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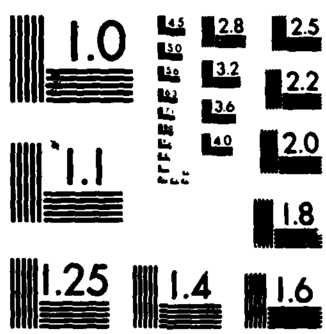

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A COMPUTER-BASED INTERACTIVE MODEL FOR INDUSTRIAL LAND USE FORECASTING

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1. INTRODUCTION

An industrial engineering activity that is growing in relevance and receiving due attention in the literature is that of identifying land areas suitable for future industrial use. As cities expand and multiply, the various activities that reflect the social-economic makeup of a community (e.g., industrial, commercial, residential, agricultural, etc.) compete with each other for use of the same fixed resource--land. It then becomes necessary and meaningful to consider the science and art (e.g., economic and behavioral aspects) of land use forecasting.

Land use forecasting has long been a planning activity of interest to the various Federal and State agencies, particularly those with mandates for the development of land and water projects. Certainly this is the case at the U.S. Army Corps of Engineers, where land use forecasting has long been applied to the evaluation of economic benefits resulting from engineering measures and associated land uses. Over the last 50 years a number of research efforts have been funded by the Corps relating to the development of analytical land use methodologies and, in some cases, the design of computer-based forecasting models.

The purpose of this paper~~, then,~~ is to review briefly the progress made in the analytical and behavioral development of land use forecasting models, to point to the modeling functions of special relevance to industrial land uses, and describe a new interactive computer model being developed at the Institute for Water Resources (IWR) of the U.S. Army Corps of Engineers.

2. BACKGROUND

A substantial number of efforts to develop land use forecasting models have been undertaken over the last 30 years. This section compiles a list of over 50 models created during that time period that cover a wide range of forecasting activities, and that represent the extent of the modeling effort in the private and public sectors.

The beginnings of land use forecasting in the United States are to be found in the schools of city planning created at Harvard University in 1929, and at the Massachusetts Institute of Technology (MIT) in 1931. These two schools spearheaded the tremendous development that resulted thereafter. Kilbridge et al.[1] presents a classification of 20 urban planning models by land use (e.g., industrial, commercial, residential, agricultural, etc.), function (e.g., projection, allocation, and derivation), theory (e.g., behavioral, gravity, trend, and growth index), and method (e.g., regression, input-output, markov process, linear programming, and simulation) that span the time period 1959-1967. Table 1 extends and updates that classification by identifying 28 other models that are considered most significant and that cover the time period (1962-1979). As Table 1 reveals, these models offer a wide range of forecasting capabilities, use diverse analytical and behavioral approaches, and have been applied to a good number of cities in the U.S. Also, as the reader can observe, industrial land use forecasting is well integrated and represented in many of these models (see refs. 2 through 29 and 38).

The remainder of this section reviews some of the previous work that led to the development of the Alternative Land Use Forecasting (ALUF) model of the Institute for Water Resources, U.S. Army Corps of Engineers.

Land Use Forecasting at the Corps of Engineers. Essential to the task of project development and evaluation is the determination of "with project" and "without project" future economic conditions. The calculation of these economic benefits has provided, in fact, the motivation for much of the effort on land use forecasting at the Corps. But substantial and continuous as this effort has been over the last decade, the need still exists to develop a computer package that offers a satisfactory balance of sound methodological framework, data base and computer time requirements. Some of the methodologies proposed in the past, although analytically correct and based on sound methodological frameworks, were inadequate for subsequent implementation for several reasons. At times the theoretical development was valid and well researched, but the computer model was incomplete. More frequent was the case, however, where the proposed

Table 1. A Classification of Land-Use Forecasting Models

#	MODEL NAME	PROJECT NAME/ CASE STUDY	FORECASTING CAPABILITIES	ANALYTICAL TOOLS EMPLOYED	REFERENCE	DATE
1	BASS-Bay Area Simulation Study	San Francisco Bay Area	o Employment (5 year inten) o Population o Industrial Land Use (21) o Residential Housing Location o Gov. Employment	o Regression o Judgmental Weighting	Center for real estate and urban economics, University of California, Berkely Also, N.J. Brown (1972) Ref. (2)	1962 - 1968
2	PLUM - Projective Land Use Model	San Francisco Bay Area	o Household Location o Population-Serving Employment o Industry Location o Land Use o Regional Employment o Regional Population	o Regression Functions o Subjective Probability	W. Goldner (1968) (3)	1968
3	Puget Sound Regional Transportation Study	Puget Sound Regional Plan-Commission Seattle, Wash.	o CBD Employment o Industrial Location o Population o Retail o Pop. by county o Employment by industry	o 16 Sector Input-Output Model o Judgmental Weighting	C.H. Grave (1964) (4)	1964 - 1970
4	SEWRPC	Southeastern Wisconsin Regional Planning Commission	o Regional Employment o Land Use Residential Industrial (L.P.) Agriculture	o Linear Programming o Judgmental o Input-Output	S. Wisconsin Regional Planning Commission Tech. Ref. 3 (5)	1966
5	TALUS	Detroit Regional Transportation and Land Use Study	o Employment by District o Households by District o Land Use o Employment o Population	o Regression o Gravity Access	Rubin, J.J. (1968) (6)	1968
6	HARVARD	Southwest Sector of the Boston Region, Exper. Study (16 week)	o Industrial Location o Residential. o Recreation, Open Space o Transportation	o Computer Simulation o Universal Transverse Mercator (UTM) Grid o Grid Network o Overlay	Steinitz and Rogers (1970) Proposal for Year Four (1974) Also, I.L. McHarg (1969) (7),(8)	1970 - 1974
7	MANGROVE	Rookery Bay Land Use Studies, Collier County Florida	Environmental Planning Strategies: o Canal Concept o Resource Buffer o Filling of Welands o Land Preservation	o Ecological System Modeling o Judgmental	Center for Urban Studies, Miami University, FL. A.R. Veri et.al (1973) (9)	1973
8	AIRPORT	Airport Environs: Land Use Control	o Coordinated Report of Land Use Planning Controls, Noise Reduction		Office of Metropolitan Planning and Development, Environmental Planning Division Washington, DC (10)	1970

9	FMS	Floodplain Management System Model: Rillito River, Tucson, Arizona	• Land Use Allocation • "With and without" Analysis • Incremental Analysis • Economic Analysis o Population Distribution	• Linear Programming • Regression	IWR Paper 74-82 WEISZ and Day (1974) (11)	1974
10	UCM	St. Louis Region	• Determine Demand for industrial location in flood plain.	• Factor • Discriminant Analysis • Statistical Analysis	IWR Paper 74-P8 Corbean and Meyer (1974) (12)	1974
11	1 DYLAM-Dynamic Land use allocation model	Cleveland Study.	o Population o Employment o Land use o Changes in Infrastructure	o Grid Network o Proximity Factors o Graphic Display	Seader and Grava (1971) (13)	1971
12	OAK RIDGE LAB.	6500-sq mile Region in Eastern Tennessee	o A cell-[illegible] land-use model o Data base of pop dist. labor available, size & freq of industries o Cumulative distribution of existing industries o Employment by zone.	o Factor analysis o Attractiveness scores o Statistical analysis o Delphi techniques	P.A. Leselie (14)	1976
13	EMPIRIC	Boston Area (Plus a dozen other cities)	o Population by Zone o Employment by Zone o Land use	o Linear Difference equations o Statistical analysis o Non-behavioral	Peat et. al. (1971) (15)	1971
14	Harvard Model	The interaction between urbanization, Land Quality and quality	o update vacant land values		Bloom and Brown (16)	1979
		- Land value model				
15	Landscape Architecture Research Office, Harvard University (See Attached computer readout)	- Housing Model	o Residential Land Use by single and multiple-family structure.		Wilkins et. al. (17)	1979
16		- Public institutions model			Vidal and Brown (18)	1979
17		- Transportation model	o Travel Demand on Transportation Facilities		Tyler and Commings (19)	1979
18		- Industrial Model	o Industrial use Siting Based on: Slope, Depth to bedrock, Zoning o Development costs used as economic criteria		Coltry et. al. (20)	1979
19		- Public expenditures model	o Land use Change based upon public local expenditures		Kirlin et. al. (21)	1979

20		- Water Quantity and Quality	o Water demand o Coliform Count o Carbonaceous BOD o Dissolved Oxygen o Salinity		Rogers and Berwick (22)	1978
21		- Vegetation-wild life Model	o Produce land classification systems o Resource Evaluation o Description Methods		Smith (23)	1979
22		- Commercial model	o A developer's perspective in estimating the location and size of commercial centers		Wilkins and Brown (24)	1979
23	Harvard (cont.)	- Solid Waste Management	o Landfilling and export-out-technologies on a town-by-town basis	o Regression o Land use exclusion criteria	Rogers and McClellan (25)	1979
24		- Legal/Implementation model	o Land use allocation in accordance with state, federal, and local land use controls		Giezentanner, Steinitz (26)	1978
		- Historical Resources Model	o Evaluates the specific, unique, often Qualitative values of areas and buildings		Steinitz and Haglund (27)	1978
26		- Recreation Model	o Identifies sites suitable for recreational development and ranks them.		Steinitz and Douglas (28)	1978
27		- Soils Model	o Identification of soil erosion zones. o transport of sediment to accumulation areas o Estimation of costs associated with mitigating procedures			
28		- Land use Descriptors	o Cover characteristics o Construction o Cost		Way, D.S. (29)	1978

computer model required vast amounts of input data, the exogeneous parameters themselves were difficult to estimate (e.g., spatial population distributions) or the amount of time required to apply the model would have been unreasonably large (in the order of months).

An alternative course of action is delineated here. Essentially, some of the computer subroutines in program RIA are combined with an economic data bank file and a search procedure to allocate land uses. Optimal land allocations are not sought; instead, "near optimal," feasible land allocations are desired.

3. ALTERNATIVE LAND USE FORECASTING (ALUF) PROGRAM

The development of a grid cell data file requires that each variable map be individually encoded and geographically registered to a common base and stored, along with data variables in the data bank, on a computer storage device.

The IWR package consists of two computer programs which are used in connection with a grid cell spatial data base as shown in Figure 1. The main program, Alternative Land Use Forecasting (ALUF) does the actual allocation of future land uses to specific grid cells. The Existing Land Use Analysis Program (ELUA) is provided to help identify significant land use location factors for the allocation process based on the relationship between land use locations and other data available in the grid cell data bank.

The final program output is a new data variable written into the data base file for each grid cell, indicating projected future land use. The programs are written in FORTRAN IV for the CDC 6600/7600 series computers.

The ALUF program incorporates the HEC RIA Attractiveness modeling program and RIA Distance Determination package. These were adapted for use in this process so that land use locator scores can be developed according to user specified criteria, as well as location criteria derived from the statistical findings.

The kinds of data variables commonly used as a basis for allocating future land use include:

- A. Access (Distance)
  1. Transportation
  2. Central Business Districts or Regional Centers
  3. Dependent Activities
- B. Proximity to Compatible Land Uses
- C. Physical Land Attributes (Developability)
  1. Slope
  2. Drainage
  3. Type of Cover
  4. Soils
- D. Infrastructure
  1. Sewers and Water
  2. Gas and Power
  3. Mass Transit
- E. Zoning
- F. Ownership
- G. Land Prices

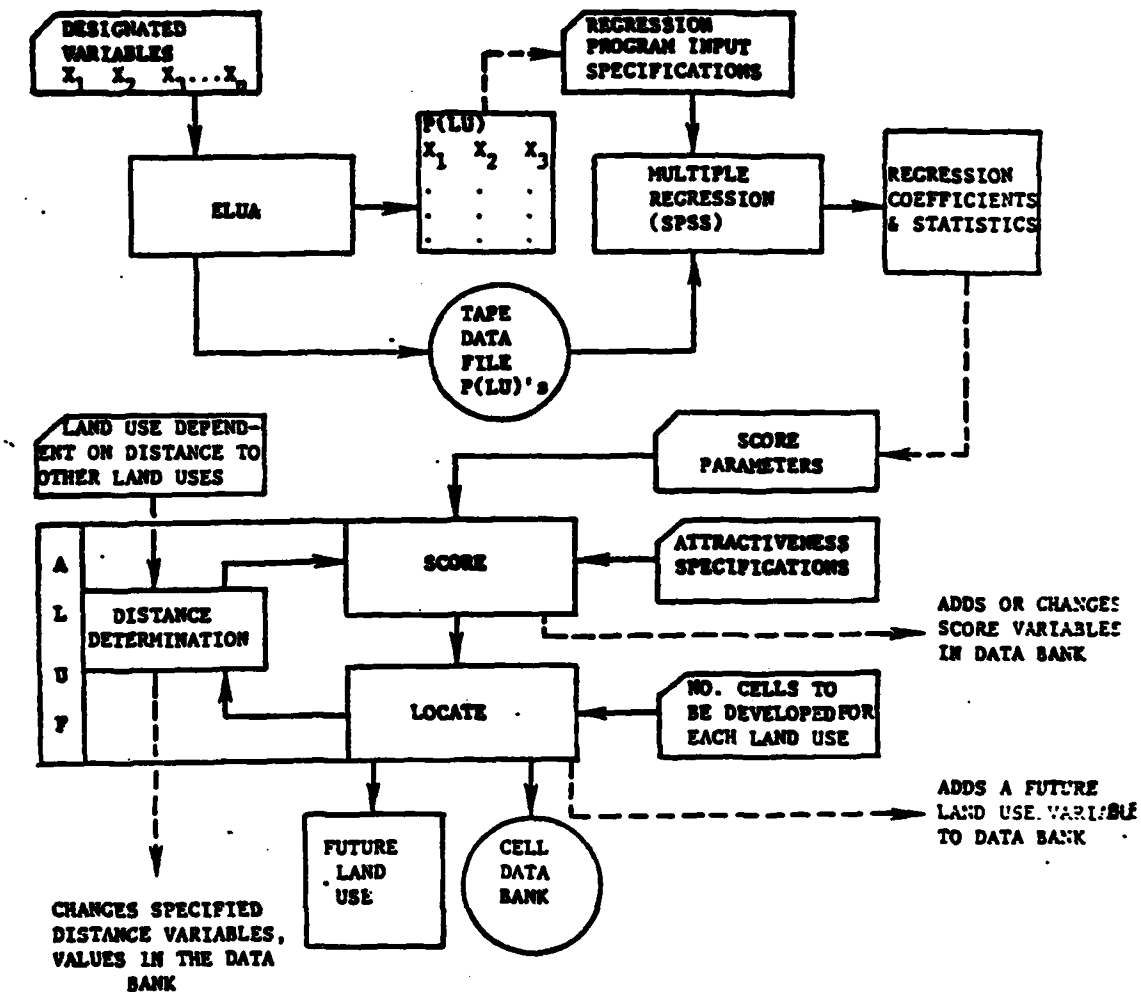

Figure 1. Current Structure of Computer Program ALUF

4. CALCULATION OF THE ATTRACTIVENESS INDICES

To demonstrate the computation of the raw attractiveness indices as performed in the computer program ALUF, consider the land use grid shown in Figure 2. Purposely, the grid is small and contains only 27 cells, so as to render the exercise workable (typically grid representatives of regions of interest may require 5,000-50,000 cells).

Listed in Figure 2 is the legend used to represent the various land uses, e.g., (1) natural vegetation, (2) developed open space, (3) low density residential, etc. In this manner, we can see that grid cell (i,j) = (1,4) is currently allocated to low density residential. A railroad track traverses the grid network, as shown.

As program ALUF is structured currently, a matrix arrangement is available to the analyst to identify the variables (topographic) of interest, as shown in Table 2. The analyst-user then is required to: (1) designate topographic variables, (2) assign relative weights to the variables, and (3) specify a shading intensity for each value of each designated variable. A matrix must be filled in for each land use (e.g., activity) being considered. For illustrative purposes, Table 2 alone is shown with the matrix values for industrial use.

We continue our illustrative computation of the attractiveness indices for industrial use with the specification of two variables only: (1) distance to Seaboard Railroad (variable #23), and slope (variable #8). Information on these two variables must be built into the data bank file prior to running the program. For our example, this information would appear as shown in Figures 3 and 4. With reference to location (i,j) = (1,4), we notice that the slope value of 2 corresponds to a "2 to 6 percent slope" (Table 5, variable 8, Appendix), and the distance to the railroad tracks is three cell units. The actual computation of the raw Attractiveness Index proceeds as follows:

Distance to R.R. = 3	:	(1)	x (2)	=	2
Slope = 2	:	(8)	x (1)	=	8
					10
		Shading Intensity	Relative Weight		Attractiveness

In a similar manner, indices (also called scores) for the remaining cells are computed in Table 3 and again shown in Figure 5.

There remains the matter of using the attractiveness scores to allocate a land use to each grid cell. Currently, the program assigns land uses according to the priority identified by the analyst in the Data Deck;

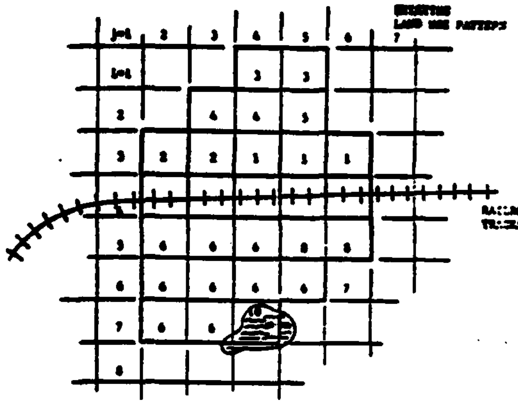

Figure 2. Existing Land Use Pattern

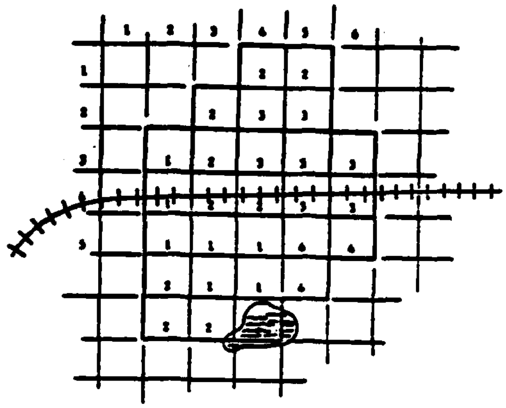

Figure 3. Slope Associated with Grid Cells (Variable 8)

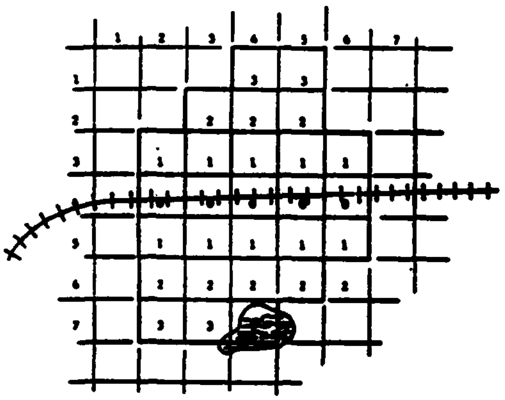

Figure 4. Distance in Cell Units to Railroad Tracks (Variable 23) .

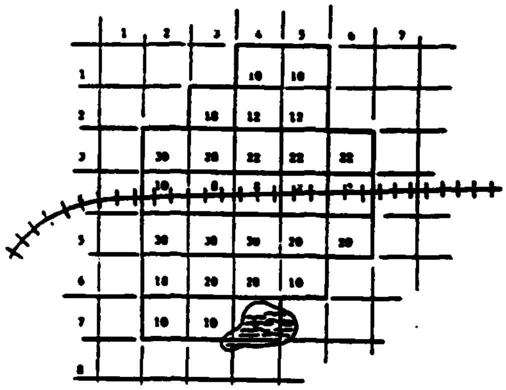

Figure 5. Raw Attractiveness Scores for Industrial Use

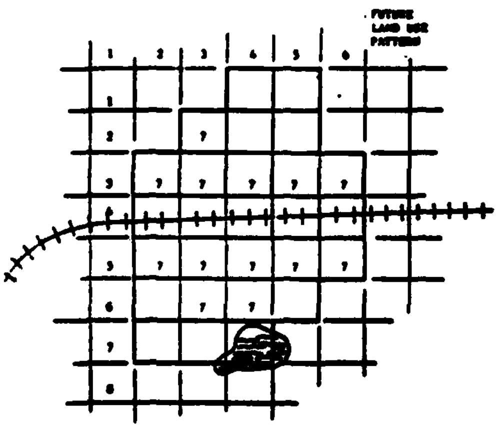

Figure 6. Future Industrial Land Use

LEGEND:

1 Natural Vegetation
2 Developed open space (parks, golf, ...)
3 Residential, Low Density
4 Residential, Medium
5 Residential, High
6 Agricultural
7 Industrial
8 Commercial
9 Pasture
10 Water Bodies

Table 2. Attractiveness Matrix for Industrial Use

	Topographic Variable	Shading Intensity 0	1	2	3	4	5	Importance Weight
(23)	Distance to R.R.	0	10	5	1	0		2
(8)	Slope	-1	10	8	2	0		1
	Existing Land Use	0	10	-1	-1			
(17)	Distance to E.R.		0					
	Distance to E.I.		10	10	9			

NOTE: Shading intensity values range from -1 to 10. A value of 10 is assigned if variable is of most significance to land use being considered. A value of -1 is assigned if variable is to be excluded completely from further consideration.

Table 3. Attractiveness Scores for Industrial Use

CELL NO. (i,j)	DIST R.R.	SLOPE	SCORES DIST R.R.	SCORES SLOPE	TOTAL
1,4	3	2	(1)(2)=2	(8)(1)=8	10
1,5	3	2	(1)(2)=2	(8)(1)=8	10
2,3	2	2	(5)(2)=10	(8)(1)=8	18
2,4	2	3	(5)(2)=10	(2)(1)=2	12
2,5	2	3	"	"	12
3,2	1	1	(10)(2)=20	(10)(1)=10	30
3,3	1	2	(10)(2)=20	(8)(1)=8	28
3,4	1	3	(10)(2)=20	(2)(1)=2	22
3,5	2	3	"	"	"
3,6	1	3	"	"	"
4,2	0	1	0	(10)(1)=10	10
4,3	0	2	0	(8)(1)=8	8
4,4	0	2	0	(8)(1)=8	8
4,5	0	3	0	(2)(1)=2	2
4,6	0	3	0	(2)(1)=2	2
5,2	1	1	(10)(2)=20	(10)(1)=10	30
5,3	1	1	"	"	30
5,4	1	1	"	"	30
5,5	1	4	(10)(2)=20	(0)(1)=0	20
5,6	1	4	"	"	20
6,2	2	2	(5)(2)=10	(8)(1)=8	18
6,3	2	1	(5)(2)=10	(10)(1)=10	20
6,4	2	1	(5)(2)=10	(10)(1)=10	20
6,5	2	4	(5)(2)=10	(0)(1)=0	10
7,2	3	2	(1)(2)=2	(8)(1)=8	10
7,3	3	2	"	"	10
7,4	3	0	(1)(2)=2	(-1) ∴ REJECT	-

that is, if the desired priority is industrial, followed by high density residential, low density residential, commercial, etc., then the analyst physically places data cards for industrial at the top of the "Data Deck," followed by data cards for high density residential, and so on. In that manner, given a request for 13 cells, say, for industrial, the program assigns a land use (Legend Code 7) to the 13 cells that exhibit the highest industrial attractiveness score. A similar allocation rationale is then used for high density residential, and so on down the priority list. For our example then, the cells allocated to industrial use are shown in Figure 6. Note that for cell(6,5) there corresponds a slope value of 4 (i.e., 10 to 15 percent grading) and that Table 3 shows a shading intensity of zero; the slope variable, then, contributes a value of zero to the attractiveness score, e.g. (0)(1.0) = 0.0. Cell(7,4), on the other hand, has a slope value 0.0 (i.e., water body) and since an intensity value of -1 has been assigned to it, the cell is excluded from industrial use.

5. AN ILLUSTRATIVE COMPUTER APPLICATION: TRAIL CREEK PILOT STUDY

Now that the computation of the raw attractiveness scores has been illustrated in a step-by-step manner, the application of the procedure to a real-world situation is demonstrated using computer program ALUF. The region of interest is the Trail Creek study area shown in Figure 7, and it exhibits variety and complexity of roads, railroad track, river lengths, urban center nearby, etc. Current land use of this area is as shown in Figure 7, with adopted dimensions for each rectangular cell of 200 and 333.3 feet.

The interactive computer mode of the program was then used to fill in the attractiveness matrices. This time it is noted that the exercise was extended beyond the industrial land use stated requirement to include residential and commercial. The number of cells required for each use was 900, 800 and 200, respectively.

Finally, shown in Figure 8 is the computer printout of the computed future land use pattern. Only the left half of the pattern is used, as the other half would be of a similar nature. The actual computer printout does yield the two halves, however. Let us now compare existing and future land use of a particular cell, say cell(35,55). It is observed that Figure 7 identifies the current use as being agricultural (i.e. code number 6), and now the future use is projected to be industrial (i.e. code number 7), as given in Figure 8.

6. SUMMARY AND CONCLUSIONS

This paper discusses the architecture and use of a new land use forecasting model labeled ALUF, Alternative Land Use Forecasting. The model makes use of information on current land uses, topographic characteristics, and preferences elicited from the planners to forecast future land uses.

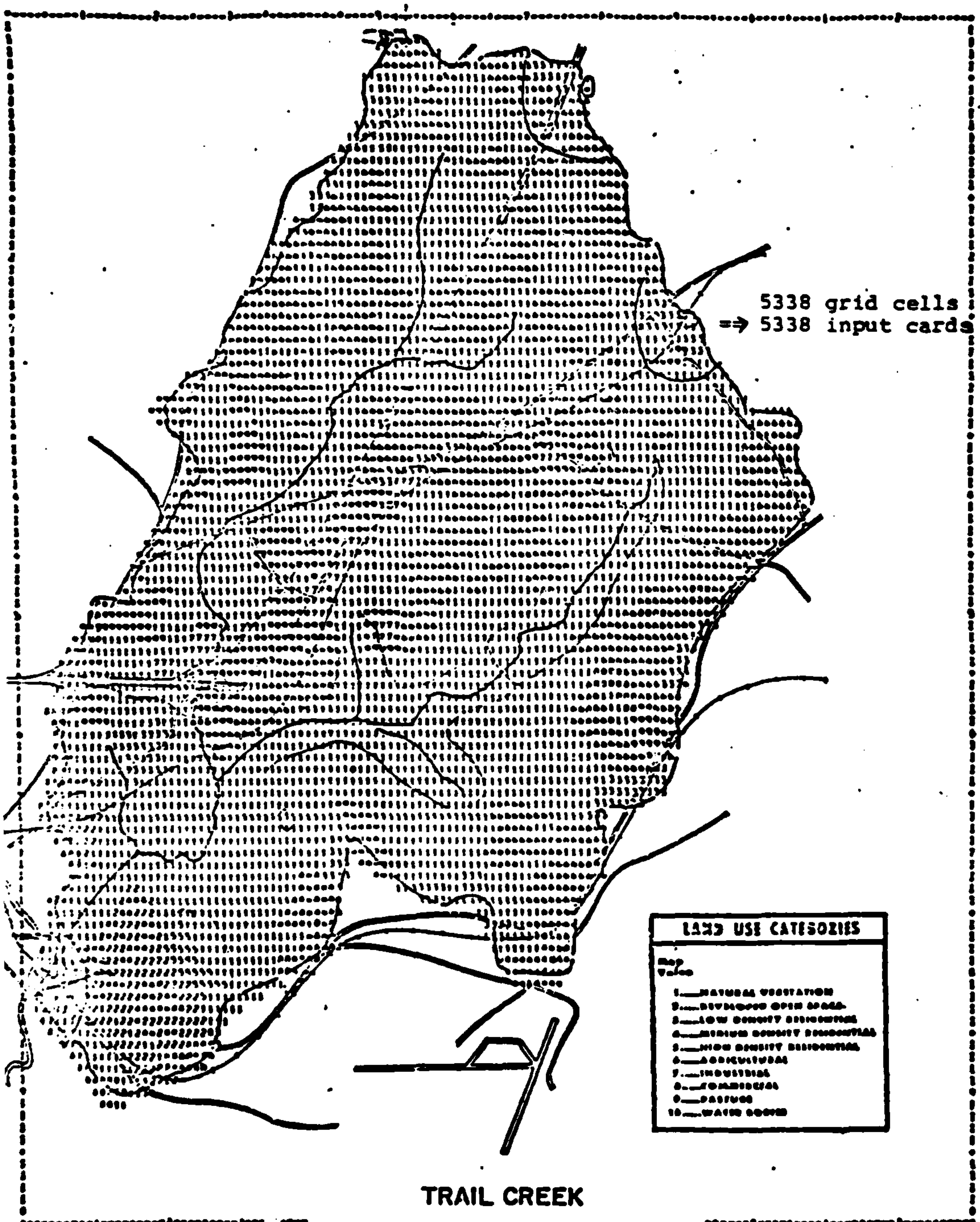

Figure 7. EXISTING LAND USE PATTERN

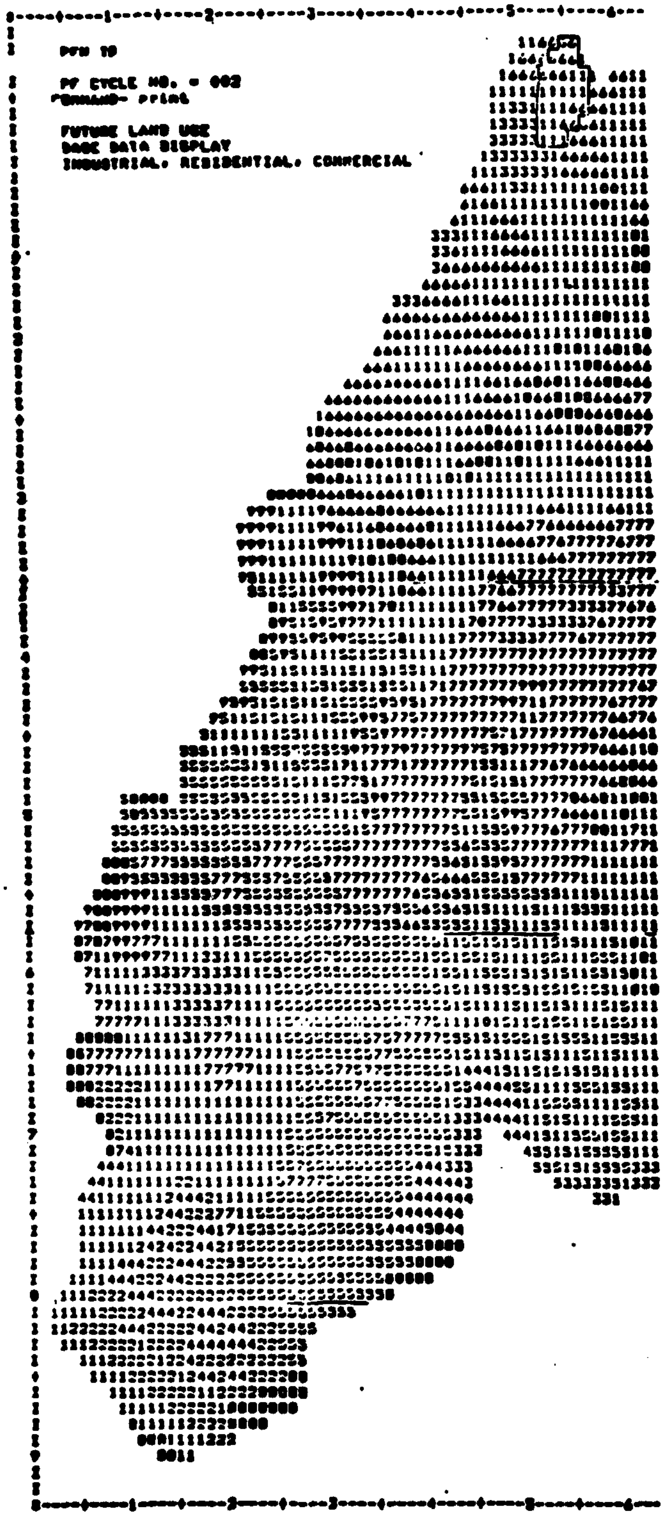

Figure 8. Computer Printout of Future Land Uses

In the process, it calculates the economic benefits to be derived from a proposed engineering measure or zoning policy. The model is currently operational and it is available to Corps personnel and general city planners involved in project development and evaluation. Also, it is hoped that industrial engineering practitioners will find it useful in their dialogue with city planners as new industrial enterprises in growing communities are discussed.

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Note — Space limitations preclude a complete listing of references. Please write to authors requesting such listing.