Automated Shoreline Extraction from UAS Imagery

Jupiter Inlet Lighthouse Outstanding Natural Area (ONA)

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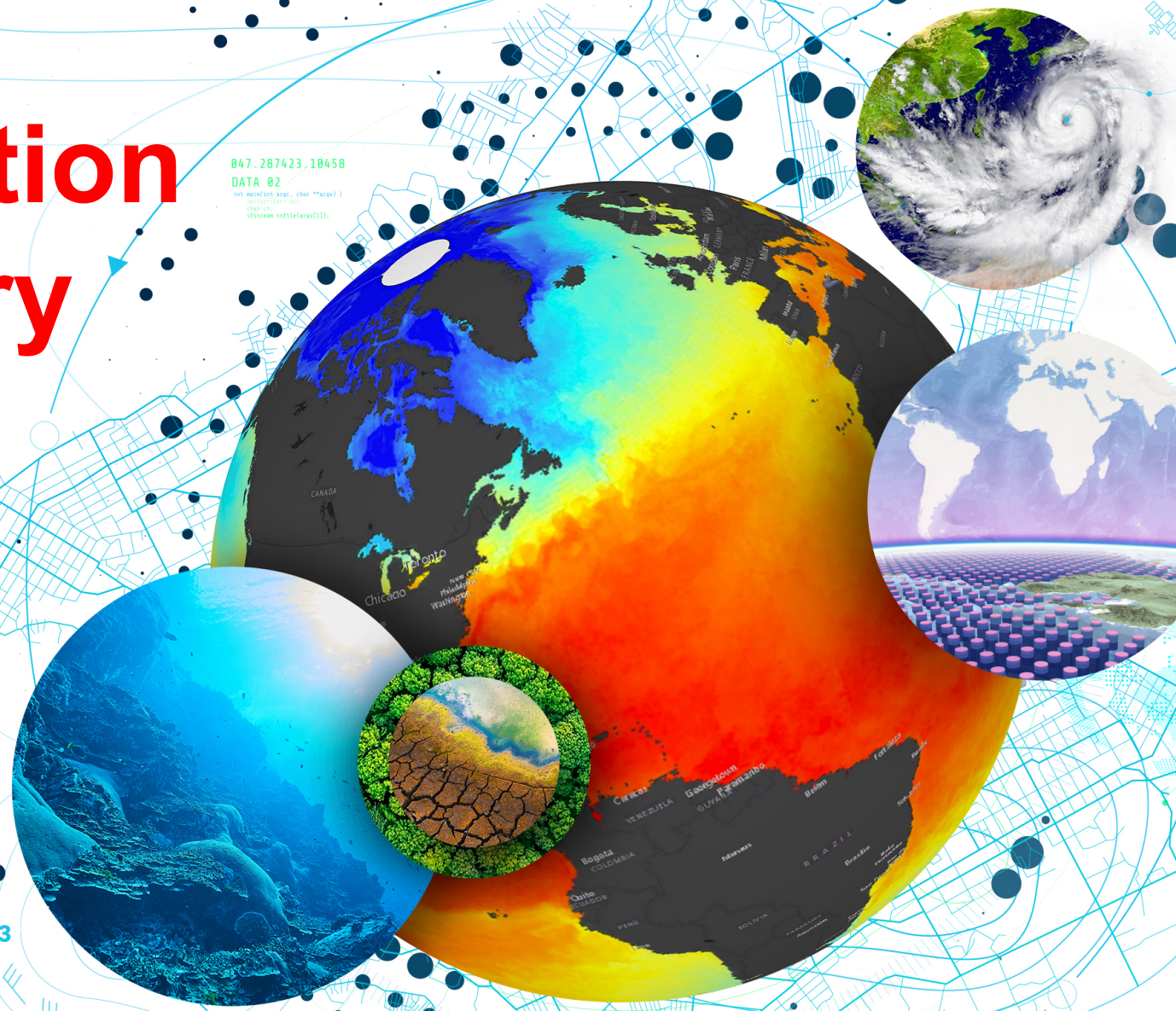

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2021
Ocean, Weather, & Climate GIS Forum

@Place: Esri Ocean, Weather, and Climate GIS Forum

@Date: 3-4 November 2021

Agenda

- Introduction & Background
- Objective
- Data collection
- Methodology
- Results and Discussion
- Future Scope

Significance of the research

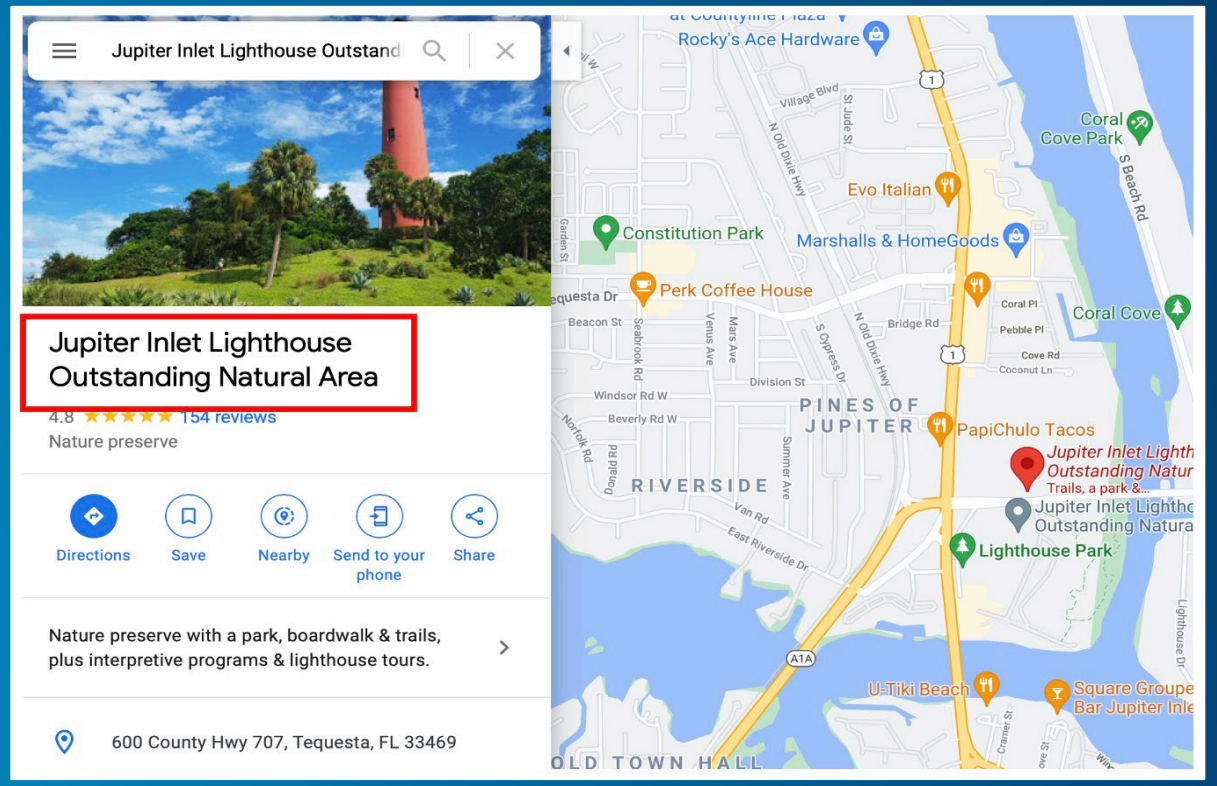
- Ever-changing features of the coastal landscape
- Reflects the natural processes of erosion as well as deposition
- Complex, dynamic, and unstable geomorphic components in the coastal environment
- Traditional extraction process are mostly manual and time-consuming
- Extract the features in a short span of time without much human intervention is of paramount importance

Significance of Study Area

- **Congressionally designated protected area – an Outstanding Natural Area**
- **Habitat for over 700 species of plant, animal, fungi, and lichen.**
  - **Includes 28 Special Status Species, including 6 federally listed as Threatened and Endangered.**
- **Important Historic and Cultural resources dating back over 8,000 years.**
  - **National Register Listed Lighthouse**
  - **Eligible Historic District**
  - **Significant Archaeological Sites**
- **Over 100,000 visitors each year.**

Study Area

- ✓ Indian River Lagoon and Loxahatchee River: US-1 Bridge to South Beach
- ✓ Road Bridge (CR/SR 707)
- ✓ 120-acre site owned and managed by the U.S. Department of the Interior Bureau of Land Management (BLM)
- ✓ Approximately 3200 feet or 0.6 mile of shoreline



Background projects of Jupiter Inlet Lighthouse ONA

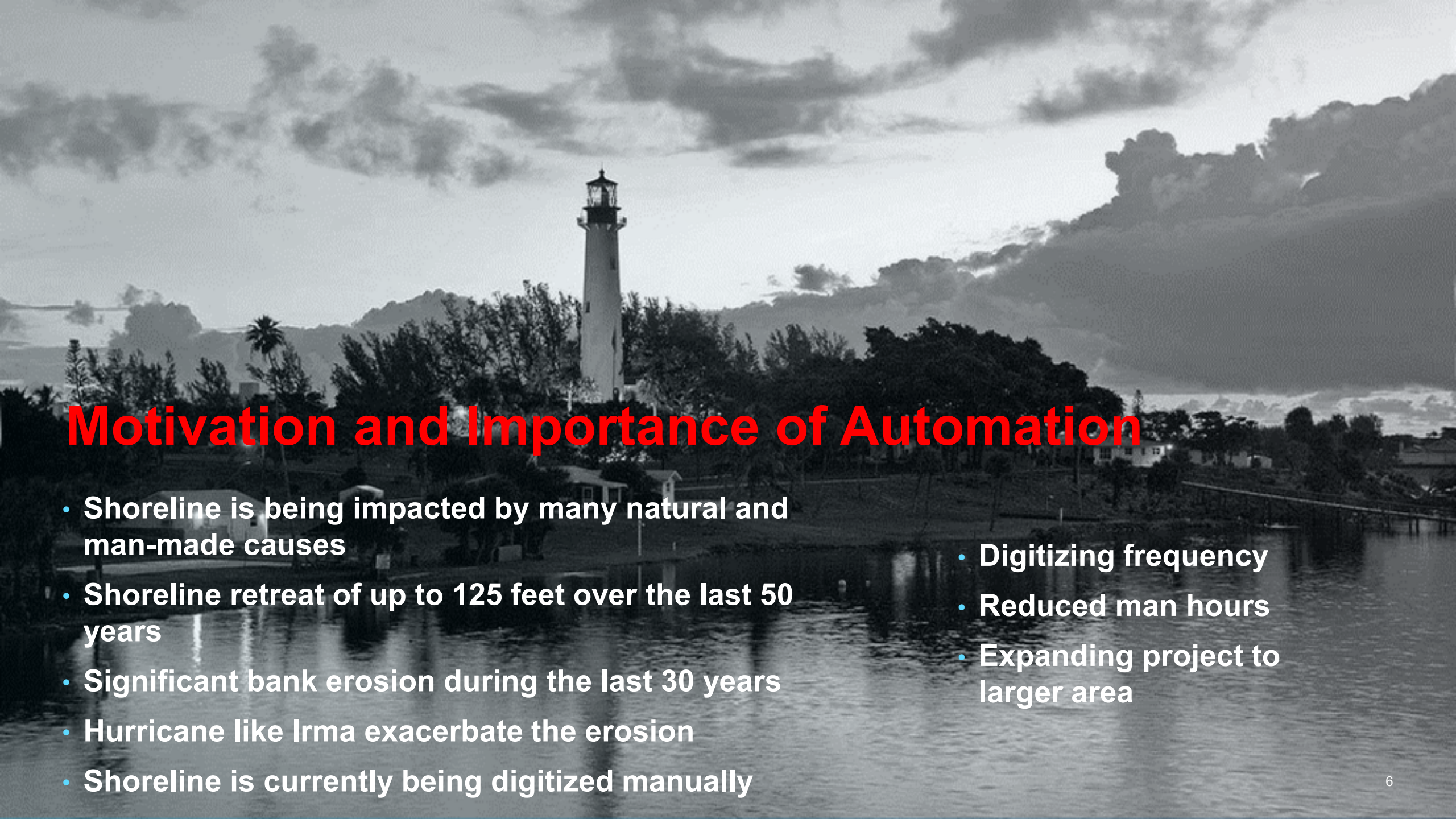
Our lab is working with Bureau of Land Management for the last 5 years

- 2017 Terrestrial Laser Scanning data along the shoreline
- 2017 Pre-Hurricane Irma – UAS RGB data
- 2017 Post-Hurricane Irma – UAS RGB data
- 2018 – UAS RGB data
- 2019 – UAS RGB data
- 2020 – UAS RGB data
- 2020 – UAS Multi-spectral data
- 2021 – UAS RGB data

Shoreline Change detection from 1953 to 2021

Volume Change along the shore

Vegetation Classification mapping using Machine & Deep Learning techniques



Motivation and Importance of Automation

- Shoreline is being impacted by many natural and man-made causes
- Shoreline retreat of up to 125 feet over the last 50 years
- Significant bank erosion during the last 30 years
- Hurricane like Irma exacerbate the erosion
- Shoreline is currently being digitized manually

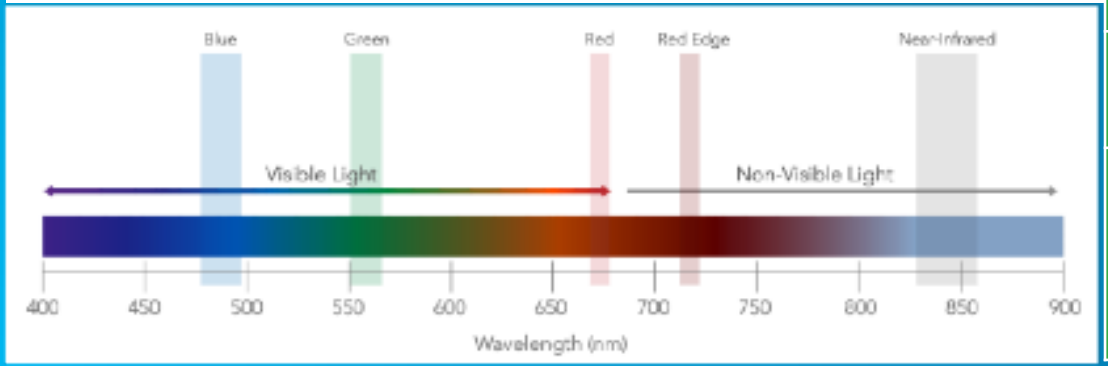
- Digitizing frequency
- Reduced man hours
- Expanding project to larger area

Literature Review

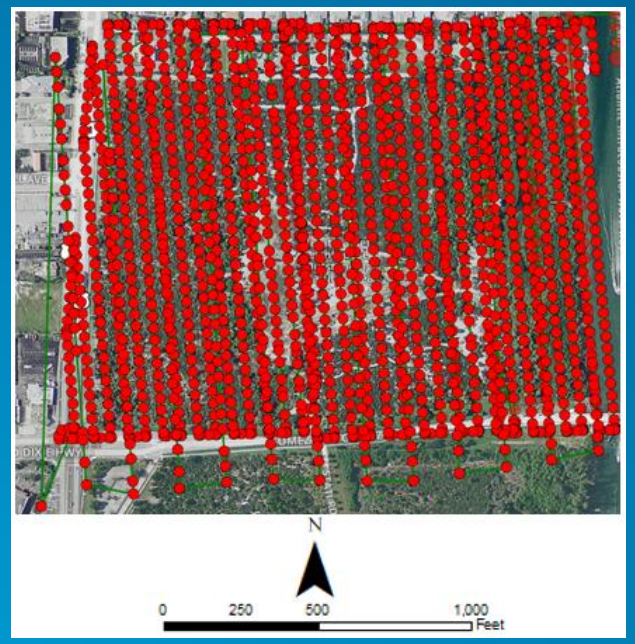
COASTLINE EXTRACTION USING LANDSAT-8 MULTISPECTRAL IMAGERY AND BAND RATIO TECHNIQUE	COASTLINE EXTRACTION USING HIGH RESOLUTION WORLDVIEW-2 SATELLITE IMAGERY	PERFORMANCE EVALUATION OF SHORELINE EXTRACTION METHODS BASED ON REMOTE SENSING DATA	INTER-COMPARISON OF REMOTE SENSING SENSING-BASED SHORELINE MAPPING TECHNIQUES AT DIFFERENT COASTAL STRETCHES OF INDIA
Shivani Pathak February 10, 2021	Pasquale Maglione, Claudio Parente, et al. February 17, 2017	Sameh B. El Kafrawy, Mohamed E. Basiouny et al. September 14, 2017	Swathy Sunder, RAAJ Ramsankaran, et al. June 13, 2017
The United States, India	Campania Region (Italy)	Ras El-Hekma, NW - Egypt	India
Used Band Ratio technique (**Blue > NIR and Blue > Red**) from 30m resolution Landsat 8 imagery	NDVI and NDWI using WorldView-2 imagery	Digitization, Thresholding band ratio, and classification, Normalized difference water index (NDWI), Normalized Difference Vegetation Index (NDVI), and Improved method using Landsat 8 imagery	NDWI, Modified NDWI, Improved Band Ratio, and Automatic Water Extraction Index using multitemporal Landsat data. Validated using Cartosat-2 (panchromatic) and multispectral images of Google Earth

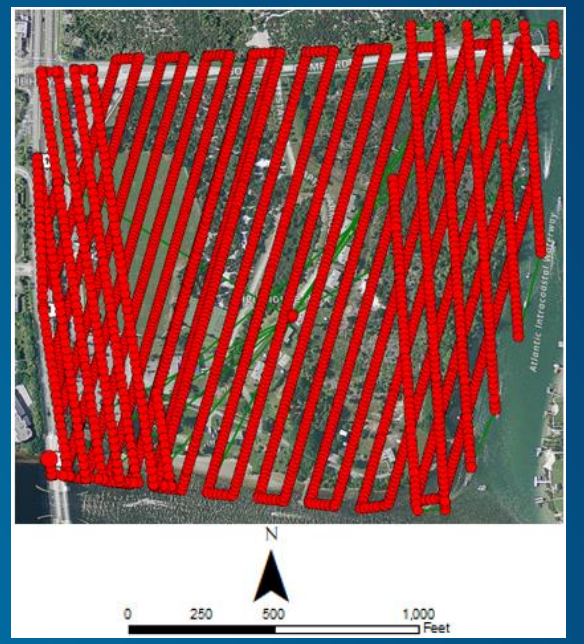
Red Edge Micasense Specifications

Band Number	Band Color	WAVELENGTH	
		Center (nm)	Bandwidth (nm)
1	Blue	475	32
2	Green	560	27
3	Red	668	16
4	Red Edge	717	12
5	Near - IR	842	57



COMPONENT	DESCRIPTION
Weight	231.9 g (8.18 oz.) - (Includes DLS 2 and cables)
Dimensions	8.7 cm x 5.9 cm x 4.54 cm (3.4 in x 2.3 in x 1.8 in)
Spectral Bands	Blue, green, red, red edge, near-infrared (NIR) (global shutter, narrowband)
RGB Color Output	Global shutter, aligned with all bands
Ground Sample Distance (GSD)	8 cm per pixel (per band) at 120 m (~400 ft) AGL
Capture Rate	One capture per second (all bands), 12-bit RAW
Interfaces	Serial, 10/100/1000 ethernet, removable Wi-Fi, external trigger, GPS, SDHC
Field of View	47.2° HFOV
Triggering Options	Timer mode, overlap mode, external trigger mode (PWM, GPIO, serial, and Ethernet options), manual capture mode

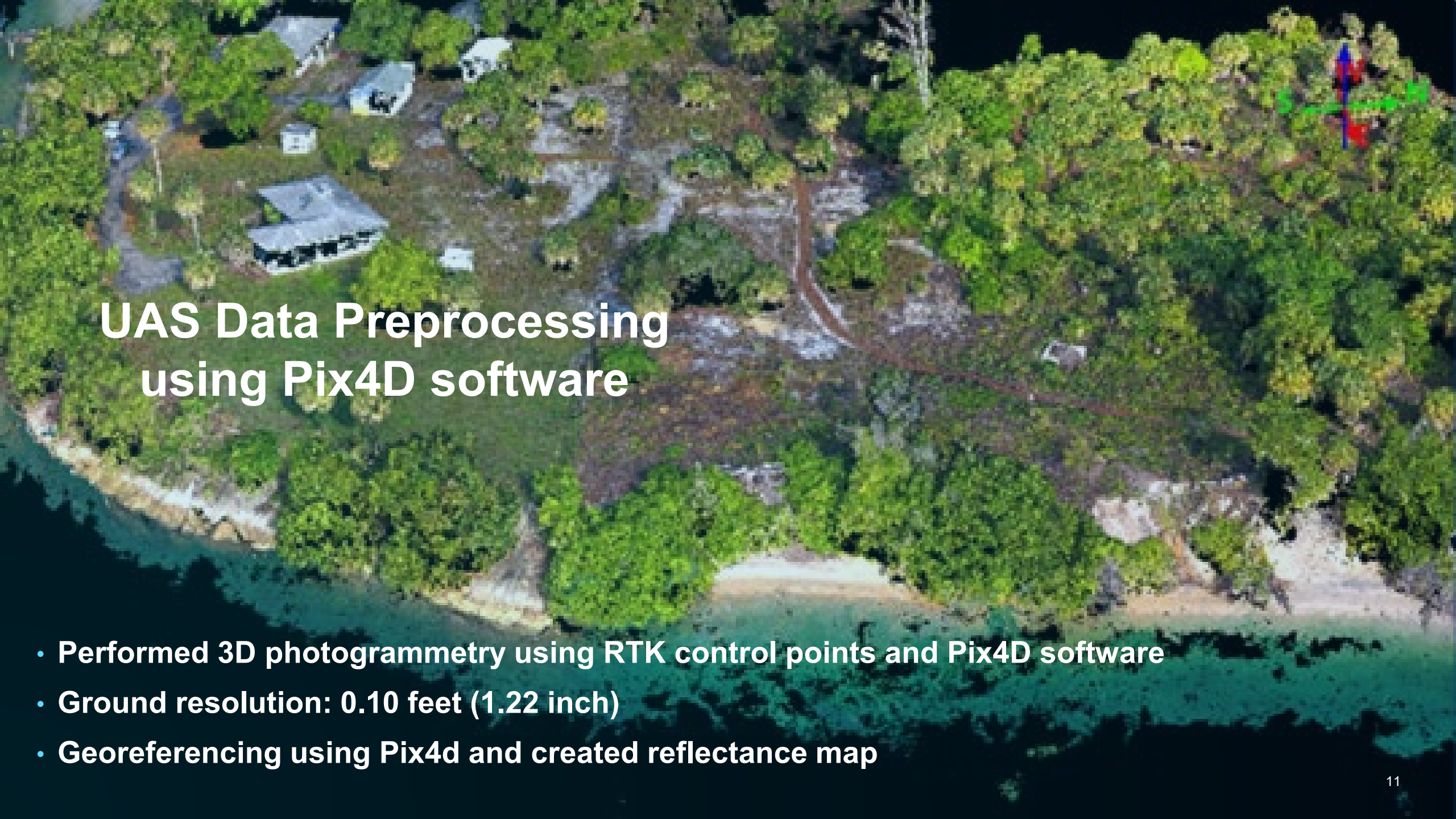




Jupiter Inlet Lighthouse ONA North and South Data

Advantages of UAS / UAV

- A low-cost device
- Ultra high spatial resolution
- Enhanced temporal resolution
- Takes lesser duration for surveying
- To study inaccessible areas
- Mapping Transmission lines, Railroad assets, Vegetation classification, Site development & monitoring etc.,



UAS Data Preprocessing using Pix4D software

- Performed 3D photogrammetry using RTK control points and Pix4D software
- Ground resolution: 0.10 feet (1.22 inch)
- Georeferencing using Pix4d and created reflectance map

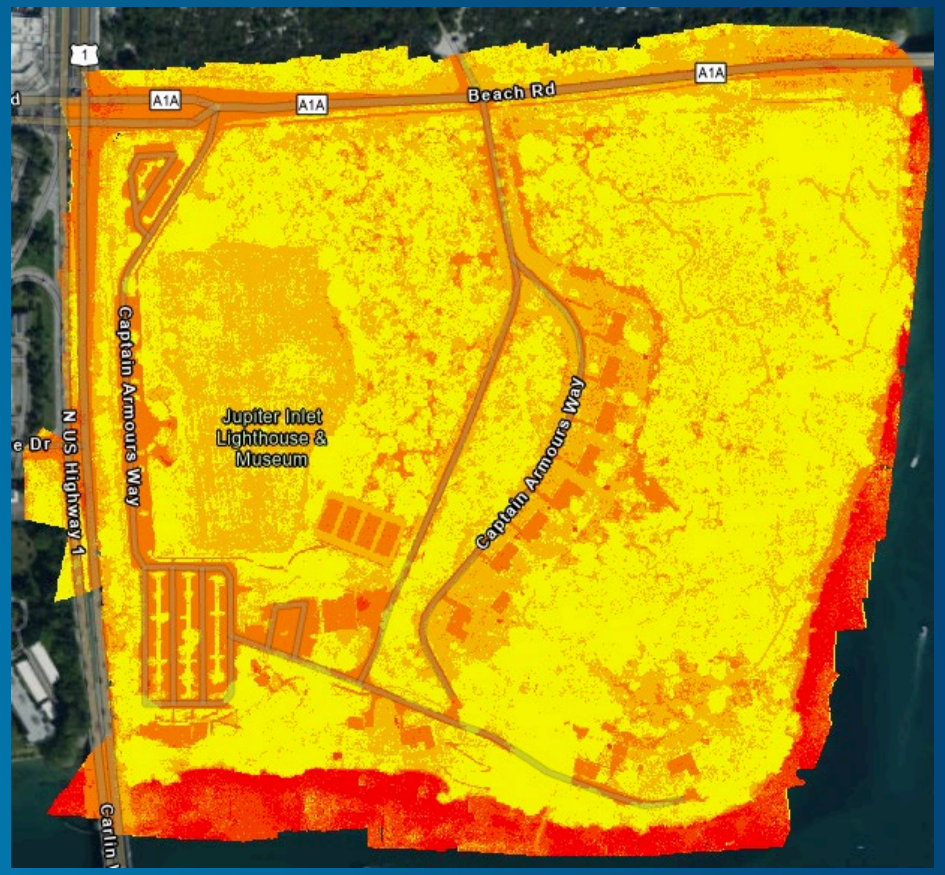
OVERALL METHODOLOGY

- Get the Raster input – 5 band imagery
- Modified NDWI generation using Green and Red Edge bands
- Thresholding NDWI raster as 0 and 1 to highlight features
- Smoothening process - Apply majority filter to each pixel to remove noise
- Raster to polygon - Create water and land polygons
- Select largest water polygon
- Polygon to line conversion
- Linear rings removal - unnecessary lines
- Unsplitting lines - Join all the lines
- Select largest line feature
- Clip extra lines using Jupiter Inlet Lighthouse AOI
- Delete intermediate results

Credits: ESRI Dev Summit 2021 - Automating coastline extraction by Aawaj Joshi & Rhea Jackson

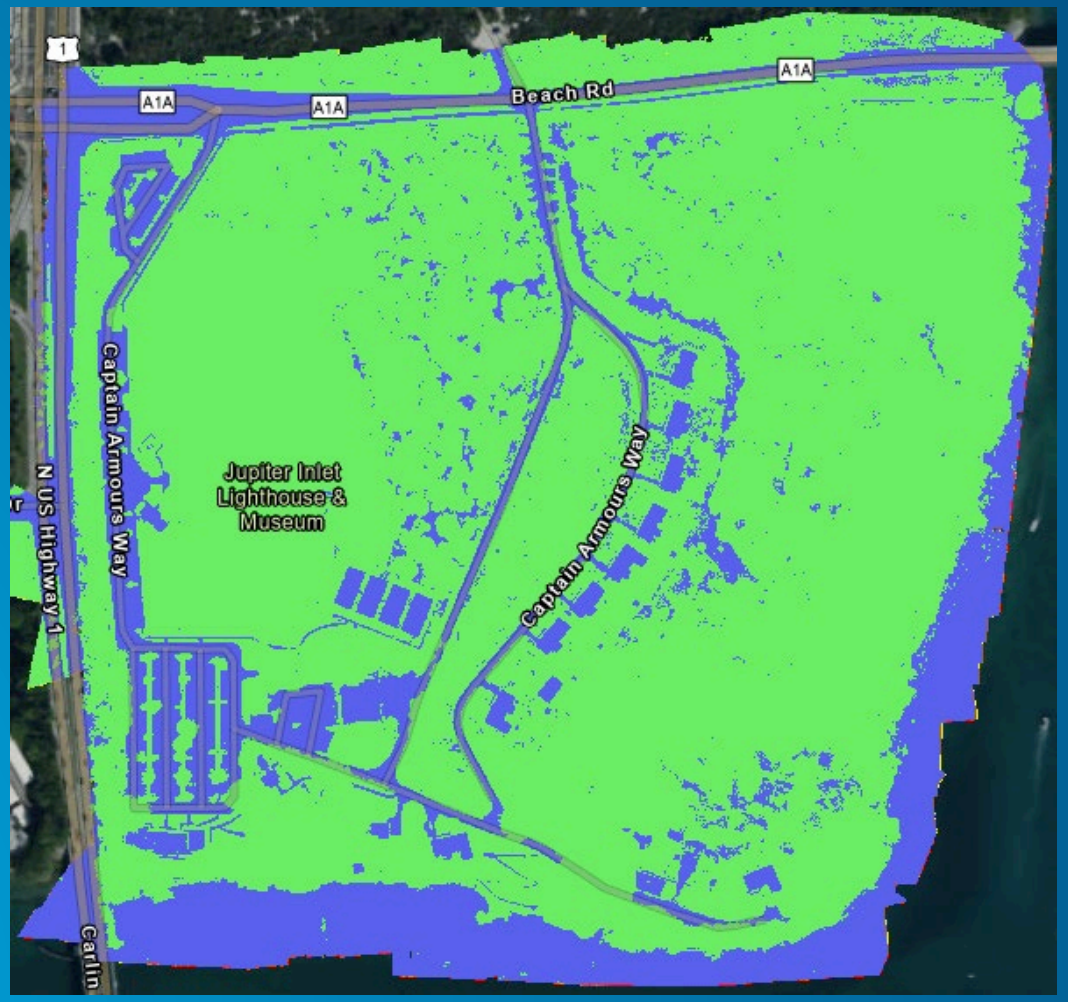
Get the Raster input – 5 band imagery

Modified NDWI generation using Green and Red Edge bands



Thresholding NDWI raster as 0 and 1 to highlight features

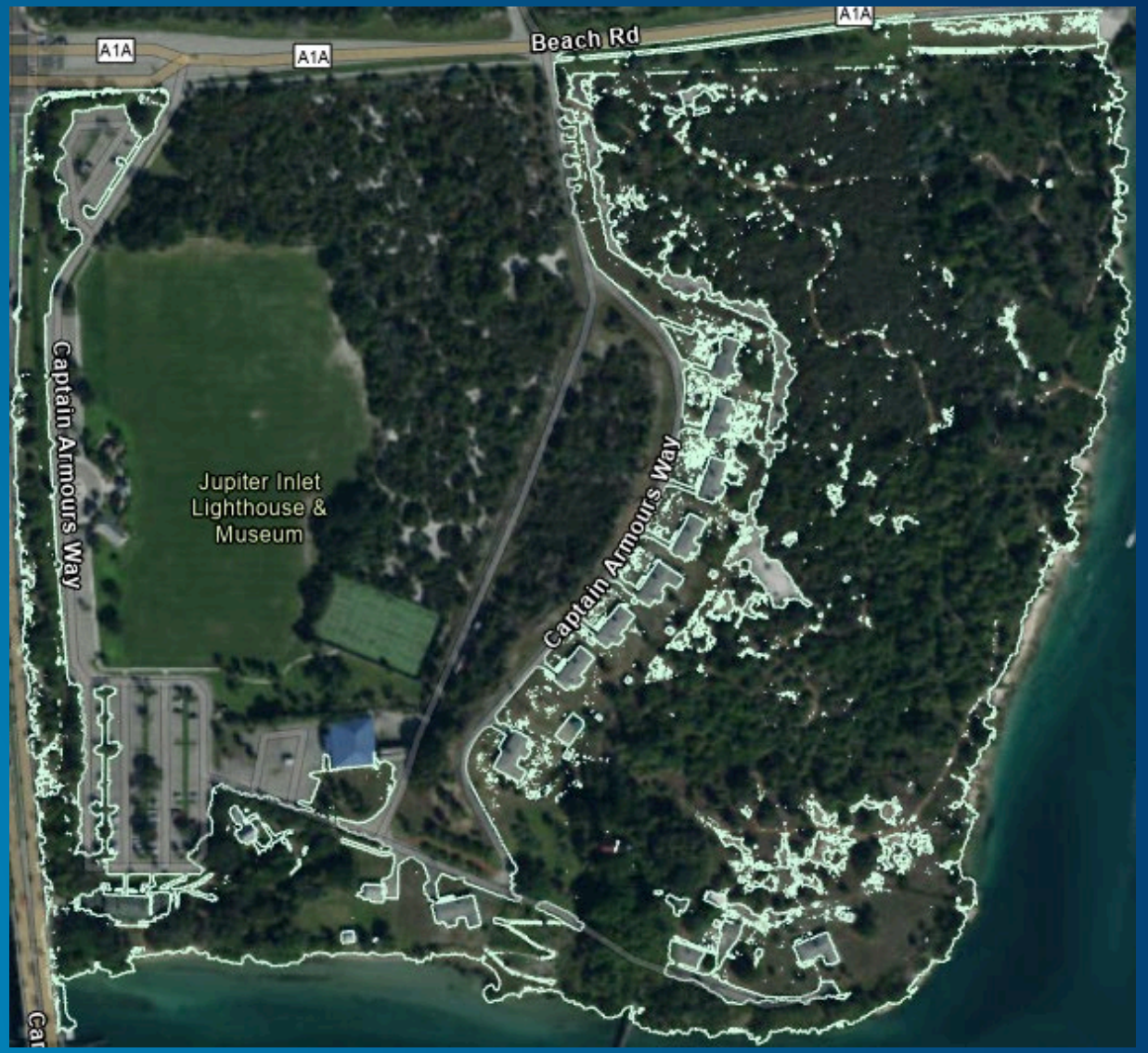
Smoothening process - Apply majority filter to each pixel to remove noise



Raster to polygon - Create water and land polygons

Select largest water polygon

Polygon to line conversion



Linear rings removal - unnecessary lines

Unsplitting lines - Join all the lines

Select largest line feature

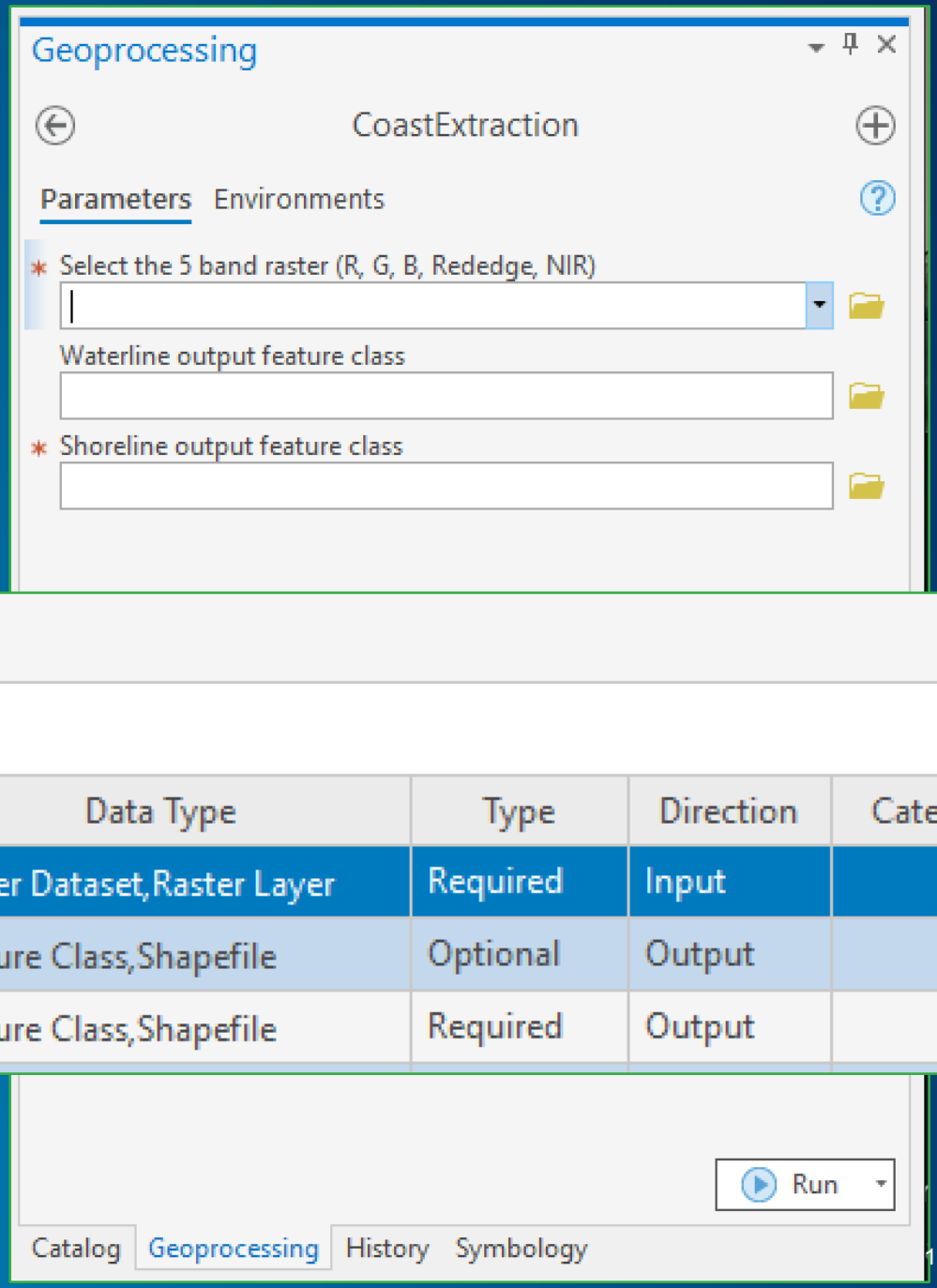
Clip extra lines using Jupiter Inlet Lighthouse AOI

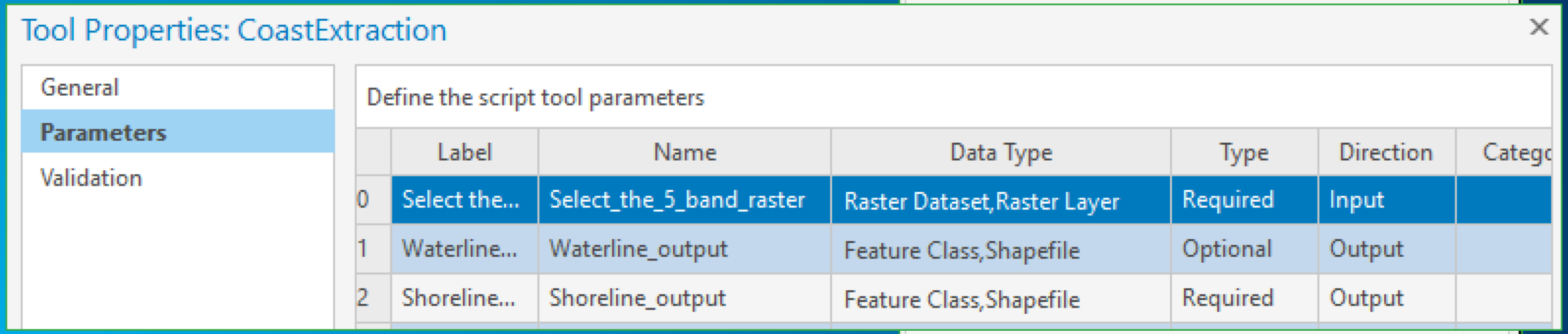
Delete intermediate results

EXTRACTION USING GEOPROCESSING TOOL

- Built using Python - ArcPy
- Can be extended as ESRI Task Workflow

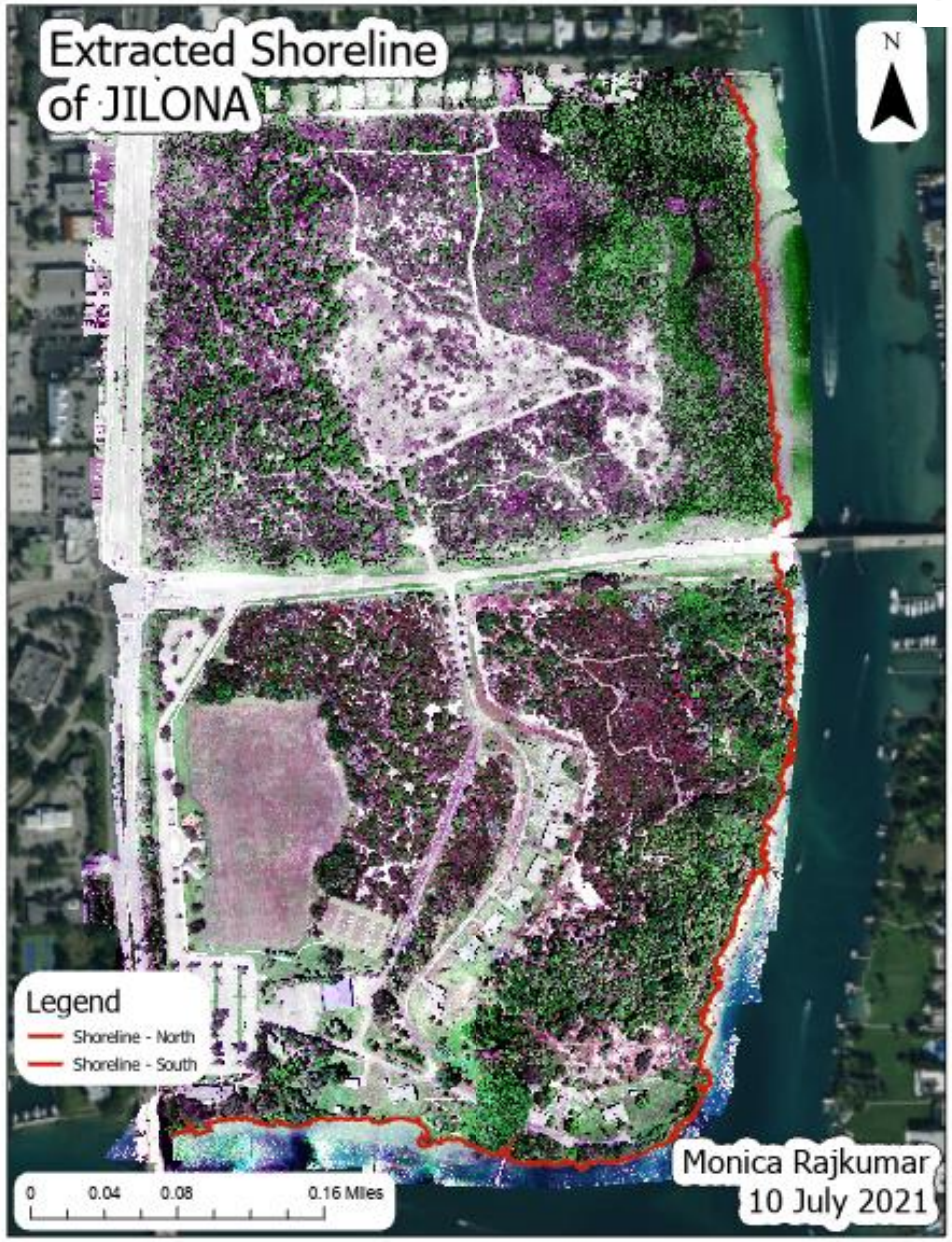
EXTRACTION TOOL
Using Python





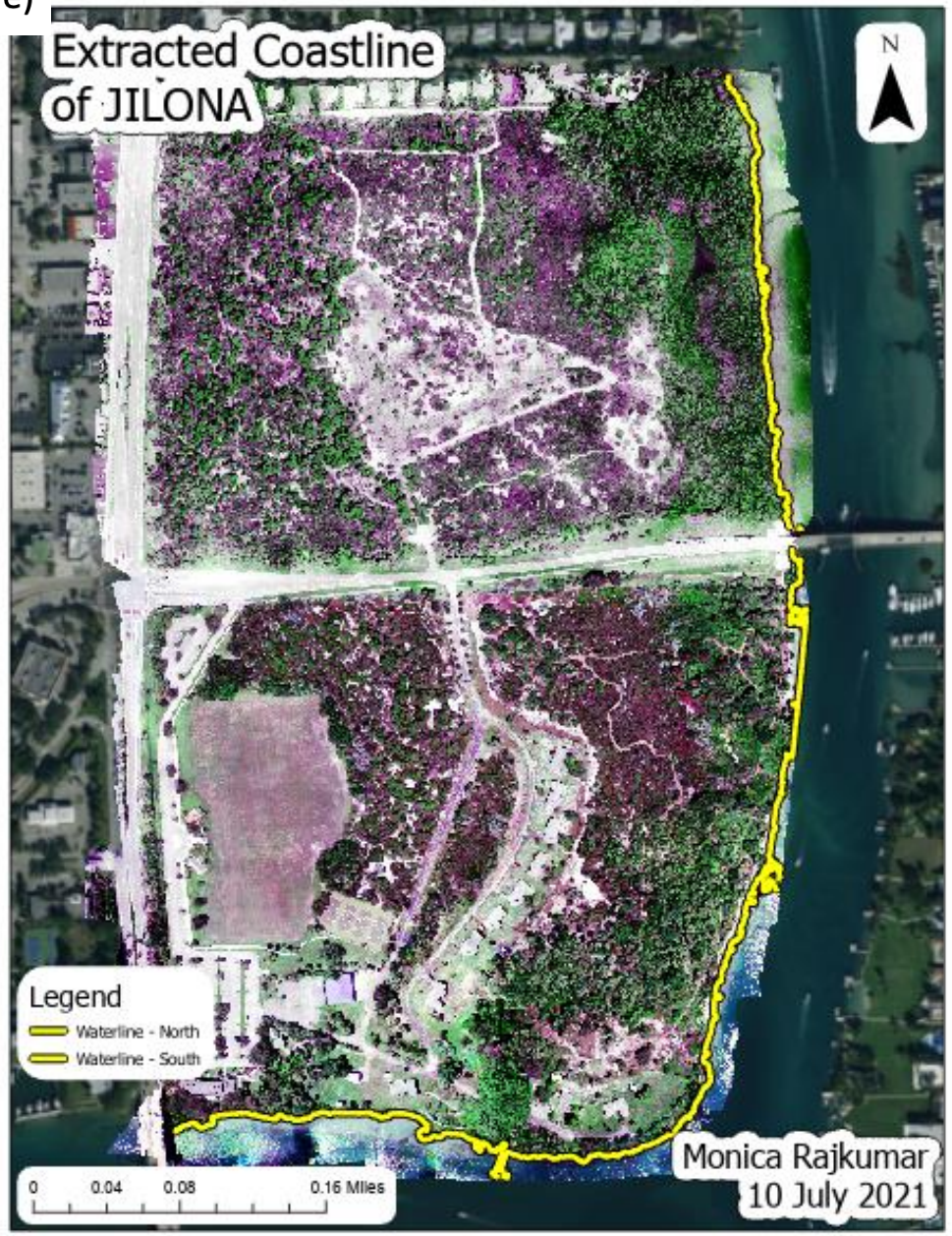
	Label	Name	Data Type	Type	Direction	Categc
0	Select the...	Select_the_5_band_raster	Raster Dataset,Raster Layer	Required	Input	
1	Waterline...	Waterline_output	Feature Class,Shapefile	Optional	Output	
2	Shoreline...	Shoreline_output	Feature Class,Shapefile	Required	Output	

Shoreline (Vector data line feature)
Coastline (Vector data line feature)

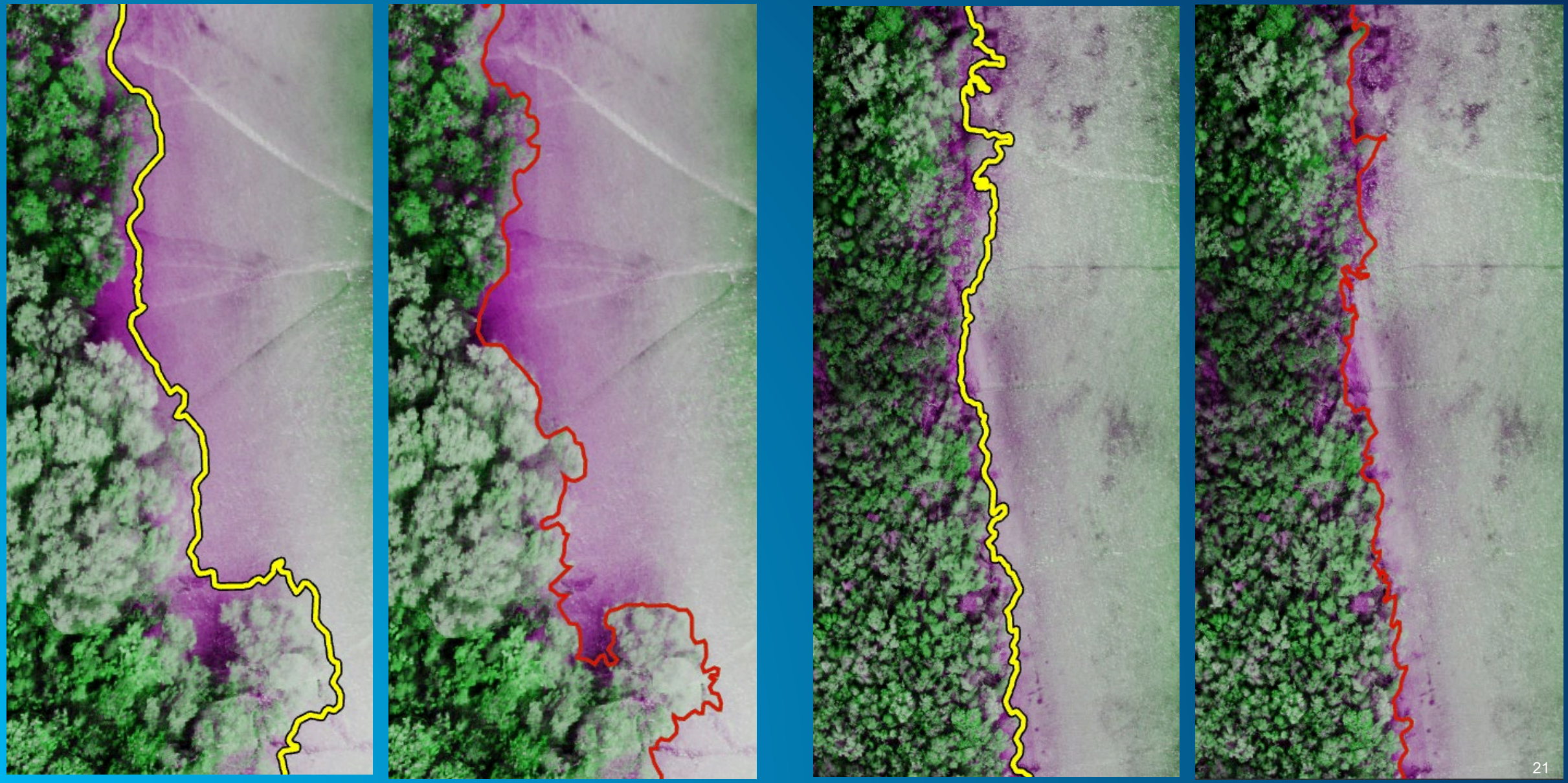


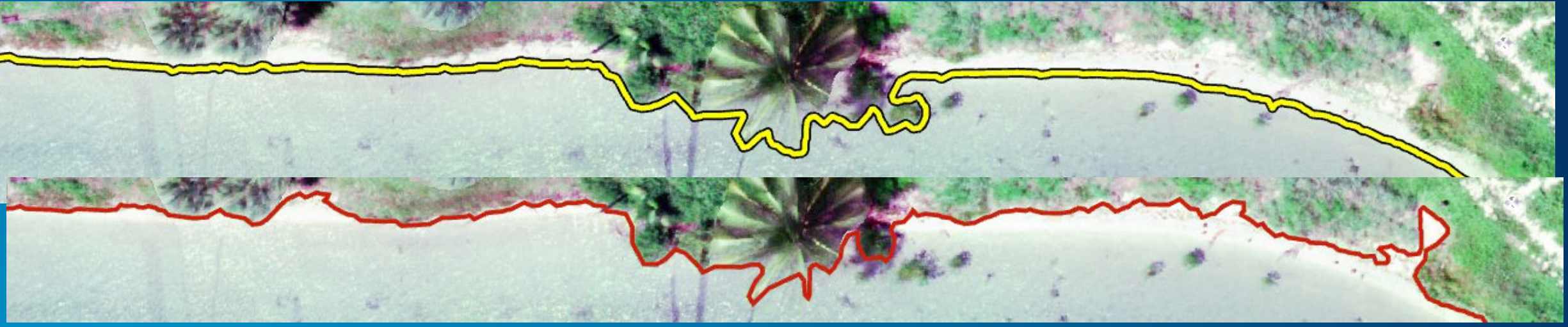
Coastline is the line that separates water body and the shore region

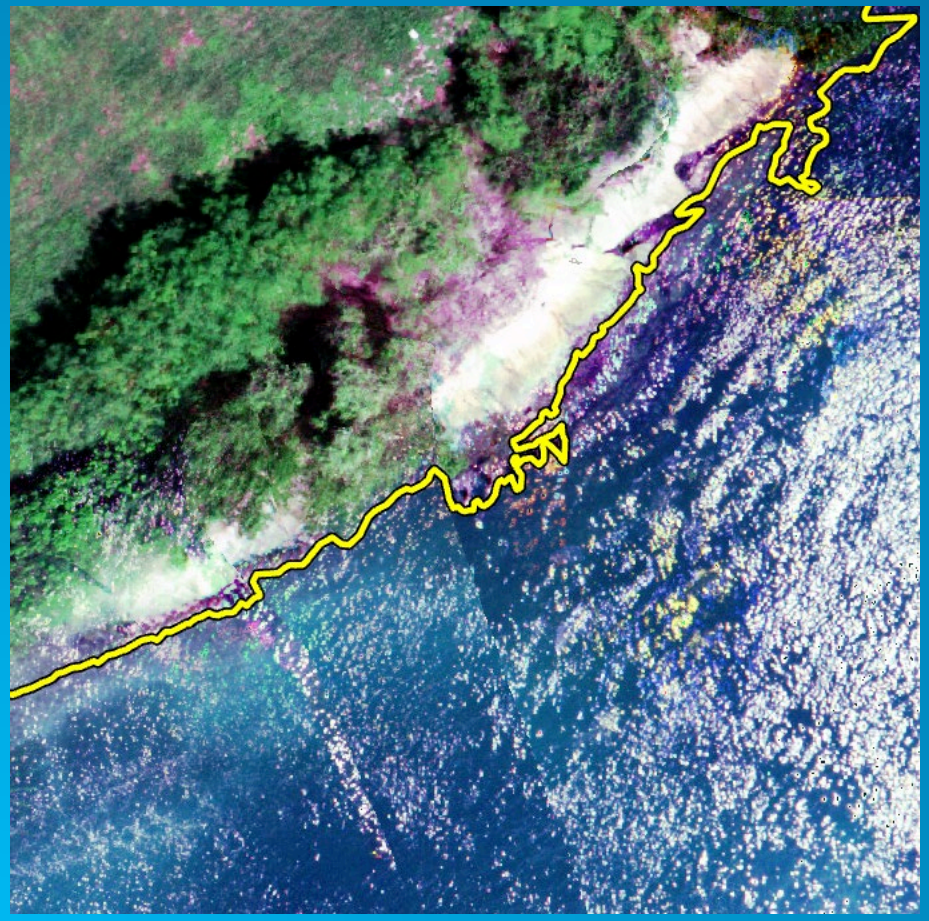
Shoreline is the line separates the shore region and the land area

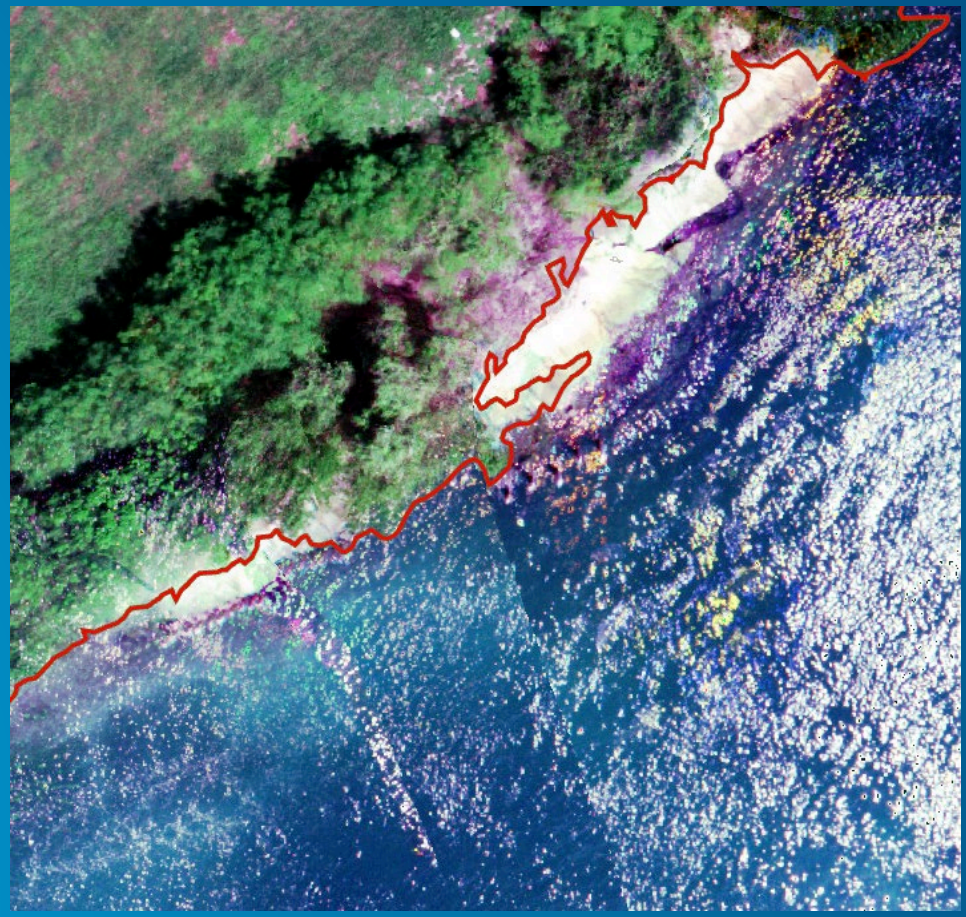


NORTH – Waterline(Yellow) and Shoreline (Red)



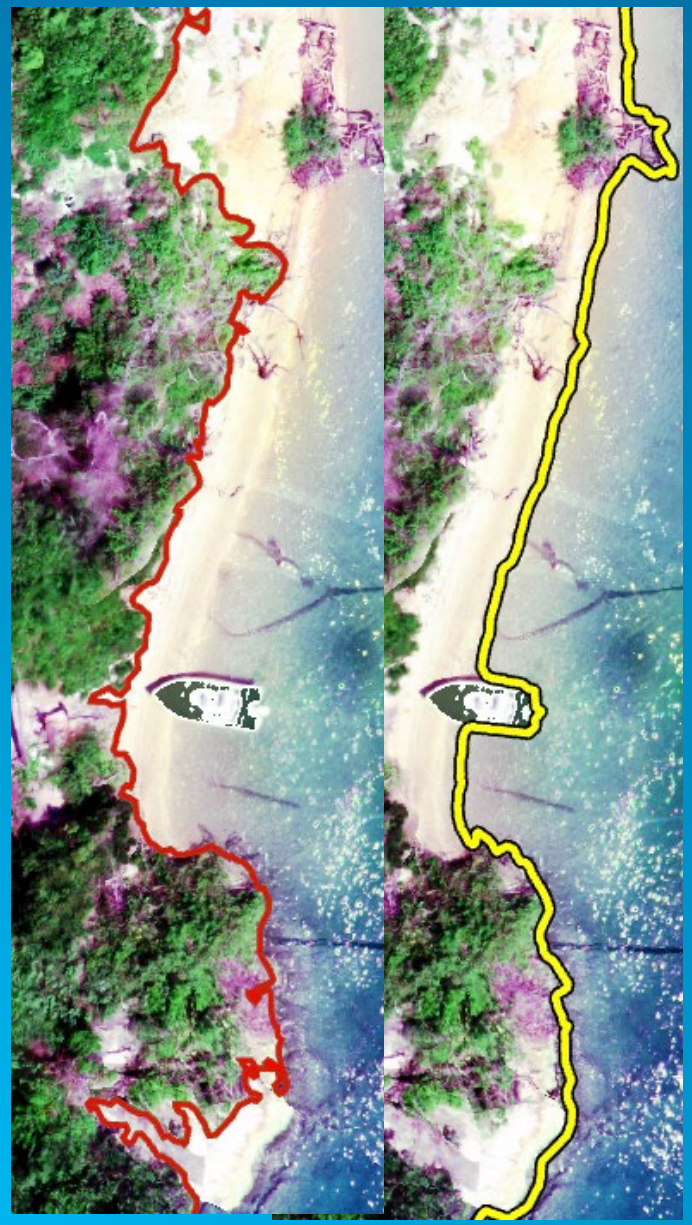


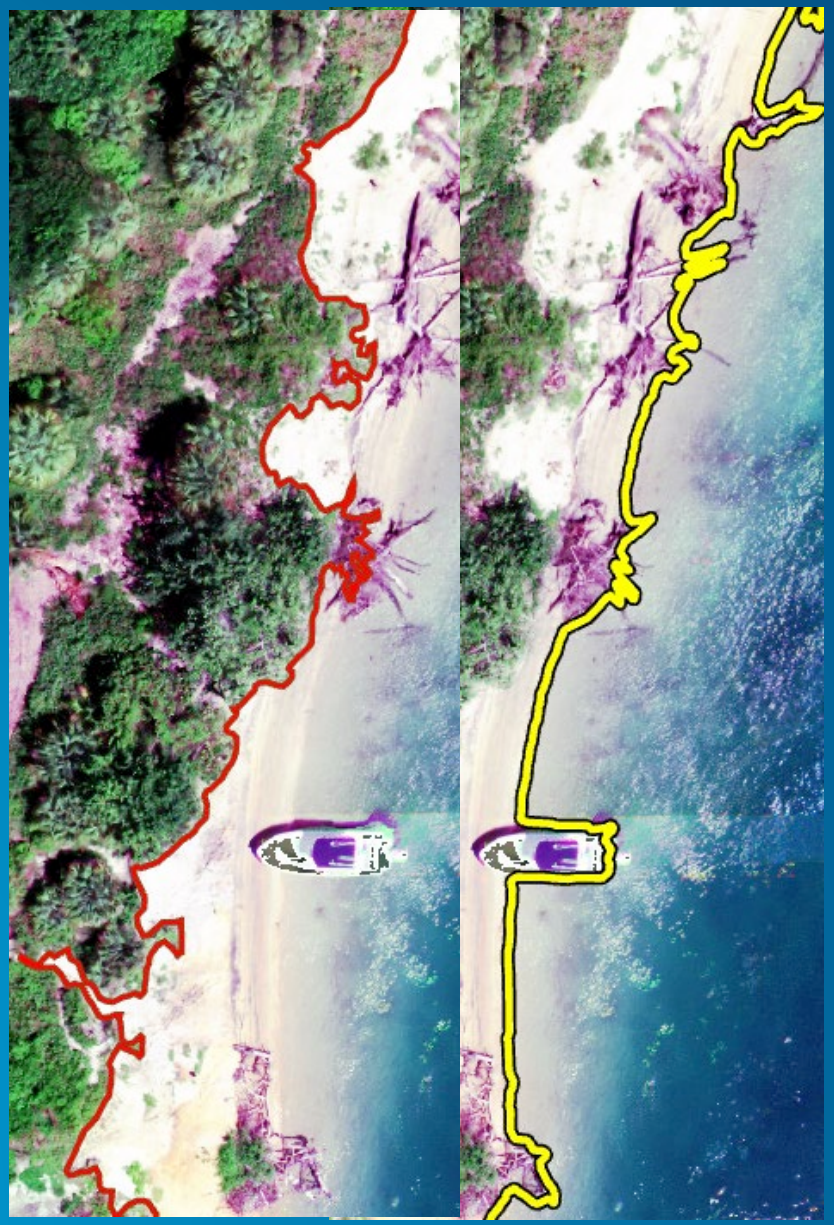


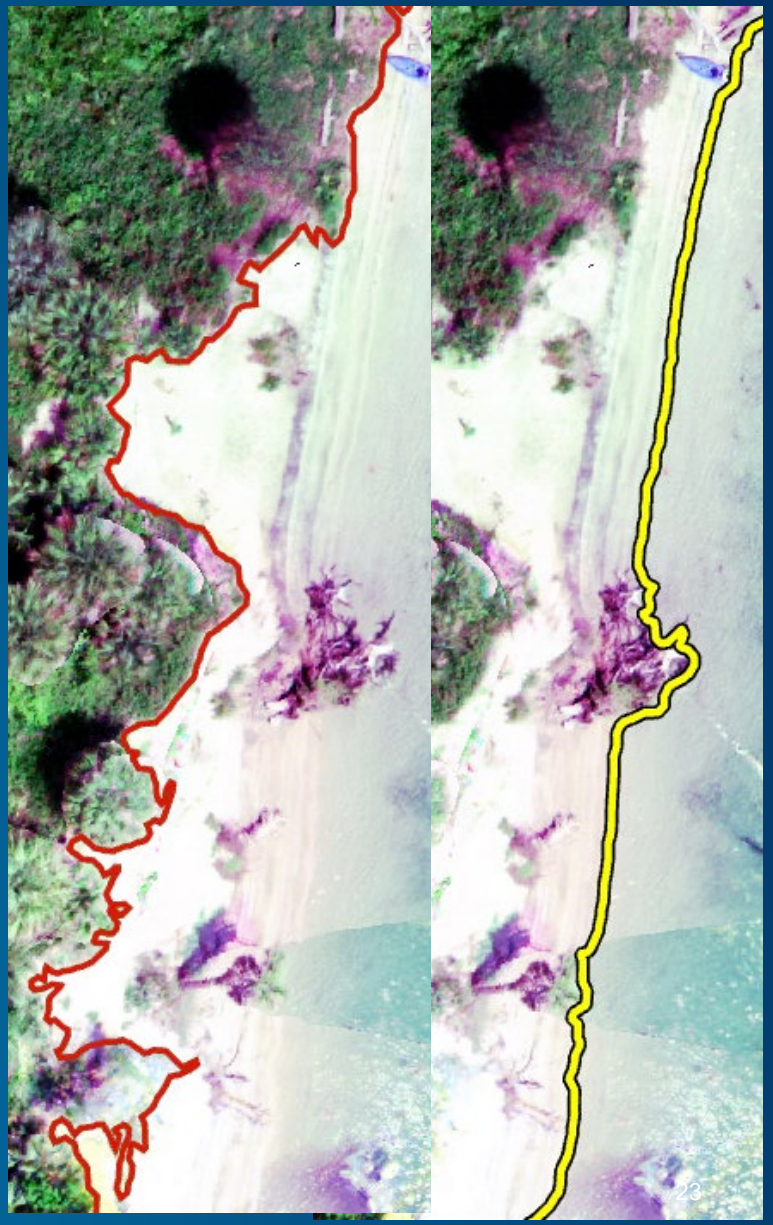


SOUTH –
Waterline (Yellow)
& Shoreline (Red)

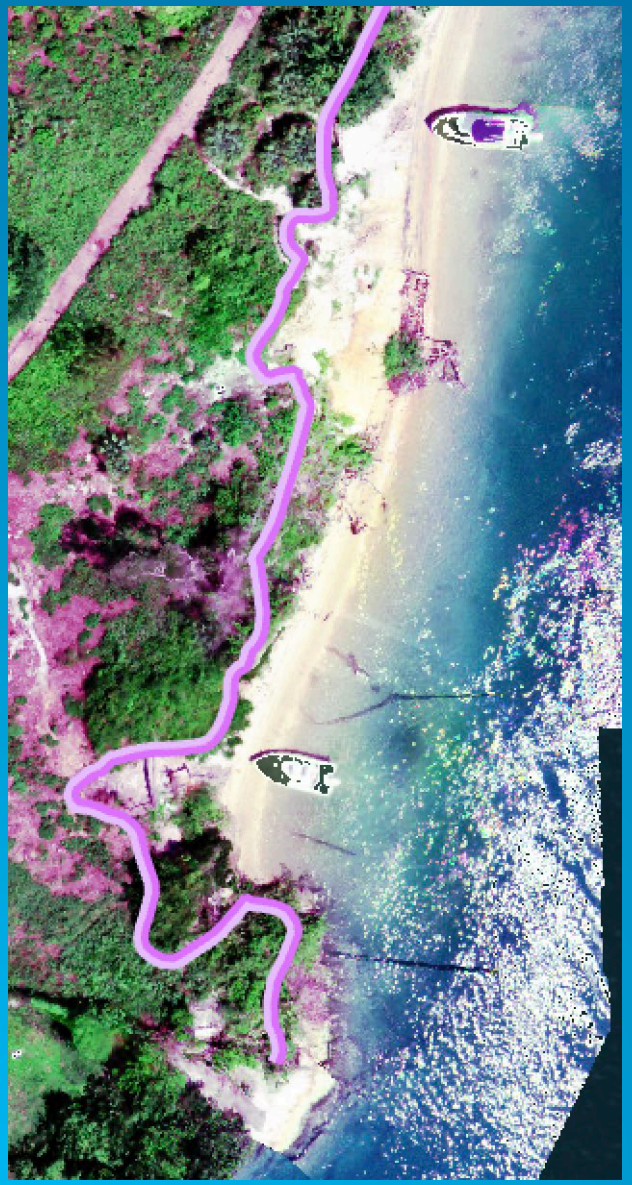
EAST – Waterline(Yellow) and Shoreline (Red)

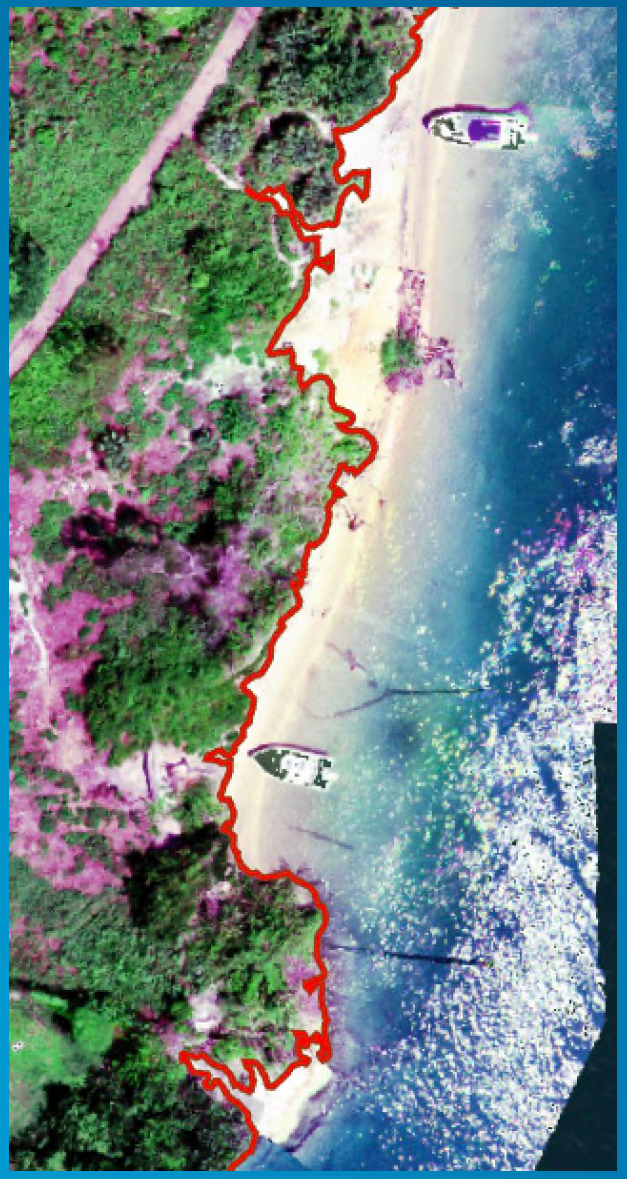




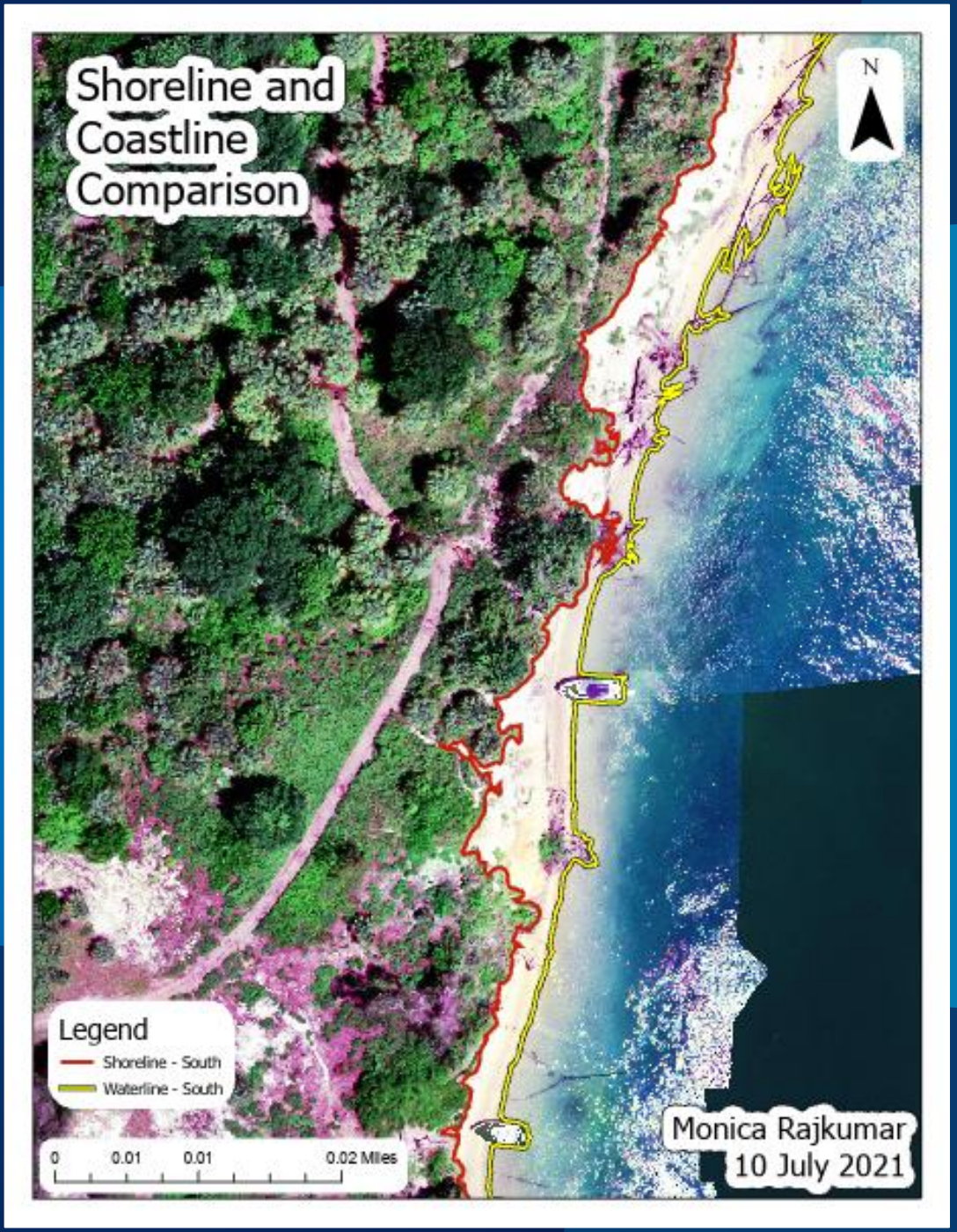


Shoreline - Manually digitized (Pink) vs Automated extraction (Red)





Conclusion


Shoreline and Coastline Comparison
N
Legend
Shoreline - South
Waterline - South
0
0.01
0.01
0.02 Miles
Monica Rajkumar
10 July 2021

Misinterpretations – Yet to be improved

SUMMARY

❖ **Advantages**

- Reduces man hours in digitizing shoreline and waterline
- Can be further automated for regular shoreline monitoring

❖ **Limitations**

- Developed tool makes use of RedEdge, which is mandatory
- Human intervention is still needed to modify the misclassified areas

Future Scope

- Perform shoreline change detection
- Compute volume of soil erosion
- Comparing results from other sensors or band combinations
- Deep learning model implementation for higher accuracy
- Reduce the execution time by optimizing majority filter tool
- Adapt the workflow for larger study area

REFERENCES

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Questions?

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THANK YOU!