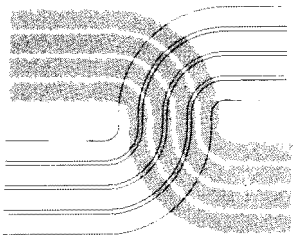
WRRC
Bulletin 108

SEVENTEENTH 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, 1981.

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



WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
GRADUATE SCHOOL

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December, 1981

PREFACE

The Seventeenth Annual Report of the University of Minnesota Water Resources Research Center presents a summary of activities for fiscal year 1981. It covers the period October 1, 1980 through September 30, 1981.

The Report describes the research activities of the Center, its involvement in training water scientists and its efforts in transferring technologic information to potential users.

Research progress reports of nine sponsored projects are included in the report. A summary of students employed and given water sciences training through the Water Resources Center are presented. A summary of the successful Regional Wetlands Conference is also reported. Projects funded outside of OWRT are also summarized.

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.

Contents of this publication do not necessarily reflect the views and policies of the Office of Water Research and Technology, U.S. Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement or recommendation for use by the U.S. Government.

CONTENTS

DIRECTOR'S REPORT, 1981

The University of Minnesota Water Resources Research Center pursued active programs in research, information dissemination and education-training in 1981. Despite an unsettling political-economic climate, the record shows continued strength in activities as shown in this Report.

Water Resources Research Planning

The Water Resources Research Center completed a Five-Year Water Resources Research & Development Plan which identified Research Priorities as well as Five-Year Research, Development and Technology Transfer Plans. These were submitted to OWRT and were also sent to interested people in State and Federal Agencies in Minnesota. The Plan was published as Water Resources Research Center Report No. 1. Copies are available from the Center.

The Water Resources Research Center also cooperated with other states in the Great Lakes and Upper Mississippi River Basin to develop regional goals and objectives.

A summary of the Five-Year Water Resources Research & Development Plan is included on page 13 of this Annual Report.

Research

The Water Resources Research Center sponsored 9 research projects funded through the U.S. Department of Interior. The projects dealt with effects of hydro-carbon spills on the environment, re-use of agricultural drainage waters, recharge of aquifers and groundwaters, affects of agricultural runoff on wetland ecosystems, septage dumping on agricultural land, evapotranspiration, zeolites for removing heavy metals from water, economic efficiency of irrigation, and mathematical hydrologic simulation of critical watersheds.

Some of the highlights from research project reports for 1980-81 are as follows:

1. Prof. Olaf Pfannkuch, assisted by Valerie Eames, Gary Cohen and Janet Smith, (A-041-Minn) has shown in column studies that displacement retardation times are greater for one-ring carbon compounds than for two-ring compounds and that crystalline overgrowth on some sands resulted in greater than expected adsorption of hydrocarbons.

2. Three-year average corn yields were increased on fine-textured soils by 37 percent from a 3-inch slug of supplemental water at mid-season in a study at Lamberton (A-042-Minn) by George R. Blake, Brad Johnson, Wallace W. Nelson and Russell Runck.

3. Professors Donald Slack and Curtis Larson assisted by Francis Idike, Brian Knoch, Stephen Bernath and Keith Markwardt have developed models whose objective is to predict direct recharge of surficial aquifers in the Anoka sand plain.

4. Prof. Gerald Van Amburg, Richard Williams and Dennis DeLand (A-044-Minn) have established two wetland-farmland areas and have collected a large number of samples in an effort to determine the affects of agricultural runoff on natural wetland ecosystems.

5. In the surface 15-cm of a fine-textured soil nitrogen, ammonia, phosphates, fecal streptococcus and fecal coliforms were unaffected by septage application rate; calcium, magnesium, sodium and potassium contents were increased. Amounts of nitrogen in the soil from septage varies with texture according to Charles J. Clanton, Roger Machmaier and James L. Anderson (A-045-Minn).

6. Donald Baker and James Swan (B-147-Minn) compared 13 methods of calculating evapotranspiration with measured water losses from a weighing lysimeter over a 3-year period and found pan evaporation, the simplest method, to be superior to others for predicting evapotranspiration from soybeans and alfalfa.

7. Using a large mass of published and unpublished data, Matt Walton, Roman Kanivetzky and student assistants Brad Birkelo, Mark Dobin, Brian Johnson, Randy Moore and John Mason (B-153-Minn) have tested methods and variables in correlation of water table levels and estimation of storage coefficients for the purpose of determining ground-water recharge rates as related to precipitation in Minnesota.

8. An economic analysis procedure for conversion from high pressure to low pressure irrigation has been developed and made available to irrigation extension specialists (B-158-Minn) by Vernon R. Eidman, Craig C. Sheaffer, Paul Carter, David Nielson and Darrell Bosch.

9. Prof. C. Edward Bowers, C. Teng and Joel Toso (B-160-Minn) have begun a mathematical hydrologic simulation study of critical watersheds in northeastern Minnesota and have tested a primary model (SSARR) for agreement of computed and observed flows.

The WRRC completed two projects for the Upper Mississippi River Basin Commission in 1981. The Center undertook to make a Summary Resource Description of the Upper Mississippi River System, and to Evaluate the Impacts of Navigation and associated operations and Maintenance

procedures on Recreation, Cultural resources and potential Wilderness areas of the river system. Both projects began in 1980, were completed in 1981 and were cooperative with Water Research Centers in Wisconsin and Illinois.

Technology Transfer

A most successful regional wetlands conference was held June 17 to 19 in St. Paul. A technology transfer grant from OWRT aided in the organization and proceedings publication. About 500 participants were present.

As a result of WRRC activities 16 technical papers, reports and bulletins were published. In addition, the Center published the following bulletins and special reports in 1981.

Bulletin 105. Quade, H.W., K.W. Boyum, D.O. Braaten, D. Gordon, C.L. Pierce, A.Z. Silis, D.R. Smith and B.C. Thompson. The Nature and Effects of County Drainage Ditches in South Central Minnesota.

Bulletin 106. King, K.E. A History of Drainage Law in Minnesota with Special Emphasis on the Legal Status of Wet Lands.

Bulletin 107. Feind, T., D. Braaten, and H.W. Quade. A Limnological Compilation of Water Quality of the Minnesota River Watershed, in Minnesota.

Special Report 1. Five-Year Water Resources Research and Development Plan, Water Resources Research Center.

Special Report 2. Jensen, J.E. The Relationship of Artificial Drainage to Soils in Blue Earth County, Minnesota

Education and Training

WRRC projects enabled 7 undergraduate and 17 graduate students to obtain part-time employment while pursuing their studies at the University. It supported the research activities of 15 professors in Minnesota Universities.

Budget

The Center's budget was $469,219 derived from the University of Minnesota, Concordia College, OWRT-U.S. Department of Interior and grants from the Upper Mississippi River Basin Commission.

Political Influences

Politically speaking fiscal year 1981 was a year of upheaval for the State Water Institutes under the Office of Water Research and Technology (OWRT). The election of 1980 brought an abolishment of OWRT by the Secretary of Interior early in 1981. Institutes had to operate without the OWRT for the remainder of the year through a greatly reduced Washington staff. Though budgets for the Institutes were fixed for FY 1981, the Department of Interior recommended no funding to the Congress for FY 1982.

In the meantime Congress was faced with demands for severe retrenchment in all federal budgets. Administration proposals for budget cuts were so far-reaching and so pervasive that action by Congress was delayed by long deliberations well past the October 1, 1982 beginning of the new fiscal year. A series of continuing resolutions into FY 1982 added to the uncertainty of continued federal funding of all agencies. This was particularly true for the state Water Institutes, funds for which were included in the Senate, but not the House bills. And as it turned out, the House version was the one adopted in the continuing resolution.

Thus the wounding of the State Water Resources Research Centers in FY 1982 and the uncertainties of continuation into FY 1983 made normal operation very difficult. And as yet the future of State Water Institutes into future fiscal years is clouded with uncertainty.

Minnesota
Water Resources Research Center
University of Minnesota

ADMINISTRATION

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

Advisory Committee

University of Minnesota

C. Edward Bowers	St. Anthony Falls Hydraulic Laboratory
Kenneth N. Brooks	College of Forestry
Dwight A. Brown	Department of Geography
K. William Easter	Department of Agricultural & Applied Economics
Lowell D. Hanson	Department of Soil Science
Warren F. Ibele	Graduate School
Curtis L. Larson	Department of Agricultural Engineering
Walter J. Maier	Department of Civil & Mineral Engineering
William P. Martin	Department of Soil Science
Gordon D. Rose	Institute of Agriculture
Richard J. Sauer	Agricultural Experiment Station
Thomas E. Straw	Division of Science & Mathematics (Morris)
Matt S. Walton	Minnesota Geological Survey
Thomas F. Waters	Department of Entomology, Fisheries & Wildlife
Thomas J. Wool	Lake Superior Basin Studies Center (Duluth)
Herbert E. Wright	Limnological Research Center

State and Private Colleges

Norman J. Baron	Dept. of Geography, Winona State University
Charles H. Fuchsman	Center for Env. Studies, Bemidji State University
A. Joseph Hopwood	Dept. of Biology, St. Cloud State University
James T. Jack	Dept. of Geography, Mankato State University
Robert T. Moline	Dept. of Geography, Gustavus Adolphus College

State, Local, and Federal Agencies

Rollin M. Dennistoun	Minn. Department of Agriculture
F.H. Geisenhoff	Minn. Department of Economic Development
Gene H. Hollenstein	Minn. Department of Natural Resources
Edwin H. Ross	Minn. Department of Health
Joseph E. Sizer	Minn. State Planning Agency

Jack C. Ditmore	Minn. Water Planning Board
Erling M. Weiberg	Minn. Water Resources Board
Marcel Jouseau	Metropolitan Council
Donald R. Albin	U.S. Geological Survey
Harry M. Major	U.S. Soil Conservation Service
Joseph Scott	U.S. Bureau of Sport Fisheries & Wildlife
Elon S. Verry	U.S. Forest Service

Interest Groups and Private Concerns

Douglas W. Barr	Consulting Hydraulic Engineer
Jeanne Crampton	League of Women Voters
Raymond A. Haik	Attorney
Ken Kadlec	MPIRG
Ford Robbins	Sierra Club
Paul Toren	Izaak Walton League of America

Research Faculty

The following faculty members were principal investigators on Water Resources Research Center Projects in FY 1981.

Donald G. Baker	Professor, Soil Science
George R. Blake	Professor, Soil Science
C. Edward Bowers	Professor, Civil & Mineral Engineering
Charles J. Clanton	Instructor, Agricultural Engineering
Vernon R. Eidman	Professor, Agricultural & Applied Economics
Donald E. Gilbertson	Associate Professor, Ecology & Behavioral Biology
Roman Kanivetsky	Hydrologist, Minnesota Geological Survey
Timothy J. Kelly	Research Associate, Water Resources Research Center
Curtis L. Larson	Professor, Agricultural Engineering
Robert T. Moline	Professor, Geography, Gustavus Adolphus College
Hans-Olaf Pfannkuch	Associate Professor, Geology & Geophysics
Gordon G. Plorin	Research Assistant, Water Resources Research Center
Craig C. Sheaffer	Assistant Professor, Agronomy
Donald C. Slack	Assistant Professor, Agricultural Engineering
James B. Swan	Professor, Soil Science
Gerald L. Van Amburg	Associate Professor, Biology, Concordia College
Matt S. Walton	Professor, Minnesota Geological Survey

FISCAL YEAR 1981 OWRT BUDGET

Annual Cooperative Program

Project Title, Principal Investigator And OWRT Project Number	Federal Funds $
Center Director's Office	61,600
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
Predicting Direct Recharge of Surficial Aquifers, D.C. Slack and C.L. Larson, Dept. of Agricultural Engineering, (A-043-Minn).	10,000
The Affects of Agricultural Runoff Upon Natural Wetland Ecosystems, G.L. Van Amburg, Biology Dept., Concordia College, (A-044-Minn).	11,700
Minimum Hydraulic and Nutrient Loading Rates of Septage to Soils, C.J. Clanton, Agricultural Engineering, (A-045-Minn).	11,700
TOTAL	115,000
Annual Allotment Non-Federal Contribution	85,238

Matching Grant Program

Project Title, Principal Investigator and OWRT Project Number	Federal Funds $	Non-Fed. Funds $	Total Funds $
The Measurement of Evapotranspiration and Comparison with Empirical Calculation Methods for Use in Minnesota and Similar Climatic Regions, D. Baker & J.B. Swan, Dept. of Soil Science, (B-147-Minn)	11,800	16,750	28,550
Ground-Water Recharge Rates in Minnesota as Related to Precipitation, M. Walton & R. Kanivetsky, Minnesota Geological Survey, (B-153-Minn)	20,537	26,752	47,289
Increasing Economic Efficiency of Water Use for Irrigation in the Upper Midwest, V.R. Eidman, Dept. of Agricultural & Applied Economics and C.C. Sheaffer, Dept. of Agronomy & Plant Genetics, (B-158-Minn)	31,630	32,269	63,899
Mathematical Hydrologic Simulation of Critical Watersheds in Northeastern Minnesota, C.E. Bowers, Dept. of Civil & Mineral Engineering, (B-161-Minn)	15,809	15,809	31,618
TOTAL	79,776	91,580	171,356

WATER RESOURCES RESEARCH CENTER
UNIVERSITY OF MINNESOTA
SOURCES OF FUNDS

Fiscal Year	Center's Budget $	Federal (OWRT) $	Matching Monies				Special Grants
			U of M $	State College $	Private College $	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	113,355	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	358,872	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	151,855	14,813	4,268	3,500	
1974	441,680	255,179	180,969	0	2,932	3,500	
1975	378,584	229,656	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	
1980	395,736	174,985	169,351	3,900	0	3,500	44,000
1981	469,219	194,776	177,842	0	12,896	0	83,705

WATER RESOURCES RESEARCH CENTER

Distribution of Federal Research Monies[1/]

1974-1981 inclusive

University Unit	Amount $
College of Agriculture	322,175
Agricultural Engineering	140,913
Agriculture & Applied Economics	43,775
Entomology Fisheries and Wildlife	23,395
Soil Science	114,092
College of Biological Sciences	14,406
Ecology and Behavioral Biology	14,406
Limnology (see IT)	
College of Forestry	77,981
Forest Resources	77,981
College of Liberal Arts	103,132
Anthropology	43,532
Sociology	59,600
Health Sciences	81,083
Public Health	81,083
Institute of Technology	355,828
Civil and Mineral Engineering	114,032
Geology and Geophysics	65,692
Limnology Center	118,933
St. Anthony Falls Hydraulic Lab	57,171
Minnesota Geological Survey	32,439
Concordia College	11,700
Gustavus Adolphus College	3,816
Mankato State University	30,000
University of Minnesota, Duluth	41,362
	1,073,922

[1/] Excludes Administrative costs of the Water Resources Research Center

FIVE-YEAR WATER RESOURCES AND DEVELOPMENT PLAN

The Five-Year Water Resources Research and Development Plan was prepared on request of the U.S. Department of Interior, Office of Water Research and Technology to fulfill a Congressional mandate. The exercise has been extremely useful in giving the Water Resources Research Centers an opportunity to examine, restate and update their goals and objectives and to prepare a program for each state for the immediate future.

The Minnesota 5-year plan was developed in consultation with interested citizen groups, with local, state and federal agency personnel, by use of agency reports, and with counsel from the Advisory Committee of the Water Resources Research Center.

The plan includes a review of the states' water resources, present and projected uses of the resource, water and related land planning and development activities, problems and concerns of the people and agencies giving input, the Water Resources Research Center priorities and the five year research, development and technology transfer plans of the Center.

Minnesota has an abundance of surface water, much of which it exports through three of Americas' major watersheds. A small part of the state lies within a fourth. Distribution is not uniform and parts of the state having lower precipitation have periodic shortages. Groundwaters are abundant in some aquifers and are scarce in others depending largely on the underlying strata.

There is widespread apprehension though very few actual cases of ground water shortages. There is statewide concern for pollution of the ground waters and acute concern in the quality of groundwater in the southern part of the state, especially the southeast.

The need for an inventory of the State's water resources was expressed by nearly every group giving input into the Center's effort. Need for data collection, classification, storage and ease of retrieval is an important need for Minnesota. Location and extent of groundwater supplies, storage of surface waters in wetlands, forests and peatlands for flood control and for groundwater recharge are problems of concern to Minnesotans.

The people of Minnesota appreciate the historical quality of their water. They are eager to maintain it and to restore it where it has been compromized. The few instances of hazardous wastes and their possible congruence with groundwaters have alarmed many people. And there is concern for the health of people and animals in specific areas of the state. Protection of groundwaters has a very high priority. Both point and non-point pollution and its control is of pervasive concern.

There is widespread concern for the maintenance and preservation of waters that relate to quality of life of the people. Lake quality and wetlands preservation are a statewide concern. The conflicts resulting

from drainage of wetlands, the control of water levels for downstream flow and for flooding are ever present.

Conservation and efficient use of surface and groundwaters is of interest to many people. On the one hand the great potential use in irrigation is likely to put significant demands on the resource. On the other hand, relatively abundant supplies have been such that the demand for conservation has not been acute. Some knowledgeable people and concerned agencies are trying to raise the consciousness of the citizens of the state to the disappearance of wetlands, to the potential consequences of peat mining or the dangers of acid rain if and as the demand for fossil fuels increases. There is need to anticipate these problems and to get on with research that deals with the impact of future shifts in energy use and development as it relates to the water resource.

Management of the state's water resources raises the need for inventory and reliable data that will allow wise use decisions. Flood management, the role and uses of wetlands in the management decisions and the development of workable systems for management of non-point pollutants are evident. Energy and water are related in many ways. Particularly in Minnesota where climate dictates many energy needs, there is interest in the uses of groundwater and waste heat from industrial waters to offset the decreasing energy supply. As stated earlier there are also environmental concerns from such potential developments.

The last two chapters of the 5-year plan define the Water Resources Research Center's priority research for the future and state the guidelines that will be used to determine which items will receive funding and receive research attention. The philosophical bases on which selection of projects will be made as well as the goals and objectives of the Center are stated.

(The foregoing statement on the Center's five-year Water Resources Research Development Plan is Chapter 1 of Special Report 1 published by the WRRC in 1981. Copies of the full report are available from WRRC)

ANNUAL ALLOTMENT PROGRAM

NARRATIVE PROGRESS REPORTS

Annual Report -- Title I Projects

OWRT Project No.: A-041-Minn

Agreement No.: 14-34-0001-1125

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

FCCSET 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
Valerie A. Eames	M.S.	Geology
Gary B. Cohen	M.S.	Geology
Janet Smith	B.S.	Geology

A. Research Project Accomplishments:

Research has concentrated on dynamic column displacement studies with combined dispersion and adsorption of hydrocarbons. The compounds tested were phenols, napthalene and phenanthrene. The results have shown that retardation time for one ring compounds is shorter than for two ring compounds. The presence of crystalline overgrowth on grains in the Ottawa sand packs resulted in more adsorption than expected when compared to less ideal porous media, such as St. Peter sand and glacial outwash material.

Batch experiments were carried out to determine static adsorption isotherms for the same compound and porous medium combinations. They are still under way, the purpose is to verify if the same relations exist as with the dynamic experiments, that is higher adsorption on surfaces with crystal overgrowths.

Further experiments dealing with retention of oil and water in the vadoxe zone were carried out and laboratory techniques with centrifuge desaturation were developed to increase the speed of desaturation. With adequate controls, transfer from centrifuge to column experiment results are feasible. At this time the accuracy has to be improved.

B. Publications:

Eames, V.A., "Influence of Water Saturation on Oil Retention Under Field and Laboratory Conditions", June 1981. M.S. Theses.

Cohen, G.B., "Dispersion and Sorption of Dissolved Hydrocarbons in Aquafier Materials", June 1981.

Eames, V.A. and H.O. Pfannkuch, "Influence of Water Saturation on Oil Retention", GSA Abstract, Vol. 13, No. 7, September 1981. Poster Session presentation at GSA Annual meeting November 3, 1981, Cincinnati, Ohio.

Pfannkuch, H.O., "Analysis, Monitoring, Abatement and Cleanup of Two Crude Oil Spills on Glacial Drift in Central Minnesota. Presented at 26th Annual Midwest Ground-Water Conference, October 28-30, 1981, Bismarck, ND.

Pfannkuch, H.O., "Problems of Monitoring Network Design to Detect Unanticipated Contamination". Groundwater Monitoring Review (in press, Winter Quarter issue, 1981).

C. Project Status:

Project is being completed. Work will end after project extension (December 31, 1981) ends.

D. Application of Research Results:

The U.S. Geological Survey and the Minnesota Geological Survey have cooperated on the data collection and will use some of the data in their programs. The Minnesota Department of Natural Resources, Division of Waters have expressed interest in using information and models from this project.

E. Work Remaining and Progress Contemplated Next Year:

The project will end December 31, 1981.

OWRT Project No.: A-042-Minn

Agreement No.: 14-34-0001-1125

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

FCCSET Research Category: 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 Investigator	Degree	Discipline
George R. Blake	Ph.D.	Soil Science

Student Assistants	Degree	Discipline or Academic Background
Brad Johnson	M.S.	Soil Science
Theresa Myers	B.S.	Soil Science

A. Research Project Accomplishments:

We obtained a third summer's data from field plots at the Southwest Experiment Station at Lamberton, Minnesota. Water was applied to corn by sprinklers using excess surface and tile waters stored in a surface reservoir near the plots. Threatments varied from the principal goal of adding a large amount of water (3 surface inches) at midseason in order to restore the soil water reservoir.

Summer precipitation was below normal in 1981 due to a dry May. June was also below normal, but July and August were above. Corn grain yield increase over the check was 24 bu/A despite a nitrogen deficiency due to an error in fertilization. Three year average yields have been increased by 42 percent from one inch of water just after planting plus 3 inches in mid July. The 30 percent increase in 1981 would have been expected to be greater had the corn been heavily fertilized.

Three years' data are now being analyzed and prepared for publication.

B. Publications:

Johnson, Bradley, M.S. Thesis, University of Minnesota. Reuse of Agricultural Drainage Waters for On-Site Soil Water Recharge and Irrigation, 1981.

C. Project Status:

Project has been extended to March 31, 1982 to allow working over the data and preparing it for publication.

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. Farmers in those areas where fine textured sub-himid soils are found will be particularly interested in these results since ground water availability is often insufficient for large-scale irrigation development. Thus the impoundments could serve as flood control structures as well as a convenient source for irrigation water and also offer the possibility of recycling some soluble plant nutrients.

Regional climatic conditions must dictate a need for soil water recharge. In those regions where moisture stress is commonly experienced during the growing season, irrigation could be a worthwhile undertaking. By investigating the relationship between meteorological conditions, soil moisture, plant stress, and crop yield for corn, we expect to improve irrigation scheduling and maximize water use efficiency.

Meetings with County Agricultural Agents and farmers are planned for January, 1982 in order to inform them of the potential for irrigation on these soils.

E. Work Remaining and Progress Contemplated During Next Year:

Corn yield results were not obtained until December 1981. Also soil moisture data must be calculated and charted. Thus there is considerable work being done at this time to summarize the three year's results and to relate the results to the feasibility of such irrigation on fine-textured soils.

OWRT Project No.: A-043-Minn

Project Title: Predicting Direct Recharge of Surficial Aquifers

Agreement No.: 14-34-0001-1125

FCCSET Research Category: 02-A, 02-F, 02-G; 1, 5, 11

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

Project Began: October 1, 1979

Scheduled Completion: September 30, 1982

Principal Investigators	Degree	Discipline
Donald C. Slack	Ph.D.	Agricultural Engineering
Curtis L. Larson	Ph.D.	Agricultural Engineering

Student Assistants	Degree	Discipline or Academic Background
Francis I. Idike	M.S.	Agricultural Engineering
Brian Knoch	B.S.	Agricultural Engineering
Stephen Bernath	B.S.	Forest Hydrology
Keith Markwardt	Undergrad	Agricultural Economics

A. Research Project Accomplishments

Water levels, soil moisture and weather data continue to be monitored at the site established on the Anoka sand plain during FY 1980. Data now encompasses two growing seasons and one winter at this site.

Component models have been developed for some of the phenomenon to be modeled. These include the evapotranspiration (ET) and soil misture extraction submodels. The infiltration and soil moisture redistribution submodels have also been formulated although not all submodels have been thoroughly tested. The ET submodel utilizes pan evaporation data and "crop" coefficients based on growth stage to predict actual ET. The soil moisture extraction model determines how ET is extracted from the soil and requires inputs of rooting depth as a function of crop growth stage.

The infiltration submodel utilizes the Green-Ampt-Mein-Larson (GAML) model to describe infiltration for both nonponded and ponded conditions. Included in this submodel are the effects of surface roughness on surface storage and subsequent infiltration or surface evaporation. The redistribution submodel predicts moisture movement within the profile by utilizing Darcy's law applied to unsaturated flow. The profile above the water table is subdivided into layers and water movement between adjacent layers calculated based on water content and hydraulic conductivity of the layers.

This submodel will be linked to a deep percolation submodel which will predict water table levels based on extraction or recharge. This submodel is still being developed.

B. Publications: None

C. Project Status

No funding has been appropriated for the current year. If funds are forthcoming, the work will be continued during FY 1982.

D. Application of Research Results

The U.S. Geological survey and Minnesota Geological survey have cooperated on the data collection phase of the project and will utilize the soil moisture and groundwater data in their programs. In addition, the USGS has expressed considerable interest in the evapotranspiration portion of the model and may utilize it in some watershed studies.

The Minnesota Department of Natural Resources, Division of Waters, have expressed interest in using the model to assess groundwater recharge in irrigated areas utilizing water from surficial aquifers. The model should be equally useful to other states with similar aquifers.

E. Work Remaining and Progress Contemplated During FY 1982

The infiltration, redistribution and deep percolation submodels will be completed and linked to the other submodels. The resulting model will comprise a growing season recharge model but will not account for snowmelt recharge.

Efforts will be made to subsequently develop a snowmelt and frozen soil infiltration model and test the entire model using the data collected at the Anoka sand plain site.

Groundwater, meteoroligical and soil moisture data collection will continue throughout FY 1982 using experiment funds if available if OWRT funds are not forthcoming. Without continued OWRT support, full development and broader testing of the model cannot be achieved. If OWRT funding is continued, the expanded model including snowmelt will be tested at both the Anoka sand plains location and in the Bonanza Valley. Effects of tillage practices which increase surface storage on recharge will be evaluated using the expanded model.

OWRT Project No.: A-044-Minn

Agreement No.: 14-34-0001-1125

Project Title: The Affects of Agricultural Runoff Upon Natural Wetland Ecosystems

FCCSET Research Category: IV, A

Name and Location of University Where Project is Being Carried Out: Concordia College, Moorhead, Minnesota

Project Began: October 1, 1980

Scheduled Completion: September 30, 1982

Principal Investigator	Degree	Discipline
Gerald L. Van Amburg	Ph.D.	Range Science (Ecology)

Student Assistants	Degree	Discipline or Academic Background
Richard Williams	B.S.	Biology
Dennis Leland	undergrad	Biology

A. Research Project Accomplishments:

Two wetlands were selected as study sites for the project during Fall 1980. One site is located in Ottertail County, Minnesota (Sec. 1 & 2, T132N, R44W) and the other in Clay County, Minnesota (NE1/4SE1/4, Sec. 29, T138N, R44W). The watersheds for both wetlands are cultivated, the principal crops being small grains, corn, soybeans, and sunflowers. The owners were interviewed and a recent history of crops, fertilization and pesticide application was recorded.

Collection of field data began on May 13, 1981. Five compartments of each system were sampled, these being: (1) watershed soils (2) watershed runoff (3) wetland water (4) wetland sediments and (5) wetland emergent vegetation. Each compartment was sampled approximately every two weeks, except for the runoff. The runoff samples necessarily depended upon sufficient precipitation to produce surface flow.

Parameters of watershed soils chosen for measurement were: (1) ammonia (2) nitrite + nitrate nitrogen (3) Kjeldahl nitrogen (4) exchangeable phosphorus and (5) exchangeable potassium. The analyses for these are not yet complete.

Runoff water measurements included the following: (1) conductivity (2) pH (3) nitrite (4) ammonia (5) nitrate (6) ortho-phosphate (7) total phosphate and (8) potassium. No runoff samples were collected until June 10 due to insufficient precipitation.

The collection devices for runoff collection were constructed by placing one-half of a plastic wading pool where runoff was likely to occur. Each of these had a drain hole with an attached hose running to a collection container. Samples were taken for analysis within 24 hours after a runoff event.

Variables being measured for the wetland water are: (1) conductivity (2) temperature (3) pH (4) ammonia (5) nitrite (6) nitrate (7) orthophosphate (8) total phsophate and (9) potassium. All analyses for these variables are run as soon as possible, usually within a few hours. Conductivity and temperature are measured on site.

The sediment compartment is being analyzed for: (1) ammonia (2) nitrate + nitrite (3) Kjeldahl nitrogen (4) exchangeable phosphorus (5) total phosphorus and (6) exchangeable potassium. The sediments are oven-dried at 100°C before analysis.

The emergent vegetation of both marsh systems is almost totally comprised of cattail (Typha latifolia, T. angustifolia and T. glauca). Thus we have restricted our chemical analysis to Typha sp. For the purpose of analysis the vegetation compartment has been subdivided into above-ground and below-ground compartments. The below-ground is further divided into roots and rhizomes. Parameters measured are: (1) above-ground production (2) below-ground production (3) Kjeldahl nitrogen above-ground (4) Kjeldahl nitrogen in roots (5) Kjeldahl nitrogen in rhizomes (6) total phosphorus above-ground (7) total phosphorus in roots (8) total phosphorus above-ground (9) potassium above-ground (10) potassium in roots (11) potassium in rhizomes (12) total non-structural carbohydrates in rhizomes, and (13) total non-structural carbohydrates in roots. Much of the chemical analyses remain to be completed.

Another aspect of the vegetation compartment being investigated is decomposition. Standing litter was collected at both sites, placed in nylon-mesh bags and replaced in the water compartment. The bags are being collected periodically to determine loss in weight and change in composition with respect to total nitrogen, phosphorus and potassium. This will be continued through the next growing season.

During late summer a part of the watershed of the Ottertail County wetland was treated with the herbicide 2,4-D. Samples of the water and sediment compartment were taken in an attempt to find how much of the herbicide entered the wetland via runoff, and how long it remained.

B. Publications:

None.

C. Project Status:

It is anticipated that the project will continue through the next growing season. However, continuance toward the original stated goals depends upon further financial support.

D. Application of Research Results:

The U.S. Fish and Wildlife Service are interested in the results of this study in that the data may have some direct applications to wetland systems for which they are responsible. The wetland system in

Ottertail County is a Waterfowl Production Area. This wetland and many others are dependent upon agricultural runoff for water.

E. Work Remaining and Progress Contemplated During Next Year:

Collection and analysis of the agricultural runoff and the wetland water compartments will continue. The decomposition study initiated during Fall 1981 will continue through the 1981 growing season. Mesh bags containing litter will be collected every two weeks, as soon as the wetlands have tahwed, and analyzed for nitrogen, phosphorus and potassium.

The submergent vegetation compartment of the wetlands will be studied to determine production and chemical composition. Emergent vegetation will also be sampled to gather further data on composition. However, belowground biomass and chemical composition of the emergents will not be followed.

Invertebrate populations will be sampled to determine the production and nutrient turnover of this compartment.

A good deal of the chemical analyses from the 1981 season are incomplete. These will be finished during the winter months.

OWRT Project No.: A-045-Minn

Agreement No.: 14-34-0001-1125

Project Title: Maximum Hydraulic and Nutrient Loading Rates of Septage to Soils

FCCSET Research Category: V-G

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

Project Began: October 1, 1980

Scheduled Completion: September 30, 1983

Principal Investigator	Degree	Discipline
Charles J. Clanton	M.S.	Agricultural Engineering
Roger E. Machmeier	Ph.D.	Agricultural Engineering
James L. Anderson	Ph.D.	Soil Morphology

Student Assistants	Degree	Discipline or Academic Background

None

A. Research Project Accomplishments:

The first year's results of this three year study indicate that soil texture, septage application rates and location in the soil profile have a significant effect on nitrate concentrations. The septage application rates used in the first year of this study indicate that there was a downward movement of nitrates. In a sandy loam soil, it was observed that precipitation has a larger effect on nitrate concentrations and movement within the soil profile than on silt loam or clay loam soils. The silt loam and clay loam soils indicated a constant concentration of nitrates in the soil profile during septage application. However, when the septage application was stopped, the top portion of the soil profile condition likely changed from a saturated condition to an aerobic condition, causing nitrification and the subsequent leaching of nitrates. In addition, there was indication that the maximum hydraulic loading limit might have been reached on the clay loam soil.

The application of septage causes a significant increase in the concentration of soil water calcium, magnesium, sodium and potassium. The application of septage did not affect the total Kjeldahl nitrogen, ammonia, phosphates, fecal streptococcus and fecal coliforms in the soil water samples extracted at any depth from any of the three soils, indicating that the top 15 cm of the soil profile was stabilizing these parameters.

During the second year the original research plots were monitored for nutrients in the soil water. In addition two other plots were installed to test a third application rate of 200 kg of nitrogen per hectare. The second year's results indicate that TKN, NH_3-N and NO_3-N in the soil water were significantly affected by different soil textures. The different levels of application rate and the depth of sample significantly affected

soil water TKN and NO_3^--N. None of the various treatments affected the concentration of fecal streptococcus or fecal coliforms in the soil water samples. Preliminary data indicates that the NO_3^--N concentrations in the soil water may be four times the concentrations measured the first year. The plots with the 200 kg of nitrogen per hectare application indicate no increase in NO_3^--N concentration in the soil water for the clay loam and silt loam soils; however, for the sandy loam there does appear to be an increase in soil water NO_3^--N.

B. Publications:

Clanton, C.J., R.E. Machmeier, J.L. Anderson and M.J. Hansel. Maximum Application Rates for Land Treatment of Septage - Progress Report. 1981. ASAE Paper No. 81-2063.

Clanton, C.J., R.E. Machmeier, J.L. Anderson, and M.J. Hansel. Maximum Loading Rates of Septage to Soils - Progress Report. 1981. Proceedings of the Third National Symposium on Individual and Small Community Sewage Treatment.

C. Project Status:

The project will continue until September 30, 1983 provided that funding is available.

D. Application of Research Results:

The Minnesota Pollution Control Agency will be able to develop guidelines for land application of septage and related wastewaters to be used throughout the state on various soil textures. In addition, there have been several requests from other state environmental or pollution agencies about our research findings to be compared with their research results and recommendations.

Consulting and design engineers will be able to utilize the information for planning land application systems. County officials will be able to utilize the information for county zoning and land use planning. And finally, septage haulers will be able to utilize the information by providing them with alternatives to delivery of the septage to municipal treatment plants.

E. Work Remaining and Progress Contemplated Next Year:

If funding is available, the data collected this summer will be further analyzed and compared with the first year's results. For the research plots that were initially loaded in 1980, the intent will be to monitor the soil water for nitrates and other pollutants from spring to fall during 1982. For the research plots that were installed in 1981, it is the intent to increase the loading rate to approximately 400 kg of nitrogen per hectare in the spring and monitor the soil water for pollutants into the fall.

MATCHING GRANT PROGRAM

NARRATIVE PROGRESS REPORTS

Annual Report -- Title I Projects

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 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 G. Baker	Ph.D.	Soil Science
James B. Swan	Ph.D.	Soil Science

Student Assistants	Degree	Discipline or Academic Background
Jon E. Ljungkull	B.S.	Soil Science
David Ruschy	B.S.	Soil Science
Dianne Feihr	undergrad	Soil Science

A. Research Project Accomplishments:

Total daily evapotranspiration measurements and calculated value are being summarized for the 1978, 1979, and 1980 growing seasons. The crop in 1978 and 1979 was soybeans, and in 1981 it was alfalfa. Although sufficient data have been obtained for this project the evapotranspiration measurements were continued in 1981. As noted in last year's report the data are restricted to days without precipitation and without irrigation.

Meteorological data measured includes solar radiation, wind, air temperature, and atmospheric humidity. Other measurements include soil moisture by tensiometers and lysimeter weight changes.

A summarization of the data permits a preliminary ranking of the various evapotranspiration calculation methods over the 3 years and 2 crops. Their performance ranked from best to worst in terms of R^2 of the daily total values are as follows:

1. Pan evaporation
2. Van Bavel method
3. Penman method
4. Turc method
5. Stephens-Stewart method
6. Makkink method
7. Jensen-Haise method
8. Grassi method
9. Priestley-Taylor method
10. Papadakis method
11. Hamon method
12. Blaney Criddel method
13. Thornthwaite method

The pan evaporation method in addition to apparently being superior has the advantage of being the simplest, requiring only a single measurement that any irrigator can take easily.

The following methods showed a better performance in 1980 with the alfalfa crop than they did in 1978 and 1979 when the crop was soybeans: Ture, Stephens-Stewart, Makkink, Jensen-Haise, and Papadakis methods.

Figures 1, 2, and 3 are examples of the results obtained with the Penman method for the 3 years of operation, 1978, 1979, and 1980, respectively.

Sample statistics for the Penman evapotranspiration calculation method are shown in Table 1.

The use of a pan coefficient is frequently employed to estimate the potential evapotranspiration from measurements of pan evaporation. The form of the relationship commonly used is

$$PE = CE_{pan}$$

where the coefficient C depends on the crop being grown and its growth stage. Fig. 4-6 show the lysimeter/pan evaporation ratios plotted versus time for 1978, 1979, and 1980 at St. Paul. The data were corrected for precipitation and, except for extenuating circumstances (irrigation and cultivation) all cases are included. The fluctuations in the 1978 data prior to July 5 are due to problems with the lysimeter weighing system. Among other differences between the 3 years is the higher ratio with alfalfa than soybeans. A feature due, of course, to the greater plant cover of alfalfa except immediately after cutting. The alfalfa also shows a ratio that is greater than soybeans and unlike soybeans nearly constant except when recovering from cutting.

As noted in last year's report over-winter measurements of snow sublimation are being made but with great difficulty.

B. Publications:

None.

C. Project Status:

The project has been completed and is in the process of being summarized and conclusions drawn.

D. Application of Research Results:

Information relative to this project has been used in Agricultural Advisories prepared by Dr. M.W. Seeley, Extension Agricultural Climatologist, University of Minnesota. These advisories are provided twice each week to farmers relative to irrigation scheduling.

E. Work Remaining and Progress Contemplated During Next Year:

Summarization of the data so that conclusions can be drawn with respect to which methods are best for this climatic region.

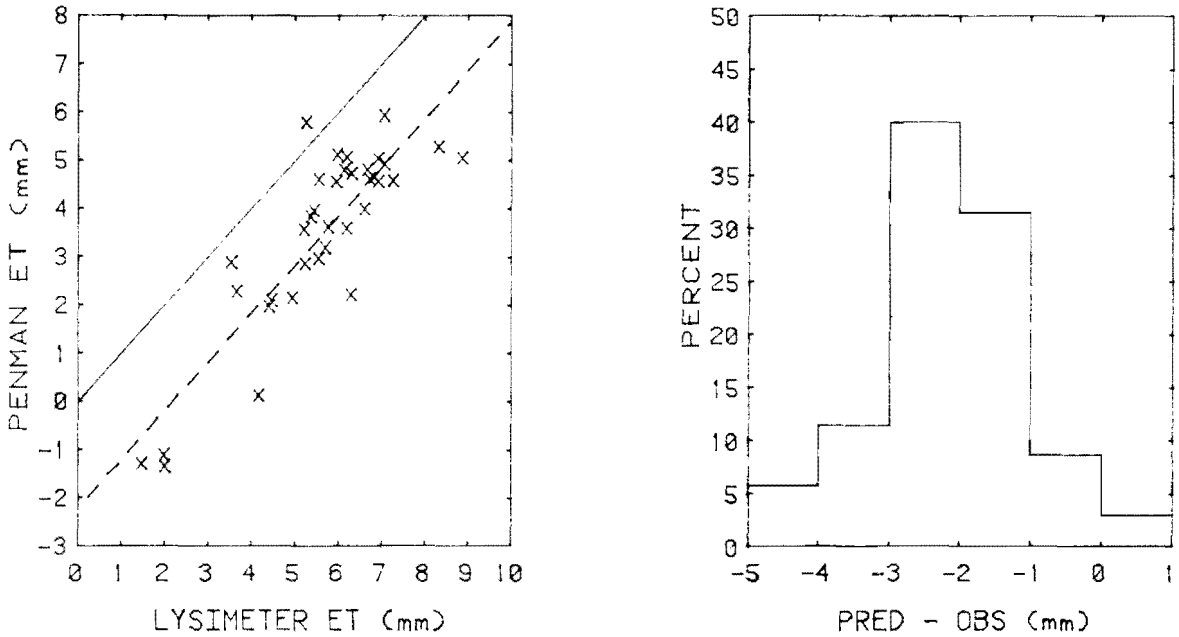

Figure 1. Comparison of evapotranspiration (in mm/day) predicted by the Penman method (PRED) and the observed evapotranspiration values (OBS) measured by a weighing lysimeter in 1978. The crop is soybeans. In the diagram to the left the solid line is the 1:1 line and the dashed line the best fit linear regression equation.

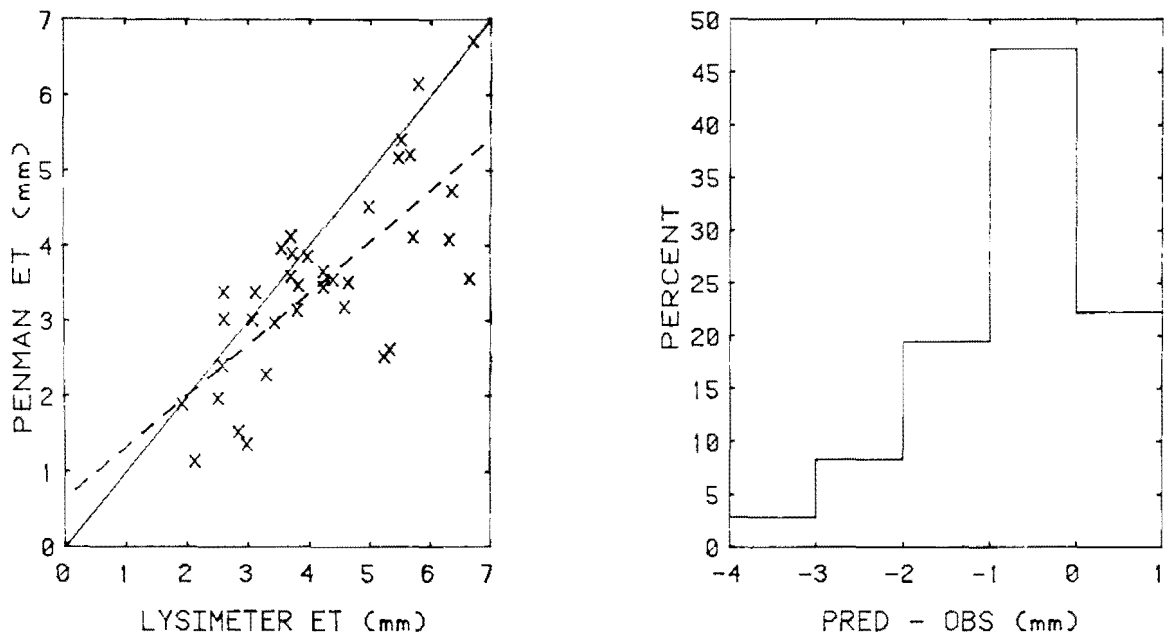

Figure 2. Same legend as Fig. 1 except year is 1979.

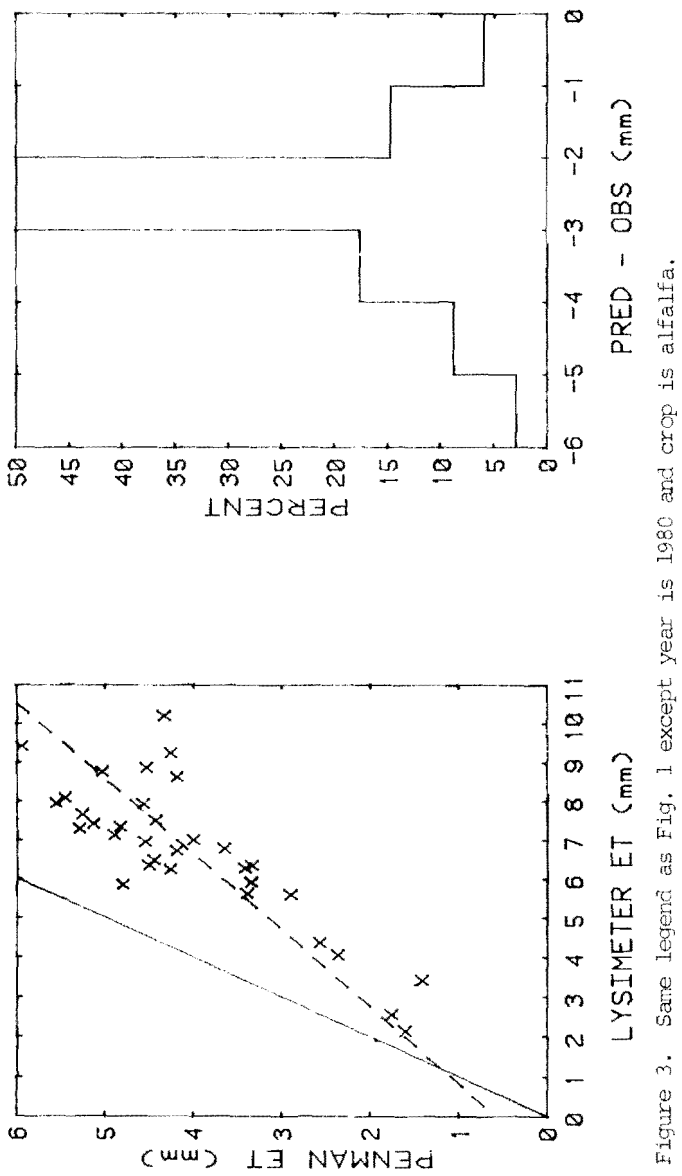

Figure 3. Same legend as Fig. 1 except year is 1980 and crop is alfalfa.

Table 1. Comparison of observed evapotranspiration values (O) and predicted values (P) by the Penman method. All values are in mm/day.

Year	Mean(O)	Std. Dev.(O)	Mean(P)	Std. Dev.(P)	Regression Line Slope	Regression Line Intercept	R^2	RMSE
1978	5.57	1.63	3.45	1.93	1.02	-2.21	0.739	2.33
1979	4.20	1.35	3.51	1.25	0.68	0.65	0.539	1.16
1980	6.71	1.85	4.05	1.15	0.52	0.57	0.690	2.88

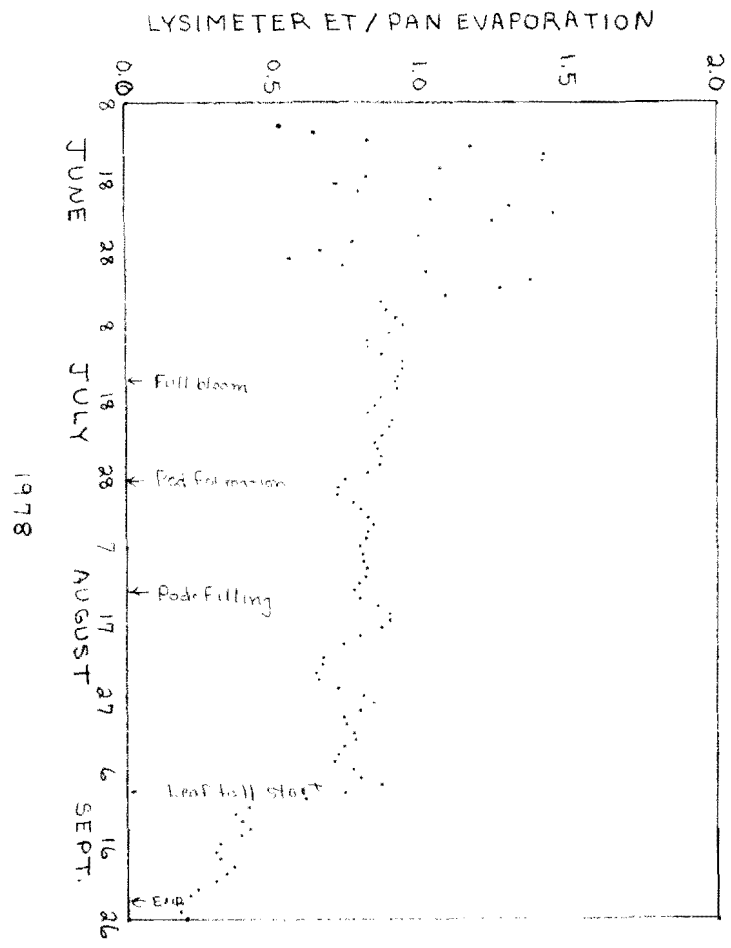

Figure 4. Lysimeter evapotranspiration/pan evaporation ratio of soybeans, 1978.

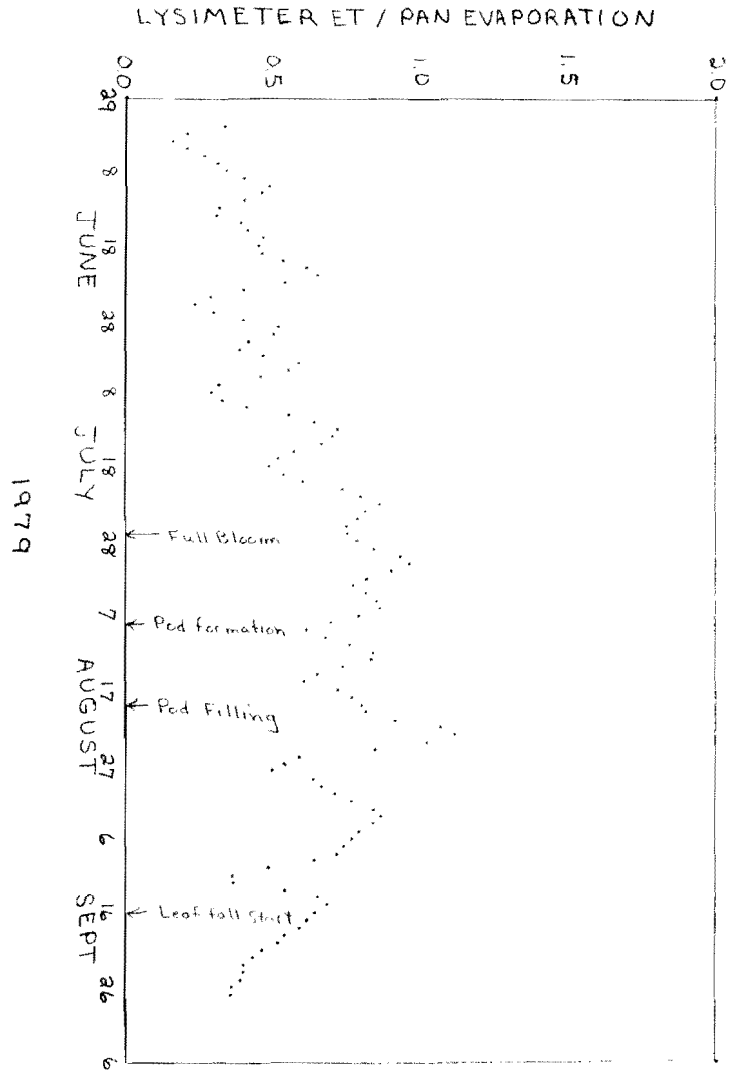

Figure 5. Lysimeter evapotranspiration/pan evaporation ratio of soybeans, 1979.

Fig 3

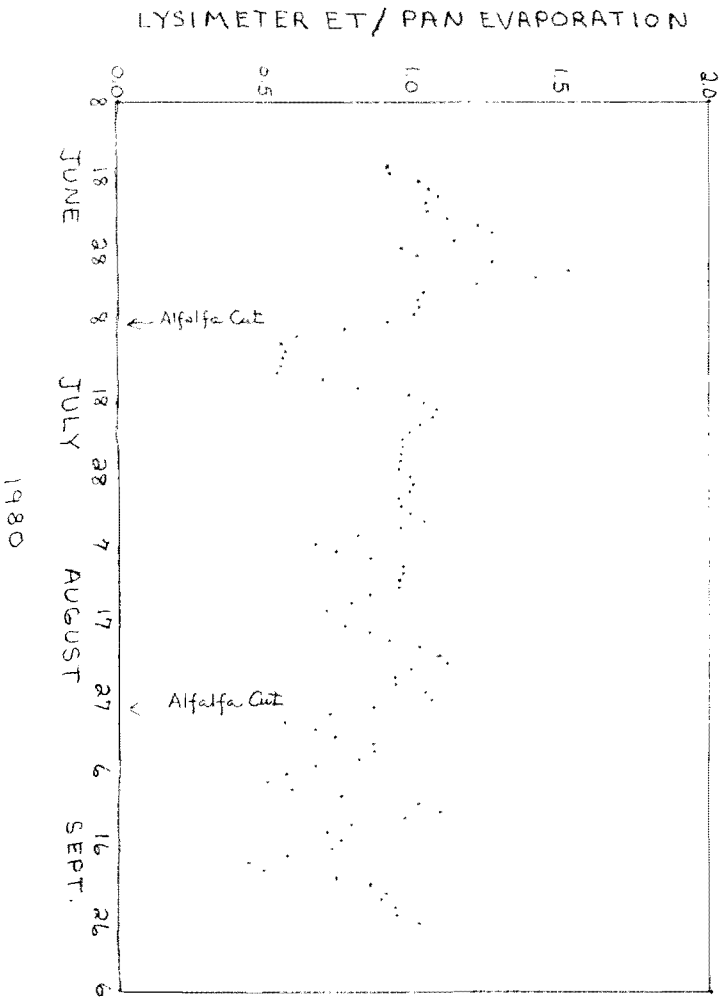

Figure 6. Lysimeter evapotranspiration/pan evaporation ratio of alfalfa, 1980.

OWRT Project No.: B-153-Minn

Agreement No.: 14-34-0001-0268

Project Title: Ground-Water Recharge Rates in Minnesota as Related to Precipitation

FCCSET Research Category: II-B, 11

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

Project Began: October 1, 1979 Scheduled Completion: March 30, 1982

Principal Investigator	Degree	Discipline
Matt Walton	Ph.D.	Geology
Roman Kanivetsky	Ph.D.	Engineering Geology and Hydrogeology

Student Assistants	Degree	Discipline or Academic Background
Brad Birkelo	Undergrad	Geology
Mark Dobin	Undergrad	Geology
Brian Johnson	Undergrad	Geology
Randy Moore	Undergrad	Geology
John Mason	B.S.	Geology

A. Research Project Accomplishment

Much of the year was spent collecting published and unpublished data necessary to the project: water level records from Minnesota, Wisconsin, Iowa, and North and South Dakota and then environmental data such as precipitation, soil and air temperatures, pumping test information, well log data and storage coefficients, summer evaporation and winter depth of snow, and stream discharge records.

Errors and gaps in data were identified. The environmental data stations relevant to each well were listed. Next came a period of trial and error testing of methods and variables in correlation of water levels and estimation of storage coefficients using various methodology.

Results to date from the long term periodicity of static water levels, correlation of annual static water level fluctuations with precipitation, and calculation of storage coefficients sections of the Aquifer Recharge Project are as follows:

I. Long Term Periodic Components

a. Autocorrelation Method

Autocorrelation of sample water level measurements, that is, correlation os the time series of the hydrograph against itself at regularly increasing time lags, was used to find long term periodic components in the records of seventy water-table condition observation wells in the five state area with more than twenty years of measurements.

A periodic time series will produce a periodic graph of the auto-correlation coefficients against the time lags called a correlogram. The time lags at the peaks and valleys in the correlogram represent the positive and negative periodic components in the water level records.

A drawback of this method is that for every increase in time lag the last measurement in the time series drops out of the sample. Thus calculated periodic components become less reliable as the time lag increases. For this reason water level measurements were sampled at intervals of one, two, three and four per year and the results of the time series analyses were compared to see if changes in the total number and frequency of measurements in the sample changed calculated periodic components. The longest water level records, of thirty to fourty-seven years, were also split into two and three parts to see if periodicities changed over the years.

Forty wells show long term periodicity (of two or more years) at less than 25 percent time lag. Of these, 13 have a 3 year period, 10 a 5 year period, 8 a 6 year period, and 11 an 8 year period. Fifty six wells reveal periodic components at less than 50 percent time lag. Of these, 24 have an 8 year period and 21 a 10 year period. Most well records show multiple periodic components.

b. Harmonic Analysis

Harmonic analysis assumes that all periodic components in one time series can be multiplied to find a common base periodicity, the first harmonic. A periodic component that runs two full cycles within the base period is the second harmonic, and so on.

Thus both periodic components and a total run length extensive enough for a common multiple to occur must be available from the sampled time series for harmonic analysis to be applicable. Furthermore, the series used in the harmonic analysis must be just the length of the base period, even if the total time series is longer, to obtain a good fit.

A computer statistical package for harmonic analysis was tried out on four long term well records in Minnesota at the beginning of the project. The base period and other periodic components, if any, were unknown. This arbitrary application of harmonic analysis modeled one water level record closely, with a maximum residual of ten percent, but produced 50 percent errors in amplitude of water level fluctuations in the remaining three times series when compared to the original hydrographs.

An extension of the computed hydrograph past the base period reproduces the same graph for the next length of the base period, and so has some forecasting potential depending on the goodness of fit.

Results of autocorrelation analysis do not in most cases reveal harmonically related periodic components within the length of record available. For most of these wells, the general hydrograph might be modeled by adding the non-harmonic sinusoidal periodic components, with trial and error modeling for amplitude.

c. Graphs of river discharge, cumulative departure of precipitation from normal and five year running averages of precipitation, were done for precipitation and stream gauging stations near three of the long term wells in Minnesota and for several wells with shorter records.

For streams with low discharge, the log of discharge correlates well with water level fluctuations.

Both cumulative departure and running averages graphs are also similar to water level fluctuations in wells. Comparing a short well hydrograph with a long precipitation record gives the relative position of the recorded water levels with respect to possible historic highs and lows.

II. Correlation of Static Water Level Fluctuations with Precipitation

Approximately 200 water table condition observation well records are available in Minnesota. For each observation well the amplitude of the spring static water level rise is graphed against various summations of spring and preceeding months' precipitation. When several years of record are available, the summation of monthly precipitation that give the best linear correlation is chosen.

This procedure has been completed for about 50 wells in central Minnesota close to the Wadena, Otter Tail, St. Cloud, Park Rapids and Morris precipitation stations and for other wells of particular interest, such as the long term wells referred to in the previous section.

Wells with shallow static water levels, less than 15 feet, show a linear relationship between amplitude of recharge and the summation of monthly precipitation for the winter months with average temperature less than 26°F plus the precipitation for the next month, during which the soil thaws, snow melts, and recharge takes place.

This correlation is dependent upon the distance between the well and the precipitation gauging station. A program to simulate monthly precipitation at a well site, given the precipitation at three surrounding stations and the locations of the well site and gauging stations in an absolute frame of reference, is being evaluated for wells distant from any weather station.

A second factor modifying the linear correlation for shallow wells is the height of the base water level before recharge begins. If the water level is relatively deep due to previous years' deficits in precipitation, a given amount of precipitation will produce a greater amplitude of recharge than if the base level is near average. Conversely, a shallower than average base water level, due to previous years' above average precipitation, results in a lesser amplitude of spring recharge for the same given amount of precipitation.

Thus, for shallow wells there is a negative correlation between this year's spring recharge and last year's precipitation.

In contrast, for wells with water levels deeper than 30 feet there is a positive correlation between this year's spring recharge and last year's precipitation. This is, a better correlation between water level fluctuations and summation of monthly precipitation is achieved if the previous six to twelve months' precipitation is added to the summation found for the wells with shallow water levels. An apparent time lag in infiltration results in an overlap of recharge from one year to another for wells with deep static water levels.

III. Calculation of Storage Coefficients

Storage coefficients have been calculated for water-table aquifers, where data was available. Pumping test, literature data and empirical equations have been used to calculate storage coefficients. A map of storage coefficients distribution is now in the verification process. The major problem in evaluation of storage coefficients is limited reliable data, changes of storage coefficient within the short distance and uneven distribution of data. Therefore, in many areas estimation of storage coefficients will bd done based on analogy with the neighboring areas. Storage coefficients has been estimated for about 500 wells.

B. Publications: None

C. Project Status

Project will be completed in February 1982.

D. Application of Research Results

DNR provided a nearly complete set of observation well water level data for Minnesota to MGS for this project and has expressed interest in the results of both autocorrelation and annual recharge analysis. An attempt was made not to infringe upon contemplated DNR projects of publishing updated graphs of all observation well data and of applying spectral analysis to water level records.

USGS has presented similar recharge analyses correlating annual recharge and annual precipitation for limited areas in its recent Open File Reports. The slightly different summation of precipitation correlated with recharge in this report may be compared to the USGS method of annual preipitation and recharge correlation.

Recharge estimates from this report may also be compared to recharge estimates previously published in USGS Water Supply Papers, Hydrologic Atlases, and Open File Reports and in DNR Technical Papers.

Recharge estimates and long term periodicites for selected well in Wisconsin, Iowa, and North and South Dakota prepared for this report will be of interest to the Geological Surveys of these neighboring states.

E. Work Remaining and Progress Contemplated During Next Year

The project report will be completed. Results will be presented in two parts:

I. Long term periodicities in water table condition observation wells.

a. Results of the autocorrelation analysis of water table condition observation wells in the five state area will be presented in a table listing the locations of the wells analyzed, aquifer, total depth, depth of average static water level, length of record, frequency of sampling, periodicities and statistical significance.

b. If the well shows harmonic periodicities, with a common multiple within the length of record, harmonic analysis will be done and a comparison of the simulated and actual water levels will be presented.

c. If a well shows non-harmonic periodicities, but the hydrograph can be simulated by addition of non-harmonic sine functions a comparison of the simulated and actual water levels will be presented.

d. The similarities between observation well water level fluctuations and both five year running averages of precipitation and cumulative departure of precipitation from normal will be shown graphically for selected wells and precipitation stations. Autocorrelation of the precipitation functions to find long term periodicities and cross correlation between well hydrographs and precipitation functions may be done, depending on time constraints.

e. The similarity between observation well water level fluctuations and a logarithmic function of the discharge of streams at nearby gauging stations will be shown graphically for selected wells. Autocorrelation and cross correlation will be done as time permits.

f. A map of well sites, weather stations and stream gauging stations used in this section of the report will be included.

g. Significance of results will be discussed.

II. Annual Recharge of Water Table Aquifers in Minnesota

a. Completion of map of distribution of storage coefficients and selection of ranges of recharge rates.

b. Results of the correlation analysis of precipitation against static water level fluctuation will be presented in a table

listing wells used, location, aquifer, depth, depth of average static water level, summation of precipitation used, regression equation, statistical significance, average recharge and observed extreme of recharge, length of record and precipitation station location and distance from the well site.

c. Selected observation wells from states bordering Minnesota will also be analyzed in this format in order to give better estimates in outlying parts of the state.

d. The relationship between static water levels in wells measured at five day or weekly intervals and five day or weekly totals of precipitation and average high and low air temperatures, soil temperatures, depth of snow on the ground and evaporation will be presented graphically for selected wells.

e. A map showing the location of wells and weather stations used in this section of the report will be included.

f. A map showing ranges of distribution fo recharge rates of water-table aquifers will be compiled.

g. Observation wells that do not correlate well with precipitation and possible reasons, such as pumping effects, will be listed.

h. Significance of results will be discussed.

OWRT Project No.: B-158-Minn

Agreement No.: 14-34-0001-1236

Project Title: Increasing Economic Efficiency of Water Use for Irrigation in the Upper Midwest

FCCSET Research Category: IV-B

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

Project Began: October 1, 1980

Scheduled Completion: September 30, 1983

Principal Investigator	Degree	Discipline
Vernon R. Eidman	Ph.D.	Agricultural and Applied Economics
Craig C. Sheaffer	Ph.D.	Agronomy

Student Assistants	Degree	Discipline or Academic Background
Paul R. Carter	M.S.	Agronomy
David Nielson	B.S.	Agricultural Economics
Darrell Bosch	M.S.	Agricultural Economics

A. Research Project Accomplishments

Accomplishments during the first year can be summarized in four parts: Development of DAta Files, Validation of Crop Models, Generation of Additional Data for Validation, and Economic Evaluation of Conversion From High Pressure to Low Pressure Irrigation.

1. Development of Data Files

Computer files of the available climatological and soils data necessary to validate crop response models have been developed for Rosemount, Waseca, and Lamberton, Minnesota. The data include daily precipitation, daily pan evaporation, daily maximum and minimum temperature, available daily solar radiation data, as well as soil moisture level at the start of the growing season and the available monthly readings. The annual corn, soybean and alfalfa yields have been obatained for the three stations.

2. Validation of Crop Models

Work has progressed on the development and validation of crop response models for corn and soybeans. An effort was made to incorporate both a time trend, to reflect technological change, and the interaction of nitrogen level with moisture stress. The lack of data on available N in the soil made it impossible to successfully model the nitrogen-moisture interaction. However, it has been possible to estimate the average annual effect of technological change on yields and incorporate that effect in the crop response models.

Shaw's model, described by Shae (1963), and Hanks' model, described by Regetta and Hanks (1980), have been evaluated as crop response models

for corn. These models attempt to predict yield as a function of stress induced by insufficient moisture. Shaw's model generates a stress index which is regressed on observed yields to develop a yield prediction equation. Hanks' model predicts actual production given an estimate of potential production. Potential production is the yield that would be produced with "an economically viable production package and weather that does not limit corn yields."

A crop growth model must meet three criteria to be considered for use in the project. First, the yield predicted by the model must be on the same side of the mean as the observed yield. Second, the predicted yield must be within 10 percent of the observed yield. Third, the distribution of yields predicted for an historic period must have similar parameters as the distribution of observed yields. The models which meet these three criteria are being compared, with the final selection based on the model that predicts most accurately under extreme conditions.

Shaw's model meets the general validation criteria for Waseca data, but does not meet the 10 percent criteria in seven of twenty years for the Lamberton data.

The yields predicted using Hanks' model generally deviated 10 percent or more from the observed yields. An attempt was made to improve the prediction accuracy of this model by regressing the seasonal ratio of actual (T) to potential transpiration (T_p) and a trend variable on observed yield. This procedure permitted treating the $\frac{T}{T_p}$ ratio in the same way as the Shaw stress index. A comparison of the two models based on this procedure revealed Shaw's model to be more accurate in predicting yields.

It is of interest to note that the correlation between Shaw's stress index and Hanks' stress index $(\frac{T}{T_p})$ was -.97 at Waseca and -.94 at Lamberton. This indicates that the two models gave measures of moisture stress which moved in the same fashion from year to year at both locations. Apparently both models are producing a reliable measure of moisture stress. However, the problem is that even after accounting for variation due to trend and fertility, moisture stress alone cannot account for all yield variation. The unexplained yield variation must then be attributed to other climatic and management factors.

Initial efforts to adatp Shaw's and Hanks' models to predict soybean yields at Waseca and Lamberton were disappointing. It was hypothesized the consideration of the threshold level of total transpiration (required for the accumulation of a sufficient amount of dry matter to avoid limiting bean yields) is important in the northern corn belt. Furthermore, the effect of wet conditions on bean yields was judged important. A model described by Hill and Johnson (1978) to predict soybean yields considering moisture stress and the above two factors was obtained. This model is doing an acceptable job of predicting soybean yields at Waseca, with somewhat less satisfactory results at Lamberton.

Work will continue during the early part of the second year to determine if Hill's model can be adapted for corn production and predict more accurately than Shaw's model. An effort also will be made to improve the predictive ability of Hill's model for soybeans at Lamberton.

3. Experimental Results

Field trials to generate additional data for use in crop response model development and validation were conducted. These data will be useful to validate existing irrigation scheduling methods on sandy soils.

"Iroquois" alfalfa, established in 1980, and "Hodgson 78" soybeans were subjected to irrigation treatments at the Sand Plains Experiment Station, Becker. The experimental design for each study was a randomized complete block with three replications. Irrigation treatments are shown in Tables 1 and 2.

Abnormally high rainfall reduced alfalfa yield differences due to treatments for the first two harvests and only at the third harvest were large differences between the unirrigated check and irrigated treatments observed. Rainfall which occurred immediately following each harvest minimized effects due to supplemental irrigation following harvest. As a result, yield differences between treatments 2 and 5, and between 3 and 6 were small. Alfalfa yields for full irrigation, the checkbook method, and 66 percent of full irrigation treatments were similar, although the 66 percent of full irrigation and checkbook treatments resulted in the greatest yields.

Soybean yields were significantly increased by all irrigation treatments compared to the untreated check (Table 2). Among the treatments to which supplemental irrigation was applied, the 33 percent of full irrigation had the lowest yields.

4. Evaluation of Conversion From High Pressure to Low Pressure Irrigation

A procedure was developed to consider the effect of the additional investment cost, the annual energy savings, the expected life of the investment and the irrigator's marginal tax rate on the profitability of converting an existing high pressure irrigation system to low pressure. A paper describing this procedure was completed and made available to irrigation extension specialists for use. The data also will be used in the economic analyses to be performed in this project.

References

R.W. Hill and D.R. Johnson. A Model for Predicting Soybean Yield. Unpublished paper, Department of Agricultural and Irrigation Engineering, Utah State University, Logan, May, 1978.

A. Regetta and R.J. Hanks. Manual for Using Model PLANTGRO. Research Utah Agricultural Experiment Station, Utah State University,

Table 1. Effect of irrigation treatments on alfalfa dry matter yield and water applied at Becker MN 1981.

	Alfalfa yield				Irrigation
	8 June	15 July	20 Aug.+	Total	Applied
	---------- metric tons/ha -------				cm
1. Unirrigated check	2.1	2.2	1.7	6.0	0
2. Full irrigation+	2.8	2.7	3.1	8.6	18.9
3. 33% of full irrigation	2.7	2.6	2.9	8.2	7.6
4. 66% of full irrigation	2.7	3.2	3.4	9.3	12.1
5. Full irrigation only after harvest‡	2.1	2.3	1.8	6.2	4.5
6. 33% of full irrigation and full irrigation after harvest ++	2.4	2.7	2.8	7.9	8.9
Checkbook method*	2.7	3.0	3.2	8.9	16.3

\+ Three harvests were taken at 1/10 bloom.

‡ Irrigation to field capacity when soil reached 50% AWD. Soil moisture level monitored via neutron probe.

++ Received no or 33% of full irrigation during the growing season and full irrigation only after harvest.

* Irrigation by method of Werner, 1978. (Minnesota Misc. Pub. 160).

Table 2. Effect of irrigation treatments on yield of Hodgson 78 soybeans at Becker, MN 1981.

Irrigation treatment	Yield	Irrigation
	Bu/a	cm
Unirrigated check	15	0
Full irrigation +	45	9.9
33% full irrigation	39	3.1
66% full irrigation	46	6.5
Full irrigation only at pod filling‡	48	7.1

\+ Irrigated by checkbook method (Werner, 1978). (Minnesota Misc. Pub. 160)

‡ Irrigated at 33% checkbook until initiation of pod filling.

R.H. Shaw. Estimation of Soil Moisture Under Corn. Iowa Agricultural Experiment Station Research Bulletin 520, Iowa State University, Ames, 1963.

B. Publications

Bosch, Darrell, Vernon Eidman and Jerry Wright. Determining the Economic Feasibility of Converting Center Pivot Irrigation Systems from High Pressure to Low Pressure. (Mimeographed). Department of Agricultural and Applied Economics, University of Minnesota, 1981.

C. Project Status

The project will be continuing during the next fiscal year.

D. Application of Research Results

The extension irrigation specialists as well as several individual irrigators have expressed interest in the economic evaluation of alternative irrigation strategies to be obtained from this project. The results will be used in extension education programs on irrigation scheduling. Staff in the Minnesota Department of Natural Resources are interested in the evaluation of irrigator's economic incentives to adopt more efficient strategies.

E. Work Remaining and Progress Contemplated During Next Year

Alfalfa stands established in 1980 will be harvested again in 1982 to determine the effects of irrigation. Soybeans and corn will be planted and subjected to irrigation treatments as outlined in the original proposal. These data will be used in combination with existing yield data to validate crop response models for soybeans, corn and alfalfa.

The validation of corn and soybean models will be completed during the second year of the project. The development and validation of an alfalfa growth model also will be carried out during the next year. These models will be used to evaluate the distribution of net returns under alternative irrigation strategies as listed in the project statement. These evaluations will be carried out for fine, medium and coarse textured soils in southern Minnesota.

Work will be initiated on the development of a programming model of representative farm businesses on alternative soils in southern Minnesota. The procedure to be followed is described in the project statement.

OWRT Project No.: B-160-Minn

Agreement No.: 14-34-0001-1237

Project Title: Mathematical Hydrologic Simulation of Critical Watersheds in Northeastern Minnesota

FCCSET Research Category: II-E

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

Project Began: October 1, 1980 Scheduled Completion: September 30, 1983

Principal Investigator	Degree	Discipline
C. Edward Bowers	M.S.	Civil Engineering

Student Assistants	Degree	Discipline or Academic Background
C. Teng	M.S.	Civil Engineering
Joel Toso	B.S.	Civil Engineering

A. Research Project Accomplishments

The objective of this project is the fitting of two hydrologic, mathematical simulation models to selected watersheds in or adjacent to the Boundary Waters Canoe Area of Northeastern Minnesota. The models will be of value in monitoring the quantity and quality of streamflow in the area. The BWCA is a protected wilderness area with no roads or habitations. Due to the presence of taconite and copper-nickel ores adjacent to the area, there is the potential for pollution of the pristine water of the many lakes and streams in the area.

During the first year of operation, the Streamflow Simulation and Reservoir Regulation Model (SSARR) was the primary model studied. The latest versions of other models REVAIL and NSRFS both prepared by the National Weather Service were acquired but have not been operated.

The SSARR is a continuous synthesis model with two modes of operation, (1) Split Basin and (2) Snow Band. The model has been fitted and operated with both modes. Input data includes physical data for the watersheds plus daily data on precipitation and temperature. In this study it has been fitted to the 1200 square-mile Kawishiwi River Basin, with 12 sub-watersheds. Parameters in the model were adjusted in test runs, each of 6 months to 1 year duration for selected past periods. Figure 1 shows a run for 1950, with a comparison of observed and computed flows for a 2-month period. This is the largest flood of record, with a flow of 16,000 cfs at Winton. Figure 2 shows a similar run for 1966, with a peak flow of about 8000 cfs. Agreement between observed and computed flows is excellent. Figure 3 shows Joel Toso, a graduate student taking current meter measurements of discharge at a location of special interest.

B. Publications: None

C. Project Status

The project will continue in progress for the next two years.

D. Application of Research Results

The Minnesota Department of Natural Resources, the Minnesota Environmental Quality Board and the Minnesota River Forecast Center of the National Weather Service have indicated an interest in the results of this study. Preliminary results have been shown to the River Forecast Center.

E. Work Remaining and Progress Contemplated During Next Year

Further fitting of the SSARR model and preliminary runs with the two National Weather Service Models will be performed during the next fiscal year.

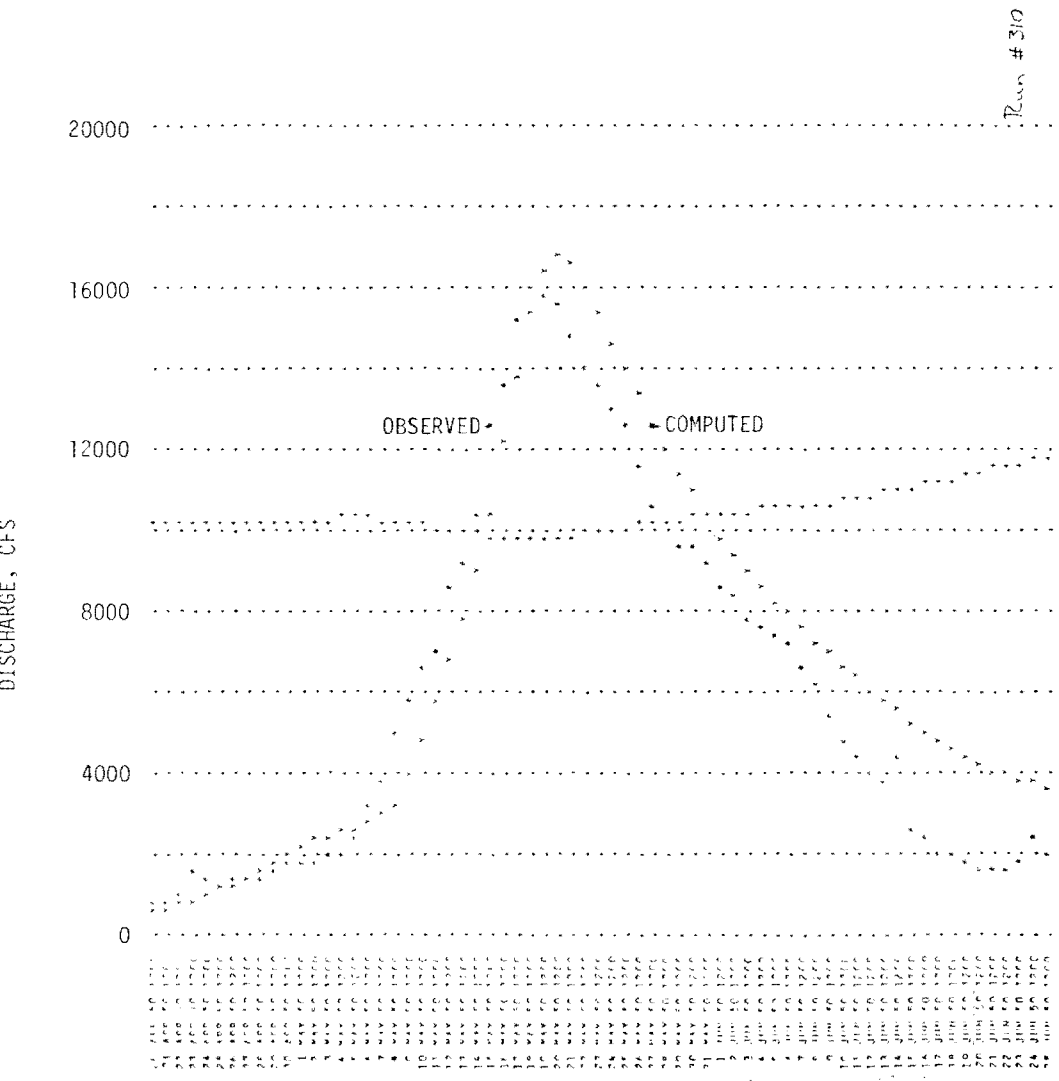

Figure 1

Observed and Computed Flow of Kawishiwi River Near Winton for Spring Flood of 1950

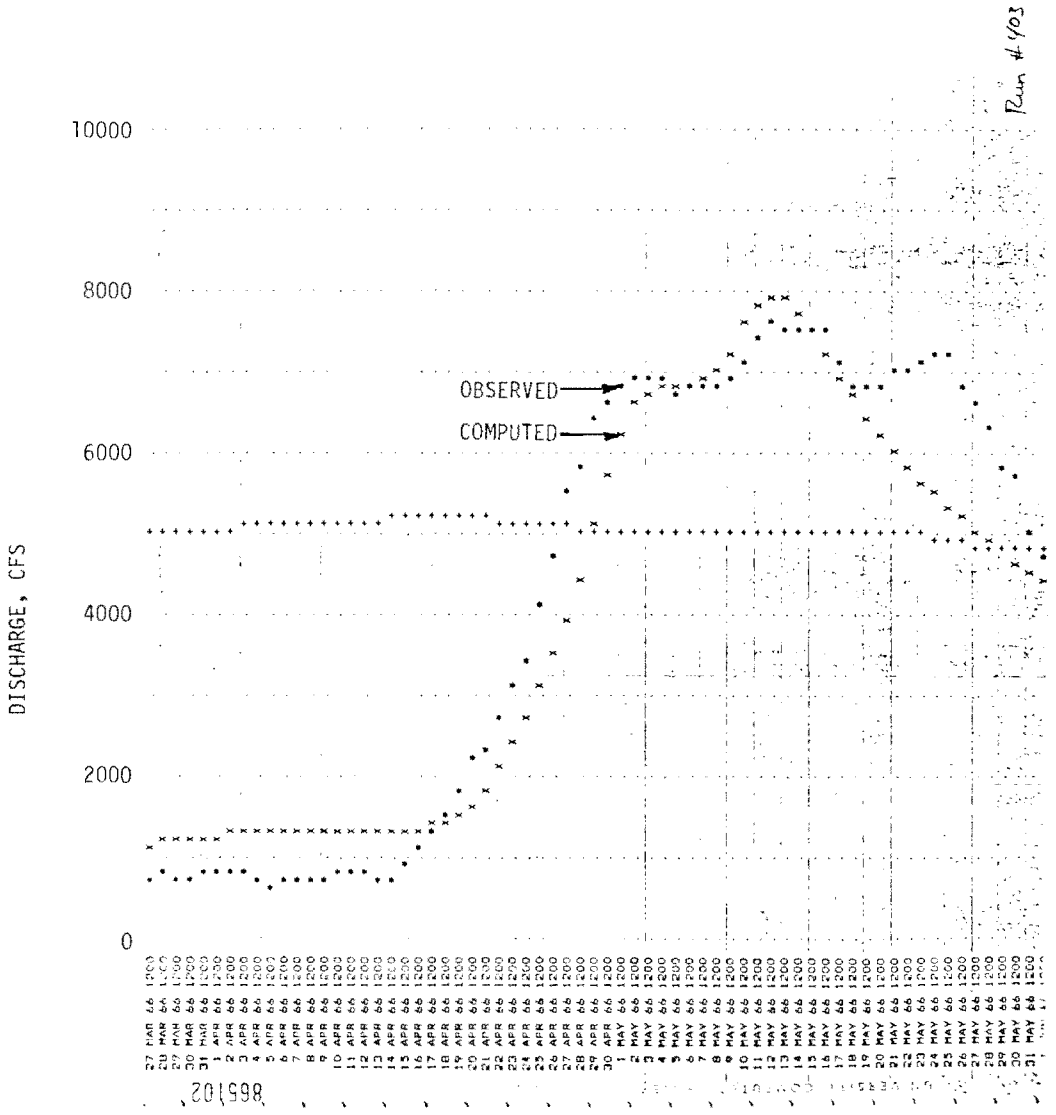

Figure 2

Observed and Computed Flow of Kawishiwi River Near Winton for Spring Flood of 1966

Figure 3

Graduate Student Joel Toso Gaging the North Kawishiwi River.

Figure 4

The Kawishiwi River Near Winton with a Flow of 6000 CFS

Two projects were undertaken by WRRC in 1980 and were completed in 1981. These were contributing parts to the Master Plan prepared by the Upper Mississippi River Basin Commission as mandated by Congress. Both WRRC projects were cooperative with Water Resources Centers of Wisconsin and Illinois.

A. Summary Resource Description

Principal Investigators for the Minnesota portion of this project were Donald Gilbertson, George R. Blake, Timothy Kelly and Robert Moline.

Purpose of the project was to collect and summarize published and unpublished data describing what is known of the biological, physical, cultural and recreational resources and the water quality status of the Upper Mississippi River System.

The report of the investigation was submitted to the Basin Commission in five volumes cited on page 54 of this Annual report.

There were also extensive Appendices for Volumes III and IV. In conjunction with the Biological Description Report, Vol. IV, a computerized file was set up through the Minnesota State Planning Agency, Land Management Information Center, INDEX Project, which helped to design and store the biological bibliographic file. It is designed to facilitate access to biological literature on the commercially navigable reaches of the Upper Mississippi River System. The computerized file permits automated literature searches for specific topical areas, organisms, and geographic regions.

B. Impacts of Navigation and Associated Operation and Maintenance Procedures on Recreation, Cultural Resources and Potential Wilderness areas of the Upper Mississippi River System.

This project was also carried out cooperatively by the Minnesota, Illinois and Wisconsin Water Resources Centers. Professor Leo H. McAvoy was the University of Minnesota representative of the team.

The project report is cited on page 55 of this Annual Report.

Publications of the Water Resources Research Center

Blake, G.R., John J. Waelti and John M. Helmberger, Jr. Five-Year Water Resources Research and Development Plan. Water Resources Research Center, University of Minnesota. November 1980.

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Feind, T., D. Braaten, and H.W. Quade. A Limnological Compilation of Water Quality of the Minnesota River Watershed, in Minnesota. Water Resources Research Center, University of Minnesota, Bulletin 107. February 1981.

Jenson, James E. The Relationship of Artificial Drainage to Soils in Blue Earth County, Minnesota. Water Resources Research Center, University of Minnesota, Report No. 2. June 1981.

King, K. Elton. A History of Drainage Law in Minnesota with Special Emphasis on the Legal Status of Wet Lands. Water Resources Research Center, University of Minnesota. Bulletin 106. November 1980.

Quade, Henry W., Fent W. Boyum, Duane O. Braaten, Donald Gordon, Clay L. Pierce, Ainars Z. Silis, David R. Smith and Bill C. Thompson. The Nature and Effects of County Drainage Ditches in South Central Minnesota. Water Resources Research Center, University of Minnesota. Bulletin 105. November 1980.

Richardson, Brandt, Editor. Wetland Values and Management. Selected Proceedings of a Midwest Conference, Water Resources Research Center, Water Planning Board, Upper Mississippi River Basin Commission and Great Lakes Basin Commission. June 17-19, 1981.

Summary Resource Description of the Upper Mississippi River Basin. On contract to the Commission.

Chesters, Gordon, University of Wisconsin, George R. Blake, University of Minnesota and Glenn E. Stout, University of Illinois. Volume I. Executive Summary. August 1981.

Stout, Glenn E. and V. Alavian. Volume II. Cross Sections and Navigation and Flood Control Structures. University of Illinois. August 1981.

Chesters, Gordon, G.V. Simsiman, T. Danovich, V. Novotny, T. Lazewski, of the University of Wisconsin; Glenn E. Stout and V. Alavian, University of Illinois. Volume III. Water Quantity and Quality. August 1981.

Gilbertson, Donald E. and Timothy J. Kelly, University of Minnesota. Volume IV. Biology. August 1981.

Robert T. Moline Gustavus Adolphus College; George R. Blake, University of Minnesota; James Absher and Ellen Absher, University of Illinois; Tony Lazewski and Doris Nagel, University of Wisconsin. Volume V. Cultural Resources and Wilderness Preservation Areas. August 1981.

Impacts of Navigation of Some Resources of the Upper Mississippi River Basin Commission. On contract to the Commission.

McAvoy, Leo, University of Minnesota; James Absher and Rabel Burdge, University of Illinois, and Robert Beeker, Thomas Bonnicksen and James Gramann, University of Wisconsin. Impacts of Navigation and Associated Operation and Maintenance Procedures on Recreation, Cultural Resources and Potential Wilderness Areas of the Upper Mississippi River System. August 1981.

PROJECT-RELATED REPORTS

Clanton, C. J., R. E. Machmeier, J. L. Anderson and M. J. Hansel. Maximum Application Rates for Land Treatment of Septage - Progress Report. ASAE Paper No. 81-2063. 1981.

Clanton, C. J., R. E. Machmeier, J. L. Anderson, and M. J. Hansel. Maximum Loading Rates of Septage to Soils - Progress Report. Proceedings of the Third National Symposium on Individual and Small Community Sewage Treatment. 1981.

Cohen, G. B. "Dispersion and Sorption of Dissolved Hydrocarbons in Aquifer Materials", June 1981.

Eames, V. A. "Influence of Water Saturation on Oil Retention Under Field and Laboratory Conditions", M.S. Thesis. June 1981.

Eames, V. A. and H. O. Pfannkuch. "Influence of Water Saturation on Oil Retention", GSA Abstract, Vol. 13, No. 7, September 1981. Poster Session presentation at GSA Annual meeting, Cincinnati, Ohio, November 3, 1981.

Johnson, Bradley. M.S. Thesis. University of Minnesota. Reuse of Agricultural Drainage Waters for On-Site Soil Water Recharge and Irrigation. 1981.

Pfannkuch, H. O. "Analysis, Monitoring, Abatement and Cleanup of Two Crude Oil Spills on Glacial Drift in Central Minnesota. Presented at 26th Annual Midwest Ground-Water Conference, Bismarck, North Dakota, October 28-30, 1981.

Pfannkuch, H. O. "Problems of Monitoring Network Design to Detect Unanticipated Contamination". Groundwater Monitoring Review. (In press, Winter Quarter issue, 1981).

Wetlands Conference

During Wetland Awareness Week declared by Governor Quie of Minnesota, more than 500 participants from the United States and Canada attended the "Midwest Conference on Wetland Values and Management" held in St. Paul, Minnesota. The conference was sponsored by the Minnesota Water Planning Board, the Water Resources Research Center of the University of Minnesota, the Upper Mississippi River Basin Commission, and the Great Lakes Basin Commission; with assistance from the Government Training Service. The focus of the conference was on wetlands throughout the Middle West, with primary consideration for the Upper Mississippi River Basin and the watershed of the Great Lakes. Inland and Great Lakes coastal wetlands were discussed.

The agenda included an introductory and a summary plenary session, eleven sessions of paper presentations, slide shows, and field trips. The schedule included invited presentations and submitted papers for the diverse array of sessions: Wetland Hydrology, Wetlands' Wildlife and Plants, Legal Issues, Wetlands and Wastewater Treatment, Economics of Agriculture and other Wetland Uses, Local Wetland Protection Methods and Case Studies, Non-Monetary Evaluation Techniques, Impacts from Wetland Losses and Perturbations, Wetlands and Water Quality, Wetlands and Energy Development and State and Federal Programs. The conference was especially useful for state and local legislators and government officials, and natural resources scientists.

Considerable discussion was generated on two related issues: the role of the current administration in wetland preservation, and proposed legislation to affect wetland preservation programs, especially the U.S. Army Corps of Engineers' 404 permit program.

Tom Tomasello, Counsel for the National Wildlife Federation, warned that program changes and proposed budget actions of the current administration could harm wetland conservation efforts. Discussion continued concerning the wetland preservation programs. Bills in the current Congressional sessions intend to weaken not only the 404 permit program but also the Endangered Species Acts, the Land and Water Conservation Fund, the Executive Order on Wetlands, the Water Resources Research Center, the Federal Water Bank program, and the Advance Wetland Loan Fund Act.

Dr. Lawrence Jahn, Vice-President of the Wildlife Management Institute, cited polls that showed strong public support for wetland conservation, and called for more citizen action toward government programs. Jahn charged scientists to focus on pragmatic research concerning wetlands rather than basic research. He also encouraged improved wetland evaluation techniques.

Numerous other presentations generated discussion concerning topics such as the role of education of wetland values, wetlands as a water issue rather than a land issue, and the size of a wetland to be protected.

Several significant studies were also presented. A University of Minnesota study demonstrated that compensation to landowners for not draining wetlands was necessary, and that the structure of the local economy was the key factor in economic return from the drainage of wetlands. A study for the Minnesota Water Planning Board indicated that total payments for not draining wetlands in Minnesota exceeded the estimated returns from draining the property. A study by the Agricultural Extension Service of the University of Minnesota showed that wetland acquisition for waterfowl production had negative fiscal effects on local units of government. This study concluded that the distribution of in-lieu payments relative to the local units of government needed to be examined. Another study deliberated on the numerous advantages of using wetlands to produce biomass crops.

In addition to a description of the wetland program of Minnesota, state wetland preservation programs of Massachusetts, Michigan, New York, North Dakota, Rhode Island, and Wisconsin were described. Conference attendees generally conceded that Minnesota's program was stronger than programs of other states represented and was used as a model for potential state legislation.

Dr. Jahn concluded the conference with an eclectic summary of wetland values and management. The major points of his presentation were:

* a need for more effective management of wetlands in flood plains and coastal zones;

* a need for more funds for natural resources and less disaster relief payments;

* courts and statutes in the U.S. are determining that public values need to be considered when tampering with the natural landscape;

* evidence from the wetland mapping program is not absolute documentation in legal issues;

* the wetlands mapping program in Minnesota should involve the public in accordance with the procedures of the National Environmental Policy Act;

* the U.S. Army Corps of Engineers has evolved into an avid protector of public waters and their programs maintain a respectable review process;

* economic calculation techniques for natural resources decision-making are imperfect;

* cropland erosion is nationally severe; and

* a need for increased public participation in government procedures.

Proceedings for the conference were published.

EDUCATION AND TRAINING PROGRAMS

Courses Developed:

No new courses have been developed.

Additional Water Resources Related Staff Members Added:

None.

Staff Members Employed to Replace Those Who Retired, or Moved:

Dr. Gary Parker, Ph.D., Water Resources, Civil Engineering
Dr. John Gulliver, Ph.D., Water Resources, Civil Engineering

New Research and Training Facilities Other Than Research Equipment Items:

None.

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

University of Minnesota, Minneapolis, MN

A. Number of students receiving employment as research project or program assistants through the P.L. 88-379 program.

(1) Undergraduates

Scientific Discipline of Student	Number
Agricultural Economics	1
Biology	1
Geology	4
Soil Science	1

(2) Master's Students

Agricultural Economics	1
Agricultural Engineering	1
Biology	1
Civil Engineering	1
Forest Hydrology	1
Geology	2
Soil Science	3

(3) Doctoral Students

Agricultural Economics	1
Agricultural Engineering	1
Agronomy	1
Civil Engineering	1
Geology	2
Soil Science	1

(4) Postdoctoral Students

none

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:	3	4	1	8
Federal Agencies		1		1
State & Local Agencies	1			1
University of College		2	1	3
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	1			1
5. No. status unknown				
6. Totals	4	5	1	10

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 of Graduates Engaged in Water-Related Work in:	Bachelor's Degree	Master's Degree	Doctoral Degree	Total
1A. Federal Agencies:				
a. Primarily Research				
b. Primarily Planning				
c. Primarily Development				
d. Primarily Operations		1		1
e. Primarily Management				
f. Other or not known				
1B. State & Local Agencies:				
a. Primarily Research				
b. Primarily Planning				
c. Primarily Development				
d. Primarily Operations				
e. Primarily Management				
f. Other or not known				
1C. University or College				
a. Primarily Teaching			1	1
b. Primarily Research		2		2
c. Primarily Research & Teaching				
d. Other or not known				
1D. Other - Including Private Enterprise				
a. Primarily Research				
b. Primarily Planning	1			1
c. Primarily Development				
d. Primarily Operations		1		1
e. Primarily Management	1			1
f. Other or not known	1			1
Totals	3	4	1	8

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

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