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"MINESITE"
An Environmental Plan

Minnesota Department of Natural Resources
Division of Waters, Soils and Minerals

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"MINESITE" An Environmental Plan

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Throughout the World there is a growing awareness to the value of mineral resources. For most minerals, it's a sellers' market; the demand is growing faster than the known supplies can be produced. Many of the easily acquired resources have already been used, and where readily available resources do exist they often occur in countries with unstable political or economic systems.

To combat this disequilibrium in the supply-demand relationship of these resources, three solutions have been presented:[1]

1. Resource recycling
2. Expansion of the mining industry
3. Reduction in demand
   a) extending product lifetime
   b) abolish non-essential uses
   c) population control

All of these proposals are worthy of consideration. However, depending on the resource, they may not be suitable. For example, recycling can be expanded for some materials if technology is available that results in net resource savings. However, in many cases, collection, transportation, processing, and redistribution of recycled materials results in a net loss in total resources. Energy shortages could quickly put many of these conservation efforts out of business, even when voluntary collection is involved.

Expanding the mining industry can also have negative aspects. As the price of resources rises, companies can mine lower and lower grade material until ultimately, everything could be theoretically mineable. Accompanying this decreasing grade is a corresponding increase in land disturbance and the potential for environmental problems along with higher recovery and environmental costs that ultimately must be paid for by the consumer.

The last solution, that of reducing demand, is also a potentially viable solution, however, it will also have to be accompanied by basic social changes in the way we utilize our mineral resources, and ultimately could require some type of population control. The beginnings of such a change are already being reflected to some degree in the energy shortage. It is also quite apparent that such a social change cannot occur quickly, and therefore must be considered more of a long-term solution. Laws can be passed overnight, but minds and attitudes require a much longer period of time to change.

As is quite obvious, I'm sure, none of these proposed solutions could be made to function alone, particularly on a short term basis. And thus it appears appropriate that a management program where all three interact must be encouraged.

This then provides a perspective for looking at the business of mining in more detail. Mining is a land intensive activity. Many land uses are completely eliminated as a result of mining, while others are seriously restricted. At the same time, mining can enhance or create new land values where they were previously very low.

The location of the mineral resource dictates the specific location of the mine. This seems like a rather simple principal. However, in many cases this may result in some rather stringent restraints on potential mining operations. These restrictions have in the past been considered primarily from an economic standpoint. Environmental and land use considerations have often been ignored. In fact, until rather recently most developmental projects including mining have been based almost entirely on economic criteria, with little or no environmental consideration. However, recent pollution laws and regulations have resulted in many new economic considerations. These laws not only require pollution control during mining, but also hold the operator responsible after mining is completed.

The Mesabi Iron Range provides many examples of land use conflicts that should be avoided. Water supplies have been cut off from lakes leaving them to stagnate. Too often, stockpiles have been placed so close to mines that they later had to be removed in order that further mining could take place. Tailings basins have been sited adjacent to each other, when often one larger basin would have been adequate. As mining progressed, whole towns have been moved in a piecemeal fashion away from mine projects. However, their new locations may still conflict with future underground mining on the Range. These are a few examples of problems that have occurred in the past and should be avoided in the future. The "MINESITE" project is a regional plan that should provide a framework for preventing many of these recurrences.

A recent Environmental Protection Agency (EPA) publication[2] illustrates this point as it relates to water pollution problems.

> "The main planning element was always the economics of mineral recovery. Quite often the cheapest means of mineral recovery resulted in the largest water pollution problems.
>
> "Recent water pollution laws have introduced a new economic element-water pollution control costs--to be considered in mine planning. Water pollution control costs can be extremely high. Foresighted planning can minimize these costs and provide better water pollution control...
>
> "Proper planning of mining and pollution control techniques should follow the concept of a complete, comprehensive reclamation plan. This plan should have control measures designed for all phases of mining from initiation through

completion. Preplanning involves acquiring complete information concerning the future mine pits, defining the reasons why mining could cause pollution from the site, and determination of available techniques to prevent or minimize formation or transportation of pollutants...

"Mine site planning is the primary step in establishing any new mining area and is the key to a successful, non-polluting and economical mining operation."

Planning then, is a necessity and a pre-requisite to the resolution of potential conflicts between mining and environmental quality.

MINNESOTA'S UNIQUE PLANNING OPPORTUNITY

Minnesota has a truly unique opportunity for mine planning. The Duluth Gabbro Complex, as shown in Figure 1, is known to contain a major copper-nickel resource.[3,4] Although this is primarily a copper resource, it contains enough nickel to be considered one of the largest domestic sources of nickel. If the price of these metals continues to rise, and if we are to maintain domestic supplies, requests to develop these resources will undoubtedly be forthcoming. The area of primary interest at this time, as shown in Figure 2, is along the footwall of the Complex and runs from Hoyt Lakes to the Boundary Waters Canoe Area (BWCA) southeast of Ely. Other than one test shaft, no development has occurred to date.

Because there has never been a producing copper-nickel mine in this potentially large mining district, and because the location of mineral resources is fairly well known, the elements for a truly unique planning experience are present. Governmental agencies such as the Department of Natural Resources, are the only organizations that are in a position to acquire and compile the necessary data for a planning study of this magnitude. In the past, a

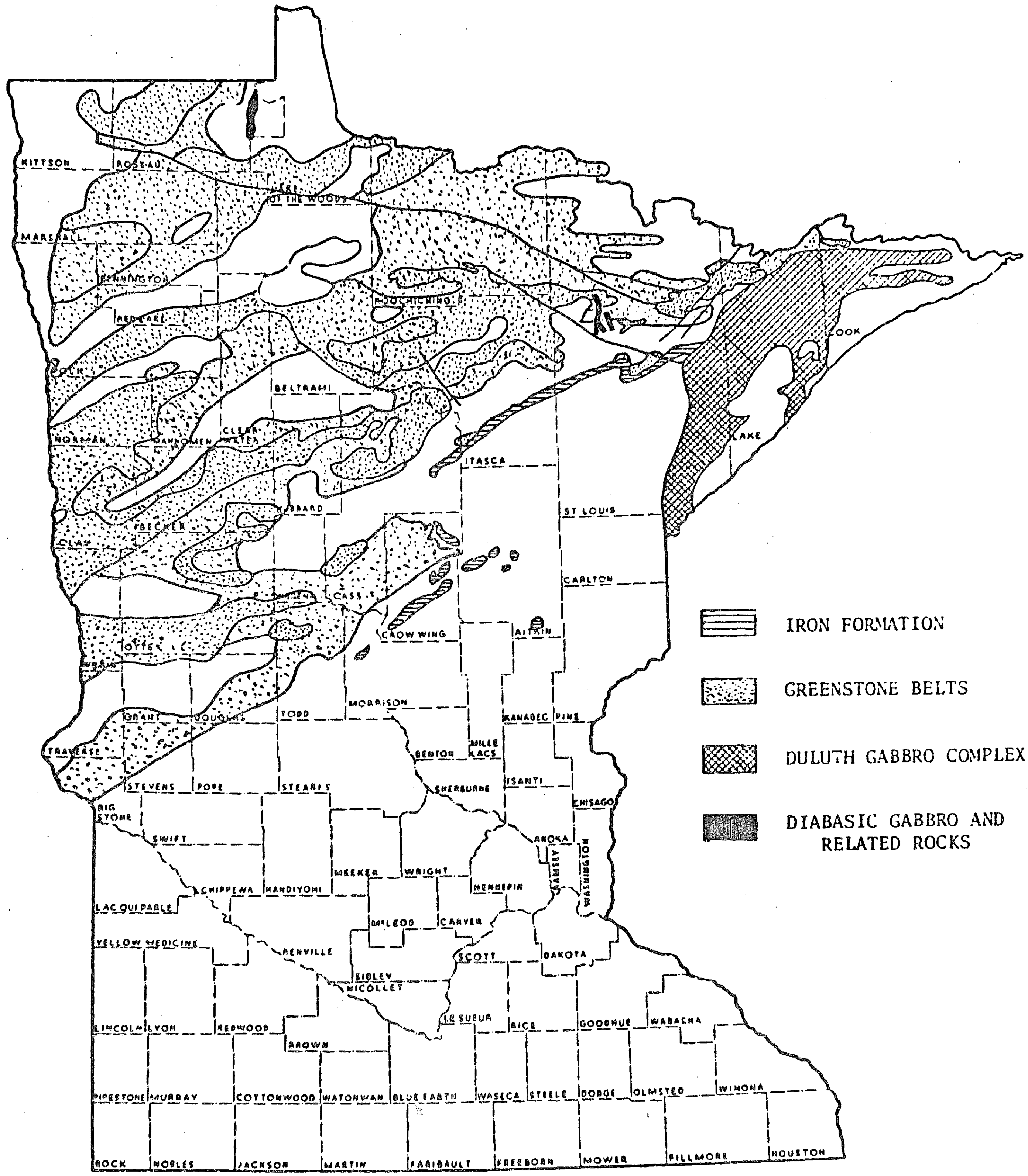


Figure 1 Minnesota Greenstone & Gabbo Formations

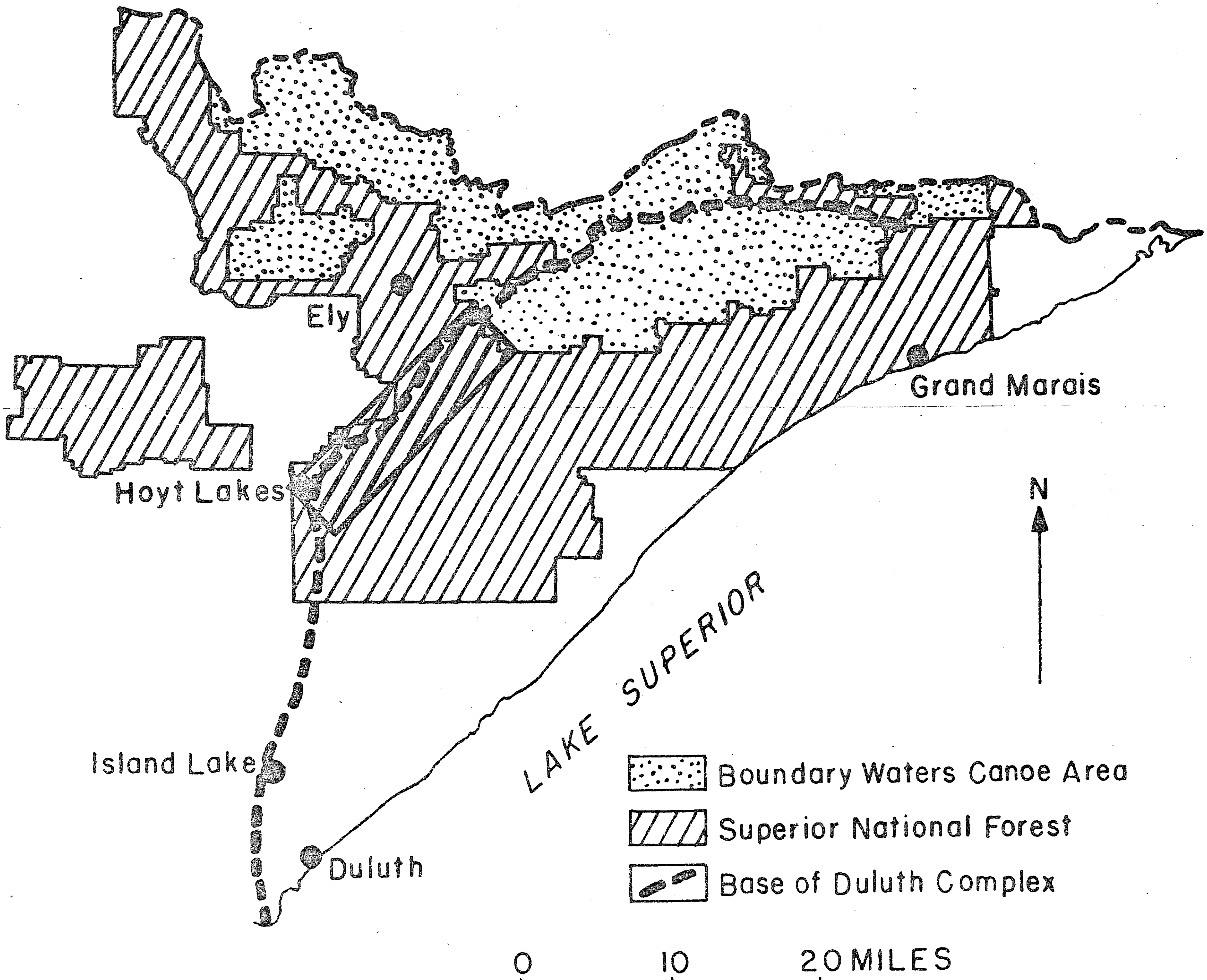


Figure 2 Prime Copper-Nickel Potential Shown in Rectangular Area

study of this sort might not have been necessary. However, the demand for land is growing rapidly and, as is true in this case, the land has already been designated for other uses. The competing uses are compatible or incompatible with mining to varying degrees. It would be highly desirable then, if a plan could be developed to evaluate and minimize a variety of potential conflicts. Some obvious potential conflicts which must be considered include:

1. The prime mineral potential area is located within the Superior National Forest, a part of the National Forest System.

2. It is adjacent to one of the most utilized wilderness areas in the United States, the BWCA.

3. The area is environmentally sensitive; streams in the northern portion of the area flow directly into the BWCA, the lakes are primarily filled rock basins, and the soils are generally shallow or non-existent.

4. Existing land uses are primarily recreation (including hunting, fishing, canoeing, hiking, camping, and scenic beauty), forest products (sawtimber,post and poles, and pulpwood), and iron mining in several portions of the Forest.

5. A number of competitive land uses already exist, including proposed land exchanges and future highway routing.

This, then, is the planning problem which confronts us. A technique must be developed which is capable of combining the existing land uses and environmental concerns into a framework that can then be used to evaluate the effects of introducing a new industry, that of copper-nickel mining, into this dynamic environment. Recognizing that any change results in some impact, the objective would be to minimize negative environmental effects and land use conflicts and develop a framework for evaluating individual project proposals.

In May of 1973, a pilot project was proposed and initiated. The purpose of the pilot project is fourfold.

1. Investigate the analysis tools and capabilities of a computer system that would be selected.

2. Develop an analysis procedure that would be applicable to the prime copper-nickel potential area, then test it by applying the procedure to the pilot study area.

3. Complete a detailed analysis of the pilot area.

4. Develop sufficient time and cost data so that reasonable estimates could be made for large study areas, specifically, the prime copper-nickel potential area.

Although the pilot study has not yet been finished, considerable work has been completed. All of the data has been collected and compiled, computer printouts are available for most of the variables, portions of the analysis have been completed, and the analysis models have been developed. The pilot study that is described in this report is organized into the following phases:

1. Computer Analysis.
2. Environmental Planning Program Language (EPPL).
3. "MINESITE" Study Area.
4. Data Collection and Inventories.
5. Data Plotting Transfer and Punching.
6. Inventory Printouts and Verification.
7. "MINESITE" Analysis Process.
8. "MINESITE" Analysis Examples.

COMPUTER ANALYSIS

At least two computer techniques have been used for environmental planning studies of this sort in the past; overlay systems and computer mapping analysis. Overlay systems have very limited analysis capabilities. Different types of environmental and socio-economic values are simply mapped by shading on transparent film and overlayed. Areas of darkest shading are considered having the highest value and to be avoided, whereas open or lightly shaded areas are of low value. Techniques of this type are useful, but have been largely superseded by computer mapping techniques.

Several computer programs were considered before selecting EPPL for the pilot study. Due to extremely limited funds, it was determined that for the pilot study, an existing program should be utilized. Four systems were evaluated:

1. GRID System - This program is an individual cell mapping system and has limited analysis capability. Analysis is done using a scoring function where high values are given to desirable characteristics and low values or negative values to undesirable characteristics. A program of this type has been used for at least three projects in Minnesota. The Minnesota Highway Department used this type of program for its "Corridor Resources Analysis-Chaska, Minnesota, TH 212" and also for an environmental impact statement on a section of road near Granite Falls, Minnesota. The Department of Natural Resources used the GRID System for its study "Upper St. Croix Resources Management Plan".

2. Polygon System[6] - With this program, irregular-shaped data can be input to the computer by defining the data boundaries as a series of straight lines. The end points of each line are defined by coordinates, and a characteristic is assigned to each polygon. This program has a definite advantage in that exact geographical locations can be plotted rather than having to generalize data into individual cells. Of course, as the individual cell size decreases, the polygon accuracy level is approached. Data input can be fairly streamlined; however, a digitizer and trained operator are required. Analysis is done basically with an overlay technique using either the original polygons or individual cells generalized from the polygons. The Center for Urban and Regional Affairs (CURA) is now doing research at the University of Minnesota with the digitizer. It was felt, however, that work was not far enough along to consider a method of this type for our study.

3. Land Use Classification System - This program is an inventory storage and data retrieval system which was developed by the Department of Natural Resources and is being utilized by the Department and participating counties on public lands. Data is input using forty acre cells and can be output in map form using a digitizer, or in list form. An update program is also available for correcting or updating inventory data. The program does not have analysis capabilities, and at present can only be used by forty acre tracts. A program is now being developed at the University of Minnesota that could transform data from one type of grid to another. When completed, this system could be a valuable source of data for studies such as the "MINESITE" study.

4. Environmental Planning Program Language (EPPL) - This program was developed by Alan Robinette and Paul Sand (University of Minnesota, CURA), for the Minnesota State Planning Agency. The program is an individual cell mapping system and has considerably more analysis packages available than with the GRID system. Several studies have been undertaken using the program, including three State Highway Department projects, (Norshor, Red Wing Bypass and Red Wing to Wabasha Corridor Study), the Lower St. Croix Scenic Corridor Study, one study for the U. S. Department of the Interior, Bureau of Sports Fisheries and Wildlife, and University of Minnesota pilot studies.

Primarily because of its superior analysis capabilities and its immediate availability, the EPPL computer program was selected for the "MINESITE" pilot study.

ENVIRONMENTAL PLANNING PROGRAM LANGUAGE

EPPL is a computer-aided technique for analyzing land and water areas to assist in determining their best use and wisest management.

The program was developed primarily as an efficient and economical aid in planning outdoor recreation facilities by a) determining the feasibility of developing an area for state park purposes, or b) analyzing the diverse natural resources of an existing state park to determine the most appropriate activities and development locations, minimize environmental impacts, and maximize the enjoyment of the visitor.[7]

Since then, the program has been used for a variety of other situations, including highway corridor studies, wildlife management areas, and now the "MINESITE" study. The "MINESITE" study is the first study that attempts to develop a regional land use plan for a large variety of uses.

EPPL was originally conceived as an extension of program GRID, to enable operations or analysis on several data maps, that could be output by program GRID. However, because of the limitations of GRID,(ten data levels), EPPL evolved its own mapping routine (37 data levels) as a module of the system. Each module is a miniprogram to perform a specific function, with one or more control cards that define the options and parameters of that function.

After using the original EPPL system for a year, it was decided that a second version, (EPPL 2), should be developed.[8] This second version is being used for the "MINESITE" pilot study. A third version, to be called Environmental Planning System (EPS) will be developed for use on the entire "MINESITE" study project. For EPPL 2, the INPUT and MAPPING routines were expanded to 64 data levels and many of the other functions are expanded, simplified,or modified. The program also contains built-in expansion modules for addition of new functions and a fairly accurate time estimating system. Future changes in EPS from the EPPL 2 version include expansion of input and output options, capability to analyze larger study areas, addition of a LIST function to the already existing MAP function for outputing data,and finally, linking the EPS program to the Minnesota Land Management Information System (MLMIS) storage and retrieval system. The input options will include: Card, tape, disc, digitizer, and cathode ray tube (CRT). The output options will include: high speed line printer, cal comp line plotter, dot matrix plotter, microfilm, and CRT.

In comparison to the other systems evaluated, EPPL has tremendously versatile analysis capabilities. There are four specialized analysis functions that can be utilized: SCORE, SEARCH, CLUSTER, and PROCESS. In addition, a specialized PROCESS function called Logic, or FLOW, has been incorporated. Another specialized technique, the VIEW Analysis Program, has now been incorporated as an additional function in EPPL. A Special Input Function is also available for data level conversion and grouping on input. Several of these analysis techniques will be considered in more detail later in the paper.

"MINESITE" STUDY AREA

About the same time that various computer programs were being considered, a study area was established. As shown in Figure 3, the study area is composed of portions of 25 townships in Northeastern Minnesota and

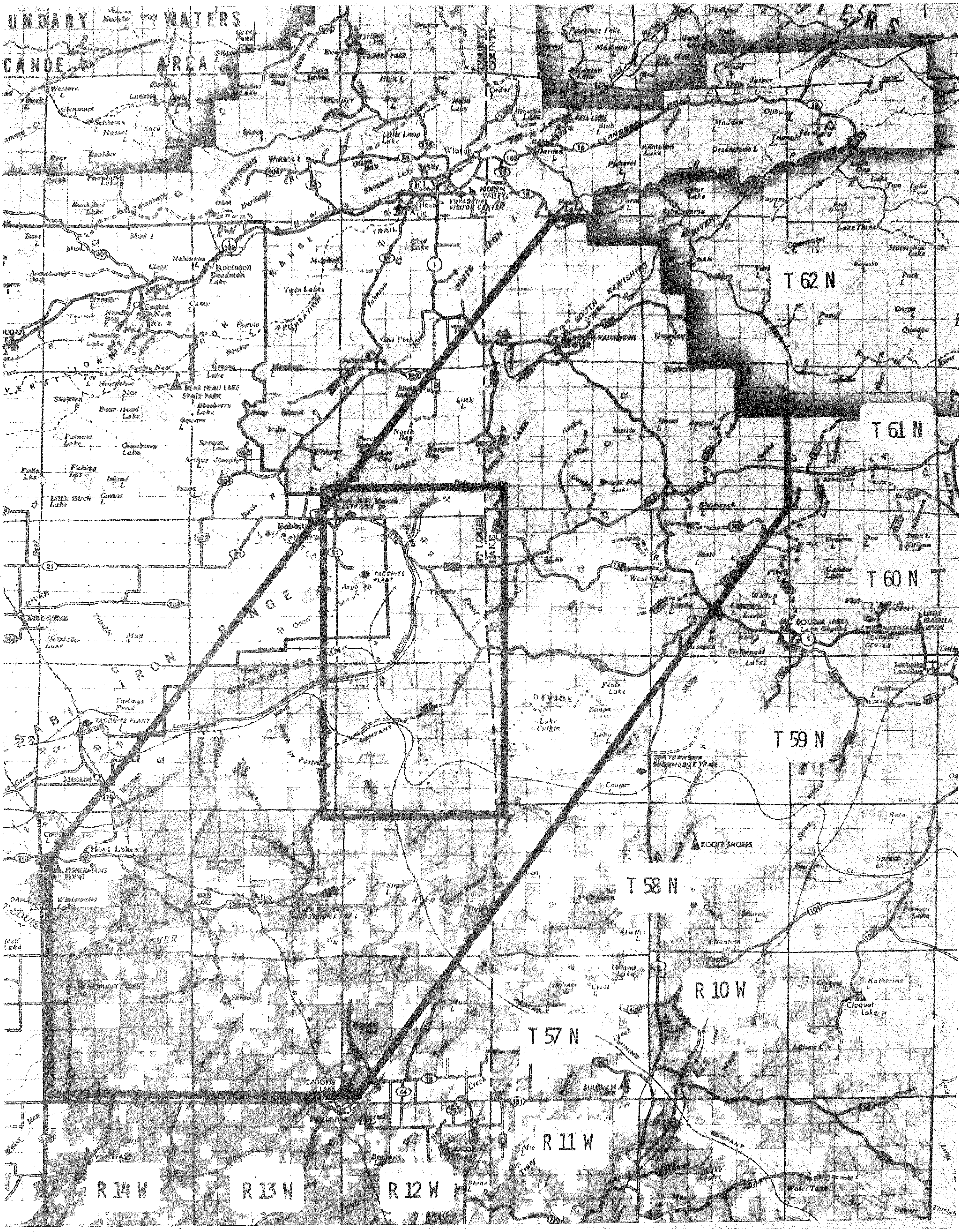


Figure 3 "MINESITE" Study Area Including Pilot Project (T59,60N-R12W) contains approximately 635 square miles. As shown in Figure 2, the prime copper-nickel potential area is contained within the study area. A pilot area was selected, consisting of approximately two townships within the study area. The pilot area was chosen primarily because of the existing land use conflicts and the abundance of detailed information available.

Due to the irregularities in the legal descriptions with the township-range system, a standard metric USGS grid was chosen called Universal Transverse Mercator (UTM). A standard GRID system was then established based on a square unit cell of approximately 2½ acres. When the line printer is used for output, this results in a vertical scale exaggeration. Each square then appears on the printout as a rectangle for the pilot study. This, however, will be corrected for the entire study when the dot matrix printer or micro-film will be used for output. The pilot area is composed of 26,400 cells, each containing approximately 2½ acres, for a total pilot area of about 100 square miles.

DATA COLLECTION AND INVENTORIES

The first step in developing a study of this type is to determine what data is necessary, and the availability and accuracy of such data. An amazing amount of data is available if it can be located. We originally began with a long list of desirable information. This was pared down to sixteen variables, including the site map, and then subsequently expanded to twenty-two variables as shown in Figure 4. Information was collected from a variety of sources. A tremendous amount of data was provided by the Superior National Forest, including soils data, surface and mineral ownership, land use and recreation plans, etc. Data from USGS Quads includes: elevation, slope orientation, percent slope, and surface hydrology. As is generally the case in a study of this type, a lot of data had to be either developed or compiled. Water availability data, (to be used by special input with the

V01 Site Map

V02 % Slope

V03 Slope Orientation

V04 Mineral Resources

V05 Surface Hydrology

V06 Watersheds

V07 Transportation & Utilities

V08 Surface Ownership

V09 Elevation

V10 Soils

V11 Mineral Ownership

V12 Land Use

V13 Shipstead Newton Nolan-Superior National Forest Boundary

V14 Recreation-Historical-Archeological Sites

V15 Potential Underground Taconite Mining

V16 Vegetation

V17 Timber Cutting History

V18 Crown Density

V19 Forest Size Classes

V20 Forest Height Classes

V21 Timber Site Conditions

V22 Lake and Stream Surveys (Fish Habitat)

Figure 4 "MINESITE" Inventories

surface hydrology and watershed variables), was developed by Dr. C. Edward Bowers, St. Anthony Falls Hydraulic Laboratory, (University of Minnesota). Vegetation data is being developed jointly by Dr. Herbert Wright, Limnological Research Center, (U of M) and Dr. Joseph Ulliman, Remote Sensing Laboratory, Agricultural Extension Division, (U of M), using aerial photos, field mapping, and Department of Natural Resources and Forest Service records. The remaining variables were developed and compiled by Department of Natural Resources personnel. However, many other groups and individuals have provided help in locating data and analysis input.

Figure 5 illustrates the data levels that were used in plotting two variables, surface hydrology and watersheds. Portions or all of the surface hydrology data will be used in the aesthetic displacement analysis, some of the copper-nickel mine facility exclusion maps, accessability, viewpoint maps, and others. Stream order data from watersheds will be used for tailings basin and stockpile alternatives, and watershed boundaries will be used in reservoir alternatives.

One of the most interesting groups of inventories is the vegetation variables. In developing the analysis for the pilot study,we found that wildlife specialists are mainly interested in ecosystems, whereas forestry specialists are more interested in timber species. To solve this problem, an inventory had to be developed that would be suitable for both types of analysis. Figure 6 illustrates the data levels as they were finally developed. Using special input, the species levels can be combined into the ecosystems as shown at the right of the Figure.

DATA PLOTTING, TRANSFER AND PUNCHING

Probably the most time-consuming and tedious task is the plotting, transfer, and keypunching phase of the study. It is also one of the most important steps because of the accuracy required. Good data is completely useless if it is plotted or transferred wrong. Its value for analysis can

V05. SURFACE HYDROLOGY

Level	Symbol	
(1)	A.	River
(2)	B.	Permanent Stream
(3)	C.	Intermittant Stream
(4)	D.	Lake (Part of a river chain with inlet and outlet)
(5)	E.	Lake (Inlet and Outlet)
(6)	F.	Lake (Outlet only)
(7)	G.	Lake (Inlet only)
(8)	H.	Lake (No inlet or outlet)
(9)	I.	Pond (5 acres=2 cells)
(10)	J.	Marsh (Wooded or grass)
(12)	L.	Mine Tailings Basins
(38)	-	No data

V06. WATERSHEDS

Level	Symbol	
(1)	A.	1st Order (South Kawishiwi and St. Louis)
(2)	B.	Drainage Directly into South Kawishiwi River
(3)	C.	Drainage Directly into St. Louis River
(4)	D.	2nd Order (Isabella, Dunka, Stony River, Partridge, Whiteface and Cloquet)
(5)	E.	3rd Order
(6)	F.	4th Order
(7)	G.	5th Order
(8)	H.	6th Order
(9)	I.	Boundary of the South Kawishiwi
(10)	J.	Boundary of the St. Louis Watershed
(11)	K.	Boundary of the Isabella Watershed
(12)	L.	Boundary of the Stony River Watershed
(13)	M.	Boundary of the Partridge Watershed
(14)	N.	Boundary of the Whiteface Watershed
(15)	O.	Boundary of the Cloquet Watershed
(16)	P.	Boundary of the Embarrass Watershed
(17)	Q.	Boundary of the Dunka River
(18)	R.	Boundary of the North River
(19)	S.	Boundary of the Colvin Creek
(20)	T.	Boundary of the Argo Creek
(21)	U.	Boundary of the Sand River
(22)	V.	Boundary of the Nip Creek
(23)	W.	Boundary of the Denley Creek
(24)	X.	Boundary of the Little Isabella River
(25)	Y.	Boundary of the Kawishiwi River
(26)	Z.	Boundary of the Bear Island River
(38)	-	No Data

Figure 5 Data Levels for the Surface Hydrology and Watershed Inventories

V16 VEGETATION

Level	Symbol	Vegetation	Ecosystem
(1)	A.	Aspen and paper birch	U1-Aspen and birch comprising about 90% of cover
(10) (18) (23)	J. R. W.	Jack pine Red pine White pine	U2-Natural pine stands. Pure or mixed white, red and/or jack pine
(13) (14)	M. N.	Northern hardwoods Mixed aspen, birch, fir pine, etc.	U3-Mixed conifer and deciduous
(8) (7)	H. G.	Hazel, pin cherry, etc. Open areas of grass	U4-Upland shrubs and grasslands $<$ 10% stocked commercial trees
(16)	P.	Planted species-species cannot be identified on aerial photos	U6-Plantation. Field checks show mostly red pine and some jack pine
(2)	B.	Spruce-fir	T1-Mixed spruce, pine and fir comprising $>$ 50%
(4) (15) (12) (11)	D. O. L. K.	Lowland shrubs Marsh Open water (lakes, ponds, etc. Non-productive swamp	B1-Wetlands generally non-forested
(3) (19) (17) (20)	C. S. Q. T.	White cedar Black spruce Mixed spruce, balsam, cedar, etc. Tamarack	B2-Conifer wetlands with $>$ 40% cover
(5)	E.	Ash, elm, soft maple, etc.	B3-Lowland hardwoods with $>$ 50% of species present being hardwoods
(24)	X.	Harvested	D1-Cutover with only one growing season elapsed
(6) (9) (26)	F. I. Z.	Farm Industrial and residental Quarry or gravel pit	D2-Under permanent unnatural use

Figure 6 Data Levels for the Vegetation Inventory

be seriously diminished if it is not accurately recorded.

The pilot area is broken down into eleven strips of six 2-kilometer squares called shorthand coding areas. Figure 7 illustrates how the pilot area was divided into individual cells. Data was plotted using transparent overlay grids at the appropriate scale, and plotted on a 2-kilometer square grid. An example of a data sheet for mineral ownership is shown in Figure 8. Information must be generalized to an individual cell, as each cell must be assigned a specific data level. This results in accuracy to at least an acre and a quarter, which is sufficient for a regional study of this type.

After the data is plotted, it is transferred to a shorthand transfer form. Data can be transferred either as individual cells or, where the data is uniform, groups of cells. The shorthand transfer form, although somewhat confusing, was developed to cut down on punching costs and computer time for inputting data maps. Where there is scattered data, such as surface hydrology, or fairly uniform blocks of data, such as surface ownership, this shorthand coding form is very useful and beneficial. However, when there is data in every cell, and the data is highly variable, such as with the percent slope or slope orientation inventories, this shorthand form is actually more costly, and individual cells are keypunched.

INVENTORY PRINTOUTS AND VERIFICATION

After keypunching is completed, the next step is to compare print-outs to original data maps and check for errors. In most cases, field checking of the original data has already been completed, although some spot checking of field data was done using these printouts. Sources of error at this stage include plotting, transfer, and keypunching.

Depending on the detail and uniformity of the data, verification was done either by spot checking specific blocks, as was done for elevation, or by detailed checking of the entire map as was done for surface hydrology. Some special precautions were also taken to attempt to insure that data was

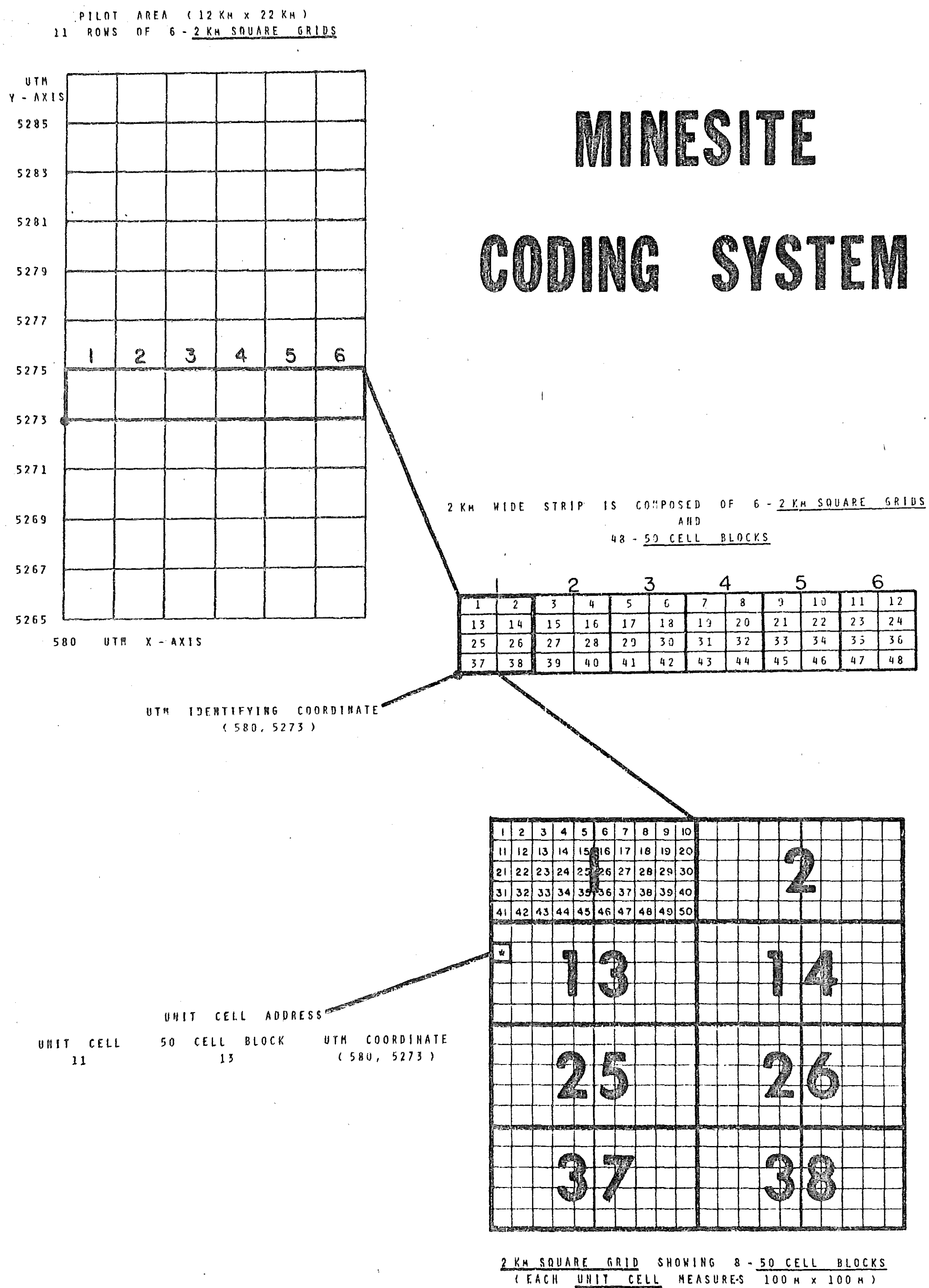


Figure 7 Pilot Area Coordinate System

1 1	5 8 0	5 2 7 3	0 1
Variable Number	UTM (X) Coord.	UTM (Y) Coord.	2 Km Square

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50

Example of Unit Cell Identification Numbers for a 50 Cell Block

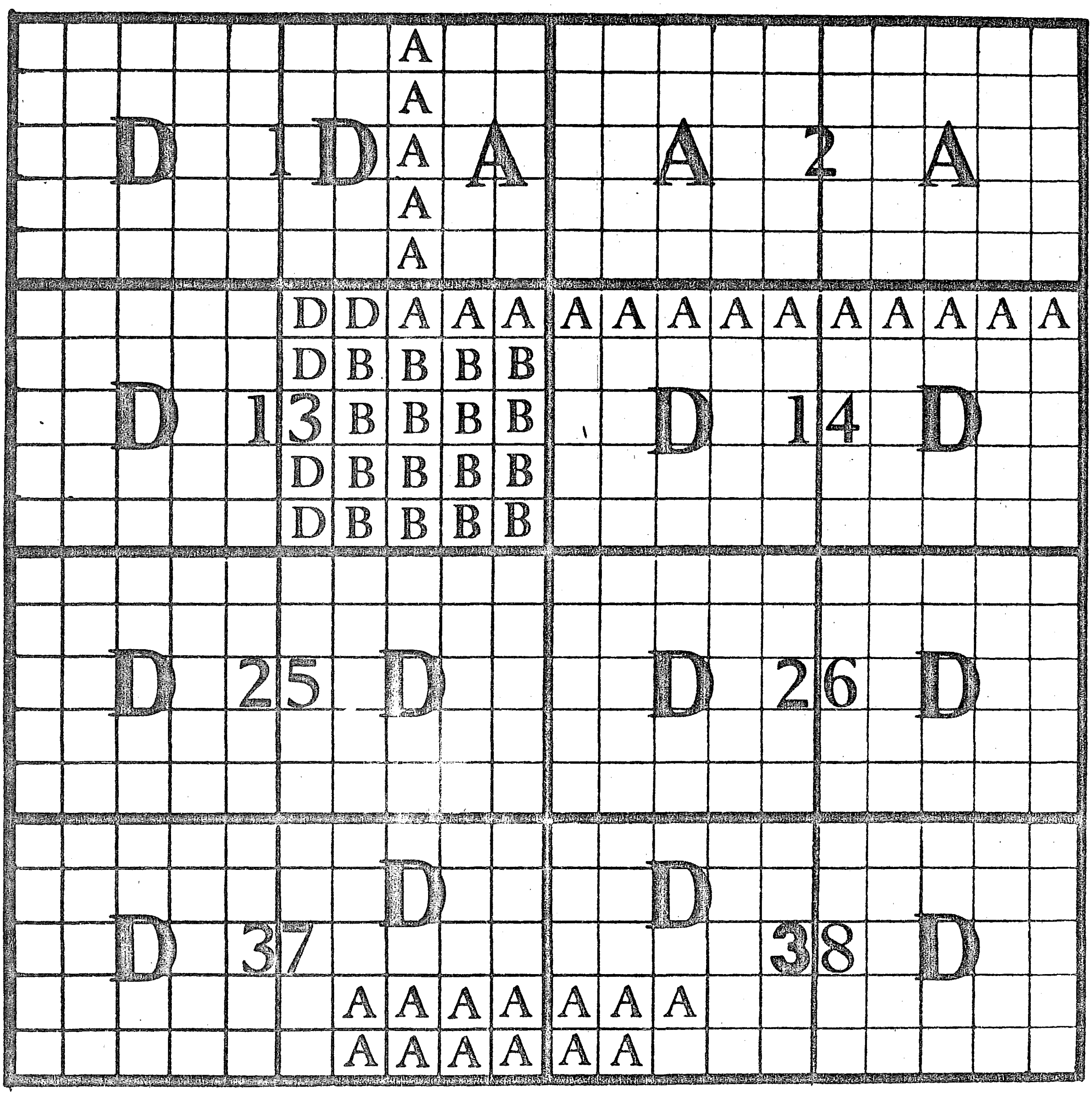


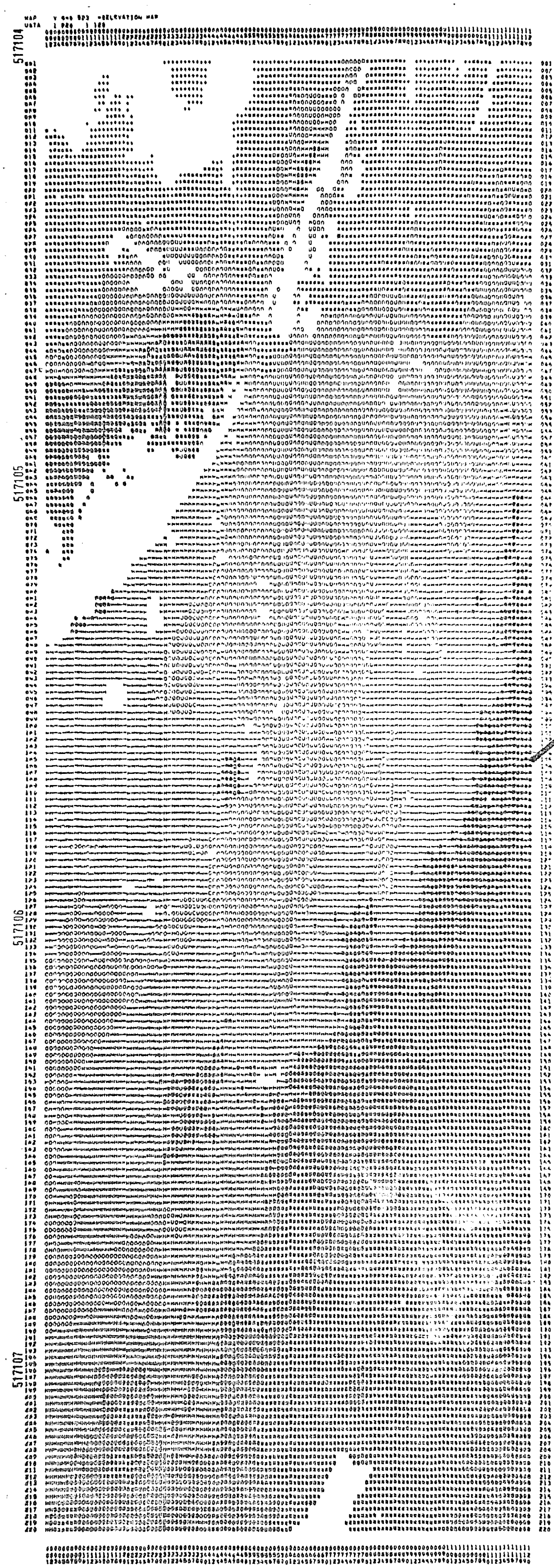
FIGURE 8. 2 KILOMETER SQUARE GRID

interpreted the same way each time. Each plotter took care of certain specific variables, and in most cases was responsible for entire maps. Where additional plotters were required on certain variables, the original plotter instructed the new people as to how the data was to be interpreted.

With the exception of the expanded vegetation variables, most of the data inventories have now been completed. Figures 9 through 13 are examples of completed inventories. Figure 14 is a combination of portions of three original inventories; land use, transportation and utilities, and surface hydrology. It should be remembered that these printouts represent a square cell as a rectangle. This results in a vertical distortion that will be corrected when the dot matrix plotter is used for the entire study area.

Figure 9 is an elevation map. Topographic data was originally plotted at twenty foot intervals, and then was compiled using overprints at sixty foot intervals. White regions on the map are lakes and mining areas. The elevation of the mining areas is unknown because of the mining disturbance. These mining areas include open pit iron mines, gravel pits, stockpiles, and one tailings basin. The map gives a good indication of the regional topographic changes and shows the continental divide between the St. Louis and Kawishiwi Watersheds in the left central portion of the map.

Figure 10 is the inventory of percent slope with the black shading indicating slopes greater than or equal to 9 percent. The lighter overprint is for 4 to 9 percent slopes. Those slopes with less than 4 percent gradient are shown as a dot. The next illustration, Figure 11, is very similar to Figure 10, only in this case, the slopes are plotted according to orientation. In general, steep sunny slopes are more difficult to revegetate once they have been disturbed than are shady slopes. As much as possible, disturbance of these slopes should be avoided. Slope orientation was plotted perpendicular to the strike and down dip. This map will primarily be used in the



Elevation shaded at 60 foot intervals (1640-1699)

Figure 9 Elevation Map - Inventory Number 9

Areas marked indicate elevation above mean sea level.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale	1 inch ≃	1.6 miles
Horizontal scale	1 inch ≃	2.6 miles

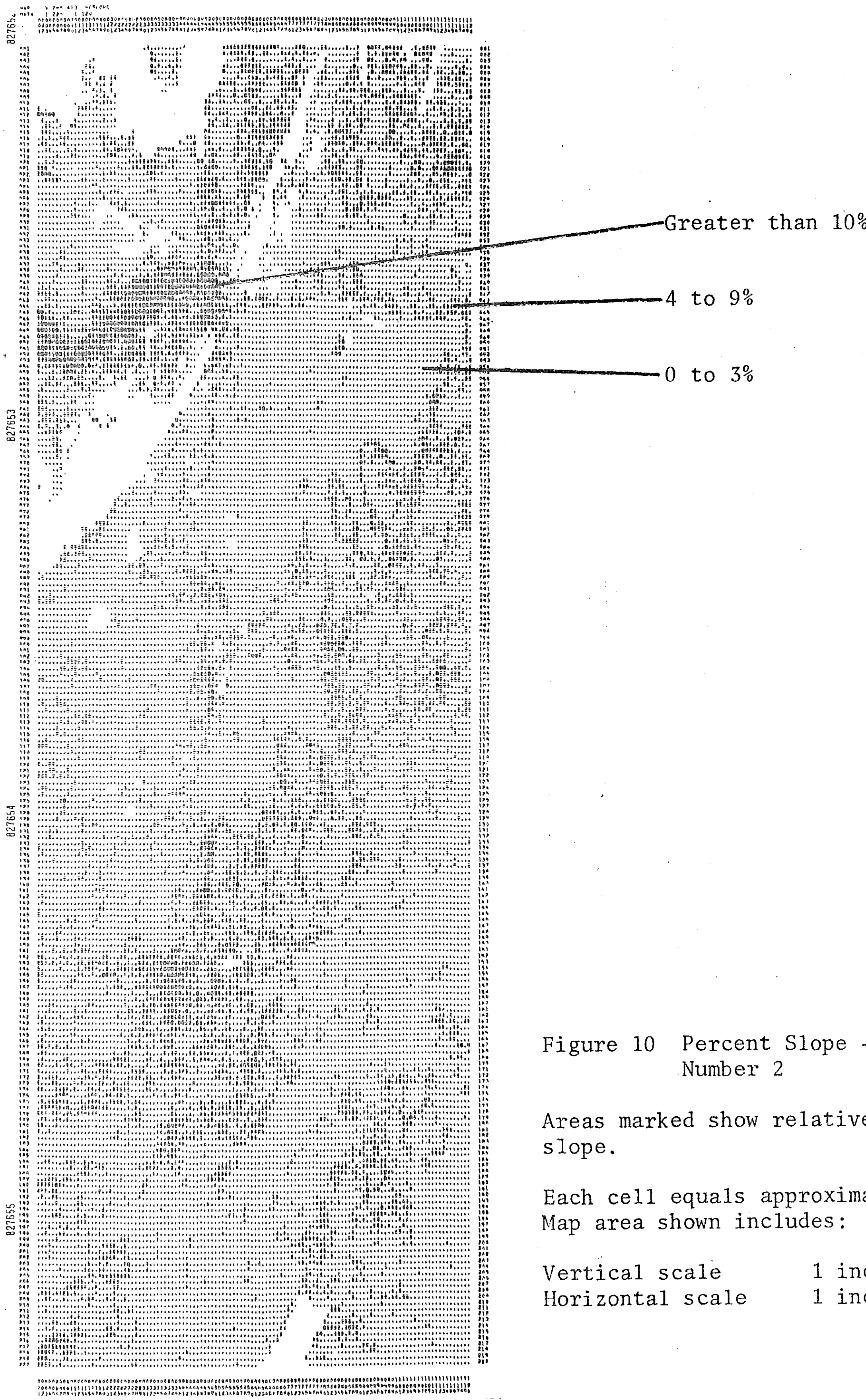


Figure 10 Percent Slope - Inventory Number 2

Areas marked show relative severity of slope.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale 1 inch ≃ 1.6 miles
Horizontal scale 1 inch ≃ 2.6 miles

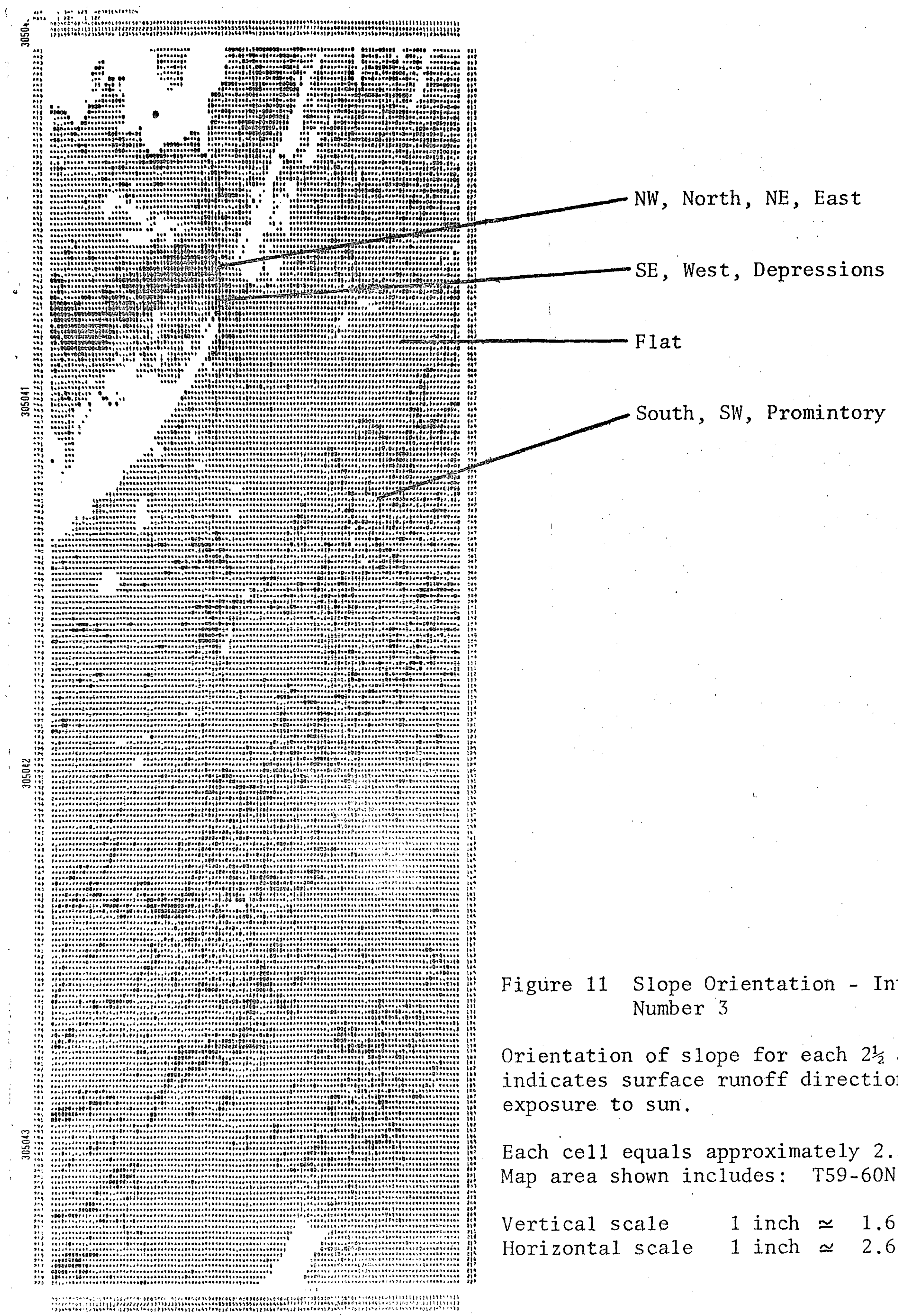


Figure 11 Slope Orientation - Inventory Number 3

Orientation of slope for each 2½ acre cell indicates surface runoff direction and exposure to sun.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale 1 inch ≃ 1.6 miles
Horizontal scale 1 inch ≃ 2.6 miles

environmental assessment and mine facility siting portion of the study.

The next two figures relate to surface waters; Figure 12, Surface Hydrology and Figure 13, Watersheds. The data is generally self-explanatory and was derived both from USGS quad data and DNR watershed data. These variables will be used extensively for recreation and aesthetic considerations, some of the wildlife analysis, mine facility siting, and environmental considerations.

The last inventory map, Figure 14, is a composite map of surface hydrology and manmade features. The manmade features were primarily derived from the land use and transportation and utilities inventories. This map is useful in providing a visual representation of the starting point for developing a land use plan.

"MINESITE" ANALYSIS PROCESS

Once all the data is compiled and verified, the most difficult technical and coordinating effort is yet to come. The analysis that must be developed is an interdisciplinary model, which uses the computer as a mechanical tool to apply professional judgments through prescribed routines. The real advantage of the computer is that the analysis routines can be complex, they can be completed rapidly, and they can be adjusted quickly to fit actual field conditions. The accuracy of this approach is dependent upon the reliability of data and the correctness of judgments and assumptions. It should always be kept in mind that the environment is a dynamic and ever-changing system. The analysis is being developed by many resource specialists, including DNR employees, other state and federal agencies, several special consultants and environmental and mining people.

The analysis is made up of three sequential steps, (Figure 15): regional assessment, land use plan, and project evaluation. The regional assessment phase is designed to evaluate "the state of the land" in the study area, and its capabilities. The assessment (Figure 16) involves taking the

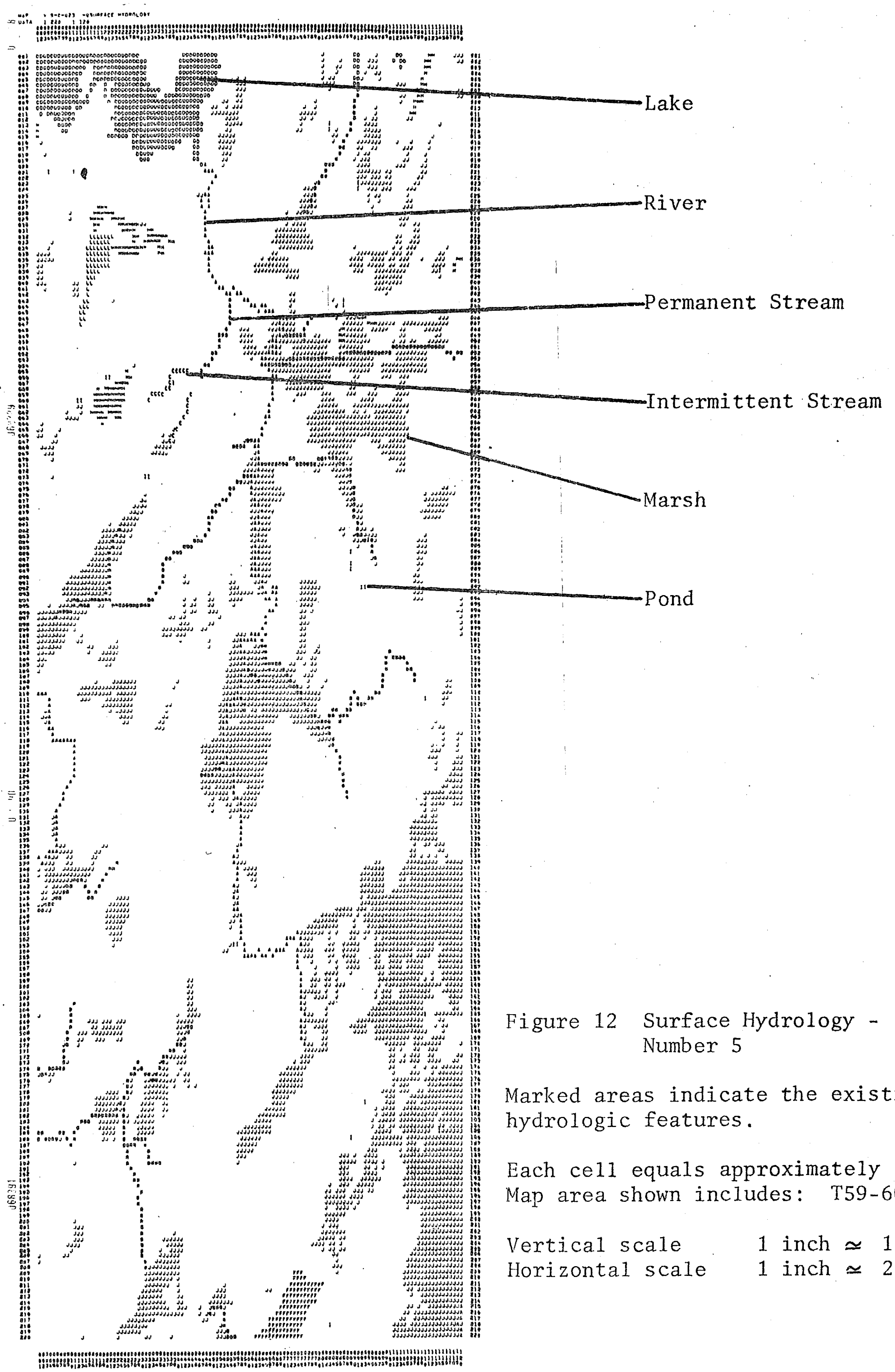


Figure 12 Surface Hydrology - Inventory Number 5

Marked areas indicate the existing surface hydrologic features.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale 1 inch ≃ 1.6 miles
Horizontal scale 1 inch ≃ 2.6 miles

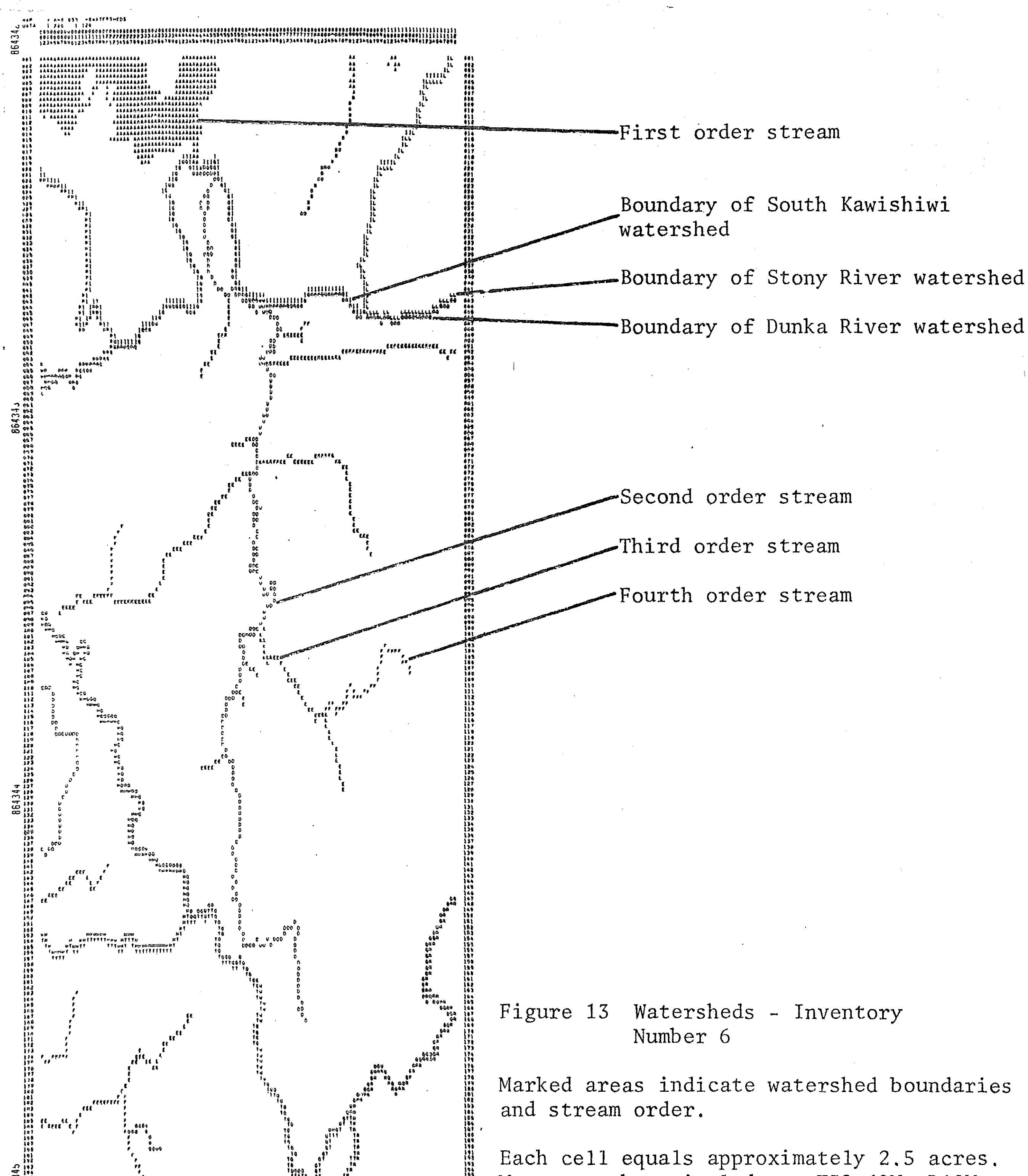


Figure 13 Watersheds - Inventory Number 6

Marked areas indicate watershed boundaries and stream order.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale 1 inch ≃ 1.6 miles
Horizontal scale 1 inch ≃ 2.6 miles

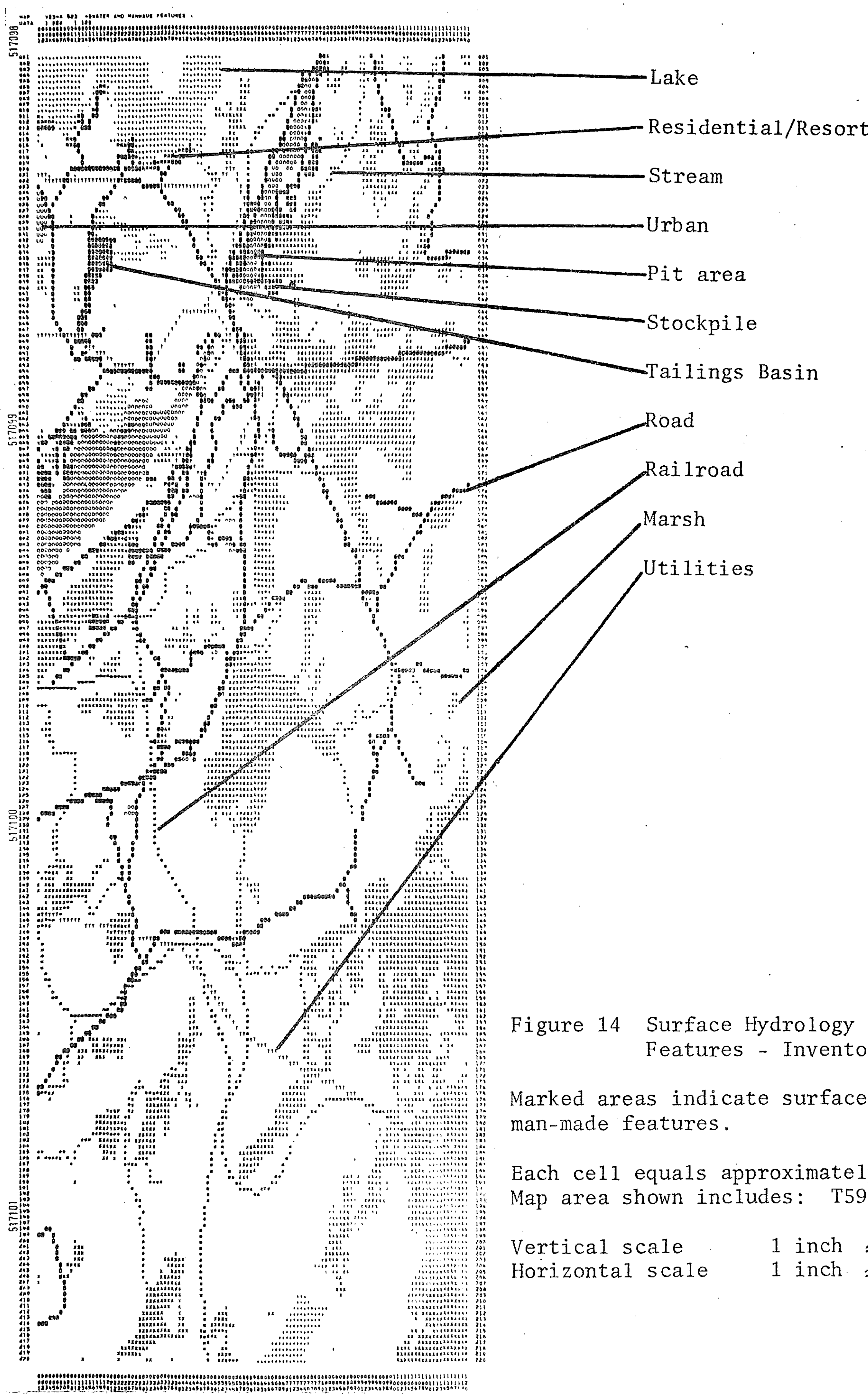


Figure 14 Surface Hydrology and Manmade Features - Inventory Number 27

Marked areas indicate surface water and man-made features.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale	1 inch ≃	1.6 miles
Horizontal scale	1 inch ≃	2.6 miles

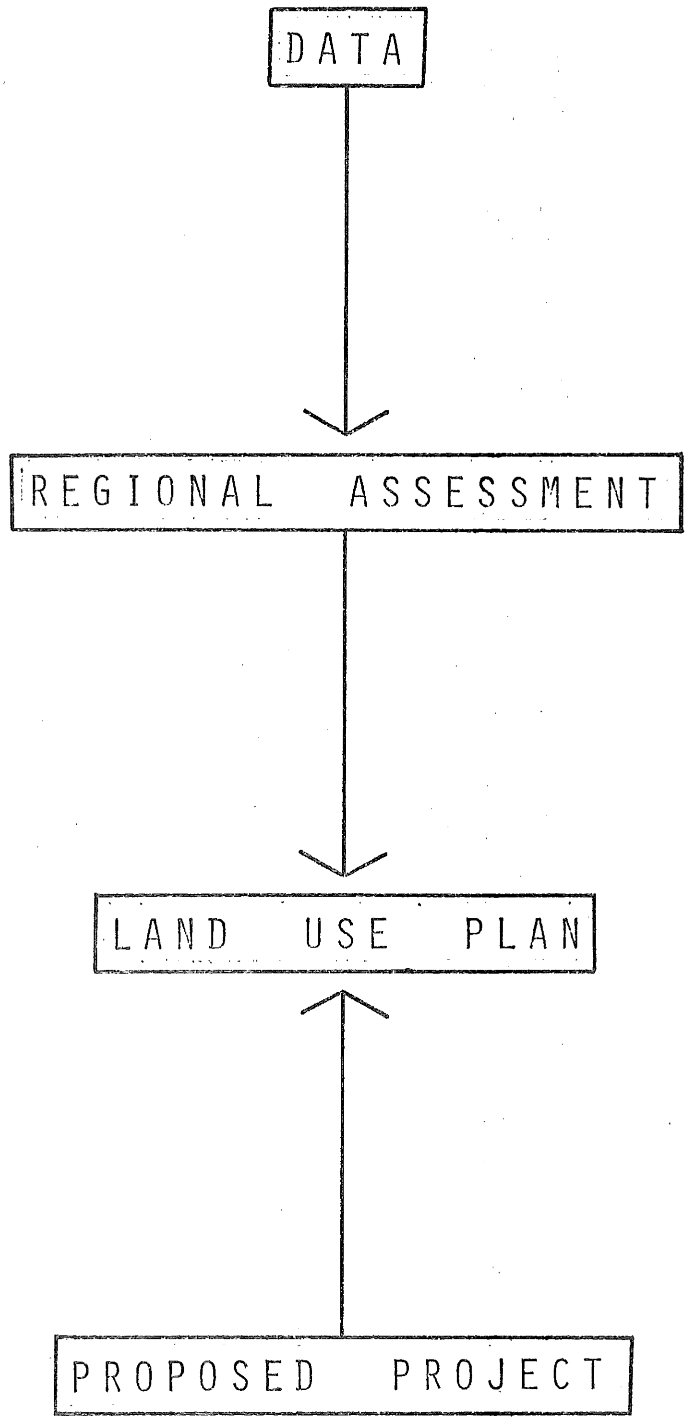


FIGURE 15. MINESITE ANALYSIS SEQUENCE

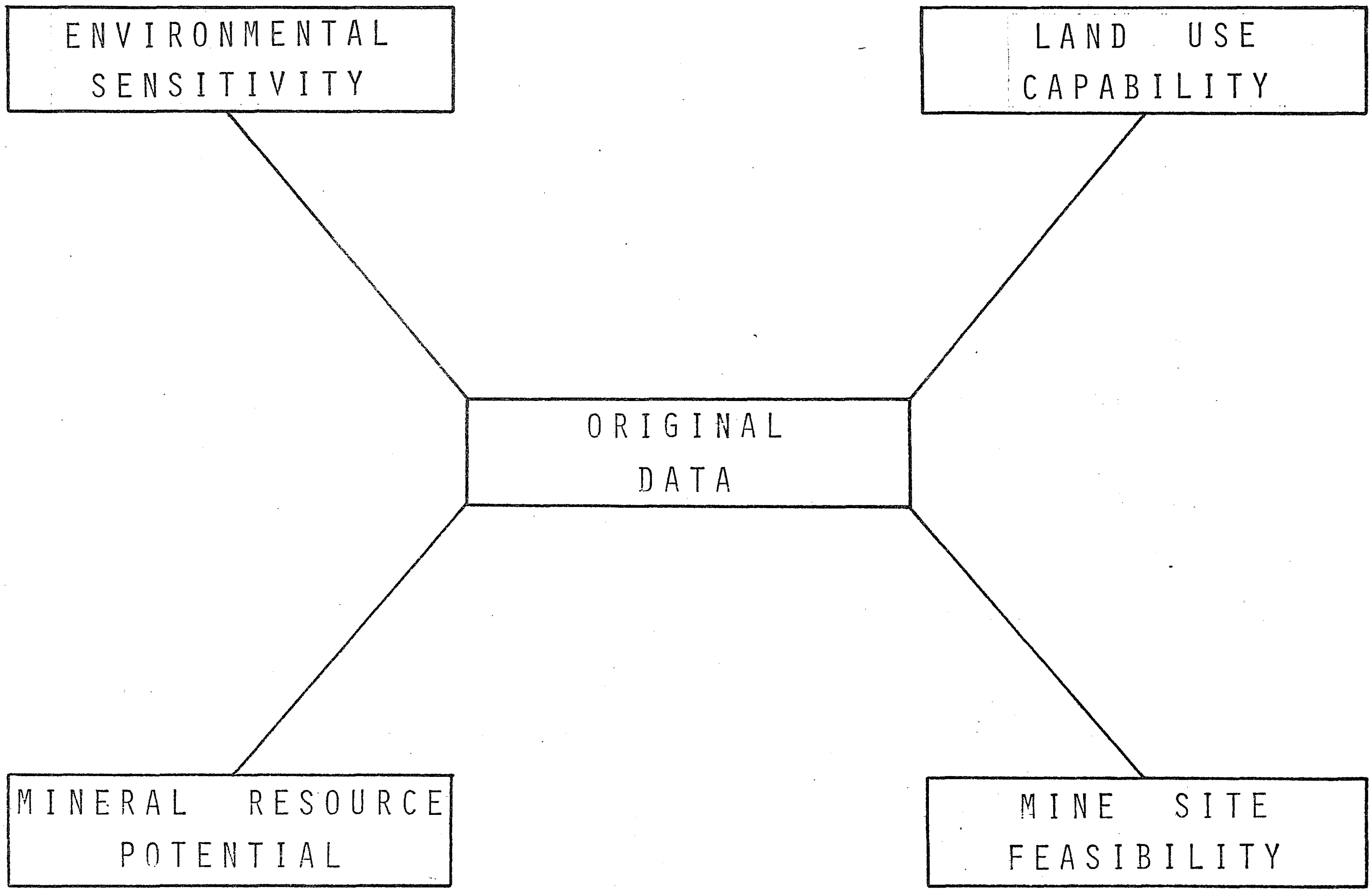


FIGURE 16. REGIONAL ASSESSMENT

original data and developing a series of environmental sensitivities, land use capabilities, feasible mine facility sites, and the mineral resource potential. Figures 17, 18, and 19 provide more detailed information on the regional assessment.

After completion of the assessment phase, the next step is to develop a land use plan (Figure 20). The plan attempts to minimize environmental effects, land use conflicts, and ownership conflicts, while at the same time maximizing compatible land uses and providing for mine site alternatives. Compatible land use is simply a table that compares existing or potential land uses in the study area. Land uses are rated as completely compatible, (they can occur simultaneously in the same unit of land), somewhat compatible, (they can occur together, however, conflicts do occasionally arise), or incompatible. The environmental factors and land use factors will be grouped using degrees of shading. The darkest areas would result in the most environmental or land use damage, and the light areas the least damage.

Those areas that will result in the least environmental and land use damage, and at the same time be feasible for mine facility sites, would then become mineral use alternatives in a land use plan. Additionally, the land use plan will contain the existing and best recreation areas, wildlife habitat, timber growth capability, and areas of high scenic and natural beauty.

The last phase in the analysis is to evaluate proposed projects as shown schematically in Figure 21. The project evaluation looks back at the land use plan and the resource assessment, along with the ownership patterns, compatible land uses, and the mineral resources. Data will be developed in this phase relating to the specific costs (environmental, land use, etc.), and benefits (compatible land uses and mineral resources), of a proposed project. This data will than be very useful when developing environmental

Air

1. Air pollutant sensitivity
2. Noise and vibrations

Water

1. Water availability
2. Discharges - surface and ground water impacts
3. Impact of level fluctuations
4. Sedimentation and critical slopes
5. Off-stream storage capabilities

Land

1. Slope stability
2. Erosion potential
3. Revegetation potential
4. Runoff sensitivity
5. Subsidence
6. Accessibility

Figure 17 Regional Assessment - Environmental Sensitivities

Aesthetics

1. View analysis from major roads and navigable waterways, etc.
2. Recreational, historical and archeological sites
3. Aesthetic displacement including: land forms, virgin areas, etc.

Recreation

1. Tent/trailer camping and picnicking
2. Spring trail system
3. Winter trail system
4. Canoeing recreation
5. Hunting and fishing
6. Existing recreation areas and recreation management plans

Wildlife Habitat

1. Grouse habitat
2. Deer habitat (wildlife openings, conifer cover and deciduous feeding)
3. Wetland furbearer habitat
4. Warm and cold water fish and spawning areas

Timber Production

1. Existing timber values
2. Timber site capability

Figure 18 Regional Assessment - Land Use Capability

Mine Facility Site Feasibility

1. Surface stockpile areas
2. Lean ore stockpile areas
3. Waste rock stockpile areas
4. Tailings basins
5. Water reservoirs
6. Beneficiation plants and auxiliary facilities
7. Mine and facility access

Mineral Resource Potential

1. Highest open pit copper-nickel potential
2. Highest underground copper-nickel potential
3. Open pit taconite potential
4. Underground taconite potential

Figure 19 Regional Assessment - Mine Site Feasibility and Mineral Resource Potential

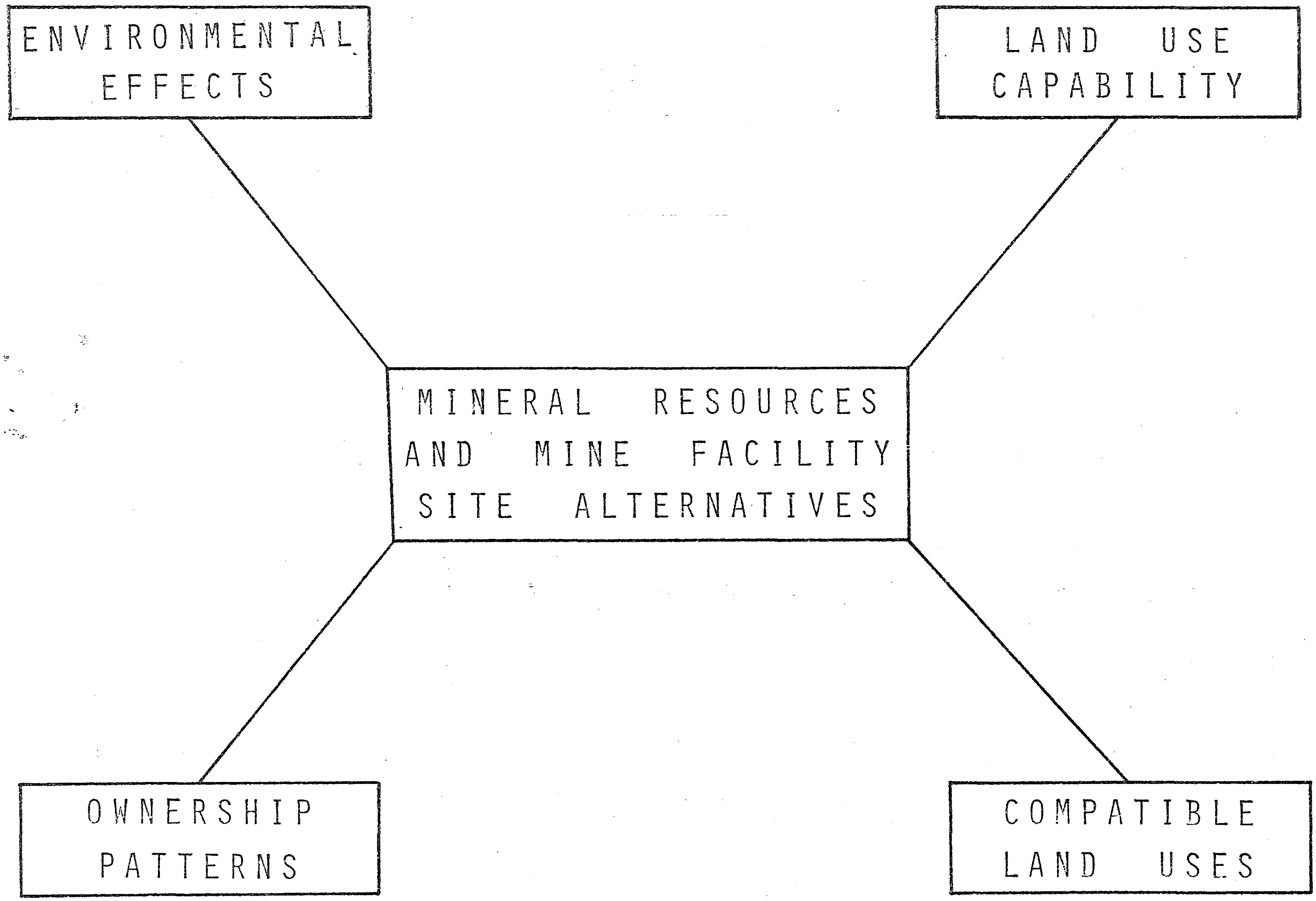


FIGURE 20. LAND USE PLAN

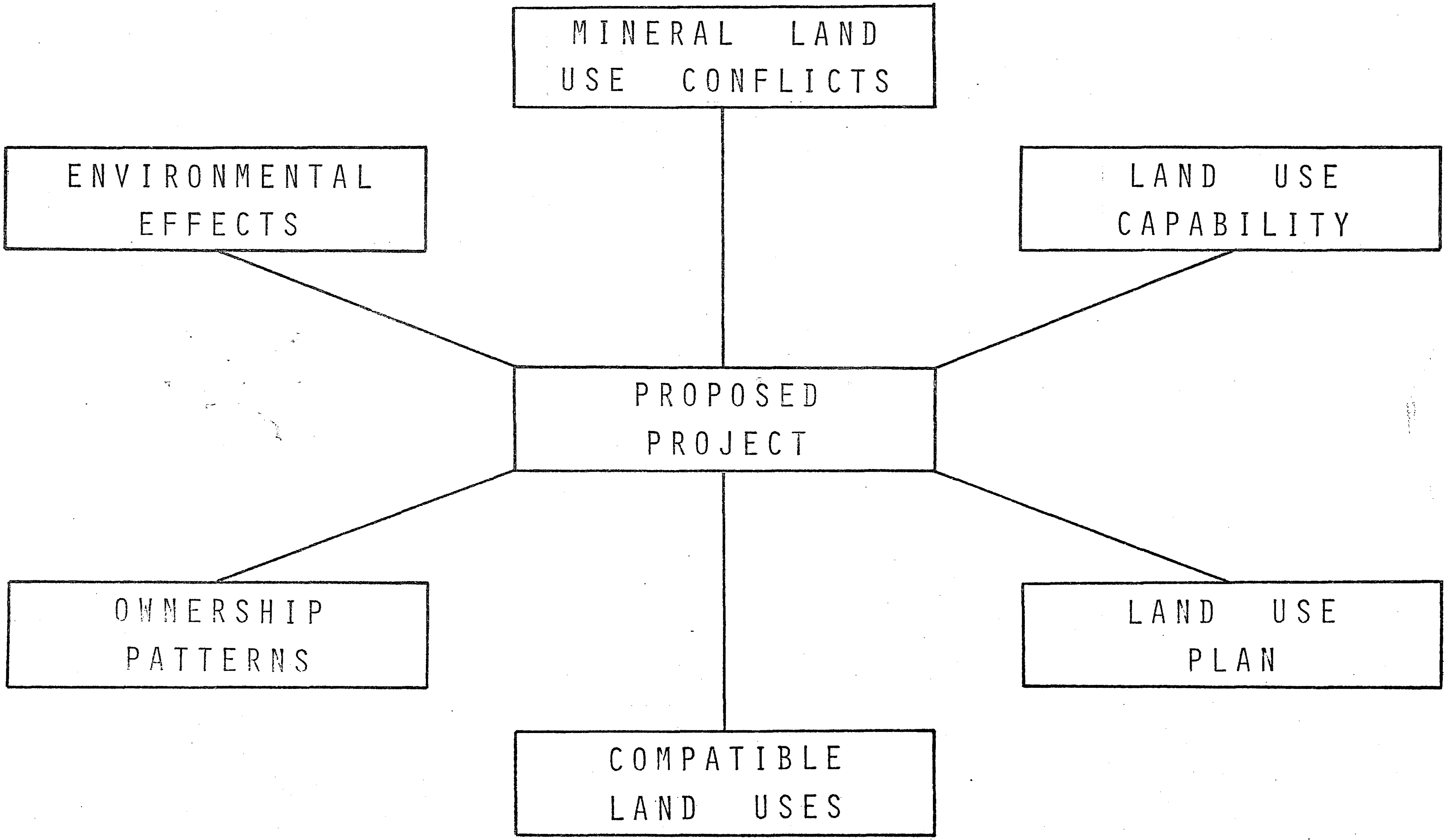


FIGURE 21. EVALUATION OF PROPOSED PROJECTS

impact statements and of particular aid in evaluating permit applications.

"MINESITE" ANALYSIS EXAMPLES

Although the analysis is not yet finalized, several examples can be used to illustrate some of the analysis techniques and how they are being used in the "MINESITE" project. The first example is one developed for the land use composite, and in particular, recreation. The computer technique is called "SCORE",which overlays data variables using relative importance weights, and is illustrated in Figure 22. In this case, we located areas most suitable for family camping and picnicking. The recreation specialists felt the most important amenity was good access from nearby roads and closeness to surface waters for recreation purposes. Therefore, a road and stream proximity map was developed, using the surface hydrology and transportation and utilities inventories. Road and stream proximity was given the highest value, x3. The next two most important factors considered were soils, from an engineering standpoint, and vegetation as an amenity. Data levels were assigned a rating and the variables were weighted x2. The remaining inventories were all assigned rates and weighted the lowest value, x1. The relative scores are then compiled, and each cell is assigned a potential value for family camping and picnicking. This map will then be used later as part of the recreation composite that was outlined in Figure 18.

The next illustration, Figure 23, is an environmental consideration, erosion potential, which uses a "FLOW" or Logic computer technique. This technique has an advantage over the previous SCORE technique because each path can be followed through the analysis precisely, and it is known exactly which combinations make up a final grouping. The example is designed to show which areas are highly erodable if the vegetation is removed or is non-existent. By following the extreme situations through the analysis chart, a steep slope, covered by a highly erodable soil on a southern exposure results in a severe

SCORE= $\sum$ Weight (Rate)

EXAMPLE: FAMILY CAMPING AND PICNICING (V.45)

FORMULA: SCORE (V.45) = $\sum$ 3 (Road/Stream Proximity) + 2 (Soils) + 2 (Vegetation) + (Slope) + (Crown Density) + (Forest Size Classes) + (Forest Height Classes) + (Slope Orientation)

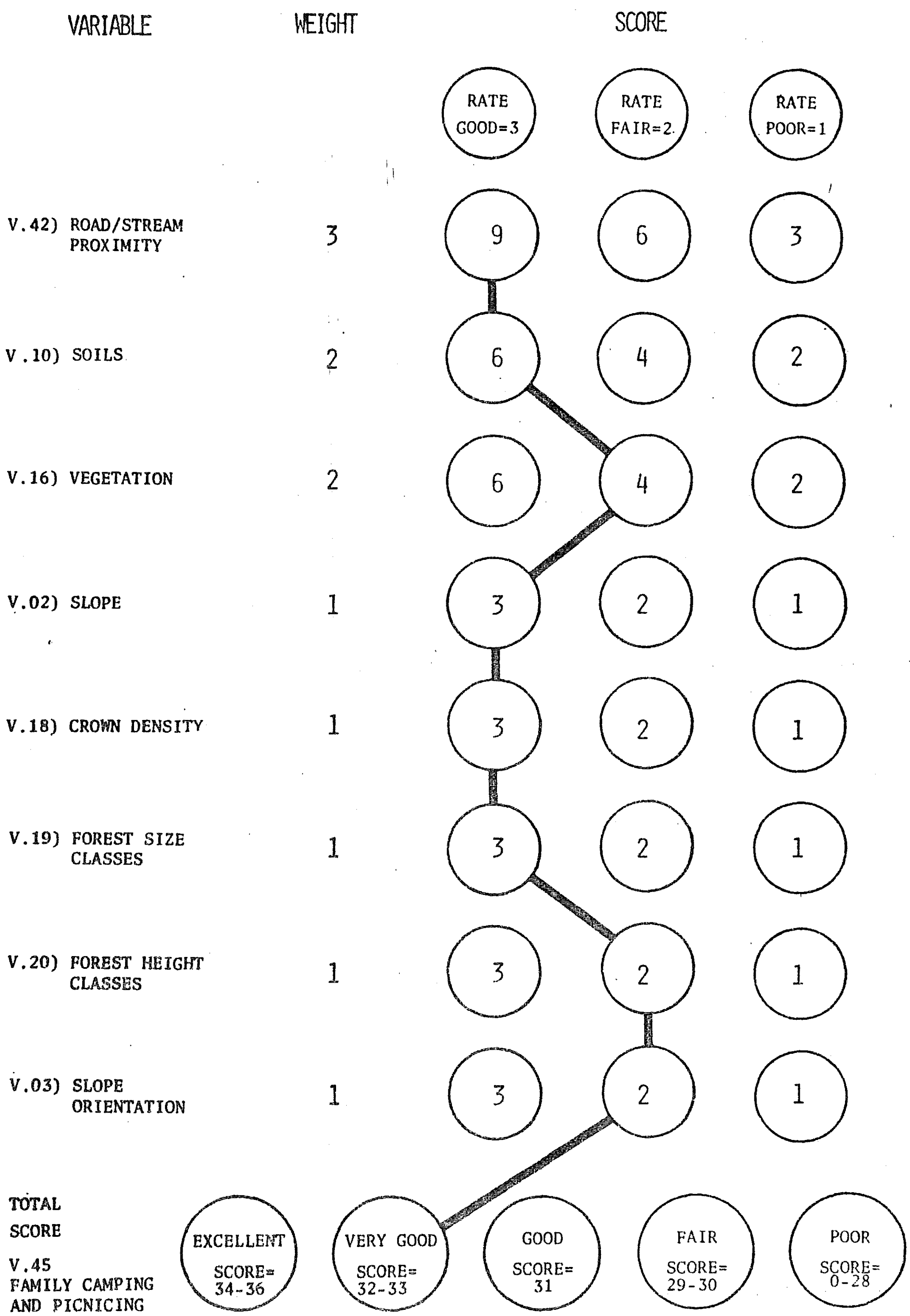


Figure 22. Family Camping and Picnicking - Score Technique

EXAMPLE: EROSION POTENTIAL (V. 25)

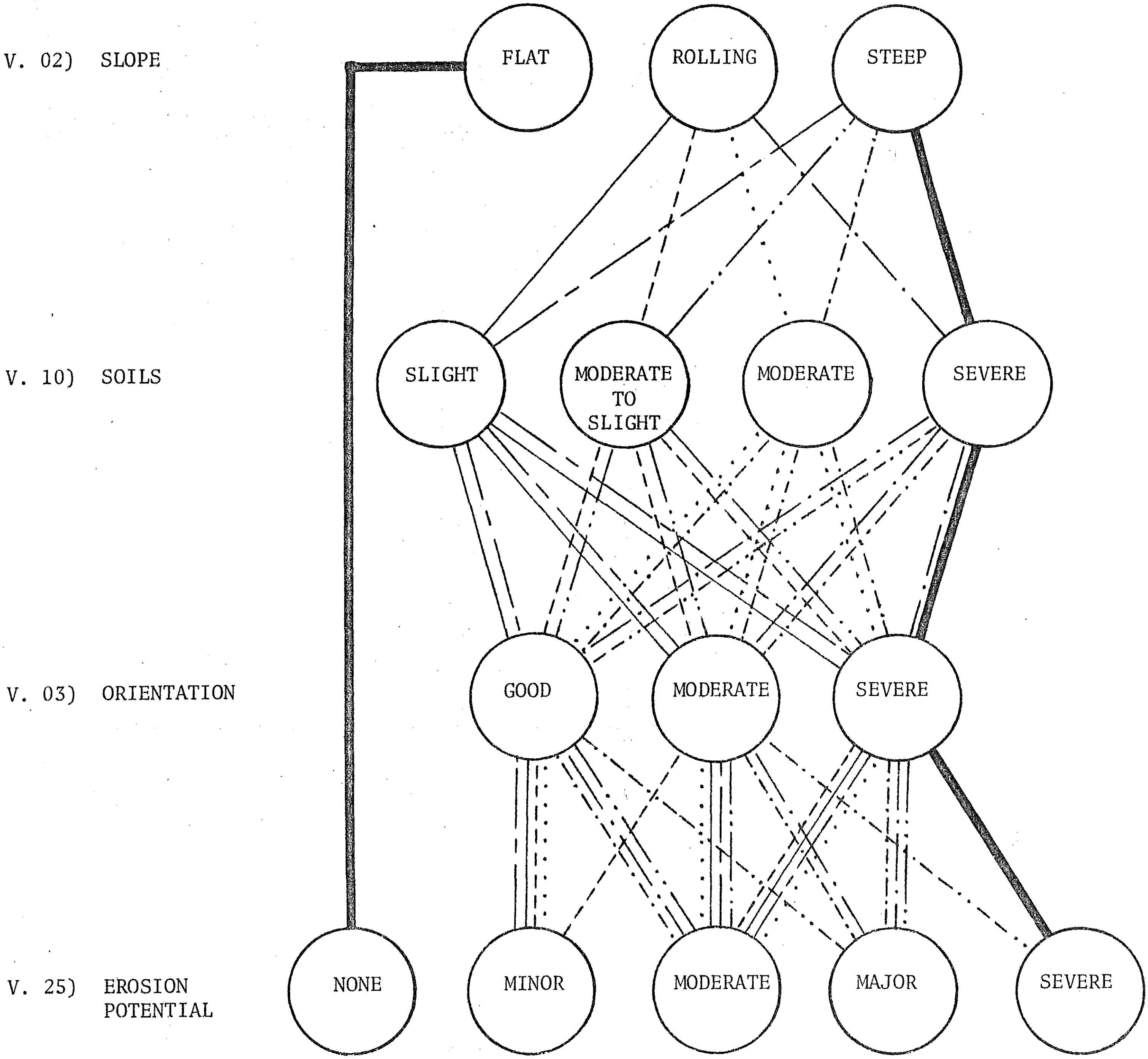


Figure 23. Erosion Potential - Logic Technique

erosion potential, while a flat slope, regardless of the soils and orientation, results in no erosion potential. Other combinations fall somewhere in between, depending on the physical characteristics associated with each path. The results of this analysis are shown in Figure 24. This figure is a computer printout in which the darkest areas are the most severe erosion potential areas, and the open areas are either flat or surface waters.

The third example uses the "SEARCH" computer technique. Figure 25 is the stream proximity map, which illustrates the shoreline within a quarter mile of lakes and streams. The darkest areas are areas in which land is within a quarter mile of both a lake and stream. The next lighter are areas within a quarter mile of only a lake, and the third degree of shading are areas within a quarter mile of a stream. In addition to the family camping and picnicking analysis that is shown in Figure 22, this analysis will be used for mine siting alternatives, aesthetic land use and fishing. With most programs, if shoreline data were to be used, it would have to be plotted as a separate inventory, whereas EPPL has the unique analysis capability to develop maps of this type.

The "VIEW" analysis is another unique analytical technique with EPPL. This analysis assesses what areas can be seen from navigable lakes and streams, asphalt roads, residential areas, and recreational cabins and resorts. Figure 26 is a computer printout of the visibility analysis. The darkest areas shown are seen the most, and as the shading becomes lighter, the cells are seen less and less. Open areas are not viewed, and the dots represent observer point locations. This particular analysis will be used in the aesthetic composite in the land use portion of the resource assessment, Figure 18. The southern area on the map is a large lake that is not presently accessible. However, the aesthetic value still exists, and certainly the lake will eventually be accessible.

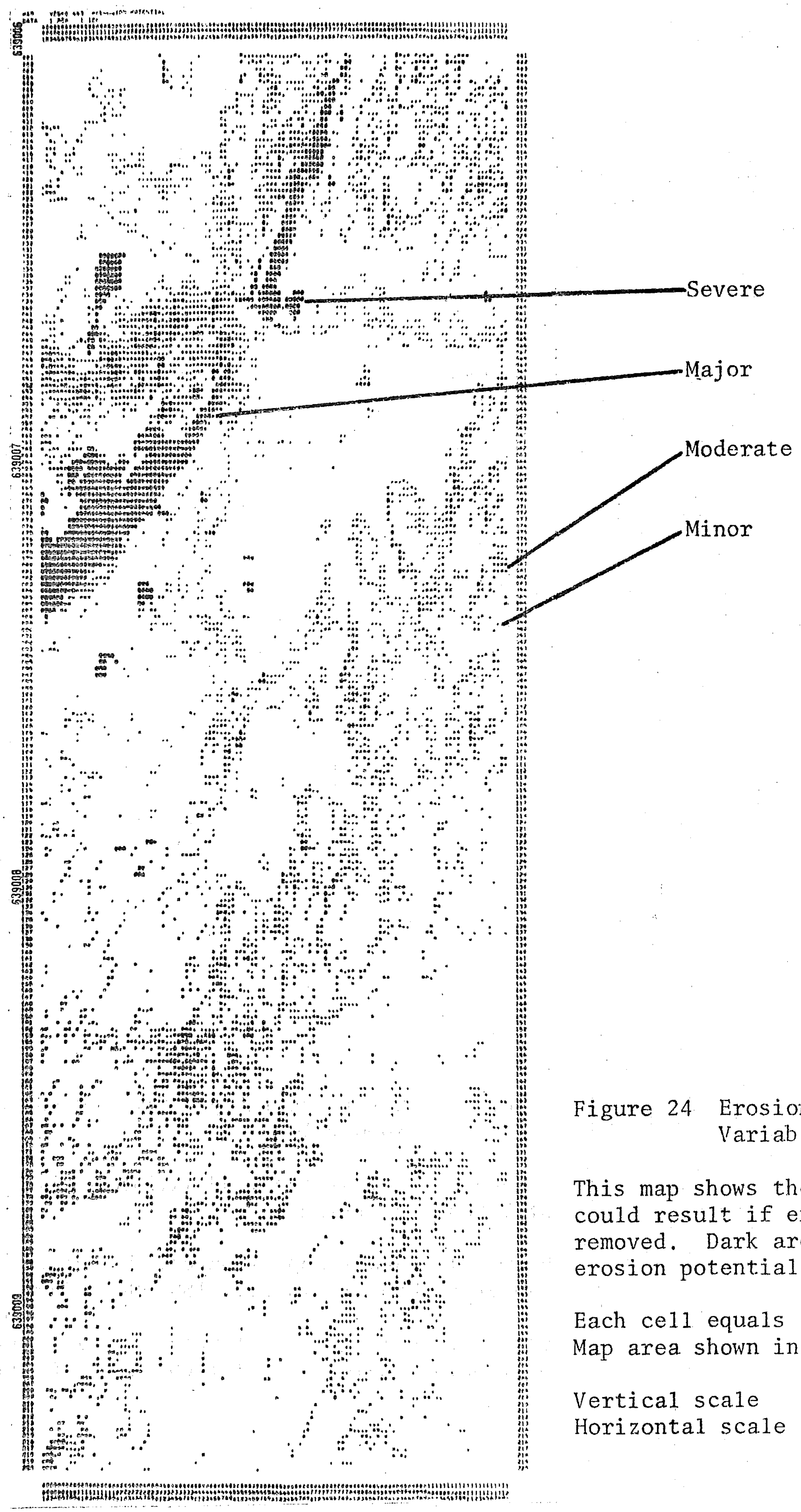


Figure 24 Erosion Potential - Created Variable Number 25

This map shows the degree of erosion that could result if existing vegetation is removed. Dark areas represent the highest erosion potential.

Each cell equals approximately 2.5 acres. Map area shown includes: T59-60N R12W

Vertical scale	1 inch $\simeq$	1.6 miles
Horizontal scale	1 inch $\simeq$	2.6 miles

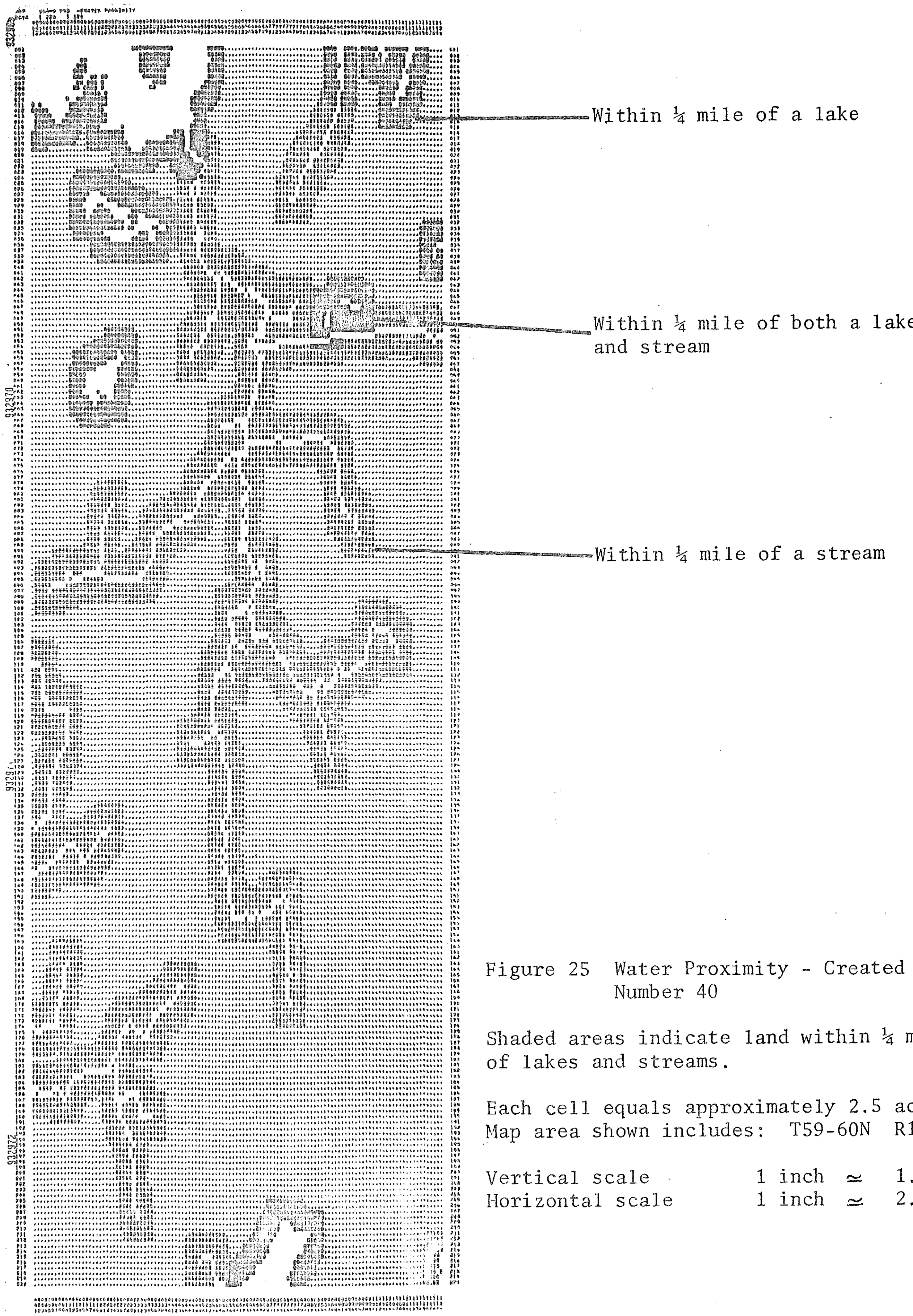


Figure 25 Water Proximity - Created Variable Number 40

Shaded areas indicate land within ¼ mile of lakes and streams.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale	1 inch ≃	1.6 miles
Horizontal scale	1 inch ≃	2.6 miles

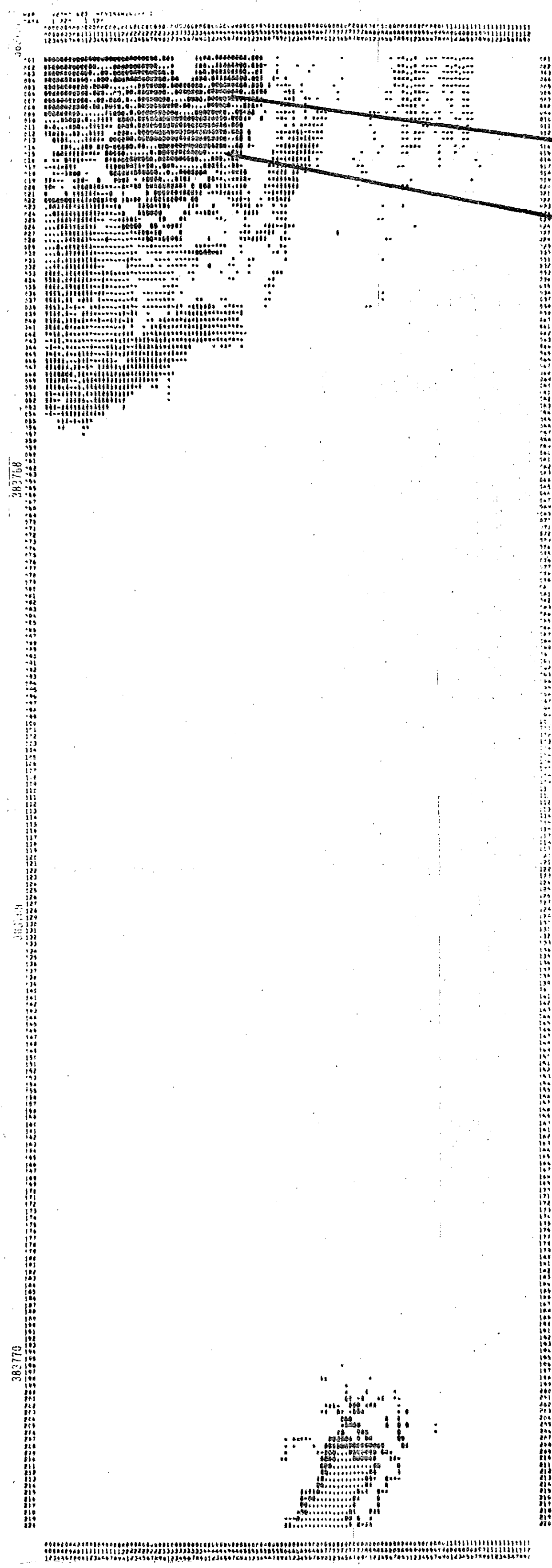


Figure 26 Visibility Analysis - Created Variable Number 27

Areas marked indicate those which can be seen from navigable waterways, main highways and resort and urban locations.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale 1 inch ≃ 1.6 miles
Horizontal scale 1 inch ≃ 2.6 miles

The last example illustrates the "PROCESS" technique of combining data from two inventory maps. Figure 27 shows the taconite resources in the pilot area. The darkest area shown is potential underground taconite resources and the medium shading is open pit reserves where two open pit mines are presently operating. Figure 28 illustrates the areas of highest potential for open pit and underground copper-nickel resources. This map is based on two criteria: state and federal leasing data and geology. In order for an area to be plotted as the highest potential, the underlying rock formation must be troctolite with small hornfels inclusions, and a company must have gone one step beyond the initial step of controlling the land. This would include holding a state lease more than five years when the rental rate increases, holding a federal lease, or having filed a preferential rights application for a federal lease. The darkest area again is shown as underground potential and medium shading is open pit potential. It should be noted that unlike the taconite resource shown in Figure 27, the copper-nickel areas are only potential resources. Undoubtedly, all areas shown do not contain copper-nickel resources, and because of private holdings, some resources may not be indicated. We feel, however, that this map provides a good idea of potential and is useful for regional planning of this type.

Figure 29 shows the taconite and copper-nickel maps superimposed. Obviously, there is potential for open pit and underground mining in the same units of land. This not only could result in some very interesting mining situations, but also some serious auxiliary land conflicts.

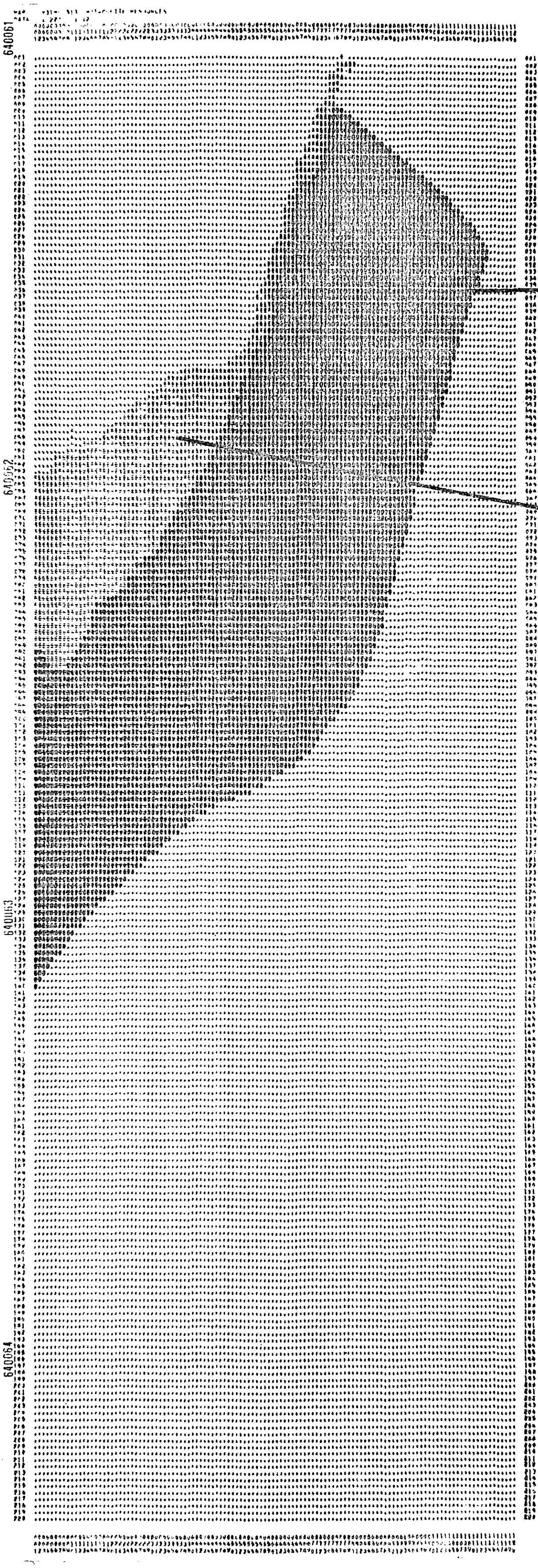


Figure 27 Taconite Resources - Created Variable Number 31

Shaded area shows existing and potential taconite resources.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale	1 inch $\simeq$	1.6 miles
Horizontal scale	1 inch $\simeq$	2.6 miles

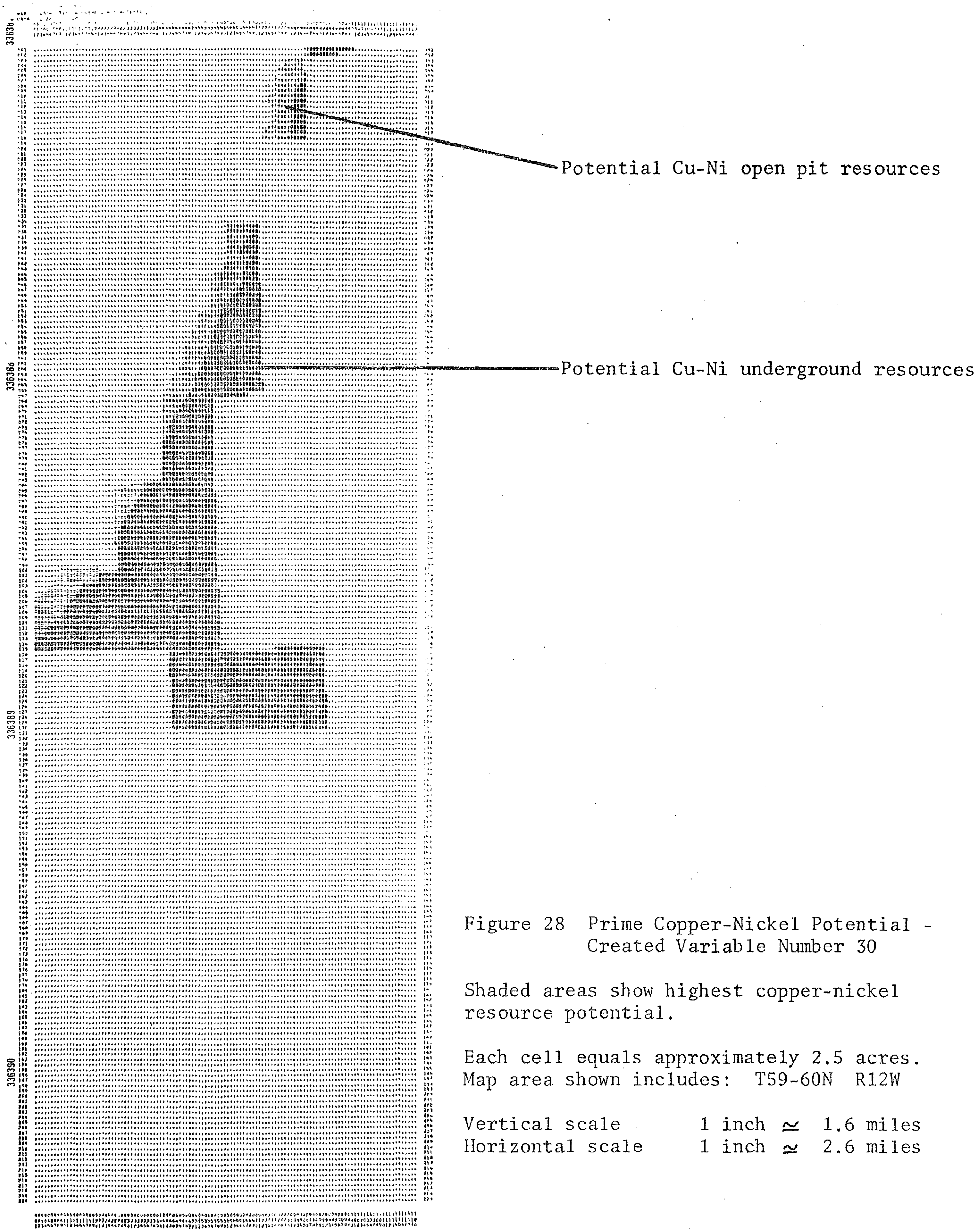


Figure 28 Prime Copper-Nickel Potential - Created Variable Number 30

Shaded areas show highest copper-nickel resource potential.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale 1 inch ≃ 1.6 miles
Horizontal scale 1 inch ≃ 2.6 miles

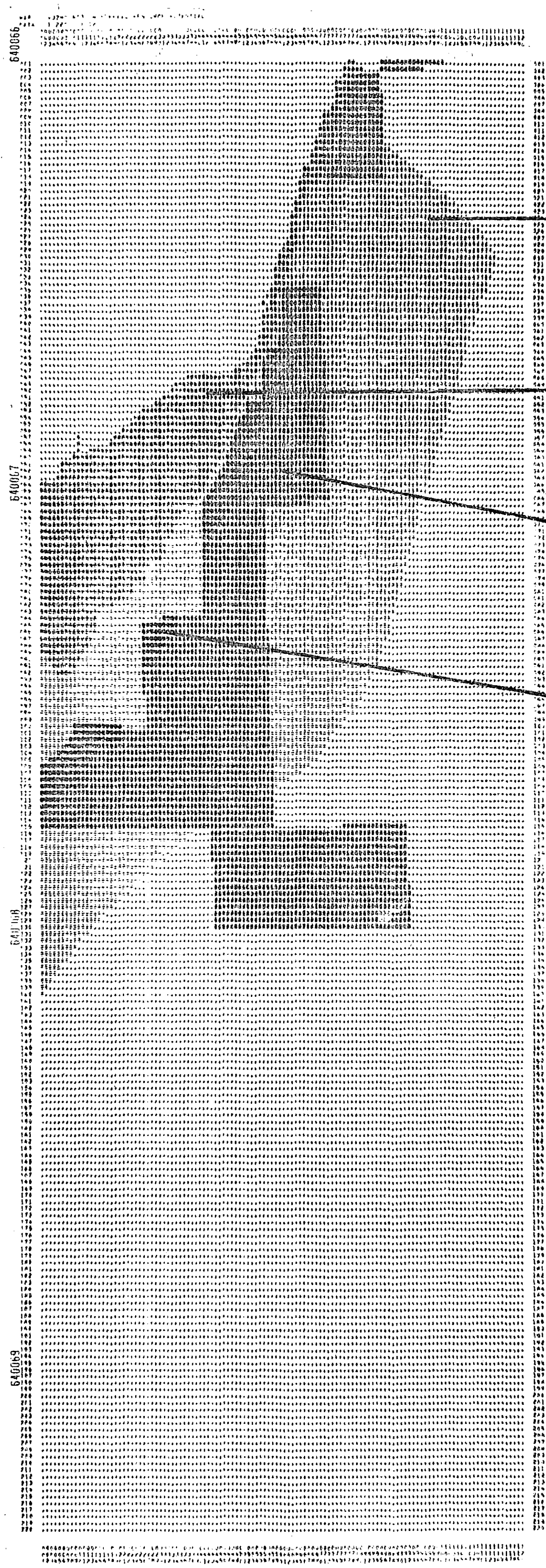


Figure 29 Mineral Resource Potential -
Created Variable Number 32

Shaded areas show where the highest potential exists for copper-nickel resources and taconite reserves.

Each cell equals approximately 2.5 acres.
Map area shown includes: T59-60N R12W

Vertical scale	1 inch ≃ 1.6 miles
Horizontal scale	1 inch ≃ 2.6 miles

CONCLUSIONS

As a result of recent land use and environmental laws, many new economic considerations have been introduced into most new developments, including mining. These laws address themselves to all phases of a mining operation and include such considerations as water and land pollution, noise, safety, etc. If potential conflicts between mining and environmental quality are to be resolved, early planning with substantial public involvement is a necessity. This means getting public participation into the planning procedure when there are still important decisions to be made. Past practices on the Mesabi Range have not always resulted in decisions that benefit the public. Stockpiles have been built that encroach on major highways and towns. Lakes on the range have been used as dump areas. And until fairly recently, revegetation was not even a common practice for overburden materials.

Minnesota has an opportunity to become involved in a truly unique planning experience. The Duluth Gabbro Complex is an important resource to the United States and to Minnesota. While at the same time, the area in which these resources are located is under growing pressures for alternative land uses and could involve several environmental considerations that have not previously been delt with in Minnesota. These land use and environmental questions must be resolved, and in a way that will benefit all involved, including the people of Minnesota. The "MINESITE" pilot project is an important first step in this planning sequence. The computer program being utilized, EPPL, is undoubtedly one of the finest comprehensive planning techniques available. The analysis procedure that is being developed includes resource assessment, a land use plan, and finally, a project evaluation phase. Considerations in each phase include environmental factors, five land use catagories, land use compatability, mineral resources, and mine siting alternatives. The "MINESITE" project is a regional plan. If individual projects are to be contemplated, a detailed environmental assessment will have to be undertaken. Preplanning will be required,and alternatives should be developed as a part of that analysis. It is anticipated that the completed "MINESITE" study will serve as a valuable framework for copper-nickel planning in Northeastern Minnesota.

FOOTNOTES

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