

# Approach to Mapping Shallow-water Benthic Habitats for the Republic of Palau

In Support of the U.S. Coral Reef Task Force



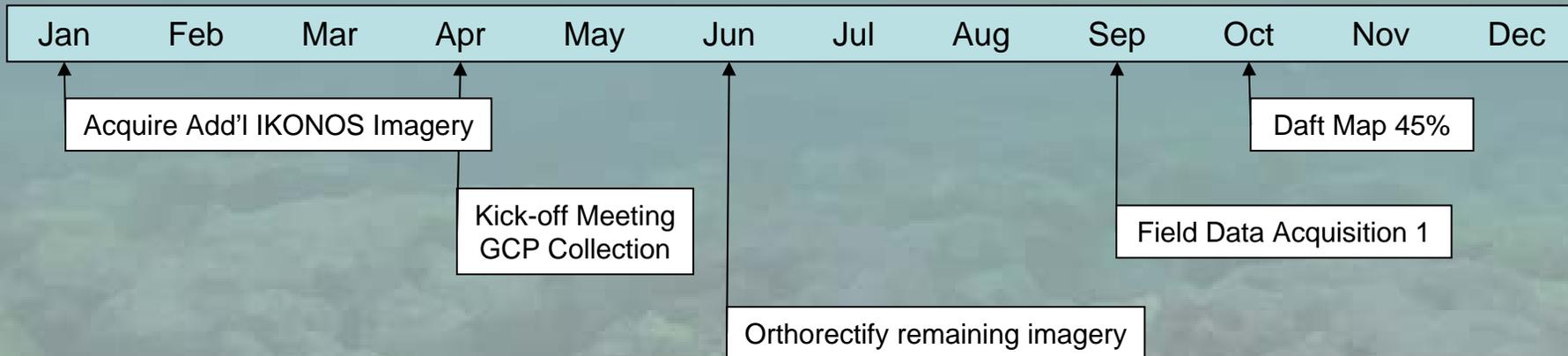
A Presentation to the Republic of Palau

By:

Mark E. Monaco, Steve Rohmann, Tim Battista, and Miles Anderson  
NOAA's National Centers for Coastal Ocean Science  
Biogeography Program  
April 5, 2005

# Timeline

## 2005



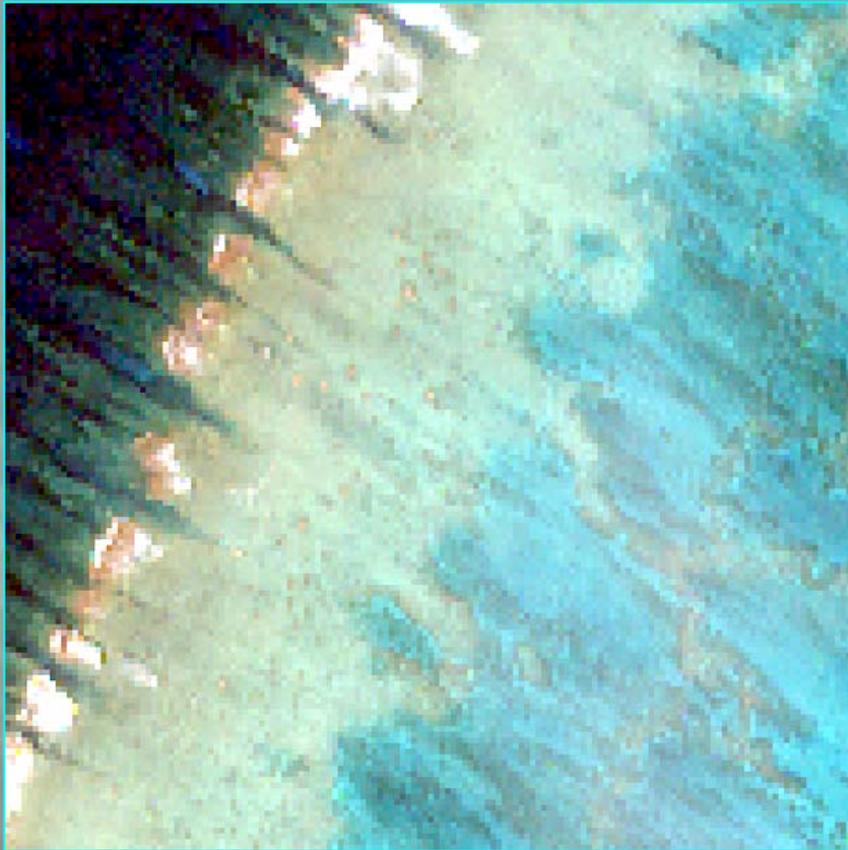
## 2006



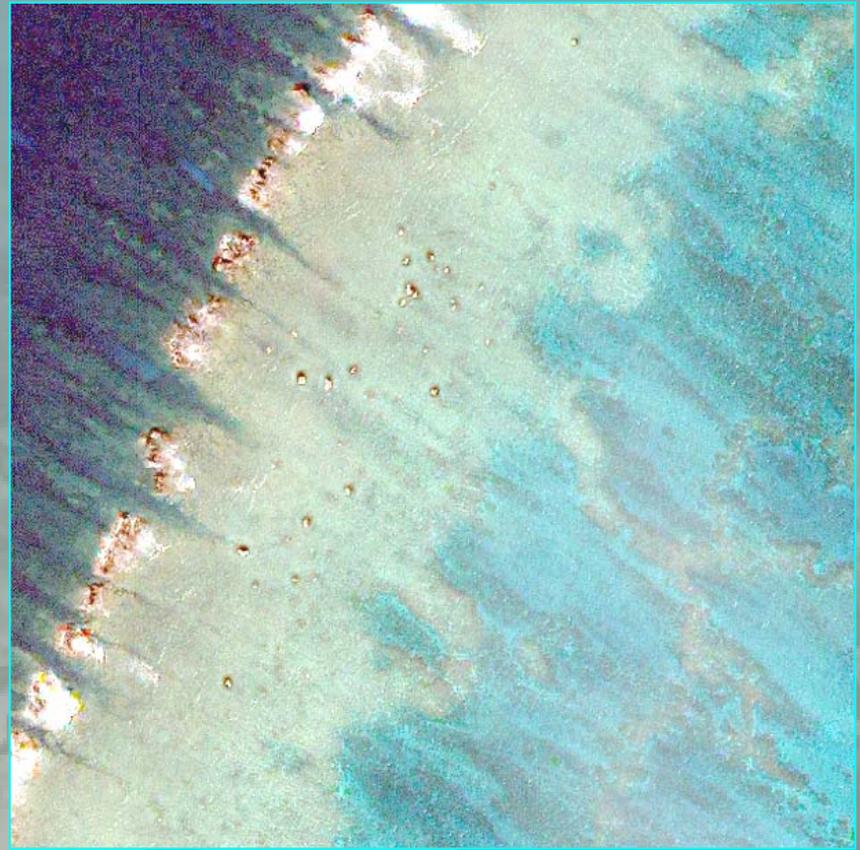
## 2007



# IKONOS image of a portion of Kure Atoll, NWHI



4-m RGB image

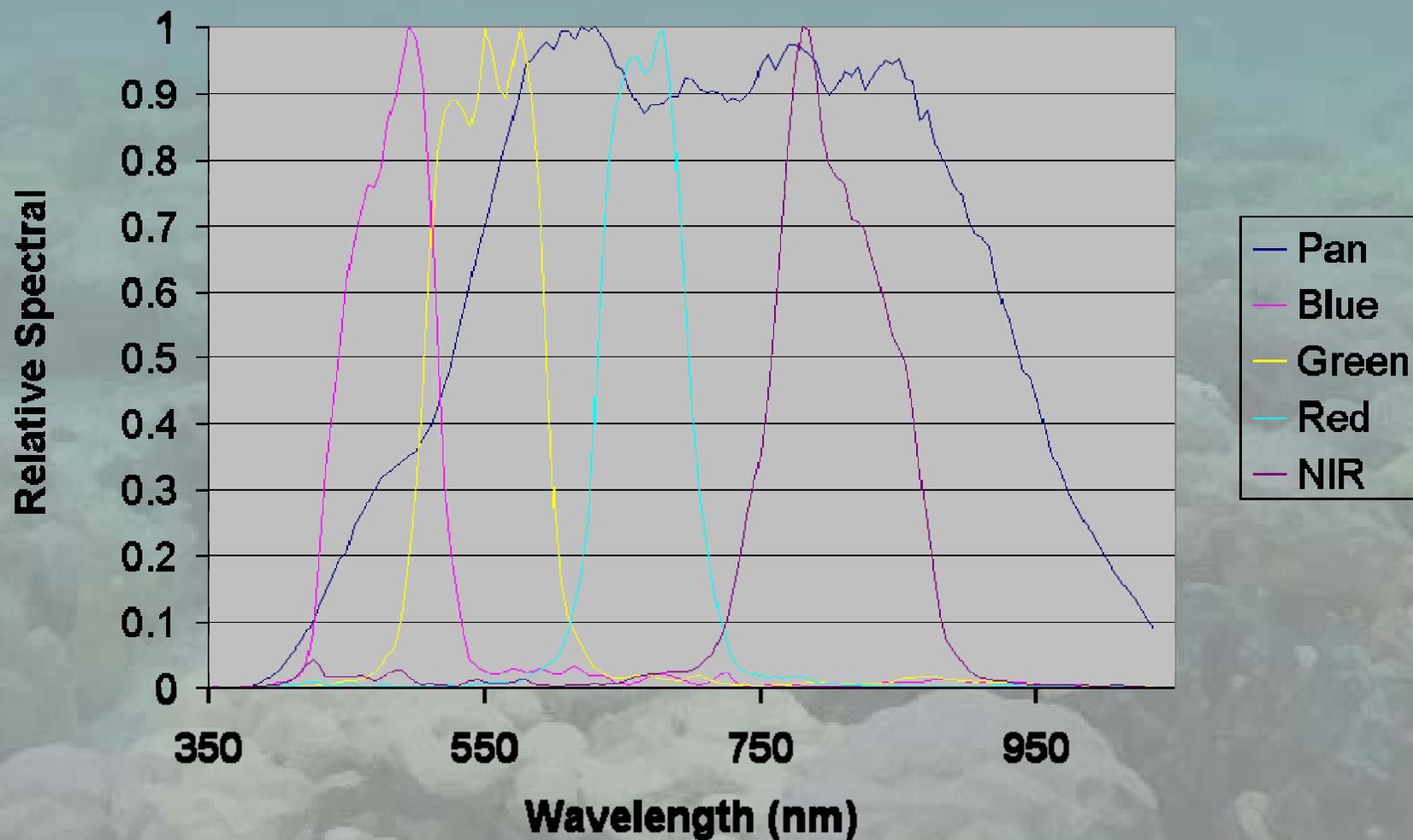


1-m pan sharpened  
RGB image

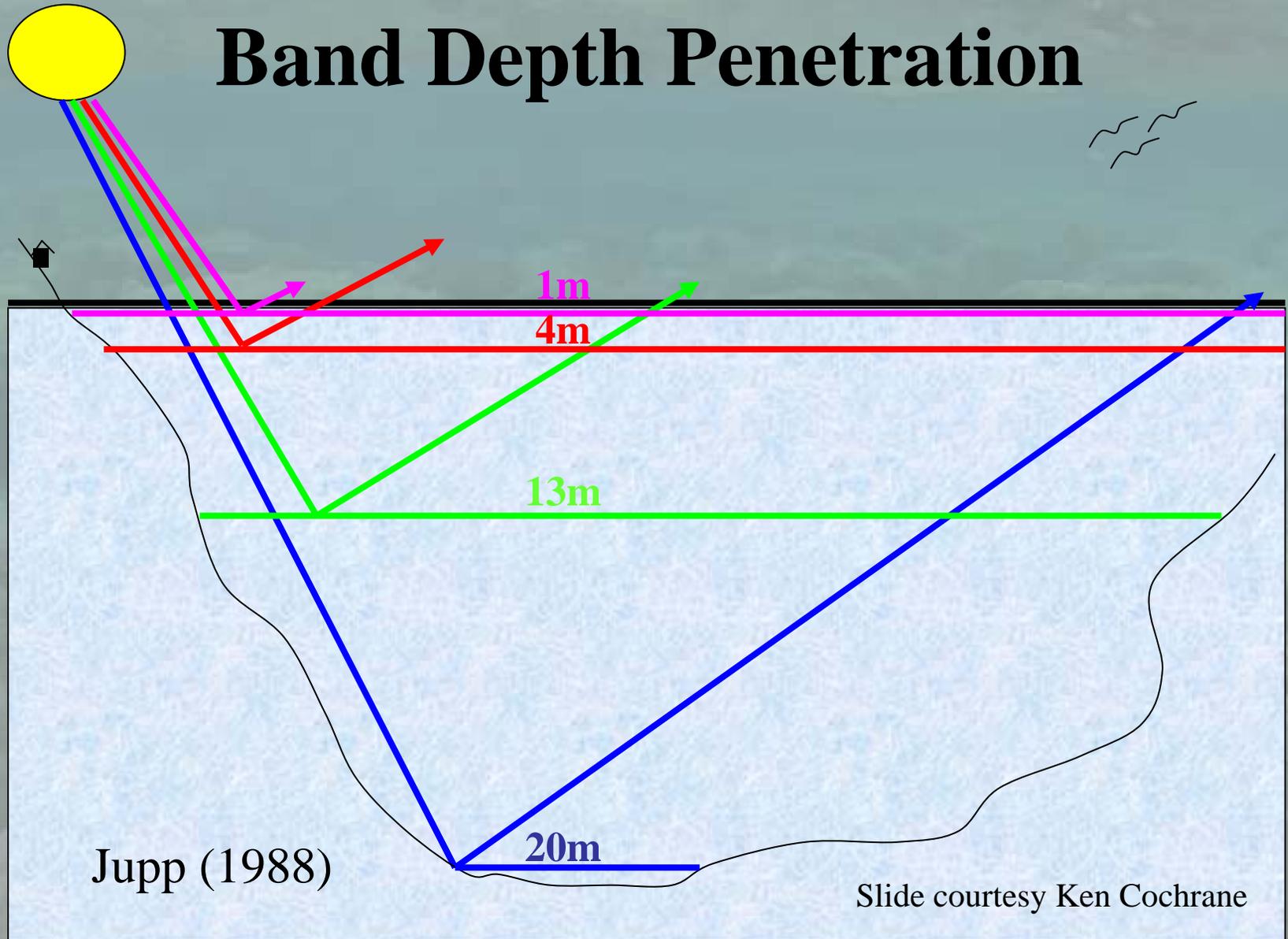
## **IKONOS commercial satellite imagery**

- 4-m multispectral (blue/green/red/nearIR); detection to ~30 m depth
- 1-m panchromatic with detection to ~4 m depth
- pointable 11 km swath (multiple swaths on a single pass)
- horizontal positioning <15 m (with orbital parameters alone)
- constrain acquisition to minimize sunglint and clouds

## IKONOS2 Relative Spectral Response

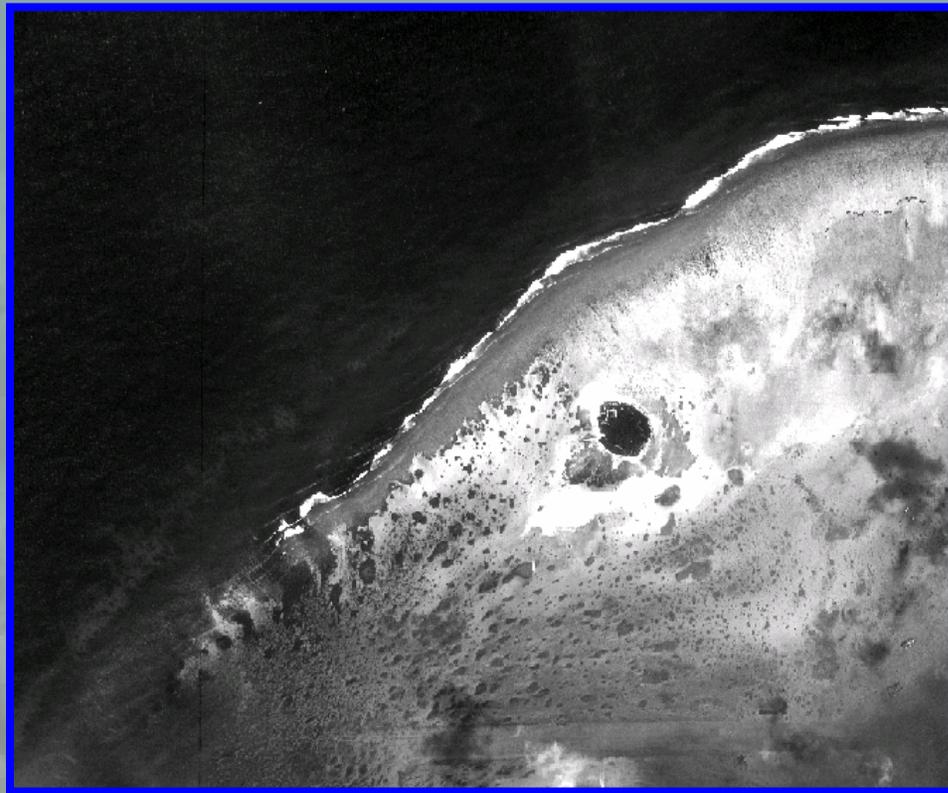


# Band Depth Penetration



- Position with orbital parameters and refine with ground control.
  - NGS acquired ground control for most of NWHI on NOS cruise
  - final horizontal accuracy < 4 meters in most cases
- Mosaic multiple swaths for study area if necessary.
- Raw imagery, MSI, Pan, Pansharpened orthorectified, water reflectance, total reflectance

# IKONOS Imagery (MS)



Blue (445-515 nm)

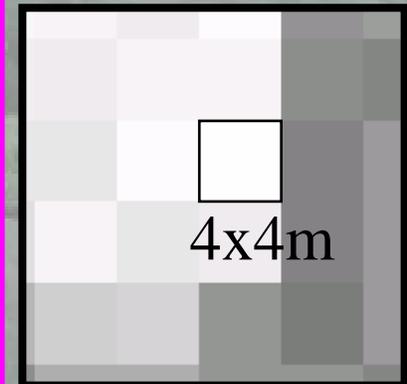
Green (510-595 nm)

Red (630-700 nm)

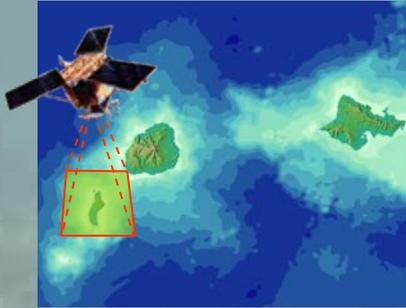
NIR (760-850 nm)

11-bit data

Values 0-2047



## Collecting and preparing the source data:



### Collect Data

June 2000

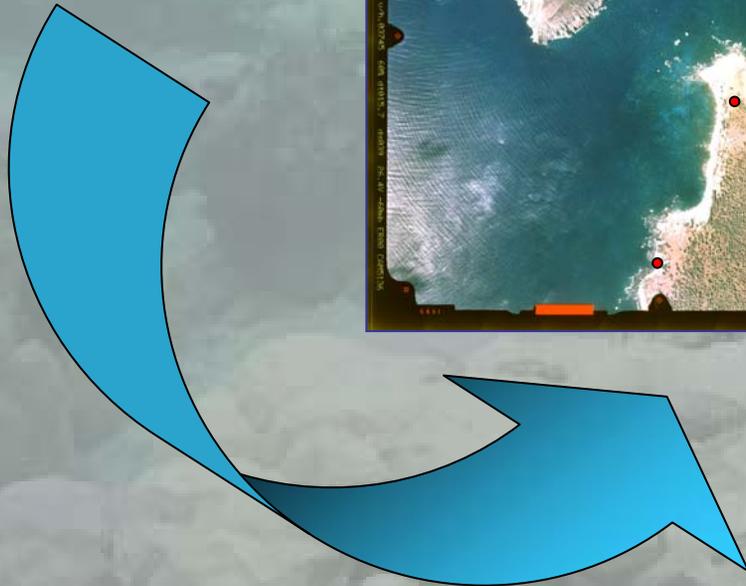
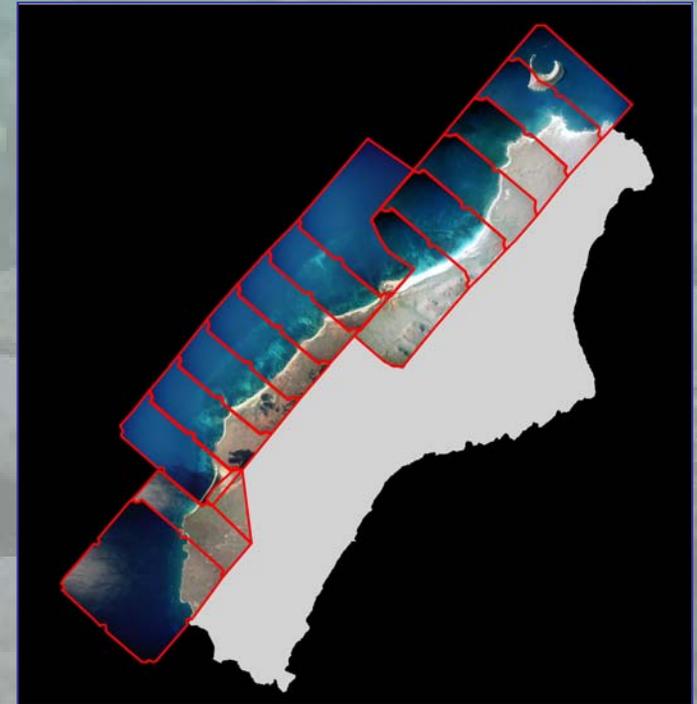
11 km swath, 11 byte, MSI + Pan



### Orthorectify

1 m pixels

Spatial corrections for: orbital parameters, terrain, better positioning



- ~ 4,300 km<sup>2</sup> of purchased IKONOS imagery.
- ~ 2,300 km<sup>2</sup> of shallow water benthic habitats to be mapped.



# NOAA Coral Reef Habitat Maps

## PALAU

**Prepared and Assisted by:  
Analytical Laboratories of Hawaii**

Analytical Laboratories of Hawaii, LLC



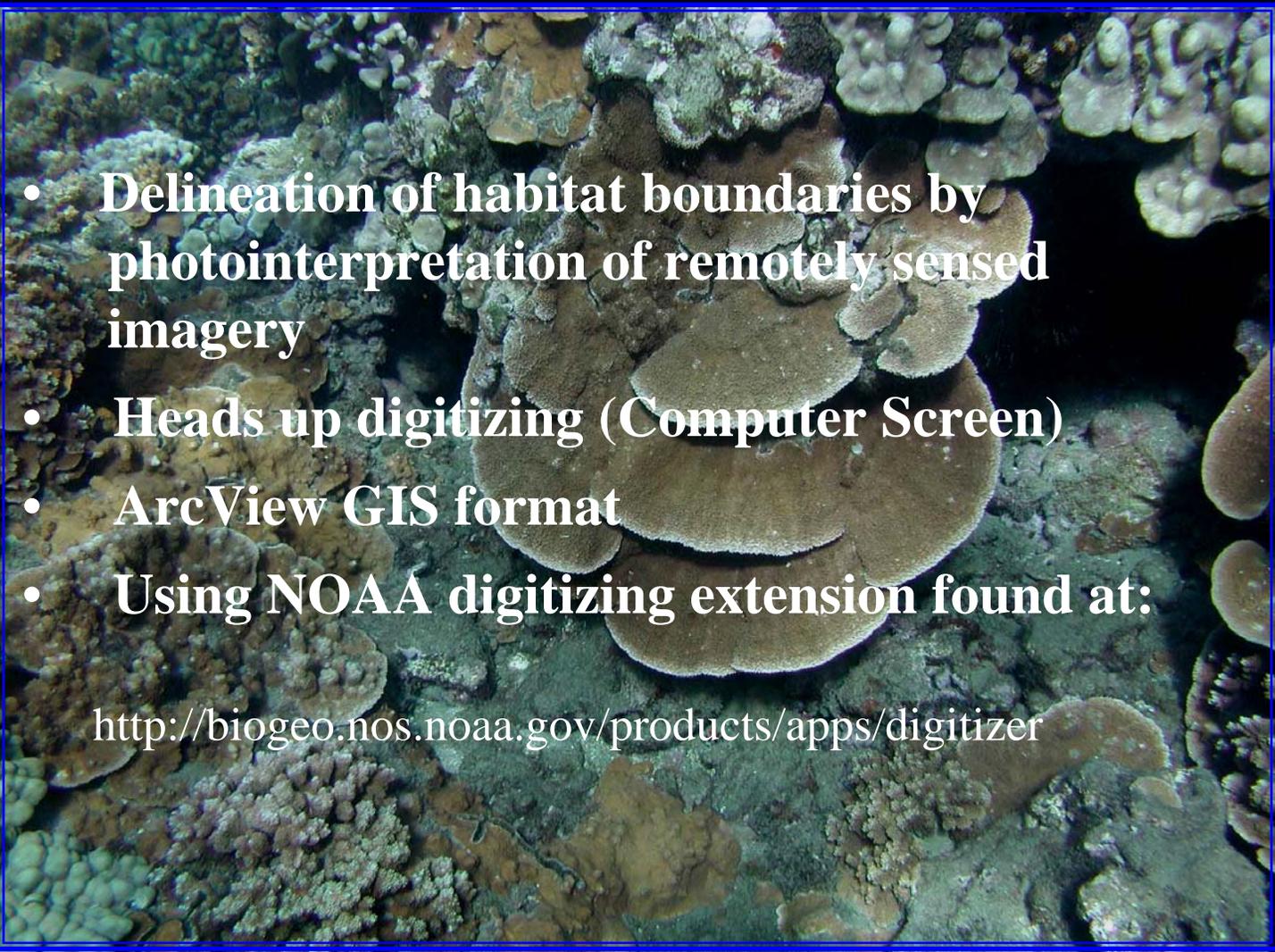
# Key Topics

- **Overview of Mapping to Date**
- **Classification Scheme**
- **Mapping Process – Five Step Process**
- **Mapping Standards**
- **Assessment of Accuracy of Habitat Maps**

# Map Preparation Methods

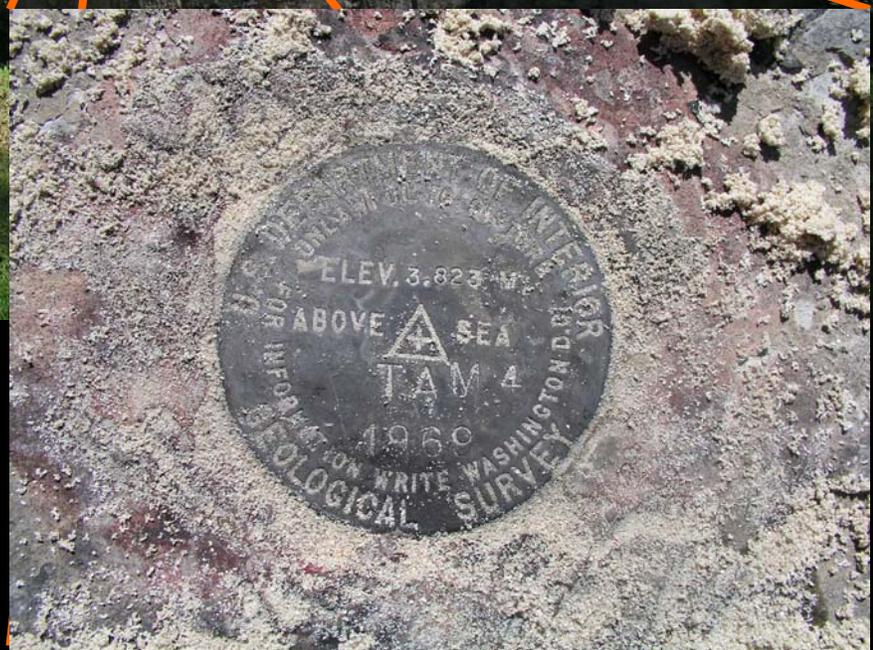
- Delineation of habitat boundaries by photointerpretation of remotely sensed imagery
- Heads up digitizing (Computer Screen)
- ArcView GIS format
- Using NOAA digitizing extension found at:

<http://biogeo.nos.noaa.gov/products/apps/digitizer>



# Spatial Control on Benchmark

- GPS Precision
- GPS Accuracy



# Five Layered Classification Scheme for Coral Reef Habitat Maps

- 1) Zone
  - 2) Major Geomorphologic Structure
  - 3) Detailed Geomorphologic Structure
  - 4) Major Biological Cover
  - 5) Detailed Biological Cover
- 

# Coral Reef Zone Classification Scheme

Land

Vertical Wall

Shoreline Intertidal

Reef Flat

Lagoon

Back Reef

Reef Crest

Fore Reef

Self

Bank/Shelf Escarpment

Channel

Dredged

Unknown

# **Second Generation Classification Scheme**

## **Geomorphologic Structural Component**

### **Unconsolidated Sediments**

**Sand**

**Mud**

### **Coral Reef and Hard Bottom**

**Spur and Groove**

**Patch Reef (Individual)**

**Patch Reef (Aggregated)**

**Scattered Rock/Coral in Unconsolidated Sediment**

**Aggregated Coral**

**Pavement**

**Volcanic Rock/Boulder**

**Pavement with Sand Channels**

**Reef Rubble**

### **Other**

**Land**

**Artificial**

**Unknown**

# Second Generation Classification Scheme

## Hierarchical Biological Cover Component

### Live Coral

Continuous (90%-100% Cover)

Patchy (Discontinuous) Macroalgae (50%-<90% Cover)

Patchy (Discontinuous) Macroalgae (10%-<50% Cover)

### Seagrass

Continuous (90%-100% Cover)

Patchy (Discontinuous) Macroalgae (50%-<90% Cover)

Patchy (Discontinuous) Macroalgae (10%-<50% Cover)

### Macroalgae

Continuous (90%-100% Cover)

Patchy (Discontinuous) Seagrass (50%-<90% Cover)

Patchy (Discontinuous) Seagrass (10%-<50% Cover)

### Coralline Algae

Continuous (90%-100% cover)

Patchy Encrusting/Coralline Algae (50%-<90% cover)

Patchy Encrusting/Coralline Algae (10%-<50% cover)

### Turf

Continuous (90%-100% Cover)

Patchy (Discontinuous) Macroalgae (50%-<90% Cover)

Patchy (Discontinuous) Macroalgae (10%-<50% Cover)

### Emergent Vegetation

Continuous (90%-100% Cover)

Patchy (Discontinuous) Macroalgae (50%-<90% Cover)

Patchy (Discontinuous) Macroalgae (10%-<50% Cover)

### Uncolonized

Continuous (90%-100% Cover)

# Hierarchical Cover Scheme

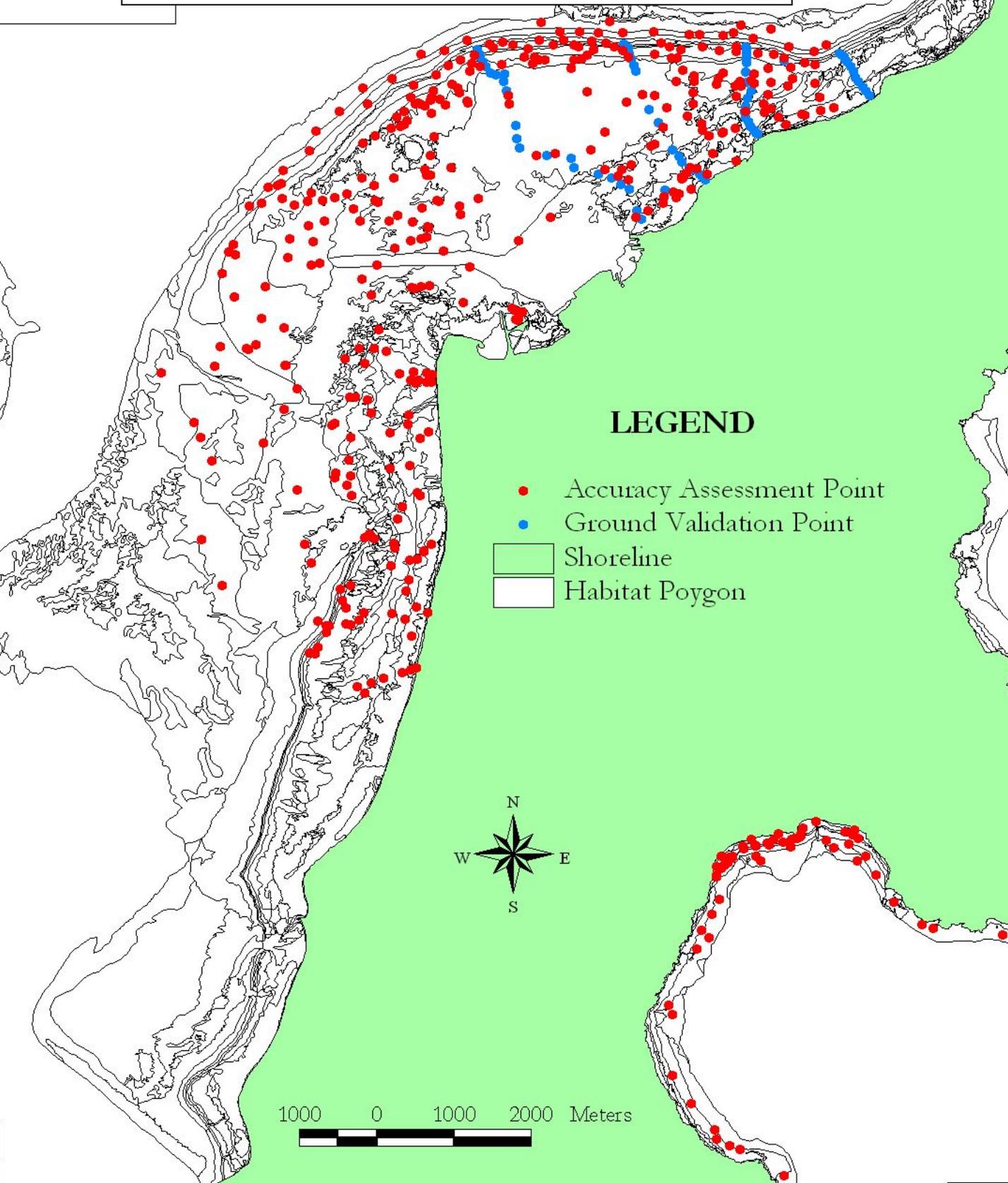
<b>Coral</b>	<b>Seagrass</b>	<b>Macroalgae</b>	<b>Coralline Algae</b>	<b>Turf</b>	<b>Emerg Veg</b>	<b>Uncol</b>	<b>Other</b>
10%-<50%	X	X	X	X	X	X	
50%-<90%	X	X	X	X	X	X	
90%-<100%	X	X	X	X	X	X	
	10%-<50%	X	X	X	X	X	
	50%-<90%	X	X	X	X	X	
	90%-<100%	X	X	X	X	X	
		10%-<50%	X	X	X	X	
		50%-<90%	X	X	X	X	
		90%-<100%	X	X	X	X	
			10%-<50%	X	X	X	
			50%-<90%	X	X	X	
			90%-<100%	X	X	X	
				10%-<50%	X	X	
				50%-<90%	X	X	
				90%-100%	X	X	
					10%-<50%	X	
					50%-<90%	X	
					90%-100%	X	
						90%-100%	



# Mapping Process

## Five Step Procedure

# Four Types of GIS Data Generated During this Work

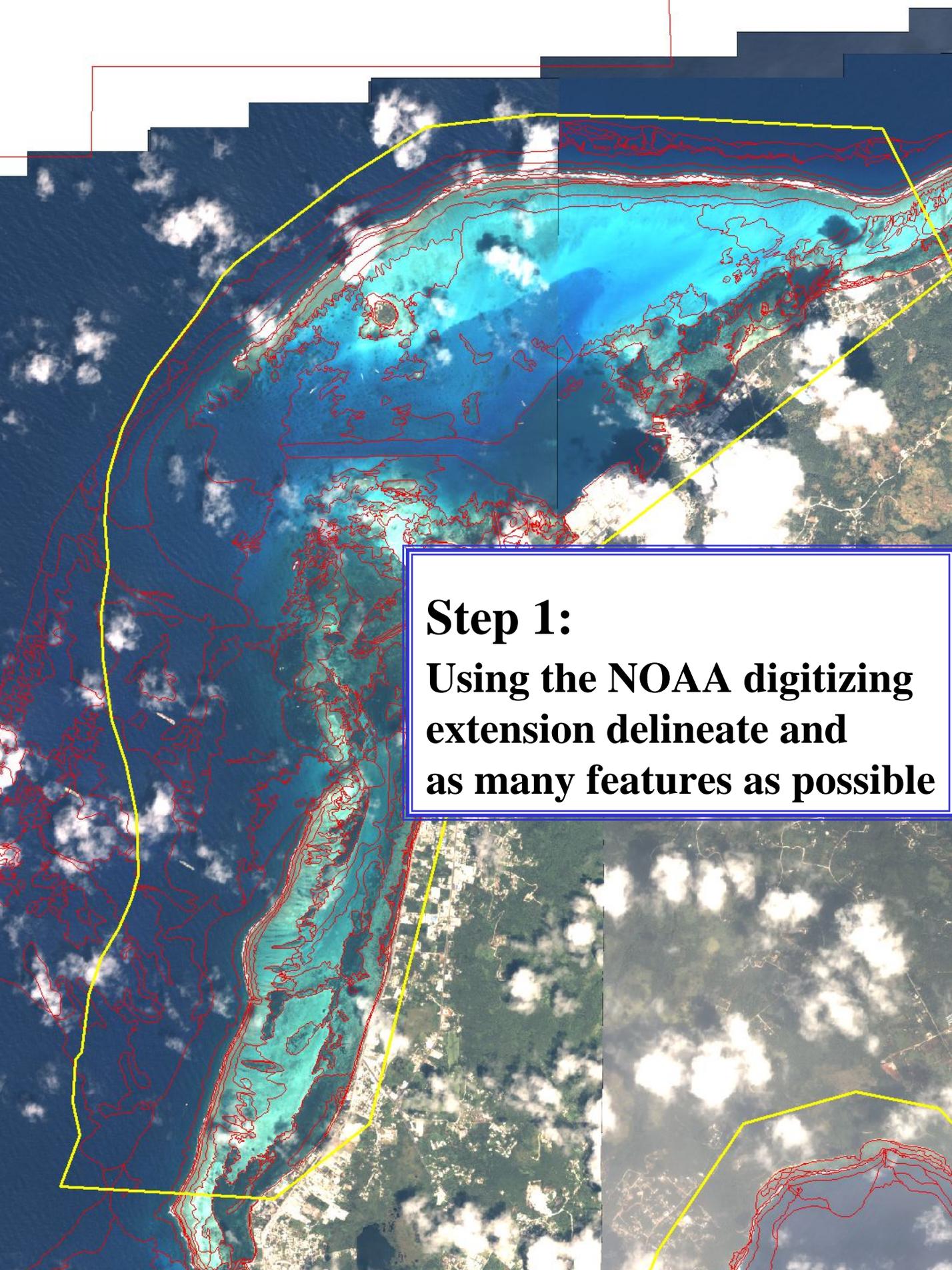


## LEGEND

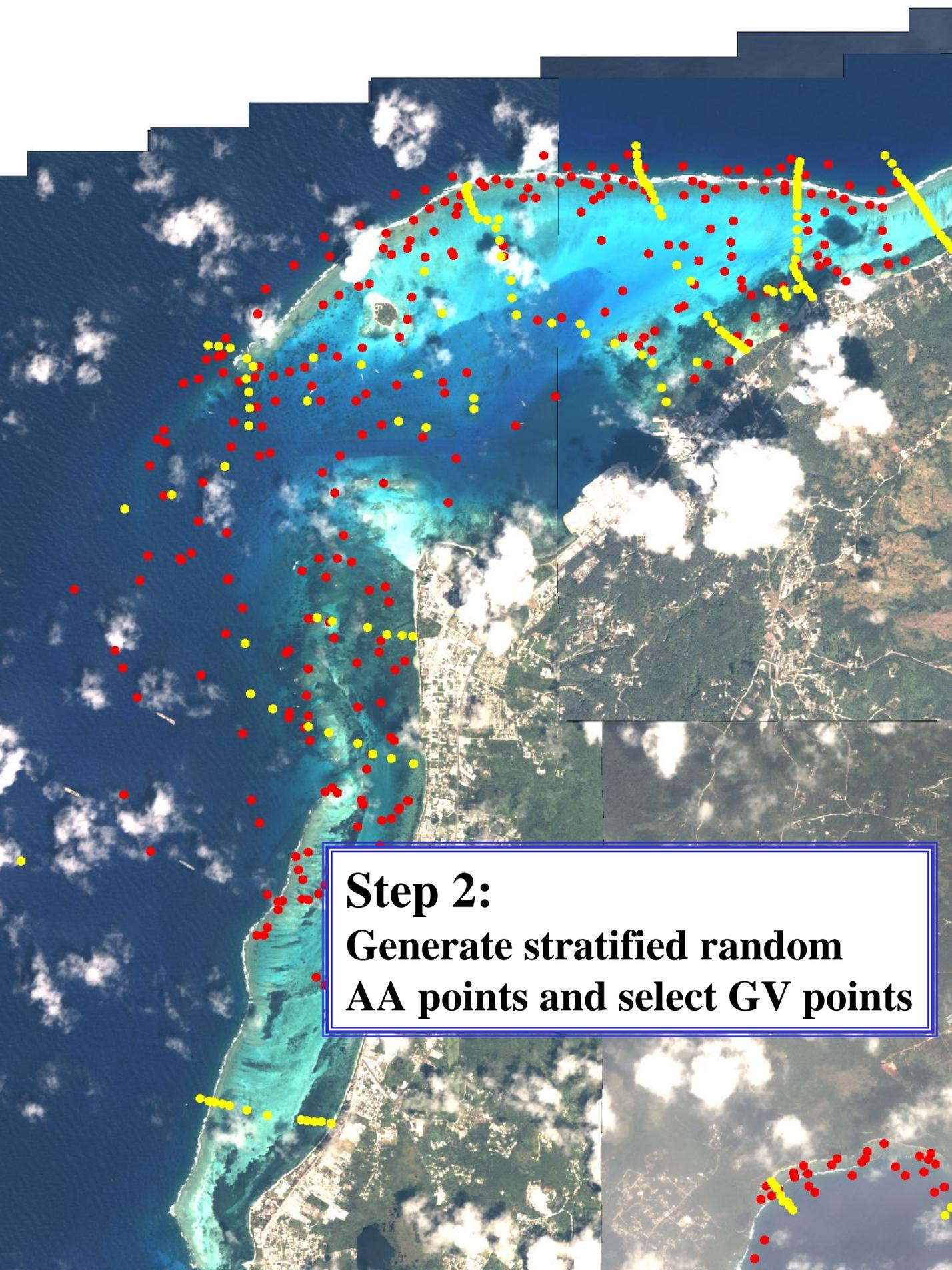
- Accuracy Assessment Point
- Ground Validation Point
- Shoreline
- Habitat Polygon



1000 0 1000 2000 Meters



**Step 1:**  
**Using the NOAA digitizing extension delineate and as many features as possible**



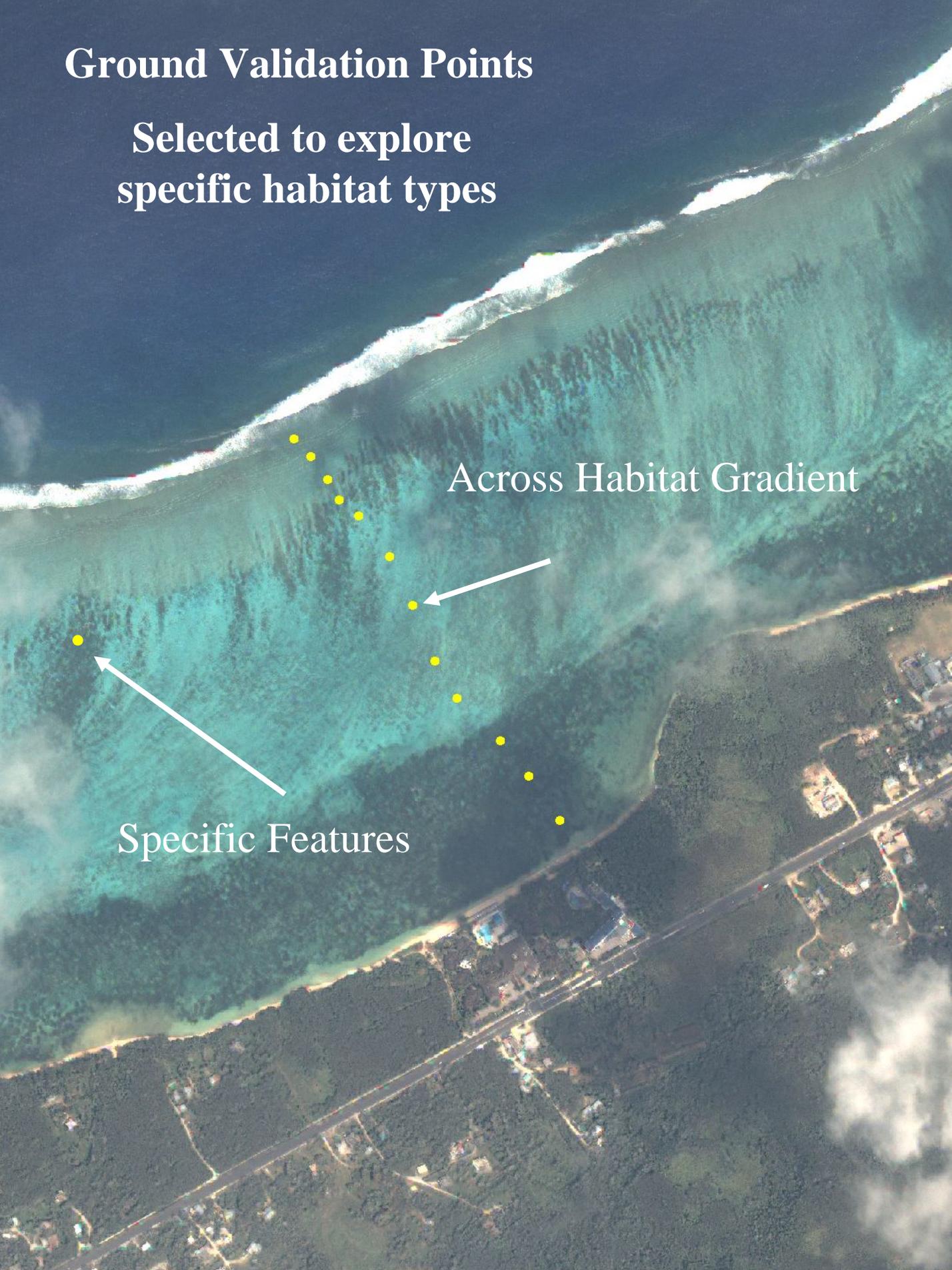
**Step 2:**  
**Generate stratified random**  
**AA points and select GV points**

# Ground Validation Points

Selected to explore  
specific habitat types

Across Habitat Gradient

Specific Features

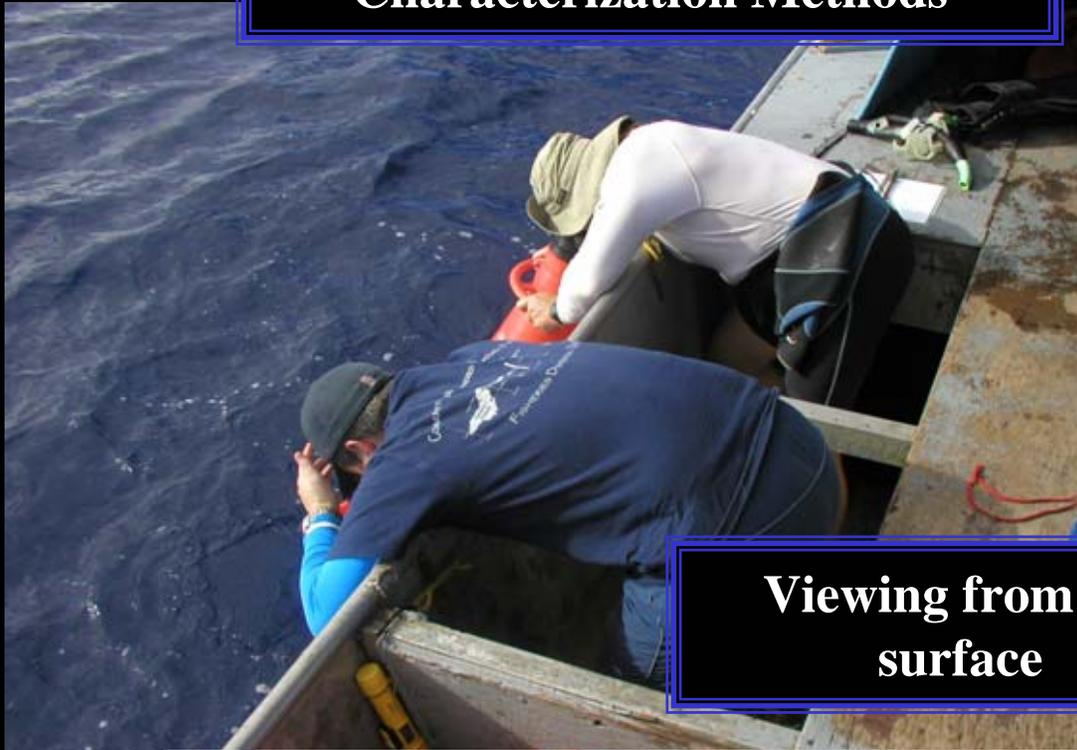




**Boats used Range  
from 65 Foot  
Charter Vessel  
to Ocean Kayak**



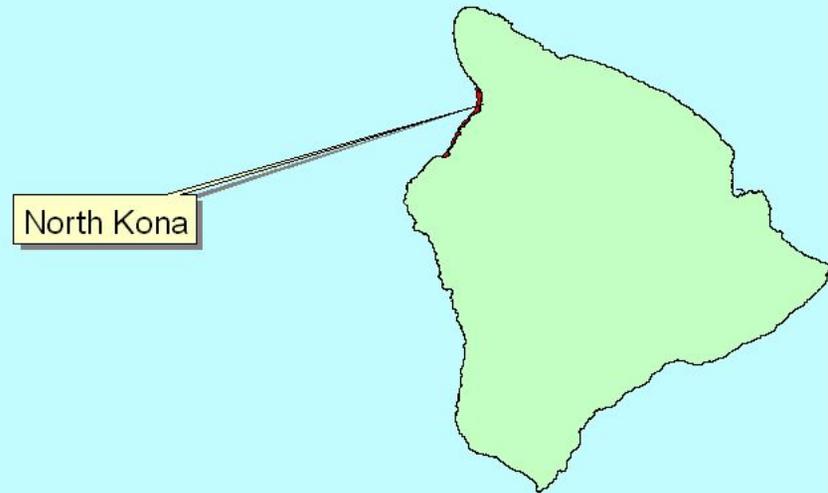
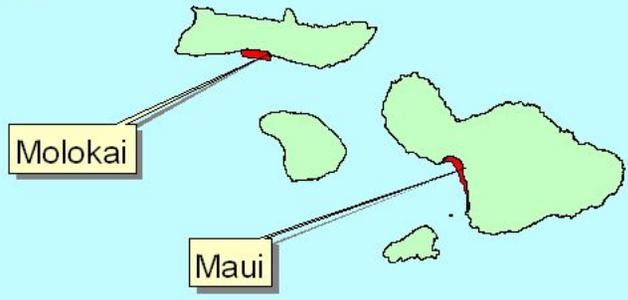
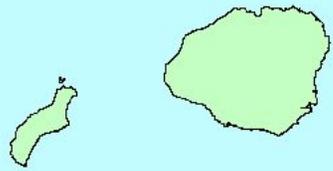
# Benthic Community Characterization Methods



Viewing from the  
surface



Drop video camera



Test Areas in the  
Main Eight Hawaiian Islands



# Field Data Collected at Each Habitat Assessment Site

## Site Data

- Site ID
- Study Area
- GPS Date
- GPS Time
- GPS Position
- GPS Statistics
- Depth
- Photo Information
- Assessment Method

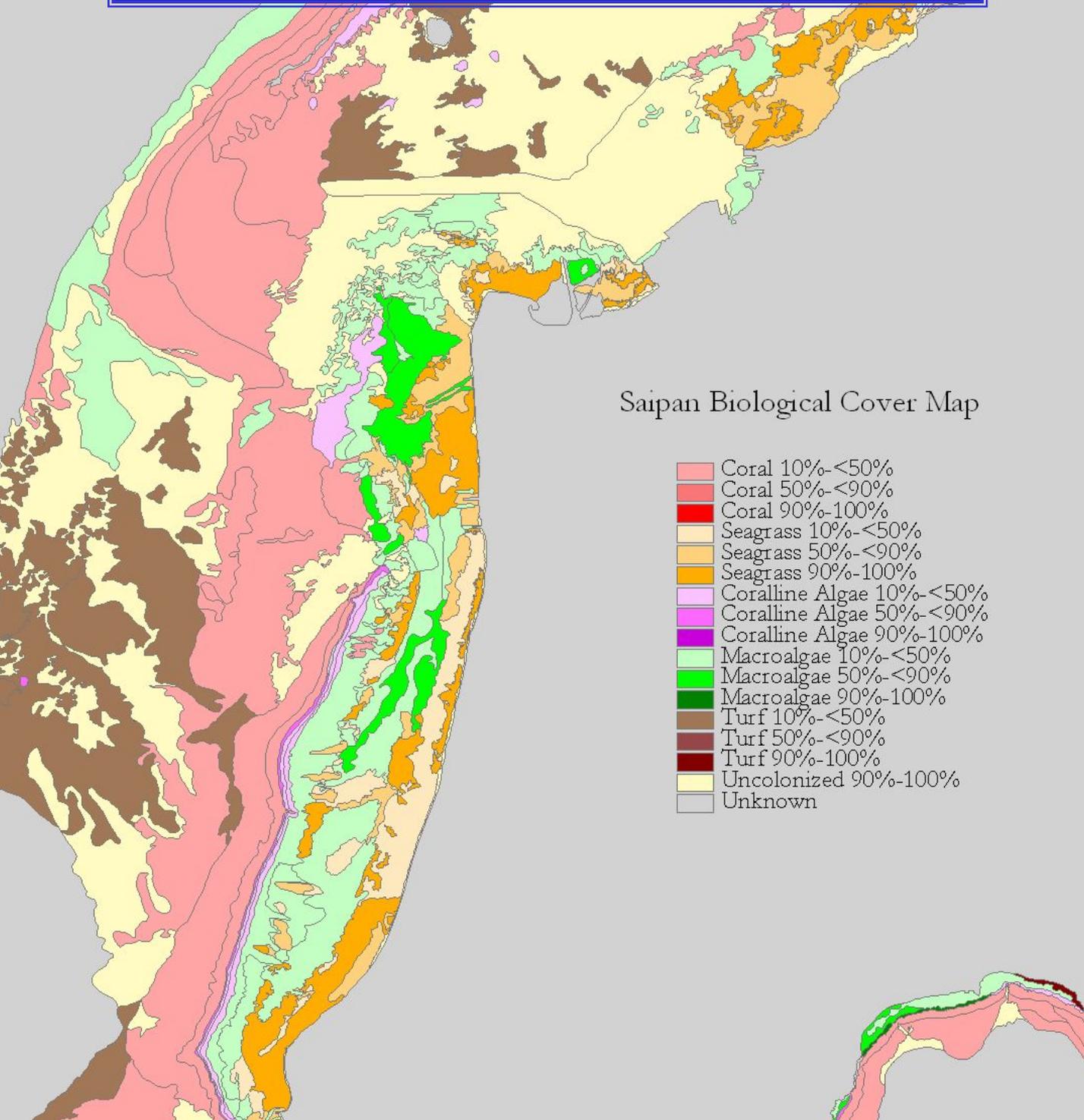
## Habitat Data

- Point Habitat Type
- Area Habitat Type
- Area 2 Habitat Type
- Major Structure
- Detailed Structure
- Cover Type
- Cover Modifier
- Area Description



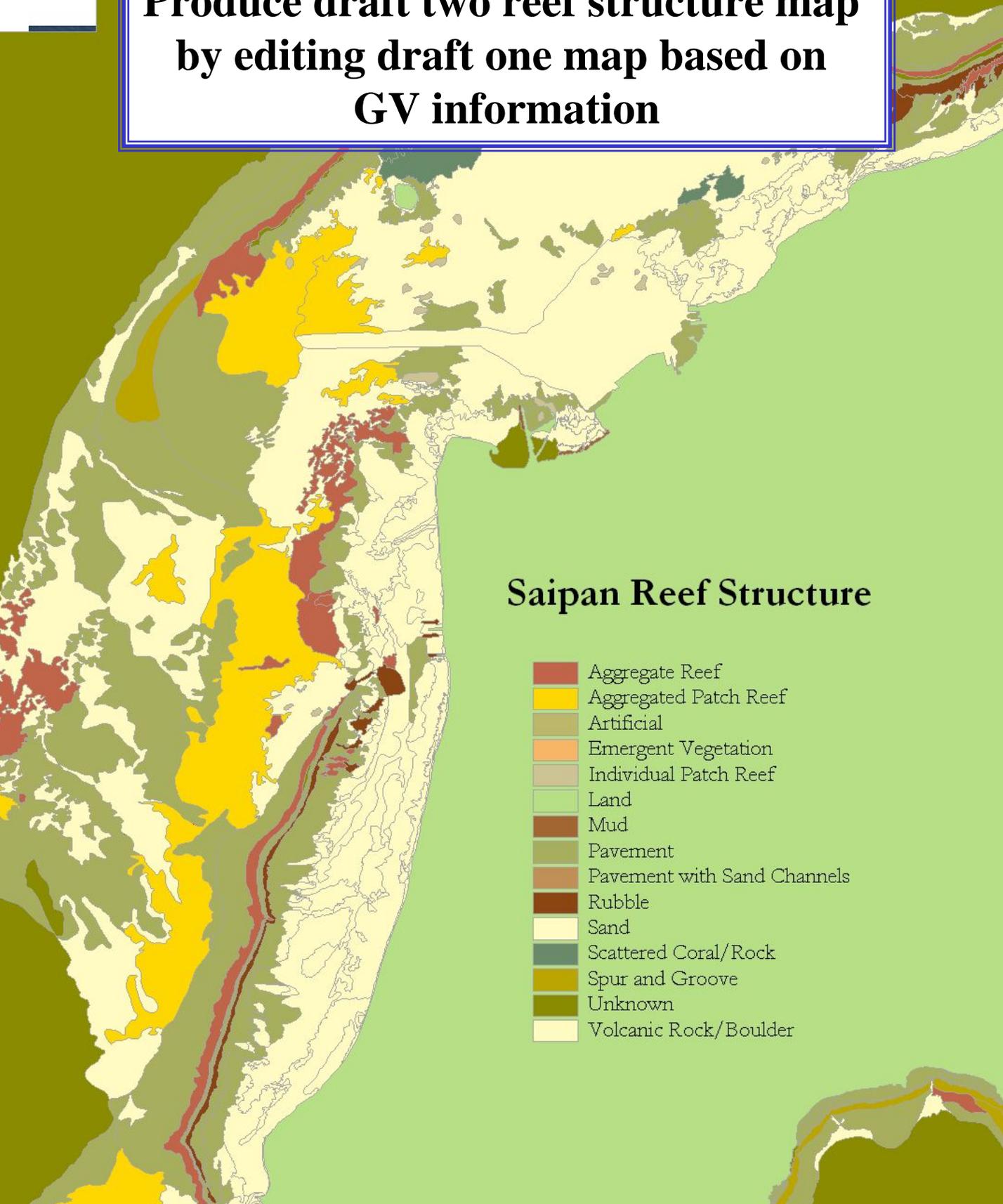
# Step 3a:

## Produce draft two biological cover map by editing draft one map based on GV information



# Step 3b:

## Produce draft two reef structure map by editing draft one map based on GV information

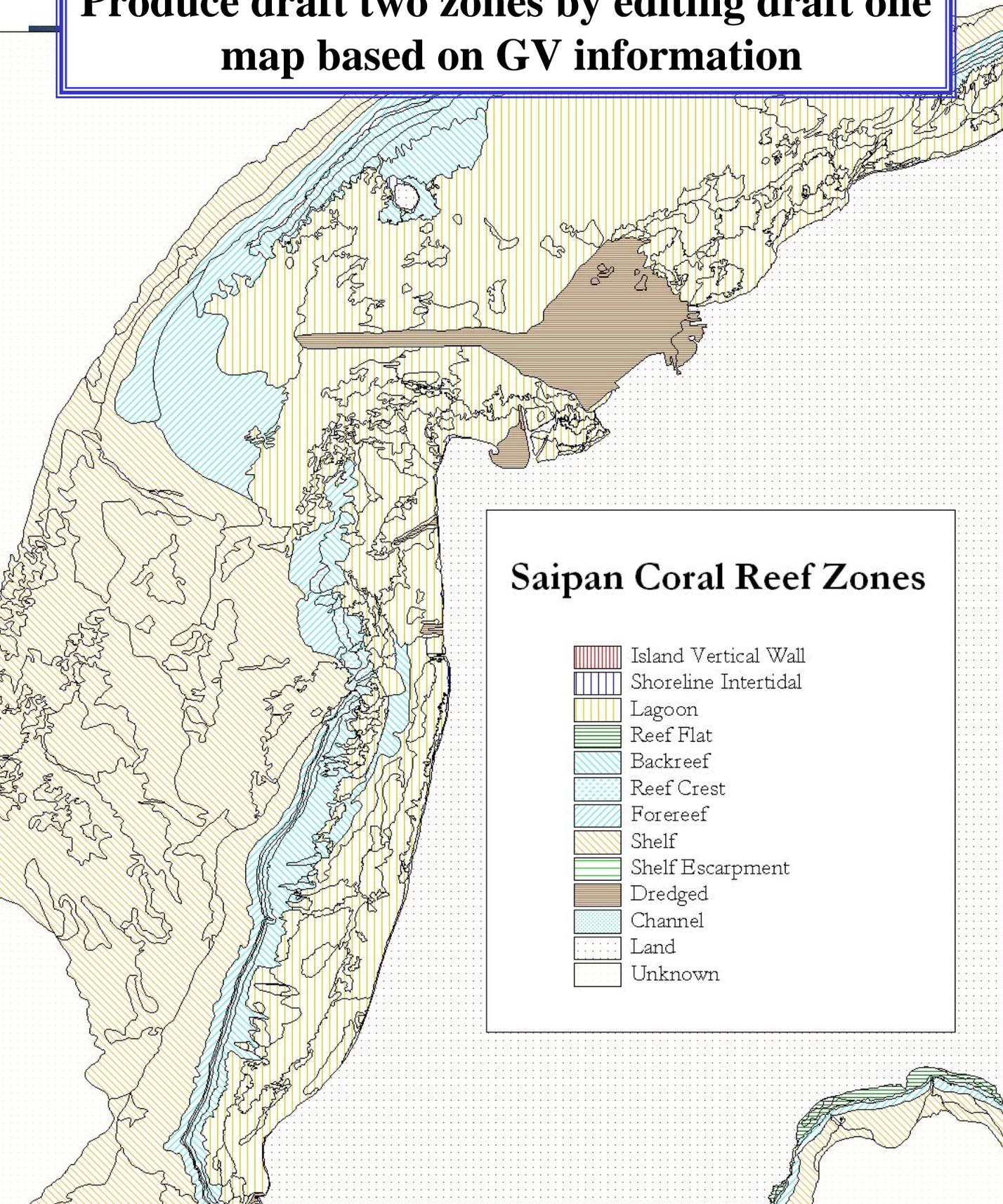


### Saipan Reef Structure

- Aggregate Reef
- Aggregated Patch Reef
- Artificial
- Emergent Vegetation
- Individual Patch Reef
- Land
- Mud
- Pavement
- Pavement with Sand Channels
- Rubble
- Sand
- Scattered Coral/Rock
- Spur and Groove
- Unknown
- Volcanic Rock/Boulder

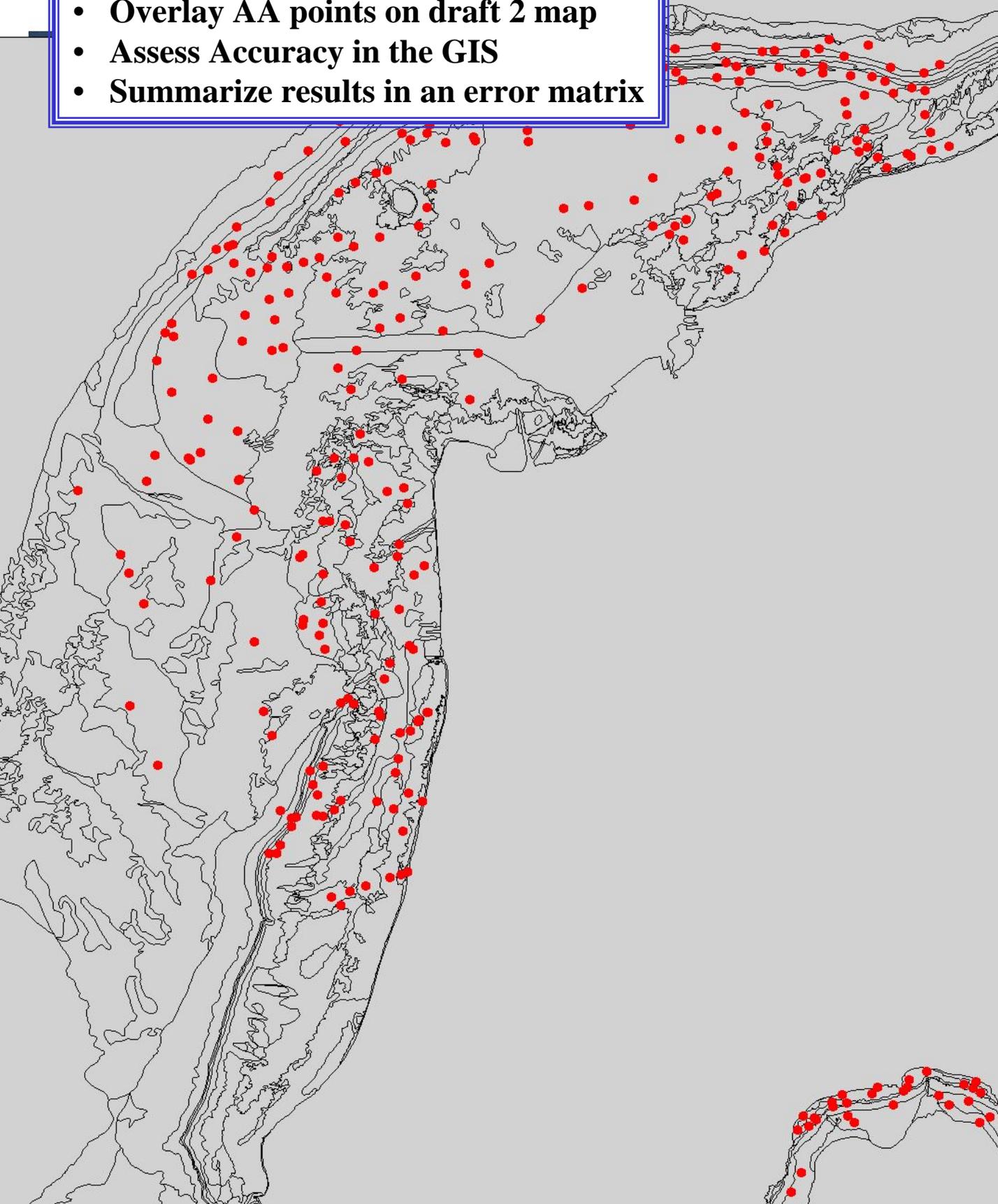
## Step 3c:

Produce draft two zones by editing draft one map based on GV information

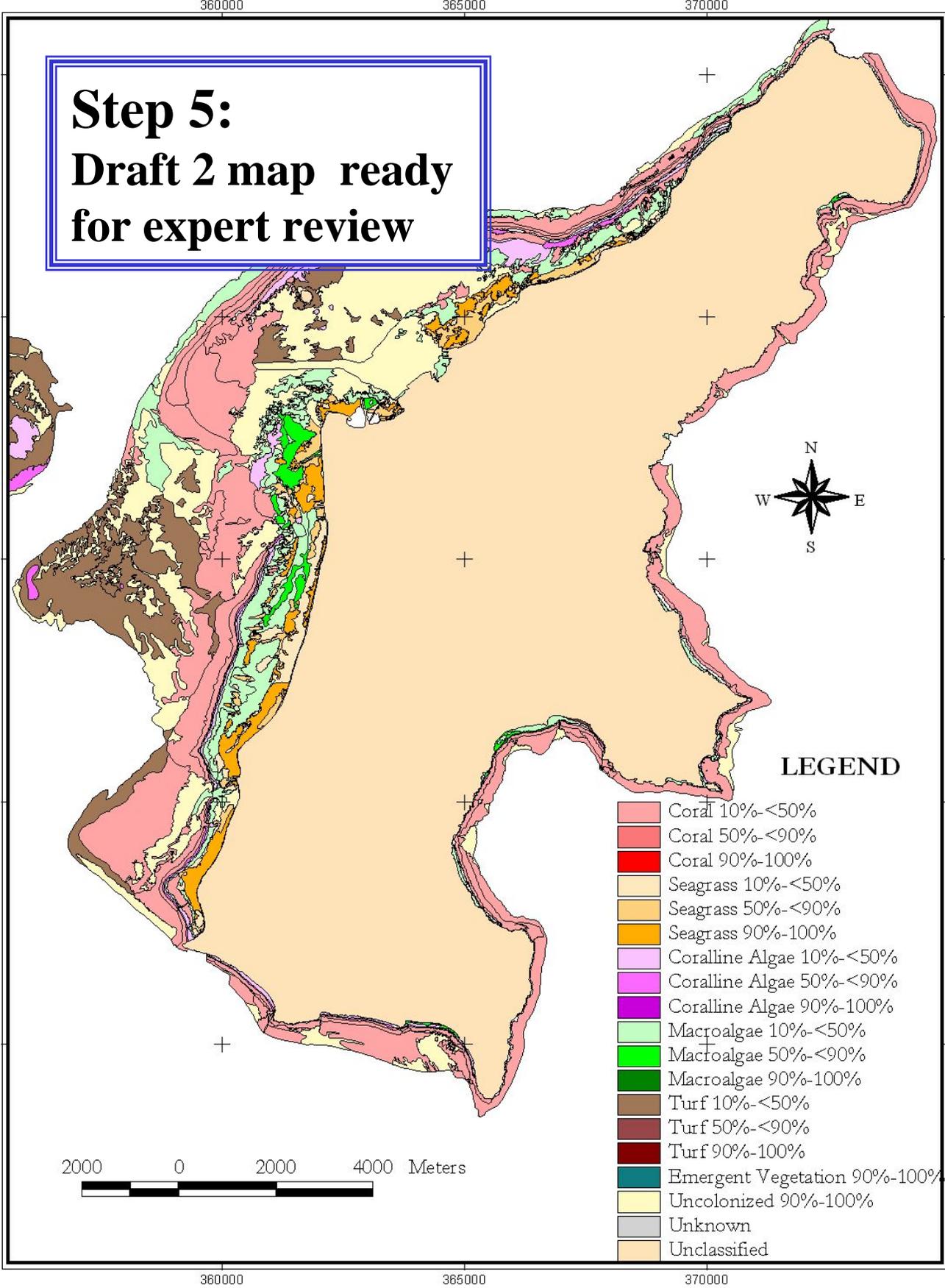


## Step 4:

- **Overlay AA points on draft 2 map**
- **Assess Accuracy in the GIS**
- **Summarize results in an error matrix**



**Step 5:  
Draft 2 map ready  
for expert review**



# Mapping Standards and Accuracy Test Areas



# Mapping Standards

## *Spatial Quality*

Imagery: Defined by provider

Digitizing accuracy (1 meter RMS)

Digitized at scale of 1:6,000

Accuracy assessment GPS (2-5 meters)

## *QA/QC*

Void polygons

Overlapping polygons

MMU: 1 acre

Clean polygons

Adjacency

Concatenated field

Standardized table format

## *Metadata*

CSDGM standard parsable - no errors

Map review

## *Thematic Accuracy*

Major Structure and Cover:

Overall 85%/0.85 Tau

Detailed Structure and Cover:

Overall 75%/0.75 Tau

# **Primary Considerations When Choosing an AA Test Area**

- 1. Habitat diversity**
  - a. Structure Type**
  - b. Biological Cover Type**
  - c. Exposure Regime**
  - d. Bathymetric Range**
  
- 2. Maintain number of test areas to a manageable number (Ideally one but up to three)**
  
- 3. Suitable imagery is available for the area**

# Area of Typical Test Sites

4 to 43 Sq. Km.

Test Area Name	Area (Sq. Km.)
----------------	----------------

## Hawaii

- |               |    |
|---------------|----|
| • Kaneohe Bay | 43 |
| • North Kona  | 27 |
| • Molokai     | 29 |
| • Maui        | 17 |

## Saipan

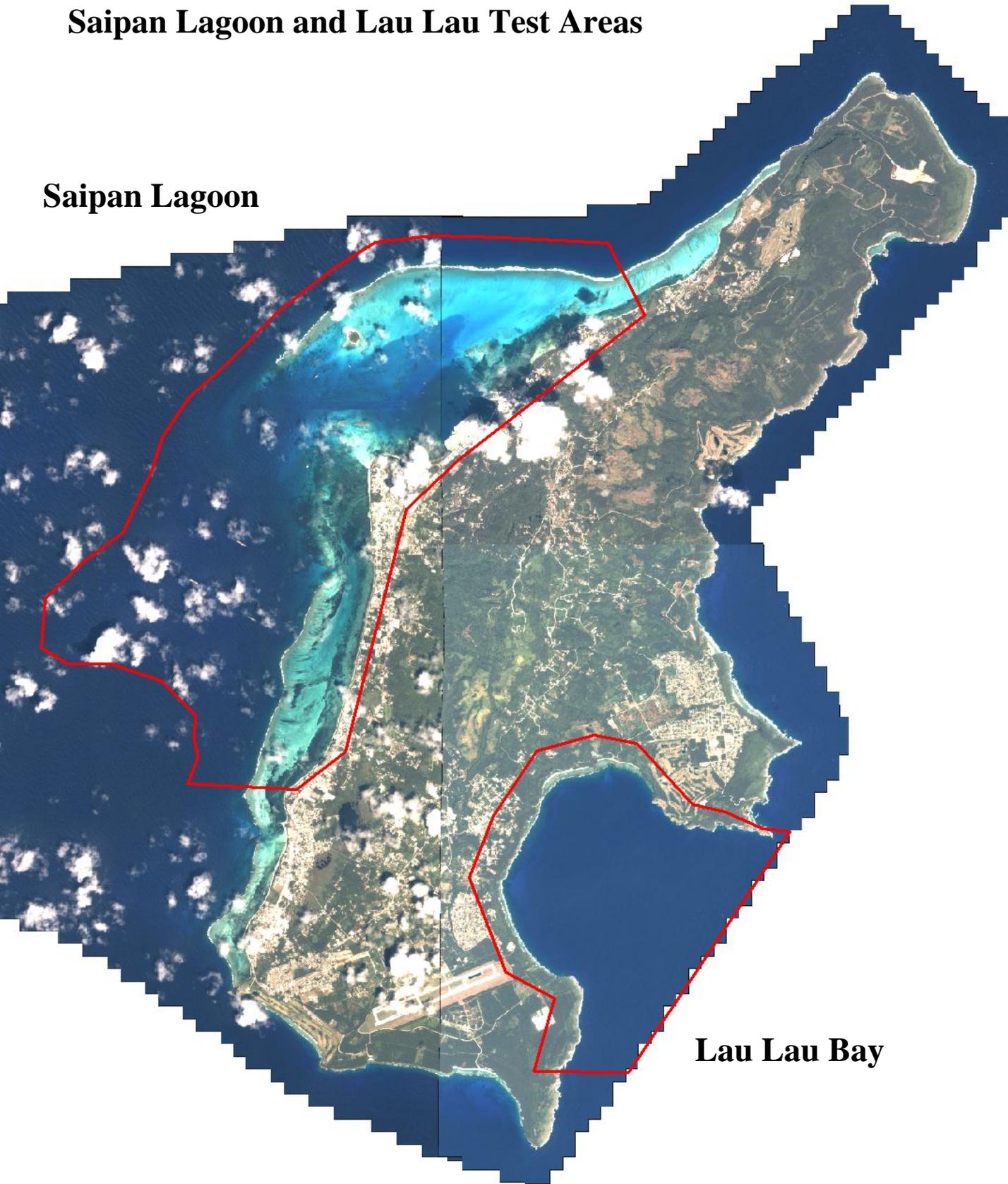
- |                 |    |
|-----------------|----|
| • Saipan Lagoon | 47 |
| • Lau Lau Bay   | 11 |
| • Tinian        | 4  |
| • Rota (2)      | 13 |

## Guam

- |                |    |
|----------------|----|
| • Cocos Lagoon | 15 |
| • Piti Bay     | 4  |

# Saipan Lagoon and Lau Lau Test Areas

Saipan Lagoon



Lau Lau Bay

# Accuracy of major structure of coral reef habitat maps of the Mariana Archipelago prepared from visual interpretation of IKONOS satellite imagery

Truth base on field observations

Map Attributes		Hard	Soft	Total	UA
	Hard	876	5	881	99.4%
	Soft	9	217	226	96.0%
	Total	885	222	Diagonal Sum: 1093	
	PA	99.0%	97.8%	Total Obs: 1107	

**Overall Accuracy of Major Structure: 98.7%**

# Accuracy of detailed structure of coral reef habitat maps of the Mariana Archipelago prepared from visual interpretation of IKONOS satellite imagery

Truth base on field observations

Map Attributes

	AgRf	AgPR	IndPR	SnG	SCRUS	Pvmt	Rock/Bldr	Rubble	Sand	Mud	Total	UA
AgRf	50					4				1	55	91%
AgPR		40				2		1		1	44	91%
IndPR		2	25								27	93%
SnG	2			74		13					89	83%
SCRUS					33	4					39	85%
Pvmt	5	4	1	15	2	369		11			405	91%
Rock/Bldr							191		2		193	99%
Rubble								26	1		29	90%
Sand		3	1	2			1	1	184		193	95%
Mud										33	33	100%
<b>Total</b>	<b>57</b>	<b>49</b>	<b>27</b>	<b>89</b>	<b>35</b>	<b>395</b>	<b>192</b>	<b>41</b>	<b>189</b>	<b>33</b>	<b>Diag. Sum: 1025</b>	
<b>PA</b>	<b>88%</b>	<b>82%</b>	<b>93%</b>	<b>83%</b>	<b>94%</b>	<b>93%</b>	<b>99%</b>	<b>63%</b>	<b>97%</b>	<b>100%</b>	<b>Total Obs: 1107</b>	

Overall Accuracy of Detailed Structure: 92.6%

# Accuracy of major cover of coral reef habitat maps of the Mariana Archipelago prepared from visual interpretation of IKONOS satellite imagery

		Truth base on field observations								
		Coral	CA	MacAl	Turf	SeaGr	EmVeg	Uncol	Total	UA
Map Attributes	Coral	387	16	7	25	0	0	2	437	89%
	CCA	23	168	1	15	0	0	0	207	81%
	MacAl	5	7	136	7	1	0	0	156	87%
	Turf	4	3	1	79	0	0	2	89	89%
	SeaGr	0	0	1	0	100	0	0	101	99%
	EmVeg	0	0	0	0	0	27	0	27	100%
	Uncol	2	3	5	4	0	1	75	90	84%
Total	421	197	151	130	101	28	79	Diag. Sum: 972		
PA	92%	85%	90%	61%	99%	96%	95%	Total Observations 1107		

Overall Accuracy of Major Cover: 87.8%

# Summary of Map Accuracy

<b>Map Category</b>	<b>Overall Accuracy</b>	<b>Tau</b>
Major Structure	98.7%	0.981
Detailed Structure	92.6%	0.919
Major Cover	87.8%	0.858
Detailed Cover	80.9%	0.799



# Geospatial Summary

# GIS Area Analysis for the Structural Component of Coral Reef Habitats of The Southern Islands of CNMI

Coral Reef Structure Type	Area (km <sup>2</sup> )	% of Total Reef Area
Pavement	55.0	35.3
Spur and Groove	13.7	8.6
Individual Patch Reef	0.2	0.1
Aggregated Patch Reef	13.5	8.5
Aggregate Reef	9.3	5.9
Rock/Boulder	0.3	0.2
Rubble	2.0	1.3
Scattered Coral and Rock in Unconsolidated Sediment	1.3	0.8
Pavement with Sand Channels	14.3	<b>9.0</b>
<b>Total Coral Reef and Hard Bottom</b>	<b>110.6</b>	<b>69.7</b>
Sand	48.1	30.3
Mud	.02	0.01
<b>Total Unconsolidated Sediment</b>	<b>48.1</b>	<b>30.3</b>
<b>Total Coral Reef Area</b>	<b>158.7</b>	<b>100</b>

## GIS Area Analysis for the Structural Component of Coral Reef Habitats of The Southern CNMI Islands

<b>Coral Reef Biological Cover Type</b>	<b>Area (km<sup>2</sup>)</b>	<b>% of Area</b>
Coral	47.7	30.0
Sea Grass	6.7	4.2
Macro Algae	18.7	11.8
Coralline Algae	22.2	14.4
Turf	24.4	15.4
Uncolonized	39.2	24.7
<b>Total Coral Reef Area</b>	<b>158.7</b>	<b>100</b>

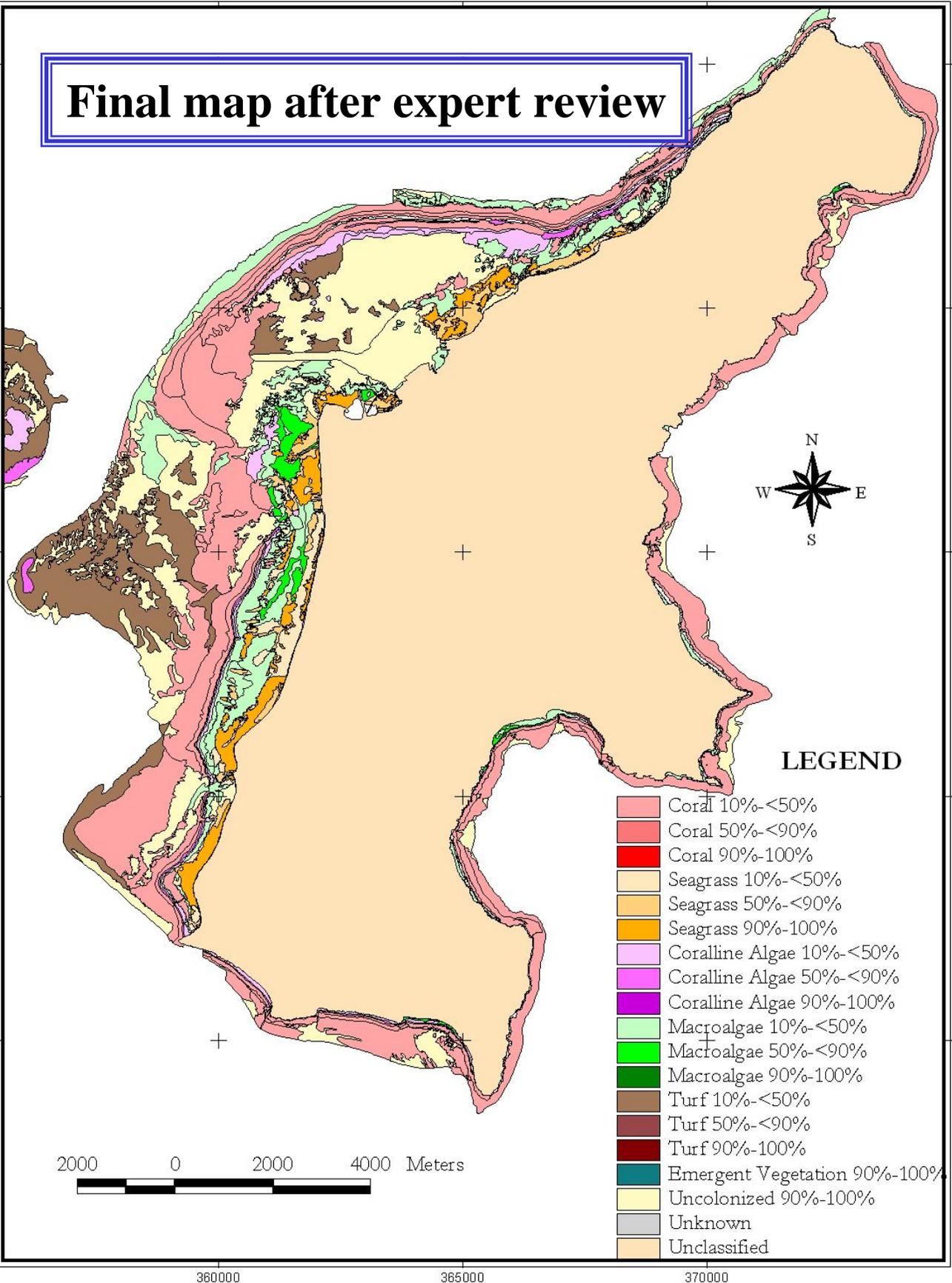
# GIS Area Analysis for the Structural Component of Coral Reef Habitats of The Northern CNMI Islands

<b>Coral Reef Structure Type</b>	<b>Area (km<sup>2</sup>)</b>	<b>% of Total Reef Area</b>
Pavement	3.8	8.4
Aggregate Reef	0.8	1.8
Rock/Boulder	36.3	80.1
Rubble	0.02	0.04
<b>Total Coral Reef and Hard Bottom</b>	<b>40.9</b>	<b>90.3</b>
Sand	4.4	9.7
<b>Total Unconsolidated Sediment</b>	<b>4.4</b>	<b>9.7</b>
<b>Total Coral Reef Area</b>	<b>45.3</b>	<b>100</b>

# GIS Area Analysis for the Structural Component of Coral Reef Habitats of The Northern CNMI Islands

<b>Coral Reef Biological Cover Type</b>	<b>Area (km<sup>2</sup>)</b>	<b>% of Area</b>
Coral	24.3	53.6
Macro Algae	1.1	2.4
Coralline Algae	9.2	20.3
Turf	7.2	15.9
Uncolonized	3.5	7.7
<b>Total Coral Reef Area</b>	<b>45.3</b>	<b>100</b>

# Final map after expert review



2000 0 2000 4000 Meters

360000

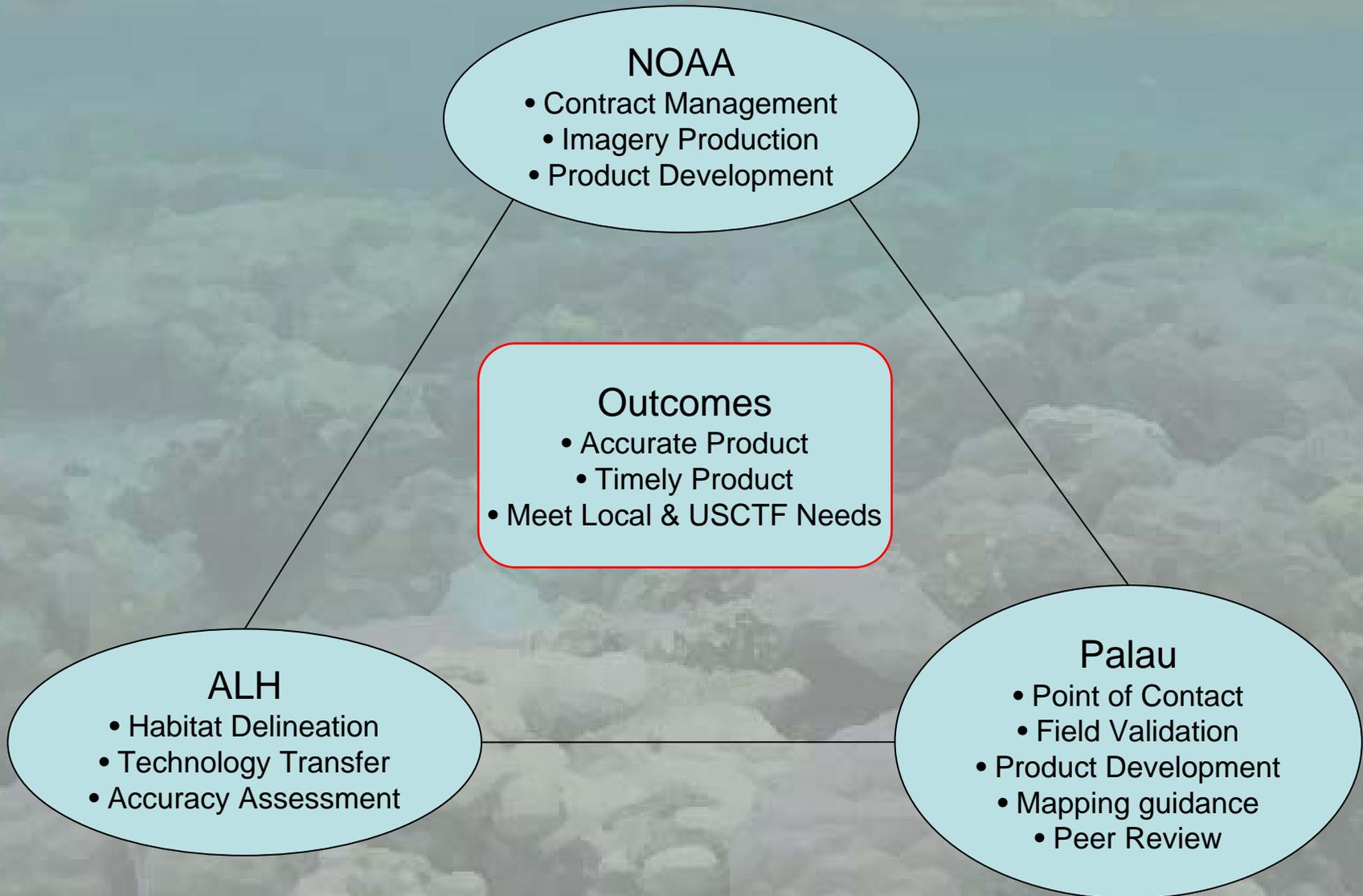
365000

370000

Conclusions  
Summaries  
Discussions



## Partnership Framework



## Products

- FTP site with access to IKONOS imagery and derivatives (copyrighted)
- Final Atlas of the shallow-water benthic habitats of the Republic of Palau
- Cd-rom/website

**NCCOS** NOAA NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE  
*science for coastal communities*

Overview    Methods    Data    Maps    Partners    About

**Shallow-Water Benthic Habitats of American Samoa,  
Guam, and the Commonwealth of the Northern Mariana Islands**

Providing a benthic habitat classification manual, a benthic habitat map for the nearshore waters of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands, and supplemental geospatial data.

  
National Ocean Service  
National Centers for Coastal Ocean Science  
Center for Coastal Monitoring and Assessment  
**Biogeography Team**