Scaling Wetland Intelligence with GeoAI: Tools, Trends and a National Vision

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Environment & Conservation Solutions

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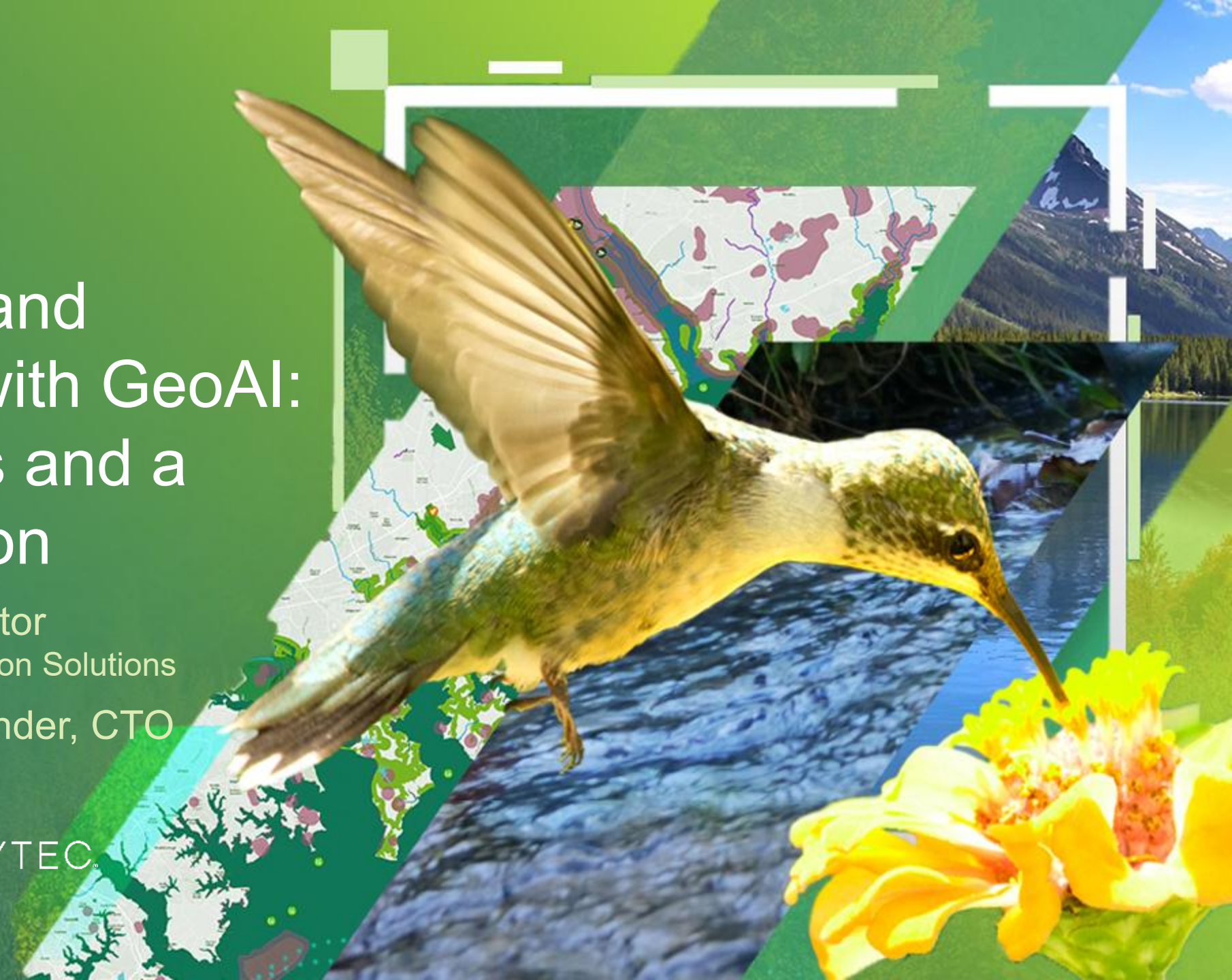
Skytec

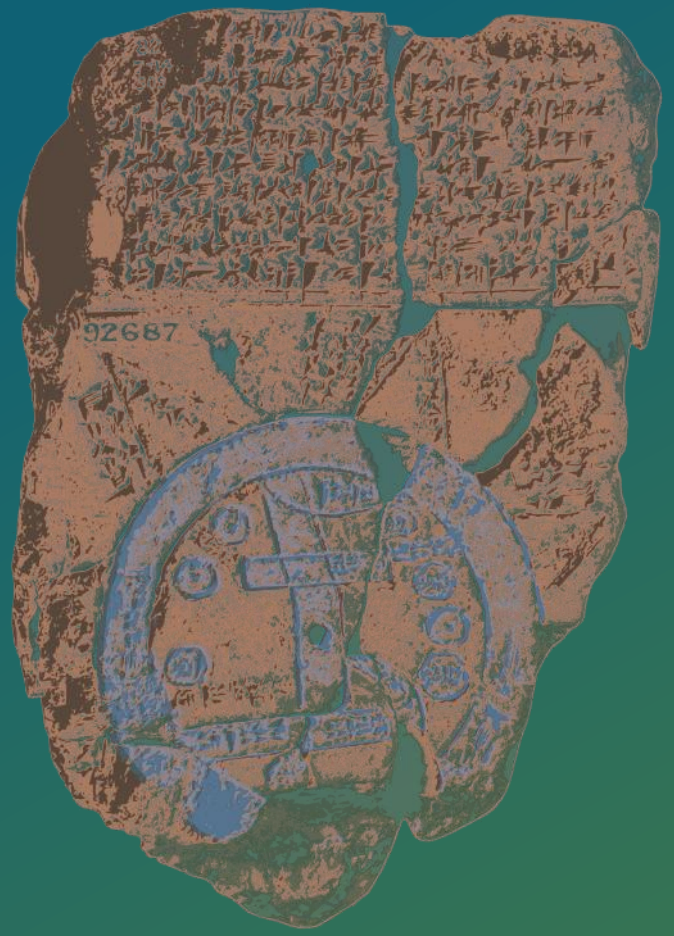


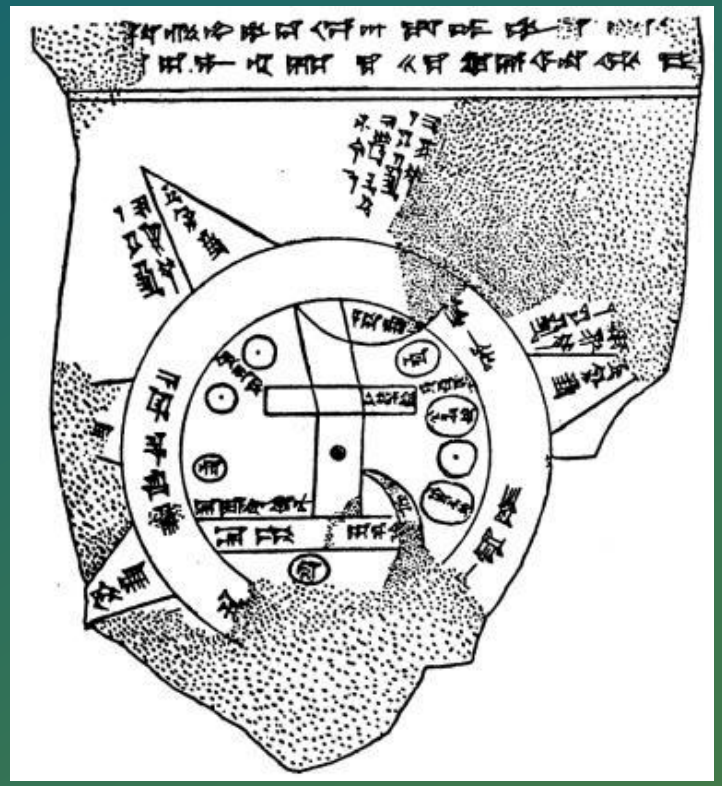
Maps Have Long Driven Our Understanding of the World…

… and continue to…

But would we make decisions today based on these maps?

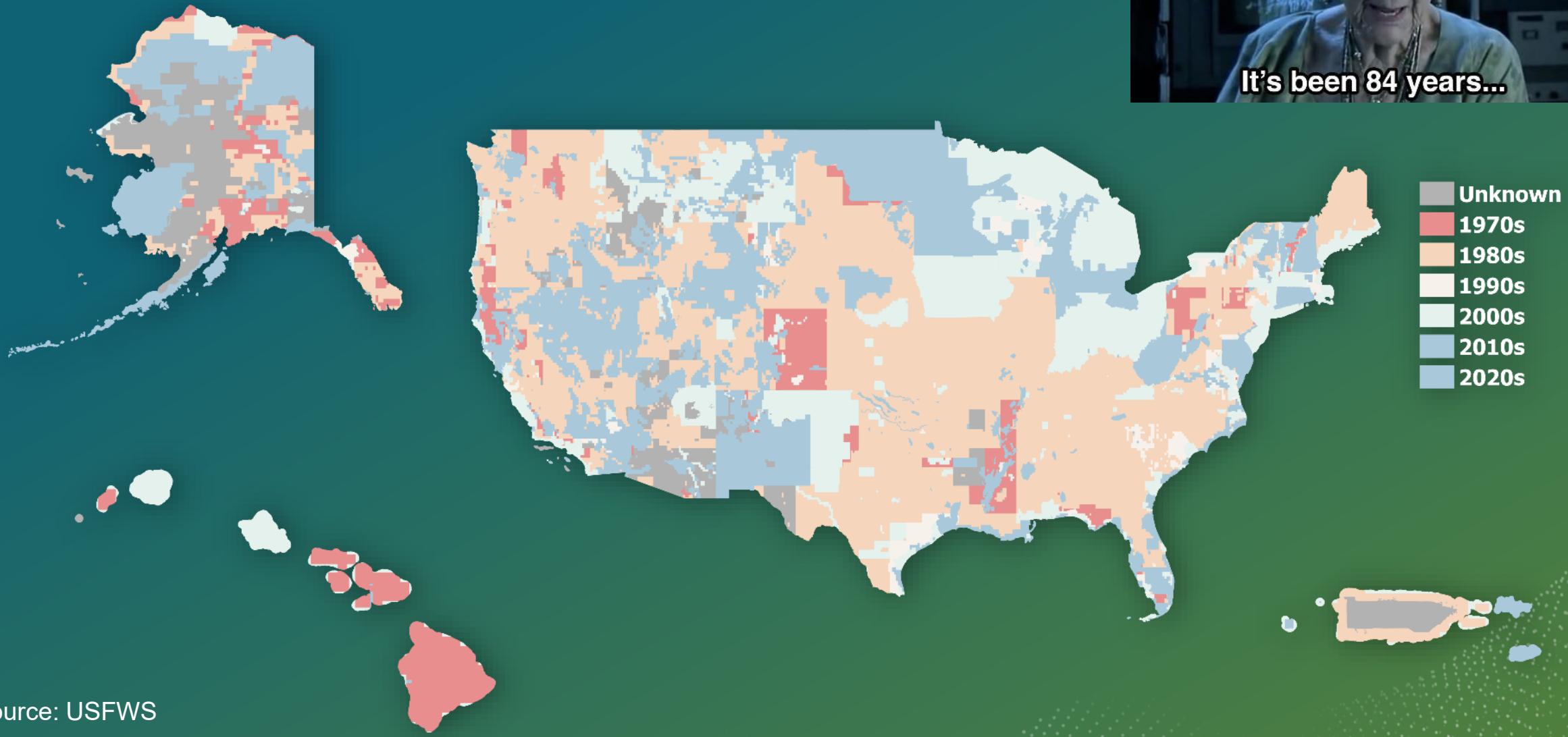
The world's oldest-known world map, ~After 9th Century BC





Are we ok with this?

21st century decisions with 20th century data…



Source: USFWS

“Streamlining”

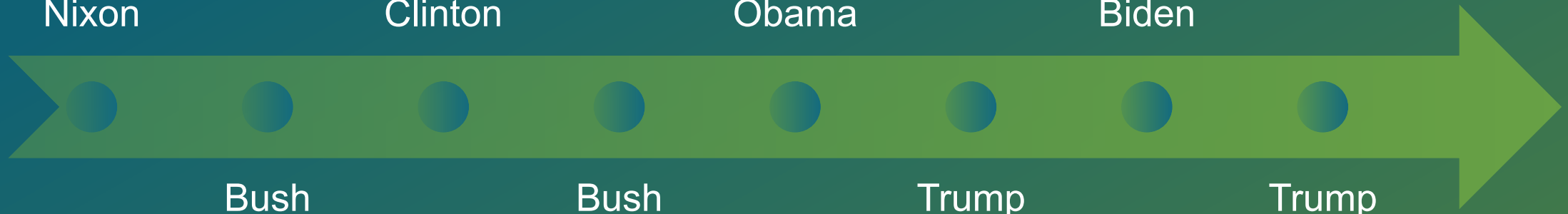
A Brief History…

Nixon
- Est. ESA
- Est. NEPA

Clinton
- National Performance Review
- Project XL

Obama
- Est. FIPSC
- Permitting Dashboard

Biden
- IIJA Provisions
- Interagency Infrastructure Permitting Improvement Center
- CEQ E-NEPA Report to Congress



Bush Sr.
- Council on Competitiveness

Bush Jr.
- E-Gov’t Act
- Project Fast Track

Trump 1.0
- One Federal Decision
- CEQ Reforms

Trump 2.0
- Updating Permitting Technology for the 21st Century

Why Streamline?

White House Memoranda

The Challenge	ArcGIS Solves by…
Eliminate Paper Workflows	Digital (Cloud or On-prem)
Reduce Time, Increase Quality	Automation & Insight
Increase Coordination	Secure Data-sharing
Improve Transparency	Persona-specific apps
Litigiously Defensible	Repeatable, time-stamped, etc
Speed up Data Gathering	Remote-sensing, GeoAI

What Is a GIS?

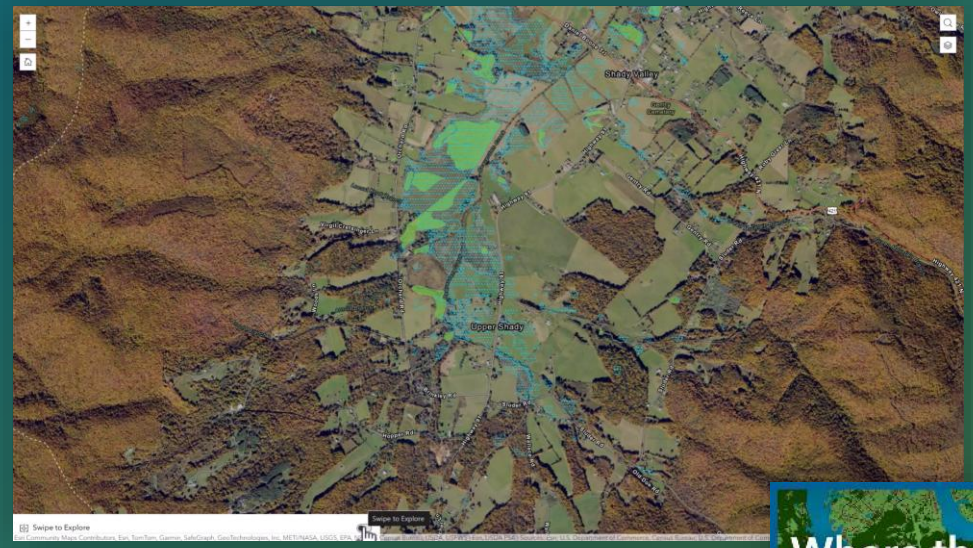
A System for Managing, Sharing and Applying Geographic Information

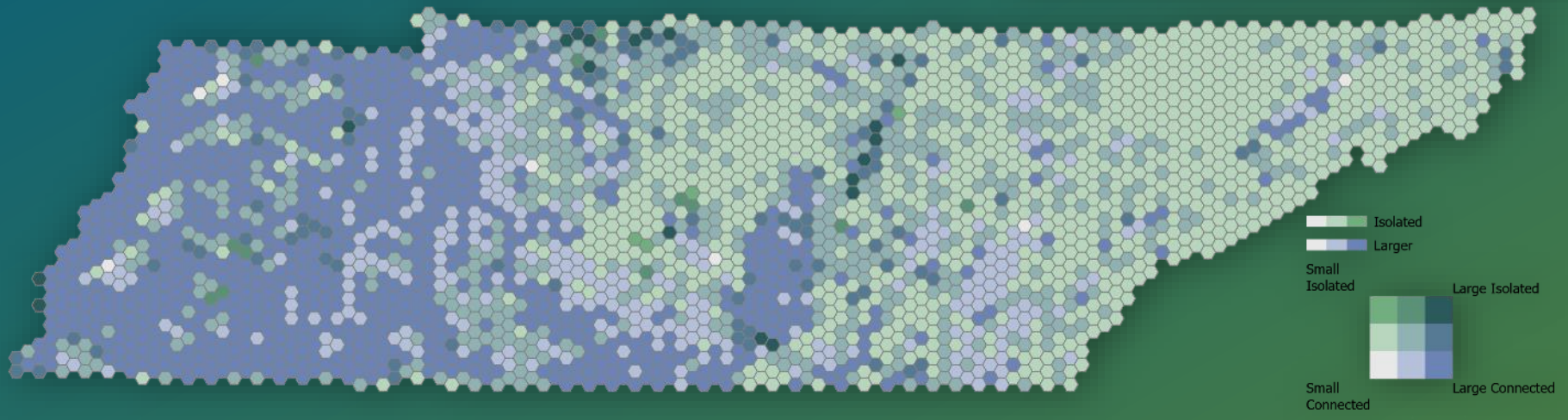
Delivering Value Across Organizations
Improving Efficiency, Communications, Decision Making and Collaboration

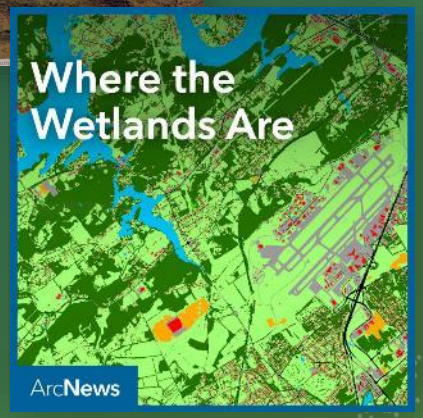
Many states are stepping up

Tennessee pioneers scaling **GeoAI** for high-resolution wetland modeling

- Visualize policy definitions
- 8 weeks
- 3m resolution
- Fraction of cost







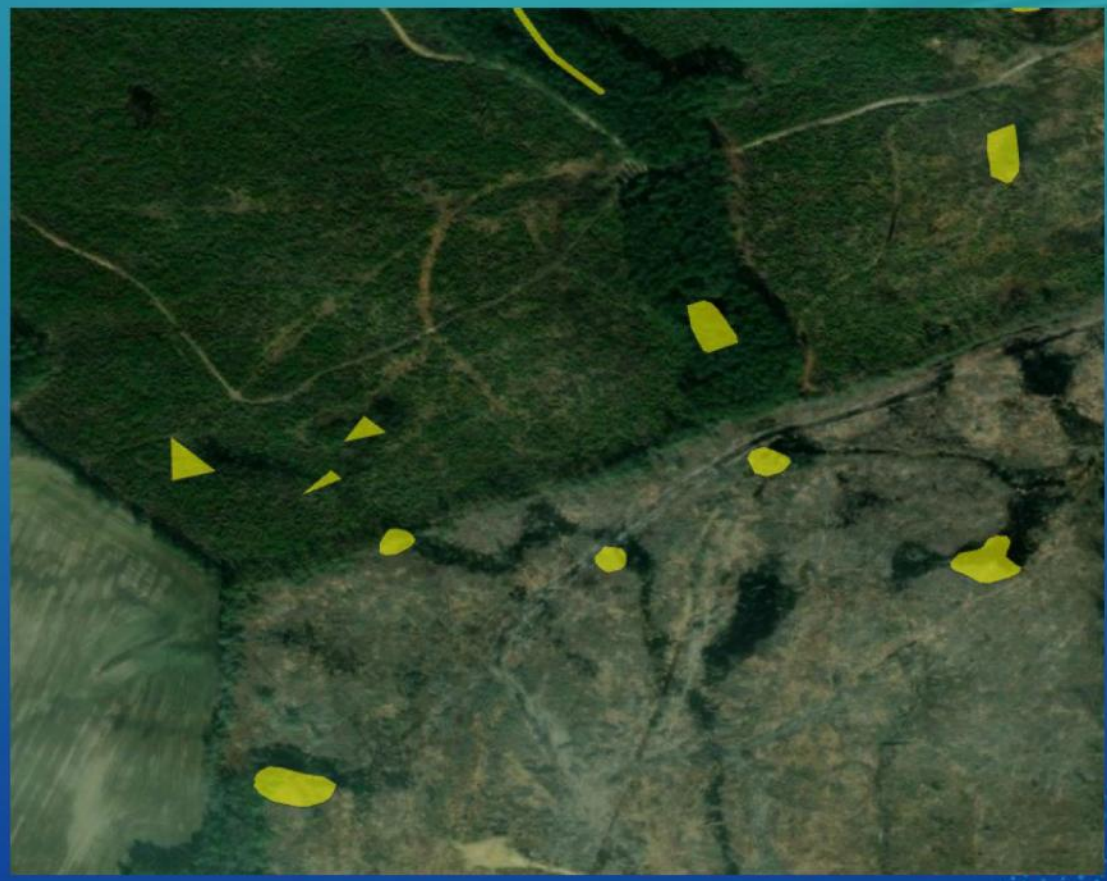
Tennessee Wetlands Screening Tool Background

- Bill Introduced to Remove Isolated Wetland Protections
- Statewide NWI Coverage in TN is 30-40 years old
- How to Quantify Policy Impacts?
  - Where are these impacts?
  - Who is impacted the most?

TWF

TN Department of Environment & Conservation

We rely on national datasets to inform conservation



Lack of funding and manual processes impede crucial, large-scale updates

Motivation

Image Source: Esri Professional Services

Massive datasets need to be updated

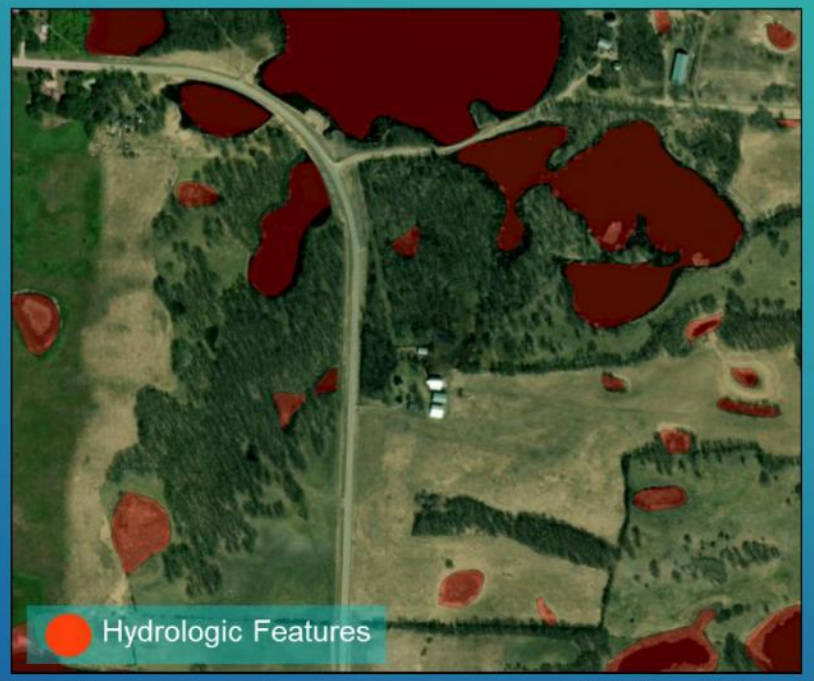
Automation will be crucial for updating conservation data efficiently and accurately

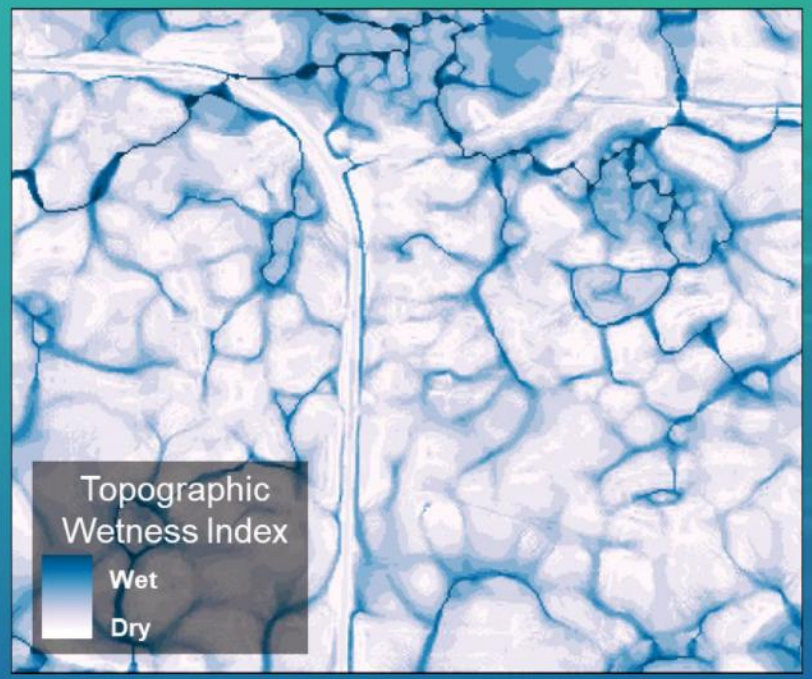
AI is an additional (more automated) automation technique

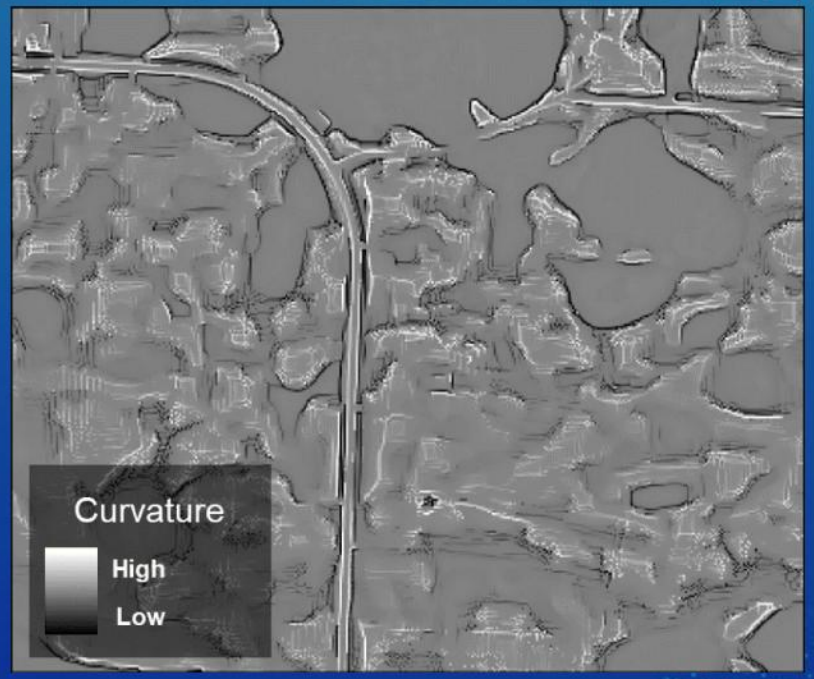
Image Source: Esri Professional Services

Tennessee Predicted Wetland Model Technique

Wetlands occur where there is important overlap of wetland indicators







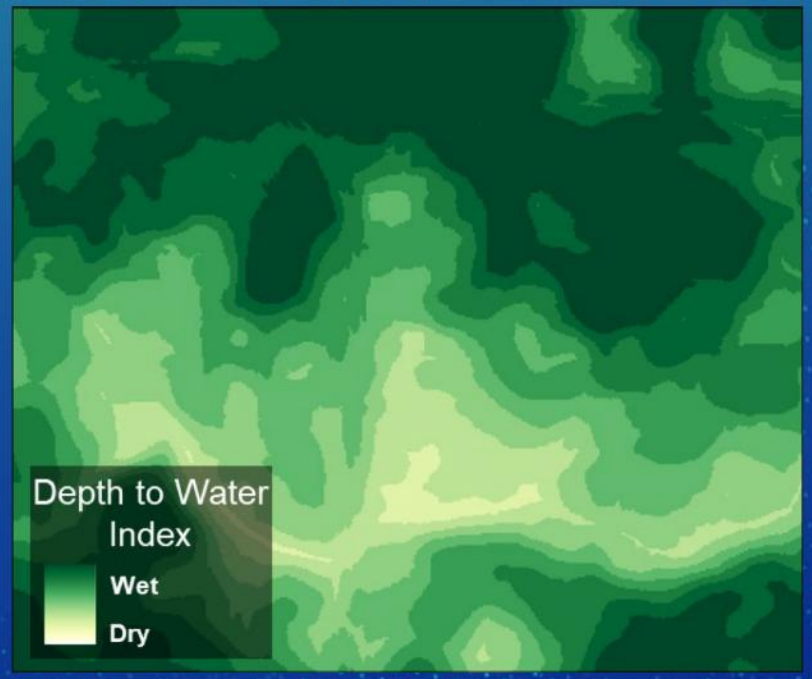
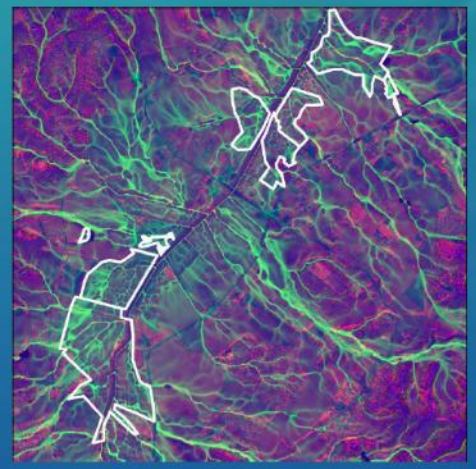


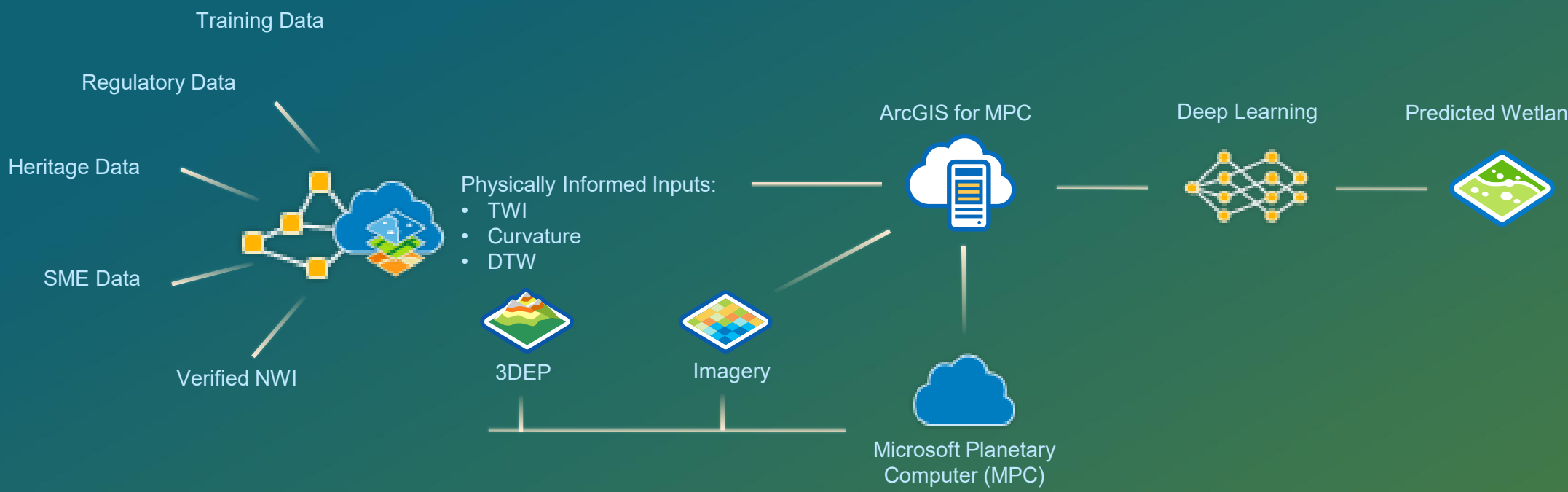
Image Source: Esri Professional Services

Scaling Statewide by HUC 12 Units



False color image of topography based predictor variables and NDVI

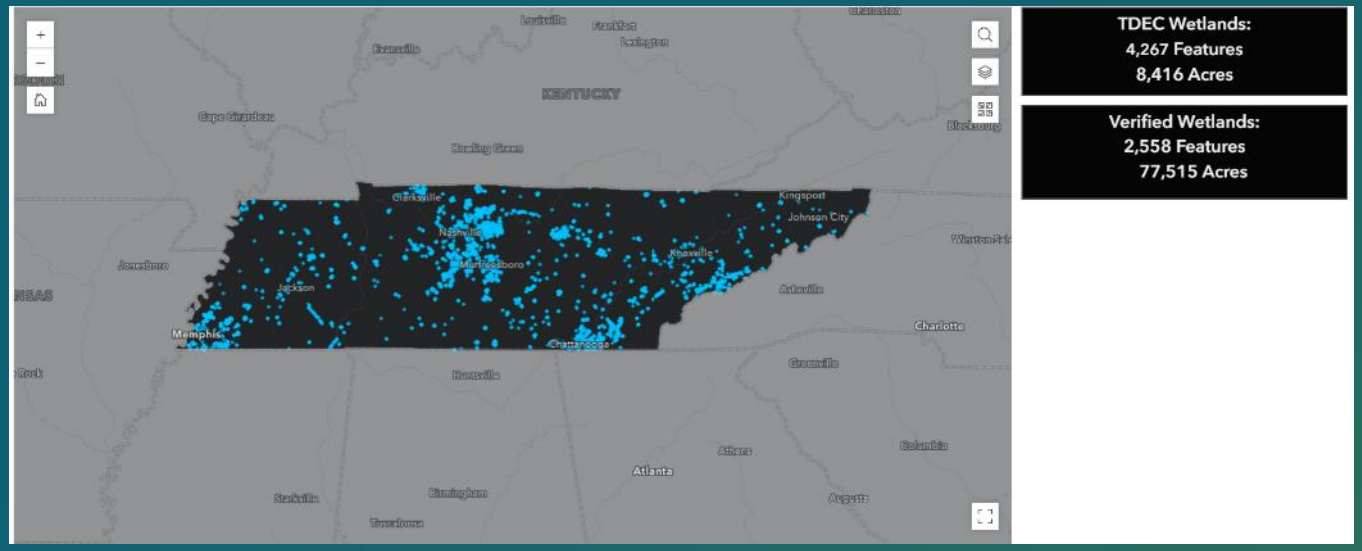
Optimized Wetland Identification Model



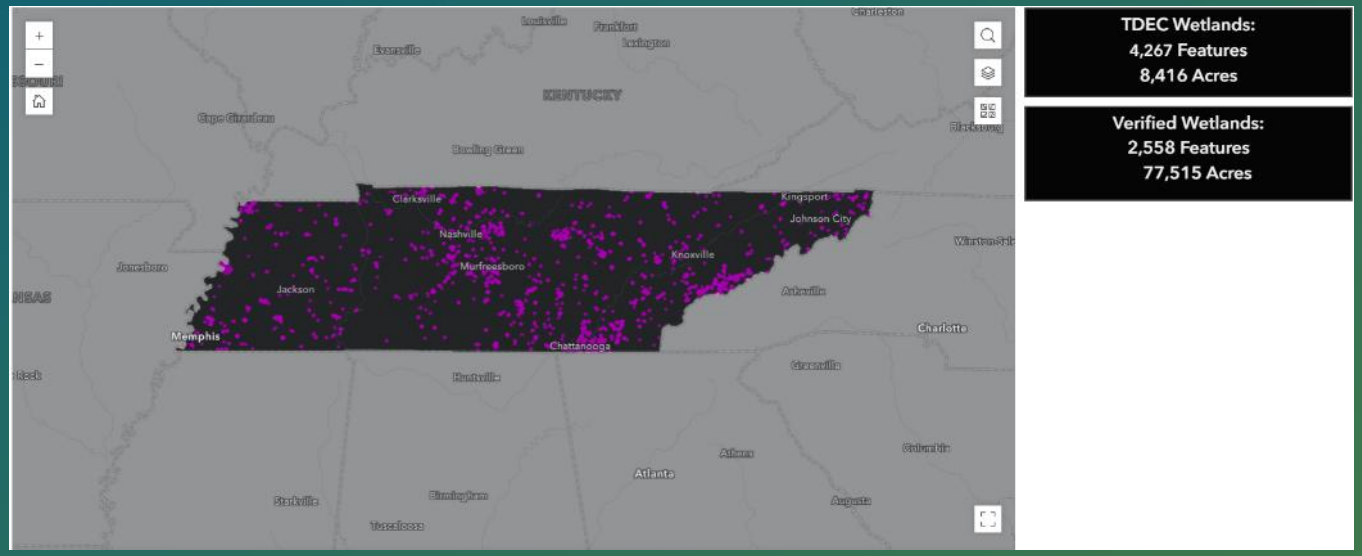
planet.

Microsoft Planetary Computer

Wetland Model Training Data



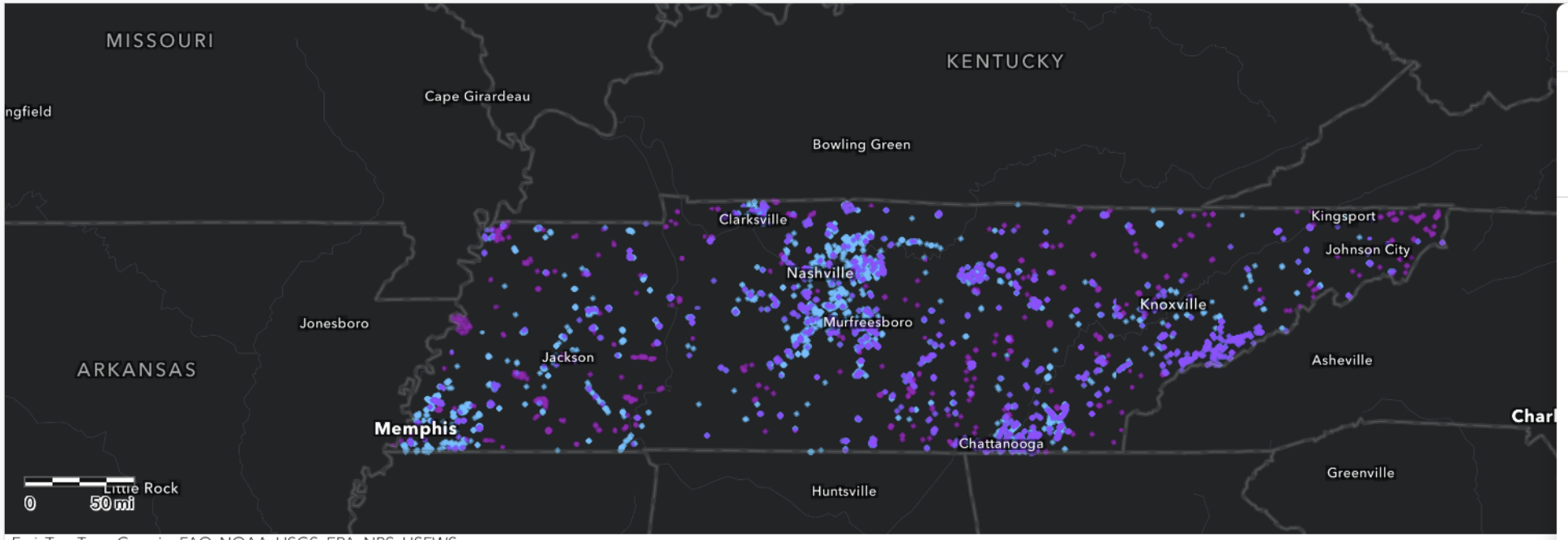
Overview of manually digitized wetland delineations submitted to TDEC between 2011- April 2024



Overview of final training dataset incorporating all data sources

Data Sources

- Regulatory Data
- Wetland boundaries and guidance provided by regional scientists and conservation organizations
- Natural Heritage data on rare, threatened, or endangered (RTE) element occurrences or habitats
- Updated National Wetland Inventory (NWI) Data (GSMNP & West TN)
- Remotely verified National Wetland Inventory



Legend

Visual Verification

TDEC Regulatory Data

Count of Delineated Training Wetlands (TDEC)

4k

Count of Training Wetlands (Updated NWI)

263

Count of Visually Verified Wetlands

2.6k

Total Acres of Delineated Wetlands (TDEC)

8.4k

Total Acres Updated NWI Wetlands

63.5

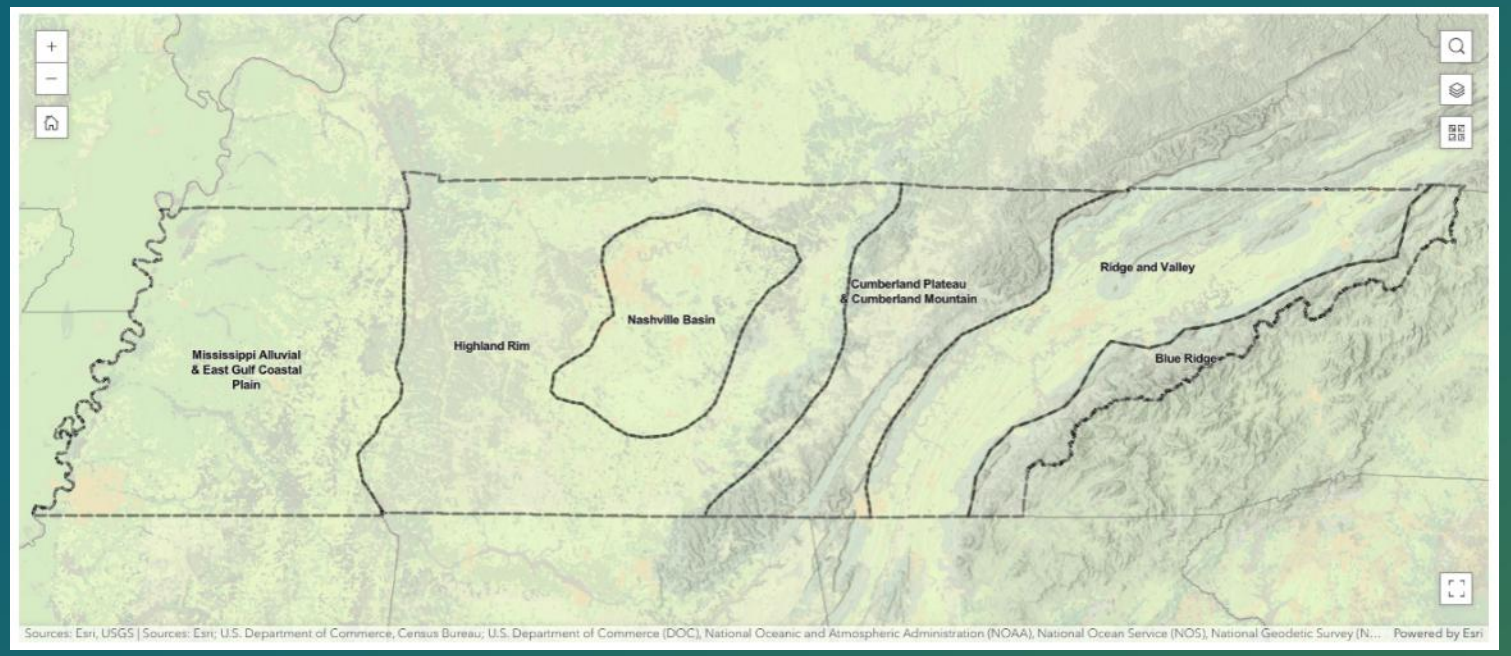
Total Acres Visually Verified Wetlands

77.5k


Castle Dr
Old Castle Dr
0
200 ft

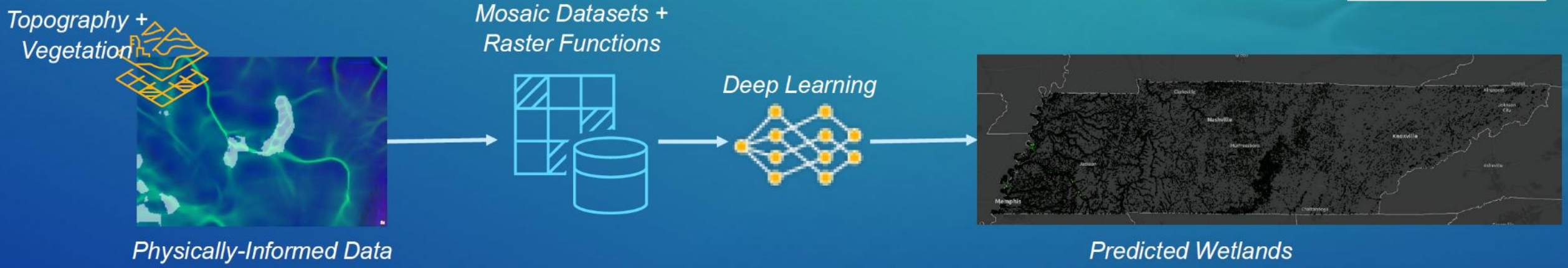

Legend
TN Wetland Training Layer
TDEC Data Review
USA NAIP Imagery: Natural Color
USA NAIP Imagery: Natural Color
Red: Red
Green: Green
Blue: Blue

Tennessee’s Diverse Terrain and Ecological Diversity



Due to the diverse topography, geology, and ecological communities in Tennessee, it was necessary to develop unique training data for each of six broadly defined ecoregions.

Solution Using AI to Identify Wetlands Across TN



Processing and data sharing enabled by Azure resources

Distributed processing with Azure machines

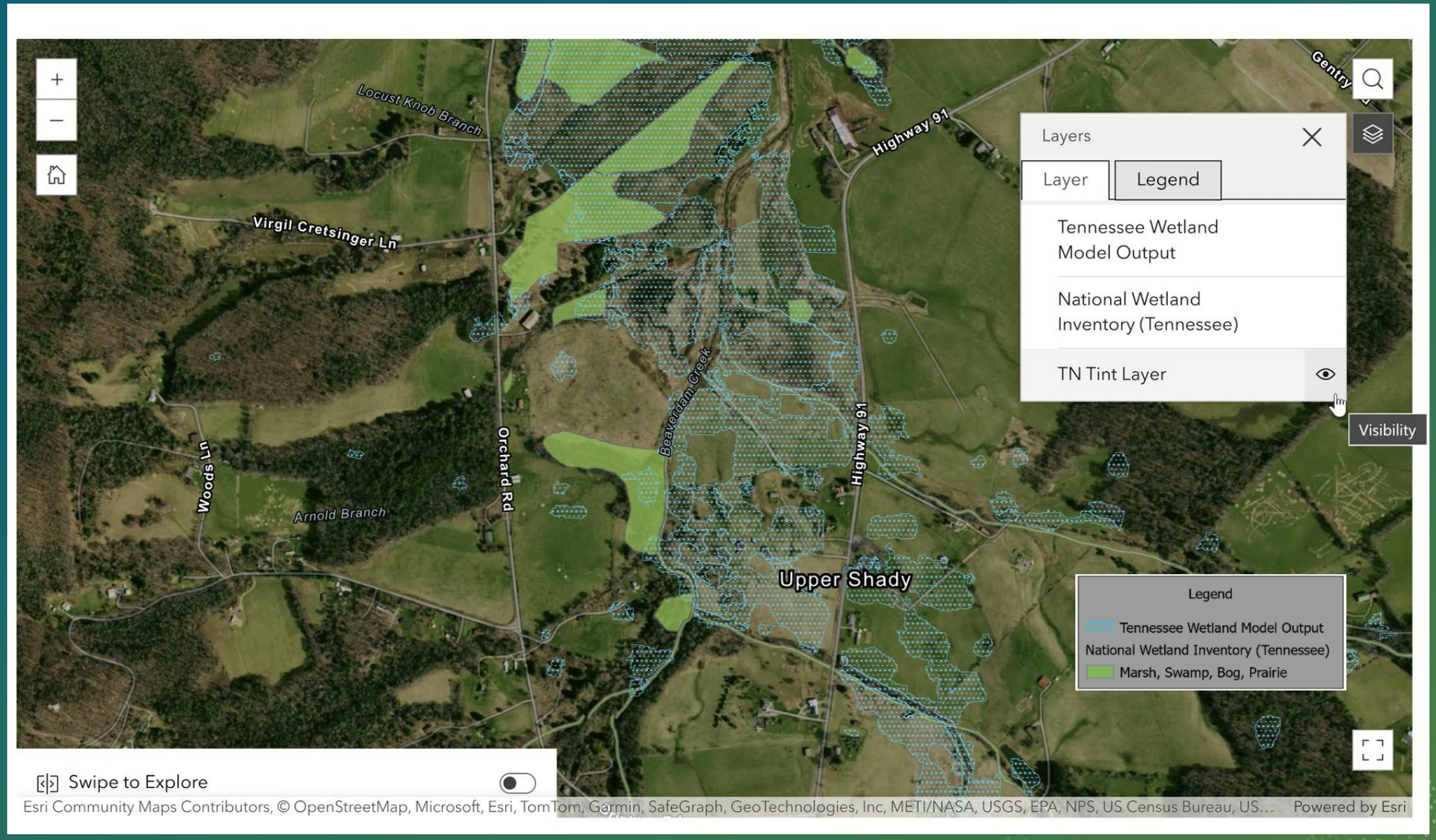
Image Source: Esri Professional Services

Predicted Wetlands – Turkey Creek

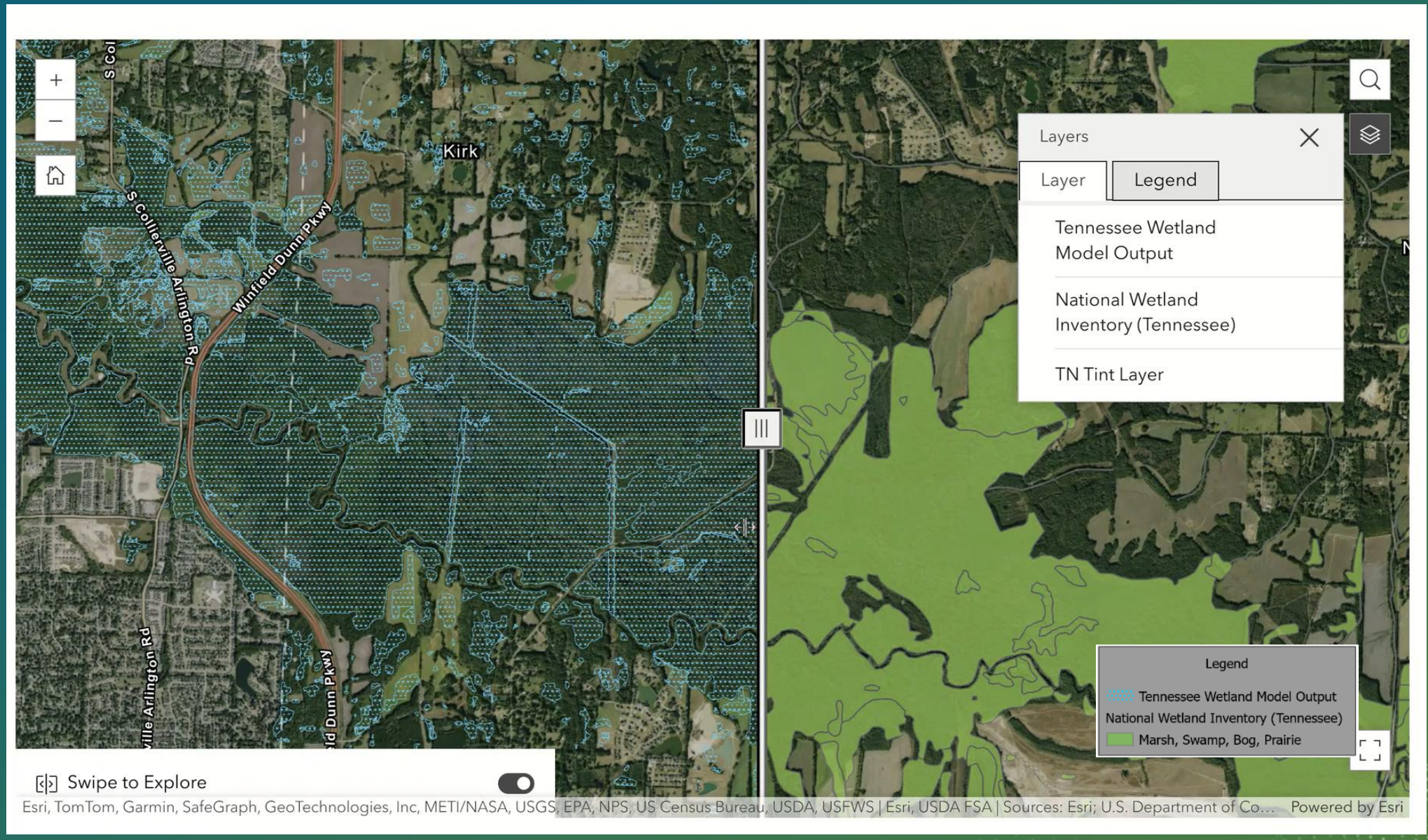
National Wetland Inventory:
1,065,661 Acres

Predicted Wetlands
1,802,495 Acres

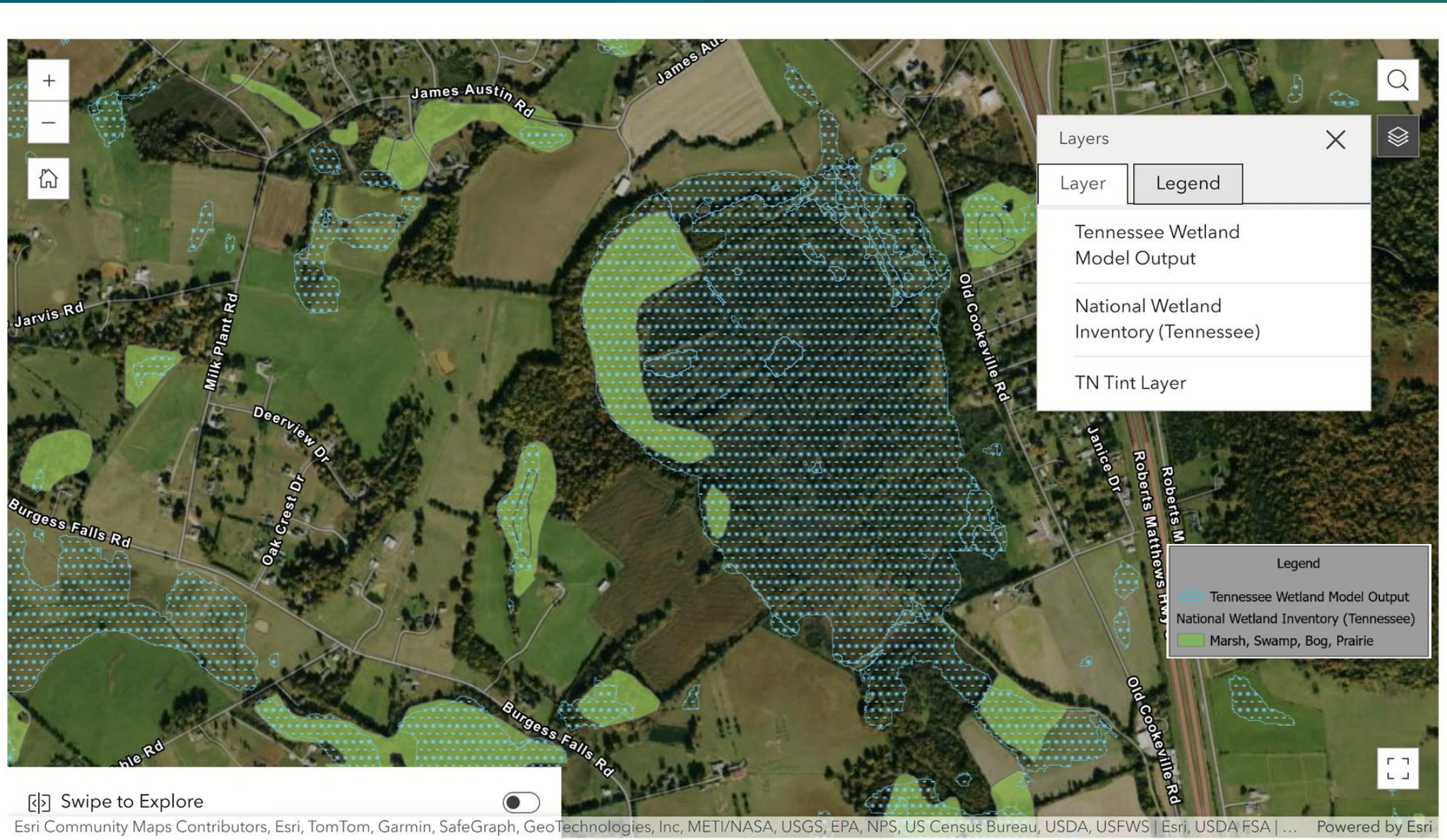
Predicted Wetlands – Shady Valley



Predicted Wetlands – Piperton Mitigation Bank

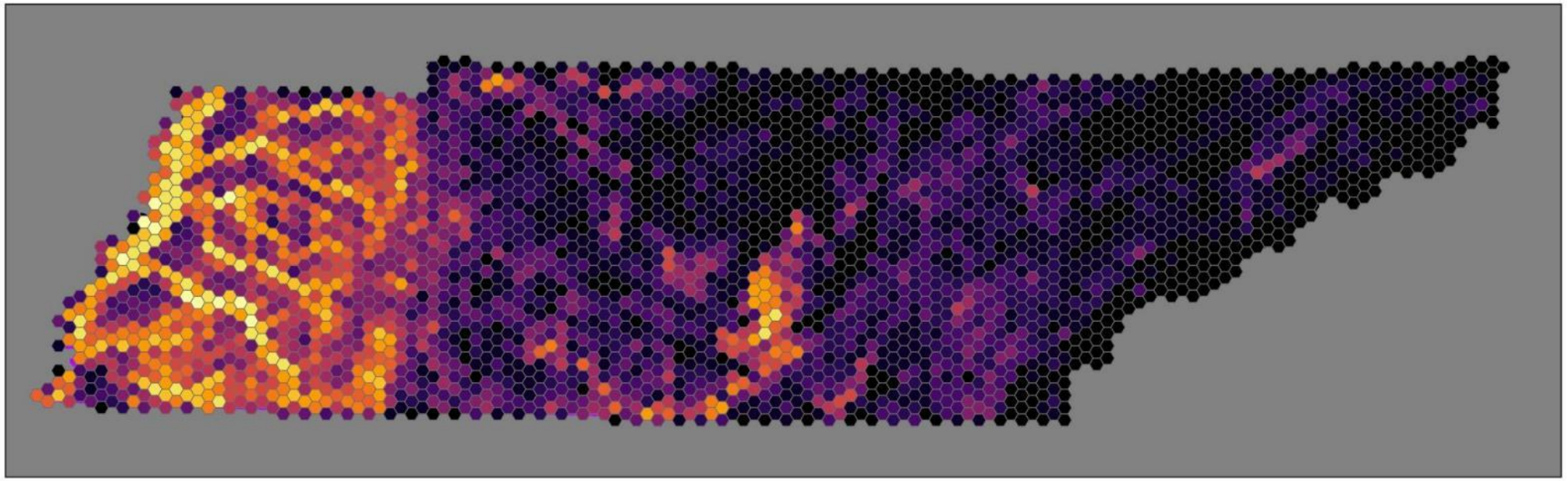


Cookeville - South



Springfield - West

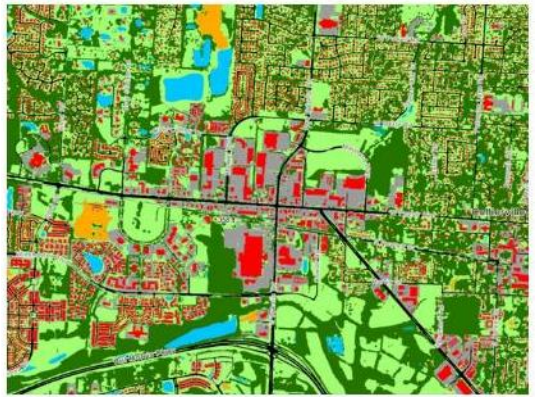
Wetland Model Output Summary



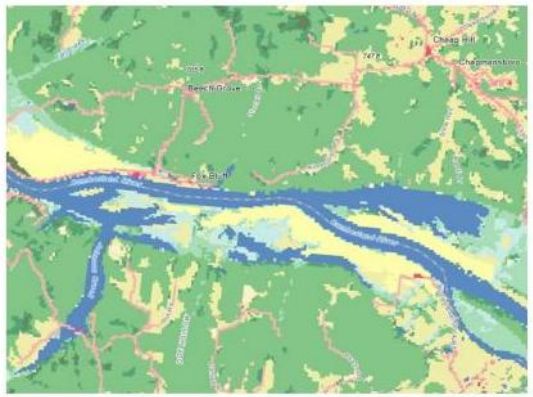
Attribution of Wetland Feature by Land Cover Type

Deep Learning Derived Land Cover

30m NLCD (2021)



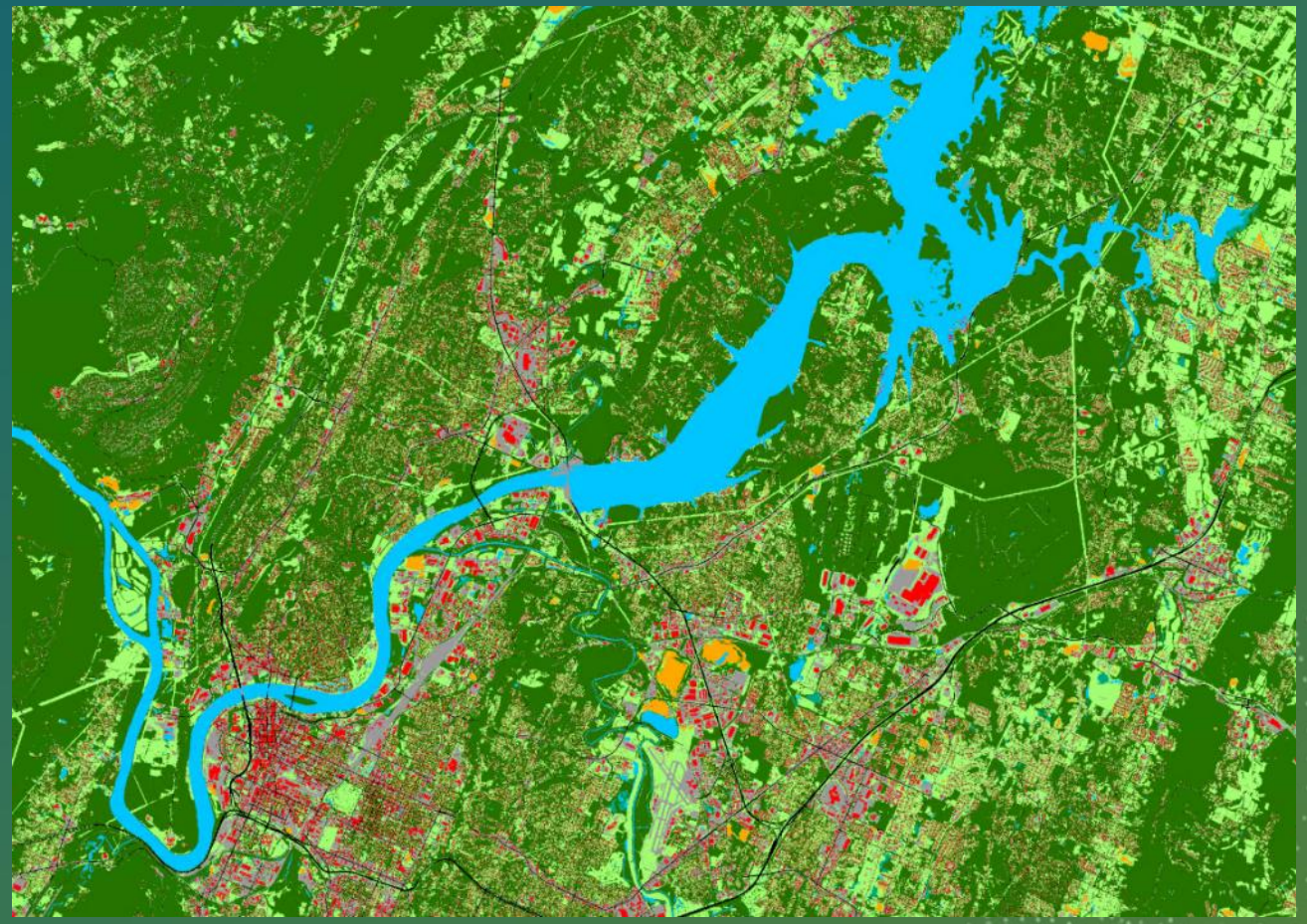
1m derived from NAIP (2023)



30m NLCD (2021)

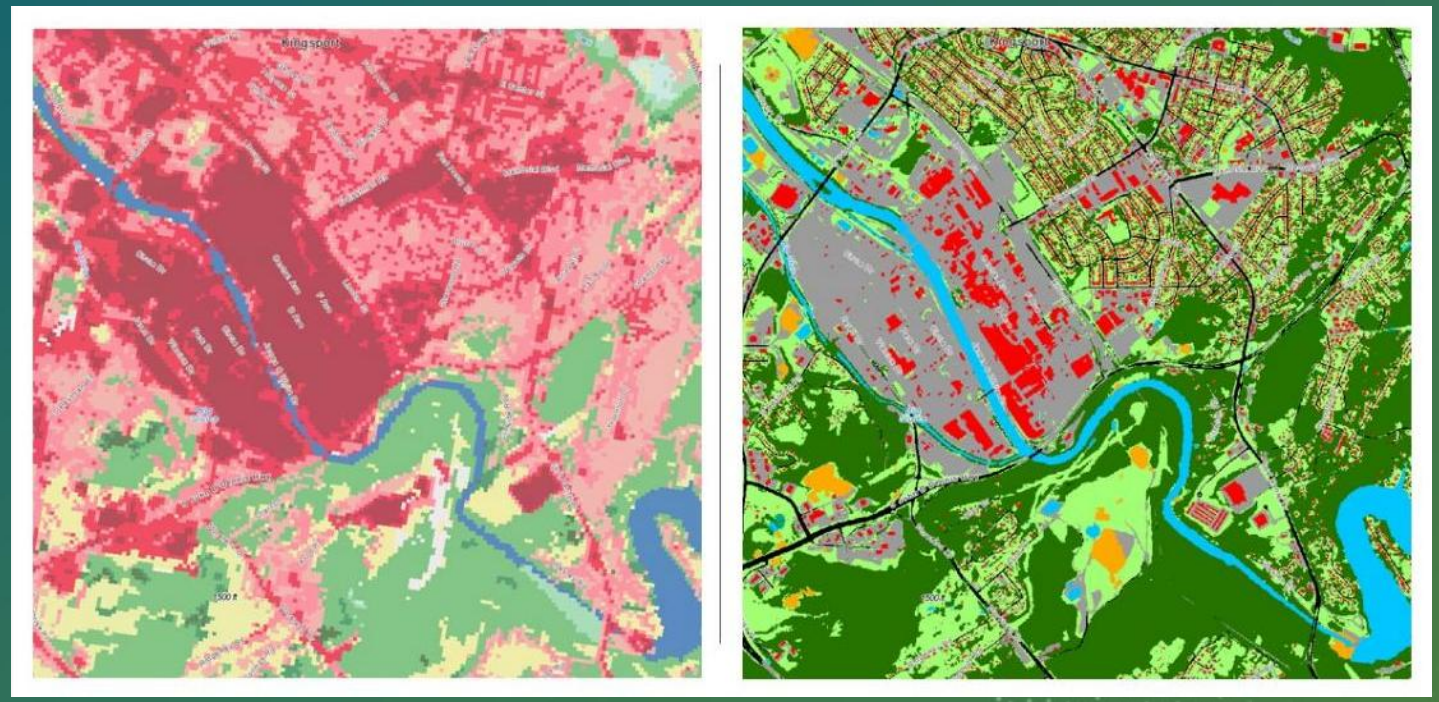
1m derived from NAIP (2023)

Chattanooga



Memphis

Kingsport

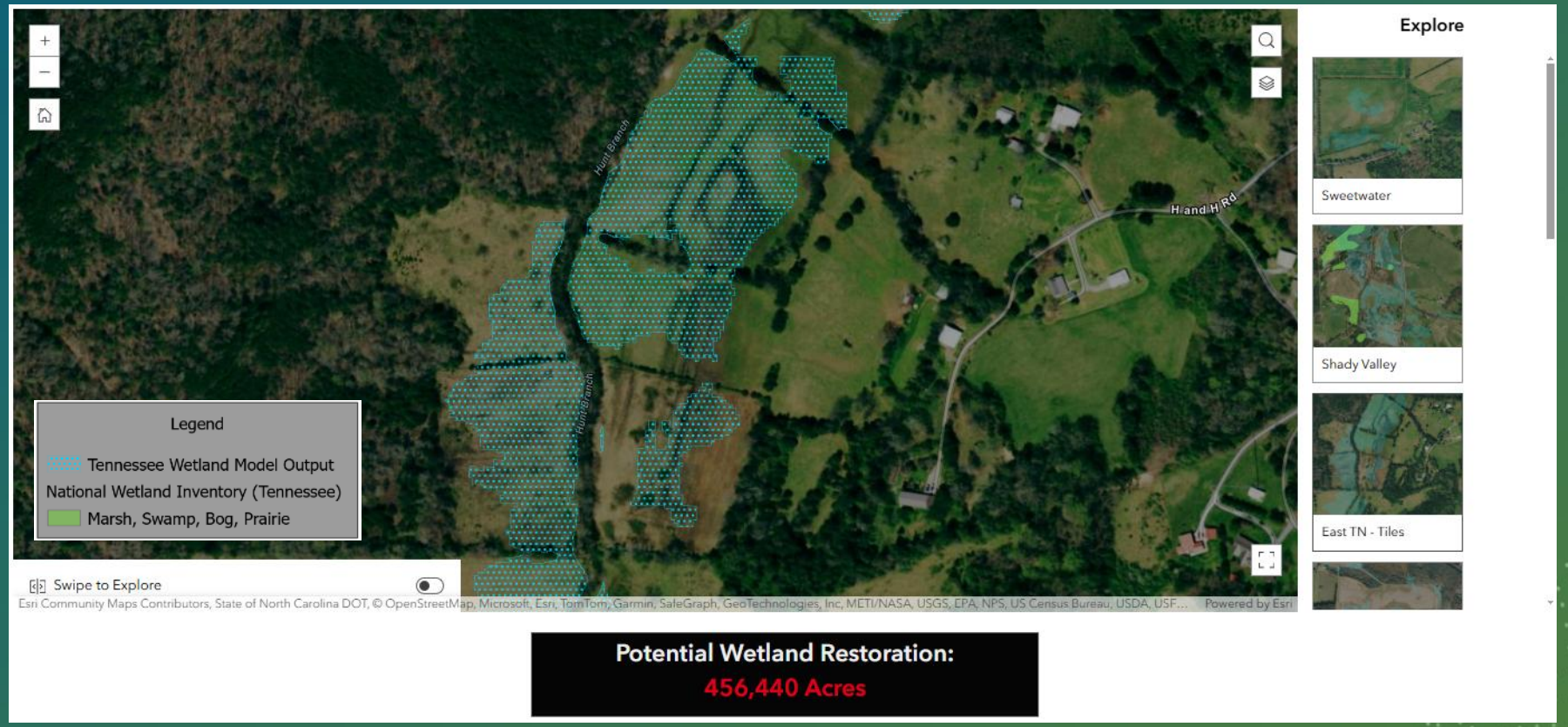


Wetland Restoration Potential

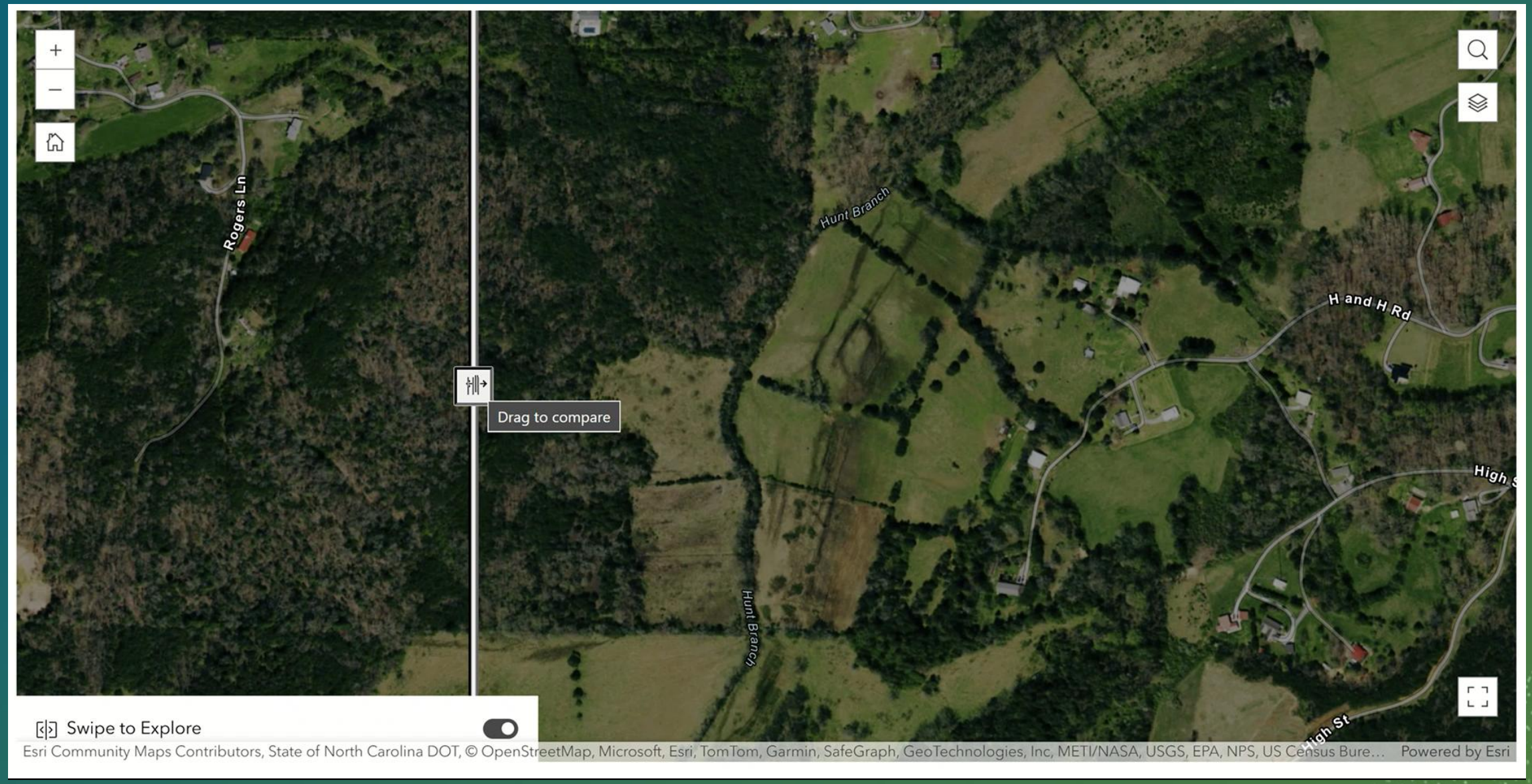
Filtered outputs by:

- Wetlands occurring in barren or low vegetation classes
- Wetlands occurring with SSURGO hydric class

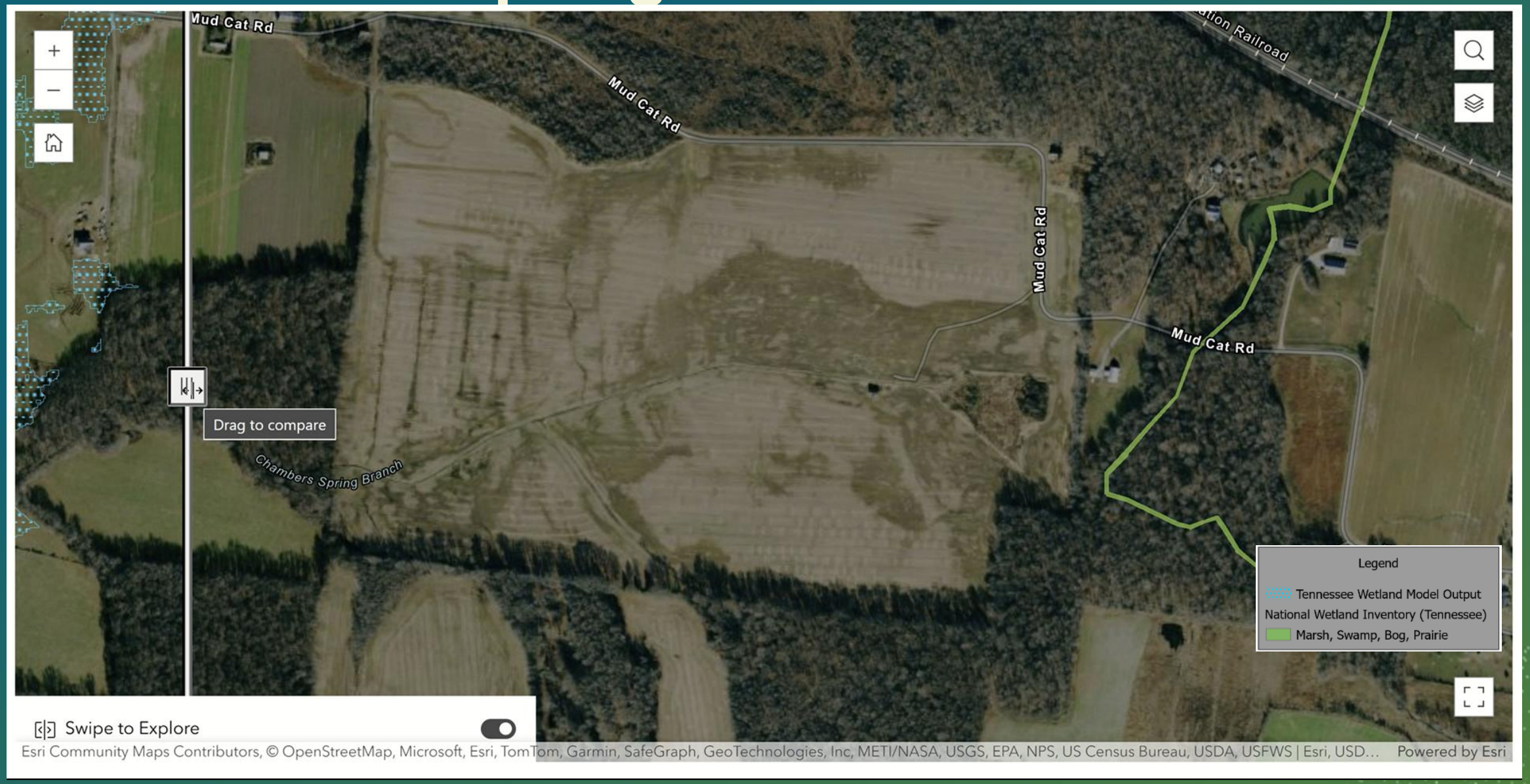
= Potential wetlands of degraded or lower quality



East Tennessee Drain Tiles



Springfield - West



Orlinda


Highway 52
Holmes Rd
Hulsey Rd
Drag to compare
Legend
Tennessee Wetland Model Output
National Wetland Inventory (Tennessee)
Marsh, Swamp, Bog, Prairie
Swipe to Explore
Esri Community Maps Contributors, © OpenStreetMap, Microsoft, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA, USFWS | Esri, USD…
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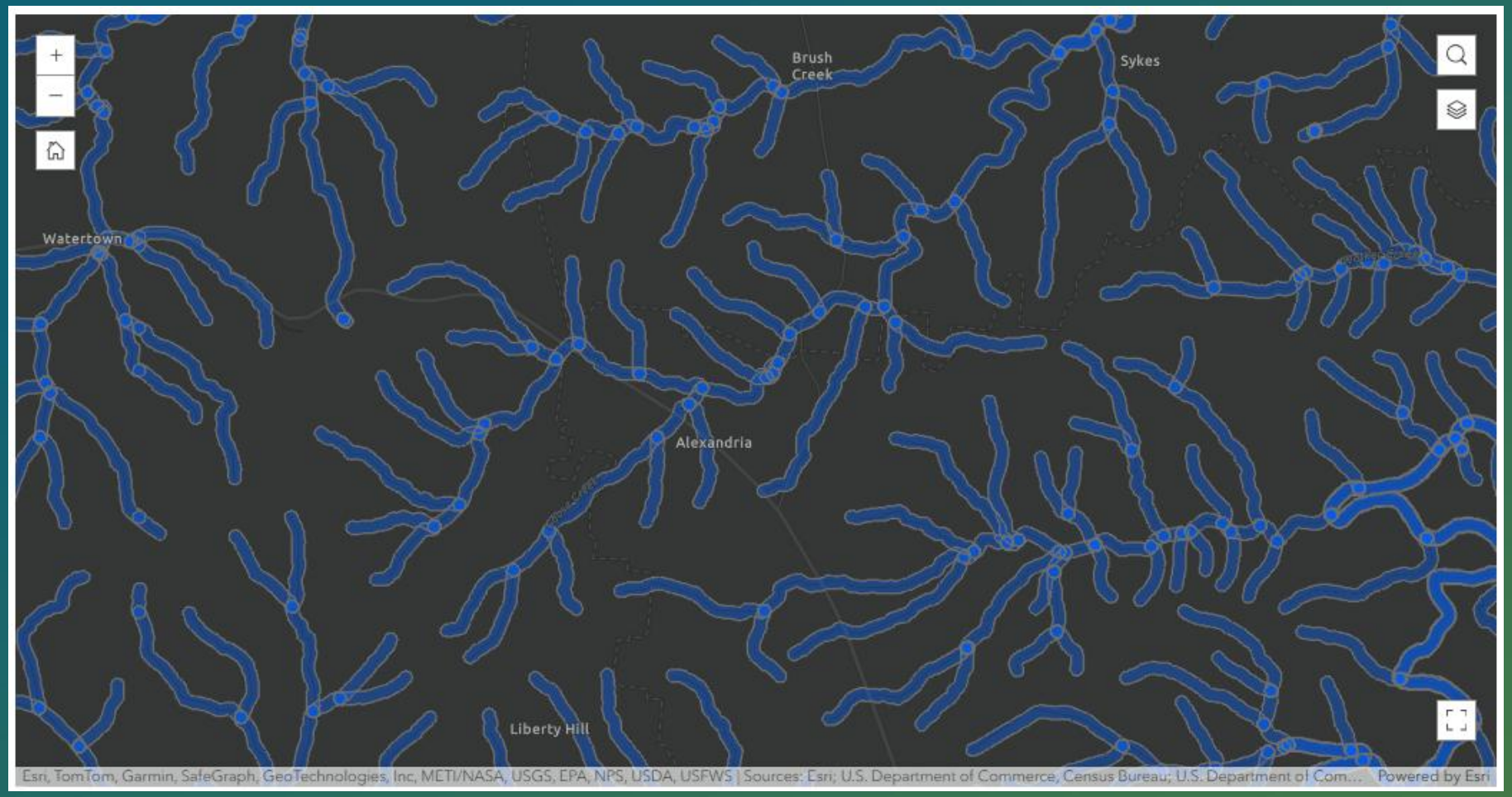
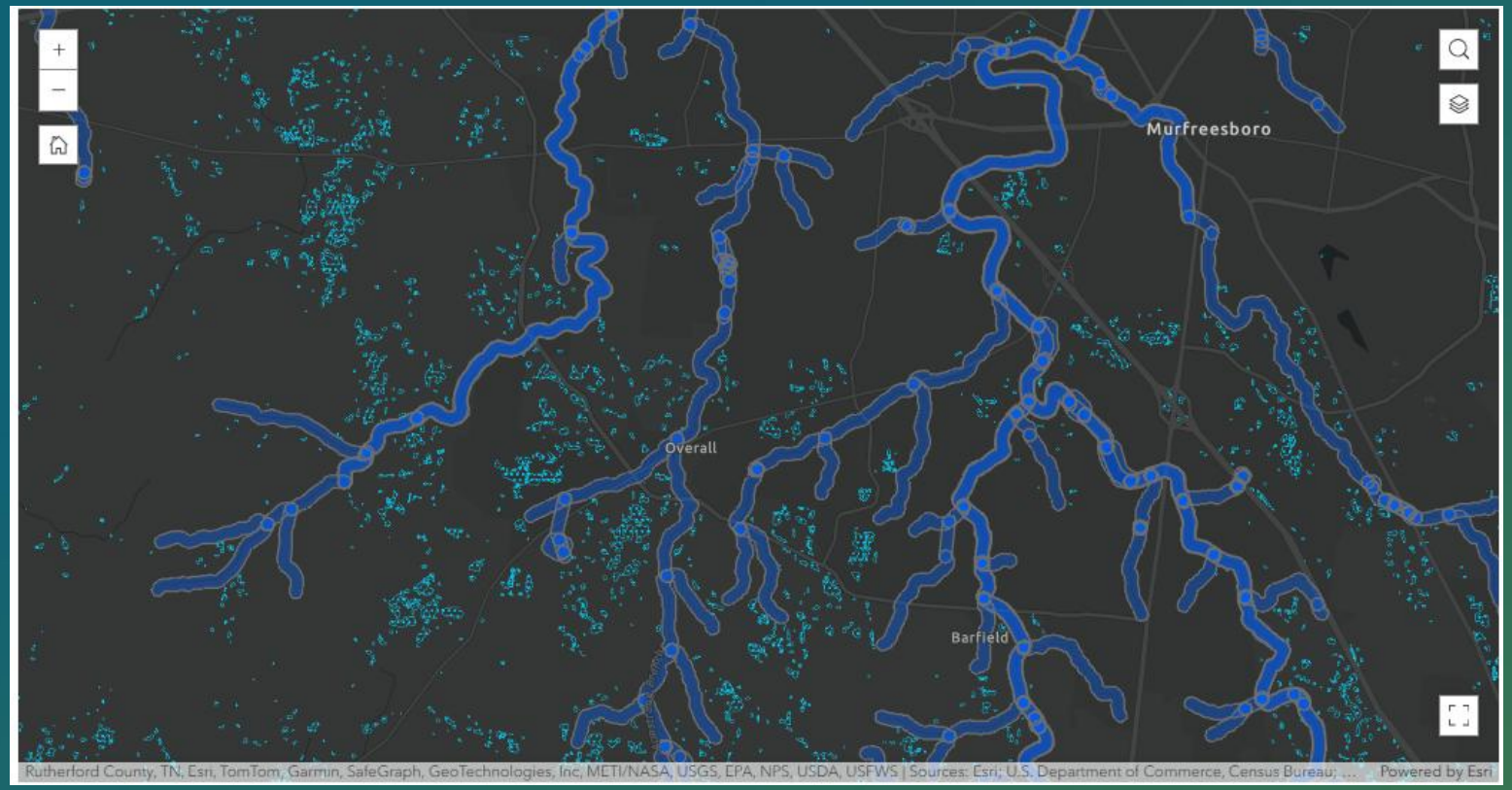
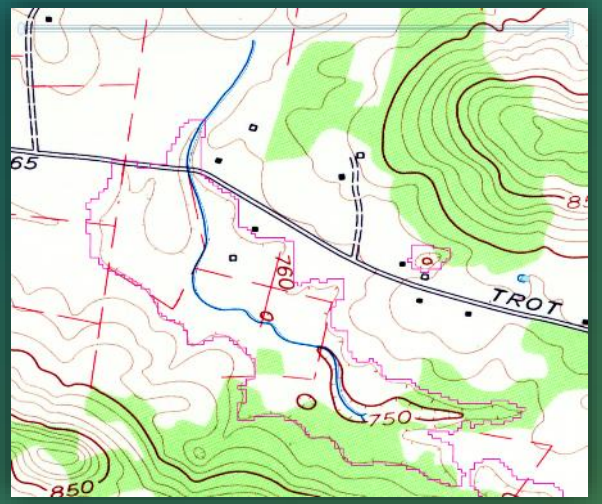
Isolated Wetlands Analysis – National Hydrography Dataset



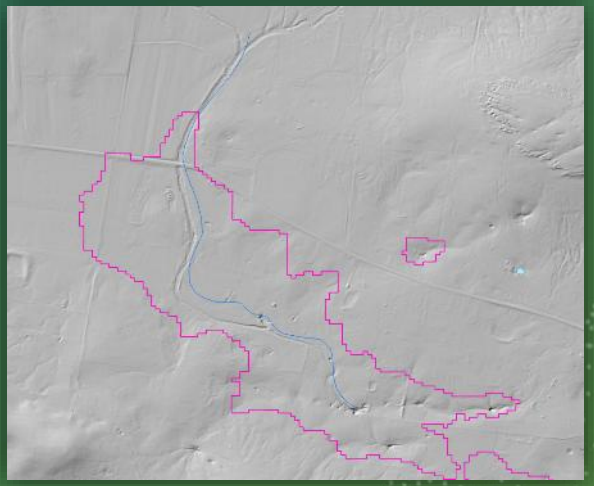
- *Utilized National Hydrography Dataset and a buffer distance based on consultation with Nashville District ACOE (conservative estimate not based on official guidance)*
- *NHD flowlines buffered on both sides 350 feet from centerline*
- *NHD waterbodies buffered by 350 feet from outer boundaries*

Isolated Wetlands Analysis
Karst Geology and Surface Connectivity





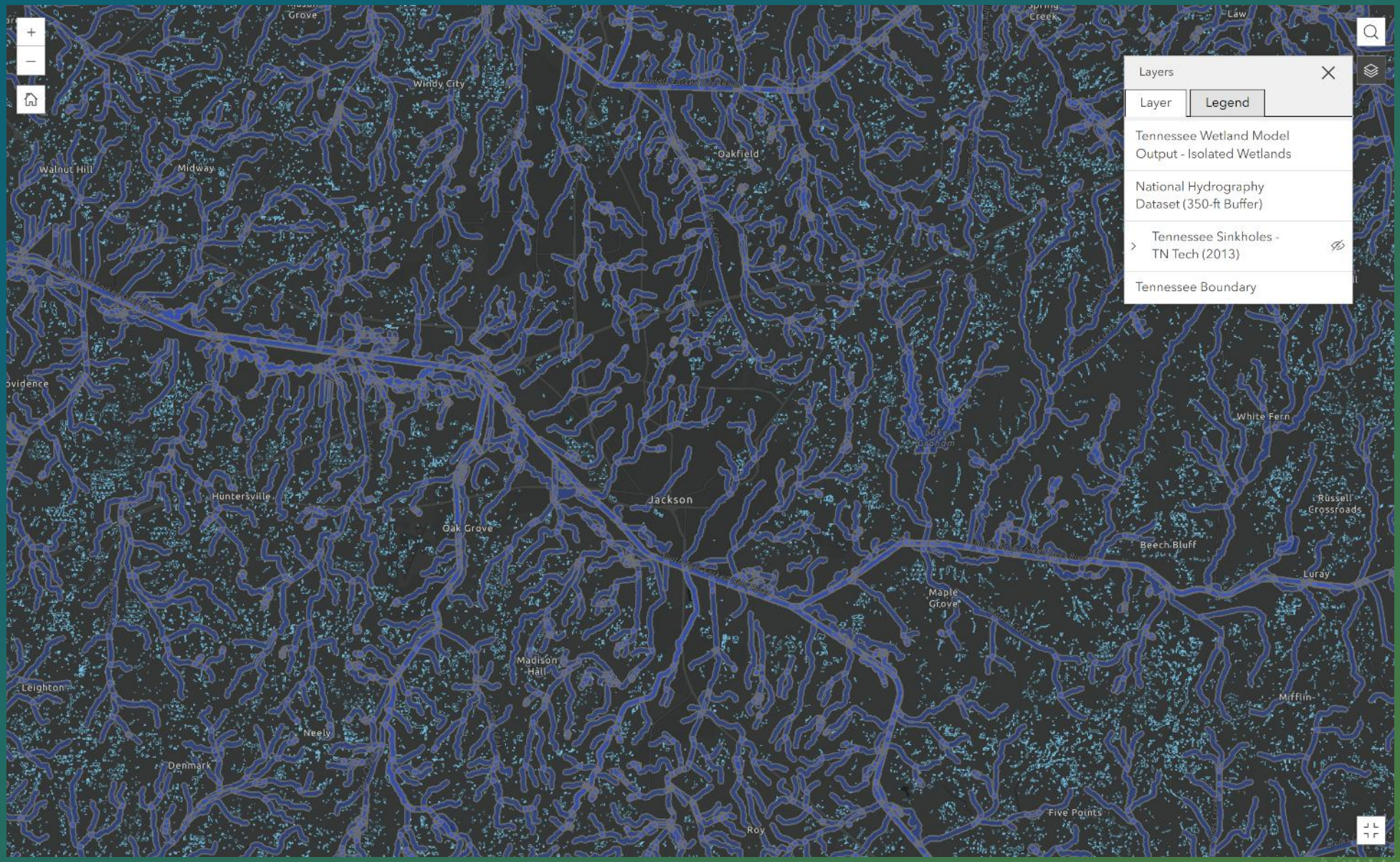
USGS 1:24,000 Topographic Quadrangles



LIDAR-derived Terrain

- *NHD flowlines queried to identity overlap with modeled sinkholes*
- *>5,100 flowlines visually assessed to determine if they terminate at discrete sinkhole and lack downstream channel*
- *These flowlines were removed from NHD dataset to identify areas of concentrated isolated wetlands due to karst geology*

Isolated Wetlands Analysis – Lacking Obvious Surface Connection



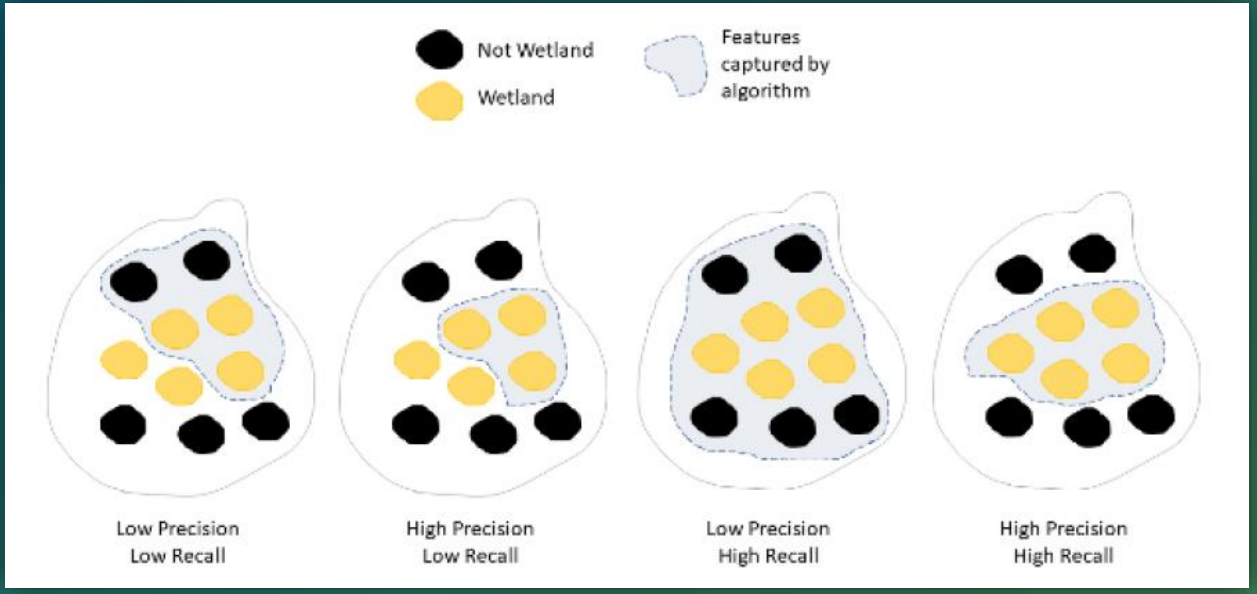
- **321,716** *acres of predicted wetlands occurring outside of buffered flowlines and waterbodies extracted to identify isolated features*

Model Raw Output Statistics

***F1 Score** is a metric to evaluate the performance of a classification model.*

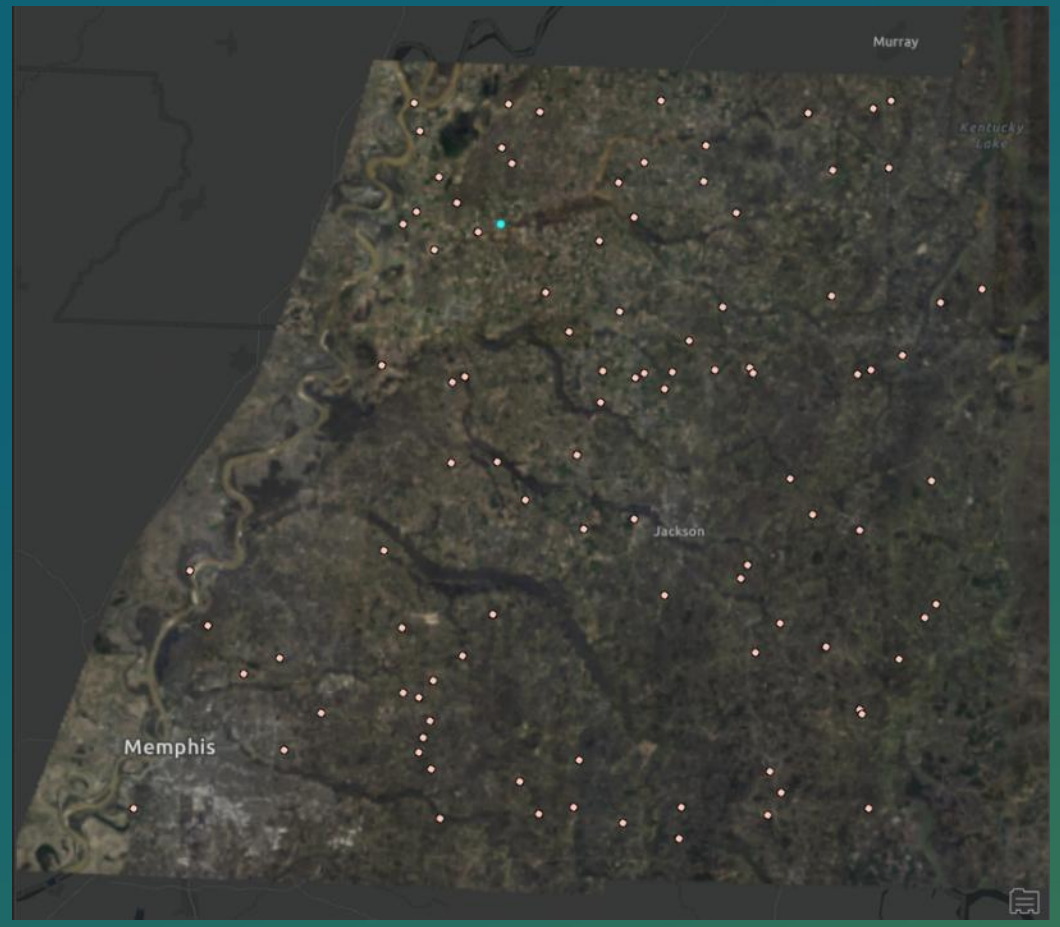
- *Value Ranges from 0 to 1*
  - *0.7 to 1.0 – considered excellent*
  - *0.4 to 0.7 – considered acceptable or good*
  - *<0.4 – indicate model needs improvement*

$$F1\ \text{Score} = 2\ x\ \frac{Precision+Recall}{Precision\ x\ Recall}$$



Ecoregion	Precision	Recall	F1 Scores
Blue Ridge	0.86	0.89	0.87
Ridge & Valley	0.86	0.94	0.90
Cumberland Plateau & Mtn	0.87	0.88	0.87
Highland Rim	0.72	0.88	0.79
Central Basin	0.86	0.96	0.91
MS Alluvial and Gulf Coastal Plain	0.72	0.88	0.79

Remotely Sensed Precision Assessment

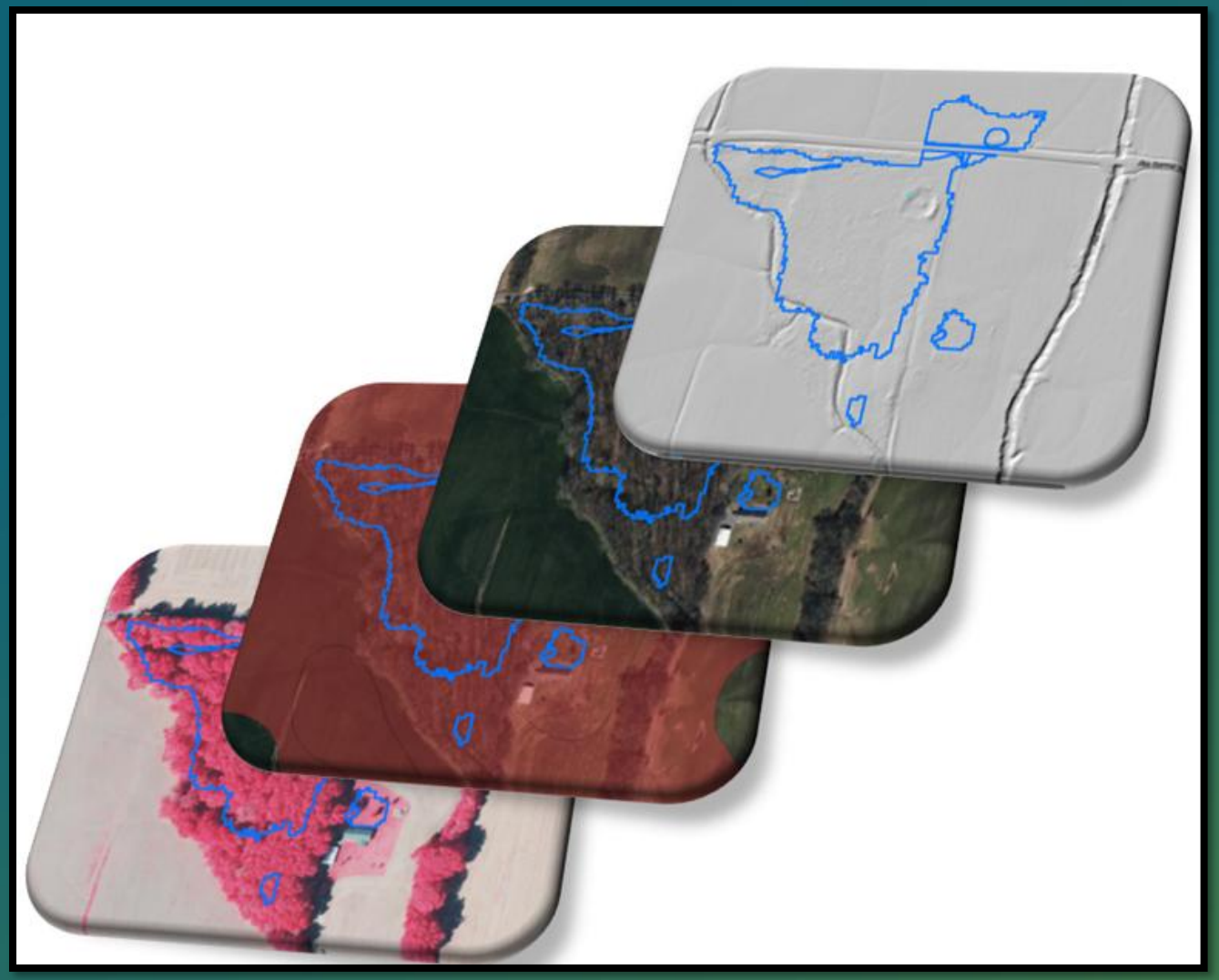


100 Randomly Selected Points to Classify Per Ecoregion

Each point was classified as one of the following categories using remote sensing:

- ***Wetland***: Entirety of feature is clearly a wetland
- ***Marginal Wetland***: Portion of feature overlaps obvious wetland or degraded wetland area with vegetation/saturation and terrain signatures
- ***Upland***: Obvious upland
- ***Unknown***: Unable to remotely sense classification based on available data

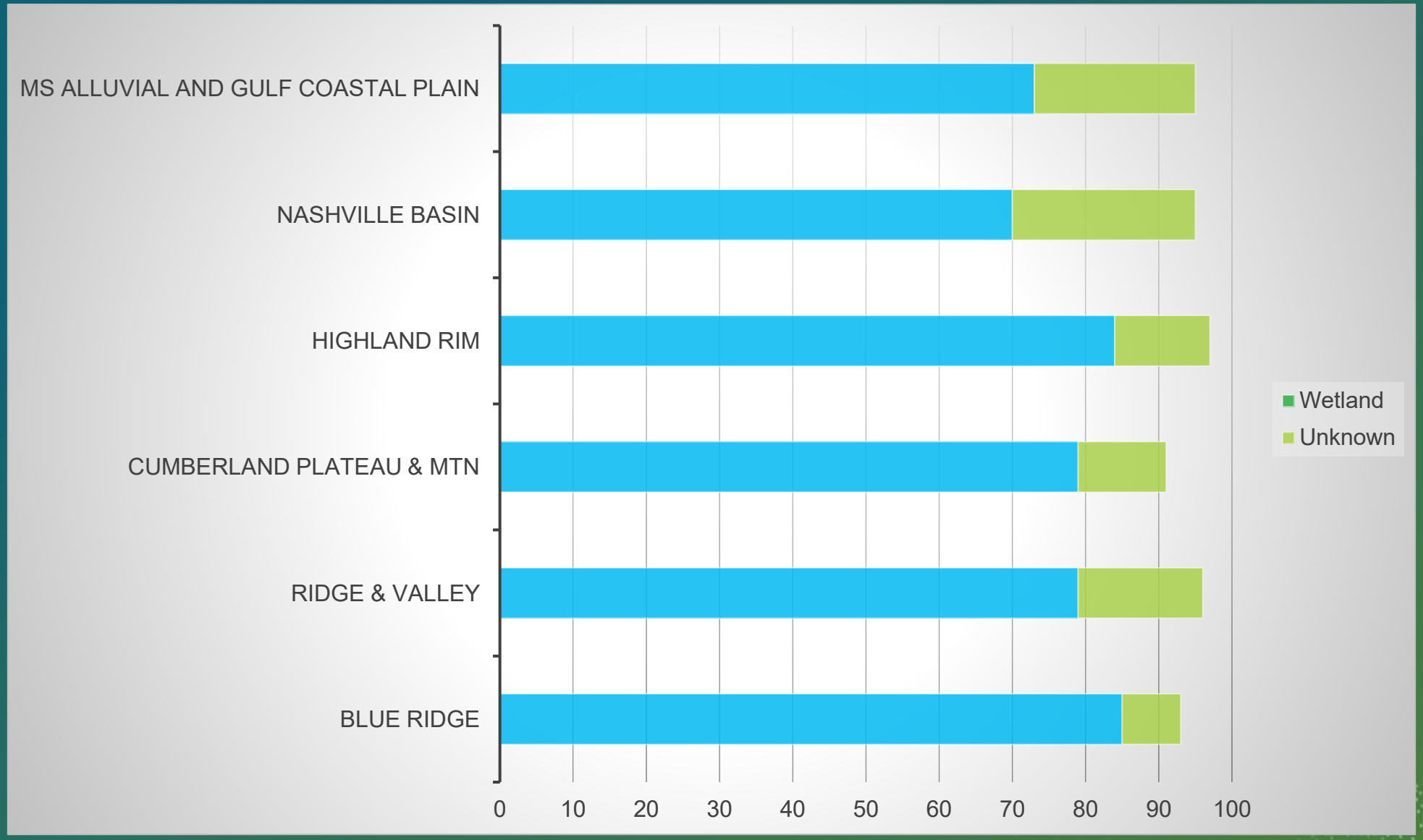
Random Point Classification Example



Referenced Datasets:

- *LiDAR-derived Terrain*
- *6-inch Resolution Vexcel Imagery*
- *SSURGO Hydric Soils*
- *NAIP Color Infrared Imagery*

Remotely Sensed Precision Assessment



Key takeaways points:

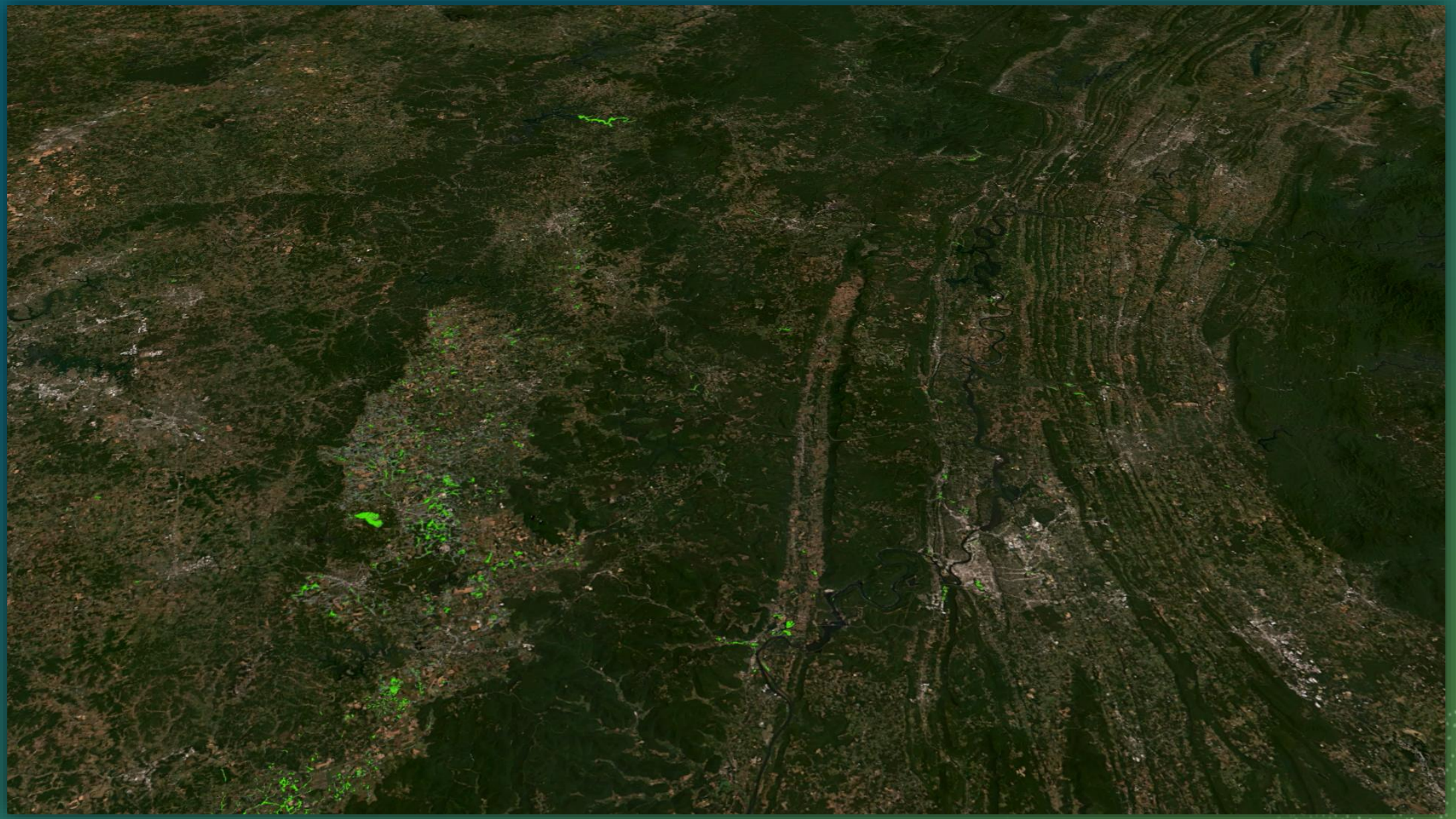
It is vital to have highly curated training data. Without it, the model would not have produced accurate wetland areas.

The effort and networking needed to create the training dataset took as much or more time than creating the models themselves.

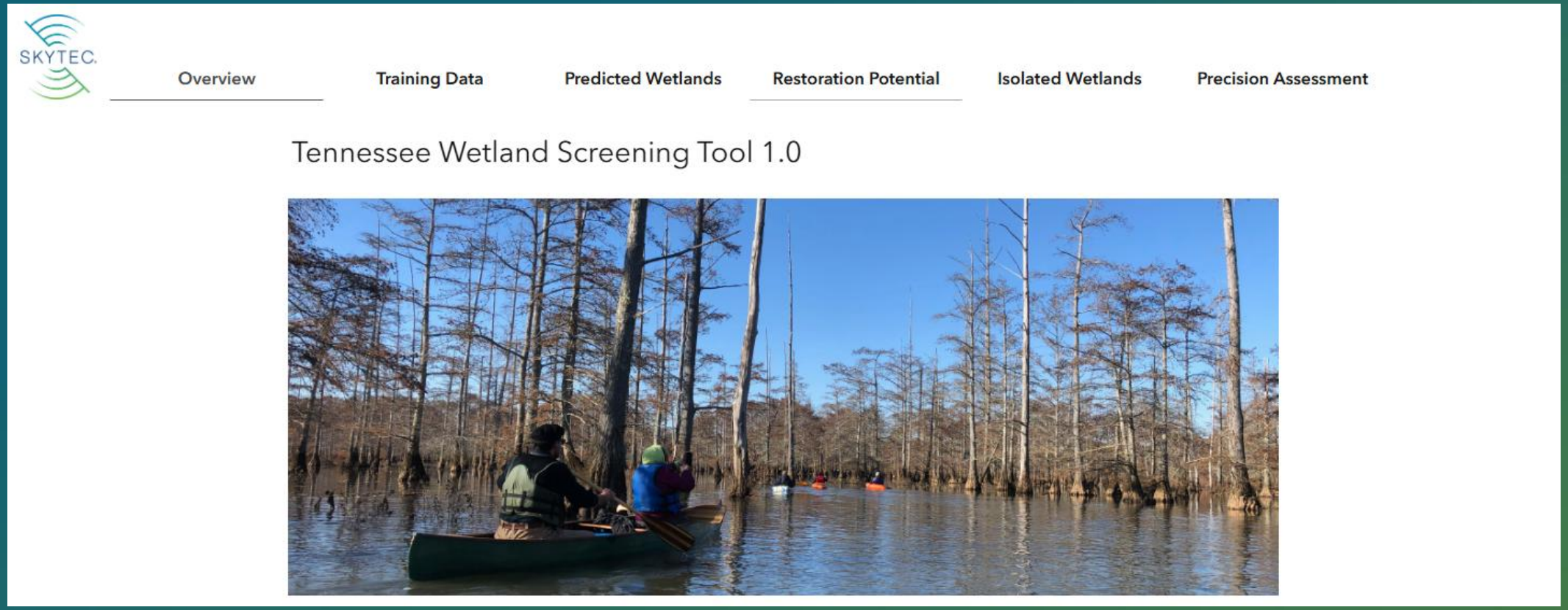
Completing a project of this scale requires significant computing power. Microsoft played a crucial role in this work by collaborating and providing us with several GPU enabled virtual machines and Azure storage.

Microsoft

Image Source: Esri Professional Services



Tennessee Wetland Screening Tool 1.0



- **Public Viewer Officially Launched on the TDEC Website on 1/13/2025**
- **25K views, 5,100 unique users, 52K events** from more than **44 countries** since launch
- **Tennessee Wetland Screening Tool 1.0 -** https://www.tn.gov/environment/program-areas/wr-water-resources/watershed-stewardship/wetlands.html

Building a Resource Management and Monitoring System

- GIS serves as backbone
- Using high performance compute and/or cloud-based GIS allows for modeling priorities at scale
- Creates a uniform system for tracking changes on the landscape and conducting risk assessment
- Extendable to field or remote monitoring

** Opportunities to Innovate*

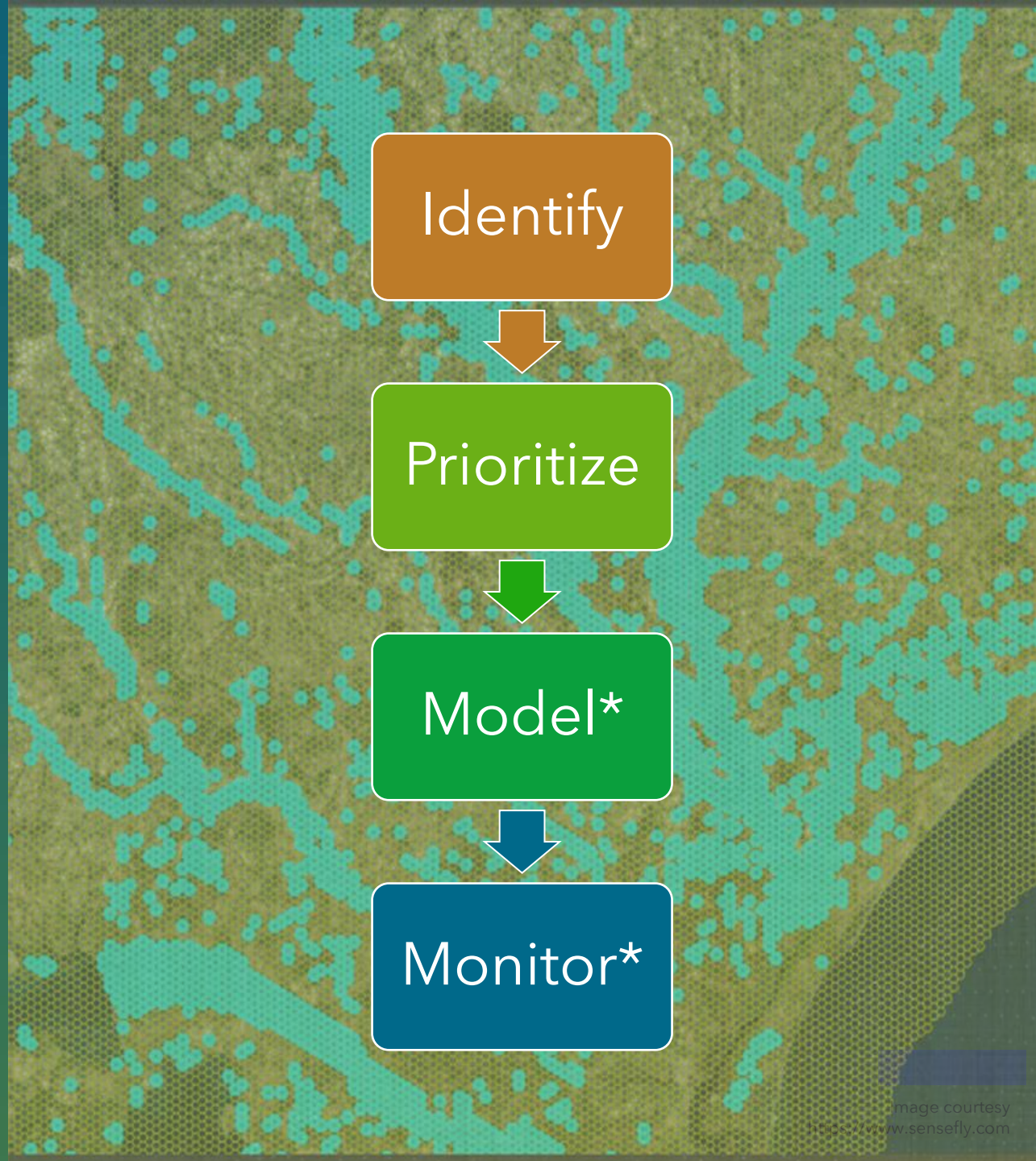


Image courtesy https://www.sensefly.com

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Key Technology Innovations in Remote Monitoring

Multiscale Sources

High Frequency Acquisition

Geo AI/ Analytics

GIS Integration

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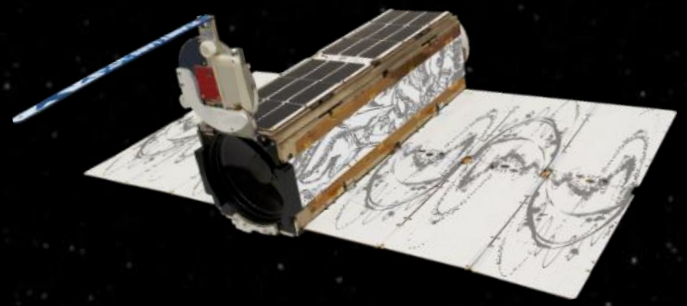
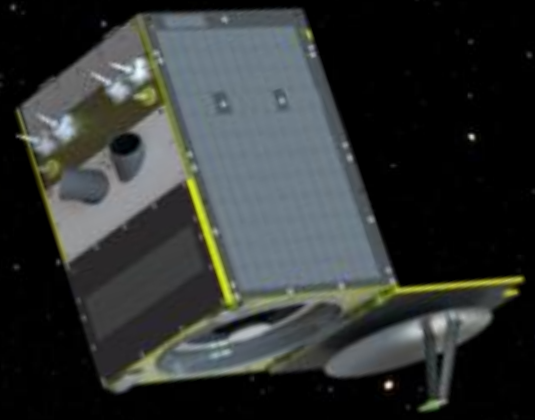
MISSION 1

To image the whole world every day, **making change visible, accessible and actionable.**

Planet’s industry-leading constellations





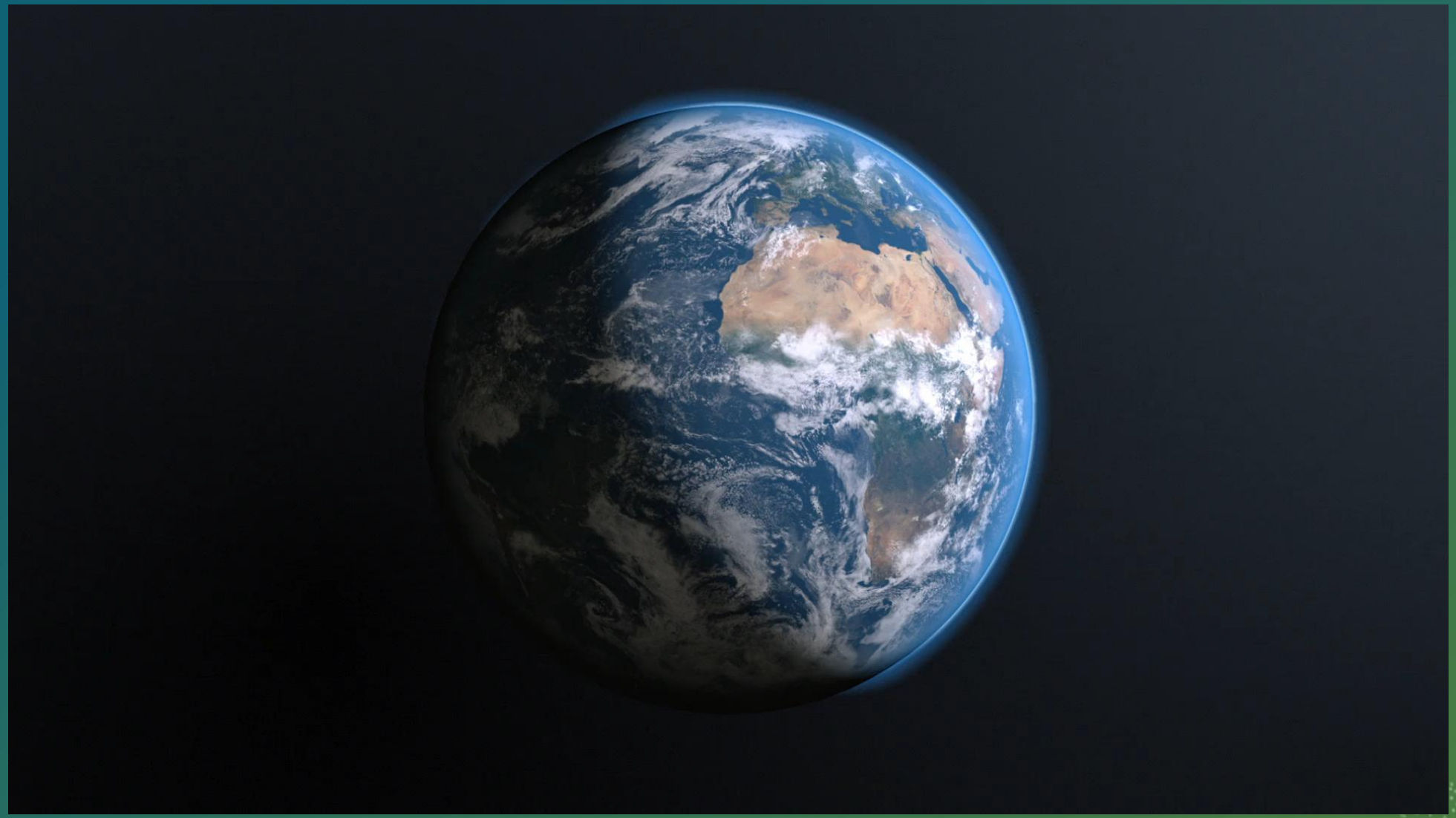
180+

Dove Satellites
PlanetScope (3.7 m)

21

SkySat
Satellites (50 cm)

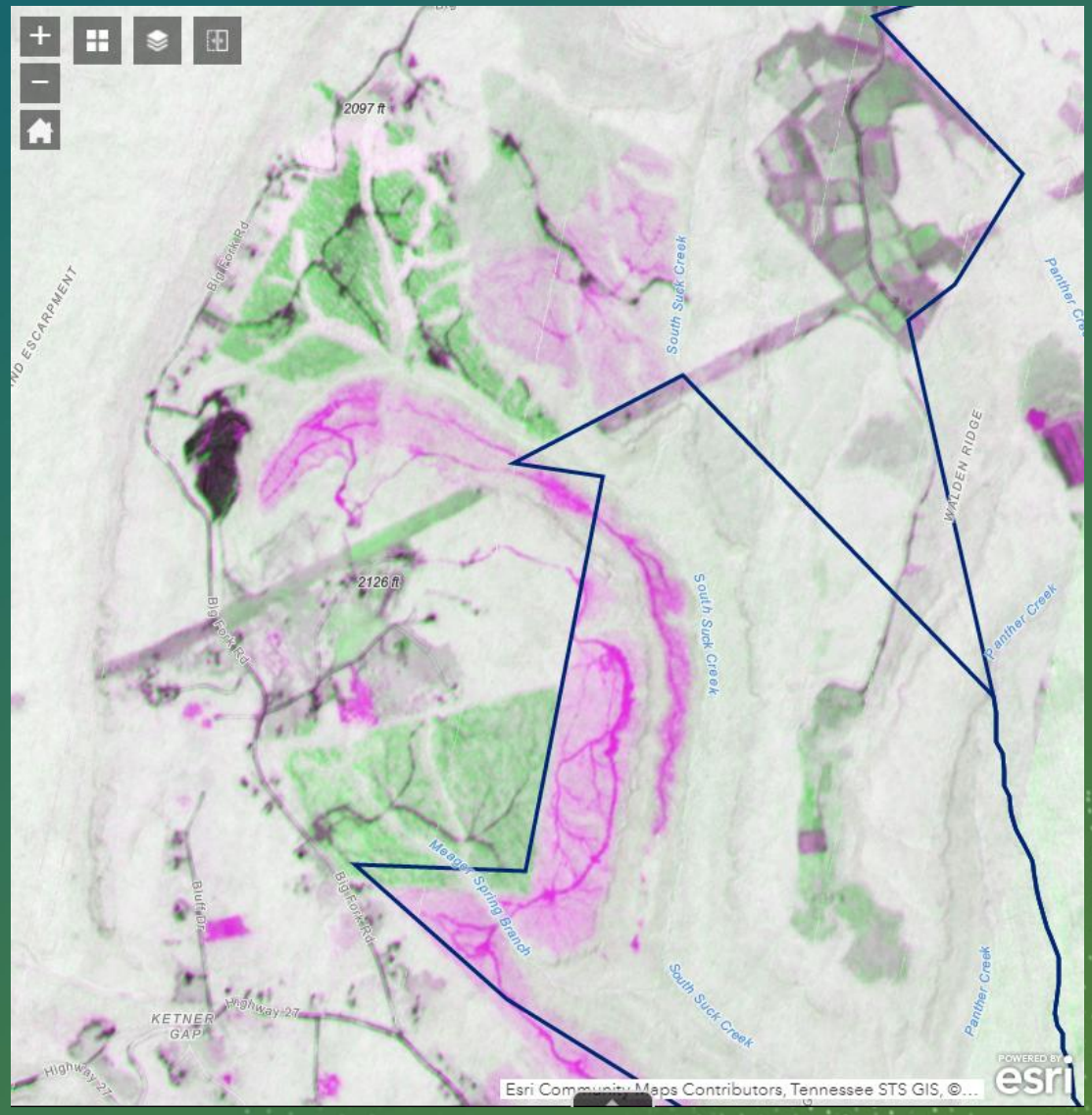
Rapid Revisit Imaging

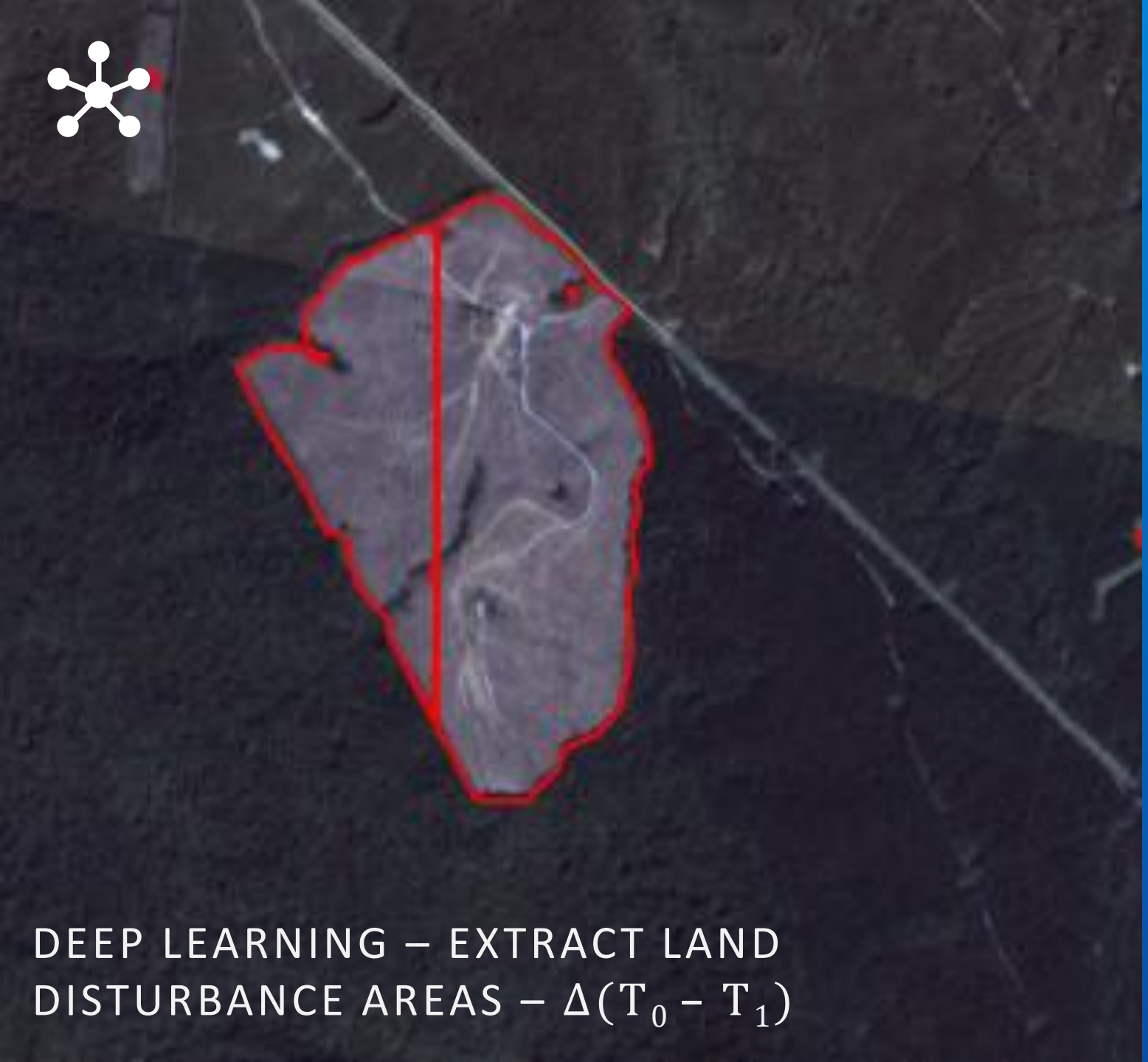


Images courtesy of Planet Labs PBC

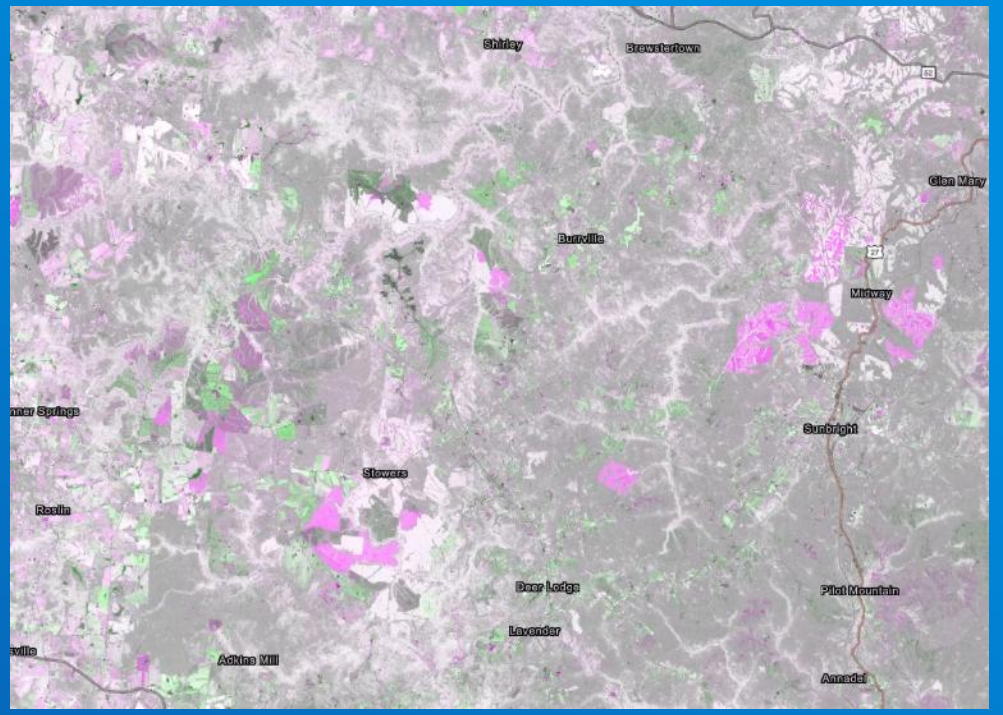
GeoAI - Monitoring Analytics

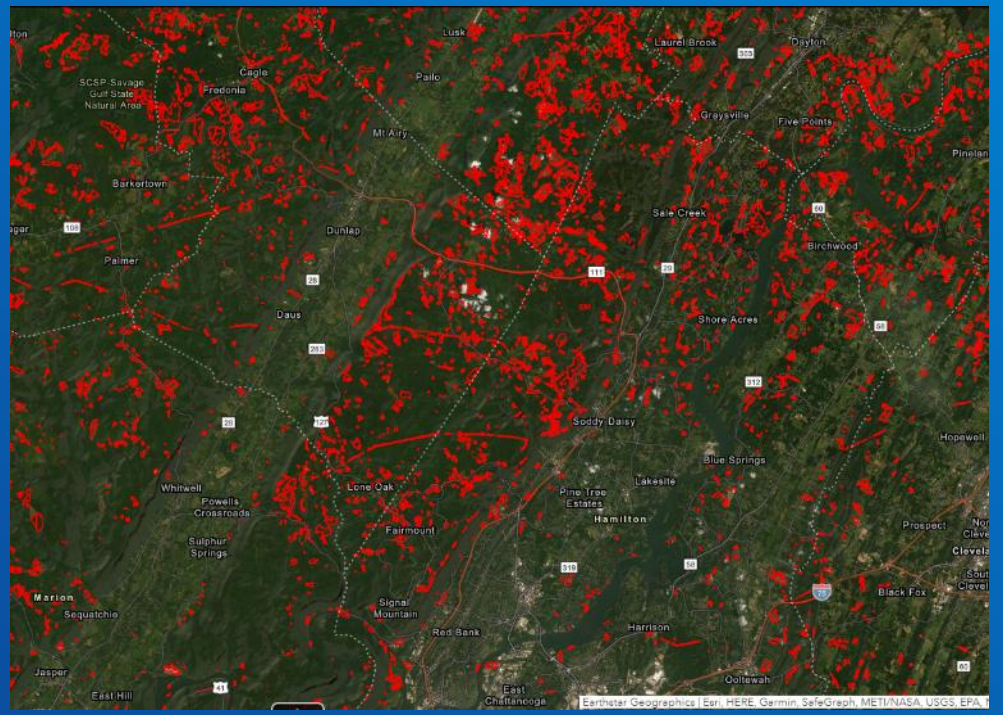
- Satellite imagery used for automating change detection
- Near Infrared band of imagery used to create indices
- **Green** areas represent vegetation growth
- **Magenta** areas represent harvesting or land disturbance
- Combination of spectral difference over time and machine learning feature extraction



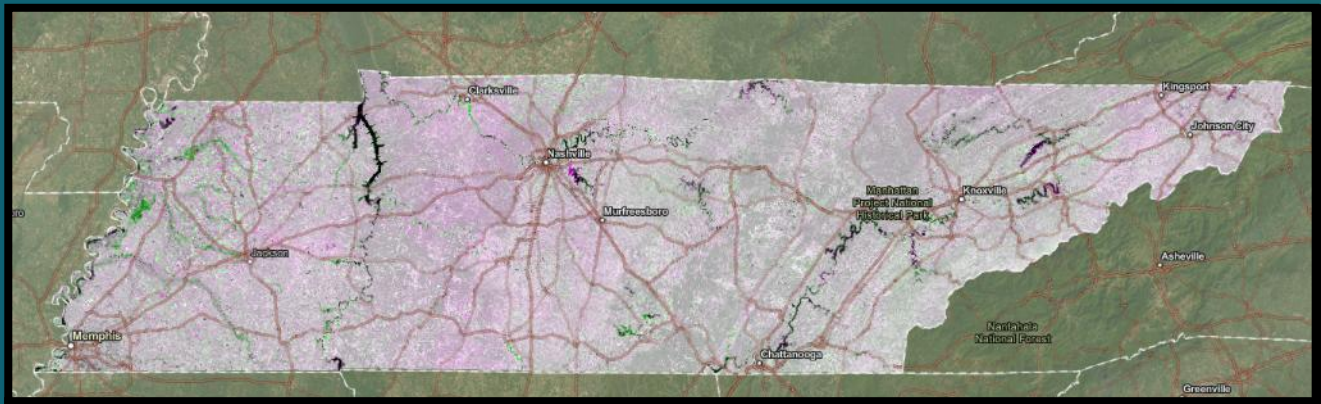


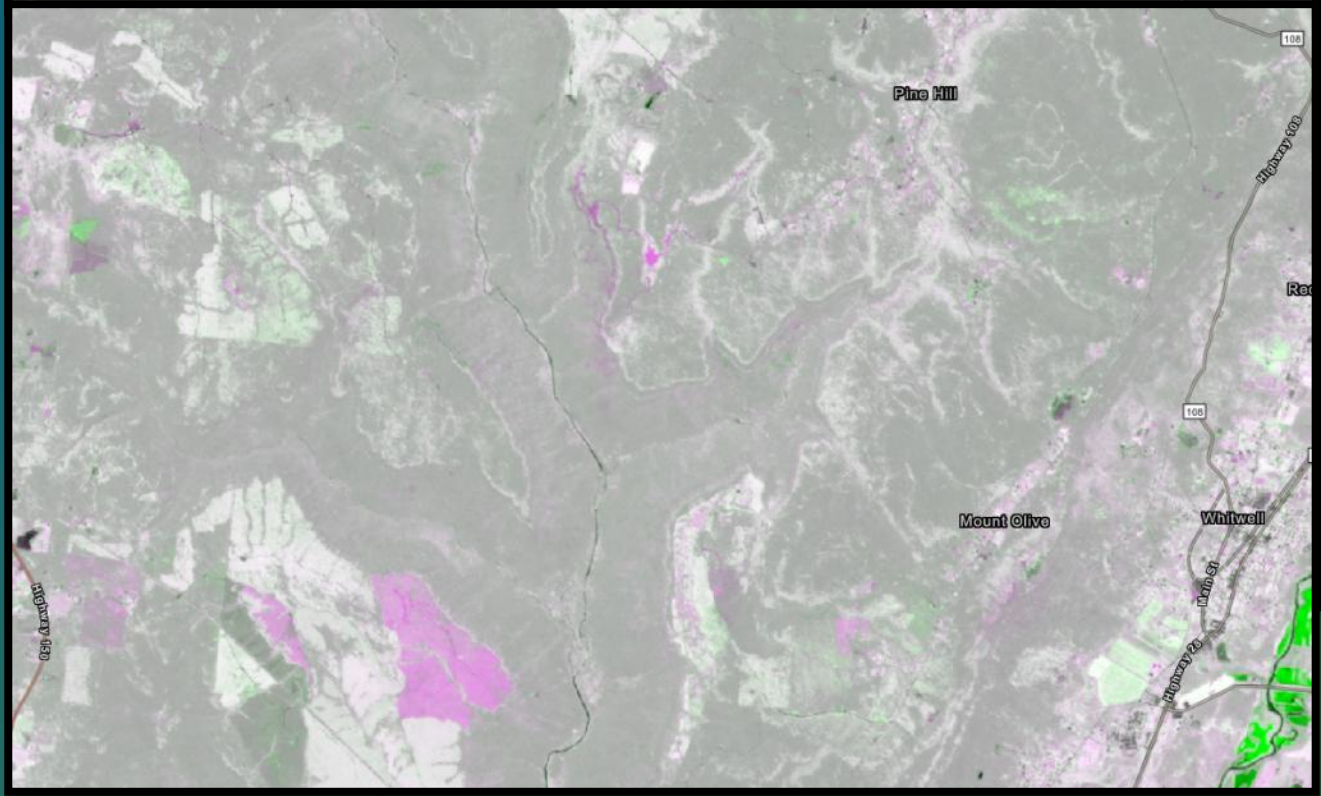
DEEP LEARNING – EXTRACT LAND DISTURBANCE AREAS – $\Delta(T_0 - T_1)$





Monitoring at Scale





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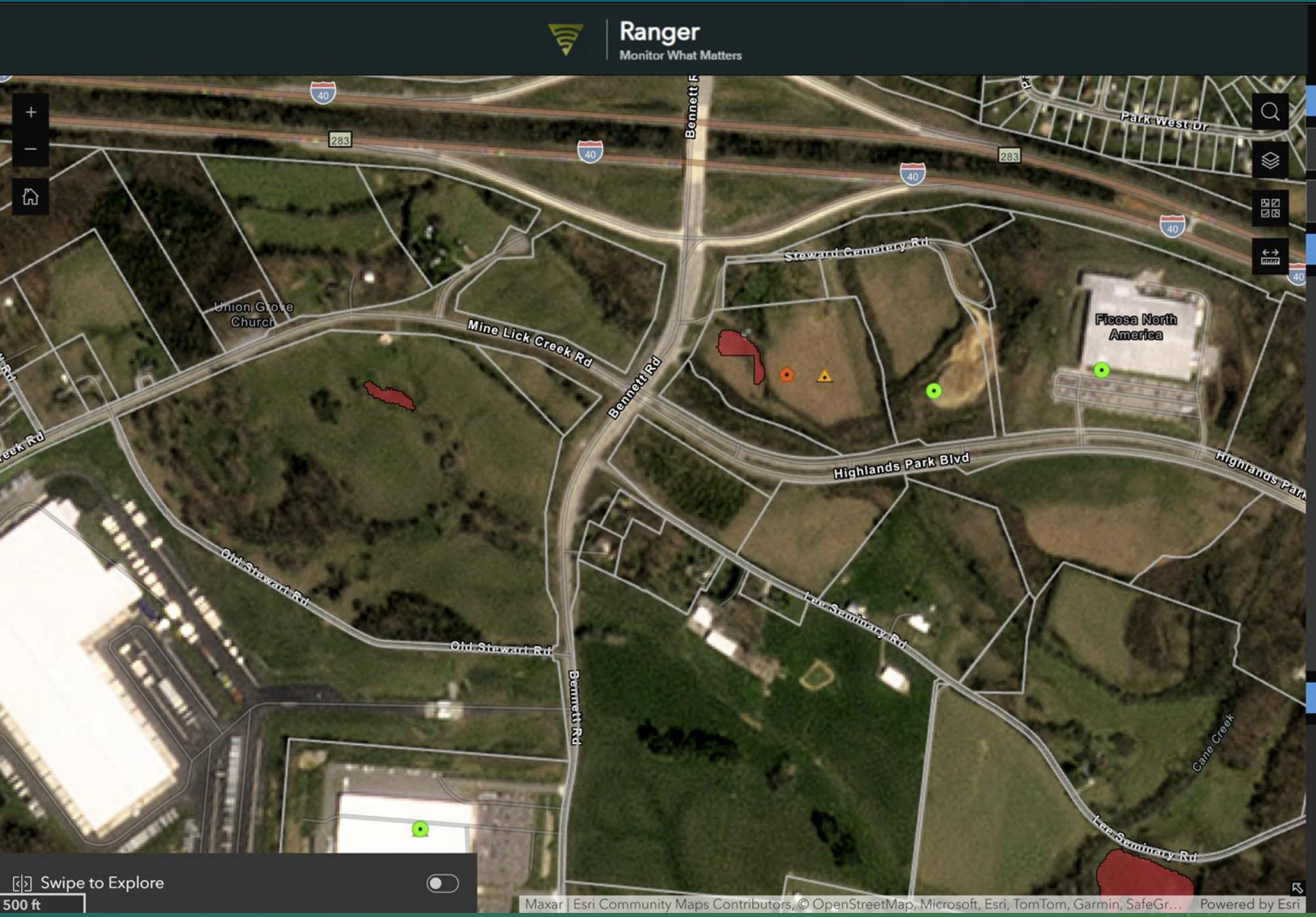
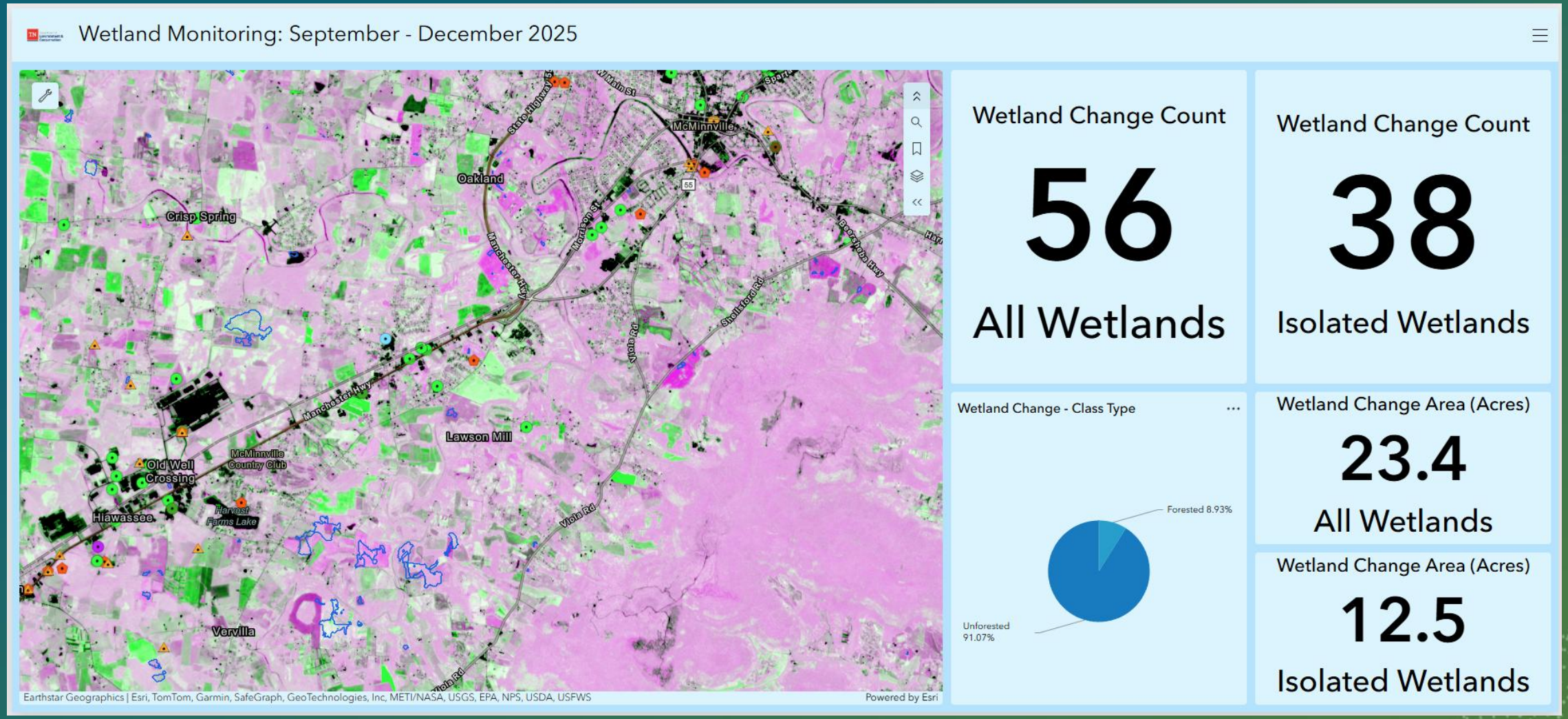
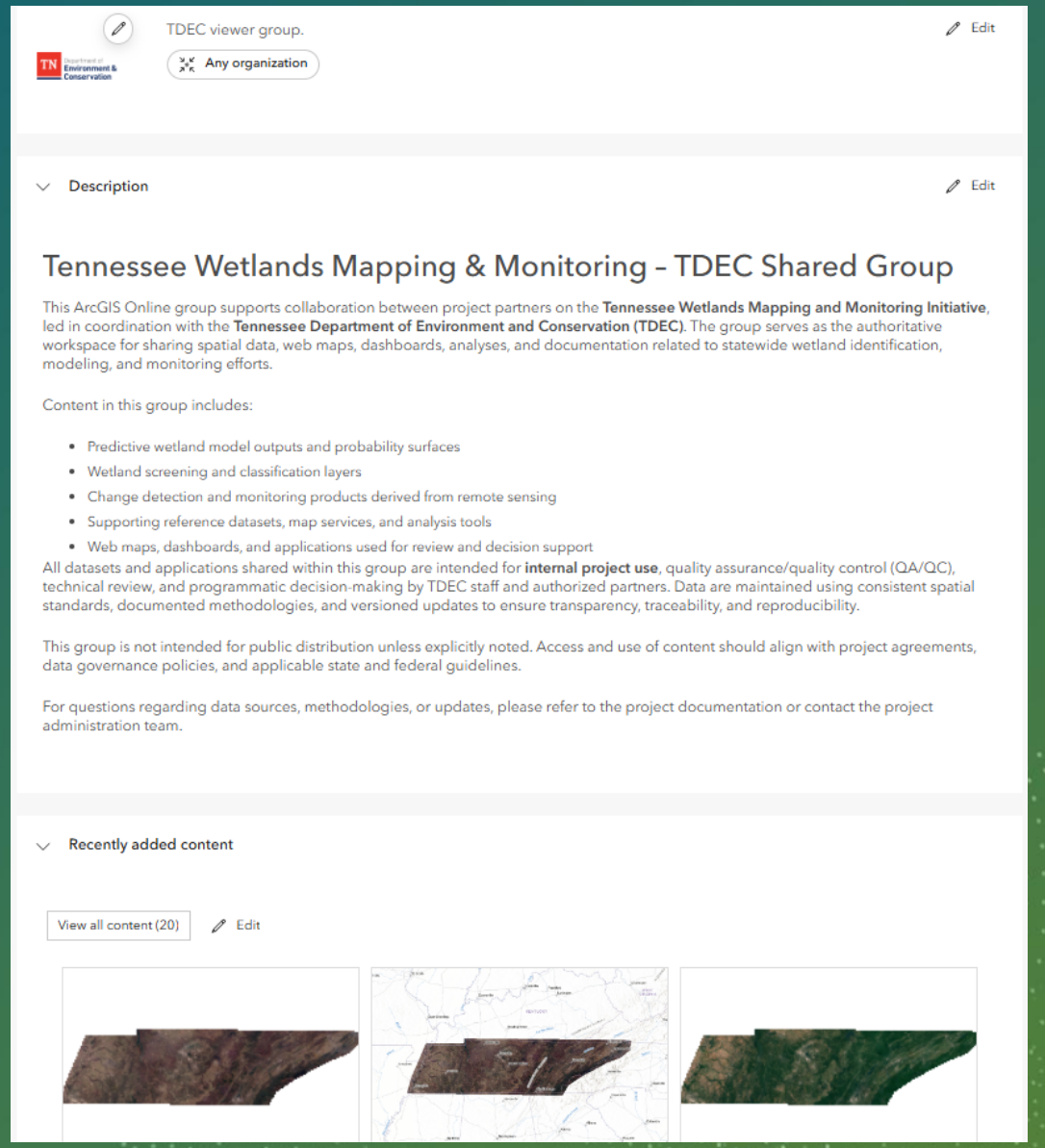

Ranger
Monitor What Matters
Add Data
Bookmark
Draw
Edit
Data Filters
Wetland Impacts > 0.05 acres
Remove Agricultural Land
Search Results
Wetland Impacts - Map View
Spatial filter
Choose the filter type
Current map extent
Apply
Reset
Imagery Layers
Change In Wetlands
Global Monthly 2025 03 Mosaic
Global Monthly 2024 03 Mosaic
CDViz March 2024-2025
Swipe to Explore
500 ft
Maxar | Esri Community Maps Contributors, © OpenStreetMap, Microsoft, Esri, TomTom, Garmin, SafeGr...
Powered by Esri
Union Grove Church
Mine Lick Creek Rd
Bennett Rd
Steward Cemetery Rd
Park West Dr
Ficosa North America
Highlands Park Blvd
Old Stewart Rd
Lee Seminary Rd
Cane Creek
283
40

Wetland Monitoring



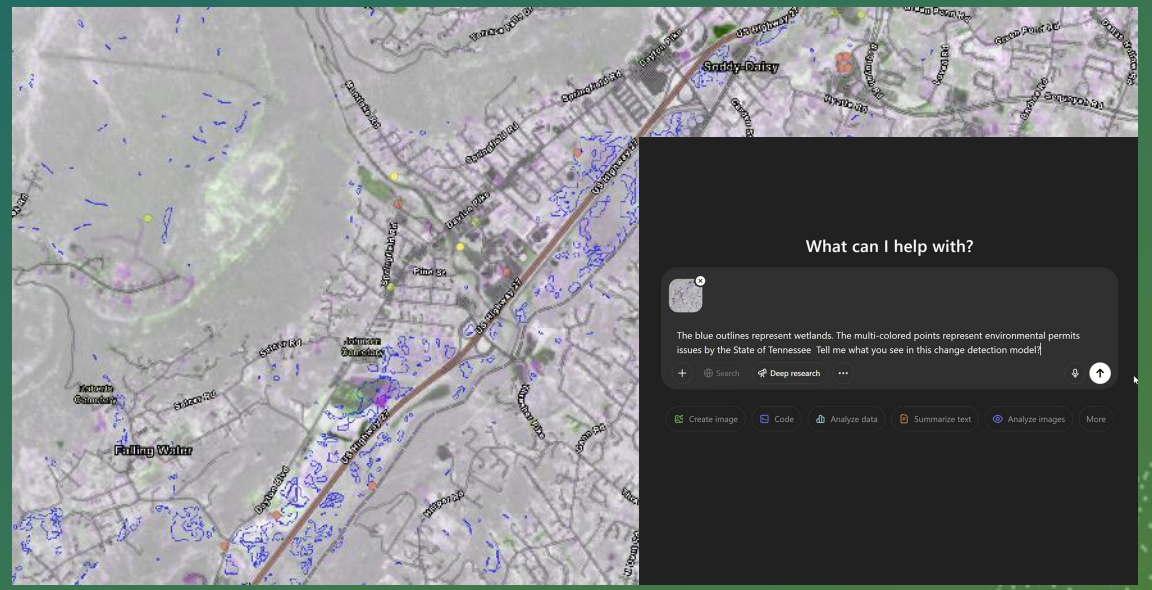
Data Delivery through ArcGIS Online

- Quarterly wetland changes and change visualization models shared through collaboration group in ArcGIS Online
- This includes statewide monthly imagery from Planet
- Available for use in any of Tennessee's Esri products

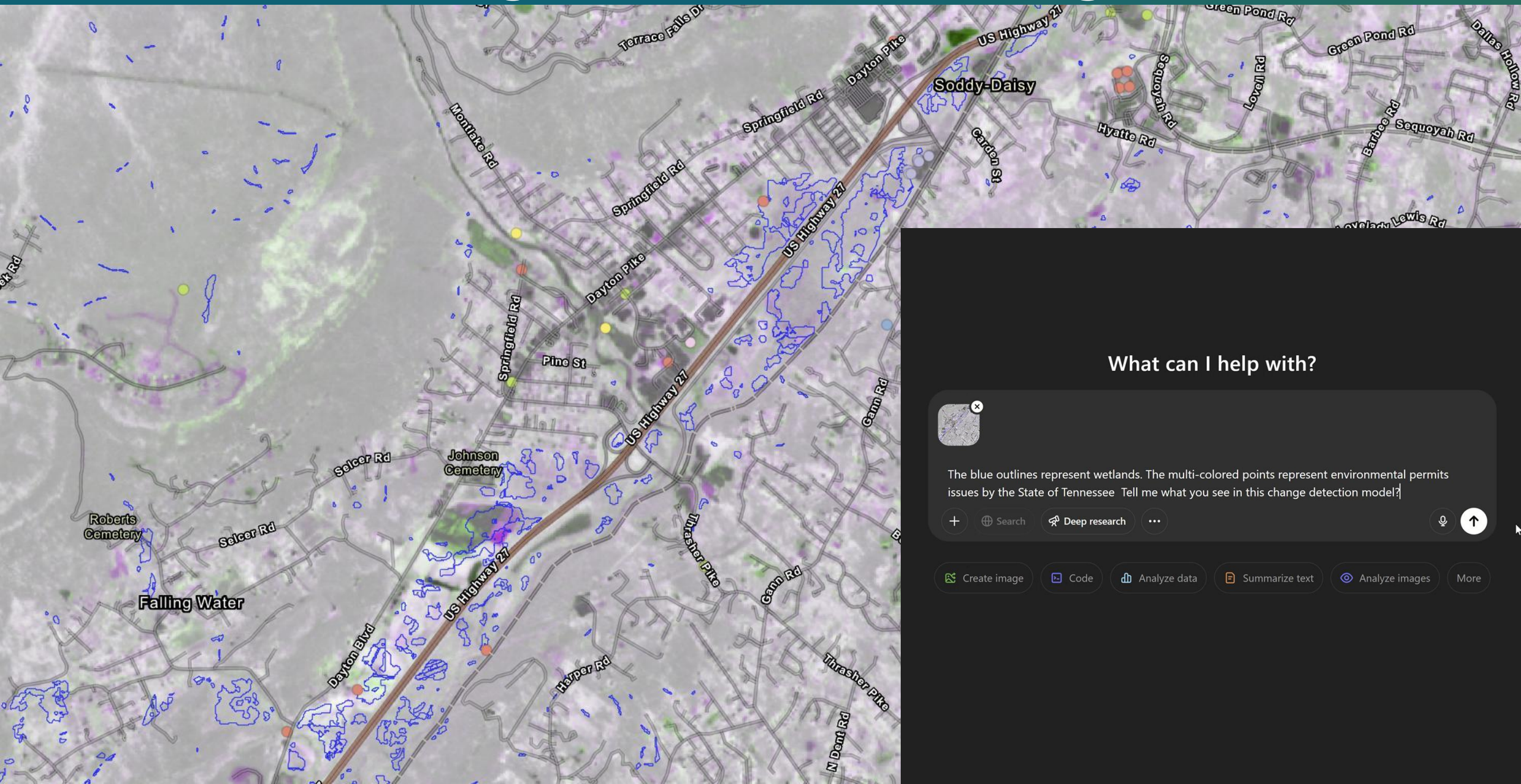


What is next?

- Wetland model updates - 2027
  - Update & refine training data
  - Integrate new LiDAR and imagery
- Refine wetland classifications
- Quarterly monitoring at scale
- AI Agent Integration - Reporting



AI Agent-Based Monitoring



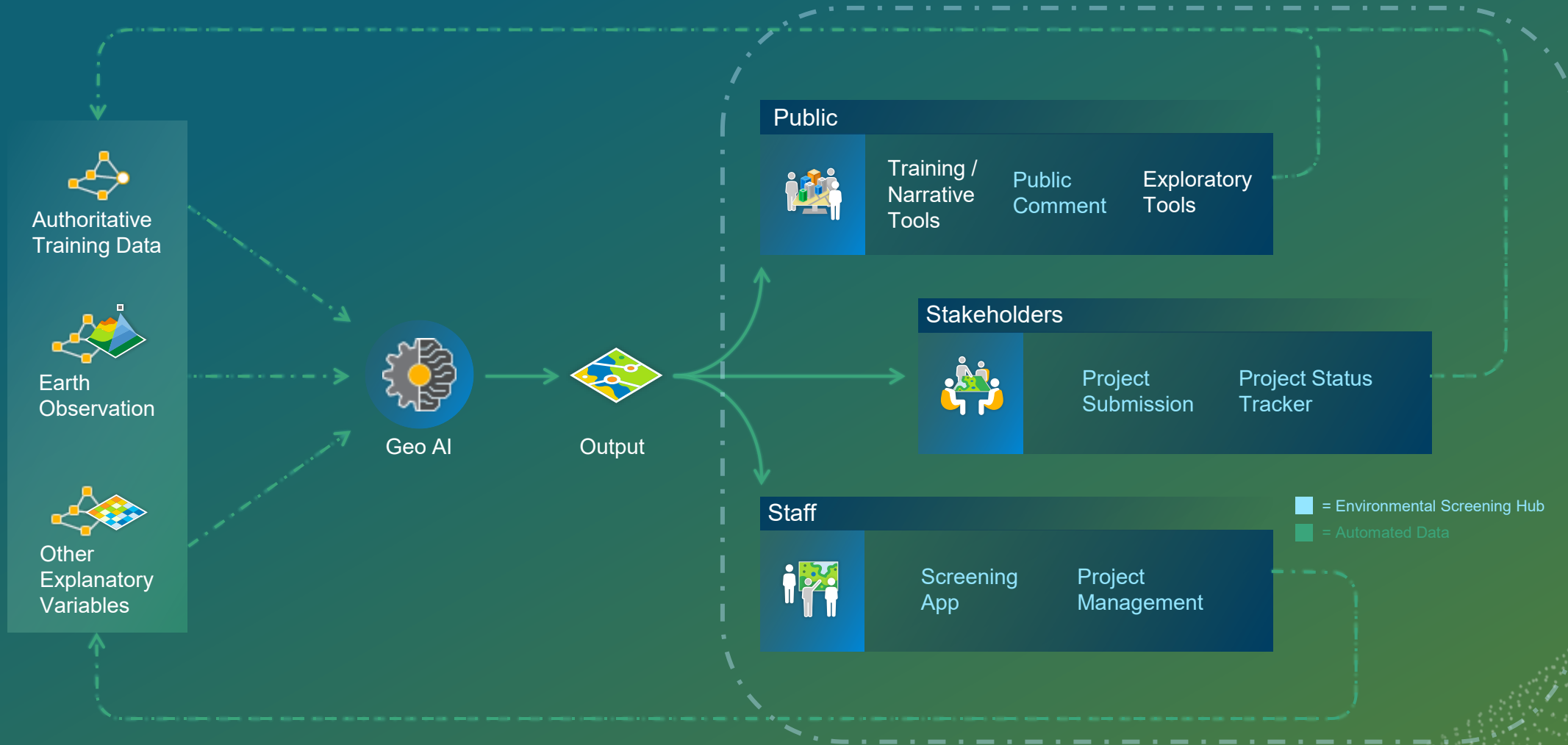
Better Customer Service

GIS Facilitating Holistic Workflows

“Legislators, nonprofits, and members of the public were calling us, and they all wanted to know how many wetlands were in the state and where did we get that number from. We knew we needed better data; a statewide number; and, importantly, [to be] able to predict **where** *they are.”* – April Grippo, Water Director, TDEC

“There are a lot of finances that go into purchasing property, and stakeholders want to know what their constraints are. So for this project, the goal was for **more informed decision-making** *no matter who you were,”* - Skytec

A Holistic Wetlands Workflow

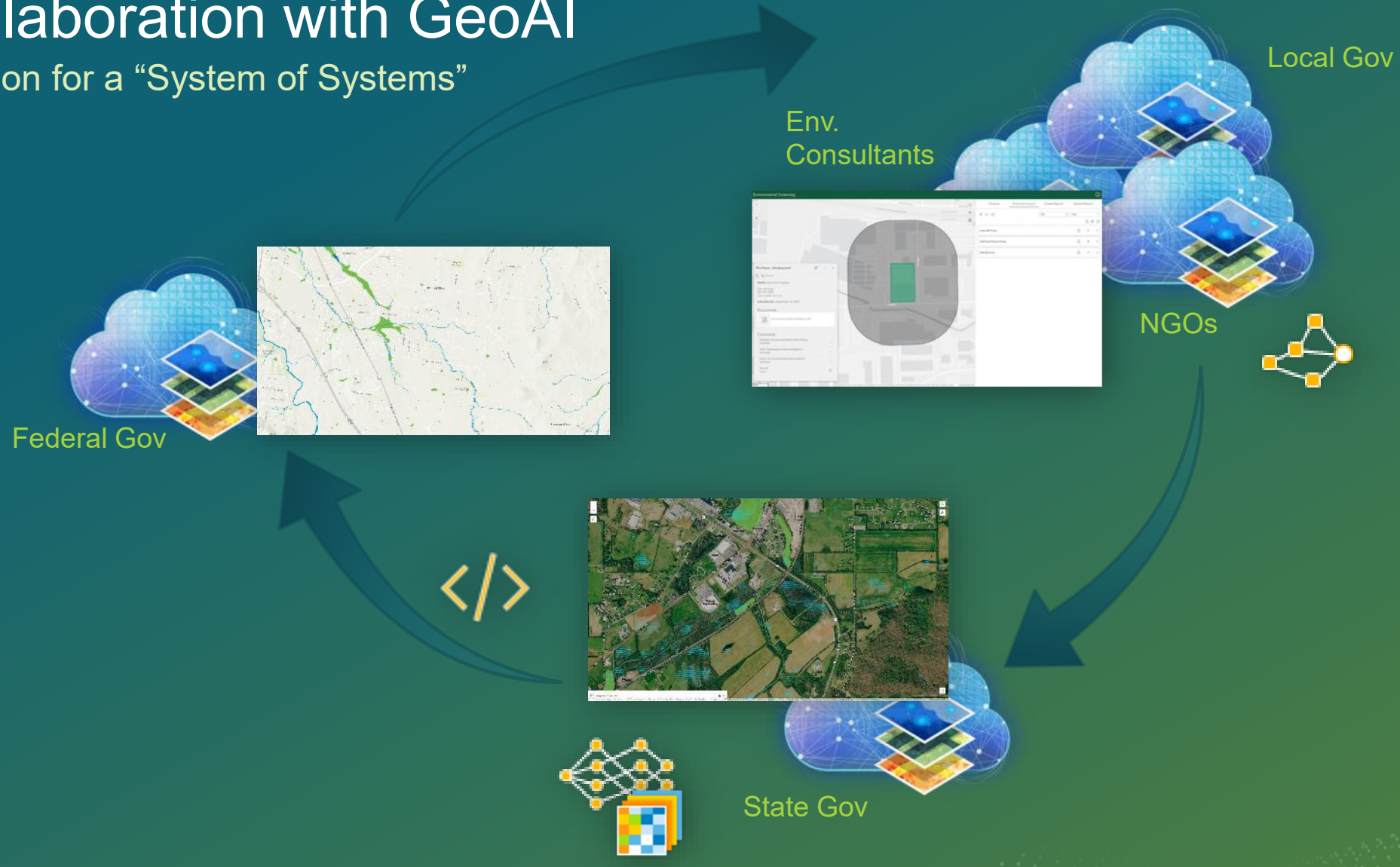


Collaboration with ArcGIS

A Vision for a “System of Systems”

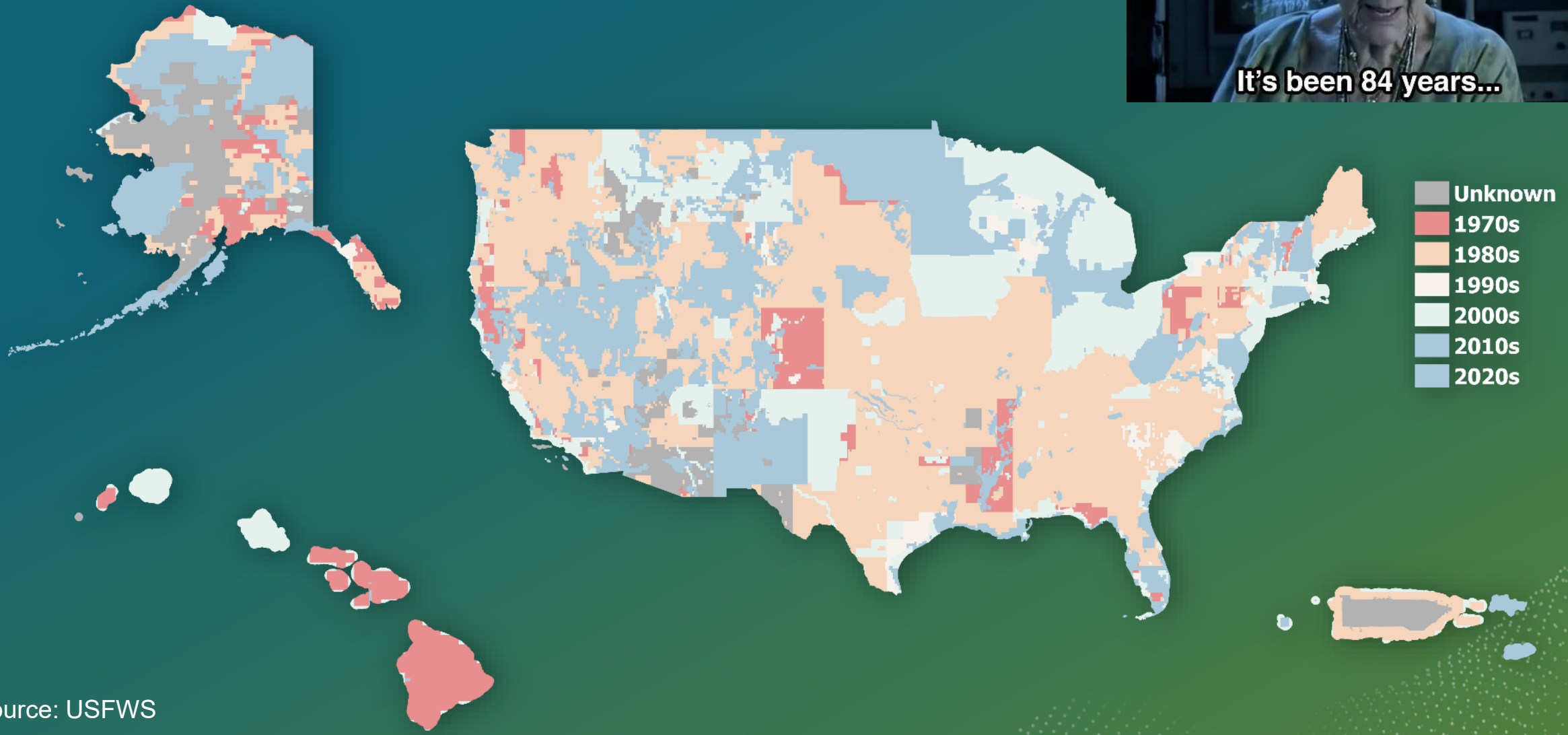
Collaboration with GeoAI

A Vision for a “System of Systems”



To Solve This…

We can all help contribute!



Source: USFWS

Get in Touch

Stay up to date

Tennessee Case Study

Esri Environment & Natural Resources e-Brief

- Does the community want a "Wetland Delineation" ArcGIS Solution?

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Andy Carroll: acarroll@skytecllc.com

Skytec Wetlands