DEVELOPMENT OF A STRUCTURED METHODOLOGY FOR EVALUATION OF POST MINING LANDUSE PLANS IN INTERIOR ALASKA

By
S. Bandopadhyay and A. Chattopadhyay

OPEN FILE 84-12

Mineral Institute Final Report
Sixth Allotment, Grant No. 1134102
Period Ending June 30, 1984

Submitted To:

United States Department of the Interior
Bureau of Mines
2401 E Street, NW
Washington, D.C. 20241

School of Mineral Engineering
Mineral Industry Research Laboratory
University of Alaska, Fairbanks
Fairbanks, Alaska 99701

APPENDIX A

DEVELOPMENT OF A STRUCTURED METHODOLOGY FOR EVALUATION OF POST MINING LANDUSE PLANS IN INTERIOR ALASKA

By

Sukumar Bandopadhyay and Asis Chattopadhyay
Department of Mining and Geological Engineering
University of Alaska-Fairbanks

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (cont.)

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87, 95th Congress) represents a significant effort on the part of the Federal Government to establish a nationwide program to protect society and the environment from the adverse effects of surface mining operations. Among the stated purposes of the 1977 Act, the following are particularly relevant to mine planning and operation:

- assure that surface coal mining operations are so conducted as to protect the environment;
- assure that adequate procedures are undertaken to reclaim surface areas as contemporaneously as possible with the surface coal mining operations;
- assure that the coal supply essential to the Nation's energy requirements, and to its economic and social well-being is provided and strike a balance between protection of the environment and agricultural productivity and the Nation's need for coal as an essential source of energy.

Several provisions of the Act and the interim regulations deal with the protection of environment from surface mining damages. Specifically with regard to obtaining a mining permit, a reclamation plan must be submitted which shall be of such a detail to demonstrate that reclamation can be achieved as required by Federal or State programs. Such a plan must cover, among other, the following important points with regard to the uses of land:

- the uses existing at the time of the application, and if the land has a history of previous mining, the uses which preceded any mining;
- the capability of the land prior to any mining to support a variety of uses giving consideration to soil and foundation characteristics, topography, and vegetative cover;
- the use which is proposed tobe made of the land following reclamation, including a discussion of the utility and capacity of the reclaimed land to support a variety of alternative uses and the relationship of such use to existing land use policies and plans, and the comments of any owner of the surface, State and local governments or agencies thereof which would have to initiate, implement, approve or authorize the proposed use of the land following reclamation.
- a detailed description of how the proposed post-mining land use is to be achieved and the necessary support activities which may be needed to achieve the proposed land use;
- the consideration which has been given to making the surface mining and reclamation operations consistent with surface owner plans, and applicable State and local land use plans and programs;
- the consideration which has been given to developing the reclamation plan in a manner consistent with local physical, environmental, and climathological conditions.

In short, the planning of surface mines, in general, and the reclamation and post mining uses of land, in specific have become very complex.

SCOPE AND OBJECTIVE OF THE PROJECT

Each individual mining project is unique, but most mine developments go through a common generic order of development by stages in which each succeeding stage reduces the uncertainties inherent in the venture. A simplified concept of this generic planning process is illustrated in Figure 1.

In the planning process a wide variety of information are identified, collected and analyzed because various element of the mine planning interact on each other and also on the environment. This relationship may also vary depending on the time of mining operation, the technology utilized, the mining method and plan, and the specific locational and site characteristics of the area selected. Figure 2 is an interaction matrix that defines the information need in various elements of a mine plan. While this matrix is not all-inclusive and does not represent any formal method of approach, it does solve a definite purpose in identifying data that will be needed for permit applications. In addition, review of existing and proposed laws will identify the information needed prior to mining that will enable planning surface mining operations to be in compliance. Figure 3 describes the various provisions of the OSM regulations for permitting requirements.

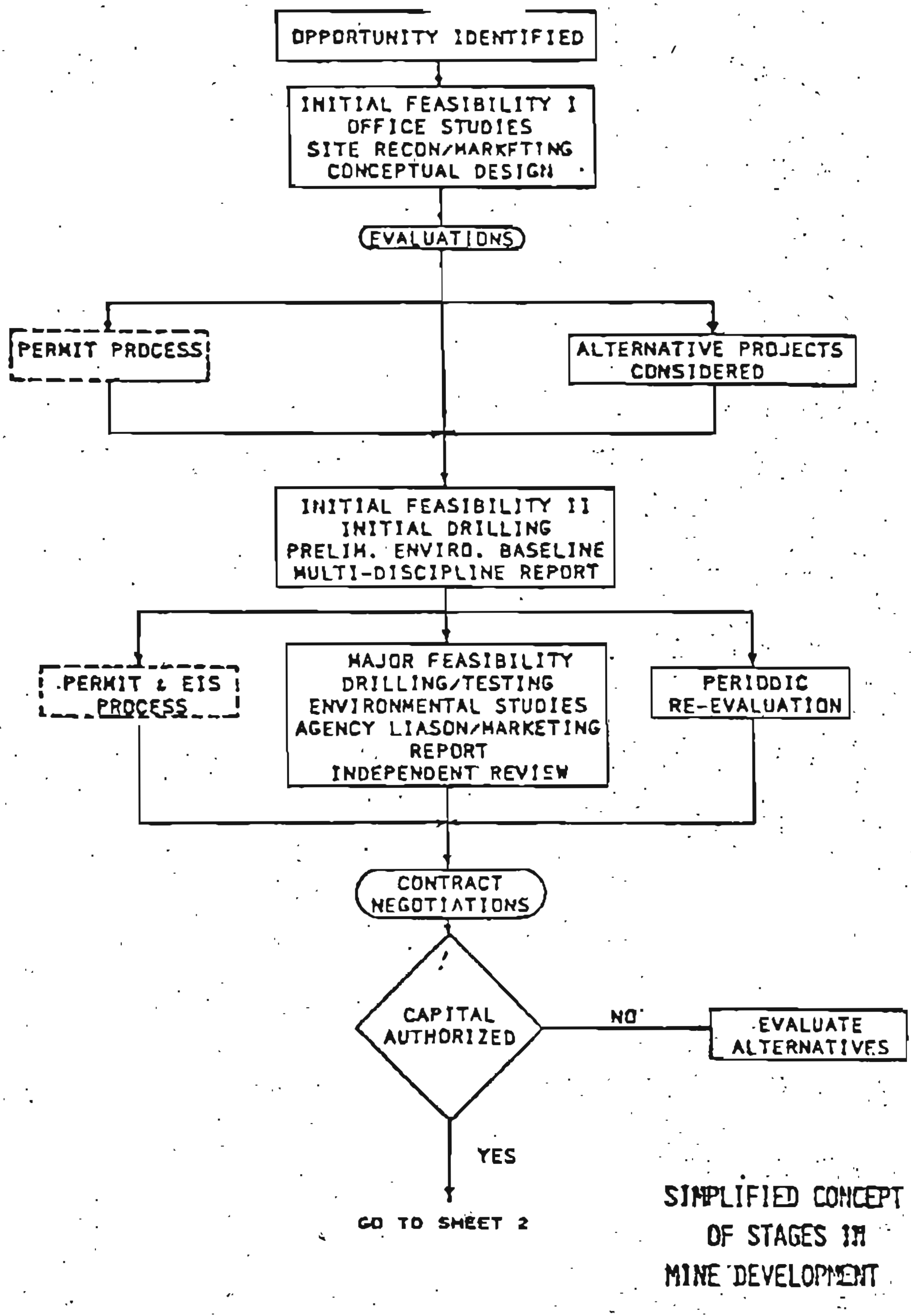
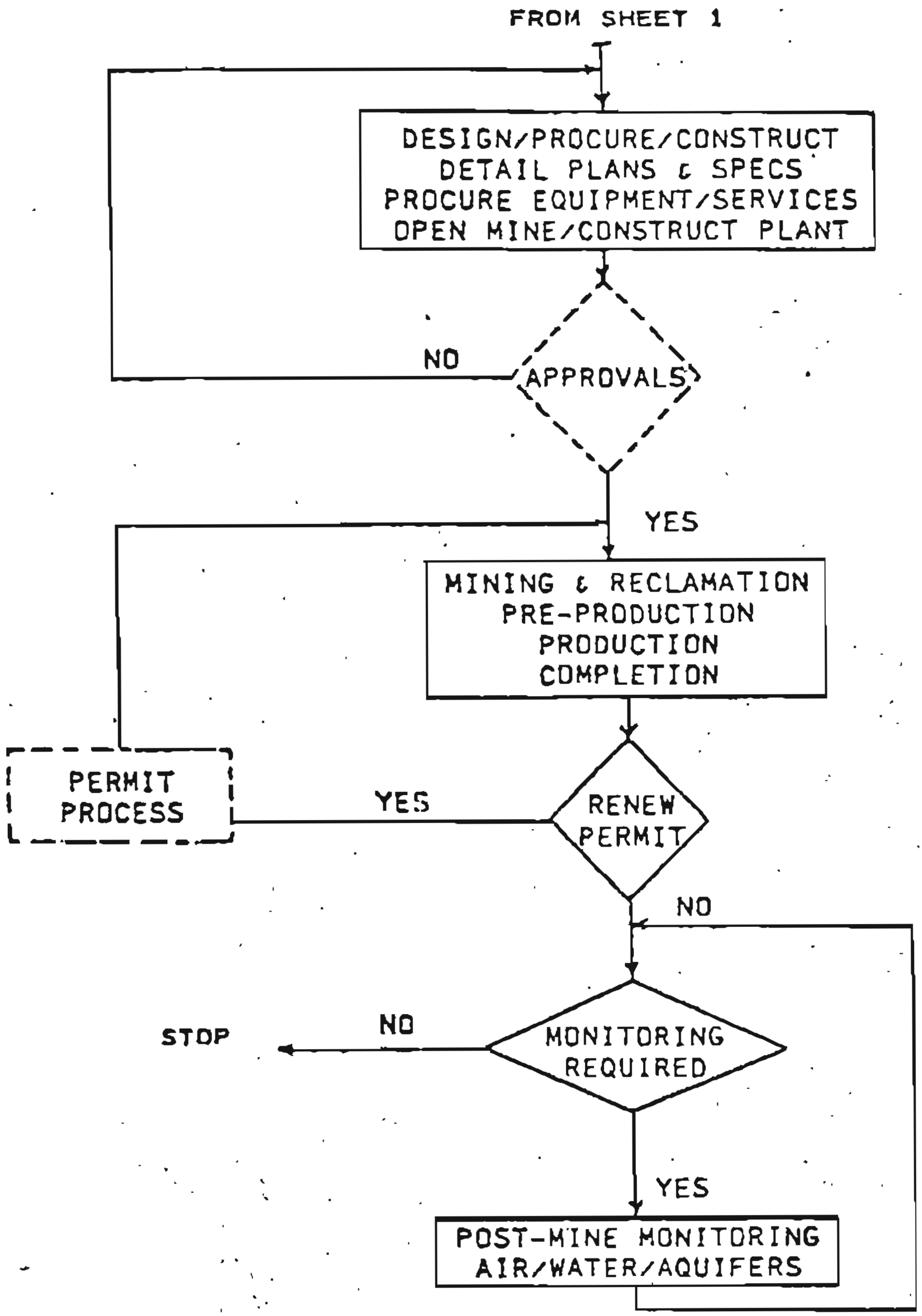


Figure 1. Simplified concept of stages in mine development (Dames & Moore, 1976)



FROM SHEET 1
DESIGN/PROCURE/CONSTRUCT
DETAIL PLANS & SPECS
PROCURE EQUIPMENT/SERVICES
OPEN MINE/CONSTRUCT PLANT
NO
APPROVALS
YES
MINING & RECLAMATION
PRE-PRODUCTION
PRODUCTION
COMPLETION
PERMIT
PROCESS
YES
RENEW
PERMIT
NO
STOP
NO
MONITORING
REQUIRED
YES
POST-MINE MONITORING
AIR/WATER/AQUIFERS

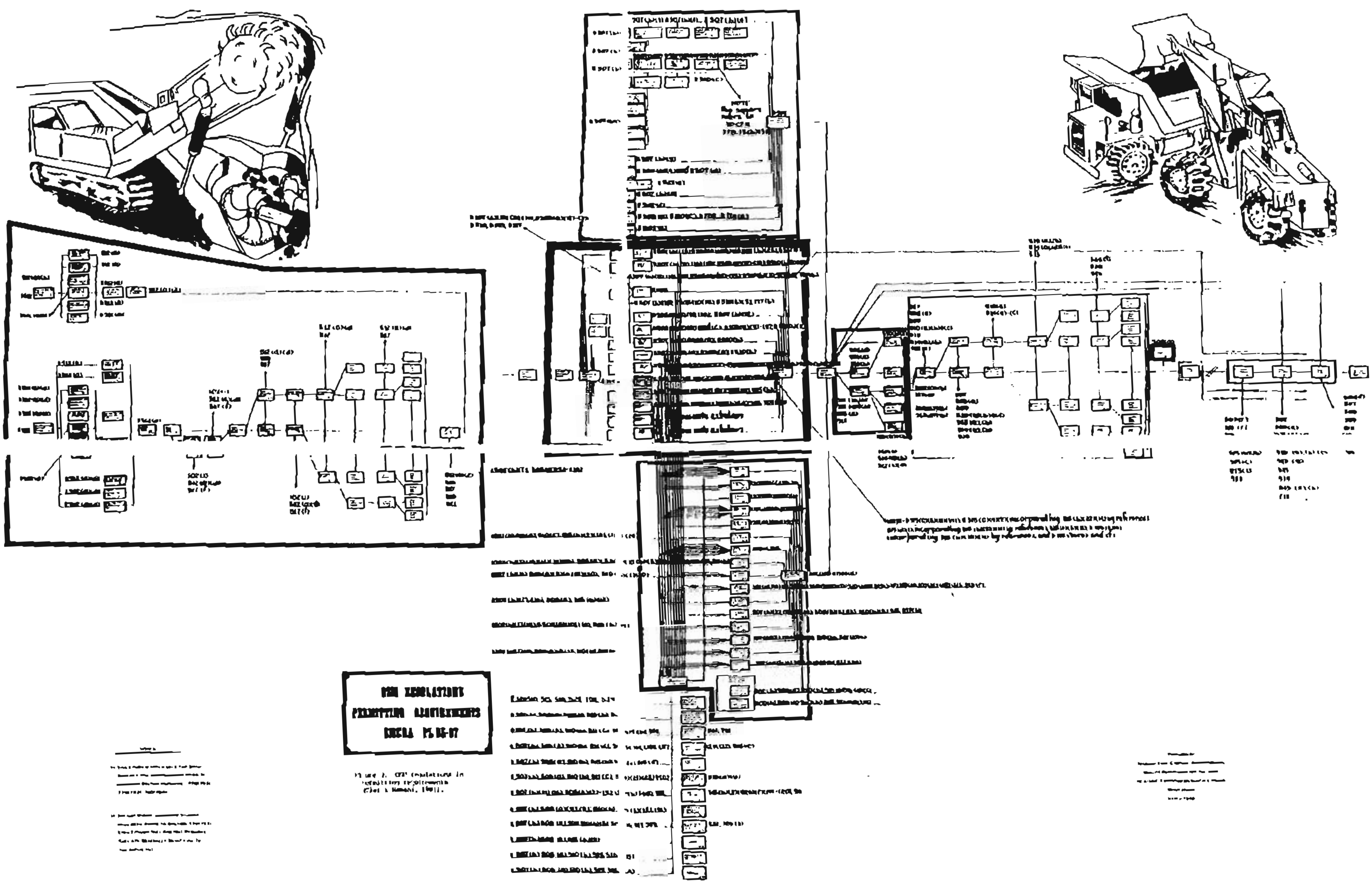
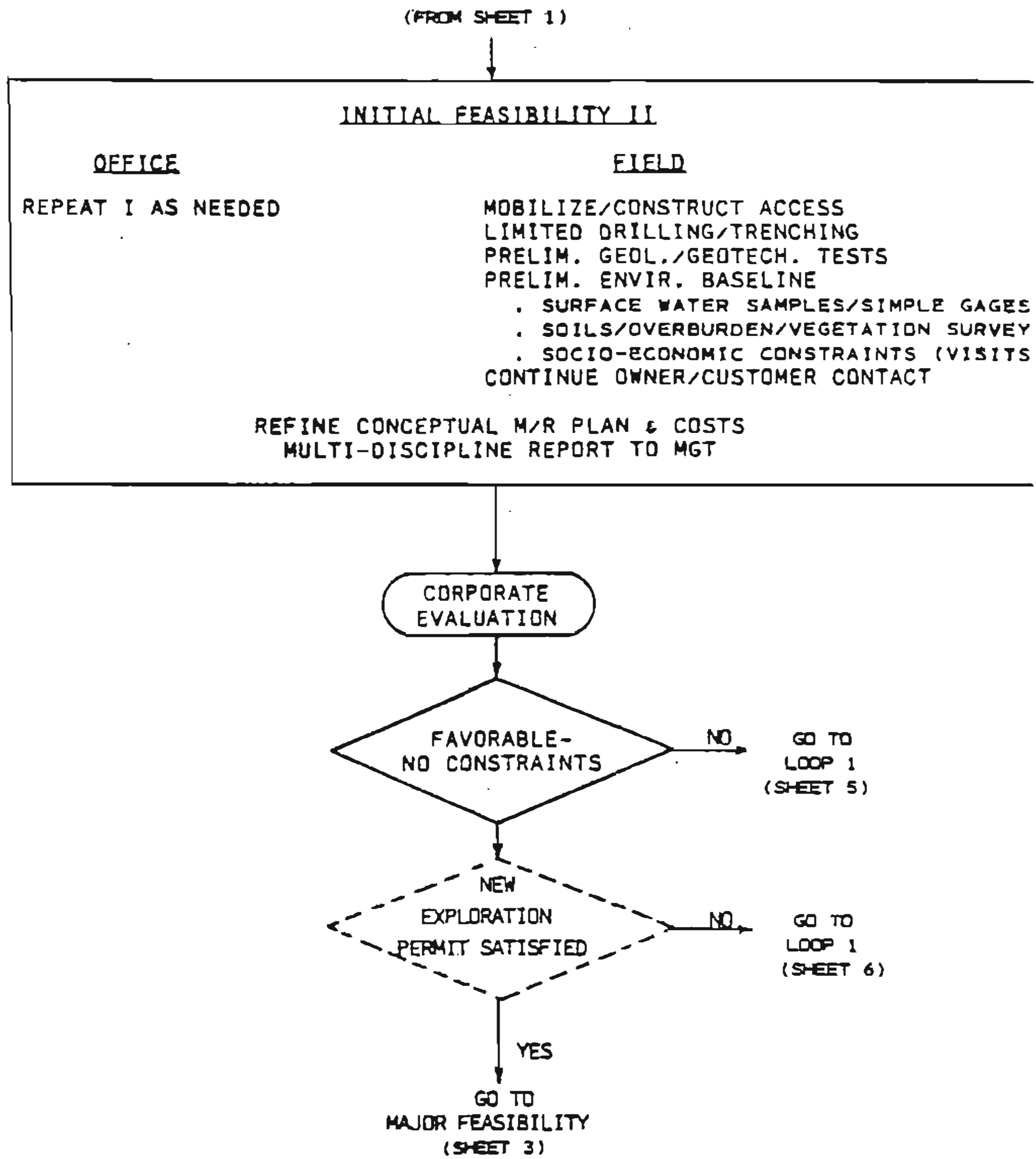
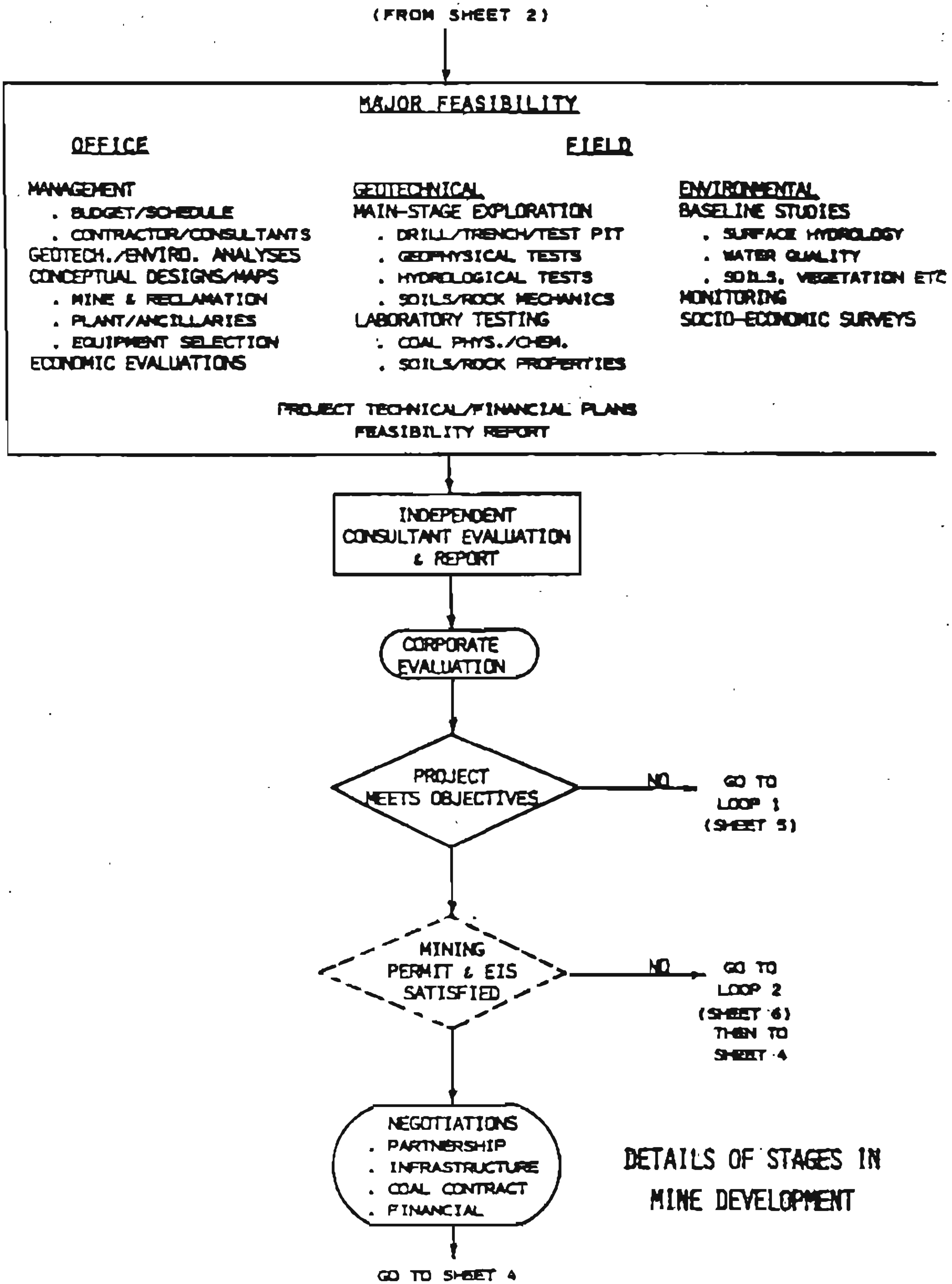


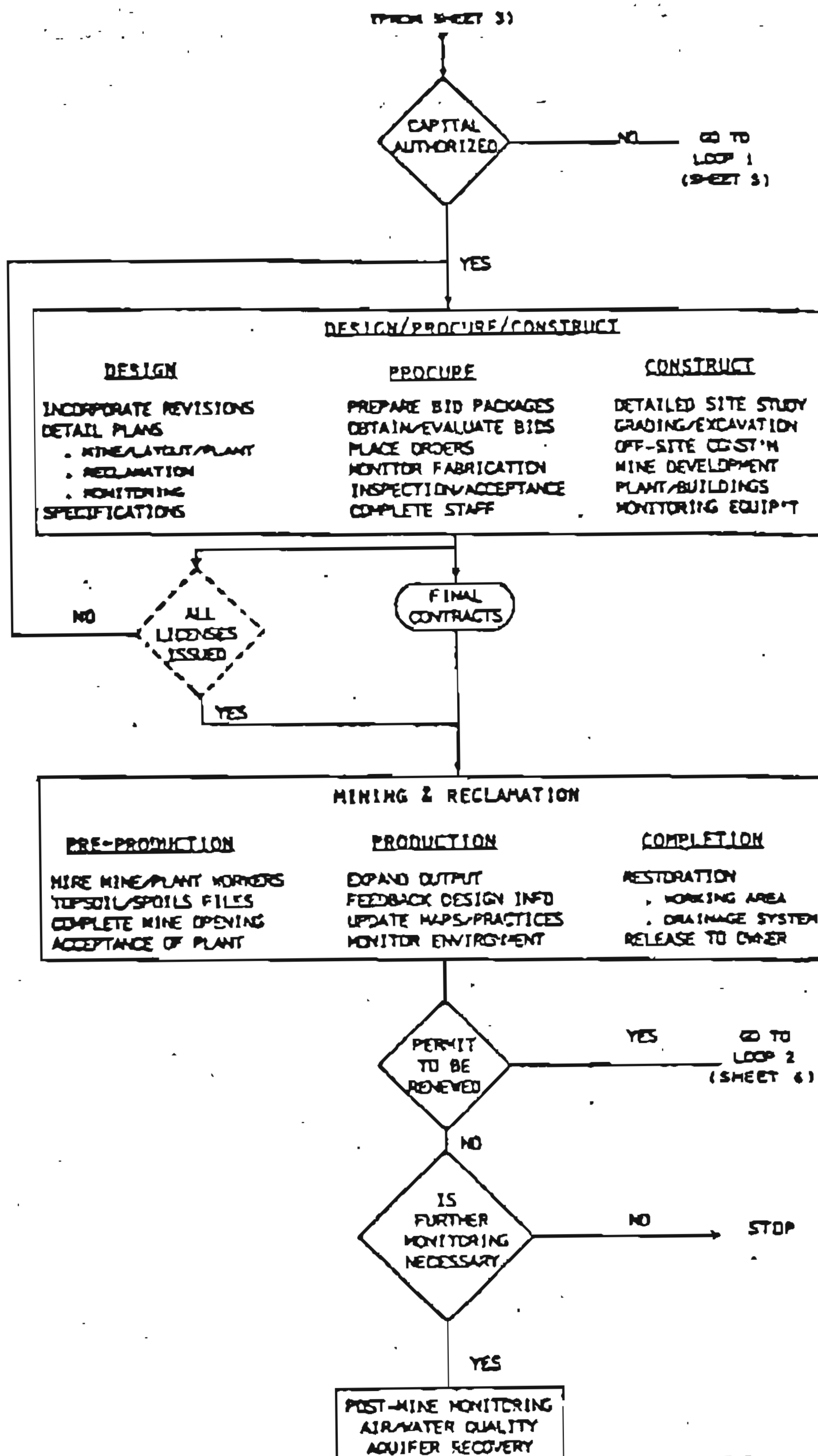
Figure 2. OSM regulations in permitting requirements



DETAILS OF STAGES IN
MINE DEVELOPMENT



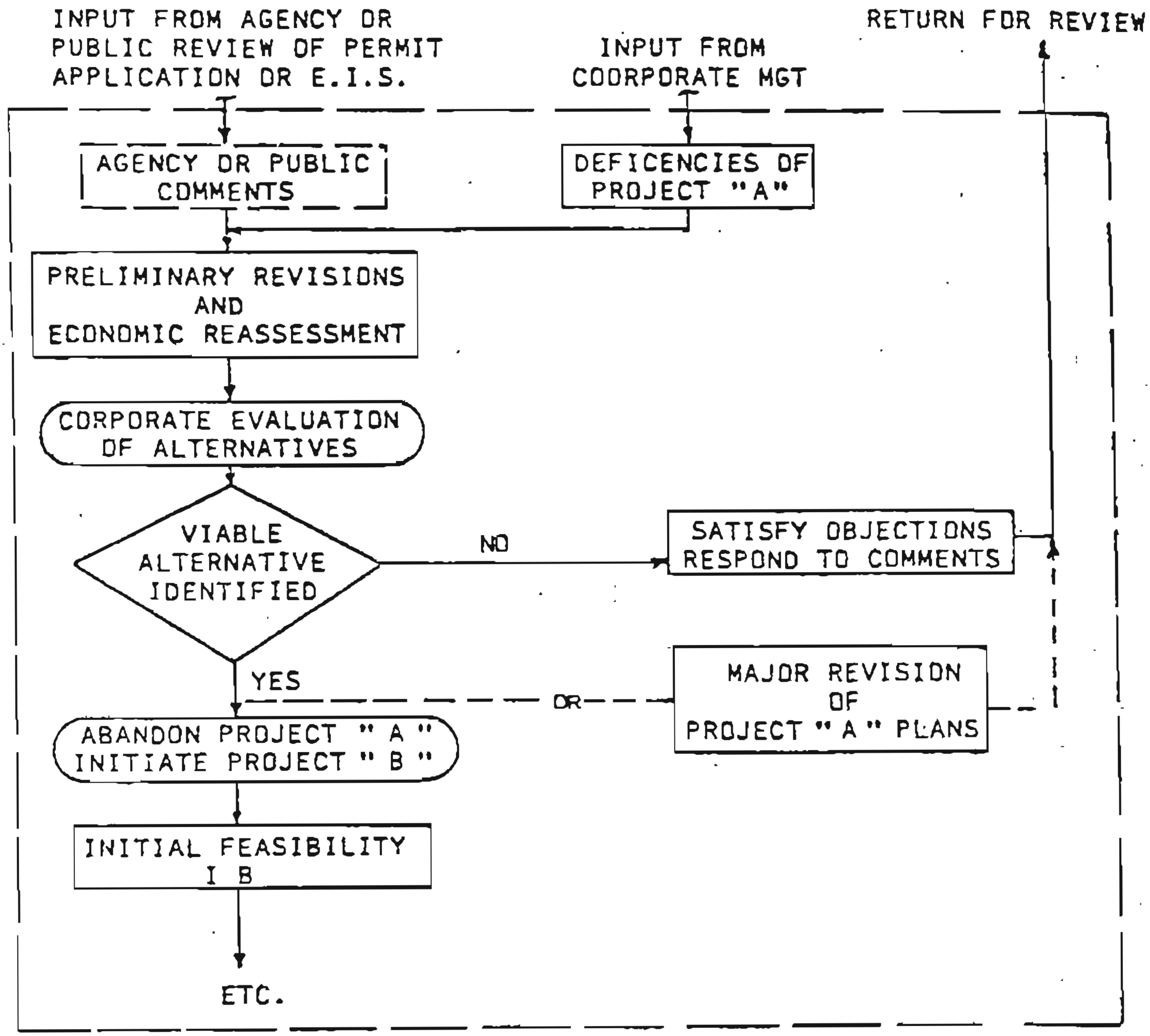
DETAILS OF STAGES IN MINE DEVELOPMENT



DETAILS OF STAGES IN MINE DEVELOPMENT

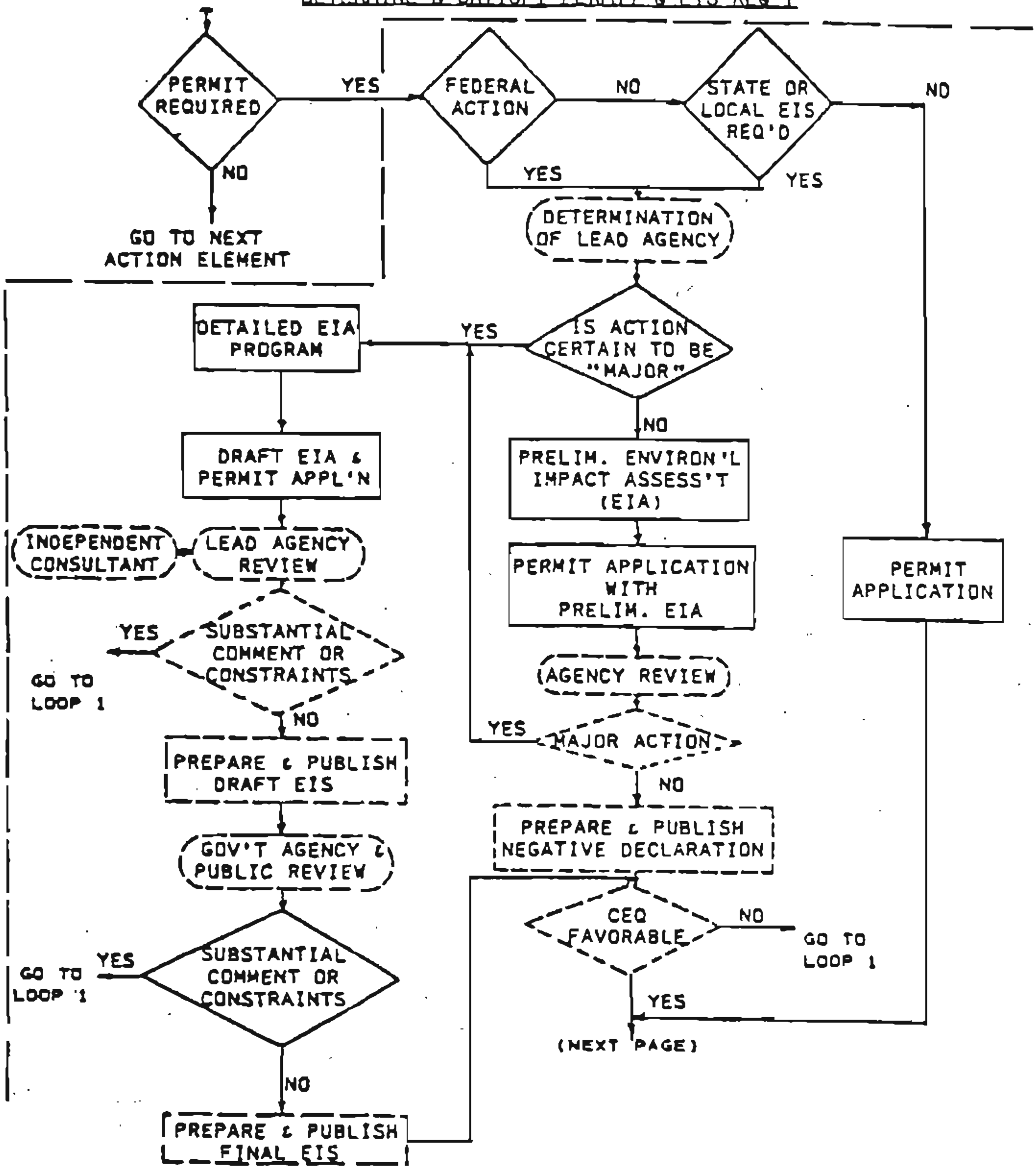
LOOP 1

PROJECT RE-EVALUATION & RESPONSE TO COMMENTS

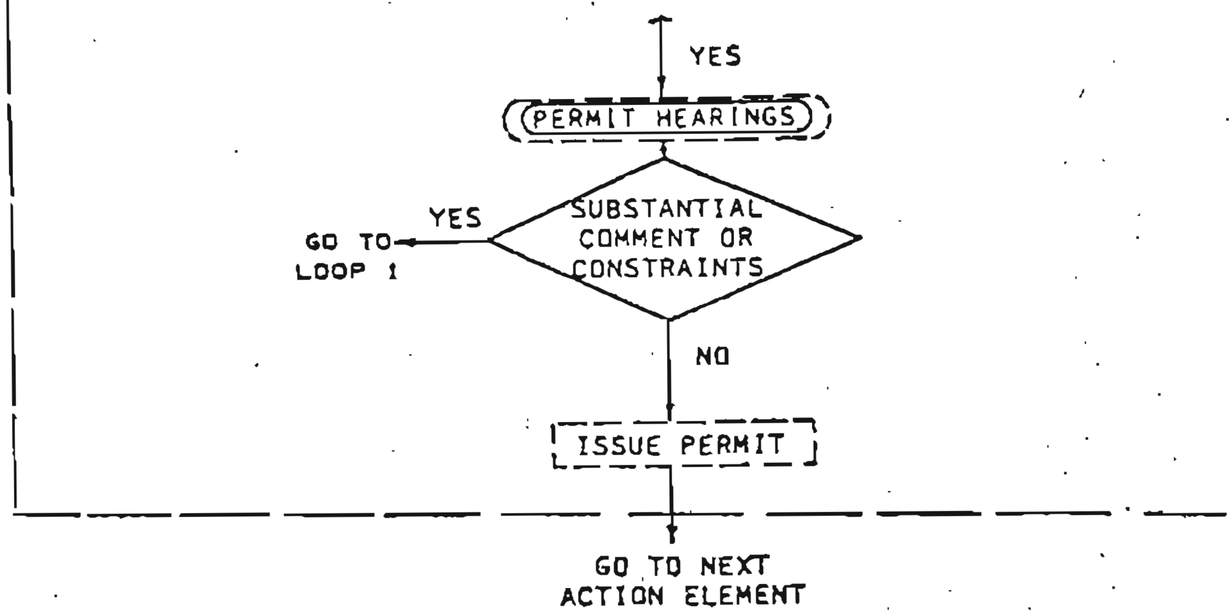


LOOP 2

DETERMINE & SATISFY PERMIT & EIS REQ'T



LOOP 2 (CONT'D)



YES
PERMIT HEARINGS
SUBSTANTIAL COMMENT OR CONSTRAINTS
YES
GO TO LOOP 1
NO
ISSUE PERMIT
GO TO NEXT ACTION ELEMENT

While the scope of the present study does not include a detailed discussion of the applicable laws and regulations, identification of the regulatory provisions is relevent since regulatory programs are measures to control and thus mitigate damage to land, air, water, fish, wildlife and other related resources as a result of mining.

This research has aimed at developing a Manual of Practice (MOP) that will assist mine operators and control personnel in developing guidelines and means of assessing alternatives in the areas of water management, land use planning and surface mine engineering. The specific objectives were (i) to review of existing and proposed laws to identify the information that need to be developed prior to mining; (ii) review of existing to identify the sources and acquisition procedures; and (iii) summarize and recommend a analysis procedure to convert the data to information needed. It has been recognized that manual of practice need not contain the details of all the method for assembly and assessing all types of data available, but merely those techniques of collecting and manipulating those type of data pertinent to the specific case. To develop the specific data type, treatment methods and other procedure necessary for each specific discipline requires however, that all types of data, all treatment methods and all other procedures possibly applicable shall have been identified.

The development of the final M.O.P. has, therefore, been identified as dependent on five supplemental areas covering (i) geology and hydrology; (ii) surface mine engineering; (iii) laws and regulations; (iv) water quality management and (v) land use management. Development of method and analysis procedure in each area

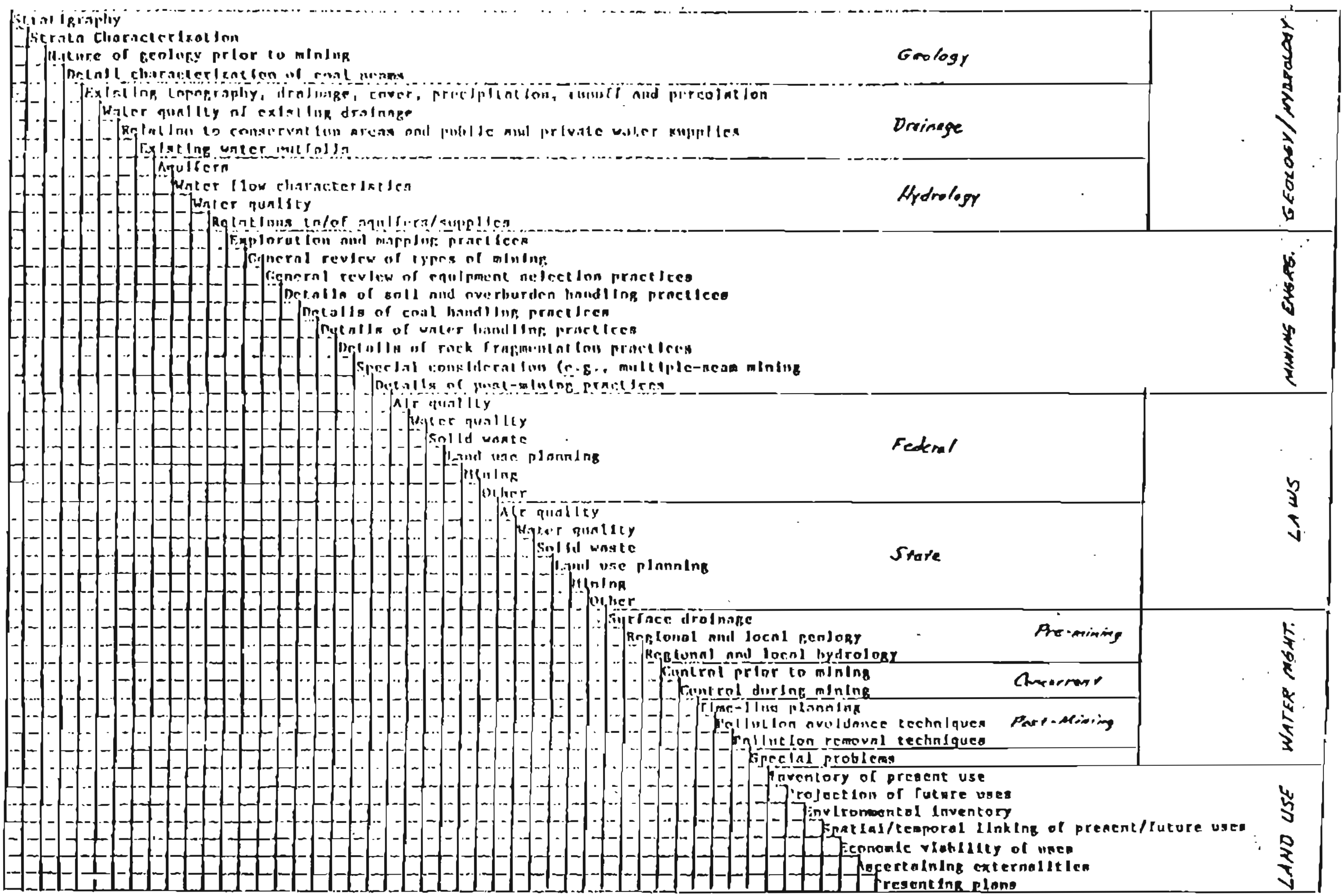


Figure 2. Interaction matrix of elements in mine planning (Clar & Ramani, 1981).

will identify such type of data and methods for using these data as could possibly relate to a specific field. This report has addressed in detail, one aspect of this complex problem that of coordinating the planning activity of the mining community with that of the land use planning agency. A mathematical "Fuzzy Programming" model has been developed for evaluation of landuse planning alternatives. The model allows explicit consideration of competing goals at different spatial scales. The approach described can simultaneously handle both qualitative and quantative information and take into account the viewpoints of the different interest groups. The analysis procedure developed in this report will provide a standarized procedure to determine most desirable post mining landuse plan.

CHAPTER II

DATA NEEDS FOR LANDUSE PLANNING

Mining activities from exploration through and including processing, obviously can disturb the environment. Current legislative controls and guide lines (in most States) help minimize operational and post-operational effects from mining; however this has not always been the case. The results from past mistakes or lack of control are abandoned mine sites. Environmental impacts from these abandoned or inactive mine sites generally fall into one or more categories:

(i) Water quality degradation

(ii) Altered landscape

(iii) Air pollution

The degree of impact is dependent on the mining methods utilized, physical and chemical characteristics of the mineral commodity and overburden, along with general hydrology and climatology condition of the area.

In mining areas characterized by the absence of any formal zoning or land use activity, the mining and reclamation operations are subject to the State and Federal laws with regard to mining, air, water and land resources; in these cases, the frequently determined post mining land use is the premining land use although a great potential may exist to create an alternative land use. Restoration of mined lands and surface water can be achieved for one of the following categories; its associated costs will depend on initial suitability of the disturbed area.

1. Agricultural
2. Pasture
3. Timber and pulp
4. Rangeland or forest
5. Wildlife habitat
6. Water related recreation
7. Reservoir
8. Home development
9. Industrial park
10. Commercial building site
11. Sanitary fill

Increase in land value after reclamation are primarily dependent on land use category and proximity to urban areas.

Land use "planning" and land use "control" evoke rather difficult and emotional questions concerning the effects on public and private ownership, jobs, county development, taxes and earnings, local State and Federal economics, and even the residence of the authority on land use decisions. It is here that the cooperation between mining companies and land use planning authorities become very important. The various interactions that are necessary between these two parties to make a reclamation planning process a success must be cognizant of the scope and limitations of each of the parties. To do this job efficiently, answers must be made available for the following questions:

(i) What kind of analysis need to be done by the mining company to select a suitable post-mining land use?

(ii) What kinds of data are needed for each analysis?

(iii) What or where are the data sources? What is the availability of these data?

(iv) What kinds of interaction is currently taking place or must take place between mining company, and the land use planning agencies (local, State and Federal) to ensure the development of a suitable plan? How this interaction can be enhanced or achieved respectively?

The objective of designing and implementing reclamation plan for mined land is the management of the State's total resources, which involves abatement of water pollution and restoration of the land. In order to successfully complete such a comprehensive program, a systematic and logical approach must be utilized. The exact method that an agency (local, State or Federal) employs will depend on the variables such as financial resources, magnitude and diversity of problem in the mine site; and the socio-economic needs of the residents.

The mine reclamation program must encompass an assessment of an area's economic needs and development demands in establishing watershed ranking and reclamation priorities. Reclamation programs may not be undertaken strictly for aesthetic environmental improvements, but can also attempt to improve utilization of local or regional water and land resources for the general public. Subsequent stimulation of an area's economy and other beneficial effects of such program should enhance general well-being of the citizenry.

Collection and analyses of socio-economic information may be accomplished utilizing anyof a number of options, depending primarily on availability of State human resource data, economic needs, developmental demands and aesthetic interest of the citizen. The complexity of the problem, and levels of planning involved in mined land planning process can be visualized with reference to Figure 4, which recognizes the various attributes that need to be considered.

Necessary to the implementation of a successful program is careful, through analyses of the various available recamation alternatives. The planning procedure and its execution must ensure that the reclamation process yields the highest possible benefit for every dollar expended. The use of a specific and effective series of planning phases allow isolation of logically related, interdependent actions, and simultaneously provides a means of estimating overall progress. The interaction needed for various attributes in the planning process and among various agencies can be visualized with refernce to Figure 5.

Inherent to the planning and evaluation of a suitable reclamation program is collection of tremendous amounts of qualitative and quantitative data. It is necessary to identify the information needs, data sources and analysis procedure fundamental to a successful reclamation plan. A brief listing of the sources and types of information needed is provided in Table 1.

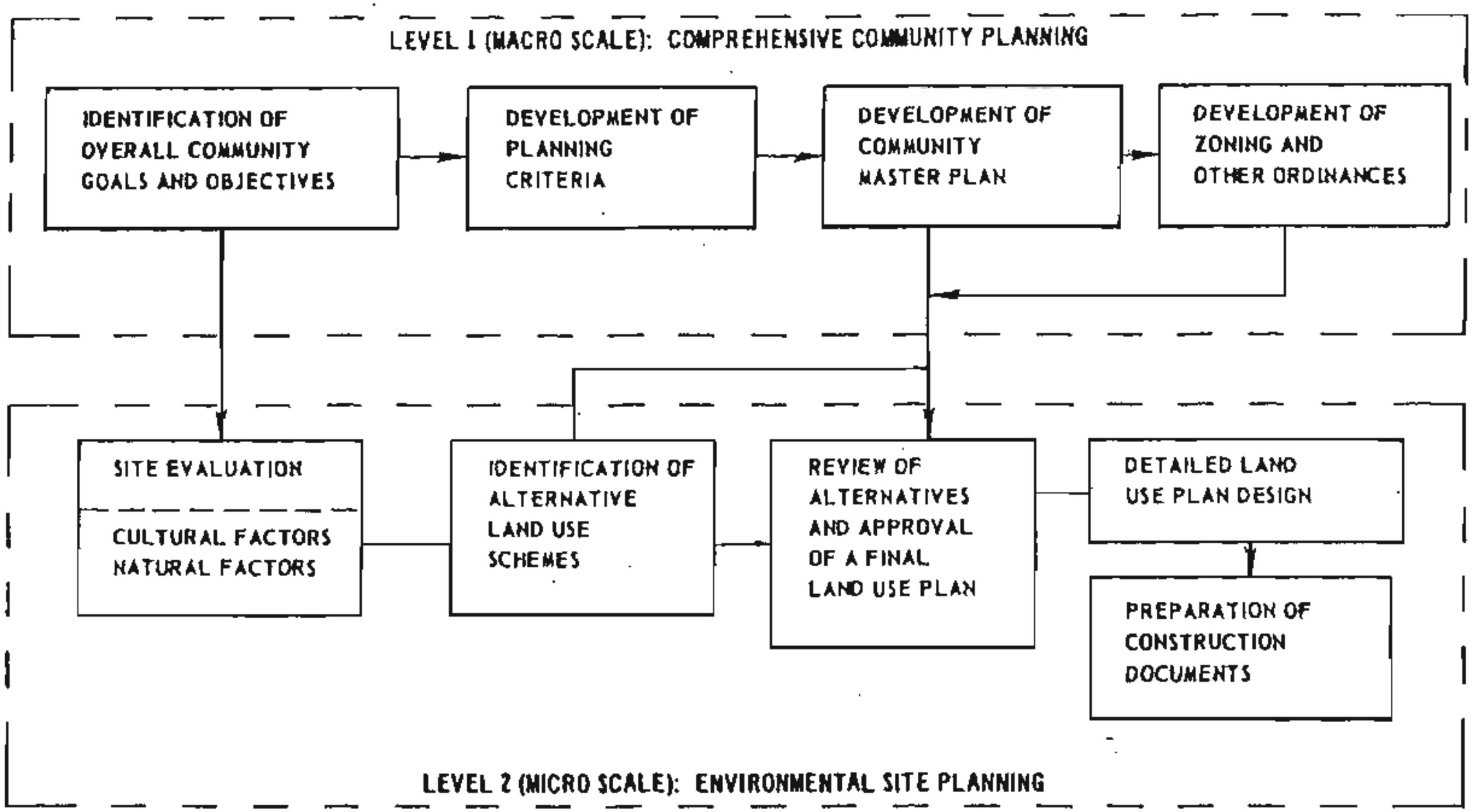


Figure LEVELS OF PLANNING INVOLVED IN THE MINE LAND PLANNING PROCESS

Figure 4. Levels of planning involved in the mine land planning process (Clar & Ramani, 1981).

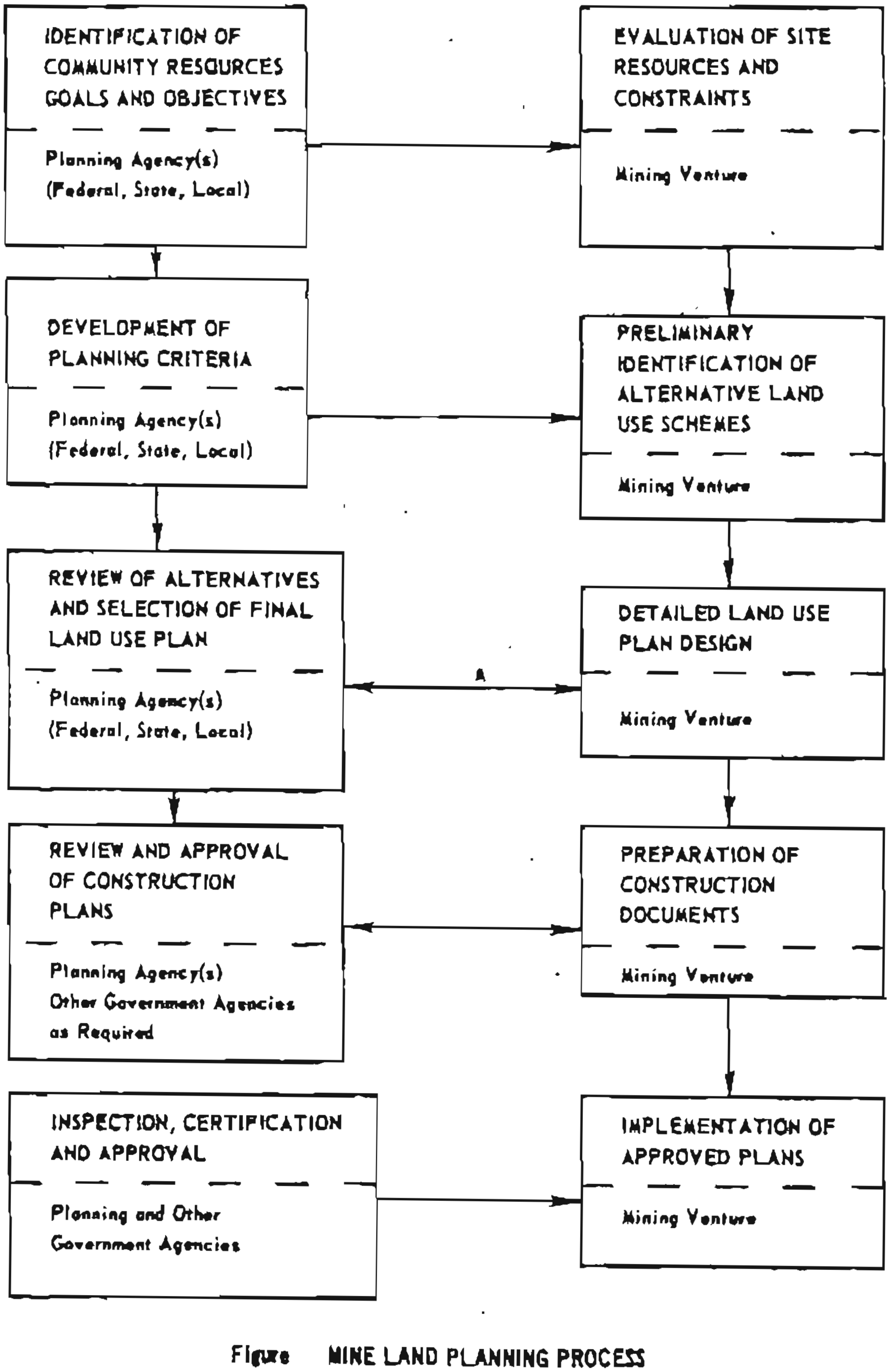


Figure 5. Mine land planning process (Clar & Ramani, 1981).

TABLE 1

SOURCES OF INFORMATION OR TECHNICAL ASSISTANCE	TYPE OF INFORMATION OR ASSISTANCE
A. FEDERAL SOURCES	
Office of Surface Mining (OSM)	Research
Bureau of Land Mangement (BLM)	Data on land status and use; land use, land ownership, and mineral ownership maps.
U.S. Geological Survey (USGS)	Collects and publishes geological data; data information systems; maps (topographical, planimetric, geologic, mineral resources, land use, land cover); satellite imagery.
Environmental Protection Agency (EPA)	Research; pollution control handbooks
Department of Energy (DOE)	Research
U.S. Forest Service (USFS)	Research (Wildlife and vegetation); geographical based information system; aerial photographs
U.S. Bureau of Mines (USBM)	Collects and distributes statistical data; research
U.S. Fish and Wildlife Service	Land use and land cover maps
Soil Conservation Service (SCS)	Soil surveys, aerial photographs
Agricultural Stabilization and Conservation Service (ASCS)	Aerial photograhs
Water Resources Scientific Information Center	Bibliographic retrieval system
U.S. Census Bureau	Demographic and economic statistics; data information system
U.S. Bureau of Economic Analysis	Employment data; data information system
National Technical Information Service (NTIS)	Bibliograhical retrieval system
U.S. Weather Bureau	Climatological data
B. STATE SOURCES	
State Geological Survey	Geographic and resource data bases; maps (topographic, planimetric, geologic, mineral resources, land use, land cover)
Department of Community Affairs	Geographic data base; maps (land use and land cover)

TABLE 1 (cont.)

SOURCES OF INFORMATION OR TECHNICAL ASSISTANCE	TYPE OF INFORMATION OR ASSISTANCE
Department of Natural Resources	Geographic and resource data bases
Agricultural Experiment Station	Research
Bureau of Mines	Resource data base
Fish and Game Commission	Resource data base
Department of Health	Environmental data (air, water, solid waste)
Department of Lands	Maps (land and mineral ownership, land use, land cover)
Department of Economic Planning and Development	Demographic data and economic forecasts
Division of Employment Security	Employment data
Department of Highways	Planimetric maps and aerial photographs
C. REGIONAL SOURCES	
(e.g., Missouri River Basin Commission: Applachian Regional Commission; Tennessee Valley Authority; Old West Regional Commission; mercer County Energy Dev. Board)	Research and demonstration programs; maps (land use and land cover); aerial photographs; bibliographic retrieval system; planning assistance
D. LOCAL SOURCES	
Planning Agency	Land use guidelines; master plan; demographic and economic data
Soil Conservation Service	Soil surveys, aerial photographs; handbooks; advice on erosion and sediment control and vegetation
E. INDUSTRY SOURCES	
(e.g., Basin Electric Power Coop, Montana Dakota Utilities)	Demographic data; socioeconomic impact analysis
F. INSTITUTIONAL SOURCES	
Libraries (local public, universities, state, governmental agencies)	Technical reports; government documents; data; bibliographic retrieval systems
Universities	Extension service
G. COMMERCIAL	
Consultants	Project assistance
Computer Science firms	Bibliographic retrieval system; data information systems
Photogrammetric firms	Aerial photographs; remote sensing

FACTORS INFLUENCING POST MINING LANDUSE

Landuse planning is predominantly a function of governmental agencies concerned with guiding growth and preventing landuse conflicts. This type of planning is known as comprehensive planning. As stricter environmental control has developed, however, surface mine operators have had to devote greater attention to developing suitable postmining landuse plans. The preparation of a land use plan for a specific site that meets certain environmental standards and compliments surrounding land uses is termed as site planning. The application of site planning principles is essential to productive and beneficial use of reclaimed land. However, conditions vary so greatly from region to region that any site planning process must allow maximum amount of flexibility to be practical in all cases. The planning methodology described herein was freely adapted from Ramani and Sweigard (1983, a, b, c, d). It's purpose is to establish basic concepts in landuse planning and to provide the necessary background for the present work on available methodologies and various approaches. Approaches have been taken to the classification of landuse factors. These factors are classified as either natural or cultural. Natural landuse factors include, atleast, the geomorphic, climatic, hydrologic, stratigraphic and soil characteristics of a site. Although these characteristics can be altered by man, they were intially the results of nature. Cultural factors include all of those geographic, demographic, and economic characteristics that are the results of man's activities. The natural and cultural factors are listed in Table 2 and 3, respectively. The relative importance of

Table 2. Relative Importance of Natural Factors as Determinants of Land Use Stability (Clar and Ramani, 1981)

Relative Importance of Natural Factors as Determinants of Land Use Suitability (Clar and Ramani, 1981)

Natural Factors	Land Use Types						
	Forestry and Wildlife	Recreational	Agricultural	Residential	Institutional	Commercial	Industrial
Topographic Relief	2*	3	1	2	2	2	2
Slope	1	3	1	2	1	1	1
Altitude	2	3	2	3	3	3	3
Exposure	2	3	2	3	3	3	3
Drainage	1	3	1	1	1	1	1
Temperature	1	2	1	3	3	3	3
Precipitation	1	2	1	3	3	3	3
Consolidated Overburden	2	2	1	2	3	3	3
Soils							
-Agricultural Properties	2	2	1	3	3	3	3
-Engineering Properties	3	3	2	1	1	1	1

*1 - Factor has high degree of influence on suitability of site for that particular land use.

2 - Factor has moderate degree of influence.

3 - Factor has low degree of influence.

Table 3. Relative Importance of Cultural Factors as Determinants of Land Use Stability (Clar and Ramani, 1981).

Relative Importance of Natural Factors as Determinants of Land Use Suitability (Clar and Ramani, 1981)

Cultural Factors	and Use Types						
	Forestry and Wildlife	Recreational	Agricultural	Residential	Institutional	Commercial	Industrial
Location	3*	1	2	1	1	1	1
Accessibility	3	2	3	1	1	1	1
Size and Shape of Site	3	3	1	2	2	1	1
Surrounding Land Uses	3	2	3	1	1	1	3
Land Ownership	3	2	3	2	2	2	2
Type and Intensity of Use	3	3	3	1	2	1	2
Population Characteristics	3	2	2	1	2	1	2
Regulatory Constraints	3	2	2	1	1	1	1
Company Attitudes	2	2	2	1	1	1	1

*1 - Factor has high degree of influence on suitability of site for that particular land use.

2 - Factor has moderate degree of influence.

3 - Factor has low degree of influence.

natural versus cultural factors in determining land use can be argued. In general, however, it seems that natural factors are most significant in determining the suitability of a site for a particular land use and the cultural factors determines the practicality of a given use. While both types of factors are important, final decisions are often based upon cultural factors after a review of natural factors has eliminated the unsuitable uses.

Land use factors are not all of equal importance in determining postmining land use. Likewise, a factor that is extremely important for one type of landuse may be relatively unimportant with regards to a different landuse. An estimate is made concerning the relative importance of each factor in determining the suitability of several land uses. The land use types considered here: forestry, wildlife, recreational, agricultural, residential, institutional, commercial, and industrial use.

Due to the lack of a suitable technique lands use plans are rarely based upon structured decisions. Data collection may be conducted in a rigorous manner and certain analyses may be performed on the data, however, the decision to put the land to a specific use is finally based upon the intuitive judgement of one or several individual. One other reason is that land use decisions remains unstructured is simply the number of factors that potentially influence land use. Pugliese and others (1979) have identified at-least 135 environmental characteristics that can have an impact on post mining landuse. The inclusion or exclusion of certain factors by the planer may influence the land use decision. Also, the relative importance of various factors mentioned here are not exhaustive, they are presented as the major factors that determines the use of surface mined land. It should also be recognized that several of these landuse factors are general categories and could be subdivided into many more minor categories.

The preliminary studies and data collection of the generic planning process mentioned earlier is typically the most expensive and time consuming. Mining companies can exercise discretion in determining what information will be pertinent to their post-mining land use plans but much of the environmental baseline data collection is mandated by Part 779 of the parmanent Regulatory Program. The list of baseline data collection specifications which can be required by the Regulatory authority includes the following:

- geology description
- ground water information
- alternative water supply information
- climatological information
- vegitation information
- fish and wildlife resource information
- soil resource information
- landuse information

In addition to the environmental baseline data and premining landuse studies, the mine planner should collect information and analyze aspects of local economy, population trends, transportation network, and location of public utilities. Because of the expense involved, the preliminary studies and data collection should be planned very carefully so that only pertinent information are gathered. Besides meeting the regulatory requirements, it should be emphasized that the data gathered will be used later in the planning process to help evaluate alternate post mining landuse plans.

The definition of local goal and objectives is basically a function of the public planners. This is an area where the mine planner should interact with local and regional planners to insure that the post mining landuse plan is compatiable with overall plan of the area. In addition to satisfying local goals and objectives, the mining company may wish to establish other goals for itself such as improving the value of the land or promoting good public relations. Ideally, comprehensive planning should precede site planning process. It is not uncommon, however, for site planning to be conducted in an area which has no comprehensive plan. In the absence of formalized goals and objectives by a planning agency, the mine planner can either rely solely on company goals or make a limited survey of goals by contacting the community and local elected officials.

A number of evaluation techniques are available to the site planner for evaluating alternate landuse plans. These techniques can be divided into three categories: economic analysis, environmental impact analysis, and local impact analysis. Once again, care should be exercised in selecting one or methodologies since complex evaluations can result in considerable expense. The level of effort should be proportional to the size of operation and the potential for creating benefits. Economic analysis of alternate land uses can range from discussions with informed individuals to detailed cost- benefit accounting or estimation of returns through increased land value. Although traditional engineering analysis alone would not satisfy all evaluation requirements, they have a place and should be considered along with environmental and local imapct analyses. There is also a range of complexity in evaluating environmental and social impacts starting with a checklists which qualitatively address the various impacts of various landuse plans.

Evaluation criteria should be selected and weighted based upon the evaluation methodologies chosen. A combination of criteria has been which reflects the economic, environmental, and social aspects of the plans is desirable. Economic criteria amy include a minimum profitability or benefit cost ratio which is less than unity. Environmental criteria should be directed towards meeting various performance standards. Social impact criteria are most difficult to establish since social impacts are difficult to quantify. Various techniques such as cost of effectiveness analysis have been developed, however, which attempt to subjectively quantify social impacts. Minimum standards can be set based upon one of these techniques.

After the evaluation methodologies and criteria have been selected, several site plans can be proposed for the reclaimed area. Certainly, one alternative to be considered is returning the land to its pre-mining use. Only viable scenarios should be evaluated. Plans which are unacceptable for economic environmental, or social reasons need not be subjected to a detailed evaluation process. Since the premining conditions and postmining landuse plans most likely combine two or more land uses, the number of alternatives that can be generated is limitless. The alternative scenarios should be kept to a managable number. In practice, by the time mine planners begins formulating alternate landuse plans it should be fairly obvious that certain landuses are unacceptable and certain others are potentially acceptable.

Once the alternate scenarios have been completed, they are subjected to the evaluation methodologies selected earlier. The result of this process is the selection of the desired alternative either by elimination of less desirable plans or ranking all the alternatives in order of acceptability. The final step of the process is reviewed by company management and regulatory personnel. In addition to the review by the mine planner and company management up until the time that the plan is implemented to insure that the landuse plan is still workable. Unforeseen changes in the economic, environmental or social conditions, may require modification of the landuse plan before it can be implemented.

In this report a proposed model for evaluating postmining landuse alternative has been developed and described in the next chapter. Although the selection of landuse alternative utilizes a mathematical model, the human element and interaction remains a basic component in the decision making process. The approach described can simultaneously handle both qualitative and quantitative information and take into account viewpoints of the different interest groups.

CHAPTER III

FUZZY SET METHODOLOGIES FOR EVALUATION OF POSTMINING LANDUSE ALTERNATIVES

From the preceding discussions, one may very well recognize that the landuse decisions are very complex. The large number of variables to be considered in the analyses, the impact of landuse decisions on such matters as jobs, housing, taxes and the socio-political natures of the issues are the principal reasons.

Mention has been made of a variety of methods of evaluating alternative landuse plans, for instance by means of cost-benefit analysis or cost-effective analysis. The basic problem inherent in the use of cost benefit analysis is the fact that the valuation of a landuse plan or an alternative must be carried out with respect to a single monetary unidimensional criterion. All effects of an alternative plan have to be projected into one single monetary dimension. There is a vast amount of interdependencies among the effects of a landuse plan, the calculation of the benefits of all these separate effects is very difficult. More importantly, intangibles can hardly be assessed in economic terms within a cost-benefit framework since a monetary evaluation of intangibles is generally impossible or otherwise arbitary or biased.

Cost effectiveness analysis, on the other hand, attempts to establish whether a certain landuse planning alternative is worth its cost. Given the cost of a series of alternative landuse plans, one has to determine which alternative is most cost effective in attaining a certain set of goals. By means of a cost effectiveness chart, more insight is obtained into the relative effectiveness of each alternative landuse plan separately. In effect, the cost-effectiveness procedure studies the way in which an 'a prior' determined set of goals is attained; the selection criteria is based on the determination ot that alternative plan which possesses the highest total effectiveness.

Once of the basic problems in cost-effectiveness analysis is the specification of the set of goals to be attained and of the marginal rate of substitution between these goals. The specification and evaluation of factors involved essentially the same problems as that in cost benefit analysis, albeit that the confrontation of effects and their evaluation are postponded to a later stage. In spite of some refinements with respect to cost-benefit analysis, the essential difficulty in any decision procedure, such as the multiplicity of values, is not completely solved by cost-effectiveness analysis.

Recently, many attempts have been undertaken to develop new evaluation methods which are more based on adequately on the multidimensionality of a decision problem (including the intangibles). These methods, which are based on weighting systems for the decision criteria are generally denoted as multiple-criteria methods. The general feature ot these methods, including goal achievement method (Hill, 1968; Hill and Tzamir; 1974), Fuzzey set analysis (Saaty, 1974; Zadeh, 1965; Bellmand and Zadeh, 1970; Tanaka, Okuda and Asai, 1974) is that the project impacts are not necessarily transformed into monetary units. Instead a weighting scheme is developed which reflects the relative importance of each of the decision criteria. The objectives are expressed both in qualitative and quantitative terms. The fuzzy set analysis, however, sets a framework that provides a natural way of dealing with problems in which the sources of impression in the absence of sharply defined criteria can be analyzed very effectively.

In this section one of the operational techniques for decision making, in fuzzy set analysis namely using the method of scaling ratio and positive pairwise comparison matrix (Saaty, 1977) will be briefly described. A detailed review of the mathematics of the fuzzy set is contained elsewhere (Zadeh, 1965; Bellmand and Zadeh, 1970; Saaty, 1974; Saaty, 1977; Tanaka, Okuda and Asai, 1974).

THE MATHEMATICS OF PAIRWISE COMPARISON

The methods of paired comparisons has great parctical simplicity. It has been used extensively in experimental situations where subjective judgements lend to qualitative comparative responses, situations where quantification through measurement is difficult or illusory. Development of paired comparison techniques for preference assessment is relatively recent and has taken place primarily within the past ten to fifteen years.

The following presentation of the general mathematical ideas behind pairwise comparisons is freely adapted from Saaty (1977). It's purpose is to establish basic concepts, terminology and notation for later use in describing the methods used in this research.

Consider n items pairs according to their relative weights which are assumed to belong to a ratio scale. Denote the items by $A_1, \ldots, A_n$ and their actual weights by $w_1, \ldots, w_n$. The pairwise comparisons may be represented by a matrix as follows where each matrix element $a_{ij} = w_i/w_j$

$$A = \begin{array}{c|cccc} & A_1 & A_2 & \cdots & A_n \\ \hline A_1 & w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ A_2 & w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & & & \vdots \\ A_n & w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{array}$$

This matrix consists entirely of positive entires and satisfies the reciprocal property, $a_{ij} = 1/a_{ji}$ (for all i and j). Since the reciprocal property holds, the matrix is completely determined by specifying a set of only $(n^2-n)/2$ elements such that: 1) none are on the main diagonal (these are by definition equal to 1.0); and 2) no two of which are reciprocal elements (i.e. both a_{ij} and a_{ji} are not members of the set). It is further true that if the actual weights, w_i, are known, the matrix satisfies the cardinal consistency property (CCP), $a_{ij}a_{jk} = a_{ik}$ and is called consistent. Under CCP, given any row of A, one can determine all other entries by this relation. In fact, it can be shown that under CCP the entire matrix can be determined by n-1 ratios of w_i/w_j where 1) $i \neq j$ and; 2) no two of which are reciprocal elements.

Now if we multiply this matrix by the transpose of the vector, $\bar{w}_T = (w_1,\ldots,w_n)$, we obtain the vector $\bar{n}w$. Therefore:

$$A\bar{w} = n\bar{w}$$

If the actual weights, $\bar{w}$, are unknown but we have the matrix A and we want to recover $\bar{w}$, we can solve the system of equations:

$$(A - nI)\bar{w} = \bar{0}$$

in the unknown $\bar{w}$. This has a non-zero solution if and only if n is an eigenvalue of A, i.e. it is a root of the characteristic equation of A. But A has a rank of 1 since, as pointed out earlier, every row is a constant multiple of the first row. Thus all the eigenvalues of A are zero except one which we call $\lambda_{max} = n$. The vector of weights, $\bar{w}$, is the eignevector corresponding to this eigenvalue.

Suppose that we are dealing with a situation in which the scale of measurements for the actual weights, $\bar{w}$ is not known but we have estimates of the ratios in the matrix. In this case cordinal consistency of the form, Ai > Aj, Aj > Ak imply Ai > Ak (where the Ai are in the rows of A). This situation is a fairly realistic representation of that in preference comparison. Once the $(n^2-n)/2$ pairwise comparisons are made and that the reciprocal property aij = 1/aji be used to fill in all non-diagonal elements of the A matrix. Once this is done the eigenvalue max, and its associated eignevector, $\bar{w}$ are calculated by methods of linear algebra.

EVALUATION OF POST-MINING LAND USE ALTERNATIVES

Since fuzzy set analysis takes account of quantitative and qualitative factors, it was recognized that it may constitute a realistic methodology for assessing various feasible landuse alternatives primarily based on environmental, economical, social and political factors. To illustrate the application of the model, four landuse planning alternatives are chosen, those are considered to be of prime importance in interior Alaska. The other alternatives (Table 4) are derived from these four alternatives.

Table 4: A few selected alternatives in landuse planning in Interior Alaska

	LAND USE PLANNING ALTERNATIVES	SYMBOL
1.	Forestry and Wildlife	A_1
2.	Forestry	A_2
3.	Agricultural Development	A_3
4.	Recreational Development	A_4
5.	Combination of Forestry, Wildlife and Agricultural Development	A_5
6.	Combination of Forestry and Recreational Development	A_6
7.	Combination of Forestry and Agricultural and Recreational Area Development	A_7
8.	Combination of Agricultural and Recreational Area Development	A_8
9.	Combination of Forestry, Wildlife and Recreational Area Deveopment	A_9
10.	Combination of Forestry, Agricultural and Recreational Area Development	A_{10}

We chose a few characteristics or factors that are common to all of the above alternatives. These factors can be listed as follows.

	FACTORS	SYMBOL	
i)	Relief	F1	
ii)	Slope	F2	
iii)	Altitude	F3	
iv)	Drainage	F4	Natural* factors
v)	Exposure	F5	
vi)	Temperature	F6	
vii)	Precipitation	F7	
viii)	Soil characteristics	F8	
ix)	Consolidated overburden	F8	
x)	Location	F10	
xi)	Accessibility	F11	
xii)	Size and shape of the site	F12	Cultural factors*
xiii)	Surrounding land uses	F13	
xiv)	Land ownership	F14	
xv)	Population characteristics	F15	
xvi)	Regulatory constraints	F16	
xvii)	Type and intensity of uses	F17	
xviii)	Water quality	F18	
xix)	Erosion and sedimentation	F19	Legal Factors*
xx)	Slope requirements	F20	
xxi)	Aesthetic values	F21	
xxii)	Economics	F22	Social Factors*
xxiii)	Political	F23	

Using the methodology described in the previous section and using a intensity scale of importance (Table 5) the relative importance of j is determined to find the value of aij in matrix A.

For the problem under consideration, there are twenty four matrixs for which eigenvalues (λ_{max}) and their corresponding eignvectors are to calculated. For this a computer program is being developed which will calculate the values of λ and corresponding eigenvectors. The following tables shows the various interaction matrices for the factors under consideration.

The matrix formed by the eigenvector provided in Table 30 (Matrix #25) of size (10 x 23) is multiplied by the transpose of the vector obtained from the eigenvector corresponding to λ_{max}, from Table 6 (matrix #1) of size (23 x 1). This gives a resulting column matrix of size (10 x 1). The resulting matrix gives the corresponding values for each alternative starting from A to A_{10}.

The alternatives can be ranked accordingly from the highest values to the lowest value. We choose that land use planning for which the alternative A_i (i = 1, 2, 3, ...10) has the highest value and is ranked first.

Table 5: The Scale and Its Description (Saaty, 1977)

Intensity of importance	Definition	Explanation
1*	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience & judgement slightly favor one activity over another
5	Essential or strong importance	Experience & judgement strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance is demonstrated in practice.
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
-2, 4, 6, 8	Intermediate values between the two adjacent judgements	When compromise is needed
Reciprocals of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

Table 6: Comparison of factors with respect to overall satisfaction with the landuse planning

MATRIX #1

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23
F1	1	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}	a_{19}	a_{110}	a_{111}	a_{112}	a_{113}	a_{114}	a_{115}	a_{116}	a_{117}	a_{118}	a_{119}	a_{120}	a_{121}	a_{122}	a_{123}
F2	a_{21}	pl	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}	a_{29}	a_{210}	a_{211}	a_{212}	a_{213}	a_{214}	a_{215}	a_{216}	a_{217}	a_{218}	a_{219}	a_{220}	a_{221}	a_{222}	a_{223}
F3	a_{31}	a_{32}	1	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}	a_{39}	a_{310}	a_{311}	a_{312}	a_{313}	a_{314}	a_{315}	a_{316}	a_{317}	a_{318}	a_{319}	a_{320}	a_{321}	a_{322}	a_{323}
F4	a_{41}	a_{42}	a_{43}	1	a_{45}	a_{46}	a_{47}	a_{48}	a_{49}	a_{410}	a_{411}	a_{412}	a_{413}	a_{414}	a_{415}	a_{416}	a_{417}	a_{418}	a_{419}	a_{420}	a_{421}	a_{422}	a_{423}
F5	a_{51}	a_{52}	a_{53}	a_{54}	1	a_{56}	a_{57}	a_{58}	a_{59}	a_{510}	a_{511}	a_{512}	a_{513}	a_{514}	a_{515}	a_{516}	a_{517}	a_{518}	a_{519}	a_{520}	a_{521}	a_{522}	a_{523}
F6	a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	1	a_{67}	a_{68}	a_{69}	a_{610}	a_{611}	a_{612}	a_{613}	a_{614}	a_{615}	a_{616}	a_{617}	a_{618}	a_{619}	a_{620}	a_{621}	a_{622}	a_{623}
F7	a_{71}	a_{72}	a_{73}	a_{74}	a_{75}	a_{76}	1	a_{78}	a_{79}	a_{710}	711	a_{712}	a_{713}	a_{714}	a_{715}	a_{716}	a_{717}	a_{718}	a_{719}	a_{720}	a_{721}	a_{722}	a_{723}
F8	a_{81}	a_{82}	a_{83}	a_{84}	a_{85}	a_{86}	a_{87}	1	a_{89}	a_{810}	a_{811}	a_{812}	a_{813}	a_{814}	a_{815}	a_{816}	a_{817}	a_{818}	a_{819}	a_{820}	a_{821}	a_{822}	a_{823}
F9	a_{91}	a_{92}	a_{93}	a_{94}	a_{95}	a_{96}	a_{97}	a_{98}	1	a_{910}	a_{911}	a_{912}	a_{913}	a_{914}	a_{915}	a_{916}	a_{917}	a_{918}	a_{919}	a_{920}	a_{921}	a_{922}	a_{923}
F10	a_{101}	a_{102}	a_{103}	a_{104}	a_{105}	a_{106}	a_{107}	a_{108}	a_{109}	1	a_{1011}	a_{1012}	a_{1013}	a_{1014}	a_{1015}	a_{1016}	a_{1017}	a_{1018}	a_{1019}	a_{1020}	a_{1021}	a_{1022}	a_{1023}
F11	a_{111}	a_{112}	a_{113}	a_{114}	a_{115}	a_{116}	a_{117}	a_{118}	a_{119}	a_{1110}	1	a_{1112}	a_{1113}	a_{1114}	a_{1115}	a_{1116}	a_{1117}	a_{1118}	a_{1119}	a_{1120}	a_{1121}	a_{1122}	a_{1123}
F12	a_{121}	a_{122}	a_{123}	a_{124}	a_{125}	a_{126}	a_{127}	a_{128}	a_{129}	a_{1210}	a_{1211}	1	a_{1213}	a_{1214}	a_{1215}	a_{1216}	a_{1217}	a_{1218}	a_{1219}	a_{1220}	a_{1221}	a_{1222}	a_{1223}
F13	a_{131}	a_{132}	a_{133}	a_{134}	a_{135}	a_{136}	a_{137}	a_{138}	a_{139}	a_{1310}	a_{1311}	a_{1313}	1	a_{1314}	a_{1315}	a_{1316}	a_{1317}	a_{1318}	a_{1319}	a_{1320}	a_{1321}	a_{1322}	a_{1323}
F14	a_{141}	a_{142}	a_{143}	a_{144}	a_{145}	a_{146}	a_{147}	a_{148}	a_{149}	a_{1410}	a_{1411}	a_{1413}	a_{1414}	1	a_{1415}	a_{1416}	a_{1417}	a_{1418}	a_{1419}	a_{1420}	a_{1421}	a_{1422}	a_{1423}
F15	a_{151}	a_{152}	a_{153}	a_{154}	a_{155}	a_{156}	a_{157}	a_{158}	a_{159}	a_{1510}	a_{1511}	a_{1513}	a_{1514}	a_{1515}	1	a_{1516}	a_{1517}	a_{1518}	a_{1519}	a_{1520}	a_{1521}	a_{1522}	a_{1523}
F16	a_{161}	a_{162}	a_{163}	a_{164}	a_{165}	a_{166}	a_{167}	a_{168}	a_{169}	a_{1610}	a_{1611}	a_{1613}	a_{1614}	a_{1615}	a_{1616}	1	a_{1617}	a_{1618}	a_{1619}	a_{1620}	a_{1621}	a_{1622}	a_{1623}
F17	a_{171}	a_{172}	a_{173}	a_{174}	a_{175}	a_{176}	a_{177}	a_{178}	a_{179}	a_{1720}	a_{1711}	a_{1713}	a_{1714}	a_{1715}	a_{1716}	a_{1717}	1	a_{1718}	a_{1719}	a_{1720}	a_{1721}	a_{1722}	a_{1723}
F18	a_{181}	a_{182}	a_{183}	a_{184}	a_{185}	a_{186}	a_{187}	a_{188}	a_{189}	a_{1810}	a_{1811}	a_{1813}	a_{1814}	a_{1815}	a_{1816}	a_{1817}	a_{1818}	1	a_{1819}	a_{1820}	a_{1821}	a_{1822}	a_{1823}
F19	a_{191}	a_{192}	a_{193}	a_{194}	a_{195}	a_{196}	a_{197}	a_{198}	a_{199}	a_{1910}	a_{1911}	a_{1913}	a_{1914}	a_{1915}	a_{1916}	a_{1917}	a_{1918}	a_{1919}	1	a_{1920}	a_{1921}	a_{1922}	a_{1923}
F20	a_{201}	a_{202}	a_{203}	a_{204}	a_{205}	a_{206}	a_{207}	a_{208}	a_{209}	a_{2010}	a_{2011}	a_{2013}	a_{2014}	a_{2015}	a_{2016}	a_{2017}	a_{2018}	a_{2019}	a_{2020}	1	a_{2021}	a_{2022}	a_{2023}
F21	a_{211}	a_{212}	a_{213}	a_{214}	a_{215}	a_{216}	a_{217}	a_{218}	a_{219}	a_{2110}	a_{2111}	a_{2113}	a_{2114}	a_{2115}	a_{2116}	a_{2117}	a_{2118}	a_{2119}	a_{2120}	a_{2121}	1	a_{2122}	a_{2123}
F22	a_{221}	a_{222}	a_{223}	a_{224}	a_{225}	a_{226}	a_{227}	a_{228}	a_{229}	a_{2210}	a_{2211}	a_{2213}	a_{2214}	a_{2215}	a_{2216}	a_{2217}	a_{2218}	a_{2219}	a_{2220}	a_{2221}	a_{2222}	1	a_{2223}
F23	a_{231}	a_{232}	a_{233}	a_{234}	a_{235}	a_{236}	a_{237}	a_{238}	a_{239}	a_{2310}	a_{2311}	a_{2313}	a_{2314}	a_{2315}	a_{2316}	a_{2317}	a_{2318}	a_{2319}	a_{2320}	a_{2321}	a_{2322}	a_{2323}	1

Table 7: Interaction Matrix of the Factor "Relief" for various landuse alternatives

MATRIX NO: 2

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	b_{12}	b_{13}	b_{14}	b_{15}	b_{16}	b_{17}	b_{18}	b_{19}	b_{110}
A2	b_{21}	1	b_{23}	b_{24}	b_{25}	b_{26}	b_{27}	b_{28}	b_{29}	b_{210}
A3	b_{31}	b_{32}	1	b_{34}	b_{35}	b_{36}	b_{37}	b_{38}	b_{39}	b_{310}
A4	b_{41}	b_{42}	b_{43}	1	b_{45}	b_{46}	b_{47}	b_{48}	b_{49}	b_{410}
A5	b_{51}	b_{52}	b_{53}	b_{54}	1	b_{56}	b_{57}	b_{58}	b_{59}	b_{510}
A6	b_{61}	b_{62}	b_{63}	b_{64}	b_{65}	1	b_{67}	b_{68}	b_{69}	b_{610}
A7	b_{71}	b_{72}	b_{73}	b_{74}	b_{75}	b_{76}	1	b_{78}	b_{79}	b_{710}
A8	b_{81}	b_{82}	b_{83}	b_{84}	b_{85}	b_{86}	b_{87}	1	b_{89}	b_{810}
A9	b_{91}	b_{92}	b_{93}	b_{94}	b_{95}	b_{96}	b_{97}	b_{98}	1	b_{910}
A10	b_{101}	b_{102}	b_{103}	b_{104}	b_{105}	b_{106}	b_{107}	b_{108}	b_{109}	1

Table 8: Interaction Matrix of the Factor "Slope" for Various Landuse Alternatives

MATRIX NO: 3

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{110}
A2	C_{21}	1	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{210}
A3	C_{31}	C_{32}	1	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}	C_{310}
A4	C_{41}	C_{42}	C_{43}	1	C_{45}	C_{46}	C_{47}	C_{48}	C_{49}	C_{410}
A5	C_{51}	C_{52}	C_{53}	C_{54}	1	C_{56}	C_{57}	C_{58}	C_{59}	C_{510}
A6	C_{61}	C_{62}	C_{63}	C_{64}	C_{65}	1	C_{67}	C_{68}	C_{69}	C_{610}
A7	C_{71}	C_{72}	C_{73}	C_{74}	C_{75}	C_{76}	1	C_{78}	C_{79}	C_{710}
A8	C_{81}	C_{82}	C_{83}	C_{84}	C_{85}	C_{86}	C_{87}	1	C_{89}	C_{810}
A9	C_{91}	C_{92}	C_{93}	C_{94}	C_{95}	C_{96}	C_{97}	C_{98}	1	C_{910}
A10	C_{101}	C_{102}	C_{103}	C_{104}	C_{105}	C_{106}	C_{107}	C_{108}	C_{109}	1

Table 9: Interaction Matrix of the Factor "Altitude" for various landuse alternatives

MATRIX NO: 4

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	d_{12}	d_{13}	d_{14}	d_{15}	d_{16}	d_{17}	d_{18}	d_{19}	d_{110}
A2	d_{21}	1	d_{23}	d_{24}	d_{25}	d_{26}	d_{27}	d_{28}	d_{29}	d_{210}
A3	d_{31}	d_{32}	1	d_{34}	d_{35}	d_{36}	d_{37}	d_{38}	d_{39}	d_{310}
A4	d_{41}	d_{42}	d_{43}	1	d_{45}	d_{46}	d_{47}	d_{48}	d_{49}	d_{410}
A5	d_{51}	d_{52}	d_{53}	d_{54}	1	d_{56}	d_{57}	d_{58}	d_{59}	d_{510}
A6	d_{61}	d_{62}	d_{63}	d_{64}	d_{65}	1	d_{67}	d_{68}	d_{69}	d_{610}
A7	d_{71}	d_{72}	d_{73}	d_{74}	d_{75}	d_{76}	1	d_{78}	d_{79}	d_{710}
A8	d_{81}	d_{82}	d_{83}	d_{84}	d_{85}	d_{86}	d_{87}	1	d_{89}	d_{810}
A9	d_{91}	d_{92}	d_{93}	d_{94}	d_{95}	d_{96}	d_{97}	d_{98}	1	d_{910}
A10	d_{101}	d_{102}	d_{103}	d_{104}	d_{105}	d_{106}	d_{107}	d_{108}	d_{109}	1

Table 10: Interaction Matrix of the Factor "Drainage" for various landuse alternatives

MATRIX NO: 5

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	e_{12}	e_{13}	e_{14}	e_{15}	e_{16}	e_{17}	e_{18}	e_{19}	e_{110}
A2	e_{21}	1	e_{23}	e_{24}	e_{25}	e_{26}	e_{27}	e_{28}	e_{29}	e_{210}
A3	e_{31}	e_{32}	1	e_{34}	e_{35}	e_{36}	e_{37}	e_{38}	e_{39}	e_{310}
A4	e_{41}	e_{42}	e_{43}	1	e_{45}	e_{46}	e_{47}	e_{48}	e_{49}	e_{410}
A5	e_{51}	e_{52}	e_{53}	e_{54}	1	e_{56}	e_{57}	e_{58}	e_{59}	e_{510}
A6	e_{61}	e_{62}	e_{63}	e_{64}	e_{65}	1	e_{67}	e_{68}	e_{69}	e_{610}
A7	e_{71}	e_{72}	e_{73}	e_{74}	e_{75}	e_{76}	1	e_{78}	e_{79}	e_{710}
A8	e_{81}	e_{82}	e_{83}	e_{84}	e_{85}	e_{86}	e_{87}	1	e_{89}	e_{810}
A9	e_{91}	e_{92}	e_{93}	e_{94}	e_{95}	e_{96}	e_{97}	e_{98}	1	e_{910}
A10	e_{101}	e_{102}	e_{103}	e_{104}	e_{105}	e_{106}	e_{107}	e_{108}	e_{109}	1

Table 11: Interaction Matrix of the Factor "Exposure" for various landuse alternatives

MATRIX NO: 6

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	f_{12}	f_{13}	f_{14}	f_{15}	f_{16}	f_{17}	f_{18}	f_{19}	f_{110}
A2	f_{21}	1	f_{23}	f_{24}	f_{25}	f_{26}	f_{27}	f_{28}	f_{29}	f_{210}
A3	f_{31}	f_{32}	1	f_{34}	f_{35}	f_{36}	f_{37}	f_{38}	f_{39}	f_{310}
A4	f_{41}	f_{42}	f_{43}	1	f_{45}	f_{46}	f_{47}	f_{48}	f_{49}	f_{410}
A5	f_{51}	f_{52}	f_{53}	f_{54}	1	f_{56}	f_{57}	f_{58}	f_{59}	f_{510}
A6	f_{61}	f_{62}	f_{63}	f_{64}	f_{65}	1	f_{67}	f_{68}	f_{69}	f_{610}
A7	f_{71}	f_{72}	f_{73}	f_{74}	f_{75}	f_{76}	1	f_{78}	f_{79}	f_{710}
A8	f_{81}	f_{82}	f_{83}	f_{84}	f_{85}	f_{86}	f_{87}	1	f_{89}	f_{810}
A9	f_{91}	f_{92}	f_{93}	f_{94}	f_{95}	f_{96}	f_{97}	f_{98}	1	f_{910}
A10	f_{101}	f_{102}	f_{103}	f_{104}	f_{105}	f_{106}	f_{107}	f_{108}	f_{109}	1

Table 12: Interaction Matrix of the Factor "Temperature" for various landuse alternatives

MATRIX NO: 7

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	g_{12}	g_{13}	g_{14}	g_{15}	g_{16}	g_{17}	g_{18}	g_{19}	g_{110}
A2	g_{21}	1	g_{23}	g_{24}	g_{25}	g_{26}	g_{27}	g_{28}	g_{29}	g_{210}
A3	g_{31}	g_{32}	1	g_{34}	g_{35}	g_{36}	g_{37}	g_{38}	g_{39}	g_{310}
A4	g_{41}	g_{42}	g_{43}	1	g_{45}	g_{46}	g_{47}	g_{48}	g_{49}	g_{410}
A5	g_{51}	g_{52}	g_{53}	g_{54}	1	g_{56}	g_{57}	g_{58}	g_{59}	g_{510}
A6	g_{61}	g_{62}	g_{63}	g_{64}	g_{65}	1	g_{67}	g_{68}	g_{69}	g_{610}
A7	g_{71}	g_{72}	g_{73}	g_{74}	g_{75}	g_{76}	1	g_{78}	g_{79}	g_{710}
A8	g_{81}	g_{82}	g_{83}	g_{84}	g_{85}	g_{86}	g_{87}	1	g_{89}	g_{810}
A9	g_{91}	g_{92}	g_{93}	g_{94}	g_{95}	g_{96}	g_{97}	g_{98}	1	g_{910}
A10	g_{101}	g_{102}	g_{103}	g_{104}	g_{105}	g_{106}	g_{107}	g_{108}	g_{109}	1

Table 13: Interaction Matrix of the Factor "Precipitation for various landuse alternatives

MATRIX NO: 8

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	h_{12}	h_{13}	h_{14}	h_{15}	h_{16}	h_{17}	h_{18}	h_{19}	h_{110}
A2	h_{21}	1	h_{23}	h_{24}	h_{25}	h_{26}	h_{27}	h_{28}	h_{29}	h_{210}
A3	h_{31}	h_{32}	1	h_{34}	h_{35}	h_{36}	h_{37}	h_{38}	h_{39}	h_{310}
A4	h_{41}	h_{42}	h_{43}	1	h_{45}	h_{46}	h_{47}	h_{48}	h_{49}	h_{410}
A5	h_{51}	h_{52}	h_{53}	h_{54}	1	h_{56}	h_{57}	h_{58}	h_{59}	h_{510}
A6	h_{61}	h_{62}	h_{63}	h_{64}	h_{65}	1	h_{67}	h_{68}	h_{69}	h_{610}
A7	h_{71}	h_{72}	h_{73}	h_{74}	h_{75}	h_{76}	1	h_{78}	h_{79}	h_{710}
A8	h_{81}	h_{82}	h_{83}	h_{84}	h_{85}	h_{86}	h_{87}	1	h_{89}	h_{810}
A9	h_{91}	h_{92}	h_{93}	h_{94}	h_{95}	h_{96}	h_{97}	h_{98}	1	h_{910}
A10	h_{101}	h_{102}	h_{103}	h_{104}	h_{105}	h_{106}	h_{107}	h_{108}	h_{109}	1

Table 14: Interaction Matrix of the Factor "Soil characteristics" for various landuse alternatives

MATRIX NO: 9

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	i_{12}	i_{13}	i_{14}	i_{15}	i_{16}	i_{17}	i_{18}	i_{19}	i_{110}
A2	i_{21}	1	i_{23}	i_{24}	i_{25}	i_{26}	i_{27}	i_{28}	i_{29}	i_{210}
A3	i_{31}	i_{32}	1	i_{34}	i_{35}	i_{36}	i_{37}	i_{38}	i_{39}	i_{310}
A4	i_{41}	i_{42}	i_{43}	1	i_{45}	i_{46}	i_{47}	i_{48}	i_{49}	i_{410}
A5	i_{51}	i_{52}	i_{53}	i_{54}	1	i_{56}	i_{57}	i_{58}	i_{59}	i_{510}
A6	i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	1	i_{67}	i_{68}	i_{69}	i_{610}
A7	i_{71}	i_{72}	i_{73}	i_{74}	i_{75}	i_{76}	1	i_{78}	i_{79}	i_{710}
A8	i_{81}	i_{82}	i_{83}	i_{84}	i_{85}	i_{86}	i_{87}	1	i_{89}	i_{810}
A9	i_{91}	i_{92}	i_{93}	i_{94}	i_{95}	i_{96}	i_{97}	i_{98}	1	i_{910}
A10	i_{101}	i_{102}	i_{103}	i_{104}	i_{105}	i_{106}	i_{107}	i_{108}	i_{109}	1

Table 15: Interaction Matrix of the Factor "Consolidated Overburden" for various landuse alternatives

MATRIX NO: 10

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	j_{12}	j_{13}	j_{14}	j_{15}	j_{16}	j_{17}	j_{18}	j_{19}	j_{110}
A2	j_{21}	1	j_{23}	j_{24}	j_{25}	j_{26}	j_{27}	j_{28}	j_{29}	j_{210}
A3	j_{31}	j_{32}	1	j_{34}	j_{35}	j_{36}	j_{37}	j_{38}	j_{39}	j_{310}
A4	j_{41}	j_{42}	j_{43}	1	j_{45}	j_{46}	j_{47}	j_{48}	j_{49}	j_{410}
A5	j_{51}	j_{52}	j_{53}	j_{54}	1	j_{56}	j_{57}	j_{58}	j_{59}	j_{510}
A6	j_{61}	j_{62}	j_{63}	j_{64}	j_{65}	1	j_{67}	j_{68}	j_{69}	j_{610}
A7	j_{71}	j_{72}	j_{73}	j_{74}	j_{75}	j_{76}	1	j_{78}	j_{79}	j_{710}
A8	j_{81}	j_{82}	j_{83}	j_{84}	j_{85}	j_{86}	j_{87}	1	j_{89}	j_{810}
A9	j_{91}	j_{92}	j_{93}	j_{94}	j_{95}	j_{96}	j_{97}	j_{98}	1	j_{910}
A10	j_{101}	j_{102}	j_{103}	j_{104}	j_{105}	j_{106}	j_{107}	j_{108}	j_{109}	1

Table 16: Interaction Matrix of the Factor "Location" for various landuse alternatives

MATRIX NO: 11

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	k_{12}	k_{13}	k_{14}	k_{15}	k_{16}	k_{17}	k_{18}	k_{19}	k_{110}
A2	k_{21}	1	k_{23}	k_{24}	k_{25}	k_{26}	k_{27}	k_{28}	k_{29}	k_{210}
A3	k_{31}	k_{32}	1	k_{34}	k_{35}	k_{36}	k_{37}	k_{38}	k_{39}	k_{310}
A4	k_{41}	k_{42}	k_{43}	1	k_{45}	k_{46}	k_{47}	k_{48}	k_{49}	k_{410}
A5	k_{51}	k_{52}	k_{53}	k_{54}	1	k_{56}	k_{57}	k_{58}	k_{59}	k_{510}
A6	k_{61}	k_{62}	k_{63}	k_{64}	k_{65}	1	k_{67}	k_{68}	k_{69}	k_{610}
A7	k_{71}	k_{72}	k_{73}	k_{74}	k_{75}	k_{76}	1	k_{78}	k_{79}	k_{710}
A8	k_{81}	k_{82}	k_{83}	k_{84}	k_{85}	k_{86}	k_{87}	1	k_{89}	k_{810}
A9	k_{91}	k_{92}	k_{93}	k_{94}	k_{95}	k_{96}	k_{97}	k_{98}	1	k_{910}
A10	k_{101}	k_{102}	k_{103}	k_{104}	k_{105}	k_{106}	k_{107}	k_{108}	k_{109}	1

Table 17: Interaction Matrix of the Factor "Accessibility" for various landuse alternatives

MATRIX NO: 12

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	l_{12}	l_{13}	l_{14}	l_{15}	l_{16}	l_{17}	l_{18}	l_{19}	l_{110}
A2	l_{21}	1	l_{23}	l_{24}	l_{25}	l_{26}	l_{27}	l_{28}	l_{29}	l_{210}
A3	l_{31}	l_{32}	1	l_{34}	l_{35}	l_{36}	l_{37}	l_{38}	l_{39}	l_{310}
A4	l_{41}	l_{42}	l_{43}	1	l_{45}	l_{46}	l_{47}	l_{48}	l_{49}	l_{410}
A5	l_{51}	l_{52}	l_{53}	l_{54}	1	l_{56}	l_{57}	l_{58}	l_{59}	l_{510}
A6	l_{61}	l_{62}	l_{63}	l_{64}	l_{65}	1	l_{67}	l_{68}	l_{69}	l_{610}
A7	l_{71}	l_{72}	l_{73}	l_{74}	l_{75}	l_{76}	1	l_{78}	l_{79}	l_{710}
A8	l_{81}	l_{82}	l_{83}	l_{84}	l_{85}	l_{86}	l_{87}	1	l_{89}	l_{810}
A9	l_{91}	l_{92}	l_{93}	l_{94}	l_{95}	l_{96}	l_{97}	l_{98}	1	l_{910}
A10	l_{101}	l_{102}	l_{103}	l_{104}	l_{105}	l_{106}	l_{107}	l_{108}	l_{109}	1

Table 18: Interaction Matrix of the Factor "Size and Shape of the Site" for various landuse alternatives

MATRIX NO: 13

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	m_{12}	m_{13}	m_{14}	m_{15}	m_{16}	m_{17}	m_{18}	m_{19}	m_{110}
A2	m_{21}	1	m_{23}	m_{24}	m_{25}	m_{26}	m_{27}	m_{28}	m_{29}	m_{210}
A3	m_{31}	m_{32}	1	m_{34}	m_{35}	m_{36}	m_{37}	m_{38}	m_{39}	m_{310}
A4	m_{41}	m_{42}	m_{43}	1	m_{45}	m_{46}	m_{47}	m_{48}	m_{49}	m_{410}
A5	m_{51}	m_{52}	m_{53}	m_{54}	1	m_{56}	m_{57}	m_{58}	m_{59}	m_{510}
A6	m_{61}	m_{62}	m_{63}	m_{64}	m_{65}	1	m_{67}	m_{68}	m_{69}	m_{610}
A7	m_{71}	m_{72}	m_{73}	m_{74}	m_{75}	m_{76}	1	m_{78}	m_{79}	m_{710}
A8	m_{81}	m_{82}	m_{83}	m_{84}	m_{85}	m_{86}	m_{87}	1	m_{89}	m_{810}
A9	m_{91}	m_{92}	m_{93}	m_{94}	m_{95}	m_{96}	m_{97}	m_{98}	1	m_{910}
A10	m_{101}	m_{102}	m_{103}	m_{104}	m_{105}	m_{106}	m_{107}	m_{108}	m_{109}	1

Table 19: Interaction Matrix of the Factor "Surrounding Land Uses" for various landuse alternatives

MATRIX NO: 14

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	n_{12}	n_{13}	n_{14}	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{110}
A2	n_{21}	1	n_{23}	n_{24}	n_{25}	n_{26}	n_{27}	n_{28}	n_{29}	n_{210}
A3	n_{31}	n_{32}	1	n_{34}	n_{35}	n_{36}	n_{37}	n_{38}	n_{39}	n_{310}
A4	n_{41}	n_{42}	n_{43}	1	n_{45}	n_{46}	n_{47}	n_{48}	n_{49}	n_{410}
A5	n_{51}	n_{52}	n_{53}	n_{54}	1	n_{56}	n_{57}	n_{58}	n_{59}	n_{510}
A6	n_{61}	n_{62}	n_{63}	n_{64}	n_{65}	1	n_{67}	n_{68}	n_{69}	n_{610}
A7	n_{71}	n_{72}	n_{73}	n_{74}	n_{75}	n_{76}	1	n_{78}	n_{79}	n_{710}
A8	n_{81}	n_{82}	n_{83}	n_{84}	n_{85}	n_{86}	n_{87}	1	n_{89}	n_{810}
A9	n_{91}	n_{92}	n_{93}	n_{94}	n_{95}	n_{96}	n_{97}	n_{98}	1	n_{910}
A10	n_{101}	n_{102}	n_{103}	n_{104}	n_{105}	n_{106}	n_{107}	n_{108}	n_{109}	1

Table 20: Interaction Matrix of the Factor "Land Ownership" for various landuse alternatives

MATRIX NO: 15

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	O_{12}	O_{13}	O_{14}	O_{15}	O_{16}	O_{17}	O_{18}	O_{19}	O_{110}
A2	O_{21}	1	O_{23}	O_{24}	O_{25}	O_{26}	O_{27}	O_{28}	O_{29}	O_{210}
A3	O_{31}	O_{32}	1	O_{34}	O_{35}	O_{36}	O_{37}	O_{38}	O_{39}	O_{310}
A4	O_{41}	O_{42}	O_{43}	1	O_{45}	O_{46}	O_{47}	O_{48}	O_{49}	O_{410}
A5	O_{51}	O_{52}	O_{53}	O_{54}	1	O_{56}	O_{57}	O_{58}	O_{59}	O_{510}
A6	O_{61}	O_{62}	O_{63}	O_{64}	O_{65}	1	O_{67}	O_{68}	O_{69}	O_{610}
A7	O_{71}	O_{72}	O_{73}	O_{74}	O_{75}	O_{76}	1	O_{78}	O_{79}	O_{710}
A8	O_{81}	O_{82}	O_{83}	O_{84}	O_{85}	O_{86}	O_{87}	1	O_{89}	O_{810}
A9	O_{91}	O_{92}	O_{93}	O_{94}	O_{95}	O_{96}	O_{97}	O_{98}	1	O_{910}
A10	O_{101}	O_{102}	O_{103}	O_{104}	O_{105}	O_{106}	O_{107}	O_{108}	O_{109}	1

Table 21: Interaction Matrix of the Factor "Population Characteristics" for various landuse alternatives

MATRIX NO: 16

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{110}
A2	P_{21}	1	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{210}
A3	P_{31}	P_{32}	1	P_{34}	P_{35}	P_{36}	P_{37}	P_{38}	P_{39}	P_{310}
A4	P_{41}	P_{42}	P_{43}	1	P_{45}	P_{46}	P_{47}	P_{48}	P_{49}	P_{410}
A5	P_{51}	P_{52}	P_{53}	P_{54}	1	P_{56}	P_{57}	P_{58}	P_{59}	P_{510}
A6	P_{61}	P_{62}	P_{63}	P_{64}	P_{65}	1	P_{67}	P_{68}	P_{69}	P_{610}
A7	P_{71}	P_{72}	P_{73}	P_{74}	P_{75}	P_{76}	1	P_{78}	P_{79}	P_{710}
A8	P_{81}	P_{82}	P_{83}	P_{84}	P_{85}	P_{86}	P_{87}	1	P_{89}	P_{810}
A9	P_{91}	P_{92}	P_{93}	P_{94}	P_{95}	P_{96}	P_{97}	P_{98}	1	P_{910}
A10	P_{101}	P_{102}	P_{103}	P_{104}	P_{105}	P_{106}	P_{107}	P_{108}	P_{109}	1

Table 22: Interaction Matrix of the Factor "Regulatory Constraints" for various landuse alternatives

MATRIX NO: 17

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	q_{12}	q_{13}	q_{14}	q_{15}	q_{16}	q_{17}	q_{18}	q_{19}	q_{110}
A2	q_{21}	1	q_{23}	q_{24}	q_{25}	q_{26}	q_{27}	q_{28}	q_{29}	q_{210}
A3	q_{31}	q_{32}	1	q_{34}	q_{35}	q_{36}	q_{37}	q_{38}	q_{39}	q_{310}
A4	q_{41}	q_{42}	q_{43}	1	q_{45}	q_{46}	q_{47}	q_{48}	q_{49}	q_{410}
A5	q_{51}	q_{52}	q_{53}	q_{54}	1	q_{56}	q_{57}	q_{58}	q_{59}	q_{510}
A6	q_{61}	q_{62}	q_{63}	q_{64}	q_{65}	1	q_{67}	q_{68}	q_{69}	q_{610}
A7	q_{71}	q_{72}	q_{73}	q_{74}	q_{75}	q_{76}	1	q_{78}	q_{79}	q_{710}
A8	q_{81}	q_{82}	q_{83}	q_{84}	q_{85}	q_{86}	q_{87}	1	q_{89}	q_{810}
A9	q_{91}	q_{92}	q_{93}	q_{94}	q_{95}	q_{96}	q_{97}	q_{98}	1	q_{910}
A10	q_{101}	q_{102}	q_{103}	q_{104}	q_{105}	q_{106}	q_{107}	q_{108}	q_{109}	1

Table 23: Interaction Matrix of the Factor "Type and Intensity of Uses" for various landuse alternatives

MATRIX NO: 18

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	r_{12}	r_{13}	r_{14}	r_{15}	r_{16}	r_{17}	r_{18}	r_{19}	r_{110}
A2	r_{21}	1	r_{23}	r_{24}	r_{25}	r_{26}	r_{27}	r_{28}	r_{29}	r_{210}
A3	r_{31}	r_{32}	1	r_{34}	r_{35}	r_{36}	r_{37}	r_{38}	r_{39}	r_{310}
A4	r_{41}	r_{42}	r_{43}	1	r_{45}	r_{46}	r_{47}	r_{48}	r_{49}	r_{410}
A5	r_{51}	r_{52}	r_{53}	r_{54}	1	r_{56}	r_{57}	r_{58}	r_{59}	r_{510}
A6	r_{61}	r_{62}	r_{63}	r_{64}	r_{65}	1	r_{67}	r_{68}	r_{69}	r_{610}
A7	r_{71}	r_{72}	r_{73}	r_{74}	r_{75}	r_{76}	1	r_{78}	r_{79}	r_{710}
A8	r_{81}	r_{82}	r_{83}	r_{84}	r_{85}	r_{86}	r_{87}	1	r_{89}	r_{810}
A9	r_{91}	r_{92}	r_{93}	r_{94}	r_{95}	r_{96}	r_{97}	r_{98}	1	r_{910}
A10	r_{101}	r_{102}	r_{103}	r_{104}	r_{105}	r_{106}	r_{107}	r_{108}	r_{109}	1

Table 24: Interaction Matrix of the Factor "Water Quality" for various landuse alternatives

MATRIX NO: 19

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	s_{12}	s_{13}	s_{14}	s_{15}	s_{16}	s_{17}	s_{18}	s_{19}	s_{110}
A2	s_{21}	1	s_{23}	s_{24}	s_{25}	s_{26}	s_{27}	s_{28}	s_{29}	s_{210}
A3	s_{31}	s_{32}	1	s_{34}	s_{35}	s_{36}	s_{37}	s_{38}	s_{39}	s_{310}
A4	s_{41}	s_{42}	s_{43}	1	s_{45}	s_{46}	s_{47}	s_{48}	s_{49}	s_{410}
A5	s_{51}	s_{52}	s_{53}	s_{54}	1	s_{56}	s_{57}	s_{58}	s_{59}	s_{510}
A6	s_{61}	s_{62}	s_{63}	s_{64}	s_{65}	1	s_{67}	s_{68}	s_{69}	s_{610}
A7	s_{71}	s_{72}	s_{73}	s_{74}	s_{75}	s_{76}	1	s_{78}	s_{79}	s_{710}
A8	s_{81}	s_{82}	s_{83}	s_{84}	s_{85}	s_{86}	s_{87}	1	s_{89}	s_{810}
A9	s_{91}	s_{92}	s_{93}	s_{94}	s_{95}	s_{96}	s_{97}	s_{98}	1	s_{910}
A10	s_{101}	s_{102}	s_{103}	s_{104}	s_{105}	s_{106}	s_{107}	s_{108}	s_{109}	1

Table 25: Interaction Matrix of the Factor "Erosion and Sedimentation" for various landuse alternatives

MATRIX NO: 20

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	t_{12}	t_{13}	t_{14}	t_{15}	t_{16}	t_{17}	t_{18}	t_{19}	t_{110}
A2	t_{21}	1	t_{23}	t_{24}	t_{25}	t_{26}	t_{27}	t_{28}	t_{29}	t_{210}
A3	t_{31}	t_{32}	1	t_{34}	t_{35}	t_{36}	t_{37}	t_{38}	t_{39}	t_{310}
A4	t_{41}	t_{42}	t_{43}	1	t_{45}	t_{46}	t_{47}	t_{48}	t_{49}	t_{410}
A5	t_{51}	t_{52}	t_{53}	t_{54}	1	t_{56}	t_{57}	t_{58}	t_{59}	t_{510}
A6	t_{61}	t_{62}	t_{63}	t_{64}	t_{65}	1	t_{67}	t_{68}	t_{69}	t_{610}
A7	t_{71}	t_{72}	t_{73}	t_{74}	t_{75}	t_{76}	1	t_{78}	t_{79}	t_{710}
A8	t_{81}	t_{82}	t_{83}	t_{84}	t_{85}	t_{86}	t_{87}	1	t_{89}	t_{810}
A9	t_{91}	t_{92}	t_{93}	t_{94}	t_{95}	t_{96}	t_{97}	t_{98}	1	t_{910}
A10	t_{101}	t_{102}	t_{103}	t_{104}	t_{105}	t_{106}	t_{107}	t_{108}	t_{109}	1

Table 26: Interaction Matrix of the Factor "Slope Requirement" for various landuse alternatives

MATRIX NO: 21

Alternatives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	u_{12}	u_{13}	u_{14}	u_{15}	u_{16}	u_{17}	u_{18}	u_{19}	u_{110}
A2	u_{21}	1	u_{23}	u_{24}	u_{25}	u_{26}	u_{27}	u_{28}	u_{29}	u_{210}
A3	u_{31}	u_{32}	1	u_{34}	u_{35}	u_{36}	u_{37}	u_{38}	u_{39}	u_{310}
A4	u_{41}	u_{42}	u_{43}	1	u_{45}	u_{46}	u_{47}	u_{48}	u_{49}	u_{410}
A5	u_{51}	u_{52}	u_{53}	u_{54}	1	u_{56}	u_{57}	u_{58}	u_{59}	u_{510}
A6	u_{61}	u_{62}	u_{63}	u_{64}	u_{65}	1	u_{67}	u_{68}	u_{69}	u_{610}
A7	u_{71}	u_{72}	u_{73}	u_{74}	u_{75}	u_{76}	1	u_{78}	u_{79}	u_{710}
A8	u_{81}	u_{82}	u_{83}	u_{84}	u_{85}	u_{86}	u_{87}	1	u_{89}	u_{810}
A9	u_{91}	u_{92}	u_{93}	u_{94}	u_{95}	u_{96}	u_{97}	u_{98}	1	u_{910}
A10	u_{101}	u_{102}	u_{103}	u_{104}	u_{105}	u_{106}	u_{107}	u_{108}	u_{109}	1

Table 27: Interaction Matrix of the Factor "Aesthetic Values" for various landuse alternatives

MATRIX NO: 22

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	v_{12}	v_{13}	v_{14}	v_{15}	v_{16}	v_{17}	v_{18}	v_{19}	v_{110}
A2	v_{21}	1	v_{23}	v_{24}	v_{25}	v_{26}	v_{27}	v_{28}	v_{29}	v_{210}
A3	v_{31}	v_{32}	1	v_{34}	v_{35}	v_{36}	v_{37}	v_{38}	v_{39}	v_{310}
A4	v_{41}	v_{42}	v_{43}	1	v_{45}	v_{46}	v_{47}	v_{48}	v_{49}	v_{410}
A5	v_{51}	v_{52}	v_{53}	v_{54}	1	v_{56}	v_{57}	v_{58}	v_{59}	v_{510}
A6	v_{61}	v_{62}	v_{63}	v_{64}	v_{65}	1	v_{67}	v_{68}	v_{69}	v_{610}
A7	v_{71}	v_{72}	v_{73}	v_{74}	v_{75}	v_{76}	1	v_{78}	v_{79}	v_{710}
A8	v_{81}	v_{82}	v_{83}	v_{84}	v_{85}	v_{86}	v_{87}	1	v_{89}	v_{810}
A9	v_{91}	v_{92}	v_{93}	v_{94}	v_{95}	v_{96}	v_{97}	v_{98}	1	v_{910}
A10	v_{101}	v_{102}	v_{103}	v_{104}	v_{105}	v_{106}	v_{107}	v_{108}	v_{109}	1

Table 28: Interaction Matrix of the Factor "Economics" for various landuse alternatives

MATRIX NO: 23

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{110}
A2	w_{21}	1	w_{23}	w_{24}	w_{25}	w_{26}	w_{27}	w_{28}	w_{29}	w_{210}
A3	w_{31}	w_{32}	1	w_{34}	w_{35}	w_{36}	w_{37}	w_{38}	w_{39}	w_{310}
A4	w_{41}	w_{42}	w_{43}	1	w_{45}	w_{46}	w_{47}	w_{48}	w_{49}	w_{410}
A5	w_{51}	w_{52}	w_{53}	w_{54}	1	w_{56}	w_{57}	w_{58}	w_{59}	w_{510}
A6	w_{61}	w_{62}	w_{63}	w_{64}	w_{65}	1	w_{67}	w_{68}	w_{69}	w_{610}
A7	w_{71}	w_{72}	w_{73}	w_{74}	w_{75}	w_{76}	1	w_{78}	w_{79}	w_{710}
A8	w_{81}	w_{82}	w_{83}	w_{84}	w_{85}	w_{86}	w_{87}	1	w_{89}	w_{810}
A9	w_{91}	w_{92}	w_{93}	w_{94}	w_{95}	w_{96}	w_{97}	w_{98}	1	w_{910}
A10	w_{101}	w_{102}	w_{103}	w_{104}	w_{105}	w_{106}	w_{107}	w_{108}	w_{109}	1

Table 29: Interaction Matrix of the Factor "Political" for various landuse alternatives

MATRIX NO: 24

Alter-natives	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	x_{110}
A2	x_{21}	1	x_{23}	x_{24}	x_{25}	x_{26}	x_{27}	x_{28}	x_{29}	x_{210}
A3	x_{31}	x_{32}	1	x_{34}	x_{35}	x_{36}	x_{37}	x_{38}	x_{39}	x_{310}
A4	x_{41}	x_{42}	x_{43}	1	x_{45}	x_{46}	x_{47}	x_{48}	x_{49}	x_{410}
A5	x_{51}	x_{52}	x_{53}	x_{54}	1	x_{56}	x_{57}	x_{58}	x_{59}	x_{510}
A6	x_{61}	x_{62}	x_{63}	x_{64}	x_{65}	1	x_{67}	x_{68}	x_{69}	x_{610}
A7	x_{71}	x_{72}	x_{73}	x_{74}	x_{75}	x_{76}	1	x_{78}	x_{79}	x_{710}
A8	x_{81}	x_{82}	x_{83}	x_{84}	x_{85}	x_{86}	x_{87}	1	x_{89}	x_{810}
A9	x_{91}	x_{92}	x_{93}	x_{94}	x_{95}	x_{96}	x_{97}	x_{98}	1	x_{910}
A10	x_{101}	x_{102}	x_{103}	x_{104}	x_{105}	x_{106}	x_{107}	x_{108}	x_{109}	1

Table 30: Matrix Formed by the Eigenvectors (with respect to the maximum Eigenvalues) that are obtained from Twenty Three Interaction Matrices for the factors.

MATRIX #25

Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23
Eigen-value (λ_{max})	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}	λ_{12}	λ_{13}	λ_{14}	λ_{15}	λ_{16}	λ_{17}	λ_{18}	λ_{19}	λ_{20}	λ_{21}	λ_{22}	λ_{23}
EIGENVECTORS	E_{11}	E_{21}	E_{31}	E_{41}	E_{51}	E_{61}	E_{71}	E_{81}	E_{91}	E_{101}	E_{111}	E_{121}	E_{131}	E_{141}	E_{151}	E_{161}	E_{171}	E_{181}	E_{191}	E_{201}	E_{211}	E_{221}	E_{223}
	E_{12}	E_{22}	E_{32}	E_{42}	E_{52}	E_{62}	E_{72}	E_{82}	E_{92}	E_{102}	E_{112}	E_{122}	E_{132}	E_{142}	E_{152}	E_{162}	E_{172}	E_{182}	E_{192}	E_{202}	E_{212}	E_{222}	E_{232}
	E_{13}	E_{23}	E_{33}	E_{43}	E_{53}	E_{63}	E_{73}	E_{83}	E_{93}	E_{103}	E_{113}	E_{123}	E_{133}	E_{143}	E_{153}	E_{163}	E_{173}	E_{183}	E_{193}	E_{203}	E_{213}	E_{223}	E_{233}
	E_{14}	E_{24}	E_{34}	E_{44}	E_{54}	E_{64}	E_{74}	E_{84}	E_{94}	E_{104}	E_{114}	E_{124}	E_{134}	E_{144}	E_{154}	E_{164}	E_{174}	E_{184}	E_{194}	E_{204}	E_{214}	E_{224}	E_{234}
	E_{15}	E_{25}	E_{35}	E_{45}	E_{55}	E_{65}	E_{75}	E_{85}	E_{95}	E_{105}	E_{115}	E_{125}	E_{135}	E_{145}	E_{155}	E_{165}	E_{175}	E_{185}	E_{195}	E_{205}	E_{215}	E_{225}	E_{235}
	E_{16}	E_{26}	E_{36}	E_{46}	E_{56}	E_{66}	E_{76}	E_{86}	E_{96}	E_{106}	E_{116}	E_{126}	E_{136}	E_{146}	E_{156}	E_{166}	E_{176}	E_{186}	E_{196}	E_{206}	E_{216}	E_{226}	E_{236}
	E_{17}	E_{27}	E_{37}	E_{47}	E_{57}	E_{67}	E_{77}	E_{87}	E_{97}	E_{107}	E_{117}	E_{127}	E_{137}	E_{147}	E_{157}	E_{167}	E_{177}	E_{187}	E_{197}	E_{207}	E_{217}	E_{227}	E_{237}
	E_{18}	E_{28}	E_{38}	E_{48}	E_{58}	E_{68}	E_{78}	E_{88}	E_{98}	E_{108}	E_{118}	E_{128}	E_{138}	E_{148}	E_{158}	E_{168}	E_{178}	E_{188}	E_{198}	E_{208}	E_{218}	E_{228}	E_{238}
	E_{19}	E_{29}	E_{39}	E_{49}	E_{59}	E_{69}	E_{79}	E_{89}	E_{99}	E_{109}	E_{119}	E_{129}	E_{139}	E_{149}	E_{159}	E_{169}	E_{179}	E_{189}	E_{199}	E_{209}	E_{219}	E_{229}	E_{239}
	E_{110}	E_{210}	E_{310}	E_{410}	E_{510}	E_{610}	E_{710}	E_{810}	E_{910}	E_{1010}	E_{1110}	E_{1210}	E_{1310}	E_{1410}	E_{1510}	E_{1610}	E_{1710}	E_{1810}	E_{1910}	E_{2010}	E_{110}	E_{2210}	E_{2310}

CHAPTER IV

SUMMARY

Landuse priorities in much of Alaska are not clearly established, although some information on land resources is available for planning purposes, and certain uses for large areas are implicit in jurisdictional patterns. For instance, extensive blocks are designated as national parks, wildlife refuges, and military sites, or are reserved as a petroleum resources. Vast stretches of the state including virtually all lands underlain by coal, are simply undesignated wilderness area. Based on predominant vegetation, these are mostly identified in current inventories either as forest or rangeland, but neither category is now exploited commercially for those purposes. More than 20 million acreas of potential farmland are also recognized but only 70,000 acres are farmed, (National Research Council, 1980).

The lack of designated landuses -- indeed, the general lack of apparent signs of active use could be misleading. The land of Alaska is valued in many ways even though little of it is intensively used. Alaskan land is an essential component of Native Subsistence economies; it provides a biological refuse of worldwide importance; it has extra ordinary recreational value; and it is an unspoiled segment of the earth's surface that can be preserved for future generations. Thus, a policy is needed by which to establish the future uses of the land. Without such a policy or landuse goals, the post mining use of reclaimed land cannot be objectively resolved. Surface coal mining, if it is to be managed with regard for public goals for land use, must be preceded by agreements on what goals are. Coordinated landuse plans are means by which goal are translated into real actions. With regards to mining, a landuse plan is the primary basis for establishing reclamation objectives, at least to the degree that the objectives concern postmining landuse.

Decision about mining involve long term landuse commitments. Trade-offs are necessary with respect to possible uses of the post mining reclaimed land. Such decisions are most desirably made in a framework in which the feasible uses of most areas are identified beforehand. For instance, pre-mining planning phase can involve not only an assessment of mining plans but also an understanding of settlement patterns, demographic trends, economic forces, employment opportunities, maintenance of renewable resources, and many other factors. Information about such variables is compiled, evaluated, and balanced by the planning process. Plans for post-mining landuses should recognize not only the possible impact of mining itself, but also the impacts of ancillary facilities, as well as the regional impacts on biological resources, social and economic conditions. One purpose of such planning could be to identify the various alternatives in post-mining landuse planning.

Furthermore, a useful and flexible nonquantitative technique, such as a fuzzy set approach, may constitute a realistic medium for assessing many types of feasibilities for various alternate post-mining landuse plans. Because the fuzzy set methodology is specifically designed to reflect many of the imprecisions and ambiguties present in the real world.

WORK IN PROGRESS

One major criterion of the work in progress is to make the technique as realistic and simple as possible, for handling real world problems. As a first step, a detailed questionnaire is being prepared that will be used to establish the post-mining landuse goals, the influence of the various factors in the preference matrix and the subjective values or the coefficients of the interaction matrices. In this way the relative importance of various factors in alternative landuse plans will be developed, taking into account the viewpoints of various interest groups. The second step of this work is to detail the application of the methodology using collected information and summarize the analysis procedure for other geographical areas.

REFERENCES

1. R. E. Bellman and L. A. Zadeh, "Decision making in a fuzzy environment", Management Science, vol. 17, no. 4, B141-164, 1970.

2. M. L. Clar and R. V. Ramani, "User's manual for pre-mining planning of Eastern surface coal mining, volume 6: Mine land Use Planning," Industrial Environmental Research Laboratory, EPA, Cincinnati, OH., 1981, 201 pp.

3. Dames & Moore, "Development of pre-mining planning and reclamation plan rationale for surface coal mines, Final Report to U.S. Bureau of Mines on Contract No. J0255002, 1976.

4. M. Hill, "A goals-achievement matrix for evaluating alternative plans". Journal of American Institute of Planners, vol. 34, no. 1, 1968, p. 19-23.

5. M. Hill, and Y. Tzamir, "Multi-dimensional evaluations of regional plans serving multiple objectives". Paper presented at Regional Scientific Association, 33, 1974, p. 127-140.

6. National Research Council, "Surface coal mining in Alaska", National Academy Press, Wash., D.C>, 1980, pp. 328.

7. Peabody Coal Co., "Personal communication", 1984.

8. J. N. Pugliese, D. E. Swanson, W. H. Englishman and T. R. Bur., "Quarry near urban areas: an aid to pre-mine planning", U.S.B.M. Information Circular 8804, Washington, D.C., 1979.

9. R. V. Ramani and R. J. Sweigard, "Development of a procedure for landuse potential evaluation for surface mine land - Final Report", Pennsylvania Mining and Mineral Resources Research Institute, University Park, PA, NTIS: PB 83-253401, 114 pp., 1983(a).

10. R. V. Ramani and R. J. Sweigard, "Development of a procedure for landuse potential evaluation for surface-mined land, Appendix I: Eastern U.S. surface mine cast study", Pennsylvania Mining and Mineral Resources Research Institute, University Park, PA. NTIS PB 83-264325, 87 pp., 1983 (b).

11. R. V. Ramani and R. J. Sweigard, "Development of a procedure for landuse potential evaluation for surface mined land, Appendix II: Central U.S. surface mine case study", Pennsylvania Mining and Mineral Resources Research Institute, University Park, PA., NTIS 83-264333, 135 pp, 1983(c).

12. R. V. Ramani and R. J. Sweigard, "Development of a procedure for landuse potential evaluation for surface mined land, Appendix III: Western U.S. surface mine case study", Pennsylvania Mining and Mineral Resources Research Institute, University Park, PA, NTIS PB 83-264341, 106 pp, 1983(d).

13. T. L. Saaty, "Measuring to fuzziness of sets", Journal of cybernetics, vol. 4, no. 4, 1974, p. 53-61.

14. T. L. Saaty, "A scaling method for priorities in Hierarchial structures", Journal of Mathematical Psycology, vol. 15, 1977, p. 234-281.

15. H. Tanaka, T. Okuda and K. Asai, "On fuzzy-mathematical programming", Journal of cybernetics, vol. 3, no. 4, p. 37-46.

16. L. A. Zodeh, "Fuzzy sets", Information and Control, Vol. 8, 1965, p. 338-353.