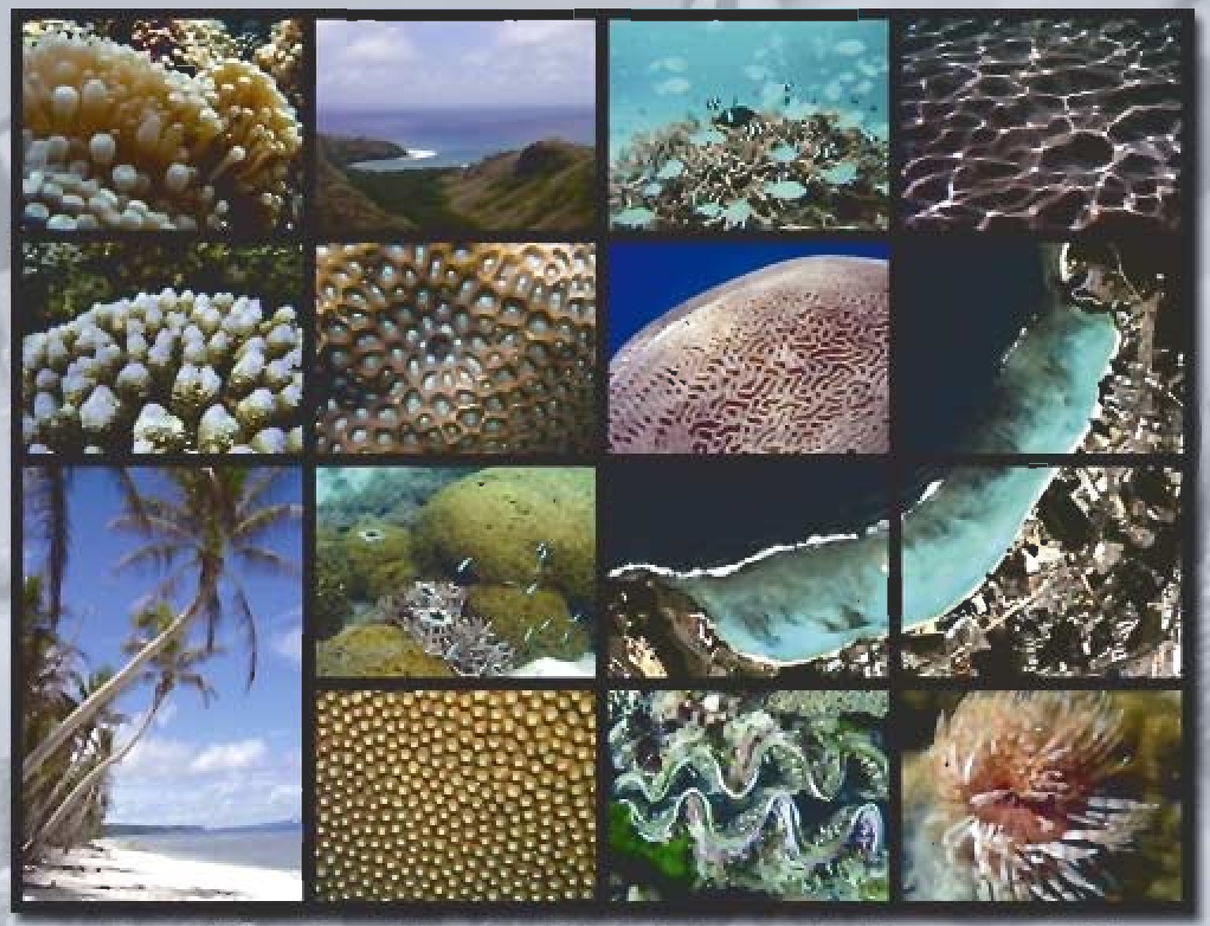
GUAM COASTAL ATLAS



Providing benthic habitat data and other coastal information for the nearshore waters of Guam

November 2005

Prepared by David Burdick, 2004-2006 NOAA Pacific Islands Assistant for Guam

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Guam Coastal Atlas

Disclaimer

The Guam Coastal Atlas was subject to a limited internal review with representatives from the University of Guam Marine Laboratory and the Guam Coastal Management Program before publication. Although this document was derived in part from benthic habitat data originally developed by the National Oceanographic and Atmospheric Administration (NOAA) National Centers for Coastal Ocean Science (NCCOS) Biogeography Team and based loosely on the "Atlas of the Shallow-Water Benthic Habitats of American Samoa, Guam, and the Commonwealth of the Northern Marianas Islands" published by the same group, it was not subject to review by NOAA. At the time of publication, an accuracy assessment for the benthic habitat data had not been performed; thus, the accuracy of the data cannot be confirmed. An accuracy assessment may occur at a later date and should become available on the Guam Coastal Atlas website (http://www/uog.edu/marinelab/coastal.atlas). The mention of trade names or commercial products within this publication does not constitute endorsement or recommendation for their use.

Important: The maps contained in this atlas are not to be used for navigational purposes

Acknowledgements

The Guam Coastal Atlas was developed by David R. Burdick, the 2004 - 2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Dr. Terry J. Donaldson, the Principle Investigator, and Barry D. Smith, Director of the University of Guam Marine Laboratory.

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Further support and contributions for the Guam Coastal Atlas project were provided by several organizations and individuals, including:

- University of Guam Marine Laboratory
- Guam Coastal Management Program
- Guam Department of Aquatic and Wildlife Resources, Guam Department of Agriculture
- NOAA National Centers for Coastal Ocean Science Biogeography Team
- NOAA Coastal Services Center
- NOAA Pacific Services Center

All photos in the Guam Coastal Atlas, including those used in the cover montage, were taken by Dave Burdick unless otherwise stated.

Related Products

In addition to the printed version of the Guam Coastal Atlas, a CD-ROM and a website are also available. The CD-ROM contains all the maps included in the printed version, as well as ground validation data, benthic habitat data, and other relevant digital spatial data that can be used within a Geographic Information System (GIS). The Guam Coastal Atlas website, located at http://www.uog.edu/marinelab/coastal.atlas/ will contain all the information included with the CD-ROM, as well as all digital spatial data and metadata.

Colonies of Acropora spp. at Gun Beach exposed during an extreme low tide. Photo by Dave Burdick.

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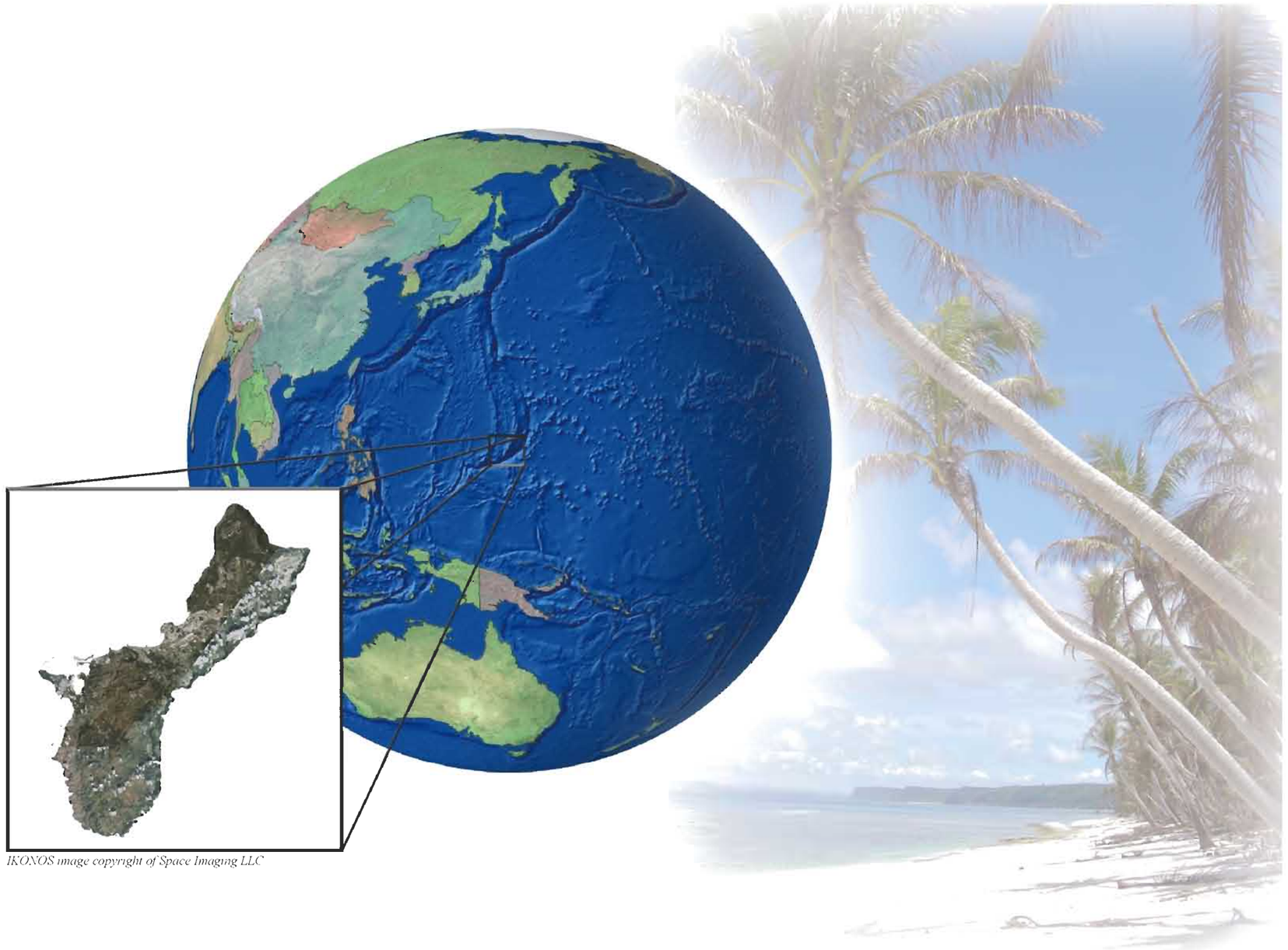

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Guam Coastal Atlas ▪ Introduction and Methods

Introduction

With the recent proliferation of Geographic Information Systems (GIS) and the availability of high-resolution satellite imagery, a new generation of coastal resource information has become available. The Guam Coastal Atlas was developed using these technologies and includes benthic habitat maps created using satellite imagery and a GIS. Marine preserve boundaries were mapped using the Global Positioning System (GPS). Other information relevant to the management of Guam's coastal resources is available, as well. The Guam Coastal Atlas, which also exists as a CD-ROM product and on the World Wide Web (http://www.uog.edu/marinelab/coastal.atlas/), provides this useful information to coastal resource managers, researchers, students, fisherman, recreational users, and the general public.

The Guam Coastal Atlas is an updated version of the "Atlas of the Reefs and Beaches of Guam," created by R. H. Randall and L. G. Eldredge in 1976. The "Atlas of the Reefs and Beaches of Guam" was developed using hand-drawn sketches of the coastline derived from aerial photographs (Figure 1). With time, some of the information presented in the 1976 atlas became outdated and the need arose for portraying the latest information about the coastal areas of Guam. While the previous atlas focused on shoreline features and presented limited benthic habitat information, the Guam Coastal Atlas focuses primarily upon detailed benthic habitat data and does not include information about shoreline features (Figure 2). The Guam Coastal Atlas is not intended to replace entirely the previous atlas, but rather should be considered supplemental to the original publication.

The benthic habitat data set used to create the maps provided with the Guam Coastal Atlas is an updated, more detailed version of the benthic habitat data set developed in 2004 by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Coastal Ocean Science (NCCOS) Biogeography Team. As described in more detail below, the considerable amount of additional ground-truthing and the use of more recent IKONOS satellite imagery in the development of the data for the Guam Coastal Atlas allowed for an improvement upon the benthic habitat data developed previously by the NOAA Biogeography Team.

Methods

Benthic habitat data for Guam developed by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Coastal Ocean Science (NCCOS) Biogeography Team served as the starting point for the benthic habitat maps used in the Guam Coastal Atlas. The NOAA Biogeography Team's benthic habitat data were created by visual interpretation of IKONOS satellite imagery captured between 2001 and 2003 and validated by *in situ* surveys (for more information regarding the methods used by the NOAA Biogeography Team to develop their benthic habitat data for Guam, please visit their Web site at http://biogeo.nos.noaa.gov). The NOAA Biogeography Team's benthic habitat data utilized an average minimum mapping unit of approximately 1 acre (4046.9 sq. meters), however, and did not fully take advantage of the high level of detail that the IKONOS imagery allowed.

In order to update the NOAA Biogeography Team's benthic habitat data and enhance the level of detail for select portions of the data set, the most recently (2001 - 2004) available multispectral IKONOS image mosaic and a significantly smaller minimum map unit was used. An average minimum map unit of approximately 1/8 acre was used for the mapping of benthic habitats in four of Guam's marine preserves and other "focus areas"; some polygons with an area less than the minimum mapping unit occur in the data, however. The IKONOS imagery was pan-sharpened using ERDAS Imagine image processing software. The heads-up digitizing functions of ArcGIS were then used to adjust the boundaries of the existing benthic habitat data, create new features, and update feature attribute information. A hierarchical classification scheme similar to that used by the NOAA Biogeography Team was adopted for the data used in the Guam Coastal Atlas.

Four of Guam's marine preserves (Tumon Bay, Piti Bomb Holes, Achang Reef Flat, and Sasa Bay Preserves), as well as Cocos Lagoon, Pago Bay, and East Agana Bay, were targeted for highly detailed benthic habitat interpretation using the smaller minimum map unit; more detailed benthic habitat maps for other coastal areas may become available at a later date. Benthic habitat maps for much of the area beyond the marine preserve boundaries and the focus areas utilized the original NOAA Biogeography Team benthic habitat data, although some alterations (e.g. polygon boundary adjustments, classification corrections/updates) were performed. Ground validation surveys were also performed during the development of the Guam Coastal Atlas habitat data with a Trimble GeoXT hand-held GPS receiver that was used to collect GPS-referenced benthic habitat information *in situ*. Accuracy assessment surveys were not conducted upon completion of the benthic habitat data set, thus the percent accuracy for the data is unknown. Because of changes made to the NOAA Biogeography Team's benthic habitat data set for use in the Guam Coastal Atlas, the level of accuracy achieved with the NOAA data does not apply to the data used in the Guam Coastal Atlas. Please refer to the NOAA Biogeography Project Web site (http://biogeo.nos.noaa.gov) for more information about their accuracy verification surveys.

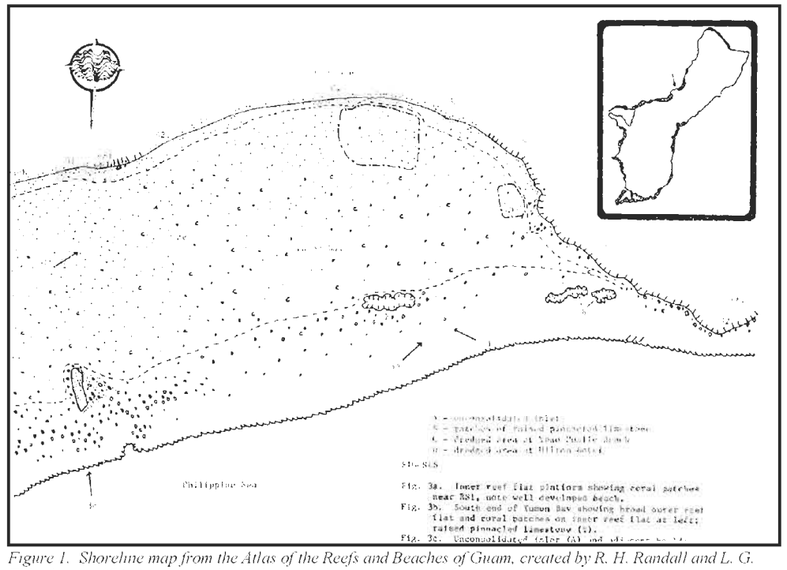

Figure 1. Shoreline map from the Atlas of the Reefs and Beaches of Guam, created by R. H. Randall and L. G. Eldredge in 1976. Maps were hand-drawn and were interpreted from aerial photos.

Figure 2. Example of benthic habitat data and satellite imagery found in maps presented in the Guam Coastal Atlas. IKONOS imagery provided by Space Imaging LLC.

Guam Coastal Atlas ▪ Classification Scheme and Ground Validation Surveys

Classification Scheme

A hierarchical classification scheme similar to that used by the NOAA Biogeography team was adopted for the development of benthic habitat data used in the Guam Coastal Atlas (Figure 3). Using this classification scheme, benthic habitats were described from the broadest level of classification (unconsolidated sediment or coral reef/hard bottom) to a very detailed level of classification (e.g. 50% to < 90% macroalgae). Major structure (unconsolidated sediment or coral reef/hard bottom), detailed structure (e.g. aggregated reef, pavement, patch reef, etc.), major cover type (e.g. coral, macroalgae, turf algae, uncolonized, etc.), and percent cover of the major cover type (e.g. 0%, 1% to < 10%, 10% to < 50%, etc.) were recorded for each habitat delineation.

Although the benthic habitat data developed for the Guam Coastal Atlas used the same classification scheme as that used by the NOAA Biogeography Team, slightly different rules were used to determine the classification an area was to receive. These changes included:

- Defining coral as the majority cover type if the coral percent cover was 10% or greater

- Defining macroalgae as the major cover type if the macroalgae percent cover was 10% or greater and if coral cover was less than 10%.

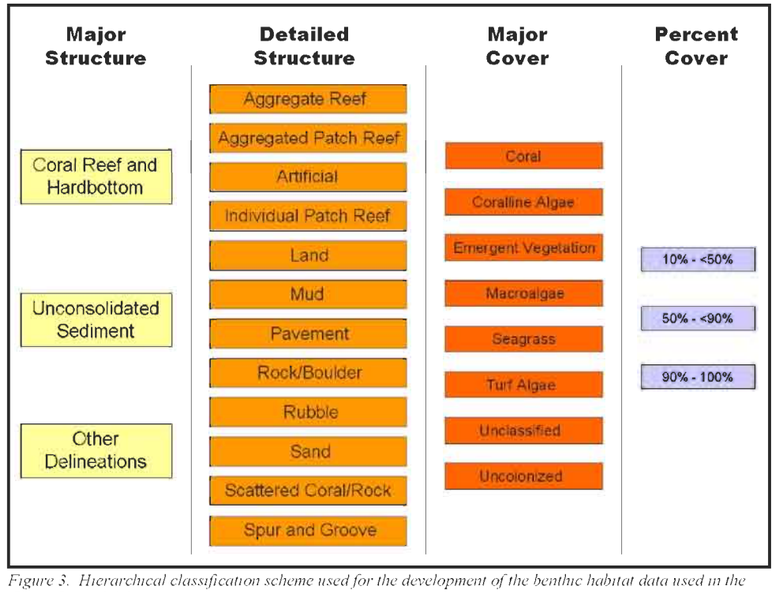

Figure 3. Hierarchical classification scheme used for the development of the benthic habitat data used in the Guam Coastal Atlas.

Additionally, reef zone attribute information provided with the NOAA Biogeography Team benthic habitat data was not preserved during the development of the data for the Guam Coastal Atlas. Instead, adjacent polygons occurring in different reef zones (e.g. reef crest, reef flat, etc.) that otherwise possessed identical habitat classifications were merged in order to simplify the data set and reduce "clutter" on the benthic habitat maps.

For more information about the classification scheme developed by the NOAA Biogeography Team and adopted for the Guam Coastal Atlas, including photos of various benthic habitat types, please visit their Web site at http://biogeo.nos.noaa.gov/products/us_pac_terr.

Ground Validation Surveys

A series of ground validation surveys were performed during the development of the benthic habitat data set. A Trimble GeoXT handheld GPS receiver was used to collect benthic habitat information (Figure 4). During these surveys, benthic habitat was described at each of the numerous data points collected throughout the study area. Using the hierarchical classification scheme mentioned above, the benthic habitat at each point was described from the most basic level of detail (unconsolidated sediment or coral reef/hard bottom) to a high level of detail (e.g. 50% to <90% macroalgae). A total of 846 ground validation points were collected at various sites around the island (Figures 5 and 6). The 203 ground validation points and the 241 accuracy assessment points collected by the NOAA Biogeography team were also used to help interpret the satellite imagery.

Because of environmental conditions, field surveys were limited mostly to the shallow reef flat areas around Guam. Ground validation data were collected with the GPS receiver within the Tumon Bay, Pati Point, and Achang Reef Flat Preserves, as well as at East Agana Bay, Cocos Lagoon, Pago Bay, Ritidian Point, and Gab Gab and Dadi Beaches on U.S. Navy Base property. A much wider cross-section of coastal area, including many fore reef areas, was observed and documented using a digital still camera during snorkeling and scuba diving excursions. These *in situ* observations allowed for a general assessment of an area's benthic habitat composition, assisted with the interpretation of the satellite imagery, and improved the accuracy of the benthic habitat classification in areas not surveyed using the GPS receiver.

Figure 4. A hand-held Trimble GeoXT GPS receiver used to record a position near Pati Point, Guam. Photo by John Tomczuk.

Figure 5. Ground validation points collected in Tumon Bay. Ikonos image copyright of Space Imaging LLC.

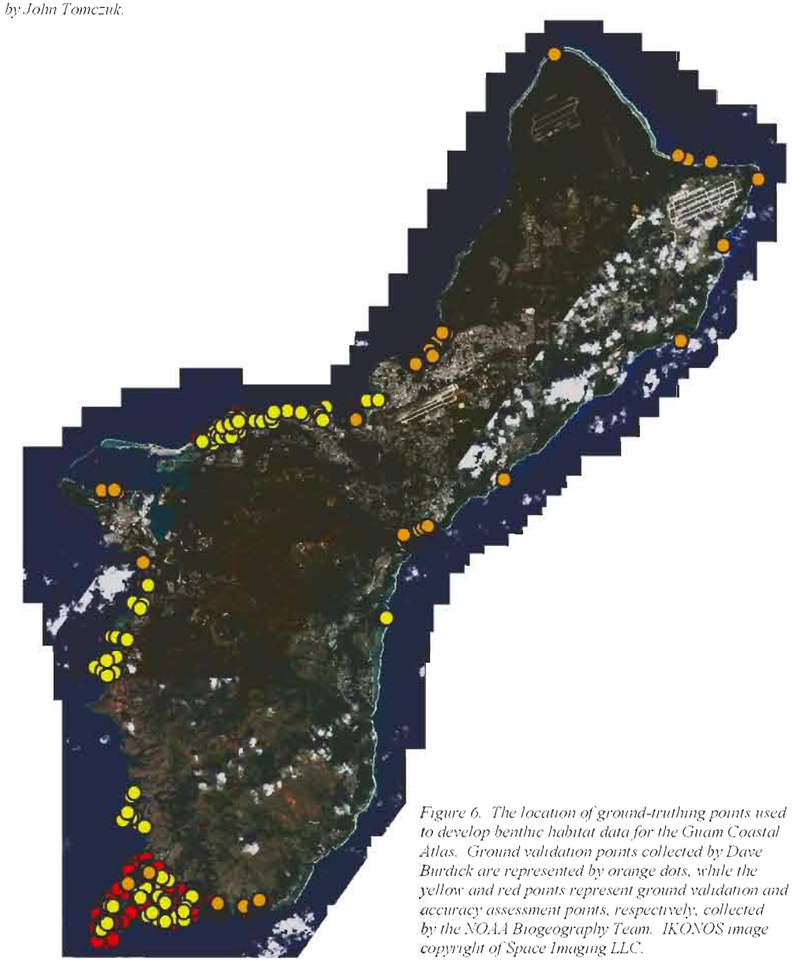

Figure 6. The location of ground-truthing points used to develop benthic habitat data for the Guam Coastal Atlas. Ground validation points collected by Dave Burdick are represented by orange dots, while the yellow and red points represent ground validation and accuracy assessment points, respectively, collected by the NOAA Biogeography Team. IKONOS image copyright of Space Imaging LLC.

Guam Coastal Atlas ▪ Classification Scheme: Structural Types

Benthic Habitat Classification Types

The following benthic habitat class descriptions were taken from "The Atlas of the Shallow-Water Benthic Habitats of American Samoa, Guam, and the Commonwealth of the Northern Marianas Islands" produced by the NOAA Biogeography Team. Photographs of various benthic habitats around Guam are provided as examples for most of the benthic habitat classifications used in this atlas.

Structural Types

The structural type of each delineated habitat refers to its predominant physical composition. The structural types are defined within a hierarchical system, ranging from a broad classification level (coral reef and hardbottom, unconsolidated sediment, other delineations, and unknown) to a more detailed classification level (pavement, aggregate reef, spur and groove, individual patch reef, aggregated patch reef, scattered coral/rock, rock/boulder, pavement, reef rubble, mud, sand, artificial, and unknown.)

Coral Reef and Hardbottom: Hardened substrate of unspecified relief formed by reef building corals and other organisms or existing as exposed bedrock or volcanic rock

Pavement: Flat, low relief, solid carbonate rock.

Photo: Pavement at Fafai Beach. Photo by Dave Burdick.

Patch Reef (Individual or Aggregated): Coral formations that are isolated from other coral reef formations by sand, seagrass, or other habitats and that have no organized structural axis relative to the contours of the shore or shelf edge. Individual patch reefs are distinctive single patches of reef that are larger than or equal to the MMU. Aggregate patch reefs are clustered patches of reef that individually are too small (less than the MMU) or are too close together to map separately.

Aggregate Reef: High relief lacking sand channels of spur and groove.

Photo: Aggregate reef structure near Gab Gab Beach dominated by hard corals. Photo by Dave Burdick.

Spur and Groove: Habitat having alternating sand/ pavement and coral formations that are oriented perpendicular to the shore or bank/shelf escarpment.

Photo: Spur and groove structure fronting the reef crest near Ipan Beach Park. Photo by Dave Burdick.

Rock/Boulder: Solid carbonate blocks and/or boulders or volcanic rock.

Photo: Boulders at the bottom of the steep cliffline north of the University of Guam Marine Lab in Mangilao. Photo by Dave Burdick.

Rubble: Dead, unstable coral rubble often colonized with coralline algae and filamentous algae or other macroalgae. This habitat often occurs landward of well-developed reef formations in the reef crest or back reef zone.

Photo: Coral rubble in Tumon Bay. Photo by Dave Burdick.

Scattered Coral/Rock in Unconsolidated Sediment: Primarily sand or seagrass bottom with scattered rocks or small, isolated coral heads that are too small to be delineated individually (i.e. smaller than the individual patch reef).

Unconsolidated Sediment: Unconsolidated sediment with less than 10% of any hardbottom structure type.

Sand: Coarse sediment found typically in areas exposed to currents or wave energy.

Photo: Sand in the shallow waters along Gab Gab Beach. Photo by Dave Burdick.

Mud: Fine sediment often associated with river discharge and build-up of organic material in areas sheltered from high-energy waves and currents.

Other Delineations - Artificial: Man-made habitats such as submerged wrecks, large piers, and submerged portions of rip-rap jetties, and the shoreline of islands created from dredged spoil.

Guam Coastal Atlas ▪ Classification Scheme: Biological Cover Types

Biological Cover Types

The "Biological Cover Type" refers to the predominant biological component colonizing the surface of the feature. A total of nine biological cover types were used, including coral, macroalgae, turf algae, seagrass, coralline algae, emergent vegetation, uncolonized, unknown, and unclassified. A density modifier that refers to the approximate percent cover of the predominant cover type (0%, 10% to < 50%, 50% to < 90%, and 90% to 100%) was also attributed to each habitat delineation.

Turf Algae: A community of low lying species of marine algae composed of any or a combination of algal divisions dominated by filamentous species lacking upright fleshy macroalgal thali.

Photo: Pavement structure near Fai Fai Beach covered primarily by turf algae. Photo by Dave Burdick.

Uncolonized: Substrates not covered with a minimum of 10% of any biological cover types. This habitat is usually on sand or mud structures.

Photo: Uncolonized sand of the intertidal zone at Ritidian Point. Photo by Dave Burdick.

Coral: Substrata colonized by live reef building corals and other organisms. Habitats within this category have at least 10% live coral cover.

Photo: Coral community in the shallow waters of Luminao Reef. Photo by Dave Burdick.

Seagrass: Habitat with 10% or more cover of seagrass.

Photo: Seagrass (Enhalus acoroides) near Ipan Beach Park. Photo by Dave Burdick.

Emergent Vegetation: Emergent habitat composed primarily of species of mangrove trees. Generally found in areas sheltered from high-energy waves. This habitat type is usually found in the shoreline intertidal or reef flat zone.

Photo: Mangrove stand along shoreline of Sasa Bay. Photo by Dave Burdick.

Macroalgae: Substrates with 10% or greater coverage of any combination of numerous species of red, green, or brown macroalgae. Usually occurs in shallow back reef and deeper waters on the bank/shelf zone.

Photo: Macroalgal bloom near Apaca Point comprised mainly of Padina sp. Photo by Dave Burdick.

Coralline Algae: An area with 10% or greater coverage of any combination of numerous species of encrusting or coralline algae. May occur along reef crest, in shallow back reef, relatively shallow waters on the bank/shelf zone, and at depth.

Photo: Coralline algae-dominated reef crest at Ipan exposed at an extreme low tide. Photo by Dave Burdick.

Unknown: Habitat uninterpretable due to turbidity, cloud cover, water depth, or other interference.

Unclassified: Non-benthic areas, such as land.

Guam Coastal Atlas ▪ Benthic Data Summary/Spatial Data Library

Benthic Data Summary

A GIS was used to calculate the absolute area occupied by each biological cover type as well the area occupied by each detailed structure type; the percent of the total area occupied by each habitat type was also calculated. The tables below provide a summary of the results. Area values are reported in both square kilometers and acres. Based upon the benthic habitat data collected for the Guam Coastal Atlas, the total reef area of Guam is approximately 108 square kilometers (26,872 acres). An estimated 31.2% of the total reef area is characterized as coral reef and hardbottom, while 68.8% is characterized as unconsolidated sediment. Approximately 32.4 square kilometers (8,016 acres), or 29.8%, of the total reef area is colonized by at least 10% live coral cover, while uncolonized substrate comprises the second most prominent cover type (30.3 sq. km., 27.8% of total reef area).

Table A. Thematic content summary of biological cover types for the coastal waters of Guam

Biological Cover Type	Area (km^2)	Area (Acres)	% of Total Reef Area
Coral	32.4	8016.0	29.8
Uncolonized	30.3	7478.5	27.8
Macroalgae	21.5	5301.2	19.7
Turf	18.8	4657.0	17.3
Seagrass	3.1	757.7	2.8
Coralline Algae	2.5	610.8	2.3
Emergent Vegetation	0.2	51.0	0.2
Total Reef Area	**108.7**	**26872.1**	**100.0**

Table B. Thematic content summary of geomorphological structure types for the coastal waters of Guam

Geomorphological Structure Type	Area (km^2)	Area (acres)	% of Total Reef Area
Total Coral Reef and Hardbottom	**74.8**	**18473.1**	**68.8**
Pavement	48.5	11981.7	44.6
Aggregate Reef	17.1	4221.7	15.7
Spur and Groove	5.5	1353.4	5.0
Rubble	1.6	384.9	1.4
Aggregated Patch Reef	0.9	217.0	0.8
Rock/Boulder	0.5	115.2	0.4
Individual Patch Reef	0.5	113.2	0.4
Scattered Coral/Rock	0.3	86.0	0.3
Total Unconsolidated Sediment	**33.9**	**8376.5**	**31.2**
Sand	33.4	8251.9	30.7
Mud	0.5	124.6	0.5
Total Reef Area	**108.7**	**26872.1**	**100.0**

Spatial Data Library

The Spatial Data Library section of the Guam Coastal Atlas provides an overview of some of the digital spatial data available through the Guam Bureau of Statistics and Plans and from other sources. The data sets described in the following pages do not represent of all the digital spatial data available for Guam, but were selected for their potential application to coastal-related management, research, and education endeavors. Brief descriptions of the data as well as previews of the data sets are provided. The digital spatial data layers covered in the Spatial Data Library include IKONOS satellite imagery mosaics, digital bathymetry, digital elevation, land cover, marine protected area boundaries, coastal features, soils, geology, and watershed data. Some of the digital spatial data layers available for Guam that are not described in the Spatial Data Library include:

Streets
Demographic data
2005 Quickbird satellite imagery
1993 Digital U.S.G.S. orthographic quadrangles
Buildings (commercial, hospitals, schools, fire stations, etc.)
Municipal boundaries
Shoreline
Land parcels
Historical Sites
Wetlands
Satellite altimetry (topographic and bathymetric) data for Mariana Islands chain

Most of the digital spatial data described in the Spatial Data Library, as well as the data listed above, are available publicly through the Guam Bureau of Statistics and Plans. Because of licensing restrictions, certain data sets can only be distributed to certain agencies/organizations. Data can be reproduced in the form of digital or paper maps and distributed without licensing restrictions, however. Please contact the Guam Bureau of Statistics and Plans for licensing information.

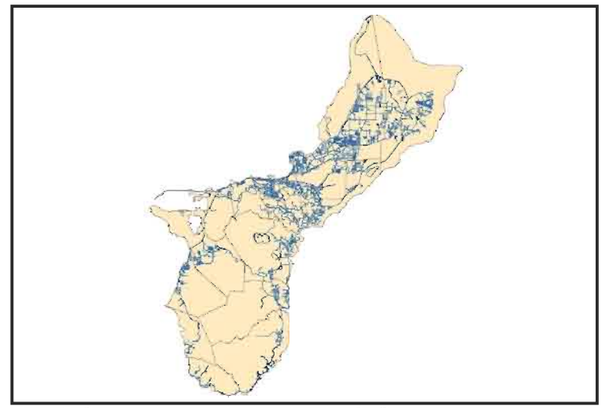

Figure 7. Streets and municipality boundary data for Guam.

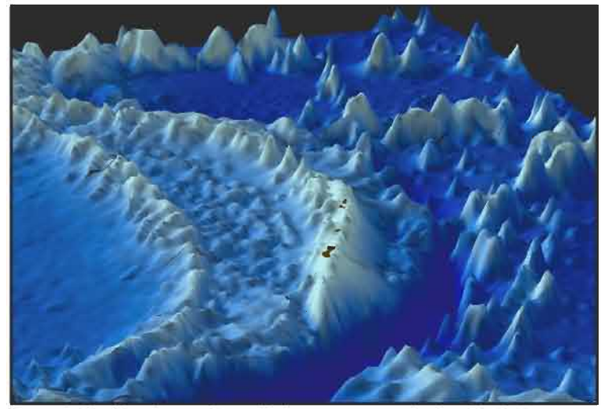

Figure 8. Satellite altimetry-derived bathymetric/topographic data for the Mariana Islands chain. Data was extracted from global data set available at http://topex.ucsd.edu/index.html.

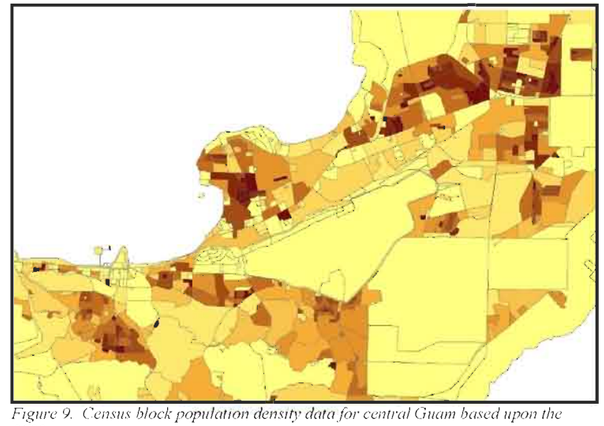

Figure 9. Census block population density data for central Guam based upon the 2000 census.

IKONOS Satellite Imagery

IKONOS image products are derived from images captured from the IKONOS-2 satellite, a sun-synchronous satellite that was.launched in September, 1999. The IKONOS-2 satellite orbits the earth about 14.7 times per 24-hour period and revisits the same location at 40 degrees latitude approximately every 3 days. The sensor aboard the IKONOS-2 satellite captures two images simultaneously: a multispectral image and a panchromatic image (Figure 10). The multispectral image is composed of 4 spectral bands (red, green, blue, and near infra-red) and has a spatial resolution of 4 square meters (i.e. each pixel is 4 x 4 meters). The panchromatic image is composed of a single black and white band and has a spatial resolution of 1 square meter. An image created by combining the spatial resolution of the panchromatic image and the spectral resolution of the multispectral image - called a "pan-sharpened" image - can be created using image processing software applications such as ERDAS Imagine. Figures 11, 12, and 13 demonstrate the spatial and spectral differences between the panchromatic, multispectral, and pan-sharpened IKONOS images.

IKONOS satellite image mosaics obtained over multiple-year periods are available for Guam. In order to reduce the amount of cloud coverage within the image, however, scenes from multiple years were used to comprise each of the mosaic images of the island. The 2004 image mosaic, for example, contains scenes from imagery obtained in 2001 through 2004. Three mosaic images are available, including mosaics from 2002, 2003, and 2004. Because licensing restrictions, only certain agencies and organizations may access the full data sets. Please contact the Guam Bureau of Statistics and Plans for licensing information. The IKONOS imagery can be distributed to non-licensed entities in a digital or printed map format or as a reduced resolution raster image (i.e. .tif, .bmp, .jpeg formats, etc.).

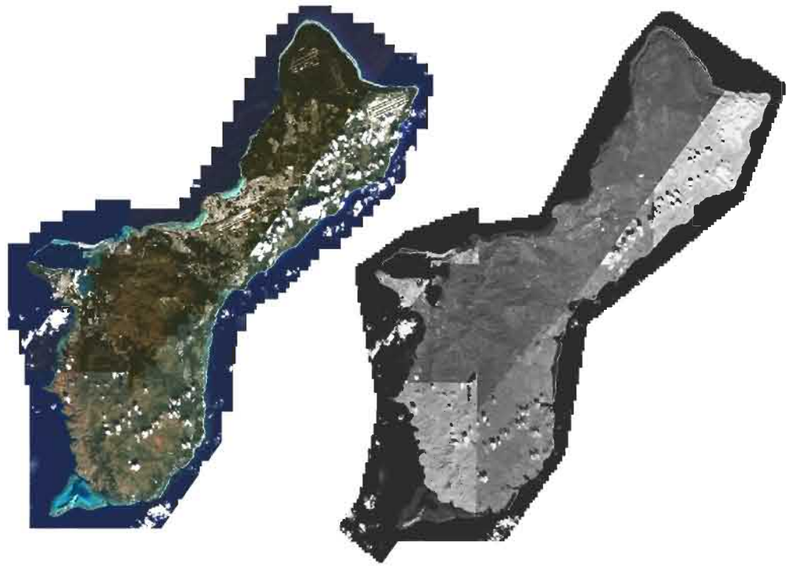

Figure 10. Multispectral (left) and panchromatic (right) image mosaics of Guam composed of images taken from the IKONOS-2 satellite between 2001 and 2004. Image copyright of Space Imaging LLC.

Figure 12. A panchromatic IKONOS image of the coastal area near Ypao Beach in Tumon Bay, Guam. Panchromatic IKONOS images are composed of a single, black and white band and have a spatial resolution of 1 meter. Image copyright of Space Imaging LLC.

Figure 11. A multispectral IKONOS image of coastal area near Ypao Beach in Tumon Bay, Guam. Multispectral IKONOS images are composed of 4 spectral bands or channels (red, green, blue, and near infra-red) and have a spatial resolution of 4 meters. Image copyright of Space Imaging LLC.

Figure 13. A pan-sharpened IKONOS image of coastal area near Ypao Beach in Tumon Bay, Guam. Pan-sharpened IKONOS images are created by combining the spectral resolution of the multispectral image with the spatial resolution of the panchromatic image. Image copyright of Space Imaging LLC.

Guam Coastal Atlas ▪ Spatial Data Library ▪ Bathymetry Data

Bathymetry (water depth data) can be collected by ship-borne or airborne sensors and are available in several formats including both paper and electronic nautical charts and digital spatial data that can be used within a GIS. Bathymetry data derived from airborne LIDAR (Light Detection and Ranging) sensors can be used for a wide variety of coastal applications, such as shoreline and beach volume change, flood risk analysis, and habitat mapping. LIDAR sensors are similar in their principle of application to RADAR sensors, which use sound waves to achieve a virtual image of a far away object. LIDAR sensors, however, use laser pulses to measure accurately and rapidly sea floor depth and topographic elevations. LIDAR can penetrate more than 40 meters beneath the water's surface, although the maximum penetration depth is greatly dependent upon water clarity.

The Guam Bureau of Statistics and Plans has obtained LIDAR bathymetry data for portions of Guam's shoreline collected by the SHOALS system (Figure 14). SHOALS, short for the Scanning Hydrographic Operational Airborne Lidar Survey system, is the most advanced airborne Lidar system available and is owned and operated by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX). The SHOALS data for Guam, collected in 2001 by the U.S. Army Corps of Engineers, is accessible to the public and can be obtained through the Guam Bureau of Statistics and Plans. SHOALS bathymetry data collected for the U.S. Geological Survey and the U.S. Navy around the same time as the USACE data provides coverage for additional potions of Guam's coastline and may become available publicly at a later date. Figures 15, 16, and 17 include sample images of Cocos Lagoon, the Achang Reef Flat Marine Preserve and the Piti Bomb Holes Marine Preserve created by overlaying, or "draping," the SHOALS bathymetry data on IKONOS satellite imagery within a 3-D GIS application.

Additional bathymetry data collected in 2003 by the National Oceanic and Atmospheric Administration's Pacific Islands Fisheries Science Center is also available. This bathymetry data, collected using multi-beam sonar, covers a large portion of the shallow waters of northern Guam and includes the waters of the Pati Point Marine Preserve (Figure 14). This data can be downloaded at http://www.pifsc.noaa.gov/cred/hmapping/.

Figure 16. 3-D model of Cocos Lagoon created by "draping" pan-sharpened IKONOS satellite imagery over digital bathymetry data collected from an airborne LIDAR sensor. IKONOS imagery copyright of Space Imaging LLC.

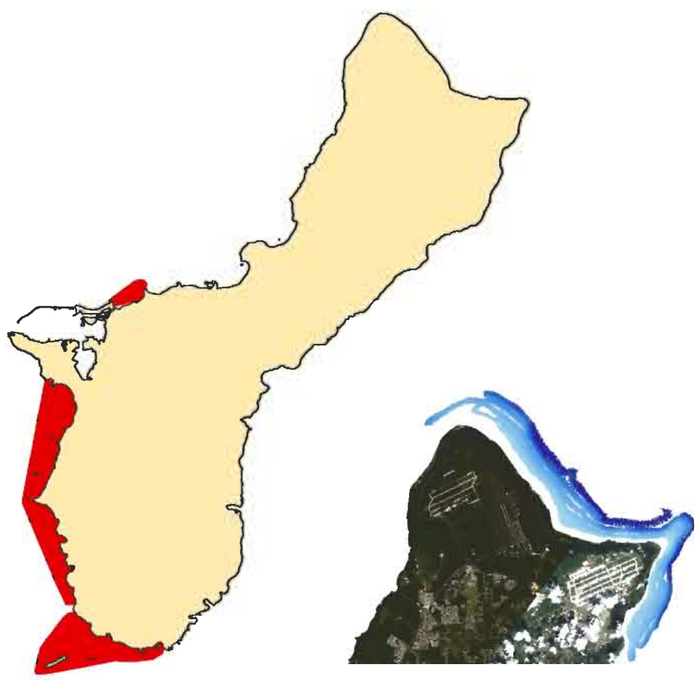

Figure 14. Spatial extent of the U.S. Army Corps of Engineers LIDAR-derived bathymetry data (left) and the NOAA Pacific Islands Fisheries Science Center's multi-beam sonar-derived bathymetry data (right).

Figure 15. 3-D model of the Piti Bomb Holes Marine Preserve created by "draping" pan-sharpened IKONOS satellite imagery over digital bathymetry data collected from an airborne LIDAR sensor. IKONOS imagery copyright of Space Imaging LLC.

Figure 17. 3-D model of the Achang Reef Flat Marine Preserve created by "draping" pan-sharpened IKONOS satellite imagery over digital bathymetry data collected from an airborne LIDAR sensor. IKONOS imagery copyright of Space Imaging LLC.

Digital Elevation Data

A digital elevation model, or DEM, of Guam created by the United States Geological Survey is also available publicly (Figures 18 and 19). The DEM presently available for Guam has a somewhat limited vertical and horizontal resolution and has not been updated for more than a decade. An updated digital elevation model for Guam created with data collected from an airborne LIDAR sensor may become available in 2006.

Land Cover Data

Detailed land cover data for the island of Guam has been developed recently by the U.S. Department of Agriculture (USDA) Forest Service Region 5 as part of the Pacific Islands Vegetation Mapping and Monitoring Project (Figure 20). This data set, made available in 2005, was created by performing supervised and unsupervised classifications with IKONOS imagery using image processing software applications such as ERDAS Imagine and eCognition. Land cover maps provide an inventory of land cover uses at a particular point in time and by comparing land cover data from different time periods, trends in land use change can be detected. Determining the rate and direction of development and the associated loss of vegetation is a common use of land cover data. The USDA Forest Service Region 5 land cover data is publicly available and can be obtained from the Guam Bureau of Statistics and Plans. This data set can be accessed also from the USDA Forest Service Region 5 web site at http://www.fs.fed.us/r5/spf/about/fhp-pacific-basin.shtml.

Figure 18. View of Cocos Lagoon and the southern mountains of Guam rendered in a 3-D GIS application by "draping" IKONOS satellite imagery over a digital elevation model of Guam. IKONOS imagery copyright of Space Imaging LLC.

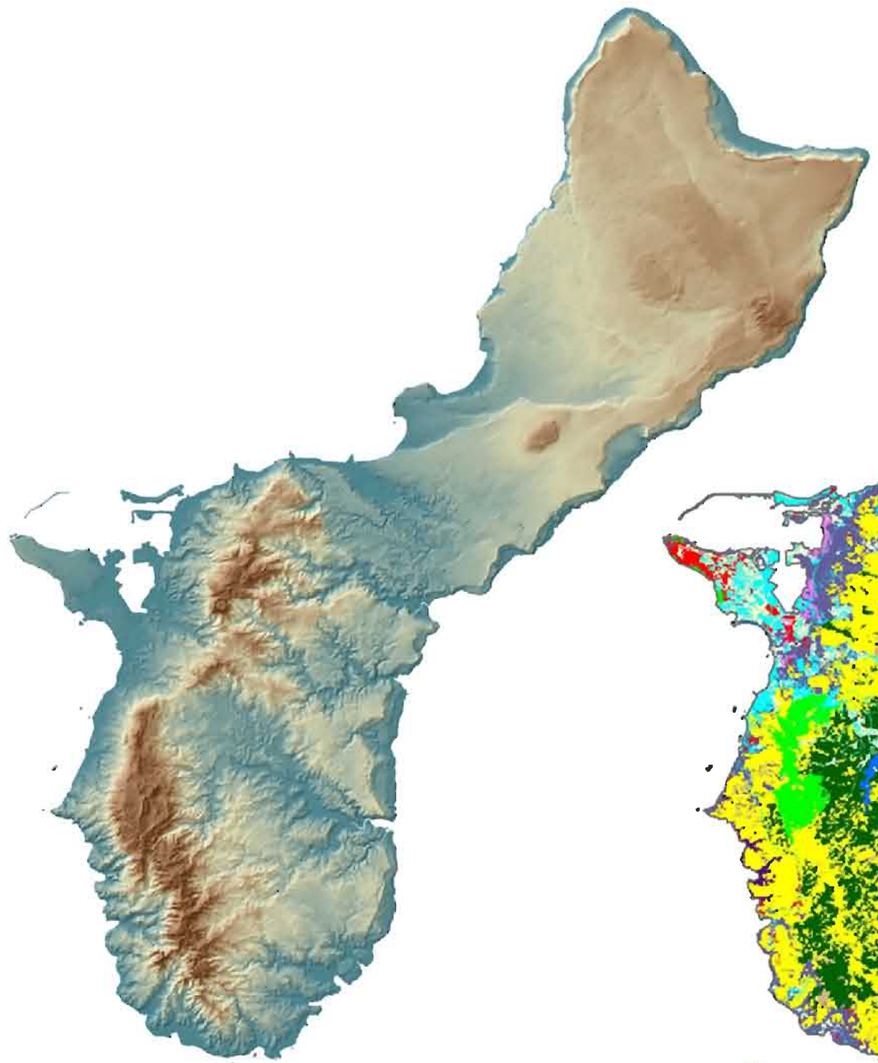

Figure 19. Shaded-relief digital elevation model (DEM) of Guam created by the United States Geological Survey.

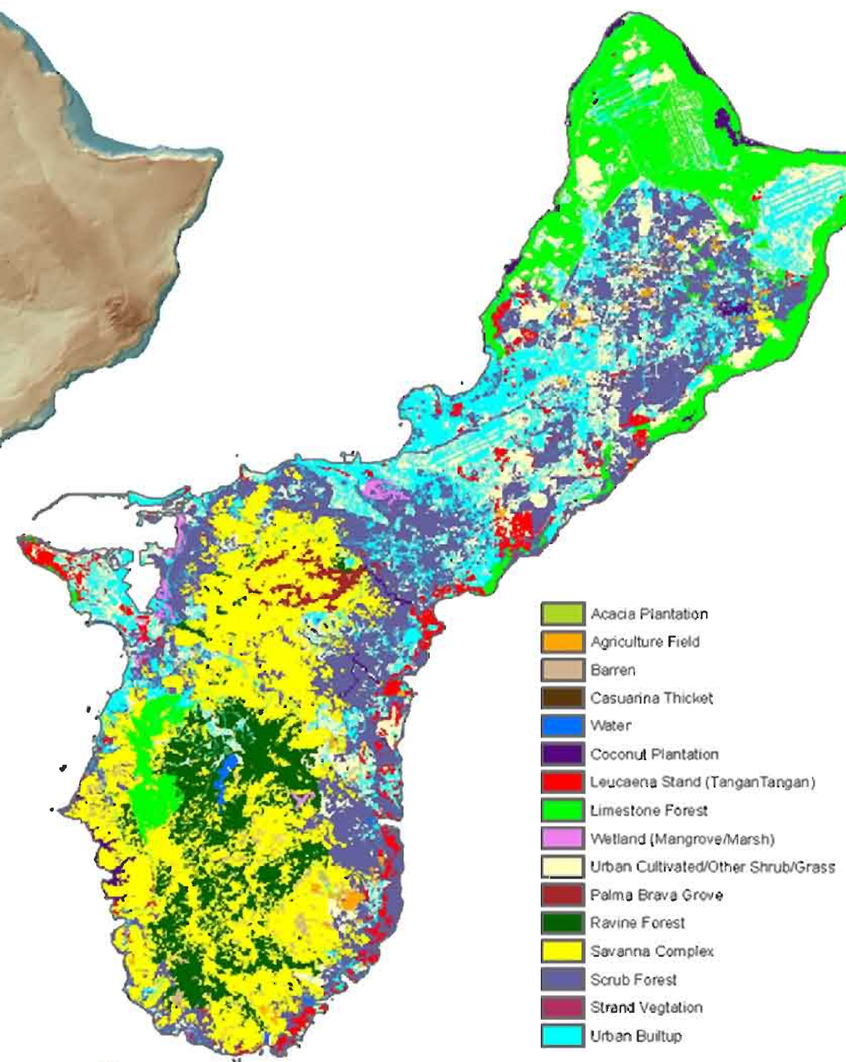

Figure 20. Detailed land cover classification data for Guam developed by the USDA Forest Service Region 5 for the Pacific Islands Vegetation and Mapping Project.

Guam Coastal Atlas ▪ Spatial Data Library ▪ Marine Protected Areas Boundaries

Digital spatial data sets for the boundaries of Guam's marine protected areas were created in 2002 by James Byrne, the 2001-2003 NOAA Pacific Islands Technical Assistant for Guam. Digital spatial data layers are available for the Tumon Bay, Piti Bomb Holes, Sasa Bay, Achang Reef Flat, and Pati Point Marine Preserves as well as the Haputo and Orote Point Ecological Reserves (Figure 21). A digital spatial data layer that contains the boundaries for all of Guam's marine protected areas is also available. Data layers containing the boundaries for each of the individual marine protected areas are available, as well. The attribute information included with each data layer include the name of the marine protected area and its area in square meters and acres. The regulations pertinent to each marine protected area are not yet available as attribute information for the digital spatial data

The marine preserves (e.g. Tumon Bay, Piti Bomb Holes, etc.) were designated as such by the Government of Guam in 1999, while the ecological reserves were designated by the Navy in 1984 as mitigation for the Navy's ammunition wharf project located in the outer reaches of Apra Harbor. Restrictions on certain fishing and non-fishing activities may apply to the marine preserves established by the Government of Guam; the types of restrictions may vary among the preserves, as well. Please contact the Guam Department of Aquatic and Wildlife Resources for more detailed information about Guam's marine preserves. Certain restrictions also apply to the ecological reserves established by the Navy. Please contact the U.S. Navy's operations command on Guam for further information.

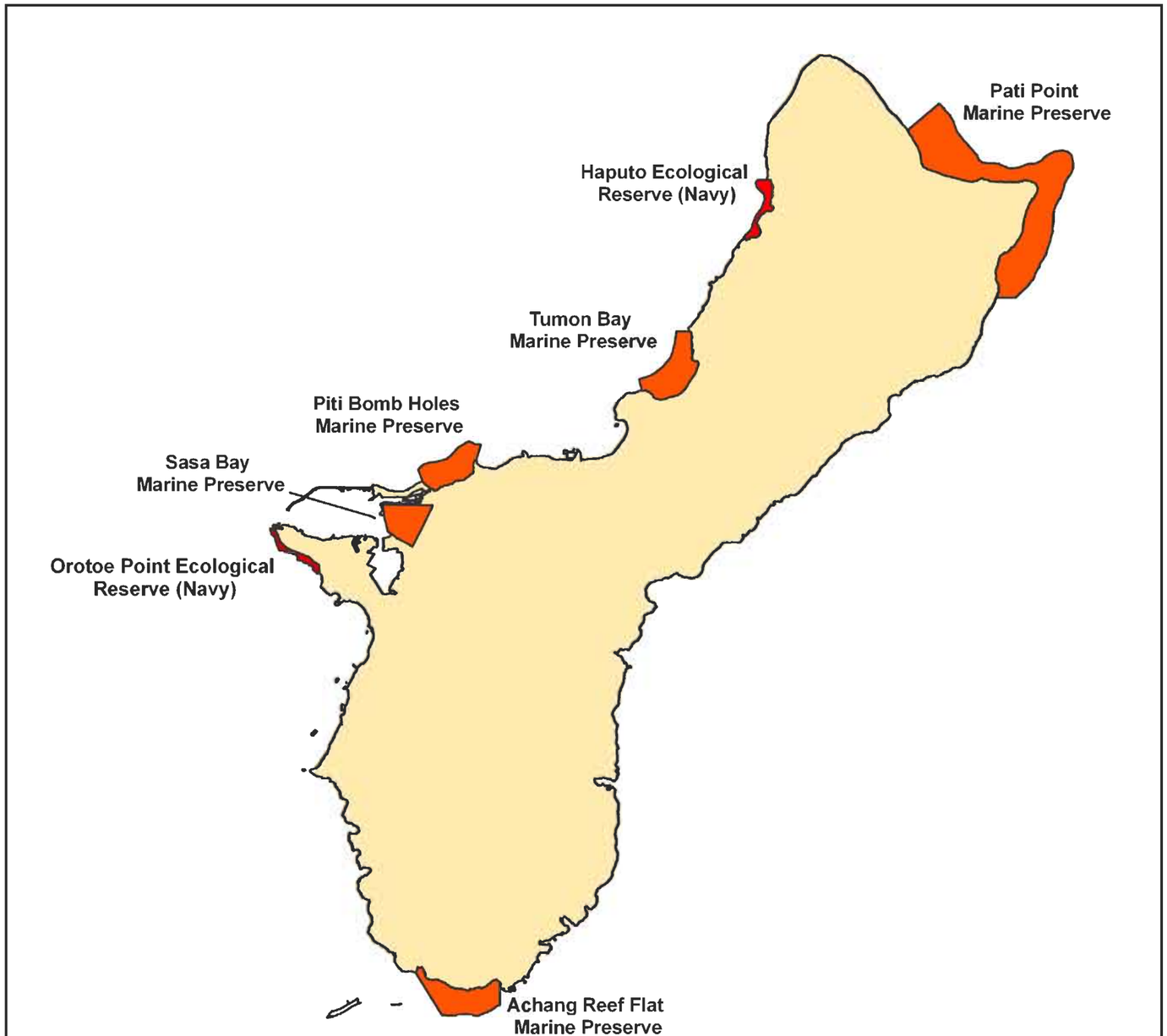

Figure 21. Map showing the locations of the boundaries for the five marine preserves designated by the Government of Guam in 1999 and the ecological reserves designated by the U.S. Navy in 1984.

Guam Coastal Atlas ▪ Spatial Data Library ▪ Coastal Features Data

The Coastal Features spatial data layer was created in 2002 by James Byrne, the 2001-2003 NOAA Pacific Islands Technical Assistant for Guam, and contains the locations of over 130 man-made structures and natural features (e.g. bays, points, beaches, marinas) along Guam's coastline. Figures 22 and 23 show the locations of most of the features represented in the data layer. These maps can provide a geographic reference for the coastal features mentioned throughout this publication.

Photos (from left to right): Cetti Bay, development along Tumon Bay, Ritidian Point, and Spanish Bridge at Sella Bay. All photos by Dave Burdick.

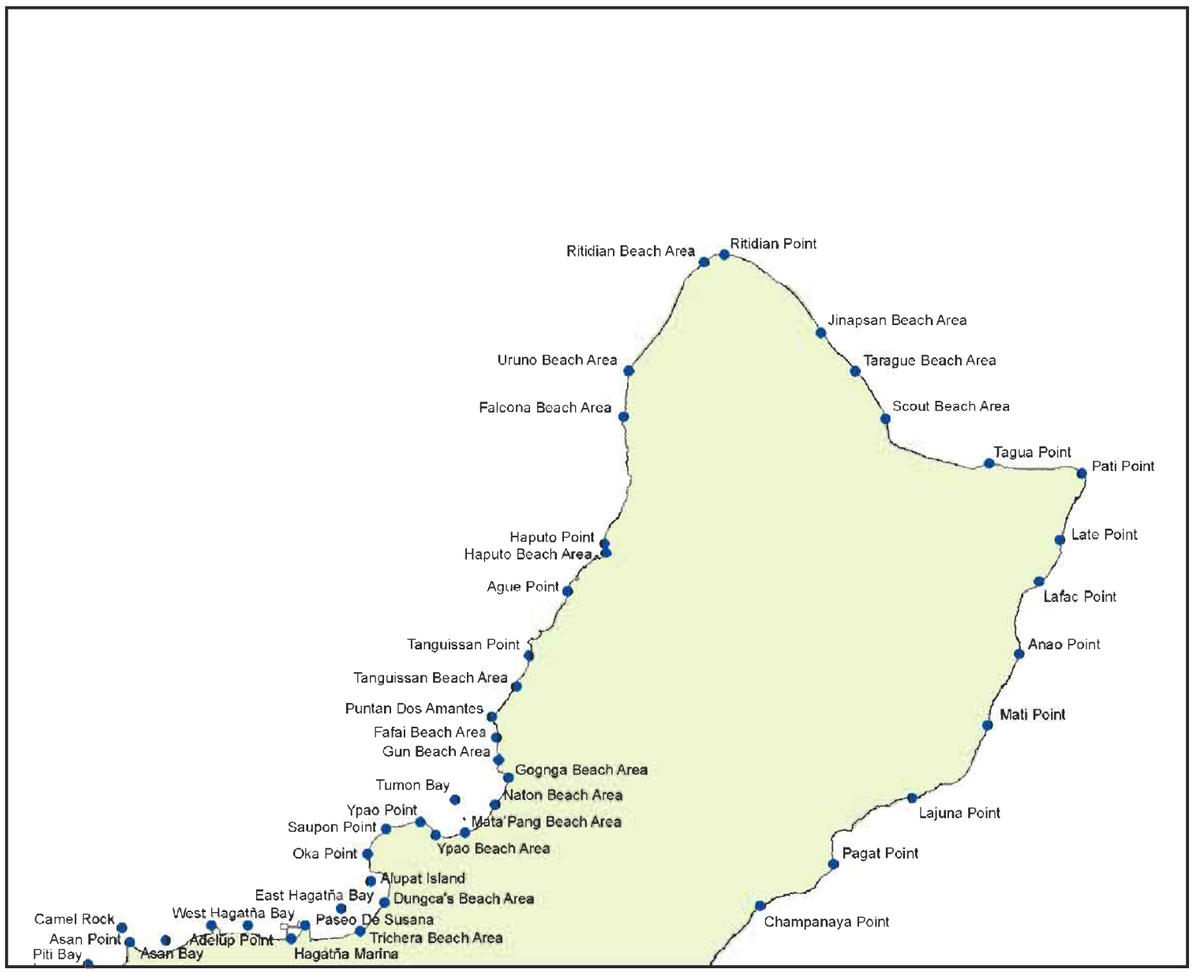

Figure 22. Coastal features in the northern half of Guam from the "Coastal Features" digital spatial data layer.

Figure 23. Coastal features in the southern half of Guam from the "Coastal Features" digital spatial data layer.

Soils, Geology, and Watershed Data

Soil, geology, and watershed data for Guam also exists in a digital form and are available through the Guam Bureau of Statistics and Plans (Figures 24, 25, and 26, respectively). The digital soils data layer was created by the USDA Natural Resources Conservation Service (NRCS) in 2004 by digitizing existing soil maps developed from land-based soil surveys. Please visit the NRCS web site at http://soils.usda.gov/ for more information about methodology and to access digital soils data for Guam and other U.S. states and territories. The digital geology and watershed data layers for Guam were both developed by the University of Guam's Water and Environment Research Institute (WERI) in 2000.

Figure 25. Digital geology data for Guam created by the University of Guam's Water and Environmental Research Institute in 2000. The geology data layer was overlaid on a digital elevation model of Guam.

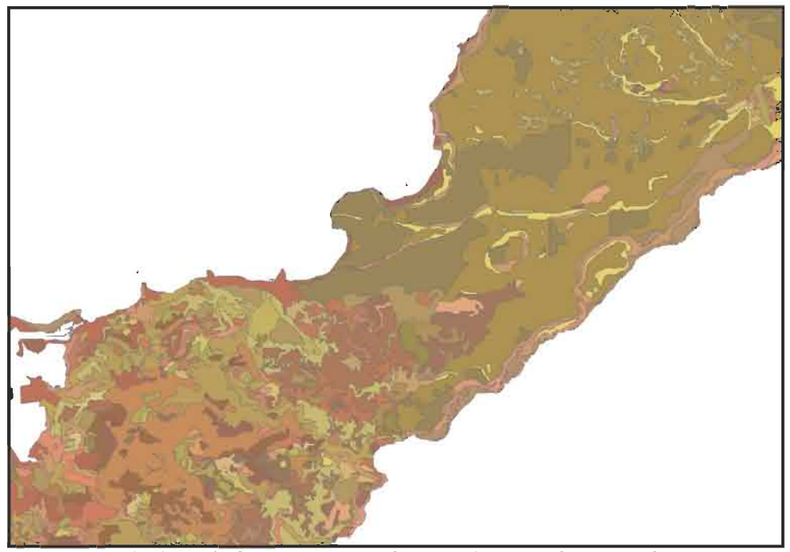

Figure 24. Digital soils data for Guam created by the USDA Natural Resources Conservation Service in 2004.

Figure 26. Digital watersheds data layer created by the University of Guam's Water and Environmental Research Institute in 2000. The watershed data layer was overlaid on a digital elevation model of Guam.

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NOAA National Centers for Coastal Ocean Science (NCCOS). 2005. Atlas of the Shallow-Water Benthic Habitats of American Samoa, Guam, and the Commonwealth of the Northern Marianas Islands. NOAA Technical Memorandum NOS NCCOS 8, Biogeography Team. Silver Spring, MD. 126 pp.

NOAA Biogeography Program Web site: http://biogeo.nos.noaa.gov

Randall, R. H. and L. G. Eldredge. 1976. Atlas of the Reefs and Beaches of Guam. University of Guam Marine Laboratory, Mangilao, Guam, 191 pp.

Citation

Burdick, David R. 2005. Guam Coastal Atlas. University of Guam Marine Laboratory, Technical Report 114. 149 pages.

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Government of Guam Bureau of Statistics and Plans
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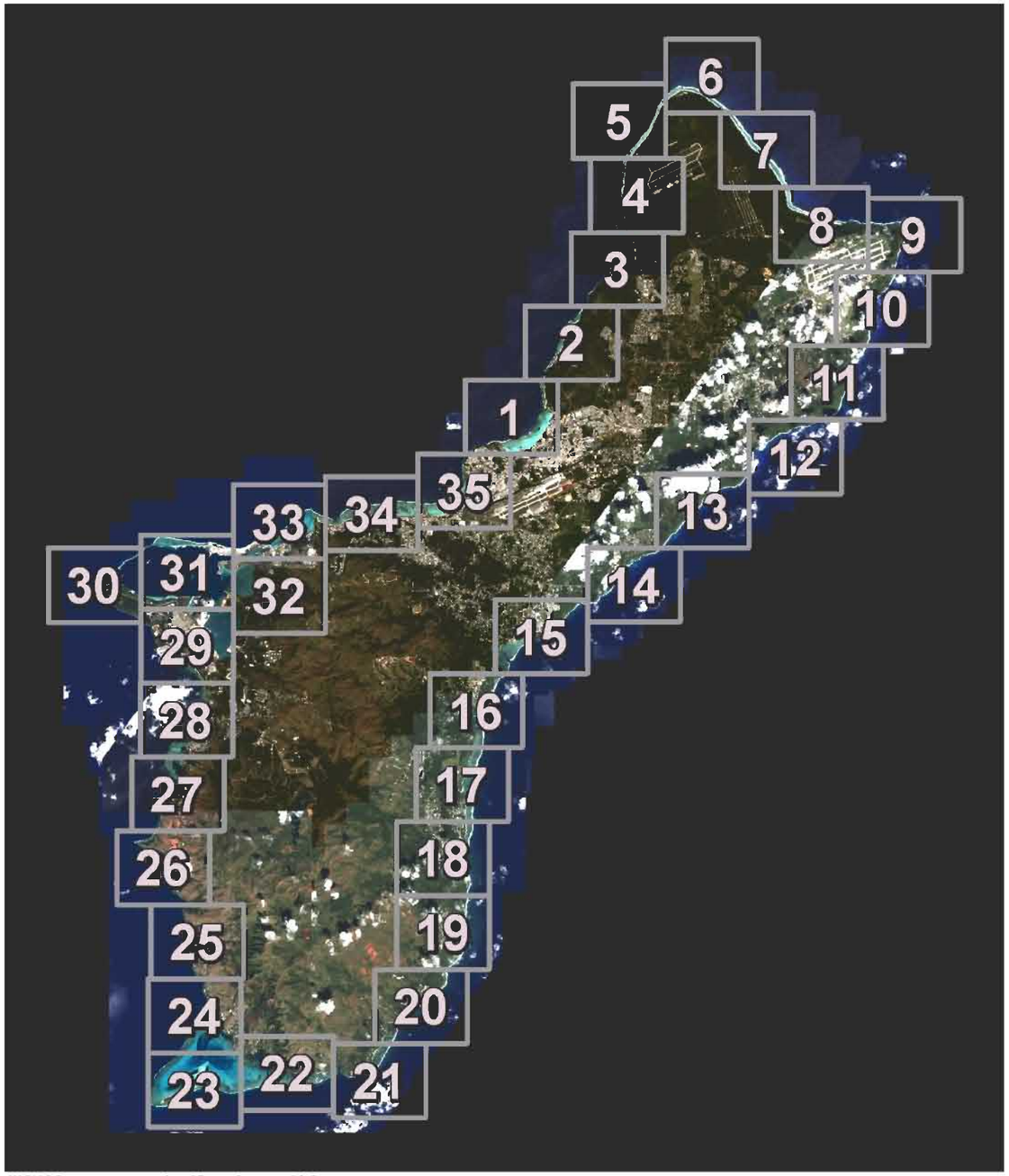
Fax: (671) 477 - 1812

Guam Coastal Atlas Web site:
Web site: http://www.uog.edu/marinelab/coastal.atlas/

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Map Index

The primary purpose of the Guam Coastal Atlas is to provide a series of maps displaying recent satellite imagery and benthic habitat data for the shallow coastal waters around Guam. For the purposes of this atlas, Guam's coastal area was divided into 35 non-overlapping sections. The Guam Coastal Atlas provides 2 maps for each of the 35 areas: the first map displays only the 2001-2004 IKONOS satellite image mosaic while the second map displays the benthic habitat data overlaid on the satellite imagery. Marine preserve boundaries are also included with both maps. These maps utilize a 1:15,000 scale. More detailed maps (1:4000 and 1:8000 scale) for limited areas within Guam's coastal environment, including 4 of Guam's marine preserves and 3 focus areas, are available beginning on pages 85 and 121, respectively.



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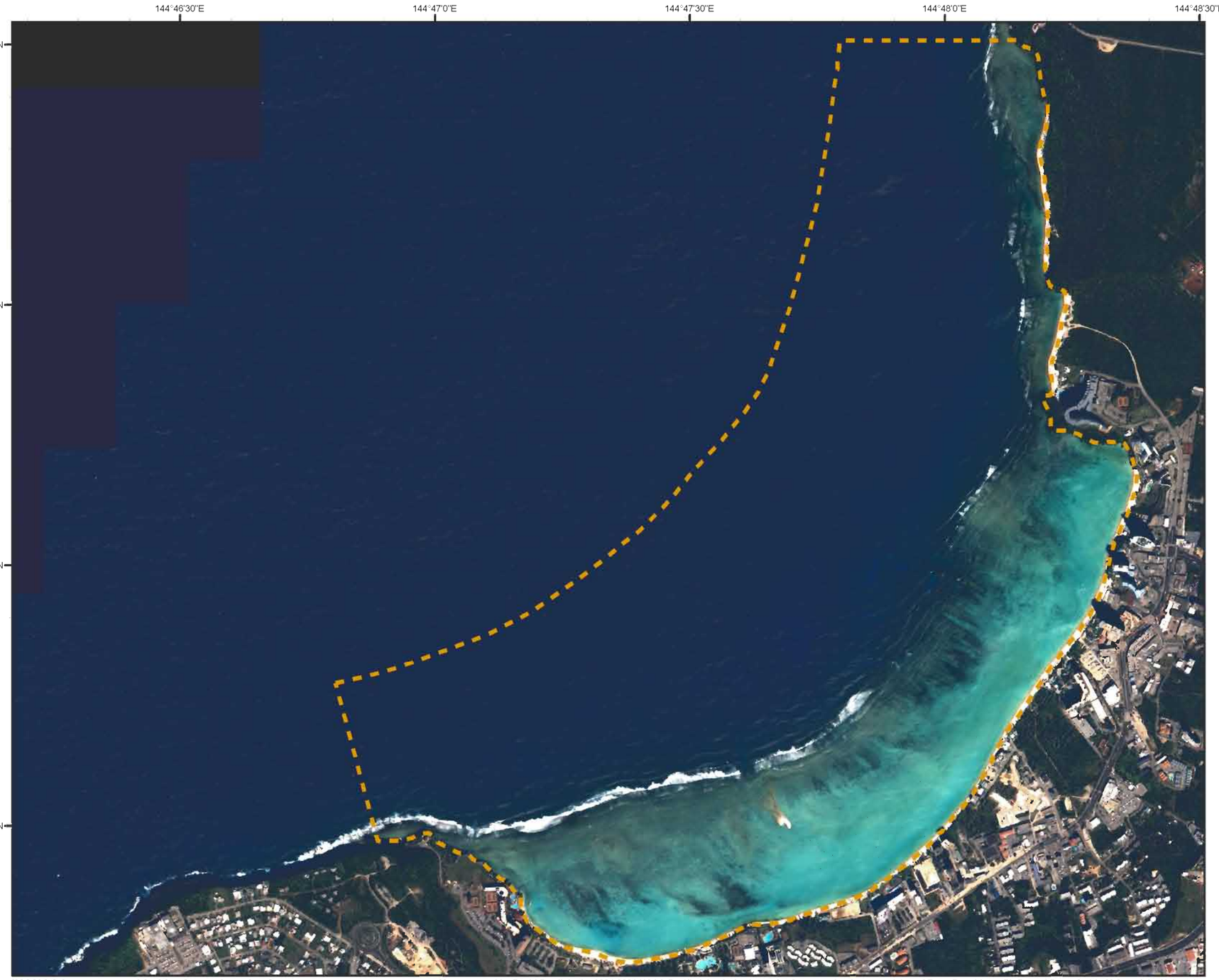
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 1



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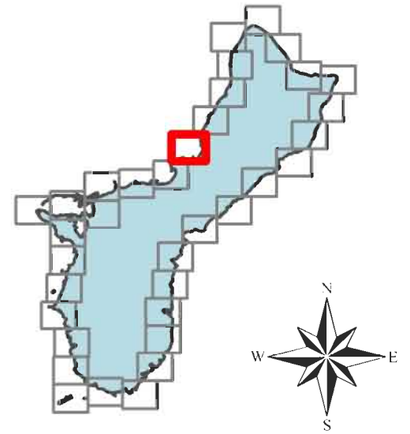

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Legend

Marine Preserve Boundaries

A view of the reef near Ypao Beach in Tumon Bay. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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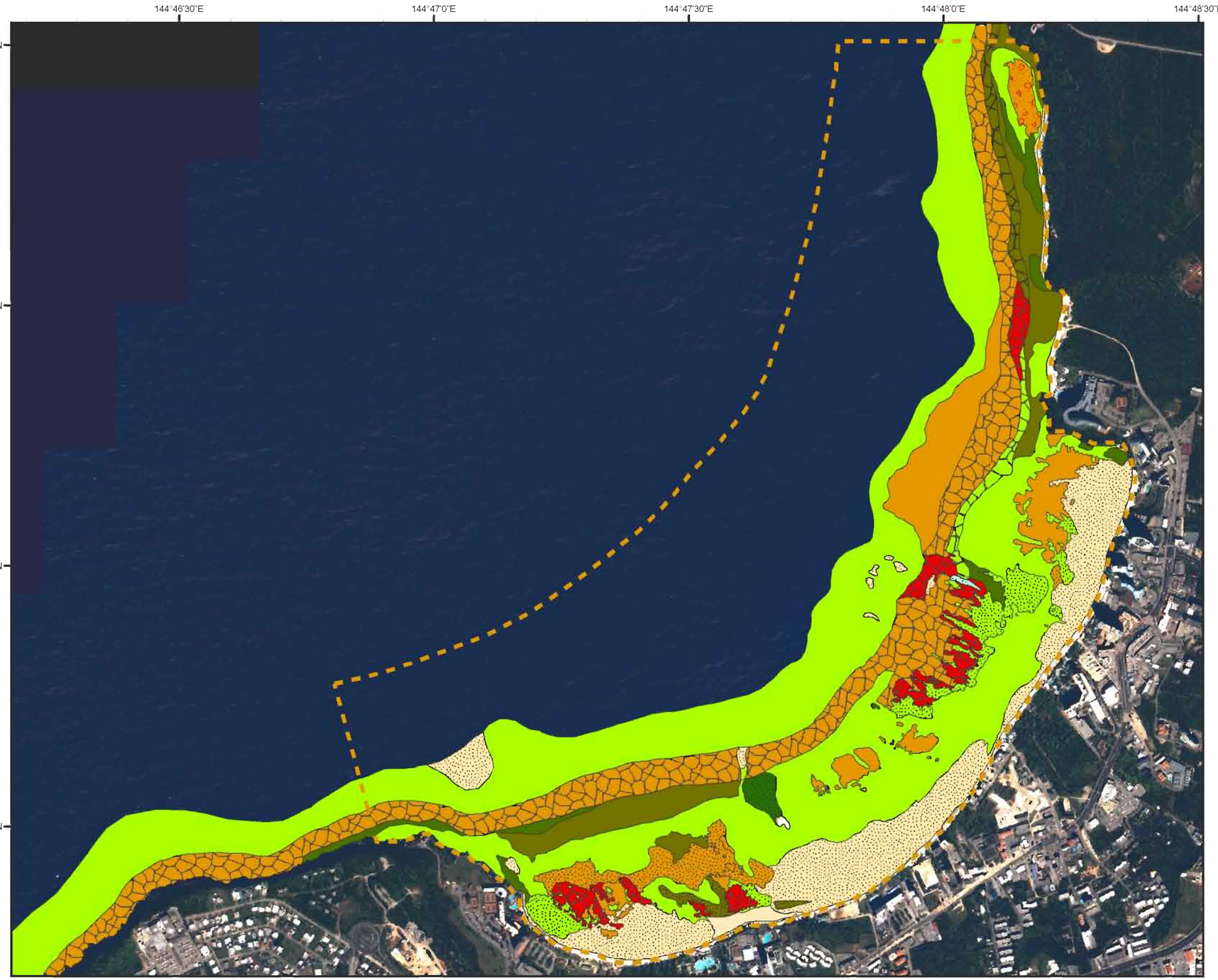
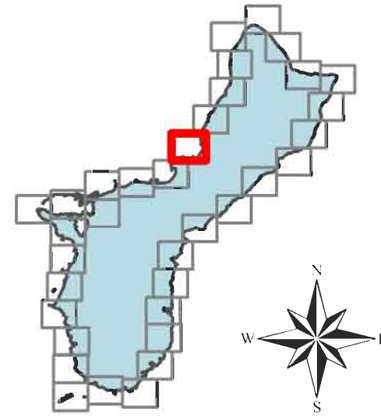
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 1





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- Marine Preserve Boundaries
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- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Pavement, Uncolonized 50%-<90%
- Rubble, Coral 10%-<50%
- Rubble, Macroalgae 10%-<50%
- Rubble, Macroalgae 50%-<90%
- Rubble, Turf 50%-<90%
- Rubble, Uncolonized 90%-100%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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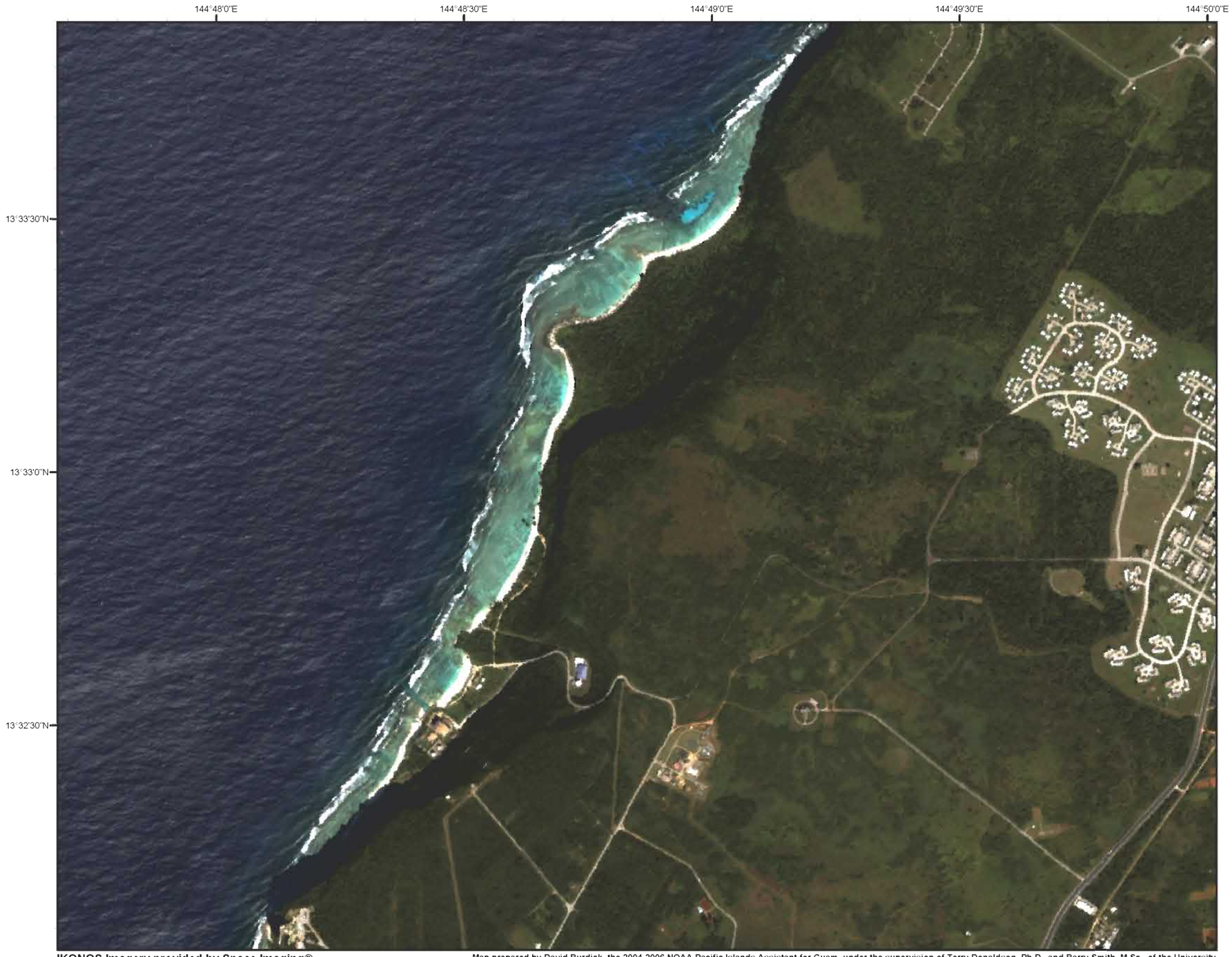
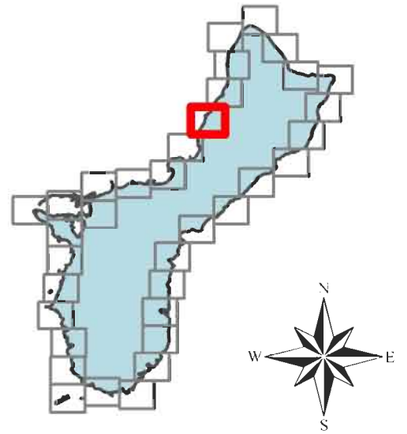
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 2





The coastline near Shark's Hole, north of the Tanguisson Power Plant. Photo by Dave Burdick.

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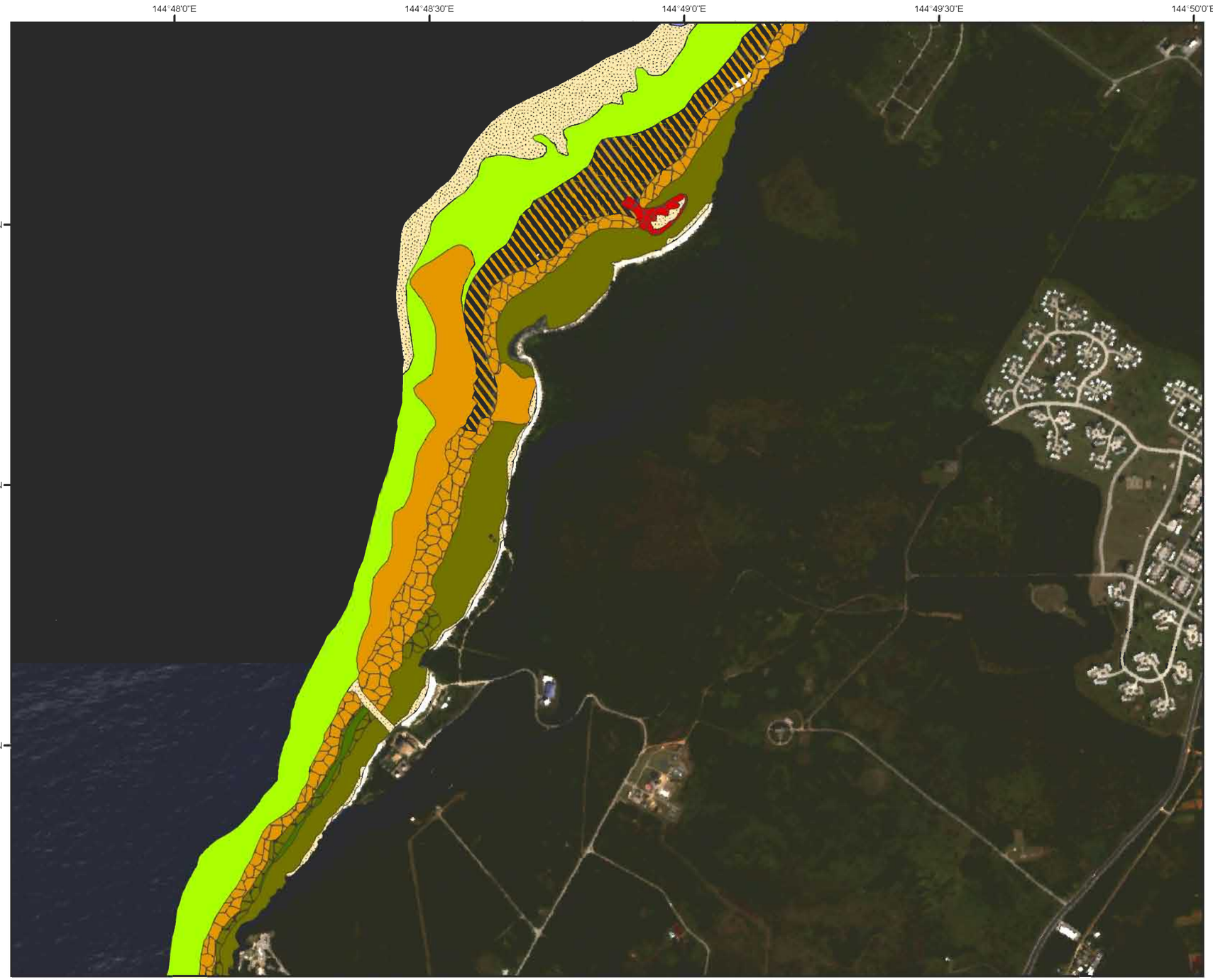
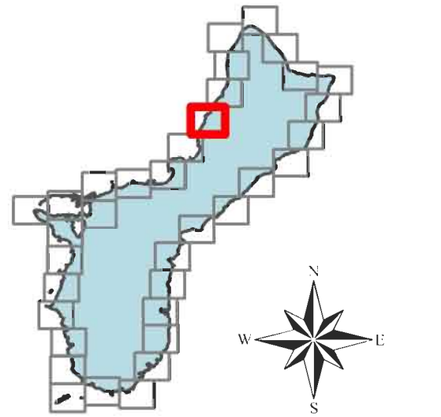
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 2





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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Macroalgae 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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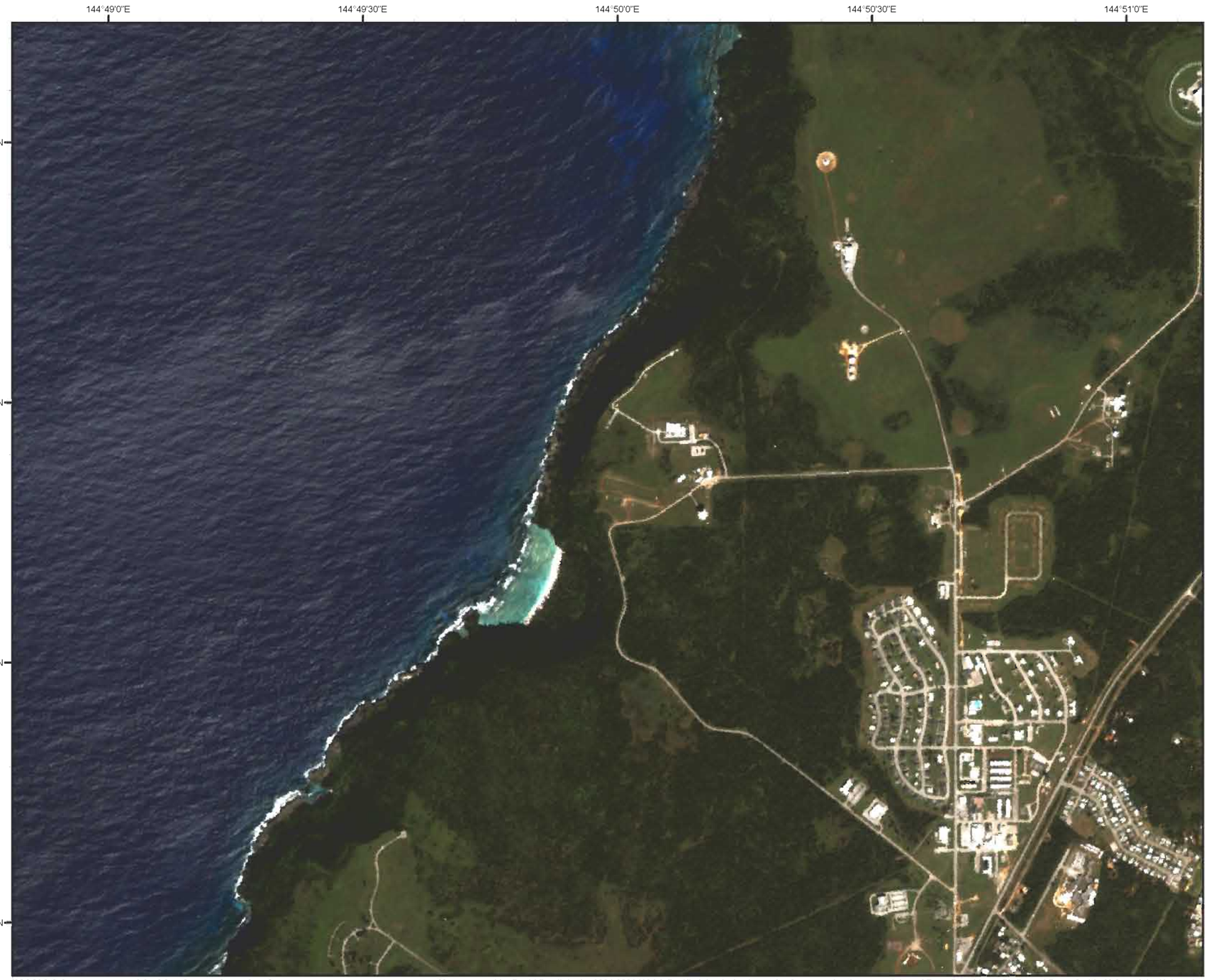
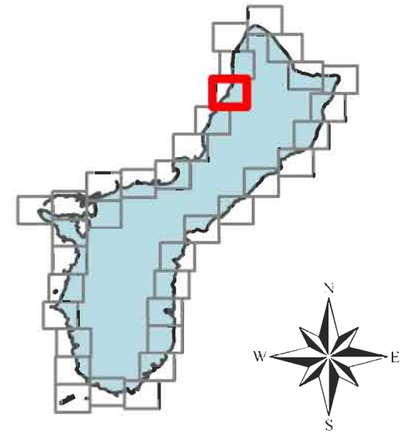
Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 3





Ague Cove, south of Haputo Bay. Photo by Dave Burdick.

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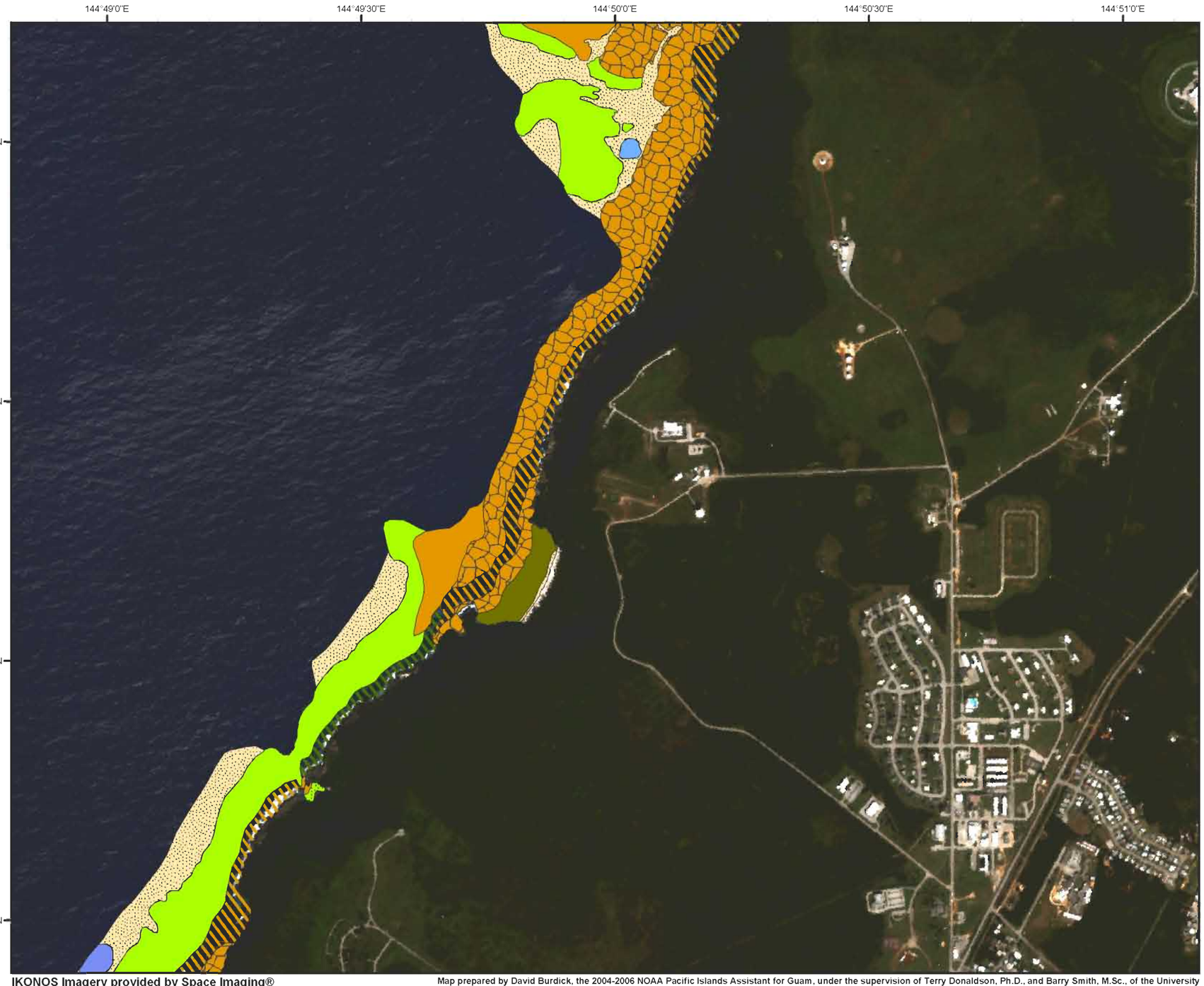
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 3



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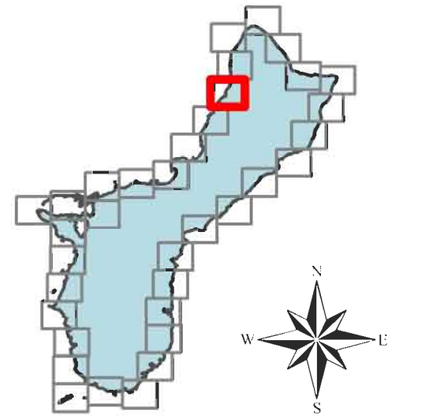

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Legend

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- Individual Patch Reef, Coral 10%-<50%
- Individual Patch Reef, Macroalgae 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Turf 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%
- Spur and Groove, Macroalgae 10%-<50%

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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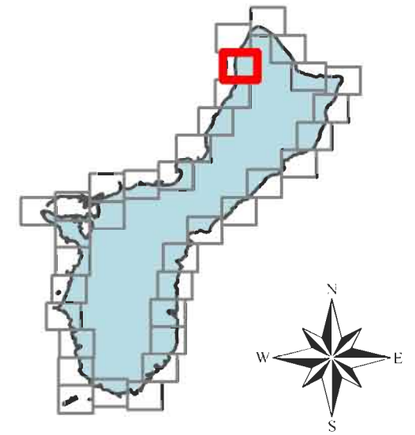
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 4



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Extensive coral cover near crest of Double Reef. Photo by Dave Burdick.

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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Guam Coastal Management Program

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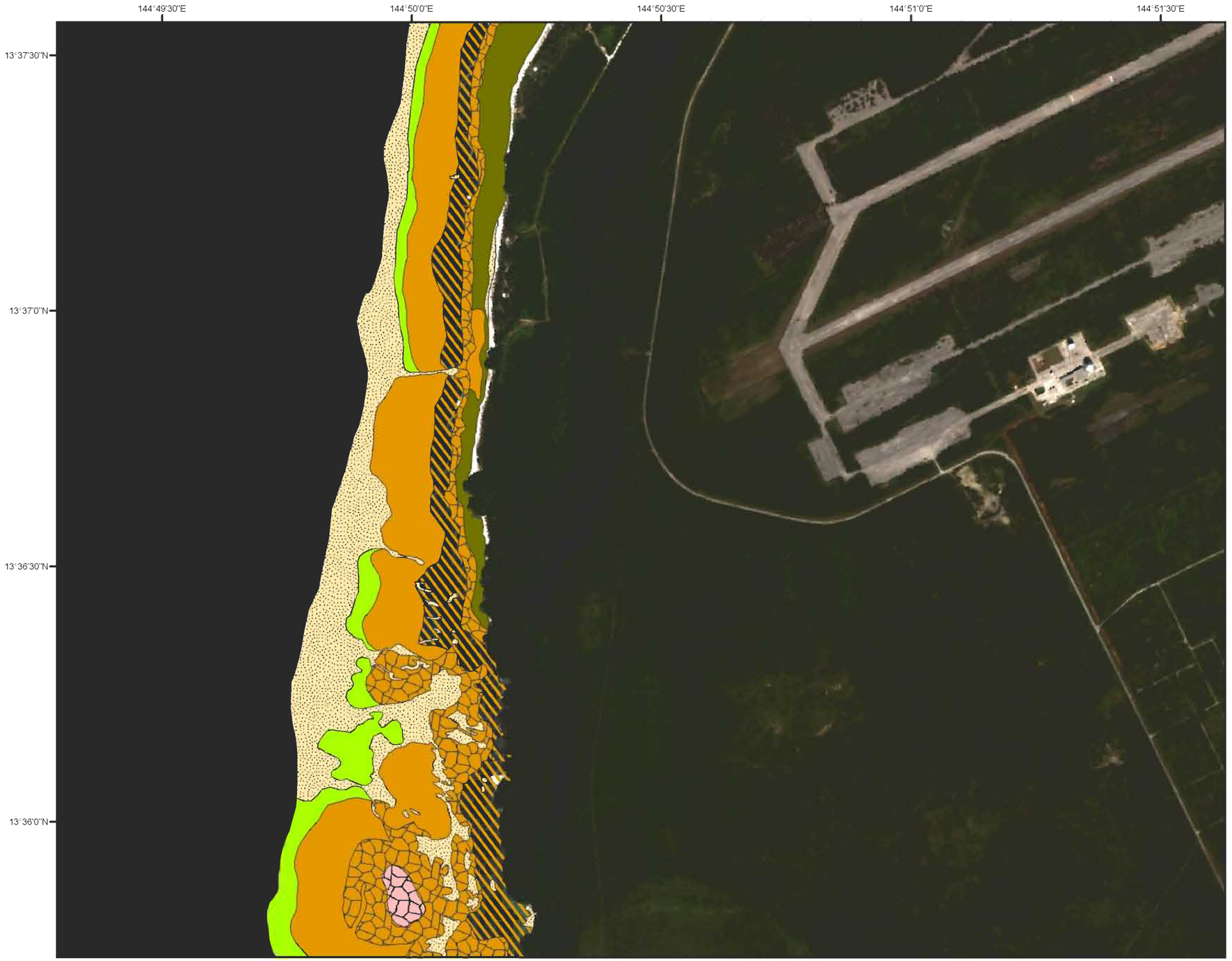
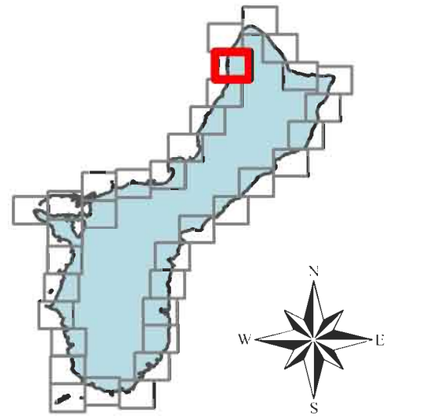
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 4





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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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Guam Coastal Management Program

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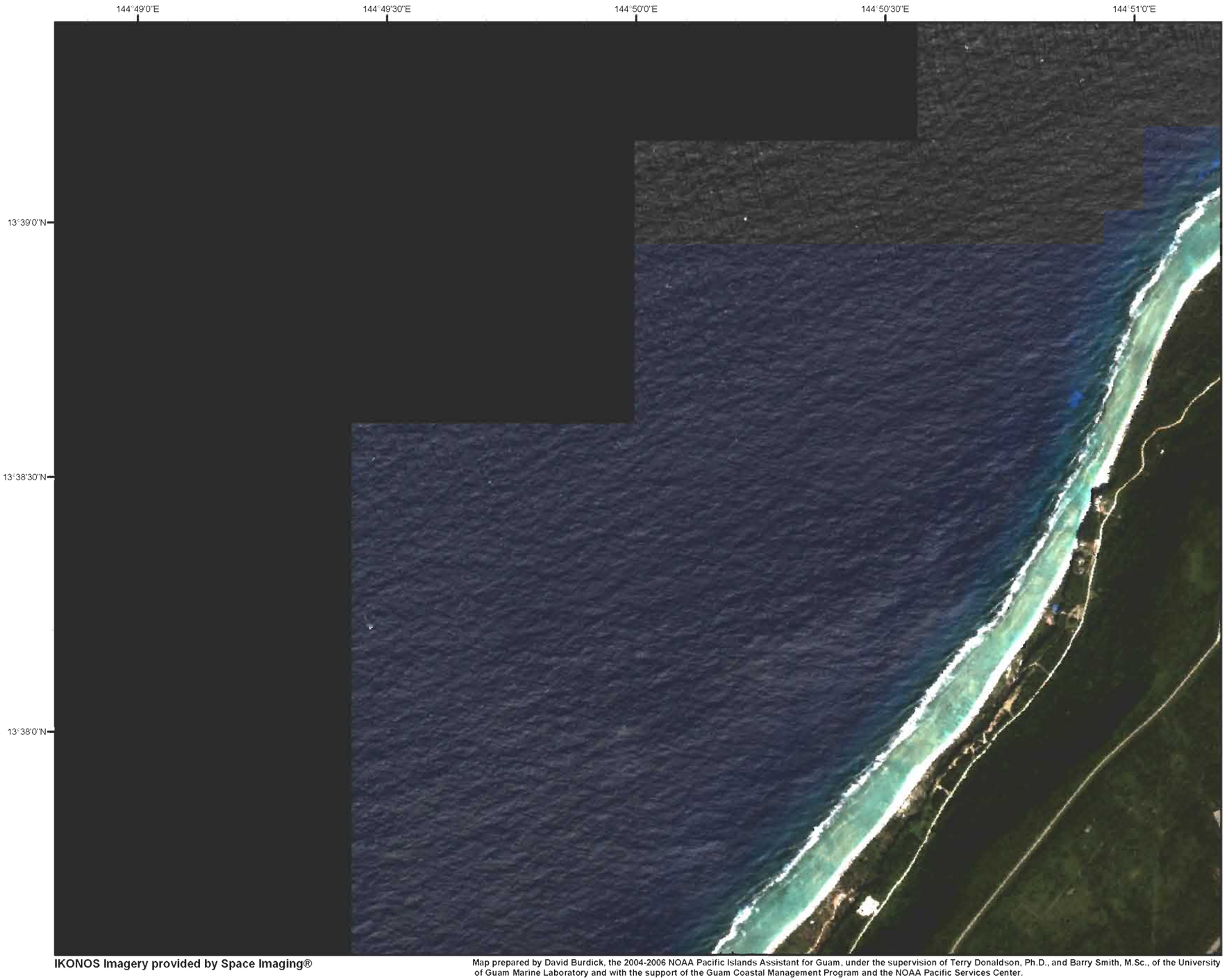
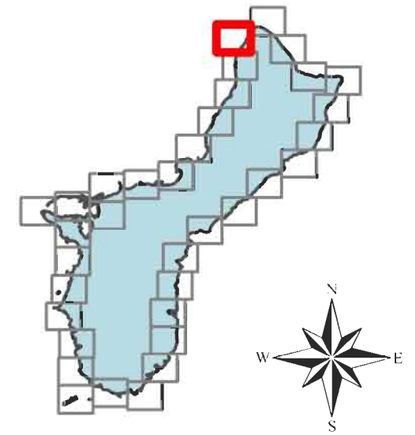
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 5





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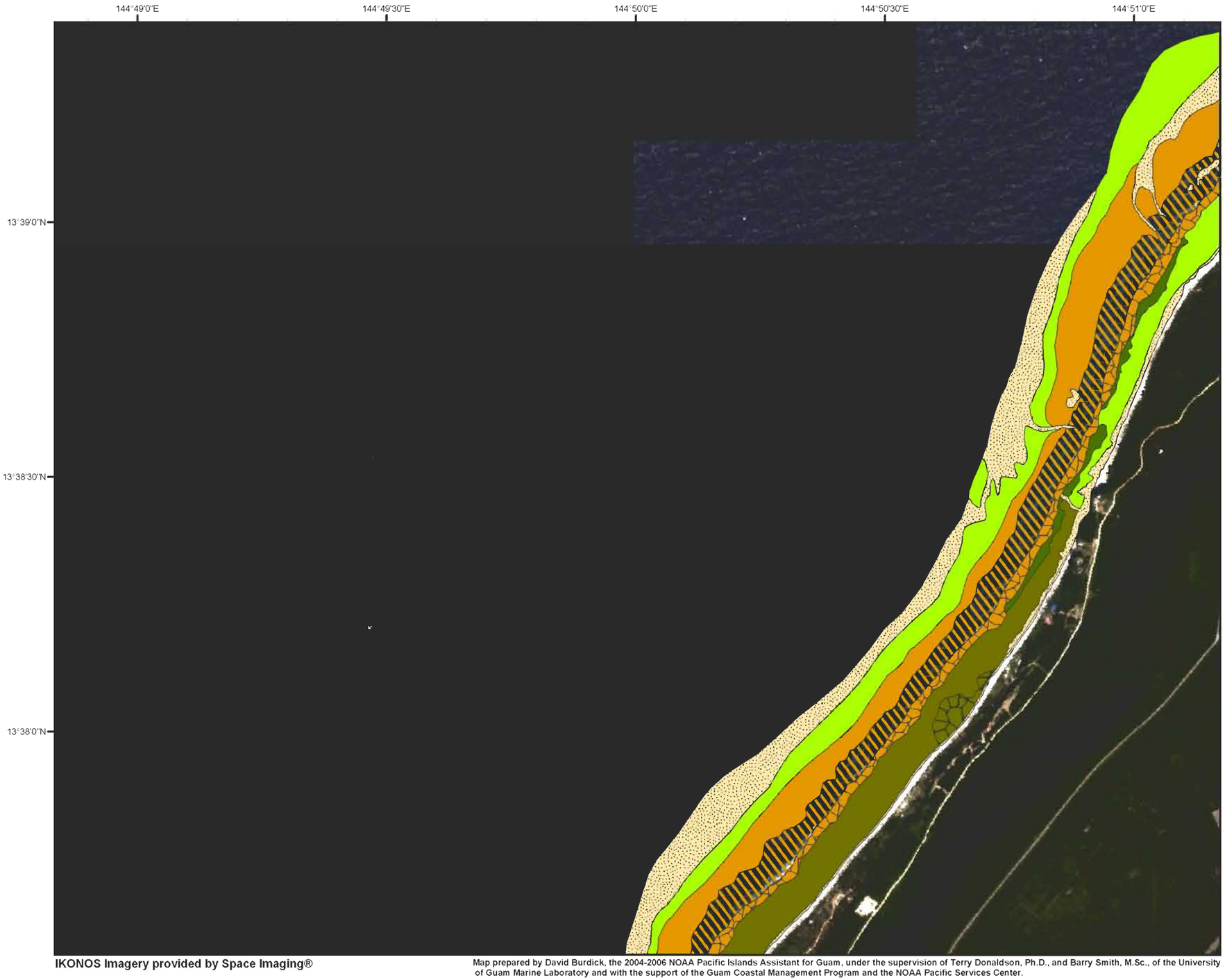
Reef flat community at Ritidian Point. Photo by Dave Burdick.

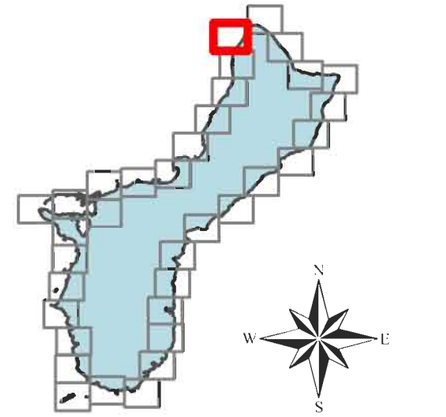
IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 5





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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Macroalgae 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

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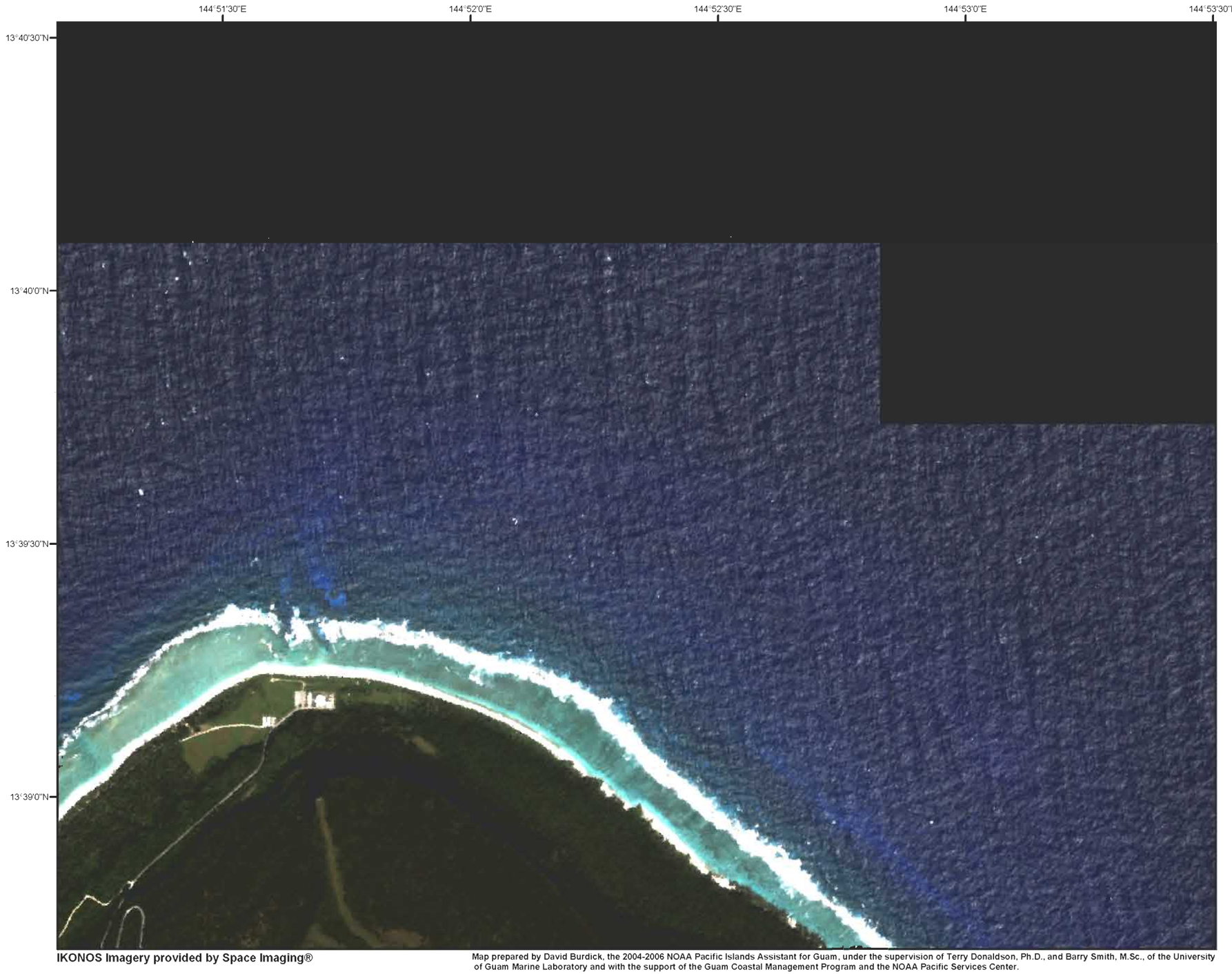
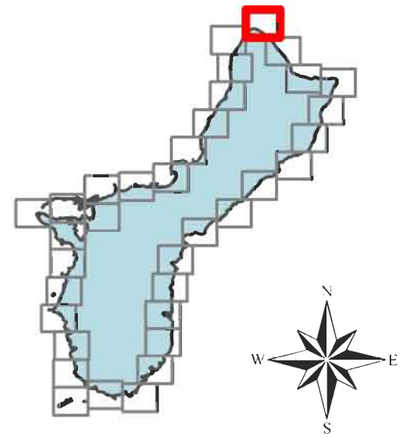
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 6





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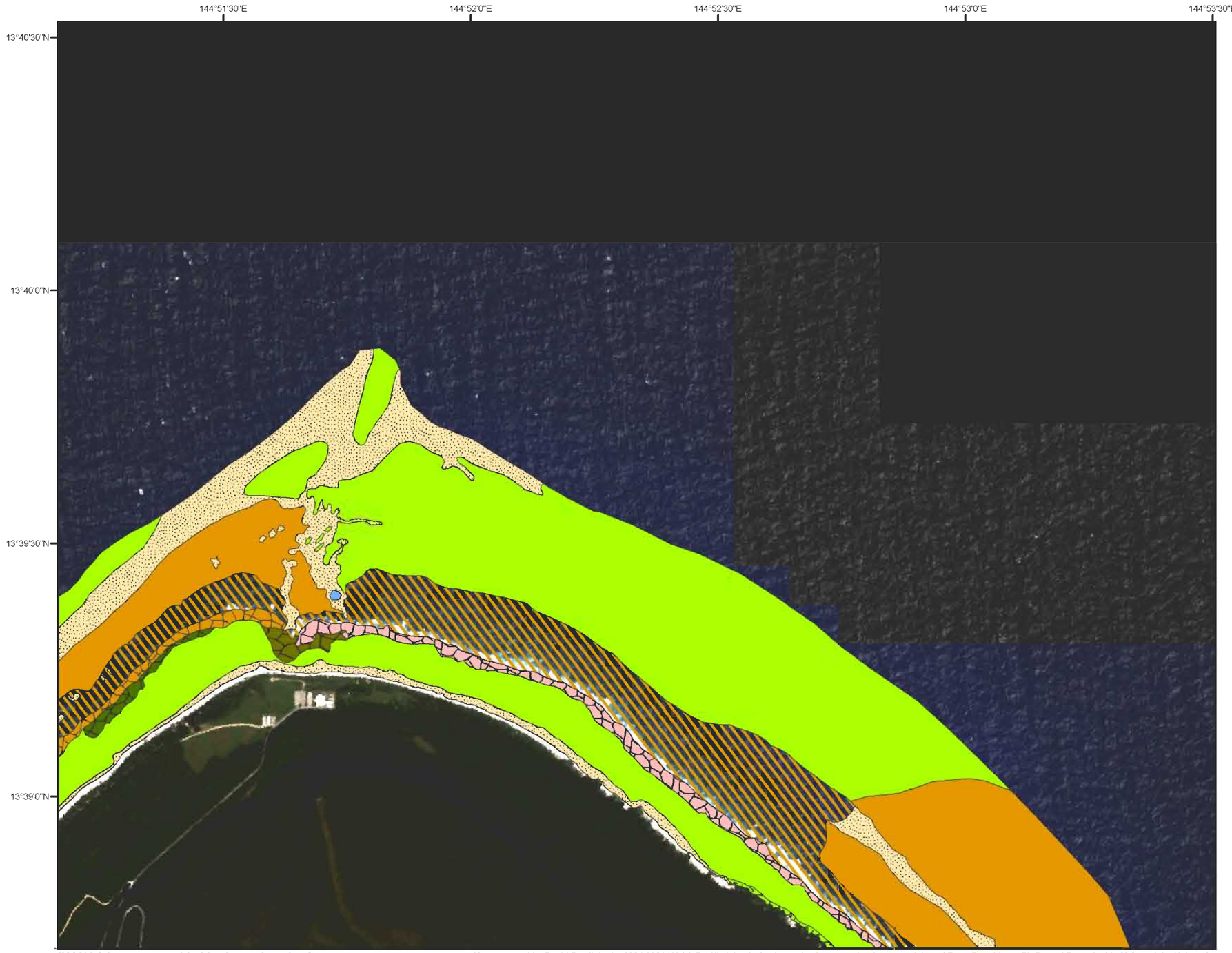
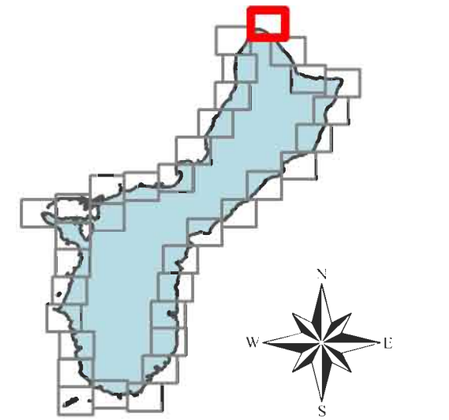
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 6





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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Individual Patch Reef, Coral 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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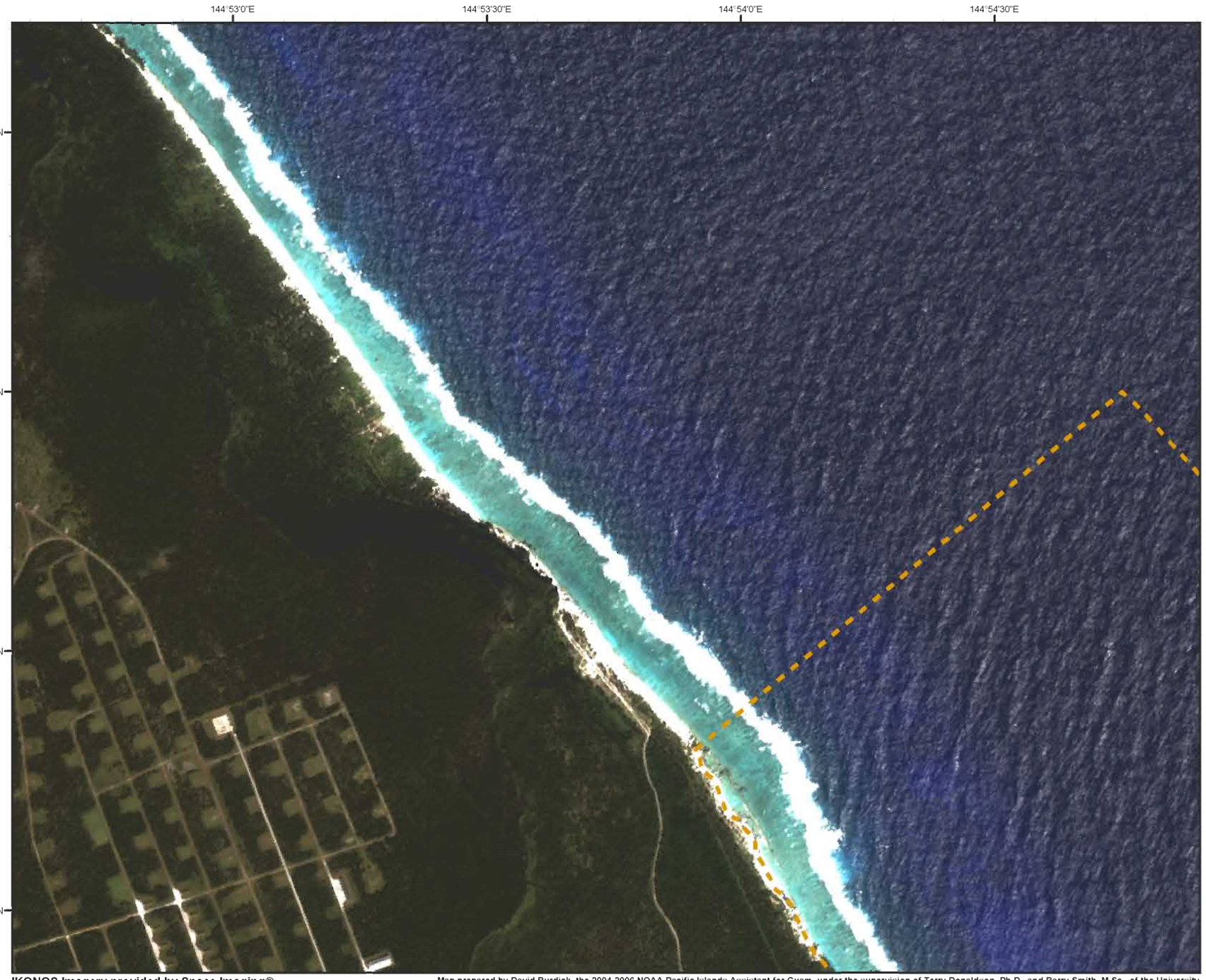
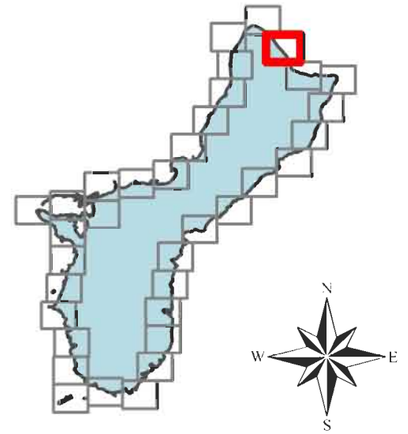
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 7





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Legend

Marine Preserve Boundaries

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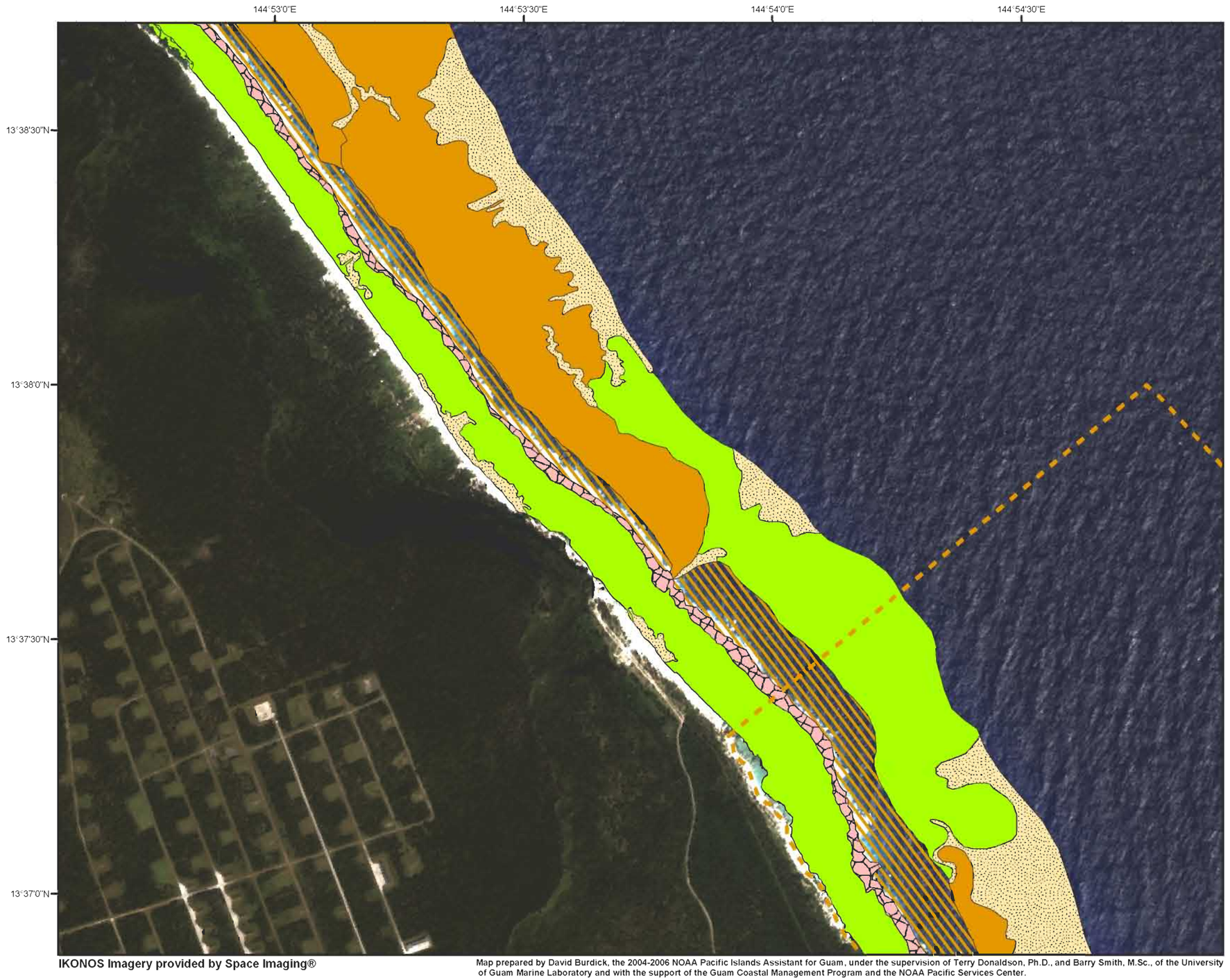
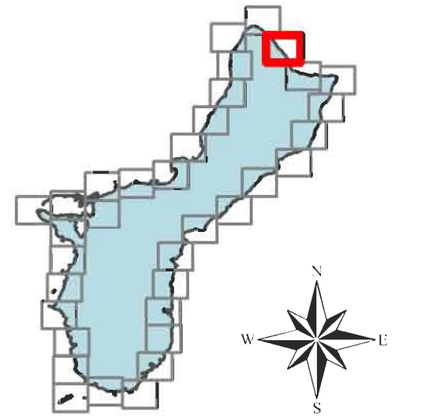
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 7





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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coralline Algae 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

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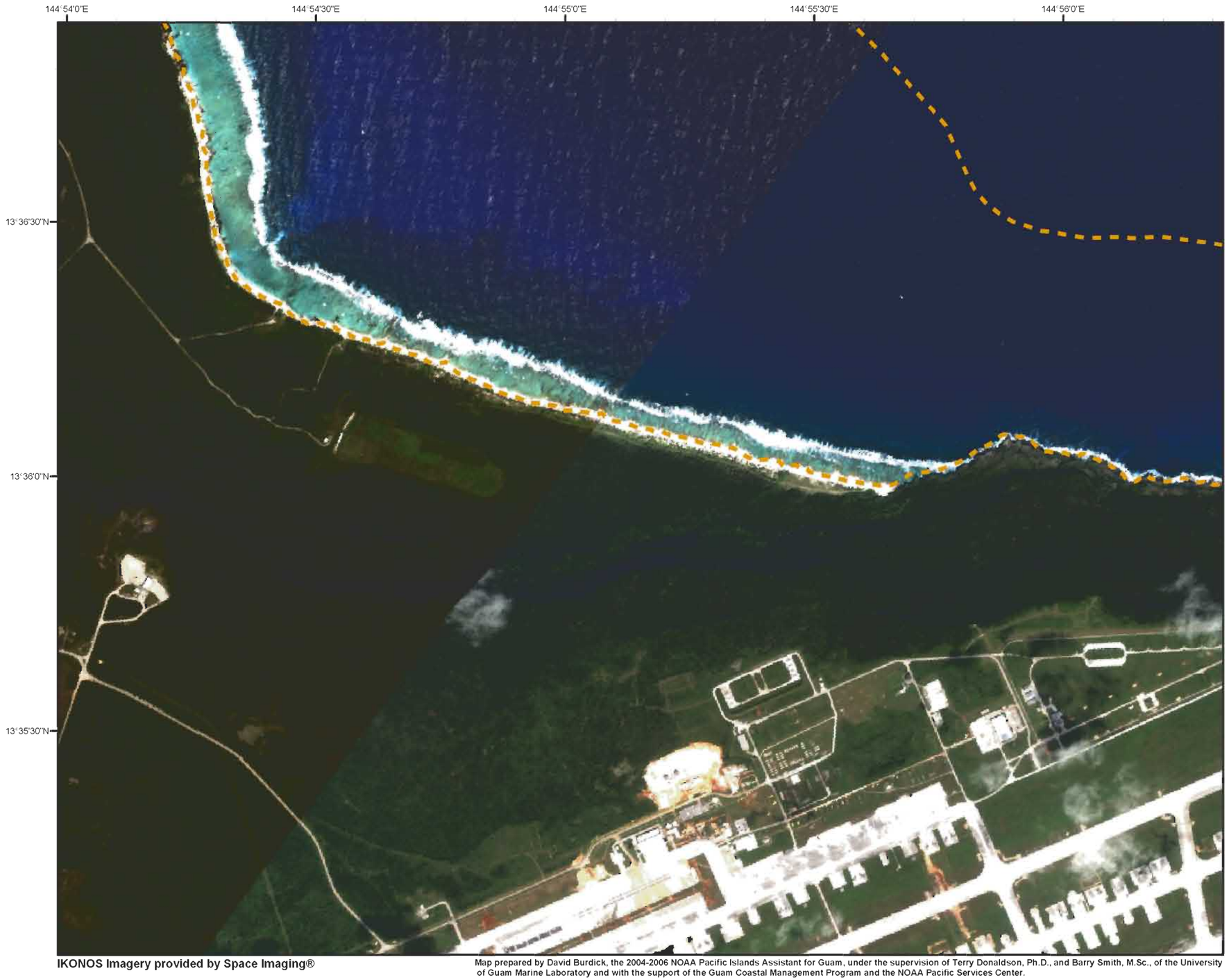
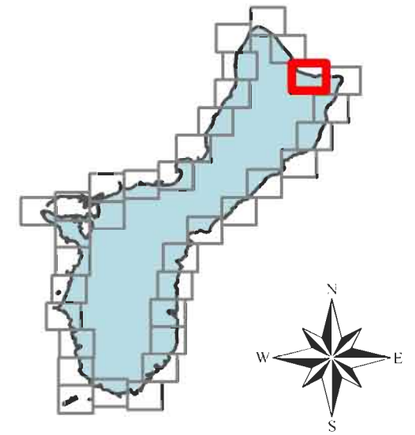
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 8





500 250 0 500 Meters

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Legend

Marine Preserve Boundaries

Coral reef community on bank/shelf to the east of Tagua Point. Note that the coral colonies, mainly Porites and Montipora species, are limited in vertical growth due to the high energy conditions of northeastern Guam. Photo by Dave Burdick.

IKONOS Imagery provided by Space Imaging®

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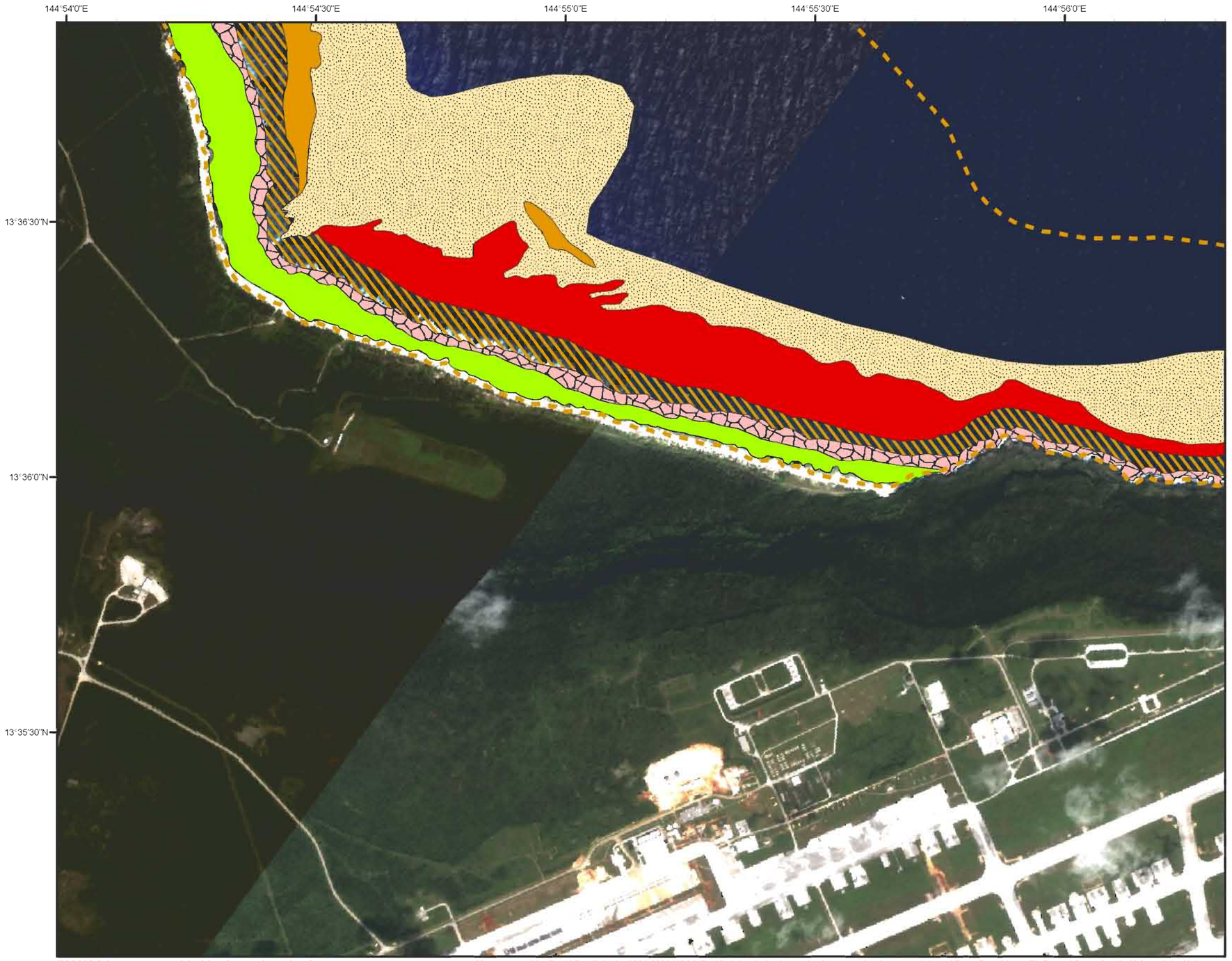
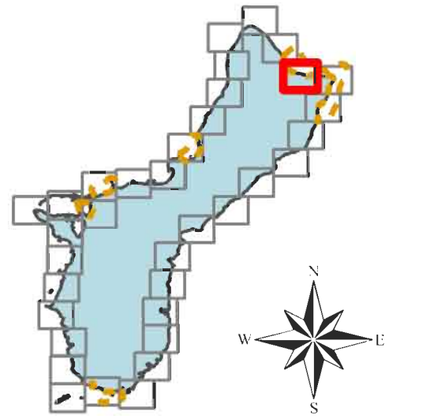


IKONOS Imagery provided by Space Imaging®



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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coralline Algae 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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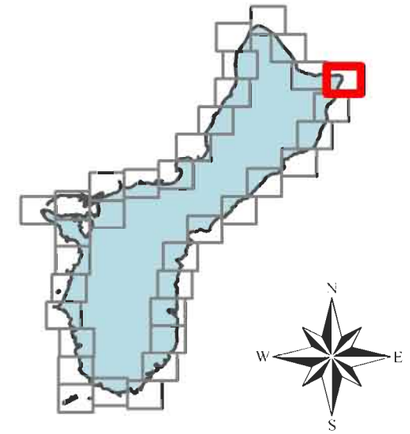
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 9

IKONOS Imagery provided by Space Imaging®



500 250 0 500 Meters

1:15,000

Legend

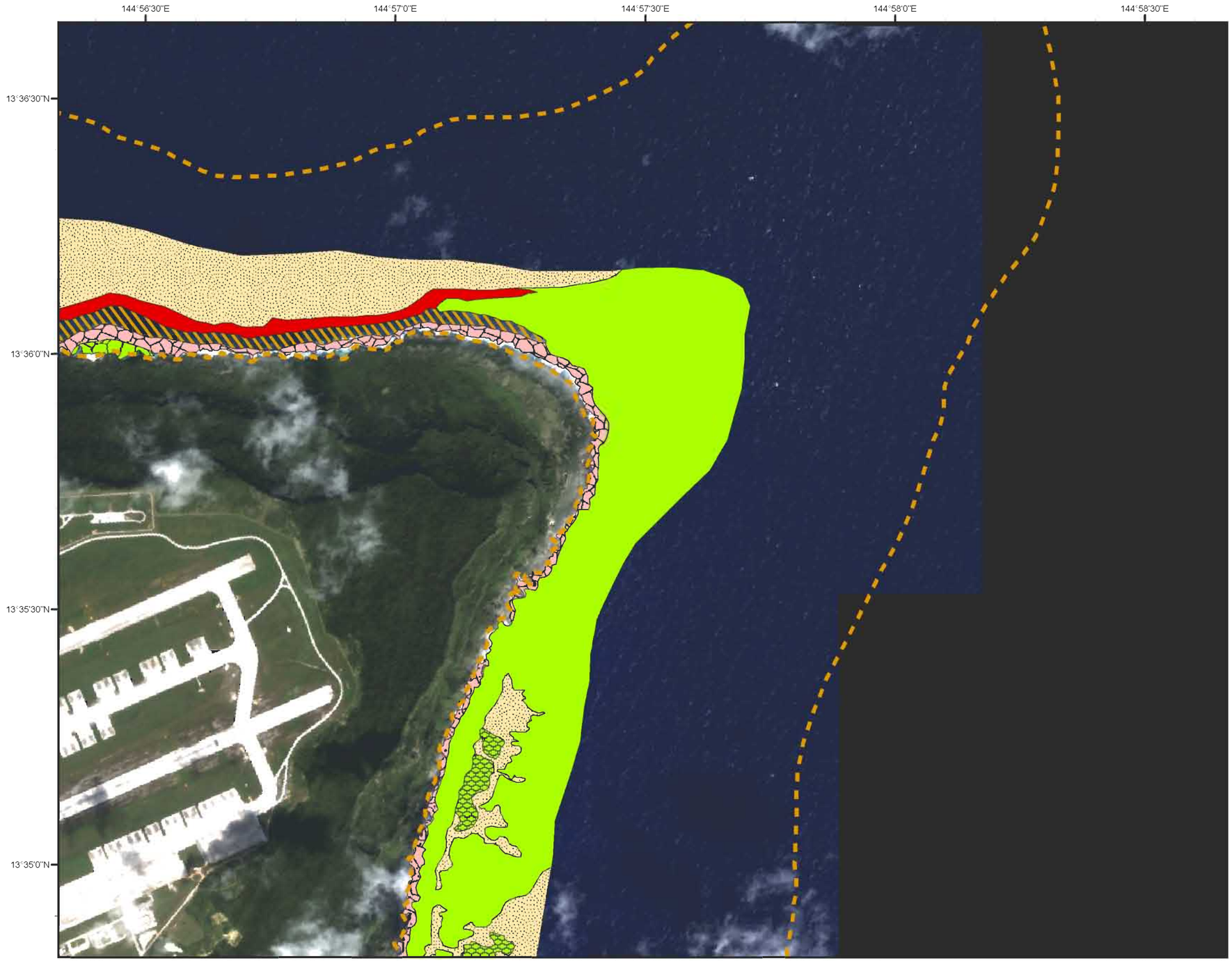
Marine Preserve Boundaries

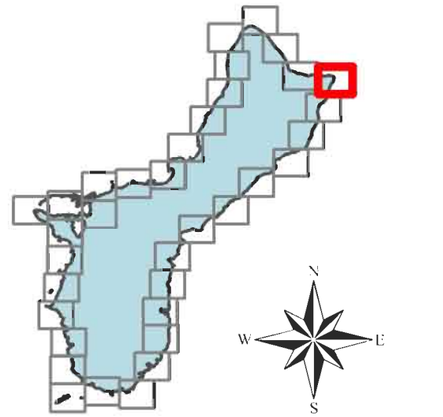
Pavement structure covered primarily by turf algae and small coral colonies on the bank/shelf just south of Pati Point. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 9





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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Turf 50%-<90%
- Pavement, Coral 50%-<90%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Coralline Algae 10%-<50%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

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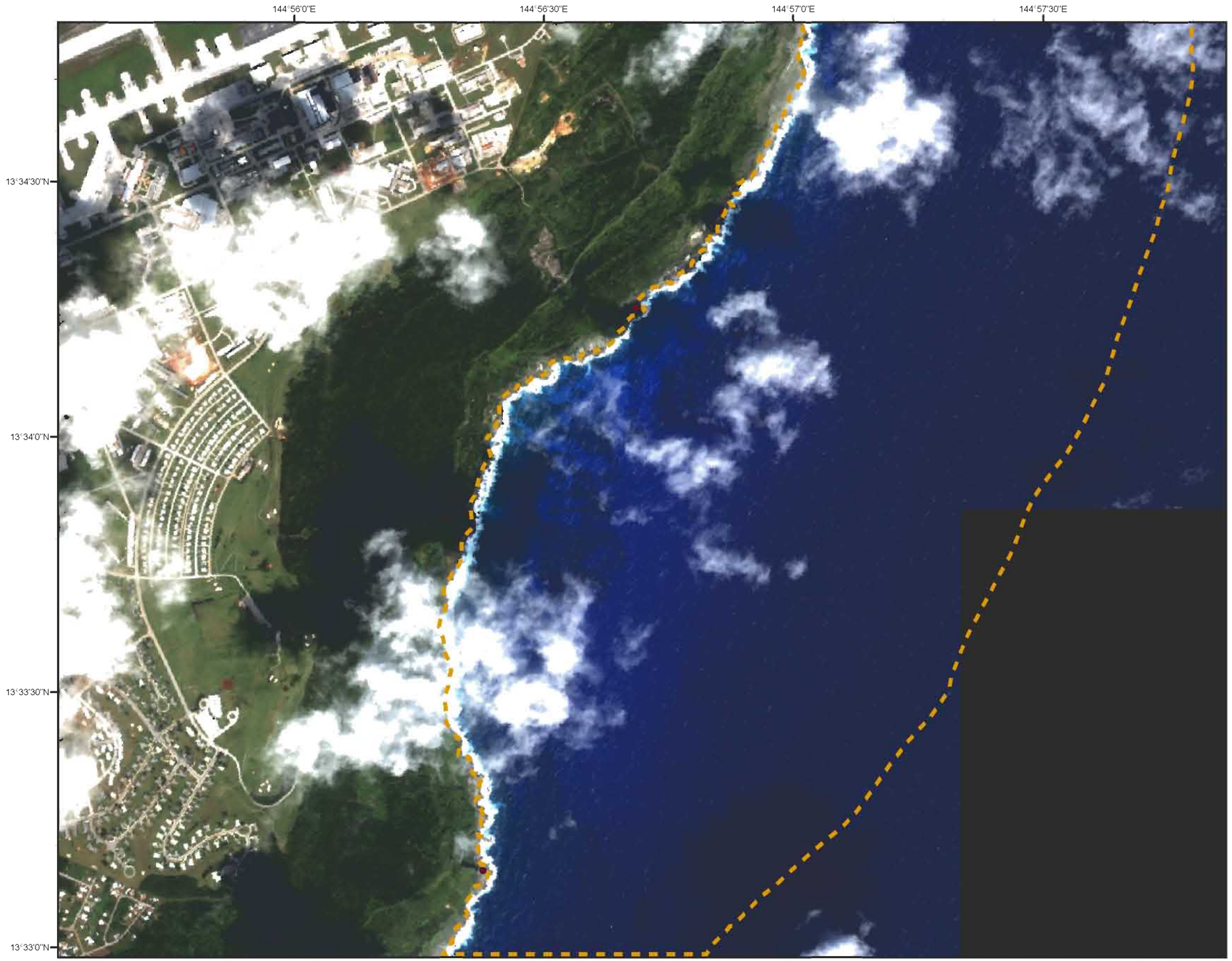
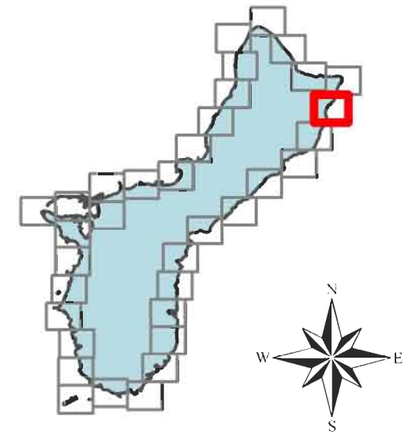
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 10





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Legend

Marine Preserve Boundaries

Looking south along the coast near Anao Point. Photo by Dave Burdick.

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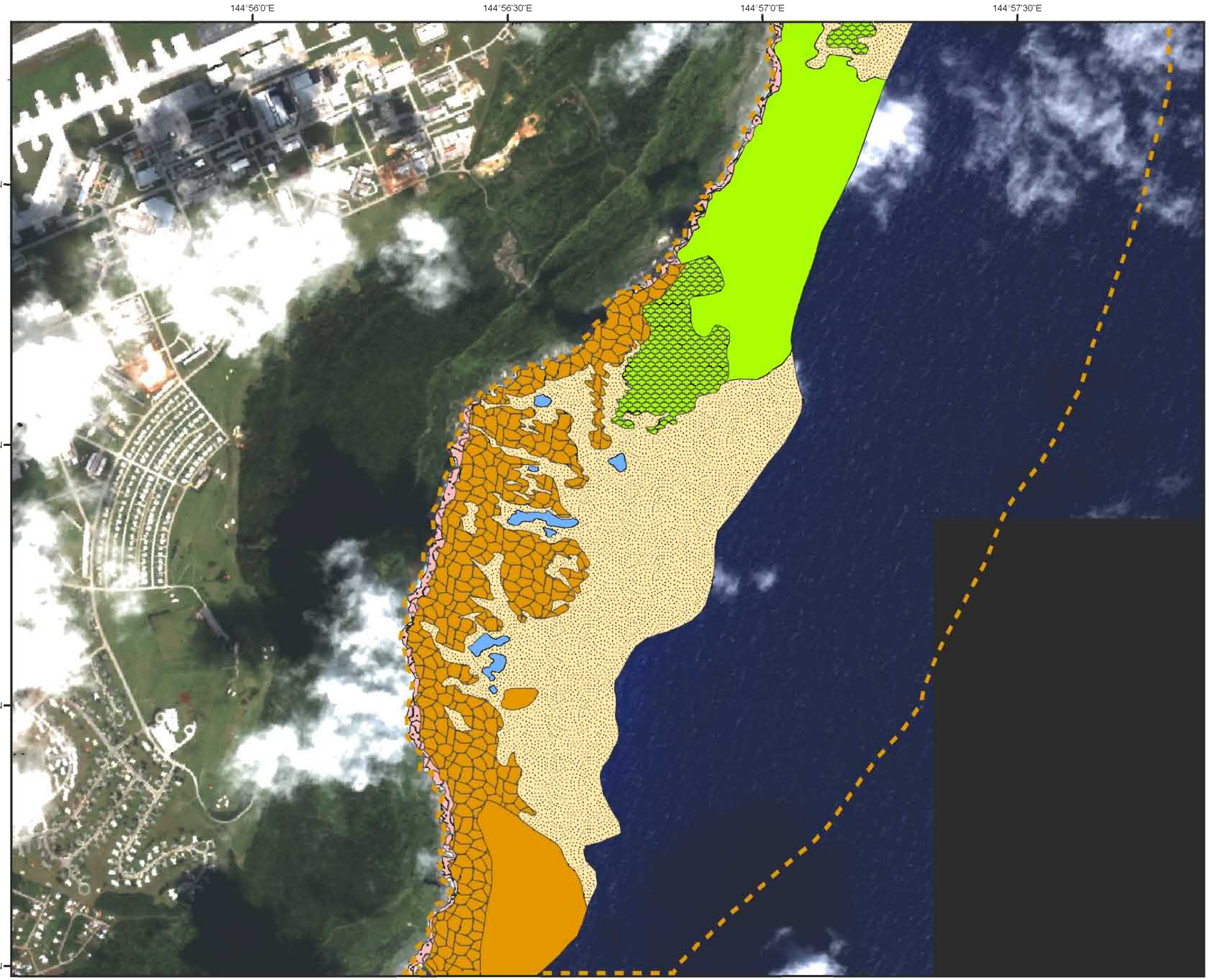
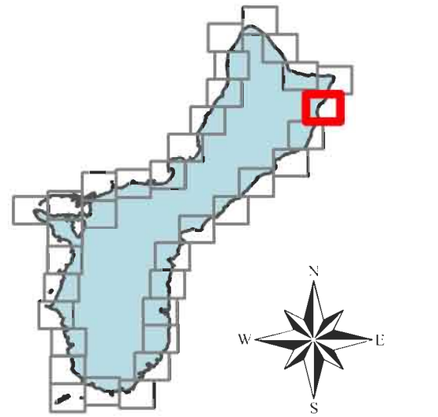
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 10





Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregated Patch Reef, Turf 50%-<90%
- Individual Patch Reef, Coral 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Coralline Algae 10%-<50%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

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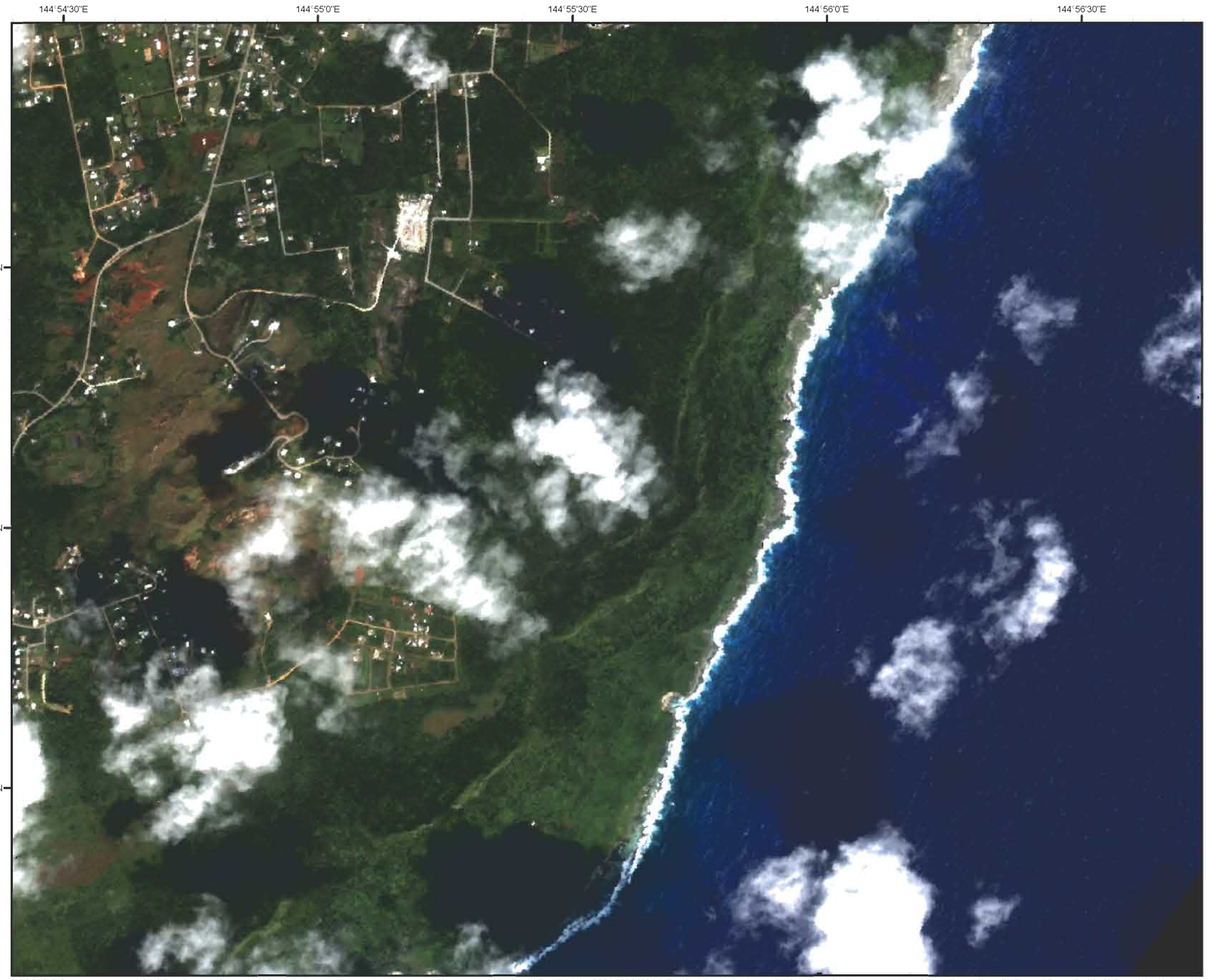
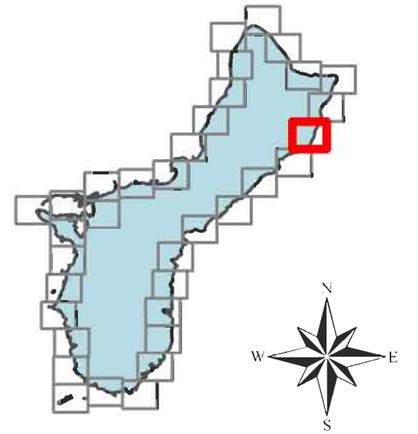
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 11





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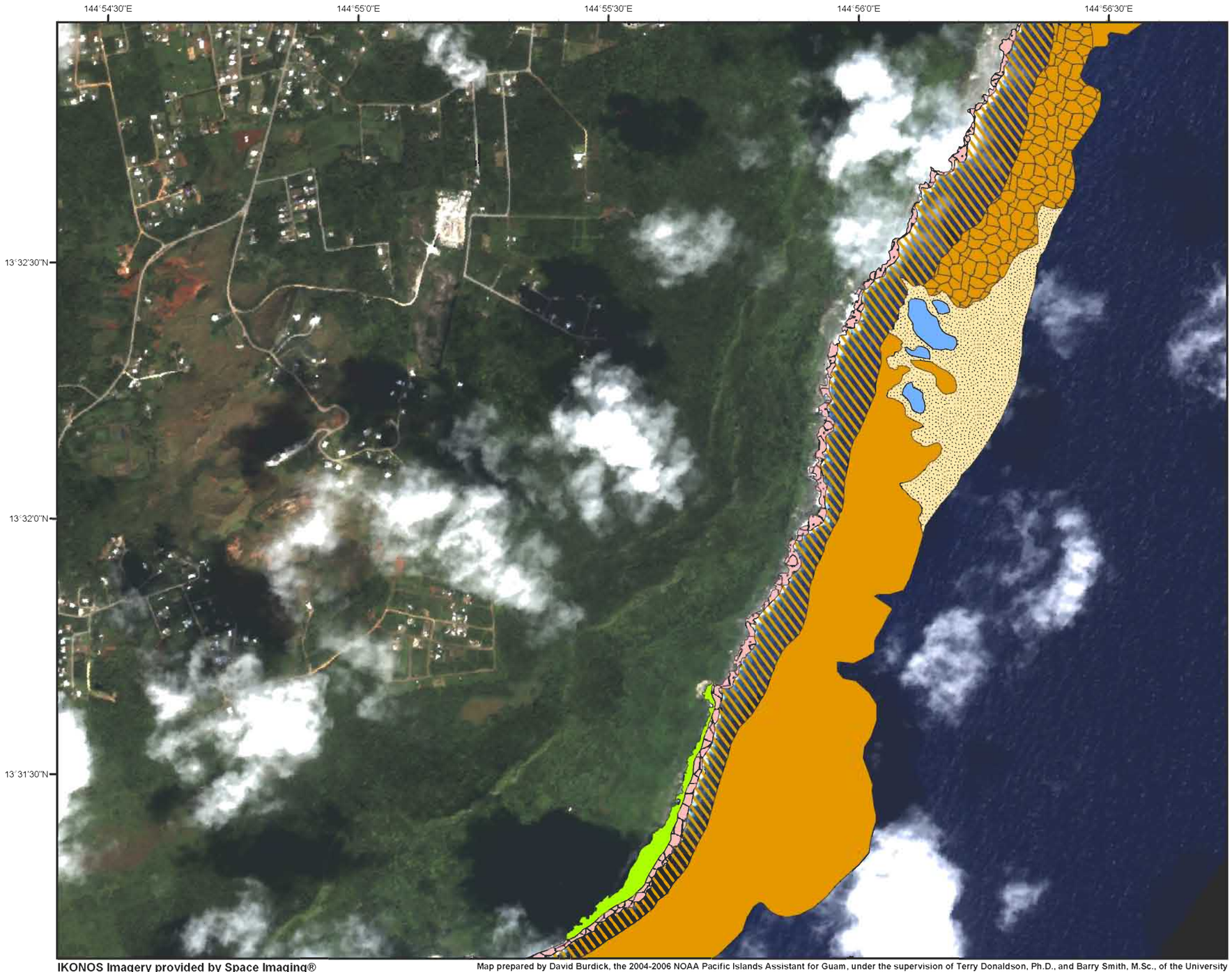
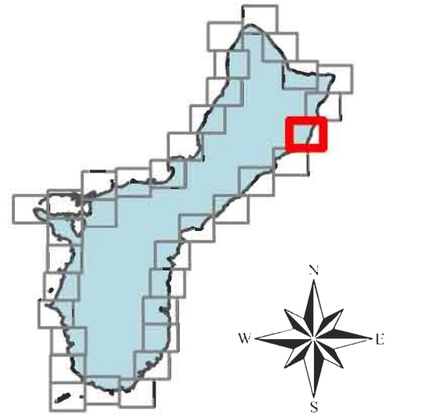
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 11





Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 10%-<50%
- Individual Patch Reef, Coral 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Coralline Algae 10%-<50%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

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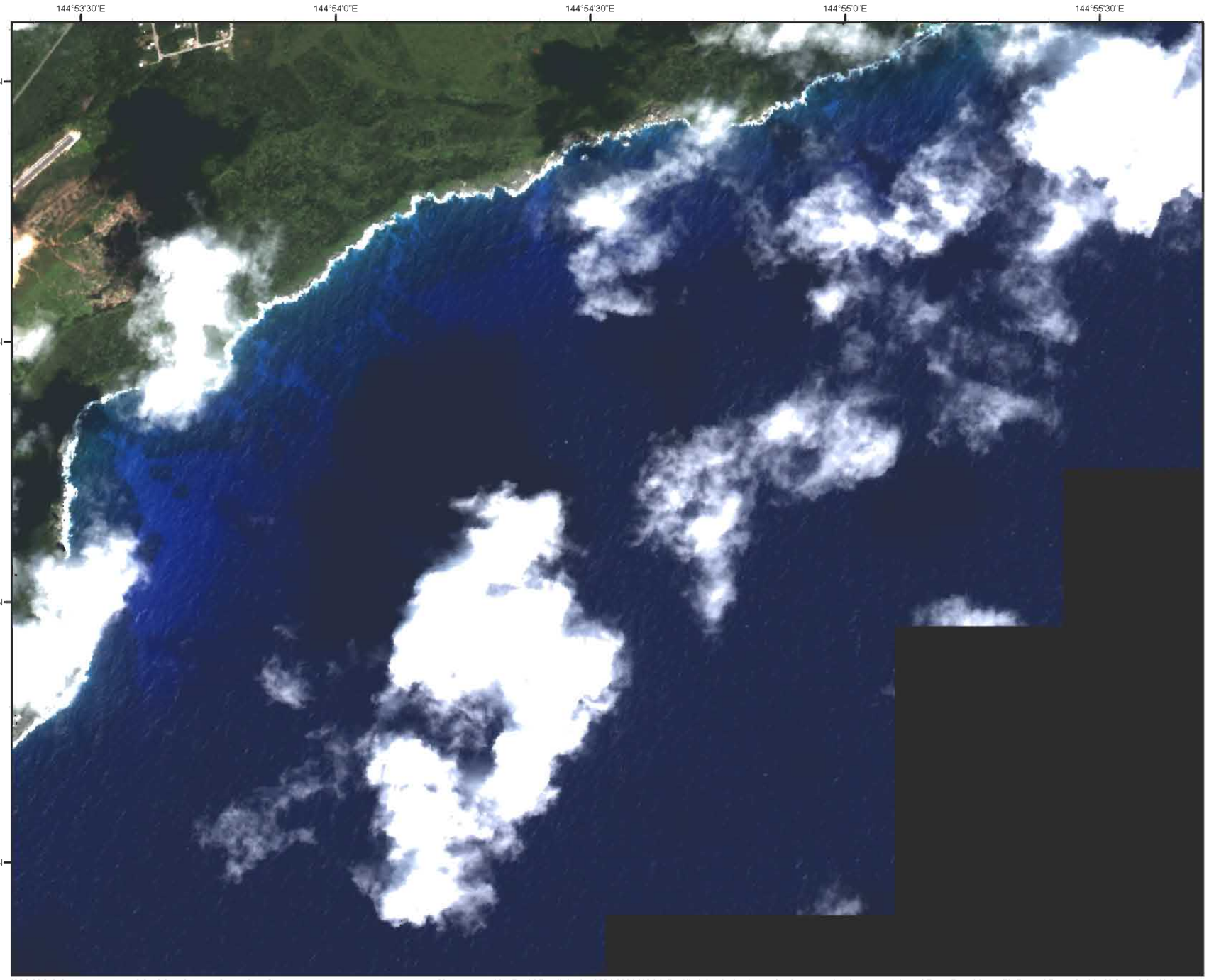
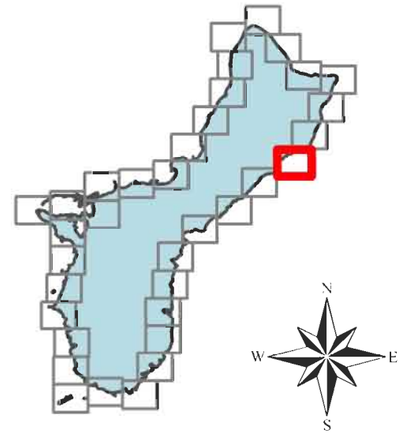
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 12





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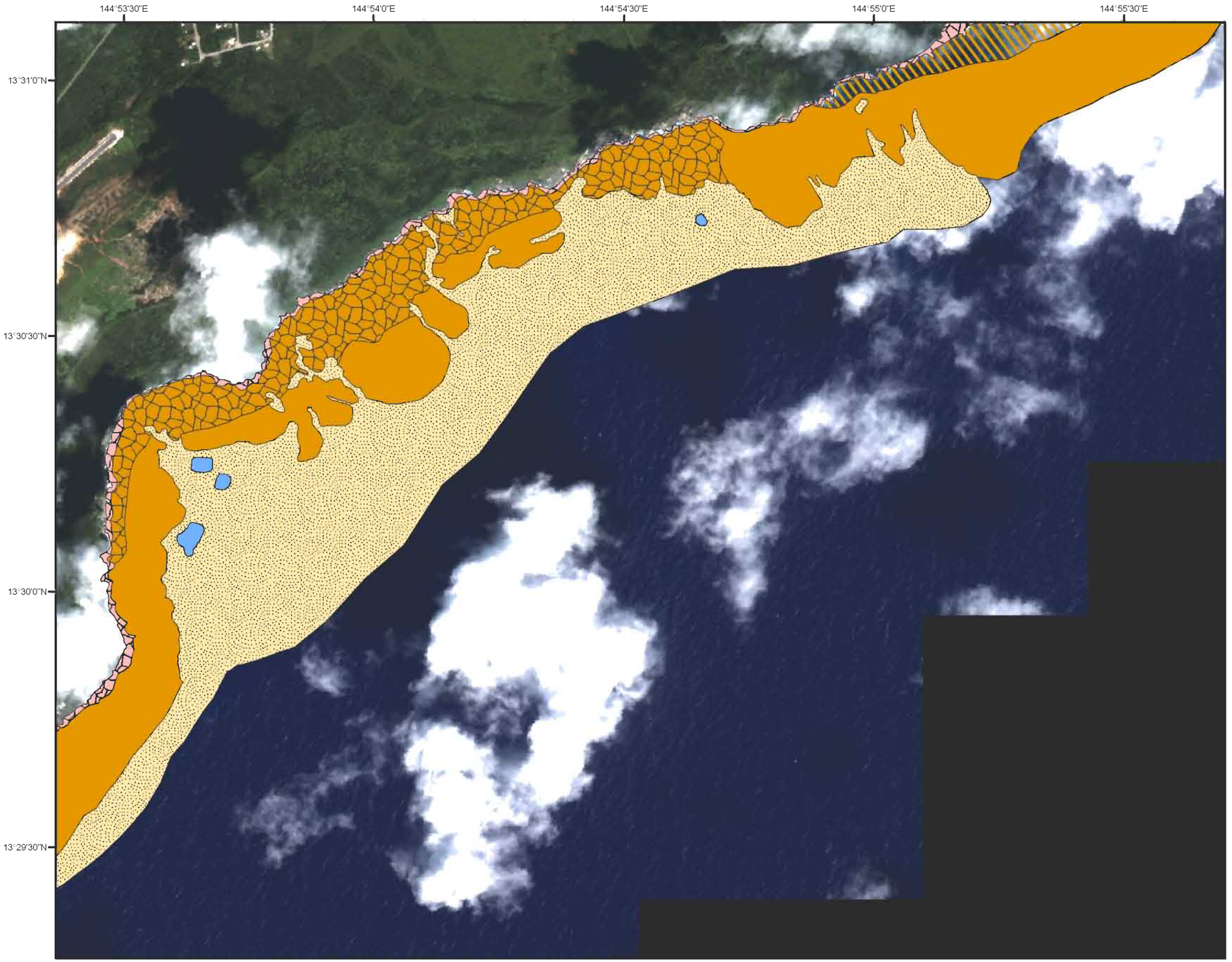
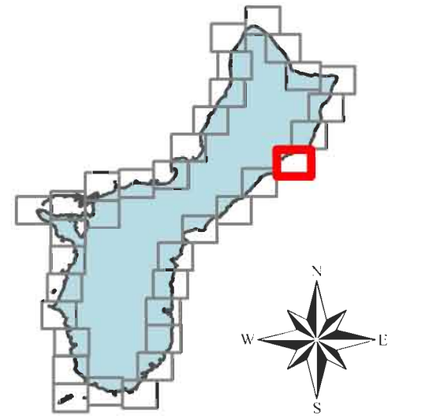
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 12





500 250 0 500 Meters

1:15,000

Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 10%-<50%
- Individual Patch Reef, Coral 10%-<50%
- Pavement, Coral 10%-<50%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

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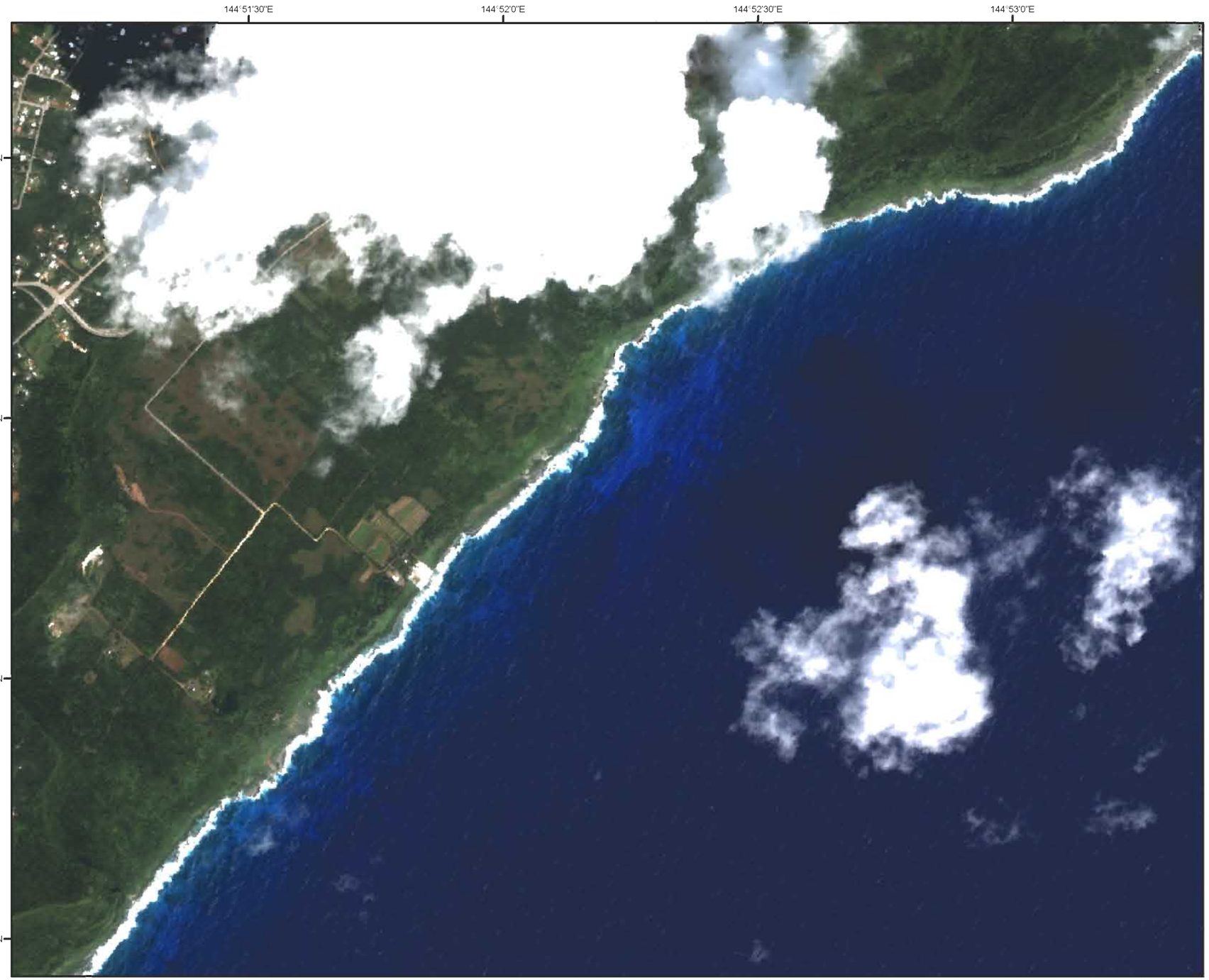
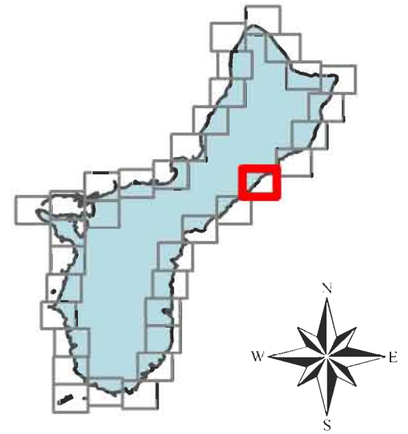
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 13





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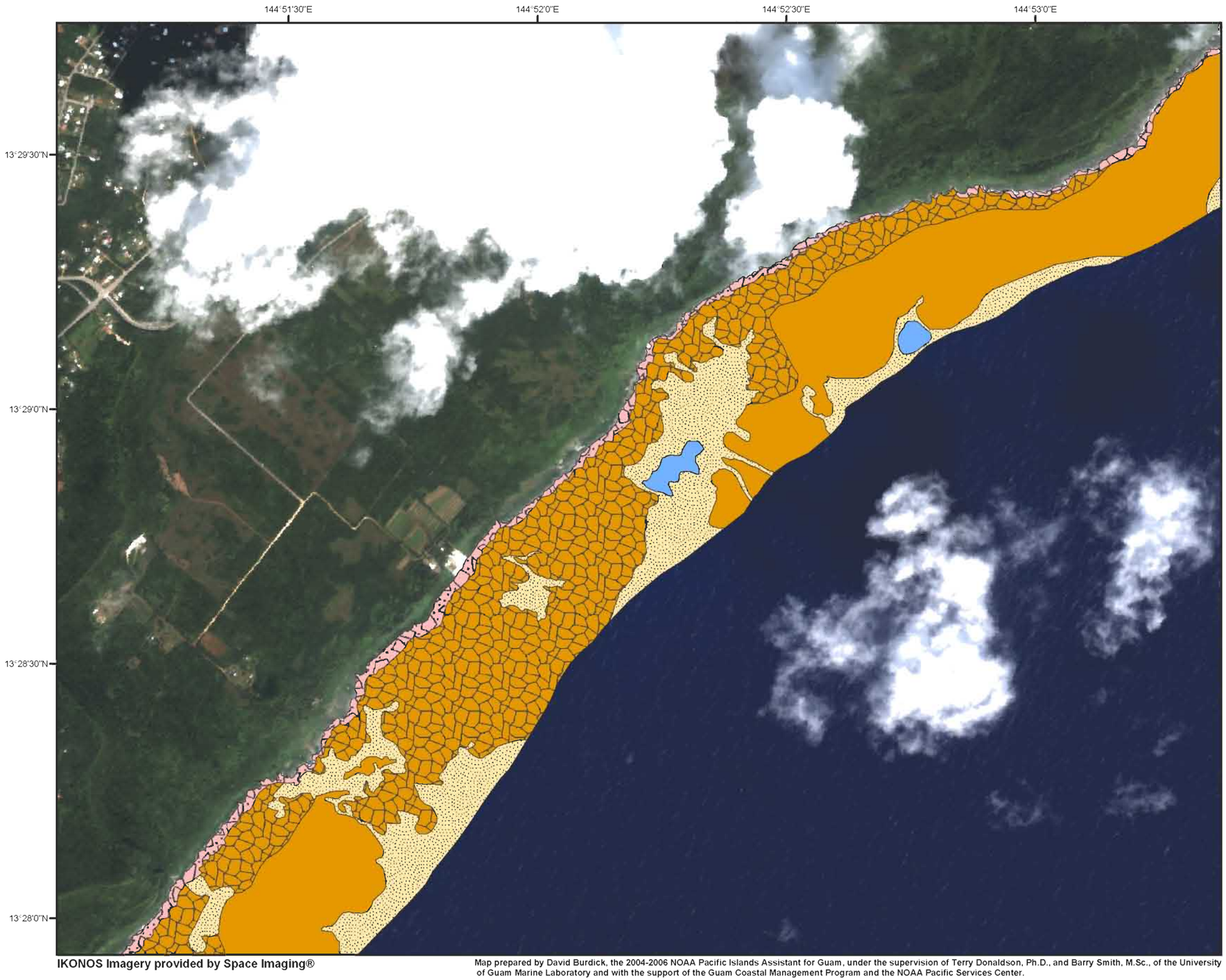
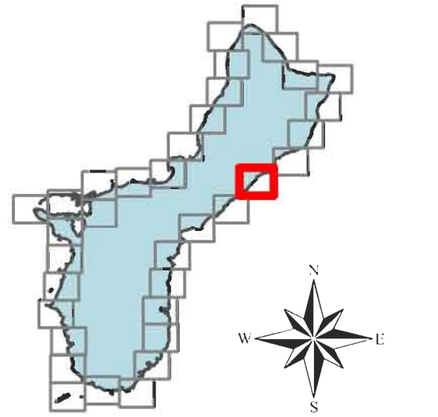
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 13





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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 10%-<50%
- Individual Patch Reef, Coral 10%-<50%
- Pavement, Coral 10%-<50%
- Rock/Boulder, Coralline Algae 10%-<50%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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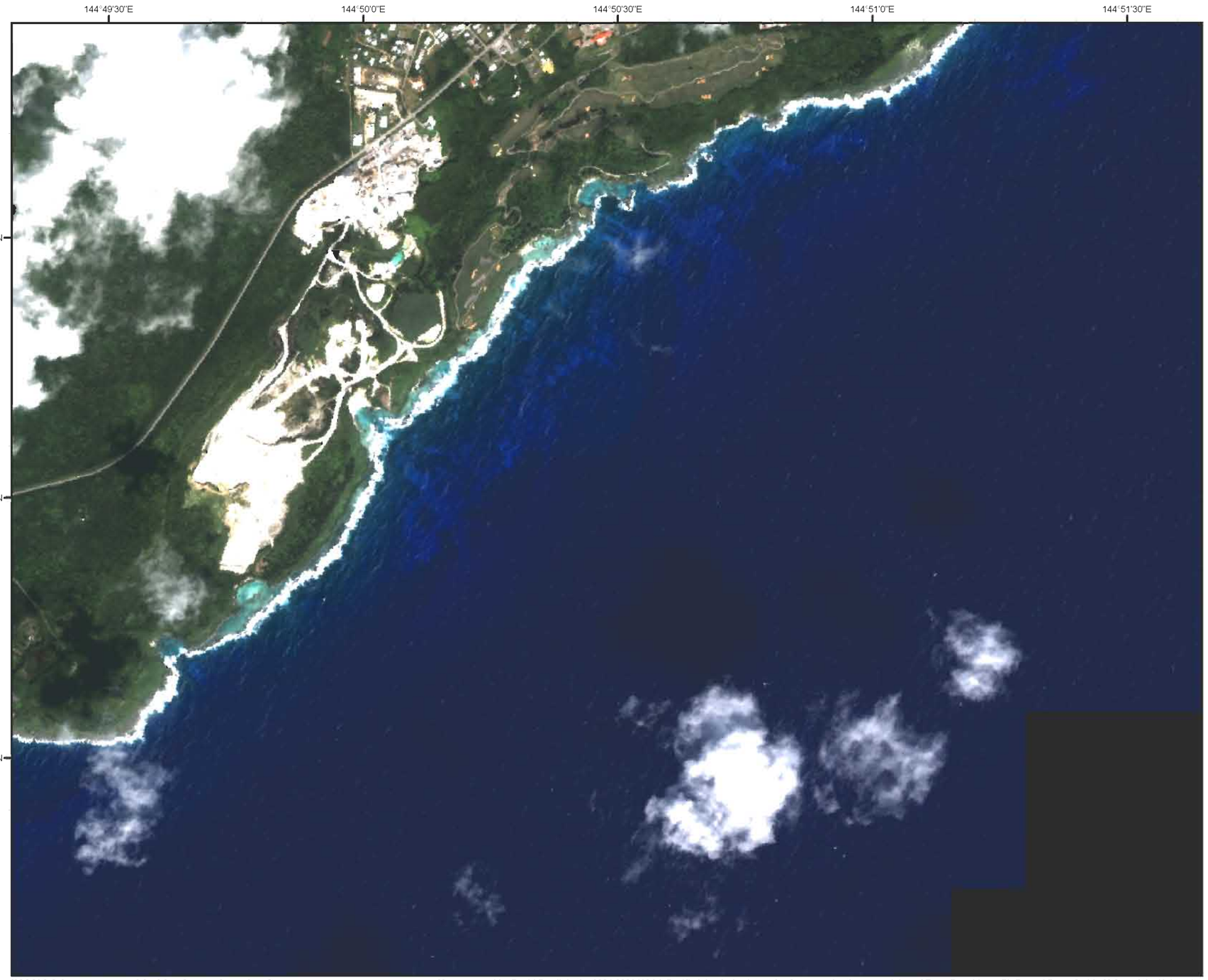
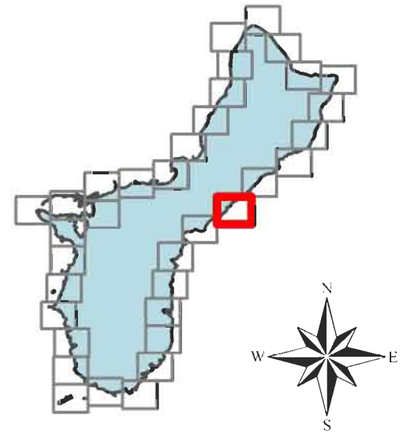
Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 14





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Coral cover, mainly comprised of small Acropora spp. and Pocillipora spp. colonies, on shallow (3-5 meter) spur formations near the Mangilao Golf Course. Photo by Dave Burdick

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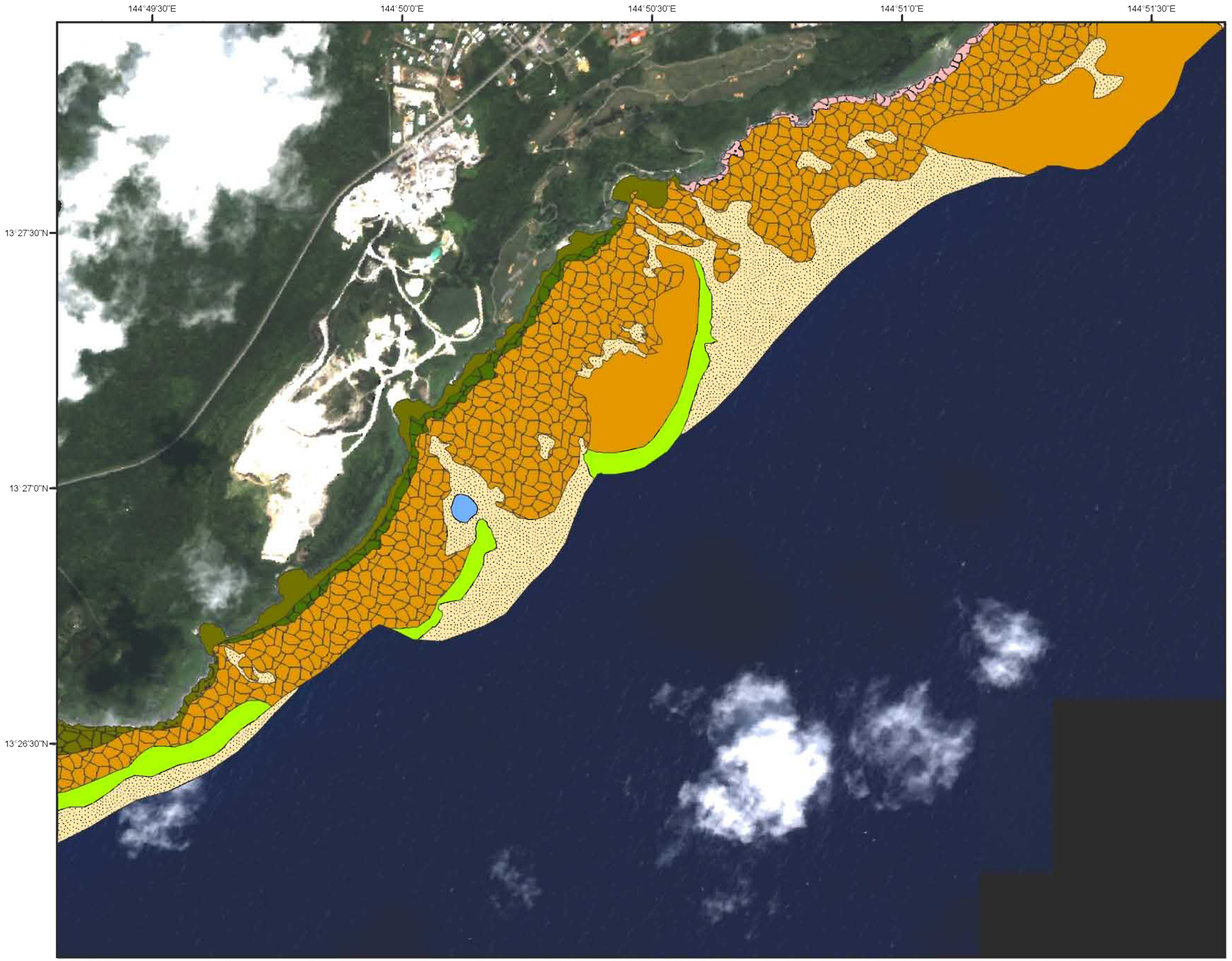
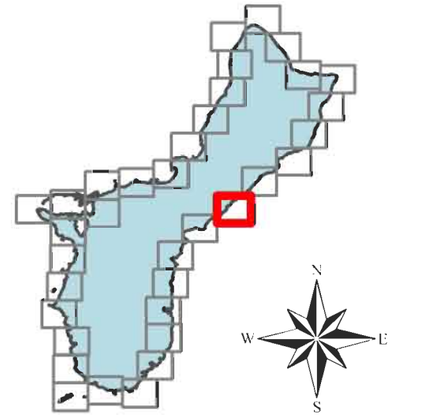
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 14





Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Individual Patch Reef, Coral 10%-<50%
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- Pavement, Turf 50%-<90%
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- Sand, Uncolonized 90%-100%

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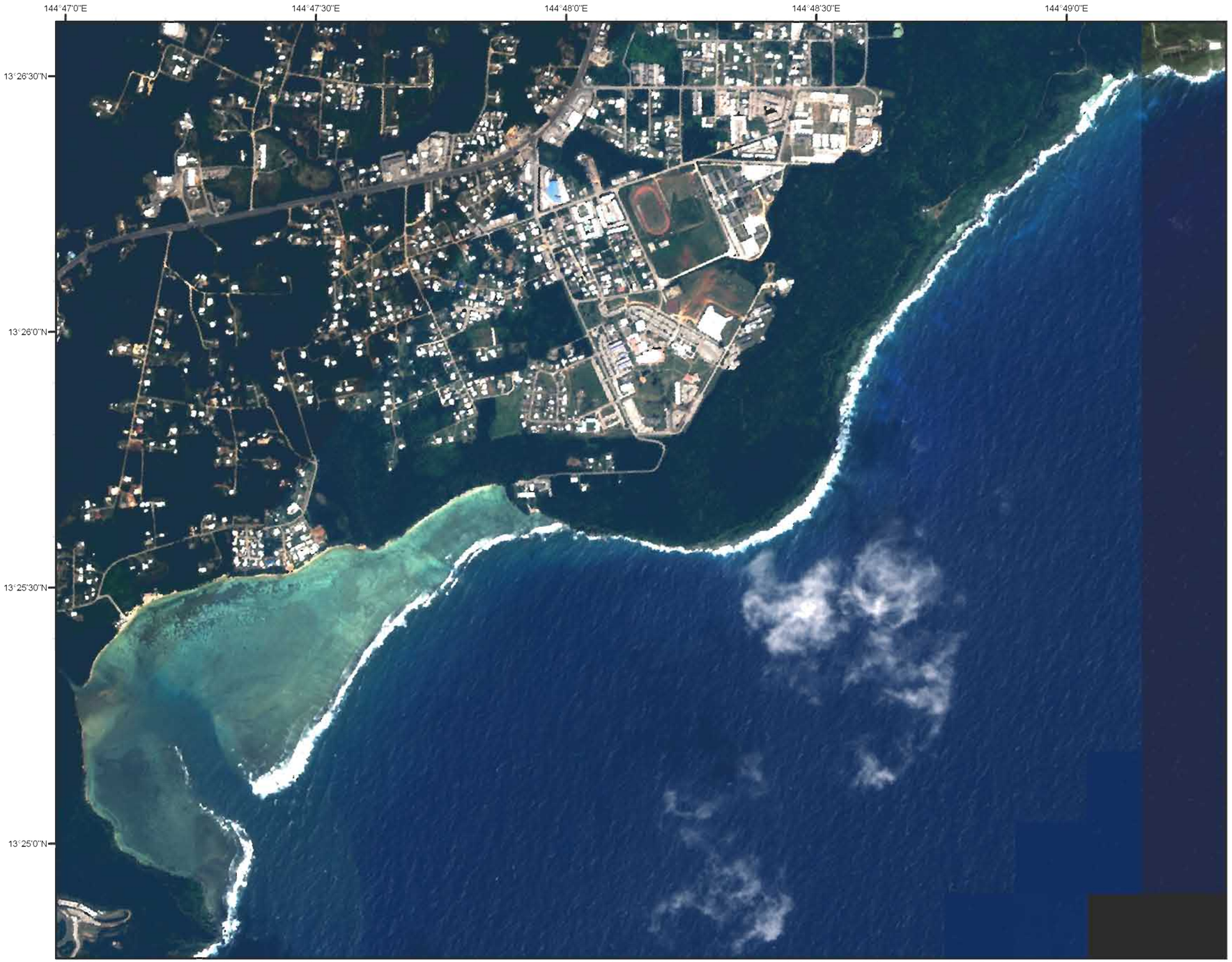
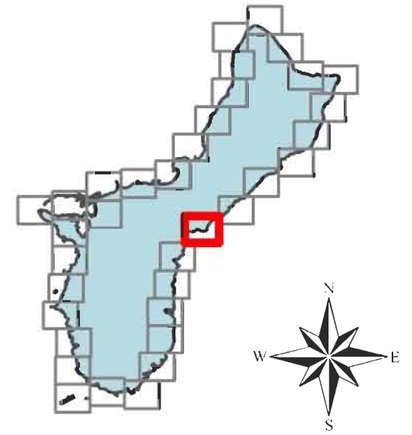
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 15





Pago Bay at low tide viewed from the south. Photo by Dave Burdick

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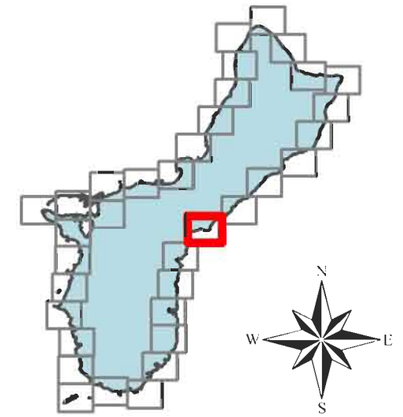

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Legend

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- Aggregate Reef. Coralline Algae 50%-<90%
- Aggregate Reef. Macroalgae 10%-<50%
- Aggregate Reef. Macroalgae 90%-100%
- Aggregate Reef. Turf 50%-<90%
- Pavement. Coral 10%-<50%
- Pavement. Macroalgae 10%-<50%
- Pavement. Macroalgae 50%-<90%
- Pavement. Turf 50%-<90%
- Rock/Boulder. Macroalgae 10%-<50%
- Rock/Boulder. Macroalgae 50%-<90%
- Rock/Boulder. Turf 50%-<90%
- Rubble. Macroalgae 10%-<50%
- Sand. Seagrass 90%-100%
- Sand. Uncolonized 90%-100%
- Spur and Groove. Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

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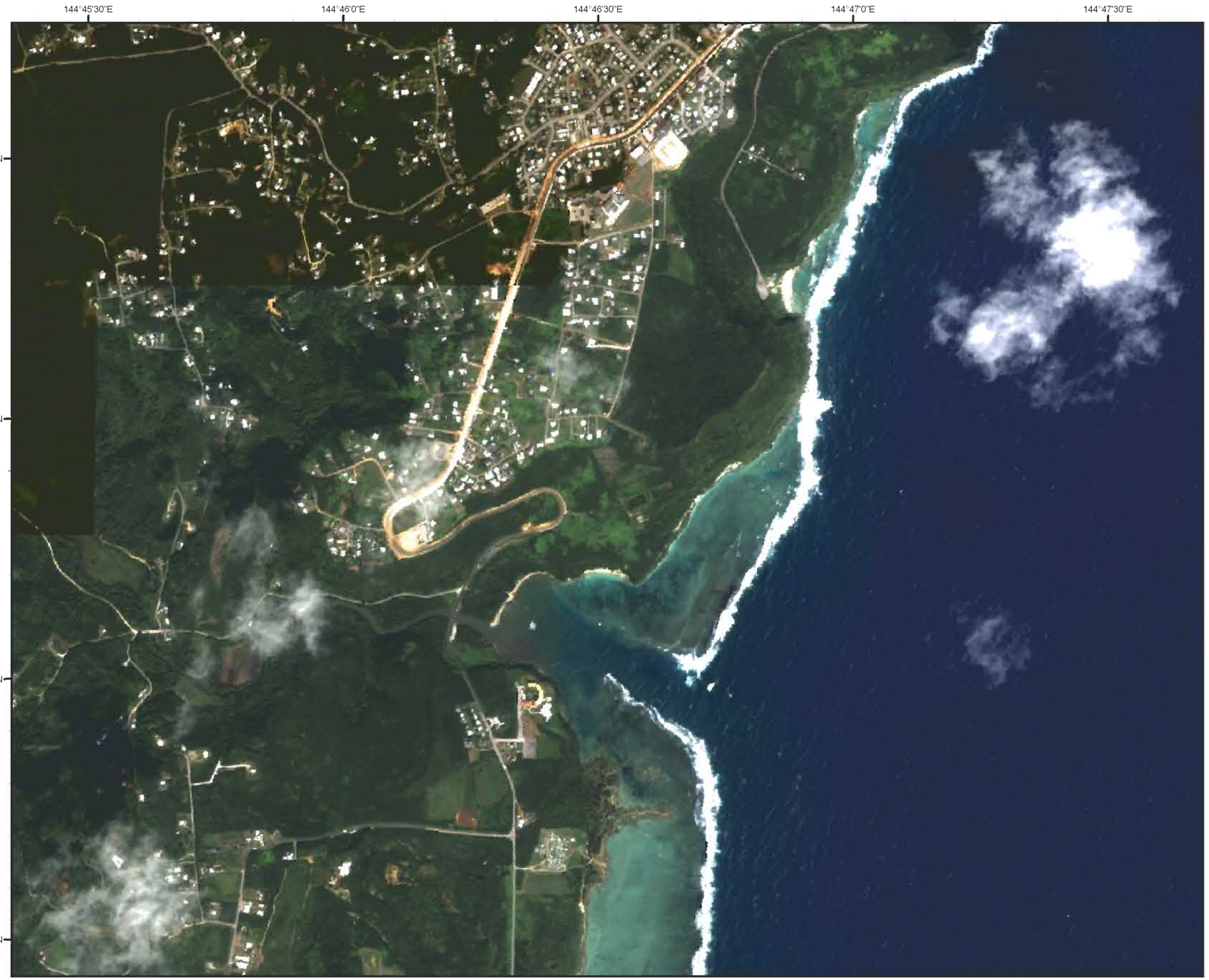
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 16



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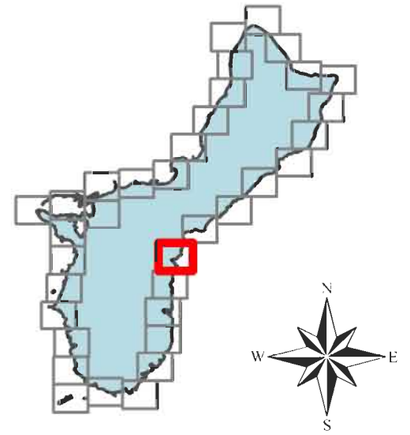

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Spur and groove coral community near Taga'chan Point. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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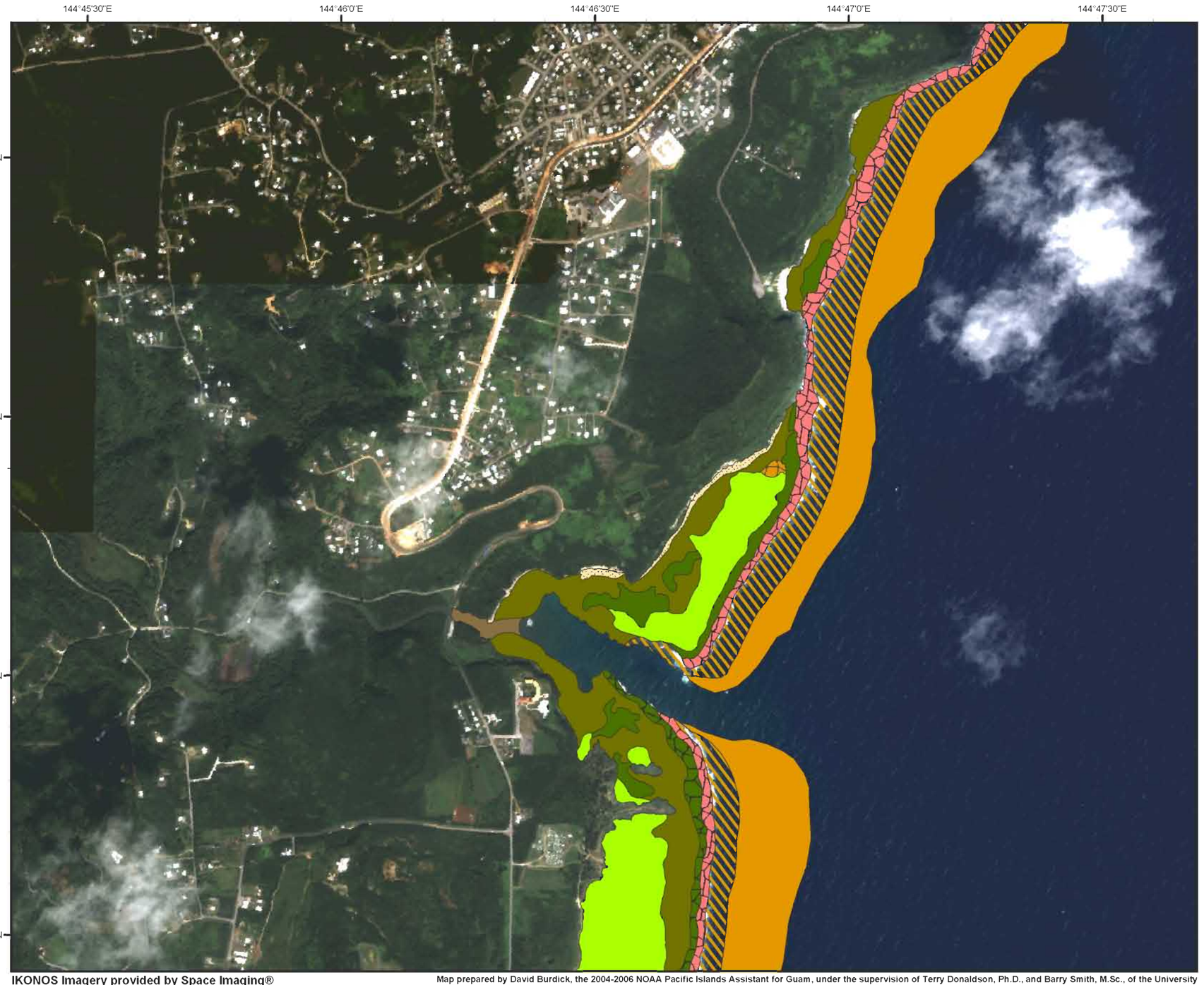

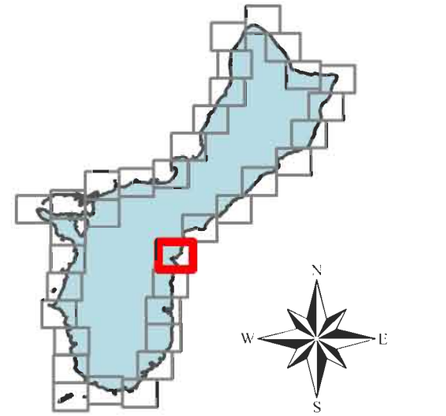

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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

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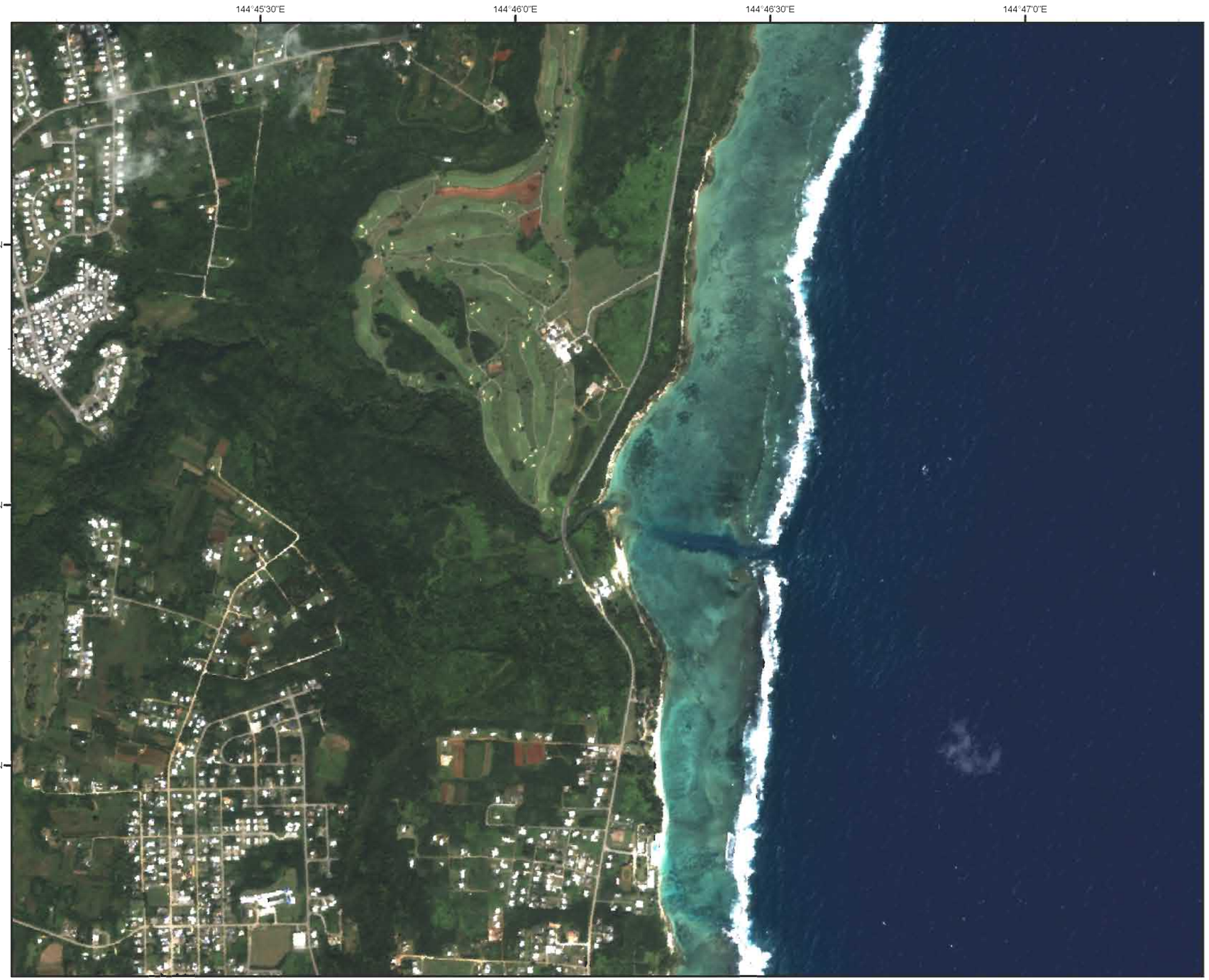

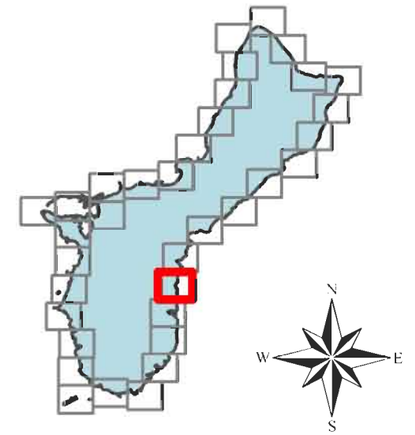

Fore reef community near Togcha Bay. Photo by Dave Burdick.

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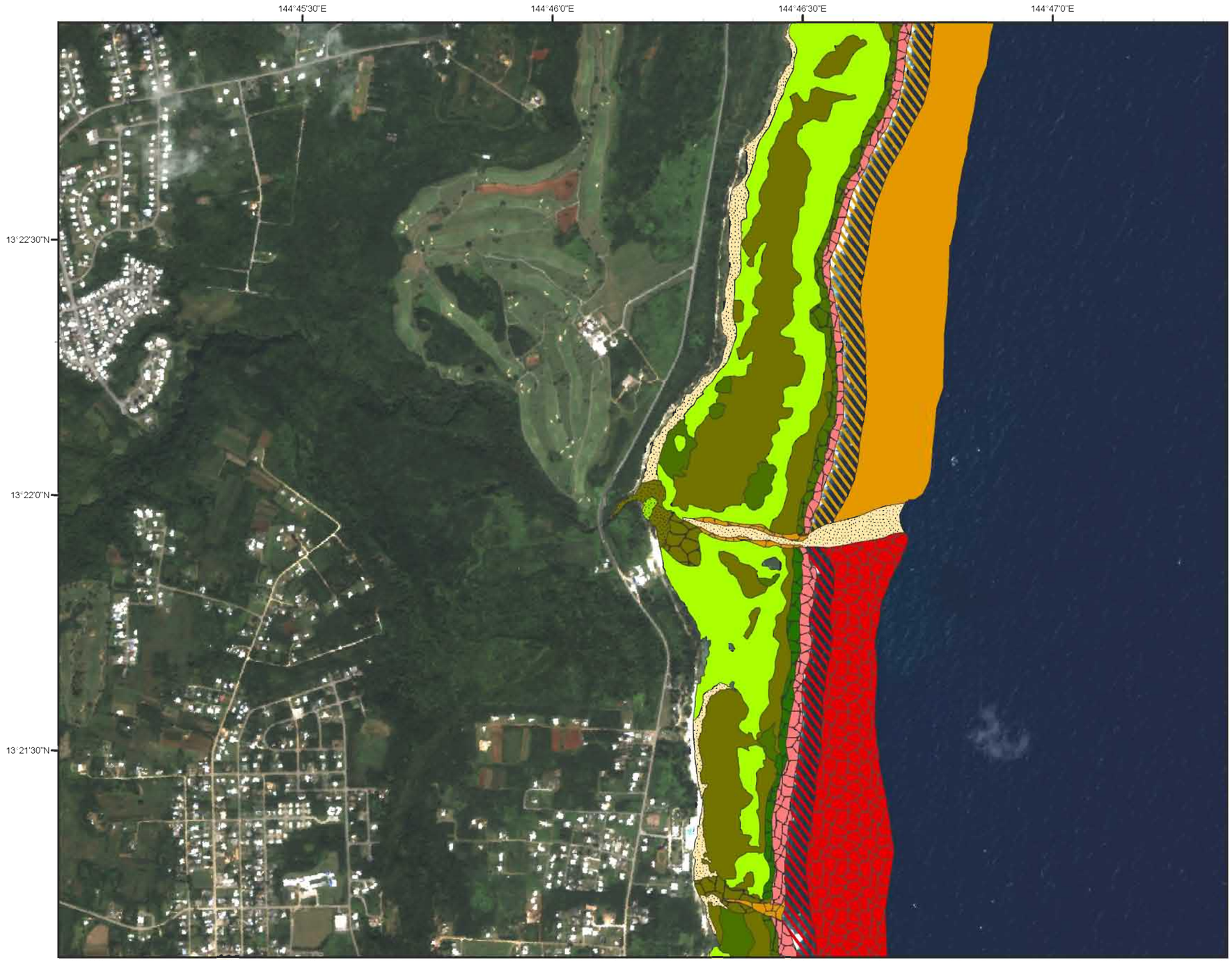

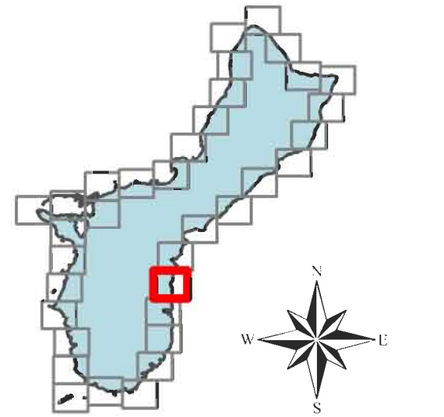

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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
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- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 10%-<50%
- Rubble, Turf 90%-100%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%
- Spur and Groove, Coral 50%-<90%

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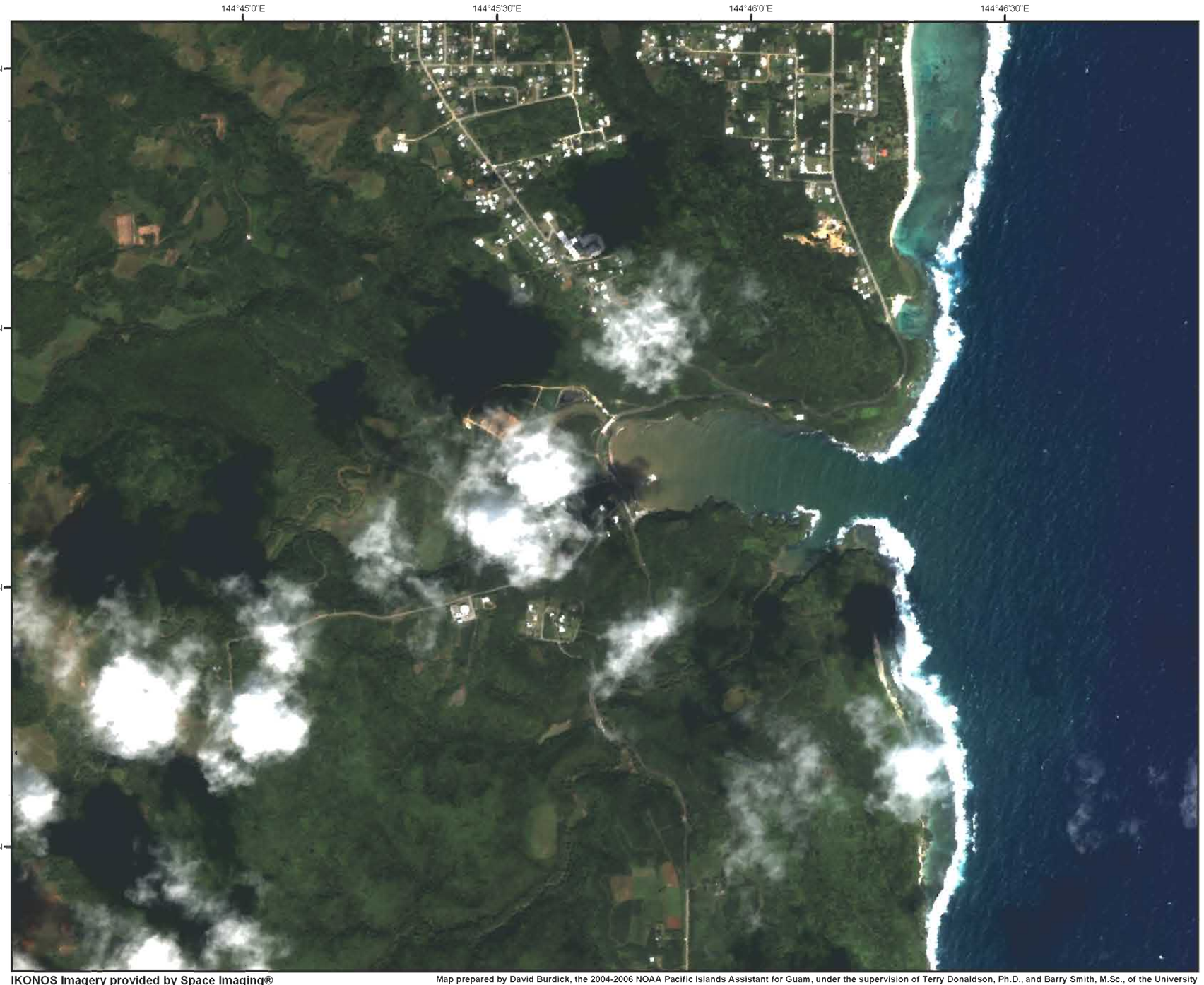
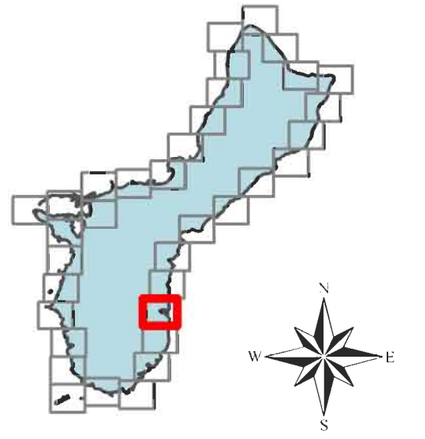
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 18



IKONOS Imagery provided by Space Imaging®



Exposed reef crest north of Talofofo Bay dominated by crustose coralline algae and turf algae. Photo by Dave Burdick.

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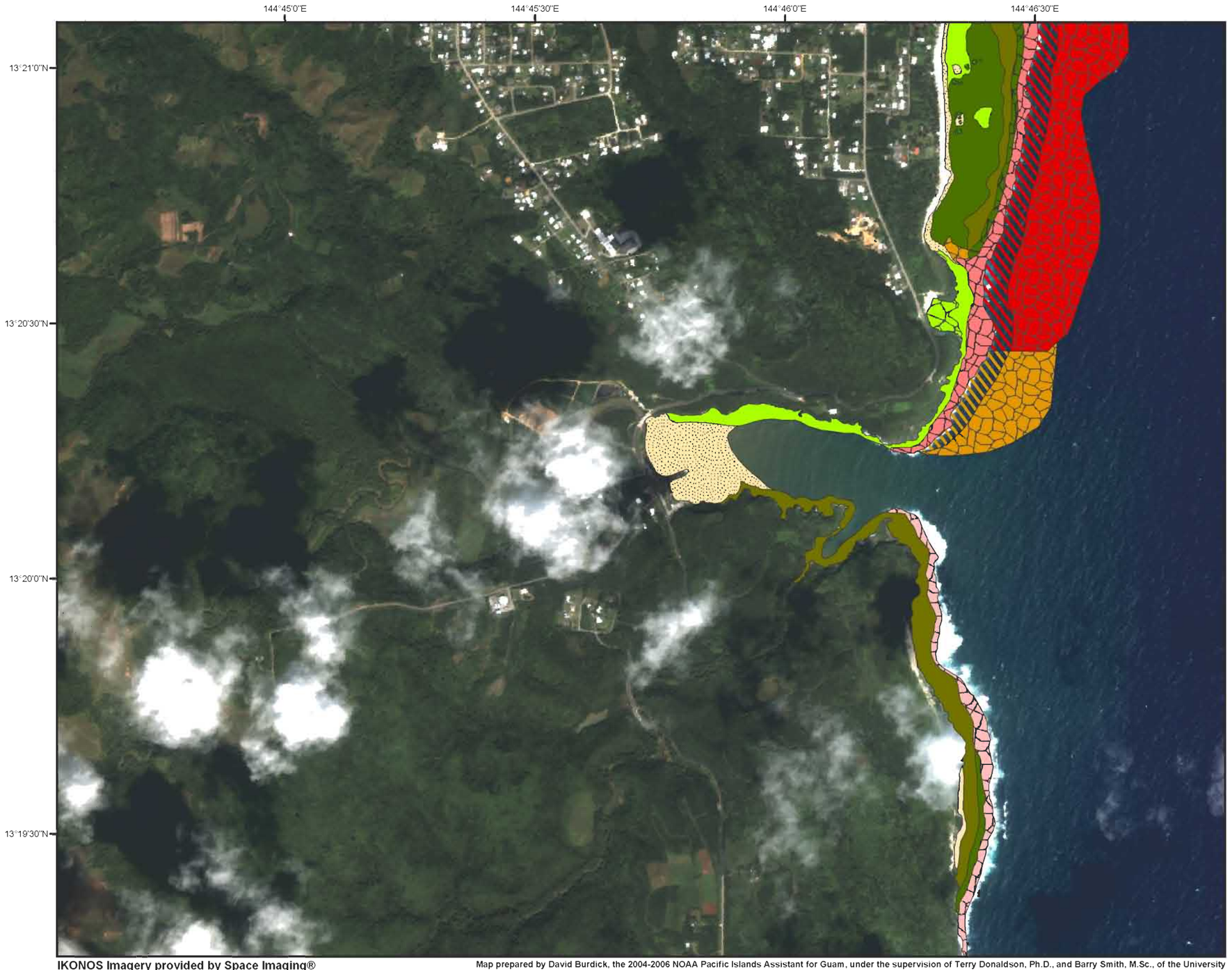

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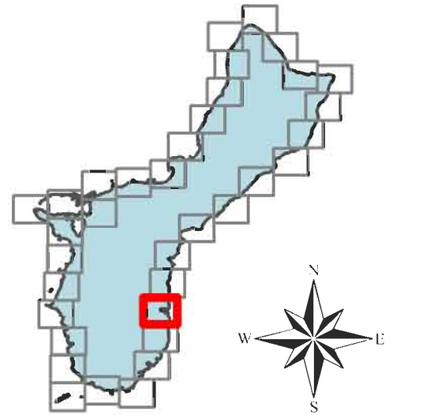

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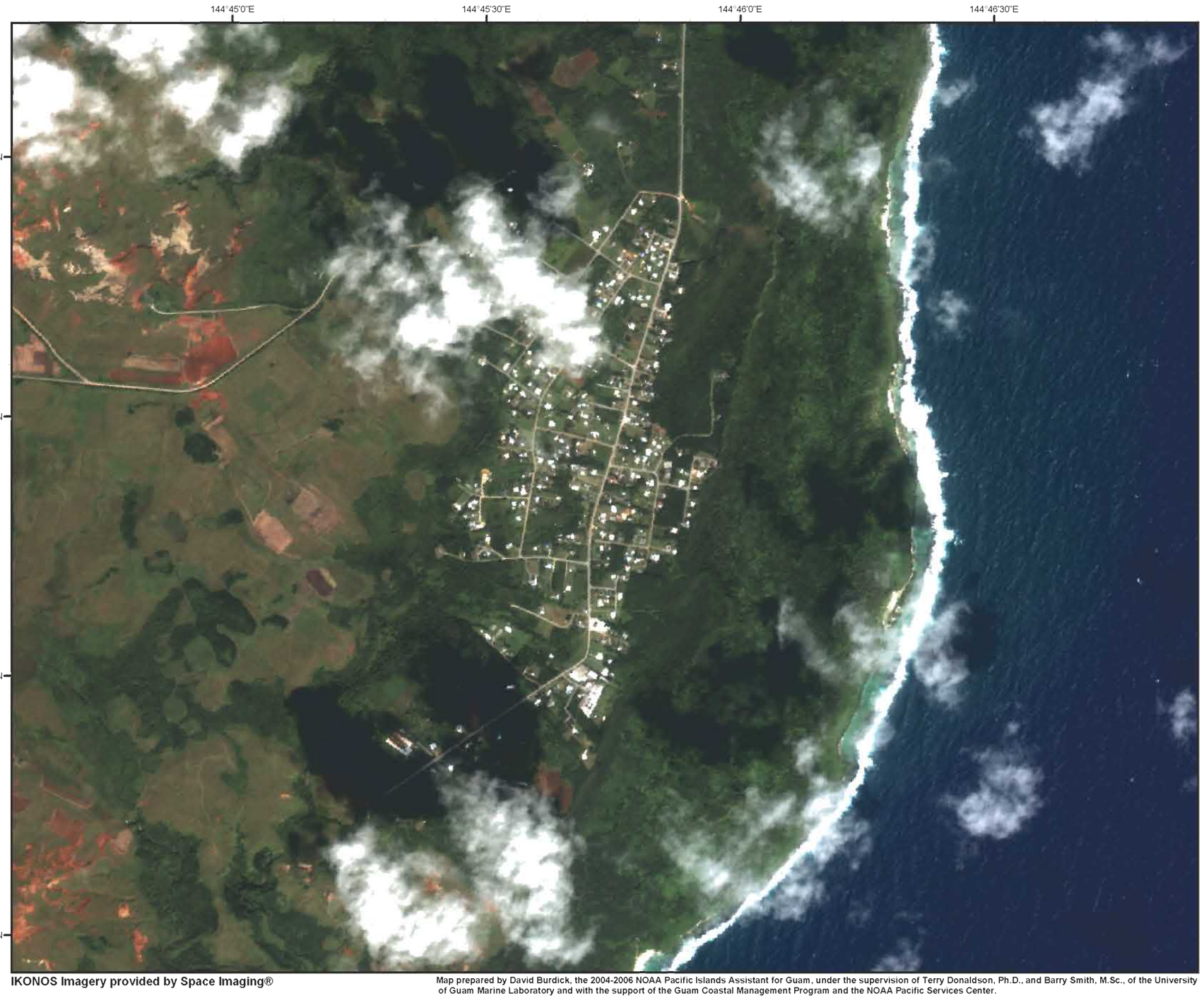

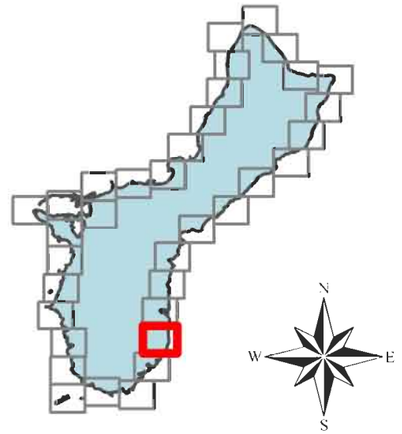

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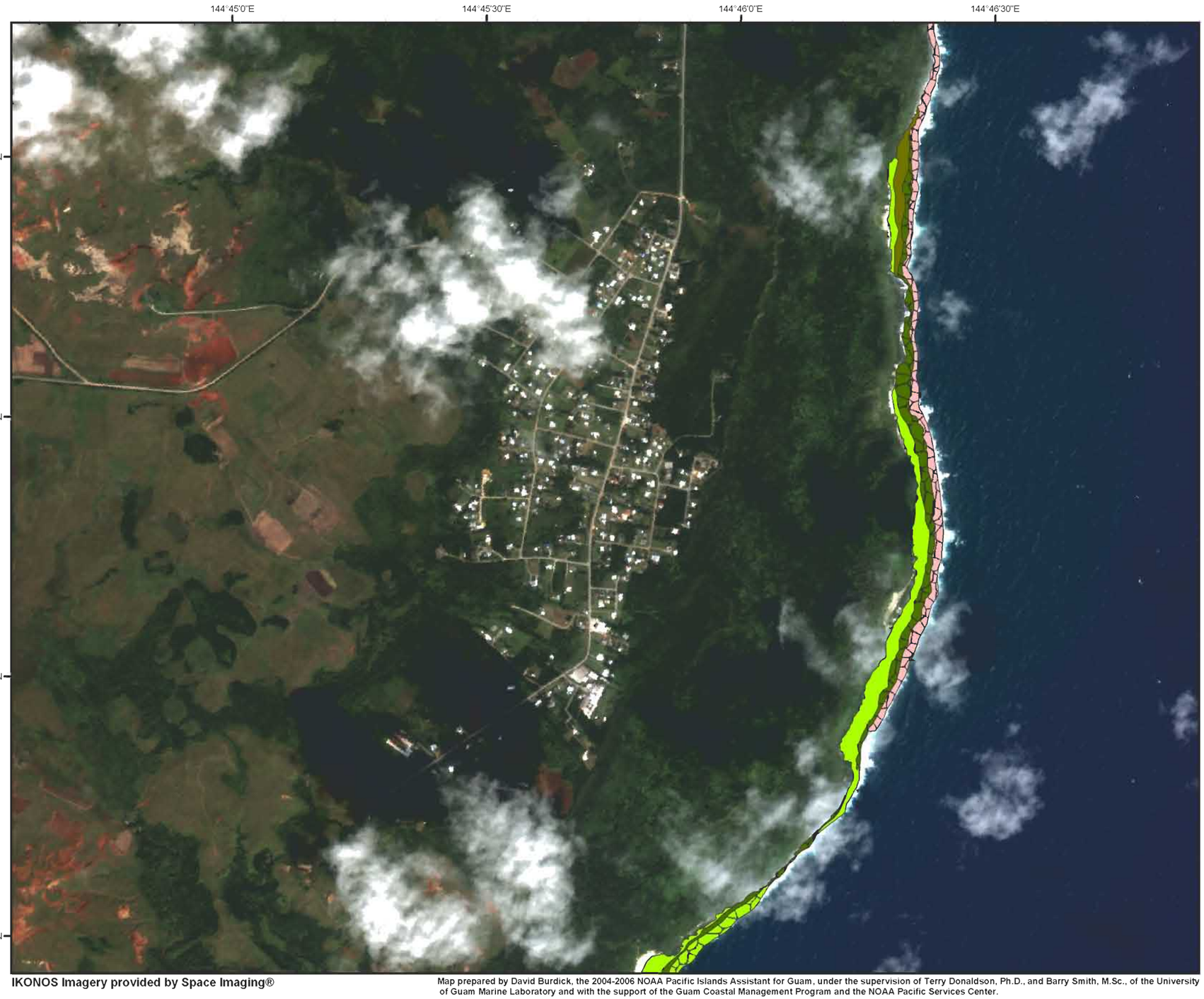
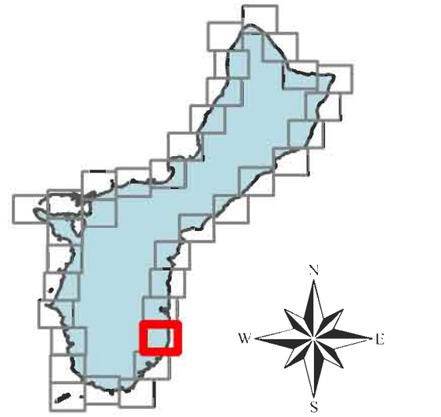
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 19





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1:15,000

Legend

- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%

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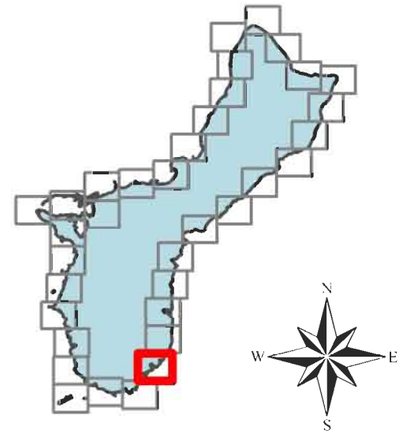
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 20



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Diverse coral community on fore-reef slope off of Agfayan Point. Photo by Dave Burdick.

IKONOS Imagery provided by Space Imaging®

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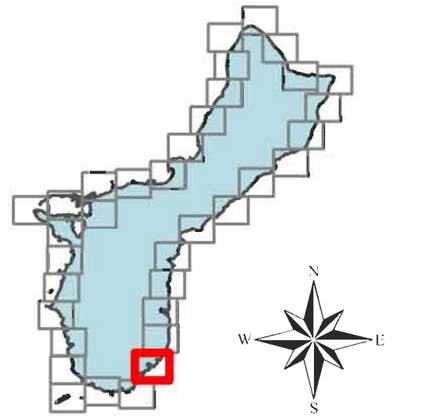
IKONOS Imagery provided by Space Imaging®



500 250 0 500 Meters

1:15,000

Legend

- Aggregate Reef, Coralline Algae 50%-<90%
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- Aggregate Reef, Turf 50%-<90%
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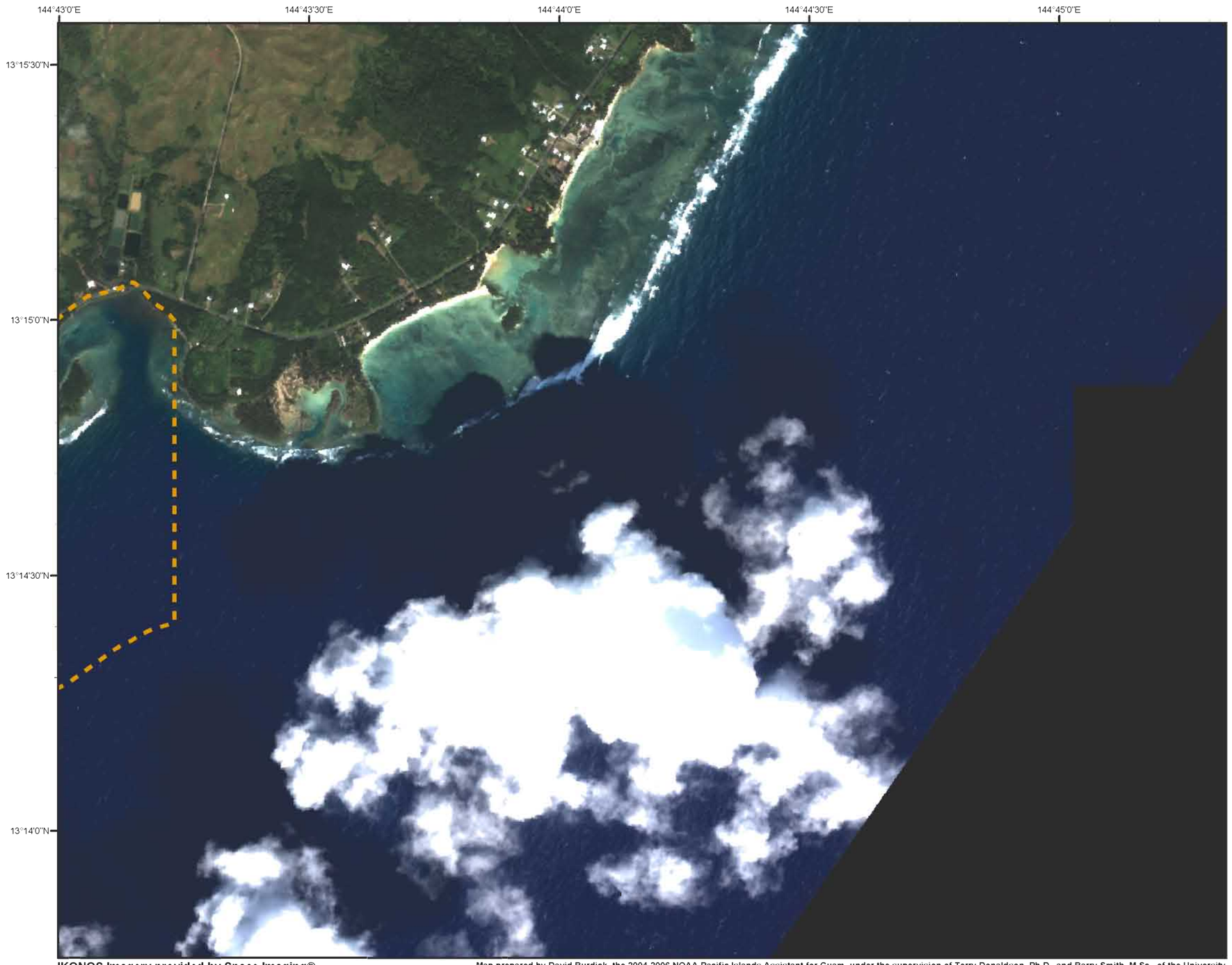

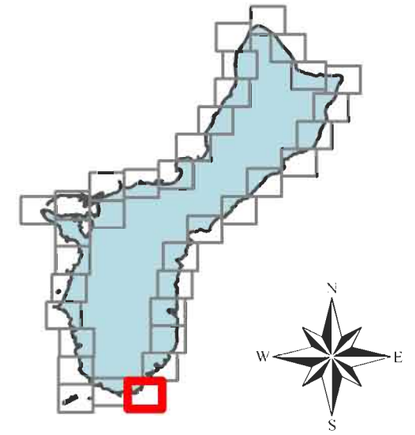

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Legend

Marine Preserve Boundaries

IKONOS Imagery provided by Space Imaging®

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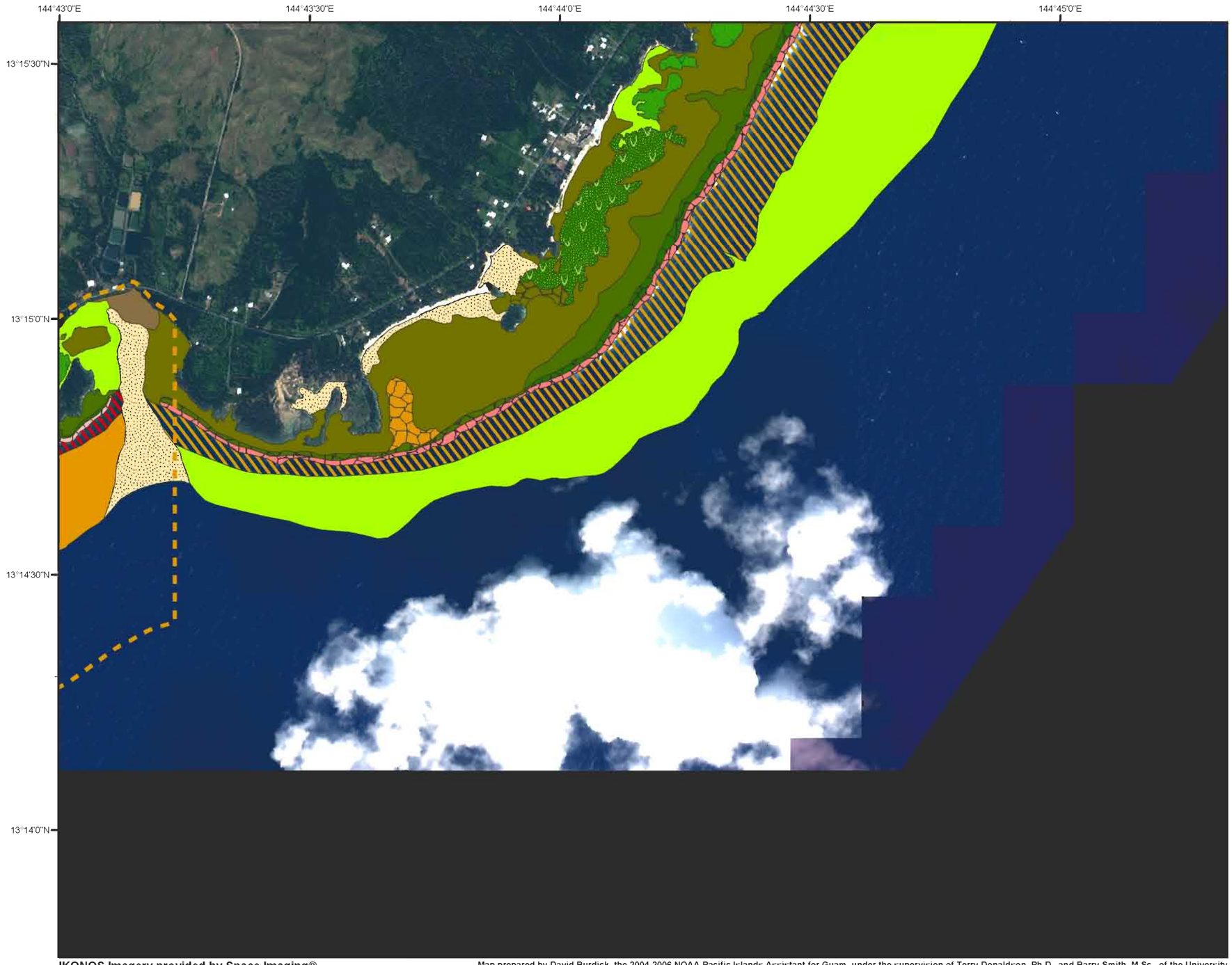

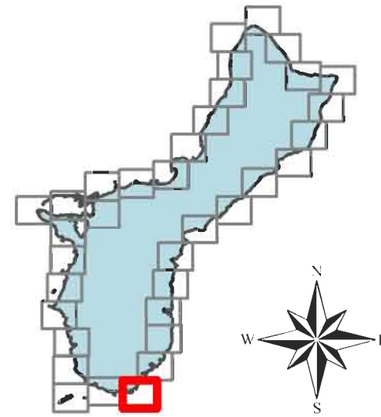

500 250 0 500 Meters

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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Macroalgae 90%-100%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%
- Spur and Groove, Coral 50%-<90%

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Guam Coastal Management Program

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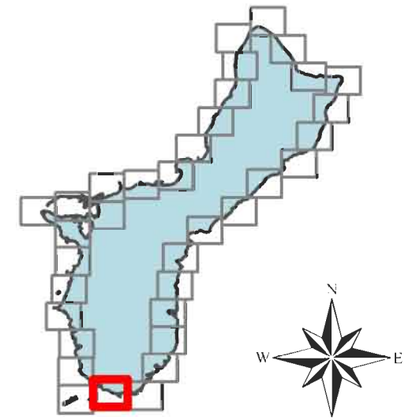
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 22

IKONOS Imagery provided by Space Imaging®



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Legend

Marine Preserve Boundaries

Large Porites colony on bank of channel in Achang Marine Preserve. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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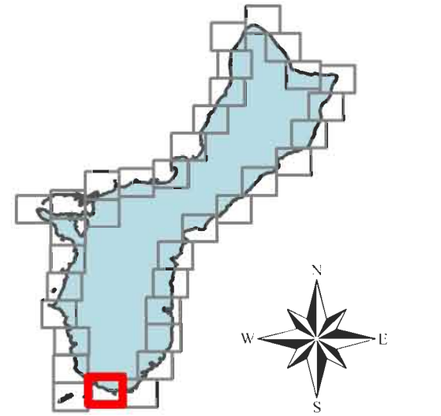
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 22



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Legend

- Marine Preserve Boundaries
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- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Macroalgae 90%-100%
- Aggregated Patch Reef, Coral 50%-<90%
- Aggregated Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Coral 50%-<90%
- Individual Patch Reef, Turf 50%-<90%
- Mud, Emergent Vegetation 90%-100%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Turf 50%-<90%
- Rubble, Macroalgae 10%-<50%
- Rubble, Turf 50%-<90%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 50%-<90%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Macroalgae 10%-<50%
- Spur and Groove, Coral 10%-<50%
- Spur and Groove, Coral 50%-<90%

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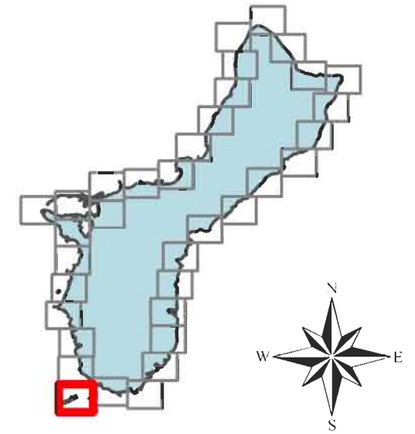
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 23

IKONOS Imagery provided by Space Imaging®



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A shallow fore-reef community on the Northwest side of Cocos Lagoon. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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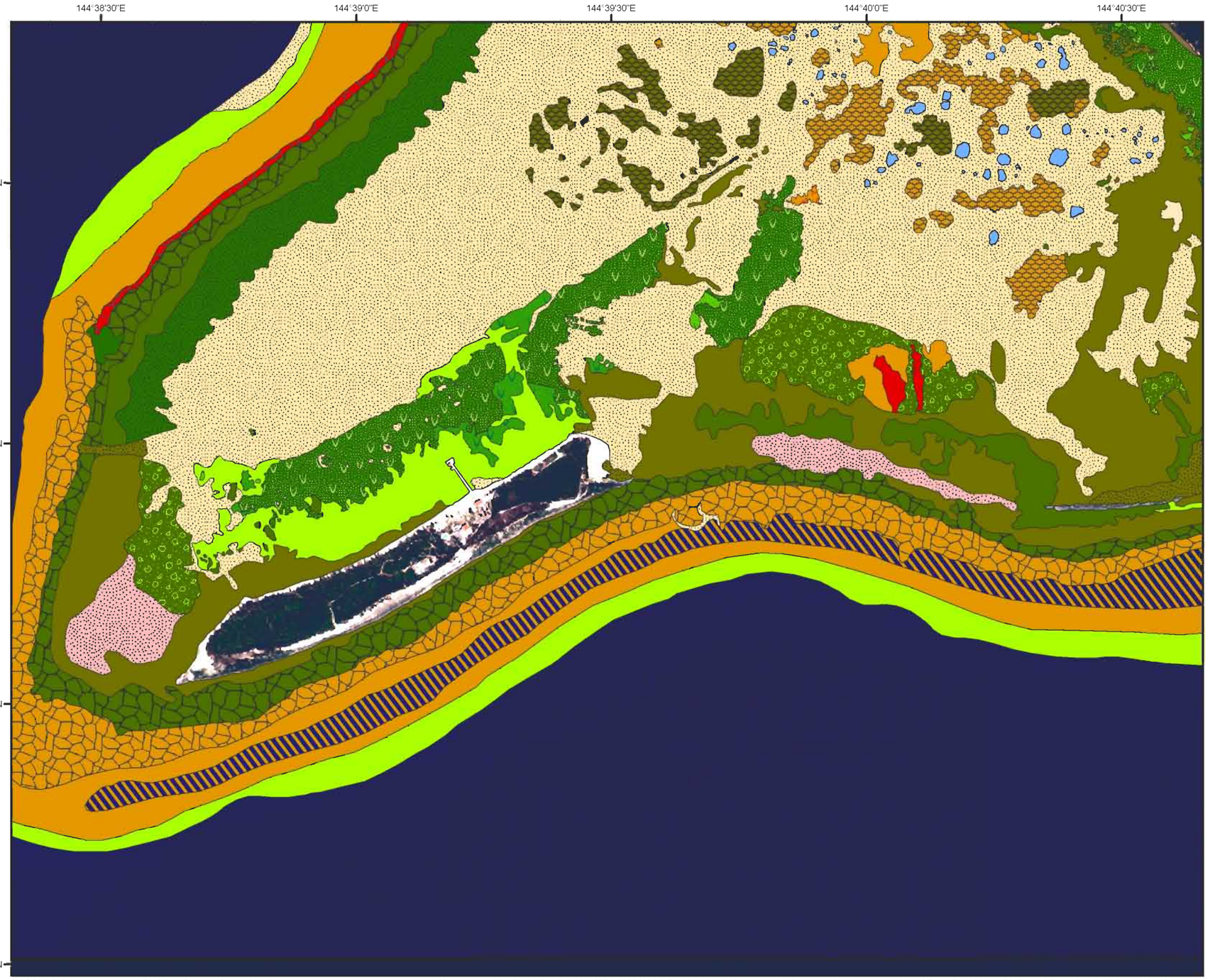
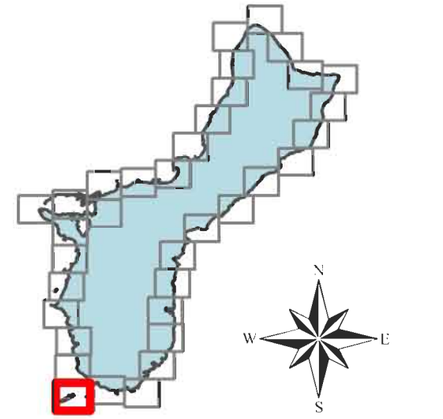
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 23





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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregated Patch Reef, Coral 10%-<50%
- Aggregated Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Coral 10%-<50%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Pavement, Uncolonized 50%-<90%
- Rubble, Coralline Algae 10%-<50%
- Rubble, Macroalgae 10%-<50%
- Rubble, Macroalgae 50%-<90%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Coral 10%-<50%
- Scattered Coral/Rock, Macroalgae 10%-<50%
- Spur and Groove, Coral 10%-<50%

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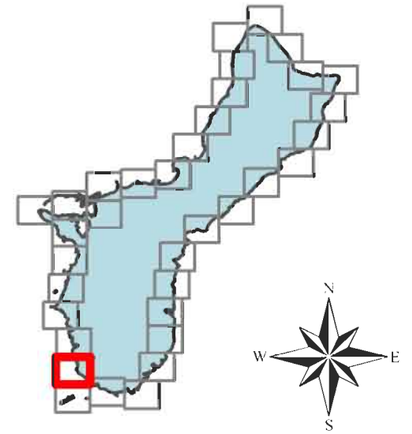

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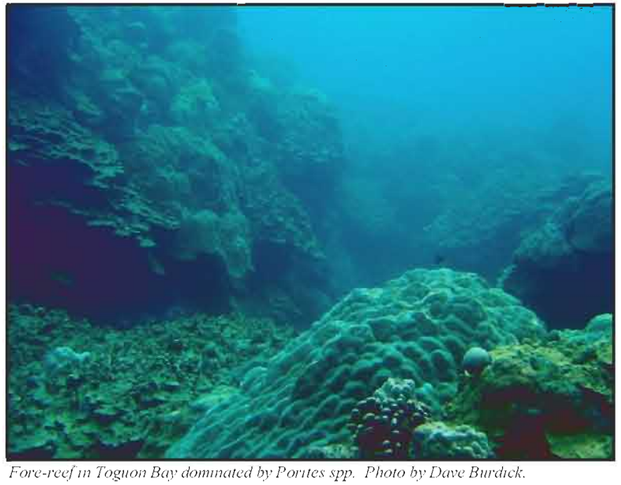

Fore-reef in Toguon Bay dominated by Porites spp. Photo by Dave Burdick.

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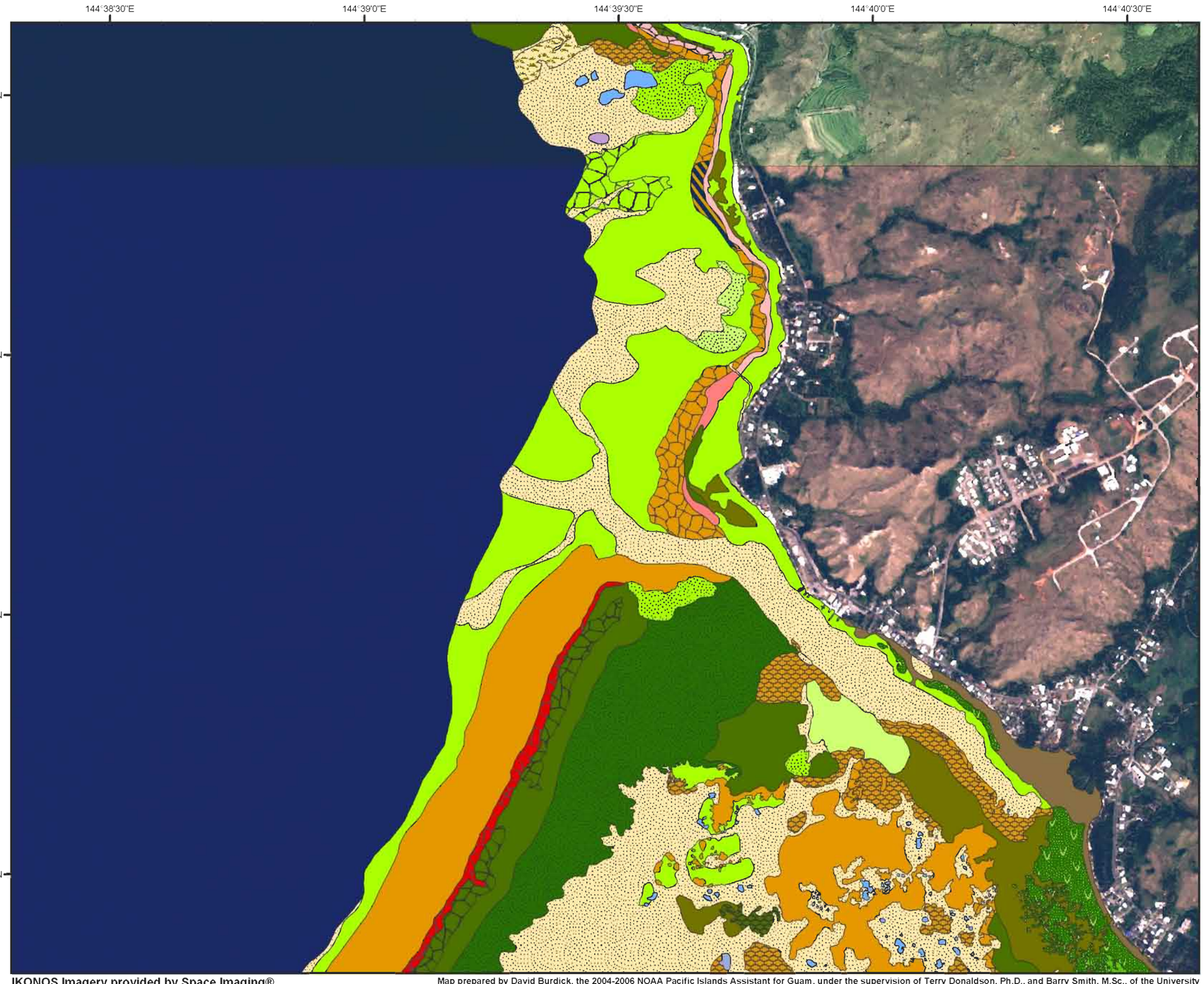
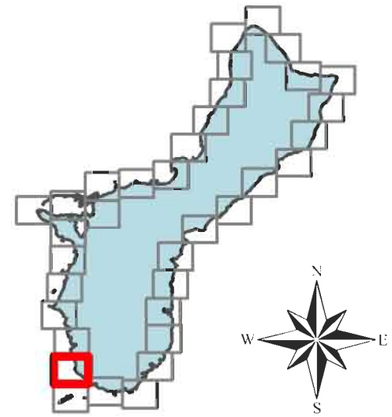
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 24





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Legend

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- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Coral 10%-<50%
- Aggregated Patch Reef, Macroalgae 50%-<90%
- Individual Patch Reef, Coral 10%-<50%
- Individual Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Turf 50%-<90%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coralline Algae 10%-<50%
- Pavement, Coralline Algae 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 10%-<50%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 50%-<90%
- Rubble, Turf 10%-<50%
- Rubble, Turf 50%-<90%
- Sand, Macroalgae 10%-<50%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

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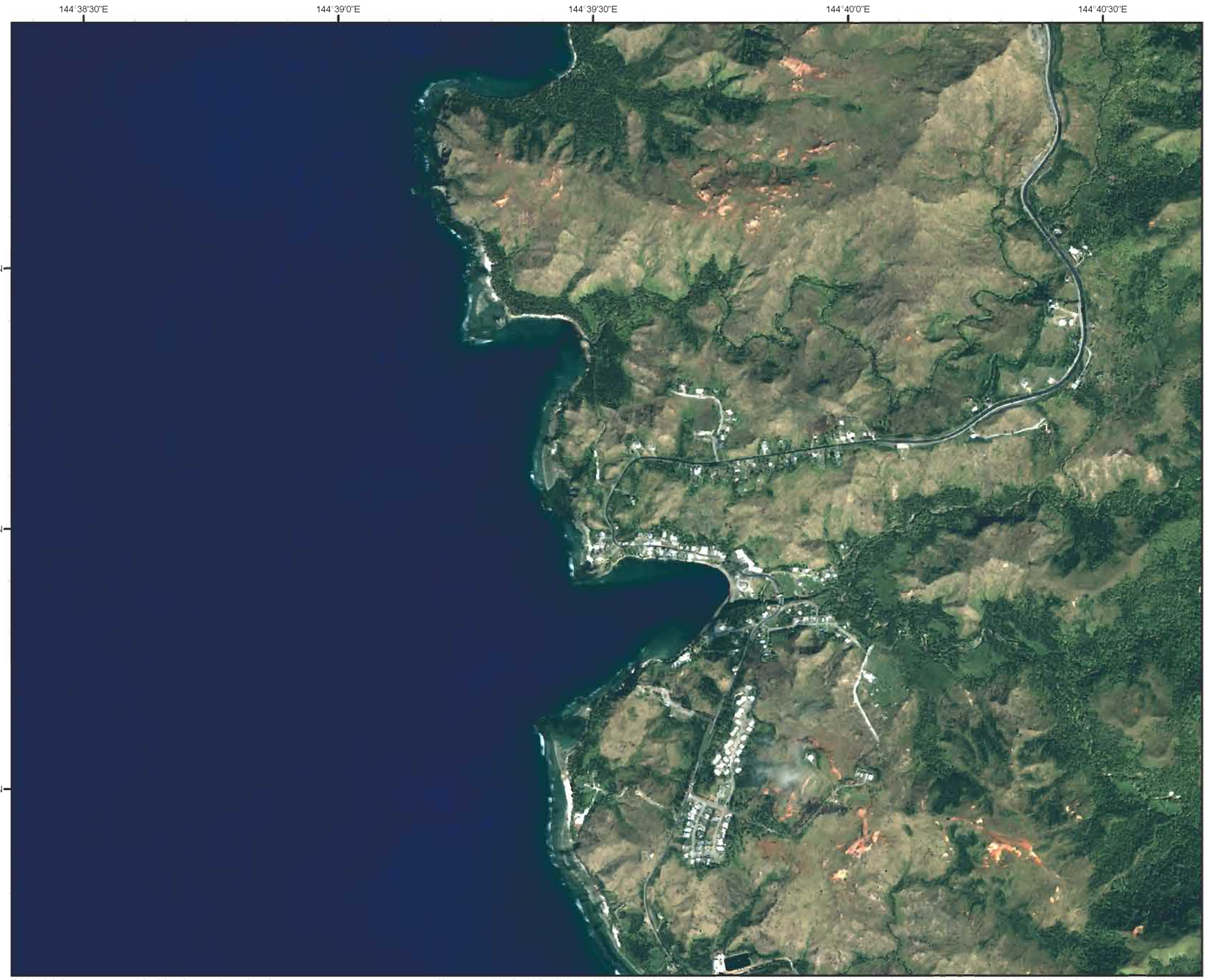

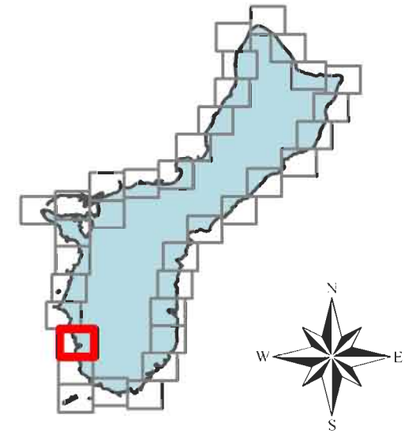

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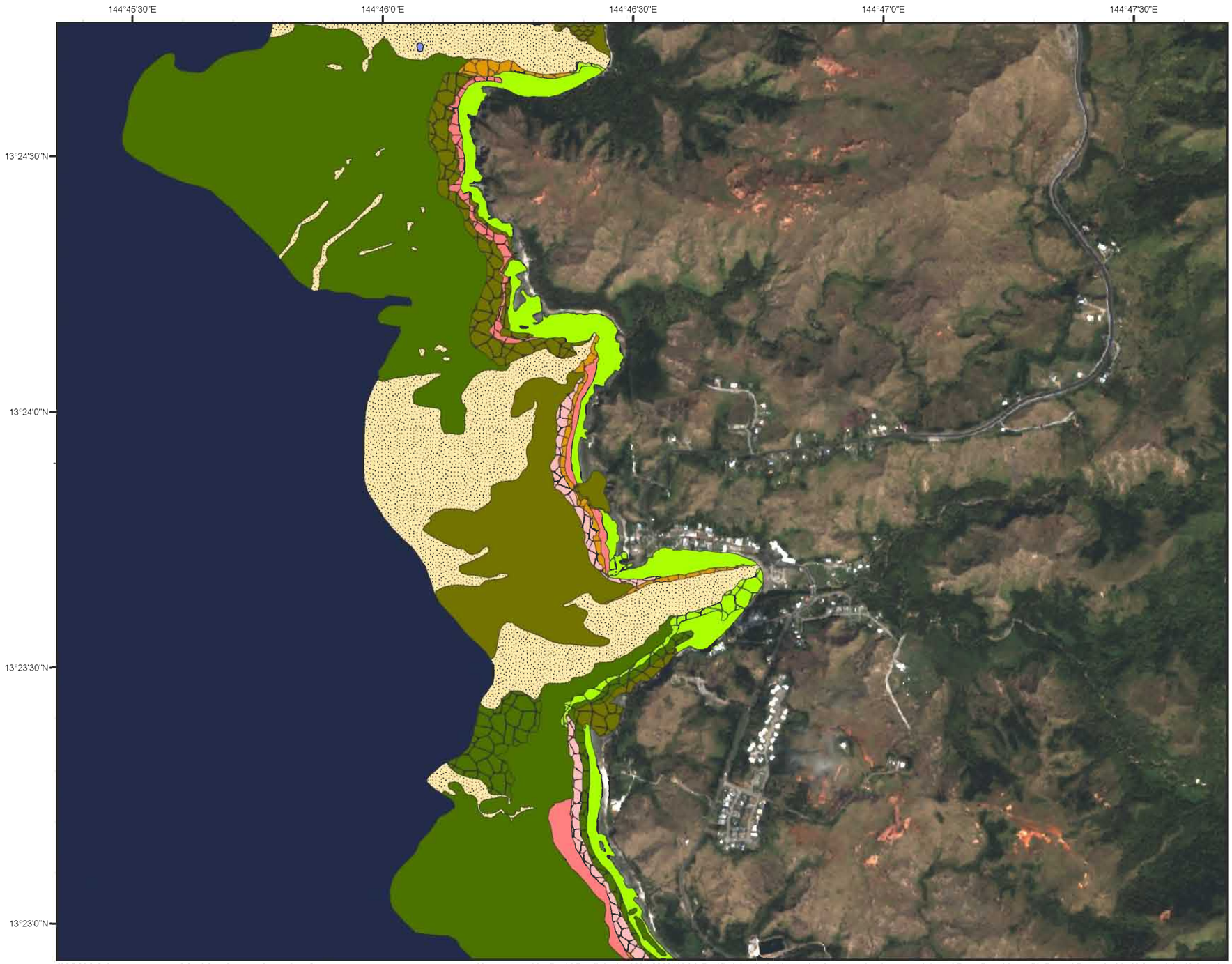
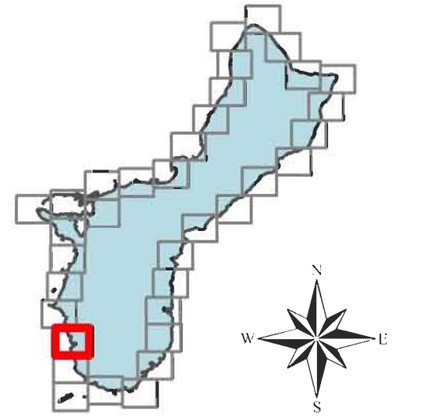
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 25



IKONOS Imagery provided by Space Imaging®



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Legend

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- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Macroalgae 50%-<90%
- Pavement, Coralline Algae 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Turf 50%-<90%
- Sand, Macroalgae 10%-<50%
- Sand, Uncolonized 90%-100%

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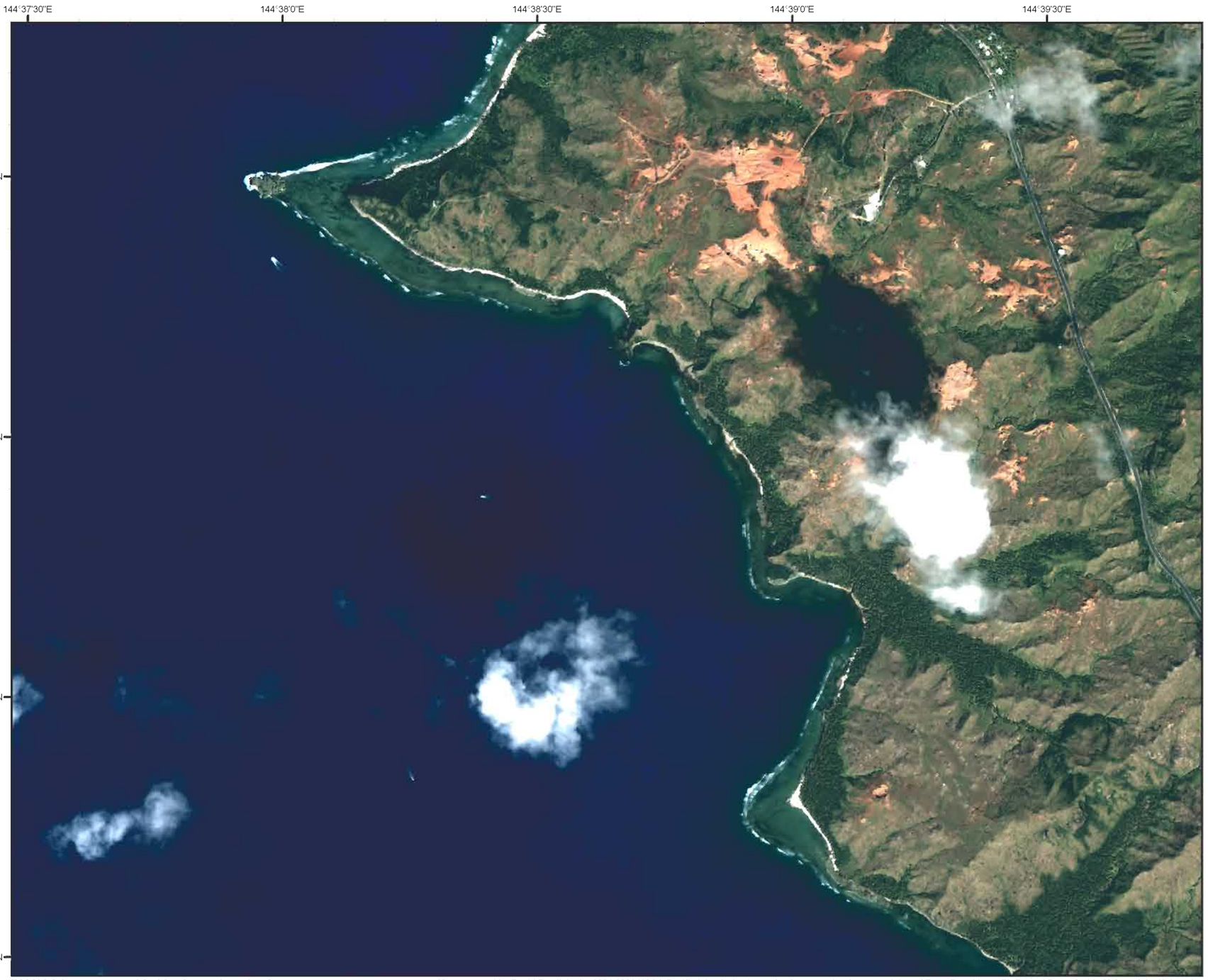
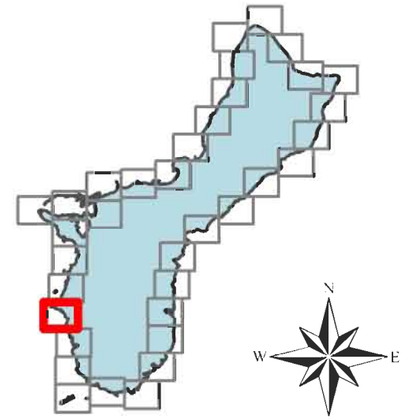
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 26





510 255 0 510 Meters

1:15,000

Pavement dominated by macroalgae and turf algae on shelf immediately south of Facpi Island. Photo by Dave Burdick.

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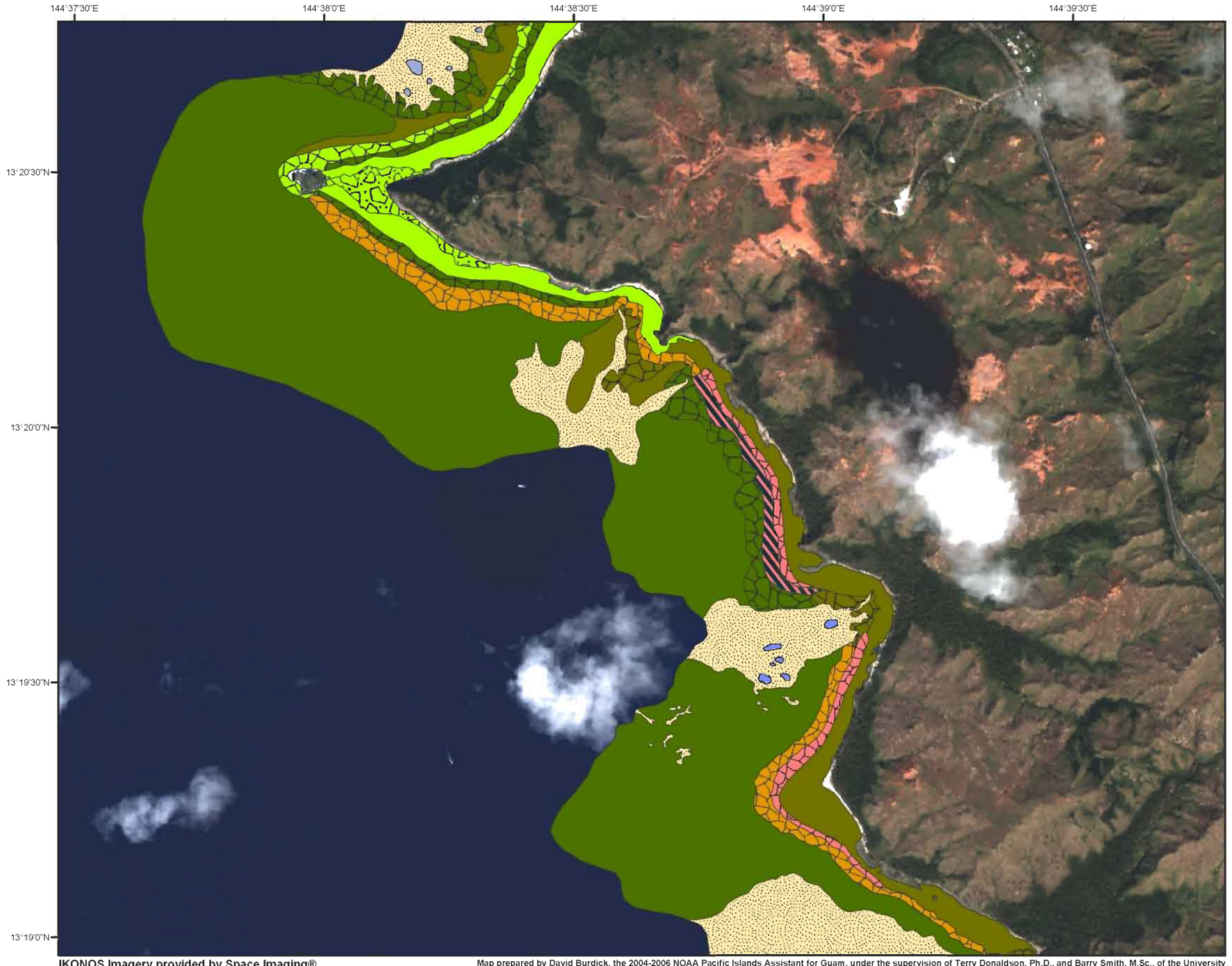

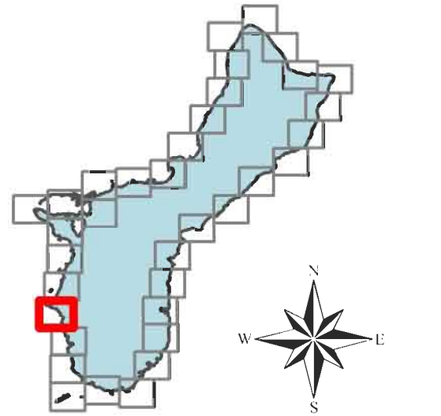

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Legend

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- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Macroalgae 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coralline Algae 50%-<90%

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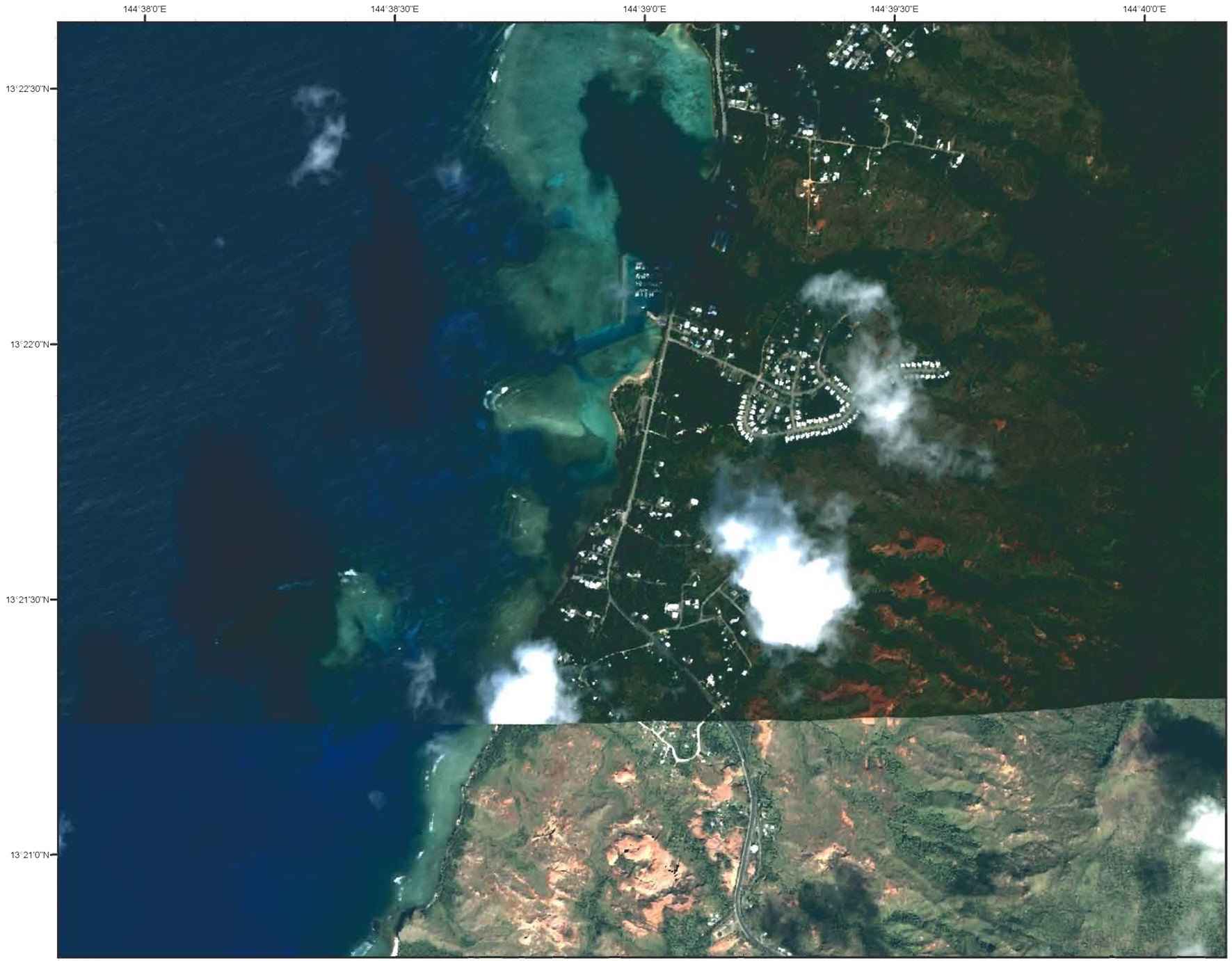
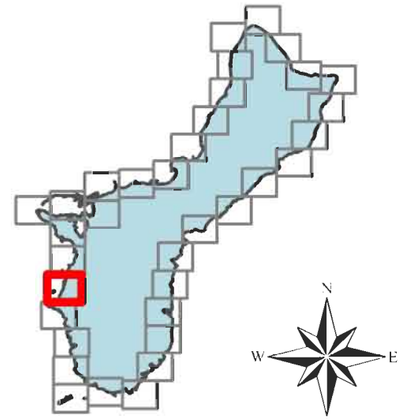
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 27



IKONOS Imagery provided by Space Imaging®



Partial mortality of Porites (Synaraea) rus colony near Nimitz Beach. Excess sedimentation is likely a major source of stress to the reef in this area. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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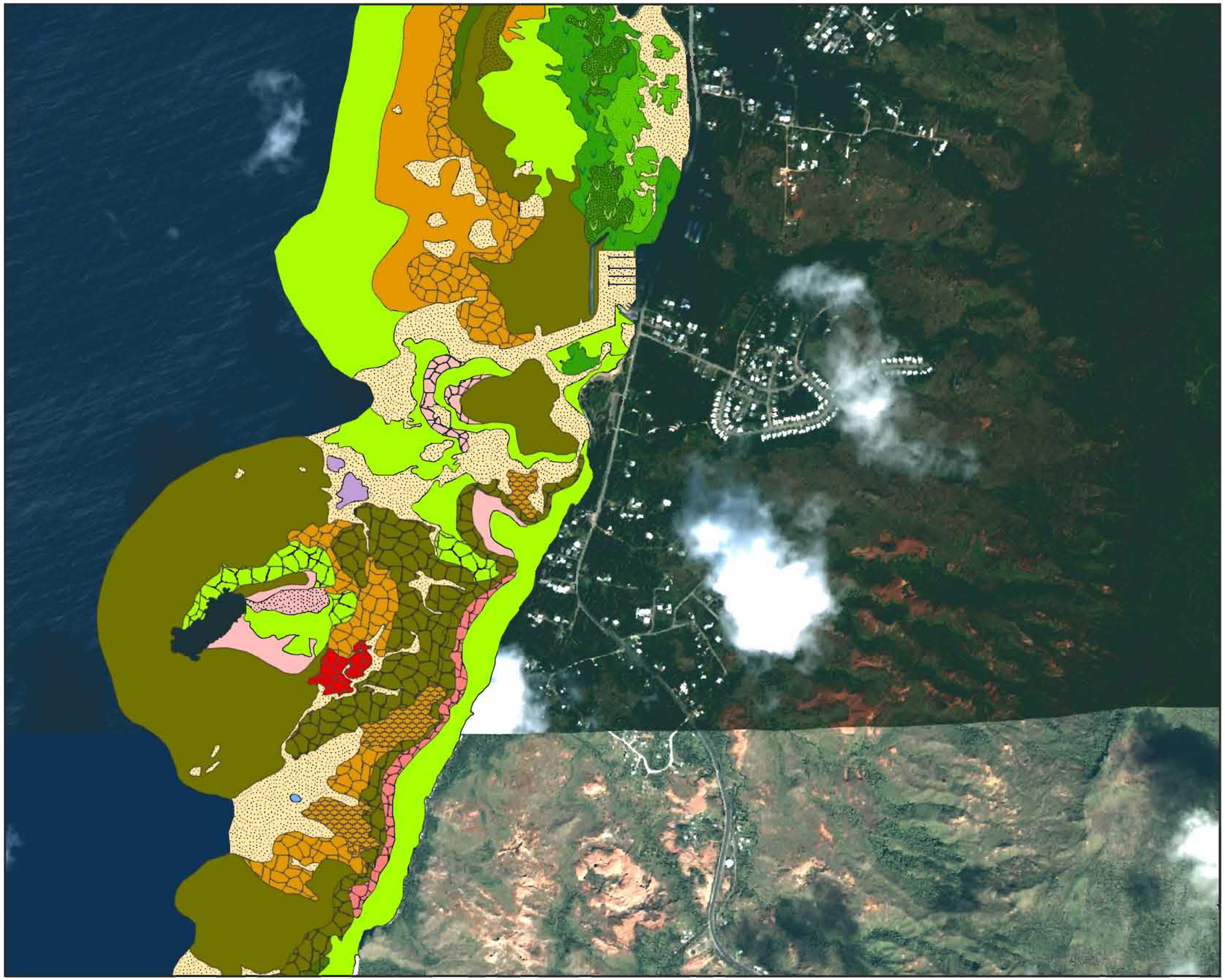

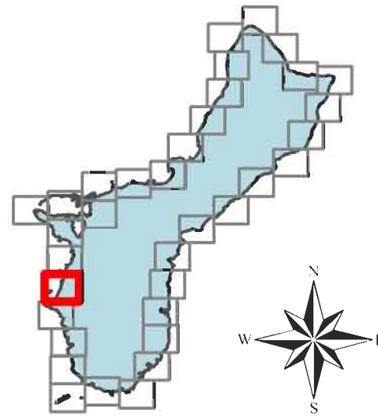

500 250 0 500 Meters

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Legend

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- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Coral 10%-<50%
- Individual Patch Reef, Coral 10%-<50%
- Individual Patch Reef, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Coralline Algae 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Coralline Algae 10%-<50%
- Rubble, Macroalgae 10%-<50%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%

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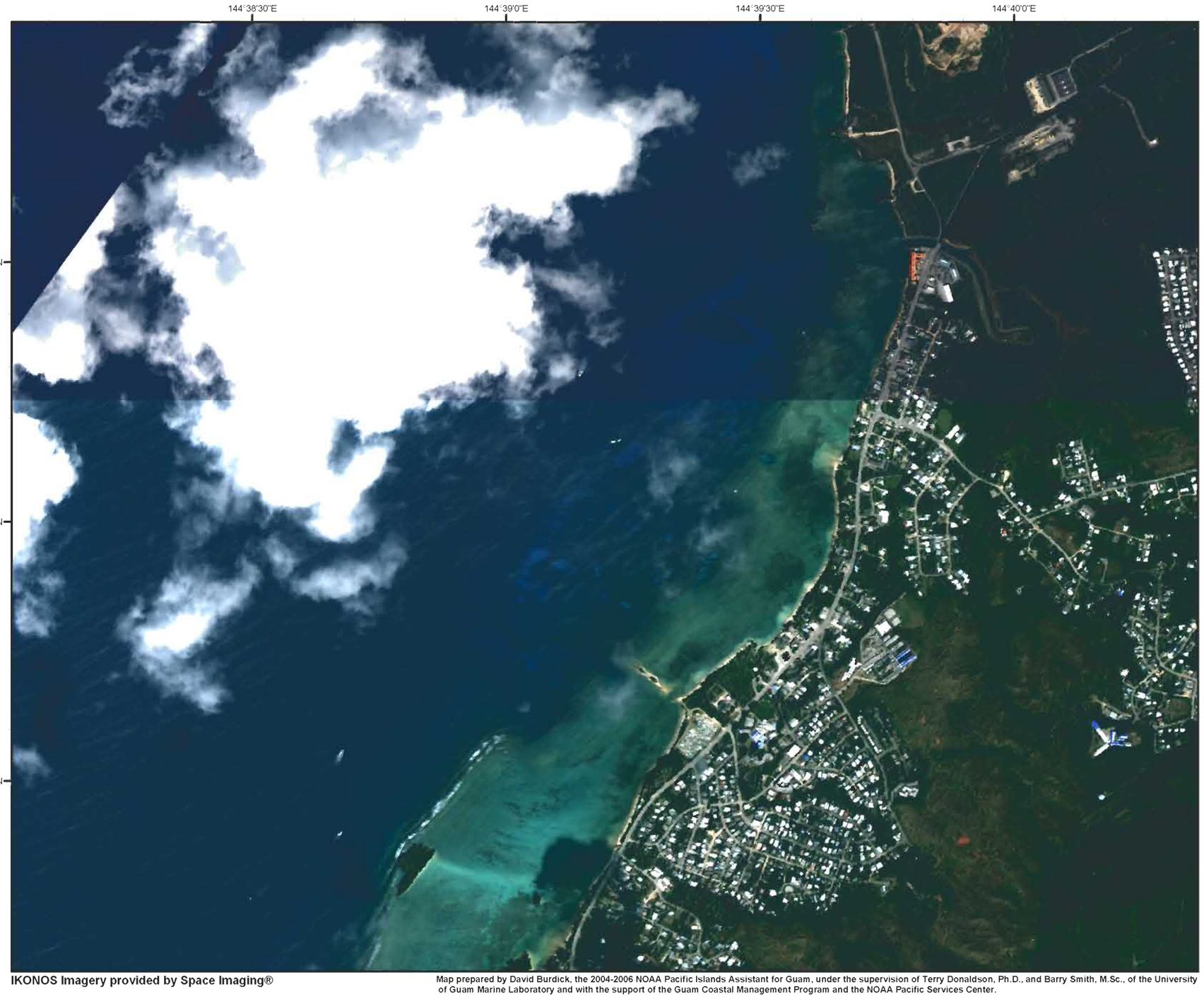

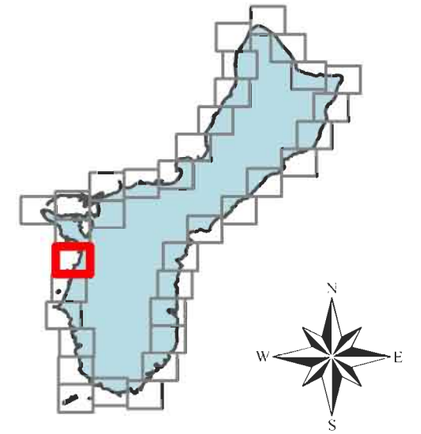

Extensive macroalgal growth, primarily Padina sp., on the fore-reef slope off of Apaca Point. Photo by Dave Burdick.

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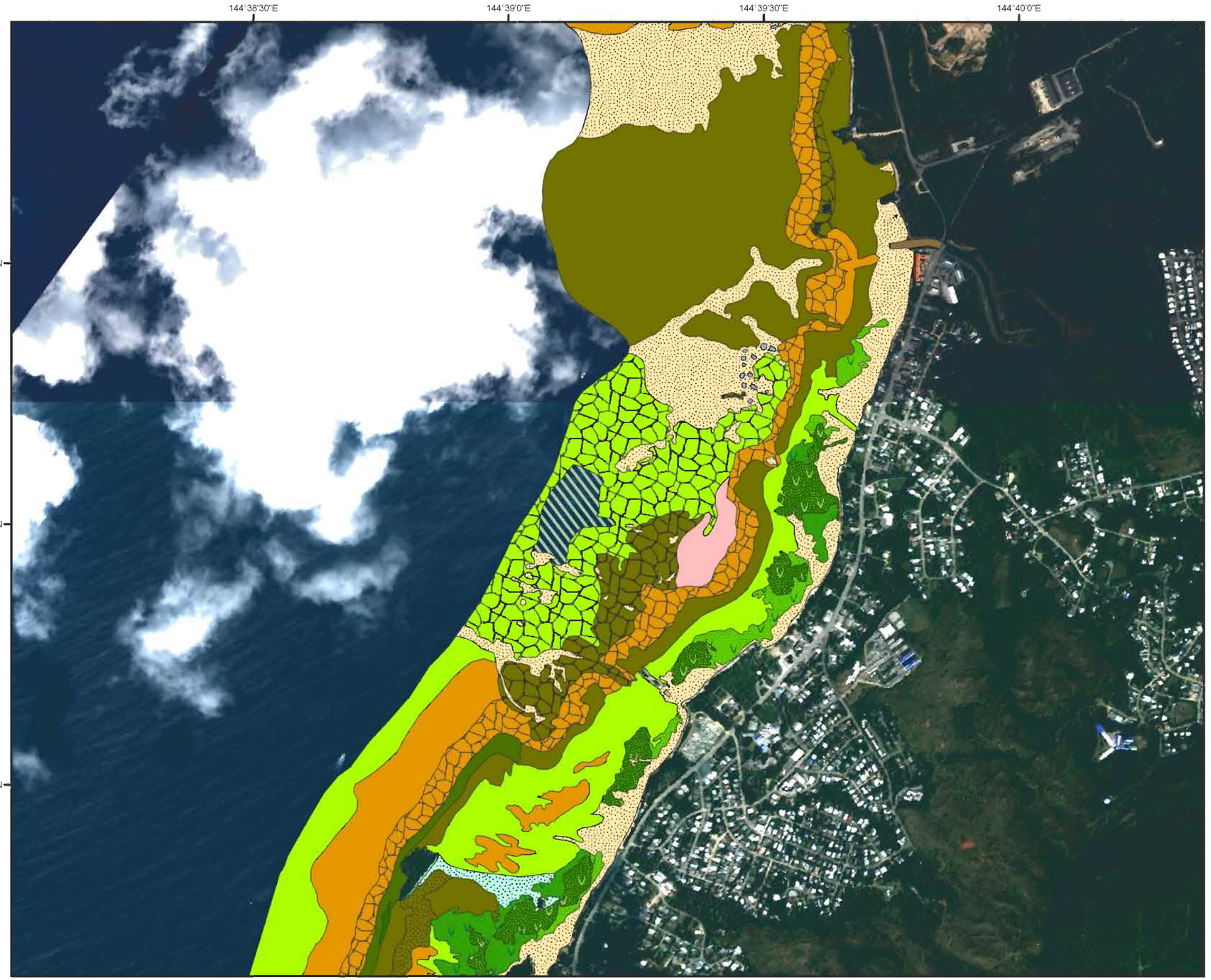

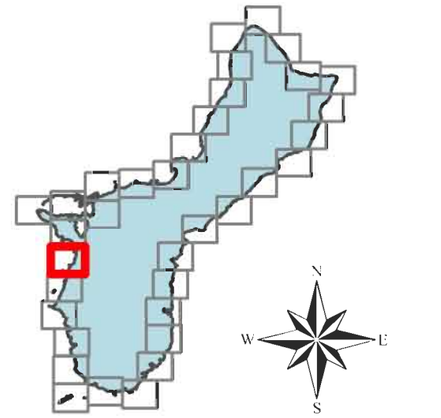

500 250 0 500 Meters

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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Coral 10%-<50%
- Individual Patch Reef, Macroalgae 10%-<50%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coralline Algae 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 10%-<50%
- Rubble, Uncolonized 90%-100%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Turf 10%-<50%

IKONOS Imagery provided by Space Imaging®

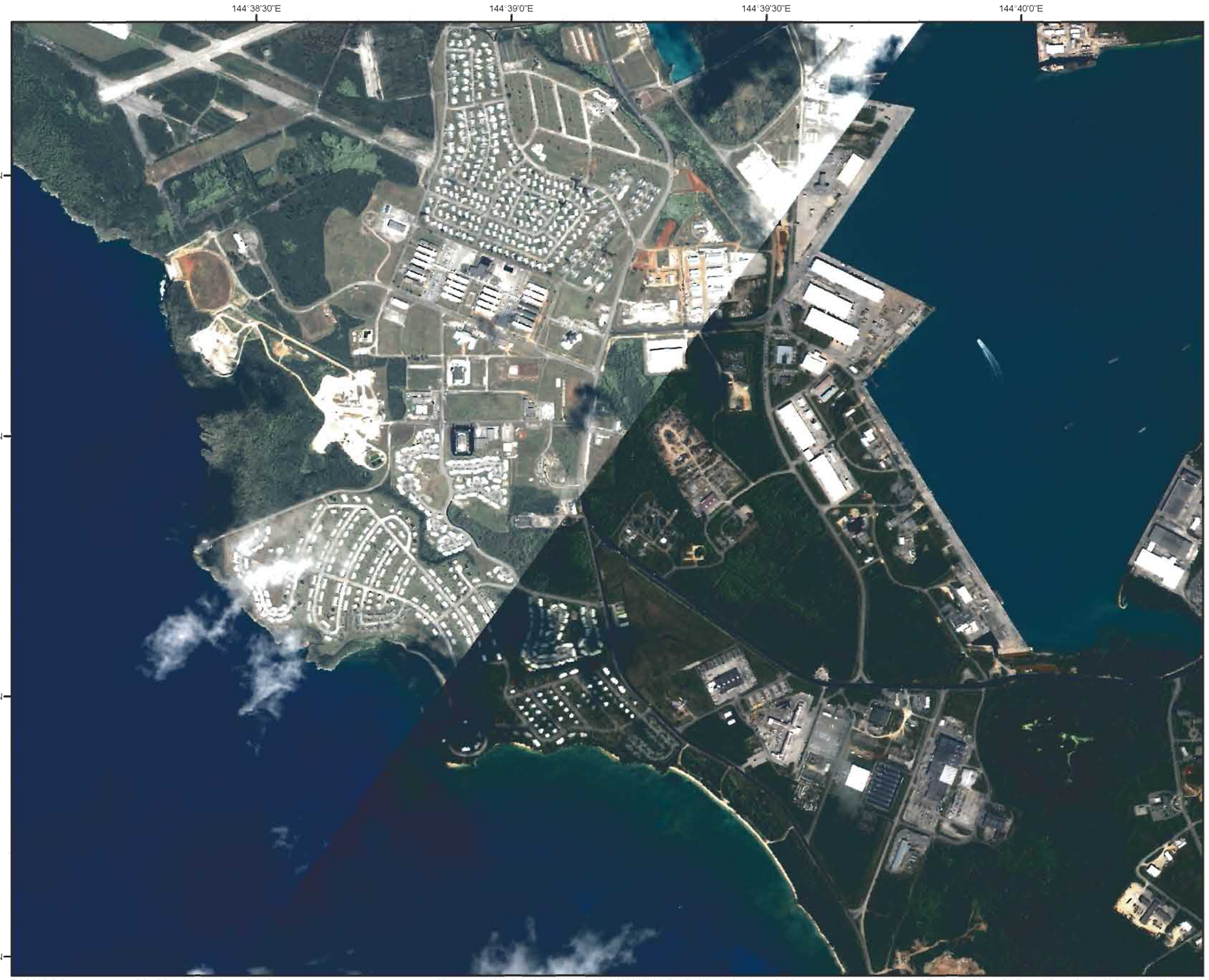
Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

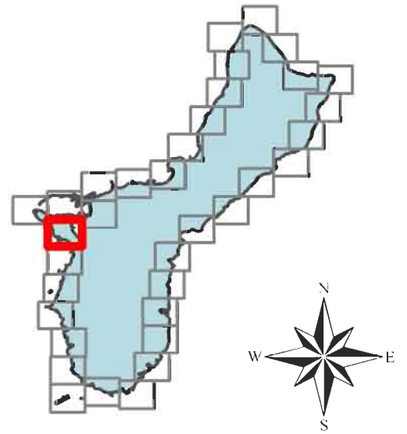
Marine Laboratory University of Guam

Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 29





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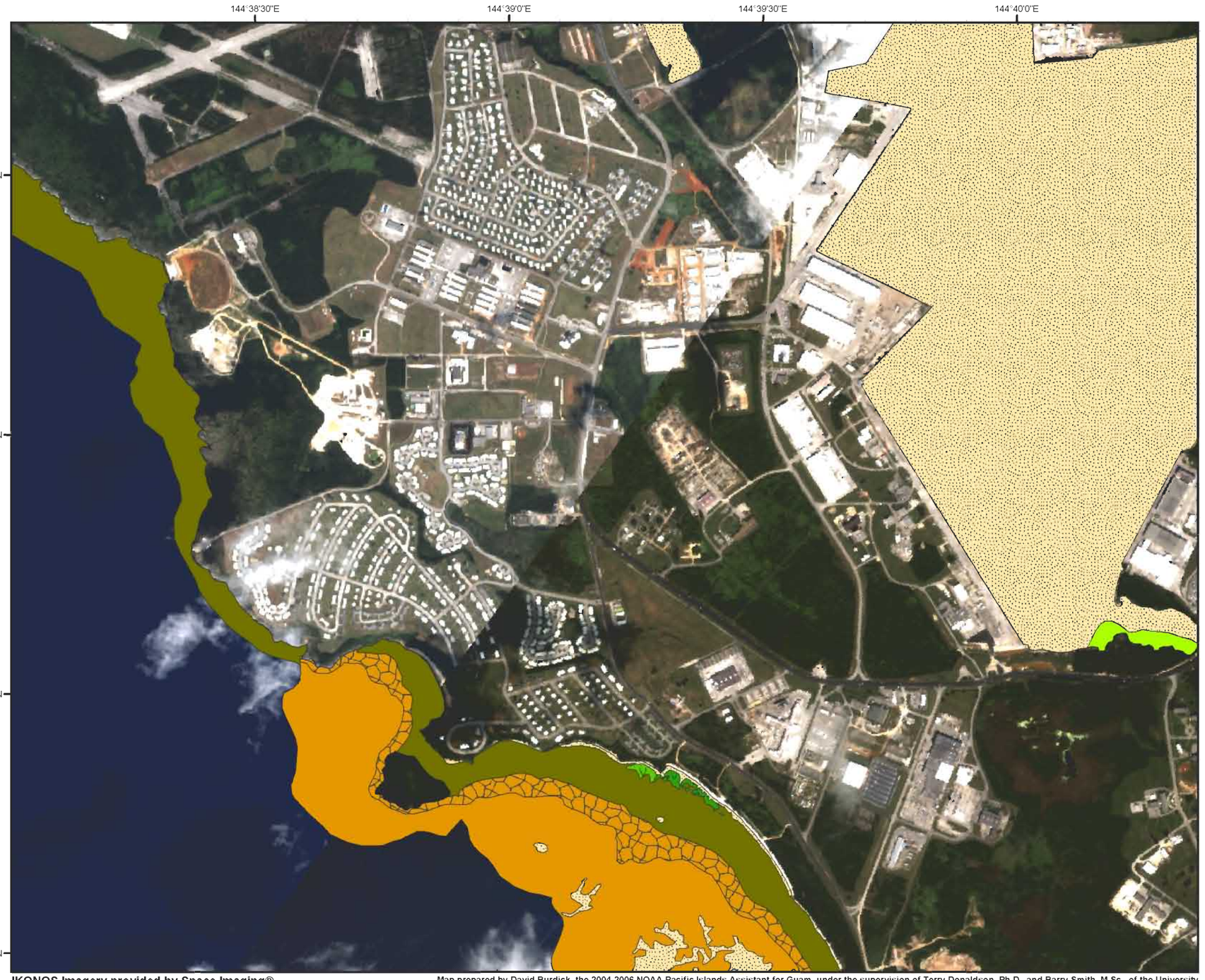
Reef slope off of Dadi Beach dominated primarily by Porites (Synaraea) rus; many coral colomes exhibit signs of stress, including extensive partial mortality. Photo by Dave Burdick.

IKONOS Imagery provided by Space Imaging®

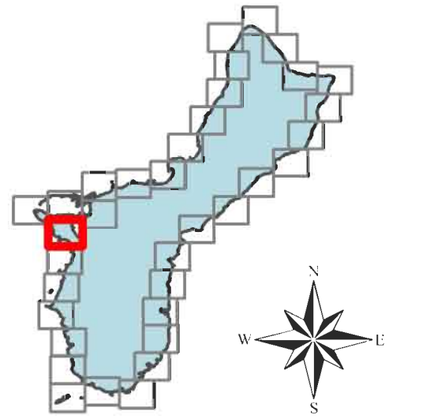
Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 29



IKONOS Imagery provided by Space Imaging®



Legend

- Aggregate Reef, Coral 10%-<50%
- Individual Patch Reef, Coral 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Turf 50%-<90%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Uncolonized 90%-100%

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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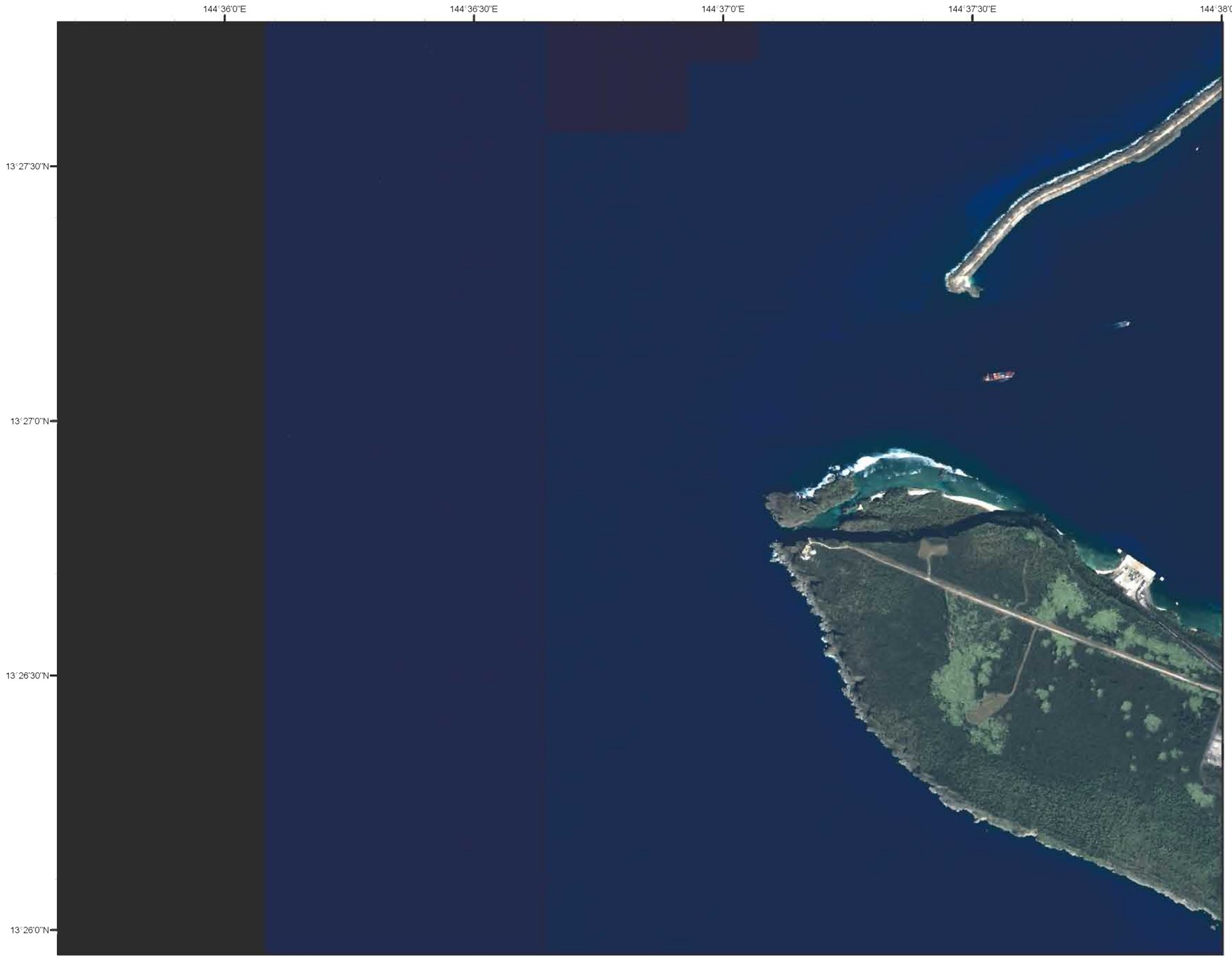
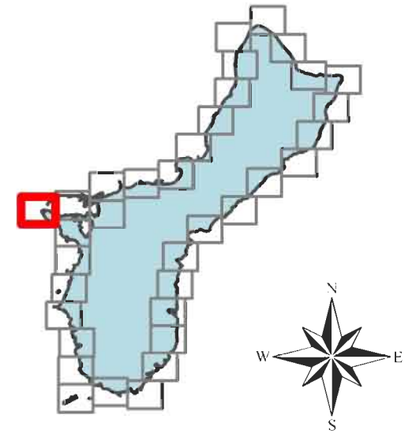
NOAA

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 30





1:15,000

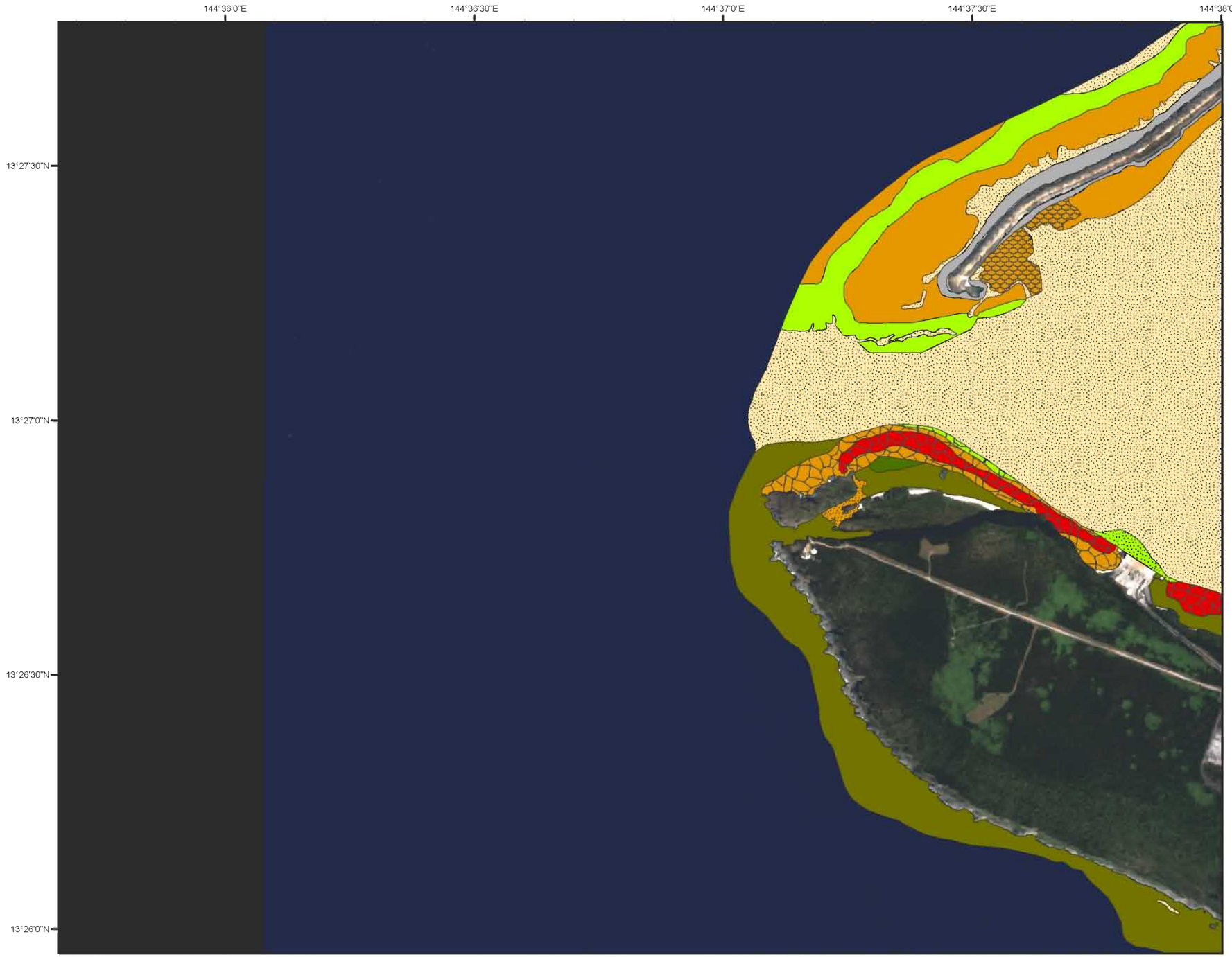
Shelf near the Blue Hole dive site, covered primarily by macroalgae and turf algae and dotted with small coral colonies. Photo by Dave Burdick.

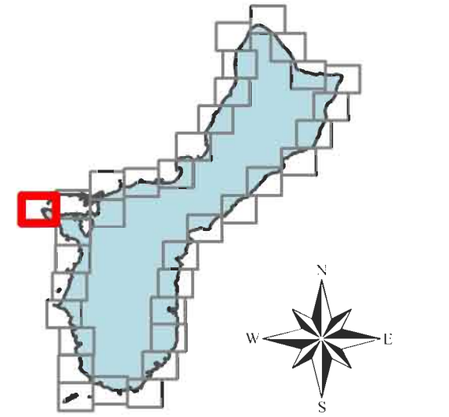
IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 30





500 250 0 500 Meters

1:15,000

Legend

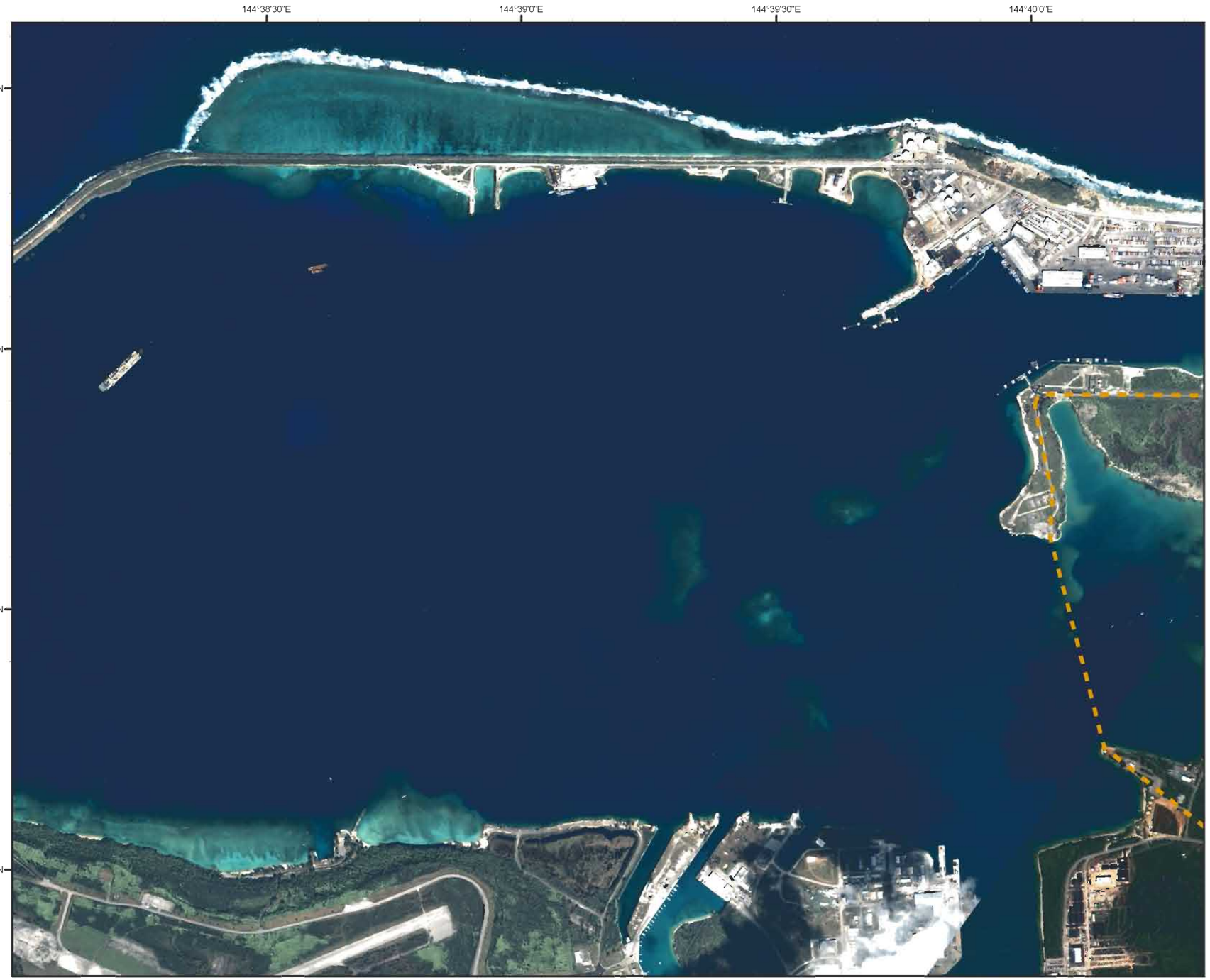
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Coral 10%-<50%
- Artificial, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Coral 10%-<50%
- Rubble, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

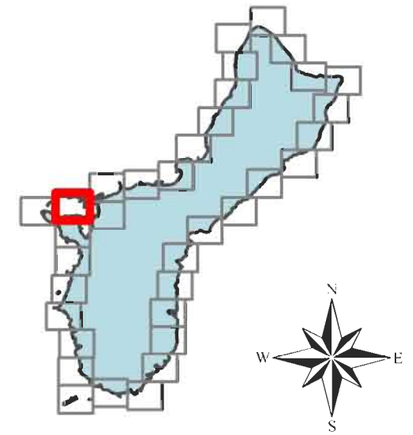
Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 31



IKONOS Imagery provided by Space Imaging®



500 250 0 500 Meters

1:15,000

Legend

Marine Preserve Boundaries

Extensive coral growth on back reef margin near GabGab Beach. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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Guam Coastal Management Program

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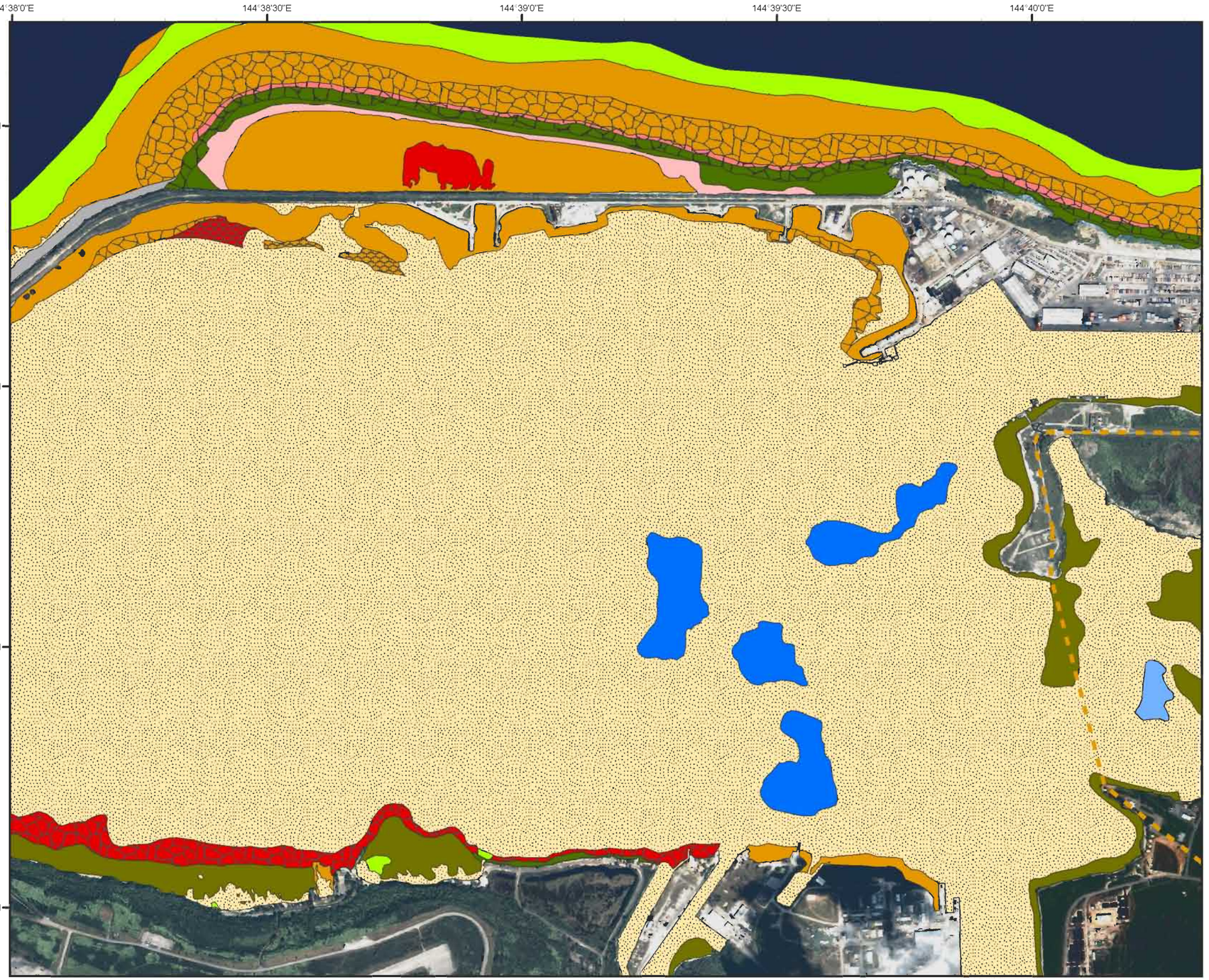
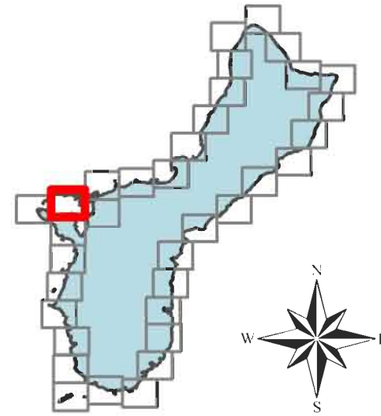
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 31





500 250 0 500 Meters

1:15,000

Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Coral 10%-<50%
- Aggregated Patch Reef, Coral 50%-<90%
- Artificial, Turf 50%-<90%
- Individual Patch Reef, Coral 10%-<50%
- Individual Patch Reef, Coral 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Coralline Algae 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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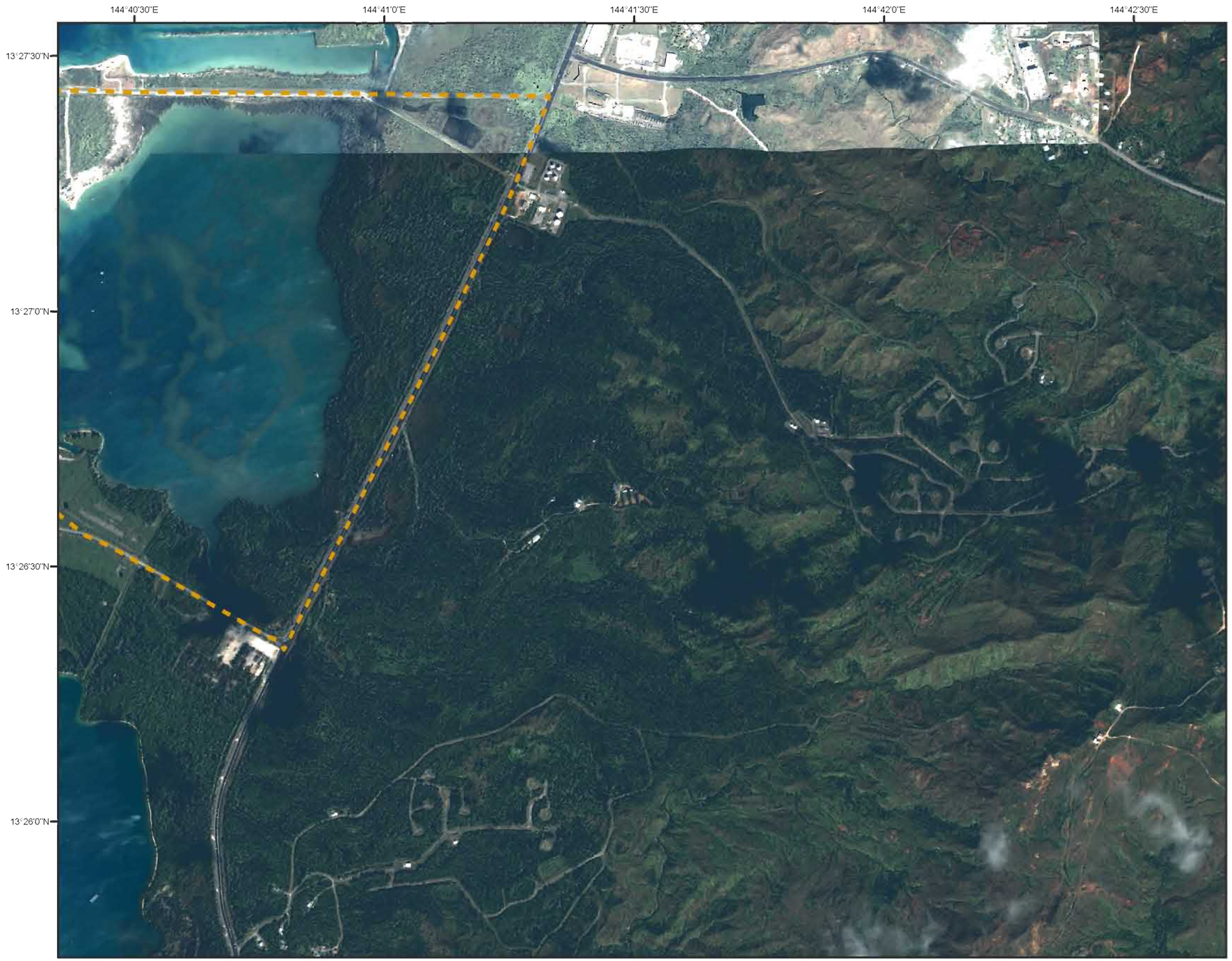
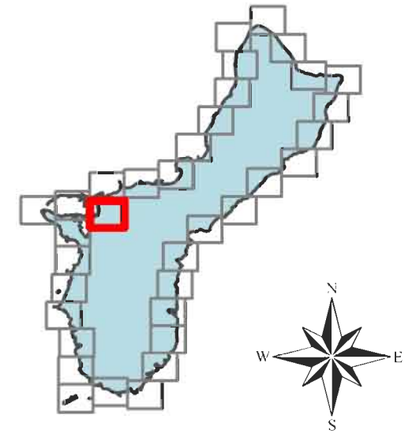
Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 32



IKONOS Imagery provided by Space Imaging®



500 250 0 500 Meters

1:15,000

Legend

Marine Preserve Boundaries

Mangrove stand in Sasa Bay Marine Preserve. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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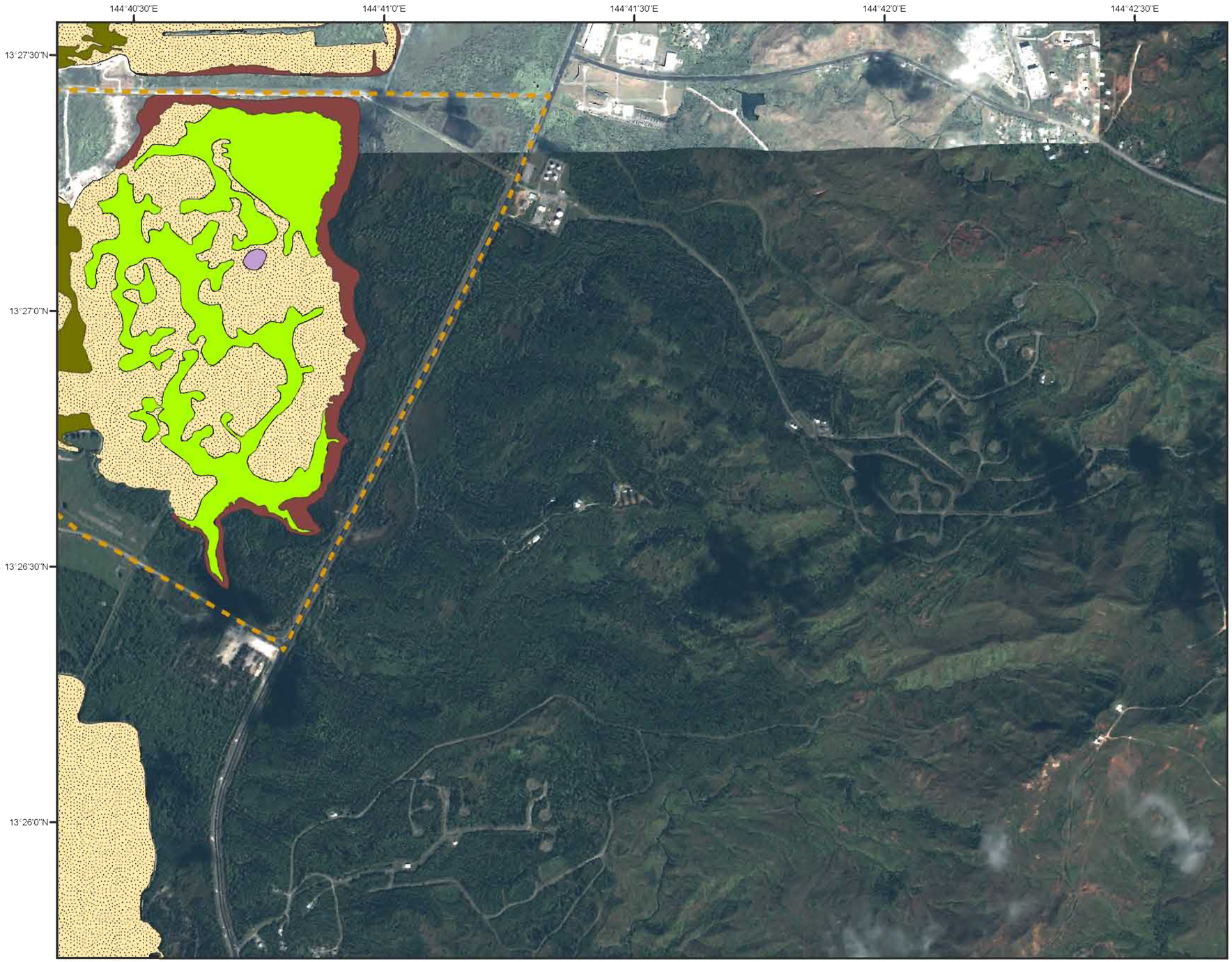
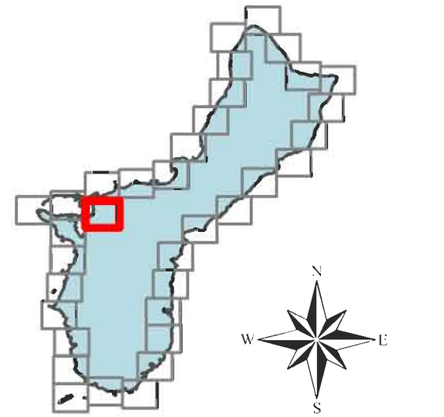
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 32





500 250 0 500 Meters

1:15,000

Legend

- Marine Preserve Boundaries
- Individual Patch Reef, Turf 50%-<90%
- Mud, Emergent Vegetation 90%-100%
- Pavement, Macroalgae 10%-<50%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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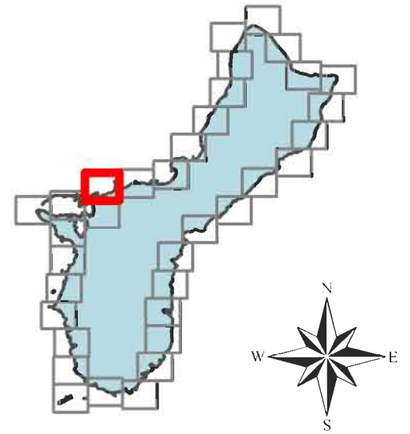
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 33



500 250 0 500 Meters

1:15,000

Legend

Marine Preserve Boundaries

A variety of soft coral species on the reef flat in the Piti Bomb Holes Marine Preserve. Photo by Dave Burdick.

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Guam Coastal Management Program

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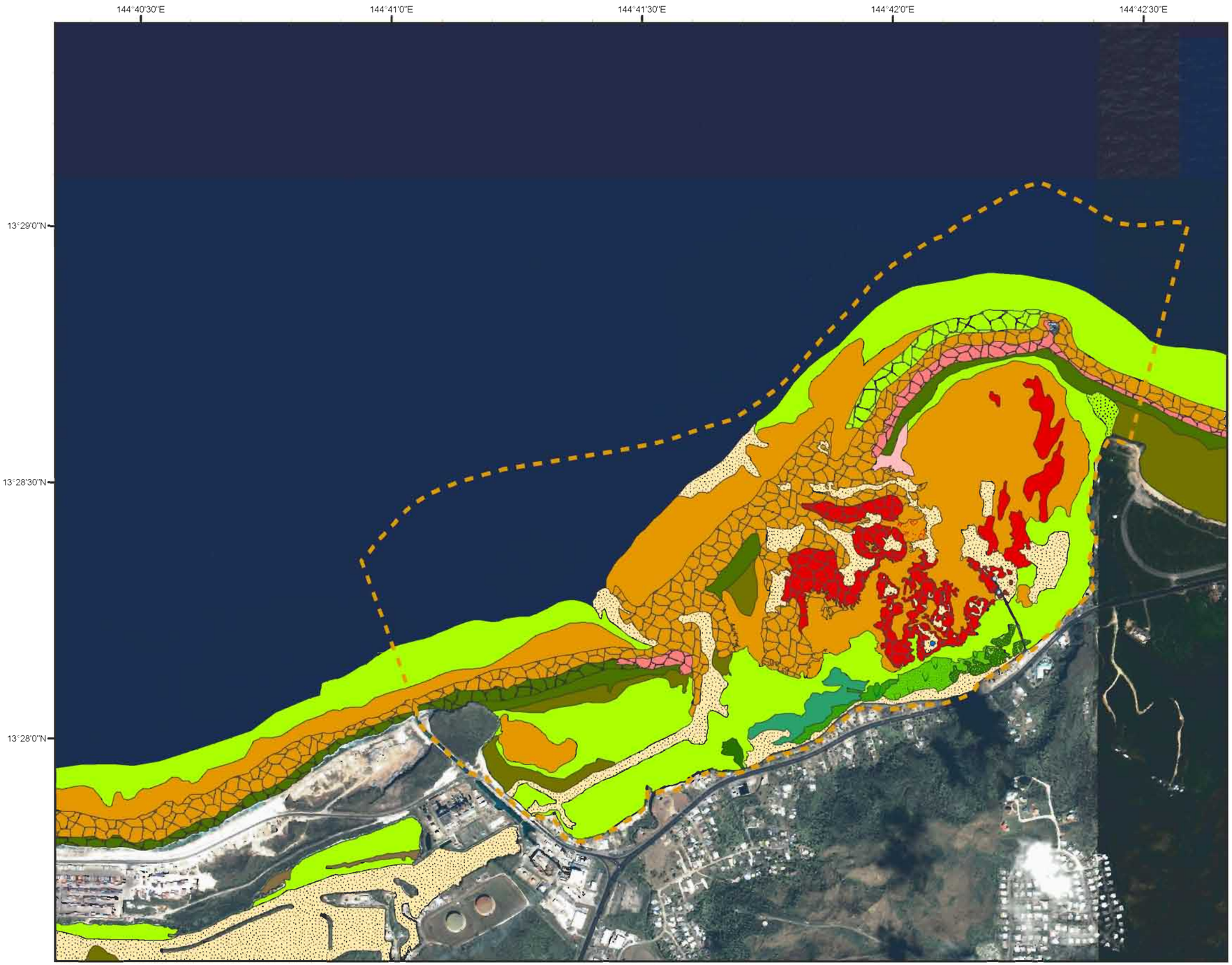
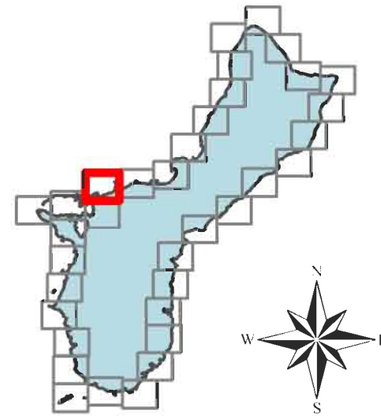
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 33





500 250 0 500 Meters

1:15,000

Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Coral 50%-<90%
- Individual Patch Reef, Coral 50%-<90%
- Mud, Emergent Vegetation 90%-100%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Coralline Algae 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Seagrass 10%-<50%
- Pavement, Turf 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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Guam Coastal Management Program

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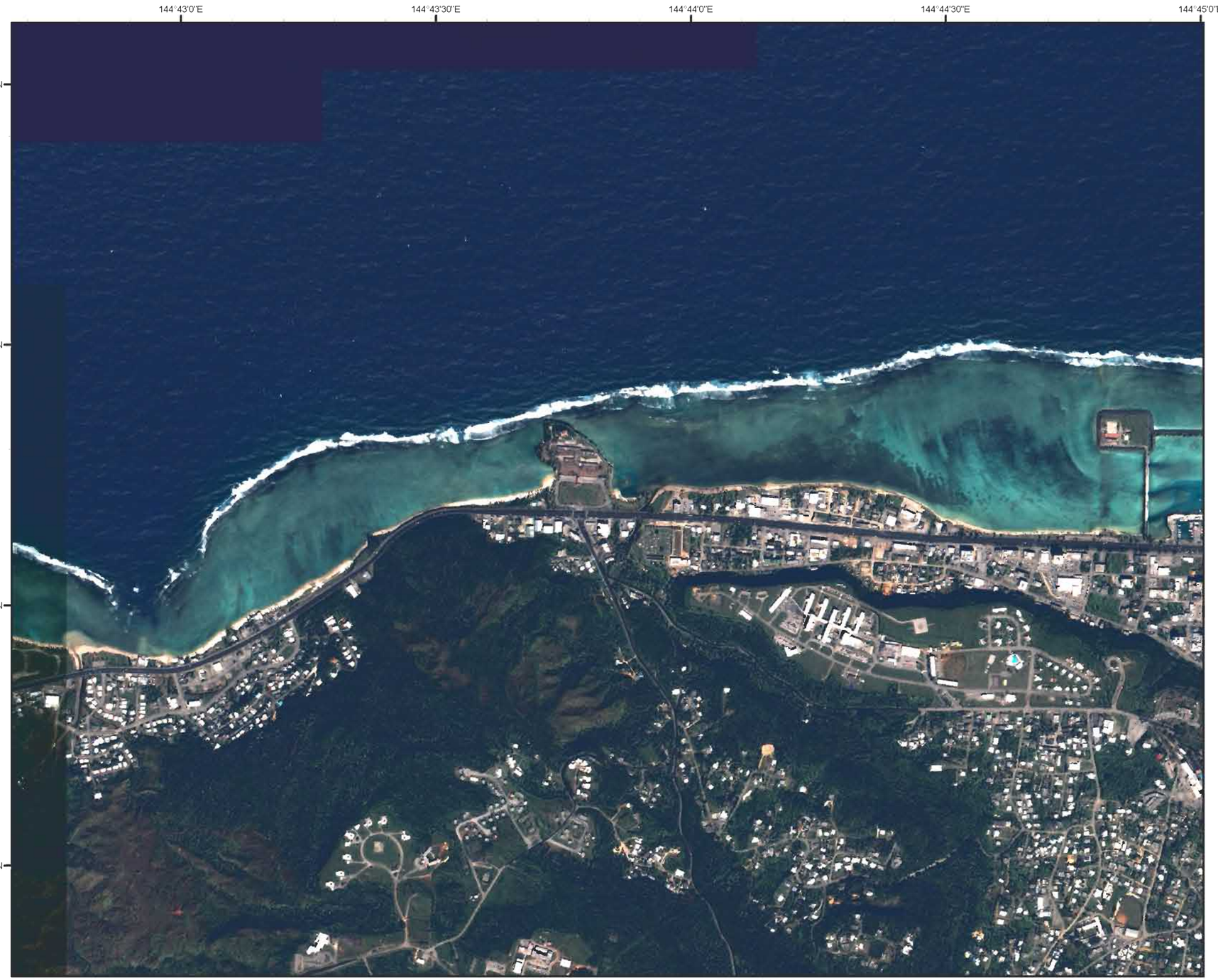
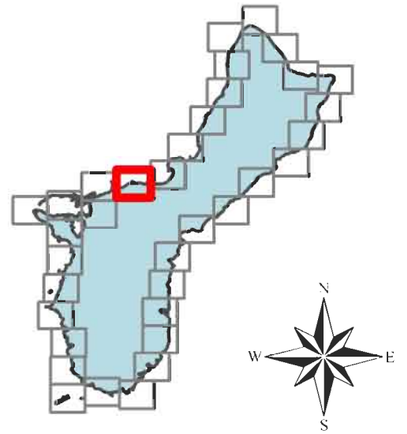
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 34





500 250 0 500 Meters

1:15,000

A view of the reef flat and reef crest of West Agana Bay at low tide looking north from Adelup Point. Photo by Dave Burdick.

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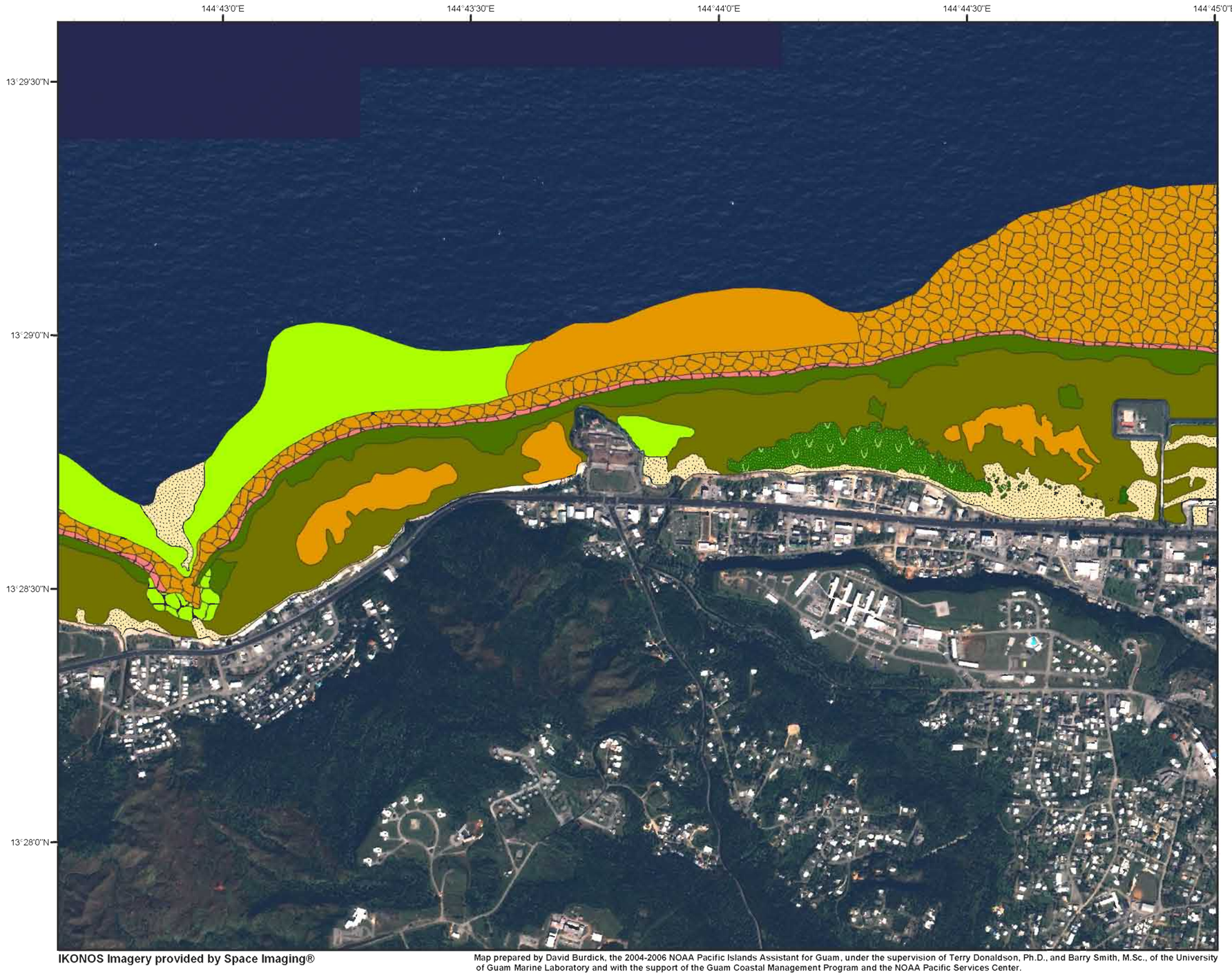
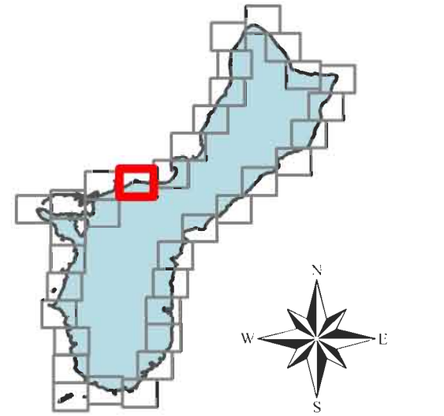
Guam Coastal Management Program

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 34





500 250 0 500 Meters

1:15,000

Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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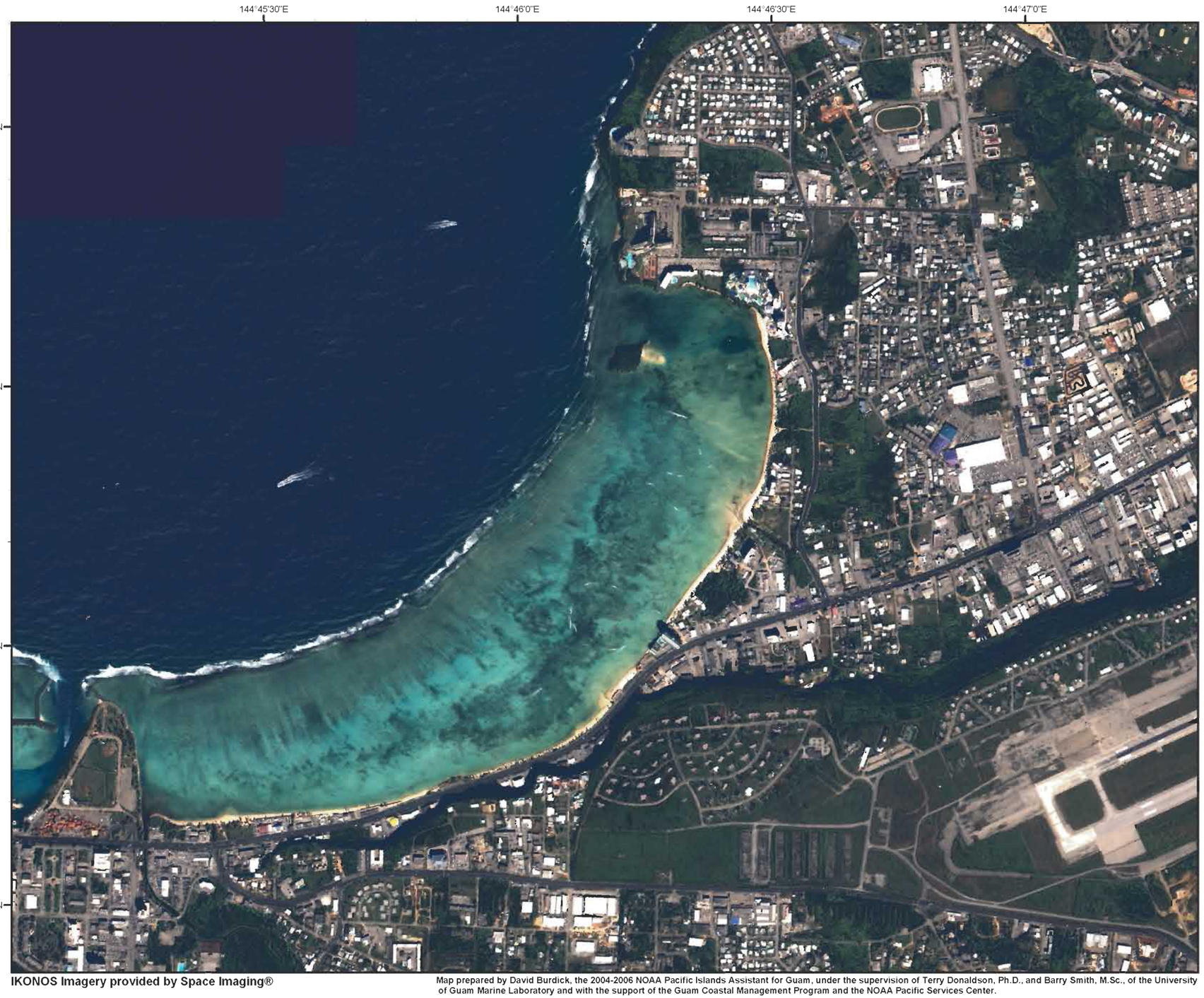
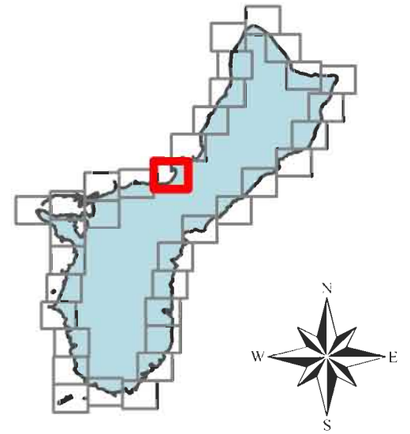
Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Satellite Image Map 35



IKONOS Imagery provided by Space Imaging®



1:15,000

Coral reef community dominated by Porites (Synaraea) rus on the fore reef slope of East Agana Bay. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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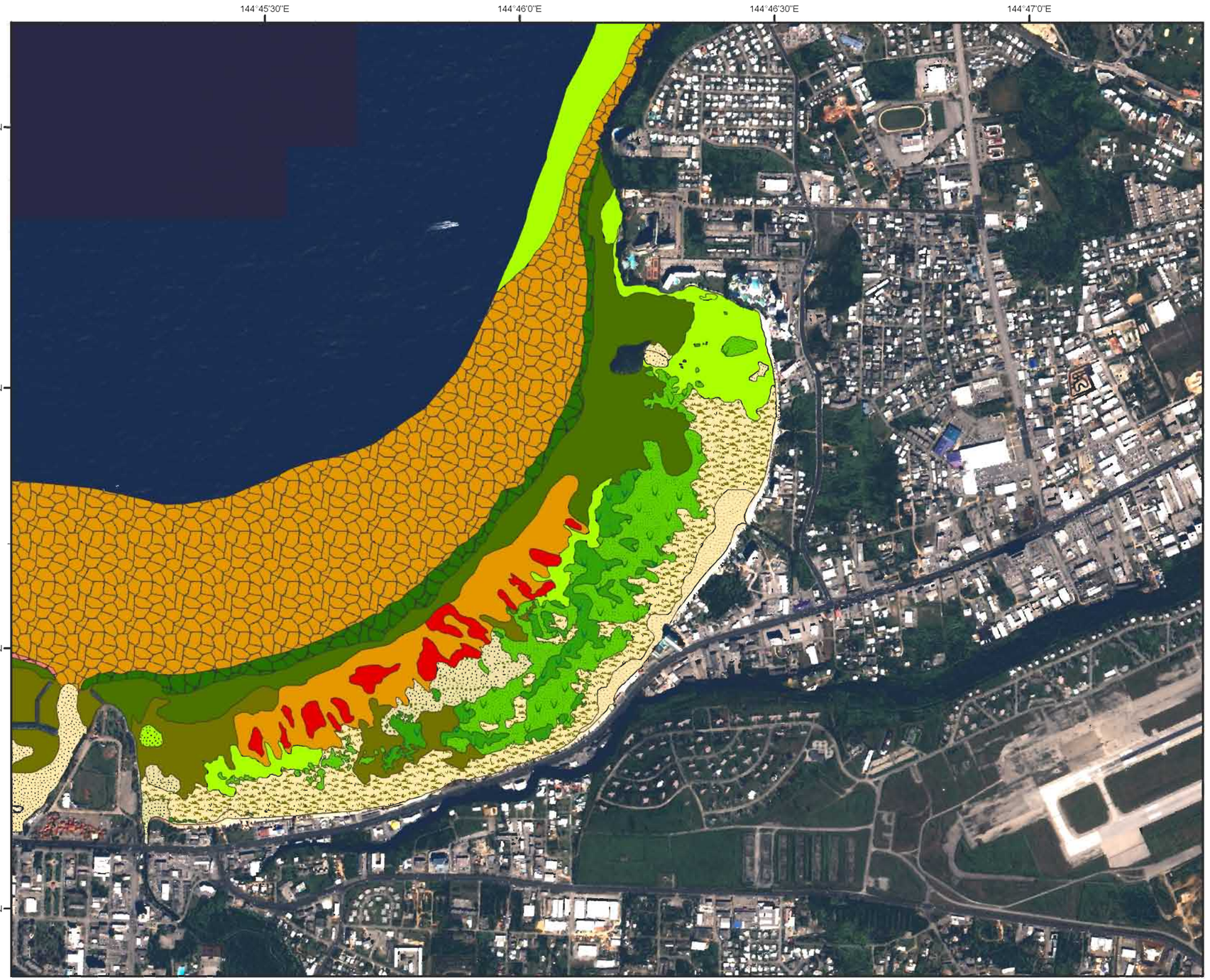
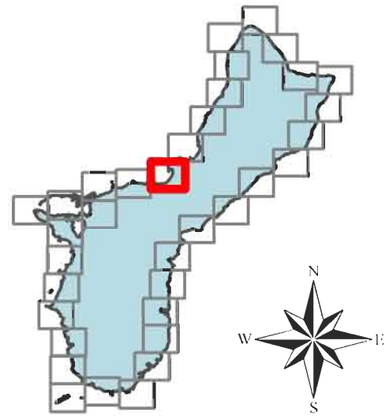
Guam Coastal Atlas ▪ 1:15000 Scale Coastal Maps ▪ Benthic Habitat Map 35



IKONOS Imagery provided by Space Imaging®



500 250 0 500 Meters

1:15,000

Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Macroalgae 10%-<50%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Turf 50%-<90%
- Sand, Uncolonized 50%-<90%
- Sand, Uncolonized 90%-100%

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Guam Coastal Management Program

NOAA

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

Guam Coastal Atlas ▪ 1:4000 Scale Marine Preserve Maps ▪ Map Index

The following pages contain detailed maps of the coastal areas within and immediately surrounding four of Guam's marine preserves. The maps, produced at 1:4000 scale, allow the user to discriminate fine-scale features within the coastal zone, including seagrass beds, patch reefs, small islands, and other features not clearly visible in the 1:15,000 scale maps. Each marine preserve was divided arbitrarily into equal sections, with each section being represented by two separate maps: the first map displaying only the 2001-2004 IKONOS satellite image mosaic and the second map displaying the benthic habitat data overlaid on the satellite imagery. The marine protected area boundaries are also included with both maps.

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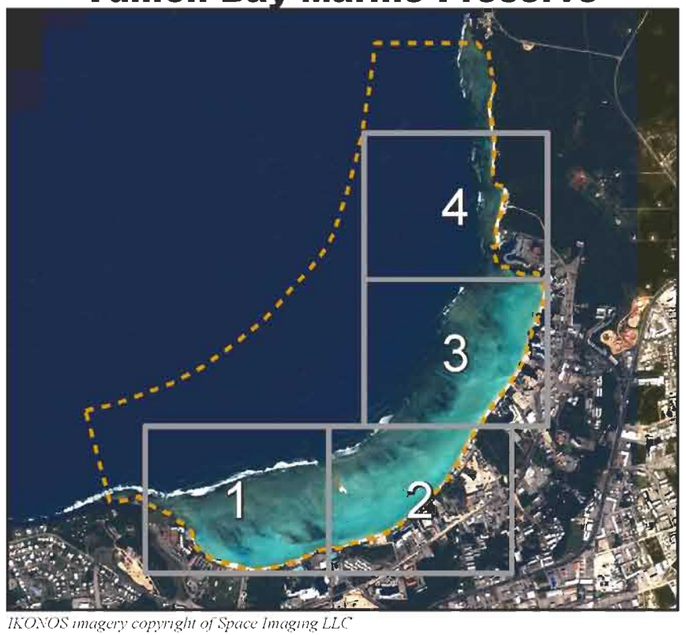
Sasa Bay Marine Preserve	1	102
	2	104
	3	106
	4	108
Achang Reef Flat Marine Preserve	1	110
	2	112
	3	114
	4	116

Tumon Bay Marine Preserve



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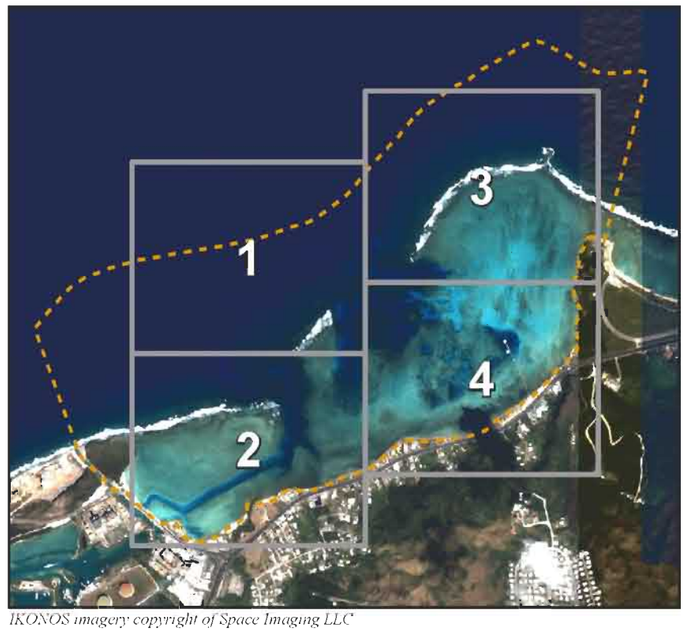
Piti Bomb Holes Marine Preserve



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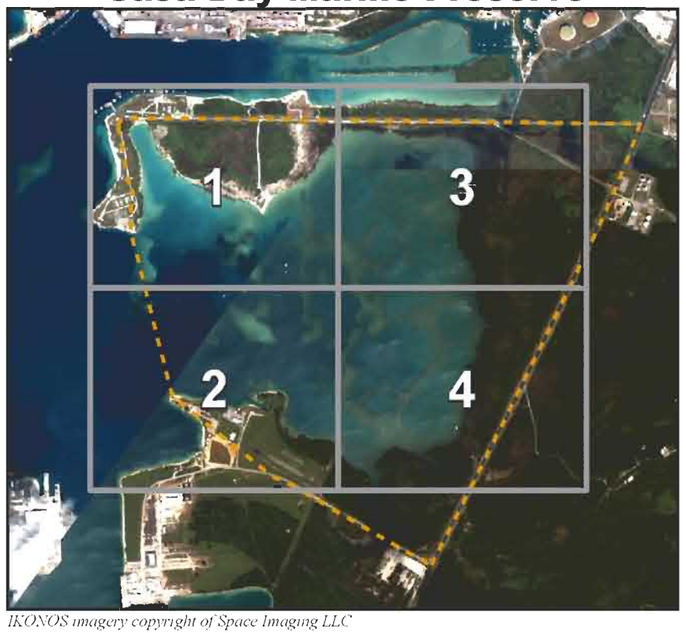
Sasa Bay Marine Preserve



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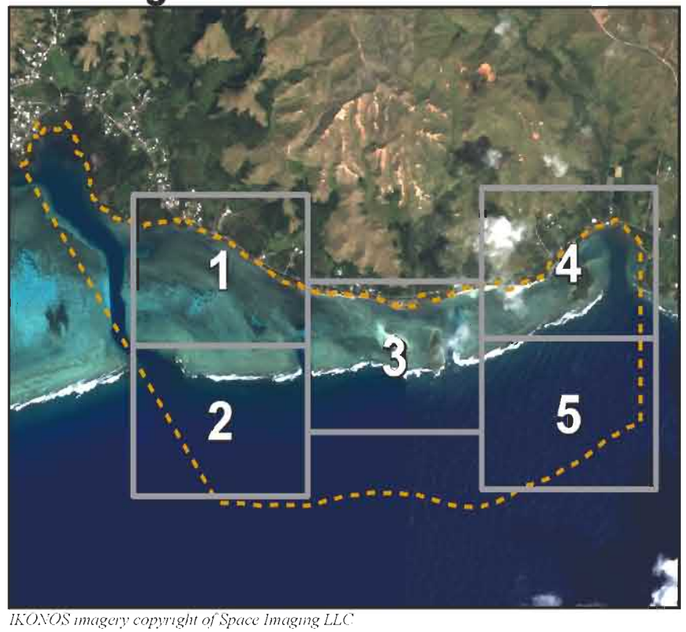
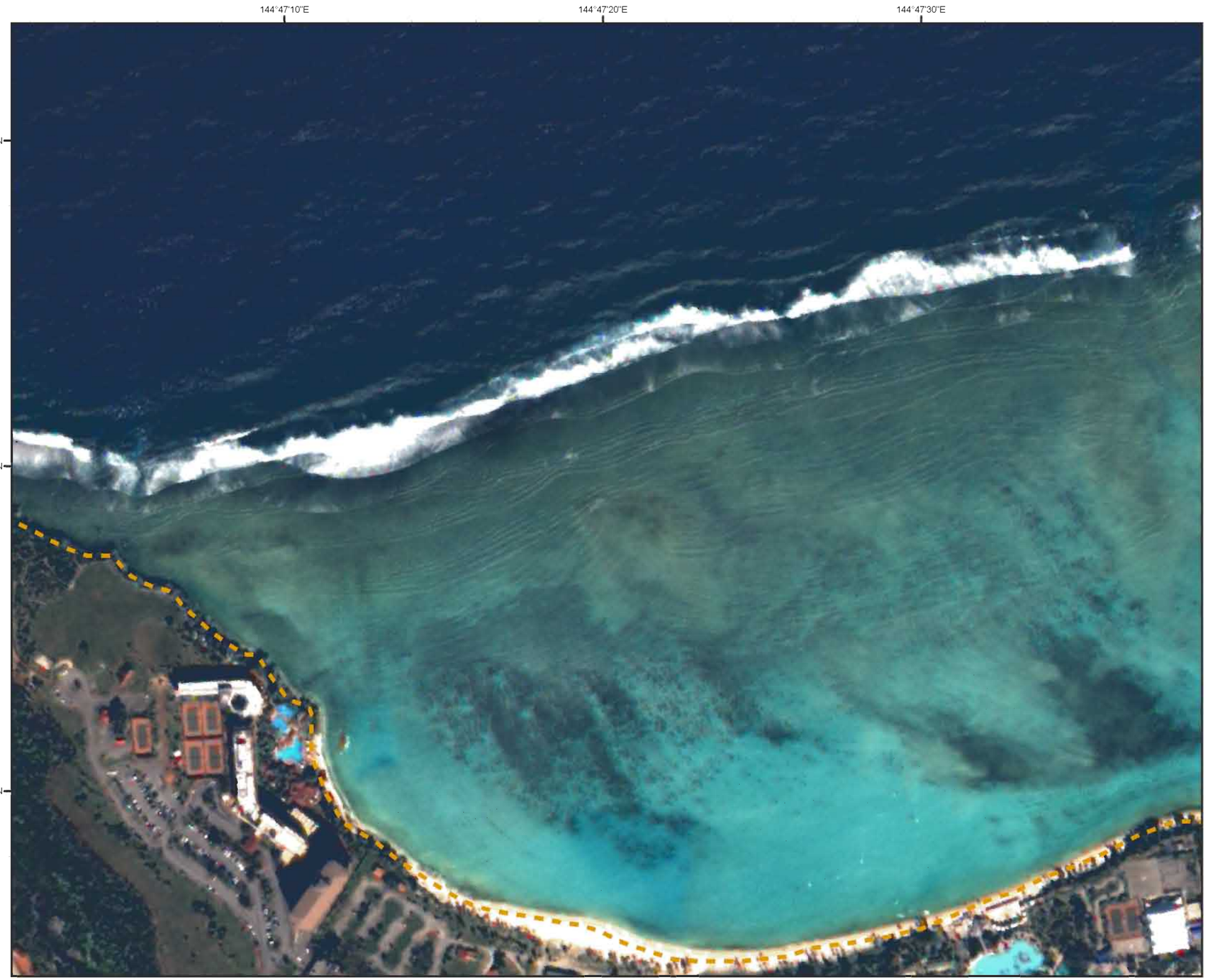
Achang Reef Flat Marine Preserve

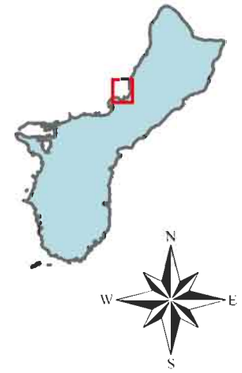


IKONOS imagery copyright of Space Imaging LLC

Guam Coastal Atlas ▪ Tumon Bay Marine Preserve ▪ Satellite Image Map 1



IKONOS Imagery provided by Space Imaging®



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Legend

Marine Preserve Boundaries

Vibrant stands of Porites cylindrica near Ypao Beach Park. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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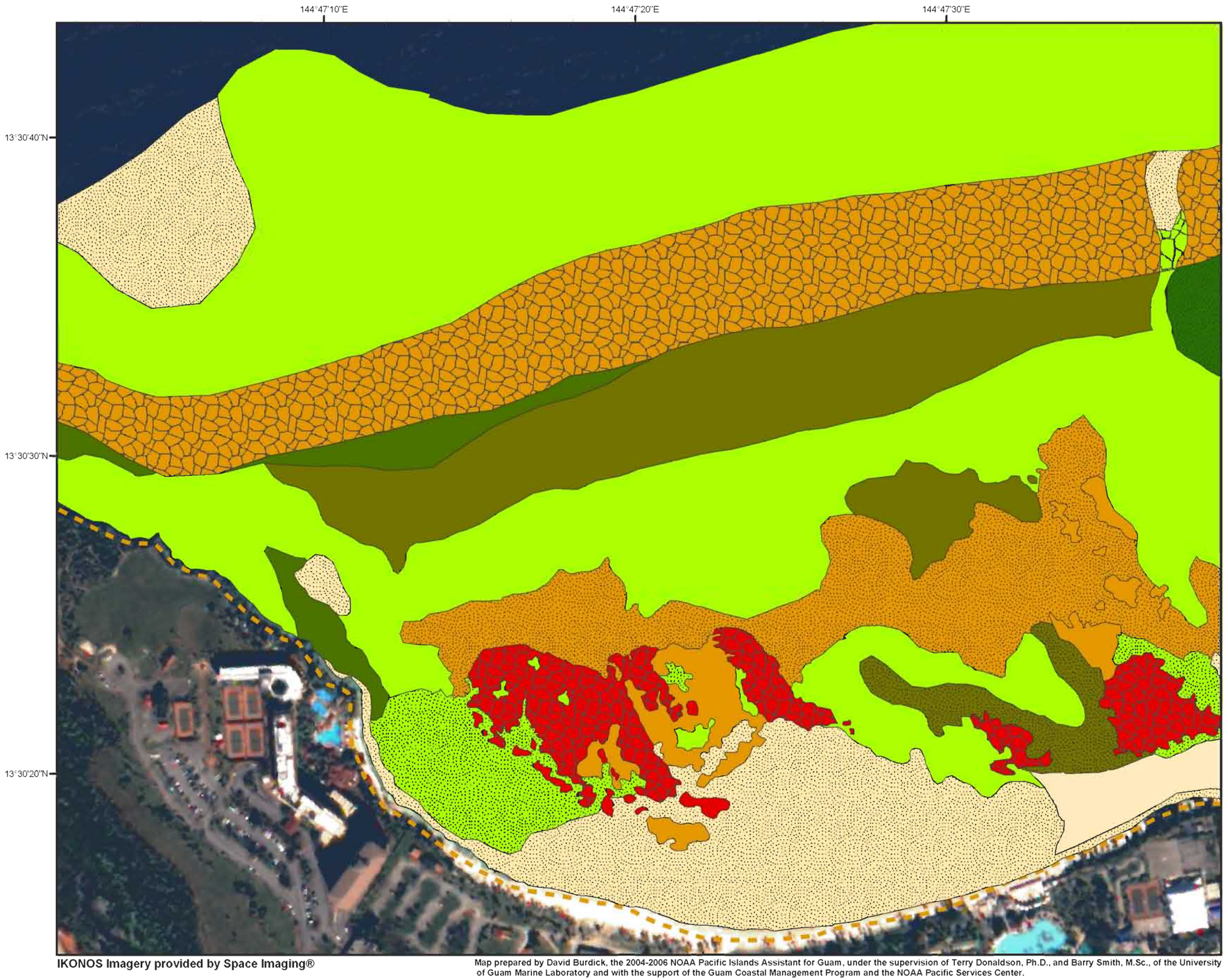
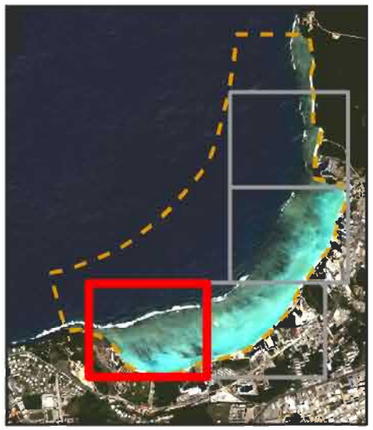
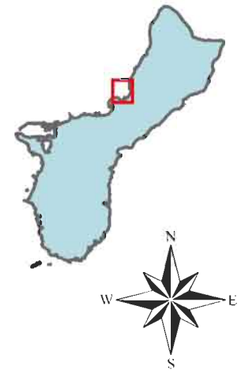


IKONOS Imagery provided by Space Imaging®





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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Pavement, Uncolonized 50%-<90%
- Rubble, Coral 10%-<50%
- Rubble, Macroalgae 10%-<50%
- Rubble, Macroalgae 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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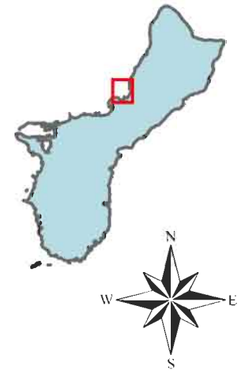
Guam Coastal Atlas ▪ Tumon Bay Marine Preserve ▪ Satellite Image Map 2

IKONOS Imagery provided by Space Imaging®



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Legend

Marine Preserve Boundaries

Clusters of branching coral colonies (Acropora sp.) on reef flat in central Tumon Bay. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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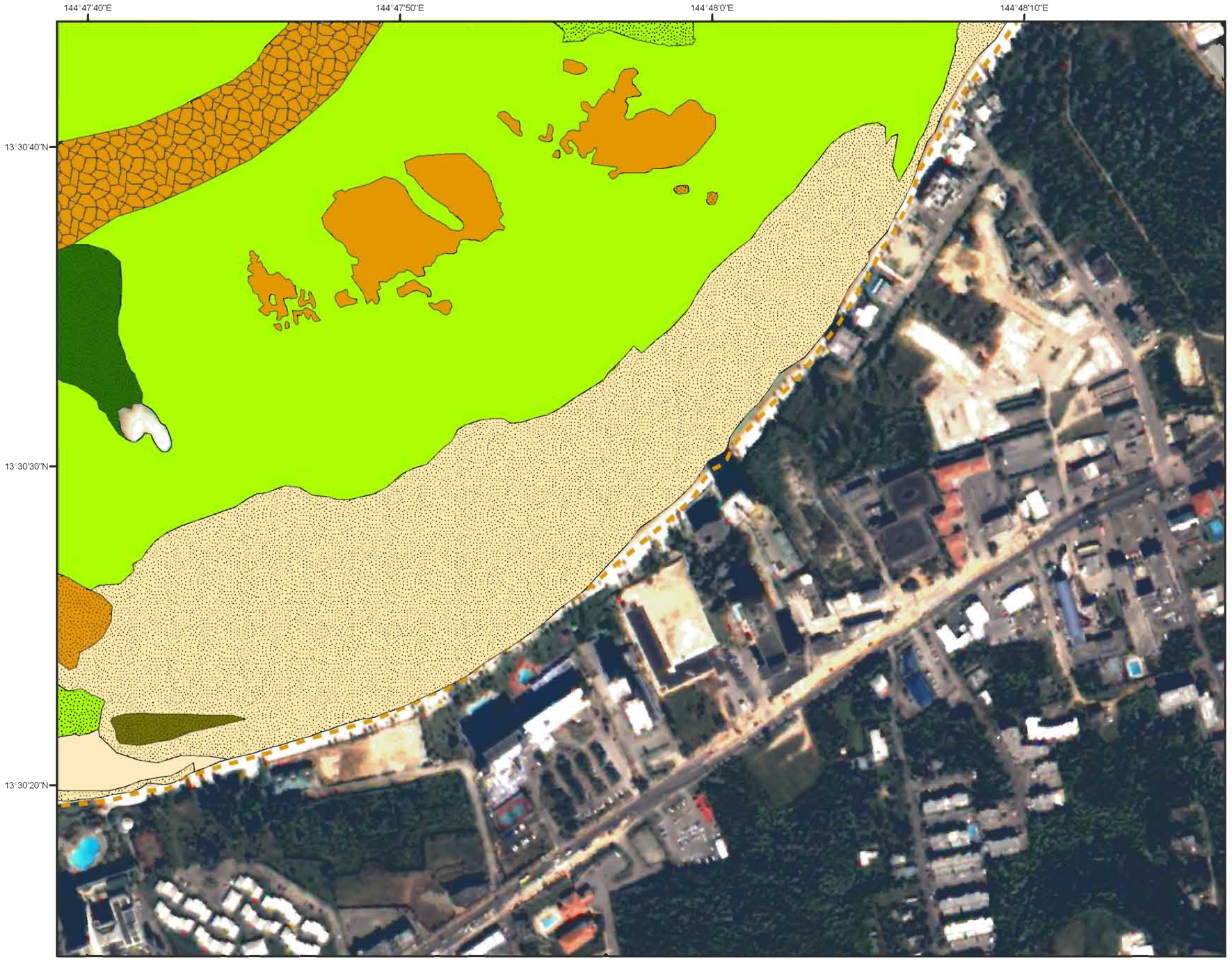
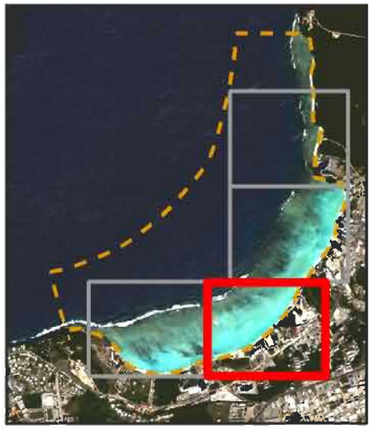
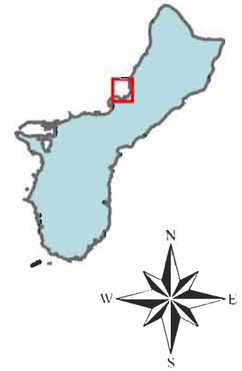


IKONOS Imagery provided by Space Imaging®





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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Turf 50%-<90%
- Pavement, Uncolonized 50%-<90%
- Rubble, Coral 10%-<50%
- Rubble, Macroalgae 10%-<50%
- Rubble, Macroalgae 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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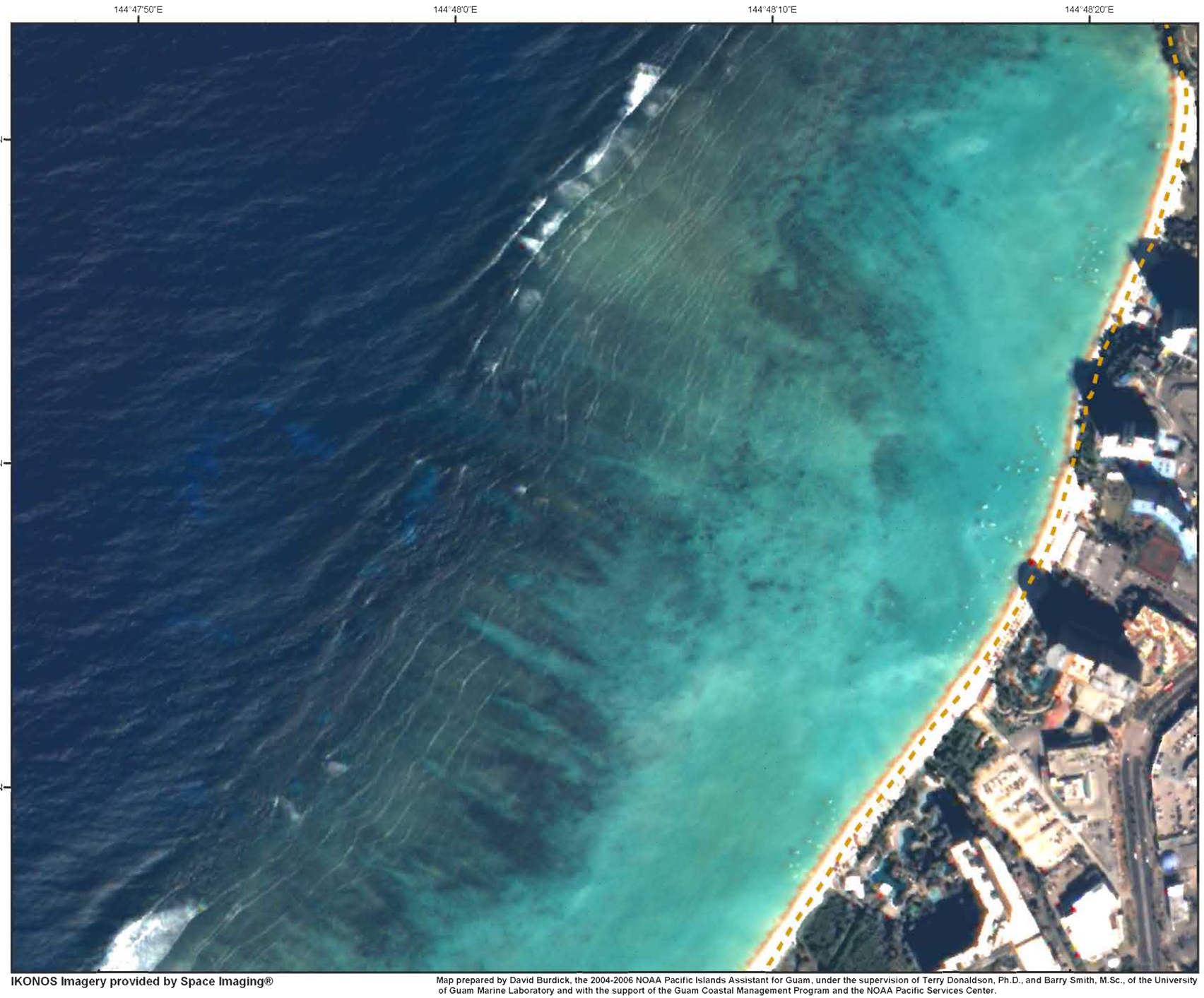
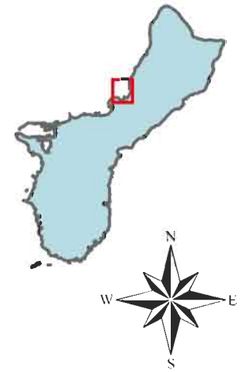
Guam Coastal Atlas ▪ Tumon Bay Marine Preserve ▪ Satellite Image Map 3





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Legend

Marine Preserve Boundaries

Shallow reef community dominated by Porites cylindrica, Pavona decussata, and Pocillopora damicornis on reef flat of northern Tumon Bay. Photo by Dave Burdick.

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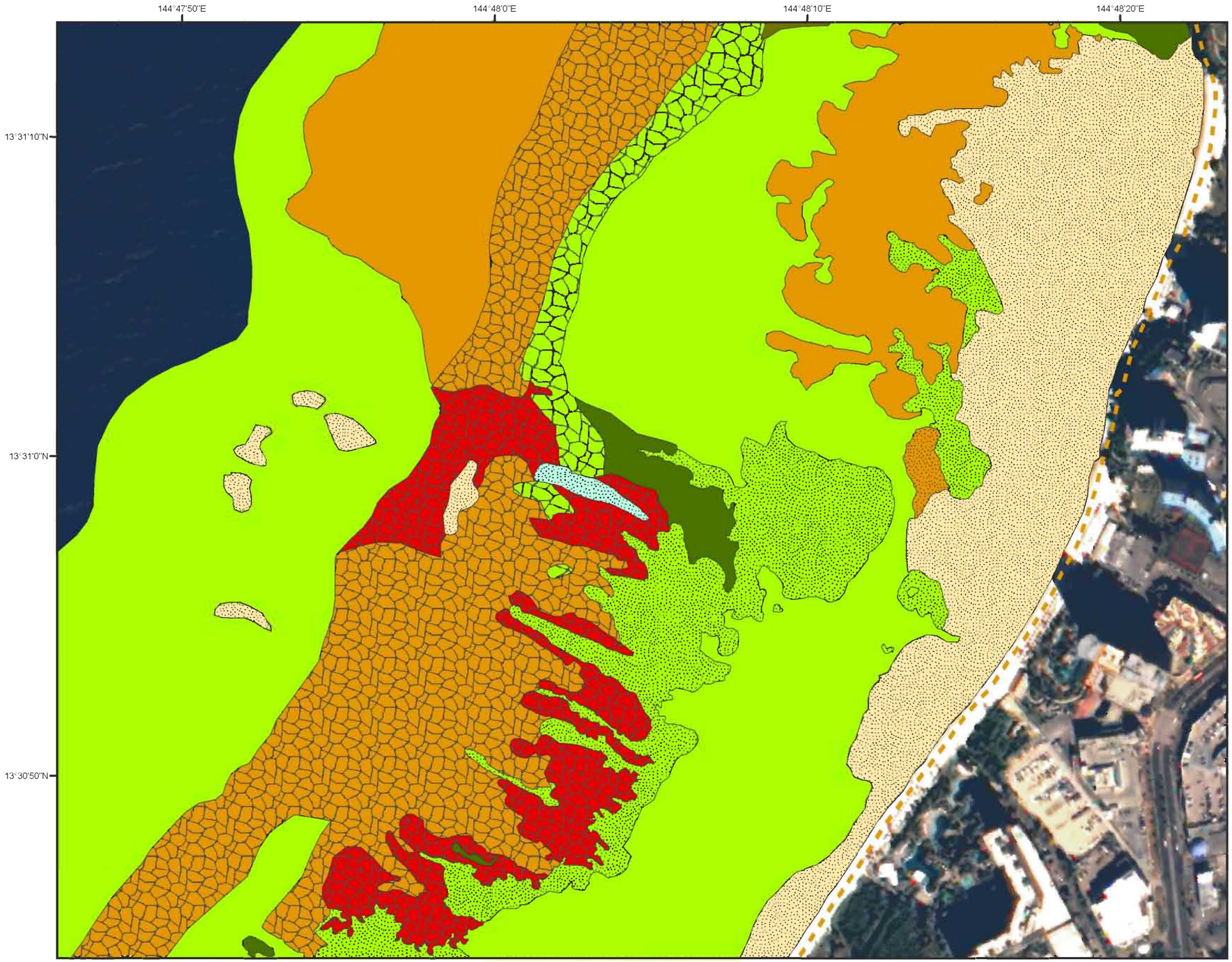

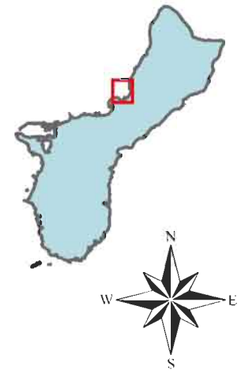

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Legend

- Marine Preserve Boundaries
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- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Coral 10%-<50%
- Rubble, Turf 50%-<90%
- Rubble, Uncolonized 90%-100%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

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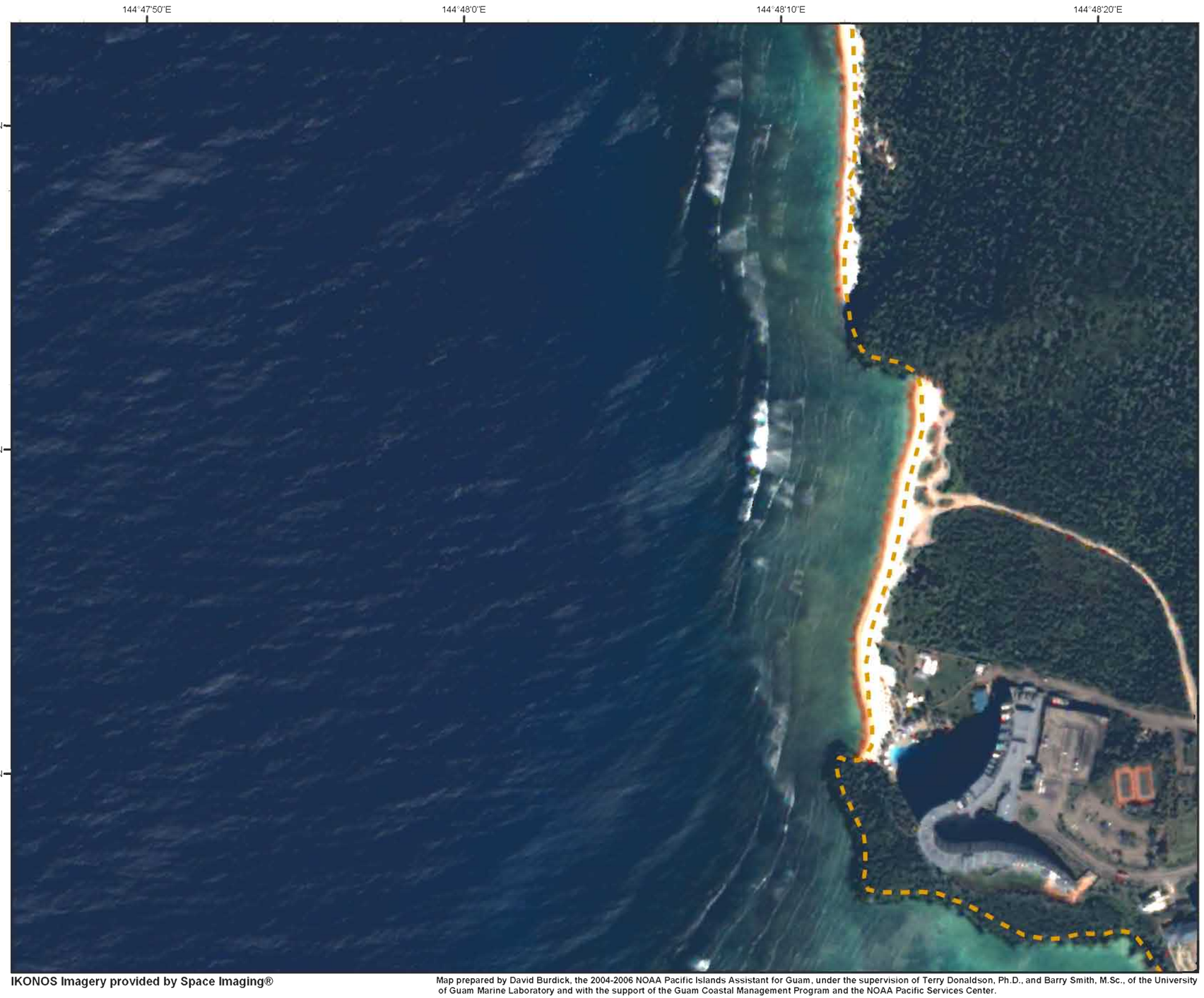
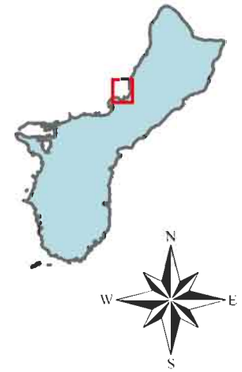
Guam Coastal Atlas ▪ Tumon Bay Marine Preserve ▪ Satellite Image Map 4





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Legend

Marine Preserve Boundaries

Acropora-dominated reef crest near Gun Beach. Photo by Dave Burdick.

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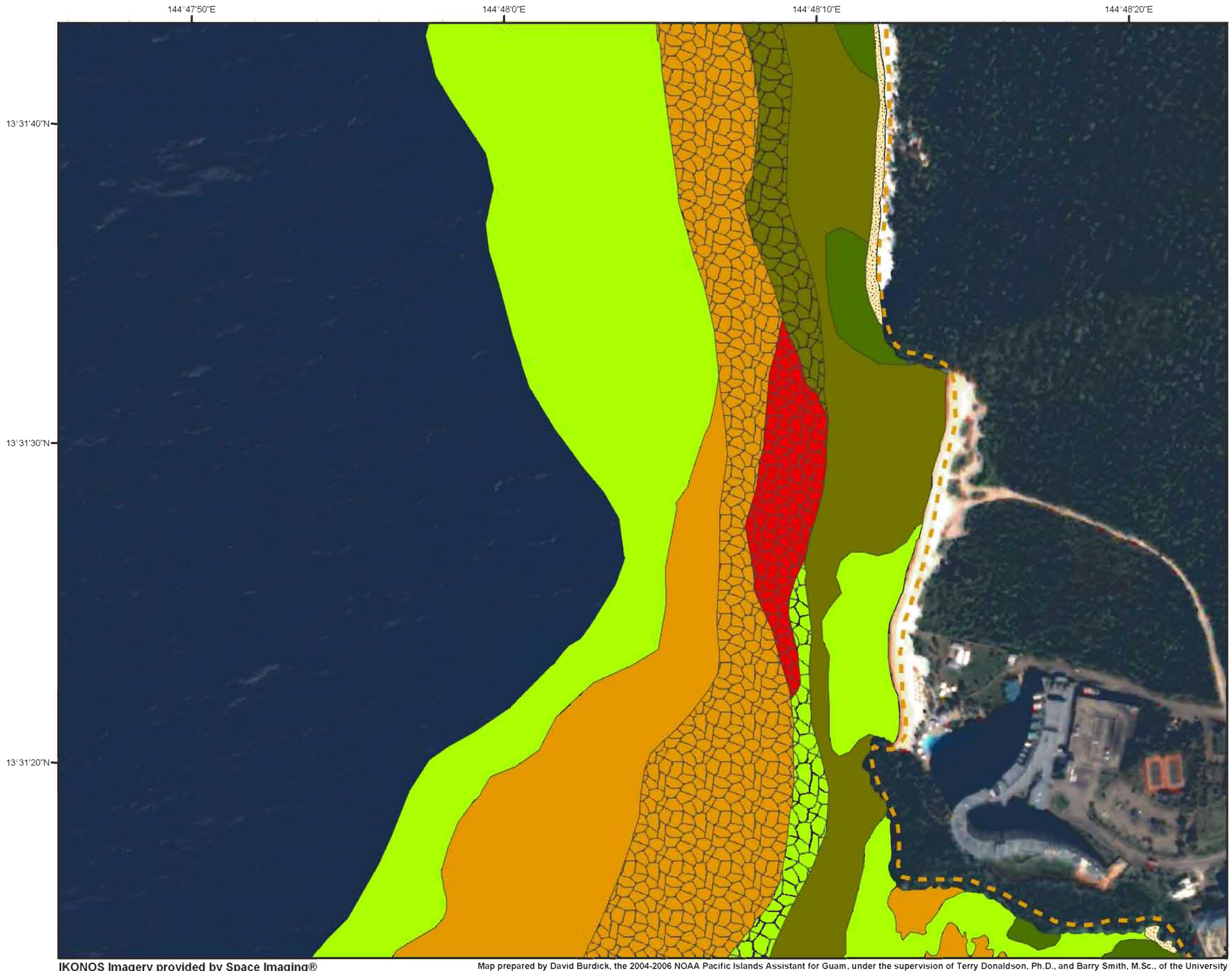

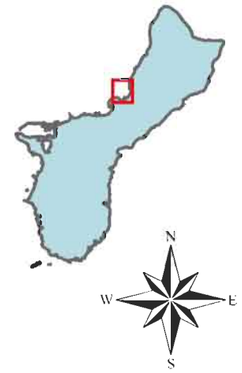

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Legend

- Marine Preserve Boundaries
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- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

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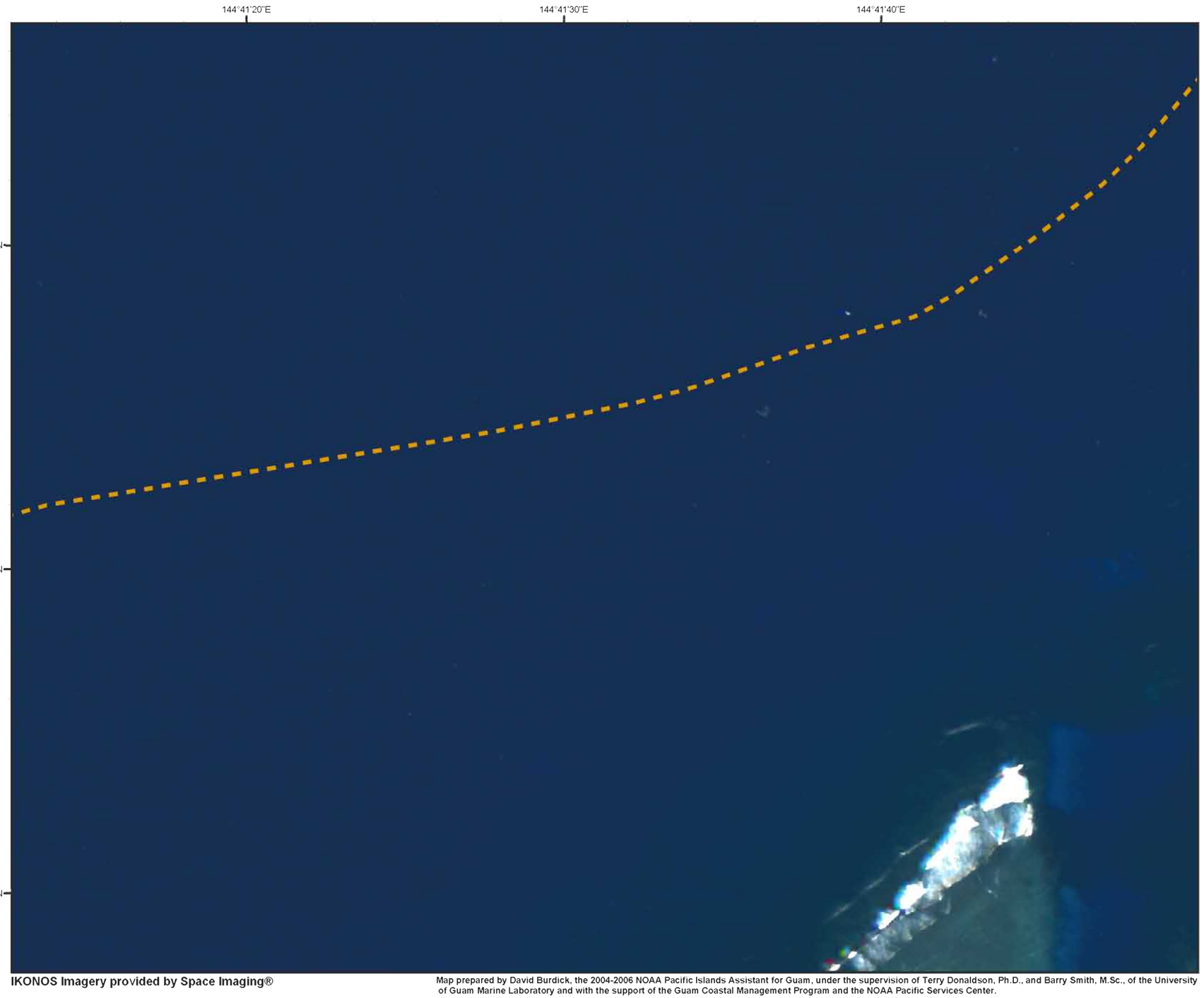
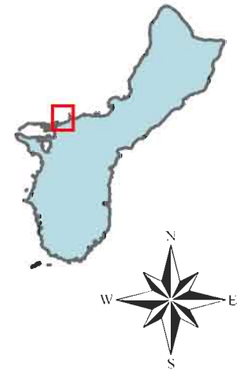
Guam Coastal Atlas ▪ Piti Bomb Holes Marine Preserve ▪ Satellite Image Map 1





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Marine Preserve Boundaries

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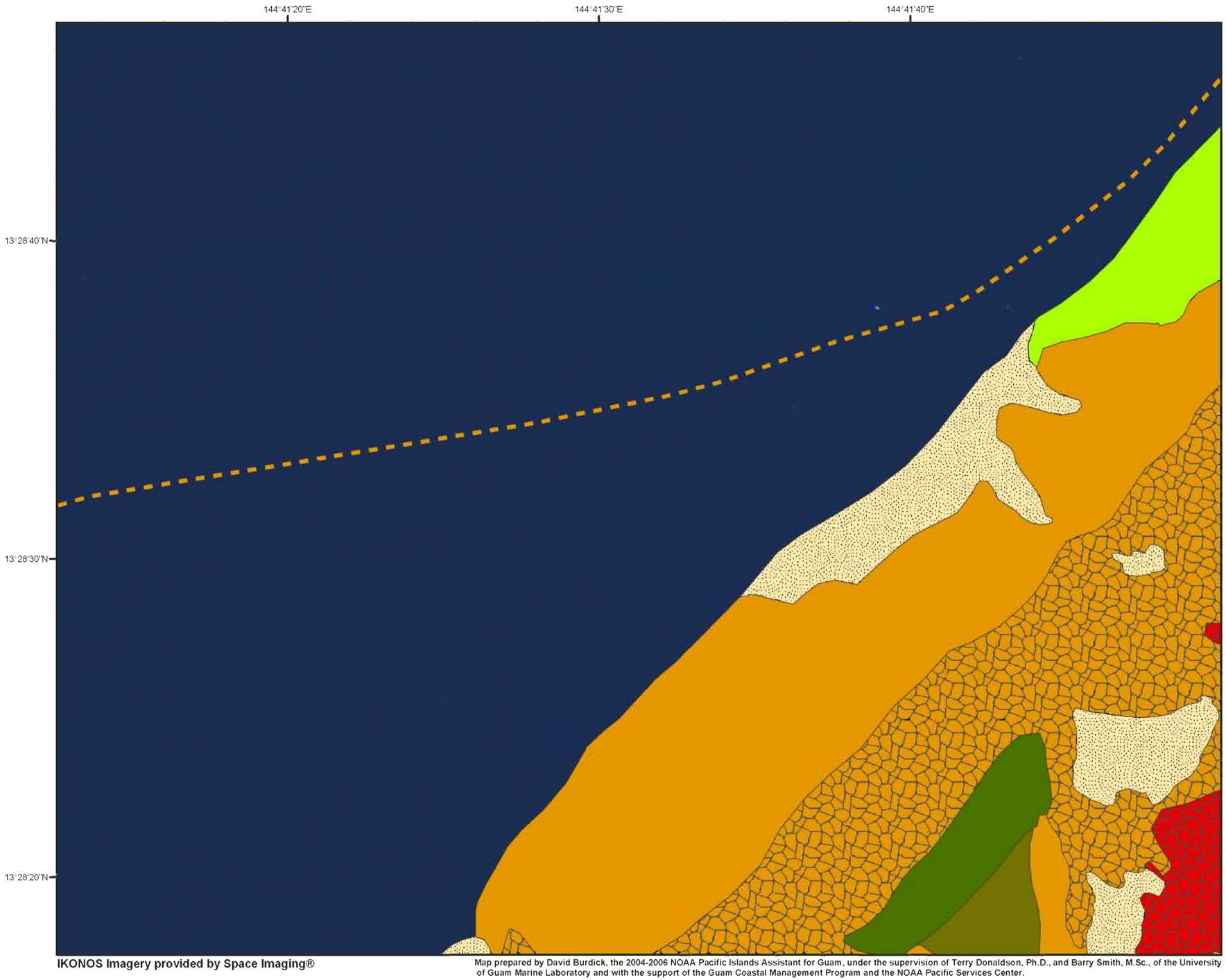
Guam Coastal Management Program

Guam Coastal Atlas ▪ Piti Bomb Holes Marine Preserve ▪ Benthic Habitat Map 1



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Legend

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- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

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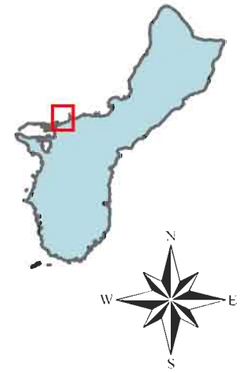
Guam Coastal Atlas ▪ Piti Bomb Holes Marine Preserve ▪ Satellite Image Map 2



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Marine Preserve Boundaries

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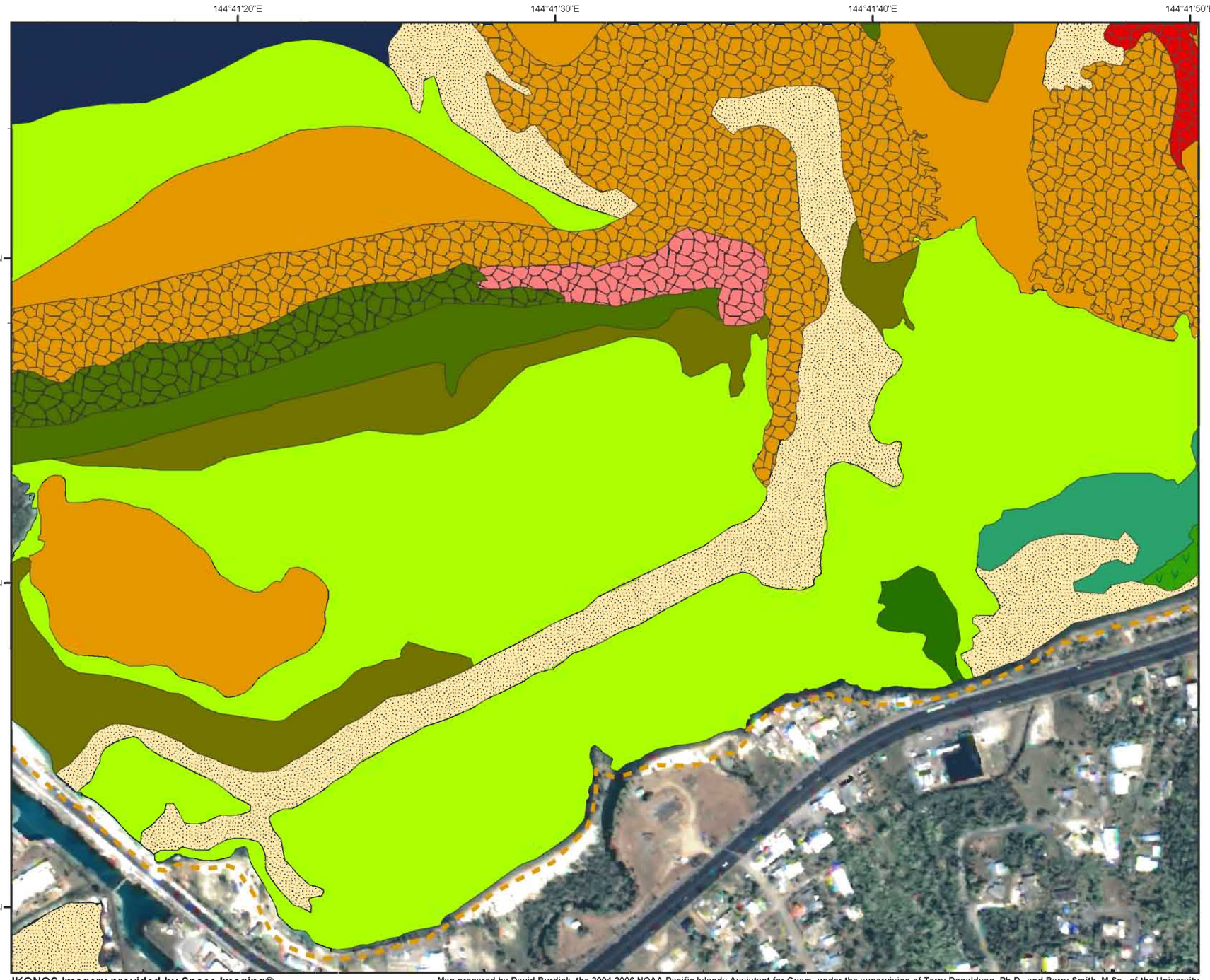
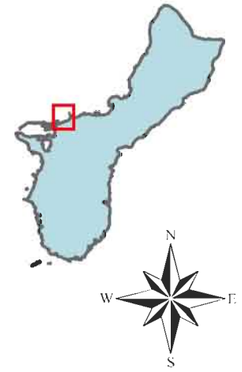
Guam Coastal Atlas ▪ Piti Bomb Holes Marine Preserve ▪ Benthic Habitat Map 2





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Legend

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- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Seagrass 10%-<50%
- Pavement, Turf 50%-<90%
- Sand, Seagrass 50%-<90%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

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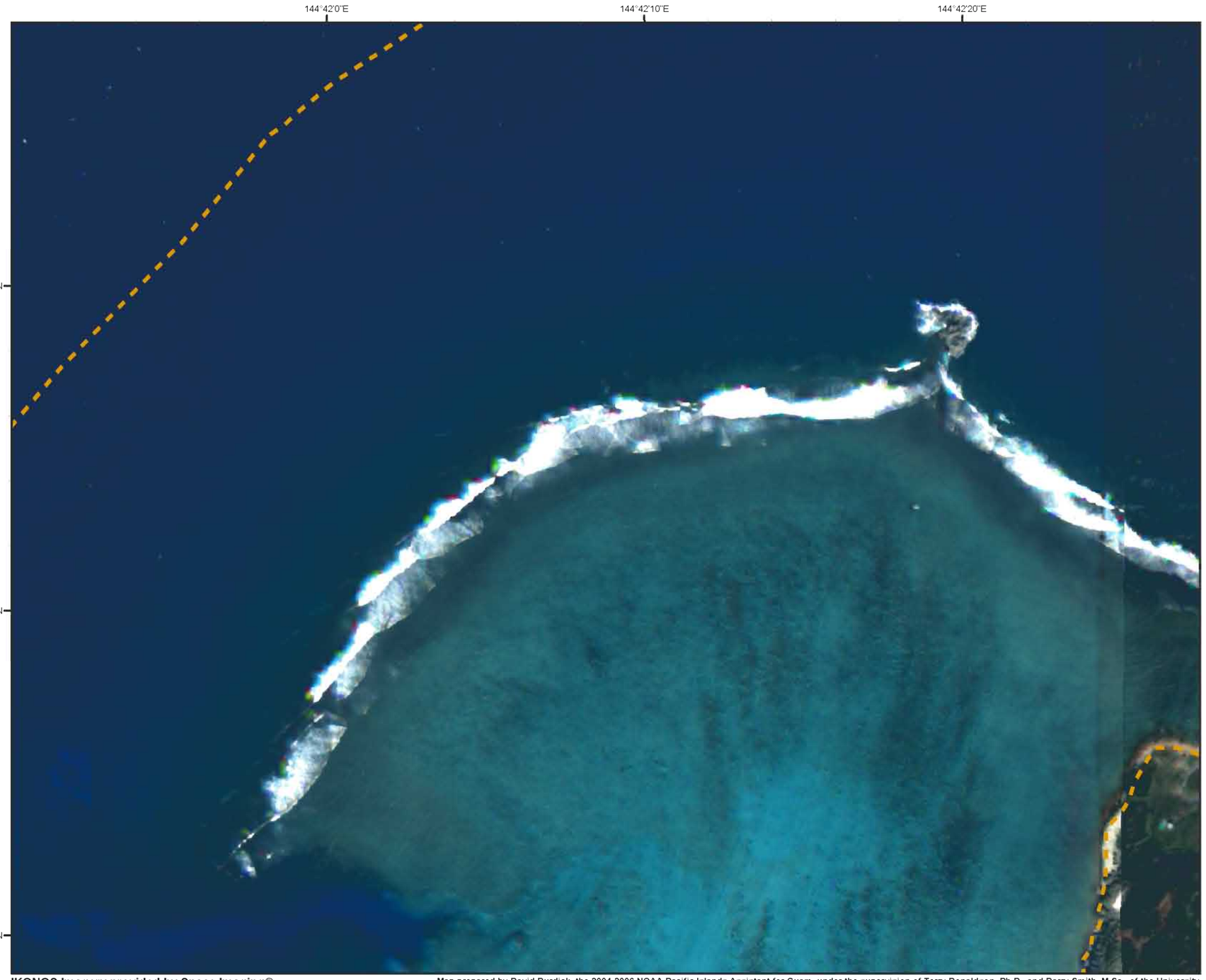
Guam Coastal Atlas ▪ Piti Bomb Holes Marine Preserve ▪ Satellite Image Map 3



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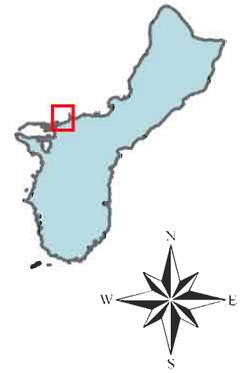

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Marine Preserve Boundaries

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Guam Coastal Management Program

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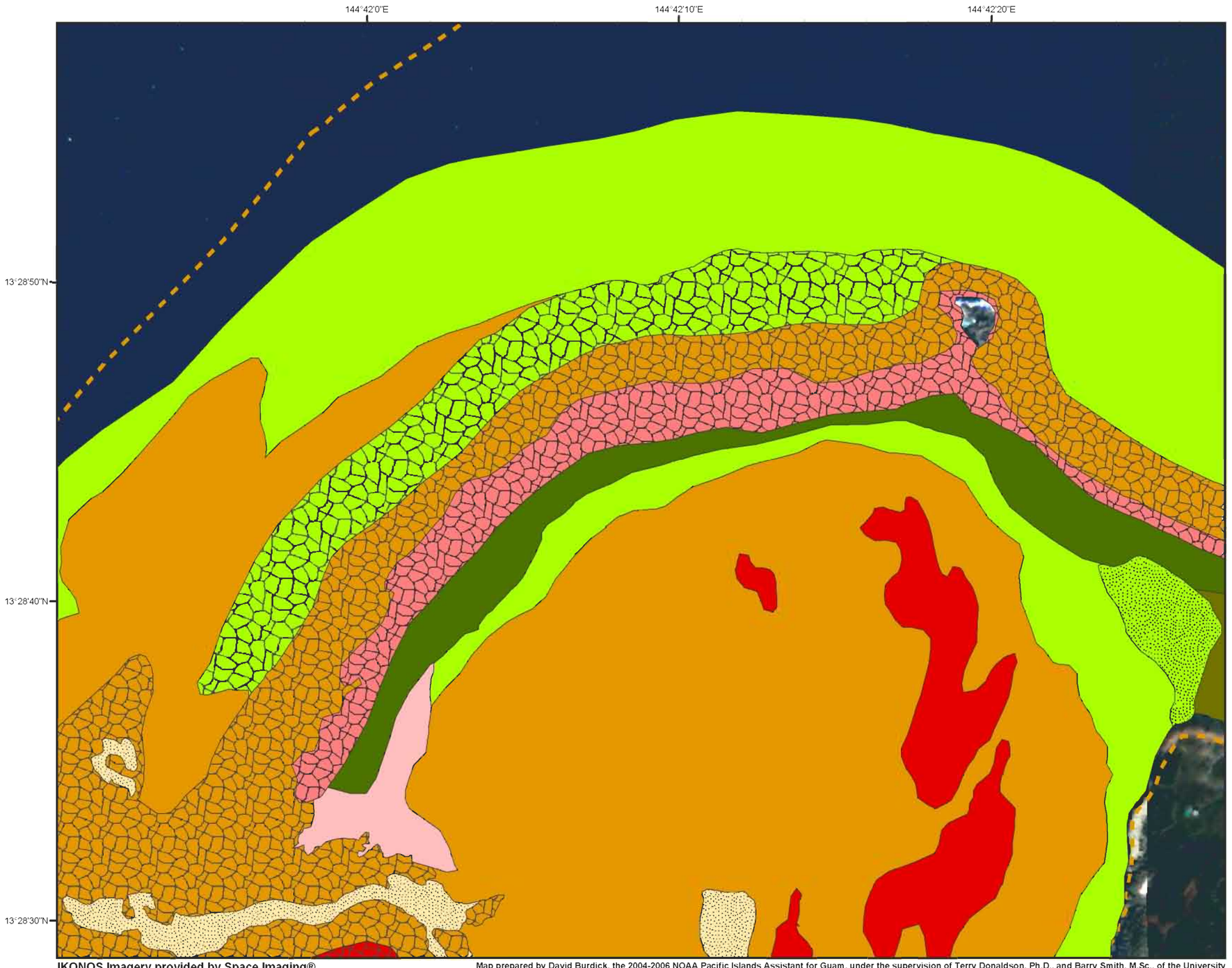

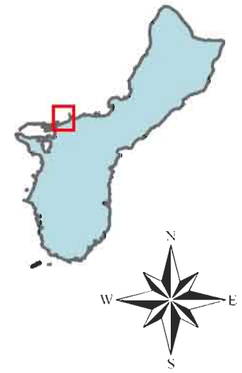

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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Coralline Algae 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
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- Rubble, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

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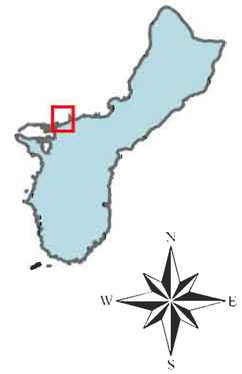
IKONOS Imagery provided by Space Imaging®



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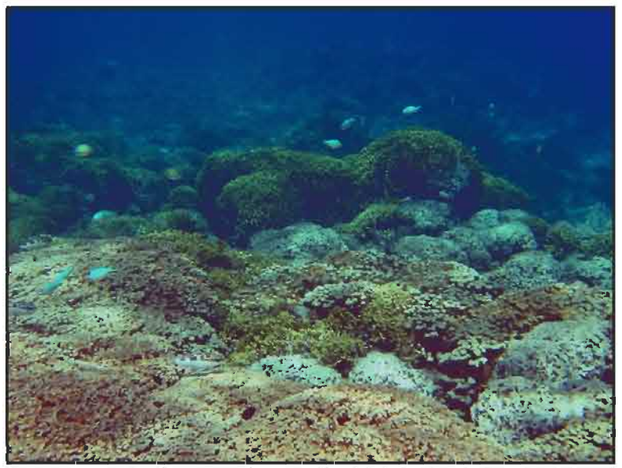
Marine Preserve Boundaries



Porites dominated reef community fringing a "bomb hole." Photo by Dave Burdick.

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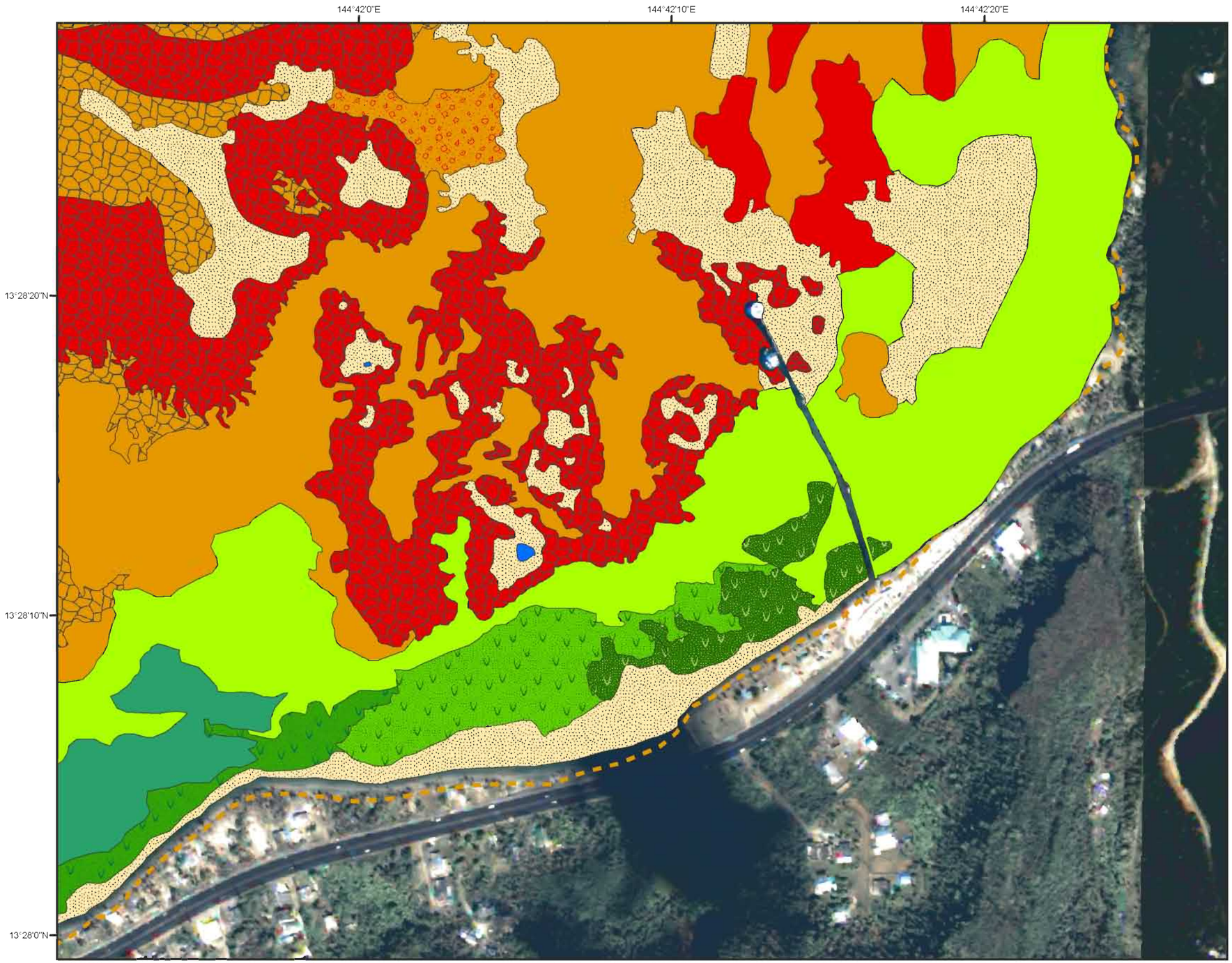
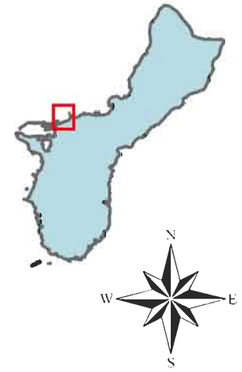
Guam Coastal Management Program

Guam Coastal Atlas ▪ Piti Bomb Holes Marine Preserve ▪ Benthic Habitat Map 4





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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregated Patch Reef, Coral 50%-<90%
- Individual Patch Reef, Coral 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Seagrass 10%-<50%
- Pavement, Turf 50%-<90%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ Sasa Bay Marine Preserve ▪ Satellite Image Map 1

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Legend

Marine Preserve Boundaries

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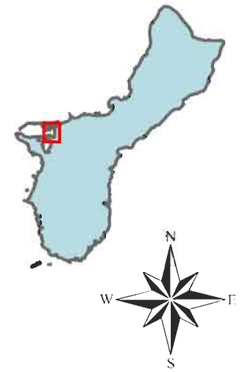
Guam Coastal Management Program

Guam Coastal Atlas ▪ Sasa Bay Marine Preserve ▪ Benthic Habitat Map 1



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Legend

- Marine Preserve Boundaries
- Mud, Emergent Vegetation 90%-100%
- Pavement, Macroalgae 10%-<50%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

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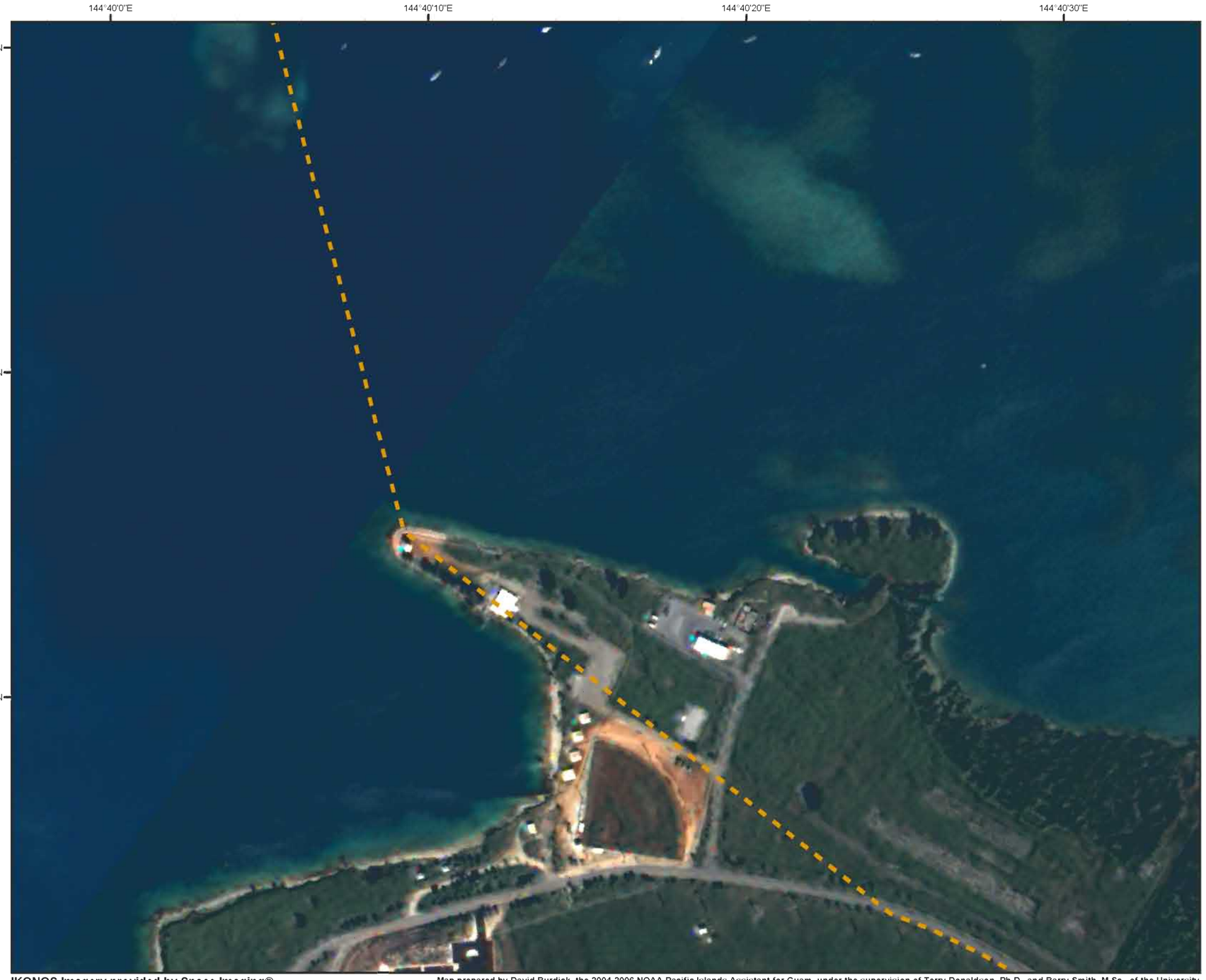
Guam Coastal Atlas ▪ Sasa Bay Marine Preserve ▪ Satellite Image Map 2



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Legend

Marine Preserve Boundaries

IKONOS Imagery provided by Space Imaging®

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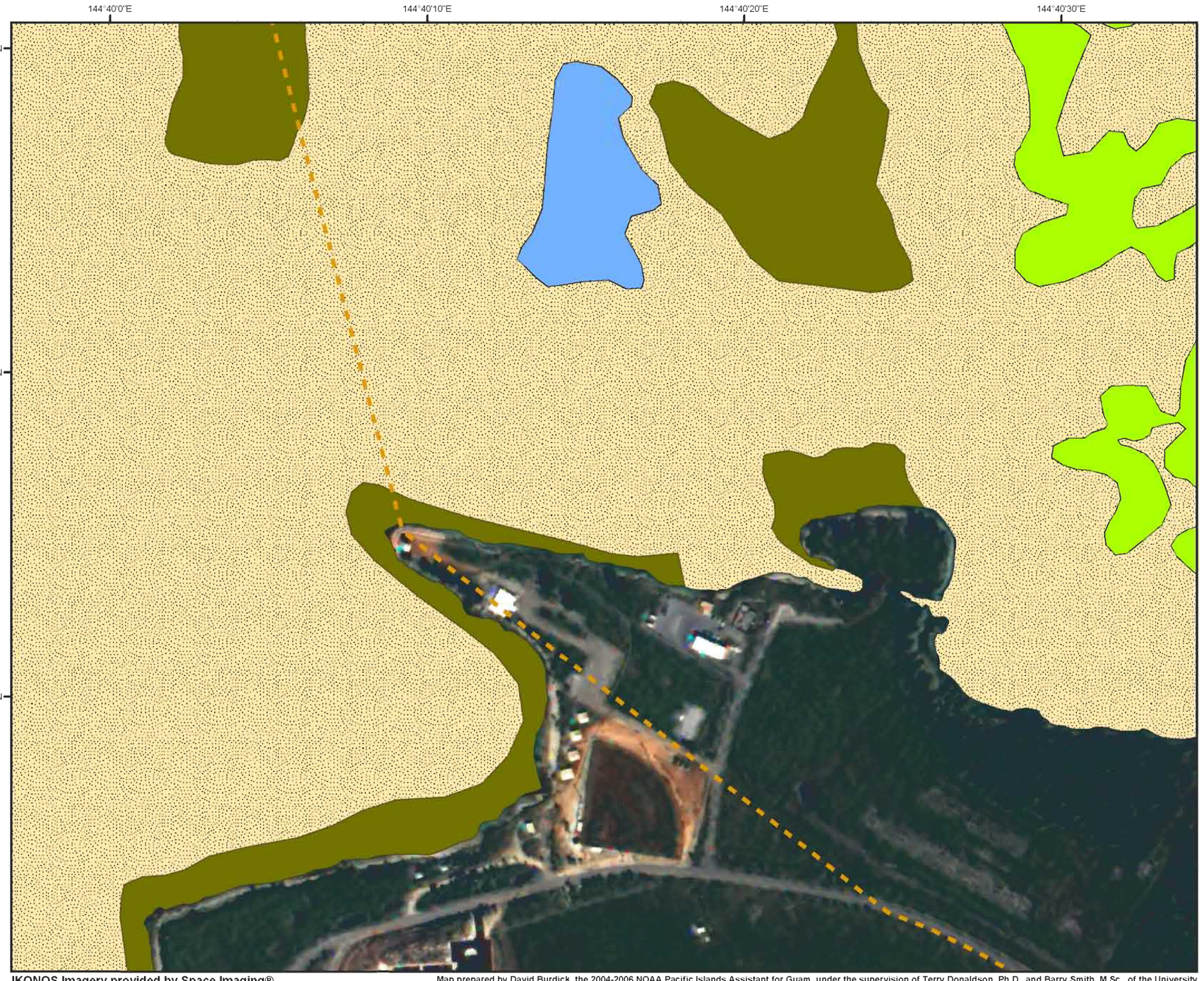
Guam Coastal Management Program

Guam Coastal Atlas ▪ Sasa Bay Marine Preserve ▪ Benthic Habitat Map 2



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Legend

- Marine Preserve Boundaries
- Individual Patch Reef, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

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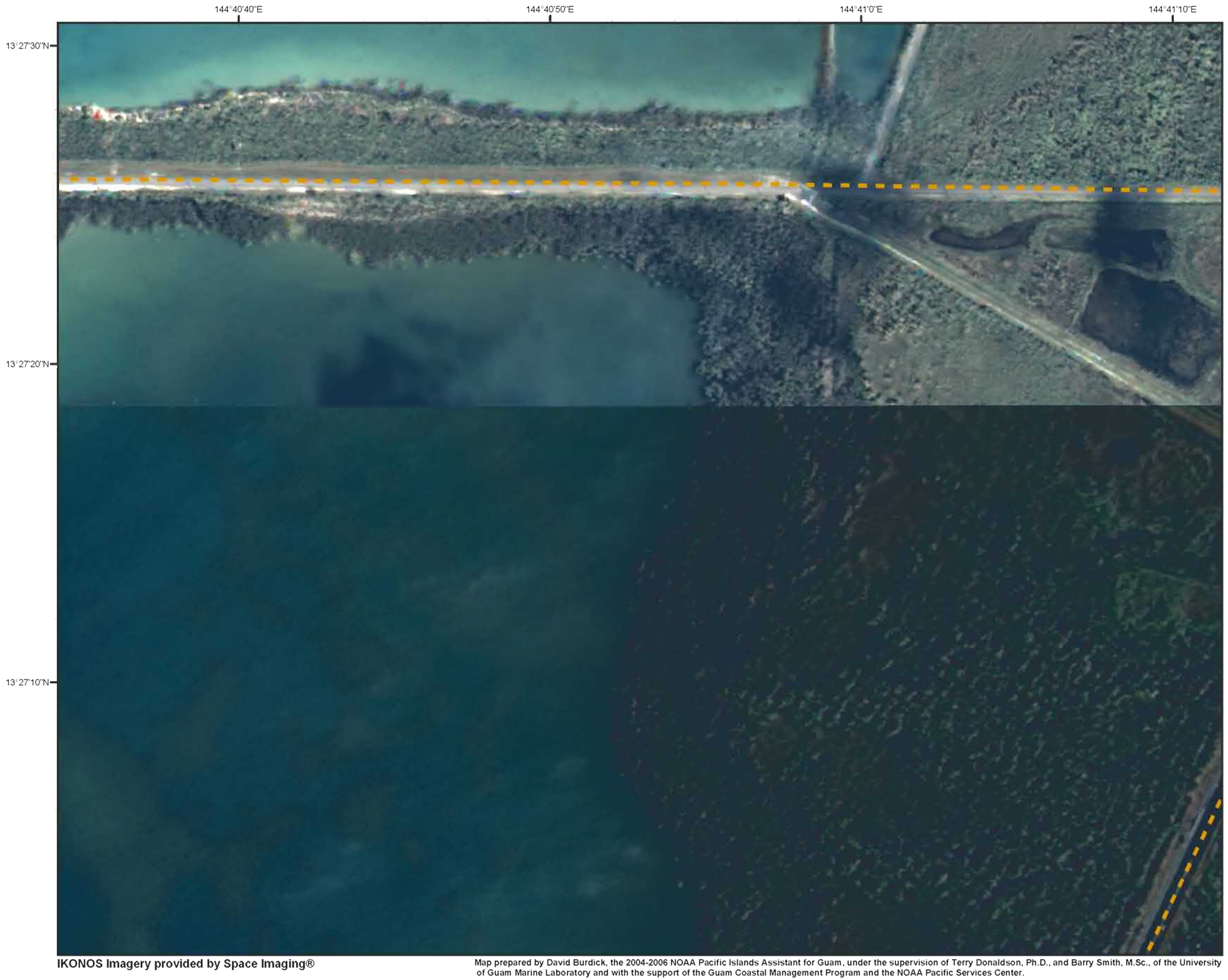
Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ Sasa Bay Marine Preserve ▪ Satellite Image Map 3



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Legend

Marine Preserve Boundaries

A mangrove tree in the Sasa Bay Marine Preserve. Photo by Dave Burdick.

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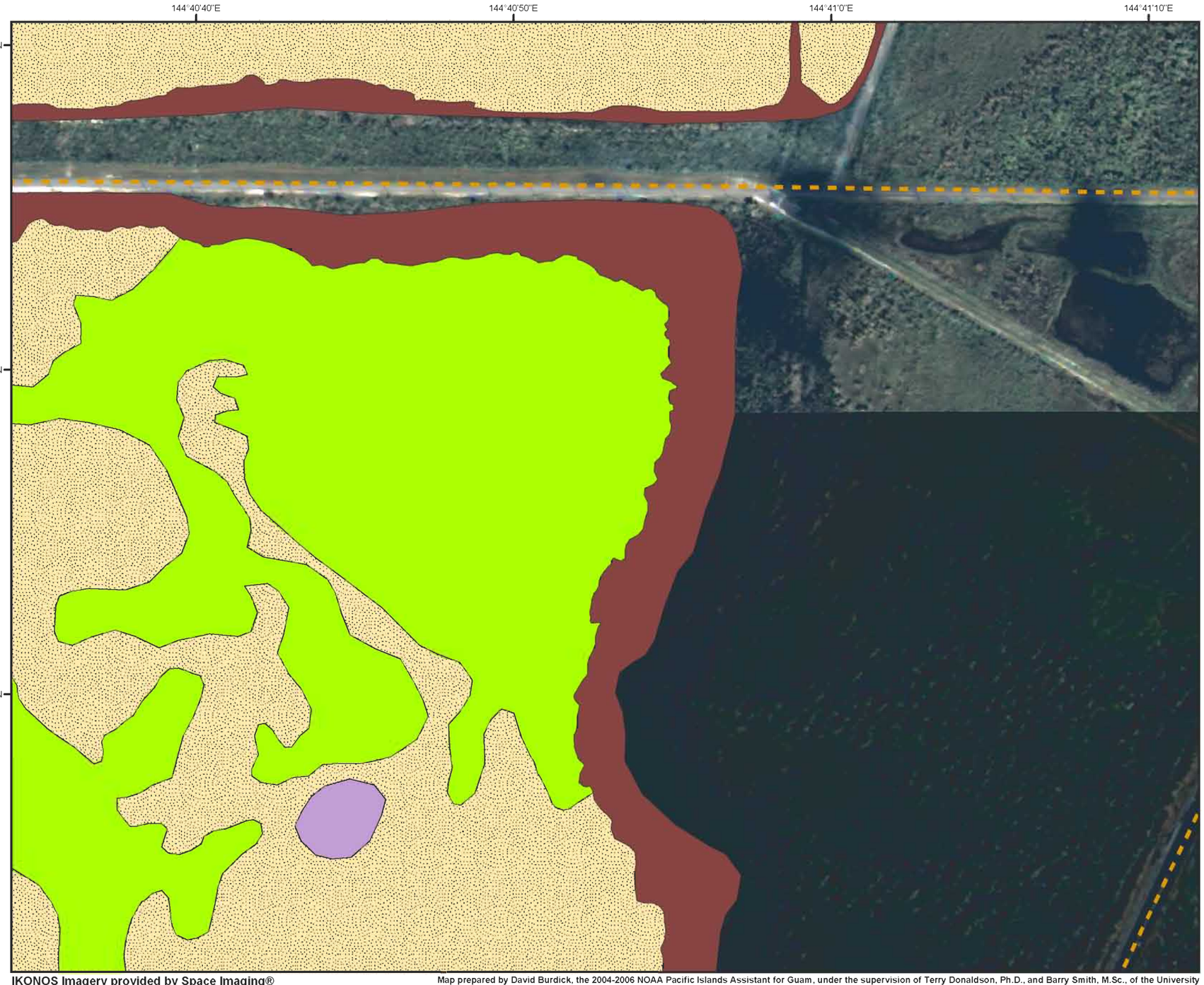
Guam Coastal Atlas ▪ Sasa Bay Marine Preserve ▪ Benthic Habitat Map 3



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1:4,000

Legend

- Marine Preserve Boundaries
- Individual Patch Reef, Turf 50%-<90%
- Mud, Emergent Vegetation 90%-100%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

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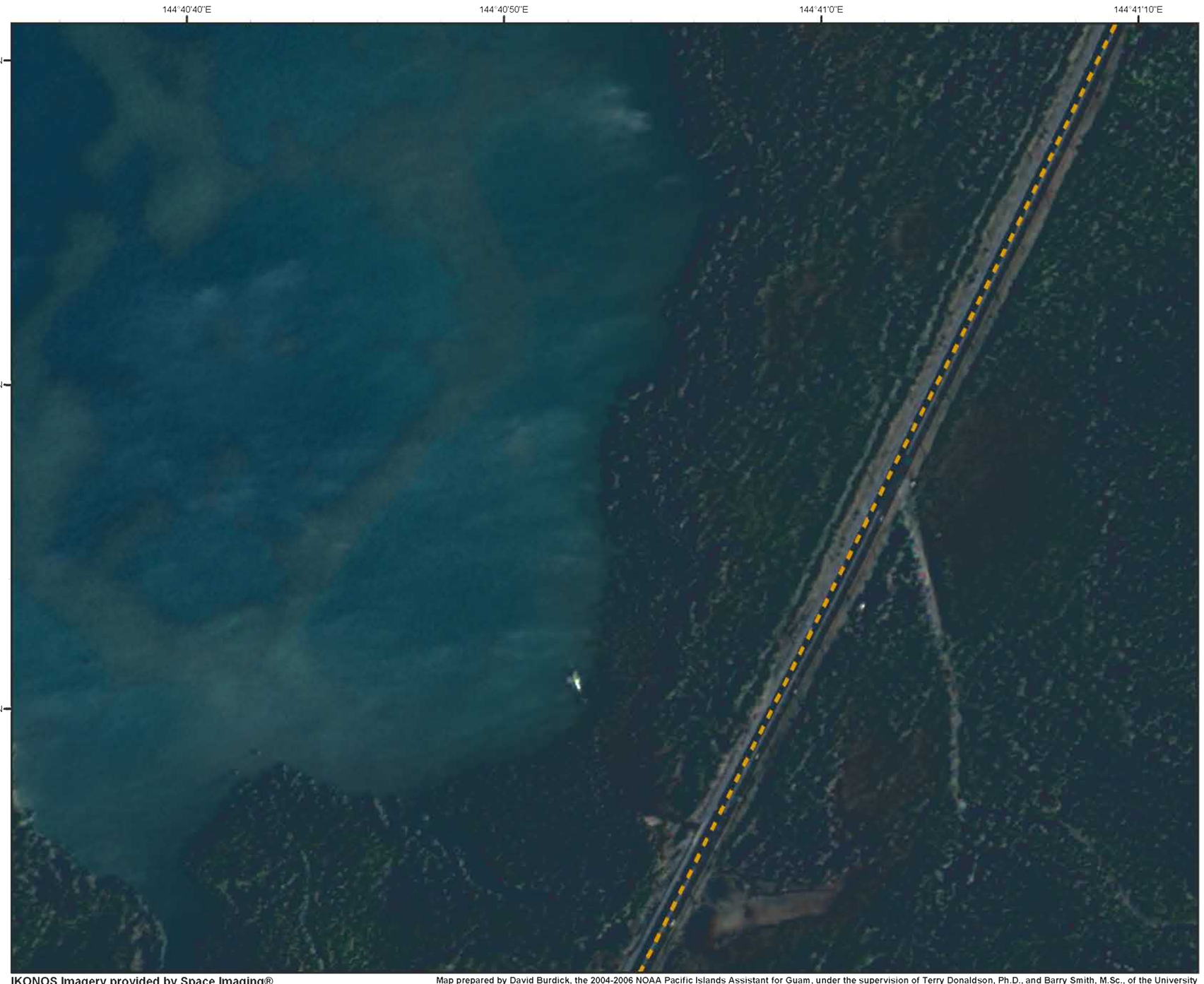
Guam Coastal Atlas ▪ Sasa Bay Marine Preserve ▪ Satellite Image Map 4



IKONOS Imagery provided by Space Imaging®

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Legend

Marine Preserve Boundaries

Wetlands east of the Sasa Bay Marine Preserve (on the east side of Rt. 1). Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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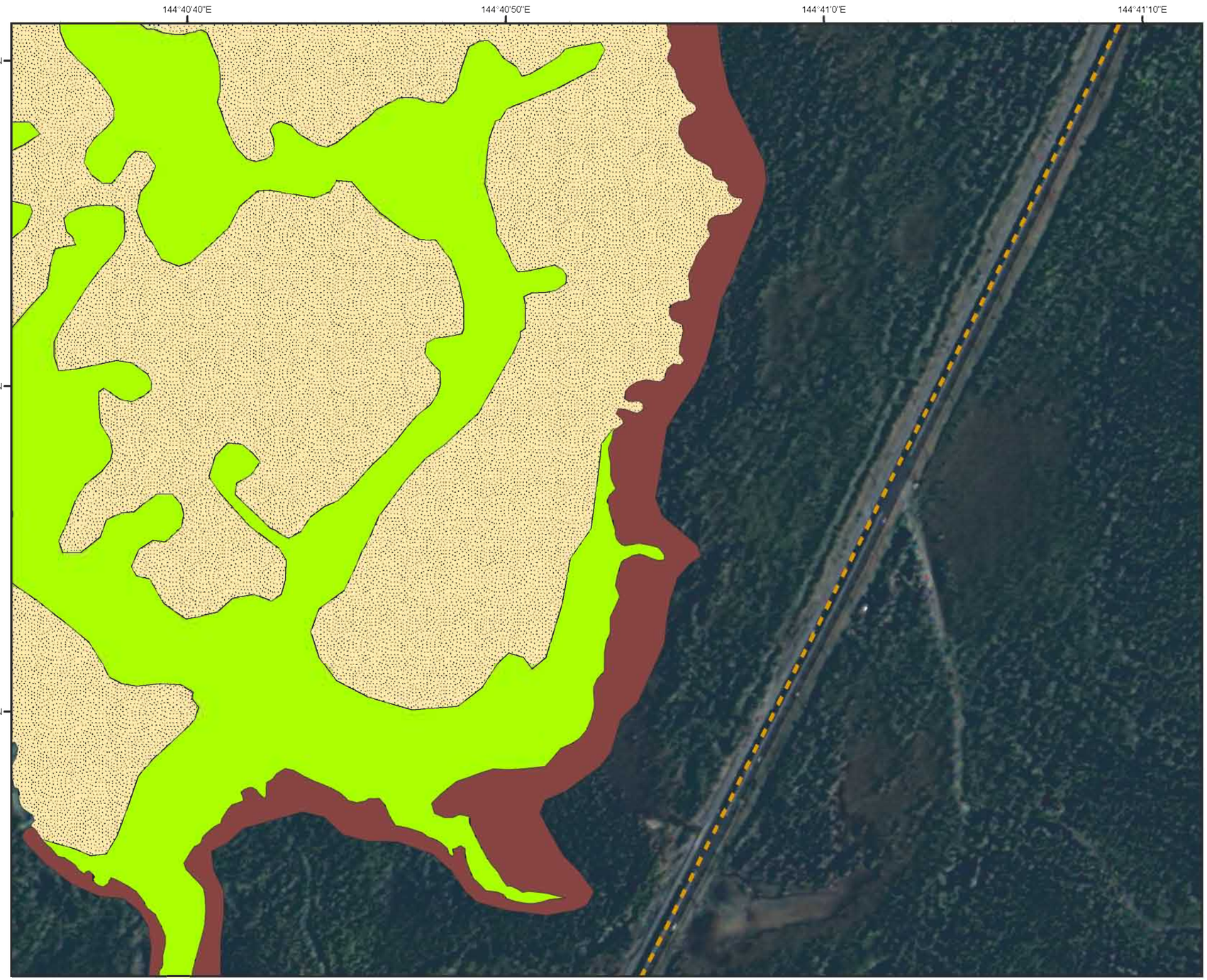
Guam Coastal Atlas ▪ Sasa Bay Marine Preserve ▪ Benthic Habitat Map 4



IKONOS Imagery provided by Space Imaging®

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1:4,000

Legend

- Marine Preserve Boundaries
- Mud, Emergent Vegetation 90%-100%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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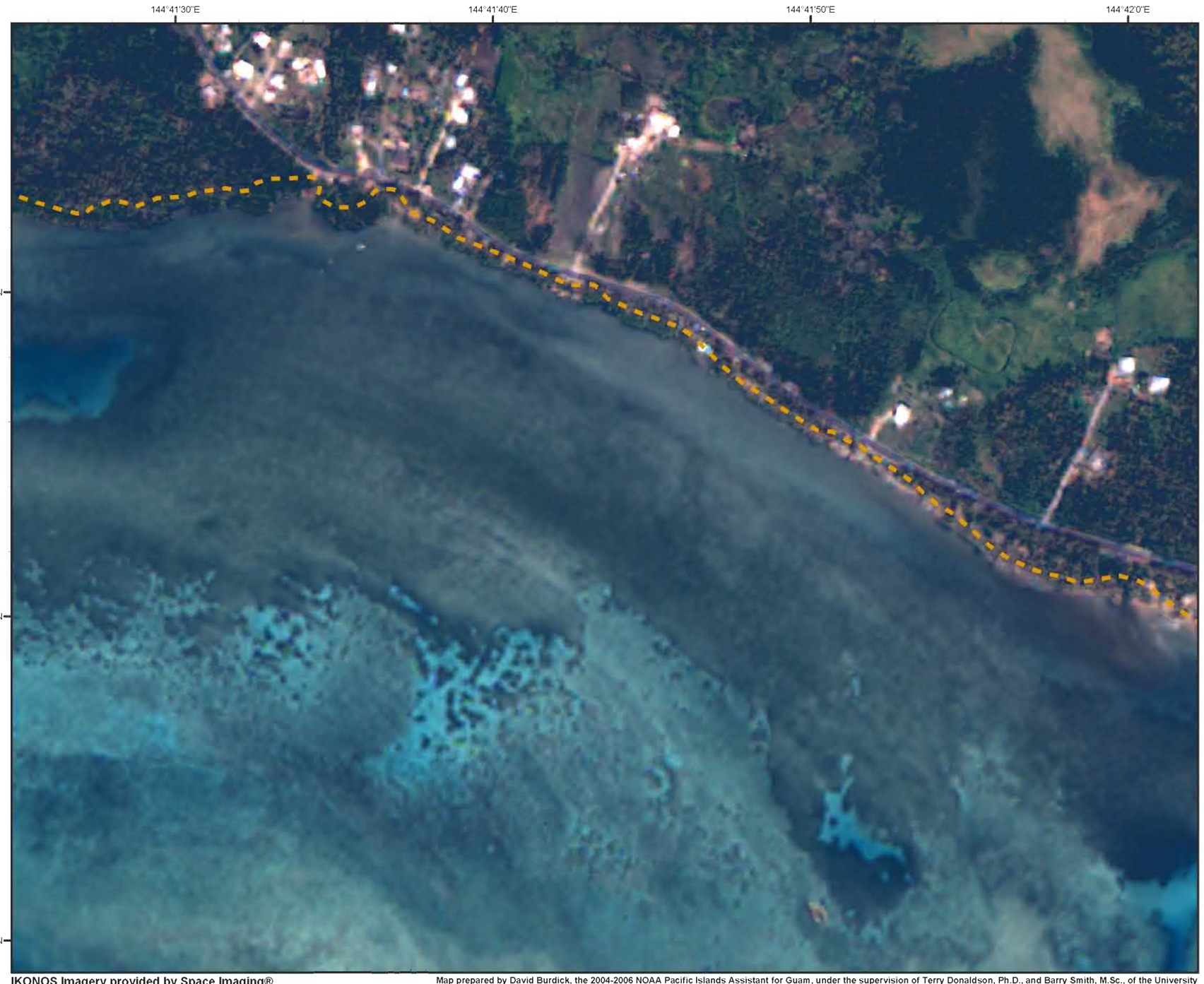
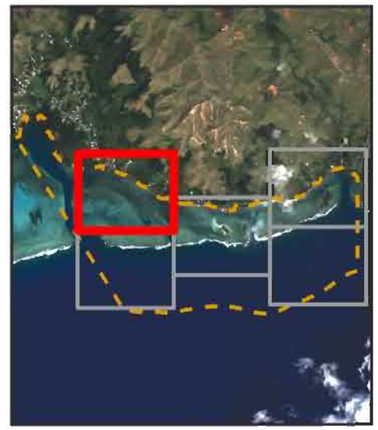
NOAA

Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Satellite Image Map 1





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Legend

Marine Preserve Boundaries

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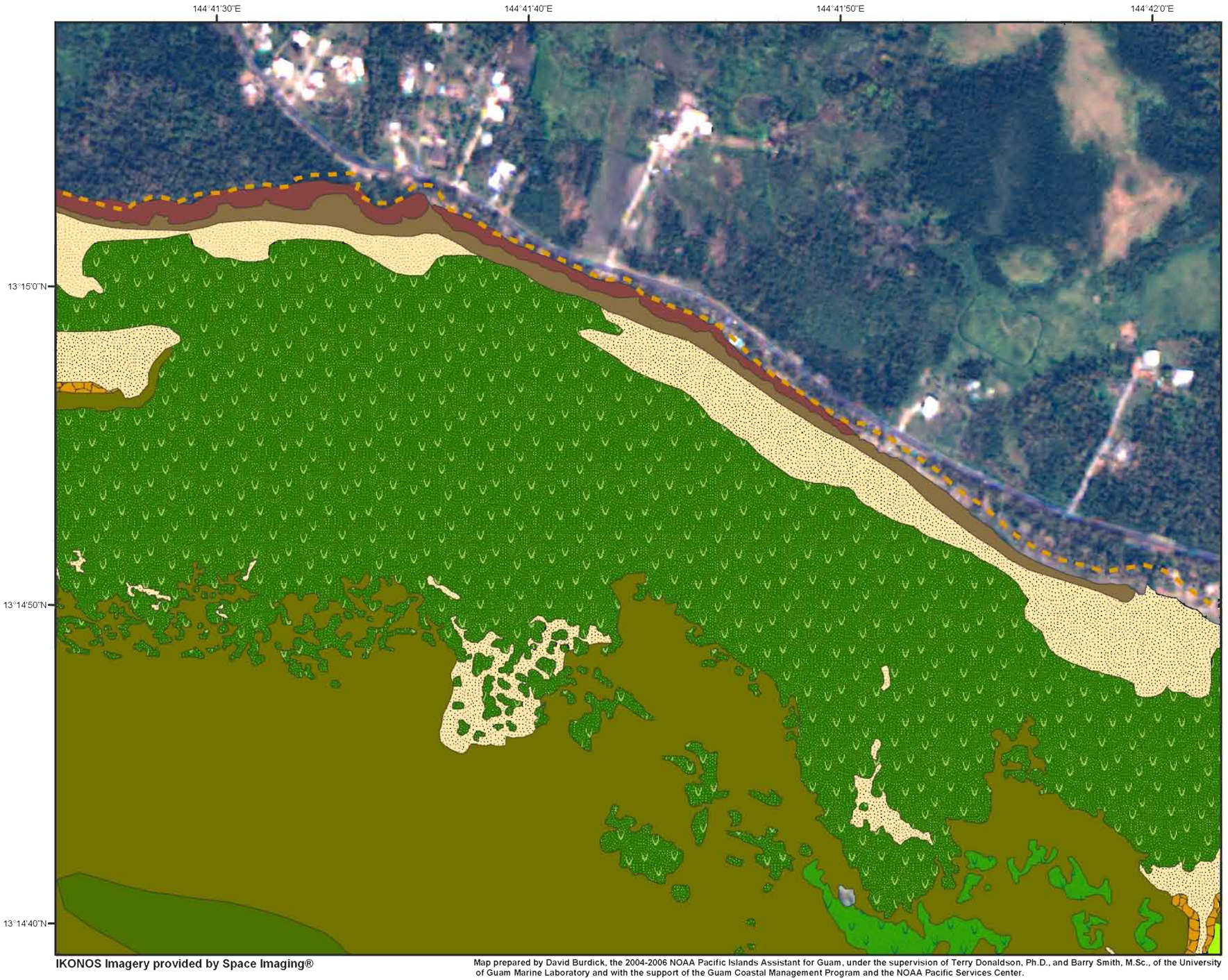
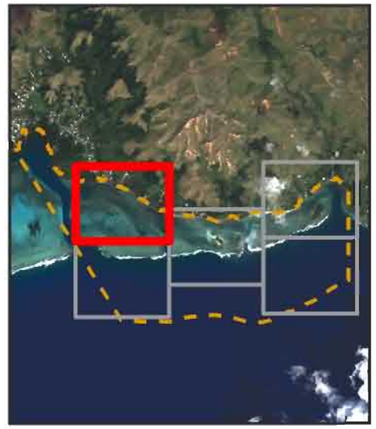
Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Benthic Habitat Map 1





150 75 0 150 Meters

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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Mud, Emergent Vegetation 90%-100%
- Mud, Uncolonized 90%-100%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 50%-<90%
- Sand, Uncolonized 90%-100%

IKONOS Imagery provided by Space Imaging®

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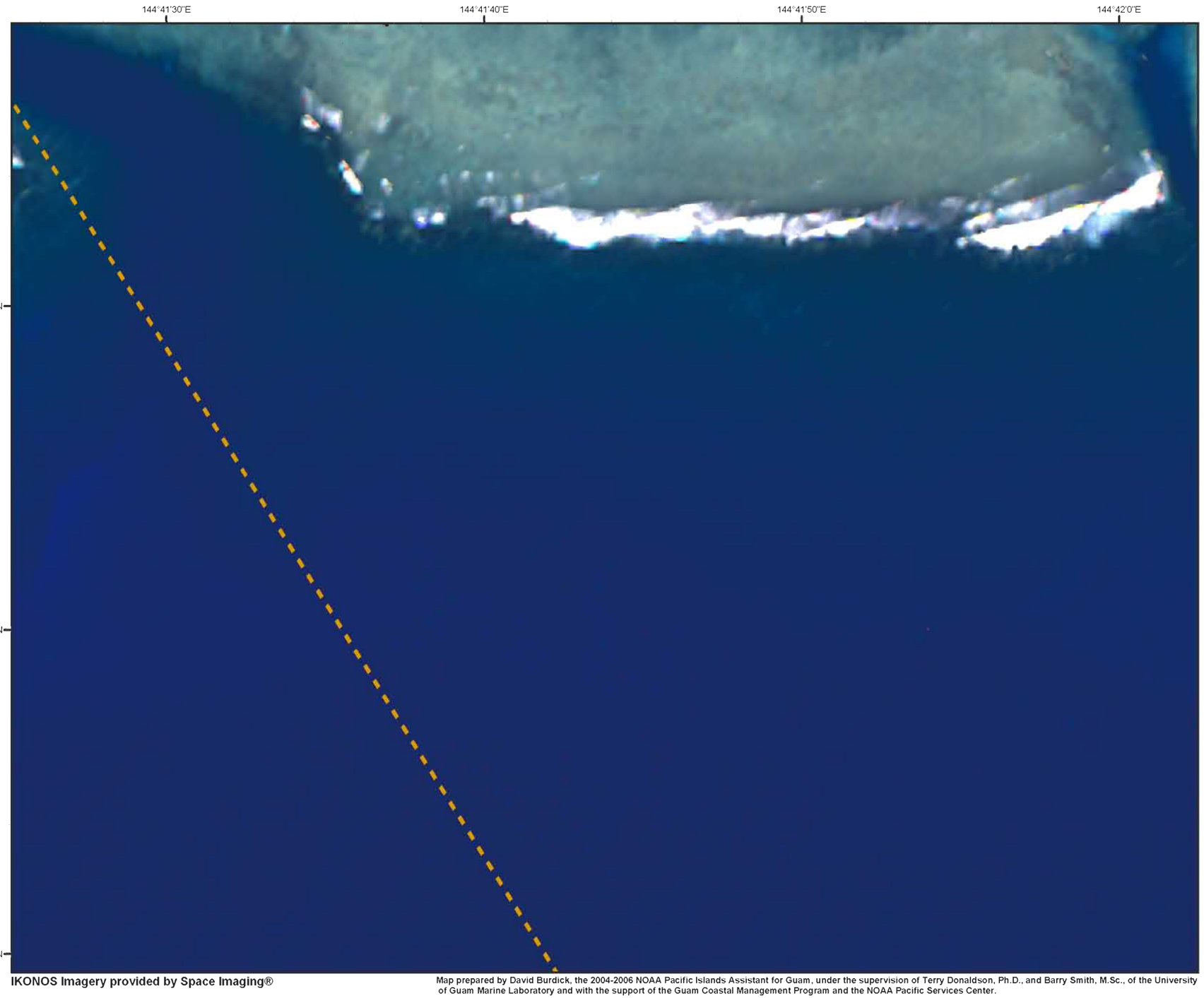
Guam Coastal Management Program

NOAA

Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Satellite Image Map 2



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Legend

Marine Preserve Boundaries

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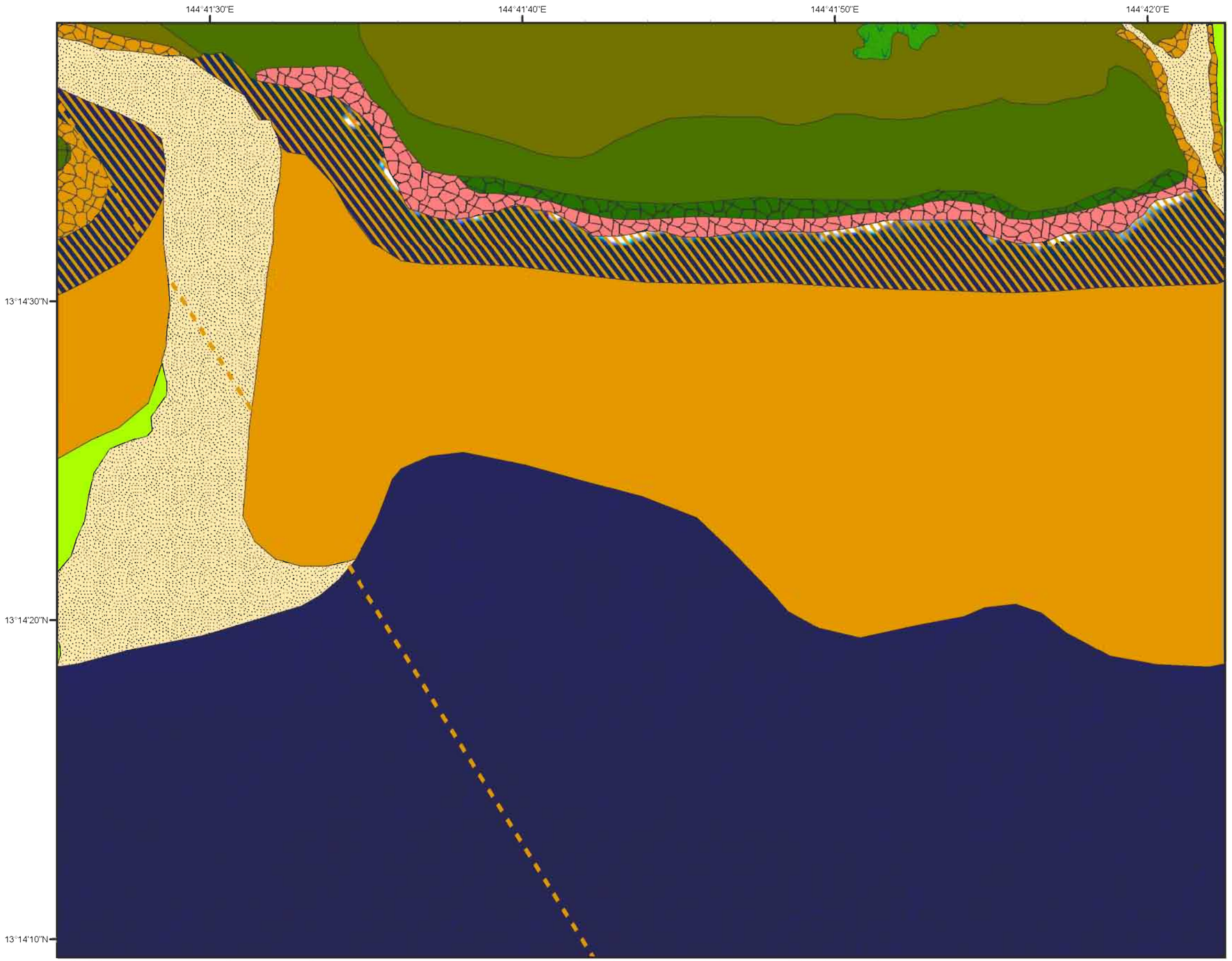
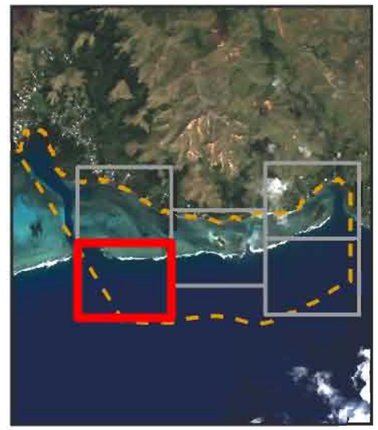
Guam Coastal Management Program

Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Benthic Habitat Map 2





150 75 0 150 Meters

1:4,000

Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Seagrass 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

IKONOS Imagery provided by Space Imaging®

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Satellite Image Map 3

IKONOS Imagery provided by Space Imaging®

150 75 0 150 Meters

1:4,000

Legend

Marine Preserve Boundaries

Lively reef fish community along channel in central portion of the Achang Marine Preserve. Photo by Dave Burdick.

Map prepared by David Burdick, the 2004-2006 NOAA Pacific Islands Assistant for Guam, under the supervision of Terry Donaldson, Ph.D., and Barry Smith, M.Sc., of the University of Guam Marine Laboratory and with the support of the Guam Coastal Management Program and the NOAA Pacific Services Center.

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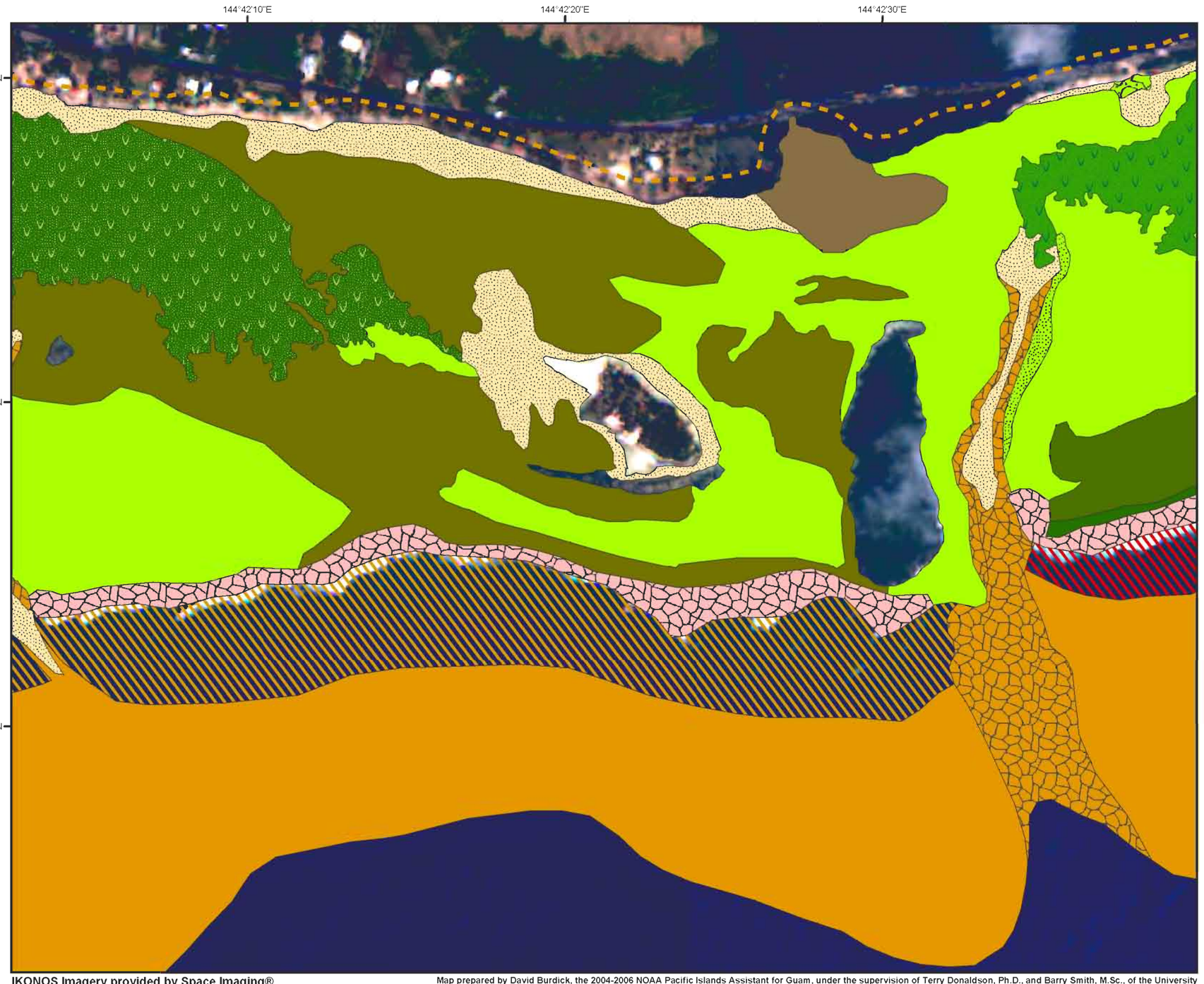
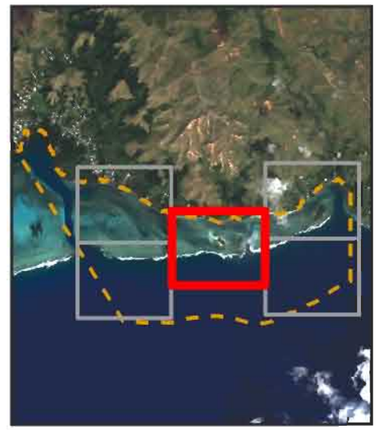
Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Benthic Habitat Map 3





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1:4,000

Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 10%-<50%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Turf 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%
- Spur and Groove, Coral 50%-<90%

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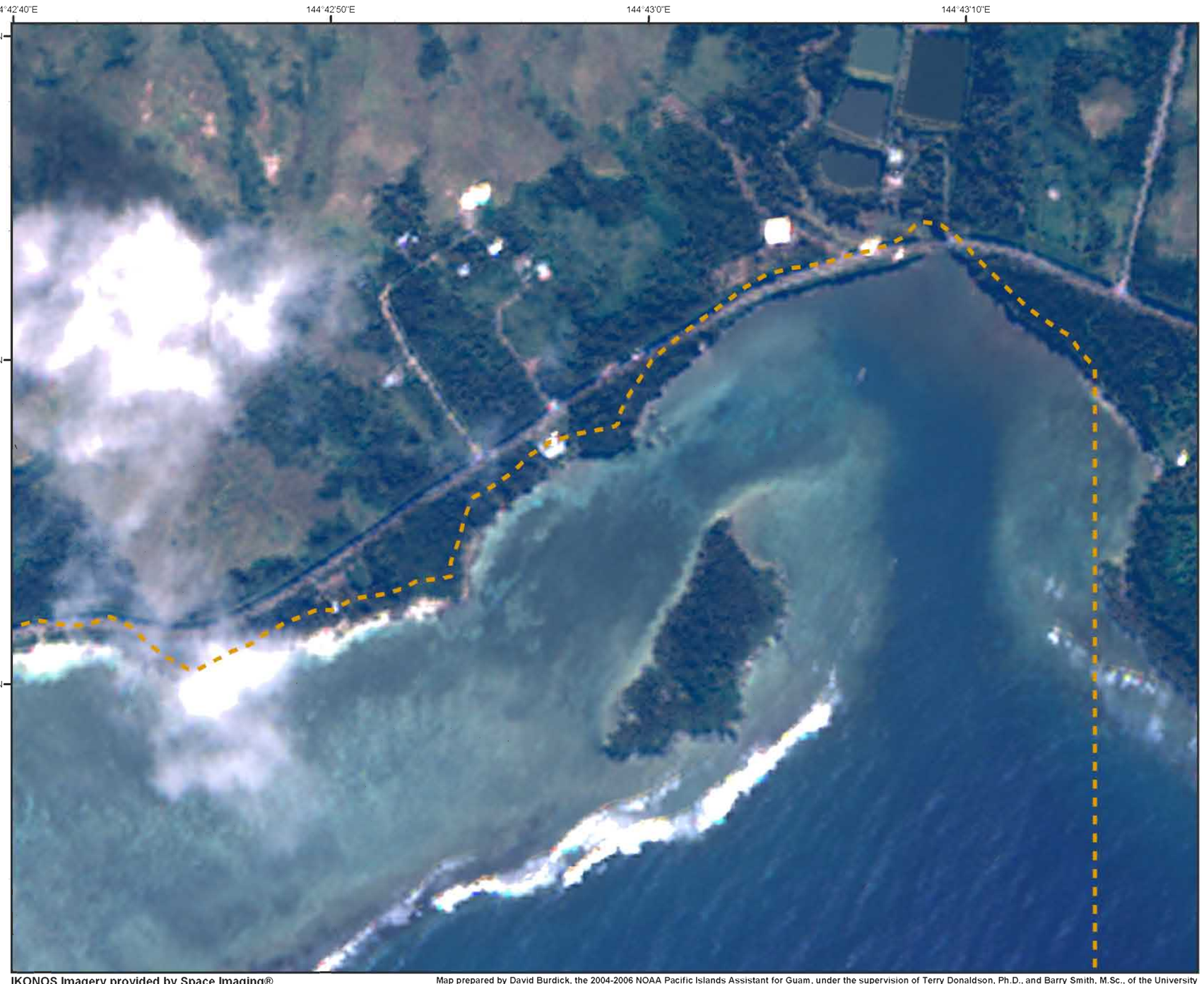
Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Satellite Image Map 4



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Legend

Marine Preserve Boundaries

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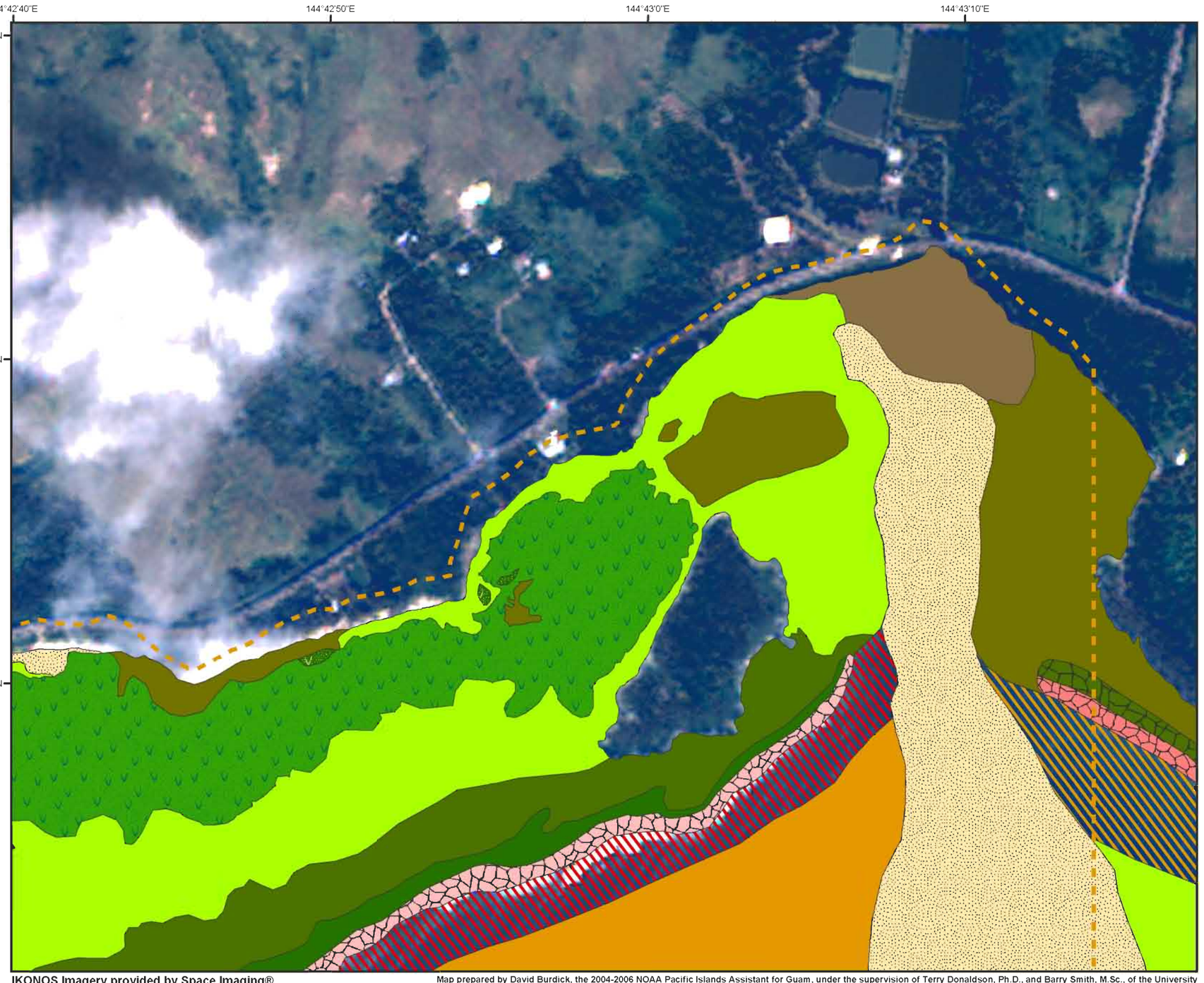
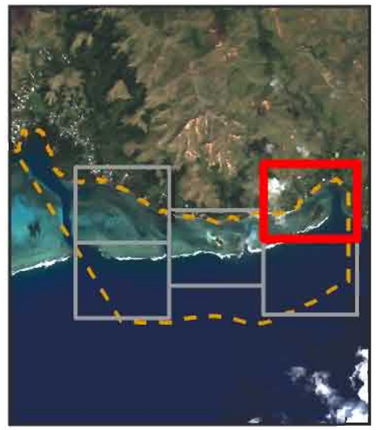
Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Benthic Habitat Map 4





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1:4,000

Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coralline Algae 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%
- Spur and Groove, Coral 50%-<90%

IKONOS Imagery provided by Space Imaging®

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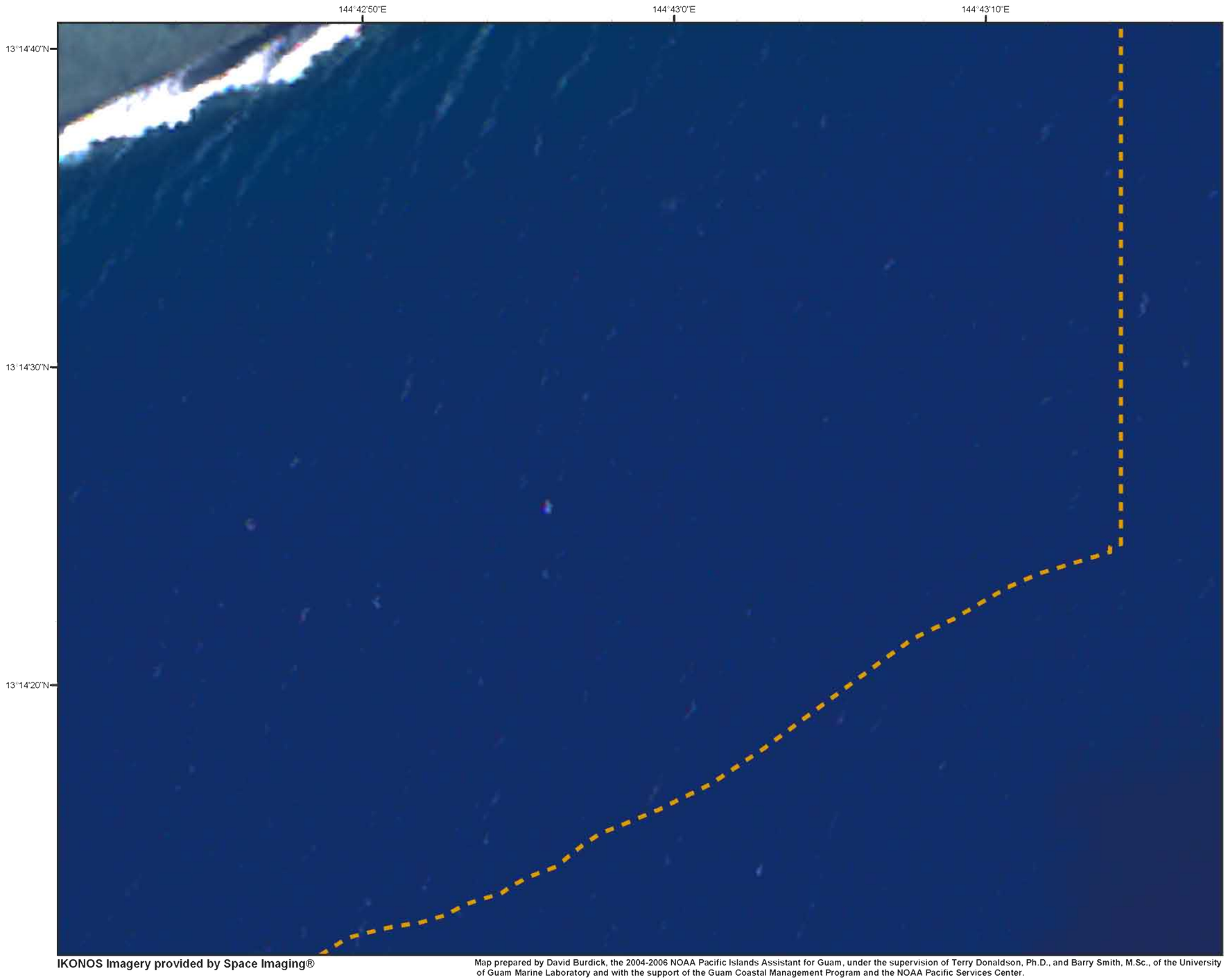
Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Satellite Image Map 5



IKONOS Imagery provided by Space Imaging®

150 75 0 150 Meters

1:4,000

Legend

Marine Preserve Boundaries

Coral community on fore-reef slope of the central portion of Achang Marine Preserve. Photo by Dave Burdick.

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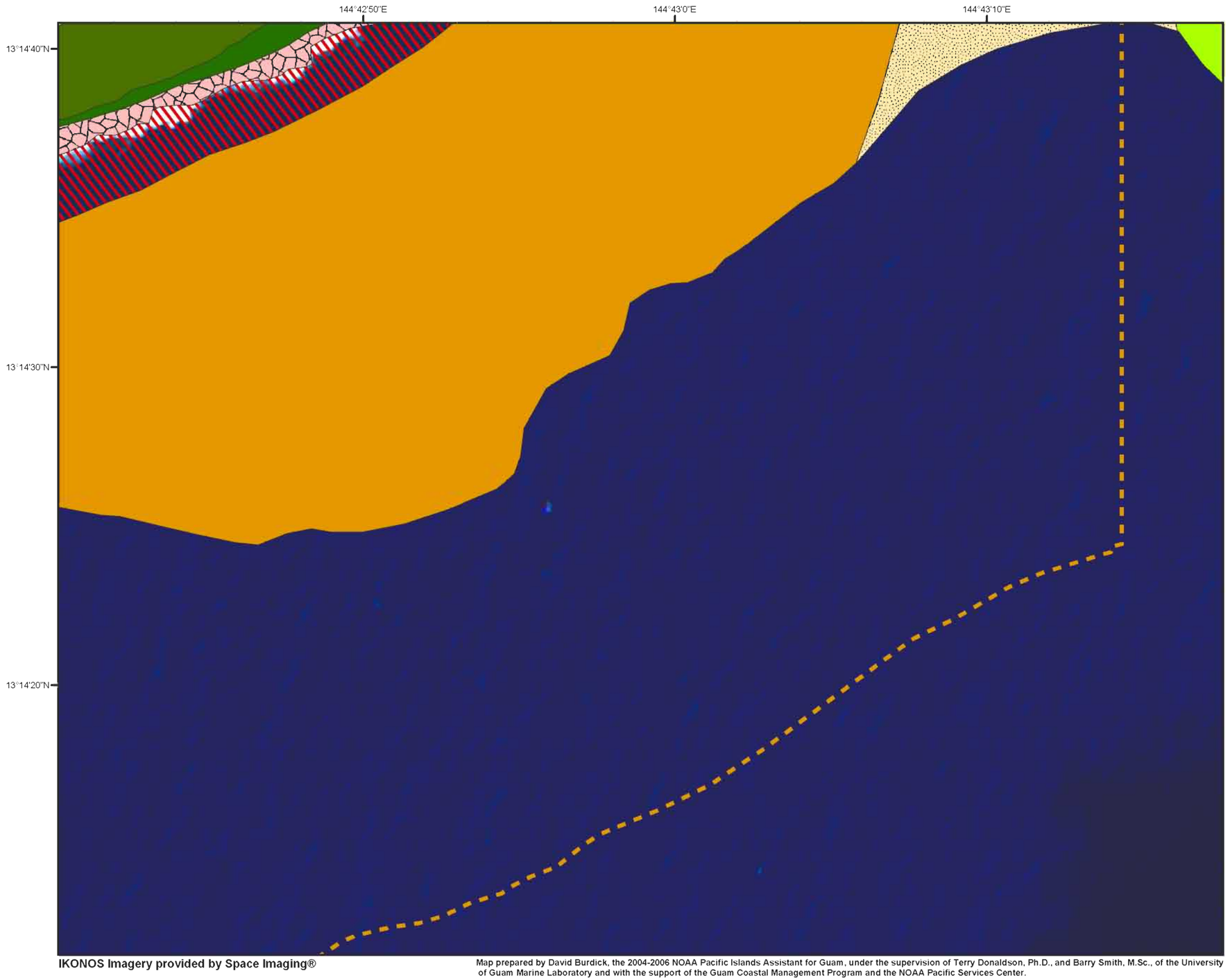
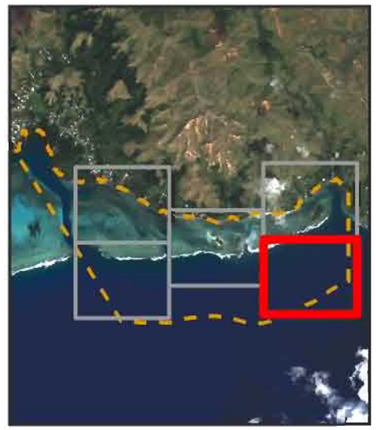
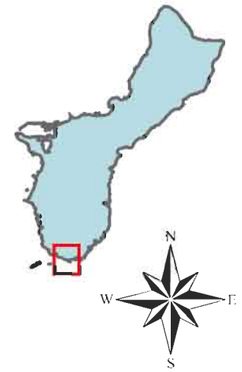
Guam Coastal Atlas ▪ Achang Reef Flat Marine Preserve ▪ Benthic Habitat Map 5







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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coralline Algae 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 50%-<90%

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Guam Coastal Atlas ▪ 1:4000 Scale and 1:8000 Scale Focus Area Maps ▪ Map Index

The following pages contain detailed maps of three areas designated as "focus" areas: East Agana Bay, Pago Bay, and Cocos Lagoon. Similar to the detailed maps provided for the four marine protected areas, the focus area maps were produced at 1:4000 scale and 1:8000 scale (for Cocos Lagoon) and allow the user to discriminate fine-scale features not clearly visible in the 1:15,000 scale maps. Each focus area was divided arbitrarily into equal sections, with each section being represented by two separate maps: the first map displaying only the 2001-2004 IKONOS satellite image mosaic, and the second map displaying the benthic habitat data overlaid on the satellite imagery.

These areas are referred to as "focus areas" only for the purposes of this atlas; this reference is not related to any current Government of Guam or U.S. federal policy or policy intent. These areas were selected because of their interest to researchers, recreational users, and other users. The inclusion of these coastal areas and the omission of others from the "focus areas" section of the Guam Coastal Atlas was not meant to imply any order of importance for parts of Guam's coastline. Detailed maps of additional focus areas, and ultimately the entire length of Guam's coastline, may become available in the future on the Guam Coastal Atlas web site (http://www.uog.edu/marinelab/coastal.atlas/) in the future.

Map		Page
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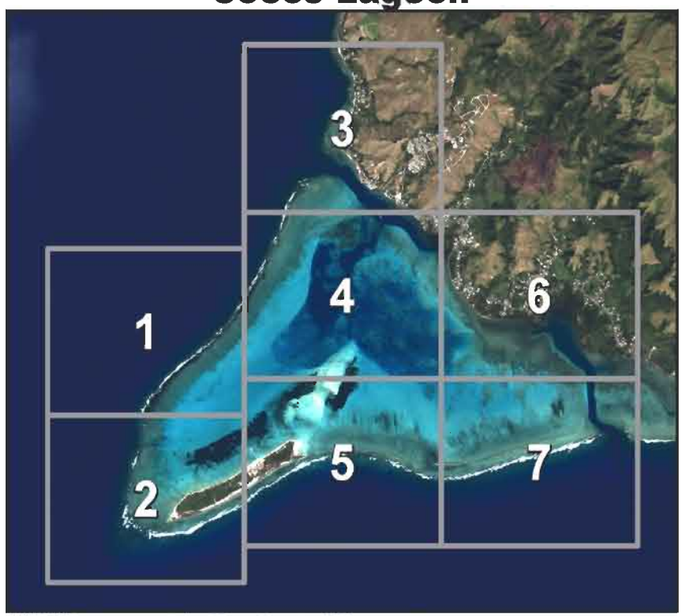
Cocos Lagoon



IKONOS imagery copyright of Space Imaging LLC

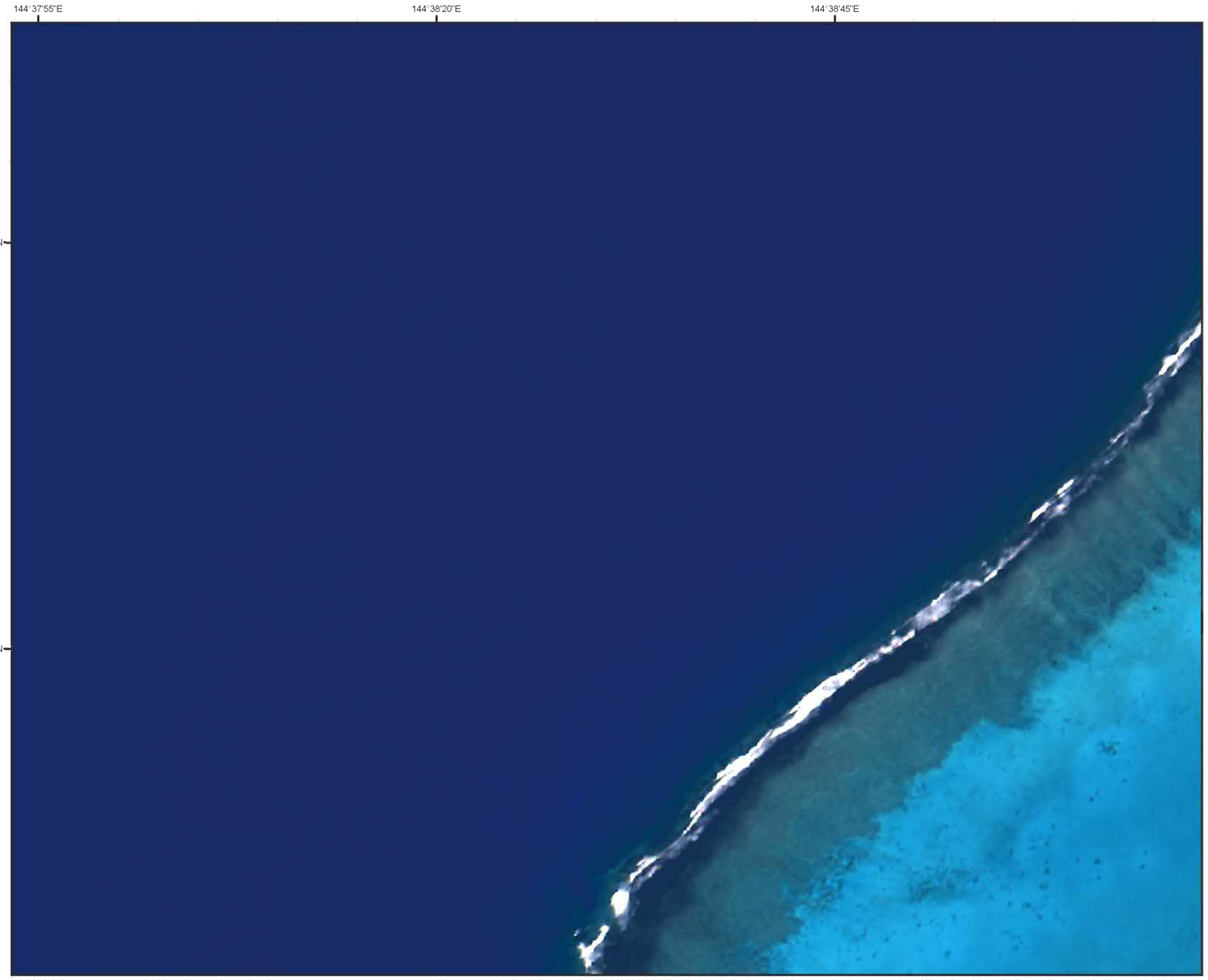
East Agana Bay

IKONOS imagery copyright of Space Imaging LLC

Pago Bay

IKONOS imagery copyright of Space Imaging LLC

Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Satellite Image Map 1



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Shallow fore reef community of western Cocos Lagoon. Photo by Dave Burdick.

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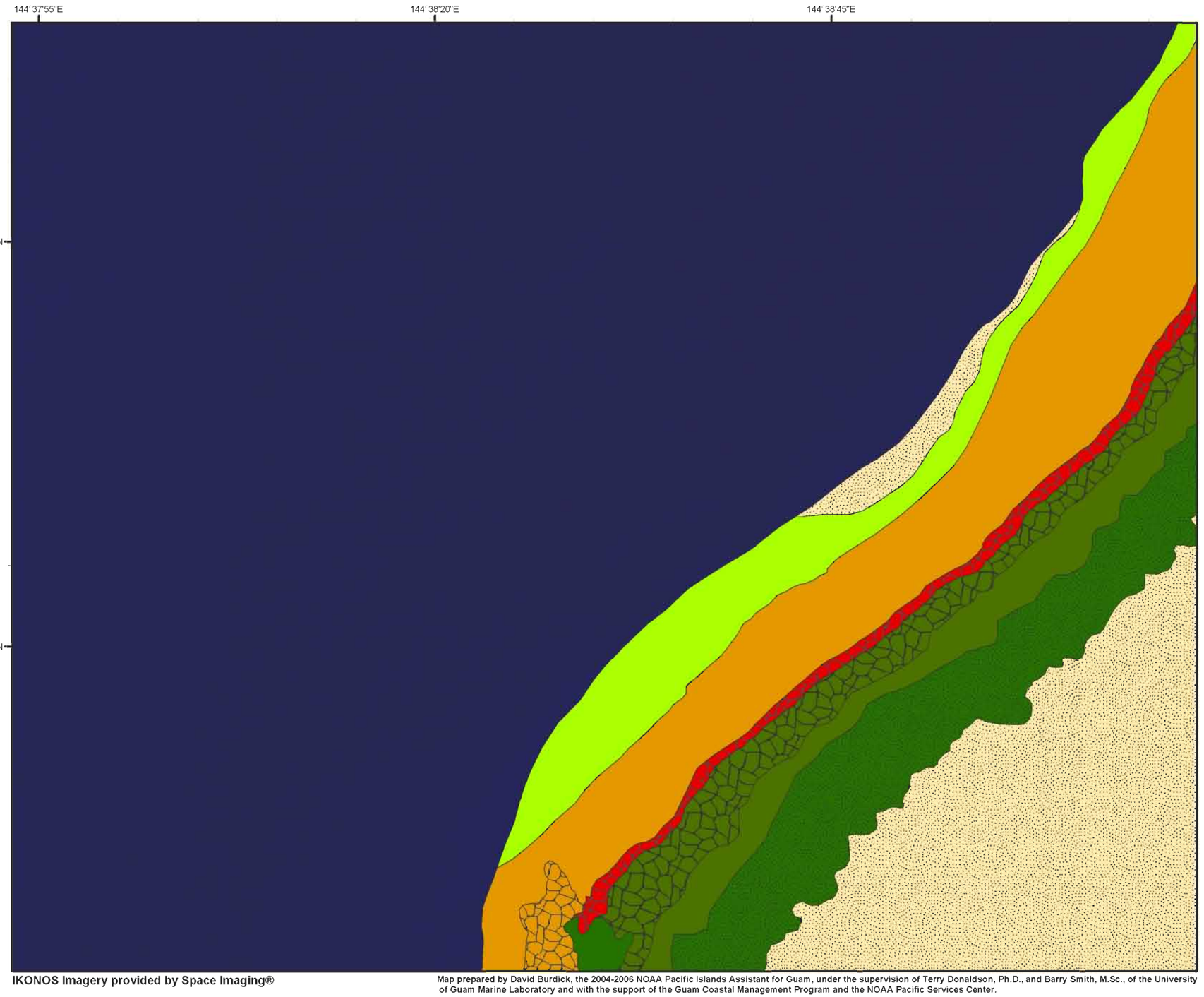
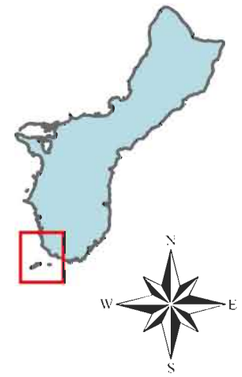
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Benthic Habitat Map 1





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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 50%-<90%
- Sand, Uncolonized 90%-100%

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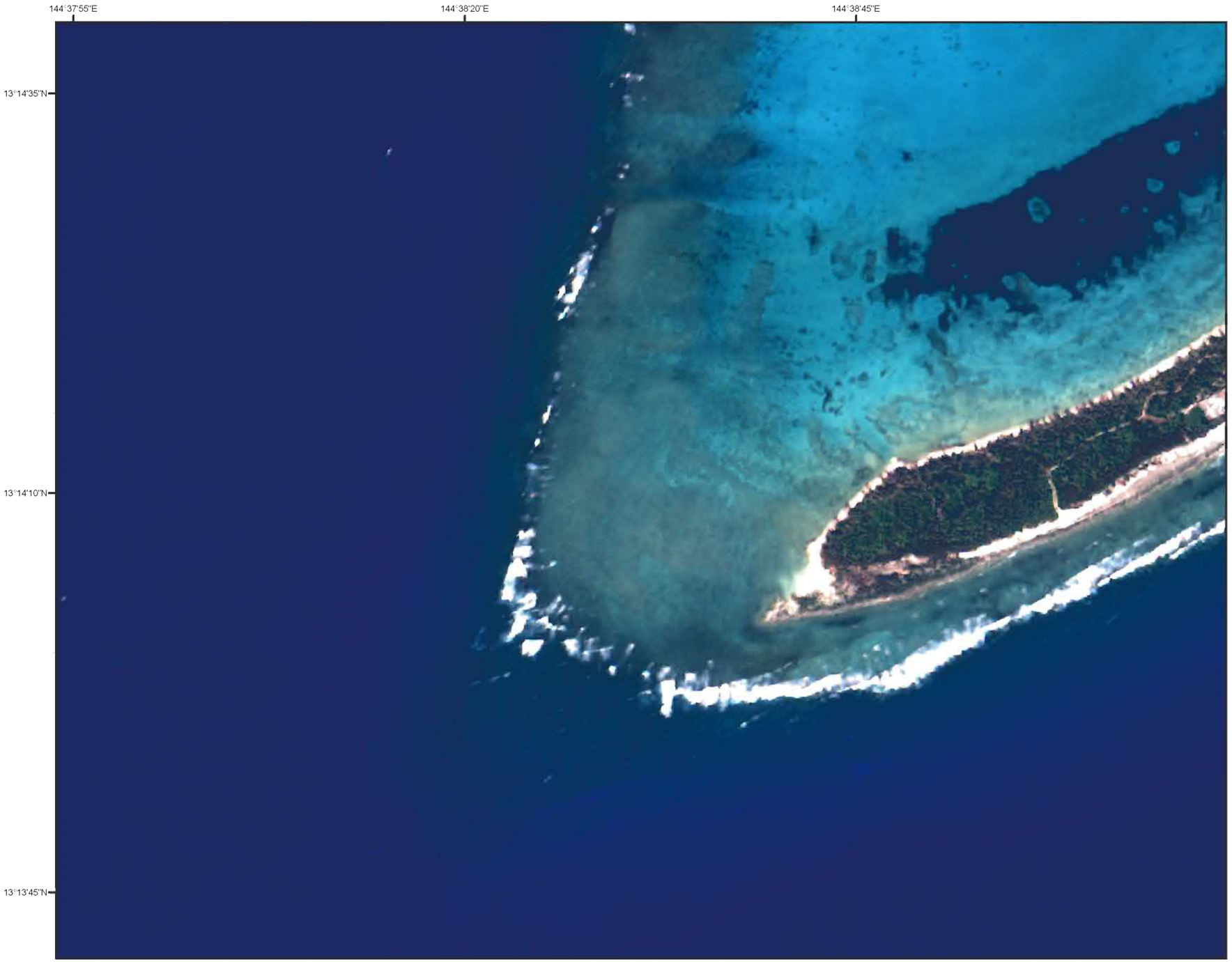
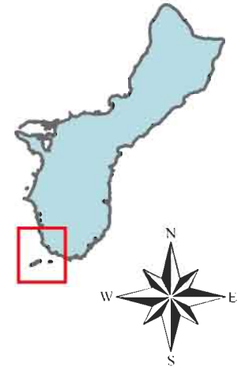
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Satellite Image Map 2





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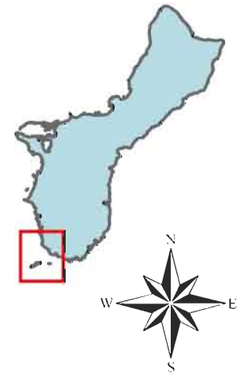
Guam Coastal Management Program

Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Benthic Habitat Map 2



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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Macroalgae 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Macroalgae 90%-100%
- Pavement, Turf 50%-<90%
- Rubble, Coralline Algae 10%-<50%
- Rubble, Macroalgae 10%-<50%
- Rubble, Macroalgae 50%-<90%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Macroalgae 10%-<50%
- Spur and Groove, Coral 10%-<50%

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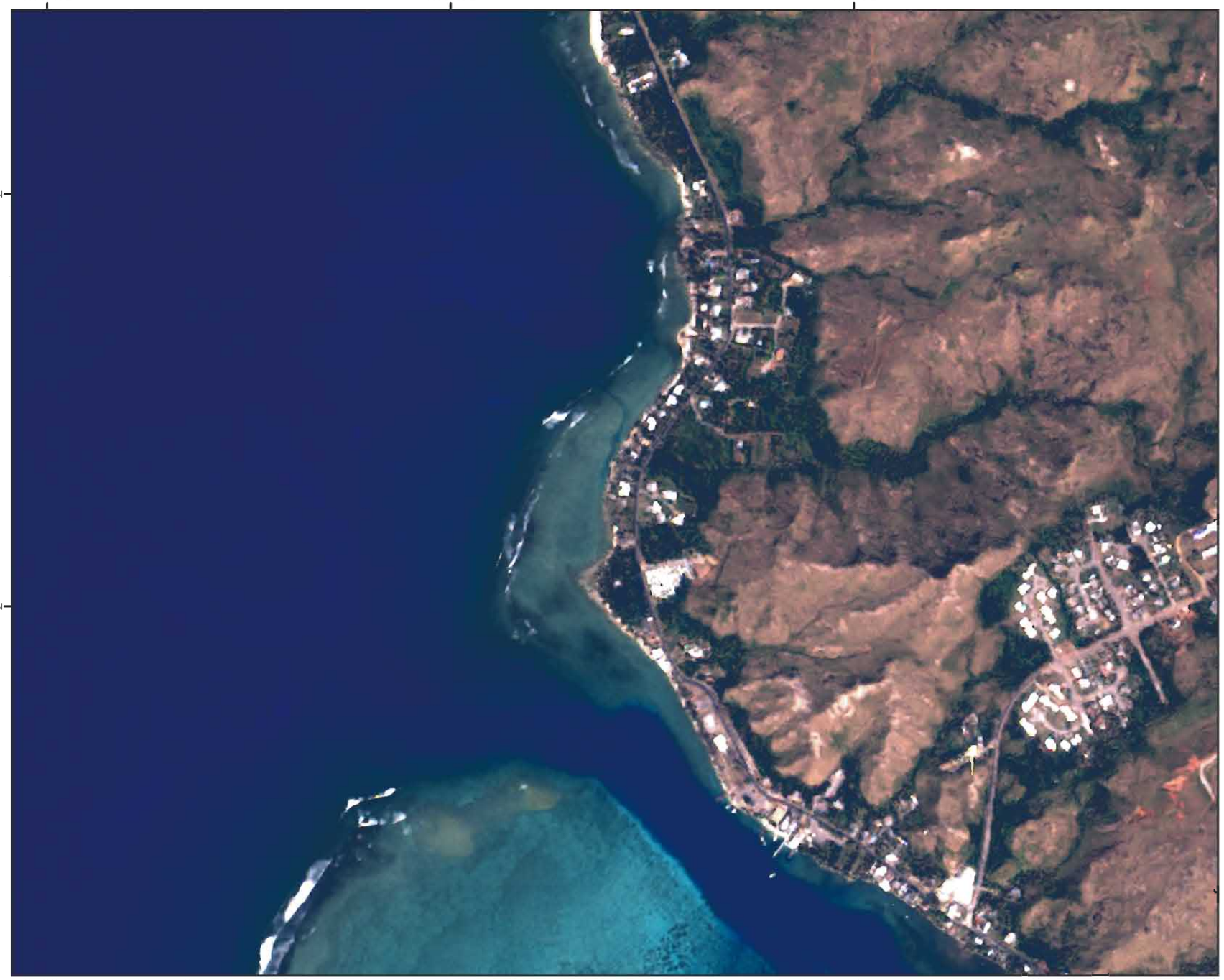
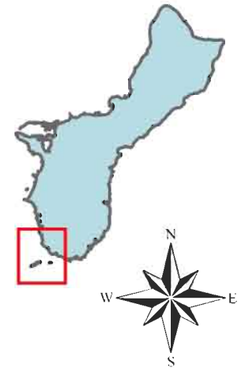
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Satellite Image Map 3





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Soft coral and butterflyfish in Cocos Lagoon . Photo by Dave Burdick.

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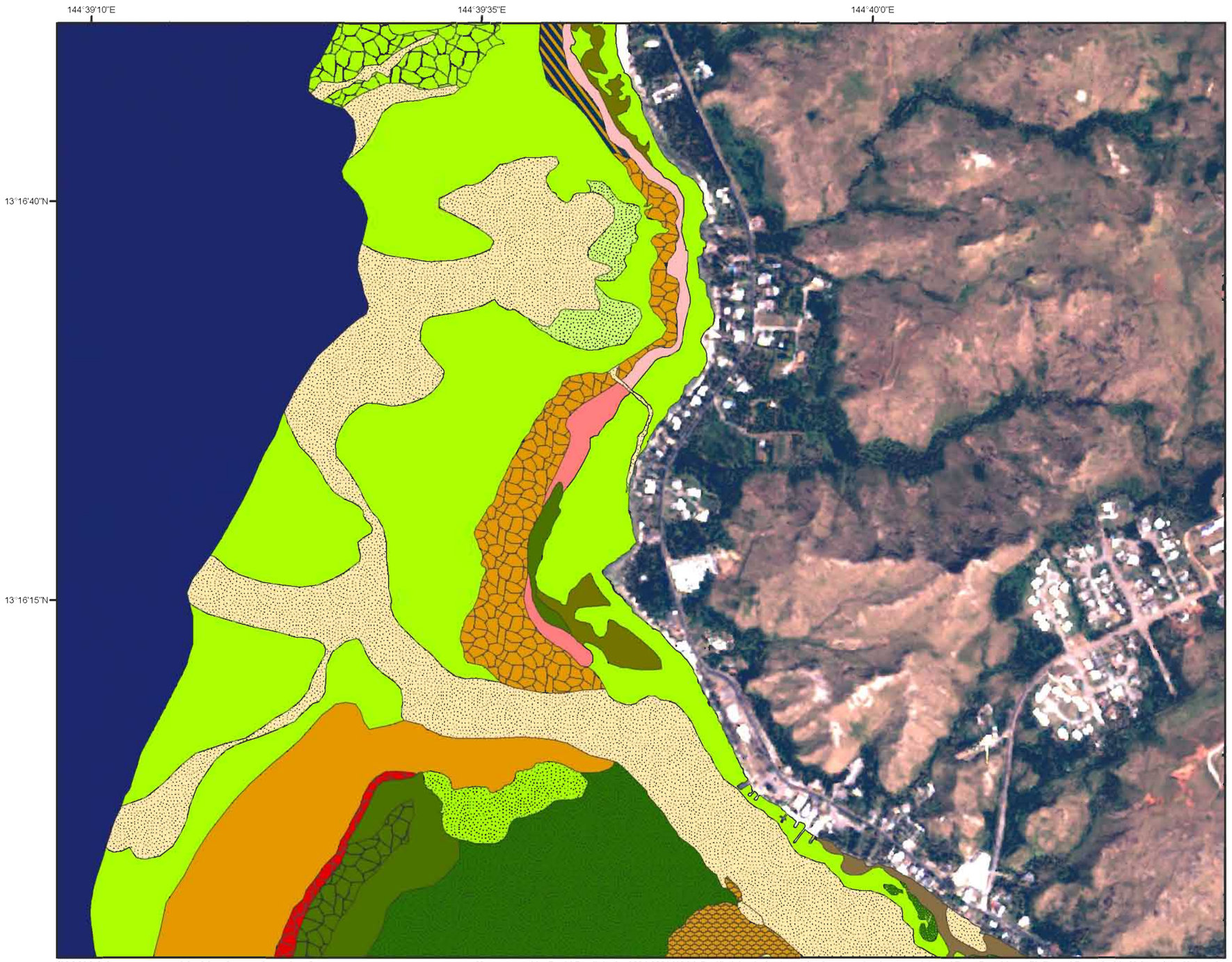
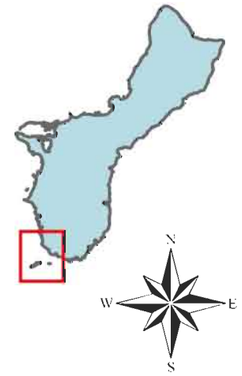
Guam Coastal Management Program

Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Benthic Habitat Map 3





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Legend

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- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Turf 50%-<90%
- Aggregated Patch Reef, Coral 10%-<50%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coralline Algae 10%-<50%
- Pavement, Coralline Algae 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 10%-<50%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 50%-<90%
- Rubble, Turf 10%-<50%
- Rubble, Turf 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

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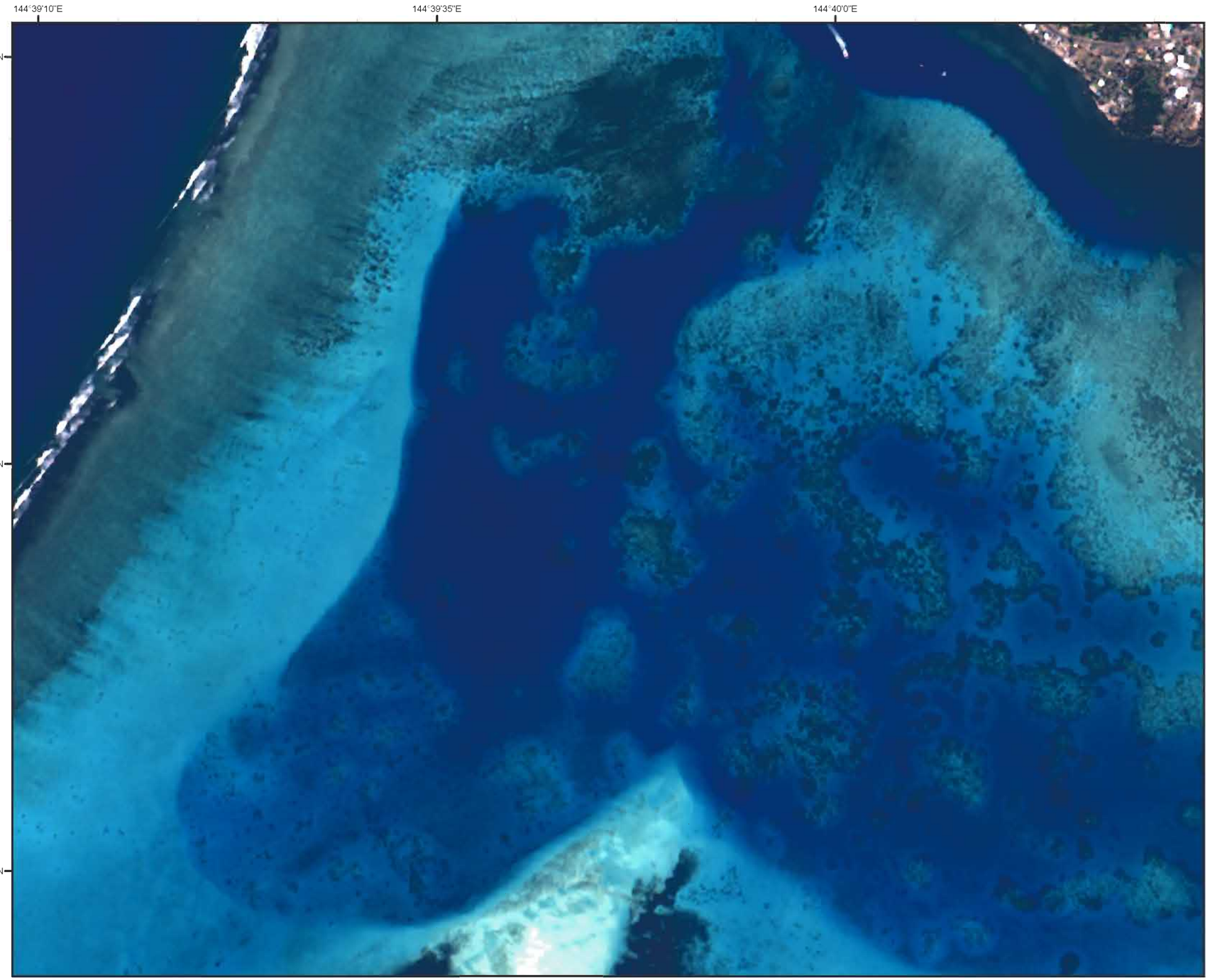
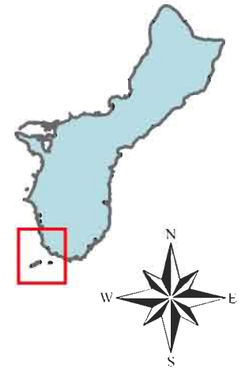
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Satellite Image Map 4





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Aggregation of Fungia fungites individuals in central Cocos Lagoon. Photo by Dave Burdick.

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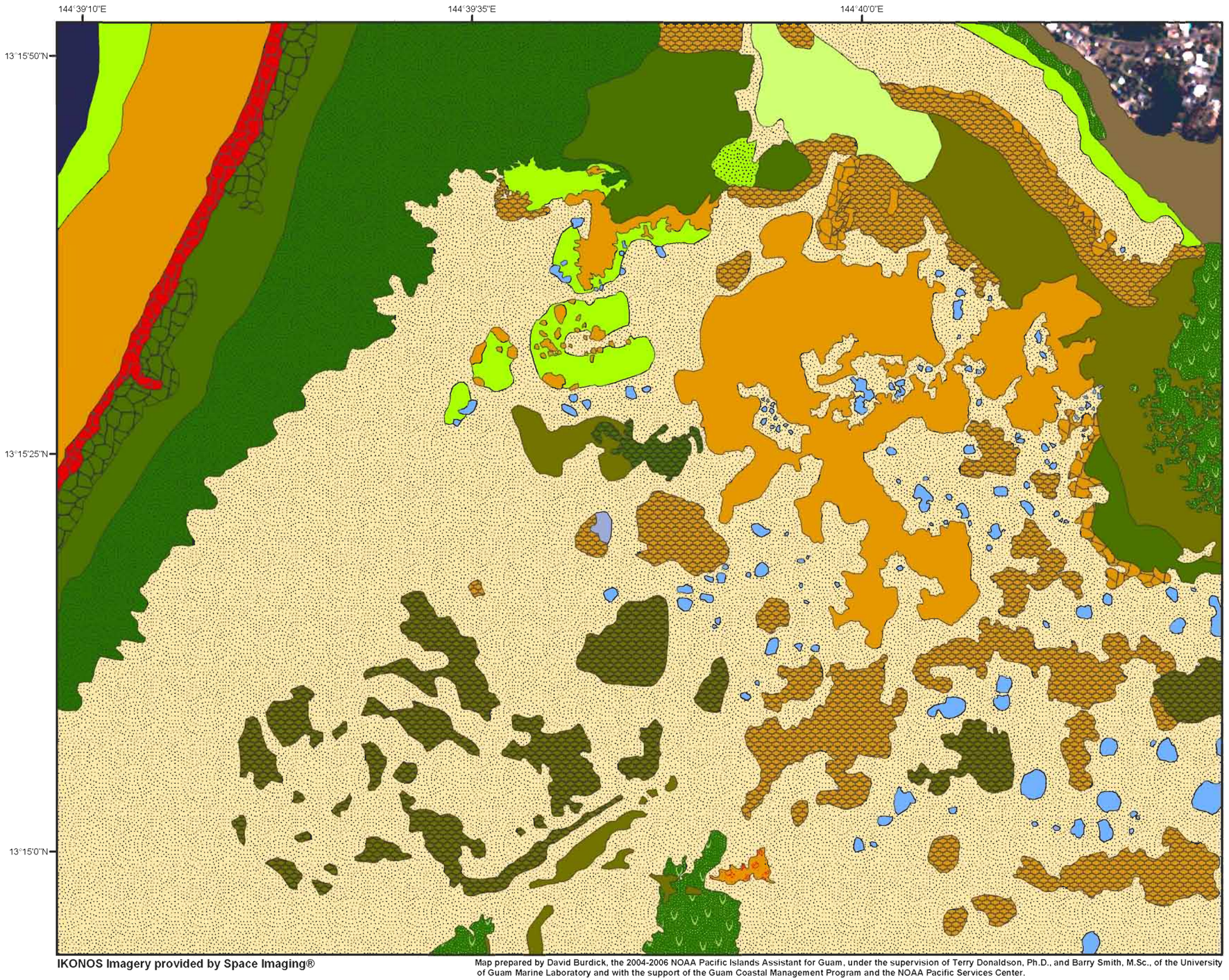
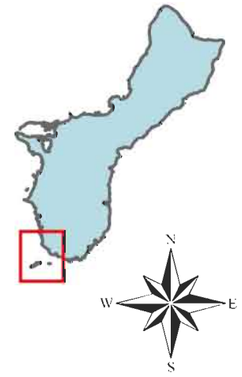
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Benthic Habitat Map 4





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Legend

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- Aggregate Reef, Coral 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregated Patch Reef, Coral 10%-<50%
- Aggregated Patch Reef, Macroalgae 10%-<50%
- Aggregated Patch Reef, Macroalgae 50%-<90%
- Individual Patch Reef, Coral 10%-<50%
- Individual Patch Reef, Macroalgae 10%-<50%
- Mud, Uncolonized 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 10%-<50%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Coral 10%-<50%

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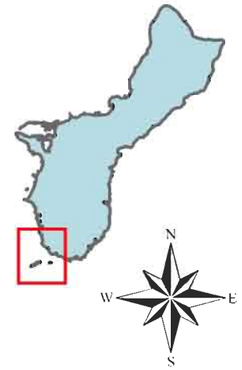
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Satellite Image Map 5



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View of southern mountains from beyond reef crest of eastern Cocos Lagoon. Photo by Dave Burdick.

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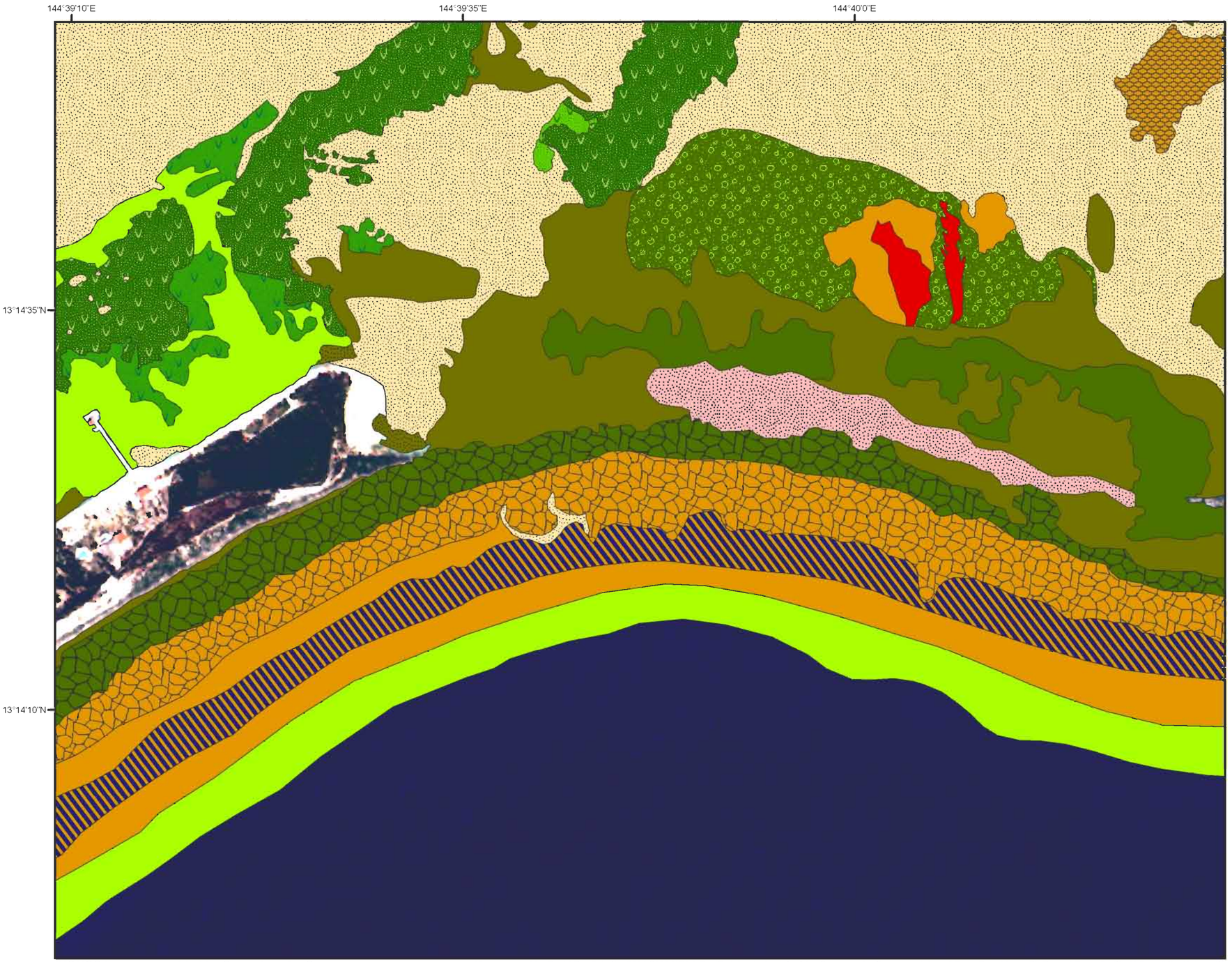
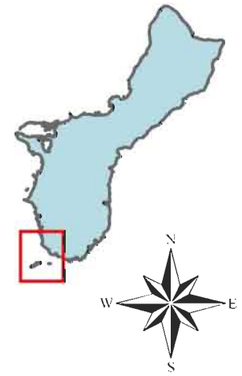
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Benthic Habitat Map 5





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Legend

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- Aggregated Patch Reef, Coral 10%-<50%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Coralline Algae 10%-<50%
- Rubble, Macroalgae 10%-<50%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Macroalgae 10%-<50%
- Spur and Groove, Coral 10%-<50%

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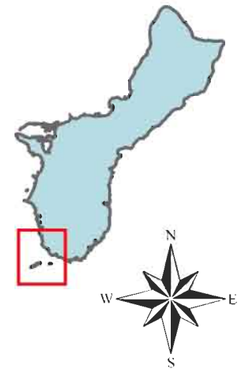
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Satellite Image Map 6



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Legend

Marine Preserve Boundaries

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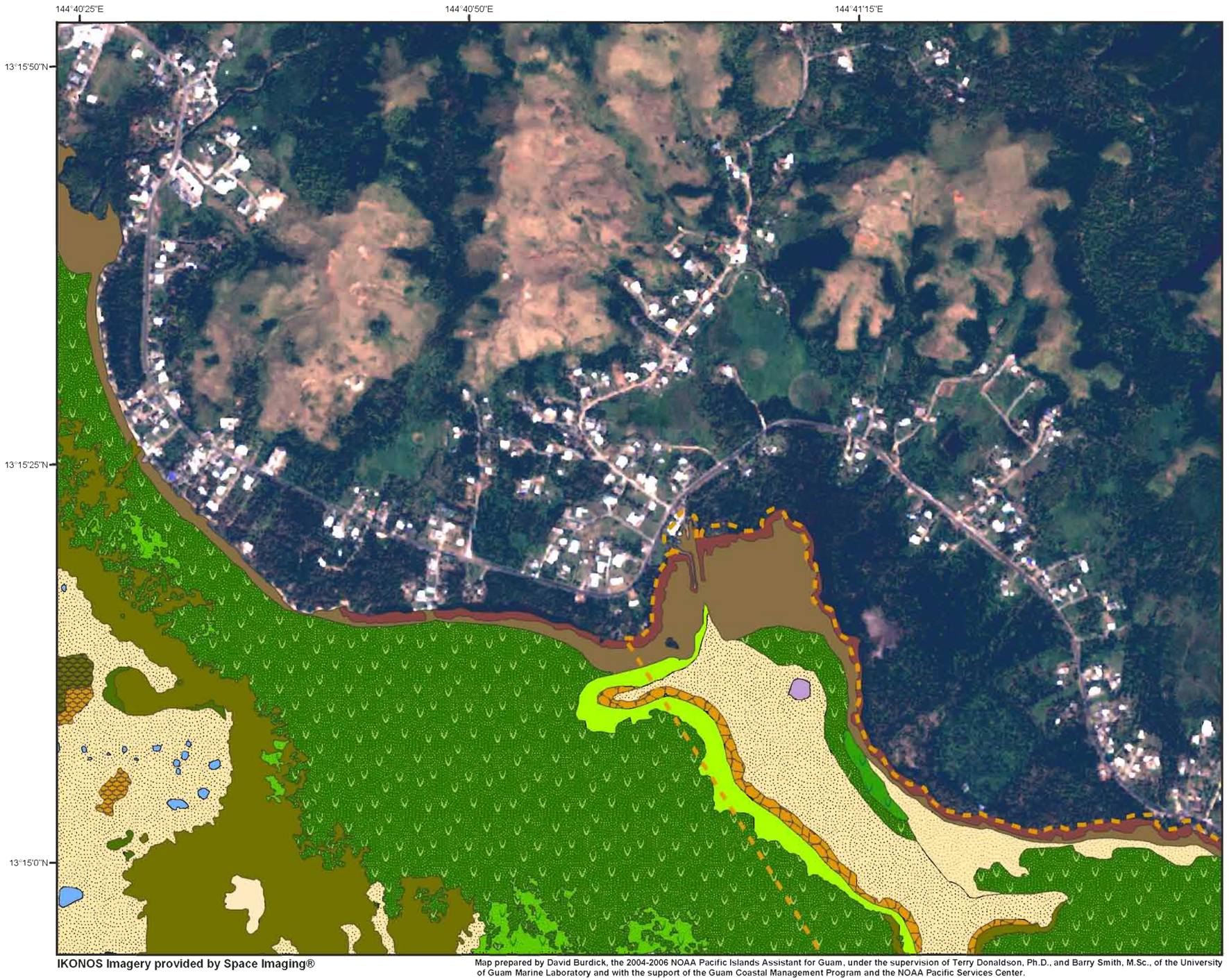
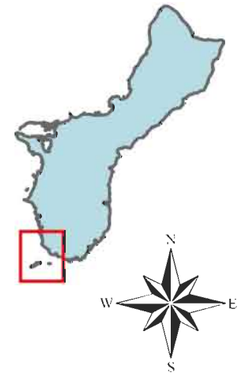
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Benthic Habitat Map 6





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Legend

- Marine Preserve Boundaries
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- Aggregated Patch Reef, Coral 10%-<50%
- Aggregated Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Coral 10%-<50%
- Individual Patch Reef, Turf 50%-<90%
- Mud, Emergent Vegetation 90%-100%
- Mud, Uncolonized 90%-100%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Pavement, Uncolonized 50%-<90%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 50%-<90%
- Sand, Uncolonized 90%-100%

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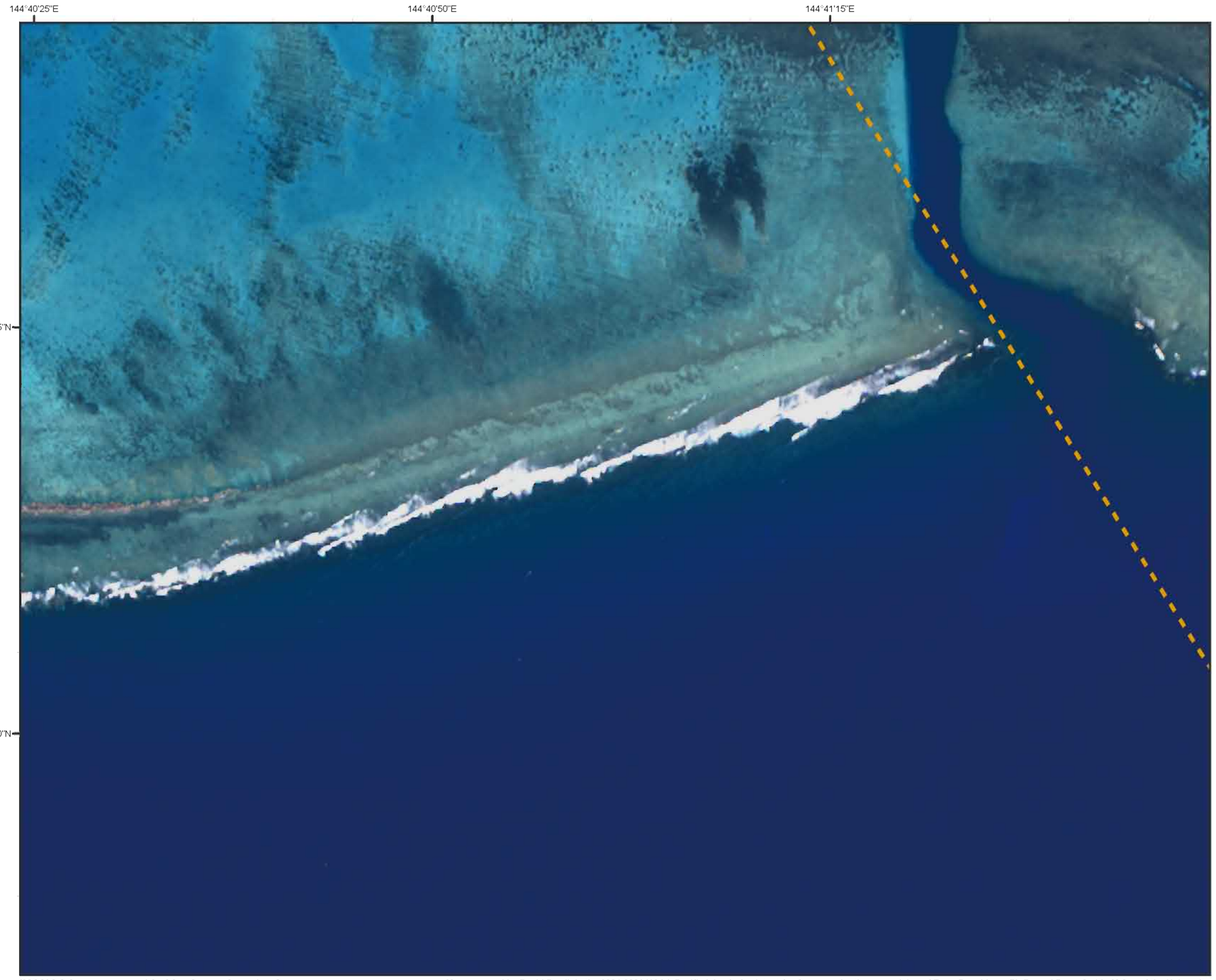
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Satellite Image Map 7



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Legend

Marine Preserve Boundaries

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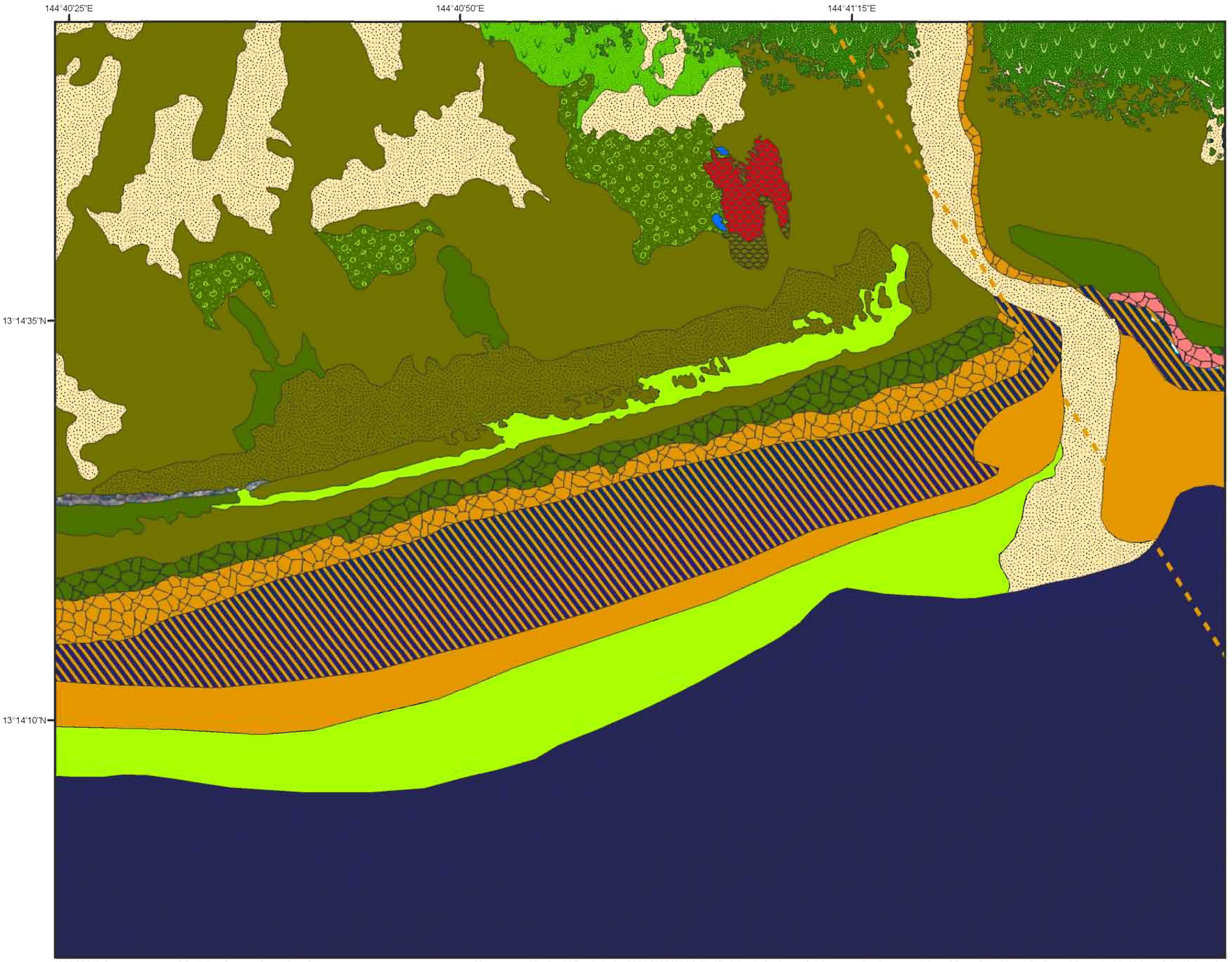
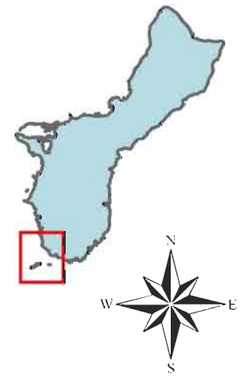
Guam Coastal Atlas ▪ Focus Area: Cocos Lagoon ▪ Benthic Habitat Map 7





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Legend

- Marine Preserve Boundaries
- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 50%-<90%
- Aggregate Reef, Macroalgae 90%-100%
- Aggregated Patch Reef, Coral 50%-<90%
- Aggregated Patch Reef, Macroalgae 10%-<50%
- Individual Patch Reef, Coral 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 10%-<50%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 50%-<90%
- Sand, Uncolonized 90%-100%
- Scattered Coral/Rock, Macroalgae 10%-<50%
- Spur and Groove, Coral 10%-<50%

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Guam Coastal Atlas ▪ Focus Area: Pago Bay ▪ Satellite Image Map 1

150 75 0 150 Meters

1:4,000

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Guam Coastal Atlas ▪ Focus Area: Pago Bay ▪ Benthic Habitat Map 1

150 75 0 150 Meters

1:4,000

Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Macroalgae 10%-<50%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%

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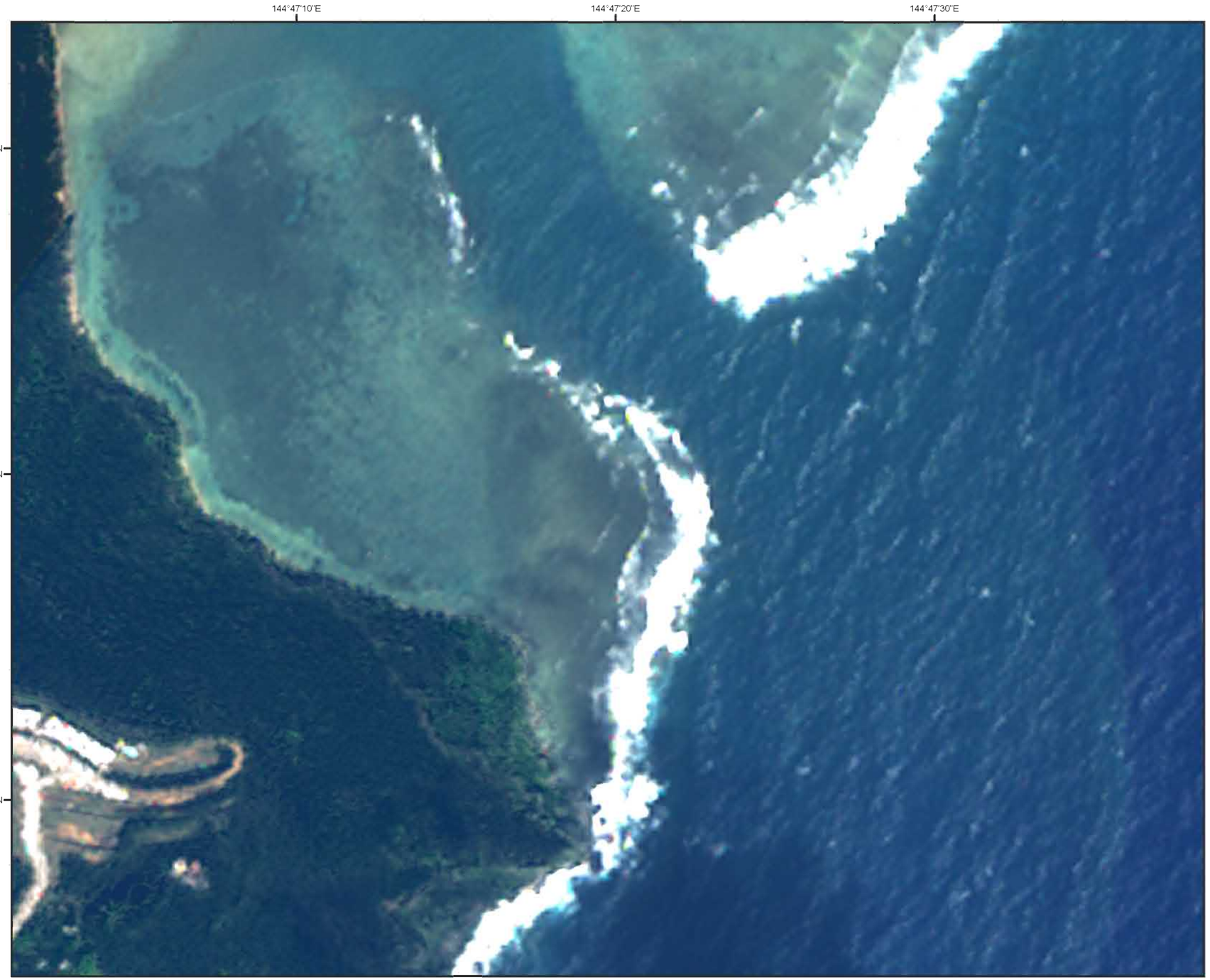
Guam Coastal Atlas ▪ Focus Area: Pago Bay ▪ Satellite Image Map 2



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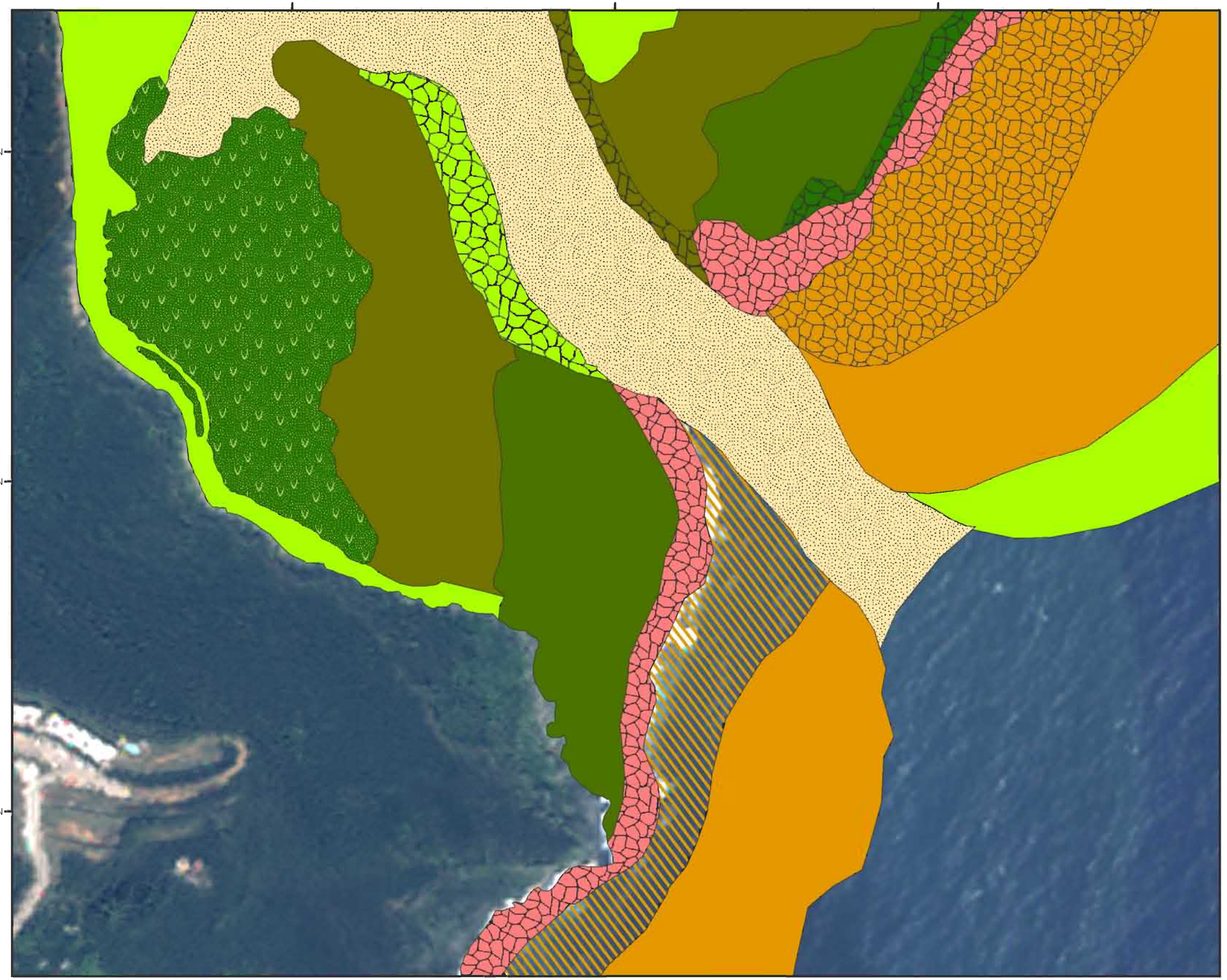
Guam Coastal Atlas ▪ Focus Area: Pago Bay ▪ Benthic Habitat Map 2



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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 90%-100%
- Aggregate Reef, Turf 50%-<90%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Seagrass 90%-100%
- Sand, Uncolonized 90%-100%
- Spur and Groove, Coral 10%-<50%

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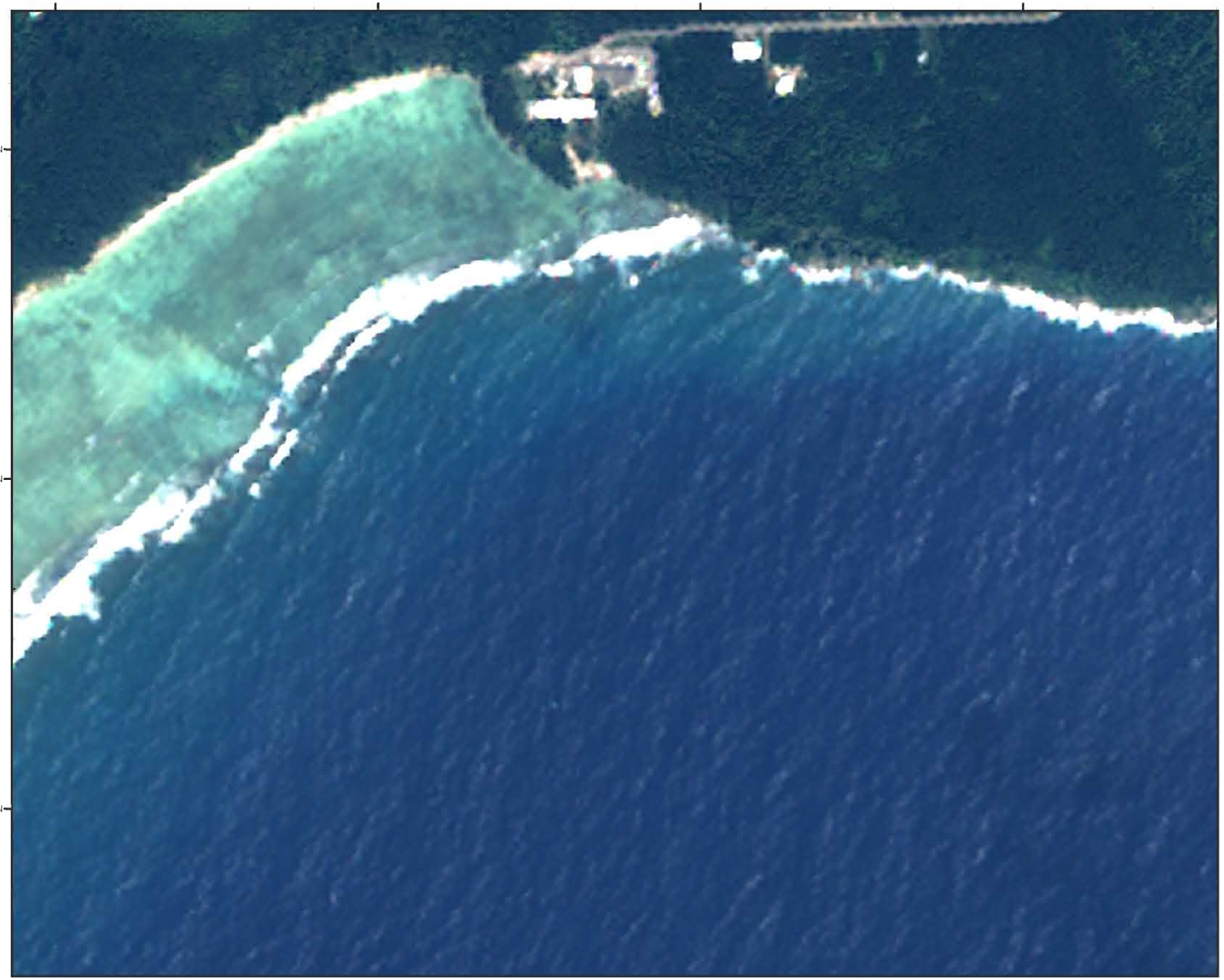
Guam Coastal Atlas ▪ Focus Area: Pago Bay ▪ Satellite Image Map 3



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Deep fore reef community in front of UOG Marine Lab. Photo by Dave Burdick.

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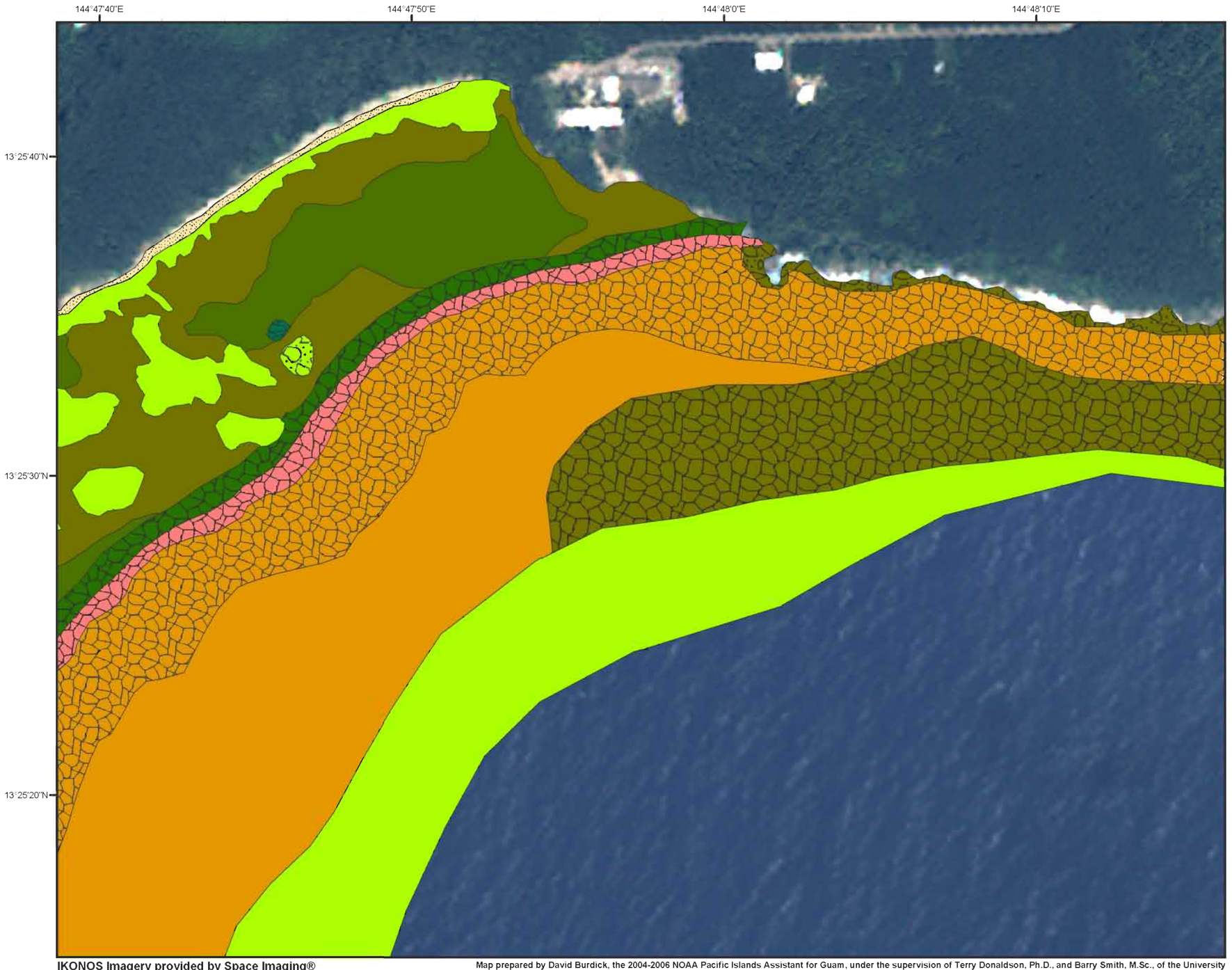
Guam Coastal Atlas ▪ Focus Area: Pago Bay ▪ Benthic Habitat Map 3



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Legend

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- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 10%-<50%
- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rock/Boulder, Macroalgae 10%-<50%
- Rock/Boulder, Macroalgae 50%-<90%
- Rock/Boulder, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

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Guam Coastal Atlas ▪ Focus Area: East Agana Bay ▪ Satellite Image Map 1

150 75 0 150 Meters

1:4,000

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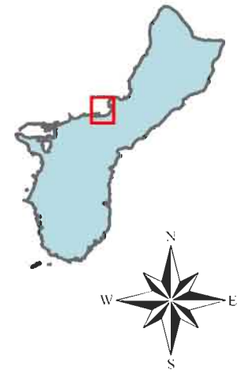
Guam Coastal Atlas ▪ Focus Area: East Agana Bay ▪ Benthic Habitat Map 1

144°44'40"E 144°44'50"E 144°45'0"E 144°45'10"E

13°29'0"N

13°28'50"N

13°28'40"N



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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Coralline Algae 50%-<90%
- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Rubble, Macroalgae 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Macroalgae 10%-<50%
- Sand, Seagrass 90%-100%
- Sand, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

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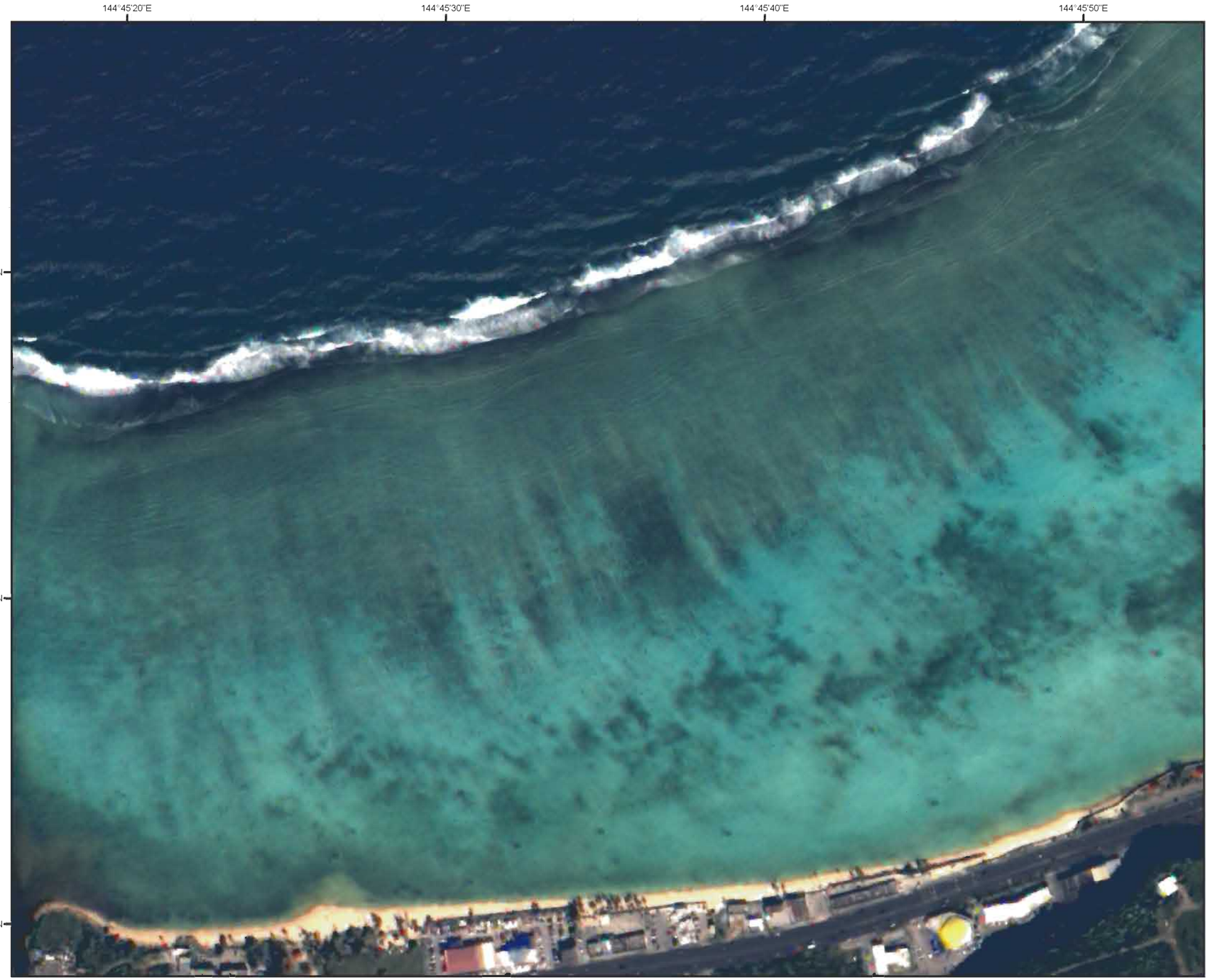
Guam Coastal Atlas ▪ Focus Area: East Agana Bay ▪ Satellite Image Map 2



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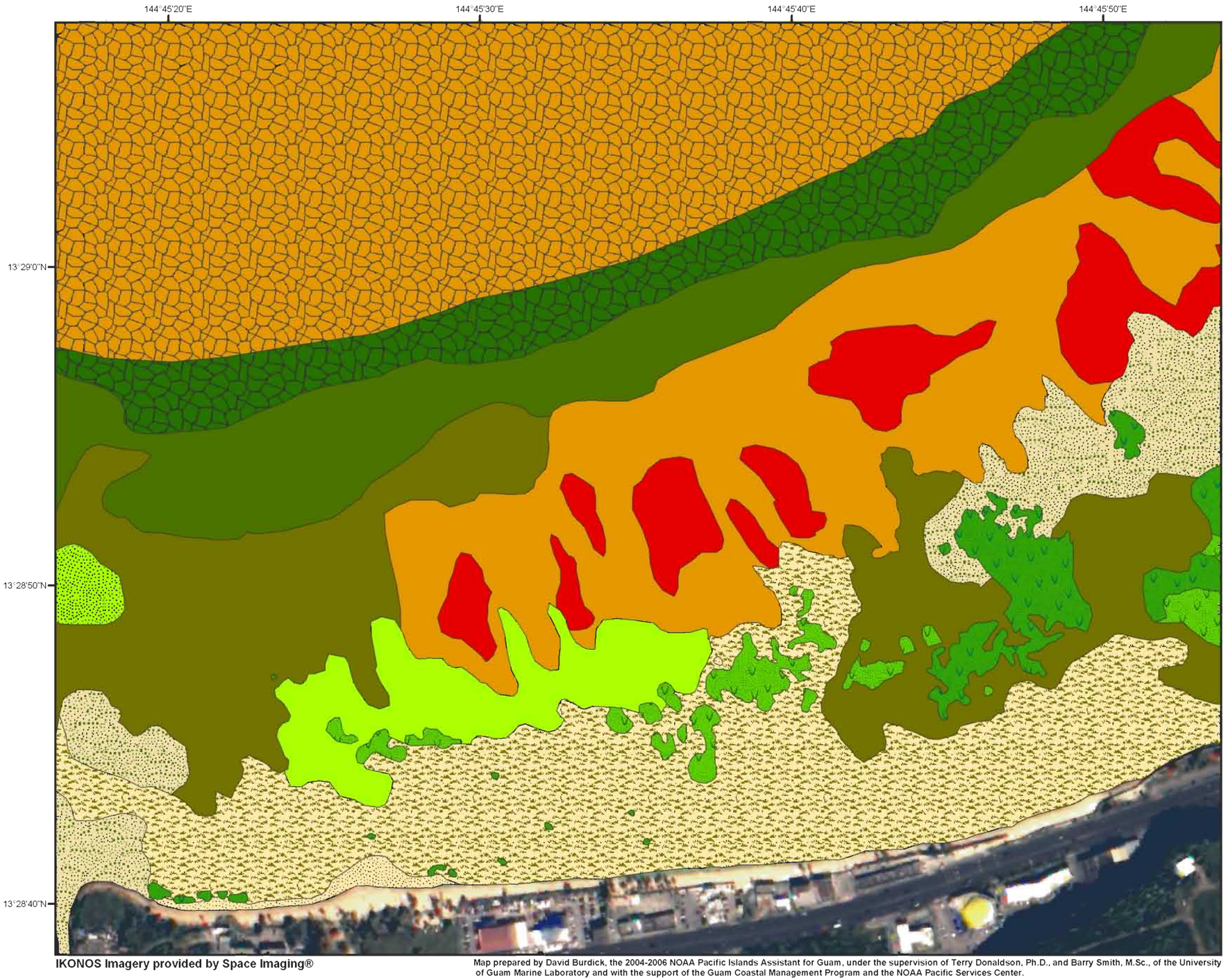
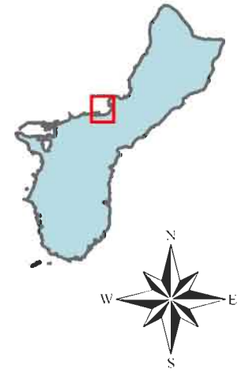
Guam Coastal Atlas ▪ Focus Area: East Agana Bay ▪ Benthic Habitat Map 2





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Legend

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- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Rubble, Turf 50%-<90%
- Sand, Macroalgae 10%-<50%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Turf 50%-<90%
- Sand, Uncolonized 90%-100%

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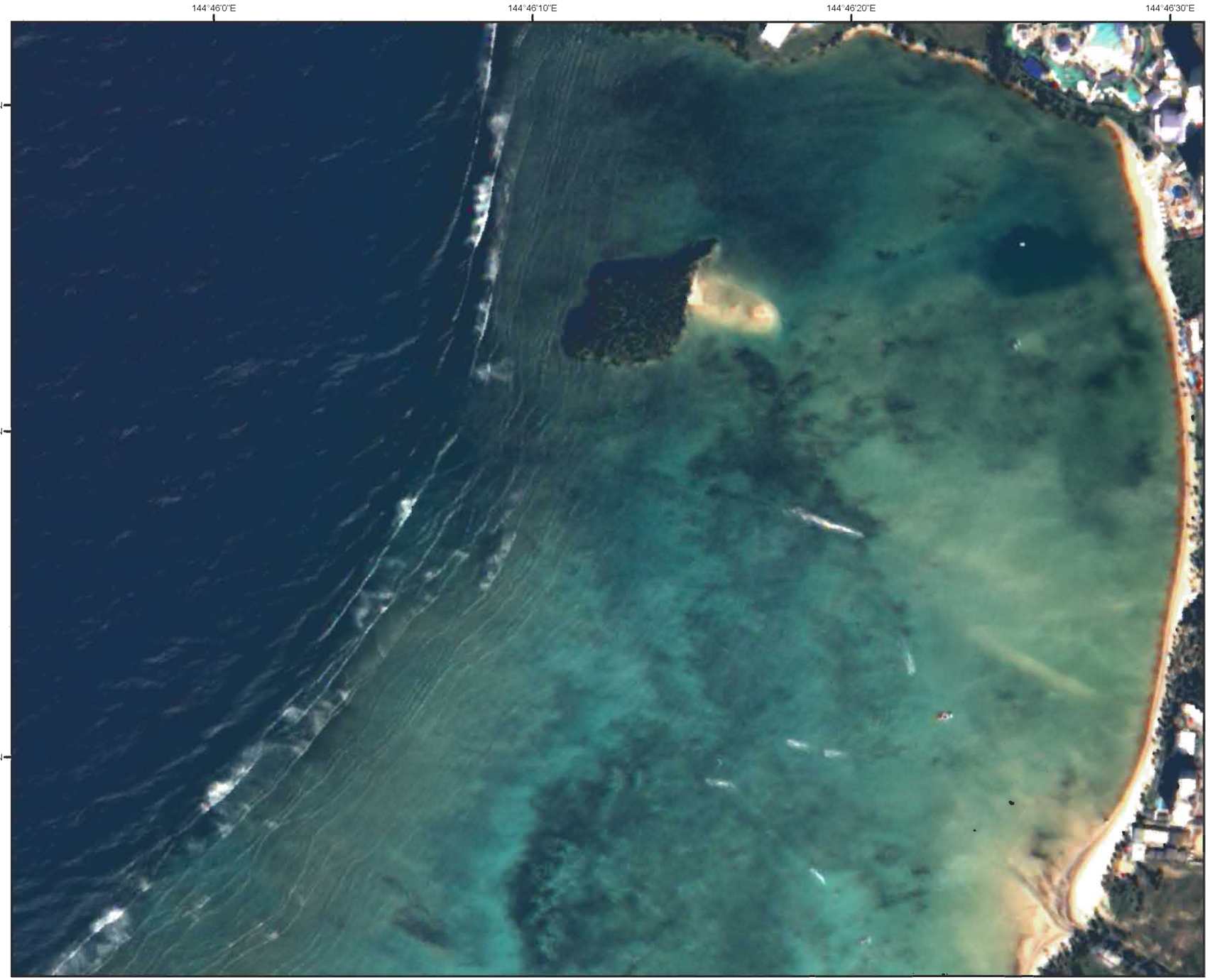
Guam Coastal Atlas ▪ Focus Area: East Agana Bay ▪ Satellite Image Map 3



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1:4,000

Steep slope dominated by turf algae and small, sparse coral colonies north of Alupang Island in East Agana Bay. Photo by Dave Burdick.

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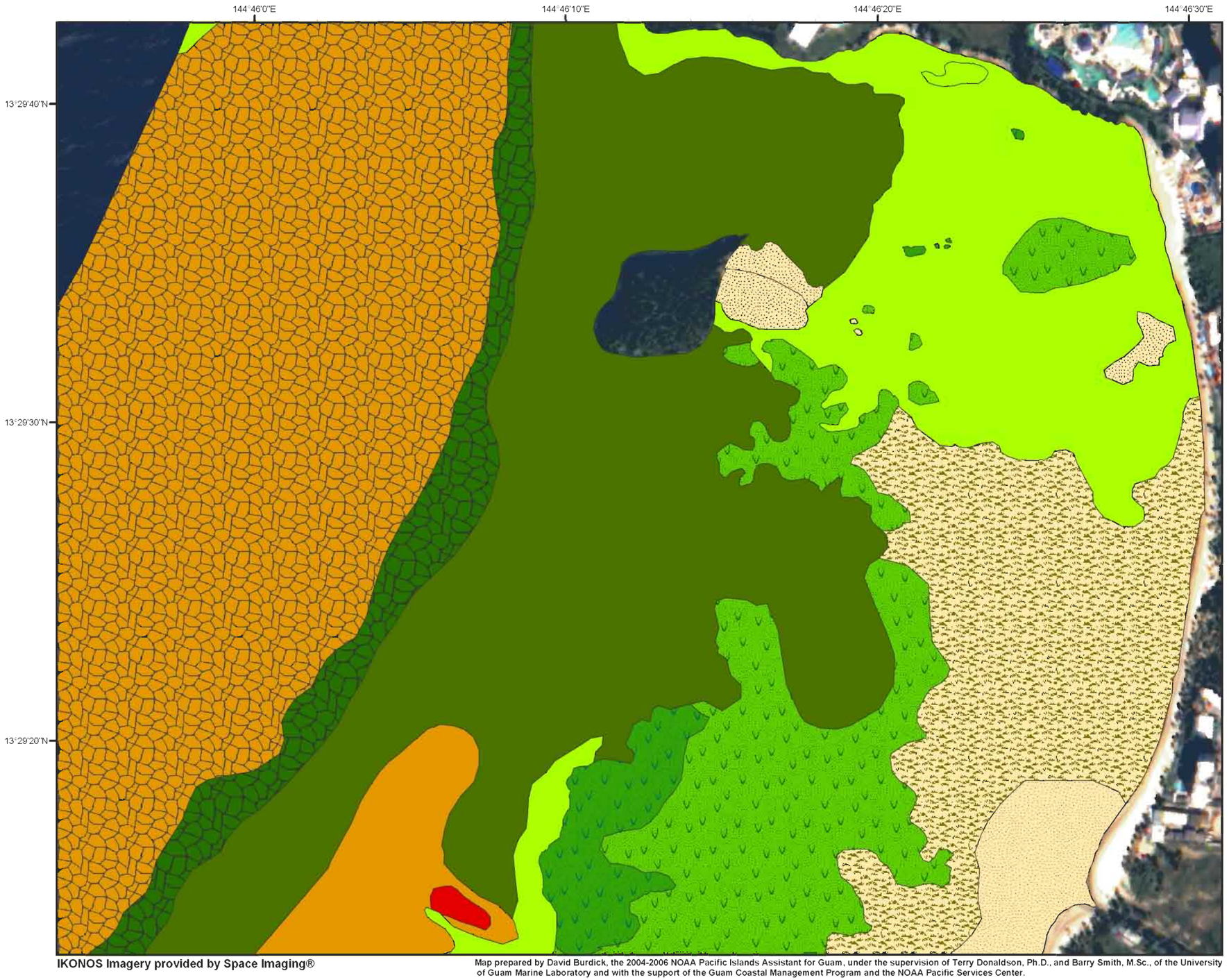
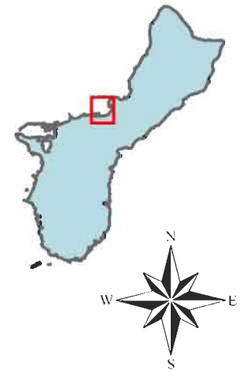
Guam Coastal Atlas ▪ Focus Area: East Agana Bay ▪ Benthic Habitat Map 3





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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Macroalgae 10%-<50%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Uncolonized 50%-<90%
- Sand, Uncolonized 90%-100%

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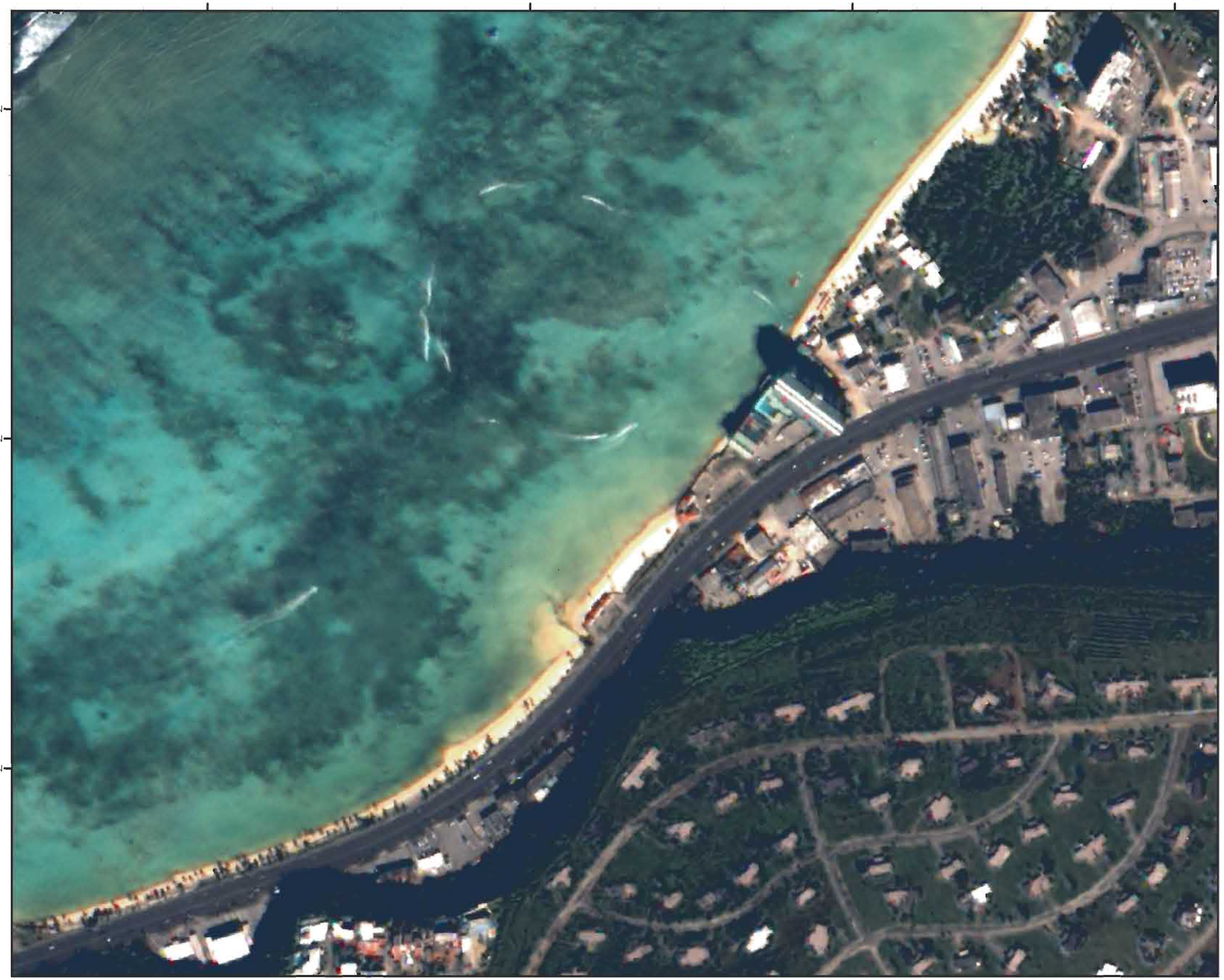
Guam Coastal Atlas ▪ Focus Area: East Agana Bay ▪ Satellite Image Map 4



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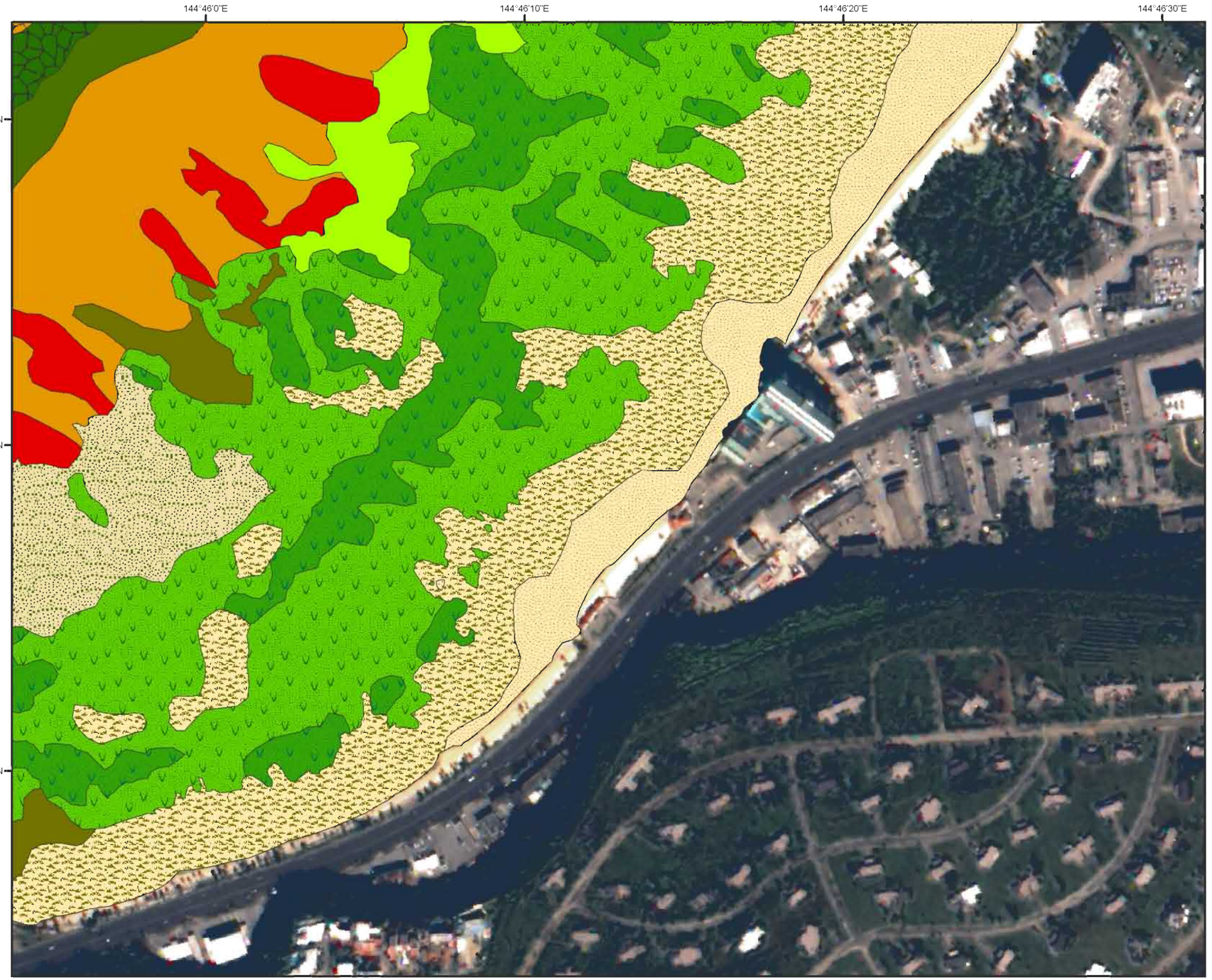
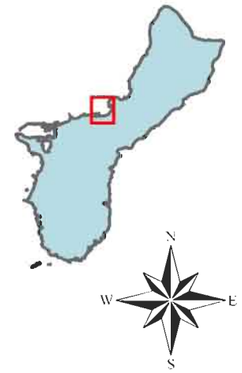
Guam Coastal Atlas ▪ Focus Area: East Agana Bay ▪ Benthic Habitat Map 4



IKONOS Imagery provided by Space Imaging®



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Legend

- Aggregate Reef, Coral 10%-<50%
- Aggregate Reef, Macroalgae 90%-100%
- Pavement, Coral 10%-<50%
- Pavement, Coral 50%-<90%
- Pavement, Macroalgae 10%-<50%
- Pavement, Macroalgae 50%-<90%
- Pavement, Turf 50%-<90%
- Sand, Macroalgae 10%-<50%
- Sand, Seagrass 10%-<50%
- Sand, Seagrass 50%-<90%
- Sand, Turf 50%-<90%
- Sand, Uncolonized 50%-<90%
- Sand, Uncolonized 90%-100%

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