Application of the Sea-Level Affecting Marshes Model (SLAMM 5.0) to Sabine NWR

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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 Sabine NWR.

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

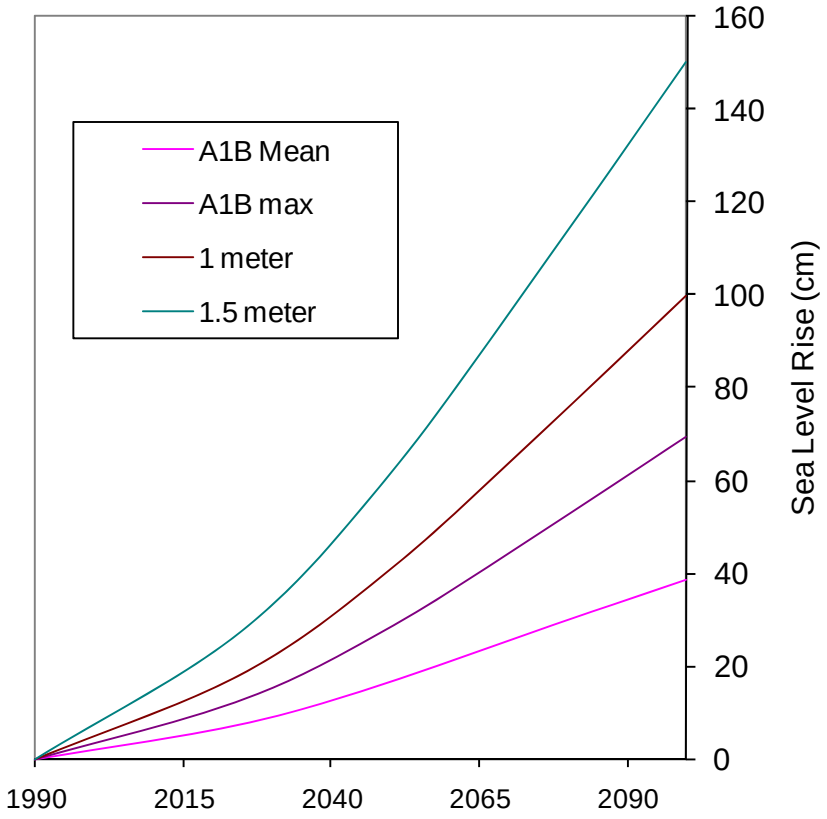
Sea-Level Rise Scenarios

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-resolution LIDAR data are available for Sabine NWR based on a 2005 flight-date. These elevation data are available through the National Elevation Dataset (NED) that was updated to reflect this high quality data. The vertical-resolution error for LIDAR data can be as low as 5-10 cm. NED elevation data were extracted a second time late in August 2008 to include data from a recent update on the USGS Seamless Data Server.

The National Wetlands Inventory for Sabine is based on a photo date of 1988. This survey, when converted to 30 meter cells, suggests that on that date, the approximately one hundred thirty thousand acre refuge (approved acquisition boundary) was composed of the categories as shown below:

Brackish Marsh	48.9%
Estuarine Open Water	23.1%
Inland Fresh Marsh	15.1%
Inland Open Water	10.5%
Dry Land	1.2%
Saltmarsh	0.9%
Estuarine Beach	0.2%

The historic trend for Sea Level Rise was estimated at 6 mm/year based primarily on the long term trend measured at Sabine Pass (NOAA station 8770570). This measured rate of 5.7 mm/year was slightly revised upward (to 6 mm/year) based on the higher trends measured from other region tide gages (Grand Isle LA at 9.2 mm/year and Eugene Island, LA at 9.6 mm/year). Historic trends in this region are considerably higher than the global average for the last 100 years (approximately 1.5 mm/year) indicating that 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 4.5 mm/year) is projected to continue over the period of projection.

The tide range at this site was estimated at 0.284 meters using the inland NOAA gage at Rainbow Bridge, TX (8770520). Using oceanic gages would likely overstate the range of tide experienced at the Sabine NWR.

The NED vertical datum of NAVD88 was related to mean tide level using results from the NOAA VDATUM model. Using the model available for the immediate vicinity of the refuge, a correction-factor of 0.269 meters was derived. This result is similar to the closest NOAA tide gages that relate NAVD88 to Mean Tide Level (table below).

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

Accretion rates were set based on an analysis of five studies of vertical accretion in Louisiana (Cahoon et al. 1994, Cahoon et al. 1995, Cahoon et al., 1999, Stevenson et al. 1986, White et al. 2002). Measured accretion rates for each marsh-type were averaged and are summarized in the table below. Accretion rates in Louisiana tend to be higher than those measured in other states.

Marsh Type	Accretion Rate (mm/yr)	
Freshwater	7.73	n=2
Brackish	7.67	n=5
Saline	9.75	n=6

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.

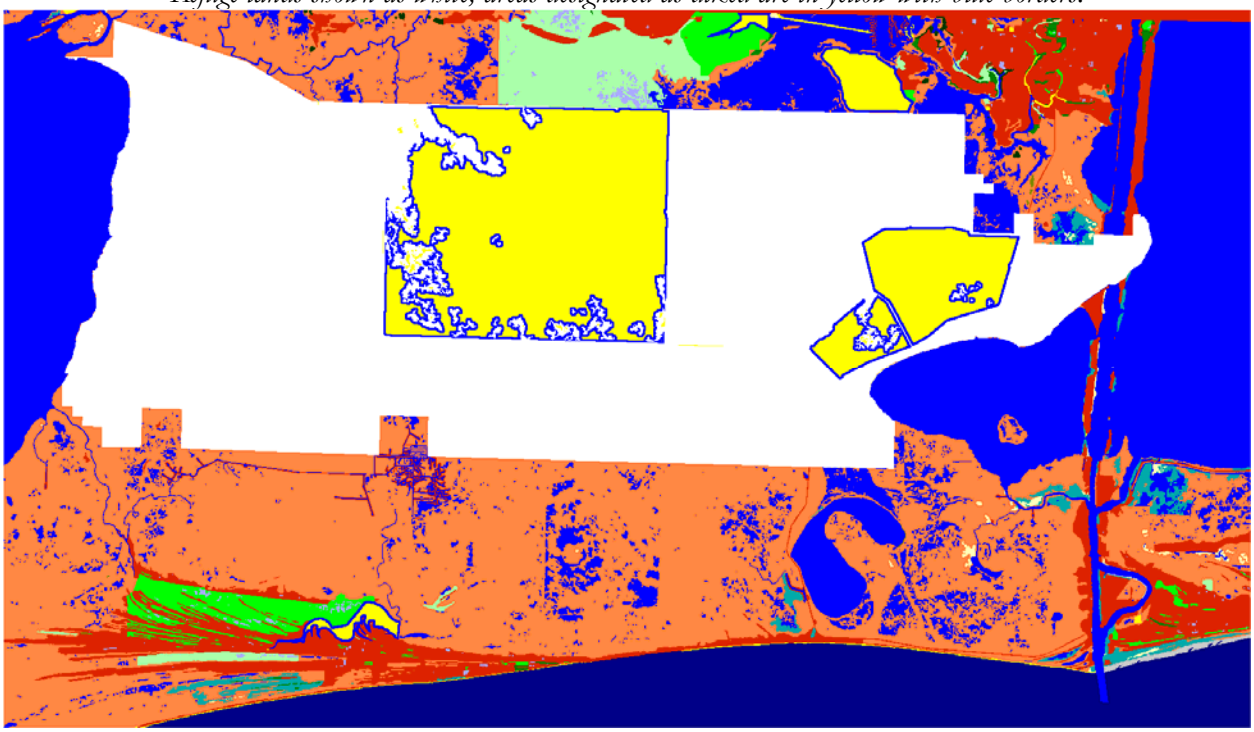
Geographic Location of Dikes

The region of Sabine is extensively affected by dikes. The SLAMM model accepts, as a model input, a designation of lands that are assumed to be protected by existing dikes. The model assumes that those lands protected by dikes are not subject to inundation but could still be subject to soil saturation due to pressure on the water table from sea level rise.

The National Wetlands Inventory demarcates significant lands protected by dikes and this coverage was used to determine the dike protection for this refuge. The NWI dike coverage is illustrated here. As shown below, these areas closely match up with all of the fresh-marsh acreage within the study area.

Figure 2: Sabine with NWI designated "Diked/Impounded" Modifier

Refuge lands shown as white; areas designated as diked are in yellow with blue borders.



SUMMARY OF SLAMM INPUT PARAMETERS FOR SABINE

Site		**Sabine**
NED Source Date (yyyy)	,	2005
NWI_photo_date (yyyy)	,	1988
Direction_OffShore (N|S|E|W)	,	S
Historic_trend (mm/yr)	,	6
NAVD88_correction (MTL-NAVD88 in meters)	,	0.269
Water Depth (m below MLW- N/A)	*,*	2
TideRangeOcean (meters: MHHW-MLLW)	,	0.284
TideRangeInland (meters)	,	0.284
Mean High Water Spring (m above MTL)	,	0.189
MHSW Inland (m above MTL)	,	0.189
Marsh Erosion (horz meters/year)	,	1.8
Swamp Erosion (horz meters/year)	,	1
TFlat Erosion (horz meters/year) [from 0.5]	,	2
Salt marsh vertical accretion (mm/yr) Final	,	9.75
Brackish March vert. accretion (mm/yr) Final	,	7.67
Tidal Fresh vertical accretion (mm/yr) Final	,	7.73
Beach/T.Flat Sedimentation Rate (mm/yr)	,	0.5
Frequency of Large Storms (yr/washover)	,	25
Use Elevation Preprocessor for Wetlands	,	FALSE

Results

Model results suggest that the Sabine National Wildlife Refuge will be subject to dramatic changes as a result of global sea level rise. The combination of global sea level rise and local subsidence results in predictions of salt water intrusion with significant effects.

SLR by 2100 (m)	0.39	0.69	1	1.5
Brackish Marsh	28%	69%	96%	100%
Inland Fresh Marsh	0%	0%	0%	2%
Dry Land	60%	65%	68%	69%
Saltmarsh	-778%	-919%	-782%	24%
Estuarine Beach	73%	75%	83%	94%

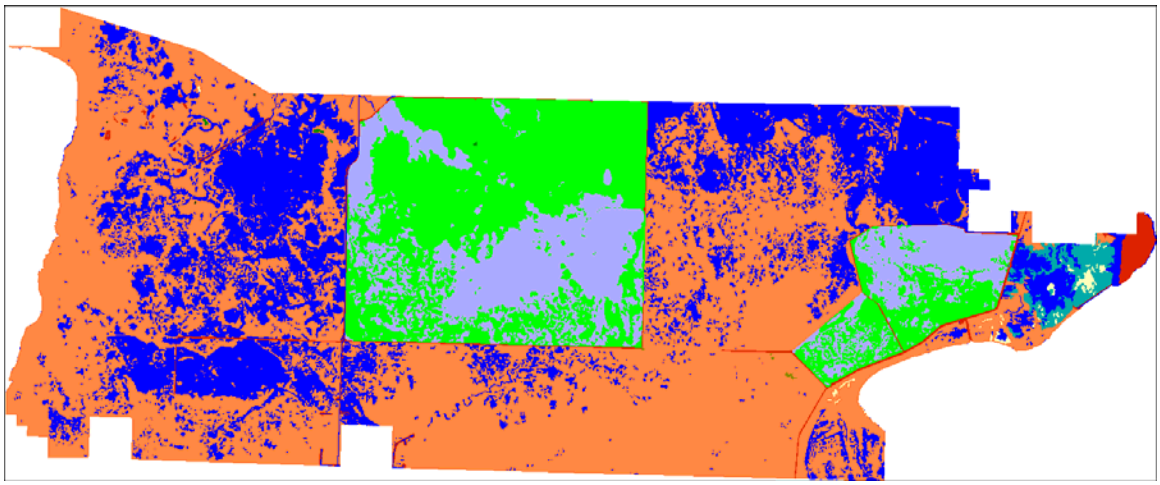
Predicted Loss Rates of Land Categories by 2100 Given Simulated Scenarios of Eustatic Sea Level Rise

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

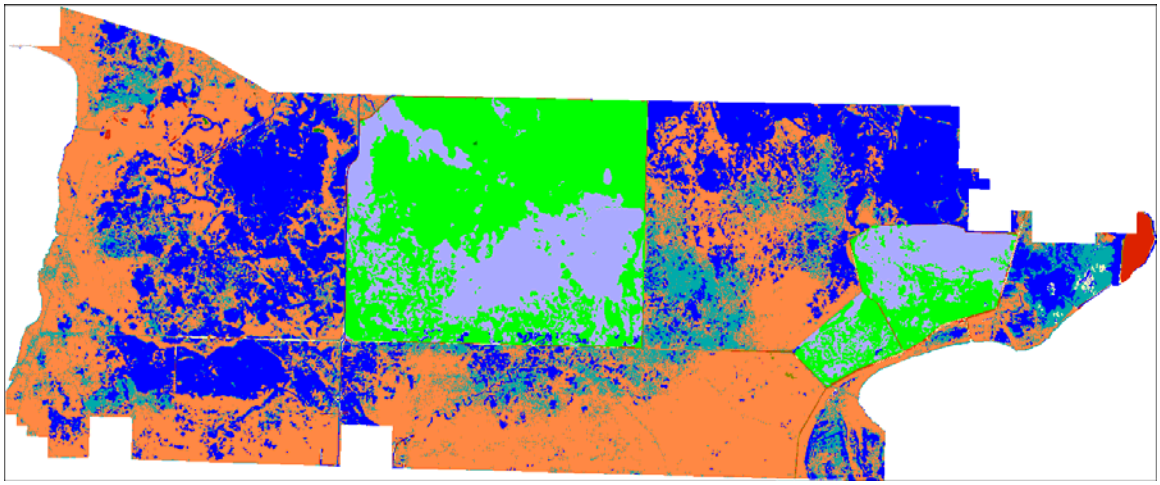
Sabine NWR
IPCC Scenario A1B-Mean, 0.39 M SLR Eustatic by 2100

Results in Acres

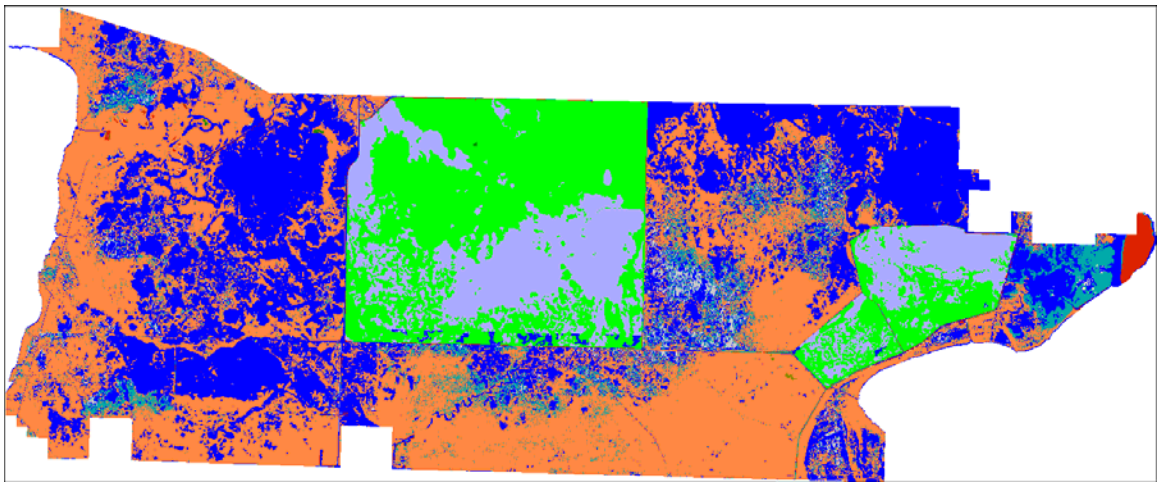
	Initial	2025	2050	2075	2100
Brackish Marsh	63216.6	50290.6	49615.7	47610.6	45611.0
Estuarine Open Water	29896.6	30322.3	36945.3	39241.1	39397.6
Inland Fresh Marsh	19541.3	19548.4	19548.9	19548.6	19547.7
Inland Open Water	13648.1	13479.3	13392.4	13371.2	13360.1
Dry Land	1581.2	1008.6	878.1	745.4	637.9
Saltmarsh	1217.2	13976.6	6768.6	8640.6	10680.7
Estuarine Beach	243.7	416.3	95.5	77.2	65.6
Swamp	25.6	23.2	16.2	7.2	1.4
Trans. Salt Marsh	24.7	286.0	109.6	96.7	76.5
Tidal Swamp	4.0	2.8	1.3	0.4	0.2
Tidal Fresh Marsh	0.4	0.2	0.2	0.2	0.2
Tidal Flat	0.0	45.2	2027.6	60.3	20.5
Total (incl. water)	**129399.5**	**129399.5**	**129399.5**	**129399.5**	**129399.5**



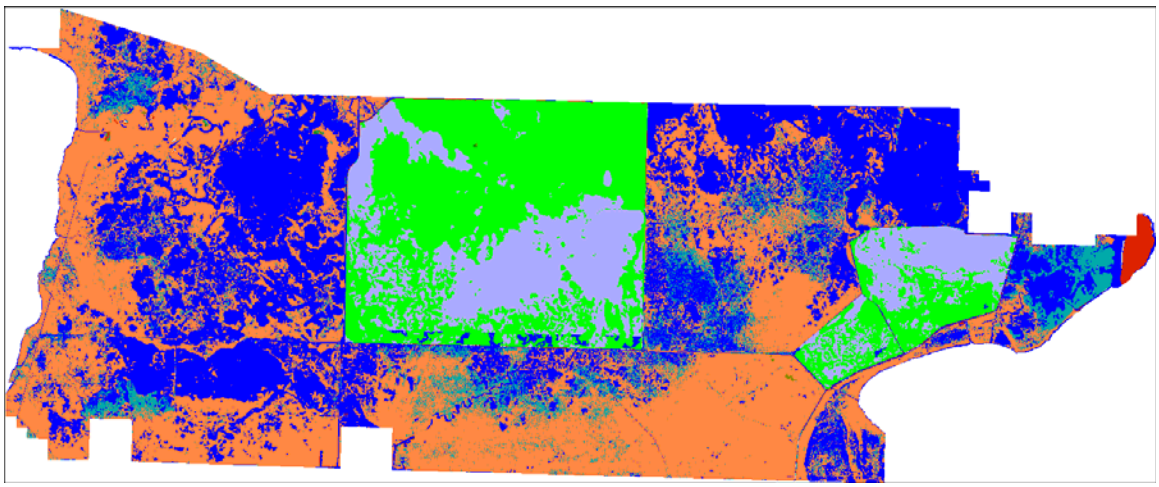
Sabine NWR, Initial Condition



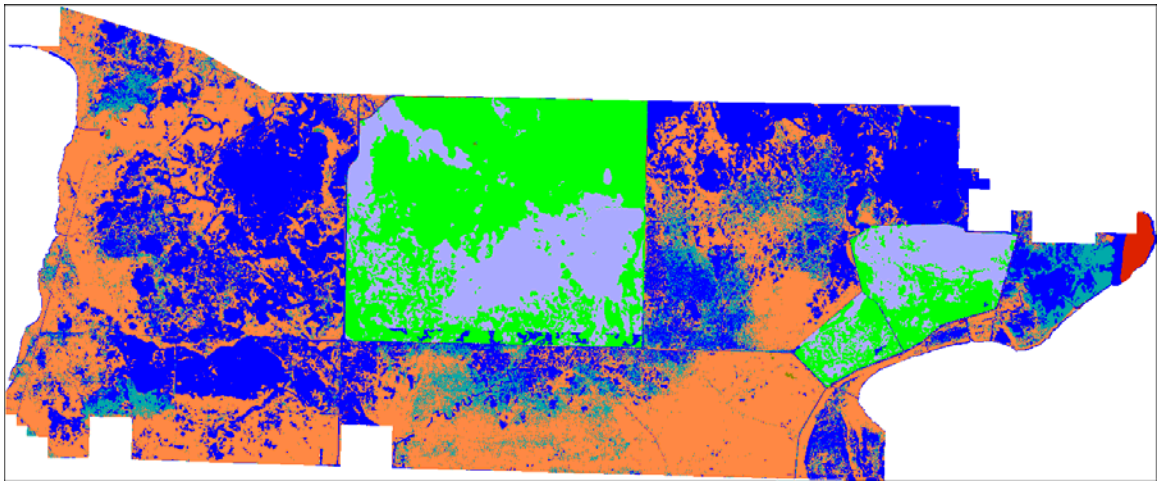
Sabine NWR, 2025, Scenario A1B Mean



Sabine NWR, 2050, Scenario A1B Mean



Sabine NWR, 2075, Scenario A1B Mean

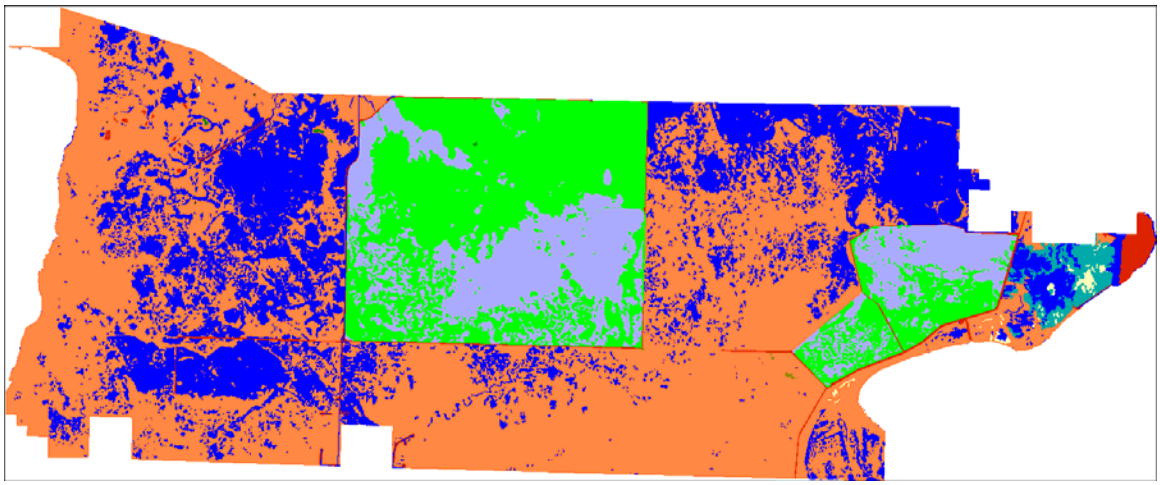


Sabine NWR, 2100, Scenario A1B Mean

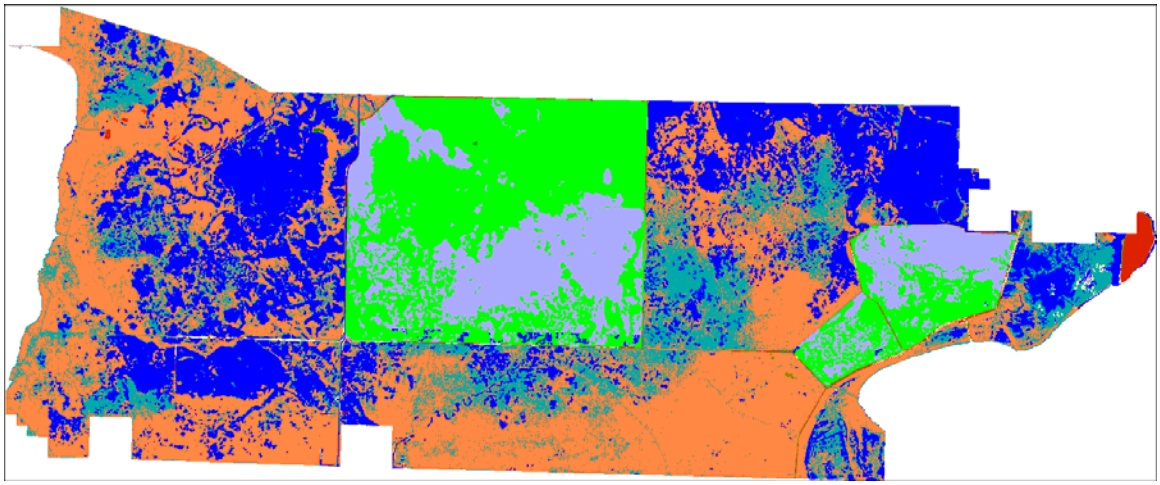
Sabine NWR
IPCC Scenario A1B-Max, 0.69 M SLR Eustatic by 2100

Results in Acres

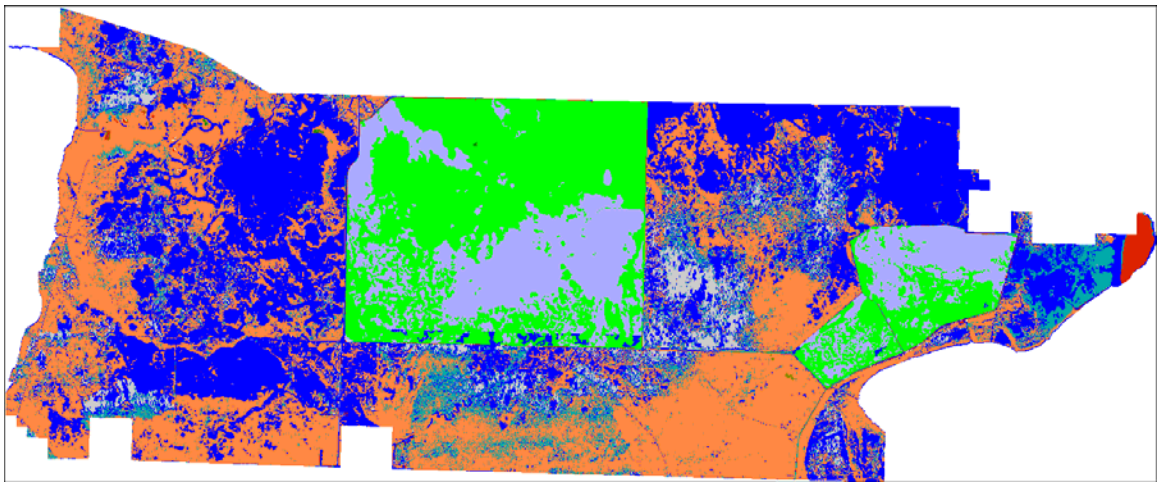
	Initial	2025	2050	2075	2100
Brackish Marsh	63216.6	47102.1	41439.5	31134.8	19744.1
Estuarine Open Water	29896.6	30397.8	39032.2	50805.4	61479.3
Inland Fresh Marsh	19541.3	19545.7	19545.9	19544.8	19542.8
Inland Open Water	13648.1	13459.7	13381.0	13363.8	13351.0
Dry Land	1581.2	977.6	805.1	643.7	549.1
Saltmarsh	1217.2	17129.3	9835.2	12089.3	12405.2
Estuarine Beach	243.7	405.4	86.3	89.1	61.3
Swamp	25.6	21.5	11.8	1.5	0.2
Trans. Salt Marsh	24.7	306.7	120.8	95.7	40.4
Tidal Swamp	4.0	2.2	0.7	0.2	0.2
Tidal Fresh Marsh	0.4	0.2	0.2	0.2	0.2
Tidal Flat	0.0	51.2	5140.9	1630.7	2225.7
Total (incl. water)	**129399.5**	**129399.5**	**129399.5**	**129399.5**	**129399.5**



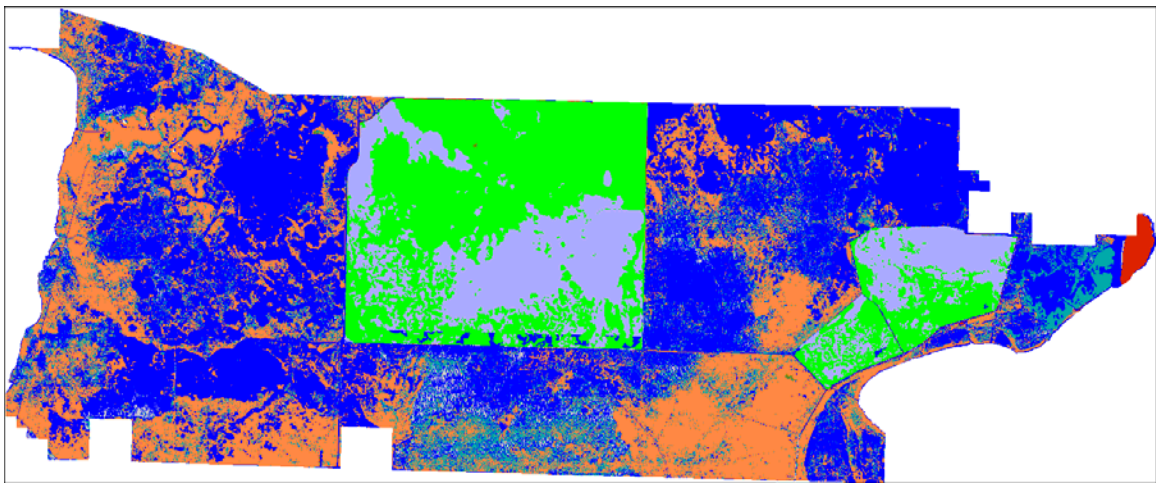
Sabine NWR, Initial Condition



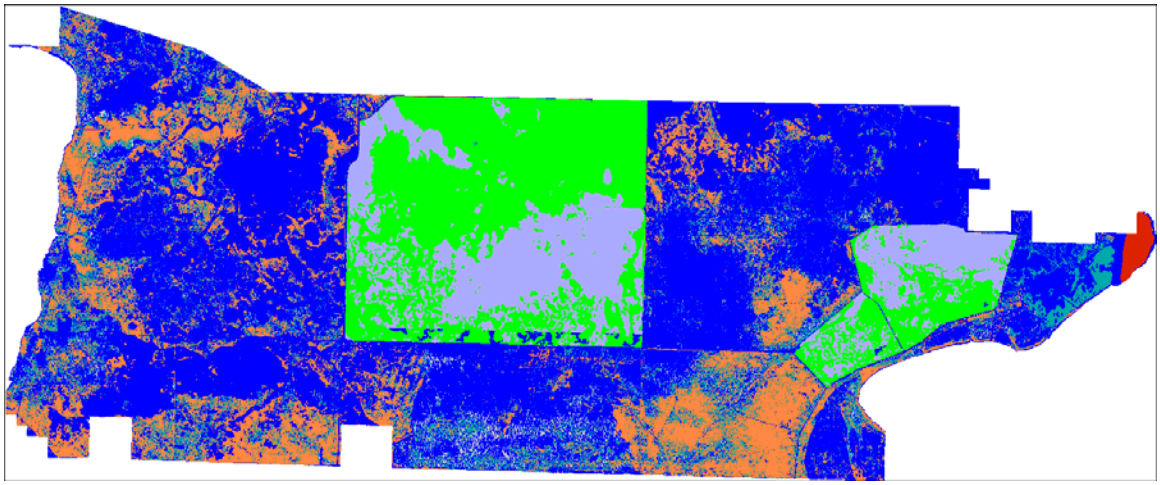
Sabine NWR, 2025, Scenario A1B Maximum



Sabine NWR, 2050, Scenario A1B Maximum



Sabine NWR, 2075, Scenario A1B Maximum

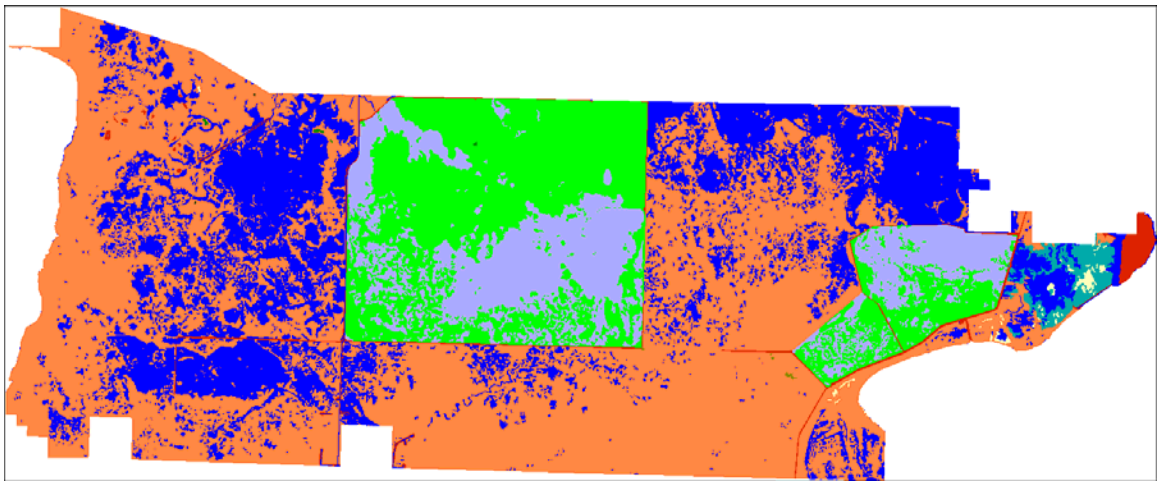


Sabine NWR, 2100, Scenario A1B Maximum

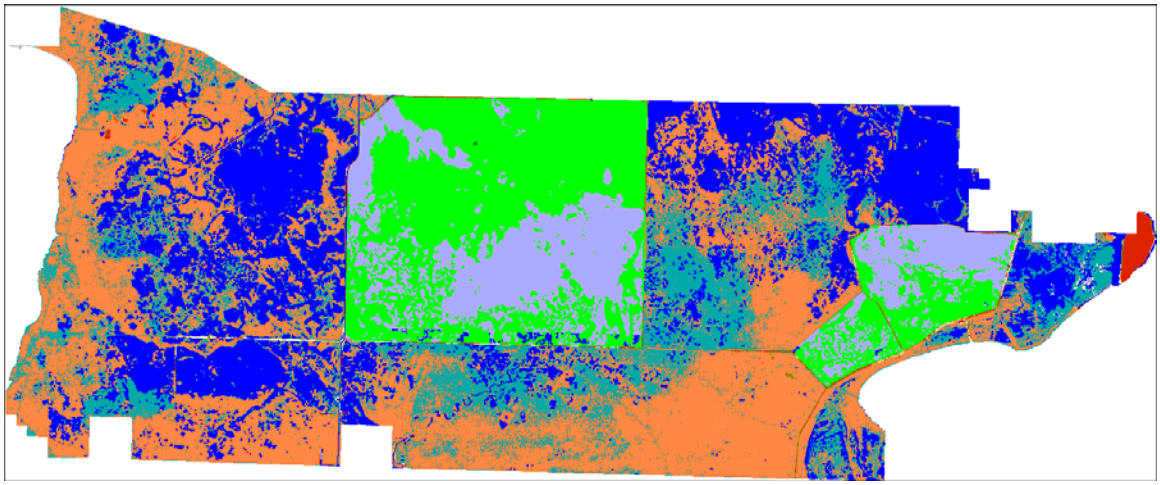
Sabine NWR
1 Meter Eustatic SLR by 2100

Results in Acres

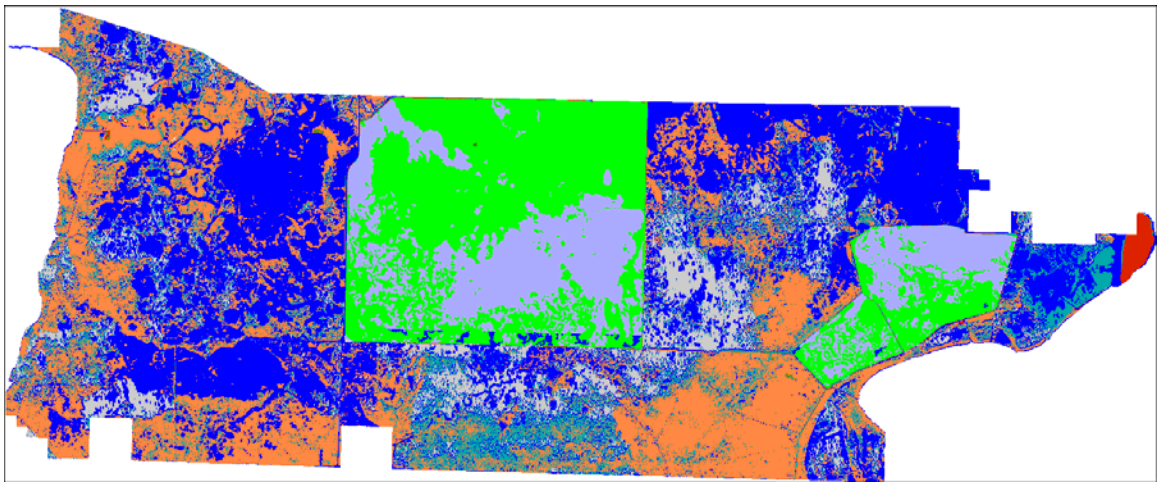
	Initial	2025	2050	2075	2100
Brackish Marsh	63216.6	43044.7	30826.3	12951.0	2531.9
Estuarine Open Water	29896.6	30476.1	41080.1	61064.1	75887.2
Inland Fresh Marsh	19541.3	19544.2	19544.4	19542.5	19533.2
Inland Open Water	13648.1	13447.0	13370.2	13356.0	13349.2
Dry Land	1581.2	940.2	734.7	573.8	509.4
Saltmarsh	1217.2	21129.9	13410.4	18612.5	10733.2
Estuarine Beach	243.7	393.8	95.1	90.6	40.8
Swamp	25.6	19.6	5.8	0.4	0.0
Trans. Salt Marsh	24.7	330.3	137.5	78.1	23.7
Tidal Swamp	4.0	1.8	0.3	0.2	0.0
Tidal Fresh Marsh	0.4	0.2	0.2	0.2	0.2
Tidal Flat	0.0	71.7	10194.5	3130.1	6790.7
Total (incl. water)	**129399.5**	**129399.5**	**129399.5**	**129399.5**	**129399.5**



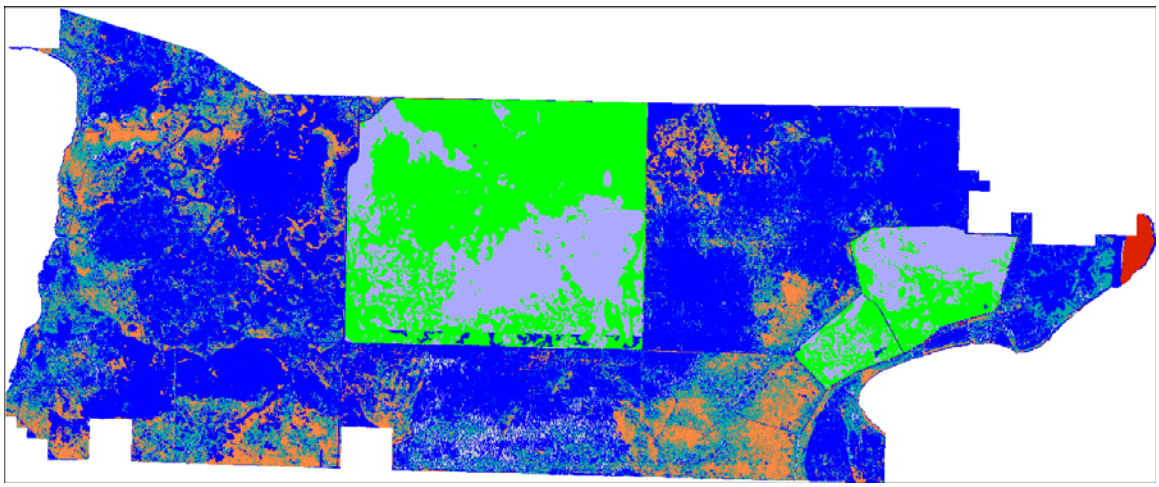
Sabine NWR, Initial Condition



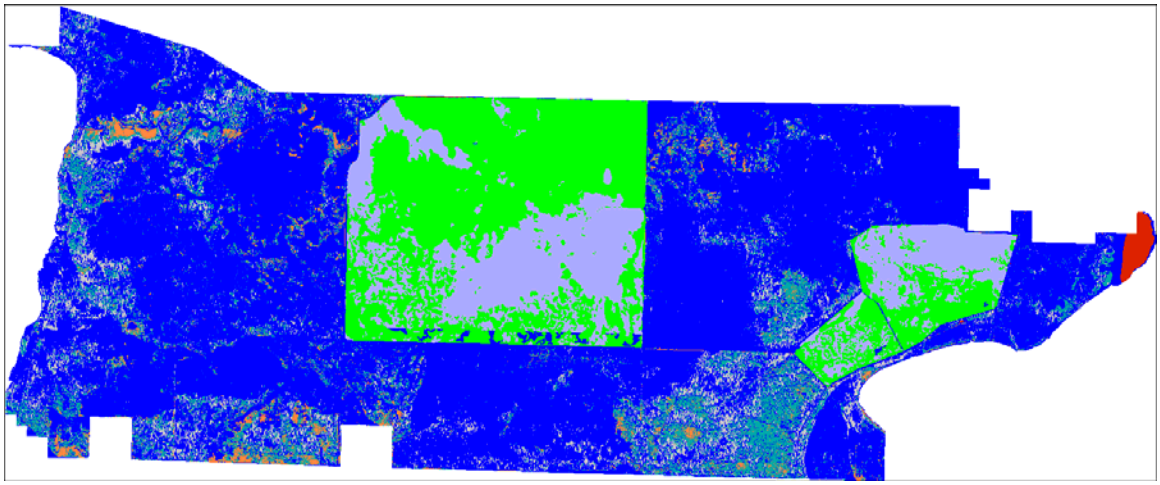
Sabine NWR, 2025, 1 meter eustatic SLR by 2100



Sabine NWR, 2050, 1 meter eustatic SLR by 2100



Sabine NWR, 2075, 1 meter eustatic SLR by 2100

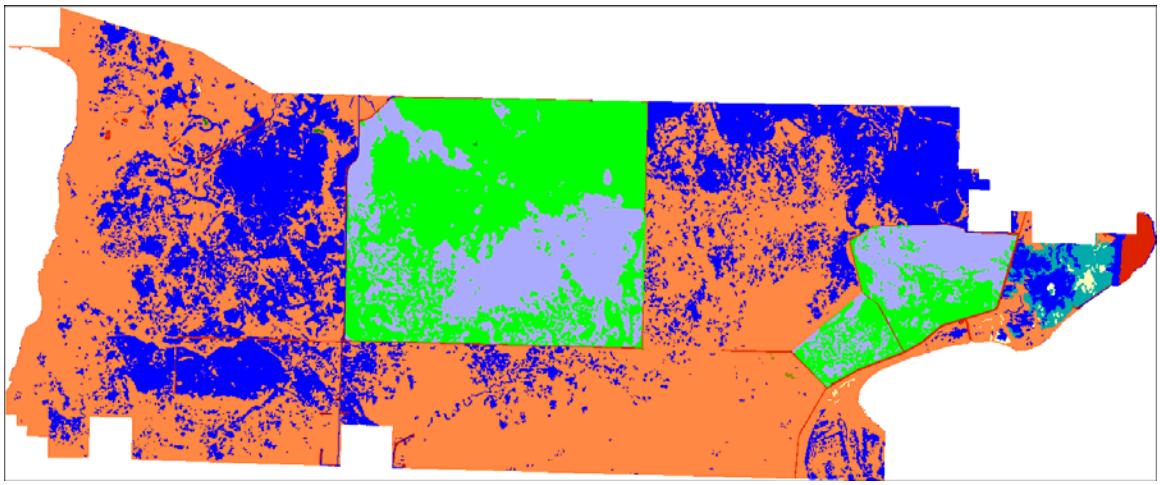


Sabine NWR, 2100, 1 meter eustatic SLR by 2100

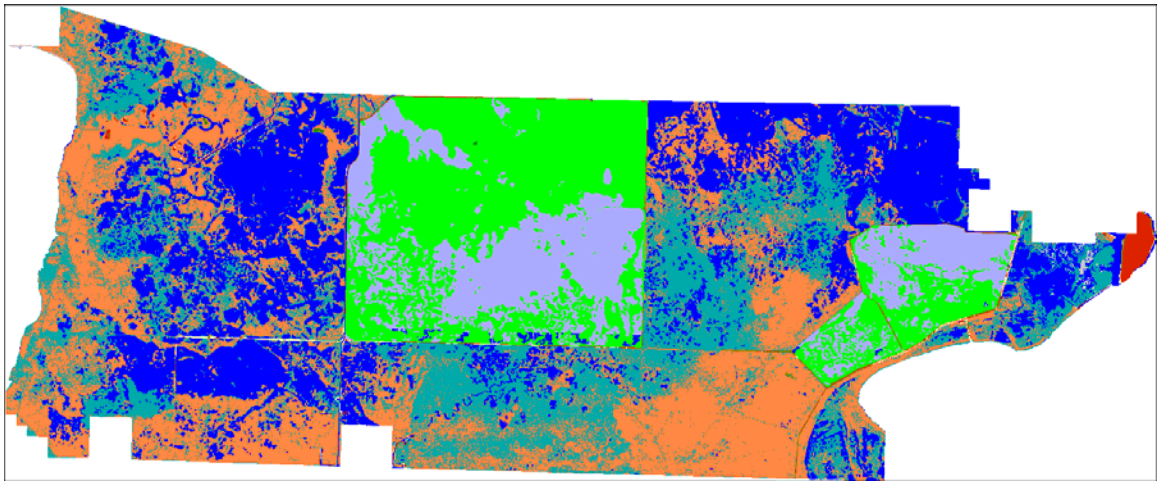
Sabine NWR
1.5 Meters Eustatic SLR by 2100

Results in Acres

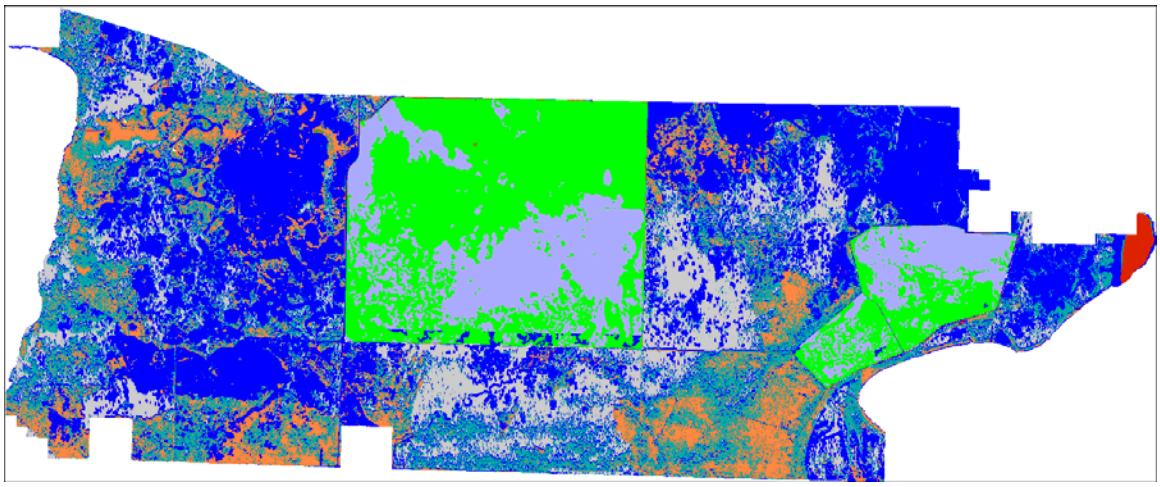
	Initial	2025	2050	2075	2100
Brackish Marsh	63216.6	35447.7	13358.9	919.9	46.8
Estuarine Open Water	29896.6	30575.9	42509.8	72108.3	89858.0
Inland Fresh Marsh	19541.3	19543.1	19542.2	19539.1	19244.6
Inland Open Water	13648.1	13428.9	13365.7	13350.1	13347.6
Dry Land	1581.2	880.9	637.5	515.6	483.2
Saltmarsh	1217.2	28618.6	22943.6	12647.1	925.6
Estuarine Beach	243.7	380.3	108.7	67.5	15.1
Swamp	25.6	16.1	1.2	0.0	0.0
Trans. Salt Marsh	24.7	365.3	151.1	54.6	15.5
Tidal Swamp	4.0	1.1	0.2	0.0	0.0
Tidal Fresh Marsh	0.4	0.2	0.2	0.2	0.2
Tidal Flat	0.0	141.5	16780.4	10197.0	5462.9
Total (incl. water)	**129399.5**	**129399.5**	**129399.5**	**129399.5**	**129399.5**



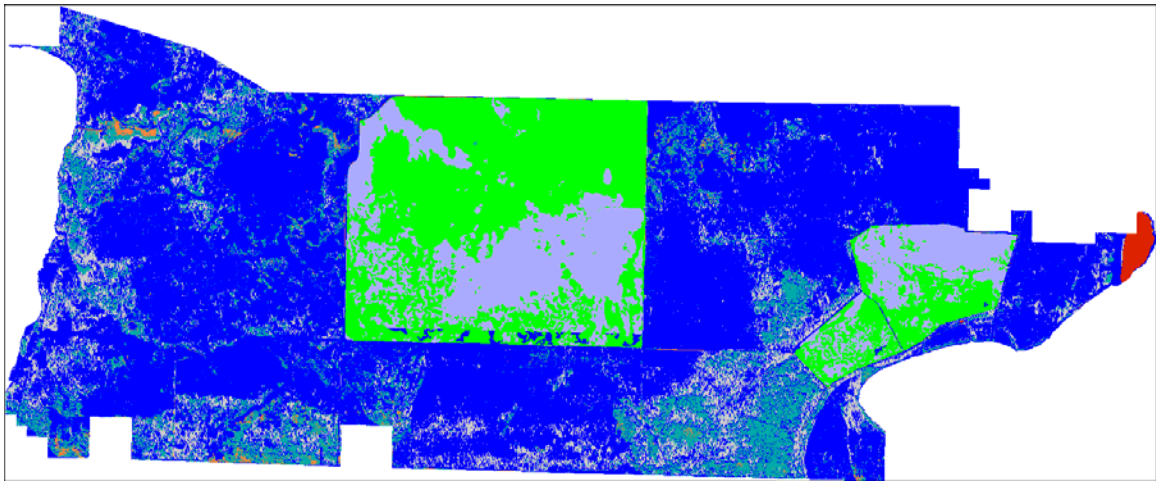
Sabine NWR, Initial Condition



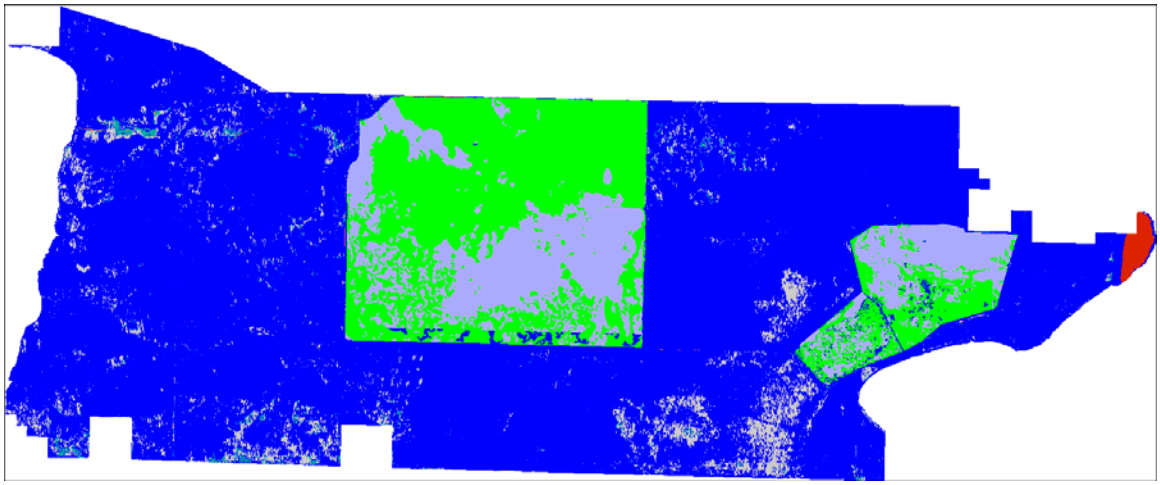
Sabine NWR, 2025, 1.5 meters eustatic SLR by 2100



Sabine NWR, 2050, 1.5 meters eustatic SLR by 2100



Sabine NWR, 2075, 1.5 meters eustatic SLR by 2100



Sabine NWR, 2100, 1.5 meters eustatic SLR by 2100

Discussion:

The high resolution elevation data for this site indicate that much of the fresh water habitat in Sabine is quite close to the salt boundary (vertically). Therefore, additional sea level rise combined with the continuation of local subsidence is predicted to have a dramatic effect at this site.

Under the most conservative projection of SLR simulated (0.39 meters eustatic by 2100), over one quarter of brackish marsh is predicted to be lost at this site. Much of this will convert to salt-marsh as irregularly flooded marsh is predicted to become regularly flooded due to higher water levels. Some of it, however, converts to open water. Over ten percent of total marsh lands are predicted to be converted to water by 2100 in this scenario. Under A1B-Max (0.69 meters by 2100) the results are much more severe with 50% of total marsh lands lost. The maps for the one meter and 1.5 meter scenarios speak for themselves as the refuge is primarily converted to water.

As a simplification, diked wetlands are assumed to be maintained in this analysis. This results in some strange looking maps of fresh-water marshes in the middle of open water under more severe scenarios.

Dry land at Sabine NWR is also predicted to be vulnerable with loss rates ranging from 60-70% under various scenarios. These dry-land elevations were based on high resolution LiDAR data so these predictions are subject to less uncertainty than for other sites that do not have such high-resolution data.

References

Cahoon, D.R., J. W. Day, Jr., and D. J. Reed, 1999. "The influence of surface and shallow subsurface soil processes on wetland elevation: A synthesis." *Current Topics in Wetland Biogeochemistry*, 3, 72-88.

Chen, J. L., Wilson, C. R., Tapley, B. D., 2006 "Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet" *Science* 2006 0: 1129007

Clough, J.S. and R.A. Park, 2007, *Technical Documentation for SLAMM 5.0.1* February 2008, Jonathan S. Clough, Warren Pinnacle Consulting, Inc, Richard A. Park, Eco Modeling. http://warrenpinnacle.com/prof/SLAMM

Craft C, Clough J, Ehman J, Guo H, Joye S, Machmuller M, Park R, and Pennings S. Effects of Accelerated Sea Level Rise on Delivery of Ecosystem Services Provided by Tidal Marshes: A Simulation of the Georgia (USA) Coast. *Frontiers in Ecology and the Environment.* 2009; 7, doi:10.1890/070219

Galbraith, H., R. Jones, R.A. Park, J.S. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002. Global Climate Change and Sea Level Rise: Potential Losses of Intertidal Habitat for Shorebirds. *Waterbirds* 25:173-183.

Glick, Clough, et al. *Sea-level Rise and Coastal Habitats in the Pacific Northwest An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon* July 2007 http://www.nwf.org/sealevelrise/pdfs/PacificNWSeaLevelRise.pdf

IPCC, 2001: *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K.Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

Lee, J.K., R.A. Park, and P.W. Mausel. 1992. Application of Geoprocessing and Simulation Modeling to Estimate Impacts of Sea Level Rise on the Northeast Coast of Florida. *Photogrammetric Engineering and Remote Sensing* 58:11:1579-1586.

Meehl GA, Stocker TF, Collins WD, Friedlingstein P, Gaye AT, Gregory JM, Kitoh A, Knutti R, Murphy JM, Noda A, Raper SCB, Watterson IG, Weaver AJ and Zhao ZC. 2007. Global climate projections. Pp. 747-845. In: Solomon S, Qin, D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor, M and Miller HL, (eds.) *Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Monaghan, A. J. *et al,* 2006 "Insignificant Change in Antarctic Snowfall Since the International Geophysical Year" *Science* 2006 313: 827-831.

Moorhead, KK and Brinson MM. 1995. Response of wetlands to rising sea level in the lower coastal plain of North Carolina. *Ecological Applications* 5: 261-271.

National Wildlife Fed 'n et al., *An Unfavorable Tide: Global Warming, Coastal Habitats and Sportfishing in Florida* 4, 6 (2006). http://www.targetglobalwarming.org/files/AnUnfavorableTideReport.pdf

Park, R.A., J.K. Lee, and D. Canning. 1993. Potential Effects of Sea Level Rise on Puget Sound Wetlands. *Geocarto International* 8(4):99-110.

Park, R.A., M.S. Trehan, P.W. Mausel, and R.C. Howe. 1989a. The Effects of Sea Level Rise on U.S. Coastal Wetlands. In *The Potential Effects of Global Climate Change on the United States: Appendix B - Sea Level Rise,* edited by J.B. Smith and D.A. Tirpak, 1-1 to 1-55. EPA-230-05-89-052. Washington, D.C.: U.S. Environmental Protection Agency.

Rahmstorf, Stefan 2007, "A Semi-Empirical Approach to Projecting Future Sea-Level Rise," *Science* 2007 315: 368-370.

Reed, D.J., D.A. Bishara, D.R. Cahoon, J. Donnelly, M. Kearney, A.S. Kolker, L.L. Leonard, R.A. Orson, and J.C. Stevenson, 2008: "Site-Specific Scenarios for Wetlands Accretion in the Mid-Atlantic Region. Section 2.1" in *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea Level Rise*, J.G. Titus and E.M. Strange (eds.), EPA430R07004, Washington, DC: U.S. EPA. http://www.epa.gov/climatechange/effects/downloads/section2_1.pdf

Stevenson and Kearney, 2008, "Impacts of Global Climate Change and Sea-Level Rise on Tidal Wetlands" Pending chapter of manuscript by University of California Press.

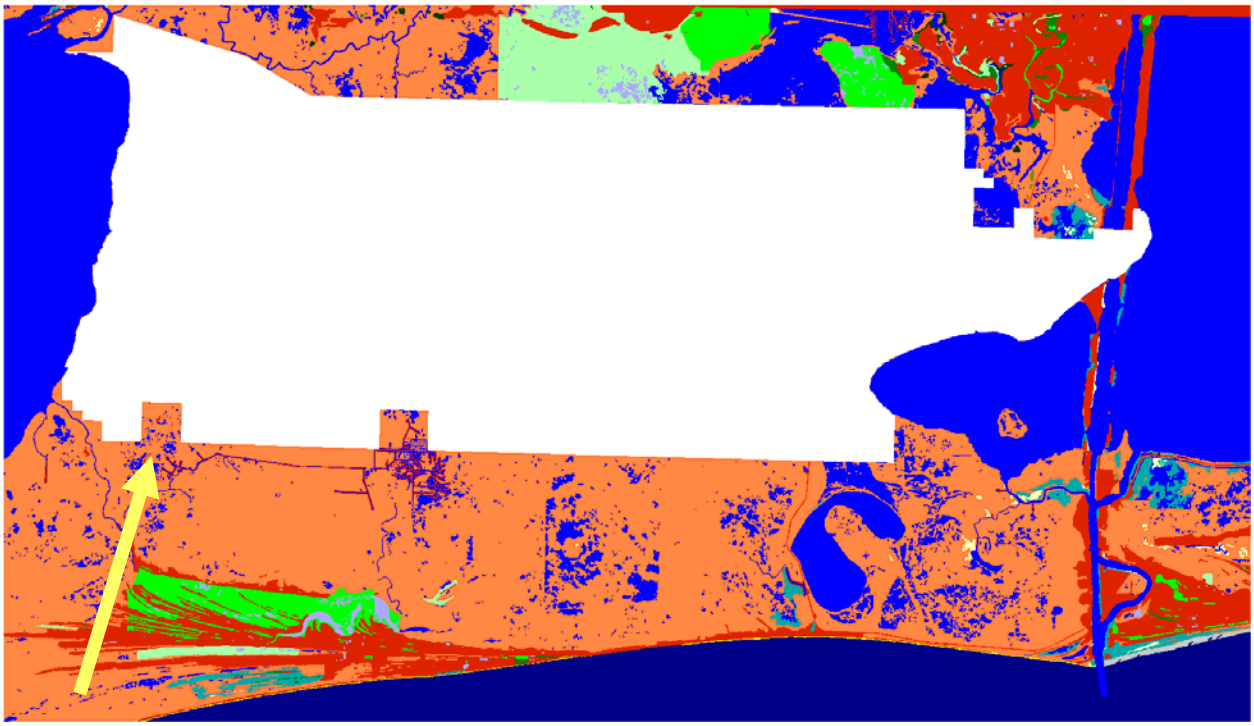
Titus, J.G., R.A. Park, S.P. Leatherman, J.R. Weggel, M.S. Greene, P.W. Mausel, M.S. Trehan, S. Brown, C. Grant, and G.W. Yohe. 1991. Greenhouse Effect and Sea Level Rise: Loss of Land and the Cost of Holding Back the Sea. *Coastal Management* 19:2:171-204.

Appendix A: Contextual Results

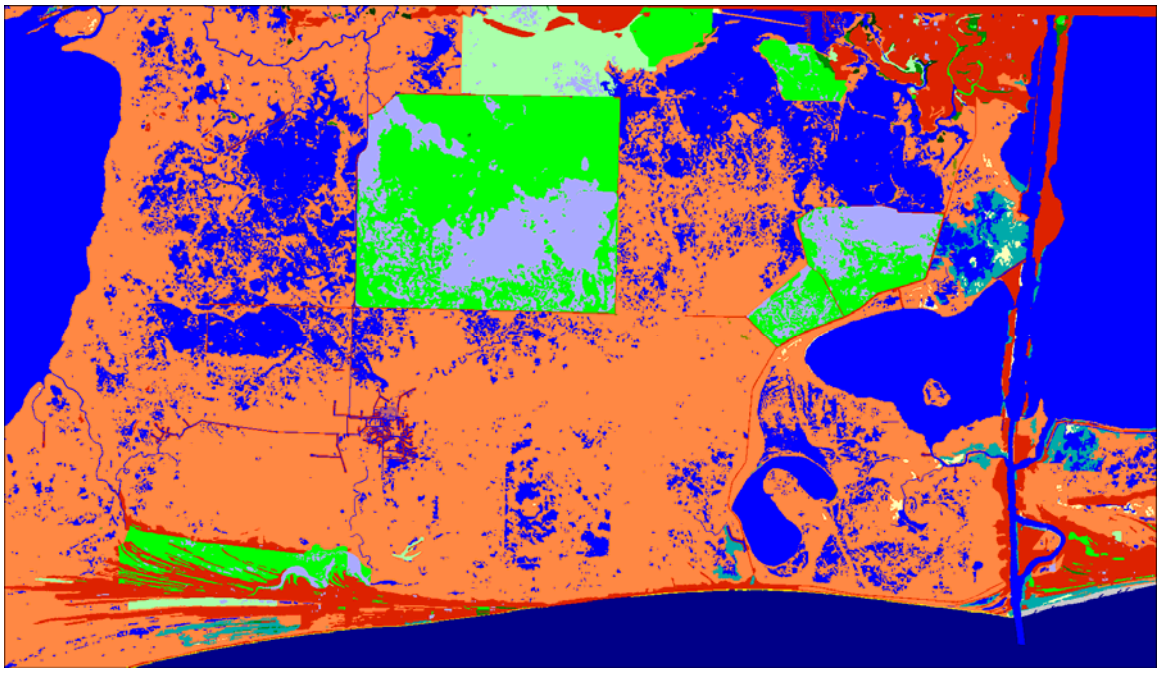
The SLAMM model does take into account the context of the surrounding lands or open water when calculating effects. For example, erosion rates are calculated based on the maximum fetch (wave action) which is estimated by assessing contiguous open water to a given marsh cell. Another example is that inundated dry lands will convert to marshes or ocean beach depending on their proximity to open ocean.

For this reason, an area larger than the boundaries of the USFWS refuge was modeled. These results maps are presented here with the following caveats:

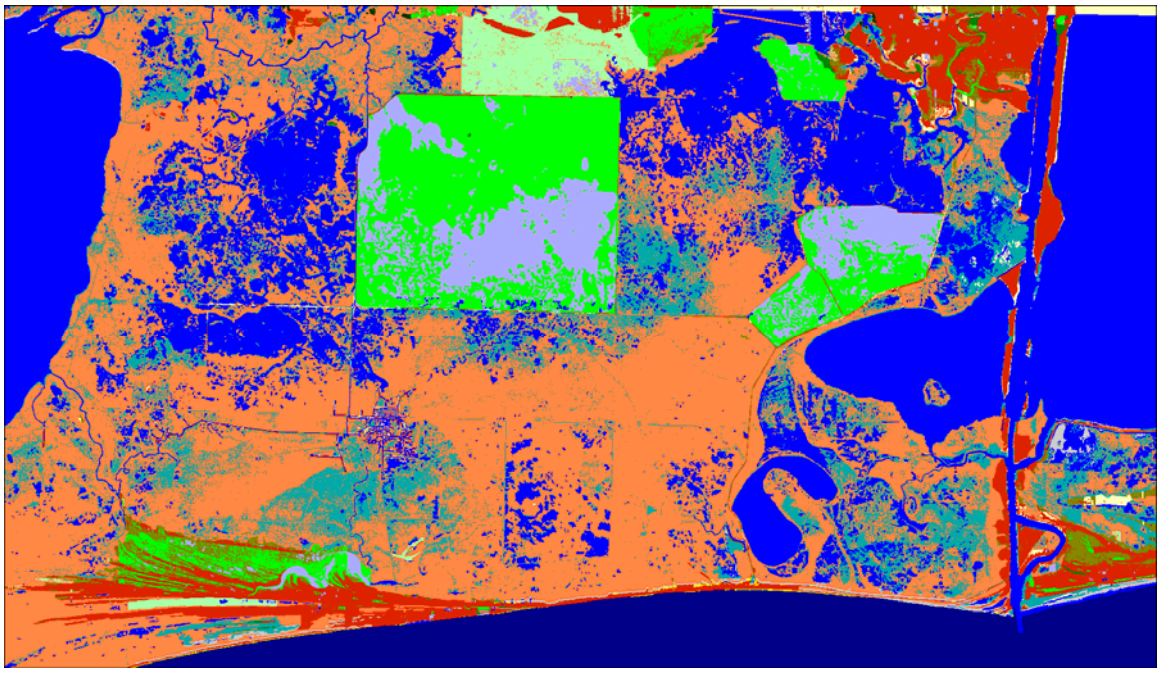
- Results were closely examined (quality assurance) within USFWS refuges but not closely examined for the larger region.
- Site-specific parameters for the model were derived for USFWS refuges whenever possible and may not be regionally applicable.
- Especially in areas where dikes are present, an effort was made to assess the probable location and effects of dikes for USFWS refuges, but this effort was not made for surrounding areas.



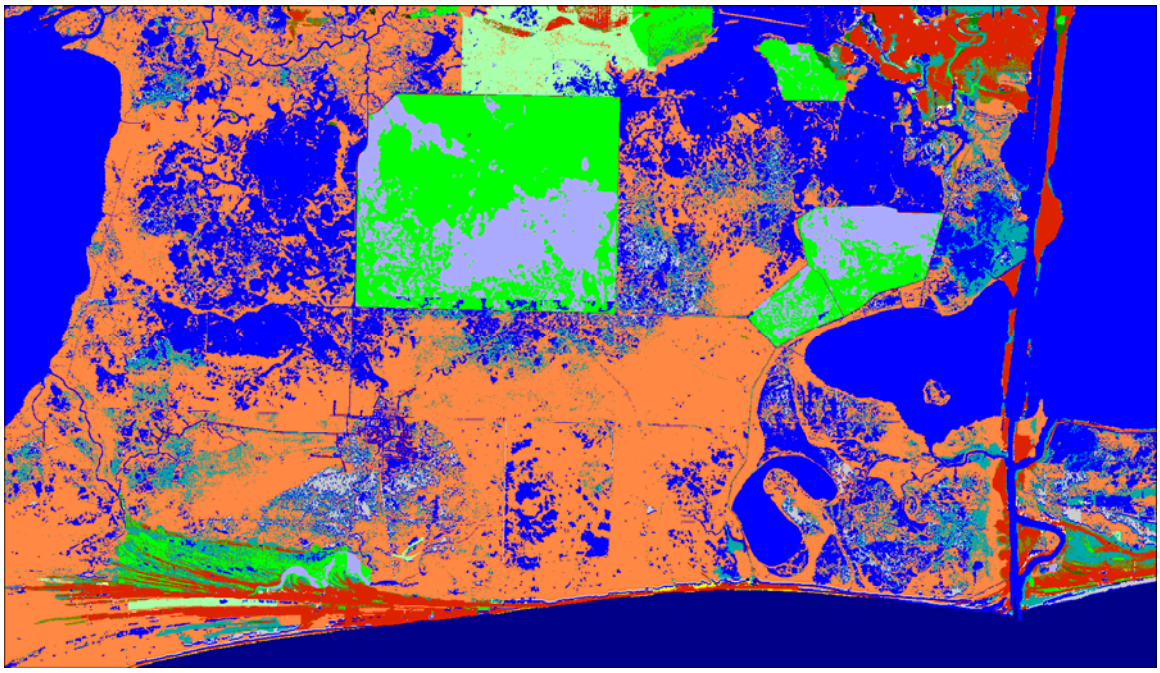
Location of Sabine National Wildlife Refuge (white area) within simulation context



Sabine NWR Context, Initial Condition



Sabine NWR Context, 2025, Scenario A1B Mean



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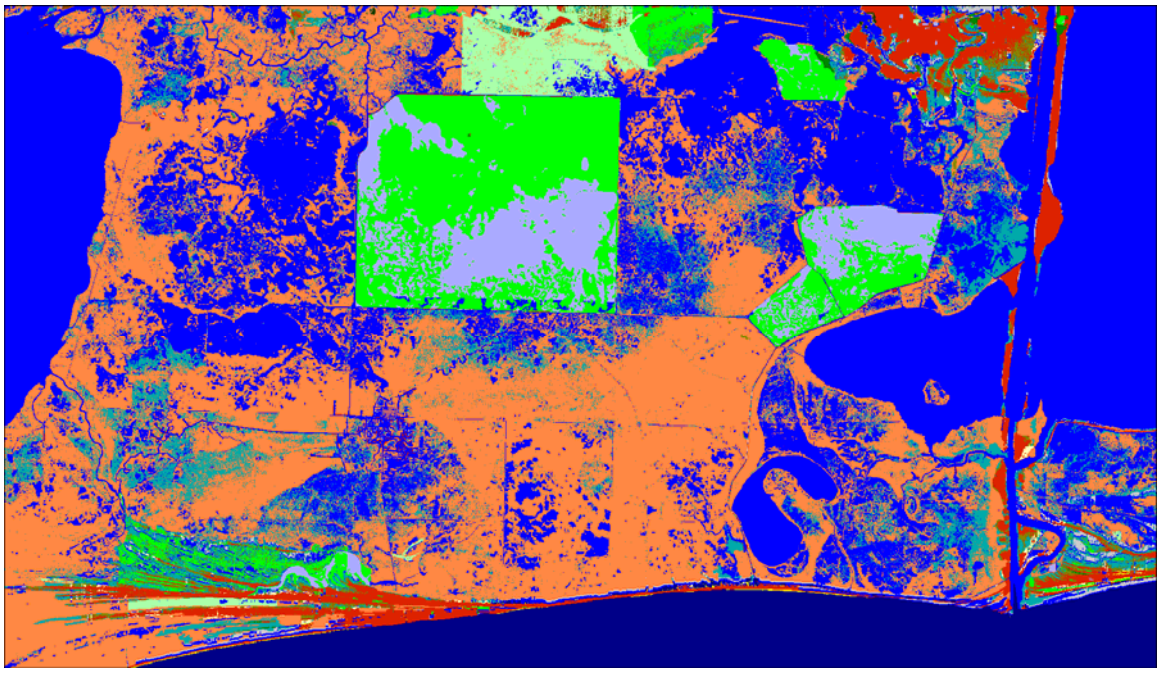
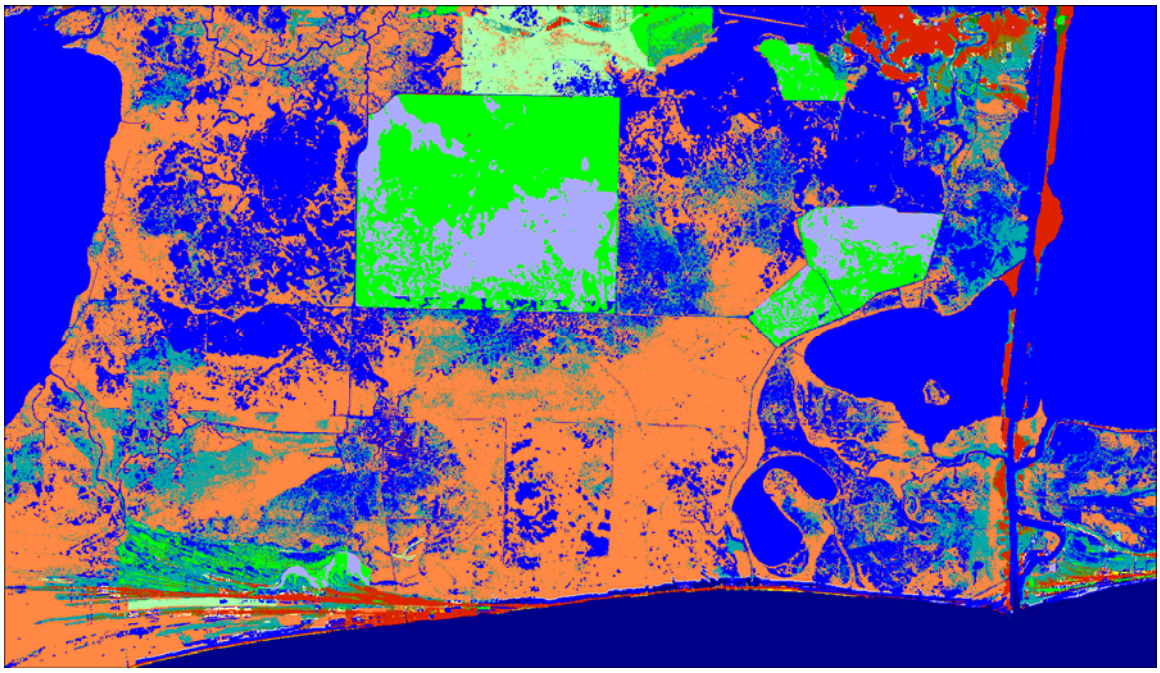
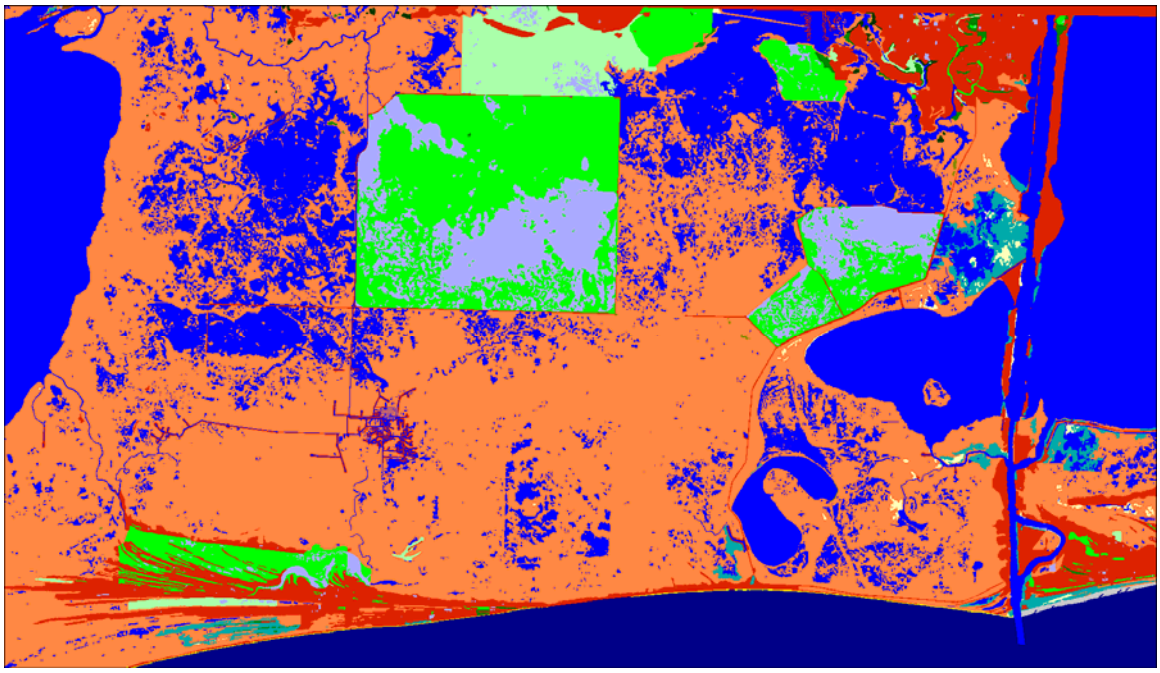


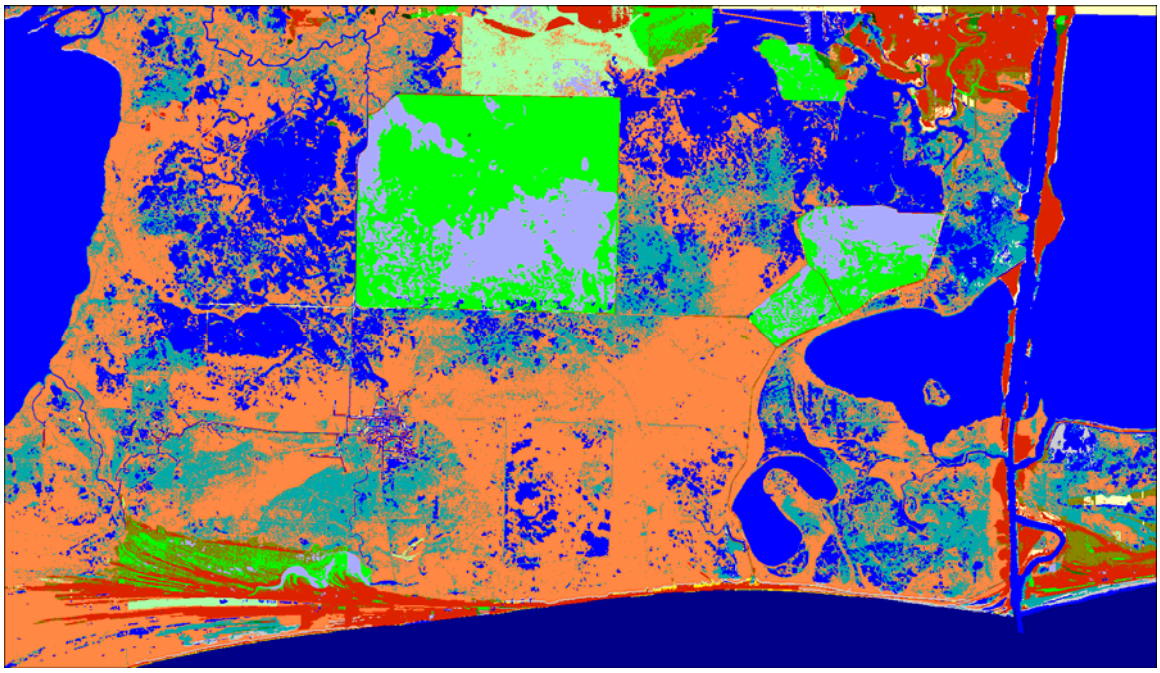
Sabine NWR Context, 2075, Scenario A1B Mean



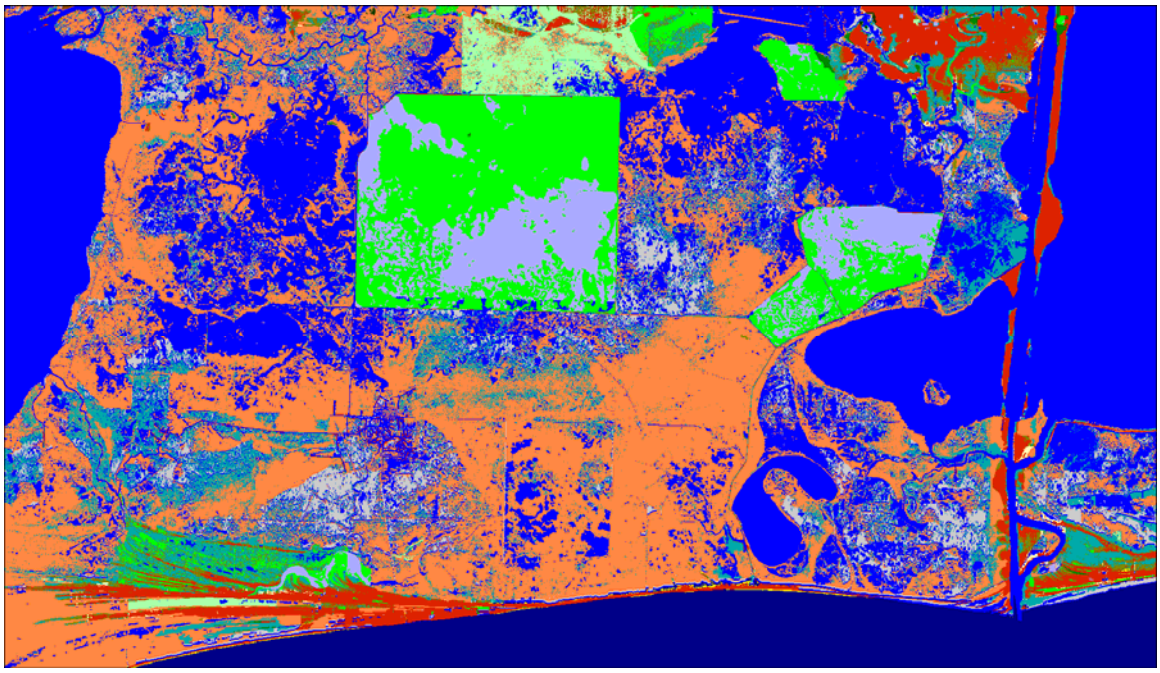
Sabine NWR Context, 2100, Scenario A1B Mean



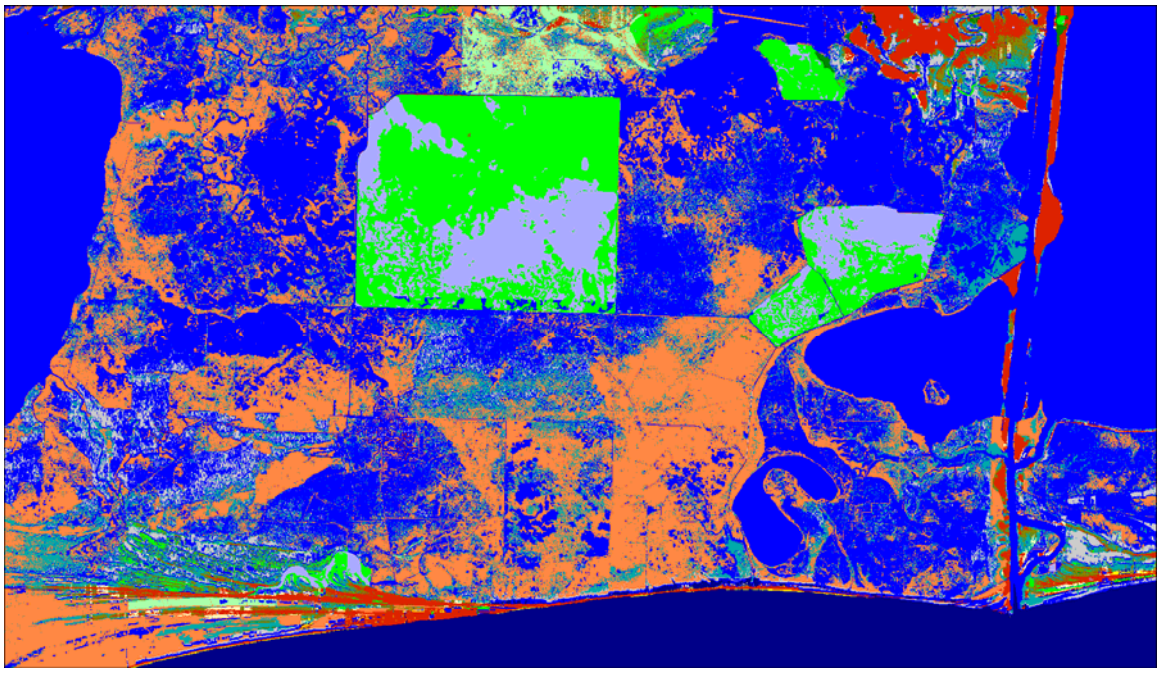
Sabine NWR Context, Initial Condition Scenario A1B Maximum



Sabine NWR Context, 2025, Scenario A1B Maximum



Sabine NWR Context, 2050, Scenario A1B Maximum



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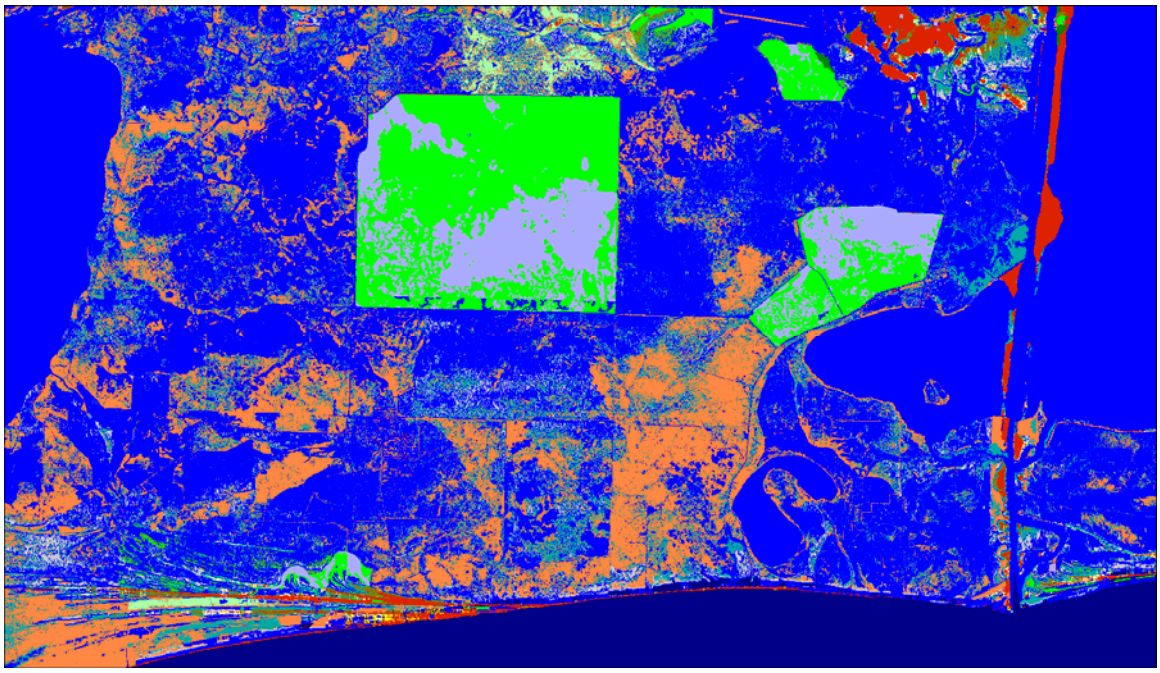
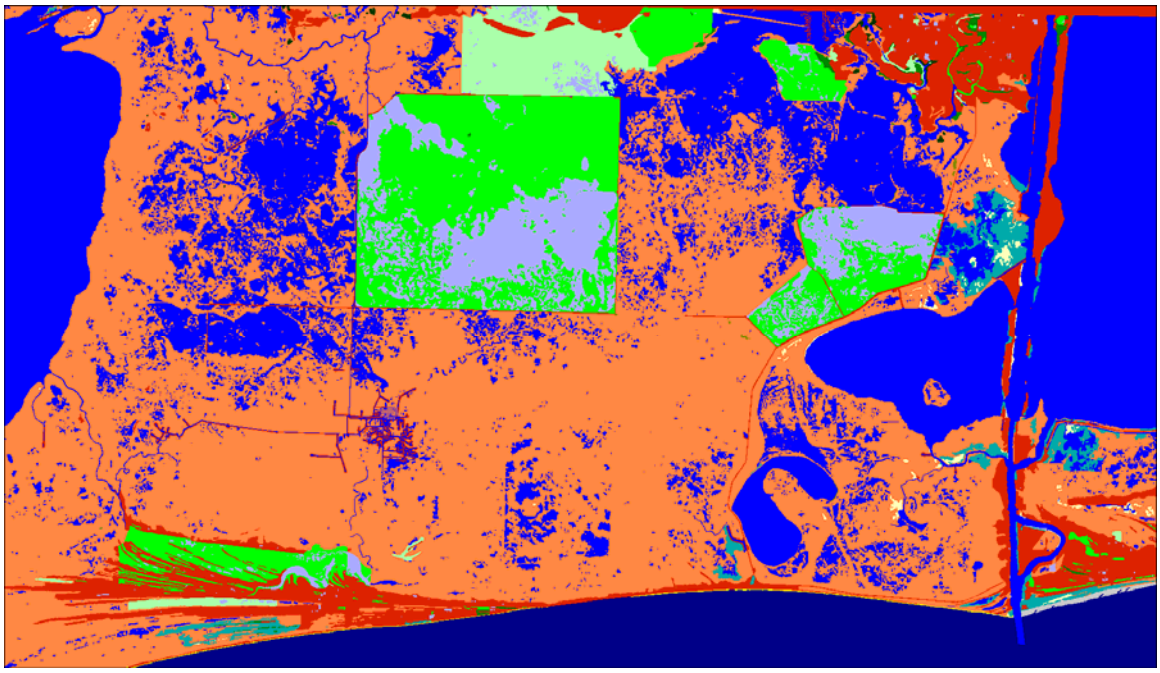
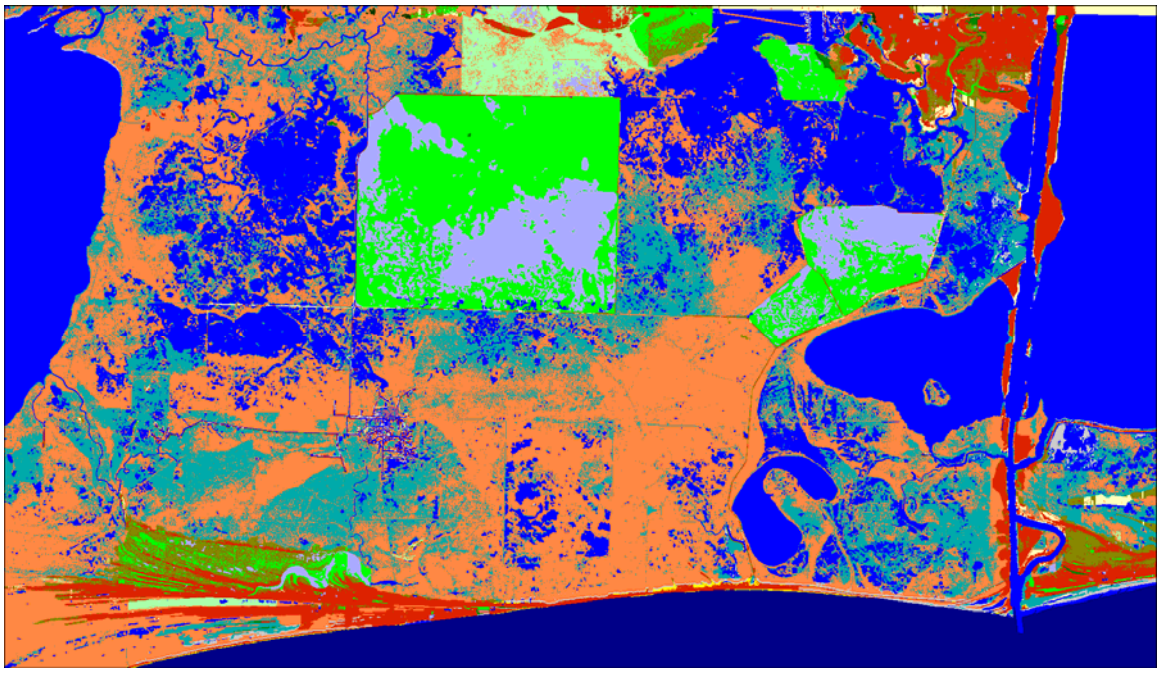


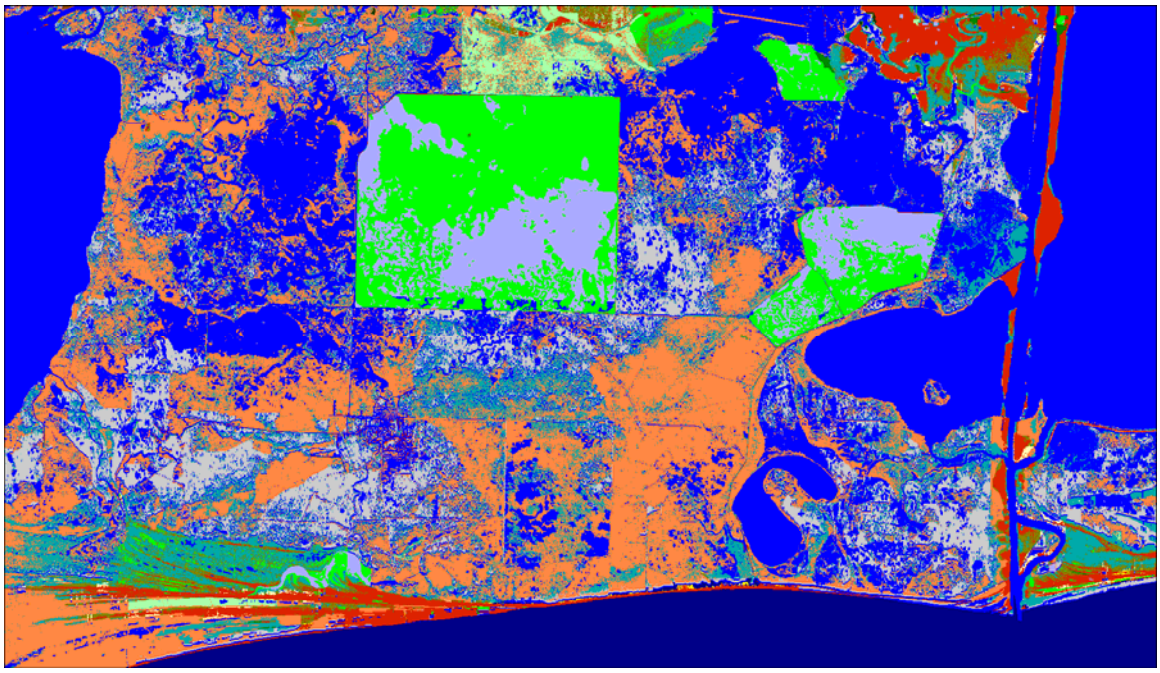
Sabine NWR Context, 2100, Scenario A1B Maximum



Sabine NWR Context, Initial Condition



Sabine NWR Context, 2025, 1 meter eustatic SLR by 2100



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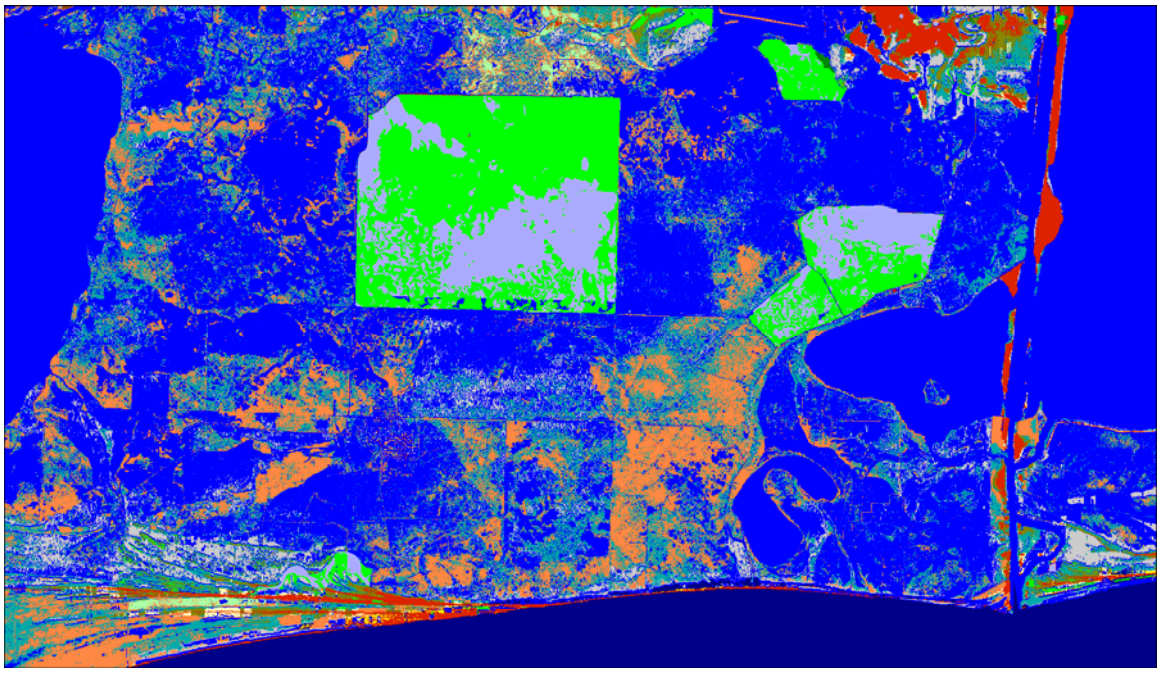

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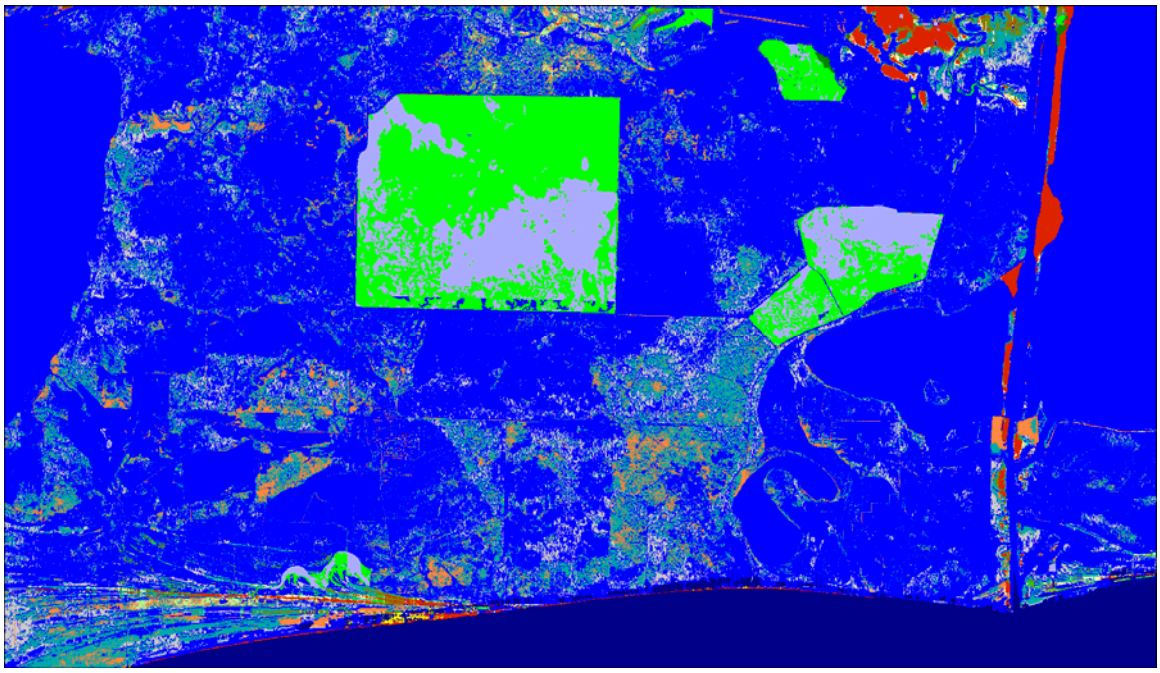
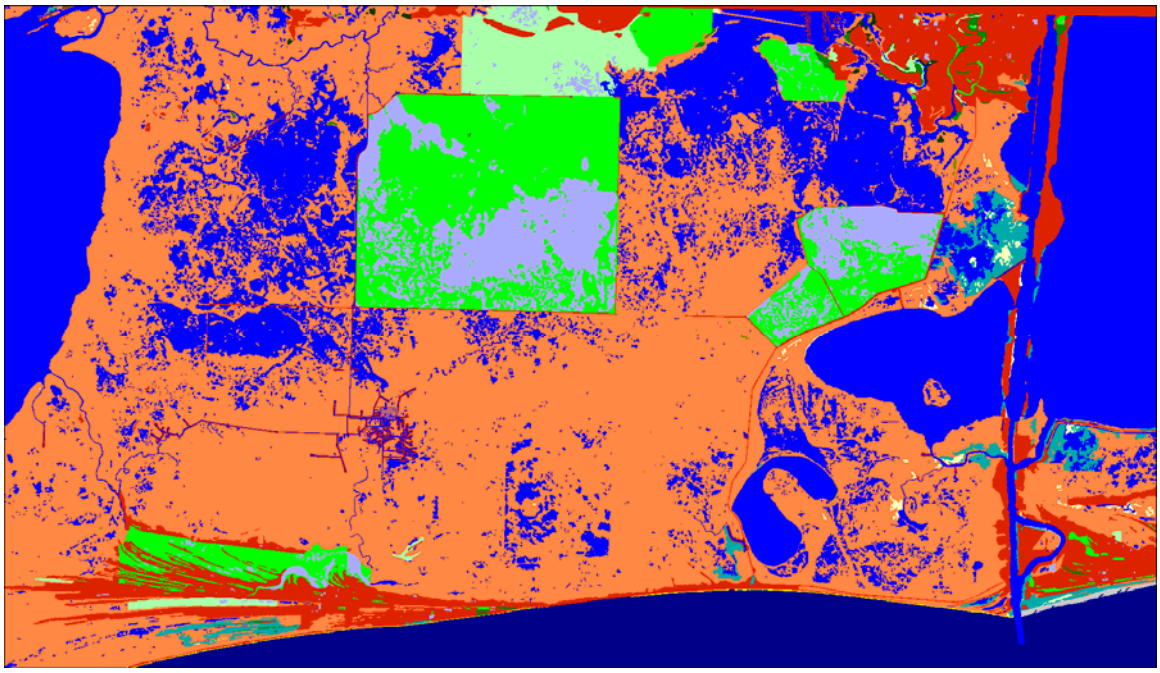
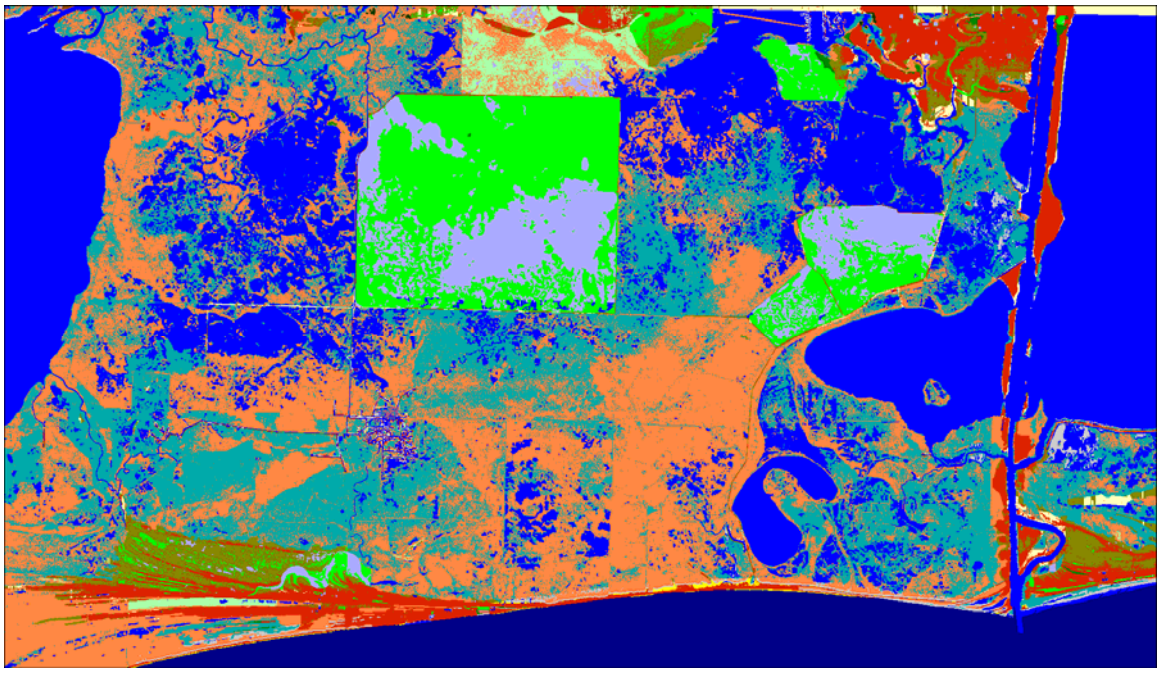


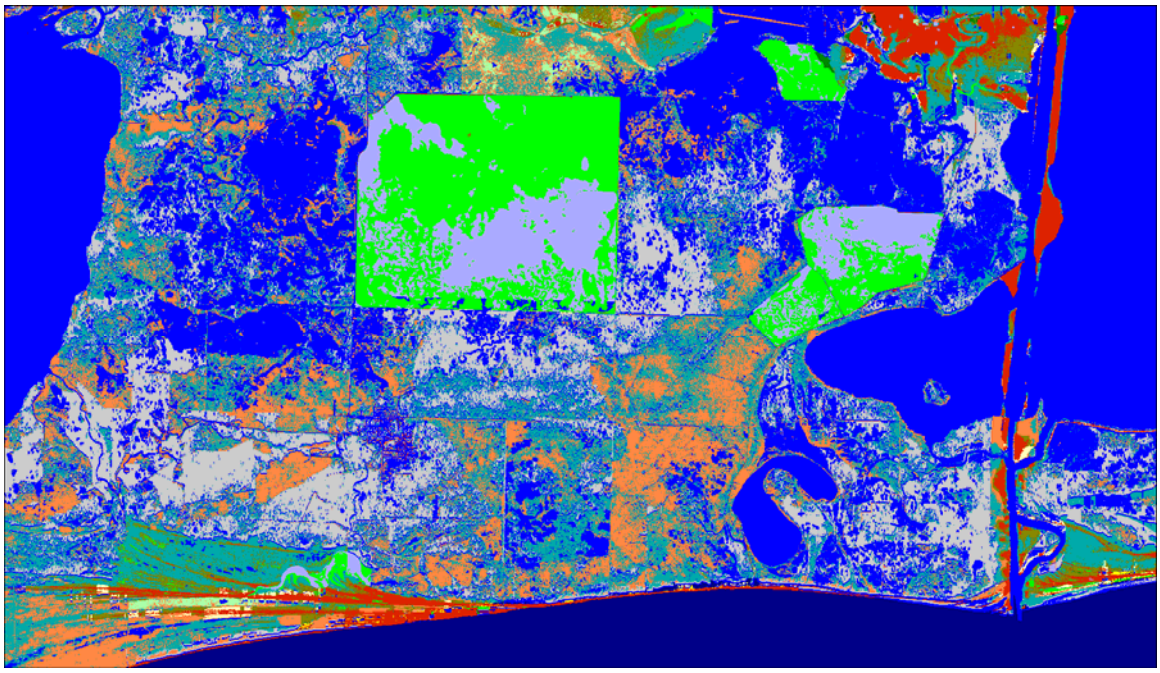
Sabine NWR Context, 2100, 1 meter eustatic SLR by 2100



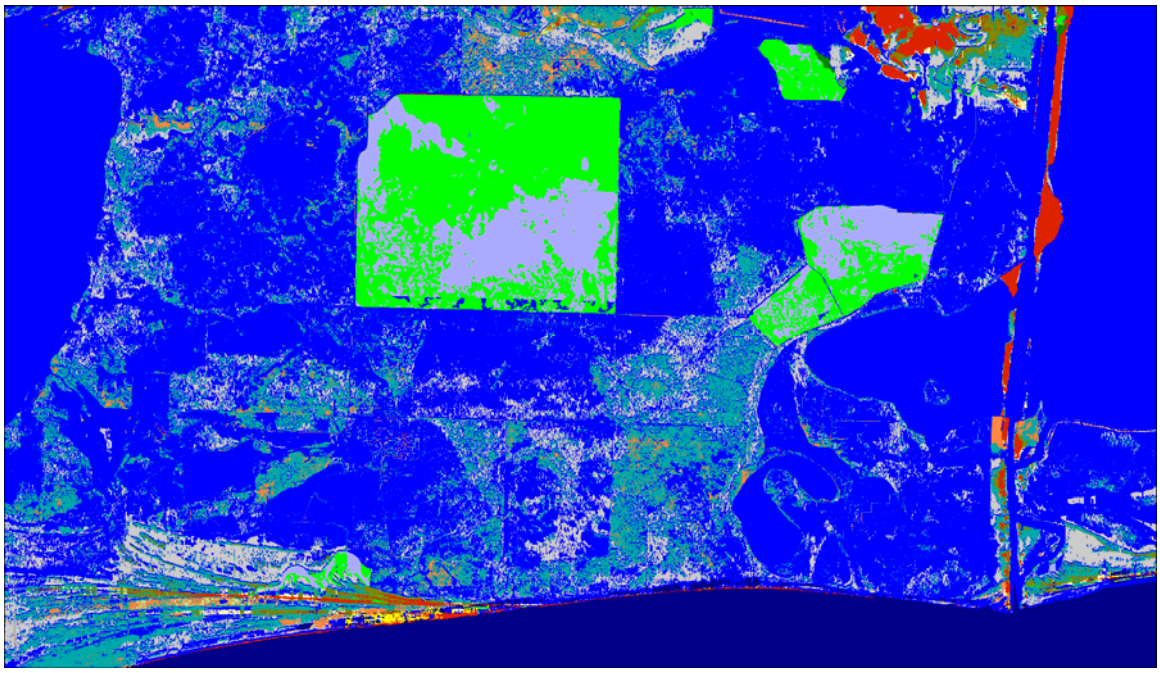
Sabine NWR Context, Initial Condition



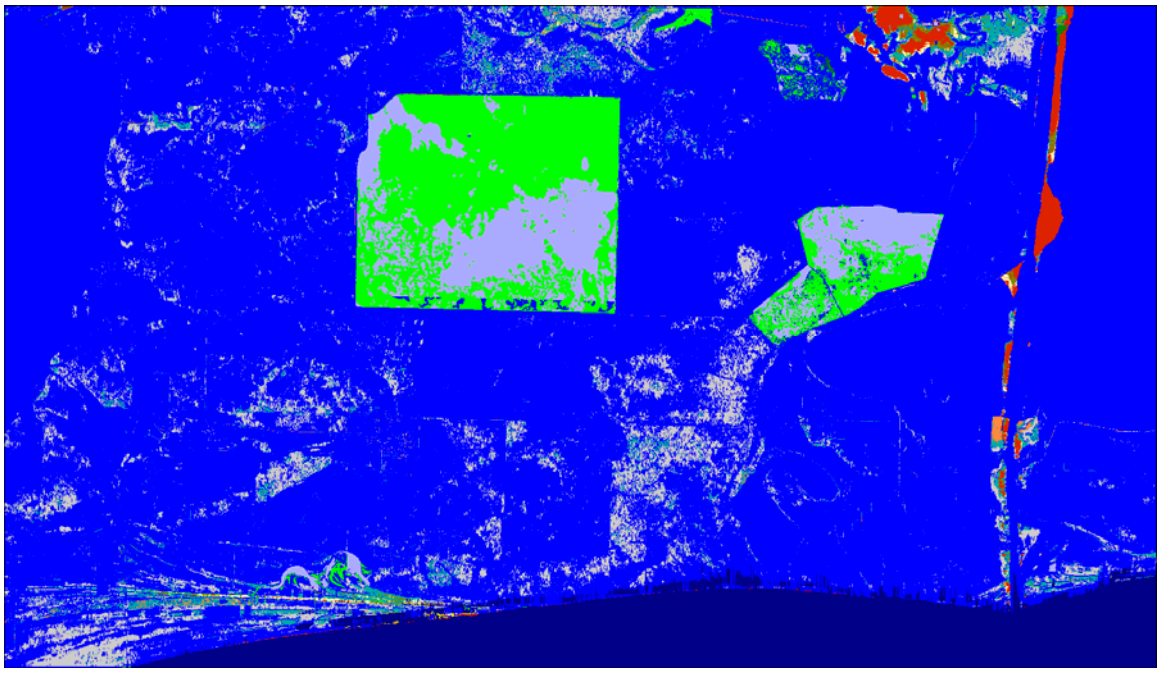
Sabine NWR Context, 2025, 1.5 meters eustatic SLR by 2100



Sabine NWR Context, 2050, 1.5 meters eustatic SLR by 2100



Sabine NWR Context, 2075, 1.5 meters eustatic SLR by 2100



Sabine NWR Context, 2100, 1.5 meters eustatic SLR by 2100