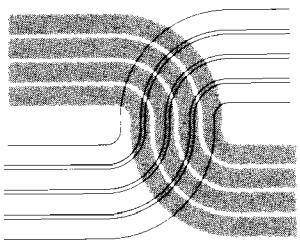
WRRC
Bulletin 101

Water Resources Research Center
University of Minnesota
866 BioScience Center
St. Paul, Minnesota 55108

FIFTEENTH ANNUAL REPORT
WATER RESOURCES RESEARCH CENTER

Prepared by
George R. Blake, Director
Elizabeth Espointour, Secretary



WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
GRADUATE SCHOOL

October 1979
Minneapolis, Minnesota

FIFTEENTH ANNUAL REPORT

WATER RESOURCES RESEARCH CENTER

A Report of Activities Supported
By the Graduate School and the
Office of Water Research and Technology
U.S. Department of the Interior
During the Fiscal Year Ending
September 30, 1979

The work upon which this publication is based was supported in part by funds provided by the United States Department of the Interior as authorized under the Water Research and Development Act of 1978, P.L. 95-467.

October 1979

Minneapolis, Minnesota

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PREFACE

This is the Fifteenth Annual Report of the Minnesota Water Resources Research Center. It covers the period October 1, 1978 through September 30, 1979. It describes the activities of the Center in research, technology transfer and training of water scientists. It also lists research cooperators, projects and Advisory Committee members.

The bulletin is related to the Center Director's office program for Fiscal Year 1979 and to the Office of Water Research and Technology Annual Allotment Agreement No. 14-34-0001-9025.

FCST-COWRR Research Category: 09-D

Publication Abstract:

During fiscal year 1979 the Water Resources Research Center sponsored 12 research projects emphasizing quality of both surface and groundwaters, public health aspects of groundwater pollution, irrigation, drainage, a trophic classification of lakes and social factors in resource development decisions.

Twenty four project-related reports were published by the Water Resources Research Center in 1979-80, including six bulletins. Each of two of the bulletins were sent to about 300 people. The other four were distributed by the Principal Investigator to about 250 people. In addition the Center answered about 500 requests for bulletins published in past years.

The budget for the Water Resources Research Center was $320,922 derived from the University of Minnesota, the University of Minnesota Graduate School and the Office of Water Research and Technology of the U.S. Department of Interior. About 33 students were employed on water-related projects funded by the Center.

Publication Descriptors: Research/Water Resources/Minnesota/Education/Projects/Water Management/ Water Pollution/Water Resources Research Act

Publication Identifiers: Researchers/Applied Research/Basic Research/Physical-Biological-Economic-Social Aspects/Faculty

Minnesota
Water Resources Research Center
University of Minnesota

ADMINISTRATION

President of the University . . . . . C. Peter Magrath
Dean of the Graduate School . . . . . Warren E. Ibele
Director, Water Resources Research Center . . . . . George R. Blake
Secretary . . . . . Elizabeth Espointour

Advisory Committee

University of Minnesota

R.G. Bond	School of Public Health
C.E. Bowers	St. Anthony Falls Hydraulic Laboratory
K.N. Brooks	College of Forestry
D.G. Brown	Department of Geography
K.W. Easter	Department of Agricultural & Applied Economics
L.D. Hanson	Department of Soil Science
K. Huston	Agricultural Experiment Station
W. Ibele	Graduate School
C.L. Larson	Department of Agricultural Engineering
W.J. Maier	Department of Civil & Mineral Engineering
W.P. Martin	Department of Soil Science
G.D. Rose	Institute of Agriculture
T.E. Straw	Division of Science & Mathematics (Morris)
M.S. Walton	Minnesota Geological Survey
T.F. Waters	Department of Entomology, Fisheries & Wildlife
T.J. Wood	Lake Superior Basin Studies Center (Duluth)
H.E. Wright	Limnological Research Center

State and Private Colleges

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

State, Local and Federal Agencies

C. Oster	Environmental Protection Agency
M. Dorton	Metropolitan Council
R.M. Dennistoun	Minn. Department of Agriculture
F.H. Geisenhoff	Minn. Department of Economic Development

G. Hollenstein	Minn. Department of Natural Resources
C.A. Johannes	Minn. Pollution Control Agency
E.H. Ross	Minn. Department of Health
J.E. Sizer	Minn. State Planning Agency
J. Ditmore	Minn. Water Planning Board
E.M. Weiberg	Minn. Water Resources Board
D.R. Albin	U.S. Geological Survey
F.T. Gay, III	U.S. Army Corps of Engineers
H.J. Major	U.S. Soil Conservation Service
J. Scott	U.S. Bureau of Sport Fisheries & Wildlife
E.S. Verry	U.S. Forest Service

Interest Groups and Private Concerns

D.W. Barr	Consulting Hydraulic Engineer
R.A. Haik	Attorney
H. Lykken	Sierra Club
P. Toren	Izaak Walton League of America
J. Crampton	League of Women Voters
K. Kadlec	MPIRG

Research Faculty

The following University faculty members were principal investigators on Water Resources Research Center Projects in FY 1979.

E.R. Allred	Professor of Agricultural Engineering
D.G. Baker	Professor of Soil Science
G.R. Blake	Professor of Soil Science
L.P. Gerlach	Professor of Anthropology
C.L. Larson	Professor of Agricultural Engineering
W.J. Maier	Professor of Civil and Mineral Engineering
J.A. Moore	Assistant Professor of Agricultural Engineering
H.O. Pfannkuch	Associate Professor of Geology and Geophysics
H.W. Quade	Professor of Biology, Mankato State University
M.J. Semmens	Associate Professor of Civil and Mineral Engineering
R.D. Singer	Associate Professor of Environmental Health
D.C. Slack	Assistant Professor of Agricultural Engineering
C.P. Straub	Professor of Environmental Health
J.B. Swan	Professor of Soil Science
H.E. Wright	Professor of Geology and Geophysics

INTRODUCTION

The Water Resources Research Center administered under the Graduate School of the University of Minnesota completes its fifteenth year in 1979. It is appropriate to briefly recount its history.

The Center began with the passage of Water Resources Research Act of 1964, PL 88-379 which was approved on July 17, 1964. This was superceded by PL 95-467 on October 17, 1978 and has since been amended. By August 4, 1964 a proposal to establish a Water Resources Research Center at Minnesota was agreed upon by ad hoc committees, the Dean of the Graduate School and the Vice President for Academic Administration. Prof. William C. Walton was chosen as its Director and assumed his duties September 1, 1964.

The Center was first located in the ground floor of Pillsbury Hall on the University Campus. Prof. Walton held an academic appointment in the Department of Geology and Geophysics. In early years of his directorship he carried out research on streambed infiltration relationships with groundwater levels. The Center prospered under his direction and made a place for itself in the consciousness of people in the University, in the State Agencies dealing with water policy and in the national network of Water Resources Centers. He became widely known and respected for his writing and speeches and for his leadership in state government circles by people developing water resources policies.

Prof. Walton resigned as Director effective October 1, 1974 to become Executive Director of the Upper Mississippi River Basin Commission. In the ten years he was Director, the Center published 76 Bulletins pertaining to its research and public service activities. It moved from its quarters in Pillsbury Hall to an off-campus location in the Hubbard Building at 2675 University Avenue in St. Paul in 1968.

Dr. John J. Waelti of the Agricultural and Applied Economics Department was appointed Assistant Director of the Water Resources Research Center in November 1967. He became Acting Director in 1974 and served in that capacity for nearly five years. Dr. Waelti carried on an active research program over the years even while bearing the full weight of Center duties as Acting Director. It is significant that 70 of the Center's 76 Bulletins published during Prof. Walton's tenure were printed while Prof. Waelti was Assistant Director. As Acting Director he oversaw the publication of an additional 23 Center Bulletins. Prof. Waelti's contributions won the respect and gratitude of the Water Resources Community. He returned to the Department of Agricultural and Applied Economics on June 1, 1979.

Before he left the Center Bill Walton had written copy for a brochure to inform laymen of the nature of Minnesota's Water Resources. Prof. Waelti used it to begin a Public Report Series whose format is different than the Center's Bulletins. The series has attracted the attention of teachers and others who could use them for instructional purposes. The three reports in the series have been enthusiastically received.

I became Director of the Center on June 1, 1979 retaining an academic home in the Soil Science Department. In the four months since then I have leaned on John Waelti a good deal and have essentially carried out plans that he developed and scheduled. I have become aware of the respect and goodwill the Center enjoys from almost every quarter. The interest and support shown by Prof. Warren E. Ibele, Dean of the University of Minnesota Graduate School has been most gratifying. He has been helpful in every way in enabling me to assume the duties of the Center. The goodwill the Center enjoys has been manifest by research people throughout the State who have in the past, or who now cooperate on Center research projects. It has also come from State Agency personnel and from members of the Center's Advisory Committee. I shall have to exert every effort to see that this support and goodwill continue in the months and years ahead.

The Water Resources Research Center's office runs smoothly because of its efficient secretary, Elizabeth Espointour. She carries out many of the details of sending notices, putting together the Center's Newsletter, preparation of bulletin copy and many other things. She is well known by our principal investigators who call her about budgets, preparation of reports, and inquire about deadlines. She has worked with the Center's three Directors since she began in May 1972.

On July 1, 1979 the Center offices were returned to the Campus. They presently occupy rooms 864 and 866 in the Biological Sciences Center.

DIRECTOR'S SUMMARY STATEMENT, 1979

Minnesota had a substantial research, service and teaching effort in FY 1979. During the year the Center also undertook to determine publicly-perceived research needs and priorities.

On July 1, the Center Offices were moved to the Campus of the University of Minnesota in St. Paul.

Current Research

The Center had 12 active projects in FY 1979 emphasizing quality of both surface and groundwaters, public health aspects of groundwater pollution, irrigation, drainage, a trophic classification of lakes and social factors in resource development decisions.

Groundwater quality studies in southeastern and southwestern Minnesota A-035-Minn and A-038-Minn were carried out by C.P. Straub and R.D. Singer of the Department of Environmental Health. This study concentrated on sources and quality of potable waters in rural areas and small towns. The questions in southeastern Minnesota are complicated by a limestone, sinkhole topography.

In project A-036-Minn James A. Moore of the Department of Agricultural Engineering studied the effect of land spread septage on water quality at four sites. No significant alterations in soil and water quality were noted on two virgin land sites when 5.7 and 16.5 acre-inches of septage were added over a two-year period.

A study of the use of selected climatic measurements for predicting irrigation scheduling (A-037-Minn) was undertaken by E.R. Allred and Donald Slack of the Agricultural Engineering Department. Leaf-air temperature difference under sunlight and with shading showed good discrimination possibility for measuring degree of plant stress.

Prof. Hans Olaf Pfannkuch of the Geology and Geophysics Department has studied the effects of grain size and sorting on retention of hydrocarbons in A-041-Minn. Though he found that such simple lithologic parameters as mean grain size and sorting could only be used as first approximations, he also found that the results could be grouped into distinct fields according to lithologic principles.

Re-use of agricultural drainage waters for on-site soil water recharge and irrigation, A-042-Minn is a study undertaken by George R. Blake of the Soil Science Department. Experimental plots at Lamberton, Minnesota were irrigated and the parameters precipitation, soil water stored in the soil and evapotranspiration were monitored in the 1979 growing season.

A trophic classification of Minnesota lakes based on lake sediments by H.E. Wright of the Limnology Center in Geology and Geophysics was completed in 1979 (B-128-Minn). Results show that the diatom content of surface-sediments is correlated with lake-water chemistry and that the diatom assemblage is indicative of trophic status of a lake. But both the assemblage and

the chemistry were strongly affected by climate and by the bedrock and associated glacial drift. Thus the trophic status is strongly affected by factors other than man-made environmental effects.

Key social factors affecting water related resource development decisions is the title of B-131-Minn with Luther P. Gerlach of Anthropology as the Principal Investigator. It was found that people who organized for political or social action started from a position that emphasized principally either self interest or, as a representative of an established organization, general ecologic principles. Later in the dialogue most people combined both principle and self interest. There was increasing development and articulation of larger principles which led to a polarization of principles -- the principle of interdependence or systemic management on the one hand, and independence or localism on the other. A dominant reality for decision makers is conflict and they must learn how to manage it.

Prof. Walter Maier of the Civil and Mineral Engineering Department, in project B-139-Minn, entitled application of new methods for routine measurement of aquatic organics, found that total organic carbon concentrations increase as one leaves the river source regions, that these occur increasingly as molecular weight fractions, the majority being nominally between 1000 and 10,000. He has defined the composition, the functional group contents and the nature of the organics in some detail.

Measuring evapotranspiration is tedious and time consuming. Comparing measurements with empirical calculation methods has potential of time, energy and cost saving. That is the goal of B-147-Minn with Donald Baker and James Swan of the Soil Science Department as principal investigators. They use a lysimeter installation to compare measured values with other values derived either from pan evaporation or from calculations involving climatic variables like solar radiation, wind and saturation deficits.

The potential of naturally occurring zeolites for removing heavy metals from water (B-150-Minn) is a study by Michael J. Semmens of Civil and Mineral Engineering. The abundant, inexpensive clinoptilolite is effective in removing seven tested metals. The effectiveness of the zeolite with pH and with the presence of naturally occurring competing ion types has received considerable study.

Regional Cooperation

In FY 1979 University of Minnesota Agricultural Economist Vernon Eidman and Agronomist Craig Schaeffer were cooperators on a University of Illinois regional OWRT project (B-120-Ill) on efficient use of water for irrigation in the Upper Midwest. The need for economic input into irrigation decisions is most timely.

Service and Teaching Activities:

The Center distributed four of its research bulletins, each to a mailing list of about 300 people during FY 1979. In addition it sent out about 500 copies of previously published bulletins. Results of six current projects were reported at a public meeting which the Advisory Committee also attended.

The Public Report Series continued to be very popular with teachers, extension agents and others. The Primer on Limnology accounted for 1000 requests.

The Center publishes four newsletters per year that inform a large mailing list of the Center's activities, grant application dates, as well as news items of general interest.

The Center's Advisory Committee of 42 persons met once in 1979. This Committee consists of 17 members from the University of Minnesota, 5 members from State and Private Universities and Colleges, 8 members from State and local agencies, 6 from Federal agencies and 6 from public interest and private groups.

Major research needs and priorities can be classified into categories that include (1) groundwater, its location, inventory, pollution and recharge sources, (2) preservation of lake quality, urban runoff as pollutant, acidification, classification, (3) land and land use problems related to flood prevention, sediment and chemical pollution of public waters from both rural and urban sources, irrigation and drainage, water recharge, sludge disposal and (4) wetlands values, preservation and protection and land drainage policies related to them.

EXAMPLES OF SELECTED RESEARCH FINDINGS AND THEIR ACTUAL OR POTENTIAL APPLICATION TO WATER RESOURCES PROBLEMS

First Example

OWRT Project Number: B-122-Minn. Started July 1, 1975, completed September 30, 1978. Principal Investigator: C.L. Larson, University of Minnesota.

There has been considerable controversy between farmers who drain farmlands and the associated depressional wetlands, and environmentalists who insist that the wetlands are important buffers for downstream flooding and that wetlands are an essential part of the pollution control ecosystem. Prof. Larson's study addressed the flooding question.

Ian Moore and Curtis Larson applied their model to two small watersheds in southwestern Minnesota and found that drainage development increases annual runoff, storm runoff and peak discharge. The physical characteristics of the main watercourse in the watershed was the major factor influencing peak discharge at the watershed outlet. Examination of annual flood flows on the Minnesota river suggests that downstream effects of drainage development on large watersheds are much less than indicated by this study on small watersheds.

There is tremendous interest in and need for the data from this study by several state and federal agencies.

The Division of Waters, Minnesota DNR, has indicated that the project results will be very useful in establishing policies and regulations with respect to drainage and protection of public waters under chapters 105 and 106, respectively, of Minnesota Law. Past efforts have been hampered by the lack of knowledge on the hydrologic effects of drainage projects. Likewise, the Minnesota Water Planning Board has indicated an urgent need for the results of the project in the preparation of it's "Framework Water and Related Land Resources Plan for Minnesota", more specifically the section on flooding. It can use the information for a technical paper on "Flooding in Minnesota", now in preparation. Also, the Governor of Minnesota has asked the Water Planning Board to study the need for further legislation dealing with flood problems.

The Corps of Engineers (St. Paul District) is very interested in using the project findings in a current comprehensive study of flooding in the Red River Valley. The area has extensive surface drainage by ditches. Flooding occurs quite often over large areas and floods appear to have increased in frequency, if not in magnitude. The Corps is faced with questions about the role of drainage, as well as what can be done to relieve the problem. The construction of miles of unauthorized levees has made the problem more urgent. The U.S. Soil Conservation Service expects to use the project results to improve planning of watershed projects involving channel enlargement. If the magnitude of the effects are known, compensating measures can be utilized. The U.S. Fish and Wildlife Service is anxious for definitive information indicating a flood-retarding benefit from marsh areas to help justify their retention in their natural state.

Second Example

OWRT Project Number: A-034-Minn. Started July 1, 1976, completed September 30, 1978. Principal Investigator: A.C. Caldwell, University of Minnesota.

Environmentalists and health officials have centered considerable interest around the increasing use of chemical fertilizers, particularly N. This is because N in the NO_3 form is highly soluble in water and will move readily with water through soil. The movement of NO_3 with water into rivers and lakes could contribute to eutrophication and movement into aquifers which are used as sources of drinking water could be hazardous to human health. Once aquifers become polluted, they can remain in that state for extended periods of time.

The effect of fertilization and irrigation on the movement of nutrients beyond the reach of plant roots and ultimately into the aquifer was determined by controlling the amounts of water and nutrients applied to soil, and then measuring by sampling and analysis, the amounts of nutrients in the plants, soil, soil solution and aquifer. Fertilizer nutrients studied in this experiment were N, S and P, with major emphasis on N.

Nitrate analysis of the soil solution at 5 and 8 feet below the soil surface showed that in all four treatments (split and one time application of 160 and 240 lbs N/A), some N was moved below the rooting zone of corn. Split applications resulted in only minimal movement of N below the root zone and did not affect the concentration of N in the aquifer, but the one-time applications showed larger amounts of N moving below the root zone and increases in the N concentration of the N in the aquifer. Results from analysis of the soil solution for ^{15}N from 150 lb one-time N treatment plots showed that nearly 70 percent of the N passing below the rooting zone was derived from fertilizer, but with split applications less than 48 percent was of fertilizer origin.

Spring and fall analysis of the soil for NO_3 to a depth of 10 feet showed there was no accumulation of NO_3 in the soil profile or underlying material. Nitrate nitrogen levels above 5 ppm were not found at any depth in the soil in spring or fall.

Total plant yields harvested at physiological maturity were not affected by the different N treatments and were near 6.7 tons of dry matter per acre. Nitrogen analysis of the plant material showed there was a higher percent N in the plants receiving split applications of N.

Data from analysis of the plant material for ^{15}N showed that splitting the 160 lb N application, rather than applying it all at once, increased the percent N in the plant derived from fertilizer to 54.5 from 33 percent. Labeled N analysis of the plant material also showed that 52 percent of the fertilizer N was recovered by the plants when it was applied in small allotments through the growing season, and that only 30 percent was recovered when it was applied all at one time prior to planting.

Data from ^{15}N analysis on the total soil N from the 0-18 inch soil layer showed that nearly one fourth of the fertilizer N from the 160 lb treatments remained in the soil at harvest. Splitting the N into several allotments did not affect the amount of N remaining in the soil.

Sulfate sulfur concentrations in the soil solution below the rooting zone of corn increased during the growing season. There was a small increase in the SO_4 concentration in the ground water late in the season.

Reliable data on the concentration of PO_4 in the soil solution were not obtained, but no PO_4 was detected in the aquifer.

Third Example

OWRT Project No. B-128-Minn. Started October 1, 1976, proposed completion 1980. Principal Investigator: H.E. Wright, University of Minnesota.

Protection and management of its approximately 16,000 lakes is an important task for Minnesota, a caretaker for this nationally-important resource. There is need to recognize that these lakes vary widely in organization and structure. Some are deep and/or large, some are shallow or small. All are affected by the climate, particularly the ratio of precipitation to evaporation, by the nature of the surrounding soils and sediments and by other factors. They vary in quality for the various utility they have, such as recreation, wildlife, water storage or nutrient traps.

Prof. H.E. Wright has proposed a trophic classification of these lakes based on sediments. This or some other classification scheme is an essential first step toward a rational management of the lake resource.

Wright found that the diatom content of surface sediment samples in Minnesota lakes can be correlated with the lake-water chemistry, and that the diatom assemblage is indicative of the trophic status of a lake. A complicating factor is that lake water chemistry and the associated diatom assemblage varied across Minnesota raising the question of confounding the influence of climate and chemical makeup of the drift soil. Sampling on opposite sides of a border between calcareous and non-calcareous drift in a restricted area of relatively uniform climate showed indeed that nature of the drift soil had a dominant influence on the diatom assemblage.

Another approach used by Wright was to study the stratigraphic changes in the sediment of a single lake under the influence of long term changes in climate or in other hydrologic factors. These studies are continuing under other funding.

The results on the technique of characterizing the trophic status of lakes by sedimentary diatom analysis, especially recent changes in lakes caused by cultural eutrophication, have been utilized in various local studies in Minnesota concerned with identifying the source and timing of lake pollution and plans for lake improvement. The results on the long-range history of lakes and their relation to paleohydrology are being used

in studies of climatic history, especially in connection with the possible climatic effects of the increase in atmospheric CO_2 resulting from the burning of fossil fuels.

(A-040-Minn)

June 12, 1979

Dr. Margaret Preska
President
Mankato State University
Mankato, MN. 56001

President Preska:

Dr. Henry Quade from the Department of Biology at Mankato State University, has presented his study on drainage in Blue Earth County to the Board of Commissioners. We would like to commend Mankato State University and in particular, Dr. Quade, for this kind of cooperative effort in which significant public benefit results from shared academic/government interests.

Hopefully we can continue this cooperation in other areas and Dr. Quade's example can be followed by other departments.

Sincerely,

(S) Lester Anderson
Blue Earth County Board of Commissioners
Lester A. Anderson, Chairman of the Board

(B-131-Minn)

March 1, 1979

Dr. L.P. Gerlach
225 Ford Hall
Department of Anthropology
University of Minnesota
Minneapolis, MN. 55455

Dear Dr. Gerlach:

Thank you for providing us the opportunity to view the accompanying film, "Grassroots Energy." It exemplifies well many of the problems of the decisionmaking process in government and of the efforts of citizens to become part of that process.

The leverage concept in transmission line routing has been used quite effectively by utilities in obtaining right-of-way permits for crossing of Federal lands. Sensitivity to the other interests has come about largely through lawsuits and is reflected in more socially-oriented corridor planning studies such as those of the Bonneville Power Administration.

Your film is evidence of the energies that might have been used more efficiently in planning of corridors had those effected been involved in the process from the outset.

Sincerely yours,

(S) Frank T. Carlson
Senior Water Research Specialist
U.S. Department of the Interior
Office of Water Research & Technology
Washington, D.C. 20240

(A-031-Minn)

December 12, 1978

Mr. Richard Gardner
Water Resources Research Center
107 Hubbard Building
2675 University Ave.
St. Paul, MN. 55114

Dear Mr. Gardner:

In December of 1977 you sent bulletin 74 to Mapleton, Minn. on water and sewer rates from the towns in Minnesota. This information was a tremendous help in getting a better sewer and water rate.

Do you have any other additional data at this time? If you do would it be possible that you could send me the data.

Sincerely,

(S) Sid L. Clobes
507 - 2nd Ave. S.E.
Mapleton, MN. 56065

(Center Director's Office)

October 25, 1978

John J. Waelti
Water Resources Research Center
2675 University Avenue
St. Paul, MN. 55114

Dear John,

I am simply delighted to be able to give you information about the uses our organization has made of your Limnology Primer. It is exactly the sort of material we need more of - the translation into layperson's language of technical material.

At the October meeting of the Minnesota Environmental Education Board (MEEB), I mentioned our conversation, and passed a tablet around asking for documentation of members' uses of the Primer. The tablet returned with even more information than I anticipated, but I'm sure it is only part of the history of our use simply because all the users are not represented at the MEEB meeting.

I am mailing a letter from Harry Buck, the person I picked up the 100 copies for, just as he wrote it. Harry is in a very good position to speak for all of us, and he has worded it very well, I think.

Here is the information from the MEEB meeting. I hope it is useful to you.

Julia Copeland, Librarian of the Environmental Conservation Library (ECOL), says: "The Environmental Conservation Library (ECOL) uses this primer and similar reports frequently. The library sees considerable interest in introductory materials on Minnesotas' water problems. While we own many excellent technical reports and statistical documents, we have very few which are suitable for the layman. The use of funds to make research accessible to the public is a valid use, and an issue we have been interested in for some time."

Howard Teague, MEEB staff member at the Bemidji office, says that 125 copies were included in a packet of basic classroom resources for teachers in the Bemidji area. The packet dealt with the Lake Bemidji wastewater situation and also included a document entitled "A Classroom Guide to Understanding the Bemidji Wastewater Issue" authored by two BSU faculty members, Patrick Trihey and Robert Baker. The Arrowhead Regional Environmental Education Council (REEC) has included the Primer in a water quality packet, which will be sent to every junior high school in the region. It's purpose is to aid teachers interested in teaching about freshwater ecology and coastal zone management.

Karen Loechler, MEEB Executive Director, included the primer in the packet of materials distributed to 100 people attending the "All About Water" conference, sponsored by MEEB with E.P.A. funding, and held in New Brighton in September. The packets, with the Primer, went to teachers, farmers, youth group leaders and environmental volunteers.

Jody Halgren, member of the Environmental Education Council (REEC) in southwestern Minnesota says most of the 74 people attending a REEC water quality conference, "Lakes and Streams in southwest Minnesota -- a Matter of Their Lives and Deaths," took a copy of the primer from a resource table. They were local and county officials, teachers, park planners and lakeshore property owners.

Joanne Franke, Region 5 REEC member has made personal use of the Primer and has loaned it to many individuals including teachers. According to Kent Gustafson, 6E REEC and Pam Landers, Regional Coordinator at our Olivia office, the Primer was the basic resource for an ongoing water monitoring activity sponsored by the 6E REEC. It was mailed to 60 participants ahead of a first meeting in order to familiarize them with the basics of limnology. Those 60 represented virtually all the lakeshore property owners in Kandiyohi County, and it was the beginning of a lakeshore monitoring program co-sponsored with Willmar Community College and aided by the Freshwater Biological Institute.

Shirley Mueller, PCA coordinator for 208 Citizen Education, lists these uses: basic water quality information for all 208 regional water quality committee members; basic water quality information for teachers; a resource available at a variety of water quality workshops, conferences and meetings sponsored or co-sponsored by the PCA.

Thanks for the chance to help.

Sincerely,

(S) Carmen Borgerding
Regional Coordinator
Minnesota Environmental Education Council
2021 E. Hennepin Avenue
Minneapolis, MN. 55413

(A-036-Minn)

September 12, 1978

Dr. J.A. Moore
Minnesota Water Resources Research Center
University of Minnesota
St. Paul, Minnesota 55101

Dear Dr. Moore:

The work that you are doing on the land application of septage as reported in the "Water Research in Action" newsletter is of interest to me. We in the Soil Conservation Service advise landowners about the proper application of sludge and septage. In order to provide the best possible advice, we need all the research data that we can obtain.

Therefore, if you have any data and published reports on the results of land application that you could share with us, it would be most appreciated. Any information on the analysis of the septage as it comes from the tank would be appreciated too.

Sincerely,

(S) James N. Krider
Waste Management Specialist
U.S. Department of Agriculture
Soil Conservation Service
1974 Sproul Road
Broomall, Pennsylvania 19008

Coordination With Water Resource Agencies and Institutions

The Minnesota Water Resources Research Center coordinates water research in a number of ways. Through its Advisory Committee it meets officially with representatives of major State and Federal agencies as well as with private interest groups. University Departments with an interest in water research are also prominantly represented on that Committee.

In addition, there is a constant interchange of seminars and structured and unstructured conferences with people in the University and the governmental agencies.

Information Dissemination

In Fy 1979 the WRRC published two bulletins and four public drainage atlases:

Bulletin 99 by Ian Moore and Curtis L. Larson entitled "Effects of Drainage Projects on Surface Runoff from Small Depressional Watersheds in the North Central Region. January 1979.

Bulletin 100 by Joseph J. Latterell, Robinson S. Abbott, Thomas E. Straw, James B. Van Alstine and Charles F. Myette entitled "Eagle Lake Pollution Control Project: Assessment of Lake Improvement". June 1979.

Public Drainage Atlas, Blue Earth County Minnesota by Laverne Dunsmore and Henry W. Quade. April 1979.

Public Drainage Atlas, LeSueur County Minnesota by Laverne Dunsmore and Henry W. Quade. May 1979.

Public Drainage Atlas, Nicollet County Minnesota by Laverne Dunsmore and Henry W. Quade. June 1979.

Public Drainage Atlas, Brown County Minnesota by Laverne Dunsmore, Randy W. Oelerich and Henry W. Quade. June 1979.

In December 1978 the Center sponsored a public seminar to which the Advisory Committee was invited to hear research reports from six of its Principal Investigators from the University of Minnesota, as follows:

Prof. C.L. Larson, Department of Agricultural Engineering
Prof. L.P. Gerlach, Department of Anthropology
Prof. Michael J. Semmens, Department of Civil & Mineral Engineering
Prof. Donald J. Baker and Jon Ljungkull, Department of Soil Science
Prof. Hans-Olaf Pfannkuch, Department of Geology & Geophysics

Source of Funds

Fiscal Year	Center's Budget $	Fed.(OWRT)$	U of M $	St. Col. $	Private Col. $	Grad School U of M $
1965	84,564	52,297	7,474	0	0	24,793
1966	195,362	106,980	78,336	0	0	10,046
1967	214,767	113,333	92,567	0	0	8,867
1968	220,525	135,396	78,054	0	6,575	500
1969	262,819	166,508	91,944	0	3,867	500
1970	328,160	180,930	123,055	20,795	0	3,200
1971	338,872	192,846	109,022	29,493	4,011	3,500
1972	432,777	240,856	156,126	27,622	4,473	3,700
1973	373,672	199,256	151,835	14,813	4,268	3,500
1974	441,680	255,179	180,969	0	2,032	3,500
1975	378,584	229,636	145,448	0	0	3,500
1976	271,079	163,159	107,920	0	0	3,500
1977	340,910	177,441	163,468	0	0	3,500
1978	307,949	152,962	154,986	3,724	0	3,500
1979	320,922	176,575	144,347	2,232	0	3,500

WATER RESOURCES RESEARCH CENTER
Distribution of Research Monies

1974-1978 Inclusive

University Unit	Amount $	Percent of Total
College of Agriculture	165,683	23.98
Agricultural Engineering	79,713	
Agriculture & Applied Economics	12,145	
Entomology Fisheries and Wildlife	23,395	
Soil Science	50430	
College of Biological Sciences	14,406	2.08
Ecology and Behavioral Biology	14,406	
Limnology (see IT)		
College of Forestry	77,981	11.29
Forest Resources	77,981	
College of Liberal Arts	88,344	12.79
Anthropology	28,744	
Sociology	59,600	
Health Sciences	51,583	7.47
Public Health	51,583	
Institute of Techuology	237,807	34.42
Civil & Mineral Engineering	49,826	
Geology and Geophysics	35,692	
Limnology Center	110,927	
St. Anthony Falls Hydraulic Lab	41,362	
Gustavus Adolphus College	3,816	0.55
Mankato State University	10,000	1.45
University of Minnesota, Duluth	41,362	5.99
	690,982	

WATER RESOURCES RESEARCH CENTER
Distribution of Research Monies

University Unit	Amount $ FY 1977	FY 1978	FY 1979
College of Agriculture	46,645	41,778	37,743
Agricultural Engineering	25,005	32,278	17,681
Entomology, Fisheries and Wildlife	9,140		
Soil Science	12,500	9,500	20,062
College of Forestry	25,426		
Forest Resources	25,426		
College of Liberal Arts	24,158	15,238	14,788
Anthropology	13,507	15,238	14,788
Sociology	10,651		
Health Sciences	12,500	19,300	16,143
Public Health	12,500	19,300	16,143
Institute of Technology	13,614	25,147	49,587
Civil & Mineral Engineering		10,734	31,581
Geology and Geophysics			10,000
Limnology Center	13,614	4,413	8,006
St. Anthony Falls Hydraulic Lab		10,000	
Center Director's Office	7,157		
Mankato State University		10,000	10,000
	129,500	111,463	96,680

FISCAL YEAR 1979 OWRT BUDGET

Annual Allotment Program

Project Title, Principal Investigator and OWRT Project Number	Federal Funds $
Center Director's Office	41,000
Ground Water Quality in Southeastern Minnesota, C.P. Straub, School of Public Health, (A-035-Minn)	9,500
A Study of the Effect of Land Spread Septage on Water Quality in Minnesota, J.A. Moore, Dept. of Agricultural Engineering, (A-036-Minn)	9,500
A Study of the Use of Selected Climatic Measurements for Predicting Irrigation Scheduling, E.R. Allred, Department of Agricultural Engineering, (A-037-Minn)	10,000
Water Quality Studies: Southwestern Minnesota, C.P. Straub, School of Public Health, (A-038-Minn)	10,000
The Effects of County Drainage Ditches on Water Quality and Quantity in South Central Minnesota, H.W. Quade, Department of Biology, Mankato State University (A-040-Minn)	10,000
Hydrocarbon Spills, Their Retention in the Subsurface and Propagation to and into Shallow Aquifers, H.O. Pfannkuch, Dept. of Geology and Geophysics, (A-041-Minn)	10,000
Re-Use of Agricultural Drainage Waters for On-Site Soil Water Recharge and Irrigation, G.R. Blake, Soil Science Department, (A-042-Minn)	10,000
TOTAL	110,000
Annual Allotment Non-Federal Contribution	72,022

Matching Grant Program

Project Title, Principal Investigator and OWRT Project Number	Federal Funds $	Non-Fed. Funds $	Total Funds $
A Trophic Classification of Minnesota Lakes Based on Lake Sediments, H.E. Wright, Limnological Research Center (B-128-Minn)	11,975	13,250	25,225
Key Social Factors Affecting Water Related Resource Development Decisions, L.P. Gerlach, Dept. of Anthropology (B-131-Minn)	15,000	14,129	29,129
Application of New Methods for Routine Measurement of Aquatic Organics, W.J. Maier, Dept. of Experimental Engineering (B-139-Minn)	15,000	15,047	30,047
The Measurement of Evapotranspiration and Comparison with Empirical Calculation Methods for Use in Minnesota and Similar Climatic Regions, D.G. Baker, Dept. of Soil Science, (B-147-Minn)	11,800	14,997	26,797
A Study to Identify the Potential of Naturally Occurring Zeolites for Removing Heavy Metals from Water, M.J. Semmens, Dept. of Environmental Engineering, (B-150-Minn)	12,800	14,902	27,702
TOTAL	66,575	72,325	138,900

ANNUAL ALLOTMENT PROGRAM - NARRATIVE PROGRESS REPORTS

Annual Report -- Title I Projects

Form OW-1
(Rev. 6-77)

OWRT Project No.: A-035-Minn

Project Title: Ground Water Quality in Southeastern Minnesota

Agreement No.: 14-34-0001-9025

FCCSET (COWRR)Research Category: 05-B, 4

Name and Location of University Where Project is Being Carried Out: University of Minnesota, Minneapolis, Minnesota

Project Began: October 1, 1976 Scheduled Completion: September 30, 1979

Principal Investigator:	Degree	Discipline
Conrad P. Straub	Ph.D.	Environmental Health
Rexford D. Singer	M.S.	Environmental Health

Student Assistants:	Degree	Discipline or Academic Background
Michael Osterholm	M.S.	Environmental Health

(A) Research Project Accomplishments:

Since the initiation of the project, a study area in Fillmore County, Minnesota was selected and sanitary surveys were conducted on 46 farms and a state park in the area. A survey form was developed which included questions on sources of potable water for human and livestock consumption, type of construction and depth of water wells used, number and location of abandoned wells and sink holes on the farm, methods used for storage and/or application of agricultural chemicals and animal wastes, and desire to participate in the study. Well water on each of the 46 farms was analyzed for coliform bacteria and nitrate. Based on this information, 21 farms were selected for further study. The wells on these farms represent a cross-section of types of construction and aquifers penetrated in the area.

Several meetings were held with staff from the Analytical Services and Water Supply Sections of Minnesota Department of Health to identify the most appropriate parameters to be investigated and sampling procedures. Since February 1977, 16 routine water samples have been collected from each of the 21 farms and analyzed for 17 physical, chemical and biological parameters. In addition, five samples were collected from each farm following periods of surface water runoff. In August 1977, September 1978 and June 1979 water samples also were collected from two springs in the area and analyzed for the same parameters. At present, results of the physical, chemical, and biological parameters tested for each of the samples obtained are being analyzed with respect to well construction, time of sampling, and precipitation events.

(B) Publications:

None.

(C) Project Status:

The study will continue in progress until September 30, 1979 at which time a final report will be made.

(D) Application of Research Results:

In April 1977, the Legislative Commission on Minnesota Resources funded programs in the Minnesota Department of Health; College of Veterinary Medicine, University of Minnesota; U.S. Geological Survey; and Minnesota Geological Survey relating to ground water quality in southeastern Minnesota. The program was concluded in January, 1979 and results of our sanitary surveys and water tests have been and will continue to be used with the above organizations. Results are being used to complement continued information gathering of each organization.

(E) Work Remaining, and Progress Contemplated During Next Year:

Results of the tests of the periodic water samples are being statistically analyzed with computer assistance. The collection and chemical/physical/biological analysis of both routine and runoff samples has been completed. Results of these analyses should aid in determining the concentration, source and potential risk of various contaminants entering each of the aquifers used for domestic water supply.

OWRT Project No.: A-036-Minn

Agreement No.: 14-34-0001-9025

Project Title: A Study of the Effect of Land Spread Septage on Water Quality in Minnesota

FCCSET (COWRR) Research Category: V-B; 4

Name and Location of University Where Project is Being Carried Out: University of Minnesota, St. Paul, Minnesota

Project Began: October 1, 1976 Scheduled Completion: September 30, 1979

Principal Investigator:	Degree	Discipline
James A. Moore	Ph.D.	Agricultural Engineering

Student Assistants:	Degree	Discipline or Academic Background
Gerald Beehler	B.S.	Agricultural Engineering

(A) Research Project Accomplishments:

Work towards achievement of research objectives has been conducted in the laboratory and the field.

Characterization of Septage

Septage samples have been collected periodically since July, 1976. Sixty-five samples were collected from two haulers. Characterization of the septage was: total solids (0.02 - 14%); total volatile solids (0.009% - 5.4%); pH (5.5 - 7.8); COD (700 - 80,000 mg/l); NH_3-N (7 - 300 mg/l); TKN (65 - 2800 mg/l); conductivity (430 - 60,000 µmhos/cm); fecal coliforms (1.4×10^3 - 2×10^7 cells/100 ml).

Large variations were observed among samples. Evidence indicates a difference between the septage of the two areas. The septage from the Brainerd area was consistently lower in examined chemical parameters than the septage from the White Bear Lake area. Pumping techniques, frequency of pumping, the nature of the septic tank system, and geographical considerations may account for the differences.

Field Plots in Cass and Crow Wing Counties

Test plots involved in the septage spreading project can be divided into actual spreading sites (Baxter, Pine River, Witt) and slug loaded experimental plots (Merrifield and Cross Lake).

Actual Practice Plots: Virgin land sites were previously identified and septage spread intermittently to mimic actual practice conditions. Loading rates varied among the plots due to variation in needs and geographical distribution of the hauler's customers. Records of the amount of septage actually spread were used to estimate the amount of nitrogen applied to each test plot. On two sites (Baxter) approximately 99,400 and 132,000 gallons have been applied on 0.367 and 0.293 acres respectively,

SEPTAGE CHARCTERISTICS, JULY 1976 - AUGUST 1979

Brainerd Area Septage[1]

Parameters	Range	Mean
% TS	0.02 - 13.62	1.86
% TVS	0.009 - 3.81	0.68
pH	6.1 - 7.8	7.2
COD mg/l	1100 - 57,600	16,100
NH_3-H mg/l	6.8 - 310	112
TKN mg/l	70 - 3000	470
Conductivity µmhos/cm	950 - 6800	2180
Fecal Coliform/ 100 ml	1.4×10^5 - 1.2×10^6	8.5×10^5

White Bear Lake Area Septage[2]

Parameters	Range	Mean
% TS	0.16 - 13.71	4.31
% TVS	0.03 - 5.47	2.45
pH	5.5 - 7.3	6.6
COD mg/l	720 - 82,000	32,600
NH_3-N mg/l	27 - 300	136
TKN mg/l	65 - 2760	948
Conductivity µmhos/cm	430 - 60,000	6290
Fecal Coliform/ 100 ml	9.5×10^5 - 2.0×10^7	6.5×10^6

[1] 32 samples, not all tested for all parameters

[2] 33 samples, not all tested for all parameters

over a two year period (1977 and 1978). These quantities are equivalent to 5.7 and 16.5 acre-inches of septage or a two year application of 612 and 1770 pounds N/acre, respectively. No significant change has been noted in groundwater nitrate levels to date, nor has there been any fecal coliform contamination of groundwater detected, except in an isolated incident due to an accidental application of septage over a monitoring well.

Slug Loaded Plots: Three experimental plots were spread during the winter and summer at projected loading rates of 50 and 200 lbs. N/acre. Slug loads were utilized to maximize the hydraulic load and pollution potential of the septage spread. No significant alterations in soil and water quality has been noted to date. In an attempt to establish maximum safe loading rates for the land spreading of septage an additional project was initiated at the Merrifield sites. Two thousand gallons of septage is applied twice weekly to an experimental plot of approximately 500 square feet; an equivalent of approximately 12 inches per week. Groundwater wells and lysimeters are monitored weekly to detect any nitrate contamination or microbial penetration of the groundwater.

(B) Publications:

J.A. Moore. "Land Spreading Impacts." Water Research in Action. July/August, 1978. Texas A&M, College Station, Texas.

(C) Project Status:

A final report is being drafted and will be submitted to Water Resources Research Center. This project ends with this fiscal year.

(D) Application of Research Results:

The Minnesota On-Site Sewage Treatment Contractors Association has indicated an interest in utilizing the results to maximize the nutrients and minimize pollution potential. The Minnesota Pollution Control Agency has expressed an interest in utilizing the results to draft state guidelines relating to the spreading of septage slurries.

(E) Work Remaining, and Progress Contemplated During Next Year:

The effects of the land spreading of domestic septage on ground water quality and microbial populations will continue until the fall of 1979. A final report will be prepared and submitted at that time.

OWRT Project No.: A-037-Minn

Agreement No.: 14-34-0001-9025

Project Title: A Study of the Use of Selected Climatic Measurements for Predicting Irrigation Scheduling

FCCSET (COWRR) Research Category: 02-D, 02-I; 06-D; 1

Name and Location of University Where Project is Being Carried Out: University of Minnesota, St. Paul, Minnesota

Project Began: October 1, 1977 Scheduled Completion: September 30, 1980

Principal Investigators:	Degree	Discipline
E. R. Allred	M.S.	Agricultural Engineering
Donald Slack	Ph.D.	Agricultural Engineering

Student Assistants:	Degree	Discipline or academic background
Francis I. Idike	M.S.	Agricultural Engineering
Kurt M. Geiser	B.S.	Agricultural Engineering
Kenneth W. Stange	B.S.	Agricultural Engineering

(A) Research Project Accomplishments:

Efforts during FY 1979 have concentrated on analysis of data from the 1978 growing season and with the planning and conduction of the 1979 fieldwork. Results obtained from 1978 data analyses indicated that leaf-air temperature difference was so highly dependent upon net radiation that the temperature difference by itself appears not to be a reliable indicator of crop stress. However, on the basis of existing data it appears that for given levels of net radiation relatively strong correlations exist between crop moisture stress and the air-leaf temperature difference.

Because of continuously changing conditions of radiation, temperature and wind speed, two infrared thermometers were used in 1978 as a means of obtaining simultaneous readings of these phenomena. Problems of adjustment between the two thermometers, to obtain common base readings, led to a redesign of field techniques to allow the future use of a single instrument for such readings.

Based on 1978 data analyses, it was concluded that an existing indicator of crop moisture stress should be used as a basis of comparison with air-leaf temerature differences. Toward this end field data were also obtained during the 1979 growing season on xylem water potential within the plant and the leaf stomatal diffusion resistance. Xylem water potential measurements were made by means of a Scholander-type pressure bomb. Stomatal diffusion resistance of the leaves was determined by a diffusion resistance porometer. Use of such instruments was obtained by loan from other projects within the University of Minnesota.

During the 1979 growing season, data were collected on corn plots subjected to irrigation treatments of one-inch every five days, no irrigation,

and irrigation of sufficient amount to avoid severe wilting. Data collected included net radiation, wind speed, dry and wet bulb temperatures, incoming long-wave radiation, soil moisture, leaf-air temperature difference, xylem water potential and stomatal diffusion resistance. It was noted from these data that when shading occurred on a well watered crop significant and rapid changes occurred in the canopy temperature, whereas similar shading of the crop under severe moisture stress caused negligible change in canopy temperature relative to air temperature. This phenomena was pursued further and showed significant promise of providing a reasonable and simple method of evaluating the degree of plant stress.

(B) Publications:

Grannes, Steven, D.C. Slack and E.R. Allred "Use of the Infrared Thermometer for Air Temperature Measurement", presented at the Winter Meeting of the American Society of Agricultural Engineers, Chicago, Illinois, December 1978. Copies of paper available for general distribution.

A masters thesis is currently being written based on the FY 1978 data.

(C) Project Status:

Project is presently at the end of the second year of a three-year study. Work to be continued, with some refinements, during the next fiscal year.

(D) Application of Research Results:

Principal interest in the results obtained in the study thus far has been expressed by the Barnes Engineering Co., Stamford, Connecticut; professional workers in the Water Conservation Laboratory (USDA), Phoenix, Arizona, and by various U.S. Agricultural Experiment Station personnel.

One of the major applications of this study is the development of a possible method to determine when crops should be irrigated. Some interest has also been expressed in using the method of air-leaf temperature differences to evaluate crop moisture stress conditions resulting from high weed populations.

(E) Work Remaining and Progress Contemplated During FY 1980:

Field work during FY 1980 will be structured on the basis of procedures developed and data obtained during the first two years of the project. Rainfall during most of the 1979 growing season was considerably above normal and occurrence such that relatively few stress periods were obtained. Thus, the form of the relationships between leaf-air temperature difference, stomatal resistance and xylem potential was inadequately defined. Greenhouse space has been secured for use during fall and winter of 1979-1980 to conduct research on defining such relationships over a full range of moisture stress conditions. In addition, the effect of shading on leaf-air temperature difference at varying levels of stress will be investigated in greater detail.

Results of the greenhouse studies, together with the field data obtained during previous years, will be used to develop criteria for scheduling irrigation on corn during the 1980 growing season. Data similar in nature to that taken during the 1979 season will be taken during the greenhouse portion of the experiment.

The FY 1979 and FY 1980 funding is providing support and thesis material for an additional M.S. student. Also the effect of shading on leaf-air temperature difference is the subject of a Plan B paper for a Masters of Engineering student.

OWRT Project No.: A-038-Minn

Project Title: Water Quality Studies: Southwestern Minnesota

Agreement No.: 14-34-0001-9025

FCCSET (COWRR) Research Category: 07-B; 8, 13

Name and Location of University Where Project is Being Carried Out: University of Minnesota, Minneapolis, Minnesota

Project Began: October 1, 1977 Scheduled Completion: September 30, 1980

Principal Investigator:	Degree	Discipline
Conrad P. Straub	Ph.D.	Environmental Health
Rexford D. Singer	M.S.	Environmental Health

Student Assistants:	Degree	Discipline or Academic Background
Jack Sahl	B.S.	Biology
Kolade Mosuro	M.S.	Environmental Health
Winthrop Watts	M.S.	Clinical Microbiology & Environmental Health

(A) Research Project Accomplishments:

The sampling program covering all wells in several communities in Nobles, Rock, and Pipestone counties initiated in April 1978 was continued. In addition, several nearby surface waters (rivers and ponds) were also sampled to compare water quality characteristics with ground waters nearby. One individual water supply was also sampled. During the past year, thirteen series of samples were collected and analyzed. Individual well samples are being collected from municipal water supplies serving the cities of Adrian, Luverne, Edgerton, Hardwick, and Leota. Analyses performed include nitrate-nitrogen (a chemical agent identified in the primary standards, Safe Drinking Water Act), sulfate, chloride, total dissolved solids, and conductivity. We have also begun to analyzed the samples for bicarbonate ions and pH as well. Approximately 40 to 45 samples are included in each sample collection series.

All the data have been tabulated and ratios of SO_4/NO_3-N, SO_4/Cl, and Cl/NO_3-N calculated. The SO_4/Cl ratios are much more consistent than are either of the other two ratios, but that is expected in part since the nitrate-nitrogen levels are believed to fluctuate as a result of agricultural and other activities extant in the areas under study.

A special study was conducted in one of the wells in Adrian which showed a high nitrate-nitrogen level and is no longer used as a source of water supply to note the effect of continuous pumping with lowering of the static water level on nitrate-nitrogen concentrations.

Some special analyses for iron and manganese were also performed at the request of one of the water works superintendents in these communities.

(B) Publications:

None.

(C) Project Status:

We intend to continue sample collection at least through the spring of 1980 to note changes in anion levels, particularly nitrate-nitrogen in these water sources. Along with the collection of data on current levels of selected chemical constituents in these waters, we are also collecting data from literature references to note changes in water quality that have occurred in these areas since about 1900.

(D) Application of Research Results:

The individual communities are informed of our analytical results as soon as these results are available. These results (particularly nitrate-nitrogen levels) have been used by one community to voluntarily close down one well from their water supply system to reduce nitrate-nitrogen levels to acceptable levels (to meet the primary Drinking Water Standards). Through a newspaper release, the townspeople were notified that their supply exceeded the permissible concentrations and that families with young infants under three months of age should find other sources of potable water for preparation of infant formulas. This announcement was made jointly by the City and the State Health Department. We provided the data.

Continued data collection through the second growing and harvest season will indicate the role of agricultural practices on nitrate-nitrogen levels in the ground water sources analyzed.

As a result of our contact with the water superintendents in these communities, we have been able to provide other information to them and have run some special analyses.

As a collateral project, we have saved composite samples of particular groups of samples for organic chemical identification hopefully being able to identify levels of pesticides and possible other organics in these waters, again contributed primarily through agricultural practices.

As a result of differences in analytical results reported by a commercial testing laboratory, we split samples with them and they confirmed our results admitting their earlier results were in error. Because of difficulties in analyzing for nitrate-nitrogen with methodologies they were using, they adopted our methods recognizing that our procedures were more costly, time-consuming, but certainly more accurate.

(E) Work Remaining and Progress Contemplated During Next Year:

The analyses of the community water supplies currently being examined will continue to provide information on the seasonal variations in concentrations of the anionic components in the water. These levels will be compared to those currently available to note changes in seasonal variations, land use practices, climatic conditions (rainfall, ground water elevations), etc.

The calculated ratios will be studied carefully to identify comparable aquifers.

The influence of surface water quality (rivers and ponds) adjacent to the well sites will be evaluated to determine their possible effect on ground water quality.

OWRT Project No.: A-040-Minn

Project Title: The Effects of County Drainage Ditches on Water Quality and Quantity in South Central Minnesota

Agreement No.: 14-34-0001-9025

FCCSET (COWRR) Research Category: 05-C, 05-A; 4

Name and Location of University Where Project is Being Carried out: Mankato State University, Mankato, Minnesota

Project Began: October 1, 1977 Scheduled Competion: September 30, 1980

Principal Investigator:	Degree	Discipline
Henry W. Quade	Ph.D.	Biology

Student Assistants:	Degree	Discipline or Academic Background
Kevin King	B.S.	Biology, Pre-Law
Laverne Dunsmore	M.S.	Biology, Botany
Ainars Gilis	B.S.	Biology, Math
Sharlene Quiring	Undergrad	Biology
Kris Princin	Undergrad	Biology
Kent Boyum	B.S.	Biology, Limnology
Clay Pierce	Undergrad	Biology, Limnology
Bill Thompson	B.S.	Biology, Limnology

(A) Research Project Accomplishments:

All background research as to extent of drainage for the four study counties has been completed. Two have been published and two are in press. The investigation of the legal and historic aspects of drainage in Minnesota is completed and will be sent to press shortly.

An investigation of the quantitative geomorphology of the drainage schemes in the four county area is in the final interpretive stages. Eighteen parameters were determined for 264 ditches and have been statistically treated by computer analysis.

Water quality sampling and flow measurements have been collected weekly since spring thaw at 18 sites within the four county area. These include drainage ditches and natural streams. This sampling will continue until late fall of 1979.

(B) Publications:

Quade, Henry W., 1978, County Drainage Ditches in South Central Minnesota: A Unique Riparian Ecosystem in Johnson, R. Roy, and J. Frank McCormick, tech. coord. 1978. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Proc. symp. Dec. 11-13, 1978, Callaway Gardens, GA. Gen. Tech. Rep. WO-12, Forest SErv., U.S. Dept. of Agric., Wash. D.C. 410 pp.

Dunsmore, L. and H.W. Quade, 1979, Public Drainage Atlas, Blue Earth County, Minnesota, Limnological Contribution Number 6, Department of Biology, Mankato State University, 69 pp.

Dunsmore, L. and H.W. Quade, 1979, Public Drainage Atlas, LeSueur County, Minnesota, Limnological Contribution Number 7, Department of Biology, Mankato State University, 61 pp.

(C) Project Status:

This project will continue in progress in the next fiscal year.

(D) Application of Research Results:

The completed portion of this project, the drainage atlases, have been used by County Commissioners, The Minnesota Pollution Control Agency in 209 Planning, the State of Minnesota Water Plan, Region 9 Development Commission, the Minnesota Department of Natural Resources, the U.S. Army Corps of Engineers, and the Minnesota Legislative Commission on Natural Resources. Results of this project will have major impacts on the 209 plans for Minnesota as well as the new State Water Plan.

(E) Work Remaining, and Progress Contemplated During Next Year:

During the next fiscal year, statistical analysis of water quality and flow data presently being collected will be undertaken along with modeling of the surface drainage for the four counties.

OWRT Project No.: A-041-Minn

Agreement No: 14-34-0001-9025

Project Title: Hydrocarbon Spills, their Retention in the Subsurface and Propagation to and into Shallow Aquifers

FCCSET (COWRR) Research Category: V-B

Name and Location of University Where Project is Being Carried Out: University of Minnesota, Minneapolis, Minnesota

Project Began: October 1, 1978 Scheduled Completion: September 30, 1981

Principal Investigator:	Degree	Discipline
Hans Olaf Pfannkuch	Ph.D.	Geology and Geophysics

Student Assistants:	Degree	Discipline or academic Background
Michael P. Convery	B.S.	Geology
Valerie A. Eames	B.A.	Geology
Gary B. Cohen	B.A.	Geology
Janet Smith	Undergrad	Geology

(A) Research Project Accomplishments:

Retention capacities of different glacial drift materials and synthetic sand packs were investigated for different saturation conditions. A wide range of field samples from SE Minnesota were used in column experiments. They included outwash, alluvium, different types of tills, weathered till and loess; all typical for this part of Minnesota, but also representative of drift lithologies in areas of central and south western parts of the state. The saturation conditions for the 18 column experiments performed were to simulate total oil saturation of a dry soil with subsequent drainage. Retention capacities ranged from low for the alluvium and outwash to high for the loess. The old gray till showed a large range of variations. The results are shown on two diagrams (Figure 53) taken from a M.S. Thesis prepared under this project, (Convery 1979). The results show that simple lithologic parameters such as mean grain size and sorting (standard deviation) can only be used as first approximations to describe systematic variations of retention capacities in complex natural porous media. The experimental results show nevertheless that results can be grouped and represented according to general lithologic principles and that they will plot in distinct fields. This information is usefull for spill retention estimates when only a general lithologic description is available.

A more systematic study of idealized sand packs (Ottawa) were carried out to reduce the number of variables and to better control the parameters. A generalized equation was developed on the basis of the experiments to estimate primary oil retention. It is

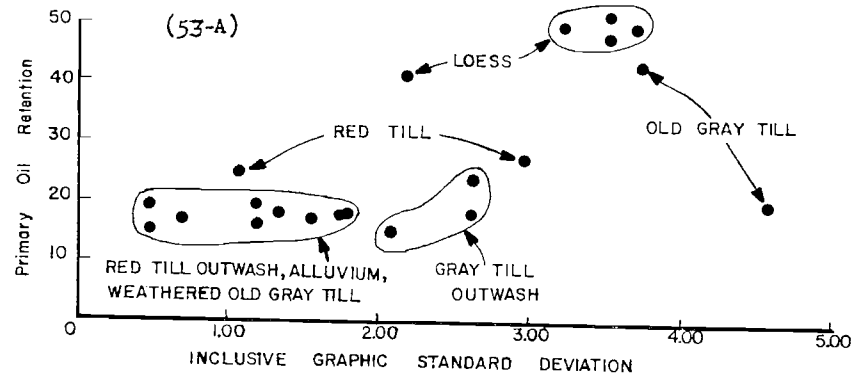
$$PR = 6.33\ (MG_{mm})^{-3/4}\ e^{0.8133^{G}g}$$

where PR : primary retention in % of pore volume

MG_{mm} : mean grain size in mm

e : base of natural logarithums

G : inclusive graphic standard deviation



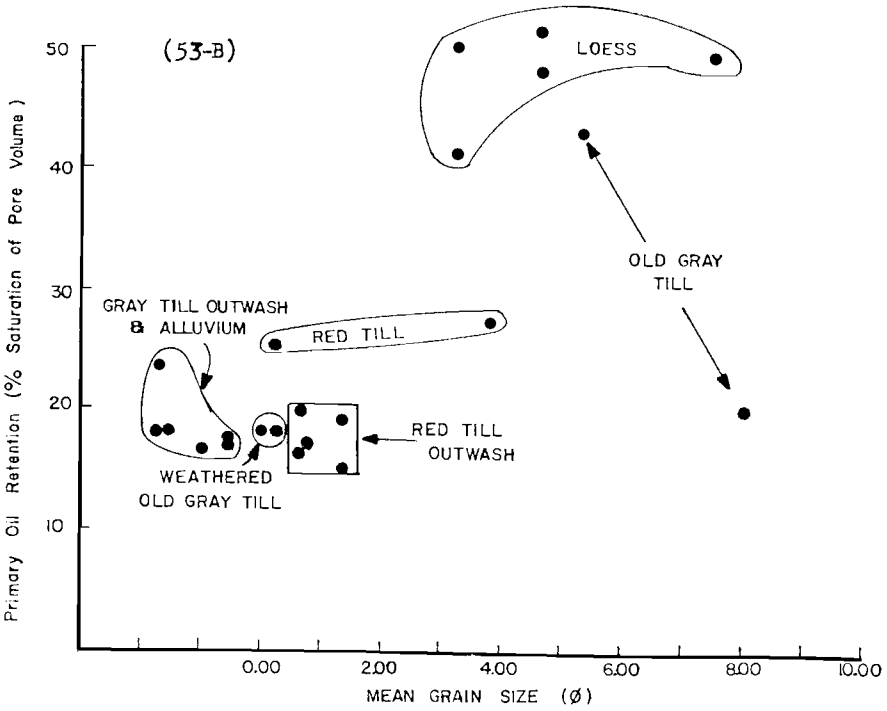


Figure 53: Primary Oil Retention of field samples from southeastern Minnesota plotted against mean grain size and inclusive graphic standard deviation.

From Convery, 1979.

The applicability of this equation is for fairly well sorted and coarser than fine sands. This result not only constitutes a refinement of previous work, but is totally new.

A similar set of test runs is under way for conditions of a 100% original water saturation of the sand before oil infiltration takes place. This work will be continued into the next fiscal year. Preliminary results on ideal single size grain packs seem to indicate a higher total liquid saturation (oil and water) and a higher partial oil saturation than for corresponding grain size packs of dry initial conditions, (20% vs 11%).

Methodology and instrumentation has been developed and implemented to study mechanical dispersion and adsorption of dissolved hydrocarbons in sand packs. Initial runs on ideal (Ottawa quartz sand) and coarse grained local sands with such compounds as phenols showed little difference with conservative tracers such as NaCl. But the situation is expected to change when more complex, especially clay containing proous media are used.

2-D, simulation runs on digital models of mass transport of the dissolved phase have been carried out using a finite element method. The main results are that in tight tills the most significant mass transport mechanism is by diffusion, whereas in outwash sands dispersion becomes the predominant phenomenon.

(B) Publications:

H.O. Pfannkuch and M.P. Convery, "On Oil Spill Propagation Mechanisms and Retention Coefficients in Glaciated Terranes - With Special Attention to Pipeline Routing Criteria", pp 26. Presented at Water Resources Research Center Advisory Committee Research Review Session, December 6, 1978, University of Minnesota, St. Paul, MN.

M.P. Convery, "The Behavior and Movement of Petroleum Products in Unconsolidated Surficial Deposits", M.S. Thesis, Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN. 1979.

A number of abstracts and manuscripts based on this thesis and project work are in preparation.

(C) Project Status:

The project completed its first year and will continue for another two years.

(D) Application of Research Results:

Results will be disseminated to Minnesota Pollution Control Agency, Spills Section (John Aho); EPA - Industrial Environmental Research Lab, Oil and Hazardous Materials Spills Branch, Edison, N.J., John Farlow (Chief Oil Spills Staff); American Wildlife Federation; American Petroleum Institute (T. Nanney).

Results will be used to design plans to contain spills and organize monitoring plans for actual spill situations. They will give some basic information and material parameters for state agencies to base policy formulations as far as pipeline routing, construction and surveillance is concerned.

(E) Work Remaining and Progress Contemplated During Next Year:

The project work remaining to be done is to measure ultimate retention capacity of field samples at different initial water saturations, to extend the empirical equation given in A to include terms containing water saturation, to observe spreading of oil in the capillary fringe and to investigate mechanical dispersion and adsorption of some critical dissolved hydrocarbon compounds for different types of porous media.

Next years work will concentrate on ultimate retention capacity determinations and mechanical dispersion of hydrocarbons in a groundwater flow field.

OWRT Project No.: A-042-Minn

Agreement No.: 14-34-0001-9025

Project Title: Re-Use of Agricultural Drainage Waters for on-site Soil Water Recharge and Irrigation

FCCSET (COWRR) Research Category: 3-F

Name and Location of University Where Project is Being Carried out: University of Minnesota, St. Paul, Minnesota

Project Began: October 1, 1977

Scheduled Completion: September 30, 1980

Principal Investigator:	Degree	Discipline
George R. Blake	Ph.D.	Soil Science

Student Assistants:	Degree	Discipline or Academic Background
B.S. Johnson	B.A.	Biology
Mark Parenteau	Undergrad	Biochemistry

(A) Research Project Accomplishments:

Virtually every year in Western Minnesota precipitation is insufficient to meet crop requirements from early July through August. As a result, soil water reserves are depleted to make up for the deficit. Lamberton, Minnesota, the site of this project, normally experiences a drawdown of 4 inches of its soil water reserve from June to August. In addition to this problem, soils in the western part of the corn belt are rarely completely recharged with water at planting time. For example, 6 to 8 inches of plant available water is usually present at planting time as opposed to 8 to 12 inches of available water present in a 5 ft. soil profile at field capacity.

The objective of this research is to monitor the amount of available water stored in the soil profile to determine when and to what extent a deficiency of the available water exists. The upper limit of plant-available water beyond which leaching losses due to irrigation would result, will be established also. By observing changes in the amount of available water present and measuring crop response to various irrigation treatments, an effective schedule of application for water recharge of the soil can be determined.

A surface reservoir for water has been established by Dr. W. W. Nelson at the Lamberton Agricultural Experiment Station of the University of Minnesota. The reservoir contains normal surface runoff and water from drain tile. Experimental plots have been established near the reservoir and were planted to corn in 1979.

Irrigation equipment was procurred and assembled. A 5 h.p. electric motor and pump assembly with a 3 in. x 30 ft. suction line, water meter, and brass gate valve are located at the reservoir. Water is conveyed from the reservoir to the experimental plots by 1500 feet of 4 inch PVC plastic pipe buried in the soil. Water is applied to the experimental plots with over-

head sprinklers, one such sprinkler located at all four corners of each plot receiving irrigation water.

The irrigation treatments in each of four replicates are as follows:

1. Check, no supplemental water.
2. One inch of water at planting time if needed.
3. Four inches, one time only when 4 feet profile is 50% depleted.
4. Four inches as 2 weekly applications of 2 inches each.
5. Like (3) except 1.25 inches water each week for 3 weeks beginning at 50% depletion.
6. Optimum irrigation. Irrigate about 1 inch whenever 30% depletion exists for full season.

Soil water content has been measured at weekly intervals throughout the 1979 growing season. Using a neutron probe, volumetric water content was measured at 1 ft. increments in a 5 ft. profile. By converting volumetric water content to inches/ft. of water, available water can be tabulated using moisture release data. Interpretation of this data awaits field calibration of the probe. Tensiometers have also been installed at each neutron site to enable a more complete assessment of the soil water status during the growing season.

A preliminary investigation of the change in plant available water during the present season was carried out using accumulative precipitation, evapotranspiration and runoff data. Precipitation has been measured on a daily basis with a recording rain gage at the site of the experimental plots. Evapotranspiration was calculated from evaporation pan data and runoff was estimated using average monthly runoff values for the Cottonwood River.

Figure 1 depicts graphically the course of the amount of available water present in the soil during the season. The change in available water is equal to precipitation (input) minus evapotranspiration minus runoff. As indicated earlier, evapotranspiration plus runoff usually exceed percipitation by 4 inches during the 3 month period from June to August. However, during the 100 day period represented in fig. 1, the available water was depleted by a mere 1.5 inches. The observed discrepancy of 2.5 inches can be attributed to precipitation which was 4 inches above normal for the period and cool temperatures. Obviously, 1979 has not been representative with respect to the rainfall of southwestern Minnesota. The full impact of these conditions will not be realized until the corn is harvested and yield determinations can be made. It is anticipated that crop response to irrigation will be less than normally expected. Certain irrigation treatments may even prove to be detrimental to the corn crop due to excessive amounts of water.

(B) Publications:

None.

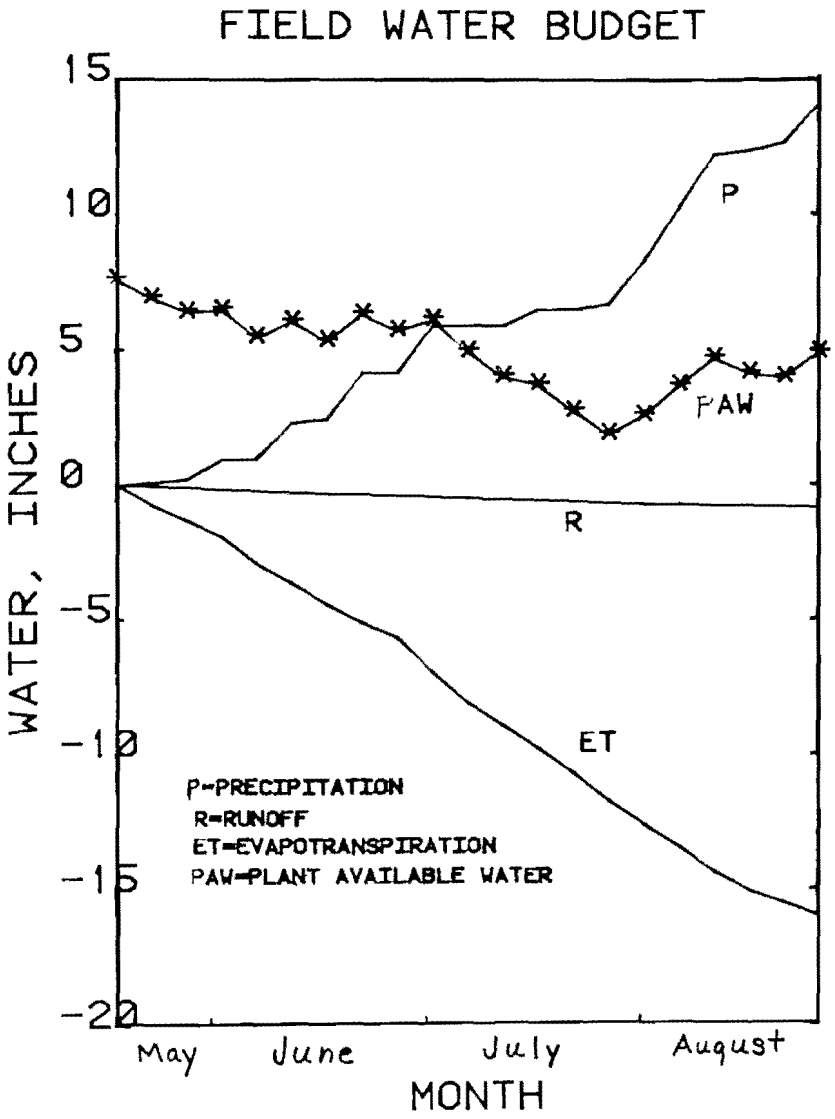


Fig. 1

(C) Project Status:

The project will continue during the 1980 fiscal year.

(D) Application of Research Results:

Research results will be used by farmers wherever soil types, slope and topography allow the impoundment of water for midseason application to crops. Of course, regional climatic conditions must dictate a need for soil water recharge. Farmers in those regions where fine textured soils are found and where moisture stress is commonly experienced during the growing season will be interested in these results.

(E) Work Remaining and Progress Contemplated During Next Year:

The remainder of the present year will be devoted to activities such as field calibration of the neutron probe. Additional soil samples will be brought to the laboratory where texture and moisture release can be established. Finally, the grain yield with respect to the various irrigation treatments will be measured.

Improvements in the irrigation equipment layout will be made in 1980. Alternation of the equipment layout may be necessary so that the rate of water delivery to the plots can be increased.

Annual Report -- Title I Projects

Form OW-1
(Rev. 6-77)

OWRT Project No.: B-128-Minn

Project Title: A Trophic Classification of Minnesota Lakes Based on Lake Sediments

Agreement No.: 14-34-0001-7164

FCCSET (COWRR) Research Category: 05-A; 4

Name and Location of University Where Project is Being Carried Out: University of Minnesota, Minneapolis, Minnesota

Project Began: October 1, 1976 Scheduled Completion: September 30, 1979

Principal Investigator:	Degree	Discipline
H.E. Wright	Ph.D.	Limnology

Student Assistants:	Degree	Discipline or Academic Background
None		

(A) Research Project Accomplishments:

Earlier work reported on this project indicates that the diatom content of surface-sediment samples in Minnesota lakes can be correlated with the lake-water chemistry, and that the diatom assemblage is indicative of trophic status of a lake. Thus the lake-water chemistry and the associated diatom assemblages show strong variations across the State from northeast to southwest. This gradient is similar to the change from relatively cool, humid climate to relatively dry climate characterized by warm summers, and a case can be made that the gradient in lake-water chemistry reflects only the climatic gradient. On the other hand, the bedrock and associated glacial drift in the northeast is non-calcareous, whereas in the west and south calcareous glacial drift prevails. It is therefore possible that the westward change in water chemistry has a geological rather than a climatic cause. To resolve this problem, 28 lakes on opposite sides of the border between calcareous and non-calcareous drift in a restricted area of relatively uniform climate were sampled. The water chemistry shows significantly higher levels for conductivity and calcium content for the lakes in calcareous drift, and the diatom assemblage in the surface mud samples of these lakes are different from those in the lakes in non-calcareous drift.

Another approach to the problem of lake classification by diatom analysis is to study stratigraphic changes in the sediment of a single lake under the influence of changes in climate or in other hydrologic factors. A stratigraphic study of a core from Kirchner Marsh in southeastern Minnesota was made with this objective, for previous investigations of pollen, seeds, and sedimentary pigments at this site had shown that the climate had changed from the early postglacial condition supporting a spruce forest in the area to the mid-postglacial regime with prairie on the upland, then reverting to the present condition favoring oak woods. The diatom stratigraphy indicates that the lake started out as a deep oligotrophic lake similar to those of northeastern Minnesota today, and that it gradually

changed to a shallow lake during the midpostglacial dry prairie period. The shallowing was a response to in-filling of sediment as well as to the lower water level resulting from decreased rainfall, and the lake was ultimately converted to a marsh. The diatom stratigraphy is now being investigated for other lakes in southeastern Minnesota that did not become excessively shallow by in-filling, so that the full effect of the mid-postglacial period of dryness and the subsequent modern wetter interval can be further examined. The stratigraphic work is supported in part by a grant from the National Science Foundation, for which the OWRT project provided an excellent foundation.

(B) Publications:

Brugam, R.B. 1979. A re-evaluation of the A/C index as an indicator of lake trophic status. Fresh Water Biology (in press).

Brugam, R.B. 1979. Toward a quantitative paleolimnology: the diatom record of human disturbance in Minnesota lakes (Submitted for publication).

Brugam, R.B. 1979. Postglacial diatom stratigraphy of Kirchner Marsh, Minnesota. Quaternary Research (in press).

Allott, Norman. Recent paleolimnology of Twin Lake near St. Paul, Minnesota, based on a transect of cores. Univ. Minnesota, M.S. Thesis, 102 p. Under revision for publication.

Brugam, R.B. and Speziale, B.J. 1979. The pololimnological documentation of cultural eutrophication using modern analogues of down-core fossil assemblages. Amer. Soc. Limnol. Oceanogr., Abstracts 1979 meeting. In preparation for publication.

Brugam, R.B. 1979. Chemistry of lake water and groundwater in areas of contrasting glacial drift in eastern Minnesota. In preparation.

(C) Project Status:

The project will be continued into the next Fiscal Year with unexpended funds from the third year of the grant.

(D) Application of Research Results:

The results on the technique of characterizing the trophic status of lakes by sedimentary diatom analysis, especially recent changes in lakes caused by cultural eutrophication, have been utilized in various local studies in Minnesota concerned with identifying the source and timing of lake pollution and plans for lake improvement. The results on the long-range history of lakes and their relation to paleohydrology are being used in studies of climatic history, especially in connection with the possible climatic effects of the increase in atmospheric CO_2 resulting from the burning of fossil fuels.

(E) Work Remaining and Progress Contemplated During Next Year:

The remaining time on the unexpended funds will be devoted to completing papers for publication.

OWRT Project No.: B-131-Minn

Project Title: Key Social Factors Affecting Water Related Resource Development Decisions

Agreement No.: 14-34-0001-7165

FCCSET (COWRR) Research Category: 06-A; 1

Name and Location of University Where Project is Being Carried Out: University of Minnesota, Minneapolis, Minnesota

Project Began: October 1, 1976

Scheduled Completion: September 30, 1979

Principal Investigator:	Degree	Discipline
Luther P. Gerlach	Ph.D.	Anthropology

Student Assistants:	Degree	Discipline or Academic Background
David Renz	M.A.	Business Administration

(A) Research Project Accomplishments:

During 1979 we continued to examine and analyze cases in Minnesota through field research in which some Minnesotans organized for political and social action to call for larger-scale and more integrated management of water resources and others organized in political and social action to protest larger-scale management and to call for local control and individual rights in water and water-related use and development. Some who organized for larger-scale management did so chiefly on general ecological principles as representatives of established environemntal organizations or water research organizations. Some did so because they felt it was the best way to protect specific individual interests -- chiefly their own -- from water or related land or energy development projects. Some protested the large-scale management programs and called for local control chiefly on general social-political principles, to protect the rights of local communities from external elites. Some used localism concerns to protect self-interest. Most people combined both principle and self-interest, particularly as their involvement in the issue and their organization continued. Most defenders of principle tried to appeal to self-interest to gain support for their larger goals, and most people protecting self-interest learned to relate to larger principle, first as a tactic, and then increasingly as an ideology. It is our hypothesis that as a result of these varied actions, there was increasing development and articulation of larger principles. This led to a polarization of principles, the principle of interdependence or systemic management on the one hand, and independence or localism on the other. Some have described this as a pull between centralization and decentralization, or between the common good and individualism or between systemic and lineal thinking. But whatever terms are used, there is clearly a conflict over principles in which water and water-related resources have become a focus, much as has been the case with energy. This, we have found, adds greatly to the problems of researchers and decision makers in water-related fields. Their attempts to keep water a more narrowly technical subject are confounded by this intrusion of general principle and symbolism.

Similarly, water-related issues become a way to speak about many other subjects of more specific concern to individuals or to local communities. For example, water management becomes a way for owners of family or "ma and pa" resorts to speak about all of the pressures threatening their way of life and economic position. Similarly, it becomes a way for farmers to speak about pressures either preventing them from intensifying or competing with farmers who have already moved into intensification such as through irrigation. It provides a framework to carry on party politiking, to extract political revenge, or to gain political power. It provides a way to extol the virtues of traditional life-styles, such as established use of northern waterways and forests against external lifeways, such as those from urban areas who call for wilderness experience, or it provides a way to call for a change in lifestyles for example from the growing use of motors or external inputs of water and energy to what some call a more ecologically sustainable system.

We have found that people who mobilize to press a position on principle or special interest in regard to any water issue seek to draw in allies, or as some say, to network with people and groups concerned with other issues. In the process, they do in fact build alliances and new networks which add to the range of interests and concerns and increase the complexity of response. The longer issues remain in dispute, the more likely it is that they become intertwined not only with diverse interests, but with diverse groups. This also confounds resolution. The most that most people and groups will agree to is to continue conflict. It is difficult for anyone or any group to claim to speak for the entire array of groups in a network. This frustrates decision making and conflict resolution.

In short, as we have found true of energy issues, water issues have become loaded with so many other concerns that the technical aspects of these issues are socially constructed. Another way of saying this is that water issues have become embedded in webs of social, political, economic, and even religious concerns. This research on water is paralleled by our research on energy development and related social controversy which has been funded by other sources. It appears from this that resources and resource development technologies are not the autonomous forces controlling social and political order, as often proposed, but instead are at best simply other factors in complex processes or perhaps even hostages to social forces.

One purpose of our research was to find ways to help decision makers resolve resource conflicts. We have argued that to understand conflicts over resources, decision makers must learn how to understand and accept all of the other factors at play in supposedly resource-related controversies. We now would argue that a dominant reality is conflict and they must learn how to manage it. Primarily through our work on energy, but also through our work on water, we are developing ways to look at conflict which we hope will help decision makers make choices among types of resource development or to make resource development decisions according to which conflicts they can best manage. We suggest that this is the most useful approach and the most realistic, although initially not the most palatable to accept.

These concepts and findings and those reported in our 1977 and 1978 annual reports will be developed and illustrated with the case study research findings in some detail in our final report on this project. Through field research, including in-depth interviewing, telephone interviews, and participant observation, and through extensive collection of media reports and newsletters, we have continued this year to study the cases identified in previous reports with special emphasis this year on the BWCA issue, and rural water system development. In addition, we have followed a watershed conflict case in Anoka county, have conducted interviews in one community in northeast Minnesota on the emerging issue there of exploration and potential development of uranium, and have conducted interviews with resisters to the Northern Pipeline project who have raised concerns about potential impact on underground water of this project.

(B) Publications:

Gerlach, Luther P. "The Growth Debate: Cosmic Concepts and Grass-Roots Adaptations," reprinted in Ethics and Energy, Decisionmakers Bookshelf, Vol. 5, Edison Electric Institute, Washington, D.C., 1979.

Gerlach, Luther P. and Gary B. Palmer, "Adaptation Through Evoloving Interdependence," in William Starbuck and Paul C. Nystrom (eds.) Handbook of Organizational Design, New York Oxford Press, forthcoming in 1980. (This book-length chapter or essay was originally written in 1975 but the water and energy case study examples were significantly updated this year.)

Gerlach, Luther P. and Betty Radcliffe, "Can Independence Survive Interdependence?", Futurics, Vol. 3, No. 3, Summer 1979.

Gerlach, Luther P., "Will Democracy Survive Our Energy Wars?", unpublished draft, 1979.

(C) Project Status:

Project will be completed as of September 30, 1979.

(D) Application of Research Results:

Concepts and findings from this research have been communicated both within and outside the academic community to raise awareness and promote understanding. Social factors in water issues have been addressed particularly in Professor Gerlach's fall quarter, 1978 seminar and his spring quarter course on energy, resource use, and system change. This fall he will be preparing this course for a televised extension version to be presented winter quarter 1980. These courses have been taken by several state agency personnel and state and local public officials. He has also been requested to present lectures in various other University courses. Those lectures which especially related to his water research were:

1) Dr. Olaf Pfannkuch's geology course, January 18, 1979

2) Dr. J. Edward Anderson's mechanical engineering course, Ecology, Technology, and Society, January 31, 1979

3) Dr. Reynold's public health course, Preventative Aspects of of Community Health Assessment, April 11, 1979, and videotaped for viewing at Mankato State University

4) Prof. Silberman's civil engineering course, Introduction to Water Resources Management, a lecture entitled "Social Conflict in Water Resources Development", May 9, 1979.

Among the lectures he has been invited to give to public audiences or at other institutions are:

1) Presented the first Loren W. Sanford lecture, March 22, 1979 at the Depot, Duluth, on "Can Independence Survive Interdependence: A Closer Look at the Conflict Between Public Rights and Private Rights in an Increasingly Complex World."

   Also spoke that afternoon to Dr. Skinner's social movement class of University of Minnesota-Duluth's School of Social Development.

2) Also in March spoke at the state-wide annual meeting of the Minnesota Environmental Education Board.

3) Speaker at the Social Science in Engineering workshop in Pittsburg, Pennsylvania, May 21, 1979, held in conjunction with the sixth national conference on Man and the Environment.

4) Dr. Roman Verostko's Senior Colloquium on Futurism at the Minneapolis Institute of Art, March 13, 1979.

We are now completing four audio-visual units for dissemination for classroom use on "Resource Issues: The Social Dimension," one of which will focus on water.

Activities our staff was invited to participate in which relate to this research were:

1) the development of a cooperative grant proposal to communicate understanding of the hazardous waste problem.

2) Luther Gerlach was a member of the Citizens League of Minneapolis, issues of the 80's Committee during spring, 1979.

3) Luther Gerlach was a participant in a workshop co-sponsored by DOE and the Institute on Man and Science, Rensselaerville, New York, June 13-16, 1979, on "The Social Impacts of Decentralization".

We anticipate that we will continue to be asked to contribute in this way. For example, Luther Gerlach has been asked to:

1) participate in the California Institute of Technology Jet Propulsion laboratory's Workshop on Social and Policy Research Methodology, October 22 and 23, 1979.

2) speak on October 25, 1979 to the Minnesota/Wisconsin Ground Water Institute.

3) speak on January 11, 1980 to the annual meeting of the Minnesota Soil and Water Conservation Society.

We also anticipate that our findings will be used by ourselves and other researchers as a springboard into other research. Our understanding of the social dynamics of the RWCA issue in northeast Minnesota will be an important basis for understanding future resource management issues. It is likely that there will be increasing pressure as we try to solve our national energy problem to promote the development there of biomass as an alternative energy resource. Development, or at least pilot project work, might well include use of peat, conversion of peat to synthetic gas, cultivation of fast-growing plants and trees, for example, cattails and poplar, and the potential conversion of these to liquid fuels. Both production and conversion of these resources will require the use of water, will have an impact on the water-related environment, and will compete with other uses of water, including water as a base for recreation.

(E) Work Remaining and Progress Contemplated During Next Year:

The project will be completed as of September 30, 1979.

OWRT Project No.: B-139-Minn Project Title: Application of New Methods for Routine Measurement of Aquatic Organics

Agreement No.: 14-34-0001-8092

FCCSET (COWRR) Research Category: 04-A; 4

Name and location of University Where Project is Being Carried Out: University of Minnesota, Minneapolis, Minnesota

Project Began: October 1, 1977 Scheduled Completion: September 30, 1980

Principal Investigator:	Degree	Discipline
Walter J. Maier	Ph.D.	Environmental Engineering

Student Assistants:	Degree	Discipline or Academic Background
Mark McCahill	undergrad	Chemistry
Theodore Miller	undergrad	Physics
Nancy Pelt	M.S.	Environmental Engineering
Pitsumai D. Nath	Ph.D.	Computer Science
Christine Macko	Ph.D.	Environmental Engineering

(A) Research Project Accomplishments:

The objective of this research program is to investigate applications of new methods for measuring and characterizing aquatic organic pollutants that could be used on a routine basis. More precise information on the physical and chemical properties of aquatic organics is needed in order to identify sources of organic pollutants and allow setting realistic standards and goals to protect the environment as required under the Water Pollution Control Act (PL 92-500). The need for more detailed information is also critical for setting standards and to provide insight on design and engineering criteria to assure safe and wholesome drinking water supplies in line with the Safe Drinking Water Act (PL 93-523). The study focuses on the upper Mississippi River because it is an important major water basin and serves a large population; furthermore, the basin is not untypical and results should be applicable to other basins.

During the first two years, research and development centered on gathering and analyzing available data, identification of sampling sites, development of sampling procedures, preparation of samples by preconcentration and fractionation, and standardization of preparation and test methods.

Analysis of the available data (obtained from STORET through the Minnesota Pollution Control Agency) identified four sampling locations. Bemidji, Royalton, St. Anthony Falls and Inver Grove Heights represent the unpolluted source region, agricultural region, lightly population stressed regions and the industry and population stressed region, respectively. These sites were identified in order to ascertain whether there are substantial changes in the types and concentrations of organic pollutants and to establish appropriate analytical procedures to measure them. Table 1 summarizes the data on organic matter on the whole water and molecular size fractionated samples.

Table 1
CHARACTERISTICS OF NATURAL ORGANIC MATTER IN RIVER WATER

Molecular Weight Fractions	Uncontaminated Source Region	Agricultural Drainage Region	Urban-Industrial Stressed Region
Total			
TOC mg/l	8.4	9.5	9.5
TON mg/l	0.5	0.6	1.3
CH_2O mg/l	0	0	1.2
1°N µg/l	33.	41.	37.
E_{200}	0.056	0.054	--
<500			
TOC mg/l	2.6	1.3	0.8
TON mg/l	0.4	0.2	0.6
CH_2O mg/l	.0	.0	0.2
1°N µg/l	11	9	3.
E_{200}	--	0.020	2.4
E_{320}	0.006	0.004	0.02
500-1000			
TOC mg/l	1.5	1.8	3.1
TON mg/l	.0	0.2	0.5
CH_2O mg/l	.0	.0	0.1
1°N µg/l	4.0	8.	10.
E_{200}	0.034	0.045	0.055
E_{320}	0.007	0.007	0.006
1000-10,000			
TOC mg/l	2.5	4.9	4.1
TON mg/l	.0	.0	.2
CH_2O mg/l	0.2	0.2	0.3
1°N µg/l	9	18	16
E_{200}	0.086	0.083	0.074
E_{320}	0.014	0.015	0.014
10,000-100,000			
TOC mg/l	0.4	1.2	0.9
TON mg/l	0.5	0.3	.0
CH_2O mg/l	0.2	0.1	0.2
1°N µg/l	1.	2.	2.
E_{200}	--	--	0.037
E_{320}	0.040	0.007	0.005
> 100,000			
TOC mg/l	0.4	0.6	0.6
TON mg/l	.0	0.1	.0
CH_2O mg/l	0.2	0.1	0.2
1°N µg/l	1.	2.	2.
E_{200}	--	--	0.037
E_{320}	0.040	0.007	0.005

TOC = Total Organic Carbon TON - Organic Nitrogen CH_2O = Glucose Equivalent
1°N = Glycene Equivalent-Primary Amine E = Extinction Coefficient

a. Total organic carbon (TOC) concentrations increase in river water from the source region as a result of agricultural and urban/industrial inflows. These changes are superimposed on the otherwise dominant seasonal variations.

b. A significant shift in molecular size distribution was observed in which a greater proportion of the TOC occurred in low MW fractions in the river source region as compared to the urban/industrial stressed region. The net effect is an increase in the TOC occurring in higher MW fractions downstream.

c. The chemical composition of the 1-10K molecular size fraction appears to be uniquely constant since identical UV extinction coefficients (200-350 nm) were observed for all samples regardless of season or location. However, the extinction coefficients of other size fractions show distinctive changes: the <0.5K MW fraction exhibited high extinction coefficients at 200 nm in the urban region, and contrastingly low values in the source region. In contrast, the > 100 K MW fraction from the source region had high extinction coefficients at 320 nm. A quantitative computer simulation program based on UV absorbance properties of river water has been developed, and suggests that compounds having spectral characteristics similar to gallic and dihydroxybenzoic acids, vanillin and lignin are present.

d. Carbohydrate constituents measured by the anthrone procedure are absent in low MW fractions but account for 10-15% of the > 100K MW fraction. Carbohydrates are apparently bound chemically and hence not biologically available. Primary amines were detected at concentrations of 1-40 µg/l, and were concentrated in the < 10K MW fraction, suggesting that they are associated with the organic carbon, and perhaps resist degradation and/or uptake due to chemical/physical binding. Total organic nitrogen (TON) ranged from 5 to 13% of TOC with the highest TON values observed in the agricultural and urban/industrial regions. TON occurred primarily in the low MW fractions (< 0.5K and 0.5-1K MW).

Research results available thus far indicate that aquatic organic matter consists of a network of aromatic ring structures substituted with -OH and $-CO_2H$ groups, and containing aliphatic (alicyclic) side chains consisting of carbohydrate and lipid moieties. The nomial molecular weight fraction between 1,000 and 10,000 accounts for the majority of organic carbon. The low and high molecular weight components of organic carbon appear as transients, and vary with season, flow and location.

A special effort has been made to extend the usefulness of ultraviolet (UV) absorbtion measurements for characterizing the composition and measuring the concentration of groups of UV active organics. Previous research had shown a strong correlation between UV absorbance and organic carbon concentration.

An algorithm for analyzing multiwavelength-multicomponent mixtures was developed and computer programmed. It allows calculating the concentration of each constituent in a mixture from the measured values of UV absorbance and

elemental composition of the mixture. The algorithm matches the absorbance spectrum of the mixture by superposition of the absorbance spectra of its constituents. The latter are provided as input in the form of an inventoried data bank. The algorithm has been validated using hypothetical compounds, with pure model compounds representative of lignin decay products and tested on Mississippi River water and sewage. The results show that the absorbance spectra and elemental composition are perfectly matched and constituent concentrations identified correctly provided that the necessary constituents are available in inventory. Calculated values of the euclidian norm for the solution vector give an indication of the fit of the calculated versus actual values. If some of the mixture's constituents are not available in inventory, the program calculates a best fit composition. This best fit composition usually includes all the major constituents actually present but not at their correct concentration; it may also identify spurious compounds that are not present in the mixture but are available in the data bank inventory. The extent of substitution and concentration errors depend on the relative importance of the absorbance and composition of the non-available compound.

Preliminary matching studies of Mississippi River water and sewage using a very small data bank of 13 "compounds" have identified four major constituents and two minor constituents. Identification of lignin, gallic and vanillin are indicative of the presence of classes of compounds whose absorbance spectra are similar to those of the identified compounds. Equally important information is obtained from the fact that a number of inventory compounds such as catechol, resorcinol, syringic and vanillic acid are not identified because this means that compounds with similar absorbance spectra are not present in the river water and sewage.

Further studies are in progress using molecular size fractionated samples to elucidate the distribution of compounds. These studies have also been extended to develop correlations between organic carbon (TOC), biochemical oxygen demand (BOD) and absorbance for wastewater and river water.

Preliminary data on the elemental composition and function group content of aquatic organics were described in the first year's progress report. It was shown that free amino acids were present at very low concentrations ranging from 33 to 0.45 µg/l of glycene equivalent which means that they are a negligible factor in terms of total organic carbon content. Total organic nitrogen concentrations measured by Kjeldahl range to 2.7 mg/l with the higher concentration occuring downstream. Carbohydrate concentrations were measured by anthrone and also showed the highest concentrations at the downstream pollution stressed site (1.3 mg/l at Inver Grove Heights).

Analysis of the UV absorbance and functional group data has provided important insight on the composition of aquatic organics. It is clear that only a fraction of aquatic organics are UV absorbers (benzene ring structures); this information, together with results from other studies, shows that a major fraction consists of saturated hydrocarbons, some carbohydrates and minor quantities of amino acids-proteins. These findings have helped to focus the continuing research.

Measurement of chlorinated organic compounds (TOCl) in natural waters has been the focus of attention because many of this class of compounds represent toxic and/or carcinogenic species. An analytical protocol for measuring the concentration-distribution of TOCl has been developed. It involves prefractionation, concentration, and washing, using ultrafiltration to remove inorganic chlorides. TOCl is then oxidized by ultraviolet irradiation and the released chloride is measured by specific ion electrode, chemical analysis or microcoulometry. In chlorinated sewage effluent TOCl was found to increase after chlorination so that from 0.002 to 0.009 mol TOCl per mole TOC was present. Thus, chlorination of sewage effluents was shown to produce small amounts of organic-chlorine compounds of molecular weight greater than 1000 as defined by ultrafiltration of the sample. In its present form this method is not sufficiently sensitive to detect TOCl in unpolluted waters. However, sensitivity can be increased, in principle, to any desired level by more extensive preconcentration of the sample.

(B) Publications:

Determination of Organically Combined Chlorine in High Molecular Weight Aquatic Organics, submitted for publication to Journal Water Pollution Control Federation, Aug. 1979.

Measurement of Organically Combined Chlorine, presented as a student paper at local American Chemical Society meeting, Spring 1979 by Mr. M. McCahill.

Multicomponent UV Spectral Analysis of Aquatic Organics. Proceedings of the International Congress on Analytical Techniques in Environmental Chemistry; edited by Dr. Albaiges, Barcelona, Spain, Nov. 27-30, 1978.

(C) Project Status:

Two years of this three year project have been completed. Three students will continue to work on the project during the third year.

(D) Application of Research Results:

The newly developed analytical procedure for measuring organically combined chlorine (TOCl) is of immediate interest to sewage treatment works as well as water treatment works and government agencies because it can be used to monitor the total concentration of TOCl. Measurements of TOCl before and after chlorination of treated sewage are being made for the Metropolitan Waste Control Commission to establish the effects of effluent chlorination. This work is sponsored by a research contract administered through Dr. R. Polta, the manager of research of the commission.

Dr. W. Combs, chief of analytical services, Rhode Island State Health Department, has requested a rough draft copy of the paper. They intend to use this procedure for measuring TOCl in waste sludges as an indicator of the effects of super chlorination prior to land spreading of sludges. The TOCl measurement procedure is particularly useful for measuring high molecular weight organics associated chlorine because these materials cannot be measured

by the available specific compound techniques involving gas chromatography and mass spectrometry.

(E) Work Remaining and Progress Contemplated Next Year

A concerted data analysis effort is currently underway and will continue into the third year. The objective is to prepare a preliminary report that describes the results and compares the findings from this study with conventional water quality data. This report will be used as a briefing device for participants in a colloquim that is planned for the third year. As indicated in the original program plan, a limited number of representatives from agencies, consulting firms and universities will be invited to review and assess the findings and to critically evaluate the significance and effectiveness of water quality data obtained by conventional analytical tests and the new methods evaluated in this program.

The scope of the data analysis effort has been extended and is complementary to a data analysis program sponsored by a National Science Foundation grant which emphasizes characterization and identification of aquatic organics and metal complexes. This combined effort is expected to lead to the formulation of models that describe the aquatic organic carbon cycle and trace metal transport. A basin-wide analysis of flows and concentrations will be used to formulate run-off coefficients that can be used to describe inputs from different regions.

The analytical protocol for measuring TOCl by UV photolysis and chloride ion analysis is being extended to the measurement of organically combined sulfur. This work is currently underway but will extend into the third year. The results are of interest because it appears likely that trace metal complexation capacity of aquatic organics is affected by the presence of sulfur and nitrogen atoms.

OWRT Project No.: B-147-Minn

Agreement No.: 14-34-0001-9119

Project Title: The Measurement of Evapotranspiration and Comparison with Empirical Calculation Methods for Use in Minnesota and Similar Climatic Regions

FCCSET (COWNR) Research Category: 02-D; 03-F

Name and Location of University Where Project is Being Carried Out: University of Minnesota, St. Paul, Minnesota

Project Began: October 1, 1978 Scheduled Completion: September 30, 1981

Principal Investigators:	Degree	Discipline
Donald Baker	Ph.D.	Soil Science
James B. Swan	Ph.D.	Soil Science

Student Assistants:	Degree	Discipline or Academic Background
Jon Ljungkull	B.A.	Physics
Martin MacGregor	undergrad	Agronomy

(A) Research Project Accomplishments:

During the 1978 growing season evapotranspiration (Et) data were collected for the months of June through September. Data from 54 days in this period were considered suitable for analysis. These were limited to those days on which the ground cover was greater than 80 percent, no precipitation occurred and no irrigation was done. Data on climatic variables such as temperature, wind, evaporation, and solar radiation were also collected. A statistical analysis was undertaken to examine how well several Et prediction equations were at estimating the actual Et. Among those tested were the equations of Penman, Jensen-Haise, Turc, Grassi, Stephens-Stewart, Makkink Thornthwaite and Blaney-Criddle. The amount of variation in daily Et explained by these equations ranged from 30 percent with Thornthwaite method to 79 percent with the Grassi method.

A multiple regression analysis was then used to construct an empirical predictive equation using easily measured climatic variables. An equation was found which contained solar radiation, wind, and saturation deficit as independent variables. This equation was capable of explaining 85 percent of the variation in the observed Et.

A regression equation which uses evaporation pan measurements as the only independent variable was also tested. This method is the simplest and requires only a single measurement that any irrigator can take readily. With this method different equations are used at different phenological stages to predict Et directly from pan measurements.

Data collection is continuing during the 1979 growing season. It is the intent of the researchers to both broaden the Et data base begun last year (1978) and to obtain new data to test the consistancy of the equations derived from the previous growing season. Due to a hailstorm which inflicted

severe damage on the soybean crop, full cover has not been established as of July 20 this year. Consequently the data collected so far cannot be integrated with that collected last year. These data can. however, be used for the study of Et under conditions of less than full cover.

Measurements were made during the winter of 1978-1979 in an effort to detect sublimation of snow. Several problems were encountered in keeping the snow pack on the lysimeter independent from that on the surrounding plot. The few days of good data which were collected in February and early March, indicated that the sublimation was of the order of magnitude of 0.25 mm (0.01 inch).

(B) Publications:

Ljungkull, J.L., D.G. Baker, and J.B. Swan. 1979. Experimental Investigation of Evapotranspiration. In 14th Conference on Agriculture and Forest Meteorology, (Minneapolis, MN., April 2-6) Amer. Meteor. Soc., Boston, Pp. 169.

(C) Project Status:

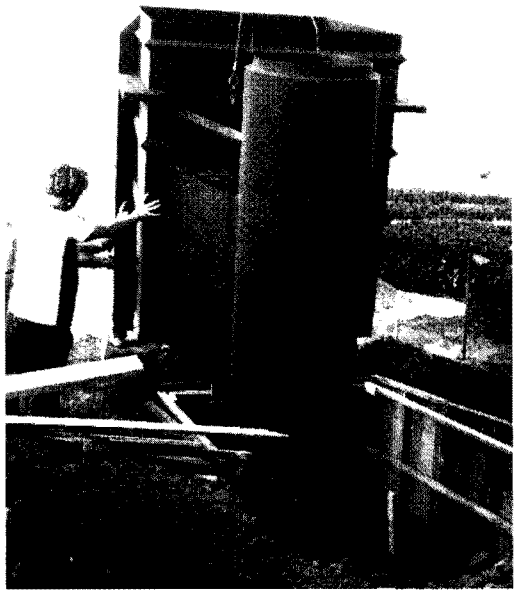
This project will continue in the next fiscal year.

(D) Application of Research Results:

Various individuals have expressed interest in this project including hydrologists, consulting engineers and county agents. The most immediate application of this project will be to aid the farmer-irrigators in providing a readily useable and practical means of estimating local crop water requirements.

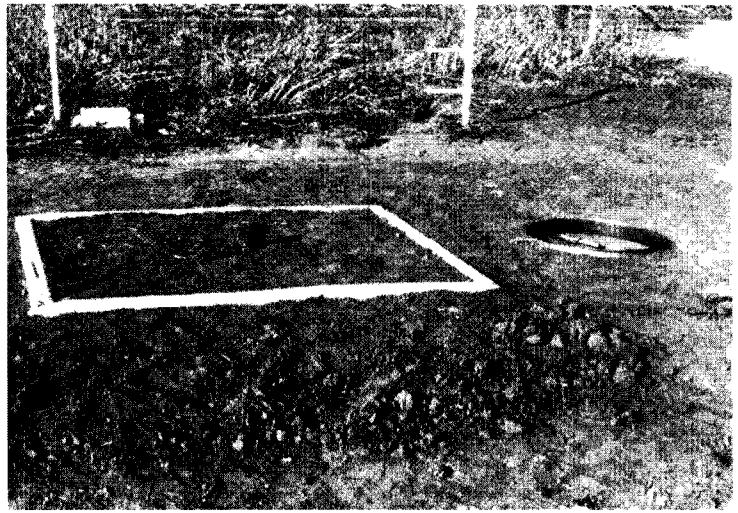
(E) Work Remaining and Progress Contemplated During Next Year:

Work will be summarized and a thesis prepared this autumn containing the recommended method of estimating Et requirements under Minnesota conditions. The Et measurements will be continued in 1980 to provide a larger data base for 0-80% plant cover, 80-100% plant cover, and winter sublimation losses.



Lysimeter tank housing lowered into the pit, St. Paul campus, July 1975.

Housing for lysimeter nearly in place on the cement floored pit. The entry hatch is the circular opening at the right.



The weighing lysimeter in place and filled with soil, August, 1975. The circular entry hatch (with cover) is at the right.

Tensiometers installed in the lysimeter tank within the soybean rows. These instruments are used to determine the moisture content of the soil at 12, 18, and 30 inch depths. The black material is a flexible cover between the inside and outside of the lysimeter tank to prevent soil or water from falling into the lysimeter tank pit. The white styrofoam along the margins of the tank is to provide insulation and decrease soil temperature differences due to the metal tank itself.

Soybeans growing in the lysimeter tank and adjacent plot, June 1979. Two tensiometers are visible. The red reflector is used to mark individual plants that are being monitored.

OWRT Project No.: B-150-Minn

Agreement No.: 14-34-0001-9078

Project Title: A Study to Identify the Potential of Naturally Occurring Zeolites for Removing Heavy Metals From Water

FCCSET (COWRR) Research Category: 05-D; 4

Name and Location of University Where Project is Being Carried Out: University of Minnesota, Minneapolis, Minnesota

Project Began: October 1, 1978 Scheduled Completion: September 30, 1980

Principal Investigator:	Degree	Discipline
Michael J. Semmens	Ph.D.	Civil and Mineral Engineering

Student Assistants:	Degree	Discipline or Academic Background
William Martin	B.S.	Civil Engineering
Donna Stephenson	B.S.	Biology
Michael Heiling	B.S.	Chemistry

(A) Research Project Accomplishments:

Of the zeolites available for study clinoptilolite is the most attractive for study for two main reasons: 1) it is abundant and therefore relatively inexpensive, and 2) it is physically stable and can withstand the conditions of use. For these reasons our early studies have centered around the use of clinoptilolite. Experiments have been conducted to evaluate the conditions influencing the removal of heavy metals by this zeolite.

It has been shown that competing ion type and concentration, and solution pH are most influential in determining the zeolites capacity for selective heavy metal removal. In addition it was shown that pretreatment of the zeolite is extremely effective in improving metal removal performance.

Batch isotherm studies have also been conducted and the rational selectivity coefficients for lead, cadmium, silver, copper, nickel, zinc and barium exchange with sodiums have been evaluted. Solution pH was found to influence metal removal strongly in the batch studies. Poor comparison of batch and column data may be attributed to differences in solution pH.

The zeolite was found to be effective in removing all the heavy metals listed above from salt solutions.

Metal removal was greatest in exchange with magnesium and decreased in the order $Mg^{++} > Na^{+} > Ca^{++}$ for lead and cadmium and in the order $Mg^{++} > Ca^{+++} > Na^{+}$ for silver. It was found that the presence of any calcium in solution had a profound effect on the extent of cadmium removal and in the presence of calcium the cadmium removal behavior was comparable to that observed for cadmium removal by exchange with calcium ions only. Removal behavior was relatively insensitive to the exact solution composition for a fixed ionic strength.

Lead removal behavior was also relatively insensitive to the exact solution composition, however lead removals more closely followed the exchange behavior observed with only sodium ions present and the presence of calcium ions did not have a significant influence.

Column studies were conducted and showed that where calcium was present in solution, cadmium removals were poor even in the presence of low competing cation concentrations (4.35 meq/l). This confirmed the predicted influence of calcium observed in the batch studies. Following base pretreatment acceptable operating capacities were obtained in column operation at a loading rate of 8-10 bed volumes/hr. Lead was extremely well removed and large volumes of water may be treated for lead removal before breakthrough occurs even in the presence of high competing cation concentrations. Silver removals were very effective at low salt concentrations but it is doubtful whether silver could be removed from solutions containing more than 43.5 meq/l of sodium or calcium economically without zeolite pretreatment.

(B) Publications:

Semmens, M.J. and W. Martin, "Studies on Cadmium, Lead and Silver Removal from Saline Waters by Clinoptilolite." In press, Water 1979. (AIChE Symposium Series).

Martin, W. and M.J. Semmens, "The Ion Exchange Behavior of Cadmium on Clinoptilolite," in preparation, to be presented at an American Institute of Mining Engineers Conference, October, 1979.

(C) Project Status:

The project will continue through the next fiscal year.

(D) Application of Research Results:

The zeolite division of the Anaconda Company is very interested in the results of this study. They see the zeolites as a potentially valuable resource for the removal and recovery of heavy metals from industrial wastewaters.

Also several industries are interested in the research since they are faced with the problems of pretreating their wastes for heavy metal removal.

The results of this study will identify the design information required by engineers to size and construct facilities for heavy metal removal by these natural zeolites.

(E) Work Remaining and Progress Contemplated During Next Year:

The influence of water chemistry on metal uptake by natural zeolites will be evaluated. The influence of different anions, (inorganic and organic) that may complex the metals will be measured. The mechanism of metal removal by clinoptilolite will be studied to identify the roles that pH and base pretreatment play in metal-zeolite interactions.

The behavior of clinoptilolite will be compared with the metal removal behavior of other naturally occuring zeolites such as Chabazite, Phillipsite and Morderite.

In addition work will continue to identify the best conditions for regeneration. In particular the influence of flowrate, acid strength, salt concentration and pretreatment on the regeneration of the zeolite will be identified.

If time permits studies will be conducted in complex systems to evaluate the zeolites ability to selectively remove heavy metals from waters containing a variety of metals and anions.

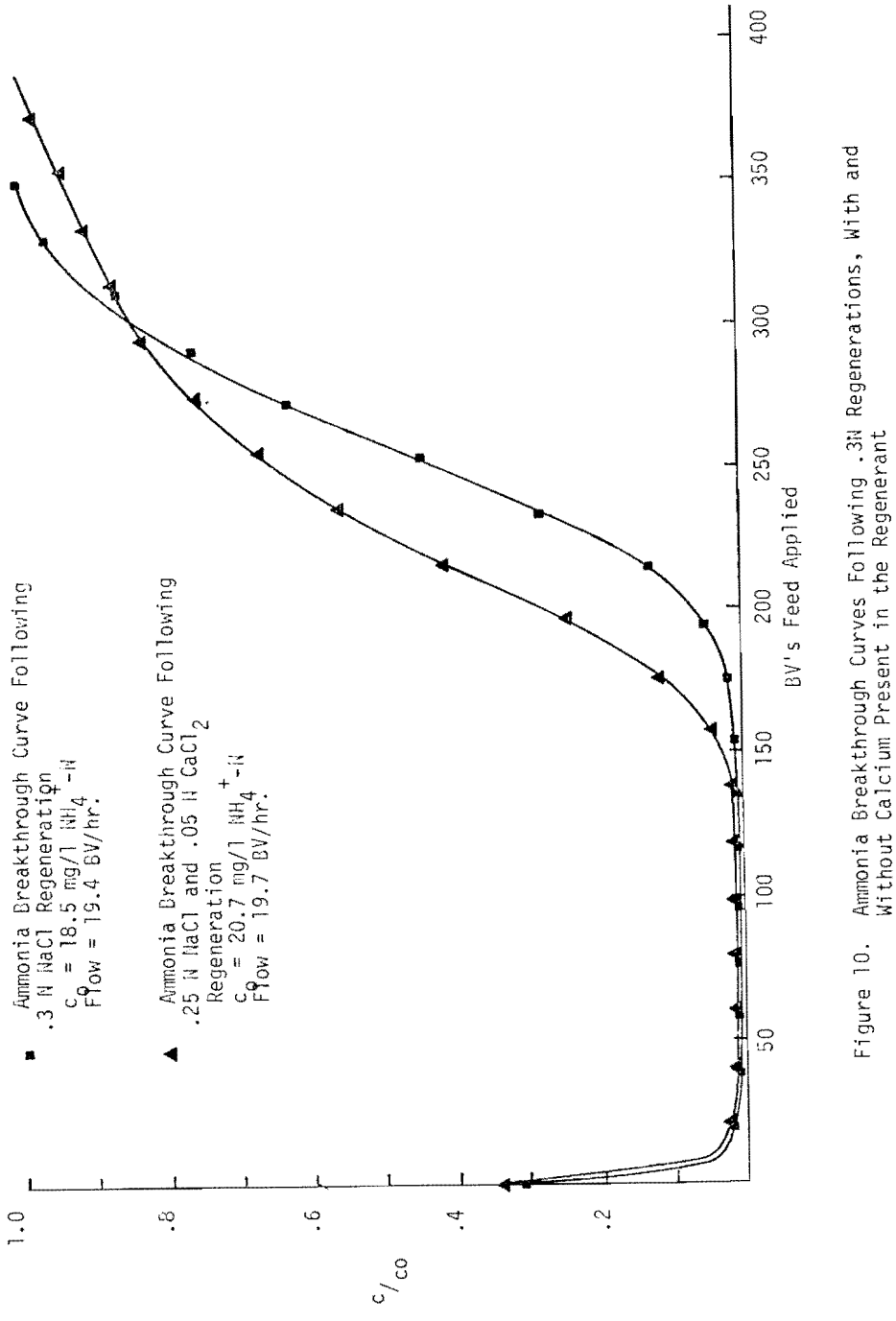


Figure 10. Ammonia Breakthrough Curves Following .3N Regenerations, With and Without Calcium Present in the Regenerant

Regional Contributing Program

OWRT Project No.: B-120-Ill

Project Title: Efficient Use of Water for Irrigation in the Upper Midwest

Name and Location of University Where Project is Being Carried Out: University of Minnesota, St. Paul, Minnesota, in cooperation with the University of Illinois.

Project Began: October 1, 1978

Scheduled Completion: September 30, 1979

Principal Investigators:	Degree	Discipline
Vernon R. Eidman	Ph.D.	Agriculture and Applied Economics
Craig C. Sheaffer	Ph.D.	Agronomy

Student Assistants:	Degree	Discipline or Academic Background
Paul Wilson	M.S.	Agricultural Economics
Larry Jacobs	B.S.	Animal Science

(A) Research Project Accomplishments:

Experiment I. Alfalfa management with irrigation-loamy sand soil.

Treatments consist of two alfalfa varieties, Ramsey and 520; K fertility levels of 0, 180, 360, and 540 lb/A; and cutting managements consisting of harvesting the alfalfa two, three and four times during the growing season. Three irrigation regimes based on plant consumptive water use and soil moisture level were applied across all fertility, cutting, and variety treatments. Preliminary results indicate a significant irrigation effect on yield with no irrigation by variety interaction. Postassium fertilization resulted in a significant yeild increase and the extent of the response varied with the amount of water applied. On treatments receiving the greatest amounts of water applied via irrigation, a larger yield response per unit of applied K was observed than for the other treatments. Data on the interaction of cutting schedules with irrigation regimes has not been analyzed.

Alfalfa management under irrigation-silty loam soil. Treatments consist of six alfalfa varieties subjected to a three and four time cutting management, Irrigation levels consist of irrigation according to crop consumptive water use and no irrigation. Due to above normal amounts of rainfall, irrigation was limited and therefore a response is not expected.

Experiment II. Alfalfa varietal response to soil moisture.

Three alfalfa varieties (Agate, Anchor, and WL 318) of varying disease resistance and fall dormancy reaction were grown in five foot (length) by one foot (diameter) tubes in the greenhouse with three soil moisture regimes: high moisture (-.2 to -.3 bars matrix potential), medium moisture (-1 to -1.5 bars matrix potential)., and low soil moisture (-6 to -15 bars matrix potential). Tubes were watered to field capacity whenever soil moisture reached an indicated soil moisture level. Yields of plants grown at medium and low soil moisture levels were not significantly different, but yields

were significantly lower than those of plants grown at the high soil moisture level. For low and medium soil moisture levels, timing of water application in relation to time of cutting had a greater effect on yield than soil moisture level at time of water application.

At the high soil moisture level, Agate alfalfa was the lowest yielding variety with Anchor and WL 318 alfalfa not significantly different. A pressure bomb was used to measure plant water potential at harvest. Significant differences in plant water potential existed in plants due to growth at the three soil moisture levels. The plant water status of the three varieties was similar across soil moisture levels.

Soil cores were taken at six inch intervals to a depth of five feet. Root and soil fractions are being separated and root weight and length will be determined for each treatment.

The field portion of Experiment II consists of growing the same alfalfa varieties on a sandy and silty loam soil. Plots on the silty loam soil were covered to avoid natural rainfall. Soil moisture treatments include: irrigation to field capacity at 50 percent available moisture depletion and to field capacity at 25 percent available soil moisture depletion. Yield data has been collected but has not been analyzed.

Due to the early due date for this report, collection and analysis of data is incomplete. As a result, conclusions relating to irrigation use and plant response cannot be reached.

Farmers irrigating heavy soils in a twenty-six county area in southwestern and south central Minnesota were interviewed to obtain data on farming and irrigation practices. The predominant soil types in this region are fine-textured loams and clay loams with moderate to high available water capacities. A list of all irrigation permits that have been granted in the twenty-six counties was obtained from the Department of Natural Resources. A potential list of interviewees was obtained by matching the legal description of the irrigator's property on their irrigation permit with a regional soils map provided by the Soil Science Department of the University of Minnesota.

Initial interviews indicated ten to thirty percent of the farm operators with permits have failed to install an irrigation system. By eliminating farms that had requested permits but had not installed irrigation systems, it was possible to interview every farmer in the 26-county region who irrigates field corn, soybeans and alfalfa on fine-textured soils. County Soil Conservation Service and Cooperative Extension Service personnel worked with the potential list to identify those farmers actually irrigating corn, soybeans or alfalfa on heavy soils in their county. The farmer was contacted in those cases where any doubt existed about the status of irrigation and the soils being irrigated. This procedure identified 40 irrigators which were interviewed. Those interviewed were asked to add names of other irrigators not included on the list. The evidence suggests all farmers irrigating heavy soils in the 26 counties were contacted during July and August of 1979.

The survey data show that 68 percent of the irrigators are farming at least 400 acres with 27.5 percent farming more than 1,000 acres. The majority of the farm operators purchased their irrigation systems in 1976 and 1977 and cited the drought of 1974-75 as the principal reason for making the investment. Other reasons cited were: insure a supply of animal feed, increase average yields, improve timing of water application and farm more intensively.

Forty-seven percent irrigate between 101-150 acres with center pivots, traveling guns, lateral move and stationary gun systems. Thirty-two percent of those interviewed irrigated more than 150 acres by using multiple center-pivot systems, towable center pivots or a lateral move system on large (greater than 1/4 section) rectangular fields. Fifty percent of the systems were financed by borrowing while 37.5 percent were purchased with cash.

The predominant type of irrigation system used on heavy soils is the center pivot. Sixty-eight percent of the irrigation systems in operation are center pivots while traveling guns, lateral moves, booms and stationary guns make up 16, 8 and 4 percent of the systems, respectively. Fifty percent of the irrigators used wells as their water source with streams/rivers, lakes and dug pits making up the remaining half. Well depths vary from less than 50 feet to more than 300 feet. However, 85 percent of the wells have a suction lift during pumping of less than 100 feet. Electricity is the principal (52.5 percent) energy used to pump irrigation water. Forty-five percent of the operators apply .50 to 1.00 inches of water per irrigation.

The predominant irrigated crop is corn with 62 percent of the irrigated acreage. Since 1977 there has been a gradual shift of irrigated acreage out of corn and alfalfa into soybeans. In 1979, 30 percent of the irrigated acreage is soybeans while only 6 percent is alfalfa. Peas and wheat make up the remaining two percent.

Obtaining data on irrigated and non-irrigated yield of the three crops was an important part of the survey. Farmers were asked to estimate non-irrigated yield levels on heavy soils in poor, average, and favorable years of rainfall. In addition, they were questioned on irrigated yields on similar soils for 1976, 1977 and 1978. Their responses were used to estimate the relationship between irrigated and non-irrigated corn yields and available water capacity (AWC), presented in Figure 1.

The relationships indicate that the expected yield of both irrigated and non-irrigated corn increases as the available water capacity of the soil increases. However, the increase in yield resulting from irrigation decreases as the available water holding capacity of the soil increases. For instance, the relationship in Figure 1 suggests the expected yield increase is 75 bushels on soils with an available water holding capacity of 8.4 inches, while the expected increase is 50 bushels on soils with an available water holding capacity of 12 inches. These convergent relationships for corn differentials will be used to analyze the profitability of irrigating corn.

The number of observations on yield differentials for soybeans and alfalfa is inadequate to estimate a continuous relationship across available

water holding capacities, but they can be used to estimate the yield differentials for two specific water holding capacities.

(B) Publications:

None completed.

(C) Project Status:

A large portion of FY 1979 objectives has been completed; continuation of research will be dependent on the level of funding. A complete analysis of plant response data will be completed by the end of the calendar year.

An evaluation of the economic feasibility of irrigation on heavy soils will be completed by the end of the calendar year. Six prototype or representative irrigation systems have been defined based on the survey results. Investment costs, operating costs and the profitability of irrigating each of the crops are being prepared by level of available water capacity.

(D) Application of Research Results:

Information on the economic feasibility of irrigation and on plant responses will be published and disseminated through the Cooperative Extension Service programs for irrigation and crop production. Extenstion specialists are planning to incorporate the results into their educational programs.

(E) Work Remaining, and Progress Contemplated Next Year:

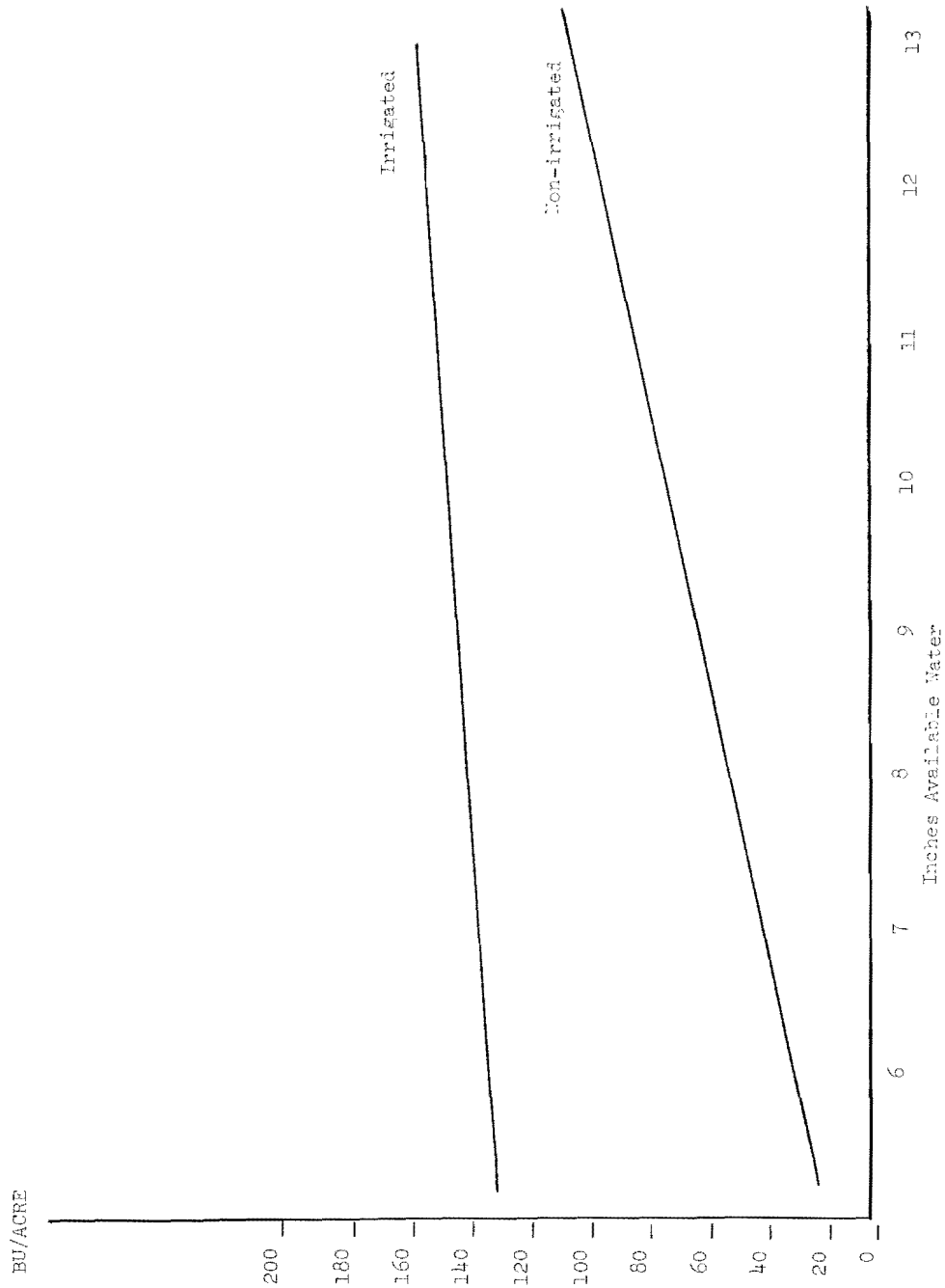
Experiment I will be continued in 1980 and 1981.

Experiment III will be initiated in spring of 1980.

Alfalfa plots were established on one farm site. Unfortunately due to an accident it was not possible to obtain data. Plots will be re-established in Spring 1980.

If another year's funding is provided, a firm planning model will be developed and used to analyze the profitability of irrigation within a framework of a whole farm business.

Figure 1: Yield Response for Corn Given the Average Water Capacity of the Soil for Non-irrigated and Irrigated Production



PROGRAM UNDER P.L. 95-467

Cources Developed:

Numerous individual lectures have been developed by Dr. Luther P. Gerlach (Project No. B-131-Minn) and given in various courses and to agency and citizen groups. University courses that these lectures have been presented in include: Geology, Mechanical Engineering, Public Health, and Civil Engineering. Other lectures are in process including an audio-visual unit for classroom use on "Resource Issues: The Social Dimension".

The Environmental Engineering program (B-139-Minn) has just received a one-year training grant from EPA. Three new courses bearing on solid waste and hazardous waste disposal will be developed under this program. Protection of ground water and surface water are dealt with. "Law for Environmental Engineers", is designed for graduate students and practitioners. It covers the rudiments of common law, constitutional law, and administrative law as they operate in that amorphous area known as environmental law. The student learns how to read cases and statutes and, using that skill, studies the making of law in general, its enforcement and modification in legislatures, agencies and courts, seeking an understanding of the functions and operations of the legal apparatus and system. Constitutional principles, statutory construction, court actions, and administrative machinery are studied as they create, control and interpret the law of the environment. Specific legislative acts are discussed as needed to give substance to the other more basic studies.

Additional Water Resources Related Staff Members Added

Limnological Research Center, Carol Patterson, Master's in Algal Studies.

David Ruschy, B.S. in Soil Science, was added to the staff in a civil service position to aid in monitoring the state-wide soil moisture survey program. In this program water content of soils is monitored during the growing at more than 50 sites under both annual crop and forest conditions.

Arrangements in Environmental Engineering have been made to have practicing professionals teach specialty courses. Mr. C. Perkett was appointed as an instructor to teach an existing course in Solid Waste Management. Mr. Perkett is a consultant in hazardous waste management. Mr. Arthur LaChappelle, who is an attorney specializing in water law, has been appointed as an instructor to teach a new course in "Law for Environmental Engineers."

Staff Members Employed to Replace Those Who Retired, Died, or moved

None.

New Research and Training Facilities Other Than Research Equipment Items

The Minnesota State Legislature has authorized construction of a new (17 million dollar) building to house the Civil and Mineral Engineering Department which includes the Water Resources and Environmental Engineering Programs. New laboratory facilities will facilitate research programs and additional equipment is included.

ANNUAL REPORT - TRAINING AND EDUCATION ASPECTS
OF THE WATER RESEARCH PROGRAM UNDER P.L. 88-379

Name of University:
(or College)

SUBMIT THE INFORMATION SPECIFIED BELOW FOR THE UNIVERSITY AT WHICH THE WATER RESOURCES RESEARCH INSTITUTE OR CENTER APPROVED UNDER P.L. 88-379 IS LOCATED, AND FOR OTHER UNIVERSITIES WITH WHICH THE INSTITUTE OR CENTER IS COOPERATING. KEEP THE STATISTICS ON ENROLLMENTS, NUMBER OF STUDENTS GRADUATING, EMPLOYMENT STATUS OF GRADUATES,NEW COURSES, ETC., SEPARATE FOR EACH UNIVERSITY. IT IS RECOGNIZED CERTAIN OF THE REQUESTED DATA ON STUDENTS MAY NOT BE READILY AVAILABLE. IF SO, PROVIDE BEST ESTIMATE FIGURES. IN OW-9, DATA ON STUDENTS ARE REQUESTED ONLY FOR THOSE STUDENTS WHO RECEIVED EMPLOYMENT AS RESEARCH PROJECT OR PROGRAM ASSISTANTS THROUGH THE P.L. 88-379 PROGRAM. IF EXTRA SPACE IS NEEDED, ADD PAGES AND NUMBER EACH CONTINUATION ITEM IN THE ORDER SHOWN BELOW.

A. Number of students receiving employment as research project or program assistants through the P.L. 88-379 program. (Include only those students, both continuing and graduating, paid wholly or in part with P.L. 88-379 funds during the past fiscal year.)

Category of Students	No. by Scientific Discipline or Major Field of Study (Engineering, Biology, Economics, etc. 2/ Scientific Discipline of Student	Number
(1) Undergraduates	Biology	3
	Geology	1
	Biochemistry	1
	Chemistry	1
	Physics	1
	Agronomy	1

2/ This refers to educational background prior to employment as research assistant on P.L. 88-379 projects--not to departments in which projects are being conducted.

A. (Continued)

Category of Students	No. by Scientific Discipline or Major Field of Study (Engineering, Biology, Economics, etc. Scientific Discipline of Student	Number
(2) Master's Students	Agricultural Engineering	3
	Biology	7
	Chemistry	1
	Geology	3
	Soil Science	1
(3) Doctoral Students	Agricultural Engineering	1
	Biology	1
	Business Administration	1
	Civil Engineering	1
	Environmental Engineering	1
	Environmental Health	3
(4) Postdoctoral Students	Computer Science	1
	Environmental Engineering	1

B. Employment status of majors in water-related fields who graduated during the school year ending about June and who receive P.L. 88-379 support.

EMPLOYMENT STATUS	CATEGORY OF SCHOOL YEAR GRADUATE BY DEGREE OBTAINED			
	Bachelor's Degree	Master's Degree	Doctoral Degree	Total
1. No. employed in water-related positions in: Total----	1	4	2	7
Federal Agencies----------	( )	( )	( )	( )
State & Local Agencies--------	(1)	(2)	(1)	(4)
University or College---------	( )	( )	( )	( )
Other - Including private enterprise----------	( )	(2)	(1)	(3)
2. No. graduates returning to school for advanced degree----------			1	1
3. No. going into military service----------				
4. No. unemployed or working in other fields----------				
5. No. status unknown----------				
6. Totals----------	1	4	3	8

C. Type of employment of those school year graduates who received P.L. 88-379 support and who are known to have gone into water-related positions. (Number should agree with total listed under item 1 of the preceding paragraph "". Graduates enrolled for further course work or training should not be listed here as employed.)

Number of Graduates Engaged in Water-Related Work In:	CATEGORY OF SCHOOL YEAR GRADUATE BY DEGREE OBTAINED			
	Bachelor's Degree	Master's Degree	Doctoral Degree	Total
1A. Federal Agencies:				
a. Primarily Research----------				
b. Primarily Planning----------				
c. Primarily Development----------				
d. Primarily Operations----------				
e. Primarily Management----------				
f. Other or not known----------				
1B. State & Local Agencies:				
a. Primarily Research----------		1		1
b. Primarily Planning----------		1	1	2
c. Primarily Development----------				
d. Primarily Operations----------	1			1
e. Primarily Management----------				
f. Other or not known----------				
1C. University or College: 3/				
a. Primarily Teaching----------				
b. Primarily Research----------				
c. Primarily Research & Teaching----				
d. Other or not known----------				
1D. Other - Including Private Enterprise:				
a. Primarily Research----------		1		1
b. Primarily Planning----------		1		1
c. Primarily Development----------			1	1
d. Primarily Operations----------				
e. Primarily Management----------				
f. Other or not known----------				
Totals----------				7

Selected summary of above data -- from the "Total" column:

Research (1Aa, 1Ba, 1Cb, 1Cc& 1Da)----------	2
Planning (1Ab, 1Bb & 1Db)----------	3
Development (1Ac, 1Bc & 1Dc)----------	1
Operations (1Ad, 1Bd & 1Dd)----------	1
Management (1Ae, 1Be, & 1De)----------	0

3/Do not include here students working as research assistants and receiving course credits.

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