PEATLAND DEVELOPMENT

Impact Assessment Methods and Application

Minnesota Department of Natural Resources Minerals Division March 1981

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Introduction

Increasing energy demands and dwindling reserves of traditional fossil fuels have forced us to consider peat as an alternative fuel. Peat, partially decomposed vegetation, is abundant in the United States and especially in Minnesota, which has about 7 million acres of peat. But before Minnesota would allow significant peat development on state lands, the Legislature instructed the Department of Natural Resources to inventory peatlands, to produce the information needed to make decisions, and to recommend policy.

The National Science Foundation provided a grant to assist in the making of policy and to document the process in a "real world" situation. The timing of the grant was fortunate: Policy could be made before any major development would occur -- a rare situation.

This report, one of two written with the grant, evaluates impact assessment methods, recommends a method and applies it to three development options: horticulture, agriculture and energy. This impact analysis process provides a systematic approach to evaluating projects. It also identifies research needs and issues to be addressed in a state peatland management policy.

I METHOD

Purpose of Impact Assessment

The analysis of environmental changes brought about by human activities is a new science. Before national attention was focused on increasing environmental degradation in the 1950s and 1960s, development's effects on the environment were not well documented. The accounting of environmental impacts caused by federally financed projects became a formal requirement when Congress passed the National Environmental Policy Act (NEPA) in 1969. Many states, including Minnesota in 1972, followed suit with environmental policy acts of their own. With the rise of statutory requirements came proposals for systematic methods of assessment. These various systems were designed to measure environmental changes brought by development activities and to provide a process for evaluating and choosing development alternatives according to social and environmental criteria.

As these analysis systems were devised, terms such as "impact," "analysis" and "evaluation" were more strictly defined.

"Impact" can be defined as a change in environmental characteristics. Measuring impact thus requires the establishment of valid baseline data against which resulting conditions can be compared (Ortolano 1973).

"Impact analysis," the first step in environmental assessment, is the forecasting of changes in selected environmental characteristics from the baseline condition. This analysis is not the making of policy; it chooses no sides, prefers no option. It is simply a prediction of change in character and magnitude.

"Impact evaluation" is the other step in environmental assessment and requires agency officials, politicians or citizens to choose development proposals and sites, or to modify the original proposals.

Common Analysis Methods

The various analysis methods and procedures that have been developed in the last decade defy description as pure types and often are found in combination in impact studies. Nevertheless, it is possible to list, in order of increasing complexity of procedure, five basic analysis methods:

*ad hoc description,
*overlay maps,
*check lists and cause-effect matrices,
*cross-impact matrices and
*networks.

In general, ad hoc description relies most heavily on intuition. Data requirements, cost and labor are greatest at the network end.

Ad Hoc Description

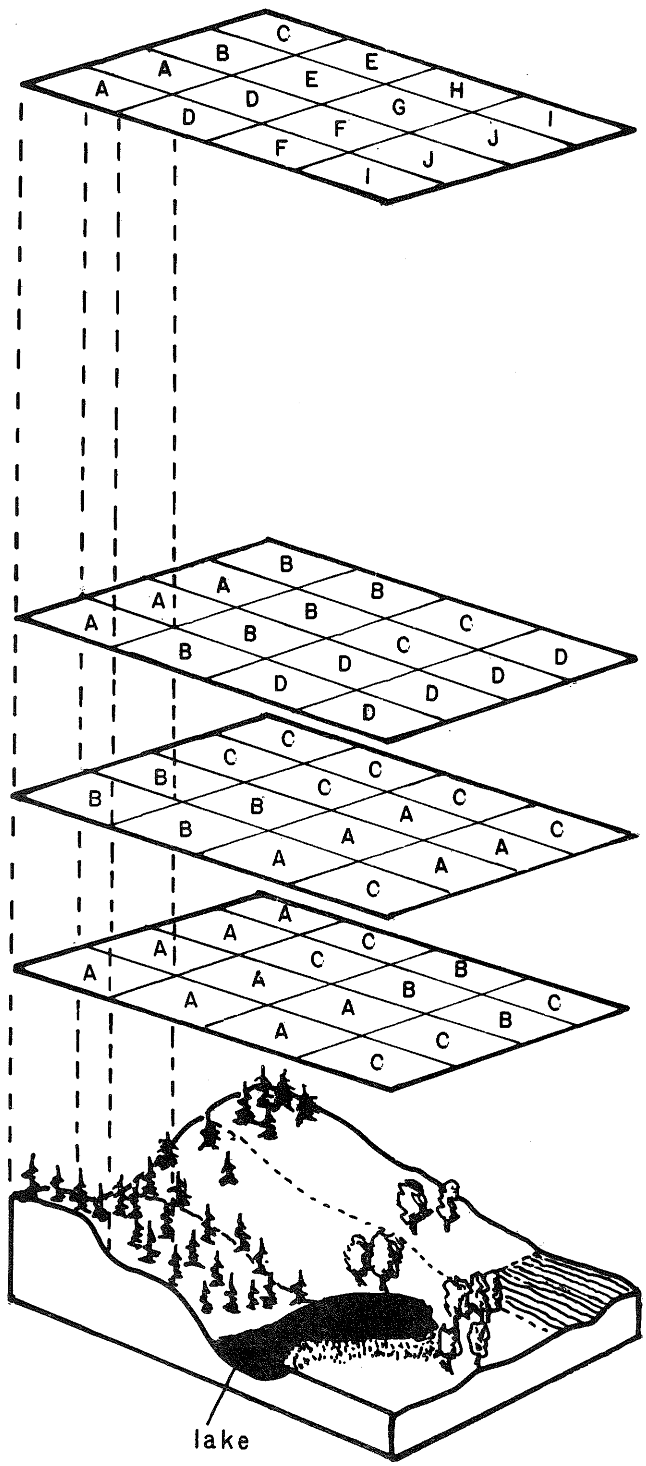
This strategy is not so much a specific method as it is a broad approach. It may employ check lists and matrices to display data and maps for visual analysis. Characteristically, it demands a preponderance of words on the environment, development and impacts, and contrasts sharply with the network method, which requires models, diagrams and less prose. Indeed, in the 10 years of NEPA, reports have become so comprehensive they intimidate. A final environmental impact statement typically addresses climate, air quality, topography, soils, minerals, water, vegetation, archaeology, aesthetics, fish and wildlife, recreation, agriculture, transportation, land ownership, socio-economics and history.

Limitations: Ad hoc descriptive impact assessments often are criticized for lacking the rigor of quantitative techniques and for ignoring a systems view of the environment. Critics say the method relies on linear reasoning about environment-impact relations and simple cause-effect conclusions. These failings, however, need not be a part of descriptive studies if attention is paid to secondary and tertiary levels of impact and the interrelationships of environmental components.

Strengths: The descriptive approach can be the cheapest and simplest way to summarize the probable impacts of proposals. Moreover, it is difficult to hide faulty assumptions and value judgments in straightforward prose analysis. Such is often not the case with modeling and simulation exercises in which the very complexity of the process and the choice of elements can hide assumptions and judgment. Moreover, descriptive techniques require less information than simulations and modeling do. In general, descriptive approaches are best when money and workers are scarce and when characterization of general impacts is preferred to precise predictions about the impacts of a specific development proposal. Thus, many preliminary impact assessments -- unlike final assessments -- are primarily descriptive.

Overlay Maps

Overlay maps could be considered descriptive except that the pioneering work of Ian McHarg has so popularized their use that they have come to be considered a distinct method. Lately, McHarg's manual overlay method has been adapted to computers. The Minnesota Land Management Information System (MLMIS) employs computer overlay techniques to show simultaneously two or more resource characteristics for



AGGREGATION OF COMPONENT VARIABLES

A CONIFEROUS, RIVER, VERY ROUGH

B CONIFEROUS, NO ORIENTATION, VERY ROUGH

C CONIFEROUS, NO ORIENTATION, ROUGH

D CONIFEROUS, RIVER, ROUGH

E NO FOREST, NO ORIENTATION, ROUGH

F CONIFEROUS, LAKE, FLAT

G ASPEN BIRCH, LAKE, ROLLING

H ASPEN BIRCH, NO ORIENTATION, ROLLING

I NO FOREST COVER, NO ORIENTATION, FLAT

J ASPEN BIRCH, LAKE, FLAT

COMPONENT VARIABLES

RELIEF

A VERY ROUGH (up to 150 foot relief)

B ROUGH (up to 100 foot relief)

C ROLLING (up to 50 foot relief)

D FLAT

WATER ORIENTATION

A LAKESHORE

B RIVERSHORE

C NO LAKE OR RIVER ORIENTATION

FOREST COVER

A CONIFEROUS TREES

B ASPEN BIRCH AND OTHER DECIDUOUS TREES

C NO FOREST COVER

Figure 1

EXAMPLE OF THE OVERLAY MAPPING PROCESS

single parcels. Overlay methods typically define the impact problem by determining places in a study area that should be dropped from consideration. In other words, they map exclusionary zones. Such is the approach in site suitability and capability studies where, through successive screening steps, each represented on maps, the most suitable areas are indicated as the remaining, non-exluded parcels.

Limitations: Overlay maps do not truly forecast the impacts of development proposals; rather, they describe the spatial setting of resources, the lay of the land. Moreover, there are limits to the number of variables that can be represented on a single map. To use too many makes the map impossible to read.

Strengths: Although impacts cannot be predicted by overlay techniques, the maps can represent areas where damage might occur should development take place. Moreover, the method can be used to rank zones of varying probable impact. For example, it is possible to distinguish peatlands of varying sensitivity to drainage or excavation. Finally, if resolution is sufficient and data is accurate, overlay maps are concrete and tangible representations of the spatial nature of resources or zones.

Check Lists and Cause-Effect Matrices

Check lists and cause-effect matrices require the listing, along one axis or two, of impacts and environmental components. The best-known example is Luna Leopold's cause-effect matrix of 1971, designed to meet the requirements of the then-new NEPA. The matrix consists of 100 possible development actions arrayed against 88 environmental characteristics. Matrix boxes are marked to show the possible impact of an action on a characteristic. Numbers from 1 to 10 are used in the marked boxes to indicate impact magnitude and significance. Variations of the original Leopold matrix include the use of x's instead of numbers, or the ranking of either magnitude or significance but not both.

Limitations: Matrix techniques have been criticized because only first-order impacts can be indicated easily and because linking actions with environmental characteristics is a subjective decision. Ranking the significance of impacts is also subjective. Frequently, the addition of numbers across rows or down columns has

Table 1 Example of a Cause - Effect Matrix

ENVIRONMENTAL CHARACTERISTICS \ ACTIONS	Drainage	Excavation	Paving	Clear Cutting	Slurry Pipeline
Vegetation	3 / 8	9 / 5			
Water Table	4 / 7	3 / 6			
Water Quality	5 / 3	4 / 3			
Precipitation	0 / 0	0 / 0			
Evapotransp.	5 / 2	3 / 1			
Birds	7 / 4	8 / 3			
Mammals	6 / 4	7 / 5			

Magnitude (1-10)

10 / 10

Significance (1-10)

been incorrectly used to rank the importance of environmental components or actions.

Strengths: Matrix procedures provide useful inventories of actions, environmental characteristics and impacts at the outset of impact analysis. Moreover, if they are used as Leopold intended, matrices are useful devices for the discussion of environmental impacts and magnitudes.

Cross-Impact Matrices

Unlike the cause-effect matrix, which lists actions opposite environmental characteristics to identify impacts, the cross-impact matrix displays the same environmental characteristics on both axes of the matrix (Marsh 1978). This arrangement permits the analyst to

Table 2 Example of Cross-Impact Matrix

ACTIVE FORCES

PASSIVE FORCES	Vegetation	Water Table	Water Quality	Preci-pitation	Evapo-transp.	Birds	Mammals	Σ X	$\bar{X}$
Vegetation	4	4	4	4	3	2	4	25	3.6
Water Table	3	1	1	4	4	1	1	15	2.1
Water Quality	4	3	1	4	4	1	1	18	2.6
Precipitation	1	1	1	1	1	1	1	7	1
Evapo-transp.	4	3	1	4	1	1	1	15	2.1
Birds	4	2	3	2	2	4	1	18	2.6
Mammals	3	2	2	2	2	1	4	16	2.3
Σ X	23	16	13	21	17	11	13		
$\bar{X}$	3.3	2.3	1.9	3	2.4	1.6	1.9		

SCORING

1 no relationship

2 low relationship

3 moderate relationship

4 high relationship

identify for each characteristic the strength of the relationship between it and any other characteristic. The process does not so much identify impacts as it indicates sensitive environmental components. Through a simple scoring system it is possible to derive numerical weights for each item in the matrix and thereby show the influence of all other items on it and its influence on all the others. For example, the use of a cross-impact matrix to analyze peatland may indicate that vegetation is the pivotal component. Of course, the success of a cross-impact matrix depends on the items selected and the judgment of analysts in assigning weights to the strengths of relationships.

Cross-impact tables often are used with networks. The matrix establishes the magnitudes of interactions and their directions, and that information is used to construct a network model.

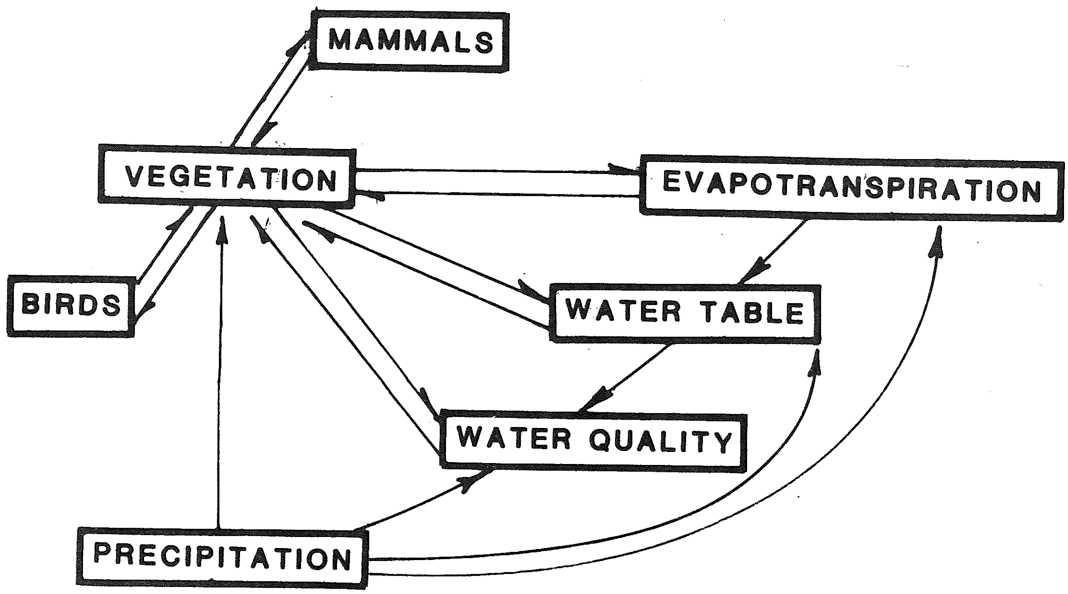


Figure 2
EXAMPLE OF AN ENVIRONMENTAL NETWORK

Limitations: The technique identifies not impacts but the strengths of relationships between components. Moreover, given a complex environmental system to analyze, the matrix becomes complicated and is difficult to assemble and interpret.

Strengths: The cross-impact matrix is extremely useful in identifying secondary links between components and provides a better perspective of a dynamic system than does the simple cause-effect matrix.

Networks

Network models sort complex environmental systems into their key parts and describe direct and indirect

Table 3 Summary of Strengths of Impact Methods

Strength Criteria	Descriptive	Overlay	Check list	Cross Impact	Network
Comprehensive	○		●		●
Explicit					
Low Cost	●		●	●	
Clear	●	●	●		
Geography Considered		●			
Assess Magnitude			●		○
Assess Indirect Impacts					●
Systems Approach				●	●
Flexible	●	●			

● clear strength

○ somewhat a strength

relationships (Marsh 1978). Network modeling, which uses the analogy of electrical pathways and connections, has been used in transportation planning and other situations where dynamic processes and flows must be defined. Networks are well-suited to environmental systems, which were described by Watt in 1966 as "an interlocking complex of

Table 4 Survey of Environmental Statements

AGENCY	DESCRIPTIVE ONLY	WITH MATRICES, TABLES
U.S. Dept. of Agriculture	8	1
Corps of Engineers	7	1
Energy, Research and Dev. Admin.	4	0
Federal Energy Admin.	1	2
U.S. Dept. of Interior	10	4
U.S. Dept. of Transportation	4	1
Other	6	1
Total	40	10

The majority of environmental statements produced in compliance with NEPA and for other purposes appear to rely on descriptive techniques, rather than quantification or modeling, to describe impacts. A survey of 50 environmental statements from six federal agencies, two state agencies and several consulting firms revealed that 40 statements used no analysis matrices or impact tables and relied wholly on narrative analysis. Ten statements made some use of matrices to describe impacts, though none of the 10 used the more sophisticated cross-impact matrices or networks. Seven of the 10 employing more than descriptive techniques are less than four years old, but only about one-half of the purely descriptive statements are that recent, which suggests a trend toward the use of systematic techniques.

The organization and writing varied widely. Some were nearly incomprehensible; others were clear, concise and orderly. The statements of the Department of the Interior and the U.S. Forest Service were some of the best reviewed. (A list of the environmental statements reviewed is given in Appendix A.)

processes and many cause-effect pathways." Networks are more effective than static methods, such as the simple cause-effect matrix or check list, in describing multiple interrelationships and sequences. When used for actual forecasting rather than conceptual planning or display, network modeling often relies on computers to track the many relationships between components and the many consequences of applying different variables. Much precise data is required, and the costs of programming and computer time can be exceedingly high; however, if the goal is conceptual modeling rather than actual forecasting, costs need not be excessive.

Limitations: In analytic or predictive applications, network models require much money and data because of their reliance on computers.

Strengths: Network models are perhaps the best method that can be used in describing the complex and dynamic aspects of natural systems, even if they are used solely as visual aids.

Requirements of Peatland Analysis

Environmental assessment methods must be tailored to the environment and the projects to be studied. The techniques used to analyze highway siting impacts, for example, may not be appropriate for assessing flood-control reservoirs, power plants or peat. In fact, a considerable specialized literature has developed which addresses water-resource impacts as a separate category.* The same has occurred for assessment of mining and highway construction impacts.**

*A prominent example is Norbert Dee et al, "Environmental Evaluation System for Water Resource Planning" (Battelle Columbus Laboratories, Columbus, Ohio, 1972).

**Examples are the Kirwin Environmental Study for AMAX (1973) and the highway study, "Optimum Pathway Matrix Analysis Approach to the Environmental Decision-Making Process" (Institute of Ecology, University of Georgia, 1971).

The amounts of money, information and time devoted to a project are also important constraints on the selection of a method since costs and time are generally greater for complex computer modeling strategies than for descriptive studies.

Knowledge Limitations

Both the kind and extent of information about peatlands are important in choosing an impact analysis strategy. Peat-program studies have gathered generic information, but not the specific data necessary for a study of impacts at a particular site. Data requirements get particularly critical when a site's natural variability (of populations or chemical parameters) must be established at some level of statistical significance so this baseline status can be compared to changes brought about by site development.

The more information there is about a natural system, the less is the degree of intuition required of the analyst in assessing the probable impacts of development. Although extensive work has been completed on the peatland environment, much remains to be done.

Proposal Limitations

Because present proposals to use state-owned peatlands are vague in regard to timing and size, they cannot be analyzed with precision or depth. Some proposals, however, are more definite than others.

Horticultural proposals: Proposals to harvest peat on state lands for horticultural uses are the most definite of the existing options. In fact, it already is being done. Nonetheless, it is difficult to predict the future extent of horticultural peat mining. Lease requests now total nearly 34,000 acres of Minnesota peatlands, but fewer than 1,000 acres have actually been mined. Moreover, mining methods may change if demand rises at the rate producers predict. This suggests that forecasting specific horticultural peat harvesting impacts is difficult, though generic impacts may be described.

Agricultural proposals: The acreage of peatlands proposed for agricultural production hardly compares to lease requests for horticulture. Requests for agricultural leases now total 918 acres: one 220-acre parcel for vegetable production and 698 acres for wild-rice production.

Analyzing the impact of agricultural use is less difficult than the analysis of other uses because we are familiar with the process. Farmers have been tilling peat soils for years.

Energy proposals: Proposals to use peat for energy production are the least specific of all. The gasification option is the most hypothetical because technological hurdles must be overcome before full-scale operation can commence. Barriers include the construction of a demonstration plant, and the development of mining and dewatering methods capable of supplying nearly 17,000 tons of peat to the proposed demonstration plant each day. (Three times that amount will be needed for the full-scale plant.) Direct burning proposals present less difficulty because the technology is well established in Europe. But for both gasification and direct burning options, many questions remain concerning the processes and timing, and the size of the peat-mining area. Analysis of the possible impacts of these options can be only of a general nature until more is known.

Other proposals: Still more hypothetical are proposals to use peat for the production of industrial chemicals such as peat coke and waxes, as a carbohydrate feed stock for yeast production and as a constituent in particle board. No firms have asked the state for leases for any of these purposes. In any case, the disturbance to peatlands likely would be less than with other proposals because these schemes would require less peat for a single profitable operation.

Recommended Assessment Method

The recommendation of an impact assessment strategy for peat use is based on a consideration of the methods available, constraints imposed by peat-program resources, the nature of the peatlands and current proposals for their use.

There is neither the need nor resources to conduct a highly quantitative computer modeling exercise to determine peatland impacts. For one thing, peatland environmental studies cannot yet supply the kind of "hard," statistically valid data that modeling exercises require. For another, peatland development proposals now are too vague to allow detailed, quantitative impact assessment, though this situation soon may change. Finally, a primarily descriptive analysis is the most efficient and cheapest in many situations.

Consequently, it is recommended that the assessment identify the generic impacts that might be expected from the development of peatlands for agricultural, horticultural and energy uses. This assessment would differ from site-specific impact studies in several ways. First, the region under consideration would be nearly the northern two-thirds of the state. Second, the proposals to be investigated would not be site-specific but categorical. Third, the purpose of such an assessment would not be to satisfy the national or Minnesota environmental policy acts but to identify first-order impacts, research needs and other peat-program priorities that become apparent in the course of assessment. Finally, the assessment would serve as a guide for analyzing impacts of specific proposals once leasing begins.

The recommended method is an ad hoc descriptive assessment employing MLMIS computer maps, matrices and networks for clarity.

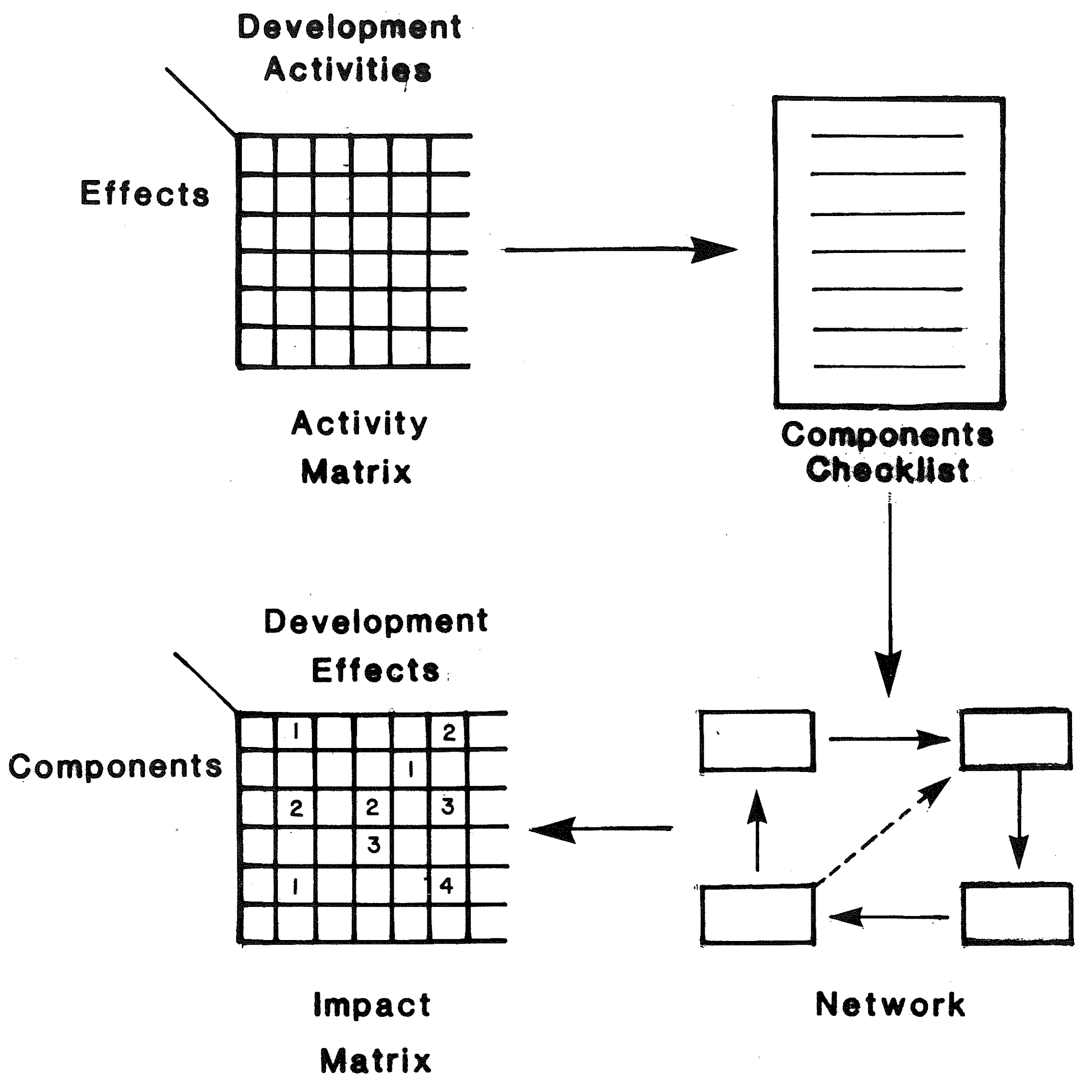
The first step, mapping, should define the boundaries for peat mining and use. Maps produced might include watersheds, forest types, soils, peat types (for limited areas), ownership, land use and others.

Step two is the systematic preparation and analysis of information (see Figure 3). This analysis, which will employ matrices and check lists, will also pinpoint where knowledge is lacking and emphasize environmental processes and components that deserve special attention in written analysis.

The final step is the writing of the descriptive report.

Figure 3

Steps in Peatland Impact Assessment



The first step in the analysis of peatland information is the development of a matrix listing the anticipated development activities on one axis against a list of potential effects, such as emissions, on the other. Matrix cells are checked when an activity generates an effect.

Step two is the listing of environmental components -- both abiotic and biotic elements -- likely to be altered by effects identified in step one. Examples of such components are wildlife, vegetation and surface water.

Third, a network is drawn to describe the relationships between environmental components, such as vegetation, wildlife and water quality. This step may be preceded by the use of cross-impact matrices.

Finally, an impact matrix is drawn to show environmental components that are affected by development. The impacts are ranked by magnitude.

Computer Data Base Review

The purpose of this section is to identify existing information sources in computer format that might be used in assessment of peat-use impacts. Now, general regional information is of greatest use to the peat program. But when leasing begins, site-specific information will be needed for impact assessment, and the peat-program staff may choose to augment existing data bases with fresh information or build a new data base for the study area. In either case, it is important to know about existing data bases.

To be appropriate for the peat program, a data base must have a study area congruent with peatlands. It also must have variables relevant to peatland impact assessment. In regard to the second criterion, for example, the MLMIS variable "Irrigation Permits" is probably not appropriate to peat-impact questions, but the variables "Forest Cover" and "Ownership" probably are.

Map scale and data resolution, though not vital, are important. Resolution refers to the locational and spatial accuracy or precision of the data. The resolution of a data base depends on the precision of original data -- a soils map, for example -- and the size of the grid on which the data is encoded. MLMIS produces maps with grids of 5 square kilometers (about one-quarter township), 40 acres and fractions of 40 acres (10 and 2.5 acres are most common). The resolution of a 2.5-acre-grid map is much greater than that of a 40-acre grid. Of course, if data precision is not equivalent to grid size, then the move to a smaller grid cell is only an illusory increase in resolution. Such is the case with the MLMIS 40-acre-cell variable, "Soils," taken from the Minnesota Soils Atlas. Original Soils Atlas data is good only to 600 acres even though it is coded and mapped in a 40-acre grid.

For regional resources surveys, the 40-acre-cell or 5-square-kilometer-cell maps have sufficient resolution. A 2.5-acre cell would be needed for the site-specific impact studies that will be done when the state grants a particular lease request.

Existing Data Bases

There are two categories of existing computer data bases in Minnesota: those that provide statewide coverage and those developed for a particular study area within the state.

Statewide coverage: The MLMIS is the only statewide data base available. The 71 major variables in the 40-acre-cell file include cultural and administrative characteristics, such as "V01 Townships," "V03 Minor Civil Divisions" and "V09 Management Unit Status of State Land." There are also resource and physical characteristics, including "V11 Bedrock Geology," "V15 Soil Associations Arrowhead" and "V17 Forest Cover." The 5-square-kilometer-cell data base in MLMIS contains 99 variables, including most of those in the 40-acre system. The 5-square-kilometer system has been used recently by the power plant siting group at the State Planning Agency and, as a result, contains additional data, including "EQB Exclusion Areas," "EQB Avoidance Areas" and "Soil Productivity." (A complete list of 40-acre-cell variables is found in Appendix B1. The complete list of variables in the 5-square-kilometer system is found in Appendix B2).

Small-area coverage: Many data bases have been assembled for particular studies: state park management plans, various site-selection exercises and general resource surveys, such as those for copper-nickel development or for iron-range planning. Unfortunately for the peat program, few of these small-area data bases cover important peatlands. The most promising is the data base of the Iron Range Information System in the Department of Natural Resources, Minerals Division. The southern section of the system's study area includes the Oglebay-Norton tailings-basin peatland, a leading candidate for early leasing. Fourteen data variables on a 2.5-acre grid include soils, watersheds, surface water, vegetation, historical sites and utility corridors -- all useful in impact anaylsis (Appendix B3). MINESITE and copper-nickel studies contain useful data variables, but the study areas include only small peat deposits of marginal interest. (A complete list of variables from those studies appears in Appendix B4).

More than 30 small-grid studies have been completed since the early 1970s, most of them by use of MLMIS. Some include peatland and may be useful in impact assessment. One, the Manitoba East Study, a power-line corridor selection exercise, includes parts of Aitkin, Itasca and St. Louis counties and employs the standard MLMIS 40-acre variables. Two power-plant studies -- one near Floodwood, the other near Cohasset -- are limited to the assessment of visual impacts of power-plant construction. (A list of these small-area studies is included in Appendix B5).

Finally, there are a couple of non-computerized data bases to consider. The Department of Natural Resources, Division of Fish and Wildlife, is about to complete management plans for several wildlife management areas in the state. Two of these are in the peatlands of the northwest -- Roseau River Wildlife Area and the Red Lake Wildlife Management Area. The management plans include vegetation and habitat maps and may be useful for peatland impact assessment.

Recommendations

For present purposes -- broad, regional peatland impact assessment -- the most appropriate computer data bases are the MLMIS 40-acre-grid and 5-square-kilometer-grid systems. They appear to contain useful data variables at appropriate resolution, and the two systems incorporate statewide coverage. When impact analysis is required on specific leased sites, some of the small-area data bases may be useful. As mentioned above, the Iron Range Information System data base could be used for assessment of the Oglebay-Norton tailings basin bog. Of course, it is possible though costly to assemble a data base for computer mapping and analysis of any specific peatland site.

II APPLICATION

Introduction

In this section of the report, the recommended impact analysis method will be applied to the three most common and likely development options: horticulture, agriculture and large-scale energy production. Only the second and third steps outlined in the previous section -- the use of matrices and check lists, and the descriptive writing -- will be used here, since the MLMIS mapping project is still underway and will be contained in other reports. The analysis method is generic -- it considers no specific site -- and focuses on three phases of each development project: construction, operation and reclamation.

Horticultural Use of Peat

About 1,400 acres of peatland are now being mined in Minnesota. The sphagnum-moss and reed-sedge peats are used to produce commercial products, including potting soil, growing mixes and bulk peat for nurseries and landscaping. Nationwide, 102 operations in 21 states produce 900,000 tons of peat products each year. The value of peat sold in 1976 is estimated at more than $17 million. The United States also imports more than 300,000 tons of peat each year, most of it from Canada. Besides the land already mined, the DNR has been asked to lease 41,000 acres for horticultural peat extraction.

Operation Description

Before horticultural mining begins, land is usually cleared and drained. Peat can be milled, scraped, cut in sods or extracted by hydraulic methods. Milling, the most common method, requires harrowing the upper one-half inch of peat and allowing this layer to air-dry. When it has dried, the peat is removed with large mechanical or vacuum harvesters. Peat can be harvested about 25 days a year in Minnesota, and to reach deep layers of peat requires many years. Peat is stored on the mining fields and at the plant, where peat is bagged or baled.

Reclamation alternatives for the mined peatland include forestry, agriculture, biomass production or returning the peatland to its natural state.

Impact Analysis

The activity matrix of development activities versus effects is shown in Table 5. Though the development effects occur throughout the various phases of the project, the nature of these effects changes from construction to operation to reclamation.

The horticultural development component checklist (Table 6) illustrates that both the natural and human environmental components are affected by the project.

The cross-impact matrix with these components shows that vegetation, water quality and aesthetics are most greatly affected (Table 7).

The cross-impact matrix is used to develop a network that shows the interrelationships among components (Figure 4). The network emphasizes that if one element is directly affected, many others are affected indirectly. For example, if the vegetation is cleared, the ground water, water quality, water quantity, peat, terrestrial wildlife and aesthetics are affected. Vegetation is clearly a pivotal environmental component of a peat bog.

The final step in the analysis is the drawing of the impact matrix (Table 8). Development effects from the activity matrix are on one axis; environmental components and processes are on the other. This step uncovers links between development activities and environmental effects and uses the additional indirect impact information obtained in the cross-impact matrix and the network.

Discussion of Impacts

Most of the initial direct impacts of milled-peat mining are caused by clearing and draining. Clearing eliminates habitat and displaces wildlife. The loss of plants also reduces evapotranspiration and increases runoff. Lowering

Table 5 Horticultural Development Activity Matrix

DEVELOPMENT EFFECTS	DEVELOPMENT ACTIVITIES: CONSTRUCTION					OPERATION						RECLAMATION						
	Clearing	Drainage	Plant Site	Roads & Parking	Utilities	Mining	Transp. & Handling	Storage	Plant Processing	Waste Disposal	Distribution	Clean-Up	Field Prep.	Maint. Drainage	Fill Ditches	Contouring	Planting	Fertilization
△ Land Use	●		●	●	●	●				●			●		●	●	●	
Clear land	●		●	●	●													
△ Surface Contours			●	●		●		●		●			●			●		
△ Drain patterns		●		●						●				●	●	●		
Create barriers	●	●	●	●										●				
Peat subsidence		●												●	●			
Peat removal						●												
Create noise	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Emit dust			●	●		●	●	●	●			●	●			●	●	
Lower water table		●												●				
reduce evapotranspiration	●	●												●				
△ Runoff	●	●	●	●									●	●	●	●	●	
△ Water Quality	●	●	●			●	●	●					●	●	●	●	●	●
Increase Traffic			●	●	●	●	●			●	●		●					
Fire Hazard		●				●	●	●	●	●				●				
Safety Hazard			●	●	●	●	●		●		●							
Create Jobs	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Require Services	●	●	●	●	●	●	●		●		●	●	●	●	●	●		

Table 6 Peatland Development Environmental Component Check List

NATURAL ENVIRONMENT	HUMAN ENVIRONMENT
X vegetation (on site)	X aesthetics
X vegetation (off site)	X health and safety
X wildlife habitat	X economy
X terrestrial wildlife	X services
X aquatic wildlife	X recreation
X water quality	X transportation
X water quantity	
X air quality	
X peat	
X ground water	

the water table by drainage causes peat subsidence, reduces evaporation from the peat surface and changes runoff peak, timing and amount. Drainage usually increases suspended sediments and nutrients in runoff and affects downstream aquatic life.

Milled-peat mining creates dust, which can further impair water quality. Heavy equipment used in excavation and processing creates noise and some air emissions.

In addition to the initial direct effects on the site, there are indirect off-site effects. Drainage is known to affect downstream vegetation when regional ground-water flow is intercepted by ditches. Air emissions carried off the site can lead to slow-acting but cumulative effects on vegetation and water quality, as is the case with acid rain. Contaminants in water are carried downstream and can indirectly impair domestic and industrial use and aquatic plant and animal life.

Reclamation activities themselves initially can cause adverse impacts, the effects varying with the reclamation scheme. After a long time, however, benefits will outweigh detriments, especially if the peatland is left to return to its natural condition.

Vegetation changes and their effects on wildlife are generally considered irretrievable. The removal of peat is also irretrievable. Reclamation of mined peatlands can only partially restore those resources.

Table 7
Peatland Development Environmental Component Cross-Impact Matrix

ACTIVE FORCES

PASSIVE FORCES	Vegetation	Terrestrial life	Aquatic life	Runoff	Ground Water	Water Quality	Peat(Mining)	Air Emissions	Noise	Aesthetics	Health & Safety	ΣX	$\bar{X}$
NATURAL ENVIRONMENT													
Vegetation	4	2	1	4	4	4	4	2	1	1	1	28	2.5
Terrestrial life	4	4	3	2	2	1	1	2	3	1	1	24	2.2
Aquatic life	1	1	4	4	2	4	1	2	1	1	1	20	1.8
Runoff	3	1	1	4	4	1	4	1	1	1	1	22	2.0
Ground Water	3	1	1	3	4	1	1	1	1	1	1	18	1.6
Water quality	4	2	3	3	3	4	4	3	1	1	1	29	2.6
Peat subsidence	4	1	1	4	4	3	4	2	1	1	1	26	2.4
Air emissions	1	1	1	1	1	1	3	4	1	1	1	16	1.5
HUMAN ENVIRONMENT													
Noise	1	1	1	1	1	1	1	1	4	1	1	14	1.3
Aesthetics	4	4	3	1	1	4	3	2	3	4	1	30	2.7
Health & Safety	1	1	1	1	1	3	3	3	3	1	4	22	2.0
ΣX	30	19	20	28	27	27	29	23	20	14	14		
$\bar{X}$	2.7	1.7	1.8	2.5	2.5	2.5	2.6	2.1	1.8	1.3	1.3		

SCORING

1 no relationship
2 low relationship
3 moderate relationship
4 high relationship

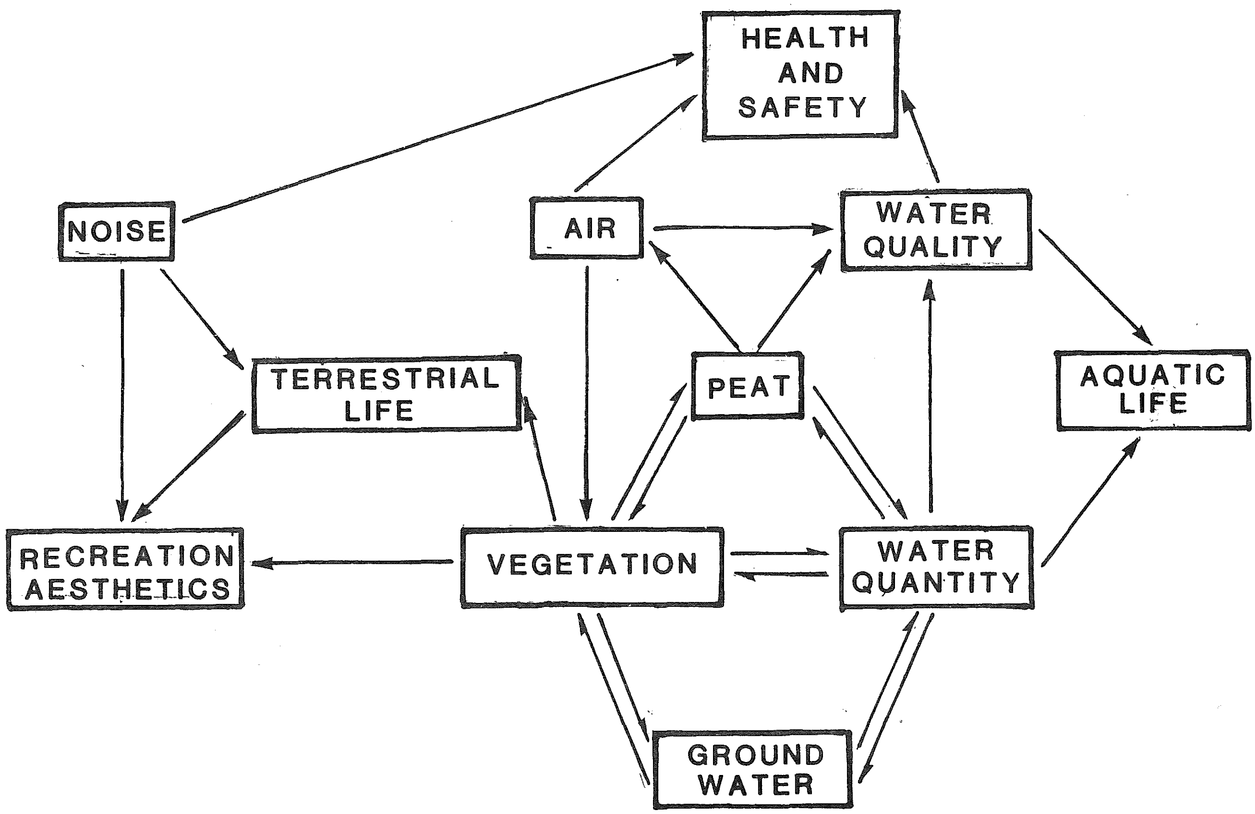


Figure 4 PEATLAND ENVIRONMENTAL NETWORK

Table 8 Horticultural Development Impact Matrix

ENVIRONMENTAL COMPONENT	Land Use	Clear land	Surface Contour	Δ drainage pattern	Create barriers	Peat Removal	Create Noise	Emit dust	Lower water table	Reduce evapotranspiration	Δ Runoff	Δ Water Quality	Increase traffic	Fire Hazard	Health & Safety	Create Jobs	Require Services
NATURAL ENVIRONMENT																	
Vegetation	2	3		2				1	3		1	2	1	1			
Terrestrial life	2	3		1	3	1	1	1	2		1	1	1	1			
Aquatic life	1	1	1	1	1			1	2	2	3	3					
Runoff		2	1	1		1			2	3	3						
Ground Water		1	1	1		1			3	3	1						
Water Quality		2	2	1		3		2	3	2	2	3		1			
Peat	2	2	1	1		1			3					2			
Air Quality		1	1			2		2					2	2			
HUMAN ENVIRONMENT																	
Noise		1	1			1	3		1				2				
Aesthetics & Recreation	2	2		1	1		2	1	1			1	1				
Health & Safety		1	1			1	2	2	1		2	2	2	2	3		
Socio-Economic		1	1			2			1				1			2	2

SCORING

blank	no impact
1	low impact
2	moderate impact
3	high impact

Agricultural Use of Peat

Peat soils demand more care than mineral soils. Farmers must find suitable peat, control water levels, prevent peat subsidence and invariably fertilize the soil. Moreover, crops grown in peat are often susceptible to frost.

Many crops are successfully grown on Minnesota peatlands, including vegetables, grains, forage crops, grass seed, sod and wild rice. Of the 678,000 acres of peatland under cultivation, about 90 percent is used for hay or pasture.

Operation Description

Peat farming usually requires clearing, draining, contouring and other preparation. Drainage varies with the kinds of peat and crops. Row crops generally require a lower water table and more drainage than pasture does. There is, however, an exception: Peatlands are usually diked and flooded for the production of wild rice.

The land is contoured and occasionally tilled to prepare it for planting and harvesting. Soil is planted, fertilized and treated for weeds and pests. Most peat has little phosphorous, and some lacks trace elements such as copper. In Europe, lime is added to the soil, but this practice is uncommon in the United States.

Reclamation alternatives for peat farmland are similar to those for horticultural sites. Forestry, biomass production and natural reclamation are the most likely options.

Impact Analysis

The activity matrix (agricultural development activities versus effects) indicates that peat farming causes fewer impacts than does horticultural extraction (Table 9). Agricultural use requires no plant or utilities and fewer roads. Moreover, peat is not removed, except perhaps in sod production. Nonetheless, the cross-impact matrix and network that were used to assess horticultural use are used for peat farming since the same environmental components are affected (Table 7 and Figure 4). The impact matrix for agricultural development is different, however, because of a difference in the magnitude of impacts (Table 10).

Discussion of Impacts

Clearing, drainage, fertilization and cultivation are the major activities that cause impacts. Except for the effects of fertilization, all the initial impacts are identical to those caused by horticultural use. Fertilization may impair water quality and affect aquatic life.

Changes in runoff and dust emissions are probably less in peat farming than in horticultural extraction because the land is planted part of the year. Generally, however, subsidence is a greater problem in peat farming.

The magnitude of some impacts varies with the crop selected and the corresponding management. For example, grasslands require less drainage, fertilization and pest control than row crops do and are usually planted year-around.

Long-term impacts are similar to those of horticultural development. Both vegetation and wildlife are irretrievably changed. Although peat is not removed, long-term subsidence may greatly reduce peat thickness and change the type of peat. The impacts of fertilization and pesticide and herbicide treatment may last long after the operation

Table 9 Agricultural Development Activity Matrix

DEVELOPMENT EFFECTS	DEVELOPMENT ACTIVITIES: CONSTRUCTION			OPERATION						RECLAMATION			
	Clearing	Drainage	Contouring	Fertilization	Planting	Pest Control	Harvesting	Transport	Storage	Maint. Drainage	Fill Ditches	Planting	Fertilization
△ Land Use	●										●	●	
Clear land	●												
△ Surface contours	●		●										
△ Drain patterns		●	●							●	●		
Create barriers	●	●								●			
Peat Subsidence		●								●	●		
Create Noise	●	●	●	●	●		●	●		●	●	●	●
Emit dust			●	●	●		●	●				●	
Lower water table		●								●			
Change runoff	●	●	●		●					●	●	●	
Change water quality	●	●	●	●	●	●	●	●		●	●	●	●
Increase traffic								●					
Fire Hazard		●											
Safety Hazard				●		●	●	●					
Create Jobs	●	●	●	●	●	●	●	●	●	●	●	●	
Require services	●	●	●				●	●		●	●		

ceases since some chemicals are retained by the peat. But because of the fertilization and scattered seeds, abandoned peat farmland is more easily replanted and reclaimed than is a mined horticultural site.

Table 10 Agricultural Development Impact Matrix

DEVELOPMENT EFFECTS

ENVIRONMENTAL COMPONENT	ΔLand Use	Clear land	ΔDrain patterns	Create barriers	Peat subsidence	Create Noise	Emit dust	Lower water table	ΔRunoff	ΔWater Quality	Fire Hazard	Health & Safety	ΔSurface Contours	Create Jobs	Require services
NATURAL ENVIRONMENT															
Vegetation	2	3	2					3	1	2	1				
Terrestrial Wildlife	2	3	1	3		1		1	1	1	1				
Aquatic life	1	1	1	1				2	3	3			1		
Runoff		2	1		1			3	3				1		
Ground Water		1	1					3	1				1		
Water Quality		2	1		1		1	3	2	3	1		2		
Peat	2	2	1		3			3			2		1		
Air Quality		1					1				2		1		
HUMAN ENVIRONMENT															
Noise		1				1		1					1		
Aesthetics & Recreation	2	2	1	1		1	1	1		1					
Health & Safety		1				1	1	1	2	2	2	2	1		
Socio-economic		1						1						1	1

SCORING

blank	no impact
1	low impact
2	moderate impact
3	high impact

Peat Gasification

Peat can be used in many ways to produce energy. It can be dried and burned in its natural form. It can be pressed into briquettes. It can be used to make alcohol. Finally, it can be gasified and burned.

Peat and peat briquettes are common fuels in the Soviet Union, Ireland and Finland. Though little peat is used for fuel in the United States, Minnesotans have long considered its use. As early as 1870, the Legislature investigated the use of peat for steam locomotives. In 1919 and 1920, a downtown Minneapolis office building was heated with peat. In 1950, Sen. Hubert H. Humphrey introduced a bill to research peat's use as a fuel.

So far, the Department of Natural Resources has received requests for leases on 200,000 acres of peatland for gasification projects. Energy utilities have expressed interest in an additional 28,000 acres.

Operation Description

The gasification of peat involves mining the peat by one of many methods and converting it to synthetic natural gas in a large facility. Because milled-peat mining was discussed earlier under the horticultural option, hydraulic mining, the method preferred by many firms, will be considered for the gasification option.

Hydraulic mining allows the removal of peat from a cleared but undrained bog. A floating dredge or other excavator removes the peat, creates a peat slurry of about 3 percent to 5 percent solids, and pumps the slurry to a dewatering plant. The peat, dewatered perhaps by mechanical pressing, is fed to the gasifier (Figure 5).

A hydro-gasification process considered by the Institute of Gas Technology would produce not only synthetic natural gas but other by-products, including sulfur, oil, benzene, phenols and ammonia. The facility would need water for gasification, cooling and recovery of by-products.

Reclamation alternatives for energy development will depend on the mining method. Milled-peat mining leaves the site drier than it was, and forestry, agriculture, biomass, and natural revegetation all are feasible reclamation alternatives. Hydraulic mining creates shallow ponds on the site and allows waterfowl production, wild-rice farming or peatland regeneration as reclamation schemes.

Impact Analysis

The activity matrix of energy development activities includes both milled-peat and hydraulic mining and direct combustion and gasification activities; thus, the impacts of different methods can be compared (Table 11).

It appears gasification will produce more effects than direct burning does. Each mining method causes similar effects, though it is the magnitude of these effects that is most important. Magnitude is shown in the energy development impact matrix (Table 12).

Discussion of Impacts

Many impacts of energy development will be identical to those of horticultural development since both uses require clearing and, often, draining. Other construction impacts will depend on the size of the operation and, according to current proposals, will be greater for energy development.

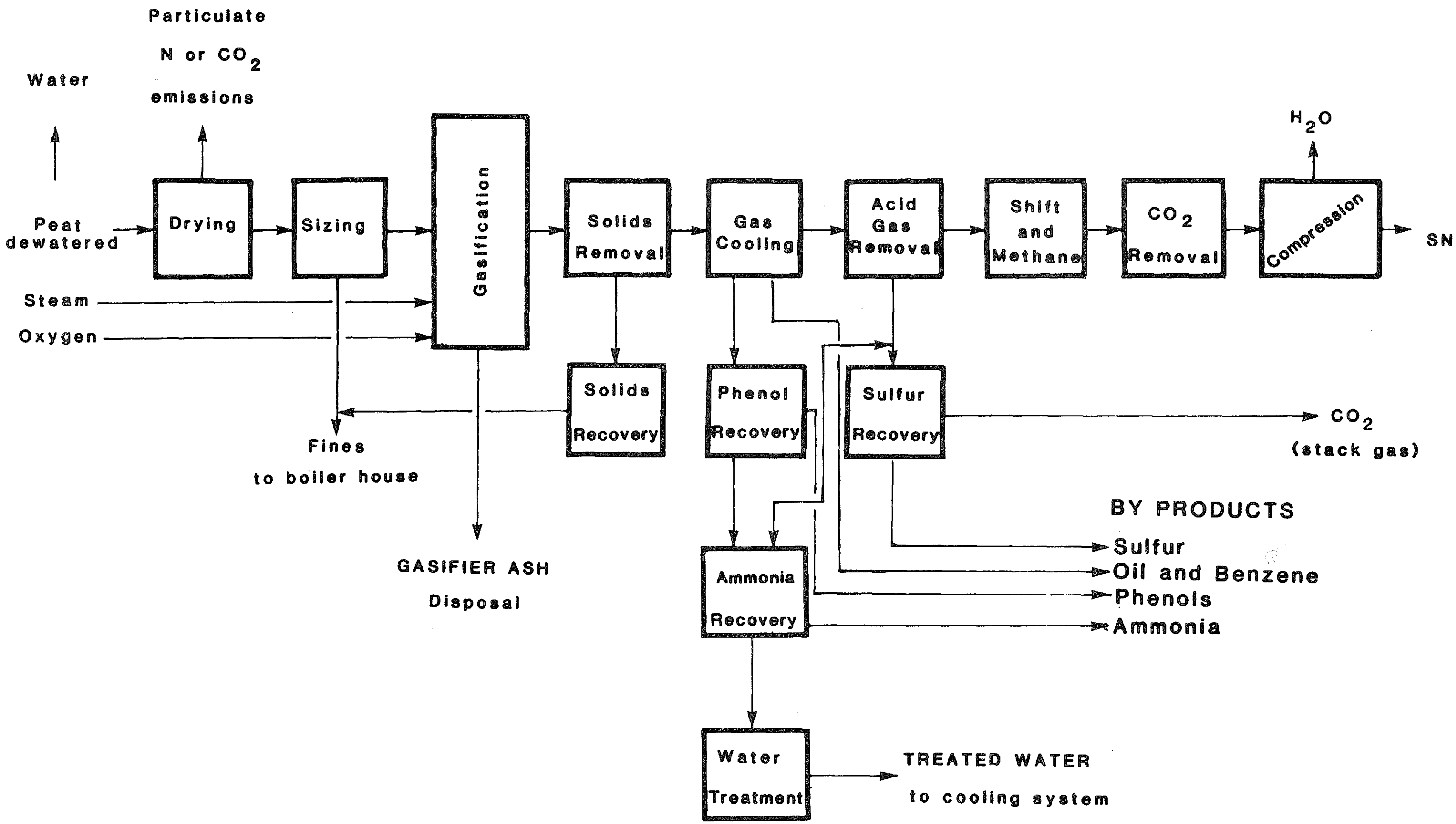


Figure 5 Peat Gasification Flow Chart

Table 11 Energy Development Activity Matrix

DEVELOPMENT EFFECTS	DEVELOPMENT ACTIVITIES: CONSTRUCTION					OPERATION												RECLAMATION						
	Clearing	Draining	Plant Const.	Roads & Parking	Utilities	Hydraulic Mining	Milled Mining	Dewatering	Equip. Operation	Transp. & handling	Storage	Direct Burning	Gasification	Solid Waste Disposal	By-product recovery	Waste water trt.	Distribution-Pipeline	Clean-Up	Field prep.	Maint. Drainage	Fill ditches	Contouring	Planting	Fertilization
△ Land Use	●		●	●	●	●	●							●			●		●		●	●	●	
Clear land	●		●	●	●	●	●										●							
△ Surface Contours			●	●		●	●				●			●					●			●		
△ Drain patterns		●		●		●	●							●			●		●	●	●	●		
Create barriers	●	●	●	●		●	●										●			●				
Peat subsidence		●																		●	●			
Peat Removal						●	●																	
Create Noise	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Emit Particulates			●	●			●		●	●	●	●	●	●				●	●			●	●	●
Emit NOx, CO2, gases													●		●									
Produce ash												●	●			●								
produce wastewater								●					●		●	●								
Produce Cooling Water													●											
Lower Water Table		●																		●				
Reduce evapotranspiration	●	●																		●				
△ Runoff	●	●	●	●		?	●	?					?				●		●	●	●	●	●	
Require Water						●						●	?											
△ Water Quality	●	●	●			?	●	?		●	●		?	●	?	●			●	●	●	●	●	●
Increase Traffic			●	●	●	●	●			●				●			●		●					
Fire Hazard		●					●		●	●	●	●	?	●						●				
Safety & Health Hazard			●	●	●	●	●		●	●		●	●		●	●	●							●
Create Jobs	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Require Services	●	●	●	●	●	●	●	●	●	●		●	●		●	●	●		●	●	●	●		

Table 12 Energy Development Impact Matrix

ENVIRONMENTAL COMPONENT	△Land Use	Clear land	△Surface Contours	△Drain patterns	Create barriers	Peat subsidence	Peat removal	Create noise	Emit particulates	Emit NOx, CO2, gases	Produce ash	Produce waste water	Produce cooling water	Lower water table	Reduce evapotranspiration	Runoff	Require Water	△Water Quality	Increase traffic	Fire Hazard	Health & Safety	Create Jobs	Require Services
NATURAL ENVIRONMENT																							
Vegetation	2	3		2					1	1				3		1		2	1	1			
Terrestrial life	2	3		1	3		1	1	1	1				2		1		1	1	1			
Aquatic life	1	1	1	1	1	1			?	?	?	?		2	2	?	?	?					
Runoff		2	1	1		1	1					1	1	2	3	3	?						
Ground Water		1	1	1			1							3	3	?	?						
Water Quality		2	2	1		1	3		?	?	?	?	?	3	2	?	?	?		1			
Peat	2	2	1	1		3	1							3						2			
Air Quality		1	1				2		?	?									2	2			
HUMAN ENVIRONMENT																							
Noise		1	1				1	3						1			1		2				
Aesthetics & Recreation	3	2		1	1		1	2	1			1	1					1	1				
Health & Safety		1	1				1	2	2	1	1	2				2		2	2	2	3		
Socio-economic		1	1				2							1					1			3	3

SCORING

blank	no impact
1	low impact
2	moderate impact
3	high impact
?	unknown magnitude

The actual operation of a peat gasification facility will cause more impacts than other options because of air and water emissions. The magnitude of hydraulic mining and dewatering impacts is unknown and may depend on whether the water from peat slurry is recycled and whether the basins gouged from peat have outlets. The magnitude of impacts caused by gasification is also unknown, though the various by-products may impair air and water quality. Gasification may release nitrous oxides, particulates, sulfur, heavy metals and aromatic hydrocarbons in amounts that will depend on controls and recovery technology. Since gasification will produce ammonia, phenols, benzene and other oils, additional water quality impacts could occur, depending on wastewater treatment. Gasification will further require the disposal of ash, which could cause additional off-site impacts. Pipelines used to transport the synthetic natural gas, like any pipeline project, will affect various environmental components.

Reclamation impacts will vary with the mining method. Reclamation of hydraulic-mining sites produces fewer effects than reclamation of milled-peat-mining areas. Milled-peat mining allows reclamation schemes similar to those for horticultural development.

Off-site effects from energy development will be similar to those of horticultural use because of changes in drainage patterns. With gasification, however, greater off-site effects can be expected because there will be more air and water emissions.

Peat mined for energy development will be irretrievable. Impacts to vegetation and wildlife will be unavoidable. The magnitude of all impacts, on and off the site, will depend largely on the size of the project.

Comparison of Development Options

Since the environmental component check lists, environmental component cross-impact matrices and networks are identical regardless of the development scheme, comparisons of the three options are best made by the activity matrices (Tables 5, 9 and 11).

Such a comparison reveals may similarities (Table 13). Clearing, draining, and the changing of surface contours, drainage patterns and land use all cause similar impacts for all development options. These activities create barriers to wildlife and make noise. Drainage also changes water quality and runoff, aggravates peat subsidence and increases the fire hazard, regardless of the use. In all cases, construction, operation and distribution increase traffic, create jobs and require local services.

Reclamation effects are similar for all development

Table 13:
Comparison of Effects of Peatland Development Options

DEVELOPMENT EFFECTS	DEVELOPMENT OPTION		
	HORTICULTURE	AGRICULTURE	ENERGY
△ land use	● (10)	● (3)	● (11)
clear land	● (4)	● (1)	● (6)
△ surface contours	● (7)	● (2)	● (7)
△ drain patterns	● (7)	● (4)	● (9)
create barriers	● (5)	● (3)	● (7)
peat subsidence	● (3)	● (3)	● (3)
peat removal	● (1)		● (1)
create noise	● (17)	● (11)	● (21)
emit dust (particulates)	● (10)	● (6)	● (13)
emit No_x, Co_2, gases			● (2)
produce ash			● (3)
produce wastewater			● (4)
produce cooling water			● (1)
lower water table	● (2)	● (2)	● (2)
reduce evapotranspiration	● (3)		● (3)
△ runoff	● (9)	● (7)	● (13)
△ water quality	● (12)	● (12)	● (17)
require water			● (3)
increase traffic	● (8)	● (1)	● (8)
fire hazard	● (7)	● (1)	● (9)
health & safety hazard	● (7)	● (4)	● (12)
create jobs	● (18)	● (13)	● (23)
require services	● (14)	● (7)	● (18)

( ) Numbers in parenthesis indicate the numder of development activities resulting in a development effect.

options -- unless hydraulic mining is used in energy development. Reclamation associated with hydraulic mining has fewer effects than reclamation of areas mined by other methods.

Nonetheless, there also are several differences among impacts caused by the different options. For example, peat farming requires no mining, and less land is cleared because a processing plant is not needed. Agriculture, however, requires fertilization and possibly the use of pesticides and herbicides. All can affect water quality. More peat subsidence is expected with farming, but because evapotranspiration is not reduced as much as with other options, less change in runoff is expected. Energy development will cause unique impacts because of ash disposal, pipeline construction, by-product production and added air and water emissions. Hydraulic mining, dewatering and gasification are unique to the energy option, though the magnitude of their impacts is still unknown. A gasification plant probably will be much larger and more permanent than a horticultural processing facility.

Generally, the magnitude of impacts from any of the three options depends largely on the size of the operation. Magnitude, however, also depends on the location within a peatland or watershed and on the operation's proximity to sensitive resources, such as lakes or sensitive plants and animals.

More detailed assessments cannot be made until specific proposals are offered and sites are selected. Nonetheless, this discussion of general impacts defines subjects requiring further research and evaluation.

Policy Implications

The potential impacts identified in the previous section are useful in formulating a policy directed toward preserving environmental quality. A sound environmental policy will aid mitigation of adverse impacts.

Table 14 suggests ways to mitigate or prevent potential impacts. For some development effects, no mitigation is apparent; these effects will be unavoidable. For others, impacts are so uncertain that mitigation cannot be proposed; additional research is needed. Generally, limiting the size of operations can reduce most impacts: A small development will have less impact than a large one. From the list of mitigations, it is evident that an environmental policy should address site selection, size, reclamation, design criteria, treatment of air and water emissions, payment for local services, and fire, health and safety programs.

Table 14 Potential Mitigation of Development Effects

DEVELOPMENT EFFECT	POTENTIAL MITIGATION
land-use change	reclamation
clear land	size, site selection, buffers
Δsurface contours	erosion control, settling basin
Δdrain patterns	size, site selection
create barriers	none apparent
peat subsidence	higher water table, vegetation
peat removal	none apparent
create noise	noise abatement equipment
emit dust	vegetative barriers, staged reclamation equipment and operation
emit gases	pollution-control equipment
produce ash	none apparent
produce waste water	tertiary treatment
produce cooling water	closed system
lower water table	site selection
reduce evapotranspiration	none apparent
change runoff	settling basin, structures, design, site selection
change water quality	filtration, settling basin, treatment, site selection
require water	closed system
increase traffic	none apparent
fire hazard	fire-control program, spark arrestors
health and safety	health and safety rules
require jobs	hire locally, stable, long term
require services	pay for services

Summary

An evaluation of common impact assessment methods identified five basic techniques: ad hoc description, overlay maps, check lists and cause-effect matrices, cross-impact matrices and networks. From first to last, these methods were found to increase in cost and in their demand for specific data. A survey of 50 environmental impact statements revealed that most (40) are ad hoc descriptive and that very few use more rigorous approaches. The descriptive method alone is inadequate for assessing peatland impacts. More sophisticated methods help define subjects where information is lacking.

This report presented an impact assessment strategy that can be used to evaluate general impacts and identify research needs, program priorities and policy issues. Such an assessment will be of great value in the making of peat policy. The method consists of the following:

*MLMIS overlay mapping;

*a number of matrices for conceptual clarity, including an activity matrix, a components check list, a cross-impact matrix, a network and an impact matrix; and

*a written discussion of impacts.

The method was applied to the three most likely peatland development options: horticulture, agriculture and energy. The cross-impact matrices and networks of environmental components were identical for all development options since these graphics describe a peatland ecosystem that will be upset by any intrusion. Identifying development phases -- construction, operation and reclamation -- proved helpful in understanding long-term consequences and the timing of impacts. Even reclamation causes some impacts.

The impact assessment process pointed out similarities and differences among development options and identified research needs, especially for peat gasification. The method helped identify environmental policy issues by suggesting ways to mitigate impacts. This report will be used in the overall peatland policy formulation process.

III APPENDICES

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Appendix A

Survey of Environmental Statements

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Appendix B1

Variables in the MLMIS 40-Acre File

1. Townships
2.
3. Minor Civil Divisions (1970 Census)
4.
*5. Public Ownership (1973)
6. Type of Acquisition, State Land (1973)
*7. Highest Recommended Use, State Land (1973)
8. Recommended Disposition, State and County Land (1973)
9. Management Unit Status State Land (1973)
10.
*11. Bedrock Geology--Arrowhead
*12. Mineral Potential--Arrowhead
13. Copper-Nickel Leases
14.
*15. Soil Associations--Arrowhead
*16. Land Use (1969)
17. Forest Cover (1962)
*18. Water Orientation
*19. Highway Orientation
20.
*21. Soil-Landscape Units
*22. Geomorphic Regions
*23. Forest Cover (1977)
24.
25.
26.
27.
28.
29.
*30. Major Watersheds: Administering Agency (1979 Ownership)
*31. Minor Watersheds: Means of Acquisition (1979 Ownership)

* Maps available. Non-starred variables still being processed.

32. Land Classification (1979 Ownership)
33. Mineral Ownership (1979 Ownership)
*34. Highest Recommended Use (1979 Ownership)
35. Second-Highest Recommended Use (1979 Ownership)
36. Recommended Disposition: Irrigation System Type (1979 Ownership)
37. Acreage (1979 Ownership): Irrigated Field Size
38. Second Administering Agency: Irrigated Crops
39. Second Mineral Ownership
40. Public-Land Survey--Sections
41. Public-Land Survey--40-acre parcels
42.
43.
44.
45.
46.
47.
48.
49.
50. Public-Land Survey--Townships
51. Public-Land Survey--Range
52.
53.
54.
*55. Federal Ownership (1978): Soil Geomorphic Combinations
56.
57.
58.
59.
60. Irrigation Appropriation Permits: Miscellaneous
61.
62.
63.
64.
65.
66.
67.
68.
69.
70. Administrative Units for Parks: Owner (State Comprehensive Outdoor Recreation Plan)
71. Administrative Units for Forest (SCORP)
72. Administrative Units for Wildlife Management Areas (SCORP)

73.
74. Resorts (SCORP)
75. Campgrounds (SCORP)
76. Marinas (SCORP)
77. Athletic Fields (SCORP)
78. Ownership (1978): Playgrounds (SCORP)
79. Water Access (SCORP)
80. Picnic Grounds (SCORP)
81. Swimming Beaches (SCORP)
82. Swimming Pools (SCORP)
83.
84.
85.
86.
87.
88.
89. Open to Public (fee-no fee) (SCORP)
90. Map Ownership: Administration Unit (SCORP)
91. County: Number of Resort Units (SCORP)
92. Watershed Boundaries, major and minor: Number of Campground Sites (SCORP)
93. Number of Ball Fields (SCORP)
94. Number of Tennis Courts (SCORP)
95. School Districts: Numbers of Ice Rinks (SCORP)
96. Number of Picnic Tables (SCORP)
97.
98.
99. Township Lines/DNR
100.

Appendix B2

MLMIS 5-Square-Kilometer Data File

V01 Site
V02 Townships
V03 Minor Civil Divisions
*V04 Central Places
V05 Minor Civil Divisions
*V06 1980 Population
*V07 Population Density
*V07 Total Particulates
*V08 Total Sulfur Dioxide Emissions

*V09 Number of Emission Sources
V08 Total Particulates-- Condensed
V09 Total Sulfur Dioxide-- Condensed
V10 Elevation
V11 Soil Productivity
V12 Composite Dominant, Second Dominant
V13 Original Vegetation-- Dominant
V14 Original Vegetation-- Second Dominant
*V15 Soils
*V16 Land Use
V17 Duration of Frost-Free Season
V18 Dissolved Solids in Aquifer
V19 Surface Soils
V20 1970 Population
*V21 Land-Use Zones
V22 Geomorphic Regions
*V23 Designated Rivers
*V24 Environmental Quality Board Exclusion Areas
*V25 Environmental Quality Board Avoidance Areas
V26 Environmental Quality Board Avoidable Areas
*V26 National Wildlife Refuges, Landmarks
*V27 Watersheds
*V28 Designated Federal Land
V29 Rainfall (old data)
*V30 Gravel-Road Density
V31 Two-Lane-Road Density
V32 State- and Federal-Highway Density
*V33 Paved-Road Density
V33 Soil Moisture
*V34 Total Road Density
*V35 Natural Preservation
*V36 National and State Forest
*V37 Minnesota State Parks
*V38 State Recreation Area
V39
V40 Total Water Density
V41 Natural-Water Density
V42 Ditch Density
V43 Stream Density
V44 Lakeshore Density
V45 Key and Intermediate Airports
V46 Environmental Quality Board Avoidance Data
V47 DNR Trout Streams
V48 County-Park Density

V49
V50 Agricultural Productivity Summary
*V51 Federal Fish-Wildlife Ownership
V52 Other Federal Ownership
*V53 Total Federal Ownership
*V54 State Fish-Wildlife Ownership
V55 Other State Ownership
V56 County Ownership
*V57 State and Federal Fish-Wildlife
*V58 Total State Ownership
*V59 Total State and Federal Ownership
V60 Surface Aquifer
V61 Bedrock Aquifer
V62 Karst Topography
*V63 Air-Quality Zones
V64 Air-Quality Monitors
V65
V66
*V67 Existing Power Plants
V68
V69
V70 Allowable Increment-- Sulfur Dioxide
*V71 Allowable Increment-- Particulates
V72 Potential Irrigation Soils
*V73 Four Major Watersheds
*V74 12 Minor Basins
*V75 River Network
V76 Municipal Intakes
V77 Steam Gauging Stations
V78 Land-Use Conflict for Environmental Quality Board
V79
V80 Growth Degree Days, Annual Average
V81 Growth Degree Days, Warm Season
V82 Growth Degree Days, Cold Season
V83 First Frost
V84 Last Frost
V85 Average Annual Precipitation
V86 July High Temperature
V86 Existing Sources of Air Pollution
V87 January High-Temperature Average
V87 Railroad Segments
V88 Annual Snowfall
V88 Railroad Nodes
V89 Snow Cover

V89 Agriculture Climate Zones
V90 Utility Corridor Service
V91 Minnesota Counties
V92 Bio-Cultural Regions
V93 Average Slope of Minnesota
V94 Detailed Slope of Minnesota
V95 K Factor (erodability)
*V96 Railroad Ownership
V97
V98
V99

Appendix B3

IRIS Study Variables

MAJOR STUDY AREA: 1,100 square miles, 2.47-acre cell

V02-V06 Public Land Survey (townships, ranges, sections, government lots)
V07 Bedrock Geology
*V08 Soils (general Soil Conservation Service)
*V09 Watersheds (Office of Water Resources Planning)
*V10 Surface Water
*V16 Roads
*V17 Urban and Rural Development
*V18 Water Appropriation and Discharge Points
*V19 Wildlife and Unique Natural Areas

PILOT STUDY AREA (Buhl-Gilbert) **
*V11,V12 Mining Land Use
*V13 Vegetation
*V14 Recreational, Historical and Archaeological Sites
*V15 Utilities

*Maps available. Non-starred variables still being processed.

**The pilot study area includes the variables listed under major study area plus the additional variables listed here.

Appendix B4

MINESITE Project Variables

V01 Site Map
V02 Percent Slope
V03 Slope Orientation
V04 Bedrock Geology
*V05 Surface Water
*V06 Watersheds
*V08 Surface Ownership
V09 Elevation
*V10 Soil Landscape Units
V11 Depth to Duluth Complex Contact
*V12 Land Use
V13 Shipstead-Newton-Nolan Area and Superior National Forest
*V14 Recreation, Historical and Archaeological Sites
V15 Taconite Reserves and Potential Taconite Resources
*V16 Vegetation
*V17 Timber-Cutting History
V18 Crown Density
*V19 Forest Size Classes
V20 Forest Height Classes
*V21 Natural Resource Sites
V22 Lake and Stream Surveys (fish habitat)
V23 Mineral Leasing
*V24 Soil Associations
*V25 Transportation
*V26 Railroads and Utilities
*V30 Watershed Areas
*V31 Proposed Recreation Areas and Research Areas
V32 Wolf, Moose, Pine Marten Habitat and Potential Caribou Release Area
V91 Units within MINESITE Area
V95 MINESITE Area
*V133 Fish Classification
V29 Polygon Map

Appendix B5

Small-Grid Data Bases

TITLE	AUTHOR*	FUNCTION	CELL SIZE (acres)	AREA OF STUDY (sq. mi.)
Blackbear	CURA	Forest plan	2.7	44
Upper St. Croix	DNR	Park-forest plan	2.7	200
Sunrise	CURA	Park plan	2.7	52
Lower St. Croix	CURA	Scenic corridor		200
EPPL	CURA	Systems		
Pigs Eye Coal	Ken Pekarek	Visual analysis	2.5	56
Muscatatock	CURA	Refuge plan	0.625	
T.H. 61, Red Wing	DOT	Highway location	2.7	30
Red Wing	UM	Class project	2.7	30
Empire Township	UM	Class project	10	36
Sherburne Refuge	BRW	Refuge plan	2.5	
MLMIS	SPA, CURA	Resource inventory	40	
Norshor	DOT	Highway location	2.7	186
Voyageurs	SPA		40, 2.5	
Chaska	DOT	Highway location	1.5	
I-94 East	DOT	Highway location	2.5	20
Reserve Mining Project	DNR	Supplemental assessment	40, 10	
ERTS LANDSAT	UM FORESTRY			
MINESITE	DNR	Mining location	2.5	455
Copper-Nickel Study	SPA	Regional study		
Natural Resource Protection Study		Airport zoning	2.5	
Power-Plant Siting	SPA	Power-plant sites	10, 40	
Manitoba East Study	SPA, NSP	Power-line location		
Power Plant Quarter Twp. file	SPA	Power facility sites		9
Duluth Recreation Plan				
Duluth Harbor Study				
Arrowhead Study	UM	Class project		
	SPA	Coastal zone		
Floodwood Power Plant Site Study	SPA	Management view study	2.5	
Cohasset Power Plant Site Study	SPA	View study	2.5	
Coastal Zone Study	SPA	Coastal zone management	2.5	

*CURA: Center for Urban and Regional Affairs
BRW: Bather, Ringrose, Wolsfeld, Jarvis and Gardner Inc.
DNR: Department of Natural Resources
DOT: Minnesota Department of Transportation
SPA: State Planning Agency
UM: University of Minnesota
NSP: Northern States Power Co.