A Decision Support System for the Brevard County's Barrier Island System

by
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Abstract

Title: A Decision Support System for Brevard County’s Barrier Island System
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Coastal development in barrier islands is an important and current issue in Integrated Coastal Zone Management. The high value of waterfront property creates a high demand for development and places great pressure on the environment, curtailing the sustainable development of the coastal zone. As people continue to move towards the coastline, landuse allocation tends to favor urban and tourism developments, which increase the negative impacts and the costs of shore protection from natural hazards (e.g. coastal erosion and flooding).

The goal of this research was to design a Decision Support System capable of quantifying through simulation the effects of the implementation of different coastal development policies over a 10-year period on the future land use patterns of a region and on the area’s capacity to sustain current population growth rates. Two areas on the Florida's Brevard County barrier island were chosen to assess the viability of the designed framework: the City of Satellite Beach and the South Beaches unincorporated area.

Land use patterns were used as a measure to quantify coastal development. Different coastal development policies were simulated and the changes in the land use patterns analyzed. The effects of chosen policies on the socio-economic reality of the areas were predicted and the potential damages and costs of tropical and extra-tropical storm surges estimated. The two case studies chosen illustrated well the capabilities of the model when simulating the effects of the different development policies on the future land use patterns of the area.

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Chapter 1
Introduction

The Need for Integrated Coastal Zone Management

The Coastal Zone is the interface between land and water, and the adjacent transitional areas, where freshwater, estuarine and saltwater systems meet. Coastal areas provide food, habitat and refuge to numerous species and "are among the most productive ecosystems on earth" (Clark, 1996). At the same time they supply the human society with a source of natural resources, culture and recreation (Clark, 1996; Costanza *et al*., 1997), and host in the majority of the coastal nations, the most important urban centers (World Resources Institute, 1996). As an example in the United States one third of the population live in the coastal zone (Clark, 1996).

The Coastal Zone has always been the preferred location for the sitting of large industrial and commercial centers due to its easy access to water for "waste disposal and transportation" (Kalo *et al.*, 1994). Along the waterfront of major coastal cities, development is primarily industrial or commercial (World Resources Institute, 1996). However, in the last decades, the shift from the manufacturing industry to the services, finance and banking, and global telecommunications industries (World Resources Institute, 1996) has driven away the sitting of the manufacturing industrial facilities, to areas further away from the coast.

Coastal areas are no longer seen as future industrial or commercial centers, but as highly valuable property with great potential for residential, tourism and recreational development. Particularly in smaller coastal cities, tourism and residential development constitutes the bulk of the developed coastal area, and has become the major contributor to the local economy for those areas.

Ironically, coastal areas are also high risk areas, having great level of exposure to the impacts of natural hazards such as: hurricanes, ocean and riverine driven floods and storm surges, sea level rise, tsunamis and shoreline changes from coastal erosion, accretion and land subsidence. In spite of this risk, population continues to grow along beaches and shores, subjecting lives and property to those dangers (Carter, 1991; Kalo *et al*, 1994; Clark, 1996; Bird, 1997). In order to protect the resident and tourist communities, from coastal erosion and natural hazards, developed country's governments, spend millions of dollars (Kalo *et al*., 1994; Clark, 1996) in shore protection measures. It is estimated that in the US about \$300,000 per km^2, are spent in prevention, reconstruction and maintenance for shore protection (Bird, 1997). In spite of the controversy over beach nourishment issues, some authors defend that these costs are usually balanced by the high value of beachfront property and by the contribution that recreational uses of the coast line makes to the local economies (Kalo *et al*, 1994; National Research Council, 1995).

The Case of Barrier Islands

Barrier Islands are one of the most sensitive and unstable lands in the coastal zone. Typically barrier islands are characterized by an "oceanic beachfront having a dune and forest interior and a back marsh or mangrove forest protecting a lagoon estuarine system on the back". Barrier islands expand and retreat in response to storms and fluctuations in sea level, currents and sediment supply, and accordingly are subject to the local sediment dynamics (erosion and accretion) (Clark, 1996). Furthermore these systems provide a combination of "aesthetic and scenic values for people, and habitat and food source for many species" (Clark, 1996; Costanza et al., 1997) and are one of the favorite recreation, tourist and residential spots of the coastal zone. For this reason, and in order to maintain development on these systems, several artificial structures have to be built and maintained, to reduce the actions of oceanic and meteorological forces (Carter, 1991; Clark, 1996).

The rate of development in barrier islands in the US has accelerated since the 1950's, which corresponded to a change from about 10 % to about 33 % of the developable shoreline acreage, by early 1990's (Kalo *et al*., 1994). The same authors give for the same period a development rate for barrier islands in the US of 5000 to 6000 acres per year. Figure 1.1 shows an example of the degree of development that can be found in many barrier islands.

Figure 1.1. Aerial view of the central region of the Brevard County, Florida barrier island system as of December 1994.

Much of this development resulted from the federal and state assistance and subsidies, with programs such as infrastructure funding, shoreline protection, flood insurance, and disaster relief. In addition, due to its degree of exposure to natural hazards, development on coastal barrier islands involves tremendous costs. The average annual storm damage to coastal property on those areas amounts to billions of dollars, not including the additional public costs needed for disaster relief (Kalo *et al*., 1994).

Integrated Coastal Zone Management

Development in coastal areas has been made mostly at the expenses of the local natural resources. In addition, pollution associated to industrial development and high density residential development, as well as the filling of coastal wetlands for commercial, residential, and recreational development (Kalo *et al*., 1994) and the changes in the natural sediment dynamics induced by man, have contributed to reduce land availability in the coastal zone. As a result development pressure in the few remaining undeveloped areas as increased greatly.

The goods and services coastal areas offer to social and economic development and its potential utility depend on the maintenance of the functional integrity of the natural systems. Over the years coastal managers have focused their management strategies on the minimization of incompatibilities between private and public uses and have disregarded the protection of the ecologically sensitive natural resources.

For this reason implementation of optimal mixes of economic activities that include not only development of new housing, industry and commercial business, but also fisheries, habitat protection, sustainable use of water resources, eco-tourism, and so forth are essential in order to maintain the integrity of the coastal areas. To find an optimal and sustainable use of resources is one of the main goals of an integrated coastal zone management approach.

With all this in mind there is a perceived need to design analysis tools to help decision makers and planners integrate all the necessary information and to predict the effects that their decisions have on the overall sustainability of the area. Decision Support Systems (DSS) can be very useful and effective in using compiled information (Timmermans, 1997), to represent the interactions and the possible synergetic affects of several issues (variables) involved in the resolution of coastal problems. Therefore they constitute a helpful tool for planning and decision making for coastal zone management.

Decision Support Systems

Decision Support Systems (DSS) are “computer-based information systems” (Uljee *et al*., 1996), built to assist planners and decision-makers to experiment in time and space with different strategies and alternatives to different problems, and to assist them in identifying the issues that can lead to future problems. There are a few decision support systems having applications to coastal zone management, which focus on land use changes, impacts of natural hazards such as sea level rise, population growth and resource economics (Engelen *et al*., 1995,1996,1997b; Uljee *et al*., 1996; Resource Analysis, 1997) and alternative ranking for environmental impact assessment (Resource Analysis, 1997). The range of application of these systems has been increasing and has the potential to be extended to the fields of environmental auditing, assessment of impacts of policy changes, finance prioritization and so forth.

In general regional DSSs make use of the spatial analysis capabilities of geographic information system, and link them with existing simulation, planning and decision models, through a “friendly” user interfaces, usually created using a programming language flexible enough to allow the designer of the DSS to integrate the two. According to Engelen *et al*., 1996 and Uljee *et al*., 1996 DSS's are constituted by:

- A graphic user interface (GUI) that “hides” the technical software code from the end user, and allows him/her to access databases, and run numerical models. The analytical models built in, are based on existing scientific, decision and statistical models, and constitute a set of tools that help simulate, compare, and evaluate different decision alternatives.

- A database Management System (DBMS), which in the case of Integrated Coastal Zone Management (ICZM) is usually a Geographic Information System (GIS), defining the geographic area. “Geographic Information Systems, in general, have additional analytical and decision support features that can enhance the capabilities of the DSS ” (Uljee *et al*., 1996).

Decision Making With Decision Support Systems

Strategic planning for sustainable development is a dynamic process (Vriens and Hendriks, 1997) which involves a preliminary investigation for data collection and needs assessment, negotiations with interest groups, and information structuring in order to better define and characterize the issue or problem and set the necessary goals and objectives that will lead to the finding of possible solutions to the problem (See Figure 1.2).

With the notable exception of the environmental impact studies, which by law (WEST, 1996) must include an evaluation of alternatives to minimize the impacts of what is being proposed, the most common planning documents do not go much further than the presentation of the collected information and the setting the goals and objectives of the issues (for example a set of policies for a region) being discussed.

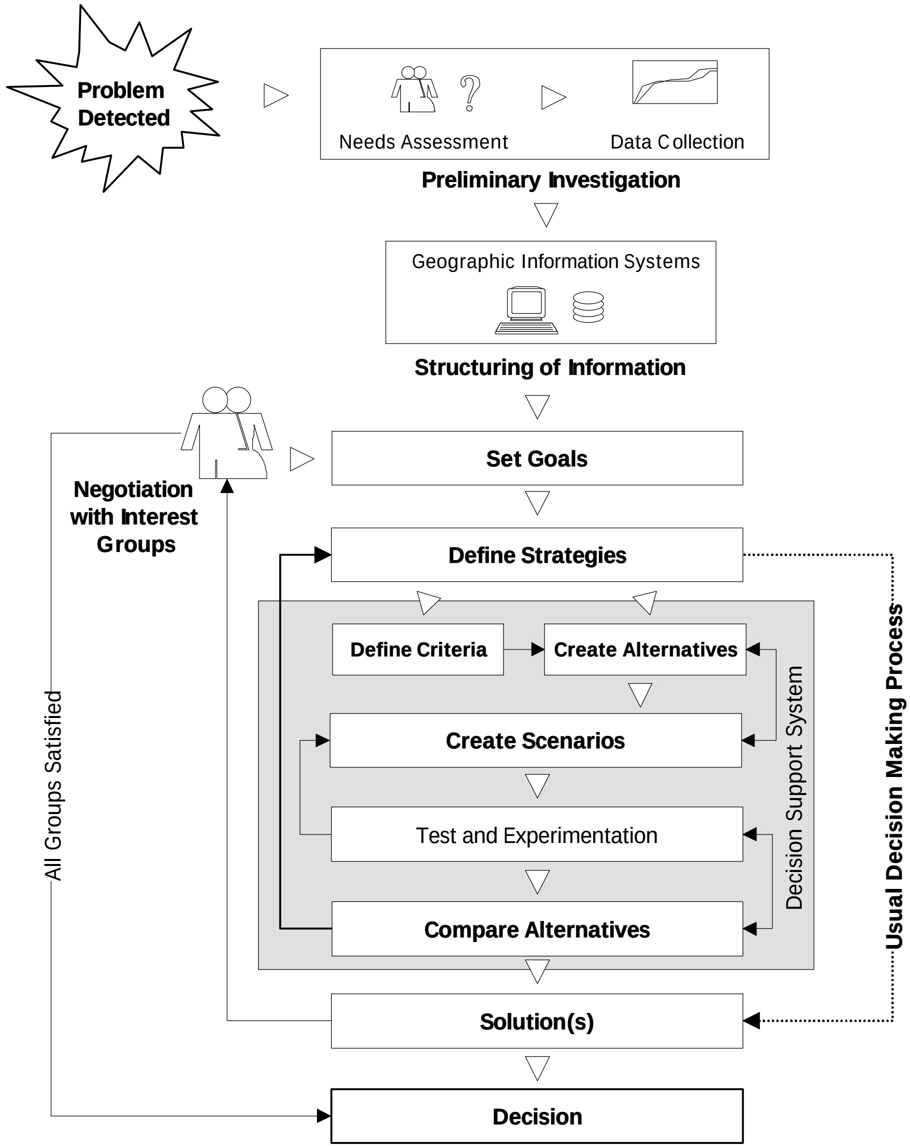


Figure 1.2. Dynamics of the decision making process with and without a Decision Support System (Adapted from Resources Analysis, 1997; Timmermans,1997; Carvalho *et al*. 2000).

As a result, managers are usually faced with the task of sorting out large amounts of information which may or may not provide solution to the problem, and forced to make a decision without a clear knowledge of the impacts their decisions may have in the future of the area.

In order to simplify this task and to provide managers with a concise summary of all the possible outcomes and risks associated with the choice of a specific alternative, the planning process must move on to the next level (See Figure 1.2) and provide the necessary set of strategies and criteria that allow the testing and comparison of all the pertinent solutions or alternatives to the problem in a timely manner.

The Decision Support System Framework presented in this research, introduces a simulation tool that provides a way to test several "What if" scenarios and makes possible the determination and selection from all the possible outcomes, the alternative that best satisfies the goals and objectives set forth for the future of the region. These are discussed in detail in Chapter 2.

Chapter 2
Research Overview

As mentioned briefly in Chapter 1, there are a few decision support systems that have been applied in the area of coastal zone management. The two systems mentioned (Engelen *et al*., 1995,1996,1997b and Resource Analysis, 1997) use two very different approaches in their design of tools for decision-making. The first makes use of "cellular automata" simulation techniques, to model the evolution of the land use patterns of a region with time. The second constitutes a framework of strategic planning steps for alternative testing and ranking in the area of environmental planning, within a friendly graphic user interface. This research constitutes an attempt to integrate these two different decision support system designs into a unique modeling framework, and to evaluate the feasibility and applicability of such design to one of the most controversial issues in coastal zone management: Coastal Development.

Key Issues

One of the main issues in this research was to find a measure to quantify coastal development. The research conducted by Engelen and White's Group, and described in detail in Chapter 6, provided the solution to this problem. In their research Engelen and White used the cellular automata methodology to simulate changes in land use patterns and to quantify the effects of different socio-economic trends on the overall sustainability of a Caribbean Island (Engelen *et al*., 1997a).

Land use patterns reflect the development policies implemented in a region over time. Accordingly if land use historical information in the form of maps or any other geographically referenced data are available for a subject region, it is possible to simulate using the cellular automata methodology the historical evolution of those land use patterns.

The second important step consisted of choosing the research area. There was a need to select at least two areas subject to the same development pressures, which could be used to test and validate the decision support system framework proposed in this research. At the same time it was important that the two areas when subject to different development policies, could help provide some insight on the different aspects that fuel the controversy over costal development: optimal sustainable development of the land versus use maximization; and competition for land allocation between residential, commercial, tourism, and conservation uses. Once these two key issues were set it was possible to set the goals and objectives of this research. These are defined next followed by an overview of the research area chosen to test the implementation of the Decision Support System design.

Research Goal

The goal of this research was to design a Decision Support System capable of quantifying the effects of the implementation of different coastal development policies over a 10-year period on the future land use patterns of a region and on the area's capacity to sustain current population growth rates.

Objectives

1. To create a simulation tool to help managers and planners experiment in computer time with the effects of the different coastal development policies.

2. To use landuse patterns as a measure to quantify coastal development, and to simulate the changes on those patterns due to the implementation of the different coastal development policies.

3. To characterize the effects that the implementation of the development policies set forth in point 2 have on the area's overall sustainability and on its capacity to allocate current population growth rates.

4. To evaluate the potential damages and costs of tropical and extra-tropical storm surges in the area for the different development policies.

Research Location

The area chosen to develop this DSS was the Brevard County barrier island system. The island is separated from the mainland to the west by the Indian River Lagoon estuarine system and has to the east the Atlantic Ocean. The project area extended from the City of Cape Canaveral south to Sebastian Inlet (Figure 1).

The coastline of the barrier island extends for about 40 miles, over which there are distinct degrees of development. Development in the northern cities was driven mostly by the existence of Port Canaveral and the Kennedy Space Center, and by the presence of Patrick Air Force Base to the south of Cocoa Beach. Within the cities of Cape Canaveral and Cocoa Beach development patterns are a mix of commercial, tourism and residential uses (See Figures 6 and 7 in Appendix A), whereas the cities in the central area of the island (Satellite Beach south to Melbourne Beach) have predominantly residential uses. The southern part of the study area from Melbourne Beach south to the Sebastian Inlet – South Beaches, is much less

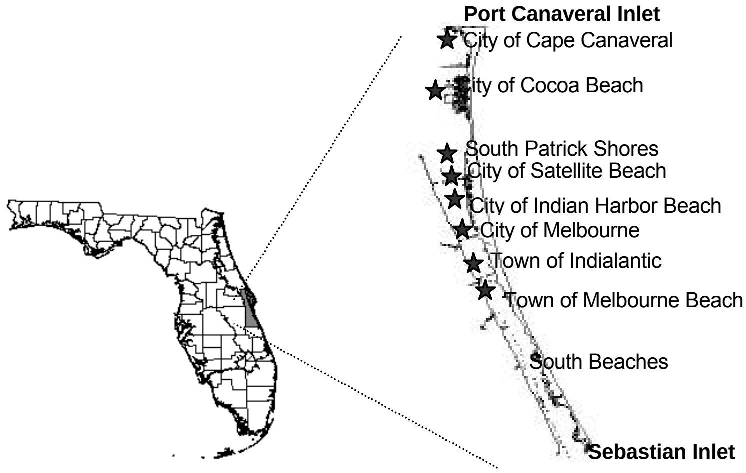


Figure 2.1. Barrier Island in Brevard County, Florida (Carvalho *et al.*, 2000)

developed constituting “a significant and valuable recreational and natural resource for Brevard County" (Rhodes, 1992).

Experimental Design and Research Hypothesis

Each land use pattern consists of a georeferenced data grid, which previously to its inclusion into the model is subject to considerable spatial analysis with a Geographic Information System (See Chapter 3 for details). There are two different groups of land use patterns:

Group one is composed of three observed historical data sets, which reflect the effects of all the land development policies implemented to date. This group is used in the calibration and validation process of the system to evaluate the capabilities of the DSS in reproducing via the cellular automata simulation the same land use patterns within the same time frame (5 years) (See Chapter 6 for details). The three land use patters are:

- The 1990 land use pattern - the calibration base year
- The 1995 land use pattern - the calibration end year and the validation base year
- The 2000 land use pattern - the validation end year and the base year for each scenario used to test each land development alternative

The second group includes all of the simulated land use patterns created via the cellular automata simulation. These are the calibration and validation land use patterns and all the future land use patterns that resulted from the runs from each scenario.

In order to assess the significance of the changes between each pair of land use patterns, the KHAT statistic or Kappa coefficient of agreement (See Chapter 5) was used to compare each pair of correspondent land use patterns. The cause effect diagram showed in Figure 2.2 illustrates the experimental design used to test the following research hypothesis:

H0: There are no significant changes in land use patterns over time as measured by kappa, explained by changes in land development policies.

Ha: There are significant changes in land use patterns over time as measured by kappa, explained by changes in land development policies.

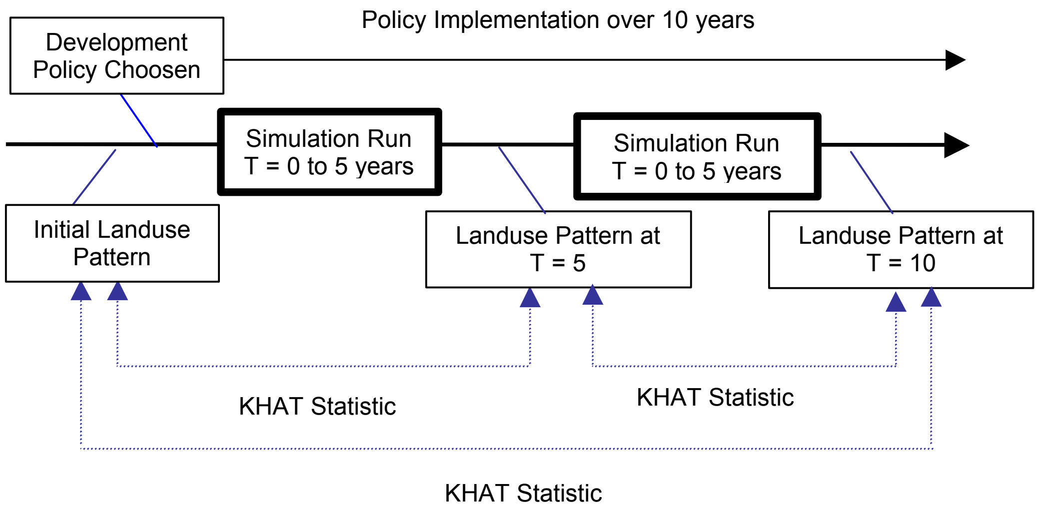


Figure 2.2. Cause effect diagram describing the procedures used to test the research hypothesis.

Choice of Representative Case Studies

It became evident as this research evolved that it would not be possible or logical to use a unique set of calibration parameters for the entire Barrier Island. In general the Comprehensive Plans of the Cities are in compliance with the County Comprehensive Plan, but at the same time the general development trends that each city has followed over the years can produce very different land use patterns.

Therefore two areas were chosen to represent the development trends in the Brevard County barrier island. The City of Satellite Beach and the South Beaches Area. The City of Satellite Beach was the pilot case that served as the basis for research organization, methodology testing and final algorithm testing and adjustment. The South Beaches Area was an attempt to apply the same methodologies to a different area having different characteristics, and evaluate the performance and applicability of the model to other areas of very different characteristics.

Application of the Research Methodology to other Areas

As will be demonstrated in Chapter 8, it is possible to apply the designed framework to other areas. It is also possible to use the same procedures to calibrate the model to the new areas. The system was initially calibrated for the City of Satellite Beach, which has a more homogeneous land use pattern than the one from the South Beaches. When transposed to the South Beach areas, a few new issues arise related to model response to the homogeneity of the land uses patterns, the boundary effects caused by the presence of fixed uses (See Chapter 3 and 5) and grid resolution. These issues are discussed in detail in Chapter 9.

Research Contribution

With this approach we show that:

- It is possible to use land use patterns as a measure for development
- The decision support system framework designed for the purposes of this research is capable of accurately reproduce the historical changes in land uses patterns for the region and that as result,
- It can provide an effective way to quantify the impacts of the local land development policies in the future land use patterns of the region, and this way help decision makers evaluate the risks and impacts its decisions carry.

Chapter 3
Data Collection, Structuring and Analysis

Socio Economic Data

Data Collection

Population data were taken from MARFIN Socio-Demographic Database, a compilation based on 1970-90 Census Statistics of the US Bureau of Census Population (LPDC 1998), and from 1990 - 97 population data from the Economic Development Commission of Florida's Space Coast (EDC 1998). Additional data from the Bureau of Economic and Business Research (BEBR, 2000) and the Florida Statistical Abstracts (BEBR, 1990, 2000) were also used to complete the socio - economic data and as a source of tourism data.

Information Structuring

Resident Population

Population data from the US Bureau of Census Population from 1970 to 1990 was available for 7 of the cities in the Barrier Island of Brevard County. Population data for the larger unincorporated area of the barrier island – the South Beaches, was taken from County reports, which give an approximate value for the 1990 population in that area (Brevard County Planning and Zoning Division 1991; 1998). The default (1990) value for the entire study area was estimated by adding the total population in each city with the unincorporated areas.

Population growth rate for individual cities was calculated by converting the total population change rate for the two decades to a yearly rate. Population growth rate for the all barrier island was calculated by averaging the 1970-1990 population growth rates for each individual city. It was assumed that the total population counts already reflected the natural growth rate and the migration rate for the 1970 to 1990 population.

Tourist Population

Tourist visitors to Florida are reported in the Florida Abstracts every year. The same report estimated that approximately 4.1 % of those tourists visit Brevard County every year. To account for the visitors to the barrier Island cities it was assumed that all visitors to Brevard County visit at some point the Barrier Island for recreation purposes and consequently stay on the local hotels and motels. An average number of tourists were attributed to each area based on the number of hotels and when available in the total yearly capacity of the hotels, assuming a average 60% occupation rate per year and three persons per room.

Job Opportunity and Economic Growth Rates

For the purpose of this research it was assumed that when the local economy is good and employment rates high, additional jobs are created in the area, causing an increase in the demand for residential waterfront property (more people are able to afford it). Based on this assumption, the function of the job opportunity growth rate in the DSS is to contribute to population growth in the area by determining the increase in local population due to the increase in the regional job opportunity.

According to the data from the 1970 – 1990 Census Bureau approximately 65 % of the population in the cities of the barrier island is in the labor force, hence the job opportunity growth is applied to the number of people that correspond to 65 % of the projected additional population for that year, and this amount added to the projected population. Furthermore if a negative job opportunity growth rate is considered the resident population will be assumed to decline, due to a decrease in job opportunities in the area (See Chapter 6 for details for growth rate function details).

The economic growth factor is used mostly to determine the tourism growth rate, based again on the fact that if the economy is good tourist visits to the county cities will increase and as a consequence the pressure to develop tourist facilities. During the simulation it is up to the user to monitor tourism growth and decide whether or not it will request land to be allocated for tourism.

Potential Population per Dwelling Unit

1970 to 1990 Census housing data (LPDC 1998) was used to determine an average occupation rate for dwelling unit for the cities. The number of vacant housing units was taken out from the number of available housing units to determine the number of housing units effectively occupied. Next, the number of total occupied housing units was divided by the total population counts for the corresponding years, and the average occupation rate per dwelling unit determined. The potential population for each area was then determined by multiplying the average dwelling unit occupation rate by the number of dwelling units allowed by the residential densities in the Zoning and Future Land Use maps for the area.

Spatial Data

Geographic Information Systems (GIS)

Geographic Information Systems (GIS) have contributed greatly to the quality of regional planning and decision-making (Timmermans, 1997), and to the study, assessment, quantification and evaluation of the impacts and risks associated with the increasing number of environmental problems caused by development. GIS capabilities go far beyond its most common use for storage, visualization and overlay of large amounts of data; It offers the user the capability to manage and query spatially referenced information, to perform advanced spatial analysis (Bernhardsen, 1992), and to link these capabilities with other modeling tools that help the planning and decision-making process. Once the data are structured into an integrated georeferenced data base system, the possibilities for data analysis and combination are greatly enhanced and studies can be performed in a very efficient and timely manner (Yaakup *et al*., 1997).

Land Suitability Analysis

The physical and environmental factors that need to be taken in consideration when determining the optimal use for a parcel of land can be analyzed using geo-referenced data and geographic information systems. Land suitability analysis is based on the idea that a "measure of the appropriateness or intrinsic suitability of a parcel of land to support a certain land use, can be calculated by combining geo-referenced data from existing landuse patterns, infrastructure and environmental features" (Bright, 1997).

Land suitability analysis, can be a very powerful tool when different demand scenarios such as the preferences of several interest groups need to be evaluated. Once the results of the land suitability analysis are combined with a decision support system that models land demand, it becomes possible to allocate the most suitable land parcels to a specific landuse based on the amount of land requested to be developed. Using this approach, a wide range of forecasts can be accomplished. Furthermore, including socio-economic data and demographic models in the analysis: for example population size and potential growth and/or employment opportunities, can be useful in planning new scenarios that are constrained by the professional ability of a relatively undeveloped area to grow based on the opportunities for social development.

Relationships between existing land characteristics and future landuse categories are quantified by assigning a weight to each land characteristic. The weight reflects the importance of that characteristic for the future landuse categories. Weight assignment as to accurately reflect not only the goals of the interest groups involved in the process (e.g. developers, the government and the community), but also the intrinsic suitability of the land for each use and the existing policies and land regulations pertinent to the situation. The combination of the characteristics and weights determines the most suitable areas that meet the future demands for the different the several landuses (Bright, 1997).

Spatial Data Structuring

ESRI' s geographic information system software Arc Info ™ and Arc View ™ and Arc View ™ 's extensions: Spatial Analyst ™ and 3D Analyst ™ were used in this research to compile and structure the area's spatial referenced information (See Appendix A), to perform spatial data analysis on available data and to prepare the input data grids for the Decision Support System designed in this research.

Data Sources

Spatial databases sources were the St. John Water Management District (SJRWMD), Brevard County (BC), the Florida's Department of Environmental Protection (DEP), the Florida Game and Fresh Water Fish Commission (FGFWFC), the Brevard County Property Appraiser Office (BCPAO). 1994 and 1999 aerial photographs from the United States Geological Survey (USGS), a video and photographs taken from a plane during 1999 and 2000 were used to assess the evolution of the different land use patterns since 1990. Table 3.1 lists the spatial data layers by origin used in this research. Metadata for each layer can be found in Appendix A.

Table 3.1 – Spatial data layers by origin and corresponding resolution

Spatial Data Layer	Origin	Scale
Land use land cover 1990	SJRWMD	1:24000
Land use 1995	SJRWMD	1:24000
Future Land Use	BC	1:24000
2000 Land Parcels and Psite data base	BCPAO	1:200
Roads	USGS	1:24000
Cities - Emergency Services Network Areas	BC PAO	1:100000
Elevation 5 foot contours	USGS	1:24000
Shoreline and Bathymetry	DEP	1:24000
CCCL 1986	BC	1:24000
Flood Hazard Areas	FEMA	1:24000
Hurricane Storm Surge	FDCA	1:24000
Conservation Lands	DEP	1:24000
District Lands	SJRWMD	1:24000

Data Manipulation

All spatial data was projected to State Plan Coordinates (in feet) and referenced to the High Precision GPS Network (HPGN) datum, using Arc Info's conversion tools. This datum is a readjustment of the National

Geodetic Vertical Datum of 1983 (NGVD 1983) to a higher accuracy level. Both datums use the GRS 1980 spheroid to represent the shape of the earth.

Polygon and line data layers were extensively edited using both Arc Info ™ and Arc View ™. Once the base data layers were built, Arc View 's Spatial Analyst ™ extension was used to convert the geo-referenced polygon and line data to spatially referenced 0.15 acres (25 m x 25 m) cell grids and to perform more detailed spatial data analysis. The percentage change (conversion error) in the total area for each classified characteristic due to conversion from polygon to a grid format was calculated when pertinent as a quantitative

The choice of the 25 x 25 meter grid cell was a compromise between being able to differentiate the intricate features of the development patterns in the barrier island and using a coarser grid, having less resolution, but that would not represent the needed detail. The resolution for each of the layers used was not uniform; source scales varied from 1:2400 to 1:200 and in the case of the original land use data some features less than 2 acres or in some cases less than 0.5 acres were not represented at all. As described in detail in the next section the land use layer had to undergo extensive editing in order to fairly represent the area.

In the majority of areas of the barrier island, such the 25 x 25 meter grid greatly surpassed the resolution of the edited land use layer, however as will be shown later in this research in areas like the South Beaches, a finer resolution could have been more helpful in dealing with the diverse landuse patterns of the area (See Chapter 6 and 8 for further details).

Spatial Data Analysis

Three main groups of grids were created to prepare the necessary data inputs for the various modules of the Decision Support System (See Chapter 4): the planning grids group, the suitability assessment grids group and the natural hazards planning group. Data manipulation applied to each original data set and the spatial data analysis performed in each group of grids is described and illustrated next. For detailed metadata information see Appendix A.

Planning Grids

1990, 1995 and 2000 Land Use Data

The reclassification of the original land use classifications in the 1990's SJRWMD land use land cover spatial data layer into sixteen land use categories (Figure 3.1.) constituted the first step of the data

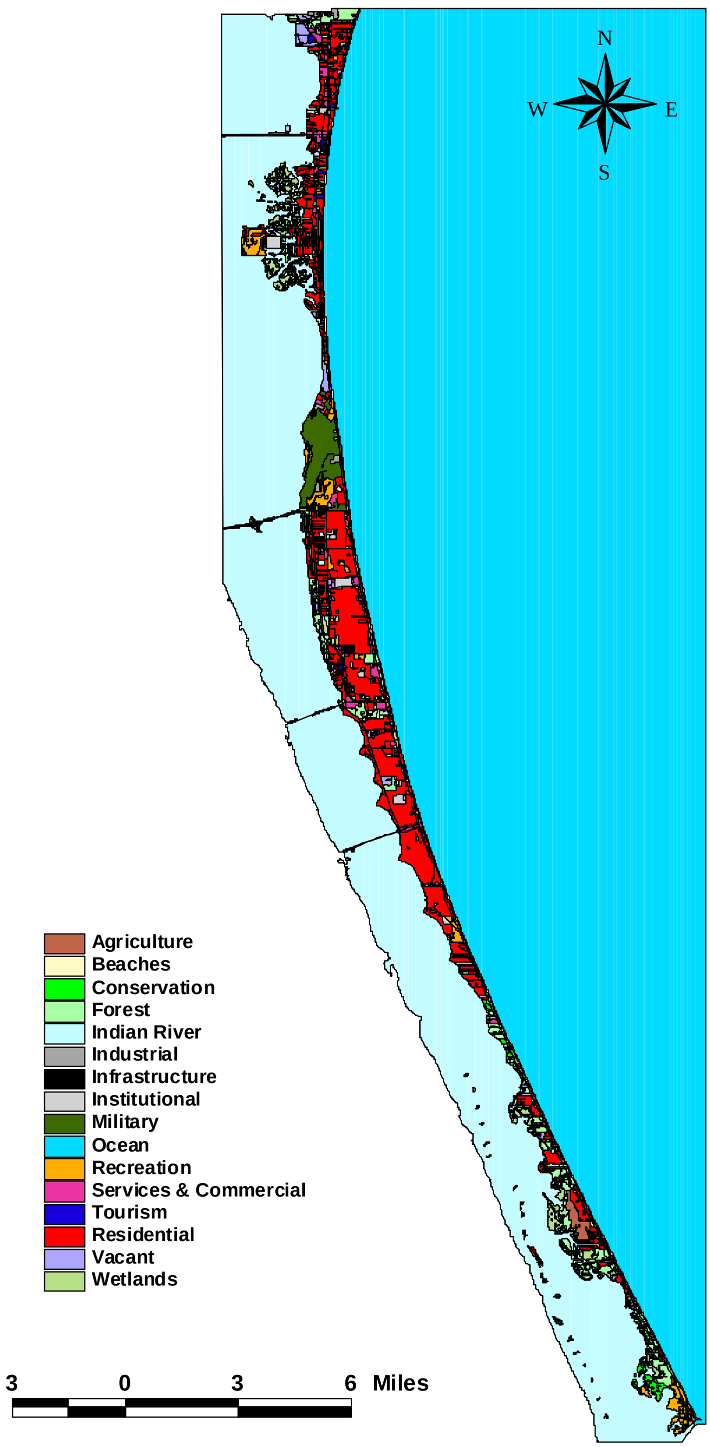


Figure 3.1. 1990 Land Use Layer

analysis process. The sixteen new land use categories created include: Vacant Land, Recreation, Industrial, Services and Commercial, Natural Forest, Infrastructure, Beaches, Wetland Areas, Residential, Institutional, Tourism Lodging, Conservation, Military, Agriculture, Indian River Lagoon and Atlantic Ocean. With this new broader land use classification it was possible to further edit this data layer by correcting some discrepancies between the 1990 and 1995 SJRWMD land use classifications, and to improve the detail (original scale 1:24000) of the 1990 landuse data layer. The parcel sale year and the built year information in the BCPAO's land parcels layer (scale 1:200) and parcel Psite database was used in this process.

Using the same BCPAO data and with additional information taken from the 1995 SJRWMD land use layer, 1994 and 1999 USGS aerial photographs and occasional visits to the study area two more land use layers were created from the original 1990 land use layer: one containing the land use changes occurred in the barrier island from 1990 to 1995 and a second one with the changes occurred from 1995 to the current year 2000.

The three layers were converted to grid format (See Appendix A - Figures 1 to 3) and the 1990 land use grid was directly imported to the DSS and used as the base year land use pattern for the land use allocation simulation. The 1995 and 2000 land use grids were kept aside for calibration purposes. The calibration and validation process is discussed in Chapter 5.

Roads Grid

The USGS roads layer classifications were grouped into two categories (See Appendix A – Figure 4): one category including major roads in the barrier island: S.R. A1A, S.R. 528, S.R. 520, S.R. 404, S.R. 518, S.R. 513 and U.S. 192 as well as some local arterial roads, and a second category with all the remaining minor and local roads. Only the main road category of this layer was converted into grid format, because when converted to grid, all roads acquire the same resolution of the rest of the grids, in this case 25 m x 25 m. As a result it was assumed a minimum width of 25 m for all the main roads in each grid. Since the second category of roads was only used as display a layer with this category was created to use when necessary.

Population Carrying Capacity Grid

The population carrying capacity grid (See Appendix A – Figure 5) represents the potential built up capacity (in number of people, of each land parcel or the parcel's capacity to accommodate a determined number of residents. The layer was built by multiplying the area's residential density information (in dwelling units per acre) available in the BCPAO Parcel and Psite database by an average resident density for the area (average number of residents / dwelling unit). When converted to grid format, the average population density was adjusted to reflect population density per cell (25 x 25 m or 0.15 acres). The population capacity grid is used by the DSS for its population growth capacity calculations and in the Natural Hazards Module to calculate the potential number of people at risk from storm surges.

Land Suitability Analysis Grids

The suitability grids represent the intrinsic suitability of the land cell to a specific activity. Land suitability analysis was used to calculate the suitability grids for the four main land use activities considered in this project: Residential, Commercial and Services, Tourism Lodging and Conservation. To create the suitability grids, first, it was necessary to prepare the grids for the land suitability analysis. These grids are described next.

Future Land Use Grids

Future land use maps are part of the required elements of county and local government's comprehensive plans, and include future land use designations and residential densities planned for the area within a 10 to 20 year planning horizon. The future land use layer (See Appendix A – Figure 6) was built by combining available future landuse information obtained from the Brevard County / SJRWMD future land use data layer, the 1998 amendments to Brevard County's Comprehensive Plan, the local cities Comprehensive Plans, and the Brevard County's Property Appraiser's Parcel Data Base. Once converted to grid format, this data set was used in the land suitability analysis discussed further in this chapter.

Planning and Zoning Grid

This planning layer (See Appendix A – Figure 7) was designed to reflect the political will and local development policies that have been shaping the development patterns in the cities and unincorporated areas of the Brevard County's barrier Island. The layer was built by combining when available, local zoning designations from the Planning and Zoning Division of the Brevard County Office and Brevard County Property Appraiser's Office. Once converted to grid format this layer was also used in the land suitability analysis.

Vacant Lands Grid

This grid was built by overlaying the vacant land parcels of 1995 and 2000 from both the land use and the planning and zoning grids (See Appendix A – Figure 8). This grid was created to calibrate the suitability grids for the land allocation simulation. Further details on the simulation calibration are discussed in Chapter 5.

Suitability Grids

Suitabilities in each of the four grids were scaled from 0 to 20, with 20 representing the highest suitability of a particular cell for that particular use z. Mostly it corresponded to all the lands developed for that particular use as of 1995.

Originally the suitability land analysis weights assigned to each participating grid was 5 meaning that if four grids contributed to the suitability, the maximum suitability would be 20. An exception had to be made in the suitability analysis for conservation, which used five grids. For this reason the suitability range intervals were ultimately set to four points for all grids.

Suitability levels had to be reduced also out for calibration purposes. For example all lands that remained vacant as of 1995 would normally be in a 12-point suitability level, since they are suitable for development, but are still vacant. However, it was found in the preliminary test runs of the model, that 12 points was to much if we needed to delay the development of those lands during the land allocation simulation (See Chapter 5 for details). Therefore land parcel in this situation was ultimately weighted four points.

Suitability for Conservation Use Grid

This suitability for conservation grid was established by combining five different grids (See Figure 3.2):

Future Land Use Conservation Public Lands	+	Planning & Zoning Conservation Public Lands	+	District Lands 98 Existing	+	Conservation Lands 1996 Existing	+	Land Use 1995 Existing	=	20
Future Land Use Conservation Public Lands	+	Planning & Zoning Conservation Public Lands	+	District Lands 98 Existing	+	Conservation Lands 1996 Existing	-	Vacant Land as of 1995	=	4
Future Land Use Conservation, Public & Agriculture	+	Planning & Zoning Conservation, Public & Agriculture	+	District Lands 98 Proposed	+	Conservation Lands 1996 Proposed	-	Vacant Land as of 2000	=	2

Figure 3.2. Layers and Categories used for the Conservation Suitability Grid and the weights assigned to each combination

- DEP's conservation lands layer, which constitutes a collection of existing and proposed conservation lands for the state of Florida as of 1996;

- SJRWMD's District and Public Lands as of 1998 layer, which contains data of all public lands owned by the District and by other public agencies, as well as some of the lands with potential to be acquired in a near the future for conservation.
- The conservation and public categories from future land use and planning and zoning grids, and
- The vacant lands grid

Some of the public (Federal, State, County and Municipal) lands are set aside for conservation are recreational areas. For the purposes of this research, if these lands were acquired after 1990, they were included in the Conservation land use category so that they could be used in the simulation. This was the case for the recreation areas: Coconut Grove and Bonsteel Beach Parks, in the South Beaches. Figure 9 in Appendix A shows the final Conservation suitability grid used in this research.

Agriculture lands categorized as such in the Future Land Use grid and in the Planning and Zoning grid were given a weight of 2 suitability points, since the possibility that agriculture lands are allocated for conservation, is considered in the Brevard County comprehensive plan. Currently the South Beaches area is the only place in the Barrier Island where there are still lands allocated to agricultural use.

For the purposes of calibration, all the proposed conservation lands were assigned a weight of zero, to avoid interference with the calibration and validation process. This step was necessary in order to keep the magnitude of the suitability weights for all the grids balanced, since normally in the suitability for conservation grid these lands would have a two-point weight. However because it was necessary to reduce the weight of the 2000 conservation lands in the planning and zoning to a 2 point weight in order to calibrate the model it was necessary to remove all the proposed lands. Otherwise they would be interpreted as equally suitable and assigned for conservation at the same time as the lands developed during the year 2000, ruining the calibration process. For the forecast runs these lands were reassigned to their original weight of two suitability points.

Suitability for Residential Use Grid

The suitability for residential use grid was created by combining the residential land use categories of the Future Land Use and Planning and Zoning Grids, and by adjusting the resulting grid, with the residential use category from the 1995 and 2000 land use grids. For calibration purposes, the suitability values were corrected with the vacant land’s residential categories for 1995 and 2000 (See Figure 3.3). Figure 10 in Appendix A shows the residential use suitability grid for the all barrier island, used in this research.

Future Land Use Residential	+	Planning & Zoning Residential	+	Land Use 1990 Residential	+	Land Use 1995 Residential	= 20
Future Land Use Residential	+	Planning & Zoning Residential	+	Planning & Zoning Tourism			= 12
Future Land Use Residential	+	Planning & Zoning Residential	+	Planning & Zoning Conservation			= 8
Future Land Use Residential	+	Planning & Zoning Residential	-	Residential Vacant Land as of 1995			= 4
Future Land Use Residential Agriculture	+	Planning & Zoning Residential, Conservation & Agriculture	-	Residential Vacant Land as of 2000			= 2

Figure 3.3. Layers and Categories used for the Residential Suitability Grid and the weights assigned to each combination

The categories where the tourism and lodging uses are included in the Future Land Use or the Planning and Zoning Grids are not classified uniformly in the local comprehensive plans and other local documentation consulted. Sometimes hotels and motels are located in residential land use categories, whereas other times they are located in mix or commercial categories. For this reason the category Tourism Lodging was adopted in this research, and given a weight of twelve suitability points in the residential suitability grid. This 12-point assignment was made to reflect the fact that since tourism development tends to compete with residential development, the lands that are currently allocated to tourism have the potential to be redeveloped into residential use in the future.

To all the lands that are currently zoned residential and are included in the Future Land Use layer as such, but that are currently allocated to conservation use, was given a height point suitability weight. This is the case mostly in the South Beaches area where the Richard King Mellon Foundation, has acquired a considerable amount of residential vacant land for conservation purposes. These lands, if ever sold, are potential residential lands are thus suitable for development.

A two point suitability weight was also given to lands currently allocated to conservation or classified in the Future Land Use and Planning and Zoning layers as conservation, and to all land classified as agriculture. Some of these lands have potential for residential use and accordingly they included in this grid.

Suitability for Services and Commercial Use Grid

The suitability for Services and Commercial grid was built by overlaying the industrial and mixed-use categories of the Future Land Use grid and the industrial and commercial use categories of the Planning and Zoning Grid. Adjustments were made with the 1990 and 1995 industrial and services and commercial 1990 and 1995's land use grid categories. For calibration purposes, the suitability values were additionally corrected with the commercial vacant land categories from the vacant lands grid for 1995 and 2000 (See Figure 3.4).

Future Land Use Mix & Industrial	+	Planning & Zoning Commercial & Industrial	+	Land Use 1990 Industry & Services & Commercial	+	Land Use 1995 Industry & Services & Commercial	= 20
Future Land Use Mix & Industrial	+	Planning & Zoning Commercial & Industrial	+	Planning & Zoning Tourism			= 16
Future Land Use Mix & Industrial	+	Planning & Zoning Commercial & Industrial	-	Vacant Land as of 1995 Services & Commercial			= 4
Future Land Use Mix & Industrial	+	Planning & Zoning Commercial & Industrial	-	Vacant Land as of 2000 Services & Commercial			= 2

Figure 3.4. Layers and Categories used for the Services and Commercial Suitability Grid and the weights assigned to each combination

The industrial use was included in this category for suitability purposes only, since some of the light Industry uses are sometimes classified as commercial and vice versa. Figure 11 in Appendix A, shows the Services and Commercial use suitability grid for the entire barrier island used in this research.

The tourism use in this grid is was given a weight of sixteen suitability points to account for the fact that in spite of the disparities in classification, lodging is a commercial use and it can be classified as such.

Suitability for Tourism Use Grid

According to the spatial data used in this research, there were no new motels or hotels built on the barrier island in the last decade. The focus of development was instead, high-density residential development – condominiums, which are very often used by the tourists but that are considered as residential use, and thus classified as such in this research.

In order to create a scenario that would contemplate tourism development along the beaches as well as high-density residential development, the Suitability for Tourism grid was created as shown in Figure 3.5.

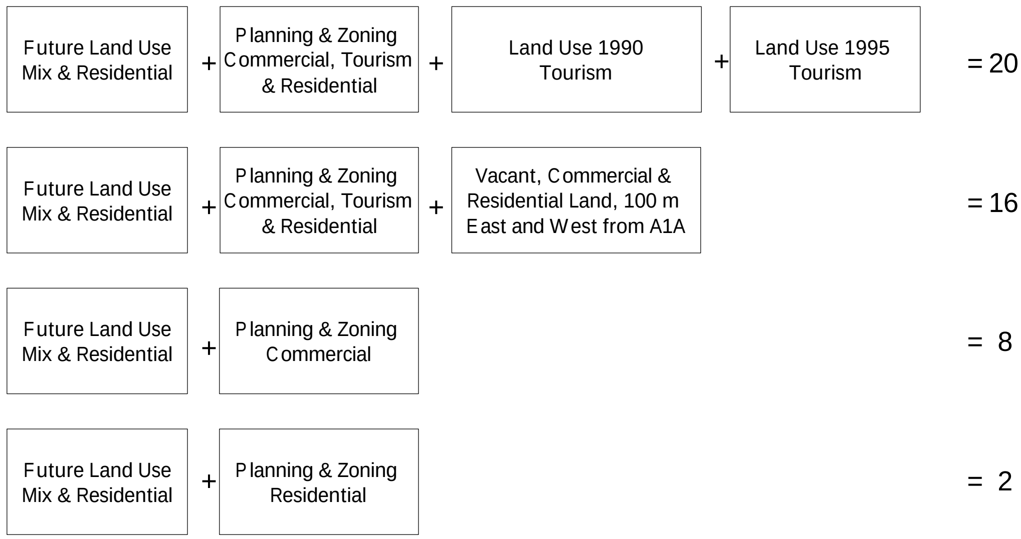


Figure 3.5. Layers and Categories used for the Tourism Lodging Suitability Grid and the weights assigned to each combination

The one hundred meters buffer to the east and west of A1A was meant to set the ocean frontline as the area with highest potential for tourism development, since it is mostly along the main roads that all commercial and tourism uses are built. Very low suitability was assigned to all residential areas within the interior of the barrier island and along the riverfront, but a height point suitability weight was given to the areas suitable for services and commercial development in the same areas, since by being already assigned to commercial use they are automatically eligible for some type of tourism development. The resulting grid is shown Figure 12 in Appendix A.

However one should keep in mind that the current State of Florida legislation (Chapter 161. Part 1. Sec.161.052 (1)) does not allow the “construction of any structure within 50 feet of the line of mean high water or of the erosion control line, when established, which ever is the most landward line”. In addition the County Coastal Construction Control Line sets additional requirement for all the construction built to the east of that line. The land use grids used as a base for this research do not include this buffer in either side of the barrier island (Atlantic Ocean Beaches and Indian River Lagoon), thus it was assumed, for the purposes of this research, that all the area classified as “developable” in these grids already includes the necessary buffers from the shoreline.

Natural Hazards Planning Grids

Elevation – Bathymetry Layer

This layer is a combination of the USGS elevation data layer containing elevations above mean high water for the entire barrier island area at 5 foot contour intervals, and the DEP's shoreline and bathymetry data layers, containing bathymetry information at 3 feet contour intervals. The resulting data layer once converted to grid format (See Figure 13 in Appendix A) was used to calculate elevation based storm surge impacts on the area within the Natural Hazards Module of the Decision System, described in Chapter 4.

Federal Emergency Management Agency (FEMA)'s Flood Hazard Areas Layer

FEMA's Flood Hazard Areas Layer data are derived from the Flood Insurance Rate Maps (FIRMs) published by the Federal Emergency Management Agency (FEMA). The FIRMs are the basis for floodplain management, mitigation, and insurance activities for the National Flood Insurance Program (NFIP) (See Appendix A for Metadata). This layer once converted to grid format (See Figure 14 in Appendix A) was used to build the potential storm surge impact risk areas grid.

Hurricane Storm Surge Impact Areas

This layer was developed by The State of Florida, Department of Community Affairs, Division of Emergency Management for the Florida Hurricane Surge Atlas. This layer contains a summary of surge height estimates made using the SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model, and depict "worst-case" storm surge inundation that provide a basis for evacuation decisions and for other study purposes. The storm tide delineations reflect simulated conditions at high tide, with an additional 1.5-foot included for oceanic values, and 1.0 foot added for inland bays and waterways. The effects of waves, rainfall, and flooding from overflowing rivers are not included in this data layer (See Figure 15 in Appendix A).

Potential Storm Surge Impact Risk Areas

The Potential Storm Surge Impact Risk Areas grid (See Figure 16 in Appendix A) was built in three steps. The first step consisted in combining the 5-foot contour USGS elevation and the bathymetry DEP layers into a single layer; the second step consisted of converting the latter to grid format along with FEMA's Flood Hazards Areas layer and the Brevard County Coastal Construction Control Line of 1996 layer. The final step consisted in combining all thee grids into four risk areas according to Table 3.2

Table 3.2 – Spatial data layers used to prepare the Potential Storm Surge Impact Risk Areas Grid

Risk Areas	Flood Hazard Areas (*)	Elevation	Relative to CCCL 1986	Relative to Riverfront Shoreline (SL)
River Front	AO, X100, X500	> 15 ft	West	100 m West < SL < 100 East
Interior of Barrier Island	X100, X500 AO, AE	> 15 ft	West	> 100 m East
Dune	AO, X500	15 – 25 ft	West	> 100 m East
Ocean Front	VE, AE, AO, X100	> 15 ft	East	> 100 m East

(*) See Appendix A for term explanation and Metadata

The 15 foot elevation limit was established because the dune front along the eastern side of the barrier island is in many areas higher than 15 feet. As a consequence, only a storm surge higher than 15 feet will over pass the dune ridge, and impact the interior areas of the island. By the same token, it would be very unlikely that a storm surge originated in the Indian River would overpass the dune area. For that reason it was created a risk area, which is only considered if the oceanic storm surge chosen by the user is above 15 ft.

Property Market Value Layer

The Property Market Value layer (See Figure 17 in Appendix A) was built from the adjusted property market value (land value and building value combined) information available from the BCPAO Parcel and Psite database for a large part of the land parcels in the Barrier Island (See Appendix A for metadata information). When market values were not available, the values from the surrounding parcels were used.

Individual Case Grids

For the City of Satellite Beach and South Beaches case studies (See Chapters 7 and 8), the barrier island grids were clipped using the city limit boundaries available from BCPAO (See Figure 18 in Appendix A). The road network grid was added to the land use grid after clipping. A summary of all the grids used in each case can be found together with the respective case study Appendix.

Variability of the Spatial Data

There are several sources of error that can be attributed to the spatial data. If one follows chronologically the creation of a GIS layer, the first errors have to do with the resolution of the source data and with the process used to create the digital data. For example digitizing the layer from paper maps, or scanning an aerial photograph and then digitizing the same area directly over the scanned map or aerial photograph will produce different results, even if both have the same resolution (Bernhardsen. 1992).

Secondly, even assuming that the feature digitalization process was fairly accurate, the classification of the different data categories is not uniform. For example a vacant parcel of land can be classified as “vacant land” or as forested land depending on the objective of the classification. In a developer’s perspective, that land is vacant because it does not have any structures, but in a biological perspective that land is “forested land” because it is not cleared and does not have any visible infrastructure. This subjectivity is acceptable if one is dealing with two different layers, and it becomes up to the user to combine the two using his/her own criteria. Unfortunately it is very common to have this subjectivity within the same layer, so it is very important that all these issues are taken into consideration when the same data are used in other applications, as is the case in this research.

The last error source discussed here occurs when the polygon data layer is converted to grid, format, and as discussed previously in this Chapter, this source of error was accounted for in this research, and was added to grid map displays shown in Appendix A.

Chapter 4
Scenario Strategic Planning

Scenarios should be flexible enough to include a maximum number of issues and problems of a subject geographic area, but the same time they should focus on points that lead to the achievement of the goals the system is designed for. The user interfaces of these types of systems can be easily customized, and its preferable to design separate modulus, focusing on a certain issue and integrate the results, than try to simulate too many variables all at once. This not only can significantly slow down the system performance in terms of time, but more importantly it can significantly increase the variability of the system.

In order to make comparisons between scenarios, it is important that the same criteria are used to assemble the different alternatives. The alternatives chosen need to be feasible, effective and cannot inhibit the accomplishment of other plans (Wyatt, 1997). Accordingly a wide choice of the alternatives should be tested, to facilitate the decision making process, and increase the probability of satisfying the goals and objectives of all the interests involved. Hence, criteria allowing the comparison between alternatives have to be objective enough to facilitate the decision, and quantitatively describe the issues being tested (Wyatt, 1997).

As stated in Chapter 2, the goal of this system was to design a tool that would apply the landuse patterns to measure development, and that would make possible to simulate the effects of different development policies on the local landuse patterns, keeping in mind the socio-economic impacts of such policies. In order to accomplish this task, a set of socio economic and land development criteria were put together, along with groups of policies to prepare a range of alternatives to research the issue. These are discussed next.

Socio – Economic Component

<u>Socio - Economic Alternatives</u>

No predetermined socio-economic alternatives were assembled. However it is possible by changing the magnitude of the growth rates, to consider scenarios having very a very high tourism growth rates, or very high population growth rates. The first scenario could consider the increase in the number of tourist visiting the area as trigger to increase the demand for tourism development to accommodate such high visitor growth rates. The second could use the same reasoning to increase the residential development demand and so forth.

Socio - Economic Criteria

Three life quality indexes were included that link population growth and development. These are the conservation Index, the recreation Index and the residential density Index. Each of these indexes is influenced by the changes in the development patterns (acreage allocated to the respective land uses) and by changes in the magnitude of the socio – economic growth rates (See Chapter 3).

Conservation Index

The Conservation Index (acres conservation land / # people) reflects changes in the amount of available public and conservation land per inhabitant. This index is an indirect measure of the development pressure, and of the response of the local governments to that pressure. If land is allocated to conservation or public use, the development potential of the area is curtailed, on one hand because land scarcity increases the market value of the available property and consequently the costs of development; and on the other hand because the longer that land remains in conservation use the longer it takes for the city to be completely build up.

Recreation Index

The Recreation Index (acres recreation land / # people) reflects the pressure added to the existing recreational areas, with increasing population. Since recreation is a fixed use category in this research, increasing population will decrease the amount of land available per inhabitant on the area, and as a consequence the amount of residential space each person cans use.

Residential Density Index

The Residential Density Index (# people /acres residential land) measures the number of inhabitants per acre of residential land, and it reflects the population density of the residential areas. This index is an adjustment of the residential density classification of the Land Regulations, which is given in dwelling units per acre, to a population count. The quality of life tends to be lower in areas where residential densities are higher.

Regional Population Carry Capacity

A fourth variable was considered based on the assumption there are physical limits to the number of people that can occupy a certain region. These limits are geographically imposed by the region's physical and political boundaries, and regulated by the limits in use density prescribed by the local ordinances (for example residential densities, or traffic levels of service). For the purposes of this research these limits were designated as the regional Population Carrying Capacity (maximum # people /acres residential land), and were included in the simulation as a way to limit population growth (See Chapter 5), and to determine the likelihood of such state being achieved within the prediction horizons of the system.

Tourism Regional Capacity

This last variable was created to overcome the lack of tourism data for the area. The total number of rooms from all the hotels in the studied area was used to calculate this variable. It was assumed that the rooms were occupied by 3 people and that the yearly occupancy rate for the hotels was of 60 %.

Land Development Component

Land Development Policies

The land development policies considered in this research are based on Brevard County Zoning Regulations (Article VI) from the Land Development Regulations (Section 62-1255.) and on the goals, objectives and policies of the Future Land Use Element of the Brevard County Comprehensive Plan (Brevard County, 1998). Additional rules and legislation were used for the specific cities when necessary.

The tourism use is not a category of the Future Land Use, but it is considered in the Land Development Regulations as a zoning classification, and as a result was included in this research.

Four groups of policies were considered: one that favors maintaining conservation and agriculture lands in its undeveloped state; a second one that favors development of all lands; and a third one that allows redevelopment of land allocated to residential, services and commercial and tourism uses; and a last policy group that allows full redevelopment of all uses, prioritizing either tourism or urban developments.

Land Development Strategies

Four developed land uses and four undeveloped land uses were chosen to represent the development patterns in the project area. Developed land uses selected: were residential, services and commercial, and tourism. An additional conservation land use was created to allow the user to also manage lands allocated or with potential to be allocated for conservation use.

Undeveloped land uses were combined into four different categories: vacant, forest, agriculture and wetlands. The partitioning of all vacant lands into these different categories allowed for more flexibility in terms of development prioritization and use restriction. Accordingly, vacant and natural forestlands, were considered to be developable to residential, services and commercial and tourism uses, or be allocable to conservation, whereas agriculture lands and wetlands are only developable for residential and conservation use (Brevard County Planning and Zoning Division, 1998).

Redevelopment alternatives add to the system the possibility of completely changing the existing development patterns. Two policies were created that allow such change: one that favors tourism development and another one that favors residential development. The first path creates the possibility of redevelopment to occur in residential and commercial areas and the second option in tourism and service and commercial areas.

Land Development Alternatives

Four development and eight re-development paths were considered. These reflect the chosen policies based on a combination of four different alternatives: Increase / Maintain Conservation Lands, Maintain Agricultural Lands, Priority to Tourism Development and Priority to Residential Development. Figures 4.1 to 4.12 show the twelve possible paths designed to work with these four policies.

Selective Development Alternatives

There are three possible development alternatives, which can be used to determine the outcome of both conservation and agriculture lands. These are shown in Figures 4.1 to 4.3:

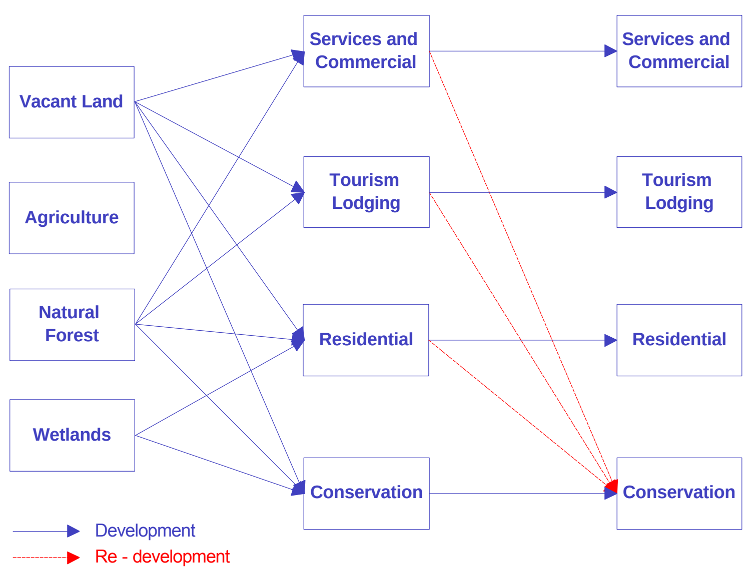
Selected Options	Paths
Maintain / Increase Conservation Land Maintain Agriculture Land	

Figure 4.1. Selective Development Path 1

Selected Options	Paths

Maintain / Increase Conservation Land

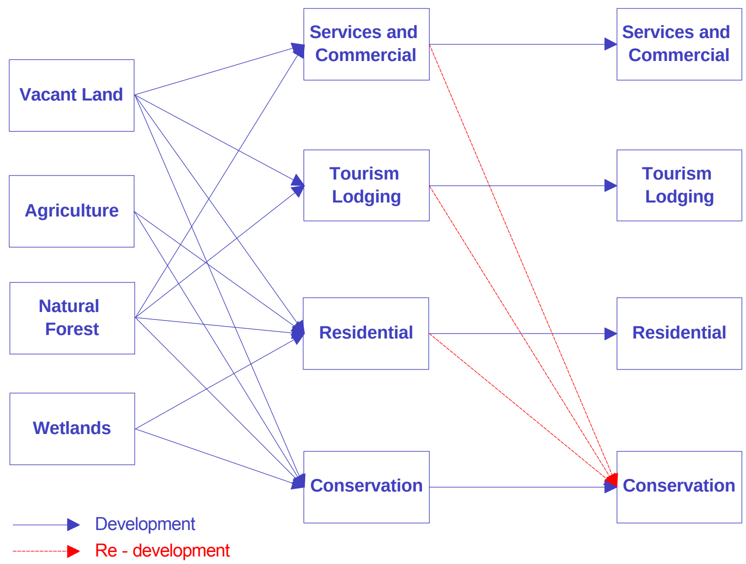


Figure 4.2. Selective Development Path 2

Maintain Agriculture Land

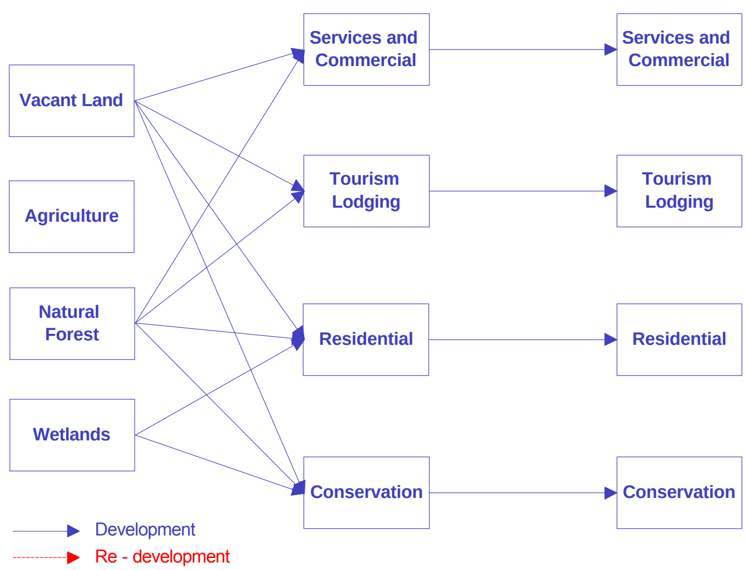


Figure 4.3. Selective Development Path 3

Full Development Alternative

If no policies are selected, all vacant and conservation land uses can be developed into one of the there developed uses (See Figure 4.4):

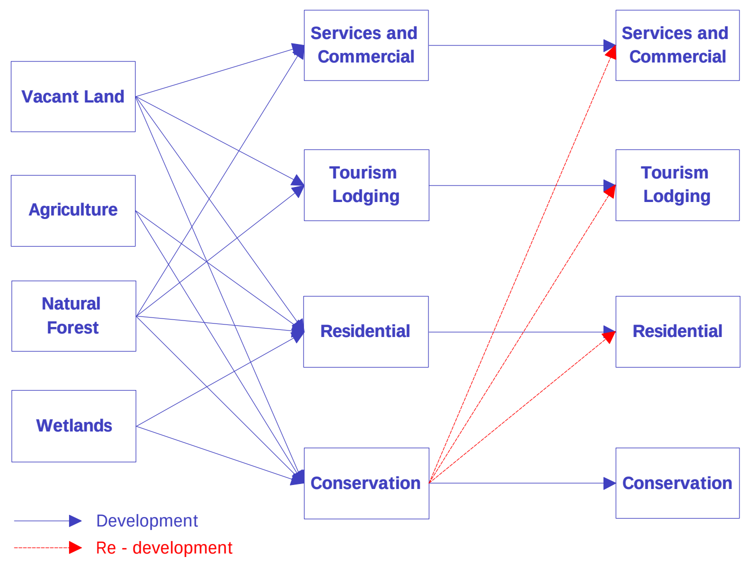
Selected Options	Paths
None	

Figure 4.4. Full Development Path

Selective Redevelopment Alternatives

There are six possible redevelopment alternatives, which determine the outcome of conservation and agriculture lands, and of the urban, tourism and service commercial developments. These are shown in Figures 4.5 through 4.10:

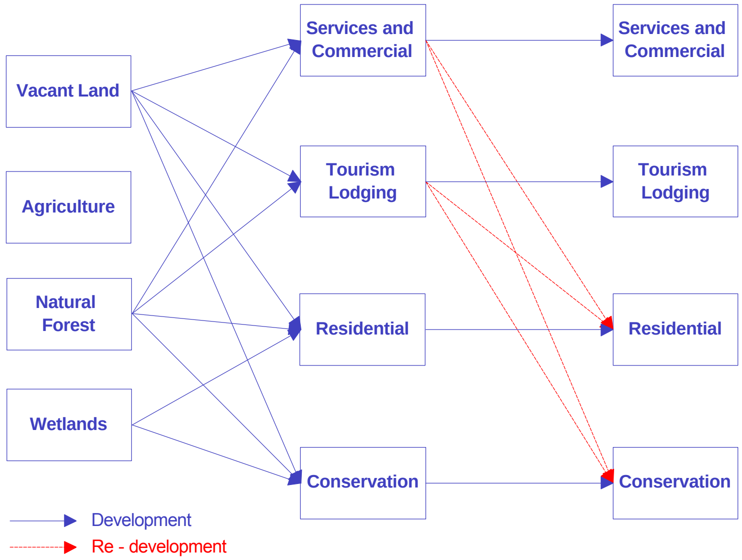
Selected Options	Paths
Maintain / Increase Conservation Land Maintain Agriculture Land Development Priority to Residential	

Figure 4.5. Selective Redevelopment Path 1

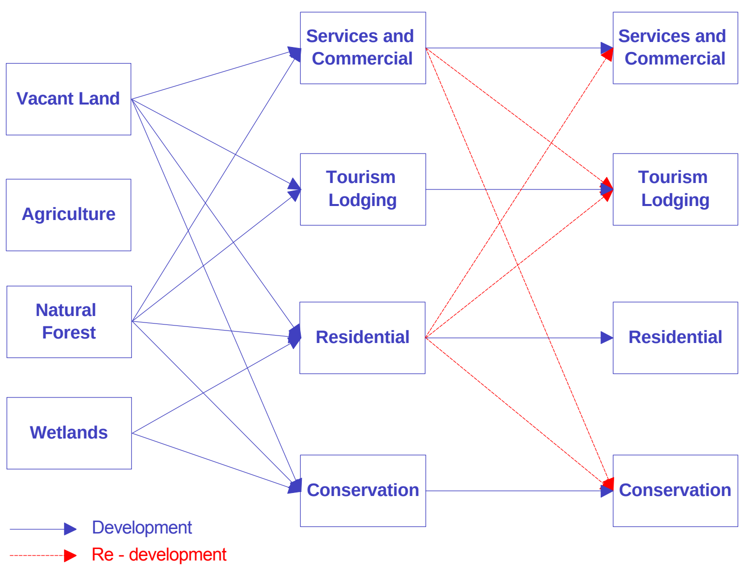
Maintain / Increase Conservation Land Maintain Agriculture Land Development Priority to Tourism Lodging	

Figure 4.6. Selective Redevelopment Path 2

Selected Options	Paths

Maintain Agriculture Land

Development Priority to Residential

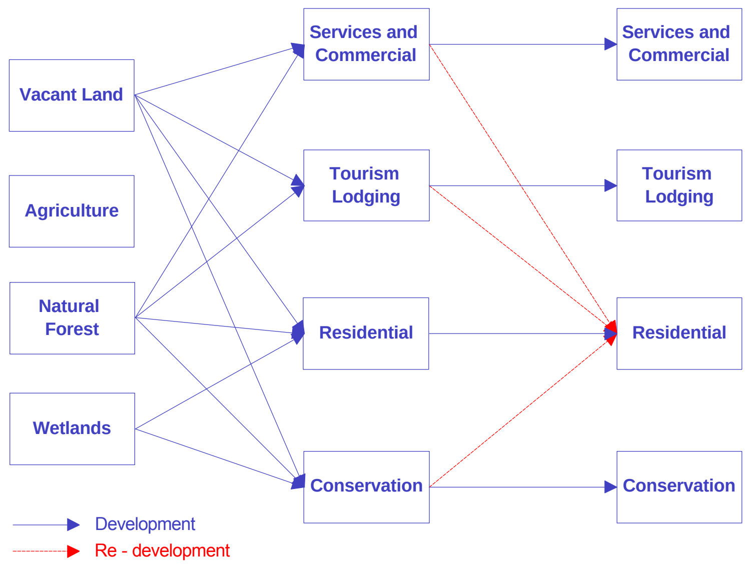


Figure 4.7. Selective Redevelopment Path 3

Maintain Agriculture Land

Development Priority to Tourism Lodging

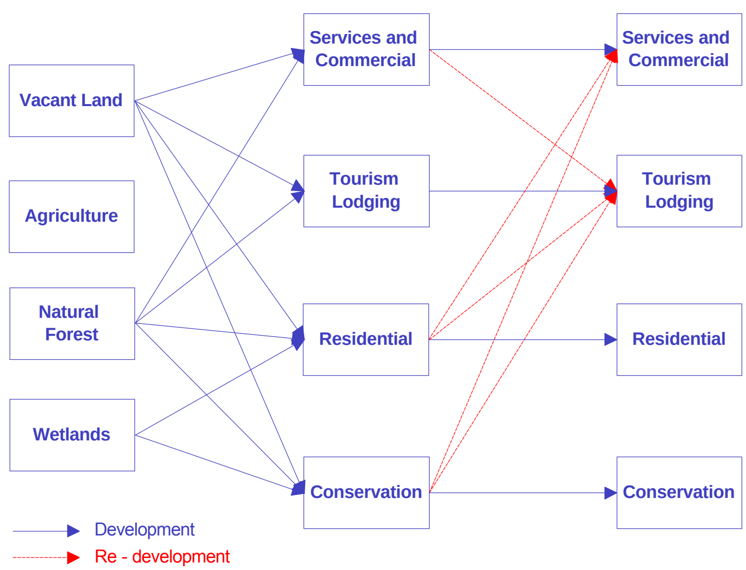


Figure 4.8. Selective Redevelopment Path 4

Selected Options	Paths

Maintain / Increase Conservation Land

Development Priority to Residential

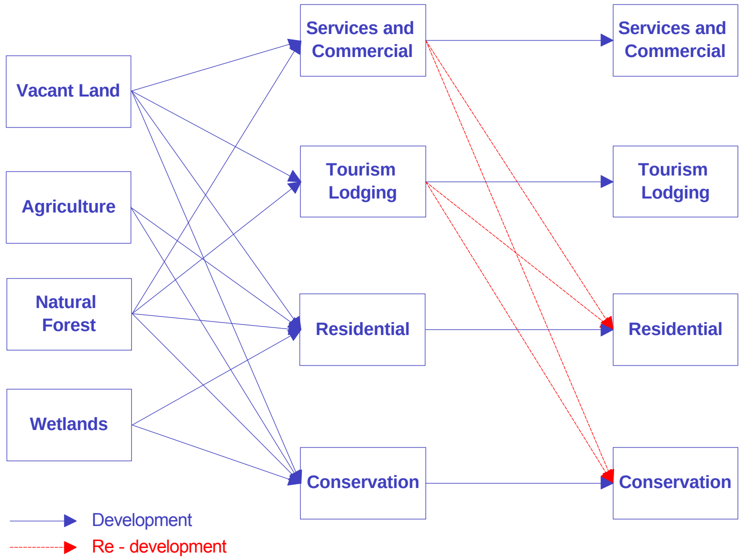


Figure 4.9. Selective Redevelopment Path 5

Maintain / Increase Conservation Land

Development Priority to Tourism Lodging

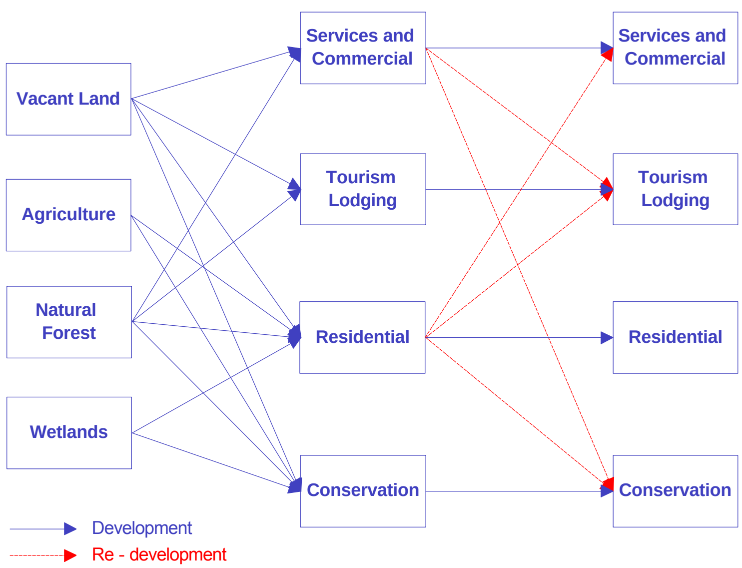


Figure 4.10. Selective Redevelopment Path 6

Full Redevelopment Alternatives

Depending on the redevelopment policy chosen all changeable uses can be redeveloped either into residential use (if residential priority is chosen) or to commercial and services or tourism uses (if priority to tourism is chosen). Figures 4.11 and 4.12 show these two possible paths.

Land Development Criteria

Three main criteria were used in each alternative to determine the changes caused by the different development policies: the acreage of land demanded and allocated per use every year (acres / year) and the development pattern developed in each simulation step.

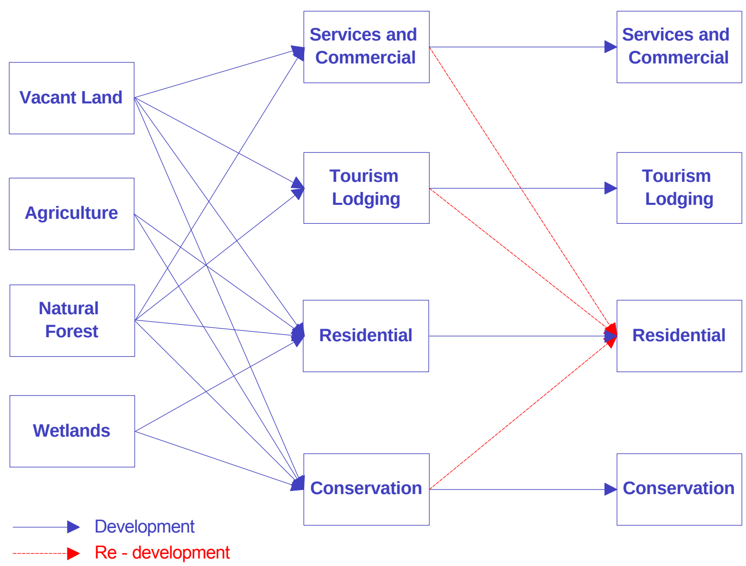
Selected Options	Paths
Development Priority to Residential	

Figure 4.11. Full Redevelopment Path 1

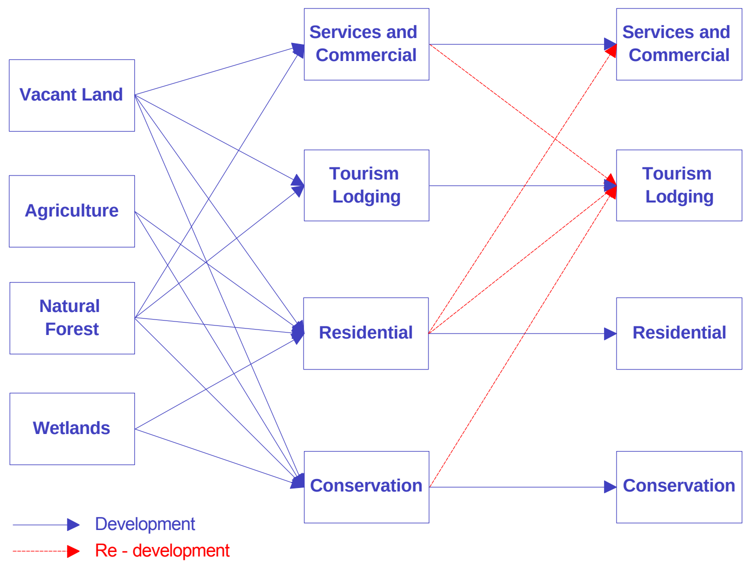
Selected Options	Paths
Development Priority to Tourism Lodging	

Figure 4.12. Full Redevelopment Path 2

Land Demand

Land demand is designed to reflect the local development pressures for each use, and is specified in the beginning of each simulation for the four main uses (residential, tourism, services and commercial, conservation).

Land Allocated

This criterion quantifies the acreage of land allocated to each use in every simulation step as a result of the development policies set forth. The amount of land allocated in each simulation step and is measure of the land availability for each particular use. The amount of land allocated also reflects the area's development status, because once all cells are allocated independently of how much land is requested, no more cells are allocated to any use, unless redevelopment is allowed.

Total Developed Land

Since conservation use is not considered a developed state once all land is allocated to all the uses, this criterion shows the area's development status, and can be used in several other applications such as calculations for capital at risk in the Natural Hazards Module.

Total Undeveloped Land

This criterion is very useful while the simulation is running to determine the amount of land one wants to develop, since unless one is running a redevelopment scenario, there is no use in asking for more land to be developed than the existing undeveloped land. This process will only slow down the simulation and increase the computational efficiency.

Development Patterns

Comparison between development patterns can be very important, since the same amount of land can be allocated in different places. Thus, the location of the changes in the land use pattern has to be compared for each combination of alternatives and scenarios.

Natural Hazards Module

The Natural Hazards Module was designed to illustrate the use of the land use model, to assess the changes in the potential risks to human life and structures from storm surges, with the changing policies. For further information and user interface see Chapter 6)

Storm Surges in the Brevard County Barrier Island

Tropical and extra tropical storms affecting the area can produce storm surges, from the Atlantic side (East) of the barrier island or from the Indian River Lagoon's side (West). Surge height depends on the intensity of the storm, to the Brevard County, the following SLOSH model values (See Table 4.1) are given for the potential storm surge heights based on hurricane category (Brevard County Planning and Zoning Division, 1991).

Table 4.1. Storm surge height calculated by the SLOSH model, for the Brevard County area (Brevard County Planning and Zoning Division, 1991).

Hurricane Category	Storm Surge (ft)	Winds (mph)
1	4 – 5	74 – 95
2	6 – 8	96 – 100
3	9 – 12	111 – 130
4	13 – 18	131 – 155
5	Above 18	Above 155

Storm Surge Module Calculations

Two options were created to assess the damages cause by a storm surge in the area. One was based on the Department of Community Affairs, Division of Emergency Management 's Florida Hurricane Surge Atlas layer described in Chapter 3. This option uses the SLOSH model outputs to define “worse-case” scenarios for hurricane impacts. The second option is based on the elevation of the area, which used the Potential Storm Surge Impact Risk Area grid discussed in Chapter 3, to assess the damages.

Figure 4.13 illustrates the areas of impact included in the grid, as well as the criteria for the calculations performed in the module based on storm surge heights. The maximum storm surge allowed in the Indian River Lagoon side is 15 feet, whereas in the Atlantic Ocean side the maximum storm surge can go over the 18 feet (as is the case in a category 5 hurricane). These values are purposely overstated to explore the possibility of a full impact scenario.

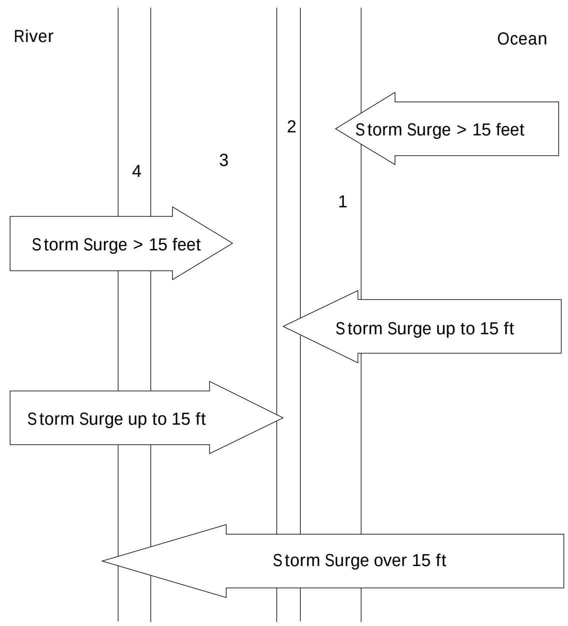


Figure 4.13. Storm Surge Impact Areas (1 - Ocean Front; 2 - Dune; 3 - Interior of Barrier Island and 4 - River Front)

The number of residents that can be potentially at risk from a storm surge, and the acreage of land at risk for each category on each side of the barrier island can be accounted for in this module. In addition based on the Property Market Value layer discussed in Chapter 3, it is possible to estimate the dollar value of the property at risk, based on a percentage of damage chosen by the user, for the cost calculations. The property values included in the referred layer are usually underestimated so the application of such estimates should be keep that in consideration.

Natural Hazards Criteria

Resident Population at Risk

The potential number of residents at risk (# of people / year) is calculated using the potential population grid discussed in Chapter 3. Using the potential population counts instead of the effective population at the impact evaluation time, links the population factor directly to the land capacity and corrects for any errors made in the scenario when choosing a population growth rate.

Residential Areas at Risk

This criterion, reports the acreage of residential land potentially at risk from the storm surge or hurricane impacts chosen. A separation was made between areas located in the oceanside and riverside of the barrier island and in the interior of the barrier island, for two main reasons. One reason is because the differences in property value between the three areas can be quite significant (See Figure 18 in Appendix A) and the second reason is because the population densities in each of the areas diverges significantly from area to area (See Figure 5 in Appendix A), mostly because of the different residential densities allowed on either side and on interior of the Barrier Island.

Other Developed Areas at Risk

Although its is possible to separately evaluate the total acreage at risk per use, this criterion, reports the total acreage of land other than the residential and tourism land potentially at risk from the selected storm surge.

Undeveloped Area At Risk

This criterion, reports the total acreage of undeveloped land at risk from a selected storm surge. Undeveloped lands include also conservation and agriculture lands.

Capital at Risk

It is possible to independently evaluate the dollar value of each category of land at risk. However this criterion sums the total value (in dollars) for the residential, tourism and other developed lands (institutional use, industrial use, commercial and services use, etc…) and gives an estimate of the potential global value for all the developed lands at risk for the chosen combination of storm surge or hurricane impacts.

Chapter 5
Simulation Functions

Socio – Economic Growth Functions

Population growth rate is generally influenced by two main groups of factors: socio-economic and population structure. The former include migration rates due to job opportunities and improvement quality of live and the later the population age structure and the fertility, birth and death rates (Masters, 1998). The details of the demographic models depend on the on the scale of the model (country, region, city) and of the forecast horizon (number of years). The more simple demographic models only take into consideration the natural growth rate of the population (birth rate – death rate) and the net migration rate (immigration and emigration). The latter reflects the potential increase/decrease in population caused for example by changes in employment opportunities, quality of living, and so forth.

Population Growth Function

Population growth follows the exponential growth curve as described in Masters (1998). Natural and migration growth rates due to factors other than job opportunity are combined in a general Population Growth Rate, which can be entered by the user. However in order to reflect the local economy, and the job opportunity related migration these two factors were added to the DSS. As mentioned briefly in Chapter 3, the job opportunity growth is used only to calculate the annual increase in population, due to the chosen population growth rate (See Equation 5.1a) that joins the labor force (See Equation 1c). Only the result of this calculation (See Equation 5.1b) is added to the annual population increase (Equation 5.1). The following equations are used to calculate the annual population change:

$$P_{t+1} = P_t + P_{Mt} + [(P_t + P_{Mt}) \times 0.10] \times RND \qquad \text{Equation 5.1}$$

$$P_t = P_{t-1} \times e^{GR} \qquad \text{Equation 5.1.a}$$

$$P_{Mt} = P_{LF} \times J_{GR} \qquad \text{Equation 5.1.b}$$

$$P_{LF} = P_t \times LF_{\%} \qquad \text{Equation 5.1.c}$$

Where:

P_{t+1} - is the total population growth at time step t (# people)

t - is simulation time (years)

P_t - is the population growth for time step t (# people)

P_{t-1} - is initial population or the population at time step t - 1 (# people)

GR - is the annual population growth rate (% / year)

P_{Mt} - is the population added at time t due to job opportunity (# people)

P_{LF} - is the population that will join the labor force at time step t (# people)

$LF_{\%}$ - is the percentage of the area population in the labor force (%)

J_{GR} - is the annual job opportunity growth rate (%)

RND – is a random number between 0 and 1

The amount of land allocated to residential use in each simulation step constrains population growth in the region. The resident population is only allowed to grow if there is enough land to be allocated for them. This way, it is possible to assess if within the simulation horizon the population carrying capacity of the area was reached (see Chapter 3 for details)

The 10 % variability added to population growth (See Equation 5.1), accounts for external factors that influence the settlement of people in the coastal areas, such as exposure to natural hazards, and in the case of the Brevard County area, the variability in the amount of temporary residents from the northern states that live in the area during the winter months.

Population Allocation Function

The population allocation function, distributes the amount of residents in each time step for the available land allocated to residential use, and "decides" if the projected population growth is viable. If this it is not the case the initial population for the following time step t + 1will be the maximum population supported by the land at the current time t , and not the projected population growth. The distribution of the resident population within the available land uses is based on the potential population density grid discussed in Chapter 3, which represents the maximum number of residents that could potentially reside in that area based on the local zoning residential densities allowed per acre.

Socio - Economic Change Analysis

Population growth projections were assessed based on the growth rates given and compared with the population potential growth for the area, for each scenario. Tourism growth was calculated using a linear function of the selected economic growth and tourism growth rates. For this reason, tourist population was compared only on an under or over capacity basis, in relation to the available tourism area's capacity discussed in Chapter 3. The changes in residential density and in the conservation and recreation indexes are also documented for each scenario, to show the effects of the different land policies on regional life quality.

Calibration of the Socio - Economic Functions

Population growth projections were compared with existing population projections for the area for the years 1995 and 2000. The results form the 2000 population census were not available at the time this research was accomplished. The 10 % variability added to the population growth function was within the limits provided in the available projections. The other socio-economic parameters could not be calibrated, because no data for 2000 was available.

Land Use Allocation Simulation

Cellular Automata

Von Newmann and Ulam introduced Cellular Automata in the 1960’s, as simple mathematical models designed to study biological processes such as self-reproduction of cells (Wolfram, 1982). The simplest cellular automata "consist of a line of cells with values of 1 and 0, where the value at each cell evolves deterministically in time according to a set of rules involving the values of its nearest neighbors" (Wolfram, 1983; Wolfram, 1984).

Two dimension cellular automata were made popular by Conway’s computer game “Life” (Gardner, 1970), and "consist of a matrix of cells in which each cell state may evolve according to a similar set of rules, to a different or similar state" (Wolfram, 1984; Packard and Wolfram, 1985). In the early 1990’s Guy Engelen and Roger White used two dimensional cellular automata in their geographic models by assigning to each cell state or value a pre-defined land use.

Engelen and White's Constrained Cellular Automata

In Engelen and White’s geographic models, the cellular automaton is an array of identical land use where the evolution of the land of each cell in the array depends on the land use of the cell in the previous step and on the land use of the cells within a pre-defined neighborhood of the cell. In most cellular automata the neighborhood structure, consists of either 5 (von Neumann neighborhood) or 9 cells (Moore neighborhood) - the cell it self plus 4 or 8 surrounding cells respectively (Figure 5.1).

Engelen and White’s applications extend the automaton neighborhood to a radius of 6 or 8 cells, covering and area of 113 (Engelen *et al*., 1995, White and Engelen, 1997) and 197 cells respectively (Engelen *et al*., 1997b). This approach, according with the authors, "creates a set of several distance groups around the center cell, and allows the assignment of different transition rules for each distance group to best reflect the socio-economic interactions that take place within a region".

Figure 5. 1.a) Von Neumann's ``five-neighbor square'' neighborhood and b) Moore ``nine-neighbor square'' neighborhood (Adapted from: Packard and Wolfram, 1985)

These transition rules (neighborhood distance functions) represent location preferences and spatial interaction mechanisms between landuses such as attraction (agglomeration effects) and repulsion (competition effects) forces. For example: residential and industrial land uses are usually incompatible, and tend to out compete each other for available land. Consequently a distance function created to describe the interaction between these two uses would favor repulsion (competition) as well as and block clustering effects (use growth).

When these models are combined with other dynamic models (for example socio-economic) a "constraint is imposed in the cellular automata simulation that dictates the overall growth of the system (Engelen *et al*., 1997a). Because the simulation is no longer driven infinitely by the transition rules, but by the dynamics of the dynamic model, these “constrained” cellular automata simulations can be quite useful when applied to integrated socio-economic geographic models.

Another useful characteristic of this “constrained” model, pertains to the fact that cellular automata simulations are “discrete and iterative and do not have to be made only between pairs of cells in the array, they are flexible enough to involve interactions between predefined regions instead”. This property facilitates the work with spatially referenced raster images [(1)] containing thousands of cells (image pixels) arranged in several different groups of different characteristics, and also makes possible the "achievement of very fine spatial resolution, which can be an advantage for the application of these methodologies to coastal and land use planning" (Engelen *et al*., 1997b).

The Brevard County’s Barrier Island Cellular Automaton

Cellular Automaton Design

The cellular automaton designed for this research is based on a 25 x 25 m grid cell size of some of the areas of Brevard County’s Barrier Island. The GIS developed grids (See Chapter 3) constitute the two dimensional arrays used for this research.

[1] Two dimensional array (grid) of discrete picture elements - pixels (Lillesand and Kiefer (1994))

Sixteen possible land use states z were assigned to the cells in the cellular automaton based on the land use patterns in the area in 1990. All of the sixteen states participate in the simulation, and intervene in the calculation of the neighborhood's distance influence function, but only eight of those land use states are allowed to change. The latter are: vacant, agriculture, natural forest, wetlands, residential, services and commercial, tourism lodging and conservation. The remaining eight states: recreation, industrial, institutional, infrastructure, military, beach, Indian River Lagoon and the Atlantic Ocean, are kept unchanged throughout the simulation.

The decision to maintain some of the uses/states as unchangeable has to do mostly with the degree of complexity that would be added to the system if the land uses of all the cells were allowed to change. Whereas, this might be considered in future research projects in this topic, it is out of the scope of the current research. As a result the following assumptions were made:

- Land allocated as of 1990 to the following uses: recreation, industrial, institutional and military, was assumed to be very unlikely to be redeveloped within the planning horizon of the simulation.
- The beach, the Indian River Lagoon and the Atlantic Ocean are static.
- Residential, services and commercial, tourism lodging and conservation land uses are the most likely future land uses to which all the undeveloped land will be allocated.
- Land allocated as of 1990 to residential, services and commercial, tourism lodging and conservation land uses is assumed likely to be redeveloped within the planning horizon of the simulation.
- Vacant, Agriculture, Natural Forest and Wetlands land uses are the most likely undeveloped land uses that will be developed into residential, services and commercial, tourism lodging and conservation land uses.

Simulation Methodology

An adaptation of Guy Engelen and Roger White constrained cellular automata methodologies described in Engelen *et al*. 1995; Engelen *et al*. 1996; Engelen *et al*. 1997a; Engelen *et al*. 1997b; White and Engelen 1997 and White *et al*. 1997 were used in this research to calculate the change potential for each cell in the land use array. In order to use this methodology, the following assumptions were made:

- The suitability of a parcel of land to support a determined land use influences the probability that, that parcel of land has to be developed accordingly to the use to which it bears the highest suitability.
- Development is influenced by the proximity of the road network and by the proximity to water bodies.
- The probability for a parcel of land to be developed for a certain use increases or decreases based on the presence or absence of the same land use in the neighboring areas.

Calculation of the Cell's Change Potential

The change potential (P_Z) quantifies the cell's aptitude to change to a requested land use z. In each simulation year the change potential for all of the changeable land use cells in the array is calculated for the four main land uses according to an adaptation of the algorithm used by Engelen and White in their research (White and Engelen, 1993; White and Engelen, 1994; White and Engelen, 1997; Engelen *et al*., 1997b; White *et al*., 1997):

$$P_Z = [S_Z \times NI] + \varepsilon \qquad \text{Equation 5.1}$$

Where:

P_Z - is the cell's change potential to land use z

S_z - is the cell's suitability for land use z

NI - is the neighborhood influence of cells of landuse z_N on the cell of land use z

ε is a stochastic disturbance factor ($0 \leq \varepsilon_z \leq 1$)

This algorithm multiplies equal index cells in each component matrix (suitability and neighborhood influence matrices) and creates new matrices with the change potential for each the four eligible land uses z: Residential, Tourism Lodging, Services and Commercial and Conservation. The individual components of the cell's change potential algorithm (Equation 5.1) are described next.

Cell's Land Use Suitability

Cell's suitability for a specific land use reflects the propensity of that land cell to a specific land use z. The four suitability grids created using the GIS system (See Chapter 3) were imported into the DSS using the system's interface (See Chapter 6) and its individual cell values used in the change potential equation without any further transformations.

Neighborhood’s Distance Influence Function

This function reflects the pressure set by the land use of the surrounding neighbor cells N of land use z_N on the landuse z of the target T cell T (Figure 5.2).

		j	
	N	N	N
i	N	T	N
	N	N	N

a

		j	
	D_2	D_2	D_2
I	D_2	D_1	D_2
	D_2	D_2	D_2

b

Figure 5.2. a) Distance Neighborhood Representation and b) Distance Weight Indexes

In each step of the simulation, a matrix holding the neighborhood influence (NI) values for each cell in the grid is calculated using Equation 5.3 (Adapted from: Engelen *et al*., 1997b; White *et al*., 1997):

$$NI_{i,j} = \sum Wz_{i,j} \qquad \text{Equation 5.3}$$

Where:

$NI_{i,j}$ - is the sum of influences of the cells of land use z_N in the target cell’s neighborhood

$Wz_{i,j}$ - is the weighting parameter applied to cells with land use z_N in the distance zone D_d

d - is the index of the distance zone D

i,j - are row, column cell indexes

Engelen and White’s expansion of the cell neighborhood was not adopted in this research, since a standard 9 cell Moore neighborhood seemed reasonable for such a narrow stretch of land, to explain the interaction between landuses, even for a resolution of 25 x 25 m.

The distance weights chosen represent the compatibility and attraction forces between land uses were chosen to reflect the local land use and zoning regulations and comprehensive plans (See Appendix A). Parameters were scaled from 0 to 300, with the highest value – 300, being assigned only to the cells of equal land use. These weights play a very important role on the calibration of the system and can be changed in the calibration menu of the DSS.

Stochastic Disturbance Factor

This term was added to Equation 2 to avoid possible ties in the cell change potential calculation, and to account for the non-controllable and unknown environmental disturbances. The stochastic factor ε, - a random generated number between 0 and 1, constitutes the only introduced source of variability in the land use allocation algorithm, and it is hard coded in to the DSS system.

Cellular Automaton Transition Rules

Figure 5.3 summarizes the cell state hierarchy, which determines the permitted state changes for each of the eight changeable uses. This hierarchy was established based on the future land use goals and objectives stated in the Future Land use element of the Brevard County's Comprehensive Plan. The paths followed by a cell from an undeveloped state until a developed state are dependent on which of the twelve available policy paths the user chooses when it creates the simulation scenarios (See Chapter 4).

Undeveloped land uses represented by vacant land and natural forest land cells are the two states with less restrictions, which can evolve to any of the developed land uses states: residential, services and commercial and tourism or be allocated for conservation. Agriculture land and wetlands can only support (according to the local land regulations) very low-density residential development and no commercial or tourism activities; consequently the correspondent cell's states are only permitted to evolve to residential or conservation states (See Figure 5.3.).

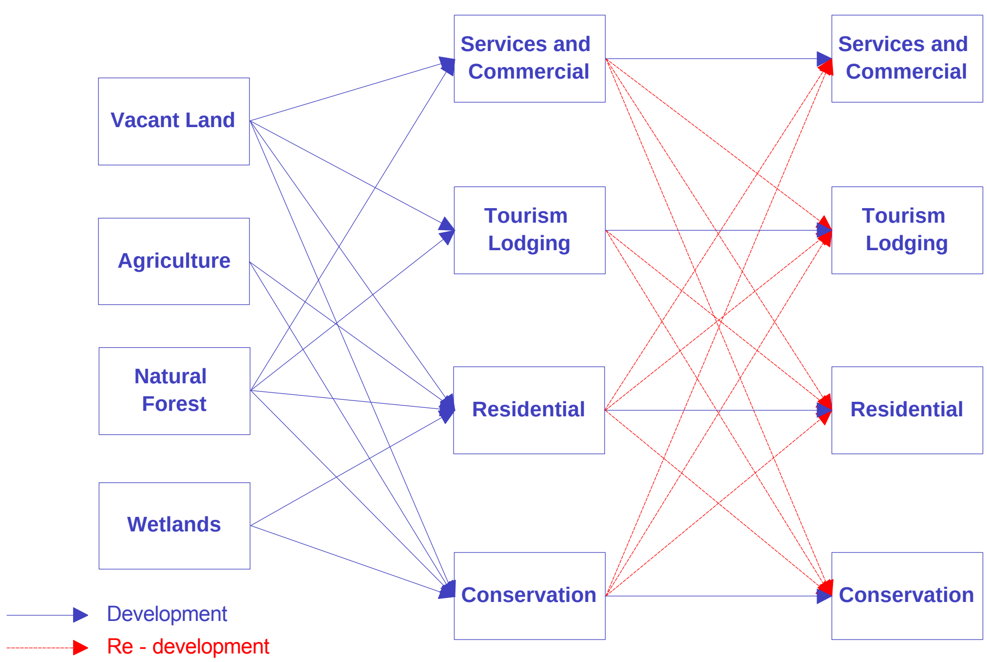


Figure 5.3. – Cell state hierarchy – permitted cell state changes

Cells already in the developed states are usually not allowed to change unless the user chooses redevelopment policies. If this is the case, the release of residential and tourism cells is not simultaneous, the user is only allowed to prioritize the development of one of these two uses over the other; however both choices trigger redevelopment of the services and commercial cell state. The conservation land use cells can be released into the pool of changeable cells if the user chooses not to maintain or increase the amount of land allocated to conservation (See Chapter 4, for a detailed description of available policies).

Landuse allocation to each of the four major land uses is an iterative process, based on the balance between the development demand for each use and the land available for development. Once the demand for land use z is requested by the user, the total number of cells (T_z) to change to land use z will depend on the amount of cells to which land use z bares the of highest change potential and on the policies chosen by the user which determine the cell's transition rules. The land allocation algorithm designed for this simulation is discussed next.

Land Allocation Algorithm

A schematic of the land use allocation algorithm designed for the land allocation simulation is shown in Figure 5.4. User specified land demands, determine the number of cells needed to be allocated in each step of the simulation. Demands are sorted from high to low to determine the order by which the allocation of available cells to each individual land use is executed first. In order to prevent ties (in case of equal land demands for more than one land use are requested), a random number is added to each demand before sorting. This addition does not affect the amount of land demanded.

The sorting of the land use demand as an approach to set the sequence for the execution of the land allocation algorithm was implemented because during test runs it was noticed that resultant land use patterns were influenced by the order by which the request for each individual land use cell allocation was executed. This particularity of the algorithm results from the fact that once a cell is allocated to a specific use it is removed from the pool of changeable cells and is no longer available to be allocated to any of the other three requested uses. If redevelopment is not permitted, by the time the algorithm is executed for the least demanded land use, the number of cells available is reduced by as much as the number of cells allocated to the previous land uses.

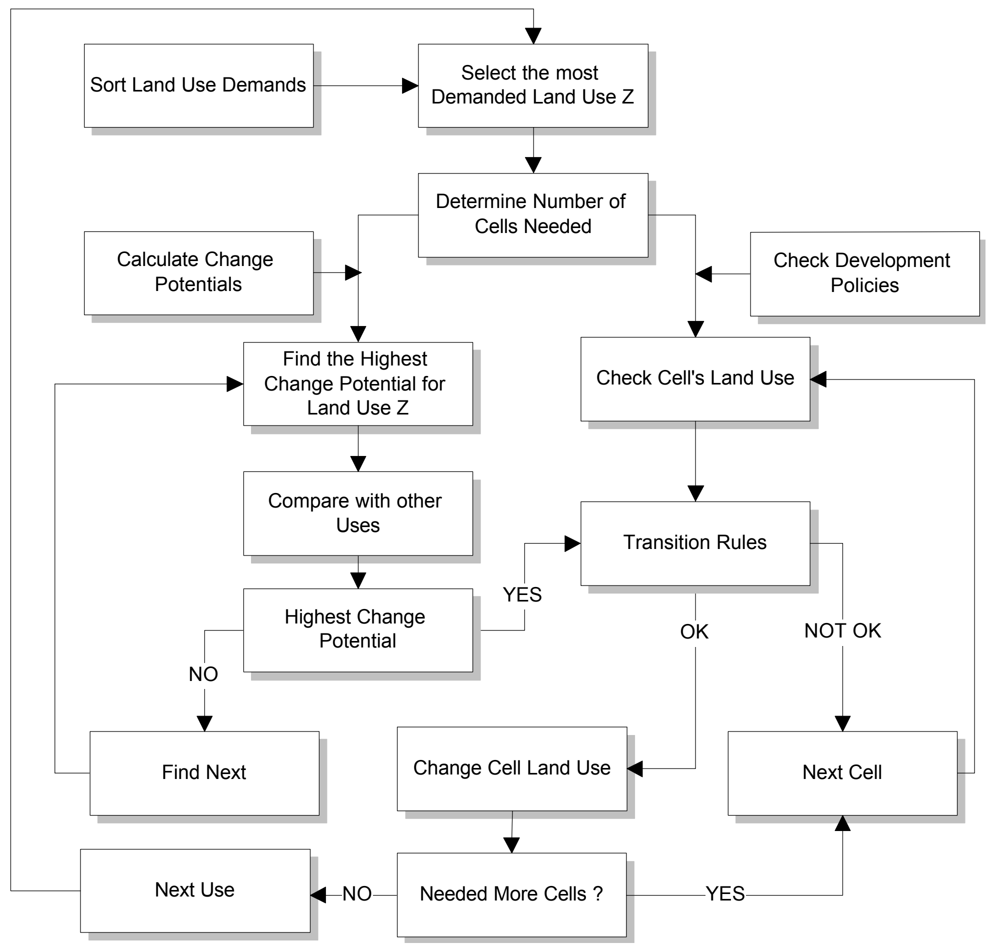


Figure 5.4. Schematic of the land use allocation algorithm

Several possible solutions to deal with this behavior were considered. It was clear that an order had to be implemented for the execution of the algorithm. For example one could use a randomly chosen order to execute each request or allocate a single cell for each landuse at a time instead of allocating all the requested cells to one land use and then move to the next land use.

As a result, instead of making further changes in the otherwise “well behaved” algorithm, which could introduce other “particularities” and, based on the nature of the parameters being simulated – land use changes, sorting the land use demand can be realistic. The reasoning being that higher land demands for a particular land use reflect, in general, market trends and / or the political will and local policies and development pressures that favor the development of one use over the other. Thus, if the priority of the local development policies is for example residential development, most of the available land will be allocated preferably to residential use.

With this in mind, the search and allocation cells to a particular land use is executed first for the highest demanded use, and only after the demand for that use is met, or there are no more cell available to allocate for that particular land use, the second most requested land use is executed and so forth until all different land use demands are met. Within each individual use, the cells are allocated by magnitude from the highest to lowest change potential. If there are not enough cells to satisfy demand for that use then the simulation moves to the next requested land use until all uses are satisfied or there are no more cells available to change.

As the simulation evolves in time, less and less cells become available to change, and eventually all changeable cells will either be allocated to residential, tourism, services commercial or conservation uses, or if conservation policies are disregarded, all cells might eventually be allocated only to residential, tourism or services & commercial land uses.

Land Use Pattern Analysis

Land use pattern analysis consisted of calculating the percentage of change for each of the land use categories; in identifying the areas where the change occurred; and in calculating the KHAT or Kappa Coefficient of Agreement (Cohen, 1960; Congalton *et al*., 1983; Congalton, 1991; Monserud and Leemans, 1992, Engelen *et al*., 1997b) to report the statistical significance of the changes between land use patterns in any given year.

Change in Land Allocated by Category

The changes in land use for each category are written to an output file by the DSS. Based on the outputs from the system the percent of change at time 5, 10, 15 and 20 was quantified for each simulation run.

Identification of Areas Changed

The user interface of the DSS allows the visualization of where the changes for each land use occurred, however it does not allow further analysis. For this reason, the land use grids created via the simulation were exported to the GIS to better analyze the results. Changes between simulated land use patterns between years 0 and 5, 5 and 10, 10 and 15 and 15 and 20 were evaluated for each scenario and then compared among the different scenarios for the same area.

KHAT Analysis

KHAT analysis is a multivariate analysis technique used to assess the degree of agreement between any two equal size matrices. Common applications of this statistical tool are the assessment of the accuracy of remotely sensed data (Congalton *et al*., 1983; Congalton, 1991; Lillesand and Kiefer, 1994), the assessment of the changes in land use patterns driven by cellular automata simulations (Engelen *et al*., 1997b) and the assessment of the similarity between global vegetation maps resulting from a series of different classification analysis by Monserud and Leemans (1992).

KHAT Analysis Methodology

Comparing a pair of land use grids cell by cell, for each land use category, generates an error matrix, which quantifies the category and overall agreement between the two land use grids. The diagonal of the matrix represents the observed agreement between the different categories of the two matrices; and the product of the category's row and column totals represents the expected chance agreement between categories (Congalton *et al*., 1983; Congalton, 1991; Monserud and Leemans, 1992). The KHAT or Kappa Statistic uses this error matrix to assess if overall and individual agreement between the two grids is significantly different (Cohen, 1960; Congalton *et al*., 1983; Congalton, 1991; Monserud and Leemans, 1992).

Hence the KHAT coefficient is simply the proportion of agreement (d) between two land use matrices after the chance expected agreement (f_e) is removed. An overall KHAT can be calculated using Equation 64 (adapted from Cohen, 1960; Congalton, 1991; Monserud and Leemans, 1992):

$$\hat{k} = \frac{\sum_{i,j=1}^{n_{i,j}} d_{i,j} - \sum_{i,j=1}^{ni,j} f_e}{N - \sum_{i,j=1}^{ni,j} f_e} \qquad \text{Equation 5.4}$$

Where:

d is the sum of all the diagonal values on the agreement matrix, representing the observed agreement between the two maps

N is the total number of cells in the matrix

f_e is the chance-expected agreement between the two maps calculated using Equation 5.5

$$f_e = \frac{n_j \times n_j}{N} \qquad \text{Equation 5.5}$$

Where

n_i is the row total for each i class

n_j is the column total for each j class

An approximation of the KHAT's standard error (Equation 5.5, adapted from Cohen, 1960) between the two land use matrices can be calculated if the chance-expected agreement f_e is assumed constant and all cells of the land use grid are used in the calculation.

$$\sigma = \sqrt{\frac{\sum_{i,j=1}^{n_{i,j}} d_{i,j}\left(N - \sum_{i,j=1}^{n_{i,j}} d_{i,j}\right)}{N\left(N - \sum_{i,j=1}^{n_{i,j}} f_e\right)^2}} \qquad \text{Equation 5.5}$$

An Individual Kappa statistic for each category can also be calculated (Adapted from Cohen, 1960; Monserud and Leemans, 1992) by:

$$\hat{k}_i = \frac{d_{i,j} - f_e}{\frac{n_i + n_j}{2} - f_e} \qquad \text{Equation 5.6}$$

Where:

d is the diagonal value on the agreement matrix, representing the agreement between the two categories

N is the total number of cells in the category

f_e is the chance-expected agreement between the two maps calculated using Equation 5.7

$$f_e = \frac{n_j \times n_j}{N} \qquad \text{Equation 5.7}$$

Where

n_i is the row value for the category

n_j is the column value for the category

Significance of the KHAT Statistic

For large values of N, the KHAT statistic approximates a normal distribution (Cohen, 1960). For this reason a test of significance of the difference between two independent KHATs, can be performed using the normal curve deviate z described in Equation 5.8

$$z = \frac{\hat{k}_2 - \hat{k}_1}{\sqrt{\sigma_{k2}^2 + \sigma_{k1}^2}} \qquad \text{Equation 5.8}$$

Evaluation of the Simulation KHAT Values

The KHAT coefficient is calculated within the DSS interface. The overall KHAT averages and standard deviations between years were evaluated and plotted for each scenario. A test of significance was made between the KHAT for each of the five-year periods to evaluate if the changes that occurred within those periods were significant different.

Plots of the KHAT calculated for the each scenario were compared for the same years and a test of significance of changes between equivalent years in each scenario was made to evaluate if the differences between scenarios were significant.

Calibration of the Land Allocation Simulation

The land use grids prepared with the GIS for 1990, 1995 and 2000 (See Chapter 3) constitute the theoretical data sets to which the simulation results for each area were compared. Changes in percentage of land allocated between 1990 and 1995, 1995 and 2000 and 1990 and 2000 and the location of those changes, as well as the curves for the observed KHAT values for each period of five years were documented. Test of KHAT significance between each five and ten-year interval were also calculated and documented for the same data sets.

The 1995 GIS grid was used to calibrate the simulation and the 2000 GIS grid was used to validate the calibration. Part of the calibration was made while preparing the suitability grids for the simulation and consisted in making sure that the suitability grids reflected both the areas developed between 1990 and 1995 and the areas still vacant by that time. This correction was necessary, because the fact that those areas are vacant has to do with factors other that the suitability of the land for a particular land use. Those vacant areas may already be zoned and platted and their future land use determined, but that does not mean that development has begun. For that reason all vacant areas as of 1995 and 2000 were given lower suitability values to balance the fact that even though they are quite suitable for development, the remain vacant as of the current year 2000. In addition to these corrections in the grids suitability, each study area’s grid boundary was extended out one cell - the size of the distance influence neighborhood - in order to avoid boundary effects in the distance influence function.

The second part of the calibration consisted in adapting the neighborhood influence distance values to the realities of each of the test areas, by making sure that through the simulation it was possible to obtain in five simulation years, a land use pattern that was not significantly different from the observed 1995 grid. In order to calibrate these values, the total land change documented from 1990 to 1995 and from 1995 to 2000 in the GIS grids, was converted to a yearly basis and inputted into the land allocation simulation in the DSS as the yearly land demand requested for each changeable use.

The calibration of the distance influence weights was a trial and error process that consisted of adding and taking 5 points at a time to each distance ring and running the simulation forward 5 and 10 years with the correspondent demand (See Appendix B and C for calibration parameters). It was fairly easy to calibrate the model from 1990 to 1995. However not all calibration combinations were able to take the model forward till 2000 with satisfactory results. The final calibration values chosen were the ones that best satisfied both the calibration and validation of the model. Therefore the calibration was considered finished when at least two of the following three criteria were satisfied:

- When the calculated KHATs (Equation 5.4) between observed and simulated land use patterns for both the t = 5 and t = 10 were non significant to a 99 % significance interval.
- When the percentage of land allocated in both the calibration and the validation runs were within the same magnitude of the observed change.
- When the cell-by-cell comparison between the observed and simulated calibration and validation land uses patterns did not show any differences.

It was found that with repeated calibration runs it is possible to satisfy the three criteria described above, Satellite Beach is a good example of such achievement. However, achieving a 99 % non-significance difference between KHATs can be very difficult, specially in circumstances where the land use patterns change drastically within a relatively small area; or when the boundary conditions imposed by the fixed uses (for example the beach, a road or the Indian River Lagoon) vary within the same grid from a distance of two or three cells to a distance of about 50 cells. This is the case in the South Beaches. For this reason it was not possible to calibrate the simulation to the point that the validation pattern's KHAT become non significantly different to a 99 % significance interval from the observed pattern's KHAT. Further details on each situation are discussed in Chapters 7 and 8 for each case individually.

Once the system is calibrated it is not recommended to change the weights of the uses that participate in the calibration of the system, in this case residential, services and commerce and conservation. However other uses can be changed to reflect the needs of each scenario. For example in the case of Satellite Beach the suitability for tourism grid was not part of the calibration. The distance weights that rule the influence of the other land uses on tourism were introduced after the calibration was done (See Chapter 7 for details).

Another important aspect of the calibration and validation process is that the model calibration was made for a five-year period and that as a consequence the current calibration may not be valid for the intermediate years. The DSS is designed to accept any land request made for use z at a given year as the total land it should allocate in that particular year to that use z. Consequently as long as there is enough suitable land available for use z, the simulator will keep allocating land to that use until that demand is satisfied.

This feature can be quite handy in the case of discrete events, such as the acquisition of a large parcel of land for conservation or public use purposes on a specific year. In this case it may be wise to run the simulation on a year-by-year basis, and introduce that event in the year it occurred instead of dividing the amount of land for the 5 years and wait for the final result. The Satellite Beach Case Study discussed in Chapter 7 illustrates this fact. For this reason the recommended minimum forecast interval for this decision support system for discrete events is one year, and five years for non-discrete events with total land demand requests for each five-year period averaged to a yearly land demand over those five years.

For example, if the user is looking at an increase in residential land of 10 acres over a five year period, it should input into the system a 2.5 acres yearly land demand for residential land use, and analyze only the t = 5 simulated land use pattern to assess the changes that occurred over those 5 year period. On the other hand if the user wants to request the 10 acres of residential land for the a specific year this can be done by running the simulation yearly and by requesting the 10 acres all at once. If the system "finds" that there are in fact 10 acres of land available for residential land use, it will allocate that amount to residential use. If on the contrary the system “finds” that there is no more available land to be allocated in that particular year to residential use it will allocate the available land and stop the search.

Chapter 6
Model User interface

System Overview

The model's entire graphic user interface (GUI) and the simulation algorithms that constitute the structure of this Decision Support System framework were built using the Microsoft Visual Basic ™ 5.0 and 6.0 programming language. The use of C++ programming language was considered for the development of the algorithms of the system, because of its superior calculation performance. However C++'s graphic user interface design capabilities are very limited. Also, the continuing increase in the processing speed of the personal computers, can greatly overcome the differences in performance between the two languages. So for this reason, the Microsoft Visual Basic ™ programming language was chosen over the C++ programming language.

The user interface is one of the most important components in this system because it gives the user the ability to create a series of "What-If" scenarios, which make use of all the functions of the model. Through the graphic interface the user is able to create the scenarios, test the alternatives, visualize and analyze the results and finally export them to be further analyzed in other software packages. The different components of the DSS's GUI are described next.

System Requirements

The system runs under Microsoft Windows 95, 98 and 2000 operating systems. There are no minimum requirements for hardware as long as the operating system is compatible. However it is recommended running the software in a system with at least a Pentium II processor with 64 MB of Ram for better performance.

System Directory Structure

The system directory structure encompasses the Program Directory, where the application files are kept; the Data Source directory where the information for each available study area is stored, and the help directory for the help files are kept. These are entirely html format files and can be read within the program interface or using a internet browser.

Every time a new project is created a new directory is created in the Projects directory to keep all the input and output files created during the simulation for each scenario.

Data Inputs

The default land use pattern for the system is the 2000 land use grid discussed in Chapter 3. However the model provides a grid file converter (See Figure 6.1.), which converts raster format grid files produced with Arc View ^{TM} to the DSS grid format. Thus, it is possible for the user to create a new land use grid and use it as the grid base case for the simulation. All the socio-economic variables are input directly in the system's user interface.

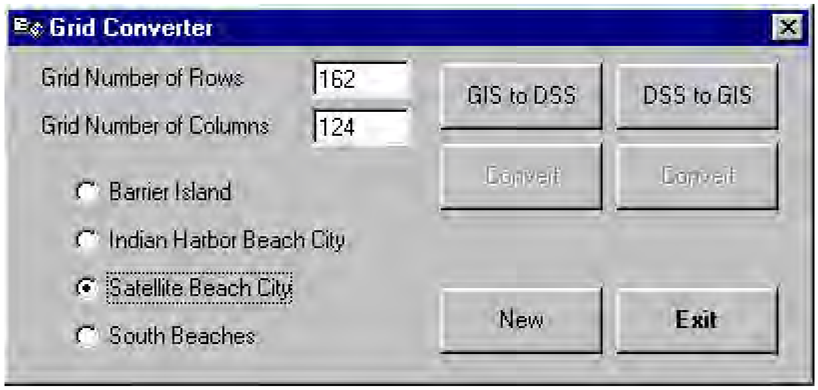


Figure 6.1. Grid Converter Menu for the 4 cities currently available in the system

Initial Settings

The two cities chosen to test this framework (See Chapter 7 and 8) have been calibrated and are both available for the user to create new. In the Initial Settings Menu (See Figure 6.2.), the user can choose an area to test different scenarios and input the values he/she thinks are best representative of the 2000 population counts for the chosen area. The default socio – economic values are currently from the 1990 population census, and will be updated as soon as the 2000 population census results are available. Once the user chooses the study area, the current amount of land allocated for each use in the chosen region, is uploaded to the form, together with an image of the area.

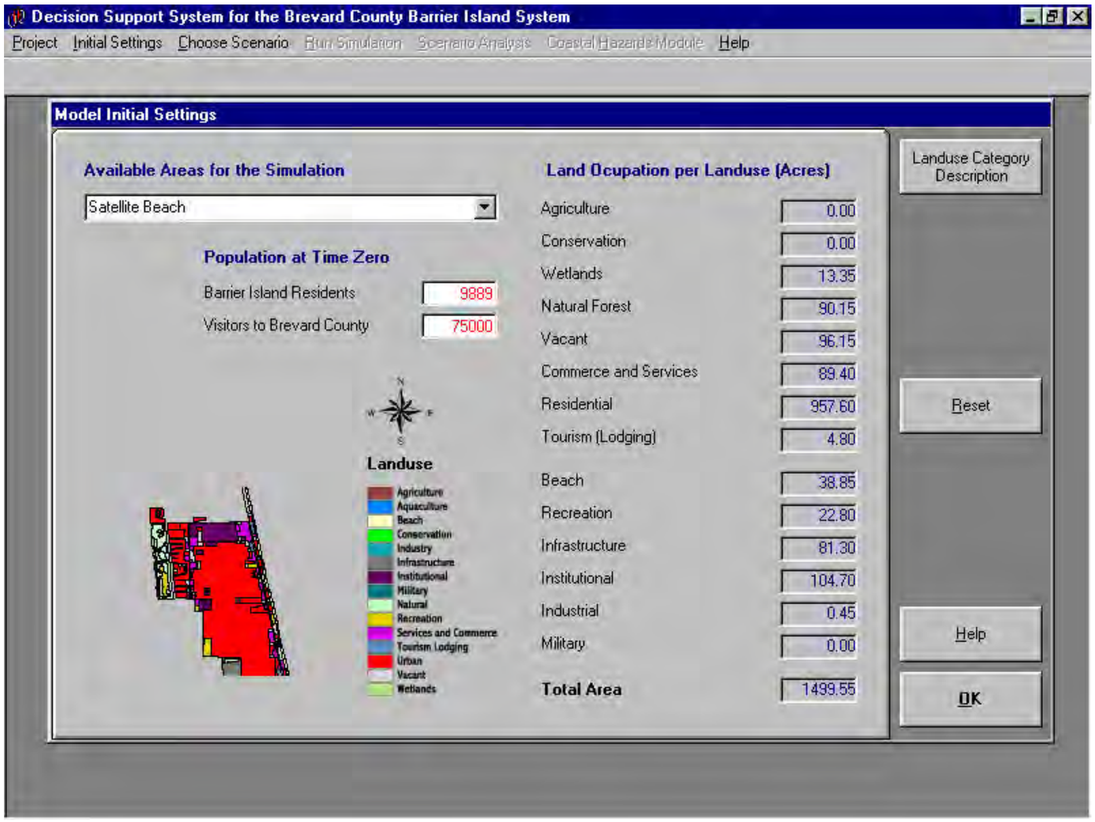


Figure 6.2. Initial Setting DSS Screen.

Scenario Setup

All the alternatives for land development and redevelopment discussed in Chapter 4 can be chosen in the Scenario Setup Screen (Figure 6.3), along with the socio-economic growth rates and land allocation demands. The choice of policies is made by selecting/deselecting the following four options:

- Maintain Agriculture Lands
- Maintain / Increase Conservation Lands
- Priority to Residential Development
- Priority to Tourism Development

The amount of developed and undeveloped land available for the area is given to the user as information so that the land demand can be requested.

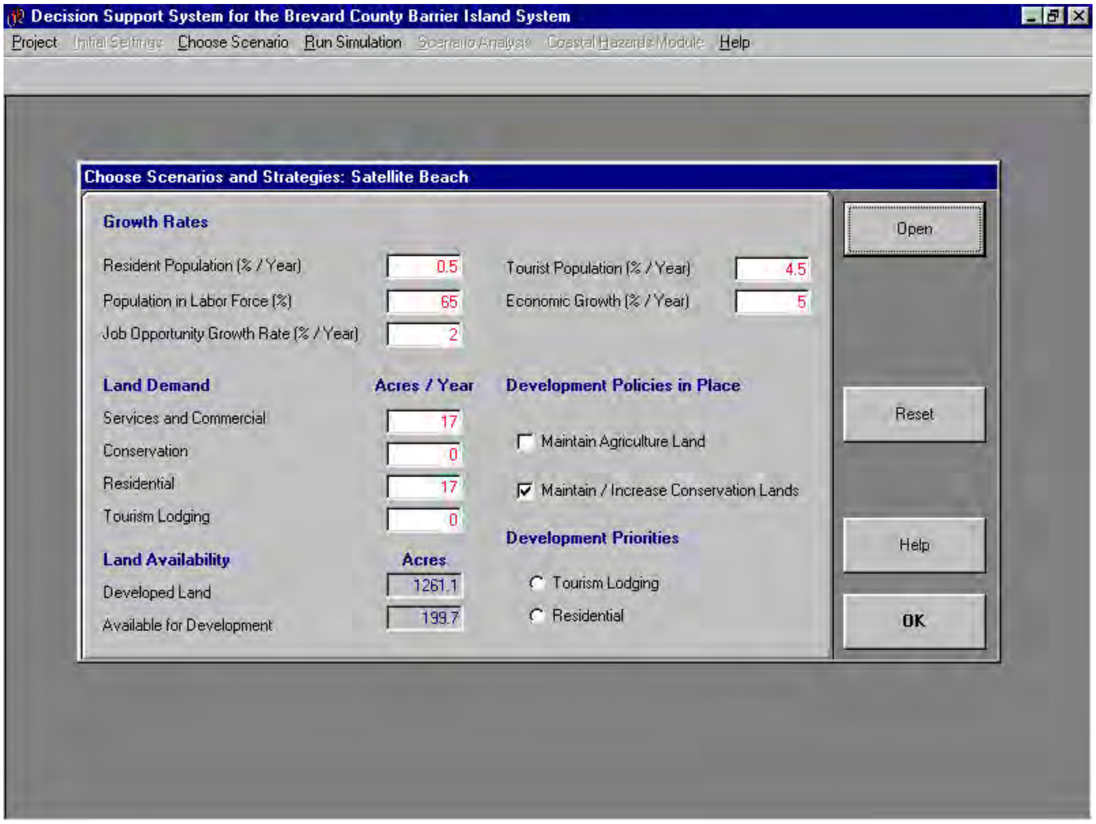


Figure 6.3. - Scenarios and Strategy Setup Screen

Simulation Menu

The simulation is controlled from the options in the top menu bar in the program main window (See Figure 6.4).

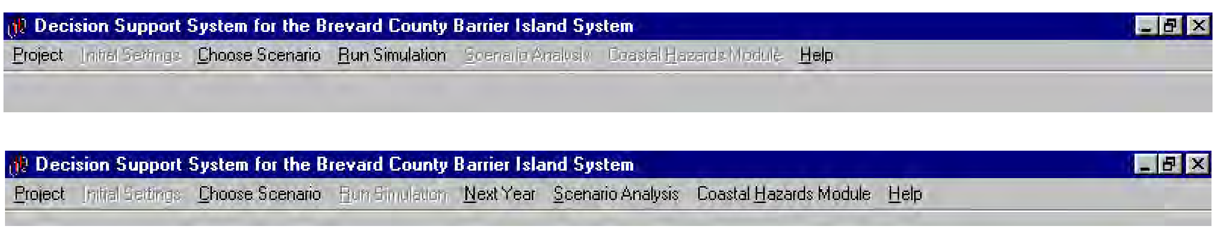


Figure 6.4. - Simulation task bars to control the simulation

The simulation can be run in three different options:

- On a yearly basis, where the user is allowed to change the scenario parameters every year and that can be very useful to introduce discrete events.
- Five years at a time, where the chosen parameters are kept the same during the 5 years without the possibility of any changes in the settings to occur (See Scenario 2 in Chapter 7).

- Ten years at a time. This is the maximum time length allowed for the simulation to run. This option is useful is the user whishes to maintain the same settings during the entire simulation without any changes. (See Scenarios 1 through 3 in Chapter 8)

A comparison between a simulation run using the yearly and five year option is made in Chapter 7 for the city of Satellite Beach.

Simulation Analysis Module

There are two options to visualize the evolution of the simulation variables with time: a quantitative screen where the current variables are quantified and where it is possible to change the land requests for the next simulation step (See Figure 6.5), and a graphic screen (Figure 6.6) where the evolution of each variable is plotted with time.

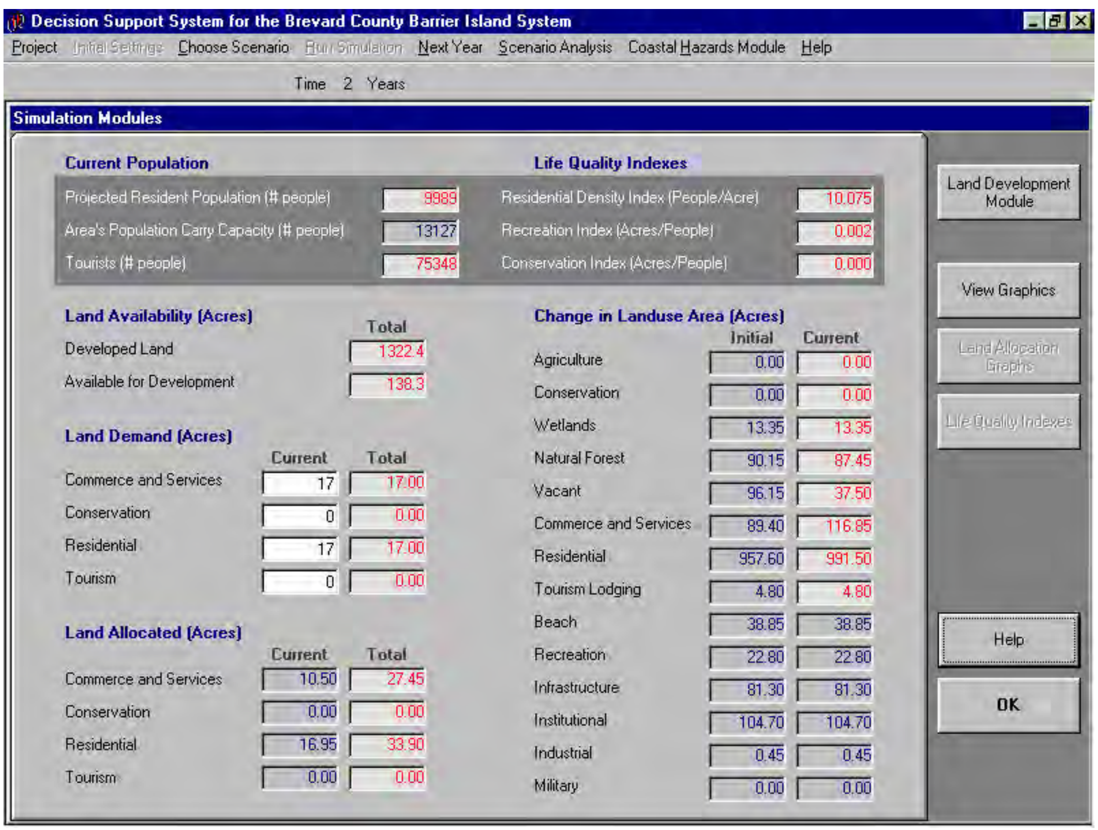


Figure 6.5. - Quantitative display in the simulation analyses screen.

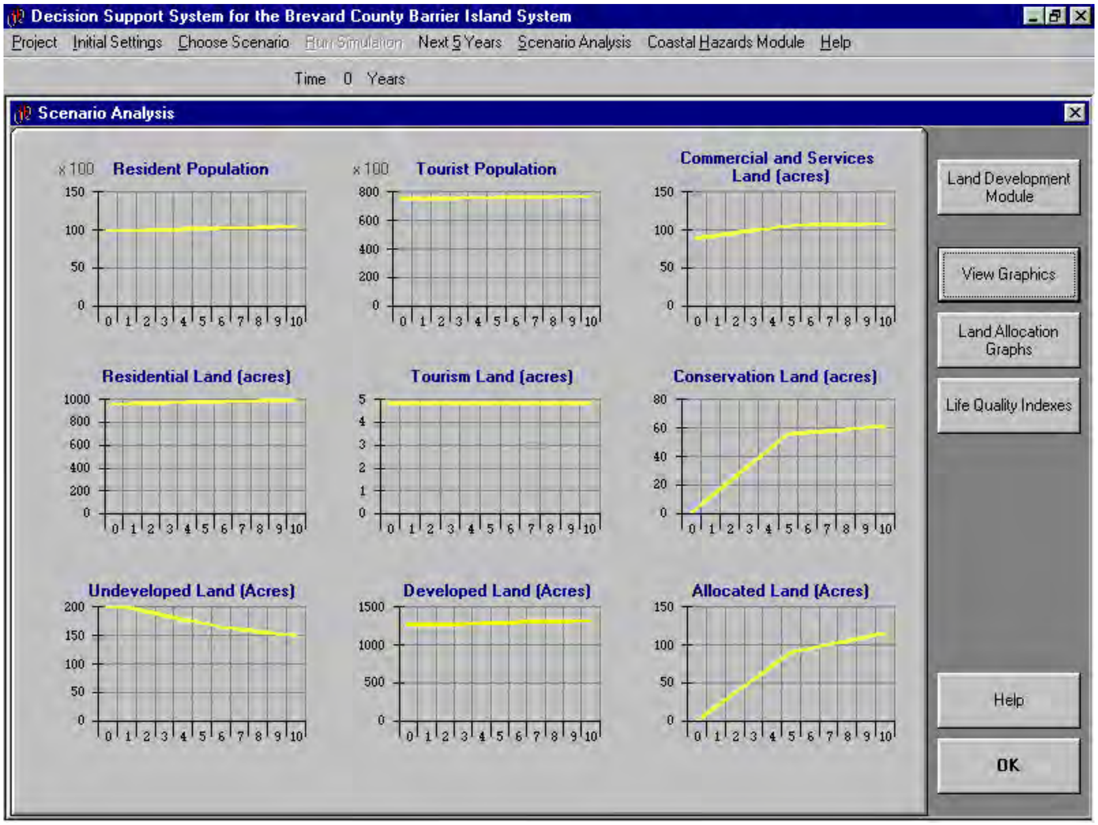


Figure 6.6. Graphic display in the simulation analysis screen.

Scenario Analysis Module

The scenario analysis screens, allow the analysis and comparison between any two given years of the simulation. The user can chose a base year and compare the evolution of the simulation any number of years from that base year. In the case of Figure 6.6. the base year chosen was step t = 0, and the year chosen to compare was t = 5. The evolution of the residential use from t = 0 to t =5 are displayed in the third image, where in red are the residential areas commonly allocated in years t = 0 and t = 5, and in blue are the new residential areas created after t = 0.

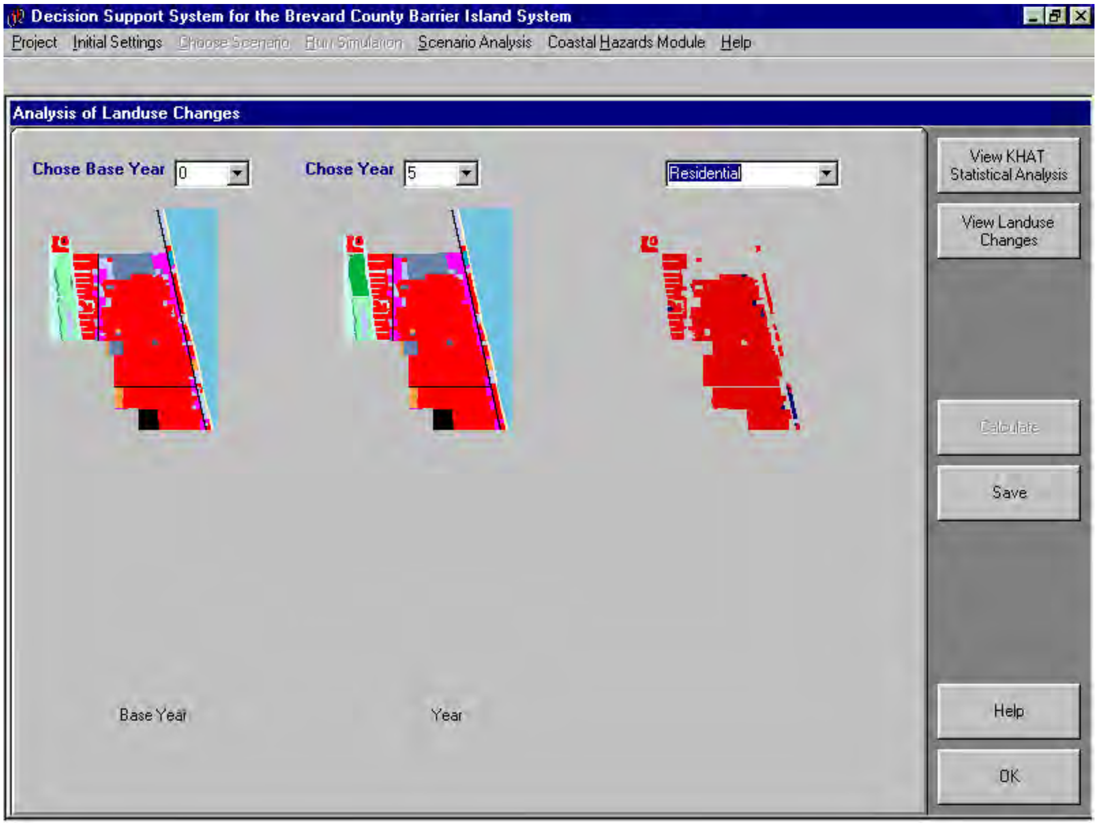
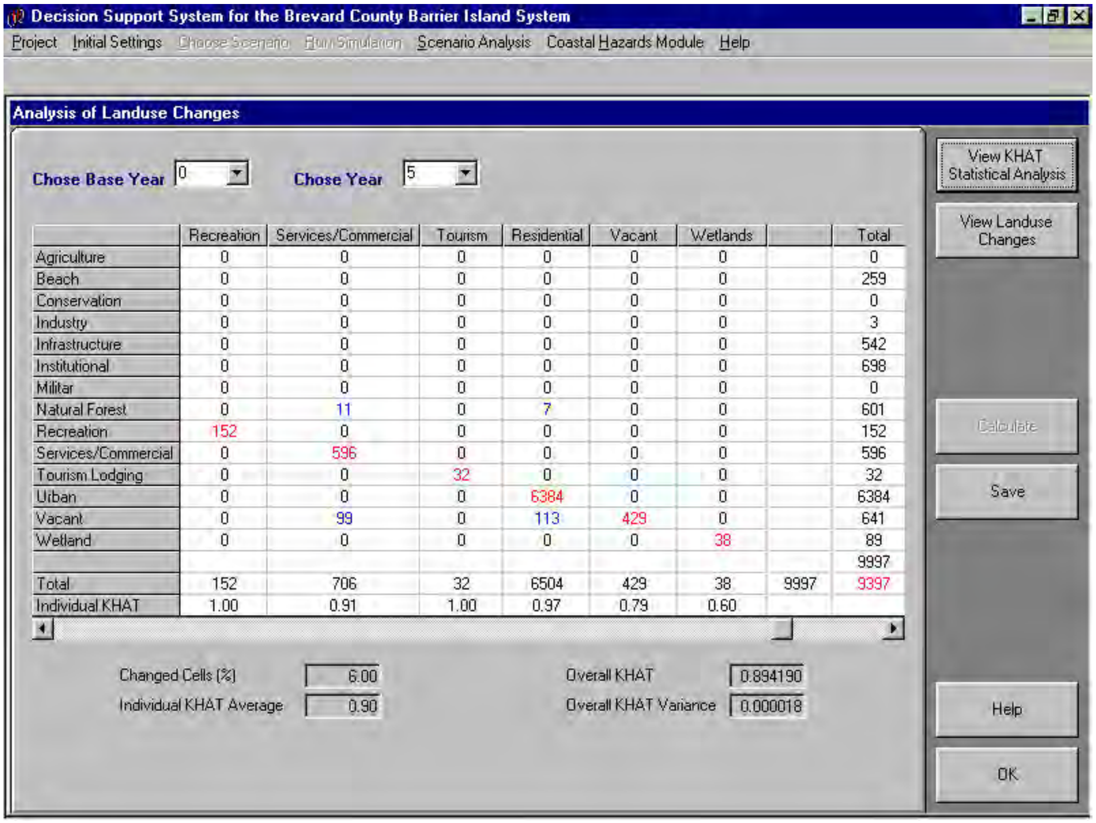


Figure 6.7. - Simulation pattern comparison screen.

In addition to this comparison, a statistical analysis of each land use pattern is calculated for the same two years (See Figure 6.8). This analysis consists of a cell-by-cell comparison in terms of number of cells changed from one use to another and on the calculation of the KHAT statistic (See Chapter 5 for details), its variability and the percentage of cells changed between the two patterns. The KHAT statistic for each individual use category is also calculated.

In Figure 6.8 the matrix displayed shows a comparison in terms of number of cells between both land use patterns allocated to the same use. Numbers in red represent cells that are common to both land patters and the numbers in blue show the cells that have been changed from one use to the other.



	Recreation	Services/Commercial	Tourism	Residential	Vacant	Wetlands		Total
Agriculture	0	0	0	0	0	0		0
Beach	0	0	0	0	0	0		259
Conservation	0	0	0	0	0	0		0
Industry	0	0	0	0	0	0		3
Infrastructure	0	0	0	0	0	0		542
Institutional	0	0	0	0	0	0		698
Militar	0	0	0	0	0	0		0
Natural Forest	0	11	0	7	0	0		601
Recreation	152	0	0	0	0	0		152
Services/Commercial	0	596	0	0	0	0		596
Tourism Lodging	0	0	32	0	0	0		32
Urban	0	0	0	6384	0	0		6384
Vacant	0	99	0	113	429	0		641
Wetland	0	0	0	0	0	38		89
								9997
Total	152	706	32	6504	429	38	9997	9397
Individual KHAT	1.00	0.91	1.00	0.97	0.79	0.60		

Figure 6.8. - KHAT Statistic calculation screen.

<u>Natural Hazards Modulus</u>

As explained in Chapter 4, the Natural Hazards module is an attempt to show how the application of the results of the socio economic and land use pattern simulation can be extended to other areas of research.

The Natural Hazards Modulus (See Figure 6.9) uses the information from the simulation and calculates the impacts of storm surges on the area for the each predicted land use pattern in terms of potential population at risk, area impacted, and capital at risk for each land use.

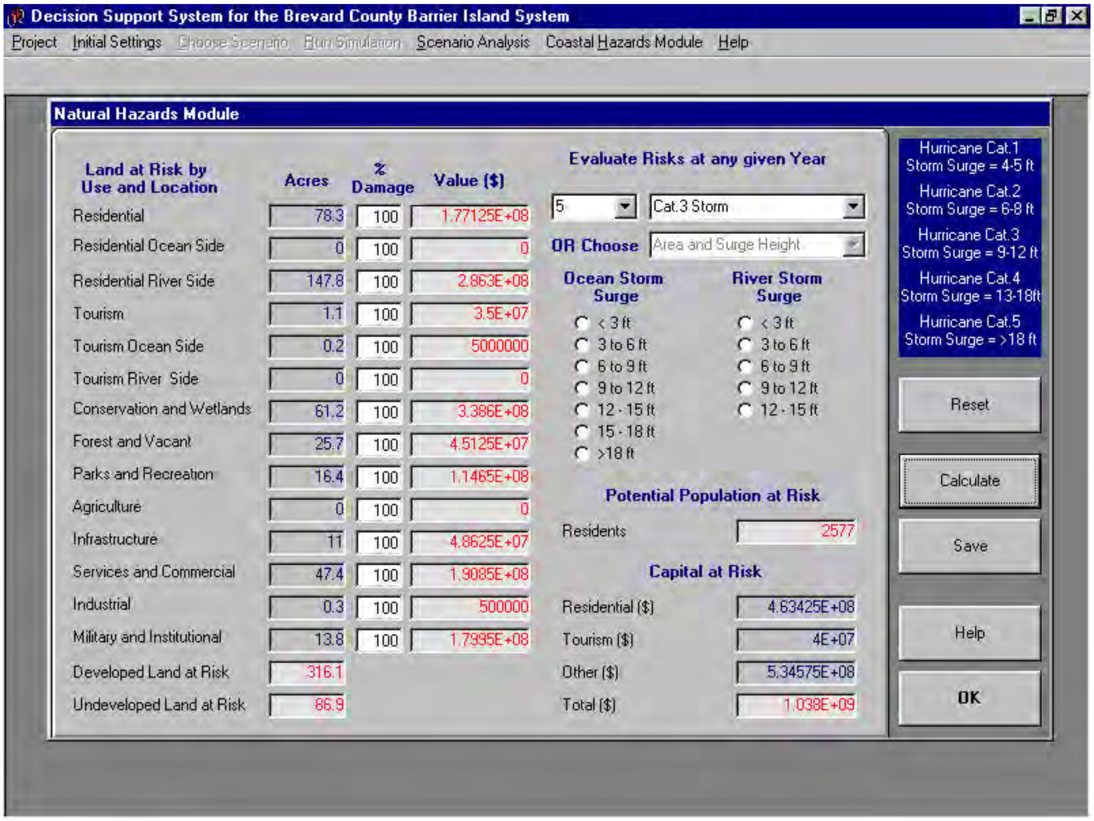


Figure 6.9. - Natural Hazards Module.

System Outputs

In addition to the screen displays, each analysis module creates a "comma separated value" (csv) export file for each variable calculated that can be read in any spreadsheet software or text editor. Also, each land use pattern displayed in the scenario analysis module is saved in the bitmap format in the project directory. Finally, each land use pattern can be exported as a raster format grid file compatible with Arc View TM , and each land use pattern can be further analyzed using that GIS software.

Chapter 7
Satellite Beach Case Study

City of Satellite Beach

The City of Satellite Beach is located in the central area of the Brevard County barrier island. The city land area is approximately 2.4 square miles (1539 acres), having an east-west length of 1.4 miles and a north-south average length of approximately 2.5 miles. City boundaries are to the north, the South Patrick Shores area and some unincorporated areas of the county, and to the south the City of Indian Harbor Beach. To the east the Atlantic Ocean provides 2.6 miles of oceanfront beaches and to the west the Banana River and the Grand Canal provide additional 0.5 square miles of water area to the city, in a total of 1.3 miles of riverfront properties (City of Satellite Beach, 1996).

According with the 1990 Census the city's population was 9889 people and the estimated seasonal population was 436 people (City of Satellite Beach, 1996). From 1990 through 1995, the population growth rate averaged 2.4 % (See Table 1a in Appendix B). The tourist capacity for the city is 80000 tourists. This number was estimated by multiplying the number of rooms in the only hotel in the city (108 rooms) by 365 days and by an average of two people per room.

According to the city's comprehensive plan, by 1995 the city was almost completely built up, with only 5 % of the city's developable area remaining vacant. As shown in Figure 7.1, the city's predominant development pattern is residential use with services and commercial development clustered along the main arterial roads. The only hotel in the city is located close to the northeast limit of the city, east of State Road A1A (See Figure 7.1).

One of the city's 6 parks, the Sampson Island Nature Park, is used later in this Chapter to point out some of the features of the DSS and its location pointed out in figure 7.1. The park was regulated as a public park during 1990, but it took about three years to clear all the land of invasive forest and reclaim some of the area for conservation and public facility construction (Fergus 2000, personal communication).

Figure 7.1. City of Satellite Beach land use grid for the year 2000

System Calibration and Validation to the City of Satellite Beach

Population Growth Functions

A 0.5 % growth rate for the residential population of Satellite Beach was chosen for the calibration runs. This growth coefficient was calculated by fitting an exponential growth curve (See Figure 7.2) to the 1990 to 1997 population data presented in Appendix B. The regional population carrying capacity growth curve also included in the Figure 7.2 was calculated as discussed in Chapter 3 and is based on the number of people that can potentially live in the area given the local residential density regulations.

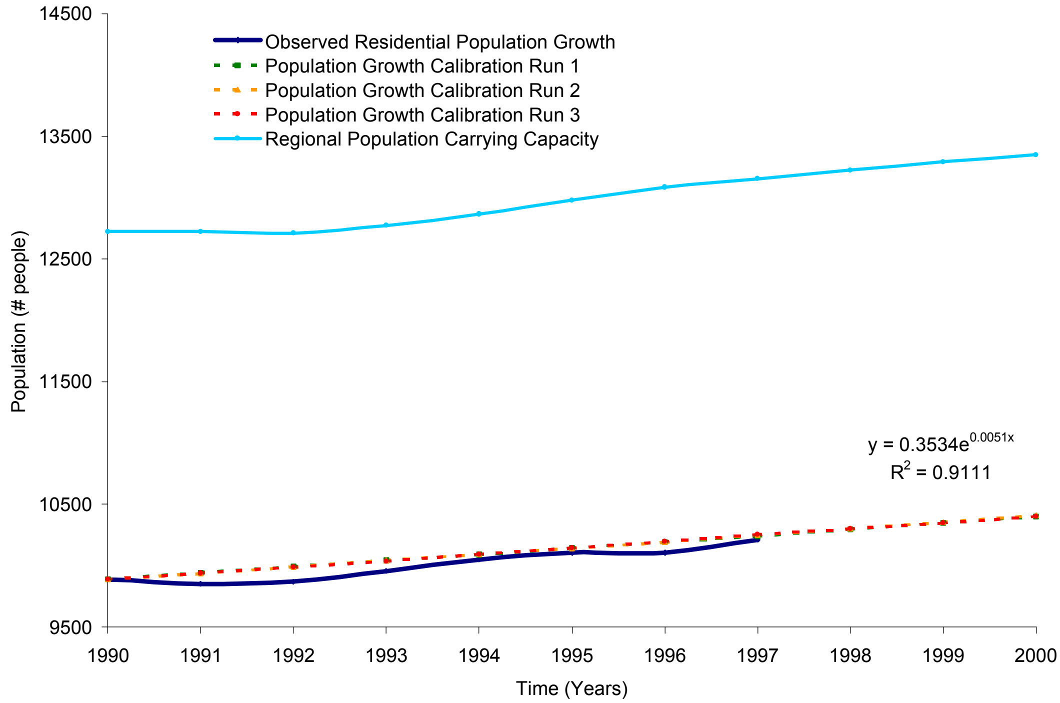


Figure 7.2. Observed and simulated residential population growth for the three calibration runs.

Quality of Life Indexes

Based on the population growth estimated for the area, the quality of life indexes were also calculated for all the runs and for the 3 observed years. Simulation values at the year that observed data are available (1990 and 1995) shown to be very close, in spite of the 10 % variability added to the system.

The simulated quality of life indexes are also in agreement with the values observed and identified in Figure 7.3. The figure shows that the City of Satellite Beach's Recreation Index is about 2.3 acres per 1000 people. However if one adds the Conservation Index values, which represents new land set aside for conservation and public use (See Chapter 3) there is an addition of approximately 6 acres per 1000 people to that amount. As a reference the acceptable level of service for recreation and open space set by the County for its unincorporated areas is 3 acres per 1000 people (Brevard County Planning and Zoning Division, 1998), so the City of Satellite Beach is above that level. The residential density index for the city is approximately 10.5 people per acre, which corresponds to an average residential density of 5 dwelling units per acre.

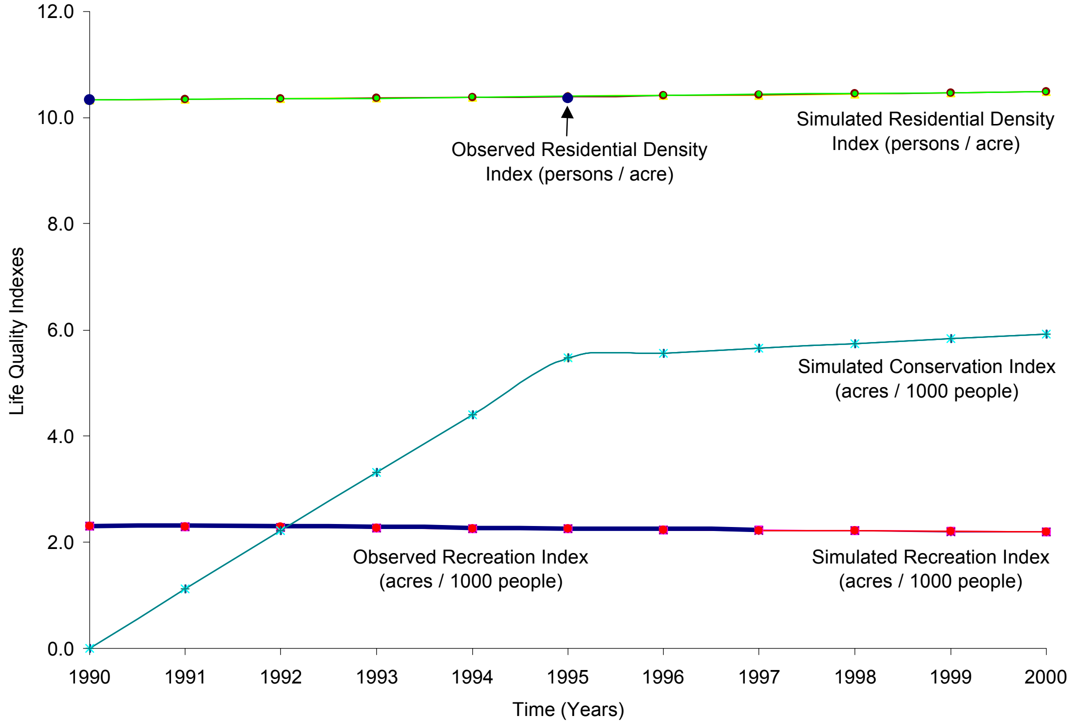


Figure 7.3. Observed and simulated Life Quality Indexes for the three calibration runs.

Matrix Dimensions and Resolution

The resolution for the City of Satellite Beach grids was the same as the general barrier island grid discussed in Chapter 3, consequently each cell in the matrix represented an area of 0.15 acres or 25 square meters (82 square feet). In terms of the correspondent ground resolution, the average residential parcel in the City of Satellite Beach is around 0.25 acres, which means that in the simulation grids each pair of cells approximately corresponds to a single-family residential lot.

The total number of cells in the matrix is 20,088. In spite of the relatively large number of cells in the matrix (See table 7.1.) only about 41 % of these cells are eligible to change their landuse state. A larger number, 60 % actively participates in the simulation by contributing to the distance neighborhood calculations. From all the ocean and river cells existing in the matrix only the cells within a 1 cell distance of any other use participate in the simulation which in the present case is a very small percentage of the those cells. The dimensions and characteristics of the land use matrices follow:

Table 7.1. Characteristics of the City of Satellite Beach land Use Matrices

Matrix Characteristics	Number of Cells	% From Total
Number of Rows	162	
Number of Columns	124	
Total in the Matrix	20088	
Zero Value Cells	5849	29.1
Participate in calculation of the KHAT statistic	9997	49.8
Fixed use cells that participate in calculation of the KHAT statistic	1654	8.2
Atlantic Ocean and Indian River Lagoon Cells	4242	21.1

Land Allocation Simulation

The barrier island general land use grids for 1990, 1995 and 2000 (See Chapter 3) were clipped to the boundaries of the City of Satellite Beach, to use as the observed data sets for calibration and validation of the DSS for the City. The Future Land Use and the Planning and Zoning general grids (Figures 2 and 3 of Appendix B) were also clipped for the City of Satellite Beach in order to create the suitability grids (Figures 4 through 6 in Appendix B) necessary for the calibration of the simulation.

The calibration process followed the methodologies described in Chapter 5. The simulation was run for 5 years, using as base year the 1990 land use grid, and a distance influence weight matrix. As part of the calibration process, these weights were continuously changed (See Table 2 in Appendix B) until:

- The changes in the simulated land use patterns between 1990 and 1995 were no longer significantly different from the changes in the observed land use patterns from 1990 through 1995 patterns (See Figure 7.4.), and
- Until the simulated patterns after the simulation was carried forward another 5 years (validation process) from 1995 and 2000 did not show significant differences from the observed land use pattern's changes for the same period (See Figure 7.4).

Therefore, the final distance influence weights chosen were the ones that best satisfied both the calibration and the validation process of the model. Figures 8 through 15 in Appendix B show the results of the calibration and validation runs.

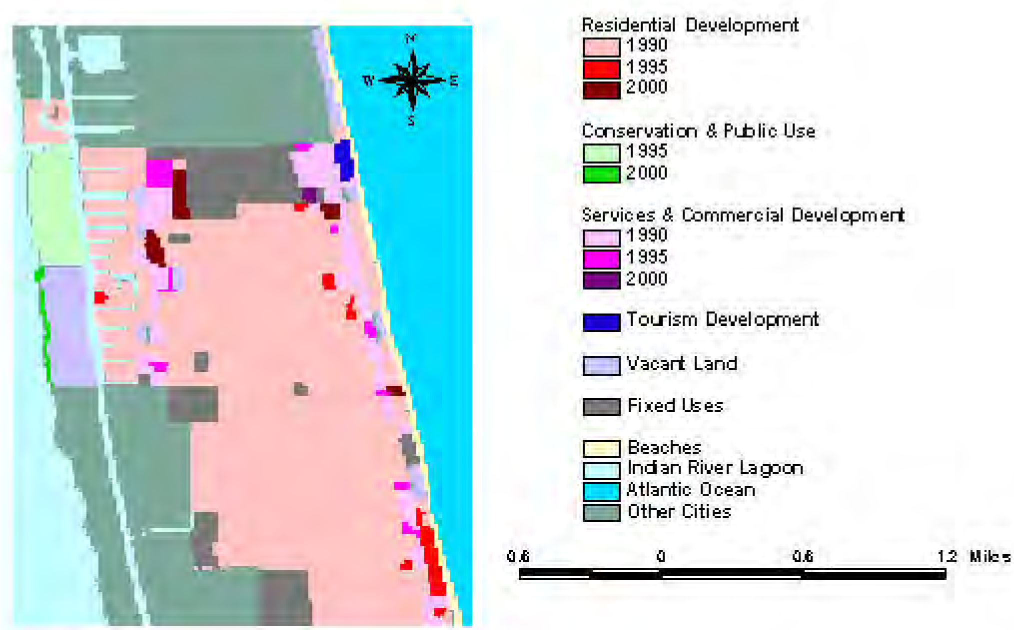


Figure 7.4. Observed changes between 1990 and 1995 and 1995 and 2000 for residential, services and commercial, tourism and conservation uses.

During the early calibration trial runs it was found that in some cases an adjustment on the amount of land demand for the five-year period had to be made in order obtain the amounts of land requested. The small correction was necessary mostly to overcome the fact that the number of cells allocated to a use, is a multiple of the grid resolution (0.15 acres cells). As a consequence the amount of land allocated to each use, will always be increased or decreased to the closest multiple of the 0.15 acres. Tables 3 and 4 in Appendix B show the amounts of land requested and allocated for each calibration run.

The KHAT statistic was calculated between each five-year period separately for the observed and simulated run. A test of significance for the KHAT between the 1990 and 1995 and the 1995 and 2000 simulated and observed patterns was also calculated. As expected in both cases the differences were significant (See Table 5 and 6 in Appendix B).

Secondly, the tests of KHAT significance were made between the previously calculated KHATs of the 1990 and 1995, 1995 and 2000 and 1990 and 2000 observed and simulated land use patterns. Table 7 in Appendix B shows that there were no significant differences between the observed and simulated land use patterns in all the runs.

Five Year versus Yearly Runs

In order to assess the model response to discrete events, the model was run between 1990 and 1995 using two different approaches:

- In the first approach the model was run over a five-year period, and the total land requested for the 5 years was averaged for each year in equal amounts.
- In the second approach the model was run on a yearly basis with the total amount of land requested over the five years averaged equally each year only for the residential and services and commercial land uses. As mentioned in the beginning of this chapter, the Sampson Island Nature Park was created between 1990 and 1993.

For the yearly runs, it was assumed that the park opened to the public in 1992, and the total park acreage was entered as the conservation land demand for that year. During the other 4 years no conservation land was requested. Figures 7.5 and 7.6 show the results of the two approaches. It is clear that the structure of the model allows enough flexibility to simulate both discrete and continuous events at the same time. This characteristic of the model can be very useful, because it allows changes in the suitability grids and / or scenarios at any point of the simulation. In each case, these changes can be introduced for the sixth year when the model is run every five years and every year when the model is run one year at a time.

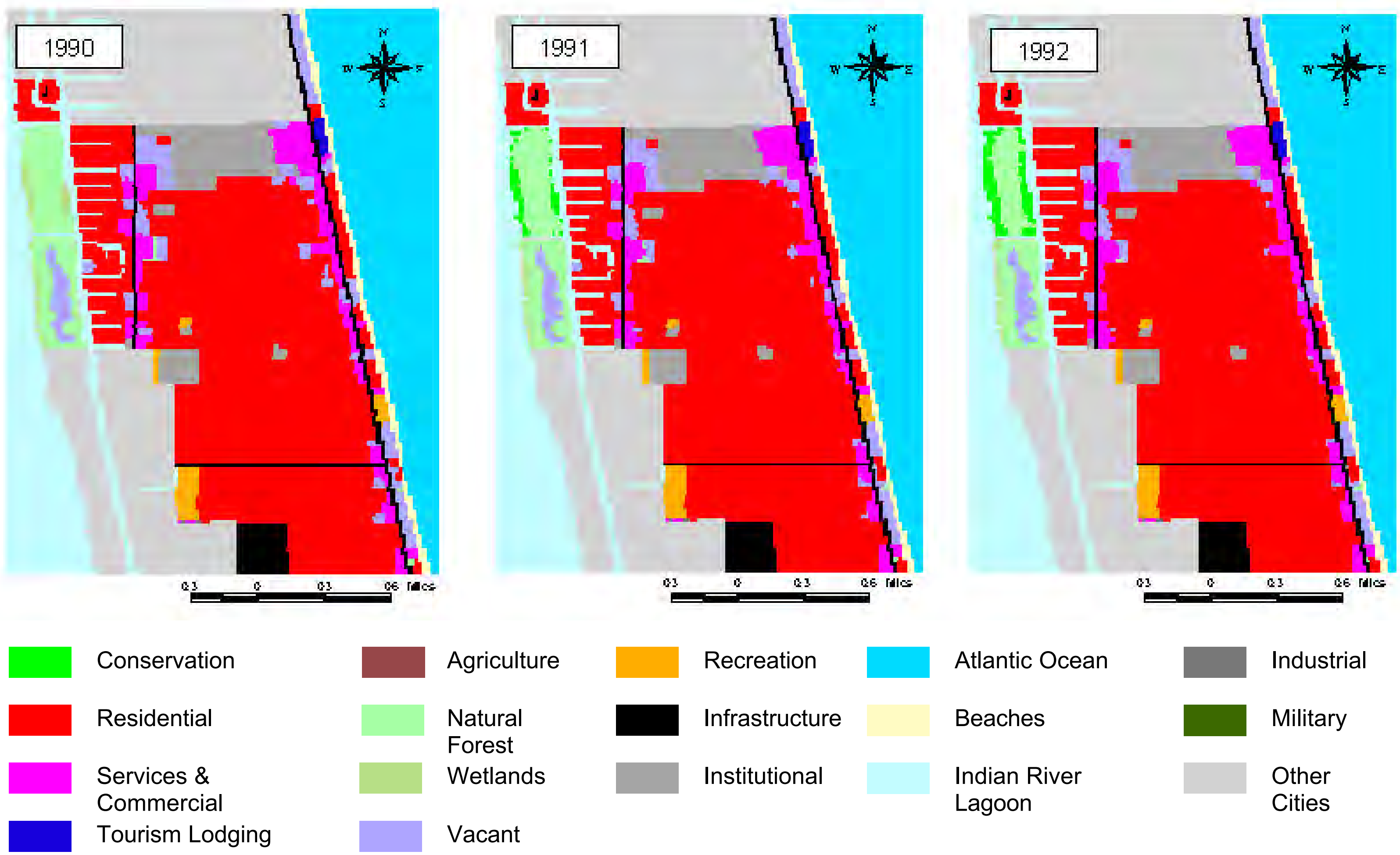


Figure 7.5.a Five years run. Land Demand for residential, services and commercial and conservation uses, averaged for the 5 years. Land use patterns from 1990 through 1992

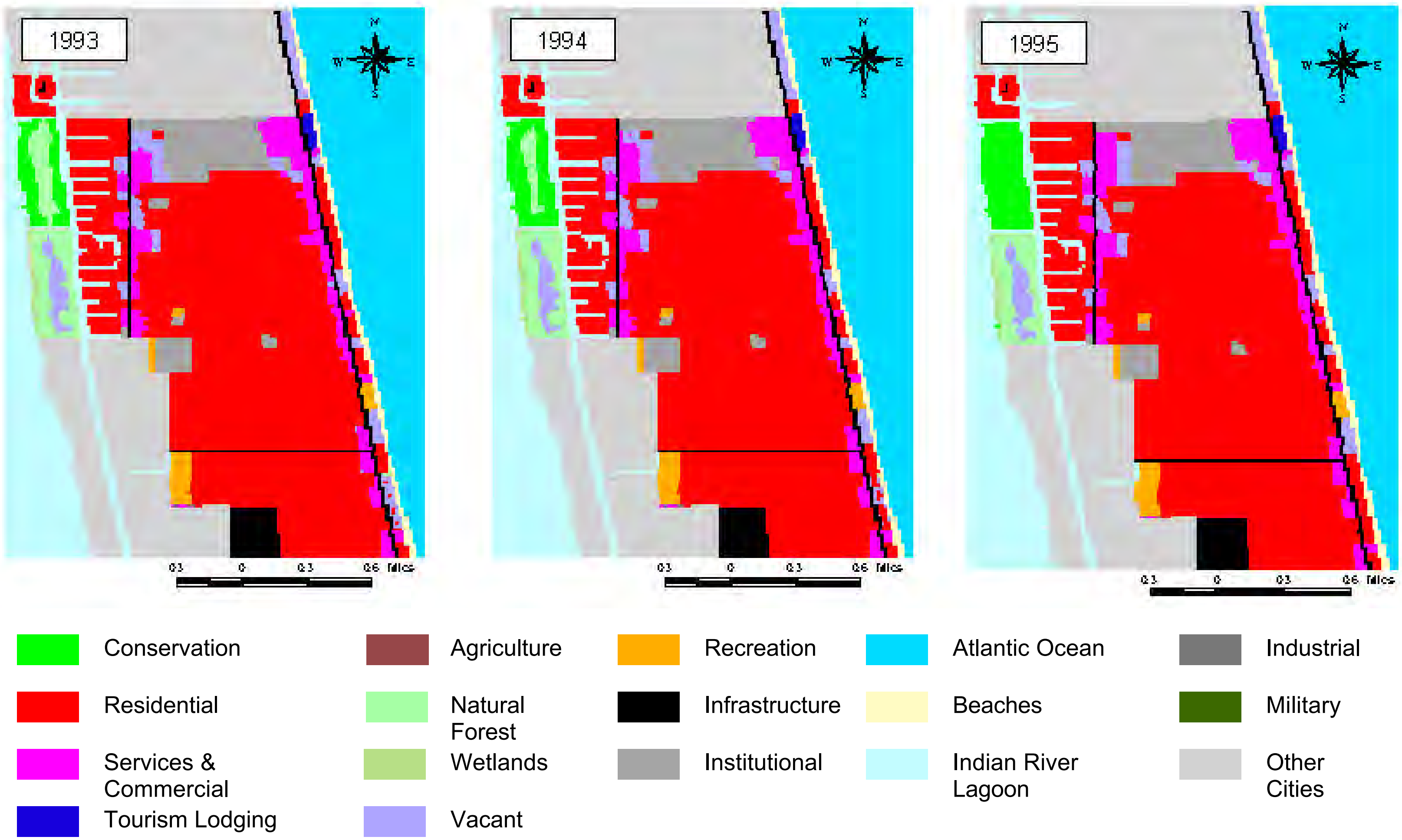


Figure 7.5.b Five years run. Land Demand for residential, services and commercial and conservation uses, averaged for the 5 years. Land use patterns from 1993 through 1995

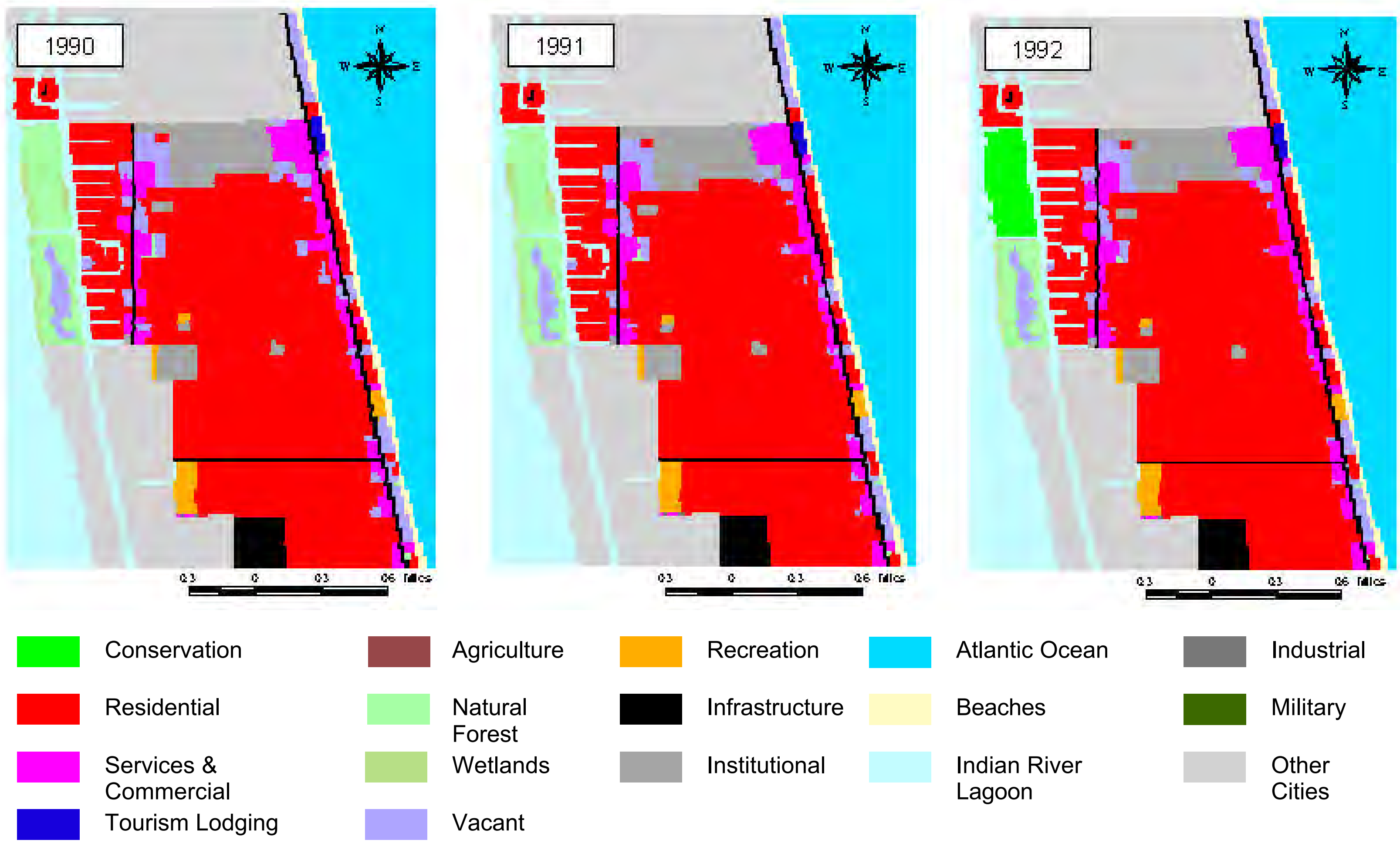


Figure 7.6.a Yearly Runs. Land Demand for residential and services and commercial uses averaged for the 5 years. The total amount conservation use was requested in 1992 only. Land use patterns from 1990 through 1992.

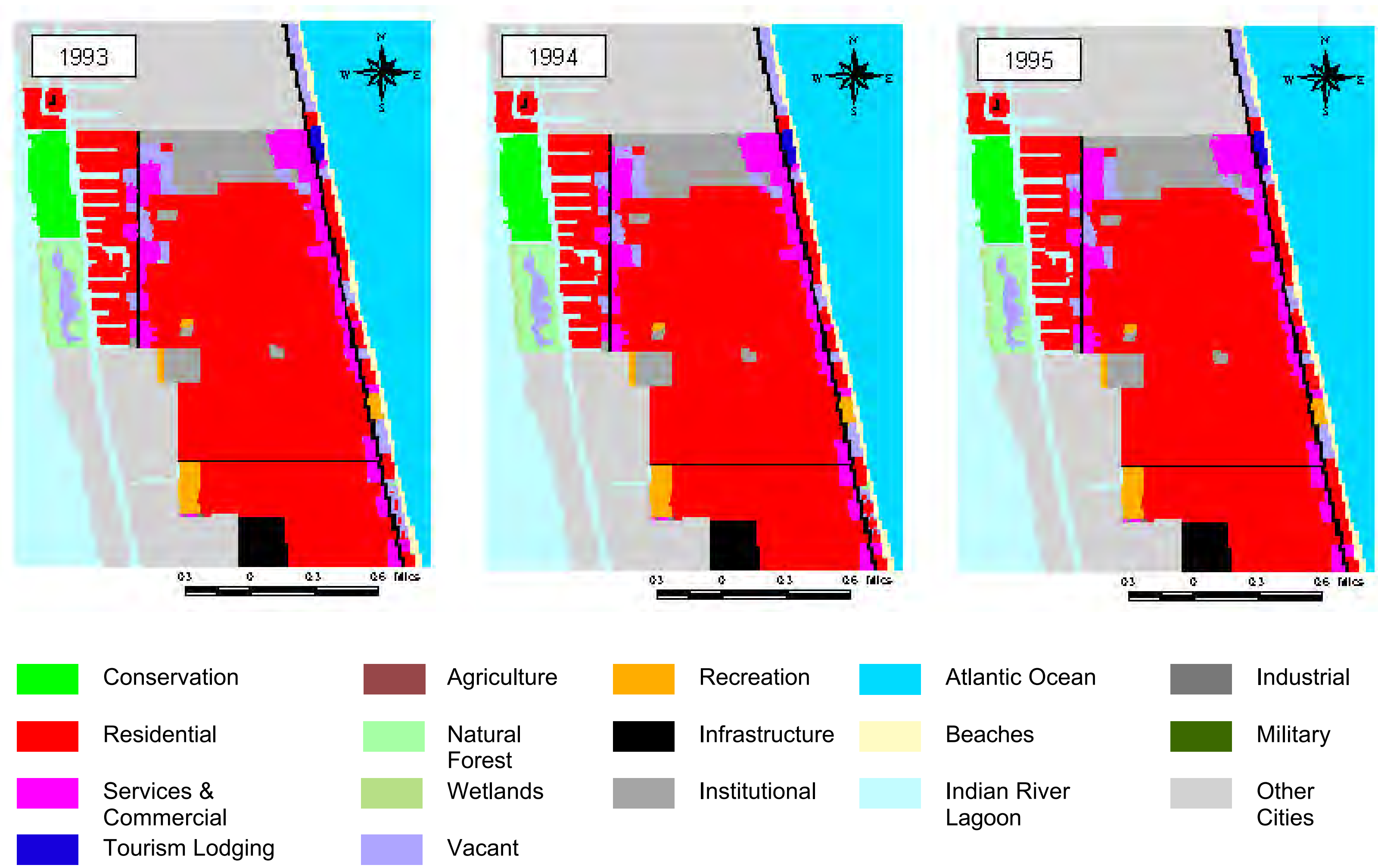


Figure 7.6.b Yearly Runs. Land Demand for residential and services and commercial uses averaged for the 5 years. The total amount conservation use was requested in 1992 only. Land use patterns from 1993 through 1995.

Effects of Development Policies in the Future Land Use Patterns of the City of Satellite Beach

The first part of this research consisted in calibrating and validating the model to the test area. The second part of this research assessed the predictive capabilities of the DSS, and its response to the different built-in development policies. The latter was completed, by designing the series of scenarios that are described next.

Scenario Design

Each scenario was designed to test both individually and together a different set of land development alternatives (See Chapter 4). In some cases some of these alternatives are likely to become real within the next 10 years, if the City maintains its land development policies as they are currently set in the City's Comprehensive Plan.

The year 2000 was used as a starting point for all the forecast scenarios. The resident and tourist population predicted during the calibration of the system for the year 2000 was used as the initial population counts for these scenarios. However, since the focus of these scenario runs was the land allocation simulation, no changes were made in the settings of the socio-economic parameters used previously to calibrate the system.

Two groups of scenarios were considered. One that maintains the current development trends and considers only the evolution of three uses: residential, Services and Commercial and Conservation. And a second group, which lifts the current “ban” on tourism development within the city limits, and introduces the possibility of such development to occur.

For this purpose two new suitability grids were added to the system. One that extends the suitability for conservation use to all the remaining vacant and forest lands in the city (See Figure 7.7) and a second one, which sets the suitability areas for tourism development (See Figure 7.8). The design of these grids is discussed in detail in Chapter 3.

The amount of land available for development within the city limits as of the year 2000 was about 85 acres, not including conservation lands. For each scenario the available land was divided equally by the 10 simulation years. Exceptionally in Scenario 2, the total amount of land available was divided equally by five years, to test the system response to a faster degree of development.

The yearly amount of land available for development was requested equally for each of the individual uses to activate the random sorting of the land demand requests and leave up to chance, the order by which

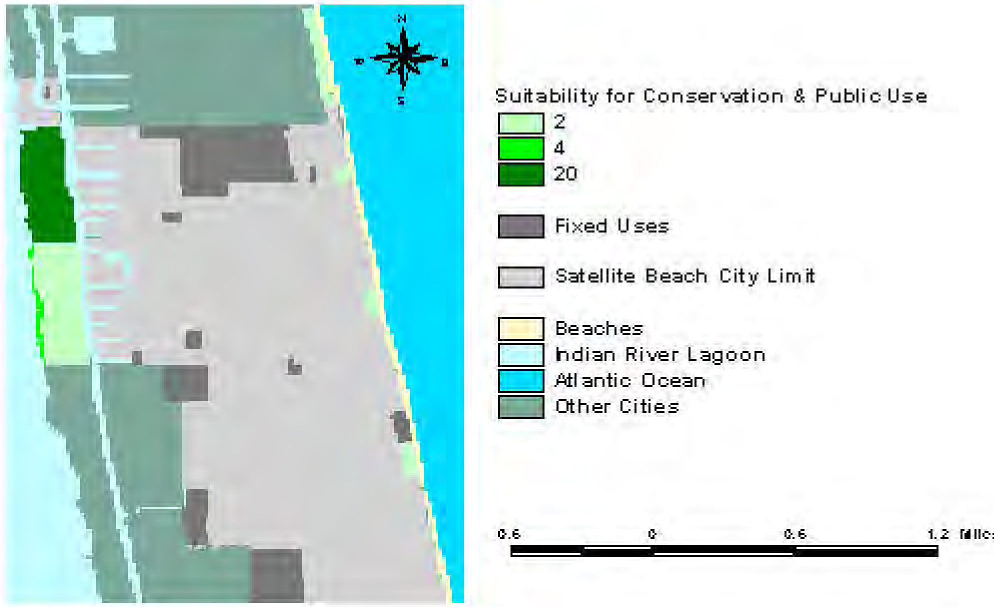


Figure 7.7. Suitability weights for conservation use, grid created for the scenario runs.

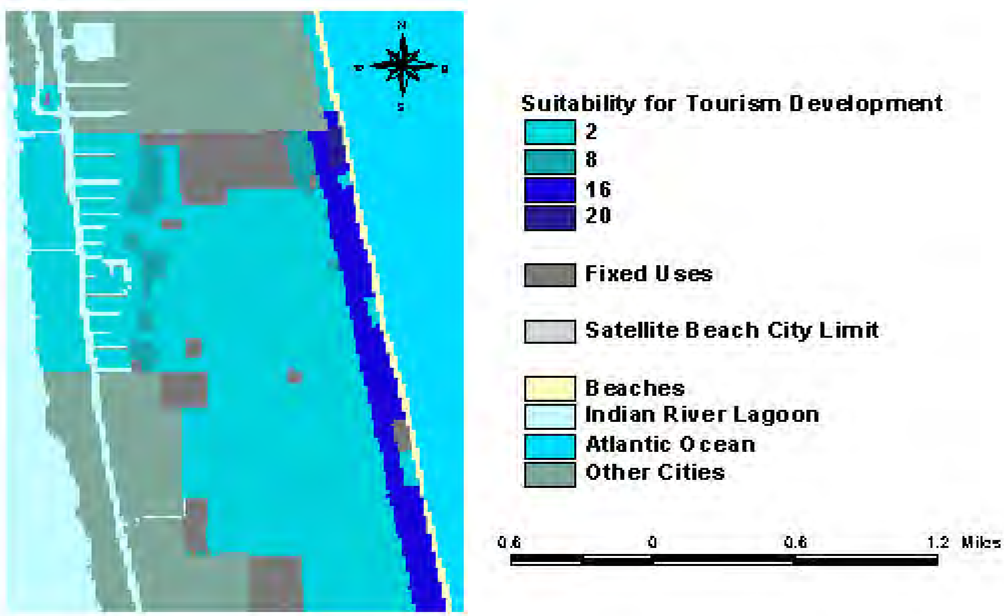


Figure 7.8. Suitability weights for tourism use, grid created for the scenario runs.

the land is allocated to each specific use. This way competition between the uses for allocation of land was assessed too, because if there are no more suitable cells for a requested use, no more cells will be allocated to that use independently of the amount of land requested.

Each scenario was run three times and the KHATs for each run were compared to asses if there were no significant differences between runs. However, it was expected that significant differences were registered randomly, because of the stochastic disturbance factors added to the system: one in the potential of change algorithm and the second one in the land allocation algorithm, which determines the order by which the allocation of land to a specific use is done. As discussed in Chapter 5, the later can significantly influence the outcome of the simulation.

The land use patterns created for the years 2005 and 2010 for run 2 of each scenario were chosen to illustrate the results obtained in each scenario.

Scenario Description

Scenario 1

Scenario 1 follows the current policies stated in the Future Land Use Element of the City of Satellite Beach Comprehensive Plan. Thus, it favors the development of the current available land with the planned uses for the land, and maintains the lands currently allocated to conservation and public use.

Within the 10 year planning horizon (2000 to 2010) the amount of land requested was 8.5 acres for both residential and services and commercial development. No additional amount of land was requested to be allocated for conservation or public use; but the “Maintain / Increase Conservation Lands” policy was kept to prevent the simulator to develop conservation lands in case it could not satisfy the land demand for the other uses.

Table 7.2 illustrates the land requests and the amounts of land allocated for each run of Scenario 1. Figure 7.9 shows the landuse patterns obtained for run 2 of the same scenario. Tables 8a and 8b in Appendix B document the KHAT statistic for each run and the tests of KHAT significance for the three runs of Scenario 1 respectively.

Scenario 2

Scenario 2 differs from Scenario 1 in two ways: first the amount of land demanded for each year was doubled to 17 acres in order to assess the effects of a more rapid growth reflected in the increase in the land demand and secondly the conservation policy was changed after the first five year run.

From 2000 to 2005, the lands currently allocated to conservation and public use were maintained in its current state. However, as the city nearly runs out of developable lands by 2005, all conservation lands were released for development for the years 2005 to 2010.

Table 7.2. Land requests per use and land allocated and percentage change for each run of Scenario 1.

Simulation	Scenario 1 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	61.2	61.2	0.0	0.0	0.0	0.0	0.0	0.0
Residential	992.1	1034.9	1068.3	42.7	33.5	4.3	3.2	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Scenario 1 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	61.2	61.2	0.0	0.0	0.0	0.0	0.0	0.0
Residential	992.1	1034.9	1068.5	42.7	33.6	4.3	3.2	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Scenario 1 - Run 3			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	61.2	61.2	0.0	0.0	0.0	0.0	0.0	0.0
Residential	992.1	1034.9	1068.2	42.7	33.3	4.3	3.2	8.5	8.5
Services & Commercial	108	116.55	116.55	8.6	0.0	7.9	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

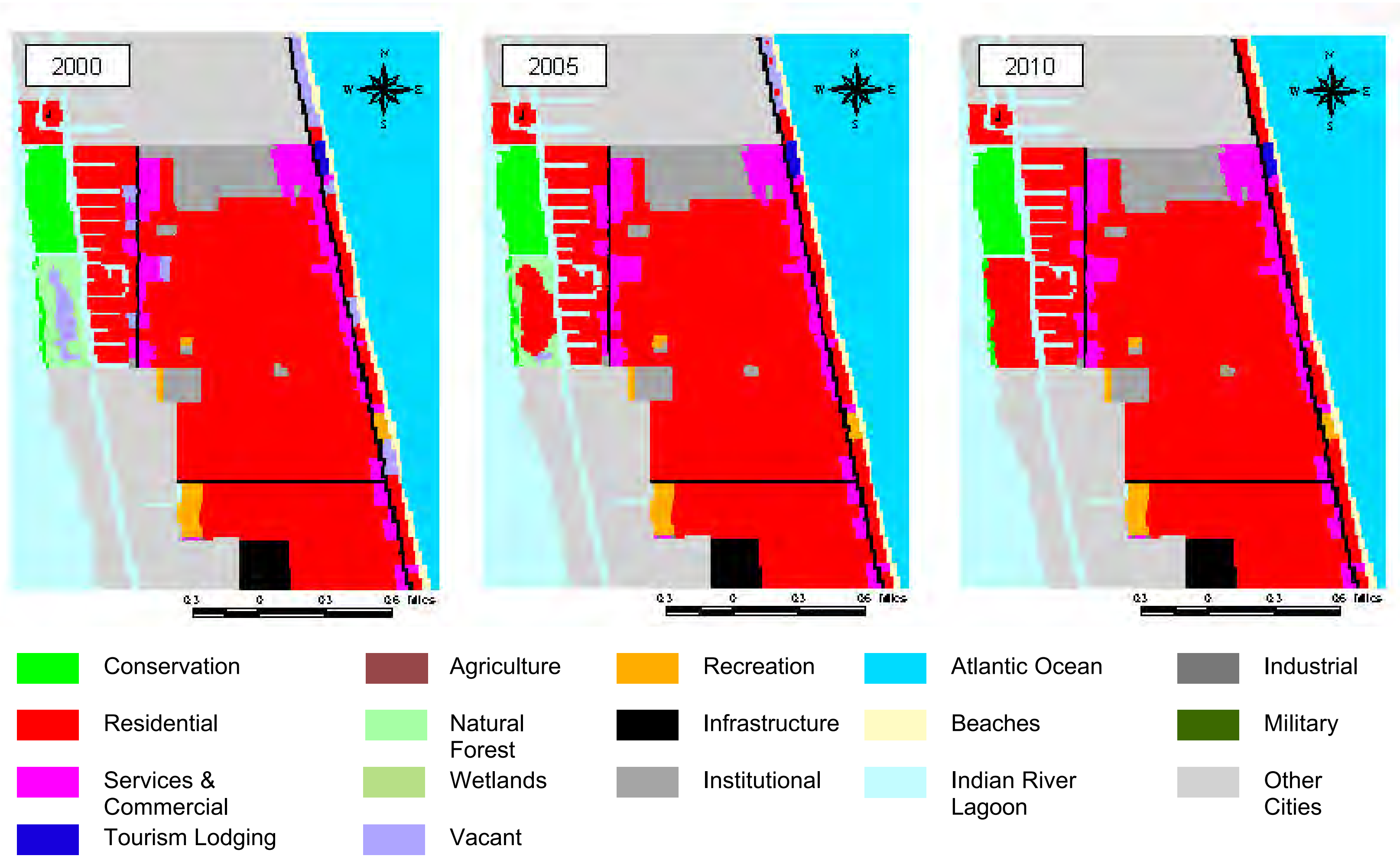


Figure 7.9 Scenario 1: Future land use pattern projections for the City of Satellite Beach for 2005 and 2010 based on 8.5 acres yearly demand for the Residential and Services and Commercial uses, keeping Conservation lands.

Table 7.3 illustrates the land requests and the amounts of land allocated for each run of Scenario 2 and Figure 7.10 shows the landuse patterns obtained for run 2 of the same scenario. Tables 9a and 9b in Appendix B document the KHAT statistic of the individual run and the respective tests of KHAT significance for the three runs of Scenario 2.

Scenario 3

In Scenario 3 the opportunity to increase conservation lands was given by requesting for the three uses (residential, services and commercial and conservation use) the same amount of land for the 10 year period: 8.5 acres.

Table 7.4 illustrates the land requests and the amounts of land allocated for each run of Scenario 3 and Figure 7.11 shows the landuse patterns obtained for run 2 of the same scenario. Tables 10a and 10b in Appendix B document the KHAT statistic of the individual run and the respective tests of KHAT significance for the three runs of Scenario 3.

Scenario 4

In Scenario 4 it was decided from the beginning of the simulation (year 2000) to allow the development of conservation lands. In this case 8.5 acres of land were requested both for residential and services and commercial use, and the “Maintain / Increase Conservation Lands” policy was removed from the simulation.

Table 7.5 illustrates the land requests and the amounts of land allocated for each run of Scenario 4 and Figure 7.12 shows the landuse patterns obtained for run 2 of the same scenario. Tables 11a and 11b in Appendix B document the KHAT statistic of individual runs and the respective tests of KHAT significance for the three runs of Scenario 4.

Table 7.3. Land requests per use and land allocated and percentage change for each run of Scenario 2.

Simulation	Scenario 2 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON/OFF)	61.2	61.2	0	0.0	-61.2	0.0	-100.0	0.0	0.0
Residential	992.1	1066.2	1129.8	74.1	63.6	7.5	6.0	17	17
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	17	17
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Scenario 2 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON/OFF)	61.2	61.2	0	0.0	-61.2	0.0	-100.0	0.0	0.0
Residential	992.1	1066.2	1129.8	74.1	63.6	7.5	6.0	17	17
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	17	17
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Scenario - Run 3			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON/OFF)	61.2	61.2	0	0.0	-61.2	0.0	-100.0	0.0	0.0
Residential	992.1	1064.9	1129.8	72.7	65.0	7.3	6.1	17	17
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	17	17
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

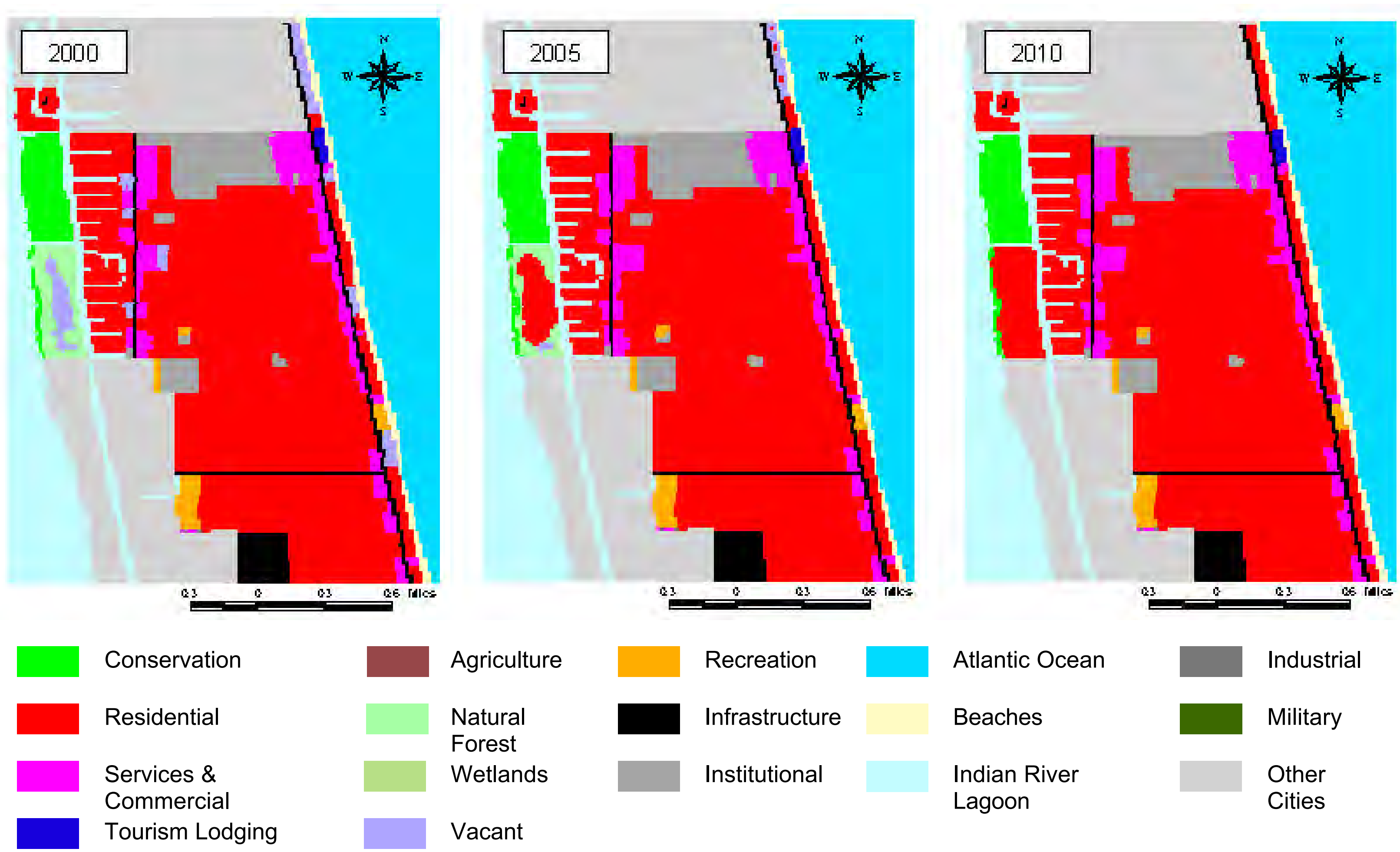


Figure 7.10. Scenario 2: Future land use pattern projections for the City of Satellite Beach for 2005 and 2010 based on 17 acres yearly demand Residential and Services and Commercial uses, keeping Conservation lands only through 2005.

Table 7.4. Land requests per use and land allocated and percentage change for each run of Scenario 3.

Simulation	Scenario 3 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	98.55	98.55	37.4	0.0	61.0	0.0	8.5	8.5
Residential	992.1	1031.3	1031.3	39.2	0.0	3.9	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Scenario 3 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	98.25	99.15	37.1	0.9	60.5	0.9	8.5	8.5
Residential	992.1	1030.1	1030.7	37.9	0.6	3.8	0.1	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Scenario 3 - Run 3			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	98.85	100.05	37.7	1.2	61.5	1.2	8.5	8.5
Residential	992.1	1029.2	1029.2	37.1	0.0	3.7	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

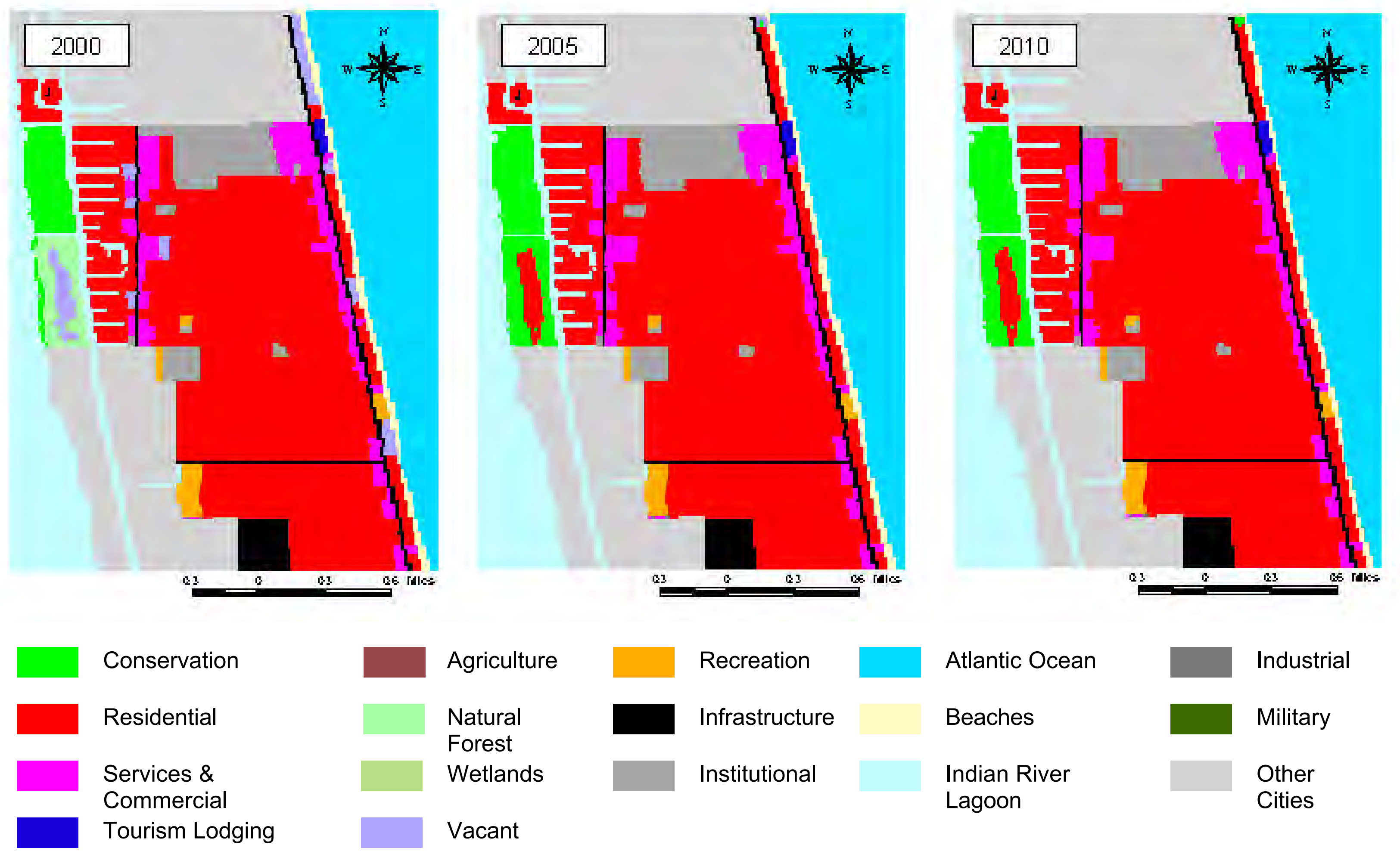


Figure 7.11. Scenario 3: Future land use pattern projections for the City of Satellite Beach for 2005 and 2010 based on 8.5 acres yearly demand for each of the following uses: Residential, Services and Commercial and Conservation.

Table 7.5. Land requests per use and land allocated and percentage change for each run of Scenario 4.

Simulation	Scenario 4 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	61.2	61.2	52.05	0.0	-9.2	0.0	-15.0	0.0	0.0
Residential	992.1	1034.9	1077.6	42.7	42.8	4.3	4.1	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Scenario 4 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	61.2	61.2	52.2	0.0	-9.0	0.0	-14.7	0.0	0.0
Residential	992.1	1034.9	1077.6	42.7	42.8	4.3	4.1	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Scenario 4 -Run 3			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	61.2	61.2	52.05	0.0	-9.2	0.0	-15.0	0.0	0.0
Residential	992.1	1034.9	1077.6	42.7	42.8	4.3	4.1	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

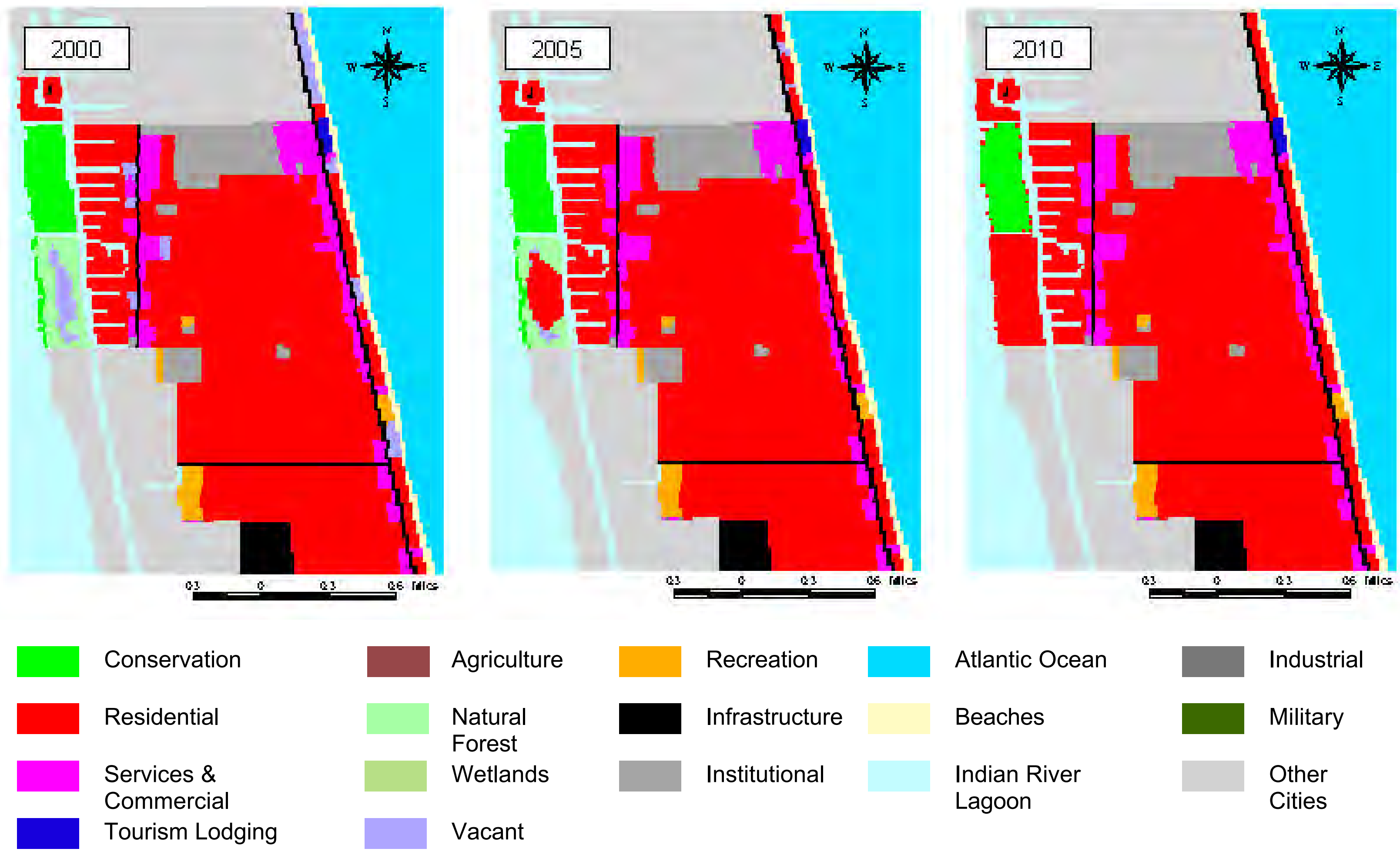


Figure 7.12. Scenario 4: Future land use pattern projections for the City of Satellite Beach for 2005 and 2010 based on 8.5 acres yearly demand for the Residential and Services and Commercial uses, without keeping Conservation lands.

Scenario 5

Scenario 5 is the first of the second group of scenarios, where the potential for tourism development is added to the development policies of the city. This scenario is very unlikely given the current development policies of the city; however there is always the possibility that a drastic change in policy occurs with the changes in the local governments.

The amount of land requested in this scenario for the 10 year planning horizon (2000 to 2010) was 8.5 acres for the four uses: residential, services and commercial tourism and conservation.

Table 7.6 illustrates the land requests and the amounts of land allocated for each run of Scenario 5 and Figure 7.13 shows the landuse patterns obtained for run 2 of the same scenario. Tables 12a and 12b in Appendix B document the KHAT statistic for the individual runs and the respective tests of KHAT significance for the three runs of Scenario 5.

Scenario 6

Scenario 6 introduces the redevelopment options into the simulation. Accordingly priority to tourism development was added to the simulation. This choice of such policy allows that cells previously allocated to residential use can be allocated to any of the other three uses: tourism, services and commercial and conservation. Tourism development, in areas such as the oceanfront shores, competes with residential use for land allocation for this reason it is very likely that redevelopment occurs between the two. However it is very unlikely that tourism cells changed into commercial or conservation uses, because if they are allocated to those uses in the first place is because its suitability is higher for those uses.

The amount of land requested in this scenario for the 10 year planning horizon (2000 to 2010) was maintained at 8.5 acres for the four uses: residential, services and commercial, tourism and conservation. For this run, the redevelopment option: “Priority to Tourism Development” was checked in the scenario setup module of the user interface.

Table 7.6. Land requests per use and land allocated and percentage change for each run of Scenario 5.

Simulation	Scenario 5 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	91.8	91.8	30.6	0.0	50.0	0.0	8.5	8.5
Residential	992.1	1023.9	1023.9	31.8	0.0	3.2	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	18.9	18.9	14.1	0.0	293.8	0.0	8.5	8.5

Simulation	Scenario 5 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	91.35	91.35	30.2	0.0	49.3	0.0	8.5	8.5
Residential	992.1	1023.8	1023.8	31.7	0.0	3.2	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	19.5	19.5	14.7	0.0	306.3	0.0	8.5	8.5

Simulation	Scenario 5 - Run 3			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	91.8	91.8	30.6	0.0	50.0	0.0	8.5	8.5
Residential	992.1	1022.3	1022.3	30.2	0.0	3.0	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	20.55	20.55	15.8	0.0	328.1	0.0	8.5	8.5

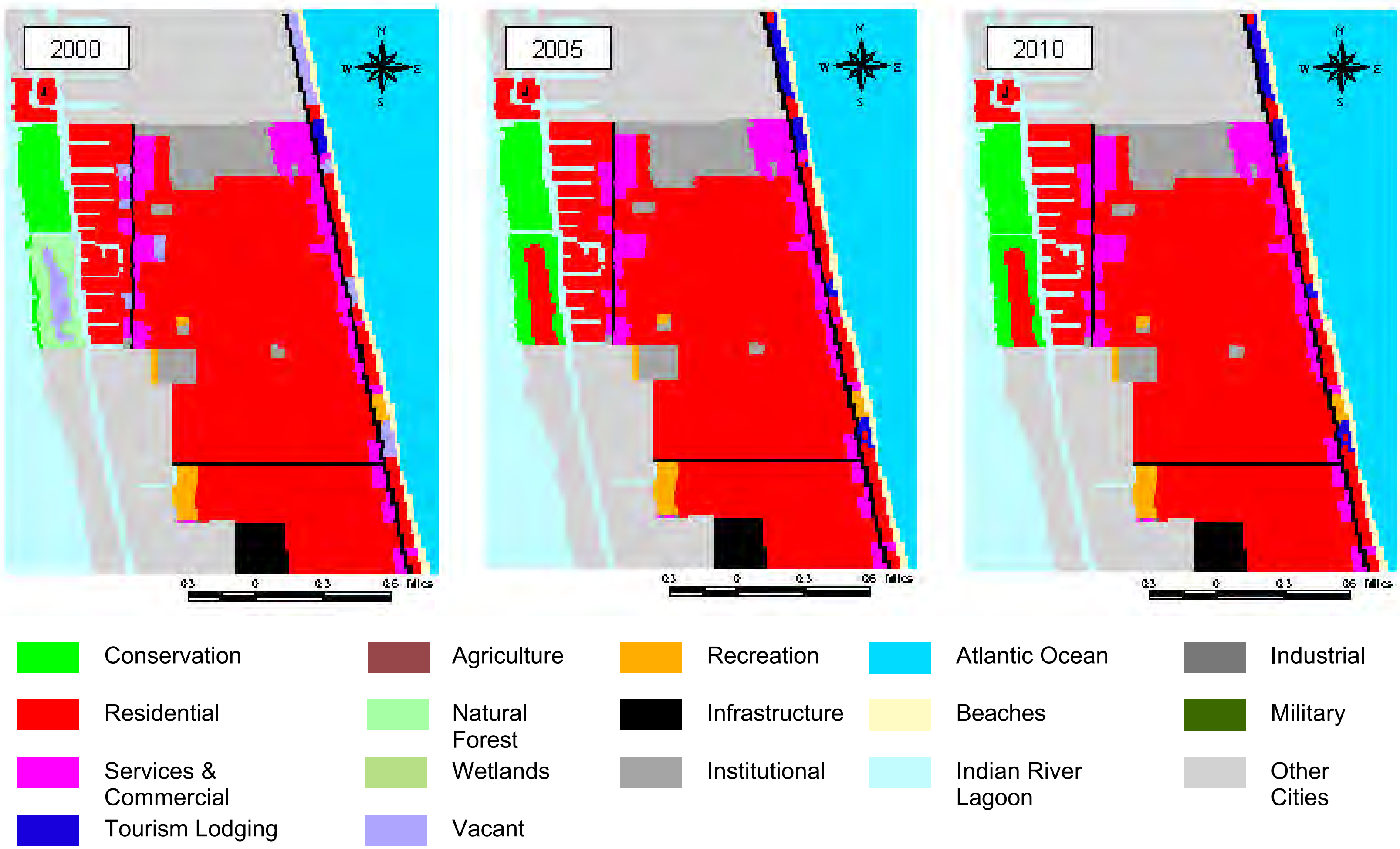


Figure 7.13. Scenario 5: Future land use pattern projections for the City of Satellite Beach for 2005 and 2010 based on 8.5 acres yearly demand for each of the following uses: Residential, Services and Commercial, Tourism and Conservation.

Table 7.7 illustrates the land requests and the amounts of land allocated for each run of Scenario 6 and Figure 7.14 shows the landuse patterns obtained for run 2 of the same scenario. Tables 13a and 13b in Appendix B document the KHAT for the individual runs statistic and the respective tests of KHAT significance for the three runs of Scenario 6.

Scenario 7

Scenario 7 changes the redevelopment option in scenario 6 to residential priority. In this case the cells allocated to tourism use became eligible to change into any of the other three uses: residential, services and commercial and conservation. In this case it is very possible that cells allocated to tourism are changed back into residential use, however it is not likely that cells allocated to services and commercial use are changed into residential use, because of their lower suitability for residential use.

The amount of land requested in this scenario for the 10 year planning horizon (2000 to 2010) was kept once again at 8.5 acres for the four uses: residential, services and commercial, tourism and conservation. The redevelopment option: “Priority to Residential Development” was checked.

Table 7.8 illustrates the land requests and the amounts of land allocated for each run of Scenario 7 and Figure 7.15 shows the landuse patterns obtained for run 2 of the same scenario. Tables 14a and 14b in Appendix B document the KHAT statistic for the individual runs and the respective tests of KHAT significance for the three runs of Scenario 7.

Scenario 8

Scenario 8 does not include any redevelopment policy but allows the lands currently allocated to conservation to be allocated to other uses if necessary to satisfy the demand.

The amount of land requested in this scenario for the 10 year planning horizon (2000 to 2010) was 8.5 acres for residential, services and commercial and tourism uses. The policy option “Maintain / Increase Conservation Lands” policy was removed from the simulation and the conservation lands were released for development.

Table 7.7. Land requests per use and land allocated and percentage change for each run of Scenario 6.

Simulation	Scenario 6 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	91.95	91.95	30.8	0.0	50.2	0.0	8.5	8.5
Residential	992.1	1018.2	1018.2	26.1	0.0	2.6	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging (PR)	4.8	24.45	24.45	19.7	0.0	409.4	0.0	8.5	8.5

Simulation	Scenario 6 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	92.1	92.4	30.9	0.3	50.5	0.3	8.5	8.5
Residential	992.1	1016.7	1016.4	24.6	-0.3	2.5	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging (PR)	4.8	25.8	25.8	21.0	0.0	437.5	0.0	8.5	8.5

Simulation	Scenario 6 - Run 3			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	91.65	91.65	30.5	0.0	49.8	0.0	8.5	8.5
Residential	992.1	1018.7	1018.7	26.6	0.0	2.7	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging (PR)	4.8	24.3	24.3	19.5	0.0	406.3	0.0	8.5	8.5

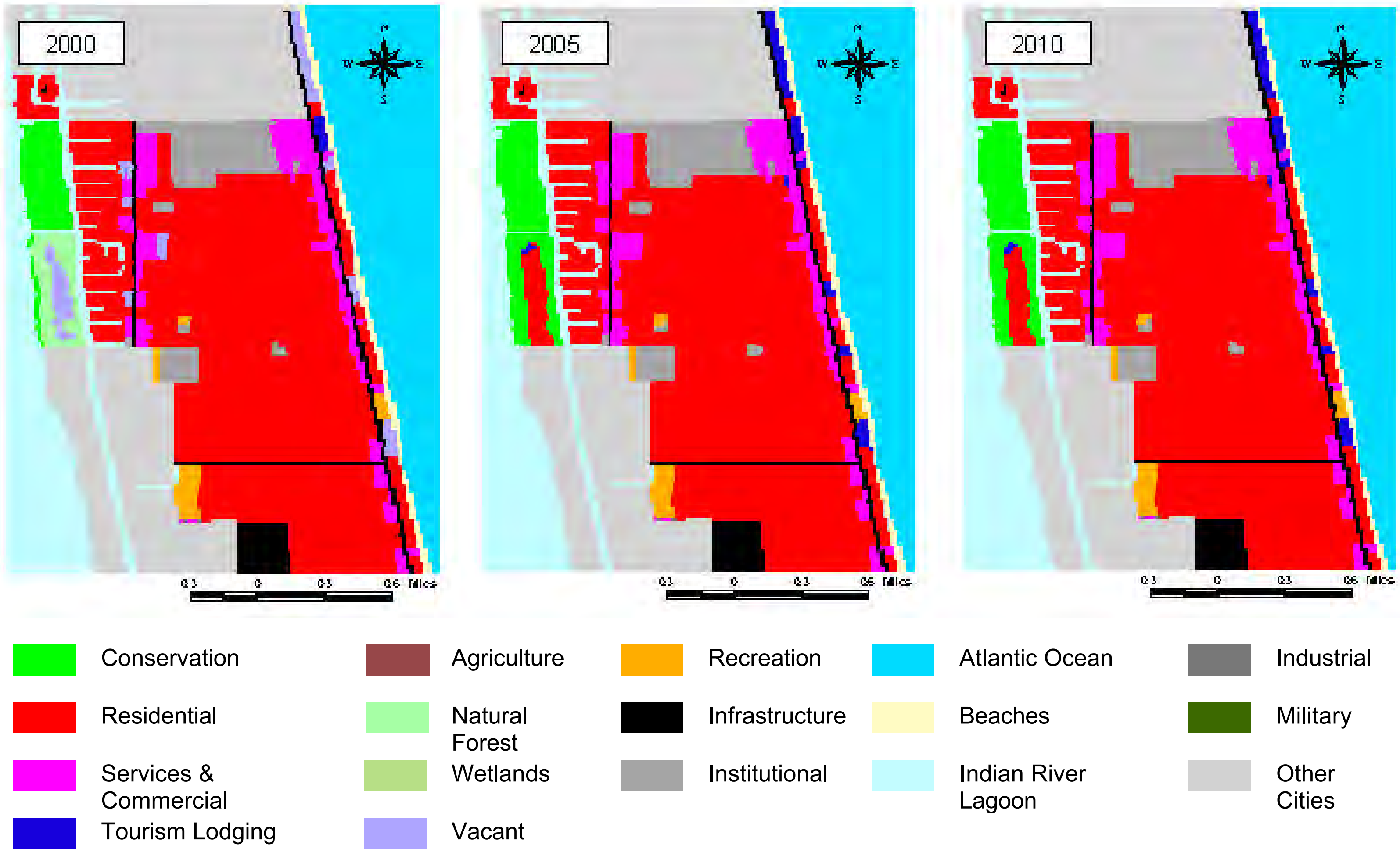


Figure 7.14 Scenario 6: Future land use pattern projections for the City of Satellite Beach for 2005 and 2010 based on 8.5 acres yearly demand for: Residential, Services and Commercial, Tourism and Conservation uses. Priority was given to Tourism development.

Table 7.8. Land requests per use and land allocated and percentage change for each run of Scenario 7.

Simulation	Scenario 7 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	92.1	92.1	30.9	0.0	50.5	0.0	8.5	8.5
Residential (PR)	992.1	1024.2	1024.2	32.1	0.0	3.2	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	18.3	18.3	13.5	0.0	281.3	0.0	8.5	8.5

Simulation	Scenario 7 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	93	93.45	31.8	0.5	52.0	0.5	8.5	8.5
Residential (PR)	992.1	1023.3	1023.6	31.2	0.3	3.1	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	18.3	17.55	13.5	-0.8	281.3	-4.1	8.5	8.5

Simulation	Scenario 7 - Run 3			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	61.2	91.8	91.8	30.6	0.0	50.0	0.0	8.5	8.5
Residential (PR)	992.1	1024.4	1024.4	32.2	0.0	3.3	0.0	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	18.45	18.45	13.7	0.0	284.4	0.0	8.5	8.5

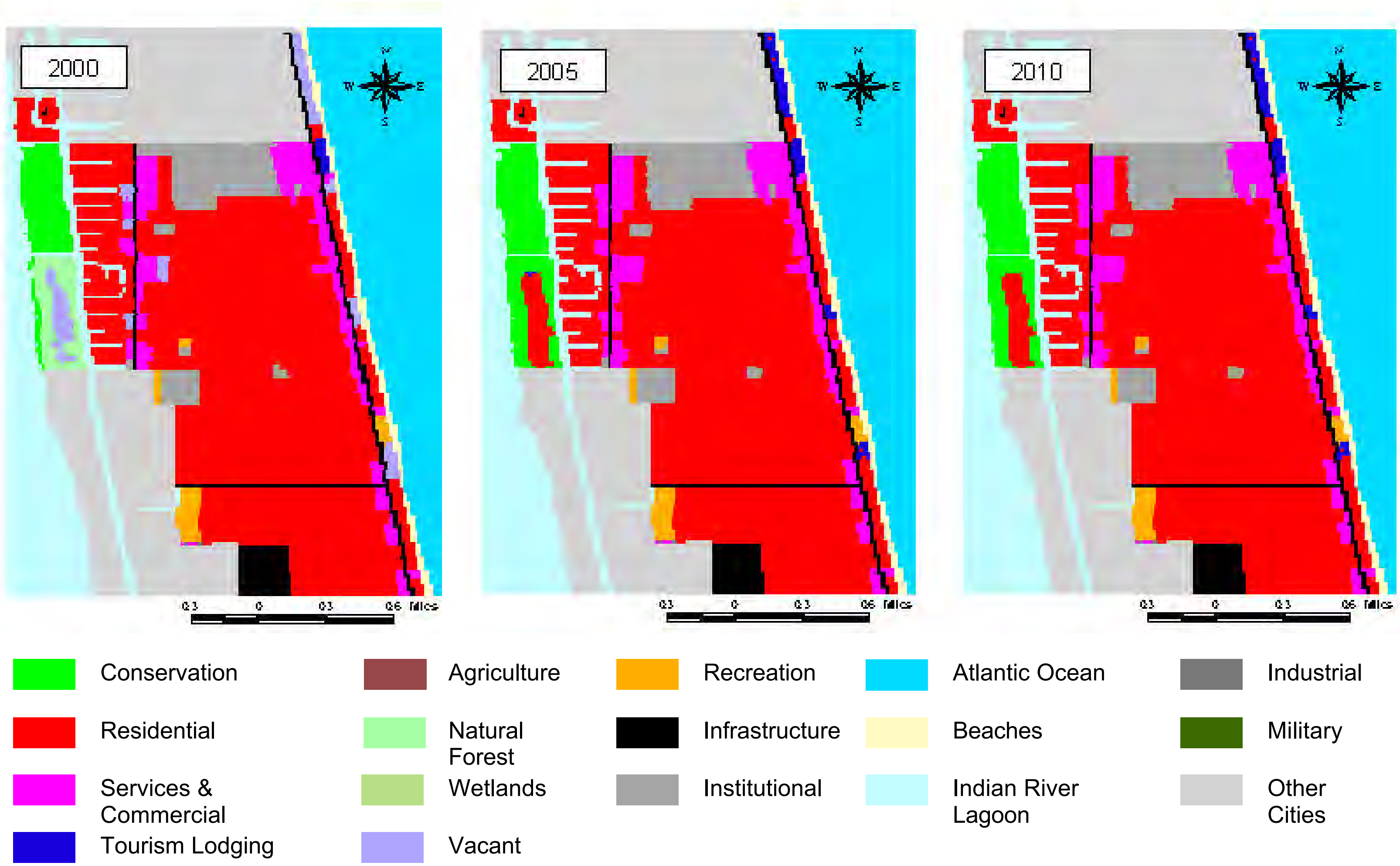


Figure 7.15 Scenario 7: Future land use pattern projections for the City of Satellite Beach for 2005 and 2010 based on 8.5 acres yearly demand for: Residential, Services and Commercial, Tourism and Conservation uses. Priority was given to Residential development.

Table 7.9 illustrates the land requests and the amounts of land allocated for each run of Scenario 8 and Figure 7.16 shows the landuse patterns obtained for run 2 of the same scenario. Tables 15a and 15b in Appendix B document the KHAT statistic for the individual run's and the respective tests of KHAT significance for the three runs of Scenario 8.

Analysis of the Scenario Results

In general, the model response to the different development policies implemented in each scenario produced the future land uses patterns that could be expected when such policies were adopted. Tourism development is not considered at all in the Future Land Use Element of the city of Satellite Beach. However, if one reclassifies the tourism category in this research to also include condominium units, the reality of the scenarios created using the tourism grid can be applied to almost any city on the Barrier Island.

The amount of land allocated for services and commercial use was the same in all the scenarios, which stresses the influence of the suitability grids used in this simulation, in limit development to suitable areas (See Figures 4 to 6 in Appendix B, and Figures 7.7 and 7.8 in this Chapter).

In all the scenarios where redevelopment was not selected the City becomes completely developed by 2010. In the Scenarios where redevelopment was selected once the city was built up, some or the residential and tourism areas started to be redeveloped. As expected, no redevelopment occurred in any of the services and commercial areas in the city.

Scenario 1

From the 85 acres requested for each use in Scenario 1, 76.2 acres were allocated to residential use and 8.8 acres to services and commercial use (See Table 7.2). In agreement with the suitability grids prepared for the city (Figures 5 and 6 in Appendix B) all the development in Scenario 1 (Figure 7.9), occurred in the areas for which the suitability for the use developed was higher.

As shown in the land use pattern for 2005, all vacant areas that had already some development around were developed first, as is the case of all the services and commercial development and of the oceanfront areas. Lansing Island and the stretch of oceanfront property in the northeastern end of the City only become fully developed by 2010.

As shown in Table 8a in Appendix B all the differences between the calculated KHAT statistics for each land use patterns were significant. There were no significant differences between the KHATs for each of the scenario runs to a 99 % significance interval (See Table 8b in Appendix B).

Table 7.9. Land requests per use and land allocated and percentage change for each run of Scenario 8.

Simulation	Scenario 8 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	61.2	61.2	36.6	0.0	-24.6	0.0	-40.2	0.0	0.0
Residential	992.1	1034.9	1077.6	42.7	42.8	4.3	4.1	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	20.4	20.4	15.6	0.0	325.0	0.0	8.5	8.5

Simulation	Scenario 8 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	61.2	61.2	37.95	0.0	-23.3	0.0	-38.0	0.0	0.0
Residential	992.1	1034.9	1077.6	42.7	42.8	4.3	4.1	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	19.05	19.05	14.3	0.0	296.9	0.0	8.5	8.5

Simulation	Scenario 8 - Run 3			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	61.2	61.2	37.95	0.0	-23.3	0.0	-38.0	0.0	0.0
Residential	992.1	1034.9	1077.6	42.7	42.8	4.3	4.1	8.5	8.5
Services & Commercial	108	116.85	116.85	8.8	0.0	8.2	0.0	8.5	8.5
Tourism Lodging	4.8	19.05	19.05	14.3	0.0	296.9	0.0	8.5	8.5

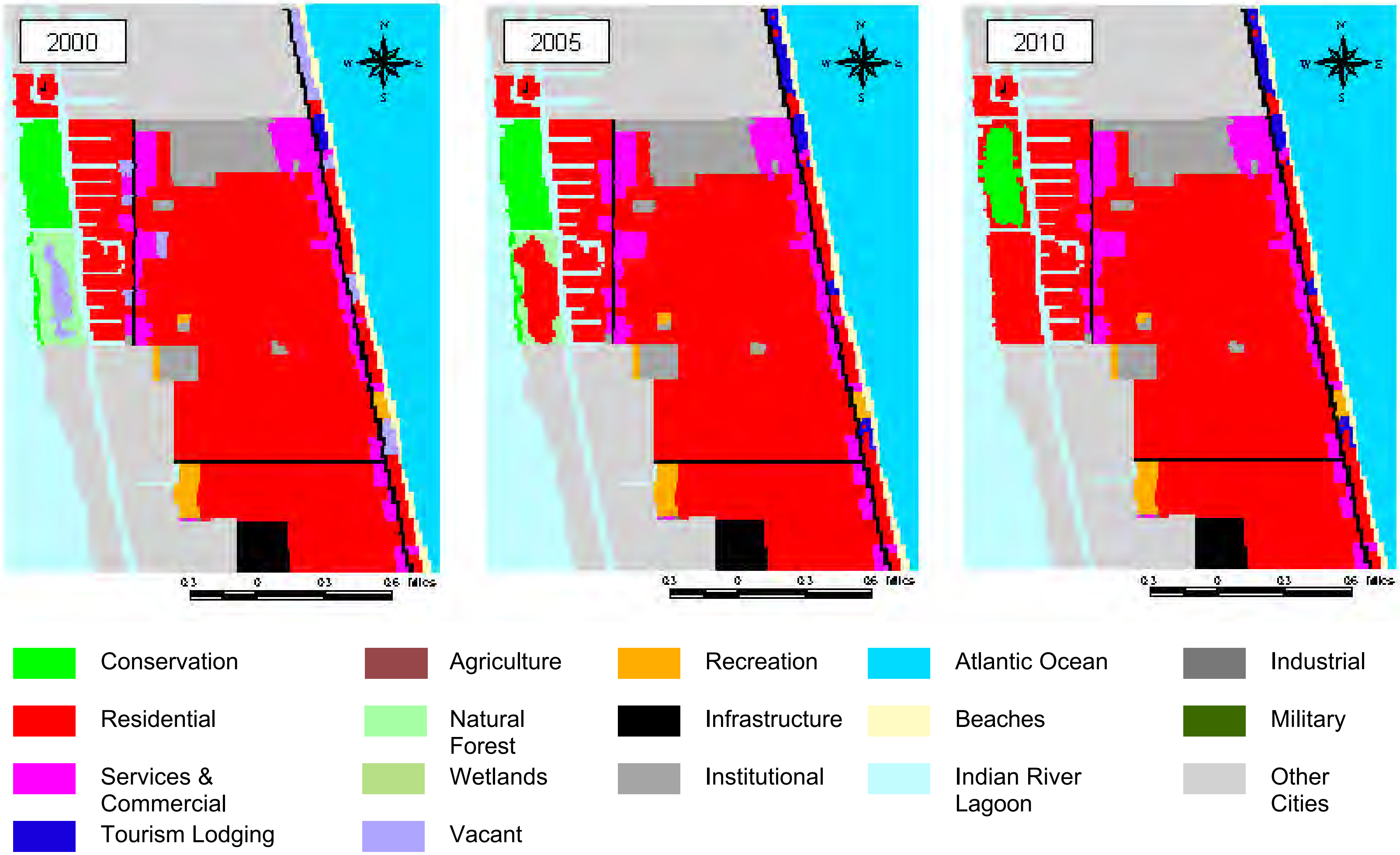


Figure 7.16 Scenario 8: Future land use pattern projections for the City of Satellite Beach for 2005 and 2010 based on 8.5 acres yearly demand for each of the following uses: Residential, Services and Commercial and Conservation.

Scenario 2

By doubling the demand for residential development for the 10 year simulation period in Scenario 2 (Figure 7.10), by 2005, almost all of the available land in the city had been developed. As shown in Table 7.3 a total of 82.9 acres, of the available 85 acres, were left by that time to be developed. If for the second period of 2005 to 2010 the lands allocated to conservation had not been developed the city would have achieved full development by 2006.

Since during this second period conservation lands were allowed to develop by 2010 the Sampson Island Nature Park was completely developed for residential use. In reality this island belongs to the City of Satellite Beach, so it would be very unlikely that the projections shown in this scenario would occur.

As shown in Table 9a in Appendix B all the differences between the calculated KHATs for each land use pattern were significant. There were no significant differences between the KHATs for each of the scenario runs to a 99 % significance interval (See Table 9b in Appendix B).

Scenario 3

In Scenario 3 it is possible to evaluate the effects of competition between conservation and residential uses for land allocation. In this case the same land that was allocated to residential use in the two previous scenarios, was divided between conservation (38.1 acres) and residential (38.3) uses (See Table 7.4).

This division occurred mostly within the lands from Lansing Island (See Figure 7.11). The allocation of lands in the island for conservation use was due mainly to two characteristics of the 2000 original land use grid. The fact that there was already a narrow stretch of conservation lands in the western part of the island, which provided the "seed" for the cellular automaton growth (See Chapter 5); and to the fact that there are two different land use classifications in that island: forest and vacant use.

As shown in Table 2 in Appendix B, distance weights of forestlands are usually higher for conservation than for residential development. For this reason the forest area in Lansing Island become favorable for conservation.

Table 10a in Appendix B shows that the differences between the calculated KHATs for each land use pattern were significant. In addition Table 10b in Appendix B shows that two out of the three scenario runs presented no significant differences between the KHATs to a 99 % significance interval.

Scenario 4

In Scenario 4, all conservation lands were allowed to be developed. However this development did not occur until all the other available lands in the city were developed (See Table 7.5 and Figure 7.12). This fact shows the effects of the different weights used in the suitability grids, which allow a certain degree of area prioritization for development.

As shown in Table 11a in Appendix B all the differences between the calculated KHATs for each land use patterns were significant. There were no significant differences between the KHATs for each of the scenario runs to a 99 % significance interval (See Table 11b in Appendix B).

Scenario 5

In Scenario 5, the Tourism suitability grid was introduced. As a consequence in this scenario, the allocation of land for residential use had to compete not only with conservation but also with tourism development.

As shown in Figure 7.13, some of the forest land use in Lansing Island was allocated to conservation (30.4 acres), however in this case more residential land was developed (31.2 acres) in the same island. This was due to the fact that almost all the vacant oceanfront lands were developed for tourism (14.9 acres), and consequently in order to satisfy the demand the residential use had to out compete the land allocation for conservation (See Table 7.6).

The suitability for tourism development (Figure 7.8) along the oceanfront of Satellite Beach was set to 16 weight points. However in the case of the vacant lands, the suitability weights given to all uses was identical in order to test competition forces between uses.

The reason why tourism development was limited to the oceanfront areas of the City is because the distance weights contribution to tourism development from the beach, ocean and infrastructure land uses, were set higher than the ones for residential development (See Table 2 in Appendix B). Nevertheless, no additional tourism land was developed after 2005, probably due to the fact that the city was almost built up by then.

As shown in Table 12a in Appendix B all the differences between the calculated KHATs for each land use patterns were significant. There were no significant differences between the KHATs for each of the scenario runs to a 99 % significance interval (See Table 12b in Appendix B).

Scenario 6

In Scenario 6, the redevelopment option was set to favor tourism development. This option created smoother tourism clusters (See Figure 7.14) along the oceanfront and two new clusters in areas that would normally be residential: one cluster in the northern east end of the city, west from the A1A, and another one in Lansing Island. The latter was created due to the fact that the same suitability weight (See Figure 7.8 and Figure 5 in Appendix B) was given to tourism and residential development in Lansing Island.

Relative to Scenario 5, giving priority to redevelopment for tourism, increased the acreage of land allocated to tourism use (20 acres), and reduced further amount of land allocated to residential use (25.8 acres), and conservation (30.7 acres) (See Tables 7.6 and 7.7).

As shown in Table 13a in Appendix B all the differences between the calculated KHATs for each land use patterns were significant. There were no significant differences between the KHATs for each of the scenario runs to a 99 % significance interval (See Table 13b in Appendix B).

Scenario 7

In Scenario 7, the redevelopment option was set to favor residential development. This option produced the opposite affect of Scenario 6 along the oceanfront of the City. It increased the residential land along the oceanfront and redeveloping some of the land allocated for tourism in 2005 back to residential by 2010 (See Figure 7.15). This was the case too with the tourism cluster developed in Lansing Island in 2005 that was redeveloped back to residential use by 2010.

Relative to Scenario 5, giving redevelopment priority to residential use, allocated approximately the same acreage to residential (31.8 acres) and conservation (31.1 acres) use, and reduced the amount of land allocated to tourism use (13.5 acres) (See Tables 7.6 and 7.8).

As shown in Table 14a in Appendix B all the differences between the calculated KHATs for each land use patterns were significant. Two out of three scenario runs presented no significant differences between the KHATs to a 99 % significance interval (See Table 14b in Appendix B).

Scenario 8

In Scenario 8 (See Figure 7.16) no redevelopment policies were implemented, but conservation lands were allowed to develop. As in Scenario 4, the development of conservation lands did not occur until all the other available lands in the city were developed. Relative to Scenario 5 the amounts of land allocated to tourism use (14.7 acres) were identical, but the amount of lands allocated to residential use increased considerably (85.5 acres) (See Tables7.6 and 7.9).

This increase was due to the fact that no additional conservation land was requested and consequently the competition between residential and conservation uses was eliminated. Also by allowing the development of the lands allocated to conservation, additional land can be allocated to other uses.

In spite of the additional land made available, once again no additional tourism development occurred after 2005. This fact shows that when subject to the same development pressure oceanfront areas favored tourism development over residential, while other areas favored residential development over tourism development. Accordingly all conservation lands stated to be developed for residential use by 2010.

As shown in Table 15a in Appendix B all the differences between the calculated KHATs for each land use patterns were significant. Two out of three scenario runs presented no significant differences between the KHATs to a 99 % significance interval (See Table 15b in Appendix B).

Socio - Economic Changes

No scenarios were prepared specially to test the socio-economic variables of the DSS. Instead, these variables were kept unchanged in all the scenario runs. This was it was possible to assess the effects of the changes in land use patterns on the regional population carrying capacity of the area and on the evolution of the quality of life indexes in the City.

The growth curve for the resident population for each scenario is plotted in Figure 7.17. The evolution of the regional population carrying capacity is shown in Figure 7.18, and the evolution of the three life quality indexes for each scenario is shown if figure 7.19 through 7.21. The values from run 2 of each scenario were chosen to illustrate the changes.

Population Growth

Since the population growth rates in each scenario were identical, and the resident population growth (See Figure 7.17) never achieved the population carrying capacity for the city, no differences between scenarios for the residential population growth occurred. If higher population growth rates are used in the scenarios the residential population curves will eventually take the shape of the population carrying capacity curves (See Figure 7.18), because this variable is used in the model to limit population growth.

The regional population carrying capacity growth curves are a direct reflection of the residential development (See Chapter 4), but they are sensitive to the physical location of such development. A residential property developed close to the ocean will add a larger number of people to this variable than a property developed close to the river, because the residential densities allowed for oceanfront property in Satellite Beach are much higher than the ones allowed for the riverfront property (See Figure 1 in Appendix B).

As a result, the scenarios where tourism development was introduced (Scenarios 5 through 8) show a much lower population carrying capacity (See figure 7.18) than any other scenario, because all the oceanfront property was "taken out" by tourism development. The same scenarios also show that after the year the population carrying capacity for the area stabilized. This was the result of all the lands in the city being allocated to one of the three developed uses or for conservation. Scenario 8 showed a continuously increasing growth curve during the 10 year forecast horizon, because all the conservation lands were allowed to become developed.

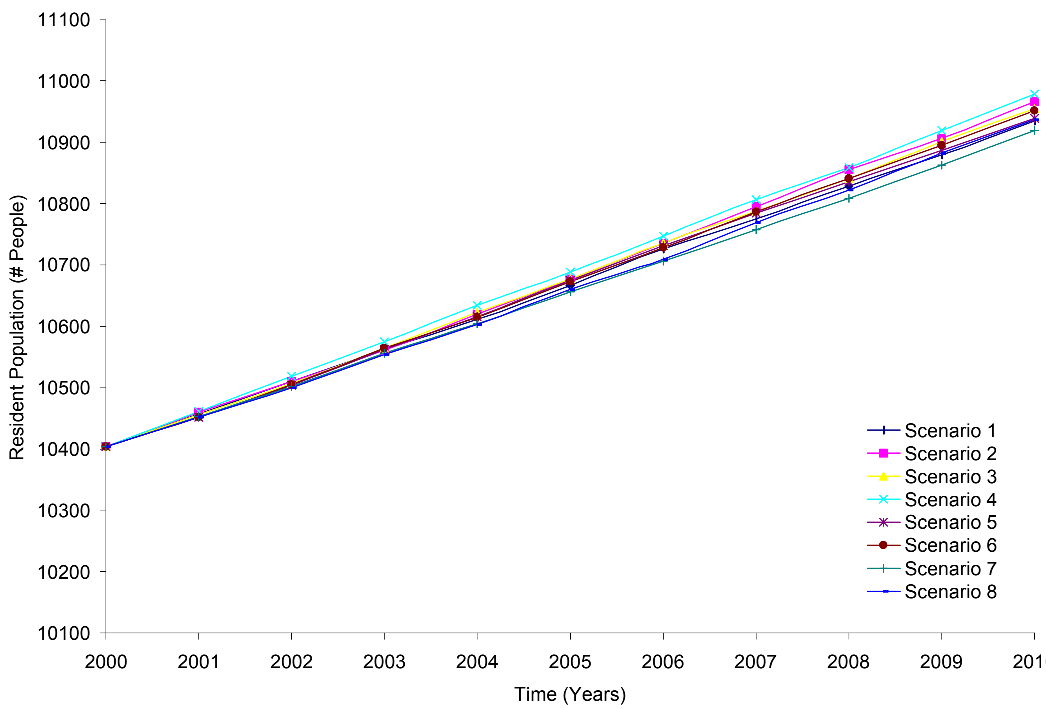


Figure 7.17. Resident population growth for each scenario.

In scenario 3 the population carrying capacity stabilized, because the city reached its maximum residential development, as the increase in conservation lands out competed the residential development in Lansing Island. When in scenario 4 conservation lands were developed, the population carrying capacity for the city continued its growth. Most likely, the population carrying capacity level achieved by the year 2005 in Scenario 2 represents the maximum population carrying capacity for the city, if the lands allocated to conservation are kept as such.

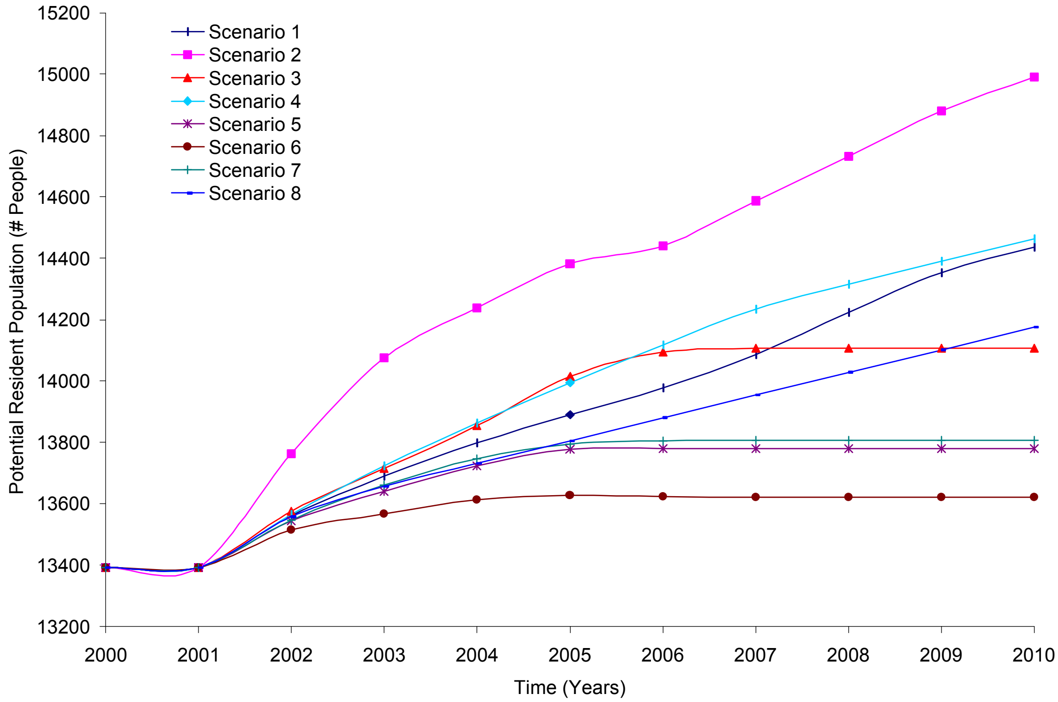


Figure 7.18. Population Carrying Capacity growth for each scenario.

Quality of Life Indexes

In the scenarios where the residential density index (Figure 7.21) declined and the land allocated to conservation (Figure 7.19) was maintained, there was an increase in the total amount of lands allocated for public and conservation use (recreational plus conservation use). With the exception of Scenario 2, the amount of public and conservation lands for 1000 people in the City of Satellite Beach was maintained above the acceptable level of service for the unincorporated areas of Brevard County which is 3 acres per 1000 people.

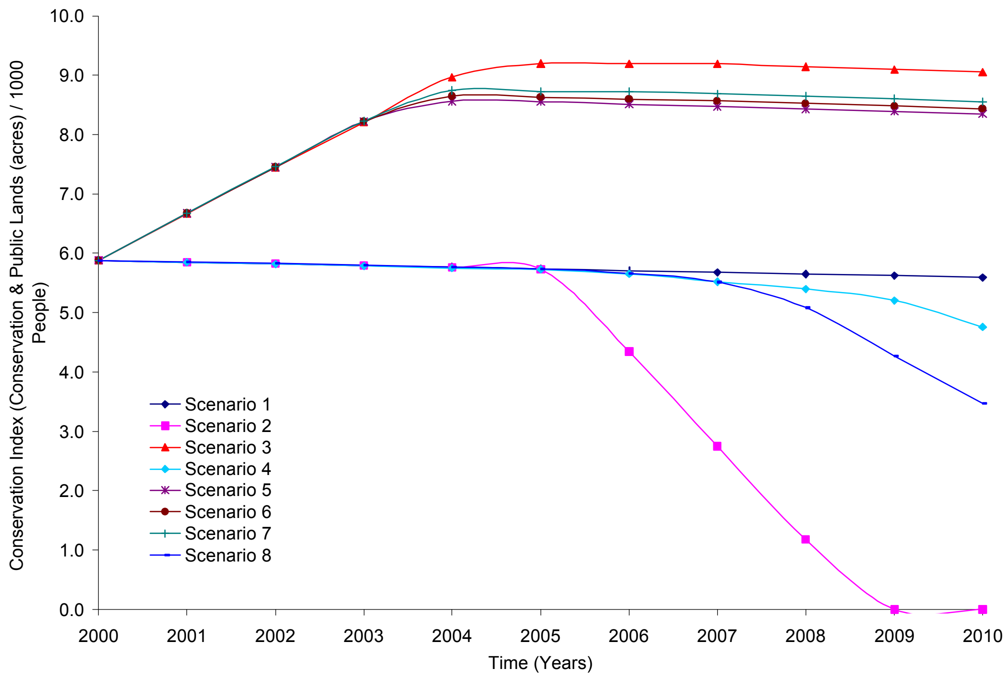


Figure 7.19. Conservation Index for each scenario.

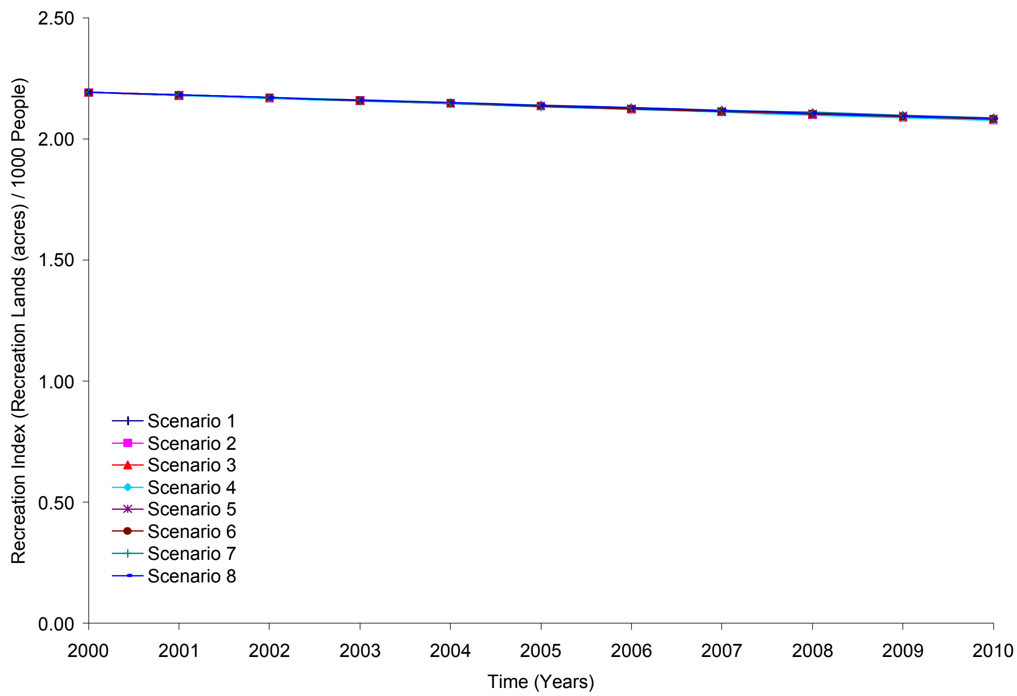


Figure 7.20. Recreation Index for each scenario.

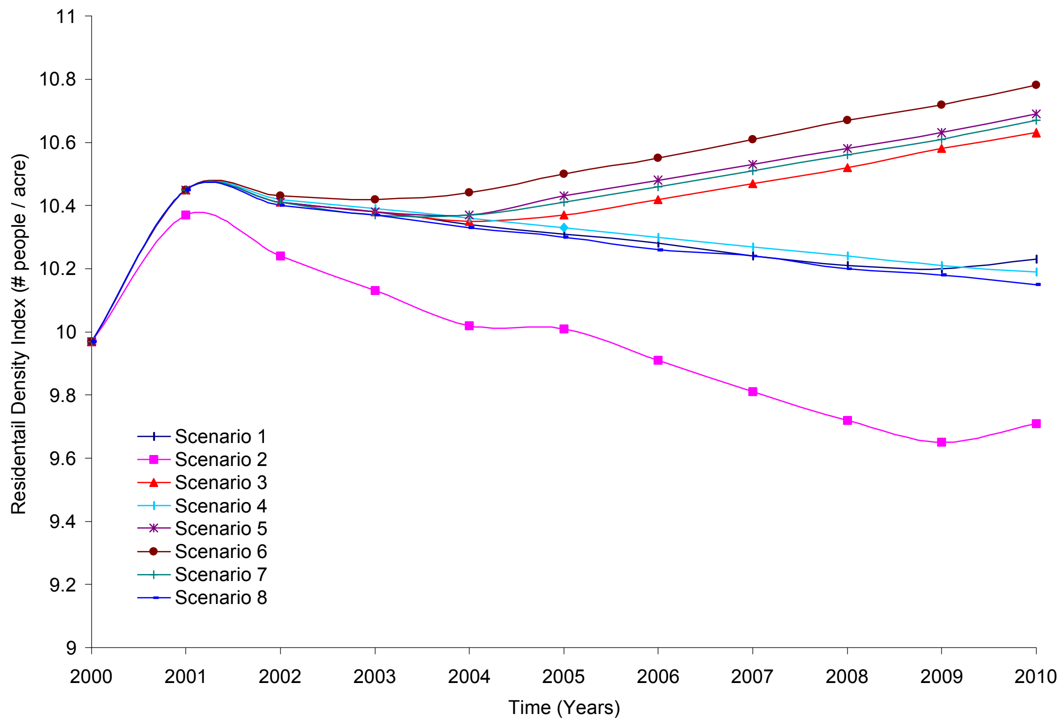


Figure 7.21. Residential Density Index for each scenario.

Application of the Natural Hazards Module to the 2000 to 2010 Future Land Use Projections for the City of Satellite Beach

In order to extend the application of these projections to other fields of research, the Natural Hazards Module was used to compare how a change in development policies can affect, in terms of people and capital at risk, the costs from a storm surge caused by a hurricane. A average strength Category 3 Hurricane was chosen to illustrate this effects. The property market value grid discussed in Chapter 3 was used to put a dollar value to the impacts assessed.

Scenario 1 and 2 described above were chosen for this purpose, because they provide the closest approach to the current trends set forth in the City's Comprehensive Plan. This analysis starts in the year 1990 and is carried forward through the year 2010, for the two scenarios.

Two approaches were used to evaluate the impacts of a Category 3 Hurricane. One used the "Hurricane Storm Surge Impact Areas" grid (See Figure 7.22) and the other one the "Potential Storm Surge Impact Risk Areas" grid (Figure 7.23). The two approaches were used because as shown in Figure 7.22, the Hurricane Storm Surge Impact Areas does not separate the different areas of impact. For that reason the grid presented in Figure 7.23 was used to isolate the impacts of a 12 feet hurricane storm surge affecting exclusively the eastern side of the barrier island.

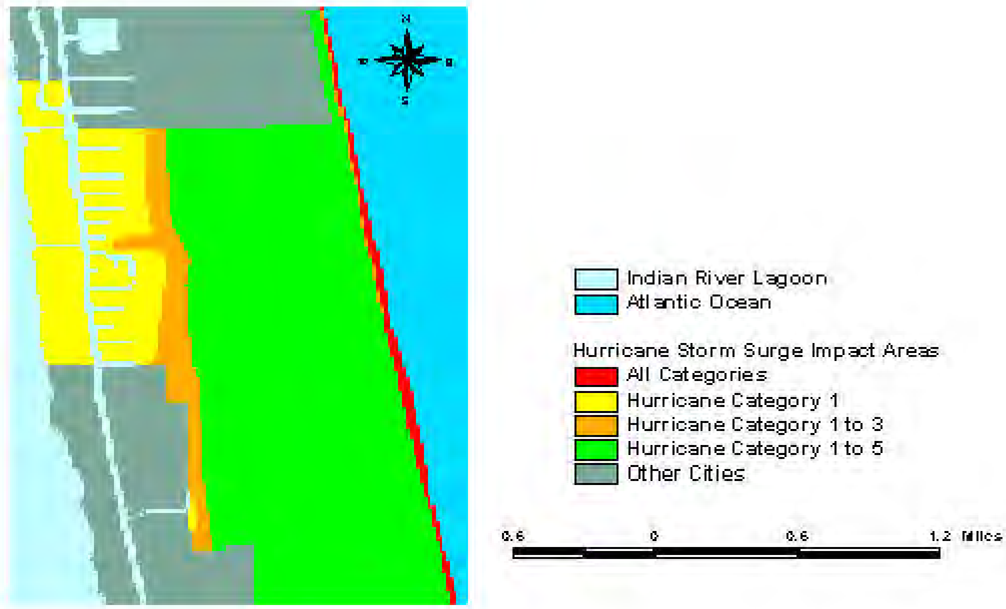


Figure 7.22. Hurricane Storm Surge Impact Areas (Source: Florida Department of Community Affairs - Office of Emergency Management).

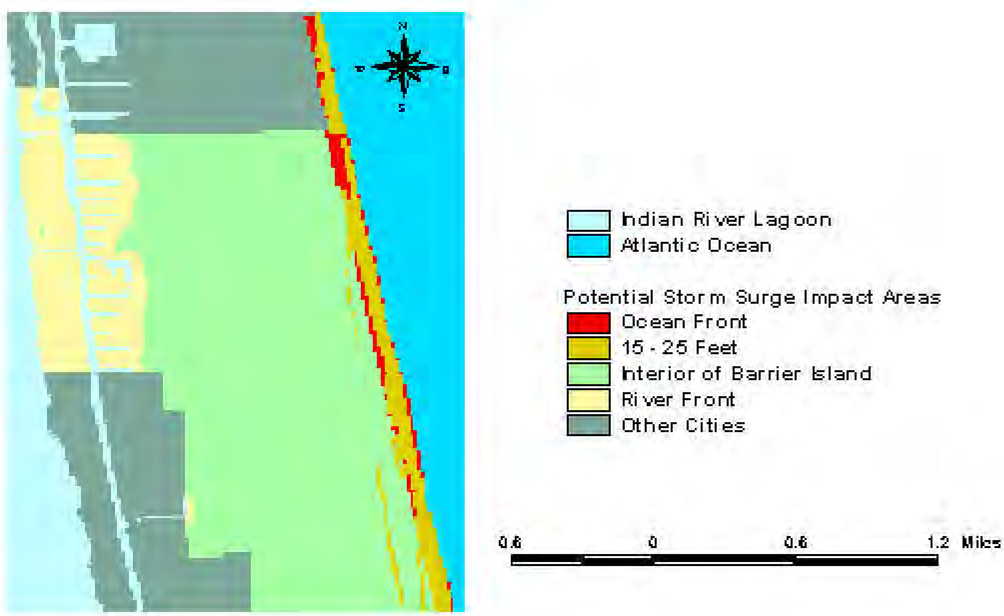


Figure 7.23. Potential storm surge impact risk areas grid.

This was accomplished by calculating the affects of such surge on the Oceanfront impact area presented in Figure 7.23 (See Chapter 3 for module overview and Chapter 6 for user interface). The storm surge height was based on the SLOSH model predictions for Brevard County (Brevard County Planning and Zoning Division 1991), which projects a 12 foot storm surge for a Category 3 hurricane. The impact curves for each methodology are plotted separately in each graph, however as one can see from figures 7.22 and 7.23.

Natural Hazards Impacts - Scenario 1

The impacts of a Category 3 Hurricane with an oceanic storm surge of 12 feet for the future land use pattern projections made in Scenario 1 are shown in Figures 7.24 through 7.26 in terms of total acreage impacted (Figure 7.24), potential people at risk (Figure 7.25) and capital costs (Figure 7.26).

As shown in Figure 7.24 a large percentage of the impacts are on residential land, which agrees with the fact that the majority of the development in the City of Satellite Beach is residential. In addition it is also possible to see that the acreage of oceanfront property impacted is very small when compared with riverfront (Lansing Island) areas. This is due to the fact the width of the land area along the Oceanfront of Satellite Beach is very narrow and as a consequence it supports only a few residential units.

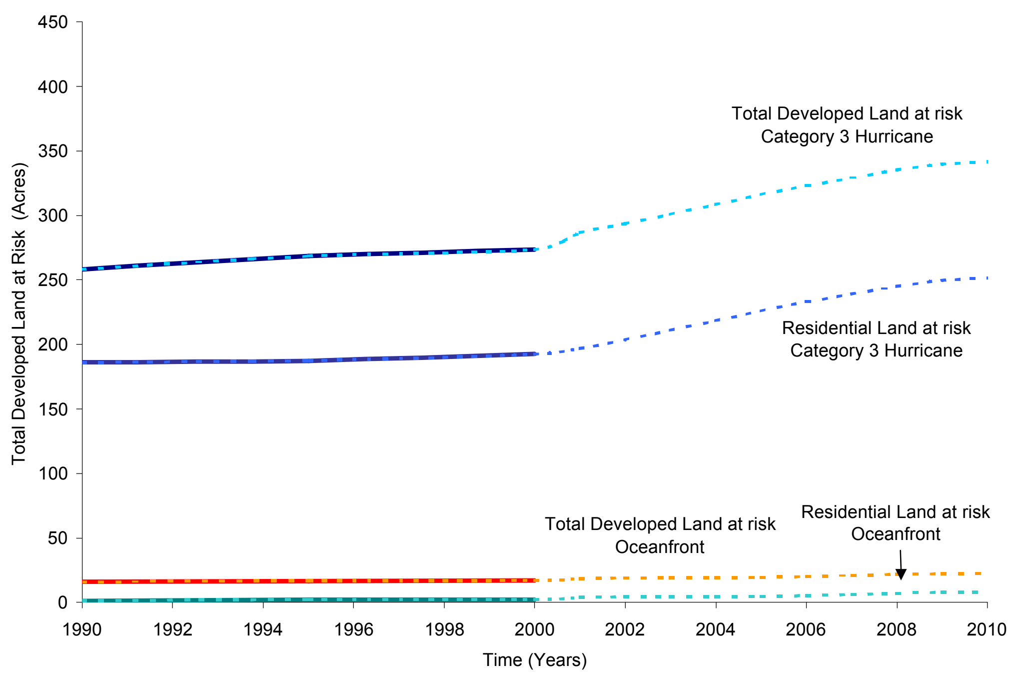


Figure 7.24. Total developed land at risk from the impacts of a Category 3 Hurricane storm surge for Scenario 1. The inset shows the residential areas at risk for the same scenario.

The potential numbers of population at risk from a similar storm are showed in Figure 7.25. This is the potential population that can occupy the areas if the maximum zone residential densities are taking in consideration (See Figure 1 in Appendix B). In this case in spite of the higher densities along the oceanfront areas of the City, the majority of the population at risk leaves in areas along the western side of the city, close to the river, since the contribution from the oceanfront elevation based calculation (in red) is very small when compared with total impacts from the hurricane (in blue).

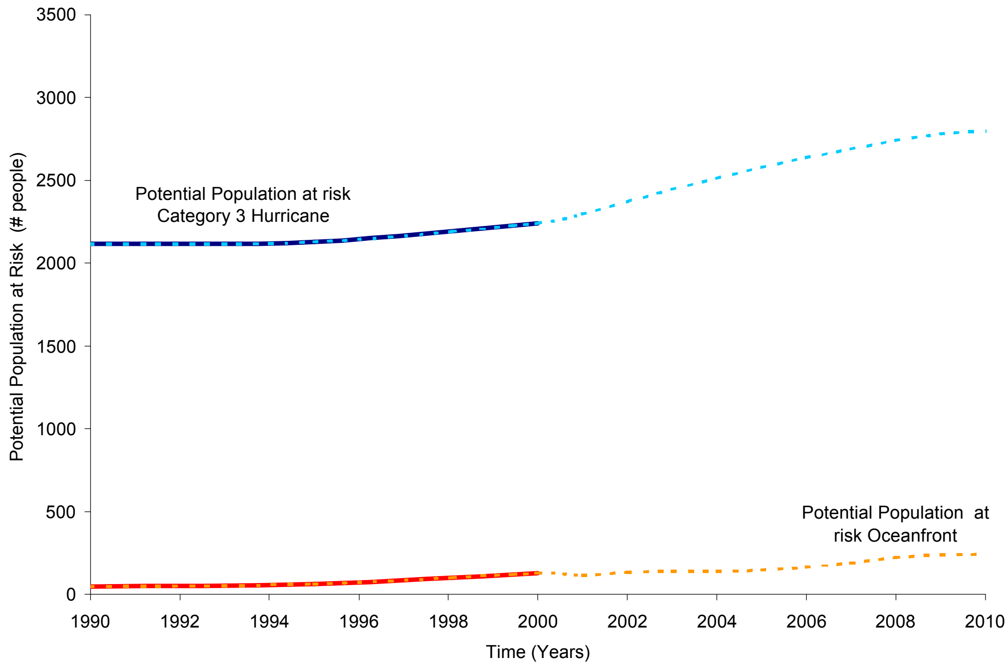


Figure 7.25. Potential population at risk from a Category 3 Hurricane storm surge, for Scenario 1.

The capital costs were evaluated assuming a 100 % property damage, and using the property market value grid described in Chapter 3 (See Figure 7 in Appendix B). The results of this evaluation are shown in Figure 7.26. As the rest of the city becomes developed from 2005 through 2010, there is significant increase in the potential damage costs. This increase is caused mostly by the oceanfront residential development projected in Scenario 1 for those areas. The large increase is due to the higher property values on the oceanfront when compared with the property values on the riverside of the City, which caused just a small increase in the capital costs in spite of the full development of Lansing Island projected in Scenario 1.

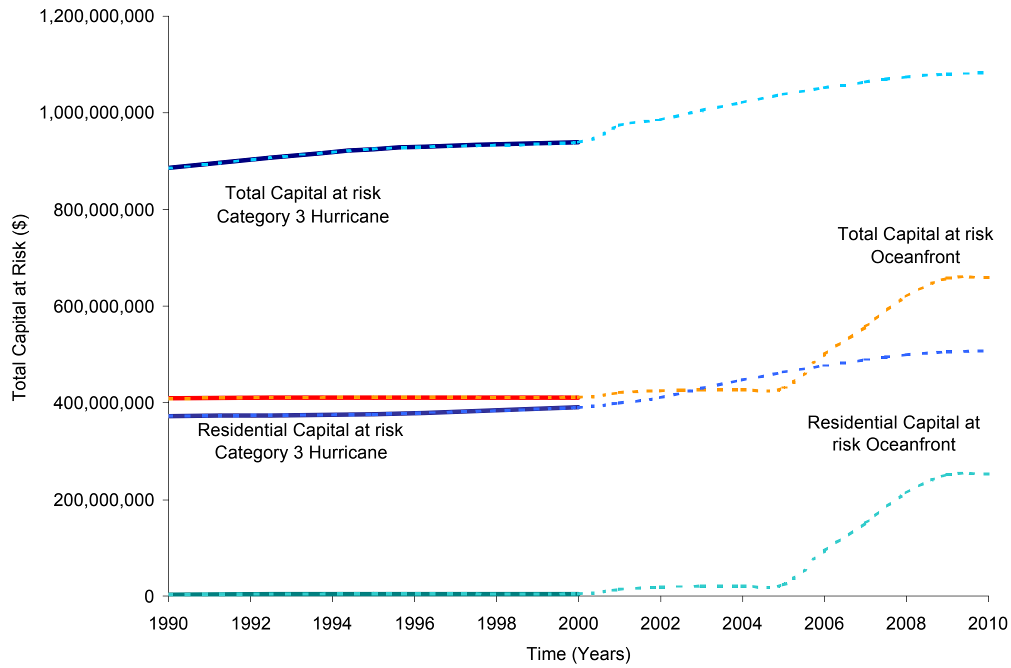


Figure 7.26. Capital costs for all developed land at risk from a Category 3 Hurricane storm surge for Scenario 1. The inset shows the residential capital at risk for the same scenario.

Natural Hazards Impacts - Scenario 2

The impacts of a Category 3 Hurricane with an oceanic storm surge of 12 feet for the future land use pattern projections made in Scenario 2 are shown in Figures 7.27 through 7.29 in terms of total acreage impacted (Figure 7.27), potential people at risk (Figure 7.28) and capital costs (Figure 7.29). In this second scenario, the amount of land requested for allocation was twice that of Scenario 1. This way, the impacts of the same storm, not only are evaluated for two different development policies, but also for two different degrees of development for the same planning horizon.

The area affected in this second scenario as expected was the same but the slope of the curve was much steeper and stabilized by 2008. The levels of development reached by 2010 in Scenario 1 were the attained in 2005 in this scenario. In addition Scenario 2 was the scenario where all conservation lands were released for developed from 2005 to 2010 (See figure 7.10). Again the larger percentage of the impacts was on residential land, and the additional increase in acreage impacted by the storm, correspond to the previously allocated conservation lands which were developed by 2010. Due to the relatively narrow oceanfront area, the contribution in terms of total acreage from oceanfront land is very low. This contrasts greatly with the contribution in terms of capital costs for the same area (See Figure 7.29).

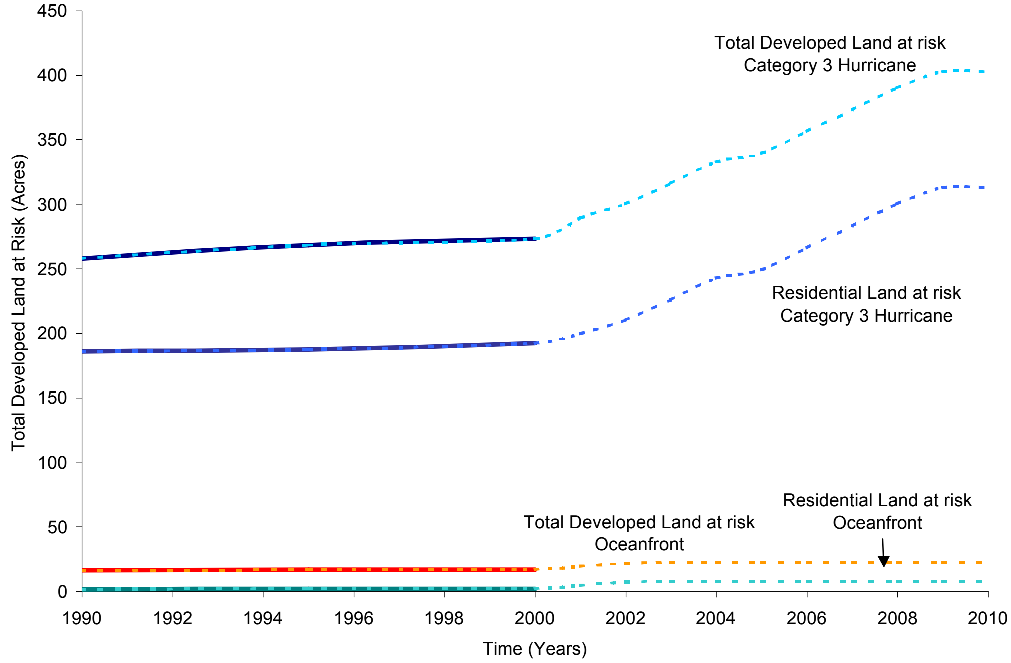


Figure 7.27. Total developed land at risk from the impacts of a Category 3 Hurricane storm surge for Scenario 2. The inset shows the residential areas at risk for the same scenario.

The potential population at risk (Figure 7.28) for Scenario 2 followed the same pattern as Scenario 1. The additional population at risk results from the residential development of the conservation lands (Sampson Island nature Park). Again in spite of the higher densities along the oceanfront areas of the City, the majority of the population at risk leaves in areas along the western side of the city, close to the river. Also the oceanfront potential population at risk achieved stabilization by 2002, which shows that all the ocean front residential property in scenario 2 become developed by that date.

The capital costs for this scenario were also evaluated assuming a 100 % property damage, and using the property market value grid described in Chapter 3 (See Figure 7 in Appendix B). The results of this evaluation for scenario 2 are shown in Figure 7.29. Since the degree of development in this scenario was much higher, the ocean front areas of the city were developed by 2002, and for that reason after that year there would be no addition to the damage costs of a 12 feet storm surge along the oceanfront shores of Satellite Beach. However, due to the additional residential development of the conservation areas after 2005, the capital costs of the Category 3 hurricane in other areas of the City kept increasing through out 2010.

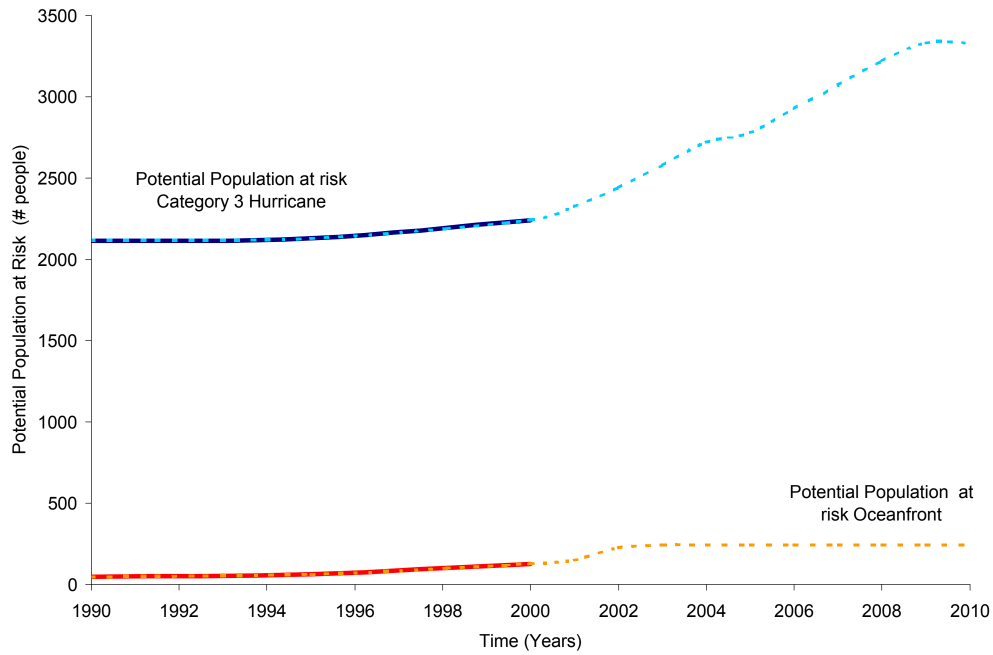


Figure 7.28. Potential population at risk from a Category 3 Hurricane storm surge, for Scenario 2.

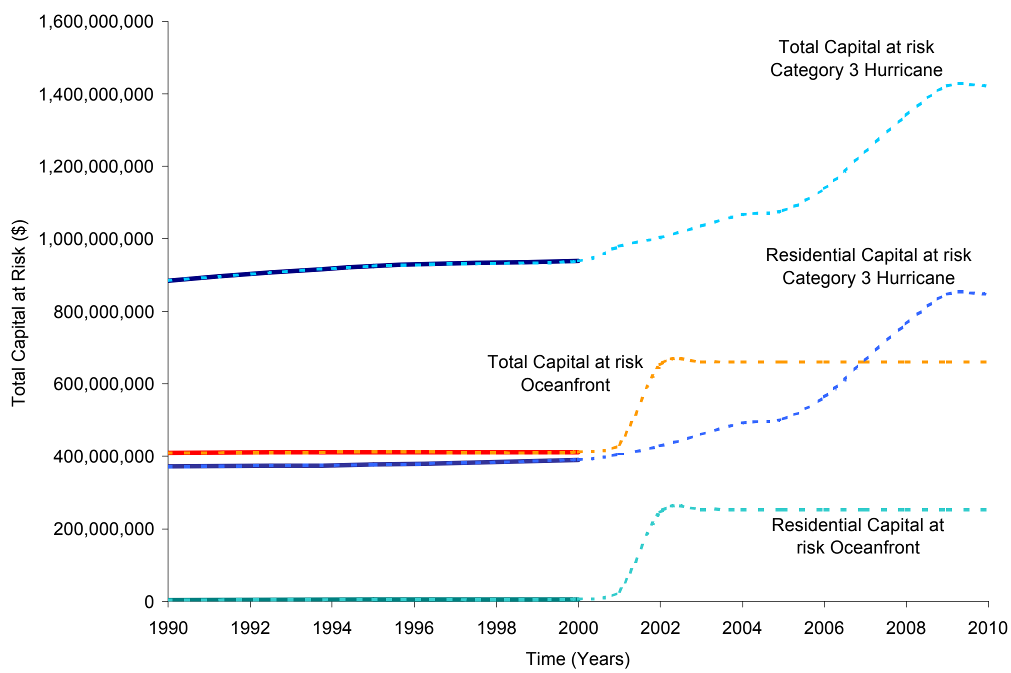


Figure 7.29. Capital costs for all developed land at risk from a Category 3 Hurricane storm surge for Scenario 2. The inset shows the residential capital at risk for the same scenario.

Chapter 8
South Beaches Case Study

The South Beaches Unincorporated Area

The South Beaches unincorporated area extends from the southern limit of the town of Melbourne Beach to the Sebastian Inlet 15 miles to the south (See Figure 1). The width of the barrier island along this area of the barrier island is highly variable with areas as narrow as 0.15 miles alternating with areas with widths of 1.15 miles.

The South Beaches are the least developed area of the Brevard County's barrier island system. Some of the most valuable natural resources of the County are located in this area. For this reason there as been some efforts to buy lands though programs like CARL (Conservation and Recreation Lands Program), or the State's Save our Coasts Program (Rhodes, 1992), and other institutions such as the Richard King Mellon Foundation, which owns a considerable acreage of land in the South Beaches.

The Archie Carr National Wildlife Refuge constitutes an effort to preserve significant beachfront habitat for the endangered sea turtles (Rhodes, 1992). In addition to this wild life refuge, the Mullet creek Islands and the wetland areas located near Hog Point Cove, Snag Harbor, Mullet Cove, Pepper Cove and Campbell's Pocket are also zoned environmental lands.

Two areas in the Barrier Island have federal protection status under the Coastal Barrier Resources Act (CRBRA) of 1982, one located near Hog Point and another located near Coconut Point. Figure 8.2 shows a combination of the DEP conservation lands grid with the SJRWMD district lands grid, showing the location of the majority of the lands with conservation potential along the South Beaches area.

The South Beaches also constitute the major recreational area in the county (Brevard County Planning and Zoning Division, 1998). In addition to the Sebastian Inlet State Recreation Area four more areas are part of the recreation lands of the county: the Spessard Holland Beach Park area to the North, the Long Point County Park, the Coconut Point Beach Park and Bonsteel Beach Park (Rhodes, 1992). Both Coconut Point and Bonsteel Parks were created after 1990 therefore they were included in the conservation and public lands land use category. Two Golf Courses complete the recreation facilities in the South Beaches.

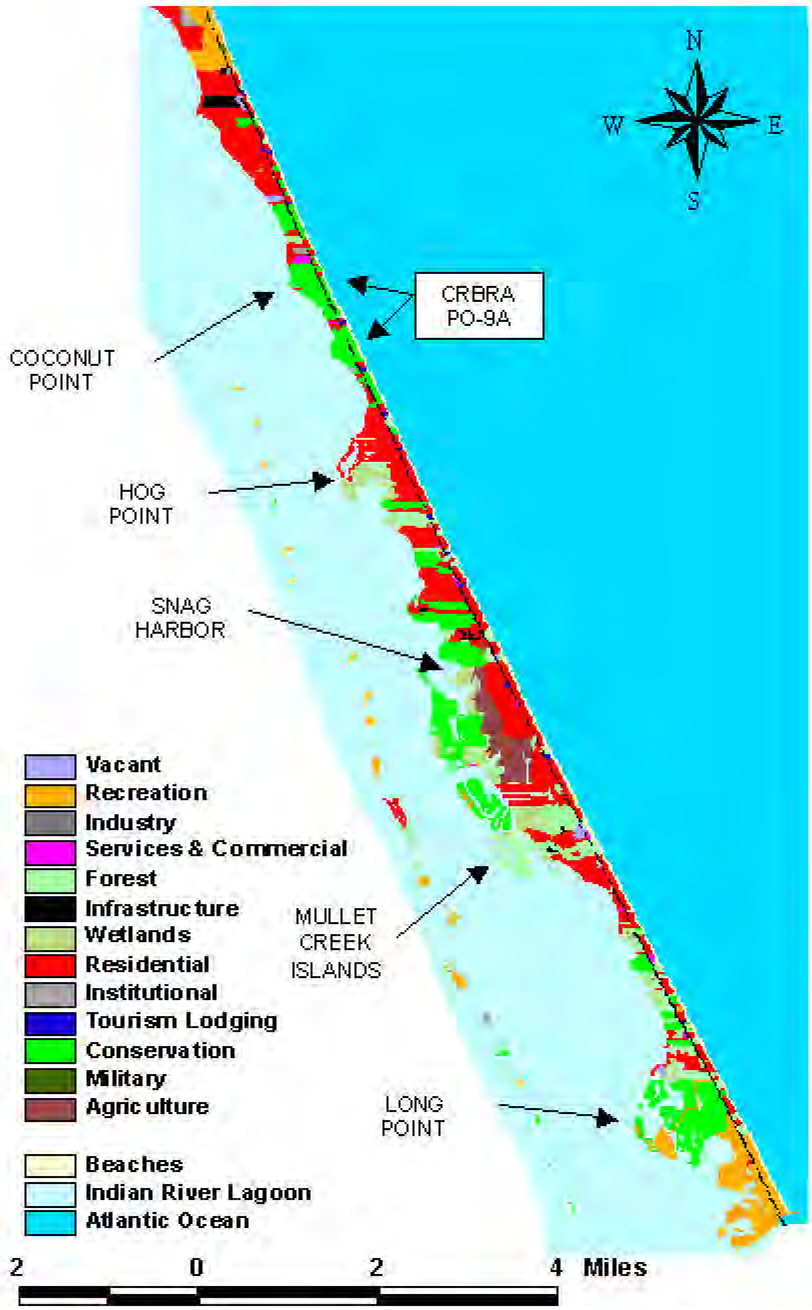


Figure 8.1. South Beaches Unincorporated Area

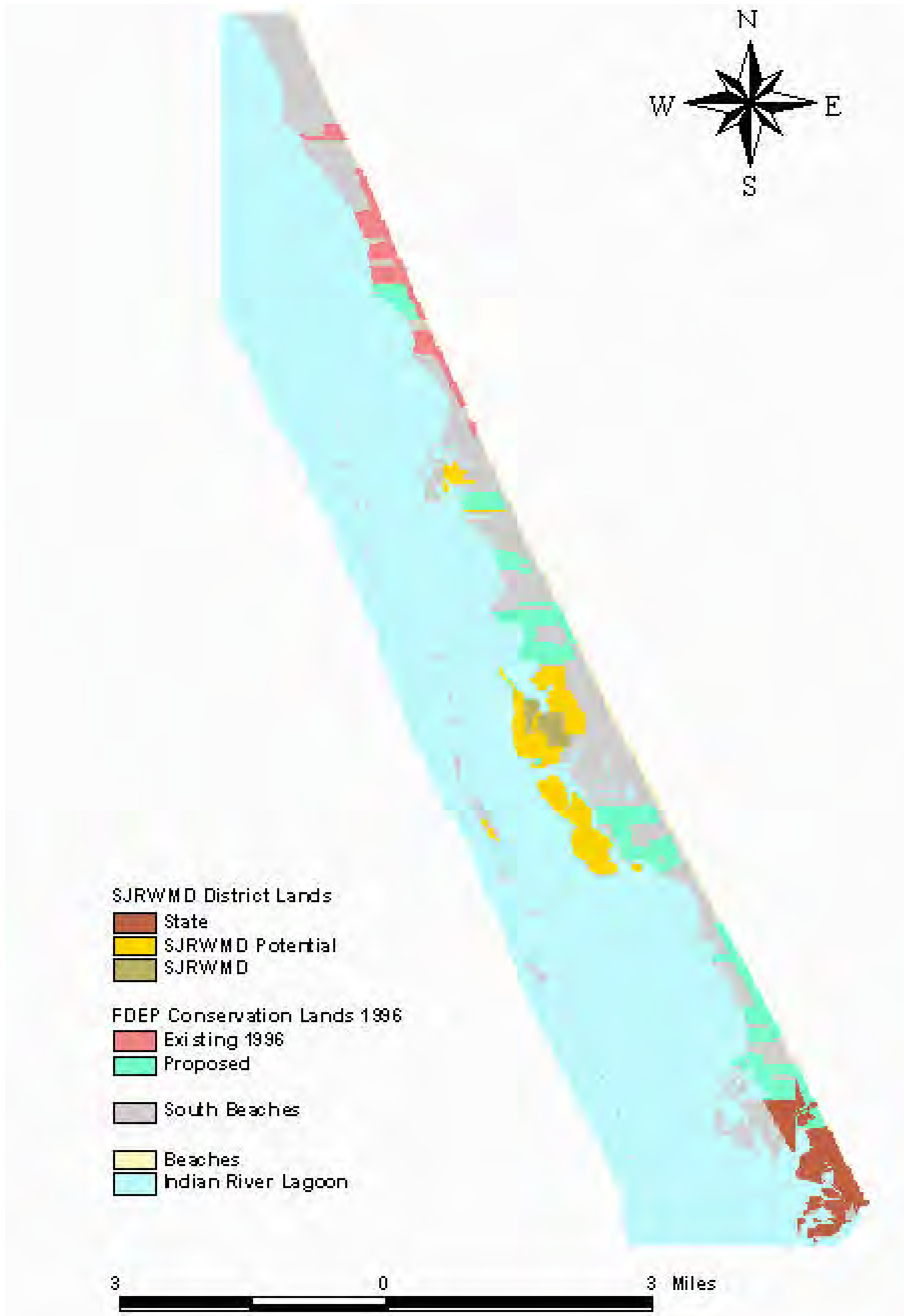


Figure 8. 2. Areas with significant conservation potential in the South Beaches

Most of the residential development in the southern part of the South Beaches is composed of low density single family units (1 and 2 dwelling units per acre). The higher residential density areas are located west of State Road A1A and in the northern areas. All the 13 hotels and motels in the south beaches are very small and have a reduced lodging capacity, for this reason the starting annual value used in the calibration runs of the model was 25000 tourists.

According to the South beaches Small Area Plan Study, the area's population was approximately 10741people in 1990. No other information was found for the area regarding other population counts.

System Calibration and Validation to the South Beaches Unincorporated Area

Population Growth

A 1 % growth rate for the residential population of the South Beaches was chosen for the calibration runs. This growth coefficient used was based on the average for the entire barrier island cities of 0.9 % per year. The simulated resident population growth and the regional population carrying capacity growth curves are shown in Figure 8.3.

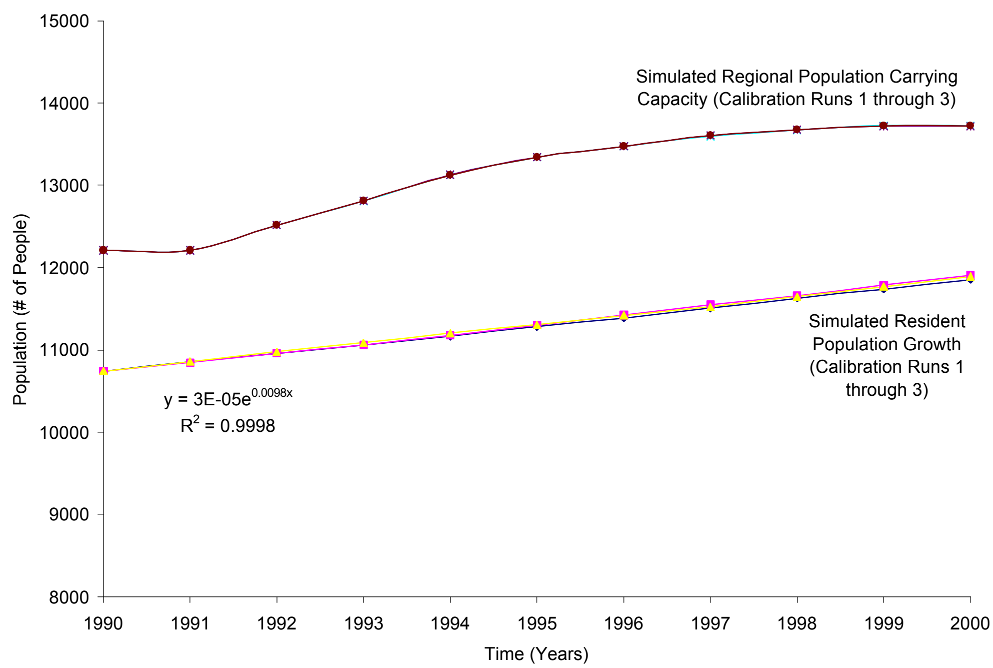


Figure 8.3. Simulated residential population growth for the three calibration runs.

Quality of Life Indexes

Based on the population growth estimations for the area, the quality of life indexes were calculated for each of the 3 calibration runs. In addition, using the same population estimates the values for the three indexes for the 1990, 1995 and 2000 observed land use data grids were also calculated. Figure 8.4 shows the evolution of these indexes in the South Beaches.

The recreation and conservation index for the South Beaches area for the year 2000 were 45 and 88 acres per 1000 people respectively. The recreation level alone is already much higher than the acceptable level of service for recreation and open space set by the County for its unincorporated areas (3 acres per 1000 people) (Brevard County Planning and Zoning Division, 1998).

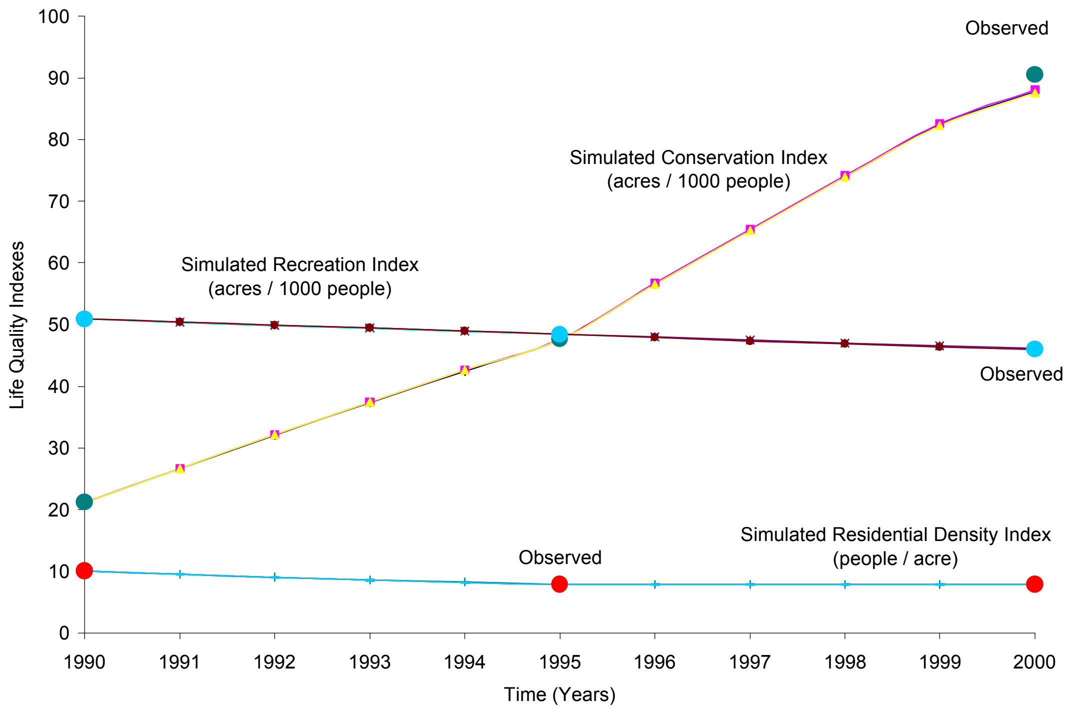


Figure 8.4.Observed and simulated Life Quality Indexes for the three calibration runs.

Also, the residential density index in the South Beaches area is 8 persons per acre of residential land. This corresponds to a residential density average of approximately 3 dwelling units per acre (assuming a residential occupancy rate of 2.3 persons per dwelling unit), which is lower than the average for the City of Satellite Beach which is: 5 dwelling units per acre.

Matrix Dimensions and Resolution

The resolution for the South Beaches grid was the same as the general barrier island grid discussed in Chapter 3. Each cell in the matrix represents an area of 0.15 acres or 25 square meters (82 square feet). The South Beaches average residential parcel size varies between 0.25 acres and 0.60 acres. Consequently in terms of ground resolution, the smaller single-family residential lots are represented by a pair of land use grid cells, whereas the larger parcels by a four cell cluster.

The total number of cells in the South Beaches land use matrix is 427,278. This grid is almost 20 times larger than the grid used for the City of Satellite Beach. However only 7.3 % of the cells are eligible to change their landuse state (See table 8.1.). In addition the number of cells actively participating in the simulation, via the distance neighborhood function is much smaller than in the case of Satellite Beach. Most likely even if one includes all the ocean and river cells within a 1 cell distance of any other use, the percentage of the contributing cells for the simulation does not go beyond 15 % of all the cells in the matrix. Table one list all the dimensions and characteristics of the land use grid for the South Beaches.

Table 8.1. Characteristics of the South Beaches Land Use Grid

Matrix Characteristics	Number of Cells	% From Total
Number of Rows	892	
Number of Columns	479	
Total in the Matrix	427278	
Zero Value Cells	104102	24.4
Participate in calculation of the KHAT statistic	31150	7.3
Fixed use cells that participate in calculation of the KHAT statistic	6953	1.6
Atlantic Ocean and Indian River Lagoon Cells	292026	68.3

Land Allocation Simulation

The barrier island general land use grids for 1990, 1995 and 2000 (See Chapter 3) were clipped to the South Beaches area and used as the observed data sets for calibration and validation of the system for the area. The Future Land Use and the Planning and Zoning general grids (Figures 2 and 3 of Appendix C) were also clipped in order to create the suitability grids (Figures 7 through 6 in Appendix C) necessary for the calibration of the simulation.

The calibration of the model to the South Beaches area was identical to the one followed for the City of Satellite Beach. The set of distance weights selected through calibration are shown in Table 1 in Appendix C. These weights produced good results in the calibration runs, but not in the validation runs. The simulated land use pattern for the year 2000 was significantly different from the observed land use pattern for the year 2000 (See Table 12 in Appendix C). Observed and simulated land use patterns for the three calibration runs for the South Beaches area are showed in Figures 7 through 12 in Appendix C

The land use pattern from the South Beaches was found to be very difficult to reproduce to a significant level over the 10 year simulation period. Several characteristics of the area were found to strongly influence the calibration / validation process:

- The geomorphology of the area: in some areas the distance between the Atlantic Ocean and the Indian River Lagoon is very small, whereas in others it is relatively large.
- The location of the beach and the roads relatively to the Indian River Lagoon and the Atlantic Ocean. There are areas in the grid where the amount of cells that are eligible to change are surrounded by these 4 fixed uses in an area that is only 10 cells wide.
- The lack of homogeneity of the land use patterns in the South Beaches area. All the 16 land use categories were present in the South Beaches, but in the majority of cases the cell clusters of a land use type are very small and dispersed all over the area.

The influence of these issues in the overall performance of the model is discussed in detail in Chapter 9.

The amounts of land requested and allocated for each calibration and validation runs are shown in Tables 2 and 3 in Appendix C. As shown in these tables, there is a difference between the amount of land requested for conservation use during the calibration and validation process and the amount of land allocated to that use via the simulation.

In the calibration runs for the City of Satellite Beach, there was a need to slightly increase (0.09 acres per year) the amount of residential land requested in the calibration run in order to allocate the same amount of cells to residential use. However, in that case the problem was caused by the grid resolution and the fact that the amount of land requested was not a multiple of 0.15 (See Chapter 7). The correction of this problem during the calibration run helped the results of the validation run to be improved, without any changes in the amount of land requested for the validation.

In the case of the South Beaches the same techniques did not produce the same effects. The difference between the land request for conservation use in the calibration run and the land allocated by the simulator was only 0.8 acres. If a correction of the land demand were to be implemented, the original yearly land request would have had to be increased by 0.16 acres. However, the difference between the amount of land requested in the validation run and the amount allocated by the simulator in the same run was approximately 30 acres (See Tables 2 and 3 in Appendix C), which corresponds to a yearly increase of 6 acres. Such a high difference is very unlikely to be caused by the same resolution problem. Thus, it was decided not to correct the amount of land requested for conservation and the calibration and validation process was terminated.

The KHAT statistic calculated between each five-year period for the observed and simulated runs as well as the tests of significance for the KHAT calculated between the 1990 to 1995 and 1995 to 2000 simulated and observed land use patterns are shown in Tables 4 and 5 in Appendix C. As expected the differences between the calibration and validation steps were significant within the observed land use patterns and within the simulated land use patterns.

The tests of KHAT significance calculated between the 1990 and 1995, the 1995 and 2000 and the 1990 and 2000 KHAT statistics of the simulated and observed land use patterns are presented in Table 6 in Appendix C. As shown in these tables there were no significant differences between observed and simulated land use pattern's KHATs for the calibration runs (1990 to 1995). However this was not true neither for the validation run (1995 to 2000), nor for the 10 year comparison between the changes observed from 1990 to 2000 and the changes produced by the simulator for the same period.

Figure 8.5 shows the changes observed between 1990 and 1995 and between 1995 and 2000, for the residential, services and commercial, tourism and conservation uses in the South Beaches area.

Effects of Development Policies in the Future Land Use Patterns of the South Beaches Area

In spite of the fact that the validation runs for the South Beaches were not significant for the 99 % significance interval, in general the patters between observed and simulated runs were quite similar. For that reason it was decided to prepare various scenarios in order to evaluate the impacts of the different development policies on the future land use patterns of the region, and of these on the socio-economic parameters for the area.

Scenario Design

Three scenarios were designed to test the influence of the development policies (See Chapter 4) in the area over the 10 year projection period: 2000 to 2010. The first scenario maintained the development trends in the areas and predicted the evolution of the residential, services and commercial and conservation uses for the planning horizon. The second scenario removed the conservation and agriculture protection policies and allowed development to occur in all agriculture and conservation lands; and the third scenario

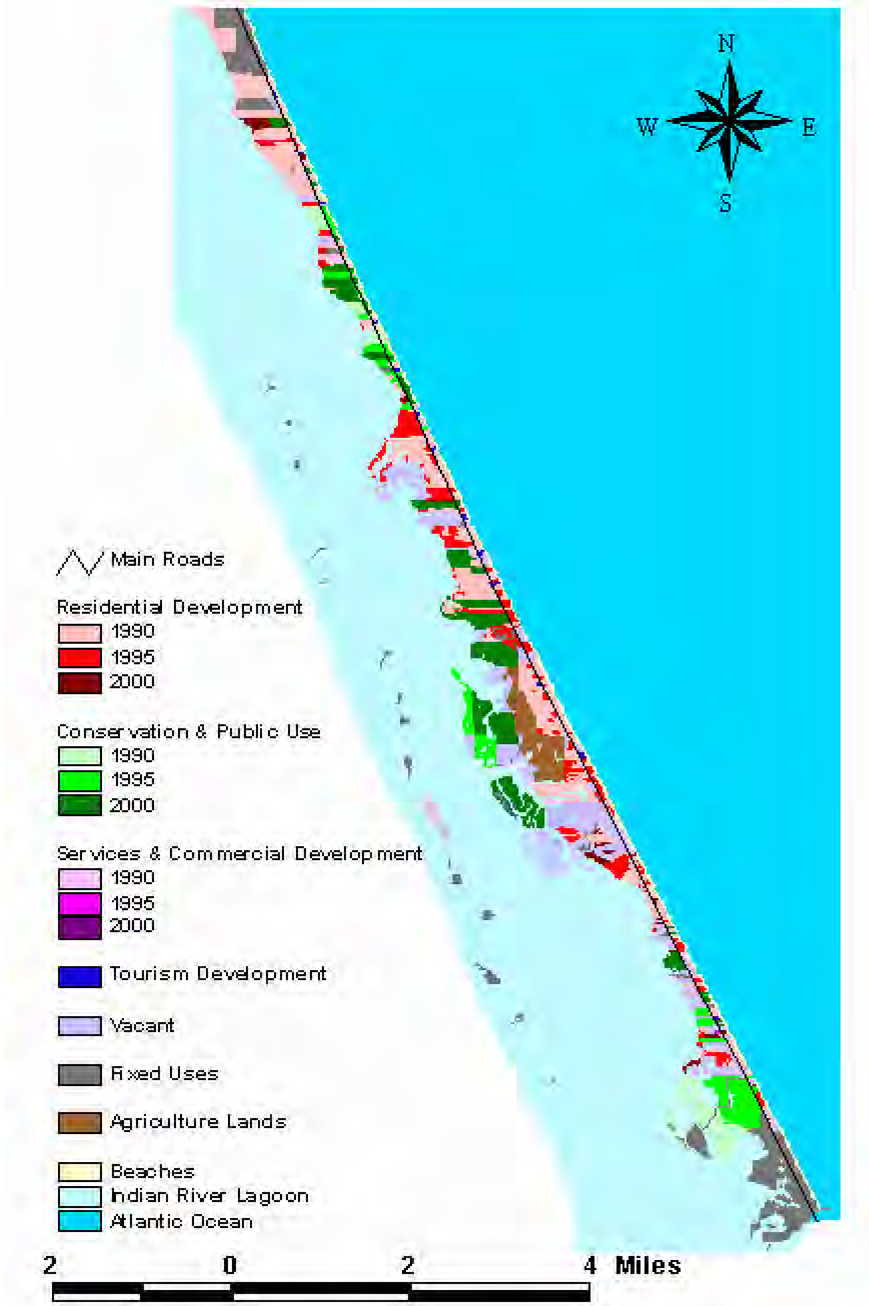


Figure 8. 5. Observed changes between 1990 and 1995 and 1995 and 2000 for the residential, services and commercial, tourism and conservation uses in the area of the South beaches.

considered only the evolution the residential and services and commercial uses but kept the agriculture and conservation lands undeveloped.

A new suitability grid for conservation use was added to the system to include the proposed conservation lands (See Figure 8.6). The amount of land available for development within the city limits was in the year 2000 approximately 1000 acres, not including conservation lands. For scenarios 1 and 3, this acreage was divided equally for the planning horizon (10 years), and the resulting 100 acres were used as the yearly development demands for each use. In Scenario 2, that amount was doubled to (200 acres) to test the system response to a faster degree of development.

The scenario setup was identical to the setup for the City of Satellite Beach. The year 2000 land uses pattern (See figure 8.7) was used as a starting point for all the forecast scenarios. The resident and tourist population predicted during the calibration of the system for the year 2000 was used as the initial valued for the scenarios in order to continue the socio-economic trends initiated in the calibration and validation process.

As explained in Chapter 7, asking the same amount of land to be developed for each use activates the random sorting of the land demands and consequently the order by which the simulator allocated the land requests for each use.

Each scenario was run three times and the KHATs for each run were tested to asses if there were any significant differences between runs. The land use patterns from Run 2 of each scenario were selected to illustrate the results obtained.

Scenario Description

Scenario 1

Scenario 1 followed the current policies stated in the South Beaches Small Area Plan and the 1998 updates to the Brevard County Comprehensive Plan. These policies encourage the allocation of land to conservation and the keeping of the agriculture lands as such.

The amount of land requested in this scenario was 100 acres for residential, services and commercial and conservation uses. The increase in conservation lands was considered in order to satisfy the continuing efforts to acquire land for conservation. Table 8.2 illustrates the land requests and the amounts of land allocated for each run of Scenario 1. Figures 8.8a and 8.9a show the landuse patterns obtained for run 2 of the Scenario 1 for the years 2005 and 2010 respectively. Figure 8.8b show the changes that occurred in the residential, services and commercial and conservation land uses from 2000 to 2005. Tables 7a and 7b in

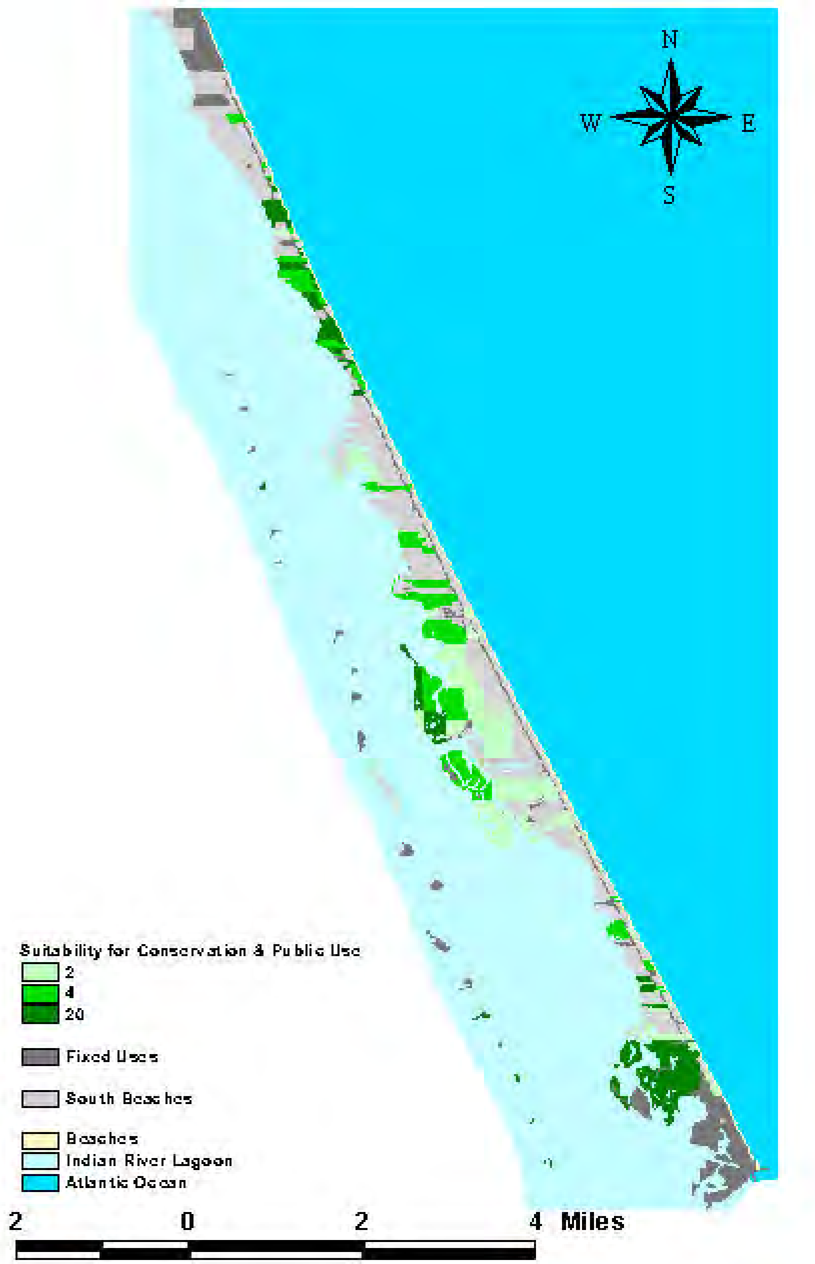


Figure 8.6. Suitability for conservation use grid used in the scenario runs

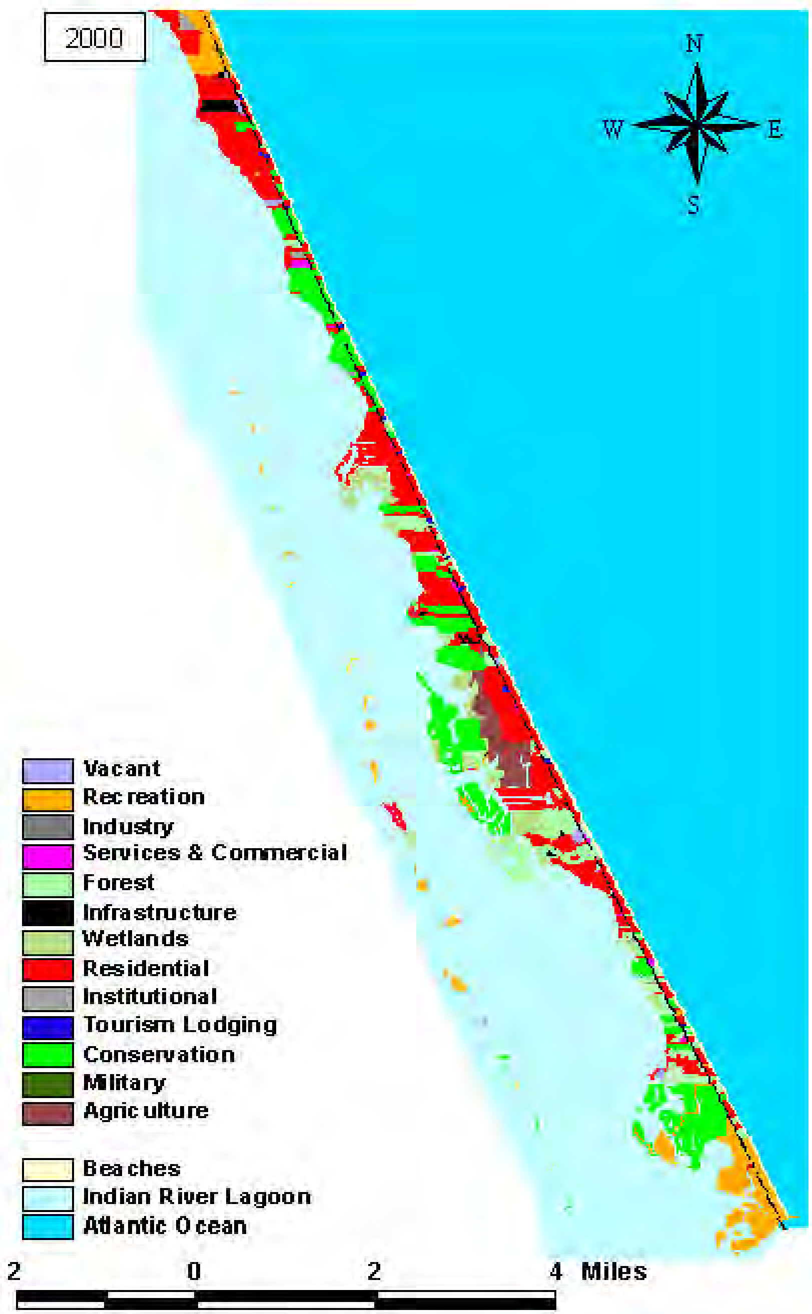


Figure 8.7. 2000 land use pattern used as the base year for the scenario runs.

Table 8.2. Land requests per use and land allocated and percentage change for each run of Scenario 1.

Simulation	Scenario 1 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	1076.7	1510.8	1510.8	434.1	0.0	40.3	0.0	100	100
Residential	1510.7	1869.3	1869.3	358.7	0.0	23.7	0.0	100	100
Services & Commercial	26.25	30.9	30.9	4.7	0.0	17.7	0.0	100	100
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0

Simulation	Scenario 1 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	1076.7	1510.2	1510.2	433.5	0.0	40.3	0.0	100	100
Residential	1510.7	1869.9	1869.9	359.3	0.0	23.8	0.0	100	100
Services & Commercial	26.25	30.9	30.9	4.7	0.0	17.7	0.0	100	100
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0

Simulation	Scenario 1 - Run 3			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	1076.7	1503.3	1506.5	426.6	3.2	39.6	0.2	100	100
Residential	1510.7	1873.7	1873.7	363.0	0.0	24.0	0.0	100	100
Services & Commercial	26.25	30.9	30.9	4.7	0.0	17.7	0.0	100	100
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0

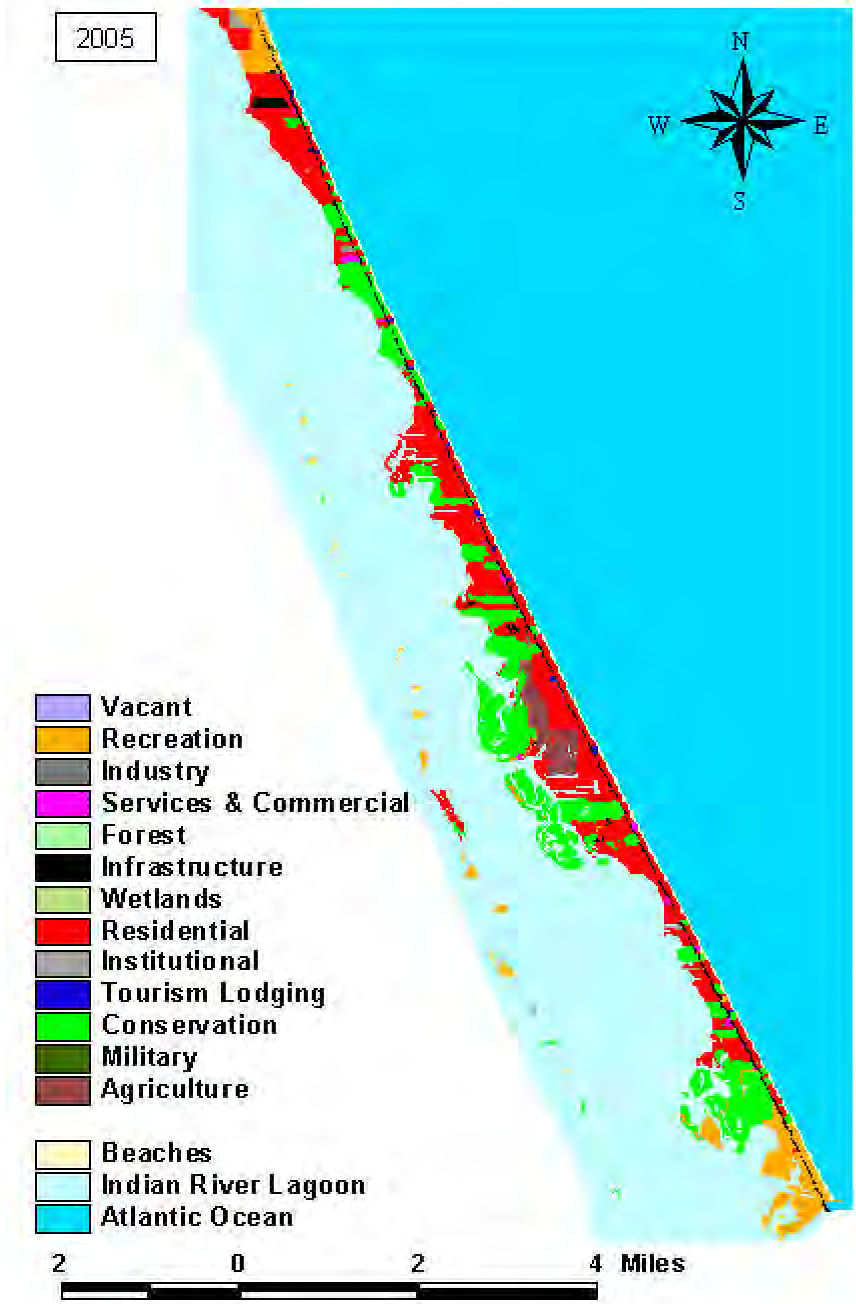


Figure 8.8a. Scenario 1: Future land use pattern projections for the South Beaches area for 2005 based on 100 acres yearly demand for the Residential and Services and Commercial and Conservation uses.

Figures 8.8b. Changes between the 2000 and 2005 simulated land use patterns for the residential, services and commercial and conservation land uses in Scenario 1

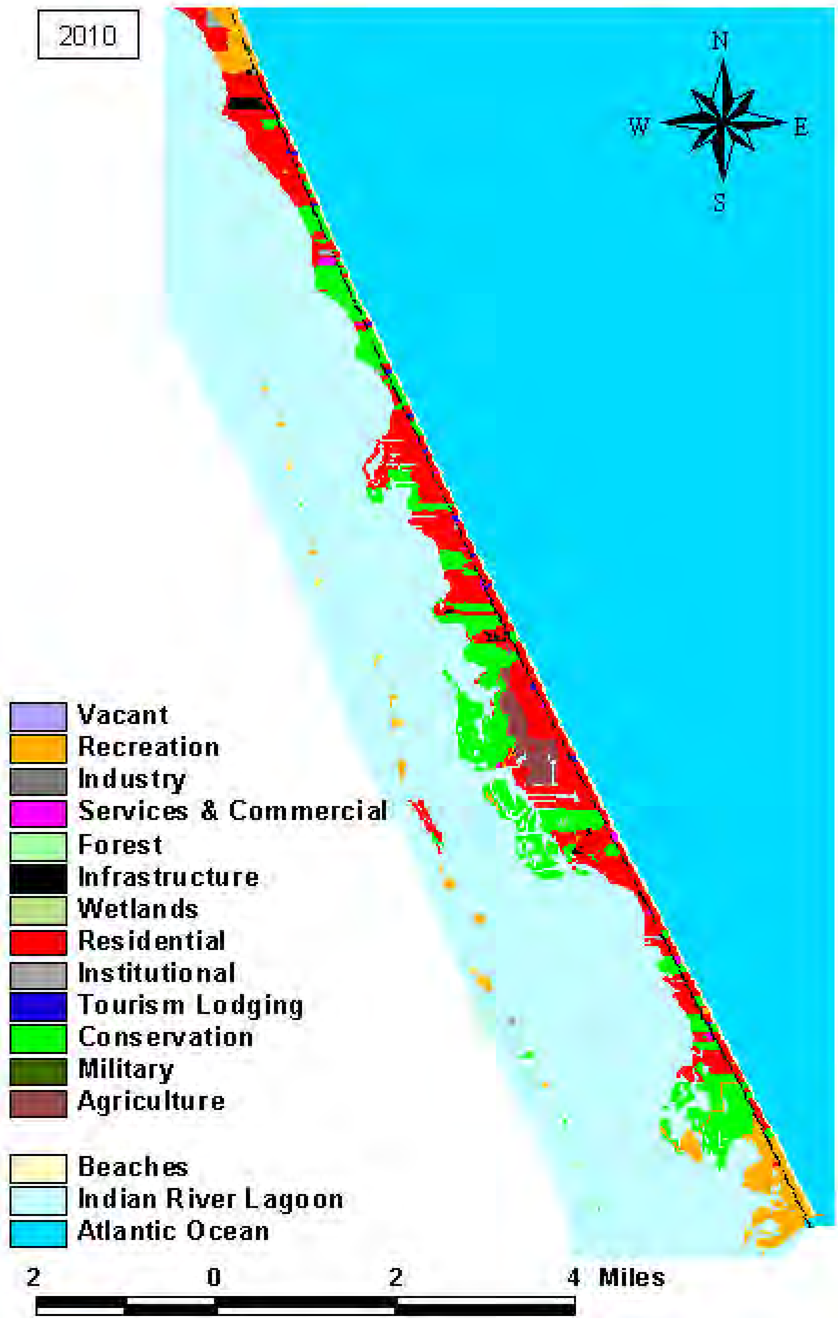


Figure 8.9a. Scenario 1: Future land use pattern projections for the South Beaches area for 2010 based on 100 acres yearly demand for the Residential and Services and Commercial and Conservation uses.

Appendix C document the KHAT statistic individual runs and the respective tests of KHAT significance for the three runs of Scenario 1.

Scenario 2

Scenario 2 differs from scenario 1 in two ways: the amounts of land requested for allocation to residential and services and commercial uses were doubled to 200 acres to evaluate the effects of a higher development rate; and secondly the conservation and agriculture protection policies were removed so that these lands could be developed.

Table 8.3 illustrates the land requests and the amounts of land allocated for each run of Scenario 2. Figures 8.10a and 8.11a show the landuse patterns obtained for run 2 of the Scenario 2 for the years 2005 and 2010 respectively. Figures 8.10b and 8.11b show the changes that occurred in the residential, services and commercial and conservation land uses from 2000 to 2005 and from 2005 to 2010 in that order. Tables 8a and 8b in Appendix C document the KHAT statistic individual runs and the respective tests of KHAT significance for the three runs of Scenario 2.

Scenario 3

Scenario 3 is very similar to Scenario 1, except for the fact that in spite of the fact that conservation and agriculture protection policies are kept in place, so more lands were requested for conservation use.

Table 8.4 illustrates the land requests and the amounts of land allocated for each run of Scenario 3. Figures 8.12a and 8.13a show the landuse patterns obtained for run 2 of Scenario 3 for the years 2005 and 2010 respectively. Figures 8.12b and 8.13b show the changes that occurred in the residential, services and commercial and conservation land uses from 2000 to 2005 and from 2005 to 2010 in that order. Tables 8.9 and 8.10 document the KHAT statistic individual runs and the respective tests of KHAT significance for the three runs of Scenario 3.

Analysis of the Scenario Results

In general the model was able to produce the future land uses patterns that would be expected in response to the development policies adopted for each scenario.

Table 8.3. Land requests per use and land allocated and percentage change for each run of Scenario 2.

Simulation	Scenario 2 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	1076.7	499.05	11.7	-577.7	-487.4	-53.7	-97.7	0	0
Residential	1510.7	2574.9	3378	1064.3	803.1	70.4	31.2	200	200
Services & Commercial	26.25	34.8	34.8	8.6	0.0	32.6	0.0	200	200
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0

Simulation	Scenario 2 - Run 2			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	1076.7	498.9	11.7	-577.8	-487.2	-53.7	-97.7	0	0
Residential	1510.7	2574.9	3377.9	1064.3	803.0	70.4	31.2	200	200
Services & Commercial	26.25	34.95	34.95	8.7	0.0	33.1	0.0	200	200
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0

Simulation	Scenario - Run 3			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (OFF)	1076.7	498	11.7	-578.7	-486.3	-53.7	-97.7	0	0
Residential	1510.7	2574.9	3377.9	1064.3	803.0	70.4	31.2	200	200
Services & Commercial	26.25	34.95	34.95	8.7	0.0	33.1	0.0	200	200
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0

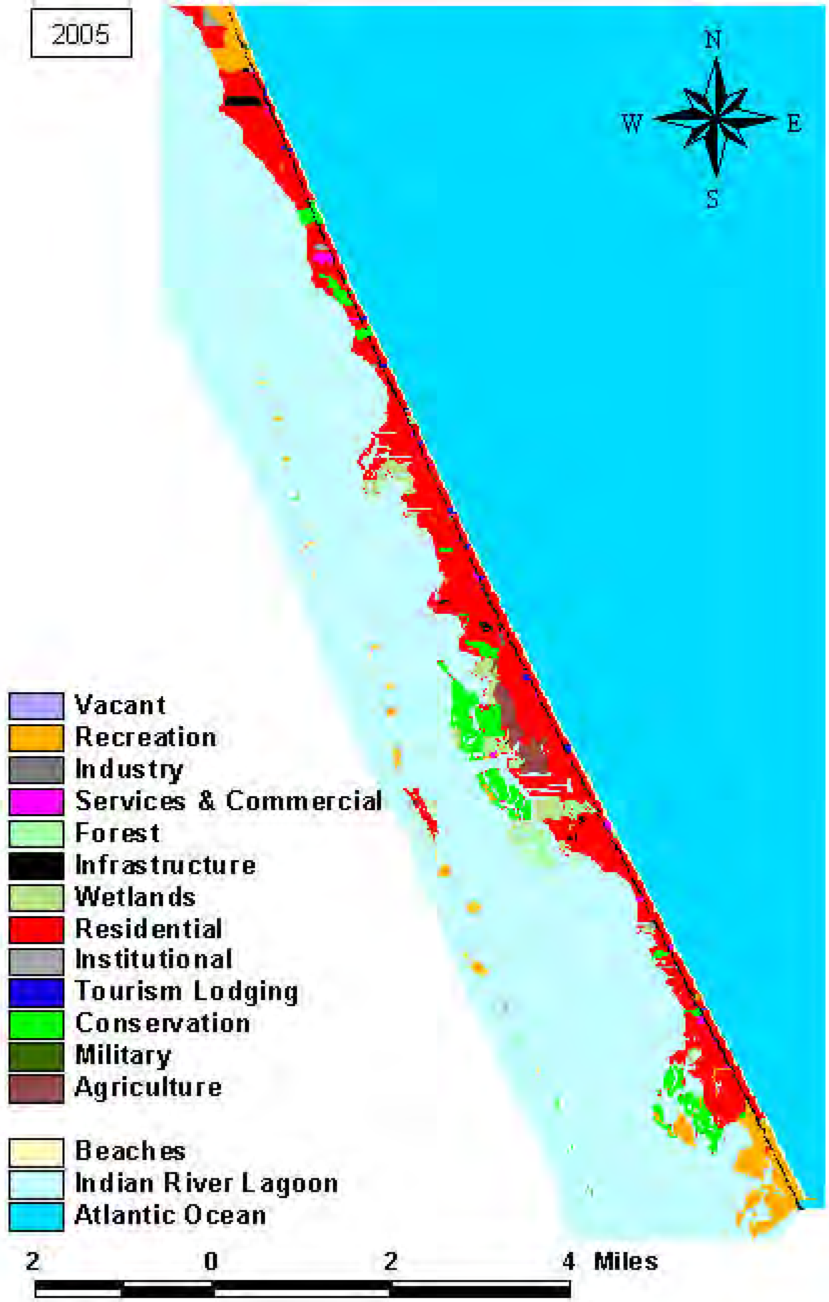


Figure 8.10a. Scenario 2: Future land use pattern projections for the South Beaches area for 2005 based on 200 acres yearly demand for the Residential and Services and Commercial uses, allowing Conservation lands to be developed.

Figures 8.10b Changes between the 2000 and 2005 simulated land use patterns for the residential, services and commercial and conservation land uses in Scenario 2

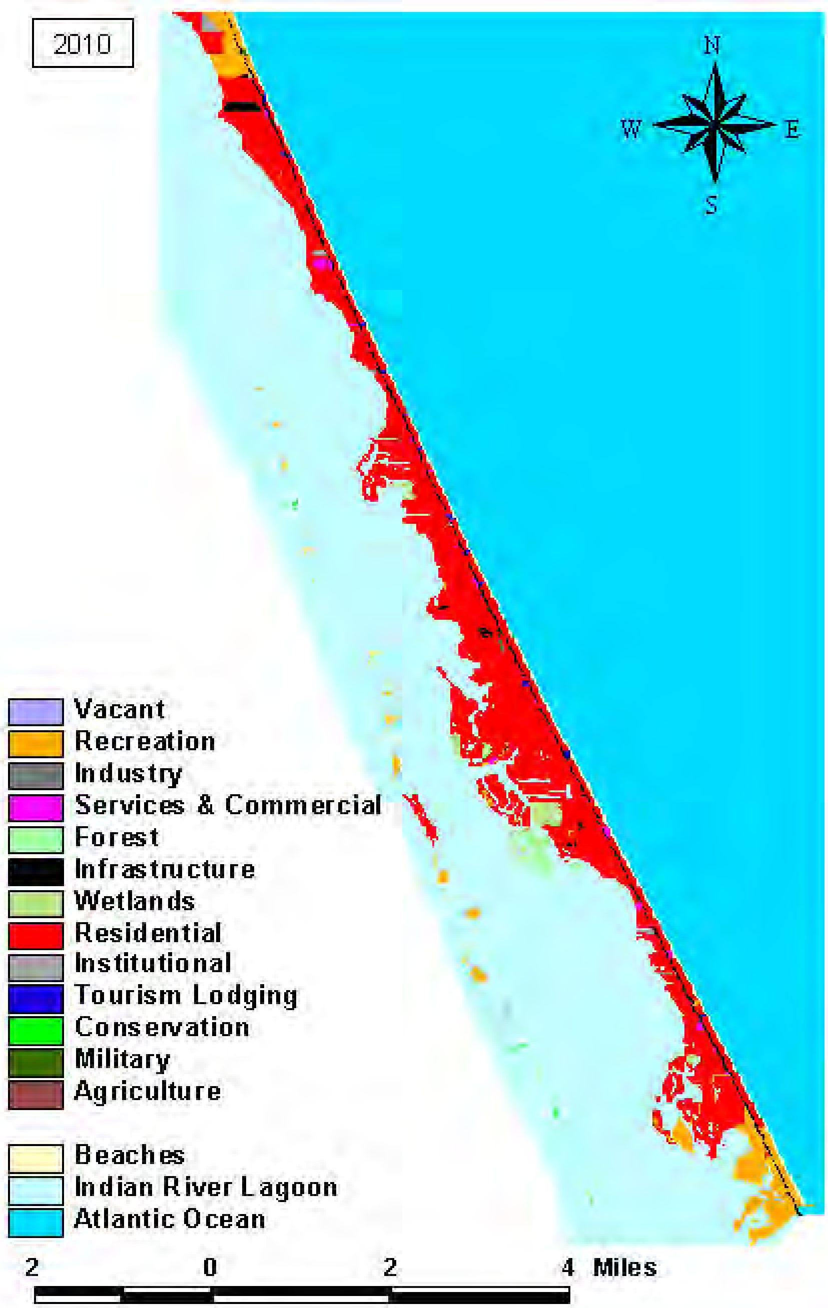


Figure 8.11a. Scenario 2: Future land use pattern projections for the South Beaches area for 2010 based on 200 acres yearly demand for the Residential and Services and Commercial uses, allowing Conservation lands to be developed.

Figures 8.11b Changes between the 2005 and 2010 simulated land use patterns for the residential, services and commercial and conservation land uses in Scenario 2

Table 8.4. Land requests per use and land allocated and percentage change for each run of Scenario 3.

Simulation	Scenario 3 - Run 1			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	2000	2005	2010	2000-2005	2005-2010	2000-2005	2005-2010	2000-2005	2005-2010
Conservation (ON)	1076.7	1076.7	1076.7	0.0	0.0	0.0	0.0	0	0
Residential	1510.7	2011.4	2097.2	500.7	85.8	33.1	4.3	100	100
Services & Commercial	26.25	29.25	29.25	3.0	0.0	11.4	0.0	100	100
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0
Simulation	**Scenario 3 - Run 2**			**Land Change (acres)**		**Land Allocated (%)**		**Annual Average (acres)**	
	2000	**2005**	**2010**	**2000-2005**	**2005-2010**	**2000-2005**	**2005-2010**	**2000-2005**	**2005-2010**
Conservation (ON)	1076.7	1076.7	1076.7	0.0	0.0	0.0	0.0	0	0
Residential	1510.7	1968.3	2081.6	457.7	113.3	30.3	5.8	100	100
Services & Commercial	26.25	31.05	31.05	4.8	0.0	18.3	0.0	100	100
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0
Simulation	**Scenario 3 - Run 3**			**Land Change (acres)**		**Land Allocated (%)**		**Annual Average (acres)**	
	2000	**2005**	**2010**	**2000-2005**	**2005-2010**	**2000-2005**	**2005-2010**	**2000-2005**	**2005-2010**
Conservation (ON)	1076.7	1076.7	1076.7	0.0	0.0	0.0	0.0	0	0
Residential	1510.7	1968.3	2081.6	457.7	113.3	30.3	5.8	100	100
Services & Commercial	26.25	31.05	31.05	4.8	0.0	18.3	0.0	100	100
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0	0

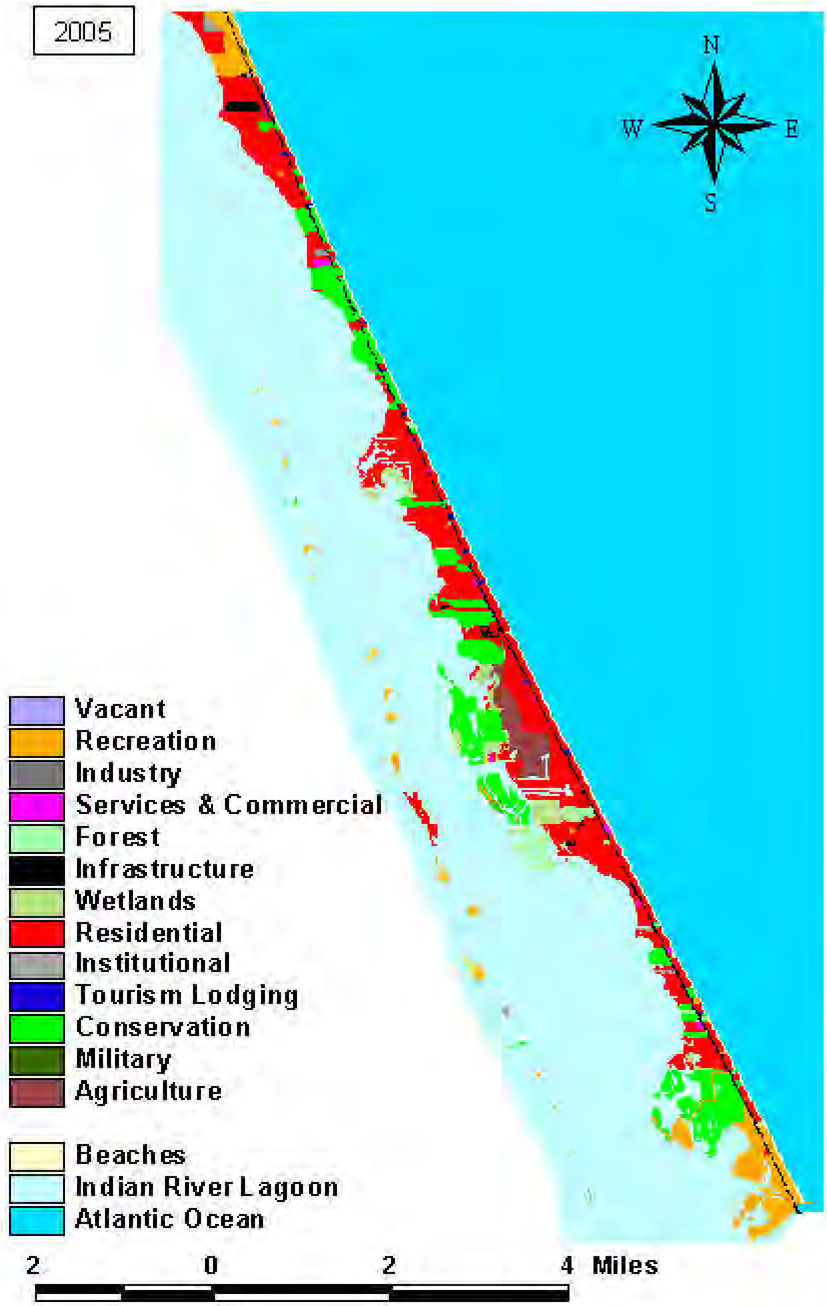


Figure 8.12a. Scenario 3: Future land use pattern projections for the South Beaches area for 2005 based on 100 acres yearly demand for the Residential and Services and Commercial uses, keeping Conservation lands.

Figures 8.12b Changes between the 2000 and 2005 simulated land use patterns for the residential, services and commercial and conservation land uses in Scenario 3

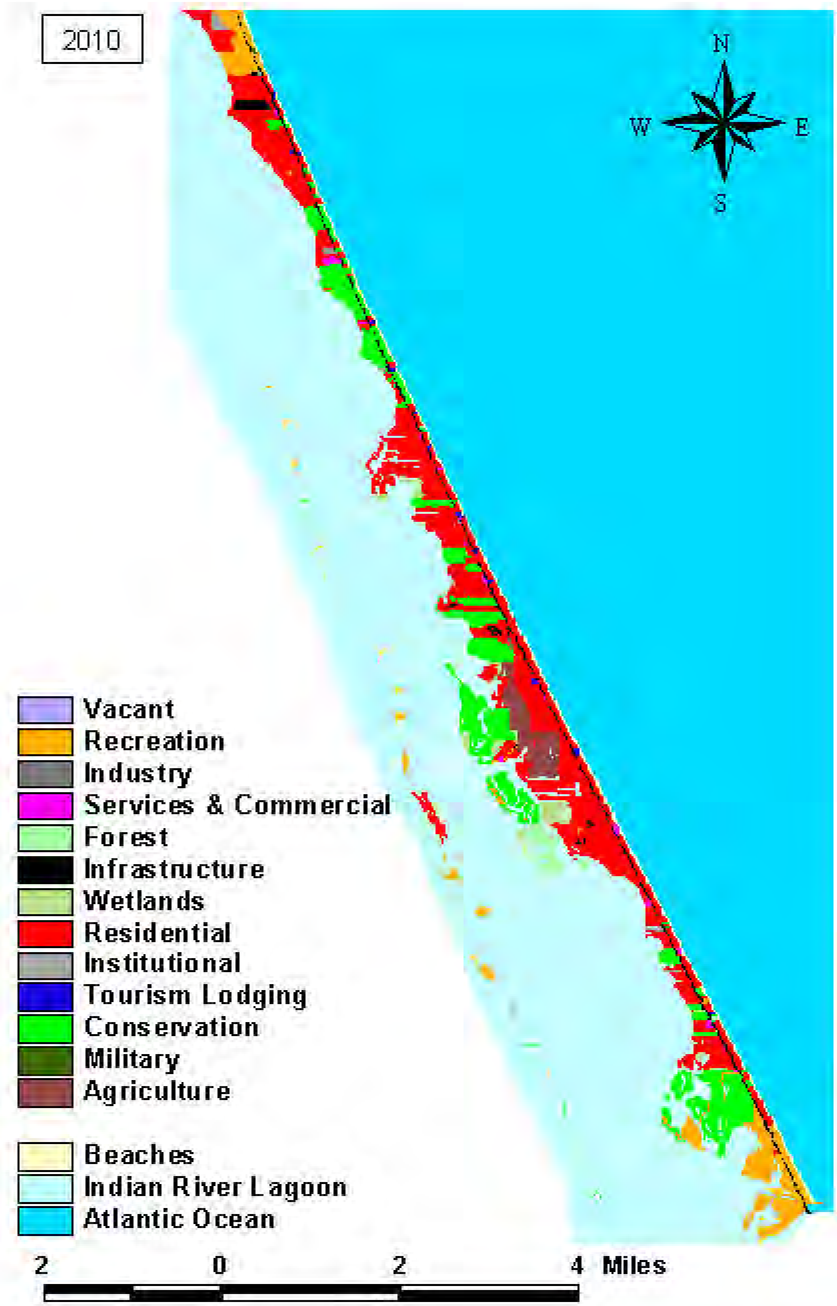


Figure 8.13a. Scenario 3: Future land use pattern projections for the South Beaches area for 2010 based on 100 acres yearly demand for the Residential and Services and Commercial uses, keeping Conservation lands.

Figures 8.13b Changes between the 2005 and 2010 simulated land use patterns for the residential, services and commercial and conservation land uses in Scenario 3

Scenario 1

Out of the 1000 acres requested for each use in this scenario 431,4 acres were allocated to conservation use, 360 to residential use and 4.7 acres to services and commercial (See Table 8.2). Approximately 200 acres were maintained undeveloped because they correspond to the agricultural lands which were maintained undeveloped. By 2005 all cells were allocated and for that reason the land use patterns between 2005 and 2010 are identical (See Figures 8.8a and 8.9a).

The majority of the lands allocated for conservation (See Figures 8.8a and 8.8b) correspond to the lands classified in the suitability for conservation grid (See figure 8.6) as suitable for conservation. This fact shows that the model response to the introduction of new suitability grids was maintained beyond the calibration and validation process, in spite of the pressure from competing residential uses.

As shown in Table 7a in Appendix C all the differences between the calculated KHATs for each land use patterns were significant, while between runs at least two out of three scenario runs (See Table 7b in Appendix C) were not significantly different from each other.

Scenario 2

The effects of a higher demand for development were reflected in the additional amount of lands allocated to residential and services and commercial uses in Scenario 1.
The lands developed in this scenario for services and commercial were lands, which the suitability for residential use was identical to the one for services and commercial use (See Figures 5 and 6 in appendix C). Since the conservation and agriculture lands become available for residential development (See Figure 8.10 a and b), less suitable lands could be allocated to services and commercial use.

The amount allocated to residential use by 2010 (See Table 8.3) was 4 times higher than in Scenario 1 (1867.4 acres). This amount was made at the expenses of conservation and agriculture lands that were almost completely developed by the end of the simulation. A total of 1064 acres previously allocated to conservation were developed along with the 200 acres from agriculture lands.

Provided that the current use compatibility policies in the Brevard County Comprehensive Plan are kept all wetlands and agriculture lands are eligible for low density residential development of 1 dwelling units per 2.5 acres. With this in mind, the current scenario might not be very far from reality if in all the agriculture lands and the lands allocated for conservation in the South Beaches area are sold for development. With the exception of some of the parks that were in this simulation classified as conservation land use instead of recreational use all other lands could eventually be developed as shown in Figure 8.11a.

The KHAT tests of significance between land use patterns simulated from 2000 to 2005 and from 2005 to 2010 were as expected significantly different (See Table 8a in Appendix C). In this scenario all the three runs were not significantly different from each other (See Table 8b in Appendix C)

Scenario 3

In Scenario 3 all the conservation and agriculture lands were kept in its 2000 level and the remaining lands ware requested to be developed either for residential use or for services and commercial use. As in Scenario 1, only 4.8 acres of land were allocated to services and commercial use (See Table 8.4). This is due to the low suitability that the majority of the lands in the south beaches have for services and commercial development; and to the fact that if no other lands with higher suitability for residential use are made available (See Scenario 2), competition forces between the two uses tend to favor residential use.

Residential development continued to increase to a total of 571 acres by 2010, which represents a net gain of 211 acres from Scenario 1. This response to the current policies was expected as the competition between conservation and residential uses was removed.

The KHAT tests of significance between land use patterns simulated from 2000 to 2005 and from 2005 to 2010 were all significantly different (See Table 9a in Appendix C). Out of the three runs for this scenario two were not significantly different from each other (See Table 9b in Appendix C)

Socio - Economic Changes

The socio-economic variables were kept unchanged in each scenario. This way the effects of the changes in the land use patterns on the regional population carrying capacity and on the evolution of the quality of life in the area was assessed.

The population growth curves for each scenario are plotted in Figure 7.14. The evolution of the regional population carrying capacity is shown in Figure 7.15, and the evolution of the three life quality indexes for each scenarios is shown if Figures 7.16 through 7.18. The values from run 2 of each scenario were chosen to illustrate the changes.

Population Growth

As expected no differences between scenarios in the residential population growth were noticed (See Figure 8.14), because the growth rates for each scenario were identical; and because the regional population carrying capacity for the area was never reached in the forecast horizon. If a higher population growth rate had been chosen to run each scenario, then the residential population curves would have taken the shapes of the regional population carrying capacity curves shown in Figure 8.15 as soon as the residential population level had reached the population carrying capacity. However in this case, in spite of the low population rate the two almost met, since the difference in the first scenario between the residential population growth and the population carrying capacity was only 633 people, which corresponds to 274 dwelling units (assuming a 2.3 occupation rate for dwelling unit - see Chapter 3).

The regional population carrying capacity growth curves are a direct reflection of residential development and of the residential densities of the developed areas. Both Scenario 1 and 3 represent the most likely outcomes if the current land development policies and residential densities are maintained. If this is the case, the residential population growth rate in the area has to be kept at a low level, in order not to surpass the regional carrying capacity.

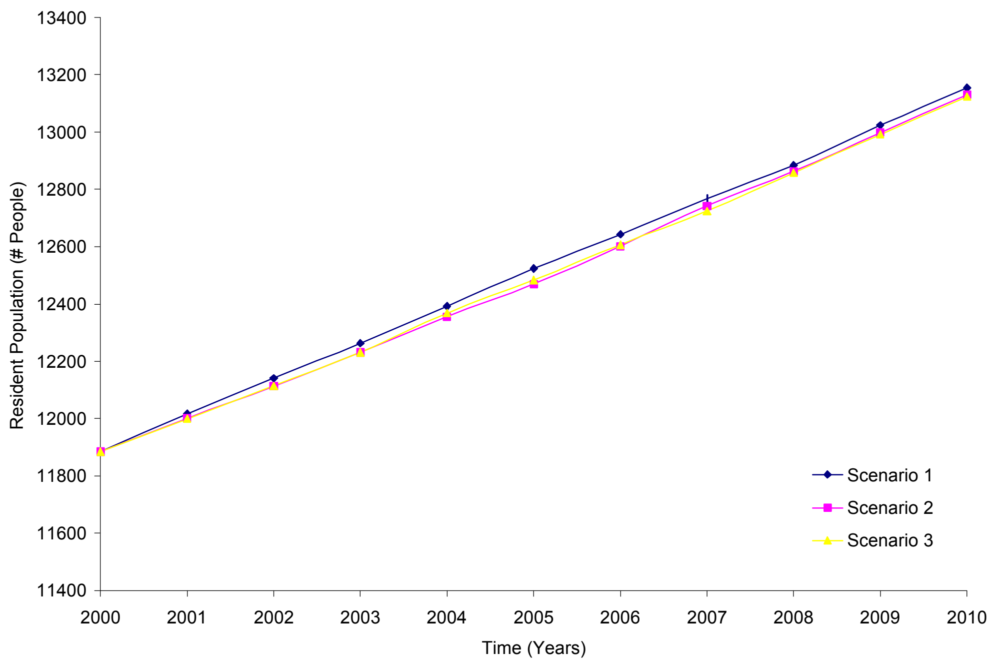


Figure 8.14. Resident population growth for each scenario.

However if the land development policies change and all the conservation and agriculture lands are developed, then there is an additional growth of approximately 4000 people or 1700 dwelling units that can be accommodated.

Quality of Life Indexes

As mentioned in the beginning of his chapter, the quality of life in the South Beaches area based on the 1990 through 2000 Index levels, was much higher than the accepted levels for the county.

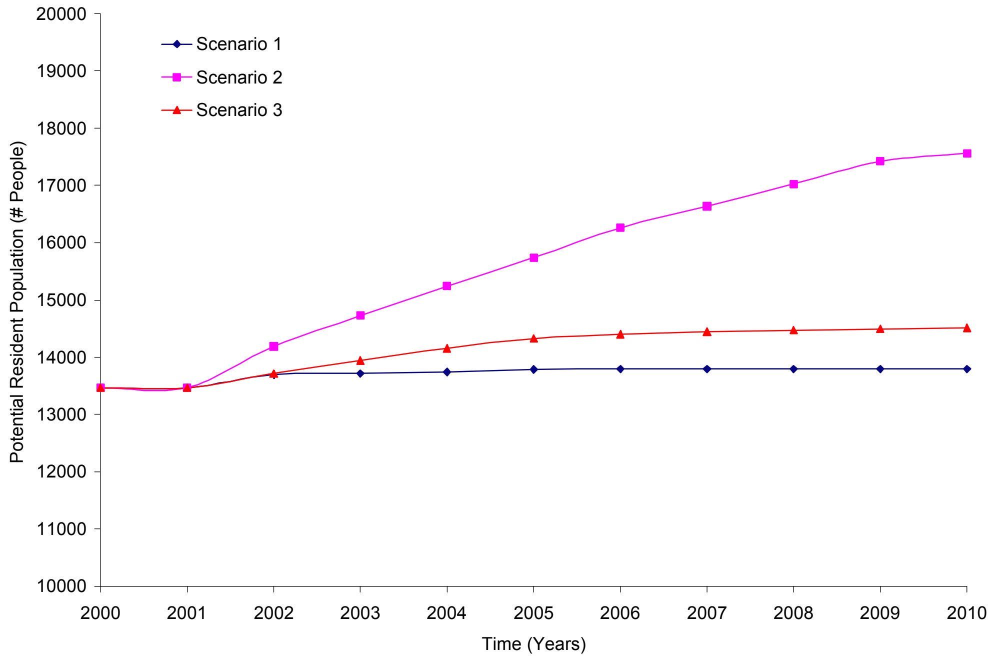


Figure 8.15. Regional Population Carrying Capacity Growth for each scenario.

The conservation index (Figure 8.16) was directly influenced by the policies chosen. When conservation lands were increased (Scenario 1) the conservation index increased too. When all the conservation lands were developed the index dropped to zero. When the conservation lands where maintained in its 2000 level the index decreased along with the population increase.

In the same way as population increased in the South Beaches, the recreation index (Figure 7.17) decreased. In any case, even if no conservation lands were available in the South Beaches area, the recreation and open space requirements by the Brevard County Comprehensive Plan of 3 acres per 1000 people would always be satisfied.

The residential density index (Figure 8.18) was for the area decreased always with population increase and as the amount of residential land available increased. Since the population growth rate was maintained at the 1 % per year in all scenarios, the differences in development rate introduced in Scenario 2 produced a much greater impact. However in the case of scenario 1 and scenario 3 where conservation and residential uses competed for land, the differences between the two scenarios only become noticeable after 2003 and eventually diverged in opposite directions.

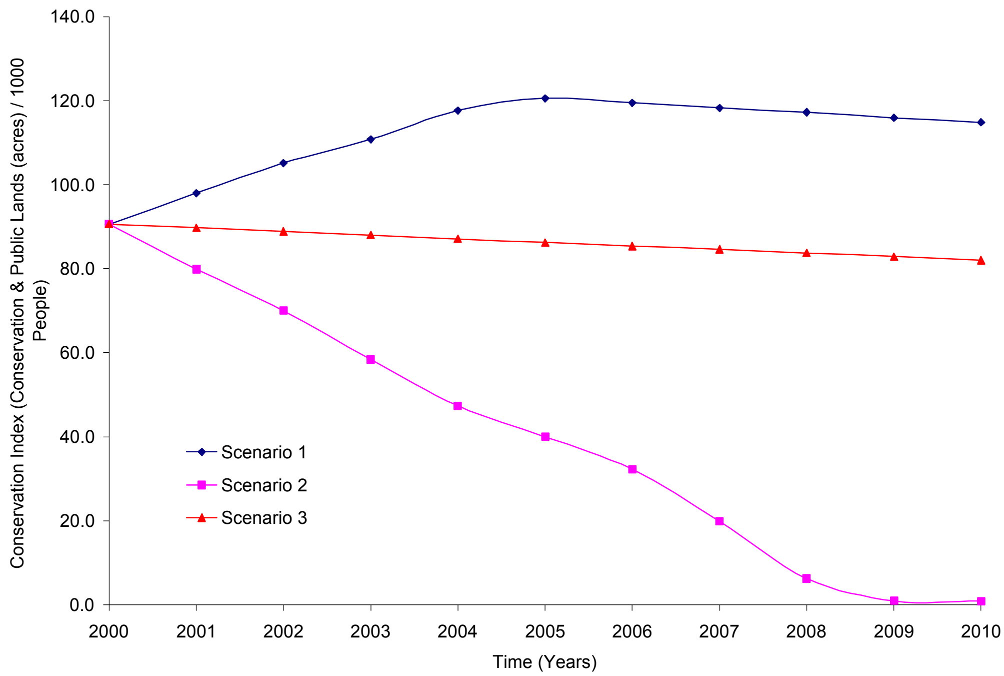


Figure 8.16. Conservation Index for each scenario.

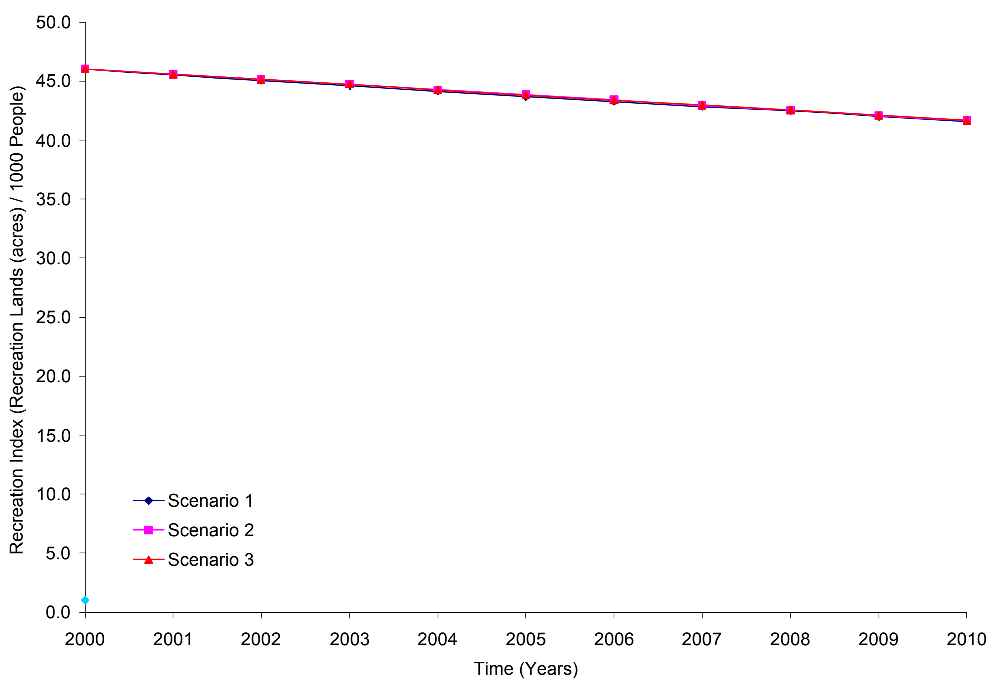


Figure 8.17. Recreation Index for each scenario.

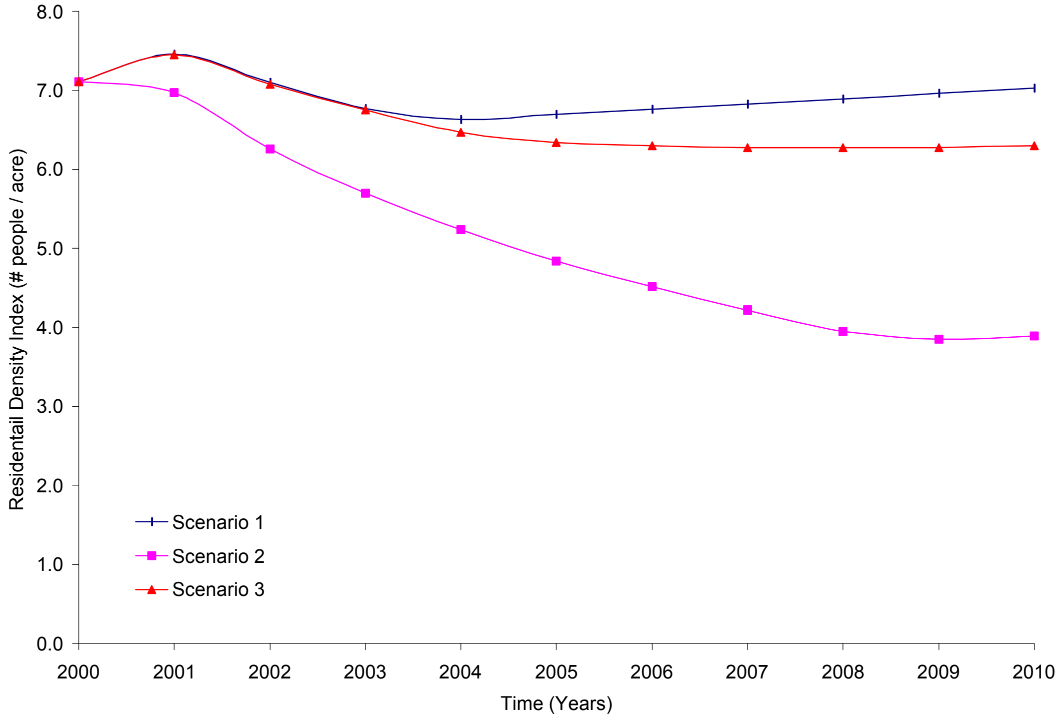


Figure 8.18. Residential Density Index for each scenario.

Chapter 9
Discussion

In general the criteria and alternatives chosen to quantify the changes in the land use patterns of the two areas due to the implementation of different development policies correctly point out coastal development issues such as land use competition, location preferences and so forth (See Chapter 7 and 8).

In both cases the KHAT or the kappa coefficient of agreement provided a way to quantify changes in land use patterns and to compare and assess the statistical significance of that change. The Satellite Beach case showed the potential of KHAT as a tool to assess the accuracy of the calibration and validation patterns. The South Beaches case uncovered the fact that there might be a limit to the application of the KHAT coefficient to very large grids. This limitation was not investigated further in this research, but it should be considered in future research in the area.

Land Allocation Simulation

One of the challenges of this research was to identify the role of each component of the land allocation simulation in the overall performance of the model. Once each role was identified it was possible to prepare the different scenarios and identify the areas where additional work was necessary. With this in mind it was found that:

- Suitability grids can be very useful in determining the areas of cellular growth and in modeling the competition forces between land uses for land allocation. The following facts support this matter:
    a. As discussed in Chapters 7 and 8, for calibration and validation purposes it was necessary not only to significantly lower the suitability of the lands that should be developed by 1995 and 2000, but also to completely remove lands that although suitable for that use, were not allocated to that use by the end of the 1990 - 2000 simulation horizon.
    b. During the scenario runs, no growth occurred in areas where the suitability for services and commercial was zero (See Chapter 7), independently of the fact that for that particular use the land demand ware never satisfied.
    c. The model responded as expected to the introduction of the new suitability grids and effectively established the existence of competition forces between tourism and residential land uses and between conservation and residential land uses in Chapter 7.
    d. When additional conservation land was requested in Scenario 1 of Chapter 8 the proposed conservation lands (See Figure 8.5) were selected accordingly by the simulator to be allocated to that use.

If in the future one needs to model the effects of building another causeway from the mainland to the barrier island in the South Beaches one should do two things:

- Add to all the suitability grids the new causeway
- Increase the suitability for commerce along the areas of access to the causeway. To reflect the fact that most likely those areas would be zoned commercial, as all the areas around the main roads in the barrier island are (See Figures 5, 7 and 11 in Appendix A).

- The distance neighborhood weights can be very useful in influencing the outcome in cases where there is a clear competition between uses. Once the system is calibrated it is not recommended to change the weights of the uses that participate in the calibration of the system, in this case residential, services and commerce and conservation. However any other uses can be changed to reflect the needs of each scenario. For example:
    a. In the case of Satellite Beach the suitability for tourism grid was not part of the calibration, as a consequence the distance weights that rule the influence of the other land uses on tourism could have been changed after the calibration was done. As discussed in Chapter 8, the fact that the weight given to the influence of the ocean, beaches and infrastructure land uses on tourism was higher than the weight given to residential use, determined the outcome of the land competition between the two uses for the oceanfront areas.

Limitations of the Land Allocation Simulation

The distance weights used in the calibration of the model to the two areas had to be flexible enough to accommodate the variability between identical use clusters that constituted each land use pattern.

- Satellite Beach land use pattern represents an almost fully developed area so it is fairly homogeneous and organized.
    a. Only 13 use categories are represented in the City's land use pattern.
    b. There is a clear dominance of residential development
    c. The majority of the services and commercial uses are located along the major roads.
    d. The fixed uses boundaries, such as the Indian River Lagoon only surround a few uses: residential and conservation in the western side of the City.
    e. In most cases the uses that constitute distance neighborhood are identical.
- The South Beaches land use pattern is exactly the opposite, most of the area is still undeveloped, and the use clusters distribution is not homogeneous.
    a. All of the 16 use categories are present and spread around the area without many apparent criteria.
    b. There isn't a land use that dominates the pattern, the closest use to that status would be the natural forest category which is not a developed use and that accordingly is eligible to change to any of the other uses.

c. Commercial uses are in most cases located along the major roads, but it is not necessarily a rule

d. The fixed uses such as the Indian River Lagoon, are part of the neighborhood of almost all the uses available on the pattern

e. The variety of uses in the distance neighborhood is very large, and varies from area to area. For example in some cases forest areas are surrounded by already developed used, in others by fixed uses and yet others by a combination of the two.

The distance influence neighborhood weights chosen in the cases of the south beaches had to be able to influence the change of a forest cell to a residential use when ever that cell was surrounded by other forest cells, a combination of Indian River cells and forest cells or any other combination. This was found to be a limiting factor in the capabilities of the land use allocation simulation while reproducing the calibration and validation land use observed patterns.

The presence of fixed uses such as roads can also be a limiting factor depending on its location. In both case studies there was a clear boundary effect created by the close distance between the roads and the beach along the eastern Atlantic shore. Balancing the effects of those two weights was the most difficult task for the City of Satellite Beach. In the case of the South Beaches, in some of the narrower areas of the island, within a distance of 10 cells, not only the road and the beach are present, but also the Atlantic Ocean and the Indian River Lagoon.

The particular case of the boundary effects caused by proximity of the fixed uses is directly related to the resolution of the grid. In these areas a 25 x 25 meter (82 x 82 feet) grid is too large to resolve the differences with the needed detail. Thus grid resolution can be a limiting factor. As discussed in Chapter 3, this was one of the factors that had to be considered during the spatial data structuring and analysis.

During the calibration and validation runs, the amount of land requested for residential use in the case of Satellite Beach (See Chapter 7) and conservation use in the case of the South Beaches (See Chapter 8) was not completely satisfied. Also it was noticed that the amount of cells that were not allocated in the South Beaches was considerably larger than in the City Satellite Beach. The latter might have to do with the fact that the amount of land requested in the case of the South beaches was also much higher.

As explained in Chapter 5, the land allocation of the cells for each use is an iterative process that finishes only when all the amounts of land requested for development is satisfied. In areas where no development clusters exist (for example large forest areas), the location of the first developed use cell, will determine the location of the larger clusters of developed cells that will satisfy the demand for that use. It is possible that there is a connection between the number of cells in that grid that failed to be allocated in a simulation step, and the fact that over the 10 year period failed to be allocated. If the initial cluster cells do not form, this effect it will probably propagate that error through out the simulation and it will end the simulation with a large deficit of cells allocated. In areas like the South Beaches, where there are still extensive undeveloped areas, the influence of the weights attributed to each use is crucial to the initial cell cluster.

Comparison with other Cellular Automata Models

The most recent versions Engelen and White's cellular automata models (Engelen et al., 1997), add to the potential of change equation, another parameter: the accessibility parameter. Initially this parameter was included in the algorithm prepared for this research. However it was found that the expansion of the cellular automata clusters was extremely limited when the accessibility parameter was used. Also problem of the close proximity between fixed uses was greatly amplified with that parameter. Consequently its use was disregarded.

The other difference between Engelen and White cellular automata model and the one designed in this research is the distance influence neighborhood. In their model, this distance extends out to a radius of 6 to 8 cells. As mentioned in Chapter 5, the neighborhood used in the DSS was composed of only the surrounding 8 cells. The case of the South Beaches reinforced the choice of such neighborhood. With the lack of homogeneity of the land use pattern of that area it would have been extremely difficult to calibrate the distance weights if 5 or 7 additional rings had to be considered.

The last important difference is the grid resolution. This research used a grid cell size of 25 x 25 m while theirs used a 250 x 250 meters grid. Engelen and White models represented much larger project areas, since most of their models were made for islands or for much larger cities such as Cincinnati (White et al., 1997).

Testing the Null Hypothesis

As demonstrated in Tables 9.1 for the case of Satellite Beach and 9.2 for the case of the South Beaches there are significant changes in land use patterns, measured by KHAT or kappa, explained by changes in development policies. In the case of the City of Satellite Beach scenarios where similar development policies were tested, for example Scenarios 5 to 8 where tourism was introduced, some of the differences between land use pattern's KHATs were not significant, however in the majority of the cases that was not true. In the case of the South Beaches area all land use patterns were significantly different from each other between scenarios. As a result the null hypothesis set forth in Chapter 2 was rejected.

Table 9.1. Test of KHAT (kappa) statistic between land use patterns of each Scenario to the 99 % significance level for the City of Satellite Beach (Shadowed areas represent non significant values)

	Z (0_5 and 0_5)							
Years: 2000-2005	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**
% Cell Change	5.59	3.44	3.44	5.53	5.69	5.86	5.7	4.39
KHAT	0.894	0.935	0.935	0.892	0.893	0.89	0.893	0.917
KHAT VAR	0.00001891	0.00001198	0.00001198	0.00001982	0.00001901	0.00001932	0.00001903	0.00001512
Scenario 1 & Others		-7.377	-7.377	0.321	0.162	0.647	0.162	-3.943
Scenario 2 & Others			0.000	7.625	7.545	8.043	7.542	3.458
Scenario 3 & Others				7.625	7.545	8.043	7.542	3.458
Scenario 4 & Others					-0.160	0.320	-0.160	-4.229
Scenario 5 & Others						0.485	0.000	-4.108
Scenario 6 & Others							-0.484	3.458
Scenario 7 & Others								-4.107

	Z (5_10 and 5_10)							
Years: 2005-2010	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**
% Cell Change	0.1	2.85	2.24	4.24	0	0.02	0.05	2.85
KHAT	0.998	0.942	0.954	0.906	1	1	0.999	0.942
KHAT VAR	0.00000039	0.00001164	0.00000906	0.00002011	0	0.00000007	0.00000019	0.00001163
Scenario 1 & Others		16.146	14.313	20.319	-3.203	-2.949	-1.313	16.152
Scenario 2 & Others			-2.638	6.389	-17.000	-16.949	-16.572	0.000
Scenario 3 & Others				8.887	-15.282	-15.224	-14.796	2.638
Scenario 4 & Others					-0.068	-0.068	-0.067	-0.026
Scenario 5 & Others						0.000	2.294	17.007
Scenario 6 & Others							1.961	16.956
Scenario 7 & Others								16.579

Table 9.1 (Cont.). Test of KHAT (kappa) statistic between land use patterns of each scenario to the 99 % Significance level for the City of Satellite Beach (Shadowed areas represent non significant values)

	Z (0_10 and 0_10)							
Years: 2000-2010	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**
% Cell Change	5.69	6.29	5.68	9.77	5.69	5.86	5.7	7.24
KHAT	0.892	0.876	0.889	0.799	0.893	0.89	0.893	0.858
KHAT VAR	0.00001924	0.00002278	0.0000204	0.00003716	0.00001901	0.00001931	0.00001904	0.00002592
Scenario 1 & Others		2.468	0.476	12.383	-0.162	0.322	-0.162	5.059
Scenario 2 & Others			0.936	0.936	0.936	0.936	0.936	0.936
Scenario 3 & Others				0.943	0.943	0.943	0.943	0.943
Scenario 4 & Others					0.894	0.894	0.894	0.894
Scenario 5 & Others						0.945	0.945	0.945
Scenario 6 & Others							0.943	0.943
Scenario 7 & Others								0.945

Table 9.2. Test of KHAT (kappa) statistic between land use patterns of each Scenario to the 99 % significance level for the South Beaches Area

		Z (0_5 and 0_5)	
Years: 2000-2005	**Scenario 1**	**Scenario 2**	**Scenario 3**
% Cell Change	17.07	22.96	9.9
KHAT	0.78	0.7023	0.8739
KHAT VAR	0.00000755	0.00000954	0.00000465
Scenario 1 & 2		18.795	
Scenario 2 & 3			-26.883
Scenario 1 & 3			-45.554

		Z (5_10 and 5_10)	
Years: 2005-2010	**Scenario 1**	**Scenario 2**	**Scenario 3**
% Cell Change	0	17.18	2.42
KHAT	1	0.7043	0.9671
KHAT VAR	0	0.00001352	0.0000014
Scenario 1 & 2		80.420	
Scenario 2 & 3			27.806
Scenario 1 & 3			-68.036

		Z (0_10 and 0_10)	
Years: 2000-2010	**Scenario 1**	**Scenario 2**	**Scenario 3**
% Cell Change	17.07	40.15	12.32
KHAT	0.78	0.4604	0.8418
KHAT VAR	0.00000755	0.00001394	0.00000572
Scenario 1 & 2		68.943	
Scenario 2 & 3			-16.965
Scenario 1 & 3			-86.018

Application of the Research Methodology to other Areas

The reliability and accuracy of this framework is completely dependent on the quality of the spatial data used as input. Unfortunately, in the case of this research, the quality of the existing spatial data was very poor. In areas where this is the case the development and implementation of these types of systems requires the additional effort of creating all the necessary spatial databases. Assuring the availability and quality of a good spatial dataset is the first step of the implementation of this framework to other areas.

Depending on the detail of the study carried on, it might not be necessary to use a resolution as fine as the one used present research. Like in the case of Engelen and White's models, if these methodologies are applied to model the general land use patterns of an entire island, county or state, a larger grid size is enough. Conversely in areas such as the South Beaches it might be necessary to increase the resolution of the grid in order to be able to resolve some of the details of the land use patterns in the area.

Research Contribution

The results presented and analyzed in Chapters 7 and 8, and the discussion presented in this Chapter showed that research goals and objectives set forth in Chapter 2 were achieved. As shown by the calibration and validation results for the City of Satellite Beach case study, it is possible to reproduce historical land use patterns within 99 % accuracy with the framework proposed in this research.

As a result the contributions brought by this research to the field of integrated coastal planning and management include:

- A methodology that quantifies coastal development and that can help planners and managers to:
    a. Predict the effects of the implementation of the different coastal development policies in the future land use patterns of a region.
    b. Predict the effects of the implementation of the different coastal development policies in the area's overall sustainability and on its capacity to allocate current population growth rates.
    c. Evaluate the potential damages and costs of tropical and extra-tropical storm surges in the area for the different development policies.
- A methodology that uses the outputs from a Geographic Information System and that enhances further the spatial data analysis capabilities of those systems by introducing the time variable in to the analysis.
- A flexible simulation shell integrated in a friendly user interface, which provides planners and manager with the capability to test in computer time the effects of their choices of development policies before they are implemented.

Chapter 10
Conclusions

The Decision Support System framework developed in this research linked scientific, statistical, socio-economic, planning and political information in order to create a tool to help coastal managers to experiment, in computer time, with the impacts of different development policies.

The system was not intended to deter economic development. It was designed to help assess the long term economic potential of the coastal zone, by allowing the user to choose the best and sustainable development strategy, and prevent the degradation of that potential. When using this framework, decision-makers will be given a chance to make a more informed decision and to assess the pros and cons of implementing a development policy, before it is implemented.

These frameworks have not yet become generally accepted in the regional planning and decision making community. These types of systems can help save time and money, by helping in the identification of issues or specific needs and by pointing out data deficiencies. If these are known, it is possible to redirect part of the monitoring and research data collection efforts towards providing new and better information that is more relevant to the area and that can be used the improvement and the accuracy of the systems.

The integration of the geographic information system with other environmental and socio-economic simulation models is not always a simple process. As shown in this research, generally the two have to be run separately and its results integrated, within the user interface. The advances in the Object Oriented Programming technology already included in some of the commercial GIS software (Johnston and Koop, 2000) have the potential to largely enhance the integration within the decision support system's interface of the geographic information system capabilities. If a GIS object is running inside the user interface, any changes or additional analysis required by the user can be done directly within the DSS. This will greatly expedite the process and efficiency of the system.

The cellular automata simulation models used in this research showed to be suited to represent relatively well the complex dynamics and the interactions within the geographical area with high level of spatial resolution. However, there is some criticism towards the application of simulation models and of decision support systems, in general, to regional planning. These criticisms involve the fact that most of the time these systems only allow testing and experimenting pre-defined alternatives and “what-if” scenarios, and "ignore the dynamic nature of the environment and of the regional planning and decision-making processes involved" (Vriens and Hendriks, 1997).

This deficiency can be overcome in some cases by adding to the system's interface the capability to create new scenarios and alternatives, using the available criteria or creating new ones, and by implementing a system that permits to rank and compare among alternatives and scenarios. The majority of these features have not been implemented in this system, however they have been considered for future developments of this framework. Other planned improvements are a better integration between the different components, more friendly and easy to use interface, and above all a better representation of the real world.

Overall the results of the pilot tests for the City of Satellite Beach show a promising future for further development of this research. The simulator was able to recreate the City's observed land use patterns within a 99 percent significant interval, and it was also able to model the coastal development issues tested in the "What if" scenarios. In addition the results obtained using the Natural Hazards Module encourage the future development of other modules that can make use of the land use simulation and further expand the DSS application.

The South Beaches example defined the major issues that have to be taken in consideration when applying the model to other areas. Based on the results of the South Beaches case it was also possible to isolate some of the limitations of the current methodology, and to focus on future strategies for model improvement.

Chapter 11
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APPENDIX A

Metadata and Barrier Island Grids

EMERGENCY SERVICES NETWORK

Source: Brevard County Property Appraiser's Office
Geographic Information and Mapping Services Division

LAYER:	ESN
MAP UNIT	FEET
SOURCE SCALE	1:100,000
DATA TYPE	POINT
SOURCE	EMERGENCY SERVICES & CODE COMPLIANCE-ADDRESS ASSIGNMENT
SUPPLIED BY	CODE COMPLIANCE-ADDRESS ASSIGNMENT
STATUS	AVAILABLE W/CONTINUOUS UPDATE
DIRECTORY	/ATLAS/SMALL/COUNTY
NOTE	

FEATURE ATTRIBUTE TABLE

ESN.PAT

COL	NAME	DEFINITION			DESCRIPTION
17	ESNNUM	3	3	I	EMERGENCY SERVICES #
20	CITY-NAME	32	32	C	CITY NAME
52	ESNTYPE	3	3	I	EMERGENCY SERVICES TYPE
55	POLICE	10	10	C	POLICE DEPT. CODE
65	FIRE	10	10	C	FIRE DEPT. CODE
75	MEDICAL	10	10	C	MEDICAL SERVICES CODE
85	RESCUE	10	10	C	RESCUE SERVICES CODE
95	SECTOR	10	10	C	SERVICE SECTOR AREAS

PARCEL DATA BASE - PSITE

Source: Brevard County Property Appraiser's Office
Geographic Information and Mapping Services Division

INFO:	PSITE.MAS
DATA TYPE	INFO DATA BASE
SOURCE	BREVARD COUNTY PROPERTY APPRAISER DATA BASE
SUPPLIED BY	PAO-GIS
STATUS	AVAILABLE W/CONTINUOUS UPDATE
DIRECTORY	/PROPDAT/INFO
	THE FOLLOWING ITEMS ARE INDEXED:
	PID23
	CONDO-NO
	SITE-HOUSE-NO
	SITE-STREET-NAME
	SITE-STREET-TYPE
	SITE-STREET-DIR
	SITE-CITY
	SITE-ZIP
NOTE	TOWNSHIP
	RANGE
	SECTION
	SUBDIV
	BLOCK
	LOT
	SLEGALC
	SITE-STREET-ALL
	CONDO#
	SLEGAL

FEATURE ATTRIBUTE TABLE

PSITE.MAS

COL	NAME	DEFINITION			DESCRIPTION
1	PID	21	21	C	PARCEL ID NUMBER
22	PID23	23	23	C	PARCEL ID NUMBER & CONDO NUMBER
45	CONDO-NO	4	4	C	CONDO NUMBER
49	SITE-HOUSE-NO	6	6	C	SITE HOUSE NUMBER
55	SITE-STREET-NAME	25	25	C	SITE STREET NAME
80	SITE-STREET-TYPE	4	4	C	SITE STREET TYPE
84	SITE-STREET-DIR	2	2	C	SITE STREET DIRECTION
86	SITE-APT-NO	6	6	C	SITE APARTMENT NUMBER
92	SITE-CITY	20	20	C	SITE CITY
112	SITE-STATE	2	2	C	SITE STATE
114	SITE-ZIP	5	5	C	SITE ZIP CODE
119	SALES-DATE	6	6	I	SALES DATE
125	SALES-VALUE	9	9	I	SALES VALUE

COL	NAME	DEFINITION			DESCRIPTION
134	BLDG-VALUE	9	9	I	BUILDING VALUE
143	ADJUST-VALUE	9	9	I	ADJUSTED VALUE
152	LAND-VALUE	9	9	I	LAND VALUE
161	ACREAGE	10	10	N	ACREAGE
171	BLDG-SQFT	7	7	I	BUILDING SQUARE FOOTAGE
178	YEAR-BUILT	4	4	C	YEAR BUILT
182	ORB-PAGE	9	9	C	OFFICIAL RECORD BOOK PAGE NUMBER
191	OWNER-NAME	33	33	C	OWNER NAME
224	MAIL-HOUSE-NO	6	6	C	MAIL HOUSE NUMBER
230	MAIL-STREET-NAME	27	27	C	MAIL STREET NAME
257	MAIL-CITY	20	20	C	MAIL CITY
277	MAIL-STATE	2	2	C	MAIL STATE
279	MAIL-ZIP	5	5	C	MAIL ZIP CODE
284	MILL-CODE	4	4	C	MILLAGE CODE
288	USE-CODE	4	4	I	USE CODE
292	S-W-UNITS	6	6	N	SOLID WASTE UNITS
298	SPEC-ASSESS	1	1	C	SPECIAL ASSESSMENT
299	SECOND-OWNER	33	33	C	SECOND OWNER NAME
332	TAZ	3	3	C	TRAFFIC ANALYSIS ZONE
335	NEIGH-CODE	6	6	C	NEIGHBORHOOD CODE
341	RES-CODATE	6	6	C	RESIDENTIAL C.O. DATE
347	COM-CODATE	6	6	C	COMMERCIAL C.O. DATE
353	ZONING	15	15	C	ZONING BY P.A.O.
368	COMP-LAND-USE	15	15	C	ZONING BY P & Z
383	RENUM	7	7	I	RE NUMBER USED FOR BLDG
390	LAND-RATE	10	10	N	LAND VALUE RATE
400	SITE-CODE	4	4	I	SITE CODE
404	MARKET-SUBAREA	6	6	C	MARKET AREA DESCRIPTION
410	DEED-TYPE	2	2	C	DEED TYPE
412	MAIL-MORE	33	33	C	ADDITIONAL MAILING ADDDRESS INFO
445	TAXABLE1	9	9	C	TAXABLE VALUE
454	EXEMPT	1	1	C	EXEMPTION CODE
REDEFINED ITEMS					
22	TOWNSHIP	3	3	C	TOWNSHIP
25	RANGE	2	2	C	RANGE
27	SECTION	2	2	I	SECTION
29	SUBDIV	2	2	C	SUBDIVISION
31	BLOCK	7	7	C	BLOCK
38	LOT	7	7	C	LOT
22	SLEGALC	27	27	C	SHORT LEGAL DESCRIPTION WITH CONDO NUMBER
55	SITE-STREET-ALL	31	31	C	COMPLETE STREET NAME
45	CONDO#	4	4	I	CONDO NUMBER
22	SLEGAL	23	23	C	SHORT LEGAL DESCRIPTION
403	MKTAREA	2	2	C	MARKET AREA CODE

PARCELS

Source: Brevard County Property Appraiser's Office
Geographic Information and Mapping Services Division

LAYER:	PARCELS
MAP UNIT	FEET
SOURCE SCALE	1:200
DATA TYPE	POLYGON
SOURCE	BC PROPERTY APPRAISAL MAPS
SUPPLIED BY	PAO-GIS
STATUS	AVAILABLE W/CONTINUOUS UPDATE
DIRECTORY	/ATLAS/LARGE/MTTRRSS
NOTE	

FEATURE ATTRIBUTE TABLE

PARCELS.AAT

COL	NAME	DEFINITION			DESCRIPTION
29	EDIT-DATE	6	6	C	PARCEL EDIT DATE (LINE WORK)
35	EDIT-NAME	8	8	C	PARCEL EDIT BY (STAFF NAME)
43	EDIT-CHECKED	1	1	I	PARCEL QA/QC CHECK

PARCELS.PAT

COL	NAME	DEFINITION			DESCRIPTION
17	TOWNSHIP	3	3	C	TOWNSHIP NUMBER
20	RANGE	2	2	C	RANGE NUMBER
22	SECTION	2	2	C	SECTION NUMBER
24	SUBDIV	2	2	C	SUBDIVISION NUMBER
26	BLOCK	7	7	C	BLOCK NUMBER
33	LOT	7	7	C	LOT NUMBER
40	CONDO#	4	4	I	CONDO NUMBER
44	CONDONAM	50	50	C	CONDO NAME
94	SEQNO	5	5	I	PID ASSIGNED TO MULTI-PARCELS
99	DUPLICATE	1	1	C	DUPLICATE P.I.D.
100	MULTIZON	1	1	C	FLAG FOR MULTI-ZONE
101	ZONING1	8	8	C	ZONING CODE (SEE ZONING)
109	FLU	5	5	C	FUTURE LAND USE DESCRIPTION
114	RES-DEN	30	30	C	RESIDENTIAL DENSITY DESCRIPTION
144	EDIT-DATE	6	6	C	PARCEL EDIT DATE (DATA BASE)
150	RENUM	7	7	I	UNIQUE PAO CODE FOR EACH PARCEL

COL	NAME	DEFINITION			DESCRIPTION
157	EDIT-NAME	8	8	C	PARCEL EDIT BY (STAFF NAME)
165	EDIT-CHECKED	1	1	I	PARCEL QA/QC CHECK

REDEFINED ITEMS

17	SLEGALC	27	27	C	SHORT LEGAL WITH CONDO NUMBER
17	SLEGAL	23	23	C	SHORT LEGAL

PARCELS.TAT

ANNO NAME	DESCRIPTION
LANDTEXT	LAND INFORMATION
LOT	LOT NUMBERS
CONDO	CONDO NAME/NUMBERS
DIMS	LOT DIMENSIONS
BLOCK	BLOCK NUMBERS
PARCEL	PARCEL NUMBERS

THE PARCEL MAPS ARE MAINTAINED ON-LINE BY TOWNSHIP/RANGE DIRECTORIES IN /ATLAS/LARGE FILE SYSTEM. THERE ARE TWO DIFFERENT TYPES OF PARCEL MAPS.

TYPE ONE THE MAJORITY OF THE PARCEL MAPS ARE BASED ON TOWNSHIP, RANGE, AND SECTION.

EXAMPLE M223301

TYPE TWO THERE ARE A SELECTED NUMBER OF PARCEL MAPS WHICH ARE BASED ON EITHER THE NORTHERN GRANT AREA OR THE SOUTHERN GRANT AREA. THE NAMING CONVENTION FOR THESE PARCEL MAPS IS BASED ON TOWNSHIP, THE TYPE OF GRANT, AND SECTION. THE GRANTS ARE IDENTIFIED BY M (NORTHERN) OR G (SOUTHERN).

EXAMPLE M20M34 = NORTHERN GRANT
M30G07 = SOUTHERN GRANT

ZONING-COUNTY-SECTION LEVEL

Source: Brevard County Property Appraiser's Office
Geographic Information and Mapping Services Division

LAYER:	ZONCNTY
MAP UNIT	FEET
SOURCE SCALE	1:200
DATA TYPE	POLYGON
SOURCE	PROPERTY APPRAISAL MAPS
SUPPLIED BY	BREVARD COUNTY GROWTH MANAGEMENT DEPARTMENT
STATUS	UNDER DEVELOPMENT
DIRECTORY	/ATLAS/LARGE/MTTRRSS
NOTE	

FEATURE ATTRIBUTE TABLE

ZONCNTY.AAT

COL	NAME	DEFINITION			DESCRIPTION
29	CODE	8	8	C	ZONING CODE

ZONCNTY.PAT

COL	NAME	DEFINITION			DESCRIPTION
17	ZONING1	8	8	C	ZONING CODE
25	BCCACTION	8	8	C	COUNTY COMM. ACTION
33	BAACTION	8	8	C	BOARD OF ADJUST. ACTION
41	ADMACTION	8	8	C	ADMINISTRATIVE ACTION
49	AZACTION	8	8	C	ADMIN. ZONING ACTION
57	PEUACTION	8	8	C	PRE-EXISTING USE ACTION
65	DENSCAP	3	3	I	DENSITY CAP
68	ZONFILE	6	6	C	ZONING FILE NUMBER
74	VARFILE	6	6	C	VARIANCE FILE NUMBER
80	PEUFILE	6	6	C	PRE-EXISTING USE FILE #
86	AAFILE	6	6	C	ADMIN. ACTION FILE #
92	AZFILE	6	6	C	ADMIN. ZONING FILE #
98	BCCFILE	6	6	C	BC COMMISSION FILE
104	GRAPHIC	8	8	C	DESCRIPTIVE TEXT
112	ORDNUM	6	6	C	ORDINANCE NUMBER
118	BLANKETF	6	6	C	BLANKET ZONING

ZONCNTY.TAT

ANNO NAME	DESCRIPTION
PARCEL	PARCEL NUMBERS
BLOCK	BLOCK NUMBERS
LOT	LOT NUMBERS
LANDTEXT	LAND INFORMATION
CONDO	CONDO INFORMATION
DIMS	LOT DIMENSIONS

CODE DESCRIPTION TABLE

ZONING	CODE DESCRIPTION TABLE	ZONING	DESCRIPTION
AA	ADMINISTRATIVE ACTION	RA-2-8	SINGLE-FAMILY ATTACHED RESIDENTIAL
AE	ADULT ENTERTAINMENT	RA-2-10	SINGLE-FAMILY ATTACHED RESIDENTIAL
AGR	AGRICULTURAL	REU	RURAL ESTATE USE
AU	AGRICULTURAL RESIDENTIAL	RP	RESIDENTIAL/PROFESSIONAL
AZ	ADMINISTRATIVE ZONING	RR-1	RURAL RESIDENTIAL
BB	BILLBOARD	RRMH-1	RURAL RESIDENTIAL MOBILE HOME 1 ACRE
BCP	BINDING CONCEPT PLAN	RRMH-2.5	RURAL RESIDENTIAL MOBILE HOME 2.5 ACRES
BDP	BINDING DEVELOPMENT PLAN	RRMH-5	RURAL RESIDENTIAL MOBILE HOME 5 ACRES
BSP	BINDING SITE PLAN	RSSF	RESIDENTIAL SOCIAL SERVICE FACILITY
BU-1	GENERAL RETAIL COMMERCIAL	RU-1-7	SINGLE-FAMILY RESIDENTIAL
BU-1-A	RESTRICTED NEIGHBORHOOD RETAIL COMMERCIAL	RU-1-9	SINGLE-FAMILY RESIDENTIAL
BU-2	RETAIL, WAREHOUSING & WHOLESALE COMMERCIAL	RU-1-11	SINGLE-FAMILY RESIDENTIAL
CUP	CONDITIONAL USE PERMIT	RU-1-13	SINGLE-FAMILY RESIDENTIAL
DAA	DENIED ADMINISTRATIVE APPROVAL	RU-2-4	LOW DENSITY MULTI-FAMILY RESIDENTIAL
DNV	DENIED VARIANCE	RU-2-6	LOW DENSITY MULTI-FAMILY RESIDENTIAL
DNZ	DENIED ZONING	RU-2-8	LOW DENSITY MULTI-FAMILY RESIDENTIAL
EA	ENVIRONMENTAL AREA	RU-2-10	MEDIUM DENSITY MULTI-FAMILY RESIDENTIAL
EU	ESTATE USE RESIDENTIAL	RU-2-12	MEDIUM DENSITY MULTI-FAMILY RESIDENTIAL
EU-1	ESTATE USE RESIDENTIAL	RU-2-15	MEDIUM DENSITY MULTI-FAMILY RESIDENTIAL
EU-2	ESTATE USE RESIDENTIAL	RU-2-30	HIGH DENSITY MULTI-FAMILY RESIDENTIAL
GH	GROUP HOME	RVP	RECREATIONAL VEHICLE PARK
GML	GOVERNMENT MANAGED LANDS	S	STIPULATION
GU	GENERAL USE	SEU	SUBURBAN ESTATE RESIDENTIAL
IU	LIGHT INDUSTRIAL	SR	SUBURBAN RESIDENTIAL
IU-1	HEAVY INDUSTRIAL	SUP	SPECIAL USE PERMIT
ZONING	CODE DESCRIPTION TABLE	ZONING	DESCRIPTION

MCIA	MOSQUITO CONTROL IMPOUNDMENT AREA
MW	MINI WAREHOUSE
PA	PRODUCTIVE AGRICULTURE
PBP	PLANNED BUSINESS PARK
PEU	PRE-EXISTING USE
PIP	PLANNED INDUSTRIAL PARK
PUD	PLANNED UNIT DEVELOPMENT
RA-2-4	SINGLE-FAMILY ATTACHED RESIDENTIAL
RA-2-6	SINGLE-FAMILY ATTACHED RESIDENTIAL
TR-1	SINGLE-FAMILY MOBILE HOME
TR-1-A	SINGLE-FAMILY MOBILE HOME
TR-2	SINGLE-FAMILY MOBILE HOME
TR-3	MOBILE HOME PARK
TRC-1	SINGLE-FAMILY MOBILE HOME COOPERATIVE
TU-1	GENERAL TOURIST COMMERCIAL
TU-2	HIGHWAY TRANSIENT TOURIST
UOR	USE ON REVIEW
V	VARIANCE
CITY	FOR INTERNAL USE

FUTURE LAND USE

Source: Brevard County Property Appraiser's Office
Geographic Information and Mapping Services Division

LAYER:	FLUCNTY
MAP UNIT	FEET
SOURCE SCALE	1:200
DATA TYPE	POLYGON
SOURCE	BC GROWTH MANAGEMENT DEPARTMENT
SUPPLIED BY	BC GROWTH MANAGEMENT DEPARTMENT
STATUS	UNDER DEVELOPMENT
DIRECTORY	/ATLAS/LARGE/MTTRRSS
NOTE	

FEATURE ATTRIBUTE TABLE

FLUCNTY.PAT

COL	NAME	DEFINITION			DESCRIPTION
17	FLU	3	3	C	FUTURE LAND USE CODE

INFO:	FLUCNTY.LUT
DATA TYPE	INFO
SOURCE	PAO-GIS
SUPPLIED BY	PAO-GIS
STATUS	UNDER DEVELOPMENT
DIRECTORY	ATLAS/LARGE/INFO
NOTE	

FEATURE ATTRIBUTE TABLE

FLUCNTY.LUT

COL	NAME	DEFINITION			DESCRIPTION
1	SYMBOL	3	3	I	FLU SYMBOL CODE
4	FLU	5	5	C	FLU CHARACTER

CODE DESCRIPTION TABLE

SYMBOL	FLU
232	AGR
362	CON
33	IND
10	MIX
697	NON
353	PIP
561	PUB
376	REC
159	RES

First, the disclaimers:
This information is being provided as a public service. The National Weather Service does not in any way guarantee the accuracy or suitability of the data. These maps were developed by The State of Florida, Dept. of Community Affairs, Division of Emergency Management.

These maps depict "worst-case" storm surge inundation, to provide a basis for evacuation decisions and for other study purposes. The storm tide delineations reflect simulated conditions at high tide, with an additional 1.5 foot included for oceanic values, and 1.0 foot added for inland bays and waterways. These maps do not, however, include effects of waves (still water is assumed for model purposes), rainfall, and flooding from overflowing rivers.

HURRICANE STORM TIDE ATLAS

(SEPTEMBER 1990)

1. INTRODUCTION

The purpose of the maps contained in this atlas are to reflect a worst case scenario of hurricane storm surge inundation (which includes the addition of an astronomical high tide). It should be noted that the data reflects only still water saltwater flooding. It is incumbent upon local emergency management officials to estimate the degree and extent of freshwater flooding, as well as to determine the magnitude of the waves that will accompany the surge.

The maps contained in this atlas summarize surge height estimates made using the SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model. The model was developed by Chester Jelesnianski of the National Oceanic and Atmospheric Administration, National Weather Service. The storm surge computations and analysis were done by the Storm Surge group of the National Hurricane Center, headed by Brian Jarvinen.

The hurricane storm surge inundation information has been developed as part of the Cape Canaveral Hurricane Evacuation Study covering Flagler, Volusia, Brevard, and Indian River Counties, and is based on the National Hurricane Center's Cape Canaveral Basin Model.

2. HOW THE MAPS WERE DEVELOPED

The SLOSH model was used to develop data for various combinations of hurricane strength, wind speed, and direction of movement. Hurricane strength was modeled by use of the central pressure (defined as the difference between the ambient sea level pressure and the minimum value in the storm's center), the storm eye size, and the radius of maximum winds (using the five categories of hurricane intensity as depicted in the Saffir-Simpson Hurricane Scale). The modeling for each hurricane category was done using the mid-range wind speed for that category. Ten storm track headings (WSW, W, WNW, NW, NNW, N, NNE, NE, ENE, E) were selected as being representative of storm behavior in the Central Florida region, based on observations by forecasters at the National Hurricane Center. Additional inputs into the model included depths of water offshore, and the heights of the terrain and barriers onshore (all measurements were made relative to mean sea level).

To determine surge values the SLOSH model uses a telescoping polar grid as its unit of analysis. Use of the grid configuration allows for individual calculations per grid square which is beneficial in two ways: (1) provides increased resolution of the storm surge at the coastline and inside the harbors, bays and rivers, while decreasing the resolution in the deep water where detail is not as important; and (2) allows economy in computation. The disadvantage associated with this telescoping grid pattern is the lack of resolution at each end of the model because of the increased size of the grids. Where the grid size is approximately 0.11 square miles near the center (Brevard County), the grids on the outer edges (Flagler County) contain approximately 8.47 square miles, consequently, the information produced in the outer grids has a decreased degree of reliability.

Once surge heights have been determined for the appropriate grids, the maximum surge heights are plotted by storm track and hurricane category. These plots of maximum surge heights for a given hurricane category and storm track are referred to as Maximum Envelopes of Water (MEOW)s. The surge inundation limits displayed on the maps in this atlas reflect a further compositing of the MEOWs into Maximums of the Maximums (MOM)s. The MOMs represent the maximum surge expected to occur at any given location, regardless of the storm track or direction of the hurricane. The only variable is the intensity of the hurricane represented by category strength (1-5). The MOM surge heights which were furnished by the National Hurricane Center, as displayed in this atlas, include an upward adjustment to reflect surges occurring during an astronomical high tide.

3. HOW TO USE THE MAPS

In order to determine the depth of surge flooding at a particular location, the ground elevation at that location must be known. At the inland extent of depicted surge inundation, water depths may be shallow, even for Category 5 storms. Time/History points have been included on the Atlases at selected locations, to define surge elevations for the Category 1-,3-, and 5- hurricanes in these areas. The depth of surge, for a given hurricane category, at these locations can be determined by deducting the known ground elevation (using local survey data, referenced to the National Geodetic Vertical Datum--NGVD) from the respective hurricane category surge elevation. United States Geological Survey Quadrangle Sheets, or other appropriate topographic reference which is based on the same datum can also be used to determine ground elevation at a specific location, but the accuracy of these elevations will be limited to the precisions and tolerances associated with that map.

Regarding interpretation of the data, it is important to understand that the configuration (narrow or wide) and depth (bathymetry) of the ocean bottom will have a bearing on surge and wave heights. A narrow shelf, or one that drops steeply from the shoreline and subsequently produces deep water in close proximity to the shoreline, tends to produce a lower surge but a higher and more powerful wave. Those regions which have a long, gently sloping shelf and shallower normal water depths, can expect a higher surge but smaller waves. The reason this occurs is because a surge in deeper water can be dispersed down and out away from the hurricane. However, once that surge reaches a shallow gently sloping shelf it can no longer be dispersed away from the hurricane, consequently water "piles-up" as it is driven ashore by the wind stresses of the hurricane.

Because waves "roll" toward shore, their height is also a function of water depth. A wave is cylindrical and rolls toward shore with its strength and size dependent on the velocity of the wind driving it, the length of time the wind has blown, and the distance the wind has driven the wave across the ocean surface. Once the wave nears the shore, where the depth of water decreases, it slowed by frictional drag against the bottom. As a result, the wave form steepens, becomes higher, leans forward, and finally breaks. A wave will break when it reaches water which is only slightly deeper than its (the wave's) height. Where water maintains a depth of 10 to 20 feet close to shore, a wave will only break when it has almost reached land, thus expending its energy directly against the shore.

DATA LINEAGE REPORT
DATA LAYER: Topography - Contours - Five Foot - SJRWMD
LOCATION: /disk4/elev05/
LAYER NAME: TOPO_CONTOURS_5
MAP UNIT: USGS 7.5 by 7.5 Minute Quad
SOURCE SCALE: 1:24,000
PROJECTION: UTM, ZONE 17
DATUM: NAD 1983, 1990 Correction
DATA TYPE: Polygon, Line
LAST TEXTFILE UPDATE: 9/22/97
SOURCE: U.S. Geological Survey 7.5 Minute Topographic Quadrangle Series
DEVELOPMENT STATUS: Complete. As of this date, this data layer is being tested and revised under work order contract to Vernon F. Meyers and Associates.
DISTRICT COVERAGE STATUS: Complete
NOTES: The topography database currently does not include a sea level shoreline. As a result, land mass between sea level and five feet is not represented. No inland shorelines are represented. Some quads on the Georgia border may be in meters.
The topos in METERS have been converted by Marvin Williams: added an item called zcoord2 defined as 4,12,f,2 calc zcoord2 = elev and multiplied by 3.28, added 1.0 to all zcoord2 and calc back to elev (3,3,i) truncating all numbers right of decimal, resulting in closest feet-to-meter relationship. METRIC: to161 Gross, to162 St. Mary's, to163 Fernandina Beach.
Some quads have ten foot instead of five foot contours. No water bodies are delineated. 45 quads do not have polygon topology, however, the arcs are coded.
August, 1996: This dataset wase projected from Stateplane, East Zone, NAD 1927 to UTM, Zone 17, NAD 1983, 1990 Correction. This dataset was copied to double precision.
April, 1997: Insertion of this data layer to ARC/INFO's Librarian data management structure in its current form is a temporary measure designed to provide easy access to the data until a repaired version of the data layer can replace it. Numerous errors exist, and are being addressed through a work order with Vernon F. Meyer & Associates, Inc.
The data layer is composed of 238 USGS 7.5' Quadrangle-based coverages, 5 of which did not possess polygon topology, labels, or poly ELEV coding.
USGS Quad boundary ARCS are not coincident with contiguous Quad boundary arcs, thus producing sliver polygons during the MAPJOIN step. Approximately 500,000 arcs and 175,000 polygons are present in the data layer.

PAT ITEM DEFINITIONS:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	AREA	8	18	F	5		-
9	PERIMETER	8	18	F	5		-
17	SJRTOPO5#	4	5	B	-		-
21	SJRTOPO5-ID	4	5	B	-		-
25	ELEV	3	3	I	-		-

UNIQUE PAT ITEM VALUES AND DEFINITIONS:

ITEM	VALUE	DESCRIPTION
----	-----	-----------
ELEV	5 -> 320	Elevation in feet in five foot intervals
	-99	Uncoded Polygons
	-98	Sliver Polygons

AAT ITEM DEFINITIONS:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	FNODE#	4	5	B	-		-
5	TNODE#	4	5	B	-		-
9	LPOLY#	4	5	B	-		-
13	RPOLY#	4	5	B	-		-
17	LENGTH	8	18	F	5		-
25	SJRTOPO5#	4	5	B	-		-
29	SJRTOPO5-ID	4	5	B	-		-
33	ELEV	3	3	I	-		-
36	EDGE	1	1	I	-		-

UNIQUE AAT ITEM VALUES AND DEFINITIONS:

ITEM	VALUE	DESCRIPTION
----	-----	-----------
ELEV	5 -> 320	Elevation in feet in five foot intervals
	777,888	Arcs to close polygons if not closed on the source
	999	NAD 1927 USGS 7.5’ Quad box boundary
EDGE	0	non-quad border arc
	1	USGS 7.5 Minute quad border arc

SPATIAL DATA LINEAGE REPORT

LAYER NAME: Land Use / Land Cover - 1995 - SJRWMD
DISK LOCATION: /disk6/lcover_luse/luse1995/
FEATURE TYPE: Poly
MAP UNIT: SJRWMD
SOURCE SCALE: 40000
PROJECTION: UTM Zone 17 meter HPGN GRS80
DESCRIPTION: Land Use / Land Cover based on 1994 aerial photography
LAST UPDATE: 05/10/00
DISTRICT COVERAGE STATUS: Complete coverage within the SJRWMD jurisdiction plus about two miles beyond the SJRWMD boundary. Seamless layers in the form of a shapefile and Arc/Info coverage for the entire SJRWMD are also available.

NOTES:
An online Photo interpretation Key (PI Key) is available. The PI Key lists each class used in the 1995 land use / land cover layer, along with a detailed description, keys to photointerpretation, a list of similar classes, special mapping conventions if they exist, a sample DOQ image, and a field picture.
SJRWMD staff may access the PI Key through GISDOC (Data, Data Users Guides, 1995 Land Use / Land Cover) or at
http://intraweb/gisdoc/data/data_user_guides/luse/lu95_pi_key/keylist.html
For those outside the SJRWMD, the PI Key has been added (as of May 2000) to the GIS export library on CD#6; the files can also be accessed with a web browser on the gislib ftp site.

This dataset was developed using an on-screen digitizing approach to capture land use/cover information. Orthorectified images (DOQ) converted from 1:40,000 scale color-infrared photography were displayed on a computer screen at a scale of approximately 1:12,000. This on-screen digitizing approach also utilized stereoplotters together with ancillary information including soils, FEMA floodplains, land parcels, etc. to assist the photointerpretation efforts. The photography was flown by the National Aerial Photography Program (NAPP) from late 1993 through early 1995 with the bulk of photos taken in 1994; see the item DOQ95_INFO in the polygon attribute table of /gislib/covs/boundaries/index12 for specific photo dates.

This data layer versioned as 2.0 has been through an extensive review process collaborated by the GIS Division and the contractor, Geonex Inc., to correct major discrepancies using the National Wetland Inventory (NWI), SJRWMD wetland vegetation, and the 1990 land use/cover datasets. This review effort was focused especially on the categories of waters (5000's) and wetlands (6000's).

Further revision of this data layer is likely; the GIS Division is drafting a plan to improve known shortcomings. Details are not yet available, but preliminary plans include soliciting feedback from SJRWMD project staff, and conducting additional ground truthing and comparative assessments with other primary data layers. The revised data will be published as updates to version 2 as soon as they become available. The final product will likely be called version 3.

An online Data User Guide will soon be available. It will contain information about completed quality assurance efforts, known problems with the data layer, and plans to update and improve the data. GIS Division staff created a shapefile /gislib/shapefiles/luse95.shp) from a single Districtwide coverage. When this shapefile is viewed in ArcView, the portion of the shape which represents the St. Marys River between U.S. 1 and U.S. 17 may exhibit intermittent shading problems, sometimes shading properly and sometimes remaining blank. GIS Division staff have investigated and believe the problem resides with limitations in ArcView for shading very complex shapes with extremely large quantities of vertexes. Plotting should not be affected.

3/07/00: Enviromental Sciences Division staff conducted a review of coding in the east central Clay County area, with a focus on agricultural land uses. As a result, the LUCODEs for 14 polygons were changed, primarily from field crop (2150) to improved pasture (2110). See for GIS Division staff for details.

PAT ITEM DEFINITIONS:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	AREA	8	18	F	5		-
9	PERIMETER	8	18	F	5		-
17	LCOVER1995#	4	5	B	-		-
21	LCOVER1995-ID	4	5	B	-		-
25	LUCODE	4	4	I	-		-
29	LUCODE2	4	4	I	-		-

UNIQUE PAT ITEM VALUES AND DEFINITIONS:

ITEM	VALUE	DESCRIPTION
----	-----	-----------
LUCODE	####	Primary Land Use / Land Cover Coding
LUCODE2	####	Secondary Land Use / Land Cover Coding

CLASSIFICATION SYSTEM: The coding scheme is based on the modified FLUCCS codes. There are 136 codes in the dataset.

SPATIAL DATA LINEAGE REPORT

LAYER NAME: Land Use / Land Cover - 1990 - SJRWMD
DISK LOCATION: /disk6/lcover_luse/luse1990/tilexxxx
FEATURE TYPE: Poly
MAP UNIT: SJRWMD
SOURCE SCALE: 24000
PROJECTION: UTM Zone 17 meter HPGN GRS80
DESCRIPTION: Land Use / Land Cover based on 1986-1990 aerial photography
LAST UPDATE: 02/22/00
DISTRICT COVERAGE STATUS: Nearly Complete. After this data layer was developed, a more accurate District boundary data layer was created. The 1990 land use data does not extend fully to the new boundary layer in some areas. However, the data has been interpreted and exists in analog (hard copy) format in the Division of GIS.

NOTES: Most of the data was photointerpreted from 1:24,000 scale black and white aerial photography captured between 1986 and 1990. Lake County was interpreted from 1:24,000 color infrared photography. The minimum mapping units are 0.5 acres for wetland categories and 2.0 acres for all other categories. The photography dates vary by county:

1988 Alachua	1988 Indian River	1989 Putnam
1989 Baker	1987 Lake	1989 Seminole
1987 Bradford	1989 Marion	1988 St. Johns
1989 Brevard	1989 Nassau	1988 Volusia
1987 Clay	1986 Okeechobee	
1988 Duval	1990 Orange	
1989 Flagler	1990 Osceola	

This data layer was developed under two contracts. The bulk of the Indian River Lagoon (IRL) basin, from just north of Cape Canaveral to the Indian River County / St. Lucie County line, was developed under contract #90G185. The rest of the District was developed under contract #90B182. See /sjr/intra/gisdoc/data/images/luse1990+fit.gif for an illustration of the spatial extent of the IRL contract. Some of the 7.5 minute quad units which intersect the IRL basin boundary were partially interpreted by both contractors. These quads have been merged, and because of the differences in photointerpretation, the polygons along the IRL basin boundary may not match well.

Feature attributes were verified by the Division of Environmental Sciences. Check plots were generated from the digital data and compared against the original aerial photos. Topological verification and error correction tasks were undertaken by the Division of GIS. The Indian River Lagoon (IRL) data were more intensively field checked than the rest of the District.

All IRL data are classified to Florida Land Use Cover Classification Scheme (FLUCCS) level three. The rest of the data layer is classified using a mixture of modified FLUCCS level two, three, and four codes. The INFO item definitions are identical, but there are differences in the land use coding.

Original quad units in the southwest corner of Lake County have land use past the District boundary to the county boundary. These are available from archives and are named

LULAKE<###>, where ### is the old, 3-digit SJRWMD quad naming convention. The ESRI Librarian version of the data has been clipped to the District boundary.

August, 1996: This dataset was projected from Stateplane, East Zone, NAD 1927 to UTM, Zone 17, NAD 1983, 1990 Correction. This dataset was copied to double precision.
May, 1999 - Revisions completed by Division of GIS staff:

- Staff updated this metadata file by adding previously unlisted FLUCCS codes that are found in the data layer.
- In the original coverage, when dual LUCODE / LUCODE2 coding was employed, the land use (e.g. military or recreation) was listed in LUCODE and the land cover (e.g. wetland or forest) was listed in LUCODE2. However, the majority of users are more interested in land cover than land use. Therefore, where both codes were nonzero, GIS staff switched LUCODE and LUCODE2 for the following LUCODE values: 1700, 1720, 1730, 1750, 1800, 1850, 1900, 1920, and 8320.

PAT ITEM DEFINITIONS:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	AREA	8	18	F	5		-
9	PERIMETER	8	18	F	5		-
17	LCOVER1990#	4	5	B	-		-
21	LCOVER1990-ID	4	5	B	-		-
25	LUCODE	4	4	I	-		-
29	LUCODE2	4	4	I	-		-

** REDEFINED ITEMS **

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
25	LUCODE3	8	8	I	-		-

UNIQUE PAT ITEM VALUES AND DEFINITIONS:

ITEM	VALUE	DESCRIPTION
LUCODE	####	Primary Land Use / Land Cover Coding
LUCODE2	####	Secondary Land Use / Land Cover Coding
LUCODE3	########	Both LUCODE and LUCODE2 concatenated for unknown purposes.

DATA LINEAGE REPORT

DATA LAYER: Future Land Use
MAP UNIT: county
SOURCE SCALE: varied
DATA TYPE: arc, polygon
LAST TEXTFILE UPDATE: 6/30/93
SOURCE: The data was derived from 1988 - 1992 local government comprehensive plan future land use maps. For comparison purposes, local government land uses were translated into a uniform set of 12 land use categories.

QA STATUS: Complete topological and coding quality assurance.

DISTRICT COVERAGE STATUS: complete

NOTES: Due to modifications, these data are not local government future land use maps. In addition, there are not updated to reflect bi-annual local government amendments to their maps. The SJRWMD public lands data (as of 1/1/93) has been added to the future land use layer. Some water bodies are represented within the future land use data layer. These water bodies include the lower St. Johns River, the Intracoastal area near Daytona Beach, and the Indian River Lagoon. Statistics on acreages will be wrong unless other major water bodies are added to the coverage using an overlay command such as UNION. Before using these data, please contact Kraig McLane in the Planning Department at ext. 4312 for more information.

PAT ITEM DEFINITIONS:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME INDEXED?
1	AREA	4	12	F	3	-
5	PERIMETER	4	12	F	3	-
9	FLU#	4	5	B	-	-
13	FLU-ID	4	5	B	-	-
17	LUCODE	3	3	I	-	-
20	LUCODE2	3	3	I	-	-

UNIQUE PAT ITEM VALUES AND DEFINITIONS:

ITEM	VALUE	DESCRIPTION
----	-----	-----------
LUCODE		This coding represents the future land use data.

DATA LINEAGE REPORT

DATA LAYER: FEMA Q3 Flood Data
LOCATION: /disk3/fema/fema_q3
LAYER NAME: FEMA_Q3
MAP UNIT: County
SOURCE SCALE: Variable (1:4800, 1:6000, 1:12000, 1:24000)
PROJECTION: UTM, ZONE 17
DATUM: NAD 1983, 1990 Correction
DATA TYPE: Polygon
LAST TEXTFILE UPDATE: 9/17/97
SOURCE: Federal Emergency Management Agency (FEMA)
DEVELOPMENT STATUS: Complete
DISTRICT COVERAGE STATUS: Bradford and Okeechobee Counties are missing.
All other SJRWMD counties are present.

NOTES: For full understanding of this data layer, please read the two FEMA documents: "Q3 FLOOD DATA USERS GUIDE" and "Q3 FLOOD DATA SPECIFICATIONS," available in encapsulated postscript (.eps), word perfect v. 5 (.wp5), and ASCII text (.txt) formats in this directory:
/net/mustang/data/intra/gisdoc/data/metadata/usergd.<ext>
/net/mustang/data/intra/gisdoc/data/metadata/q3spec.<ext>

ABSTRACT
The Q3 Flood Data are derived from the Flood Insurance Rate Maps (FIRMs) published by the Federal Emergency Management Agency (FEMA). The file is georeferenced to the earth's surface using the Universal Transverse Mercator (UTM) projection and a zonal coordinate system (units in meters). Specifications for the horizontal control of Q3 Flood Data files are consistent with those required for mapping at a scale of 1:24000. Maintenance and Update Frequency by FEMA: Irregular.

PURPOSE
The FIRM is the basis for floodplain management, mitigation, and insurance activities for the National Flood Insurance Program (NFIP). Insurance applications include enforcement of the mandatory purchase requirement of the Flood Disaster Protection Act which "... requires the purchase of flood insurance by property owners who are being assisted by Federal programs or by Federally supervised, regulated or insured agencies or institutions in the acquisition or improvement of land facilities located or to be located in identified areas having special flood hazards" (Section 2 (b) (4) of the 1973 Flood Disaster Protection Act). In addition to the identification of Special Flood Hazard Areas (SFHAs), the risk zones shown on the FIRMs are the basis for the establishment of premium rates for flood insurance coverage offered through the NFIP.

Q3 Flood Data files are intended to convey certain key features from the existing hard copy FIRM to provide users with automated flood risk data. Edge-matching errors, overlaps and deficiencies in coverage, and similar problems are not corrected during digitizing or post-processing. This data layer may be used to determine whether or not features fall within SFHAs if the feature is located farther than 250 feet from the nearest SFHA boundary. More detailed and complete information may be obtained from the hardcopy **FIRM.**
May, 1997: This dataset was projected from Geographic, NAD 1927 to UTM, Zone 17, NAD 1983, 1990 Correction.

The metadata provided with this data set may contain errors. Example: the metadata indicated a an original projection of UTM; however the projection was Geographic. County boundary arcs are not coincident, thus producing sliver polygons during the MAPJOIN step; the fips item for those polygons has been coded 999 to facilitate subsetting.
Data from the panhandle area of Florida (Zone 16) was not included in the Library Layer; the data is archived and available on CD-ROM.
Approximately 168,000 arcs and 80,000 polygons are present in the data layer.

PAT ITEM DEFINITIONS:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME INDEXED?
1	AREA	8	18	F	5	-
9	PERIMETER	8	18	F	5	-
17	FEMA_Q3#	4	5	B	-	-
21	FEMA_Q3-ID	4	5	B	-	-
25	FIPS	5	5	C	-	-
30	COMMUNITY	4	4	C	-	-
34	FIRM_PANEL	11	11	C	-	-
45	QUAD	8	8	C	-	-
53	ZONE	5	5	C	-	-
58	FLOODWAY	5	5	C	-	-
63	COBRA	9	9	C	-	-
72	SFHA	3	3	C	-	-
75	SYMBOL	4	5	B	-	-
79	PANEL_TYP	4	4	C	-	-
** REDEFINED ITEMS **						
25	ST-FIPS	2	2	C	-	-
27	CO-FIPS	3	3	C	-	-
25	STATE	2	2	C	-	-
36	PCOMM	4	4	C	-	-
40	PANEL	5	5	C	-	-
Continue?						
45	LAT	2	2	C	-	-
47	LONG	3	3	C	-	-
51	QUAD_UNIT	2	2	C	-	-

UNIQUE PAT ITEM VALUES AND DEFINITIONS:

ITEM	VALUE	DESCRIPTION
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FIPS	999	Sliver Polygons
	###	3-Digit County FIPS Code
COMMUNITY	CCCC	See Q3 Spec
FIRM_PANEL	CCCCCCCCCCC	See Q3 Spec
QUAD	CCCCCCCC	See Q3 Spec
ZONE	V	An area inundated by 1% annual chance flooding with velocity hazard (wave action); no BFEs have been determined.
	VE	An area inundated by 1% annual chance flooding with velocity hazard (wave action); BFEs have been determined.
	A	An area inundated by 1% annual chance flooding, for which no BFEs have been determined.
	AE	An area inundated by 1% annual chance flooding, for which BFEs have been determined.
	AO	An area inundated by 1% annual chance flooding (usually sheet flow on sloping terrain), for which average depths have been determined; flood depths range from 1 to 3 feet.
	AOVEL	An alluvial fan inundated by 1% annual chance flooding (usually sheet flow on sloping terrain), for which average flood depths and velocities have been determined; flood depths range from 1 to 3 feet.
	AH	An area inundated by 1% annual chance flooding (usually an area of ponding), for which BFEs have been determined; flood depths range from 1 to 3 feet.
	A99	An area inundated by 1% annual chance flooding, for which no BFEs have been determined. This is an area to be protected from the 1% annual chance flood by a Federal flood protection system under construction.
	D	An area of undetermined but possible flood hazards.
	AR	An area inundated by flooding, for which BFEs or average depths have been determined. This is an area that was previously, and will again, be protected from the 1% annual chance flood by a Federal flood protection system whose restoration is Federally funded and underway.
	X500	An area inundated by 0.2% annual chance flooding; an area inundated by 1% annual chance flooding with average depths of less than 1 foot or with drainage areas less than 1 square mile; or an area protected by levees from 1% annual chance flooding.
	X	An area that is determined to be outside the 1% and 0.2% annual chance floodplains
	100IC	An area where the 1% annual chance flooding is contained within the channel banks and the

		channel is too narrow to show to scale. An arbitrary channel width of 3 meters is shown. BFEs are not shown in this area, although they may be reflected on the corresponding profile.
	500IC	An area where the 0.2% annual chance flooding is contained within the channel banks and the channel is too narrow to show to scale. An arbitrary channel width of 3 meters is shown.
	FWIC	An area where the floodway is contained within the channel banks and the channel is too narrow to show to scale. An arbitrary channel width of 3 meters is shown. BFEs are not shown in this area, although they may be reflected on the corresponding profile.
	FPQ	An area designated as a “Flood Prone Area” on a map prepared by USGS and the Federal Insurance Administration. This area has been delineated based on available information on past floods. This is an area inundated by 1% annual chance flooding for which no BFEs have been determined.
	IN	An area designated as within a “Special Flood Hazard Area” (or SFHA) on a FIRM. This is an area inundated by 1% annual chance flooding for which BFEs or velocity may have been determined. No distinctions are made between the different flood hazard zones that may be included within the SFHA. These may include Zones A, AE, AO, AH, A99, AR, V, or VE.
	OUT	An area designated as outside a “Special Flood Hazard Area”(or SFHA) on a FIRM. This is an area inundated by 0.2% annual chance flooding; an area inundated by 1% annual chance flooding with average depths of less than 1 foot or with drainage areas less than 1 square mile; an area protected by levees from 1% annual chance flooding; or an area that is determined to be outside the 1% and 0.2% annual chance floodplains. No distinctions are made between these different conditions. These may include both shaded and unshaded areas of Zone X.
	ANI	An area that is located within a community or county that is not mapped on any published FIRM.
	UNDES	A body of open water, such as a pond, lake, ocean, etc., located within a community’s jurisdictional limits, that has no defined flood hazard.
FLOODWAY	FW	An area that includes the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water-surface elevation by more than a

		designated height. (Note: this area is normally in Zone AE.)
	EASE	An area within a community, usually bordering a stream, that has more restrictive floodplain development criteria imposed upon it by the governing body (town, city, etc.) than the criteria imposed as a prerequisite to participation in the NFIP. (Note: Unlike the floodway, this area may overlap any other flood zone.)
	STATE	An area within a community, usually bordering a stream, that has more restrictive floodplain development criteria imposed upon it by the state, than the criteria imposed as a prerequisite to participation in the NFIP. (Note: Unlike the floodway, this area may overlap any other flood zone.)
COBRA	COBRA_IN	An area designated as within the Coastal Barrier Resources System in which flood insurance is unavailable for structures newly built or substantially improved after the Coastal Barrier date. The specific Coastal Barrier designation date is available on the printed FIRM.
	COBRA_OUT	An area outside the Coastal Barrier Resources System.
SFHA	IN	An area inside a Special Flood Hazard Area
	OUT	An area outside a Special Flood Hazard Area

ANNOTATION: None
Level#:
Notes:

DATA LINEAGE REPORT

DATA LAYER: District and Public Lands 1998 - Current and Potential Ownership
LOCATION: /disk1/basemap/cadastral/sjr_lands/distlands
LAYER NAME: DISTRICT LANDS
MAP UNIT: District
SOURCE SCALE: Various
PROJECTION: UTM, ZONE 17
DATUM: NAD 1983, 1990 Adjustment
DATA TYPE: Polygon, Line
LAST TEXTFILE UPDATE: 05/15/98
SOURCE: Various
DEVELOPEMENT STATUS: On going as public entities acquire land
DISTRICT COVERAGE STATUS: Complete coverage

NOTES: The polygons and lines are from various sources including surveys that have been submitted as a requirement for purchase. Users should check the DIG-SOURCE attribute to determine the confidence of property boundaries. This data is intended to produce graphic representations of ownership for planning and inventory purposes only. Any one wishing to obtain boundary information should contact the Division Surveying Services, Department of Water Resources, St. Johns River Water Management District.

PAT ITEM DEFINITIONS:

COLUMN	ITEM NAME	IDTH	OUTPUT	TYPE	N.DEC	INDEXED?
1	AREA	4	12	F	3	-
5	PERIMETER	4	12	F	3	-
9	LANDS#	4	5	B	-	-
13	LANDS-ID	4	5	B	-	-
17	DIG-SOURCE	20	20	C	-	-
37	SYMBOL	4	5	B		-
41	ACRES	4	12	F	3	-
45	LA-NO	12	12	C	-	-
57	TRANS_DATE	8	8	I	-	-
65	DEED_ACRES	10	10	N	4	-
75	PARCEL_NAME	40	40	C	-	-
115	SJRWMD_PRICE	12	12	N	2	-
127	BASIN	20	20	C	-	-
147	PROJECT_AREA	30	30	C	-	-
177	MGMT_AREA	40	40	C	-	-
217	MANAGER	20	20	C	-	-
237	COOP_MGR	20	20	C	-	-
257	PRM_COUNTY	20	20	C	-	-
277	TOTAL_PRICE	12	12	N	2	-
289	FUND_SOURCE	40	40	C	-	-
329	BASIC_FUND	20	20	C	-	-
349	ACQ_TYPE	40	40	C	-	-
389	GOVBRD_APRV_DATE	8	8	I	-	-
397	TITLE_INTEREST	20	20	C	-	-
417	OWNERSHIP	10	10	C	-	-
427	TYPE	20	20	C	-	-
447	ACQ_SYM	3	3	I	-	-

450	CONTRACT	1	1	C	-	-
451	OLD_ACQ_SYM	3	3	I	-	-

UNIQUE PAT ITEM VALUES AND DEFINITIONS

ITEM	VALUE	DESCRIPTION
----	-----	-----------
DIG-SOURCE		Source of polygon
SYMBOL		Not utilized currently
ACRES		Calculated acreages
LA-NO		SJRWMD land acquistion number
TRANS_DATE		Closing date of real estate transaction
DEED_ACRES		Acreage figure used in closing documents for trans-action
PARCEL_NAME		Common name for parcel usually the name of the former land owner
SJRWMD_PRICE		SJRWMD portion of the purchase price, does not include partner's share or associated acquisition costs such as appraisals, timber cruises, environmental audits, attorney's fees or other closing costs
BASIN		Major surface water drainage basin or watershed
PROJECT_AREA		Geographical location naming the area of potential acquisition (Private Lands)
MGMT_AREA		Post closing name given to the acquired public lands by the managing agency
MANAGER		Lead land managing agency responsible for the parcel
COOP_MGR		Secondary or cooperating managing agency(s)
PRM_COUNTY		Primary county where the majority of the parcel is located
TOTAL_PRICE		Total purchase price includes all partners' shares but does not include closing costs or other acquisition expenses
FUND_SOURCE		Exact source of funding specifies SOR or SOR Bond, and P2000 bond year. Currently this refers to SJRWMD funding source only
BASIC_FUND		Generalized funding source(s) (SOR; P2000; Ad Valorem) Currently this refers to SJRWMD funding source only
ACQ_TYPE		Buy = acquired through purchase Donation/Mitigation = acquired through regulatory mitigation or charitable donation Transfer = transferred from another public agency
GOVBRD_APRV_DATE		Date purchased agreement was approved by the JRWMD governing board (public hearing date)
TITLE_INTEREST		Type of title interest in the property (fee simple, less-than fee, public access or no, joint fee)
ACQ_SYM		70 SJRWM District owned 71 SJRWM District owned less than fee 72 SJRWM Joint ownership 73 Potential acquisition 74 Potential acquisition full fee only 75 Other public conservatoin lands 76 Private conservation lands

DATA LINEAGE REPORT

DATA LAYER: roads
MAP UNIT: 1:24,000 quad
SOURCE SCALE: 1:24,000
DATA TYPE: arc
LAST TEXTFILE UPDATE: 5/10/93
SOURCE: Digitized from 1:24,000 USGS topographic maps.
QA STATUS: The status of quality assurance on each quad is not known. Most quads are currently going through quality assurance. For status of quality assurance contact the Division of GIS.
DISTRICT COVERAGE STATUS: Most of the quads in the district are available.

NOTES: The level of detail varies tremendously throughout the district. The quads were digitized by several different contractors and the specs varied for each contractor. Some quads represent only major features, while others capture every detail. A map showing every quad in the district and the arcs within each quad is available from the Division of GIS that will show the level of detail of each quad.

AAT ITEM DEFINITIONS:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ALTERNATE NAME	INDEXED?
1	FNODE#	4	5	B	-		-
5	TNODE#	4	5	B	-		-
9	LPOLY#	4	5	B	-		-
13	RPOLY#	4	5	B	-		-
17	LENGTH	4	12	F	3		-
21	RD361#	4	5	B	-		-
25	RD361-ID	4	5	B	-		-
29	ROAD/CLASS	1	1	C	-		-
30	SOURCE	20	20	C	-		-

UNIQUE AAT ITEM VALUES AND DEFINITIONS:

ITEM	VALUE	DESCRIPTION
ROAD/CLASS	H	Heavy-duty
	M	Medium-duty
	L	Light-duty
	U	Unimproved dirt
SOURCE	USGS QUAD 1982	source for the digital map

ANNOTATION: yes
Level#: 1
Notes: Some coverages have annotation and some don't. Usually the more detailed coverages have annotation.

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION LINEAGE REPORT

DATA LAYER NAME : CONLANDS
DESCRIPTION : A digital spatial database of the existing and proposed conservation lands for the state.
TYPE : Polygons
SCALE : 1:24,000; 1:100,000; 1:250,000 (varies per source)
DATUM : HPGN
PROJECTION : Albers Conformal Area
MAP UNITS : meters
GENERAL AREA COVERED : State of Florida
REPORT PREPARED BY : Eric W Brockwell/Rachel Hough
DATE OF PREPARATION : October 7, 1996, modified January 22, 1998
PROVIDING ORGANIZATION
AGENCY : Florida Department of Environmental Protection
CONTACT PERSON : Guy Browning
TITLE : Systems Project Administrator
PHONE NUMBER : 850/488-0892
AGENCY DATA NAME : conlands

NOTES ON DERIVATION :
Please see UF GeoPlan's documentation below for details on coverage derivation.

EXPLANATION OF PROCEDURES USED TO TRANSFORM THE DATA
(verbal description, algorithms, projection, commands, etc., as needed) The coverage was projected to the HPGN datum using the PROJECT command in ARCINFO 7.1.1.

ATTRIBUTE DESCRIPTION :
Please see UF GeoPlan's documentation below for details on attribute description.
PROJECTION FILE USED:
PROJECTION ALBERS
DATUM HPGN
UNITS METERS
24 0 0.000
31 30 0.000
-84 0 0.000
24 0 0.000
400000.00000
0.00000

LIMITATIONS OF THE DATA / WARNINGS TO THE USER :
Aquatic Preserves Database
The Florida Aquatic Preserves GIS Database developed by the Department of Environmental Protection's Florida Marine Research Institute (DEP-FMRI) is not being distributed with Version 1 of the Conservation Lands Database at the request of DEP-FMRI. Those persons interested in obtaining this database should contact Leslie Ward at FMRI (813-896-8626).

Summary Statistics Issues
Some conservation lands straddle water management district boundaries. To facilitate initial database development, the entire polygon representing a particular park, etc. was

included in only one of the water management district coverages. Hence, caution should be exercised in generating statistics from a single coverage for areas within a water management district. Similarly, some polygons in the database include both terrestrial and marine areas. Summary statistics for conservation lands within the St. John's River Water Management District and the South Florida Water Management District which were published with the final report of the FL Greenways Commission (December 1994) were calculated by subtracting the area of overlap with marine waters (by unioning the coverages with 1:100K DLG hydrography) from the areas calculated for the polygons in the conservation lands coverages. The final report summary statistics for area in aquatic preserves was calculated from the DEP-FMRI aquatic preserves database, not the aquatic preserve polygons found in this version.

Accuracy and Appropriate Uses
This database was compiled to support the planning of a statewide greenways system by the Florida Greenways Commission and may not be suitable for other purposes.

The original map scales and sources for much of the boundary data collected by others is unknown, hence the spatial accuracy of any given boundary is not known. 1:250,000 scale maps depicting the database have been reviewed by representatives of each of the water management districts, the Department of Environmental Protection, and several other state and federal agencies cooperating with the Florida Greenways Commission. The unofficial consensus is that the database offers a representation of the boundaries of existing and proposed conservation lands in Florida which is appropriate for regional and statewide planning. Some conservation lands' boundaries are known to be missing from the database; no boundary data was available during the development period for Version 1.

DOCUMENTATION
FLORIDA GREENWAYS PLANNING PROJECT
FLORIDA GREENWAYS DATABASE

GENERAL DESCRIPTION
The Florida Conservation Lands database was initially compiled and standardized from the existing digital GIS databases maintained by each Florida Water Management District. The compiled database was subsequently enhanced at the Geoplan Center by the addition/standardization of attribute data (such as name, type, status, etc.). The Geoplan Center also corrected all boundary and location inaccuracies identified by reviewers. In addition, every effort was made to incorporate boundary changes precipitated by acquisitions and proposals which occurred as late as March 1996.

Digital/hardcopy boundary and hardcopy attribute data were contributed by the St. Johns River Water Management District, South Florida Water Management District, Southwest Florida Water Management District, Suwannee River Water Management District, Northwest Florida Water Management District, Florida Department of Environmental Protection, Florida Natural Areas Inventory, Florida Game and Freshwater Fish Commission, Florida
Department of Transportation, Florida Division of Forestry, U. S. Fish and Wildlife Service, U. S. Forest Service, several local government agencies, and 1000 Friends of Florida.

FEATURE ATTRIBUTE TABLES
Datafile Name: CONLANDS.PAT

Col	Item Name	WIDTH	OPUT	TYP	N.DEC	ALTERNATE NAME
1	AREA	8	18	F	5	
9	PERIMETER	8	18	F	5	
17	CLAN3#	4	5	B		
21	CLAN3-ID	4	5	B		
25	NAME_A	50	50	C		
75	ATTRIBUTE	16	16	C		
91	NAME_C	60	60	C		
151	ALTNAME	60	60	C		
211	TYPE	8	8	C		
219	ALT_TYPE	8	8	C		
227	OWNER	6	6	C		
233	STATUS	1	1	C		
234	SOURCE	3	3	C		
237	ACRES	4	12	F	2	
241	HECTARES	8	16	F	3	
249	DESCRIPT	50	50	C		

PAT Codes and Values:

ITEM CODES OR DESCRIPTION

NAME_A Acquatic Preserve Name

ATTRIBUTE Acquatic Preserve Type:
LAND = Land inside Aquatic Preserve Boundary
NONE = Not an Aquatic Preserve
WATER = Water body
WETLAND = Classified as Wetland by FDEP-FMRI

NAME_C Conservation Land Name

ALTNAME Alternative Name

TYPE
APR = State-Owned Aquatic Preserves
CARL = CARL Project
CE = Conservation Easement
COE = Corps of Engineers
FCT = Florida Communities Trust
FH = Fish Hatchery
GW = Greenway
HS = Historic Site
IR = Indian Reservation
LAND = Land inside Aquatic Preserve Boundary
LP = Local Park
MIL = Military Reservation
NF = National Forest
NM = National Monument
NP = National Park
NPR = National Preserve
NS = National Seashore
NWR = National Wildlife Refuge
OP = Other Public Land (Airport, Etc.)
OUT = Outparcel
PPR = Private Preserve/Park

SAS = State Archaeological Site
SCS = State Cultural Site
SF = State Forest
SG = State Garden/Botanical Site
SGS = State Geologic Site
SOR = Save Our Rivers Project
SP = State Park
SPR = State Preserve
SR = State Reserve
SRA = State Recreation Area
UNK = Type Unknown
WCA = Water Conservation Area
WEA = Wildlife & Environmental Area
WMA = Wildlife Management Area
WMD = Water Management District Land

ALT_TYPE See TYPE for Descriptions

OWNER FED = Federal
STA = State
LOC = Local
TNC = The Nature Conservancy
PRI = Private
SJWMD = St. Johns River Water Management District
SRWMD = Suwannee River Water Management District
SFWMD = South Florida Water Management District
SWWMD = South West Florida Water Management District
NWWMD = North West Florida Water Management District
UNK = Unknown

STATUS E = Existing
P = Proposed
U = Unknown

SOURCE The source of the digital boundary data for the polygon
0 = Out Parcels
1 = Water Management District Databases

ARC/INFO Coverages received from each of the WMD.
2 = CARL Project boundaries from coverages received from SJRWMD
3 = CARL Project boundaries from coverages received from SJRWMD. Questionable Level of Accuracy
5 = CARL and Public Lands Boundaries from FNAI Coverages
6 = Boundaries digitized by the Geoplan Center from 1:24,000 Quad maps
8 = Boundaries digitized by the Geoplan Center from 1:100,000 quads provided by 1000 Friends of Florida
9 = Aquatic Preserves Database, UF GeoPlan Center
10 = Carl 1995
13 = Water Management District 1995 updates
14 = National Wildlife Refuge Maps
15 = County data
16 = Updates recommended during review by Erik Johnson
17 = CARL 1996 FNAI digital data / CARL 1996 Report

18 = Atlas of Outstanding Florida Waters
19 = 1994 Florida Greenway Commission Community Action Survey
20 = State Parks Base Maps/ Brochures
21 = Map corrections / Additions from Fall 1996
22 = FNAI - FLMA coverage
23 = SFWMD 1996 updates
24 = USDOI, NPS, S.E. Region Land Acquisition Field Office March 1997.
25 = SFWMD, 1997 Save Our Rivers Five Year Plan
26 = DEP Project Location Map - Old Bellamy Road Project, 1997. River Rise State Preserve.
27 = Avon Park AF Range, GPS Boundary digital coverage Spring, 1997.
28 = UF Forest Service, Ronald Trailer, Apalachicola National Forest. April, 1997.
29 = The Nature Conservancy, Susan Feller May, 1997.
30 = FL Game and Freshwater Fish Commission, Dan Miller May, 1997.
31 = FNAI - FLMA coverage April, 1997
32 = St. Johns River Water Management District public lands coverage June, 1997.
33 = Maps furnished at RGTF Meeting June, 1997.
34 = South Florida Water Mangement District Save Our Rivers 5 year plan.
35 = CARL 1997 updates
36 = Red Hills Regional Map
37 = Flagler County Parcel Map
38 = South West Florida Water Management District - Received both proposed and acquired lands, June 1997.
39 = Broward County Public Landholdings
40 = Map provided by St. Lucie County of Environmentally Significant Lands.
41 = Data received from Broward County showing both county and city parks.
42 = Suwannee River Water Management District updates, July 1997.
43 = Map received from Metro-Dade Dept. of Planning
44 = Map received from Hernando County Planning Department
45 = Map received from Southwest Florida Regional Planning Council
46 = Survey maps received from Charlotte County.
47 = Map received from Highlands County
48 = Data received from West Palm Beach July 1997.
49 = Data and map received from Hillsborough County July 1997.
50 = Hard copy map received from Indian River County.
51 = GeoPlan plot received back from Central District RGTF meeting May 1997.
52 = Data received from Florida Game and Freshwater Fish Commission
53 = Data received from North West Florida Water Management District
54 = Coverage received from St. Johns Water Management District August, 1997.
55 = Map received from Northwest RGTF meeting showing Miccosukee Canopy Road Greenway
56 = Coverages received from the Forest Service August, 1997.

57 = Maps received from the September RGTF meetings.
58 = Map of Caloosahatchee ecoscape and Okaloochee Slough from Tom Hoctor, GeoPlan Center.
59 = Map from SWFWMD representing changes of Econfina Recharge Area.
60 = Data received showing the Loxahatchee Greenways Network
99 = Unknown Source

ACRES Calculated from the polygon area as digitized using the equation Area (m^2)/4046.86.

HECTARES Calculated from the polygon area as digitized using the equation Area (m^2)/10000.

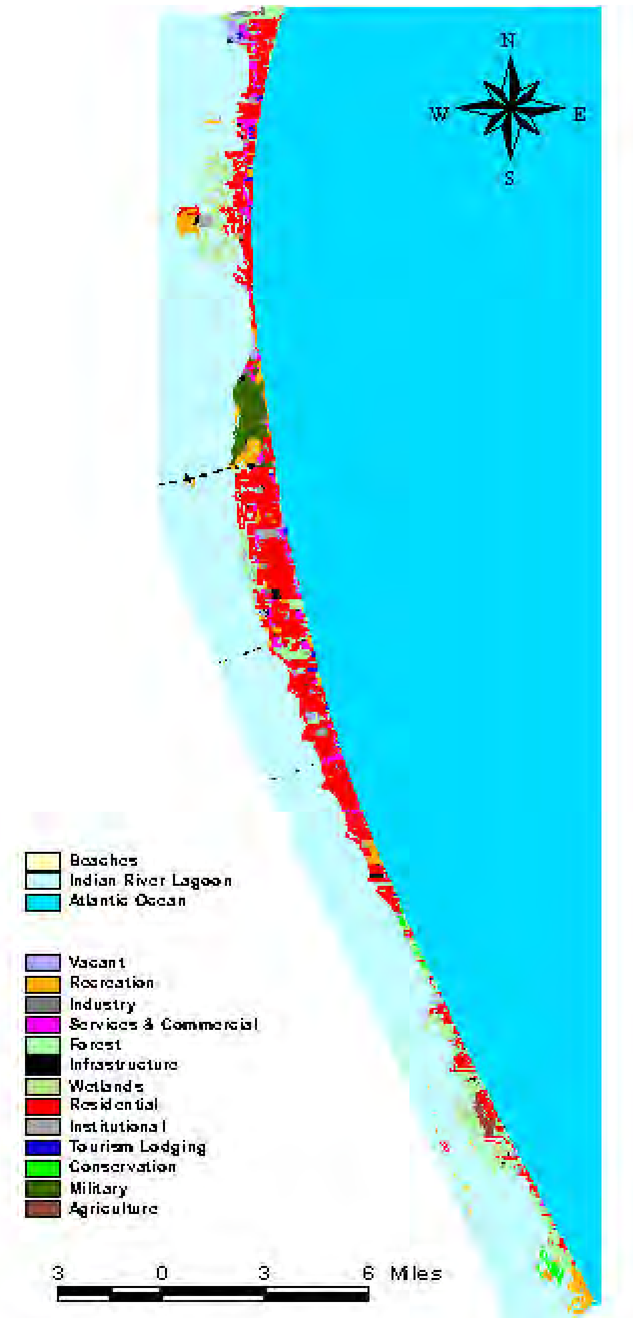

Figure 1. Land Use 1990 (Source: SJRWMD, BCPAO)
(Polygon to grid conversion: 1%)

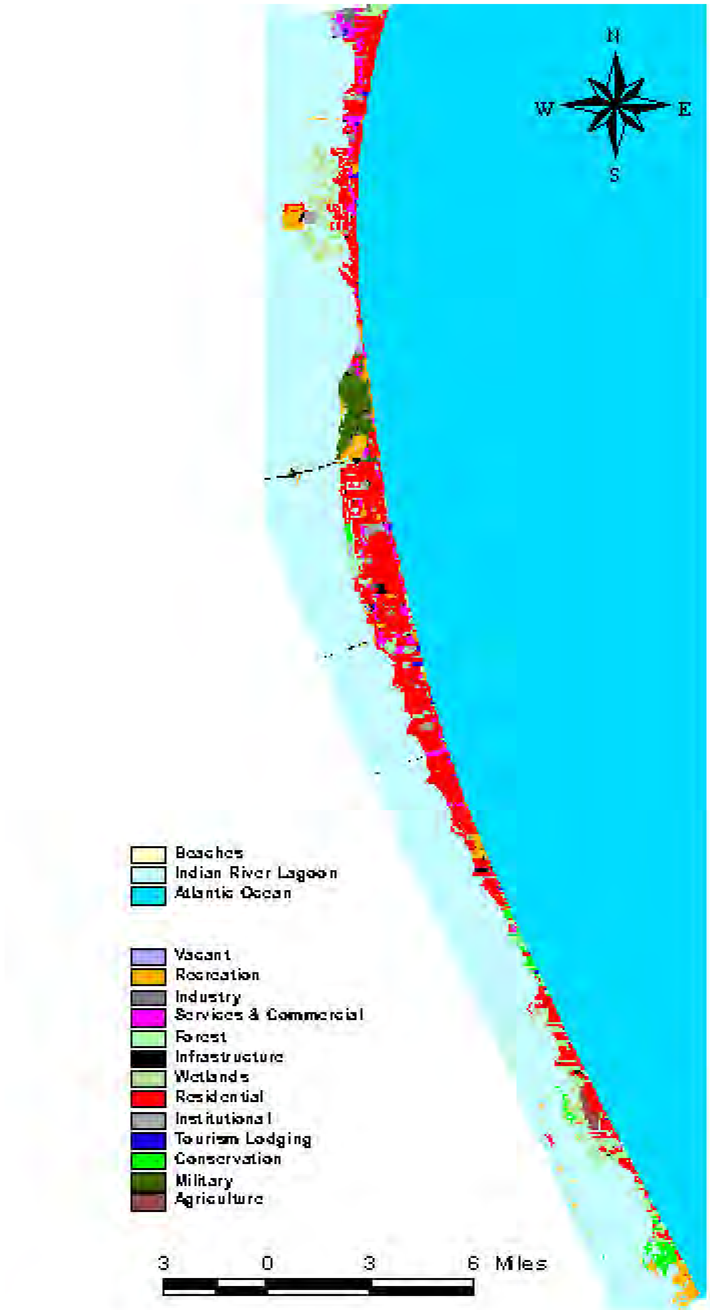

Figure 2. Land Use 1995 (Source: SJRWMD, BCPAO)
(Polygon to grid conversion: 1%)

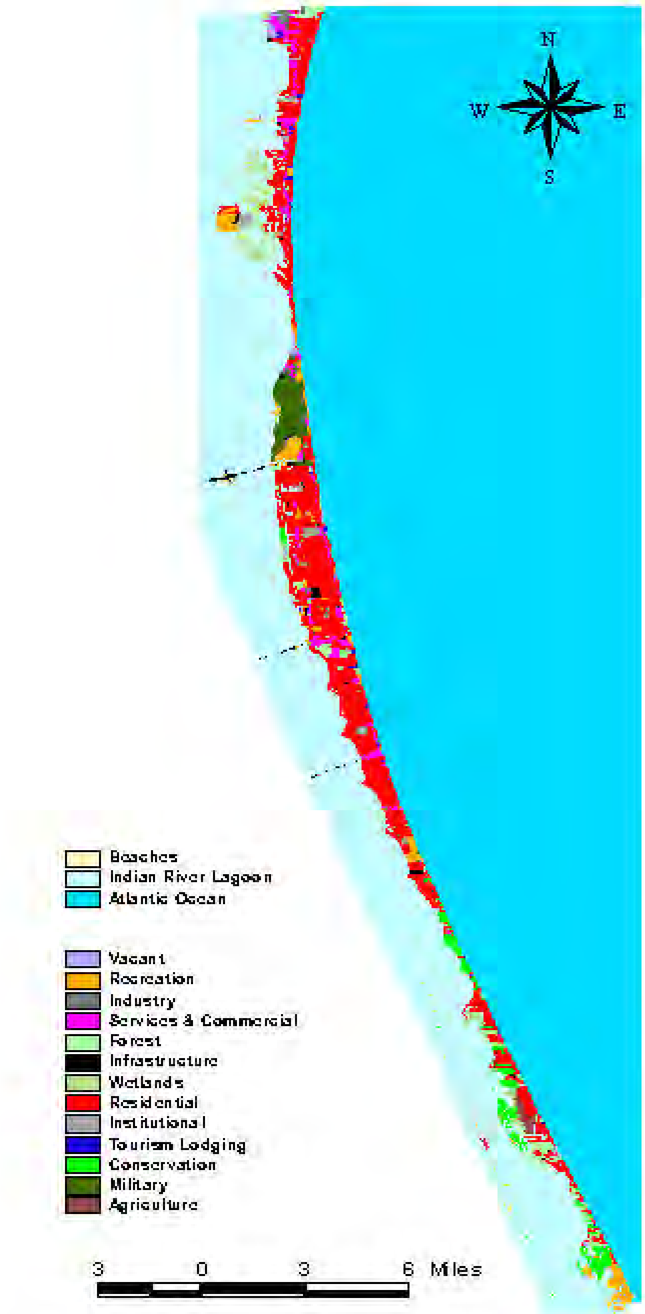

Figure 3. Land Use 2000 (Source: SJRWMD, BCPAO)
(Polygon to grid conversion: 1%)

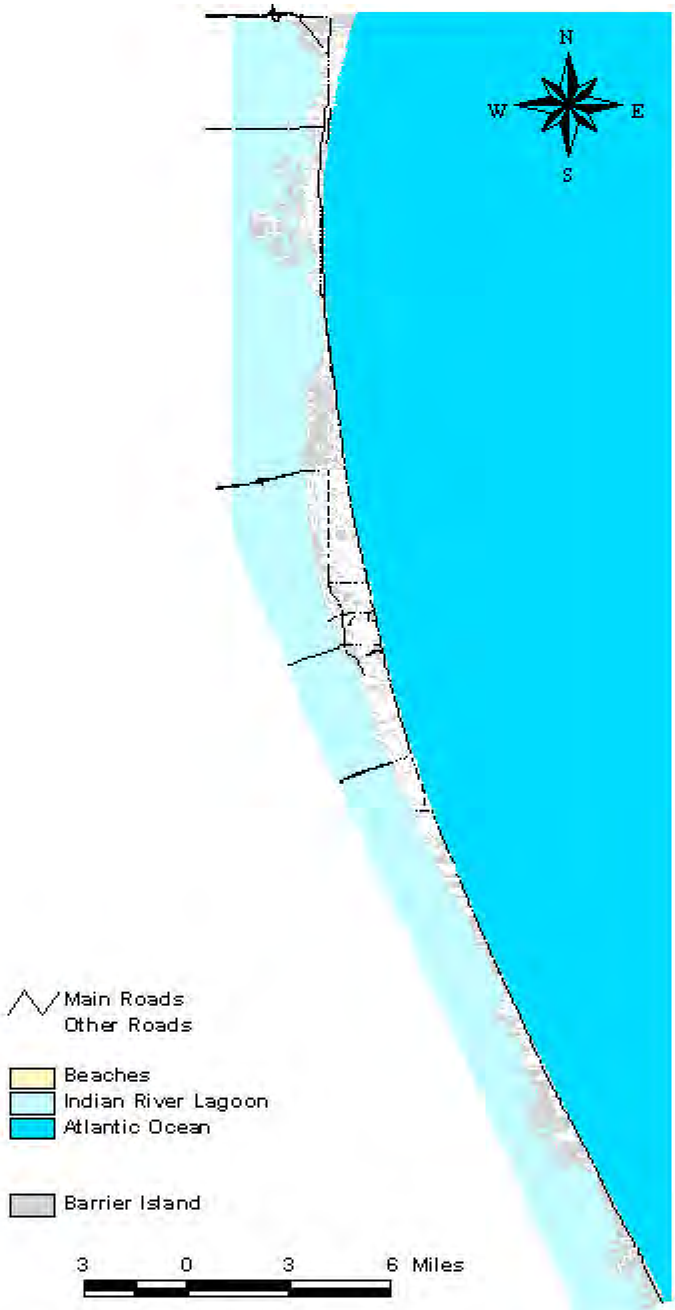

Figure 4. USGS Roads (Source: USGS, SJRWMD)

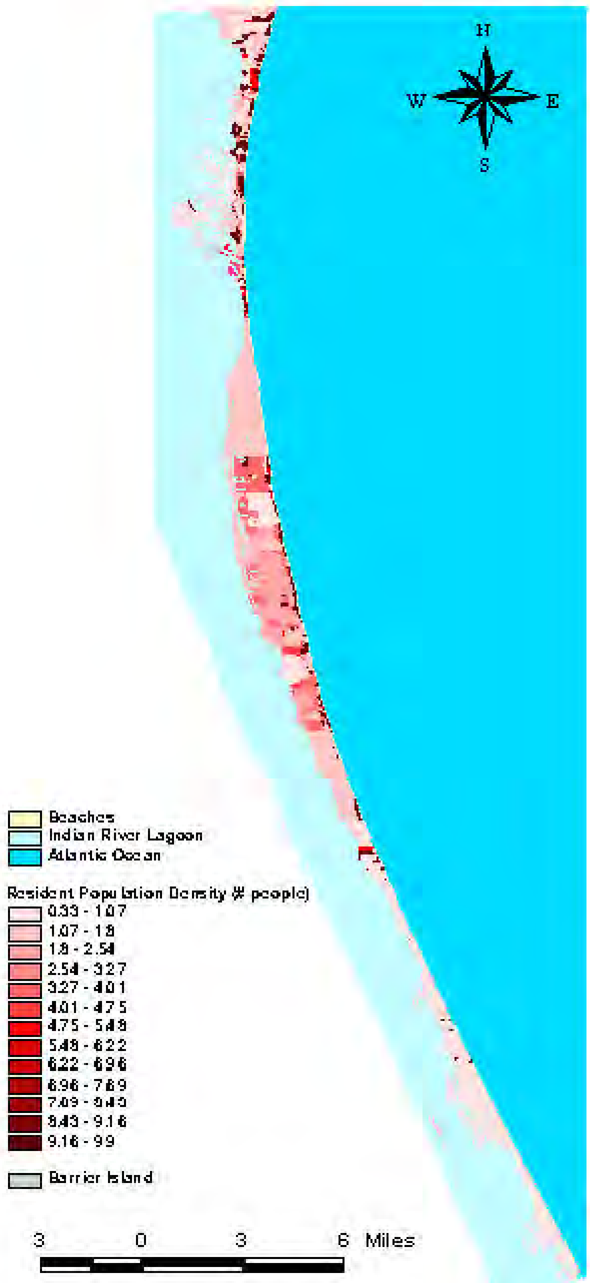

Figure 5. Resident Population Density.

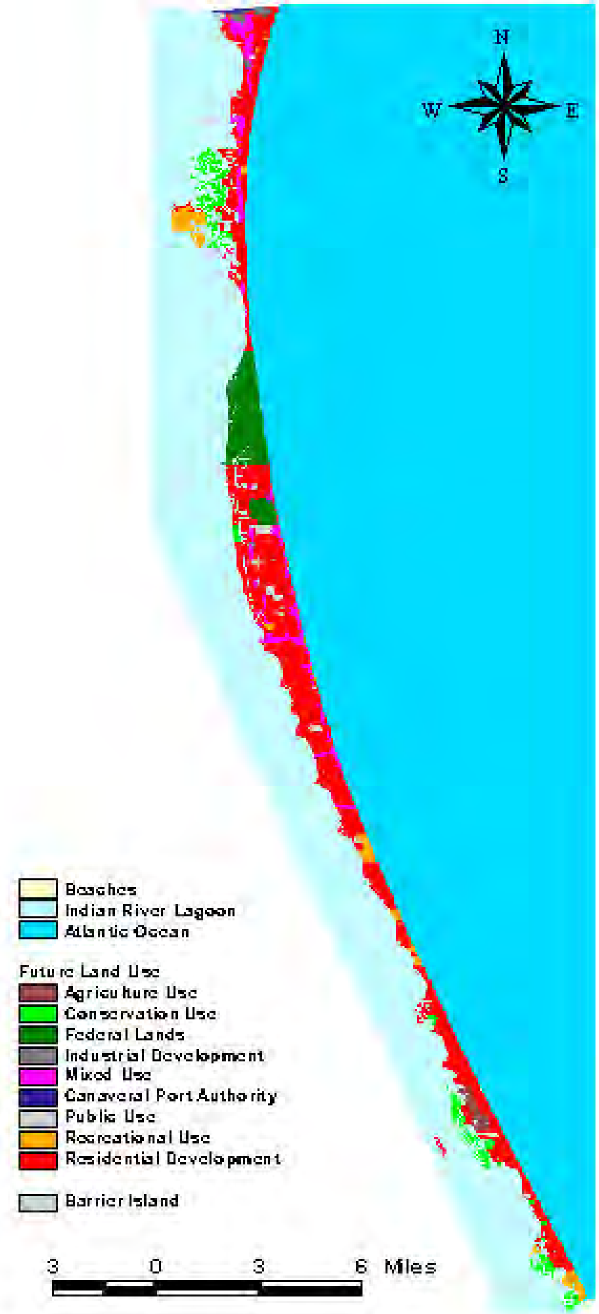

Figure 6. Future Land Use (Source: BC, BCPAO)
(Polygon to grid conversion error: 1%)

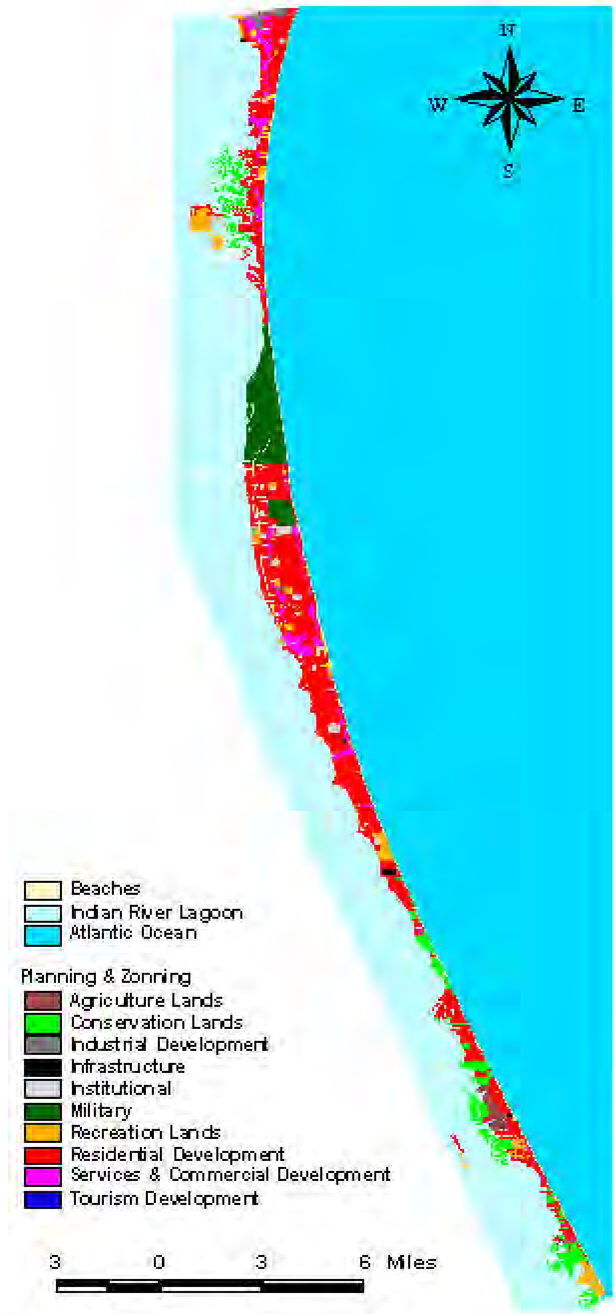

Figure 7. Planning and Zoning Grid (Source: BCPAO)
(Polygon to grid conversion error: 1%)

Figure 8. Vacant Lands (Source: BCPAO)
(Polygon to grid conversion error: 1%)

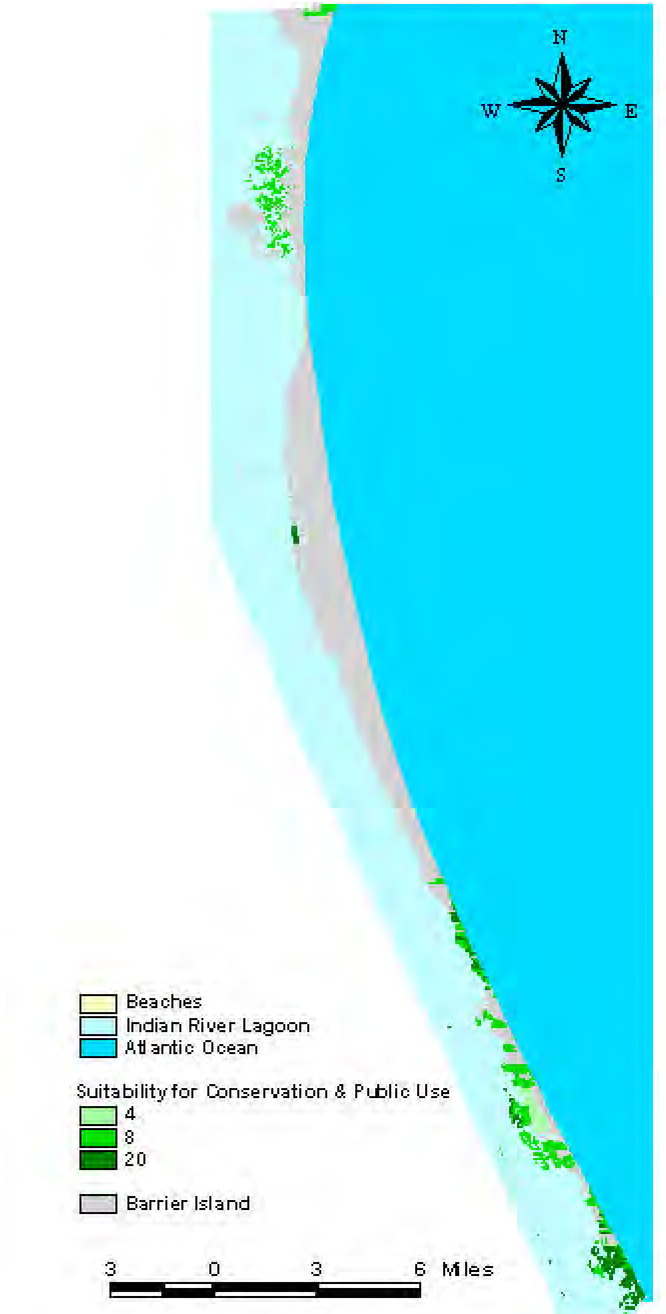

Figure 9. Suitability weights for conservation use.

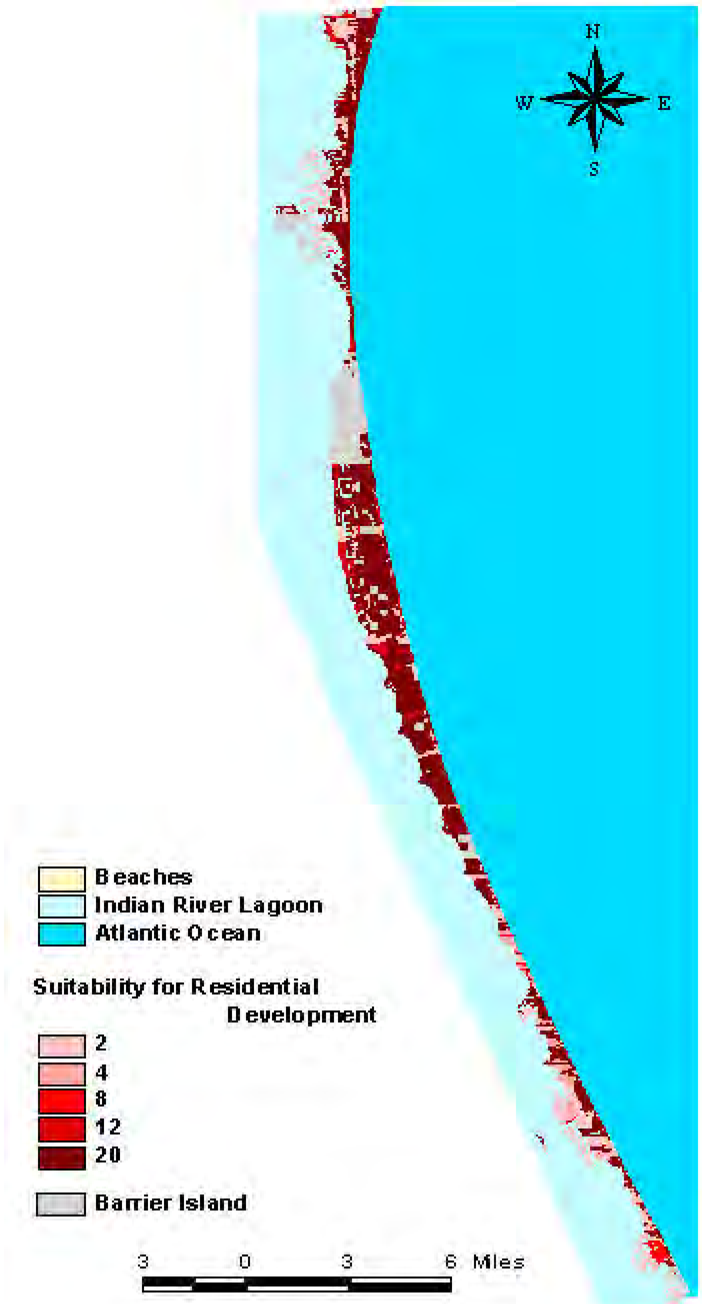

Figure 10. Suitability weights for residential use

Figure 11. Suitability weights for services and commercial use

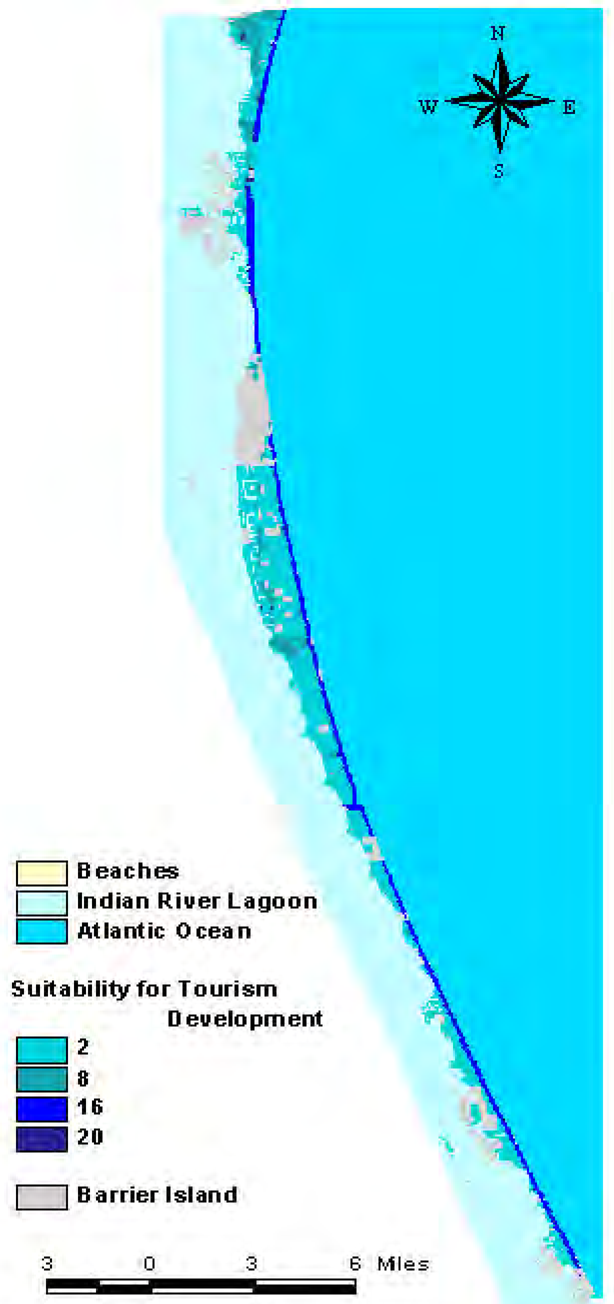

Figure 12. Suitability eights for tourism use

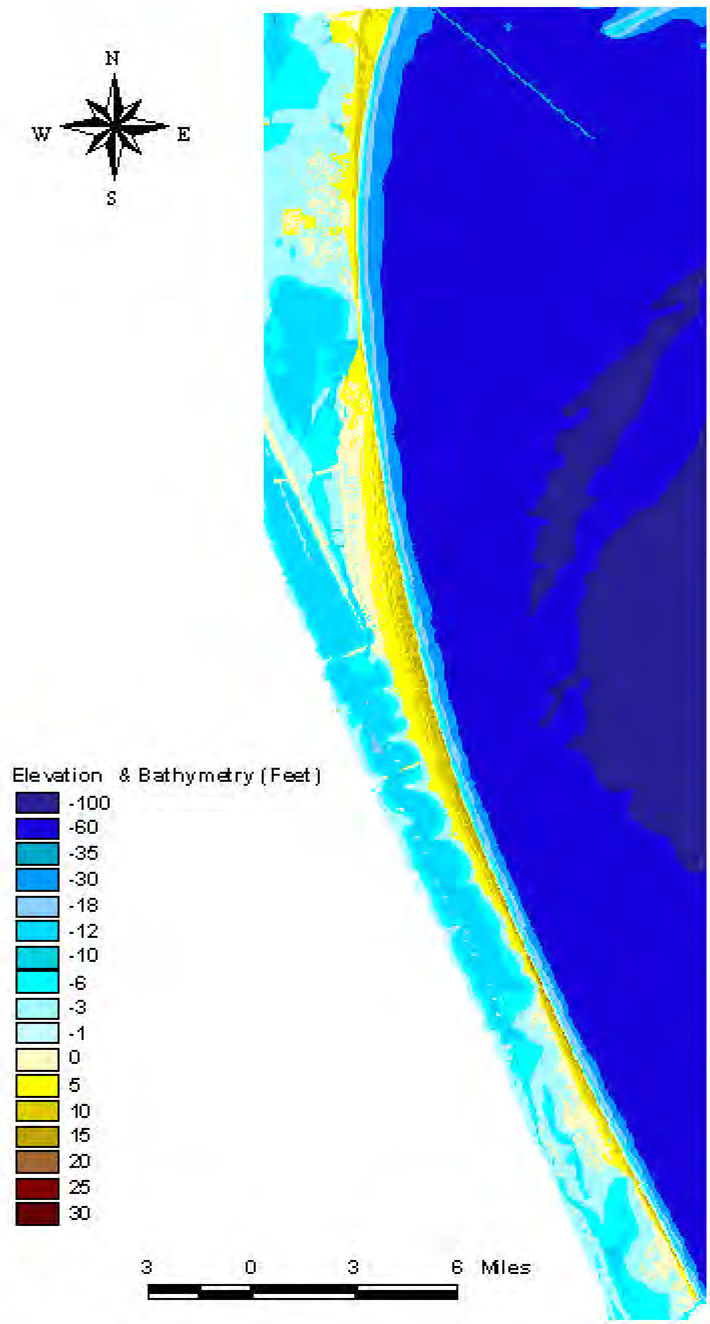

Figure 13. Elevation and Bathymetry (Source: USGS, SJRWMD, FDEP)
(Polygon to Grid Conversion error: 1%)

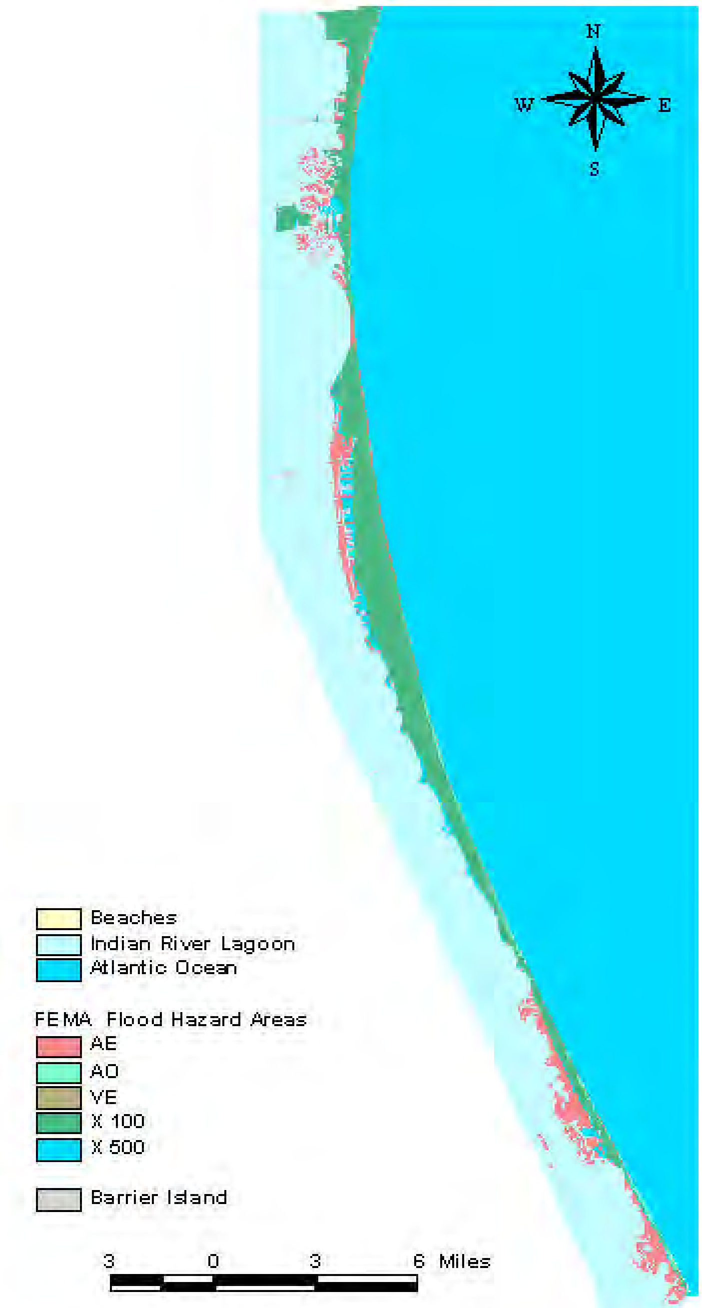

Figure 14. Flood Hazard Areas (Source: FEMA, SJRWMD)
(Polygon to Grid Conversion error: 1%)

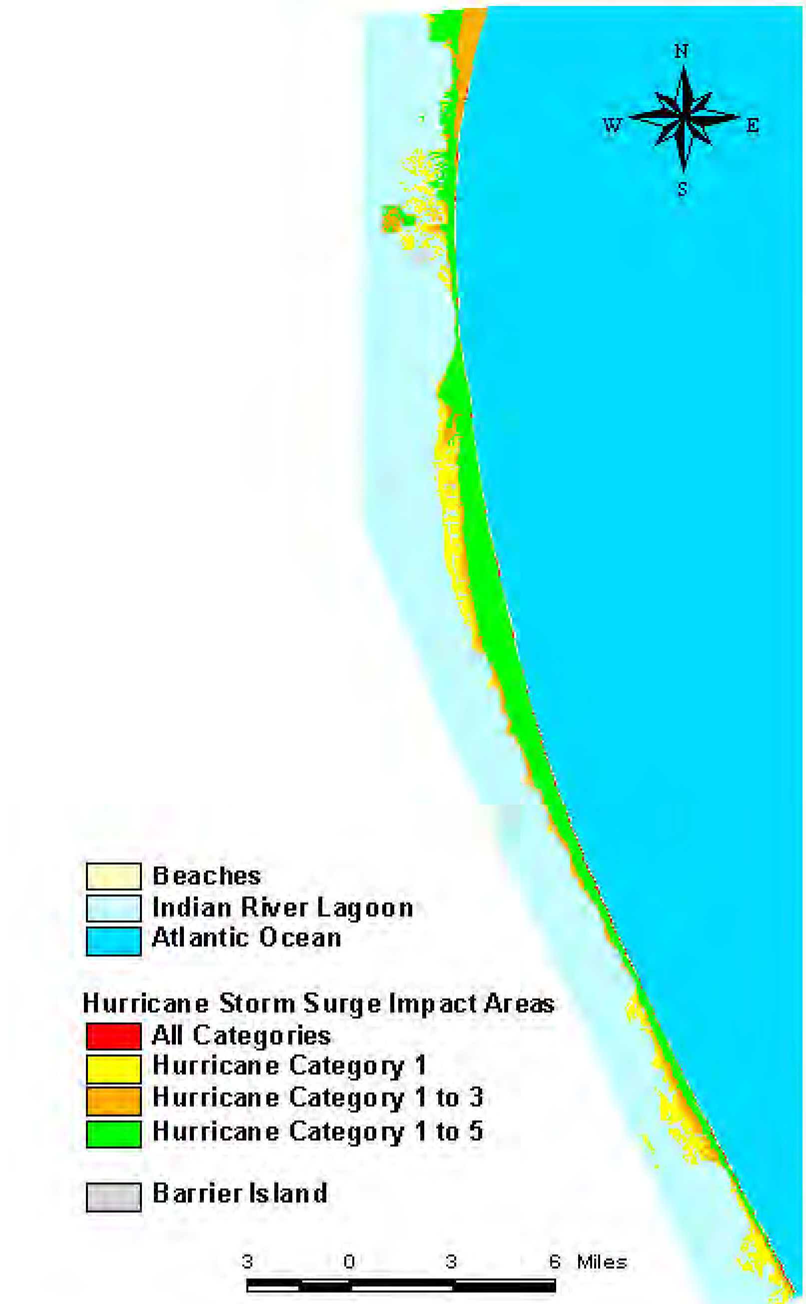

Figure 15. Hurricane Storm Surge (Source: FDCA, BCPAO).
(Polygon to Grid Conversion error: 1%)

Figure 16. Potential Impact Risk Areas
(Polygon to Grid Conversion error: 1%)

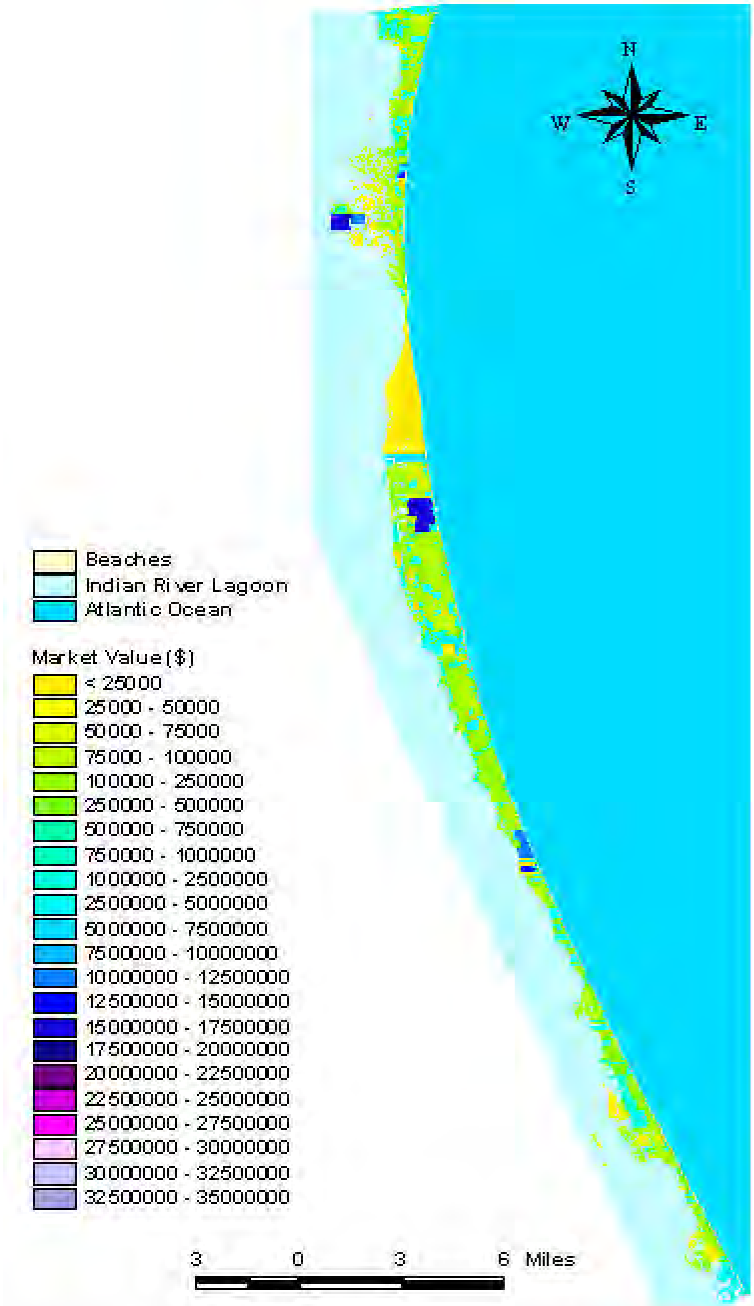

Figure 17. Property Market Value (Source: BCPAO)
(Polygon to Grid Conversion error: 1%)

APPENDIX B

Satellite Beach Case Study

Socio Economic Data for the City of Satellite Beach

Table 1a. Population Census 1970 - 1990 (Source: L.P.D.C., 1998)

Population Characteristics	1970	1980	1990
Total Population (# People)	6558	9163	9889
Population Growth Rate (%)		4	0.8
Labor Force (# People)	4071	7199	8182
Population in Labor Force (%)	62.1	78.6	82.7

Table 1b. Housing Characteristics 1980 - 1990 (Source: L.P.D.C., 1998)

Housing Characteristics	1980	1990
Total Housing Units	3421	4205
Vacant Housing Units	291	392
One Unit Structures	2750	3443
5 or more Unit Structures	490	480
Persons per Housing Unit	2.9	2.6
Potential Number of Persons	10015	10906

Table 1c. Tourism Facilities

Tourism Facilities	1990	1995	2000
Number of Hotels	1	1	1
Hotel Capacity (Rooms)	108	108	108
Potential Number of Tourists (65 % occupancy)	76869	76869	76869

Population Curves for the Calibration and Validation Runs

Years	Observed (*)	Population Growth Rate (%)	Predicted (0.5 % Growth Rate)		
			Run 1	Run 2	Run 3
1970	6558				
1980	9163	39.72			
1990	9889	7.92	9889	9889	9889
1991	9852	-0.37	9942	9935	9940
1992	9871	0.19	9993	9990	9986
1993	9954	0.84	10043	10044	10036
1994	10048	0.94	10089	10092	10092
1995	10105	0.57	10143	10139	10145
1996	10106	0.01	10193	10192	10197
1997	10212	1.05	10240	10249	10253
1998			10296	10300	10300
1999			10346	10353	10347
2000			10401	10411	10401

(*) Source: 1970 - 1990 Population Census
1991 - 1997 Economic Development Commission of the Florida Space Coast (www.edc-space.org)

Years	Observed (*)	Potential (**)		
		Run 1	Run 2	Run 3
1970				
1980	10015			
1990	10906	12722	12722	12722
1991		12722	12722	12722
1992		12710	12710	12710
1993		12773	12773	12770
1994		12865	12865	12866
1995		12979	12979	12979
1996		13085	13085	13085
1997		13152	13152	13152
1998		13224	13224	13224
1999		13293	13293	13293
2000		13349	13346	13349

(*) Based on the average number of people per dwelling unit taking in consideration the number of vacant units
(*) Based on the average number of people per dwelling unit, taking in consideration the local residential density.

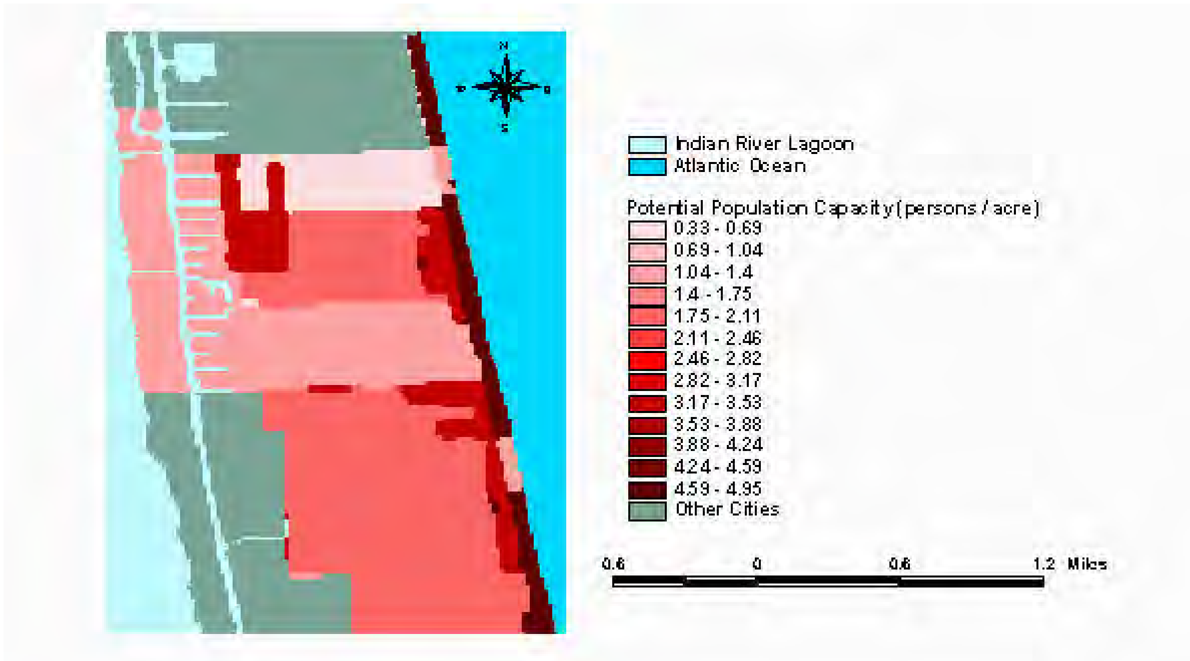

Figure 1. Resident Population Density

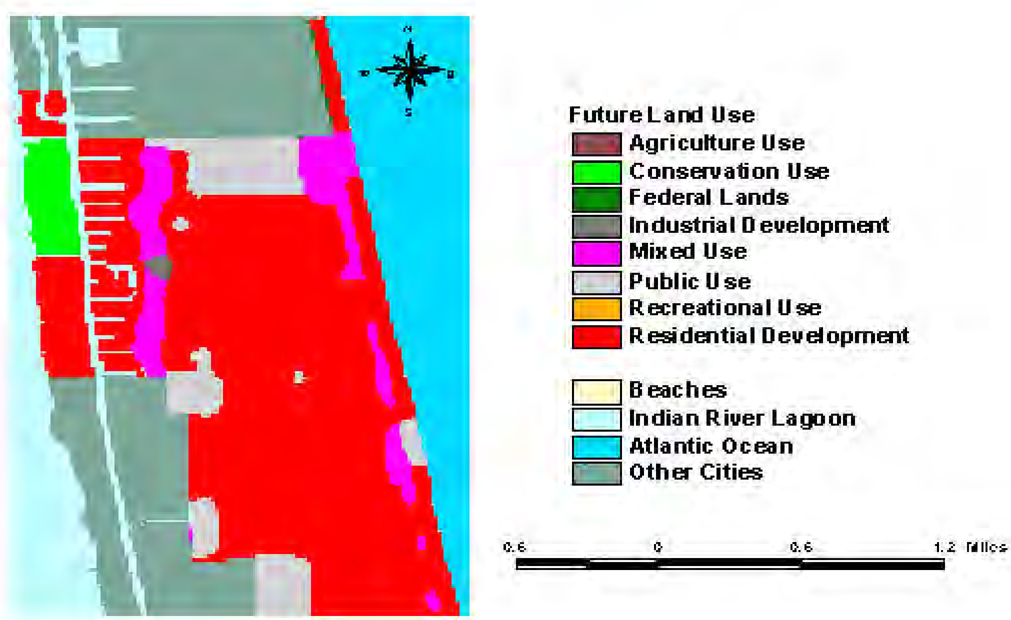

Figure 2. Future Land Use (Source: BC, BCPAO, City of Satellite Beach)

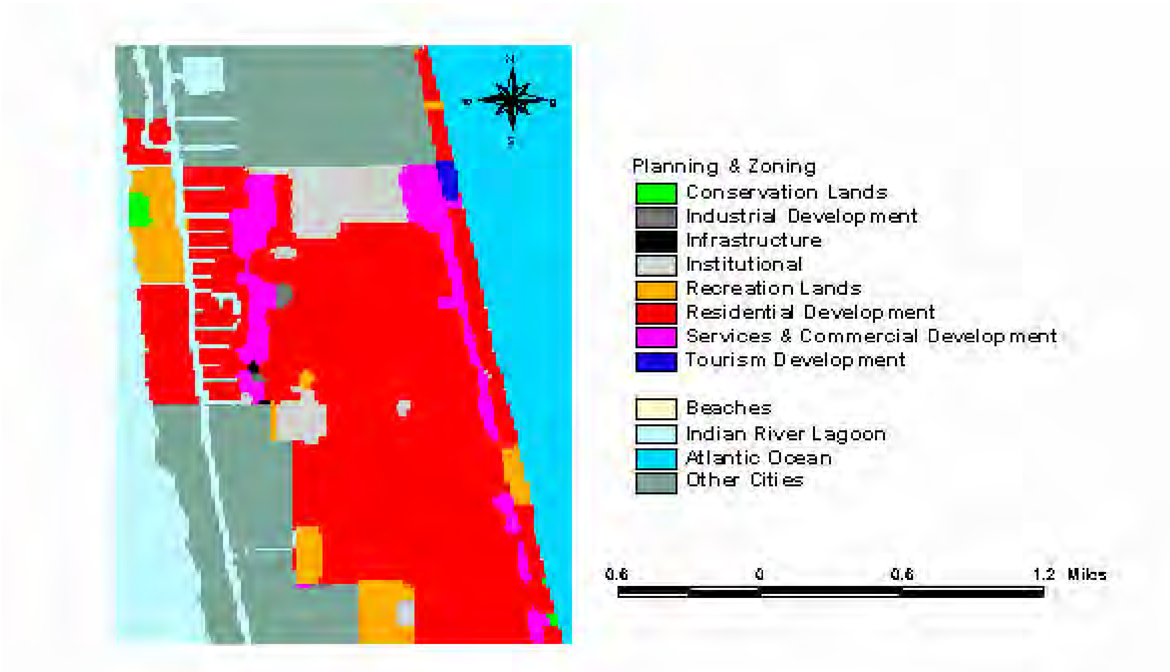

Figure 3. Planning and Zoning (Source: BCPAO)

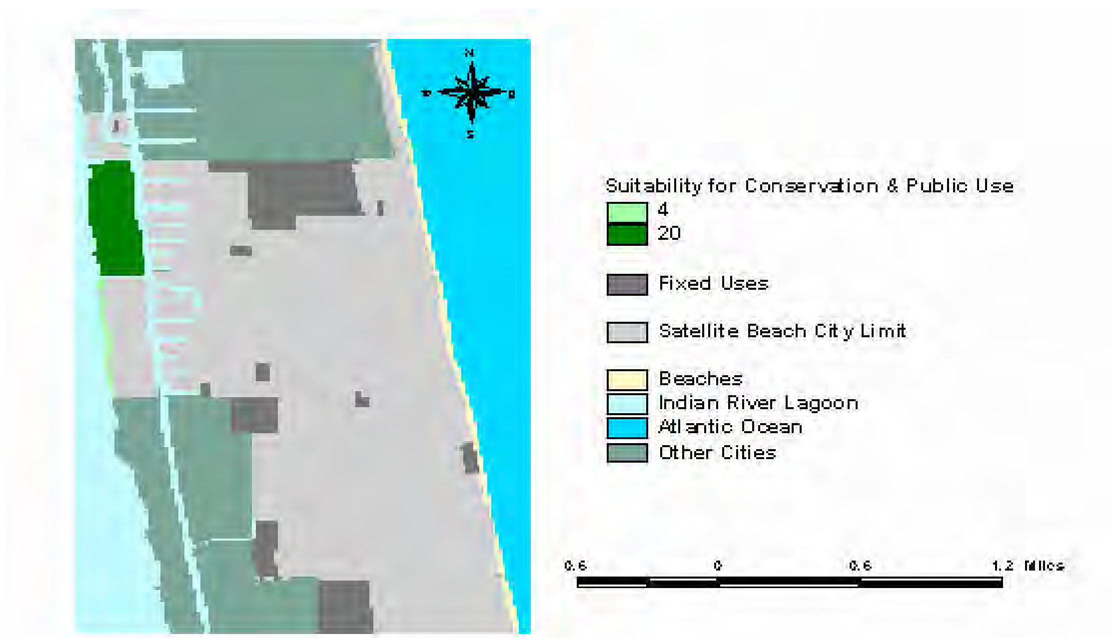

Figure 4. Suitability weights for Conservation Use

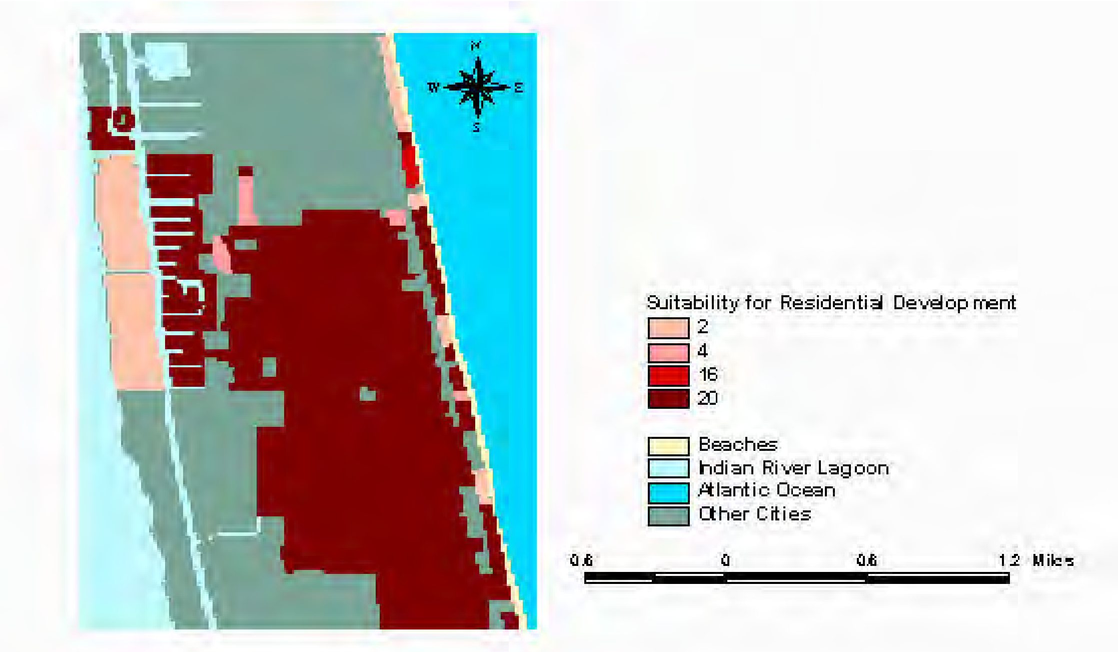

Figure 5. Suitability weights for Residential Use

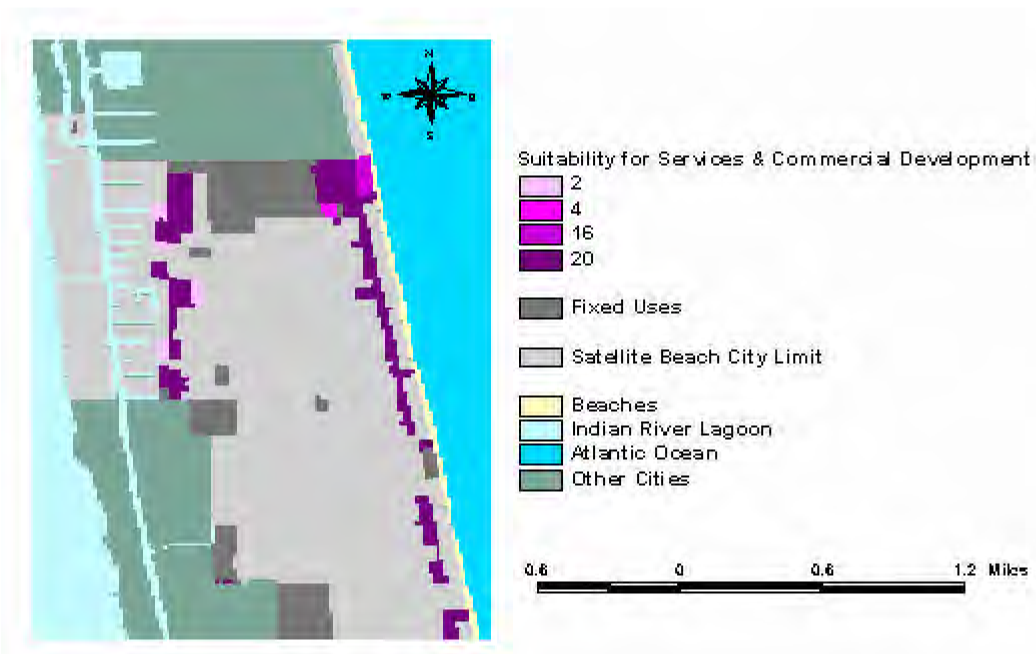

Figure 6. Suitability weights for Services and Commercial Use

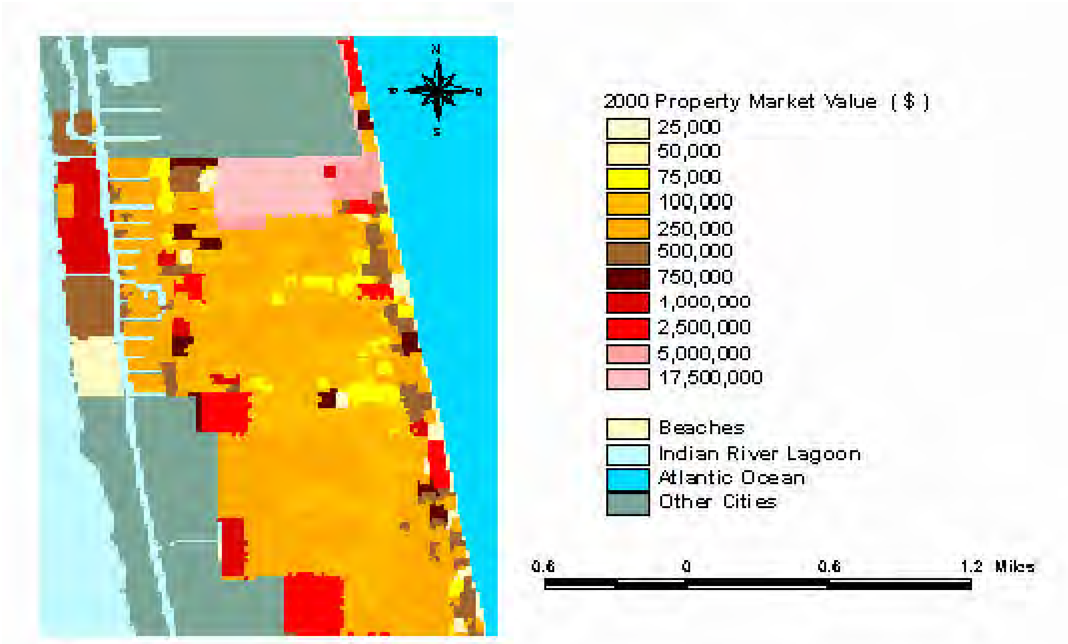

Figure 7. Property Market Value (Source: BCPAO)

Distance Neighborhood Calibration

Table 2 - Distance neighborhood weights that represent the influence of the different land uses on one another for the City of Satellite Beach

LAND USE	Conservation		Services & Commerce		Residential		Tourism Lodging	
	D1	D2	D1	D2	D1	D2	D1	D2
Indian River Lagoon	0	100	0	10	0	50	0	25
Ocean	0	0	0	0	0	50	0	75
Beach	0	25	0	10	0	40	0	80
Agriculture	0	25	0	5	0	10	0	5
Services & Commercial	0	5	250	250	0	110	0	40
Conservation	300	300	0	0	0	10	0	0
Industrial	0	0	0	50	0	0	0	0
Infrastructure	0	0	0	75	0	35	0	65
Institutional	0	5	0	40	0	75	0	0
Natural Forest	0	75	0	25	0	40	0	25
Military	0	0	0	15	0	10	0	0
Recreation	0	15	0	20	0	25	0	30
Tourism Lodging	0	5	0	60	0	10	300	300
Residential	0	5	0	60	300	300	0	0
Vacant	0	5	0	60	0	60	0	60
Wetlands	0	100	0	0	0	10	0	0

Table 3. Comparison between simulated results and the calibration (1995) and validation grids (2000) in terms of land allocated and percentage change

Existing	Observed			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	1990	1995	2000	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Conservation	0.0	55.4	61.2	55.4	5.8	-	10.6	**11.07**	**1.17**
Residential	957.6	975.2	992.1	17.6	16.9	1.8	1.7	**3.51**	**3.39**
Services & Commercial	89.4	105.8	108.0	16.4	2.3	18.3	2.1	**3.27**	**0.45**
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	**0.00**	**0.00**

Table 4. Comparison between simulated results and the calibration (1995) and validation grids (2000) in terms of land allocated and percentage change

Simulation	Run 1			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	1990	1995	2000	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Conservation	0	55.5	61.5	55.5	6.0	-	10.8	11.1	1.2
Residential	957.6	975.6	992.85	18.0	17.3	1.9	1.8	3.60	3.4
Services & Commercial	89.4	105.9	108.15	16.5	2.3	18.5	2.1	3.25	0.45
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. (Cont). Comparison between simulated results and the calibration (1995) and validation grids (2000) in terms of land allocated and percentage change

Simulation	Run 2			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	1990	1995	2000	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Conservation	0	55.5	61.5	55.5	6.0	-	10.8	11.1	1.2
Residential	957.6	975.6	992.85	18.0	17.3	1.9	1.8	3.60	3.4
Services & Commercial	89.4	105.9	108.15	16.5	2.3	18.5	2.1	3.25	0.45
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Run 3			Land Change (acres)		Land Allocated (%)		Annual Request (acres	
	1990	1995	2000	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Conservation	0	55.5	61.5	55.5	6.0	-	10.8	11.1	1.2
Residential	957.6	975.6	992.85	18.0	17.3	1.9	1.8	3.60	3.4
Services & Commercial	89.4	105.9	108.15	16.5	2.3	18.5	2.1	3.25	0.45
Tourism Lodging	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0

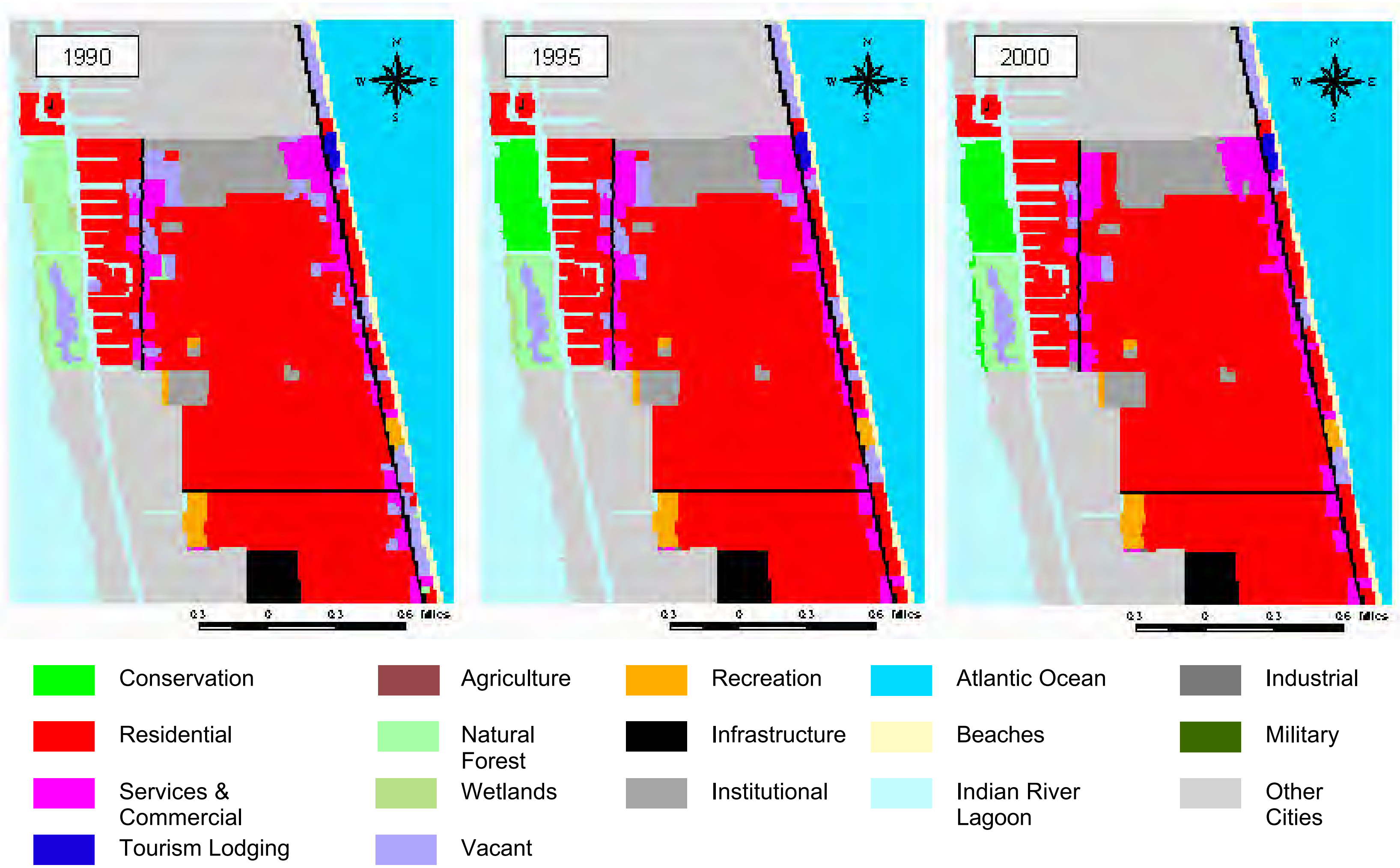

Figure 8. Observed land use pattern for the City of Satellite Beach for 1990, 1995 and 2000.

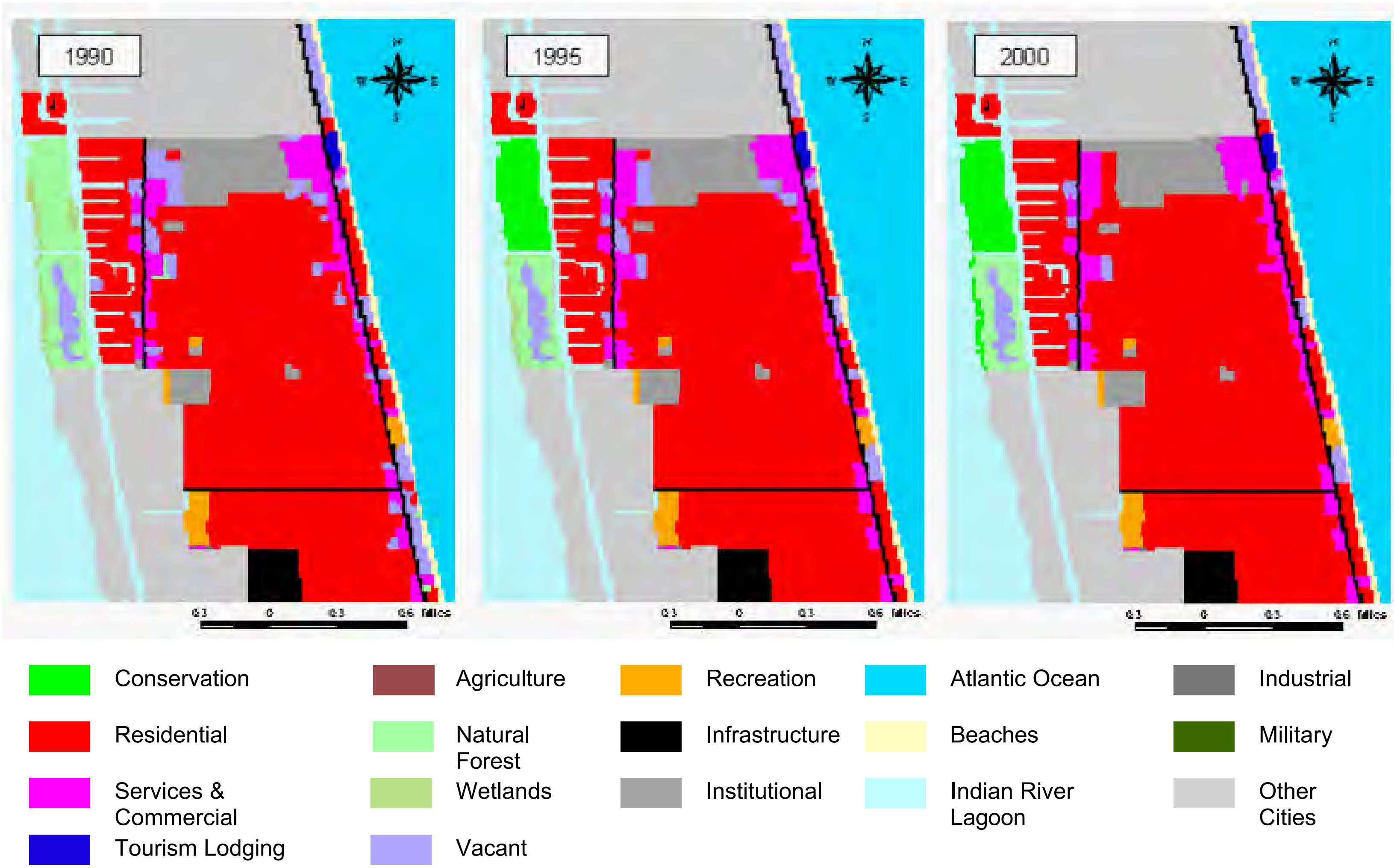

Figure 9. Simulation Run 1 - Calibration (1995) and Validation (2000) land use patterns for the City of Satellite Beach

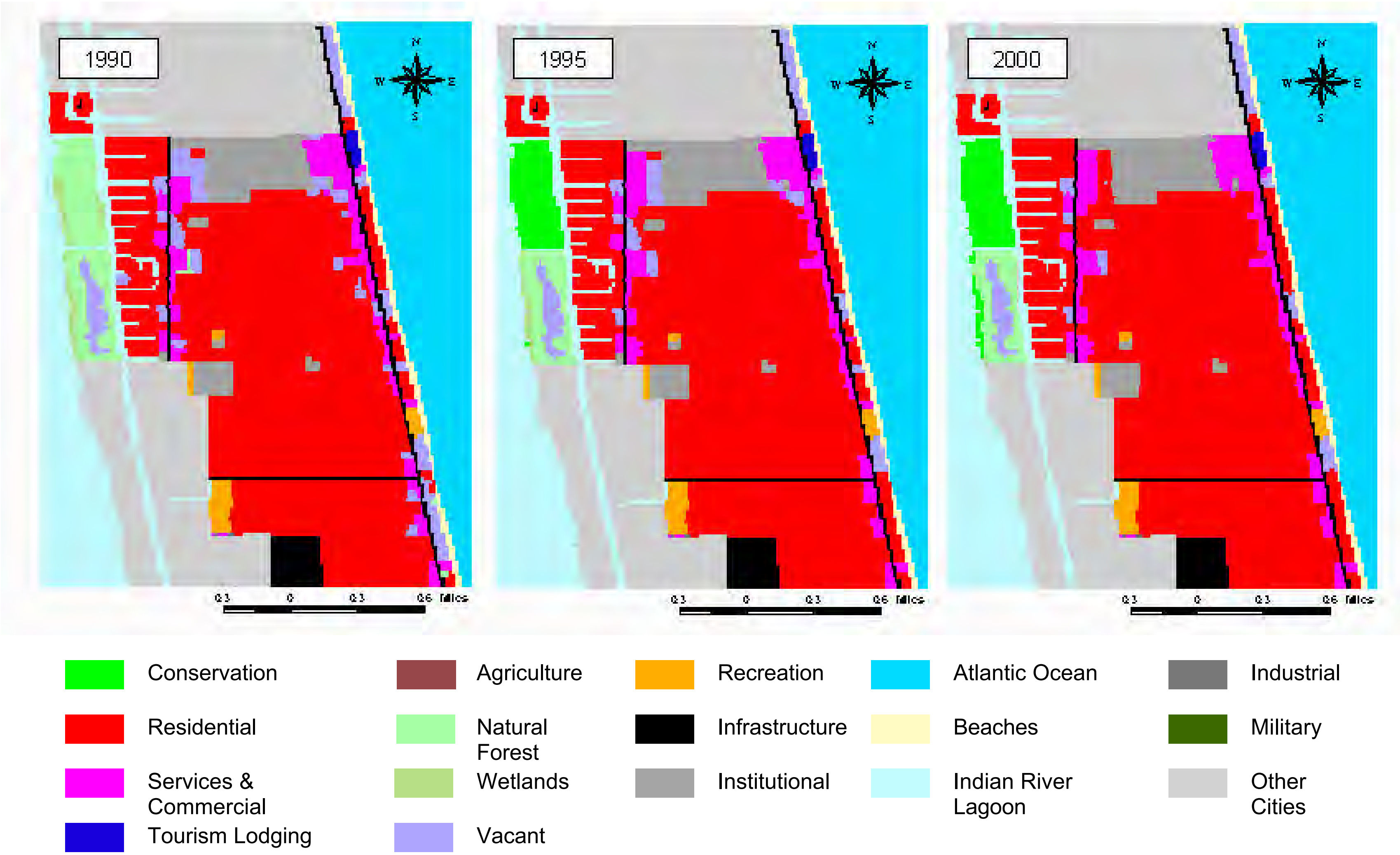

Figure 10. Simulation Run 2 - Calibration (1995) and Validation (2000) land use patterns for the City of Satellite Beach

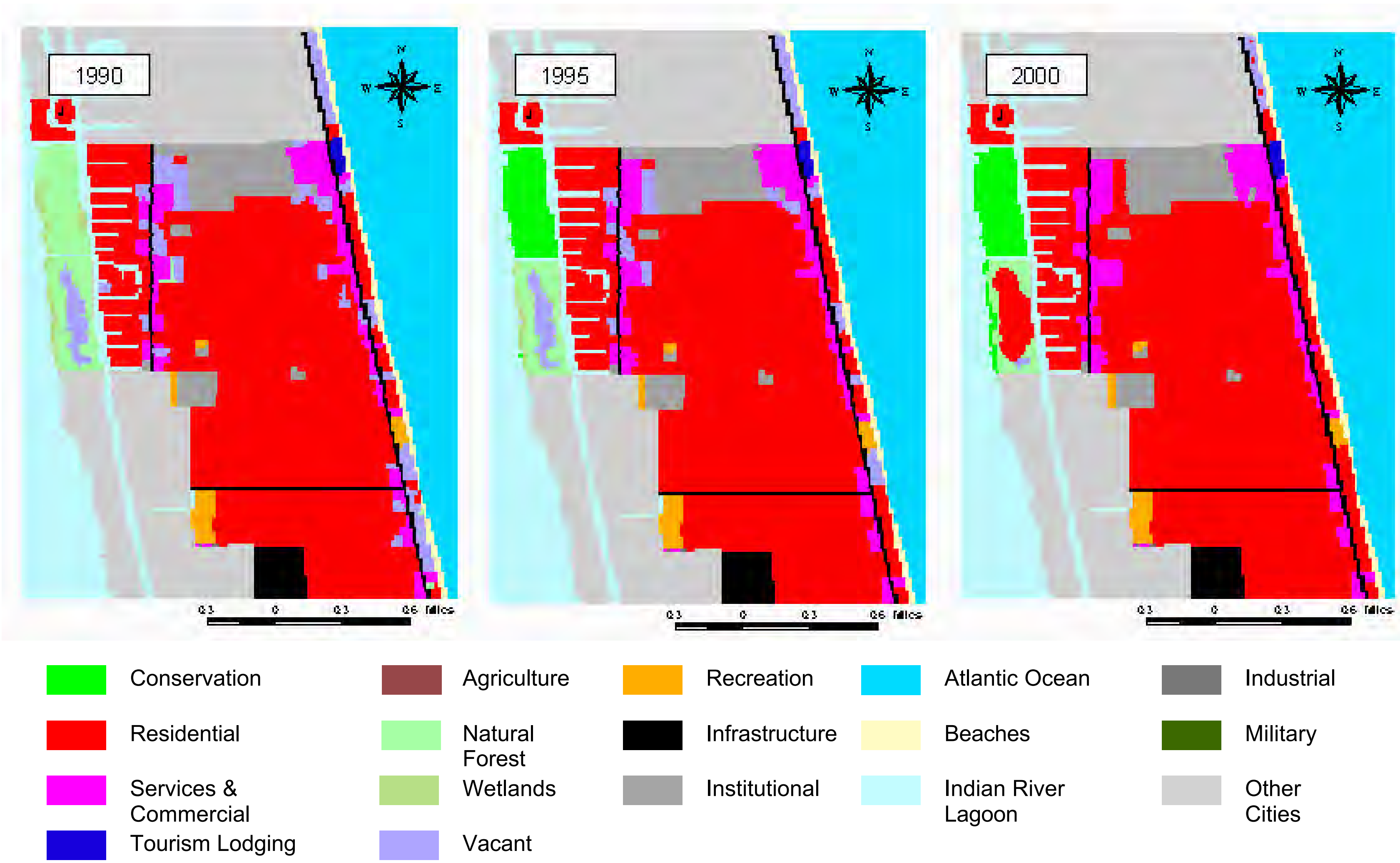

Figure 11. Simulation Run 3 - Calibration (1995) and Validation (2000) land use patterns for the City of Satellite Beach

KHAT Statistics

Table 5. KHAT Statistic for the observed land use patterns for the City of Satellite Beach

		Observed	
Years	**1990-1995**	**1995-2000**	**1990-2000**
% Cell Change	5.95	1.67	7.62
KHAT	0.895	0.97	0.864
KHAT VAR	0.00001739	0.00000538	0.00002238
Z (0_5 and 5_10)		-15.717	
Level of Significance		99 %	

Table 6. KHAT Statistic for each calibration run for the City of Satellite Beach

		Run 1	
Years	**1990-1995**	**1995-2000**	**1990-1995**
% Cell Change	6	1.7	7.7
KHAT	0.894	0.969	0.863
KHAT VAR	0.00001754	0.00000549	0.00002262
Z (0_5 and 5_10)		-15.628	
Level of Significance		99 %	

		Run 2	
Years	**1990-1995**	**1995-2000**	**1990-1995**
% Cell Change	6	1.7	7.7
KHAT	0.894	0.969	0.863
KHAT VAR	0.00001754	0.00000549	0.00002262
Z (0_5 and 5_10)		-15.628	
Level of Significance		99 %	

		Run 3	
Years	**1990-1995**	**1995-2000**	**1990-1995**
% Cell Change	6	1.7	7.7
KHAT	0.894	0.969	0.863
KHAT VAR	0.00001754	0.00000549	0.00002262
Z (0_5 and 5_10)		-15.628	
Level of Significance		99 %	

Table 7. Test of KHAT Statistic between Observed and Simulated land use patterns to the 99 % Significance Interval

Years: 1990-1995	Observed	Run 1	Run 2	Run 3	Significance Level
% Cell Change	5.95	6	6	6	
KHAT	0.895	0.894	0.894	0.894	
KHAT VAR	0.00001739	0.00001754	0.00001754	0.00001754	
Z (0_5 Observed and 0_5 Run 1)		0.169			99 %
Z (0_5 Observed and 0_5 Run 2)			0.169		99 %
Z (0_5 Observed and 0_5 Run 3)				0.169	99 %

Years: 1995-2000	Observed	Run 1	Run 2	Run 3	
% Cell Change	1.67	1.70	1.7	6	
KHAT	0.97	0.969	0.969	0.894	
KHAT VAR	0.00000538	0.00000549	0.00000549	0.00001754	
Z (5_10 Observed and 5_10 Run 1)		0.303			99 %
Z (5_10 Observed and 5_10 Run 2)			0.303		99 %
Z (5_10 Observed and 5_10 Run 3)				0.169	99 %

Years: 1990-2000	Observed	Run 1	Run 2	Run 3	
% Cell Change	7.62	7.7	7.7	7.7	
KHAT	0.864	0.863	0.863	0.863	
KHAT VAR	0.00002238	0.00002262	0.00002262	0.00002262	
Z (0_10 Observed and 0_10 Run 1)		0.149			99 %
Z (0_10 Observed and 0_10 Run 2)			0.149	0.149	99 %
Z (0_10 Observed and 0_10 Run 3)					99 %

Table 8a. KHAT Statistic for each Run for Scenario 1

Scenario 1		Run 1	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	3.44	2.23	5.67
KHAT	0.935	0.955	0.889
KHAT VAR	0.00001198	0.00000902	0.00002036
Z (0_5 and 5_10)		-4.364	
Level of Significance		99 %	

Scenario 1		Run 2	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	3.44	2.24	5.68
KHAT	0.935	0.954	0.889
KHAT VAR	0.00001198	0.00000906	0.0000204
Z (0_5 and 5_10)		-4.142	
Level of Significance		99 %	

Scenario 1		Run 3	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	3.44	2.22	5.66
KHAT	0.935	0.955	0.89
KHAT VAR	0.00001198	0.00000897	0.00002032
Z (0_5 and 5_10)		-4.370	
Level of Significance		99 %	

Table 8b. Test of KHAT Statistic between Runs for Scenario 1 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	3.44	3.44	3.44	
KHAT	0.935	0.935	0.935	
KHAT VAR	0.00001198	0.00001198	0.00001198	
Z (0_5 Run 1 and 0_5 Run 2)		0.000		99 %
Z (0_5 Run 1 and 0_5 Run 3)			0.000	99 %
Z (0_5 Run 2 and 0_5 Run 3)			0.000	99 %
Years: 2005-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	2.23	2.24	2.22	
KHAT	0.955	0.954	0.955	
KHAT VAR	0.00000902	0.00000906	0.00000897	
Z (5_10 Run 1 and 5_10 Run 2)		0.235		99 %
Z (5_10 Run 1 and 5_10 Run 3)			0.000	99 %
Z (5_10 Run 2 and 5_10 Run 3)			-0.236	99 %
Years: 2000-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	5.67	5.68	5.66	
KHAT	0.889	0.889	0.89	
KHAT VAR	0.00002036	0.0000204	0.00002032	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			-0.157	99 %
Z (0_10 Run 2 and 0_10 Run 3)			-0.157	99 %

Table 9a. KHAT Statistic for each Run for Scenario 2

Scenario 2		Run 1	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.53	4.24	9.77
KHAT	0.892	0.906	0.799
KHAT VAR	0.00001982	0.00002011	0.00003716
Z (0_5 and 5_10)		-2.216	
Level of Significance		99 %	

Scenario 2		Run 2	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.53	4.24	9.77
KHAT	0.892	0.906	0.799
KHAT VAR	0.00001982	0.00002011	0.00003716
Z (0_5 and 5_10)		-2.216	
Level of Significance		99 %	

Scenario 2		Run 3	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.44	4.33	9.77
KHAT	0.894	0.904	0.799
KHAT VAR	0.00001947	0.00002045	0.00003716
Z (0_5 and 5_10)		-1.583	
Level of Significance		99 %	

Table 9b. Test of KHAT Statistic between Runs for Scenario 2 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	5.53	5.53	5.44	
KHAT	0.892	0.892	0.894	
KHAT VAR	0.00001982	0.00001982	0.00001947	
Z (0_5 Run 1 and 0_5 Run 2)		0.000		99 %
Z (0_5 Run 1 and 0_5 Run 3)			-0.319	99 %
Z (0_5 Run 2 and 0_5 Run 3)			-0.319	99 %
Years: 2005-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	4.24	4.24	4.33	
KHAT	0.906	0.906	0.904	
KHAT VAR	0.00002011	0.00002011	0.00002045	
Z (5_10 Run 1 and 5_10 Run 2)		0.000		99 %
Z (5_10 Run 1 and 5_10 Run 3)			0.314	99 %
Z (5_10 Run 2 and 5_10 Run 3)			0.314	99 %
Years: 2000-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	9.77	9.77	9.77	
KHAT	0.799	0.799	0.799	
KHAT VAR	0.00003716	0.00003716	0.00003716	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			0.000	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

Table 10a. KHAT Statistic for each Run for Scenario 3

Scenario 3		Run 1	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.69	0	5.69
KHAT	0.892	1	0.892
KHAT VAR	0.00001926	0	0.00001926
Z (0_5 and 5_10)		-24.609	
Level of Significance		99 %	

Scenario 3		Run 2	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.59	0.1	5.69
KHAT	0.894	0.998	0.892
KHAT VAR	0.00001891	0.00000039	0.00001924
Z (0_5 and 5_10)		-23.673	
Level of Significance		99 %	

Scenario 3		Run 3	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.57	0.12	5.69
KHAT	0.895	0.998	0.892
KHAT VAR	0.00001882	0.00000046	0.00001922
Z (0_5 and 5_10)		-23.458	
Level of Significance		99 %	

Table 10b. Test of KHAT Statistic between Runs for Scenario 3 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	5.69	5.59	5.57	
KHAT	0.892	0.894	0.895	
KHAT VAR	0.00001926	0.00001891	0.00001882	
Z (0_5 Run 1 and 0_5 Run 2)		-0.324		99 %
Z (0_5 Run 1 and 0_5 Run 3)			-0.486	Significant
Z (0_5 Run 2 and 0_5 Run 3)			-0.163	99 %
Years: 2005-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	0	0.1	0.12	
KHAT	1	0.998	0.998	
KHAT VAR	0	0.00000039	0.00000046	
Z (5_10 Run 1 and 5_10 Run 2)		3.203		Significant
Z (5_10 Run 1 and 5_10 Run 3)			2.949	Significant
Z (5_10 Run 2 and 5_10 Run 3)			0.000	99 %
Years: 2000-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	5.69	5.69	5.69	
KHAT	0.892	0.892	0.892	
KHAT VAR	0.00001926	0.00001924	0.00001922	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			0.000	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

Table 11a. KHAT Statistic for each Run for Scenario 4

Scenario 4		Run 1	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	3.44	2.85	6.29
KHAT	0.935	0.942	0.876
KHAT VAR	0.00001198	0.00001164	0.00002278
Z (0_5 and 5_10)		-1.440	
Level of Significance		99 %	

Scenario 4		Run 2	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	3.44	2.85	6.29
KHAT	0.935	0.942	0.876
KHAT VAR	0.00001198	0.00001164	0.00002278
Z (0_5 and 5_10)		-1.440	
Level of Significance		99 %	

Scenario 4		Run 3	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	3.44	2.85	6.29
KHAT	0.935	0.942	0.876
KHAT VAR	0.00001198	0.00001164	0.00002278
Z (0_5 and 5_10)		-1.440	
Level of Significance		99 %	

Table 11b. Test of KHAT Statistic between Runs for Scenario 4 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	3.44	3.44	3.44	
KHAT	0.935	0.935	0.935	
KHAT VAR	0.00001198	0.00001198	0.00001198	
Z (0_5 Run 1 and 0_5 Run 2)		0.000		99 %
Z (0_5 Run 1 and 0_5 Run 3)			0.000	99 %
Z (0_5 Run 2 and 0_5 Run 3)			0.000	99 %
Years: 2005-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	2.85	2.85	2.85	
KHAT	0.942	0.942	0.942	
KHAT VAR	0.00001164	0.00001164	0.00001164	
Z (5_10 Run 1 and 5_10 Run 2)		0.000		99 %
Z (5_10 Run 1 and 5_10 Run 3)			0.000	99 %
Z (5_10 Run 2 and 5_10 Run 3)			0.000	99 %
Years: 2000-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	6.29	6.29	6.29	
KHAT	0.876	0.876	0.876	
KHAT VAR	0.00002278	0.00002278	0.00002278	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			0.000	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

Table 12a. KHAT Statistic for each Run for Scenario 5

Scenario 5		Run 1	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.69	0	5.69
KHAT	0.893	1	0.893
KHAT VAR	0.00001902	0	0.00001902
Z (0_5 and 5_10)		-24.535	
Level of Significance		99 %	

Scenario 5		Run 2	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.69	0	5.69
KHAT	0.893	1	0.893
KHAT VAR	0.00001901	0	0.00001901
Z (0_5 and 5_10)		-24.541	
Level of Significance		99 %	

Scenario 5		Run 3	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.69	0	5.69
KHAT	0.893	1	0.893
KHAT VAR	0.00001896	0	0.00001896
Z (0_5 and 5_10)		-24.573	
Level of Significance		99 %	

Table 12b. Test of KHAT Statistic between Runs for Scenario 5 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	5.69	5.69	5.69	
KHAT	0.893	0.893	0.893	
KHAT VAR	0.00001902	0.00001901	0.00001896	
Z (0_5 Run 1 and 0_5 Run 2)		0.000		99 %
Z (0_5 Run 1 and 0_5 Run 3)			0.000	99 %
Z (0_5 Run 2 and 0_5 Run 3)			0.000	99 %
Years: 2005-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	0	0	0	
KHAT	1	1	1	
KHAT VAR	0	0	0	
Z (5_10 Run 1 and 5_10 Run 2)		-	-	99 %
Z (5_10 Run 1 and 5_10 Run 3)			-	99 %
Z (5_10 Run 2 and 5_10 Run 3)			-	99 %
Years: 2000-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	5.69	5.69	5.69	
KHAT	0.893	0.893	0.893	
KHAT VAR	0.00001902	0.00001901	0.00001896	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			0.000	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

Table 13a. KHAT Statistic for each Run for Scenario 6

Scenario 6		Run 1	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.86	0	5.86
KHAT	0.89	1	0.89
KHAT VAR	0.00001937	0	0.00001937
Z (0_5 and 5_10)		-24.994	
Level of Significance		99 %	

Scenario 6		Run 2	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.86	0.02	5.86
KHAT	0.89	1	0.89
KHAT VAR	0.00001932	0.00000007	0.00001931
Z (0_5 and 5_10)		-24.981	
Level of Significance		99 %	

Scenario 6		Run 3	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.86	0	5.86
KHAT	0.89	1	0.89
KHAT VAR	0.00001938	0	0.00001938
Z (0_5 and 5_10)		-24.987	
Level of Significance		99 %	

Table 13b. Test of KHAT Statistic between Runs for Scenario 6 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	5.86	5.86	5.86	
KHAT	0.89	0.89	0.89	
KHAT VAR	0.00001937	0.00001932	0.00001938	
Z (0_5 Run 1 and 0_5 Run 2)		0.000		99 %
Z (0_5 Run 1 and 0_5 Run 3)			0.000	99 %
Z (0_5 Run 2 and 0_5 Run 3)			0.000	99 %
Years: 2005-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	0	0.02	0	
KHAT	1	1	1	
KHAT VAR	0	0.00000007	0	
Z (5_10 Run 1 and 5_10 Run 2)		0.000		99 %
Z (5_10 Run 1 and 5_10 Run 3)			-	99 %
Z (5_10 Run 2 and 5_10 Run 3)			0.000	99 %
Years: 2000-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	5.86	5.86	5.86	
KHAT	0.89	0.89	0.89	
KHAT VAR	0.00001937	0.00001931	0.00001938	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			0.000	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

Table 14a. KHAT Statistic for each Run for Scenario 7

Scenario 7		Run 1	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.7	0	5.7
KHAT	0.893	1	0.893
KHAT VAR	0.00001906	0	0.00001906
Z (0_5 and 5_10)		-24.509	
Level of Significance		99 %	

Scenario 7		Run 2	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.7	0.05	5.7
KHAT	0.893	0.999	0.893
KHAT VAR	0.00001903	0.00000019	0.00001904
Z (0_5 and 5_10)		-24.178	
Level of Significance		99 %	

Scenario 7		Run 3	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	5.7	0	5.7
KHAT	0.893	1	0.893
KHAT VAR	0.00001906	0	0.00001906
Z (0_5 and 5_10)		-24.509	
Level of Significance		99 %	

Table 14b. Test of KHAT Statistic between Runs for Scenario 7 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	5.7	5.7	5.7	
KHAT	0.893	0.893	0.893	
KHAT VAR	0.00001906	0.00001903	0.00001906	
Z (0_5 Run 1 and 0_5 Run 2)		0.000		99 %
Z (0_5 Run 1 and 0_5 Run 3)			0.000	99 %
Z (0_5 Run 2 and 0_5 Run 3)			0.000	99 %
Years: 2005-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	0	0.05	0	
KHAT	1	0.999	1	
KHAT VAR	0	0.00000019	0	
Z (5_10 Run 1 and 5_10 Run 2)		2.294		Significant
Z (5_10 Run 1 and 5_10 Run 3)			-	99 %
Z (5_10 Run 2 and 5_10 Run 3)			-2.294	Significant
Years: 2000-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	5.7	5.7	5.7	
KHAT	0.893	0.893	0.893	
KHAT VAR	0.00001906	0.00001904	0.00001906	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			0.000	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

Table 15a. KHAT Statistic for each Run for Scenario 8

Scenario 8		Run 1	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	4.48	2.85	7.33
KHAT	0.915	0.942	0.856
KHAT VAR	0.00001541	0.00001163	0.00002621
Z (0_5 and 5_10)		-5.192	
Level of Significance		99 %	

Scenario 8		Run 2	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	4.39	2.85	7.24
KHAT	0.917	0.942	0.858
KHAT VAR	0.00001512	0.00001163	0.00002592
Z (0_5 and 5_10)		-4.834	
		99 %	

Scenario 8		Run 3	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	4.39	2.85	7.24
KHAT	0.917	0.942	0.858
KHAT VAR	0.00001512	0.00001163	0.00002592
Z (0_5 and 5_10)		-4.834	
		99 %	

Table 15b. Test of KHAT Statistic between Runs for Scenario 8 to the 99 % Significance Interval

Years: 2000-2005	**Run 1**	**Run 2**	**Run 3**	**Significance Level**
% Cell Change	4.48	4.39	4.39	
KHAT	0.915	0.917	0.917	
KHAT VAR	0.00001541	0.00001512	0.00001512	
Z (0_5 Run 1 and 0_5 Run 2)		-0.362		90 %
Z (0_5 Run 1 and 0_5 Run 3)			-0.362	90 %
Z (0_5 Run 2 and 0_5 Run 3)			0.000	99 %
Years: 2005-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	2.85	2.85	2.85	
KHAT	0.942	0.942	0.942	
KHAT VAR	0.00001163	0.00001163	0.00001163	
Z (5_10 Run 1 and 5_10 Run 2)		0.000		99 %
Z (5_10 Run 1 and 5_10 Run 3)			0.000	99 %
Z (5_10 Run 2 and 5_10 Run 3)			0.000	99 %
Years: 2000-2010	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	7.33	7.24	7.24	
KHAT	0.856	0.858	0.858	
KHAT VAR	0.00002621	0.00002592	0.00002592	
Z (0_10 Run 1 and 0_10 Run 2)		-0.277		99 %
Z (0_10 Run 1 and 0_10 Run 3)			-0.277	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

APPENDIX C

South Beaches Unincorporated Area Case Study

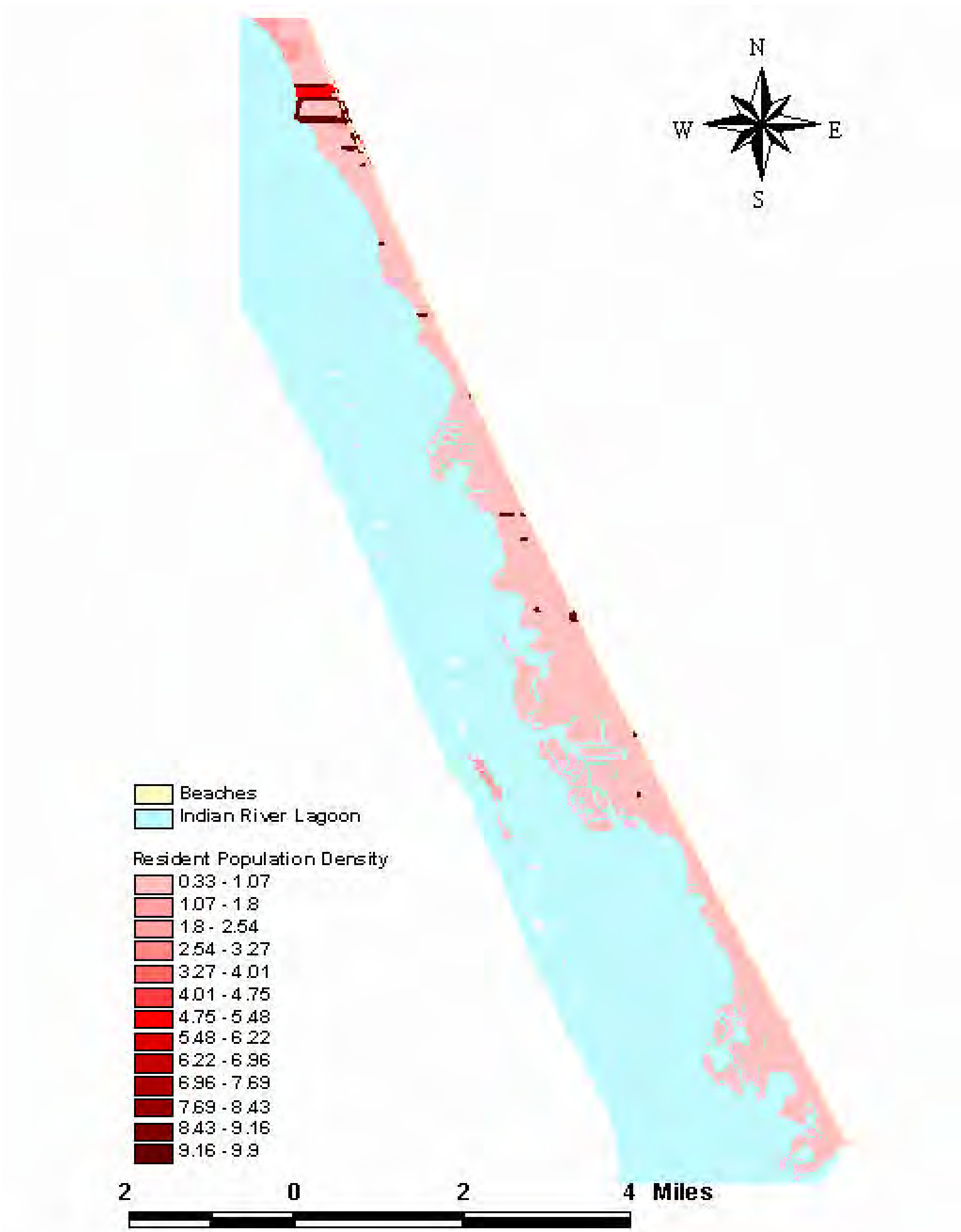

Figure 1. Resident Population Density

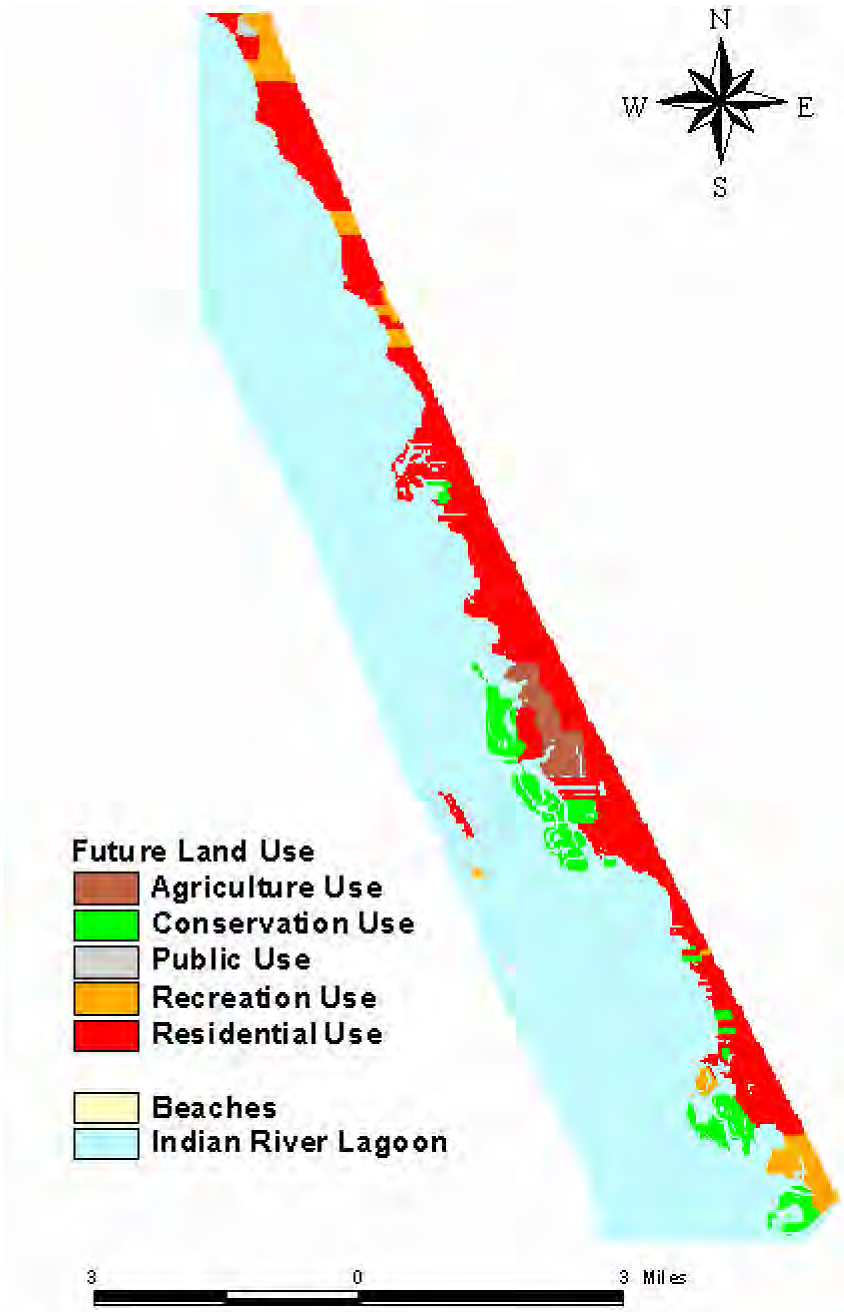

Figure 2. Future Land Use (Source: BC, BCPAO)

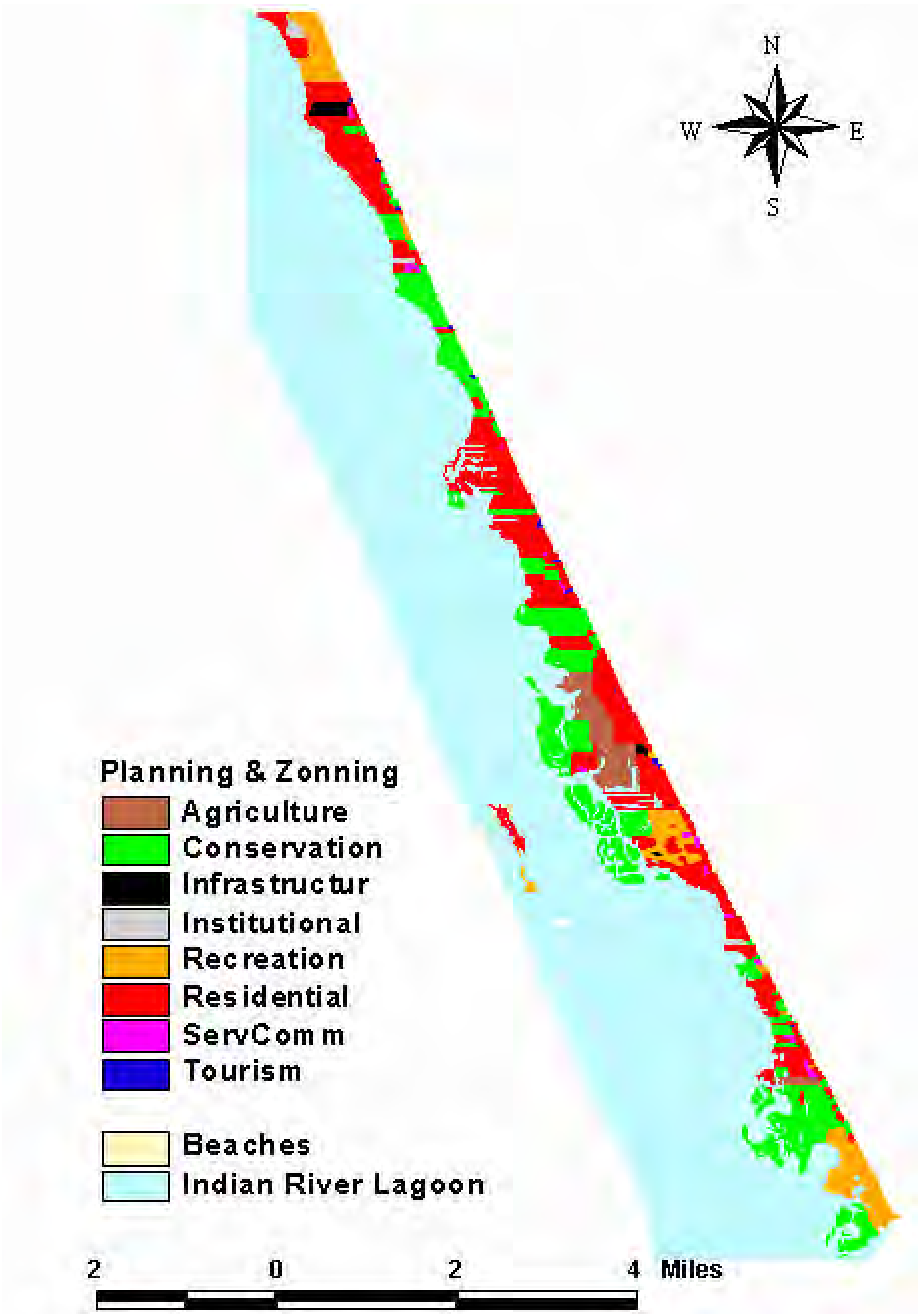

Figure 3. Planning and Zoning (Source: BCPAO)

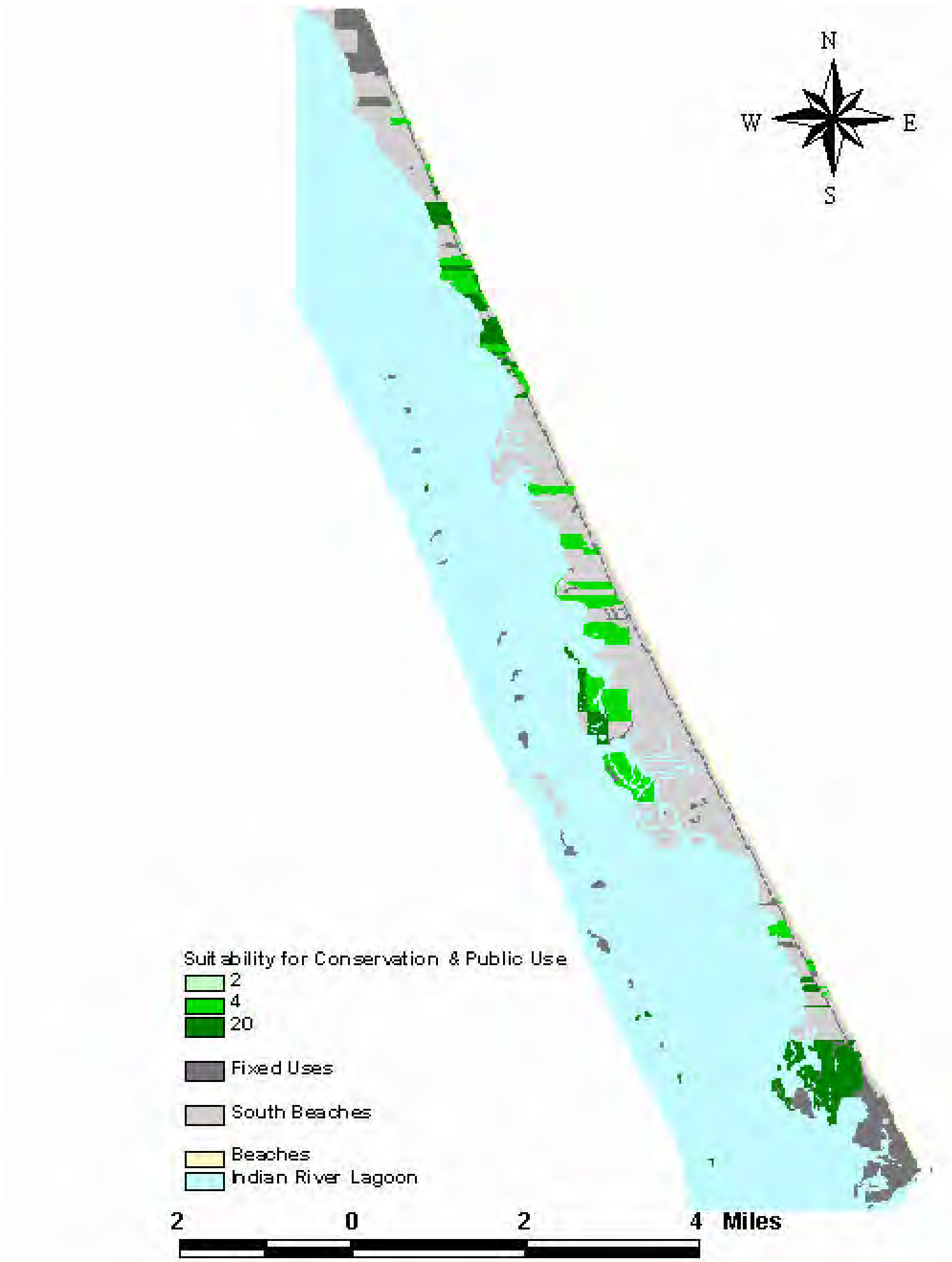

Figure 4. Suitability for Conservation Use

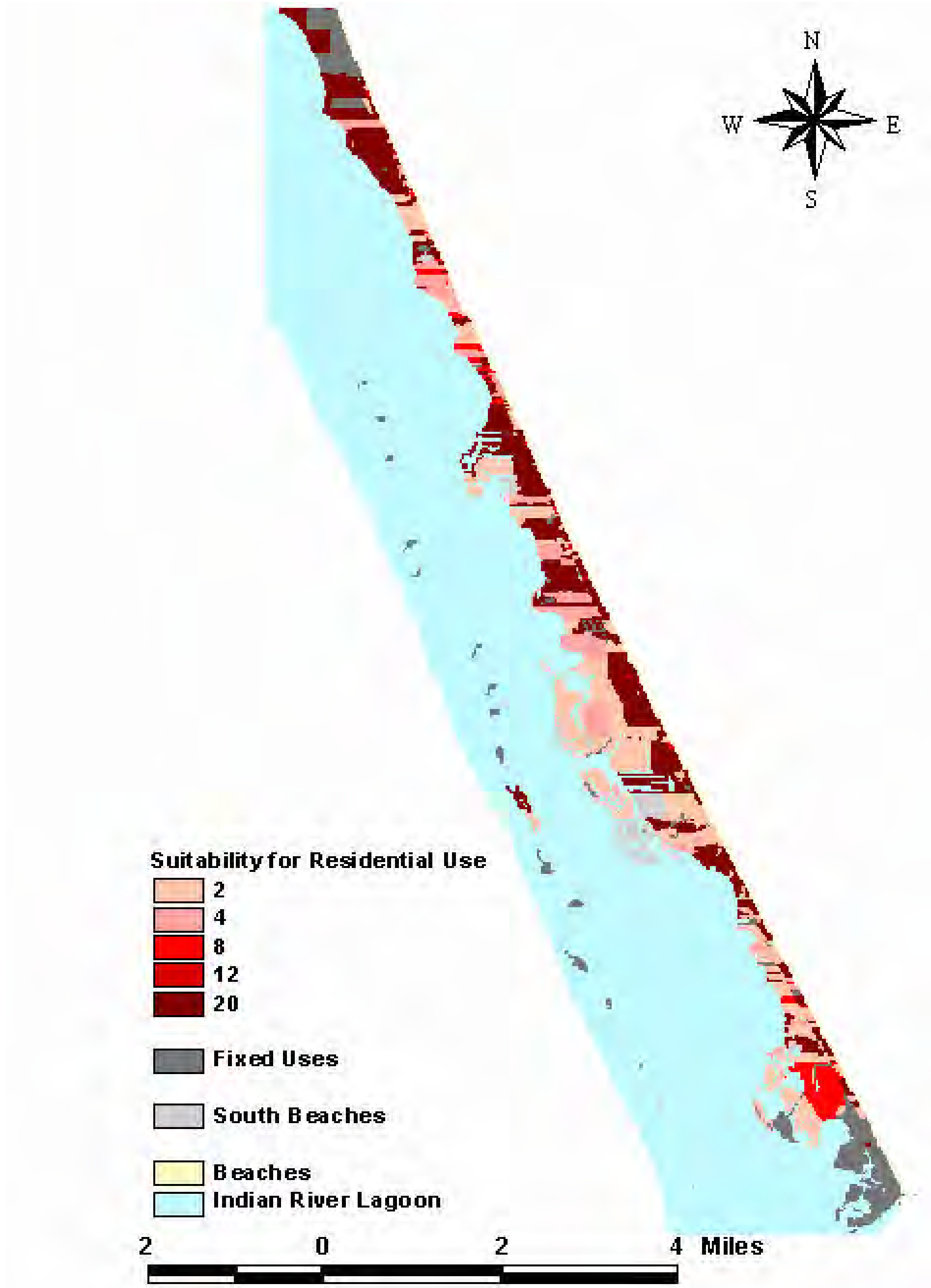

Figure 5. Suitability for Residential Use

Figure 6. Suitability for Services and Commercial Use

Distance Neighborhood Calibration

Table 1 - Distance neighborhood weights that represent the influence of the different land uses on one another for the South Beaches Unincorporated Area

LAND USE	Conservation		Services & Commerce		Residential		Tourism Lodging	
	D1	D2	D1	D2	D1	D2	D1	D2
Indian River Lagoon	0	75	0	10	0	80	0	25
Ocean	0	50	0	50	0	50	0	75
Beach	0	50	0	10	0	65	0	85
Agriculture	0	30	0	5	0	20	0	5
Services & Commercial	0	10	250	250	0	100	0	40
Conservation	300	300	0	0	0	25	0	0
Industrial	0	0	0	50	0	0	0	0
Infrastructure	0	70	0	75	0	75	0	65
Institutional	0	20	0	40	0	85	0	0
Natural Forest	0	140	0	30	0	75	0	25
Military	0	5	0	15	0	10	0	0
Recreation	0	20	0	20	0	25	0	30
Tourism Lodging	0	10	0	60	0	20	300	300
Residential	0	40	0	60	300	300	0	20
Vacant	0	30	0	70	0	80	0	60
Wetlands	0	80	0	0	0	45	0	0

Table 2. Comparison between simulated results and the calibration (1995) and validation grids (2000) in terms of land allocated and percentage change

Existing	Observed			Land Change (acres)		Land Allocated (%)		Annual Average (acres)	
	1990	1995	2000	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Conservation	227.1	538.65	1076.7	311.6	538.1	137.2	99.9	62.3	108
Residential	1068.9	1435.7	1510.7	366.8	75	34.3	5.2	73.4	15.0
Services & Commercial	23.7	24.45	26.25	0.75	1.8	3.2	7.4	0.2	0.4
Tourism Lodging	19.2	19.2	19.2	0	0	0.0	0.0	0.0	0.0

Table 3. Comparison between simulated results and the calibration (1995) and validation grids (2000) in terms of land allocated and percentage change

Simulation	Run 1			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	1990	1995	2000	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Conservation	227.1	537.9	1044.3	310.8	506.4	136.9	94.1	62.3	108
Residential	1068.9	1435.7	1510.7	366.8	75.0	34.3	5.2	73.4	15
Services & Commercial	23.7	24.45	26.7	0.8	2.3	3.2	9.2	0.15	0.4
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0.0	0.0

Table 3. (Cont.). Comparison between simulated results and the calibration (1995) and validation grids (2000) in terms of land allocated and percentage change

Simulation	Run 2			Land Change (acres)		Land Allocated (%)		Annual Request (acres)	
	1990	1995	2000	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Conservation	227.1	537.9	1043	310.8	505.1	136.9	93.9	62.3	108
Residential	1068.9	1435.7	1510.7	366.8	75.0	34.3	5.2	73.4	15
Services & Commercial	23.7	24.45	26.7	0.8	2.3	3.2	9.2	0.15	0.4
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0.0	0.0

Simulation	Run 3			Land Change (acres)		Land Allocated (%)		Annual Request (acres	
	1990	1995	2000	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Conservation	227.1	537.9	1043.4	310.8	505.5	136.9	94.0	62.3	108
Residential	1068.9	1435.7	1510.7	366.8	75.0	34.3	5.2	73.4	15
Services & Commercial	23.7	24.45	26.7	0.8	2.3	3.2	9.2	0.15	0.4
Tourism Lodging	19.2	19.2	19.2	0.0	0.0	0.0	0.0	0.0	0.0

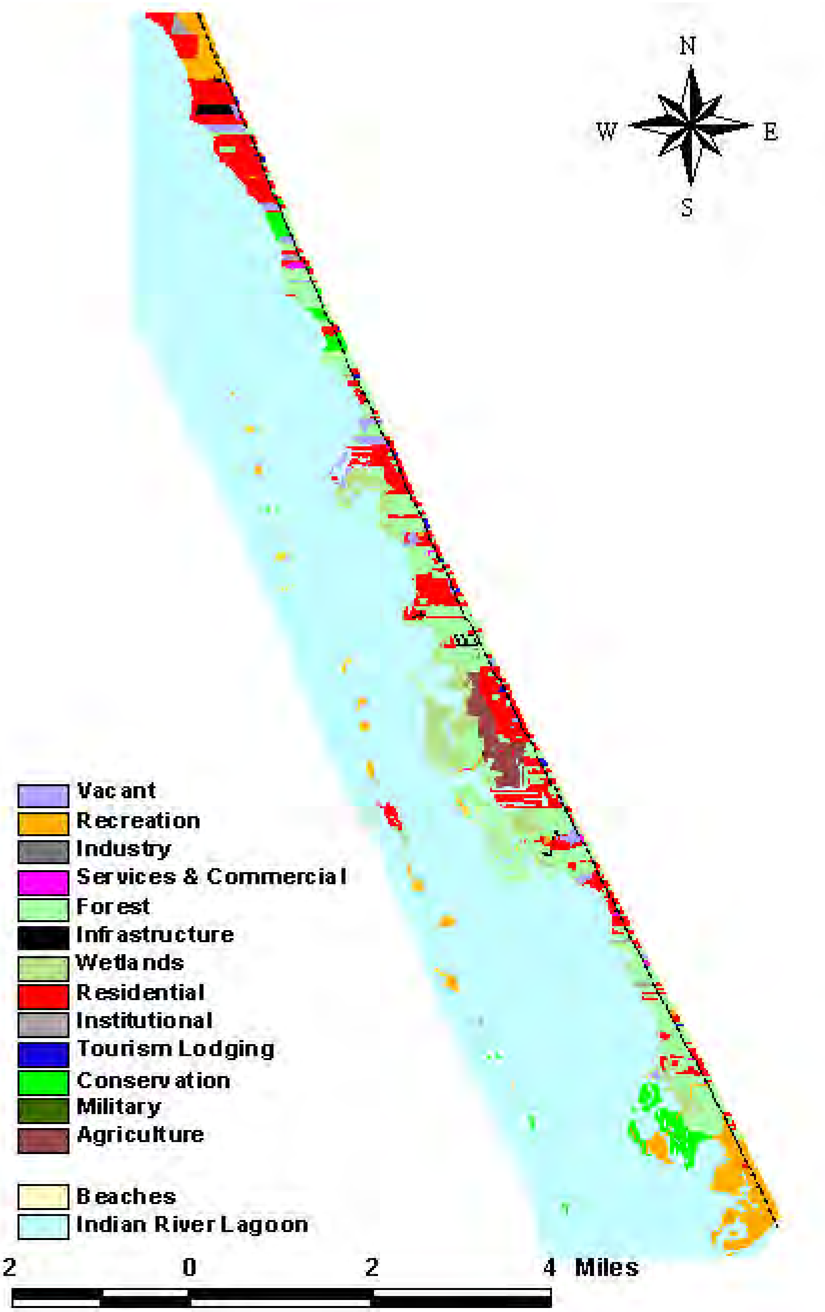

Figure 7a. Observed land use pattern for the South Beaches Area for 1990.

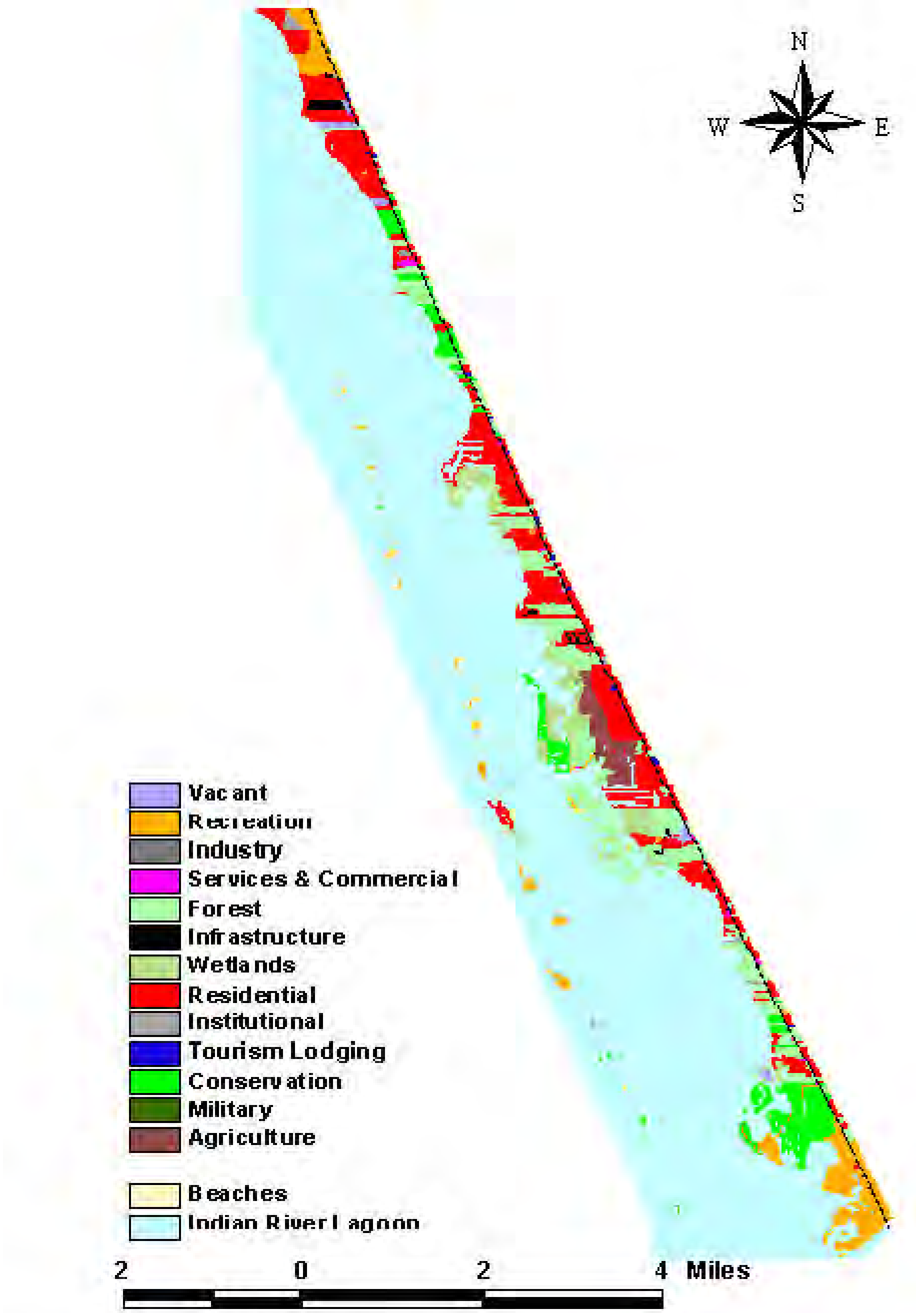

Figure 7b. Observed land use pattern for the South Beaches Area for 1995.

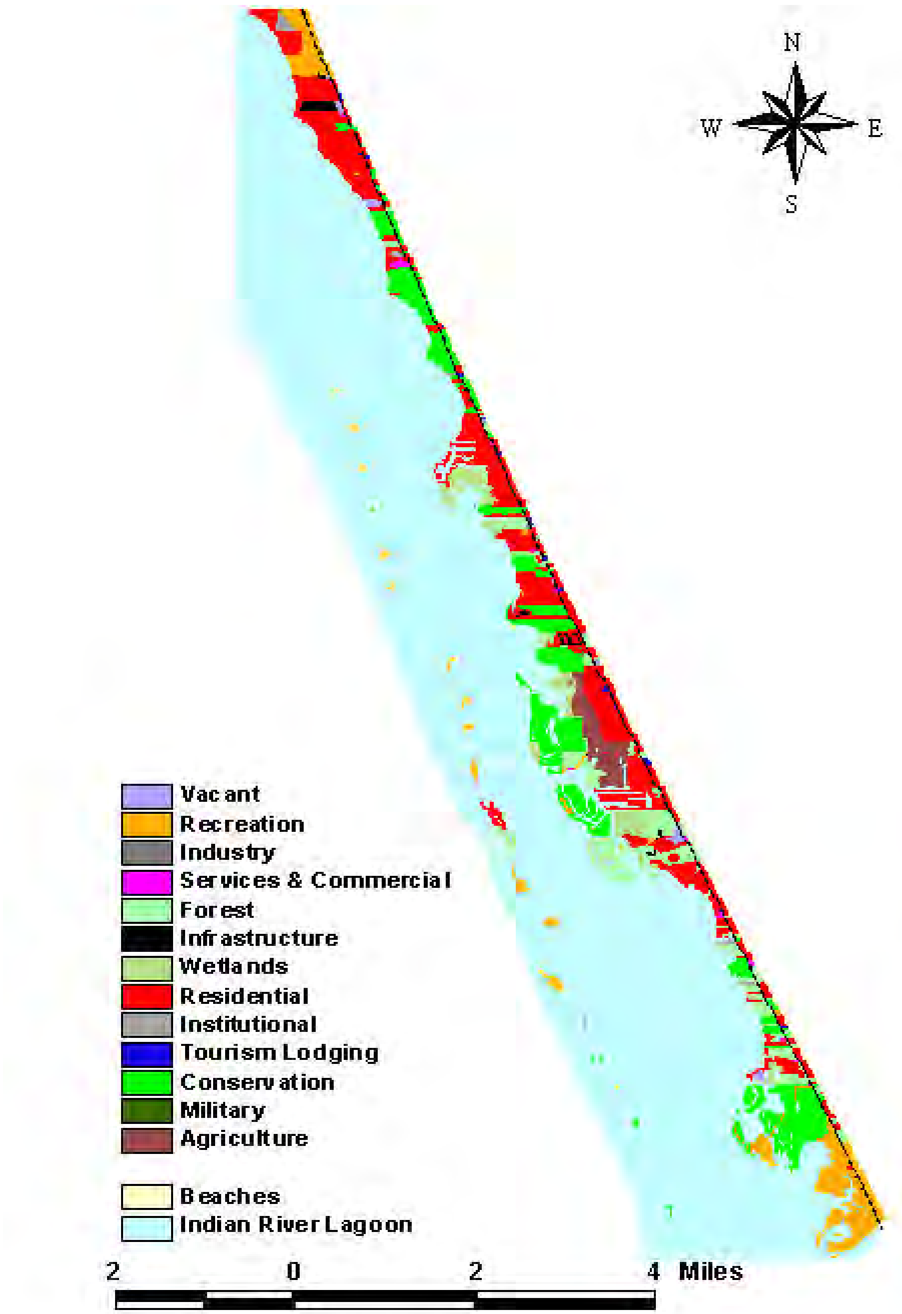

Figure 7c. Observed land use pattern for the South Beaches Area for 2000.

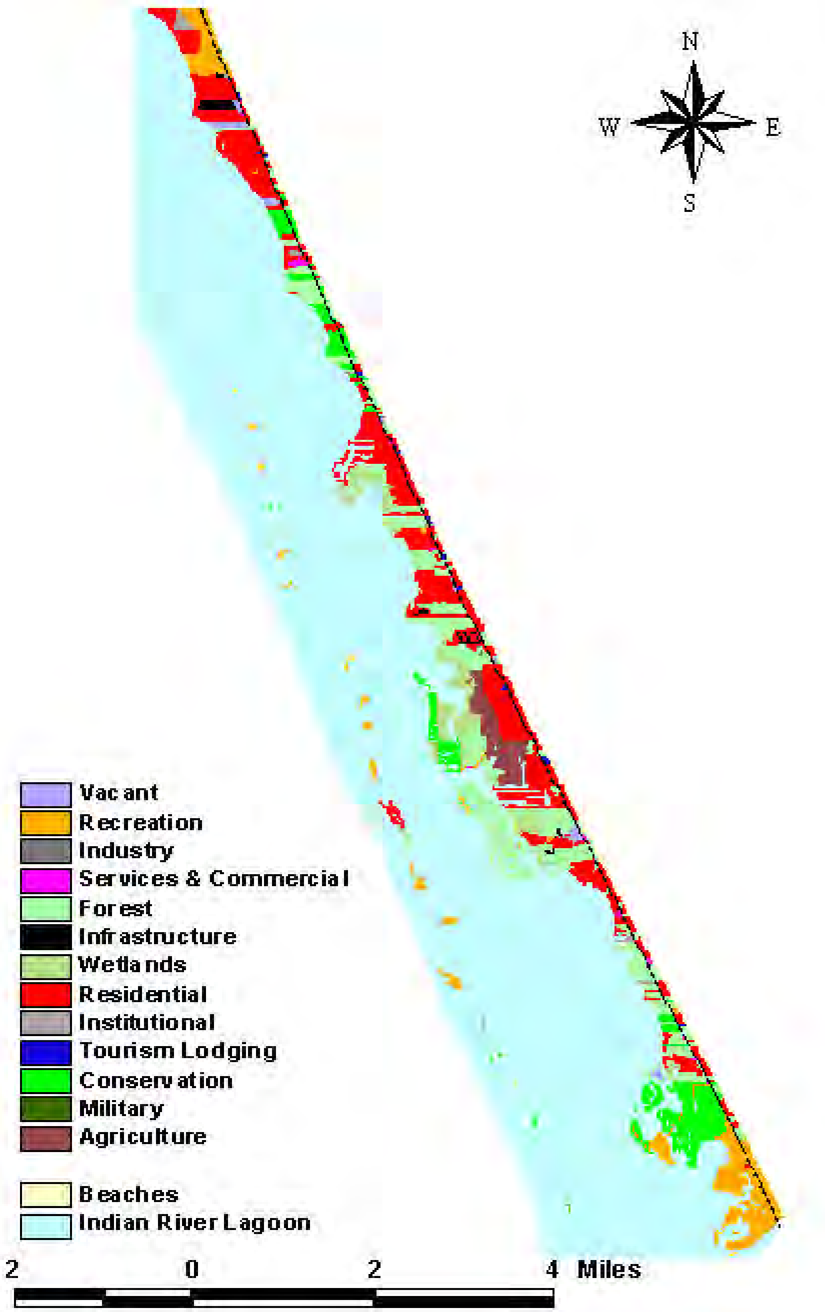

Figure 8a. Simulation Run 1 - Calibration (1995) land use pattern for the South Beaches Area

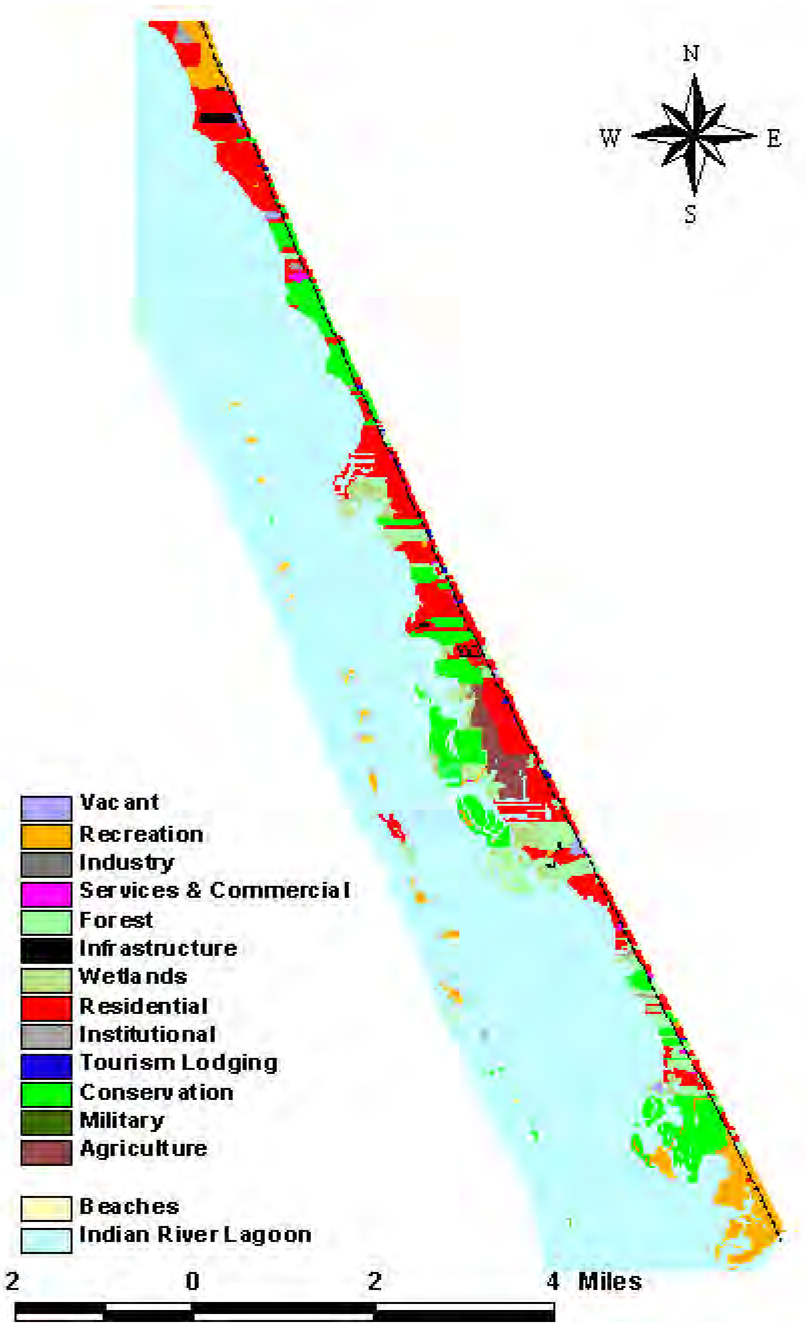

Figure 8b. Simulation Run 1 - Validation (2000) land use pattern for the South Beaches Area

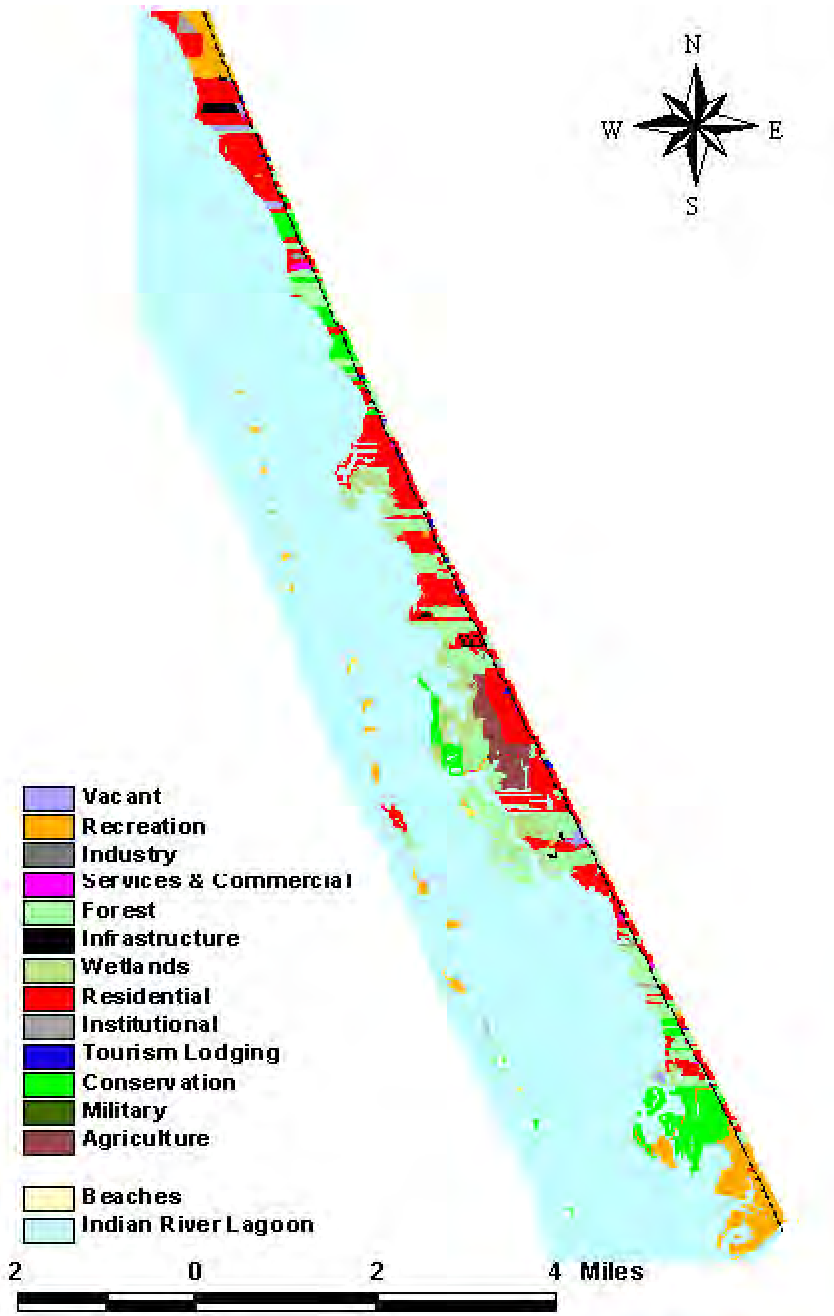

Figure 9a. Simulation Run 2 - Calibration (1995) land use pattern for the South Beaches Area

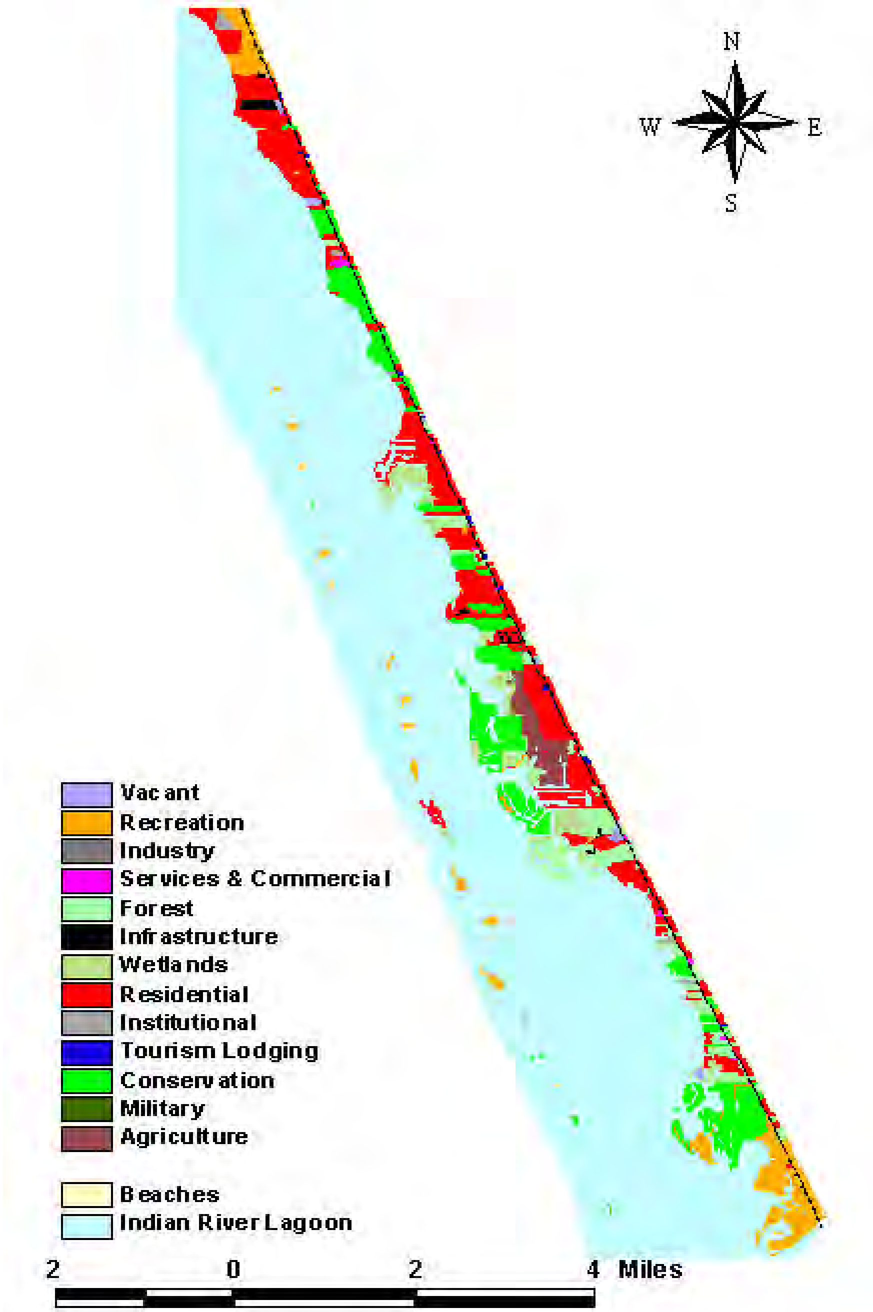

Figure 9b. Simulation Run 2 - Validation (2000) land use pattern for the South Beaches Area

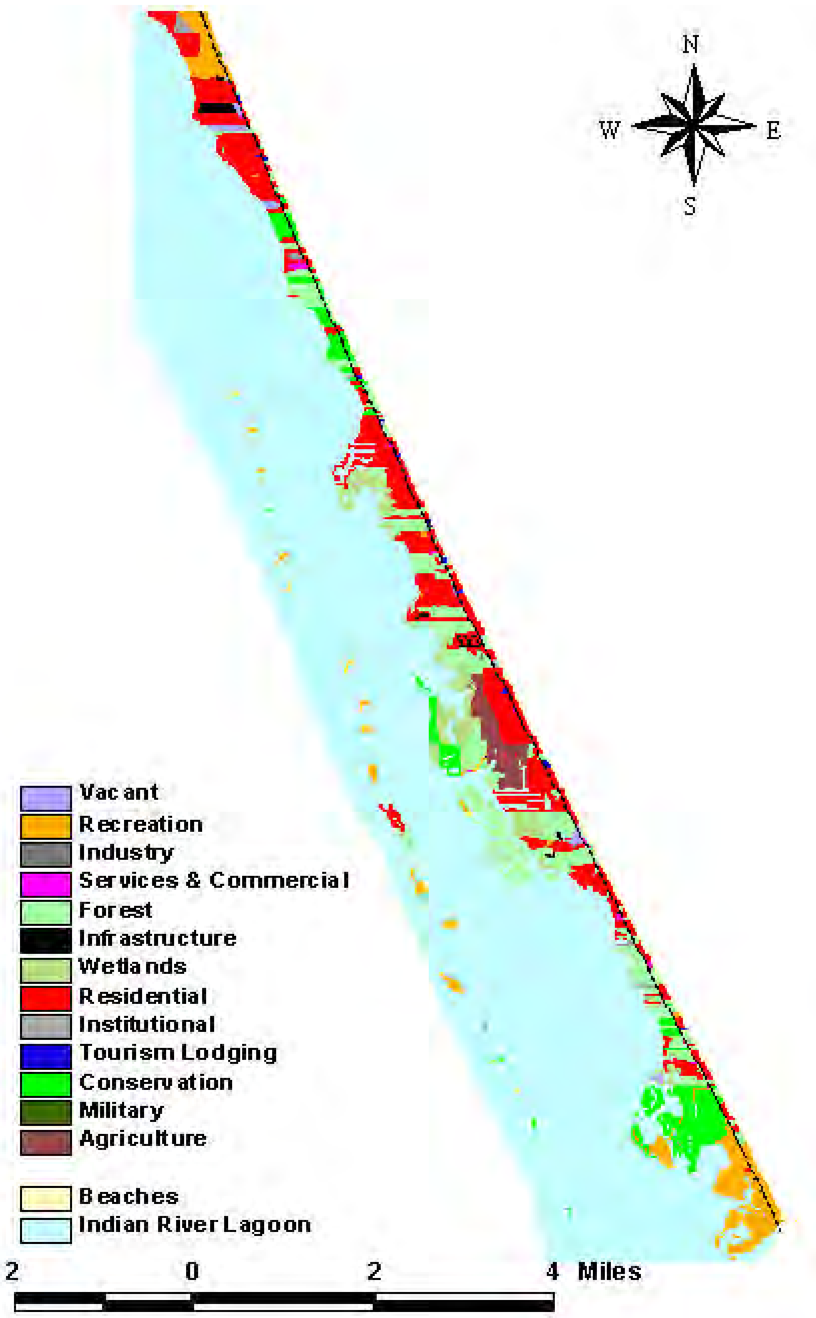

Figure 10a. Simulation Run 3 - Calibration (1995) land use pattern for the South Beaches Area

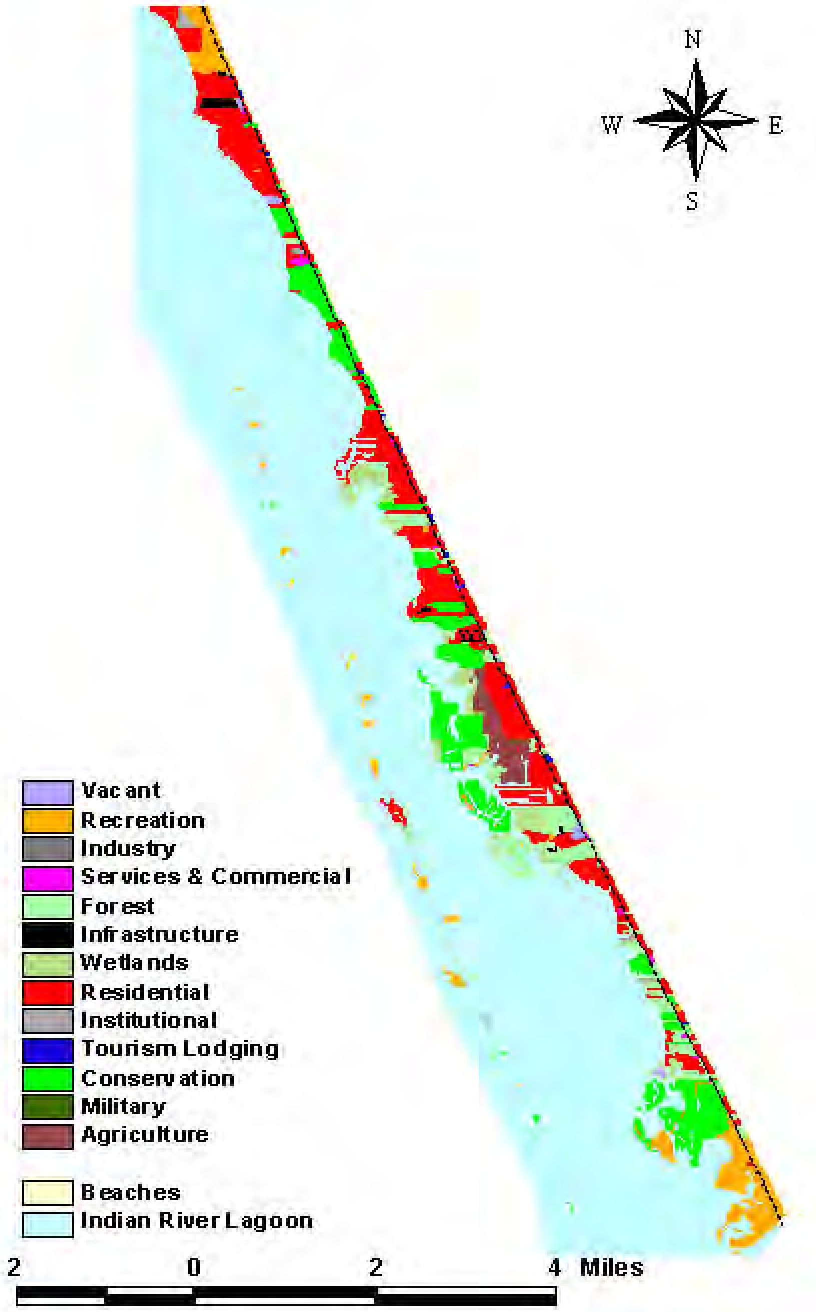

Figure 10b. Simulation Run 3 - Validation (2000) land use pattern for the South Beaches Area

KHAT Statistics

Table 4. KHAT Statistic for the observed land use patterns for the South Beaches Area

		Observed	
Years	**1990-1995**	**1995-2000**	**1990-2000**
% Cell Change	14.56	13.16	27.71
KHAT	0.825	0.841	0.677
KHAT VAR	0.00000576	0.00000535	0.00000876
Z (0_5 and 5_10)		-4.800	
Level of Significance		99 %	

Table 5. KHAT Statistic for each calibration run for the South Beaches Area

		Run 1	
Years	**1990-1995**	**1995-2000**	**1990-2000**
% Cell Change	14.52	12.49	27.01
KHAT	0.8256	0.849	0.6842
KHAT VAR	0.00000575	0.00000513	0.00000865
Z (0_5 and 5_10)		-7.094	
Level of Significance		99 %	

		Run 2	
Years	**1990-1995**	**1995-2000**	**1990-2000**
% Cell Change	14.52	12.46	26.98
KHAT	0.8256	0.8494	0.6845
KHAT VAR	0.00000575	0.00000512	0.00000865
Z (0_5 and 5_10)		-7.219	
Level of Significance		99 %	

		Run 3	
Years	**1990-1995**	**1995-2000**	**1990-2000**
% Cell Change	14.52	12.47	26.99
KHAT	0.8256	0.8493	0.6844
KHAT VAR	0.00000575	0.00000512	0.00000865
Z (0_5 and 5_10)		-7.188	
Level of Significance		99 %	

Table 6. Test of KHAT Statistic between Observed and Simulated land use patterns to the 99 % Significance Interval

Years: 1990-1995	**Observed**	**Run 1**	**Run 2**	**Run 3**	**Significance Level**
% Cell Change	14.56	14.52	14.52	14.52	
KHAT	0.825	0.8256	0.8256	0.8256	
KHAT VAR	0.00000576	0.00000575	0.00000575	0.00000575	
Z (0_5 Observed and 0_5 Run 1)		-0.177			99 %
Z (0_5 Observed and 0_5 Run 2)			-0.177		99 %
Z (0_5 Observed and 0_5 Run 3)				-0.177	99 %

Years: 1995-2000	**Observed**	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	13.16	12.49	12.46	12.47	
KHAT	0.841	0.849	0.8494	0.8493	
KHAT VAR	0.00000535	0.00000513	0.00000512	0.00000512	
Z (5_10 Observed and 5_10 Run 1)		-2.471			Significant
Z (5_10 Observed and 5_10 Run 2)			-2.596		Significant
Z (5_10 Observed and 5_10 Run 3)				-2.565	Significant

Years: 1990-2000	**Observed**	**Run 1**	**Run 2**	**Run 3**	
% Cell Change	27.71	27.01	26.98	26.99	
KHAT	0.677	0.6842	0.6845	0.6844	
KHAT VAR	0.00000876	0.00000865	0.00000865	0.00000865	
Z (0_10 Observed and 0_10 Run 1)		-1.726			Significant
Z (0_10 Observed and 0_10 Run 2)			-1.797	-1.774	Significant
Z (0_10 Observed and 0_10 Run 3)					Significant

Table 7a. KHAT Statistic for each Run for Scenario 1

Scenario 1		**Run 1**	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	17.07	0	17.07
KHAT	0.78	1	0.78
KHAT VAR	0.00000755	0	0.00000755
Z (0_5 and 5_10)		-80.066	
Level of Significance		99 %	

Scenario 1		**Run 2**	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	17.07	0	17.07
KHAT	0.78	1	0.78
KHAT VAR	0.00000755	0	0.00000755
Z (0_5 and 5_10)		-80.066	
Level of Significance		99 %	

Scenario 1		**Run 3**	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	17	0.07	17.07
KHAT	0.7809	0.9991	0.78
KHAT VAR	0.00000753	0.00000004	0.00000755
Z (0_5 and 5_10)		-79.306	
Level of Significance		99 %	

Table 7b. Test of KHAT Statistic between Runs for Scenario 1 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	17.07	17.07	17	
KHAT	0.78	0.78	0.7809	
KHAT VAR	0.00000755	0.00000755	0.00000753	
Z (0_5 Run 1 and 0_5 Run 2)		0.000		99 %
Z (0_5 Run 1 and 0_5 Run 3)			-0.232	99 %
Z (0_5 Run 2 and 0_5 Run 3)			-0.232	99 %

Years: 2005-2010	Run 1	Run 2	Run 3	Significance Level
% Cell Change	0	0	0.07	
KHAT	1	1	0.9991	
KHAT VAR	0	0	0.00000004	
Z (5_10 Run 1 and 5_10 Run 2)		-		99 %
Z (5_10 Run 1 and 5_10 Run 3)			4.500	Significant
Z (5_10 Run 2 and 5_10 Run 3)			4.500	Significant

Years: 2000-2010	Run 1	Run 2	Run 3	Significance Level
% Cell Change	17.07	17.07	17.07	
KHAT	0.78	0.78	0.78	
KHAT VAR	0.00000755	0.00000755	0.00000755	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			0.000	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

Table 8a. KHAT Statistic for each Run for Scenario 2

Scenario 2		Run 1	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	22.96	17.19	40.15
KHAT	0.7023	0.7043	0.4604
KHAT VAR	0.00000954	0.00001353	0.00001394
Z (0_5 and 5_10)		-0.416	
Level of Significance		99 %	

Scenario 2		Run 2	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	22.96	17.18	40.15
KHAT	0.7023	0.7043	0.4604
KHAT VAR	0.00000954	0.00001352	0.00001394
Z (0_5 and 5_10)		-0.416	
Level of Significance		99 %	

Scenario 2		Run 3	
Years	**2000-2005**	**2005-2010**	**2000-2010**
% Cell Change	22.96	17.18	40.15
KHAT	0.7023	0.7043	0.4604
KHAT VAR	0.00000954	0.00001352	0.00001394
Z (0_5 and 5_10)		-0.416	
Level of Significance		99 %	

Table 8b. Test of KHAT Statistic between Runs for Scenario 2 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	22.96	22.96	22.96	
KHAT	0.7023	0.7023	0.7023	
KHAT VAR	0.00000954	0.00000954	0.00000954	
Z (0_5 Run 1 and 0_5 Run 2)		0.000		99 %
Z (0_5 Run 1 and 0_5 Run 3)			0.000	99 %
Z (0_5 Run 2 and 0_5 Run 3)			0.000	99 %

Years: 2005-2010	Run 1	Run 2	Run 3	Significance Level
% Cell Change	17.19	17.18	17.18	
KHAT	0.7043	0.7043	0.7043	
KHAT VAR	0.00001353	0.00001352	0.00001352	
Z (5_10 Run 1 and 5_10 Run 2)		0.000		99 %
Z (5_10 Run 1 and 5_10 Run 3)			0.000	99 %
Z (5_10 Run 2 and 5_10 Run 3)			0.000	99 %

Years: 2000-2010	Run 1	Run 2	Run 3	Significance Level
% Cell Change	40.15	40.15	40.15	
KHAT	0.4604	0.4604	0.4604	
KHAT VAR	0.00001394	0.00001394	0.00001394	
Z (0_10 Run 1 and 0_10 Run 2)		0.000		99 %
Z (0_10 Run 1 and 0_10 Run 3)			0.000	99 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %

Table 9a. KHAT Statistic for each Run for Scenario 3

Scenario 3		Run 1	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	10.78	1.84	12.62
KHAT	0.8622	0.9749	0.8378
KHAT VAR	0.00000505	0.00000108	0.00000585
Z (0_5 and 5_10)		-45.519	
Level of Significance		99 %	

Scenario 3		Run 2	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	9.9	2.42	12.32
KHAT	0.8739	0.9671	0.8418
KHAT VAR	0.00000465	0.0000014	0.00000572
Z (0_5 and 5_10)		-37.891	
Level of Significance		99 %	

Scenario 3		Run 3	
Years	2000-2005	2005-2010	2000-2010
% Cell Change	9.9	2.42	12.32
KHAT	0.8739	0.9671	0.8418
KHAT VAR	0.00000465	0.0000014	0.00000572
Z (0_5 and 5_10)		-37.891	
Level of Significance		99 %	

Table 9b. Test of KHAT Statistic between Runs for Scenario 3 to the 99 % Significance Interval

Years: 2000-2005	Run 1	Run 2	Run 3	Significance Level
% Cell Change	10.78	9.9	9.9	
KHAT	0.8622	0.8739	0.8739	
KHAT VAR	0.00000505	0.00000465	0.00000465	
Z (0_5 Run 1 and 0_5 Run 2)		-3.757		Significant
Z (0_5 Run 1 and 0_5 Run 3)			-3.757	Significant
Z (0_5 Run 2 and 0_5 Run 3)			0.000	99 %

Years: 2005-2010	Run 1	Run 2	Run 3	Significance Level
% Cell Change	1.84	2.42	2.42	
KHAT	0.9749	0.9671	0.9671	
KHAT VAR	0.00000108	0.0000014	0.0000014	
Z (5_10 Run 1 and 5_10 Run 2)		4.953		Significant
Z (5_10 Run 1 and 5_10 Run 3)			4.953	Significant
Z (5_10 Run 2 and 5_10 Run 3)			0.000	99 %

Years: 2000-2010	Run 1	Run 2	Run 3	Significance Level
% Cell Change	12.62	12.32	12.32	
KHAT	0.8378	0.8418	0.8418	
KHAT VAR	0.00000585	0.00000572	0.00000572	
Z (0_10 Run 1 and 0_10 Run 2)		-1.176		90 %
Z (0_10 Run 1 and 0_10 Run 3)			-1.176	90 %
Z (0_10 Run 2 and 0_10 Run 3)			0.000	99 %