Lake and Golf Residential Deterministic Model for the Oconee Watershed

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Abstract

Lake gentrification is a major issue confronting planning. With the boomers aging, there is pressure on water resources by retirement homes. In South Carolina, Lakes Jocassee, Keowee and Hartwell, are experiencing these issues. This paper demonstrates the development of a deterministic model to find the most suitable lake and golf areas for development in the Seneca Creek Watershed. The study framework follows Carl Steinitz's Alternative Futures for Changing Landscapes. The model explores the criteria underlying land use location for high-end property in a fragile environmental region through a deterministic approach in which a set of criteria combine to produce a mapped index of priority based on different selected variables by the researcher and not randomly as in a probabilistic model. The display of the deterministic variables through tables, combined with the mapping capacity of ArcGIS, allow the region's stakeholders to assess the impact of future development decisions in the watershed. This in turn, brings transparency to the process of search, analysis and choice in planning and development decision making.

Key Words: South Carolina, alternative futures, lake-view, golf, land use

Introduction

The first section of this paper describes the origins and evolution of Geographic Information Systems (GIS) in landscape planning and development, as well as the land use of the area under study. The second section describes the process and criteria in developing the deterministic model and what is to be expected of the lake and golf residential development/attractiveness model. The third section presents a diagram of the deterministic model's process that describes the flow of the model, its data input, tools and outputs from the sub-models and model. The fourth section describes each of the model's variable and data items as applied to the stored existing database. The fifth section explains the model results and identifies the best sites for lake and golf residential development for the Oconee Watershed. The sixth section recommends steps to minimize development impacts that have not been included in the deterministic model. The use of deterministic models for landscape planning and development within the historical evolution of GIS is discussed in section seven. Finally, tables, figures and references are presented in the last section of the paper.

Origins and Evolution of GIS in Landscape Planning and Development

Steinitz, Parker and Jordan (1976) describe the beginnings of Geographic Information Systems in the early twentieth century as hand-drawn overlays which has been called the first stage of GIS development. Hand-drawn overlays were primitive maps constructed on carefully selected and available data and were the basis for analyzing relationships among different elements of the landscape. Both data search and analysis of relationships were related to decision-making processes of landscape planning and development. In the case of hand-drawn overlays, spatial and temporal variables were added as well, because the geographic analysis allowed for different layers of information in which each layer was a different variable selected by the researcher and considered appropriate for the study. With the passage of time, this type of studies became more and more complex as the researchers included weightings and hierarchical combinations of the variables.

Steinitz, Parker and Jordan (1976), Gollins, Steiner and Rushman (2001) and Chrisman (2006) describe the second stage of GIS development in which computer assisted overlay mapping or hand drawn data files become prominent. During this period, Howard Fisher realizes that computers can make simple grid maps by printing statistical values on a grid of plain paper. All of the sudden, computing capacity has permitted researchers to expand their analysis capabilities and not only include more variables but also handle more information in land planning and development analysis. The Harvard Laboratory for Computer Graphics & Spatial Design under Howard Fisher's guidance becomes the eminent center for early GIS software development (Chrisman, 2006). For instance, Chrisman (2006) argues that SYMAP established the functions that any subsequent cartographic display program has had to provide ever since: the ability to separate the base geometric data from the thematic attribute, scaling the map to different sizes, and permitting distinct treatment of the same source material. Chrisman (2006) claims that topological structures relations are fundamental to define and enforce data integrity rules, to support topological relationship queries and navigation, to support editing of data, and to allow construction of features from unconstructed geometry. Therefore, Chrisman (2006) argues that topology makes information not only accessible, but also available for transformation and combination. Chrisman (2006) concludes that the development of map algebra by Dana Tomlin allowed the interface of information within the space and time domains into algebraic matrices for modeling simulation. It is in this stage of development that Roger Tomlinson coins the term GIS in his study of Canada Geographic Information System (CGIS).

Gollins, Steiner and Rushman (2001) and Malczewski (2004) argue that during the third stage of GIS development in which redefinition of data and development of multicriteria evaluation occurred, GIS became even more powerful because of two reasons. First, boolean logic and fuzzy logic were defined. In the former, a number takes a 0 value if it is not in the set while it takes a value of 1 if it is in the set; therefore, the definition of boundaries to include or exclude an element in the set is clean and does not permit partial membership of an element in the set. In the latter, a number takes any number between and including 0 and 1, allowing flexibility in defining variable boundary thresholds to be set and permits partial membership of an element in a fuzzy set. Second, alternative methods for using preferences were developed. Among the most important were the Multiple Criteria Decision Analysis (MCDA) or Multiple Criteria Evaluation (MCE), Cellular Automata (CA), and Linear Programming (LP). These alternative methods centered in incorporating decision-makers' preferences within land-use allocation and suitability analysis, usually by using mathematical programming (optimization) methods.

In the fourth stage of GIS development, Gollins, Steiner and Rushman (2001) and Perry, Hakimpour and Sheth (2006) argue that GIS is developing into two areas. First, GIS is attempting to replicate expert knowledge through artificial intelligence. Second GIS is adopting an ontology based approach in which theme, time and space fully converge in order to predict and design.

This brief review of GIS summarizes almost one hundred years since the first hand-drawn overlay of four maps and one recommendation that Warren Manning prepared of Billerica, Massachusetts for decision makers to decide on the town's circulation routes and land use patterns. GIS has become a powerful tool used among public, private and non-profit organizations to handle search, analysis and decision processes through computerized modeling. Examples of GIS deployments by organizations within nations are abundant and are mainly grouped into socioeconomic applications and environmental applications (Maguire, Batty and Goodchild, 2005). The power of GIS resides in its ability to convey and display information for both policy analysts and policy makers, and most specially to bring transparency to the processes of search, analysis and choice in decision making.

The Oconee Watershed

The Oconee Watershed is located in the northwest of South Carolina and southwest of North Carolina. The most important cities within the area of study are Anderson, Easley, Seneca, Pendleton, Walhalla, Westminster, Six Mile and Clemson in South Carolina while Cashiers is the only city in North Carolina (Figure 1: Area of Study). The three major lakes in the area of study are Lake Hartwell, Lake Keowee and Lake Jocassee from south to north. I-85 is located in the southern part of the study-area and it is the most important highway, followed by federal highways 76, 123 and 178, and state roads 11, 86, 88, 133, 135 and 183.

According to the National Land Cover Set of 2001 the most important land uses in the Oconee Watershed are pasture/hay, deciduous forest, open water and evergreen forest (Figure 2: Land Use). Developed land (open space, low intensity, medium intensity, and high intensity) in this area is of lesser importance. However, developed land is located along I-85 and federal highways 76 and 123. Since these lakes have been man-made and water levels are regulated by the Army Corp of Engineers, woody wetlands and emergent wetlands are nonexistent. Also, row-crop agriculture production is practically non-existent in the area of study. There is grassland use in the region in the form of golf fields close to the lakes in South Carolina and in the Appalachian Mountains in North Carolina.

Most of the change in the land use for the Oconee Watershed, between the National Land Cover Sets of 2001 and 1992, has occurred along roads and highways (Figure 3: Land Use Change).This change has occurred in the following highways and roads: SC-8 between Easley and Pickens, US-76 among Anderson, Pendleton and Clemson, US-123 among Clemson, Seneca and Westminster, SC-28 between Seneca and Walhalla, and SC-93 among Clemson, Central, Liberty, Norris and Easley. Transportation network seems to play a major role in land development in the area of study. Agriculture decline, on the other hand, is ubiquitous and distant from the road and highway network. Row crops have been transformed to pasture and hay in the given time period. Finally, golf courses have been developed both in the mountains and around the major lakes. Among the three lakes in the region, Lake Keowee has been the one targeted for development following a south to north trend.

Lake Keowee is an exceptional "blue water lake" located in the northwest foothills of South Carolina. It has an area of 18,372 acres and is about 29 miles long with approximately 300 miles of shoreline (FOLKS, 2007 and Sperry, 2006a). The lake averages 54 feet in depth but can exceed 150 feet (FOLKS, 2007). Lake Keowee is the recipient of upstream waters of Lake Jocassee and Sumter National Forest and provides water to Lake Hartwell downstream. The lake is served by the Oconee watershed which is distributed both in the states of South Carolina (Pickens, Oconee and Anderson counties) and North Carolina (Jackson and Transylvania counties).

Lake Keowee was created in 1971 by Duke Power for cooling the Oconee Nuclear plant and as a hydropower generating source, but it also serves as the source of drinking water for the city of Seneca and a portion of Greenville, both in South Carolina (Sperry, 2006a). Since its creation, the lake has attracted tourism, recreation and new residents while the population growth rates have increased four fold since the early 1970's (Sperry, 2006a). The lake is experiencing an extraordinary residential growth along its shoreline and it is a primary reason for the overall economic growth of the area (Sperry, 2006a). The area of study is set along the I-85 corridor between Atlanta, Greenville and Charlotte, one of the highest sprawling regions in the United States (Cotton et al, 2005). Finally, Myers and Ryu (2008) estimated that South Carolina has the third highest net annual percent of persons aged 65-69 buying homes in the United States, behind Nevada, Arizona and Florida; thus arguing for the state to become a top destination for retiring baby boomers.

Process and Criteria in Developing the Model

The study framework used in this paper was taken from Steinitz's Alternative Futures for Changing Landscapes (Steinitz et al, 2003 and 2005). This framework consists of six questions that are asked several times during the course of the study of the region. These questions are answered through models and application which are particular to the case of the study, in our case, the Oconee Watershed and their highest attractions: Lake Hartwell, Lake Keowee, and Lake Jocassee. The six questions and the models generated for each of them are included in table 1.

The model created for this paper was a deterministic attractiveness/development model to find the most suitable land for lake and golf residential within the area of study. The model explored the criteria underlying land use location for high end property. In a deterministic approach, a set of criteria is combined to produce a mapped index of priority based on different selected variables (Steinitz et al, 2003). Therefore, the land use allocation is made in a priority order based on the variables selected (criteria) by the researcher and not randomly as in a probabilistic model (Steinitz et al, 2003).

According to the classification of Multiple Criteria Decision Analysis (MCDA) proposed by Malczewski (2006), the model employed in this paper has the following characteristics: first, it is a multi-attribute decision analysis (MADA) model as it has a predetermined, limited, and discrete number of possible alternatives; second, the model has a single goal preference structure; third, the model is deterministic as the decisions are assumed to be made under conditions of certainty. Malczewski (2006) argues that this model has been the most popular within all the different MCDA models. Malczewski (2006) argues that weighted summation/Boolean overlay, ordered weighted averaging (OWA), and the analytical hierarchy process (AHP) have been the most common combination rules in MADA models.

The lake and golf residential model discussed in this paper was used with development/opportunities models and constraints/impact models, in order to forecast the land development and environmental impact of the Oconee Watershed by the year 2030 under different assumed scenarios of population and employment growth (Sperry, 2008). The lake and golf residential model was part of the development/opportunities model for land use/allocation together with a commercial/industrial/mixed use model, a multi-family residential model, a suburban single family residential model, a rural single family residential model, and a recreational/fishing model. The constraints/impact models for environmental assessment included a surface water quality and erosion model, a groundwater quality and septic systems model, a fresh water ecology model, a GAP and landscape ecology model, and a visual resource (agricultural preservation) model. These models, together with the population and employment growth scenarios for 2030 allowed visualizing the Alternative Futures for the Oconee Watershed as discussed in table 1. The Alternative Futures in turn allowed discussing policies for land development and environmental impact (Sperry, 2008).

The GIS mapping system in the present research was ArcGIS 9.2. This software allowed combining the set of criteria selected by the researcher to produce the abovementioned mapping index. Learning ArcGIS 9, ArcGIS Spatial Analyst, ArcGIS Geoprocessing online courses were taken in order to develop training on this software. Lectures from Professor Sperry were also helpful in developing the model (Sperry, 2006b through j). Finally, the Greenville Land Use Study from Cotton et al (2005) was also used as a guide for the development of the attractiveness/development model.

The available spatial data was divided in three sub-models: avoidance, constraints and opportunities sub-models. The "avoidances" sub-model included land where development for lake and golf residential was not possible and land where it was possible. The "constraints" model was developed to consider data that determined a range of values regarding allocation for development. Finally, land that could be considered for lake and golf residential was selected in an "opportunities" model. These three sub-models are discussed in detail in the following paragraphs.

Avoidances Sub-Model

Large water bodies (Lakes Hartwell, Keowee, and Jocassee), state parks (Devils Fork, Keowee Toxaway, Oconee, Table Rock, and South Carolina Botanical Garden), national forests (Sumter and Pisgah) and wilderness conservation areas were considered prohibitive to lake and golf residential development. Layers were pooled together to create a raster (*AVOIDANCES* raster) which included land that was an avoidance for development (value 0) and land that was not an avoidance for development (value 1). This raster defined areas that could and could not be physically developed in the final model (Figure 4: Avoidances Sub-Model Output).

Constraints Sub-Model

The different constraints to lake and golf residential were divided into three sub-models: proximities to amenities (Figure 5: Close To Sub-Model), proximities to dis-amenities (Figure 6: Away From Sub-Model) and site suitability (Figure 6: Site Suitability Sub-Model). The constraints considered in this part of the analysis could be prohibitive to lake and golf residential development, or could be useful in delineating key areas suitable for development. This raster (*CONSTRAINTS*) defined the best or worst sites for lake and golf development in the final model.

The amenities sub-model considered in the development analysis were: water bodies, commercial services (shopping centers and malls), education services (public and private schools and colleges), medical services (health centers and hospitals), water lines, sewage, and finally, highways and roads. It was assumed that these amenities were attractive and valuable for lake and golf residential development. Euclidian Distances and Reclassifications were used with Single Output Map Algebra to obtain a raster that weighted these factors (Figure 5: Close To Sub-Model Output). Water lines, sewer, roads, education services, medical services, and commercial services were given a weight value of 5 percent, while water bodies was given a weight value of 70 percent in order to stress the importance of the proximity to the lakes in development selection. Every amenity was reclassified into three classes according to the distance to the origin. For instance, in the case of water bodies the classes were short distance (< 500 meters), medium distance (> 500 meters but < 1,000 meters), and long distance (> 1,000 meters). The reclassification values and the weights in the single output map algebra are shown in table 2.

The dis-amenities sub-model considered in the development analysis were the Oconee Nuclear Power Plant, power lines, and railroads. It was assumed that these dis-amenities were unattractive and no valuable for lake and golf residential development. Euclidian Distances and Reclassifications were used with Single Output Map Algebra to obtain a raster that weighted these factors (Figure 6: Away From Sub-Model Output). However, in the case of the Power Plant, Viewshed was used and combined with Euclidian Distance in order to determine the visual impact of the mentioned plant. Railroads were given a weight of 30 percent, power lines a weight of 60 percent, and the Oconee Nuclear Power Plant weight of 10 percent in order to stress the visual impact of the transmission lines in development selection. Every dis-amenity was reclassified into three classes according to the distance to the origin. For instance, in the case of power lines the classes were short distance (< 100 meters), medium distance (> 100 meters but < 200 meters), and long distance (> 200 meters). The reclassification values and the weights in the single output map algebra are shown in table 3.

The site suitability sub-model included slope, orientation and soil permeability. Slope and aspect were obtained from the Digital Elevation Model (DEM) for the area using Percent Slope and Aspect Tools. In the case of permeability, k-sat values were obtained for each horizon and weighted in order to have a k-sat value for the whole soil profile. All the rasters obtained were reclassified and weighted through Single Output Map Algebra (Figure 7: Site Suitability Sub-Model Output). It was assumed that the best orientation was for land facing northern and southeastern sun exposure was preferred as have a better view of the Appalachian Mountains and the water bodies. It was also assumed that land with lower slope were better for building as they have better stability and lower construction costs. Finally, it was assumed that soils with higher permeability were better for development. Orientation had a weight of 40 percent while slope and permeability a weight of 30 percent each. Every site suitability factor was reclassified into three classes according to their characteristics. For instance, in the case of percent slope, the classes were optimal (< 24.9 percent), sub-optimal (> 24.9 percent but < 107.80) and avoidance

(> 107.8 percent). The reclassification values and the weights in the single output map algebra are shown in table 4.

The estimation of soil permeability in the site suitability sub-model needed an extra step. Since permeability values depend on the horizons that are present in the soil, a permeability weighted value had to be constructed from the three horizons in the soils of the Oconee Watershed. The three horizons had different characteristics and therefore each had a different weight and reclassification values. The reclassification values and the weights in the weighted overlay to obtain permeability from the different k-sat values through the horizons are shown in table 5.

The layers Close-To, Away From and Site Suitability were weighted through Single Output Map Algebra to obtain the raster *CONSTRAINTS* (Figure 8: Constraints Sub-Model Output). Since the most important factor in lake and golf residential development is distance to water bodies, the layer Close To was given a weight of 62.5 percent while the layer Away From a weight of 25 percent and the layer Site Suitability a weight of 12.5 percent. The weights to obtain the *CONSTRAINTS* raster are shown in table 6. Then, the *CONSTRAINTS* raster was reclassified into five classes in order to list the development classes given the values from the different sub-models.

<u>Opportunities Sub-Model</u>

In this case, undeveloped land facing the different water-bodies was considered as best opportunities for lake and golf residential development. This included land where there was no development in the 2001 NLCD and was given a value of 1. Already developed land (open space, low intensity, medium intensity, and high intensity) and barren land were given a value of 0 as it was not possible to develop there. Therefore, only one layer was used in the *OPPORTUNITIES* raster (Figure 9: Opportunities Sub-Model Output).

<u>Development Model</u>

The *DEVELOPMENT* raster was obtained by multiplying the *AVOIDANCES* raster times the *CONSTRAINTS* raster times the *OPPORTUNITIES* raster through Single Output Map Algebra (Figure 10: Development Model Output). Since both the *AVOIDANCES* and the *OPPORTUNITIES* rasters had boolean logic, this is 0 or 1 values for development, they displayed the land were lake and golf residential could be developed. The *CONSTRAINTS* raster on the other hand, with fuzzy values for development, it displayed in five classes, the land for golf and lake development.

Flow Chart

The lake and golf residential deterministic model process is displayed in a Microsoft Visio flow chart showing the steps for obtaining the *AVOIDANCES*, *CONSTRAINTS*, *OPPORTUNITIES*, and *DEVELOPMENT* rasters (Figure 11). The model is also displayed in an ArcMAP Model Builder flow chart showing the data inputs, processes and data outputs (Figure 12).

Data Variables Used

The data layers used in the creation of the attractiveness/development model for lake and golf residential are included in table 9. These layers were obtained from multiple sources and were in both vector and raster formats. However, the Oconee Nuclear Power Plant layer was created in order to assess the negative visual impact on lake and golf residential selection for land. Data layers were set in the same coordinate system and were clipped according to the area under study.

Model Output

The most suitable land for lake and golf residential development was the land close to the major water bodies (Figure 10: Development Model Output). Land within 500 meters from the major lakes was the most suitable for development as the weight from the water bodies layer was higher for this amenity than to any other amenity; this is, water lines, sewer lines, education services, medical services, commercial services and roads within the Close To raster. Also, the Close To raster had the highest weight in the *CONSTRAINTS* raster which sets the water bodies in advantage over the dis-amenities (Away From raster) and site suitability (Site Suitability raster) properties.

Land with a high ranking for lake and golf residential development was the land close to the major water bodies, but in the 500 to 1000 meters range which is in line with what was explained above (Figure 10: Development Model Output). However, in this category we also found attractive land for development in the 500 to 1,000 meters lake range. This land is located in the outskirts of the cities of Walhalla, Westminster, Six Mile, Liberty, Norris, Easley, Clemson and Pendleton. In this case, the other amenities –water lines, sewer lines, education services, medical services, commercial services and roads– are explaining the higher ranking for this land. As this land is not close to the water bodies, it is not going to be demanded by lake residential development, but it has a great potential for golf residential development as it is close to other desired amenities.

Land with a low ranking for lake and golf residential development was the land close to power lines and railroads (Figure 10: Development Model Output Map). Also, the land north of Lake Jocassee had also a low ranking as it is far from all the amenities besides the water bodies (water lines, sewer lines, education services, medical services, commercial services and roads). In the latter case, Lake Jocassee and Lake Mountain are the only drivers of lake and golf residential development as there are no other amenities available to be weighted. Development basic infrastructure in this northern area will have positive impact on lake and golf development as land will become more attractive for this type of development.

The least suitable land for lake and golf residential development was the land included in the *AVOIDANCES* raster –large water bodies, state parks, national forest and wilderness conservation areas– and land excluded in the *OPPORTUNITIES* raster –developed land (open space, low intensity, medium intensity, and high intensity) and barren land– which forbidden development (Figure 10: Development Model Output Map). Finally, land with medium ranking for lake and golf development was land that was punished by low scores in the site suitability sub model. Slope, aspect or permeability problems negatively affected the attractiveness for land that could be developed (Figure 10: Development Model Output Map).

Performance Standard

Since lake and golf residential is considered a high-end type of residential demand, usually houses developed within this category are single-family houses and custom-built. The assumed lot size for each house is approximately half an acre. Because the density of lake and golf houses is lower than other residential types (e.g. urban and suburban) sewer is not necessary for lake and golf residential development. According to FOLKS (2007), current septic regulations in Lake Keowee do not consider slopes or soil types and the septic field has to be at least 50 feet from the water and 6 inches above the water table which affects septic suitability. Therefore, an increase in the development of lake houses could bring septic contamination in the major water bodies. This impact could be minimized by imposing a 100 feet buffer from the lake and 12 inches above the water table in order to ensure zero contamination in the case of higher slope areas or high permeable soils.

Lake and golf residential development in high-sloped terrain brings associated the problem of hidric soil erosion and consequent sedimentation of water bodies. This is further enhanced by the change in land cover from pasture/hay, deciduous forest and evergreen forest into developed open space or developed low intensity. This increases impervious surface and the amount of water that runs off into streams, rivers and water bodies. This impact could be minimized by forbidding construction in high-sloped terrain and ensuring erosion mitigation practices, such as soil retainer, increased vegetation cover and construction practices diminishing soil steepness and slope length. Finally, it would be important to estimate soil loss for the area using the Universal Soil Loss Equation – USLE (Marsh, 2005).

These two environmental impacts –septic contamination and lake sedimentation– from lake and golf development, in the major water bodies should be minimized in order to guarantee the same lake water quality in the future as in the present. Therefore, environmental assessments ex-ante and ex-post development are fundamental in order to monitor and to preserve the most important amenity that attracts both tourists and residents into the study area. However, these two environmental impacts were not modeled in the lake and golf residential deterministic model presented here. This model can be employed in conjunction with more complex models in land planning and development, such as rule based models that rely on relative probability or cellular automata to determine the future land use (Allen and Lu, 2003).

Conclusions

Despite the simplicity of the lake and golf residential determinist model developed in the present paper, the model yields powerful conclusions regarding land planning and development. First, although lake and golf residential development has positive economic impacts on the local economy, it has associated negative impacts on the natural environment and lake ecosystems. Natural land converted to single-unit family housing is a process that involves altering natural environments, building barriers to natural processes, and altering both geochemical cycles and energy flows. Most of the land converted to developed land will come from forest land and pasture land. Second, the Alternative Futures for Changing Landscapes Framework employed in developing the model allows cultural knowledge of the decision-making stakeholders to become visible and shared among the participants. Finally, the construction of this lake and golf residential deterministic model in the field of land planning and development shows the power of GIS by conveying and displaying relevant information for both policy analysts and policy makers in decision making.

Tables

Table 1: Questions and Answers for Alternative Futures Studies.

Number	Question	Answer (Model and Application)
1	How should the state of the landscape be described in content, space and time?	Representation Models. The study relies on these data.
2	How does the landscape operate?	Process Models. Provide information for several analyses which are the content of the study.
3	Is the current landscape working well?	Evaluation Models. Dependent upon cultural knowledge of the decision-making stakeholders.
4	How might the landscape be altered – by what policies and actions, where and when?	Change Models. Tested in the study and provide data for future research.
5	What differences might the changes cause?	Impact Models. Information produced by the process models under changed conditions.
6	How should the landscape be changed?	Decision Models. Also dependent upon cultural knowledge of the decision-making stakeholders.

Source: Steinitz et al, 2003; and Sperry, 2006a.

Table 2: Reclassification of Amenities Layers in the Close To Sub-Model.

Layer	Old Value	New Value	Weight	Comments
Water	0 – 1000 1000 – 8503 8503 – 34356 No Data	3 2 1 0	x 5	Old values are distance in meters from water lines. The closer to water lines, the higher the value.
Sewer	0 – 1000 1000 – 12080 12080 – 36644 No Data	3 2 1 0	x 5	Old values are meters from sewer lines. The closer to sewer lines, the higher the value.
Roads	0 – 1000 1000 – 3733 3733 – 25156 No Data	3 2 1 0	x 5	Old values are distance in meters from roads and highways. The closer to roads and highways, the higher the value.
Education Services	0 – 4105 4105 – 8116 8116 – 28271 No Data	3 2 1 0	x 5	Old values are distance in meters from schools and colleges. The closer to education services, the higher the value.
Medical Services	0 – 6926 6926 – 15643 15643 – 49005 No Data	3 2 1 0	x 5	Old values are distance in meters from hospitals and health centers. The closer to medical services, the higher the value.
Commercial Services	0 – 13471 13471 – 24860 24860 – 57229 No Data	3 2 1 0	x 5	Old values are distance in meters from shopping centers and malls. The closer to commercial services, the higher the value.
Water bodies	0 – 500 500 – 1000 1000 – 34396 No Data	3 2 1 0	x 70	Old values are distance in meters from major water bodies. The closer to water bodies, the higher the value.

Table 3: Reclassification of Dis-amenities Layers in the Away From Sub-Model.

Layer	Old Value	New Value	Weight	Comments
Rail roads	0 – 100	1	x 30	Old values are distance in meters from railroads. The farther away from railroads, the higher the value.
	100 – 200	2		
	200 – 47736	3		
	No Data	0		
Power lines	0 – 100	1	x 60	Old values are distance in meters from power lines. The farther away from power lines, the higher the value.
	100 – 200	2		
	200 – 35161	3		
	No Data	0		
Power plant	0 – 2000	1	x 10	Old values are distance in meters from Duke's Oconee Nuclear power plant at Lake Keowee. The farther away from the plant, the higher the value.
	2000 – 5000	2		
	5000 – 54476	3		
	No Data	0		

Table 4: Reclassification of Suitability Layers in the Site Suitability Sub-Model.

Layer	Old Value	New Value	Weight	Comments
Aspect	-1 – 0	3	x 30	Aspect is the compass direction that a topographic slope faces, usually measured in degrees from north. Old values are expressed in degrees. Northern and south-eastern sun exposures are preferred over western sun exposures.
	0 – 22.5	1		
	22.5 – 67.5	1		
	67.5 – 112.5	2		
	112.5 – 157.5	2		
	157.5 – 202.5	1		
	202.5 – 247.5	2		
	247.5 – 292.5	3		
	292.5 – 337.5	1		
	337.5 – 359.5	1		
	No Data	0		
Percent Slope	0 – 8.3	1	x 40	The slope is the incline, or steepness, of a surface. Percent slope is the rise divided by the run, multiplied by 100. Old values are expressed in percentage. Slopes smaller than 25 percent were considered optimal.
	8.3 – 24.9	1		
	24.9 – 49.8	2		
	49.8 – 74.7	2		
	74.7 – 107.8	2		
	107.8 – 182.5	3		
	182.5 – 597.3	3		
	597.3– 1310.7	3		
	1310.7 – 2115	3		
	No Data	0		
Permeability	9	3	x 30	Permeability is the ability of water to pass through the soil when it is fully saturated. Values above 60 were considered optimal for soil conducing water fully saturated.
	9 – 30	3		
	30 – 40	2		
	40– 50	2		
	50– 60	2		
	60 – 70	1		
	70 – 80	1		
	80 – 90	1		
	No Data	0		

Table 5: Reclassification of Permeability Values to Obtain Permeability in the Site Suitability Sub-Model.

Layer	Old Value	New Value	Weight	Comments
ksat-h	0	3	x 30	k-sat values are the flow of water through the h soil horizon when it is fully saturated.
	0 – 0.07	3		
	0.07 – 14	3		
	14 – 42	2		
	42 – 90	1		
	90 – 141	1		
	No Data	0		
ksat-r	0	3	x 30	k-sat values are the flow of water through the r soil horizon when it is fully saturated.
	0 – 0. 035	3		
	0.035 – 7	3		
	7 – 9	2		
	9 – 14	2		
	14 – 23	1		
	23 – 28	1		
	28 – 42	1		
	42 – 92	1		
	No Data	0		
ksat-l	0 – 0.01	3	x 40	k-sat values are the flow of water through the l soil horizon when it is fully saturated.
	0.01 – 0.4	3		
	0.4 – 4	2		
	4 – 9	2		
	9 – 14	1		
	14 – 42	1		
	No Data	0		

Table 6: Weights Employed in Obtaining the Constrains Raster from the Sub-Models: Close To, Away From and Site Suitability.

Layer	Weight	Comments
Single Output Close To	x 5	This CONSTRAINTS raster was then reclassified before being used with the AVOIDANCES raster and OPPORTUNITIES raster to obtain the DEVELOPMENT raster.
Single Output Away From	x 2	
Single Output Site Suitability	x 1	

Table 7: Reclassification of the Constraints Raster According to Five Classes.

Layer	Old Value	New Value	Comments
Constraints	1010 – 1280.9	1	This CONSTRAINTS raster was then used with the AVOIDANCES raster and OPPORTUNITIES raster to obtain the DEVELOPMENT raster.
	1280.9 – 1360.6	1	
	1360.6 – 1440.3	2	
	1440.3 – 1509.4	2	
	1509.4 – 1620.9	3	
	1620.9 – 1759.1	3	
	1759.1 – 1902.5	4	
	1902.5 – 2051.3	4	
	2051.3– 2168.1	5	
	2168.1 – 2370	5	
	No Data	0	

Table 8: Reclassification of the NLCD 2001 Raster In Order To Assess Land Available for Development.

Layer	Old Value	New Value	Comments
NLCD 2001	11 Open Water	1	This OPPORTUNITIES raster was then used with the AVOIDANCES raster and CONSTRAINTS raster to obtain the DEVELOPMENT raster.
	21 Developed Open Space	0	
	22 Developed Low Intensity	0	
	23 Developed Medium Intensity	0	
	24 Developed High Intensity	0	
	31 Barren	0	
	41 Deciduous Forest	1	
	42 Evergreen Forest	1	
	43 Mixed Forest	1	
	52 Short Shrub-land	1	
	71 Herbaceous Grassland	1	
	81 Pasture/Hay	1	
	82 Row Crops	1	
	90 Woody Wetlands	1	
	95 Emergent Wetlands	1	
	No Data	0	

Table 9: Data Layers Used in the Creation of the Attractiveness/Development Model for Lake and Golf Residential for Lake Keowee.

Data	Source
Water bodies	US Census, Tiger Line Files from ESRI
Parks, National Forests and Wilderness Preserves	South Carolina DNR
Elevation	USGS, National Elevation Dataset Shaded Relief
Commercial Services	University of South Carolina GIS Server
Medical Services	University of South Carolina GIS Server
Schools	University of South Carolina GIS Server
Colleges	University of South Carolina GIS Server
Roads	US Census, Tiger Line Files from ESRI
Sewer	University of South Carolina GIS Server
Water	University of South Carolina GIS Server
Railroads	US Census, Tiger Line Files from ESRI
Power lines	University of South Carolina GIS Server
Soils	USDA, NRCS Soil Survey Geographic Database
Land Use Classification	USGS, National Land Cover Dataset, 2001
Power Plant	Edited

Figures

Figure 1: The Oconee Watershed Area of Study in South and North Carolina.

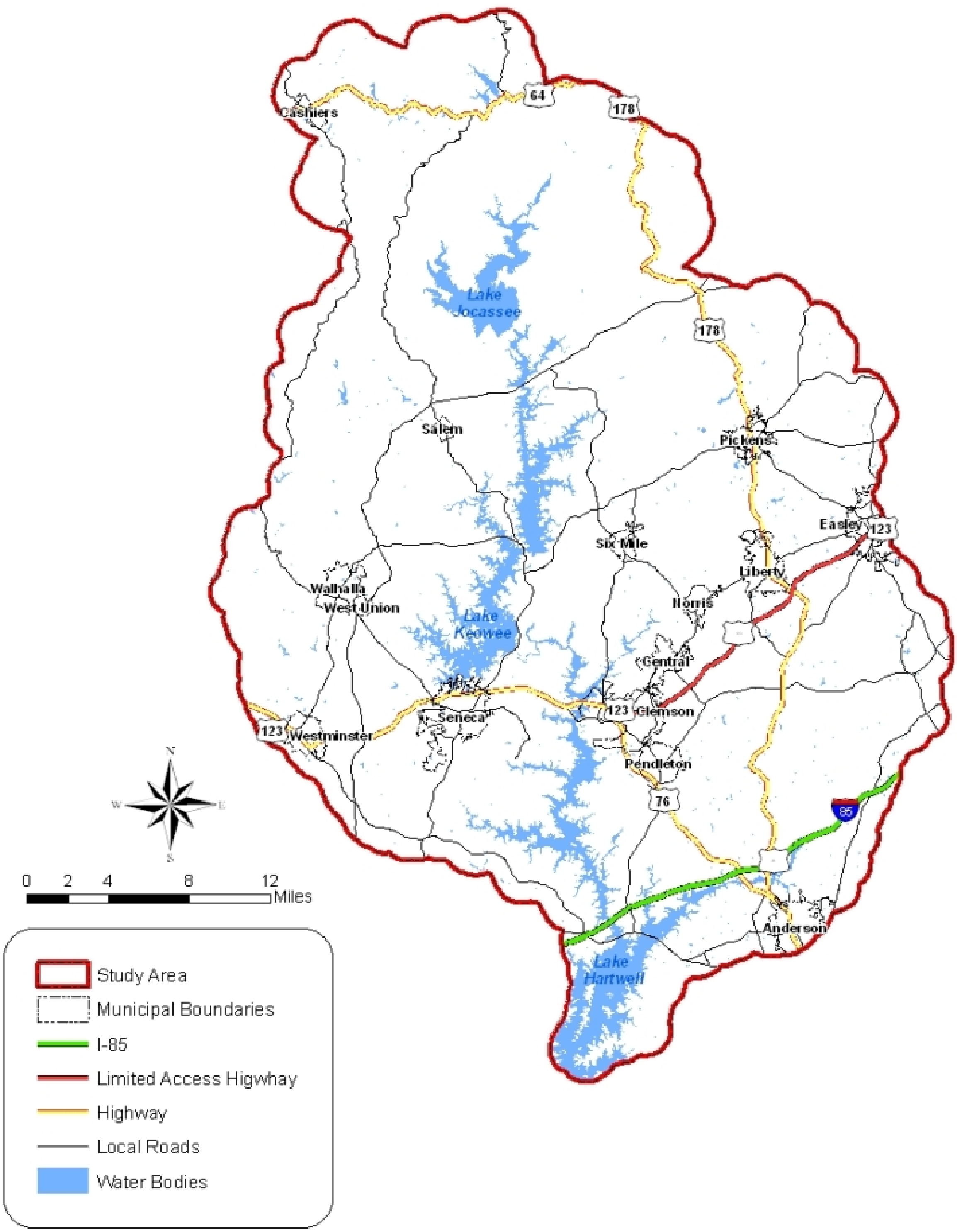


Figure 2: Land Use in the Oconee Watershed as of 2001.

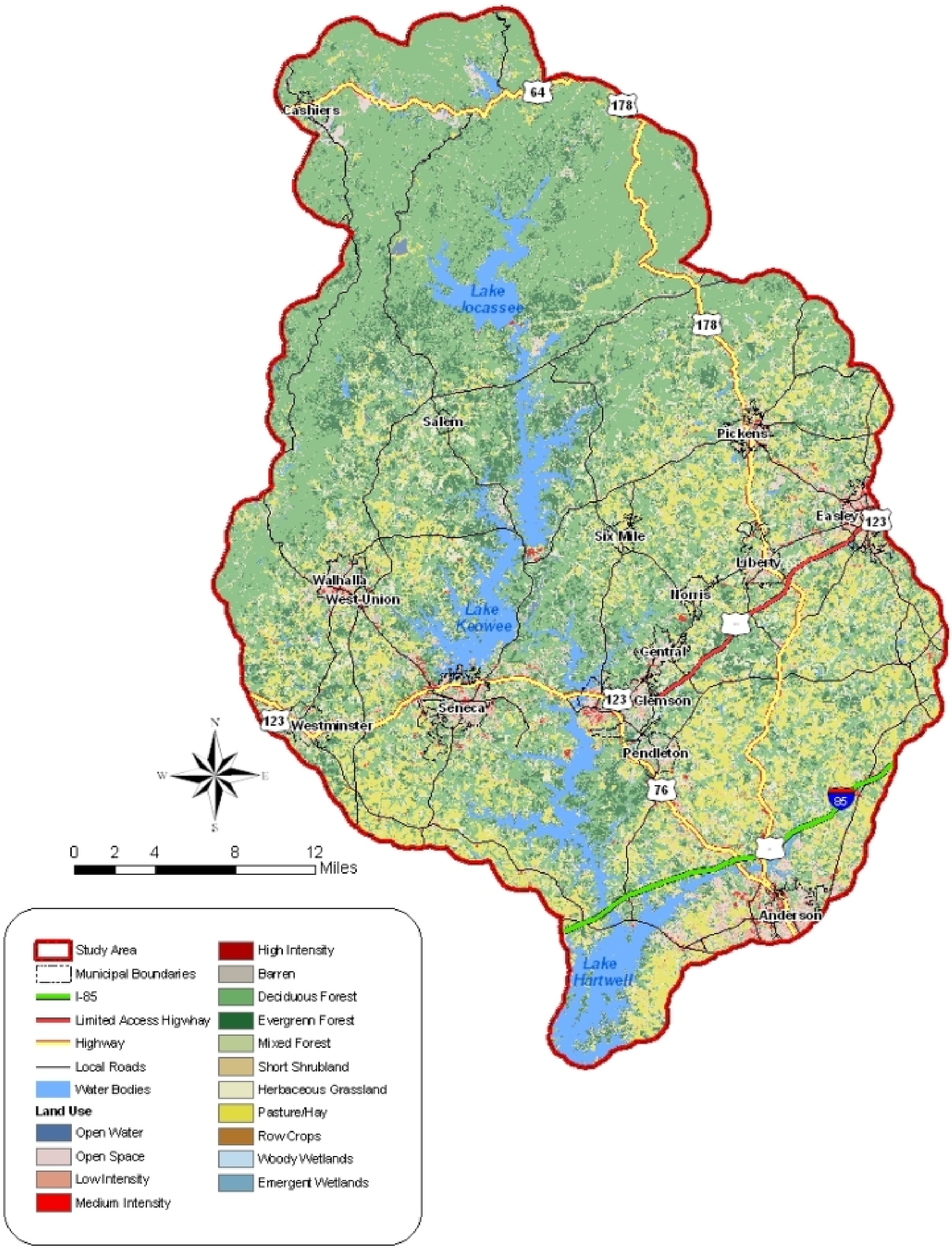


Figure 3: Land Use Change in the Oconee Watershed between 1992 and 2001.

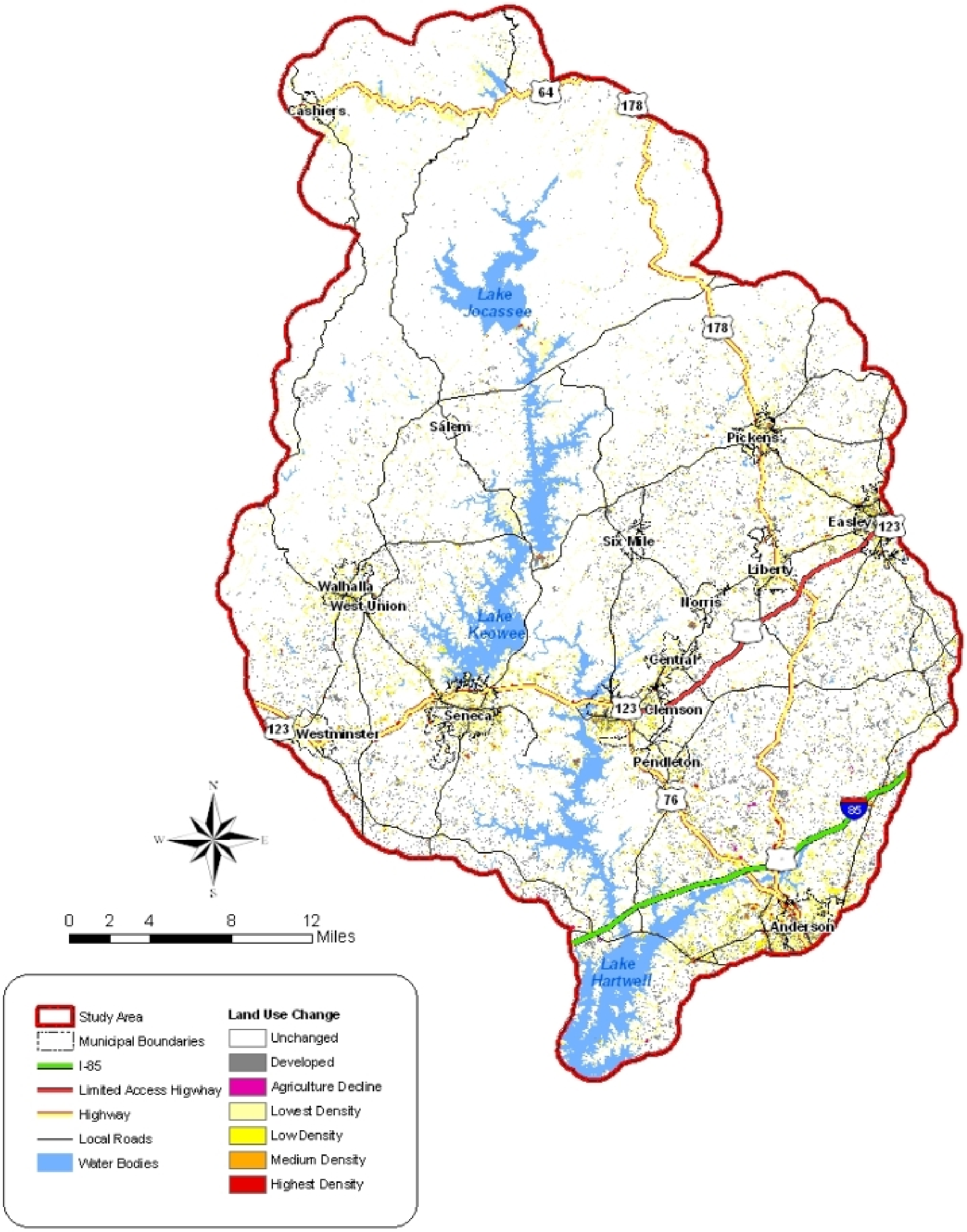


Figure 4: Avoidances Sub-Model Output for the Oconee Watershed.

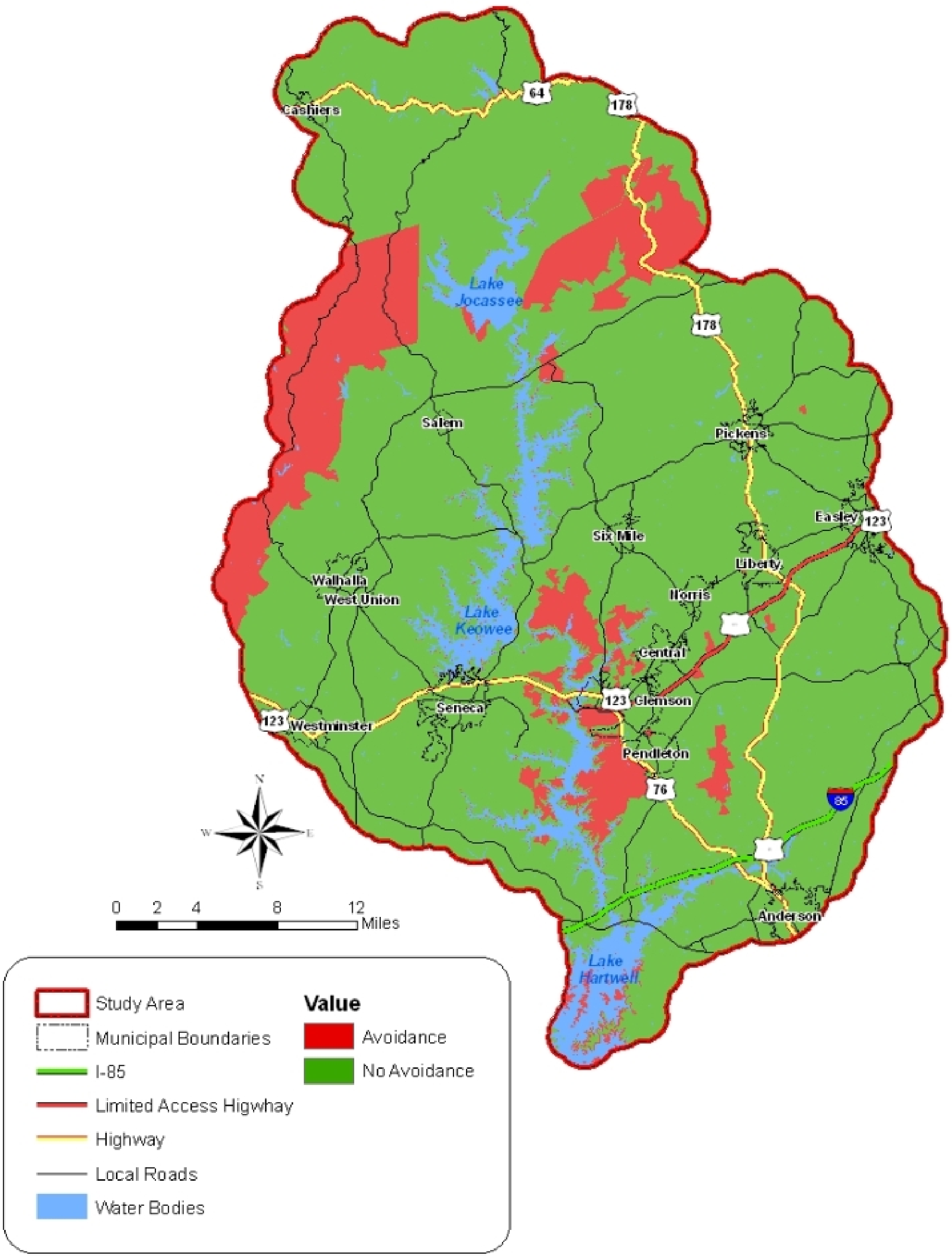


Figure 5: Close To Sub-Model Output for the Oconee Watershed.

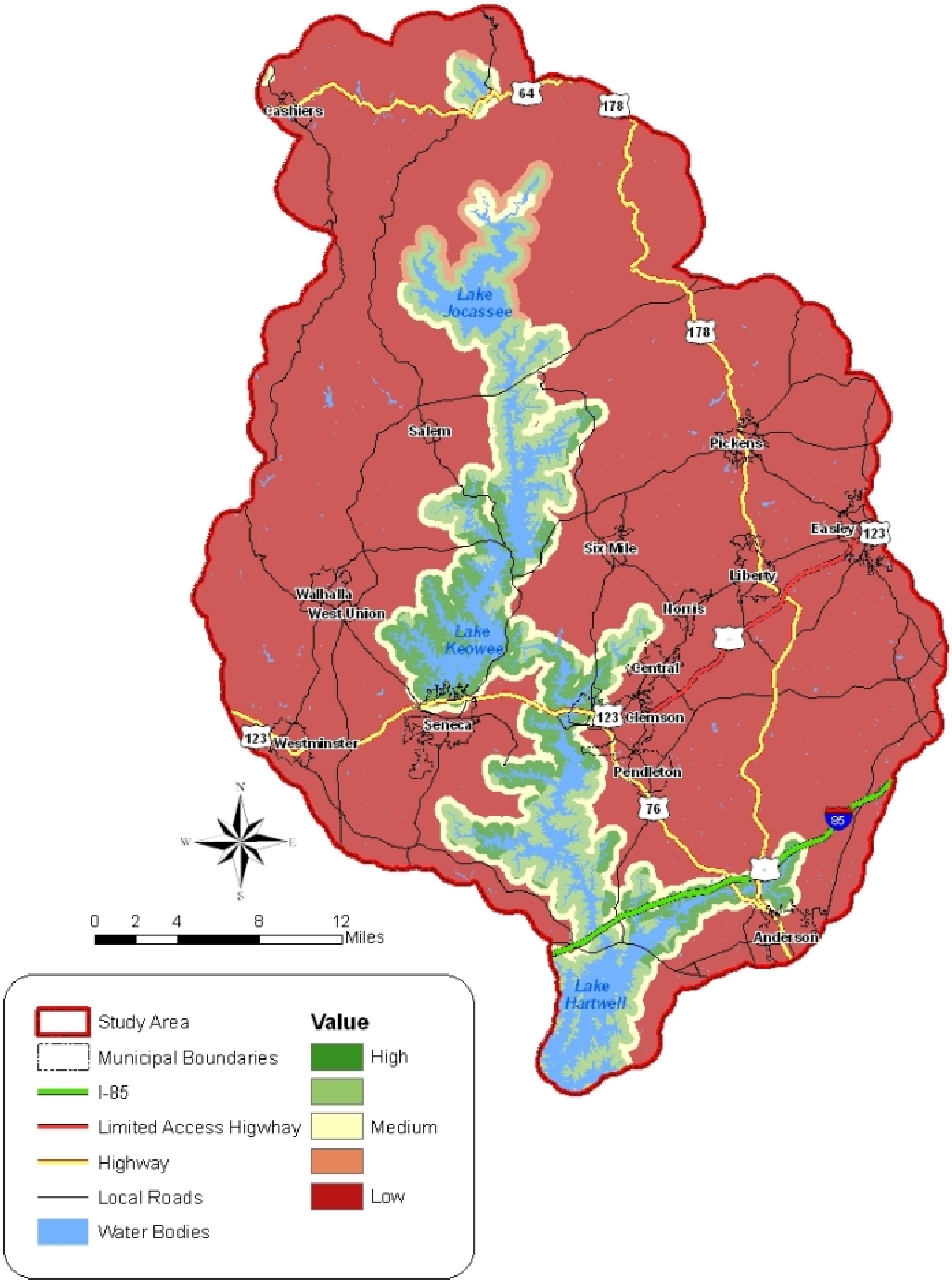


Figure 6: Away From Sub-Model Output for the Oconee Watershed.

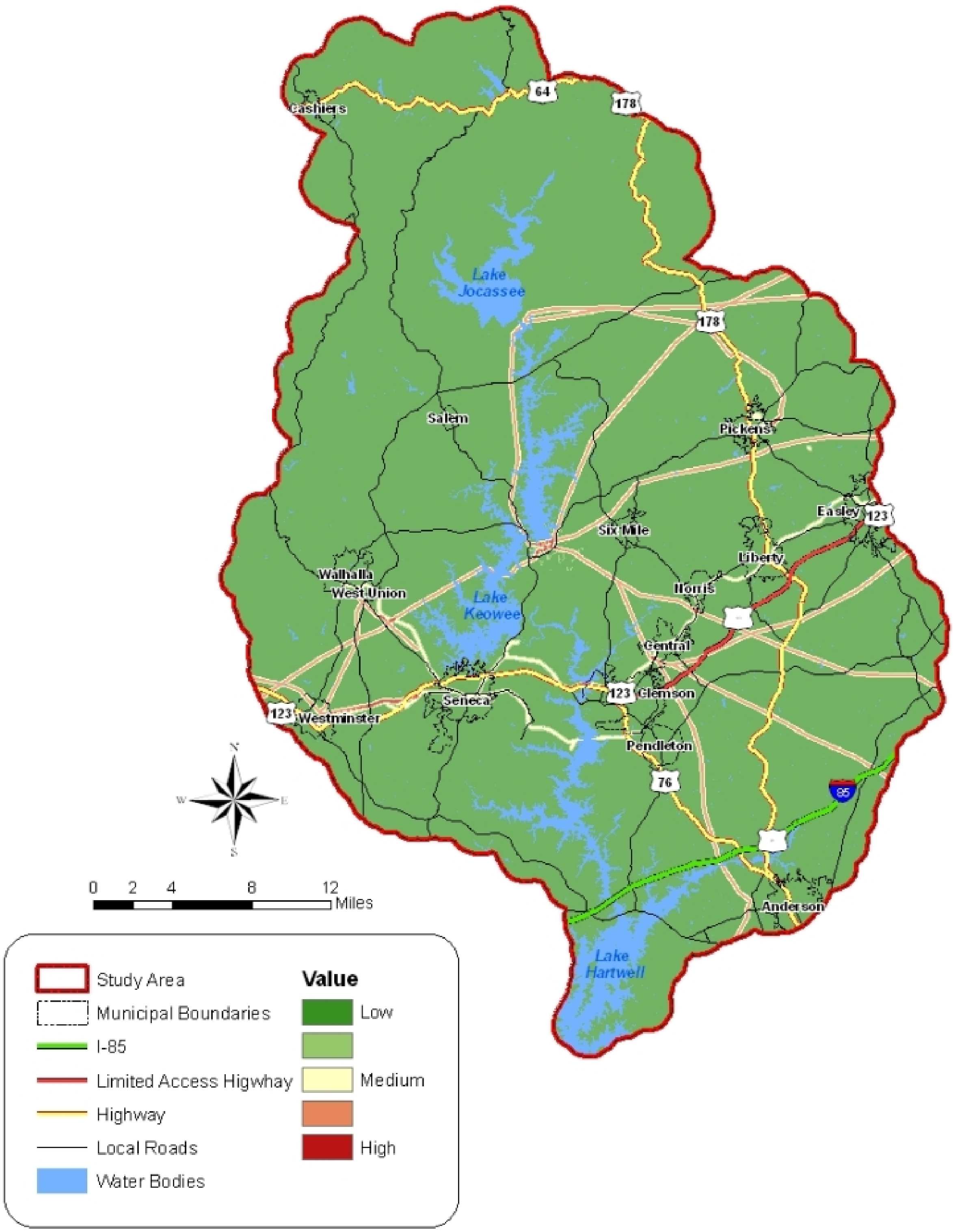


Figure 7: Site Suitability Sub-Model Output for the Oconee Watershed.

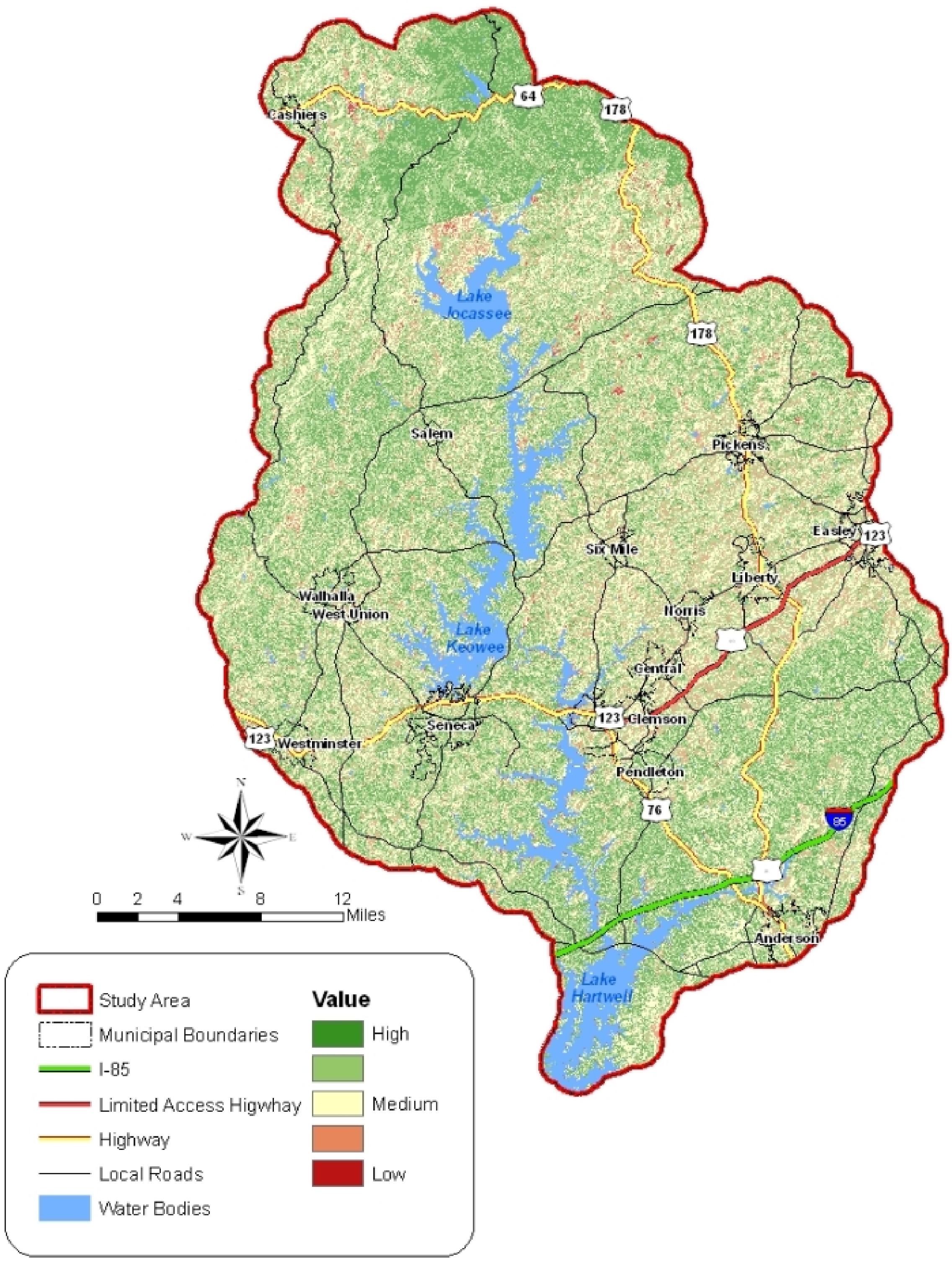


Figure 8: Constraints Sub-Model Output for the Oconee Watershed.

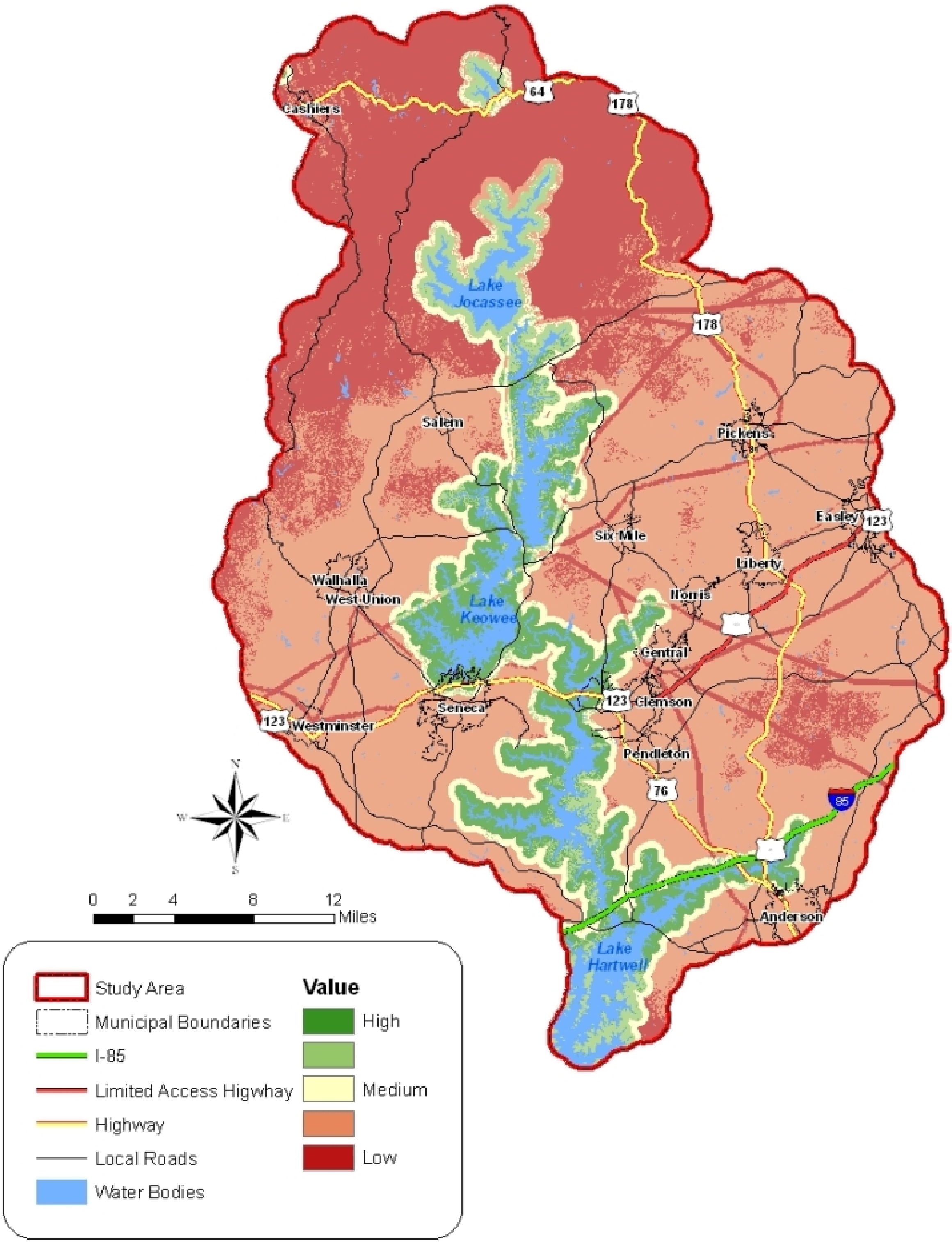


Figure 9: Opportunities Sub-Model Output for the Oconee Watershed.

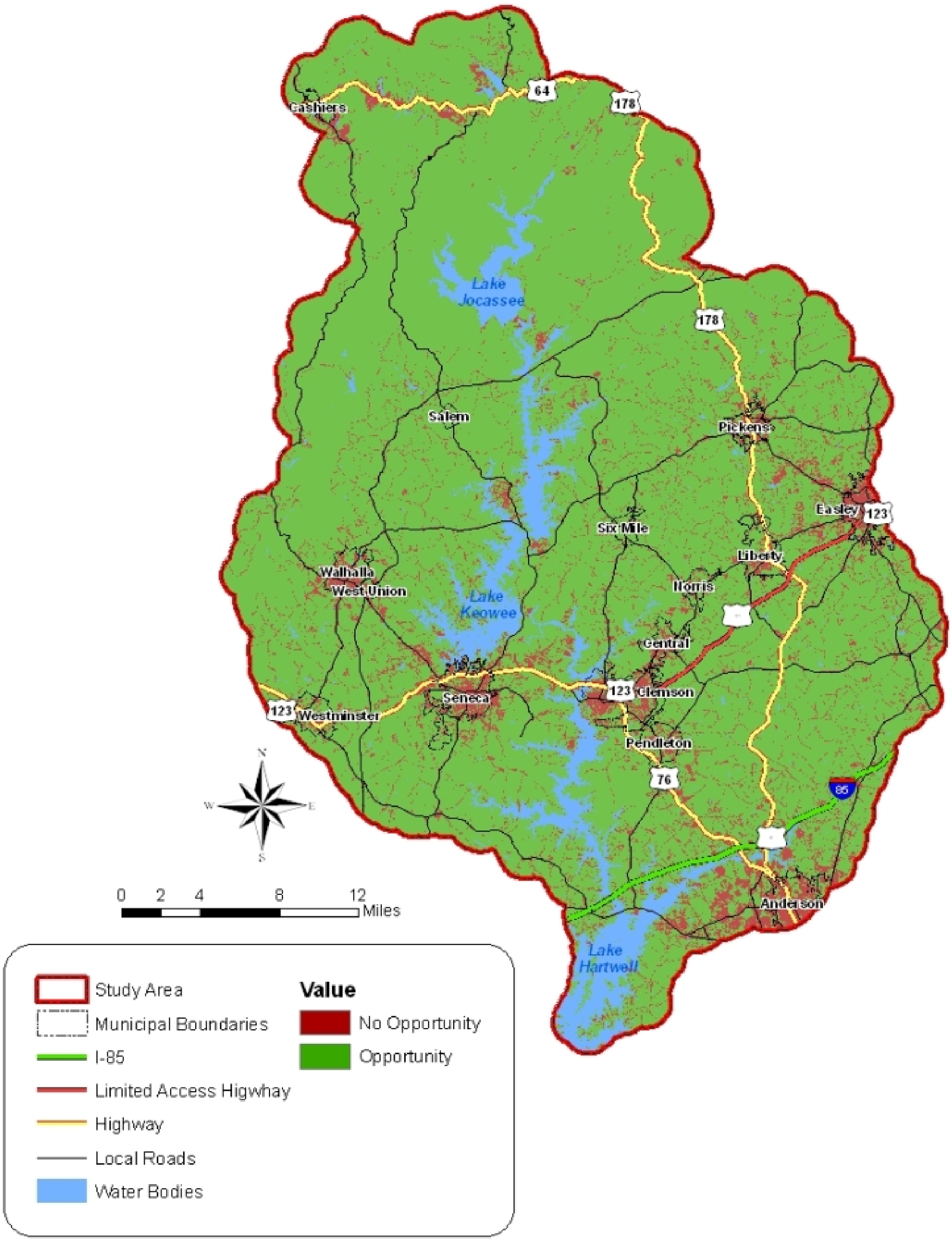


Figure 10: Development Model Output for the Oconee Watershed.

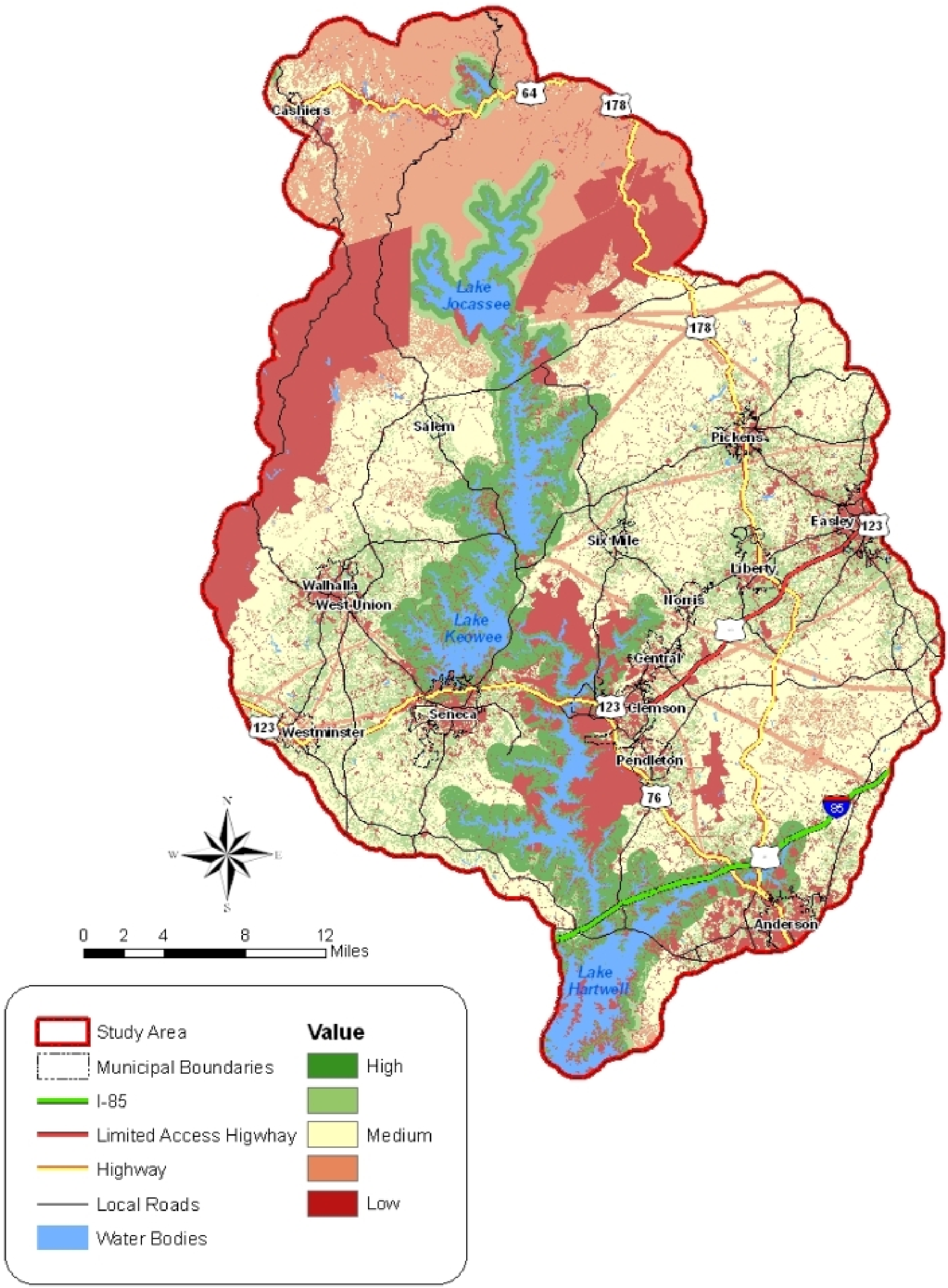


Figure 11: Flow Chart of the Models Employed for the Oconee Watershed.

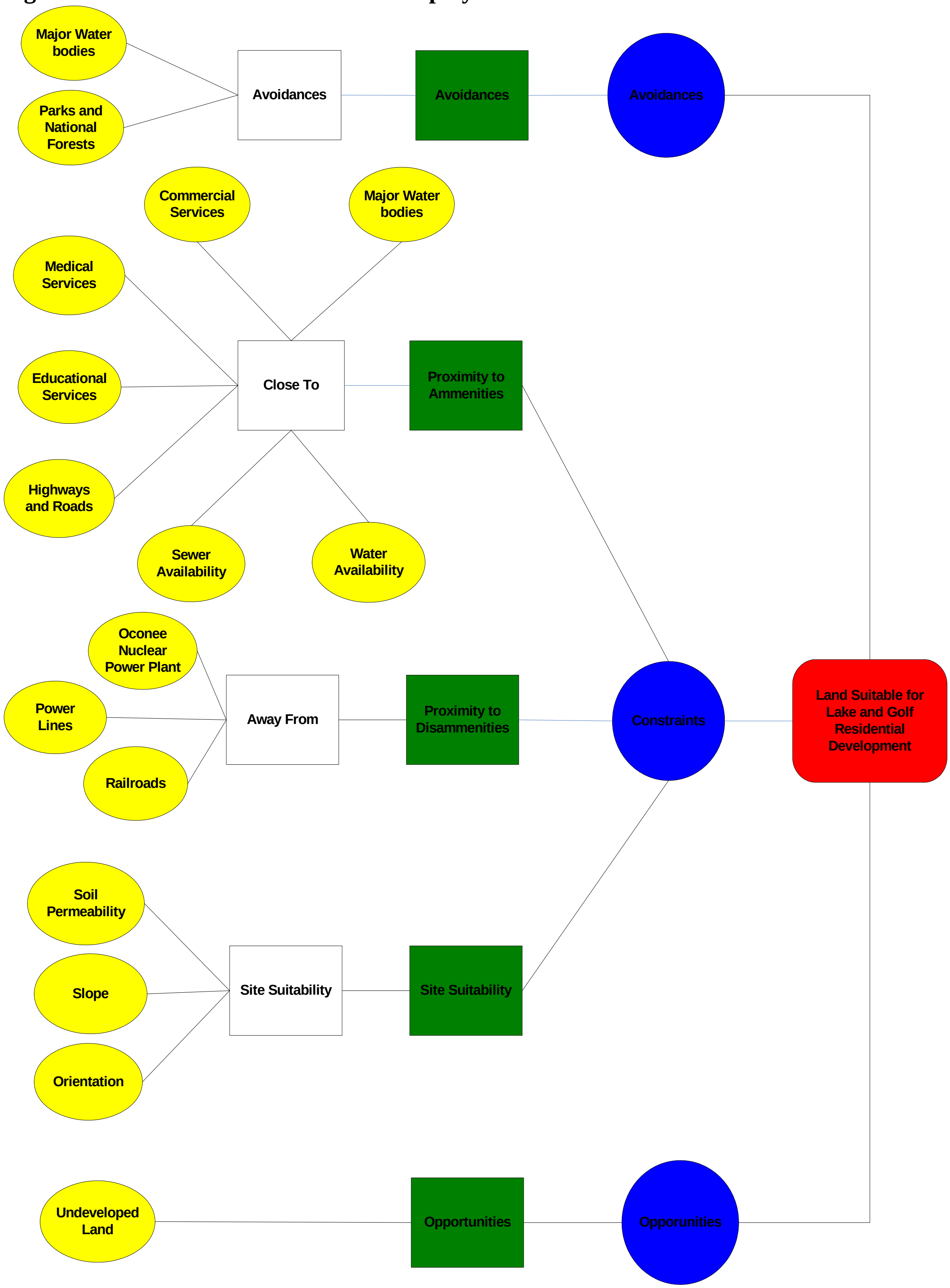
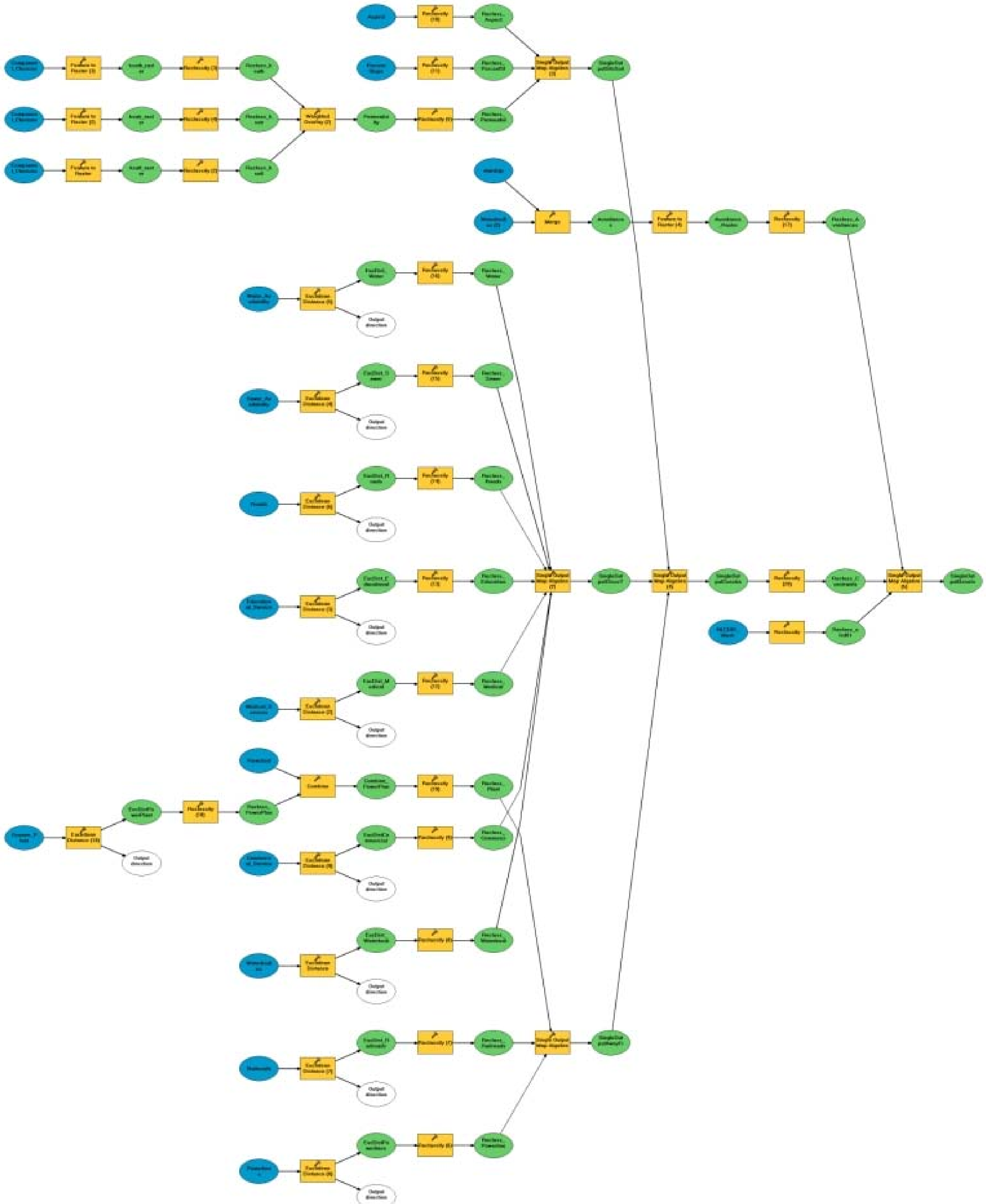


Figure 12: Flow Chart in Model Builder® within ArcMAP.



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