Using an Adaptive Management Framework to Examine Remote Sensing Applications for Wetlands: A few Examples from the Chesapeake Bay

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Purpose of Presentation

- Provide some examples and necessary context for how remote sensing is being leveraged in Chesapeake Bay, using adaptive management as a framework
- Share these messages with a broader geographical audience
- Attract attention to each project

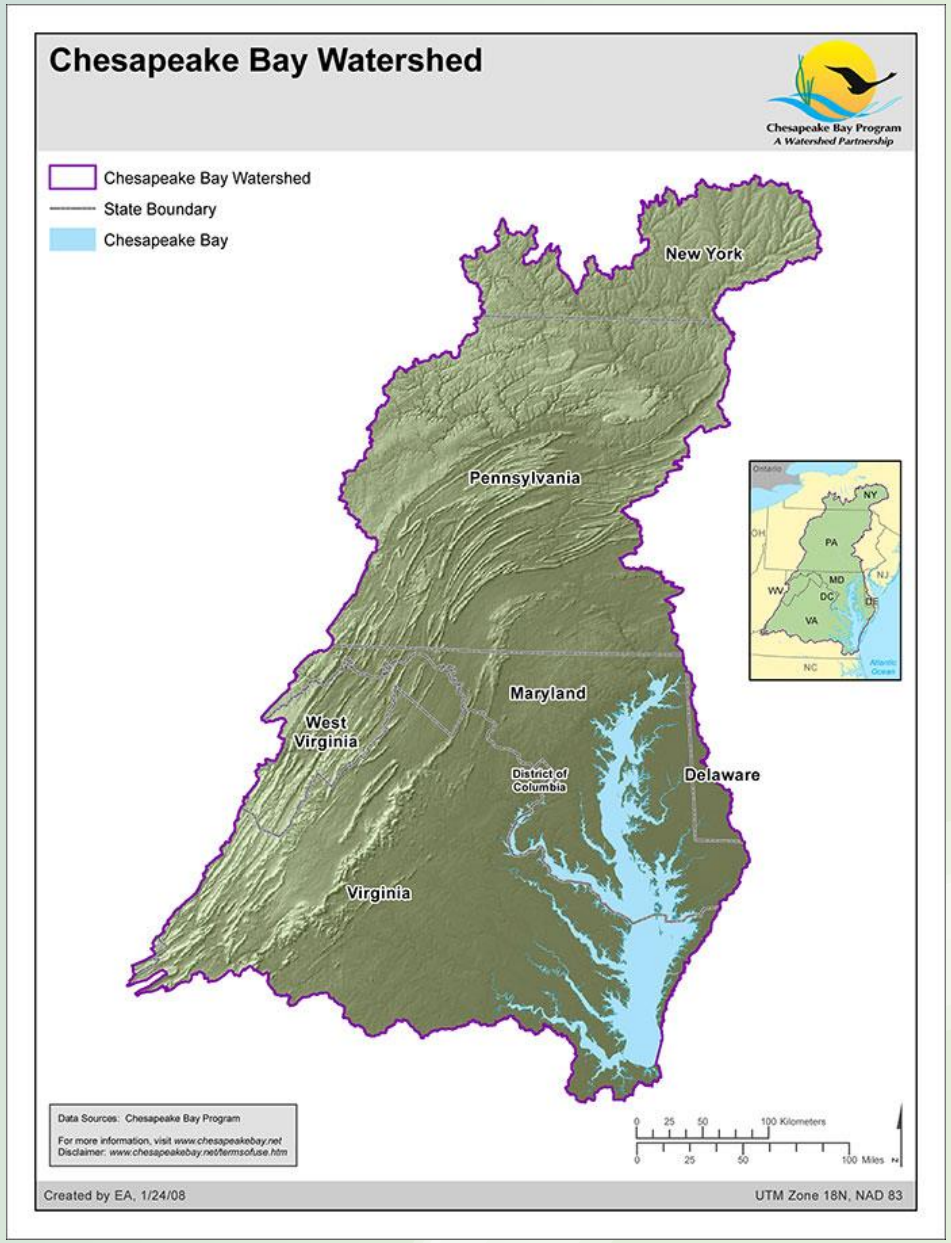
- **Caveat: I am not a wetlands expert, nor an expert of remote sensing techniques for mapping wetlands. These are only a few examples of ongoing and upcoming projects in the region – this list is not exhaustive.**

Outline

- Context
  - Chesapeake Bay Watershed, Chesapeake Bay Program, Watershed Agreement
  - Land Use Methods & Metrics Development Outcome and Wetlands Outcome
  - Adaptive Management Response
- Selected Remote Sensing Wetlands Projects
  - Nontidal
    - Convolutional neural network for high-resolution wetland mapping
    - Mapping Non-Tidal Vegetated Wetlands in Areas with Outdated Wetland Maps
  - Tidal
    - UVVR USGS
    - Marsh Migration Project
    - Marsh Adaptation Project

Chesapeake Bay Watershed

- Home to over 18 million people and growing
- 64,000 square miles in size (~165,000 sq. km)
- Six U.S. states (New York, Pennsylvania, West Virginia, Virginia, Maryland, & Delaware) and DC
- >100,000 streams, creeks, and rivers



Source: [What Is a Watershed? (chesapeakebay.net)]

Chesapeake Bay Program (CBP)

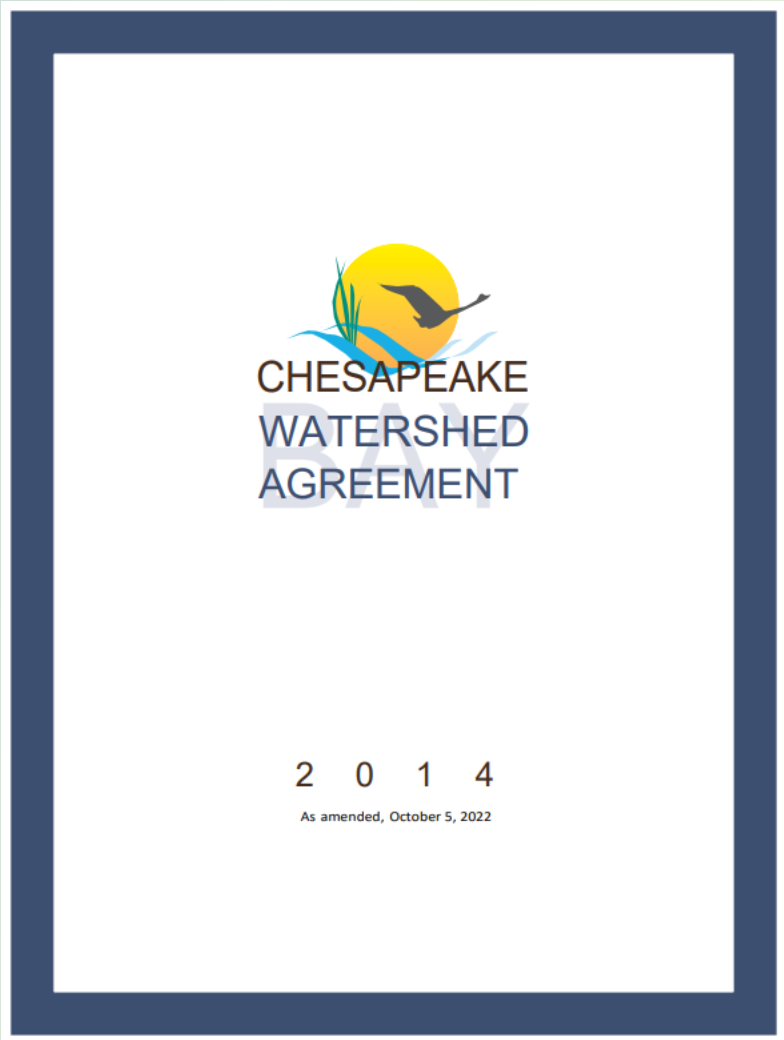
- Partnership of federal and state agencies, local governments, nonprofit organizations and academic institutions

- CBP based in Annapolis at EPA office

Source: Our Partners (chesapeakebay.net)

2014 Chesapeake Bay Watershed Agreement

- Current framework for Chesapeake Bay restoration
- Five themes, 10 goals, and 31 outcomes
- Target deadline of 2025



Source: Chesapeake Bay Watershed Agreement

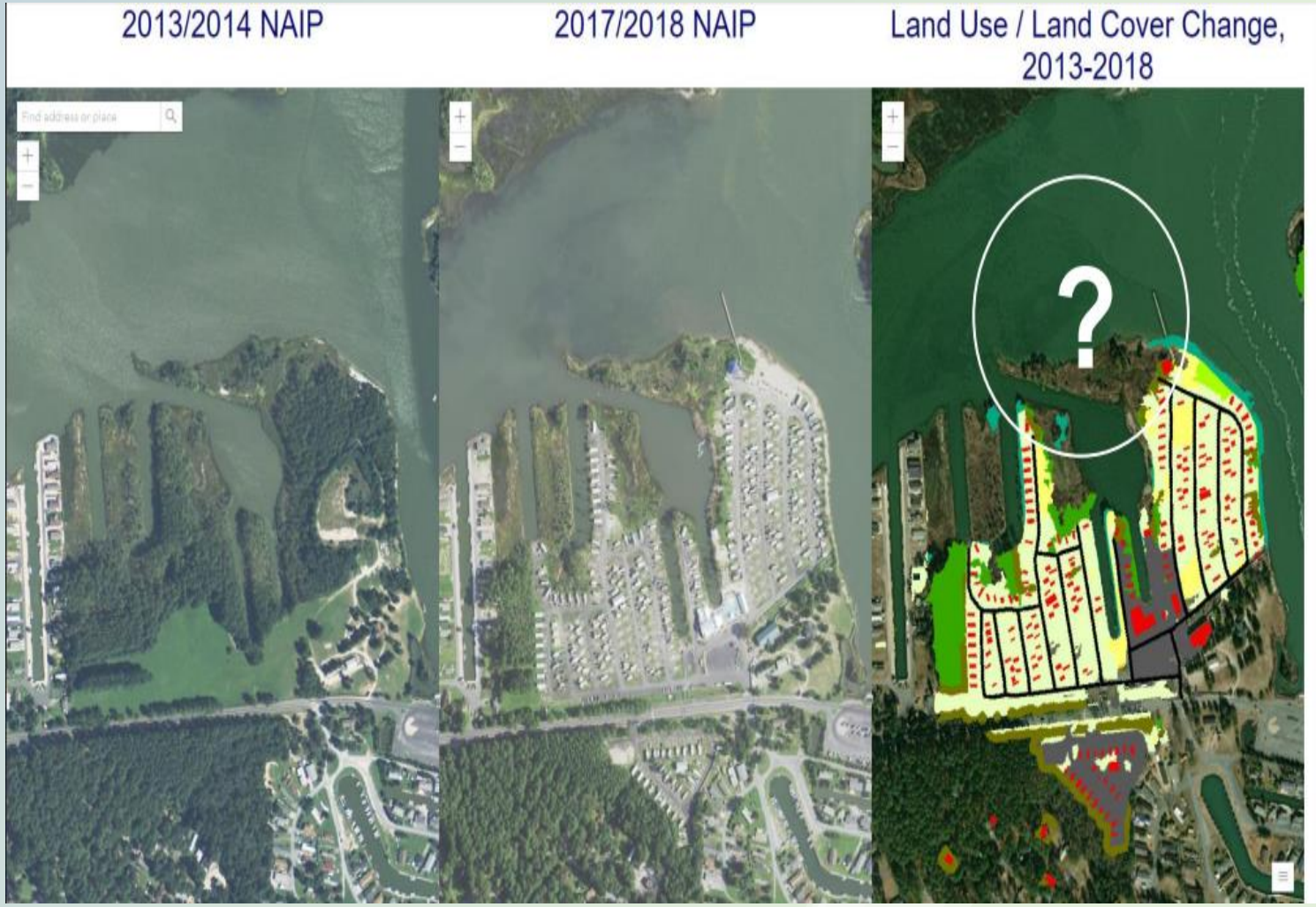
Land Use Methods and Metrics Development Outcome

- "Continually improve our knowledge of land conversion and the associated impacts throughout the watershed. By December 2021, develop a **watershed-wide methodology and local-level metrics for characterizing the rate** of farmland, forest and **wetland conversion**, measuring the extent and rate of change in impervious surface coverage and **quantifying the potential impacts of land conversion to water quality, healthy watersheds and communities**. Launch a public awareness campaign to share this information with local governments, elected officials and stakeholders"

Source: Land Conservation (chesapeakebay.net)

CBP Land Use/Land Cover Data Project

- 1-meter land use and land cover data from 2013/2014 and 2017/2018
- 50+ unique classers
- Key data source for informing progress of many CBP outcomes, including the Wetlands and Land Use Methods and Metrics Development Outcomes



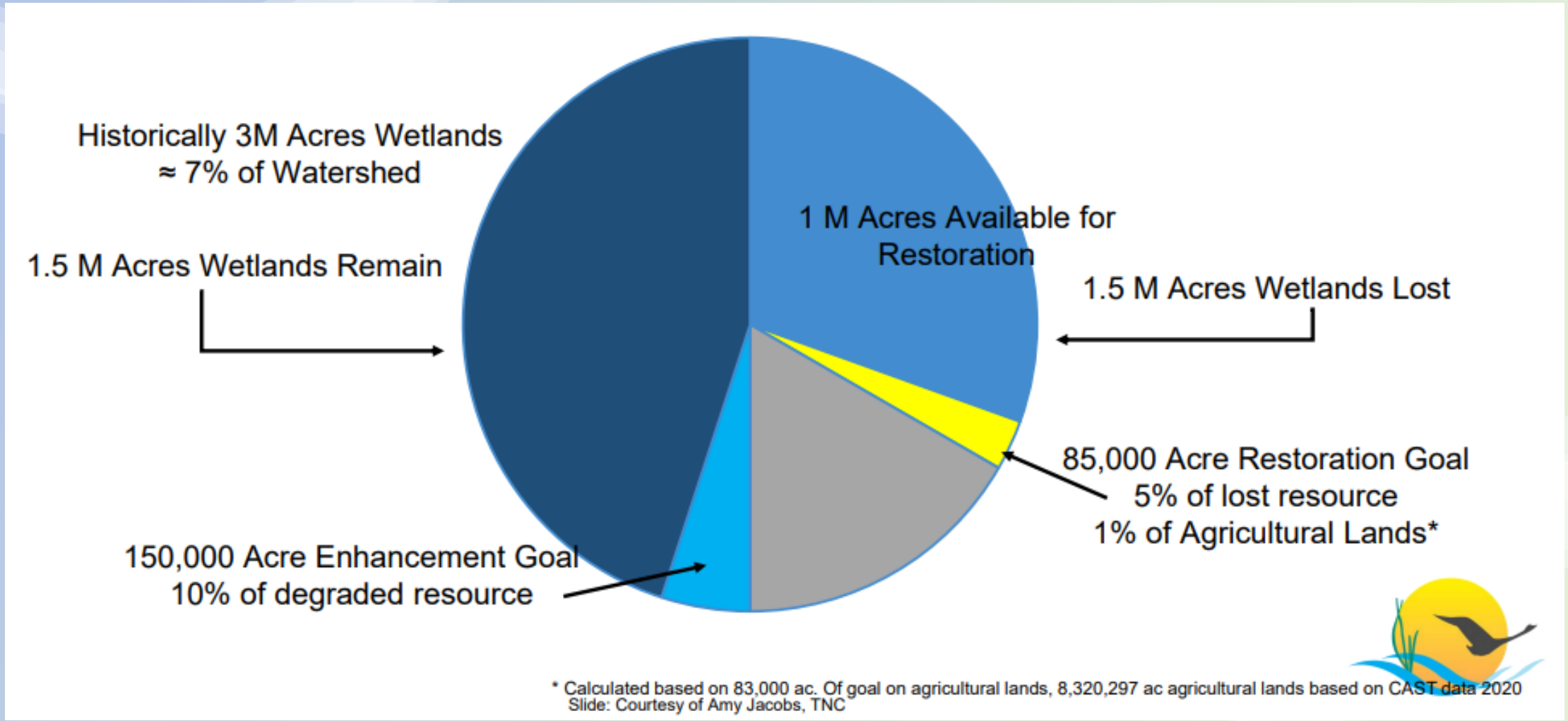
Source: Chesapeake Bay Program Land Use/Land Cover Data Project - Chesapeake Conservancy, This is your presentation title (d18lev1ok5leia.cloudfront.net)

Wetlands Outcome

- "Continually increase the capacity of wetlands to **provide water quality and habitat benefits** throughout the watershed. Create or reestablish **85,000 acres** of tidal and non-tidal wetlands and enhance the function of an additional **150,000 acres** of degraded wetlands by 2025. These activities may occur in any land use (including urban) but primarily occur in agricultural or natural landscapes"

Source: Vital Habitats (chesapeakebay.net), Wetland Workgroup (chesapeakebay.net)

Wetlands Outcome - Chesapeake Bay Wetlands



Source: [PowerPoint Presentation (d18lev1ok5leia.cloudfront.net)]

Wetlands Outcome

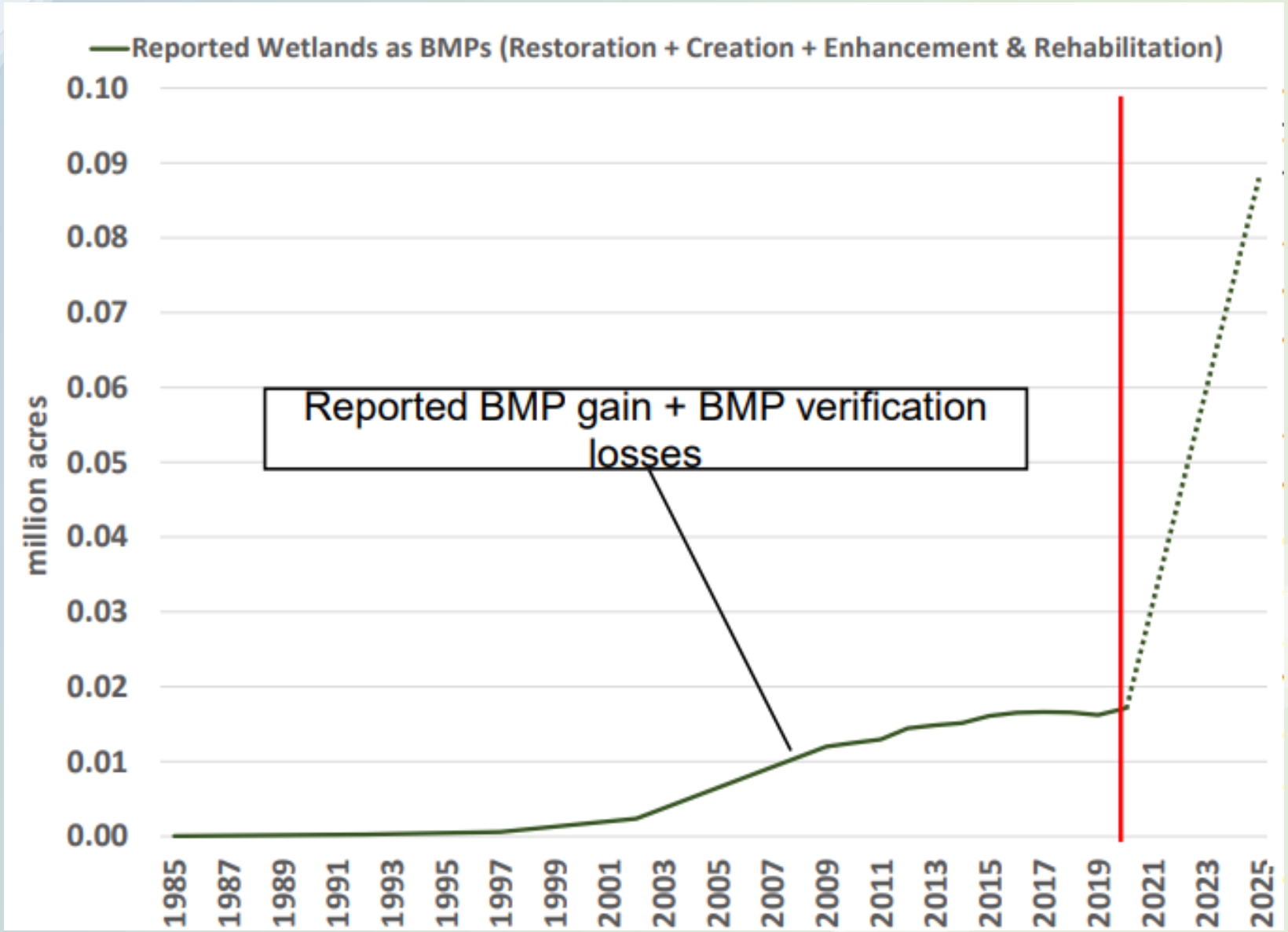
- What is the progress of the Wetlands Outcome?

- Difficult question to answer since the CBP only tracks wetland creations recorded as Best Management Practices (BMPs) for the purposes of improving water quality through the National Environmental Information Exchange Network (NEIEN)
- Wetland restoration for the purpose of providing benefits to living resources or functional enhancement of existing wetlands are not included in the dataset.

Source: Wetlands - Chesapeake Progress; II.b.-Wetlands-Narrative-Analysis.pdf (d18lev1ok5leia.cloudfront.net)

Wetlands Outcome

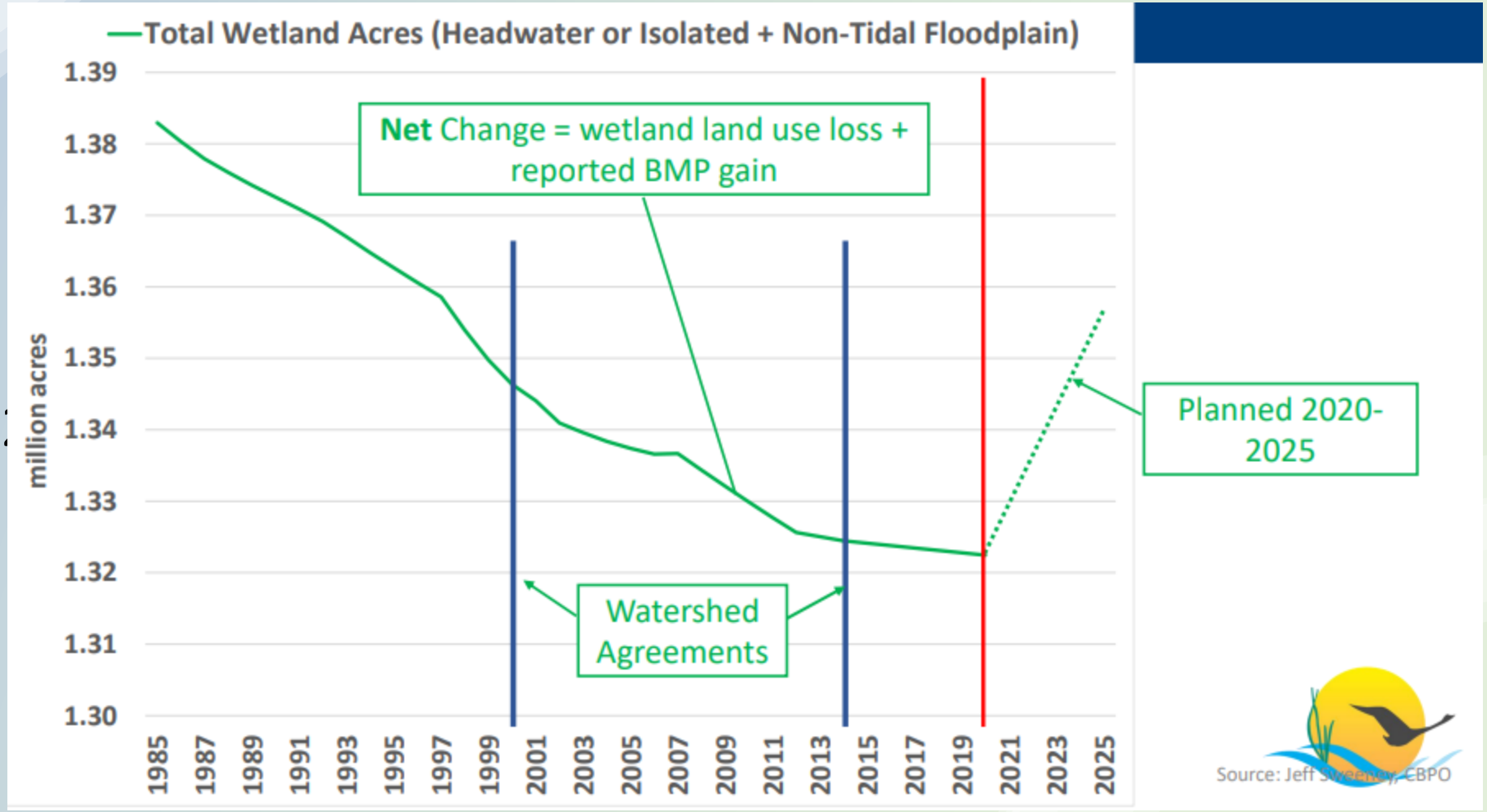
- Wetland BMP Changes (1985–2020 + 2025)
- Slide Courtesy Jeff Sweeny, EPA CBP 2022



Source: Wetlands - Chesapeake Progress; II.b.-Wetlands-Narrative-Analysis.pdf (d18lev1ok5leia.cloudfront.net)

Wetlands Outcome

- CBW Wetland Acre Changes (1985–2020 + 2025)
- Slide Courtesy Jeff Sweeny, EPA CBP 202



Source: Wetlands - Chesapeake Progress; II.b.-Wetlands-Narrative-Analysis.pdf (d18lev1ok5leia.cloudfront.net)

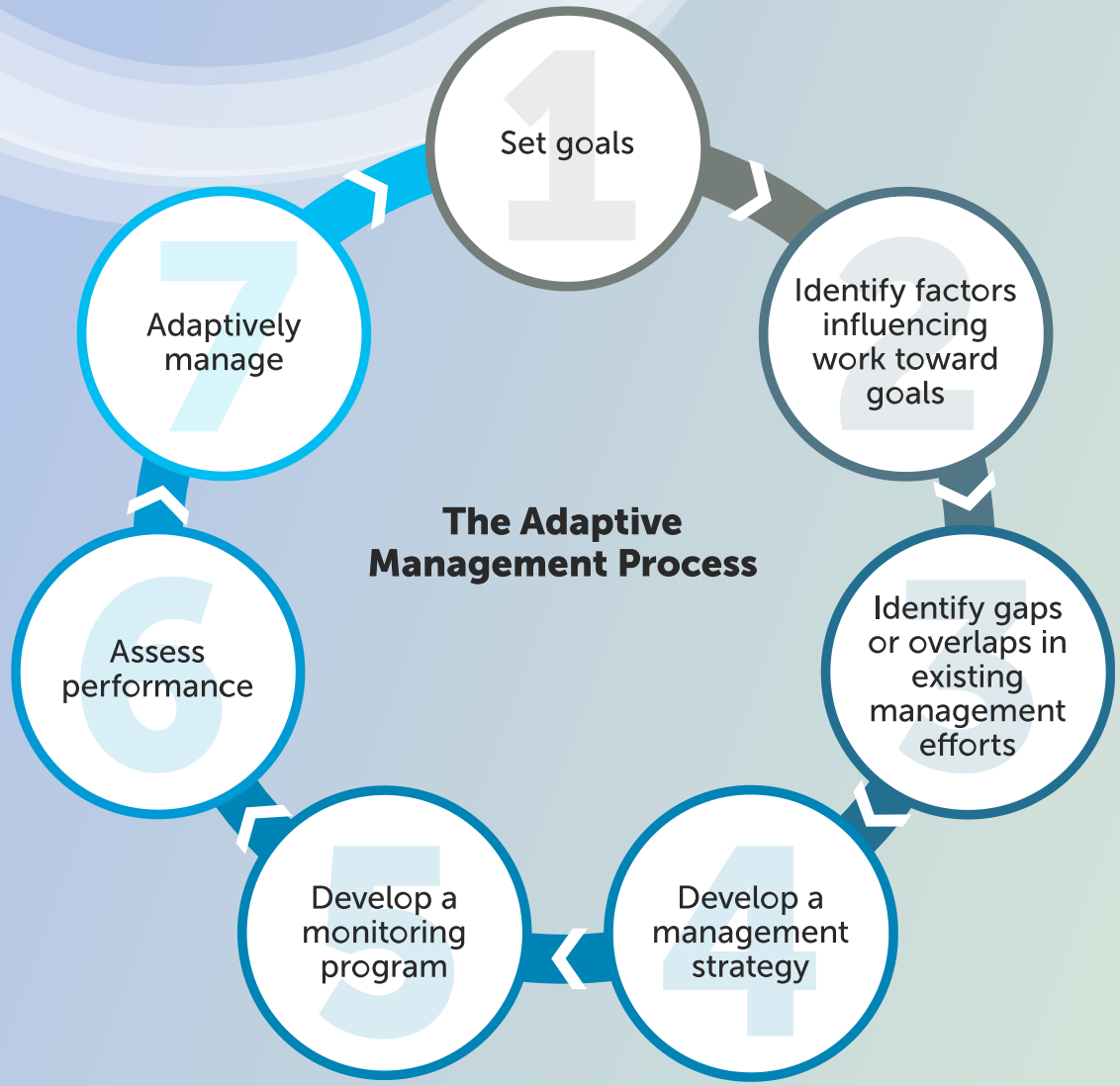
Wetlands Outcome

- What is the progress of the Wetlands Outcome?

- Wetland acreage data are inconsistently reported and inaccurate for assessing progress toward this outcome. Work is underway to identify a consistent means for collecting data by maximizing existing data reporting processes.

Source: Wetlands - Chesapeake Progress; II.b.-Wetlands-Narrative-Analysis.pdf (d18lev1ok5leia.cloudfront.net)

Adaptive Management



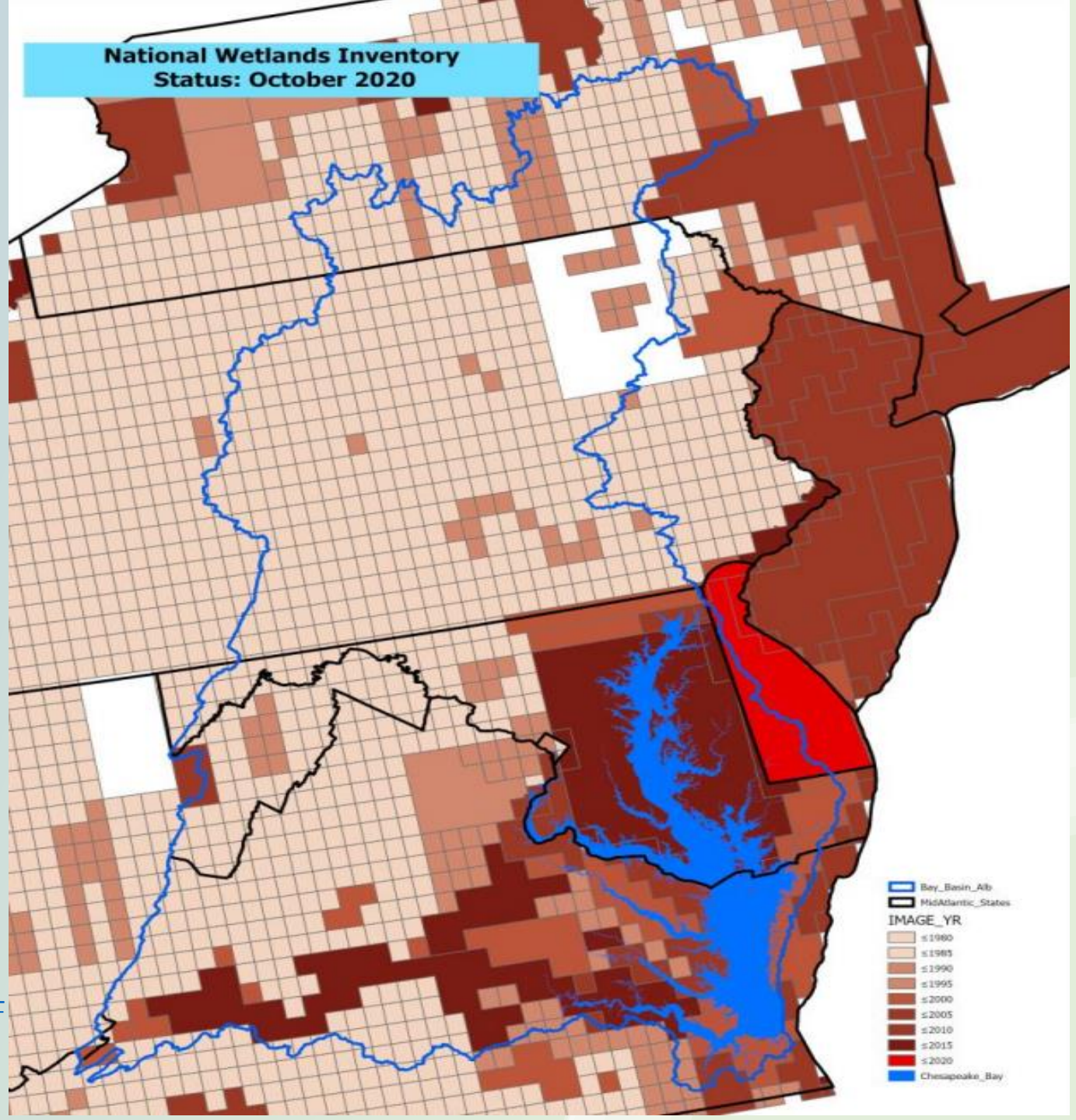
- CBP Adaptive Management Resources
  - Management Strategy
  - Narrative Analysis
  - Logic and Action Plan
  - Quarterly Progress Meeting Presentation

Source: [ChesapeakeDecisions (chesapeakebay.net)]

Adaptive Management

- Challenge: Outdated Wetlands Maps
- Wetlands Management Strategy:
  - "Regularly updated National Wetland Inventory or equivalent maps for each state" would support identifying wetland restoration opportunities
- Wetlands Logic and Action Plan:
  - Management Approach 1: Improve wetland mapping, and the wetland restoration reporting and tracking process

Source: 2020-2021_wetlands_management_strategy.pdf (d18lev1ok5leia.cloudfront.net); 2023.01.27-Wetlands-Outcome-2023-2024-Logic-Action-Plan-FINAL.pdf (d18lev1ok5leia.cloudfront.net), PowerPoint Presentation (d18lev1ok5leia.cloudfront.net), This is your presentation title (d18lev1ok5leia.cloudfront.net)



Adaptive Management - Comprehensive Evaluation of System Response (CESR) Report

Policy implication: Opportunities exist to adjust approaches to prioritize management actions that improve living resource response.

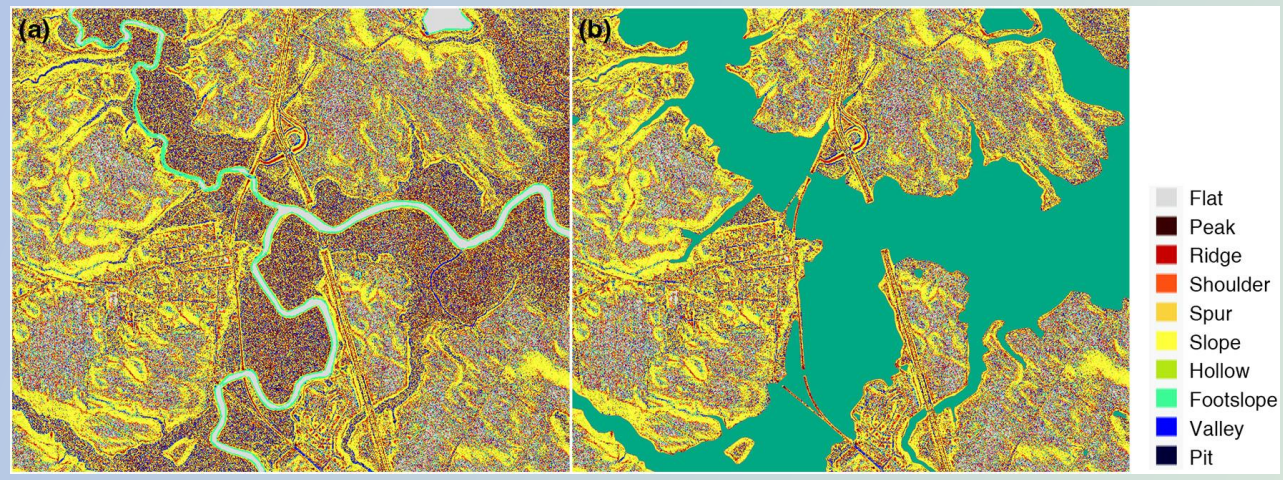
What this means for wetlands:

- Wetlands are critical for the living resource goals of the CBP
- Based on earlier identified adaptive management needs, the CBP needs higher spatial-temporal resolution monitoring and modeling of wetlands
- The CESR report provides added emphasis to the importance of wetland mapping

Source: CESR – STAC (chesapeake.org)

AI Wetlands Mapping Project

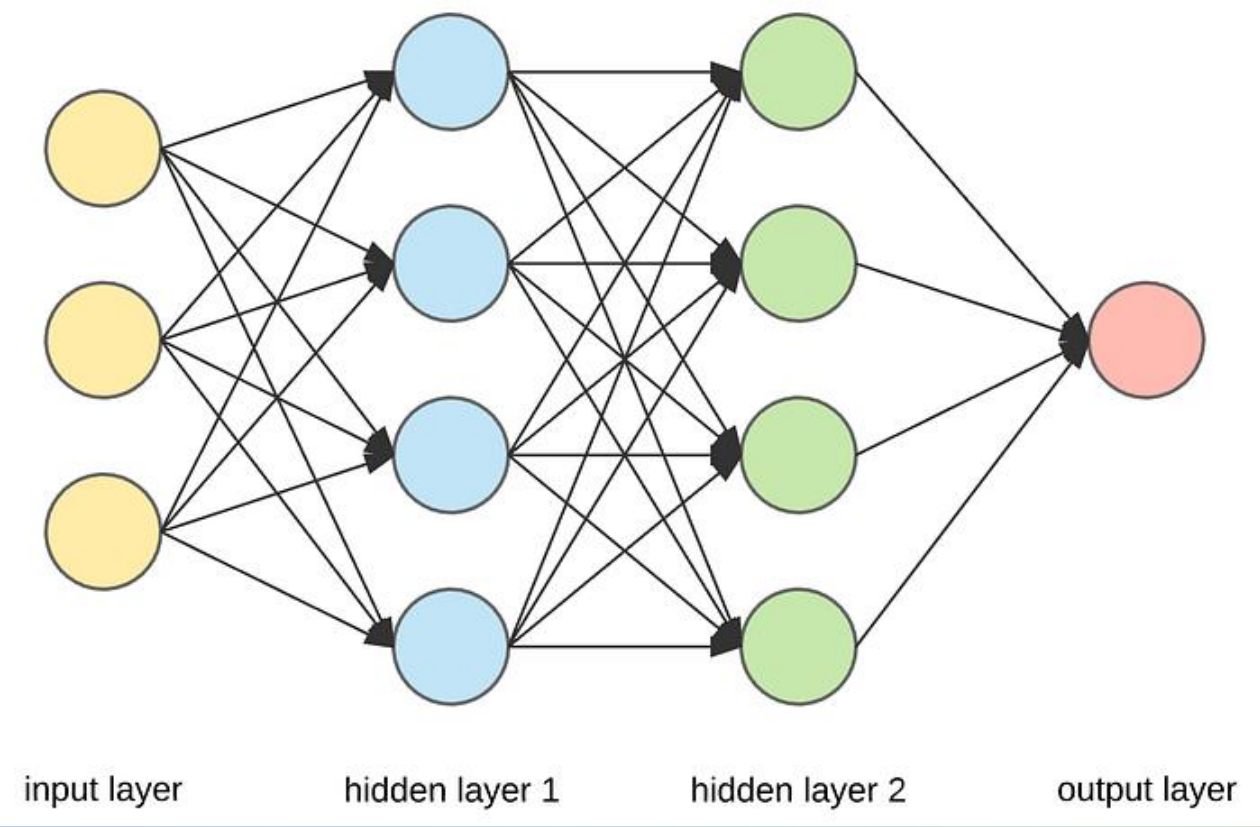
- Partners: Chesapeake Conservancy, Electric Power Research Institute
  - Authors: Kumar Mainali, Ph.D., Michael Evans, Ph.D., Emily Mills, David Saavedra, Susan Minnemeyer, Becca Madsen



- Data inputs:
  - USDA National Agriculture Imagery Program (NAIP) aerial imagery (1 meter)
  - Sentinel-2 optical satellite imagery (10-20 meters)
  - LiDAR derived products
    - Geomorphons – an approach to mapping landforms that Chesapeake Conservancy has been applying to advance high-resolution stream mapping
    - Intensity – index that is frequently used to identify water and persistently wet soils

Source: Artificial Intelligence Deep Learning Model for Mapping Wetlands Yields 94% Accuracy - Chesapeake Conservancy

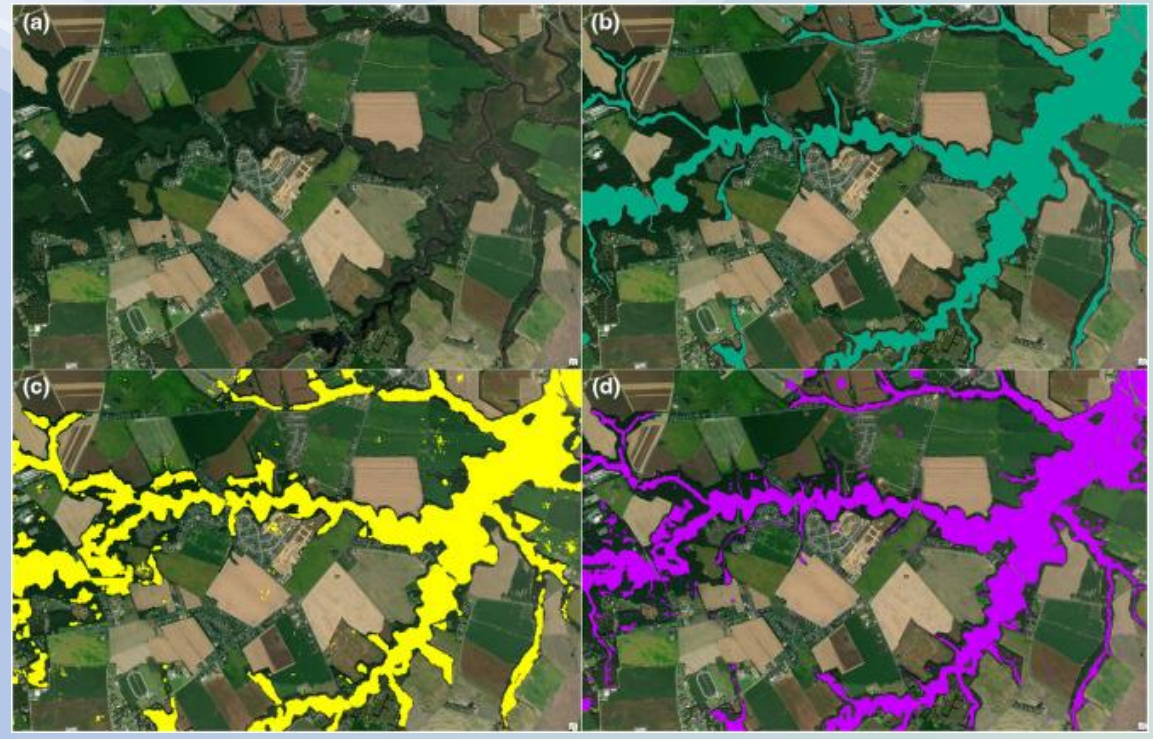
AI Wetlands Mapping Project



- Methods
  - Utilized deep learning convolutional neural network
  - Machine learning approach typically used for image detection

Source: Artificial Intelligence Deep Learning Model for Mapping Wetlands Yields 94% Accuracy - Chesapeake Conservancy; Image Classification with Convolutional Neural Networks | by Ksenia Sorokina | Medium

AI Wetlands Mapping Project



- 94% accurate when using NAIP, Sentinel-2, and LiDAR derived products
  - Simpler model (only uses NAIP and Sentinel-2) resulted in 91% accuracy
- Spatially generalizable contingent on limited retraining data

Source: Convolutional neural network for high-resolution wetland mapping with open data: Variable selection and the challenges of a generalizable model - ScienceDirect

Upcoming Nontidal Wetlands Mapping Project

- GIT Funding "Mapping Non-Tidal Vegetated Wetlands in Areas with Outdated Wetland Maps"
  - Purpose: develop a new approach to cost-effectively model the likely location of non-tidal vegetated wetlands within the Chesapeake Bay watershed west of the fall line, and to develop a workflow and cost estimate for making these features FGDC standard compliant
  - $90,000 set aside for development of necessary techniques for mapping

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USGS
science for a changing world

Source: EPA-CBP-GIT-FFY22-RFP-w-Appendix_2-10-23_extended-deadline.pdf (cbtrust.org) (pages 34-37); This is your presentation title (d18lev1ok5leia.cloudfront.net)

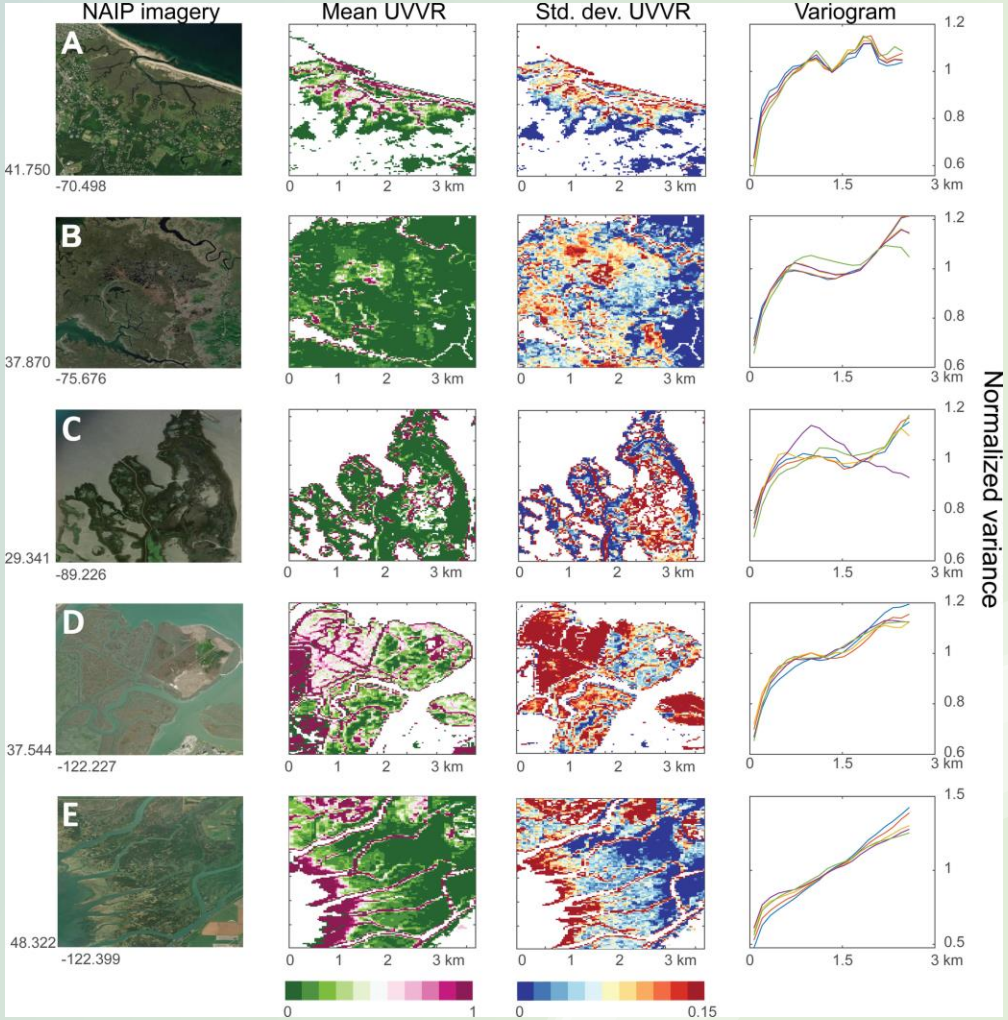
USGS UVVR Wetland Cover Mapping Project

- Authors: Neil K. Ganju, Brady R. Couvillion, Zafer Defne, Katherine V. Ackerman
- Data Inputs:
  - Assessment: Landsat 8
  - For calibration purposes: Sentinel-2 and NAIP
- Methods
  - UVVR = Unvegetated – vegetated marsh ratio
  - Applied UVVR to Landsat 8 for the conterminous US using spectral indices

Source: Development and application of Landsat-based wetland vegetation cover and unvegetated-vegetated marsh ratio (UVVR) for the conterminous United States | U.S. Geological Survey (usgs.gov)

USGS UVVR Wetland Cover Mapping Project

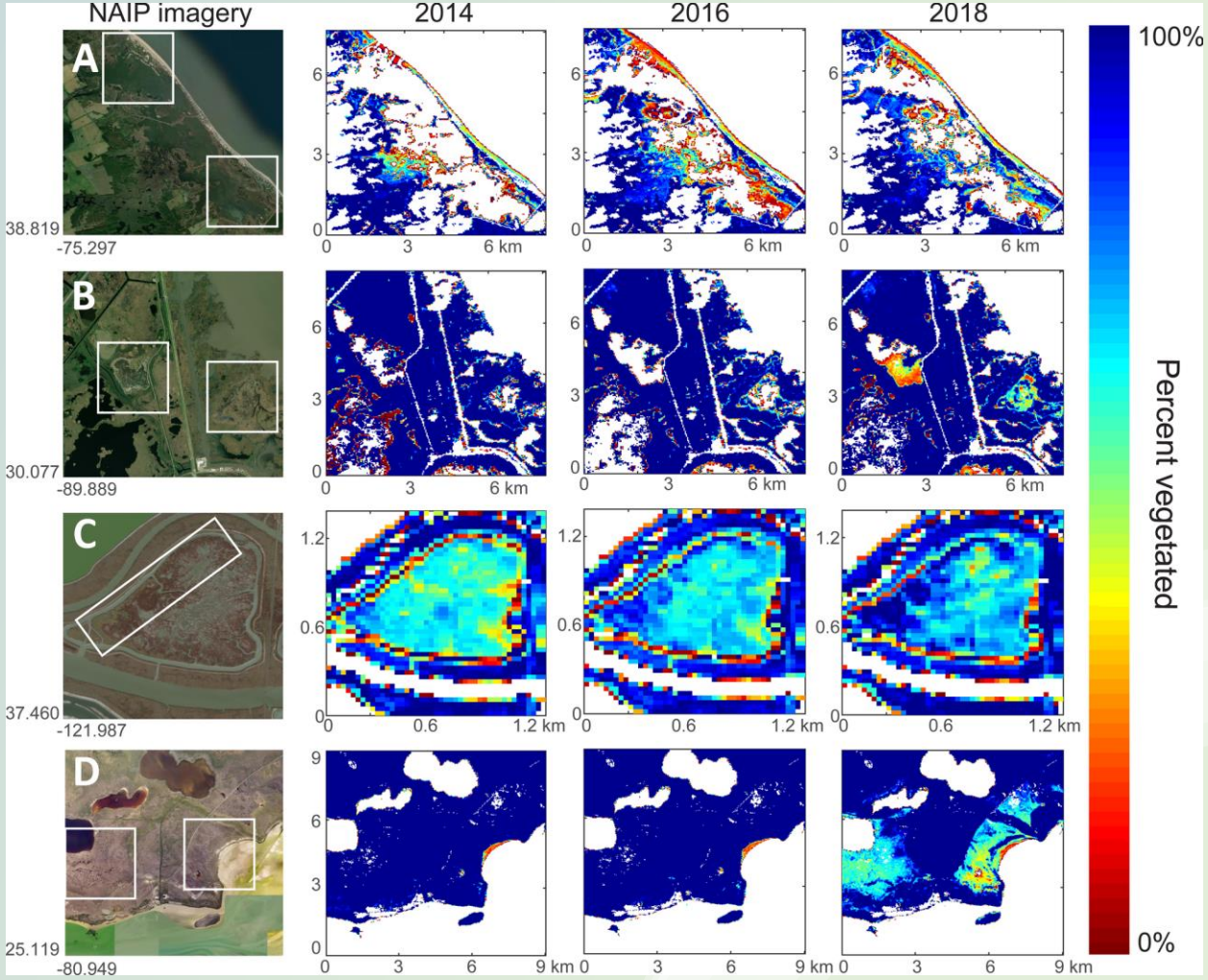
- Results:
  - Tracks wetland extent, expansion, and loss
  - Wetland stability thresholds
  - Classification methodology allows delineating wetlands vulnerable to open water conversion



Source: [Development and application of Landsat-based wetland vegetation cover and unvegetated-vegetated marsh ratio (UVVR) for the conterminous United States | U.S. Geological Survey (usgs.gov)]

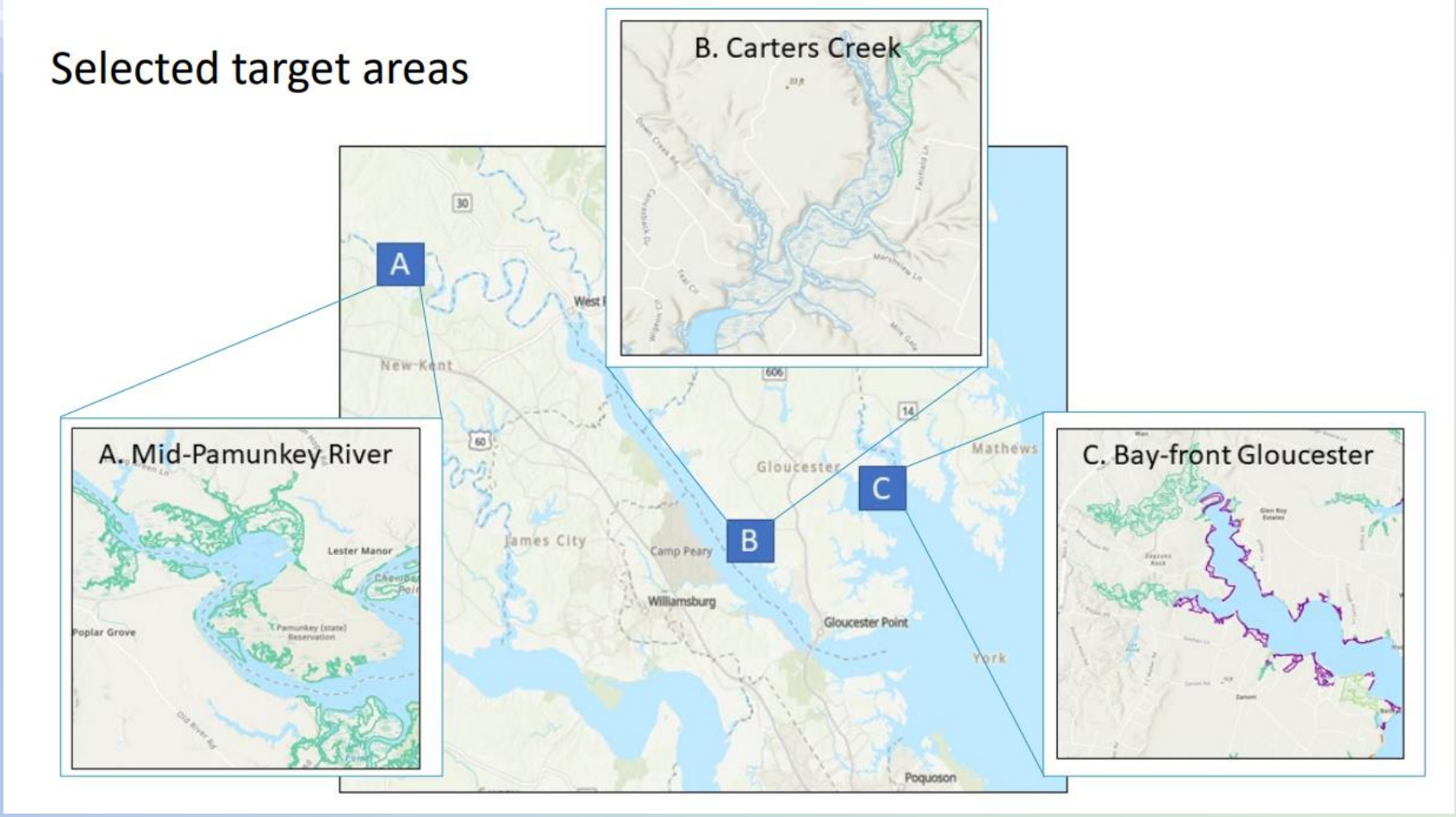
USGS UVVR Wetland Cover Mapping Project

- Implications
  - This methodology will support the CBP Wetland Outcome by tracking tidal marsh restoration and loss with freely available data



Source: [Development and Application of Landsat-Based Wetland Vegetation Cover and UnVegetated-Vegetated Marsh Ratio (UVVR) for the Conterminous United States | SpringerLink]

Applied Remote Sensing Uses for Wetlands: Tidal Marsh Migration In Response to Sea Level Rise



- Compared models:
  - SLAMM (Sea Level Affecting Marshes Model) 5.0
  - InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs)
  - NOAA SLR Viewer: Marsh Migration
  - ETM (Evolution of Tidal Marsh)
  - TMM (Tidal Marsh Model)

Source: [PowerPoint Presentation (d18lev1ok5leia.cloudfront.net)]

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Applied Remote Sensing Uses for Wetlands: Tidal Marsh Migration In Response to Sea Level Rise

- Model Comparison Results
  - Differences between models come from:
    - Water level alignment not being precise
    - Resolution of underlying data
    - Source of underlying data
  - There are not strong patterns between marsh model parameters and migration results
  - Results are not consistent across locations

Source: PowerPoint Presentation (d18lev1ok5leia.cloudfront.net)

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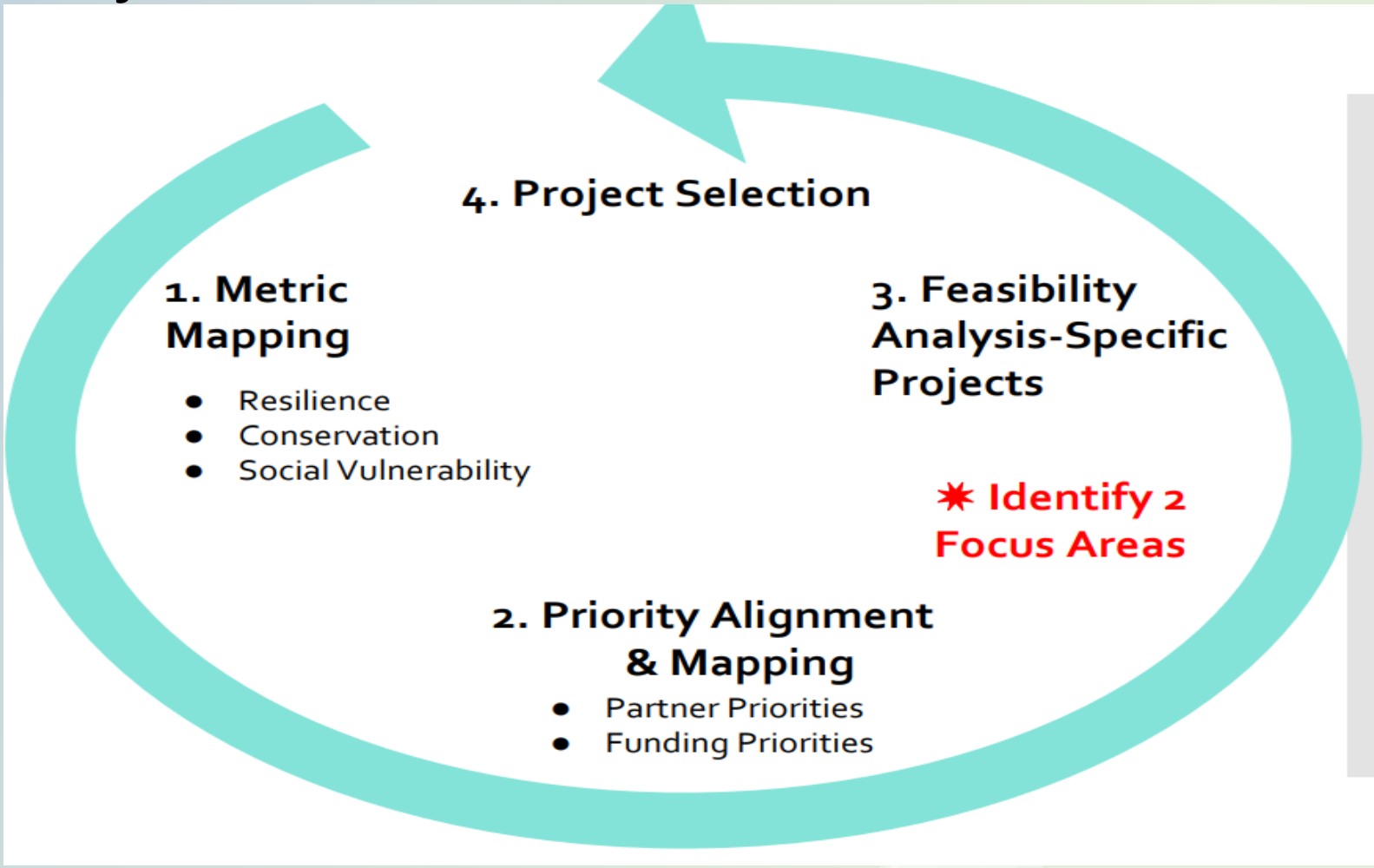
Applied Remote Sensing Uses for Wetlands: Partnership-Building and Identification of Collaborative Marsh Adaptation Projects

- Draft framework for targeting projects



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Source: [Partnership-Building and Identification of Collaborative Marsh Adaptation Projects February, 21 2023 Wetland Workgroup Meeting (d18lev1ok5leia.cloudfront.net)]

Conclusion

- In the context of the Chesapeake Bay, remote sensing techniques are supporting efforts to meet wetland restoration goals
- Adaptive management is tracking the role remote sensing is playing in mapping wetlands, especially the pivot of resources for nontidal vegetated wetlands
- Given the widely available data in the Chesapeake Bay watershed, the region is dynamic in its usage of remote sensing for tracking wetlands

Source: EPA-CBP-GIT-FFY22-RFP-w-Appendix_2-10-23_extended-deadline.pdf (cbtrust.org) (pages 34-37)

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