Appropriate Combinations of Technology for Solving Landscape Management Problems— Session E: Surface Mining and Reclamation

Texas Lignite and the Visual Resource: An Objective Approach to Visual Resource Evaluation and Management[1]

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Abstract: This paper relates the evolution of an empirical model used to predict public response to scenic quality objectively. The text relates the methods used to develop the visual quality index model, explains the terms used in the equation and briefly illustrates how the model is applied and how it is tested. While the technical application of the model relies heavily on existing computer technology and remote sensing techniques for assembling and manipulating the data, the primary value of the work lies in what was learned about using photo response tests and surveys as measures of predicting public response, and how this relates to managing the visual resource.

PREFACE

Since 1930, nearly 100 percent of the electrical energy produced in the state of Texas was from steam generators fired by natural gas. However, with the rapid escalation of fuel prices since the 1960's, there has been an almost unbelievable shift in emphasis from natural gas to lignite (low grade coal) as the primary energy source.

In 1979, there was only one major lignite producing surface mine in the state, the Sandow Mine at Rockdale, Texas. This mine produced coal to generate power for the Alcoa Aluminum Plant located there. Between 1970 and 1976, two new mines were opened and by 1980, there will be a total of eight or nine major lignite producing operations in the state. In less then 10 years, mine production will grow from 10 million short tons per year to more than 40 million short tons per year; an increase of 4 times the 1976 rate. And, all of the coal will be recovered by surface mining.

On an average, each 1 million tons of coal mined will disturb 125 surface acres, therefore an annual production of 40 million tons will disturb 5,000 acres a year. Based on the estimated coal reserves there are potentially 1 million acres that will be disturbed by surface mining for lignite alone.

Even by Texas standards 1 million acres are a sizable chunk of real estate but what makes this particular chunk even more important is the fact that all of the coal bearing deposits lie within 100 miles of the state's major urban centers (Figure 1).

The proximity of these reserves to the major urban centers has increased the desirability of development of lignite as an energy resource. At the same time the location also increases the potential for generating adverse public reaction to the mining activities because there will be frequent visual contact with the mines. Recognizing this, and the documented success and value of Visual Resource Management (VRM) projects in other parts of the country, the Center for Energy and Mineral Resources at Texas A&M University initiated a VRM study of the Texas Lignite Belt to find out

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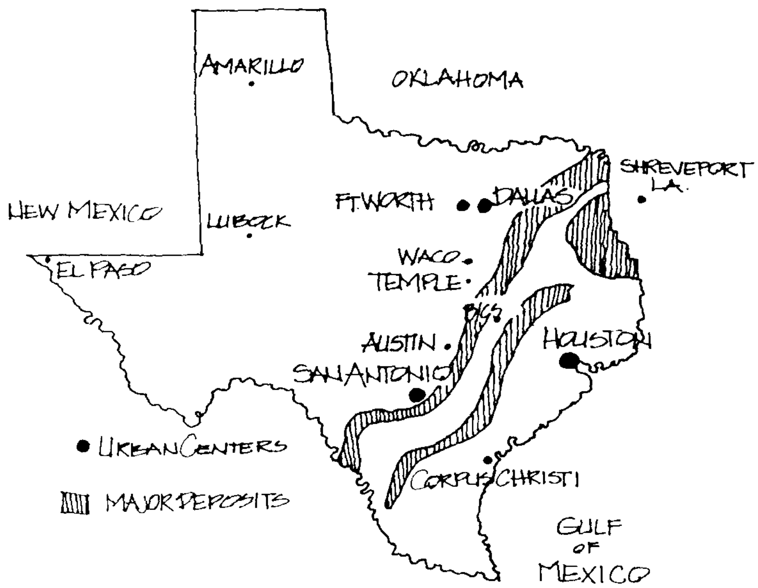


Figure 1. Location of Major Lignite Deposits in Texas

what problems might exist and how they can be managed.

When the study was initiated in January 1978,it was the intent to utilize the visual resource evaluation techniques developed by Leopold (1968,1969) Litton (1967,1968, 1971,1973, 1974) and others (see Literature Cited). This effort included the basic photograph evaluation surveys and field surveys of the central portion of the lignite belt. These early efforts did not yield high results that showed any consistency. The major concern was the large discrepancy between the way people valued photographs of representative landscapes and how the group responded to these same landscapes when experienced in the field.

The reasons for the inconsistencies in the early work cannot be positively stated at this point, but it appears to be a function of two major parameters; the wide variation in vegetation and subtleness of the landscape, and the geographic influence on the public's opinion of scenic quality. The topography of the lignite bearing region is predominately rolling but the vegetation changes radically from pine forest in the east to near desert in the west. Associated with the change in vegetation system there appears to be a corresponding change in the public's opinion of what scenic quality is.

The geographic relationship to public opinion of scenic quality would seem to have caused the variety of response obtained in the early photographic survey and attempts to validate them in the field.

Faced with these inconsistencies and realizing that a substantial data volume was going to be required to achieve any valid results, the entire project was reorganized and redirected. First, the data base was coded for computer storage and manipulated to handle the volume. Then it was decided that the public opinion sample would be restructured to a mail survey format that would allow larger samples and closer control of geographic differences.

While most of the techniques and methodology explained in the study were developed by independent evaluation and empirical field observation, the process that has evolved parallels the "Scenic Beauty Estimation" method developed by Terry Daniel and R. S. Boster (1976) at the University of Arizona. Review of their work and the similarities between the systems tends to support the thesis that scenic beauty can be objectively measured using common resource data frequently used for other types of resource planning.

The primary objective of this paper is to present the hypothesis of the "Visual Quality Index" (VQI) model. The paper explains how the model evolved and discusses how it is being applied in Texas. It should be kept in mind that we are still in the process of completing the project and it is reasonable to expect that changes and refinements will take place as the work progresses.

VISUAL RESOURCE EVALUATION MODEL

Introduction

The concept of Visual Resource Management has quickly taken its place among the contemporary buzz-words of the profession, along with Environmental Planning, Natural Resource Analysis and all the other analyses. In most quarters the concept has achieved wide acceptance as a valid land management concern, NEPA aside. But it should not be forgotten that VRM is still a concept, an idea, not a science. Most of us interested in the visual environment and its management realize this all too well when it comes time to justify our conclusions and recommendations to the ultimate client. However, thanks to pioneers in the field like; Litton (1967,1968,1971,1973,1974), Leopold (1968),Lewis (1964), Jones (1975), Hamill (1971), Boster and Daniel (1976) and others, we at least have some benchmarks to draw on.

This point is emphasized since the ideas presented in this study are drawn freely from the work of the authors cited. There is nothing in the paper that can be claimed as being earth-shakingly new. It is however, an attempt to model the visual resource in a more objective way so that subjective judgement plays a limited part in the process.

Visual Quality Index

Evolution of the Concept

The concept of the Visual Quality Index system grew out of an interest in objective ranking systems and the need to be able to predict with some degree of certainty visually sensitive landscapes using readily available data. In reviewing the work of the authors cited earlier and studies similar to this project it was noted that, for the most part, evaluation criteria were developed by the professional team involved in the study and applied with acceptable results. Specific examples of similar studies are the Mineral King Visual Analysis, Johnson (1974) and Smith River Highway Visual Analysis, U. S. Forest Service (1973).

In order to get a feeling for how a similar process would work it was decided to go through a full cycle in an adjacent county and test our findings by field visits and by public opinion survey. The preliminary studies were accomplished in March of 1978, based on criteria similar to those set down by Leopold (1971) and Litton (1967). The map in Figure 2 indicates those areas identified by the team as having high scenic value and most sensitive to change.

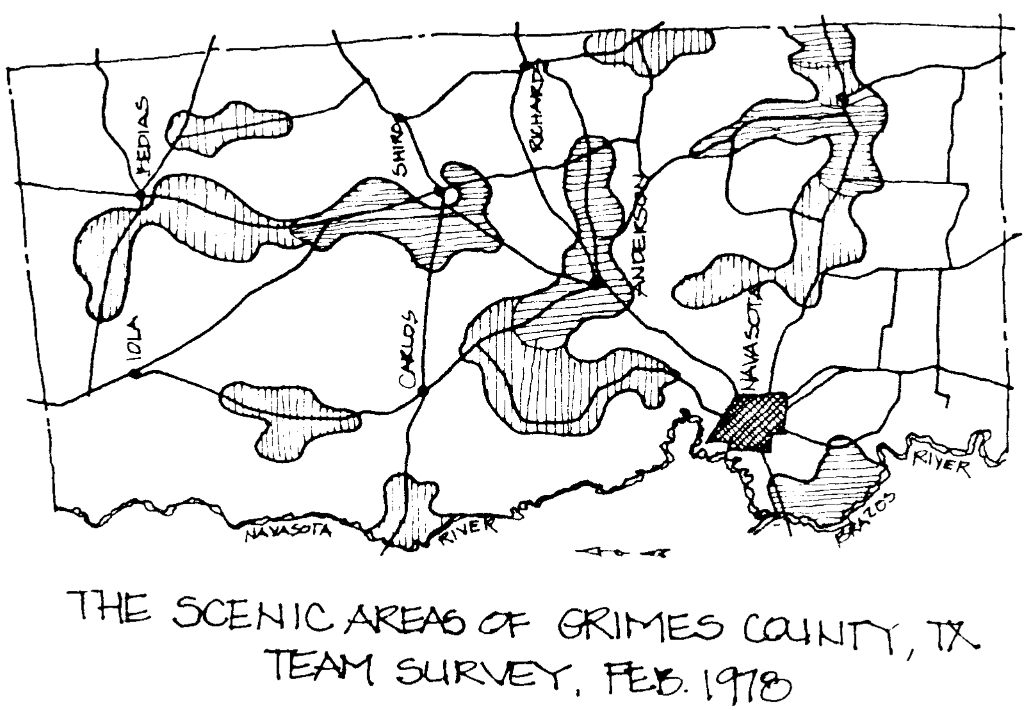


Figure 2.

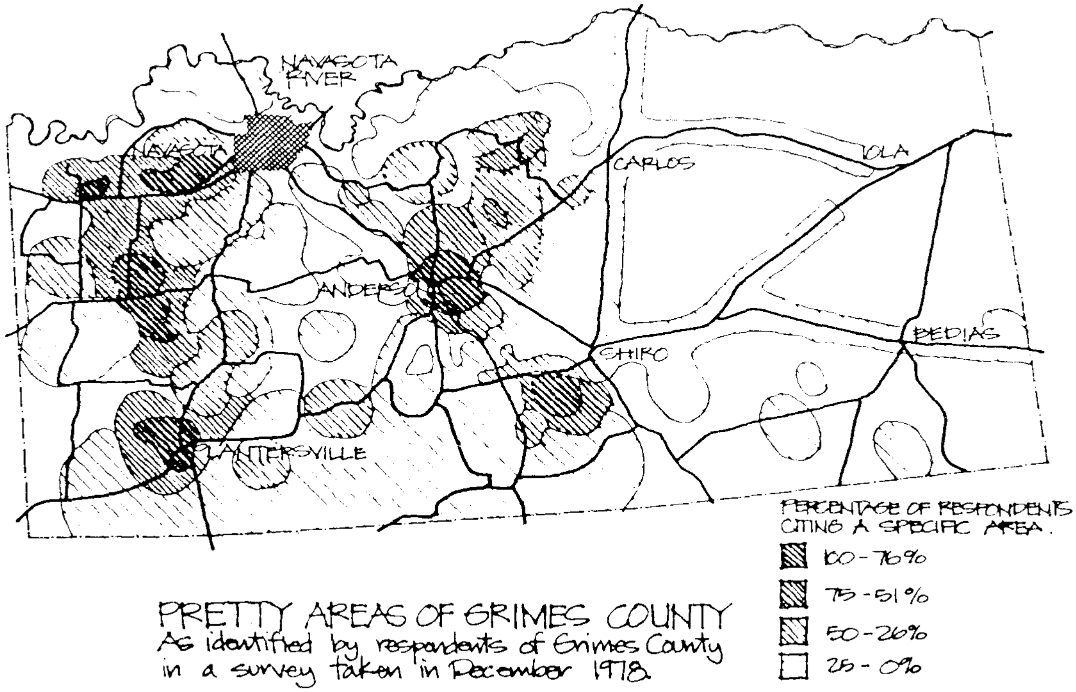


Figure 3.

In addition to the team evaluation a series of random photos were taken along the major roads in the county and ranked by 60 college students (30 political science majors, 18 horticulture students and 12 landscape architecture students) and 10 Grimes County residents. The results of this survey have variation but tended to support the professional team judgement. To check the results further we took the student group to the field and asked them to rank the scenic areas on a map while driving along the same route used to take the photographs. This test yielded radically different results with very little correlation between the photo survey and the field survey.

This put the early work on a very shaky ground so a mail survey was initiated to find out what the county residents thought were the prettiest and ugliest parts of the county. Figures 3 and 4 are maps of pretty and ugly areas identified by the residents of Grimes County in the mail survey. The population sample totaled 500 (10 percent of the population) selected by random number from telephone subscribers in the county. There were 50 valid questionnaires returned representing a 1 percent actual sample. At first this sample seemed too low until the results were compiled and compared regarding place of residence, age, etc. When this was done, the correlation of response was so close that the results could be considered statistically valid.

Examination of the two maps quickly shows that there is considerable variation in the public's opinion of what is scenic and that of the now humble study team. A quick comparison of the overall results indicates that the study team had anti-culture, anti-urban, pro-topography, pro-pine forest biases. This early failure to predict scenic quality successfully was enough to generate a burning desire in the study team to find a more objective methodology to predict scenic quality. To this end a serious field study was initiated of the scenic areas identified in the survey.

Some of the general points noted were that scenic sites related strongly to corridors as Lewis (1964) stated and that evidence of culture; e.g., fences, barns, improved pasture, tended to enhance public awareness. Other patterns such as vegetation type, topography, depth of field and viewer station did seem to play a part but not with the consistency one might predict. With further study and follow up interviews, several major points of significance became more apparent:

- The general public does have an opinion of what is scenic and what is not scenic.
- The public's opinion of what is scenic or ugly is relatively consistent within the geographic area if they have been in residence for a reasonable period (1 or more years).

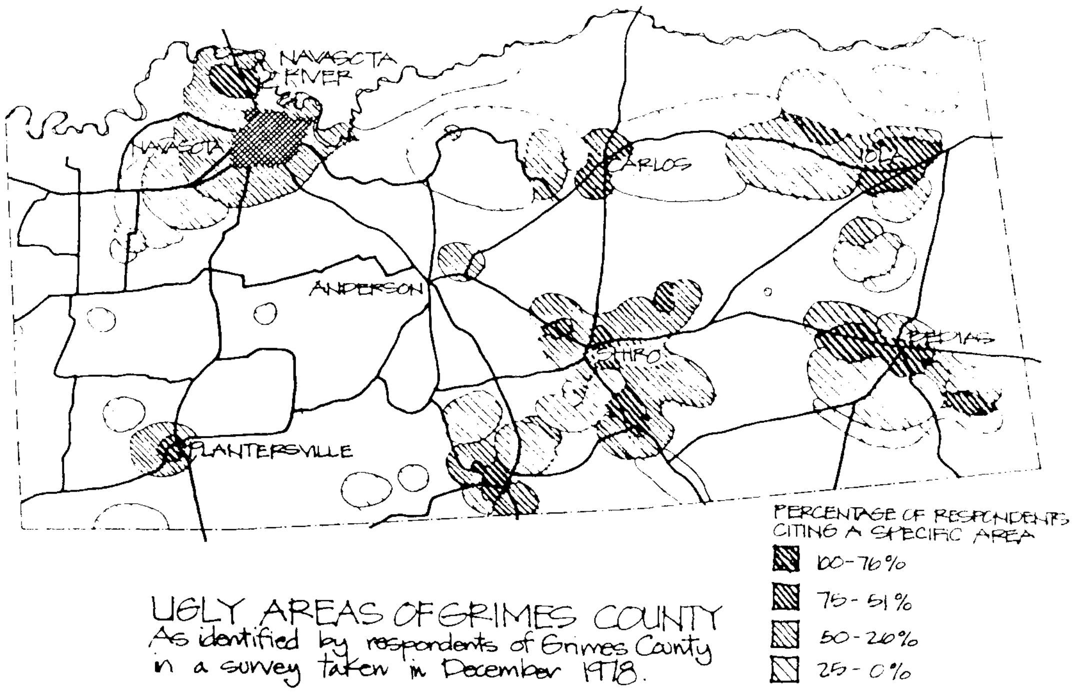


Figure 4.

- Scenic occurrences are related to highway corridors and the frequency of citation increased adjacent to urban centers. This tended to correspond with commuting routes, i.e., frequent observation.
- Comparison of areas with similar physical qualities not cited as scenic and those identified as scenic revealed that these areas were obscured from the corridors limiting the duration of observation.
- A study of the areas considered scenic indicated that as the diversity of elements visible increased the area was cited more frequently, e.g., the photo in Figure 5 was among the most cited. It shows evidence of culture, forest, savannah, pasture, crop land, very simple foreground (uncultured) with the major complexity occurring in the middle ground. Figure 6 is a site rated equally high and has a similar composition with respect to foreground, middle ground and background, yet it does not have the diversity of components.
- The comparison above suggests that a diversity to homogeneity scale, as some have indicated, will not be a valid measure by itself. Further comparison of areas cited as scenic suggest that a second variable is at work that we have called order. It seems at this point that people are inclined to accept a landscape as scenic so long as everything is in its place.

Finally, there seems to be a definite preference in Grimes County For landscapes that provide a broad open vista or at least depth of field. Areas where the vegetation forms a narrow corridor along the highway were infrequently cited as having scenic value. In this case there also seems to be a definite lack of preference for pine forest which is a somewhat anomalous condition in this region. It is also interesting to note that the change from pine forest to hardwood forest is not a gradual transition, an one might expect, it is abrupt. Figures 7 and 8 were taken on Highway 30 exactly half a mile apart. The fact that pine forest was not cited as scenic tends to support the idea that people do not recognize anomalous vegetation as scenic. Yet when it was presented in the photo survey, Figure 7 was ranked consistently high.

Many of these points correspond to observations in other studies but they have not been used jointly and tested to see if then can in fact be objectively quantified. For this reason it was decided to approach the questions as a simple weighted linear model and test the hypothesis by similar surveys to the one conducted in Grimes County.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

The Model Hypothesis

From the observations made in the review of Grimes County survey, four primary variables were identified: frequency of visibility, duration of visibility, diversity of landscape elements and landscape order. The relationship between these variables is hypothesized to be

$$I = \frac{d}{o} \, . \, f \, . \, t.$$

Frequency and duration of visibility are hypothesized to have a proportional relationship. That is, as both frequency of visibility and duration of visibility of any given landscape increased the greater the chance of the landscape being considered scenic or ugly. The two terms essentially form an awareness component. For the purpose of this study, frequency of visibility is measured by the average daily traffic (ADT) rating of the highway. These figures are obtained from the District Engineer of the Texas Highway Department of Highways and Public Transportation. Where data are not available by actual count the engineers are consulted to obtain a reasonable estimate of the traffic load. The duration of visibility is simulated by computer model based on average driving speeds.

The awareness component of the model can be expressed mathematically as (f . t) where:

f = the frequency of visual contact measured in the thousands of occurrences/day

t = the duration of visibility at the average highway measured in seconds

At this time we are not weighting frequency (f) or duration (t) in the model but we believe that as our work progresses further we will find that frequency (f) will have to be weighted heavier. This can be handled quite simply by adding an empirical constant to the basic equation. In addition the entire awareness component may eventually have to be weighted by an additional constant.

The second term of the model considers the inverse relationship between landscape diversity (complexity) and order (neatness). The logic behind this hypothesized relationship is that the sum of individually attractive parts does not necessarily equal an attractive whole. To be attractive or scenic, a landscape must have a number of components to generate visual interest and at the same time there must be a harmony among the components to achieve scenic quality.

This component is called the quality index. It is expressed by the term $\frac{d}{o}$ where:

d = the number and value of physical landscape elements present on a site ranked on a scale of 0 to 9.

0 = the value of order characteristics ranked on a scale of 9 to O.

Application

Based on field evaluation of Grimes County four categories of variables were identified that contribute to landscape diversity and three categories of variables effect order. These are summarized in Tables 1 and 2. These tables do not list the data in the same way they are stored in the computer. They are shown here to illustrate the major factors that contribute to diversity and order.

In the early field work it was not clear how the order term in the landscape quality index hypothesized could be measured, however, further study of base data overlays revealed that there was a strong correlation between the resource area, soil and surface geology. The net effect of these three variables shows up in the vigor and mix of the vegetation, particularly with respect to grasses and understory.

Table 1.

Variables Affect in Diversity of Landscape Units

1 Structures	2 Vegetation	3 Land Use	4 Land Character
Barn & Residence	Post Oak Savannah	Crops	Bottan
Barn(s) only	Post Oak Forest	Pasture	Rolling
Residence only	Elm - Water Oak	Range	Sharply Rolling
Tanks	Pine Forest	Forest	Hilly
Wells (oil & gas)	Pine/Hardwood	Residential	
Power Station	Crops	Rural Residential	
Pens (other than wood)	Pasture		
Wood Fences	Range		
Other Buildings			

Table 2.

Variables Effecting Landscape Order

Resource Area	Surface Geology	Soil
Fast Texas Timberland	Fleeing	Gowen
Blackland Prairie	Alluxium	Miller - Hardwood
Clay Pan	Whitsett	Navasota
Lower Trinity River	Catahoula	Lakeland
Lower Brazos River	Yegua Jackson	Lufkin - Edge
		Lufkin - Tabor

A good example of this is in photographs in Figures 9 and 10. Figure 9 has a ragged, unkept look and was cited once in the survey as being ugly, while Figure 10 was cited four times as being scenic. In this case several things seem to contribute to the low order value of Figure 9. The forest vegetation is anomalous to the resource area, the soil is very unfertile clay and the geologic formation is not a water bearing strata. So far this way of measuring order has proven rather reliable. As one might expect even intensive management cannot compensate deficiencies in the resource.

The measurement of diversity was much easier since it involves a simple inventory of common resource planning variables. Most of the information can be obtained from USGS maps and aerial photographs that can be obtained from the ASCS. The vegetation classification could have been a problem but fortunately the state of Texas has been mapped by the State Parks and Wildlife Department from LANDSAT data. Field checks have proven the maps about 85 percent accurate which has proven sufficient so far.

All of the data given in Tables 1 and 2 have been computer coded using a 1000 ft (304.8 m) square grid cells, approximately 23 acres (9.29 ha). The cell size is based on the assumption that it requires a land area on the order of 100 acres to form a landscape unit that is perceived as a whole. Smaller areas tend to be point occurrences that cannot be effectively predicted at the scale of this study. Therefore, the 1000-ft square cell provides four data points for a minimum unit.

To give a general idea of how the data are modeled, consider a group of adjacent cells as illustrated in Figure 11.

These cells represent a single viewshed with a common t factor of .30 seconds and an f factor of .750 (ATD in thousands of units per

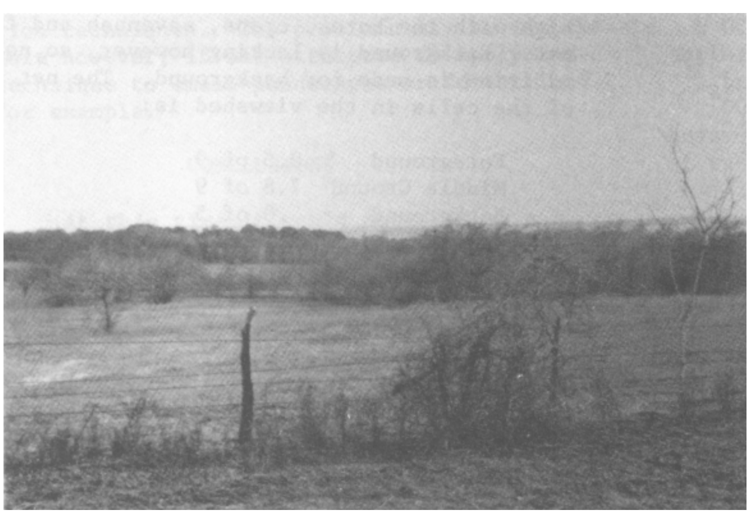
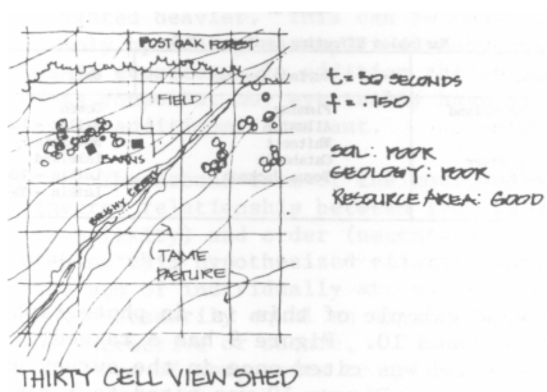


Figure 9.

Figure 10.

Figure 11.



day), thus the awareness component is .750 x 30 = 22.50. The diversity values are obtained in three stages; foreground, middle ground and background. For the foreground, 3,000 feet, the most desirable condition is improved pasture. The least desirable is structures other than fences. Other combinations of events are ranked between. For the middle ground, 3,000 feet to 7,000 feet, a variety of buildings and vegetation is most desirable, i.e., all post oak forest has a low value. Finally, the background is considered for contrast. If a defined background is present it is a plus. If no background is present, i.e., the middle ground terminates the view, then the background value is O.

In this case the viewshed has a high fore-ground rank because of the pasture and the creek. Likewise, the middle ground will be reasonably high with the barns, crops, savannah and forest. Background is lacking however, so no addition is made for background. The net value of the cells in the viewshed is:

Foreground	8.5 of 9
Middle Ground	7.8 of 9
Background	0 of 5
Total	16.3

The order value for these cells is the average of the soil, geology and resource area scores for all cells. In this case the soil and geology values are high; indicating poor soil and geology, but the resource area is good which nets a neutral order value.

Geology	7.6
Soil	8.2
Resource	2
Total	17.8

Therefore the quality index is:

$$\frac{16.3}{17.8} = .92$$

Under this system, values around one are average.

The overall scenic quality index for this viewshed is:

$$22.50 \times .92 = 20.70$$

For an area to be scenic, it needs a value of 30 or greater.

In this example the computed viewshed is only thirty cells, therefore, t, the duration of visibility decreased the awareness factor of the equation. Likewise, the potential for a high diversity value is reduced which is consistent with the hypothesis, and this is the major reason the example ranks low. One big problem that this model presents is that the index will not pick up highly scenic point occurrences as mentioned earlier. It is also possible that if a particular population has a preference for closed scenic corridors there are some questions about how the data can be modeled to predict them successfully.

These problems are not critical to the work being accomplished in Texas, largely because of the scale of the project (±2,000,000 acres) and since the primary objective is to identify major scenic units that will affect mine management and reclamation techniques. The problems may be insurmountable however, if one attempted to apply the technique to small landscapes or forest land, for example.

CONCLUSIONS

At this time it would appear that a successful set of objective descriptors have been devised that can be empirically modeled to reproduce a map that matches the public's idea of scenic landscapes, but it cannot be stated with any degree of certainty, at this time, if the system will work well when applied to a similar landscape until more testing is done. This work is underway now and we are encouraged by what we are finding so far.

To test the hypothesis described further we have selected two additional study areas within the same geographic region that have, in our opinion, similar visual characteristics, Milam County and Freestone County. The same empirical model used to produce the Grimes County map will be used to evaluate both Milam and Freestone counties. During the same period a public survey will be conducted identical to the Grimes County survey. The results of this work will then be compared to see if there is sufficient correlation.

What is most encouraging at this time is that we have done some quick hand overlay studies to make some initial predictions. A windshield survey seems to verify that scenic areas can be identified from the natural resource data with fair accuracy. What we do not know is whether the people of Freestone and Milam counties are of the same mind as the population of Grimes County, and we will not know for sure until mid-August of 1979.

If this work goes as it is hoped, the entire lignite belt will be mapped and evaluated for visual sensitivity using this system.

While the system presented here shows a great deal of promise and raises some exciting new questions, the value of the work is not the system itself. The major benefit will be the landscape management implications brought forward by understanding the landscape better and translating this to better design and lower costs. One very good example of this has already been inferred from our early work. One of our early concerns about surface mining was that the removal of all surface vegetation and reclaiming to pasture would meet with unfavorable response. This appears to be almost the reverse of the truth, as evidenced by the high scenic value of pasture versus forest. Speculation about why is of no value here. What is important is that we are learning.

LITERATURE CITED

Arthur, Louise M.
1977. Predicting Scenic Beauty of Forest Environments: Some Empirical Tests. Forest Science, Volume 23, No. 2, p. 151-159.

Arthur, L. M., Daniel, T. C., Boster, R. S.
1977. Scenic Assessment: An Overview. Landscape Planning, Volume 4, p. 109-129.

Daniel, Terry C,
1977. Mapping the Scenic Beauty of Forest Landscapes. Leisure Sciences, Volume 1, No. 1, p. 35-51.

Daniel, Terry C., and Boster, Ron S.
1976. Measuring Landscape Esthetics: The Scenic Beauty Estimation Method. USDA For. Ser. Res. Pap. RM-167, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Hamill, Louis
1974. Statistical Tests of Leopold's System for Quantifying Aesthetic Factors Among Rivers. Water Resour. Res., Volume 10, No. 3, p. 395-401.

Leopold, Launa B.
1969. Landscape Esthetics. Natural History, Volume 78, p. 38-45.

Leopold, Launa B.
1969. Quantitative Comparison of Some Aesthetic Factors Among Rivers. U.S. Dept. of Int. Geol. Surv., Washington, D C. Geol. Surv. Circ. 620, p. 1-16.

Lewis, Philip H.
1964. Quality Corridors for Wisconsin. Landscape Architecture, Volume 54, NO. 2, p. 100-107.

Litton, R. Burton, Jr.
1968. Forest Landscape Description and Inventories: A Basis for Land Planning and Design. Pac. Southwest For. and Range Exp. Stn., Berkeley, CA, USDA For. Serv. Res. Pap. PSW-49, 64 p.

Litton, R. Burton, Jr.
1972. Aesthetic Dimensions of the Landscape in Natural Environments: Studies in Theoretical and Applied Analysis. John V. Krutilla, ed., p. 262-291. Johns Hopkins University Press, Baltimore, MD.

Litton, R. Burton, Jr.
1974. Visual Vulnerability of Forest Landscapes. J. For., Volume 72, No. 7, p. 392-397.

Litton, R. Burton, and Twiss, Robert H.
1967. The Forest Landscape: Some Elements of Visual Analysis. Proc. Soc. of Am. For. Meet., Washington, D.C., p. 212-214.

Jones, Grant R., Ilze Jones, Bryan A. Gray, Bud Parker, Jon C. Coe, John B. Burnham, and Neil M. Geitner
1975. A Method for Quantification of Aesthetic Values for Environmental Decision Making. Nuclear Tech., Volume 25, p. 628-713.