Appropriate Combinations of Technology for Solving Landscape Management Problems— Session I: Utility Corridors; Siting of Power Plants

Northwest Montana/North Idaho Transmission Corridor Study: A Computer-Assisted Corridor Location and Impact Evaluation Assessment[1]

Timothy J. Murray, Daniel J. Bisenius and Jay G. Marcotte [2/]

ABSTRACT

A computer-assisted method was used to locate and evaluate approximately 1,200 miles of alternative corridors within an 8,000 square mile study region. The method involved in-depth impact analyses for nine major location criteria or determinant models. Regional "experts" from the Rocky Mountain area participated with BPA in developing model structure. Software were used to process linear and topographic data and to "optimize" least impact routes. Impact maps and statistics were generated. Computer output was tempered with extensive field work to develop preferred transmission line locations. Despite encountering problem areas in this application, the method is considered an effective, systematic analytical tool for regional scale planning and location projects where extensive and diverse resource data must be processed.

INTRODUCTION

The Bonneville Power Administration (BPA) is the Federal Power Marketing agency for electric energy generated at the 29 dams in the Federal Columbia River Power System. The Pacific Northwest is linked by more than 12,300 circuit miles of high voltage transmission lines operated by the BPA. A major concern of BPA is the physical and visual impact of transmission lines; in recent years BPA has increased its efforts to select transmission routes considering environmental, visual, and socioeconomic impact.

Recently BPA has acquired and developed a computer-assisted resource analysis method for the location and evaluation of transmission corridors. [3/] [4/]

This tool was used in a major study from 1975-1978 to examine alternatives for integrating additional electrical generation from Libby Dam into the BPA electrical grid and reinforcing service in the north

---

[1/] Presented at the National Conference on Applied Techniques for Analysis and Management of the Visual Resource, Incline Village, Nevada, April 23-25, 1979.

[2/] Landscape Architect, Environmental Planner, Geographer; Bonneville Power Administration, Portland, Oregon.

[3/] The software system (PERMITS) was purchased by BPA from Landscapes Limited, Madison, Wisconsin. The system is an adaptation of the GRID program developed by the Harvard Graduate School of Design for use in land use and resource planning (Lewis 1975). Through agency and public workshops held by BPA and Landscapes Limited, the system has developed into one which has gained recognition throughout the country.

[4/] The corridors in this analysis are approximately one mile wide.

Idaho/northwest Montana area. The study was undertaken in cooperation with Region One of the U.S. Forest Service. BPA was responsible for overall project coordination.

The study demonstrates an integrated approach to land management which encompasses the successive steps of organizing resource data, identifying alternative locations, analyzing potential impacts of high voltage transmission lines and finally supporting a route/plan selection. A work management plan was developed for the study which set forth major phases and specified objectives, responsibilities and a schedule for their completion. This paper discusses the project chronologically.

STUDY AREA DELINEATION

BPA system engineers identified potential origin and terminal points for integrating new power from Libby Dam and satisfying other power requirements in the study area. Four systems plans were identified. Upgrading the existing 115 mile 115 kV line between Albeni Falls and Libby, Montana and building a new line from Libby Reregulating Dam and Libby Substation are common to all four plans of service. Plan A requires a second 23C kV line between Libby and Noxon, Montana and a substation and associated facilities. Plan B requires a second 230-kV line from 120 to 140-miles long from Libby to Rathdrum Substation in Idaho. A 115 to 140-mile, 230 kV line would be built between Libby and Sacheen Substation in Washington under Plan C. Plan D provides for one 230 kV line between Libby and Noxon and another from Noxon to Rathdrum for a total of 115 to 145 miles. The above locations are shown on figure 4.

The next task was to define a study area that would include all feasible electrical plans of service. Criteria for study area delineation included political jurisdictions, recreation and wilderness areas, topography and data availability. The study area encompasses approximately 8000 square miles in eastern Washington, north Idaho and northwest Montana (fig. 1).

MODEL REVIEW AND ASSESSMENT

Nine models that predict impact from construction, maintenance or operation of a transmission facility form the analytical basis for the method. Workshops involving resource experts were conducted by BPA and Landscapes Limited in 1974 to organize the models, establish the data requirements and assign relative impact weights. A modified

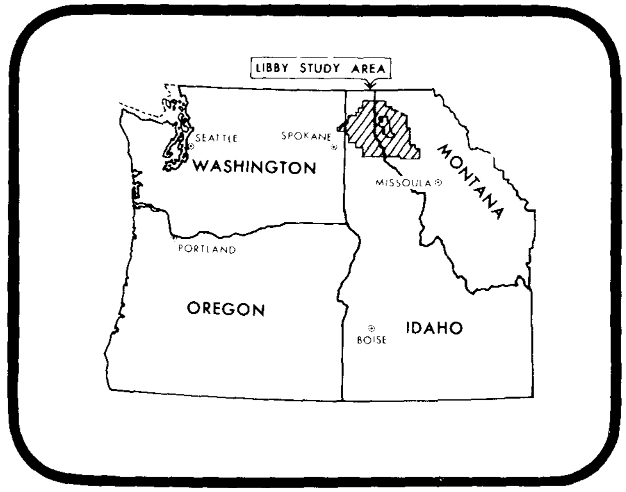


Figure 1--Study area location within BPA's four-state service area.

nominal group procedure developed by Andre L. Delbecq (Huber and Delbecq 1973) facilitated this process. The nine impact models are:

1. Urbanized Land Uses
2. Natural Systems
3. Potential Visual Impacts
4. Recreational Activities
5. Agricultural Land Use Practices
6. Forestry Land Uses
7. Extractive Land Uses
8. Potential Right-of-Way Sharing
9. Transmission Facility Problems

The models were assessed to ensure data practicality and availability and model logic and appropriateness. Two models --visual and forestry-- were insufficient. Consultants were hired to prepare more effective analysis models for visual and forest resources (Blair 1976, Moore 1976). Four determinant models (transmission facility problems, potential right-of-way sharing, recreation and natural systems) needed modification and adjustment. Workshops were conducted to refine these models. The products of this study phase were a final set of models and the data list.

DATA COLLECTION, INTERPRETATION AND DIGITIZATION

The analysis demanded a systematic approach to data collection, mapping, interpretation and storage. Data bank development involved collecting information and organizing it into a computer compatible format. Primary data sources included public and private published documents, ERTS imagery, low-level aerial photography and USGS topographic quadrangles. As part of the cooperative effort, the U.S. Forest Service provided considerable mapped resource information.

In most cases data were interpreted from the primary sources and mapped on 1:125,000 or 1:250,000 scale work maps. A grid of 8000 1-minute latitude by 1-minute longitude cells was established for data storage, retrieval and analysis. Average cell dimensions are 6080 ft. (1850 m) by 4160 ft. (1270 m), or 570 acres (230 ha). The grid was superimposed on data work maps and more than 150 data items were coded for each cell by percent of cell, presence/absence, frequency, or length depending on the data characteristics. General data categories included:

1. Climatological factors
2. Slope/aspect
3. Geologic hazards
4. Soil erosion susceptibility
5. Hydrologic factors
6. Wildlife habitat areas
7. Rare/endangered wildlife habitat
8. Vegetation cover
9. Special status areas
10. Agricultural land
11. Forest land
12. Developed recreational land
13. Dispersed recreational land
14. Other recreational land (designated natural areas)
15. Historic and cultural places
16. Existing land use
17. Planned land use
18. Zoned land use
19. Transportation features
20. Utilities
21. Visual quality
22. Landscape visibility
23. Land ownership

Most of the data was coded manually and keypunched. Data were checked using the Harvard GRID mapping program (Sinton 1973) and entered onto the data base. A digitizing software package was developed by BPA to facilitate the coding process and to process various data items for input to the models. Another routine was developed to convert digital terrain data from Defense Mapping Agency (DMA) tapes into BPA system compatible form for use, in conjunction with the U.S. Forest Service's VIEWIT program (Travis 1975), in the visual and engineering models. This software package has been a catalyst for further research and development. BPA's current tower-spotting program, for example, uses much of the same software.

Data accuracy and validity were tested. From field review of a one-percent sample of study cells, it was determined that data locations within the test cells were highly accurate.

DETERMINANT MODEL ANALYSIS

Analysis maps were generated for each model using programs which multiply the potential impact weight by the percent of cell data values to yield relative impact indexes. Normalized scores range from 0 (little impact potential) to 100 (high potential for impact).[5/] The output is a set of impact files which were used to produce a variety of analytical and descriptive information. For each model, computer maps were generated that spatially describe potential impact (fig. 2).

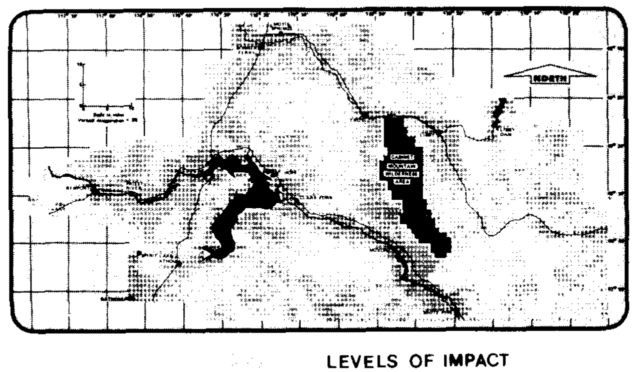


Figure 2--Visual impact potential, displayed in distinct shades of gray. Darker shades indicate greater impact.

Data maps were visually and statistically correlated with model maps to identify patterns and additive effects of data. Model validity was assessed by resource experts familiar with both model composition and study area characteristics. Model realism and logic were judged qualitatively. The models reasonably represented and measured the potential for impact across the study region. A thorough examination of the data maps, backed up by first-hand knowledge of the region itself, supported this conclusion.

CORRIDOR DELINEATION

This study phase involved synthesizing the model analysis results to derive alternative corridors for each of the four plans of service. The method incorporates an optimization program that computes and defines a "least impact" route between two points. Since the least impact value system connotes maximum impact on highly weighted data items, cells having high percentages of valued resources are theoretically avoided. For example, optimizing the recreation model

---

5/ Numeric scores are calculated for each grid cell in the study area and for each model and sub-model data grouping (Wisconsin Power and Light 1973).

should generate corridors which avoid roadless areas, developed recreation sites, and special status areas such as wild and scenic rivers.

A least impact corridor was computed for the land use, natural systems, visual, recreation, forestry and transmission facility problems models for each plan of service. The remaining determinants (agricultural land use, extractive land use and right-of-way sharing) were not optimized because those resources are concentrated in rather specific areas. Specific sets of evenly weighted determinants were optimized, including a combination of all determinants, to yield 12 basic sets (i.e., six individual determinants and six sets of unweighted combinations) for each of the four system plans (fig. 3).

Synthesizing the analyses proved to be a difficult undertaking. In theory policy/decision makers could work together, guided by a nominal group process, to establish "weights" that would accurately reflect the overall importance of each determinant. The resource weights could then be used to prepare a composite map that would guide the facility location process. Such a weighting procedure was not attempted as part of the study. It was not only difficult because of pronounced resource and value differences across the study area, but conceptually questionable to combine impact measures by relative weights.

The reasoning is that each analysis model at the determinant level predicts impact on a particular resource or set of resources. For example, a value is calculated that indicates the impact on forestry in a cell. A value for visual impact is also computed for the same cell. In short, discrete values are calculated for all resource concerns. To combine the values for each cell, numerically weighted to reflect the concern of a group of "decisionmakers," destroys the inherent value of the analysis for any of the nine major resource concerns (models). For the same cell, low impact on one resource would tend to moderate high impact on another. The resultant value in the cell then says little about what the overall impact is likely to he and seemed too elementary for use in determining corridors. It appears from observation that the decision process must recognize that different resource concerns are impacted differently but that meaningful synthesis requires that all values remain discrete during the allocation process.

A classical approach to land and site design was chosen for the corridor delineation process. This process is based on: data describing the study area; the predictive impact analyses; and, familiarity with the site gained during field reconnaissance. Model maps and optimized routes were carefully studied, by a manual overlay technique, to discern spatial differences and commonalities. Attention was given to determining which resources tended to force corridor deviation from the most direct path. Sensitivity indices (Wisconsin Power and Light 1973) for each optimized route were an integral part of the process. Whereas optimizations represent the "best possible" route between two points spatially, sensitivity indices do so statistically. Other optimized or field-generated routes can be statistically evaluated to determine

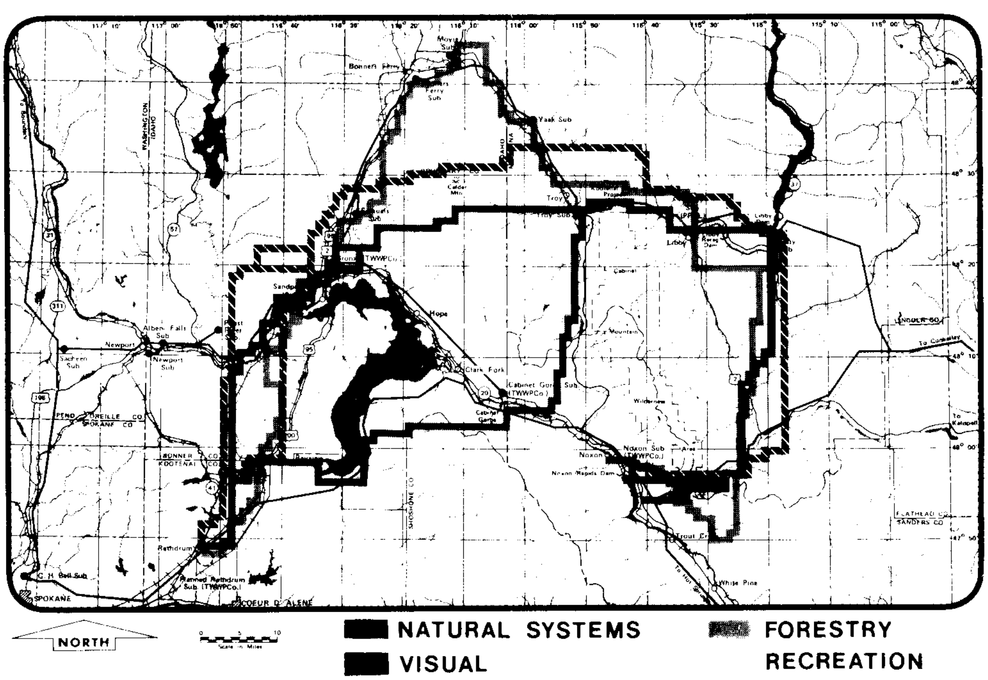
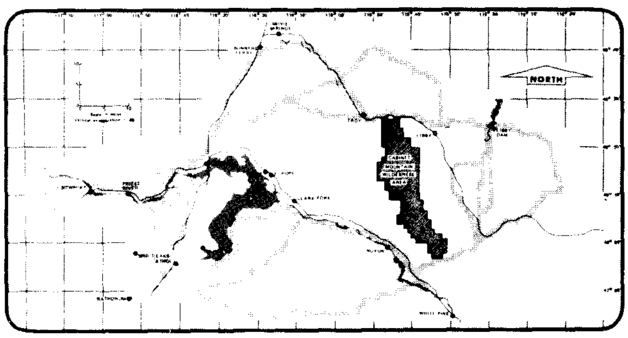


Figure 3--Optimized corridors from combining the natural systems, visual, recreation and forestry models.

deviation from this "best case" route. These comparisons were of significant value.

The study team spent time in the field, then synthesized the data, determinant analyses, optimizations, ground truth and study area knowledge. In essence, the synthesis involved manually overlaying analyses maps and by comparison, evaluation, and refinement ultimately defining all possible corridors. More than 1200 miles of alternative corridors were delineated (fig. 4). They constitute frames-of-reference for subsequent discussions of potential impact.



ALTERNATIVE CORRIDORS

Figure 4--Alternative corridors are the feasible paths for integrating power between Libby Dam and various terminal points.

ENVIRONMENTAL IMPACT STATEMENT

The Draft Facility Planning Phase to BPA's annual Environmental Impact Statement (EIS) (USDI 1977) is the culmination of the study process. BPA specialists evaluated the analysis information for each plan of service. These evaluations form the basis of the EIS document.

The EIS is a summary of the potential impacts of the alternative corridors. Its objective was to present these results as accurately and efficiently as possible to facilitate the decisionmaking process. The document had to demonstrate that applicable legal requirements had been adequately addressed during the study. Legislation including the National Environmental Policy Act of 1969 (NEPA), the Endangered Species Act and other legal mandates specify such requirements as obtaining public involvement and conducting applicable endangered species consultation.

To produce a concise decisionmaking document, a summary approach to impact analysis was completed. An impact consensus, based on all impact analyses, was arrived at using modified nominal group procedures. A summary impact table was incorporated in the EIS.

To obtain an accurate account of public response during the EIS review process, a content-analysis procedure was adapted to quantify and categorize, systematically, the significant content of information.[6/] The core meaning for each independent unit of written or voiced communication received was distinguished, summarized and categorized. All public meeting transcripts and all written public and agency correspondence were interpreted. Major response categories were:

Major Concerns	# of Comments	# of Respondents
Power Corridor Plans	27	31
Existing Corridors	19	19
Other Proposals in Area	27	18
RARE II and Wilderness Areas	13	10
System Reliability	13	7
Costs/Benefits	11	6
Project Need	5	5
Wildlife	12	2
Forest Products	6	5
EIS Preparation	19	9
Kootenai River Diversion	5	4
Conservation and Consumption	10	5
Herbicides	13	4
Miscellaneous	10	6
Other	36	11

A third effort of this study phase involved endangered species consultation. Possible adverse impact on the grizzly bear (Ursus arctos horribilus), a Federally threatened species, was predicted from the analysis.

BPA initiated formal consultation with the U.S. Fish and Wildlife Service to determine possible consequences of the plan of service alternatives. The consultation also included the Northern Rocky Mountain Timber wolf (Canis lupus irremotus), listed as endangered. Consultation regarding the bald eagle (Haliacetus leucocephalus) was subsequently entered into and is to be concluded prior to issuance of the final EIS. BPA-sponsored eagle habitat studies are currently underway, and will serve as critical input to the final biological determination.

An electrical system plan was selected by BPA in June 1978. Plan B, the selected plan, combines upgrading existing facilities and constructing new lines on existing

[6/] Personal Communication, Eldon H. Baker, chairman, Department of Interpersonal Communication, University of Montana, Missoula, Montana.

right-of-way to meet the long term electrical needs of the study area. Factors important in the decision included using existing right-of-way; developing a flexible, reliable, multi-purpose facility; conserving power transmission losses; and minimizing environmental impacts. Specific inputs to the decision included (1) engineering and economic studies, (2) the draft facility planning phase and (3) concerns expressed during review of the document. In that the latter two are direct products of this study, the impact analysis process discussed herein has had a important role in facilitating the making of a major land use decision.

FINAL PROJECT PHASES

Centerline route studies are scheduled to start during 1979. Site specific impacts will be identified and appropriate mitigating measures will be determined. Engineering surveys and construction work follow these activities. The transmission facilities are scheduled to be energized in the Fall of 1983.

CONCLUSIONS

This study is the first major application of a computer assisted location and evaluation process at BPA. The Environmental Planning Unit at BPA is currently undertaking a methods analysis study to evaluate this process as well as others. The methods study will recommend procedures for BPA to use for a wide range of location and evaluation projects. However, a few interim observations regarding the present study can be made.

An extensive array of data was required for the analysis. The benefits versus costs associated with the data base have yet to be assessed. What is certain, however, is that the task of limiting data collection to essential items was not entirely successful. A more thorough evaluation and restructuring of the models would rectify this.

The time required to build and maintain a data base is a function of its comprehensiveness. Data requirements often conflict with the realities of shorter-than-ideal study lead times and completion schedules. Although not a problem for this study, BPA (as do other agencies) usually faces strict project time constraints. There is no ready solution to this dilemma, although a combination of reduced data comprehensiveness, simpler models and/or smaller study areas can considerably reduce the data collection effort.

The process is designed for the location of new corridors. Therefore, the impact models do not adequately reflect the impact or problems associated with paralleling and/or rebuilding existing lines. However, with more than 12,000 circuit miles of existing transmission facilities, these are often practical options and reflect BPA policy. Models adequate to measure such impacts need to be developed, as BPA will continue to use existing facilities as appropriate.

Data cell size has been a critical issue. Cell size appropriateness is determined by many factors including data availability and scale, type of land use, study area size and computer capabilities. Many optimized corridors encountered environmental conditions not satisfactorily reflected by the one-minute grid cell. That the "best" routes were not initially generated was due primarily to too large a cell size.

The study area is characterized by steep topography and associated physiographic constraints. Field evaluation revealed places where optimized corridors encountered topography excessively steep to be technically feasible for construction. Provisions to reflect more adequately selected contraints, such as topography, exist but involve defining absolute constraints for appropriate categories of data. Such refinement would have helped initially define more satisfactory corridors.

Completing a "cycle" of optimizations based on additional model runs involved considerable time and several "cycles" were not possible. Thus, the many analytical tools and subprograms of the system could have been used more extensively by converting to a 'real-time' mode whereby processing would be more-or-less instantaneous.

The level of data accuracy was reassuring; the data base was satisfactory; and the analysis models appeared to reflect potential impact systematically. These conclusions were corroborated by model review, consultation with resource experts and field review. The visual and forestry analyses--based on different techniques than the other models--became two of the better predictive models.

Despite its shortcomings, the study represents a successful effort by BPA to develop and apply a systematic resource analysis method to transmission location. It has been recognized by other agencies and groups as a positive contribution to land use assessment. Much of this recognition derives from the benefits of using an integrated approach. The approach has proved capable of organizing, storing and analyzing data reflective of landscape variations across a large study area. The comprehensive data inventory and analysis procedures are evidence of adequate study with regard to Federal legislation and other executive, state and local legal mandates. The study process also incorporated public participation, thus providing government agency and public input into BPA's planning process as required by sections 101 and 102 of NEPA. Additionally, the study has served as a catalyst for adapting computer programs, refining systematic data gathering techniques for use on other projects and enhancing relationships with other state and Federal agencies. Overall, through the use of computer technology it has been shown that a wide range of resource and cultural concerns can be systematically considered in locating corridors and assessing impacts.

Substantial information is required to make sound electrical transmission decisions at the plan of service, route and centerline levels. As one of the decision factors--along with engineering and economic data--resource information must be pertinent and accurate. It is fortunate that BPA management has made a commitment to the use of state-of-the-art procedures in location and evaluation studies. This study is significant and will be of special value for evaluating analysis procedures for wide scale use in BPA .

ACKNOWLEDGEMENTS

The authors wish to acknowledge the many people in BPA and the U.S. Forest Service without whose efforts this project could not have been undertaken.

LITERATURE CITED

Blair, William G. E., Brian A. Gray, John A. Hebert, Grant R. Jones
1976. Visual impact of high-voltage transmission facilities in northern Idaho and northwestern Montana. For the Bonneville Power Administration. 157p. Jones and Jones Inc., Seattle, Washington.

Huber, George, and Andre L. Delbecq
1972. Guidelines for combining the judgements of individual group members in decision conferences. J. Acad. Management 15(2): 161-174.

Lewis, Philip H., Bruce H. Murray, Bernard J. Niemann, Jr., James A. Wright
1974. PERMITS methodology, phase II. For the Bonneville Power Administration. 2 vols. Landscape Limited, Madison, Wisc.

Moore, Gerald L., Joe C. Elliott, Dana Schmidt, Tom Olson
1976. Some management implications of habitat type classifications. For the Bonneville Power Administration. 80p. Olson-Elliott and Associates, Helena, Montana.

Sinton, David and Carl Steinitz
1970. GRID. In: Computer graphics and spatial analysis. Carl Steinitz, ed. p. III. 42-43. Laboratory for Computer Graphics and Spatial Analysis, Harvard University, Cambridge, Massachusetts.

Travis, M.R., G. H. Elsner, W. D. Iverson, and C. G. Johnson
1975. VIEWIT: Computation of seen areas, slope, and aspect for land use planning. USDA Forest Serv. Gen. Tech. Report PSW-11, 70p. Pacific Southwest Forest and Range Exp. Sta., Berkeley, Calif.

U.S. Department of the Interior, Bonneville Power Administration
1977. Draft facility planning supplement for Libby integrating transmission. Supplement to the Environmental Statement, FY 1979 Proposed Program. 52p. BPA, Portland, Oregon.

Wisconsin Power and Light
1973. EDAP System/Environmental decision alignment process: computer system documentation. 311p. Madison, Wisconsin.