin. The model used was the SSARR (Streamflow Synthesis and Reservoir Regulation) model developed by the Corps of Engineers and the National Weather Service for the Columbia Basin. A stochastic water quality model was developed and fitted to portions of the Minnesota Basin for use with the quantity model. A deterministic water quality model was written for the main stem of the Minnesota River. Preliminary results using water temperature data show good agreement with measured data. The mathematical model can be used as a tool for forecasting the quantity and quality of flow at selected locations, for studying the systems response to future water resources projects, and for systems analysis to achieve optimum management.

OWRR Project No.: A-025-Minn

Project Title: Alleviation of Lake Pollution by Utilization of Aquatic Plants for Nutritional, Medicinal or Industrial Purposes.

Principal Investigator: E. John Staba, Department of Pharmacognosy, College of Pharmacy

Project Began: July 1, 1970      Project Completed: June 30, 1973

Cost of Project: \$32,860 federal funds

Man Years of Effort: 2.73

Publications Resulting from Project: Su, K. and E.J. Staba. 1972. Aquatic Plants from Minnesota. I-Chemical Survey. Water Resources Research Center, Univ. of Minn. Bull. 46.

Su, K. and E.J. Staba. 1972. Aquatic Plants from Minnesota. II-Toxicity, Anti-Neoplastic, and Coagulant Effects. Water Resources Research Center, Univ. of Minn. Bull. 47.

Su, K., E.J. Staba, and Y. Abul-Hajj. 1972. Aquatic Plants from Minnesota. III-Antimicrobial Effects. Water Resources Research Center, Univ. of Minn. Bull. 48.

Lin, J., E.J. Staba, R.D. Goodrich and J.C. Meiske. 1973. Aquatic Plants from Minnesota, IV-Nutrient Composition. Water Resources Research Center, Univ. of Minn. Bull. 56.

Su, K.L., E.J. Staba and Y. Abul-Hajj. 1973. Preliminary Chemical Studies of Aquatic Plants from Minnesota. Lloydia, Vol. 36, No. 1.

Su, K.L., Y. Abul-Hajj, and E.J. Staba. 1973. Antimicrobial Effects of Aquatic Plants from Minnesota. Lloydia, Vol. 36, No. 1.

Su, K.L., and E.J. Staba. 1973. Toxicity, Anti-Neoplastic, and Coagulation Effects of Aquatic Plants from Minnesota. Lloydia, Vol. 36, No. 1.

#### Research Results:

The aquatic plants in Minnesota have not been surveyed medicinally for useful chemical compounds. A study was conducted with a reasonable anticipation of finding compounds such as alkaloids, flavonoids, tannins, saponins, steroids and lipids which might be useful in medicine. Examination of chemical constituents was accomplished on the following plants collected from various lakes in Minnesota: Anacharis canadensis, Calla Polustris, Carex lacustris, Ceratophyllum demersum, Chara vulgaris, Eleocharis smallii, Lemna minor, Myriophyllum exalbescens, Nuphar variegatum, Nymphaea tuberosa, Potamogeton amplifolius, P. natans, P. pectinatus, P. richardsonu, P. zosteriformis, Sagittaria cuneata, S. latifolia, Sparganium eurycarpum, S. fluctuans, Typha angustifolia, Vallisneria americana, and Zizania aquatica. Thin-layer chromatographic detection studies indicated original extracts did not appear to contain alkaloids. Several plant species demonstrated Dragendorff positive spots. Flavonols were most widely distributed in the plant extracts studies. Tannins, especially the condensed type, were widely distributed in the plants screened. Five species of plants are saponin positive. Beta-sitosterol was tentatively identified as being present in 8 species. The lipid contents of 3 species may be considered for their nutritional value.

Toxicity, antineoplastic, coagulant and anticoagulant effects of the 22 Minnesotan aquatic plants were evaluated in terms of pharmacological properties. Toxicity of skellysolve F, chloroform, 80% ethanol and water extracts of these aquatic plants were evaluated in a number of animal experiments in Swiss Webster mice. Antineoplastic experiments involved amelanoma tumor cells. In vivo prothrombin time (PT) and partial thromboplastin time (PTT) were assayed in anticoagulation experiments. The

toxicity of the aquatic plants in general was found to be relatively low. The LD<sub>50</sub> for the most toxic one, i.e., N. tuberosa (stem), in mice was 3 gm of dry plant material/kg (ca. 25.4 gm of wet plant material /kg). Only Nuphar variegatum indicated an anticancer possibility, the remaining aquatic plants had no significant inhibition activity at the doses selected. Normal partial thromboplastin time for mice was 51 seconds and only the prolongation of PTT (longer than 61 seconds) was observed in 50% of the aquatic plants tested. Among these plants, the most significant increase of PTT (more than 20 minutes) was observed in Carex lacustris, Myriophyllum exalbescens, Nuphar variegatum and Nymphaea tuberosa.

The antimicrobial activity of the 22 Minnesotan aquatic plants was investigated. Furthermore, the chemical constituents responsible for the significant antimicrobial effect were isolated and identified. The skellysolve F, chloroform, 80% ethanol and fresh water extracts of plant species were tested for antimicrobial activity employing the qualitative filter paper disc diffusion method and reference antibiotic discs. Ethanol (80%) extracts of Myriophyllum exalbescens (activity ratio of 0.34 as compared to the 30 mcg chloramphenicol discs), Nymphaea tuberosa (leaf: 0.40, stem: 0.38) and Nuphar variegatum collected in Lake Minnetonka (leaf: 0.43, stem: 0.45) were moderately active against S. Aureus. Ethanol (80%) extracts of Carex lacustris (activity ratio of 0.34 as compared to the 10 mcg streptomycin discs), Nymphaea tuberosa (leaf: 1.01, stem: 1.10) and Nuphar variegatum collected in Lake Minnetonka (leaf: 0.73, stem: 0.58) were active against M. smegmatis. All extracts were relatively inactive against E. coli except the water extract of Potamogeton natans where a low activity ratio of 0.10 as compared to the 30 mcg chloramphenicol discs was indicated. Skellysolve F stem extracts of Nuphar variegatum collected in the Pine Lake and Sparganium fluctuans showed a rather distinct action against C. albicans, the activity ratio as compared to the 100 units mycostatin discs were 2.06 and 1.08 respectively. Regarding antifungal activity, ethanol (80%) extracts of Carex lacustris (activity ratio of 1.08 as compared to 5% aq. phenol standard), Nymphaea tuberosa (stem: 0.72) and skellysolve F extract of Potamogeton zosteriformis (0.60) were active against Alternaria sp., 80% ethanol stem extracts of Nymphaea tuberosa and Nuphar variegatum were active against F. roseum with the activity ratios of 0.41 and 0.48, respectively, as compared to the 5% aqueous phenol standard. In general, the plant pathogenic fungi are more resistant than animal pathogenic organisms toward the actions of aquatic plant extract. Samples of the 22 freshwater aquatic plants were analyzed to determine their potential feeding value for ruminants. Proximate analyses (mean-SD), on a dry matter basis were: crude protein, 12.7<sup>±</sup>4.4%; ether extract, 1.46<sup>±</sup>0.98%; crude fiber, 19.2<sup>±</sup>6.4%; ash, 2.05<sup>±</sup>1.24%; and NFE 64.6<sup>±</sup>6.5%. NDF, ADF and ADL contents averaged 41.6<sup>±</sup>13.4%; 32.0<sup>±</sup>9.6% and 6.35<sup>±</sup>2.76%, respectively. Mineral contents (mean-SD) of the 22 aquatic plants were: P, 0.25<sup>±</sup>0.19%; Ca, 1.83<sup>±</sup>1.68%; K, 1.54<sup>±</sup>92%; Na, 0.30<sup>±</sup>0.25%; mg, 0.31<sup>±</sup>0.16%; Fe 924<sup>±</sup>730 ppm; Zn, 80.6<sup>±</sup>96.6 ppm; Cu, 13.8<sup>±</sup>34.0 ppm, Mo, 19.7<sup>±</sup>9.7 ppm and Mn, 269<sup>±</sup>152 ppm. Van Soest's estimated apparent digestibility averaged 63.0<sup>±</sup>8.3%.

The objective of the research was to find a nutritional, medicinal or industrial use for the unwanted aquatic plants in lake shoreline areas. Some aquatic plants contain industrially useful gums, mucilages, or new useful antimicrobial, anticoagulant, or antineoplastic therapeutic principles. The results of the research could provide an economic incentive for aquatic plant collection and control. The successful completion of the project will significantly assist the State and Nation in partially solving their lake pollution problems.

Projects Underway:

OWRR Project No.: A-026-Minn.

Project Title: Phytoplankton Nutrition and Photosynthesis in Eutrophic Lakes

Principal Investigator: R. O. Megard, Limnological Research Center

Project Began: July 1, 1971      Scheduled Completion: June 30, 1974

Anticipated Cost of Project: \$37,435 federal funds

Anticipated Man Years of Effort: 3.43

Expected Research Results:

The objective of this project is to analyze the nutritional requirements and the photosynthetic system of the phytoplankton in four Minnesota lakes that receive nutrients from different sources and produce dense populations of nuisance algae. Algal nutrition, photosynthesis, and population densities will be studied before and after the nutrient influx to one lake is reduced, whereas nutrient-abatement programs for the others are either being discussed or they are in various stages of implementation. Analyses of algal nutrition, photosynthesis, and population densities that were begun during a regional limnological survey will be continued, but the emphasis will be somewhat different at each lake. The research will monitor the effects of stopping the flow of sewage on the productivity of Lake Minnetonka. Advanced sewage treatment as a lake-management procedure and its effectiveness compared to sewage diversion will be evaluated in Shagawa Lake studies. The effectiveness of diverting sewage effluent from Sallie Lake and using the effluent for spray irrigation will be appraised. The results of the research project should assist the State in solving its lake pollution problems.

OWRR Project No.: A-027-Minn.

Project Title: Study of Criteria and Models Establishing Optimum Level of Hydrogeologic Information for Groundwater Basin Management

Principal Investigator: H. O. Pfannkuch, Department of Geology and Geophysics

Project Began: July 1, 1971      Scheduled Completion: June 30, 1974

Anticipated Cost of Project: \$30,672 federal funds

Anticipated Man Years of Effort: 2.87

Expected Research Results:

In the management of groundwater systems geohydrological information concerning aquifer parameters, geological boundaries, and boundary conditions become of utmost importance in the decision-making process. This research project attempts to study the following questions: What data exactly are needed and are any of these critical to management problems? How much information and to what degree of accuracy while obtaining the data affect interdependent parameters in a multivariate field? Can any relationship between the cost of additional information and increase of overall benefits be established? The research procedure will comprise the conceptualization of a simple management model and its mathematical and analog computer manipulation. Model studies will be correlated with ongoing field studies. The research will determine whether optimum levels of investigation can be set for such groundwater reservoirs as the Twin Cities Artesian basin. The results of the project will assist State, Federal and local agencies in designing future investigation programs.

OWRR Project No.: A-028-Minn.

Project Title: Developing a Water Resources Research Plan for Minnesota

Principal Investigator: William C. Walton, Graduate School

Project Began: July 1, 1972      Scheduled Completion: June 30, 1974

Anticipated Cost of Project: \$31,780 federal funds

Anticipated Man Years of Effort: 2.12

Expected Research Results:

The objective of this project is to develop a long-range comprehensive plan for water resources research in Minnesota. Research programs and projects which will assist in solving existing and projected water resources problems will be identified. Guidelines for improving the coordination of research efforts throughout the State will be formulated. Research costs and manpower needs will be estimated and funding opportunities will be reviewed. The capabilities of existing water resources researchers in Minnesota will be evaluated and needed future capabilities will be projected. The results of the research should assist the State in increasing the efficiency and relevance of water resources research efforts, improving the timely dissemination of research results, and scheduling expansions in research capabilities in advance of demands. Information concerning future research needs, manpower requirements, and costs should assist the State Legislature in formulating legislation concerning water resources research funding. The results of the research should assist the State in administering research funds associated with the Federal Water Resources Research Act of 1965 and other Federal legislation.

OWRR Project No.: A-029-Minn

Project Title: Water Quality Status and Trends in Minnesota - Indices for Water Supply and Groundwater Pollution

Principal Investigator: Conrad P. Straub, School of Public Health

Project Began: July 1, 1973      Scheduled Completion: June 30, 1976

Anticipated Cost of Project: \$40,500 federal funds

Anticipated Man Years of Effort: 3.21

Expected Research Results:

The objectives of this research project relate to: identification of the number and kinds of water supply treatment facilities in Minnesota; supply treatment facilities in Minnesota; the health aspects of water supplies as indicated by chemical analyses of constituents known to be health-related, such as nitrates, sodium, and fluorides, and those indirectly related to health such as the physical or aesthetic characteristics considered with taste, odor, and color; the adequacy of water treatment in Minnesota vis-a-vis the criteria given in the U.S. Public Health Service Standards, Environmental Protection Agency and the goals proposed as a matter of policy on water quality to natural sources of groundwater contamination or as a result of use of the groundwater resource for disposal of waste products; and the development of indices for evaluation of statewide water supply quality status and trends.

OWRR Project No.: A-030-Minn

Project Title: Analysis of Organic Carbon as a Pollution Index

Principal Investigators: Walter Maier and Lawrence Conroy, Department of Civil and Mineral Engineering and Department of Chemistry

Project Began: July 1, 1973      Scheduled Completion: June 30, 1976

Anticipated Cost of Project: \$41,770 federal funds

Anticipated Man Years of Effort: 3.33

Expected Research Results:

The objectives of this proposed research project are to establish organic-carbon concentration levels and define seasonal variations in the major bodies of water in Minnesota and to determine the composition of organic materials in terms of specific constituents and classes of compounds. If the characteristics of the organic can be defined then the best means for removal or prevention can be recommended, and a basis for passing judgement on the acceptance of waters from a public health standpoint can be provided. The results of the research could assist the Minnesota Pollution Agency in ensuring the safety of drinking water in the State. A Beckman Carbonaceous Analyzer, gas chromatography and/or mass spectrometry, and standard functional-group tests of organic chemistry will be employed in the research.

Authorized Projects:

OWRR Project No.: A-031-Minn

Principal Investigator: William C. Walton, Graduate School

Project Title: Developing a Statewide Water Information System for Minnesota

Project Began: July 1, 1974      Scheduled Completion: June 30, 1977

Anticipated Cost of Project: \$46,800 federal funds

Anticipated Man Years of Effort: 2.19

Expected Research Results:

One of the major Acts of the 1973 Minnesota Legislature was the amendment of Minnesota Statutes 1971, Section 105.37 by the announcement of a State policy to establish a statewide water information system. The specific project objective is to assist State agencies in developing that system by conducting supportive research concerning data collection and handling. Research will be conducted to facilitate the development and operation of a statewide water information network and statewide water information exchange and to maintain a catalog of information on water data. Institutional arrangements will be devised to develop and operate a statewide water information system.

OWRR Project No.: A-032-Minn

Principal Investigators: R.E. Rickson, G.A. Donohue, and P.J. Tichenor, Department of Sociology, School of Journalism

Project Title: Water Quality Status and Trends in Minnesota - Social Dimensions

Project Began: July 1, 1974      Scheduled Completion: June 30, 1977

Anticipated Cost of Project: \$41,200 federal funds

Anticipated Man Years of Effort: 2.94

Expected Research Results:

The objective of the proposed research project is to measure the level of public knowledge about water quality by means of a standardized water quality scale. Also, the preferences citizens have for action and how levels of general and specific knowledge are related to choice of action alternatives will be measured. Citizen judgments will be compared with those of scientists and policy-makers involved with the development of water resource quality. Another objective is to better understand how water quality standards are set and the relationship between the values, knowledge, and preferences of citizens, scientists, and leaders in policy-formation. Indices for evaluating the status and trends of water quality are urgently needed by water resources planners. There are essentially two ways to approach the issue. One is to measure the technical aspects of water quality and the other is to study its social dimensions. The focus of the research project is the latter.

OWRR Project No.: A-033-Minn

Principal Investigators: Arnett C. Mace, Jr., Merle P. Meyer and Arthur P. O'Hayre, College of Forestry, University of Minnesota

Project Title: Assessment of Water Quality Status and Trends in Minnesota by Remote Sensing Techniques

Project Began: July 1, 1974      Scheduled Completion: June 30, 1977

Anticipated Cost of Project: \$40,000 federal funds

Anticipated Man Years of Effort: 2.66

Expected Research Results:

The objective of this research project proposal is to examine the capabilities of using remote sensing techniques to rapidly and economically assess water quality status and trends of lake systems in Minnesota. Specifically, the study will focus on the use of remote sensing techniques for evaluating the following water quality parameters: occurrence and population of phytoplankton and higher order aquatic vegetation to evaluate levels and changes in productivity and nutrient and chemical composition of the water systems; concentration and distribution of suspended solids and lake color to relate to ecological changes; and mean lake depth for determination of qualitative loading rates for nitrogen and phosphorus to ascertain probable eutrophication. This research will provide additional information related to the capability of remote sensing technology to monitor water quality parameters and the accuracy of such systems. In addition, information may be obtained which will permit qualitative estimates of the potential loading rates of nitrogen and phosphorus for lake systems. Operational procedures will be addressed. Information obtained will be used by Federal, State, and local pollution control agencies responsible for standard promulgation and enforcement of water quality regulations. It will provide information on operational procedures for establishment of monitoring systems for these agencies.

MATCHING GRANT PROGRAM

Completed Projects

OWRR Project No.: B-001-Minn

Project Title: Diatoms and Zooplankton in Minnesota Lakes

Principal Investigator: H.E. Wright, Jr., Limnological Research Center

Project Began: October 1, 1965      Project Completed: September 30, 1967

Cost of Project: \$16,846 federal funds; \$28,272 non-federal funds

Man Years of Effort: 5.03

Publication Resulting from Project:

Bright, R.C. 1968. Surface-Water Chemistry of Some Minnesota Lakes, with Preliminary Notes on Diatoms. Limnological Research Center, Univ. of Minn. Interim Rept. No. 3. 59 p., 53 fig., 41 ref.

Research Results:

A comprehensive field study of solutes and diatom ecology in 42 least polluted lakes of Minnesota and adjacent parts of South Dakota was made. There is a general increase in salinity and in the concentrations of sodium, potassium, calcium, magnesium, sulfate, bicarbonate, and silica from northeast to southwest in Minnesota. During the last 13,500 to 11,000 years more solutes have been concentrated by the influence of climate in lakes in the southwest than in lakes to the northeast. With some exceptions, solutes in lakes closely reflect the regional differences of bedrock and surficial materials. The most striking exception is in regions where limestone and dolomite are abundant or where the surficial drift is quite calcareous. The lakes here are not necessarily richer in calcium and bicarbonate and do not have higher equivalent proportions of those two ions than the lakes in areas with less abundant calcareous material. One obvious factor that explains these anomalies is the ionic composition, of inflowing groundwater, which may or may not reflect the composition, by ion exchange, of the material through which it flows. There is more manganese, copper, and zinc available to lakes in areas of podzols and podzolic soils than to lakes in areas of other soils. Lakes in the coniferous forest are chemically distinct from those in deciduous forests or prairies. About 350 different diatom species have been found living in lakes that range from very low to extremely high salinity and that range in pH from <6 to <9. Tabellaria and Asterionella are the dominant planktonic forms in the northeastern lakes of low salinity and alkalinity and low pH. Stephanodiscus astraca, Fragillaria, and Melosina are the most common in waters with intermediate salinity. In the more nutrient-rich lakes of the southwestern part, Fragillaria, Synedra, and Melosira are the most abundant planktonic types. Knowledge of the regional distribution of solutes and diatom ecology in lakes will be useful in isolating causes of pollution.

OWRR Project No.: B-002-Minn

Project Title: Effect of Natural Sealing of Potholes upon Water Movement and Groundwater Resources

Principal Investigator: P.W. Manson, Department of Agricultural Engineering

Project Began: July 1, 1965      Project Completed: June 30, 1968

Cost of Project: \$17,000 federal funds; \$48,050 non-federal funds

Man Years of Effort: 4.62

Publications Resulting from Project:

Pothole Drainage and Deep Groundwater Supplies. 1964. Minn. Sci. Transactions of the ASAE.  
Effect of Pothole Drainage on Deep Groundwater Supplies. 1967. Transactions of the ASAE.

Continued Studies relative to the Hydrology of Ponds and Small Lakes. 1970. Agricultural Experiment Station. Univ. of Minn.

Research Results:

Data on the following four potholes were collected, processed and analyzed to study the hydrology of potholes and specifically the relationship between the pothole water and the recharge of deep groundwater reservoirs: 1) Booster Lake, Isanti quadrangle, in Isanti County, Minnesota. 2) Pitcher Lake, Big Marine quadrangle, in Washington County, Minnesota. 4) Mud Lake, Gaylor quadrangle, in Sibley County, Minnesota. Continuous records were obtained on rainfall, wind, humidity, temperature (air, water, ground), radiation, soil moisture, groundwater elevations, and evaporation. Water-balance calculations indicate a seepage loss from the potholes into the ground of about 0.002 to 0.004 ft. per day. This water movement from a pothole into the adjacent soil does not seem significant or important to the possible recharge of deep groundwater supplies. When the small surface area of potholes is considered, then the small seepage water movements become even less significant in relation to deep groundwater reservoirs. The results of the research will assist federal and state agencies in appraising recharge to groundwater reservoirs.

OWRR Project No.: B-003-Minn

Project Title: Storage and Movement of Water in Soils as Related to Spatial and Time Changes in the Clay-quartz Matrix

Principal Investigator: G.R. Blake, Department of Soil Science

Project Began: January 1, 1966      Project Completed: February 28, 1969

Cost of Project: \$20,990 federal funds, \$26,802 non-federal funds

Man Years of Effort: 3.84

Publications Resulting from Project:

Blake, G.R. and R.D. Gilman, 1969. Thixotropic Aging of Synthetic Soil Aggregates. Soil Science Proceedings.

Chye-Sheng Hwang. 1970. Role of quartz in clay-quartz bonding in soil aggregates. M.S. Thesis, Department of Soil Science, University of Minnesota.

Research Results:

Soils consist of particles ranging from perhaps 0.1 micron to 2 mm diameter (Gravelly soils are an exception). These particles of varying sizes are grouped into domains called aggregates that impart porosity important in storage and movement of water within the soil matrix. The stability of aggregates and thus of the whole matrix is an important consideration for infiltration, runoff, and hence also erodability. Agricultural practices that maintain stable structure are practiced meticulously by careful farmers. Nevertheless, stability is a dynamic property that changes with time because constructive and destructive forces are constantly in process. In this project two aspects of aggregate stability were studied: a) effects of time or reestablishment of interparticle bonding between soil particles pulverized by shearing and formed into synthetic aggregates, and b) effect on aggregate stability of quartz in

the matrix of synthetic aggregates. Increase in relative stability of artificially prepared aggregates held at constant water content followed a pattern analogous to a thixotropic sol-gel transformation and strength aging of packed soil. Aggregates were not perceptibly stable to wet sieving at time of formation. Matrix stability of aggregates increased at a rate dependent on water content at which aggregates were stored, on soil type and on storage temp. High relative stabilities were commonly attained in 24-48 hours at intermediate water contents and at 25°C. Extent of slaking resistance was dependent on aging from time of aggregate formation rather than from time of wetting pulverized soil in preparation for pressing into aggregates. The aging phenomenon was independent of organic matter content and of a viable microflora. Data are compatible with the explanation that orientation of water molecules and associated cation equilibrium, and spontaneous shifting of clay particles to positions of lowered potential energy account for the build-up during aging. Silica is found in all soils in varying quantity, but usually in amounts greater than 20% by weight. Sodium silicate is known to be a powerful soil stabilizer even in small quantity. There are indications that on the silica surface there exists a readily soluble monolayer of silicic acid that could be a strong bonding agent in soil aggregates. The extent of this cementing effect was measured on synthetic aggregates made from soil and silica particles. Variables included the quantity, particle size and shape of added silica. Relative stability of synthetic aggregates to which silica was added decreased as the amount of silica increased. The larger the silica particles the greater the decrease. The relationship between these was found to be:  $Y=0.49 - 0.009X_2$ . Where Y is relative stability,  $X_1$  is the size of the added quartz and  $X_2$  is percent by weight of added quartz. It is believed that possible long term effects could enter if systems were maintained for periods of perhaps a year or longer but these were not measured. Particle shape of silica had little effect on stability in like amounts and sizes.

OWRR Project No.: B-007-Minn

Project Title: Study of Factors Affecting the Channel Phase of Runoff from Small Watersheds by Mathematical Modeling.

Principal Investigator: C.L. Larson, Department of Agricultural Engineering

Project Began: January 1, 1966      Project Completed: June 30, 1969

Cost of Project: \$14,244 federal funds; \$34,216 non-federal funds

Man-Years of Effort: 3.09

Publications Resulting from Project:

Machmeier, R.E. and C.L. Larson. 1968. Runoff Hydrographs for a Mathematical Watershed Model, Journal of Hydr. Div., Am. Soc. of Civil Engrs., Vol. 94, No. HY6, p. 1453-747, 7 fig., 5 tables.

Wei, T.C., C.L. Larson, and C.E. Bowers, Calculated and Observed Hydrographs for Lab. Channels Above and Below a Channel Junction.

Golony, P., Effects of Watershed Characteristics on the Time Parameters of Runoff Hydrographs, Ph.D. Thesis, Univ. of Minn.

Research Results:

A Mathematical Model Watershed, idealized but representative of watersheds in S.E. Minnesota, was developed. The model utilizes the partial differential equations for unsteady flow in open channels, solved by finite difference methods on a large digital computer. A variety of storm patterns were used as inputs to the model to determine the extent of non-linearity of hydrographs within channels, i.e. without overbank flow. These results show that runoff time parameters are not constant but, instead, decrease significantly as flow rates increase. Time to 97% of equilibrium, for example, was found to vary as the  $-0.27$  power of supply rate. Likewise, lag time and time to peak decrease with increasing flow rate. It was shown also that peak discharges are not proportional to runoff amount as assumed in unit hydrograph procedures. For flow within channels, the linearity assumption leads to underestimation of peak flows.

A junction routing procedure including the effects of backwater above channel junctions was developed for incorporation in the watershed model. To test the junction model, 3 channels each 40 ft. long, with a connecting junction, were constructed in the lab. Hydrographs of differing size and timing were measured flowing through the channels and junction. The calculating procedure involved the use of 6 simultaneous equations at the junction and finite difference routing through the channels. The calculated and observed hydrographs were in close agreement for all tests, including those with reverse flow above the junction. The watershed model has been modified considerably to include the backwater effect (junction routing) and other improvements. The model was used experimentally to determine the effects of watershed and channel characteristics on time to equilibrium and other time parameters. The characteristics studied included channel roughness, channel slope, channel size and shape, and watershed size. Analysis of these data is not completed but is being continued and will be completed soon. In planning any water development of water control projects, whether large or small, an estimate of peak flows in various parts of the system with and without the project is essential. The unit hydrograph method and other linear methods are widely used for this purpose. The results of this study provide evidence that peak discharges estimated by such methods should be adjusted upward by significant amounts in many cases to avoid underdesign. Estimates of peak flow rates from small, ungaged watersheds are necessarily based on rainfall data and the physical characteristics of the watershed. The results of this study are being used both by the Principal Investigator and others to develop new methods for peak flow determination which will use more of the actual factors affecting peak flow and avoid the use of the linearity assumption.

OWRR Project No.: B-009-Minn

Project Title: Relation of phosphorus in lake-bottom deposits and pollutional history of Minnesota lakes

Principal Investigator: Joseph Shapiro, Limnological Research Center, School of Earth Sciences

Project Began: July 1, 1967

Project Completed: June 30, 1970

Cost of Project: \$44,493 federal funds; \$46,018 non-federal funds

Man Years of Effort: 5.22

Publications Resulting From Project:

Shapiro, J., W. Chamberlain & J. Barrett. 1969. Factors Influencing Phosphate Use by Algae. Water Research 2:12 p.

Chamberlain, W. & J. Shapiro. 1969. On the Biological Significance of Phosphate Analysis: Comparison of Standard and New Methods with a Bioassay. Limnology & Oceanography 14:921-923.

Chamberlain, W. & J. Shapiro. 1971. Methods for the Measurement of Biologically Available Phosphate. "Environmental Phosphorus Handbook", published by John Wiley & Sons.

Research Results:

The phosphate concentration of 13 waters in Minnesota was measured by several chemical procedures including a new six-second method and a solvent extraction procedure. Results were compared with estimates from an algal bioassay procedure to determine which method most accurately measured biologically available phosphorus. Where estimates obtained by these methods differed appreciably, arsenate interference rather than hydrolysis of organic phosphate compounds accounted for the discrepancies. The new extraction method proved less sensitive to arsenate interference than that of Stephens and gave results in agreement with the bioassay.

The so-called molybdenum blue method for assaying the inorganic phosphate concentration of solutions is well established in scientific circles. Numerous modifications of the method have appeared and the method is the basis of almost all routinely employed techniques for assaying phosphate in natural waters. This study was concerned with what, specifically, is being measured by the molybdenum blue method and whether or not the method is providing valid estimates of the dissolved inorganic phosphate concentration of natural waters. It is concluded that neither a hidden blank error or the hydrolysis of organic phosphate esters will seriously bias the results obtained by the molybdenum blue method. Except in instances where arsenate is a problem, the molybdenum-reactive material present in natural waters may be regarded as inorganic phosphate, although not necessarily as free phosphate ion. Any attempt to differentiate or define phosphorus availability without considering the time element is futile. If investigators continue to measure concentrations of dissolved inorganic phosphorus and refer to them as such that they be aware of certain problems and attempt to circumvent them. The adoption of a technique for surface waters is urged such as a 6-second procedure where arsenic is definitely shown to be absent, or a short period (e.g. 10 seconds) extraction technique where arsenic is, or may be, present, either method to be done on 0.5 micron filtered water.

OWRR Project No.: B-010-Minn

Project Title: A Study of Techniques for Determining Changes in Phytoplankton in Clouds of Fluorescent Dye Moving in the Mississippi River.

Principal Investigator: Edward F. Miller; The project was initiated by Dr. Clarence McNabb, formerly a faculty member in the Biology Department of St. Mary's College. During the course of the study, Dr. McNabb joined the Faculty of Michigan State Univ. and Mr. Edward F. Miller continued the study as he in turn joined the faculty of St. Mary's Biology Department.

Project Began: July 1, 1967      Project Completed: June 30, 1969

Cost of Project: \$9,271 federal funds; \$10,442 non-fed. funds.

Man Years of Effort: 0.60

Publications Resulting from Project: Johann, D. 1970. A New Fluorescent Technique for the Determination of Changes in Selected Phytoplankton Populations in Lotic Aquatic Ecosystems. M.S. Thesis, Biology Department, St. Mary's College.

Research Results:

This study concerns movement of and maintenance of identity of a mass of water in the Mississippi River. The portion of the Mississippi River used in this study is between mile 722.4 and mile 719.8 located in pool no. b which lies between the dams at Trempealeau, Wisconsin and Winona, Minnesota. The Mississippi River in the Winona area carries a rich planktonic flora principally composed of blue-green algae and diatoms. Little is known concerning parameters of population dynamics for species of these organisms in the river. If the identity of a particular mass of water could be maintained to any degree, then estimates might be made on fecundity, mortality rate, immigration and emigration in a plankton population. The sloughs and marshy areas along a river which contribute heavily to the plankton of the main stream could be identified. A new technique involving Rhodamine WT was used to identify a mass of moving water traveling across two transects. Due concentrations along the course indicated regular patterns of 3-dimensional mixing. The best estimate of cloud shape is one of an equal-sided parallelogram having a depth equivalent to the mean or the depth at the transect. The water in which the periphery of the cloud moved in expanding contained essentially the same number of individual plankton individuals per unit volume as the upstream cloud, with the exception of the general Melosira. The water gained by the cloud while in transit contained fewer Melosira per unit volume thus diluting the population so that the downriver mean was significantly different from that upriver. The technique developed will lend itself to future work involving organisms as bacteria, zooplankters, and aquatic fungi. The technique should also allow investigators to measure changes in pollutant concentrations while simultaneously measuring effects upon planktonic organisms.

OWRR Project No.: B-012-Minn

Project Title: Development of a mathematical model to predict the role of surface runoff and groundwater flow in overfertilization of surface waters.

Principal Investigator: C.P. Straub, School of Public Health

Project Began: July 1, 1968      Project Completed: December 31, 1970

Cost of Project: \$22,028 federal funds; \$25,186 non-federal funds

Man Years of Effort: 3.64

Publications Resulting from Project:

Johnson, J.D. and C.P. Straub. 1971. Development of a Mathematical Model to Predict the Role of Surface Runoff and Groundwater Flow in Overfertilization of Surface Waters. Water Resources Research Center, Univ. of Minn. Bull. 35. 176 p., 58 fig., 65 tab., 78 ref.

Results of Research:

A nutrient enrichment accounting mathematical model was devised for the New Prague watershed in Minnesota. The New Prague watershed is 29.3 square miles in area and is predominantly a rural watershed. Model input data was collected over a 2 1/2 year period from a stream gaging station and two automatic sampling stations. Over 800 water samples were analyzed. Extensive effort was placed on better understanding the nitrogen and phosphorus cycles. It is evident that the spring runoff process and accumulative winter fertilizer applications constitute the major portion of diffuse sources of nutrients in the watershed. Point sources from feedlots and municipal and industrial effluents contribute only 11 percent of the annual EN (total nitrogen, four components) and 7 percent TP (total phosphorus). Disperse sources accounted for 89 percent of EN and 93 percent of TP, with spring runoff in the two months of March and April accounting for 79 percent of the annual EN and 64 percent of the TP. The nutrient output from the watershed could be decreased by increasing penetration of the large amounts of EN and TP in snowpacks into the soil through land terracing to retard rapid spring runoffs and sub-surface drains to allow rapid drainage during the crop season. The model is general enough to be utilized by pollution control agencies to determine the relative magnitude of nutrient sources. This then will enable them to rank or place priorities on control measures, and such analysis can proceed on drainage basis.

OWRR Project No.: B-013-Minn

Project Title: Influence of mist irrigation on moisture stress, growth yields, and quality of potatoes and other vegetable crops

Principal Investigator: R.E. Nylund, Department of Horticultural Science

Project Began: July 1, 1968      Project Completed: December 31, 1971

Cost of Project: \$38,704 federal funds; \$43,078 non-federal funds

Man Years of Effort: 6.33

Publications Resulting from Project:

Sanders, D.C. 1970. Studies on the influence of mist irrigation on the microenvironment, growth, and development of the potato (Solanum tuberosum). Ph.D. Thesis, University of Minnesota, 112 pp. December 1970.  
Sanders, D.C. and R.E. Nylund. 1972. The influence of mist irrigation on the potato. I. Microenvironment and leaf water relations. American Potato Journal 49:123-137.

Sanders, D.C. and R.E. Nylund. 1972. The influence of mist irrigation on the potato. II. Growth and development. American Potato Journal 49:187-195.

Sanders, D.C., R.E. Nylund and E.C. Quisumbing. 1972. The influence of mist irrigation on the potato. III. Nutrient content of leaves. American Potato Journal 49:218-226.

Sanders, D.C., R.E. Nylund, E.C. Quisumbing and K.F.P. Shetty. 1972. The influence of mist irrigation on the potato. IV. Tuber quality factors. American Potato Journal 49:243-254.

Sanders, D.C., P.H. Li, and R.E. Nylund. 1972. The influence of a short period of evaporative cooling on the distribution of <sup>14</sup>C in potato plants. HortScience 7 (4):420-421.

Schaefer, Ronald L. 1972. A study of the effects of mist irrigation on the potato (Solanum tuberosum L.). M.S. Thesis, University of Minnesota. 64 pp. July, 1972.

#### Results of Research:

The influence of irrigation method on potato growth and development was assessed during three years. Low volume "mist" irrigation (M), furrow irrigation (F), mist plus furrow (MF) and no irrigation (NI) were compared. During a high and moderate stress season misting maintained the haulm later into the season and increased the proportion of small and medium size tubers. Further during the high stress season misted plots (M and MF) yielded more than NI plots. The influence of low gallonage "mist" irrigation on the following parameters were measured: leaf, air and soil temperature; and soil moisture, relative turgor and stomatal aperture. Misted canopies had lower leaf, air and soil temperature and higher soil moisture than than the non-irrigated plants. The influence of irrigation method on nutrient content of potato leaves throughout the season was assessed during three years. Low gallonage "mist" irrigation (M), furrow irrigation (F), mist plus furrow (MF), and no irrigation (NI) were compared. Leaf blades and petioles from Kennebec (1967, 1968, 1969) and Irish Cobbler (1968, 1969) plants were analyzed for P, K, Ca, Mg, Fe, Zn, Mo, Mn, Cu, B and N. Levels of Mo, Mn, Cu and B did not differ either between treatments or during the season. Leaves from different irrigation methods did not differ consistently in levels of N, K, Mg, Ca or Fe. However, during the latter part of two seasons NI plants contained less P and K and more Fe than M or MF plants. F plants were similar to NI plants in nutrient content except that P was lower in the latter. No matter what the irrigation method, N declined as plants matured. Irrigation treatment did not influence the K or Fe levels of petioles consistently. On several sampling dates MF plants were intermediate. Leaves and petioles of M and MF plants consistently contained more ZN throughout all three seasons than non-irrigated or furrow irrigated plants and, in contrast to the latter, Zn content did not decline as plants matured. The influence of irrigation method on tuber quality factors was assessed during three seasons. Low volume "mist" irrigation (m), furrow irrigation (f), mist plus furrow (MF) and no irrigation (NI) were compared. Tubers from misted treatments (M and MF) tended to be lower in dry matter, had a high incidence of secondary growth and hollowheart, yielded darker chips, required more time to condition, were less mature, and contained more reducing sugars than those from NI treatments. Further the tubers from misted treatments tended to contain more P, Mg, Ca, Fe, Al, B and Mn, than those from NI plots at various times during the latter part of the season.

OWRR Project No.: B-015-Minn.

Project Title: Characteristics of the Soil Matrix that Affect Water Storage and Movement

Principal Investigator: G.R. Blake, Dept. of Soil Science.

Project Began: January 1, 1969      Project Completed: June 30, 1973

Cost of Project: \$52,550 federal funds; \$71,478 non-federal funds

Man Years of Effort: 8.59

#### Publications Resulting from Project:

- Arya, L.M. 1969. Stabilization of shear-generated soil aggregates. M.S. Thesis. University of Minnesota.
- Gilman, R.D. and G.R. Blake. 1970. Thixotropic changes with aging of synthetic soil aggregates. Soil Sci. Soc. Amer. Proc. 34:561-564.
- Fuentes, Victor C. 1970. Soil matric suction changes with time in pressed soil briquettes. M.S. thesis. University of Minnesota.
- Blake, G.R. 1970. Thixotropic changes in tillage-induced soil structure. Proc. Inter. Conf. Tillage Res. Methods, Silsoe, England. 1970.
- Blake, G.R. 1971. Asphalt moisture barriers. Minn. Agr. Expt. Sta. Misc. Report 14.
- Palta, J.P. 1971. Effect of an asphalt barrier on water redistribution after infiltration in sandy soils. M.S. thesis. University of Minnesota.
- Arya, L.M. and G.R. Blake. 1971. Stabilization of newly-formed soil aggregates. Agron. Journ. 64:177-180.
- Palta, J.P., G.R. Blake and D.A. Farrell. Water transmission properties of an asphalt barrier. Soil Sci. Soc. Amer. Proc. 36:709-714.
- Blake, G.R. and J.B. Swan. 1972. Tillage, the modern problem. Handbook 19th World Ploughing Contest, New Ulm, Minnesota.
- Arya, L.M. 1973. Water flow in soil in presence of soybean root sinks. Water Resources Research Center, Univ. of Minn. Bull. 60.
- Blake, G.R., E. Schlichting and U. Zimmermann. 1973. Water recharge in soil with shrinkage cracks. Soil Sci. Soc. Amer. Proc. Vol. 37, No. 5.
- Schweikle, V. and G.R. Blake and L.M. Arya. 1974. Matric suction and stability changes in sheared soil. Minn. Agr. Expt. Sta. Journal Series paper 8089 accepted by organizing Committee of Xth Int. Congr. Soil Sci., Moscow, USSR.
- Palta, J.P. and G.R. Blake. 1973. Effect of an asphalt barrier on water storage and drought probability. Minn. Agr. Expt. Sta. Journal Series paper 8259, accepted for publication by Agron. Jour.

#### Results of Research:

The soil moisture reservoir is not constant. It varies with packing and with structural quality of the particles. Sand, silt or clay particles interact to form soil aggregates that lend porosity and water storage space. Soil that consolidates under influence of water and of machines and animals is usually loosened by tillage. Soil sheared by plows or other tillage implements re-forms with time giving a more water-stable matrix. A spontaneous increase in slaking resistance occurs over hours or days after

sheared soil particles are brought together. Thus the matrix ages in a way that it is stabilized. The reaction was shown to be independent of drying of the mass. Soil matric suction increased with time in pulverized, moistened, pressed soil sealed to prevent water loss. A closely similar reaction occurred when the soil was sterilized, treated with H<sub>2</sub>O<sub>2</sub> or saturated with various cations. Water stability also increased with time for simulated aggregates formed by extrusion under pressure. Time-dependent suction and stability increases suggest spontaneous shift from face-face to edge-face orientation of clay in the matrix. An interesting field application that increased the soil moisture storage reservoir was established on two sandy soil types where moisture deficiency is the principal yield-limiting factor. Treatment consisted of plowing in a nearly continuous, hot sprayed asphalt barrier 55 cm deep in two replicated experiments. Various vegetable crops were grown. Water movement through the barrier was affected by the capillary potentials on both sides of the barrier if these potentials exceeded a critical value of 'breakpoint' which ranged from -32 to -20 cm depending on the flow rate. When the potential below the barrier dropped below the critical value, the potential above the barrier remained relatively unchanged. The practical result of this barrier was to increase the plant available water in Zimmerman fine sand from 2.9 cm to 7.5 cm in the surface 55 cm. In Hubbard loamy coarse sand a sand-gravel layer at 25 to 50 cm itself acted as a barrier to water movement. In the Zimmerman soil it was shown that over a 3-year period supplemental water needed to keep an active growing crop could be reduced by 58% with a barrier. Probable water loss by percolation, on the other hand, would have been less than half as great with a barrier as without.

The surface meter of the earth's crust is a dynamic buffer for water. Not only is infiltration and runoff dependent on the dynamic, momentary condition, but storage of water for plant sustenance between rains is a necessary function. Many soils will store 8 to 10 surface inches of available water in the root zone. Droughty sandy soils, the most deficient in this regard, but valuable for vegetable production can be made to store double their normal amount of available water by use of an asphalt barrier. The study of matrix changes in sheared soil contributes to our understanding of soil structure formation, necessary in maintaining adequate infiltration and conductivity of soil for water. Effects of root sinks on water movement and root zone hydraulic characteristics helps in developing good water management practices under growing crops.

OWRR Project No.: B-020-Minn

Project Title: Pollution and the Ecology of Nearshore Periphyton of Lake Superior

Principal Investigator: T.A. Olson, School of Public Health

Project Began: July 1, 1969      Project Completed: June 30, 1972

Cost of Project: \$45,883 federal funds; \$46,439 non-federal funds

Man Years of Effort: 5.47

#### Publications Resulting from Project:

D.B. Brown, T.A. Olson, and T.O. Odlaug. 1972. Pollution and the Ecology of Nearshore Periphyton of Lake Superior: The Effects of Calcification of Periphyton. Linresta, Research Report No. 3, Lake Superior Limnological Research Station - Duluth. 6 p., 1 fig., 2 ref.

Nelson, R.R., T.O. Odlaug, B.O. Drogstad, O.R. Ruschmeyer, T.A. Olson and W.C. Parkos. 1973. The Effects of Enrichment on Lake Superior Periphyton. Water Resources Research Center, Univ. of Minn. Bull. 59. 183 p., 19 tab., 60 fig., 219 ref.

#### Results of Research:

Two natural rock basins were constructed at the lakeside along the north shore at Castle Danger, Minnesota for the purpose of exposing naturally grown and regrowth periphyton to higher-than-normal levels of phosphate and nitrate. At weekly intervals during 1969 and 1970, samples were collected and productivity was measured by enumeration of organisms, chlorophyll analysis, and weight, dry and organic. Lake Superior periphyton responds dramatically to increased additions of phosphorus and nitrogen. If the near-shore area of Lake Superior ever received nutrients, such as those added to the experimental test pool at Castle Danger, a drastic change in the Lake's biota could occur. For example, as enrichment increased, the predominant clean-water diatom forms could eventually be replaced by the more tolerant green or blue-green algae. In addition, the very composition of the macrobenthic forms found in Lake Superior could be altered as a result of their dependence on the periphyton, which, as primary producers, from the first link in the food chain. Likewise, certain fish which depend on benthic organisms for their food may be adversely affected as an indirect result of a changing periphyton community.

There have been extensive investigations of water pollution sources and continuing water quality studies on the Great Lakes. However, the effect of changes in water quality on the attached, filamentous periphyton development in the Great Lakes and eutrophication processes appears to be very sketchy. It is anticipated that results from this research will provide fundamental information about the present quantity, composition, growth and distribution of the near shore, attached algae in Western Lake Superior. These data will be useful as baseline information in the future. Hopefully, the data obtained may also provide information useful in the development of a supplemental means for more rapid assessment of water quality of Lake Superior as reflected by transformation in species composition, characteristics and growth of the nearshore periphyton in response to future environmental perturbation.

OWRR Project No.: B-031-Minn

Project Title: Participatory Ecology: A study of citizens groups involved at the grass roots to improve the water resources environment.

Principal Investigator: L.P. Gerlach, Department of Anthropology

Project Began: July 1, 1969      Project Completed: June 30, 1972

Cost of Project: \$33,394 federal funds; \$34,015 non-federal funds

Man Years of Effort: 3.45

Publications Resulting from Project:

- Gerlach, L.P. 1970. Eco-Gemini: Two for the Teach-In. Natural History.  
Gerlach, L.P. 1970. Eco-Valuator: A Questionnaire. Natural History.  
Gerlach, L.P. 1971. Movements of Revolutionary Change: Some Structural Characteristics. In special issue on General Systems Theory, edited by Bertram Gross, American Behavioral Scientist, July/August.  
Gerlach, L.P. 1971. The Ecology Movement and Revolutionary System Change. Spirit Magazine, Concordia Press. June/July.  
Gerlach, L.P. 1973. Mobilization and Participation of Citizens Groups in Improving the Quality of Water Resources Environments. Water Resources Research Center, Univ. of Minn. Bull. 57. 16 p., 6 ref.  
Gerlach, L.P. and V.H. Hine. 1973. Lifeway Leap - The Dynamics of Change in America. University of Minnesota Press, Minneapolis.

Results of Research:

The ecology movement has the same general characteristics of segmentary, polycentric, reticulate organization as such other movements as the Black Power Movement and the Pentecostal Movement. The diverse groups concerned with environmental issues can be arranged on a continuum from established and routinized to new and radical. These groups proliferated rapidly from about 1969-1972. The ecology movement functions as a whole because of the way its different segments interweave in a network. There is considerable overlap between ecology groups and various "counter-culture" segments. Recruitment to ecology groups is characteristically through face-to-face contact instead of via large scale advertising. Commitment to the ecology movement was not accomplished as dramatically as with Black Power or Pentecostalism. The opposition to the ecology movement was real and often powerful but environmentalists often perceived it to be more sinister and powerful than was the case. Common ideology concepts of the ecology movement are: doomsday theme, share guilt for environmental degradation, finite resources leading to a zero sum game, closed system and spaceship earth, need for recycling, need to control or limit growth, ecosystem and interdependence, need for significant change, and system change means lifestyle change.

The research was designed to provide crucial information on the structure and process of the ecology-environmental movement, particularly as it relates to water resource issues. It analyzes the dynamics of ecology movement thrust, established order response and resulting patterns of trial and error experimentation and adaptation in water resource management. Hopefully it will contribute to the ability of concerned Americans to utilize more effectively such capacity for exploration and for fundamental change so that this time of environmental crisis will become our time of adaptive transformation.

OWRR Project No.: B-032-Minn

Project Title: Mississippi River Ecology Associated with Heated Power Plant Effluent.

Principal Investigator: A.J. Hopwood, Department of Biology, St. Cloud State College.

Project Began: July 1, 1969      Project Completed: June 30, 1972

Cost of Project: \$46,302 federal funds; \$61,531 non-federal funds

Man Years of Effort: 7.60

Publications Resulting from Project:

- McConville, D.R. 1969. Macroinvertebrates of the Mississippi River in the Monticello Region. M.S. Thesis. St. Cloud State College, Biology Department.  
Morgenweck, R.O. 1971. A Survey and Distribution Study of the Cyprinid Minnows (Family Cyprinidae) in the Monticello Region of the Mississippi River. M.S. Thesis. St. Cloud State College, Dept. of Biology.  
Anderson, R.A. 1972. Food Habits, Length-weight Relations, and Condition of the Shorthead Redhorse, *Moxostoma macrolepidotum* (lesuer), and the Carp, *Cyprinus carpio* L., Collected from the Mississippi River near Monticello, Minnesota. M.S. Thesis. St. Cloud State College, Biology Dept.  
Nemanick, J.M. 1973. Recolonization of Macroinvertebrates on Artificial Substrate Samplers in the Mississippi River near Monticello, Minnesota. M.S. Thesis. St. Cloud State College, Biology Dept.  
Throne, S.V. 1973. Bank and Rough-winged Swallow Use of the Mississippi River near Monticello, Minnesota. M.S. Thesis. St. Cloud State College, Biology Dept.  
Hopwood, A.J. 1974. Thermal Effects of a Nuclear Power Plant on the Mississippi River at Monticello, Minnesota. Water Resources Research Center, Univ. of Minn.

Results of Research:

The thermal effects of the nuclear power plant at Monticello, Minnesota were assessed by comparing postoperational (1971-1972) data to baseline data (1968-1971) on the Mississippi River. Macroinvertebrate samples from artificial substrates placed upstream were compared to those from the heated zone downstream. Trichopteran biomass increased, ephemeropterans and dipterans decreased in the heated zone. Significant responses to heated water were observed for Trichoptera in the July-October period, Ephemeroptera were most affected in the May-August period, Dipterans declined significantly during September through November. The number of species was not affected by the heat. Growth rates of macroinvertebrate groups in upstream and downstream areas were not significantly different in four of seven 35-day cycles observed. The trichopteran seasonal cycle showed higher peaks of numbers and depressed peaks of weights in the heated zone, but the overall pattern was the same in heated and unheated areas. Cycles of ephemeropterans and dipterans had depressed summer peaks in the heated zone and the general pattern was disrupted, especially in the spring and early summer. Flow characteristics caused the heated water to remain along the bank from the point of discharge to about 3 miles downstream. A comparison of the number of fish caught by electrofishing along the opposite sides of the river showed that black crappies, smallmouth bass, and

walleyes were more numerous on the heated side, and were often attracted to the discharge canal from adjacent areas of the river. Rough fish were generally indifferent to the heated water in most areas, but carp were more attracted by the discharge canal than other species. Normal movements of minnows and other population characteristics seemed unaffected by the temperature rise. Food studies of the shorthead redhorse, carp, and the minnows and darters showed that the carp ate Cladophora when it was available, but were more opportunistic than the other species which were generally insectivorous. Fish in the heated water had a lower percentage of stomachs containing food than the same species in unheated areas, but the sample size was insufficiently large to test the significance of the difference. Effects of the power plant upon other organisms, such as birds have been minor.

Information generated by this project was used by the Atomic Energy Commission in the preparation of an environmental statement and recommendations for licensing referred to below:

United States Atomic Energy Commission, Directorate of Licensing.  
May 1971. Draft Environmental Statement on the Northern States  
Power Company Monticello Nuclear Generating Plant. Washington,  
D.C. 170 p.

OWRR Project No.: B-042-Minn

Project Title: Spatial Variations in the Perception of Water Resources and Water Problems in South Central Minnesota

Principal Investigator: Robert T. Moline, Gustavus Adolphus College

Project Began: July 1, 1970      Project Completed: December 31, 1973

Cost of Project: \$11,460 federal funds, \$14,785 non-federal funds

Man Years of Effort: 2.43

Publications Resulting from Project:

Moline, R.T. 1974. The Citizen and Water Management: An Atlas of Water Attitudes in Southern Minnesota. Gustavus Adolphus College. 68 p., 25 fig., 14 tab., 11 ref.

Results of Research:

Comprehensive water resources planning is just beginning in southern Minn. with two basin studies currently underway by the Army Corps of Engrs. The passage of the Regional Development Act of 1969 by the Minnesota State Legislature authorizes the creation of regional development commissions that will make decisions affecting water resource development. Local Citizen's groups with interest in water resources have recently become active in the area. It is believed that the degree to which water resource planning can be successfully implemented is a function of local perceptions of water. The purpose of this research was to determine the areal variation in ways local people perceive water resources, effect

of professional water planning studies on local attitudes toward the water resource base. A "Perceptual" model was constructed, that will be useful in other areas where water resource planning is getting underway. Data was gathered through the use of two mailed questionnaires and a series of personal interviews with an extensive list of local decision makers and other citizens. It appears that the amount of discussion of water related problems in local newspapers is directly proportional to the intensity of local water crises. Almost no continuing discussion of general water problems is carried in newspapers. This is especially true of the weeklies. Respondents were asked to rank their top three sources of information about water problems. Broadcast media were declared the primary source by the largest number of respondents (22 percent) with newspapers and magazines chosen by 16 percent. Respondents were asked to rank what they perceived to be the three most important water problems in their area. Water pollution was ranked first in 10 of the 13 sub-basins of the Minnesota River with recurrent drought ranked first in three of the western sub-basins, the Little Minnesota in South Dakota, the Yellow Bank in Minnesota and the Big Stone basin in Minnesota. For the entire Minnesota River basin 32 percent of the respondents ranked water pollution as the primary water problem, 16 percent ranked inadequate water resources planning first, 12 percent ranked wet fields first, and surprisingly, only 10 percent ranked flooding as the primary problem. Most respondents have confidence in water resources planning and do not wish to simply accept water problems as inevitable, but most would prefer that water planning be done by State and local agencies rather than Federal units. Most respondents are strongly supportive of more rigorous control of private lakeshore development, preserving wetlands as holding areas for surplus water or as wildlife habitat and encouraging upstream watershed land treatment practices as a major solution to flood damages. There seems to exist divided feelings about the value of small or large dams in reducing flood damages. Similarly divided are the responses to statements about the opportunity of citizens to participate in water resources planning, the use of irrigation in agricultural land management, the use of weather modification to increase water supplies, the adequacy of water based recreation opportunities, and the relationship of agricultural drainage to flooding. The research results should assist the Southern Minnesota Rivers Basin Commission and the Upper Mississippi River Basin Commission in assessing public opinion concerning water and related land resources plans being developed for the Minnesota river basin.

OWRR Project No.: B-044-Minn

Project Title: Area Financing of Water Resource Development

Principal Investigator: W.R. Maki, Department of Agricultural and Applied Economics

Project Began: July 1, 1970      Project Completed: June 30, 1972

Cost of Project: \$19,764 federal funds; \$26,171 non-federal funds

Man Years of Effort: 2.64

Publications Resulting from Project:

Maki, W.R. 1973. Social/Environmental Systems for Regional Development Planning. Department of Agricultural and Applied Economics, Univ. of Minn. Mimeographed Report. 29 p., 1 fig., 1 tab., 43 ref.

Maki, W.R. 1973. Financing Alternatives for Regional Resource Development. Department of Agricultural and Applied Economics. Univ. of Minn. Mimeographed Report. 16 p., 1 fig., 6 tab., 20 ref.

Maki, W.R. 1973. Area Financing of Water Resources Development in West Minnesota. Water Resources Research Center, Univ. of Minn. Bull. 66. 123 p., 7 fig., 56 tab., 94 ref.

Results of Research:

A 14-county environmental planning area in West Minnesota was identified for the purpose of studying financing alternatives in water resources development. Altogether, 719 units of local government (exclusive of the newly established planning commissions) were included in the study area in 1967, which is the base year for the study. Economic and organizational structures in the 14-county area are described and analyzed in this study. A computable model of the area economy is presented. Estimates of the degree of internal interdependence of the area economy are derived as basis for assessing the current status of the area economy and its public financing potentials. The base-year data are used subsequently in the preparation of a projected 1980 inter-industry transactions table. An expanded system, of area product and income accounts is presented, also, for both the base year and the target year. These accounts are used in assessing the public economy as part of a total area economy. Water resource development potentials and financing requirements and alternatives are identified in the context of all public expenditures and outlays in a multi-county area.

Project results are being used in educational programs and consulting in the study area and other resource planning areas in Minnesota. In addition, segments of the project were used in classroom activities on the University of Minnesota campuses. A summary of specific applications of project results includes: Public affairs programs and conferences for resource planning groups in outstate Minnesota; data and information services for local government planning and decision making in 14-county study area; consulting services for regional planning commissions, resource conservation and development project committees and other groups; undergraduate and graduate courses in resource development and planning; and continuing education classes for local government officials, staff members, community leaders, and others interested in financing water-resource development and related activities.

OWRR Project No.: B-047-Minn

Project Title: Social & Economic Factors in the Adoption by Industry of Water Pollution Control Measures

Principal Investigator: R.E. Rickson, Department of Sociology

Project Began: July 1, 1970      Project Completed: June 30, 1973

Cost of Project: \$28,658 federal funds; \$29,948 non-federal funds

Man Years of Effort: 3.54

Publications Resulting from Project:

Rickson, R.E. 1973. Research and Development in Industrial Corporations: Can Advanced Societies Learn to Contain Pollution? Water Resources Research Center, Univ. of Minn. Bull. 62. 23 p., 34 ref.

Rickson, R.E., and C.E. Simpkins. 1972. Industrial Organizations and the Ecological Process: The Case of Water Pollution, in M.B. Brinkerhoff and P.R. Kunz, Complex Organizations and Their Environment. Dubuque, Iowa: W.C. Brown Co., Publishers.

Rickson, R.E. 1972. Self Interest and Pollution Control, the Journal of Environmental Education, 4(Fall): 1972, pp. 43-49.

Rickson, R.E. 1974. Social and Economic Factors in the Adoption by Industry of Water Pollution Control Measures in Minnesota. Water Resources Research Center, Univ. of Minn. Bull. 67.

Results of Research:

Change in industrial organizations is one of the elemental facets of change in modern industrial societies because of their power and the immense volume of waste, solid and liquid that comes from industrial production. Change is a complex phenomena at all levels of analysis; industrial changes in water use are preceded by general societal changes as to priorities and values regarding economic production as opposed to living quality or a clean physical environment. Numerous agencies and organizations, private and public, now exist for the sole purpose of changing and regulating private and public water use. The conservation ethic has been part of society for some time but it gained power only in the last decade to the point where fundamental issues related to the organization of industrial production have come to the fore. Any study of industrial change, therefore, has to consider the relationship that industrial organizations have to such groups. Under the model of development emphasizing economic growth per se, there was little if any pressure upon industries to consider the affect of their production on external factors like water quality. There is pressure now and the pressure can be expected to continue. Water has always been one of man's most vital resources and its importance has increased as industrial and agricultural development began to accelerate. Water is, at the same time, basic to human health and consumption, a basic ingredient of agriculture, of public recreation, and, of course, a principal input to industrial production of all kinds. Industry uses more water as direct and indirect input to production than any other single source. As a result of its many uses and the mutual dependence of various groups upon water but with decidedly different goals and responsibilities, water use has become a focal point of controversy and change. Fundamental change is in the offering in terms of past and current debates about the relative responsibility of industry to clean public water after they use it in vast quantities and usually at rather low economic cost. Certainly, there are now differences among groups calling for changes in industrial water use and within industry itself as to what kinds of changes are to be made. There is, however, one constant factor. Industry and other groups, private and public, can no longer use water as they have in the past.

This study is an attempt to further understand the process by which industrial organizations change the way they dispose of waste. Substantively, the relationship of organizational characteristics to rates of change in waste procedures is of interest. A general model of change is envisioned. The two major forces creating change in industrial organizations are the internal pressures within the organization that result from such factors as the complexity of its division of labor and production technology, and the kinds of pressure the organization faces as the result of powerful and aggressive regulatory agencies and other groups. Finally, the nature of dependence the firm has upon water affects change. An analysis of industrial change, therefore, requires that attention be given to the cultural values of the societies in which they function, the internal structure of industrial organizations, and the nature of their contact with other organizations, public and private, that are trying to change the way industries use water. Finally, a relationship that students of complex organizations have generally overlooked is the ultimate dependence of all human groups on the inanimate environment. The latter has increased importance given the existence of three contemporary conditions: (1) although the extent is not fully determined, serious damage has been done to the natural environment as the result of advanced industrial production; (2) to a considerable degree, the technology and the scientific knowledge needed by industries to reduce their pollution is available, and (3) the current debates over the definition of a quality environment and the general rules for the use of the physical environment directly involves industry and has far reaching consequences for the role of industrial production in contemporary society. The general question of interest is "When do industries search for information?" The question is more than one of public image for industries. The future role of industrial organization and environmental quality is at stake. Their capacity to change the way they use natural resources is important to understanding the association, conflictive or cooperative, between industries and other groups also dependent on the natural environment.

Results can be applied to overall problems of planned development. Both industrial and agency representatives have requested final reports of the project's findings. Numerous requests for speaking and reporting to industrial groups and public agencies at all levels of government have been answered. The results of this research should improve the understanding of the social dimensions of the problem and provide valuable information concerning the process by which change occurs or is resisted.

OWRR Project No.: B-049-Minn

Project Title: A Survey of Attitudes towards the Mississippi River as a Total Resource in Minnesota

Principal Investigator: J.P. Ludwig, Director - Center for Environmental Studies Division of Science & Mathematics, Bemidji State College

Project Began: July 1, 1970      Project Completed: September 30, 1972

Cost of Project: \$31,790 federal funds, \$32,682 non-federal funds

Man Years of Effort: 3.45

Publications Resulting From Research:

Baron, N.J., E.J. Cecil, P.I. Tideman and J.P. Ludwig. 1972. A Survey of Attitudes Towards the Mississippi River as a Total Resource in Minnesota. Water Resources Research Center, Univ. of Minn. Bull. 55. 160 p., 19 fig., 70 tab., 23 ref.

Results of Research:

A survey of the attitudes of Minnesotans toward the use, maintenance and development of the Mississippi River in Minnesota was conducted. Background information on the diverse physical nature of the project Universe (those 23 Minnesota counties which the River flows through or is adjacent to) was collected covering the topics of waterflow, soils, population change, changing riparian land use, and recreational opportunities. Great physical and cultural diversity was found in the project Universe. Attitudes of residents were measured by a 40 item mail questionnaire sent to 5,000 residents of the project Universe; 101 in-depth interviews were also conducted. Respondents provided data on their characteristics, evaluated the desirable and undesirable characteristics of the River, evaluated the role of media in providing them with environmental information, expressed attitudes towards the use of the River, how River pollution should be controlled and financed, and provided data on what aspects of their life styles they were and were not willing to change to improve environmental quality. Secondary students were also surveyed in a separate effort to quantify significant difference of attitudes held by youth and adults. Two significant findings were that Minnesotans do not desire to curtail their uses of energy to improve environmental quality, and the perceived present uses of the River are exactly opposite to the uses the public desires.

A wide variety of people including politicians, the League of Women Voters, and more than 100 non-state-college persons at large have requested copies of the final report. The planning sections of several power companies, the cities of Minneapolis and St. Cloud, and faculty from eleven colleges of Minnesota and Wisconsin have requested copies of the final report as well. Since a major portion of the study has assessed current attitudes toward river development and use, it seems clear that this study will be exceptionally valuable to estimate public response to development programs and hence valuable for all levels of planners.

OWRR Project No.: B-060-Minn

Project Title: Forecasting Rainfall and Snowmelt Floods on Upper Midwestern Watersheds

Principal Investigator: C.E. Bowers, St. Anthony Falls Hydraulic Laboratory

Project Began: July 1, 1971      Project Completed: June 30, 1972

Cost of Project: \$15,631 federal funds, \$16,108 non-federal funds

Man Years of Effort: 1.70

Publications Resulting from Research:

Pabst, A.F., C.E. Bowers, and D.G. Baker, 1972. Flood Forecasting in the Upper Midwest - Data Assembly and Preliminary Analysis. St. Anthony Falls Hydraulic Laboratory, University of Minnesota. Project Report No. 137. 57 p., 17 fig., 9 tab.

Results of Research:

This project was Phase I of a three-phase study whose objective is the development of analytical procedures and the correlation of hydrological data to aid in the prediction and control of spring floods in large Upper Midwest watersheds. Phase I has involved the assembly of meteorological and hydrological data for various periods and the procurement and preliminary evaluation of selected mathematical simulation models of watersheds. Phases II and III have been authorized under a project which began July 1, 1972. The major portion of the hydrological and meteorological data were procured on magnetic tape to facilitate input into the mathematical models. This form is highly desirable, as some runs were performed with up to one year's data. Approximately 28 magnetic tapes were received and a duplicate was made of each to serve as a backup copy. Of special interest in this study were the SSARR model developed by the Corps of Engineers and the National Weather Service, the Kentucky-Stanford model, the HEC-1 model of the Corps of Engineers Hydrologic Engineering Center, and programs in use by the National Weather Service River Forecast Center in Kansas City. The project has resulted in the assembly, in readily useable form, of meteorological and hydrological data that can be used in mathematical models to compute daily flows on large watersheds for the period 1963 to the present. Output can be for a single flood or with some models continuous periods up to a year or more.

Projects Underway:

OWRR Project No.: B-053-Minn

Project Title: A Hydromorphic Analysis of Forest Management Alternatives

Principal Investigators: A.C. Mace, School of Forestry

Project Began: July 1, 1971      Scheduled Completion: June 30, 1974

Anticipated Cost of Project: \$34,000 federal funds, \$34,000 non-federal funds

Anticipated Man Years of Effort: 4.36

Expected Research Results:

The specific objective of the research project is to evaluate the use of input-output analysis to determine effects of alternative forest management systems on environmental quality in terms of water, aesthetic and economic parameters. Water use and environmental deterioration in Itasca County in northern Minnesota will be integrated into an economic system in order to provide planners and administrators with additional information on environmental effects so that alternative forest management systems can

be evaluated. The research project will focus on the trade-offs resulting from the choice of one management system as opposed to another. Estimates will be made of thermal pollution and increased nitrate and phosphate levels associated with alternative forest management systems. Estimates of deterioration of fish and migratory water fowl habitat and suitability for resort and summer homes as a result of different forest management systems also will be made. Subsequent impact of effects of environmental quality deterioration on individual sectors and the overall economy will be estimated using the input-output framework. Results of this project will provide Federal, State, local and private agencies with a tool and information to evaluate effects of alternative land management systems on water requirements, economic and environmental elements for multi-objective planning.

OWRR Project No.: B-054-Minn

Project Title: Socio-Economic Implications of Alternative Water Resources Policies in Minnesota

Principal Investigator: John J. Waelti, Department of Agricultural & Applied Economics

Project Began: July 1, 1971      Scheduled Completion: June 30, 1974

Anticipated Cost of Project: \$27,000 federal funds, \$27,000 non-federal funds

Anticipated Man Years of Effort: 3.48

Expected Research Results:

The objectives of this project are to: delineate the more immediate and crucial sets of water and related land resources planning policy alternatives being considered by the people of Minnesota, identify the economic and social consequences of alternative courses of action associated with possible future programs and projects, and evaluate the economic and social consequences of these alternative courses of action so that a rational basis for planning decision making can be presented. The Minnesota State Planning Agency with the assistance of all other State agencies is preparing a statewide framework water and related land resources plan. The plan with program and project priorities cannot be formulated until the State adopts major planning policies. The information generated by this project will assist the State legislature and Executive Branch in making decisions concerning alternative planning policies.

OWRR Project No.: B-057-Minn

Project Title: Subsurface Irrigation With Heated Water, Its Management and Application Toward Reduction of Thermal Pollution Problems.

Principal Investigator: E.R. Allred, Department of Agricultural Engineering

Project Began: July 1, 1972      Scheduled Completion: June 30, 1974

Anticipated Cost of Project: \$32,643 federal funds, \$32,643 non-federal funds

Anticipated Man Years of Effort: 3.33

Expected Research Results:

The research project will provide valuable information as to the feasibility of utilizing irrigation and groundwater recharge as means for disposal of heated water from power plants or other sources in Minnesota. The basic objectives of this research are to: (1) utilize heated water for the subsurface irrigation of crops in Minnesota, and to determine its effect upon plant growth processes; (2) determine the optimum depth of placement of a subsurface water source, relative to the cooling rate of a soil mass and the heat tolerance of crops; (3) evaluate the economic feasibility of extended crop production in Minnesota through lengthening of the growing by use of heated water; and (4) determine the feasibility of subsurface irrigation as a method for disposing of heated water through groundwater recharge in selected Minnesota soils.

Several power companies and other industries have expressed an interest in the data being obtained in this project. Most notable of these inquiries have come from representatives of Northern States Power Company, Minnesota Power Company, and Otter Tail Power Company. Certain data and methods employed relative to soil heating are of direct interest to NSP in their attempts to utilize waste heat for agricultural purposes at their Monticello and Becker generator plants. Farmers are also interested in the results being obtained in this study with an eye toward increasing their income through the higher prices obtainable for early market crops, and from double cropping.

OWRR Project No.: B-067-Minn

Project Title: Role of the Scientist-Technician in Water Policy Decisions at the Community Level: A Study in Purposive Communication

Principal Investigators: R.E. Rickson, P.J. Tichenor and G.A. Donohue, Department of Sociology and School of Journalism

Project Began: July 1, 1972      Scheduled Completion: June 30, 1974

Anticipated Cost of Project: \$31,018 federal funds; \$31,018 non-federal funds

Anticipated Man Years of Effort: 3.30

Expected Research Results:

The objective of this research project is to analyze the role of scientists and technicians, in private and public organizations, in community-level decisions concerning water quality and use in Minnesota. The principal investigators will identify and analyze the structural and social psychological factors associated with the performance of various types of decision-making roles among scientists and technicians, study the relative impact of various information sources utilized by scientists and technicians performing various roles in community decisions about environmental quality, and study the extent and nature of the relationship between various

role performances by scientist-technicians creation of consensus among community leaders about environmental issues. The results of the research will assist decision makers and scientists concerned with environmental matters to better coordinate their efforts.

OWRR Project No.: B-068-Minn

Principal Investigator: Donald G. Baker, Department of Soil Science

Project Title: Spatial and Temporal Variation of Precipitation of a Concentrated Network in Both Urban and Rural Environment

Project Began: July 1, 1972      Scheduled Completion: June 30, 1975

Anticipated Cost of Project: \$31,316 federal funds, \$31,316 non-federal funds

Anticipated Man Years of Effort: 4.02

Expected Research Results:

The objective of this project is to determine and attempt to explain the temporal and spatial precipitation patterns in the Twin City metropolitan area and also across a midwestern state of relatively topography. The information gained from this study will provide the basic and detailed precipitation data required by all professions concerned with the planning and design of structures that either carry water or impede its movement, water resource planning, and soil conservation. The meteorologist whose local forecasts are based largely upon the point measurement of a single station will benefit from the information obtained by this project.

OWRR Project No.: B-077-Minn

Project Title: Forecasting Rainfall and Snowmelt Floods on Upper Midwestern Watersheds

Principal Investigator: C. Edward Bowers, St. Anthony Falls Hydraulic Laboratory

Project Began: July 1, 1972      Scheduled Completion: June 30, 1974

Anticipated Cost of Project: \$32,137 federal funds, \$32,137 non-federal funds

Anticipated Man Years of Effort: 2.36

Expected Research Results:

The objective of this research project is the development of analytical procedures and the correlation of hydrologic data to aid in the prediction and control of spring floods in large Upper Midwest watersheds. The study is divided into three phases. The first phase, presently under way, involves the assembly of meteorologic and hydrologic data concerning past spring floods and new data pertaining to floods during the project period. Under Phases II and III the data will be analyzed using available mathematical models, modifications of such models, and new models to assist in synthesizing continuous runoff records, particularly for the spring season. The Upper Midwest is a relatively flat area compared to

the mountainous regions of the country; a study of the contribution of snowmelt to spring floods and the critical combinations of hydrologic conditions that are characteristic of major floods in this area is urgently needed. Of special interest will be the water content of snow over large watersheds together with data concerning late winter and early spring values of precipitation, air temperature, soil temperature, frost depths, soil moisture, wind, antecedent conditions, and basin or watershed characteristics. The National Weather Service (Washington, Kansas City, and Minnesota offices) and the Corps of Engineers (Hydrologic Engineering Center and St. Paul District) have indicated interest in the studies and have cooperated in providing programs and data.

OWRR Project No.: B-081-Minn

Project Title: The Geochemical and Biostratigraphic Record of Natural and Pollutational Eutrophication of Minnesota Lakes

Principal Investigators: Eville Gorham, Botany Department, H.E. Wright, Jr., Limnological Research Center

Project Began: July 1, 1973      Scheduled Completion: June 30, 1975

Anticipated Cost of Project: \$55,000 federal funds, \$55,000 non-federal funds

Anticipated Man Years of Effort: 5.82

Expected Research Results:

A series of representative Minnesota lakes will be studied to increase the knowledge of both the natural and the man-induced aspects of the eutrophication process and the development of blue-green algal blooms. A survey of the standing crop of plant pigments (chlorophylls and carotenoids) and of various pigments ratios will be made. Fossil chlorophyll derivatives and carotenoids, including those characteristic of the blue-green algae, will be analyzed in sediment cores from diverse lakes. Stratigraphic studies of the proportions of the various clastic fractions (sand, silt, clay), and of their mineralogy and elemental composition, will be undertaken to provide information concerning post-glacial variations in erosion rate and degree of weathering and leaching of the soils surrounding various lakes. Stratigraphic analysis of changes in the abundance and type of certain microfossils will also be carried out to test how well they reflect increased availability of nutrients on additions of mineral materials to the ecosystem. In this way the degree and nature of changes owing to pollution can be perceived, and lake restoration can be planned with better perspective. Lake restoration in Minnesota is the basic objective of many water resources programs. The proposed research will provide an indication of the natural condition in a lake before pollution, so that the restoration plan can have a specific goal that is both realistic and valid. Stratigraphic studies will be supplemented by seasonal analysis of material collected in sediment traps, which will answer the important question of whether sedimentary pigments integrate the total phytoplankton rain or represent mainly the fallout of major plankton blooms. The project should contribute substantially to the knowledge of the balance between allochthonous and autochthonous sources of sedimentary organic matter in lakes and thereby assist water resources managers in solving lake eutrophication problems.

OWRR Project No.: B-087-Minn

Project Title: Bio-Manipulation of Lakes for Elimination of Blue-green Algae

Principal Investigator: J. Shapiro, Limnological Research Center

Project Began: July 1, 1973      Scheduled Completion: June 30, 1976

Anticipated Cost of Project: \$41,432 federal funds, \$41,432 non-federal funds

Anticipated Man Years of Effort: 3.64

Expected Research Results:

The purpose of this project is to learn how to manipulate the biology of lakes, and especially to change blue-green algae to green algae, and to assess the feasibility of doing so. The Principal Investigator will: perform laboratory experiments and experiments to include, in addition to levels of nitrogen and phosphorus and CO<sub>2</sub>, specific pH values, temperature, and light, determine the effects of food chain involvement on the green algae produced (i.e. if zooplankters and small planktivorous fish are introduced can the algae be reduced quantitatively as well as changed qualitatively), determine the extent to which the biomanipulation works in different parts of Minnesota and, if possible, on other states, and evaluate the applicability of the procedures developed to full scale manipulation of lakes of different size and chemical constitution. If the Principal Investigator is able to learn how to manipulate lakes so as to grow green algae instead of blue-greens, he will have come a long way toward resolving the "nuisance algae" problem. Green algae are inherently less of a nuisance because they do not float to the surface and die and decay on shore. Also, he will have gotten lakes "back on the tract" ecologically in that green algae are vastly superior food for zooplankton, which are in turn fed upon by fish. Thus in addition to reducing the nuisance value of the algae they will become food so that the increased production could very well end up as catchable fish. Furthermore, once the basic parameters of biomanipulation are elucidated the technique of artificial circulation can be used in a far more effective and intelligent fashion than now possible.

OWRR Project No.: B-097-Minn

Project Title: Thermal Pollution and Second Trophic Level Fauna in Lake Superior

Principal Investigators: Wayland R. Swain and Robert S. Pozos, School of Medicine-Duluth, Duluth, Minnesota

Project Began: July 1, 1973      Scheduled Completion: June 30, 1975

Anticipated Cost of Project: \$41,362 federal funds, \$41,362 non-federal funds

Anticipated Man Years: 4.28

Expected Research Results:

The proposed research project will attempt to ascertain the effects of increase in the thermal environment of Lake Superior on second trophic level organisms, the zooplankton and macrobenthic forms by both laboratory and field experimentation. Thus, the consumers of the second trophic level would be used as a parameter to measure the effects of thermal pollution. As the demands for power generating plants continue to grow, Lake Superior becomes an increasingly desirable cooling water resource. The research should provide information which will be helpful in anticipating any effects, either harmful or beneficial, resulting from possible future additions of heat to Lake Superior.

Authorized Projects:

OWRR Project No.: B-102-Minn

Project Title: Feasibility of Using Iron-Ore Overburden Material as a Media for Disposal of Secondary Sewage Effluent in Northeastern Minnesota

Principal Investigator: Arnett C. Mace, Jr., Department of Forest Biology, College of Forestry, University of Minnesota

Project Began: July 1, 1974      Scheduled Completion: June 30, 1976

Anticipated Cost of Project: \$45,873 federal funds, \$48,873 non-federal funds

Anticipated Man Years of Effort: 3.6

Expected Research Results:

The objectives of this study are to determine: (1) the efficiency of overburden material from open pit mining to neutralize secondary sewage effluent and reduce deterioration of surface and groundwater systems; (2) the potential amelioration characteristics of secondary sewage effluent for increasing the utilization of unproductive overburden material through establishment of grasses, forest species and wildlife forage. Small replicated plots will be irrigated with secondary sewage effluent by sprinklers at rates of 0.5-inches per hour and 1.0, 2.0, 3.0, and 4.0-inches per week for the period of May through October. Water samples of surface, soil-water complex and groundwater will be taken from wells and tension lysimeters bimonthly and analyzed to determine changes in water quality parameters. Post-treatment and annual analysis of the soils chemical and physical characteristics will be used to evaluate alteration of these components. Determination of percent germination, establishment and dry matter productivity of grasses, forest species, and wildlife forage will provide the basis for evaluation of this technique for amelioration of these unproductive areas.

LIST OF REPORTS AND THESES

During the period 1964 through 1974, 141 reports and 21 theses related to the programs of the Water Resources Research Center have been published. A list of these reports and theses is provided below. Copies of the reports (except those indicated as being out of print) published by the Water Resources Research Center can be obtained free of charge by contacting the following address:

Water Resources Research Center  
University of Minnesota  
Room 107 Hubbard Building  
2675 University Avenue  
St. Paul, Minnesota 55114

Copies of other reports and theses can be obtained by contacting the authors. Copies of all reports and theses are on file at the office of the Water Resources Research Center for reference purposes.

<u>Date</u>	<u>Publication</u>	<u>Reports (** - Out of Print)</u>
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