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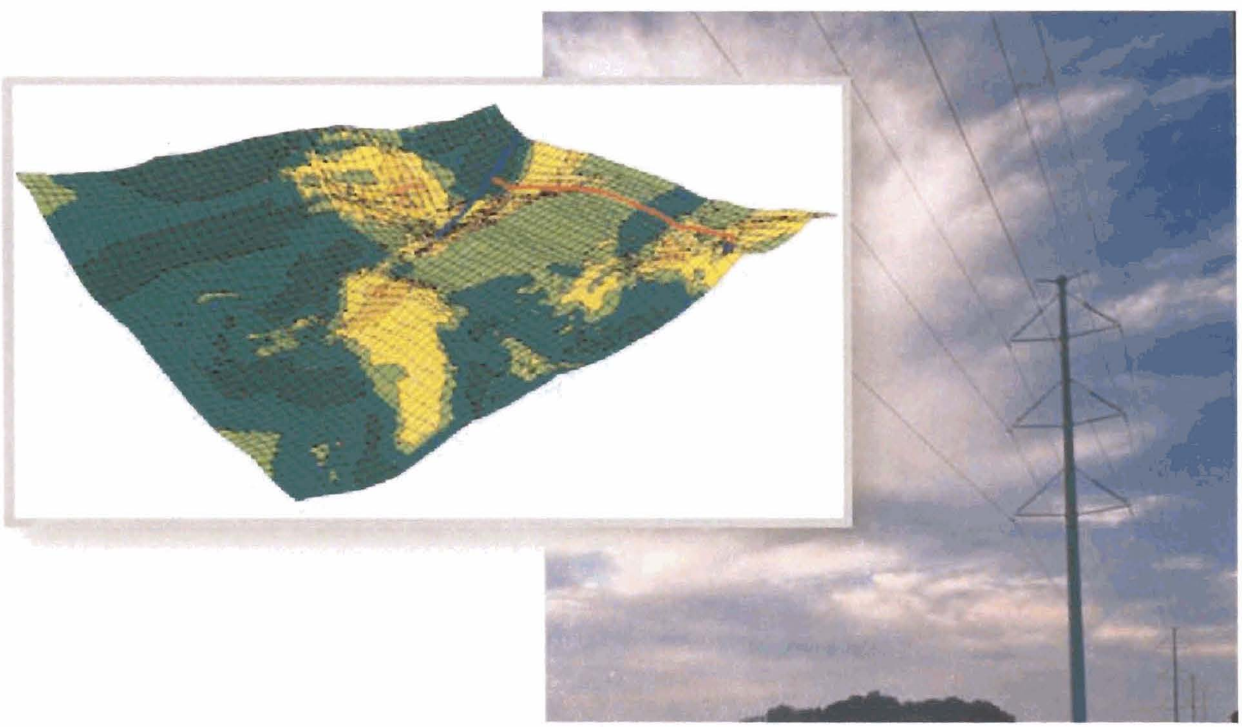
EPRI-GTC Overhead Electric Transmission Line Siting Methodology

Technical Report



EPRI-GTC Overhead Electric Transmission Line Siting Methodology

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REPORT SUMMARY

This report explains and documents a standardized process that utilities could use to improve the way transmission line routes are evaluated and selected.

Background

Starting in 2002, EPRI and Georgia Transmission Corporation (GTC) joined forces to study transmission line siting and to find ways to make siting decisions more quantifiable, consistent, and defensible. Using GTC's existing siting process, the project team incorporated geographic information system (GIS) technology, statistical evaluation methods, and stakeholder collaboration to produce a new siting methodology. The tools, techniques, and procedures developed by the team were demonstrated through practical application on sample projects.

Objectives

- To review and improve GTC's overhead transmission line siting practice.
- To develop a new GIS siting model and new siting processes that produce site-selection decisions that are more objective, quantifiable, and consistent.
- To obtain internal and external stakeholders' critical reviews and achieve consensus on ranking GIS database features and weighting of data layers.
- To ensure the process conforms to federal and state environmental regulations.
- To apply the corridor and route selection process to actual transmission line siting projects and evaluate the results.

Approach

The project team presents the EPRI-GTC overhead electric transmission line siting methodology by defining the phases used in the new process and taking sample electric transmission siting projects from initial planning to preferred route selection. To begin, the team performed landscape analysis at different scales, from large regional areas called macro corridors, to alternative corridors, to constructible alternative routes, and to a preferred route. Analysis was performed at each phase, using off-the-shelf geographical databases and other datasets. A new GIS siting model was developed and used to manage data, produce macro and alternative corridors, generate statistics on alternative routes, and create graphic depictions. The model used a common land suitability technique that combines data layers into a comprehensive surface to identify areas of opportunity and constraint. The model employed GIS, global positioning system (GPS), and visual simulation technologies. Database features were ranked and data layers were weighted through collaboration with more than 400 internal and external stakeholders at five workshops. Consensus was achieved by using two research techniques: the Delphi and the analytical hierarchy processes. The new methodology was tested on a group of GTC's construction projects.

Results

All study objectives were achieved. The project developed better decision-making procedures and an analytical tool that successfully integrated GIS technology and statistical evaluation methods to generate corridors and routes. Stakeholder consensus was achieved on the ranking of GIS database features, such as geographic, environmental, and engineering elements, and the weighting of various data layers. The methodology was tested on existing transmission line siting projects. In addition, study parameters and decisions built into the process were studied and made consistent with applicable environmental regulations.

The new methodology succeeded in producing more quantifiable, objective, and consistent siting decisions than the procedures GTC used prior to the study. As a result, GTC benefits from having a siting practice that is backed by a standard, scientifically rigorous, and peer-reviewed methodology. In addition to improvements in planning productivity achieved through automated data analysis, an unexpected result was a reduction in data collection and analysis costs. Savings result from the EPRI-GTC process reducing study area boundaries for each transmission line siting project, thus reducing data acquisition costs and analytical time. GTC's legal, public relations, and environmental efforts also benefit from decisions being well documented and reproducible.

EPRI Perspective

Electric utilities continue to face challenges in siting new transmission lines. In a prior EPRI report (1009291), *Survey of Electric and Gas Rights-of-Way Practitioners: Current Practices and Views of Future Transmission Line Siting Issues*, eighty-eight percent of electric utility respondents said their company encountered opposition from the public and from landowners, and sixty-five percent cited environmental obstacles as barriers. Clearly, there was a need for a methodology to capture and address public opinion and other factors in siting new transmission lines. While this methodology does not attempt to ameliorate publicly controversial aspects of transmission line construction, utilities and the public can realize significant benefits from its use. To the extent that this methodology involves the public and explains and documents decisions that are more objective, quantitative, and consistent, sound public policy goals have been substantially advanced.

Keywords

Electric transmission lines
Siting
Power lines
GIS

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

In fast-growing states like Georgia, demand for electricity is outpacing rapid population growth, placing pressure on electric utilities to build more electric transmission power lines. In 2004, for instance, Georgia's utilities built more than 100 new miles of transmission lines and Georgia Transmission Corporation is currently investing more than $100 million annually in construction. With more construction comes more public scrutiny on a range of issues, including the decisions made when determining locations for new electric transmission lines.

In 2002, a team sponsored by the Electric Power Research Institute (EPRI), Palo Alto, CA, and Georgia Transmission Corp. (GTC), Tucker, GA, began analyzing existing transmission line siting procedures to find ways to make decisions more quantifiable, consistent and defensible. The team set out to develop a standard siting methodology that other utilities could adopt. The project team included GIS consultants from academia and the private sector, NEPA compliance and legal experts and environmental, engineering and land acquisition staff members from GTC and other utilities (Appendix A: EPRI-GTC Overhead Electric Transmission Line Siting Methodology Project Team).

The study examined GTC's existing siting practice, including data collection, analysis, project study area identification and selection of Preferred Routes. Preferred Routes are the areas deemed most suitable for building power lines. This report describes new siting processes and standard decision-making procedures developed by the team. Current Geographic Information System (GIS) technology, statistical evaluation methods and stakeholder collaboration were employed to produce this new siting methodology. The tools, techniques and procedures developed by the team were tested with GTC's existing siting projects.

This EPRI-GTC Overhead Electric Transmission Line Siting Methodology report defines the new siting methodology and new GIS Siting Model. The report then illustrates how the methodology and GIS Siting Model are integrated by following a sample transmission line project from start to finish. Conclusions and potential improvements are then described. The study accomplished the following objectives:

1. Developed a new methodology and GIS Siting Model for producing more objective, quantifiable and consistent siting decisions,
2. Obtained more than 400 stakeholders' critical reviews and achieved consensus on the ranking of geographic, land use, environmental, engineering and other GIS database Features, as well as the weighting of Data Layers,
3. Ensured the process conforms to environmental regulations, and
4. Improved Georgia Transmission's transmission line siting practice.

Overview of the Siting Methodology

The EPRI-GTC Overhead Electric Transmission Line Siting Methodology consists of three phases:

1. Generation of a Macro Corridor, a large geographic swath that defines the project boundaries;
2. Generation of Alternative Corridors, linear areas within a Macro Corridor that are deemed most suitable when the Natural Environment, Built (manmade) Environment and Engineering Requirements Perspectives, and a Combined Perspective, are considered; and
3. Analysis of Alternative Routes, constructible areas within the Alternative Corridors, and selection of the Preferred Route.

Once Alternative Routes are scrutinized using detailed geographical data, a Preferred Route, the most suitable location for a power line, is determined through professional collaboration guided by study results. At each phase, satellite land cover data, aerial photography or statewide and local digital data are used to reach decisions.

A number of factors influence the suitability of power line locations, such as housing density, wetlands and land cover. The project team developed a list of database Features that were evaluated, modified and weighted with the help of more than 400 stakeholders. One group of shareholders included representatives of neighborhood groups, regulatory agencies and natural resources and land conservation organizations. A second group was made up of utility professionals from Georgia Transmission Corporation, Georgia Power Company (GPC) and Municipal Electric Authority of Georgia (MEAG) Power. Features were ranked using the Delphi Process, a research decision-making technique, and Data Layers were weighted using the Analytical Hierarchy Process (Appendix D: Least Cost Path, Delphi Process and Analytical Hierarchy Process Techniques).

The EPRI-GTC Overhead Electric Transmission Line Siting Methodology is based on land suitability analysis techniques developed in the 1970s by Ian McHarg.[1] These techniques combine Data Layers into a comprehensive surface that identifies areas of opportunity and constraint. McHarg's process is commonly used for siting shopping centers, subdivisions, linear utility corridors and other facilities. The EPRI-GTC effort automated much of this data processing and analysis with the use of the GIS Siting Model. The model combines contemporary GIS, visual simulation and Global Positioning Systems (GPS) applications. GIS technology provides the modeling environment, and other applications manage data, produce corridors and routes, create graphic depictions and generate reports.

Chapter 2 of this report describes how different database Features and Data Layers were selected, ranked and weighted, and it illustrates how the GIS Siting Model generates corridors and routes. Chapter 3 demonstrates each phase of the siting methodology by following a case study from the beginning, the identification of two endpoints, through selection of a Preferred

[1] McHarg, Ian L. Design with Nature (1969) Natural History Press, New York, NY.

Route. Chapter 4 describes the main research actions and timeframes. Chapter 5 presents conclusions and potential improvements that could be made to the methodology and GIS Siting Model.

GTC's routing and siting practice was standardized in accordance with the EPRI-GTC siting methodology. This standardization fosters sound siting decisions by ensuring that selection criteria and choices are based on more objective and uniform information. In addition, the process provides consistency in data acquisition and use. The structured nature of the methodology helps ensure its consistent application across projects, locations and siting teams. In addition, information and assumptions used in choosing one route over a less suitable alternative are well documented and reproducible (Appendix C: Geographic Information Systems Metadata).

2
SITING METHODOLOGY PHASES

The project team examined Georgia Transmission Corporation's current transmission line siting methodology to identify areas that could be standardized and otherwise improved. Several major issues were identified, including potential adverse impacts to existing and proposed development, cultural resources and sensitive biotic resources. To address the issues, the project team established three important phases in the EPRI-GTC Overhead Electric Transmission Line Siting Methodology.

The three phases are as follows:

- **Phase 1 – Macro Corridor Generation**

  During Phase 1, land cover data derived from satellite imagery, consisting of 30-meter grid cells, and existing statewide databases, e.g., roads, slope and existing overhead electric transmission lines, are used to generate Macro Corridors between two endpoints determined by Georgia Transmission's Electric System Planning department. Because Macro Corridors parallel or collocate along existing linear facilities or cross largely undeveloped areas, they are expected to include the most suitable areas for locating overhead electric transmission lines. The outside limits of the Macro Corridors become the boundaries of a project study area.

- **Phase 2 – Alternative Corridor Generation**

  In Phase 2, Alternative Corridors are developed within the Macro Corridors. During this phase, one-foot aerial photography is acquired and digital orthophotography is produced. More detailed digital data are collected for wetlands, floodplains, land use/land cover and other Features and entered into the GIS database. This more detailed data is used to identify four distinct types of Alternative Corridors. Input from stakeholders was used to define the four types of Alternative Corridors.

- **Phase 3 – Alternative Route Analysis and Evaluation**

  In Phase 3, the siting team identifies a set of Alternative Routes within the Alternative Corridors. Each route is then scored using a standard set of evaluation criteria and compared. The preferred route is selected on the basis of this comparison.

As the project progresses from Macro Corridor generation to Alternative Route analysis and evaluation, the methodology uses more detailed data to refine the route selection. This chapter describes in greater depth the actions that take place during each of the three phases.

Phase 1: Macro Corridor Generation

After reviewing GTC's existing study area delineation practices, the project team developed a new technique for determining project boundaries. This technique, termed Macro Corridor Generation, departs from a more traditional siting process where boundaries of the project study area are determined by four major criteria:

1. Distance between termini, such as generator to substation,
2. Natural and manmade physical barriers, including major rivers and interstates,
3. Administrative barriers, such as military bases and wilderness areas, and
4. Budgets and schedules for data collection.

Macro Corridor Generation was chosen to replace this method of study area delineation because of cost and time concerns and the need for more detailed analysis of feasible routes. By using inexpensive and free off-the-shelf digital data and sophisticated GIS modeling, a costly and time-consuming data collection and data processing step was eliminated.

Development of Macro Corridors is based on land cover products derived from satellite imagery and other off-the-shelf digital data. The GIS Siting Model identifies corridors that minimize adverse impacts to built and natural environments. In many cases, paralleling existing transmission lines or paralleling existing road rights-of-way can minimize adverse impacts to these environments. The GIS Siting Model eliminates from consideration those areas where there is no viable option for building a transmission line. Macro Corridors define the area where orthophotography and other detailed data collection and analysis will occur in Phase 2.

Macro Corridor Model Testing

The Macro Corridor Phase of the GIS Siting Model was calibrated by testing it on GTC's completed overhead transmission line projects. Twelve projects were selected for the test because they were representative of various landscape characteristics within Georgia. In addition, the projects were chosen because they were sited on schedule, within budget, and with minimal adverse impacts to the built and natural environments.

Using satellite imagery and other off-the-shelf data, suitability grids were generated for each completed project. The suitability grid generated for these tests covered 100 percent of the study area on each project. The boundaries of the Macro Corridors were determined by identifying the percentage of the suitability grid that consistently included all alternative routes that had been generated during the route selection process on the completed projects.

Superimposing the alternative routes from the test projects on the new suitability grid showed that all alternative routes fell within the first five percent of the numeric values of the suitability grid. In future uses, the suitability grids on new projects will be reviewed in order to validate the numeric value essential to generating consistent Macro Corridor boundaries.

Macro Corridor Data Layers

Macro Corridor Generation uses available digital Data Layers, allowing for quick identification of a project area. These datasets include land cover derived from Landsat satellite imagery, a Digital Elevation Model (DEM), existing roads from Geographic Data Technologies (GDT) and overhead electric transmission lines from the Georgia Integrated Transmission System (ITS). The suitability of these Features is ranked for cross-country, road parallel and existing transmission line rebuild/parallel routes.

The source layer for the Macro Corridor GIS dataset is Landsat satellite imagery that was developed by NASA and is maintained by the U.S. Geological Survey (USGS). The USGS collects current imagery through a satellite system that scans electromagnetic energy reflected from the surface. The satellite repeats its data collection every 16 days. These data have a minimum ground resolution of 30 meters and a single image covers approximately $180km^2$. A scanner collects data from seven different bands of the electromagnetic spectrum, including visible light, infrared and thermal infrared reflectance (Figure 2-1: Raw Landsat Imagery). These raw data typically are classified into 15 to 30 land cover classes based on the Anderson Land Use/Land Cover Classification Level II (Figure 2-2: Anderson Level II Landsat Imagery Classification). Although these land cover data are much coarser in resolution than aerial photographs, it is fairly inexpensive to obtain and can be updated regularly at a relatively low cost. A number of national land cover datasets are widely available at no charge. It is important to note, however, that there is a lag time between availability of national land cover products and the dates of the original imagery. It is important to assess whether the land cover data are timely. For Georgia, the available datasets include a 1988 land cover map developed by the Georgia Department of Natural Resources, 1992 National Land Cover Dataset (NLCD) developed by the USGS, and a 1998 land cover map developed by USGS GAP Analysis Program. A 2001 NLCD is under development.

In addition, each state is being mapped as part of the National Gap Analysis Program (GAP). According to the GAP mission statement, the USGS provides regional, state and national assessments of the conservation status of native vertebrate species and natural land cover types of the United States. A number of states are beginning to generate their own versions of land use/land cover datasets for planning and monitoring. In Georgia, the land use/land cover dataset was developed by the Georgia GAP Program from 1998 Landsat imagery and the Georgia Land Use Trends Project (GLUT). GLUT tracks and analyzes changes in Georgia's land use over the past 25 years. It uses an Anderson Land Use/Land Cover Level II Classification that includes 18 classes. These data are available for a minimal cost from the Georgia GIS Clearinghouse (Figure 2-3: Land Use/Land Cover Dataset).

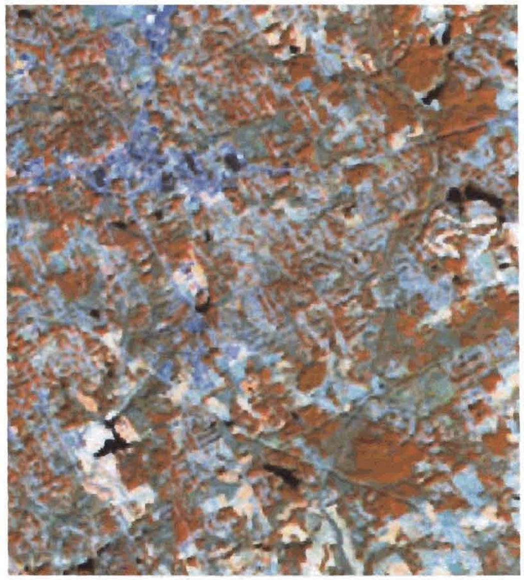

Figure 2-1
Phase 1: Macro Corridor Generation – Raw Landsat Imagery

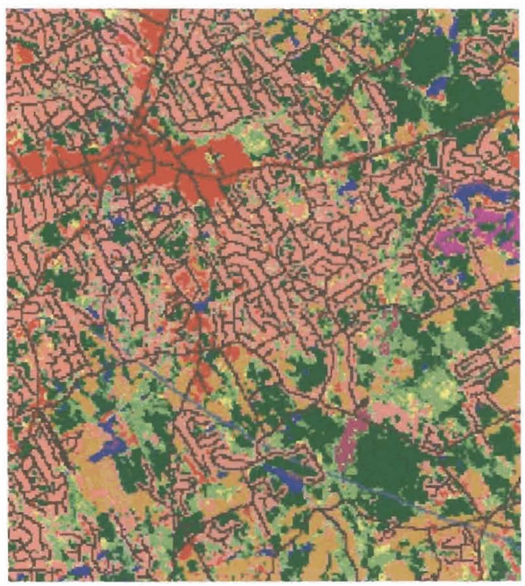

Figure 2-2
Phase 1: Macro Corridor Generation – Anderson Level II Landsat Imagery Classification

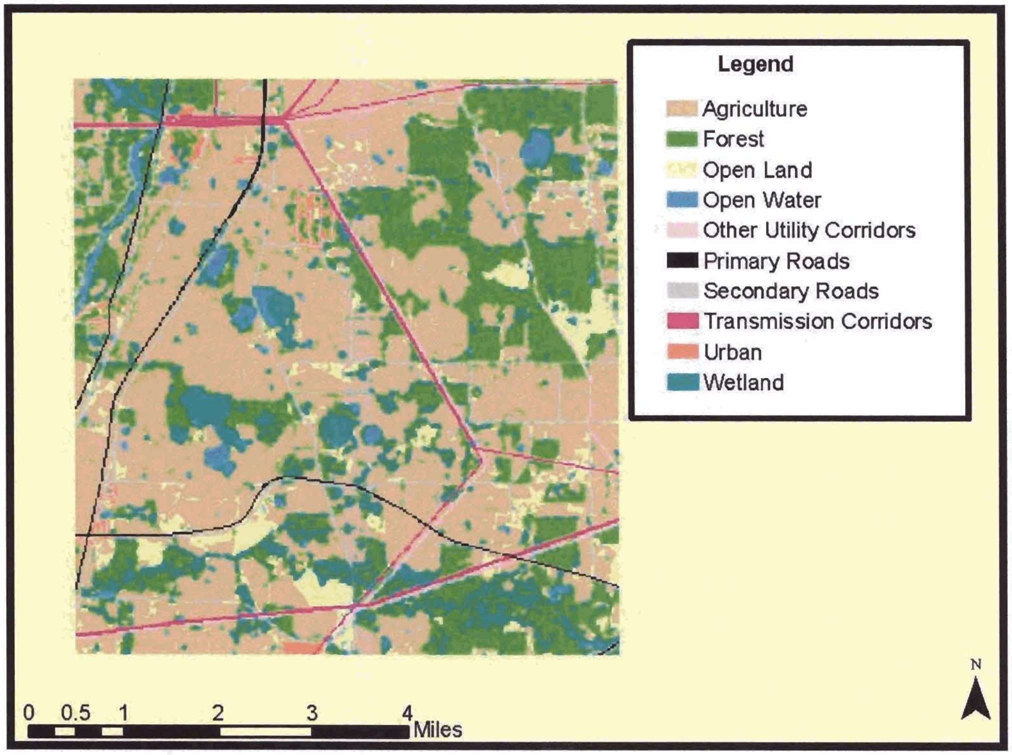

Figure 2-3
Phase 1: Macro Corridor Generation – Land Use/Land Cover Dataset

The team also identified areas that are significant barriers to constructing an overhead electric transmission line and should be avoided. These "Avoidance Areas" include locations where routes are prohibited either by physical barriers and administrative regulations, and locations where significant permitting delays would be expected. These areas include National Register of Historic Places (NRHP), historic or archeological districts, airports, EPA Superfund sites, military bases, national and state parks, non-spannable water bodies, U.S. Forest Service (USFS) wilderness areas, national wildlife refuges (NWR), mines and quarries, wild and scenic rivers and sites of ritual importance. Data for most of these Avoidance Areas are available currently in GIS format.

Macro Corridor Avoidance Areas

The first step in the Macro Corridor development process is to remove all Avoidance Areas from the Macro Corridor database. Eliminating these Avoidance Areas prohibits the proposed Macro Corridor from crossing places that internal and external stakeholders identified as requiring maximum protection.[1]

[1] As noted above, some "Avoidance Areas" may be reconsidered later in the decision-making and route selection processes when justified by specific, consistent, quantitative and defensible site-specific information.

Macro Corridor Scenarios and Weights

To locate Macro Corridors in the most suitable areas, the project team identified three Macro Corridor GIS Siting Model scenarios:

1. Rebuilding or paralleling existing transmission lines,
2. Paralleling existing road rights-of-way, and
3. Crossing undeveloped land (cross-country).

Next, a weighting system was designed to identify areas where transmission line development is most or least suitable. A suitability value is assigned to each Feature in the Macro Corridor GIS database. Assigned values range from 1 to 9, reflecting the suitability of each grid cell. A value of 1 identifies an area of greatest suitability, and 9 identifies an area of least suitability. A Feature is suitable if a transmission corridor through it is feasible with little adverse impact, such as undeveloped land. A Feature is considered unsuitable if a transmission line going through it would have some adverse consequences, such as steep terrain or densely populated areas. Numbers between 1 and 9 are used to represent intermediate degrees of suitability.

Description of Suitability Values

Areas of High Suitability for an overhead electric transmission line (1, 2, 3): These areas do not contain known sensitive resources or physical constraints, and therefore should be considered as suitable areas for the development of Macro Corridors. Examples include undeveloped land, pasture and rebuilding an existing transmission line.

Moderate Suitability for a transmission line (4, 5, 6): These areas contain resources or land uses that are moderately sensitive to disturbance or present a moderate physical constraint to line construction and operation. Resource conflicts or physical constraints in these areas generally can be reduced or avoided using standard mitigation measures. An example is a primary road crossings.

Low Suitability for a transmission line (7, 8, 9): These areas contain resources or land uses that present a potential for significant adverse impacts that cannot be readily mitigated. Locating a transmission line in these areas would require careful siting or special design measures. Examples include wetlands and densely populated urban areas. These areas can be used, but it is not desirable to do so if other alternatives are available.

Table 2-1
Phase 1: Macro Corridor Generation – Macro Corridor GIS Database Values

Land Cover Classification	Source	X-Country	Roads	T/Ls
Open Water	LANDSAT	7	7	7
Secondary Roads	LANDSAT	5	1	5
Other Utility Corridors	LANDSAT	5	5	5
Urban	LANDSAT	9	9	9
Open Land	LANDSAT	1	2	2
Surface Mining/ Rock Outcrop	LANDSAT	9	9	9
Forest	LANDSAT	1	2	2
Agriculture	LANDSAT	1	2	2
Wetland	LANDSAT	9	9	9
Transmission Corridors	ITS*	5	5	1
Primary Roads	GDT**	5	1	5
Interstate	GDT	9	9	9
Slopes > 30 degrees	USGS	9	9	9
Avoidance Features				
Airports	GDT			
Military Facilities	GDT			
NRHP Listed Historic Structures	NPS			
NRHP Listed Historic Districts	NPS			
NRHP Listed Archaeology Sites	NPS			
NRHP Listed Archaeology District	NPS			
State and National Park Interiors	NPS			
Non-spannable Water Bodies	USGS			
Wildlife Refuges	GA DNR			
USFS Wilderness Areas	GA DNR			
EPA Superfund Site	EPA			
Mines and Quarries	LANDSAT			

* Georgia Integrated Transmission System (ITS)
** Geographic Integrated Data Technologies (GDT)

Macro Corridor Composite Suitability Surface

Once all data for the project area are collected, entered into the Macro Corridor GIS database, and numeric values assigned to each feature, a composite suitability surface is created for the entire study area. The composite suitability surface provides an overview of the study area. Each grid cell in the composite suitability surface is assigned a ranking associated with its underlying land cover type (Figure 2-4: Composite Suitability Surface).

A separate suitability surface is developed for each of the three types of routes:

1. Rebuilding or paralleling existing transmission lines,
2. Paralleling existing road rights-of-way, and
3. Crossing undeveloped land (cross-country).

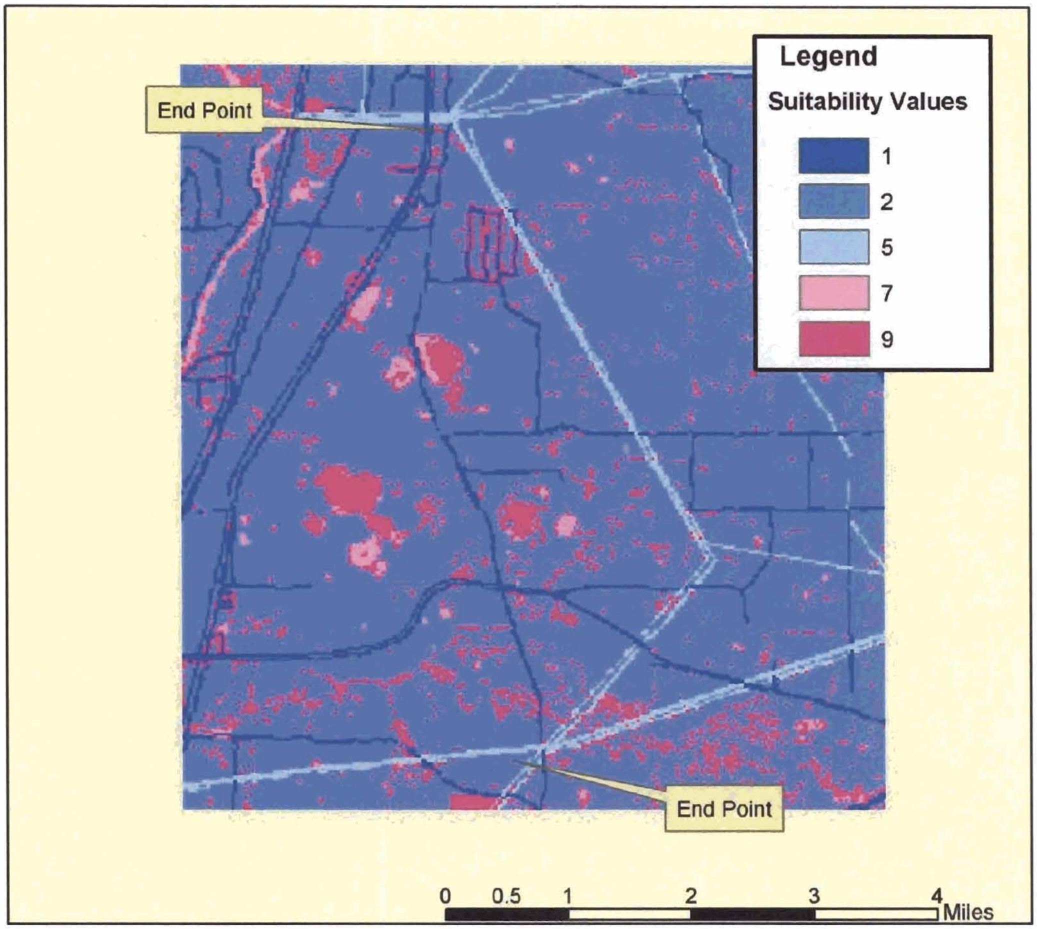

Figure 2-4
Phase 1: Macro Corridor Generation – Composite Suitability Surface

The Macro Corridor GIS Siting Model uses a "Least Cost Path" (LCP) algorithm to work its way across each of the three composite suitability surfaces. Figure 2-5, the Least Cost Path Calculation Diagram, illustrates the operation of the LCP algorithm. If a transmission line must go from Point A to Point B, the LCP algorithm will find the path across the accumulated surface (represented by suitability values in the grid cells) that minimizes the sum of the values along that route. Any other path will result in a larger suitability sum and therefore be less optimal. For example, the "optimal" route indicated in green has a suitability sum of 21 (3+1+6+1+7+3), compared to a sum of 35 (3+8+20+1+3) for the most direct route. The lower sum indicates higher overall suitability of the green route (Appendix D: GIS Siting Model Techniques).

The sum of the LCP calculation is a function of the number of cells crossed (distance) and the values in the individual cells. The path will turn to avoid less preferred areas or Avoidance Areas (high "cost" cells), but still follow the most direct path possible. If cells have the same score, the resulting path between the two points would be a straight line.

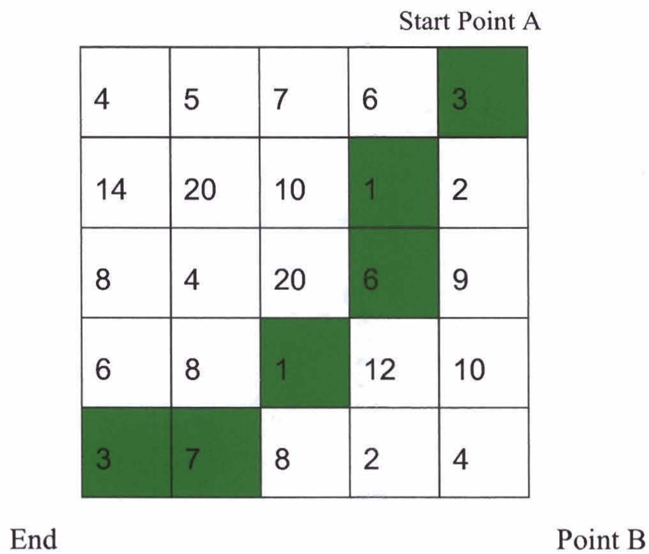

Figure 2-5
Phase 1: Macro Corridor Generation – Least Cost Path Calculation Diagram

Numeric Analysis and "Least Cost Path" Areas

Numeric analysis assigns a suitability value from 1 to 9 to each Feature in the Macro Corridor GIS database. These values are assigned to each of three composite suitability surfaces based on subsets of the criteria layers: rebuilding or paralleling existing transmission lines, paralleling existing road rights-of-way and crossing undeveloped lands. Then, GTC's GIS siting software, Corridor Analyst™, uses standard routing algorithms to identify the areas of "avoidance and opportunities" on each of the three composite suitability surfaces. The software begins at the designated starting point and adds one grid cell at a time by adding an adjacent cell with the lowest suitability score until it reaches the endpoint.

Generating Macro Corridors from the Composite Suitability Surface

After the three Composite Suitability Surfaces are generated, a histogram is developed for each surface. The histogram shows the cumulative value of each of the grid cells within the project study area. It is used to identify the most suitable areas for each of the three Macro Corridors scenarios: rebuilding or paralleling existing transmission lines, paralleling existing road rights-of-way and crossing undeveloped lands (cross-country) (Figure 2-6: Existing Transmission Line Macro Corridor; Figure 2-8: Roadside Macro Corridor; and Figure 2-10: Cross Country Macro Corridor). In each scenario, the Macro Corridor boundary is determined by the first statistical break in its histogram. A statistical break occurs when the grid cell value, as shown on the X-axis of the histogram, abruptly decreases.

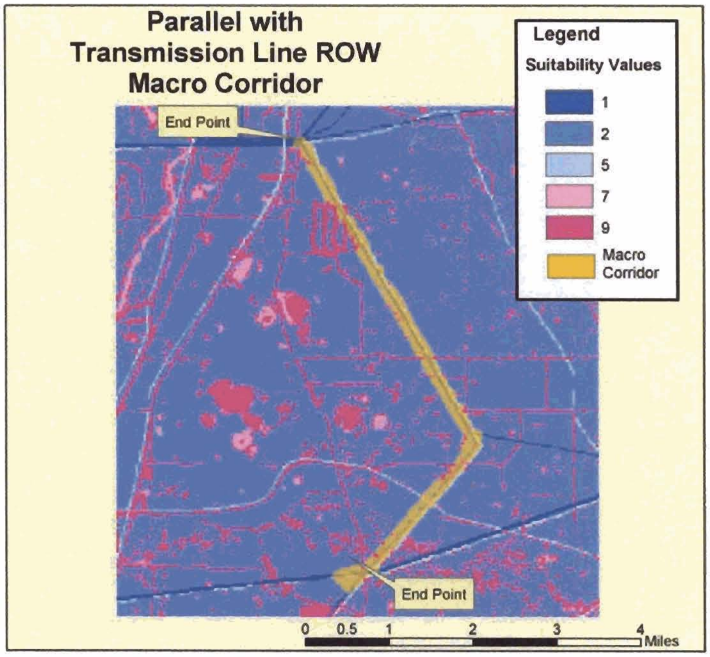

Figure 2-6
Phase 1: Macro Corridor Generation – Existing Transmission Line Macro Corridor

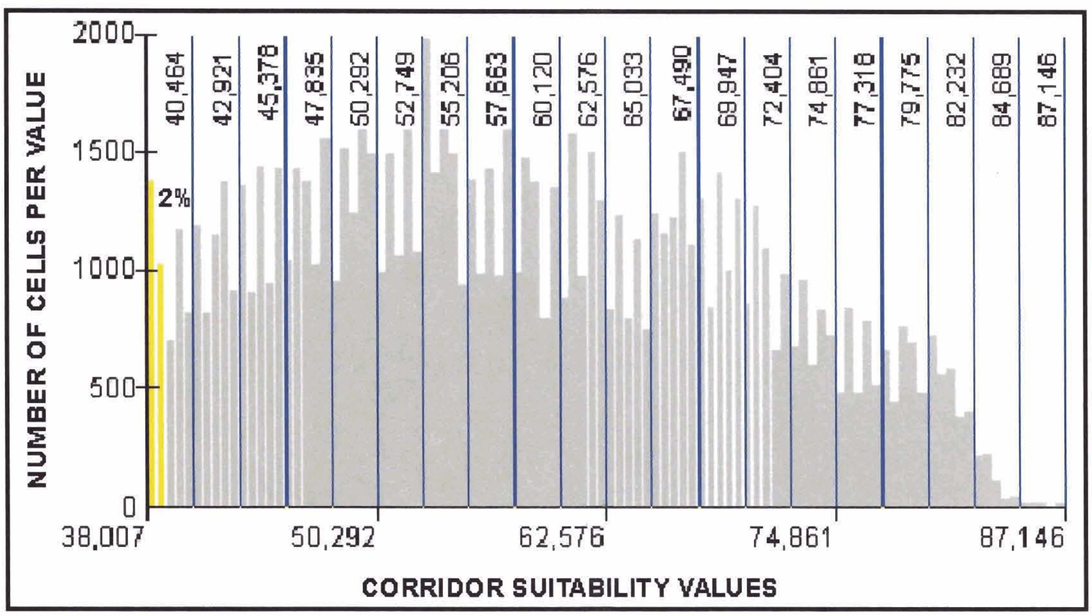

Figure 2-7
Phase 1: Macro Corridor Generation – Existing Transmission Line Macro Corridor Histogram

To validate this method, Macro Corridor boundaries were tested on 12 projects and the statistical break occurred within the first 1 and 5 percent of the grid cell value. In Figure 2-7: Existing Transmission Line Macro Corridor Histogram, Figure 2-9: Roadside Macro Corridor Histogram, and Figure 2-11: Cross Country Macro Corridor Histogram, the X-axis represents "grid cell values" and the Y-axis represents the "number of grid cells." These figures show that a statistical break occurs after two percent on the X-axis, the grid cells values. This two percent area is the area of greatest suitability for Macro Corridor Generation. The variable-width Macro Corridors may have a width of as much as a mile or greater for segments that have substantial length through areas of high suitability, while still allowing enough width in the low suitability areas for the right-of-way requirements of the project.

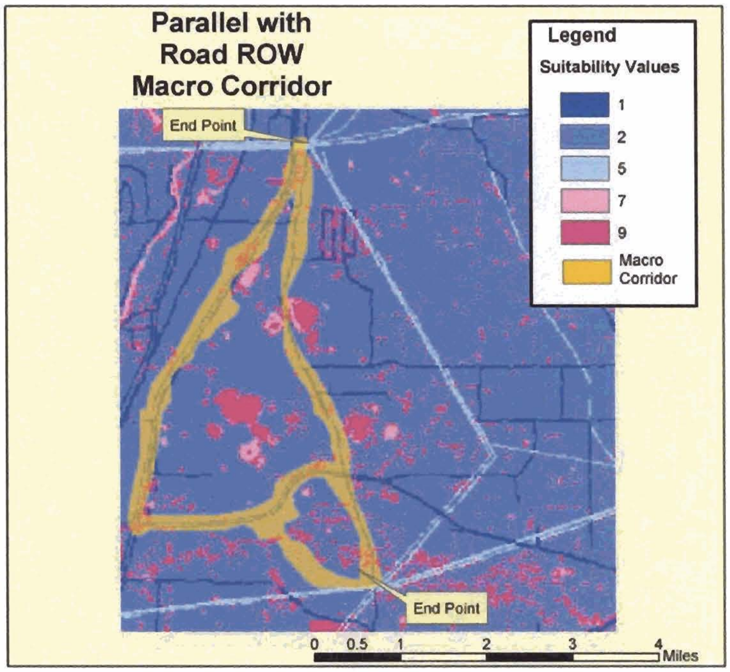

Figure 2-8
Phase 1: Macro Corridor Generation – Roadside Macro Corridor

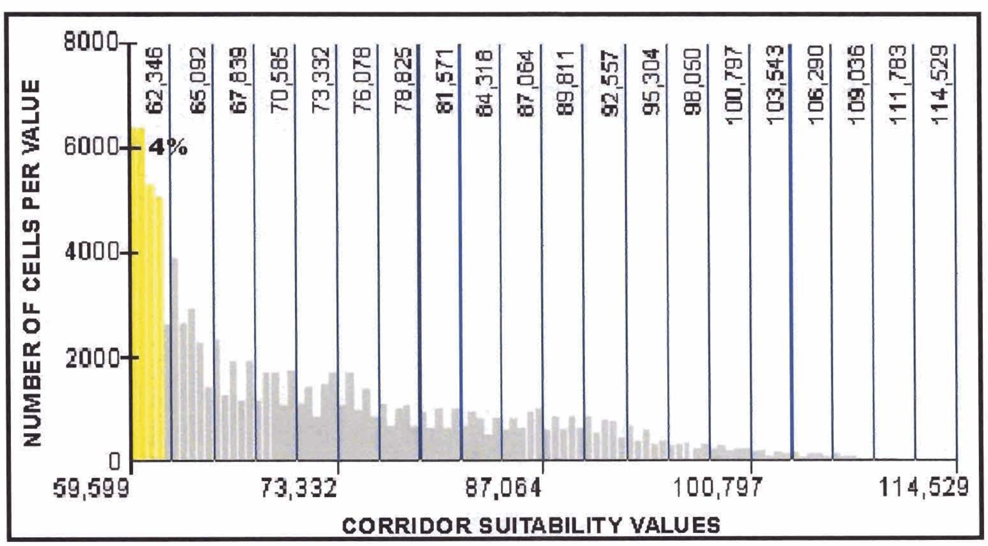

Figure 2-9
Phase 1: Macro Corridor Generation – Roadside Macro Corridor Histogram

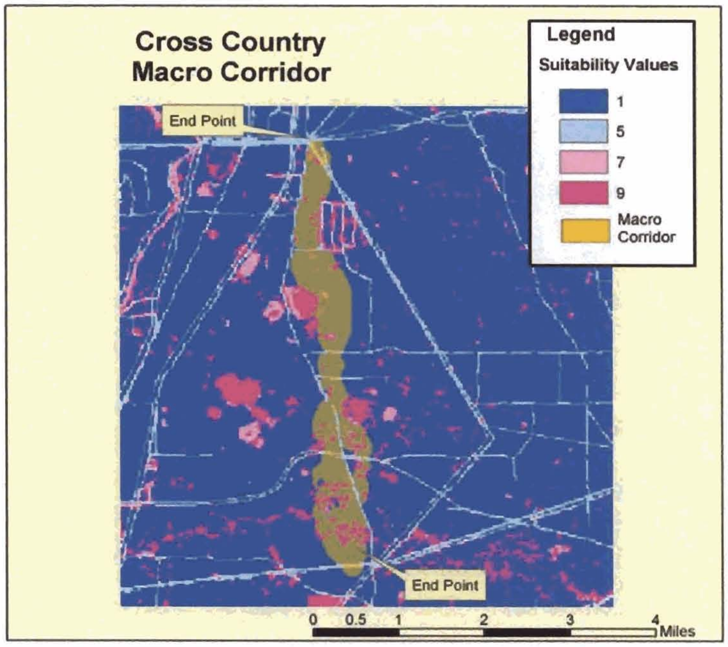

Figure 2-10
Phase 1: Macro Corridor Generation – Cross-Country Macro Corridor

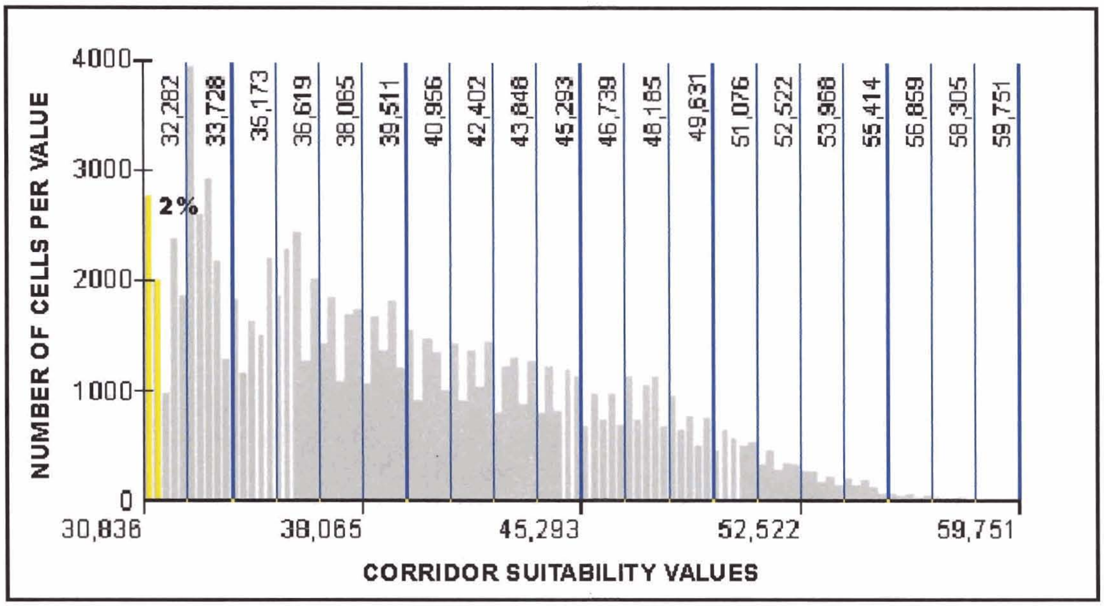

Figure 2-11
Phase 1: Macro Corridor Generation – Cross-Country Macro Corridor Histogram

Macro Corridor Composite

After the most suitable area of each Macro Corridor is identified, the three corridors are merged into a final Macro Corridor Composite Suitability Surface (Figure 2-12 – Final Macro Corridor Composite Suitability Surface).

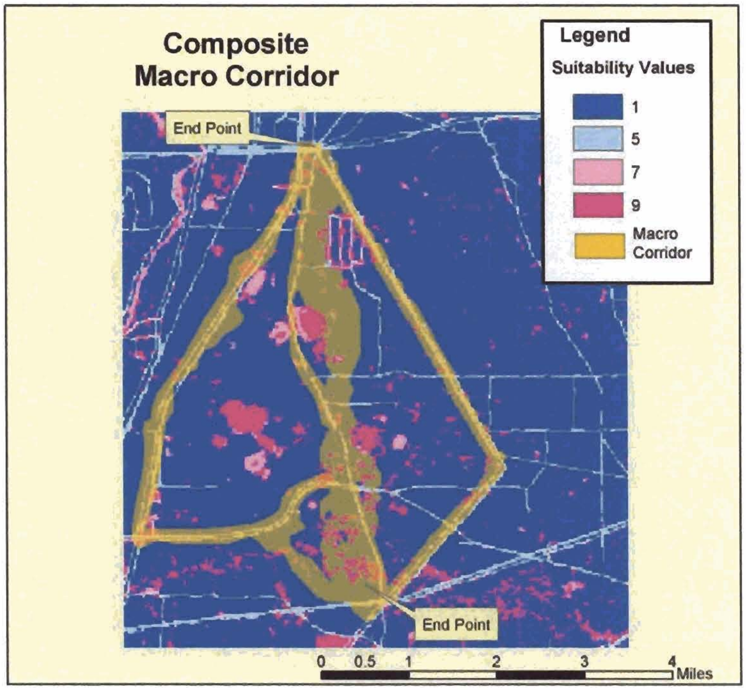

Figure 2-12
Phase 1: Macro Corridor Generation – Final Macro Corridor Composite Suitability Surface Combined Parallel Existing Transmission Lines Macro Corridor, Parallel Roadside Macro Corridor and Cross-Country Macro Corridor

Phase 2: Alternative Corridor Generation

In Phase 1, the outer limits of the Macro Corridors Composite Suitability Surface were used to define the project study boundaries and to generate a final Macro Corridor Composite Surface. During Phase 2, four Alternative Corridors were generated within the Macro Corridor boundaries. With input from stakeholders, the project team decided to standardize the alternatives for transmission line corridor selection by the following:

- Protecting people places and cultural resources (Built Environment Perspective),
- Protecting water resources, plants and animals (Natural Environment Perspective),
- Minimizing costs and schedule delays (Engineering Requirements Perspective) and
- A composite of the Built, Natural and Engineering alternatives (Simple Combined Perspective).

Alternative Corridor Data Collection

Following Macro Corridor Generation, additional data are collected to produce Alternative Corridors within the Macro Corridors. Data are collected or derived from several sources. Some Data Layers are gathered from existing off-the-self data warehouses, while others are created specifically for each project based on aerial photo interpretation. For example, data on roads, interstates and railways are purchased from a data provider that updates these Features every year. Some datasets are created and maintained by GTC and Integrated Transmission System (ITS) companies. However, just as in the Macro Corridor Phase of the EPRI-GTC methodology, some of the data for Alternative Corridor Generation must be derived. For example, USGS Digital Elevation Models (DEMs) are acquired as off-the-self data, but slope must be derived from the DEMs to be included in the model.

The Land Use/Land Cover Map used in the Macro Corridor Phase is not detailed or accurate enough to define Alternative Corridors. Instead, more detailed datasets are developed for Land Use/Land Cover and Intensive Agriculture from digital orthophotography. This orthophotography is used to "derive" data for the building dataset. Although buildings are identified in the orthophotography, the buildings themselves are not used in Alternative Corridor Phase of the GIS Siting Model. Instead, building density, building proximity and building buffers are derived from the building dataset using standard functionality commonly available in GIS software. Then, the derived datasets are inserted into the GIS Siting Model.

Alternative Corridor Database

The GIS database for the Alternative Corridor Phase can be thought of on three levels (Figure 2-13: GIS Siting Model Data Tiers). At the lowest level is Tier 1, which consists of Features that are important in siting a transmission line, e.g., slope, building density and wetlands. The Tier 1 Features contain grid cells that are assigned a value ranging from 1 to 9 and cover the entire study area. Tier 1 Features include distinct categories, such as overhead electric transmission lines, roads and railroads. They also include numerical ranges for Features like building density.

In the second level (Tier 2), similar Features are grouped into Data Layers, e.g., land cover that contains managed pine forests, row crops, undeveloped land and developed land. At the highest level, Tier 3, Data Layers are grouped into three Perspectives: Built Environment, Natural Environment and Engineering Requirements. Each perspective reflects distinct stakeholder viewpoints on critical siting issues.

Legend	Avoidance Areas	Built Environment	Natural Environment	Engineering Requirements
	NRHP Listed Archaeology Sites	**Proximity to Buildings**	**Floodplain**	**Linear Infrastructure**
Avoidance Areas	NRHP Listed Archaeology Districts	Background	Background	Rebuild Existing Transmission Lines
Tier 3 - Perspectives	NRHP Listed Historic Districts	900-1200	100 Year Floodplain	Parallel Existing Transmission Lines
Tier 2 - Data Layers	NRHP Listed Historic Structures	600-900	**Streams/Wetlands**	Parallel Roads ROW
Tier 1 – Features	NRHP Eligible Historic Districts	300-600	Background	Parallel Gas Pipelines
	EPA Superfund Sites	0-300	Streams < 5cfs	Parallel Railway ROW
	Airports	**Eligible NRHP Historic**	Non-forested Non-Coastal	Background
	Military Facilities	Background	Rivers/Streams > 5cfs	Future GDOT Plans
	Mines & Quarries	900 – 1200	Non-forested Coastal Wetlands	Parallel Interstates ROW
	Buildings + Buffers	600 – 900	Trout Streams (50' Buffer)	Road ROW
	School Parcels (K – 12)	300 – 600	*Forested Wetlands + 30' Buffer*	Scenic Highways ROW
	Day Care Parcels	0 – 300	**Public Lands**	**Slope**
	Church Parcels	**Building Density**	Background	Slope 0-15%
	Cemetery Parcels	0 - 0.05 Buildings/Acre	WMA - Non-State Owned	Slope 15-30%
	Non-Spannable Water Bodies	0.05 - 0.2 Buildings/Acre	Other Conservation Land	Slope >30%
	Wild & Scenic Rivers	0.2 - 1 Buildings/Acre	USFS	**Intensive Agriculture**
	Wildlife Refuge	1 - 4 Buildings/Acre	WMA - State Owned	Background
	USFS Wilderness Areas	4 - 25 Buildings/Acre	**Land Cover**	Fruit Orchards
	National & State Parks	Proposed Development	**Open Land, Pastures,**	Pecan Orchards
	County & City Parks	Background	Managed Pine Plantations	Center Pivot Agriculture
	Sites of Ritual Importance	Proposed Development	Row Crops and Horticulture	
		Spannable Lakes and Ponds	Developed Land	
		Background	Hardwood/Natural Coniferous	
		Spannable Lakes and Ponds	**Wildlife Habitat**	
		Land Divisions	Background	
		Edge of field	Species of Concern Habitat	
		Land lots	Natural Areas	
		Background		
		Land Use		
		Undeveloped		
		Non-Residential		
		Residential		

Figure 2-13
Phase 2 Alternative Corridor Generation – GIS Siting Model Data Tiers

Avoidance Areas

The first step in Alternative Corridor Generation is to remove all Avoidance Areas from the Alternative Corridor database. Removing these sensitive areas from consideration means they will not be used in the Alternative Corridor selection process.

As stated in the Macro Corridor Phase, Avoidance Areas are not suitable for locating overhead electric transmission lines. The GIS Siting Model will avoid these areas except in specific situations.[2] An exception, for example, is where a road right-of-way is adjacent to a military base. The existence of the road "trumps" the military base as an Avoidance Area by weighting the roadside edge grid cells as suitable for a transmission line corridor. Internal and external stakeholder groups identified Avoidance Areas as shown in Table 2-2.

Table 2-2
Phase 2: Alternative Corridor Generation – Avoidance Areas

Avoidance Areas
NRHP Archaeology Districts
NRHP Archaeology Sites
NRHP Historic Districts
NRHP Structures
Eligible NRHP Districts
EPA Superfund Sites
Airports
Military Facilities
Mines and Quarries
Building and Buffers
School Parcels
Day Care Parcels
Church Parcels
Cemetery Parcels
Non-Spannable Water Bodies
Wild and Scenic Rivers
Wildlife Refuges
USFS Wilderness Areas
National and State Parks
County and City Parks
Sites of Ritual Importance

[2] "Avoidance Areas," which are identified at an early stage of the transmission line siting process to assure that "community preferences" or to avoid significant permitting delay factors, may be reconsidered when justified by specific, consistent, quantitative and defensible site-specific information.

Tier 1 – Feature Value Calibration

The project team decided to normalize the Tier 1 Features within each Data Layer. Stakeholders were asked to calibrate the Features in a Delphi Process. This collaborative process involves iterative discussion and structured input designed to assist each stakeholder group in reaching consensus as they calibrated the Feature maps.

The suitability of each Feature was calibrated on a scale of 1 (most suitable) to 9 (least suitable). Putting Features into a common 1-9 scale allows Data Layers to be mathematically combined without being distorted by differences in measurement scale. For example, if one foot is measured as 30.48 centimeters rather than 12 inches, the larger number would give it more weight in any mathematical operations even though the physical length is the same. Putting all data on the same scale allows data to be combined into Data Layers and compared. These Feature Calibrations were developed through stakeholder input (Appendix D: GIS Siting Model Techniques and Appendix E: Phase 2-Alternative Corridor Model Delphi Feature Calibrations).

For example, a new transmission line right-of-way that parallels an existing transmission line was considered more suitable than one that parallels a scenic highway. Therefore, areas adjacent to the existing transmission line received a 1. Those adjacent to the scenic highway received a 9. Characterizing suitability for slope for a transmission line is another example. Stakeholders assigned 1 (most suitable) to slopes between 0 and 15 percent, 5.5 (fairly neutral) to slopes between 15 and 30 percent and a 9 (least suitable) to slopes greater than 30 percent.

Tier 2 – Data Layer Weighting

In the second tier, Data Layers were weighted as to their relative importance using the Analytical Hierarchy Process (AHP). This collaborative procedure involves pairwise comparison among the set of Feature maps to determine the relative importance of each map layer. The result is the derivation of an importance weight assigned to each map layer (Appendix F: Phase 2-Alternative Corridor Model AHP Percentages by Data Layer). Once weighted, the Data Layers are combined to form a group perspective. The stakeholders and the project team developed Data Layer weights, reflecting the importance of each Data Layer in the transmission line siting methodology.

Tier 3 – Perspectives

In Tier 3, individual Data Layers were combined to form three distinct Perspectives: the Built Environment, Natural Environment and Engineering Requirements. The Built Environment Perspective recognized that the most significant opposition to overhead electric transmission lines comes from residential neighborhoods and over special places of value to the community (such as proximity to existing and proposed buildings or historic sites). The Natural Environment Perspective sought to minimize the disturbance to ecological resources and natural habitat. The Engineering Requirements Perspective focused on minimizing the cost of construction by seeking the shortest path, while avoiding areas that pose significant construction obstacles. The Simple Combination Perspective placed an equal weighting on the Built Environment, Natural Environment and Engineering Requirements Perspectives to form a composite perspective.

Within each perspective, the Data Layers in that group are emphasized. However, Data Layers from other perspectives must be included so the model does not completely ignore those factors. For example, the model must account for the location of houses even when emphasizing the Natural Environment Perspective.

These four different perspectives produce a set of distinct Alternative Corridors that are evaluated and compared prior to developing Alternative Routes. The weighted Data Layers are combined to create a perspective that reflects the "Optimal Path" for each Alternative Corridor. This "Optimal Path" is the most suitable route because it receives the lowest score, representing the route with the least impact considering that perspective. Figure 2-14, Delphi Calibrations and Analytical Hierarchy Weightings, illustrates the 1 to 9 calibration of the Feature Values established by the Delphi Process. The Layer Weights that were developed using the Analytical Hierarchy Process are shown as percentages beside each Feature and Data Layer (Figure 2-14: Delphi Calibrations and Analytical Hierarchy Weightings).

SITING MODEL

AVOIDANCE AREAS

PERSPECTIVES

LAYERS

AHP PERCENTAGES

FEATURES

DELPHI RANKS

Avoidance Areas
NRHP-Listed Archaeology Sites
NRHP-Listed Archaeology Districts
NRHP-Listed Historic Districts
NRHP-Listed Historic Structures
NRHP-Eligible Historic Districts
EPA Superfund Sites
Airports
Military Facilities
Mines & Quarries
Buildings + Buffers
School Parcels (K – 12)
Day Care Parcels
Church Parcels
Cemetery Parcels
Non-Spannable Water Bodies
Wild & Scenic Rivers
Wildlife Refuge
USFS Wilderness Areas
National & State Parks
County & City Parks
Sites of Ritual Importance

Built Environment	
Proximity to Buildings	11.5%
Background	1
900-1200	1.8
600-900	2.6
300-600	4.2
0-300	9
Eligible NRHP Historic Structures	13.9%
Background	1
900 – 1200	2.8
600 – 900	3.6
300 – 600	5.2
0 – 300	9
Building Density	37.4%
0 - 0.5 Buildings/Acre	1
0.5 - 0.2 Buildings/Acre	3
0.2 - 1 Buildings/Acre	5
1 - 4 Buildings/Acre	7
4 - 25 Buildings/Acre	9
Proposed Development	6.3%
Background	1
Proposed Development	9
Spannable Lakes and Ponds	3.8%
Background	1
Spannable Lakes and Ponds	9
Land Divisions	8.0%
Edge of Field	1
Land Lots	7.9
Background	9
Land Use	19.1%
Undeveloped	1
Nonresidential	3
Residential	9

Engineering	
Linear Infrastructure	48.3%
Rebuild Existing Transmission Lines	1
Parallel Existing Transmission Lines	1.4
Parallel Roads ROW	3.6
Parallel Gas Pipelines	4.5
Parallel Railway ROW	5
Background	5.5
Future GDOT Plans	7.5
Parallel Interstates ROW	8.1
Road ROW	8.4
Scenic Highways ROW	9
Slope	9.1%
Slope 0-15%	1
Slope 15-30%	5.5
Slope >30%	9
Intensive Agriculture	42.6%
Background	1
Fruit Orchards	5
Pecan Orchards	9
Center Pivot Agriculture	9

Natural Environment	
Floodplain	6.2%
Background	1
100-Year Floodplain	9
Streams/Wetlands	20.9%
Background	1
Streams < 5cfs+ Regulatory Buffer	5.1
Non-forested Non-Coastal Wetlands	6.1
Rivers/Streams > 5cfs+ Regulatory Buffer	7.4
Non-forested Coastal Wetlands	8.4
Trout Streams (50' Buffer)	8.5
Forested Wetlands + 30' Buffer	9
Public Lands	16.0%
Background	1
WMA - Non-State-Owned	4.8
Other Conservation Land	8.3
USFS	8
WMA – State-Owned	9
Land Cover	20.9%
Open Land, Pastures, Scrub/Shrub, etc.	1
Managed Pine Plantations	2.2
Row Crops and Horticulture	2.2
Developed Land	6.5
Hardwood/Natural Coniferous Forests	9
Wildlife Habitat	36.0%
Background	1
Species of Concern Habitat	3
Natural Areas	9

Figure 2-14
Delphi Calibrations and Analytical Hierarchy Weightings

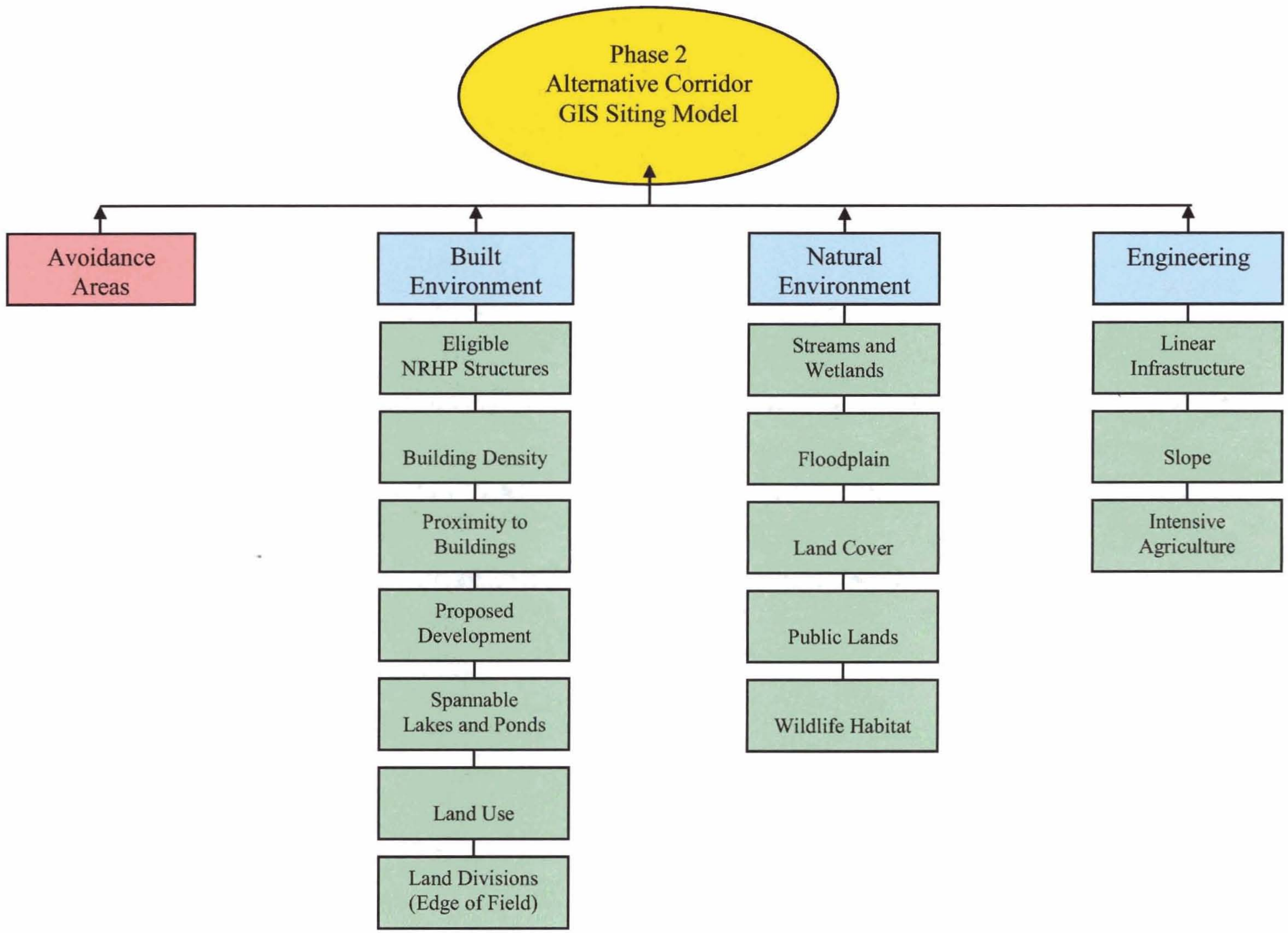

Figure 2-15
Phase 2: Alternative Corridor Generation – GIS Siting Mode

Built Environment Perspective

Public controversy over the siting of new transmission power lines can cause significant delays to a construction project. The purpose of the Built Environment Perspective is to select routes that avoid or minimize impacts to communities.

As shown in Figure 2-16, Built Environment Perspective, building locations are a critical component of this perspective. All buildings are buffered and treated as Avoidance Areas.[3] In the Built Environment Layer Group, additional protection is provided to building avoidance areas by adding 300-foot proximity zones. As one approaches a building Avoidance Area, each 300-foot proximity zone becomes increasingly less suitable.

The Built Environment Perspective also considers clusters of buildings, such as subdivisions or urban neighborhoods by assigning a higher weight that makes the area less preferable for a transmission line. Therefore, it is difficult for the line to go through a densely populated urban area, even if it skirts individual, isolated buildings. Listed National Landmark sites, National Register sites, traditional cultural sites and eligible historic districts and their properties are treated as "Avoidance Areas," providing maximum protection. In Georgia, a 1,500-foot Adverse Potential Effect (APE) buffer is created around listed and eligible NRHP structures.

Stakeholders requested that land use be emphasized in the procedure. The project team created three land use categories in the Land Use Layer: residential, non-residential developed and undeveloped. Residential land is the least preferred, and undeveloped land is the most preferred. A Proposed Development Layer anticipates future development, including subdivisions, commercial developments, public facilities and other projects that have been permitted by a local government, but not constructed.

One of the most suitable areas for a transmission line is along a property line of an undeveloped parcel. Land lot lines, comparable to section lines in the West, and edges of fields identified on aerial imagery are included in a Land Division Layer. These locations are preferable because they are associated with property boundaries. Spannable Lakes and Ponds are included in the Built Environment Perspective because they are considered amenity features that are less preferred than other areas. Table 2-3 shows the weights associated with each layer.

Taken together, these layers capture the salient features of the Built Environment Perspective. Alternative Corridors for the Built Environment Perspective will avoid developed areas whenever possible. Table 2-3 identifies the relative importance applied to the seven map layers forming the Built Environment Perspective. Building density has the most influence (37.4%) and is nearly twice as important as land use considerations. As previously discussed, the AHP process involving group collaboration with stakeholders determined the weights (AHP process is described in Appendix D: GIS Siting Model Techniques).

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[3] "Avoidance Areas," which are identified at an early stage of the transmission line siting process to assure that "community preferences" or to avoid significant permitting delay factors, may be reconsidered when justified by specific, consistent, quantitative and defensible site-specific information.

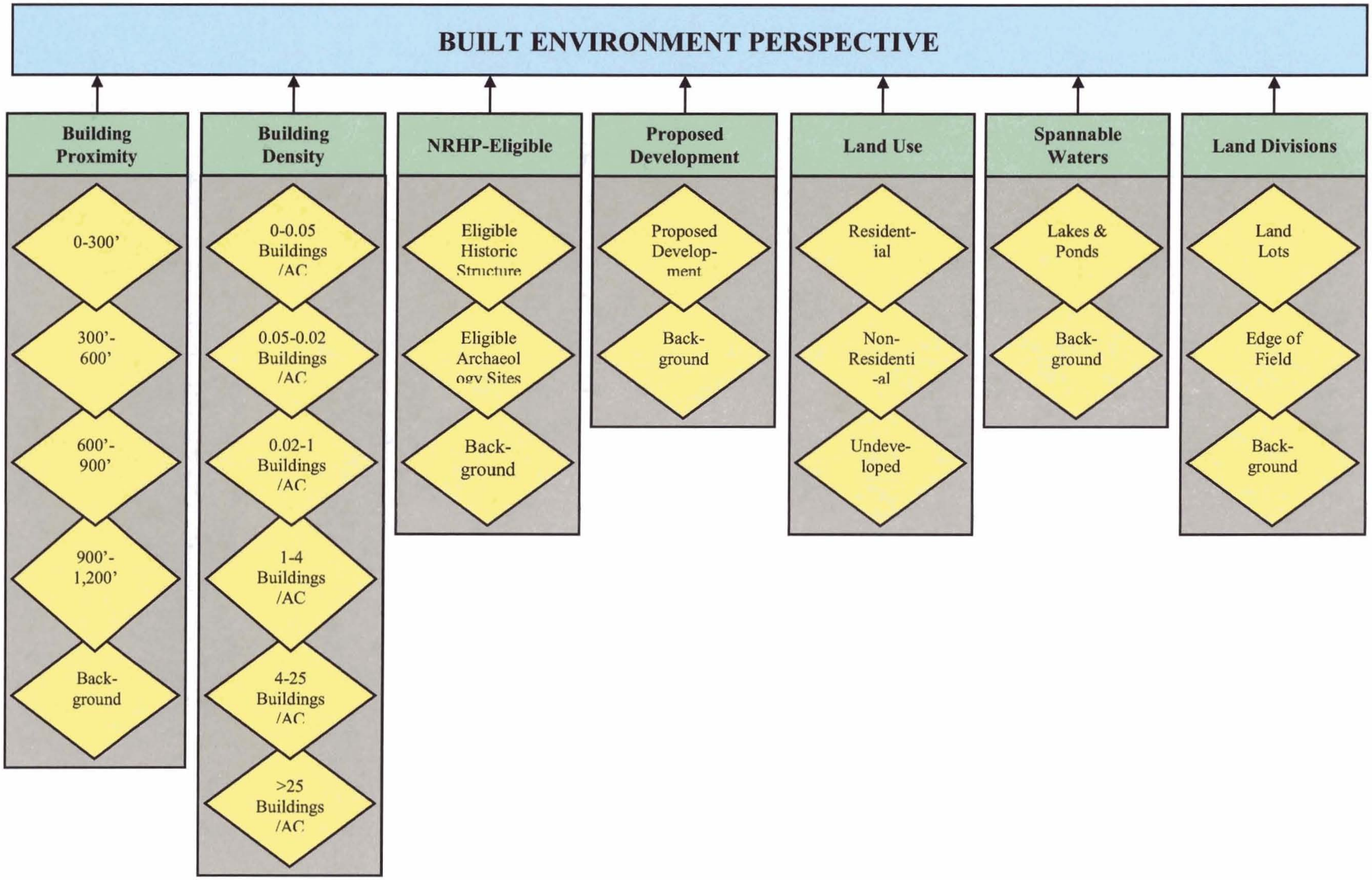

Figure 2-16
Phase 2: Alternative Corridor Generation – Built Environment Perspective

Table 2-3
Phase 2: Alternative Corridor Generation – Built Environment Perspective Data Layer Weights

Data Layer	Layer-Weights
Proximity to Buildings	11.5 %
Eligible NRHP Structures	13.9 %
Building Density	37.4 %
Proposed Development	6.3 %
Spannable Lakes and Ponds	3.8 %
Land Divisions	8.0 %
Land Use	19.1 %

Natural Environment Perspective

The Natural Environment Perspective seeks to minimize the effects of construction and maintenance of overhead electric transmission lines on sensitive natural resources. Federal and state environmental regulations require the identification and protection of environmentally sensitive areas. At the federal level, environmental regulations cover wetland protection under the Clean Water Act and protection of endangered animal and plant species under the Endangered Species Act. State regulations protect riparian buffer through the state of Georgia's Erosion and Sedimentation Control Act and the Metropolitan River Protection Act. In addition, the Georgia Department of Natural Resources monitors a number of listed endangered plant and animal species. This list includes state candidate species that require additional concern beyond those listed under federal law. Environmental permits are required from many federal, state and local government agencies.

Because of their span length and the small footprint for structure placement, overhead electric transmission line construction and maintenance activities generally have minor impacts on the natural environment. There are two areas of concern, however, that must be accounted for during data collection: habitat fragmentation and encroachment on environmentally sensitive areas. These concerns can be avoided by minimizing the amount of the transmission line rights-of-way located in environmentally sensitive, undeveloped areas.

This perspective includes five Data Layers: public lands, streams and wetlands, floodplains, land cover and wildlife habitat. Although some public lands, such as state and national parks, city and county parks, wild and scenic rivers, U.S. Forest Service (USFS) wilderness areas and wildlife refuges were included as Avoidance Areas, the remainder have been included as part of the Natural Environment Perspective (See Table 2-4: Natural Environment Perspective Data Layer Weights). Inclusion in this perspective ensures that impacts to these areas would be considered in the routing process.

Table 2-4
Phase 2: Alternative Corridor Generation – Natural Environment Perspective Data Layer Weights

Data Layer	Layer-Weights
Public Lands	16.0 %
Streams/ Wetlands	20.9 %
Floodplain	6.2 %
Land Cover	20.9 %
Wildlife Habitat	36.0 %

Many agencies have developed Data Layers that can be used in the planning of transmission line routes. The commonly available datasets include: U.S. Fish and Wildlife's National Wetland Inventory (NWI), Federal Emergency Management Agency's (FEMA) floodplain maps and U.S. Geological Survey's (USGS) National Hydrological Dataset. State Heritage programs often provide some level of information on the distribution of threatened and endangered species within a state. However, this information is limited because few comprehensive surveys have been completed for these plants and animals. It is important to note that although these datasets have been developed with high standards, they were produced at a scale much larger than the width of a transmission line and also may not be updated frequently enough to capture changes in the landscape. Therefore, it is always necessary to check the proposed route to be certain nothing was inadvertently overlooked (Figure 2-17: Natural Environment Perspective).

To minimize adverse impacts of transmission line construction and maintenance on streams and wetlands, it is critical to collect accurate data about their location and characteristics during the routing step. In the Streams and Wetlands Data Layer, information is collected on streams, forested wetlands and non-forested coastal wetlands. Streams with flows greater than 5 cubic feet per second create construction and maintenance access problems. In Georgia, trout streams are protected with a 100-foot vegetative buffer (50 feet either side of the stream). Clearing for an overhead transmission line right-of-way in forested wetlands causes adverse impacts to the wetlands by removing the tree canopy. The absence of tree canopy increases water temperatures in the wetland and may contribute to sedimentation. Non-forested coastal wetlands were included in this category because of construction and maintenance access problems.

FEMA Q3 Flood information is used for the floodplain delineation, because NEPA regulations prohibit steel tower structures from being located in a floodplain because they can trap debris and obstruct the flow.

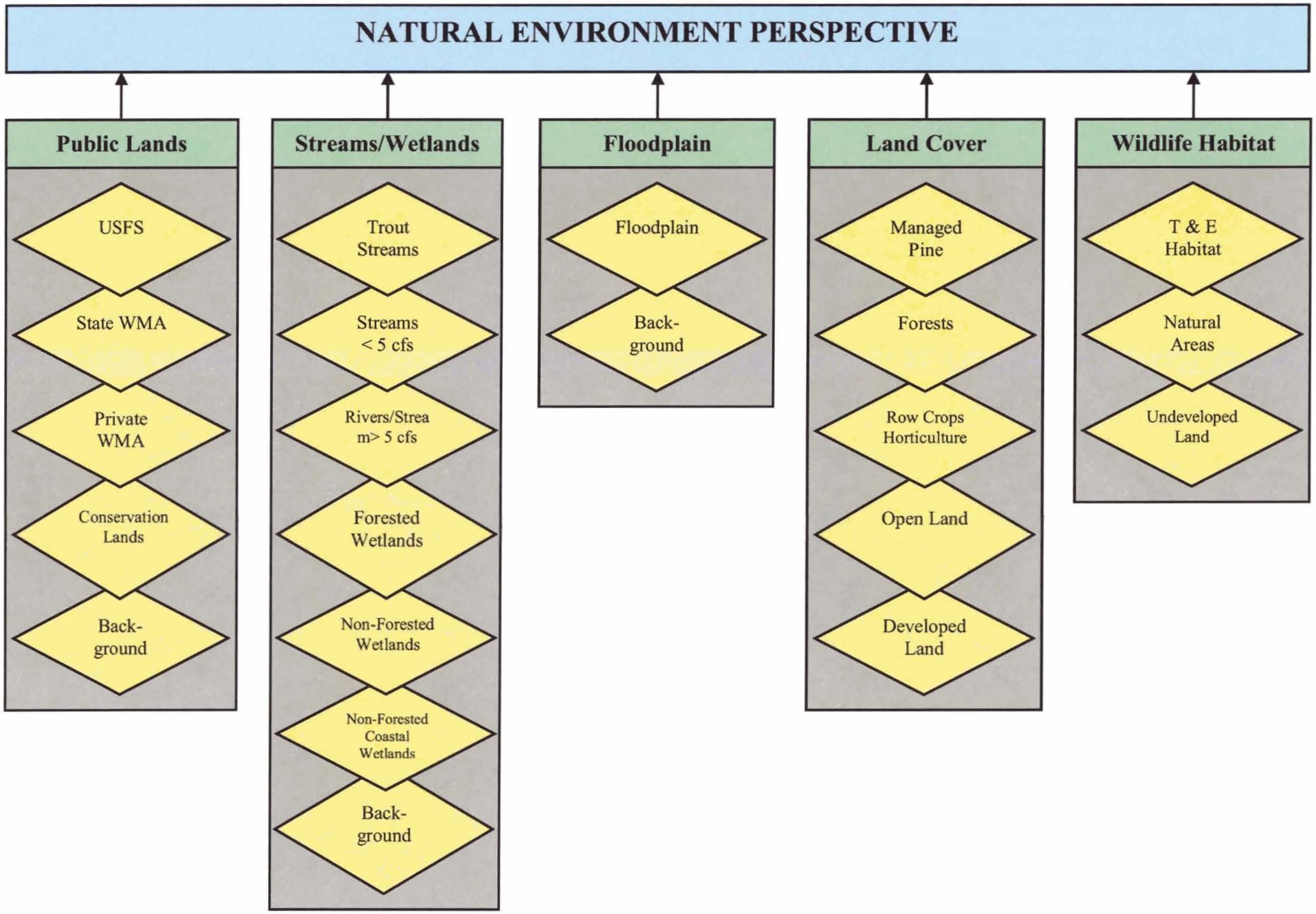

Figure 2-17
Phase 2: Alternative Corridor Generation – Natural Environment Perspective

Land cover data are digitized from orthophotography and includes the following land cover types: managed pine, row crops and horticulture, hardwood mixed and natural forests, undeveloped land and developed lands. Other categories in the Land Cover Data Layer include land use information, such as transportation, utility rights-of-way, low intensity urban, high intensity urban, clear cut/sparse vegetation, quarries/strip mines, rock outcrops, deciduous forest, mixed forest, evergreen forest, golf courses, pastures, row crops, forested wetlands, coastal marshes and non-forested wetlands.

In Georgia, it was difficult to locate timely and accurate data on threatened and endangered species. For this project, the Wildlife Data Layer includes terrestrial endangered species and Natural Area data used as a surrogate for listed plant species. These data, from the Georgia GAP analysis program, contain potential distribution of terrestrial vertebrates and a map of natural vegetation.

Engineering Requirements Perspective

The criteria in this perspective focused on the engineering requirements for routing, constructing and maintaining overhead transmission lines. External stakeholders who took part in the study included engineers and scientists from utilities and state agencies involved in site selection for linear facilities. The group was selected to provide specific knowledge regarding the co-location of power lines with other linear features, including pipelines, roadways and other power lines. There are three Data Layers within this perspective: linear infrastructure, slope and intensive agriculture (Table 2-5: Engineering Requirements Perspective Data Layer Weights).

Table 2-5
Phase 2: Alternative Corridor Generation – Engineering Requirements Perspective Data Layer Weights

Data Layer	Layer-Weights
Linear Infrastructure	48.3 %
Slope	9.10 %
Intensive Agriculture	42.6 %

If the Data Layers were equally suitable, the engineering solution would be a straight line connecting the two endpoints. Since this rarely occurs, the Engineering Requirements Perspective utilizes the Data Layer suitability information to represent actual conditions. Categories in the Linear Infrastructure Data Layer include rebuilding existing transmission lines or paralleling (co-locating) with other linear infrastructure.

The most cost-effective solution with the least adverse impact to the natural and cultural resources is rebuilding an existing transmission line in its existing right-of-way. In the Linear Infrastructure Data Layer, the stakeholders ranked the rebuild alternative as the most suitable alternative.

Paralleling (co-locating) other linear facilities is ranked as "the second most suitable place," mainly due to lower construction and maintenance access costs. Use of an existing transmission line or road right-of-way decreases the acreage needed for a new right-of-way, significantly reducing land acquisition costs. Access for construction and maintenance is improved, since there are existing transmission line rights-of-way access roads. Paralleling existing linear features places new transmission lines in areas where natural resources already have been disturbed. Paralleling also reduces the amount of land clearing needed for a new transmission line corridor.

Another engineering consideration is slope. Slopes less than 15 percent are most suitable for the construction and maintenance of an overhead transmission line. Slopes of 16 to 30 percent pose a moderate constraint by increasing construction costs and having a greater chance of erosion. Slopes greater than 30 percent should be avoided, if possible, because of the high costs of construction and maintenance. Construction costs in these areas are significantly greater due to soil stabilization requirements, equipment constraints and environmental permits. In addition, heavily sloped terrain can limit access to areas and result in construction and maintenance work being performed from the air.

Three types of agriculture that pose significant engineering constraints are included in the Intensive Agriculture Data Layer: center pivot irrigation, pecan orchards and fruit orchards. Avoiding these areas provides an opportunity to minimize the cost of affecting expensive orchards and agricultural irrigation facilities (Figure 2-18: Engineering Requirements Perspective).

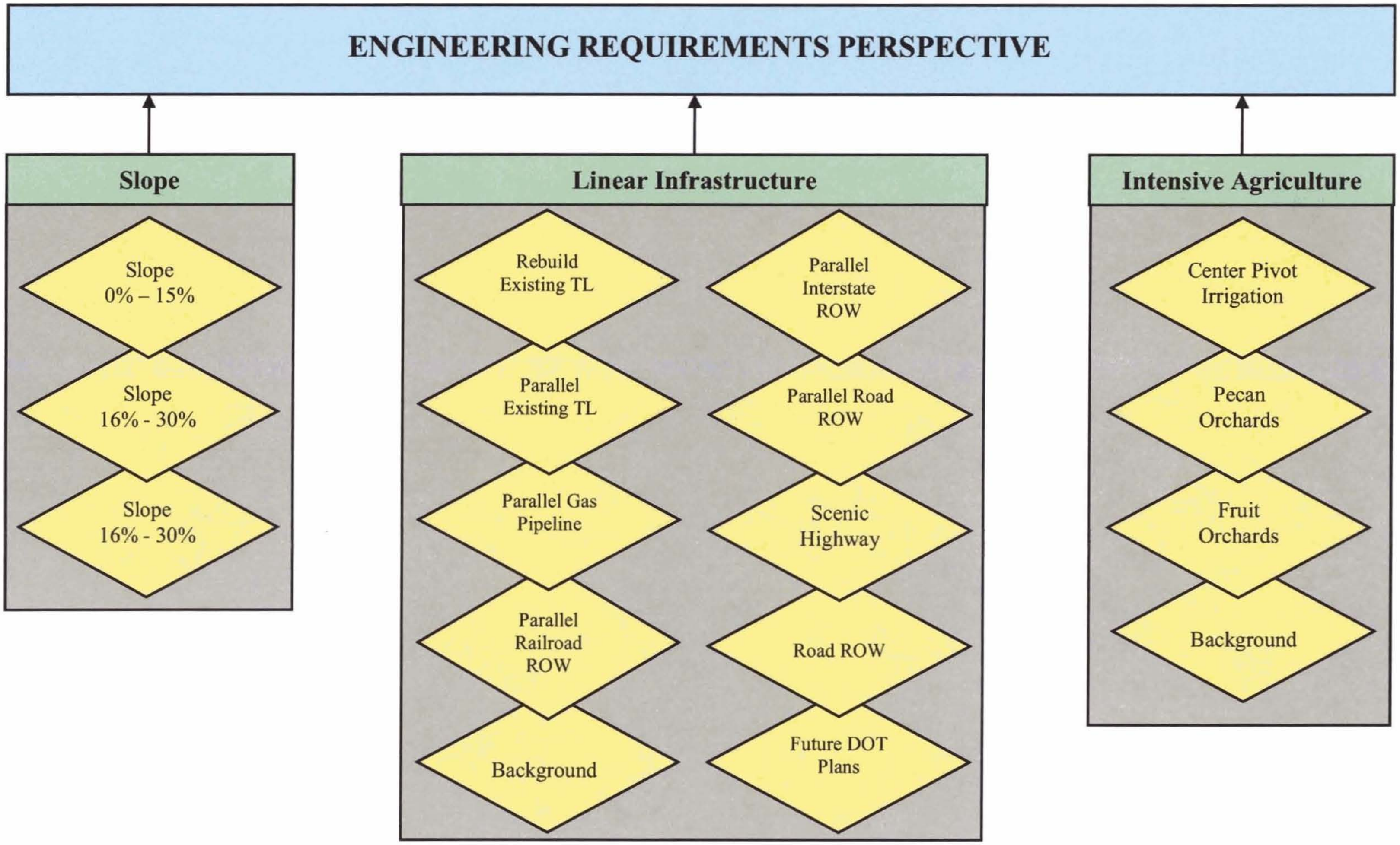

Figure 2-18
Phase 2: Alternative Corridor Generation – Engineering Requirements Perspective

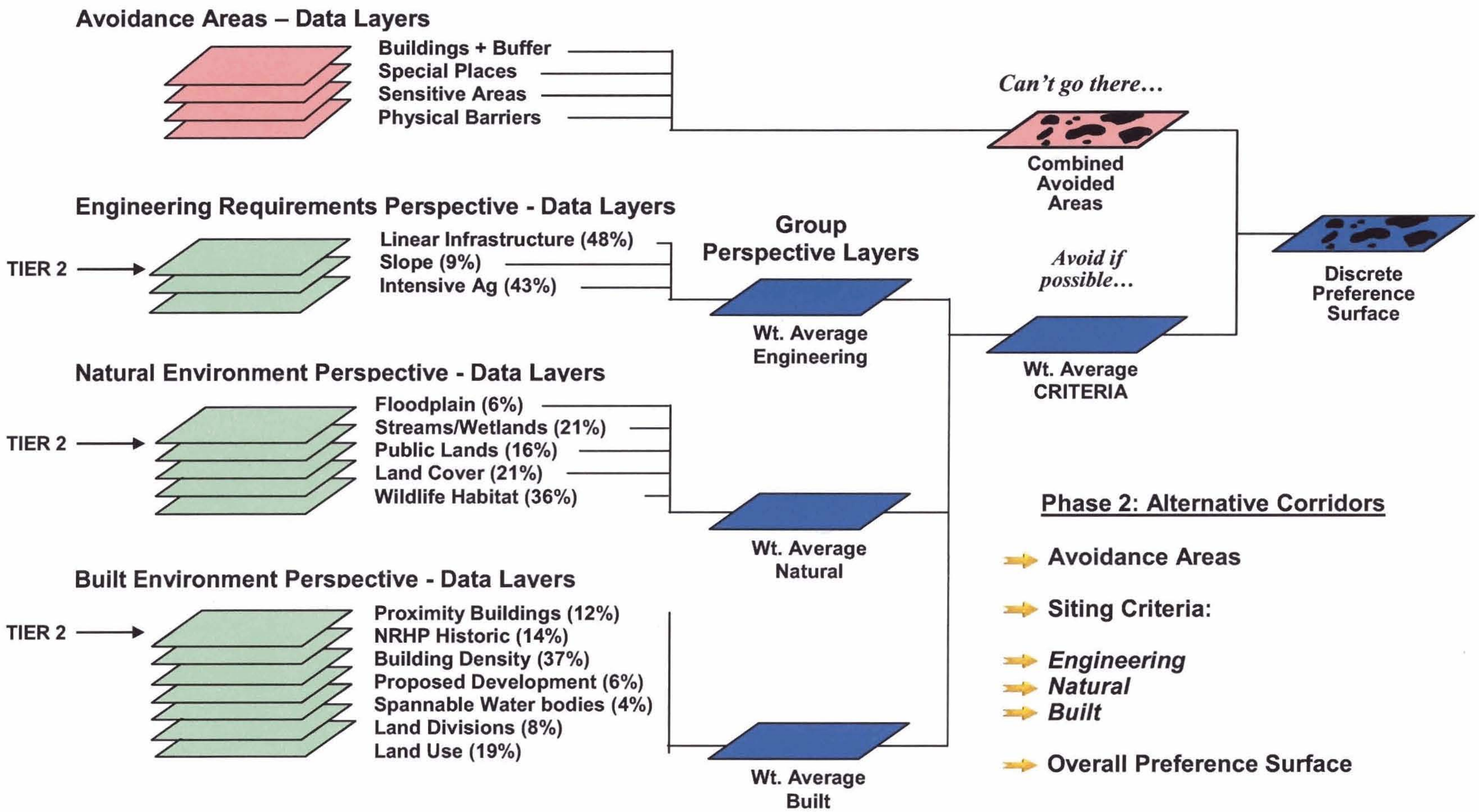

Figure 2-19
Phase 2: Alternative Corridor GIS Data Layers Least Cost Path Algorithm

Least Cost Path Algorithm

As in the Macro Corridor Generation phase, the least cost path (LCP) procedure is used to identify the most suitable corridor for each of the three perspectives. As discussed in Appendix D, the LCP approach involves the following three basic steps:

1. Deriving a *discrete preference* surface,
2. Calculating an *accumulated preference* surface, and
3. Determining the "*Optimal Path,*" respecting the spatial distribution of the relative preferences for locating an overhead electric transmission line.

By far, the most critical step is the first one. This step identifies the relative preference for locating a transmission line at any location within a perspective. A series of Features are calibrated on a scale of 1 (most suitable) through 9 (least suitable). The Calibrated Features are combined to form Data Layers. Data Layers are weight-averaged to reflect the relative importance of the different perspectives.

In practice, three tiers of weights are applied: Tier 1 for the Feature Calibration, Tier 2 for the Data Layer Weighting within each group perspective (Built, Natural, Engineering) and Tier 3 for reflecting the relative importance among the group perspectives. A map of areas to absolutely avoid is combined with the weighted criteria map to characterize the relative "goodness" of routing an overhead electric transmission line at every location in the project area, as depicted by the discrete preference surface (See the right side of Figure 2-20: EPRI-GTC Routing Model Criteria and Weights).

The second step in the LCP procedure uses this information to calculate the most suitable corridor for each perspective. The result is an accumulation preference surface that simulates routing of a transmission line from a starting location to all other locations in a project area. The final step identifies the "path of least of resistance" along the accumulated cost surface that minimizes the less preferred areas that are crossed along a route connecting the starting and ending locations. This route identifies the "Optimal Path," as any other path incurring more "less preferred crossing" (sub-optimal). This route is derived by identifying the steepest down hill path from the end point to the bottom of the accumulated cost surface (Figure 2-21: Optimal Path). The least cost procedure for determining surfaces and the Optimal Path is defined in Appendix D.

A corridor of optimality can be generated by identifying the next best route, then the next best and so on. In practice, however, a more efficient procedure is to add the accumulation surfaces from both the starting and endpoints as shown in Figure 2-22: Sum of Accumulated Surfaces. The result is a surface that identifies the total cost of forcing an Optimal Path through every location in the project area.

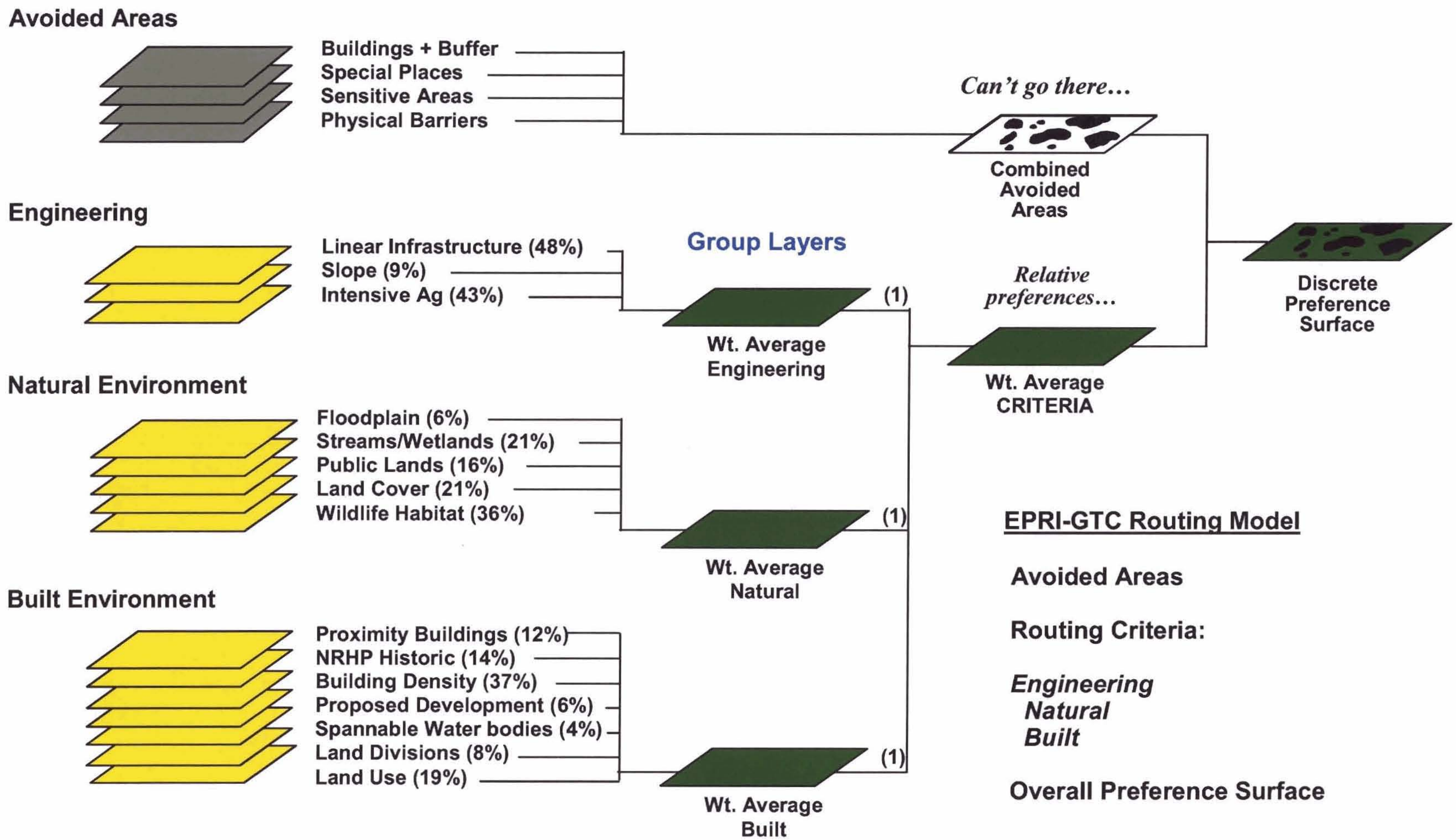

Figure 2-20
Phase 2: Alternative Corridor Generation – Data Layer Features are Calibrated and Weighted to Derive a Map of the Relative Preference for Locating the Alternative Corridors

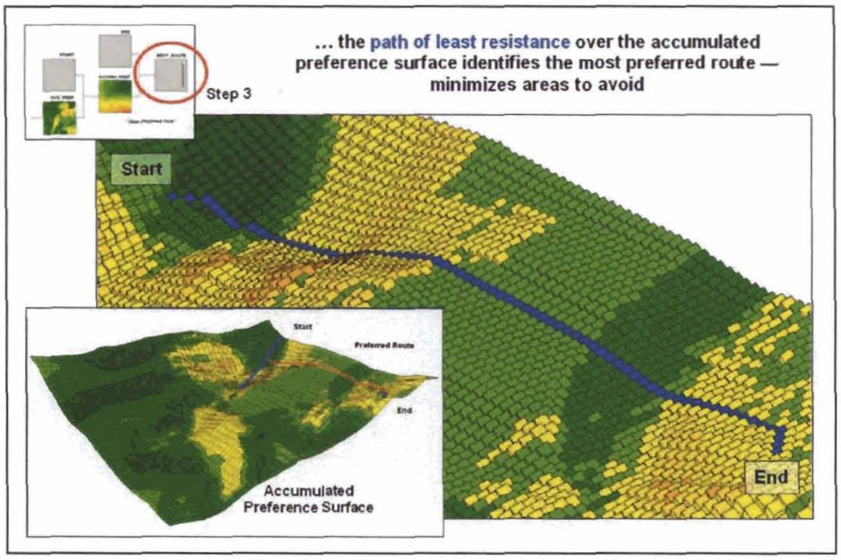

Figure 2-21
Phase 2: Alternative Corridor Generation – The Optimal Path from Anywhere in a Project Area is Identified by the Steepest Downhill Path Over the Accumulated Cost Surface

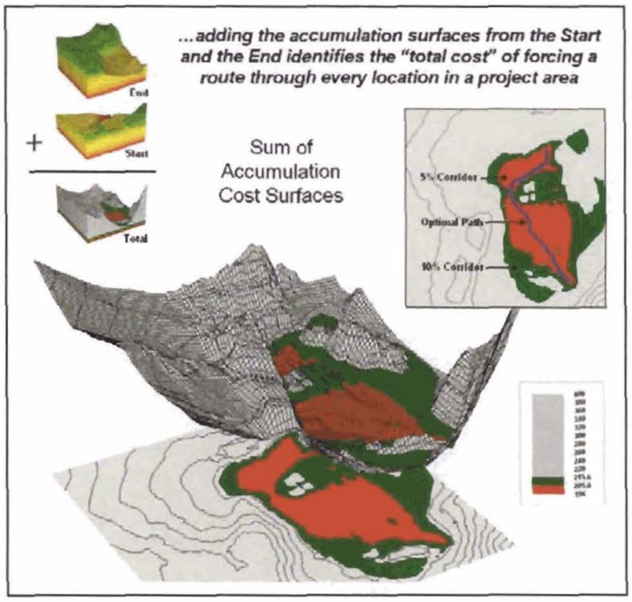

Figure 2-22
Phase 2: Alternative Corridor Generation – The Sum of Accumulated Surfaces is used to Identify Corridors as Low Points on the Total Accumulated Surface

The series of lowest values on the total accumulation surface (valley bottom) identifies the best route. The valley walls depict increasingly less optimal areas. The red areas in Figure 2-22 identify all locations that are within 5 percent of the "Optimal Path." The green areas indicate 10 percent sub-optimality.

The corridors are useful in delineating boundaries for detailed data collection, such as high-resolution aerial photography and parcel ownership records. The detailed data within the Alternative Corridor is helpful in making slight adjustments in identifying Alternative Routes within each of the perspectives.

Generating Alternative Corridors from the Composite Suitability Surface

As in the Macro Corridor Phase, a histogram is generated and interpreted. In the case of Alternative Corridor Generation, it is run on surfaces for each of the Built Environment, Natural Environment and Engineering Requirements Perspectives. The histogram is used to choose the corridors for each of the three perspectives. The boundaries of these corridors are chosen by the first statistical break in the histogram. Typically, the statistical break occurs between 1 and 5 percent. Alternative Corridors are shown in:

- Figure 2-23: Built Environment Alternative Corridor,
- Figure 2-25: Natural Environment Alternative Corridor,
- Figure 2-27: Engineering Requirement Alternative Corridor, and
- Figure 2-29: Simple Average Alternative Corridor.

The histograms below each of these figures illustrate that the breaks occur between one and five percent in:

- Figure 2-24: Built Environment Alternative Corridor Histogram,
- Figure 2-26: Natural Environment Alternative Corridor Histogram,
- Figure 2-28: Engineering Requirement Alternative Corridor Histogram, and
- Figure 2-30: Simple Average Alternative Corridor Histogram.

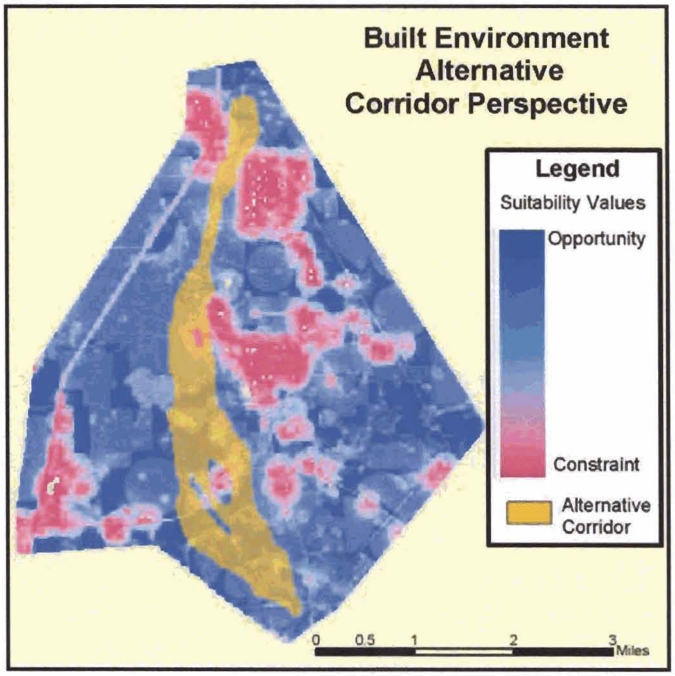

Figure 2-23
Phase 2: Alternative Corridor Generation – Built Environment Alternative Corridor

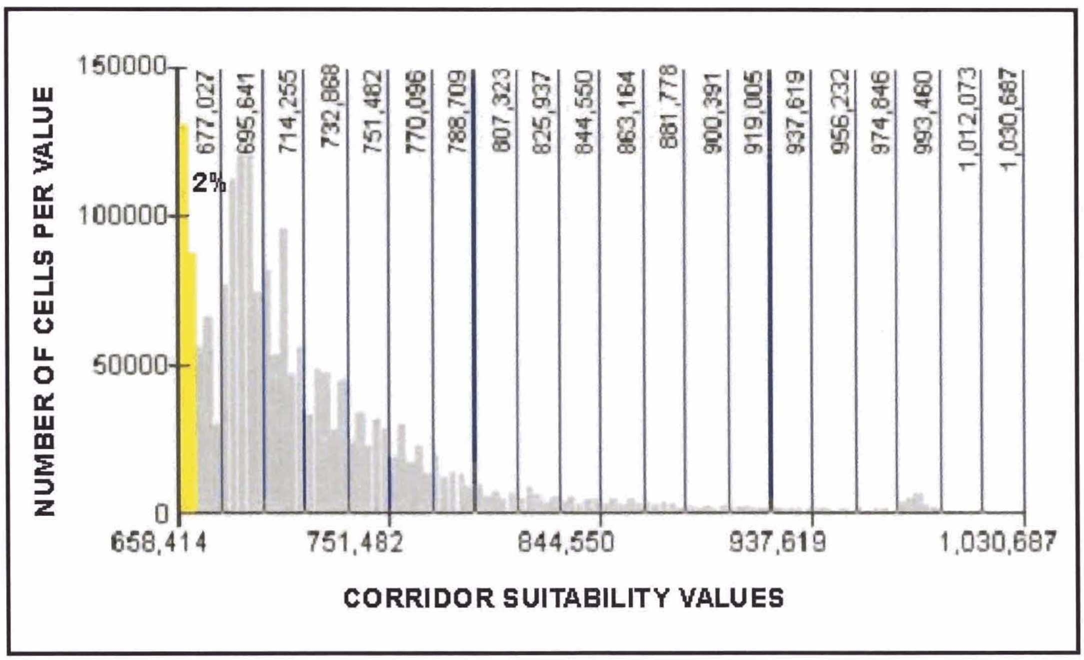

Figure 2-24
Phase 2: Alternative Corridor Generation – Built Environment Alternative Corridor Histogram

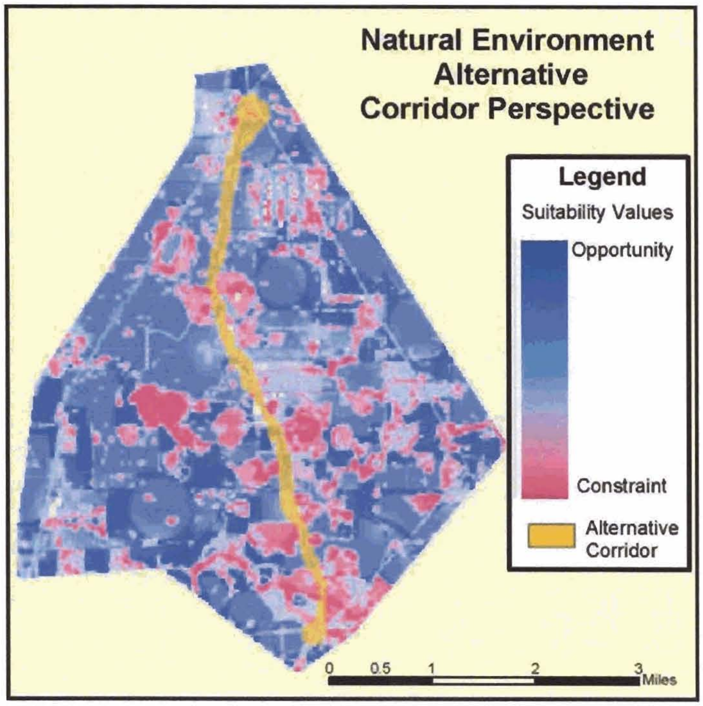

Figure 2-25
Phase 2: Alternative Corridor Generation – Natural Environment Alternative Corridor

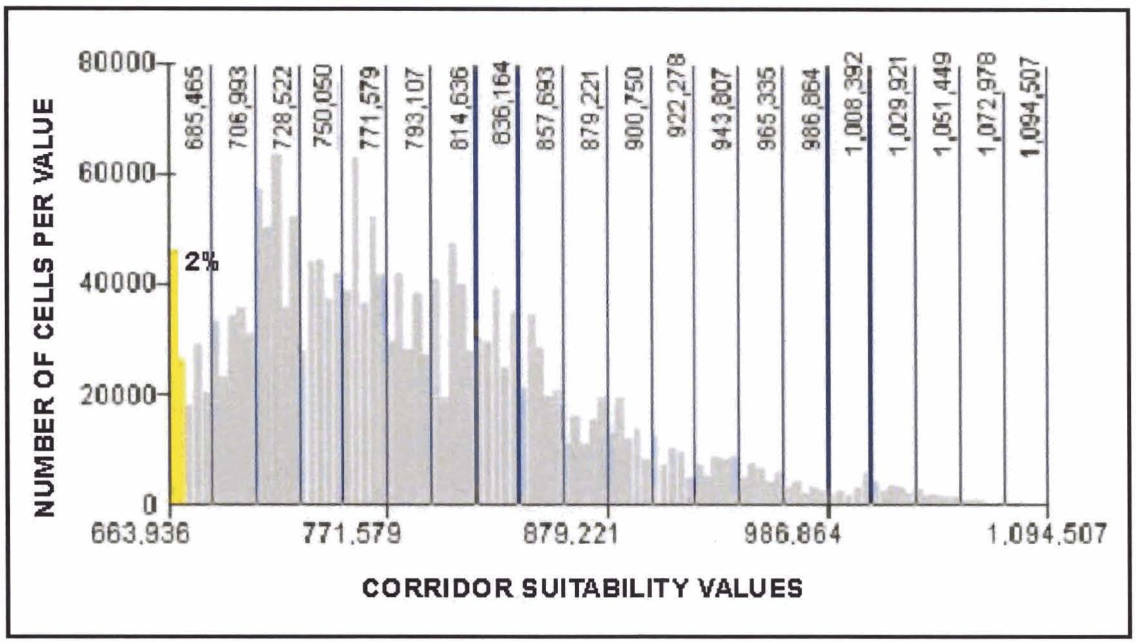

Figure 2-26
Phase 2: Alternative Corridor Generation – Natural Environment Alternative Corridor Histogram

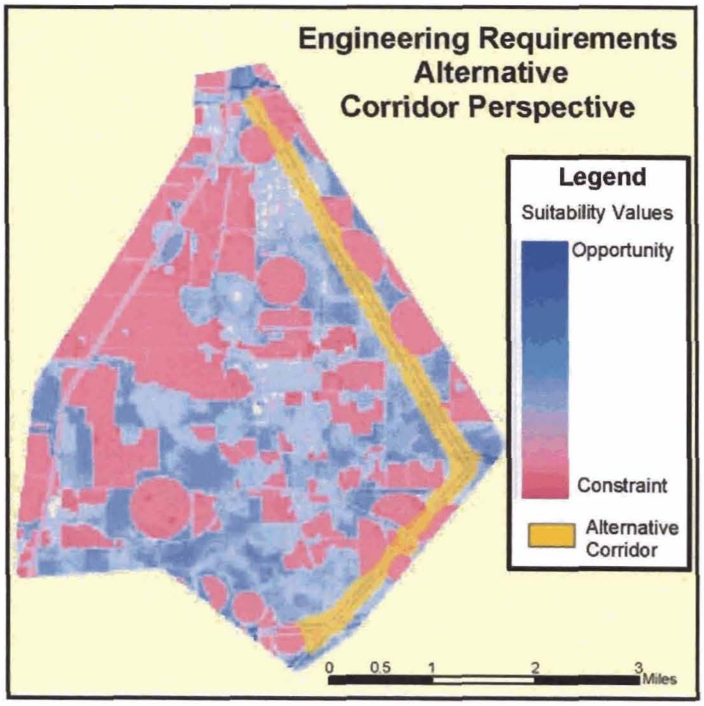

Figure 2-27
Phase 2: Alternative Corridor Generation – Engineering Requirement Alternative Corridor

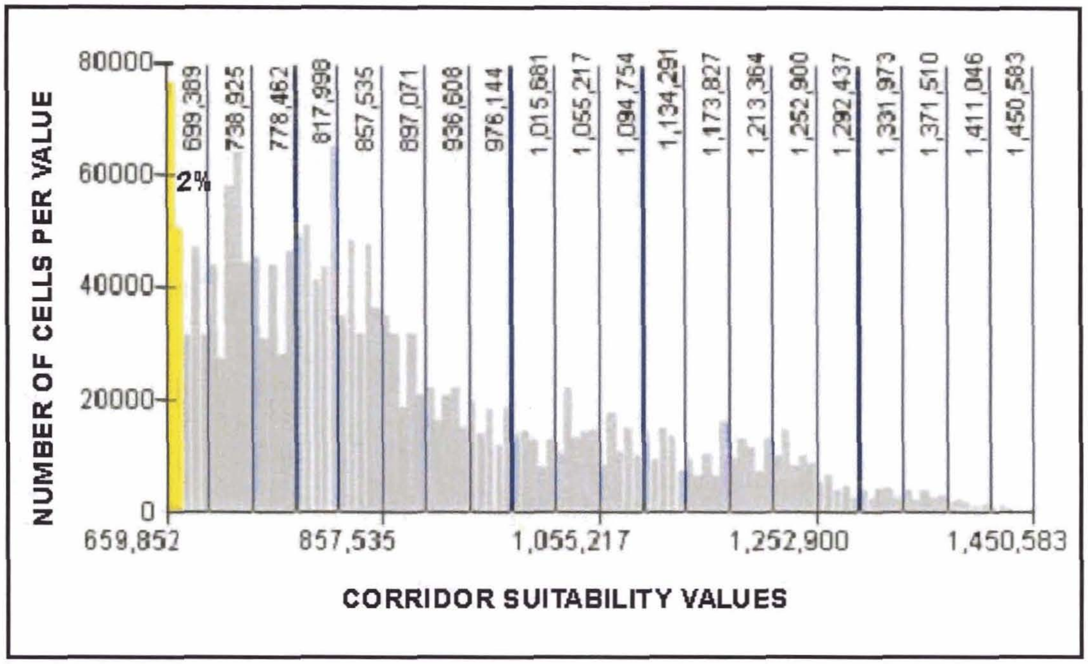

Figure 2-28
Phase 2: Alternative Corridor Generation – Engineering Requirement Alternative Corridor Histogram

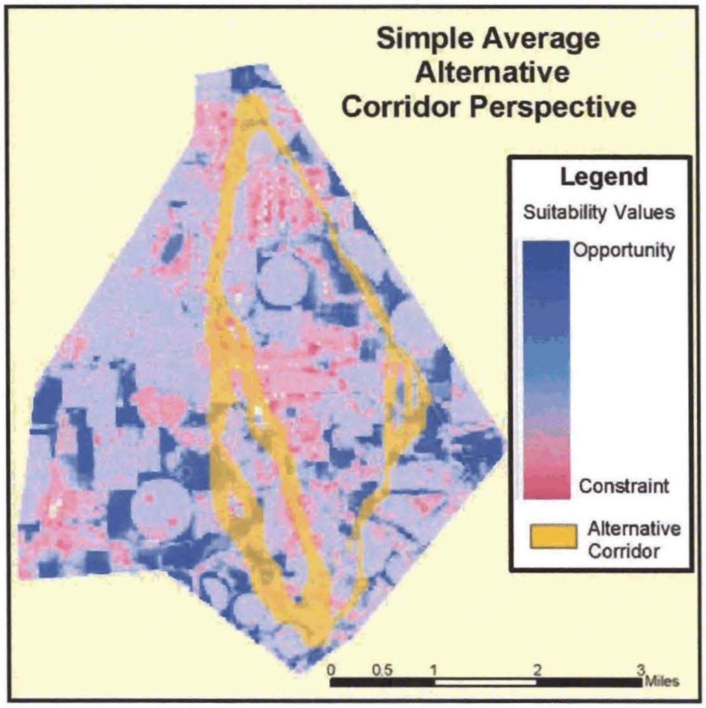

Figure 2-29
Phase 2: Alternative Corridor Generation – Simple Average Alternative Corridor

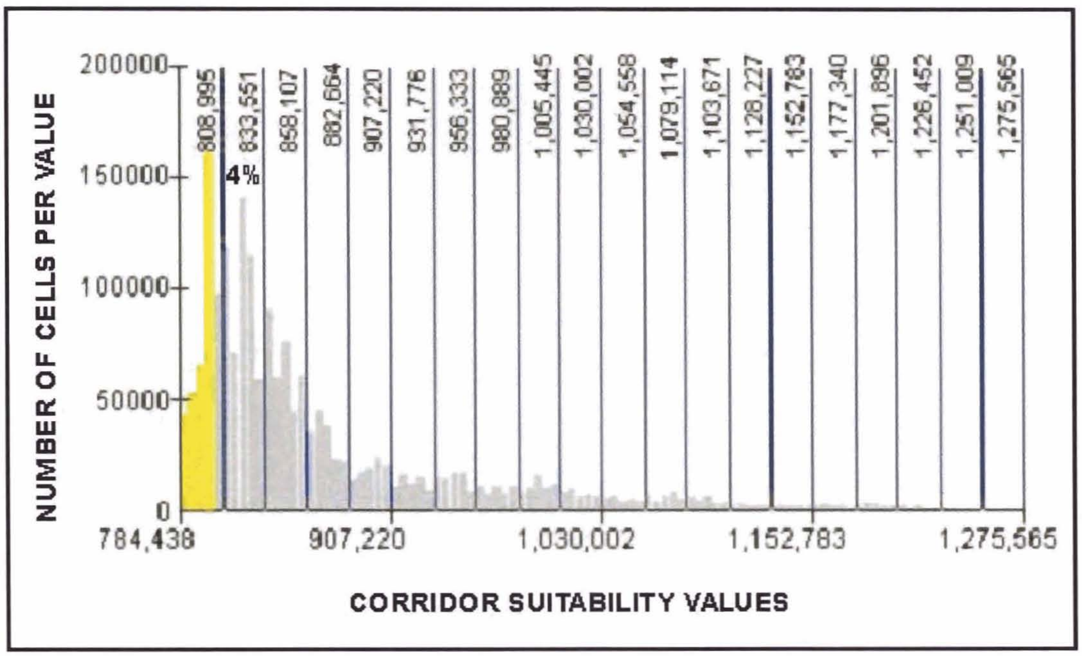

Figure 2-30
Phase 2: Alternative Corridor Generation – Simple Average Alternative Histogram

Alternative Corridor Weighting and Simple Average Corridor

Alternative Corridors are generated by emphasizing the different perspectives (Figure 2-31 – Alternative Corridor Generation Diagram). Emphasis is achieved by combining the three preference surfaces with a weighted average in which one of the perspectives is considered five times more important than the other two. Testing of weight averaging on various projects demonstrated that the weighting of five times was most effective in emphasizing one perspective over the others while still retaining some influence from the other two perspectives.

The result is three different corridors as shown in Figure 2-31. In this figure, the Built Environment corridor was generated by weighting the Built Perspective Data Layers five times more than the Natural and Engineering Perspectives. In a similar manner, Engineering and Natural emphasized alternatives are over-weighted to identify distinct solutions for those Perspectives.

In addition to the corridors generated for each perspective, a simple average preference surface is used to establish a consistent base line for all three perspectives. Alternative Corridors are combined to identify the optimal "decision space" for locating an overhead electric transmission line, considering the different siting perspectives. A proposed route venturing outside the combined Alternative Corridors is sub-optimal from all three perspectives and would need to be justified by extenuating factors not included in the model's set of map criteria.

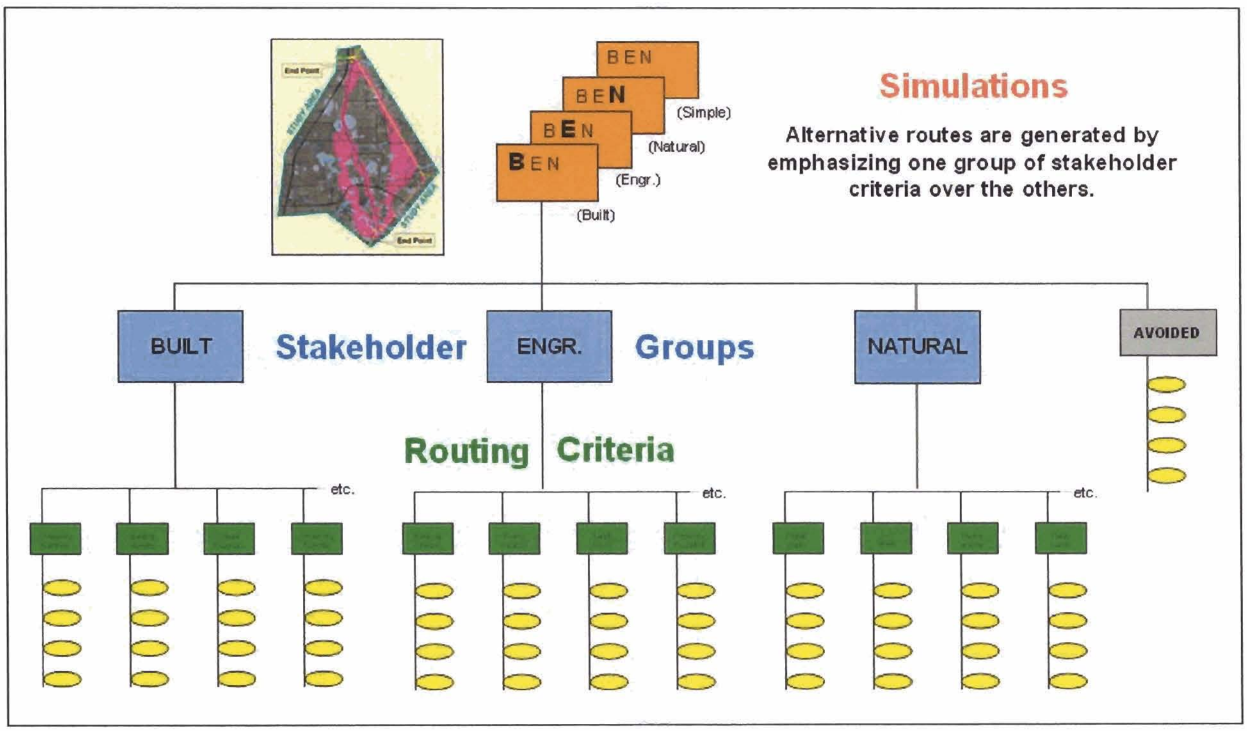

Figure 2-31
Phase 2: Alternative Corridor Generation Diagram – A Conceptual Diagram Showing how Alternative Corridors are Generated by Systematically Emphasizing Different Perspectives

Phase 3: Alternative Route Analysis and Evaluation

Alternative Route Generation

In Phase 2, the Least Cost Path (LCP) algorithm was run to generate Alternative Corridors for the Built, Natural, and Engineering Perspectives and an overall Simple Combination Corridor for all three. This algorithm generates a 15-foot wide "Optimal Path" the size of one grid cell in each Corridor (Figure 2-32 Alternative Routes within Alternative Corridors). As with the other two phases, additional detailed data are collected for areas within the Alternative Corridors. Property lines are identified and building centroids that were digitized during the Phase 2 Alternative Corridor are classified by types: occupied house, commercial building or industrial building. These additional data are entered into the GIS Siting Model. These data aid the project team in refining the "Optimal Path" within each Alternative Corridor. Waiting until these Alternative Corridors have been identified before collecting this very detailed data, the total time and cost to the project are greatly reduced.

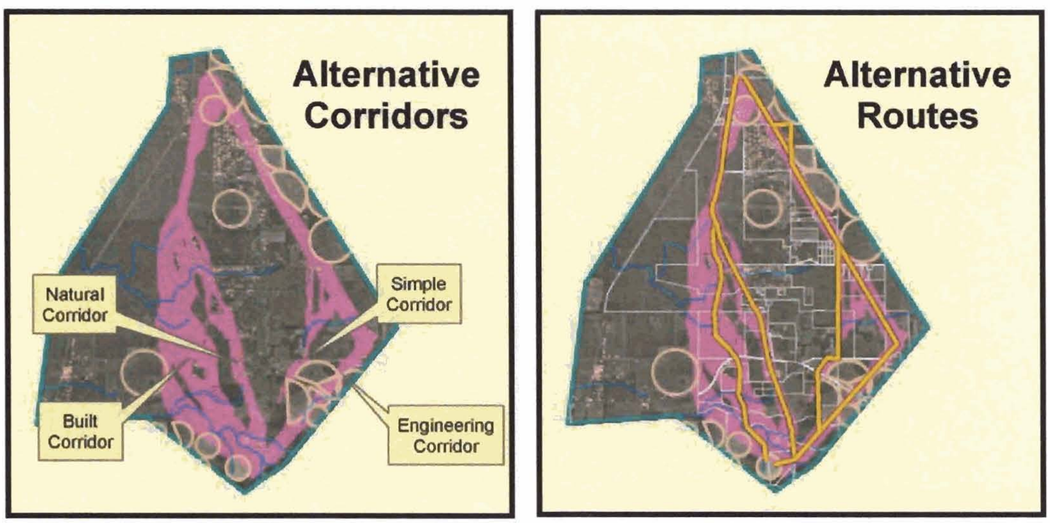

Figure 2-32
Phase 3: Alternative Route Generation – Alternative Routes within Alternative Corridors

Right-of-Way Considerations

Because the width of the "Optimal Path" is 15 feet, it is too narrow for meaningful analysis of the Alternative Routes by the current GIS Siting Model. To increase the "Optimal Path" from 15 feet (width of one grid cell) to the right-of-way width for the voltage of the project, additional grid cells must be added to each side of the "Optimal Path." This refinement creates an "Optimal Route." For example, an "Optimal Route" for a 500-kilovolt transmission line would require a width of 12 grid cells to form a 180-foot right-of-way.

Map Overlay Analysis

The route evaluation process is designed as a productivity tool for siting professionals. Staff members from engineering, land acquisition, environmental and other areas can easily evaluate the advantages and disadvantages of the Alternative Routes and selection of the Preferred Route. They can evaluate siting criteria and summaries of Data Layers (preferences layers) using map overlay analysis, spreadsheet processing, interactive geo-queries and other quantitative and qualitative metrics. Variations among the Built Environment Perspective, Natural Environment Perspective and Engineering Requirements Perspective (preference surface alternatives) can be illustrated graphically, using Map Overlap Analysis (Figure 2-33: Map Overlay Analysis).

In analyzing a composite Alternative Route, the GIS Siting Model isolates the evaluation criteria for all Data Layers. The results can be reported in a variety of formats: map display, inspection of "drill-down data," graphic illustrations and summary statistics. For example, the hypothetical route in Figure 2-33 shows that only a small stretch at the top of the route crosses a "least preferred" area (red), while the majority of the route crosses "moderate" to "most preferred" areas (green).

In a similar manner, a siting team member can "click" at any location along the route and pop-up a table listing preference conditions on any of the other active map layers. This interactive geo-query feature facilitates rapid retrieval of information to support siting team discussions. In addition to graphical display, interactive geo-query can produce spreadsheet tables for evaluation criteria, metrics summarizing individual segments and Alternative Routes.

Table 2-6, Tabular Summary of Alternative Routes, shows an example spreadsheet of summary information (rows) for several Alternative Routes (columns). Corridor Analyst™ software is used to summarize the evaluation metrics in terms of counts for the siting team discussion of relative lengths and acres of easement.

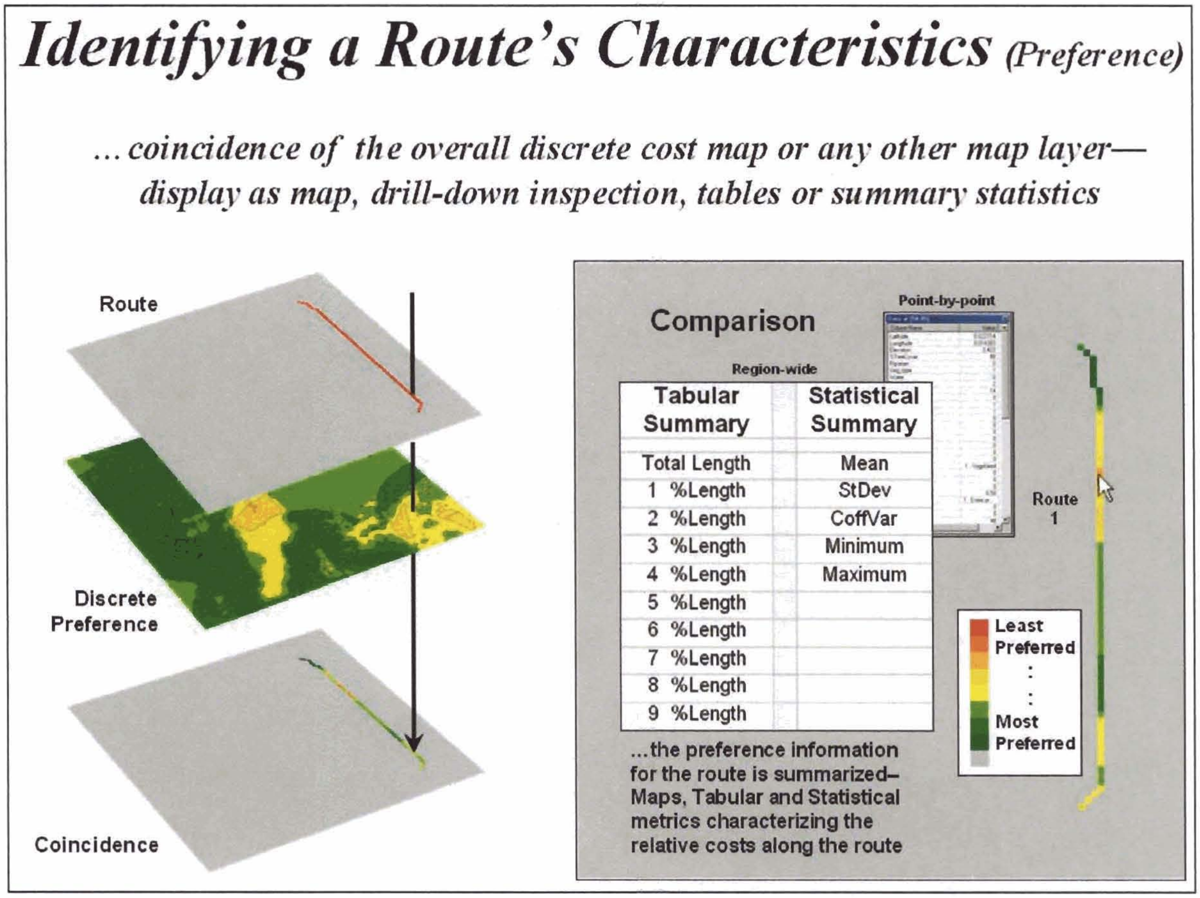

Figure 2-33
Phase 3: Alternative Route Generation – Map Overlay Analysis is Used to Summarize the Relative Siting Preference along an Alternative Route

Table 2-6
Phase 3: Alternative Route Generation – Spreadsheet Statistics Summarizing Evaluation Criteria for Alternative Routes

Tabular Summary of Alternate Routes Data for All Routes						
Built	**Route A**	**Route B**	**Route C**	**Route D**	**Route E**	**Route F**
Feature	**Unit**	**Unit**	**Unit**	**Unit**	**Unit**	**Unit**
Relocated Residences (within 75' Corridor)	0.0	0.0	1.0	0.0	1.0	0.0
Normalized	0.0	0.0	1.0	0.0	1.0	0.0
Proximity to Residences (300')	5.0	37.0	13.0	9.0	14.0	10.0
Normalized	0.0	1.0	0.3	0.1	0.3	0.2
Proposed Developments	2.0	0.0	1.0	0.0	0.0	0.0
Normalized	1.0	0.0	0.5	0.0	0.0	0.0
Proximity to Commercial Buildings (300')	3.0	4.0	1.0	1.0	1.0	5.0
Normalized	0.5	0.8	0.0	0.0	0.0	1.0
Proximity to Industrial Buildings (300')	1.0	0.0	0.0	0.0	3.0	3.0
Normalized	0.3	0.0	0.0	0.0	1.0	1.0
School, DayCare, Church, Cemetery, Park Parcels (#)	8.0	2.0	2.0	1.0	1.0	1.0
Normalized	1.0	0.1	0.1	0.0	0.0	0.0
NRHP Listed/Eligible Strucs./ Districts (1500' from edge of R/W)	2.0	1.0	0.0	0.0	0.0	0.0
Normalized	1.0	0.5	0.0	0.0	0.0	0.0
Natural						
Natural Forests (Acres)	1.2	6.4	5.8	7.0	9.6	10.7
Normalized	0.0	0.5	0.5	0.6	0.9	1.0
Stream/River Crossings	4.0	5.0	4.0	4.0	6.0	6.0
Normalized	0.0	0.5	0.0	0.0	1.0	1.0
Wetland Areas (Acres)	2.0	1.9	5.4	5.9	6.9	7.5
Normalized	0.0	0.0	0.6	0.7	0.9	1.0
Floodplain Areas (Acres)	4.3	2.6	8.3	7.4	6.4	4.3
Normalized	0.3	0.0	1.0	0.9	0.7	0.3
Engineering						
Length (Miles)	12.5	11.2	15.3	17.2	11.4	16.3
Normalized	0.2	0.0	0.7	1.0	0.0	0.8
Miles of Rebuild with Existing T/L*	5.2	4.7	5.1	4.6	4.8	4.8
Normalized	1.0	0.2	0.8	0.0	0.4	0.3
Inverted	0.0	0.8	0.2	1.0	0.6	0.7
Miles of Co-location with Existing T/L*	2.58	1.25	8.5	2.36	3.69	9.5
Normalized	0.2	0.0	0.9	0.1	0.3	1.0
Inverted	0.8	1.0	0.1	0.9	0.7	0.0
Miles of Co-location with Roads*	0.0	0.1	0.0	0.1	0.8	0.8
Normalized	0.0	0.2	0.0	0.2	1.0	1.0
Inverted	1.0	0.8	1.0	0.8	0.0	0.0
Number of Parcels	4.05	1.04	3.63	0.62	0.43	0.23
Normalized	1.0	0.2	0.9	0.1	0.1	0.0
Total Project Costs	45	34	48	37	34	34
Normalized	0.8	0.0	1.0	0.2	0.0	0.0

Evaluation Metrics

- ✓ **Relocated Residences**
- ✓ **Proximity of Residences**
- ✓ **Proposed Developments**
- ✓ **Proximity to Commercial Buildings**
- ✓ **Proximity to Industrial Buildings**
- ✓ **School, Daycare, Church, Cemetery, Park Parcels**
- ✓ **NRHP Listed/Eligible Structures/ Districts**
- ✓ **Natural Forests**
- ✓ **Stream/River Crossings**
- ✓ **Wetland Areas**
- ✓ **Floodplain Areas**
- ✓ **Total Length**
- ✓ **Miles of Rebuild**
- ✓ **Miles of Co-location**
- ✓ **Number of Parcels**
- ✓ **Total Project Costs**

Metrics, such as the number of relocated residences or length of the route passing through natural forests, are used to guide discussions comparing the advantages and disadvantages of the Alternative Routes. These discussions help organize and focus the siting team's review, as well as provide ample opportunity for free exchange of expert experience and opinion.

Qualitative Expert Judgment

The project team uses evaluation metrics that are normalized and assigned weights developed using AHP to derive a relative score for each Alternative Route (Appendix G: Phase 2-Alternative Corridor Weighting: AHP Pairwise Comparison Questions). The scores are combined for the three Perspectives (Built Environment, Natural Environment and Engineering Requirements) and then totaled for an overall score. The numerical score provides an objective reference for comparing Alternative Routes and stimulates discussion of their relative merits.

The left side of Table 2-7, Evaluating Alternative Routes, shows the translation of the "raw" evaluation metrics to a normalized and weighted score. In this example, the sub-criteria for each perspective are assigned relative weights. For example, the Built Environment Perspective's consideration of relocated residences is much more important (40 percent) than close Proximity to Industrial Buildings (2 percent). The three perspectives are weighted equally (33 percent) in this example, but these weights could be changed to make a routing solution more sensitive to the Built Environment Perspective, Natural Environment Perspective or the Engineering Requirement Perspective.

Table 2-7
Phase 3: Alternative Route Generation – Expert Judgment is Applied to the Top Three Routes to Identify their Relative Rankings

Evaluating Alternative Routes

Built	33%	Route A	Route B	Route C	Route D	Route E	Route F
Feature		Unit	Unit	Unit	Unit	Unit	Unit
Relocated Residences (within 75' Corridor)	44.3%	0.00	0.00	1.00	0.00	1.00	0.00
Weighted		0.00	0.00	0.44	0.00	0.44	0.00
Proximity to Residences (300')	13.1%	0.00	1.00	0.25	0.13	0.28	0.16
Weighted		0.00	0.13	0.03	0.02	0.04	0.02
Proposed Residential Developments	5.4%	1.00	0.00	0.50	0.00	0.00	0.00
Weighted		0.05	0.00	0.03	0.00	0.00	0.00
Proximity to Commercial Buildings (300')	3.6%	0.50	0.75	0.00	0.00	0.00	1.00
Weighted		0.02	0.03	0.00	0.00	0.00	0.04
Proximity to Industrial Buildings (300')	1.8%	0.33	0.00	0.00	0.00	1.00	1.00
Weighted		0.01	0.00	0.00	0.00	0.02	0.02
School, DayCare, Church, Cemetery, Park Parcels (#)	16.3%	1.00	0.14	0.14	0.00	0.00	0.00
Weighted		0.16	0.02	0.02	0.00	0.00	0.00
NRHP Listed/Eligible Strucs./Districts (1500' from edge of R/W)	15.5%	1.00	0.50	0.00	0.00	0.00	0.00
		0.16	0.08	0.00	0.00	0.00	0.00
TOTAL	100.0%	0.40	0.26	0.53	0.02	0.50	0.07
WEIGHTED TOTAL		0.13	0.09	0.17	0.01	0.16	0.02
Natural	33%						
Natural Forests (Acres)	9.3%	0.00	0.54	0.49	0.61	0.88	1.00
Weighted		0.00	0.05	0.05	0.06	0.08	0.09
Stream/River Crossings	38.0%	0.00	0.50	0.00	0.00	1.00	1.00
Weighted		0.00	0.19	0.00	0.00	0.38	0.38
Wetland Areas (Acres)	40.3%	0.02	0.00	0.62	0.72	0.90	1.00
Weighted		0.01	0.00	0.25	0.29	0.36	0.40
Floodplain Areas (Acres)	12.4%	0.29	0.00	1.00	0.85	0.67	0.29
Weighted		0.04	0.00	0.12	0.11	0.08	0.04
TOTAL	100.0%	0.04	0.24	0.42	0.45	0.91	0.91
WEIGHTED TOTAL		0.01	0.08	0.14	0.15	0.30	0.30
Engineering	33%						
Miles of Rebuild with Existing T/L*	65.6%	1.00	0.16	0.84	0.00	0.43	0.32
Weighted		0.66	0.11	0.55	0.00	0.28	0.21
Miles of Co-location with Existing T/L*	19.2%	2.58	1.25	8.50	2.36	3.69	9.50
Weighted		0.50	0.24	1.63	0.45	0.71	1.82
Miles of Co-location with Roads*	7.8%	0.84	1.00	0.12	0.87	0.70	0.00
Weighted		0.07	0.08	0.01	0.07	0.05	0.00
Total Project Costs	7.4%	4.05	1.04	3.63	0.62	0.43	0.23
Weighted		0.30	0.08	0.27	0.05	0.03	0.02
TOTAL	100.0%	1.52	0.50	2.46	0.57	1.08	2.05
WEIGHTED TOTAL		0.50	0.17	0.81	0.19	0.36	0.68
SUM OF WEIGHTED TOTALS		0.65	0.33	1.12	0.34	0.82	1.00

FOR TOP 3-5 ROUTES (INTERNAL)

EXPERT JUDGEMENT **Sample Weights**

	Per Project	Route A	Route B	Route D
Visual Issues	5%	1	5	1
Weighted		0.05	0.25	0.05
Community Issues	25%	1	5	3
Weighted		0.25	1.25	0.75
Schedule Delay Risk	30%	2	5	1
Weighted		0.60	1.50	0.30
Special Permit Issues	30%	4	5	1
Weighted		1.20	1.50	0.30
Construction/ Maintenance Accessibility	10%	5	1	2
Weighted		0.50	0.10	0.20
TOTAL	**100%**	2.6	4.6	1.6

Expert Judgment

- ✓ **Visual Concerns (5%)**
- ✓ **Community Concerns (25%)**
- ✓ **Schedule Delay Risk (30%)**
- ✓ **Special Permit Issues (30%)**
- ✓ **Construction/Maintenance Accessibility (10%)**

...the evaluation metric are normalized and assigned weights to derive a relative score for the alternative routes. The siting team applies expert judgment to rank the top three routes (routes A, B and D).

Selecting the Preferred Route

The final step in the evaluation process applies expert judgment for ranking the top Alternative Routes (Appendix H: Phase 3: Preferred Route Weighting AHP Pairwise Comparison Questions). Each siting team member ranks the top scoring routes based on several important considerations: visual concerns, community concerns, schedule delay risk, special permit issues and construction and maintenance accessibility. These considerations are assigned weights (5, 25, 30, 30, and 10 percent respectively), and individual responses are combined for an overall team ranking.

It is important to note that the specific evaluation criteria can be expanded or contracted as the unique aspects of routing situations vary. However, the general process of deriving and evaluating explicit metrics remains the same. The process is designed to encourage thorough discussion of clearly defined evaluation criteria that explicitly captures the thought process of the siting team in evaluating and selecting a final route. The process is objective, consistent and comprehensive, while directly focusing and capturing siting team deliberations.

Environmental justice is evaluated as a part of GTC's risk analysis work and is not part of the route selection process. Thus, environmental justice is included in the methodology and siting model to indicate the point where environmental justice reviews would be typically performed. GTC plans to perform them when alternative routes have been established (Appendix I: Environmental Justice).

3
SITING CASE STUDIES

Macro Corridors

The project team tested the Macro Corridor Model on 17 of Georgia Transmission Corporation's (GTC) existing transmission line projects. Alternative Corridors, Alternative Routes, Alternative Route analysis and selection of the Preferred Route were tested on seven of the company's existing transmission line projects. The tests represented projects from different regions of Georgia, including rural projects in the Coastal Plains and Piedmont areas to urban and suburban projects around Atlanta. The methodology will be tested further, and possibly refined, as GTC uses it on new transmission line projects.

For the purposes of this report, one transmission line project was selected as a case study to illustrate the EPRI-GTC Overhead Electric Transmission Line Methodology and GIS Siting Model. This project is located in southern Georgia, in a predominantly rural area with pockets of residential development. Sensitive project area resources include wetlands, agriculture fields with center pivot irrigation, pecan orchards and a church and cemetery listed on the NRHP.

In Phase 1, Macro Corridor generation, the Least Cost Path (LCP) algorithm was used to identify the boundaries of the project study area by generating three well-defined Macro Corridors. As expected, the test resulted in one corridor paralleling an existing transmission line, another paralleling a road and the third running cross-country. The combination of the three Macro Corridors defines the boundaries of the project area by creating boundaries that capture all possible co-location opportunities as well as sufficient areas for cross-country corridors to be generated. Repeated testing on other projects established that the Macro Corridor Phase of the Siting Methodology would consistently produce successful project area boundaries (Figure 3-1: Macro Corridor Composite).

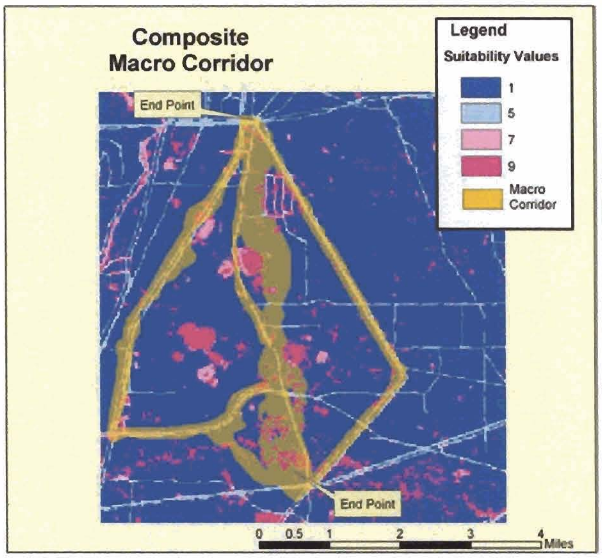

Figure 3-1
Siting Case Studies – Macro Corridor Composite

Alternative Corridors

Running the Composite Suitability Surfaces for each of the three perspectives produced four primary corridors: Built Environment, Natural Environment, Engineering Requirements and the Simple Combined. Two corridors, the Built Environment and the Simple Combined, had cross-country sections and co-locations sections. The other two models co-located with an existing transmission line or a road.

The Built Environment Corridor minimizes adverse impacts to roadside residences by running cross-country behind them. Although the road appears to be a direct route between the endpoints, it has scattered residences, as well as several churches. One church and cemetery lot is listed on the NRHP. This NRHP Avoidance Area causes the Built Environment Corridor to go cross-country west of the road until it is north of the constraints. The Built Environment Corridor crosses environmentally sensitive areas, however, it manages to maneuver around large wetlands (Figure 3-2: Built Environment Alternative Corridor Perspective).

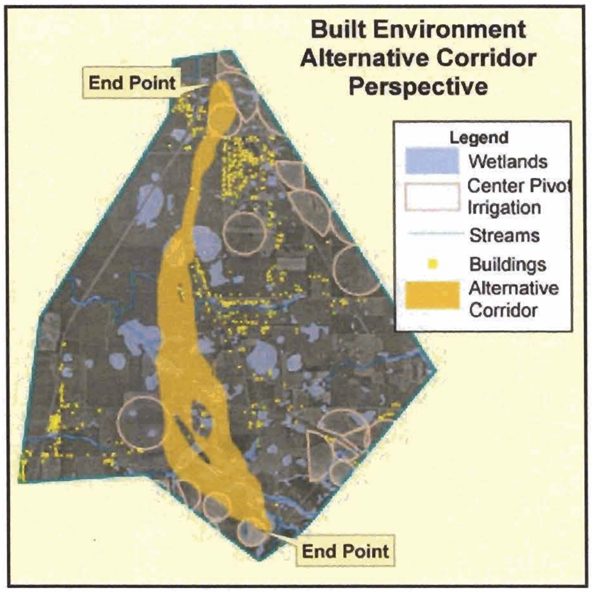

Figure 3-2
Siting Case Studies – Built Environment Alternative Corridor Perspective

The Natural Environment Corridor co-locates with an existing road that appears to be a direct route between the endpoints of the project. Scattered along the roadside route are residences and churches. The Natural Environment Corridor passes in front of a NRHP listed church and cemetery. By co-locating with the road, this corridor avoids environmentally sensitive areas, such as wetlands, and adverse impacts to intensive agriculture, such as row crops with center pivot irrigation (Figure 3-3: Natural Environment Alternative Corridor Perspective).

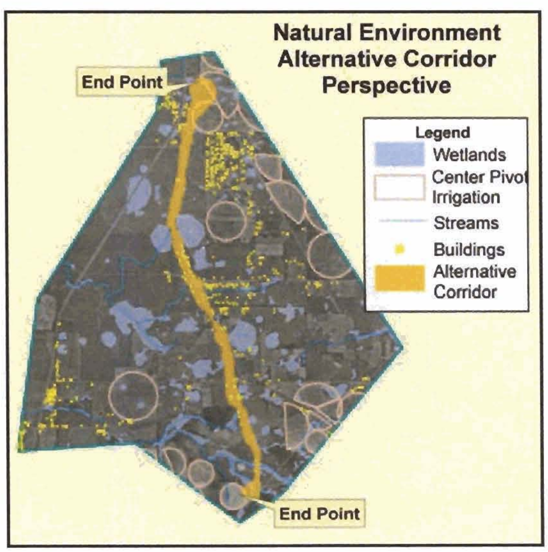

Figure 3-3
Siting Case Studies – Natural Environment Alternative Corridor Perspective

The Engineering Requirements Corridor co-locates with an existing transmission line between the two project endpoints. It co-locates with the existing transmission line even though there are row crops with center pivot irrigation adjacent to the right-of-way. The irrigation system and its infrastructure preclude the proposed transmission line from paralleling the existing line without relocating or removing the irrigation system. The existing transmission line cuts through a subdivision near the northern end of the route (Figure 3-4: Engineering Requirements Alternative Corridor Perspective).

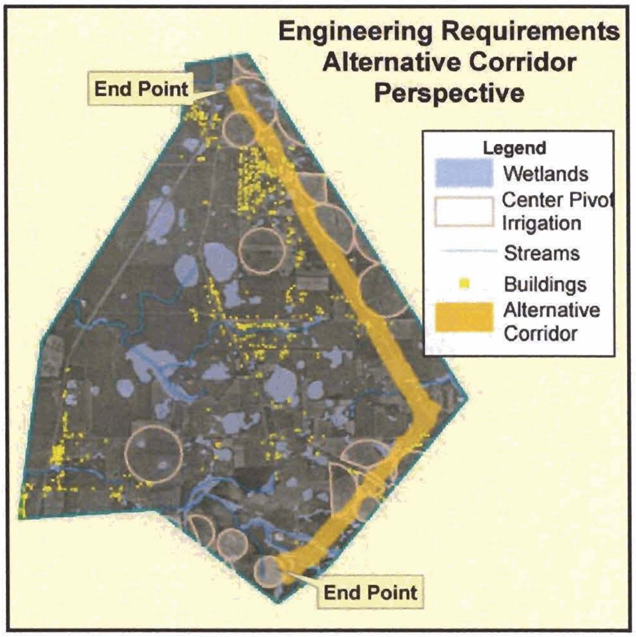

Figure 3-4
Siting Case Studies – Engineering Requirements Alternative Corridor Perspective

Engineering Requirements Alternative Corridor Perspective

The Simple Average Corridor begins by avoiding row crops with center pivot irrigation. It utilizes edge-of-field opportunities along the center pivot fields and pecan orchards. This corridor intersects with the existing transmission line about halfway and then co-locates with the transmission line through the residential area to the north endpoint. It also contains similar paths as the Built and Natural Environment models.

In each case, the Built, Natural Environment and Engineering Requirements Corridors minimized adverse impacts to sensitive features (Figure 3-5: Simple Average Alternative Corridor Perspective).

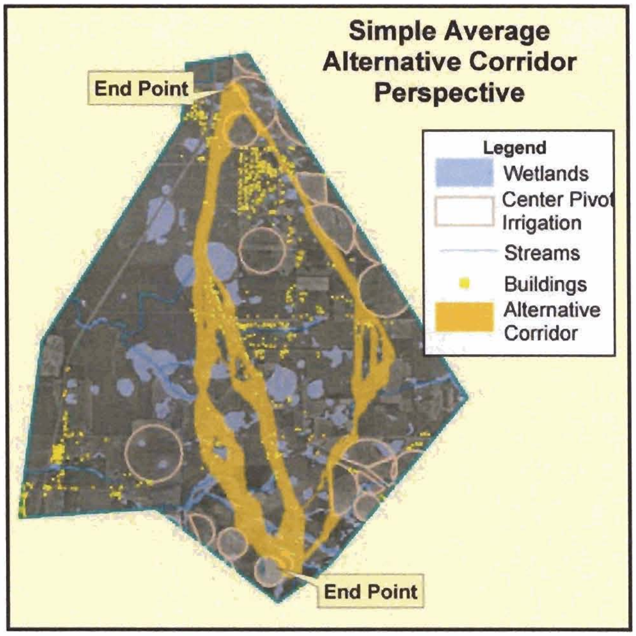

Figure 3-5
Siting Case Studies – Simple Average Alternative Corridor Perspective

Alternative Routes

Once the Alternative Corridors are generated, data on property lines and building classifications are collected and entered into the GIS Siting Model. These data are used to refine the "Optimal Paths" into six routes for further evaluation.

Route A – Built Route: This route was developed within the Built Environment Corridor, which is primarily cross-country, until joining the road at the northern end. The cross-county section avoided wetlands, residences, the NRHP listed church and cemetery and pecan orchards. It utilized pine plantations when appropriate (Figure 3-6: Route A).

Route B – Natural Route: This route parallels the road that connects the two project endpoints. The route was developed to minimize adverse impacts to ecological resources although it impacts residences that are located along the road and a listed NRHP church and cemetery on the opposite side of the road (Figure 3-7: Route B).

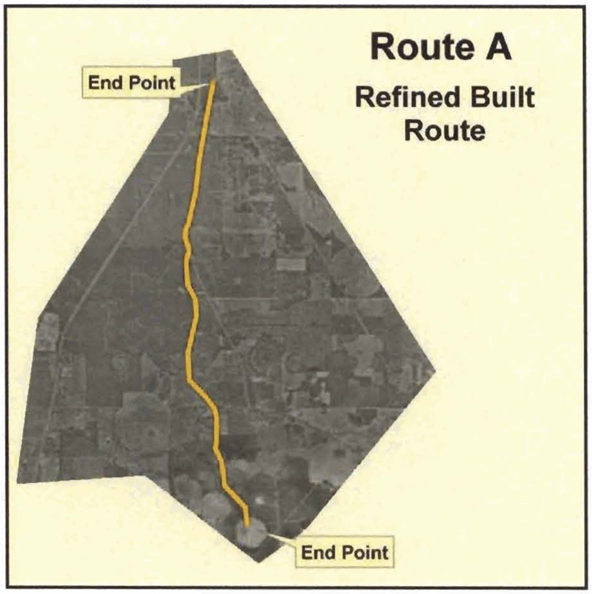

Figure 3-6
Siting Case Studies – Route A

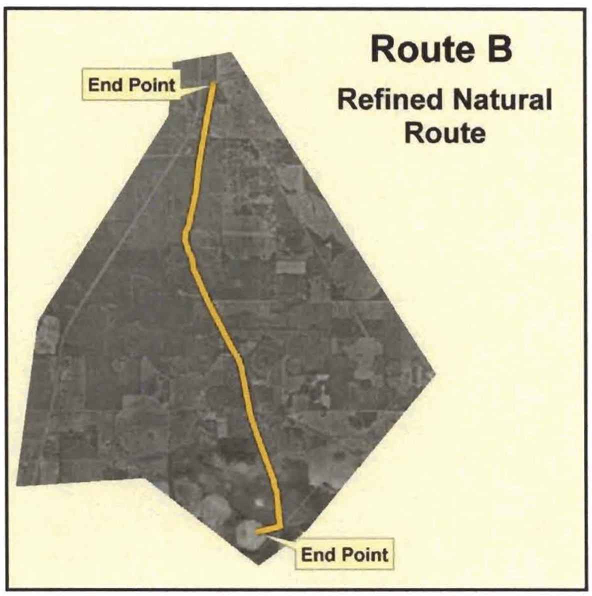

Figure 3-7
Siting Case Studies – Route B

Route C – Simple Average Route: This route was developed within the Simple Combination Corridor. It is adjacent to the edge of fields and land lot features throughout the southern half of the route. This alignment minimized adverse impact to center pivot irrigation in the project area. About midway, the route turns and parallels an existing transmission line. However, paralleling the existing transmission line would require relocating a residence (Figure 3-8: Route C).

Route D – Simple Average Route (avoids relocation): This is the second route developed within the Simple Combination Corridor. To avoid relocating a residence, the proposed route must go cross-country for a short distance before returning to the parallel alignment (Figure 3-9: Route D).

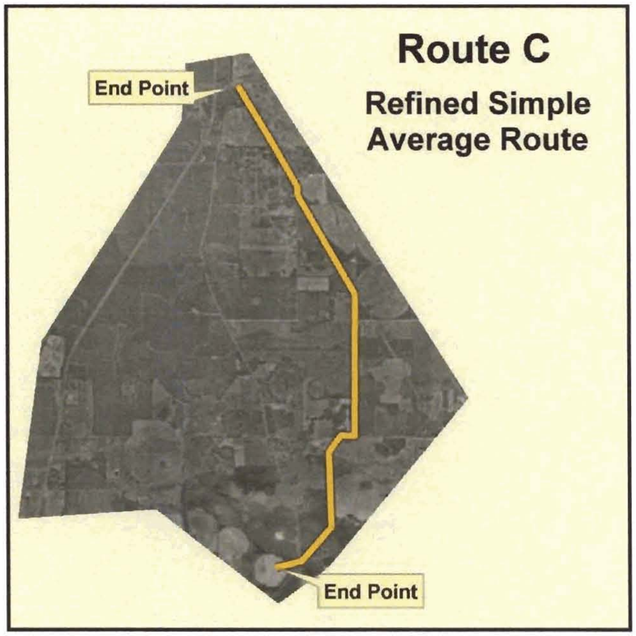

Figure 3-8
Siting Case Studies – Route C

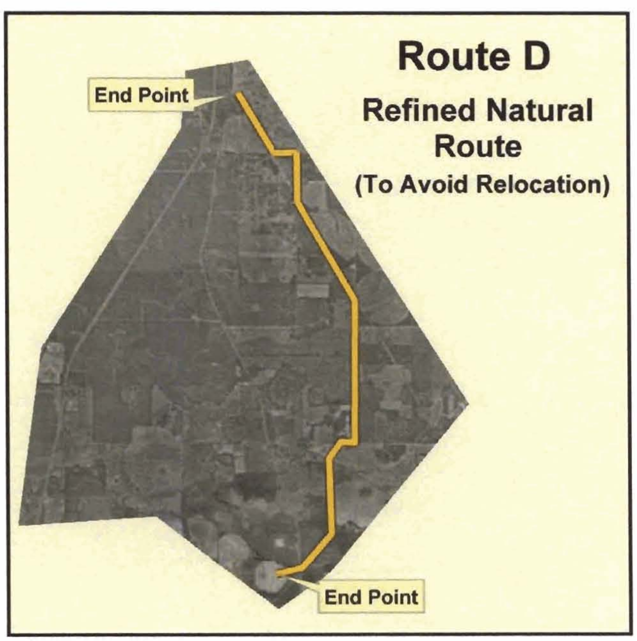

Figure 3-9
Siting Case Studies – Route D

Route E – Engineering Requirements Route: This route was developed within the Engineering Corridor. It parallels the existing transmission line between both project endpoints. However, like Route C, it would be necessary to relocate a residence (Figure 3-10: Route E)

Route F – Engineering Requirements Route (avoids relocation): This is the second route developed within the Engineering Corridor. To avoid relocating a residence, the proposed route must go cross-country for a short distance before returning to the parallel alignment (Figure 3-11: Route F).

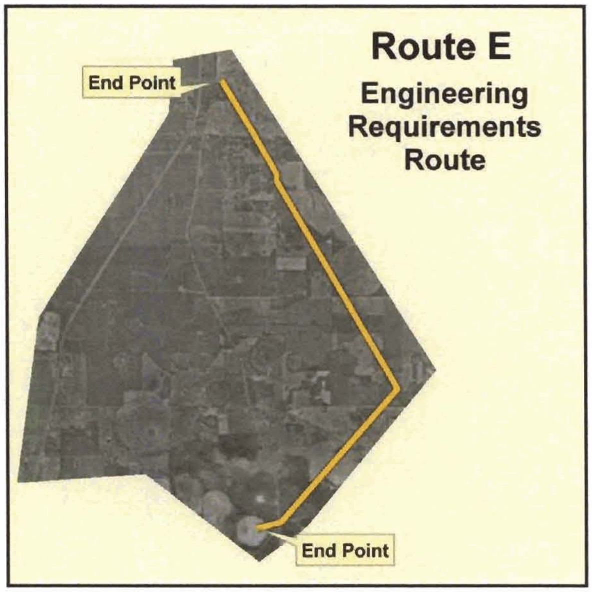

Figure 3-10
Siting Case Studies – Route E

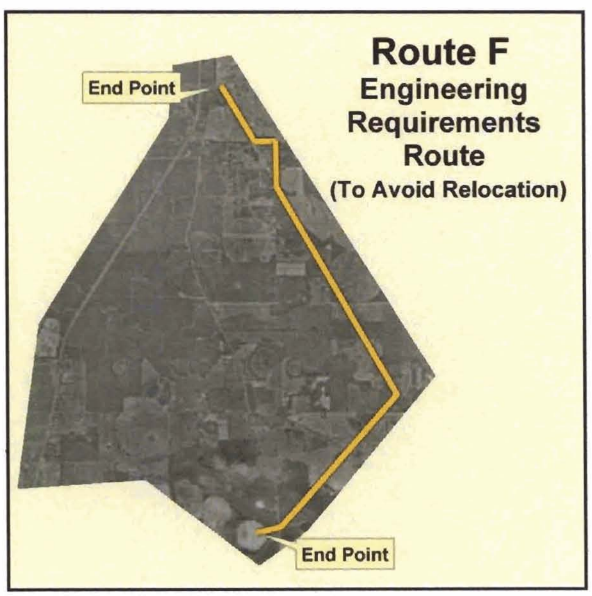

Figure 3-11
Siting Case Studies – Route F

Alternative Route Analysis

Statistics were generated for each route and tabulated into an Excel spreadsheet. They are normalized and weighted by importance of the statistic, and the resulting scores were calculated (Figure 3-12: Alternative Routes).

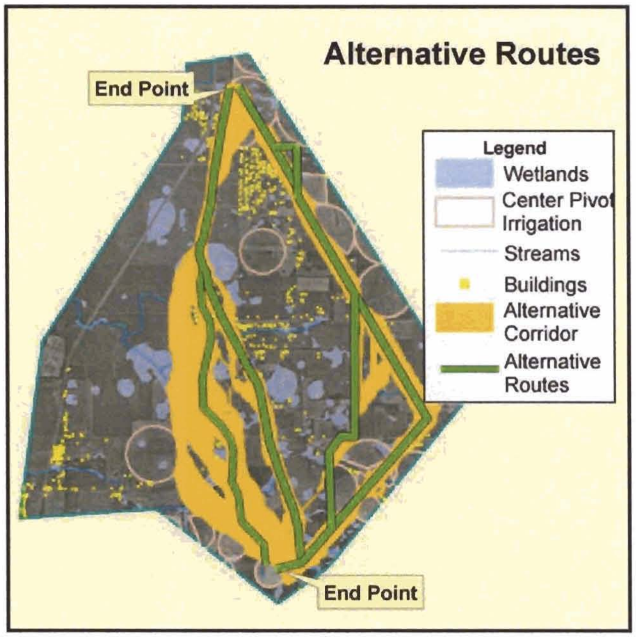

Figure 3-12
Siting Case Studies – Alternative Routes

Routes A, B and D were chosen for further study. These routes had the best score based on the weighted Alternative Route Analysis. Routes C and E scored higher, or worse, in the Built Environment Category because of the relocation of a residence. Routes E and F scored higher, or worse, because of high adverse impacts to Features in the Natural Environment Category. No significant differences were obvious among the routes in the Engineering Category (Table 3-1: Evaluating Alternative Routes).

Table 3-1
Siting Case Study – Evaluating Alternative Routes

Built	33%	Route A	Route B	Route C	Route D	Route E	Route F
Feature		**Unit**	**Unit**	**Unit**	**Unit**	**Unit**	**Unit**
Relocated Residences (within 75' Corridor)	44.3%	0.00	0.00	1.00	0.00	1.00	0.00
Weighted		0.00	0.00	0.44	0.00	0.44	0.00
Proximity to Residences (300')	13.1%	0.00	1.00	0.25	0.13	0.28	0.16
Weighted		0.00	0.13	0.03	0.02	0.04	0.02
Proposed Residential Developments	5.4%	0.00	0.00	0.00	0.00	0.00	0.00
Weighted		0.00	0.00	0.00	0.00	0.00	0.00
Proximity to Commercial Buildings (300')	3.6%	1.00	1.00	1.00	1.00	1.00	1.00
Weighted		0.04	0.04	0.04	0.04	0.04	0.04
Proximity to Industrial Buildings (300')	1.8%	0.33	0.00	0.00	0.00	1.00	1.00
Weighted		0.01	0.00	0.00	0.00	0.02	0.02
School, Daycare, Church, Cemetery, Park Parcels (#)	16.3%	1.00	1.00	1.00	1.00	1.00	1.00
Weighted		0.16	0.16	0.16	0.16	0.16	0.16
NRHP Listed/Eligible Structures/Districts (1500' from edge of R/W)	15.5%	1.00	0.50	0.00	0.00	0.00	0.00
		0.16	0.08	0.00	0.00	0.00	0.00
Total	100.0%	0.36	0.41	0.67	0.22	0.70	0.24
Weighted Total		0.12	0.13	0.22	0.07	0.23	0.08
Natural	33%						
Natural Forests (Acres)	9.3%	0.00	0.54	0.49	0.61	0.88	1.00
Weighted		0.00	0.05	0.05	0.06	0.08	0.09
Stream/River Crossings	38.0%	0.00	0.50	0.00	0.00	1.00	1.00
Weighted		0.00	0.19	0.00	0.00	0.38	0.38
Wetland Areas (Acres)	40.3%	0.02	0.00	0.62	0.72	0.90	1.00
Weighted		0.01	0.00	0.25	0.29	0.36	0.40
Floodplain Areas (Acres)	12.4%	0.00	0.00	0.00	0.00	0.00	0.00
Weighted		0.00	0.00	0.00	0.00	0.00	0.00
Total	100.0%	0.01	0.24	0.29	0.35	0.82	0.88
Weighted Total		0.00	0.08	0.10	0.11	0.27	0.29
Engineering	33%						
Miles of Rebuild with Existing T/L	65.6%	0.00	0.00	0.00	0.00	0.00	0.00
Weighted		0.00	0.00	0.00	0.00	0.00	0.00
Miles of Co-location with Existing T/L	19.2%	0.96	1.00	0.51	0.66	0.00	0.15
Weighted		0.18	0.19	0.10	0.13	0.00	0.03
Miles of Co-location with Roads	7.8%	0.49	0.00	0.86	0.77	0.97	1.00
Weighted		0.04	0.00	0.07	0.06	0.08	0.08
Total Project Costs	7.4%	0.00	0.17	0.50	0.64	0.83	1.00
Weighted		0.00	0.01	0.04	0.05	0.06	0.07
Total	100.0%	0.22	0.20	0.20	0.23	0.14	0.18
Weighted Total		0.07	0.07	0.07	0.08	0.05	0.06
Sum of Weighted Totals		0.19	0.28	0.39	0.26	0.55	0.43

Selection of Preferred Route

Once the Preferred Route(s) were ranked by the weighted Alternative Route Analysis, the routes were analyzed further by applying qualitative expert judgment. The project team ranked expert judgment criteria. as 1 = low impact, 2 = medium impact, and 3 = high impact (Table 3-2: Qualitative Expert Judgment).

Table 3-2
Siting Case Study – Qualitative Expert Judgment

Expert Judgement	Weights Per Project	Route A	Route B	Route D
Visual Issues	10%	1	3	1
Weighted		0.1	0.3	0.1
Community Issues	20%	1	3	2
Weighted		0.2	0.6	0.4
Schedule Delay Risk	0%	0	0	0
Weighted		0	0	0
Special Permit Issues	40%	1	3	1
Weighted		0.4	1.2	0.4
Construction/ Maintenance Accessibility	30%	3	1	2
Weighted		0.9	0.3	0.6
Environmental Justice	0%	0	0	0
Weighted		0	0	0
Total				
	100%	1.6	2.4	1.5

The weights were applied to the rankings and summed. In Table 3-1, Evaluating Alternative Routes, Route D scored the best and Route B scored the worst out of the top three routes. This was due primarily to the close proximity of the listed NRHP church to Route B. In Table 3-2: Qualitative Expert Judgment Process, the two best routes, Route D and A, are close but Route D scored slightly better due to construction and maintenance accessibility. Therefore, Route D was selected as the Preferred Route. (Figure 3-13: Preferred Route)

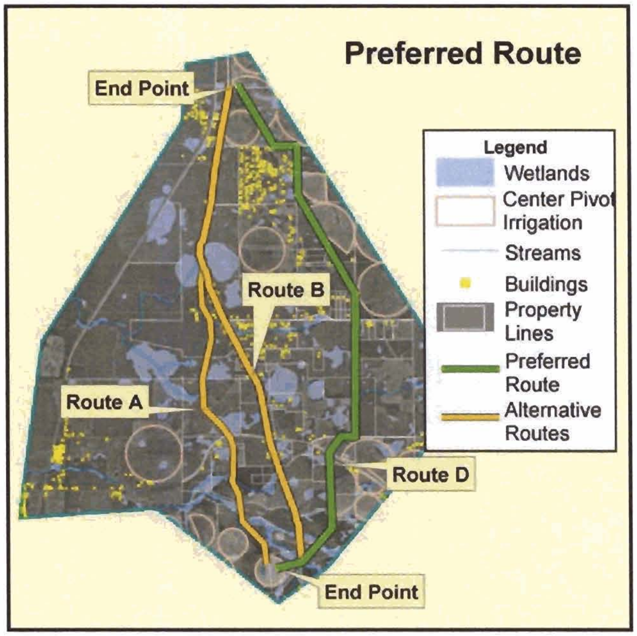

Figure 3-13
Siting Case Study – Preferred Route

Validation of Results

Georgia Transmission Corporation is actively routing many new transmission lines. There are also a number of new projects that will soon be released for routing to begin. To further test and validate this new siting process, GTC will use the EPRI-GTC Overhead Electric Transmission Line Siting Methodology and GIS Siting Model on its new transmission line projects. An internal GTC team will analyze the results of the methodology for each new transmission line project during the next year. If areas of weakness are discovered in the siting methodology, GIS Siting Model, Feature Calibration or Data Layer Weighting, sensitivity testing will be performed to determine the causes and solutions.

4
PROJECT MILESTONES

Team Formation – 2002

An EPRI-GTC study team was formed in 2002. Team members were Dr. Joseph K. Berry, Dr. Steven P. French, Jesse Glasgow, Dr. Elizabeth A. Kramer, Steven Richardson, Chris Smith and Dr. Paul D. Zwick. Project managers were Georgia Transmission Corporation's (GTC) Gayle Houston and Christy Johnson and EPRI's J.W. Goodrich-Mahoney. GTC staff members assisted the team and Photo Science Inc. developed the siting software used in the GIS Siting Model (Appendix A: EPRI-GTC Overhead Electric Transmission Line Siting Methodology Project Team).

Project Meetings – January 2003

From January 2003 to August 2004, the project team focused their efforts on creating a methodological framework for overhead electric transmission line siting that was scientific, comprehensive and defensible and that integrated advanced GIS technology.

The team developed goals and objectives of the project, determined the project agenda and timeline and discussed responsibilities of individual team members. The project was divided into three major phases: Macro Corridor Generation, Alternative Corridor Generation and Alternative Route Analysis and Evaluation.

During the initial meeting, the strengths and weaknesses of the current transmission line siting methodology were evaluated. The team concluded that inconsistent use of data from project to project was a flaw in the existing process. Subsequent team meetings focused on determining data features and layers for each of the three phases. After this, a series of five workshops was held with external and internal stakeholders to calibrate and weight the data.

External Stakeholder Workshop – June 2003

Based on recommendations from the academic consultants, GTC included external stakeholders as early in the process as practical. GTC held the first workshop after the Macro Corridor selection process was identified. Prior to the workshop, the EPRI-GTC team analyzed information from the GIS database and determined the resource categories needed for the siting model to identify Alternative Corridors within the Macro Corridors. Participants included federal and state officials, community and economic groups' representatives and other professionals (Appendix J: Stakeholder Meeting Invitees).

During the workshop, participants assigned ranks using the Delphi process to categories of resources. They then used the AHP process to weight the three major corridor types: the Built Environment, Natural Environment and Engineering Requirements Perspectives. Participants completed several iterations of both ranks and weights to reach consensus and to demonstrate how changes in Delphi ranks and AHP weights affected corridor and route locations (Appendix E: Phase 2 – Alternative Corridor Model: Delphi Feature Calibration; Appendix F: Phase 2 – Alternative Corridor Model: AHP Percentages by Data Layer; and Appendix G: Phase 2 – Alternative Corridor: AHP Pairwise Comparison Questions).

Georgia Integrated Transmission System Stakeholder Workshop – August 2003

A goal of this project was to provide a comprehensive, consistent and defensible process for overhead transmission line siting in Georgia. Attendees at this workshop were employees of Georgia Transmission Corp., Georgia Power Company and MEAG Power. These companies are part of the Georgia's Integrated Transmission System (ITS), a statewide electric transmission planning and operations group. The agenda for the ITS workshop was the similar to the one used for the external stakeholder workshop.

The EPRI-GTC project team thought that extensive electric transmission line siting experience would provide members of this group a different perspective on the ranks and weights than external stakeholders who had little or no siting experience.

GIS consultants and members of Photo Science Inc. and Georgia Transmission Corp. ran models using the Delphi rankings and AHP weights developed in two workshops. These rankings and weights were tested on several existing power line siting projects. The academicians and project team members analyzed the model results and adjusted model calibrates and weights where tests indicated obvious inconsistencies and/or missing criteria.

Stakeholder/ITS Update Workshop – November 2003

The external stakeholders (from the June workshop) and ITS attendees (from the August workshop) were invited to attend an update meeting to see a presentation of the results of the workshops they attended. The comments during the discussion session indicated that the participants thought the model was working well at that stage of development. Several participants thought that GTC should hold more meetings to obtain input from additional stakeholders.

Electric Utility Workshop – January 2004

Representatives from electric utility companies attended a meeting to see a presentation of the EPRI-GTC Overhead Electric Transmission Line Siting Methodology Project. The presentation explained the siting tasks. The attendees participated in a discussion and filled out comment forms (Appendix K: Electric Utility Stakeholder Workshop Summary of Questionnaire Responses).

External Stakeholder Workshop – March 2004

A second External Stakeholder Meeting was held to provide another opportunity for new stakeholders and stakeholders who could not attend the June meeting. The agenda was the similar to the Electric Utility Meeting in January 2004.

EPRI-GTC Report – 2005

In the third quarter of 2004 and in 2005, the project team documented the study and results and prepared this EPRI-GTC Overhead Electric Transmission Line Siting Methodology Report.

5 CONCLUSIONS

The research team from the Electric Power Research Institute (EPRI) and Georgia Transmission Corporation (GTC) achieved its primary objective of developing a new electric transmission line siting methodology that produces more quantifiable, consistent and defensible siting decisions.

To do this, the team accomplished the following:

1. Developed a new siting methodology and integrated it with a new data analysis tool called the GIS Siting Model,
2. Obtained internal and external stakeholders' critical reviews and achieved consensus on the ranking of GIS database features and weighting of data layers,
3. Ensured the process conforms to federal and state environmental regulations, and
4. Applied the corridor and route selection processes to actual transmission line siting projects and evaluated the results.

Georgia Transmission Corporation has revised its transmission line siting practice to conform with the new methodology. As a result, the company's siting practice is now more consistent and scientifically rigorous, and officials are in a better position to explain, justify and defend their siting decisions.

The team's project managers reported that the two most successful aspects of the effort were integrating GIS technology with a new methodology, and obtaining stakeholder involvement in the study's outcome. Additional improvements came in the areas of unexpected cost savings in data collection and the GIS Siting Model producing reports that support GTC's environmental reporting. In addition, a group of electric utility professionals from companies throughout the Southeast reviewed the EPRI-GTC methodology and siting model and offered their opinions. Their viewpoints are documented in survey results contained in Appendix K.

The project team listed four potential improvements: incorporating rights-of-way access in the methodology, incorporating visual impacts, GIS Siting Model refinements and future testing. Accomplishments and improvements are defined in next few pages.

Accomplishments

As envisioned by EPRI and GTC, the project team and stakeholders developed a GIS Siting Model and incorporated stakeholder input into the siting methodology utilizing the AHP and the Delphi Process. In addition, the team assessed the objectivity and predictability of results when applying the criteria to corridor and route selection, and ensured that the Siting Methodology complied with the National Environmental Protection Act (NEPA) and other environmental regulations.

Integrating GIS Technology With a New Methodology

GTC integrated a proprietary transmission line siting software, Corridor Analyst™, with off-the-shelf digital data to automate the siting methodology. This GIS approach ensures a comprehensive, objective and consistent methodology for siting transmission lines that can be implemented by other electric industry companies nationwide. GTC is actively working with other members of the Georgia ITS to use this methodology when siting new overhead electric transmission lines in Georgia.

Obtaining Stakeholder Involvement

Siting experts from the electric industry, federal and state agencies and external stakeholders participated in the EPRI-GTC Overhead Electric Transmission Line Siting Methodology development and provided feedback on its strengths and weaknesses. As confirmed by stakeholders' comments, calibration of Features using the Delphi Process and weighting of Data Layers using the Analytical Hierarchical Process provided a scientifically rigorous methodology.

Another achievement of the project was getting stakeholders' input during five multi-day workshops. Transmission line siting professionals indicated that the involvement of external stakeholders throughout the development of the siting methodology was an uncommon approach. This approach is a significant departure from most other transmission line siting methodologies because it integrated stakeholders' input into the methodology and standardized the calibrating and weighting that will be applied to subsequent projects.

Data Collection Cost Savings

An important benefit of standardizing the siting methodology is a savings in data collection costs. Savings result from the GIS Siting Model and off-the-shelf digital data reducing the study area boundaries of the Macro Corridors, Alternative Corridors and Alternative Routes. Reducing study area boundaries eliminates the need for extensive data collection and verification that is both costly and time-consuming. This methodology shortens the time required for the siting portion of the transmission line construction project.

Documentation for Supporting GTC's Environmental Reporting

As a side benefit, the EPRI-GTC Siting Model will help Georgia Transmission Corporation complete its environmental reports. Among the benefits of the land suitability analysis underlying this approach is the improved consistency and objectivity of information that describes, explains, analyzes and discloses the direct, indirect, and cumulative environmental impacts that would result from proposed actions and alternatives. Along with developing an advanced land suitability analytic modeling capability, GTC has adopted a standardized template for its environmental documents.

As envisioned by EPRI and GTC, the successful Overhead Electric Transmission Line Siting Methodology should encompass several critical tasks, including compliance with the NEPA and other environmental regulations.

Most important, this process created new transmission line siting tools, techniques and procedures that produce siting decisions that are more objective, quantitative, predictable, consistent and defensible. As such, the team has compiled an effective new mechanism for documenting relevant data, selection of a preferred alternative and the rational connection between the facts found and choices made.

Improvements

Potential improvements are presented in four categories: incorporating rights-of-way access into the methodology, incorporating visual impacts, possible refinements to the GIS Siting Model and additional testing and evaluation on real-world siting programs.

Incorporating Rights-of-Way Access

A potential improvement to the GIS Siting Model would be including access for construction and maintenance in routing an overhead electric transmission line. For example, an area considered suitable for a transmission line right-of-way should be downgraded if it is found to be an isolated parcel that is difficult to access without considerable adverse impact to the environment and local property owners. Currently the routing model does not consider relative access. GIS has been used for years to solve complex off-road construction and maintenance access questions, particularly by the forest industry in valuing timber parcels and by wildfire response units interested in travel-time maps to remote locations.[1]

The procedure to derive an effective distance map from a road network is shown in Figure 5-1, Identifying Alternative Route Access. In this instance, the gray areas are environmentally sensitive areas that act as absolute barriers to access from the roads. The movement off the roads has to go around the barrier locations like the ripples in a pond have to go around islands. The result is the construction and maintenance access map in the upper right portion of the figure with yellow/red tones indicating relatively remote locations. The bottom set of figures identifies a procedure for identifying the relative access along a proposed overhead electric transmission line route.

Like other criteria maps in the routing model, the effective distance map can be "calibrated" on a preference scale of 1 to 9 and "weighted" with other maps depending on its perceived relative importance. The ability to incorporate relative construction and maintenance accessibility at the onset of analysis is an important extension to the EPRI-GTC routing model for regions with pockets of sensitive terrain conditions and ownerships.

[1] For more information on effective distance see http://www.innovativegis.com/basis/MapAnalysis/Default.html, Topic 14, Deriving and Using Travel-Time Maps, online Map Analysis book by Joseph K. Berry

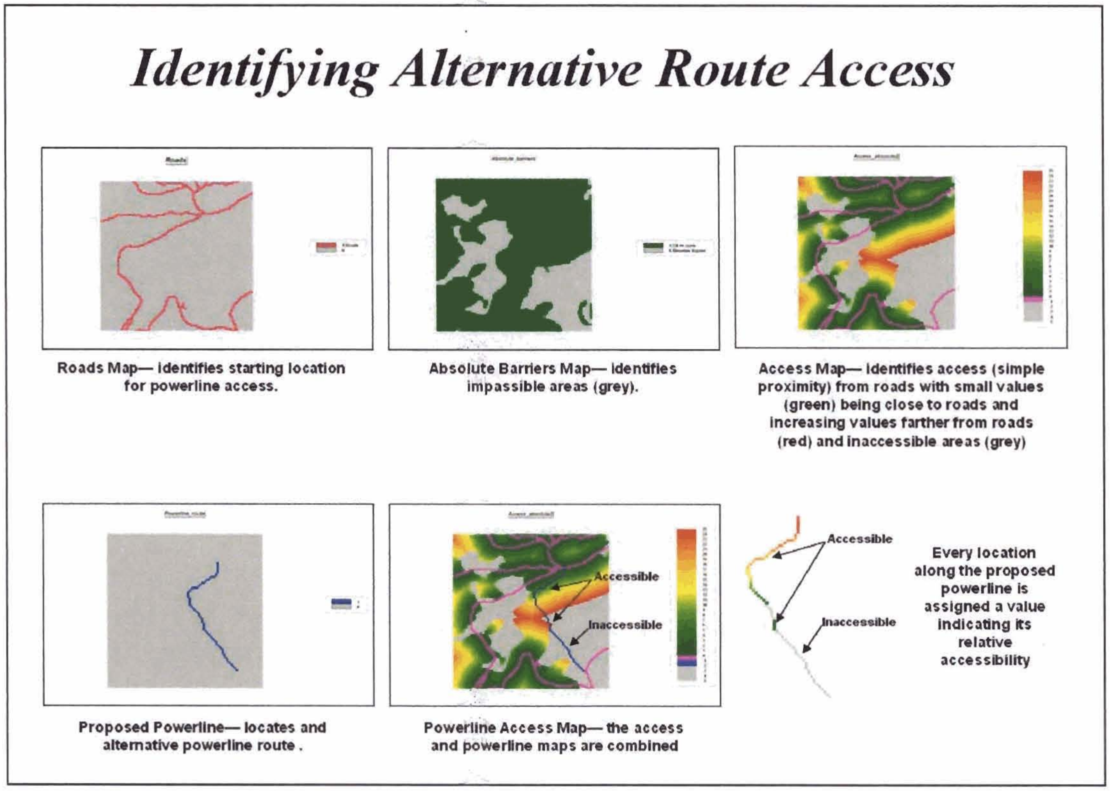

Figure 5-1
Future Initiatives: Effective Distance Map – Calculating an Effective Distance Map that Shows the Relative Access from Roads to All Locations in a Project Area

Incorporating Visual Impacts

Visual impacts are a top community concern with many transmission line construction projects. With the EPRI-GTC methodology, these visual impacts are considered when professional judgment is used to compare Alternative Routes and identify the most suitable site.

If desired, GIS technology could be used to identify the relative visual exposure from "sensitive viewer" locations, such as roads and houses, to all locations throughout a project area. This capability has been part of the GIS toolbox for decades and generates useful information for electric transmission line routing. Relative importance of certain features, such as steep slopes, land cover and building density, could be established.

Figure 5-2, Establishing Visual Connectivity, depicts how visual exposure is calculated. The algorithm uses simple trigonometry relationships to identify whether a location is seen from a given location. The schematic in the top portion of the figure shows how the "rise to run" relationship (tangent) is used in calculating line-of-sight connectivity. The ratio of the elevation difference (*rise* indicated as striped boxes) to the distance away (*run* indicated as the dotted line) is used to determine visual connectivity. Whenever the ratio exceeds the previous ratio, the location is marked as seen (red); when it fails, it is marked as not seen (gray).

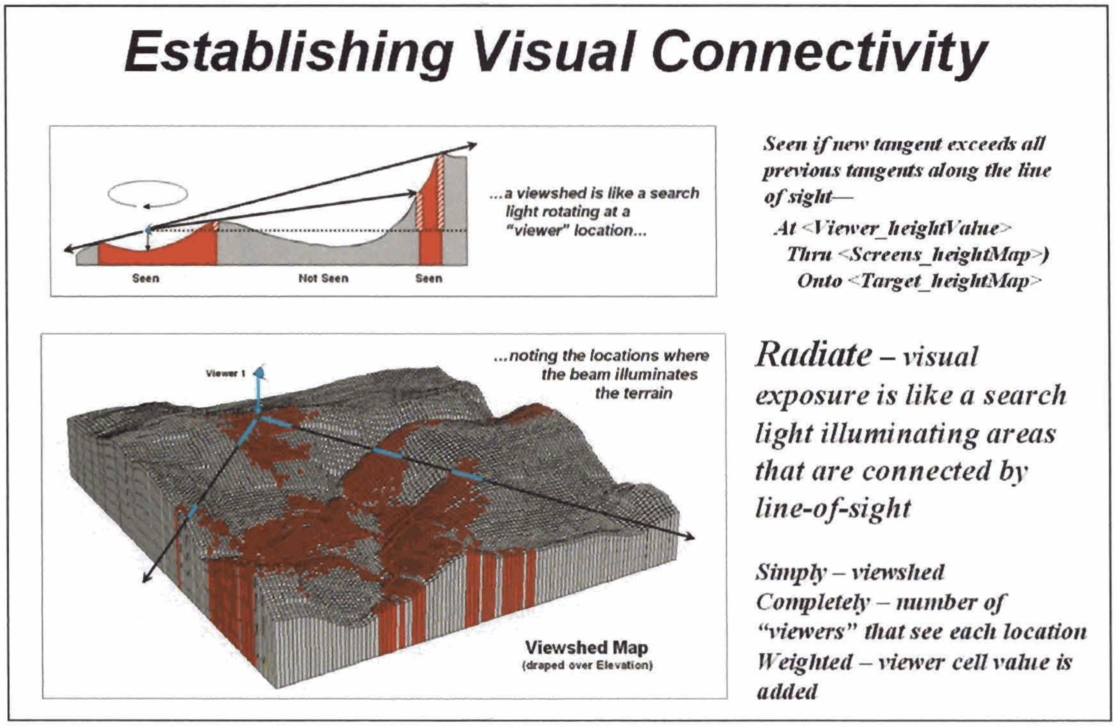

Figure 5-2
Future Initiatives: Viewshed Map – Calculating a "Viewshed" Map that Identifies all Locations in a Project Area that can be seen from a Given Location

The lower portion of the figure characterizes the conceptual result. Imagine a searchlight illuminating portions of a landscape. As the searchlight revolves about a viewer location, the lighted areas identify visually connected locations. Shadowed areas identify locations that cannot be seen from the viewer (nor can the viewer be seen). The result is a Viewshed map over the elevation surface. Additional considerations, such as tree canopy, viewer height and view angle/distance, provide a more complete rendering of visual connectivity.

If the procedure is repeated for multiple viewer locations, the relative visual exposure can be calculated for all locations in a project area. A Visual Exposure map (Figure 5-3: Visual Exposure from Extended Features) is generated by noting the number of times each location is seen from a set of viewer locations. Figure 5-3 shows the result, considering an entire road network as a set of viewer locations. In the example, the exposure values range from zero times seen (light gray) to one location that is seen from 270 times from the set of all road locations …highly exposed to roads.

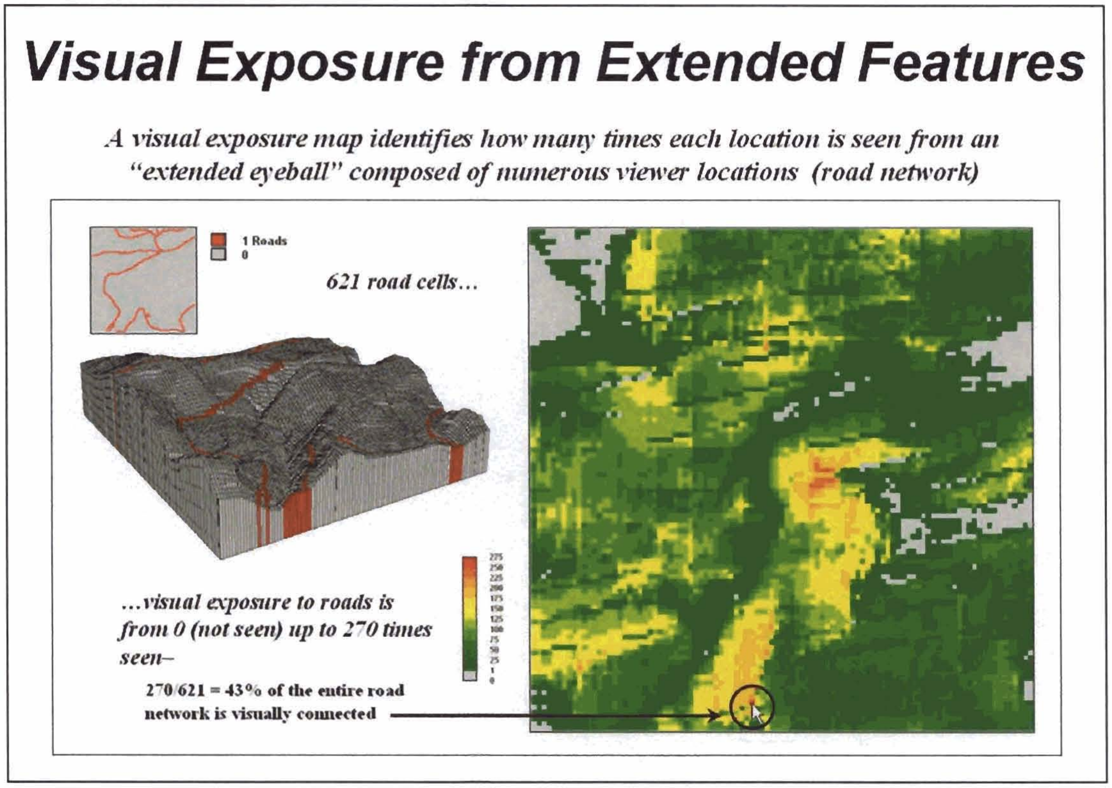

Figure 5-3
Future Initiatives: Visual Exposure Map – Calculating a "Visual Exposure" Map that Identifies the Relative Exposure for All Locations from an Extended Feature, Such as a Road Network

Other locations, such as individual houses, subdivisions and parks, can be included in the "sensitive viewers" layer to generate a comprehensive Visual Exposure map.[2] In addition, the different types of viewers (houses vs. roads) can be considered to identify a relative visual exposure map that reacts to both the number of times seen and the importance of the locations that are visually connected.

GIS Siting Model Refinements

Some enhancements to the GIS Siting Model itself could increase capabilities and automate several key tasks. Four of the most important enhancements are: "Optimal Path" right-of-way development; interactive tools for querying information and refining portions of the computer generated routes; software development for identifying right-of-way road access for construction and maintenance; and computer generated identification of visual resources.

[2] For more information on effective distance, see http://www.innovativegis.com/basis/MapAnalysis/Default.html, Topic 15, Deriving and Using Visual Exposure Maps, online Map Analysis book by Joseph K. Berry

As currently applied, the "Optimal Path" is limited to the width of a single grid cell. Future enhancements to Corridor Analyst™ could include designing a least cost path (LCP) algorithm that can vary the required width of rights-of-way. Thus, the LCP would be several cells wide instead of the current single cell width.

In addition to map analysis tools, new technologies are available for interacting with model results. One such technology is the Interactive Mapping Methodology (IMM)[3] developed by the Colorado Division of Wildlife that uses a real-time, stand-up digitizing environment. The process integrates ArcGIS software and a SMART Board interactive whiteboard system that uses a pen/marker as a mouse. The procedure enables GIS and field personnel to work together as a project team to query, edit and capture spatial data. Field personnel edit and enter map features directly into the GIS database by drawing on base maps projected onto the interactive whiteboard. Supporting map layers can be panned, zoomed and queried to assist the managers as they draw habitat boundaries on the whiteboard.

Another enhancement would be the incorporation of Georgia Power Corporation's *Smart/PowerTrack* system for evaluating Alternative Routes. With such a system, siting teams can quickly retrieve pertinent information, identify questionable routing segments, digitize alternative routing around an area using the pen/marker, evaluate the possible re-routing options and select the best option.

As part of this research project, the EPRI-GTC team has used an extensive number of GIS resources, many of them online. The list of sources is included in Appendix L: Location of Online Reference Materials.

Future Testing and Evaluation

During the development of this methodology, tests were run on a series of case study sites. This testing was extremely helpful in identifying the strengths and limitations of the approach. This testing identified significant omissions and oversights and uncovered several unanticipated interactions among the data layers. However, the use of the methodology on actual siting projects will inevitably reveal additional strengths and weaknesses.

After this methodology has been used on a significant number of projects, its performance and results should be rigorously evaluated. A representative set of projects could be analyzed to see how well the methodology has performed. Also a structured evaluation could compare the projects done using the methodology with a set of controls that were sited using traditional methodologies. The analysis could identify differences between the two groups with respect to project duration, project cost, percent of Preferred Routes within each perspective, data layers not relevant to the project study area, additional data layers needed, number and kind of regulatory permits required and major delays encountered.

[3] More information on IMM see http://www.geoplace.com/gw/2003/0303/0303nrs.asp, online article in GeoWorld, March 2003, by Michelle Cowardin and Michelle Flenner

The analysis also could test whether there are significant differences in these measures by physiographic region, by transmission line length or between metropolitan and rural locations. This analysis could determine whether one model can address all regions of the state or if regional variations are needed. In addition, the evaluation should explore further the interactions among the data layers. For example, the relative weighting of the layers changes significantly when a data layer is not present for a particular study area. The behavior of the model under these conditions needs to be more fully understood.

Appendices

The appendices of this report include biographies of the team members; a glossary; GIS metadata used in the study; explanation of Least Cost Path, Delphi and Analytical Hierarchy Process techniques; a list of stakeholders invited to workshops; online reference materials; and a list of articles and conferences where the methodology was presented.

6
POST FACE

Legal statement about the relationship of the EPRI-GTC methodology and eminent domain and National Environmental Policy Act regulations

Building overhead electric transmission lines requires companies like Georgia Transmission Corporation (GTC) to acquire the rights to use and occupy land. Acquisitions are accomplished through voluntary transactions and through the use of eminent domain.

Eminent domain is an attribute of sovereignty. The U.S. and State Constitutions and laws require that this authority be used sparingly and have restricted its use. Article III of the Georgia Constitution "grants to the General Assembly the power to make all laws... consistent with [its] Constitution, and … the Constitution of the United States, which it shall deem necessary and proper for the welfare of the state and, among other things, to provide by law for... instrumentalities of the state ... to condemn property."

In fact, eminent domain law in Georgia requires a state-authorized entity, including GTC and other electric utility companies, to justify the public purpose for which the property is taken, and provides the owner with the right to just compensation as guaranteed by the U.S. and Georgia constitutions. Condemnation proceedings are judicial proceedings that require the exercise of judicial power and are subject to judicial review. Procedural safeguards in such matters allow the owner to interpose objections to the claim of a public purpose of the taking and to litigate the fair value of the property taken.

A standardized siting methodology for overhead transmission lines implemented using GIS is not a substitute for evidence, witnesses, judicial proceedings, judicial review or procedural safeguards that allow property owners to interpose objections to a claim of public purpose or to litigate the fair value of the property taken. In fact, to be successful and defensible, the siting tools, techniques and procedures developed here must be complimentary to the processes of law and produce results that are objective, quantitative, predictable and consistent. To this end, the methodology must explain and document decisions so that all information and assumptions used in choosing a Preferred Route and avoiding other less suitable alternatives are available to the courts and the public. In other words, any decision based on GIS technology must be well documented and reproducible.

The National Environmental Policy Act is the basic national charter for protection of the environment. NEPA is intended to ensure that environmental information is available to federal agencies and the public before decisions are made and before actions requiring federal involvement are taken. It helps assure that federal agencies make decisions that are based on understanding of environmental consequences. NEPA establishes policy, sets goals (Section 101), and provides means (Section 102) for carrying out the policy. Section 102(2) contains certain "action-forcing" provisions to ensure that federal agencies act according to the letter and spirit of the Act.

GTC prepares environmental documents in compliance with NEPA, and other relevant federal and state regulations. Among other reasons, GTC does so to be eligible for federal actions on its projects by the U.S. Department of Agriculture's (USDA) Rural Utilities Service (RUS). RUS actions may, for example, involve providing a loan commitments or approval necessary for GTC to construct a project. GTC's NEPA documentation and actions must be in compliance with 7 CFR Part 1794 (RUS Environmental Policies and Procedures) and 40 CFR Part 1500 (the President's Council on Environmental Quality (CEQ) regulations for implementing NEPA), 42 USCA §§4321-4347.

In the end, NEPA imposes procedural, not substantive, requirements on federal agencies such as RUS. "NEPA does not work by mandating that agencies achieve particular substantive environmental results." Instead, "NEPA 'works' by requiring that the environmental consequences of an action be studied before the proposed action is taken." It is well settled law that a court's "only role [under NEPA]" is to ensure that the agency has taken a 'hard look' at the environmental consequences of the proposed action." An agency has satisfied its "hard look" requirement if it has "examine [d] the relevant data and articulate [d] a satisfactory explanation for its action including a rational connection between the facts found and the choice made."

As envisioned by Electric Power Research Institute (EPRI) and GTC, the successful Overhead Electric Transmission Line Siting Methodology should encompass several critical tasks, including compliance with the NEPA and other environmental regulations. To the extent that this process develops new transmission line siting tools, techniques and procedures that are objective, quantitative, predictable, consistent, and defensible, GTC has compiled an effective new mechanism to describe the relevant data and articulate a satisfactory explanation for selection of a preferred alternative and established a rational connection between the facts found and the choice made.

While this new methodology does not attempt to ameliorate publicly controversial aspects of transmission line construction, utilities and the public can realize significant benefits from such innovations. To the extent the innovations prepare, explain and document decisions that are more objective, quantitative and consistent, sound public policy goals have been substantially advanced.

A
EPRI-GTC OVERHEAD ELECTRIC TRANSMISSION LINE SITING METHODOLOGY PROJECT TEAM

Dr. Joseph K. Berry

Dr. Joseph K. Berry is the principal of Berry and Associates // Spatial Information Systems (BASIS), consultants and software developers in Geographic Information Systems (GIS) technology. He is a contributing editor and author of the Beyond Mapping column for GeoWorld magazine since 1989. He has written over two hundred papers on the analytic capabilities of GIS technology, and is the author of the popular books Beyond Mapping (Wiley, 1993), Spatial Reasoning (Wiley 1995) and Map Analysis (in preparation, online). Since 1977, he has presented workshops on GIS technology and map analysis concepts to thousands of professionals. Dr. Berry taught graduate level courses and performed basic research in GIS for twelve years as an associate professor and the associate dean at Yale University's School of Forestry and Environmental Studies, and is currently a special faculty member at Colorado State University and the W.M. Keck Scholar at the University of Denver. He is the author of the original Academic Map Analysis Package and the current MapCalc Learner-Academic educational materials used in research and instruction by universities worldwide and by thousands of individuals for self-instruction in map analysis principles. Dr. Berry's research and consulting has been broad. Such studies have involved the spatial characterization of timber supply, outdoor recreation opportunity, comprehensive land use plans, wildlife habitat, marine ecosystem populations, haul road networks, surface and ground water hydrology, island resources planning, retail market analysis, in-store movement analysis, hazardous waste siting, air pollution modeling, precision agriculture and site-specific management. Of particular concern have been applications that fully incorporate map analysis into the decision-making process through spatial consideration of social and economic factors, as well as physical descriptors.

Dr. Steven P. French

Steven French, an urban planner, completed his PhD at the University of North Carolina at Chapel Hill in 1980. He is also a member of the American Institute of Certified Planners, Urban and Regional Information Systems Association and Earthquake Engineering Research Institute. Dr. French, is the director of the City Planning Program at the Georgia Institute of Technology in Atlanta. His teaching, research and consulting activities are primarily in the areas of computer applications in city and regional planning and in analysis of the risk posed to urban development by earthquakes and other natural hazards.

Dr. French has had a long involvement in teaching and research on the application of database management techniques and geographic information systems to urban systems. He has prepared several parcel level land use databases for local communities on the central coast of California. As a consultant to the county of San Luis Obispo he recently conducted a user needs assessment to determine the feasibility and requirements of an automated mapping system to serve the planning, engineering and assessor departments. His primary teaching areas are in computer applications in city and regional planning, including quantitative methods, database management and geographic information systems. Dr. French has participated in a number of National Science Foundation projects dealing with flood and earthquake hazards. With colleagues at Stanford University he is currently developing an expert system for conducting building inventories based on secondary data sources. He recently developed a risk analysis method that uses a GIS to model damage to urban infrastructure as a part of a National Science Foundation research project. He has also had NSF support to analyze damage to urban infrastructure caused by the Whittier Narrows and Loma Prieta earthquakes. As a part of a previous NSF project, he demonstrated the application of a raster-based geographic information system to earthquake damage modeling for land use planning. This work entailed the development of a structural inventory in a case study community and damage modeling based on structure type, ground motion and site conditions over a large area. An earlier NSF project supported Dr. French's dissertation and a subsequent book on flood plain land use management.

Prior to his doctoral work at North Carolina, Mr. French was a professional planner in Colorado in both public and private practice. He served as the land use administrator for Garfield County, Colorado, and worked in two civil engineering firms involved with land use and oil shale development. He was a major contributor to the 1975 report "Evaluation of Selected Community Needs," which detailed the infrastructure and fiscal capabilities of fifteen communities in Western Colorado subject to energy related growth.

Jesse Glasgow

Jesse Glasgow is the GTC operations manager for Photo Science, Inc. Since December 1998, Jesse has been responsible for managing the Georgia Transmission Corporation (GTC) Contract for Photo Science, Inc. GTC out sources its GIS, photogrammetry and surveying services to Photo Science. In this position, he coordinates with GTC associates to assess needs, prepare project plans and ensure that projects are completed to the clients' satisfaction. Jesse has led the development of a geographic information system/process used for siting, permitting, surveying, designing and constructing new facilities. He also manages GIS software development projects and coordinates survey activities. Prior to joining Photo Science, Jesse was a planner at the Northwest Alabama Council of Local Governments. In this position he worked on several local government initiatives. He also participated in transportation planning for the Metropolitan Planning Organization. Jesse holds a Bachelor of Science in Professional Geography from the University of North Alabama, with a Certificate in GIS.

John W. Goodrich-Mahoney

John Goodrich-Mahoney is a technical leader and program manager with the Electric Power Research Institute and project manager for the EPRI-GTC Overhead Electric Transmission Line Siting Methodology. He manages the Mercury, Metals and Organics in Aquatic Environments and the Rights-of-Way Environmental Issues in Siting, Development and Management research programs within the Water and Waste Management Business Area. He develops, with input from staff and members, the research portfolios for these two research programs and manages research budgets. Research subjects include: water quality criteria (e.g., mercury and selenium); development of site-specific criteria; bioaccumulation of metals; integrated risk assessments; vegetation management (e.g. use of herbicides); endangered species; bank and trade; avian interaction; and remote sensing. For seven years, he served as a project manager in the Land and Water Quality Studies Program, where he was responsible for research projects for assessing the effects on ground-water quality from the land disposal and land application of utility solid wastes. He developed and continues to manage an innovative research program on the use of constructed wetlands and other passive technologies for the treatment of wastewater. The program includes a plant genetic research component to improve plants for phytoremediation. John earned a Bachelors of Science in Geology from St. Lawrence University, Canton, N.Y., and a Master of Science in Geochemistry from Brown University, Providence, R.I.

Gayle Houston

Gayle Houston is an environmental and regulatory coordinator for Georgia Transmission Corporation and project manager for the EPRI-GTC Overhead Electric Transmission Line Siting Methodology. Ms. Houston is a landscape architect and planner with significant experience in site and route evaluations and selections, environmental studies, regulatory compliance, land management and natural resource planning. Gayle has many years of experience managing complex transmission, substation and power generation siting projects in the southeastern United States. She is a technical expert in the analysis and development of creative solutions for specific project needs. She is experienced in process-oriented strategic planning and utilizes the latest technologies, such as geographic information systems, image processing of satellite and aerial photography, and viewshed analysis, including visual simulations, to enhance the decision making process.

Prior to joining Georgia Transmission Corporation, she served as a senior environmental project manager for Burns and McDonnell; senior project manager, environmental studio manager and GIS manager for EDAW, a landscape architecture and planning company; application analyst, configuring hardware and software systems on multiple platforms, for ERDAS, Inc., an industry leader in image processing and GIS; and consultant to NASA's Institute for Technology Development Space Remote Sensing Center at the Stennis Space Center in Mississippi where she designed Real Estate Geographic Information System (REGIS) for the Multiple Listing Service industry. Ms. Houston has a Bachelor of Business of Administration from Tulane University and a Master of Landscape Architecture from Louisiana State University. She managed Burns & McDonnell's Transmission Siting Seminar in Atlanta in 2000; the Edison Electric Institute's Land Management and Transmission Line Siting Workshop for over 100 electric utility managers in Atlanta in 1993; and was a team leader for the Edison Electric Institute's Land Management Planning Workshop in Portland, Oregon in 1990.