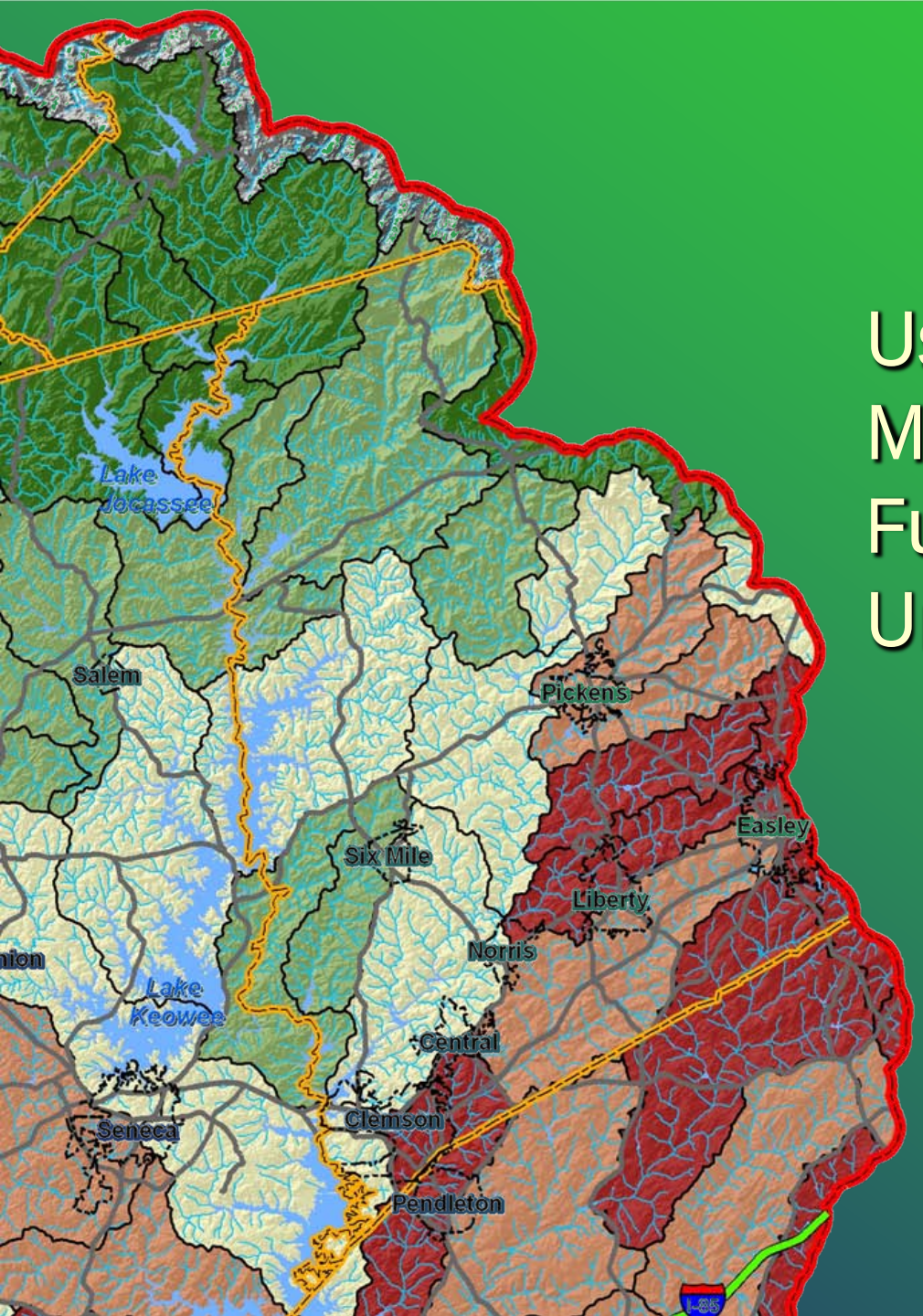

Using Deterministic Models for Long Range Future Growth in an Urban/Rural Watershed

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GeoTools 2009
Myrtle Beach, March 2009

Outline

- Spatial Modeling Concepts
- Alternative Futures Process
- Overall Models
  - Development Models
  - Constraints Models
- Planning Scenarios
  - Environmental
  - Projected growth
  - Economic
  - Urban Footprints
- Green Infrastructure
- Conclusion

View of the Oconee Watershed from Nantahala National Forest.

Spatial Modeling

- Deterministic models
  - Models having no random components
  - A given input always produces the same output
- Stochastic models
  - Models whose output is described by a probability distribution
- Suitability models verses climate change models

Goodchild, 1993

Model Terms

- The development of modeling terms
  - Grid cells
    - Developed for display and analysis during the 1960s by Howard Fisher and Carl Steinitz, (Chrisman,2006)
    - Commercially by ESRI in 1970 and ERDAS in 1976
  - Raster or pixels
    - Initially a remote sensing term from the 1970s with Landsat
    - Commercially used by ERDAS and ESRI in 1988 with the ERDAS/ArcInfo Live Link
  - Cellular Automatica (CA)
    - The concept was initially proposed by John Von Neumann during the 1950s (Batty, 1997)
  - Agent Models – rule-based
    - A term developed by IDRISI and Ron Eastman in the 1990's (Goodchild, 2005)
    - The first rule-based modeling was commercially introduced by ERDAS in 1995
- In many ways they are all the same
  - *If it looks like a duck …*
  - The commonly accepted term for commercial software is raster

Stochastic Growth Models

- UrbanSim
  - Combines vector analysis transferred to a grid display – 150 meters
  - A simulation model for integrated planning and analysis of urban development,
    - Incorporates interactions between land use, transportation, and public policy
    - Data intensive
    - Processes of residential location, housing supply, prices, job location, and travel
  - Stochastic model of optimal behavior of land owners
    - Models *processes*
  - Develops disaggregate discrete choice models and linking them in an agent-based simulation system

(Waddell, 2002 - 2008)

- SLEUTH
  - Cellular Automatica based urban growth model – 30 meters
  - Stochastic process regulated by conceptually simple transition rules.
    - Models *patterns* or *trends*
  - Calibrated to simulate urban development over a historic time period
  - Forecasts these patterns into the future

(Clarke et al. 1997, Clarke and Gaydos 1998, Candau 2002, US Geological Survey 2003).

GIS and Urban Growth Models: Loose-Coupling or Purpose–Built Software?

- Essentially most models either use canned functions or modelers write their own code
- Most models have loose coupling to a GIS
  - Simply takes in the shape and other file formats
- Recurrent issues in any urban model are:
  - The extent to adapt the code to any real application
  - Only addressing a single scenarios
    - Limits discussion by stakeholders
  - How can non-programmers (planners) use these models
- The growth models for the Seneca Sub-basin are developed using the common tools in ArcGIS and Excel

Standard Model Processes - Common Modeling Tools

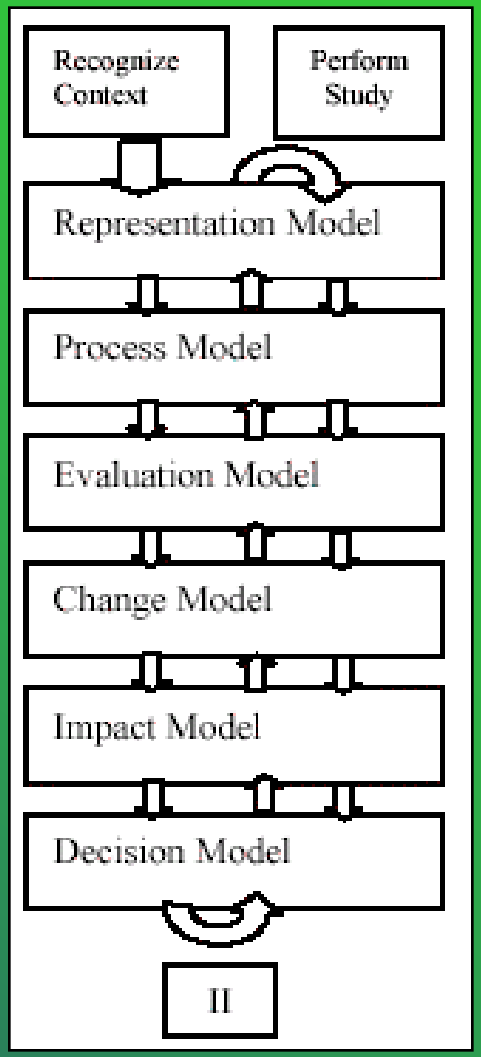
- Spatial Proximity
  - Distance
- Simplify and Rank
  - Reclassify
- Surface - Topography
  - Slope and Aspect
- Matrix Analysis
  - Combine and Reclassify
- Indentifying Contiguous Pixels
  - RegionGroup
- Statistics
  - Cell
  - Neighborhood
  - Zonal
- Add and Weight
  - Arithmetic Operations
  - Normalize in Properties
- Map Algebra
  - Formulas

Computer Models

- Human verses Computer
  - To much emphasis on the machine to do it all
  - It is better to look at a combination of both
- Humans are stronger at understanding patterns than a computer
- Models should not be a black or gray box
  - Models must be understood and easily explained
    - Fred Smith, Harvard University (1974)
  - Models are really tools for discussion
    - Lew Hopkins, University of Illinois (2005)
- Scenario development offers a good approach for discussion

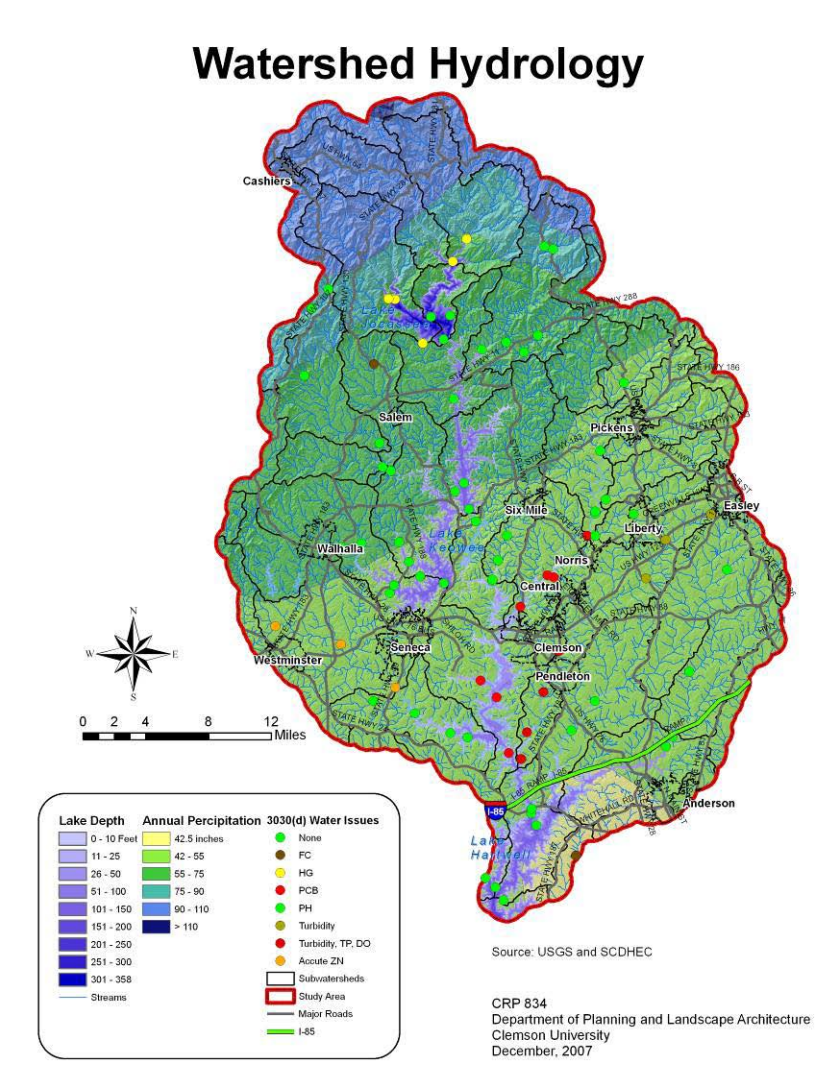
Alternative Futures Planning Process

- Followed Carl Steinitz's Alternative Futures for Changing Landscapes (2003)
  - Developed over 3 decades from his original work at Harvard (NSF, 1975)
- Developed deterministic attractiveness and impact models
- Objectives were:
  - To find the most suitable land for development and quantify impacts
  - To forecast population and employment growth to 2030
  - Developed alternative futures based on three different growth scenarios



The Seneca SubBasin

- Located in the upstate of South Carolina
- A 1028 square mile watershed with 926 square miles in SC
  - Includes portions of 5 counties
    - Anderson, Pickens and Oconee in SC, and Jackson and Transylvania in NC.
  - Pastures and forests are the predominant land uses
  - Three major water-bodies
    - Lake Jocassee, Lake Keowee and Lake Hartwell
- Streams and lakes in the watershed are impaired for:
  - Metals, fecal coliform bacteria, mercury, PCBs, phosphorus, and turbidity
- Anderson and Easley are the two urban developments
  - Major highways include:
    - I-85, US 11, 123 and US 76



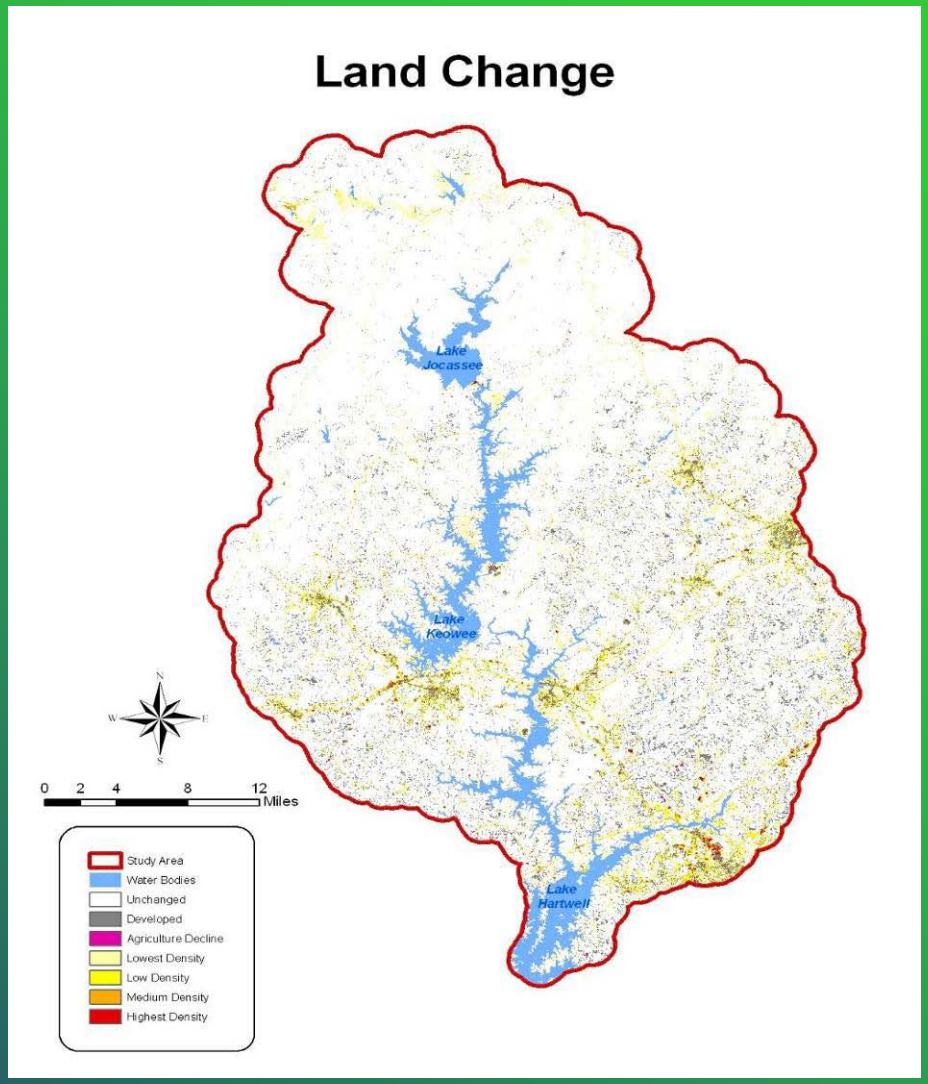
The Boomers Are Coming

- The lakes have attracted tourism, recreation and new residents
  - Thus there has been significant growth
- Lake gentrification is a major issue confronting the area
  - There is pressure on water resources by retirement and second homes

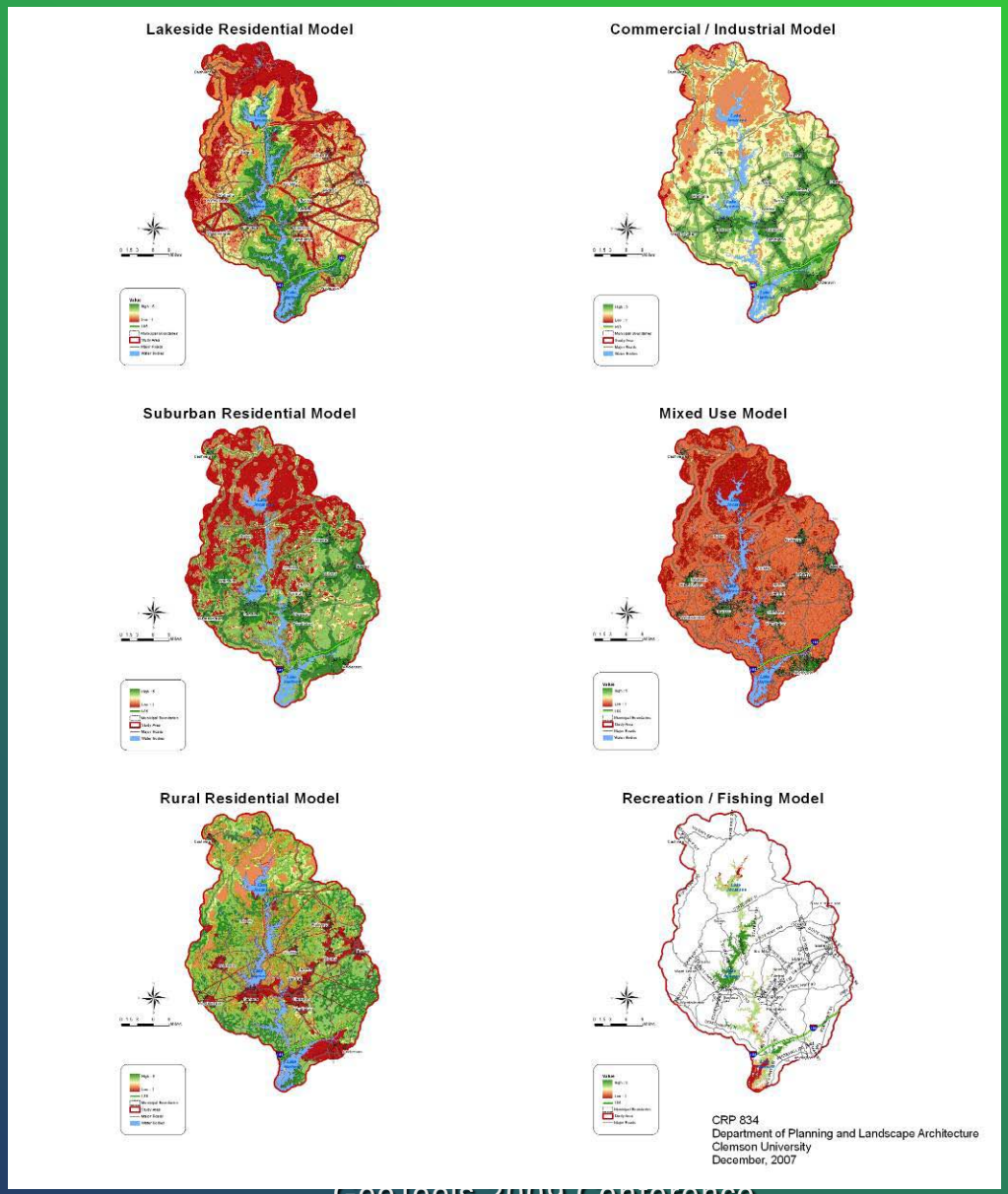
Lake Keowee

Development Models

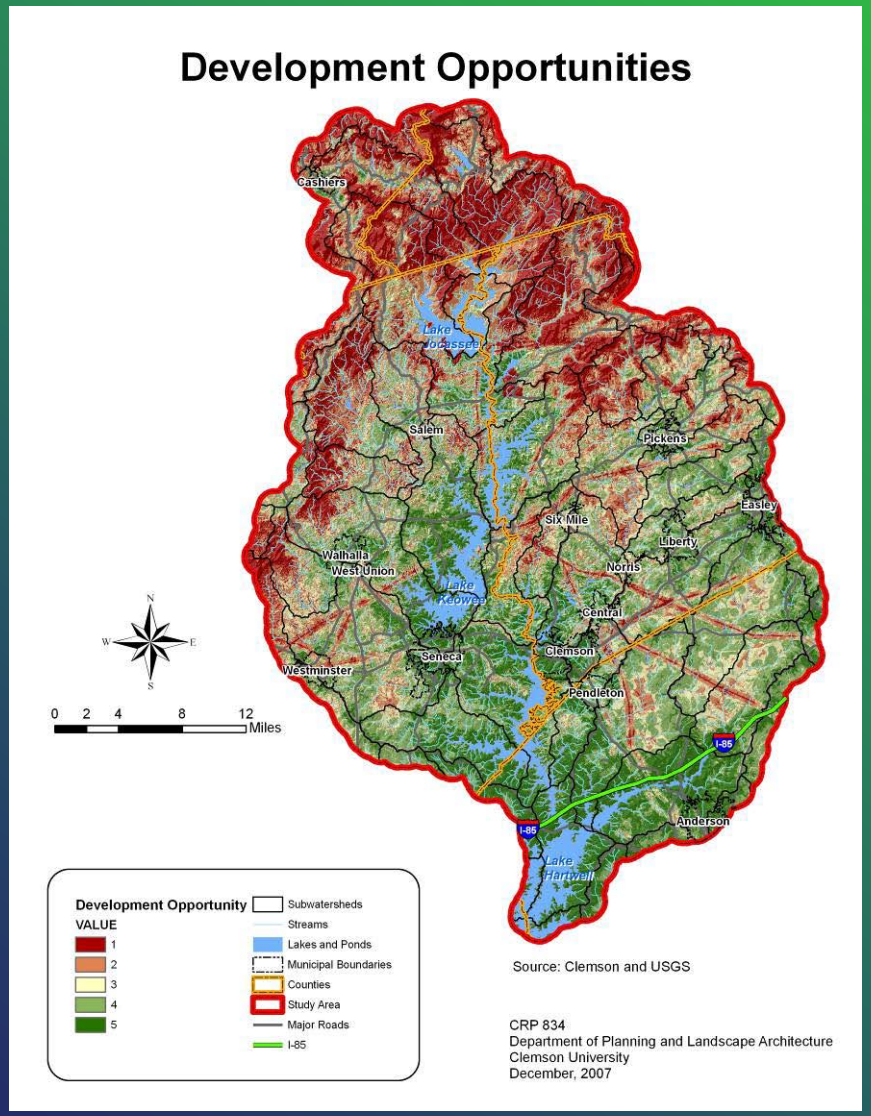
- Located in the fifth most sprawling metropolitan region in the United States (Ewing et. al., 2002)
- The models explore the criteria underlying land use location for:
  - High-end residential
  - Suburban residential
  - Rural residential
  - Mixed Use
  - Commercial/Industrial
- Opportunities were based on Land Cover Change from 1992 through 2001 (USGS)

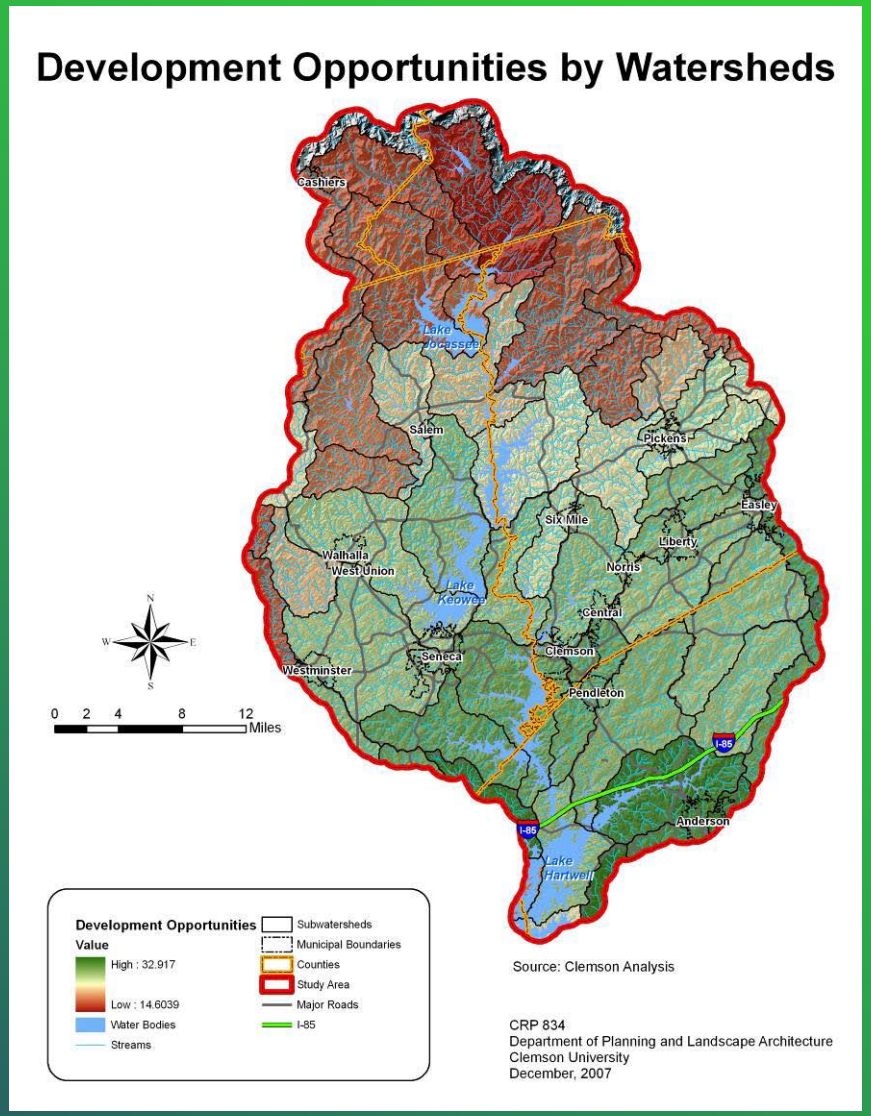


Development Models



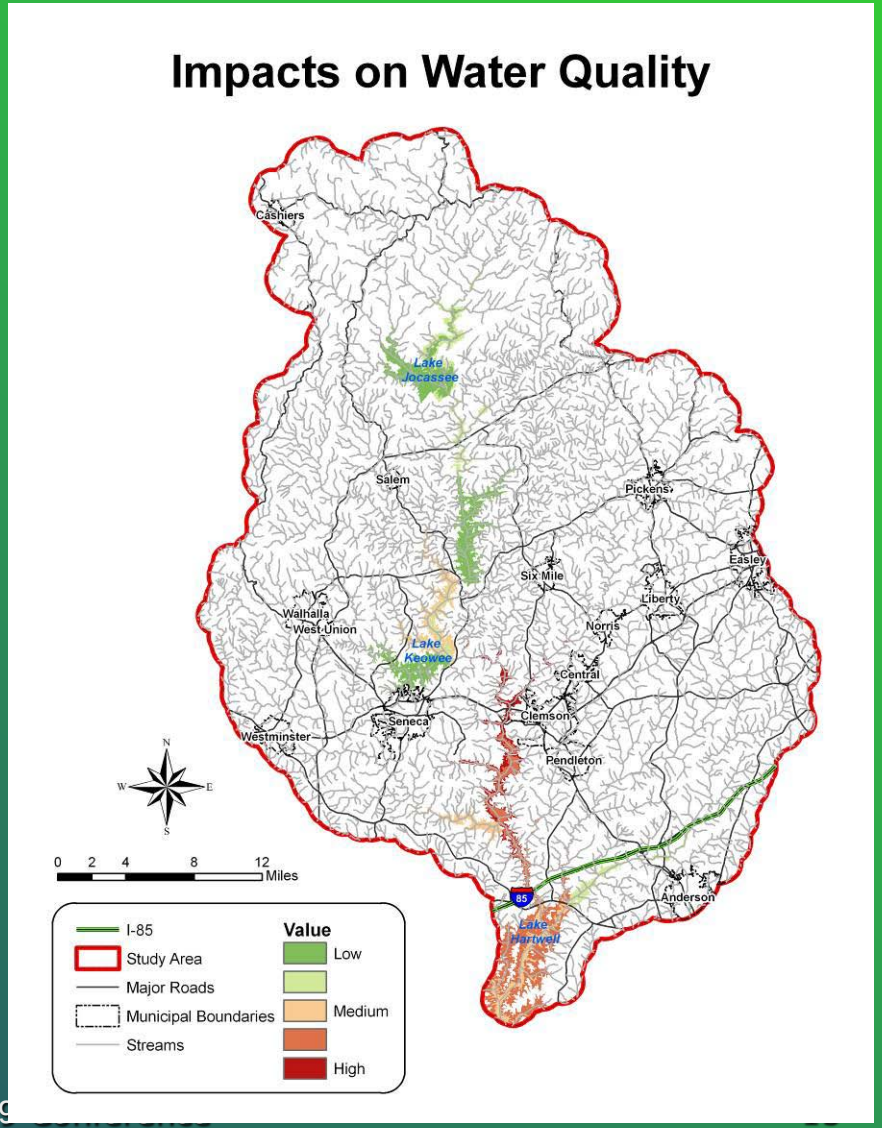
Development Potential Locations



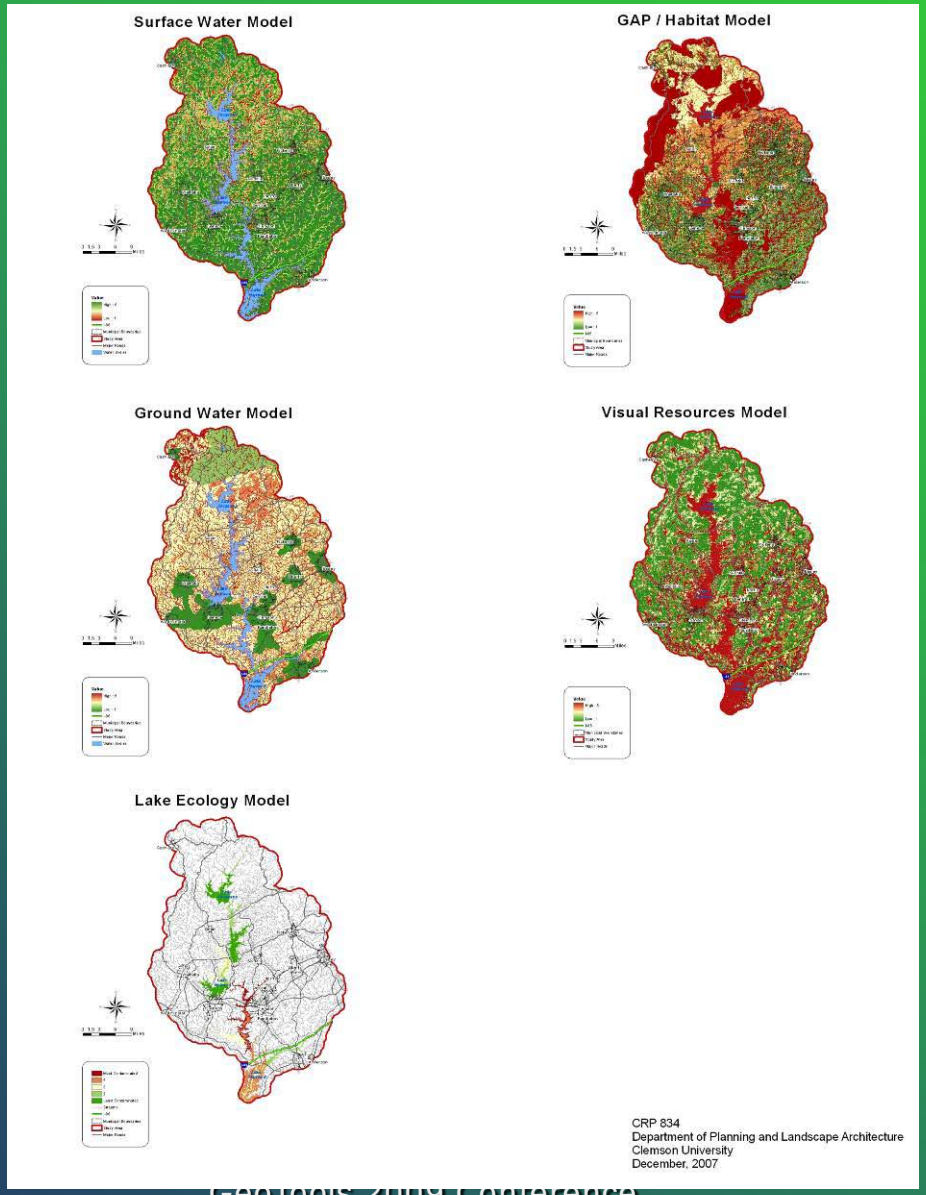


Final Constraints Model

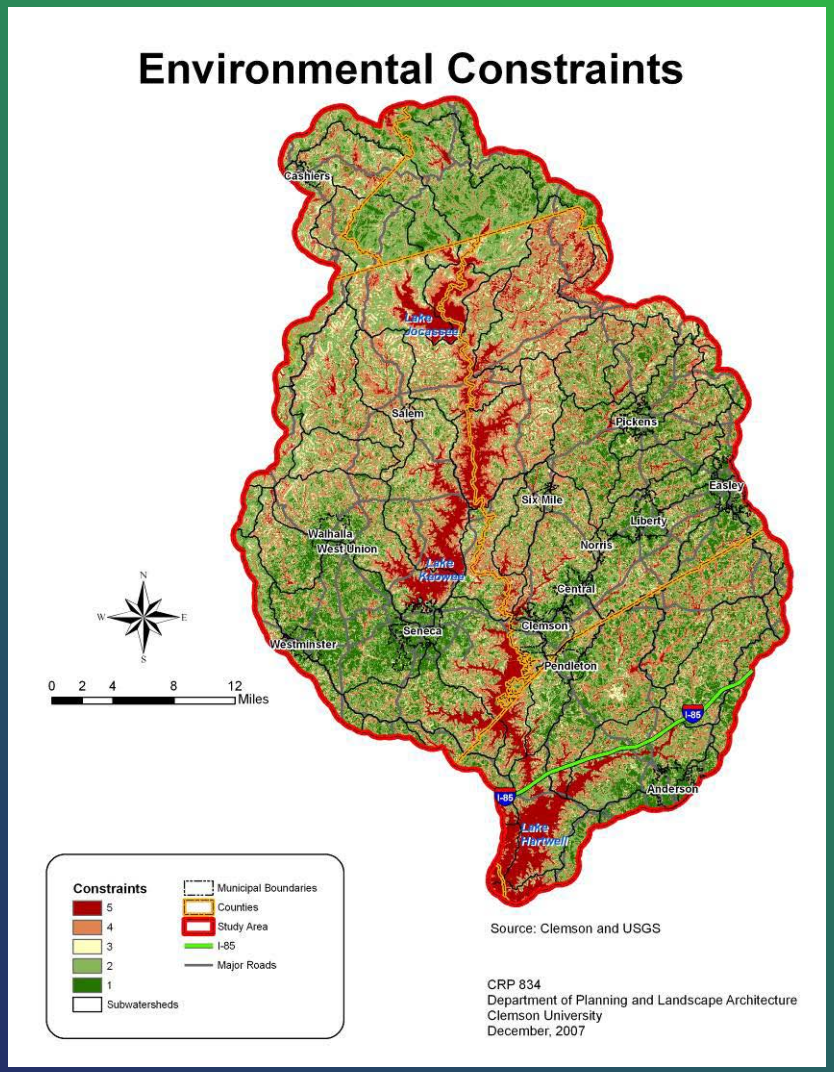
- The models explore the constraint of the fragile environment
- The models explored:
  - Lake Ecology
  - Surface Water Quality
  - Groundwater Quality
  - GAP Analysis
  - Viewshed Analysis
- Combined on relative rankings

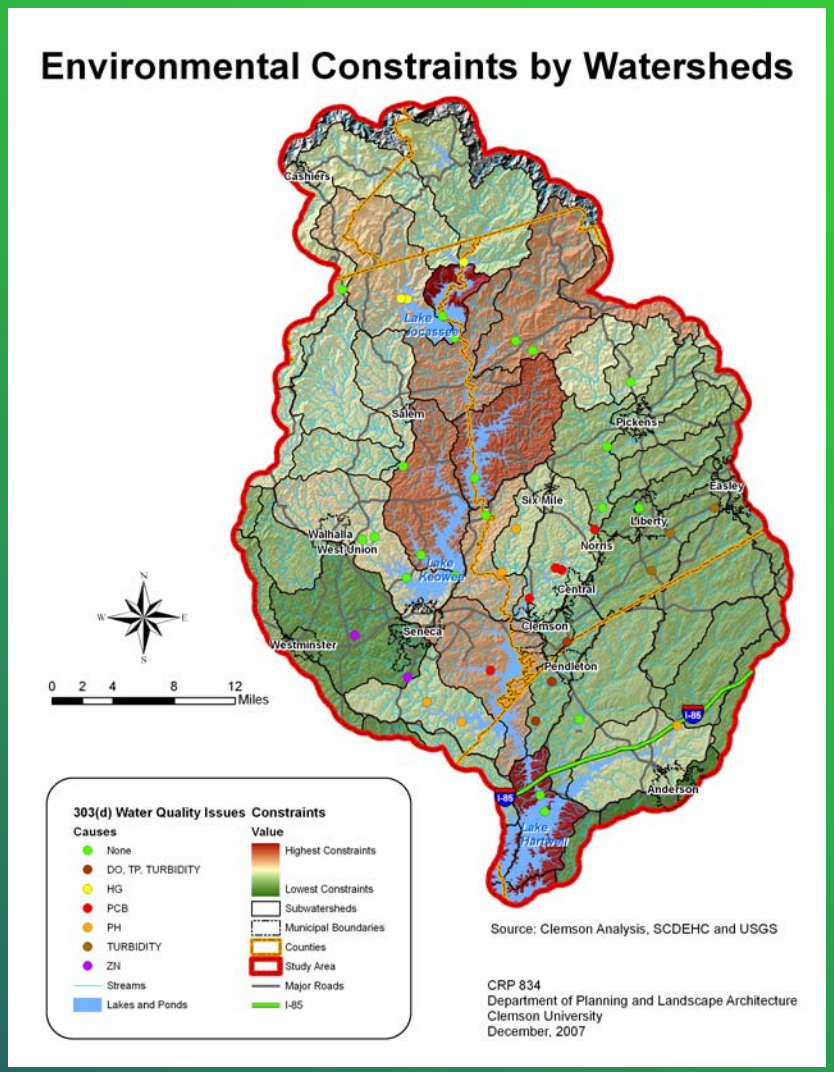


Environmental Models

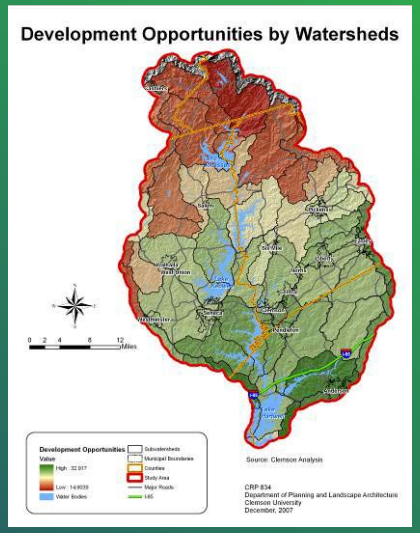


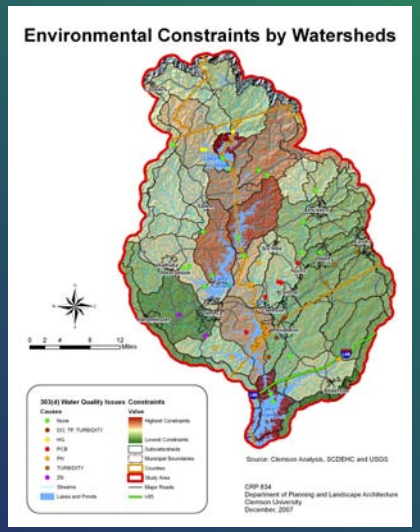
Environmental Constraints Location

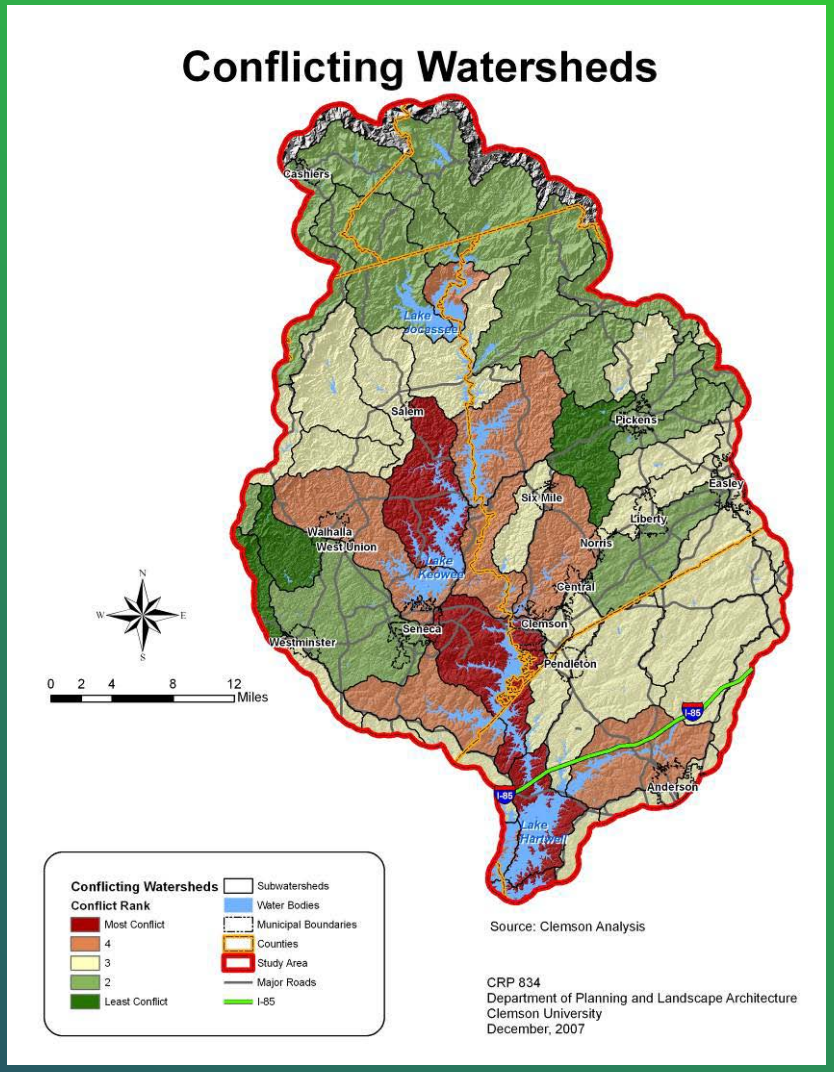




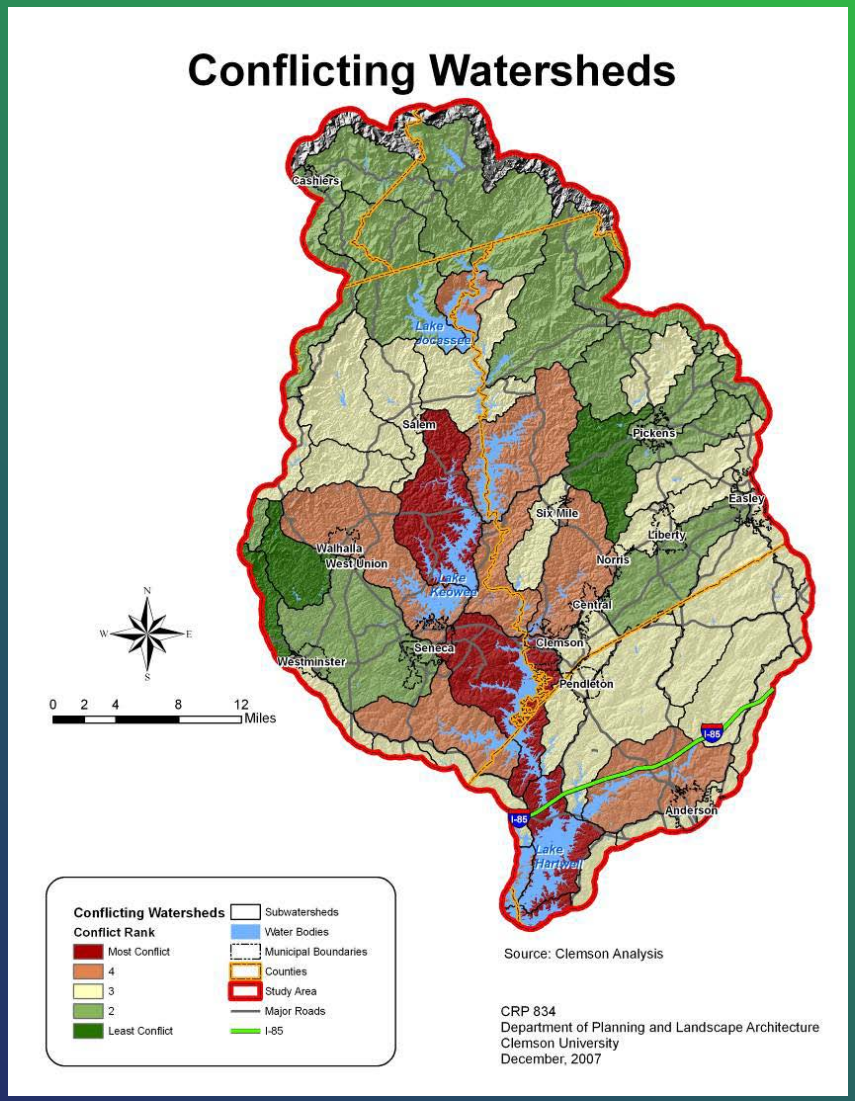
Conflicting Watersheds

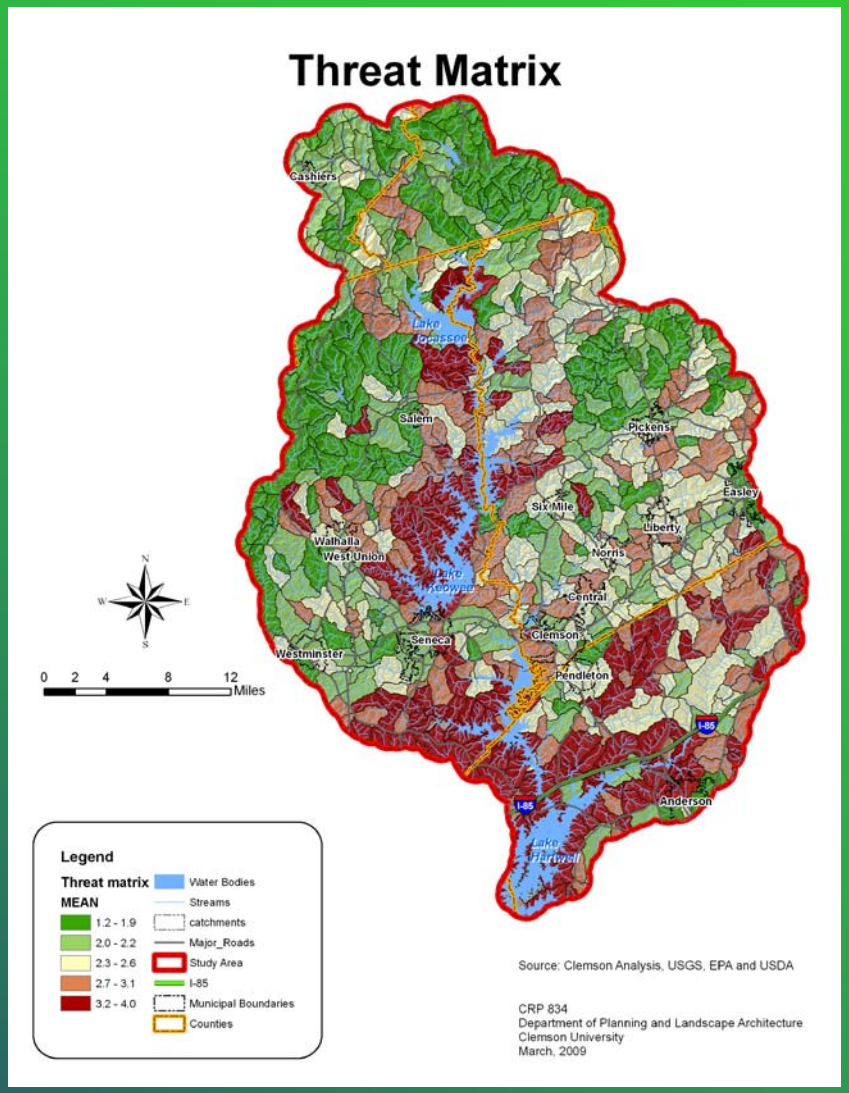






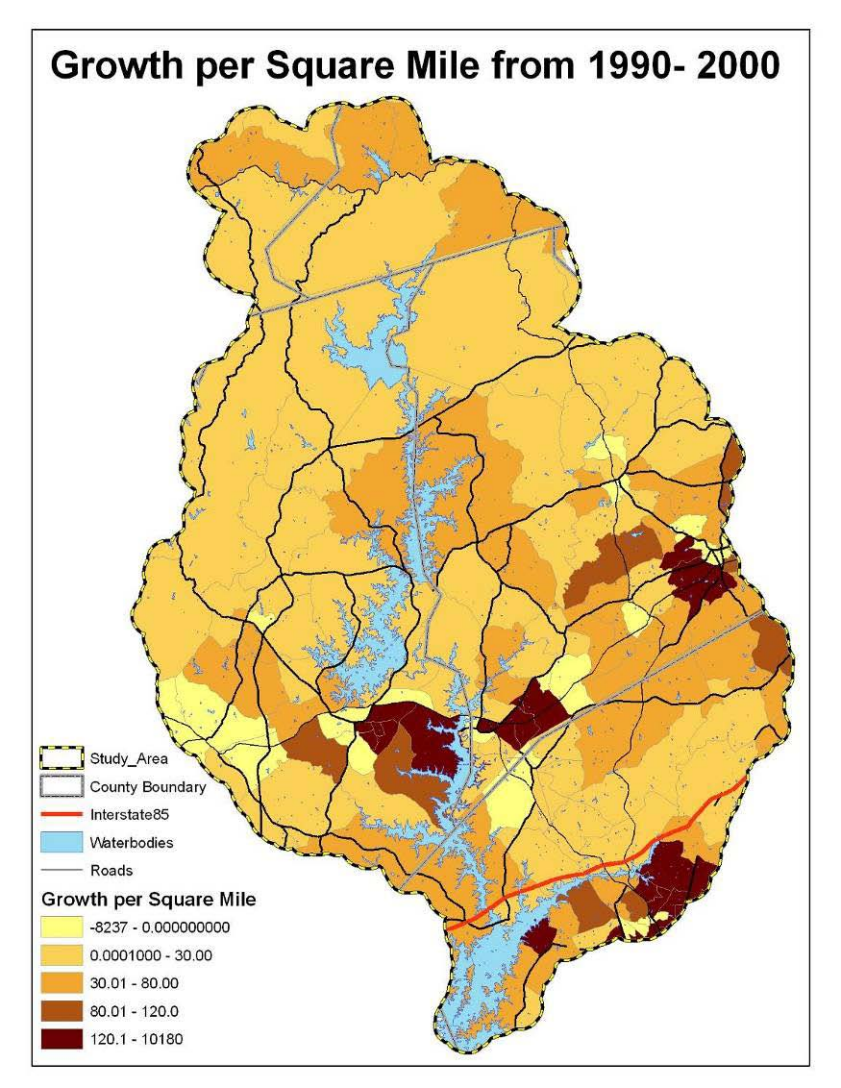
Now at the Catchment Levels





Population Change 1990 to 2000

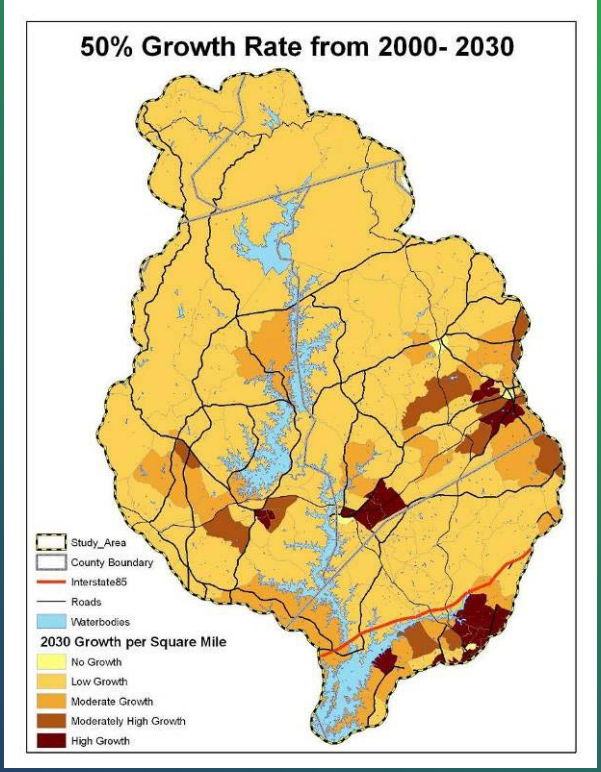
- Population Change from 1990 to 2000 per square mile
- Mapped at the Census Block Groups level
- Growth 1990 to 2000
  - Growth expanding from cities.
  - Growth along US Highway 123 and Interstate 85
  - Growth around the lakes.
- 2000 Population was 250,000
- Growth rates are projected to be greater that 30% between 2000 to 2030

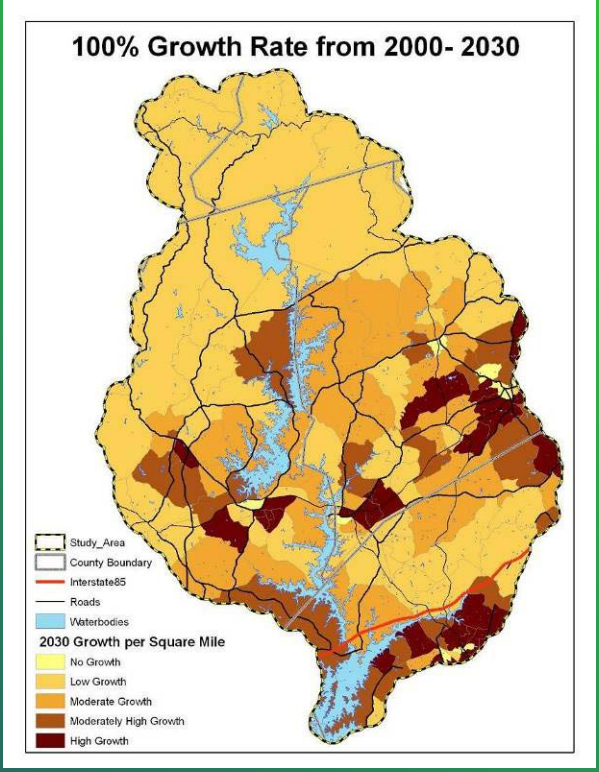


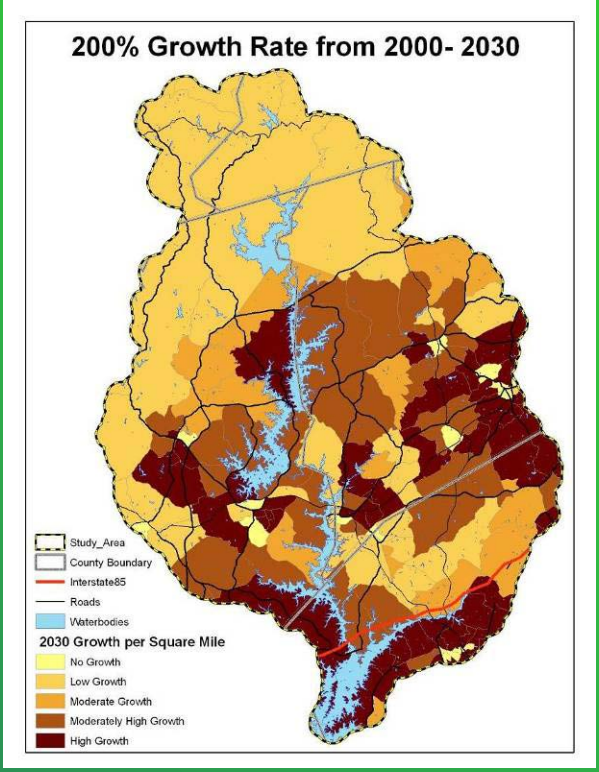
Planning Scenarios

- Environmental Protection Emphasis
- Projected Population Emphasis
- Economic Development Emphasis

2030 Scenario Projections







- 310,750
- 371,500
- 492,000

Employment Areas- Projections

- National employment growth predictions from the U.S. Bureau of Labor Statistics
- Relative employment by employment sectors for study area in 2000
  - 2000: 70% in service - 30% in goods producing
  - 2030: 79% in service - 21% in goods producing

Total Employment	*Forecasted Employment Increase*	*Employment 2000*	*Employment 2030*
Service	**99%**	**62,113**	**103,719**
Education and health services	31%	6,640	15,950
Professional and business services	28%	4,059	9,137
Information	12%	925	1,386
Leisure and hospitality	18%	10,551	18,552
Trade, transportation, and utilities	10%	12,566	18,184
Financial activities	11%	2,244	3,265
Government	10%	17,860	25,634
Other services (except government	14%	7,268	11,611
Goods Producing	**-4%**	**26,294**	**27,649**
Construction	11%	6,340	9,451
Manufacturing	-5%	19,541	17,840
Agriculture, forestry, fishing, and hunting, mining	-7%	413	358
Total Employment		**88,408**	**131,369**

Employment Areas- Projections

2000-2030	Population Growth Low	Medium	High
Increase in Land (Acres)	1,893	3,730	6,853

- Land space per employee =
  Internal space + Parking Space + Open Space

- Internal Space: Survey of floor space and employment trends (Berke et. al., 2005)
- Parking Space : Based on Pickens County's Off-Street Parking Standards for various land use classifications
- Open Space: Requirements for Pickens County (5% to 12% of total land)

Assigning Land Uses

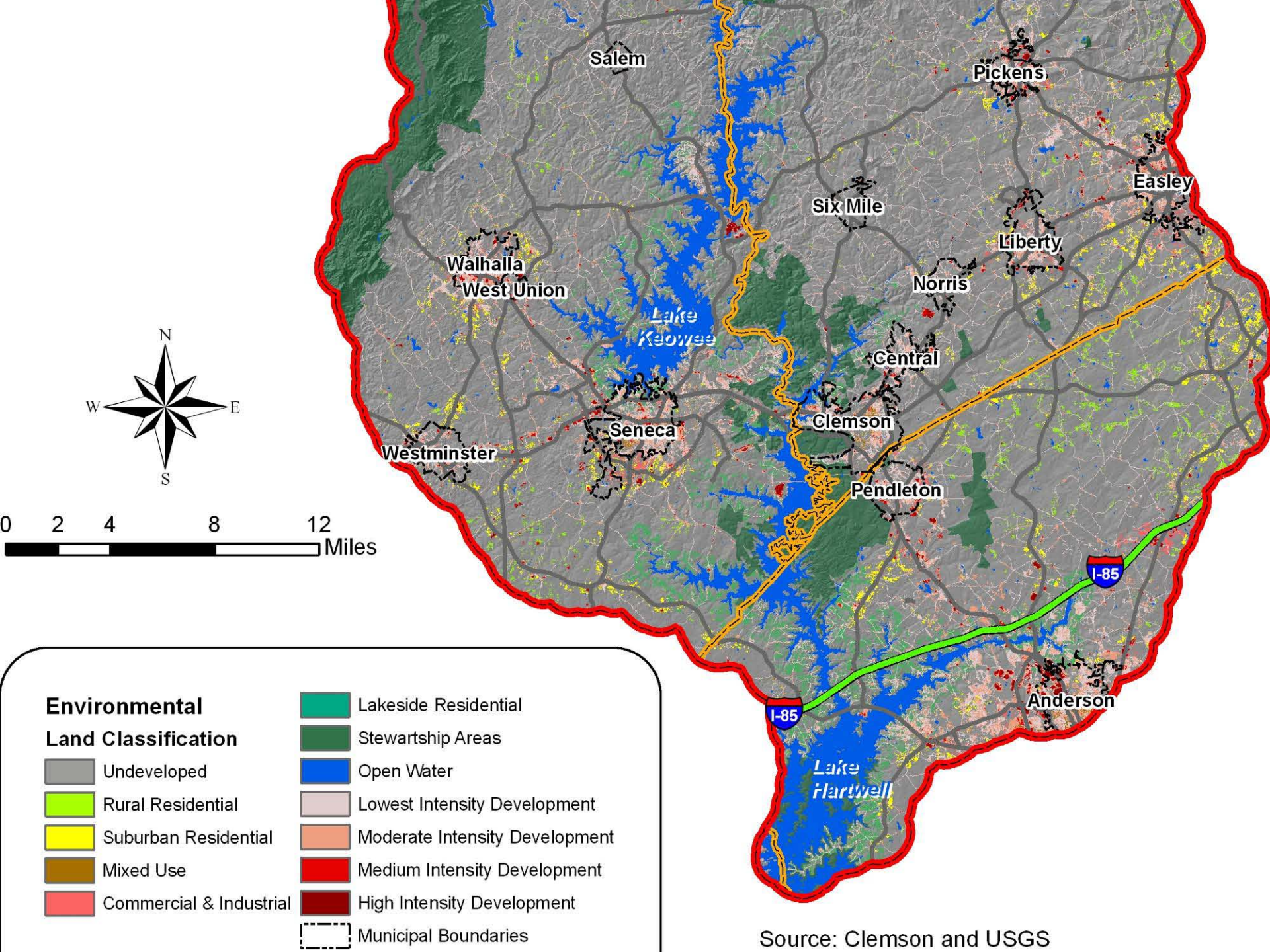
- Combine Land Uses and Environmental Constraints
- Use Excel to assign land use values
- Classified land uses based on the demand models
  - Highest 20th percentile
  - A tie was broken by selecting the higher-valued land use first
    - For example, select high-end residential over suburban residential
- Focused growth in the areas with minimal environment constraints
  - Lowest 20th percentile first

Environmental Scenario

- Need 22,363 acres of new development
  - Assume the lowest growth rate
  - Assume lower household size because many new homes are second homes and retirees
- Focused all growth in the areas with minimal environment constraints
  - Lowest 20th percentile

Population Forecast	
Item	***Amount***
Population, 2030	310,750
Population, 2000	250,000
Increase in Population, 2000-2030	60,750
Average Household Size, 2030	1.3
Increase in Households, 2030	46,735

Environmental Land Use Forecast (2000-2030)				
Type of Development	***2030 Density (units/acre)***	***Percent of Total Units***	***Distribution of 2030 Households***	***New Development (Acres)***
High-End	0.50	50%	23,367	11,684
Suburban	0.75	15%	7,010	5,258
Rural	0.25	25%	11,684	2,921
Mixed Use	0.13	10%	4,673	608
Employment Acreage				1,893
				22,363



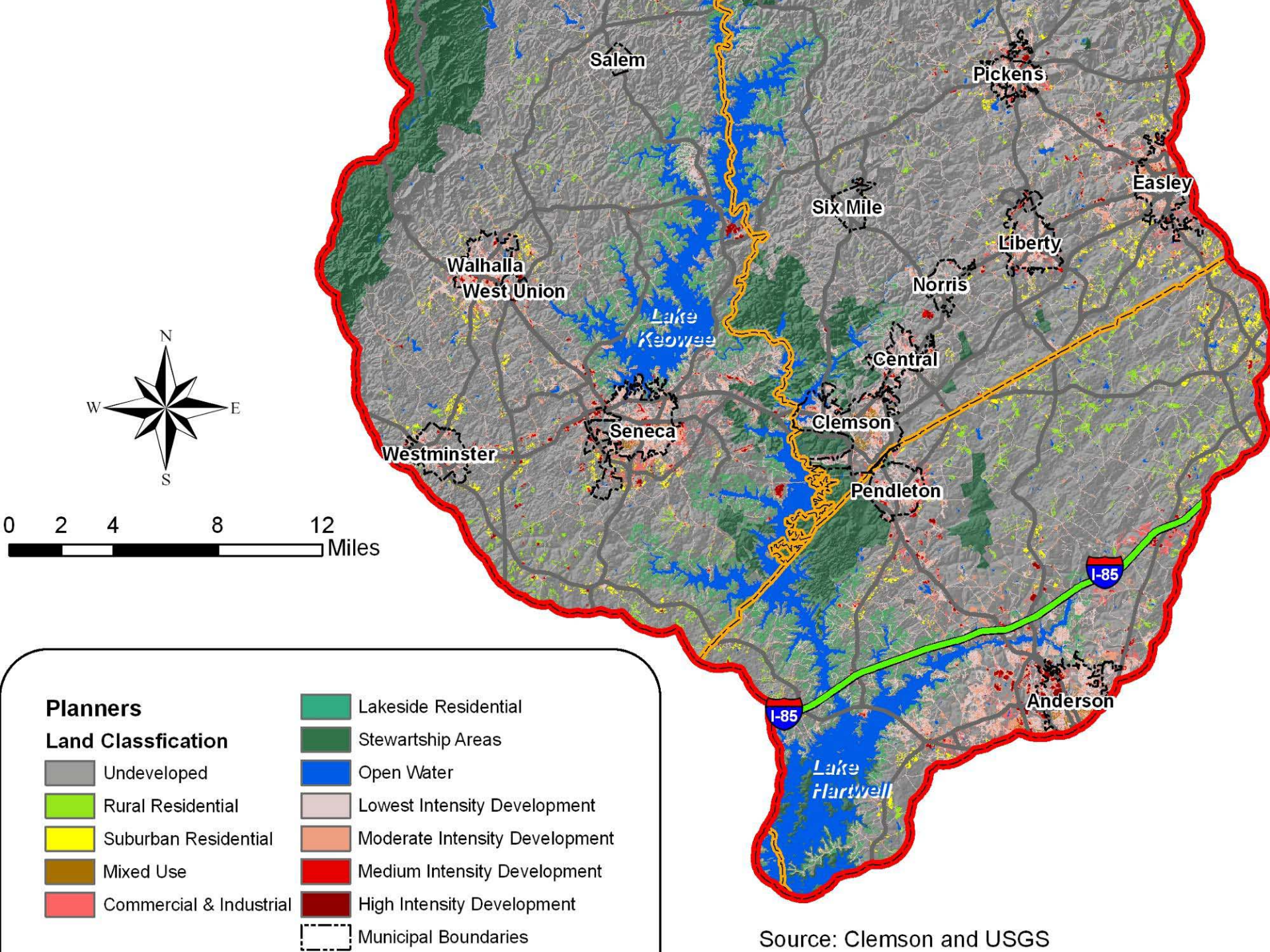
Source: Clemson and USGS

Projected Scenario

- Need 33,295 acres of new development
  - Assumed the mean projected growth rate
  - Assume mean household size because of more full time residents and workers
- Classified land uses based on the demand models
  - Highest 20th percentile
- Focused growth in the areas with minimal environment constraints
  - Lowest 20th percentile

Population Forecast	
Item	***Amount***
Population, 2030	371,500
Population, 2000	250,000
Increase in Population, 2000-2030	121,500
Average Household Size, 2030	1.8
Increase in Households, 2030	67,500

Projected Land Use Forecast (2000-2030)				
Type of Development	***2030 Density (units/acre)***	***Percent of Total Units***	***Distribution of 2030 Households***	***New Development (Acres)***
High-End	0.50	50%	33,750	16,875
Suburban	0.75	15%	10,125	7,594
Rural	0.25	25%	16,875	4,219
Mixed Use	0.13	10%	6,750	878
Employment Acreage				3,730
				33,295



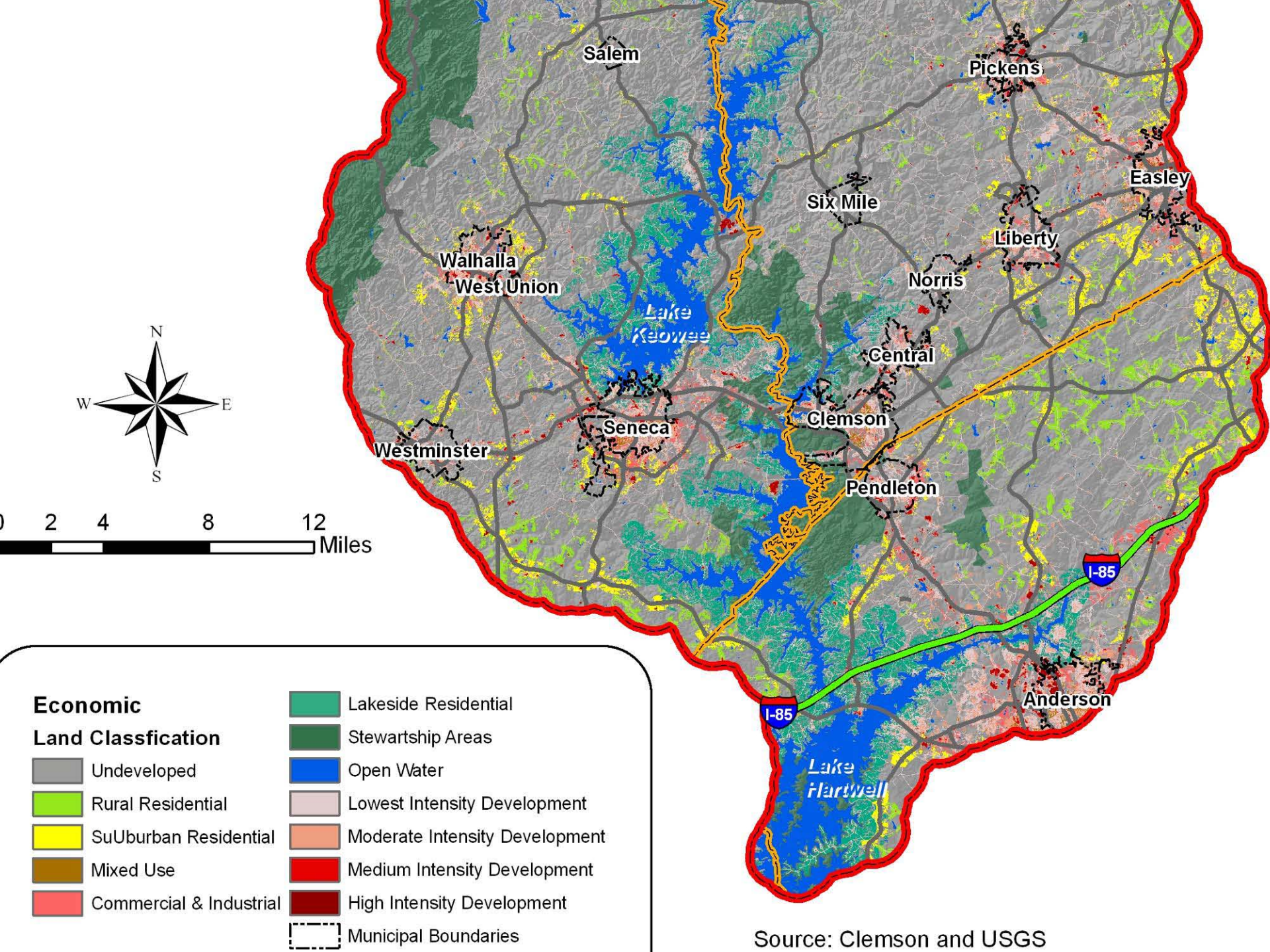
Source: Clemson and USGS

Economic Scenario

- Need 55,919 acres of new development
- Assume a doubling of the projected growth rate
- Assume highest household size because the emphasis on jobs
- All land uses are in the top 20th percentile
- Environmentally sensitive lands are not as critical
  - Focused growth in the areas with the moderate environmental constraints
  - The lower 40th percentiles

Population Forecast	
Item	***Amount***
Population, 2030	492,000
Population, 2000	250,000
Increase in Population, 2000-2030	242,000
Average Household Size, 2030	2.0
Increase in Households, 2030	121,000

Economic Land Use Forecast (2000-2030)				
Type of Development	***2030 Density (units/acre)***	***Percent of Total Units***	***Distribution of 2030 Households***	***New Development (Acres)***
High-End	0.50	33%	39,930	19,965
Suburban	0.75	17%	20,570	15,428
Rural	0.25	40%	48,400	12,100
Mixed Use	0.13	10%	12,100	1,573
Employment Acreage				6,853
				55,919



Source: Clemson and USGS

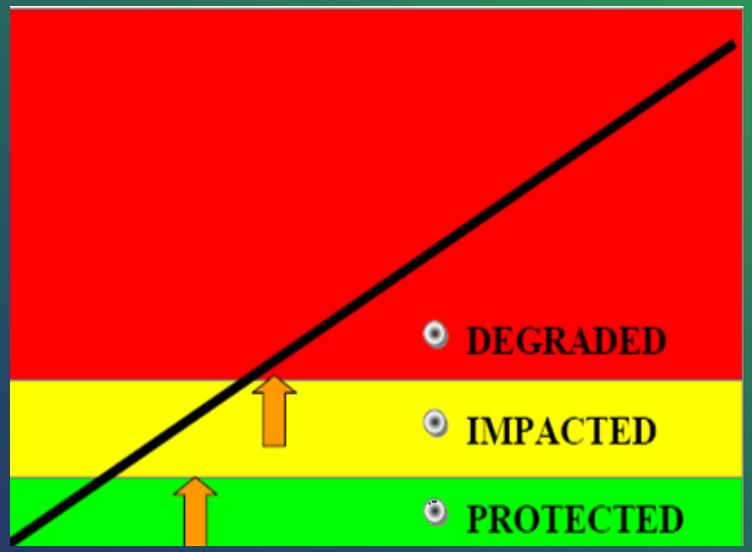
Scenarios Comparison

- Over the 30 year period the plans' new development were:
  - Environmental adds 28% to the developed acreage
  - Planning adds 42%
  - Economic adds 70%

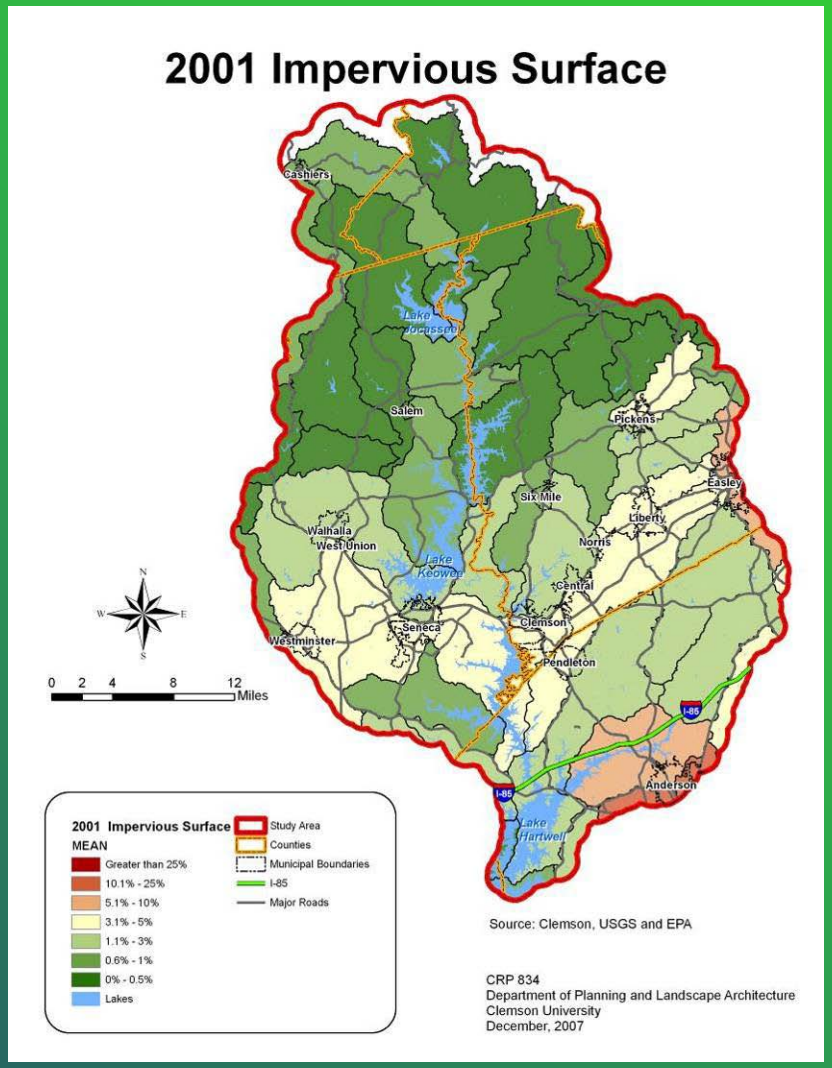
Development Category	Environmental Acreage	Projected Acreage	Economic Acreage
Undeveloped	505,870	494,646	463,601
Rural Residential	2,921	4,219	12,100
Suburban Residential	5,257	7,594	15,428
Mixed Use	608	878	1,573
Commercial/Industrial	1,893	3,730	6,853
High-end Residential	11,683	16,875	19,965
Stewardship Areas	109,377	109,377	109,377
Lakes	51,093	51,093	51,093
Existing Low Intensity Development	52,802	52,802	52,802
Existing Moderate Intensity Development	19,302	19,302	19,302
Existing Medium Intensity Development	5,074	5,074	5,074
Existing High Intensity Development	2,371	2,371	2,371

Stream Health and Impervious Surface

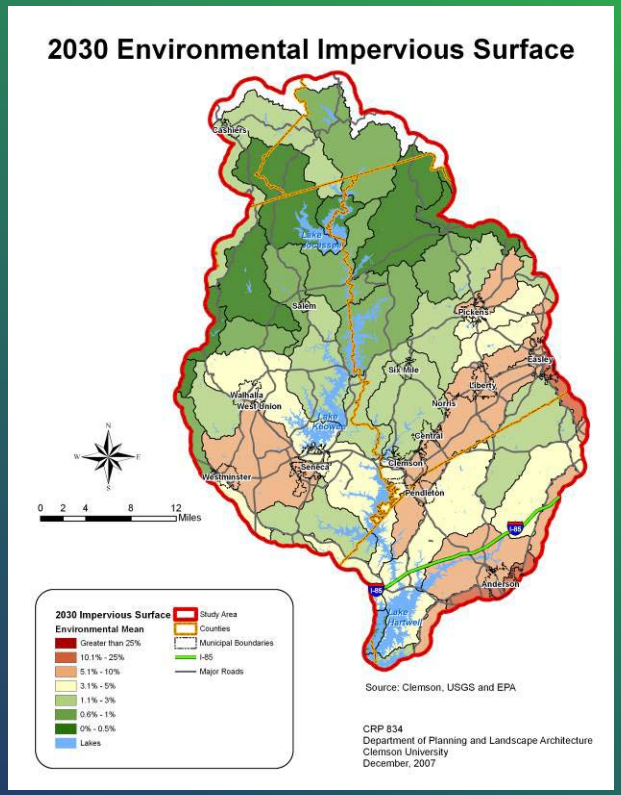
- Analysis at the subwatershed level
- Affects water quality, habitat, hydrology and stream stability
  - Impacted at 10%
  - Degraded at 25%

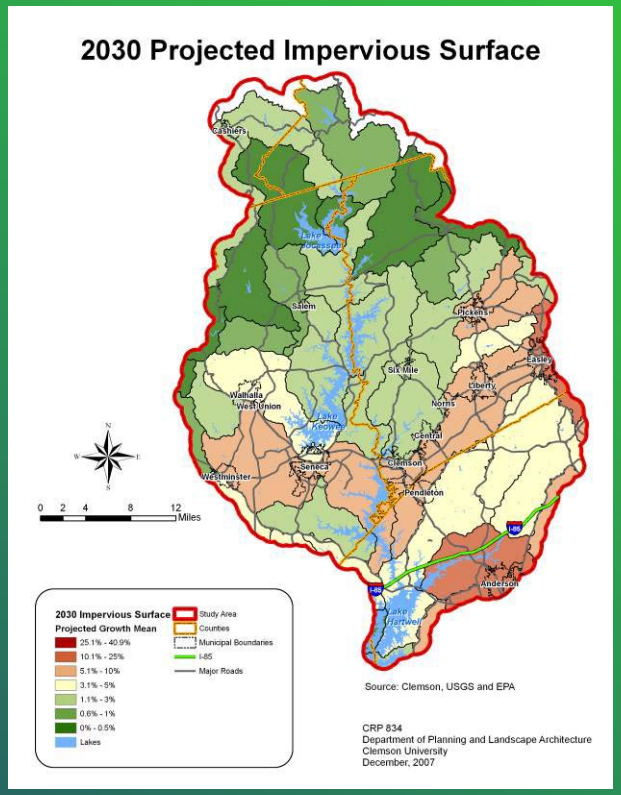


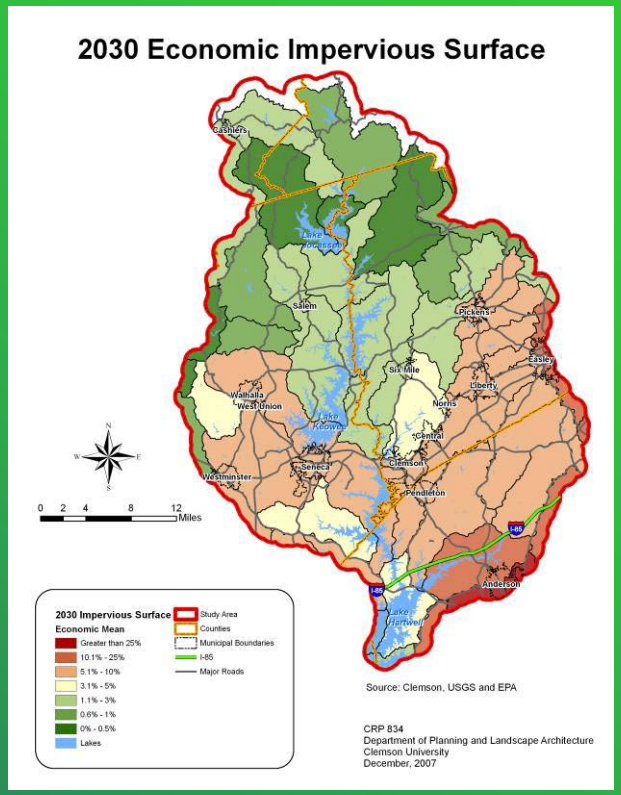
Adapted from Schueler et al, 1994



Impervious Surface





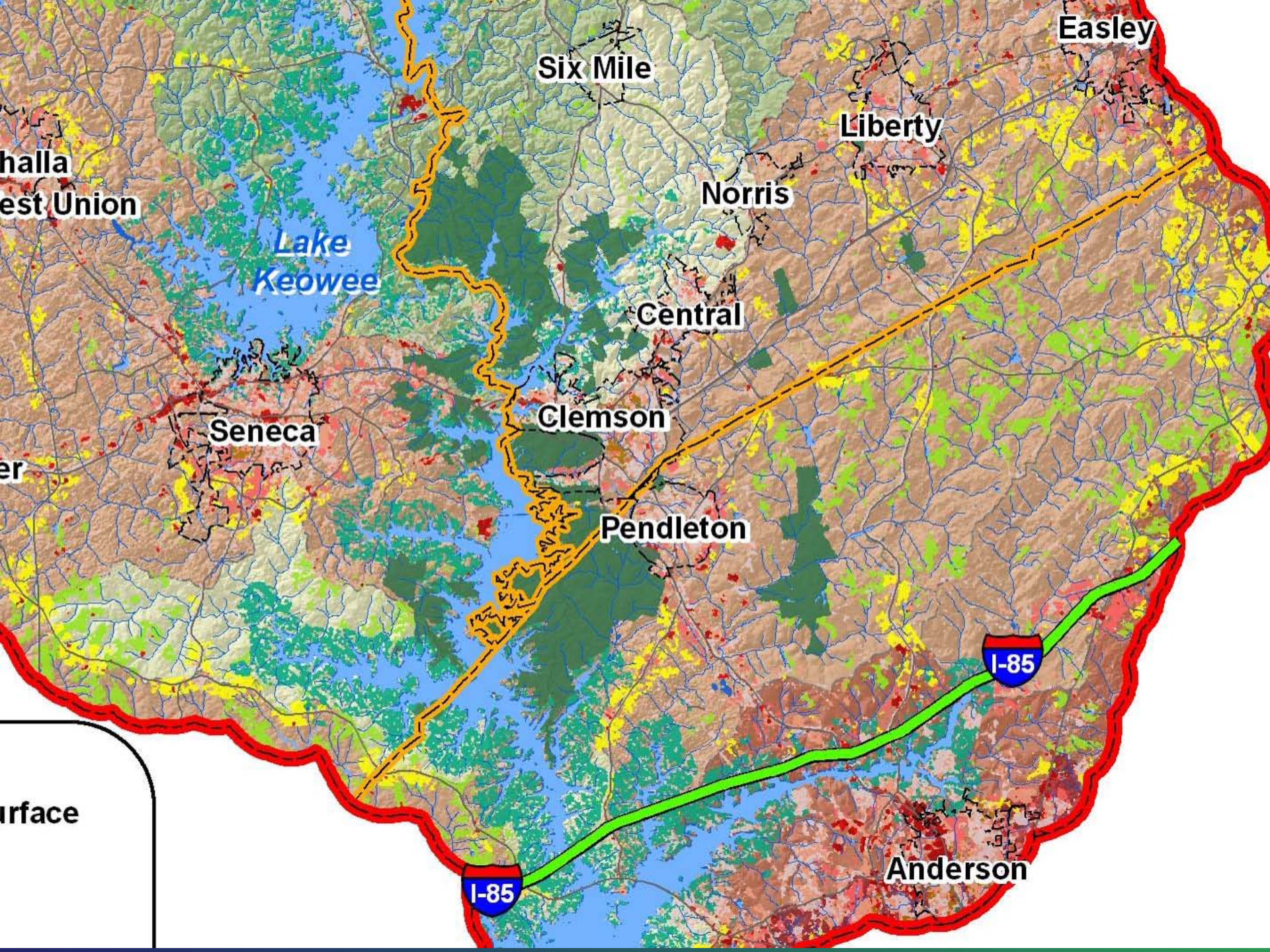


Impacted Watersheds

- Lake Hartwell will be impacted by development from Anderson and Easley

Scenario	Watersheds by Percent Change					
	>25%	>50%	>100%	>150%	>200%	Average
Evironmental	43	29	14	4	1	80%
Projected Growth	43	37	18	7	4	110%
Economic	44	43	31	16	12	174%

Scenario	Category	Subwatersheds	Square Kilometers	Hectares	Square Miles	Acres	Percent of Seneca Watershed	Mean Impervious Surface
2001	Mean <10%	42	2,864	286,355	1,106	707,584	99%	2.26
Evironmental	Mean <10%	42	2,864	286,355	1,106	707,584	99%	3.52
Projected Growth	Mean <10%	41	2,761	276,121	1,066	682,295	96%	3.94
Economic	Mean <10%	39	2,721	272,052	1,050	672,241	95%	5.28
2001	Mean>10%	2	26	2,613	10	6,455	1%	13.56
Evironmental	Mean>10%	2	26	2,613	10	6,455	1%	18.27
Projected Growth	Mean>10%	3	128	12,847	50	31,745	4%	18.14
Economic	Mean>10%	5	169	16,916	65	41,798	5%	17.84


Easley
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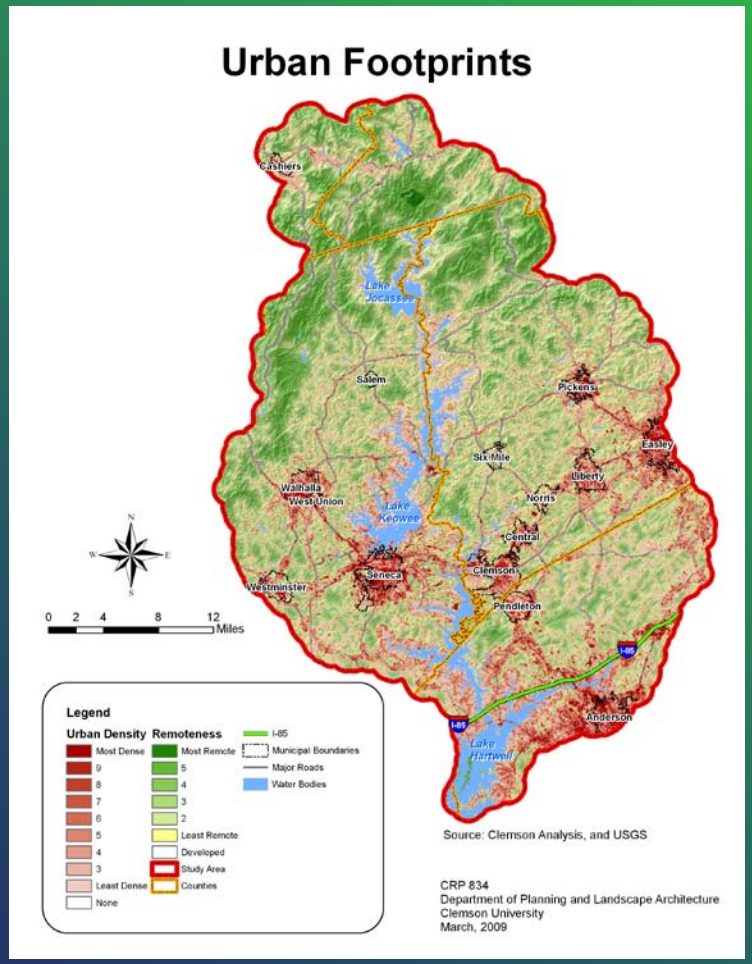
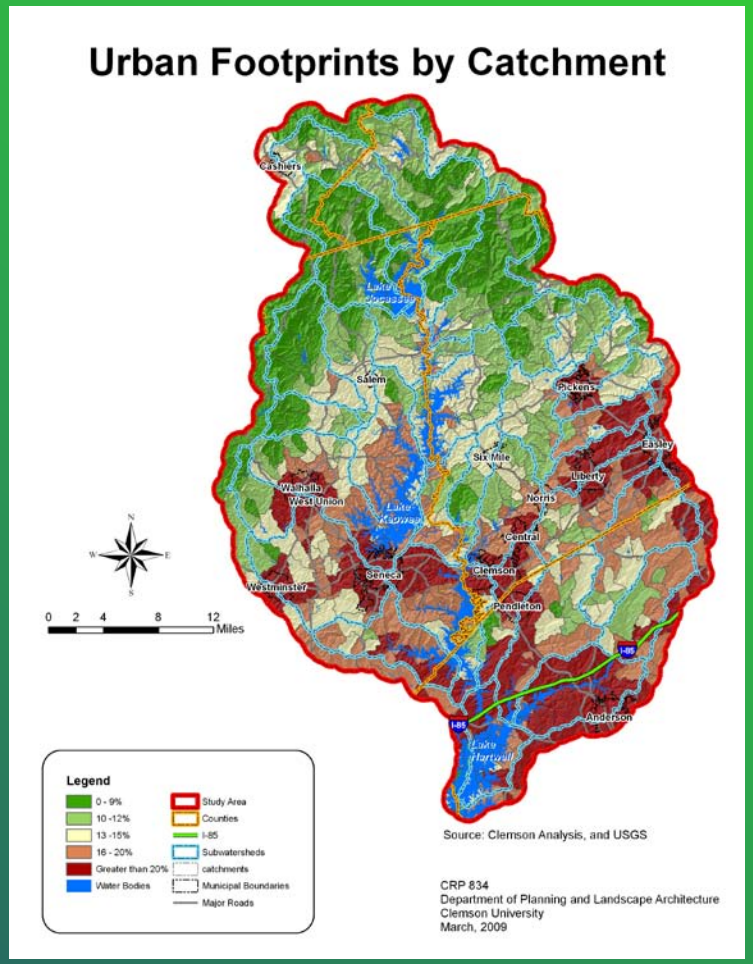
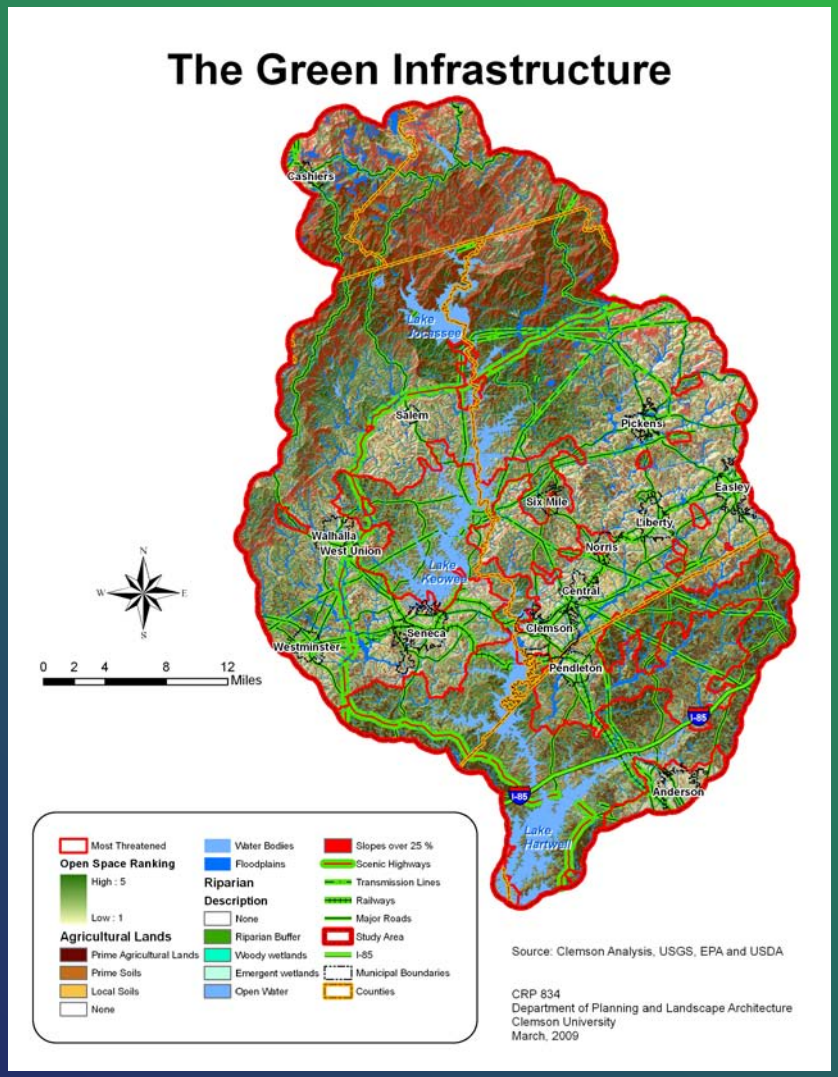
Urban Footprints

Urban Footprints





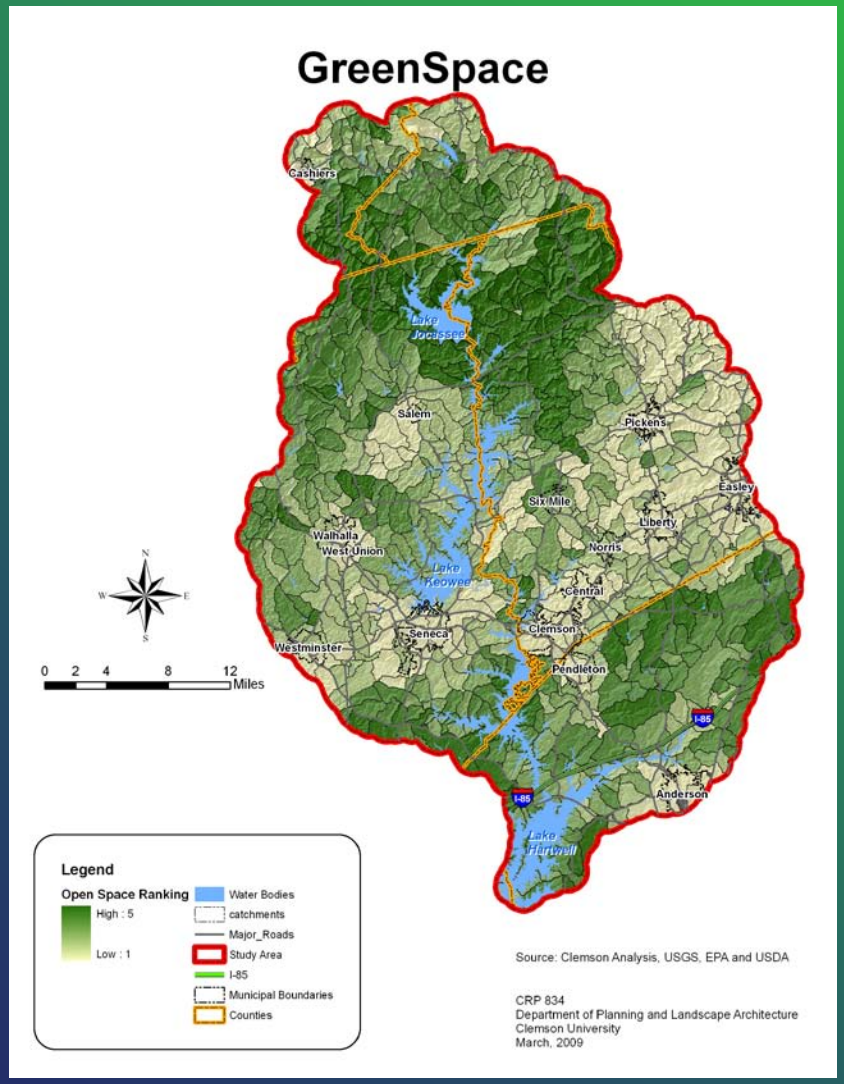
The Landscape Mosaic

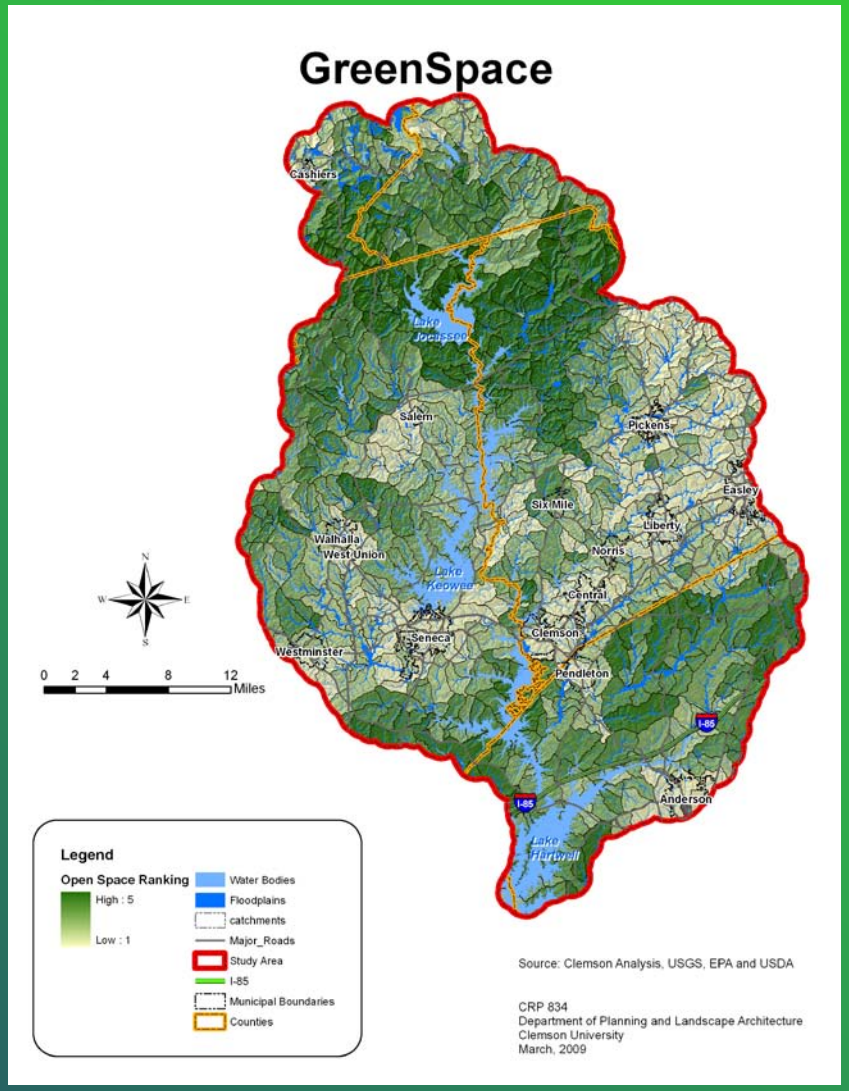


- It is made up of both natural systems and human land uses
- It is entirely composed of three types of elements:
  - Patch - a relatively homogeneous area
  - Corridor - a strip of land that differs from the land on both sides and links patches
  - Matrix - the background ecosystem or land use type in a landscape

Richard T.T. Forman (1995)

GreenSpace


GreenSpace
Cashiers
Lake Jocassee
Salem
Pickens
Easley
Six Mile
Liberty
Walhalla
West Union
Norris
Lake Keowee
Central
Seneca
Clemson
Westminster
Pendleton
I-85
Anderson
Lake Hartwell
N
W
E
S
0 2 4 8 12 Miles
Legend
Open Space Ranking
High : 5
Low : 1
Water Bodies
catchments
Major_Roads
Study Area
I-85
Municipal Boundaries
Counties
Source: Clemson Analysis, USGS, EPA and USDA
CRP 834
Department of Planning and Landscape Architecture
Clemson University
March, 2009


GreenSpace
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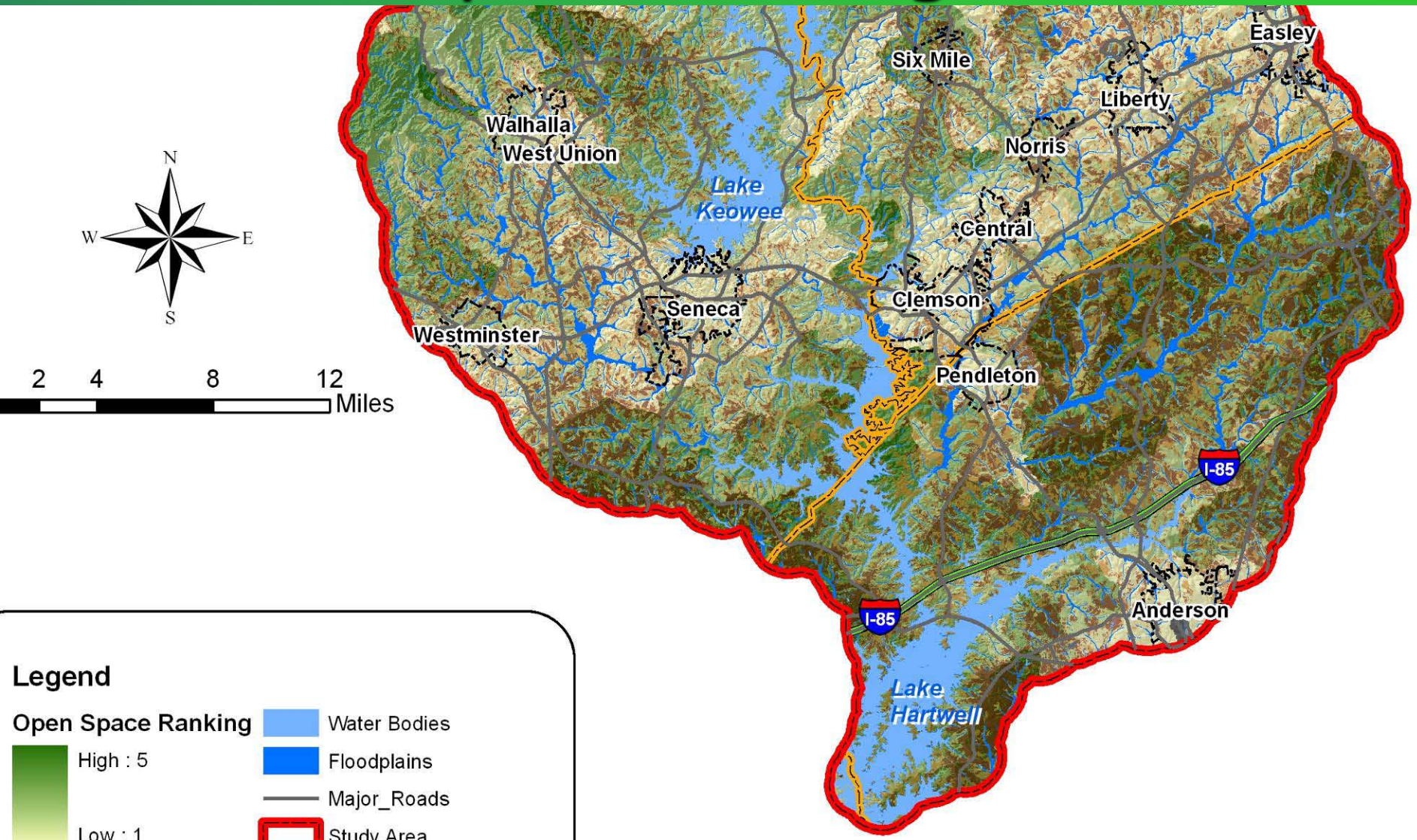
GreenSpace and Agriculture



Legend

Open Space Ranking

High : 5

Low : 1

Agricultural Lands

Prime soils in use

Water Bodies

Floodplains

Major_Roads

Study Area

I-85

Municipal Boundaries

Source: Clemson Analysis, USGS, EPA and USDA

Green Infrastructure

Conclusion

- Growth & Competition for Land:
  - Commercial & Residential
  - Conservation
  - Water quality
- Using Standard GIS capabilities and National Data
  - Familiar interface
  - All planners can use
- Using common tools and generating multiple scenarios can lead to positive discussions

- The Next Steps
  - Work with stakeholders to develop a sustainable plan
  - Revise models
  - Tie to parcels
  - Future outlook:
    - Policy Development & Implementation
    - A Focused Overlay
  - Make the process relevant to the public
    - Address local issues: Traffic, housing costs, open space