Application of the Sea-Level Affecting Marshes Model (SLAMM 5.0) to Shell Keys National Wildlife Refuge

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Introduction

Tidal marshes are among the most susceptible ecosystems to climate change, especially accelerated sea level rise (SLR). Sea level is predicted to increase by 30 cm to 100 cm by 2100 based on the International Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) (Meehl et al. 2007). Rising sea level may result in tidal marsh submergence (Moorhead and Brinson 1995) and habitat migration as salt marshes transgress landward and replace tidal freshwater and brackish marsh (Park et al. 1991).

In an effort to address the potential effects of sea level rise on United States national wildlife refuges, the U. S. Fish and Wildlife Service contracted the application of the SLAMM model for most Region 4 refuges. This analysis is designed to assist in the production of comprehensive conservation plans (CCPs) for each refuge. A CCP is a document that provides a framework for guiding refuge management decisions. All refuges are required by law to complete a CCP by 2012.

Model Summary

Changes in tidal marsh area and habitat type in response to sea-level rise were modeled using the Sea Level Affecting Marshes Model (SLAMM 5.0) that accounts for the dominant processes involved in wetland conversion and shoreline modifications during long-term sea level rise (Park et al. 1989; www.warrenpinnacle.com/prof/SLAMM).

Successive versions of the model have been used to estimate the impacts of sea level rise on the coasts of the U.S. (Titus et al., 1991; Lee, J.K., R.A. Park, and P.W. Mausel. 1992; Park, R.A., J.K. Lee, and D. Canning 1993; Galbraith, H., R. Jones, R.A. Park, J.S. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002; National Wildlife Federation et al., 2006; Glick, Clough, et al. 2007; Craft et al., 2009.

Within SLAMM, there are five primary processes that affect wetland fate under different scenarios of sea-level rise:

- **Inundation:** The rise of water levels and the salt boundary are tracked by reducing elevations of each cell as sea levels rise, thus keeping mean tide level (MTL) constant at zero. The effects on each cell are calculated based on the minimum elevation and slope of that cell.
- **Erosion:** Erosion is triggered based on a threshold of maximum fetch and the proximity of the marsh to estuarine water or open ocean. When these conditions are met, horizontal erosion occurs at a rate based on site-specific data.
- **Overwash:** Barrier islands of under 500 meters width are assumed to undergo overwash during each 25-year time-step due to storms. Beach migration and transport of sediments are calculated.
- **Saturation:** Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response of the fresh water table to rising sea level close to the coast.

- **Accretion:** Sea level rise is offset by sedimentation and vertical accretion using average or site-specific values for each wetland category. Accretion rates may be spatially variable within a given model domain.

SLAMM Version 5.0 is the latest version of the SLAMM Model, developed in 2006/2007 and based on SLAMM 4.0. SLAMM 5.0 provides the following refinements:

- The capability to simulate fixed levels of sea-level rise by 2100 in case IPCC estimates of sea-level rise prove to be too conservative;
- Additional model categories such as "Inland Shore," "Irregularly Flooded (Brackish) Marsh," and "Tidal Swamp."
- *Optional.* In a defined estuary, salt marsh, brackish marsh, and tidal fresh marsh can migrate based on changes in salinity, using a simple though geographically-realistic salt wedge model. This optional model was not used when creating results for Shell Keys.

Model results presented in this report were produced using SLAMM version 5.0.1 which was released in early 2008 based on only minor refinements to the original SLAMM 5.0 model. Specifically, the accretion rates for swamps were modified based on additional literature review. For a thorough accounting of SLAMM model processes and the underlying assumptions and equations, please see the SLAMM 5.0.1 technical documentation (Clough and Park, 2008). This document is available at http://warrenpinnacle.com/prof/SLAMM

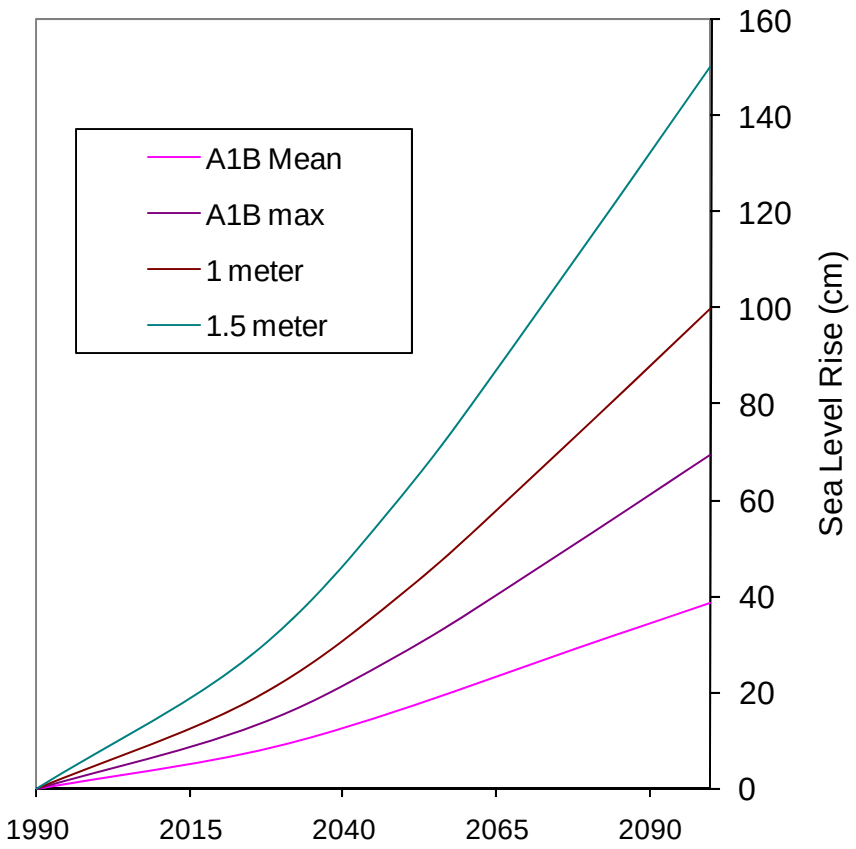
Sea-Level Rise Scenarios

The primary set of eustatic (global) sea level rise scenarios used within SLAMM was derived from the work of the Intergovernmental Panel on Climate Change (IPCC 2001). SLAMM 5 was run using the following IPCC and fixed-rate scenarios:

Scenario	Eustatic SLR by 2025 (cm)	Eustatic SLR by 2050 (cm)	Eustatic SLR by 2075 (cm)	Eustatic SLR by 2100 (cm)
A1B Mean	8	17	28	39
A1B Max	14	30	49	69
1 meter	13	28	48	100
1.5 meter	18	41	70	150

Recent literature (Chen et al., 2006, Monaghan et al., 2006) indicates that the eustatic rise in sea levels is progressing more rapidly than was previously assumed, perhaps due to the dynamic changes in ice flow omitted within the IPCC report's calculations. A recent paper in the journal *Science* (Rahmstorf, 2007) suggests that, taking into account possible model error, a feasible range by 2100 might be 50 to 140 cm. To allow for flexibility when interpreting the results, SLAMM was also run assuming 1 meter, 1½ meters of eustatic sea-level rise by the year 2100. The A1B- maximum scenario was scaled up to produce these bounding scenarios (Figure 1).

Figure 1: Summary of SLR Scenarios Utilized



Methods and Data Sources

High precision LiDAR data are available for Shell Keys as is the case for most of coastal Louisiana.

The National Wetlands Inventory for Shell Keys is based on a photo date of 1985. This survey, when converted to 30 meter cells, suggests that on that date, there were 7.3 acres of dry land, 3.1 acres of ocean beach, and 3.1 acres of tidal flat.

The historic trend for Sea Level Rise was estimated at 9 mm/year using the average of the long term trends measured on Grand Isle, Louisiana (NOAA station 8761724), Eugene Island, Louisiana (8764311), and Galveston Pleasure Pier, TX (8771510). This historic trend is dramatically higher than the global average for the last 100 years (approximately 1.5 mm/year) indicating that significant land subsidence is occurring in this region. When estimating the local effects of eustatic sea level rise in this region, this rate of subsidence (approximately 7.5 mm/year) is projected to continue over the period of projection.

The tide range for this site was estimated at 0.563 meters using the average of the three closest NOAA stations as shown below.

8766072	FRESHWATER CANAL LOCKS, LA	**0.638**
8765251	CYPREMORE POINT, LA	**0.525**
8764227	LAWMA, AMERADA PASS, LA	**0.525**

There were no stations within 25 miles of the study area that relate the NED vertical datum of NAVD88 to mean tide level. To be conservative, the lower range of several of the nearest stations was used (0.155). Using the low end of this range means that land elevations are set to higher levels as compared to mean tide level and predicted effects will be minimized as a result of this uncertainty.

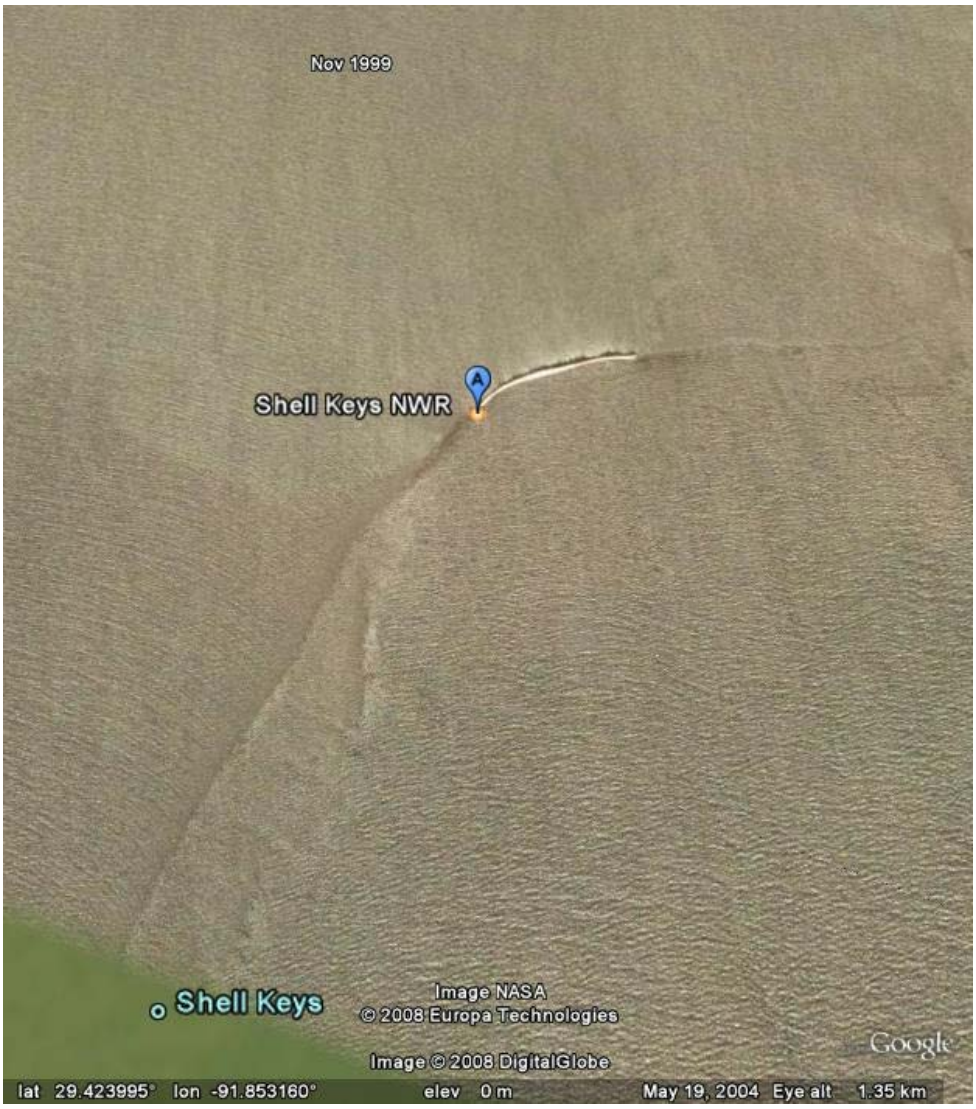
Station	Site Name	MTL-NAVD88 (m)
8771510	GALVESTON PLEASURE PIER	0.155
8771450	GALVESTON PIER 21	0.200
8761826	CHENIERE CAMINADA, CAMINADA PASS	0.331
8747437	BAY WAVELAND YC, BAY ST. LOUIS	0.164
8746819	PASS CHRISTIAN YC, MISS. SOUND	0.155
8761426	GREENS DITCH, LAKE ST. CATHERINE	0.217

Parameters pertaining to marshes (i.e. accretion rates and erosion rates) are not relevant to this site as there are no wetlands identified based on the National Wetlands Inventory, nor are any predicted to occur. Default values are therefore used, though the model will not be sensitive to those choices.

Modeled U.S. Fish and Wildlife Service refuge boundaries are based on Approved Acquisition Boundaries as received from Kimberly Eldridge, lead cartographer with U.S. Fish and Wildlife Service, and are current as of June, 2008.

The cell-size used for this analysis was 30 meter by 30 meter cells. However, the SLAMM model does track partial conversion of cells based on elevation and slope.

A conversation with Terry Delaine, the U.S. Fish and Wildlife Service refuge manager for Shell Keys occurred in July of 2008. He stated that at times this refuge is permanently submerged. When the site was visited most recently the small pieces of the island to the south are gone; only the larger piece in the north is remaining. This submergence is generally reflected in the SLAMM modeling results for 2025..



Shell Keys as viewed from Google Earth.

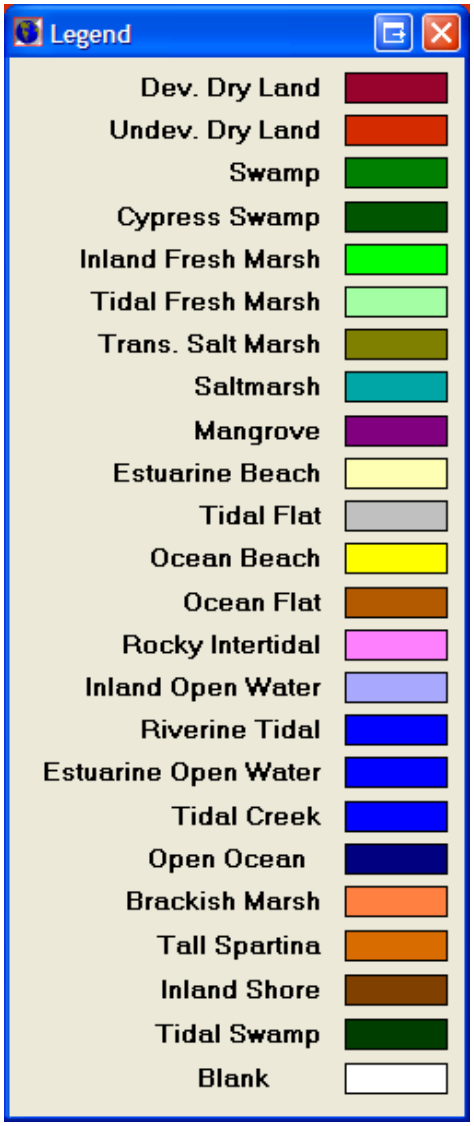
SLAMM INPUT PARAMETERS FOR SHELL KEYS

Site	**Shell Keys**
NED Source Date (yyyy)	2002
NWI_photo_date (yyyy)	1985
Direction_OffShore (N|S|E|W)	S
Historic_trend (mm/yr)	9
NAVD88_correction (MTL-NAVD88 in meters)	0.155
Water Depth (m below MLW- N/A)	2
TideRangeOcean (meters: MHHW-MLLW)	0.563
TideRangeInland (meters)	0.563
Mean High Water Spring (m above MTL)	0.374
MHSW Inland (m above MTL)	0.374
Marsh Erosion (horz meters/year)	1.8
Swamp Erosion (horz meters/year)	1
TFlat Erosion (horz meters/year) [from 0.5]	0.5
Salt marsh vertical accretion (mm/yr) Final	3.9
Brackish March vert. accretion (mm/yr) Final	4.7
Tidal Fresh vertical accretion (mm/yr) Final	5.9
Beach/T.Flat Sedimentation Rate (mm/yr)	0.5
Frequency of Large Storms (yr/washover)	25

Results

Results for all four scenarios of sea level rise result in complete loss of Shell Keys by 2050. Greater loss by 2025 is predicted under the greatest scenarios of sea level rise.

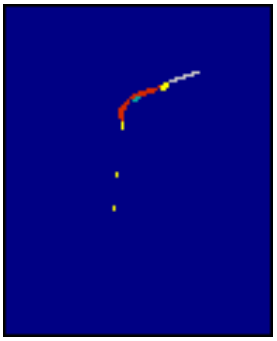
Maps of SLAMM input and output to follow will use the following legend:

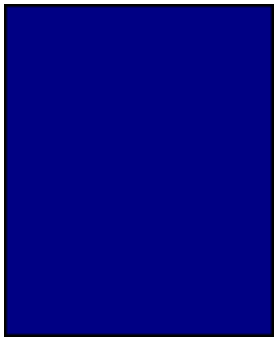


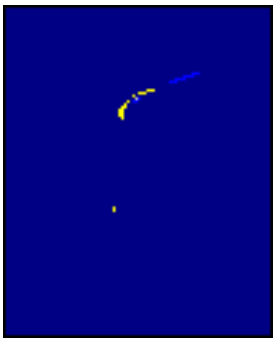
Shell Keys
IPCC Scenario A1B-Mean, 0.39 M SLR Eustatic by 2100

Results in Acres

	Initial	2025	2050	2075	2100
Open Ocean	2431.4	2438.2	2445.4	2445.9	2445.9
Dry Land	7.3	0.0	0.0	0.0	0.0
Ocean Beach	3.1	3.6	0.0	0.0	0.0
Tidal Flat	3.1	0.4	0.0	0.0	0.0
Saltmarsh	0.9	0.0	0.0	0.0	0.0
Estuarine Open Water	0.0	3.6	0.4	0.0	0.0
Total (incl. water)	**2445.9**	**2445.9**	**2445.9**	**2445.9**	**2445.9**


Shell Keys Initial Condition


Shell Keys 2075 IPCC Scenario A1B-Mean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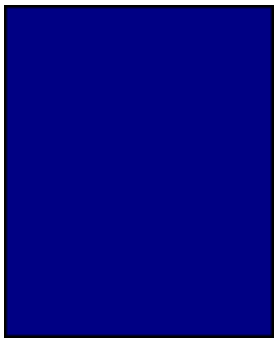
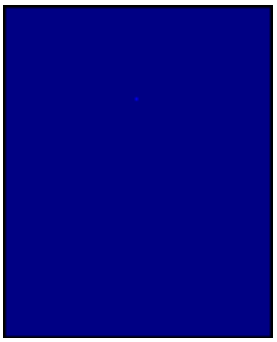
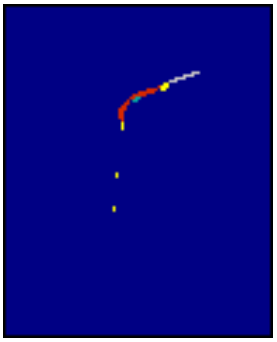

Shell Keys 2100 IPCC Scenario A1B-Mean

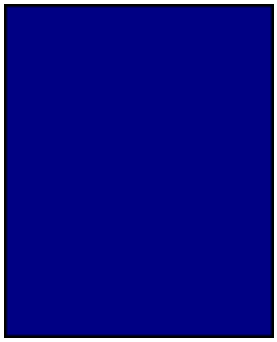

Shell Keys 2050 IPCC Scenario A1B-Mean

Shell Keys
IPCC Scenario A1B-Max, 0.69 M SLR Eustatic by 2100

Results in Acres

	Initial	2025	2050	2075	2100
Open Ocean	2431.4	2439.0	2445.4	2445.9	2445.9
Dry Land	7.3	0.0	0.0	0.0	0.0
Ocean Beach	3.1	2.9	0.0	0.0	0.0
Tidal Flat	3.1	0.4	0.0	0.0	0.0
Saltmarsh	0.9	0.0	0.0	0.0	0.0
Estuarine Open Water	0.0	3.6	0.4	0.0	0.0
Total (incl. water)	**2445.9**	**2445.9**	**2445.9**	**2445.9**	**2445.9**


Shell Keys Initial Condition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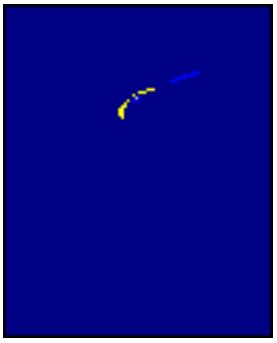
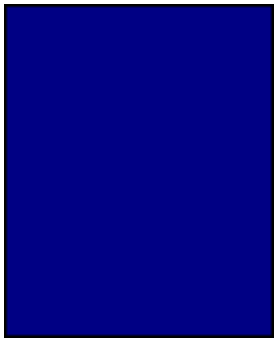
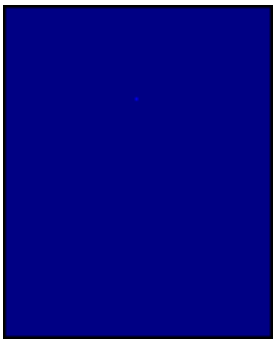

Shell Keys 2025 IPCC Scenario A1B-Max.

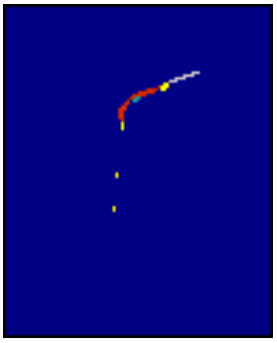

Shell Keys 2100 IPCC Scenario A1B-Max.

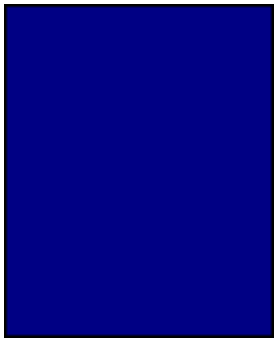

Shell Keys 2050 IPCC Scenario A1B-Max.

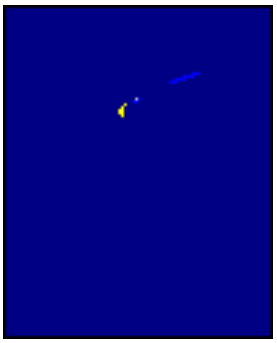
Shell Keys
1 Meter Eustatic SLR by 2100

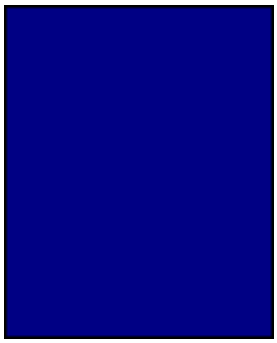
Results in Acres

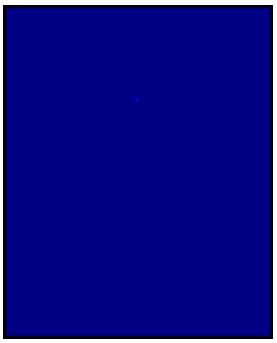
	Initial	2025	2050	2075	2100
Open Ocean	2431.4	2439.4	2445.4	2445.9	2445.9
Dry Land	7.3	0.0	0.0	0.0	0.0
Ocean Beach	3.1	2.4	0.0	0.0	0.0
Tidal Flat	3.1	0.4	0.0	0.0	0.0
Saltmarsh	0.9	0.0	0.0	0.0	0.0
Estuarine Open Water	0.0	3.6	0.4	0.0	0.0
Total (incl. water)	**2445.9**	**2445.9**	**2445.9**	**2445.9**	**2445.9**


Shell Keys Initial Condition


Shell Keys 2075 1 meter Eustatic by 2100


Shell Keys 2025 1 meter Eustatic by 2100

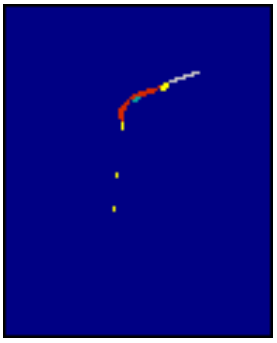

Shell Keys 2100 1 meter Eustatic by 2100

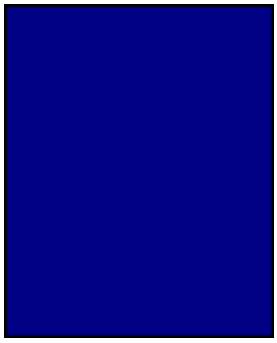

Shell Keys 2050 1 meter Eustatic by 2100

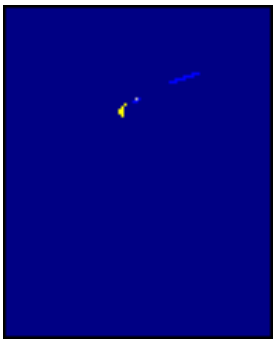
Shell Keys
1.5 Meters Eustatic SLR by 2100

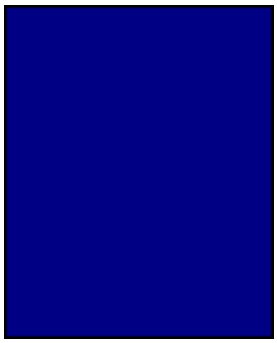
Results in Acres

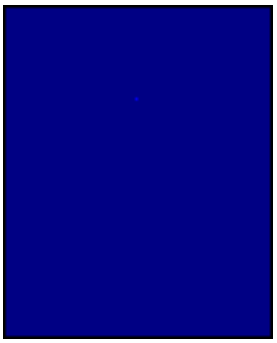
	Initial	2025	2050	2075	2100
Open Ocean	2431.4	2440.2	2445.4	2445.9	2445.9
Dry Land	7.3	0.0	0.0	0.0	0.0
Ocean Beach	3.1	1.7	0.0	0.0	0.0
Tidal Flat	3.1	0.4	0.0	0.0	0.0
Saltmarsh	0.9	0.0	0.0	0.0	0.0
Estuarine Open Water	0.0	3.6	0.4	0.0	0.0
Total (incl. water)	**2445.9**	**2445.9**	**2445.9**	**2445.9**	**2445.9**


Shell Keys Initial Condition


Shell Keys 2075 1.5 meter Eustatic by 2100


Shell Keys 2025 1.5 meter Eustatic by 2100


Shell Keys 2100 1.5 meter Eustatic by 2100


Shell Keys 2050 1.5 meter Eustatic by 2100

Discussion:

A discussion with the refuge manager for this site indicates that much this refuge is already permanently submerged. At present time, the small pieces of the refuge to the south are gone. The SLAMM modeling recognizes this trend in that by 2025 the southern portion of the refuge is predicted to disappear in every scenario utilized. A continued process of submergence is predicted for this site with complete loss by 2050 in all scenarios.

It is possible that Shell Keys NWR may reappear due to consolidation of submerged sediments and storm activities. The SLAMM model does not estimate such potential consolidation and reemergence of submerged lands. However, the results from this modeling indicate that permanent reemergence is unlikely due to the significant pressures of rising sea levels.

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