Prime Hook National Wildlife Refuge Marsh Restoration & Shoreline Resilience Project

A Carbon Sequestration Case Study in the Coastal Zone

Session HS10.2

Aspen Tabar
Co-Founder of A Generation of Change

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EGU General Assembly 2021

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Agenda

- Project Overview
  - Shoreline Reconstruction
  - Marsh Restoration
- Vegetation Monitoring
- Carbon Sequestration
- Future Projections

Acknowledgment

Susan Guiteras

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USFWS – Coastal Delaware National Wildlife Refuge Complex

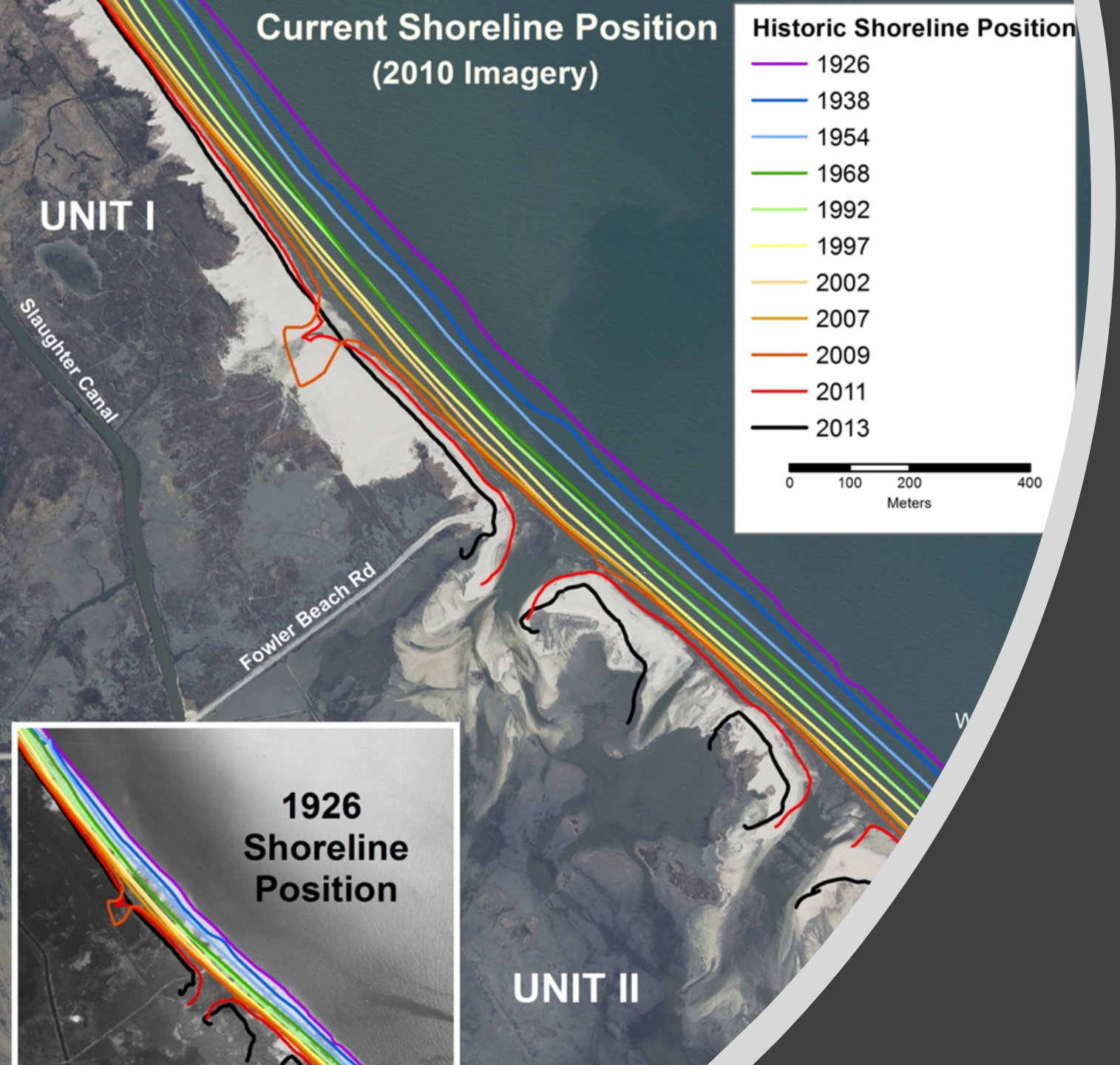
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Project Overview

Prime Hook National Wildlife Refuge

- 10,000 acres, mostly wetlands
- Two central units – Unit II and Unit III – managed as freshwater impoundments for waterfowl habitat through installation of water control structures in 1980's
- Impoundment management successful until series of storms created breaches in Unit II shoreline
- Hurricane Sandy brought largest final blow to the system
- Rapid peat collapse and extensive conversion to open water in Unit II and Unit III





Historic Shoreline (1926 to present)



History of Shoreline Overwashes & Breaches

- **2006 – Hurricane Ernesto**
  - In Unit I only
  - Rejuvenated the Unit I salt marsh
  - Decision not to repair, natural salt marsh
- **2008 – Mother's Day Storm**
  - Moderate overwash in Unit II
  - Repaired in October 2008
  - 2009 freshwater vegetation management successful
- **2009 – October/November Nor'Easters**
  - Two breaches formed in Unit II
  - Salt marsh fared well
  - Impounded freshwater wetlands experienced peat loss and rapid conversion to mostly open water
  - Reconsidered wetland management
- **2012 – Hurricane Sandy**
  - Two new large breaches
  - Total breached area nearly tripled

Shoreline Reconstruction

- Largest tidal marsh restoration project in the east at ~4000 acres
- Based on extensive hydrodynamic modeling with local data

- Closure of large breaches
- Restoration of 8,900 ft of shoreline, dune, and back barrier platform



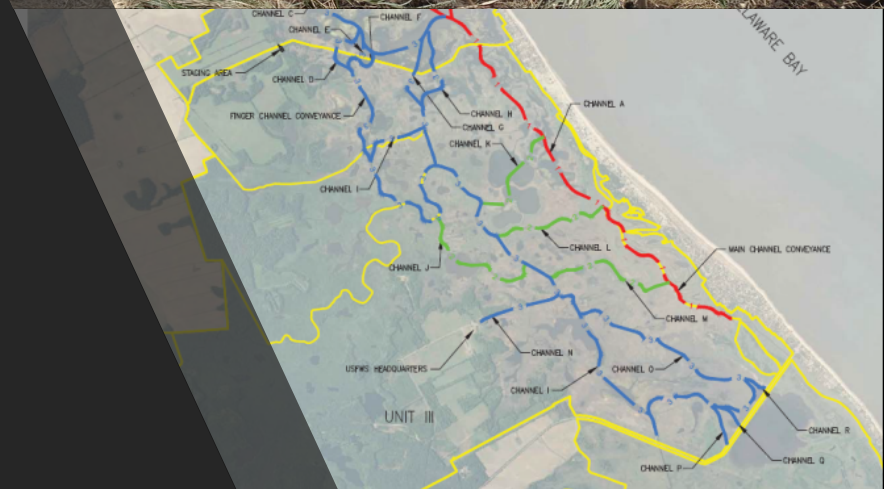
Marsh Restoration

- Dredged ~25 miles of interior tidal channels in Unit II and Unit III
- Remove water control structures and constructed a new bridge
- Thin layer deposition on site

- **Aerial Seeding on 1000 acres**
- **Back barrier planting**
  - **58 acres, ~300,000 plugs**







Vegetation Monitoring

Vegetation Monitoring Overview

<u>METHODS</u>

Remote Sensing Methods

- Quantifying acres/% of open water, vegetation, bare ground
- Remote sensing from imagery

On-the-ground Metrics

- Saltmarsh Habitat and Avian Research Program (SHARP) (University of Delaware)
  - 15-20 points per unit
  - Vegetation metrics within 50-meters around each point
  - Includes Unit I and Unit IV as reference / control
- Mid-Atlantic Tidal Rapid Assessment Method (MidTRAM) (DNREC)
  - More intensive metrics at a subset of points





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Imagery Acquisition

2015

USDA National Agriculture Imagery Program (NAIP)

Lacks the added spectral bands for more advanced analysis

2016 to present

Maxar (Previously DigitalGlobe) satellite imagery

WorldView 2 and WorldView 3 satellite sensors

8 band multi-spectral imagery

Imagery access is provided to federal agency employees through the National Geospatial-Intelligence Agency

EnhancedView Web Hosting Service (EVWHS)

USGS – Commercial Remote Sensing Space Policy (CRSSP)

CRSSP Derived Imagery Requirements (CIDR)

Request of imagery available to federal agencies

Specify criteria such as location polygon, imagery type, cloud cover, dates, frequency



Analysis Methodology

NDVI (Normalized Difference Vegetation Index)

- Common vegetation index, simple but effective
- Measures the difference of the visible and near-infrared light absorbed and reflected by vegetation, respectively
- The only analysis done on 2015 imagery

Additional Analysis in 2016-2019

- Better distinction between Water, Bare Ground, Vegetated Marsh, and “Other Than Marsh”

NDSI (Normalized Difference Soil Index)

- Used the additional WV spectral bands to identify soil pixels

NDWI (Normalized Difference Water Index)

- Sensitive to changes in vegetation canopy water content

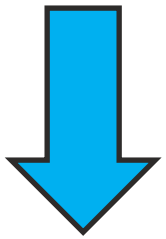




Results

Location	*Total Unit Acres*	Open Water (acres)					Vegetated Marsh* (acres)				
		Pre-Restoration	Post Restoration				Pre-Restoration	Post Restoration			
		Year					Year				
		2015	***2016***	***2017***	***2018***	***2019***	***2015***	***2016***	***2017***	***2018***	***2019***
Unit II	*1438*	1249	1077	796	797	851	189	370	638	623	569
% Total		87%	75%	55%	55%	59%	13%	26%	44%	43%	40%
Unit III	*2335*	1504	1516	1262	1202	1293	830	822	1070	1094	983
% Total		64%	65%	54%	51%	55%	36%	35%	46%	47%	42%
TOTAL	*3773*	2753	2593	2058	1999	2144	1019	1192	1708	1717	1552
% TOTAL		73%	69%	55%	53%	57%	27%	32%	45%	46%	41%

*** Includes Bare Flat/Mud Areas**



Trend Post Restoration

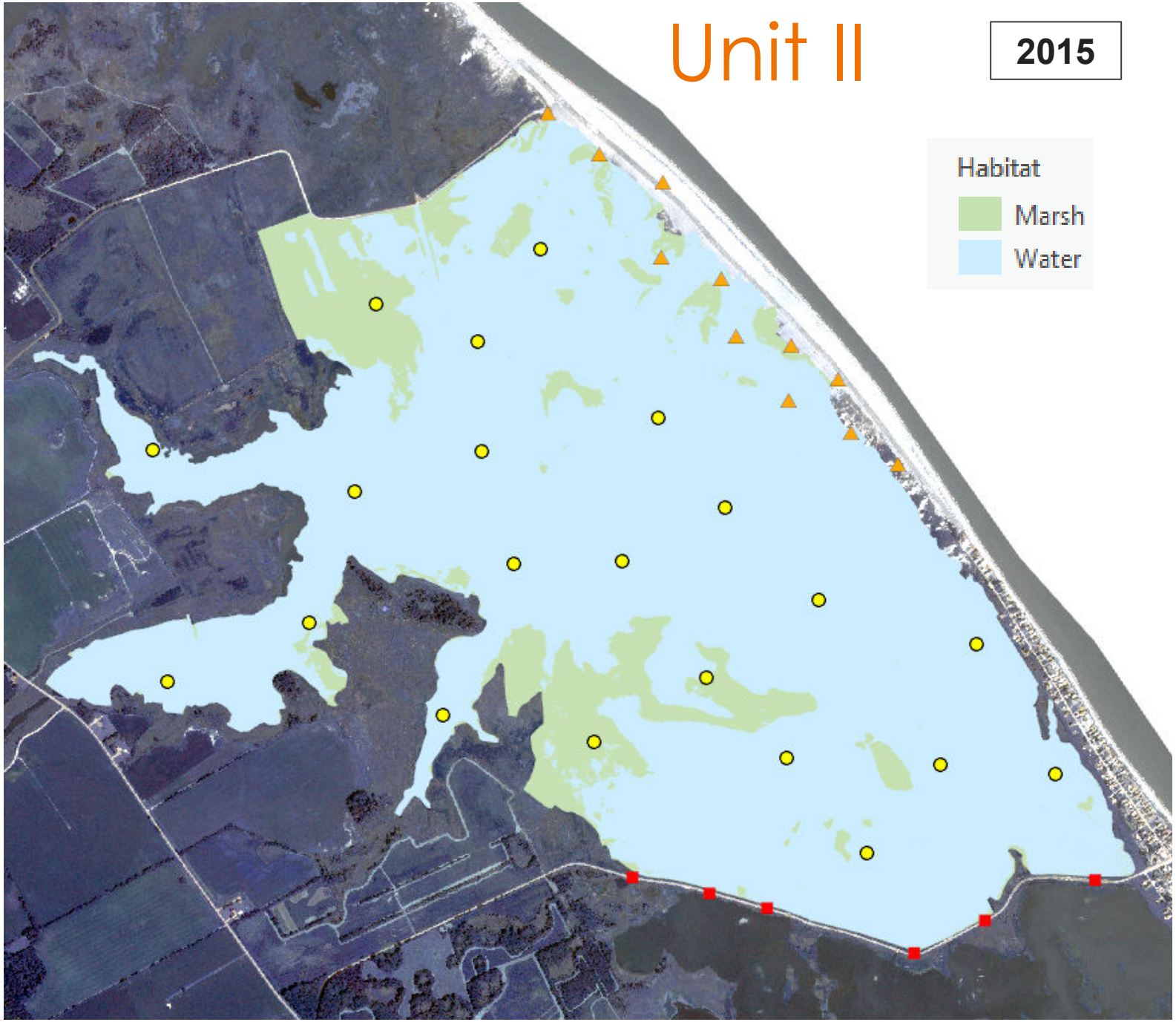


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Unit II

Unit II

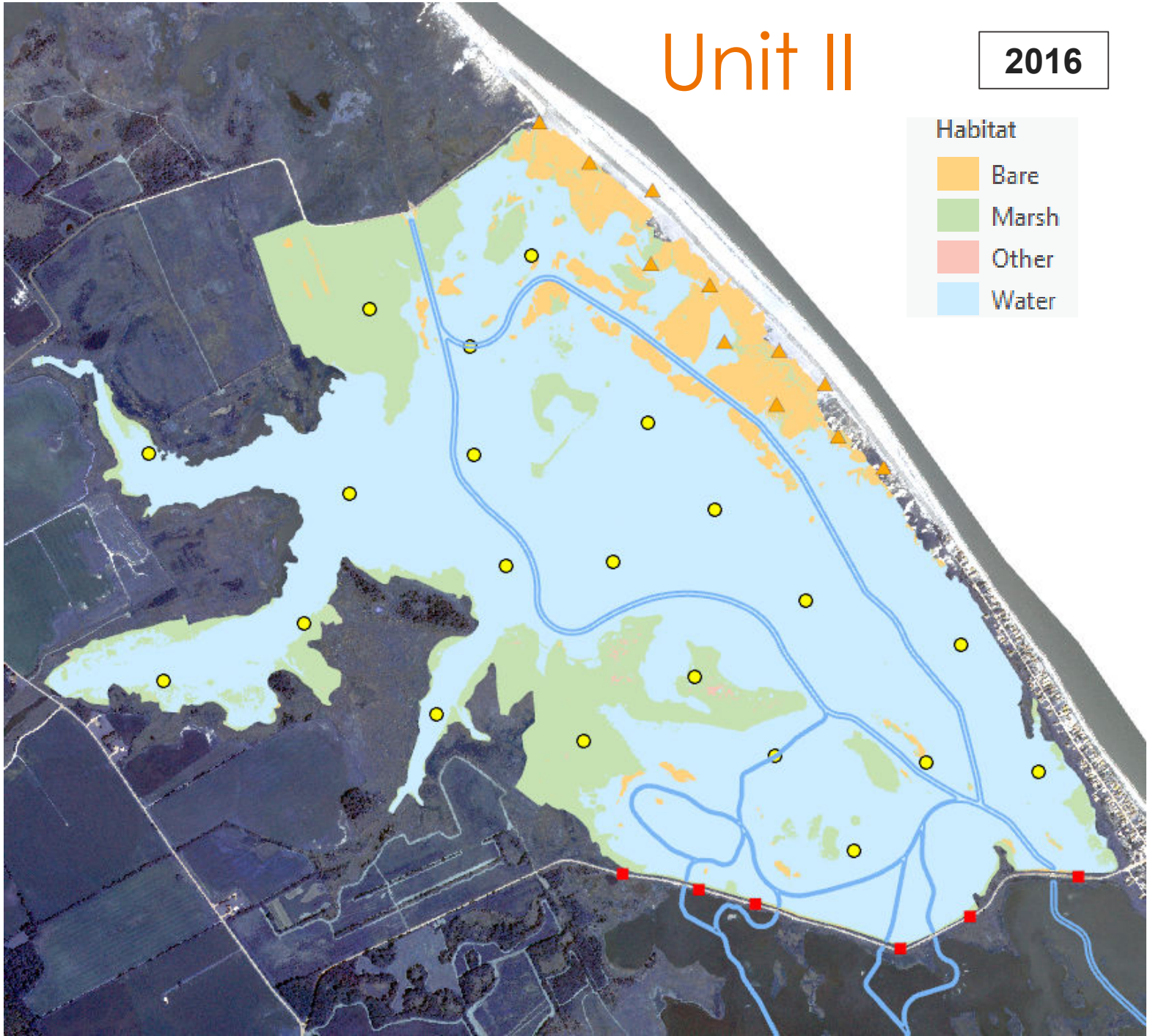
2015



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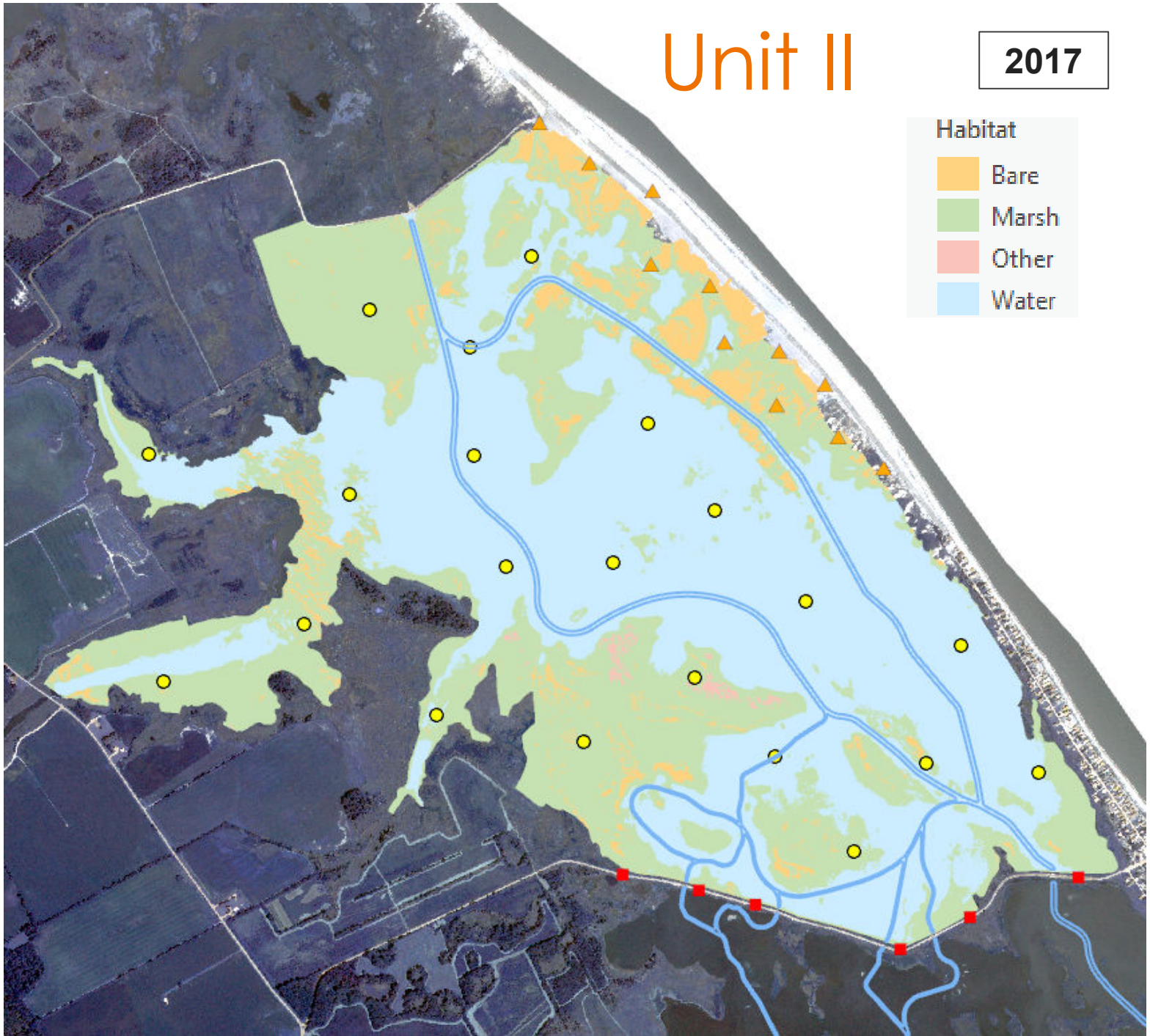
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Unit II

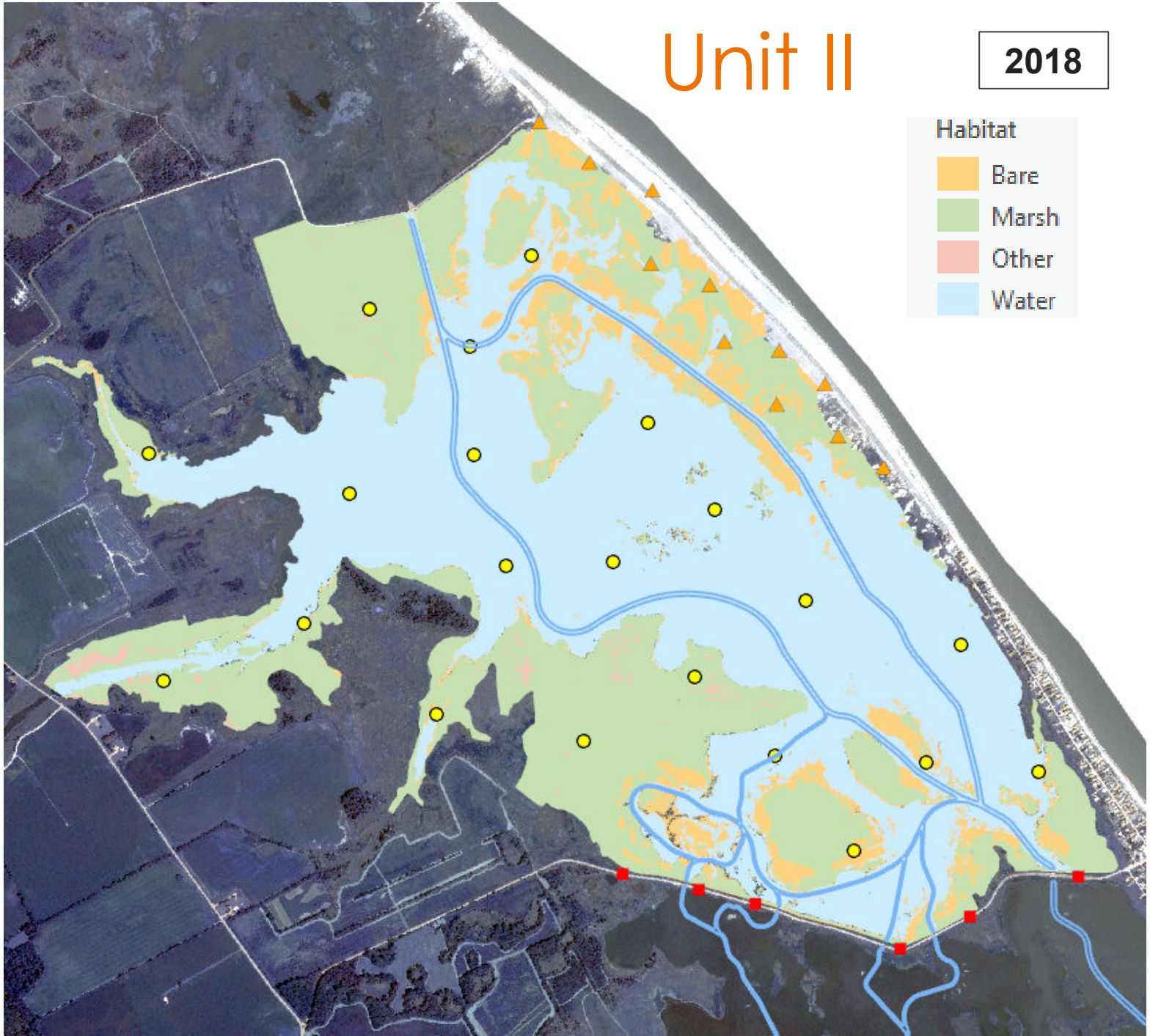
2017



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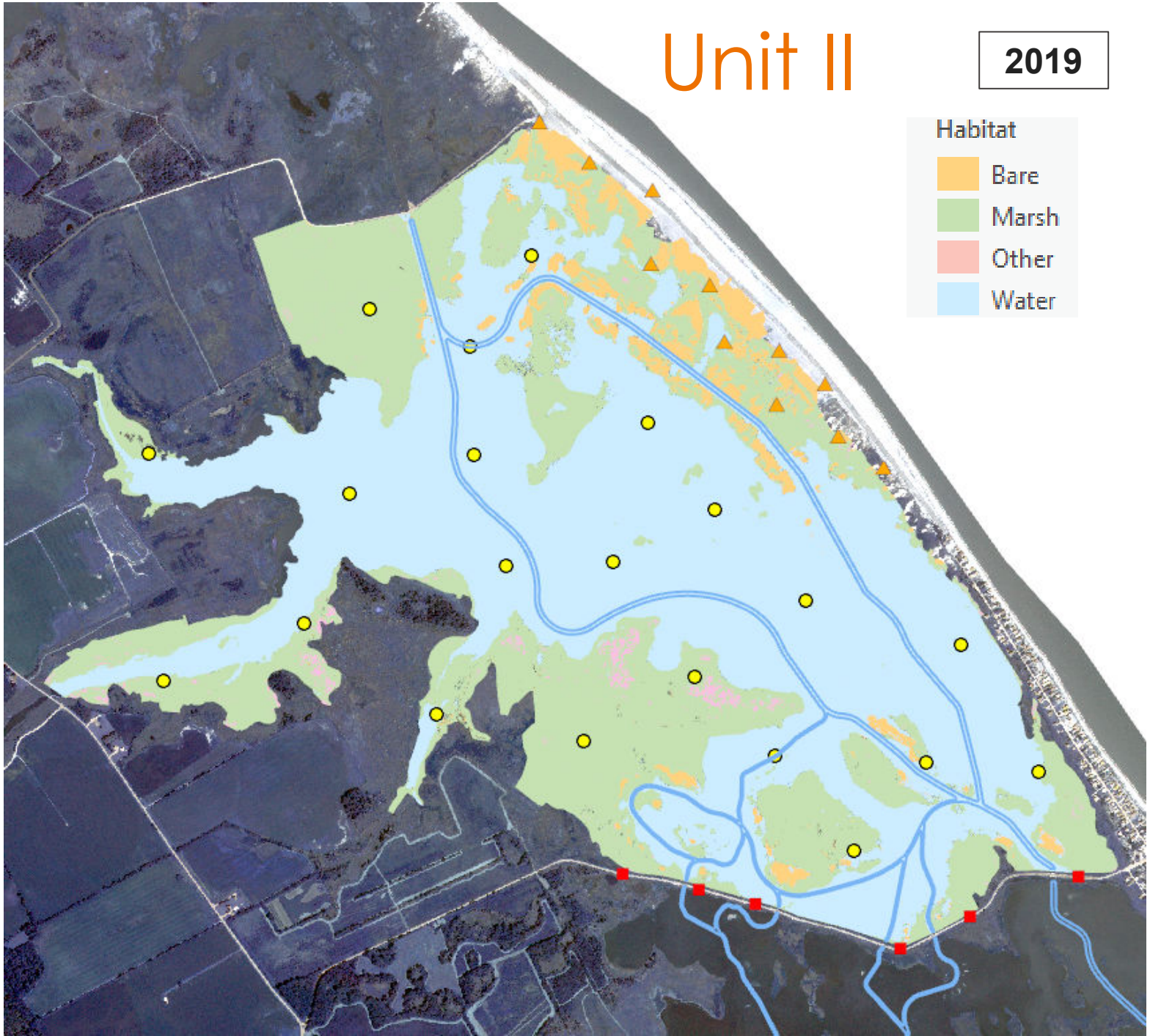
Unit II

2018



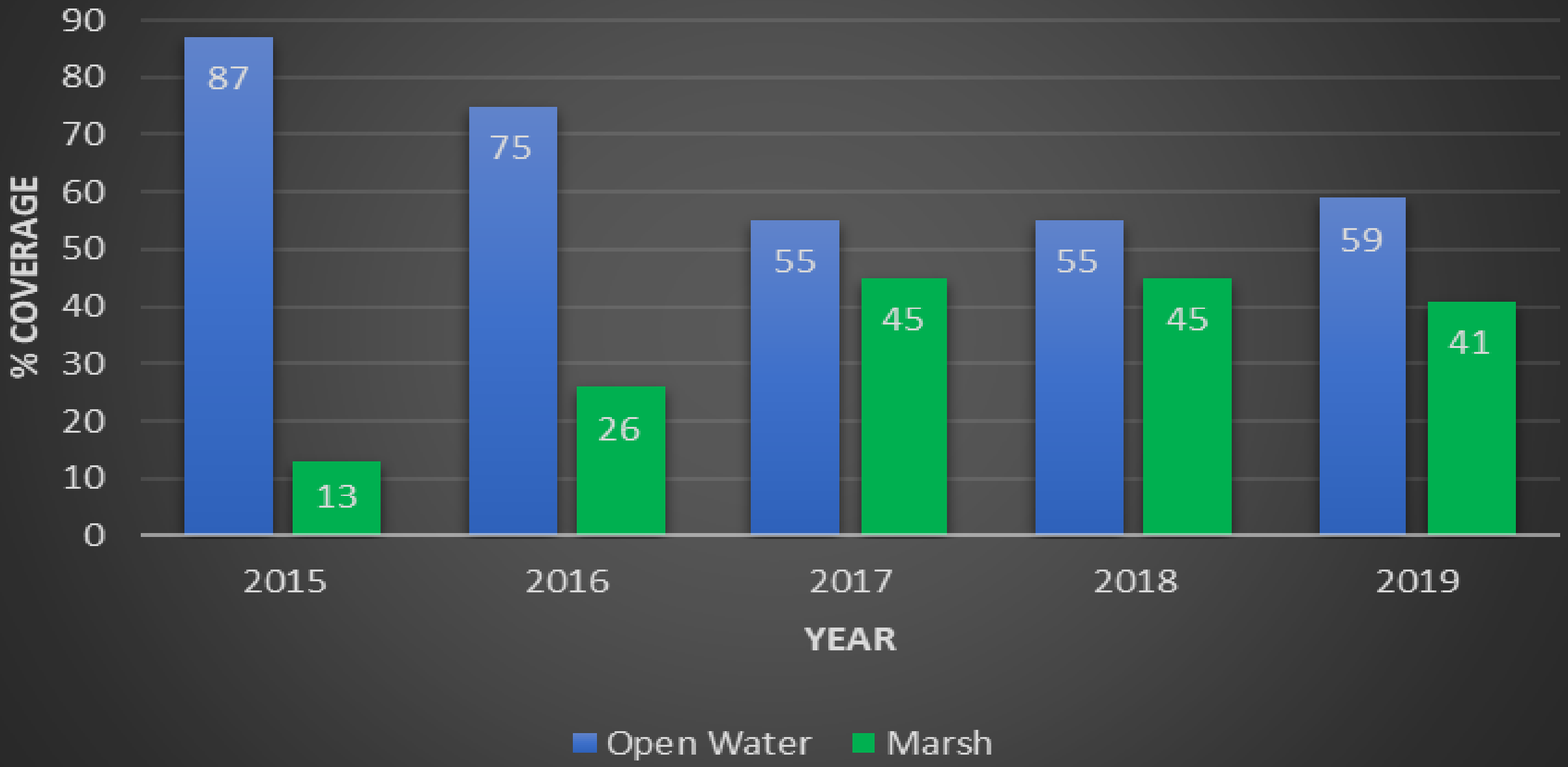
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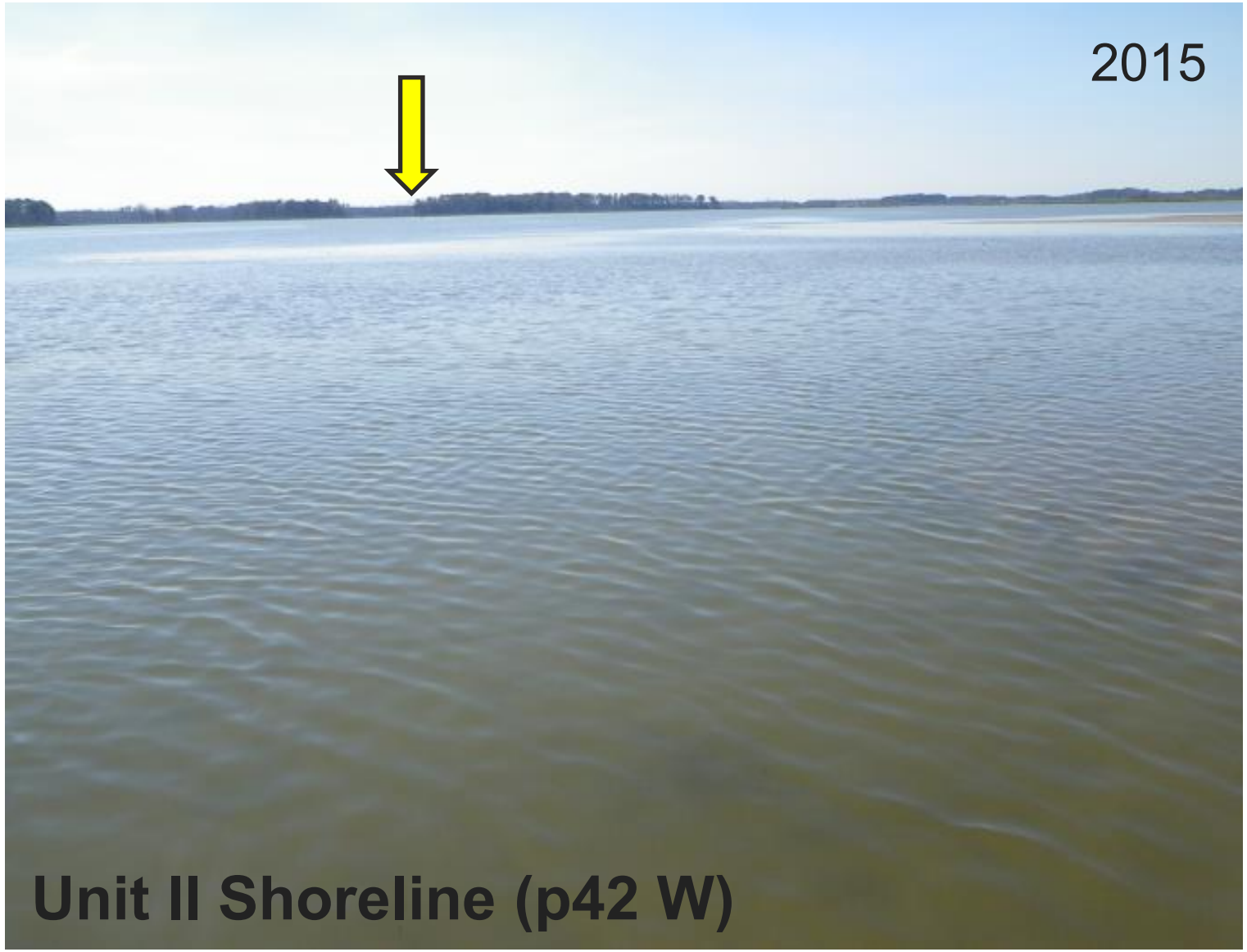


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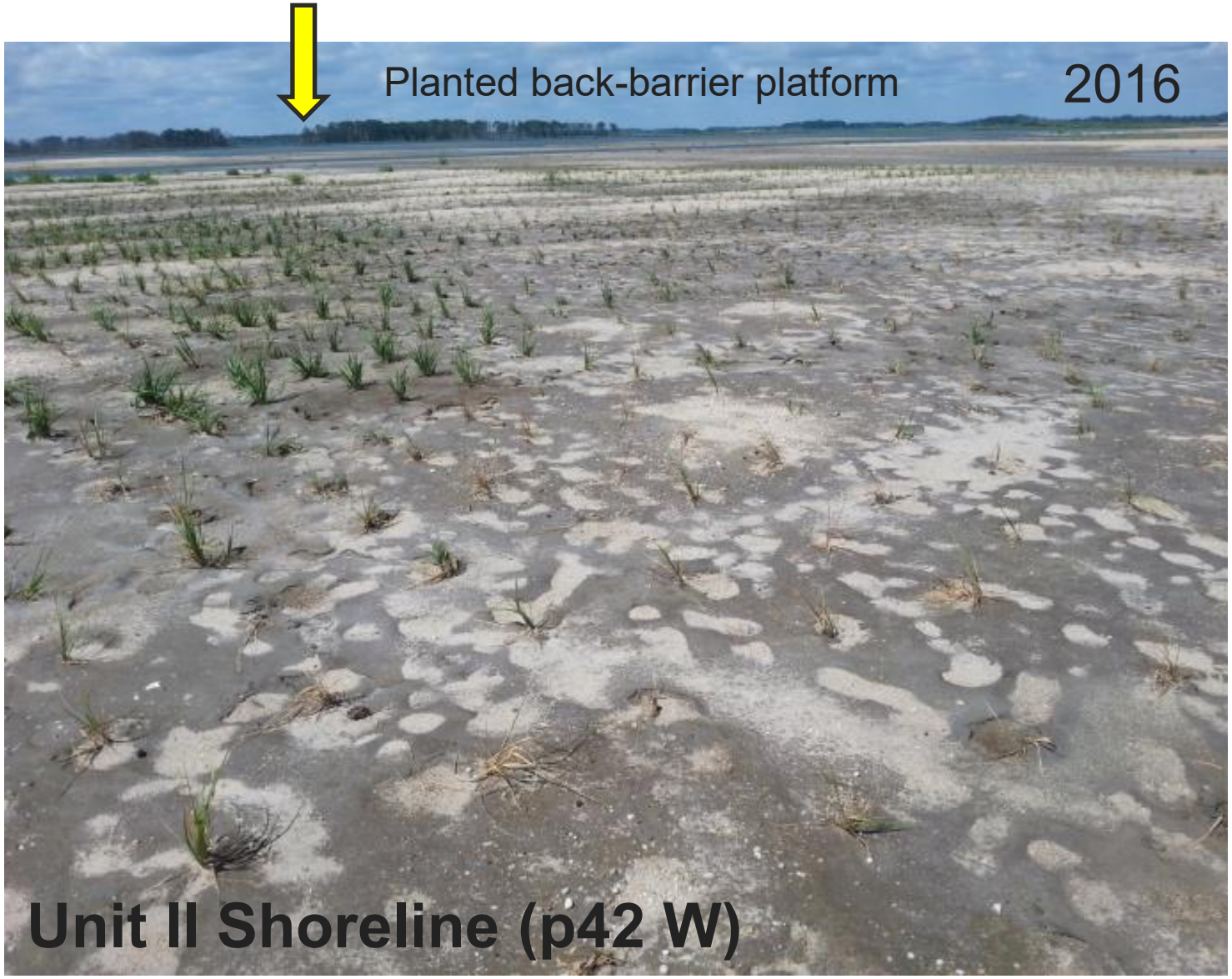

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Vegetation Community Response



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Vegetation Community Response



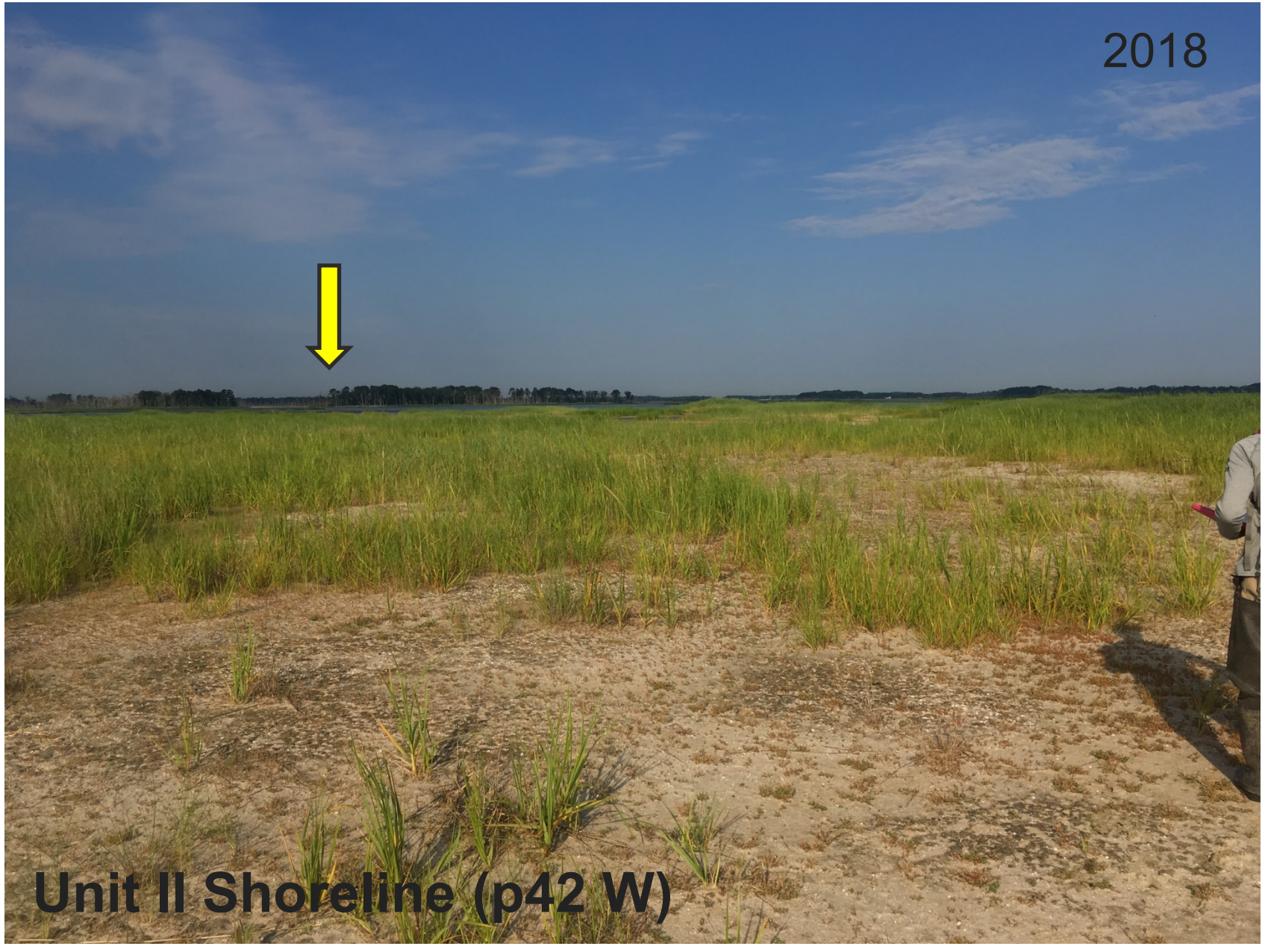
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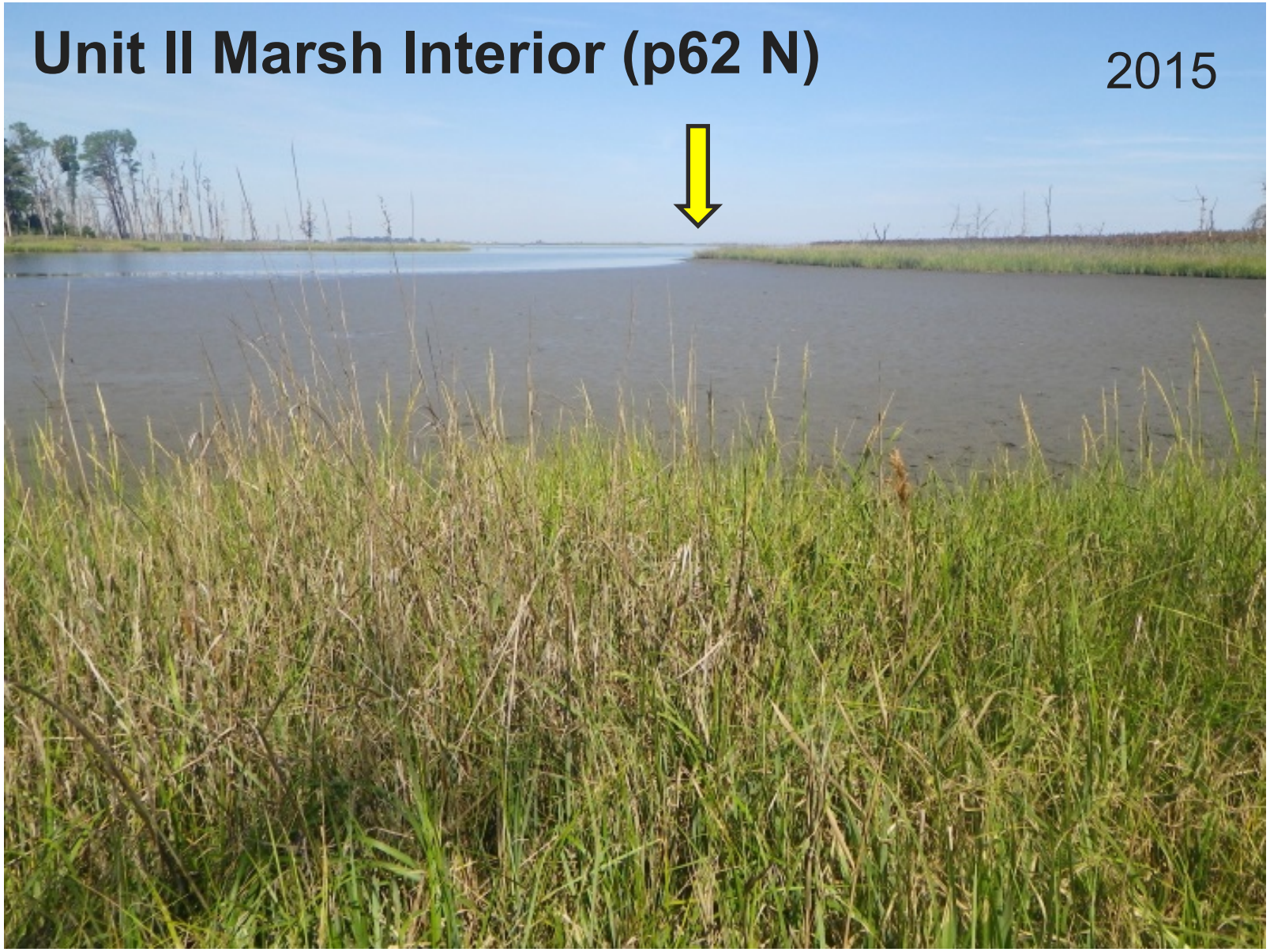
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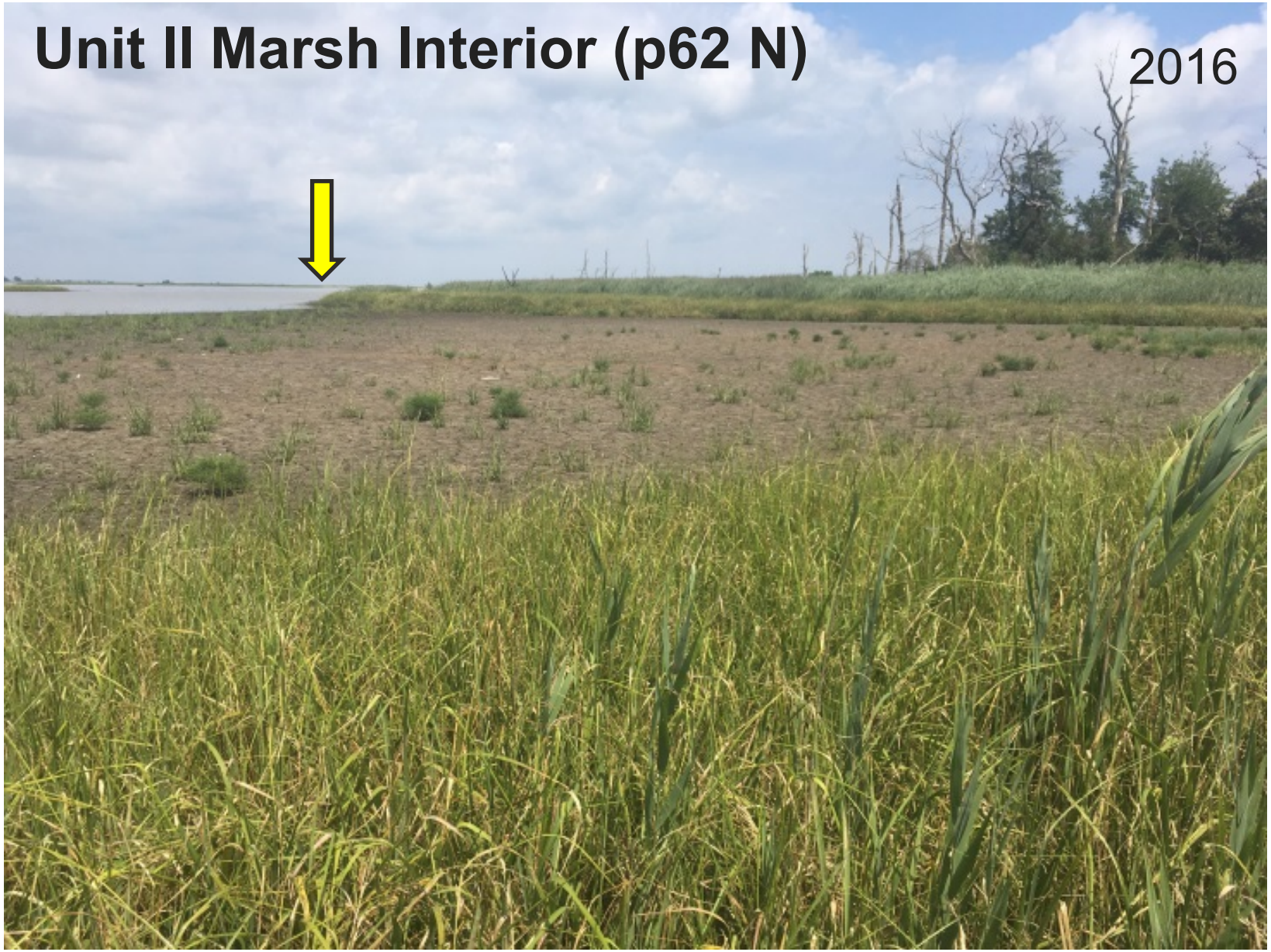
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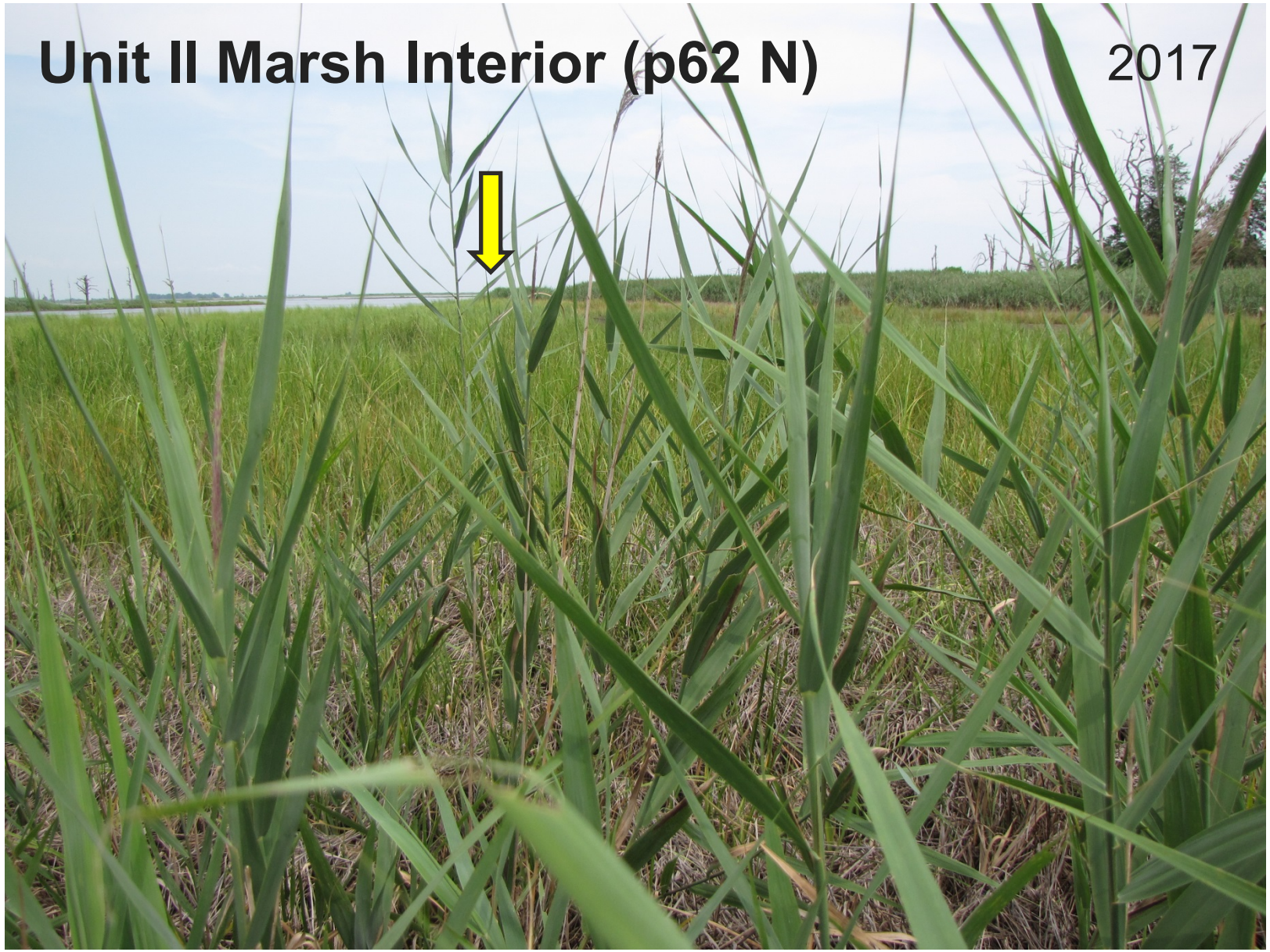
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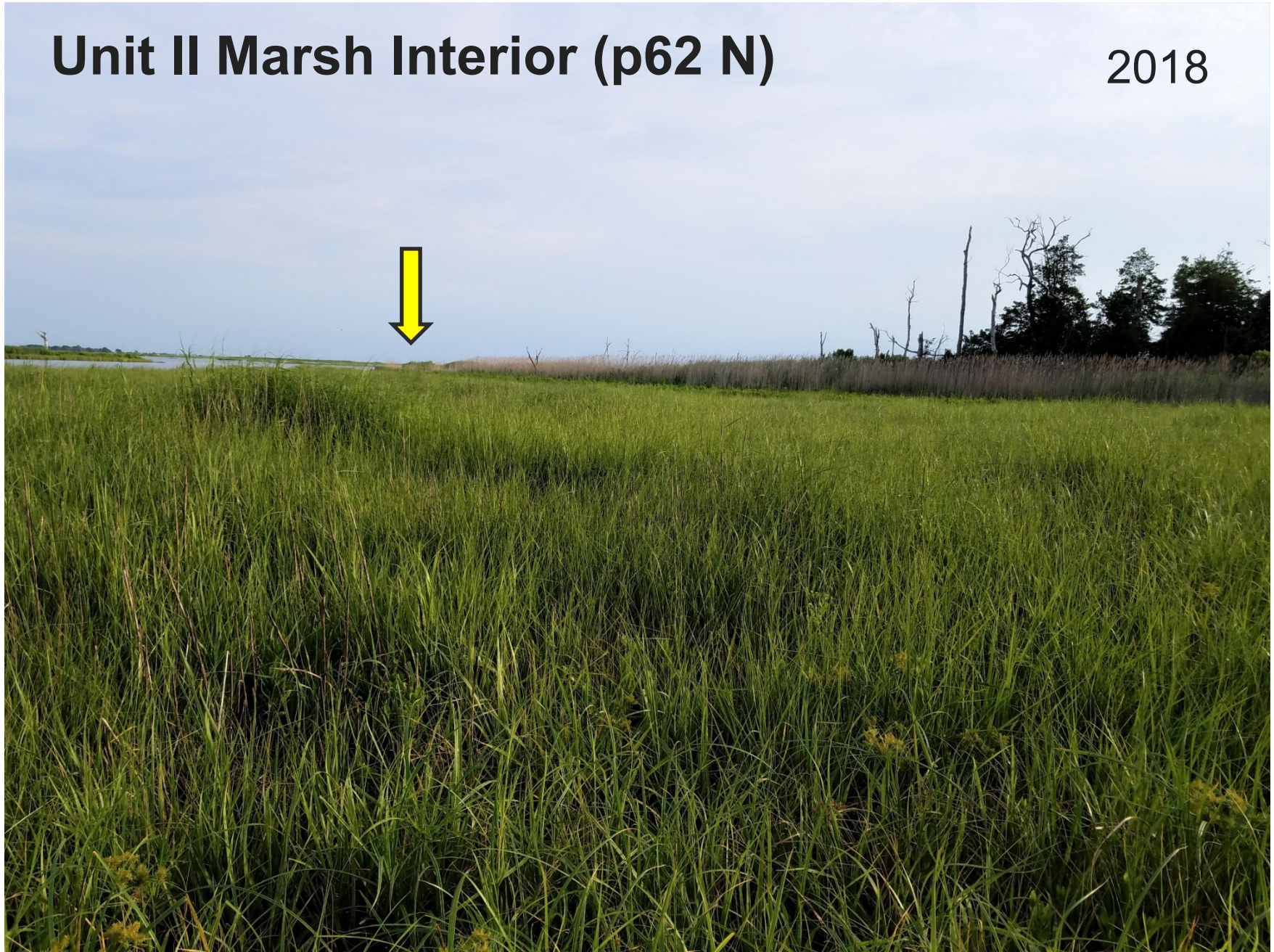
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Vegetation Community Response



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Vegetation Community Response

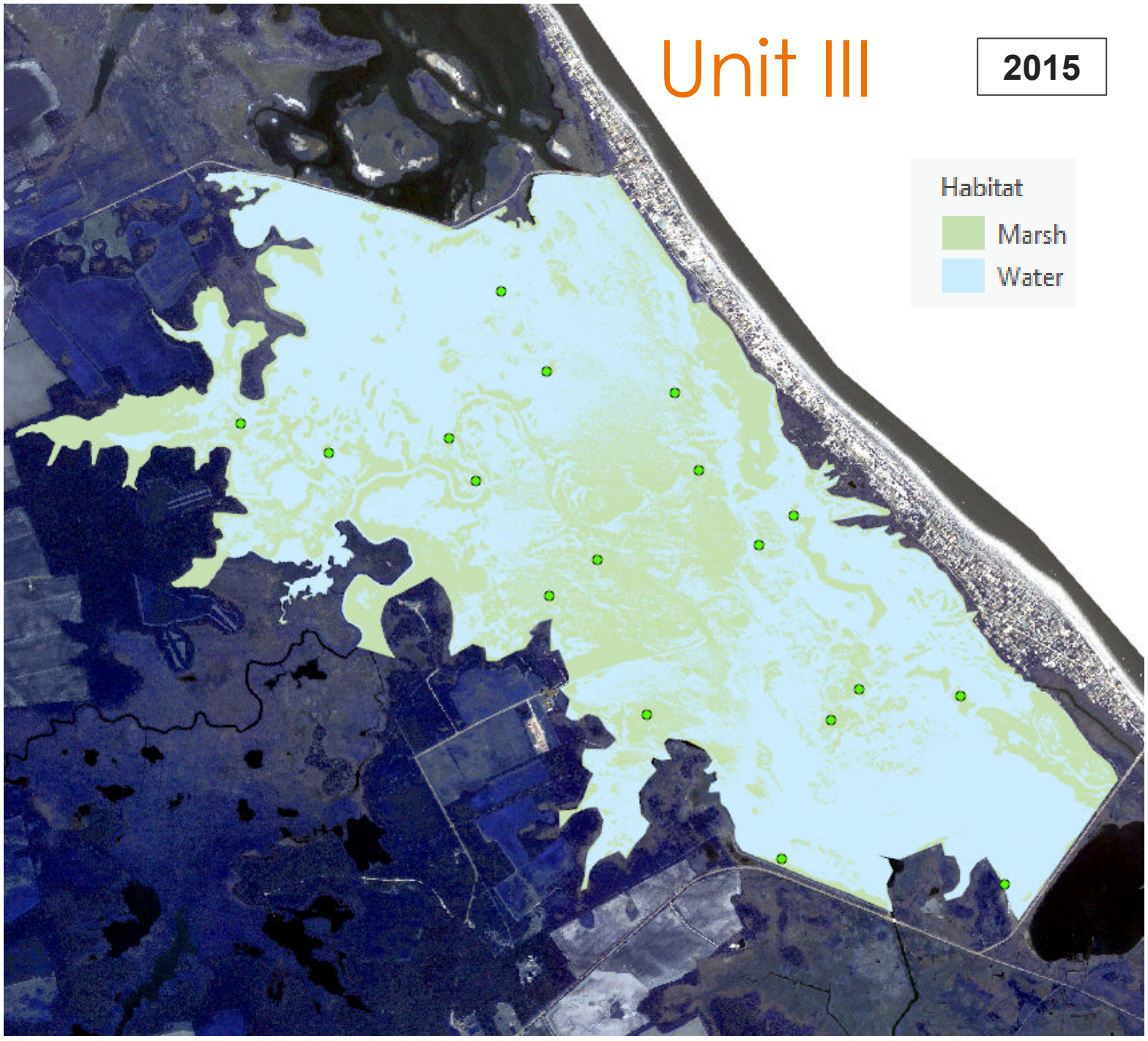


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Unit III

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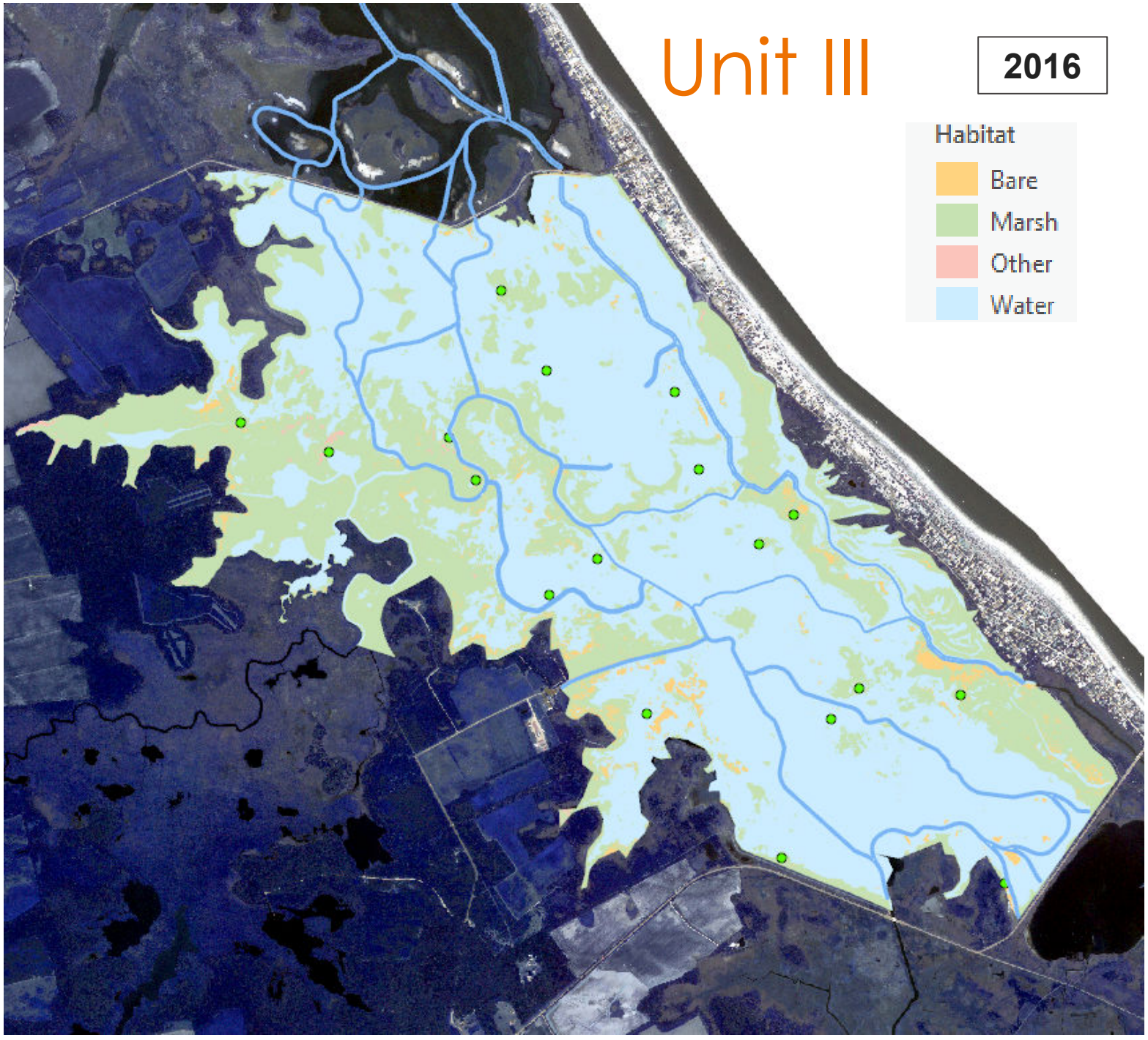
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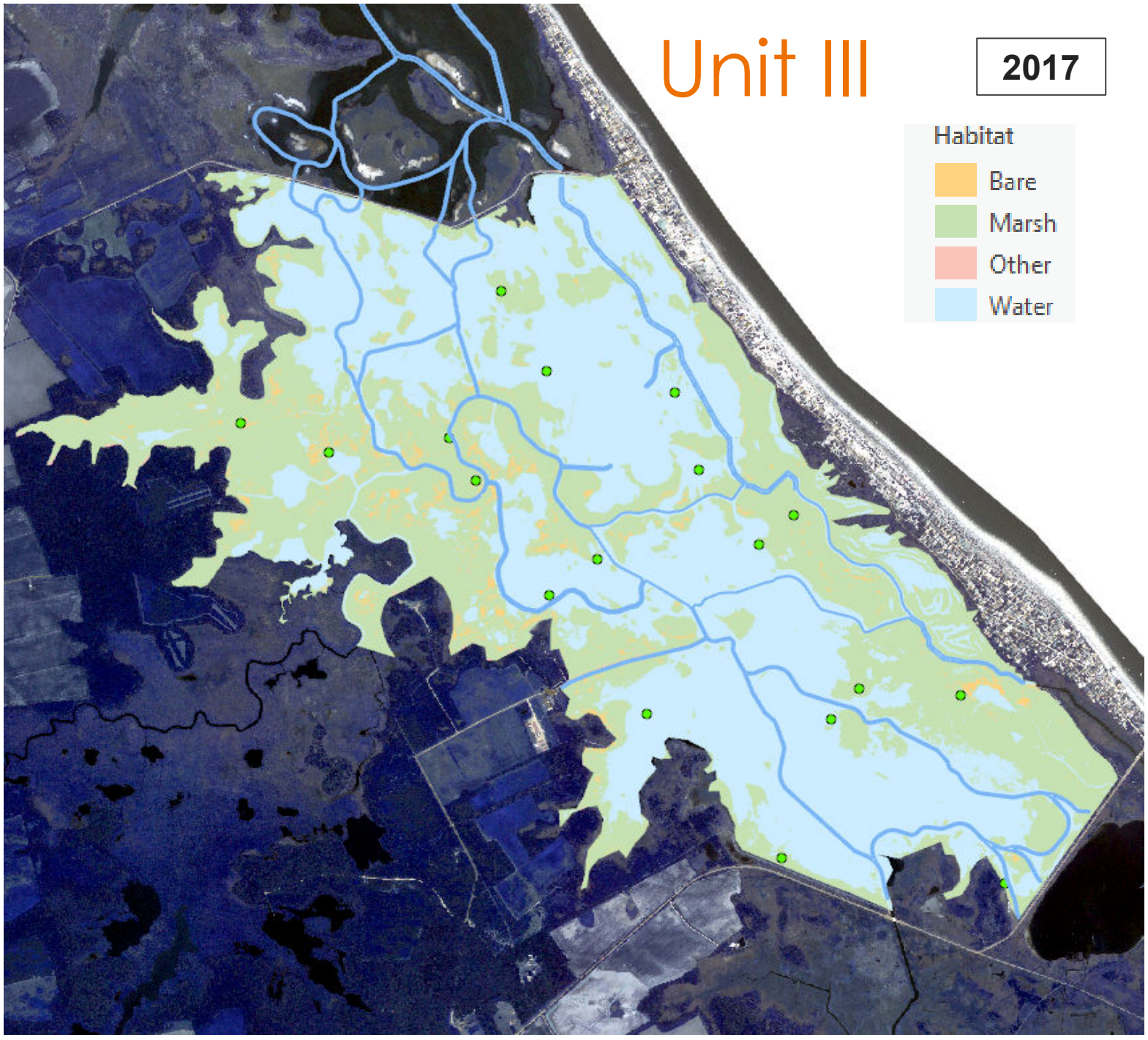
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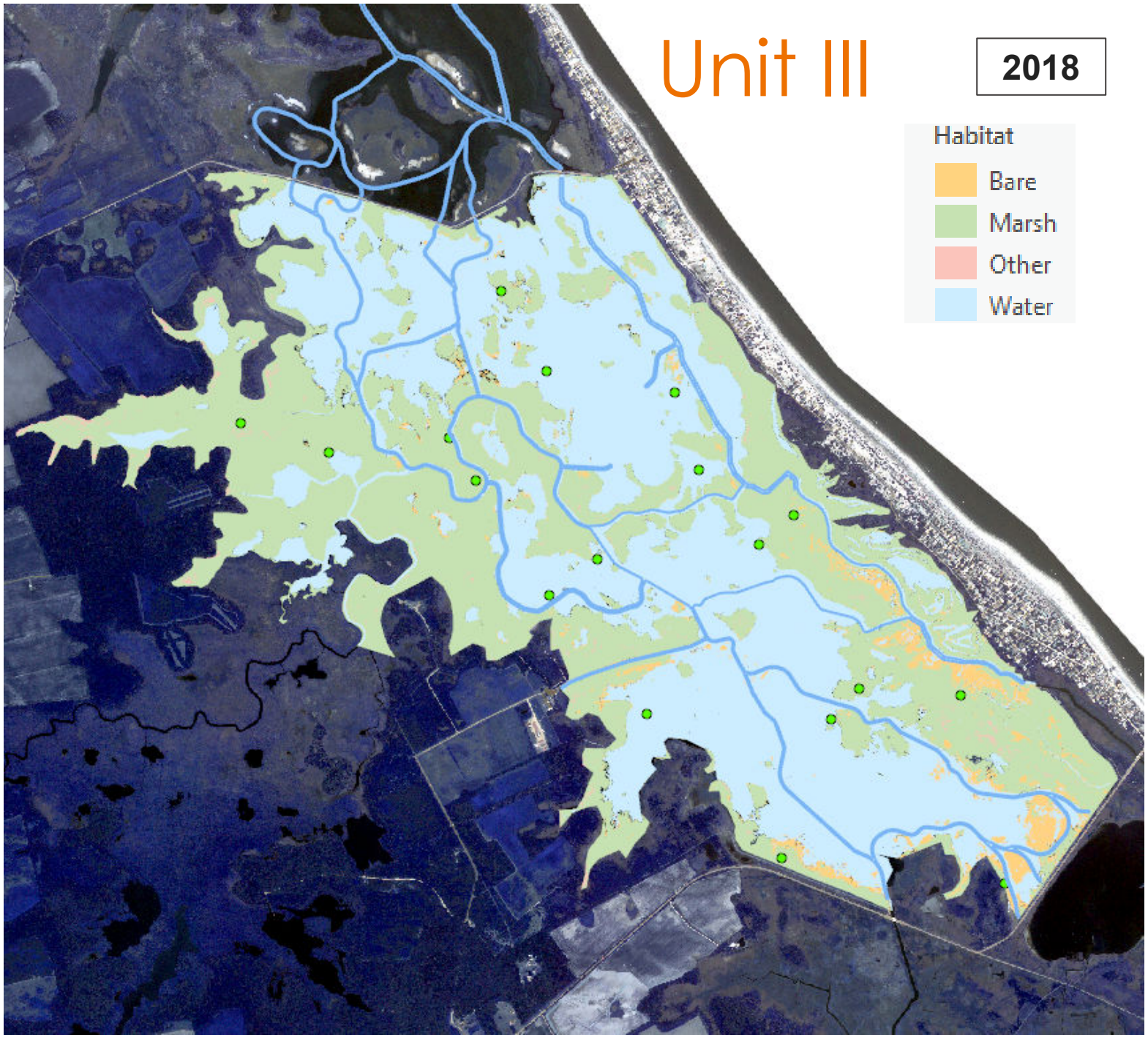
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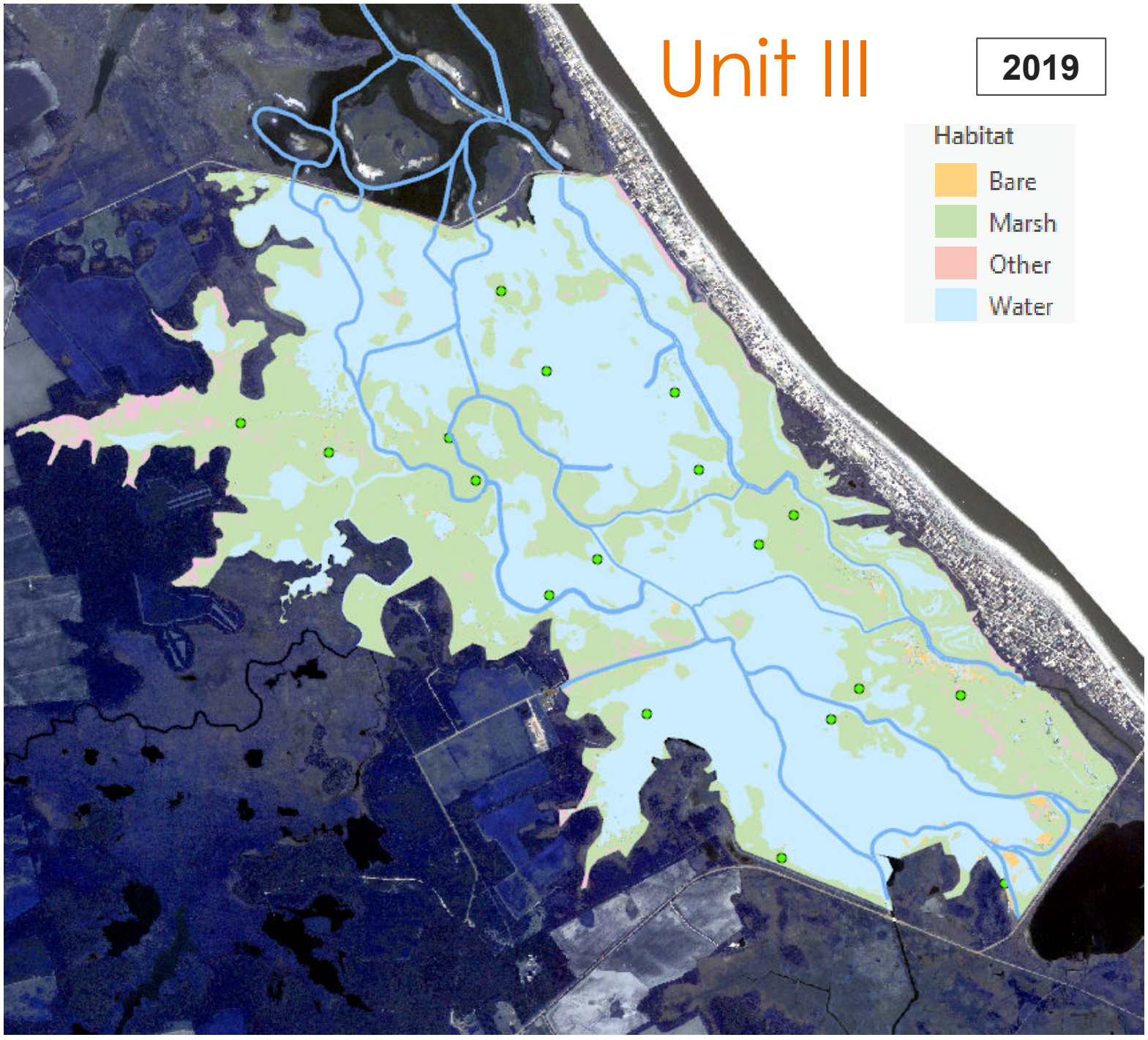
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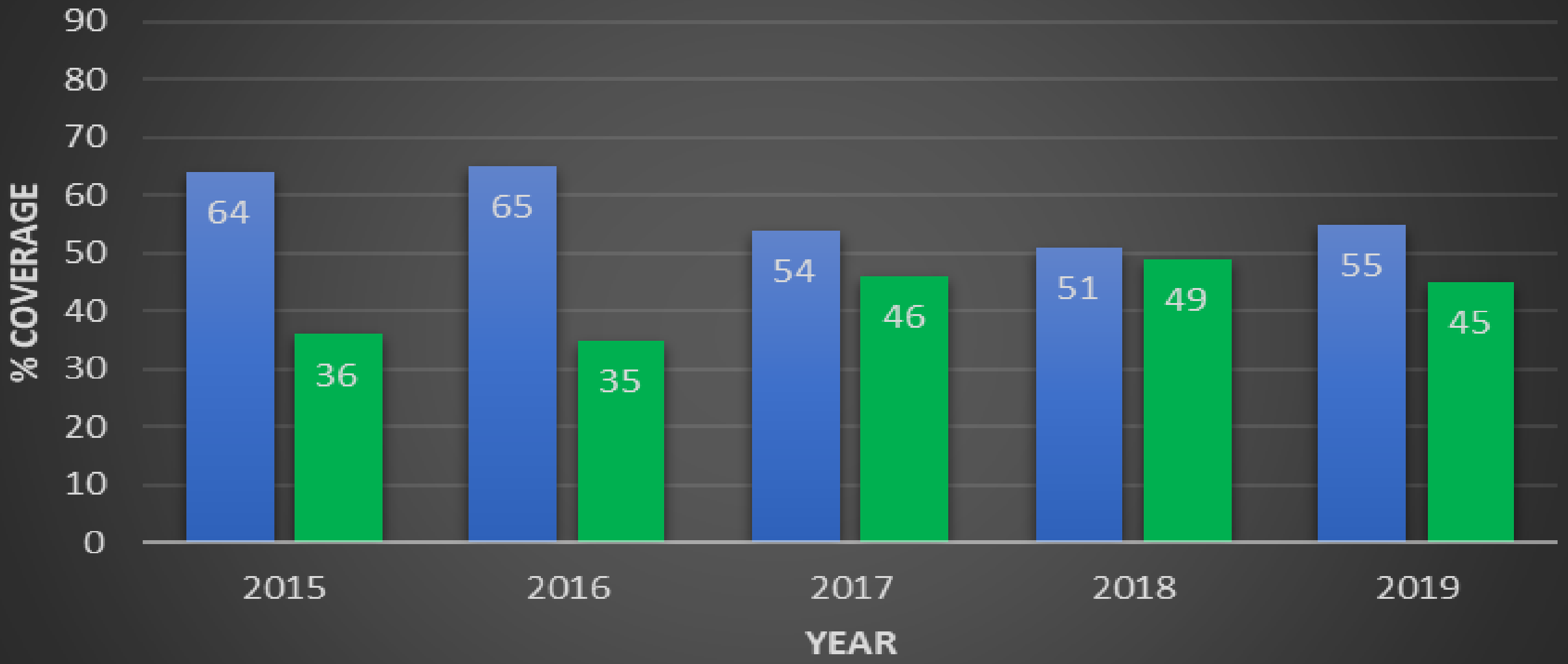
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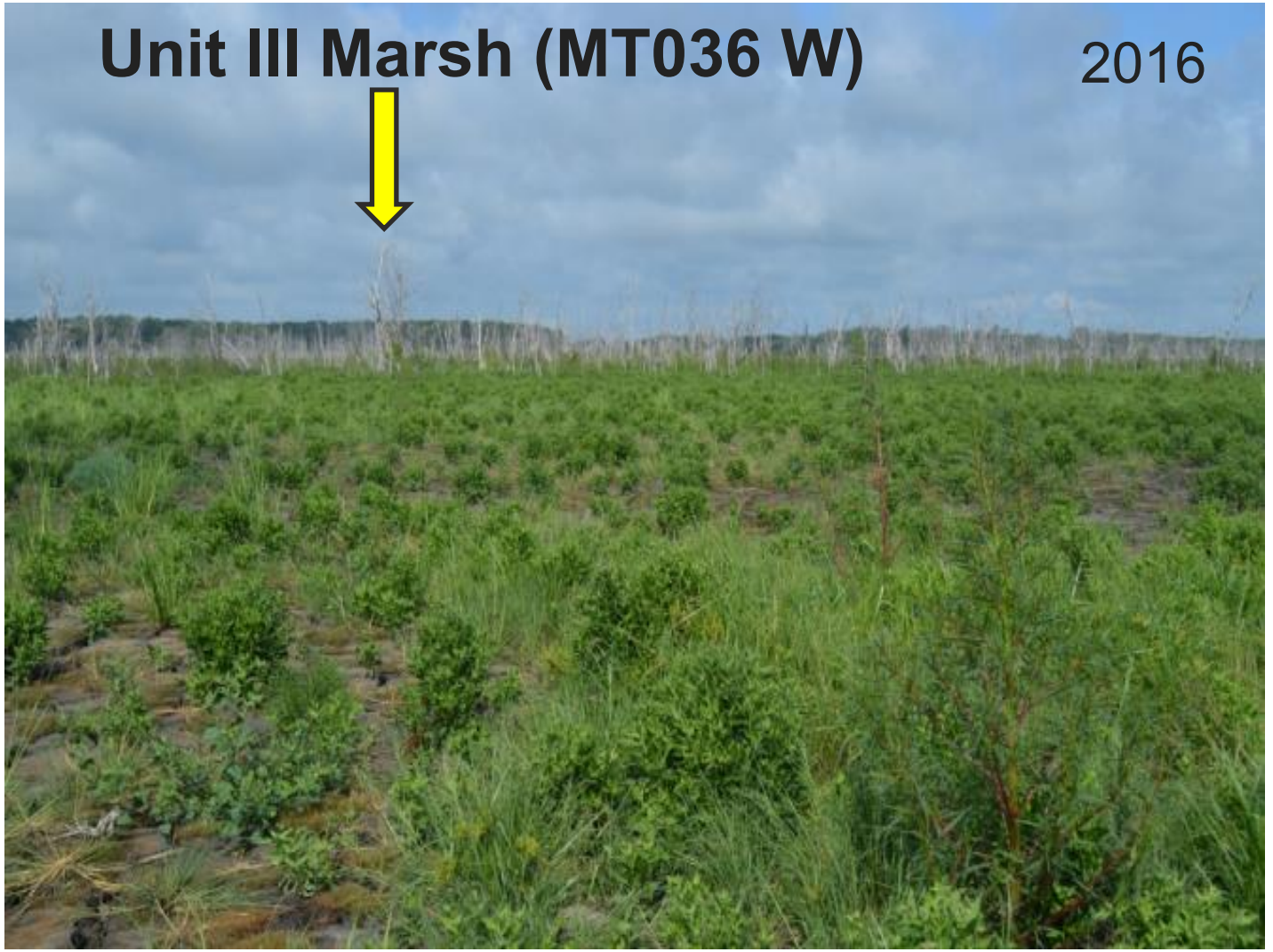
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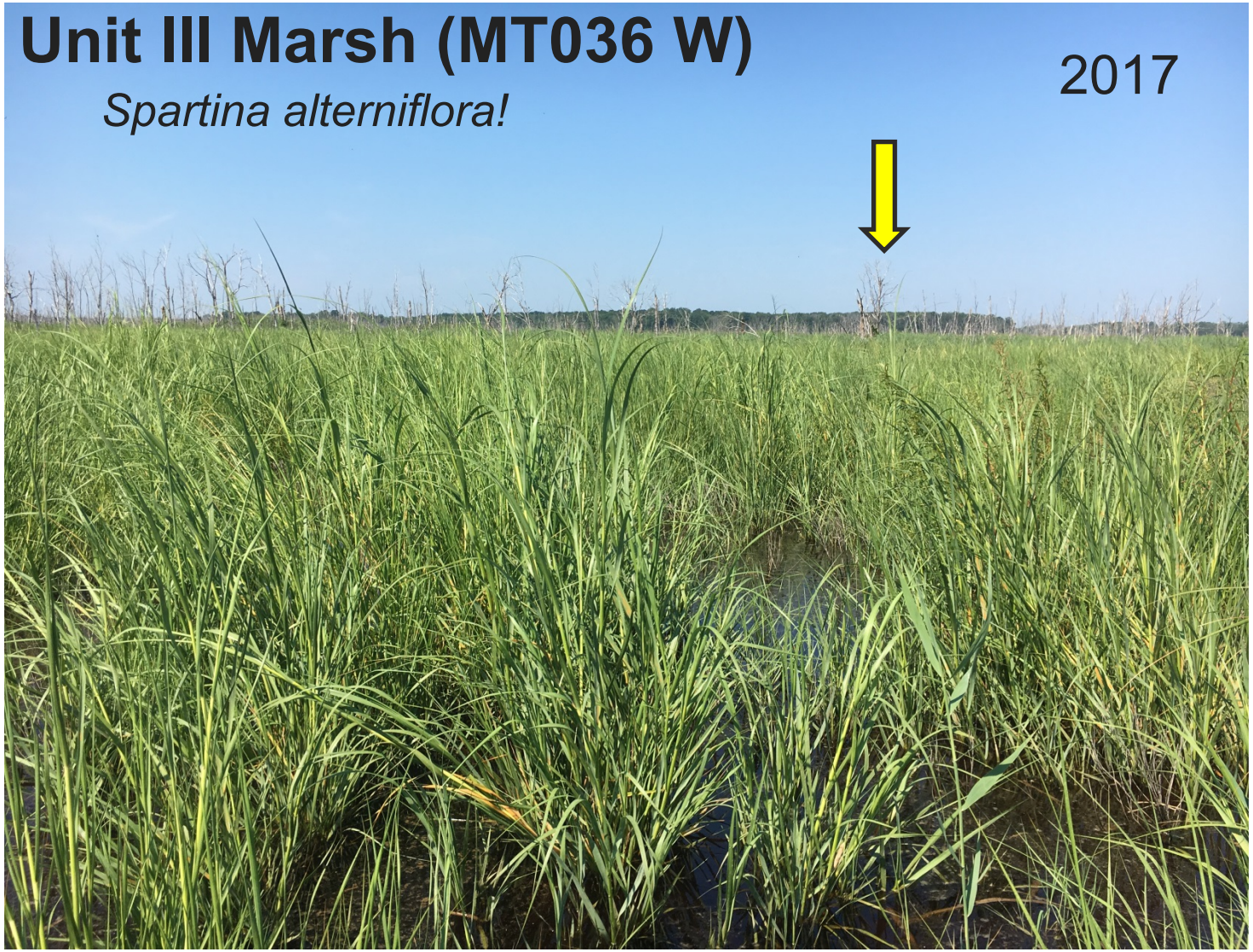


Vegetation Community Response



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Vegetation Community Response



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Vegetation Community Response



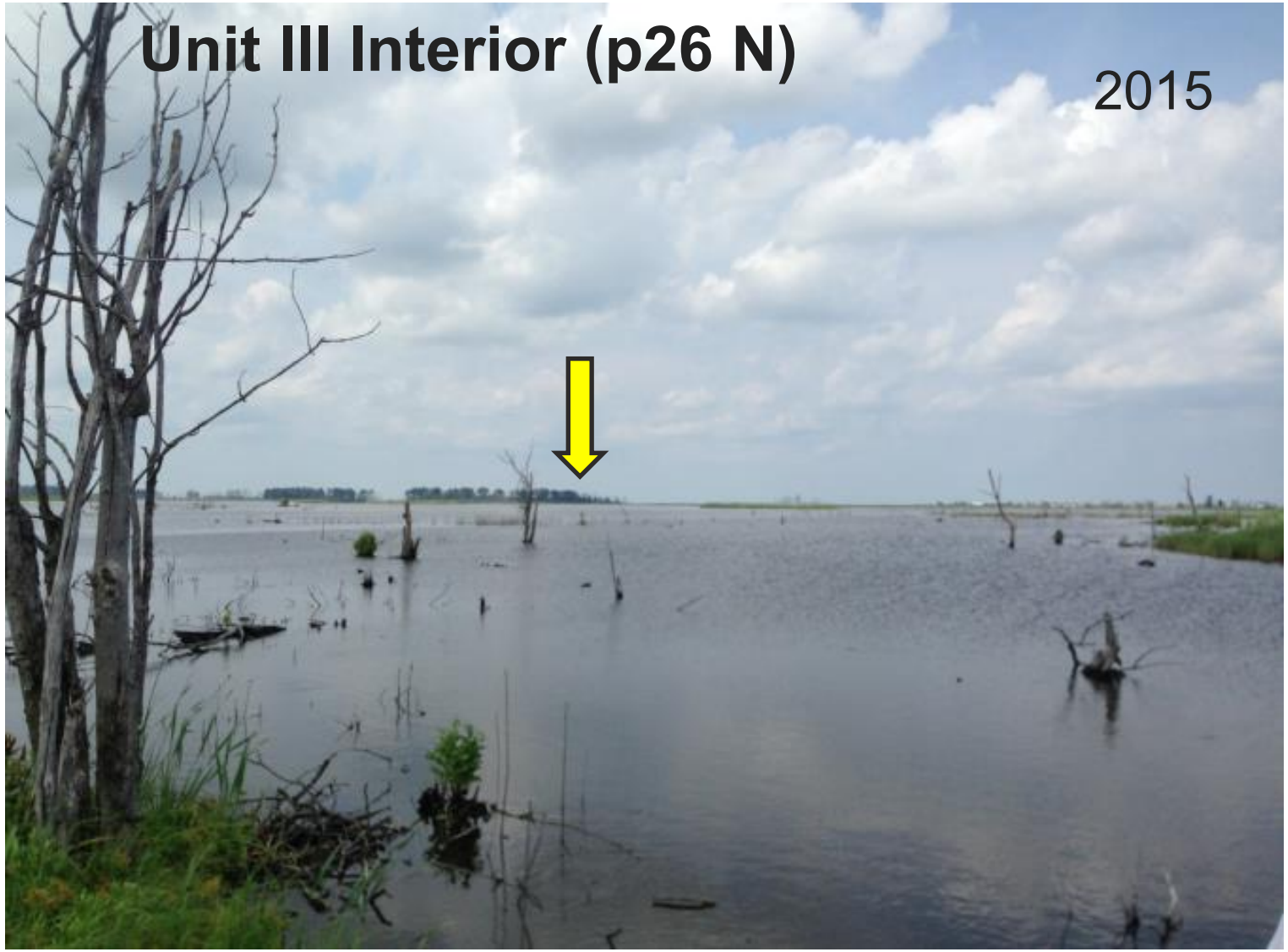
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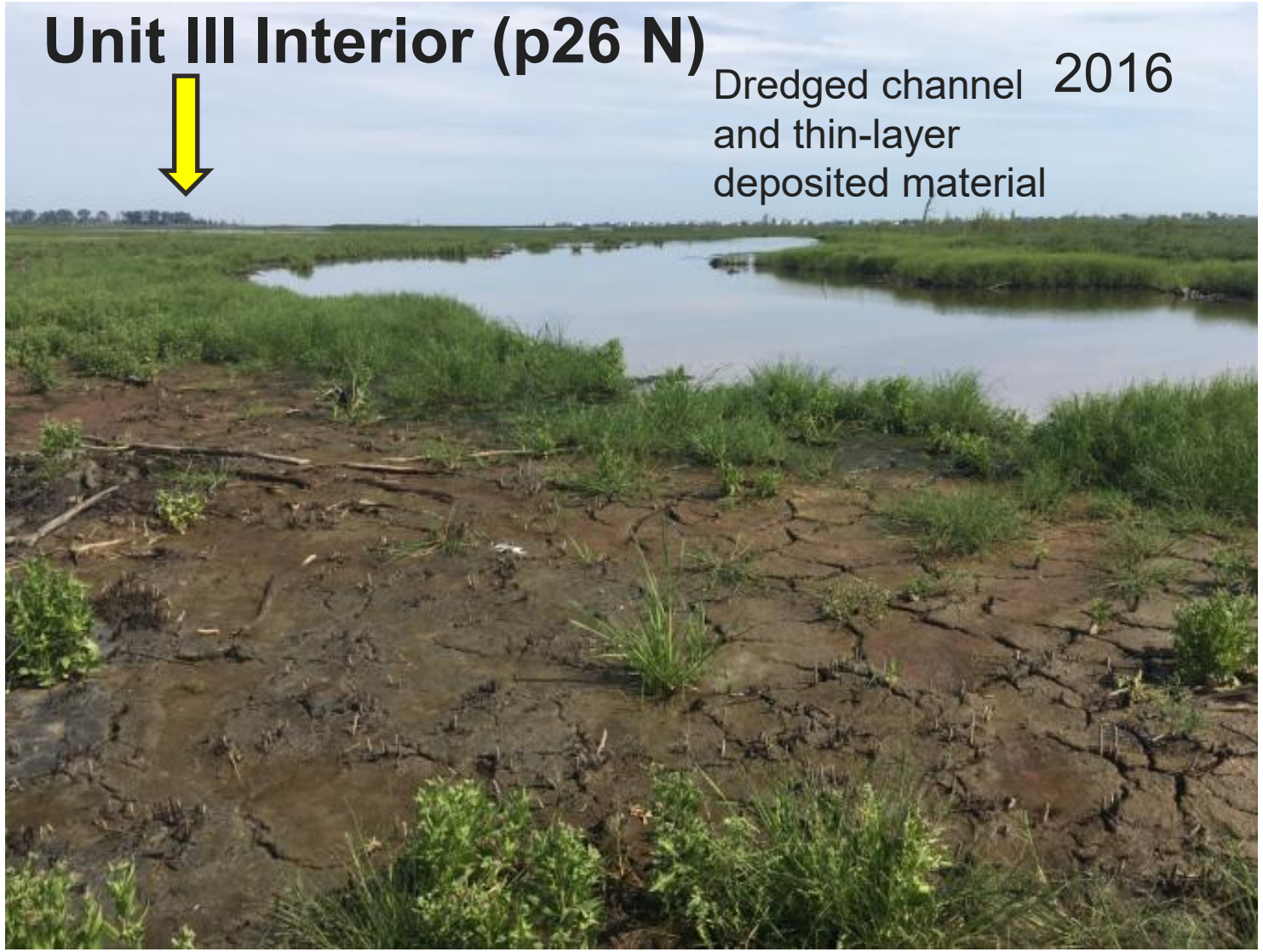
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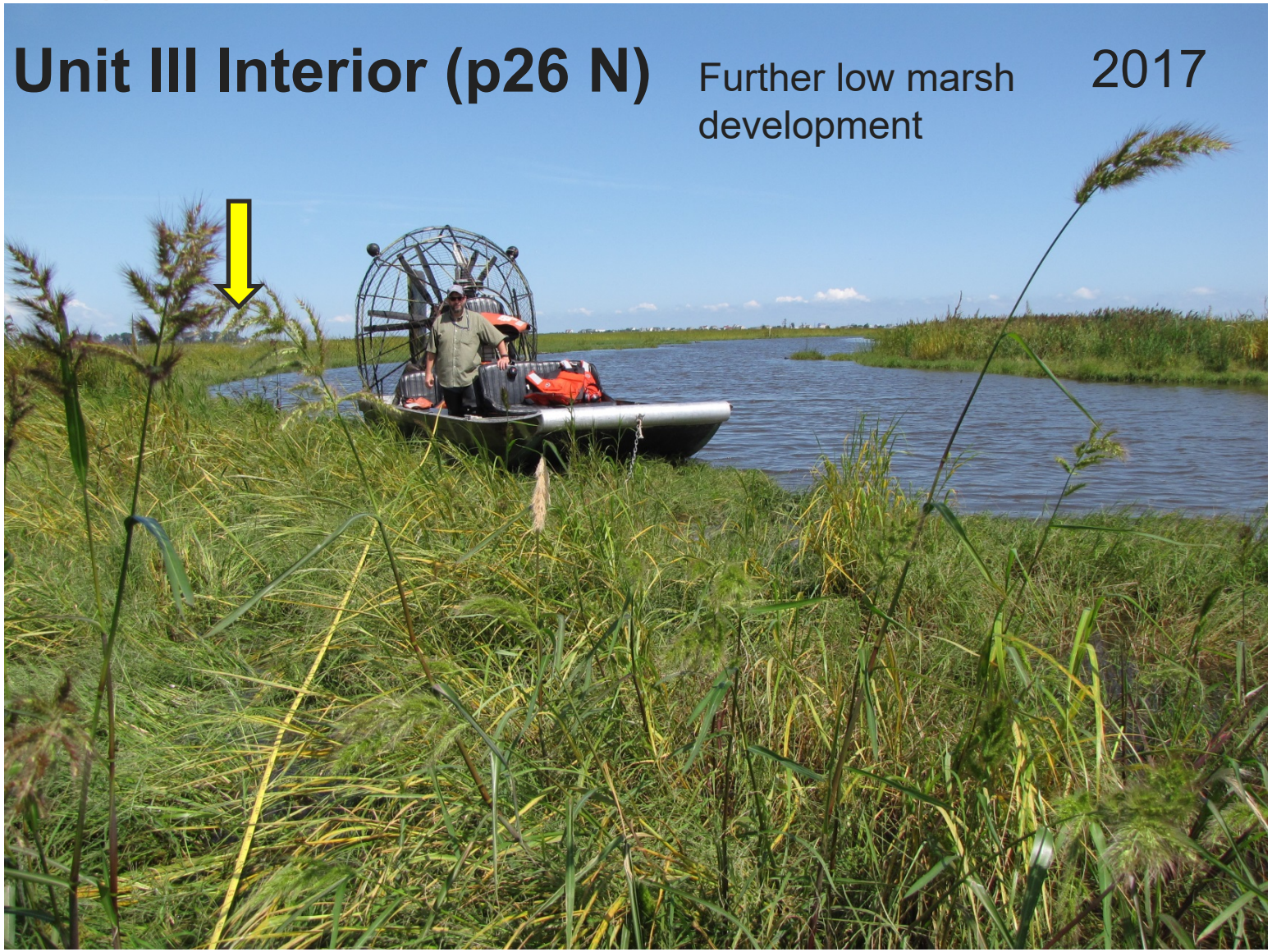
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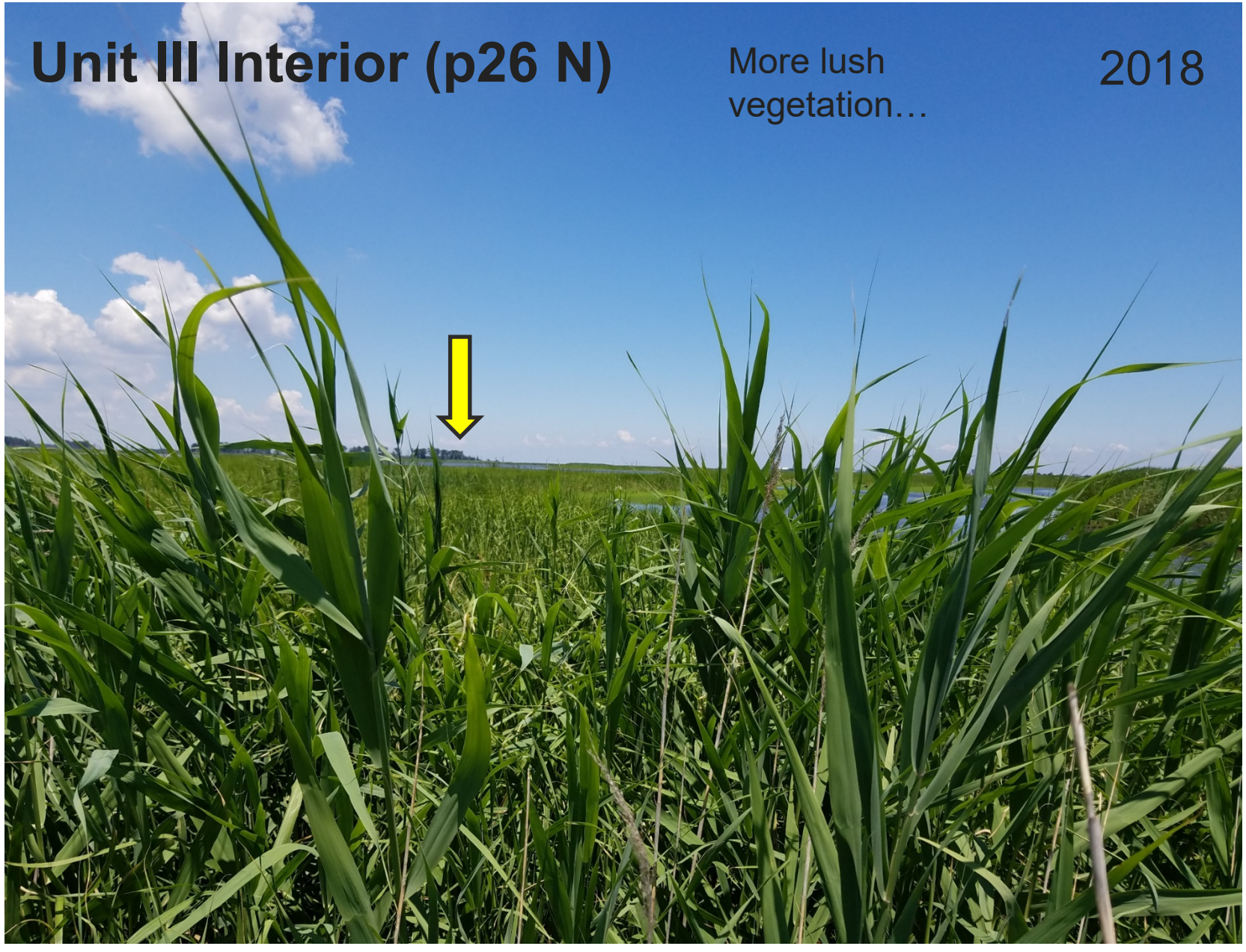
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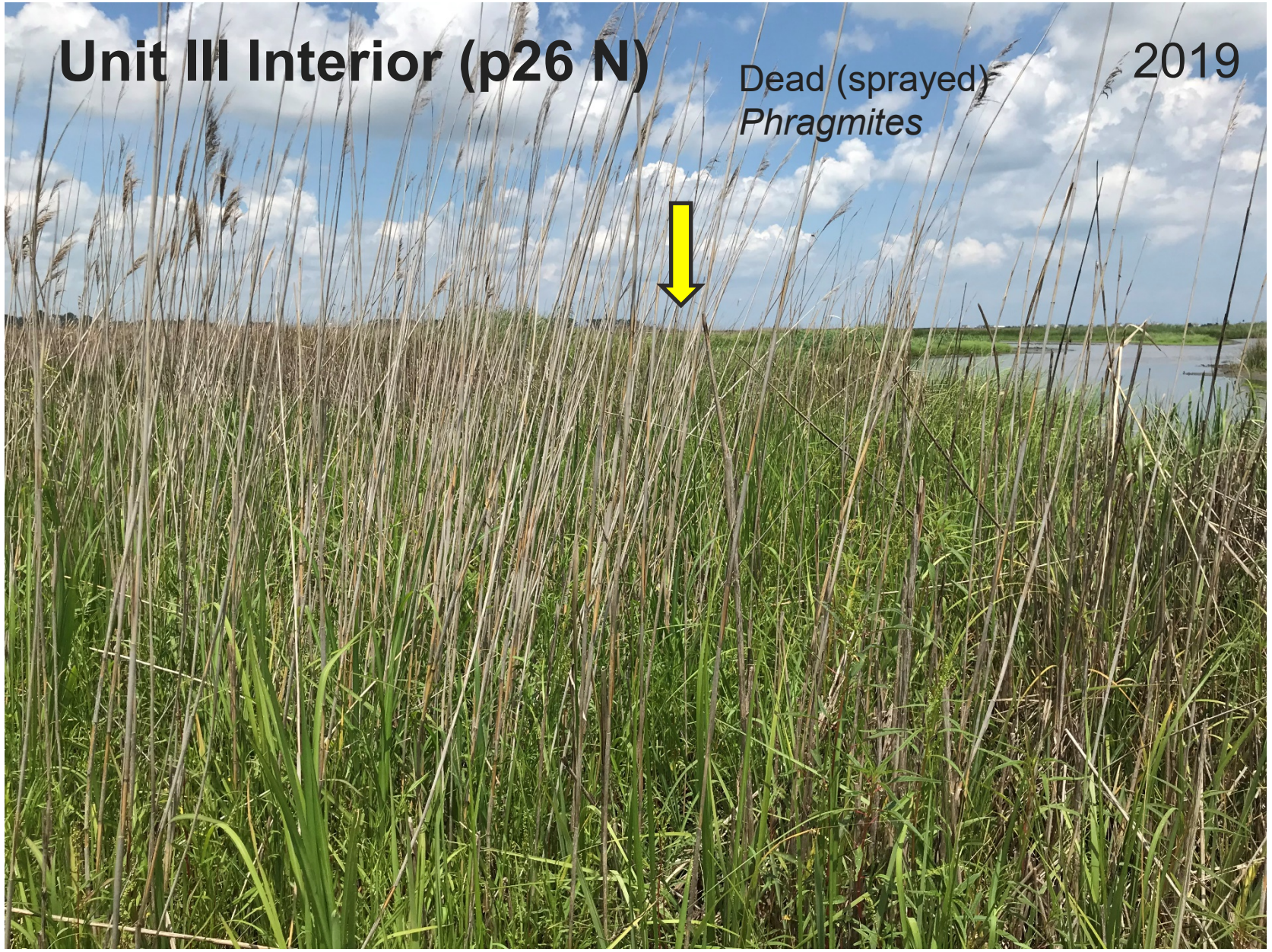
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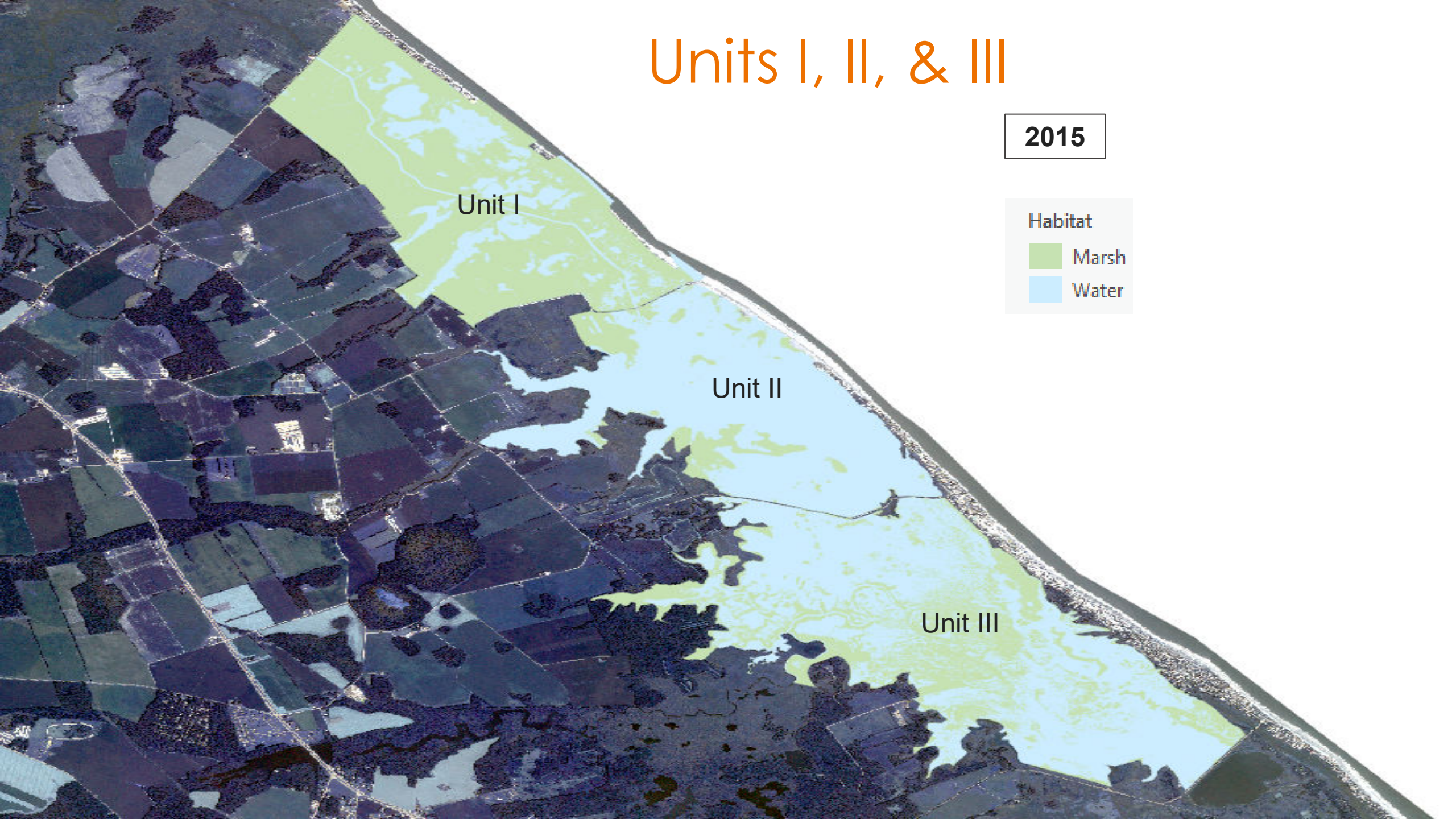
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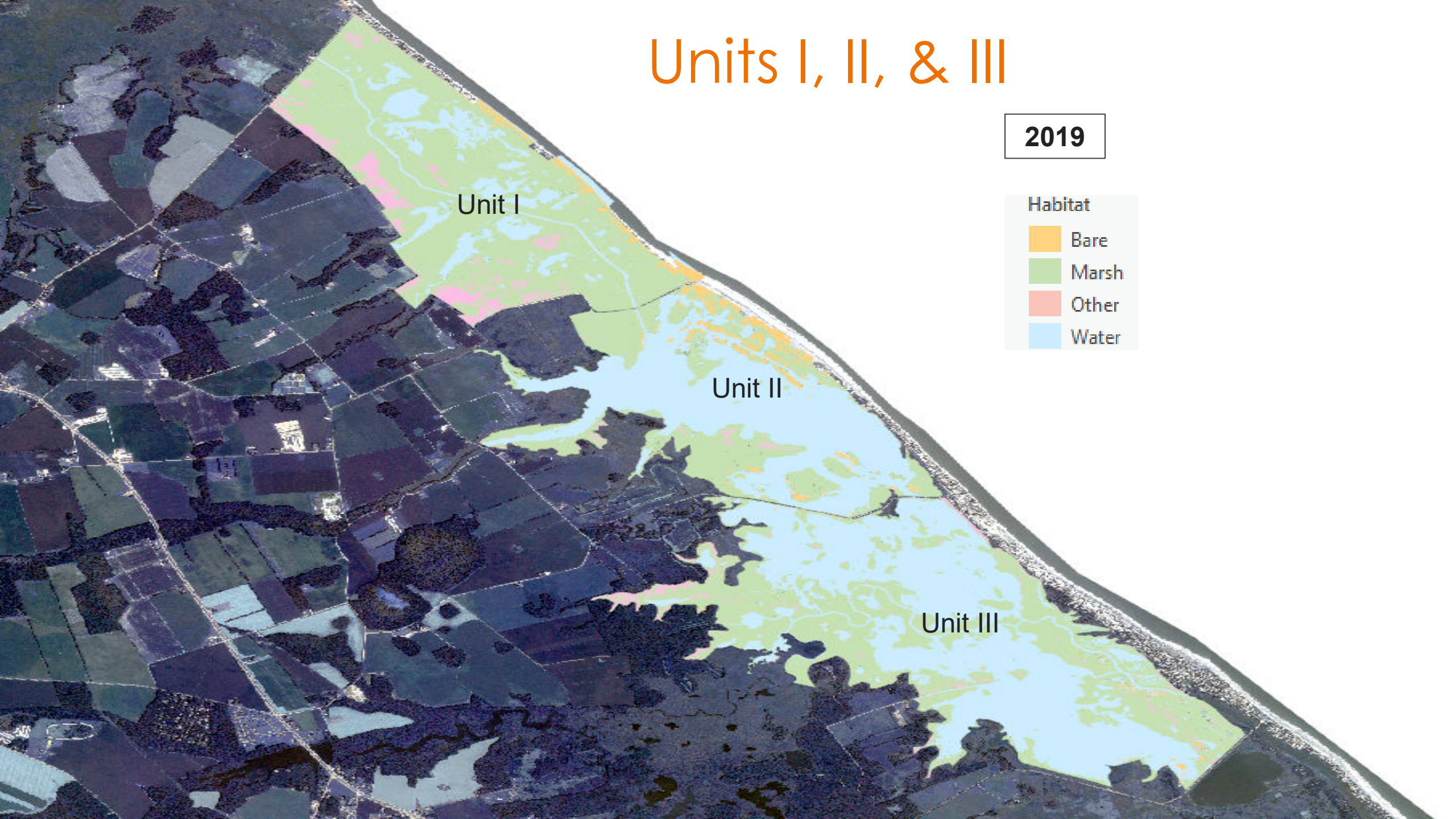
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Summary of Units II & III

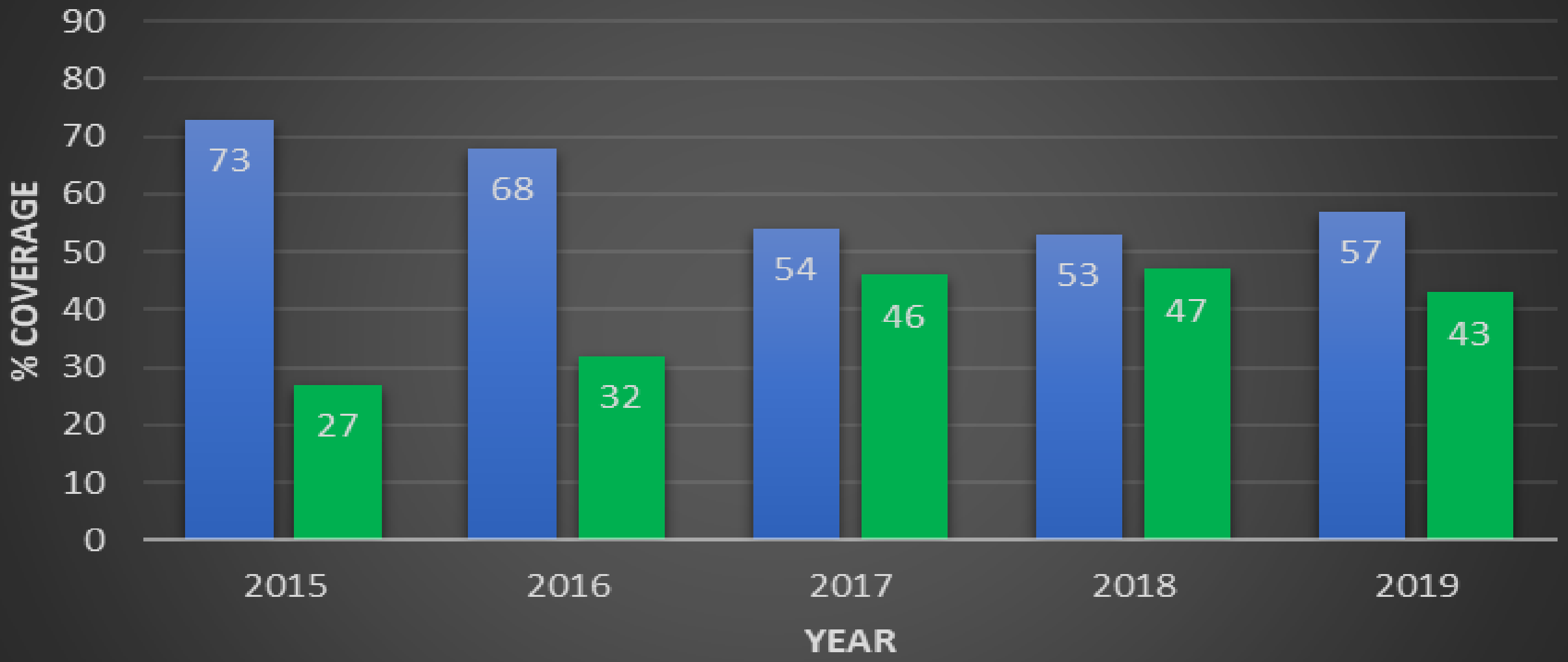
Units I, II, & III



Units I, II, & III



Total of Units II & III



Carbon Sequestration

Methodology for Determining the Carbon Sequestration (Blue Carbon) of Aquatic Ecosystem Restoration Projects

The Blue Carbon Calculator is based upon the following sources:

- Commonwealth of Massachusetts Division of Ecological Restoration (MassDER)
- Results of a literature search, emphasizing empirical evidence specific to wetlands ecosystems in the northeastern U.S.;
- Wetlands classification system used by U.S. Environmental Protection Agency (EPA); and
- Recent guidance from the Intergovernmental Panel on Climate Change (IPCC) on accounting for Greenhouse Gas (GHG) emissions and removals associated with wetlands management.

Massachusetts Department of Fish and Game
Division of Ecological Restoration
Invested in Nature and Community

Commonwealth of Massachusetts
Department of Fish & Game

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Methodology for Determining the Carbon Sequestration (Blue Carbon) of Aquatic Ecosystem Restoration Projects

Massachusetts Department of Fish and Game
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The Blue Carbon Calculator includes the following:

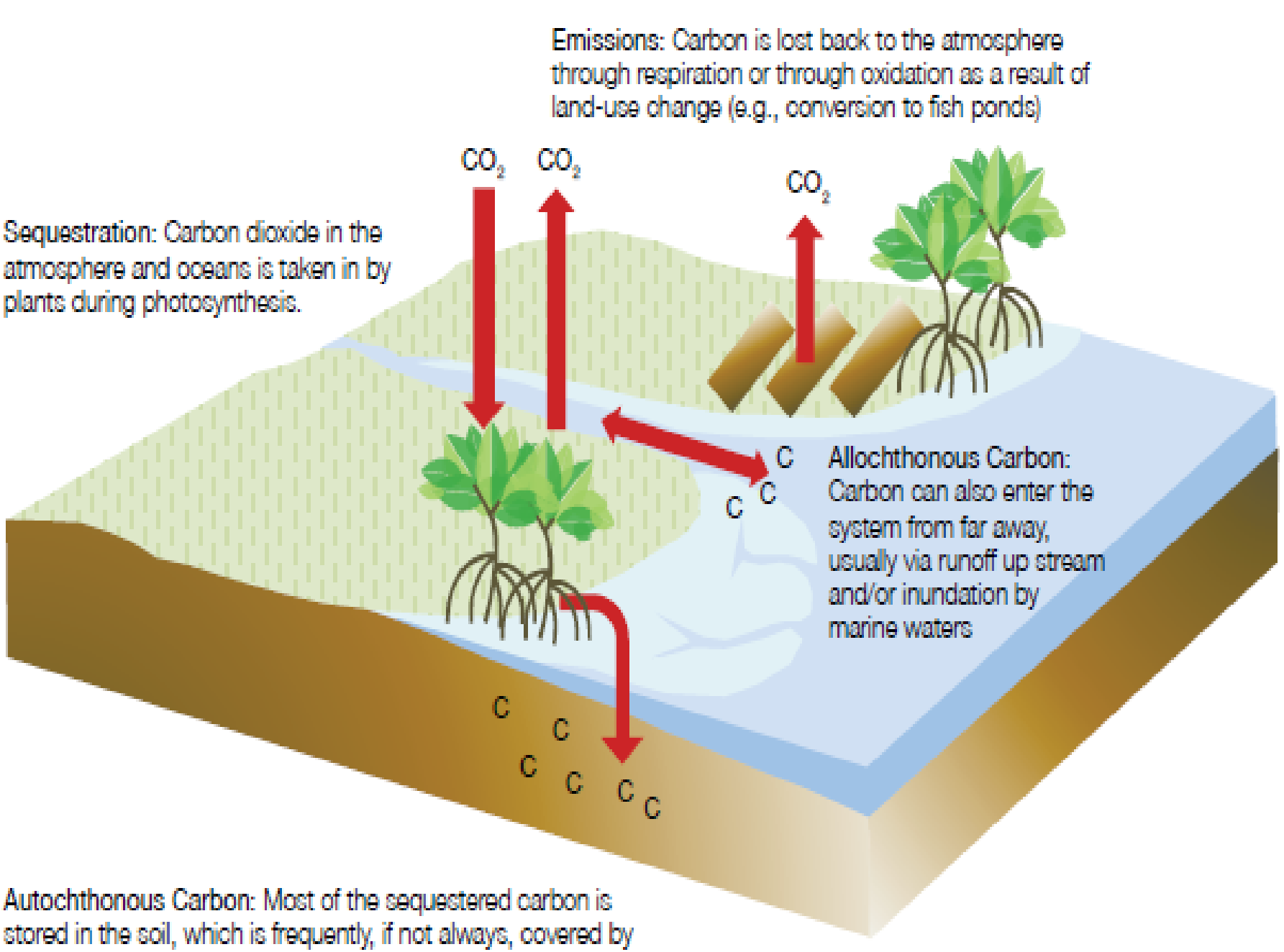
- A look-up table containing best available data and GHG emission factors for estimation of fluxes in GHG emissions from managed wetland soils; and
- A spreadsheet-based tool for estimating changes in GHG emissions and sequestration from soils resulting from changes to wetlands due to restoration and management activities, based on land cover data and emissions factors detailed in the look-up table.

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Mechanisms by which carbon moves into and out of tidal marshes



Resulting Emissions and Unit Conversions

Conversion to CO2e:

$$CO_2e = ((CO_2 - C) * \frac{16\ grams\ CO_2}{12\ grams\ C}) + ((CH_4 - C) * \frac{44\ grams\ CH_4}{12\ grams\ C} * 34)$$

Where:

CO_2e= CO_2 equivalents

$CO_2 - C$=mass of carbon (in tons) resulting from CO_2

$CH_4 - C$=mass of carbon (in tons) resulting from CH_4

34= Global warming potential of CH_4 in a 100 year period.

Conversion to gallons of gasoline:

$$Gallons\ of\ gasoline = CO_2e * \frac{113\ gallons\ of\ gasoline\ consumed}{1\ metric\ ton\ CO_2e}$$

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Resulting Emissions for Pre/Post Restoration

Location	Soil Type	Land Use Category	Restoration Area		Emissions Factor CO2	Emissions Factor CH4	Emissions CO2-C	Emissions CH4-C	Emissions CO2e	Emissions gasoline	
			(acres)	(ha)	tonnes CO2-C/ha/yr	tonnes CH4-C/ha/yr	tonnes CO2-C/yr	tonnes CH4-C/yr	tonnes CO2e/yr	gallons of gasoline equivalents/yr	liters of gasoline equivalents/yr
Coastal Wetland	Organic	Pre-Restoration									
		Salt marsh - low	1,019	455	-1	0	-414	0	-1,517	-171,437	-648,959
		Open water salt	2,753	1,228	0	0	0	0	0	0	0
					Total:	**Total:**	**-414**	**0**	**-1,517**	**-171,437**	**-648,959**
		Post-Restoration									
		Salt marsh - low	1,552	693	-1	0	-630	0	-2,311	-261,109	-988,404
		Open water salt	2,144	957	0	0	0	0	0	0	0
					Total:	**Total:**	**-630**	**0**	**-2,311**	**-261,109**	**-988,404**
						Difference between pre and post Total:	**-216**	**0**	**-794**	**-89,672**	**-339,446**

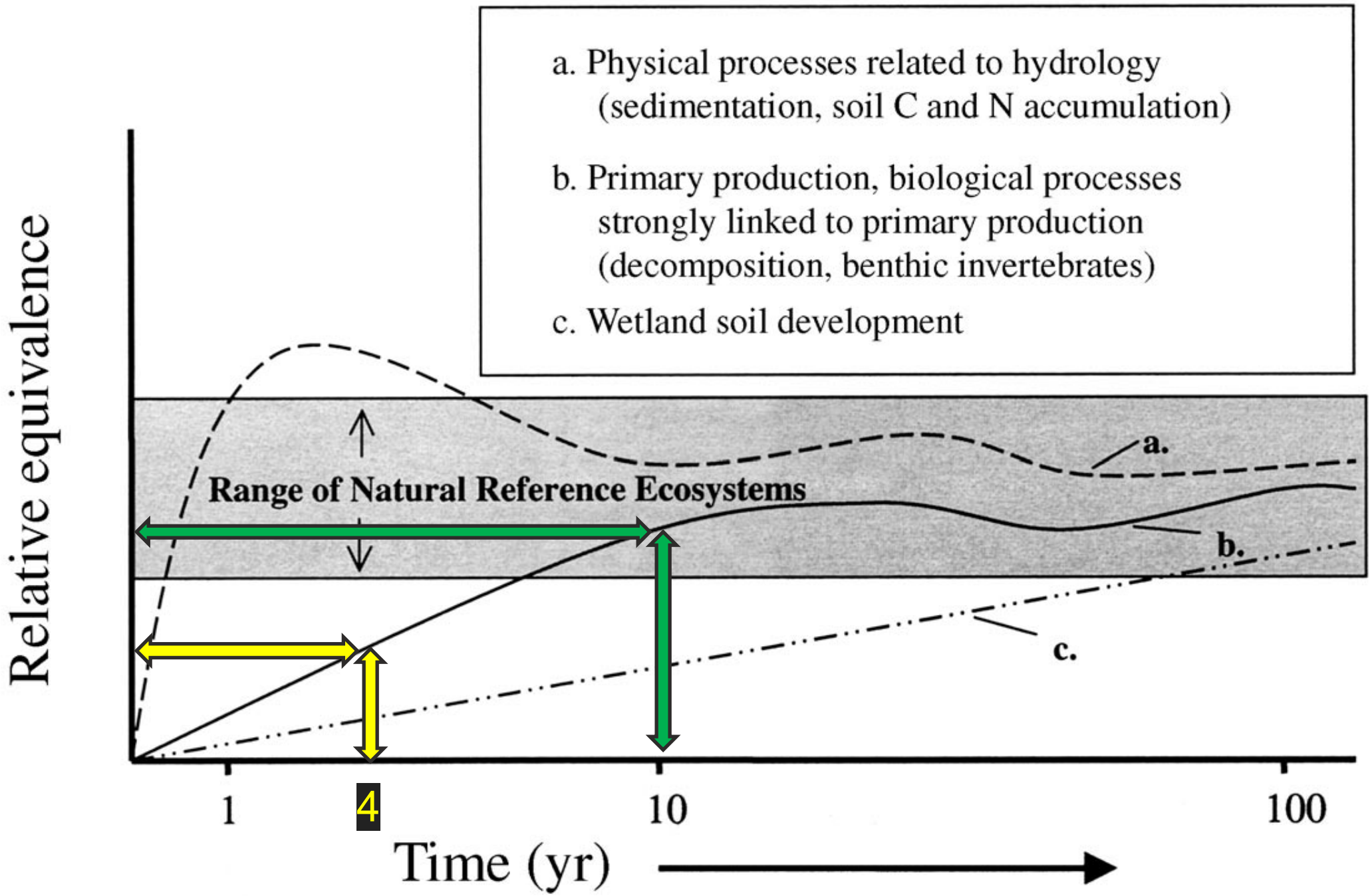
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Resulting Consumption Equivalent

Consumption gasoline/person in US		Emissions reduction in US
gallons of gasoline/yr	liters of gasoline/yr	equivalent to per person/yr
656	2,483	-137

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Future Projections of Marsh Vegetation



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2019 Drone Flight





Thank You

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References:

Commonwealth of Massachusetts. 2016. Blue Carbon Calculator: A Simple Methodology for Determining the Green House Gas Budget of Aquatic Ecosystem Restoration Projects. Massachusetts Division of Ecological Restoration.

Crooks, Stephen, I. von Emmer, M. Under, B. Brown, M.K. Orr, and D. Murdiyarso. 2014. Guiding Principles for Delivering Coastal Wetland Carbon Projects. United Nations Environment Program and Center for International Forestry Research.

Guiteras, S. 2013. Comprehensive marsh and water monitoring guides wetland management planning and restoration at Prime Hook National Wildlife Refuge on the Delaware Bay – Presentation for Coastal & Estuarine Research Federation (CERF). By United State Fish & Wildlife Service (USFWS).

Guiteras, S. and Bush, N. 2020. Using Remote Sensing to Monitor Vegetation Community Response to Large-Scale Tidal Marsh Restoration at Prime Hook National Wildlife Refuge – Annual Monitoring Presentation. By United State Fish & Wildlife Service (USFWS).

Houghton, R.A., and G.M. Woodwell. 1980. The flax pond ecosystem study: exchanges of CO2 between a salt marsh and the atmosphere. Ecology 61 (6):1434-1445.

https://www.fool.com/investing/2017/01/14/heres-how-much-gasoline-the-average-american-consu.aspx

https://www.globalpetrolprices.com/articles/52/#:~:text=Most%20European%20countries%20are%20somewhere, of%20gasoline%20consumption%20per%20day.

https://www.mass.gov/orgs/division-of-ecological-restoration

MIT Sea Grant. Evaluating Salt Marsh Ecosystem Restoration: Quantifying Soil Carbon Accumulation and Greenhouse Gas Emissions Across a 12-y Chronosequence n.d. [cited July 21, 2015. Available from http://seagrant.mit.edu/proj_desc.php?prjID=1338.

Pendleton, L.H., A.E. Sutton-Grier, Gordon D.R., B.C. Murray, B.E. Victor, R.B. Griffis, J.A.V. Lechuga, and C. Giri. 2015. Considering “Coastal Carbon” in Existing U.S. Federal Statutes and Policies. Coastal Management 41:439-456.

Tabar, J.R., and DeMunda, T.J.. 2013. Hydrodynamic Modeling of Prime Hook National Wildlife Refuge Final Report. USFWS Prime Hook National Wildlife Refuge, Milton, DE.

Tabar, J.R., and DeMunda, T.J.. 2014. Final Numerical Modeling Study and Marsh Restoration Plan Development. USFWS Prime Hook National Wildlife Refuge, Milton, DE.

Tabar, J.R., and DeMunda, T.J.. 2016. Prime Hook NWR – Modeled conditions with as-built elevations. USFWS Prime Hook National Wildlife Refuge, Milton, DE.

U.S. EPA. U.S. Greenhouse Gas Inventory Report: 1990-2013, July 21, 2015 2015 [cited Aug 28, 2015. Available from http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

Yu, O. & Chmura, G. (2009). Soil carbon may be maintained under grazing in a St Lawrence Estuary tidal marsh. Environmental Conservation, 36, 312–320.

Prime Hook National Wildlife Refuge Marsh Restoration & Shoreline Resilience Project
A Carbon Sequestration Case Study in the Coastal Zone



Session HS10.2

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Summary

1. **Restoration Project – 2016, $40m US**
   - 4,000 acres (1,660 ha) Salt Marsh Restored
   - 1.7 miles (2.8 km) Barrier Island Restored
2. **Vegetation Monitoring**
   - Remote Sensing
   - Field Measurements
3. **Carbon Sequestration Calculations**
   - Based on 4-years of monitoring
   - Spreadsheet-based tool for estimating changes in greenhouse gas emissions and sequestration
   - Estimated emissions -90,000 gallons of gasoline equivalents/year
   - Equal to reduction of -137 US drivers/year
4. **Future Projections**
   - Estimate vegetation coverage to double in next 5-10 years
   - Carbon sequestration estimates could double/triple

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