ENVIRONMENTAL MAPPING: AN ECOLOGICAL METHODOLOGY FOR HIGHWAY IMPACT ANALYSIS

Joseph A. Kuhn, Ecologist, California Division of Highways; and
James L. Goggin, Geographic Research Consultant

ABRIDGMENT

Environmental mapping is proposed as an ecological methodology for systematic analysis of highway impact, an important part of the planning process. An exploratory investigation of a forest highway corridor was conducted to demonstrate potential applications. Maps at three scales are presented and analysis, synthesis, and display techniques discussed. The methodology is viewed as a modeling procedure involving the inventory and analysis of the regional ecosystem elements; the synthesis and organization of inventory information through environmental mapping; analysis of environmental impact through modeling techniques; and the communication of environmental inventory and impact information through effective graphics.

•IN addition to the need for meeting the legal requirement for an environmental impact statement, impact analysis of project alternatives is an essential component of the planning process because it provides a means for comparative evaluation of alternatives.

More than 25 environmental impact statements were read by the authors prior to developing the thesis presented here. None was found to contain a modeling approach, and very little graphic material was presented in an attempt to define and quantify environmental elements and anticipated changes; i.e., there was no evidence to indicate "the integrated use of the natural and social sciences" as called for by the National Environmental Policy Act (NEPA).

A study was therefore conducted to examine the potential applications of the principles and techniques of environmental mapping as a methodology to be used in environmental impact analysis and for presenting the information developed in such a manner that diverse groups and individuals can relate to and draw conclusions from it. This latter consideration is especially relevant in that community interaction has been identified as the appropriate means of determining community concerns and establishing significance of impact (1,3).

METHODOLOGY PROPOSED

Geographers, foresters, and regional planners have developed proven regional analysis and modeling techniques, utilizing maps, that are well-suited to impact studies. These methods have been applied previously to route location problems (2,4). As applied to environmental impact studies, the environmental mapping methodology involves

1. Inventory and analysis of the regional ecosystem elements;
2. Synthesis and organization of this information through environmental mapping;
3. Analysis of environmental impact through modeling techniques; and
4. Communication of environmental inventory and impact information through effective graphics.

Publication of this paper sponsored by Committee on Social, Economic and Environmental Factors of Transportation.

The initial step is a thorough survey of all available sources of data for the study area. Maps, aerial photographs, management plans, and other sources are gathered from agencies and individuals having interest or involvement in the area. Through interpretation and evaluation of the data by a professional interdisciplinary team and interviews with knowledgeable citizens, identification of social and ecological systems elements and their significance can be made. In many instances additional field research will be necessary to supplement available data.

Emphasis is placed on the systematic preparation of an ecological inventory of the natural features that are indicators of natural processes. Data are collected for the study area in the following sequence as suggested by Ian McHarg (4):

1. Climate
2. Historical geology
3. Physiography
4. Hydrology
5. Pedology (soils)
6. Plant associations
7. Animals
8. Land use

McHarg stresses this causal sequence of data collection because each succeeding consideration relies on the preceding one to achieve maximum understanding of the entire process.

The second stage of the methodology involves organization and synthesis of the information generated in the inventory into a workable framework. This is a classification process where the data are interpreted and synthesized into a smaller, more workable number of variables, e.g., natural communities, land use classes, areas of pollutant concentration, flow patterns.

An abbreviated model of the existing environment is therefore assembled, with both generalized and critical key elements identified and mapped. Analysis of impact on these environmental elements from human activity (specifically, the construction and use of a highway facility) is made in the third stage through expansion of this model. The analysts interpret the elements individually and, through the "stacking" of transparent overlay maps, study any combination desired in order to clarify interrelationships. In addition, patterns at different points in time are developed and compared, thus modeling the process of change. This property—the capacity to simulate environmental relationships and environmental change—is what makes the model dynamic, i.e., ecological.

An important aspect of this methodology, listed here as stage 4, is the need for effective communication as an integral part of the impact analysis-planning process. The analysts must be able to communicate in order to identify elements and relationships and especially to obtain evaluations of significance.

Environmental mapping not only is useful as a tool of analysis by professionals, but also is a means of effective graphic illustration of facts and judgments. It is therefore an excellent vehicle for achieving informed public participation, especially when combined with attractive and creative use of photographs and other supporting material. One method of achieving this participation is to present maps and aerial photographs at public information stations and meetings, with transparent overlay sheets on which anyone may indicate areas of concern and relevant information.

FIELD STUDY: US-50 FROM PLACERVILLE TO SOUTH LAKE TAHOE

The US-50 corridor study was not a complete testing and evaluation of the modeling approach. The intention of this phase of methodology development was to introduce, discuss, and explore potentials. A complete environmental impact analysis based on the suggested methodology has not yet been conducted. The field study did provide the following:

1. Examples and discussion of how techniques of regional ecosystem analysis through environmental mapping can be used in a forest highway situation;

2. Examples and comparisons of different mapping techniques;
3. Discussion of information sources and problems of data gathering; and
4. Demonstration of how effective graphics can aid communication.

Working at various scales, a series of environmental maps of the US-50 corridor was prepared depicting elements of the ecosystem that might be significantly affected by a highway project.

The following discussion of three of the maps prepared in the field study will serve to demonstrate various aspects of the methodology.

Macro-Area: Rare and Endangered Plants Map

The base for the small-scale, macro-area maps was made from Army Map Service 1:125,000-scale sheets of the region. All information outside El Dorado County (the county containing the study area) was eliminated, and the base map was reduced to the desired dimension of 11 by 17 in. for publication. Each subject map was prepared on a transparent overlay and printed on the base.

The rare and endangered plants map (Fig. 1) demonstrates the following points with regard to ecosystem analysis and environmental mapping:

1. Mapping of a specific natural environment element with special social significance;
2. Small-scale, large-area mapping;
3. Use of black and white with and without added color (originals only);
4. Use of a base map with selected information printed as an ovelay on the base; and
5. Use of private organizations as information sources.

The topic of rare and endangered wildlife species has been prominent for a number of years. A much more recent concern, just coming to the attention of the general public and state agencies, is that of rare and endangered plant species. The California Native Plant Society was founded in 1965 in response to growing concern over threats to the state's native plants posed by the rapid pace of development. Its purpose is to determine which native plants are rare and/or endangered, locate where these species are found, and present these facts to the public.

The accompanying map of rare and endangered plants is the only such effort made for El Dorado County to date. Through discussion with the local Society representative in El Dorado County, the approximate location of those plants currently listed in the inventory was made. Many biologists and resource managers prefer that information on certain sensitive environmental sites remain guarded in order to protect the resources; therefore, the map does not give precise field locations of the plants in question. Its purpose is to indicate the existence and general location of these sensitive areas to be considered early in the planning process. Key habitat for rare and endangered animals could be located in a similar manner.

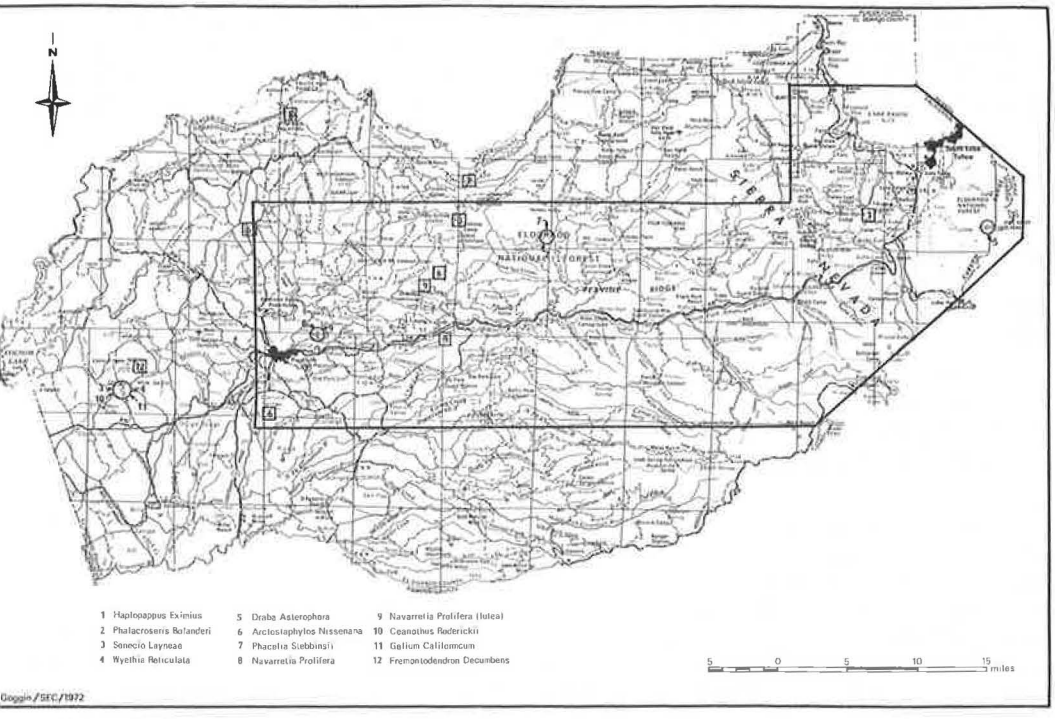
Meso-Scale: Corridor Vegetation Map

The corridor vegetation map (Fig. 2) demonstrates the following points:

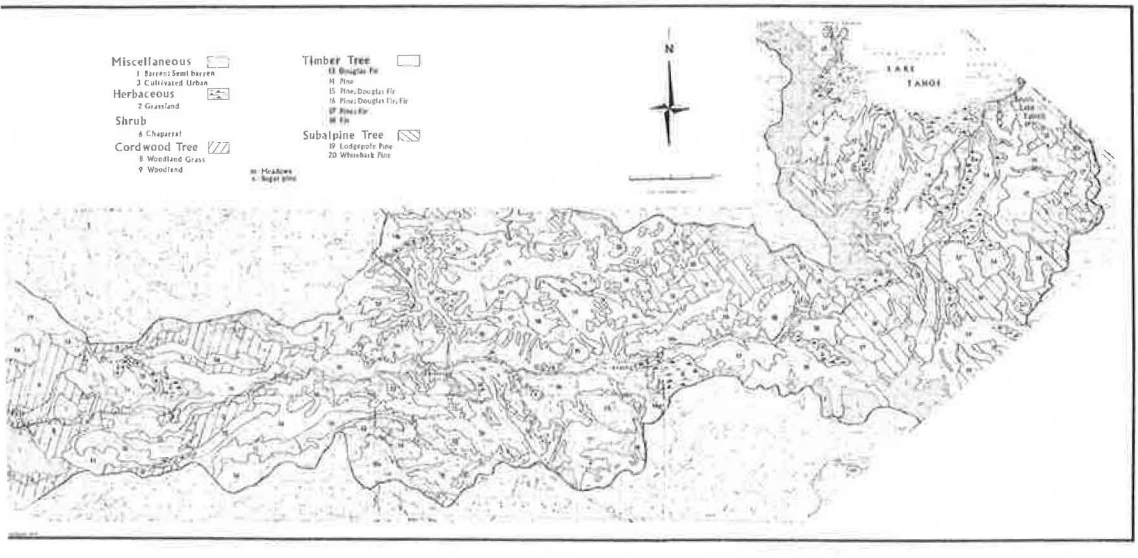
1. Mapping of generalized elements of the ecosystem;
2. Mapping of an entire study corridor at a meso-scale;
3. Use of overlay technique;
4. Use of two colors (originals only); and
5. Use of numbers and patterns to differentiate elements.

The base map was prepared by combining adjacent portions of nine USGS topographic quadrangles of a scale 1:62,500. The subject maps, e.g., vegetation, were prepared on transparent overlay sheets and printed individually on the base map. The base and the overlay maps were printed in different colors. The combined maps were then reduced to an optimum (11 by 24 in.) size for publication. At this size, the scale is approximately ½ in. to the mile and the contour lines are plainly discernible. Meso-scale maps of this nature are best for giving a broad view of the corridor and are of more use in impact analysis than the small-scale maps.

gure 1. Rare and endangered plants.



ure 2. Vegetation types.



The assembling of vegetation data is of great importance in the regional ecosystem modeling procedure. Every example of environmental mapping reviewed includes vegetation mapping, e.g., step 6 of McHarg's inventory procedure. Vegetative cover is an important indicator of ecological relationships and social values such as recreation use, commercial timber production, and wildlife habitat. The vegetation map serves as a focus for discussions with professional resource managers and planners concerning location of habitats or land use.

Micro-Area: Sequential Land Use Map

The sequential land use map (Fig. 3) is a complex of three maps and a series of bar graphs. At this larger (1:24,000) scale more detailed information can be shown for smaller areas. An even larger scale is needed for consideration of such factors as highway design features. The sequential land use map demonstrates the following points:

1. Large scale-small area mapping.
2. Time phase or sequential mapping of environmental change.
3. Use of black and white patterns with added colors (originals only).
4. Aerial photography as a supplementary graphic aid (Fig. 4).

The sequential land use map consists of the same area mapped at three time intervals. The base map was traced from USGS 7½-minute quadrangles, selecting only the major features—roads, rivers, etc. Land use information was then delineated on this edited base map. Distributions were coded in black and white with three additional colors applied later. The colors serve to highlight the land use distributions.

A sequential map series must first show the geographical patterns that precede the present conditions in the environment. This is done by assembling all available information (aerial photos, land use maps, management plans, etc.) indicating patterns at one or more earlier points in time. Next, a map showing the current environmental situation is prepared, with data coming from the same general sources simply updated. By comparing and relating past conditions to present conditions and seeking interpretation of the processes responsible for the changes, a basis from which to project future change in the environment is established.

At all stages of the inventory and impact modeling process, the analysts must seek out and evaluate the observations and judgments of those professionals involved in planning, research, and management of the land and resources in the study area. This is especially true when projecting change. Where conflicting views are noted, in-depth studies will often be required. Some reluctance to provide evaluative information and especially to make projections, will be encountered. Our studies to date indicate that an interviewer will have greater success in obtaining such information when discussions are centered on an environmental model.

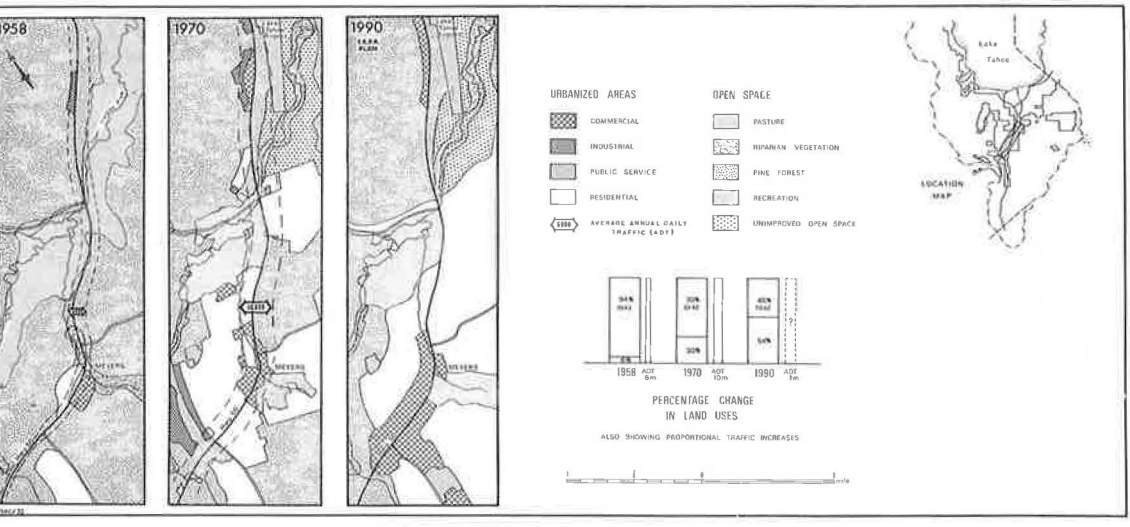
The map showing projected land use patterns was based on the General Plan for the Tahoe Region produced by the Tahoe Regional Planning Agency. As implied by the nam general plan maps include a certain degree of generalization. It is therefore especially important to work closely with those responsible for developing the plans and knowledge able businessmen and property owners who may provide information on potential development not anticipated in a general plan when projecting patterns.

Time-phase mapping of an environment can focus on different social and ecological system elements. For this portion of the corridor, land use classifications were selected for demonstration purposes. For this and other segments, changes in wildlife population dynamics, vegetation, recreation activity, and other elements could be examined and presented in the same sequential manner.

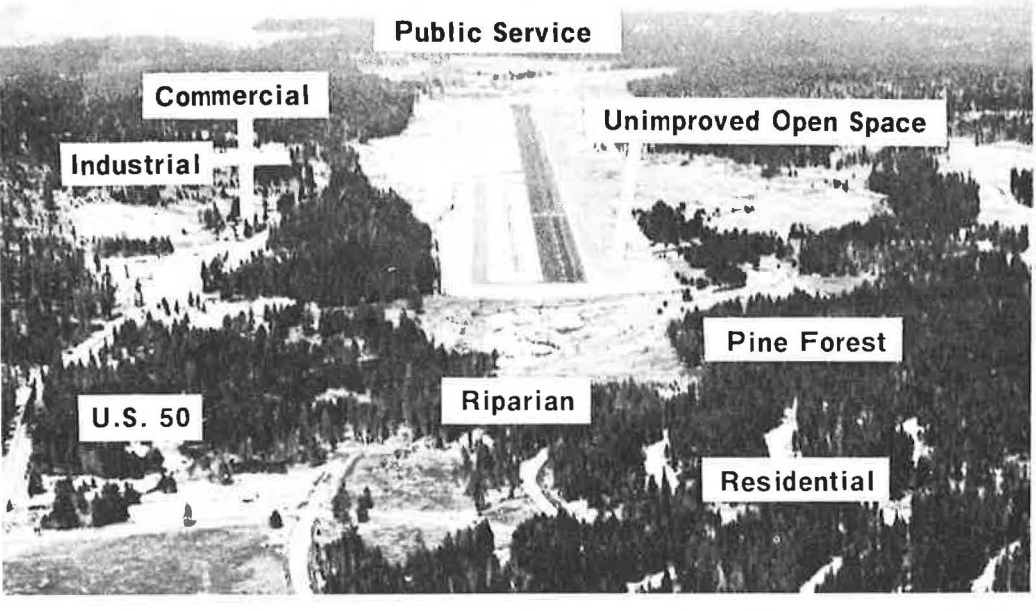
COMPUTER GRAPHICS AND ENVIRONMENTAL MAPPING

Computers are used in studies requiring the storage, manipulation, and array of larg sets of data. Since environmental investigation is increasingly in need of improved data-handling systems, computer technology is developing methods useful to the environmental researcher.

gure 3. Sequential land use.



gure 4. Aerial oblique photograph of Meyers area in 1970 (Department of Public Works photo).



Two methods of computer mapping found to be in use in California are the grid system and the polygon system. With the grid system, a series of rectangular grid cells are overlaid on a base map. Each item of information stored is defined and given a numerical code, which is entered in the grid cell. The drawback of the grid system is the degree of generalization necessary to enter information in the cells. Precise line and point data cannot be transferred.

The second form of computer mapping, which is still in the developmental stage, is known as the polygon or digitizer system. This method allows the operator to trace areas on the source map or aerial photograph with a stylus, which enters the outline and the area—i.e., acres, square miles—of the polygon in the computer memory. The stored information can be retrieved in the form of printout maps of single items, combinations of items, or tabulated numerical data.

An example of a promising digitizer system in the developmental stage is the Wildland Resources Inventory System (WRIS) being developed in two of California's national forests. Information concerning timber types and other related resources such as soils and wildlife is recorded for each township in the forest. The computer can then return a map or tabulated information on one topic forest-wide or several topics in one township or any variation thereof. The resulting computer maps are fractionally coded and can be colored to emphasize special information. Maps from such a polygon or digitizer system are more accurate and more attractive than the product of the grid cell method.

The State of California's Office of Planning and Research is now developing a computer data bank of environmental information to be operated by the Office of Intergovernmental Management. The goal of the data bank is to pool all available natural and man-made environmental information, referenced by USGS 7½-minute quadrangles, in one source. An agency seeking environmental information in a certain area of the state will be able to quickly obtain from the computer all the currently stored data of relevance to environment investigation, thus eliminating much of the hit-and-miss legwork now required to gather information. Such an environmental data bank also allows all state agencies with interest or responsibility in an area to be notified of studies under way in that region, considerably reducing duplication of effort.

The application of computer technology to the problem of highway impact analysis is not always needed, especially where impact areas are small and relatively uncomplicated. Hand mapping remains a useful and efficient alternative for many corridor studies. The main problem facing agencies such as highway departments is knowing what information to gather, how to gather it, and how to interpret and apply that information.

SUMMARY AND CONCLUSIONS

Environmental mapping offers a systematic methodology needed for the interdisciplinary study and reporting of environmental impact. Through geographical identification of the elements of a man-environment ecosystem and the historic and projected changes associated with the system, impact can be identified in both quantitative and qualitative terms. The modeling procedure proposed involves systematic data gathering, synthesis, time interval representations, and graphic display.

A graphic model showing anticipated changes associated with various highway project alternatives, and the no-project alternative, provides opportunity for quantitative consideration of changes in distribution, density, frequency of events, and productivity. It also provides a basis for studying interrelationships and for qualitative judgments leading to beneficial transportation and environmental planning.

The use of maps is especially valuable in this modeling process because maps represent real-world conditions in a manner readily understood by most people. In this way, the necessary community interaction at both the professional and general public levels will produce maximum benefits, in terms of both better plans and better public acceptance.

A number of environmental inventory and mapping studies have been conducted and are presently under way that incorporate various aspects of the techniques and pro-

cedures proposed here. A considerable amount of useful geographical data was found to be available for the US-50 corridor study area in an exploratory field research effort. Much of the available data was in need of updating as well as interpretation and synthesis. In corridors where little environmental study has been conducted, more reliance will have to be placed on photographic, interview, and other field data gathering.

Additional application of the proposed methodology is needed for further evaluation and refinement. It also should be tested in environments other than forests.

REFERENCES

1. Bishop, A. B. Socio-Economic and Community Factors in Planning Urban Freeways. Stanford Univ., Rept. EEP-33, Oct. 1969.
2. Lacate, D. S. The Role of Resource Inventories and Landscape Ecology in the Highway Route Selection Process. Rept. to Office of Regional Resources and Development, Cornell Univ., 1970.
3. Bleiker, H., Suhrbier, J. H., and Manheim, M. L. Community Interaction as an Integral Part of the Highway Decision-Making Process. Highway Research Record 356, 1971, pp. 12-25.
4. McHarg, I. L. Design With Nature. Natural History Press, Garden City, N.Y., 1969.