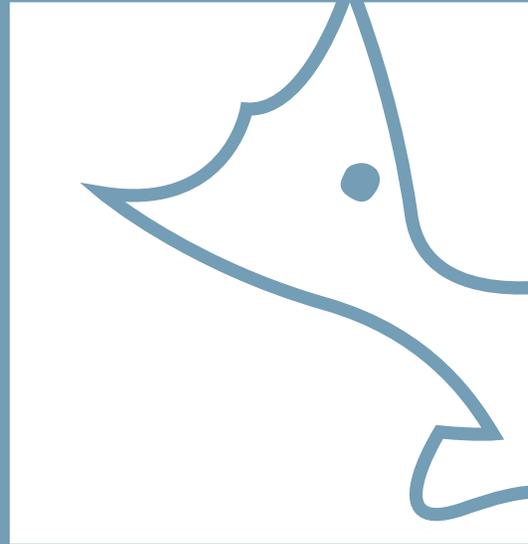


MISSION-ARANSAS NERR ECOSYSTEM  
BASED MANAGEMENT TOOL  
DEMONSTRATION PROJECT: AN  
INTEGRATED APPROACH TO LAND USE  
PLANNING IN ARANSAS COUNTY

November 18, 2011

UT Technical Report No. TR/11-001



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*The Mission-Aransas  
NERR brings together  
scientists, landowners,  
policy-makers, and the  
public to ensure that coastal  
management decisions benefit  
flora and fauna, water quality,  
and people.*



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## **Disclaimer:**

This technical report is intended to convey the results of an Ecosystem Based Management Tool Demonstration Grant funded within the watershed of the Mission-Aransas National Estuarine Research Reserve (NERR). The discussion and conclusions are intended to show the benefits of an integrated land-sea planning approach, and are not intended to be used directly for planning purposes. This publication also does not constitute an endorsement of any commercial product nor does it intend to be an opinion beyond scientific or other results obtained by the Mission-Aransas NERR.

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## Executive Summary

Increased population growth in coastal areas can result in pollution, habitat loss and degradation, overfishing, invasive species, and increased threats due to coastal hazards. Understanding the linkages between land use strategies and their effects on coastal-marine ecosystems is critical to the development of sound land use policies that minimize impacts from population growth and maintain the social, economic, and ecological values of our coasts. A unique partnership of local, state, and federal agencies; academic institutions; and non- and for-profit organizations worked together to develop an integrated land-sea planning toolkit that assists planners/resource managers in applying ecosystem based management to land use planning.

Aransas County, Texas was an ideal study location for the development of an integrated land-sea planning toolkit. The county's watershed promotes a healthy estuary with highly diverse habitats that support the area's growing recreation and tourism industry, as well as estuarine-dependent commercial and recreational fisheries. However, Aransas County has recently experienced rapid population growth and there is a strong community interest and involvement in maintaining the resource-dependent quality of life in this region as the population increases. The goal of the toolkit was to provide Aransas County with the ability to make land use planning decisions that maintain the desired, eco-driven quality of life.

Ecosystem based management considers the whole ecosystem, including humans and the environment, rather than managing one issue/resource in isolation. The partnership collaborated with the local community to apply three decision support tools: CommunityViz, NatureServe Vista, and N-SPECT. Each tool has a particular role in the toolkit:

- CommunityViz® (provided by Placeways) supported development and analysis of land use scenarios and socio-economic indicators.
- NatureServe Vista® (provided by NatureServe) provided the ability to depict ecological values, evaluate impacts from land use scenarios, and develop alternative land use scenarios.
- N-SPECT (provided by the National Oceanic and Atmospheric Administration Coastal Services Center) was used to predict sedimentation and pollution changes from different land use scenarios and identify areas that are key contributors of these inputs.

The three tools were integrated to: (1) evaluate the current condition and sustainability of the ecosystem and socio-economic indicators, (2) evaluate future development trends based on current policies and economic forces, and (3) develop alternative land use strategies to meet sustainability objectives for ecological and socio-economic values.

Ecological and socio-economic indicators were used to quantify impacts of land use/land cover conditions and compare the relative merits of potential alternative future growth scenarios. While most socio-economic goals were met for the Future Trend Scenario, there was an overall decrease in conservation and water quality goal achievement when compared to the current land use/land cover. The Mitigation Scenario, however, was much more responsive to conservation and water quality goals, while still showing high results for many socio-economic indicators.

The results of this project clearly showed that the integrated land-sea planning toolkit supports ecosystem based management and can be used to mitigate many of the potential problems associated with increased human activity in coastal communities. This type of land use planning approach ensures that ecological goals are achieved, while still accomplishing socio-economic objectives. Although this type of planning approach requires a significant commitment from planners, resource managers, local officials, scientists, and stakeholders, its benefits are tremendous and can assist growing coastal communities with land use planning and resource management decisions.

## Introduction

Coastal ecosystems contain a rich diversity of species and habitat types that provide many of the world's natural resources (WRI, 2000). These coastal ecosystems also support a wealth of economic activity associated with recreation and tourism, waterborne commerce, and energy and mineral production. This economic activity has been one of the driving forces behind increased population growth in coastal communities. However, the activities that make coastal communities desirable are also the same activities that threaten many of our natural resources. As a result, resource managers, land use planners, and political officials face the difficult challenge of balancing increasing human uses of coastal ecosystems with environmental protection.

In 2003, approximately 53 percent of the United States' total population was estimated to live on the coast. This represented an influx of 33 million people to coastal communities since 1980. In many coastal ecosystems, the recent population growth has resulted in pollution, habitat loss and degradation, overfishing, invasive species, and increased threats due to coastal hazards such as sea-level rise (WRI, 2000; Hinrichsen, 1998; National Safety Council, 1998). The increasing population density in coastal counties, combined with the fast-growing economy of these areas (Colgan, 2004), makes the task of managing coastal resources more difficult.

The watershed of Aransas County, Texas currently promotes a healthy estuary with highly diverse habitats that support the area's growing recreation and tourism industry, as well as estuarine-dependent commercial and recreational fisheries. However, the population of Aransas County is projected to increase 13% by the year 2050 (TWDB, 2007). A 2006/2007 survey of Aransas County residents showed that most respondents felt positively about the increased growth that was occurring in the county, but at the same time, the majority wanted to preserve the county's natural resources, coastal charm,

and small-town atmosphere. Respondents also felt that citizens should play a role in guiding the "character" of future growth (Schuett et al., 2008). With the county experiencing rapid population growth and a strong community interest in maintaining the resource-dependent quality of life, the ability to minimize impacts from population growth through a stakeholder-driven process is essential. The primary focus of this project was on the Live Oak and Lamar Peninsulas since these areas have seen the greatest population growth in Aransas County in the last decade.

Understanding the linkages between land use strategies and their effects on coastal-marine ecosystems is critical to the development of sound policies that minimize impacts from population growth and maintain the social, economic, and ecological values of our coasts. Development of land use strategies that restore and sustain the health, productivity, resilience, and biological diversity of coastal systems while also promoting a sustainable and enhanced quality of life for people requires an ecosystem based management (EBM) approach. Rather than managing one issue or resource in isolation, EBM considers the whole ecosystem, including both humans and the environment.

Land use planners, resource managers, and political officials, however, often lack the necessary tools to make decisions in an EBM framework. Consequently, numerous organizations and agencies have produced various types of decision support tools (DSTs) to assist these groups with decision making. For example, there are DSTs available that address land use planning, biodiversity conservation, and water quality. However, these tools were usually developed independently without conscious planning for how they could be interoperated (i.e., outputs of one tool utilized as an input to another tool) to achieve a more complete project analysis.

Interoperation of DSTs enables coastal communities to develop land use strategies that promote coastal environmental quality, while also maintaining a high quality of life

for residents and visitors. The integration of these tools helps decision makers understand the ramifications of land use policy on biodiversity and ecosystem function, as well as how ecological function affects human health and socioeconomic values. The application of these support tools will also help resource managers gauge future threats to the coastal ecosystems they manage and find effective ways to mitigate those threats.

A unique partnership of local, state, and federal agencies; academic institutions; and non-profit and for-profit organizations worked together on the development of an integrated land-sea planning toolkit that would assist Aransas County planners and resource managers with employing an EBM approach to develop land use strategies. The project was funded by the David & Lucile Packard Foundation under the Coastal and Marine Ecosystem Based Management Tools Program (EBM Tools). The project was led by the Mission-Aransas National Estuarine Research Reserve (NERR) at the University of Texas Marine Science Institute with Co-Principal Investigators from NatureServe, the National Oceanic and Atmospheric Administration Coastal Services Center (NOAA CSC), Placeways, LLC, and the Texas Coastal Watershed Program.

The partnership collaborated with the local community in Aransas County to apply three decision support tools: CommunityViz provided by Placeways, LLC; NatureServe Vista provided by NatureServe; and the Nonpoint-Source Pollution and Erosion Comparison Tool (N-SPECT) provided by NOAA CSC. The three DSTs were integrated to: (1) evaluate the current condition and sustainability of the ecosystem and socio-economic indicators, (2) evaluate trends based on current policies and economic forces, and (3) develop alternative land use strategies to meet sustainability objectives for ecological and socio-economic values. The primary objectives of the project were to:

- Develop a toolkit that supports integrated land-sea planning and test it in a real-world situation.

- Create a documented methodology for the application of the toolkit.
- Support the pilot location (Aransas County, Texas, USA) in utilizing the tools to create analyses supporting their request for greater planning authority from the state.

## Methods

The three core tools of the integrated land-sea toolkit are all extensions to ESRI's ArcGIS® software and thus are able to interoperate by utilizing the same software platform. A common geospatial database was developed and used in all three tools to create and assess a series of scenarios that depicted: (1) current land use (called the Current Condition Scenario); (2) expected land use at a future time (called the Future Trend Scenario), and (3) preferred future land use (called the Mitigation Scenario) (Figure 1).

Indicators (or performance measures) were calculated for each development scenario and compared for differences in indicator performance. Two categories, ecological and socio-economic, were used to group indicators. Ecological indicators were related to habitat type (e.g., acres of wetland, acres of coastal prairie), species habitat requirements (e.g., acres of available habitat for Whooping Cranes, acres of available habitat for the black spotted newt), and water quality (e.g., acres of seagrass beds with low concentrations of total suspended solids). Consideration of socio-economic indicators is also important for achieving an effective ecosystem based management approach. Therefore, demographic (e.g., population, family size), economic (e.g., jobs, commercial floor space), social (e.g., housing, incomes), and service (e.g., schools, traffic) indicators were calculated to try and design a built environment that best serves the human population. CommunityViz provides tools for easily estimating indicators and was used in this project to summarize both socio-economic and ecological indicators and assess the impact of different development scenarios.

Input from local stakeholders, scientific experts, resource managers, and political officials was required at several stages of the tool workflow (Figure 1). Information regarding current land use policy (e.g., zoning regulations), development trends (e.g., newly proposed residential developments), conservation elements (e.g., species of concern, cultural features), conservation goals (e.g., 95% of seagrass beds), and habitat/species viability requirements (e.g., water clarity requirements in seagrass beds) was gathered through a series of workshops, as well as through personnel communication. In addition to providing information for model inputs, these workshops also provided an opportunity for local stakeholders, scientific experts, and resource managers to see the potential applications of the toolkit, as well as

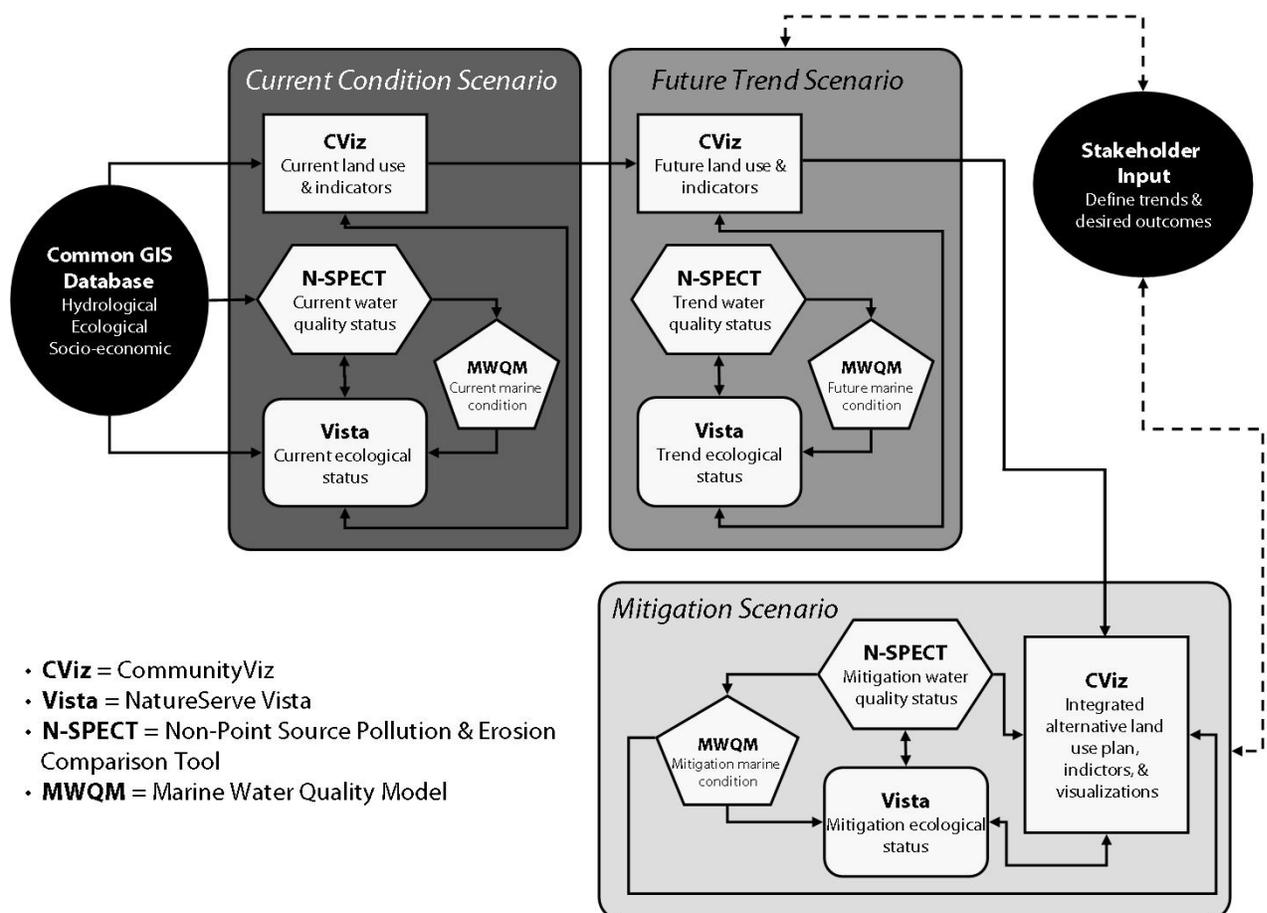
some of its limitations and assumptions. In addition, the workshops gave opportunities for stakeholders to provide input on potential project modifications and the implementation process of final project results.

### Workflow

The boxes in Figure 1 depict the idealized tool workflow for developing a complete scenario. This workflow was repeated three separate times to create multiple development scenarios. Outputs from scenarios were used to inform the development of additional scenarios.

In order to develop a complete scenario for assessment, land use/land cover and zoning regulations, where applicable, were mapped in CommunityViz. Land use/land

Figure 1. Idealized tool workflow and iterations across scenarios.



**Table 1. Common land use classification list for Mission-Aransas NERR demonstration project.**

Land Use	
1. Developed, High Intensity	9. Scrub/Shrub
2. Developed, Medium Intensity	10. Palustrine Wetland
3. Developed, Low Intensity	11. Estuarine Wetland
4. Developed, Open Space	12. Unconsolidated Shoreline
5. Cultivated Cropland	13. Bareland
6. Pasture and Hay	14. Aquatic Bed
7. Grassland/Herbaceous	15. Lakes, Ponds, and Streams
8. Forestland	

cover categories were designated using the common land use classification list (Table 1). The map was then imported to Vista where it was supplemented with additional “land use” layers (e.g., right of ways, dredge sites) that were beneficial for assessing ecological and socio-economic impacts.

Next, the land use/land cover map created in Vista was imported to N-SPECT for modeling water quality results. N-SPECT is capable of modeling loadings of a number of different types of pollutants, but this demonstration project focused on concentrations of total suspended solids (TSS) due to the potential impact of TSS on water clarity, light penetration, and seagrass growth. N-SPECT modeled TSS concentrations for the terrestrial and freshwater components of the study area but was not able to predict TSS concentrations in the marine environment. Therefore, TSS concentrations along the shoreline were selected and incorporated into a simple Marine Water Quality Model (i.e., Inverse Distance Weighted ArcGIS model) to extrapolate TSS concentrations and predict the contribution of TSS to the marine environment.

All modeled results for land use and water quality were then combined in Vista in order to evaluate compatibility of the

scenario with conservation elements and to determine achievement of conservation goals. These goals were defined by local experts, stakeholders, and state rankings of endangered, threatened, and rare species (Table 2). In order to depict and assess the impact of “marine water quality condition” on seagrass growth, TSS values for the marine environment were grouped into three categories in Vista (i.e., good for seagrass growth (0-12 mg/L), okay for seagrass growth (13-26 mg/L), and bad for seagrass growth (>26 mg/L)). The effect of TSS on seagrass growth was a priority of this study, but a similar approach could have been used to assess the effect of additional water quality parameters on other conservation elements.

Since it is often useful for planners to view a summary assessment of results, CommunityViz was used to graph and display selected socio-economic and ecological indicators for each scenario. Geospatial results for each scenario were exported to Google Earth™ for display.

### ***Current Condition Scenario***

During the development of the Current Condition Scenario, the workflow described above was used to integrate the tools and depict/assess outcomes for water quality and

**Table 2. Conservation elements included in scenario evaluations. Goals were based on state rankings whenever applicable. Input from stakeholders and local experts were used for all other goals.**

Conservation Elements	State Rank	Element Goal (%)
Aquatic Bed	Not Applicable	80
Atlantic Hawksbill Sea Turtle ( <i>Eretmochelys imbricate</i> )	Critically Imperiled	100
Bareland	Not Applicable	85
Beach Access Points	Not Applicable	100
Black Spotted Newt ( <i>Notophthalmus meridionalis</i> )	Critically Imperiled	100
Bluestem Grasslands	Not Applicable	75
Boat Ramps (non-TPWD)	Not Applicable	100
Coastal Preserves	Not Applicable	100
Cultivated Cropland	Not Applicable	50
Forestland	Not Applicable	75
Freshwater Wetland	Not Applicable	95
Grasslands	Not Applicable	75
Gulf Salt Marsh Snake ( <i>Nerodia clarkia</i> )	Apparently Secure	40
Jaguarundi ( <i>Nerpailurus yaguarondi</i> )	Critically Imperiled	100
Lakes and Ponds	Not Applicable	80
Live Oak ( <i>Quercus</i> spp.)	Not Applicable	80
Mangroves	Not Applicable	75
Marinas	Not Applicable	100
Mud and Tidal Flats	Not Applicable	85
National Audubon Society Sanctuaries	Not Applicable	100
National Register of Historic Places	Not Applicable	100
Oyster Reef	Not Applicable	95
Pasture and Hay	Not Applicable	50
Peregrine Falcon ( <i>Falco peregrinus</i> )	Vulnerable	90
Salt Marsh	Not Applicable	95
Saltwater Wetland	Not Applicable	95
Scrub/Shrub	Not Applicable	50
Seacoast Bluestem Gulf-Dune Paspalum Series ( <i>Schizachyrium scoparium</i> var. <i>littoralis-paspalum</i> )	Vulnerable	90
Seagrass Beds	Not Applicable	95
Shoreline	Not Applicable	90
Streams	Not Applicable	80
Tall Todder ( <i>Cuscuta exaltata</i> )	Vulnerable	90
Texas Diamondback Terrapin ( <i>Malaclemys terrapin littoralis</i> )	Vulnerable	90
Texas Scarlet Snake ( <i>Cemophora coccinea lineri</i> )	Imperiled	100
Tharps Rhodododon ( <i>Rhodododon angulatus</i> )	Critically Imperiled	100
TPWD Boat Ramps	Not Applicable	100
Velvet Spurge ( <i>Euphorbia innocua</i> )	Vulnerable	90
Water Bird Rookeries	Not Applicable	100
Whooping Crane ( <i>Grus americana</i> )	Critically Imperiled	100

ecological indicators based on current land use.

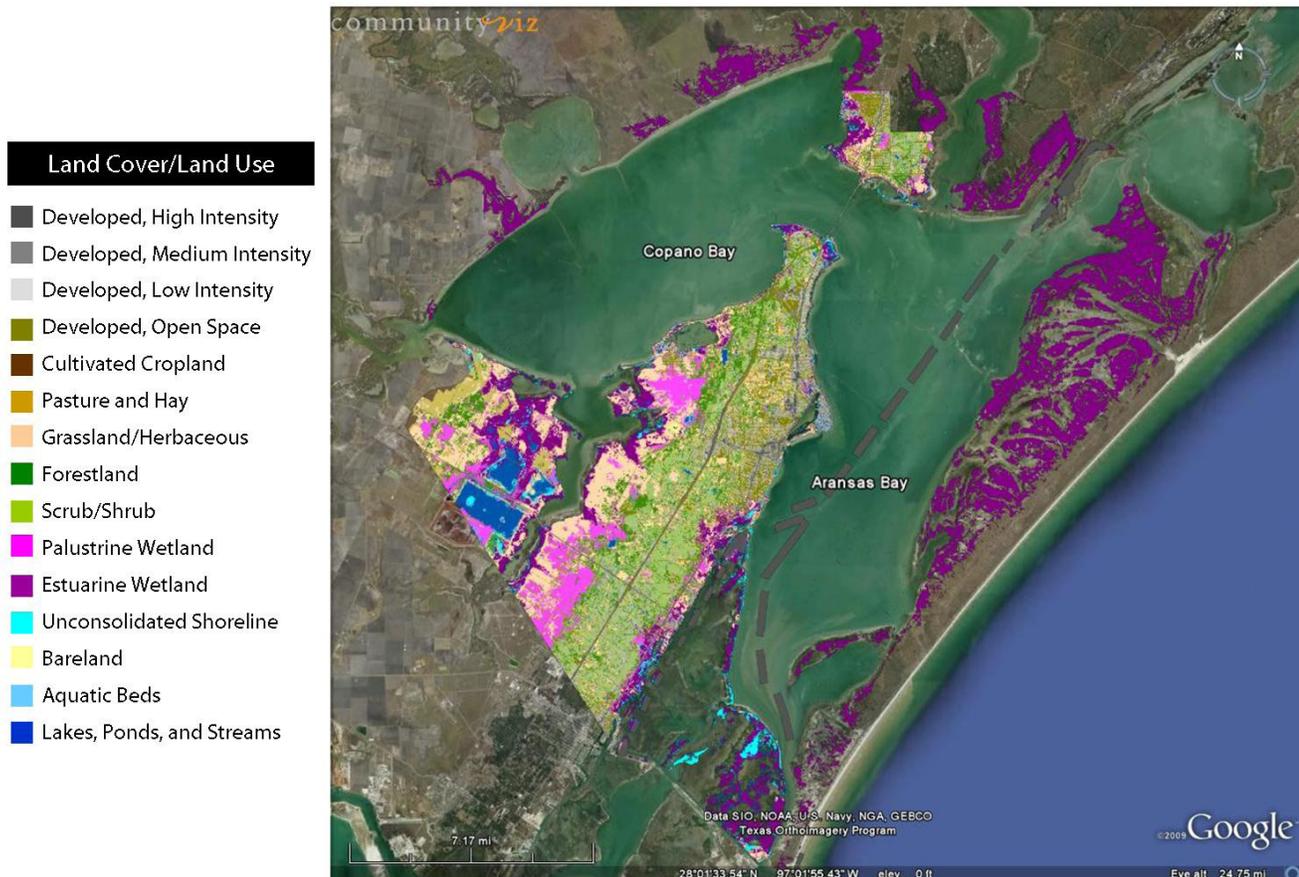
The primary source for land use/land cover data in the Current Condition Scenario was the 2005 Coastal-Change Analysis Program (C-CAP) data available from NOAA CSC. CommunityViz was used to “adapt” several of the C-CAP land use/land cover classes into the common land use classification list, and the land use data was then supplemented with additional “land use” information in Vista (Figure 2). Next, land use/land cover maps were imported from Vista to N-SPECT and combined with additional data to model TSS concentrations in runoff (Figure 3). Shoreline values were selected and incorporated into the Marine Water Quality Model to extrapolate TSS

concentrations into the marine environment (Figure 3). N-SPECT and Marine Water Quality Model results were combined in Vista (Figure 4) to evaluate compatibility of the Current Condition Scenario with conservation elements and to determine achievement of conservation goals. Finally, CommunityViz was used to summarize indicators and GoogleEarth™ was used to display geospatial results.

### ***Future Trend Scenario***

The Future Trend Scenario was developed to depict the maximum theoretical future development allowed in the study area under current land use regulations. Future development was modeled using the “build-out” feature in CommunityViz. The build-

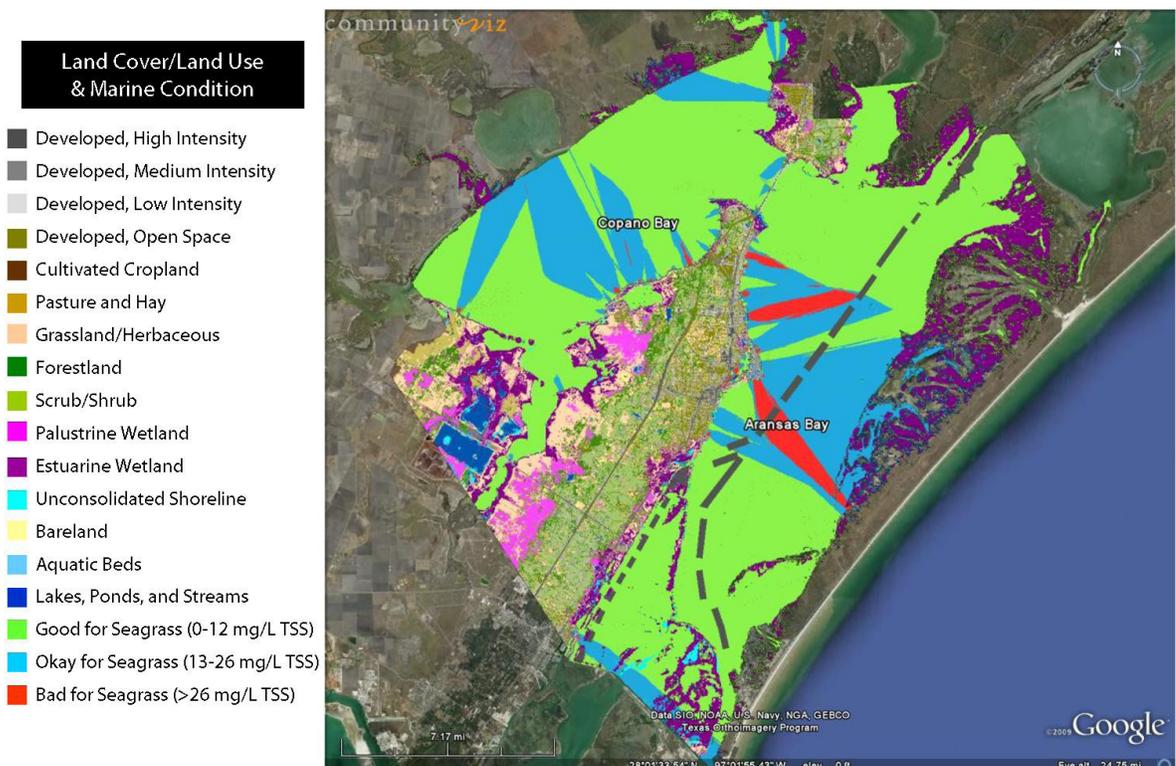
**Figure 2. Current land use/land cover data was developed in CommunityViz and supplemented with additional data in Vista to produce the Current Condition Scenario land use/land cover.**



**Figure 3. N-SPECT results (purple) show the concentration of total suspended solid (TSS) produced by runoff in the terrestrial and freshwater components of the study area based on the Current Condition Scenario land use/land cover. Shoreline and river mouth values were used to model TSS concentrations in the marine environment (brown).**



**Figure 4. Marine water quality modeling results incorporated with Current Condition Scenario land use/land cover.**



out analysis was based on a map of land use designations (Figure 5) and associated density rules that specified maximum building densities for each land use type (see Appendix A). The build-out analysis focused on a sub-section of Live Oak Peninsula where information on current land use policy (i.e., City of Rockport zoning ordinance) and future development trends (i.e., location of new infrastructure) was available.

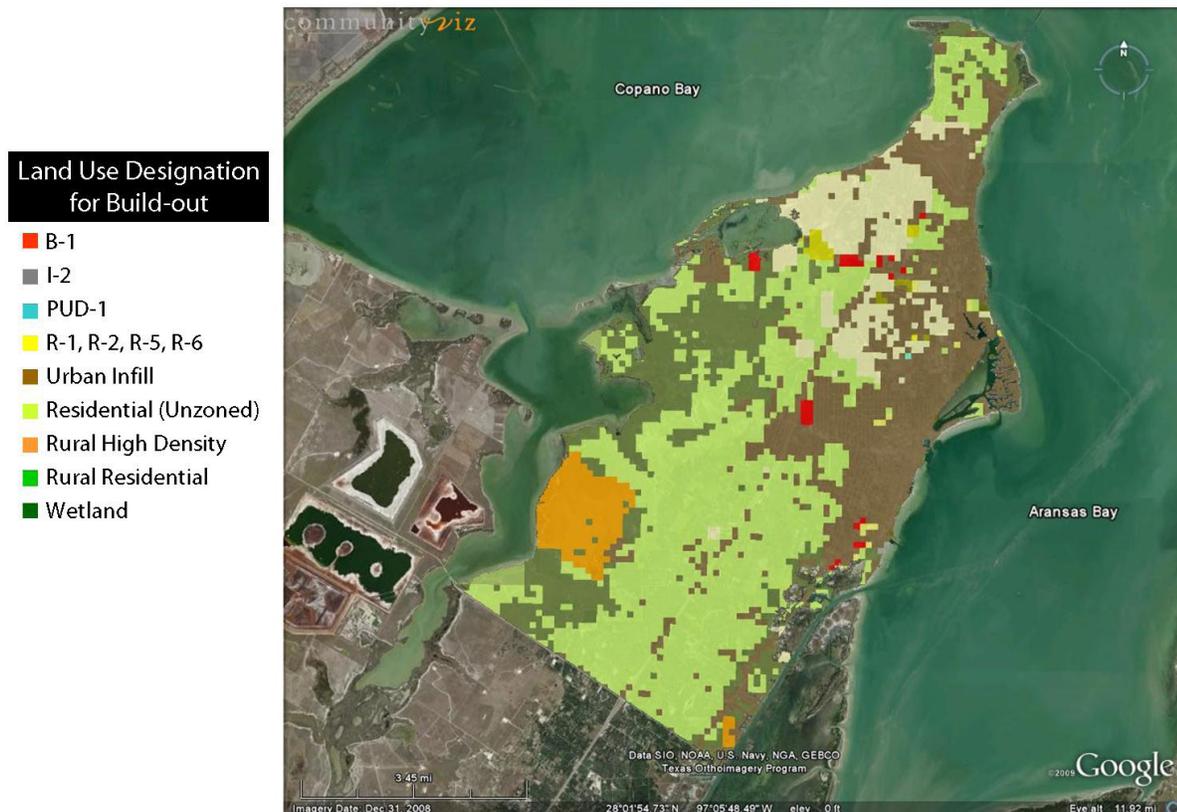
The build-out analysis generated numeric calculations of the maximum number of future buildings that could be developed based on the hypothetical set of density rules. The analysis also produced calculations of the total number of future buildings that could be developed within the project area based on spatial layout restrictions (i.e., setbacks and layout patterns). Finally, the analysis created a map that showed the potential location of these future buildings (Figure 6).

Future buildings were added to the land use layer based on a specified build rate

and order. The rate at which buildings were added to the study area was based on historic population growth rates for the region (www.census.gov). The order in which buildings were added was based on the “suitability” of each building location. A suitability score was assigned to every building using: (1) proximity to roads, (2) proximity to water/sewer infrastructure, (3) overlap with wetlands, and (4) overlap with sea level rise inundation areas. Suitability scores were combined with growth rate information to determine the build date for each building (e.g., higher suitability score is built earlier), and subsequently, the number of buildings that were built each year. The build-out area reached maximum capacity in the year 2030.

In Vista, modified C-CAP land use/land cover data was merged with the results of the CommunityViz build-out analysis pertaining specifically to Live Oak peninsula. Layers such as dredge disposal sites and right of ways were also added as additional land use layers to the map (Appendix B – Figure

**Figure 5. Land use designations used in CommunityViz for the Future Trend Scenario build-out analysis. See Appendix for definitions of land use designations.**



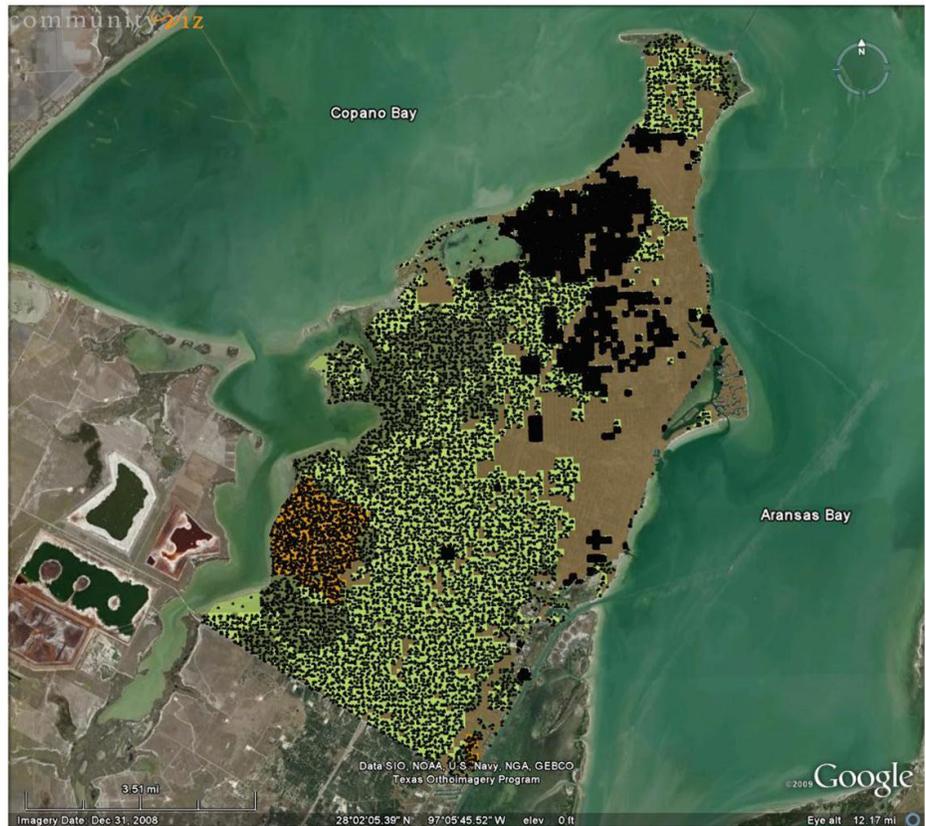
**Figure 6. Results of CommunityViz “build-out” analysis for Future Trend Scenario. Shown at full scale (A) and zoomed (B).**

(A)

**Land Use Designation for Build-out**

- B-1
- I-2
- PUD-1
- R-1, R-2, R-5, R-6
- Urban Infill
- Residential (Unzoned)
- Rural High Density
- Rural Residential
- Wetland

Building



(B)

**Land Use Designation for Build-out**

- B-1
- R-1
- R-2
- Urban Infill
- Residential (Unzoned)
- Wetland

Building



18). Next, future land use/land cover was exported from Vista and added to N-SPECT to model TSS loads (Appendix B – Figure 19). Shoreline/river mouth TSS loadings were selected and incorporated into the Marine Water Quality Model (Appendix B – Figure 19) before combining future land use and marine water quality results in Vista (Appendix B – Figure 20) and evaluating compatibility and goal achievement. Finally, indicators were summarized in CommunityViz and geospatial results were exported to GoogleEarth™.

### ***Mitigation Scenario***

A Mitigation Scenario was developed as an alternative to the Future Trend Scenario. This new scenario was based on a CommunityViz build-out analysis that used the same land use designations as the Future Trend Scenario (see Appendix A) but used a new land use grid that restricted development in wetland areas and designated more higher density development areas on the eastern side of Live Oak Peninsula (Figure 7). Specifically, density rules for “residential (unzoned)” polygons in the eastern part of the build-out area were changed to “R-1,” which increased the housing density from one dwelling unit per acre to six units per acre (Figure 7).

The changes incorporated in the Mitigation Scenario build-out were designed to depict the maximum theoretical future development allowed under hypothetical land use regulations and to explore how development alternatives could increase performance of socio-economic and ecological indicators. The proposed changes were based on examination of N-SPECT and Vista results from the Future Trend Scenario.

“Suitability” scores for the Mitigation Scenario were calculated using the same method as the Future Trend Scenario. The same build rate was also used. Figure 7 shows the predicted location of future buildings in the year 2030 of the Mitigation Scenario. Results of the new build-out analysis were combined in Vista with modified C-CAP land use/land cover data and additional land use

layers (i.e., right of ways, dredge disposal site) (Appendix C – Figure 21). Only those land use changes present in the year 2030 were included in the analysis to allow for comparison with the Future Trend Scenario. Vista results were exported to N-SPECT and selected values were incorporated in the Marine Water Quality Model (Appendix C – Figure 22). Then, both land use and marine water quality results were combined in Vista (Appendix C – Figure 23) to assess compatibility and goal achievement. CommunityViz and GoogleEarth™ were used to summarize indicators and display geospatial results, respectively.

## **Results**

The figures and tables provided in this section describe the scenario evaluation results for each of the three scenarios. Every evaluation produced a hierarchy of reports and maps. The CommunityViz build-out results and socio-economic indicators for the Future Trend and Mitigation Scenarios are also described here.

### ***Current Condition Scenario***

The scenario evaluation report summarized the performance of the Current Condition Scenario in terms of the number and percentage of elements that met their conservation goals (Figure 8). Nineteen elements met their conservation goals in the current scenario - fourteen ecological (e.g., lakes and ponds, freshwater wetland, forestland) and five socio-economic elements (e.g., pasture and hay, cultivated cropland). There were an additional four ecological conservation elements (e.g., Live Oak) that were close to achieving their goals (i.e., >90% of goal was met).

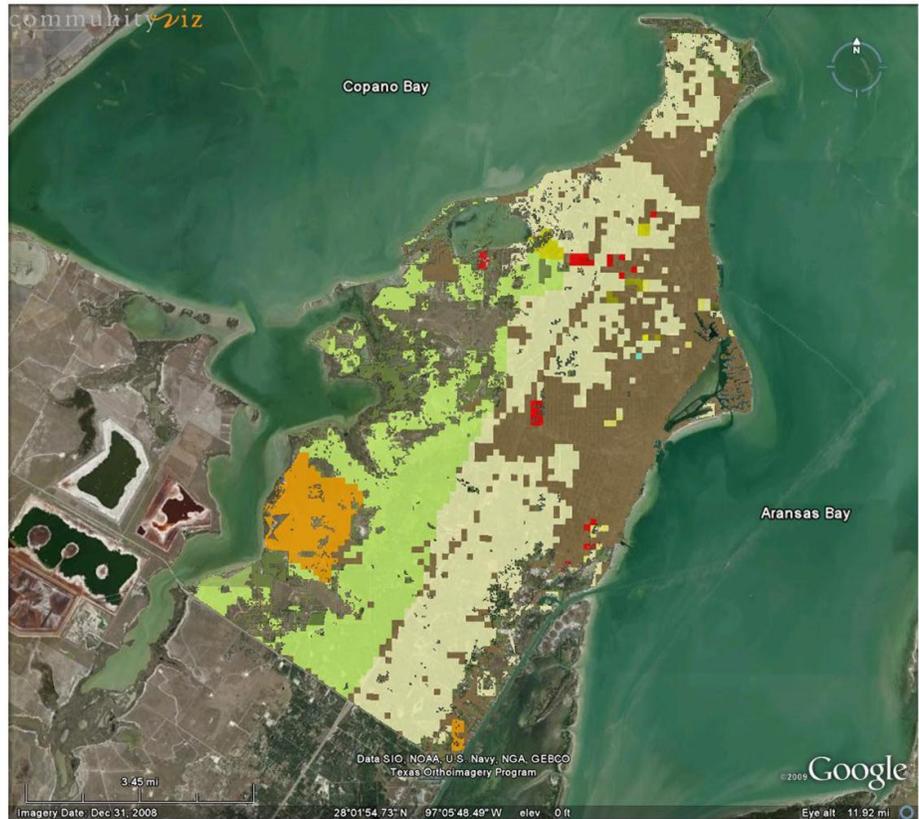
The summary report also provided detailed performance numbers for individual and groups of elements, including the original element distribution and the amount that was retained in areas with compatible land use/marine condition (Figure 8). For example,

**Figure 7. Land use designations (A) and results (B) of the CommunityViz build-out analysis for the Mitigation Scenario. Results indicate the location of future building.**

(A)

**Land Use Designation for Build-out**

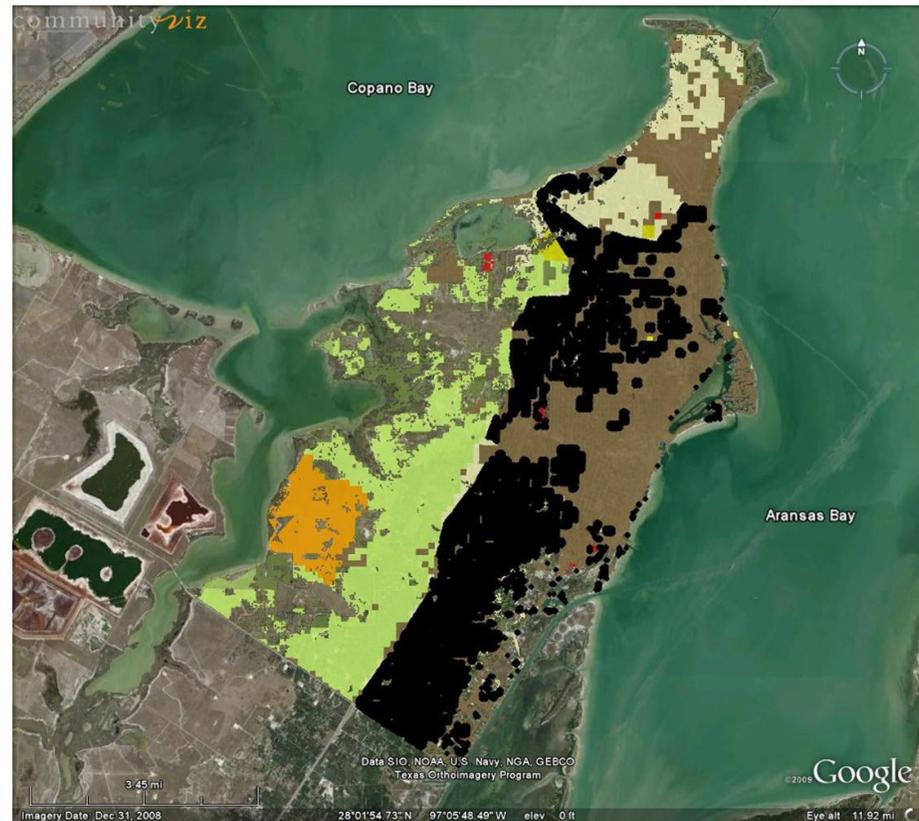
- B-1
- I-2
- PUD-1
- R-1, R-2, R-5, R-6
- Urban Infill
- Residential (Unzoned)
- Rural High Density
- Rural Residential
- Wetland



(B)

**Land Use Designation for Build-out**

- B-1
- I-2
- PUD-1
- R-1, R-2, R-5, R-6
- Urban Infill
- Residential (Unzoned)
- Rural High Density
- Rural Residential
- Wetland
- Building



the Texas diamondback terrapin (*Malaclemys terrapin littoralis*) is listed as vulnerable on the state ranking system and was given a conservation goal of 90%. According to the scenario evaluation report, 13,468 acres of the terrapin distribution was compatible with

current land use/land cover, resulting in 109% goal achievement. The Texas scarlet snake (*Cemophora coccinea lineri*) distribution, on the other hand, was an example of an element that was not compatible with current land use/land cover. The Texas scarlet snake

**Figure 8. Report from Current Condition Scenario evaluation showing compatibility between conservation elements and current land use/land cover and marine condition in order to determine goal achievement.**

**Overall Scenario Performance**

**All Elements (42 Total)**

	Goals Met For	% of Goals Met	Goals Unmet For	% of Goals Unmet
Compatible	19 elements	45.24%	23	54.76%

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**Goal Performance by High-Order Classification**

**Summary**

Name	Protected and Compatible Goal Met For	Goal Unmet For	Compatible Goal Met For	Goal Unmet For
Ecological (35 elements)			14 elements (40%)	21 elements (60%)
Socio-economic (7 elements)			5 elements (71.43%)	2 elements (28.57%)

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**Details**

**Ecological (35 elements)**

Name	Distribution			Compatible					Percent of goal
	Area (acres)	Occs	Avg Condition	Goal	Goal Met	Area (acres)	Occs	Avg Condition	
Bluestem Grassland	2,305	1	NaN	75 percent of area	🟢	804	1	NaN	34.94%
Rookeries	9,294.5	21	NaN	100 percent of area	🟢	8,723.75	21	NaN	93.86%
Tharps rhododod (low precision)	3,092.5	1	NaN	100 percent of area	🟢	1,032.75	1	NaN	33.4%
Preserves	1,497.75	6	NaN	100 percent of area	🟢	1,224.5	6	NaN	81.76%
Peregrine Falcon	5,790	2	NaN	90 percent of area	🟢	3,419	2	NaN	65.61%
Mud and Tidal Flats	1,484.5	195	NaN	85 percent of area	🟢	1,125.25	170	NaN	89.18%
Marsh	3,578	742	NaN	95 percent of area	🟢	3,393.75	676	NaN	99.84%
Whooping Crane	41,447.5	1	NaN	100 percent of area	🟢	31,066.75	1	NaN	74.95%
Mangroves	1,689.5	517	NaN	75 percent of area	🟢	1,673.25	505	NaN	132.05%
Live Oak	18,993	6972	NaN	80 percent of area	🟢	13,912	5144	NaN	91.56%
Lakes and Ponds	2,026.5	561	NaN	80 percent of area	🟢	1,997.75	555	NaN	123.23%
Jaquarundi (low precision)	430.25	1	NaN	100 percent of area	🟢	248.5	1	NaN	57.76%
Jaquarundi (high precision)	3,080.75	1	NaN	100 percent of area	🟢	587.25	1	NaN	19.06%
Gulf Saltmarsh Snake (low precision)	17,563	1	NaN	40 percent of area	🟢	12,167.5	1	NaN	173.2%
Gulf Saltmarsh Snake (good precision)	10,636.75	4	NaN	40 percent of area	🟢	8,555	4	NaN	201.07%
Velvet Spurge	7.75	1	NaN	90 percent of area	🟢	3.25	1	NaN	46.59%
Grasslands	9,403.25	3977	NaN	75 percent of area	🟢	8,569.75	3636	NaN	121.51%
Texas Scarlet Snake	3,509.5	1	NaN	100 percent of area	🟢	1,447	1	NaN	41.23%
Freshwater Wetland	6,347.25	1492	NaN	95 percent of area	🟢	6,023.25	1413	NaN	99.89%
Tharps rhododod (good precision)	11.5	2	NaN	100 percent of area	🟢	0	0	NaN	0%
Forestland	9,927	2520	NaN	75 percent of area	🟢	9,160.75	2311	NaN	123.04%
Tall Dodder	231.25	1	NaN	90 percent of area	🟢	93	1	NaN	44.68%
Texas diamondback terrapin	13,767.5	6	NaN	90 percent of area	🟢	13,467.5	6	NaN	108.69%
Shoreline	2,337.25	2616	NaN	90 percent of area	🟢	2,264.25	2533	NaN	107.64%
Black-spotted Newt	25,022	1	NaN	100 percent of area	🟢	3,919.5	1	NaN	15.66%
Streams	8.25	4	NaN	80 percent of area	🟢	8	4	NaN	121.21%
Bivalve Reef	2,944	511	NaN	95 percent of area	🟢	2,902.75	500	NaN	103.79%
Sanctuaries	641.25	5	NaN	100 percent of area	🟢	363.75	5	NaN	56.73%
Seagrass	16,440.25	3489	NaN	95 percent of area	🟢	12,910.5	2943	NaN	82.66%
Bareland	158	289	NaN	85 percent of area	🟢	135	221	NaN	100.52%
Seacoast Bluestem Gulf-dune Paspalum Series	1,195.25	1	NaN	90 percent of area	🟢	66.25	1	NaN	6.16%
Atlantic Hawksbill Turtle	86.5	1	NaN	100 percent of area	🟢	75.5	1	NaN	87.28%
Scrub and Shrub	5,046.25	5205	NaN	50 percent of area	🟢	4,689.75	4919	NaN	185.87%
Saltwater Wetland	27,943	3558	NaN	95 percent of area	🟢	27,243.25	3439	NaN	102.63%
Aquatic Bed	421	808	NaN	80 percent of area	🟢	414	792	NaN	122.92%

**Socio-economic (7 elements)**

Name	Distribution			Compatible					Percent of goal
	Area (acres)	Occs	Avg Condition	Goal	Goal Met	Area (acres)	Occs	Avg Condition	
Pasture and Hay	1,852.75	398	NaN	50 percent of area	🟢	1,802	392	NaN	194.52%
National Register of Historic Places	7.75	4	NaN	100 percent of occurrences	🟢	7.75	4	NaN	100%
Marinas	2	7	NaN	100 percent of occurrences	🟢	2	7	NaN	100%
TPWD Boat ramps	2	8	NaN	100 percent of occurrences	🟢	1.5	6	NaN	75%
Cultivated Cropland	174.25	19	NaN	50 percent of area	🟢	172.5	18	NaN	197.99%
Boat Ramps	1	4	NaN	100 percent of occurrences	🟢	1	4	NaN	100%
Beach Access Points	1.25	5	NaN	100 percent of occurrences	🟢	1	4	NaN	80%

**Abbreviations & Icons**

- Occ = Occurrences
- 🟢 = Goal has been met (100% or more)
- 🟡 = Goal has almost been met (90% - 99.9%)
- 🔴 = Goal has not been met (less than 90% has been met)

is listed as imperiled and was assigned a conservation goal of 100%, but only achieved 41% of its goal. Only 1,447 acres of the reptile's total distribution (3,510 acres) were compatible. The distribution of waterbird rookeries also did not achieve its conservation goal of 100% compatibility. However, the 8,724 acres that were compatible resulted in 94% of the goal being met for this element, much closer to the conservation goal.

The scenario evaluation also produced a map of compatibility conflicts that identified areas where elements are incompatible with land use and do not meet conservation goals (Figure 9). The compatibility conflict map is helpful for identifying locations in the project region where opportunities exist for improving the ability to meet conservation goals.

### ***Future Trend Scenario***

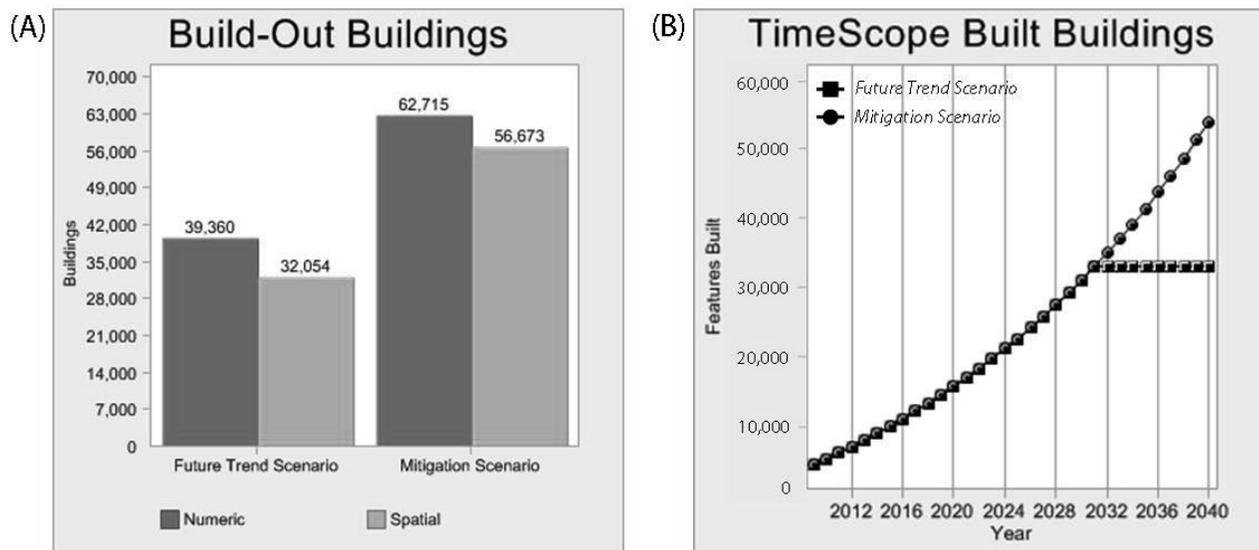
Based on land use designations, density rules, build rate, and build order for the Future Trend Scenario, over 39,000 buildings were proposed for the developable area, but only 32,054 buildings were "built" due to spatial restrictions (Figure 10A). Results also showed that this area would be completely "built-out" (i.e., no new buildings could be added) by the year 2030 (Figure 10B).

Numerous socio-economic indicators were calculated for the Future Trend Scenario using tools in CommunityViz (Figure 11). Results of the build-out analysis indicate that the number of school children and commercial jobs will increase with the new development, but this will in turn lead to increases in residential water and energy usage, as well as

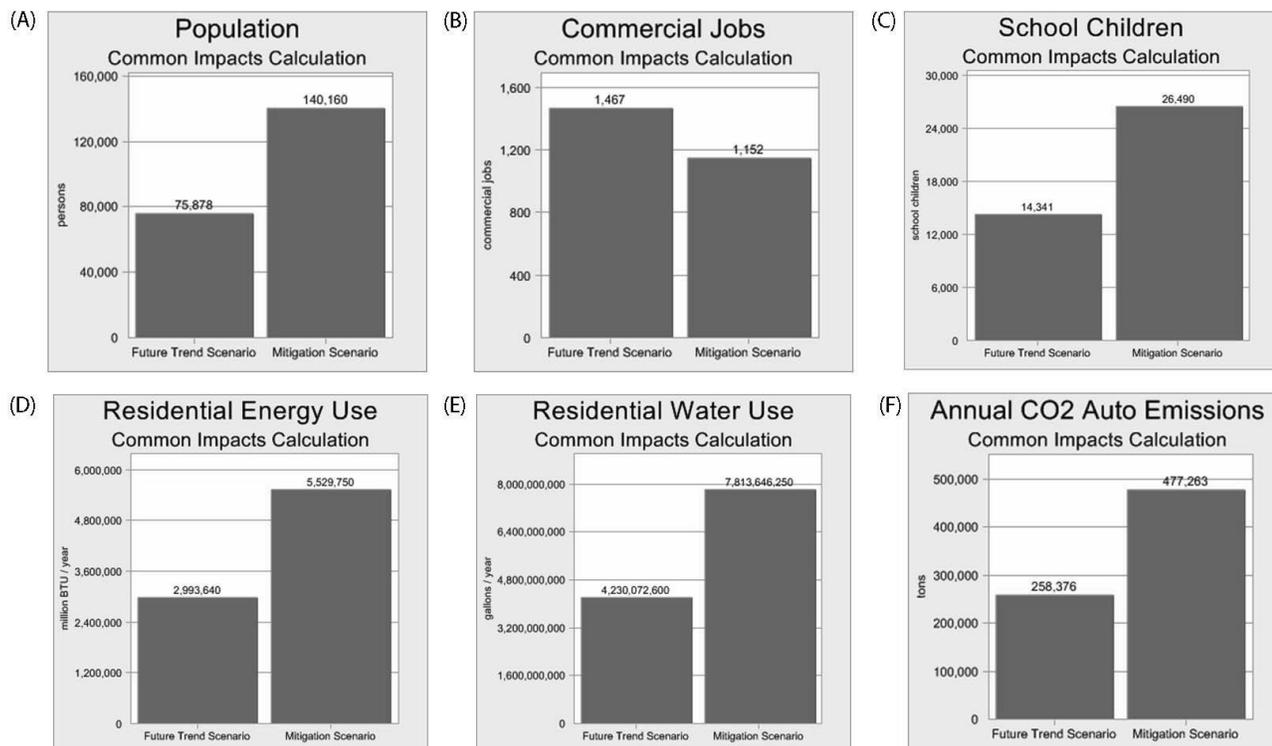
**Figure 9. Compatibility conflict map for Current Condition Scenario. NOTE: Tan color represents areas where there are no conflicts between elements and land use, while red indicates areas where conflict does exist.**



**Figure 10. Comparison of the total number of dwelling units (A) and number of buildings (i.e., features) built per year (B) based on “build-out” analysis results for Future Trend Scenario and Mitigation Scenario.**



**Figure 11. Socio-economic indicators calculated based on build-out analyses. Bars represent predicted values at the completion of the build-out in 2030 for the Future Trend Scenario and completion of the build-out in 2042 for the Mitigation Scenario.**



the amount of carbon dioxide produced from auto emissions.

The scenario evaluation report (Figure 12) for the Future Condition Scenario showed that thirteen conservation elements met their

goals - eight ecological (e.g., Gulf saltmarsh snake) and five socio-economic (e.g., historic places). An additional five ecological elements (e.g., shoreline) were close to achieving their conservation goal (i.e., >90% of goal was met).

**Figure 12. Report from Future Trend Scenario evaluation showing compatibility between conservation elements and future land use/land cover and marine condition in order to determine goal achievement.**

**Overall Scenario Performance**

**All Elements (42 Total)**

	Goals Met For	% of Goals Met	Goals Unmet For	% of Goals Unmet
Compatible	13 elements	30.95%	29	69.05%

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**Goal Performance by High-Order Classification**

**Summary**

Name	Protected and Compatible Goal Met For	Goal Unmet For	Compatible Goal Met For	Goal Unmet For
<a href="#">Ecological</a> (35 elements)			8 elements (22.86%)	27 elements (77.14%)
<a href="#">Socio-economic</a> (7 elements)			5 elements (71.43%)	2 elements (28.57%)

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**Details**

**Ecological (35 elements)**

Name	Distribution			Compatible					Percent of goal
	Area (acres)	Occs	Avg Condition	Goal	Goal Met	Area (acres)	Occs	Avg Condition	
<a href="#">Bluestem Grassland</a>	2,305	1	NaN	75 percent of area	🟢	604	1	NaN	34.94%
<a href="#">Rookeries</a>	9,294.5	21	NaN	100 percent of area	🟢	8,680	21	NaN	93.39%
<a href="#">Tharps rhododon (low precision)</a>	3,092.5	1	NaN	100 percent of area	🟢	881	1	NaN	28.49%
<a href="#">Preserves</a>	1,497.75	6	NaN	100 percent of area	🟢	1,224.5	6	NaN	81.76%
<a href="#">Peregrine Falcon</a>	5,790	2	NaN	90 percent of area	🟡	3,419	2	NaN	65.61%
<a href="#">Mud and Tidal Flats</a>	1,484.5	195	NaN	85 percent of area	🟡	1,029.5	150	NaN	81.59%
<a href="#">Marsh</a>	3,578	742	NaN	95 percent of area	🟡	3,096.5	601	NaN	91.1%
<a href="#">Whooping Crane</a>	41,447.5	1	NaN	100 percent of area	🟢	31,066.75	1	NaN	74.95%
<a href="#">Mangroves</a>	1,689.5	517	NaN	75 percent of area	🟡	1,673.25	505	NaN	132.05%
<a href="#">Live Oak</a>	18,993	69724	NaN	80 percent of area	🟡	14,104.5	52115	NaN	92.83%
<a href="#">Lakes and Ponds</a>	2,026.5	561	NaN	80 percent of area	🟡	1,834	441	NaN	113.13%
<a href="#">Jaguarundi (low precision)</a>	430.25	1	NaN	100 percent of area	🟢	248.5	1	NaN	57.76%
<a href="#">Jaguarundi (high precision)</a>	3,080.75	1	NaN	100 percent of area	🟢	587.25	1	NaN	19.06%
<a href="#">Gulf Saltmarsh Snake (low precision)</a>	17,563	1	NaN	40 percent of area	🟡	12,167.5	1	NaN	173.2%
<a href="#">Gulf Saltmarsh Snake (good precision)</a>	10,636.75	4	NaN	40 percent of area	🟡	8,541.5	4	NaN	200.75%
<a href="#">Velvet Spurge</a>	7.75	1	NaN	90 percent of area	🟡	3.25	1	NaN	46.59%
<a href="#">Grasslands</a>	9,403.25	3977	NaN	75 percent of area	🟡	4,307.5	2197	NaN	61.08%
<a href="#">Texas Scarlet Snake</a>	3,509.5	1	NaN	100 percent of area	🟢	1,447	1	NaN	41.23%
<a href="#">Freshwater Wetland</a>	6,347.25	1492	NaN	95 percent of area	🟡	3,730.5	863	NaN	61.87%
<a href="#">Tharps rhododon (good precision)</a>	11.5	2	NaN	100 percent of area	🟢	0	0	NaN	0%
<a href="#">Forestland</a>	9,927	2520	NaN	75 percent of area	🟡	3,841.75	1367	NaN	51.6%
<a href="#">Tall Dodder</a>	231.25	1	NaN	90 percent of area	🟡	93	1	NaN	44.68%
<a href="#">Texas diamondback terrapin</a>	13,767.5	6	NaN	90 percent of area	🟡	13,458.5	6	NaN	108.62%
<a href="#">Shoreline</a>	2,337.25	2616	NaN	90 percent of area	🟡	2,004.25	2165	NaN	95.28%
<a href="#">Black-spotted Newt</a>	25,022	1	NaN	100 percent of area	🟢	1,754	1	NaN	7.01%
<a href="#">Streams</a>	8.25	4	NaN	80 percent of area	🟡	8	4	NaN	121.21%
<a href="#">Bivalve Reef</a>	2,944	511	NaN	95 percent of area	🟡	2,902.75	500	NaN	103.79%
<a href="#">Sanctuaries</a>	641.25	5	NaN	100 percent of area	🟢	363.75	5	NaN	56.73%
<a href="#">Seagrass</a>	16,440.25	3489	NaN	95 percent of area	🟡	12,378.5	2888	NaN	79.26%
<a href="#">Bareland</a>	158	289	NaN	85 percent of area	🟡	47.5	106	NaN	35.37%
<a href="#">Seacoast Bluestem Gulf-dune Paspalum Series</a>	1,195.25	1	NaN	90 percent of area	🟡	66.25	1	NaN	6.16%
<a href="#">Atlantic Hawksbill Turtle</a>	86.5	1	NaN	100 percent of area	🟢	75.5	1	NaN	87.28%
<a href="#">Scrub and Shrub</a>	5,046.25	5205	NaN	50 percent of area	🟡	2,127.5	2448	NaN	84.32%
<a href="#">Saltwater Wetland</a>	27,943	3558	NaN	95 percent of area	🟡	25,766.75	3047	NaN	97.07%
<a href="#">Aquatic Bed</a>	421	808	NaN	80 percent of area	🟡	398.5	737	NaN	118.32%

**Socio-economic (7 elements)**

Name	Distribution			Compatible					Percent of goal
	Area (acres)	Occs	Avg Condition	Goal	Goal Met	Area (acres)	Occs	Avg Condition	
<a href="#">Pasture and Hay</a>	1,852.75	398	NaN	50 percent of area	🟡	1,535.75	256	NaN	165.78%
<a href="#">National Register of Historic Places</a>	7.75	4	NaN	100 percent of occurrences	🟢	7.75	4	NaN	100%
<a href="#">Marinas</a>	2	7	NaN	100 percent of occurrences	🟢	2	7	NaN	100%
<a href="#">TPWD Boat ramps</a>	2	8	NaN	100 percent of occurrences	🟢	1.75	7	NaN	87.5%
<a href="#">Cultivated Cropland</a>	174.25	19	NaN	50 percent of area	🟡	171.75	15	NaN	197.13%
<a href="#">Boat Ramps</a>	1	4	NaN	100 percent of occurrences	🟢	1	4	NaN	100%
<a href="#">Beach Access Points</a>	1.25	5	NaN	100 percent of occurrences	🟢	1	4	NaN	80%

**Abbreviations & Icons**

- Occ = Occurrences
- 🟢 = Goal has been met (100% or more)
- 🟡 = Goal has almost been met (90% - 99.9%)
- 🔴 = Goal has not been met (less than 90% has been met)

**Figure 13. Compatibility conflict map for Future Trend Scenario. NOTE: Tan color represents areas where there are no conflicts between elements and land use, while red indicates areas where conflict does exist.**



When compared to the Current Condition Scenario, conservation goal achievement for several individual elements of the Future Trend Scenario showed interesting changes. For example, freshwater wetlands were deemed very important because of their role in providing food and habitat for wildlife, mitigating flood damage, and filtering excess nutrients from runoff and were therefore given a conservation goal of 95% by stakeholders. However, only 62% of this goal was achieved in the Future Trend Scenario, indicating much higher incompatibility with future land use and water quality than with the current land use. This was a dramatic decline from the Current Condition Scenario in which 99% of the goal was projected to be achieved for freshwater wetlands. In fact, six ecological elements that met their conservation goals in the Current Condition Scenario were no longer compatible with land use/land cover

in the Future Trend Scenario. These elements included: grasslands, forestland, shoreline, bareland, scrub/shrub, and saltwater wetland.

The evaluation of the Future Trend Scenario also produced a map of compatibility conflicts that identified areas where elements were incompatible with future land use/marine condition and did not meet conservation goals (Figure 13). The compatibility conflict map was helpful for identifying locations in the project region where opportunities existed for mitigating impacts to conservation elements and developing the Mitigation Scenario described below.

### ***Mitigation Scenario***

Build-out analysis for the Mitigation Scenario proposed over 62,000 buildings for the developable project area, but only 56,673

were “built” due to spatial restrictions (Figure 10A). This was much higher than the Future Trend Scenario and was due to the land use designation and density rule changes made in the Mitigation Scenario. These changes also

resulted in a much later “build out” date for the Mitigation Scenario. Unlike the Future Trend Scenario, there were areas available for future development after the year 2030. In the Mitigation Scenario, the developable project

**Figure 14. Report from Mitigation Scenario evaluation evaluation showing compatibility between conservation elements and alternative future land use/land cover and marine condition in order to determine goal achievement.**

**Overall Scenario Performance**

**All Elements (42 Total)**

	Goals Met For	% of Goals Met	Goals Unmet For	% of Goals Unmet
Compatible	17 elements	40.48%	25	59.52%

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**Goal Performance by High-Order Classification**

**Summary**

Name	Protected and Compatible Goal Met For	Goal Unmet For	Compatible Goal Met For	Goal Unmet For
Ecological (35 elements)			12 elements (34.29%)	23 elements (65.71%)
Socio-economic (7 elements)			5 elements (71.43%)	2 elements (28.57%)

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**Details**

**Ecological (35 elements)**

Name	Distribution			Compatible					Percent of goal
	Area (acres)	Occs	Avg Condition	Goal	Goal Met	Area (acres)	Occs	Avg Condition	
<a href="#">Bluestem Grassland</a>	2,305	1	NaN	75 percent of area	Y	604	1	NaN	34.94%
<a href="#">Rookeries</a>	9,294.5	21	NaN	100 percent of area	Y	8,712.25	21	NaN	93.74%
<a href="#">Tharps rhododod (low precision)</a>	3,092.5	1	NaN	100 percent of area	N	914	1	NaN	29.56%
<a href="#">Preserves</a>	1,497.75	6	NaN	100 percent of area	N	1,224.5	6	NaN	81.76%
<a href="#">Peregrine Falcon</a>	5,790	2	NaN	90 percent of area	N	3,419	2	NaN	65.61%
<a href="#">Mud and Tidal Flats</a>	1,484.5	195	NaN	85 percent of area	N	1,119.25	170	NaN	88.7%
<a href="#">Marsh</a>	3,578	742	NaN	95 percent of area	Y	3,393.5	675	NaN	99.84%
<a href="#">Whooping Crane</a>	41,447.5	1	NaN	100 percent of area	N	31,066.75	1	NaN	74.95%
<a href="#">Mangroves</a>	1,689.5	517	NaN	75 percent of area	Y	1,673.25	505	NaN	132.05%
<a href="#">Live Oak</a>	18,993	69724	NaN	80 percent of area	N	10,080.5	37387	NaN	66.34%
<a href="#">Lakes and Ponds</a>	2,026.5	561	NaN	80 percent of area	Y	1,978.25	532	NaN	122.02%
<a href="#">Jaquarundi (low precision)</a>	430.25	1	NaN	100 percent of area	N	248.5	1	NaN	57.76%
<a href="#">Jaquarundi (high precision)</a>	3,080.75	1	NaN	100 percent of area	N	587.25	1	NaN	19.06%
<a href="#">Gulf Saltmarsh Snake (low precision)</a>	17,563	1	NaN	40 percent of area	Y	12,167.5	1	NaN	173.2%
<a href="#">Gulf Saltmarsh Snake (good precision)</a>	10,636.75	4	NaN	40 percent of area	Y	8,549.75	4	NaN	200.95%
<a href="#">Velvet Spurge</a>	7.75	1	NaN	90 percent of area	N	3.25	1	NaN	46.59%
<a href="#">Grasslands</a>	9,403.25	3977	NaN	75 percent of area	Y	7,715.75	3068	NaN	109.41%
<a href="#">Texas Scarlet Snake</a>	3,509.5	1	NaN	100 percent of area	N	1,447	1	NaN	41.23%
<a href="#">Freshwater Wetland</a>	6,347.25	1492	NaN	95 percent of area	Y	5,969.25	1361	NaN	98.99%
<a href="#">Tharps rhododod (good precision)</a>	11.5	2	NaN	100 percent of area	N	0	0	NaN	0%
<a href="#">Forestland</a>	9,927	2520	NaN	75 percent of area	N	5,953.75	1853	NaN	79.97%
<a href="#">Tall Dodder</a>	231.25	1	NaN	90 percent of area	N	93	1	NaN	44.68%
<a href="#">Texas diamondback terrapin</a>	13,767.5	6	NaN	90 percent of area	Y	13,467.25	6	NaN	108.69%
<a href="#">Shoreline</a>	2,337.25	2616	NaN	90 percent of area	Y	2,219	2466	NaN	105.49%
<a href="#">Black-spotted Newt</a>	25,022	1	NaN	100 percent of area	N	3,801.5	1	NaN	15.19%
<a href="#">Streams</a>	8.25	4	NaN	80 percent of area	Y	8	4	NaN	121.21%
<a href="#">Bivalve Reef</a>	2,944	511	NaN	95 percent of area	Y	2,902.75	500	NaN	103.79%
<a href="#">Sanctuaries</a>	641.25	5	NaN	100 percent of area	N	363.75	5	NaN	56.73%
<a href="#">Seagrass</a>	16,440.25	3489	NaN	95 percent of area	N	12,400.25	2847	NaN	79.4%
<a href="#">Bareland</a>	158	289	NaN	85 percent of area	N	113.25	180	NaN	84.33%
<a href="#">Seacoast Bluestem Gulf-dune Paspalum Series</a>	1,195.25	1	NaN	90 percent of area	N	66.25	1	NaN	6.16%
<a href="#">Atlantic Hawksbill Turtle</a>	86.5	1	NaN	100 percent of area	N	75.5	1	NaN	87.28%
<a href="#">Scrub and Shrub</a>	5,046.25	5205	NaN	50 percent of area	Y	3,817	3937	NaN	151.28%
<a href="#">Saltwater Wetland</a>	27,943	3558	NaN	95 percent of area	Y	27,199.75	3417	NaN	102.46%
<a href="#">Aquatic Bed</a>	421	808	NaN	80 percent of area	Y	407.5	767	NaN	120.99%

**Socio-economic (7 elements)**

Name	Distribution			Compatible					Percent of goal
	Area (acres)	Occs	Avg Condition	Goal	Goal Met	Area (acres)	Occs	Avg Condition	
<a href="#">Pasture and Hay</a>	1,852.75	398	NaN	50 percent of area	Y	1,758.75	378	NaN	189.85%
<a href="#">National Register of Historic Places</a>	7.75	4	NaN	100 percent of occurrences	Y	7.75	4	NaN	100%
<a href="#">Marinas</a>	2	7	NaN	100 percent of occurrences	N	2	7	NaN	100%
<a href="#">TPWD Boat ramps</a>	2	8	NaN	100 percent of occurrences	N	1.5	6	NaN	75%
<a href="#">Cultivated Cropland</a>	174.25	19	NaN	50 percent of area	Y	172.5	18	NaN	197.99%
<a href="#">Boat Ramps</a>	1	4	NaN	100 percent of occurrences	Y	1	4	NaN	100%
<a href="#">Beach Access Points</a>	1.25	5	NaN	100 percent of occurrences	N	1	4	NaN	80%

**Abbreviations & Icons**

- Occ = Occurrences
- Y = Goal has been met (100% or more)
- Y = Goal has almost been met (90% - 99.9%)
- N = Goal has not been met (less than 90% has been met)

area would not be completely built out until 2042 (Figure 10B). Interestingly, despite the constraints placed on building in wetlands in the Mitigation Scenario, the change to higher housing density throughout a large portion of the study area still resulted in a longer time horizon for future development and more overall buildings.

When compared to the Future Trend Scenario, the increased development in the Mitigation Scenario resulted in higher values for most socio-economic indicators (Figure 11). For example, total population and number of schoolchildren increased in this new scenario. Consequently, this resulted in higher residential water/energy use and higher carbon dioxide from auto emissions. The number of commercial jobs, however, decreased in the Mitigation Scenario (Figure 11). This was most likely due to the restrictions placed on building in wetlands, which eliminated some areas that were previously designated for commercial development.

The summary evaluation report (Figure 14) for the Mitigation Scenario showed that seventeen conservation elements met their goals - 12 ecological (e.g., grasslands) and five socio-economic (e.g., cultivated cropland). Three ecological elements (e.g., freshwater wetlands) were also close to achieving their conservation goal (i.e., >90% of goal was met).

Detailed performance numbers for several conservation elements showed interesting changes when compared to results of previous scenarios (Figure 14). For example, freshwater wetlands were more compatible with the land use/land cover of the Mitigation Scenario (99% of goal was met) than they were Future Scenario land use/land cover (62% of goal was met). In fact, four of the six ecological elements that were incompatible with the Future Trend Scenario (but had previously been compatible with the Current Condition Scenario), were compatible once again with the land cover/land use of the Mitigation Scenario. These conservation elements included: grasslands, shoreline, scrub/shrub, and saltwater wetlands. The

conflicts for forestland and bareland, however, still remained. In addition, goal achievement decreased from 93% to 66% for Live Oaks. This was an important result since this element had a high conservation value, as evidenced by the relatively high conservation goal of 80% chosen by stakeholders.

Finally, the evaluation of the Mitigation Scenario produced a map of compatibility conflicts that identified areas where elements were incompatible with the new, modified future land use/aquatic condition and did not meet their conservation goals (Figure 15). This compatibility conflict map was helpful for identifying locations in the project region where conflict existed and comparing the spatial distribution of conflict between the different scenarios.

## Discussion

### *Iterative analysis sequence*

Informed land use decision-making calls for fair consideration of alternatives before one particular path is chosen. The land-sea toolkit developed and implemented for Aransas County supports this approach through the use of alternative scenarios and an iterative analysis sequence. For this project, the general sequence was to: (1) assess current and future trend scenarios, (2) identify problems, and (3) suggest potential mitigation options that can be used to construct a preferred scenario. It is difficult to mitigate all impacts with a single mitigation scenario, and therefore, it is often beneficial to develop several potential mitigation scenarios in order to reach conservation goals. Due to time constraints in the Mission-Aransas NERR EBM tool demonstration project, only one Mitigation Scenario was developed. Overall, however, this scenario was very successful at improving the socio-economic and ecological impacts that resulted from the Future Trend Scenario.

The compatibility of all conservation elements were summarized for each of the three scenarios (Table 3). Seven elements

**Figure 15. Compatibility conflict map for Mitigation Scenario. Vista evaluated scenario compatibility and identified potential areas of conflict between modified future land use/land cover and marine condition. NOTE: Tan color represents areas where there are no conflicts between elements and land use, while red indicates areas where conflict does exist.**



(bareland, forestland, freshwater wetland, grassland, saltwater wetland, scrub/shrub, and shoreline) achieved greater than 90% of their conservation goal in the Current Condition Scenario, but were incompatible with the land use/land cover of the Future Trend Scenario. Five of these elements (freshwater wetland, grassland, saltwater wetland, scrub/shrub, and shoreline), however, returned to greater than 90% goal achievement with the modifications made in the Mitigation Scenario. Despite these changes, though, two elements (bareland & forestland) remained incompatible, and one element (Live Oak) actually decreased to less than 90% goal achievement.

Although an additional mitigation scenario was not created to improve compatibility of the remaining incompatible elements, the Mitigation Scenario produced a compatibility map (Figure 15) that provides an indication as to where changes to future scenarios would be most beneficial. Modifying land use in the areas of high conflict is likely to improve the results for ecological indicators. Examples of land use/land cover scenario modifications include: changes in density rules, designation of no-build areas, addition of mixed-use zoning, or changes in building setbacks. It is important to remember, however, that further modifications of the

land use/land cover scenarios will also result in changes to socio-economic indicators, such as the number of jobs. Therefore, the socio-economic impacts of changes to the Mitigation Scenario should be carefully considered when making further changes.

### ***Endangered, threatened, & rare species***

Many endangered, threatened, and rare species/communities were included as conservation elements in the current project and were evaluated to determine their compatibility with the different land use/land cover scenarios. Results indicated that the majority of these elements were not compatible with any of the land use scenarios, including the current land use/land cover (Table 3). One possible explanation for the high levels of conflict for these species/communities of concern is the type of spatial data used to describe the distribution/extent of these elements.

Spatial data for species and communities of concern was obtained from the Texas Natural Diversity Database (TNDD), maintained by the Texas Parks and Wildlife Department. This data depicted areas of land and/or water in which species, natural communities, or other significant features of natural diversity had been observed. As a result of the methods used to produce the TNDD polygons (see Appendix D), they do not represent the total distribution of the species/community of concern, but instead, are geographic representations of species/community observations in the best, most accurate way possible. The lack of polygons on the map can also not be interpreted as an absence of rare, threatened, or endangered species. This simply indicates a lack of any observations for that particular area. The TNDD data does not provide a definitive report as to the presence, absence, or condition of species or natural communities of concern, which made interpretation of the scenario evaluation results for endangered, threatened, and rare elements somewhat complicated.

During the scenario evaluation, Vista examined the entire polygon for areas where land use/land cover were incompatible with the habitat requirements of each species, despite the fact that the polygon did not represent the true extent of a particular species. Subsequently, each scenario (including the Current Condition Scenario) had large areas of incompatible land use/land cover and low conservation goal achievement.

Although the TNDD data resulted in an overestimation of species and community distributions (and subsequently conflict), this may still be an acceptable dataset to use when considering the effects of land use/land cover changes on endangered, threatened, or rare elements. Since future development will likely result in additional negative impacts to these species and communities, using polygons that overestimate the extent of these elements provides a more “conservative” approach for assessing impacts. By overestimating their extent, it decreases the chances of overlooking potential impacts to the habitats upon which these elements rely, even if their presence within them is somewhat uncertain.

Since overall goal achievement was low for endangered, threatened, and rare elements for all three scenarios, it was more useful to compare evaluation results across the different land use/land cover scenarios. Interestingly, for many of the endangered, threatened, and rare species and communities, the number of compatible acres did not change between the different land use/land cover scenarios. This was simply due to the fact that the polygons that represented the distributions of these particular elements were located outside any areas of future development (i.e., no land use/land cover changes occurred).

Conversely, all elements that were located within areas of future development saw a decrease in the number of compatible acres when land use/land cover changed with future development. The amount of compatible acres, however, did increase for these elements when the development scenario was modified to form the Mitigation Scenario. Most of these elements achieved, or were very close

**Table 3. Summary of conservation element compatibility for all three land use scenarios included in the Aransas County project (Y = conservation goal met, N = conservation goal not met, N\* = achieved greater than 90% of conservation goal). Bold type indicates conservation elements that saw a decrease in compatibility from current condition and gray shading indicates conservation elements that returned to the compatibility level of the current condition.**

Conservation Element	Current Condition	Future Trend	Mitigation
Aquatic Bed	Y	Y	Y
Atlantic Hawksbill Sea Turtle ( <i>Eretmochelys imbricate</i> )	N	N	N
<b>Bareland</b>	<b>Y</b>	<b>N</b>	<b>N</b>
Beach Access Points	N	N	N
Black Spotted Newt ( <i>Notophthalmus meridionalis</i> )	N	N	N
Bluestem Grasslands	N	N	N
Boat Ramps (non-TPWD)	Y	Y	Y
Coastal Preserves	N	N	N
Cultivated Cropland	Y	Y	Y
<b>Forestland</b>	<b>Y</b>	<b>N</b>	<b>N</b>
<b>Freshwater Wetland</b>	<b>N*</b>	<b>N</b>	<b>N*</b>
<b>Grasslands</b>	<b>Y</b>	<b>N</b>	<b>Y</b>
Gulf Salt Marsh Snake ( <i>Nerodia clarkia</i> )	Y	Y	Y
Jaguarundi ( <i>Nerpailurus yaguarondi</i> )	N	N	N
Lakes and Ponds	Y	Y	Y
<b>Live Oak (<i>Quercus</i> spp.)</b>	<b>N*</b>	<b>N*</b>	<b>N</b>
Mangroves	Y	Y	Y
Marinas	Y	Y	Y
Mud and Tidal Flats	N	N	N
National Audubon Society Sanctuaries	N	N	N
National Register of Historic Places	Y	Y	Y
Oyster Reef	Y	Y	Y
Pasture and Hay	Y	Y	Y
Peregrine Falcon ( <i>Falco peregrinus</i> )	N	N	N
Salt Marsh	N*	N*	N*
<b>Saltwater Wetland</b>	<b>Y</b>	<b>N*</b>	<b>Y</b>
<b>Scrub/Shrub</b>	<b>Y</b>	<b>N</b>	<b>Y</b>
Seacoast Bluestem Gulf-Dune Paspalum Series ( <i>Schizachyrium scoparium</i> var. <i>littoralis</i> -paspalum)	N	N	N
Seagrass Beds	N	N	N
<b>Shoreline</b>	<b>Y</b>	<b>N*</b>	<b>Y</b>
Streams	Y	Y	Y
Tall Todder ( <i>Cuscuta exaltata</i> )	N	N	N
Texas Diamondback Terrapin ( <i>Malaclemys terrapin littoralis</i> )	Y	Y	Y
Texas Scarlet Snake ( <i>Cemophora coccinea lineri</i> )	N	N	N
Tharps Rhododon ( <i>Rhododon angulatus</i> )	N	N	N
TPWD Boat Ramps	N	N	N
Velvet Spurge ( <i>Euphorbia innocua</i> )	N	N	N
Water Bird Rookeries	N*	N*	N*
Whooping Crane ( <i>Grus americana</i> )	N	N	N

to achieving, the same level of compatibility as the Current Condition Scenario. The black spotted newt provided a good example of this situation. In the Current Condition Scenario, 3,920 acres of the newt’s “distribution” were compatible with land use/land cover. This decreased to 1,754 acres in the Future Trend Scenario, but returned to 3,802 acres in the Mitigation Scenario. This indicates that the land use/land cover changes proposed by the Mitigation Scenario were sufficient at conserving almost all the compatible habitat of the black spotted newt (Figure 16).

Although better habitat distribution data would improve the overall accuracy of the compatibility results and provide more precise information about the potential impacts of future development to species/communities of concern, the TNDD data did still provide some useful information on impacts of different land use/land cover scenarios. Comparisons of the three scenario evaluations revealed that the Mitigation Scenario was effective in returning compatibility levels to their original values for almost all threatened, endangered, and rare elements affected by future development. However, the overall amount of compatible acres for most species was still well below conservation goals for each scenario. This is likely due to an overestimation of conflict

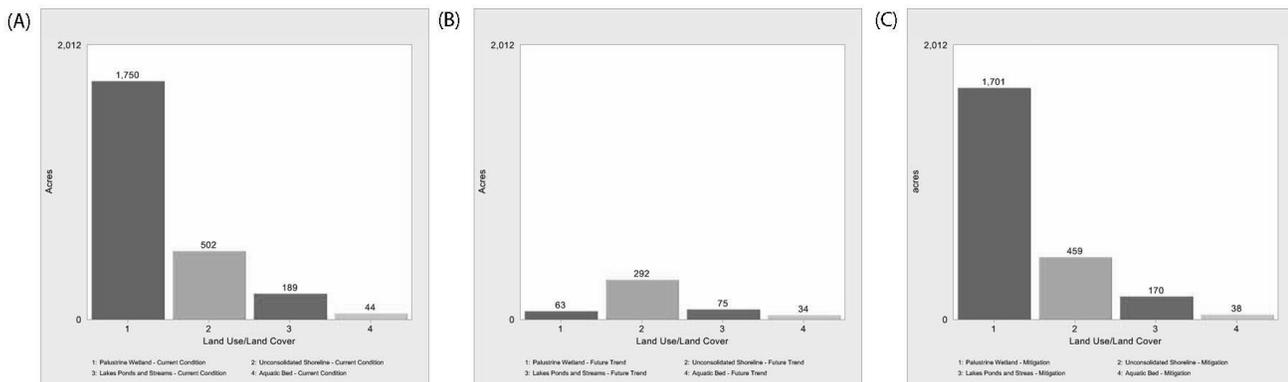
caused by the type of habitat distribution data used, but a cautious approach, such as this may be useful with species that are especially sensitive. Therefore, it may be more effective to try and mitigate these overestimated conflicts and decrease the possibility of overlooking potential areas of conflict in the future.

### Water Quality in Seagrass Beds

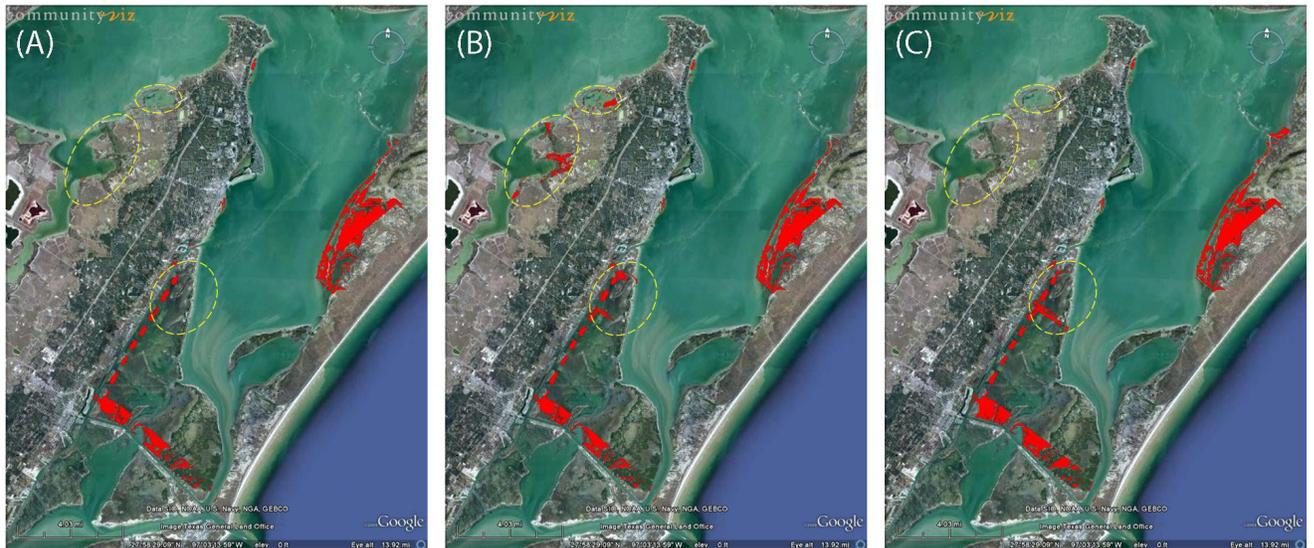
Seagrass beds provide numerous ecosystem services (e.g., nursery habitat, stabilization of sediments, biological indicators of ecosystem health) and were identified by stakeholders and researchers as a focal point of this project. Seagrasses are sensitive to changes in water clarity and often suffer negative effects from decreased light attenuation. As a result, land use/land cover changes that increase the amount of runoff and sediment (i.e., total suspended solids [TSS]) transported to the marine environment can have negative impacts on seagrass beds.

The current project examined (1) the effect of different land use/land cover scenarios on the amount of TSS transported to the marine environment and (2) the effect of subsequent changes in water quality on compatibility of seagrass beds. To assess

**Figure 16. Acres of compatible land use/land cover located within the distribution of the critically imperiled Black spotted newt. Results are shown for the (A) Current Condition Scenario, (B) Future Trend Scenario, and (C) Mitigation Scenario.**



**Figure 17. Areas in which seagrass beds are incompatible with water quality and management practices are displayed in red. Differences between the (A) Current Condition Scenario, (B) Future Trend Scenario, and (C) Mitigation Scenario are highlighted by the dashed yellow lines.**



compatibility, the marine environment was classified into three categories based on water quality conditions (i.e., TSS concentration) and their relationship to seagrass growth. Only those seagrass beds that were located in “good” areas of water quality were counted towards goal achievement.

Results showed that conservation goals (95% of total area) were not met for seagrass beds in any of the three scenarios (Table 3). However, a closer examination of the scenario evaluations showed that compatibility of seagrass beds did change slightly between the three scenarios (Figure 17). Since all management activities (e.g., placement of dredge material) were the same for every scenario, any changes in compatibility could be attributed to changes in water quality due to variations in land use/land cover from development. In the Current Condition Scenario, 12,911 acres of seagrass beds were located in areas where both management activities and water quality were “good” for seagrass growth (83% overall goal achievement). This decreased in the Future Trend Scenario to 12,378 acres (79% achievement), and there was only a slight

increase in goal achievement in the Mitigation Scenario which had 12,400 compatible acres (79% achievement). This indicates that future development had negative impacts on water quality and that the Mitigation Scenario was not as effective in eliminating all of these impacts.

Differences between the Current Condition Scenario and the Future Trend Scenario in seagrass bed compatibility primarily occurred along the western shoreline of Live Oak Peninsula (i.e., Copano and Port Bays) where the amount of seagrass beds located within areas of “good” water quality decreased in the Future Trend Scenario (Figure 17). In the western portion of the Peninsula, land use/land cover was changed from its current condition (wetlands, grasslands, and forestland) to medium/low intensity development, which resulted in a large increase in runoff and TSS concentrations. Ultimately, this resulted in lower water quality in areas of the marine environment in the Future Trend Scenario, and this explains the decrease in compatibility observed for seagrass beds. There was also a small decrease in the number of compatible

acres on the eastern shoreline of Live Oak Peninsula (i.e., Aransas Bay), but this was a much smaller area than along the western shoreline.

When compared to the Future Trend Scenario, the Mitigation Scenario did show an increase in the number of acres of compatible seagrass beds, but this increase was relatively small. The land use/land cover changes made in the Mitigation Scenario (i.e., building constraints for wetlands; higher housing density in certain areas) were effective at eliminating almost all of the seagrass impacts from the previous Future Trend Scenario that were observed in Copano and Port Bays. The change to higher density development on the eastern side of the Live Oak Peninsula, however, actually resulted in an increase in the amount of incompatible seagrass area on the eastern side in Aransas Bay (Figure 25). The Mitigation Scenario was not as effective at eliminating future land use/land cover impacts to seagrass beds and conflicts with water quality simply occurred in a different area. However, by identifying the areas that are large contributors of TSS in the Mitigation Scenario and altering the land use/land cover in those locations, many of the negative impacts that were observed in seagrass beds in Aransas Bay could be eliminated. Careful consideration should be taken though, since socio-economic variables are also likely to change when altering land use/land cover.

## Conclusions

Ecological and socio-economic indicators were used in the current study to quantify impacts of land use/land cover conditions and compare the relative merits of potential alternative future growth scenarios. The Future Trend Scenario was based on the maximum amount of theoretical development that could take place under current land use regulations and knowledge of expected growth patterns. While most socio-economic indicators were high for this scenario, there was an overall decrease in ecological goal achievement when compared to the

current land use/land cover. The Mitigation Scenario was developed in response to the results of the Future Trend Scenario and was much more responsive to ecological goals, while still showing high results for many of socio-economic indicators. In fact, almost all ecological indicators for the Mitigation Scenario were similar to the results of the Current Condition Scenario and the majority of socio-economic indicators were higher than those of the Future Trend Scenario.

There were, however, a small number of indicators that either did not show improvement or showed a decrease due to the land use/land cover proposed in the Mitigation Scenario. For example, when constraints were placed on building in wetlands, the amount of area available for commercial development decreased, resulting in fewer commercial jobs. The Mitigation Scenario also increased the development density along the eastern side of Live Oak Peninsula, which had a negative impact on forestland, bareland, and Live Oaks. These density changes also decreased the water quality in seagrass beds in Aransas Bay through increased runoff and sediment deposition in the marine environment.

The preferred scenario is one in which all socio-economic, ecological, and water quality goals are met, and further modifications to the Mitigation Scenario (such as inclusion of mixed zoning to increase commercial areas, or addition of no-build buffer zones around wetlands to reduce TSS contributions) may improve results for indicators such as those mentioned above. It is important to remember, however, that it might not be possible to achieve all goals in a single scenario, and in this case, goals may need to be modified for any one or a combination of objectives. This will require negotiation among stakeholders to determine new goals and priorities.

The results of this project clearly show that implementing an integrated land-sea planning method can help mitigate many of the potential problems associated with increased human activity in coastal communities. This leads to an ecosystem based management approach in which ecological and water

quality objectives are achieved, while also still accomplishing socio-economic goals. Although this type of planning approach requires a significant commitment from planners, resource managers, local officials, scientists, and stakeholders, its benefits are tremendous and it will greatly assist growing coastal communities, such as Aransas County, with land use planning and resource management decisions.

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## Appendix A - Build Out Analysis

A build-out analysis requires a map of land-use designations and a set of simple rules that specify the maximum densities and intensity of development allowed for each land-use type (Table 4). These rules are usually the density rules commonly found in zoning regulations or growth management plans. In the current project, City of Rockport zoning ordinances were used whenever applicable. There was a lack of land use regulations, however, throughout much of the project area. As a result, land use designations in these areas were based on local development trends and stakeholder input about known future development. Following

the build-out analysis in CommunityViz, the land use designations were translated into the “Common Land Use Classification List” in Vista.

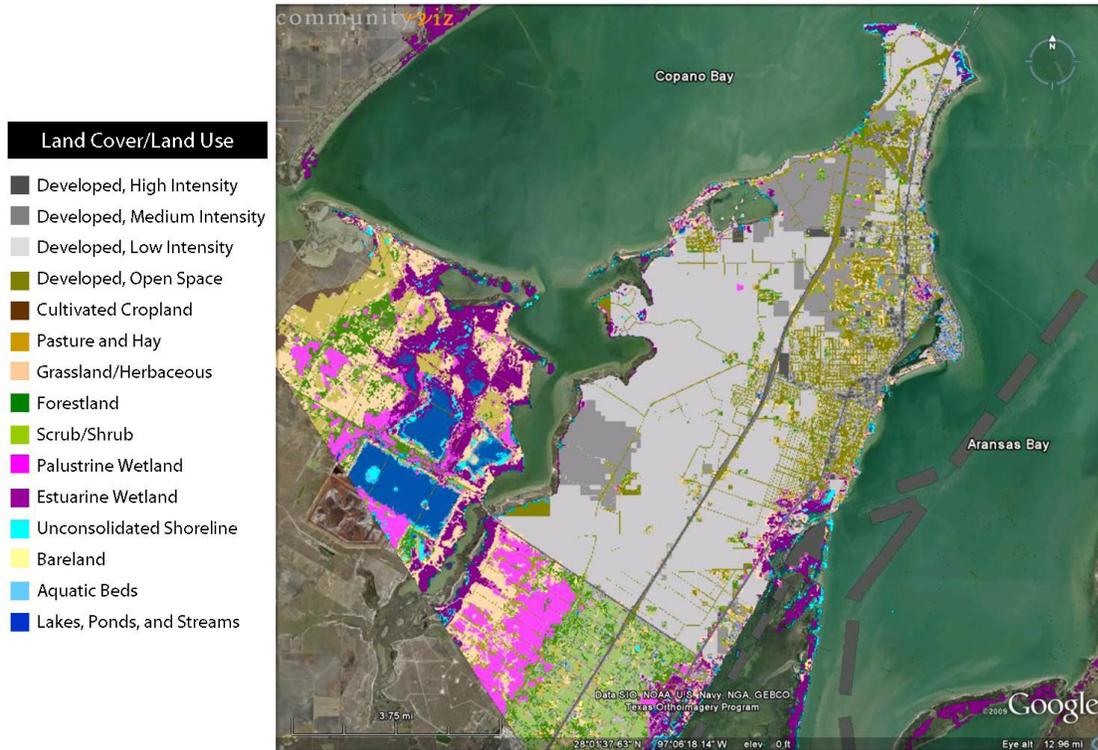
For residential designations, the maximum future development was designated using density (dwelling units per area) and minimum lot size (minimum area required for each dwelling unit). For non-residential designations, maximum future development intensity was measured with a floor-area-ratio (FAR). This was the percentage of site development based on the overall square footage of buildings divided by the parcel area.

**Table 4. CommunityViz land use designations and density rules applied to Mission-Aransas NERR project area. The table also shows the relationship between the CommunityViz land use designations and the common land use classification list.**

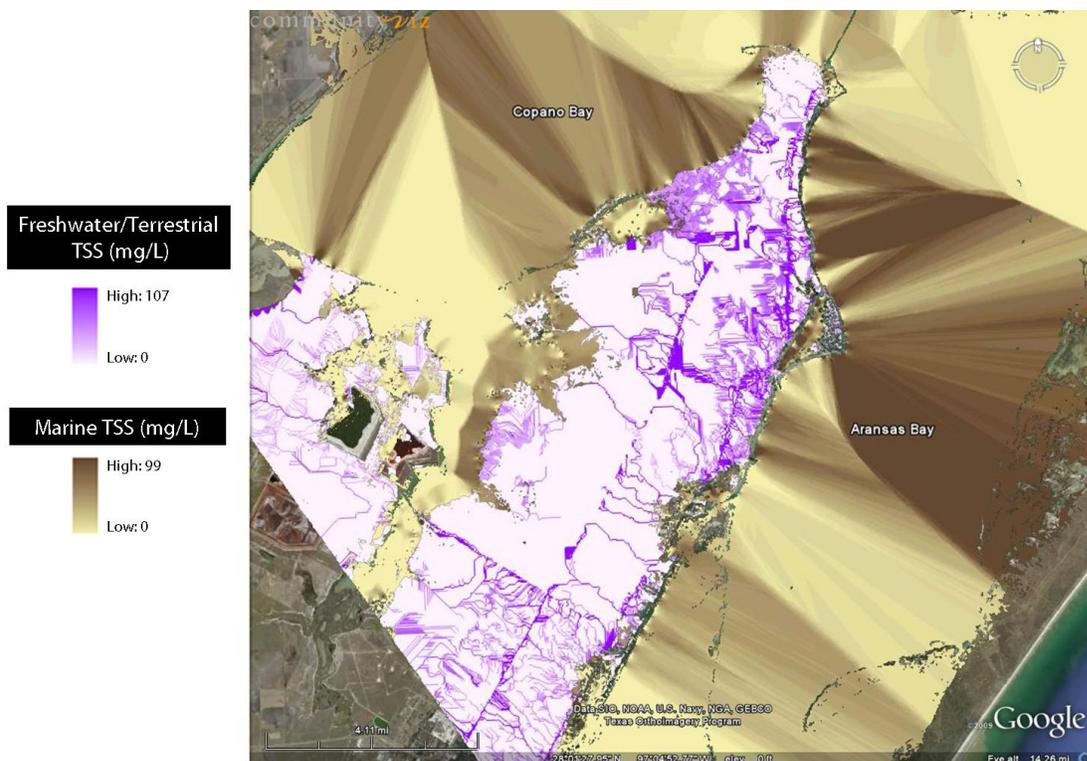
CommunityViz Land Use Designation	Density Rules	Common Land Use Classification List
Business-1	0.6 FAR	Developed, High Intensity
Industrial-2	0.6 FAR	Developed, High Intensity
Planned Urban Development-1	30 dwelling units	Developed, High Intensity
Residential-1	0.16 minimum lot size	Developed, Medium Intensity
Residential-2	0.12 minimum lot size	Developed, Medium Intensity
Residential-5	0.12 minimum lot size	Developed, Medium Intensity
Residential-6	0.12 minimum lot size	Developed, Medium Intensity
Urban Infill	N/A	N/A
Rural Low Density	1 dwelling unit/acre	Developed, Low Intensity
Rural High Density	1.5 dwelling unit/acre	Developed, Medium Intensity
Rural Residential	0.05 dwelling unit/acre	Developed, Low Intensity
Preservation	1 dwelling unit/acre (Future Trend Scenario) or 0 dwelling unit/acre (Mitigation Scenario)	Developed, Low Intensity

## Appendix B - Future Trend Scenario

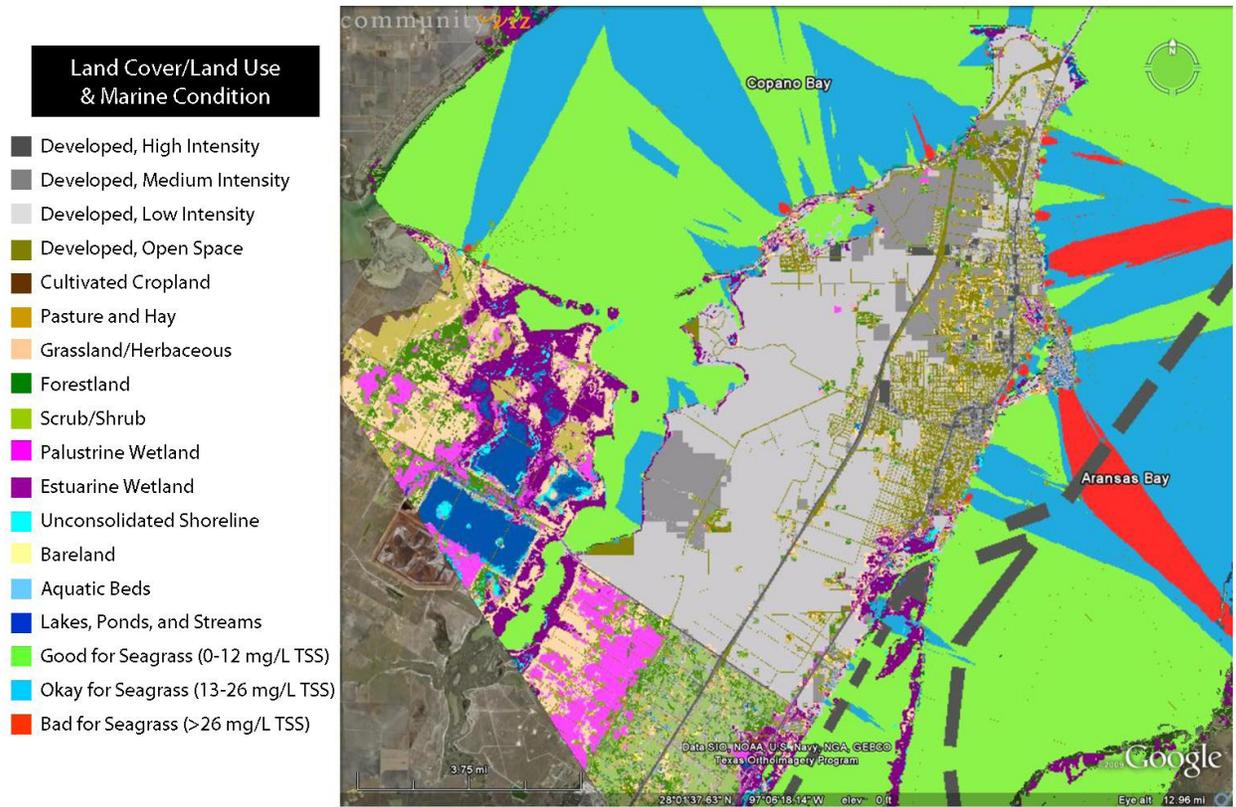
**Figure 18. Future land use/land cover data was developed in CommunityViz and supplemented with additional data in Vista to produce the Future Trend Scenario land use/land cover.**



**Figure 19. N-SPECT results (purple) show the concentration of total suspended solid (TSS) produced by runoff in the terrestrial and freshwater components of the study area based on the Future Trend Scenario land use/land cover. Shoreline and river mouth values were used to model TSS concentrations in the marine environment (brown).**



**Figure 20. Marine water quality modeling results incorporated with Future Trend Scenario land use/land cover.**

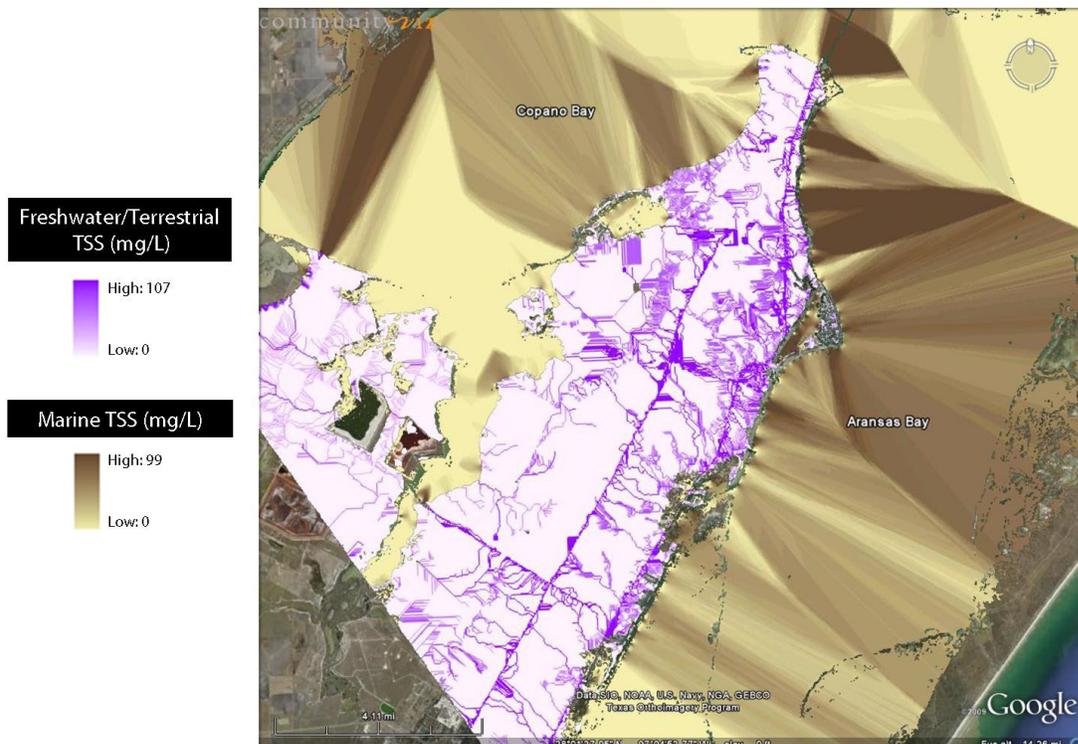


## Appendix C - Mitigation Scenario

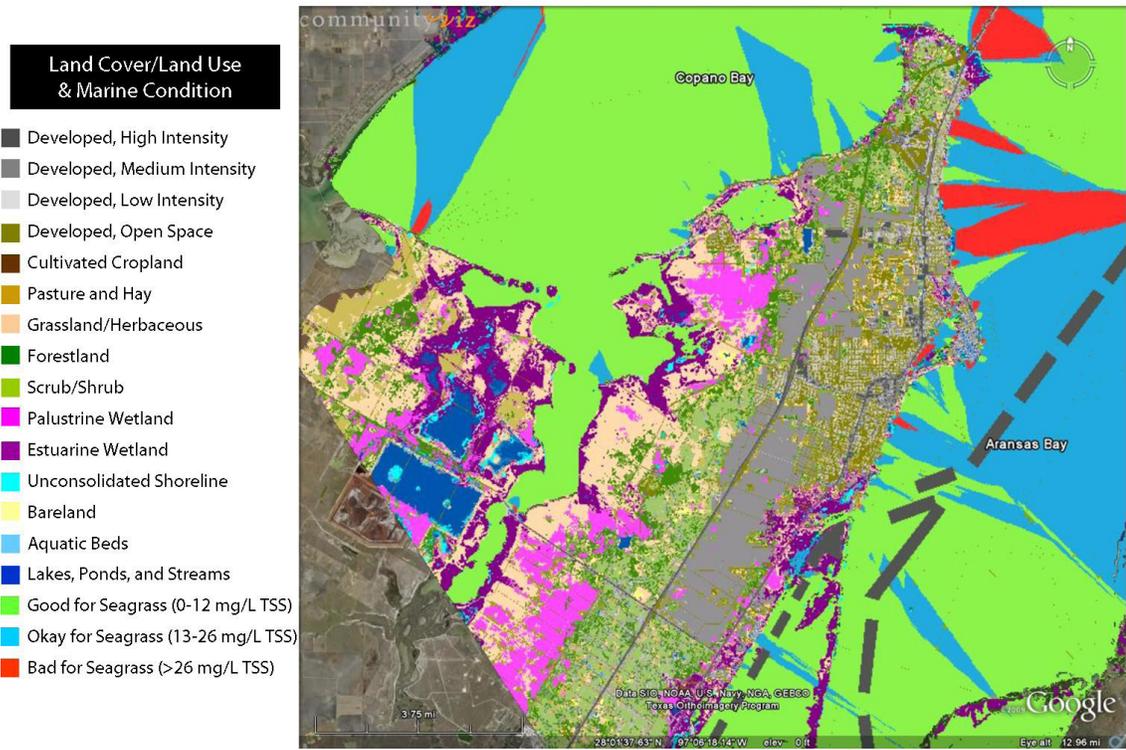
**Figure 21.** Future land use/land cover data was modified in CommunityViz and supplemented with additional data in Vista to produce the Mitigation Scenario land use/land cover.



**Figure 22.** N-SPECT results (purple) show the concentration of total suspended solid (TSS) produced by runoff in the terrestrial and freshwater components of the study area based on the Mitigation Scenario land use/land cover. Shoreline and river mouth values were used to model TSS concentrations in the marine environment (brown).



**Figure 23. Marine water quality modeling results incorporated with Mitigation Scenario land use/land cover data in Vista.**

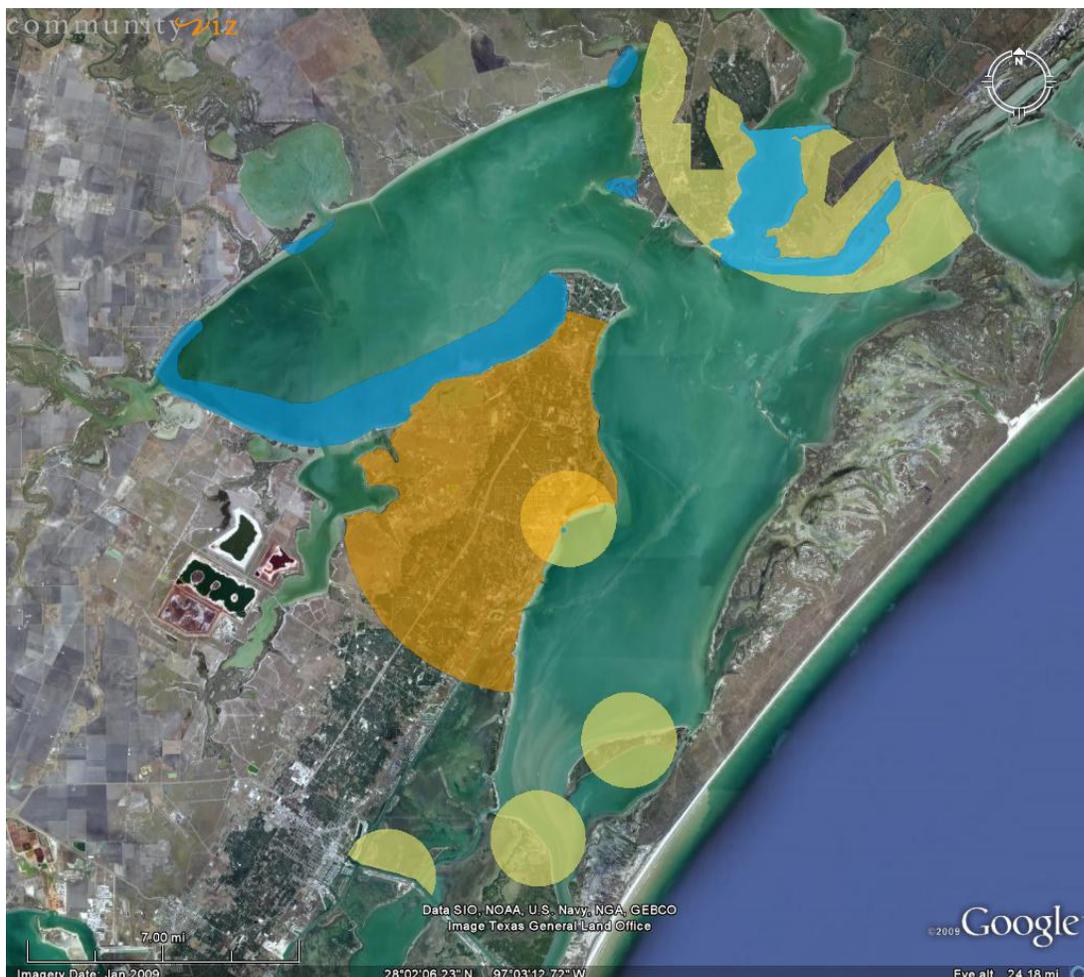


## Appendix D - TNDD Data

Spatial data for species and communities of concern was obtained from the Texas Natural Diversity Database (TNDD), maintained by the Texas Parks and Wildlife Department. The spatial data provided by the TNDD was produced using one of two methods. The first method produces polygons that are based on “meaningful” boundaries. For example, the blue polygons in Figure 24 represented areas along the shoreline where Texas diamondback terrapins (*Malaclemys terrapin littoralis*) were likely to be found. The TNDD adds a buffer of 100 m to each of these “meaningful” boundaries to account for a lack of information about the precision of the boundary.

The second method uses one-time observations at single locations (i.e., points) to produce polygons. A “buffer” is added around each point to produce a polygon for every observation. The size of the circular buffer is based on the precision of the data collected for that particular observation. Records with a high precision receive a buffer of 100 meters, records of medium precision receive a buffer of 2,000 meters, and records with low precision receive a buffer of 8,000 meters. These circular polygons represent the smallest area that can be drawn with confidence that an element will occur inside the boundary. The TNDD data does not provide any information about the distribution of the element within

**Figure 24. Spatial data gathered from the Texas Natural Diversity Database that describes areas of land and/or water where the black spotted newt (orange), Gulf saltmarsh snake (yellow), and Texas Diamondback Terrapin (blue) are known to exist.**



the buffered circle. It only indicates that on the day of the observation, the element could be found, with confidence, within the boundary of that polygon.

For example, the polygon that represented the “distribution” of the critically imperiled black spotted newt (*Notophthalmus meridionalis*) was based on one historic observation of low precision. This point was buffered to produce a large polygon that covered almost the entire Live Oak Peninsula (orange - Figure 24). This polygon did not represent the true total extent of the newt, but instead, signified an area where there was confidence that a black spotted newt had previously been observed. The exact location of the newt within that polygon was not known. The orange polygon in Figure 24 was produced using this method. The original circle produced for the black spotted newt observation was clipped to fit within the project area boundary or the terrestrial/aquatic environments. This clipping was done for several of the circles and accounts for the non-circular shape of many of the polygons.







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