FINAL REPORT

PEAT PROGRAM

PHASE 1. ENVIRONMENTAL EFFECTS AND PRELIMINARY TECHNOLOGY ASSESSMENT

Final Report On

PEAT PROGRAM

PHASE 1. ENVIRONMENTAL EFFECTS AND PRELIMINARY TECHNOLOGY ASSESSMENT

For

UPPER GREAT LAKES REGIONAL COMMISSION

And

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

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PREFACE

Summarized in this report are the results of the first year of study on a continuing program of research to assess the effects on the State of Minnesota, with eventual application to the other Upper Great Lakes States as well, created by a sudden expansion of the peat industry. The principal objective of the program is to provide information helpful in furthering the development of a State Peatland Policy.

The program is supported by the Upper Great Lakes Regional Commission and has been administered by the Minnesota Department of Natural Resources.

The study is being carried out by Midwest Research Institute's Center for Peat Research under the direct supervision of Roy Larson. Major participants in the research effort include Roscoe Colingsworth, Associate Ecologist; Edward Miller, Senior Resource Specialist; and Tom Stern, Associate Resource Specialist, with the collaboration of Professor R. S. Farnham of the University of Minnesota.

Center for Peat Research
MIDWEST RESEARCH INSTITUTE

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Roy E. Larson, Head

Approved:

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A. E. Vandegrift, Director
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ACKNOWLEDGMENTS

It would not have been possible to carry out the first phase of the Peat Program without the whole-hearted cooperation of many individuals. Their efforts have contributed in an essential way to this report, and Midwest Research Institute wishes to acknowledge the assistance provided by the following people:

Mr. Mike Pintar of the Minnesota Governor's Office and the Upper Great Lakes Regional Commission, who coordinated and planned the initial formation of the program and assisted in obtaining funding.

Mr. Robert Herbst, Commissioner, Minnesota Department of Natural Resources, who helped plan the program and has provided a continuing source of advice and guidance during the past year.

Dr. James Carter, Director, Research Division, Minnesota Energy Agency, who was one of the first state officials to recognize the importance of peat as a resource in Minnesota and who was the catalyst in initiating the present program.

Professor Rouse Farnham, Department of Soil Sciences, University of Minnesota, who provided valuable consulting advice and project assistance, both during the formative stages of the program and while the study was being executed.

Mr. Elwood Rafn and *Mr. Ralph Morgenweck* of the Minnesota Department of Natural Resources, who have monitored the research efforts of the program and have provided continuous evaluation of the program's many activities.

Representative Irvin Anderson, Majority Leader, Minnesota House of Representatives; *Senator Norbert Arnold,* Chairman, Finance Committee, Minnesota Senate; *Senator Roger Moe,* Chairman, Natural Resources and Agriculture Committee, Minnesota Senate; and *Representative Willard Munger,* Chairman, Environment and Natural Resources

Committee, Minnesota House of Representatives, who participated in the trip to Europe and assisted in the planning of the informational seminars that were carried out as a part of the Technology Transfer portion of the program.

Finally, MRI wishes to thank the members of the Advisory Committee, which was formed by Commissioner Herbst to provide advice and guidance during the program. This committee includes representatives from state and local government, Minnesota state agencies, Minnesota universities, regional development commissions, and the federal government. The members of the Committee are the following:

Ronald C. Briggs, Liaison Officer, U. S. Bureau of Mines
James E. Carter, Director, Research Division, Minnesota Energy Agency
Armando M. De Yoannes, Minnesota Department of Economic Development
Rouse S. Farnham, Professor of Soil Science, University of Minnesota
Charles H. Fuchsman, Director, Center for Environmental Studies, Bemidji State University
Don Grubich, Minnesota Iron Range Resources and Rehabilitation
Robert Hansen, Executive Director, Legislative Commission on Minnesota Resources
Roger Jourdain, Chairman, Red Lake Band of Chippewa Indians
Gary Lockner, Zoning Administrator, Lake of the Woods County
Bob Louiseau, Arrowhead Regional Development Commission
Ruth McLinn, Koochiching County Zoning Administrator
James E. Moore, Minnesota Department of Economic Development
Innes F. Nesbitt, Koochiching County Commissioner
John S. Ostrem, Planning Director, Headwaters Regional Development Commission
William Patnaude, Zoning Administrator, Belatrami County
Mike Pintar, Minnesota Governor's Office
Elwood Rafn, Supervisor, Minerals Section, Minnesota Department of Natural Resources
Vladimir Shipka, Commission on Minnesota's Future
Gordon Voss, State Representative, Minnesota House of Representatives
Ron Way, Assistant Director, Minnesota Pollution Control Agency
Herbert Wright, Jr., Director, Limnological Research Center, University of Minnesota

TABLE OF CONTENTS

1. SUMMARY

Presented in this report are the results of the first year study on the Peat Program, a continuing research effort to assess the environmental, economic, and social effects of a large-scale peat development in Minnesota. The principal objective of the program is to provide information that will be useful to the State of Minnesota in developing a state peatland policy. Much of the information obtained on the program will be of use to the other Upper Great Lakes States as well.

During the first phase of the Peat Program, effort was directed toward the following tasks:

1. The present status of peat development in the state was determined by visiting several commercial peat operations, by field observations, and by reviewing previous peat mapping and inventory efforts.

2. A first-hand impression of peat development in Europe was obtained by a technical study trip to the leading European peat-producing countries.

3. By means of informational seminars, technical presentations, and other communications, the information obtained in Tasks 1 and 2 was transmitted to interested parties in Minnesota and the Upper Great Lakes Region.

4. Using the concept of a representative peatland area and three development scenarios--a commercial peat operation, an agricultural development, and a large-scale gasification plant--a methodology was devised for evaluating the relative environmental, economic, and social impacts of a large-scale development.

5. Information pertinent to several possible peatland policy options was obtained by studying European regulations, by evaluating the nature of possible large-scale developments in the state, and by reviewing statutes and regulations related to peatland areas.

On the basis of the first phase study, MRI recommends that the Phase 2 efforts be initiated to continue the progress that has been made so far. We believe that such a program would benefit by the continued and intensified involvement of the Advisory Committee. Participation of other parties-at-interest in the state should also be encouraged.

2. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations summarize the results of the preliminary investigations carried out during the first phase of the Peat Program. For ease of presentation and better understanding, the statements have been grouped into three areas--environment, socioeconomics, and technology and development. Because the study was non-site-specific, the conclusions and recommendations should be regarded as generally applicable, not considered as equally applicable in all areas and under all circumstances. Only a site-specific study can produce site-specific recommendations. With this qualification stated, the conclusions and recommendations are presented below.

ENVIRONMENT

1.1 CONCLUSION:

Ecologic and environmental baseline data pertaining to Minnesota's peatlands are sparse and inadequate. It is not now possible to answer with a high degree of certainty the concerns that many people have pertaining to possible deleterious ecologic and environmental effects that would be associated with an intensive peat extraction operation.

1.2 RECOMMENDATION:

Field measurements should be made in several selected peatland areas that are suited for various large-scale development. An important part of the Phase 2 efforts should include a program of baseline environmental measurements in these peatland areas. These data should be obtained before any intensive peatland developments are initiated.

2.1 CONCLUSION:

The peatlands of the Lake Agassiz National Natural Landmark (Registered) and the Upper Red Lake National Natural Landmark (Designated) are situated within potential peatland development areas.

2.2 RECOMMENDATION:

The implications of any peatland development in or near the Lake Agassiz National Natural Landmark and the Upper Red Lake National Natural Landmark should be carefully studied.

3.1 CONCLUSION:

The wilderness-like character of some peatlands in northern Minnesota provide special living conditions for several unusual species of plants (orchids) and animals (timber wolf, moose, lynx, mink) that have a low tolerance for man's activities.

3.2 RECOMMENDATION:

An effort should be made to study the implications of large-scale developments within those peatland areas which provide essential living conditions for any endangered species or any unusual or unique species of plant or animal.

4.1 CONCLUSION:

The waters within the peatlands of northern Minnesota characteristically contain weakly buffered organic acids and therefore exhibit a low pH. The water in nearby streams and ditches, however, normally is not acid. This may be due to the buffering action of the carbonaceous materials common in the mineral soils of the more western peatland areas.

4.2 RECOMMENDATION:

More extensive studies should be carried out on the buffering action of mineral soils on these acid waters during higher flow rates and under more controlled conditions.

5.1 CONCLUSION:

Due to climatic and hydrologic factors, the ecosystems of the peatlands of northern Minnesota exhibit a relatively low productivity and apparently recover slowly from the effects of man's activities.

5.2 RECOMMENDATION:

A special effort should be made to investigate and anticipate any adverse impacts on peatland ecosystems associated with large-scale development.

SOCIOECONOMICS

6.1 CONCLUSION:

The local economies in the peatland areas of northern Minnesota tend to be narrowly based, lack manufacturing industries, have high seasonal unemployment, and exhibit relatively low per capita income levels.

6.2 RECOMMENDATION:

If peatlands are developed, an effort should be made to support a peatland development plan that would promote a more broadly based local economy and offer year-round employment opportunities.

7.1 CONCLUSION:

Large-scale development could overburden existing governmental services before additional revenues provide sufficient funding.

7.2 RECOMMENDATION:

A peatland development plan should include provisions for anticipatory financial support for municipal services.

TECHNOLOGY & DEVELOPMENT

8.1 CONCLUSION:

Minnesota statutes and regulations pertaining to peatland leasing are not now structured to deal with a rapid and extensive development. Existing statutes and regulations do not set forth management policies and priorities, do not address the issue of reclamation, and do not provide a mechanism for determining the present and future value of this resource.

8.2 RECOMMENDATION:

An intensive study of possible peatland policy options should be performed. This study should be made with the input of various parties-at-interest, including the general public, state legislators, regional development representatives, and state and county officials.

9.1 CONCLUSION:

Much useful information on bog preparation and harvesting techniques, environmental impacts, and land reclamation procedures exists in foreign literature or is possessed by foreign peat researchers.

9.2 RECOMMENDATION:

An intensive effort should be made to gather and summarize existing peat information that is pertinent to peatland development in Minnesota and the Upper Great Lakes Region. Contacts with foreign researchers should be continued and expanded.

10.1 CONCLUSION:

The inventory and mapping information pertaining to the types and distribution of Minnesota's peatlands is inadequate.

10.2 RECOMMENDATION:

The results of previous inventories should be collected and compiled and a strategic inventory of representative peatlands should be carried out.

11.1 CONCLUSION:

Extensive agricultural development on the peatlands in northern Minnesota is not likely to take place before more suitable upland areas are developed for agricultural purposes. It is estimated that the agricultural use of Minnesota's peatlands will not exceed a very small percent of the state's peatlands by the year 2000. The horticultural peat industry in Minnesota promises to be a slow growth industry which, under the most favorable conditions, would consume less than .2 of 1 percent of the state's peatland area by the year 2000. The high volume removal of peat for consumption by a gasification plant represents the most intensive use of Minnesota's peatland and would consume about three percent of the state's peatlands by the year 2000.

11.2 RECOMMENDATION:

A continuing effort should be directed toward assessing the environmental and socioeconomic implications of the several potential uses for Minnesota's peatlands.

12.1 CONCLUSION:

Several counties in the major peatland areas of northern Minnesota have not adopted county-wide zoning ordinances. Many of the municipalities in the major peatland areas of Minnesota have not adopted municipal zoning or development plans.

12.2 RECOMMENDATION:

The counties and municipalities in the major peatland areas of northern Minnesota should be encouraged to adopt county-wide and municipal zoning and development plans that address peat development.

13.1 CONCLUSION:

Many people in the State of Minnesota and the region have a strong interest in the possible large-scale development of the peat industry and have expressed concerns pertaining to possible environmental, economic, and social disbenefits that could be associated with such a development.

13.2 RECOMMENDATION:

A program should be established in Phase 2 to both solicit and disseminate information related to peat research and development.

3. INTRODUCTION

BACKGROUND

The peat reserves of the United States (approximately 19 million acres exclusive of Alaska, which is estimated to have about 100 million acres) amount to roughly 14 billion tons. This places the U. S. fourth in the world behind Finland, Canada, and the Soviet Union, which has 60 percent of the world's peat resources, or approximately 200 billion tons. The total annual peat production in the United States now is about 600.000 tons, which is quite small when compared with the 200 million tons produced annually in the U.S.S.R. (70 million tons for energy use and 130 million tons for agricultural and horticultural uses). European countries have made considerable progress during the past twenty years in developing their peat industries. Ireland and, now, Finland are using peat as a source of energy for steam and electrical generating plants. Other countries including Germany, Sweden, Poland, and Ireland are producing significant quantities of horticultural peat.

The development of the peat industry in Europe is due, partly at least, to the fact that peat is a highly versatile resource. It can be combusted in process steam boilers, electrical generating plants, and in combined district heating/power operations. It can be milled and compressed into briquettes to be used as a domestic heating and cooking fuel, and it can be processed to produce activated carbon, peat, coke, tars, phenolic by-products, and wax. It can be used, when properly treated, as a medium for absorbing oil spills and as a filtration material. Natural and reclaimed peat bogs can be drained, prepared, and used *in situ* for the production of vegetables, grasses, grass seed, and many varieties of trees. After harvesting and drying, peat can also be used as a potting soil and soil conditioner, and when fortified with fertilizer it can be spread on fields like manure. The list of actual and potential uses for peat is extensive, and research is continually lengthening it.

In addition to predicted energy shortages, which could be partially overcome by using peat as an energy supply, present and predicted world shortages of food, fertilizer, and fiber crops point to the enormous potential that Minnesota's peatlands hold for these other uses as well. This potential should be carefully examined. And it is equally important to study, and to weigh against the pressures of man's needs, the value many of these peatlands have as unique natural and scenic areas.

Of the total peat resources in this country, 90 percent are located in the states of Minnesota, Wisconsin, Michigan, and Florida. The 17.5 million acres of peatlands in these four states remain virtually undeveloped. Minnesota alone has 7.2 million acres of peatlands, many of which are very large, some encompassing contiguous areas up to 1.5 million acres.* Of the total peatland acreage in Minnesota, only 2.7 percent (roughly 200,000 acres) is presently being used.

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* These numbers are based on the Conservation Needs Inventory carried out by the Soil Conservation Service in 1959 and 1967.

MINNESOTA'S PEATLAND USES

Since the early 1900's various uses for Minnesota's peatlands have been suggested. But while the potential uses of peat are many--as a horticultural product, agricultural resource, natural wetland, energy source, petrochemical feed stock, wastewater filtration material--Minnesota's peatlands have been tapped primarily as a horticultural and agricultural resource.

AGRICULTURE, INDUSTRIAL, NATURAL

For decades the only significant harvesting of peat in Minnesota has been for the production of horticultural soil conditioners from fibric and hemic peats. But the combined annual production of the three largest horticultural peat producers in Minnesota in 1973 is estimated to have been about 20,000 short tons (dried), which when compared to Minnesota's total estimated supply of peat--9 billion short tons (dried)--indicates that even this traditionally most active sector of peat development represents a very limited use of the state's peat resources.

The use of peatlands to grow vegetables and other crops represents a significant use of Minnesota's peatlands at the present time, especially in Freeborn and Anoka Counties where such peatland use has proven highly productive for decades.

The other commercial uses of peat--as wastewater filtration material and petrochemical feedstock--have been evaluated by researchers. The results of the Iron Range Resources and Rehabilitation and Forest Service filtration research and the results of the University of Minnesota's "Chemical Products from Peat" project indicate that there might be an increased demand for these products in the future (Piret, 1958).

Most peat areas in Minnesota have remained in a nearly natural state. Some have been managed for timber or wildlife. There are also peatland areas which support unique flora and fauna, represent unusual peatland types (such as the "patterned bogs" north of Upper Red Lake), contribute to water management, or contain peat profiles which exhibit special palynological records. These areas should be located and preserved in a peatland development plan.

ENERGY

Over the years, several research studies have been carried out in which consideration was given to the use of peat as a source of fuel in Minnesota. In the early 1870's, a Minnesota legislative committee investigated its use as a fuel for locomotives. The Phoenix Building in Minneapolis was heated by powdered peat during the winter of 1919-1920. In the 1920's, E. K. Soper of the Minnesota Geological Survey made an estimate of peat reserves in Minnesota, giving consideration to those suitable for use as fuel. These estimates were based on fairly cursory examinations and since that time only about two percent of Minnesota's peatlands have been surveyed in any detail.

The U.S. Bureau of Mines published a bulletin on the commercial utilization of fuel peat. During the 1930's and in the 1940's, various groups and organizations in Minnesota studied the fuel potential of peat for such uses as taconite ore processing and boiler operations. The results of all of these early studies showed that although peat could be used successfully as a fuel, other energy sources such as coal were cheaper.

The Iron Range Resources and Rehabilitation Commission started research on peat in 1946 but also soon decided that it was not suitable as a source of energy because of the low cost of other fuels. From 1946 to 1971 they continued research on peat for other uses at a total cost of about $1,400,000.

In 1950, Senator Hubert Humphrey and Representative Fred Marshall of Minnesota introduced a bill in the U.S. Senate and the House requesting $1,000,000 for research on peat as a source of energy and $2,500,000 for private industry to develop peat resources, but the bill did not pass.

During the past year, a strong interest has again arisen regarding the development of Minnesota's fuel peat resources. This interest in a resource that has been almost overlooked for the past 20 years has developed largely because of the widespread concern that our country's energy supplies will not be adequate to meet the demands anticipated during the coming years. Shortages of natural gas and oil have developed because these resources have been used more rapidly than new reserves have been developed. Although the reserves of coal are large, their unrestricted use is somewhat limited due to air pollution regulations and difficulties in mining.

From information supplied by the Minnesota Energy Agency it is projected that the State of Minnesota will be facing an energy supply deficit of about 600 trillion BTU's by the year 1985 if the historical energy demand trend is followed. This assumption is based upon a curtailment of Canadian oil supplies and a decrease in natural gas supplies. Curtailments in natural gas supplies have created serious problems during the past year and the situation could get worse. Canada has announced increases that will bring the price to about $1.80 per thousand cubic feet during the next year. These price increases and curtailments threaten to have a significant impact on employment and industrial output, especially in those regions most dependent upon interstate natural gas.

The use of Minnesota's fuel peat reserves could play a significant role in overcoming the expected deficit in Minnesota's energy supplies during the next 10 to 20 years. For instance, it is conservatively estimated that Minnesota has 3.6 billion tons of peat suitable for fuel use. This is about 40 percent of the total peatland acreage of 7.2 million acres or roughly 3 million acres. Assuming a calorific value of 10,000 BTU's per pound (oven dried), this would result in a total energy resource of 72 Quads (72×10^{15} BTU). If all of this peat were used, this amount would be adequate for about a 50 year supply. However, because of the expected availability of other conventional sources of fuel, it would be necessary to use only about 35 percent of the total fuel peat to ensure the total energy supply equalling the demand for the next 50 years.

Because peat holds great potential as a source of energy, a horticultural product, an agricultural resource, a chemical feedstock, and as a vast natural area which has been left largely untouched by man, it is appropriate at this time that Minnesota, and the other Upper Great Lakes States as well, examine the full potential of this valuable resource.

DESCRIPTION OF PROGRAM

In June, 1975, the Upper Great Lakes Regional Commission awarded a grant to the Minnesota Department of Natural Resources (DNR) to initiate the first phase of a comprehensive peat research program. The DNR subsequently contracted with Midwest Research Institute (MRI) to carry out the one-year study.

After the program was approved, Minnegasco announced its intention to build a large synthetic natural gas facility on state-owned land in northwestern Minnesota. The lease application covers state-owned land in a 491-square-mile tract located in Koochiching, Beltrami, and Lake of the Woods Counties, and it is estimated that it contains at least 200,000 acres of peat that could be used for commercial energy production.

The major objective of the MRI program was not to respond specifically to the Minnegasco proposal but to supply information that would be useful to the State of Minnesota in developing a peatland policy applicable to any large-scale development pressure.

The thrust of the first phase of the program was as follows:

1) The present status of peat development in Minnesota was determined by performing a preliminary survey of peatland areas and present land use, and anticipated large-scale developments.

2) A first-hand impression of the status of peat technology in Europe was obtained by a technology transfer visit during the fall of 1975. Information obtained on this trip was extremely useful in helping to determine how similar progress could be made in Minnesota. This information was presented to interested parties in the state by means of a series of information seminars and a special report.

3) The impacts of several potential large-scale peat development efforts were analyzed by the development of a representative peatland area and a scenario approach describing three large-scale peatland developments, namely, commercial peat, agriculture, and a gasification plant, combined with appropriate input-output analyses.

4) An impact ranking and comparison procedure was developed which allows a quantitative comparison of impacts in the environmental, social, and economic areas for the three development scenarios.

5) Several policy considerations were enumerated based on information obtained during the technology transfer visits to Europe, the analysis of Minnesota peatland development, and the preliminary evaluations of the impacts for the three development scenarios.

The first phase of the Peat Program, which has now been completed, has been carried out under the scrutiny of a 21-member advisory committee composed of federal, state and county officials, regional development commission members, and university staff members, and was monitored by the Minnesota Department of Natural Resources.

CONTENT OF REPORT

Presented in this report is a summary of the research efforts carried out during Phase 1 of the Peat Program. Included are the following:

1) Technology Transfer Program

   This very important portion of the study included a trip to the major peat producing countries in Europe. First-hand observations of energy and horticulture uses, harvesting techniques, peat research activities, and reclamation progress were obtained. The details of this trip are presented in a separate document referenced later in this report. Other important efforts of this part of the program included a series of informational seminars presented in four northern Minnesota towns in the peatland area and at the St. Paul Campus of the University of Minnesota. Several technical presentations on peat were made and two papers were prepared. In addition, much information on the program was disseminated by personal communication and informal meetings.

2) Peat Areas in Minnesota

   Included in this effort are a summary of peatland uses in Minnesota, a description of previous inventory and mapping efforts in the peatland areas, and a discussion of field visits made to peatland areas.

3) A Preliminary Analysis of a Large-Scale Peat Development In Minnesota

   This part of the report includes a description of the natural and socioeconomic environments in the peatland areas. These descriptions are based on the peatland types, environmental conditions, and socioeconomic characteristics in seven northern Minnesota counties: Roseau, Lake of the Woods, Beltrami, Koochiching, St. Louis, Carlton, and Aitkin. This information was then used to create natural and socioeconomic environmental settings for a representative peatland area. Three development scenarios were also selected for detailed analysis within this representative area--a commercial peat operation, an agricultural development, and a gasification plant. A methodology for comparing and ranking the ecological, environmental, aesthetic, and socioeconomic impacts was developed. This method is based on using a series of indicator curves that relate measurable quantities to environmental quality (EQ) units, a method of normalizing impacts in the four areas into a single parameter that can be summed over the four impact areas, thus allowing comparison of the different scenarios.

4) Policy Evaluation

   Various state and county policies that apply to peatland areas were gathered and analyzed to determine how they would relate to a large-scale peatland development. Other policy considerations were also taken into account, and these considerations are presented in the report.

MRI thought the best interests of the state would be served by preparing a report that successfully presented technical information to a broad spectrum of readers, including legislators, State and county officials, research professionals, and also people who might have no special knowledge of peatland ecology, peat technology, or the policy-making process. The report is *not* an Environmental Impact Statement, nor is it, properly speaking, an Environmental Impact Assessment. It is an analysis of *non-site-specific* development potential which, depending on policies yet to be written, could take any number of forms.

It was not anticipated that the first phase of the Peat Program would provide sufficient information to allow the State of Minnesota to develop a complete peatland policy. However, the progress that has been made suggests that additional studies carried out as an extension of the first phase efforts could yield the information that will be needed to complete the development of such a policy. Efforts during Phase 2 of the program will include more evaluations of the impacts for the three development scenarios. In addition, MRI strongly believes that additional public participation is necessary to ensure the development of an effective peatland policy. This can be accomplished by procedures already established in the first phase; that is, additional informational seminars in northern Minnesota communities, presentation to groups and organizations interested in Minnesota peatland development, presentation of papers and speeches pertaining to the research efforts, and testimony before Minnesota legislative committees that would have an interest in the development and protection of the state's peat resources.

4. TECHNOLOGY TRANSFER

BACKGROUND

The Technology Transfer portion of the Peat Program was conceived as a vehicle for transmitting peat technology from the European peat producing countries, where peat harvesting, combustion, and reclamation techniques are highly developed, to Minnesota and the other Upper Great Lakes States, where the potential for peat development is high but where peat technology has not developed to the level it has in Europe. The Technology Transfer program was also planned as a vehicle for disseminating technological and environmental information to interested parties outside the scientific community.

To meet these objectives, effort was directed toward several activities, some of which were not envisioned in the original work schedule, but all of which became important to the success of the overall program. The most important activity was a technical study trip to Europe arranged by MRI and Professor Rouse Farnham of the University of Minnesota. The trip provided an opportunity to study peat harvesting and combustion technology and the techniques employed to reclaim harvested peatlands in several European peat producing countries, where peat related technology is highly developed.

An equally important activity, and one which was planned to follow directly from the technical study trip, was a series of Information Seminars held at the University of Minnesota (St. Paul) and in several of the northern Minnesota communities which would likely be impacted by any peat developments in the state. The purpose of these seminars was to report on the status of European peat technology and to present a preliminary evaluation of the potential environmental impacts that might be expected as a result of a large scale peat development. Because the Information Seminars provided an excellent opportunity to disseminate information to and to solicit information from local citizens and municipal, county, and regional representatives, a questionnaire was prepared to solicit the attitudes of persons attending the meetings toward the prospect of a large-scale peat development in their area. This questionnaire, like the seminars themselves, facilitated the exchange of information between the public and the scientific community. Also arising from the technical study trip was a trip report which was distributed to members of the Advisory Committee and other parties interested in the Peat Program.

In addition to the trip, Information Seminars, and trip report, other activities were engaged in in an effort to respond to the numerous requests from county, regional, and state officials, legislators, representatives of citizens' organizations, researchers, teachers, librarians, and the media for information pertaining to peat harvesting and combustion technology and the impacts which such technology, if allowed to develop in Minnesota, would have on the state's environment, economy, and way of life. Distributing such information--which included preparing appropriate information packets--was viewed by MRI as part of its responsibility to keep all interested parties informed of its research activities. Technical presentations were also made to the Agriculture and Natural Resources Committee (Minnesota Senate) and to the U.S. Bureau of Mines (Twin Cities); a paper was presented at the Conference on Alternative Energy; and a paper ("A Methodology for Evaluating the Impact of a Large-Scale Peat Development in Minnesota, U.S.A.") was submitted to and accepted by the International Peat Society as part of its proceedings on the environmental implications of peat development, which took place in September 1976.

TECHNICAL STUDY TRIP

The European peat industry has been in active operation for almost fifty years. For that reason, European peat technology represents by far the most advanced state of the art. The technical study trip provided an opportunity for Minnesota legislators, state officials, and scientists to review the current status of peat technology in Europe with an eye to evaluating the implications that such technology might hold for peat development in Minnesota. The purpose of the technical study trip was fivefold:

PURPOSE

1. Attend a symposium of Commission II of the International Peat Society at Kuopio, Finland, September 23-26, 1975, on *Combustion of Peat* and present two papers. Also, participate in a field trip to peat areas and power plants.
2. Obtain firsthand information from research scientists and technicians in Finland, the Soviet Union, Sweden and Ireland concerning technology of peat harvesting, handling, processing, transport, storage, and combustion.
3. Study land use, reclamation, and leasing procedures of peatlands now practiced in Ireland and Finland. In addition, study the land reclamation procedures associated with the brown coal (lignite) operations in the Cologne, Germany ,area, which can be directly related to peat operations.
4. Visit copper-nickel mining and smelting operations in Oravikoski and Harjavalta, Finland, and study their environmental effects.
5. Visit the coal gasification facility at Westfield Development Centre in Scotland.

ITINERARY

Friday, September 19	Depart Minneapolis for Helsinki
Saturday through Monday, September 20-22	Helsinki, Finland: Technical Research Centre of Finland
Tuesday through Friday September 23-26	Kuopio, Finland: International Peat Society *Combustion of Peat* Symposium
Wednesday and Friday September 24, 26	Oravikoski, Harjavalta, Finland: Outokumpu Company Copper-Nickel Operations
Saturday and Sunday September 27, 28	Leningrad, U.S.S.R.: Soviet Peat Institute and Leningrad Power Station No. 1t
Monday September 29	Hasselholm, Sosdala, Sweden: Svensk Torvforadling, Swedish Peat Industry
Tuesday, September 30	Cologne, Germany: Brown Coal Operations

Wednesday and Thursday October 1, 2	Edinburgh, Scotland: Westfield Development Centre, Aberdeen, Scotland: Macaulay Institute for Soil Research
Friday through Sunday October 3-5	Dublin, Midlands, Ireland: Bord na Mona, Irish Peat Industry Lullymore Agricultural Research Institute
Sunday, October 5	Depart Dublin for Minneapolis

The Minnesota delegation first visited (September 22) the Technical Research centre of Finland, located near Helsinki, where the group toured the Fuel and Lubricant Research Laboratory. The delegation was there briefed on the research activities of the laboratory, which are mainly in the areas of peat storage and combustion, the use of peat for oil-spill cleanup, and lubrication research.

The delegation also attended the *Combustion of Peat* Symposium at Kuopio, Finland, organized by the International Peat Society (IPS) Commission II together with the Finnish National IPS Committee and the City Electricity Works in Kuopio. The symposium was held last year in response to the critical international fuel situation. About 150 representatives of science and technology from Canada, England, Finland, the Federal Republic of Germany, Ireland, the Netherlands, Norway, Sweden, the U.S.A., and the U.S.S.R. attended the meetings.

During the symposium many useful contacts were made with peat researchers from the major peat producing countries in the world, and final arrangements were made for the visits to the Soviet Union and Sweden.

The program of sessions was as follows:

1. Review of the present use of peat as fuel in different countries and estimates of the future competitive use of peat as an energy source
2. Quality standards for fuel peat, and the possibilities of using different peat qualities
3. Receiving, handling and storage of fuel peat at site
4. Combustion equipment and boilers
5. Control of combustion
6. Ash handling and emission
7. Safety arrangements and regulations
8. Peat burning power plants

The papers presented at the symposium by members of the Minnesota delegation were as follows:

1. *Minnesota's Peat as an Energy Source--Quality and Quantity*, by *Rouse Farnham*, *Roy Larson*, and *James Carter* (presented by Professor Farnham).

2. *Potential and Economic Implications of a Large-Scale Peat Development in the Northern Lake States--U.S.A.* by *Robert Herbst*, *Michael Pintar*, and *Peter Gove* (presented by Commissioner Herbst).

The delegation also toured the Kuopio peat-fired district heating plant (September 24) and visited the Rastunsuo fuel peat site of the State Fuel Centre at Rautalampi and the peat boiler plant of the G.A. Serlachius Company in Mantta (September 25). The peat-fired heating plant of the Finnish Defense Forces in Niimisalo was also visited by the Minnesota delegation (September 26).

From Finland the Minnesota delegation traveled to the Soviet Union, where the group visited the Soviet Peat Institute in Leningrad (September 27) and was briefed on the research activities of the Institute. The group also toured a peat-fired heating/power plant which supplies both district heat and electricity to the city of Leningrad.

In Sweden the delegation toured the peat harvesting and production facilities of Svensk Torforadling (Swedish Peat Industry) at Hasselholm and Sosdala (September 29). From there the Minnesota delegation traveled to Cologne, Germany, (September 30) to study the German brown coal operations there and the reclamation techniques which have been applied to return extensive mined areas to agricultural, recreational, and natural use.

The Minnesota delegation next traveled to Scotland where the group toured the Lurgi coal gasification plant at the Westfield Development Centre (October 1). In light of Minnegasco's announced intention to build a peat gasification plant in northwestern Minnesota, the visit to Westfield was thought to be most appropriate; it provided the members of the group with their first view of a gasification plant. The last stop on the tour was Dublin, Ireland, where the delegation toured the facilities and operations of Bord na Mona (Irish Peat Industry) and the Lullymore Agricultural Research Institute, at Lullymore, where peat reclamation techniques are studied (October 2).

A summary of the information and technical data obtained in the course of the study trip appears in a separate report ("A Report on European Peat Technology") prepared and distributed by MRI, May 1976, to the Advisory Committee, the DNR, other state agencies, regional and county officials, researchers, and private citizens. Included in the report is a discussion of European peat research activities, peat harvesting techniques, peat combustion technology, and land reclamation procedures.

INFORMATION SEMINARS

SCHEDULE AND CONTENT

The principal purpose of the information seminars was to report on the status of European peat harvesting and combustion technology and to present a preliminary evaluation of the potential environmental impacts that might be expected as a result of a large-scale peat development in Minnesota. The first information seminar was held at the University of Minnesota (St. Paul) on December 18, 1975. This initial seminar was arranged to present a summary of European peat harvesting and combustion technology to an audience of researchers, engineers, state and federal agency staff, planners, and other professionals interested in the implications which such technology might hold for Minnesota. The seminar's program is outlined below:

PEAT SEMINAR PROGRAM

TECHNOLOGY TRANSFER SEMINAR:
EUROPEAN PEAT TECHNOLOGY

University of Minnesota St. Paul Campus

WELCOME	Dr. Eugene Vandegrift, MRI
INTRODUCTION	Mr. Roy Larson, MRI
EUROPEAN ENERGY STATUS	Dr. James Carter, Energy Agency
PEAT HARVESTING	Professor Rouse Farnham, University of Minnesota
PEAT ENERGY TECHNOLOGY	Mr. Roy Larson, MRI
ENVIRONMENTAL PROTECTION & RECLAMATION	Commissioner Robert Herbst Department of Natural Resources
REFRESHMENTS	
PANEL & DISCUSSION	

Also in December, a list of potential locations for the information seminars was drawn up and, after consultation with DNR personnel and those State legislators who participated in the trip, four northern Minnesota communities were chosen as sites for the seminars: Baudette, Big Falls, Blackduck, Grand Rapids. Final arrangements with local officials were made in December and the seminars were scheduled for four consecutive evenings in January:

Baudette	Monday, January 12 Lake of the Woods County Courthouse	7:30 PM
Big Falls	Tuesday, January 13 Big Falls Town Hall	7:30 PM
Blackduck	Wednesday, January 14 Blackduck High School	7:30 PM
Grand Rapids	Thursday, January 15 Itasca Community College (Davies Theatre)	7:30 PM

News releases announcing the information seminars were sent to papers in International Falls, Baudette, Grand Rapids, Northome, Little Fork, Bemidji, Eveleth and Cloquet, and similar releases were sent to twelve northern Minnesota radio stations and to KCMT-TV in Alexandria, KNMT-TV in Walker, and WDIO-TV in Duluth. In addition, MRI prepared a brochure describing the seminars and announcing their dates, times and locations. More than 600 of these brochures were distributed via local officials and members of the Peat Program Advisory Committee. Brochures were also sent to Regional Development Commission representatives, State legislators whose districts might be affected by peat development, and to appropriate staff in the State agencies.

The information seminar team included Messrs. Roy Larson and Rock Colingsworth (MRI) and Professor Rouse Farnham of the University of Minnesota. Commissioner Robert Herbst of the Minnesota Department of Natural Resources presented a portion of the seminar in Baudette. In addition, State Representative Irvin Anderson made introductory remarks in Baudette, Big Falls, and Blackduck, and State Senator Norbert Arnold spoke at the seminars in Blackduck and Grand Rapids.

The content of the seminars included a description of the Peat Program, a review of environmental and reclamation progress in Europe and of European peat harvesting technology, a description of peat energy uses in Europe, and a discussion of some of the field work being carried out as a part of the preliminary environmental portion of the program.

The seminar program received good press coverage in all the newspapers in the region, and the meeting in Blackduck was covered by television. The public response to the seminars was excellent: over 85 percent of the attendees thought the seminars were valuable and timely. It is MRI's opinion that additional meetings of this type should be continued in Phase 2 of the Peat Program.

ATTITUDE QUESTIONNAIRE

PROCEDURE

At each seminar the questionnaire was distributed during the break between the formal presentation and the discussion period. A total of 192 people filled out the questionnaire: Baudette (46), Big Falls (38), Blackduck (83) and Grand Rapids (25). Not everyone attending the seminars completed a questionnaire. Some left early. Some did not bother to fill one out. A few blank questionnaires were carried away from the meetings, filled out elsewhere, and returned by mail to MRI. Because this procedure was considered non-standard and because the results from this batch of questionnaires were conspicuously out of line with the results as a whole, these absentee responses were not included in the results which are presented in the following tables. A sample of the actual questionnaire form is shown in Figure 4.1. Tables presenting the results of the "check-off" portion of the 192 questionnaires--the first four tables contain the number of responses and the second four tables contain the percentage responses--are presented in Appendix A.

The results of the attitude questionnaire were submitted on February 25, 1976, to all members of the Advisory Committee for evaluation and comment. Six members of the committee responded with comments and suggestions--Mr. Ron Briggs, Professor Charles Fuchsman, Mr. Bob Louiseau, Ms. Ruth McLinn, Mr. John Ostrem, and Mr. Vladimir Shipka--and many of their comments were taken into consideration in revising the presentation of the data. The representatives of both the Arrowhead and Headwaters Development Commissions noted that the results of the questionnaire seemed to be representative of the feelings of local people and their elected officials.

Peat Program
Citizen Response Document
Baudette, Big Falls, Blackduck, Grand Rapids
January 12-15, 1976

We need your help. It is important to our evaluation of peat development in Minnesota that we learn what people in this area think about a large-scale effort such as the proposed Minnegasco peat harvesting and gasification operation.

By completing this short questionnaire, you will help us better understand local concerns and will assist us in making your feelings known to State policy makers.

A peat harvesting and gasification operation in your area would:	Strongly Agree	Agree	Slightly Agree	No Opinion	Slightly Disagree	Disagree	Strongly Disagree
1. Seriously damage the area's wildlife							
2. Seriously damage the area's water quality							
3. Seriously damage the area's air quality							
4. Seriously threaten your personal health							
5. Badly hurt your job/business							
6. Adversely affect your present way of life							
7. Adversely affect your community							

(Continued on back side.)

What do you think might be the most serious problem created by a peat harvesting and gasification operation?

What do you think might be the most important benefit created by a peat harvesting and gasification operation?

What do you think would be the "best use" of Minnesota peatlands?

Do you believe this seminar was valuable?

Please add any additional comments:

Midwest Research Institute
3100-38th Avenue South
Minneapolis, Minnesota 55406
(612) 721-6373

Male/Female ________________

Occupation ________________

Figure 4.1 Sample of Questionnaire

QUANTITATIVE RESPONSES

It is important to note, before any comment is made about the results of the questionnaire, that no effort was made, and indeed no effort could be made under the circumstances, to control the make-up of the sample. Whether or not the 192 people who filled out the questionnaire at the four seminars were, as a group, representative of the population in those areas most likely to be affected by peat development has not been determined. Indications are that they were not entirely representative. This matter will be discussed in more detail later.

In constructing the questionnaire, it was decided to directly face the issue which was shaping the public's interest in the state's peatlands. Thus, although the questionnaire solicited an open-ended response to the "best use(s)" of the state's peat resources, it primarily addressed attitudes toward a large-scale harvesting and gasification operation.

It should be pointed out, furthermore, that the questionnaire recorded people's *attitudes*, which sometimes are based on careful consideration of the facts and sometimes based on prejudice and very little knowledge of the facts. Whatever the case, these attitudes shape public sentiment and, frequently therefore, public policy.

The largest number of questionnaires (83) was obtained at the Blackduck seminar and the smallest number (25) at the Grand Rapids seminar. The Blackduck questionnaires represent, in fact, almost half of the total sample (192) and therefore carried almost as much weight in the final results as the questionnaires from the other three locations combined. It is important to remember this because the respondents at the Blackduck meeting showed, as a group, more concern for the environmental impacts of peat development, and more concern for the impact on their community and way of life, than did the respondents at the other three seminars. Although the Blackduck responses carry considerable weight in the final results, it seems appropriate to consider the sample as a whole as representative of the "increasing" concern which might be expected with increasing geographical proximity to a potential development site, in this case the proposed Minnegasco project which was obviously in the minds of the people who attended not only the Blackduck meeting but the other meetings as well.

The respondents were asked to agree or disagree with the following statements:

A peat harvesting and gasification operation in your area would:

1. Seriously damage the area's wildlife.
2. Seriously damage the area's water quality.
3. Seriously damage the area's air quality.
4. Seriously threaten your personal health.
5. Badly hurt your job/business.
6. Adversely affect your present way of life.
7. Adversely affect your community.

A respondent could agree or disagree slightly, moderately, or strongly with each statement.

A comparison of the results from the four locations will reveal several significant differences and several significant similarities. The differences will be found mostly in the responses to the environmental statements (1-3) and "way-of-life" statements (6-7). The respondents at Blackduck, for example, were as a group in general agreement with statements 6 and 7 by margins of 53.0/39.8 and 47.0/43.3, respectively. At the other three seminars, the respondents were in general disagreement with the same two statements by an average margin of 29.2/57.0 for statement 6 and 32.2/50.4 for statement 7 (Appendix A).

The differences in the responses to the environmental statements (1-3) are more complicated. The respondents at Blackduck were in agreement with all three statements by margins of 51.8/37.3, 47.0/25.3, and 42.2/38.6, respectively. The respondents at Big Falls were in disagreement with those same three statements by margins of 26.3/63.2, 23.7/50.0, and 10.5/60.5, respectively. The respondents at both Baudette and Grand Rapids were split in their response to this group of statements (Appendix A).

Despite these differences, the results reveal some similarities between the reponses at the four locations. At all four seminars the largest number of "disagree" responses were entered, as might be expected, in response to statement 5, and the second largest number were entered in response to statement 4. At Blackduck these were the only statements which elicited a majority in disagreement.

In the case of three of the seven statements--1, 6, and 7--the respondents at all four seminars appear to have made up their minds more emphatically than in the case of the remaining four statements. The percent "No Opinion" response to these three statements is on the average about half that of the average "No Opinion" response to the remaining four statements (11.3/22.8). Thus, while 20 to 30 percent of the 192 respondents expressed "No Opinion" about the impact of a large-scale peat development on water quality, air quality, their personal health, and their job/business, more than 90 percent of the respondents had made up their minds, one way or the other, about the effect of such a development on wildlife, on their own way of life, and on their communities. (Appendix A.)

A closer look at a break-down of the response scale will reveal another important fact. The respondents who disagree with the statements in the questionnaire tend to do so more emphatically than those who agree with the same statements. This is especially true in the case of statement 4 concerning the impact of peat development on the respondent's personal health:

A peat harvesting and gasification operation in your area would:	Strongly Agree	Agree	Slightly Agree	No Opinion	Slightly Disagree	Disagree	Strongly Disagree
4. Seriously threaten your personal health.	3.1	4.2	9.4	22.4	5.2	38.0	17.7

The split here between "Total Agree" and "Total Disagree" is 21.5/78.5. But when the responses are weighted (slight agree/disagree = 1, agree/disagree = 2, and strong agree/disagree = 3), the split widens and shifts even more decidedly in the direction of disagreement (16.8/83.2). The same is true, to a lesser degree, with the response to the environmental statements 1-3:

A peat harvesting and gasification operation in your area would:	Strongly Agree	Agree	Slightly Agree	No Opinion	Slightly Disagree	Disagree	Strongly Disagree
1. Seriously damage the area's wildlife. 2. Seriously damage the area's water quality. 3. Seriously damage the area's air quality.	10.4	11.3	17.0	18.2	11.3	21.9	10.6

The average split here between "Total Agree" and "Total" Disagree" is 46.8/53.2. But when the responses were weighted, the split widens somewhat and shifts slightly more in the direction of disagreement (44.8/55.2).

A summary of the results of the 192 questionnaires also shows that, when taken together, *the plurality of all respondents is in disagreement with all the statements except statement 2*, which concerns the impact of peat development on water quality:

*SUMMARY (Percent)

A peat harvesting and gasification operation in your area would:	Total Agree	No Opinion	Total Disagree
1. Seriously damage the area's wildlife.	40.6	8.9	50.5
2. Seriously damage the area's water quality.	38.0	25.5	36.5
3. Seriously damage the area's air quality.	37.5	20.3	42.2
4. Seriously threaten your personal health.	16.7	22.4	60.9
5. Badly hurt your job/business.	6.8	22.9	70.3
6. Adversely affect your present way of life.	39.6	10.9	49.4
7. Adversely affect your community.	38.5	14.1	47.4

* 192 respondents

When the complete results are tallied, moreover, it becomes apparent that the "Total Agree" and "Total Disagree" responses to statements 1,2,3,6, and 7 are separated by no more than 10 percentage points and, in one case, by less than 2 percentage points. This narrow spread seems to indicate that these five issues remain highly controversial, with proponents and opponents almost equally divided. The spread is considerably wider (40-60 percentage points) in the case of statements 4 and 5, indicating that these two issues are presently much less hotly debated.

QUALITATIVE RESPONSES

The second page of the questionnaire solicited more open-ended responses to four questions:

1. What do you think might be the most serious problem created by a peat harvesting and gasification operation?
2. What do you think might be the most important benefit created by a peat harvesting and gasification operation?
3. What do you think would be the "best use" of Minnesota's peatlands?
4. Do you believe this seminar was valuable?

In tabulating the responses it was found that many respondents supplied *more than one response* to questions 1 and 2. All such responses were taken into account in the final tabulations although this procedure gave a disproportionate weight to those questionnaires which supplied more than was specified.

The responses to question 1 were grouped into five major clusters: environmental problems, life-style problems, population problems, service problems, and "no problem." The results, which are summarized below by location, indicate that the threat to the environment is considered the most serious problem by most respondents:

MOST SERIOUS PROBLEM (Percent)	Baudette	Big Falls	Blackduck	Grand Rapids	Total
Environmental	69.4	32.7	42.1	52.0	46.3
Life-Style	4.1	9.1	13.2	20.0	11.1
Population	2.0	14.5	21.9	16.0	15.6
Service	0.0	25.5	9.6	4.0	10.7
Other	10.2	7.3	7.0	4.0	7.1
No Problem	14.3	10.9	6.1	4.0	8.6

The environmental cluster can be broken down into six sub-problems--air pollution, water pollution, ground water table lowering, wildlife, flooding, and the problem of reclamation, which was regarded as essentially an environmental concern. The breakdown of the environmental cluster for the total sample is presented as a percent of total responses:

ENVIRONMENTAL PROBLEMS (Percent)

Problem	Total
Air Pollution	10.2
Water Pollution	9.8
Ground Water	6.1
Wildlife	7.8
Flooding	1.2
Reclamation	5.3
Environmental Problem (not specified)	5.7
No Problem	8.6

The breakdown indicates that air and water pollution are considered the most serious environmental threats, with wildlife destruction, ground water lowering, reclamation, and flooding coming in third, fourth, fifth, and sixth, respectively. A significant portion of the respondents (8.6 percent) believe there will be no problem of any kind.

The responses to question 2 had to be grouped into more classes than the responses to question 1 due to the diversity of the responses to question 2. The benefits of a large-scale peat development are tabulated below by location:

MOST IMPORTANT BENEFIT (Percent)	Baudette	Big Falls	Blackduck	Grand Rapids	Total
Economy	25.5	16.4	20.2	22.6	20.6
Employment	32.7	35.8	33.7	12.9	31.5
Energy	12.7	20.9	21.2	45.2	22.2
Agriculture	10.9	4.5	2.9	6.5	5.4
Forestry	0.0	0.0	1.9	0.0	0.8
Wilderness Area	0.0	1.5	1.9	0.0	1.5
Tax base	1.8	11.9	3.8	0.0	5.1
Use of Wasteland	10.9	4.5	2.9	0.0	4.7
Other	0.0	4.5	6.7	6.5	5.1
No Benefit	5.5	0.0	4.8	3.2	3.5

By far the three most important benefits in the eyes of the respondents at all four seminars are in the areas of employement, economy, and energy production. Moreover, since "employment", "economy", and "tax base" are terms which could easily be grouped as economic benefits, it could be said that almost 60 percent of the respondents believed that the economic benefits of peat development were the most important. Energy production comes in a somewhat distant second to these economic benefits.

Responses to question 3 concerning the "best use" of Minnesota's peatlnads are presented below by locations:

BEST USE (Percent)	Baudette	Big Falls	Blackduck	Grand Rapids	Total
Energy	27.7	34.7	21.7	26.3	26.7
Agriculture	18.0	18.7	21.7	13.2	18.8
Horticulture	11.5	8.2	2.3	18.4	8.3
Forestry	13.1	10.2	9.8	13.2	11.3
Multiple Use	4.9	6.1	5.4	10.5	6.3
Limited Development	4.9	2.0	5.4	15.8	6.3
No Development	4.9	6.1	13.0	2.6	7.9
Don't Know	3.3	2.0	7.6	0.0	4.2
Other	11.5	12.2	13.0	0.0	10.3

A look at the responses concerning best use will reveal that energy production leads all the other categories of use by a substantial margin. Agriculture and forestry surpass horticulture in the area of non-energy use. It is worth pointing out that the respondents at all four meetings chose some use of the state's peatlands over "No Development" by margins ranging from 66.3/13.0 to 97.4/2.6, the average margin being 77.7 in favor of some development and 7.9 percent in favor of no development. It should also be pointed out, however, that uses which would be less intensive than gasification--horticultural, agricultural, forestry, and "limited development"--when taken as a group, are favored over the potentially more intensive gasification use by a margin of 44.7 to 26.7. Multiple use does not exclude gasification.

The results for question 4 and the biographical data are summarized below:

Was the Seminar Valuable? (Percent)	
Yes	82.2
Somewhat	5.4
No	2.0
Too Long	5.4
Too Technical	2.0
Other	2.5

SEX (Percent)	Baudette	Big Falls	Blackduck	Grand Rapids	Total
Male	88.9	71.1	81.8	95.7	83.1
Female	11.1	28.9	18.2	4.3	16.9

OCCUPATION (Percent)	Baudette	Big Falls	Blackduck	Grand Rapids
Professional and Technical	19.5	31.4	40.8	78.3
Manager	9.8	20.0	12.7	4.3
Sales	4.9	0.0	1.4	0.0
Clerical	4.9	5.7	4.2	0.0
Craftsman	9.8	5.7	7.0	0.0
Operatives	0.0	5.7	2.8	0.0
Laborers (Non-Farm)	12.2	8.6	0.0	0.0
Farm Managers & Farm Laborers	31.7	5.7	11.3	0.0
Service	0.0	5.7	1.4	0.0
Housewife	2.4	5.7	5.6	4.3
Retired	2.4	5.7	5.6	4.3
Student	2.4	0.0	5.6	8.7
Not Employed	0.0	0.0	1.4	0.0

In the table summarizing the "occupational" characteristics of the questionnaire sample, the 192 respondents were classified by occupation according to the classification scheme used in the 1970 census for employed persons over 16 years old (four additional classes were added to allow for a count of non-employed respondents). For those who wish to evaluate the representativeness of the questionnaire sample, reference should be made to the table below,which compares employed persons by occupation in the Headwaters and Arrowhead development regions, as tabulated in the 1970 census, to employed persons by occupation in the sample. For the purposes of this comparison, only employed persons in the sample were counted.

OCCUPATION OF EMPLOYED WORKERS (Percent)	Headwaters Region	Arrowhead Region	Questionnaire Sample
Professional, Technical	14.2	14.0	45.2
Manager	9.0	8.5	14.4
Sales	5.6	6.1	2.1
Clerical	12.6	13.8	4.8
Craftsman	11.5	17.3	7.5
Operatives	10.9	17.6	2.7
Laborers (Non-Farm)	4.9	5.8	5.8
Farm Managers, Farm Laborers	14.2	1.7	15.8
Service	17.2	15.3	2.1

It is worth pointing out that, as one might expect, there was a disproportionately high turnout of professional people, technicians, researchers, and administration types at the meetings, or at least a disproportionate number of these people filled out the questionnaire. On the other hand, the data show that clerical workers, manufacturing and transport operatives, and service workers were under-represented. The representation of farmers, farm laborers, and non-farm laborers (exclusive of craftsmen and operatives) was more in line with their numbers in the population as a whole. The audience which was least representative of the population as a whole was the one at Grand Rapids, which consisted primarily of research scientists.

5. MINNESOTA'S PEATLANDS

DISTRIBUTION

About 14.1 percent of Minnesota's land area is peat (organic soil). This amounts to about 7.2 million acres of peatland, of which 75.8 percent (5.4 million acres) is estimated to have deep peat over 5 feet in thickness, and 24.2 percent (1.7 million acres) is estimated to have shallow peat less than 5 feet in thickness. These peatlands are scattered throughout the state, but by far the most extensive deposits are located in northern Minnesota, principally in the Agassiz, Upham, and Aitkin Lacustrine Plains and in adjacent moraine, outwash, and drumlin areas. Outside this northern peatland area, the most significant peatlands are those occurring in Anoka and Freeborn Counties, which together possess roughly 120,000 acres of organic soil, much of which is used for crop and forage production, especially in Freeborn County.

The vast peatlands of northern Minnesota occur almost entirely within the Northern Minnesota Swamps and Lakes Land Resource Area, as delineated in USDA Handbook No. 296. More scattered peatlands occur in the Central Wisconsin and Minnesota Thin Loess and Till Land Resource Area and the Wisconsin and Minnesota Sandy Outwash Land Resource Area. In the Northern Swamps and Lakes LRA, which corresponds roughly to the Agassiz, Upham, and Aitkin Lacustrine Plains in Minnesota, more than 80 percent of the area is in forest and lakes, between 10 and 15 percent in cropland, and less than 5 percent in pasture. The principal corresponding land uses in this LRA are, in order of importance, recreation and lumbering, farming, and livestock production. Farming is considerably more important in the Central Wisconsin and Minnesota Till LRA, which stretches in a broad band across central Minnesota from the Wisconsin border on the east to Todd and Stearns Counties on the west. Nearly all of this LRA is in farms, mainly for growing feed grains, forage, and some vegetables. The remaining area is in forest, mostly farm woodlots. Farming is an equally important land use in the Wisconsin and Minnesota Outwash LRA, which lies in the south of the Central Till. About 90 percent of this LRA is in farms, mostly cropland for raising feed grains, forage crops, and vegetables. In all these LRA's, agricultural and recreational developments have tended to skirt peatland areas, which must be drained for cultivation and which offer little in the way of recreational opportunities (USDA Handbook No. 296). See Figure 5.1.

Extensive peatlands in northern Minnesota are found mainly in seven counties arranged in an arch from southwest of Lake Superior, in the mixed coniferous-deciduous forest, into the prairie-forest transition in the northwest corner of the state. See Figure 5.2. These counties in general, and the peatlands in particular, are less populated and developed than other areas in the state, leaving these extensive peatlands with a wilderness-like character. This wilderness refuge is inhabited both by plants and animals that are very uncommon in the 48 contiguous states and frequently exhibit a low-level tolerance to man's activities, and by others that contribute significantly to the character of the northern ecosystems.

Because peat occurs in more than 60 of Minnesota's 87 counties, a complete and detailed inventory of local uses of these lands is beyond the scope of this study. Presented here, in lieu of such an inventory, is a review of peat resources and uses in several respresentative Minnesota counties:

Aitkin
Anoka
Freeborn
Koochiching
Lake of the Woods
Roseau
St. Louis

The data are taken from the computer tapes of the Conservation Needs Inventory and the Minnesota Land Management Information System data file.

The purpose of the Conservation Needs Inventory (CNI) was to systematically collect information pertaining to soil and water resources for each county in the United

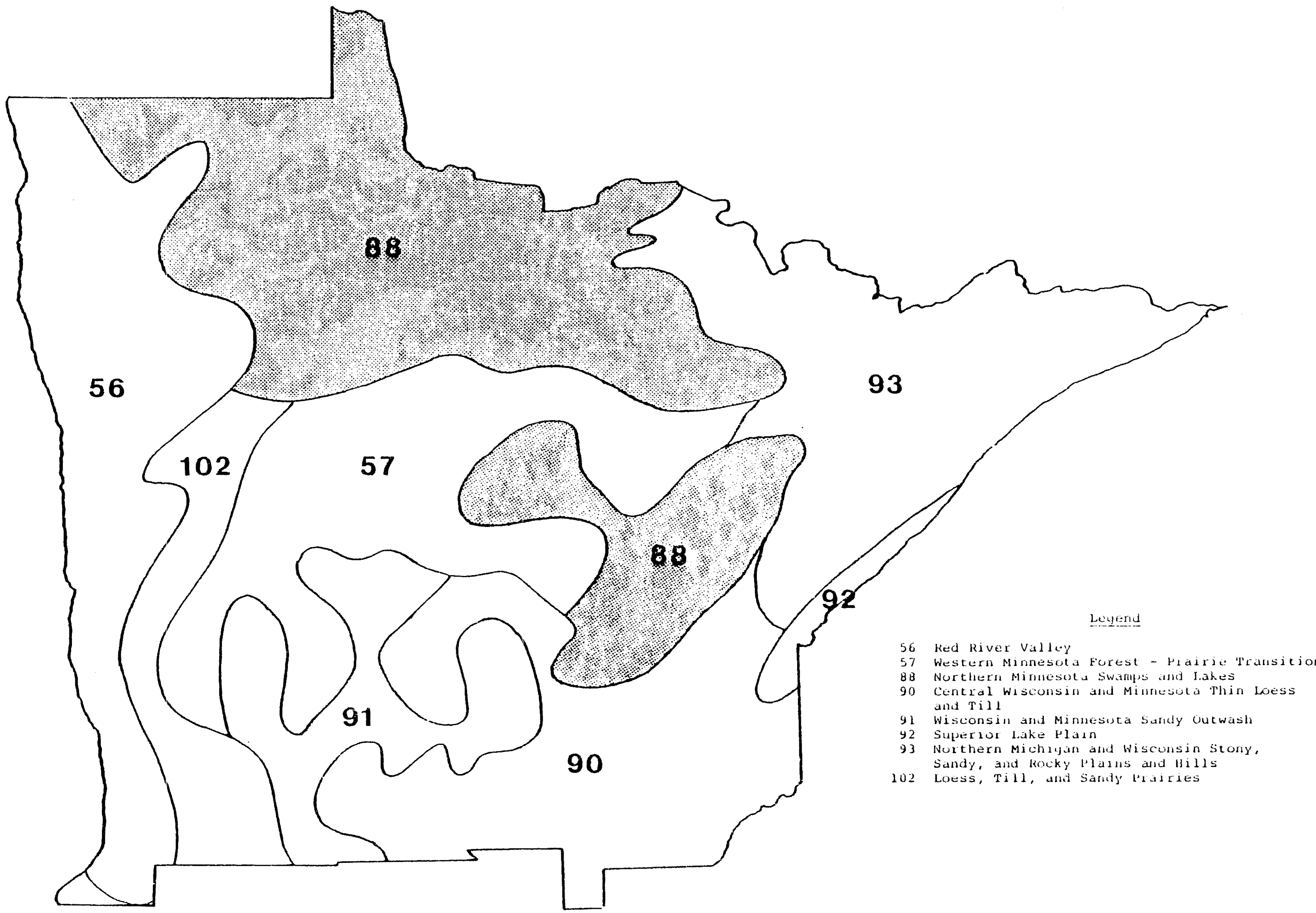


Figure 5.1. Land Resource Areas

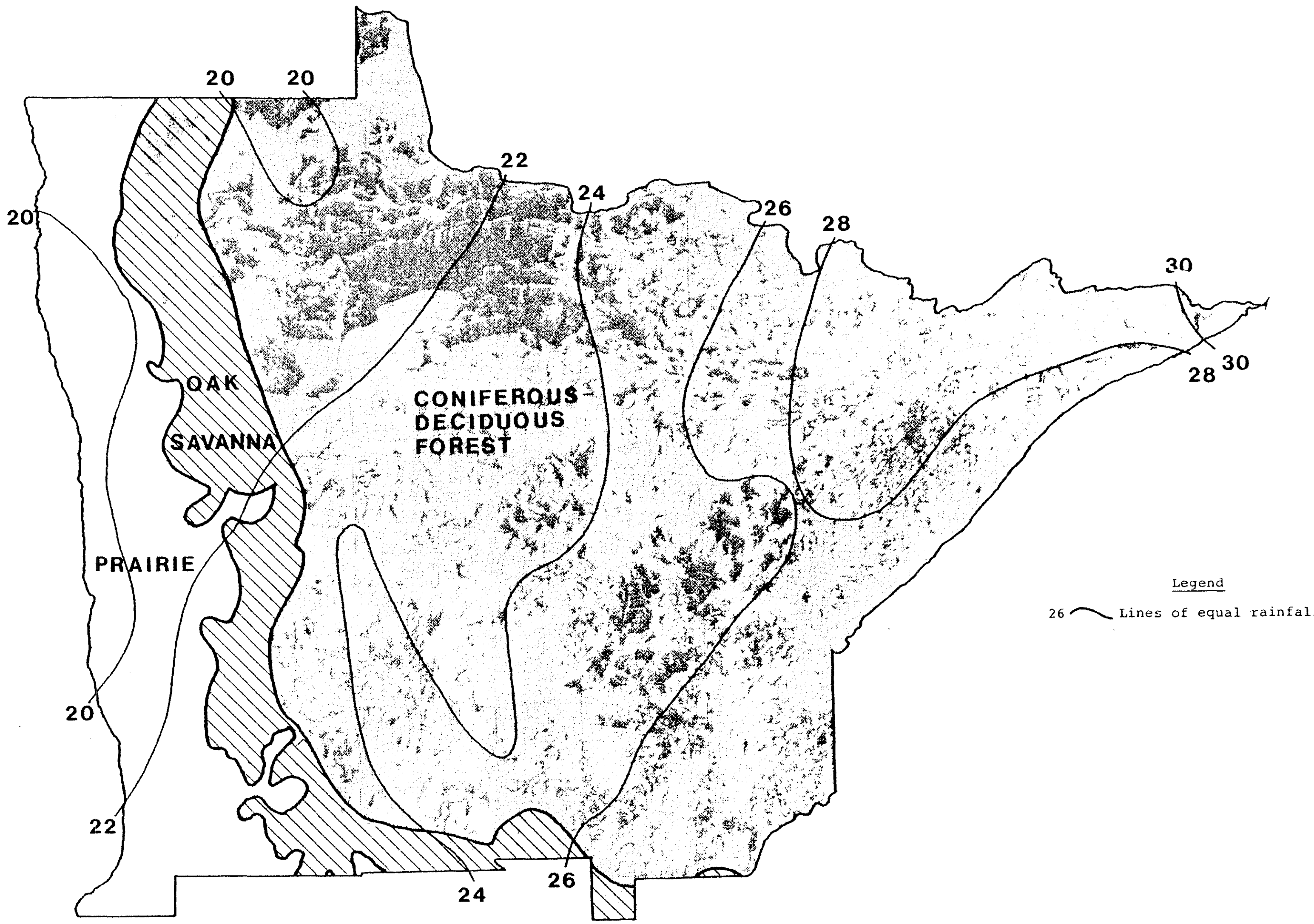


Figure 5.2. Vegetation and Climatic Gradients

States. To collect this information, the USDA developed a statistical sampling technique which was applied uniformly across the country. The soil mapping which provided the basis for the inventory of land use and treatment needs was carried out in 1959. The inventory itself was carried out twice -- in 1959 and in 1967.

In most counties in Minnesota a 2 percent sample was used, but the sample rate was lowered to 0.5 or 0.25 percent in some of the larger counties in the northern part of the state. Each sample site encompassed 1/4 section. The soil mapping units within each 1/4 section were then delineated by standard field procedures. To determine land use by soil type (and capability class), 36 "points" distributed at random within each sample site were examined and the land use and treatment needs for each point were recorded. These data were tabulated and extended to the entire county.

The CNI data presented below were taken from the 1959 and 1967 inventories. The acreages of organic soils (as well as other soil types) were determined in 1959. These acreages were also used as the basis for the 1967 inventory. The land use data presented below were taken from the 1967 inventory.

Because the CNI did not inventory urban areas, Federal non-croplands, or Indian lands under trusteeship, the tabulations for some soil types do not include all the acreage of that type within a county. Of the 51.2 million acres of land area in the state, approximately 45.8 million acres were inventoried in 1967.

The Minnesota Land Management Information System (MLMIS), a land use information base being developed by the State Planning Agency and the Center for Urban and Regional Affairs (CURA), was compiled in a different manner. To determine state-wide land use patterns, aerial photos of the entire state, flown in 1969, were interpreted and the land use for each 40-acre government lot was determined. This land use data was then sorted into nine land use categories and each 40-acre "data cell" was tagged by dominant land use. These data were then entered into MLMIS. By consulting MLMIS it is possible to determine the total acreage in each land use category for all counties in Minnesota. The *total acreage* for cropland, pasture, open, and forest use presented in the tables below have been taken from MLMIS. These data are prsented here to allow comparisons to be made between peatland use and total land use within each county.

LAND USE

According to the Conservation Needs Inventory, the peatlands in Minnesota are used principally for forest production, crop production, pasture/forage and "open space" in the proportions listed in Table 5.1.

Table 5.1. Peatland Uses in Minnesota. Based on Conservation Needs Inventory.

Peatland Use	Acres	Percent
Forest	4,321,000	60.4
Cropland	192,000	2.7
Pasture/Forage	759,000	10.7
Open (Native Grass and Marsh)	1,863,000	26.2

Although peatlands generally show only marginal potential for timber production due to excessive wetness, they nevertheless provide a valuable production area for black spruce, tamarack, and white cedar, all of which species are important in the pole timber and pulpwood industries. There is a considerable amount of commercial forest production on the natural peat bogs of northern Minnesota. Minnesota's peatlands exhibit a moderate potential for crop production, but this potential is frequently limited by excessive wetness, low natural fertility, fire and frost hazards, and (when tilled and dry) susceptibility to soil blowing. When properly drained and prepared, peatlands can be used for vegetable crop production (potatoes, carrots, radishes, onions, cabbags, cauliflower, celery, soybeans, small grains, cultured sod, bluegrass seed, and wild rice). Peatlands can also be used for pasture and forage, including the production of hay, reed-canary grass for seed, and pasture grasses. The remainder of the state's peatlands are mostly in open reed-sedge fens and marshes. The characteristics of organic soils are significantly different from those of mineral soils, and those characteristics determine, to a considerable extent, what uses are compatible with each soil type. Because peat has a very low bulk density, it can hold up to 20 times its dry weight in water (compared to 1/2 to 2/5 dry weight for mineral soils), and is susceptible to frost and flooding, it makes a very unstable foundation for buildings and roads. If not drained, peat also makes a very poor agricultural soil. But when properly drained and prepared, organic soils are porous, easy to cultivate, and are excellent for vegetable production, pasture and forage, sod, grass seed, and even for growing small grains. Shallow peat, properly banked and underlaid by clay, also makes excellent wild rice paddies. One persistent problem with organic soils is that when tilled they tend to dry out, drift in the wind, and become potential fire hazards. Peat soils are high in organic content and contain considerable nitrogen. But they frequently show low levels of phosphorus and potassium, and these nutrients, in addition to certain trace elements, must be applied to ensure maximum crop yields.

The properties of organic soils not only make them poor foundation for buildings and roads; their normally high water tables, high shrink-swell potential, and high organic content also severely restrict their use as septic tank filter fields, sewage lagoons, camp areas, picnic areas, playgrounds, and hiking trails (Table 5.2). A low diversity of wildlife habitat, and hence a low diversity of wildlife, is also typical of peatland areas. Representative organic soils are described in Table 5.3.

Table 5.2. Landuse Restrictions for Organic Soils. Based on U.S. Soil Conservation Service Soil Interpretations

	Slight	Moderate	Severe
Buildings With Basements	--	--	X
Buildings Without Basements	--	--	X
Local Roads and Streets	--	--	X
Shallow Excavations	--	--	X
Septic Tank Filter Fields	--	--	X
Sewage Lagoons	--	--	X
Sanitary Landfill	--	--	X
Camp Areas	--	--	X
Picnic Areas	--	--	X
Playgrounds	--	--	X
Hiking Paths/Trails	--	--	X

Table 5.3. Representative Organic Soil Series. Based on U.S. Soil Conservation Service Soil Interpretations.

Cathro Series

These series consist of very poorly drained soils formed in deposits of herbaceous organic material, 16 to 51 inches thick, over loamy mineral deposits. Cathro soils have black mucky peat surface layers, black mucky peat and muck subsurface layers over grayish brown, calcareous, sandy loam underlying material. Cathro soils are in depressional areas within till plains, moraines, lake plains and outwash plains. Slopes are generally less than 2 percent.

Seelyeville Series

These are very poorly drained, deep organic soils. They are on broad depressional areas. The reaction is slightly acid. The available water capacity is very high. The permeability is moderately rapid. The inherent fertility is low. They are usually ponded or wet. The water table is at 0 to 1 foot.

Millerville Series

These soils primarily consist of 16 to 51 inches of moderately decomposed organic soil materials over muck. Reaction in the organic soil materials ranges from medium acid to neutral and from slightly acid to mildly alkaline in the muck. These soils are very poorly drained, have moderate permeability, very high organic matter content, moderate fertility, high water supplying capacity, occur in depressions, potholes, small lake basins and drainageways. The areas vary in size and shape. The main associated soils are Urness, Markey, Cathro and Rifle.

Markey Series

These series consist of very poorly drained soils formed in deposits of organic material, 16 to 50 inches thick, over sand. Markey soils have a very dark brown much surface layer, very dark grayish brown and very dark brown much subsurface layers, underlain in gray sand. Markey soils are in bogs and other depressional areas within outwash plains, lake plains, till plains and moraines. The slope gradient is less than 2 percent.

Rifle Series

These are very poorly drained soils. They formed in primarily herbaceous organic deposits, more than 51 inches thick. Rifle soils have a yellowish brown peat surface layer and black peat subsurface layer, 4 inches in combined thickness, over layers of black and dark reddish brown mucky peat. Rifle soils are in bogs and depressional areas within lake plains, outwash plains, till plains and moraines. Slopes are less than 2 percent. Most of these soils are in brush or woodland.

Haug Series

These are very poorly drained depressional soils that have a thin peat surface layer over loamy underlying material. The permeability is moderate. The reaction of the surface is slightly acid to mildly alkaline. The underlying material has a reaction of mildly to moderately alkaline. The permeability is moderate. The organic matter content of the surface is very high. The inherent fertility is low. They are usually ponded. Water table is generally at 0 to 1 foot. The available water capacity is high.

Table 5.3. Representative Organic Soil Series. Based on U.S. Soil Conservation Service Soil Interpretations (Continued).

Deerwood Series

These series are very poorly drained soils which lie in bogs or depressions. It has a 2 to 16 inch layer of black herbaceous peat over a thin layer of black loamy sand. This is underlain by a layer of light grayish brown fine sand underlain by light grayish brown gravelly sand. The permeability is moderate to moderately rapid in the organic layer and rapid in the underlying sandy portion. It is mildly alkaline in reaction. The available water capacity is moderate. The inherent fertility is low. They are in small to large irregularly shaped areas in shallow depressions or potholes. They are closely associated with the Arveson, Potamo and Markey soils.

Waskish Series

These soils formed in brown and reddish brown slightly decomposed, extremely acid organic soil materials primarily derived from Sphagnum mosses. Organic soil materials extend to depths in excess of 63 inches and commonly to depths ranging from 10 to 20 feet. Content of woody fragments ranges from 0 to 20 percent in the control section, but contents in excess of 10 percent are only in the surface tier. Mean annual soil temperature ranges from 35 to 47^{o}F. These soils are never frozen within the control section about 2 months after the summer solstice. They are saturated with water during most of the year. Fibric material commonly is the dominant material in all parts of the control section and this material extends to depths of as much as 10 feet in some pedons. Layers of sapric or hemic material are in the control section in some pedons. The sapric material primarily is only in the surface tier and the maximum aggregate thickness of this material is less than 5 inches. Hemic material primarily is only in the lower part of the bottom tier, and its maximum aggregate thickness is less than 10 inches. The fibric material has hue of 5YR, 7.5YR, or 10 YR with redder hues being more common, value is 3 through 7 and chroma is 2 through 4. The higher values primarily are in the upper part of the surface tier. Pressed the color value is typically 1 through 3 units higher and ranges from 1 through 3 units higher than the broken face and chroma that is as much as 2 units higher than the broken face. The content of fiber typically is more than 90 percent, but ranges to as low as 75 percent in a few pedons. The content of fiber after rubbing ranges from 60 to 95 percent. The fibric material is massive or has weak platy structure. The fiber is mostly to entirely derived from sphagnum Mosses. Content of fiber derived from herbaceous and woody plants comprises less than 10 percent of the fiber volume. Content of mineral matter in the fibric material typically ranges from 2 to 5 percent. Reaction (in C.01 M $CaCl_2$) is 3.0 to 4.5. Hemic material commonly underlies the fibric material.

REPRESENTATIVE COUNTIES

The counties listed in Table 5.4 were selected as representative of Minnesota's peatland areas.

Table 5.4. Representative Peatland Counties. Based on Conservation Needs Inventory

County	Area Inventoried (Acres)	Peat Acres	Percent	Peat Depth >5'	Peat Depth <5'	Peatland Use Cropland	Peatland Use Pasture	Peatland Use Open	Peatland Use Forest
Aitkin	1,126,667	393,466	34.9	58.4	41.6	0.0	2.9	47.3	49.9
Anoka	195,057	72,882	37.4	73.9	26.1	3.6	6.5	88.7	1.2
Freeborn	430,775	48,423	11.2	47.0	53.0	68.1	14.7	16.8	0.4
Koochiching	1,926,050	1,154,399	60.0	90.1	9.9	0.0	0.3	0.0	99.7
Lake of the Woods	820,404	482,528	58.8	84.0	16.0	2.5	1.2	59.8	36.5
Roseau	1,049,783	245,356	23.4	79.0	21.0	2.3	1.1	43.9	52.7
St. Louis	3,049,931	801,644	26.3	67.9	32.1	0.0	0.2	15.6	84.2

AITKIN

Peat accounts for almost 35 percent of the land area of Aitkin County. Much of this peat occurs in broad contiguous areas within the shorelines of Glacial Lake Upham and scattered in pockets through surrounding moraine areas. Of the more than 393,000 acres of peat in the county, 58.4 percent (229,784 acres) is estimated to be deep peat over 5 feet in thickness, and 41.6 percent (163,681 acres) is estimated to be shallow peat less than 5 feet in thickness. The present use of these peatlands is split almost 50-50 between forest and "open." Only 2.9 percent of these peatlands (11,410 acres) is in pasture and forage, and none is used for crop production. A significant portion of the peatlands in Aitkin County have been included within Solana State Forest, Wealthwood State Forest, Savana State Forest, Hill River State Forest, Moose-Willow Wildlife Management Area, and Rice Lake National Wildlife Refuge (Figure 5.3).

Aitkin County	Percent Cropland	Percent Pasture	Percent Open	Percent Forest
Peat Area (CNI)	0.0	2.9	47.3	49.3
Total Land Area (MLMIS)	5.7	--	21.8	71.3

ANOKA

Anoka County, on the northern edge of the Twin Cities Metropolitan Area, has about 73,000 acres of peat, almost all of which lies within the Anoka Sand Plain, an outwash area formed during the retreat of the Grantsburg sublobe of the Wisconsin Ice Sheet. It is estimated that 73.9 percent (53,860 acres) of this peatland is deep peat over 5 feet in thickness and that 26.1 percent (19,022 acres) is shallow peat less than 5 feet deep. A large portion of this peatland, roughly 89 percent, is presently in "open" use, mostly reserved within the Carlos Avery Wildlife area. A small but economically significant portion of the peat in the country is in pasture and forage (4737 acres) and vegetable crop production (2624 acres). Truck farming and the production of Kentucky Bluegrass sod, both of which operations have established themselves in peat areas in the county, contribute significantly to Anoka's agricultural production and

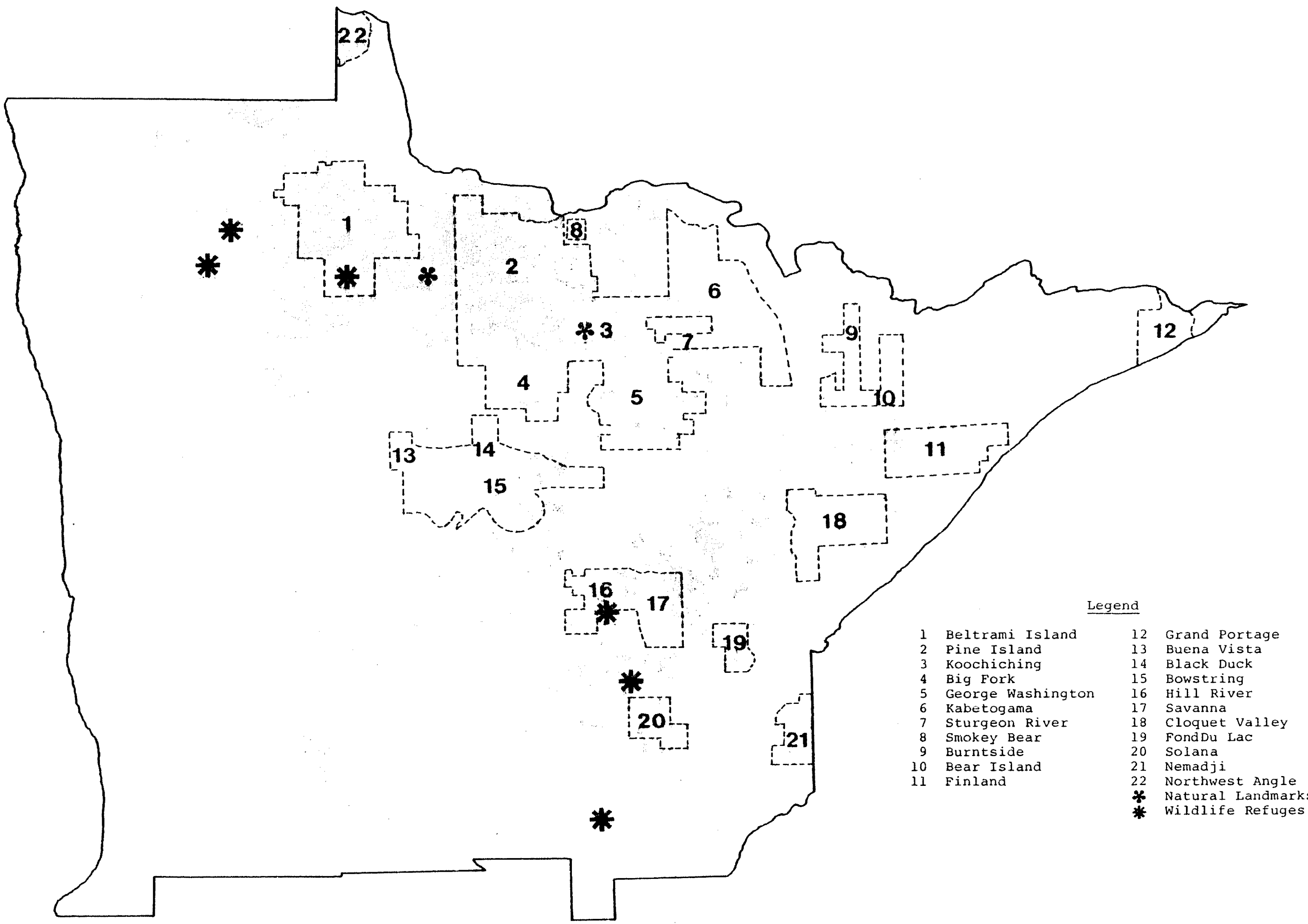


Figure 5.3. State Forest Peatlands

provide fresh vegetables and sod to the nearby Twin Cities' market. More recent figures actually show that almost 10,000 acres of peatland in Anoka County are now in vegetable crop (2750 acres) and sod (7000 acres) production. The truck farms produce mainly radishes, carrots, lettuce, onions, and potatoes, although trials have been carried out with the other vegetables, blueberries, and small grains.

Anoka County	Percent Cropland	Percent Pasture	Percent Open	Percent Forest
Peat Area (CNI)	3.6	6.5	88.7	1.2
Total Land Area (MLMIS)	28.4	--	40.0	24.6

FREEBORN

A little more than 11 percent of the land area in Freeborn County is peat (roughly 48,500 acres), almost all of which occurs in the Owatonna moraine that stretches north from Freeborn to Hennepin County. The moraine "pot-hole" bogs in Freeborn County, unlike the larger and more contiguous bogs of the northern glacial lake plains, are relatively isolated from one another and tend to be limited in area to between 400 and 800 acres. It is estimated that deep and shallow peat are split about 50-50. Of the more than 48,500 acres of peat in the county, only 0.4 percent (194 acres) is under forest use. Somewhat more extensive areas occur as "open" peatlands (8135 acres). The majority of the peatlands in the county, however, are in pasture/forage (7118 acres) and crop production (32,976 acres). The Hollandale peatlands in the north-central part of the county constitute one of the major truck farming areas in the state. None of the peatland in Freeborn County is reserved within a state forest or wildlife management area.

Freeborn County	Percent Cropland	Percent Pasture	Percent Open	Percent Forest
Peat Area (CNI)	68.1	14.7	16.8	0.4
Total Land Area (MLMIS)	80.2	--	16.2	1.0

KOOCHICHING

Koochiching County, with over 1,154,000 acres of peatlands, has more peat than any other county in Minnesota. Almost all of these peat areas lie within the Beltrami arm of the Agassiz Lacustrine Plain, which stretches from the eastern edge of the Red River Valley almost to the Mesabi Range. The Agassiz Lacustrine Plain, in particular that peat which extends through Lake of the Woods, Koochiching, and St. Louis counties, contains what are probably the largest contiguous peat bogs in the United States, exclusive of Alaska, many exceeding 200,000 acres. More than 90 percent of the peat in Koochiching County is estimated to be deep peat over 5 feet in thickness and, as the data show, almost all of the peatlands are in forest use, 9917 percent (1,151,434 acres). An almost insignificant amount (0.3 percent) is used for pasture and forage, and none is classed as either cropland or "open." The most common species of trees found on these peatlands include black spruce (Picea mariana), tamarack (Larix lariciana) and northern white cedar (Thuja occidentalis). All of these species are commercially harvested for pulpwood and poles, and the black spruce is frequently harvested for Christmas trees. With the exception of the peatlands east of State Highway 65, almost all of the peat in Koochiching County lies within Pine Island State Forest, Koochiching State Forest, Smokey Bear State Forest, and the Nett Lake Indian Reservation.

Koochiching County	Percent Cropland	Percent Pasture	Percent Open	Percent Forest
Peat Area (CNI)	0.0	0.3	0.0	99.7
Total Land Area (MLMIS)	0.9	--	11.7	86.7

LAKE OF THE WOODS

The peatlands of Lake of the Woods County also lie entirely within the Beltrami arm of the Agassiz Lacustrine Plain. But here the frequency of open fen bogs is higher than in Koochiching. It is estimated that 36.5 percent of the peat in the county (176,113 acres) is forested, while 59.8 percent (288,551 acres) is open fen. Most of the forested peatland in Lake of the Woods is estimated to be incapable of yielding commercial wood products. A substantial portion of the peatland in the county lies within Beltrami Island State Forest, Northwest Angle State Forest, Red Lake Wildlife Management Area, and Red Lake Indian Reservation.

Lake of the Woods County	Percent Cropland	Percent Pasture	Percent Open	Percent Forest
Peat Area (CNI)	2.5	1.2	59.8	36.5
Total Land Area (MLMIS)	11.0	--	29.2	58.0

ROSEAU

Roseau County has more than 245,000 acres of peatland, 79 percent of which is estimated to be deep peat more than 5 feet in thickness, and 21 percent shallow peat less than 5 feet in depth. These peatlands are predominantly in forest (129,303 acres) and "open" (107,711 acres) use, the latter being mostly grass-sedge areas with dogwood and alder growth in some places. The small amount of peatland in forage and crop production (8342 acres total) are used for growing both Kentucky bluegrass and timothy as seed crops. About one-quarter of the approximately two dozen seed production fields in Roseau County are established on peat soils which developed from reed-sedge grass vegetation. A significant portion of the peatlands in Roseau County are within Beltrami Island State Forest and the Roseau River Wildlife Area.

Roseau County	Percent Cropland	Percent Pasture	Percent Open	Percent Forest
Peat Area (CNI)	2.3	1.1	43.9	52.7
Total Land Area (MLMIS)	43.1	--	27.8	28.2

ST. LOUIS

St. Louis County has over 810,000 acres of peatland--almost as much as Koochiching--although peat accounts for only about 27 percent of the county's land area. Most of these peatlands occur in the extreme eastern corner of the Agassiz Lacustrine Plain, Upham Lacustrine Plain, and surrounding moraine and drumlin areas. It is estimated that about 68 percent of this peat is over 5 feet in thickness and that in some areas the peat might reach a depth of 30 to 50 feet. Shallow peat accounts for the remaining 32 percent. Almost none of the peatlands in St. Louis County is used for forage and crop production (1621 acres total), while 15.6 percent (126,460 acres) is "open" peatland and 84.2 percent (682,562 acres) is in forest use, both commercial and noncommercial. A considerable portion of the peatland in St. Louis County is included within Cloquet State Forest, Kabetogama State Forest, Sturgeon River State Forest, Whiteface River State Forest, and Superior National Forest. Some of the extensive peatlands of the Upham Lacustrine Plain near Floodwood, Meadowlands, and Toivola, are privately owned and used for the production of horticultural peat.

St. Louis County	Percent Cropland	Percent Pasture	Percent Open	Percent Forest
Peat Area	0.0	0.2	15.6	84.2
Total Land Area (MLMIS)	1.9	--	5.7	88.8

LAND USE PATTERN

A few observations can be made about the pattern of peatland use in Minnesota by comparing peatland use to total land use. As the data from the CNI and MLMIS show, the peatlands in Freeborn County, which tend to be scattered "pot-hole" bogs, have been largely incorporated into the surrounding croplands. This is the typical pattern of peatland use in the southern part of the state where the native bogs were small, accessible, and easily drained. Also typical of the peatlands in the southern portion of the state is the predominance of open fen bogs over forested bogs. The data from Anoka County show a similar predominance of open fen peatlands. But in Anoka, where there are fairly extensive areas of contiguous peat, fewer bogs have been brought under cultivation. In Aitkin County the use of peatland for agricultural crops and pasture drops to almost zero. This pattern is typical of the more extensive northern peatlands where early attempts at drainage and cultivation failed entirely. Another shift in the typical land use pattern also takes place from south to north: while most of the southern bogs are open fens, most of the northern peat bogs are forested, the most conspicuous exception to the pattern in the northern part of the state being the extensive open "patterned" bogs in Lake of the Woods and western Koochiching Counties. Only 1.0 percent of the peatland in Freeborn County is forested; 24.6 percent of the peatland in Anoka is forested; and 49.3 percent of the peatland in Aitkin is forested. In St. Louis and Koochiching Counties, forest use of peatland rises to 84 percent and 99 percent, respectively.

INVENTORY AND MAPPING

MAPPING JURISDICTION

The peatlands that cover approximately 7.2 million acres of Minnesota's land area have, over the past seven decades, fallen within the purview of several mapping and inventory efforts. With only a few notable exceptions, however, these efforts have not had a peatland inventory as their principal objective. As a consequence of this fact, Minnesota's peatlands have been mapped, as it were, incidentally and in a somewhat *ad hoc* manner. Moreover, peatland areas have generally been given low priority (for good reasons) within the framework of such established mapping programs as those carried out by the USGS and Soil Conservation Service. There are, therefore, many "holes" in the various maps and inventories which might otherwise have provided policy makers with detailed information concerning the topography, soil stratification, surficial geology, hydrology, and vegetation of Minnesota's peatlands.

These two facts must be pointed out here: (1) a detailed inventory of Minnesota's peatlands *does not now exist;* and (2) despite the absence of such an inventory, valuable information has been collected and mapped within the framework of several mapping and inventory programs which, if compiled and collected, could contribute significantly to the assessment of the state's peat resources and aid in directing further inventories.

The agencies which have, or have had, jurisdiction over mapping in peatland areas include the following:

Soil Science Department, University of Minnesota
Iron Range Resources and Rehabilitation Commission
U.S. Geological Survey
Minnesota Geological Survey
Soil Conservation Service
U.S. Forest Service
State Planning Agency (MLMIS)
Department of Natural Resources
Minnesota Highway Department

The inventories carried out by these agencies have had differing objectives, have not been done in commensurate scales, and exist in various stages of completeness; but each inventory contributes a valuable piece to the whole picture.

E.K. SOPER'S INVENTORY

The history of peat mapping actually begins in 1919 with the publication of E. K. Soper's study entitled "The Peat Deposits of Minnesota." The publication was presented as a survey of "every county in Minnesota" and represented the fruits of two summers' labor (1914 and 1915) by Soper and one field assistant. The project was an enormous and ambitious undertaking, and Soper soon realized that "detailed testing of the bogs could be done only on certain selected areas" and that he would have to be satisfied with "a report of a more general nature" than the one he originally envisioned. His work nevertheless stands as the first and most comprehensive survey of Minnesota's peat deposits (Soper, 1919).

Traveling the length and breadth of the state, mostly by rail, Soper concentrated on "localities" which in his eyes had potential for commercial fuel peat development. This meant, in terms of his final report, that one county was sometimes represented by the one or two localities within that county which had such commercial fuel potential. This also meant that Soper tended to ignore areas which exhibited a potential for other uses, especially if the same area also showed a potential for fuel peat development. It is not uncommon to find, therefore, that Soper's survey of some of the smaller counties with extensive peat deposits consists of a description of as few as two localities, as is the case with both Anoka and Carlton Counties in his study. Soper intensified his survey in such counties as Beltrami, which at that time included what is now Lake of the Woods County (25 localities) and Koochiching (20 localities), but considering the extent of peat deposits in these counties, even such intensified efforts encompassed only an extremely small percentage of the total. What we learn from Soper in the end is, for that time and criteria, which counties in the state possess extensive peat deposits having commercial fuel potential, which counties possess relatively modest peat deposits having commercial fuel potential and/or agricultural potential, and which counties possess small, isolated peat deposits having little or no commercial value (Figure 5.4).

It should be noted with particular emphasis that, in judging the potential of a peat deposit, Soper made no apparent attempt to assess the environmental impact of such development. The principal problem, as far as Soper was concerned, was whether or not a peat deposit was extensive enough, and therefore valuable enough to justify commercial development. It was this rationale which to a considerable extent shaped Soper's survey. In 1922 Soper published, with C. C. Osborn, a survey of peat deposits in the United States entitled "The Occurrence and Uses of Peat in the United States." In that publication Soper estimated that there was 5,217,100 acres of peat deposits in Minnesota which were capable of yielding 6.8 billion short tons of air-dried peat (Soper and Osborn, 1922).

INVENTORIES AND MAPPING

Soper's survey still stands as the only state-wide survey of Minnesota's peat resources, although since then some peat deposits surveyed by him have been significantly modified by cultivation and extraction and perhaps by lumbering and drainage ditches. Recently, other mapping programs have slowly developed a more precise description of at least some of the peat deposits in the state, and of some of the geological and land use variables which have a bearing on peat development. The surveys and mapping programs listed below will be reviewed in the following discussion:

Conservation Needs Inventory
County Soil Surveys and General Soil Maps
Cooperative Soil Survey
Soil Atlas
IRR & R Surveys
Geological Surveys
Minnesota Land Management Information System

CONSERVATION NEEDS INVENTORY

The Conservation Needs Inventory (CNI) was prepared by the Soil Conservation Service in 1959 and 1967. This inventory, which was compiled for each county in the state, was intended to provide a basic inventory of the state's soil resources and indicate, statistically, the type and amount of conservation treatment required to insure proper management of that resource. But the most recent inventory, published in 1971 by the Minnesota Conservation Needs Committee, classified all non-Federal, non-urban land by "capability class," not by soil series or soil association. Thus, from this publication alone, it is impossible to decipher references to organic (peat) soils. In 1973, however, the computer tapes of the inventory, which also identified the data by soil series, were reprogrammed and an inventory of non-Federal, non-urban land by soil series was produced. This modified inventory includes an accounting of organic soil series, called "histosols" in this tabulation, by county, and further breaks down this general class into 10 subclasses (not exactly the same as soil series, however).

A careful examination and compilation of these histosols, both state-wide and county-by-county, should therefore provide a more up-to-date description of the state's peatlands, although that description will lack the precision of geographical delineation. The 1959 Minnesota Conservation Needs Inventory estimated that there are approximately 7.2 million acres of organic soil in the state (Table 5.5).

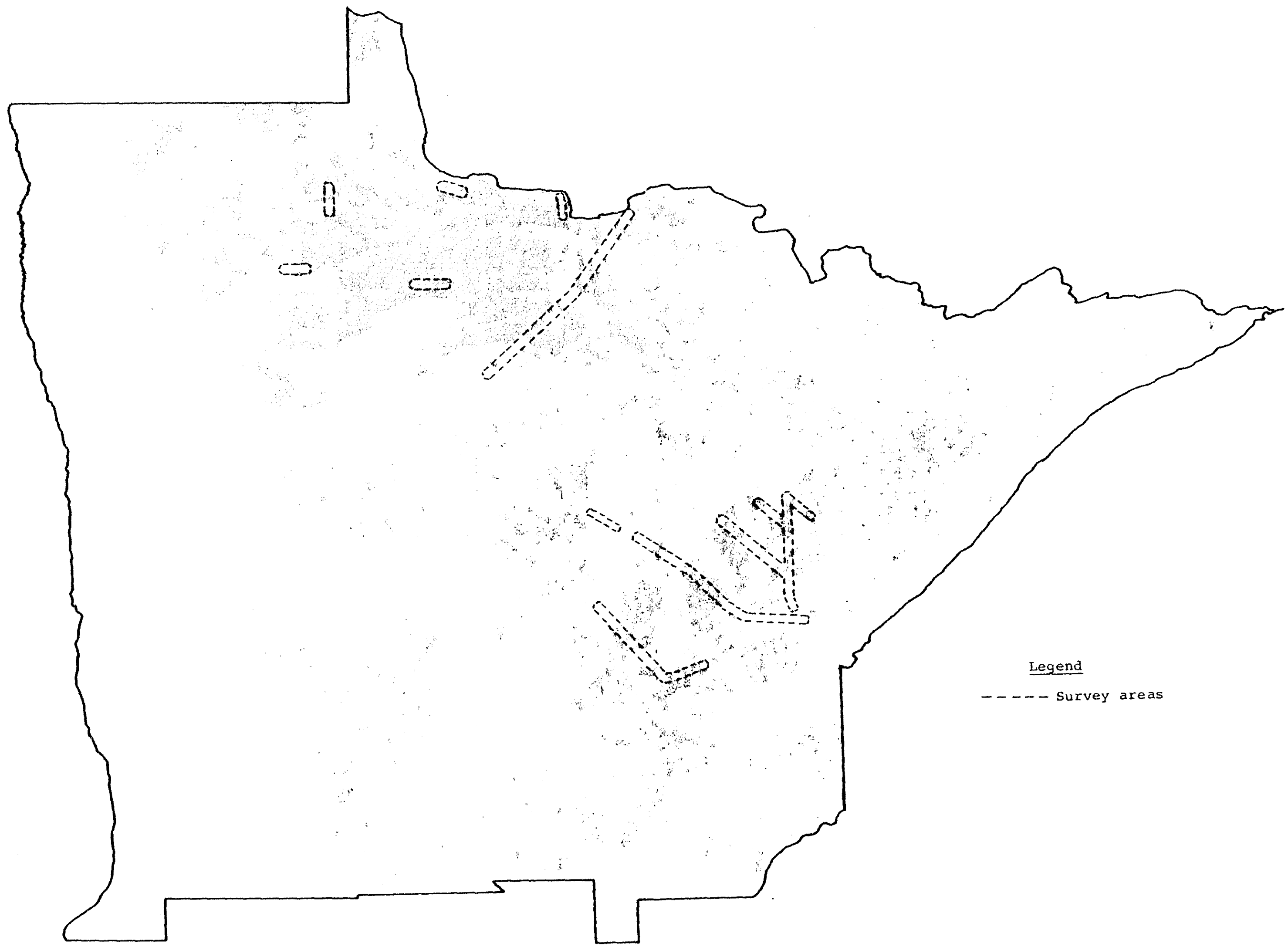


Figure 5.4. E. K. Soper's Survey Sites (Selected)

Table 5.5 Minnesota Peatland Uses (Selected Counties)

Counties	Area Inventoried (Acres)	* Peat Acres	Per-cent Peat	Peat Depth >5'	Peat Depth <5'	** Peatland Use Cropland	Pasture	Forest	Open
Aitkin	1,126,667	393,466	34.9	58.4	41.6	0.0	2.9	49.8	47.3
Anoka	195,057	72,882	37.4	73.9	26.1	3.6	6.5	1.2	88.7
Becker	753,518	113,542	15.1	84.4	15.6	0.7	13.5	26.0	59.8
Beltrami	1,513,467	785,661	34.9	84.8	15.2	0.0	3.0	76.6	20.4
Carlton	529,663	97,700	18.4	74.5	25.5	0.0	4.6	86.6	8.8
Cass	992,398	199,693	20.1	78.7	21.3	0.0	4.8	30.9	64.3
Chisago	238,501	28,183	11.8	82.3	17.7	1.4	26.5	25.2	46.9
Clearwater	622,554	124,338	20.0	75.6	24.4	0.7	22.0	30.0	47.3
Crow Wing	614,061	111,931	18.2	61.4	38.6	0.0	16.3	31.5	52.2
Freeborn	430,775	48,423	11.2	47.0	53.0	68.1	14.7	0.4	16.8
Hennepin	177,040	28,244	15.9	91.2	8.8	13.8	14.4	1.2	70.6
Isanti	272,126	57,847	37.4	97.8	2.2	1.9	23.6	10.9	63.6
Itasca	1,352,464	356,588	26.4	60.5	39.5	0.0	1.0	98.3	0.7
Kanabec	325,404	41,193	12.6	65.1	34.9	0.5	50.3	19.6	29.6
Koochiching	1,926,050	1,154,899	60.0	90.1	9.9	0.0	0.3	99.7	0.0
Lake	622,421	95,987	15.4	90.6	9.4	0.0	0.0	6.2	93.8
Lake of the Woods	820,404	482,528	58.8	84.0	16.0	2.5	1.2	36.5	59.8
Le Sueur	269,533	37,965	14.1	71.3	28.7	26.9	52.6	0.0	20.5
Marshall	1,051,640	147,967	14.1	48.0	52.0	2.3	24.3	46.9	26.5
Mille Lacs	342,289	59,760	17.4	66.3	33.7	0.0	21.8	10.5	67.7
Morrison	675,121	94,135	13.9	29.8	70.2	2.5	45.5	7.1	44.9
Otter Tail	1,206,335	191,576	15.9	95.2	4.8	0.9	28.4	18.3	52.4
Pine	867,699	174,446	20.2	80.8	19.2	0.5	12.7	60.0	26.8
Rice	298,116	12,279	4.1	81.5	18.5	33.3	37.0	0.0	29.7
Roseau	1,049,783	245,356	23.4	79.0	21.0	2.3	1.1	52.7	43.9
St. Louis	3,049,931	810,644	26.6	67.9	32.1	0.0	0.2	84.2	15.6
Sherburne	242,785	36,722	15.1	79.4	20.6	1.7	40.6	16.0	41.7
Sterns	823,739	100,947	12.2	78.4	21.6	5.6	38.5	7.4	48.5
Todd	583,438	72,875	12.5	62.9	37.1	0.1	27.5	4.8	67.1
Wadena	329,794	74,706	22.6	46.5	53.5	0.6	28.8	14.1	56.5
Wright	411,777	40,540	9.8	76.1	23.9	6.0	28.8	1.6	63.6
State of Minnesota	45,820,324	7,155,078	15.6	75.8	23.2	2.7	10.7	60.4	26.2

*Based on Conservation Needs Inventory (1959)
**Based on Conservation Needs Inventory (1967)

The Conservation Needs Inventory does not describe where a particular histosol is located within a county; it only estimates that a certain number of acres of that histosol will be found somewhere therein. For precise location, therefore, it is necessary to turn to maps, mostly soil maps, which are available in one form or another for most but not all of the counties in the state. This county soil mapping began in the early 1900's, and it has a complicated history which will not be detailed here. But in general the situation is this: The first soil surveys, done for individual counties and sometimes groups of counties, as was the case with the Red River Valley Area Reconnaissance Survey (1939) which included eight counties, were intermediate-scale (1 inch = 2 miles) maps showing sometimes individual soil series and sometimes undifferentiated soil groups. The latter was usually the case with organic soils, which were almost always grouped under the term "peat." Peat tends to appear on these maps, therefore, as one class, the only exception being the two-class scheme (deep peat/shallow peat) used on the Lake of the Woods Reconnaissance Soil Survey (1926).

The virtue of these early soil surveys, however, lies not so much in their answer to "how much" as in their answer to "where." They at least provide a fairly accurate delineation, at that time, of peat deposits within the counties surveyed. But it should also be noted that many counties, some with the state's most extensive peat deposits, were never mapped in this manner. No published county surveys are available for Aitkin, Beltrami, Carlton, Clearwater, Itasca, Koochiching, St. Louis, Anoka, and Freeborn Counties. And some of these early county soil surveys, such as the Lake of the Woods Survey, are not now considered adequate for multi-purpose use. The result is that these early soil surveys include only a very small percentage of the state's peat deposits and, even then, fail to describe and differentiate those deposits adequately.

GENERAL SOILS MAPS

General Soil Maps have also become available for several counties in the state, some of which have important peat deposits, like Anoka and Clearwater Counties. These maps, produced by the Soil Conservation Service, map soils by "association," each association being composed of two or more major soil series and perhaps several minor series. These maps, usually published on a scale of 1:250,000, are less precise than even the early soil surveys in locating peat deposits, especially if the deposits appear as "islands" in the midst of a major non-peat association. On these maps only major peat areas will be delineated and minor peat areas will be masked by the non-peat association in which they occur. Much of the peat acreage that is in vegetable and sod production in Anoka County, for example, is not delineated as peat soil on the Anoka General Soil Map. These maps appear to have a limited value for inventory purposes.

One of the most recent General Soil Maps, and a somewhat different type, is the Arrowhead General Soil Map prepared by the Soil Conservation Service in cooperation with the Forest Service and the Agricultural Experiment Station, University of Minnesota. The virtue of this map, which consists of aerial photos overlaid with soil information, is that it delineates three types of organic soil--fibric, and two classes of fibric-hemic--and does so for some of the most extensive peat deposits in the state, including the vast peat bogs of the Agassiz, Upham, and Aitkin Lacustrine Plains. The map remains, however, a "general" map whose value lies more in its use as a preliminary planning tool than in its use as an inventory of peat deposits in the Arrowhead Region. The map also possesses some additional shortcomings. It is large (about 20 3' x 3' sheets), expensive to reproduce in its present form, does not have a cultural base, and does not clearly show hydrology. The map promises to be very useful as a preliminary planning tool but it does not have much more precision than other general soil maps.

Another general soil map, that is, a map whose scale is not large enough to allow for the mapping of individual soil series, is the Soil Atlas prepared by the Soil Science Department of the University of Minnesota in cooperation with the Soil Conservation Service and the Minnesota Geological Survey. It, too, is meant to be used as a tool in regional planning. The mapping is done at an intermediate scale (1:250,000) on sheets which use as a base the USGS 1 x 2's which cover the state in eleven sheets. Three of these Soil Atlas sheets have been published (St. Paul, Brainerd, Hibbing), along with a special Metropolitan Area sheet, and the cartography has been, or is being, completed on the Stillwater, St. Cloud, and Duluth sheets. Several of these sheets include important peat areas. The St. Paul sheet includes the Hollandale agricultural peat area in Freenborn County; the Metro sheet includes the Anoka peatlands; the Brainerd sheet includes the peat deposits of the Todd, Cass, and Wadena drumlin areas; and the Hibbing sheet includes the extensive peat deposits of the Upham Lacustrine Plain and of the southeastern portion of the Agassiz Lacustrine Plain. All sheets of the Soil Atlas also show scattered peat deposits of more than approximately 400 acres in size, usually located in outwash plains, moraines, and drumlin areas.

The Soil Atlas, as a regional planning tool, possesses some advantages over the Arrowhead General Soil Map. The published sheets are printed in multicolor on a base map which shows cultural information, political boundaries, and hydrology. The individual sheets are of a manageable size and are relatively inexpensive. Also drawn on the map are the boundaries of major "geomorphic areas," which for most of the state consist of areas of similar surficial deposits left behind by glacial activity. The close relationship between these deposits and the soils which developed from then, and especially the close relationship between the type of geomorphic area (lake basin, moraine, outwash) and the type of peat deposits found therein, make the Soil Atlas a particularly valuable tool in planning peat development.

But the Soil Atlas also shows some of the shortcomings of other general soil maps. Like the early county surveys, the Soil Atlas sheets published so far, and the next three sheets to be published, group all organic soils in one class, as "peat." In this respect, at least, the Soil Atlas is less precise than the Arrowhead General Soil Map. An attempt is being made to reclassify organic soils on the Roseau, International Falls, and (possibly) Two Harbors sheets into five sub-classes. If this reclassification is accomplished, it will greatly enhance the value of those yet-to-be-published sheets. The field sheets of the Soil Atlas have recently been used to produce a peat distribution map for the entire state. That map, published by the Agricultural Experimentation Station at the University of Minnesota, represents the first time the state's peatlands have been delineated on one map.

A final point should be made concerning all general soil maps and surveys which lump peat into one class: although they locate rather precisely "where" the peat is, they say very little about "how much" there is (depth), and nothing about stratification, substratum topography, and chemical analysis. Without this data no one can know the extent, value, and ecological importance of the state's peat resources.

COOPERATIVE SOIL SURVEY

The Cooperative Soil Survey, prepared by the Soil Conservation Service in cooperation with the Agricultural Experiment Station, University of Minnesota, represents the most detailed soil mapping (1:20,000) currently underway. The mapping unit in these county-by-county surveys is the soil series, which means that each soil with a unique "profile" is named and mapped as a separate soil unit. In a Cooperative Soil Survey, therefore, peat will be differentiated into several soil series, the number of series depending on the variety of organic soil profiles occurring in the county. The Douglas County Cooperative Survey, for example, includes six organic soil series and one "variant" in each of two of these series. These detailed soil surveys also include crop productivity estimates, engineering properties analyses, and recreational potential estimates for each soil series. The level of detail exhibited in these maps, coupled with this additional information, makes them very valuable for inventory purposes.

Detailed soil surveys such as these are now available for about twenty agricultural and urban counties in the state, and field mapping is complete, or in progress, in a dozen and a half more. Very little detailed mapping of this type has been done, however, in the extensive peat areas of the northern part of the state (Figure 5.5). As of June 30, 1974, detailed mapping had been completed for only 1 percent of Beltrami County, 1 percent of Clearwater County, 6 percent of Koochiching County, 1 percent of Lake of the Woods County, and 5 percent of St. Louis County. And most, if not all, of these scattered surveys have been done in non-peat areas. Almost all the detailed mapping in Koochiching County, for example, has been done in urban areas, along roadways, and in mineral soil "islands" within the vast expanses of peat.

These detailed soil surveys are especially appropriate for field management, site selection, and local drainage planning since the maps have a resolution of about 2-1/2 acres and accurately delineate every local soil peculiarities. But this accuracy comes at a fairly high price. It is estimated that the cost of mapping the approximately 32 million acres of not-yet-surveyed land in Minnesota by 1990 will run to about 24 million dollars in Federal, state, and local money. While this project extends far beyond the scope of the peat inventory, such detailed mapping will be vital to the proper management of those peat areas which will actually be developed, and will undoubtedly be needed where any construction of drainage systems, roadbeds, and building sites is contemplated.

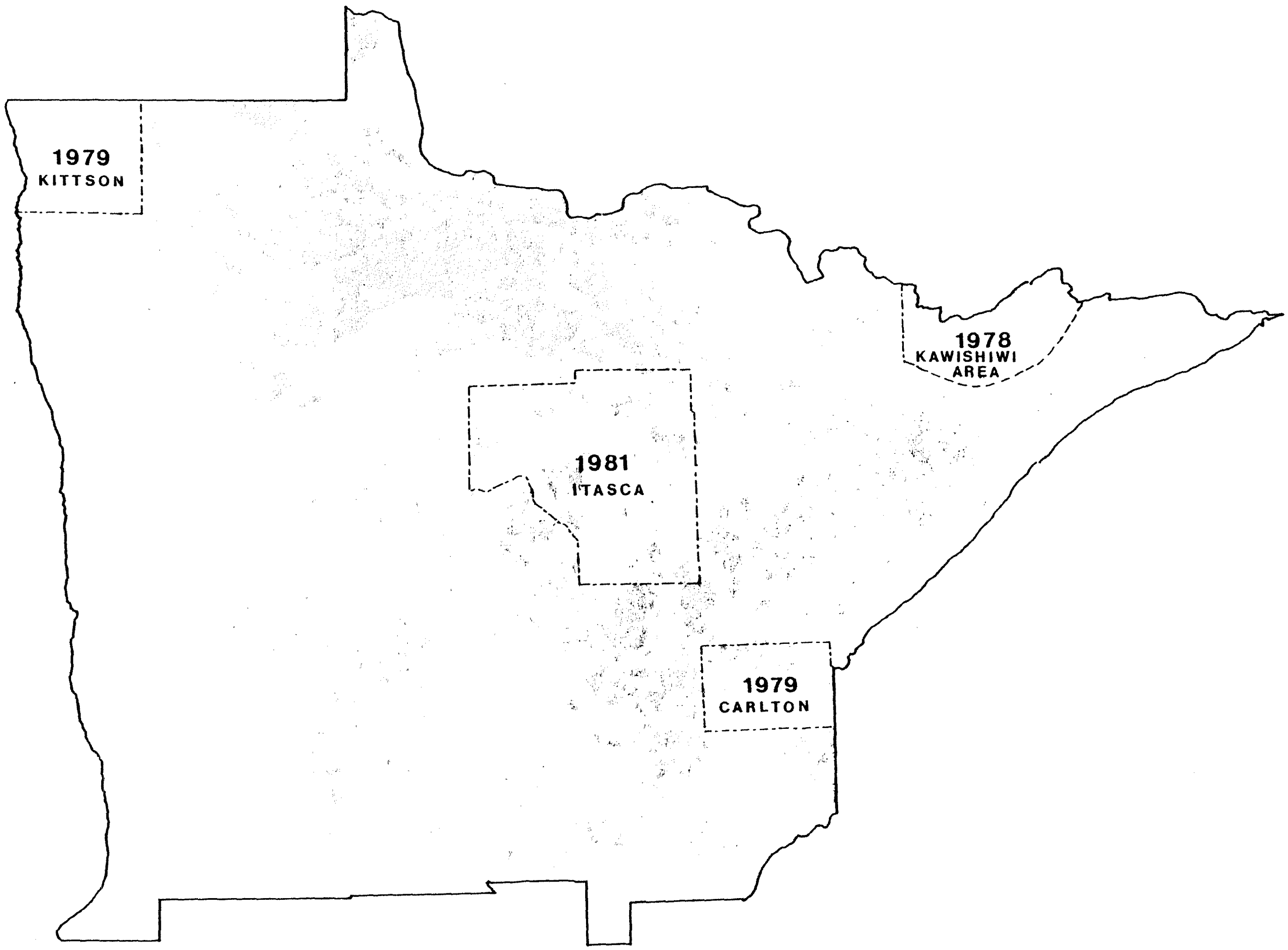


Figure 5.5. Cooperative Soil Survey (Anticipated Publication Dates)

IRR & R SURVEYS

Between 1960 and 1970, the Department of Iron Range Resources and Rehabilitation in cooperation with the Soil Science Department, University of Minnesota, maintained a peat inventory program which, during that decade, mapped and inventoried more than 50 individual peat bogs in the northern part of the state. This mapping and inventory program, unlike the soil mapping programs described above, focused solely on peat, which made it the first peat survey in the state since Soper's survey of 1914-1915. And in some ways the IRR & R survey bears a resemblance to that earlier inventory. It is a wide-ranging inventory which includes bogs in St. Louis, Koochiching, Beltrami, Lake of the Woods, Aitkin, Itasca, and Carlton Counties. The purpose of this peat mapping, as stated in the 1962-1964 Biennial Report of the IRR & R, was to ultimately provide "a complete inventory of Minnesota's peat deposits." But to date only four of the field surveys have actually been published--West Central Lakes Bog, St. Louis County (1969); Cook Bog, St. Louis County (1965); Red Lake Bog, Beltrami County (1966); and Fens Bog Area, St. Louis County (1970). The remaining surveys are in the possession of the IRR & R (Table 5.6). These surveys have been made available to various state agencies.

The published inventories include a map of each bog surveyed and a brief description of the area's geology, hydrology, vegetation, wildlife, climate, and land ownership. Also included are cross sections of the bog and a record of each core sample's soil horizons, pH, ash content, and water holding capacity. The purpose of these surveys was primarily to locate and evaluate potential horticultural peat harvesting areas (both Sphagnum and reed/sedge), and consequently the selection of survey sites was shaped by that purpose.

GEOLOGICAL SURVEYS

The close relationship which exists between the type of surficial deposit left behind by glacial activity and the type of peat deposit associated with such geomorphic areas has already been mentioned in the discussion of the Soil Atlas. The earliest surficial map of the state appeared in 1932 in a USGS Professional Paper (No. 161) written by Frank Leverett entitled "Quaternary Geology of Minnesota and Parts of Adjacent States." That early map, supplemented by H.E. Wright's discussion of glaciation in a chapter entitled "Quaternary History of Minnesota" in P.K. Sims and G.B. Morey's *Geology of Minnesota* and supplemented by local surficial surveys here and there in the state, still stands as the most valuable survey of Minnesota's surficial geology.

In 1965 the Geologic Atlas Program was initiated to provide generalized, and updated, geologic information (both bedrock and surficial) for the purpose of regional planning. But while three sheets of the Bedrock Atlas have been published (St. Paul, New Ulm, Hibbing) and more sheets are in preparation, no sheets of the Surficial Atlas have appeared. As an interim measure, therefore, the Minnesota Geological Survey is in the process of preparing a 1:500,000 surficial map of the state based on existing surficial data, new aerial photography, and satellite imagery.

This map, however, as well as the planned Surficial Atlas, is meant to be used primarily for regional planning and, like the Soil Atlas and General Soil Map, will not supply a detailed description of the glacial topography underlying the state's peat deposits.

MLMIS

The Minnesota Land Management Information System (MLMIS), which is being developed cooperatively by the State Planning Agency and the Center for Urban and Regional Affairs (CURA) at the University of Minnesota, represents the state's attempt to devise a comprehensive data system to assist in regional land use planning.

Information is recorded in the system by 40-acre "data cells," which were selected because both land ownership and land use tend to follow 40-acre parcel and/or section lines. There are some "variables," such as land use, which have been entered into the system, by 40-acre data cell, for the entire state. There are other variables which have been entered into the system for only part of the state. Such is the case with

Table 5.6. IRR&R Peat Surveys (Unpublished)

Name	County	Location
McGregor Bog	Aitkin	T47N-T48N R23W-R24W
McGregor S. Bog	Aitkin	T45N-T46N R23W
Hill City SE. Bog	Aitkin	T50N-T51N R25W-R26W
McGregor N. Bog	Aitkin	T48N R23W
North Cromwell Bog	Carlton	T49N R20W-R21W
South Cromwell Bog	Carlton	T48N R19W-R20W
Deer River Bog	Itasca	T145N-T146N R25W T57N-T58N R27W
Jacobson W. Bog	Itasca & Aitkin	T52N-T53N R25W-R24W
Pine Island Bog	Koochiching	T155N-T156N R29W
International Falls Bog	Koochiching	T70N R23W-R24W
Ridge Bog	Koochiching	T152N-T153N R27W-R28W
Porter Ridge Bog	Koochiching	T153N-T154N R25W
North Pine Island Bog	Koochiching	T158N R27W-R28W
Nakoda Bog	Koochiching	T69N-T70N R24W-R25W
Floodwood NW. Bog	St. Louis	T52N-T53N R21W
Floodwood E. Bog	St. Louis	T51N-T52N R19W-R20W
Meadowlands E. Bog	St. Louis	T53N R18W
Little Swan Bog	St. Louis	T56N-T57N R19W
E. Cotton Bog	St. Louis	T54N-T55N R16W-R17W
Cotton Bog	St. Louis	T54N R19W-R18W
Central Lakes Bog	St. Louis	T55N-T56N R16W-R17W
Canyon Bog	St. Louis	T53N R16W-R17W
Toivola Bog	St. Louis	T54N-T55N R18W-R19W
E. Toivola Bog	St. Louis	T54N-T55N R19W
Toivola South Bog	St. Louis	T54N R19W-R20W
Floodwood Bog	St. Louis	T52N R20W
Ely Lake Bog	St. Louis	T157N-T158N R16W-R17W

Table 5.6. IRR&R Peat Surveys (Unpublished) Continued

Name	County	Location
Prairie Lake Bog	St. Louis	T50N-T51N R20W-R21W
Cook SE. Bog	St. Louis	T62N R18W
Riley Bog	St. Louis	T56N R20W
Arlberg Bog	St. Louis	T51N-T52N R18W-R19W
Sturgeon Bog	St. Louis	T61N-T62N R20W
Lost Lake Bog	St. Louis	T62N R17W

the Soil Atlas information. The plan, however, is to ultimately enter numerous variables into the system for the entire state, in particular such variables as forest cover, hydrology, potential and actual mineral deposits, soil landscapes, geomorphic areas, and land ownership.

MLMIS has already published a land use map of the state (1:500,000) which distinguishes nine classes of land use. The data for this map were obtained from 1969 high-altitude aerial photos which were interpreted for dominant land use per 40-acre cell. The real potential of MLMIS, however, lies not so much in one-variable maps like the land use map as in multi-variable maps which sort out 40-acre data cells possessing the same set of characteristics, such as all 40-acre data cells which show copper-nickel potential and state ownership.

MLMIS has also recently published a computer map of the peat resources in Koochiching County with overlays showing federal, state, tax-forfeit, and private lands. The soil information for the MLMIS map was taken from the Arrowhead General Soil Map, which distinguishes three classes of organic soils by soil association: Mooselake Association, Greenwood Association, and Washkish-Lobo Association. According to a computer count of 40-acre cells, the State of Minnesota owns about 78 percent (765,100 acres) of the peatlands in Koochiching County. The rest of the peatlands are federal, private, or tax-forfeit:

Ownership	Mooselake (Acres)	Greenwood (Acres)	Washkish-Lobo (Acres)	Total	Percent
Federal	26,440	38,280	4,800	69,520	7.5
State	383,080	350,800	31,200	765,080	77.6
Tax Forfeit	49,440	11,200	280	60,600	6.2
Private	64,040	25,640	920	90,600	9.2
Total	523,000	425,920	37,200	986,120	

This pattern of peatland ownership is typical of northern Minnesota. It might be noted that the Conservation Needs Inventory shows Koochiching County with 1.15 million acres of peatlands, while the Arrowhead General Soil Map shows Koochiching with 986,000 acres, a difference of about 165,000 acres.

6. PEATLAND SETTING

PEATLAND FORMATION

The peatlands of northern Minnesota have developed like a blanket primarily over broad, gently sloping glacial lake basins and outwash plains, formed by the retreating Wisconsin Ice Sheet about 10,000 years ago. The largest peatlands occur on the eastward extending arm of Glacial Lake Agassiz, mainly in Roseau, Lake of the Woods, Beltrami, and Koochiching Counties. Extensive peatlands are found also on the abandoned beds of glacial Lakes Upham and Aitkin, through which the St. Louis and Mississippi Rivers presently flow, respectively. These basins are located in southwestern St. Louis and northern Aitkin Counties. Other examples of extensive peatlands are found on the outwash plains in the northeastern portion of the Brainerd-Automba drumlin area, mainly in northwestern Carlton and southeastern Aitkin Counties. Natural topography, composition of soil parent material, water quality, and drainage patterns as well as abandoned glacial lake basins and outwash plains in the peatland area are primarily the result of the last ice sheet. Climate to a much more limited degree was perhaps indirectly affected.

The lacustrine deposits are essentially sealed at the surface by clay and/or saturated by runoff from the surrounding glacial moraines and beckrock outcrops. Thus a sufficient amount of surface moisture was available for growth and accumulation of peat.

The formation processes of these large peatlands are not as yet well understood but may occur basically in the following manner. The shallow lakes and ponds left when the former glacial lakes were drained may have gone through the typical Clementsian hydrarch succession: i.e., the filling of a lake basin by a bog habitat in which peat accumulation gradually obliterates the open water. However, this bog vegetation apparently continued to gradually advance outward from the former lake basin into the surrounding terrestrial habitat because of the availability of sufficient moisture as described above. This process is termed "paludification." Typically, this raises the water table because, as peatland plants grow and die, they form a sponge-like matrix of partially decomposed plant debris termed "peat" that retains some of the precipitation and/or surface water runoff. Peat accumulates because the trapped water is depleted in dissolved oxygen by bacterial respiration before very much of the plant material is decayed. Thus, as the oxygen-rich surface-water is more and more isolated from the peat, less and less peat is decayed, which also improves its water-holding capacity. When a hole or ditch is dug in peat, actually very little of this trapped water is lost; most of the water lost comes from about the upper 6 inches of the peat, a fact not clearly understood by many.

As this peatland "grows" outward the mineral-rich surface runoff is blocked from direct access to the more central regions of the bog. Thus, a different flora, with the capacity to thrive in a very low nutrient regime, and fauna develops. Growth of this flora is rapid relative to the fens and to the advance of the bog outward; thus the peatland surface begins to develop a convexity. Furthermore, as this convexity increases the peatland becomes more and more dependent upon precipitation rather than surface waters for its moisture supply. The limits to this growth in convexity is dependent upon the ratio of precipitation to evapotranspiration.

This type of peatland development has proceeded to the extent that these bogs now cover or reach nearly to the crest of some of the lower hills. Thus peatlands are elevated *above* the streams and in some places form the drainage divide between adjacent stream systems or watersheds.

Currently in the larger peatlands in northern Minnesota, there are characteristic vegetation patterns consisting on the one hand of noticeably convex bogs called "raised bogs," with their own striking patterns of spruce, tamarack, heath shrubs and *Sphagnum*. Peat accumulation in these areas is mainly moss (or fibric) peat, sometimes over seed-sedge peat. On the other hand the flat areas with mainly sedges, grasses, swamp birch and willow, which are termed "fens," are more moist than the raised bogs. These areas produce seed-sedge (or hemic) peat. In between are the slightly raised *Sphagnum* areas which often bear stunted spruce and tamarack as islands.

In addition there are islands, ridges, and peninsulas of terrestrial vegetation on mineral soil; plus the contours of this soil underneath the peat apparently have some influence upon the vegetation patterns. For instance, the flat, sedge areas are found to bear some of the mineral-rich, surface water runoff from these exposed mineral soils downhill toward the headwaters of the streams. Thus these sedge areas are termed "water-tracks." In the "bays" of the peatland, in the "shadow" of some of the islands and ridges, and other depressions in the mineral soil raised bogs may develop. In the latter location, the lowest layer of peat may be of lake origin, forming a highly decomposed (Sapric) peat.

Where the water-tracks are constricted by the raised bogs, stunted spruce islands or the upland mineral soil, the sedge fens developed another characteristic pattern. A series of pools and ridges developed perpendicular to the direction of the surface-water flow. These areas are termed "patterned fens" and, as with the raised bogs, occur mainly in the northwestern (but not extreme western) peatlands. Minnesota's patterned peatlands have received national recognition and are preserved as federal natural landmarks, the Lake Agassiz Peatlands National Landmark and the Red Lake Peatlands National Landmark. The former consists of 22,000 acres in Koochiching County south of International Falls and east of Big Fork. The Upper Red Lake Peatland contains approximately 132,000 acres located just north of Upper Red Lake. (See Flaccus, 1972 and Heinselman, 1963 and 1970 for ecologic descriptions). The National Natural Landmarks Program of the National Park Service and the location of Lake Agassiz and Red Lake Peatlands are discussed in more detail in Appendix B.

NATURAL ENVIRONMENT SETTING

In this section of the report, the biogeochemical, paleoecological, and meterological features of the extensive peatland area are summarized. Representative conditions of these features, including physico-chemical gradients and plant and animal distributions, are elaborated to construct a hypothetical peatland. This is a necessary simplification of the complexities of these northern ecosystems and their interactions for the purposes of this preliminary study. This landscape, along with the socioeconomic features described in the following section, sets the stage for the discussion of the possible cause-effect relations of the three scenarios of large-scale peatland development.

VEGETATION

Within the coniferous-deciduous forest, plant and animal distributions are influenced by local climate, topography, soil, and exposure (direction and angle of soil surface to sun's angle).

The mixed coniferous-deciduous forest covers much of the peatland area, with climate exerting a strong control particularly in the western area where aspen parkland and oak savanna replace the mixed forest. Further west, beyond the extensive peatlands, prairie vegetation becomes widespread (Figure 5.2). Vegetational characteristics of peatlands are discussed in more detail in the section on the "Representative Peatland."

One example of topographic and climatic effects on upland vegetation may be cited from the Red Lake area (Buell and Bormann, 1955), although the local climate as influenced by the presence of these large lakes may not be closely similar to that of wetlands. The lower, poorly drained sites on the north side of the transect next to the lakeshore are occupied by a basswood-fir-black ash community (*Tilia americana, Abie balsamia,* and *Fraxinus nigra*), which may benefit from an extended frost-free period (about 125 days compared with 100-110 in the surrounding area) and higher humidities (Figure 6.1). Moist sites at somewhat higher elevations and those next to the lakeshore on the south side are dominated by a sugar maple-basswood community (*Acer saccharum* and *T. americana*). The driest and most exposed sites are dominated by paper birch, red maple, and aspens (*Betula papyrifera, Acer rubrum, Populus grandidentata* and *P. tremuloides*). Prior to logging in the early 1900's and on unlogged dry sites, white and red pine (*Pinus strobus* and *P. resinosa*) dominated.

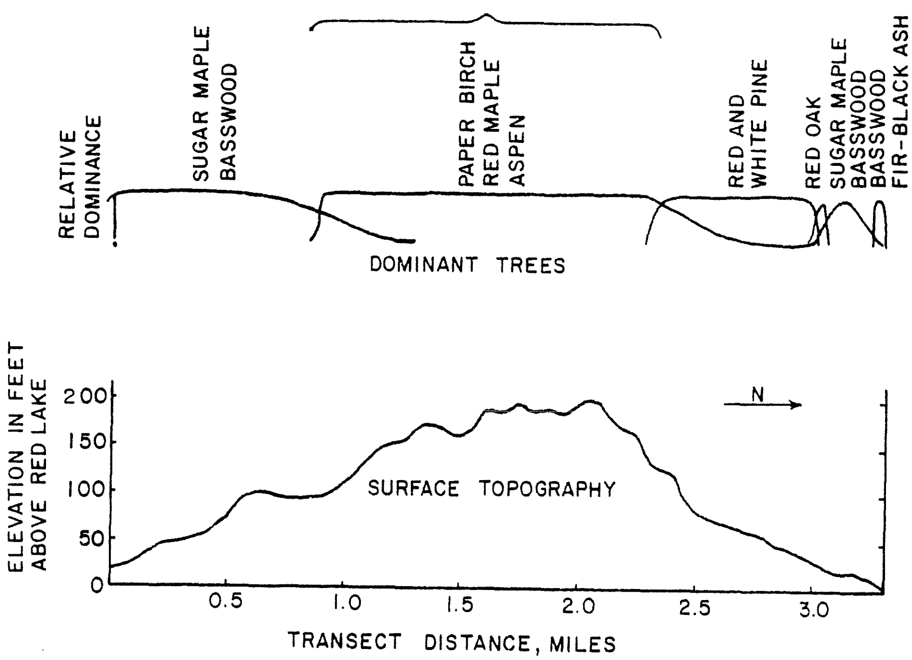


Figure 6.1. Topographic and Climatic Effects

This region is an important timber producing area in Minnesota, yielding mainly pulpwood and lumber logs, fuel wood, veneer logs, mine timbers, post, poles and piling. Deciduous trees (except tamarack, a deciduous conifer) comprise 35 to 62 percent of the commercial forest area, of which aspen species are predominant. Conifers occupy 19 to 40 percent of the forest area, of which black spruce and tamarack are most common. (Remaining percentages are mainly brush lands.) Conifers exceed hardwood areas only in the central portion of the peatland area.

ANIMALS

The quality and quantity of surface waters and soil characteristics exert a strong influence on the plant and animal communities. A soft-water aquatic flora occurs in the easternmost peatlants along with stream and lake trout and walleye, perch, and pike. Westward more commonly occurs the more productive hard-water flora with predominantly walleye, black bass, sunfish, crappie, and pike (Moyle, 1956).

The peatlands are part of a broad group of different types of wetlands. Twenty such types are classified by the U.S. Fish and Wildlife Service according to their suitability as waterfowl habitat (Shaw and Fredine, 1956). The classification is based upon the depth and duration of flooding, and are recognizable in the field by characteristic plant species. Other classifications exist but no attempt to compare them was made for this preliminary study.

The extensive peatland area in northern Minnesota may be included in four of the OSFS wetland types: Types 2 (inland fresh meadows), 6 (shrub swamps), and 7 (wooded swamps) are used somewhat by waterfowl for nesting and supplemental feeding, but do not constitute prime habitat; Type 8 (bogs) is the least significant waterfowl habitat by far of all 20 types of wetlands in the U.S. Thus the extensive peatlands are of little significance as direct hunting areas and lie outside (north) of the general distribution of most ducks. These wetland types are described in more detail in Appendix E.

Most other game birds also are found in other habitats, with the exception of grouse species. The peatlands are the prime habitat of the spruce grouse, and ruffed grouse are common in the area also. Sharptail grouse occur to some extent in the southeastern peatlands in Aitkin County, but their prime habitat are the northwesternmost peatland areas.

Big game and other large mammals and furbearers are found primarily in northern and especially northeastern Minnesota (Figure 6.2). The wild nature of the peatlands is particularly attractive to these species. The white-tailed deer is found here but these peatlands in general are not the prime habitat. The major range of bear and moose is in this northern area. Non-game large mammals such as timber wolf, bobcat and lynx also are found primarily in the northeastern region. The elk range, the smallest range of all large mammals, however, is located near where Roseau, Lake of the Woods, Beltrami and Marshall Counties have common borders. Of the harvestable furbearers, muskrat is generally ubiquitous in Minnesota, while beaver are more common to the north and northeastern parts of the state. They are quite common in the peatland area. They are often found in the old drainage ditches. River otter occur in the north and northeastern part of the state also, but are not plentiful.

Few data are available on the size of animal populations. They are collected mainly on those animals which are important commercially and for recreation. Aerial censuses for beaver and moose are made during winter. The 1974-1975 census data show that, in the peatland area, there were 0.5 to 0.7 live beaver colonies per mile of flight path (compared with 0.3 to 2.2 per mile over all areas sampled) (Karns, 1975c). At the same time there are about 1.1 moose per square mile (compared with a range 0.1 to 2.2 over all counties) (Karns, 1975b).

On the basis of hunting and trapping data, the northern peatland counties are important sources for deer, bear, and beaver during the 1975 seasons (See Table 6.1) (Karns, 1975a and Langley, 1976).

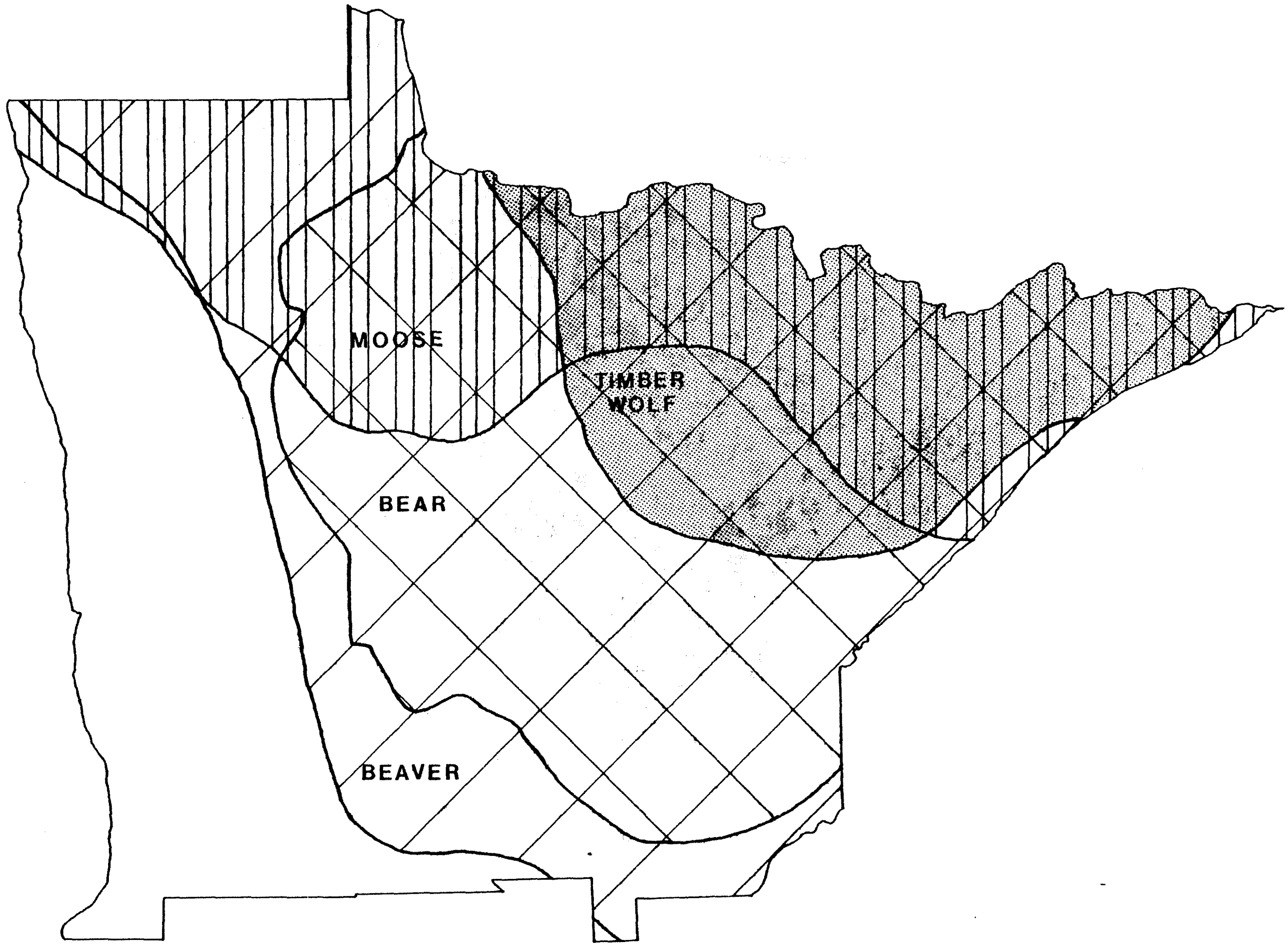


Figure 6.2. Large Mammal and Furbearer Ranges

Table 6.1. Game and Furbearer Harvest in Northern Minnesota, 1975 (Karns, 1975a and Langley, 1976).

Species	Range of Harvest/County Peatland Co.	All Co.	Ranking of Peatland Counties	Counties Harvested
Black Bear	12-81	1-81	1,4,7,9,10,12,18	19
White-tailed deer	21-5505	482-4451	2,4,7,8,14,23,34	87
Beaver	120-920	20-3430	2,3,4,8,12,18	26

River otter are also trapped but the harvest is quite small (1975 data): 315 otters (valued at about $9,000) compared with 12,750 beaver (valied at over $173,000). Further study could reveal important population and harvest trends in the peatlands areas which are essential to understanding the importance of the peatlands to the maintenance and the hunting and trapping success of these wildlife species.

The distributions and population sizes of other plants and animals in the peatlands is little known. The occurrence of these species in the peatlands is obtained from several readily available references and discussed in the next section on the representative peatlands (See also Appendix E). This literature is not very detailed, however, and the data are generally not recent. Further search of the literature and field studies are planned for the Phase 2 program.

WATER

Situated in the headwaters of three major drainage systems at elevations generally from 1200 to 1400 feet, these water-saturated ecosystems impact a characteristic reddish-brown or "tea" color to most of the area tributaries and lakes. These elevations are mostly intermediate between higher drainage divides on mineral soil and the lower streams and lakes. Westward, however, peat accumulation in some places is sufficient such that some drainage divides occur on peatland areas.

The three major drainage systems are the Gulf of Mexico, (the Mississippi River) the St. Lawrence (the St. Louis River) and the Hudson's Bay or Laurentian (the Rainy River, Lake of the Woods, and Red River of the North) (Figure 6.3).

Several surface water quality parameters other than color increase in concentration westward, including alkalinity (about 50 to 150 mg/l), total phosphorus (about 0.025 to 0.05 mg/l), total nitrogen (about 0.2 to 0.5 mg/l), sulphate (less than 2 to about 10 mg/l), and chloride (less than 1 to more than 2 mg/l) (Moyle, 1956). More recent data suggest that in a few instances these average values are presently somewhat higher (See data in Appendix C; Helgeren, et al., 1973 and 1975; and Ropes, et al., 1969). Further effort is required to establish reasons for these differences and to update the earlier picture. However, these water quality parameters are naturally somewhat variable with season and depth in lakes, and inversely with discharge in streams.

At existing population levels there are generally sufficient quantities of good quality of surface water to meet the needs of municipalities, livestock watering, irrigation, industrial, recreation and wildlife needs. Many peatland tributaries to the larger rivers in northern Minnesota are classified in terms of water quality as suitable for cold or warm water sport and commercial fish and for aquatic recreation of all kinds, including bathing (MPCA-WPC Classification 2B). Numerous streams are of higher quality, being classified for drinking water (with simple chlorination); for cold and warm water sport and commercial fish, and recreation including bathing; and for general industrial purposes, except food processing, with only a moderate degree of treatment (MPCA-WPC Classification 1B, 2A, 3B, which are presented in detail in Appendix D) (Minnesota Regulations WPC 14 and 24, 1973).

Ground water quality in glacial drift aquifers also exhibits a gradient of increasing concentration westward. Data show that this ground water is moderately hard (about 170 mg/l) and low in dissolved solids (about 200 mg/l) on the eastward end of the gradient. At the westward extent of the peatland area, the ground water becomes very hard (about 300 mg/l) and contains a moderate amount of dissolved solids (about 400 mg/l). Everywhere the iron content is relatively high. The quantity of ground water available is sufficient to meet the moderate volume needs of rural residences and livestock watering, but not of large enough capacity for municipalities and industrial users, except for those aquifers in outwash plains (Bidwell, et al., 1970; Helgesen, et al., 1973 and 1975; Oakes and Bidwell, 1968; Ropes, et al., 1969; and Winter, et al., 1967).

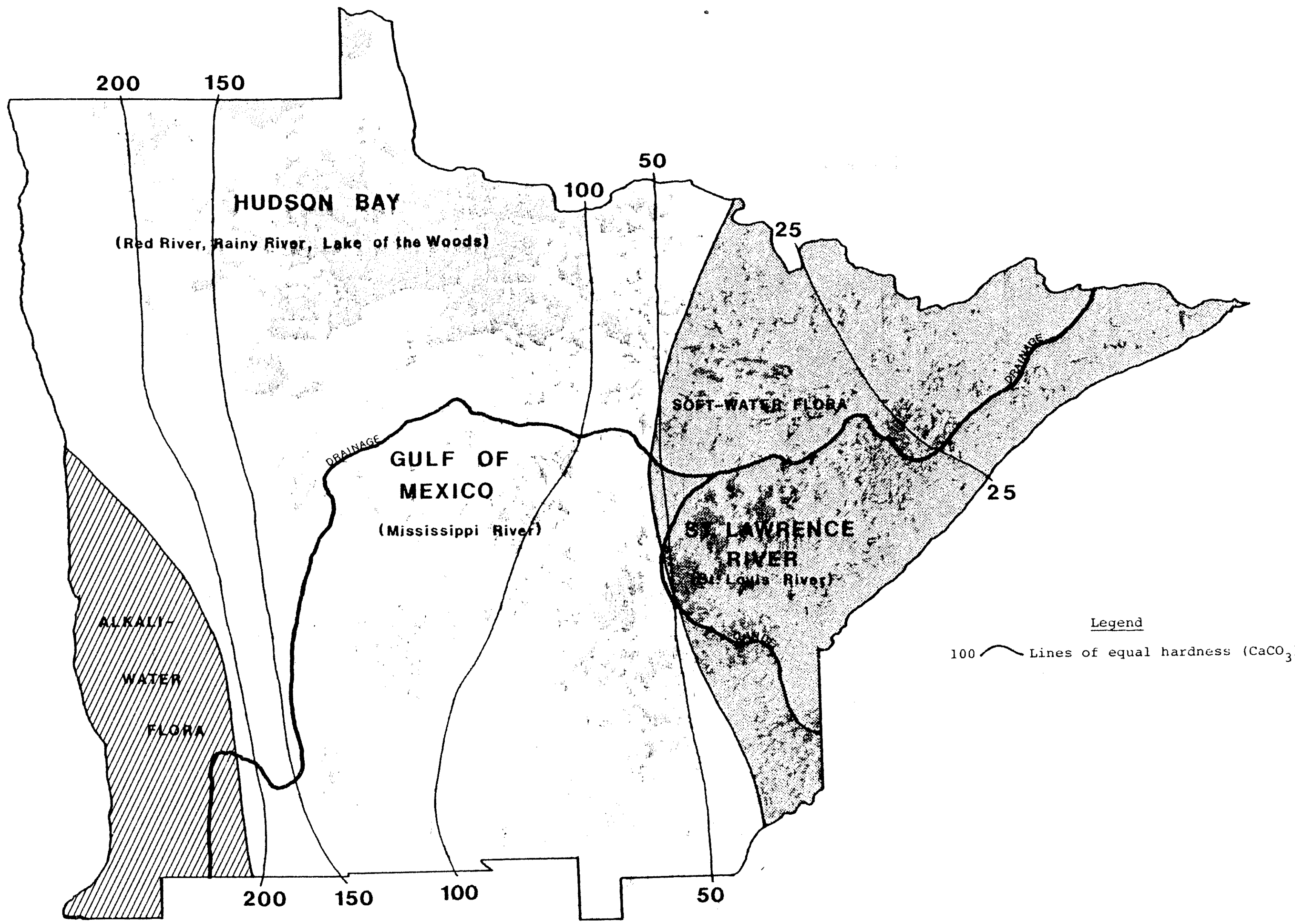


Figure 6.3. Drainage Basins and Water Quality Gradients

CLIMATE AND AIR QUALITY

Climatic gradients approximate those of water quality. Precipitation decreases from about 28 inches on the eastern peatlands to about 20 inches on those in the west, while surface runoff decreases from about 9 to 2 inches (Figure 5.2). Precipitation exceeds by 25 percent the amount of moisture evaporated and this percentage decreases to 5 percent on the western and southern limits of the study area. No extensive peatlands occur beyond where precipitation equals evaporation. Average monthly snowfall reaches nearly 13 inches but declines to about only 6 inches along this same gradient, with the greatest snowfall occurring from December through March. Annual average snowfalls reach 60 inches on the east and 35 inches on the west.

The temperature gradient is more strongly oriented southwest-northeast with the other gradients, compared with the southeastern peatlands area experiencing mean annual temperatures of nearly 39°F and those in the west have nearly 41°F. The northernmost areas are coolest at about 36.5°F. However, first frost occurs two weeks earlier, usually on September 1, and the last frost in spring two weeks later, about June 8 on the average, on the eastern peatlands than on those in the west (Watson, 1975). Other data suggest that the frost-free period ranges from 100 to 130 days. This is probably dependent on topography. However, the frost-free period is generally shorter on the peatlands, by as much as ten days in southern St. Louis County.

Present air quality in the peatland area is generally excellent. However, airsheds of some cities and areas may locally and occasionally adversely affect air quality on the peatland area, including the Duluth, Cloquet, Iron Range, Cohasset, and International Falls airsheds. Ambient air quality standards apply throughout the state at primary and secondary levels (MPCA-APC 1). The primary levels are based on percent knowledge, health hazards (including production, aggravation, or possible production of disease), or impairment (including sensory irritation and impairment such as by odors). Secondary standards are those desirable to protect public welfare from any known or anticipated adverse effects, including injury to agricultural crops and livestock, damage to or deterioration of property, an annoyance and nuisance of person, sensory impairment and obstruction, or hazards to air and ground transportation. The details of these standards and the federal standards are presented in the Appendices of this report.

Limited air quality data are available. Annual atmospheric loading of air pollutants from major sources is presented for two broad regions which include the extensive peatlands as well as non-peatland area (Ritchie, 1974). These regions are the Arrowhead (EDA region 129) and northwestern Minneosta (EPA region 132). Concentrations of air pollutants is available mainly in the larger cities.

The major pollutant in both regions by tonnage is carbon monoxide, followed by particulates and sulfur dioxide (see Figure 6.4).

The important sources are fuel combustion activities (excluding transportation) and industrial processes for particulates, sulfur dioxide and some nitrogen dioxide. Most of the carbon monoxide and hydrocarbons are derived from transportation sources. On a regional basis, more tonnages of pollutants (except hydrocarbons) are generated in the Arrowhead area. Sources of pollutants in the two regions differ only with respect to nitrogen oxide and carbon monoxide: the former primarily from fuel combustion activities in the Arrowhead and from transportation in the northwest. For the latter the industrial contribution drops out in the northwestern region, leaving transportation as the main source of carbon monoxide.

Data on the concentrations of air pollutants measured some distance from large cities are very sparse; what is available shows no regional differences. Annual geometric means of particulates range from 25 to 38 mg/m^3 (ppt = part per trillion). The concentration of sulfur dioxide is 1 ppt (no range is reported).

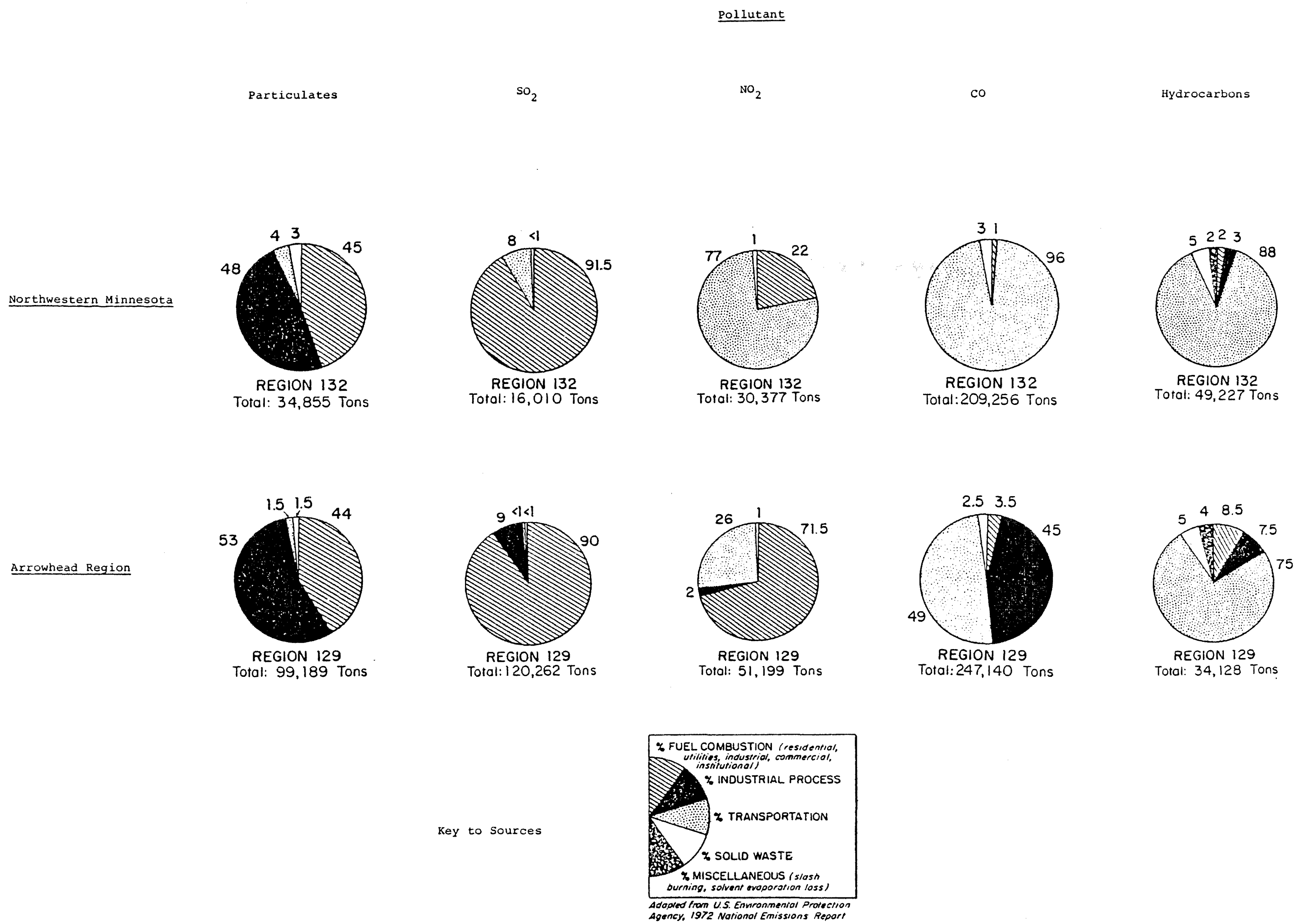


Figure 6.4. Annual Atmospheric Leadings of Air Pollutants by Source

SOCIOECONOMIC SETTING

A large-scale peat development would most likely occur somewhere in seven northern Minnesota counties (Aitkin, Beltrami, Carlton, Koochiching, Roseau, St. Louis and Lake of the Woods). These counties, like the other counties in the northeastern and north-central part of the state, exhibit similar socioeconomic characteristics, although there are also important differences among them. Many of the socioeconomic characteristics of these counties have been shaped by the natural characteristics described in the previous section of this report. The inaccessibility of extensive areas in all of these counties, coupled with early settlement patterns which reflected that resistance to penetration, has worked to keep population, transportation, agriculture, and urban development at a relatively low density, except in the Duluth metropolitan area and along the Mesabi Range, which are the major urban-industrial centers of northern Minnesota.

This pattern of low density development has in turn produced numerous socioeconomic consequences, some good and some not so good. The wilderness-like quality of much of the area has provided a prime tourist attraction, especially in the central "lakes district"--Aitkin, Crow Wing, Itasca, Cass, Hubbard, and Beltrami counties--and in the more rugged wilderness areas of Voyageur's National Park, the Boundary Waters Canoe Area, and Superior National Forest. These areas, and the central lakes district in particular, have sustained a thriving, though seasonal, tourist industry for many decades. But the wilderness-like quality of these areas is to some extent maintained at the expense of high seasonal unemployment and low per capita income among local residents.

The forest products and mining industries provide more stable employment than the service industries which have grown up around tourism, but still the peat counties of northern Minnesota appear to be economically depressed areas when they are compared to counties in the central and southern parts of the state. The following discussion of the socioeconomic "setting" should be read with such socioeconomic trade-offs as these in mind.

The socioeconomic setting in which any potential peat development might take place will vary, naturally, from one location to another, and also as a function of time. This variability makes it difficult to pin down the most "typical" socioeconomic setting, but there is sufficient homogeneity in the data to support some representative numbers. The seven counties in which a peat development would most likely take place together account for more than 20 percent of Minnesota's total area and contain more than 50 percent of the state's peatlands. Because it has been determined to select a representative bog of 200,000 contiguous acres for the purposes of this assessment, and because such extensive areas of contiguous peatland are fairly rare even in these large-sized counties in northern Minnesota, the potential sites of a development of this size are fairly easy to locate, at least approximately. Two of the counties have more than one potential site within their boundaries.

POPULATION

The population of northern Minnesota is distributed in three zones of different population density. The zones are approximately equal in size and run from the southeast to the northwest (Figure 6.5). The northernmost zone occupies the area north of a line from Two Harbors on the east to the northwest corner of the state. The population density of that area is less than 2 people per square mile (Commission on Minnesota's Future, 1975).

The middle zone occupies the area between the second zone and a line from Taylors Falls on the east and Browns Valley on the west.

The density of the third zone is in the 10-25 people per square mile range. The general trend in northern Minnesota is for the population density to increase from the northeast to the southwest. Along that line population increases from under 2 people per square mile to 2-10 people per square mile and eventually to 10-25 people per square mile.

There are two major exceptions to the trend just indicated. The first is that there are isolated islands of higher density distributed evenly over the northern portion of the state. The second exception is the iron range and its vicinity.

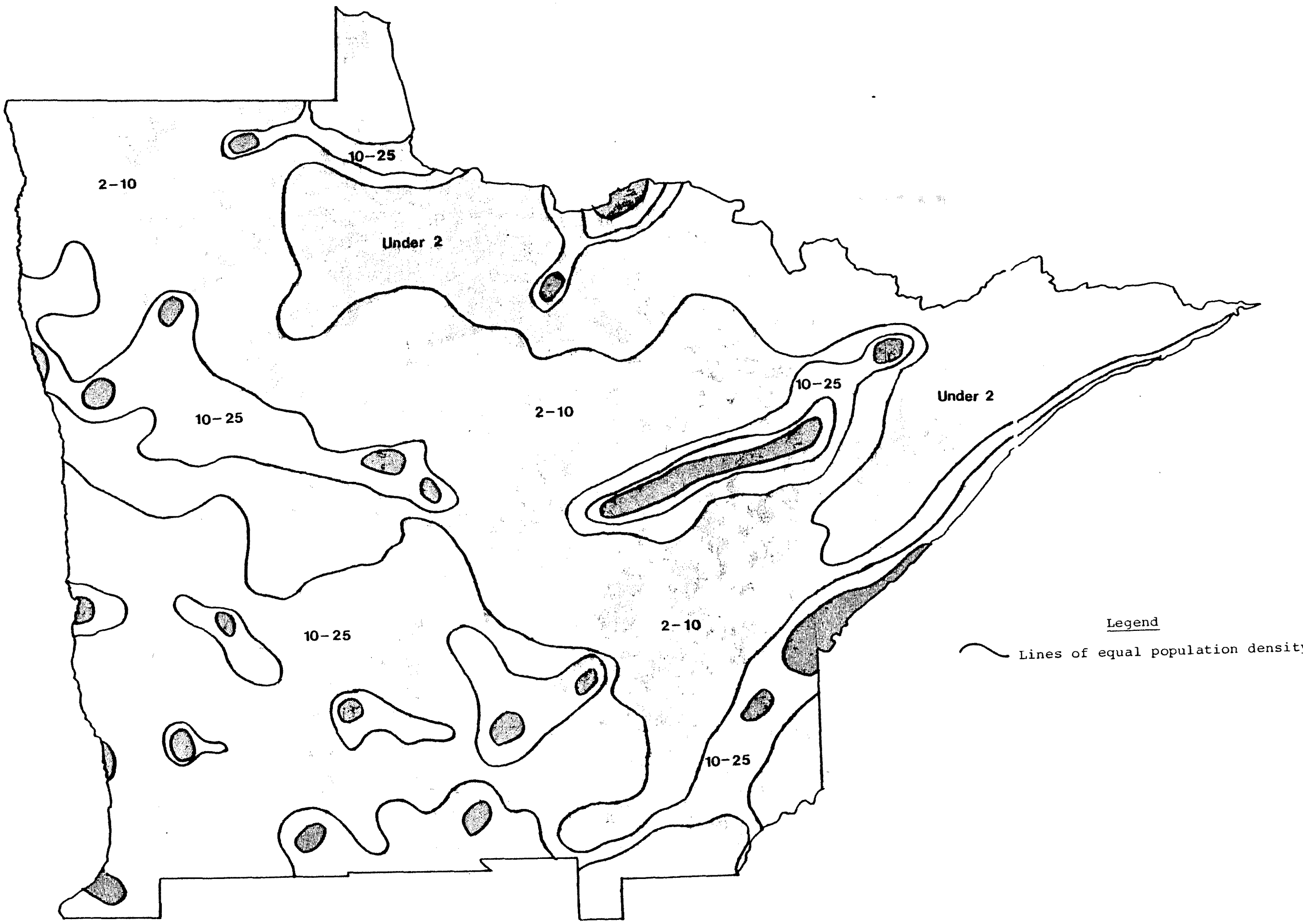


Figure 6.5. Population Density

The isolated islands of high density indicate the location of the larger towns and cities. The higher the density the larger the town. Some of the islands are connected by corridors which have a higher density than the surrounding area. The corridors generally follow major highways which have commercial and residential development along their routes.

The iron range and its vicinity comprise the second exception. The iron range appears on the population density map as an oblong band of higher density which runs along Highway 169 from near Grand Rapids to Ely.

The largest of Minnesota's peatlands fall within the northernmost zone of population density. The density of that zone is less than 2 people per square mile. The peat deposits in St. Louis and Aitkin Counties, south of the iron range, fall within the second population density zone. The density range in that area is 2-10 people per square mile. The high density islands mentioned earlier are generally located well away from peat deposits.

TRANSPORTATION

The highway system of northern Minnesota is a combination of primary and secondary paved roads. Most roadways run either north-south or east-west, diagonal roadways are not common. The highways of northern Minnesota are lightly traveled and are fewer and farther between than are the highways in the southern half of the state.

The most heavily traveled roads are those portions of roads which extend 15 to 20 miles from the municipal limits of larger towns and cities. This pattern reflects the additional traffic which regional trade and employment centers generate. Some roads receive heavy seasonal traffic when tourists travel to and from resort and recreation facilities.

In most cases the roads of northern Minnesota have been constructed so that they bypass the larger peat bogs. If one looks at an overlay of Minnesota highways on a map of peat deposits it can be easily noted that the roadways seem to frame the perimeter of large bogs (Figure 6.6). One reason for this is that road construction and maintenance is complicated and made more expensive when peat lands are crossed. The roads which do cross peatlands generally cross them at their narrowest point.

The northern portion of the state is served by about 2500 miles of railroad trackage. A significant portion of the trackage is privately held by mining companies. The rail network is used primarily to transport iron ore, farm produce, and wood products to major shipping points such as Duluth or to processing plants within the state.

ECONOMY

The dominant industries in northern Minnesota vary as one crosses the state. Differences in climate, soil types, mineral deposits and recreation opportunities dictate which industry or combination of industries dominates the local economy.

The economy of the northwestern portion of the state is dominated by agriculture and agriculture-related industries, while tourism and manufacturing play a secondary role. The northeastern section is dominated by iron and taconite production. Tourism and wood products are supportive industries in the northeast.

NORTHWEST

The economy of the northwestern agricultural region is subject to the effects of frequent fluctuations in the prices of farm products and to changing weather conditions. When agriculture experiences a good year, positive affects are felt throughout the local economy. If product prices are low or if weather conditions are poor causing agriculture to have an unprofitable year, negative effects are felt in the economy. In 1970, for example, the northwest portion of the state had normal crop yields and a per capita income that year of about $2,900. Three years later, due to increased yields, the per capita income for the same area was about $5,800. The increase in disposable farm income for 1973 greatly improved the economic activity and the economic health of northwestern Minnesota.

The soil fertility of the northwest ranges from low to high, with the majority of land being in the fair or high categories. The counties of the Red River Valley which hold the high quality land are intensively cultivated. At least 85 percent of the total land area of the counties in the Valley is under cultivation. The other counties of the northwest cultivate between 55 percent and 85 percent of their land area.

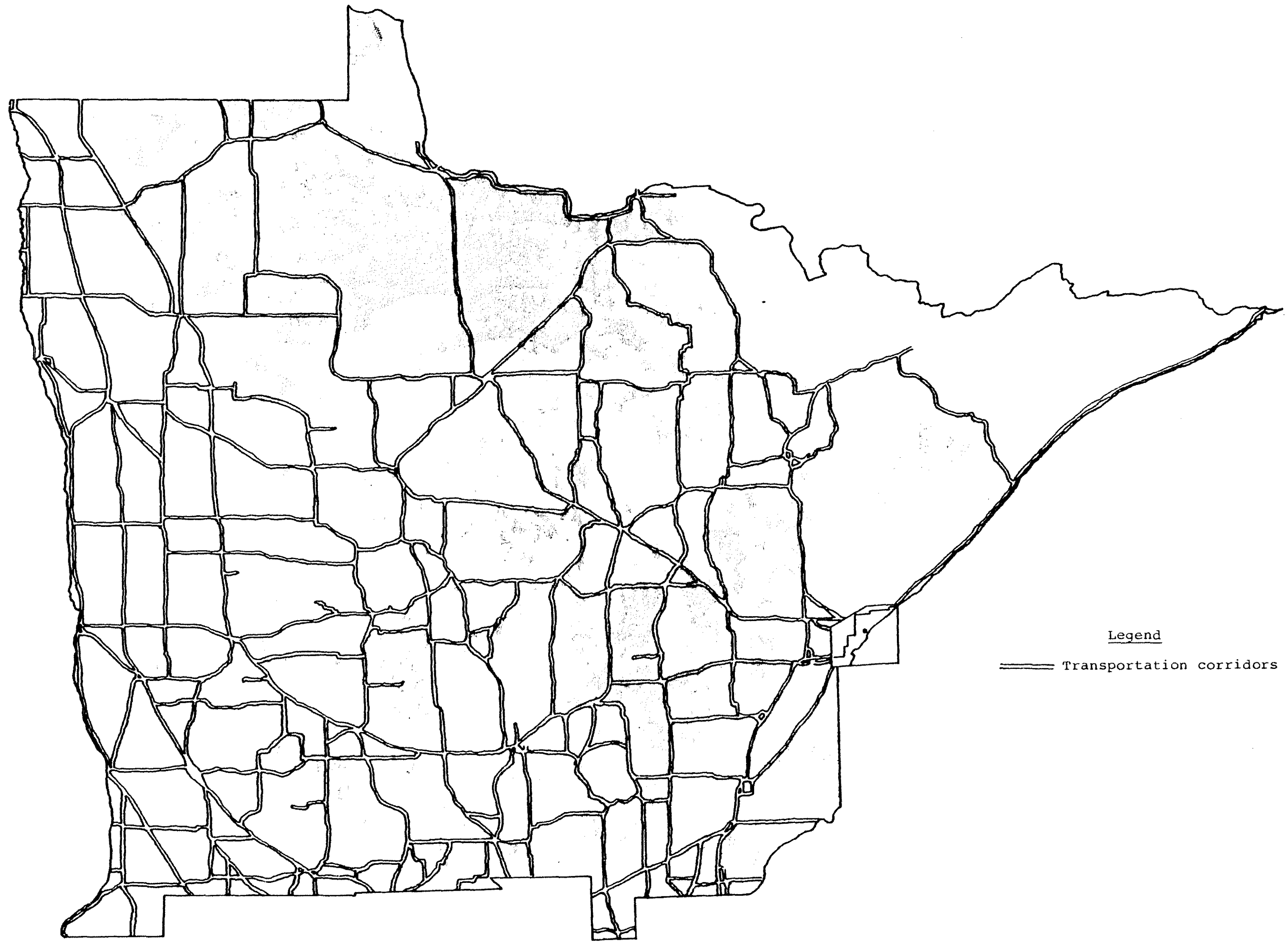


Figure 6.6. Transportation Corridors

Crops of importance in the northwest are sunflowers, malting barley, sugar beets and potatoes. Some wild rice is grown and some beef is produced.

Sunflower production and processing has rapidly increased in recent years. The Red River Valley of Minnesota and North Dakota currently produce 80 percent of the nations sunflower crop. Several processors which extract oil from sunflowers, or hull and salt the sunflower nutmeats, are operating in Minnesota.

Plants also operate in the northwest which possess sugar beets, potatoes, and wild rice. The close proximity of production to processing has been an economic benefit to the northwest. Jobs and income are generated by the growers and processors. The income earned is then recycled back through the local economy when locally produced products are purchased.

NORTH CENTRAL

The economy of the north central portion of the state is dominated by the wood and wood-products industry. That industry includes manufacturers of saw timbers, pulp wood, paper, pallet and crate wood, plus posts and poles. The industry harvests large trees for building materials and smaller, less valuable trees for pulpwood. Most of the trees harvested are taken for pulpwood.

The economy is bolstered by tourist trade and some agriculture. Tourists are attracted by the areas' wilderness-like quality, by the lakes and streams and by the excellent hunting and fishing opportunities. The area also serves as summer residence for thousands of Minnesotans and out-of-staters.

Less than 20 percent of the land in the north central region is under cultivation. The major products produced are hay and silage, beef and dairy cattle, wild rice and some grains. The soil fertility of the area ranges from low to good with the majority being in the low or fair categories. Peatlands are sometimes drained and used for agricultural purposes in this region. Hay is commonly grown on peat, as are some grains and vegetables. Peatlands also serve as grazing land for beef and dairy cattle. Wild rice is particularly well suited to peatland conditions. Before the 1930's peat was extensively cultivated but the cost of maintaining drainage and adverse economic conditions forced most homesteaders to abandon their land.

Employment in the north central region is particularly prone to large seasonal fluctuations. Unemployment rates frequently reach 12 percent in the winter months and drop to 2 to 3 percent during the summer. These fluctuations occur as a result of changes in demand for labor by the tourist and agriculture industries. Many people who are unemployed during the colder months move into the loggin industry until spring arrives. The logging industry is able to absorb some of the excess labor but the rate of unemployment remains high for six or seven months each year. Although the economy of the north central region is a mixed one, it is not a stable one. High seasonal rates of unemployment, as well as under-employment, cause the economy of the area to remain weak.

NORTHEAST

The economy of the northeastern portion of the state is dominated by the influence of the iron range. Iron mining employs the largest percentage of workers in the region. The wood and wood-products industry and tourism play a secondary role. The iron mining industry employs about 12,000 people most of whom live in the northeast portion of the state. Iron mines generate about 180 million dollars in personal income each year. The mines provide employment for local people and for people who keep homes elsewhere but work in the iron range area. The taconite industry is expected to expand and as a result will employ even more people in the future.

The logging industry of the northeast produces more pulpwood than any other region in Minnesota. Aspen and Jack pine are the two major types of trees harvested. Logging has been a traditional source of income and employment in the northeast. However, it is subject to seasonal fluctuations in employment and to rising stumpage costs. These factors have made logging a less desirable employment alternative for some workers.

The numerous lakes, as well as the hunting and fishing opportunities in the northeast, attract many tourists and sportsmen each year. During the summer months many jobs are created in the tourist sector. As the season tapers off, unemployment rates rise. Some of the surplus labor is absorbed by the logging and iron mining industries but unemployment rates remain elevated in the winter.

The local economy of the northeast is influenced by the cyclical nature of the tourist and timber industries. But, those ups and downs are stabilized by the dominant force in the economy, the iron industry.

EMPLOYMENT

In 1974, 2.3 percent of the state's work force received unemployment compensation. But in the peat counties of northern Minnesota the ratio tended to be considerably higher (Minnesota Department of Employment Services, Statistical Supplement, 1975):

County	Ratio
Beltrami	4.9
Lake of the Woods	5.3
Koochiching	3.7
Itasca	5.1
Aitkin	8.2
St. Louis	2.8

The average wages of experienced workers were also lower in the peat counties of northern Minnesota than in the state as a whole. The average annual wage paid in Minnesota in 1974 was $8808. In Koochiching, Itasca, and St. Louis counties, which have paper product and mining industries, the average annual wage approached this figure. In some of the other peat counties, however, average wages were considerably below the state mean:

County	Average Wage (As Percent of State Mean)
Beltrami	78.3
Lake of the Woods	61.2
Koochiching	97.6
Itasca	98.8
Aitkin	63.2
St. Louis	97.1

One factor which contributes to the lower income levels in several of the peat counties is the highly seasonal nature of employment in some sectors of the local economies. This seasonal fluctuation in employment is especially obvious in those counties which have few basic industries, such as Beltrami, Lake of the Woods, and Aitkin (Figure 6.7).

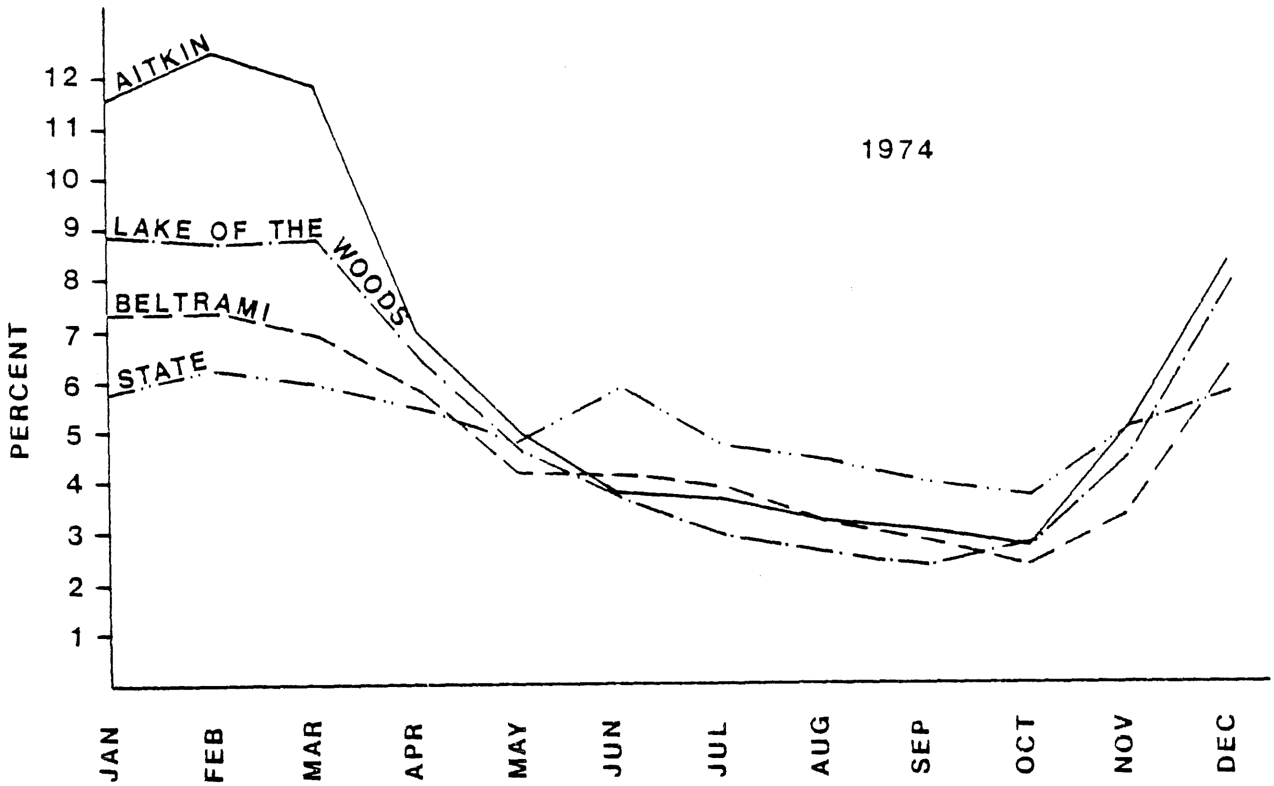


Figure 6.7. Seasonal Unemployment

As Figure 6.7 indicates, the seasonal fluctuation in employment as evidenced by the fluctuation in the unemployment rate has a much higher amplitude in Aitkin, Beltrami, and Lake of the Woods counties than in the state as a whole. It should also be noted that, with the exception of Koochiching and Lake counties, all the peat counties in northern Minnesota have been designated labor surplus areas by the Minnesota Department of Employment Services.

Capital expenditures (per capita) by incorporated cities and municipalities also tend to fall behind state averages in Minnesota's peat counties. This pattern of low capital outlay per capita, coupled with a pattern of high per capita transfer payments, suggests that some of these peat counties are not able to generate the revenue needed to supply public services and facilities. The assessed value (per capita) of many of these counties tends to run between 45 and 80 percent of the assessed value (per capita) of the state as a whole. (Sales Ratio Study, 1974). Again, these numbers illustrate the relatively depressed economies in the peat counties of northern Minnesota

7. ANALYSIS OF A LARGE-SCALE DEVELOPMENT

GENERAL

Minnesota's peatlands, as was stated earlier, have experienced a very low level of use, and the small portion that has been developed has not been developed very intensively. Such low intensity development as forage production and pasture use is by far the most common type of peatland development in Minnesota. The utilization of peatland for vegetable crop production and sod culture represents a more intensive use, but even this type of development is relatively small scale and, except for the truck farming areas in Freeborn and Anoka Counties, is scattered widely through the south-central and northwestern parts of the state. The 20,000 tons of horticultural soil conditioner produced annually in Minnesota are produced on no more than 1,200 acres of peatland, prepared and developed for that purpose. In sum, considering the extent of Minnesota's peat resources, the present and past use of those resources must be classified as small scale. Because of that fact, there exists no previous experience against which to measure the implications and consequences of a large-scale development, were it to occur.

In response to that dilemma and to the necessarily non-site-specific nature of the present study, MRI outlines in this report a "scenario" approach to analyzing the implications of a large-scale development. A crucial aspect of this approach involved creating a *representative peatland area* and three *development scenarios*. An equally important part of the approach is an *impact ranking methodology*. The representative peatland and the three scenarios contain the data base for the impact ranking methodology. The latter is a means to quantitatively evaluate impacts and is intended to *supplement* other impact assessment approaches.

To create the representative peatland area, an area extensive enough in size to allow for, say, an intensive agricultural operation or a power plant facility, six peatland areas in the state encompassing more than 100,000 contiguous acres each were studied. On the basis of this examination, which considered both the natural characteristics of these actual peatlands and the socioeconomic setting in which they occur, a representative peatland area was delineated. Next the scenarios were selected. Because a "large-scale development" hypothetically could be just about anything--a commercial peat operation, a large-scale agricultural operation, a direct burning power plant, a gasification plant, a chemical feedstock plant, or the development of recreational areas--it was necessary to select for study several representative types and scales of development for the scenarios. Finally, an impact ranking methodology was devised to allow the implications of each scenario to be quantitatively weighed and evaluated.

REPRESENTATIVE PEATLAND

A representative peatland area of 200,000 acres was selected as the "setting" for the three development scenarios. This setting also serves as the no-development scenario. The selected peatland is representative of several large bog areas in northern and northwestern Minnesota which could be sites for a large-scale peat development. This representative bog was selected by comparing peat types and depths, surface water flow patterns, hydrology, physiography, forest and vegetation cover, game, fish and wildlife, and other natural environmental characteristics. In addition, social and economic characteristics were introduced by postulating several small towns and communities in the vicinity of the representative bog.

About one-half of the representative peatland area, approximately 90,000 acres, and about 150,000 acres of mineral uplands with various amounts of land development are described. The natural habitats include the open, grassy fens, which are also water courses during periods of high water, dwarfed black spruce and tamarack or muskeg, and raised *Sphagnum* bogs with tall stands of black spruce. Land development is of very low intensity, consisting of a few small towns, light industry, and little agriculture.

DEVELOPMENT SCENARIOS

To allow consideration of several large-scale developments of the peat industry in Minnesota, three development scenarios were selected:

- A large agricultural development
- A commercial (horticultural) peat operation
- A large-scale gasification plant

The three development scenarios were selected in an effort to provide a fairly broad spectrum and analysis of impacts, ranging from the agricultural development, in which no peat is removed, to the commercial peat operation, in which a moderate amount of peat is removed, to the gasification plant, which would consume large amounts of peat.

It should be stated at this time that the scenarios selected by MRI are wherever possible based upon existing data; however, much of the information contained in the scenarios is by necessity, for lack of substantive data, largely hypothetical and are only meant to provide a vehicle to allow the performance of initial impact calculations. It was beyond the scope of the present program to perform the calculations and evaluations that would be necessary before actually carrying out any of these postulated development efforts. We believe that many of the features incorporated into the scenarios probably would be encountered in a "real world" situation.

IMPACT ANALYSIS

A tentative procedure is proposed for identifying and ranking the major environmental, economic, and social impacts related to each of the postulated scenarios. Because of the different impacts that would be associated with the construction, operation, and land reclamation phase for the various scenarios, the magnitudes of the impacts are related to the undeveloped or "natural" conditions so in reality, a fourth scenario--no development--is also considered. This selection of scenarios, with their associated impacts, is considered sufficient to allow preliminary evaluation of a broad range of policy options. The impact ranking procedure allows evaluation of anticipated impacts between the years 1980 and 2000.

REPRESENTATIVE PEATLAND

GENERAL

A hypothetical peatland representative of northern Minnesota peatlands is shown as a map in Figure 7.1. It incorporates the essential features of the natural environment, generally the midpoint along the climatological and biogeochemical gradients, and the average social and economic characteristics of the northern Minnesota peatlands. This hypothetical peatland, of which 90,000 acres out of a total of 200,000 acres are illustrated, serves as the setting for three development scenarios which are described later. It also serves as the no-development scenario. This smaller acreage developed as a compromise only to illustrate the characteristic features of both the natural environment of the peatland and the surrounding socio-economic setting on the upland. One of several peatland drainage streams forms the focus of the vegetation patterns in this section of the bog.

About 35 percent of the representative peatland is open fen, and another 35 percent is stunted spruce habitat. About 10 percent each is patterned fen, raised bog, and shrubby wetland.

The open fen is represented by stippled areas and serves as the main pathway for surface flows of snow melt and storm water.

The alternate light and dark stippling transverse to the long axis (and hence flow) of the fens represents differences in elevation and type of vegetation. The dark areas are ridges; the lighter areas the pools. The longitudinal streaks represent concentrations of trees and shrubs, including the small tree and shrub islands characteristic of the western peatlands.

Stunted spruce and tamarack are represented by the widely spaced conifer-shaped tree silhouettes, while the more densely spaced silhouettes depict timber-quality spruce and tamarack. The raised bogs have this dense pattern of tree symbols, but with rays from the crest of timber quality trees. The extensive, lattice-like pattern of drainage ditches prevalent in the larger, western peatlands is not included in this figure. These ditches were dug in the early 1900's to dewater the peatlands for agricultural purposes. This venture proved unsuccessful and ownership of many of these peatlands eventually went to the state. Recent studies show that a much closer spacing of ditches is necessary to effectively drain such bogs, on the order of every 75 to 150 feet compared with 1 mile. These drainage ditches are readily apparent on aerial photos and are included on the U.S. Geological Survey topographic maps. Many of these ditches presently are filled with vegetation. Some still function as carriers of surface waters, and are dammed in many places by beaver which use the aspen growing on the old spill sides. Black ducks also frequent these ditches. Aerial photos indicate that these drainage ditches have had very little effect on vegetative patterns even a short distance from the ditch.

Shrubby wetlands are found primarily on mineral soil, which is represented by the areas, along streams and generally at the margins of the extensive peatlands. The shrubby areas are depicted on the map by bars and shrubby spikes with and without bars.

Surrounding this peatland is wet-to-dry mineral upland and stream valleys, the upper at elevations nearly 30 feet lower than the peatland. Towns, roads, forested lands, and farms representative of northern Minnesota are located on the upland.

The upland forest is represented by a symbol spreading the crown of numerous deciduous trees. Portions of this forest which have been cut for timber are represented by the rectangular intrusions into this forest.

Adjacent agricultural land is indicated by narrow rows of dots depicting fence rows. Other examples of the human environment features are illustrated on the map of the representative peatland.

The towns range in size from approximately 11,000 people, e.g., "Range City," down to about 110, e.g., "Fenberg." The highway system is mostly county roads connecting with the relatively few state and federal highways and more numerous dirt roads. A railroad is depicted crossing the bog using mineral islands and buried ridges where the peat is shallower. These socioeconomic characteristics are more fully described later in this section.

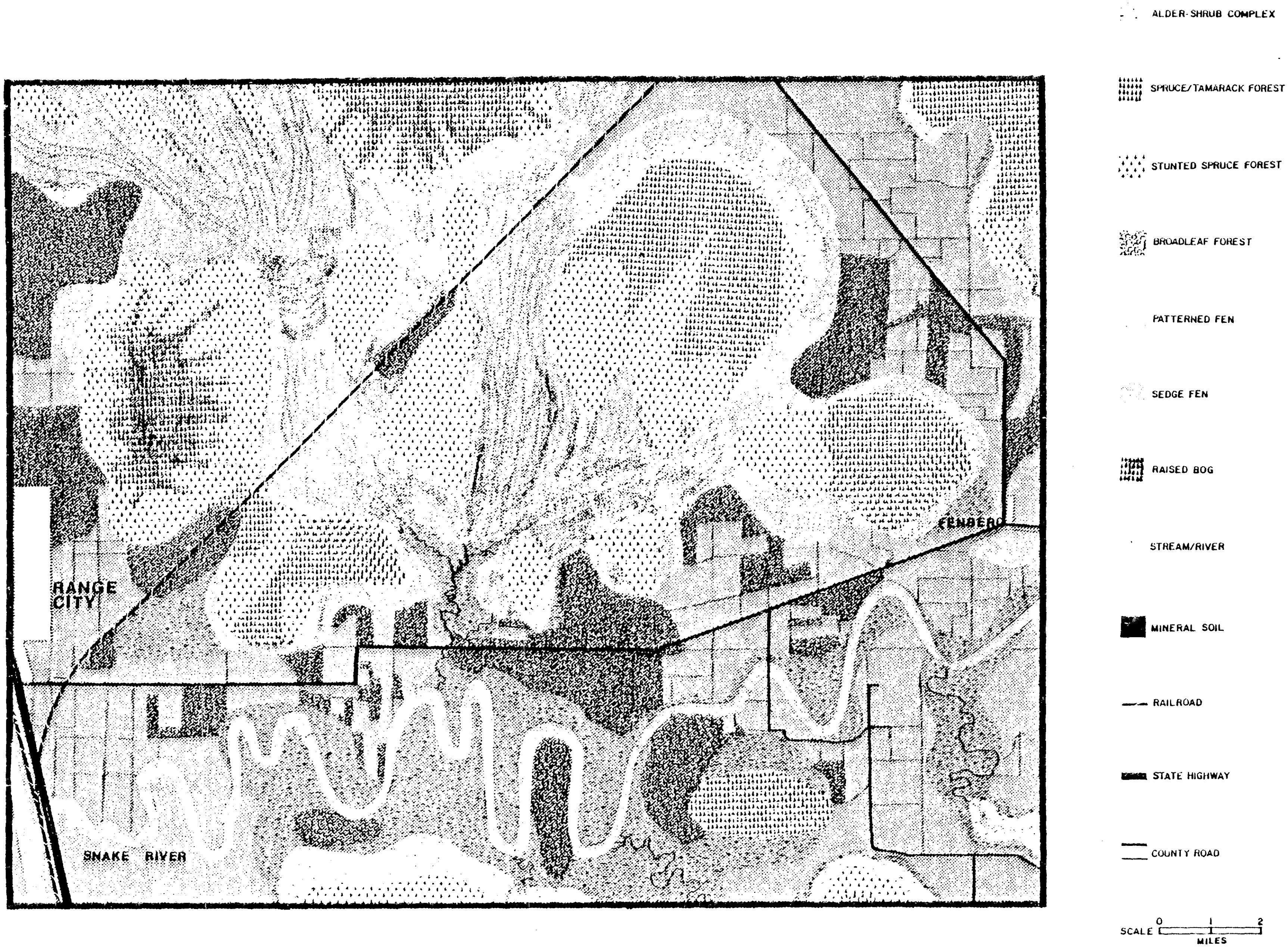


Figure 7.1. Representative Peatland

NATURAL

A cross-section along a typical transect on this peatland shows the relations between elevation, water table depth, peatland drainage, vegetation, animals, and three general types of peat (Figure 7.2). There is insufficient information on which to base a detailed discussion of these relationships. A list of representative plant and animal species (condensed from Appendix E) is superimposed over the transect and grouped according to habitat(s).

VEGETATION

The open fen and ridge tops in the patterned fen are dominated primarily by sedges, grasses, wildflowers and shrubs such as raspberry, swamp birch, cinquefoil and leatherleaf. Mosses, including *Sphagnum*, are common. Narrow ridges are occupied primarily by sedges, grasses, and some shrubs, while the larger ridges also have spruce and tamaracks. The pools in the patterned fen contain a more aquatic flora, including *Menyanthes*, pondweeds, bladderworts, and the more aquatic species of sedges and mosses.

At slightly greater elevations than the adjacent fens are located the stunded spruce and tamarack habitats. The water table is very close to the peat surface here, as it is also in the fens. While these trees dominate visually, shrubs and *Sphagnum* moss are more abundant. Characteristic shrubs are leatherleaf, bog rosemary, and blueberry. The last species is most abundant on sites recently disturbed by fire or logging.

Timber spruce sites and raised bogs are higher still than either adjacent stunted spruce and tamarack or fen. There appears also to be a greater depth from the peat surface to the water table, probably because of the greater evapotranspiration rates caused by the vegetation. Leatherleaf, labrador tea, bog laurel, cranberry are common and orchids may be found, except where the spruce is especially dense. In this deep spruce forest only mosses (other than *Spaghnum*) carpet the forest floor.

The shrubby wetlands on shallow peat near the mineral uplands consist predominantly of willows and alder with sedges and grasses. Along the stream banks, trees are common which prefer moist mineral soils, including silver maple, paper birch, black ash, and basswood. Willow and alder shrubs occur here also, as do many kinds of wildflowers.

The drier mineral uplands are dominated by a mixed coniferous-deciduous forest. Red and jack pines characterize the conifer portion, while the deciduous portion is composed mainly of silver and red maple, aspen, basswood, ash and paper birch. Ferns, clubmosses and many wildflowers, especially orchids, may be found.

ANIMALS

Seven plant habitats may be recognized, which are grouped into four animal habitats because of the limited information available. Because of fragmentary information, the animal associations depicted are somewhat conjectural. Further efforts will be directed towards the literature and field studies for the Phase 2 program.

The open and patterned fens are frequented mainly by only a few small mammals and birds. Perhaps the most common mammal is the bog lemming, which occurs in no other type of habitat. The star-nosed mole and least weasel also occur here. (Other small mammals may be common also, but information is inadequate). The small birds are typically sparrows and the short-billed marsh wren, and occasionally the American woodcock and yellow rail; less frequently a hawk owl makes an appearance. In winter these fens may be frequented by large mammals, particularly moose and timber wolf.

A greater variety of birds and mammals are found in the stunted spruce and tamarack and the timber spruce habitats. Sparrows, warblers, thrushes, flycatchers, and woodpeckers are common. This is the prime habitat of the secretive spruce grouse and the red squirrel as well. On the forest floor are species of mouse, mole, shrew and chipmunk. This is the major habitat of the snowshoe hare and the lynx, which preys principally on the hare. Wolf, deer, and moose may be found on the less dense sites in winter.

Streams and stream banks, shrubby wetlands, and the uplands are the common habitats of the more familiar birds and mammals. In these habitats most of the furbearers such as beaver, otter, muskrat, and mink are found, as are big game species including ruffed grouse, white-tailed deer, moose and bear.

	Streams and Banks		Patterned and Open Fen		Stunted Spruce and Tamarack	Timber Spruce (Raised Bog)	Shrubby Wetland	Upland
Animals	Merganser Black Duck Common Goldeneye Belted King-fisher Gray Jay Raven Osprey Bald Eagle Red-Winged Blackbird	Beaver Mink Otter Muskrat Water Mice Fisher Long-tailed Weasel Raccoon Bobcat Moose White-tailed Deer	Yellow Rail Hawk Owl American Woodcock Short-billed Marsh Wren Sparrows	Star-nosed Mole Bog Lemming Least Weasel White-tailed deer Moose Timber Wolf Coyote	Spruce Grouse Goshawk Saw-whet Owl Woodpeckers Flycatchers Boreal Chickadee Winter Wren Thrushes Golden-crowned Kinglet Warblers Sparrows White-tailed Deer Moose	Woodland Deer-mouse Star-nosed Mole Saddle-backed Shrew Red-backed Vole Snow-shoe Hare Least Chip-munk Red Squirrel Lynx Timber Wolf	Ruffed Grouse Sharp-tailed Grouse Short-eared Owl Alder and/or Willow Fly-catcher Nuthatches Chicadees Gray Jay Cardinal Raven Red-tailed Hawk Sparrows	White-tailed Deer Black Bear Timber Wolf Bobcat Fisher Weasels Porcupine Squirrels Mice Shrews Rabbit Bats
Vegetation	Willow Alder Sedges Grasses Pondweed Silver Maple Paper Birch Black Ash	Basswood Cattails Burweed Beggar's Ticks Ferns Horsetails Orchids	Menyanthes Pondweed Bladderwort Sedges Mosses Liverwort	Sedges Violets Aster Bedstraw Raspberry Swamp Birch Shrubby Cinquefoil Leatherleaf Phragmites Sphagnum Mosses	Spruce Tamarack Swamp Birch Leatherleaf Bog Rosemary Blueberry Cranberry Pitcher Plant Sundew Sphagnum	Timber Spruce Leatherleaf Labrador Tea Orchids Bog Laurel Cranberry Sundew Sphagnum Mosses	Willow Alder Sedges	Red Pine Jack Pine Silver Maple Basswood Black Ash Paper Birch Ferns Club Mosses Orchids Indian Pipe Liverwort
Habitats	Streams and Banks		Patterned and Open Fen		Stunted Spruce and Tamarack	Timber Spruce (Raised Bog)	Shrubby Wetland	Upland

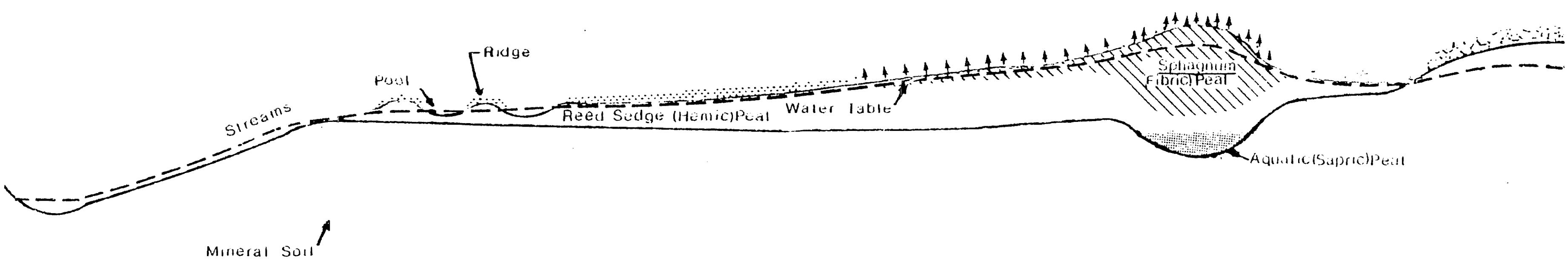


Figure 7.2. Representative Transect Across Peatland

UNIQUE SPECIES

Some of these plant and animal species occur in such small numbers in the U.S. and/or Minnesota that they are scarce or in danger of becoming extirpated or extinct. Thus they are given special recognition for protection and management. The U.S. maintains only one category, while Minnesota recognizes six categories, of scarce species. Both the U.S. and Minnesota list as (1) "Endangered" those species whose populations are so small that the species are on the verge of becoming extinct. Minnesota's five other categories are: (2) "Threatened", (3) "Species of changing or uncertain status," (4) Species of special interest," (5) Species extripated or rare in Minnesota," and (6) "Extinct species."

Based on the information available for this preliminary study, plant and animal species occurring in the representative peatland area include (1) one endangered species (U.S.), (2) one threatened, (3) ten species of changing or uncertain status, and (4) three in the special interest group. None of the two extripated or rare in Minnesota are included in the representative peatland.

The eastern timber wolf, greatly reduced in range in the eastern U.S. compared with earlier times, is recognized as (1) "Endangered" by the U.S. In Minnesota where it is not so scarce, it is classified by the State as (3) "Species of changing or uncertain status."

The sandhill crane, which nests in stunded spruce and tamarack and visits willow marshes, is recognized as two subspecies: The Mississippi and Greater Sandhill Cranes. The former subspecies is listed as U.S. (1) "Endangered", while the Greater Sandhill Crane is listed by Minnesota as (2) "Threatened."

Two species in the (3) "Species of changing or uncertain status" category frequent the peatland: the eastern timber wolf (discussed above under (1) "Endangered") and Canada lynx. Spruce bogs are the prime habitat of the lynx. The remaining eight species in this category are found in the upland forests and grassy areas or around streams and lakes in the peatland area. This species include the fisher, northern bald eagle (the southern bald eagle is on the U.S. Endangered list), osprey, marsh hawk, Cooper's hawk, double-breasted comorant, common tern, and rock mole. (However, the last species, a small mouse-like roden is known from only St. Louis County and by two specimens; the last one was collected in 1940.)

The category of (4) "Species of special interest" includes, in the representative peatland area, the bobcat (in the uplands), common loon (on lakes), and great blue heron (on lakes and streams).

SPECIES DIVERSITY AND PRODUCTIVITY

Plants and animals possess more or less interdependent reactions and rhythms. When one species reacts to the physical environment or another species, interactions with other species can also be affected. Thus a complex network of interactions exists among plants and animals in any area, forming an endogenously maintained unique natural (ecological) system. And the characteristics of these ecosystems extend beyond the sum of those of the component species. Unusual changes in the environment may significantly alter or even disrupt the entire ecosystem.

Species diversity and productivity are two important characteristics of ecosystems which indicate the degree of system disfunctioning. The former characteristic is an index of the variety of functioning biological units i.e., the number of species. The size of each of these units may also be considered by using a more complex index which considers both the abundance and variety of species. A high index of diversity occurs when an ecosystem contains a large number of species, and relatively equal abundance of individuals in each species populations. Coral reef and tropical forests are good examples. These systems are characterized by moderate and quite stable conditions for plants and animals. In areas where physico-chemical stresses are more extreme, because of man or nature, diversity is less. For example, discharge of abnormally large quantities of otherwise limiting nutrients produces masses of a few species, and less tolerant forms die. An abundance of one species (low diversity) occurs naturally in the salt-grass tidal marshes and the cattail marshes. Other physically stressful habitats are thermal springs, deserts, polar regions, and nutrient poor lakes.

Species diversity of the representative peatland area is high compared with the whole state (Table 7.1). Little of this diversity can be accounted for in the fen and spruce habitats on the basis of the limited information available.

Table 7.1 Preliminary Data of the Relative Species Diversity of Peatlands

Species	Minnesota[1]	Peatlands[2]	Spruce	Fen
Conifers	13	5	2	0
Mammals	73	55	11	6
Birds	293	154	30	9

[1]Moyle, 1974

[2]Includes mineral uplands.

Productivity (rate of production) is the other important indicator of ecosystem functioning, and is determined as the amount of biomass (weight) produced per unit area (or volume) per unit time. When nutrients and other environmental factors are at optimum, productivity is very high; e.g., salt-grass tidal marshes, cattail marshes, and lakes receiving abundant and rich sewage treatment plant effluent. Where nutrients are very low, or other factors are limiting, there is little productivity as in trout lakes.

Northern Minnesota peat habitats are probably low in productivity as well as diversity compared with other types of habitats (Table 6.2). Shrubby wetlands and other more mineral rich peatland sites, however, may be as productive as upland communities. Kjelvik and Kärenlampi (1975) report willow thicket productivity greater than 800 g/m^2/year in southern Norway.

Table 7.2. Productivity of Peatlands Compared with Other Habitats (Moore and Bellamy, 1974)

Habitat	Net Production g/m^2/year
Arctic tundra	100
Sphagnum bog (no spruce)	340
Blanket bog (England)	635
Temperate Oak Forest	900
Cattail Marsh	2900

LAND

The soils found in the fen habitats are termed reed-sedge (hemic) peat and are finer-particled, more decomposed, richer in nutrients, and circum-neutral in pH than are the *Sphagnum* (fibric) peat soils in the spruce habitats. The latter soils have a better water-holding capacity. *Sphagnum* peat develops to great depths on the raised bogs compared with the stunted spruce and tamarack areas. Reed-sedge peat may occur underneath this deep *Sphagnum* peat, and aquatic (sapric) peat may occur as a basal layer in shallow depressions in the underlying mineral soil surface. These depressions may represent former ponds and small lakes.

Probably very little waste disposal occurs on peatlands and, thus, none is depicted on the representative peatland in the undeveloped state.

In fens as well as stunted spruce and tamarack habitat, the water table is at or very close to the surface as shown in the cross-section (Figure 6.2). Better drainage and increased evapotranspiration in the raised bog depresses the water table, which is suggested by the literature and limited field studies during this Phase 1 program (See Appendix C).

round water within the peat soils is of very limited quantity. The peat holds it like a sponge; when a well is bored but not cased, almost all of the water entering the well enters from the uppermost levels of the water table. This water is soft and low in dissolved solids, although high in iron. On the mineral uplands the water table is considerably deeper than in the peatland. Here the quantity of available water is greater, although wells are generally not high volume. The mineral soil ground water is typically very hard (235 mg/l $CaCO_3$ hardness), moderately high in total dissolved solids (300 mg/l), and very high in iron.

AIR

The saturated soils and their wide occurrence characteristic of the representative peatland has impeded development in the area. Thus a wilderness-like atmosphere pervades. Noise and air pollutants are nearly absent except for an occasional vehicle or small-scale and infrequent timber harvest. Particulates average 31 $\mu g/m^3$ while sulfur dioxide averages 0.001 $\mu g/m^3$ annually. The main sources of these air contaminants are distant industrial processes and fuel combustion (probably power plants).

The climate is typical of northern Minnesota, except that there are only 90 frost-free days on the peatland compared with 115 on the upland. Mean annual temperature is 29°F. Precipitation amounts to 24 inches annual and falls mainly from spring through early fall. Snowfall is about 9.5 inches/month, with a total annual accumulation of about 47 inches. Precipitation exceeds evaporation by about 15 percent.

WATER

Surface waters in the peatland area are mainly streams. During snow melt and heavy rains large areas of the peatland may be under water, however. Streams provide an abundant supply of high quality water for most purposes. Discharge varies from several hundred cubic feet per second during summer to about ten thousand cubic feet per second during spring melt. The streams are "tea" colored as a result of the iron-rich dissolved organic substances coming from the peatlands. Pathogens, nutrients at levels which promote eutrophication, and toxic substances are absent from the peatland, except just downstream from "Range City." Except in this zone, total phosphorus is less than 0.04 mg/l and total nitrogen is 0.35 mg/l.

Dissolved oxygen in the streams is always sufficient for cold water fish such as trout, and walleye, bass, pike and pan fish are also common. The streams support a hard water flora. The streams have an alkalinity of 100 mg/l, and sulfates and chlorides are low, at 6 and 1.5 mg/l, respectively (see Tables C-1 and C-2, Appendix C). The pH is neutral to slightly alkaline. Drainage ditches in contact with mineral soil possess a similar characteristic. Well sites on peatlands within 150 feet of ditches indicate typical peatland water quality: acid pH, low in alkalinity, calcium, magnesium and sodium, and apparently higher in ammonia and total phosphorus. Thus, water draining from the representative peatland quickly loses its acidity, acquires calcium and other substances causing hard water, and perhaps loses nutrients.

SOCIOECONOMIC

The representative site is located in a fairly remote area of a sparsely populated county. The population density within a 30-mile radius of the site averages 3.8 persons/sq mi, which is somewhat less than both the population density for the county as a whole (5.5 persons/sq mi) and the population density for the "development region" to which this county belongs (18.6 persons/sq mi). Within 30 miles of the site are located several small unincorporated towns, several small incorporated municipalities, and one relatively large full-service regional trade center. The population density and transportation systems in Minnesota's peatlands are illustrated in Figures

SMALL TOWNS

The smaller towns and communities within 30 miles of the site range in population from less than 100 to more than 600. The smallest is an unincorporated town with only 25 residents. The more intermediate size towns, with populations ranging from 110 to 650, are all incorporated municipalities which offer some services and employment to their residents. The largest of these intermediate municipalities is located within 6 miles of the site of the proposed development. The regional trade center, with its population of somewhat over 11,000 is the only municipality in the entire county with a population over 1000. It is the manufacturing and retail trade center for the county and for a portion of the neighboring county, and is the place of employment for almost 80 percent of the county's labor force.

The town of Fenberg, with its population of 110, is located within 3 miles of the large bog that is the representative peatland area. The residential area of the town includes areas where mobile homes are interspersed with frame houses, some delapitated stores and service facilities. There is a sawmill at one end of the town, a wild rice processing plant, a bulk fuel storage site, and a pulpwood storage area. The town has no municipal water or sewer facilities.

Spruceville, which has a population of 650, is a considerably larger community. It is located about 20 miles from the development site. The residential area is made up primarily of frame buildings, with mobile homes and pre-fab houses scattered here and there. The commercial area has developed on both sides of the trunk highway which runs through the town, dividing the shopping district roughly in half. Several municipal streets cross the highway. The town has two sawmills, a pulp loading area, and bulk fuel storage facilities. The sewage facility consists of a primary settling tank, a high-rate trickling filter, and a final clarifier. The treatment plant is producing an end-pipe effluent quality that is better than the final effluent standards set by the MPCA.

A brief characterization of the two towns is presented in Table 7.3, and town maps are presented in Figure 7.3.

Table 7.3 . Demographic Characteristics

	Total Population	Male	Female	Median Age	Percent Under 18	Percent Over 65	Households	Persons/ Households
Fenberg	110	60	50	32.3	34.8	17.1	31	3.54
Spruceville	650	320	330	38.2	31.9	19.5	230	2.82

Fenberg

Spruceville

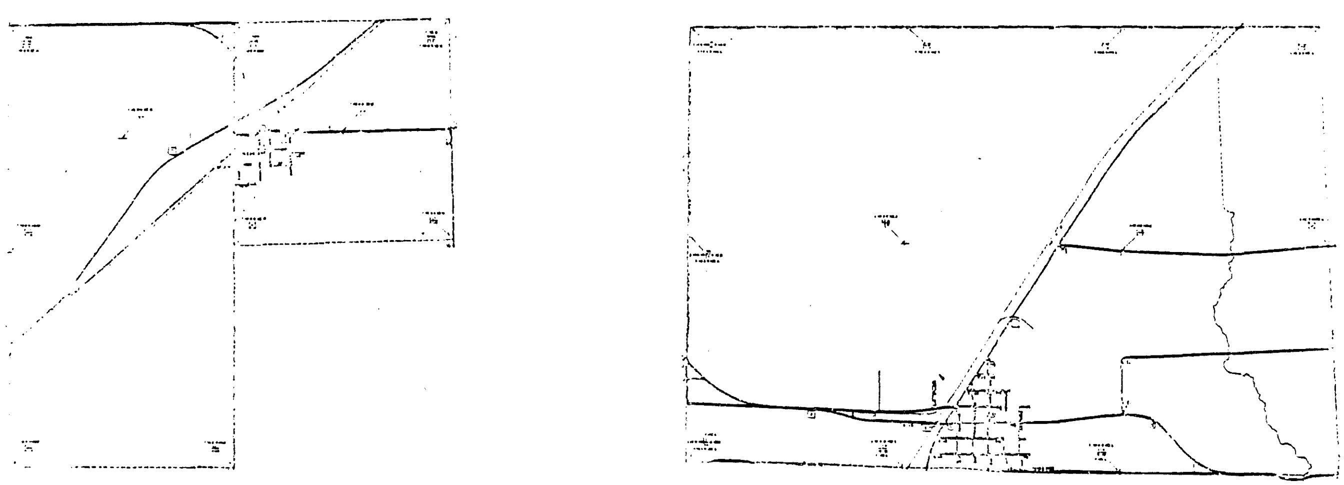


Figure 7.3 . Town Maps

REGIONAL TRADE CENTER

Range City, which has a population of more than 11,000, is the largest city in the county and functions as one of the regional trade centers in the north-central part of the state. Roughly 80 percent of the county's work force is employed in this trade center, working principally in the wood products and mining industry. Much of the land within the city is used for residential housing. The older homes are over sixty years old and are closely situated on "city" sized lots. Newer subdivisions, which have leap-frogged over vacant areas nearer to the older residential areas, constitute an incipient urban sprawl.

The city has a 60 bed hospital, which is hard-pressed to meet present (not to mention future) demand, five elementary schools, a junior high school, and high school. The elementary and junior high school enrollments are currently slightly under the capacity of the facilities. The high school enrollment is 30 percent over its capacity. Municipal water and sewer lines are provided within the city limits. Plans to extend these lines are currently being made.

A community "profile" of Range City is presented below:

Population

	City
1950	10,200
1960	10,900
1970	11,300

Industry

	No. Employees
Paper Industry	700
Mining Industry (Taconite)	800
Clothing	100
Small Manufacture	500
Wood Products	100

Employment

	Male	Female
Manufacturing	1,768	142
Non-Manufacturing	2,336	984
Total	4,104	1,126
Total Total	5,230	Percent Population: 46.4

Transportation

Rail Lines: North Central
Frequency: 2 daily   Passenger: No
Reciprocal Switching: Yes
Distance to Main Line: On Main Line

Truck Lines: State Motor Freight, Local Transfer
No. Terminals: 2   Overnight Service to: Mpls/St. Paul

Railway Express: Yes   United Parcel: Yes

Airport: Yes
Airlines: Central Airlines

Bus: Greyhound

Highway Route Numbers: Interstate: None Federal U.S. 75 State # 37, 377

Load Limits: 37 (5 tons) 377 (7 tons)

Distance to Interstate: 95 miles to I-35

Taxes

Municipal Rate	5.43/100.00 valuation
County	5.69/100.00 valuation
School	8.06/100.00 valuation
Total rate	19.18/100.00 valuation

Government

Organization: (X) Mayor Council ( ) Limited Mayor ( ) Management Council

Area within city limits: 5400 acres Undeveloped: 860 acres
Parks: 50 acres

Police Force, Regular: 16 Fire, Regular: 10 Volunteer: 25

Annual Budget: $1,400,000 Primary Source: Taxes

Streets % Paved: 80 Territory covered by zoning: Municipality (X)

Master Plan: (X) Yes ( ) No

Insurance Rating: 1 2 3 4 5 6 7 8 9 10

Utilities

Water

Municipal Source: (X) Stream ( ) Wells ( ) Lake
Storage Capacity: 800,000 gals
Pumping Capacity: 1,600 gal/min Ave. Demand: 700 gal/min
Peak Demand: 1,300 gal/min
Total Hardness: 390 ppm

Sewer

Capacity Treatment Plant: 1.20 mil G/D Peat: 2.0 mil G/D
Area Covered: City

Electricity

Electric Service by: Minnesota Power/Light

Gas

Gas Service by: Propane gas only

Telephone:

Telephone Service by: Northwestern Bell

Community Services

Hotels: 1 Total rooms: 100 Number Motels: 10
Hospital Beds: 120 Doctors: 16 Dentists: 12
Churches: Protestant: 10 Catholic: 2 Jewish: None
Parks & Playgrounds: Municipal: 11 State: 1 Private: None
News Media: Papers: Daily: 1 Weekly: 1 Radio: AM: 1 FM: 1
T.V. Network Affiliations: None Reception: ABC, NBC, CBS, NET
Meeting Facilities, No. of: 6 Capacity of largest three: 5,000
No. Chain Retail Stores: 12 Major Dept. Stores: 1
Banks/S&L/Deposits:

Mid-National	$10,000,000
Security Federal	$ 7,000,000
First Minnesota S&L	$23,000,000

Public Libraries: 1 No. Volumes: Technical: 1,000 Total: 40,000

Education

No. Elementary Schools:	5	enrollment:	2,100	grades:	K-6
No. Junior High Schools:	1		1,100		7-9
No. High Schools	1		1,000		10-12

Annual Cost Per Pupil: $860.00 Pupil/Teacher Ratio: 23:1

No. Parochial Schools: 2 enrollment: 400

Nearest Vo-Tec School: 100 miles

Nearest Junior College: In City

Nearest Liberal Arts: 70 miles

Nearest Engineering: 250 miles

Nearest Graduate School: 150 miles

COUNTY

The county in which the development scenario has been set is, as has been stated, a sparsely populated county. Like several other counties in the north-central part of the state, it experienced declining population between 1960 and 1970. Between 1970 and 1974, however, the site county experienced a new period of growth (8.7 percent), spurred mainly by a high rate of in-migration (5.8 percent) of non-agricultural workers and, to some extent, of retired persons over 65. The county's growth rate and migration rate between 1970 and 1974 were higher than the growth and in-migration rates for the state as a whole (2.9 percent and 0.1 percent, respectively) during that same period. Between 1975 and the year 2000, however, the site county is expected to maintain a fairly stable population, while the state's population is expected to grow more than 20 percent (Figure 7.4).

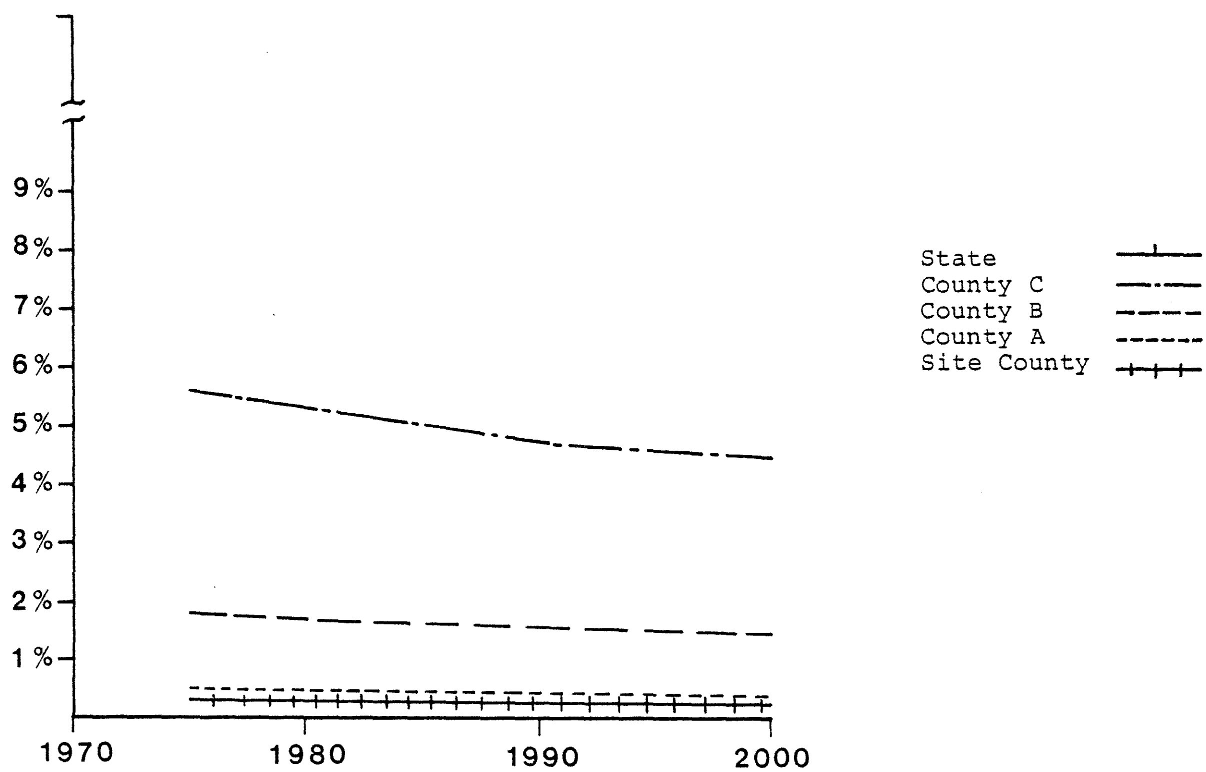


Figure 7.4. Population Growth

One consequence of this difference in growth rates is that the population density of the county, at predicted rates of natural change and migration, will remain relatively stable between 1975 and 2000 (5.5 persons/square mile and 5.6 persons/square mile, respectively), while the population density of the entire state will move upward between those same dates (49.1 persons/square mile and 58.2 persons/square mile, respectively). Refer to Figure 7.5.

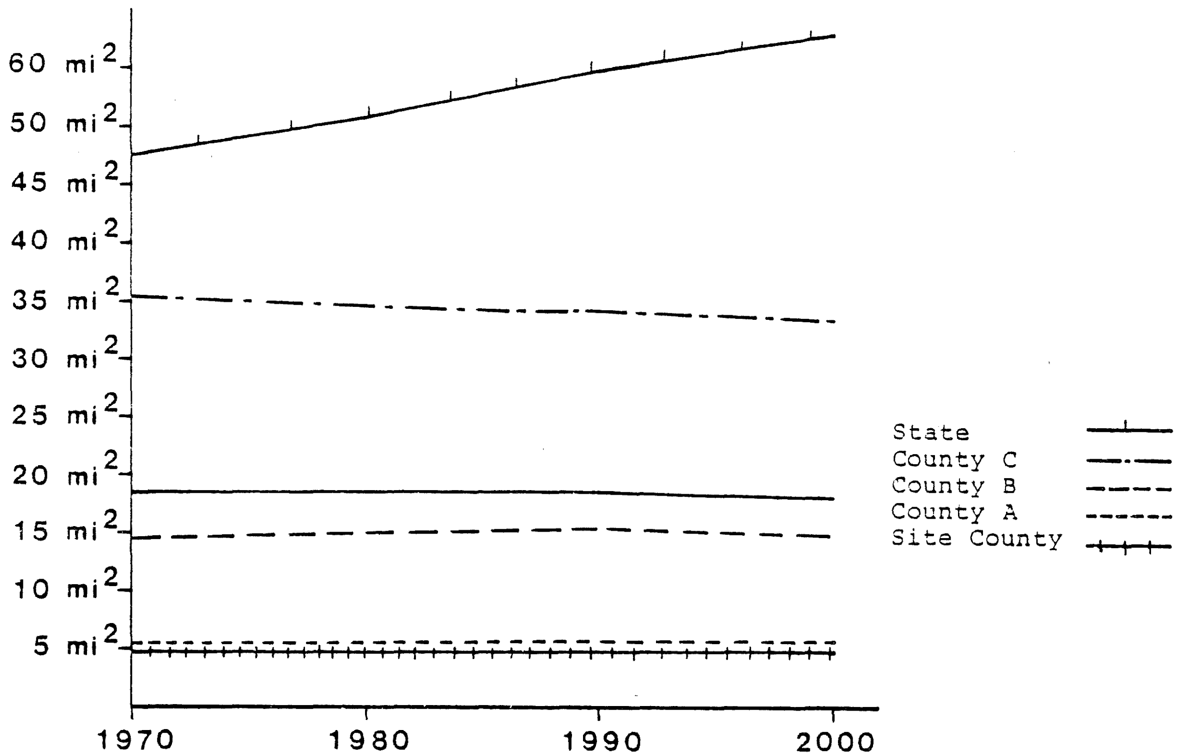


Figure 7.5. Population Density

Other projected changes in socioeconomic characteristics, given present trends, are summarized in Table 7.6.

Table 7.6. Projected changes in selected socioeconomic characteristics

		1970-1980	1980-1990	1990-2000	1970-2000
Population (Percent change)	County	5.5	3.5	-1.7	7.1
	Region	0.2	0.6	-2.1	-1.2
	State	7.1	8.5	5.2	22.3
Population Under Age 20 (Percent)	County	39.1	28.3	25.5	24.7
	Region	39.3	30.5	27.5	26.6
	State	40.1	33.0	29.8	28.7
Population Over Age 65 (Percent)	County	13.3	16.7	18.1	16.7
	Region	11.6	14.0	15.4	15.2
	State	10.7	11.2	11.3	10.9
Median Age	County	32.2	37.1	38.2	39.9

Table 7.6. Projected changes in selected socioeconomic characteristics (continued)

Persons/ Household	County	3.08	2.71	2.47	2.40
	Region	2.96	2.78	2.61	2.59
	State	3.06	2.90	2.69	2.62
School Population (Percent of 1970)	County	100.0	70.9	64.2	65.4
	Region	---	---	---	---
	State	100.0	83.4	81.2	86.1
Elementary School Population (Percent of 1970)	County	100.0	57.0	73.1	63.5
	Region	---	---	---	---
	State	100.0	69.7	83.2	80.2

Several observations can be made here concerning the socioeconomic condition of the site county. The county in which the development scenario is set lags significantly behind the state as a whole in family income and average housing unit value. The average family income in the state in 1970 was $11,097. Average family income in the site county that same year was $7,850. Of the 87 counties in Minnesota, this hypothetical county ranked 78 in 1973 in per capita income, down from 70th in 1969. Per capita income in the state rose from $3,571 in 1969 to $5,143 in 1973. During that same period, per capita income in the site county rose from $2,332 to $3,365, which enabled the site county to just keep pace with the state as a whole (Figure 7.6).

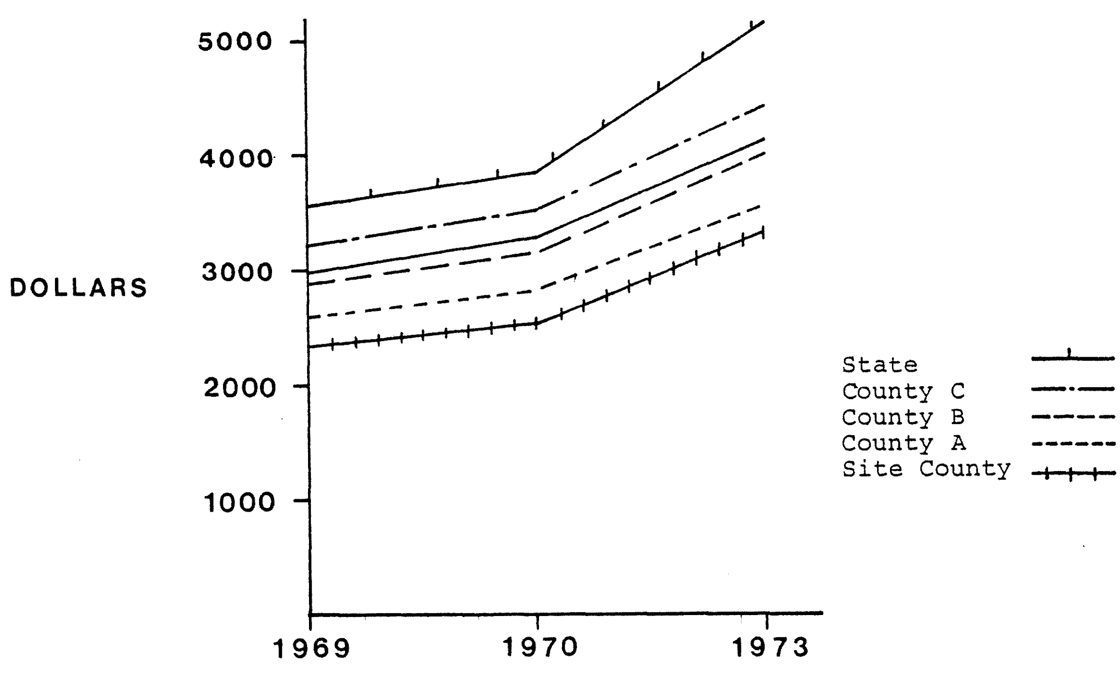


Figure 7.6 Per Capita Personal Income

In the site county, as in the state as a whole, elementary enrollment is expected to decline rather sharply between 1975 and 1980, and then increase gradually over the long run although enrollment will still show a net decrease by the year 2000. Enrollment in secondary schools is expected to increase somewhat in the short term, especially in the county's trade center, but that enrollment, too, is expected to stabilize in the longer run. At the present time, there is overcrowding in several of the county's secondary schools. Projected elementary school enrollment in the county is presented in Figure 7.7.

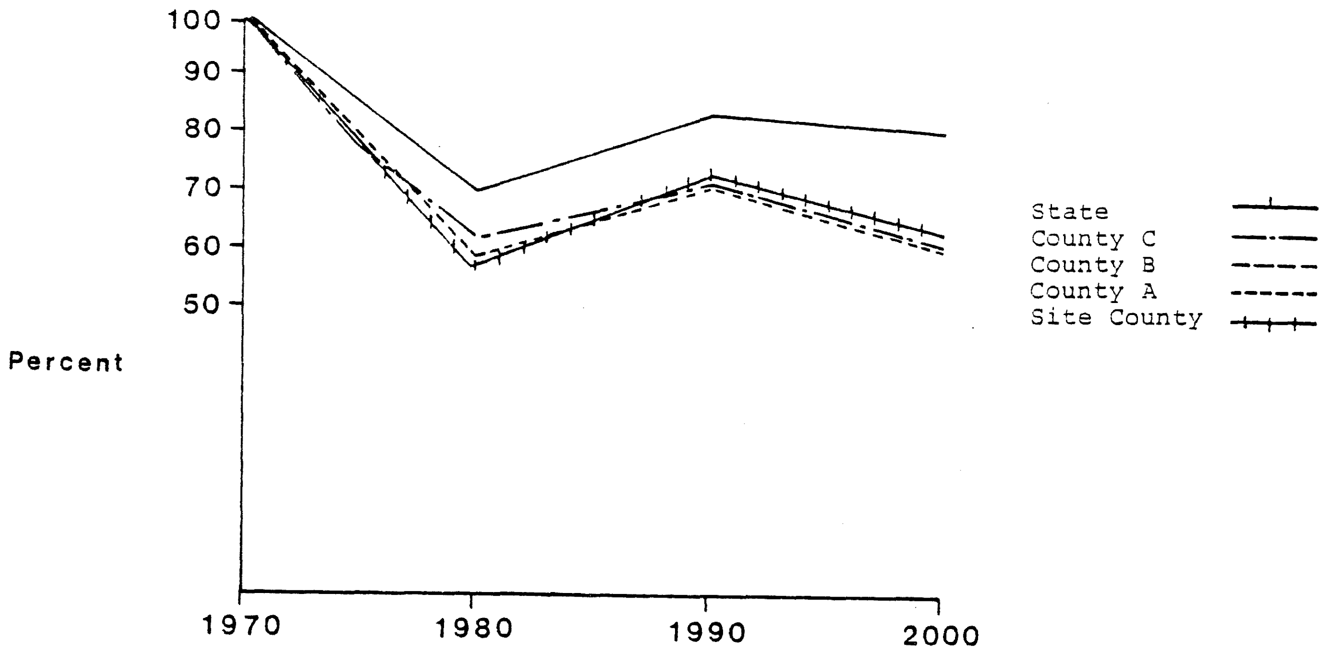


Figure 7.7 . Elementary School Population, Percent 1970

In the site county, as in many of the other counties in the region, seasonal unemployment is relatively high and wages are considerably less than union scale and state averages. In 1974, for example, 2.3 percent of the state's work force received unemployment compensation. But that same year 5.7 percent of the site county's work force received unemployment compensation. Capital expenditures per capita by the incorporated communities in the county were also considerably below the state average in both 1972 and 1973. This pattern of low capital outlay per capita by municipalities in the county, coupled with a pattern of high per capita transfer payments to the county, suggests that the county is not able to generate the revenue it needs to supply public services and facilities. The total assessed value of the county is $20.4 million (1974). This indicates an actual market value of $90.8 million, or $7,800 per capita, which compares to an aggregate assessed value for the entire state of $31.9 billion (1974) and an aggregate indicated actual market value for the entire state of $10,400 per capita. A comparable difference exists between average state and rural land values and average rural land values in the site county. The estimated average rural land value per acre was $423 for state in 1974 but only $144 per acre in the development region of which the site county is a part. The price per acre of rural land rose an average of 42 percent in the state between 1973 and 1974. The price per acre of rural land in the development region of which the site county is a part, however, rose only 25 percent during the same year. Again, these numbers illustrate the slow growth rate and relative depressed economy in the site county.

DEVELOPMENT SCENARIOS

Three development scenarios have been selected for initial study, namely a commercial-horticultural peat operation, an agricultural development, and a large-scale gasification plant. For all three scenarios, it is assumed that the development will begin in 1980 and will be followed through the year 2000. Although three important timeframes can be selected for detailed analysis--early development phase, midpoint development phase, and final development phase--detailed consideration is given in this report only to the year 1990, midpoint in the development period. In the next phase of the Peat Program, consideration should also be given to the other two time periods as well so as to obtain an overall comparison of the impacts that would occur during the entire development period.

For all three development scenarios, the peatland area has to be cleaned and prepared for the operations that are to take place. The greatest amount of preparation is required for the commercial peat scenario, so it will be discussed first. Variations of these procedures will be used for the other scenarios, although less preparation will be required for the agricultural scenario, and probably a different type of preparation will be required for the peat gasification plant scenario because advanced methods of peat harvesting will be required to obtain the large amounts of peat needed for operation of the facility.

COMMERCIAL PEAT

BACKGROUND

Peat possesses excellent qualities as a soil conditioner. *Sphagnum* peat has the capacity to hold a tremendous amount of water, even when it has dried to a relatively low moisture content. Although peat is not a fertilizer, it has the ability to loosen compacted soils and add organic matter. It is clean and easy to handle when properly processed. *Sphagnum* peat is in great demand in the American market and historically this demand has been met partially by imported peat moss.

At the present time, a total of 960 thousand tons per year of horticultural peat is used in the United States. This consists of 630 thousand tons per year of domestic peat and 330 thousand tons per year of imported peat. The assumption for this scenario is that this usage will double by the year 2000. That is, it is assumed that this country will be using 1 million tons of *Sphagnum* peat and 1 million tons of reed-sedge peat for a total of 2 million tons per year. Further, it is assumed that Minnesota will produce 1/4 of the *Sphagnum* peat and 1/4 of the reed-sedge peat for a total annual production of 500 thousand tons per year by the year 2000. (Minerals Yearbook, 1975).

For purposes of development of the scenario, we will assume that the peat usage will increase at a linear rate from the year 1980 to 2000 for both types of peat. It will be assumed that by the year 2000, 10 thousand additional acres will have been devoted to the production of commercial (horticultural) peat.

At the present time, the major commercial peat producer in Minnesota is Red Wing Peat Company, Cromwell, which produces 10,000 tons of baled *Sphagnum* peat annually on 400 acres of developed bog area.

GENERAL DESCRIPTION

The commercial peat operation is shown schematically in Figure 7.8. It is postulated that by the year 2000 a total of 10,000 acres of peatland will be in commercial peat production. This acreage will be equally divided between the fibric type of peat (*Sphagnum*) and the more decomposed hemic (reed sedge). By the year 1990, a total of 5,000 acres will be under production, 2500 acres for each type of operation. It is postulated that both harvesting operations will be serviced by the single processing plant shown in the map. The *Sphagnum* harvesting operation will be on the raised bog

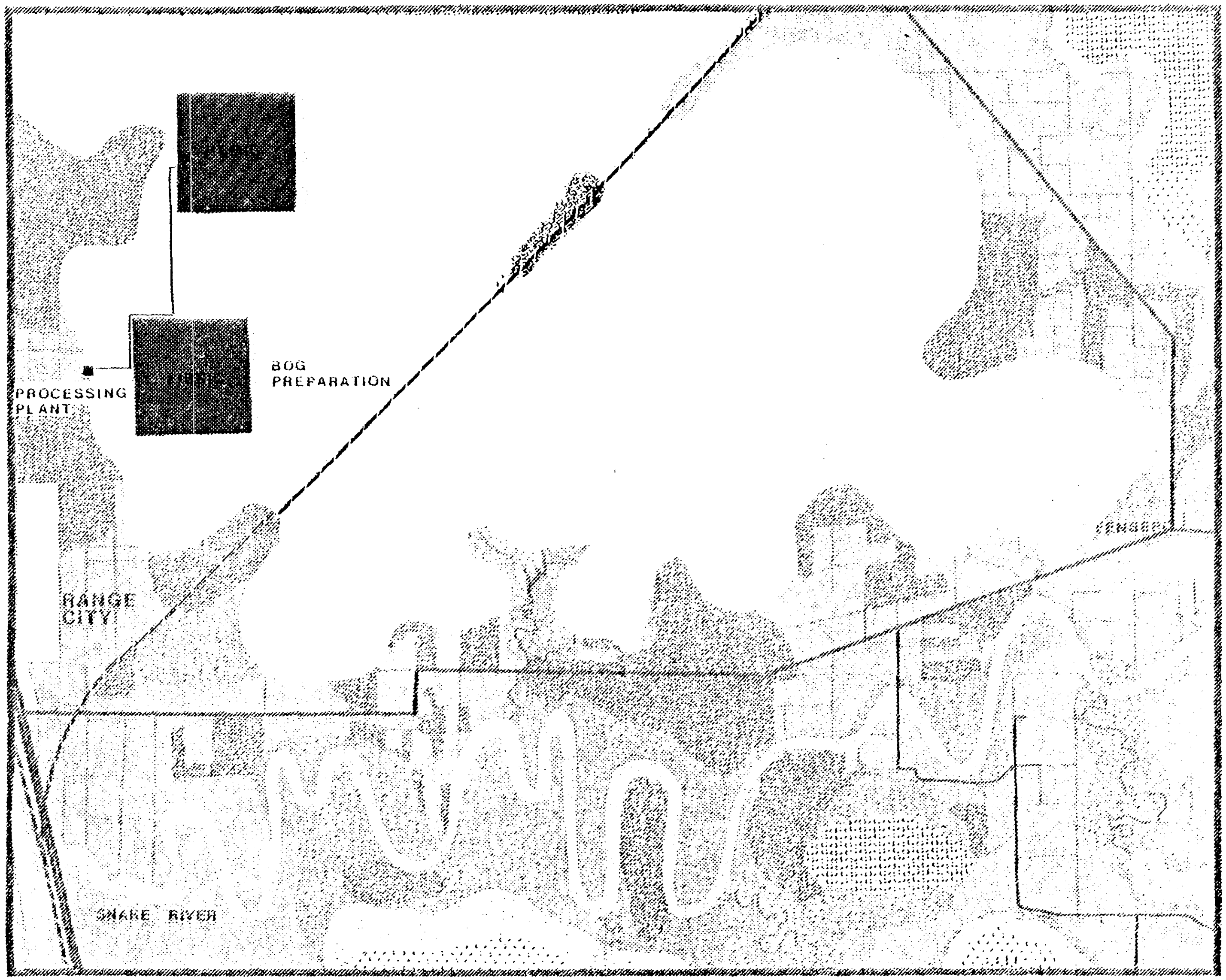


Figure 7.8. Commercial Peat Scenario

area shown adjacent to the processing plant. The hemic peat operations will take place in the sedge-fen area to the north of the *Sphagnum* peat operation. It is estimated that 250 acres for each type of operation will be put into production each year. These are shown as the orange bog preparation areas to the right of each production area. It should be noted that although the commercial peat areas are small compared to the gasification plant peatland acreage, an operation of this size (5,000 acres by the year 1990) is much larger than existing commercial peat plants in Minnesota.

After the peat has been completely harvested in the commercial peatland harvesting areas it is assumed that the land will be reclaimed and put into other uses. This reclamation process is of a much smaller scale, however, than that required for the gasification plant scenario. In addition, the reclamation efforts would not start until about the year 1992. This is because only about 6 inches of peat would be removed each year from the harvesting sites. A harvestable depth of 6 feet is sufficient to provide enough peat for 12 years of operation.

PROCESS DESCRIPTION

INITIAL PREPARATION

To prepare a bog for harvesting, a system of drainage ditches must be installed to adjust the level of the water table and to accommodate rainfall and water runoff. Adjustment of the water level also allows movement of the equipment on the bog surface and facilitates the desired operations. Usually the water level in the bog area is only lowered to about one and a half feet; because of the slow movement of water through the peat, the water content still remains about 80 percent after drainage. *

The first step is to lay out the pattern of the main drainage ditches, access roads, and boundaries of the area that is to be cleared. If plant buildings are a part of the operation, the next step is to provide good access to the plant site and from the plant site to the intended harvesting area. Ditching is usually done along both sides of the roads to lower the water level and stabilize the roadbed. Temporary buildings and workshops are also built as required. And, if necessary, electrical power is brought to the site. In addition, gasoline, diesel oil, and water storage facilities must be provided at the beginning. The bog preparation will usually start around the first of August and is planned for completion by the first of the following year. The actual clearing of the harvesting areas can only be done during the months of January, February, March, and April due to the fact that the peat surface must be well frozen to support the heavy equipment required to do the job. New equipment developed in Europe will allow operation on non-frozen peat.

CLEARING

The objective in clearing a bog is to provide an even surface completely free of all surface growth on which to operate the harvesting quipment or carry out the horticultural operation. Access roads are provided to the areas that are to be cleared, and the overall boundaries of these areas are marked with stakes. All commercial timber is harvested and removed before surface preparation begins. Heavy bulldozers, fitted with special serrated cutting blades, pass over the entire area to smooth irregularities and remove stumps and stunted trees in line with the ditches. After completing the first pass, the process of staking out the windrows is started. Surface removal is started using the big tractors with assistance from small tractors. These tractors, working together, push the debris from the center of the harvesting area to the windrows. At the end of each day's work, the big cats flatten down the windrows they have formed, creating roads. As the frost is going out of the bog, the bulldozers make a third pass and remove the last vestiges of surface growth. Upon completion of this third pass, the bog will be ready for plowing, discing, and root removal.

The next step involves laying out all the secondary drainage systems and plowing the areas. This breaks the capillary action and allows air to circulate in the peat, speeding up the drying actions considerably. After plowing, the remaining roots are removed using a scarifier machine followed by discing.

*For a more complete discussion of various horticultural peat processes see MRI's Report on European Peat Technology, May 1976.

DITCHING

In ditching a bog, care must be exercised in determining the natural drainage patterns. All ditches are designed to take advantage of the natural flow as much as possible. The first step is to provide the main ditches in the bog and plant site area which will carry the water from the site to the natural drainage system. These ditches have dimensions of about 12 feet wide at the top, 3 feet wide at the bottom and 8 feet deep (Figure 7.9). The next step is to cut ditches along the perimeters of the harvesting area segments. These ditches are placed so as not to interfere with the clearing operation. The system should be designed to accommodate runoff from the surrounding watershed to prevent flooding in the harvest area. These ditches are approximately 10 feet wide at the top, 8 feet deep and 3 feet wide at the bottom. The actual spacing of these ditches depends upon whether it is to be an agricultural operation or a commercial peat operation. When the secondary ditches have been completed the bog area is ready for use.*

HARVESTING

Various methods are available for harvesting commercial peat. One that is commonly used in this country, Canada, and several European countries is the milled peat method. The term "milled peat" describes peat in crumb or powder form. It has a mean particle size of about 1/4 inch in diameter, ranging from about 1/2 inch to fine dust. Milled peat is produced over the entire working area of the bog by slicing off a thickness of about 1/4 to 1/2 inch at a time.

Before the peat is harvested, the bog surface is prepared by rotary hoes which pass over the surface at a good rate of speed. Before these small particles are harvested, the surface is raked with a special machine to remove the majority of the roots that always seem to be present. The purpose of this procedure is to break up the capillary connections between the peat particles and the bog surface to accelerate air drying. After a short time period, the layer of milled peat is harrowed to accelerate drying; when it has been air dried to 40 to 50 percent moisture it is then ready for harvesting. The harvesting can either be accomplished using vacuum harvesting machines, which have been developed in the Soviet Union and Canada, or by conventional mechanical methods, in which the peat is scraped mechanically into ridges along the center of each drying field. These ridges are then transferred by harvesting machines into center piles, from which they are gathered for transport to the central storage area.

In Minnesota the harvesting season is from about April 1 through the end of October. There is a 50 percent chance that there will be no harvesting weather in April and October. During the period May through September, Minnesota has about 100 days of harvesting season. Experience in Minnesota has been that, for the first two to three years after clearing and draining an area, it takes from 3 to 5 days of good weather to get a layer of dry surface peat that can be removed. Generally, peat is harvested whenever it can be obtained at less than 70 percent moisture; it is then air dried to 40 percent moisture content.

STOCKPILING AND TRANSPORT

The peat can be stockpiled either at the harvesting site or at the processing plant. Both methods have their advantages and disadvantages. Stockpiling in the fields is the most economical method, since the requirements for tractors are reduced. Stockpiling in the field also allows for the most versatile use of the labor force. A disadvantage of stockpiling in the field is that it must then be brought to the processing plant during the wet months when transport over the bog surface is difficult. In addition, the movement is slower and extra equipment is needed to deliver the same volume to the processing plant that would be obtained during the summer months. The major advantage of stockpiling at the plant is that the baling operation is not hampered by lack of supply and can proceed during the summer months. In addition, if the storage area is on mineral soil there will not be any capillary wetting action between the peat and the surface, resulting in dryer peat. A good compromise is to stockpile some peat in the field and some at the plant, with, say, 60 percent in the field and 40 percent at the plant. The peat is moved from the bog area to the plant site using tractors and specially designed hauling vehicles equipped with hydraulic hoists to permit rapid discharge of their loads.

*Much of the information presented here has been obtained from a report prepared by Robert Brower, entitled "Description of Methods, Projections of Costs, and a Typical Budget for a Conventional (Field Harvestor) Peat Operation," December, 1966. The report was prepared for Iron Range Resources and Rehabilitation.

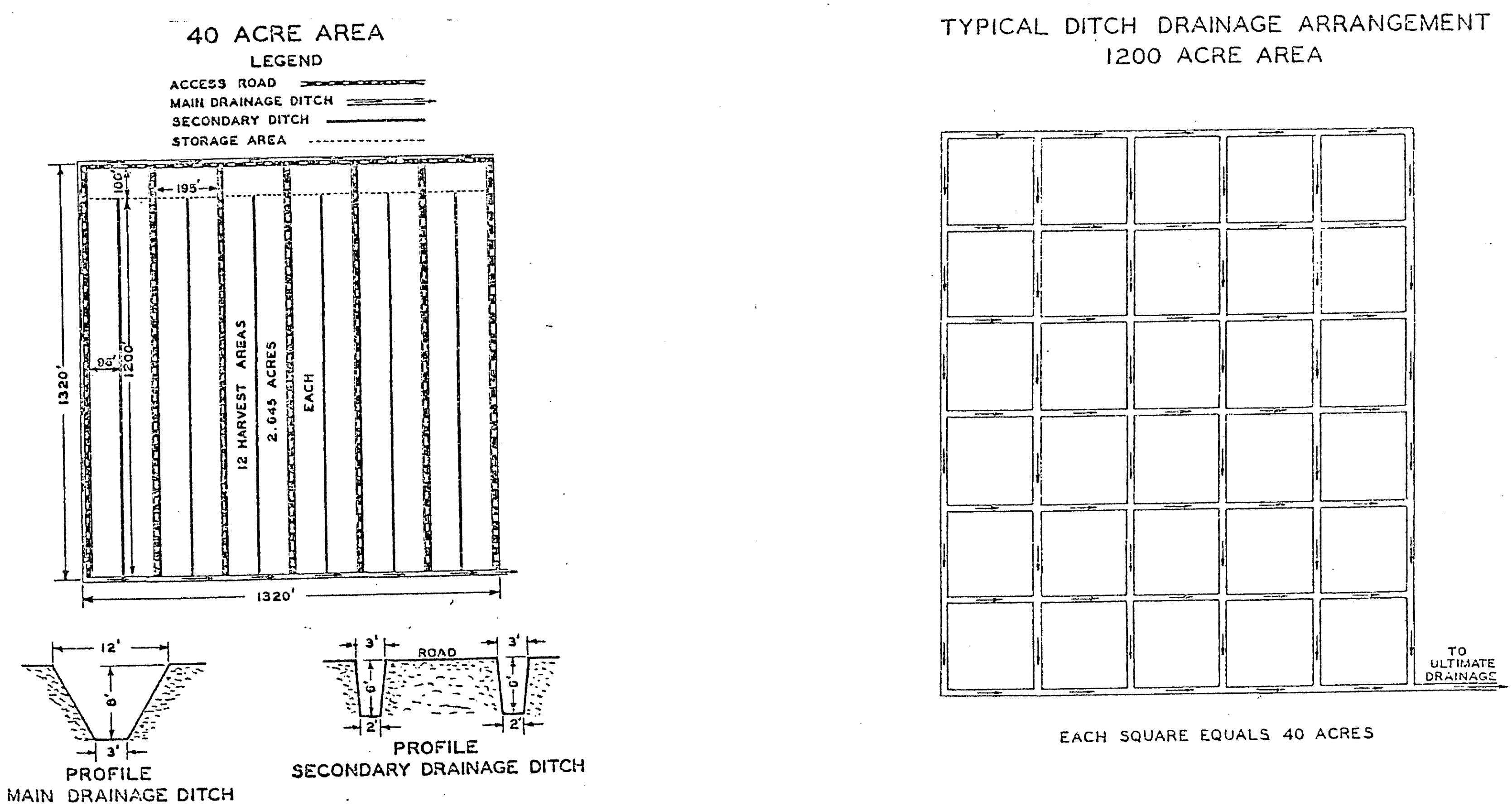


Figure 7.9. Drainage and Ditching Systems. Based on Robert Brower's "Conventional (Field Harvester) Peat Operations." Iron Range Resources and Rehabilitation.

BAGGING AND BALING

Before shipment to the market the peat is formed into a compressed bale. The bales can vary in size from 8 cubic feet to 1-1/2 cubic feet. The larger bales are produced for the nursery trade while the smaller bales are used for the market place. A good 6-cubic-foot bale of compressed *Sphagnum* peat will contain about 12-1/2 cubic feet of fluffed peat and will weigh about 100 pounds. The actual density depends on the moisture content in the air and can vary during the baling process. A baling machine that has been used with good success in Minnesota has been developed by the Canadian peat industry. It operates at 1,000 pound pressure and is powered by a 15 horsepower motor along with 27 gallon permitted hydraulic pump. The baler is rugged in construction and can be operated by two men to provide a steady production of 70 bales per hour. The configuration of the baler can be changed to produce different sized bales by adding blocks to the bottom of the baling chamber. Two problems encountered in the baling operation are maintaining a steady supply of peat to the balers, and dust. The supply of peat is maintained using drag conveyors, and the dust problem is minimized by using a dust collecting system. Peat dust can become explosive after it accumulates in massive quantities, and the danger of explosion is quite high after the peat has remained dormant in such areas as rafters, ledges, and similar places for 6 months or more. Good housekeeping practices are necessary to minimize the explosion danger.

CARLOADING AND WAREHOUSING

Most horticultural peat companies maintain an adequate inventory of baled peat. Generally, the bales are stacked not over 8 units high and in a "criss-cross" form. The most efficient operation, however, is to transport the bales directly to the railroad cars for shipment.

TECHNOECONOMIC DATA

Assuming a total annual production of *Sphagnum* of 125 thousand tons by the year 1990, at 20 bales per ton, this will be equivalent to 2.5 million bales. With an assumed royalty of 10¢ per bale, this will amount to 250 thousand dollars to the State (the present royalty rate is 5¢ per bale). *Sphagnum* peat now sells at a wholesale price of $3/bale F.O.B. By the year 1990, the return to the *Sphagnum* peat operation would be 15 million dollars per year.

Assuming a production rate of 125 thousand tons of reed-sedge peat by the year 1990 and a royalty rate of 50¢ per ton, the state would receive $62,500 per year. At a selling price of $25 per ton, this would result in 3.12 million dollars a year gross sales for the company.

The costs for clearing 500 acres are estimated to be about $300,000 or a cost per acre of $600. These calculations are based assuming a work force of 20 people during a 10-month period ($250,000) and a total equipment purchase of $250,000. Such equipment is normally amortized over a 5-year period.

Labor and salary requirement for an annual production of 5 million bales is 700 workers at a total daily rate of $22,000. Production usually averages 100 days between May 1 and November 1. This results in a total labor cost of about 2.2 million dollars per year.

Thus, adding the labor for the clearing and harvesting operations, a work force of 720 workers is required to produce a total 250 thousand tons of peat per year.

AGRICULTURAL

BACKGROUND

At the present time the total acreage of peatland in row-crop production in Minnesota is about 60,000 acres, with the major emphasis on potatoes, vegetables, and special crops. In addition there are 130,000 acres of other crops including grains, resulting in a total area of 190,000 acres. Most of the vegetable production is in southern Minnesota with the largest acreage being about 30,000 acres in the Hollandale area of Freeborn County and about 3,000 acres in Anoka County.

The peatlands in several northern Minnesota areas are also well suited for development of intensive vegetable production. The suitability of these organic soils, together with the large reserves of extensive and readily available peatlands, makes this area particularly attractive to large vegetable crop processors. At present, most vegetable crops grown in the Midwest states are located in areas further south. Future expansion, however, brought on by increased demand for canned and frozen vegetable products may well take place in the northern Minnesota peatland area.

A variety of crops can be successfully raised on organic soil, including carrots, cabbage, celery, potatoes, cauliflower, lettuce, radishes, onions, sod, wild rice, blueberries, cranberries, hay, bluegrass seed, Christmas trees and ornamentals. Crops that are now being raised in Minnesota and marketed in commercial quantities are carrots, cabbage, cauliflower, celery, potatoes, lettuce, cultured sod, radishes, onions, and wild rice. The best crops are the ones that have short growing seasons or can withstand light frost. In addition, black spruce is grown for pulp, tamarack for poles, and white cedar for posts. Black spruce is also harvested for Christmas trees. Some average yields, to be expected are: carrots--10 tons per acre, potatoes--300 hundred-weight, celery---up to 50 tons per acre (fresh weight), and cauliflower--1000 crates per acre.

Potential new developments on peatlands include the growth of winter wheat. It has been estimated that a potential of 50 bushels per acre might be possible. Winter wheat is more valuable than spring wheat since it can be used for flour; whereas spring wheat is used mostly for durham macaroni and similar products and is not good for flour. Other new uses include seed potatoes. For the development of the seed potato it is good to separate them from the other crops to avoid cross-pollination by bees. Peatlands would be ideally suited for this purpose. Other new uses include the growth of high protein grasses such as quack, reed-canary, and orchard. Other crops which could be grown include new varieties of grass seeds and varieties of vegetation for energy farms and forage crops. The potential is also there for an expansion of wild rice production.

Other uses could include commercial scotch pine and sitka spruce trees as well as ornamental and nursery crops. It is estimated the proper drainage and fertilization could increase the production of trees by about 25 percent on peatlands.

GENERAL DESCRIPTION

Assuming a total peatland acreage of 200,000 acres, approximately 25 percent, or 50,000 acres, would be suitable primarily for agricultural development. Of this about 7,500 acres would be used for vegetable crops; 15,000 acres for forage crops, grass seed and high protein grasses; approximately 7,500 acres for wild rice; and about 20,000 acres for forest crops. This apportionment should be considered a seasonal projection based upon current practices and projected market demands.

The rate of development is assumed to be about 2,500 acres per year from 1980 to the year 2000. This rate is, of course, affected by the availability of development capital and of mineral lands becoming more scarce and expensive owing to urban encroachment and world food-supply needs.

The agricultural scenario is shown schematically in Figure 7.10, depicting conditions in the year 1990. It is assumed that about 7500 acres would have been put into use as grasslands, 3700 acres into vegetable crops, 3700 acres into rice paddies, and 10,000 acres into broadleaf forests. Again, the actual acreages to be put into use and the type of crops to be harvested depend upon many factors that cannot be predicted at this time, such as market supply and demand characteristics, infusion of the necessary private sector capital, and availability of more easily harvested areas in other parts of the state. The scenario postulates, by the year 1990, a total of about 25,000 acreas will have been put into production. In addition, a bog preparation area of 2500 acres is shown on the right-hand portion of the harvesting area.

For an agricultural operation of this size, it is possible that a large food processing plant be included as a part of the overall operation. Such a plant was included in this scenario to make it comparable to the other scenarios. This plant may be either a canning operation, a freezing operation, or a combination of both.

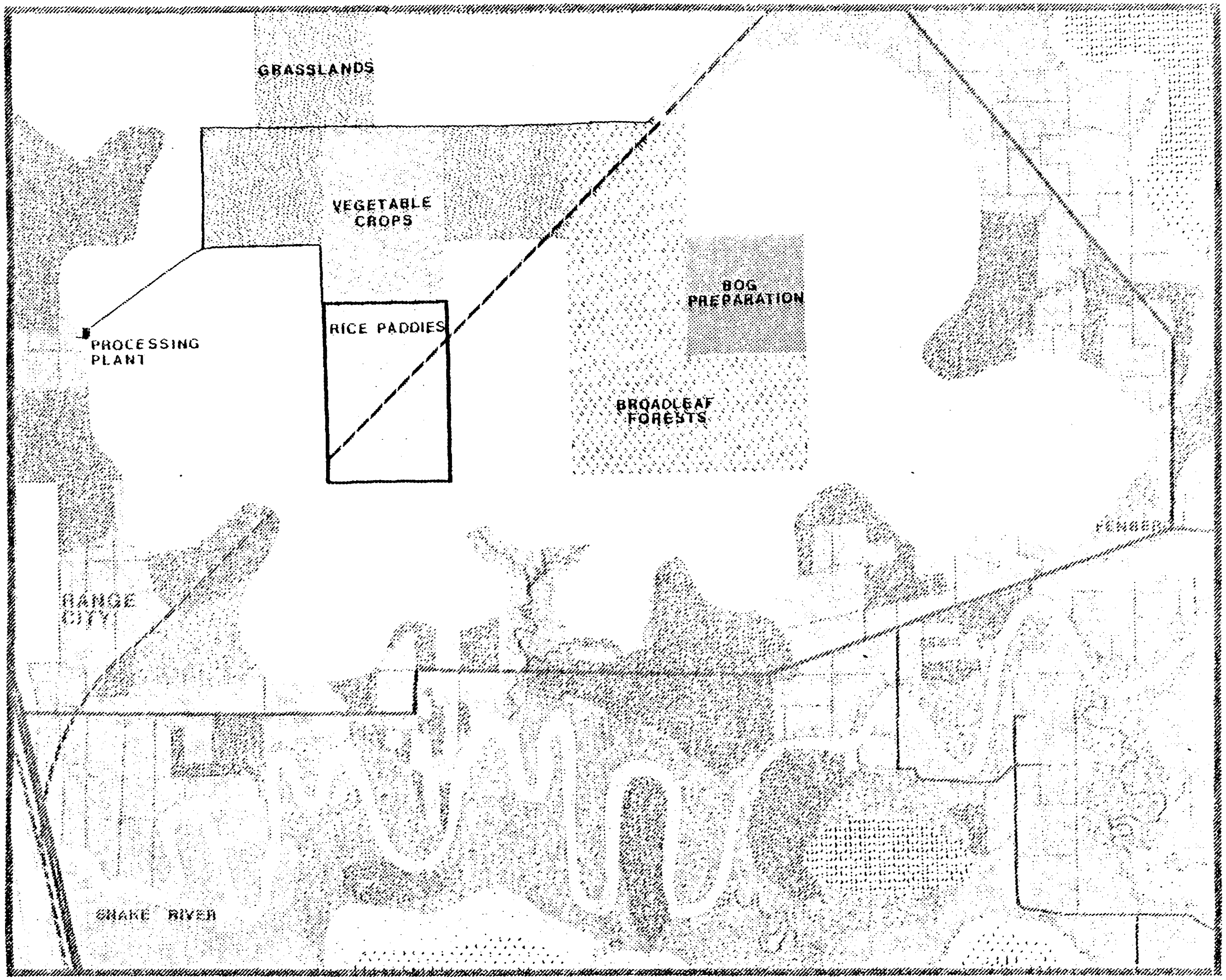


Figure 7.10. Agricultural Scenario

PROCESS DESCRIPTION (FIELD)

For purposes of this scenario it will be assumed that the latest farming technology will be used, employing mechanized procedures whenever possible. Highly mechanized procedures will permit more timely tilling of the soil and harvesting of crops, better and more effective methods of applying pesticide chemicals, less loss of crops during the harvest operation, manipulation of the soil in a manner to improve the soil environment for crop production, and improved mechanical means for reducing erosion and water runoff. The field operations are summarized as follows:

BOG PREPARATION

The bog preparation steps are similar to those used in the commercial peat scenario. However, the ditching system and surface contouring procedures will be slightly different so that an adequate supply of moisture will be available for the crops.

TILLAGE AND SEEDING

In this step the soil is prepared and seeded. New energy conservation techniques have been leading toward methods of reduced tillage.

FERTILIZATION AND PEST CONTROL

Fertilizers and lime play an important role in the maintenance and improvement of productive potential of agricultural lands. New concepts in weed and pest control include the use of biological substitutes as replacements for chemical pesticides; and energy savings in weed control could be effected by using the rotary hoe twice in cultivation instead of a herbicide application.

HARVESTING

Many crops such as corn, tomatoes, spinach, beans, cranberries and beets are now wholly, or in part, mechanically harvested. Other crops such as asparagus, artichokes, cauliflower, broccoli, brussel sprouts must still be hand harvested because differences in maturation of the fruits or vegetables and because of damage incurred during mechanical harvesting procedures.

IN-FIELD PROCESSING

In-field processing of many crops is now commonplace. Recent developments include removal of stems, sticks, leaves, and soil from the crops which have been mechanically harvested. Size, separation, prewashing and presorting are also accomplished.

TRANSPORT TO PLANT

Many crops such as beets, carrots, peas, corn and tomatoes are transferred directly from mechanical harvesters into dry bulk loading trucks or tote bins, which eliminates the use of smaller containers such as sacks, baskets, hampers or lug boxes. Some experimentation has been done in transportation of crops such as cherries, tomatoes, and potatoes in water, which provide several economic advantages as well as other partial benefits such as washing, soaking and cooling.

PROCESS DESCRIPTION (PLANT)

Fruit and vegetable processing plants are major water users and waste generators because the raw foods must be rendered clean and wholesome for human consumption, requiring that the processing plant be sanitary at all times. The maintenance of these required sanitary conditions requires the use of relatively large volumes of clean water which is sometimes reused before discharge into the receiving water bodies. During the past 20 years, there has been a constant trend toward consolidation of smaller fruit and vegetable processing operations into larger, more centralized plants. These large centralized operations require greater use of water and discharge more wastes per operation. The fruit and vegetable industry is a highly seasonal operation and it is not uncommon for a large processing operation to generate more waste and to use more water than the host-community. These waste loads are discharged during a relatively short harvesting season at a time of the year when the waste treatment systems must be geared to prevent pollution when rainfall and streamflow are at their minimum.

Considerable progress has been made by the fruit and vegetable processing industry to minimize the uses of water, including the use of recycling systems, segregation of strong wastes for separate treatment, modification of processes to minimize waste generation, education of plant personnel regarding pollution control and water conservation, and development of more sophisticated and less costly treatment procedures.

The fruit and vegetable industry discharges a large proportion of its liquid waste to public sewers and to land treatment systems. Because the declared objective of the "Federal Water Pollution Control Act Amendments of 1972" (public law 92-500) was to eliminate the generation of pollutants from "point" and "non-point" sources by making the discharge of any pollutants by any person in the United States unlawful, land disposal has become the favored method of waste disposal within the fruit and vegetable industry. In 1974, about 40 percent of each plant discharged wastewaters into the land. Discharges to land are principally by spray irrigation, seeping from ponds or lagoons, and by pumping into non-productive wells.

Wastes from the fruit and vegetable industry are usually soluble, of high strength, and are discharged seasonally. Thus, they are well suited to land disposal. The latter reason is important because most fruit and vegetable plants process in the summer and early autumn when surface waters streams are at minimum flows. In addition, evapotranspiration rates are high during the summer, which also tends to enhance land disposal. Usually, pretreatment is required prior to land disposal, with the primary objective being to remove solids that tend to reduce soil porosity. Of the various types of land disposal methods only spray irrigation combined with proper soil and hydrologic conditions, proper systems design, and diligent operations will result in attainment of the "zero discharge" standards.

The characteristics of food processing wastewaters that must be considered for land treatment include BOD_5, total suspended solids, total fixed dissolved solids, pH, heavy metals, sodium absorption ratio (SAR), total nitrogen, and temperature. In the food processing industry, wastewaters applied to the land have generally the following values:

Constituent	Unit	Value Range
BOD_5	mg/l	200 - 4,000
COD	mg/l	300 - 10,000
Suspended Solids	mg/l	200 - 3,000
Total Fixed Dissolved Solids	mg/l	less than 1,800
Total Nitrogen	mg/l	10 - 400
pH	--	4.0 - 12.0
Temperature	^{o}C	less than 68

The basic steps in the process include the following:

STORAGE

In most cases, fruits and vegetables grown for processing are prepared and processed soon after harvesting, usually within a few hours. However, in some cases storage is required for the accumulation of sufficient supplies, holding over weekends and holidays, breakdown of equipment or lack of labor, and the desirability of extending the operation beyond the normal period of harvest.

RECEIVING

This is usually accomplished using 40 to 50 pound lug boxes, half-ton bins, or larger bulk loads. Recent developments include the use of water during the receiving operation.

WASHING AND RINSING

Washing and rinsing is necessary to remove soil, dust, pesticides, extraneous matter, occluded solubles or insolubles and for cooling. A large amount of water is required for this operation; it may be as much as 50 percent or higher of the total usage in the process operations.

SORTING

This is done either mechanically or by hand, and it is an important part of the process because it facilitates the handling operations and affects the number of servings or pieces that can be secured from a package of a specified size.

IN-PLANT TRANSPORT

Various mechanical methods such as fluming, elevating, vibrating, screw conveying, and air propulsion have been used. Water has been tried as an economical means to transport fruits and vegetables within the plant.

IN-PLANT PROCESSING OPERATIONS

Depending on the type of fruit or vegetable to be processed, a variety of processing steps are required including: stemming, snipping and trimming, and peeling. After this comes pitting and coring, slicing and dicing, and pureeing and juicing. Not all of these steps are performed on each food product,but they are carried out as required. Many of these operations are carried out using highly mechanized and automated equipment. These steps are necessary to improve the quality of the final product by removing unwanted portions such as stems, stones, and outer layers that are not edible or degrade the taste or appearance of the product.

DEAERATION AND CONCENTRATION BY EVAPORATION

Deaeration process is performed to remove oxygen and other gases present in freshly pressed or extracted fruits and vegetables juices. The concentration step is performed to remove excessive liquids.

CANNING AND EXHAUSTING

In the canning step the cans are first washed before being filled. The commodity is then filled into the can by hand, semi-automatic machines, or fully-automatic machines, depending on the product involved. Exhausting is usually accomplished mechanically to remove excess gases.

CLEANUP

Plant and equipment are cleaned at the end of each shift, usually by washing down the equipment and floors with water. The water used in cleanup operations generally flows through drains directly into the wastewater system.

TECHNOECONOMIC DATA

Data are not available at this time for all of the agricultural operations planned in this scenario. However, actual data are available for vegetable and turf operations on peatlands in Anoka County. For 10,000 acres of vegetable cropland, 164 full-time and 3,112 part-time employees are required. A gross crop value of 12.4 million dollars annually is realized. For turf operations on the acreage, 143 full-time and 214 part-time employees are required which gross 7.14 million dollars annually.

If an average yield of about 20 tons per acre is assumed, the 3700 acres that would be put into vegetable crops by the year 1990 would result in 74,000 tons of produce per year. The wild rice operation on 3700 acres would produce about 250 pounds per acre, resulting in a total output of 450 tons per year. This would result in a processing plant work force of about 800 people. Adding about 200 field workers (on a full-time equivalent basis), this would result in a total work force of 1000 people. A plant of 500 tons per year employs 40 people and a plant of 700,000 tons per year employs 4,000 people.

GASIFICATION PLANT

BACKGROUND

The conversion of coals, peat, and various organic wastes to methane (the major constituent of natural gas) has been the object of considerable interest since the oil embargo and the sudden realization by the United States that the days of limitless quantities of cheap energy were apparently over. But faced with rapidly rising capital costs, many projects to utilize alternate sources for fuel (oil shale, oil sands, coal gasification) are being slowed down, and several large programs have been postponed or permanently cancelled. However, the need for developing data for the future use of such processes is undoubted.

The production of synthetic natural gas (SNG) from peat has several major advantages over the production of SNG from coal. The advantages are:

1. The presence of a large water supply. The proposed peat gasification sites have adequate water supplies. The large water supply also reduces thermal pollution problems.

2. A low sulfur content. This low sulfur content reduces the size of the equipment necessary to remove the sulfur (in the form of hydrogen sulfide). Removal is necessary not only to lower sulfur emissions where the gas is used, but also because sulfur poisons the catalysts used in the gas formation process.

3. Peat has a somewhat higher hydrogen-to-carbon ratio than coal. This eases the problem of supplying hydrogen to the process that is necessary to form methane from carbonaceous materials.

4. Peat is an indigeneous fuel source in Minnesota, Wisconsin, and Michigan. These states must import essentially all of their fuel.

5. Peat has a somewhat higher content of volatile materials than coals. These materials are relatively simple to recover and require less processing before addition to a gas pipeline. In addition, the organic content of peat contains more carbon compounds than coal. These compounds contain oxygen and hydrogen and tend to volatilize more readily than does coal.

Coal gasification products have three major end uses: 1) pipeline quality substitute (with a BTU content of about 1000 BTU per cubic foot), 2) a producer gas (with a low BTU content), and 3) a feed-stock gas for the production of chemicals (with a BTU content and hydrogen-carbon dioxide ratio suitable for the particular end use). The object of the peat gasification project is the production of pipeline quality gas.

The coal gasification process has four basic steps. First, the coal is heated and the volatile materials are collected. Second, oxygen (or air) and water are added (to supply hydrogen to the system) and the coal is converted to a mixture of carbon dioxide, carbon monoxide, and hydrogen. Third, this mixture is passed through a catalyst bed to achieve the desired gas mixture. The third basic step is the shift conversion step where the desired carbon monoxide-hydrogen balance is obtained by use of catalysts. Such processes have been in wide use in the chemical process industry for many years, but are still being actively investigated. Fourth, another catalyst system completes the conversion to methane. The final basic step, the nickel-catalyst, using conversion of carbon monoxide and hydrogen to obtain the desired methane (and waste carbon dioxide) has not been commercially demonstrated. These steps and some intermediate steps are shown in Figure 7.11.

The actual gas yield is a function of the chemical composition of the fuel, such as hydrogen-to-carbon ratio and amount of carbon compounds. While the higher-rank materials are more suitable for combustion to produce heat and electrical energy, the lower-rank materials (such as lignite and peat) are notable for their higher degree of reactivity, especially toward gasification with steam to produce combustible gases. The types of carbon bonds or linkages in these lower-rank materials enhance the reactivity, and lower the activation energies and heats from reaction. The

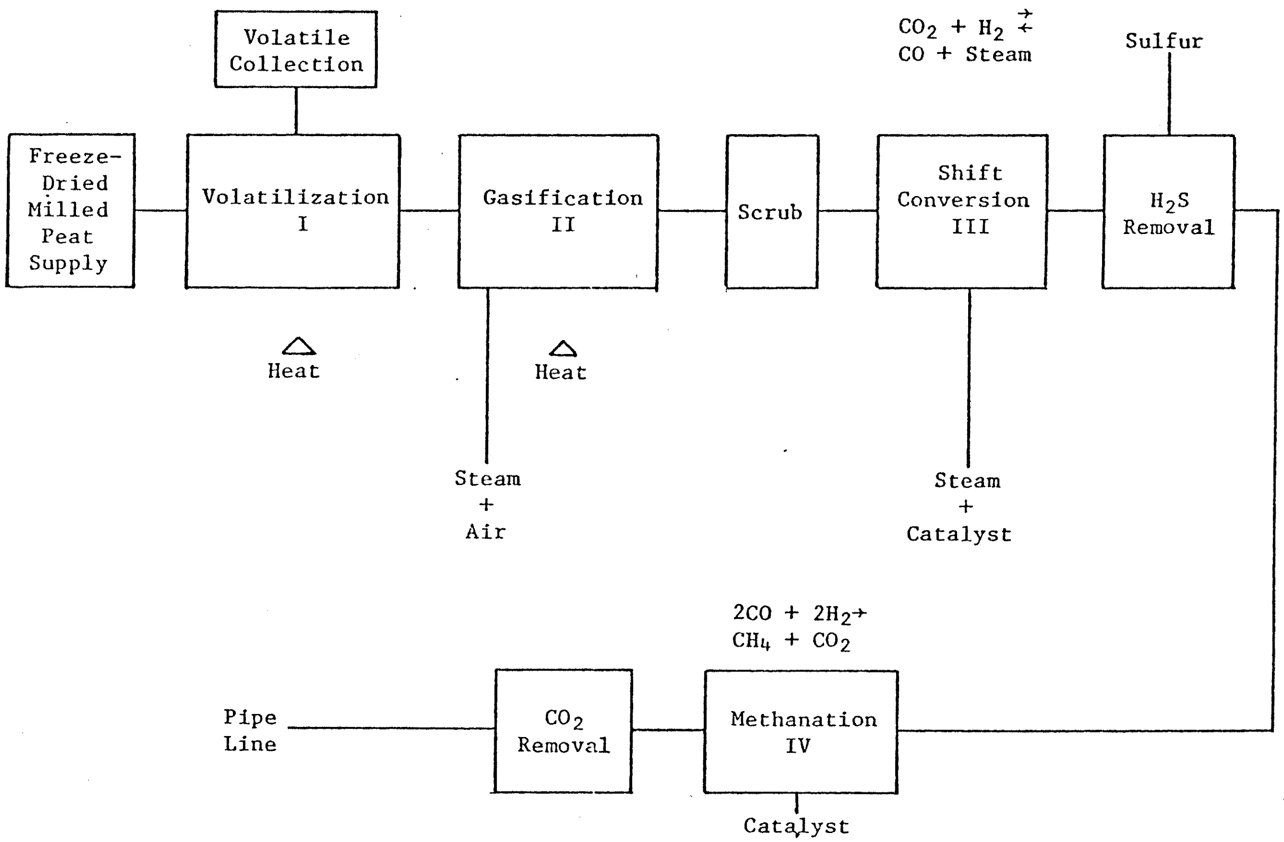


Figure 7.11. Basic Gasification Steps

theoretical upper limits for methanation of lignite coal is about 18,000 cubic feet per ton (900 BTU per cubic foot gas), which amounts to an energy value of 16.2×10^6 BTU per ton.

There are several variations of this basic method under investigation. The variations are mostly in the steps where the coal is volatilized and coal is heated with oxygen (or air) and steam. Several of the better known processes are as follows:

Lurgi. High-pressure (300 to 500 psig) fixed-bed process with an ash waste. Its disadvantages are that it requires a sized, non-coking coal, and it is a low throughput system.

Koppers-Totzek. Atmospheric pressure system with slag waste. It requires more oxygen than the Lurgi process but it can use all of the coal, including the fines.

HYGAS. High-pressure fluidized bed system, with the substitution of a reaction with coal as a substitute for the shift conversion step. Hydrogen is reacted directly with coal at high pressure (1,000 to 1,500 psig).

Carbon Dioxide Acceptor. Calcined dolomite (a lime) is added to a fluidized coal bed. Its major advantage is that it avoids use of oxygen; it might be suitable for peat because it works best with low-rank, reactive coals.

Synthane. A fluidized bed method where the gasifier has three vertical zones. In the top the volatiles are driven off and the coal then falls through two fluidized beds at different temperatures. This process also produces some coal tar and usable char material.

Molten Salt. A high-pressure system using molten salt (sodium carbonate) which eases coal handling and catalyzes the reaction. Early work was terminated because of corrosion problems. M. W. Kellog Company is working on a variation of the process.

BI-GAS. A high-pressure system using a two-step gasification with some char being carried over in the gas stream. This char is returned to the reactor.

All the processes under investigation can be classified in various ways: by the method of supplying heat for the gasification reaction (internal heating or external heating); by the method of achieving contact between the reactants (fixed bed, fluidized bed or entrainment in the gasifying medium); by the flow of reactants (cocurrent or countercurrent); by the gasifying medium (hydrogen or steam plus oxygen, air or enriched oxygen), and by the condition of the residue removed (slagging, which means that the residue is liquid ash, or nonslagging, which means that it is dry ash). Nearly all the combinations of ways to gasify coal represented by these classifications have been investigated.

Although at least three of the above processes have been commercially adapted for producing medium-BTU gas from coal, the methanation step for producing pipeline-quality gas has not been applied on a large scale. The only experimental data on methanation of peat of which we are aware has been obtained by the Institute of Gas Technology.

GENERAL DESCRIPTION

Many of the details of the gasification plant's operation are not yet available. Although several countries in Europe have built low BTU peat gasification plants over the years, none has been built to produce high BTU pipeline quality gas. In fact, no coal gasification plants producing pipeline quality gas are yet in continuous operation. To the present time, the only high BTU systems that have been put into operation are based upon the Lurgi gasification method: one at the Westfield Development Centre in Scotland and the other in South Africa. Both of these plants are demonstration systems, and neither has been put into full time operation as yet. The Institute of Gas Technology, under contract with the Minnesota Gas Company, has been doing research on gasification of peat using their Hygas process. It is our understanding that Minnegasco is soon to obtain a $1.5 million program with the Energy Research and Development Administration (ERDA) to develop a pilot-plant operation for producing high BTU gas from peat. The scenario will have to be modified as additional data are obtained on the Minnegasco peat gasification operation. The information contained in this scenario should be valuable, nevertheless, for initial evaluations.

The first step in the development is the construction of $300 million demonstration plant producing 80 million cubic feet of synthetic natural gas per day with construction estimated to start about 1980 and completion about 1982. This demonstration plant would be operated for about 1 year. If the project is successful, a full-scale plant would be built at a cost of about $1 billion and would produce 250 million cubic feet of synthetic natural gas per day. The construction of the full-scale plant would start around 1983 and it would be in full-scale operation by about 1986; the plant would operate for 20 years. It is assumed that the full-scale plant would be of modular construction and that the demonstration plant would be the first module of a three-component unit. Thus, much of the demonstration plant would be kept in operation and two other similar units would be built to complete the full-scale plant.

Large amounts of peat would be required for the gasification plant operation. It is estimated that about 6 million tons of air-dried peat (at 35 percent moisture) would be required for the demonstration plant each year. The full-scale plant would require about 18 million tons of peat each year. Over the 20-year operational lifetime of the full-scale plant, this would require the complete harvesting of a peatland area of about 200,000 acres to a depth of 6 feet. Thus, the lower half of the peatland area shown in Figure 7.1 along with an equivalent area in the northern portion would be completely harvested of peat.

A plan for a gasification plant operation on the representative peatland is shown in Figure 7.12. On the scale shown on the map the squares are 2500 acre segments. The figure shows the gasification operation in the year 1990 after about 4 or 5 years of operation. It is estimated that the full-scale plant will require the harvesting of about 10,000 acres of peatland to a depth of 6 feet each year, or about 4 of the 2500-acre segments. Thus, after five years of operation, the plant would have required about 50,000 acres of peatland.

Shown in the upper left hand portion of the figure is a 2500 acre bog preparation area; four of these areas would have to be prepared each year. Adjance to the bog preparation area is a 5,000 acre harvesting area. The remainder of the figure depicts a large area of about 40 to 50,000 acres that has been completely harvested and is in various stages of reclamation. In addition two, 2500-acre water storage reservoirs are shown in the lower portion of the peatland area. These reservoirs will also act as holding ponds to treat the water drained from the peatland area before it is released to the receiving water bodies. In addition, after separation of the particulate matter, large quantities of water will be required for the gasification plant operation.

PROCESS DESCRIPTION

The basic steps of the overall process are as follows:

BOG PREPARATION

Again, many of the bog preparation procedures used in the other two scenarios will be followed. The actual arrangement of the drainage system and amount of drying required will depend on the harvesting process to be used.

HARVESTING

Because of the large quantities of peat required each year, conventional harvesting techniques, such as the milled peat or the sod peat methods, would not be suitable. In addition, new peat drying processes would be required to provide the necessary amounts of peat at 35 percent moisture. It is assumed that some type of high output process would be required to provide the necessary amount of peat. This might be a dredging operation or a hydraulic operation in which high velocity water jets are used to cut and remove the peat. Mechanical methods similar to those used in the lignite operations in the United States or the brown coal operations in Germany might also be used. The U.S. Bureau of Mines station in Minneapolis is now nearing completion of the first phase of an investigation of high yield peat mining methods. However, these data have not yet been made available to MRI and therefore we will not discuss the actual peat harvesting methods that would be used. However, several general statements can be made:

1. Because of the high volume mining methods to be used, along with new peat drying methods, the peat harvesting season would be considerably extended over that available for conventional harvesting methods.

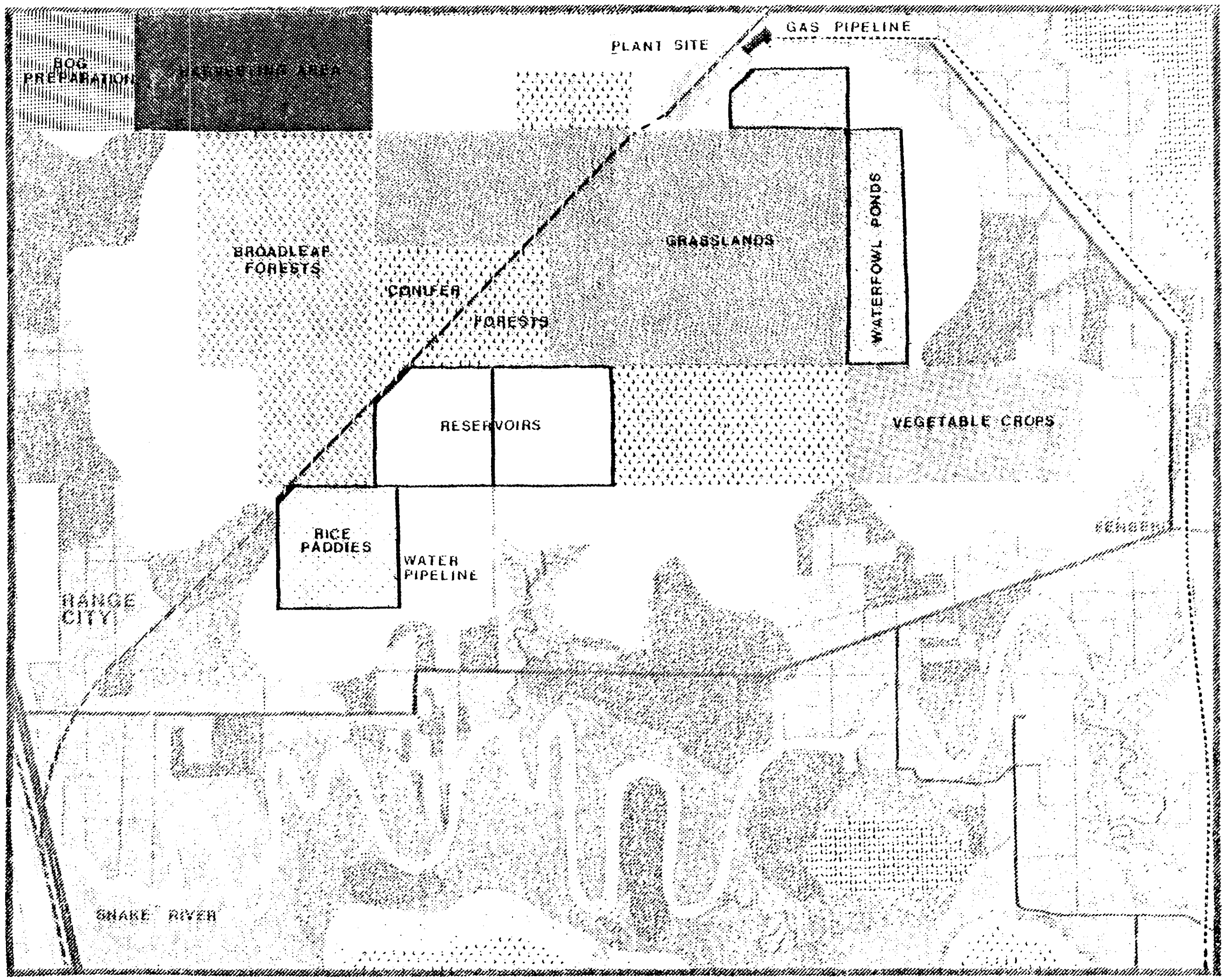


Figure 7.12. Gasification Plant Scenario

2. As the peat will be harvested to a full 6 foot depth in the harvesting area each year, using highly mechanized methods, the amount of bog area that will have to be kept open will be considerably smaller to produce the same amount of peat than would be required by the milled peat or sod peat methods.

TRANSPORTATION

It is quite likely that the peat will be moved from the harvesting area in a moist state, either by transport on narrow gauge railway lines or trucks or by hydraulic methods using large-diameter pipes. This would indicate that air pollution problems would be considerably decreased.

DRYING

The high moisture content and moisture rentention properties of peat creates difficulties with the Hygas process, both as related to particle size and adsorption of the slurrying liquid. It is estimated that the peat will have to be dried to about 35 percent moisture to minimize these effects. In addition, pretreatment may be necessary to reduce the oil absorption properties of the peat particles. It is not likely that natural drying processes can be relied upon for complete drying of the peat. After the peat is transported to the plant site, mechanical pressing techniques can be used to remove much of the water. Wet carbonization or microwave drying methods are among several that could be used to complete the drying process.

STOCKPILING

After the peat is dried, an adequate quantity must be stockpiled for operation during the non-harvesting months. These stockpiles will be placed in the immediate vicinity of the plant.

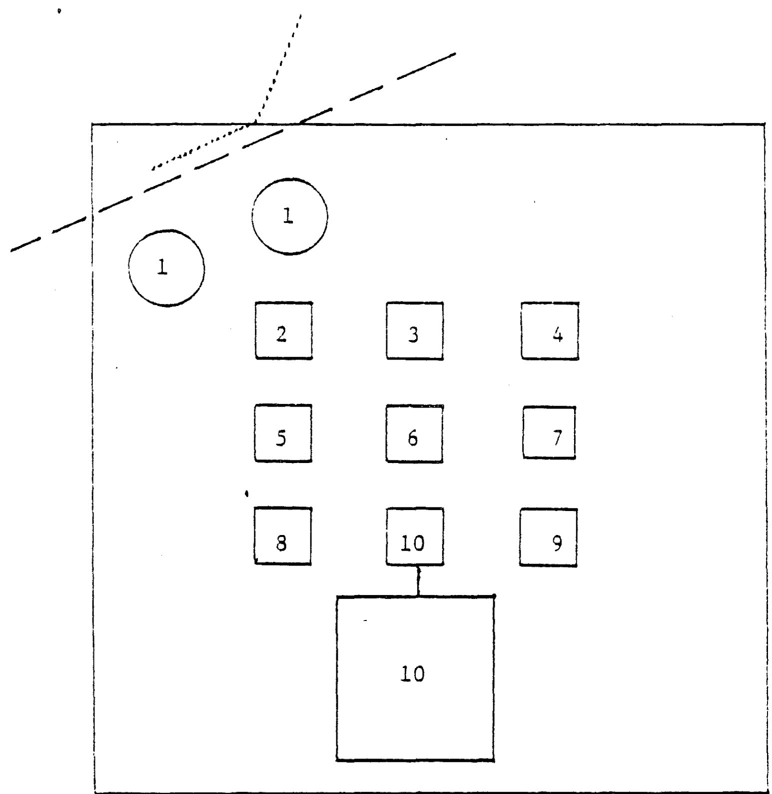
PLANT OPERATION

The plant itself would require about 100 acres as near the peatland as possible and near a water supply. A large reservoir would have to be built to assure an adequate water supply. The relatively large land requirement is necessary to accommodate the plant, peat storage and wastewater treatment ponds. An enlargement of the plant site is shown in Figure 7.13. Through a well-designed wastewater treatment system, much of the water can be recycled. In Figure 7.14 the Westfield Coal gasification plant in Scotland is shown to give an idea of the general appearance of a gasification operation.

The raw material inputs to the plant are estimated to be 50,320 tons per day of 35 percent moisture peat along with 5,000 gallons of water per minute. The peat harvesting season could be as short as four months but will probably be longer. Whatever the case, at the end of the harvesting season, there should be an inventory of 4 months supply of peat, or 6 million tons. Most of this will be stored in the bog area in many different stockpiles to protect against fire. The water use of 5,000 gallons per minute is greater than what could be supplied by streams that are representative of those in the peatland area. This amount of water is equivalent to 8,000 acre-feet, so a large water reservoir must be constructed. Even if there is considerable recycling of the water (how much is not known at this time), there must be a safety factor built into the reservoir both for dry periods and for very cold periods. Therefore, the reservoir probably will need to be 16,000 acre-feet, if the recycle is 50 percent.

The output from such a plant includes ash for disposal, ammonia, oil, sulfur and 263×10^6 standard cubic feet per day of gas with 950.4 BTU/SCF for a total SNG energy value of 250×10^9 BTU per day. Connection to a rail line is necessary for transporting the by-products to market areas as well as for bringing equipment to the plant site in the first place. The remaining outputs are the various wastes. Discharges to the atmosphere will include water vapor, carbon dioxide and a small amount of heat. Holding ponds, and possibly other wastewater treatment systems must be employed to meet standards for temperature and cleanliness of the water effluent as well as for making some of the water usable for recycling.

Plant Site



Existing Railroad

Narrow Gage Railroad

1. Peat Storage
2. Peat Preparation
3. Steam Boiler
4. Power Plant
5. Gasifiers
6. Gas Cleanup
7. By-Product Recovery
8. Ash Handling
9. Methanation and Gas Drying
10. Wastewater Treatment

Figure 7.13. Gasification Plant Components

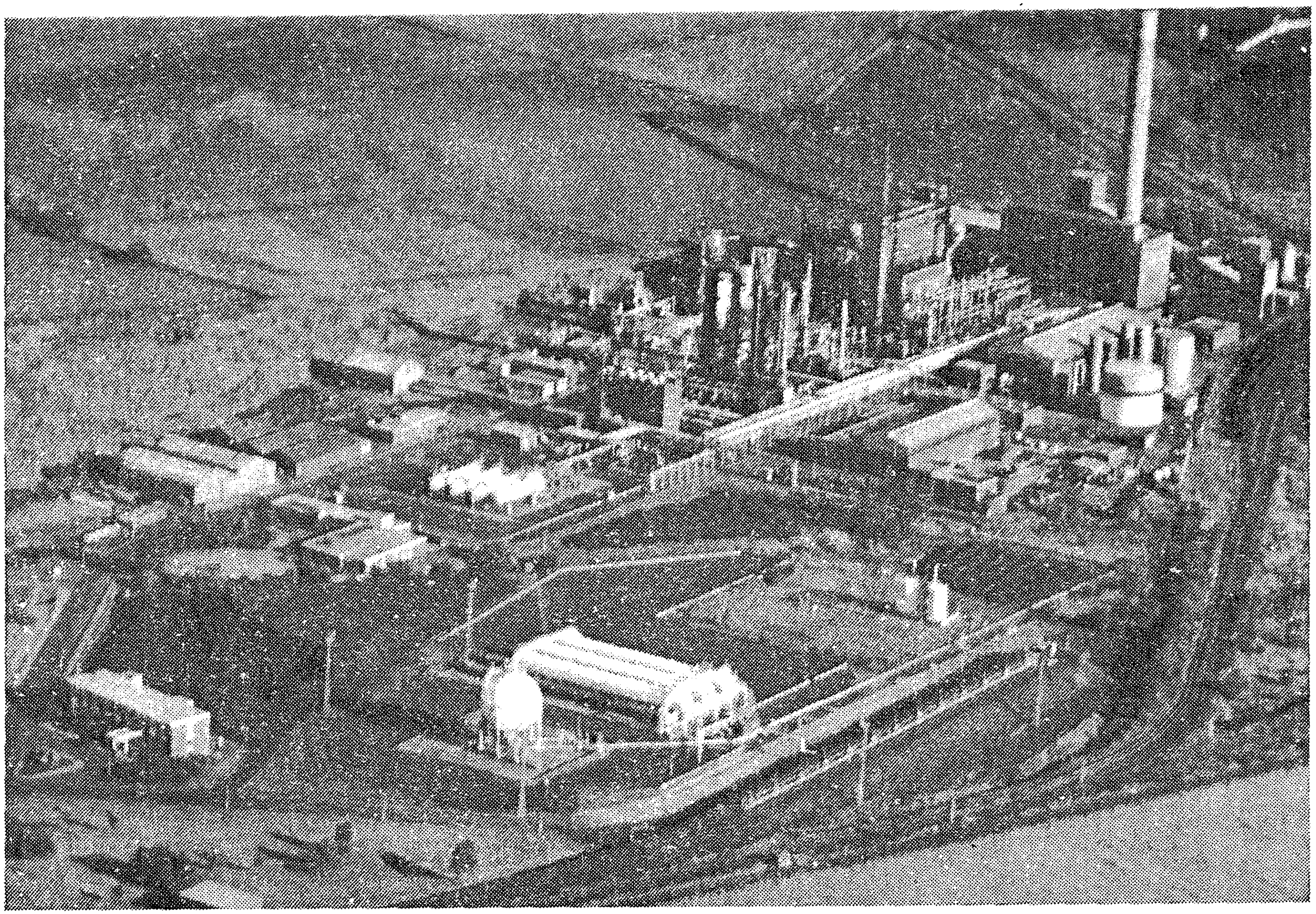


Figure 7.14. Westfield Gasification Plant

RECLAMATION

Because the only experience with reclamation of peatlands has been in Europe, several features typical of European peatland reclamation are included in our scenario. The German brown coal operation has shown that it costs about $4,000 to $5,000 to reclaim one acre of brown coal mining area. This is due to the deep cuts that must be made to remove the coal, which goes down as deep as 800 feet or more. Experience in Ireland has shown that peatland reclamation is not nearly as expensive or difficult because after the peat has been removed the area has already been contoured and cambered, and basically all that is necessary is blocking of some of the drainage ditches to maintain the proper water table level in the area and treatment of the soils to add trace mineral elements that are required for various types of trees and plants.

In the postulated reclamation effort for the gasification plant operation, we have assumed that about 5,000 acres will have been put into vegetable crop production, 2500 acres into rice paddies, 10,000 into broadleaf forests, 8700 acres into conifer forests, 17,000 acres into grasslands, and 3700 acres into waterfowl ponds. Of course each of these reclamation efforts requires special land management and land preparation efforts. The actual amount of acreage dedicated to each type of land use must be studied in considerable detail before final decisions are made. It should be stated that in the German brown coal industry, all of the land reclamation plans have been formulated before any of the brown coal has been mined.

TECHNOECONOMIC DATA

The costs of construction for coal gasification plants have been moving continuously upward, in practically all cases going considerably beyond the originally budgeted values. For instance, the cost of a Lurgi plant was estimated at under $300 million in early 1971. An estimate for the same-sized plant in the fall of 1973 by El Paso Natural Gas was just under $500 million. The costs now are estimated in the billion dollar range. For purposes of this scenario, it is estimated that the demonstration plant will cost 300 million dollars and the full-scale plant will cost 1 billion dollars.

Construction of the demonstration plant would require about 1,000 workers over a 2-year period, while the full-scale plant would require approximately 3,000 construction workers over a 3-year period. About 200 people would be required to operate the demonstration plant and 600 for the large-scale facility. We estimate that about 500 workers will be required to harvest and transport the peat required for the demonstration plant and 1500 workers will be required to havest and transport peat for the full-scale operation during the harvesting season. Fewer will be needed during the winter for transporting peat to the plant, clearing new areas and laying the rail lines to the next season's harvesting area.

SUMMARY OF SCENARIOS

Presented in Table 7.5 is a summary of field operations, plant information, plant input/output data, plant effluents and emissions, and work force data for the three scenarios.

Table 7.5 Summary of Scenarios

	Parameter	Agriculture	Commercial Peat	Gas Plant
1.	Acres under development 1990:	25,000	5,000	50,000
2.	Total acres developed by 2000:	50,000	10,000	150,000
3.	Peat type:	Hemic	Hemic Fibric	Hemic
4.	Vegetation cover:	Reed Sedge Grasses	Reed Sedge Grasses Sphagnum Moss Black Spruce Tamarack	Reed Sedge Grasses Black Spruce (stunted) Tamarack
5.	Habitat type:	Open fen	Open fen/ Raised bog	Open fen and spruce/tamarack forests
6.	Acres natural habitat lost by 1990:	25,000	5,000	50,000
7.	Area replanted by 1990:	24,900	None	46,900
8.	Reclamation (planted) acres/type by 1990:	Grasslands 7,500 Row crops 3,700 Rice 3,700 Broadleaf forest 10,000	None	Grasslands 17,000 Row crops 5,000 Rice 2,500 Broadleaf forest 10,000 Conifer forest 8,200 Waterfowl ponds 3,700
9.	Type of peat removal:	None	Vacuum	Excavation
10.	Removal rate:	None	250,000 tons/year	18 million tons/year
11.	Maximum exposed:	2500 bog preparation (growing season) 9900 (non-growing season)	5,500	20,000
12.	Plant area:	5 acres	5 acres	100 acres

Table 7.5 Summary of Scenarios (Continued)

	Parameter	Agriculture	Commercial Peat	Gas Plant
13.	Plant structures:	One-story building	One-story building	Steam/power plant (400' stack) asifier (150' tower x 3) O_2 plant and tank scrubber Scrubber tower Shifter Methanator Slurry plant Liquid recovery plant Ash recovery plant Sulfur recovery system Wastewater treatment plant Gas drying plant
14.	Support facilities:	Truck yard	Rail line Truck yard	Peat drying plant Rail yard Pipeline Reservoir
15.	Storage Acres/type:	None	Raw peat storage Bagged peat storage	peat storage ash storage
16.	Plant Inputs:			
	Peat	None	2500 tons/day	50,000 tons/day
	Water	2.1 million gal/day		10 million gal/day
	Gas/Electricity:	Yes	Yes	None
	Other Materials:	Package materials	Package materials	Catalyst
17.	Principal Product(s):	Processed vegetables (900 tons/day)	Processed soil conditioner (2500 tons/day)	SNG (260×10^5 cubic feet/day)
18.	By-product(s):			Ammonia phenols
19.	Waste products:	Vegetable wastes	Wood wastes ebris	Sulfur Oil Ash Sludge
20.	Plant air emissions:	None	Particulates	CO CO_2/Water H_2S SO_2 NH_2 Particulates Low Hydrocarbons
21.	Treatment required:	Yes	Yes	Yes
22.	Plant effluents:	Suspended solids	None	Ammonia Phenols Sulfides Suspended Solids Dissolved Organics {BOD Dissolved Inorganics {COD

Table 7.5 Summary of Scenarios (Continued)

		Agriculture	Commercial Peat	Gas Plant
23.	Treatment required:	Yes	No	Yes
24.	Plant noise:	Steam equipment Processing machinery Vehicles	Processing machinery Vehicles	Processing Flaring Gasification Motor whine Boiler/Steam leaks Turbines
25.	Particulates:	Dewatered sludge Debris	Wood wastes Field debris	Ash Sludge Wood wastes
26.	Treatment required:	Yes	Yes	Yes
27.	Field Noise:	Light vehicles	Light vehicles	Heavy vehicles Fumes
28.	Plant odor:	"Cooking odors"	None	H_2S; CH_3SH
29.	Field odor:	None	None	None
30.	Rail traffic generated:	Possible	Possible	100 rail cars/day
31.	Truck traffic generated:	Yes	Yes	Yes
32.	Non-truck traffic generated:	150-4000 ADT	0 - 1200 ADT	1200-2400 ADT
33.	Work Force			
	Preparation:	100 (12 months)		200 (12 months)
	Field workers:	2500 (3 months)		
	Pre-process:			100 (12 months)
	Process:	700 (3 months)	720 (100 days)	
	Reclamation:			100 (6 months)
34.	Total Labor:	10,800 man-months	2880 man-months	12,000 man-months

IMPACT ANALYSIS

BACKGROUND

In an effort to provide policy makers with a tool for assessing the impacts (both beneficial and detrimental) of a large-scale peat development in Minnesota, MRI has developed a preliminary methodology for quantifying and ranking the anticipated impacts, including consideration of the ecologic, environmental, aesthetic, and socioeconomic effects, of such a development. The methodology allows for the input of researchers, planners, citizens, developers, and policy makers. The method was developed recognizing that policy usually arises from a compromise between differing values and assumptions and that these values and assumptions must not be allowed to distort the consequences of impacts which are measurable, reasonably predictable, or verified by previous experience.

During recent years a number of techniques have been devised to assess and compare the environmental impacts of large-scale developments. And, indeed, some progress has been made in evaluating impacts to the natural environment, both in damage to ecosystems and in the visual degradation associated with these developments. However, when attempting to evaluate the potential disbenefits and benefits associated with any contemplated action, it has been found extremely difficult to compare and evaluate the broad spectrum of impacts associated with even a single development project. When several developments are being considered simultaneously, the problem is compounded and policy makers are presented with volumes of technical data pertaining to anticipated impacts with no easy way of impact quantification in commensurate units to facilitate the comparison of the alternative actions contemplated.

Most of the techniques that have been developed in recent years consider both the *magnitude* of an impact on a particular component of the natural or socioeconomic system (measured by the impact's intensity, duration, extent, and irreversibility) and the relative *importance* which that component is perceived to have vis-a-vis the other components which make up the system. In most cases, however, the magnitude of an impact has been obtained through the use of highly qualitative procedures which only loosely relate the impact to some anticipated action--for instance, relating the magnitude of the impact on the fish population in a lake to an increase in dredging activity. The relative importance of ecologic, environmental, aesthetic, and socioeconomic impacts has also been determined normally by the judgment of the impact assessor, which can be strongly influenced by the particular viewpoint and biases of the person(s) making the judgment. Moreover, it has been found extremely difficult to compare and rank impacts in the natural environment, which are often measurable if the parameter is specific enough, with many impacts in the human environment, which are generally impossible to quantify to everyone's satisfaction. For instance, degradation of the water quality in a stream can be measured through such parameters as dissolved oxygen, acidity, turbidity, and a wide variety of other parameters, while the loss in aesthetic appeal created by diverting a stream or changing its flow characteristics is extremely difficult to evaluate objectively.

Some progress in the quantification of impact analysis has been made by investigators such as Belknap, et al. (1967); Leopold, et al (1971); Dee, et al (1972); and the U.S. Army (1975). In addition, Warner (1973) and Dickert (1974) have compared and evaluated some of the more prominent methods.

More recently, under contract with the Energy Research Development Administration, MRI has completed the development of a Regional Energy Analysis Program (REAP) to study and evaluate the impacts associated with the implementation of various alternative energy sources, an extension of the technique initiated by Dee (1972).

Basically, the Dee method involves analysis of 78 impact measures grouped into four categories--Ecology, Environmental Pollution, Aesthetics, and Human Interest. Using a normalizing procedure and assigning importance values to the impact measures, application of this technique allows calculation of the net impacts for a specific development scenario, comparing all impacts to the undeveloped conditions. But the Dee method was developed mainly for the analysis of water resources problems and many of the impact measures are not suitable for conditions in Minnesota. In addition, the importance values for the impact measures were determined not to be appropriate for use on the present program.

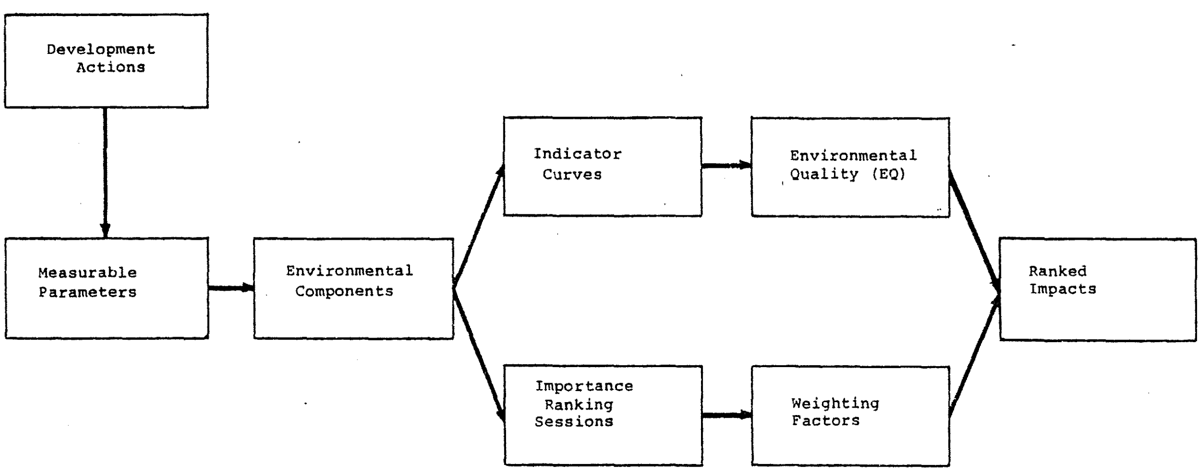
During the course of the Peat Program, a number of the most promising assessment techniques were thoroughly examined and evaluated to establish their suitability for comparing the environmental impacts of the various developmental programs for Minnesota's peatlands. As a result of this evaluation, it was concluded that the Dee approach, after a number of substantive modifications and improvements, would provide the best available technique for making those comparisons.

DETAILS OF PROCEDURE

Basically, the impact ranking procedure incorporates five important concepts: 1) *components*, each consisting of a group of environmental parameters, serving as an indicator of development impacts and which are prominent characteristics of natural or human systems; 2) *weighting factors*, which demonstrate the relative importance of the components and are obtained through a ranking procedure carried out by various groups of citizens; 3) *indicator curves*, which translate development impacts on components into impacts on overall environmental quality (EQ); 4) *environmental quality (EQ)*, which serves to normalize "impacts" into comparable units in widely different parts of environmental systems; and 5) *ranked impacts*, the mathematical combination of the weighting factors and EQ computations.

Components. The components of environmental systems play a central role in the ranking procedure. They form the nucleus for developing these concepts into two quantitative evaluation pathways: in one, the components convert the detailed impacts (by use of the indicator curves) into more general effects on EQ; in the other, the components register (by use of the weighting factors) the relative importance which groups of citizens place upon various aspects of environmental systems. These two quantitative evaluations are combined mathematically to produce a numerical ranking of environmental impacts.

Schematically, these pathways are related to one another as follows:



Because they play a central role in this evaluation procedure, components were selected which possess several important attributes. They are:

1) Important indicators of impacts to environmental systems
2) Based on information on existing conditions
3) Measurable in baseline and monitoring studies
4) Forecastable on a scenario scale
5) Familiar to laymen

Thirty-six components were tentatively selected for this study (see Figure 7.15.). These components are grouped into four broad categories which represent the hierarchical organization of environmental systems:

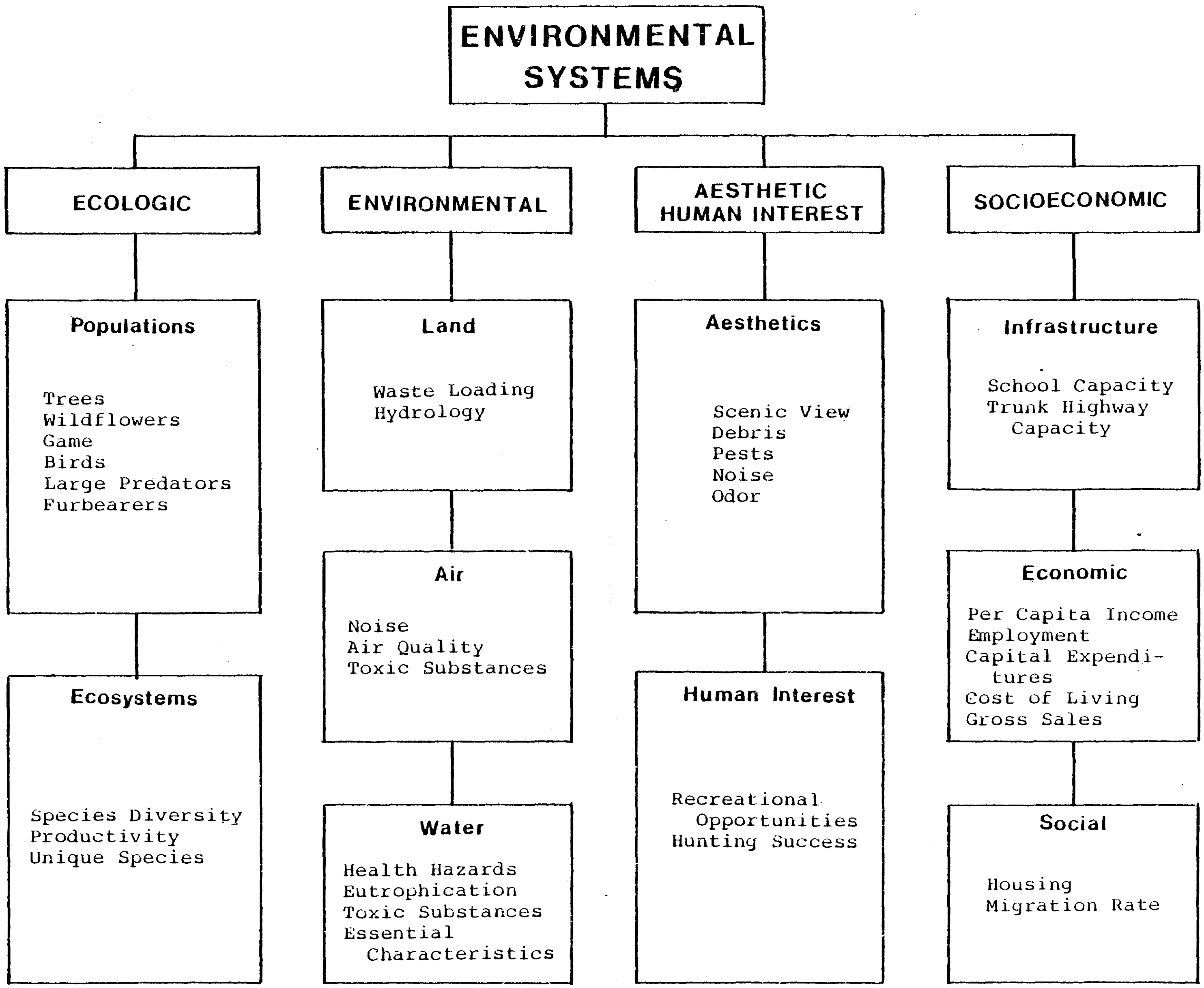


Figure 7.15. Impact Components of Peatland Environmental Systems

Ecologic--biological and ecosystem components
Environmental--primarily physical and chemical components
Aesthetic-Human Interest--components of beauty and quality of life
Socioeconomic--components of community and human characteristics

Within each category, components are divided into two or three subcategories. For each component, one or more measurable parameters are used to illustrate development impacts, thus completing the hierarchical organization as summarized in Figure 7.16. As an example, the Environmental category is shown in detail, with further breakdown of the Air Quality component into three parameters--SO_2, CO, and Particulates.

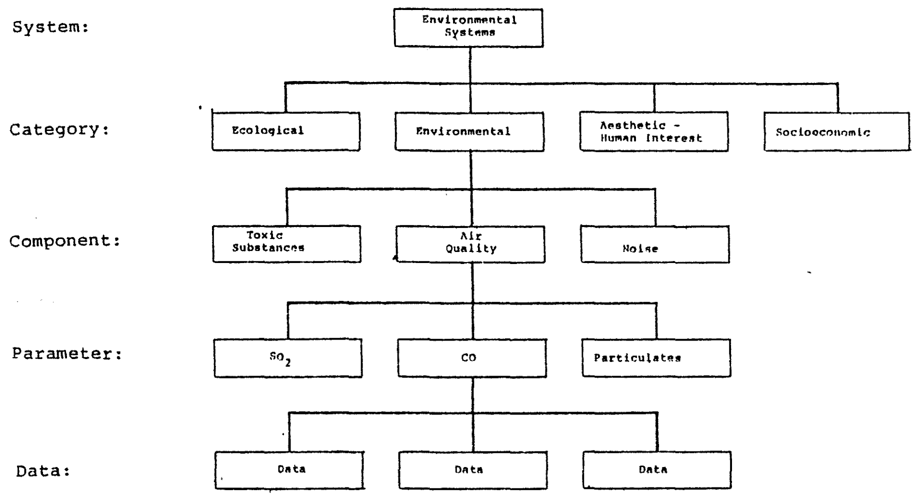


Figure 7.16 Hierarchical Organization

Weighting Factors. If all components contributed equally to the total EQ, an appropriate measure of this total would be obtained by summing the individual EQ values. However, some components may be perceived to be of greater importance than others, and therefore an appropriate weight must be ascribed to each component to reflect the assessor's judgment concerning the relative importance of each component. The selected components are ranked or weighted by assigning a portion of an arbitrary total of 100 points to each component. These weights can best be determined in a "ranking session." The ranking sessions will provide a broad-scale view of the relative importance of each component. Groups to be included in this ranking during Phase 2 of the Peat Program will include:

1) Residents of the affected area
2) Policy makers
3) Agency(ies) managing the resources to be utilized and/or the area affected
4) Development-oriented interests involved
5) Scientists on MRI's staff
6) Scientists from local colleges and universities

Preliminary information has already been obtained in in-house ranking sessions at MRI and in contact with Advisory Committee members and several scientists at the University of Minnesota and the U.S. Forest Service.

Indicator Curves. These curves are used to convert development impacts on a specific level into commensurate EQ units to obtain a measure of systems-level changes. This broad-scale conversion is perhaps the most essential step in identifying and communicating the significance of environmental impacts. These conversions, which provide the basis for comparing impacts in the widely diverse aspects (essentially like apples and oranges) of environmental systems, imply an underlying interconnection between the components and the integrity of the systems involved. Many of these relationships are generalized and still remain tenuous verbal concepts rather than formal methematical models that attempt to integrate quite detailed environmental interactions which are better understood. It is on the basis of this more detailed level of understanding that the rationale for indicator curves is developed; however, at this time many of the curves, by necessity, are based upon qualitative reasoning.

An example of an indicator curve is shown in Figure 7.17. Illustrated in this figure are the *effects of development upon air quality* to *overall impacts upon environmental quality (EQ)*; effects upon respiratory conditions are added for reference. Averages of the *air pollution index*, a composite number including changes in three measurable parameters, are used to represent the air quality component.

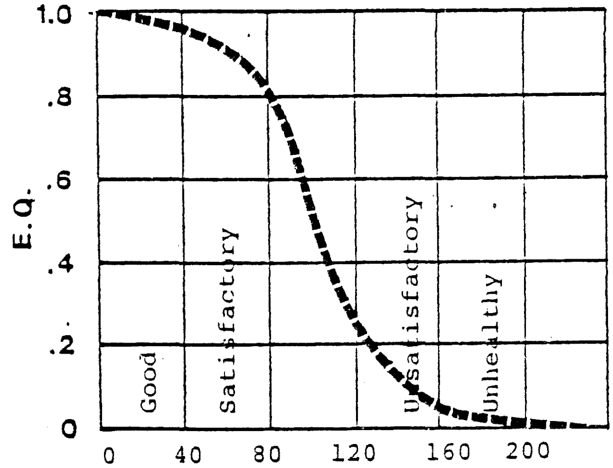


Figure 7.17. Indicator Curve

Indicator curves such as this are intended to illustrate the general relationships between each component and environmental quality (EQ). They represent a suggested midpoint in a wide band of possible relationships, which must be defined for this procedure. Further study should more clearly articulate these relationships, ultimately, it is hoped, to where confidence limits may be drawn. Indicator curves are discussed in greater detail in a later section of this report.

Environmental Quality (EQ). The concept of environmental quality provides a vehicle for comparing widely diverse development impacts in commensurate units. Environmental quality (EQ) is defined, for this procedure, as the condition of the environmental (including natural and human) system, and "impacts" are defined as disruptions of the integrity among components of this system. Depending on the severity and persistance of the disruptions, a more or less altered system is established since "integrity" is required by definition.

This conversion to commensurate units is based upon data and the relationships of these parameters to the system in each category. The environmental quality (EQ) associated with each parameter is a value between 0 and 1, with 0 denoting extremely bad quality and 1 very good quality. Therefore, since each EQ value is determined to be in the 0-1 range, one can compare the relative quality of differing parameters on a commensurate scale.

At this time it should be noted that the transition from air quality to EQ requires a "leap of faith," in which it is implicitly understood that the measured air pollution index can be related to air quality, which in turn can be normalized into a related EQ value.

Ranked Impacts. Bringing the two analytical pathways together and denoting the environmental quality (EQ) of parameter i by Q_i and the relative importance (weight) of component i by W_i, the ranked environmental impact (RI) in each of the four environmental systems categories is obtained by the following relationship:

$$TEQ = \sum_{i=1}^{N} W_i Q_i$$

where N represents the total number of components under consideration in each of the four categories. The absolute limits of RI are 0 and 1000. This sum of ranked impacts is determined for all scenarios by category and for all categories combined as shown in the sample worksheet in Figure 7.18.

Figure 7.18. Impact Calculation Worksheet

Ecologic Category

_________ Time Period

(Operations: Enter Weighting Factors, Effect Indication Values, and Multiply and Enter Product.)

SCENARIOS

Parameters	Weighting Factors	No Development		Agricultural		Commercial (Horticultural)		Gasification Plant	
		Effect Indicators	Products	Effect Indicators	Products	Effect Indicators	Products	Effect Indicators	Products
Populations									
Trees									
Wildflowers									
Game									
Birds									
Large Predators									
Furbearers									
Ecosystems									
Species Diversity									
Productivity									
Unique Species									
Sum									

Environmental Category

_________ Time Period

(Operations: Enter Weighting Factors, Effect Indication Values, and Multiply and Enter Product.)

SCENARIOS

Parameters	Weighting Factors	No Development		Agricultural		Commercial (Horticultural)		Gasification Plant	
		Effect Indicators	Products	Effect Indicators	Products	Effect Indicators	Products	Effect Indicators	Products
Land									
Waste Loading									
Hydrology									
Air									
Noise									
Air Quality									
Toxic Substances									
Water									
Health Hazards									
Eutrophication									
Toxic Substances									
Essential Characteristics									
Sum									

Aesthetic - Human Interest Category

__________ Time Period

(Operations: Enter Weighting Factors, Effect Indication Values, and Multiply and Enter Product.)

SCENARIOS

Parameters	Weighting Factors	No Development		Agricultural		Commercial (Horticultural)		Gasification Plant	
		Effect Indicators	Products	Effect Indicators	Products	Effect Indicators	Products	Effect Indicators	Products
Aesthetics									
Scenic View									
Debris									
Pests									
Noise									
Odor									
Human Interest									
Recreational Opportunities									
Hunting Success									
Sum									

Socioeconomic Category

__________ Time Period

(Operations: Enter Weighting Factors, Effect Indication Values, and Multiply and Enter Product.)

SCENARIOS

Parameters	Weighting Factors	No Development		Agricultural		Commercial (Horticultural)		Gasification Plant	
		Effect Indicators	Products	Effect Indicators	Products	Effect Indicators	Products	Effect Indicators	Products
Infrastructure									
School Capacity									
Trunk Highway Capacity									
Economic									
Per Capita Income									
Employment									
Capital Expenditures									
Cost of Living									
Gross Sales									
Social									
Housing									
Migration Rate									
Sum									

Several important comparisons among impacts can be made using this impact ranking procedure. For example, a comparison of impacts can be made between categories within each development scenario. Also the impact of a development scenario can be compared with the no development case. And finally, the net impacts between the development scenarios can be compared. Time related changes in development impacts are obtained by completing an additional set of calculations for each major phase of the development scenarios. For example, the years 1980 (facility construction and peatland cleaning and ditching), 1990 (midpoint in peatland development), and 2000 (maximum development) are important time periods to be studied.

Information presented in the natural environment and socioeconomic settings, the development scenarios, and the technical impact analysis serves as the data base for the MRI procedure. In Phase 2, further efforts will be focused on improving this data base, the indicator curves, and, if needed, expanding the number of components included in the procedure. Delphi sessions with the earlier mentioned groups of citizens will be conducted to determine the weighting factors.

Implementation of the environmental impact ranking procedure has been simplified by the preparation of a computer program to perform all the computations. Through use of the computer program, an evaluator can quickly answer "what-if" questions by varying one or more parameters and observing the effect on the total environmental impact for each scenario. Once completed, the procedure can be used by the development and/or monitoring agency(ies) and by policy makers to assess impacts of additional developments of the same nature on northern Minnesota's peatlands.

The effects of development on natural and human systems is assessed in this procedure by determining the changes caused by development in important components of these systems. The significance of these important components is illustrated by means of graphical relationships between changes in an indicator parameter and the related impacts these changes may have on the integrity of the environmental system.

The construction of the indicator curves assumes that the natural environment is essentially undeveloped, that the human population density is low and clustered in three small towns, that people in the area desire an improvement in the economy but would like to maintain their present lifestyle, and that both the natural and human systems are in equilibrium, i.e., components are not changing status in response to some recent environmental change.

Development impacts which are beneficial to certain components of the socioeconomic system may be considered beneficial, within limits, also to environmental quality. However, these same impacts are often deleterious to environmental quality in the aesthetic, environmental, and ecologic systems especially in an area of low population density and wilderness nature such as the northern Minnesota peatlands.

The present environmental quality can be determined by information presented in the natural and socioeconomic "setting" sections of this report. Changes in environmental quality due to development can be obtained from the information presented in the scenarios.

In the Ecologic, Environmental, and Socioeconomic categories impact indicators are frequently quantifiable and, particularly in the socioeconomic, more data are available with which to assess the level of impacts to the human system. Many components within the Aesthetic And Human Interest category are difficult to quantify.

LIMITATIONS OF PROCEDURE

It should be pointed out that if this MRI method is used in other situations, especially when the type of habitat or development is markedly different from that being examined in the present study, the procedures should be reexamined by environmental professionals to determine the appropriateness of 1) the selected components; 2) the indicator curves used to describe the relationship between components; and 3) the importance weights given the various components.

It must also be emphasized that this procedure implicitly relies upon conceptual "models" of the interactions between the diverse components of complex natural and human systems, although this procedure is not itself a model. It is a tool to demonstrate impacts of peatland development upon the quality of the environment, and to assess their importance for policy makers and planners. The MRI procedure, by itself, does not allow one to make a final judgment about the total environmental impact of a particular development. This judgment must be based upon a comparison of the EQ values for each of the alternative proposed projects, with the technical assessment of the environmental impacts. Thus the environmental ranking procedure, with further improvement, complements the MRI assessment methodology. In combination, reasonably accurate estimates of the net positive or net negative impacts of a project can be made. Ultimately, it will be the responsibility of the appropriate decision-making body to evaluate these relative impacts and decide which policy should be pursued.

For the purposes of this ranking procedure, the primary impacts are defined as the effects of major development-induced changes in the selected components upon EQ at the development site and in nearby towns. Although only one,or at most a few specific parameters,are used to construct the indicator curves, and thereby demonstrate changes in overall EQ, it is nevertheless felt that a more holistic view of environmental systems is presented than is usually achieved by other methods. This is of course necessary in order to bring environmental considerations more fully into the decision making process.

When determining the weighting factors and using the indicator curves, it is necessary to avoid coupling one component with another. These couplings already are included in the EQ number.

In so doing, the judgment of trained professionals is relied upon because this process includes more factors, complex interactions, and generalizations than are usually employed in modeling even subcategories of these systems. As a consequence, some specificity, precision, and sensitivity to impacts is relinquished.

ADVANTAGES OF PROCEDURE

The MRI procedure possesses several advantages over other methods. First, it is better adapted to analyze the conditions in northern Minnesota and the impacts of a potential large-scale peatland development. The procedure has evolved from discussions with numerous people of widely different backgrounds who are especially knowledgeable about the characteristics of northern Minnesota. These people include staff members of the Arrowhead and Headwaters Regional Development Commissions; the zoning administrators of several northern counties; and professionals at MRI, the University of Minnesota, and the U.S. Forest Service. Second, the MRI procedure allows diverse groups of citizens, as well as professionals, to participate in the impact ranking procedure. Third, each environmental category is treated at more equal levels of generalization than in other methods. That is, in the other procedures of similar design, some very specific parameters were compared with highly generalized impact indicators. Fourth, the breadth of the environmental system is expanded in the MRI approach to include the very important socioeconomic category. And finally, a more thorough consideration of the basic concepts of the procedure, its limits, and assumptions is presented.

INDICATOR CURVES

The effects of development on natural and human systems is assessed in this procedure by determining the changes caused by development on important components of these systems. The significance of these important components is illustrated by means of graphic relationships between changes in an indicator parameter and the related impacts these changes may have on the integrity of the environmental system.

The construction of the indicator curves assumes that the natural environment is essentially undeveloped, that the human population density is low and clustered in three small towns, that people in the area desire an improvement in the economy but would like to maintain their present lifestyle, and that both the natural and human systems are in equilibrium, i.e., components are not changing status in response to some recent environmental change.

Development impacts which are beneficial to certain components of the socioeconomic system may be considered beneficial, within limits, also to environmental quality. However, these same impacts are often deleterious to environmental quality in the aesthetic, environmental, and ecologic systems, especially in an area of low population density and wilderness nature such as the northern Minnesota peatlands.

In the Ecologic, Environmental, and Socioeconomic categories, impact indicators are frequently quantifiable and, particularly in the Socioeconomic, more data are available with which to assess the level of impacts to the human system. Many components within the Aesthetic and Human Interest category are difficult to quantify.

The indicator curves are presented in Appendix F.

8. POLICY DEVELOPMENT

STATUTES

The sale and leasing of *state-owned* peatlands presently are governed by two Minnesota statutes: § 92.461 (Subdivisions 1 and 2) and § 92.50 (Subdivision 1). These two statutes delegate to the Commissioner of Natural Resources the responsibility for determining which state-owned peatlands are eligible for sale, which peatlands are not eligible for sale, and what terms should apply to the leasing of peatlands which are considered valuable by reason of deposits of peat in commercial quantities.

> § 92.461 Peat lands
> Subdivision 1. Peat lands withdrawn from sale. All lands now or hereafter owned by the state which are chiefly valuable by reason of deposits of peat in commercial quantities are hereby withdrawn from sale.
> Subdivision 2. Examination by commissioner of natural resources. Before any state land is offered for sale the commissioner of natural resources shall cause such land to be examined to determine whether the land is chiefly valuable by reason of deposits of peat in commercial quantities.

Until 1935, state-owned peatlands could be sold under the same provisions which applied to the sale of other state-owned land. In 1935, however, the state legislature passed a law (1935, Chapter 322) which withdrew from sale all state-owned lands that were determined to be chiefly valuable by reason of deposits of peat in commercial quantities. § 92.461 now gives to the Commissioner of Natural Resources the responsibility and authority to determine whether any state-owned lands are valuable by reason of deposits of peat in commercial quantities. If that determination is positive, the Commissioner of Natural Resources is required under § 92.461 to prohibit the sale of those lands.

> § 92.50 Unsold lands subject to sale may be leased
> Subdivision 1. The commissioner of natural resources may, at public or private vendue and at such prices and under such terms and conditions as he may prescribe lease any state-owned lands under his jurisdiction and control for the purpose of taking and removing sand, gravel, clay, rock, marl, peat, and black dirt therefrom, for storing thereon ore, waste materials from mines, or rock and tailings from ore milling plants, for roads or railroads, or for any other uses not inconsistent with the interests of the state. No such lease shall be made for a term to exceed ten years, except in the case of leases of lands for storage sites for ore, waste materials from mines, or rock and tailings from ore milling plants, or for the removal of peat, which may be made for a term not exceeding 25 years, provided that such leases for the removal of peat shall be approved by the executive council. All such leases shall be made subject to sale and leasing of the land for mineral purposes under legal provisions and contain a provision for their cancellation at any time by the commissioner upon three months written notice, provided that a longer notice period, not exceeding three years, may be provided in leases for storing ore, waste materials from mines or rock or tailings from ore milling plants; provided further, that in leases for the removal of peat, the commissioner may determine the terms and conditions upon which the lease may be canceled. All money received from leases under this section shall be credited to the fund to which the land belongs.

The leasing of state-owned peatlands for the removal of peat was first addressed by the state legislature in 1917. In 1915 the legislature passed a law (1915, Chapter 192, Subdivision 1) which allowed the State Auditor to lease unsold state-owned school, improvement, or swamp land for removing sand, gravel, or black dirt. In 1917 this law was amended to allow the leasing of unsold state-owned land for removing clay, rock, marl, and peat, as well as sand, gravel, and black dirt. The amended law (1917, Chapter 31) set a maximum term of 1 year on leases for taking clay, rock, marl, sand, dirt, and peat. The law was amended in 1919 (1919, Chapter 405, Subdivision 1) to extend the term for leasing state-owned lands for removal of clay, rock, marl, sand, dirt, and peat to 10 years. In 1945 the leasing authority described in § 92.50 Subdivision 1 was shifted from the State Auditor to the Commissioner of Conservation.

§ 92.50 Subdivision 1, as amended in 1959, now allows a maximum term of 25 years on leases of state-owned lands for the removal of peat, provided that such leases for removing peat are also approved by the Executive Council. The amendment passed in 1959 also clearly places the responsibility for determining the terms and conditions under which a peat lease could be canceled upon the Commissioner of Natural Resources.

§ 92.50 specified that "all money received from leases under this section shall be credited to the fund to which the land belongs." Most of the state-owned lands under the jurisdiction of the Commissioner of Natural Resources are either Trust Fund Lands or Consolidated Conservation Lands and "belong" to those two funds. Money received from leasing Trust Fund Lands is deposited in the state's trust fund. The interest on that fund is distributed to all school districts in the state on a per-pupil basis. Money received from leasing Consolidated Conservation Lands is split 50-50 between the state government and the county in which the leased land is located. All Consolidated Conservation Lands are located in the following seven counties: Aitkin, Beltrami, Koochiching, Lake of the Woods, Marshal, Mahnomen, and Roseau.

Minnesota statues § 92.461 and § 92.50 (as they apply to peat development), can be summarized as follows:

§ 92.461

1. Withdraws from sale all state-owned lands which are chiefly valuable by reason of deposits of peat in commercial quantities.
2. Delegates responsibility to the Commissioner of Natural Resources for determining whether or not state-owned lands have deposits of peat in commercial quantities.

§ 92.50

1. Authorizes Commissioner of Natural Resources to lease state-owned lands under his jurisdiction for the removal of peat.
2. Authorized Commissioner of Natural Resources to prescribe terms and conditions of leases for removing peat from state-owned lands under his jurisdiction.
3. Allows a maximum term of 25 years on leases for the removal of peat.
4. Specifies that the Executive Council must approve such leases for the removal of peat.
5. Authorizes Commissioner of Natural Reosurces to determine terms and conditions upon which leases for the removal of peat may be canceled.
6. Specifies that all money received from the leasing of land for the removal of peat shall be credited to the fund to which the land belongs.

While § 92.461 and § 92.50 clearly delegate specific authority and responsibilities to the Commissioner of Natural Resources pertinent to the leasing of state-owned peatlands, neither statute lays out management priorities, addresses the issue of reclamation, or specifies a mechanism for determining the value of the peat deposits.

The state policy pertaining to tax-forfeited peatlands is outlined in § 282.04, Subdivision 1. See Appendix G.

POLICY OPTIONS

MRI believes that there is a need to examine several policy options pertaining to the development and protection of Minnesota's peat resources by examining, in Phase 2 of the present study, the implications and consequences of the policy options appearing in the preliminary list below. To this list should be added policy options suggested by the Advisory Committee, the Minnesota Department of Natural Resources, Minnesota State Legislators, and other parties-at-interest. The policy options open to the state, generally speaking, as these:

1) To maintain Minnesota's peatlands in their natural and primitive condition and to conserve these peatlands as natural habitat areas for use by the people of Minnesota.

2) To allow the controlled enhancement of Minnesota's peatlands, by means of judicial drainage and clearing, and thereby encourage the production of native species of trees, grasses, and berries.

3) To allow the agricultural, commercial, and industrial development of Minnesota's peatlands within the limits prescribed by policies which specify where and under what conditions such a development will be allowed to take place.

The implications of the following, more specific, policies pertaining to any development of Minnesota's peatlands will also be examined. This list is also preliminary.

RESTRICTIONS

The following restrictions might be considered:

1. That no development of Minnesota's peatlands should be allowed to take place in violation of any federal or state law, or in violation of any regulation duly established by any federal or state agency.

2. That no development of Minnesota's peatlands should be allowed to take place in the following areas, or within an appropriate distance of the following areas: The BWCA, or any other national wilderness area; Voyageurs National Park or any other national park; the Lake Agassiz Peatlands National Landmark, Upper Red Lake Peatlands National Natural Landmark, or any other national natural landmark; the Agassiz National Wildlife Refuge, Rice Lake National Wildlife Refuge, Sherburne National Wildlife Refuge, or any other national wildlife refuge; national historic sites, landmarks, or districts; national monuments; national wild, scenic, and recreational rivers; Hayes Lake State Park, Zipple Bay State Park, Franz Jevnue State Park, Savanna Portage State Park, or any other state park; state conservancy areas; state scientific and natural areas; or state wild, scenic and recreational rivers.

3. That no development of Minnesota's peatlands should be allowed to adversely affect the water quality of lakes, or the water quality or discharge rates of the streams or rivers receiving waters from peatland areas being developed.

4. That no development of Minnesota's peatlands should be allowed to adversely affect ground water levels, whether by pumping or draining such waters, or by removing such waters by any other method.

5. That no development of Minnesota's peatlands should be allowed to adversely affect air quality.

6. That no development of Minnesota's peatlands should be allowed to adversely diminish the habitat of any animal designated an endangered species, or to disrupt any area where a landform or vegetation is considered to be rare and unique.

DEVELOPMENT

The following development policies might be considered:

1. That those Minnesota peatlands not owned or held in trust by the state should be left open to development, subject only to the restrictions previously cited and to whatever county or municipal zoning practices are in effect.

2. That those peatlands lying within the boundaries of any state forest should be examined to determine whether or not those lands could be put to better use, and the commissioner of natural resources should determine what uses are most appropriate for those peatlands.

3. That the economic development of the communities in the peatland areas of Minnesota should be taken into account in determining the best use of those peatlands that do not fall under the restrictions previously cited.

PLANNING

The following planning policies might be considered:

1) That the appropriate regional development commissions should coordinate the planning of any development of Minnesota's peatlands.

2) That a strategic mapping and inventory of Minnesota's peatlands should be initiated before any major development is allowed to take place.

3) That broad peatland development "zones" should be established to preserve the wilderness-like quality of the most remote peatland areas, and to keep separate from those areas any agricultural, commercial, or industrial development.

4) That land exchange agreements should be encouraged in an effort to consolidate differing land uses on Minnesota's peatlands and to prevent scattered and piecemeal developments.

5) That the use of "greenbelts" and similar articulation zones should be encouraged in an effort to segregate non-compatible developments on Minnesota's peatlands.

6) That a detailed reclamation and land use plan should be submitted to the appropriate state agencies prior to any lease agreement permitting the removal of peat from Minnesota's peatlands.

7) That a determination should be made concerning the amount of peat to be left in place in areas where peat is removed for commercial or industrial purposes.

8) That the state should initiate a program of research to examine the effects of clearing, draining, harvesting, and reclamation on the ecosystems, groundwater levels, water quality and mineral lands in the peatland areas of Minnesota.

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APPENDIX A. ATTITUDE SURVEY

BAUDETTE (Number)

A Peat Harvesting and Gasification Operation in Your Area Would:	Total Agree	Strongly Agree	Agree	Slightly Agree	No Opinion	Slightly Disagree	Disagree	Strongly Disagree	Total Disagree
1. Seriously damage the area's wildlife.	13	7	2	4	3	8	13	9	30
2. Seriously damage the area's water quality.	16	9	4	3	13	3	9	5	17
3. Seriously damage the area's air quality.	19	3	7	9	10	3	10	4	17
4. Seriously threaten your personal health.	12	3	3	6	10	2	17	5	24
5. Badly hurt your job/business.	4	1	1	2	9	1	12	20	33
6. Adversely affect your present way of life.	14	6	6	2	7	2	16	7	25
7. Adversely affect your community.	14	5	5	4	8	2	16	6	24

BIG FALLS (Number)

A Peat Harvesting and Gasification Operation in Your Area Would:	Total Agree	Strongly Agree	Agree	Slightly Agree	No Opinion	Slightly Disagree	Disagree	Strongly Disagree	Total Disagree
1. Seriously damage the area's wildlife.	10	2	1	7	4	1	14	9	24
2. Seriously damage the area's water quality.	9	2	2	5	10	6	10	3	19
3. Seriously damage the area's air quality.	4	0	2	2	11	7	8	8	23
4. Seriously threaten your personal health.	2	0	0	2	6	1	18	11	30
5. Badly hurt your job/business.	1	0	0	1	7	2	8	20	30
6. Adversely affect your present way of life.	14	4	5	5	4	2	11	7	20
7. Adversely affect your community	15	5	7	3	7	1	9	6	16

BLACKDUCK (Number

A Peat Harvesting and Gasification Operation in Your Area Would:	Total Agree	Strongly Agree	Agree	Slightly Agree	No Opin-ion	Slightly Disagree	Dis-agree	Strongly Disagree	Total Disagree
1. Seriously damage the area's wildlife.	43	14	12	17	9	10	16	5	31
2. Seriously damage the area's water quality.	39	11	13	15	23	7	13	1	21
3. Seriously damage the area's air quality.	35	8	9	18	16	8	19	5	32
4. Seriously threaten your personal health.	15	3	5	7	22	5	29	12	46
5. Badly hurt your job/business.	8	3	2	3	25	3	22	25	50
6. Adversely affect your present way of life.	44	15	18	11	6	11	16	6	33
7. Adversely affect your community	39	15	13	11	8	7	17	12	36

GRAND RAPIDS (Number)

A Peat Harvesting and Gasification Operation in Your Area Would:	Total Agree	Strongly Agree	Agree	Slightly Agree	No Opin-ion	Slightly Disagree	Dis-Agree	Strongly Disagree	Total Disagree
1. Seriously damage the area's wildlife.	12	1	3	8	1	4	5	3	12
2. Seriously damage the area's water quality.	9	2	3	4	3	5	6	2	13
3. Seriously damage the area's air quality.	14	1	7	6	2	4	3	2	9
4. Seriously threaten your personal health.	3	0	0	3	5	2	9	6	17
5. Badly hurt your job/business.	0	0	0	0	3	1	10	11	22
6. Adversely affect your present way of life.	4	0	1	3	4	3	9	5	17
7. Adversely affect your community	6	0	1	5	4	2	8	5	15

BAUDETTE (Percent)

A Peat Harvesting and Gasification Operation in Your Area Would:	Total Agree	Strongly Agree	Agree	Slightly Agree	No Opinion	Slightly Disagree	Disagree	Strongly Disagree	Total Disagree
1. Seriously damage the area's wildlife.	28.3	15.2	4.3	8.7	6.5	17.4	28.3	19.6	65.2
2. Seriously damage the area's water quality.	34.8	19.6	8.7	6.5	28.3	6.5	19.6	10.7	37.0
3. Seriously damage the area's air quality.	41.3	6.5	15.2	19.6	21.7	6.5	21.7	8.7	37.0
4. Seriously threaten your personal health.	26.1	6.5	6.5	13.0	21.7	4.3	36.6	10.7	52.2
5. Badly hurt your job/business	8.7	2.2	2.2	4.3	19.6	2.2	26.1	43.5	71.1
6. Adversely affect your present way of life.	30.4	13.0	13.0	4.3	15.2	4.3	34.8	15.2	54.3
7. Adversely affect your community.	30.4	10.7	10.7	8.7	17.4	4.3	34.8	13.0	52.2

BIG FALLS (Percent)

A Peat Harvesting and Gasification Operation in Your Area Would:	Total Agree	Strongly Agree	Agree	Slightly Agree	No Opinion	Slightly Disagree	Dis-Agree	Strongly Disagree	Total Disagree
1. Seriously damage the area's wildlife.	26.3	5.3	2.6	18.4	10.5	2.6	36.8	23.7	63.2
2. Seriously damage the area's water quality.	23.7	5.3	5.3	13.2	26.3	15.8	26.3	7.9	50.0
3. Seriously damage the area's air quality	10.5	0.0	5.3	5.3	28.9	18.4	21.2	21.2	60.5
4. Seriously threaten your personal health.	5.3	0.0	0.0	5.3	15.8	2.6	47.4	28.9	78.9
5. Badly hurt your job/business.	2.6	0.0	0.0	2.6	18.4	5.3	21.2	52.6	78.9
6. Adversely affect your present way of life.	36.8	10.5	13.2	13.2	10.5	5.3	28.9	18.4	52.6
7. Adversely affect your community.	39.5	13.2	18.4	7.9	18.4	2.6	23.7	15.8	42.1

BLACKDUCK (Percent)

A Peat Harvesting and Gasification Operation in Your Area Would:	Total Agree	Strongly Agree	Agree	Slightly Agree	No Opin-ion	Slightly Disagree	Dis-agree	Strongly Disagree	Total Disagree
1. Seriously damage the area's wildlife.	51.8	16.7	14.6	20.5	10.8	12.0	19.3	6.0	37.3
2. Seriously damage the area's water quality.	47.0	13.3	15.7	18.1	27.7	8.4	15.7	1.2	25.3
3. Seriously damage the area's air quality.	42.2	9.6	10.8	21.7	19.3	9.6	22.9	6.0	38.6
4. Seriously threaten your personal health.	18.1	3.6	6.0	8.4	26.5	6.0	34.9	14.5	55.4
5. Badly hurt your job/business.	9.6	3.6	2.4	3.6	30.1	3.6	26.5	30.1	60.2
6. Adversely affect your present way of life.	53.0	18.1	21.7	13.3	7.2	13.2	19.3	7.2	39.8
7. Adversely affect your community.	47.0	18.1	15.6	13.3	9.6	8.4	20.5	14.5	43.2

GRAND RAPIDS (Percent)

A Peat Harvesting and Gasification Operation in Your Area Would:	Total Agree	Strongly Agree	Agree	Slightly Agree	No Opin-ion	Slightly Disagree	Dis-Agree	Strongly Disagree	Total Disagree
1. Seriously damage the area's wildlife.	48.0	4.0	12.0	32.0	4.0	16.0	20.0	12.0	48.0
2. Seriously damage the area's water quality.	36.0	8.0	12.0	16.0	12.0	20.0	24.0	8.0	52.0
3. Seriously damage the area's air quality.	56.0	4.0	28.0	24.0	8.0	16.0	12.0	8.0	36.0
4. Seriously threaten your personal health.	12.0	0.0	0.0	12.0	20.0	8.0	36.0	24.0	68.0
5. Badly hurt your job/business	0.0	0.0	0.0	0.0	12.0	4.0	40.0	44.0	88.0
6. Adversely affect your present way of life.	16.0	0.0	4.0	12.0	16.0	12.0	36.0	20.0	68.0
7. Adversely affect your community	24.0	0.0	4.0	20.0	16.0	8.0	32.0	20.0	60.0

APPENDIX B. NATIONAL NATURAL LANDMARKS

The information in this appendix describes the purpose of the National Natural Landmark Program as well as the location, history, and status of the Lake Agassiz Peatlands and the Upper Red Lake Peatlands National Natural Landmarks.

The National Registry of Natural Landmarks and the Natural Landmarks Program are administered by the National Park Service under the Historic Sites, Buildings and Antiquities Act, August 21, 1935 (Title 16). The program has as its objective the preservation of sites which 1) illustrate the geological and ecological character of the United States, 2) have special scientific and educational value, or 3) enhance the nation's natural heritage.

A natural landmark usually displays one or more of the following characteristics (Goodwin and Niering, 1975):

1. Outstanding geological features that significantly illustrate geologic processes.
2. Significant fossil evidence of the development of life on earth.
3. An ecological community significantly illustrating characteristics of a physiographic province or biome.
4. A biota of relative stability maintaining itself under prevailing natural conditions, such as a climatic climax community.
5. An ecological community significantly illustrating the process of succession and restoration to natural conditions, following disruptive change.
6. A habitat supporting a vanishing, rare, or restricted species.
7. A relict flora or fauna persisting from an earlier period.
8. A seasonal haven for concentration of native animals or a vantage point for observing concentrated populations, such as a constricted migration route.
9. A site containing significant evidence illustrating important scientific discoveries.
10. Examples of scenic grandure of our nature heritage.

Potential natural landmarks are first recommended in a Theme Study, carried out by experienced field evaluators, and then reviewed by the Secretary of the Interior's Advisory Board on National Parks, Historic Sites, Buildings and Monuments. If the Advisory Board agrees with the recommendation made by the field evaluators, the site is recommended to the Secretary of the Interior who must make the final decision regarding designation. If the Secretary designates the site a national natural landmark, the owner(s) is(are) invited to have the site registered. To register the site, the owner(s) must informally (by letter) agree to keep the site in its natural condition.

The Natural Landmarks Program is voluntary on the part of the owners, Landmark designation does not change ownership or responsibility for the property. There is no legislative authority for acquisition of natural landmarks. Nor is there legislative authority to prevent the owner(s) from selling, leasing, altering, or in any way developing the land designated a natural landmark.

The Lake Agassiz Peatlands were designated a national natural landmark in 1965. The site is located in south central Koochiching County where it encompasses about 22,000 acres of peatland between Highway 6 and the western edge of the Nett Lake Indian Reservation (Figure B-1), (Land Ownership Map, Koochiching County, Minnesota. 1973):

Sections 25 through 27
34 through 36 of Township 65N Range 25W

Sections 1 through 4
7 through 18
23 through 27 of Township 64N Range 25W

Sections 6 through 7
17 through 20
25 through 30
33 through 35 of Township 64N Range 24W

Sections 2 through 4 of Township 63N Range 24W

Located in the Lake Agassiz Peatlands is Myrtle Lake which is considered an unusual natural phenomenon. Heinselman (1970) has shown that the surface of the peat bog surrounding the lake has naturally "built up" over the centuries, thus raising the water table and elevating the lake's surface approximately 12 feet. The Agassiz Peatlands also include examples of raised and patterned bogs.

The Upper Red Lake Peatlands site was originally studied by Heinselman (1963) and Hofstetter (1969) and is also included in the Theme Study entitled *Inland Wetlands of the United States* (1971). This later study was compiled by Richard H. Goodwin and William A. Niering and encompassed a total of 358 potential landmark sites. In this study, three peatland areas in Minnesota were examined as potential landmark sites--Lost River Peatlands, North Black River Peatlands, and Upper Red Lake Peatlands. The Lake Agassiz Peatlands National Natural Landmark had already been designated and registered as a natural landmark prior to the date of this study.

As a result of the subsequent evaluation procedure, both the North Black River Peatland and the Upper Red Lake Peatlands were recommended as potential landmark sites. The Lost River Peatlands, which encompassed more than 200,000 acres in southwest Koochiching County, were placed on the "inactive" list (1975), meaning the site was considered of "less than national significance." Of the two remaining sites, the Upper Red Lake Peatlands was first to be designated a natural landmark by the Secretary of the Interior (May 15, 1975). An invitation to register the site was sent to the Department of Natural Resources shortly thereafter, and is now being reviewed by the DNR.

The North Black River Peatlands remain a potential site. They encompass probably over 100,000 acres of (mostly) Bureau of Land Management land north of the Black River in north central Koochiching County.

The Upper Red Lakes Peatland National Natural Landmark, as finally designated by the Secretary of the Interior, is located in Beltrami County north of Red Lake and encompasses 137,920 acres west of Highway 72 (Figure B-2). Its location can be described as follows (Ugolini, 1976):

Sections 2 through 6
7 through 11
14 through 18
19 through 23
26 through 30
31 through 35 of Township 156N Range 31W

Sections 2 through 6,
7 through 11
14 through 18 of Township 155N Range 31W
Township 156N Range 32W

Sections 1 through 18,
19, 20, 30, 31, and 32 of Township 155N Range 32W

Sections 19 through 36 of Township 156N Range 33W

Sections 1 through 18 of Township 155N Range 33W

Sections 19 through 36 of Township 156N range 34W

Sections 1 through 18 of Township 155N Range 34W

Sections 21 through 24
25 through 28
33 through 36 of Township 156N Range 35W

Sections 1 through 4
9 through 12
13 through 16 of Township 155N Range 35W

Although these national natural landmarks are *not* protected by federal law, and although there is no legislative authority to prevent the owner(s) from selling, leasing, altering, or in any way developing the land designated a natural landmark, attention should probably be given to the following considerations before any development of these areas is allowed to take place:

1. These two national landmarks have received national recognition by the Department of the Interior.

2. These two national landmarks have significant historical and ecological value.

3. These two national landmarks represent a very small portion (6.6 percent) of the peatland in Lake of the Woods, Beltrami, and Koochiching Counties.

4. The Power Plant Siting procedure, which derives its authority and criteria from Minnesota Statutes 116C. 51-59, has already *excluded* national natural landmarks as potential sites for large fossil fuel and nuclear power plants.

5. There are extensive peatlands in north central Minnesota lying outside these natural landmarks.

It should be remembered, however, the the final decision concerning the disposition ofthe Lake Agassiz Peatlands National Natural Landmark and the Upper Red Lake Peatlands National Natural Landmark rest with the State of Minnesota, which owns almost all of the property within them.

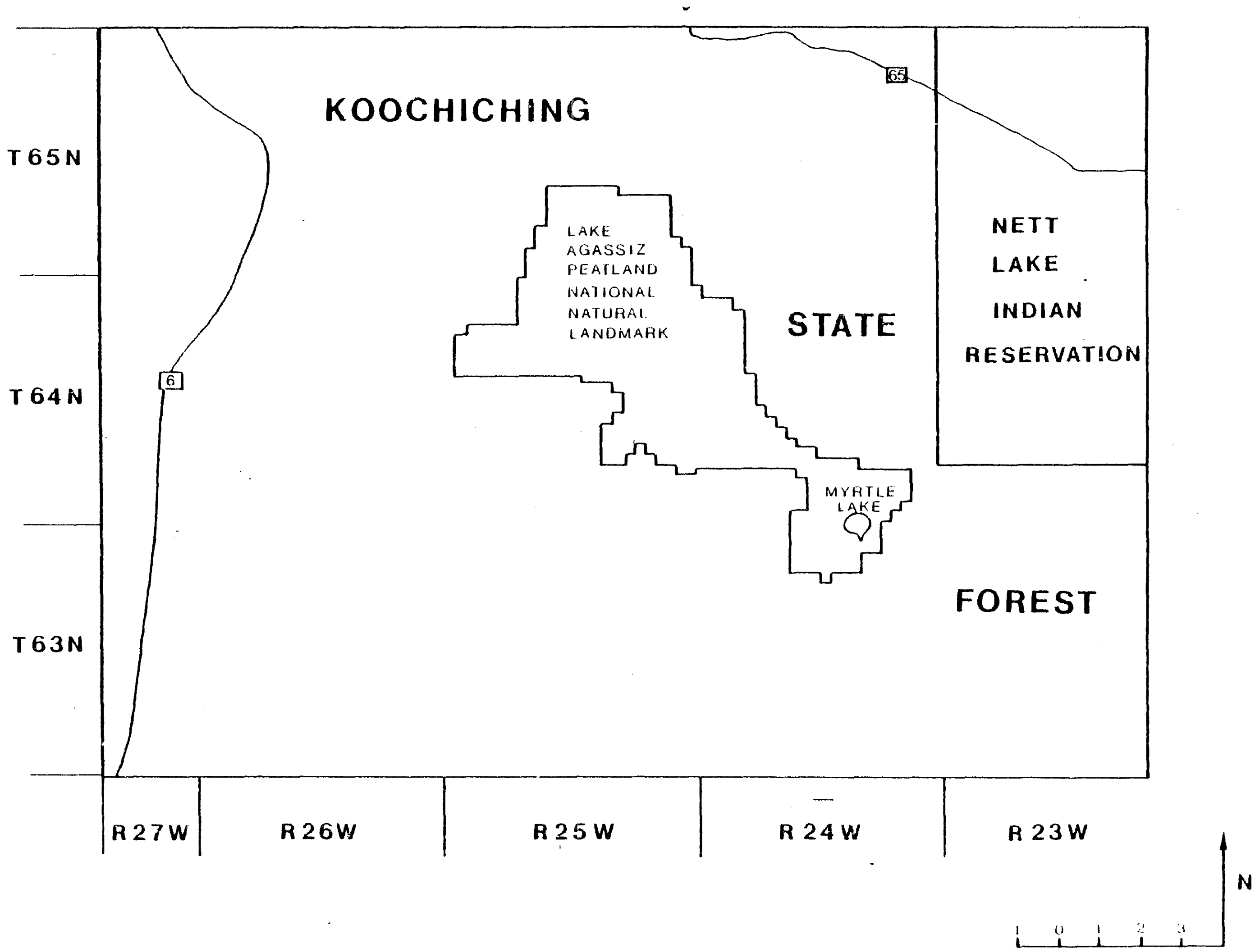

Figure B-1. Lake Agassiz Peatlands National Natural Landmark (Registered), Koochiching County, Minnesota.

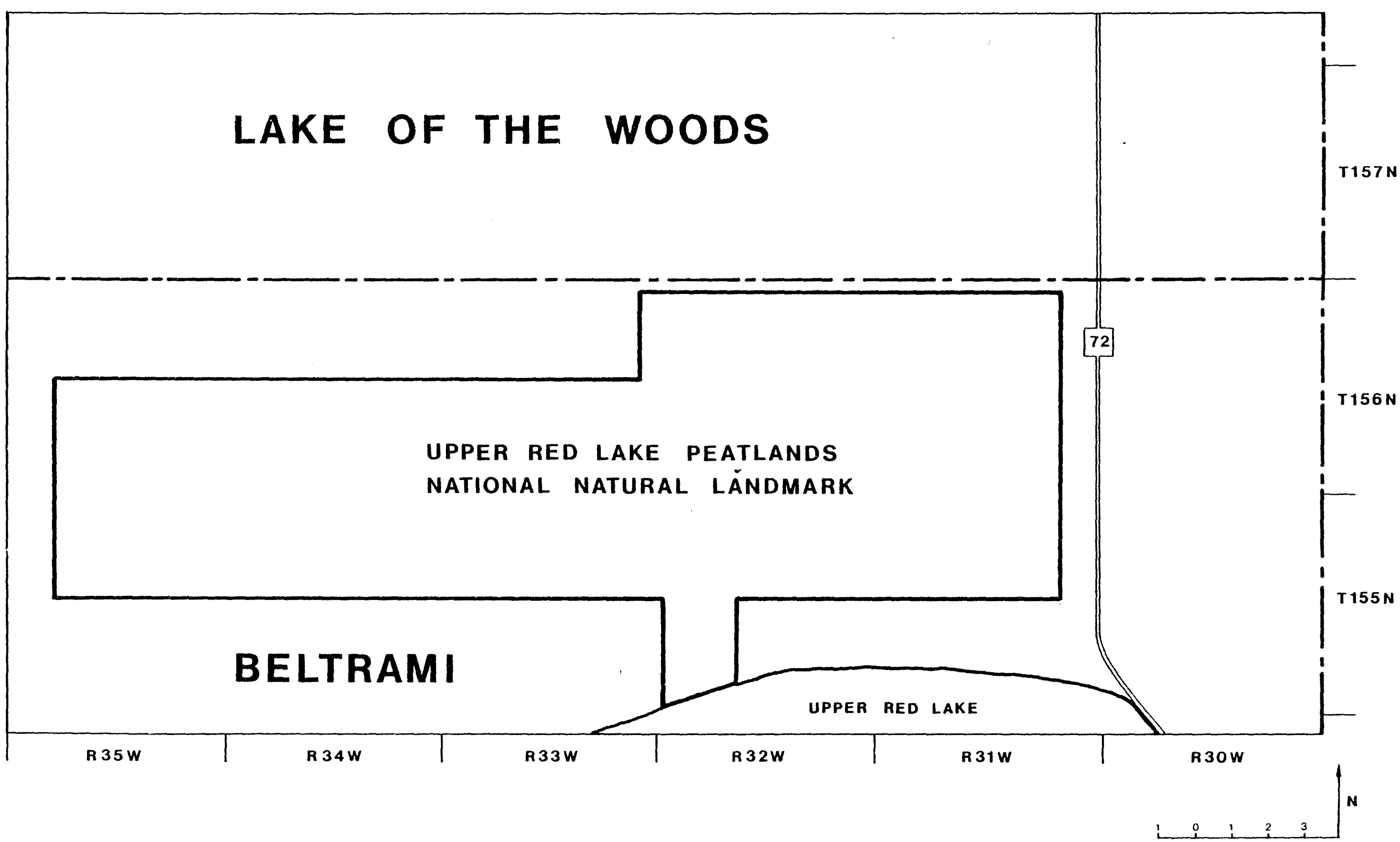

Figure B-2. Upper Red Lake Peatlands National Natural Landmark (Designated), Beltrami County, Minnesota.

Land Ownership Map. Koochiching County, Minnesota. 1973. Minnesota Department of Iron Range Resources and Rehabilitation and Minnesota Department of Highways.

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APPENDIX C. WATER QUALITY

Water quality data from northern Minnesota peatlands and adjacent lakes and streams is apparently very scarce. The relationship between the chemical composition of surface water and vegetation patterns at several stations in the Red Lake peatland was investigated during 1964-1966 (Hofstetter, 1969). In the October 1975 field effort of the present program, sampling at these stations was prevented because they were inaccessible with available transportation. In 1972 both Upper and Lower Red Lakes water quality was investigated at six stations (Elwell, et al., 1973); these also were not revisited in October 1975 because these are beyond the scope of the Phase 1 program. Other studies are available for comparison with the preliminary results discussed in this report, including other data from the Red Lakes (Maderak, 1962; Allison, 1932) and 1975 data from streams among the smaller peat deposits in northeastern Minnesota (MRI, 1975).

This scarcity of literature indicated the need for some additional although preliminary field data. Samples for water quality determinations were collected at several sites in northern Minnesota peatlands in October 1975 during a dry fall season. The objectives of this water quality study were: 1) to obtain more recent data because the last collections were made in 1966; 2) to evaluate sampling and analytical methodologies and sensitivity levels encountered in Peatland water quality analyses; and 3) to provide additional information not currently available on (a) ecologic transition zones such as wet versus dry sites and mineral versus peatland sites, (b) developed versus undeveloped sites, (c) parameters not previously measured, and (d) habitat homogeneity. However, due to program contraints only a very few stations and analyses could be conducted. Analysis for other parameters as well as greater levels of sensitivity remain for the Phase 2 program.

Stations from which preliminary water quality data were collected in October 1975 are located between Big Falls, Minnesota, and Upper Red Lake (See Figure C-1). Ten stations were sampled including a station on each of three natural streams, a station each on three old drainage ditches, and two stations at each of two bog sites. While a more intensive investigation of peatland water quality is necessary, such an effort is beyond the scope of the preliminary studies planned for the Phase 1 program.

The three streams and one drainage ditch apparently drain a portion of the Red Lake peatland. West Two Rivers (Station 1), Deer Creek (Station 2) and "Birch Island" Ditch (Station 3) flow through old beach ridges, where the water samples were collected, and discharge into Upper Red Lake. Deer Creek is a clear-water stream located between two characteristically tea-colored waters. This anomaly hopefully can be investigated during the Phase II effort.

Troy Creek flows northward from the Red Lake peatland into the Rapid River, which joins the Rainy River about eight miles east from Baudette, Minnesota. A water sample was collected where the peatland water begins to flow across mineral soil (Station 8).

A ditch draining a raised bog in the Pine Island State Forest (Station 5) and a ditch along the Fiero Road about 10 miles south of Fairland (Station 6) were also sampled. Station 5 is on the drainage divide between the Sturgeon River to the south and the Black River to the north. At Station 6 the flow is northward into the Black River.

One of the bog sites is adjacent to Station 6. It was selected to investigate the change in water quality between the bog and the nearby drainage ditch, and between a 40 acre site which had been logged (Station 7) and the adjacent spruce and cedar forest (Station 8). Borings into the peat were made to obtain water depth in the peat between Stations 7 and 8; there was no water on the surface. After about 24 hours a water sample was collected from Station 7, which had filled to within about 6 inches of the peat surface. In contrast at Station 8, the water level was about 30 inches below the peat surface, about 5 inches deep, which was insufficient to obtain a water sample.

A spruce forest site, including a dry area with trees of normal-appearing height (Station 9) and a wet site with stunted trees (Station 10) is located on the Twomey Williams Truck Trail about 17 miles northwest from Big Falls, Minnesota. A hole was

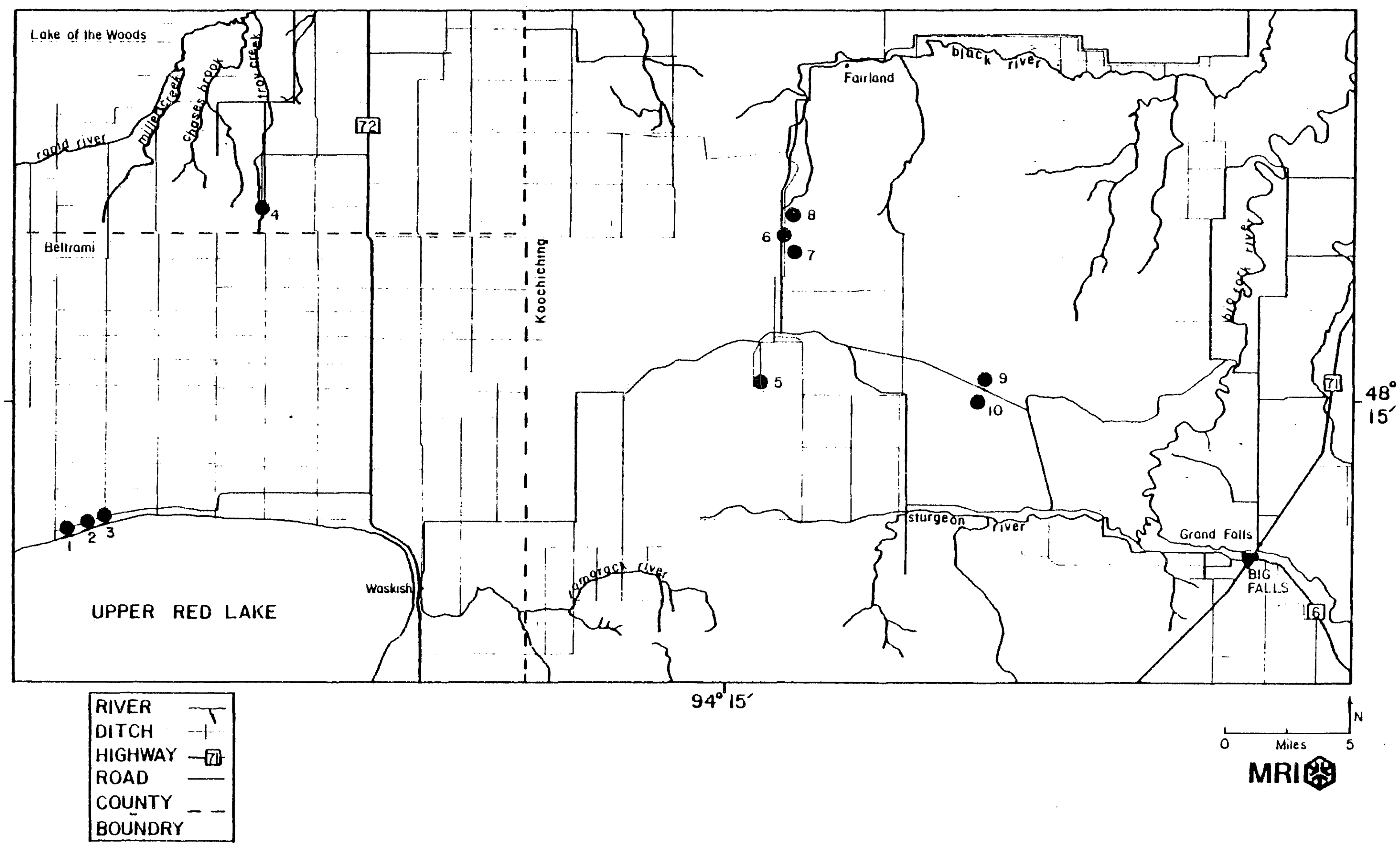

Figure C-1. Water Quality Sampling Stations, Northern Minnesota Peatlands, October 1975.

bored in the peat at each site to obtain the water depth and to collect a water sample (again after 24 hours). There was no surface water at these sites.

The results of this preliminary water quality investigation are shown in Table C-1. The limnological parameters analyzed include temperature, turbidity, conductivity, pH, bicarbonate alkalinity, ammonia, nitrate, total and dissolved orthophosphate as well as total Kjeldahl nitogen. The iron, nickel and copper were also determined. Water quality parameters used in classifying peatland habitats were analyzed, including chloride, sulfate, calcium, magnesium, sodium and potassium. Dissolved oxygen concentrations were determined but are not included because of equipment malfunction (the faulty apparatus has since been replaced). The data shown were obtained from a single sample at each station and thus the data are preliminary and are of no statistical significance. Therefore, an estimate of habitat homogeniety with respect to water quality could not be accomplished as part of the Phase 1 program.

These preliminary water quality data suggest that generally the waters studied are similar in composition to others investigated in northern Minnesota (Hofstetter, 1969; MRI, 1975; MPCA, 1969; Moyle, 1956). The streams and ditches are about neutral in pH and moderate in alkalinity and conductivity. However, these parameter values for Troy Creek are unusually bog-like for a stream because the sample was collected at the edge of the bog perhaps before the water had much, if any, contact with the mineral soil.

Turbidity is quite low except in the water collected from the bore-holes on the bog sites. Evidently more than 24 hours should elapse before sampling to allow settling of particulates. Incorporated suspended matter, which is probably peat particles from the bore-hole walls, may be the source of the high concentrations of total Kjeldahl nitrogen, total phosphorus, and total iron.

Chloride and, at only four stations, the sulfate concentrations in the peatland waters appear to be higher than has been reported in northern Minnesota (Moyle, 1956). On the other hand, the chloride levels appear to be within the ranges reported for the Rainy River at Baudette (MPCA, 1969). (See also Table C-2 for comparisons, where the October 1975 data are tentatively summarized by habitats as in Hofstetter, 1969.)

Of the metallic elements analyzed, the nickel concentrations were at or below the sensitivity level of the analyses employed. Iron concentrations are in the middle to upper range of concentrations reported from the Rainy River at Baudette (MPCA, 1969).

Further comparison of the October 1975 water quality data (in summary form) with data from previous studies in the Red Lake area shows relatively few differences in concentrations of most parameters (Table C-2). Notable exceptions are that chloride is higher and sulfate lower in concentration in October 1975 than reported previously from the Red Lakes (Elwell, et al., 1973; Maderak, 1962; Allison, 1932). While the calcium concentrations and alkalinity are characteristically lower in the bog sites than in the streams and ditches, unexpectedly the sodium and sulfate concentrations are not higher in the bogs compared with the streams and ditches as suggested by the more numerous European data (Moore and Bellamy, 1974).

Several tentative conclusions may be drawn from these preliminary data which would be further studied in Phase 2. Water from a bog which is coming into contact with mineral soil quickly attains neutral pH. Then perhaps some distance downstream it gains bicarbonate and calcium but loses iron. These changes in water quality are suggested by the data from Troy Creek and from the Pine Island and Fiero Road ditches, which are located in the bogs.

The high water level in the logged site on Fiero Road, compared with the water levels in the adjacent forest, indicate that perhaps trees may play a significant role in the lowering of water levels in some bogs, as well as being stunted by excess water in other instances. Thus transpiration is probably a highly significant factor in the bog hydrologic budget. This logged site also had the highest concentration of total phosphorus and total iron, and nearly the highest levels of ammonia, nitrate, total Kjeldahl nitrogen, magnesium and potassium compared with the other stations. Thus logging may have an effect on *in situ* water quality because all parameters were analyzed on filtered water except total phosphorus, Kjeldahl nitrogen and iron.

Differences in water quality between wet sites with stunted spruce and dryer forest sites lacking stunted spruce, appear to be minor. The wet site seems scmewhat more acid and nutrient poor, although it had the highest nitrate concentration.

Table C-1. Preliminary Water Quality for Northern Minnesota Peatlands, October 1975

WATER QUALITY PARAMETERS Data in mg/l, except as noted	West Two Rivers	Deer Creek	Birch Island Ditch	Troy Creek	Pine Island Ditch	Fiero Road Ditch	Fiero Road Logged Site	Twomey Williams Road Site (West)	Twomey Williams Road Site (East)
Dissolved Oxygen	*	*	*	*	*	*	*	*	*
Temperature (°C)	7.2	6.4	6.9	8.1	7.6	8.0	7.5	8.2	9.0
Turbidity (NTU)	2.0	1.4	1.4	1.3	1.2	3.0	210	160	240
Conductivity (μmhos)	370	290	128	65	325	425	305	90	75
pH (units)	7.5	7.5	7.2	7.2	7.6	8.0	6.2	5.4	4.4
Alkalinity, Bicarbonate (as $CaCO_3$)	124	76	38	24	126	176	92	16	<1
Ammonia (as N)	0.36	0.17	0.13	0.16	0.75	0.41	1.1	2.8	0.5
Nitrate (as N)	0.64	0.48	0.60	0.36	0.52	0.40	0.80	0.53	0.94
Total Kjeldahl Nitrogen (as N)	1.6	0.8	0.9	0.9	1.7	1.1	5.6	12	0.5
Total Phosphorus (as P)	0.10	<0.05	<0.05	<0.05	<0.05	<0.05	1.3	0.56	<0.05
Dissolved Ortho phosphorus (as P)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloride (as Cl)	2	7	3	2	2	1	4	4	5
Sulfate (as SO_4)	7	7	11	1	1	<1	<1	<2	4
Calcium (as Ca)	24	22	16	8	37	47	30	6	3
Magnesium (as Mg)	7.6	6.0	3.6	3.2	9.4	11	9.8	3.0	3.0
Sodium (as Na)	2.0	1.5	1.0	1.2	3.2	4.0	3.2	0.75	0.75
Potassium (as K)	0.95	0.50	0.35	0.2	0.65	1.0	1.1	0.35	0.60
Total Iron (as Fe)	0.50	0.50	0.90	0.70	0.90	0.30	4.0	1.3	2.0
Total Nickel (as Ni)	0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.05	0.05	<0.05
Total Copper (as Cu)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

*No data due to equipment failure.

Table C-2. A Comparison of Water Quality Data from Northern Minnesota

Water Quality Parameters, in mg/l except as noted	Northern Peatlands (1975)[1]			Red Lake Peatlands (1969)[2]			Red Lakes				N.E. Minnesota Lakes & Streams	Rainy River Baudette
							(1973)[3]		(1962)[4]	(1932)[5]		
	Streams	Ditches	Bogs	Streams	Ditches	Bogs	Upper	Lower	Lower	Lower	(1975)[6]	(1969)[7]
Conductivity, μmhos	242	293	83	--*	--	--	251	276	283	--	--	--
pH, units	7.3	7.6	4.9	7.8	7.5	4.0	8.1	7.6	7.6	--	5.6-8.1	7.1-8.2
Alkalinity, bicarbonate, (as $CaCO_3$)	75	113	36	140	62	<1	--	--	171	151	--	24-210
Ammonia (as N)	0.23	0.43	1.6	--	--	--	0.15	0.10	--	--	<0.1-1.8	0.05-0.38
Nitrate (as N)	0.57	0.43	0.73	--	--	--	0.05	0.10	0.63	5.4	0.01-4.0	0.02-2.4
Chloride (as Cl)	4	2	5	0.4	0.3	0.9	--	--	0.2	1.8	--	<1-44
Sulfate (as SO_4)	5	4	2	11.6	13.5	13.9	--	--	12.0	3.0	<1-5	--
Calcium (as Ca)	18	33	5	35.6	20.0	4.4	36	38.5	34.0	31.0	2-30	--
Magnesium (as Mg)	5.6	8.0	3.0	9.4	4.1	0.5	12.0	12.8	15.0	15.0	1.9-18	--
Sodium (as Na)	1.6	2.7	0.7	1.3	0.8	1.1	--	--	3.2	23.0	0.2-14.5	--
Potassium (as K)	0.5	0.6	0.6	0.6	0.4	1.5	2.4	2.8	2.0	9.0	<0.2-2.1	

*No data
[1]MRI samples collected October 1975
[2]Hofstetter, 1969
[3]Elwell, et al., 1973
[4]Maderak, 1963
[5]Allison, 1932
[6]MRI, 1975
[7]MPCA, 1969

The information obtained in this preliminary water quality study is valuable for planning the more detailed investigations scheduled for Phase 2. It is recognized, however, that the unexpected relationships of concentrations between certain parameters within and between several stations, plus the sampling limitations encountered, and few samples as well, tend to cloud interpretations with respect to ecologic transition zones and developed versus undeveloped sites.

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APPENDIX D. STATE AIR AND WATER REGULATIONS

Table D1. Ambient Air Quality

PRIMARY STANDARD	SECONDARY STANDARD	WORDING OF STANDARD	POLLUTANT
75 μg/m^3 260 μg/m^3	60 μg/m^3 150 μg/m^3	Max. annual geometric mean Max. 24 hr. concentration Not to be exceeded more than once per year.	PARTICULATE MATTER
.20 ppm (60 μg/m^3) .10 ppm (260 μg/m^3) .25 ppm (655 μg.m^3)	.02 ppm (60 μg/m^3) .10 ppm (260 μg/m^3) .25 ppm (655 μg/m^3)	Max. annual arith. mean Max. 24 hr. concentration Not to be exceeded more than once per year. Max. 3 hr. concentration Not to be exceeded more than once per year.	SULFUR OXIDES
9 ppm (10 mg/m^3) 30 ppm (35 mg/m^3)	9 ppm (10 mg/m^3) 30 ppm (35 mg/m^3)	Max. 8 hr. concentration Not to be exceeded more than once per year. Max. 1 hr. concentration Not to be exceeded more than once per year.	CARBON MONOXIDE
.07 ppm (130 μg/m^3)	.07 ppm (130 μg.m^3)	Max. 1 hr. concentration Not to be exceeded more than once per year.	OXIDANTS
.24 ppm (160 μg/m^3)	.24 ppm (160 μg/m^3)	Max. 3 hr. concentration (6 to 9 a.m.) not to be exceeded more than once per year.	HYDROCARBONS (Less Meth.)
.05 ppm (100 μg/m^3)	.05 ppm (100 μg/m^3)	Max. annual arith. mean	NITROGEN OXIDES
.05 ppm (70 g/m^3)	.03 ppm (42 g/m^3)	1/2 hr. average not to be exceeded over two times per year for primary standard. 1/2 hr. average not to be exceeded over two times in any five consecutive days for secondary standard.	HYDROGEN SULFIDE

Table D.1. Ambient Air Quality (Continued)

POLLUTANT	WORDING OF STANDARD	SECONDARY[b] STANDARD	PRIMARY[a] STANDARD
PARTICULATE MATTER	Annual geom. mean conc. Max. 24 hr. concentration Not to be exceeded more than once per year	60 μg/m^3 150 μg/m^3	75 μg/m^3 260 μg/m^3
SULFUR OXIDES	Annual arith. avg. conc. Max. 24 hr. concentration Not to be exceeded more than once per year Max. 3 hr concentration Not to be exceeded more than once per year	.50 ppm (1300 μg/m^3)	.03 pm (80 μg/m^3) 14 ppm (365 μg/m^3)
CARBON MONOXIDE	Max. 8 hr. concentration Not to be exceeded more than once per year Max. 1 hr. concentration Not to be exceeded more than once per year	9 ppm (10 mg/m^3) 35 ppm (40 mg/m^3)	9 ppm (10 mg/m^3) 35 ppm (40 mg/m^3)
OXIDANTS	Max. 1 hr. concentration Not to be exceeded more than once per year	.08 ppm (160 μg/m^3)	.08 ppm (160 μg/m^3)
HYDROCARBONS (Less Meth.)	Max. 3 hr. concentration (6-9 a.m.) Not to be exceeded more than once per year	.24 ppm (160 μg/m^3)	.24 ppm (160 μg/m^3)
NITROGEN OXIDES	Annual arith. avg. conc.	.05 ppm (10 μg/m^3)	.05 ppm (100 μg/m^3)
HYDROGEN SULFIDE	(At present there is no federal standard for H_2S)		

(a) Primary standard: Enforcement by summer 1975
(b) Secondary standard: No time limit on enforcement

Table D-2. Minnesota Water Quality Use Classifications and Standards for the Northern Minnesota Peatland Area.

1. Domestic Consumption

Class B. The quality of this class of the intrastate waters of the state shall be such that with approved disinfection, such as simple chlorination or its equivalent, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards-1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface and underground waters with a moderately high degree of natural protection.

Substance or Characteristic	Limit or Range
Fecal coliform organisms	10 most probable number per 100 milliliters
Total coliform organisms	1 most probable number per 100 milliliters
Turbidity value	5
Color value	15
Threshold odor number	3
Methylene blue active substance (MBAS)	0.5 milligram per liter
Arsenic (As)	0.01 milligram per liter
Chlorides (Cl)	250 milligrams per liter
Copper (Cu)	1 milligram per liter
Carbon Chloroform extract	0.2 milligram per liter
Cyanides (CN)	0.01 milligram per liter
Fluorides (F)	1.5 milligrams per liter
Iron (Fe)	0.3 milligram per liter
Manganese (Mn)	0.05 milligram per liter
Nitrates (NO_3)	45 milligrams per liter
Phenol	0.001 milligram per liter
Sulfates (SO_4)	250 milligrams per liter
Total dissolved solids	500 milligrams per liter
Zinc (Zn)	5 milligrams per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Hexavalent, Cr)	0.05 milligram per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.01 milligram per liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

2. Fisheries and Recreation

Class A. The quality of this class of the intrastate waters of the state shall be such as to permit the propagation and maintenance of warm or cold water sport or commercial fishes and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the intrastate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 7 milligrams per liter from October 1st and continuing through May 31st, and Not less than 6 milligrams per liter at other times
Temperature	No material increase
Ammonia (N)	0.2 milligram per liter
Chlorides (Cl)	50 milligrams per liter
Chromium (Cr)	0.02 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value

Table D-2. Minnesota Water Quality Use Calssifications and Standards for the Northern Minnesota Peatland Area. (Continued)

Substance or Characteristic	Limit or Range
Cyanides (CN)	0.02 milligram per liter
Oil	0.5 milligram per liter
pH value	6.5 - 8.5
Phenols	0.01 milligram per liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bio-assays and tastes panels will be required to determine whether tainting is likely or present
Turbidity value	10
Color value	30
Fecal coliform organisms	200 most probable number per 100 milliliters as a monthly geometric mean based on not less than 5 samples per month, nor exceed 400 most probable number per 100 mililiters in more than 10 percent of all samples during any month
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use

Class B. The quality of this class of the intrastate waters of the state shall be such as to permit the propagation and maintenance of cool or warm water sport or commercial fishes and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the intrastate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 6 milligrams per liter from April 1 through May 31, and not less than 5 milligrams per liter at other times
Temperature	5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature, except in no case shall it exceed the daily average temperature of 86°F
Ammonia (N)	1 milligram per liter
Chromium (Cr)	0.05 milligram per liter
Copper (Cu)	0.01 milligram per liter or not greater than 1/10 the 96 hour TLM value
Cyanides (CN)	0.02 milligram per liter
Oil	0.5 milligram per liter
pH value	6.5 - 9.0

Table D-2. Minnesota Water Quality Use Classifications and Standards for the Northern Minnesota Peatland Area. (Continued)

Substance or Characteristic	Limit or Range
Phenols	0.01 milligram per liter and none that could impart odor or taste to fish flesh or other freshwater edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present
Turbidity value	25
Fecal coliform organisms	200 most probable number per 100 milliliters as a monthly geometric mean based on not less than 5 samples per month, nor equal or exceed 2000 most probable number per 100 milliliters in more than 10 percent of all samples during any month
Radioactive materials	Not to exceed the lowest concentration permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use

3. Industrial Consumption
Class B. The quality of this class of the intrastate waters of the state shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment.

Substance or Characteristic	Limit or Range
Chlorides (Cl)	100 milligrams per liter
Hardness	250 milligrams per liter
pH value	6.0 - 9.0
Fecal coliform organisms	200 most probable number per 100 milliliters
Arsenic (As)	0.05 milligram per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Cr + 6)	0.05 milligram per liter
Cyanide (CN)	0.02 milligram per liter
Fluoride (F)	1.5 milligrams per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by any person to gain access to any intrastate waters classified for domestic consumption so as to cause any material undesirable increase in the taste, hardness, temperature, toxicity, corrosiveness or nutrient content, or in any other manner to impair the natural quality or value of the intrastate waters for use as a source of drinking water.

Minnesota State Regulations. 1973. Criteria for the classification of the intrastate waters of the state and the establishment of standards of quality and purity. WPC 14. 17 pp.

APPENDIX E. LISTS OF BIOTA

The flora and fauna of northern Minnesota's peatlands and adjacent areas are listed in the following three tables, where designation of rareness of species and the habitat preference of the animals is also given. An additional table lists peatlands by ecologic type.

These lists of biota were assembled from the available literature. While they are as complete and accurate as this information allows, errors may exist. It should be realized that the peatland biota have not been adequately inventoried. Problems of remoteness, inaccessability, animal mobility, and perhaps perceived low value as wildlife habitat have detracted from the study of peatland biota.

In this literature, the flora is usually reported from specific bog sites, whereas the occurrence of many animal species is more general, frequently on a county basis. However, reports on the location of bird species and species under Minnesota DNR management were used as available. For the other animal species, the reported habitat preference(s) is noted in the list.

Table E-1. Flora of Minnesota's Peatlands: A Preliminary List (Hofstetter, 1969; Conway, 1949; Griffin, 1975)

COMMON NAME	SCIENTIFIC NAME
TREES AND SHRUBS	
Balsam Fir	Abies balsamea (L.) Mill
Speckled alder	Alnus rugosa var. americana (Regal) Fern.
Bog-rosemary	Andromeda glaucophylla Link
Low or Swamp Birch	Betula pumila var. glandulifera Regel
Leather-leaf	Chamaedaphne calyculata (L.) Moench
Princes Pine	Chimaphila umbellata (L.) Bart
Bunchberry	Chamaepericlymenum canadense (L.) Asch. & Graebn.
Black Ash	Fraxinus nigra Marsh.
Creeping snowberry	Gaultheria hispidula (L.) Bigel.
Common Juniper	Juniperus communis var. depressa Purch
Bog-Laurel	Kalmia polifolia Wang.
Tamarack	Larix laricina (Du Roi) K. Koch
Labrador Tea	Ledum groenlandicum Oeder
Mountainfly-Honeysuckle	Lonicera coerulca L.
Sweet Gale	Myrica gale L.
Black or Bog-Spruce	Picea mariana (Mill) BSP
Jack Pine	Pinus banksiana Lamb.
Balsam poplar	Populus balsamifera
Shrubby Cinquefoil	Potentilla fruticosa L.
Cinquefoil	Potentilla palustrix
Black Chokeberry	Pyrus melanocarpa (M)
Buckthorn	Rhamnus alnifolia L'Her.
Raspberry	Rubus idaeus var. strigosus (Mich.) Maxim.
Long-beaked Willow	Salix bebbiana Sarg.
Hoary willow	Salix candida
Heart-leaved Willow	Salix cordata
Pussy Willow	Salix discolor
Shrub Willow	Salix gracilis Anderss.
Sandbar Willow	Salix interior
Willow	Salix pedicellaris var. hypoglauca Fern.
Balsam Willow	Salix pyrifolia Anderss.

COMMON NAME	SCIENTIFIC NAME
TREES & SHRUBS (cont.)	
Rigid Willow	Salix rigida
Autumn Willow	Salix serissima (Bailey) Fern.
White Cedar	Thuja occidentalis L.
Low Sweet or Late Sweet Blueberries	Vaccinium angustifolium Ait.
Sour-Top-Bluebrries or Velvet-Leaf-Blueberries	Vaccinium myrtilloides Michx.
Small Cranberry	Vaccinium oxycoccus L.
Mountain-Cranberry	Vaccinium vitis-idaea var. minus Lodd.
Marsh speedwell	Veronica scutellata
HERBS	
Wild Sarsaparilla	Aralia nudicaulis L.
Swamp-Pink	Arethusa bulbosa L.
Aster	Aster junciformis Tydb.
Aster	Aster puniceus L.
Beggar Ticks	Bidens cernua L.
Beggar Ticks	Bidens coronata (L.) Britton
Beggar-Ticks	Bidens connata var. petiolata (Nutt.) Farw.
Wild Calla	Calla palustris L.
Grass-Pink	Calopogon pulchellus (Salisb.) F. Br.
Marsh Marigold	Caltha palustris L.
Marsh Bellflower	Campanula aparinoides Pursh
Marsh Bellflower	Campanula uliginosa Rydb
Smaller Enchanter's Nightshade	Circaea alpina L.
Water-Hemlock	Cicuta bulbifera L.
Canada Thistle	Cirsium arvense (L.) Scop.
Swamp thistle	Cirsium muticum
Goldthread	Coptis groenlandica (Oeder) Fernald
Red-osier Dogwood	Cornus stolonifera Michx.
Sundew	Drosera anglica Huds.

Table E-1. Flora of Minnesota's Peatlands: A Preliminary List (Continued)

COMMON NAME	SCIENTIFIC NAME
HERBS (cont.)	
Sundew	Drosera linearis Goldie
Sundew	Drosera intermedia Hayne
Round-Leaved Sundew	Drosera rotundifolia L.
Willow-Herb	Epilobium leptophyllum Raf.
Willow-Herb	Epilobium palustre L.
Joe-Pye Weed	Eupatorium maculatum L.
Thoroughwort	Eupatorium perfoliatum L.
Woodland Strawberry	Fragaria vesca L. var. americana Porter
Bedstraw	Galium labradoricum Wieg.
Small bedstraw	Galium trifidum
Bedstraw	Galium triflorum Michx.
Small fringed gentian	Gentiana procera
Slender gerardia	Gerardia tenuifolia
Ragged Orchis	Habenaria lacera (Michx.) Lodd.
Sneezeweed	Helenium autumnale
St. John's Wort	Hypericum virginicum var. Fraseri (Spach) Fern.
Touch-me-not	Impatiens biflora Walt
Blue Flag	Iris versicolor L.
Rice-cutgrass	Leersia oryzoides (L.) Swartz.
Northern Twinflower	Linnaea borealis L. var. americana (Forbes) Rehder
Bog Twayblade	Liparis loeselii (L.) Richard
Lobelia	Lobelia kalmii L.
Water Horehound	Lycopus americanus
Water-Horehound	Lycopus uniflorus Michx.
Tufted Loosestrife	Lysimachia thyrsiflora L.
Yellow or Swamp-Loosestrife	Lysimachia terrestris (L.) BSP.
Wild Lily-of-the-Valley	Maianthemum canadense Desf.
Wild Mint	Mentha arvensis
Monkey-Flower	Mimulus ringens L.

COMMON NAME	SCIENTIFIC NAME
HERBS (cont.)	
Indian-Pipe	Monotropa L.
Bishop's Cap	Mitella nuda
Marsh Grass-of-Parnassus	Parnassia palustris var. neogsea Fern.
Lousewort	Pedicularis lanceolata Michx.
Sweet Coltsfoot	Petasites sagittatus (Pursh) Gray
Blue Grass	Poa palustris
Pogonia	Pogonia ophioglossoides (L.) Ker
Arrow-Leaved Tearthumb	Polygonum sagittatum L.
Marsh-Five-Finger	Potentilla palustris (L.) Scop.
One-sided Wintergreen	Pyrola secunda L.
Dwarf Raspberry	Rubus acaulis Michx.
Raspberry	Rubus idaeus L. (agg.)
Dwarf Raspberry	Rubus pubescens Raf.
Great Water Dock	Rumex orbiculatus
Pitcher Plant	Sarracenia purpurea L.
Swamp Saxifrage	Saxifraga pennsylvanica L.
Common Skullcap	Scutellaria epilobiifolia A. Hamilton
False Solomon's-Seal	Smilacina trifolia (L.) Desf.
Canadian Golden Rod	Solidago canadensis L.
Narrow-leaved Goldenrod	Solidago graminifolia
Golden Rod	Solidago juncea Ait.
Golden Rod	Solidago uliginosa Nutt.
Sow Thistle	Sonchus L.
Chickweed	Stellaria longifolia Muhl.
St. John's Wort	Triadenum virginicum
Marsh-St. John's Wort	Trientalis borealis Raf.
Marsh Speedwell	Veronica scutellata
Violet	Viola pallens (Banks) Brainerd

Table E-1. Flora of Minnesota's Peatlands: A Preliminary List (Continued)

COMMON NAME	SCIENTIFIC NAME
AQUATICS	
Buckbean	Menyanthes trifoliata L.
Bullhead-Lily	Nuphar variegatum Engelm
Pondweed	Potamogeton gramineus L.
Pondweed	Potamogeton natans L.
Snowbird	Sagitlaria latifolia Willd
Hardstem bulrush	Scirpus acutus
Bullrush	Scirpus hudsonianus (Michx.) Fern.
Great or Sort-Stem Bulrush	Scirpus validus Vah.
Water parsnip	Sium suavé
Bur reed	Sparganium minimum (Hartm.) Fries
Cat Tail	Typha latifolia L.
Bladderwort	Utricularia cornuta Michx.
Bladderwort	Utricularia intermedia Hayne
Bladderwort	Utricularia minor L.
Bladderwort	Utricularia vulgaris L.
GRAMINIDS	
Rough Hairgrass	Agrostis hyemalis (Wolf) B.S.P.
Ticklegrass	Agrostis scabra
Swamp Milkweed	Asclepias incarnata
Brome-Grass	Bromus ciliatus L.
Blue-Joint Grass	Calamagrostis canadensis (Michx.) Nut.
Northern Reedgrass	Calamagrostis inexpansa
Sedge	Carex aquatilis
Sedge	Carex atherodes
Sedge	Carex bebbii Olney
Sedge	Carex brunnescens (Pers.) Poir
Sedge	Carex canescensL.
Sedge	Carex chordorrhiza L.
Sedge	Carex comosa Boot
Sedge	Carex diandra Schramk
Sedge	Carex disperma Dew
GRAMINIDS (cont.)	
Sedge	Carex interior Bailey
Sedge	Carex lacustris Willd.
Sedge	Carex laeviconica
Sedge	Carex lasiocarpa var. americana Fern.
Sedge	Carex leptalea Wahlenb.
Sedge	Carex limosa L.
Sedge	Carex livida (Wahlenb.) Willd.
Sedge	Carex oligosperma Michx.
Sedge	Carex pauciflora Lightf.
Sedge	Carex paupercula Michx.
Sedge	Carex pseudo-cyperus L.
Sedge	Carex rioania Curtis var. lacustris (Willd.)
Sedge	Carex rostrata var. utriculata (Boott) Bailey
Sedge	Carex stricta var. strictior (Dew.) Caroy
Sedge	Carex tenuiflora Wahlenb.
Sedge	Carex trisperma Dew.
Twig-Rush	Cladium mariscoides (Muhl.) Torr.
Three-way-sedge	Dulichium arundinaceum (L.) Britton
Spikerush	Eleocharis calva
Spikerush	Eleocharis compressa Sulliv.
Horsetail	Equisetum fluviatile L.
Cotton-grass	Eriophorum chamissonis Mey
Cotton-grass	Eriophorum gracile Koch
Hare's Tail	Eriophorum spissum Fern.
Tawny Cotton-Grass	Eriophorum virginicum L.
Cotton-grass	Eriophorum varidi-carinatum (Engelm.) Fern.
Small fringed gentian	Gentiana procera
Rush	Juncus brevicaudatus (Engelm.) Fern.
Rush	Juncus canadensis J. Gay
Muhly	Muhlenbergia glomerata (Willd.) Trin.
Marsh Muhly	Muhlenbergia racemosa

Table E-1. Flora of Minnesota's Peatlands: A Preliminary List (Continued)

COMMON NAME	SCIENTIFIC NAME
GRAMINIDS (cont.)	
Reed	Phragmites communis Trin.
Beak-Rush	Rhynchospera alba (L.) Vahl
Scheuchzeria	Scheuchzeria palustris var. americana Fern.
Arrow-Grass	Triglochin maritima L.
Arrow-Grass	Triglochin palustris L.
FERNS	
Spinulose Wood-Fern	Dryopteris spinulosa
Marsh-Fern	Dryopteris thelypteris (L.) Gray var. pubescens (Lawson) Nakai
Interrupted Fern	Osmunda claytoniana L.
HEPATICAE	
Liverwort	Riccardia pinguis
BRYALES (Major species only)	
Moss	Aulacomnium palustre (Hedw.) Schwaegr.
Moss	Bryum bimum Schreb.
Moss	Calliergon cordifolium (Hedw.) Kindb
Moss	Calliergon giganteum (Schimp.) kindb.
Moss	Calliergon stramineum (Brid.) Kindb.
Moss	Calliergon trifarium (Web. & Mohr) Kindb.
Moss	Calliergonella cuspidata (Hedw.) Loeske
Moss	Campylium stellatum (Hedw.) C. Jens.
Moss	Climaceum americanum Brid
Moss	Climaceum dendroides (Hedw.) Web. & Mohr.
Moss	Dicranum bergeri Bland.
Moss	Dicranum undulatum Ehrh
Moss	Drepanocladus aduncus (Hedw.) Warnst. var Kneiffii (Bry. Eur.) Mönkem
Moss	Drepanocladus aduncus (Hedw.) Warnst. var. typicus (Ren.) Wynne
Moss	Drepanocladus intermedius
Moss	Drepanocladus vernicosus (Lindb. ex C. Hartm.) Warnst.

COMMON NAME	SCIENTIFIC NAME
BRYALES (Major Species only) cont.	
Moss	Helodium blandowii (Web. & Mohr) Warnst.
Moss	Hylocomnium proliferum (L.) Lindb
Moss	Hylocomnium splendens
Moss	Hypnum crista-castrensis L.
Moss	Hypnum lindbergii Mitt.
Moss	Hypnum patientiae Lindb
Moss	Meesia tristicha (trifaria Crum, Steere & Anderson)
Moss	Mnium rostratum Schrad.
Moss	Pleurozium schreberi (Brid.) Mitt.
Moss	Polytrichum affine Funck (strictum Banks)
Moss	Polytrichum commune L.
Moss	Polytrichum strictum Banks
Moss	Scorpidium scorpioides (Hedw.) Limpr.
Moss	Thiudium delicatulum (L.) Lindb.
Moss	Thiudium virginianum (Brid.) Lindb.
Moss	Thuizium B.S.G.
Moss	Tomenthypnum nitens (Hedw.) Loeske
Aquatic Moss	Fontinalis sp.
SPHAGNALES	
Sphagnum or peat moss	Sphagnum amblyphyllum Russ.
Sphagnum or peat moss	Sphagnum apiculatum H. Lindb.
Sphagnum or peat moss	Sphagnum centrale C. Jens.
Sphagnum or peat moss	Sphagnum contertum C. Jens
Sphagnum or peat moss	Sphagnum capillaceum (Weiss) Schrank
Sphagnum or peat moss	Sphagnum fimbratum Wils.
Sphagnum or peat moss	Sphagnum fuscum Klinggr.
Sphagnum or peat moss	Sphagnum magellanicum Brid.
Sphagnum or peat moss	Sphagnum nemereum Scop.
Sphagnum or peat moss	Sphagnum obtusum Warnst.
Sphagnum or peat moss	Sphagnum palustre L.
Sphagnum or peat moss	Sphagnum papillosum Lindb.
Sphagnum or peat moss	Sphagnum parvifolium Warnst.

E6

Table E-1. Flora of Minnesota's Peatlands: A Preliminary List (Continued)

COMMON NAME	SCIENTIFIC NAME
SPHAGNALES (cont.)	
Sphagnum or peat mosses	*Sphagnum platyphyllum* Sull. ex. Lindb.
Sphagnum or peat mosses	*Sphagnum plumulosum* Roll
Sphagnum or peat mosses	*Sphagnum recurvum* Beauv
Sphagnum or peat mosses	*Sphagnum robustum* Roll
Sphagnum or peat mosses	*Sphagnum rubellum* Wils.
Sphagnum or peat mosses	*Sphagnum squarrosum* Pers.
Sphagnum or peat mosses	*Sphagnum subsecundum* Nees
Sphagnum or peat mosses	*Sphagnum teres* Angstr.
Sphagnum or peat mosses	*Sphagnum warnstorfianum* Du Rietz

Table E-2. Animal Species of Minnesota's Peatlands and Adjacent Areas: A Preliminary List (Gunderson and Beer, 1953; Elwell, *et al.*, 1973; Knapp, 1960)

● Spruce bogs; o Fen
* Streams and banks
\+ Lakes
No Symbol=Wooded Uplands & Grasslands

Endangered Status
E - Endangered Species
T - Threatened
C - Changing/Uncertain Status
S - Special Interest

-p - Protected
-u - Unprotected

	Common Name	Scientific Name
	MAMMALS	
o●	Star-Nosed Mole	Condylura cristata
	Cinereous Shrew	Sorex cinereus
●	Saddle-Backed Shrew	Sorex arcticus
*	Water Shrew	Sorex palustris
	Pigmy Shrew	Microsorex hoyi
●	Short-Tailed Shrew	Blarina brevicauda
	Little Brown Bat	Myotis lucifugus
	Keen's Little Brown Bat	Myotis keenii
	White-Tailed Jack Rabbit	Lepus townsendii
●	Snowshoe Hare	Lepus americanus
	Cottontail Rabbit	Sylvilagus floridanus
*	Woodchuck	Marmota monax
	Richardson's Ground Squirrel	Citellus richardsonii
	Striped Ground Squirrel	Citellus tridecemlineatus
	Franklin's Ground Squirrel	Citellus franklinii
●	Least Chipmunk	Eutamias minimus
	Eastern Chipmunk	Tamias striatus
●	Red Squirrel	Tamiasciurus hudsonicus
	Gray Squirrel	Sciurus carolinensis
*	Fox Squirrel	Sciurus niger
	Little Flying Squirrel	Glaucomys volans
	Northern Flying Squirrel	Glaucomys sabrinus
*	Beaver	Castor canadensis
	Canadian White-Footed (Woodland Deer) Mouse	Peromyscus maniculatus gracilis
	Northern White-Footed Mouse	Peromyscus leucopus noveboracensis
o	Bog Lemming	Synaptomys cooperi
●	Northern Bog Lemming	Synaptomys borealis
●	Red-Backed Mouse (Vole)	Clethrionomys gapperi
	Common Meadow Mouse (Vole)	Microtus pennsylvanicus
	Rock Vole (C-u)	Microtus chrotorrhinus
*	Muskrat	Ondatra zibethica
	Norway Rat	Rattus norvegicus
	House Mouse	Mus musculus
	Meadow Jumping Mouse	Zapus hudsonius
*	Woodland Jumping Mouse	Napaeozapus insignis
	Porcupine	Erethizon dorsatus
	Black Bear	Ursus americanus
*	Raccoon	Procyon lotor
*	Fisher (C-p)	Martes pennanti
	Short-Tailed Weasel	Mustela erminea
*	Long-Tailed Weasel	Mustela frenata
o	Least Weasel	Mustela rixosa
*	Mink	Mustela vision
*	Otter	Lutra canadensis
*	Striped Skunk	Mephitis mephitis
	Badger	Taxidea taxus
	Red Fox	Vulpes fulva
	Gray Fox	Urocyon cinereoargenteus
●	Coyote	Canis latrans
●	Timber Wolf (E-p)	Canis lupus

Table E-2. Animal Species of Minnesota's Peatlands and Adjacent Areas: A Preliminary List (Gunderson and Beer, 1953; Elwell, *et al.*, 1973; Knapp, 1960).

• Spruce bogs; o Fen
* Streams and banks
+ Lakes
No symbol-Wooded Uplands & Grasslands

Endangered Species
E = Endangered Species
T = Threatened
C = Changing/Uncertain Status
S = Special interest
-p = Protected
-u = Unprotected

	Common Name	Scientific Name
o	Canada Lynx (C-U)	*Lynx canadensis*
	Bobcat (S-U)	*Lynx rufus*
	American Elk	*Cervus canadensis*
o•	White-Tailed Deer	*Odocoileus virginianus*
	Mule Deer	*Odocoileus hemionus*
o*	Moose	*Alces alces*
	FISH	
+	Walleye	*Stizostedion vitreum vitreum*
+	Yellow perch	*Perca flavescens*
+	Whitefish	*Coregonus clupeaformis*
+	Northern pike	*Esox lucius*
+	Goldeye	*Hiodon alosoides*
+	Sheepshead	*Aplodinotus grunniens*
+	Black bullhead	*Ictalurus melas*
	INVERTEBRATES (Aquatic)	
+	Water fleas	Cladocera
+	Fingernail clam	*Pisidium* sp.
+	Fingernail clam	*Sphaerium* sp.
+	Snail	*Amnicola* sp.
+	Snail	*Lymnea stagnalis*
+	Snail	*Physa* sp.
+	Snail	*Valvata tricarinata*
+	Snail	*Promenetus exacuatus*
+	Leech	*Helobdella stagnalis*
+	Leech	*Dina parva*
+	Flatworm	Turbellaria
+	Flatworm - planaria	Planariidae
+	Aquatic annelids	Oligochaeta
+	Burrowing mayfly	*Ephemera* sp.
+	Burrowing mayfly	*Hexagenis* sp.
+	Bottom sprawler mayfly	*Caenis* sp.
+	Net-spinning caddisfly	Hydropsychidae
+	Caddisfly	Molannidae
+	Silken tube-spinners, Finger net caddisfly	Philopotamidae
+	Tube-making, trumpet net caddisfly	Psychomyiidae
+	Midge	Chironomidae
+	Midge	Chironomidae
+	Biting midge	Ceratopogonidae
+	Riffle beetles	Elmidae
+	Scud	Gammaridae
+	Scud	*Hyalella azteca*
+	Seed shrimp	Ostracoda
+	Clam shrimp	Eubranchiopoda

Table E-3. Breeding Birds in Minnesota's Peatlands and Adjacent Areas: A Preliminary List (Eckert, 1974; Green and Jansen, 1975).

Habitat Key

- \+ = Coniferous Forests
- • = Spruce Bogs
- o = Fens
- No symbol = Wooded uplands and Grasslands

Endangered Species

- E = Endangered Species
- T = Threatened
- C = Changing/Uncertain Status in Minnesota
- S = Special Interest in Minnesota
- -p = Protected
- -u = Unprotected

	Common Loon
	Horned Grebe
	Double-crested Cormorant (C-u)
	Great Blue Heron (S-p)
	American Bittern
	Canada Goose
	Mallard
+	Black Duck
	Green-winged Teal
	Blue-winged Teal
+	American Widgeon
	Wood Duck
+	Ring-Necked Duck
+	Common Goldeneye
+	Hooded Merganser
+	Common Merganser
+	Red-breasted Merganser
	Turkey Vulture
•	Goshawk
	Cooper's Hawk (C-p)
	Red-tailed Hawk
	Broad-winged Hawk
+	Bald Eagle (C-p)
+	Marsh Hawk (C-p)
+	Osprey
+	Merlin
	American Kestrel
•	Spruce Grouse
	Ruffed Grouse
o	Sharp-tailed Grouse
•	Sandhill Crane (T-p)
o	Yellow Rail
	Sora Rail
	Killdeer
o	American Woodcock
o	Common Snipe
	Spotted Sandpiper
+	Solitary Sandpiper
+	Herring Gull
+	Common Tern (C-p)
	Black-billed Cuckoo
+	Great Horned Owl
+	Hawk Owl
+	Barred Owl
+	Great Gray Owl
o	Short-eared Owl
	Long-eared Owl
•	Saw-whet Owl
	Whip-poor-will
	Common Nighthawk
	Chimney Swift
	Ruby-throated Hummingbird
	Belted Kingfisher
	Common Flicker
	Pileated Woodpecker
	Red-headed Woodpecker
	Yellow-bellied Sapsucker
	Hairy Woodpecker
	Downy Woodpecker
•	Black-backed Three-toed Woodpecker
•	Northern Three-toed Woodpecker
	Eastern Kingbird
	Great Crested Flycatcher
	Eastern Phoebe
•	Yellow-bellied Flycatcher
o	Alder Flycatcher
	Least Flycatcher
•	Olive-sided Flycatcher
	Eastern Wood Pewee
	Tree Swallow
	Bank Swallow
	Rough-winged Swallow
	Barn Swallow
	Cliff Swallow
	Purple Martin
	Blue Jay
+	Gray Jay
+	Common Raven
	Common Crow
	Black-capped Chickadee
•	Boreal Chickadee
+	Red-breasted Nuthatch
	Brown Creeper
	House Wren
•	Winter Wren
o	Short-billed Marsh Wren
	Gray Catbird
	Brown Thrasher
	Wood Thrush
•	Hermit Thrush
•	Swainson's Thrush
	American Robin
	Veery
	Eastern Bluebird
•	Golden-crowned Kinglet
+	Ruby-crowned Kinglet
	Cedar Waxwing
	Starling
•	Solitary Vireo
	Red-eyed Vireo
+	Philadelphis Vireo
	Black and White Warbler
•	Golden-winged Warbler
•	Tennessee Warbler
•	Orange-crowned Warbler
•	Nashville Warbler
•	Northern Parula
	Yellow Warbler
•	Magnolia Warbler
•	Cape May Warbler
•	Black-Throated Blue Warbler
•	Yellow-rumped Warbler
•	Black-Throated Green Warbler
•	Blackburnian Warbler
	Chestnut-sided Warbler
•	Bay-breasted Warbler
•	Pine Warbler
•	Palm Warbler
	Ovenbird
+	Northern Waterthrush
+	Connecticut Warbler
+	Mourning Warbler
+	Common Yellowthroat
+	Wilson's Warbler
+	Canada Warbler
	American Redstart
	House Sparrow
	Eastern Meadowlark
	Bobolink
	Red-winged Blackbird
	Northern Oriole
+	Rusty Blackbird
	Common Grackle
	Brown-headed Cowbird
	Scarlet Tanager
	Rose-breasted Grosbeak
	Indigo Bunting
+	Evening Grosbeak
+	Purple Finch
+	Pine Siskin
	American Goldfinch
+	Red Crossbill
+	White-winged Crossbill
	Rufous-sided Towhee
	Savannah Sparrow
o	LeConte's Sparrow
o	Sharp-tailed Sparrow
+	Dark-eyed Junco
	Chipping Sparrow
	Clay-colored Sparrow
•	White-throated Sparrow
•	Lincoln's Sparrow
	Swamp Sparrow
	Song Sparrow

Table E-4. Ecological Types of Freshwater Wetlands (Shaw and Fredine, 1959)

Type 2 - Inland fresh meadows. The soil usually is without standing water during most of the growing season but is waterlogged within at least a few inches of its surface. Vegetation includes grasses, sedges, rushes, and various broad-leaved plants. In northern United States representative plants are carex, rushes, redtop, reedgrasses, mannagrasses, prairie cordgrass, and mints. Meadows may fill shallow lake basins, sloughs, or farmland sags, or these meadows may border shallow marshes on the landward side. Wild hay sometimes is cut from such areas. These meadows are valuable mainly as supplemental feeding areas, and somewhat as nesting areas in the northern U.S.

Type 7 - Wooded swamps. The soil is waterlogged at least to within a few inches of its surface during the growing season, and is often covered with as much as 1 foot of water. Wooded swamps occur mostly along sluggish streams, on flood plains, on flat uplands, and in very shallow lake basins. In the North, trees include tamarack, arborvitae, black spruce, balsam, red maple, and black ash. Northern evergreen swamps usually have a thick ground covering of mosses. Deciduous swamps frequently support beds of duckweeds, smartweeds, and other herbs. Wooded swamps often occur in association with shrub swamps, and waterfowl often use the two types interchangeably.

Type 6 - Shrub swamps. The soil is usually waterlogged during the growing season, and is often covered with as much as 6 inches of water. Vegetation includes alders, willows, buttonbush, dogwoods, and swamp-privet. Shrub swamps occur mostly along sluggish streams and occasionally on flood plains. They are used to a limited extent for waterfowl nesting and feeding in the North.

Type 8 - Bogs. The soil is usually waterlogged and supports a spongy covering of mosses. Bogs occur mostly in shallow lake basins, on flat uplands, and along sluggish streams. Vegetation is woody or herbaceous, or both. Typical plants are heath shrubs, sphagnum moss, and sedges. In the northern U.S., leather-leaf, Labrador-team, cranberries, carex, and cottongrass are often present. Scattered, often stunted, black spruce and tamarack may occur in northern bogs. Bogs have the lowest waterfowl rating, country-wide, of all the 20 types.

Conway, V. M. 1949. The bogs of central Minnesota. Ecol. Monogr. 19: 1-66.

Eckert, K. R. 1974. A birder's guide to Minnesota. Minnesota Ornithologists Union. Minneapolis, Minnesota. 114 pp.

Elwell, A. S., C. S. Holt, K. Lundberg, D. L. Thompson, J. A. Oliphant, and B. J. R. Gudmundson. 1973. Environmental impact assessment of the Red Lake project. North Star Research and Development Institute. Minneapolis, Minnesota. 189 pp.

Green, J. C. and R. B. Janssen. 1975. Minnesota birds. Where, when and how many. University of Minnesota Press. Minneapolis, Minnesota. 217 pp.

Griffin, K. O. 1975. Vegetation studies and modern pollen spectra from the Red Lake peatland, northern Minnesota. Ecology. 56: 531-46.

Gunderson, H. L. and J. R. Beer. 1953. The mammals of Minnesota. University of Minnesota Press. Minneapolis, Minnesota. 190 pp.

Hofstetter, R. H. 1969. Floristic and ecological studies of wetlands in Minnesota. Ph.D. Thesis. University of Minnesota. Minneapolis, Minnesota. 255 pp.

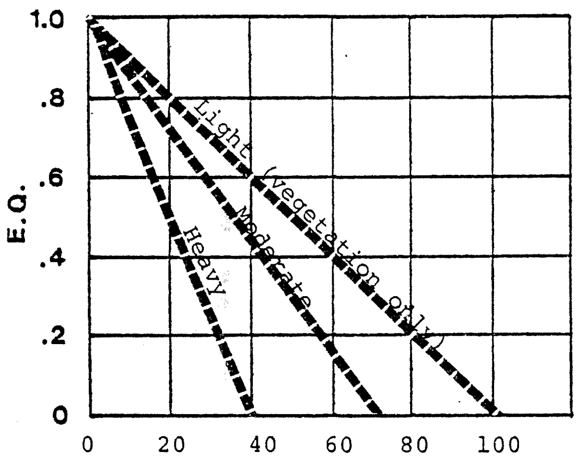
Knapp, R. J. 1960. Plankton fluctuations in the Lower Red Lake and food utilization by young of the year perch in 1956 and 1957. M.S. Thesis. University of Minnesota. Minneapolis, Minnesota. 185 pp.

Shaw, S. P. and C. G. Fredine. 1959. Wetlands of the United States and their extent and their value to waterfowl and other wildlife. Circular 39. Fish and Wildlife Service, U.S. Department of the Interior. 67 pp.

APPENDIX F. INDICATOR CURVES

ECOLOGIC

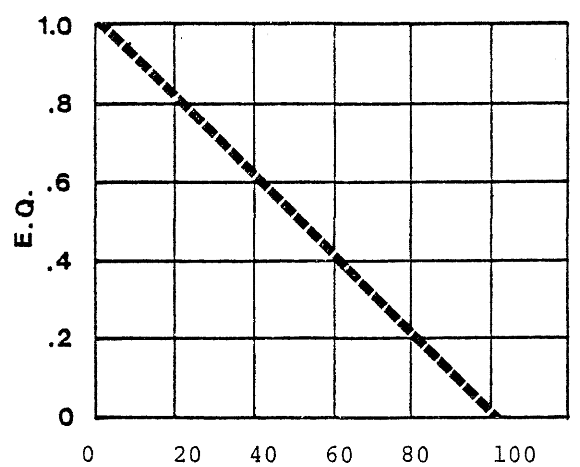
POPULATIONS



Impact of Development Activity on Populations Measured as a Percent of Area Affected

This figure delineates the relationship between EQ and the area, measured as a percent of total site area, impacted by various levels of human activity. The *indicator curves* are designed to serve all six categories of populations. For vegetation populations only the "Light" line is used. All three lines are used for animal populations. The "Moderate" and "Heavy" lines reflect the carrying of impacts beyond the physically disturbed area due to the effects of noise, movement, and smell of human activity on animal populations.

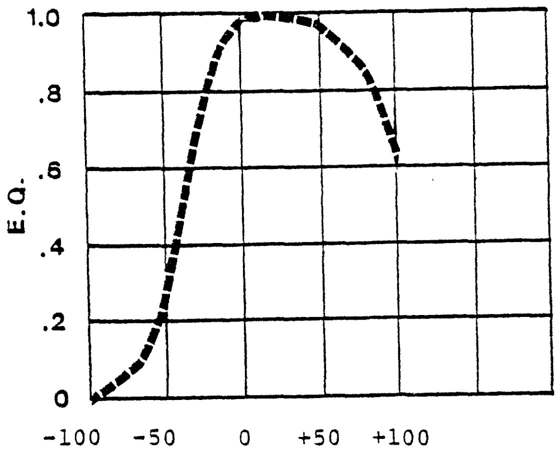
SPECIES DIVERSITY



Species Diversity Measured as Percent Change in Number of Species per Thousand Individuals

This figure shows the relationship between EQ and species diversity. When an ecosystem is in equilibrium, as the peatlands of Minnesota are assumed to be, species diversity is at an optimal level. Any disturbance due to development could disrupt species populations and affect whole ecosystems. This *indicator curve* assumes that EQ decreases at a linear rate as the number of species per thousand changes, whether the number decreases or increases.

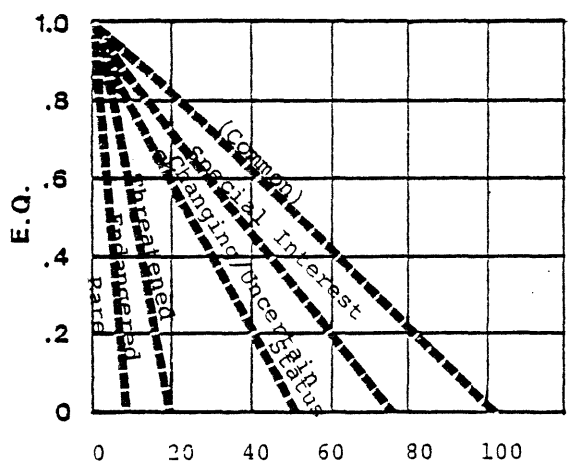
PRODUCTIVITY



Percent Change in Biomass Production

This figure shows the relationship between EQ and productivity of the site, measured in terms of change in biomass production. The *indicator curve* assumes that EQ is highest when there is no net change in biomass production. EQ decreases rapidly with decreasing biomass. A drastic increase in biomass is also assumed to lower EQ, but not as rapidly. A doubling of biomass (100 percent increase) is not equivalent to the complete elimination of biomass.

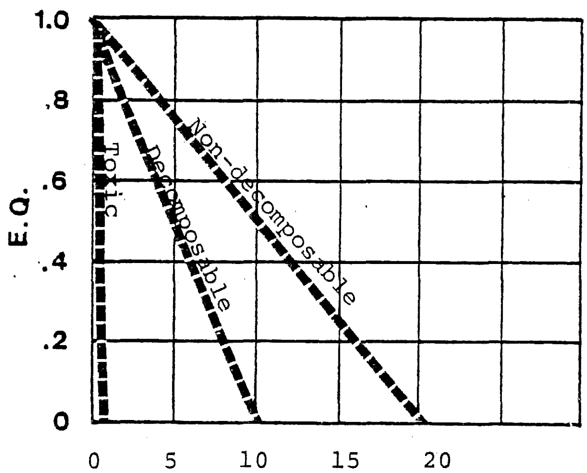
HABITAT LOSS



Loss of Habitat Areas Measured as a Percent of Total Habitat Area

This figure shows the relationship between EQ and loss of habitat area for common, less common, and endangered species. The *indicator curves* assume that a loss of habitat area has a more deleterious impact on unique species than on more common ones. The severest impact is shown to be on species "endangered in the U.S." and threatened in Minnesota." A somewhat less deleterious impact is shown to be on species "threatened in the U.S." and "rare in Minnesota." The impact of loss of habitat on more common species is even less severe.

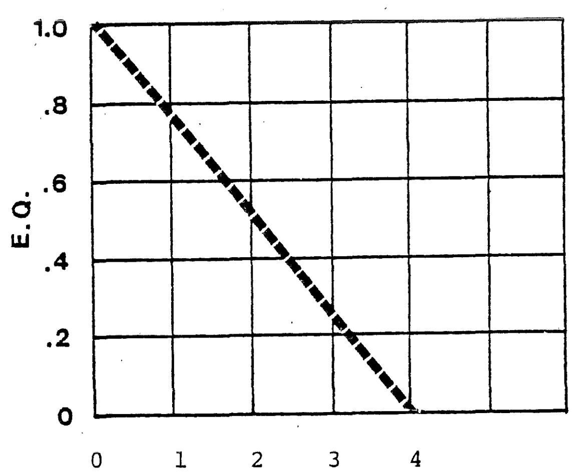
WASTE LOADING



Waste Loading Measured As
Tons Per Acre

This figure shows the relationship between EQ and the level of waste loading on the development site. The most important considerations in the dumping of wastes upon land are the nature of the wastes themselves and the rate at which they are deposited. This *indicator curve* assumes that EQ declines as the amount of waste loading increases, measured in tons/acre. It is also assumed that EQ drops very sharply, almost vertically, for toxic wastes and that EQ drops with decreasing rate for decomposable and non-decomposable wastes, respectively.

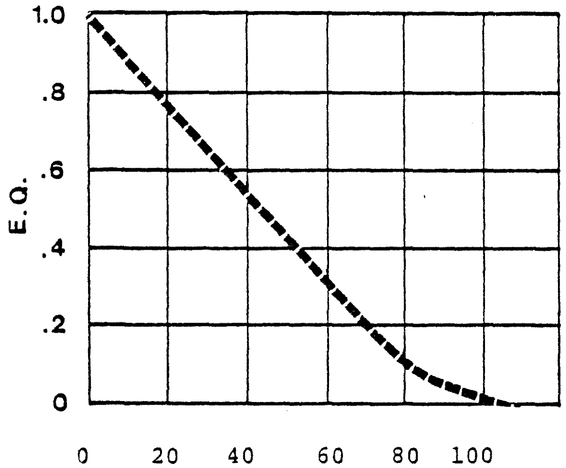
HYDROLOGY



Change in Average Annual Depth of
Groundwater Levels Measured in Feet

This figure delineates the relationship between EQ and the change in the average annual depth of the water table in a peatland area brought about by land clearing and/or drainage. The *indicator curve* assumes that any significant departure from existing levels will be detrimental to present ecosystems and should result, therefore, in a lower EQ value. Zero change in average annual depth of water table rates an EQ of 1.0. The EQ drops rapidly as the change in average annual depth moves toward 4 feet (increase or decrease).

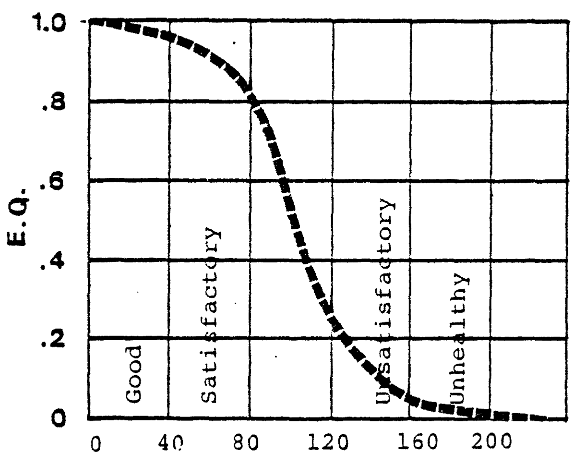
NOISE



Noise Measured in Decibels at
50 Feet From the Source

This figure shows the deleterious effect of man-made noise on EQ. The *indicator curve* assumes that EQ decreases as the noise level, measured in decibels, increases from zero to 100 decibels.

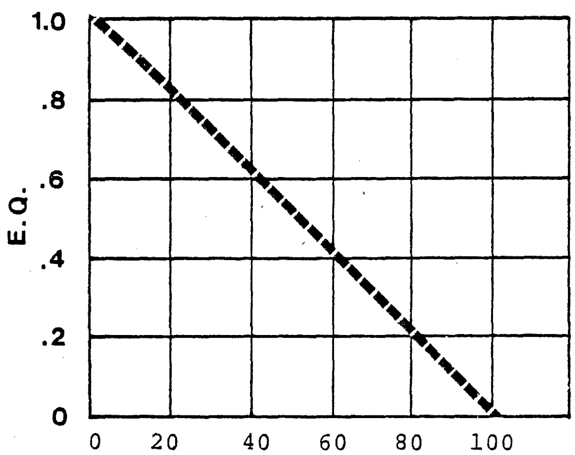
AIR QUALITY



Air Quality Measured as Average
Annual Air Quality Index

This figure delineates the relationship between EQ and air quality as measured by the average annual Air Quality Index. The average air pollution index number is a measure of air quality which registers levels of three specific air quality indicators: 1) concentration of sulfur oxides; 2) level of carbon monoxide; 3) concentration of particulates. The *indicator curve* assumes that EQ declines rapidly as the average annual Air Quality Index rises above 100.

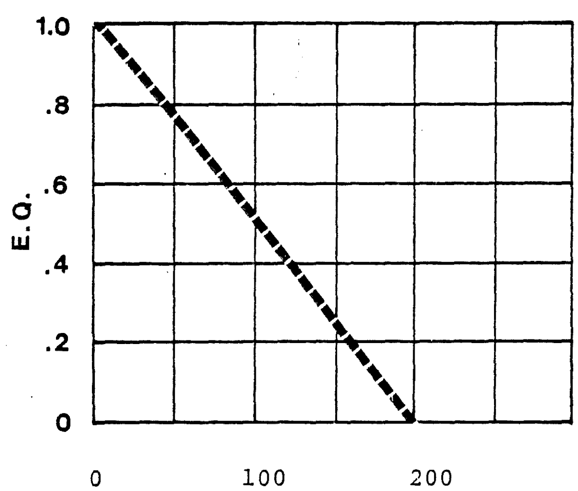
TOXIC SUBSTANCES (AIR)



Toxic Substances Emitted Into the Air As Measured by the Percent of the Mean Toxic Level at Which 50 Percent of an Experimental Population Would be Exterminated (TLM_{50})

This figure delineates the relationship between EQ and the level of toxic substances emitted into the air. While it is assumed that there will be no discharge of pollutants from point sources, there is always the liklihood of some toxic substances escaping into the atmosphere. The *indicator curve* assumes a straight line relationship between EQ and toxic emissions as the concentration of toxic substances reaches the mean toxic limit.

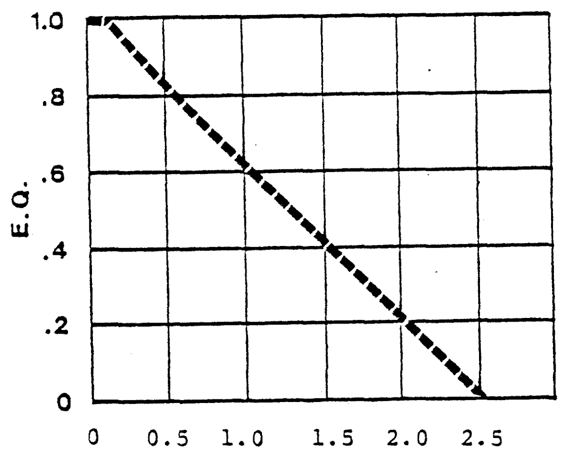
HEALTH HAZARDS



Fecal Coliforms as Measured by Most Probable Number Per 100 ml

In this figure is shown the relationship between EQ and water quality as measured by the level of fecal coliforms. The *indicator curve* assumes that EQ drops as the fecal coliform counts increase from zero to 200, as determined by the most probable number method per 100 ml. The 200 counts (mpn) per 100 ml is that maximum limit established by the MPCA for almost all classifications for interstate waters (WPC No. 14).

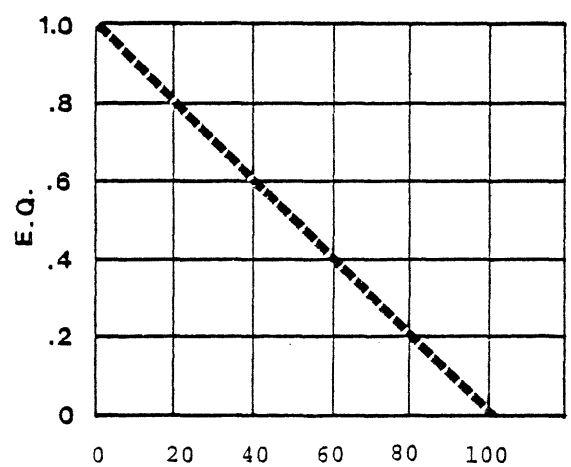
EUTROPHICATION



Eutrophication as Measured by The Ratio Between Post and Prior Nutrient Levels

This figure delineates the relationship between EQ and eutrophication caused by nutrients reaching peatland waters and thereby promoting the production of plant materials. When eutrophication advances rapidly, it results in both ecologic and aesthetic deterioration of the waters. The *indicator curve* assumes that EQ declines as the amount of nutrients (such as phosphorus and nitrogen) added to the waters as a result of development surpasses the amount added prior to development. Present nutrient levels are, thus, taken to bé ideal, and any additional loading is assumed to detract from the EQ value.

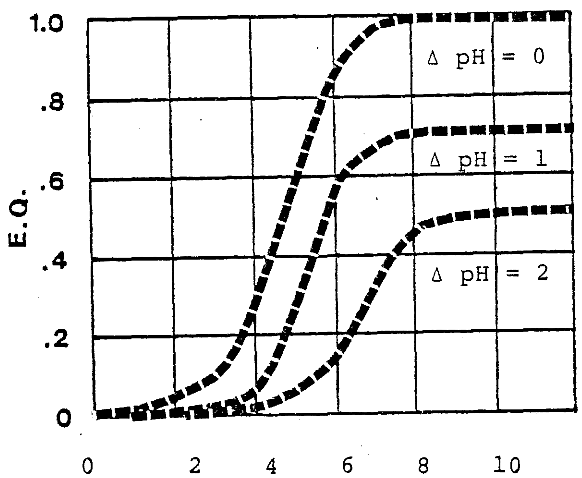
TOXIC SUBSTANCES (WATER)



Toxic Substances Emitted Into the Air As Measured by the Percent of the Mean Toxic Level at Which 50 Percent of an Experimental Population Would be Exterminated (TLM_{50})

This figure delineates the relationship between EQ and the level of toxic substances emitted into the water. While it is assumed that there will be no discharge from point sources, there is always the liklihood that contaminants will get into the surface waters from nonpoint sources. The *indicator curve* assumes a straight line relationship between EQ and toxic emissions as the concentration of toxic substances reaches the mean toxic limit.

ESSENTIAL CHARACTERISTICS

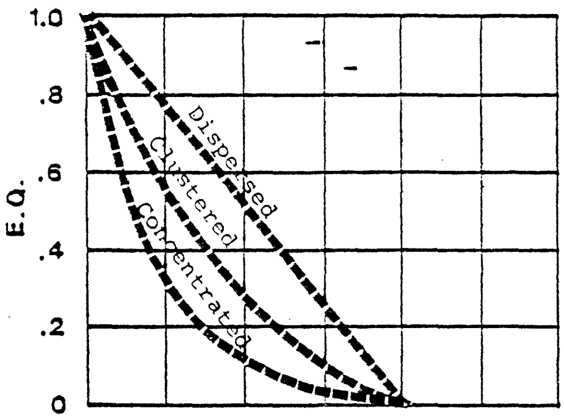


Essential Characteristics of Water
Measured in Relationship to
Changes in pH

In this figure is shown the relationship between EQ and the essential characteristics of water, including dissolved oxygen, pH, and other parameters not shown in the figure. In this figure, the changes in dissolved oxygen (in mg/l) at different levels of pH are related to various EQ values. The *indicator curves* assume that changes in pH influence the toxicity of various other substances, such as ammonia. This is particularly true with respect to fish existing under more toxic conditions of elevated pH (above normal). These fish require a higher level of dissolved oxygen to prevent deleterious physiological and behavioral effects.

AESTHETIC-HUMAN INTEREST

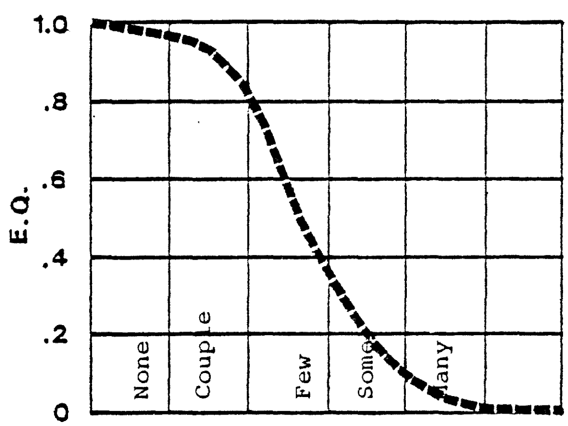
SCENIC BEAUTY



Impact of Man-Made Structures on Scenic Beauty Measured As Total Enclosed Volume of Structures

In this figure is shown the relationship between EQ and the appearance of man-made structures, as measured by total enclosed volume, situated in a natural setting. The *indicator curves* assume that dispersed structures are less unsightly than large, concentrated structures. It should be noted that the perceived concentration or dispersement of structures is, like other aesthetic perceptions, a highly qualitative judgment.

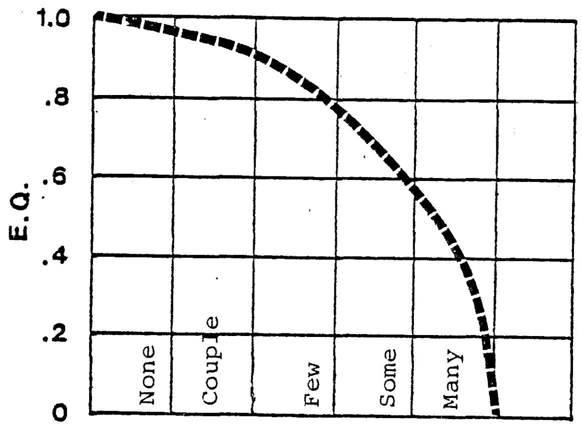
DEBRIS



Impact of Debris Measured As Number of Sitings Per Unit Area

This figure shows the relationship between EQ and the number of sitings of debris that could be expected per unit area. The *indicator curve* assumes that EQ falls rapidly with increased sitings.

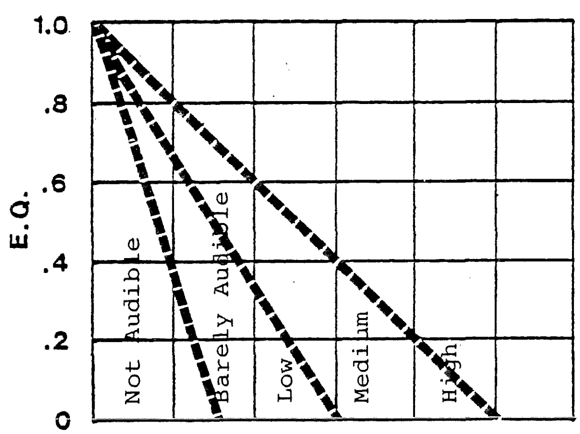
PESTS



Impact of Pests Measured As
Number of Sitings Per Unit Area

This figure relates EQ to the number of sitings of pests per unit area. The *indicator curve* assumes that EQ falls gradually with increased sitings.

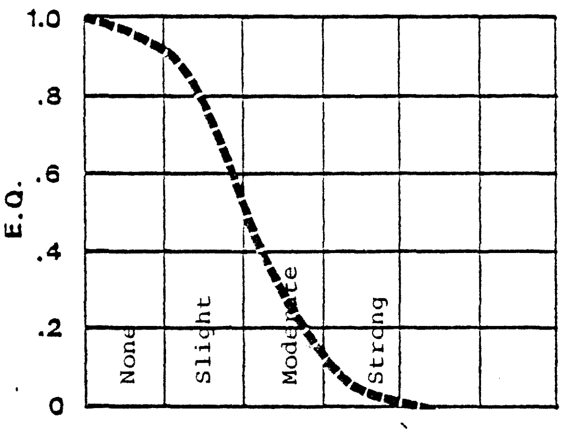
NOISE



Noise Measured As Perceived
Loudness and Frequency

In this figure is shown the relationship between EQ and perceived man-made noise. The *indicator curves* assume that both perceived loudness and perceived frequency have a bearing on the EQ value.

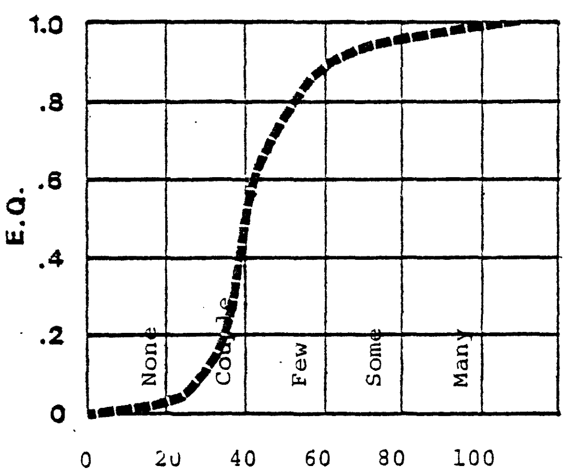
ODOR



Man-Made Odor Measured As
Perceived Strength

This figure shows the relationship between EQ and the perceived "strength" of odors. The *indicator curve* assumes that EQ falls rapidly with increasing perceived strength.

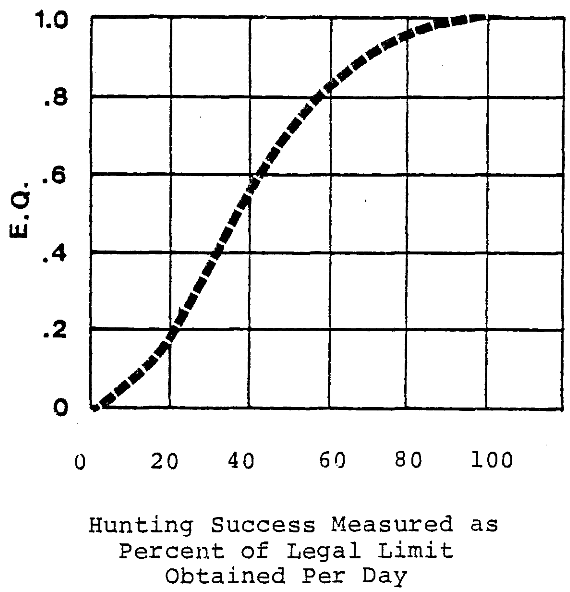
RECREATIONAL OPPORTUNITIES



Recreational Sites Lost
Measured As a Percent of
Total Sites Available

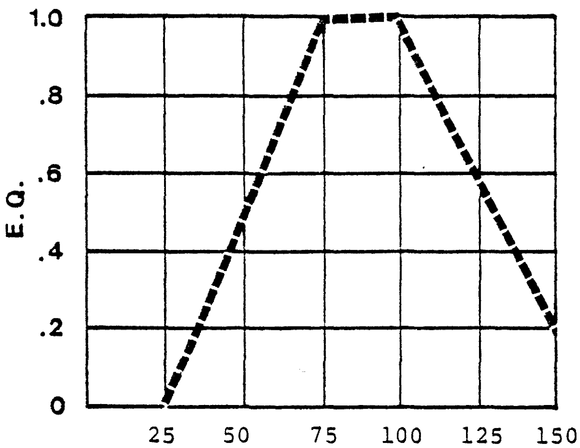
This figure delineates the relationship between EQ and the number of recreational sites lost due to development, measured as a percent of total sites available. The *indicator curve* assumes that EQ drops into the low range when more than 40 percent of the recreational sites are lost.

HUNTING SUCCESS



In this figure is shown the relationship between EQ and hunting success measured as the percent of legal limit obtained per day. The *indicator curve* assumes a more than linear increase in EQ as the percent of legal limit per day increases from 0 to 100.

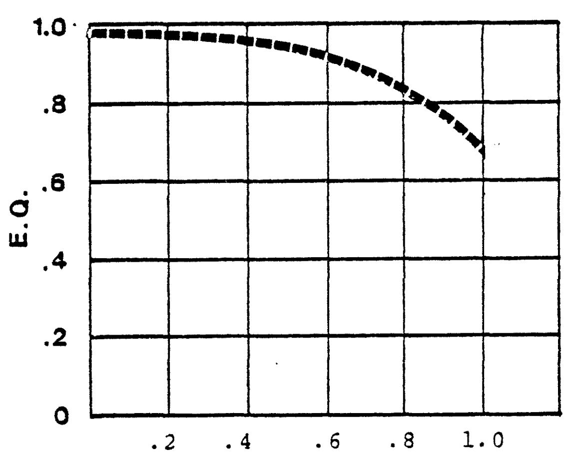
SCHOOL CAPACITY



Demand on School System Capacity
Measured as Percent of Full Capacity

In this figure is shown the relationship between EQ and the demand on school capacity in a school system or group of school systems. The *indicator curve* assumes that EQ is highest in the range between 75 and 100 percent capacity. Both overcrowding and underuse deviate from the ideal, overcrowding placing severe pressure on existing facilities and staff and underuse causing numerous inefficiencies in school operations and creating a gap between operating costs and state aid delivered.

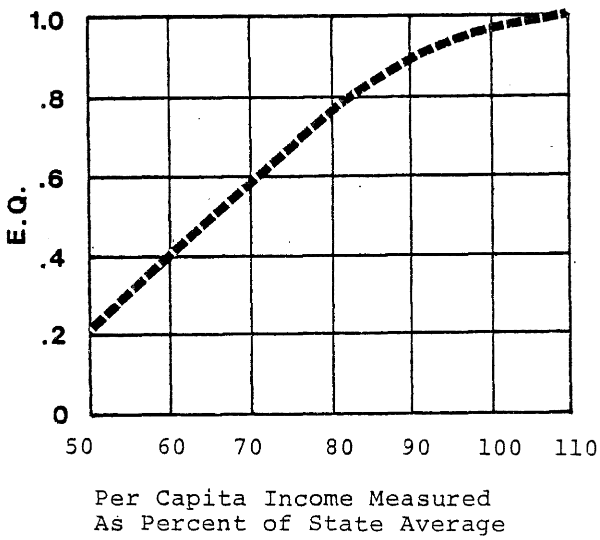
TRUNK HIGHWAY CAPACITY



Trunk Highway Adequacy Measured
As a Volume/Capacity Ratio

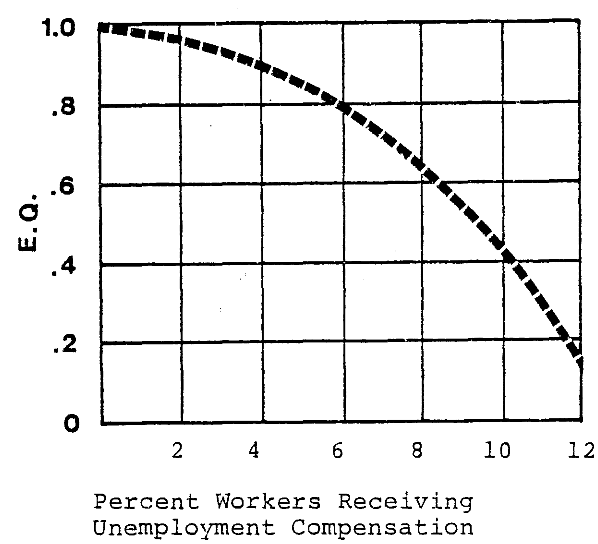
This figure delineates the relationship between EQ and the level of use on trunk highways. The *indicator curve* assumes that EQ is highest when a trunk highway is being used at 60 percent of its designed capacity, where level of use is measured in terms of ADT, percent truck traffic, and peak volume. It is assumed that underuse does not lower EQ, since an underused trunk highway is nevertheless necessary for access.

PER CAPITA INCOME



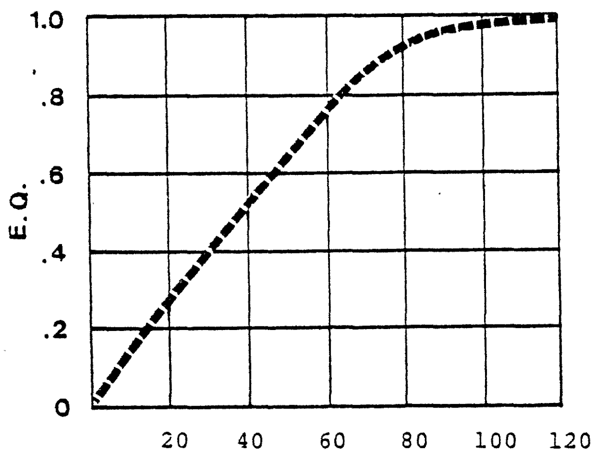
This figure relates EQ to per capita income measured as a percent of the average per capita income in the state. The *indicator curve* here assumes that EQ is low in areas where per capita income averages between 50 and 60 percent of the State average and that it rises rapidly to .8 at 80 percent of the State average. Thereafter it rises more gradually, finally reaching 1.0 at 110 percent of the average State per capita income. Roughly 80 percent of the counties in the State would rate an EQ of .6 or higher.

EMPLOYMENT



This figure shows the relationship between EQ and the availability of jobs to the local labor force. The percent of workers receiving unemployment compensation is here used as a measure of labor surplus. The State average in 1974 was 2.3 percent. The *indicator curve* here assumes that EQ remains relatively high in the area of "residual" unemployment (where between 1 and 4 percent of the workers are receiving unemployment compensation) but declines rapidly as the percent of workers receiving unemployment compensation passes 6 percent. The number of unemployed workers an economic system will tolerate will vary somewhat from year to year and will depend also on the distribution of those workers through the various sectors of the system.

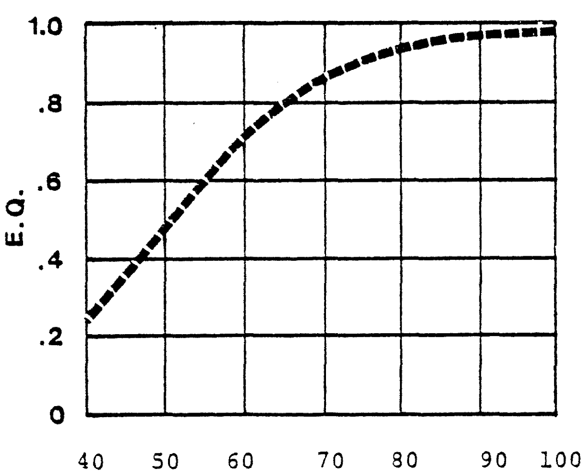
CAPITAL EXPENDITURES



Capital Expenditures Per Capita Measured As a Percent of State Average Per Capita Capital Outlay by Incorporated Municipalities

This figure delineates the relationship between EQ and capital expenditures per capita by incorporated cities and villages. A certain number of capital expenditures are usually necessary to build (possibly rennovate) facilities and buy equipment. While a very low level of capital outlay lessens the local tax burden, a continually low level of such expenditures most likely indicates that a community is unable to support such expenditures due to insufficient revenue. The *indicator curve* assumes that a per capita capital outlay of less than 40 percent of the state average corresponds to a low EQ. As such expenditures rise to 80 percent of the state average, the EQ approaches 1.0.

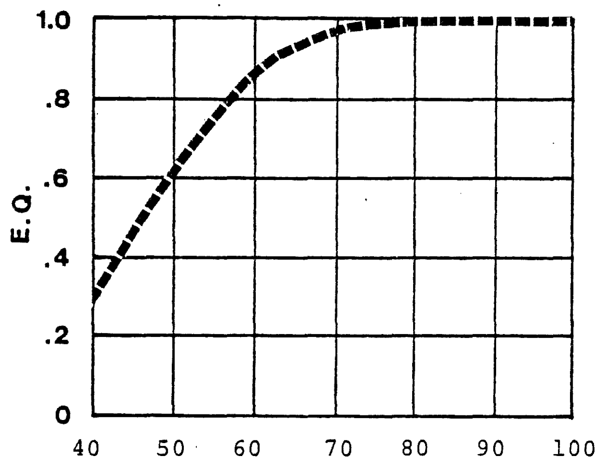
GROSS SALES



Gross Sales Per Capita Measured As Percent of State Average

This figure shows the relationship between EQ and gross sales per capita, which is here taken as a measure of retail sales activity. The *indicator curve* here assumes that EQ will be low in areas where gross sales per capita amount to less than 40 percent of the state average.

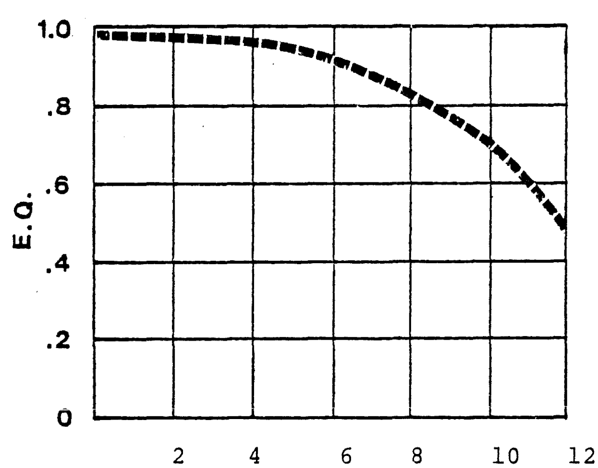
COST OF LIVING



Cost of Living As Measured by Average Family Income As a Percent of the Average Value of Owner-Occupied Housing Units (Above Poverty Level)

This figure shows the relationship between EQ and cost of living as measured by the ratio of average family income to the average value of owner-occupied housing units, where the owner has an income above the poverty level. The cost of living is a useful, but sometimes ambiguous, indicator of an area's economic health. The cost of living in most outstate areas of Minnesota is significantly lower than is the cost of living in the Twin Cities Metropolitan Area. This reflects, on the one hand, both the level of goods and services available in outstate areas and the relatively low per capital income in some rural areas. This also indicates, on the other hand, that it costs less to live in some outstate areas. The *indicator curve* assumes, however, that a low cost of living, relative to the state average, indicates a depressed economy.

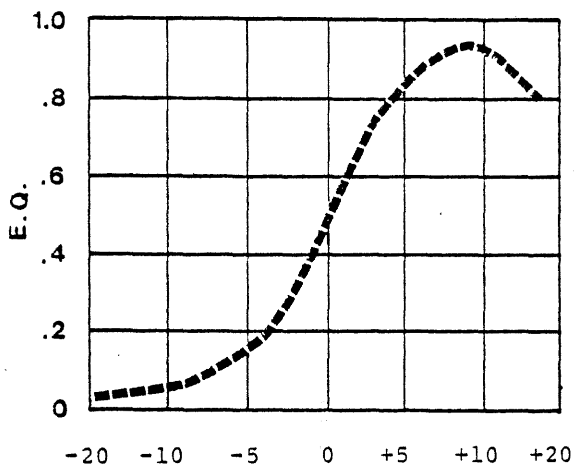
HOUSING



Overcrowding Measured As Percent Year Round Housing Units Having More Than One Person Per Room

This figure delineates the relationship between EQ and overcrowding, which is defined as more than 1 person per room, in residential housing. In the last 20 years, the average number of persons per room in residential housing units has declined markedly both in the nation as a whole and in Minnesota. At the present time, about 8 percent of the residential housing units in the state are overcrowded. The *indicator curve* assumes that EQ begins to fall off from 1.0 when about 6 percent of the housing becomes overcrowded and that EQ then declines rapidly after passing the state cost.

MIGRATION RATE



Migration Measured as Percent Migration Between 1970 and 1974

In this figure is shown the relationship between EQ and net migration. The *indicator curve* assumes that net out-migration, even if a relatively small percent of county population, results in a rapidly decreasing EQ value since such out-migration increases the tax burden on a (usually) declining population and indicates, indirectly, that more attractive opportunities exist elsewhere. A net in-migration is here assumed to be an indication of a county's "attractiveness" in competition with other areas. However, very rapid in-migration, over 5 percent a year, can strain a county's resources and cause uncontrolled growth. EQ is therefore assumed to decline as in-migration surpasses this rate.

APPENDIX G. PRESENT POLICIES

PEATLANDS

Chapter 92.461. Subdivisions 1 and 2

92.461 PEAT LANDS. Subdivision 1. Peat lands withdrawn from sale. All lands now or hereafter owned by the state which are chiefly valuable by reason of deposits of peat in commercial quantities are hereby withdrawn from sale.

Subd. 2. Examination by commissioner of natural resources. Before any state land is offered for sale the commissioner of natural resources shall cause such land to be examined to determine whether the land is chiefly valuable by reason of deposits of peat in commercial quantities

Chapter 92.50. Subdivision 1

92.50 UNSOLD LANDS SUBJECT TO SALE MAY BE LEASED. Subdivision 1. The commissioner of natural resources may, at public or private vendue and at such prices and under such terms and conditions as he may prescribe, lease any state-owned lands under ~~his~~ jurisdiction and control for the purpose of taking and removing sand, gravel, clay, rock, marl, peat, and black dirt therefrom, for storing thereon ore, waste materials from mines, or rock and tailings from ore milling plants, for roads or railroads, or for any other uses not inconsistent with the interests of the state. No such lease shall be made for a term to exceed ten years, except in the case of leases of lands for storage or for the removal of peat, which may be made for a term not exceeding 25 years provided that such leases for the removal of peat shall be approved by the executive council. All such leases shall be made subject to sale and leasing of the land for mineral purposes under legal provisions and contain a provision for their cancellation at any time by the commissioner upon three months written notice, provided that a longer notice period, not exceeding three years, may be provided in leases for storing ore, waste materials from mines or rock or tailings from ore milling plants; provided further that in leases for the removal of peat, the commissioner may determine the terms and conditions upon which the lease may be canceled. All money received from leases under this section shall be credited to the fund to which the land belongs.

TAX-FORFEITED LANDS, LEASE, PARTITION, EASEMENTS

Chapter 282.04. Subdivisions 1

282.04 TIMBER SALE: TAX-FORFEITED LANDS, LEASE PARTITION, EASEMENTS. Subdivision 1. Timber sold for cash. The county auditor may sell dead, down and mature timber upon any tract that may be approved by the natural resources commissioner. Such sale of timber products shall be made for cash at not less than the appraised value determined by the county board to the highest bidder after not less than one week's published notice in an official paper within the county. Any timber offered at such public sale and not sold may thereafter be sold at private sale by the county auditor at not less than the appraised value thereof, until such time as the county board may withdraw such timber from sale. The appraised value of the timber and the forestry practices to be followed in the cutting of said timber shall be approved by the commissioner of natural resources. Payment of the full sale price of all timber sold on tax-forfeited lands shall be made in cash at the time of the timber sale. The county board may require final settlement on the basis of a scale of cut products. Any parcels of land from which timber is to be sold by scale of cut products shall be so designated in the published notice of sale above mentioned, in which case the notice shall contain a description thereon and the appraised price of each specie of timber for 1,000 feet, per cord or per piece, as the case may be. In such cases any bids offered over and above the appraised prices shall be by percentage, the percent bid to be added to the appraised price of each of the different species of timber advertised on the land. The purchaser of timber from such parcels shall pay in cash at the time of sale at the rate bid for all of the timber shown in the notice of sale as estimated to be standing on the land, and in addition shall pay at the same rate for any additional amounts which the final scale shows to have been cut or was available for cutting on the land at the time of sale under the terms of such sale. Where the final scale of cut products shows that less timber was cut or was available for cutting under terms of such sale than was originally paid for, the excess payment shall be refunded from the forfeited tax sale fund upon the claim of the purchaser, to be audited and allowed by the county board as in case of other claims against the county. No timber, except hardwood pulpwood, may be removed from such parcels of land or other designated landings until scaled by a person or persons designated by the county board and approved by the commissioner of natural resources. Landings other than the parcel of land from which timber is cut may be designated for scaling by the county board by written agreement with the purchaser of the timber. The county board may, by written agreement with the purchaser and with a consumer designated by him when the timber is sold by the county auditor, and with the approval of the commissioner of natural resources, accept the consumer's scale of cut products delivered at the consumer's landing. No timber shall be removed until fully paid for in cash. Small amounts of green standing, dead, down, dying, insect infected or diseased timber not exceeding $750 in appraised valuation may be sold for not less than the full appraised value at private sale to individual persons without first publishing notice of sale or calling for bids, provided that in case of such sale involving a total appraised value of more than $100 the sale shall be made subject to the final settlement on the basis of a scale of cut products in the manner above provided and not more than two such sales, directly or indirectly to any individual shall be in effect at one time. As directed by the county board, the county auditor may lease tax-forfeited land to individuals, corporations or organized subdivisions of the state at public or private vendue, and at such prices and under such terms as the county board may prescribe, for use as cottage and camp sites and for agricultural purposes and for the purpose of taking and removing hay, stumpage, sand, gravel, clay, rock, marl, and black dirt therefrom, and for garden sites and other temporary uses provided that no leases shall be for a period to exceed ten years; provided, further that any leases involving a consideration of more than $300 per year, except to an organized subdivison of the state shall first be offered at public sale in the manner provided herein for sale of timber. Upon the sale of any such leased land, it shall remain subject to the lease for not to exceed one year from the beginning of the term of the lease. Any rent paid by the lessee for the portion of the term cut off by such cancellation shall be refunded from the forfeited tax sale fund upon the claim of the lessee, to be audited and allowed by the county board as in case of other claims against the county. The county auditor, with the approval of the county board is authorized to grant permits, licenses, and leases to tax-forfeited lands for the depositing of stripping, lean ores, tailings, or waste products from mines or ore milling plants, upon such conditions and for such consideration and for such period of time, not exceeding 15 years, as the county board may determine; said permits, licenses, or leases to be subject to approval by the commissioner of natural resources. Any person who removes any timber from tax-forfeited land before said timber has been scaled and fully paid for as provided in this subdivision is guilty of a misdemeanor. The county auditor may, with the approval of the county board, and the commissioner of natural resources, and without first offering at public sale, grant leases, for a term not exceeding 25 years, for the removal of peat from tax-forfeited lands upon such terms and conditions as the county board may prescribe. Provided, however, that no lease for the removal of peat shall be made by the county auditor pursuant to this section without first holding a public hearing on his intention to lease. One printed notice in a legal newspaper in the county at least ten days before the hearing, and posted notice in the court house at least 20 days before the hearing shall be given of the hearing.

STATE FOREST USE POLICY

Chapter 89.01. Subdivisions 1 through 6.

89.01. COMMISSIONER, POWERS AND DUTIES. Subdivision 1. The commissioner shall ascertain and observe the best methods of reforesting cut-over and denuded lands, foresting waste and prairie lands, preventing destruction of forests and lands by fire, administering forests on forestry principles, encouraging private owners to preserve and grow timber for commercial purposes, and conserving the forests around the head waters of streams and on the watersheds of the state.

Subd. 2. The commissioner shall execute all rules and regulations pertaining to forestry and forest protection within the jurisdiction of the state; have charge of the work of protecting all forests and lands from fire; shall investigate the origin of all forest fires; and prosecute all violators as provided by law; shall prepare and print for public distribution an abstract of the forest fire laws of Minnesota, together with such rules and regulations as may be formulated.

The commissioner shall prepare printed notices calling attention to the dangers from forest fires and cause them to be posted in conspicuous places.

Subd. 3. Damage by fire occurring to state timber, reproduction or lands, when coming to the knowledge of the commissiner, shall be promptly reported to the attorney general, who, at his discretion, may either enforce collection of such demands directly or may employ private attorneys therefor on such terms, not contingent, as he deems for the best interests of the state. The amount so collected, after deducting therefrom the fees of such attorneys, if any, and other necessary expenses incurred in investigation, preparation for trial, and trial, shall be paid into the state treasury and credited to the fund that would have been entitled to receive the sale price of the lands, reproduction, or timber if sold; or, if there be no such fund, then such money shall be credited to the general fund. The attorney general, either in or out of court, may compromise and settle state claims for fire damage to state lands, reproduction, or timber, on such terms as he deems for the best interests of the state.

Subd. 4. The commissioner shall cooperate with the several departments of the state and federal governments and with counties, towns, corporations, or individuals in the preparation of plans for forest protection, management, replacement of trees, wood lots, and timber tracts, using his influence as time will permit toward the establishment of scientific forestry principles in the management, protection, and promotion of the forest resources of the state.

Subd. 5. When any tract or tracts of land that are included in areas set apart as state forests are found to be more valuable for agricultural than for forestry or other conservation purposes, the commissioner by written order may eliminate such lands from state forests whereupon such lands shall be subject to sale the same as other lands not reserved. When any tract or tracts of land that are included in areas set apart as state forests are found to be more valuable for the construction of industrial plants or for purposes including forestry essential to the establishment of or expansion of substantial commercial developments, the commissioner, by written order, with the unanimous approval of the Land Exchange Commission may eliminate such lands from state forests whereupon such lands shall be subject to sale the same as other lands not reserved.

Subd. 6. When any state lands not reserved or set aside are found by the commissioner to be more valuable for the production of timber than for agriculture, he may by written order designate such lands as state forest subject to the approval of the state legislature at its next regular session.

Chapter 89.021. Subdivision 1

89.021 STATE FORESTS. Subdivision 1. Established. There are hereby established and reestablished as state forests, for growing, managing, and harvesting timber and other forest crops and for the establishment and development of recreation areas and for the protection of watershed areas, and the preservation and development of rare and distinctive species of flora and fauna native to such areas, all lands and waters now owned by the state or hereafter acquired by the state, excepting lands acquired for other specific purposes or tax-forfeited lands held in trust for the taxing districts unless incorporated therein as otherwise provided by law, in the townships and sections described as follows:

Chapter 89.19.

89.19 RULES AND REGULATIONS. The commissioner shall have power to prescribe such rules and regulations governing the use of state forest lands, or any part thereof, by the public or governing the exercising by holders of leases or permits upon state forest lands of all their rights under such leases or permits as may be necessary to carry out the purposes of this chapter.

Title 16.471. National forests: establishment: limitation on additions in certain States; lands suitable for production of timber.

The President of the United States may, from time to time, set apart and reserve, in any State or Territory having public land bearing forests, in any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as national forests, and the President shall, by public proclamation, declare the establishment of such forests and the limits thereof.

(a) No national forest shall be created, nor shall any additions be made to one created prior to June 25, 1910, within the limits of the States of California, Oregon, Washington, Idaho, Montana, Colorado, or Wyoming, except by Act of Congress.

(b) The President, in his discretion, is authorized to establish as national forests or parts thereof, any lands within the boundaries of Government reservations, other than national parks, reservations for phosphate and other mineral deposits, or waterpower purposes, national monuments and Indian reservations, which in the opinion of the Secretary of the department not administering the area and the Secretary of Agriculture are suitable for the production of timber, to be administered by the Secretary of Agriculture under such rules and regulations and in accordance with such general plans as may be jointly approved by the Secretary of Agriculture and the Secretary formerly administering the area, for the use and occupation of such lands and for the sale of products therefrom. Any person who shall violate any rule or regulation promulgated under this subdivision shall be guilty of a misdemeanor and upon conviction thereof shall be fined not more than $500 or imprisoned for not more than one year, or both. (Mar. 3, 1891, ch. 561, § 24, 26 Stat. 1103; Mar. 4, 1907, ch. 2907, 34 Stat. 1271; June 25, 1910, ch. 421, § 2, 36 Stat. 847; Aug. 24, 1912, ch. 369, 37 Stat. 497; June 7, 1924, ch. 348, § 9, 43 Stat. 655).

Title 16.472. Laws affecting national forest lands.

The Secretary of the Department of Agriculture shall execute or cause to be executed all laws affecting public lands reserved under the privisions of section 471 of this title, or sections supplemental to and amendatory thereof, subject to the provisions for national forests established under subdivision (b) of section 471 of this title, after such lands have been so reserved, excepting such laws as affect the surveying, prospecting, locating, appropriating, entering, relinquishing, reconveying, certifying, or patenting of any such lands. (Feb. 1, 1905, ch. 288, § 1 33 Stat. 628.)

Title 16.473. Revocation, modification, or vacation of orders or proclamations establishing national forests.

The President of the United States is authorized and empowered to revoke, modify, or suspend any and all Executive orders and proclamations or any part thereof issued under Section 471 of this title, from time to time as he shall deem best for the public interests. By such modification he may reduce the area or change the boundary lines or may vacate altogether any order creating a national forest. (June 4, 1897, ch. 2 § 1, 30 Stat. 34, 36.)

Title 16.475. Purposes for which national forests may be established and administered

All public lands designated and reserved prior to June 4, 1897, by the President of the United States under the provisions of section 471 of this title, the orders for which shall be and remain in full force and effect, unsuspended and unrevoked, and all public lands that may hereafter be set aside and reserved as national forests under said section, shall be as far as practicable controlled and administered in accordance with the following provisions. No national forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States; but it is not the purpose or intent of these provisions, or of said section, to authorize the inclusion therein of lands more valuable for the minerals therein, or for agricultural purposes, than for forest purposes. (June 4, 1897, ch. 2, § 1, 30 Stat. 34.

Title 16.481. Use of waters

All waters within the boundaries of national forests may be used for domestic, mining, milling, or irrigation purposes, under the laws of the State wherein such national forests are situated, or under the laws of the United States and the rules and regulations established thereunder. (June 4, 1897, ch. 2, § 1, 30 Stat. 36.)

Section Referred to in Other Sections

This section is referred to in sections 478, 482, 551 of this title.

Title 16. 482. Mineral lands; restoration to public domain; location and entry.

Upon the recommendation of the Secretary of the Interior, with the approval of the President, after sixty days notice thereof, published in two papers of general circulation in the State or Territory wherein any national forest is situated, and near the said national forest, any public lands embraced within the limits of such forest which, after due examination by personal inspection of a competent person appointed for that purpose by the Secretary of the Interior, shall be found better adapted for mining or for agricultural purposes than for forest usage, may be restored to the public domain. And any mineral lands in any national forest which have been or which may be shown to be such, and subject to entry under the existing mining laws of the United States and the rules and regulations applying thereto, shall continue to be subject to such location and entry, notwithstanding any provisions contained in sections 473 to 478, 479 to 482, and 551 of this title. (June 4, 1897, ch 2, § 1, 30 Stat. 36.

COUNTY ZONING POLICY (KOOCHICHING)

Sections 2.84 and 2.85

Sec. 2.84 - 0-1 OPEN SPACE DISTRICT

This district is intended to prevent destruction of natural or man-made resources; maintain large tracts of permanent open spaces, provide for the continuation of forest management and production programs, and foster certain seasonal residential uses, and other activities which are not incompatible with the public welfare

(a) Permitted Uses+

(1) Seasonal dwellings not requiring school or other related public services.
(2) Forest management programs
(3) Soil and water conservation programs
(4) Wildlife preserves
(5) Grazing

(b) Uses Authorized by Conditional Permit

(1) Public and private parks
(2) Dams, plants for the production of electric power and flowage areas.

\+ Any use determined to be objectionable by the County Planning Commission with County Board approval on the basis of pollution, noise, dust, smoke, vibration, odor, flashing lights, or danger of explosion may be permitted only upon the issuance of a conditional use permit setting for dimensional and site requirements, performance standards, aesthetic controls, and pollution standards for that particular use.

(4) Accessory structures
(5) Orchards and wild crop harvesting
(6) Telephone telegraph and power tramission towers, poles and lines including transformer, substations, relay and repeater stations, equipment housings and other necessary appurtenant equipment and structures, radio and television stations and transmission towers, fire towers, and microwave radio relay towers.

(7) Signs, subject to the provisions of Section 4.00

<u>*No use shall involve dumping or filling of mineral soil or peat removal or any other use that would disturb the natural fauna, flora, water courses, water regimen, or topography.</u>

Sec. 2.85 - 0-2 OPEN SPACE DISTRICT

This district is intended to be used to prevent destruction of natural or man-made resources and to protect water courses including the shorelands of navigable waters, and areas which are not adequately drained, or which are subject to periodic flooding, where developments would result in hazards to health or safety; would deplete or destroy resources; or be otherwise incompatible with the public welfare.

(a) Permitted Uses

(1) Soil and water conservation programs.
(2) Forest management programs
(3) Wildlife preserves

(b) Uses Authorized by Conditional Permit

(1) Public and private parks
(2) Grazing where such activities will not be in conflict with the state purposes of this distrct.
(3) Orchards and wild crop harvestings.

<u>*No use shall involve dumping or filling of mineral soil or peat removal that would disturb the natural fauna, flora, water courses, water regimen, or topography.</u>

APPENDIX H. ARCHEOLOGICAL AND HISTORICAL SITES

This preliminary inventory of cultural resources within the peat bog area of Northern and North Central Minnesota lists approximately fifty-eight archeological sites, and one hundred and seven historical sites. Within the study area there are thirteen sites on the National Register of Historic Places, three sites listed as Registered National Historic Landmarks, and two National Natural Landmarks. There are no National Monuments in this area.

Based on our professional experience, we have tentatively evaluated the sites of the most importance in the following order:

<u>National Natural Landmarks:</u> (2)

Lake Agassiz Peatlands, Koochiching County
Upper Red Lake Peatlands, Lake-of-the-Woods and Beltrami Counties

<u>Registered National Historic Landmarks:</u> (3)

Hull-Rust-Mahoning Mine, St. Louis County (Hibbing, Minnesota)
Mountain Iron Mine, St. Louis County (Mountain Iron, Minnesota)
Soudan Mine, St. Louis County (Tower-Soudan State Park)

<u>National Register of Historic Places:</u> (12)

Savanna Portage, Aitkin County
Grand Portage of the St. Louis River, Carlton County
Itasca State Park, Clearwater & Becker Counties
Old Cut Foot Sioux Ranger Station, Itasca County
Turtle Oracle Mound, Itasca County
White Oak Point, Itasca County
Laurel Mounds, Koochiching County
Nett Lake Petroglyph Site, Koochiching County
Northwest Point, Lake-of-the-Woods County
Hull-Rust-Mahoning Mine, St. Louis County
Mountain Iron Mine, St. Louis County
Soudan Mine, St. Louis County

(There are other sites on this Register, but not in the study area)

<u>Excavated Archeological Sites:</u> (21)

Malmo Site, AK1, Aitkin County
Schocker Site, BL1, Beltrami County
Washkish Site, BL2, Beltrami County
(Seven excavated sites in Clearwater County, but in the Itasca State Park)
White Oak Point Site, IC1, Itasca County
Osufsen Site, IC2, Itasca County
Stangland Site, IC3, Itasca County
Nett Lake Site, KC1, Koochiching County
McKinstry Site, KC2, Koochiching County
Smith Site, KC3, (Laurel Mounds or Grand Mound Site), Koochiching County
Houska Point Site, KC6, Koochiching County
Little Fork Site, KC7, Koochiching County
Snake River Site, MA1, Marshall County
Haarstad Site, MA6, Marshall County
Red Lake River Site, RL1, Red Lake County
Boyle Site, RL2, Red Lake County
Roseau River Site, RO4, Roseau County
Roseau River Site, RO4, Roseau County
Greenbush Borrow Pite Site, RO11, Roseau County
Pike Bay Site, SL1, St. Louis County
Pearson Site, SL3, St. Louis County

The Registered National Historic Landmarks and sites on The National Register of Historic Places are protected by Federal regulations. The excavated archeological sites are regarded as scientific areas. Some of them are afforded state protection by being listed on a State Register, by being within State Parks, or as Historic Sites.

It must be emphasized that this is merely a preliminary inventory, and that there are many little known or unknown historic and prehistoric sites within the study area which should be found by research and ground surveys.

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Historian

February 24, 1976

Table F-1. A Preliminary Inventory of Archeological and Historical Sites in Selected Counties in Northern Minnesota

AITKIN COUNTY

1. Savannah Portage Marker - Savannah Portage State Park
2. Big Sand Lake Marker
3. William Aitkin American Fur Trading Post-1830, T.149N, R.24W, at Libby on 65.
4. Northwest Company Post of 1794, Beaver's Point, Big Sandy Lake, 2 miles south of Libby on Highway 65.
5. Red Cedar Lake Post, Red Cedar River.

National Monuments or Registered National Historic Landmarks: No sites

Sites on the National Register of Historic Places:

Savannah Portage, Savannah Portage State Park

Minnesota Inventory of Historic and Prehistoric Places:

AK 1. Malmo Village Site, Malmo Township, excavated 1936 and 1962
AK 2. Red Cedar Lake Mounds, Red Cedar Lake
AK 3 Clear Lake, Glen Township
AK 4. Workman Township
AK 5. Nichols Group, Hazleton Township
AK 6. Shamrock Township
AK 7. Shamrock Township
AK 8. Shamrock Township
AK 9. Spirit Lake, Farm Island Township

BELTRAMI COUNTY

6. County Beltrami Marker, Turtle Lake Township
7. Ghost Town of Dumas, T.154N, R.30W on Upper Red Lake
8. Joseph Reaume's Post on the north side of Tamarac River on Upper Red Lake
9. Nebish-Redby Railroad, Red Lake Reservation
10. Red Lake Agency, Lower Red Lake
11. Red Lake Catholic Mission, Red Lake
12. Red Lake Trail, Red Lake to Leech Lake

National Monuments or Registered National Historic Landmarks: No sites

National Register of Historic Places: No sites

Minnesota Inventory of Historic and Prehistoric Places:

BL 1. Blackduck, Hines Township, Excavated 1932 and 1937
BL 2. Waskish Village Site, Upper Red Lake, Excavated 1933, 1956 and 1959.
BL 3. Waskish, Upper Red Lake

CARLTON COUNTY

13. Cloquet Fire Marker
14. Grand Portage of the St. Louis River Marker, Jay Cooke State Park
15. St. Mary's and St. Joseph's Church, T.49N, R.18W
16. Mounds on Big Lake, T.48N, R.19W
17. Ghost Town of Atkinson or Otter Creek
18. Sawyer Chapel - Foun du Lac Reservation
19. Cloquet Boom House and Sorting Sheds Site, Cloquet
20. Cloquet Steam Mill Company Site, Cloquet
21. Dunlap Island, Cloquet
22. Johnson-Wentworth Sawmill Company Site, Cloquet
23. Lindholm House, Cloquet
24. Northern Lumber Company, Cloquet
25. Northwestern Hotel, Cloquet
26. Upper Northern Sawmill Company Cloquet
27. Water POwer Sawmill Company Ruins, Cloquet

CARLTON COUNTY (Continued)

National Monuments or Registered National Historic Landmarks: No sites

National Register of Historic Places: One site

No archaeological sites listed

CLEARWATER COUNTY

28. Windsor Townsite, Windsor Township
29. Red Lake Indian Reservation

National Monuments or Registered National Historic Landmarks: No sites

National Register of Historic Places: No sites

Minnesota Inventory of Historic and Prehistoric Places:

Approximately 17 archaeological sites are within the boundaries of the Itasca State Park Historic District. Five of these sites are within the boundaries of Itasca State Park. None of the others are within the study area. Eight of the sites within this park have been excavated.

ITASCA COUNTY

30. Birgit Anderson Cabin, Big Fork Township
31. Chief Busticocan Wigwam Site, Big Fork Township
32. Seth Carpenter Homestead, Carpenter Township
33. Deer Creek Farm Camp, Carpenter Township
34. Stitt Ranch, Togo Township, Highway 65
35. Old Cut Foot Sioux Ranger Station

National Monuments or Registered National Historic Landmarks: No sites

National Register of Historic Places: three sites listed, of which two are archaeological in nature.

Minnesota Inventory of Prehistoric and Historic Places:

Chief Busticocan Wigwam Site, Big Fork Township
IC 1. White Oak Point, Morse Township, excavated 1940, 1954
IC 8. Effie
IC 11. Stokes Township
IC 13. Carpenter Township
IC 14. Thistledew Lake

KOOCHICHING COUNTY

36. Little American Mines, Island View, T.71N, R.22W
37. Russian Orthodox Church, Rauch Township
38. Ghost towns of Rauch and Bramble, Rauch Township
39. Carlson Sawmill, T.64N, S.22W, near Silverdale
40. Ghost Town of Ray, T.70N, R.22W
41. Alexander Baker House, under Mando Paper Mill, Sec. 27, T.70N, R.24W
42. Ghost Town of Ericsburg, T.69N, R.23W
43. C.W.W. Borup's Trading Post, Sec. 27, T.70N, R.24W
44. Vincent Roy's House, T.70N, R.25W

National Monuments or Registered National Historic Landmarks: No sites

National Register of Historic Places: (two archeological sites)

KC 3. Laurel Mounds, (Grand Mound)
KC 8. Nett Lake Petroglyph Site, Island in Nett Lake

Minnesota Inventory of Historic and Prehistoric Places:

KC 1. Nett Lake Village Site, Nett Lake Township
KC 2. McKinstrey Mounds, Pelland, excavated 1939 and 1962
KC 4. Pine Island State Forest
KC 5. Koochiching State Forest
KC 6. Ranier
KC 7. Pelland

LAKE-OF-THE-WOODS COUNTY

46. Baudette Newspaper Office, Baudette
47. Fort St. Charles, Magnuson's Island
48. Massacre Island, Lake of the Woods
49. Silver Creek School, Baudette
50. Northwest Point/Northwest Angle, Red Lake Reservation
51. Great Fire of 1910, Baudette

National Monuments or Registered National Historic Landmarks: No sites

National Register of Historic Places: (one geographical site)

Northwest Point (Northwest Angle), U.S. Canadian Border

Minnesota Inventory of Historic and Prehistoric Places:

LW 1. Red Lake Reservation
LW 2. Williams
LW 3. Zipple Bay Reserve
LW 4. Red Lake Reservation
LW 5. Northwest Angle State Park

MARSHALL COUNTY

52. Old Mill Park and Marker, T.156N, R.46W

National Monuments or Registered National Historic Landmarks: No sites

National Register of Historic Places: (one site)

Minnesota Inventory of Historic and Prehistoric Places:

MA 1. Snake River Mounds, Viking Township, excavated 1936
MA 2. Viking Township
MA 3. Viking Township
MA Haarsted Mound, Foldahl Township, excavated 1961
MA Mount (?), Viking Township

MILLE LACS COUNTY

53. Kathio Historic District
54. Battle of Kathio Marker
55. Father Hennepin State Park

PENNINGTON COUNTY

56. First House in County, Thief River Falls
57. Landstad Church, Sanders Township
58. Norden Lutheran Church, Norden Township
59. St. Hilaire Mille, St. Hilaire Township

National Monuments or Registered National Historic Landmarks: No sites

National Register of Historic Places: No sites

79. Geggen Test Pits, Sect. 20, T.59N, R.14W
80. Mallman Iron Mine, Sect. 11, T.59N, R.14W
81. Hughes Logging Camp, Sect. 31, T.59N, R.14W
82. Polo Ghost Town, T.57N, R.15W
83. Norlander, Aurora and Meadows Ghost Towns, Sect. 3, T.58N, R.15W
84. Markham, Ghost Town, T.56N, R.15W
85. Pineville and Bangor Ghost Town, T.58N, R.15W
86. Miller and Mohawk Mines, T.58N, R.15W
87. Stephens Mine, T.59N, R.15W
88. Weed Mine, T.59N, R.15W
89. Oliver Mine, T.59N, R.15W
90. Ghost Town of Merritt, T.59N, R.16W and T.60N, R.15W
91. Ghost Town of Webster, Sect. 29, T.61N, R.15W
92. Island Farm, Floodwood
93. Eli Wetanen Homestead, Markham
94. North American Iron Mine, Sect. 4, T.61N, R.15W
95. LaChance Iron Mine, Sect. 4, T.61N, R.15W
96. Shank Logging Camp on Cedar Island Lake at Storybrook Lodge
97. Ghost Town of McKinley, T.58N, R.16W
98. Ghost Town of Belgrade, T.58N, R.16W
99. Ghost Town of Biwabik, Sect. 3, T.58N, R.16W
100. Biwabik Mine, Sect. 3, T.58N, R.16W
101. Kanawaha Mine, Sect. 1, T.58N, R.16W
102. Hole Mine, Sect. 1, T.58N, R.16W
103. J. Salmela Homestead, Sect. 26, T.61N, R.16W
104. Ghost Town of Peyla, T.61N, R.16W
105. Winton Village Ghost Town, T.61N, R.16W
106. Fon du Lac Marker
107. Miner's Lookout at Chisholm

National Monuments: No sites

Registered National Historic Landmarks:

Hull-Rust-Mahoning Mine, Hibbing
Mountain Iron Mine, Mountain Iron
Soudan Mine, Tower, Soudan State Park

National Register of Historic Places: No sites

Minnesota Inventory of Historic and Prehistoric Places:

SL 1. Pike Bay Mound, Lake Vermillion, Tower, excavated 1940
SL 2. Lindstrom Site, Lake Vermillion, excavated 1961
SL 3. Pearson Site, Lake Vermillion, excavated 1961
SL 4. Huttula Mound Site, Lake Vermillion, excavated 1961
SL 5. Hannas Site, Lake Vermillion excavated 1961
SL 6. Soudan Mound, Soudan
SL 7. Old Indian Cemetery, Tower
SL 8. Lake Vermillion
SL 9. Beatty Site, Boundary Waters Canoe Area
SL 10. Sugarbush Island
SL 11. Lake Kabetogama
SL 12. Cemetery Island, Namakan Lake
SL 13. Hegman Lake Pictographs, Hegman Lake, Superior National Forest
SL 14. Lake Vermillion

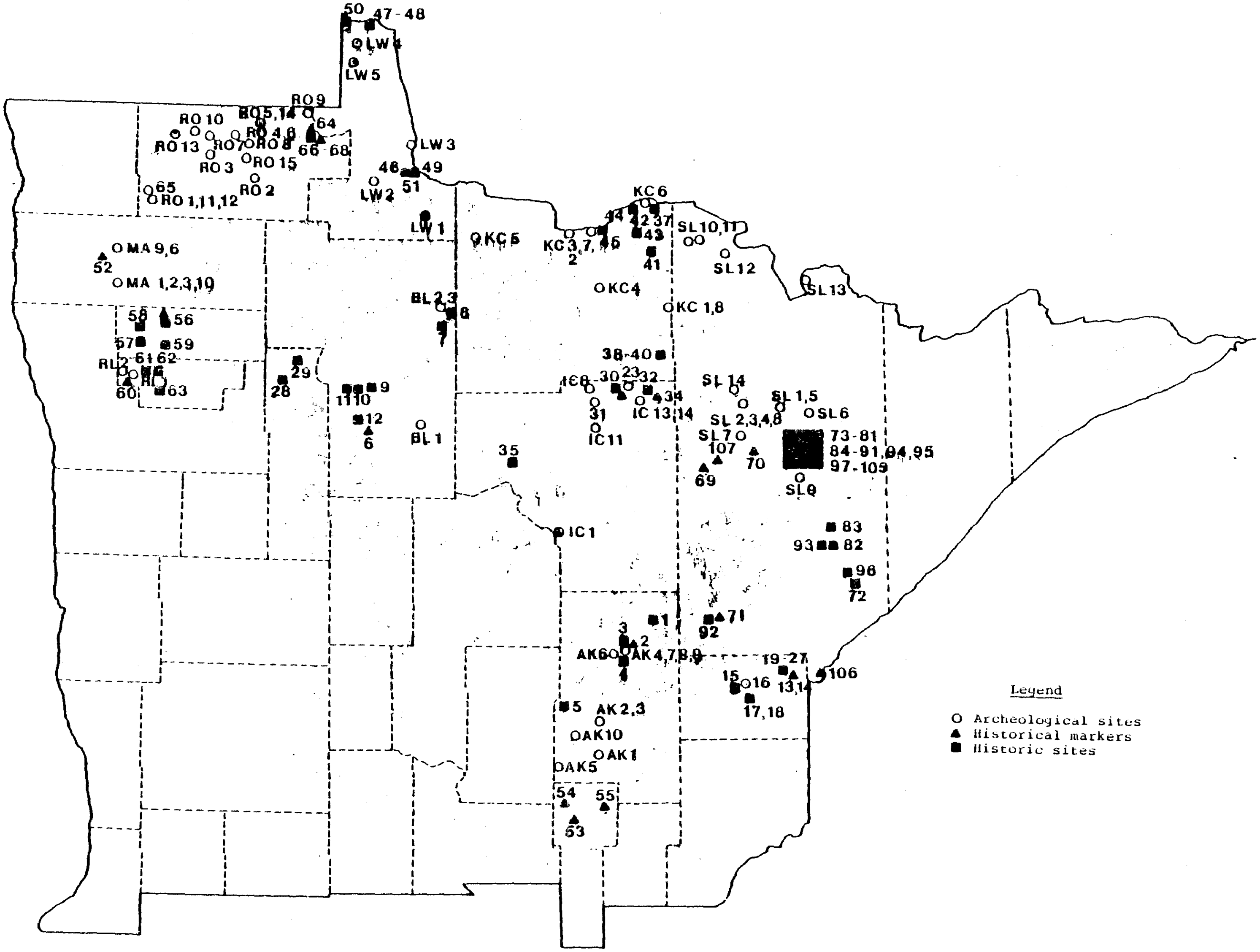

Figure H-1. Location of Archeological and Historical Sites in Northern Minnesota