Mapping of Benthic Habitats for U.S. Pacific Territories:

American Samoa, Guam, and The Commonwealth of the Northern Mariana Islands

Task Order II Project Completion Report

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Biological Cover	LCoral	Coral 10% - <50%
	MCoral	Coral 50% - <90%
	HCoral	Coral 90% - 100%
	LSeaGr	Seagrass 10%-<50%
	MSeaGr	Seagrass 50%-<90%
	HSeaGr	Seagrass 90%-100%
	LMac	Macroalgae 10% - <50%
	MMac	Macroalgae 50% - <90%
	HMac	Macroalgae 90% - 100%
	LCA	Coralline Algae 10% - <50%
	MCA	Coralline Algae 50% - <90%
	HCA	Coralline Algae 90% - 100%
	LTurf	Turf 10% - <50%
	MTurf	Turf 50% - <90%
	HTurf	Turf 90% - 100%
	Uncol	Uncolonized hard bottom
Geomorphologic Structure	AgRf	Aggregate Reef
	AgPtchRf	Aggregated Patch Reef
	IndPtchRf	Individual Patch Reef
	SnG	Spur and Groove
	SCRUS	Scattered Coral and Rock in Unconsolidated Sediment
	Pvnt	Pavement
	Rock/Bldr	Rock/Boulder
Statistics	UA	User’s Accuracy
	PA	Producer’s Accuracy

1. Introduction and Background

BAE Systems Spectral Solutions has been provided IKONOS satellite imagery from NOAA for the near shore waters of the U.S. Pacific Territories. The images are being used to create maps of the region's marine resources including coral reefs and other important habitats for fisheries, tourism and other aspects of the coastal economy. Accurate habitat maps are necessary for resource managers to make informed decisions about the protection and use of these areas. Analytical Laboratories of Hawaii (ALH) has been subcontracted to provide mapping and other services to meet the goals of this project.

Primary products of this effort are benthic coral reef habitat maps in geographic information system (GIS) format. The maps are produced by delineating habitat boundaries by visual interpretation from the imagery provided. These maps are generated in GIS format to generate a powerful tool for management of important patterns and trends that are possible only from this intelligent mapping methodology. In all cases, benthic features have been classified using a hierarchical two tiered Coral Reef Habitat Classification Scheme. The scheme has been prepared from consultation, meetings and workshops that included the key coral reef biologists, mapping experts and professionals throughout the island territories mapped. The Coral Reef Habitat Classification Scheme that was developed by NOAA for all islands of the Caribbean and Hawaii and was used as a starting point for this work. Subsequent to an intermediate scheme that was developed and used to generate the habitat maps prepared from the NOAA imagery collected during the year 2000, comments and suggestions have been incorporated into a new scheme that includes GIS data organized to separate the geolomorphologic substrate structure of the reef system from the biological cover colonizing its surface. For the purpose of this work, habitat is defined by the major and detailed attributes of these two layers.

An integral part of this work includes scientifically sound statistical accuracy estimates of the coral reef habitat maps. These analyses are presented and conclusions are drawn that can be integrated into long term coral reef mapping objectives.

It has been the goal of this work to map the coral reef habitats of all islands of American Samoa, Guam and the Commonwealth of the Northern Mariana Islands. This work has been completed and is reported on here.

2. Approach

2.1 Development of the Benthic Habitat Classification Scheme for the Pacific

The benthic features depicted in these map products were classified using a hierarchical, two level, Coral Reef Habitat Classification Scheme. In this work, habitats are defined using a two tiered classification scheme consisting of a geomorphologic reef structure and biological cover. The scheme was prepared through consultation, meetings and workshops that included the key coral reef biologists, mapping experts and professionals in the State of Hawaii and the US Pacific Territories. The Coral Reef Habitat Classification Scheme that was developed by NOAA for the Caribbean and Hawaii was used as a starting point for this work. This classification scheme was influenced by many factors including but not limited to:

- Requests of the management community
- NOS's coral reef mapping experiences
- Existing classification schemes for the Pacific and Hawaiian Islands and other coral reef ecosystems
- Quantitative habitat data for the Hawaiian Islands
- Consideration of various minimum mapping units and technological trends toward preparation of living resource map products using digital techniques from remotely sensed imagery including satellite data.

For this work, the goals of the areas to map were divided into four regions. American Samoa and all of its islands constituted region one. Guam was designated as region two. The Commonwealth of the Northern Mariana Islands was divided into two regions. Saipan, Tinian, Aguijan and Rota were assigned to region three and the ten small islands north of Saipan were assigned to region four.

The scheme is separated into two levels, the geomorphologic structure of the reef and the biological cover on the substrate. Map classes that were determined to be undetectable from the imagery were not included in the scheme.

Four major structural components for the classification scheme that has been developed for this work include:

- Unconsolidated Sediments
- Coral Reef and Hard Bottom
- Other Delineations
- Unknown

These have been subdivided to include the following detailed coral reef structural classification system:

Unconsolidated Sediments

1. Sand
2. Mud
3. Unclassified
4. Unknown

Coral Reef and Hard Bottom

1. Unknown
2. Aggregate Reef
3. Spur and Groove
4. Individual Patch Reef
5. Aggregated Patch Reef
6. Scattered Coral/Rock
7. Pavement
8. Rock/Boulder
9. Pavement with Sand Channels
10. Rubble
11. Unclassified
12. Unknown

Other Delineations

1. Land
2. Artificial
3. Unclassified
4. Unknown

Unknown

1. Unknown

Cover type has been divided into nine classes:

Coral
Seagrass
Macroalgae
Coralline algae
Turf
Emergent Vegetation
Uncolonized
Unclassified
Unknown

Each of the biological cover types are then subdivided into six density classes:

1. 0%-<10%
2. 10%-<50%
3. 50%-<90%
4. 90%-100%
5. Unclassified
6. Unknown

Thirteen zones have been developed as:

Shoreline Intertidal
Vertical Wall
Reef Flat
Back Reef
Reef Crest
Fore Reef
Lagoon
Bank/Shelf
Bank/Shelf Escarpment
Channel
Dredged
Land
Unknown

2.2 Remotely Sensed Imagery

NOAA provided multispectral IKONOS satellite imagery to complete the objectives of this project. This high spatial resolution (4 meter raw multispectral and 1 meter pan sharpened) color balanced imagery, proves suitable for visual extraction of the habitat classes mapped here. Furthermore, acquiring imagery by satellite facilitates convenient imaging in areas that are too remote to economically acquire the imagery by fixed wing or other platform. For this work, all imagery was provided by NOAA completely processed to ALH. NOAA processing included atmosphere correction, deglinting, color balancing, orthorectification, correction for water column effects and pan sharpening. Collection constraints were set to control environmental effects such as glare, glint and other interferences that would limit visualization of benthic features. Multiple collects were conducted to mosaic multiple scenes to a maximum of 10% cloud cover. These images were used to manually interpret and delineate geomorphologic features, zones and cover type. This task was accomplished using on screen digitizing in ArcView GIS format facilitated by the Coral Reef Digitizer Extension developed by NOS and published on the NOAA web site (http://biogeo.nos.noaa.gov/products/apps/digitizer/).

2.3 Spatial Data Acquisition

Collection of new GPS data was needed to complete this work. Methods that accommodate levels of accuracy needed to meet the objectives of each task were used. GPS data was acquired for accuracy assessment of the habitat maps. It was also collected for ground validation information that was used to investigate uncertainties on the photointerpreter's behalf during the decision making process of the manual delineation of zone, structure and biological cover. The accuracy assessment data was generated on a random stratified point basis. Ground validation data was generated by selecting specific targets in areas where habitat type was not certain during photointerpretation and needed to be examined in the field or where gradients through habitat type resulted in uncertain habitat boundaries.

2.4 Habitat Map Preparation

Traditional methods of stereoplotter digitizing of photo interpreted habitat classes have been nearly completely replaced by computerized on screen digitizing methods. The latter method has distinct advantages.

- It eliminates the intermediate digitizing step reducing positional error of the habitat boundaries.
- Productivity is higher.
- It develops an active link between the mapped image and the associated database.

Thus a Geographic Information System (GIS) is the superior and desired. The application of GIS provides a powerful analytical tool that yields critical information and contributes to the ability of making sensible long-term natural resource management plans. The maps and mapping methods described in this report were developed using Environmental Systems Research Institute (ESRI) ArcView GIS software.

All benthic habitats were mapped from the shoreline to a depth of 30 meters.

2.5 Habitat Map Accuracy Assessment

To determine the overall accuracy of the mapped product, conventional assessment of the accuracy of resource maps prepared from remotely sensed data was completed. It was proposed that specific areas being mapped be used as test areas for this work. A statistically robust data set composed of random field habitat observations were made to assess the accuracy of the mapped product. These areas were chosen based on input from the local marine biologists and coral reef managers. These groups provided advice on the location of the most diverse benthic communities and also areas of particular importance based on management strategies and marine protected areas. Thus, it was the goal of this team to collect accuracy assessment field data representing as many of the habitats that occur in these regions as possible.

2.6 Safety

During all fieldwork, the team placed safety at maximum priority. A safety kit with first aid, spare floatation, emergency flares, drinking water and an emergency position indicating radio beacon (EPIRB) was included on each field mission. All fuel-powered vessels were compliant with US Coast Guard commercial vessel safety regulations.

2.7 Training of Local Staff

Another objective of this work was to work with local coral reef managers and marine biologists to familiarize them with the methods that the NOAA/ALH team has developed for acquisition of field benthic habitat characterization and map accuracy assessment. This effort was undertaken to transfer the techniques of mapping technologies so that the local community would be proficient in habitat mapping for future interaction or updates to the NOAA product. This training was conducted for the American Samoa staff during previous contract tenure. Therefore, training sessions were developed for the staff on Guam and Saipan and were completed during this work.

3. Methods

3.1 Survey Methodologies Used to Perform this Work

The tasks in this work required the acquisition of a significant amount of new GPS data. GPS acquisition methods were used that met the level of spatial accuracy specified in the scope of work and needed to complete the task. Less than 5 meter RMS horizontal error was required for the accuracy assessment and benthic habitat characterization positions and vertical data were all set to sea level as all data was collected there. While the requirements for positional accuracy of the ground validation data were the same as the accuracy assessment field data, the descriptive information in the ground validation data was more general. The purpose of the ground validation survey was to investigate areas in the imagery where interpretation of the habitat type was uncertain during the delineation of the first draft map.

3.1.1 Reference Systems

ALH has provided all geospatial deliverable products referenced to the North American Datum of 1983 (NAD83) on geoid model 99. All such coordinates in this datum are affixed to the Pacific Plate. All spatial data was projected in Universal Transverse Mercator (UTM) Zone 2 South for American Samoa and Zone 55N for the Mariana Archipelago. Vertical heights are all reported at sea level.

3.1.2 Acquisition of GPS and Habitat Characterization Data

A Trimble Geo Explorer 3 was used to collect the GPS data and Trimble Pathfinder Office Software was used for all post processing and differential correction of the raw GPS data to the geographically closest CORS. Habitat attribute information was collected on site using the GPS data logger with a custom data dictionary designed to reflect the NOAA classification scheme for benthic habitats of the Pacific (Table 1). The GPS data was post processed for differential correction using a Continually Operating Reference System (CORS).

3.2 Accuracy Assessment and Ground Validation Habitat Characterization

These data were used as ground truth to determine the accuracy of the maps produced in this work and to refine areas where habitat determination was uncertain. Waypoints were generated using a stratified random sampling regime or were selected to explore specific features in the imagery. Each waypoint that could be safely occupied was navigated to in a small boat and a weighted buoy deployed. After deployment of the buoy, 100 GPS positions were collected at one-second intervals and were averaged to generate a single position. After GIS data collection was complete the habitat characterization was conducted in a circular area of 7.5 meter radius centered on the weighted buoy. Each feature was populated with site-specific data using a custom designed data dictionary and processed using Trimble Pathfinder Software (Table 1).

Table 1. Data collected using Trimble Geo Explorer 3 GPS data logger at each benthic habitat characterization site during field habitat surveys

Site Data	**Habitat Data**
Study Area	Point Habitat Type (0.5 meter radius)
Site ID	Area 1 Habitat Type (7 meter radius)
GP Date	Major Structure and Detailed Structure
GPS Time	Hierarchical Biological Cover and Modifier
GPS Position	Estimated Coral Cover
GPS Statistics	Estimated SAV Cover (Macroalgae and Turf)
Depth	Estimated Coralline Algae Cover
Photo Information	Estimated Uncolonized Bottom

Two benthic habitat assessments were undertaken at each field site. A point assessment was conducted by surveying the one square meter area around the point where the weight dropped and an assessment was conducted in an area of a 7.5 meter radius around the weight. The geomorphologic structure was determined and estimates of each of the biological cover types in the classification scheme were made. The depth of the site was recorded using a hand held depth sounder. The benthic habitat assessments were made using a glass bottom look box, free diving or observing from the surface. All diving was conducted by breath holding or snorkeling on the surface. In areas where waves and sea conditions were prohibitive to safely access the waypoint by boat, the GPS was placed in a watertight box and swam to the survey point.

All observations at each position were recorded on the GPS data logger using a custom data dictionary designed to meet the specifications of the Coral Reef Habitat Classification Scheme. The second most common habitat and general area descriptions as well as the point habitat, the habitat in one m^2 at the point of GPS data collection, were entered in waterproof notebooks and transferred to the GIS by hand.

At the end of each field day, the data was downloaded from the GPS data logger and differentially corrected to the closest CORS. The Trimble GPS file was then converted to an ArcView GIS shape file and the data was compared with the handwritten field notes. All data were processed at the end of each field day.

Observer Objectivity

During the field habitat surveys, ALH mapping personnel made field observations for ground validation and accuracy assessment purposes. Ground validation data were used to elucidate the habitat types where uncertainty existed on the part of the photo interpreter during map preparation and enhance reef habitat and zone interpretation. The field accuracy data collection team independently conducted benthic habitat characterizations and conducted the assessment of the extent to which the photointerpretation met the field assessment determinations. These accuracy assessment field data were not made available to the photo interpreter during manual delineation of habitat boundaries.

3.2 Habitat Delineation, Identification and Mapping Methodologies

The coral reef benthic habitat maps were prepared in a five step process.

1) A first draft coral reef habitat map was produced by delineating all features that could be identified by visual inspection of the IKONOS imagery. This first draft map includes all zones, geomorphologic structure and biological cover types. It was generated by heads up “on screen” manual photointerpretation and delineation in ArcView GIS format. NOAA staff has published an editable ArcView extension that allows for a custom habitat classification scheme to be developed based on the user’s needs. The software also allows for zone classifications to be included and toggles between the legends of the habitats and zones within the GIS system. It also provides the option of setting the area of minimum mapping unit (MMU). It informs the photointerpreter when a polygon is being closed that has an area below the selected MMU and provides the option of including or eliminating that polygon.

NOAA supplied georeferenced imagery to ALH through BAE. Manual delineation process was conducted with the image scale at 1:6,000 with the MMU set to one acre.

All manual delineation was conducted based on the color and texture of the features in the imagery as well as the subcontractor’s extensive knowledge of the coral reef systems and field observations.

2) Areas that were difficult to interpret or where the photo interpreter needed additional field information were identified and labeled as ground validation positions. These locations were explored in the field to enhance map accuracy. A second set of field survey positions were created and used for accuracy assessment of the map products. This second set of points was generated by stratifying each habitat and structure type and generating randomly distributed field positions. This process step is completely described in section 3.3. These surveys were completed and the maps were edited based on the ground validation information to generate a second draft map product. During this edit, the accuracy assessment data was withheld from the photo interpreter.

3) The accuracy of the second draft map was determined based on the field accuracy assessment data. If the accuracy met NOAA standards, the process proceeded to step 4. If it did not, it was returned to the photo interpreter to be further refined. If additional ground validation observations were needed to improve accuracy, they were collected at this time.

4) These map products were then reviewed by local marine biologists, coral reef scientists and marine recourse managers. Comments were integrated into the map products to generate a third draft map.

5) Content Standard for Digital Geospatial Metadata (CSDGM) compliant metadata summaries were prepared for all point and polygon GIS data generated during this tenure. These GIS data and metadata summaries were provided to be reviewed by NOAA and prepared for publication.

3.3 Habitat Map Accuracy Assessment

An accuracy assessment system was designed and executed to quantify the thematic accuracy of the maps generated at all levels of the classification scheme. Statistical analysis methods have been applied that have been developed by other researchers (Hudson and Ramm 1987, Congalton 1991, Rosenfield et al. 1982). In this work, 20 to 30 field habitat observations have been completed per detailed structure as well as detailed biological cover type. The accuracy assessment is prepared from a matrix that compares the attribute assigned to a polygon that was generated from the interpretation of the image with that of the determination from field observation. Traditionally, the data is organized into columns that represent the field habitat validation data and the rows are organized into the interpretation of the images. The overall accuracy is typically measured by dividing the total correct determinations by the total number of assessments. This result only incorporates the major diagonal of the table and excludes the omission and commission errors where as the Kappa analysis (Cohen, 1960) indirectly incorporates the off-diagonal elements as a product of the row and column marginals. Furthermore, the Tau analysis generates a similar statistic as Kappa but compensates for unequal probabilities of groups or for differences in numbers of groups (Ma and Redmond, 1995).

For this work, a total of five accuracy assessment test areas were selected for American Samoa and eleven locations for the Mariana Archipelago (Table 2). Each was selected by a team of local marine and coral reef biologists and coral reef managers. Consideration was taken to select areas the constituted as comprehensive representation of the habitats in this scheme as possible.

Table 2. Accuracy assessment test areas surveyed during this work

Region	Island	Test Area
1	Tutuila	Pala Lagoon
1	Tutuila	Fagatele Bay
1	Tutuila	Fagaitua Bay
1	Tutuila	Tafeu
1	Manua Group	All Islands
2	Guam	Piti Bay
2	Guam	Cocos Lagoon
3	Saipan	Saipan Lagoon
3	Saipan	Lau Lau Bay
3	Tinian	South Beach
3	Rota	West Rota
3	Rota	South East Rota
4	Sarigan	Lee Side of Island
4	Pagan	Entire Island
4	Agrigan	Entire Island
4	Maug	Entire Island

3.4 Ground Validation

The purpose of this survey is to investigate areas of imagery where uncertainties exist on the photo interpreter's behalf during the decision making process of determining benthic habitat type. The GPS data acquisition methods used in this investigation are the same as those used for acquiring habitat data for accuracy assessment. Selection of waypoints and summary of data are significantly modified. Waypoints were selected by manually identifying the areas in the imagery where uncertainty existed in interpretation of benthic habitat. These areas are typically gradients through a transition of two or more habitat types or general areas where the habitat type is uncertain. These positions are then converted to GPS waypoints and occupied in the field.

3.5 Geodetic Control, Accuracy and Verification

Quality control was established by implementation of four steps. These assured a final product meeting the specification of spatial accuracy of GPS data not exceeding 5 meters at a 95% sigma RMS error from their true geographic location. This plan ensured the reliability and accuracy of the field data collected for benthic habitat accuracy assessment and the final GIS map output.

3.5.1 Spatial Accuracy and Precision

Data are collected to determine the spatial accuracy of the GPS positions acquired during this work. At least 20 positions were collected at a fixed feature such as a jetty, channel marker or other fixed feature during each field survey. The variability in this data quantifies spatial precision without error due to navigation. The field team also navigated to a waypoint in the field at least 20 times and circular error was calculated for that data. This quantifies the spatial error in relocating field positions and incorporates error due to navigation. The difference between these two positions gives the error due to station drift in the survey vessel.

Spatial geodetic accuracy was established by occupying established registered benchmarks in the field and collecting at least 20 GPS positions (Figure 1). The GPS data were collected using the same methods used to collect GPS accuracy assessment and ground validation GPS data in the field. Circular RMS error was calculated to establish GPS accuracy.

Figure 1. Sample GPS spatial control site; Tank Monument on Saipan

3.5.2 GIS Quality Control

All GIS map products generated during this work were closely examined (Table 3). Errors such as multipart, overlapping, sliver and void polygons were identified and corrected using an ArcView GIS Quality Control extension downloaded from the ESRI web site. The extension was also used to topologically clean the GIS data. Polygons that are adjacent and have the same zone and habitat attributes are identified using an ArcView script and all errors are corrected. Attribution of GIS polygons was conducted seamlessly using the NOAA habitat digitizing extension software thus errors are not expected. As an additional step in quality control, a tool within this extension searches the GIS database and identifies all polygons where mismatches occur between the polygon attributes and the habitat classification scheme and all errors corrected. GIS data from this work were delivered to BAE free of errors and a final review by ALH confirmed this.

Table 3. Quality control of GIS data delivered in this work

Topology - All GIS data is built and cleaned
Void polygons – Data are free of void polygons
Adjacent polygons with the same zone or habitat do not exist in the data
Multipart polygons do not exist in the data
Overlapping polygons do not exist in the data
Sliver polygons do not exist in the data
All polygons attributed consistent with the classification scheme
All fields in the GIS data base are populated
All “unknown” zones have unknown habitats

3.5.3 Data Security

All digital and hard copy records were kept in secure locations and daily backups were made of field data. The field data acquired each day were archived on CD ROM and handwritten records were collected. Chain of custody records were not needed as all data were maintained in secure custody of ALH at all times.

3.5.4 Tabular Data Quality Control

ALH made a paramount effort to include seamless software processing of all tabular data. Manual entry of data was minimized to limit the possible introduction of human error. However, in some cases, manual entry of information was unavoidable. These steps were identified and particular attention was given to control these processes. An original handwritten record was made for all data where manual entry was required. This record was securely archived and two independent reviews were conducted of the data subsequent to the transfer of the data to the GIS database.

3.6 Records and Metadata Summaries

All physical records, with the exception of accuracy assessment field data, were kept in secure archives at the ALH facilities. Accuracy assessment field data was stored with the field assessment team outside of ALH facilities as this information was not privileged to ALH until map attribute accuracy had been shown to meet NOAA standards. Metadata summaries are prepared in CSDGM compliant format for all GIS point and polygon data and original field notes are included with this delivery.

3.7 Training for Local Staff

A syllabus was developed through which a thorough classroom lecture and hands on field training were conducted for local staff and counterparts to familiarize them with the field data acquisition methods and accuracy assessment used in this work. A two day lecture series in a classroom setting was undertaken to train the participants in the classification scheme, benthic characterization methods, hands on GPS training and preparation for field work. Subsequent to the classroom lecture series, the methods were transferred to the field and each participant was given ample opportunity to conduct benthic assessments and record the data in hard copy notebooks and automated GPS data logger system. The staff members were then trained in the methods of differentially correcting the GPS data and transferring the data to the GIS. After completion of a week of conducting data acquisition and hands on data processing, the group returned to the classroom setting to complete the assessment of map thematic accuracy using the field data they had collected.

4. Results

This Task Order had been organized into four regions. However, as Guam, Southern CNMI and Northern CNMI all occur on the Mariana Archipelago, it was appropriate to combine these three in to a comprehensive accuracy analysis. Therefore, one accuracy assessment was conducted for American Samoa and another for the Mariana Archipelago.

4.1 American Samoa

A complete report on the results of the work conducted during this tenure is included here. All four island areas of American Samoa including Tutuila, The Manua Group, Rose Atoll and Swains Island in included in this report.

4.1.1 Acquisition of GPS Data for American Samoa

Six hundred and thirteen randomly distributed waypoints that were stratified within each detailed habitat type were visited and habitat characterizations conducted during this work. Each position is in ArcView GIS format and all contain the full complement of data described in section 3.1.2.

4.1.2 Accuracy Assessment Data

It was the objective of this work to collect at least 25 field assessments for each of the detailed structure and detailed cover classes that were encountered in the American Samoa test areas. The GIS was queried and the number of positions where each was encountered was tallied (Tables 4 and 5).

During this work, several structural features and biological cover types were not encountered or were encountered only rarely. At the structural level of the classification scheme individual patch reefs were only encountered in the Fagaitua test area where only a few occur. The goal of acquiring 25 positions was met for all other classes of detailed structure.

Table 4. Summary of major and detailed reef structure classes encountered during field accuracy assessment surveys of American Samoa

Major Structure	Count	Detailed Structure	Count
Coral Reef and Hard Bottom	438	Aggregated Patch Reef	38
		Aggregate Reef	34
		Pavement	197
		Rubble	76
		Individual Patch Reef	5
		SCRUS	17
		Spur and Groove	56
		Rock and Boulder	15
Unconsolidated Sediment	128	Sand	52
		Mud	76
Other	47	Land	29
		Artificial	18
Total	**613**	**Total**	**613**

Table 5. Summary of major and detailed biological cover classes encountered during field accuracy assessment surveys of American Samoa

Major Cover	Count	Modifier	Count
Live Coral	264	10%-<50% (Low)	235
		50%-<90% (Medium)	29
Macroalgae	18	10%-<50% (Low)	16
		50%-<90% (Medium)	2
Coralline Algae	137	10%-<50% (Low)	68
		50%-<90% (Medium)	60
		90%-100% (High)	9
Turf	6	10%-<50% (Low)	2
		50%-<90% (Medium)	4
Emergent Vegetation	15	90%-100% (High)	16
Uncolonized	173	90%-100% (High)	173
Total	**613**	**Total**	**613**

A similar tally was generated for primary and detailed biological cover type. Seagrass beds were not encountered during this survey. It is also recognized that high cover of coralline algae as well as all categories of turf and high cover macroalgae were only rarely encountered. It is believed that this is representative of the distribution of biological cover in these study areas.

4.1.3 Ground Validation Data

In this work, 346 ground validation positions were occupied throughout all of the coral reef systems of American Samoa. All islands were visited with the exception of Rose Atoll and Swains Island.

4.1.4 GIS Products, Quality Control Performed and Spatial Accuracy

GPS Data and Field data Collection

Both point and polygon GIS data were generated in this work. Six hundred and fifty one (651) GPS positions were created using the random stratified method, converted to waypoints and navigated to in the test areas of American Samoa. GPS data and habitat characterization data were collected at each point during two field survey periods. Two field surveys were conducted for this work (September 2002 and May 2003). During these visits the data was collected and maps were made using the old classification. Subsequent to this work, comments and suggestions have been incorporated into the new scheme wherein GIS data is organized to separate the geolomorphologic substrate structure of the reef system from the biological cover. The field data and the habitat polygons were converted to the new scheme and are included in this delivery. However, the information in the accuracy assessment data base did not support the conversion of all field data collected during the first work to the new classification scheme. In a limited number of benthic characterizations, the descriptive information did not include biological cover information in the "Turf" category which had been classified as uncolonized in the first classification scheme. It was therefore not scientifically sound to assign a biological cover type to these points. Thirty eight positions were encountered that met this criterion and were therefore not included in the analysis. As a result, six hundred and thirteen positions were converted and used for this accuracy assessment.

In addition, 50 positions were collected for spatial control on conspicuous features in the imagery and registered survey benchmarks. These data have been controlled by executing all quality control measures compliant with the proposed methods. CSDGM metadata summaries have been provided for all of these data and circular RMS error has been calculated for GPS positions as well as on screen digitizing accuracy (Table 6).

All GPS raw data has been included in this delivery along with the correction files obtained from the CORS. All the files needed to recreate the project are included here.

Table 6. Results of spatial accuracy generated from empirical measurements of GPS field positions and onscreen digitizing

Type of Replicate	N	Circular RMS (M)
Accuracy generated from replicates on survey benchmark	18	1.47
Precision generated from replicates on ground condition	50	0.96
On screen digitizing accuracy at 1:6,000 scale	32	0.94

GIS Map Products

Four GIS Map products have been generated in this work and are included in this delivery as ArcView GIS shape files. Each product includes a projection file and CSDGM metadata summary. These include:

- Habitat Map
  - Tutuila
  - Manua
  - Rose Atoll
  - Swains Island
- Accuracy Assessment Field Surveys
  - All American Samoa
- Ground Validation Field Surveys
  - All American Samoa
- Spatial Control Field Surveys
  - All American Samoa

4.1.5 Coral Reef Habitat Map Thematic Accuracy

A comprehensive accuracy assessment has been conducted of the coral reef habitat map product that included all the data collected for the five test areas of American Samoa. Six hundred and thirteen benthic habitat characterizations were conducted for this purpose. These data were overlaid on the second draft maps generated from visual interpretation of the IKONOS imagery and error matrixes developed. As the coral reef habitat maps for American Samoa were originally delineated using the old coral reef habitat classification scheme and subsequently converted to the new, the accuracy of all levels of both schemes is reported on here. Error matrices were generated for the old scheme (Tables 7, 8, and 9) and a second set were generated for the new scheme (Tables 10, 11, 12, and 13). In this summary, the overall accuracy, user and producer accuracy as well as incorrect classifications are presented. The Tau coefficient was also calculated. It will be noted that the detailed cover error matrix is not tabulated for either the old or new classification scheme. Due to the large number of classes at the detailed level, the tables are too large to display. However, the results of these error calculations are presented in the overall summaries for each scheme (Tables 9 and 13).

Table 7. Coral reef habitat thematic map accuracy of major habitats of American Samoa based on the old classification scheme

		Truth Based on Field Observations					
Polygon Attributes		Coral Reef and Hard Bottom	Submerged Vegetation	Unconsolidated Sediment	Other	Total	UA
	Coral Reef and Hard Bottom	**453**	1	10		464	98%
	Submerged Vegetation	1	**14**			15	93%
	Unconsolidated Sediment	8	3	**114**		125	91%
	Other				**47**	47	100%
	Total	462	18	124	47	Diag. Sum:628	
	PA	98%	78%	92%	100%	Total Observations: 651	
	Overall Accuracy					**96%**	

It can be seen from these data that the coral reef habitat maps prepared for American Samoa meet contractual standards of 0.75 and 0.85 Tau for the detailed and major levels of the classification scheme respectively.

4.1.6 Coral Reef Habitat Maps and Thematic Content Summary

A GIS summary has been prepared that presents the areas of each of the detailed structure classes and major cover classes encountered in the American Samoa Region (Tables 14 and 15). The information is presented in absolute areas (km^2) and percentage of the total coral reef area mapped. From this data it can be seen that of the 71.5 km^2 mapped, 83.5% is coral reef and hard bottom and 14.7% is composed of unconsolidated sediment. Fifty three percent of the total area mapped is colonized by at least 10% live coral cover.

Sample maps have been provided of the detailed structure (Figure 2) and detailed biological cover (Figure 3) of the Pala Lagoon test area on Tutuila, American Samoa.

4.2 Mariana Archipelago

A complete report on the results of the work conducted during this tenure is included here. Regions 2, 3 and 4 which consist of all islands of the Mariana Archipelago were combined into a single accuracy assessment. Eleven test areas were surveyed for this work (Table 2).

4.2.1 Acquisition of GPS Data for The Mariana Archipelago

Within the 11 test areas, 1113 randomly distributed waypoints that were stratified within each detailed habitat type were visited and habitat characterizations conducted during this work. Each position is in ArcView GIS format and all contain the full complement of data outlined in section 3.1.2. Four hundred nineteen ground validation positions were occupied and 133 GPS positions were collected to meet the objectives of spatial control.

4.2.2 Accuracy Assessment Data

It was the objective of this work to collect at least 25 field assessments for each of the detailed structure and detailed cover classes that were encountered in the Mariana Archipelago. The GIS was queried and the number of positions where each was encountered was tallied (Tables 16 and 17). All detailed structure and cover biological classes that occur in this area were completely sampled.

Table 8. Coral reef habitat thematic map accuracy of second level habitats of American Samoa Based on the old classification scheme

Polygon Attribute	Truth Based on Field Observations:	Colonized	Uncolonized	Coralline Algae	Macroalgae	Sand	Mud	Emergent Vegetation	Land	Artificial	**Total**	**UA**
	Colonized	**273**	12	14	1	4					304	90%
	Uncolonized	5	**85**	5		6					101	84%
	Coralline Algae	7	4	**48**							59	81%
	Macroalgae	1			**14**						15	93%
	Sand	5	3		2	**51**					61	84%
	Mud				1	2	**61**				64	95%
	Emergent Vegetation							**15**			15	100%
	Land								**14**		14	100%
	Artificial									**18**	18	100%
	Total	291	104	67	18	63	61	15	14	18	Total Observations	Diagonal Sum
	PA	94%	82%	72%	78%	81%	100%	100%	100%	100%	651	579
	Overall Accuracy											**89%**

Table 9. Summary of thematic accuracy of American Samoa benthic habitat map based on the old classification scheme

	Overall Accuracy (%)	**Tau**
Major Level	96	0.92
Second Level	89	0.85
Detailed level	85	0.84

Table 10. Coral reef habitat map accuracy of major reef structure classes of American Samoa based on the new classification scheme

		Truth Based on Field Observation				
		Coral Reef and Hard Bottom	Unconsolidated Sediment	Other	Total	UA
Polygon Attribute	Coral Reef and Hard Bottom	430	4		434	99%
	Unconsolidated Sediment	8	124		132	94%
	Other			47	47	100
	Total	438	128	47	Diagonal Sum: 601	
	PA	98%	97%	100%	Total Observations: 613	
	Overall Accuracy					**98.0%**

Table 11. Coral reef habitat map accuracy of detailed reef structure classes of American Samoa based on the new classification scheme

		Truth Based on Field Observations													
Polygon Attributes		AgRf	AgPR	IndPR	SnG	SCRUS	Pvnt	Rock/Bldr	Rubble	Sand	Mud	Land	Artificial	Total	UA
	AgRf	**26**	3		2	1	18	4	3	2				59	44%
	AgPR	1	**28**						2	1				32	88%
	IndPR			**5**										5	100%
	SnG	1			**52**		2							55	95%
	SCRUS		2			**15**	1							18	83%
	Pvnt	4	1		2	1	**161**	5		1				188	86%
	Rock/Bldr						1	**5**		1				7	71%
	Rubble	1	1				12	1	**55**					70	79%
	Sand	1	3				2		2	**45**				53	85%
	Mud									3	**76**			79	96%
	Land											**29**		29	100%
	Artificial												**18**	18	100%
	Total	34	38	5	56	17	197	15	76	52	76	29	18	Diag. Sum 515	
	PA	46%	74%	100%	93%	88%	82%	33%	72%	87%	100%	100%	100%	Total Obs. 613	
	Overall Accuracy														**84%**

Table 12. Coral reef habitat map accuracy of major biological cover classes of American Samoa based on the new classification scheme

	Truth Based on Field Observations								
Polygon Attributes		Coral	Coralline Algae	Macroalgae	Turf	Emergent Vegetation	Uncolonized	Total	UA
	Coral	**247**	32	1	2		11	293	84%
	Coralline Algae	12	**102**	1	1		1	117	87%
	Macroalgae		1	**13**			1	15	43%
	Turf		1		**3**		3	7	43%
	Emergent Vegetation					**15**		15	100%
	Uncolonized	5	1	3			**157**	166	95%
	Total	264	137	18	6	15	173	Diag. Sum: 537	
	PA	94%	74%	72%	50%	100%	91%	Total Obs: 613	
	Overall Accuracy								**87.7%**

Table 13. Summary of thematic accuracy of American Samoa benthic habitat map based on the new classification scheme

Map Category	Overall Accuracy	Tau
Major Structure	98.0%	0.97
Detailed Structure	84.0%	0.83
Major Cover	87.6%	0.86
Detailed Cover	77.3%	0.76

Table 14. Coral reef habitat thematic content summary of structure classes of American Samoa

Coral Reef Structure Type	Area (km^2)	% of Total Reef Area
Pavement	29.9	41.4
Spur and Groove	8.8	12.4
Individual Patch Reef	0.3	0.4
Aggregate Patch Reef	0.7	1.0
Aggregated Reef	9.4	13.2
Rock/Boulder	1.9	2.7
Rubble	8.4	1.8
Scattered Coral and Rock in Unconsolidated Sediment	1.6	2.3
Total Coral Reef and Hard Bottom	**60.9**	**85.3**
Sand	8.9	12.4
Mud	1.7	2.4
Total Unconsolidated Sediment	**10.5**	**14.7**
Total Coral Reef Area	**71.5**	**100**

Table 15. Coral reef habitat thematic content summary of biological cover classes of American Samoa

Coral Reef Biological Cover Type	Area (km^2)	% of Area
Coral	38.3	53.0
Macroalgae	2.6	3.6
Coralline Algae	14.9	20.8
Turf	4.9	6.9
Emergent Vegetation	0.3	0.4
Uncolonized	10.5	14.7
Total Coral Reef Area	**71.5**	**100**

Figure 2. Coral reef habitat map of detailed structure classes of the Pala Lagoon test area on Tutuila, American Samoa

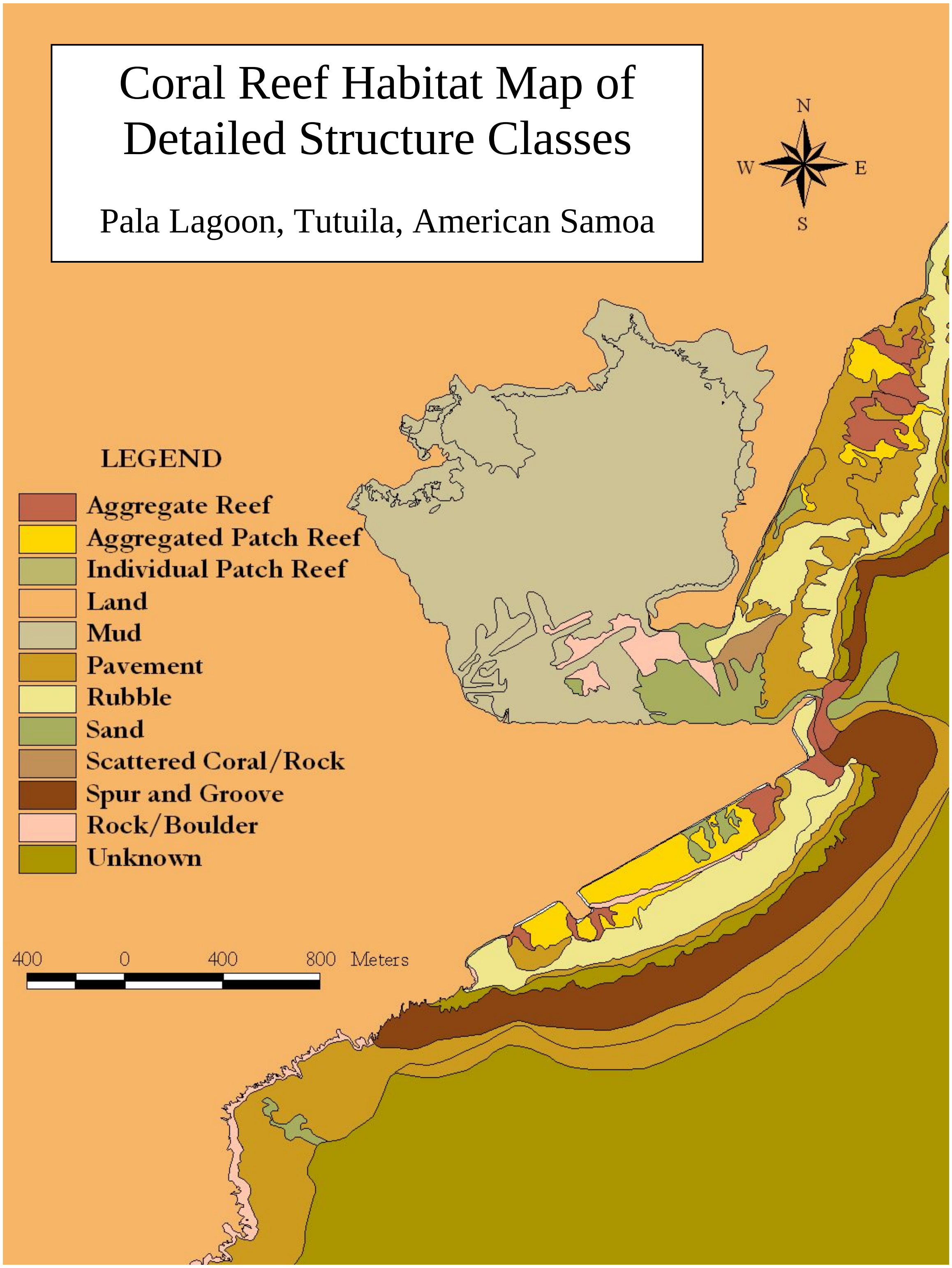

Figure 3. Coral reef habitat map of detailed biological cover classes of the Pala Lagoon test area on Tutuila, American Samoa

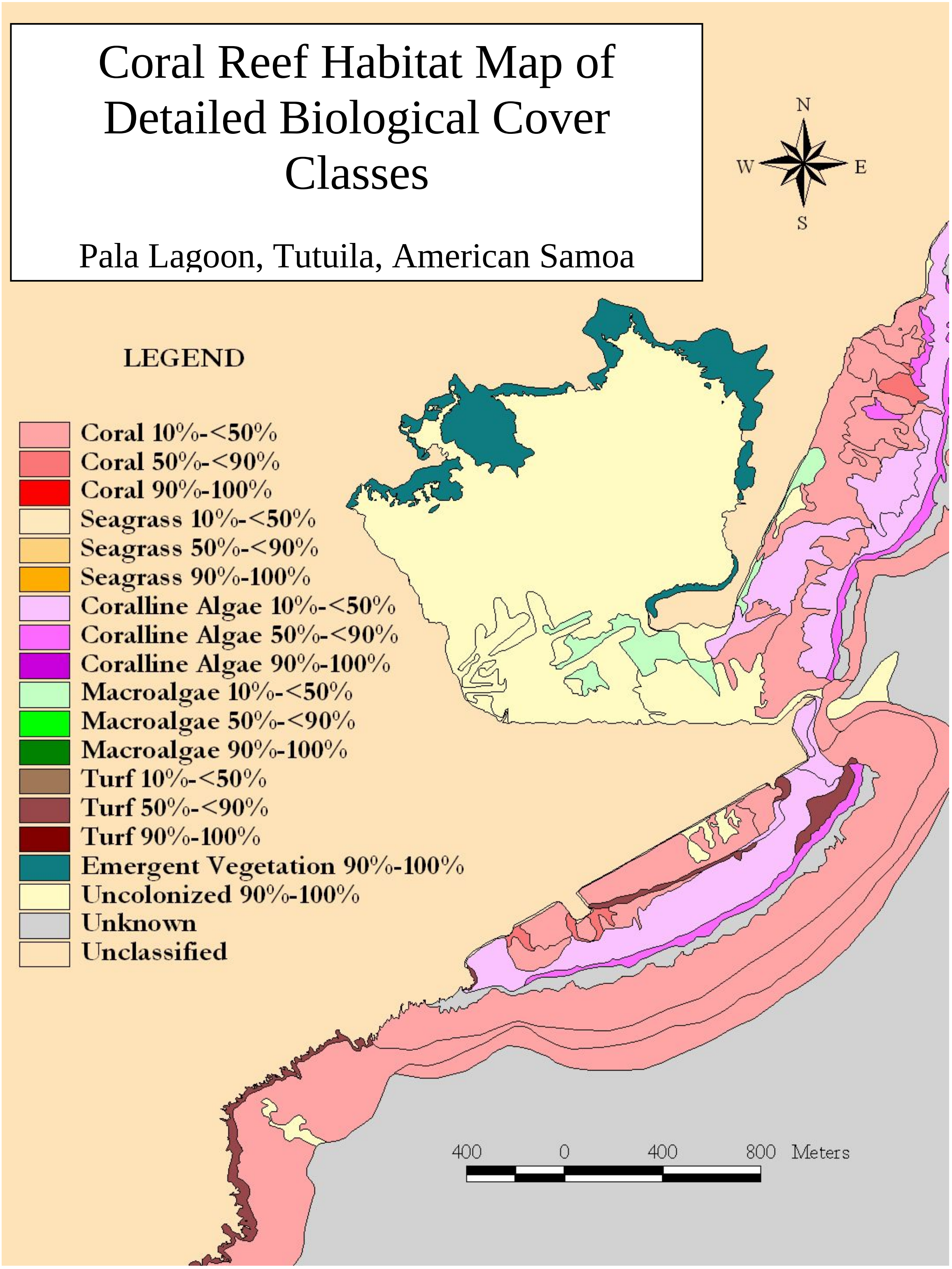

Table 16. Summary of major and detailed reef structure classes encountered during field accuracy assessment surveys of the Mariana Archipelago

Major Structure	Count	Detailed Structure	Count
Coral Reef and Hard Bottom	885	Aggregated Patch Reef	49
		Aggregate Reef	57
		Pavement	395
		Rubble	41
		Individual Patch Reef	27
		Spur and Groove	89
		Rock and Boulder	192
		SCRUS	35
Unconsolidated Sediment	222	Sand	189
		Mud	33
Total	**1107**	**Total**	**1107**

Table 17. Summary of major and detailed biological cover classes encountered during accuracy assessment field surveys of The Mariana Archipelago

Major Cover	Count	Modifier	Count
Live Coral	421	10%-<50% (Low)	390
		50%-<90% (Medium)	31
Seagrass	101	10%-<50% (Low)	38
		50%-<90% (Medium)	30
		90%-100% (High)	33
Macroalgae	151	10%-<50% (Low)	98
		50%-<90% (Medium)	23
		90%-100% (High)	30
Coralline Algae	197	10%-<50% (Low)	104
		50%-<90% (Medium)	67
		90%-100% (High)	26
Turf	130	10%-<50% (Low)	48
		50%-<90% (Medium)	54
		90%-100% (High)	28
Emergent Vegetation	28	90%-100% (High)	28
Uncolonized	79	90%-100% (High)	79
Total	**1107**	**Total**	**1107**

4.2.3 Ground Validation Data

In this work, 419 ground validation positions were occupied throughout all of the coral reef systems of The Mariana Archipelago. The Islands surveyed include:

- Guam
- Rota
- Tinian
- Saipan
- Sarigan
- Pagan
- Agrigan
- Maug

4.2.4 GIS Products, Quality Control Performed and Spatial Accuracy

GPS Data and Field Data Collection

Both point and polygon GIS data were generated in regions 2, 3 and 4. Eleven hundred and thirteen (1113) GPS positions were created using the random stratified method, converted to waypoints and navigated to in all eleven test areas throughout the Mariana Archipelago. Of these positions, five were inaccessible due to safety concerns and were collected at alternate locations. These five positions were inadvertently collected in areas where wave action obscured the benthic features in the imagery and were therefore not included in the analysis. One position was accidentally included during the training session on Saipan that was on land and was therefore also not included in the accuracy analysis. Therefore, of the 1113 benthic habitat characterizations that were collected for assessment of thematic accuracy, 1107 were included in the final analysis.

In addition, 133 positions were collected for spatial control on conspicuous features in the imagery and registered survey benchmarks. These data have been controlled by executing all quality control measures compliant with the proposed methods. CSDGM metadata summaries have been provided for all of these data and circular RMS error has been calculated for GPS positions as well as on screen digitizing accuracy (Table 18).

All GPS raw data has been included in this delivery along with the correction files obtained from the CORS. All the files needed to recreate the project are included here.

Table 18. Results of spatial accuracy generated from empirical measurements of GPS field positions and onscreen digitizing for the Mariana Archipelago

Type of Replicate	N	Circular RMS (M)
Accuracy generated from replicates on survey benchmark s	100	1.14
Precision generated from replicates on ground condition	133	1.04
On screen digitizing accuracy at 1:6,000 scale	32	0.94

GIS Map Products

Four types of GIS Map products have been generated in this work and are included in this delivery as ArcView GIS shape files. Each product includes a projection file and CSDGM metadata summary. These include:

- Habitat Map
  - Guam
  - Rota
  - Tinian and Aguijan
  - Saipan
  - Farallon de Mendinilla
  - Anatahan
  - Sarigan
  - Guguan
  - Alamagan
  - Pagan
  - Agrigan
  - Asuncion
  - Maug
  - Farallon de Pajaros
- Accuracy Assessment Field Surveys
  - All of the Mariana Archipelago
- Ground Validation Field Surveys
  - All of the Mariana Archipelago
- Spatial Control Field Surveys
  - All of the Mariana Archipelago

4.2.5 Coral Reef Habitat Map Thematic Accuracy

A comprehensive accuracy assessment has been conducted of the coral reef habitat map product for the eleven test areas of the Mariana Archipelago. Eleven hundred and seven benthic habitat characterizations were conducted for this purpose. These data were overlaid on the draft 2 maps generated from visual interpretation of the IKONOS imagery and error matrixes developed (Tables 19, 20 and 21). In this summary, the overall accuracy, user and producer accuracy as well as incorrect classifications are presented. The Tau coefficient was also calculated. It will be noted that the detailed cover error matrix is not tabulated. Due to the large number of classes at the detailed level, the tables are too large to display. However, the results of these error calculations are presented in the overall summaries (Table 22).

Table 19. Coral reef habitat map accuracy of major reef structure classes of the Mariana Archipelago based on the new classification scheme

	Truth Based on Field Observation				
Polygon Attribute		Coral Reef and Hard Bottom	Unconsolidated Sediment	Total	UA
	Coral Reef and Hard Bottom	**876**	5	881	99.4%
	Unconsolidated Sediment	9	**217**	226	96.0%
	Total	885	222	Diagonal Sum: 1093	
	PA	99.0%	97.7%	Total Observations: 1107	
				Overall Accuracy	**98.7%**

4.2.6 Coral Reef Habitat Maps and Thematic Content Summary

A GIS summary has been prepared that presents the areas of each of the detailed structure classes and major cover classes encountered in the three regions of the Mariana Archipelago (Tables 14 and 15). The information is presented in absolute areas (km^2) and percentage of the total coral reef area mapped. From this data it can be seen that of the 308.5 km^2 mapped, 72.4% is coral reef and hard bottom and 26.6% is composed of unconsolidated sediment. Thirty two percent of the total area mapped is colonized by at least 10% live coral cover.

Sample maps have been provided of the detailed structure (Figures 4, 6, and 8,) and detailed biological cover (Figures 5, 7, and 9) of the Cocos Lagoon, Saipan Lagoon and Maug Islands, one sample from each region.

Figure 4. Coral reef habitat map of detailed structure classes of the Cocos Lagoon test area on Guam

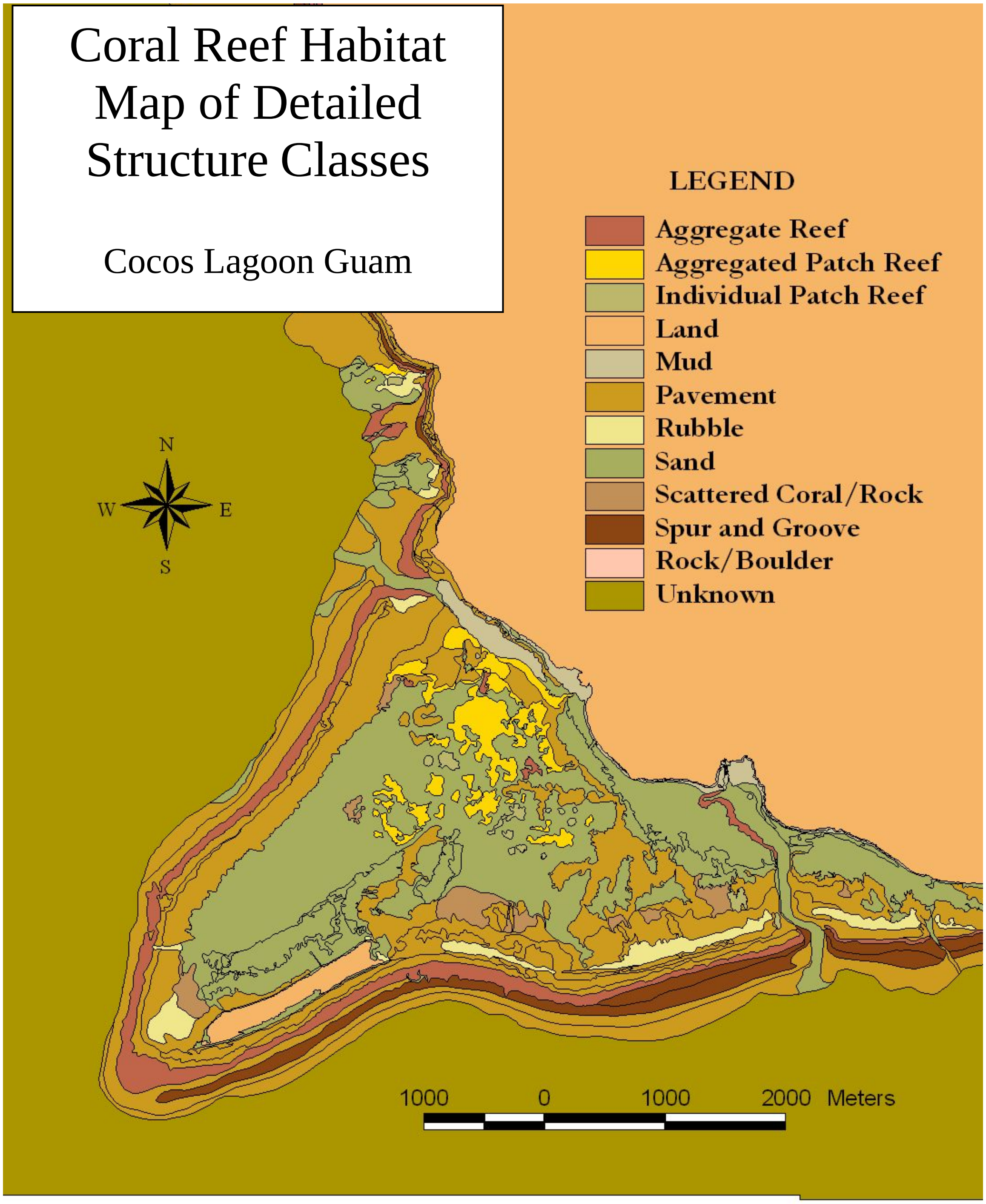

Figure 5. Coral reef habitat map of detailed biological cover classes of the Cocos Lagoon test area on Guam

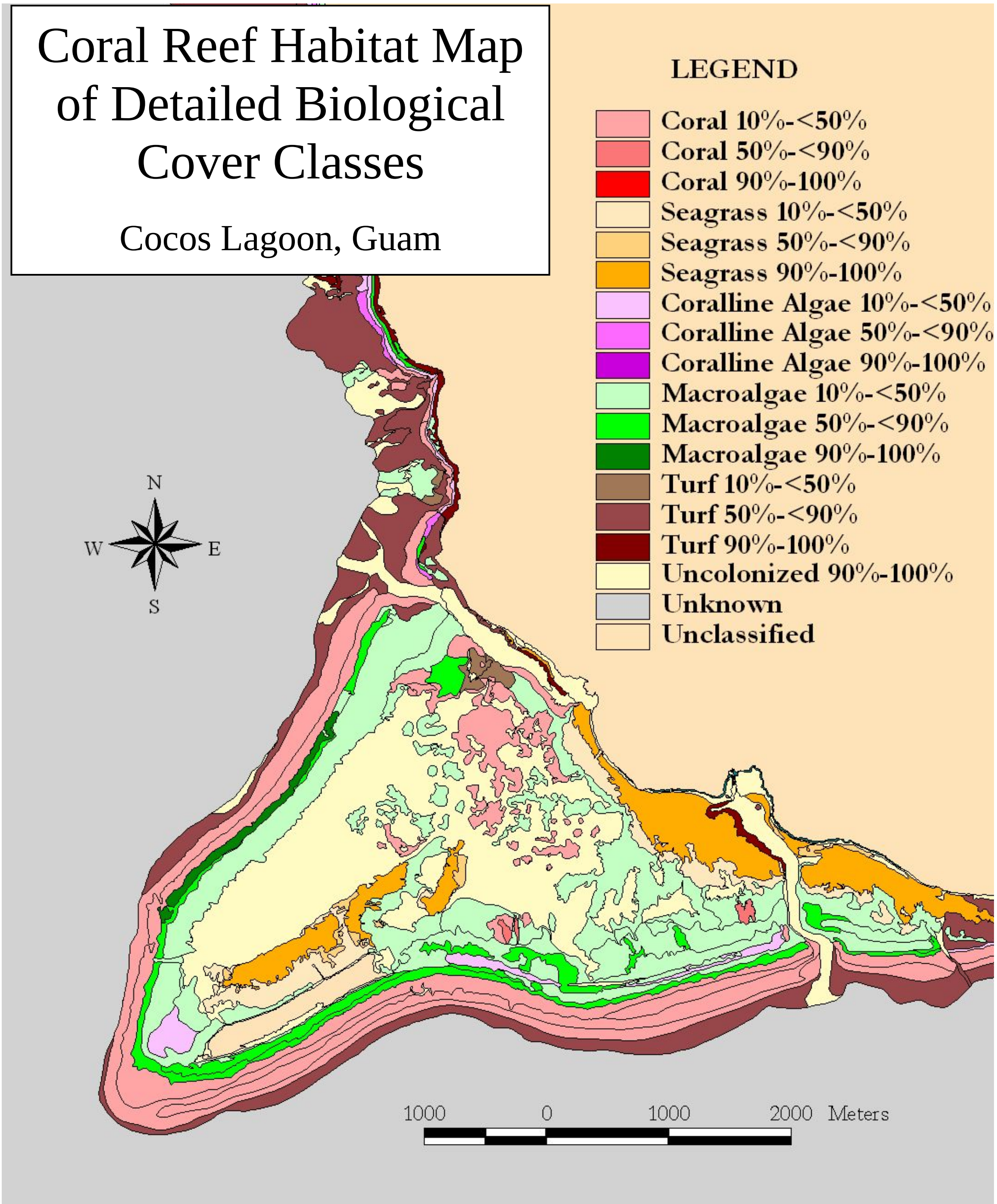

Figure 6. Coral reef habitat map of detailed structure classes of the Saipan Lagoon test area on Saipan

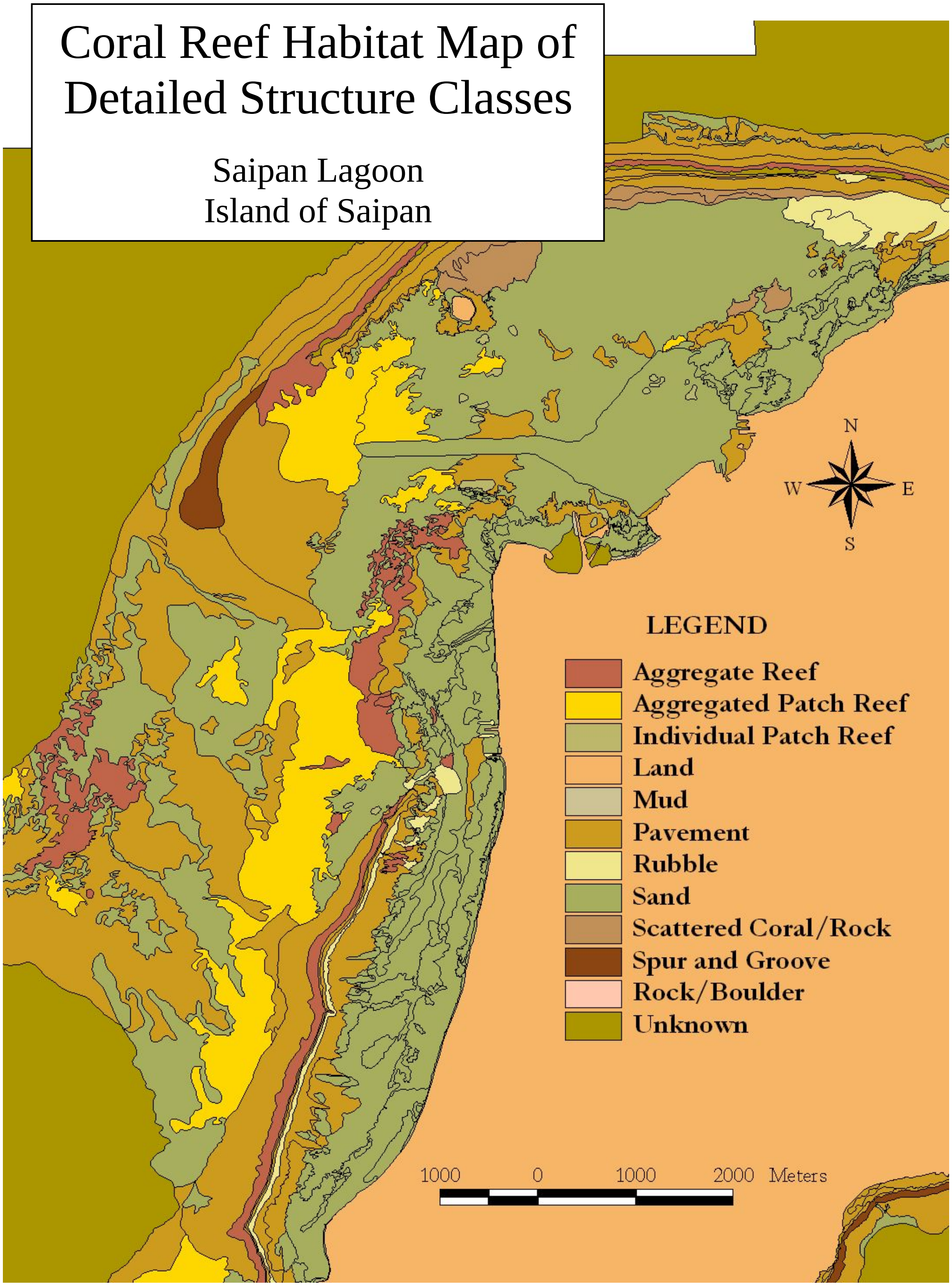

Figure 7. Coral reef habitat map of detailed biological cover classes of the Saipan Lagoon test area on Saipan

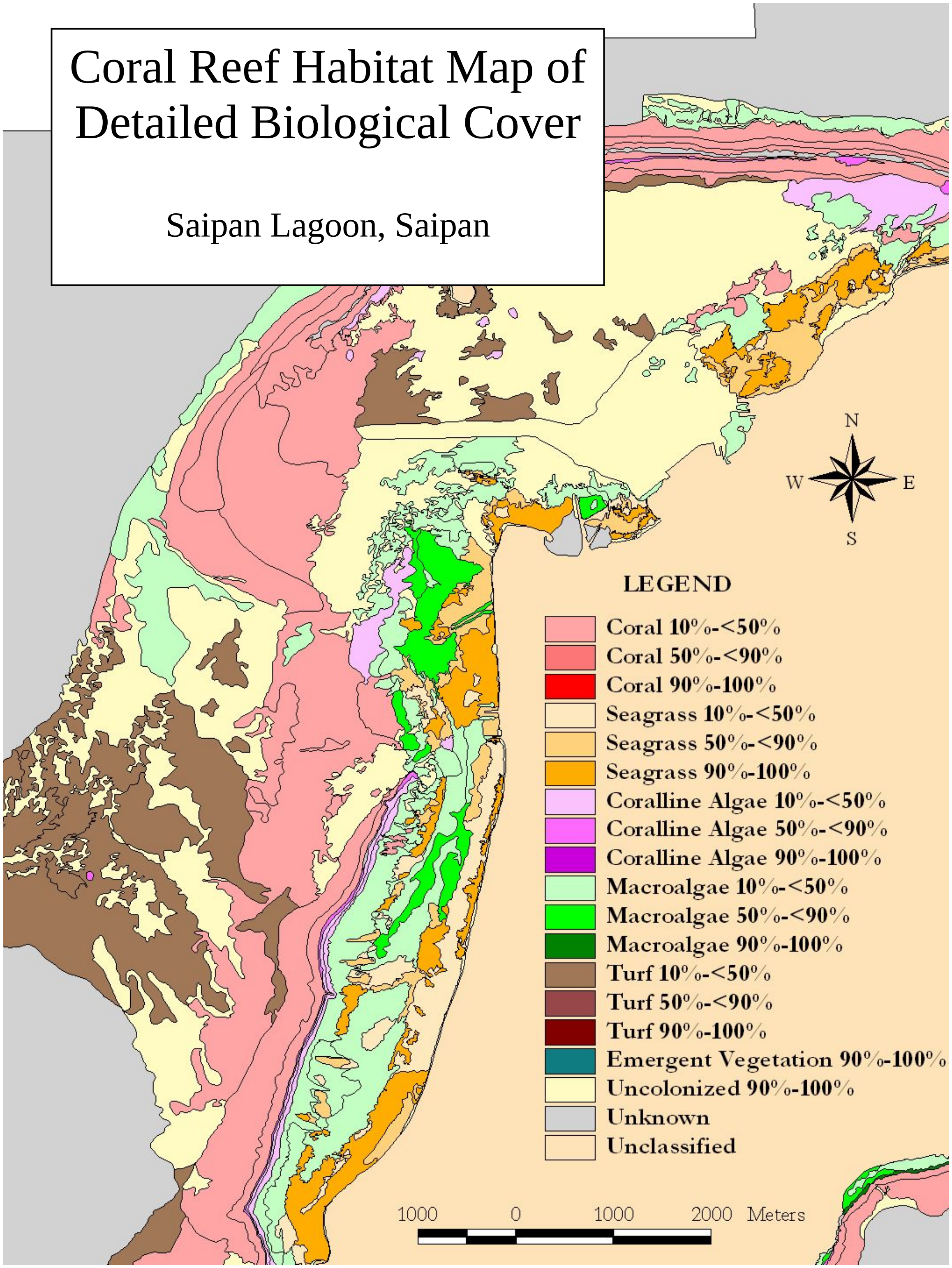

Figure 8. Coral reef habitat map of detailed structure classes of the Maug Islands test area in the northern islands of CNMI

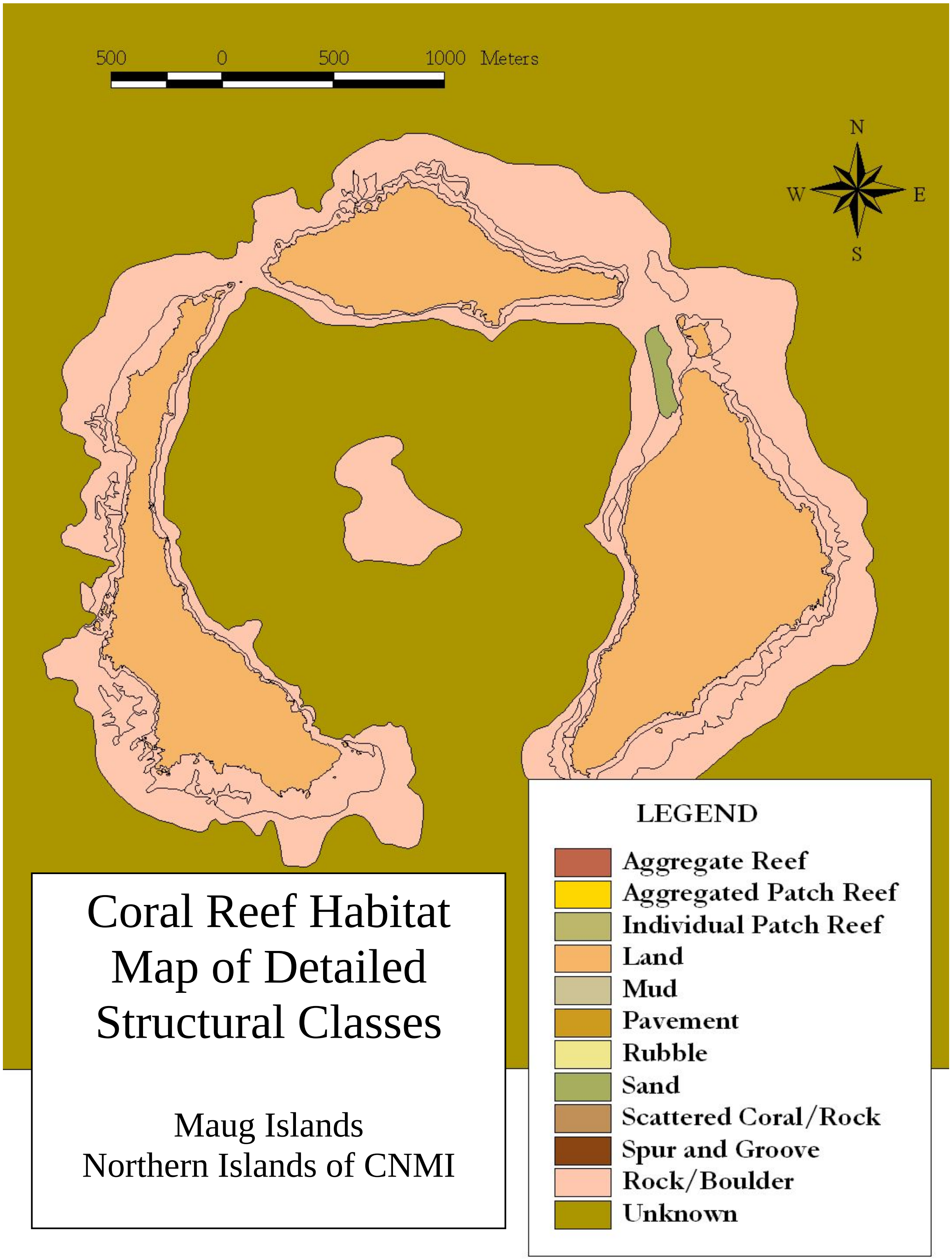

Figure 9. Coral reef habitat map of detailed biological cover classes of the Maug Islands test area in the northern islands of CNMI

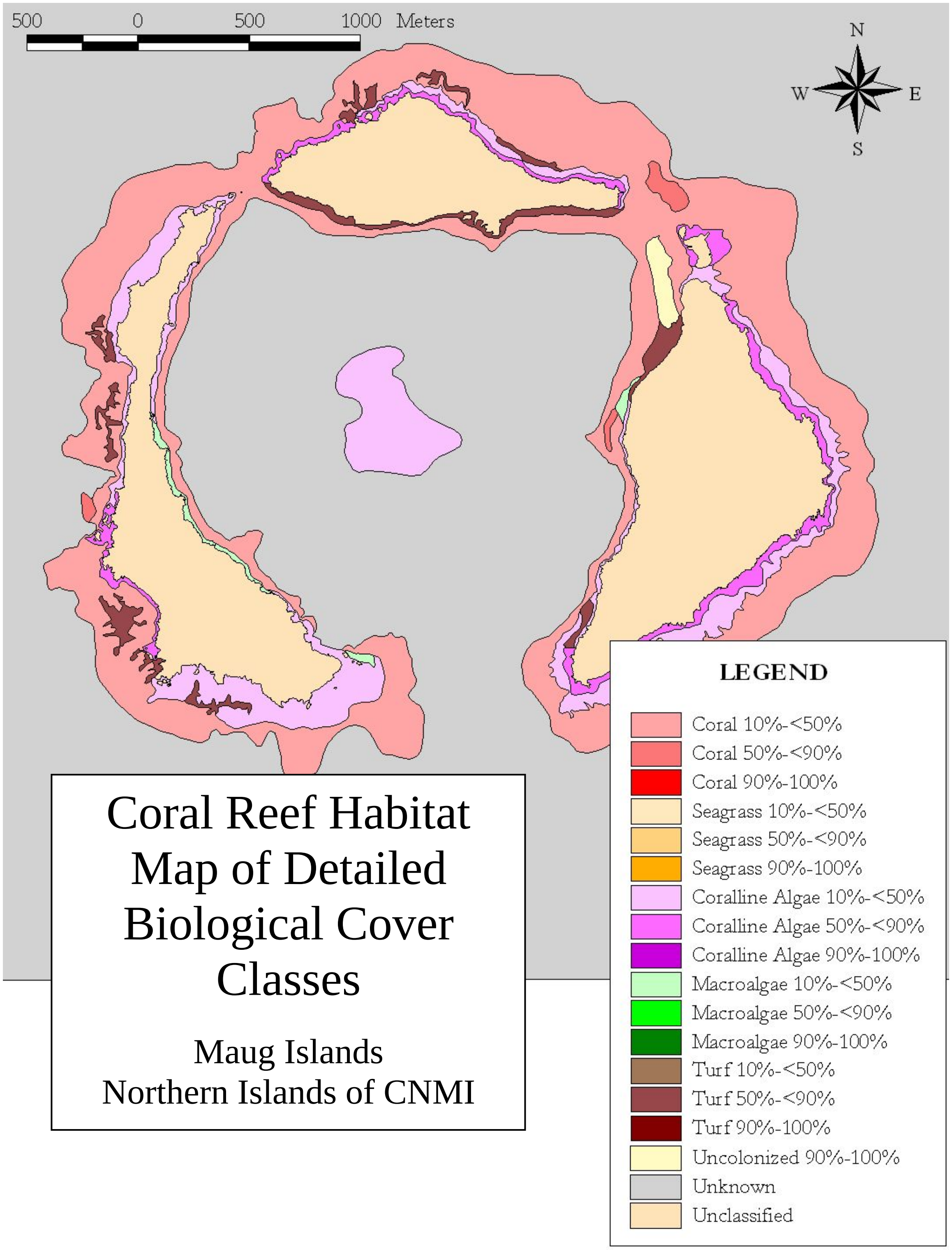

Table 20. Coral reef habitat map accuracy of detailed reef structure classes of the Mariana Archipelago based on the new classification scheme

	Truth Based on Field Observations												
Polygon Attributes		AgRf	AgPR	IndPR	SnG	SCRUS	Pvnt	Rock/Bldr	Rubble	Sand	Mud	Total	UA
	AgRf	**50**					4				1	55	91%
	AgPR		**40**				2		1		1	44	91%
	IndPR		2	**25**								27	93%
	SnG	2			**74**		13					89	83%
	SCRUS					**33**	4					39	85%
	Pvnt	5	4	1	15	2	**369**		11			405	91%
	Rock/Bldr							**191**		2		193	99%
	Rubble								**26**	1		29	90%
	Sand		3	1	2			1	1	**184**		193	95%
	Mud										**33**	33	100%
	Total	57	49	27	89	35	395	192	41	189	33	Diag. Sum:1025	
	PA	88%	82%	93%	83%	94%	99%	63%	97%	100%		Total Obs. 1107	
	Overall Accuracy												**84%**

Table 21. Coral reef habitat map accuracy of major biological cover classes of the Mariana Archipelago based on the new classification scheme

	Truth Based on Field Observations									
Polygon Attributes		Coral	Coralline Algae	Macro algae	Turf	Seagrass	Emergent Vegetation	Uncolonized	Total	UA
	Coral	**387**	16	7	25			2	437	89%
	Coralline Algae	23	**168**	**1**	15				207	81%
	Macroalgae	5	7	**136**	7	1			156	87%
	Turf	4	3	1	**79**			2	89	89%
	Seagrass			1		**100**			101	99%
	Emergent Vegetation						**27**		27	100%
	Uncolonized	2	3	5	4		1	**75**	90	84%
	Total	421	197	151	130	101	28	79	Diag. Sum: 972	
	PA	92%	85%	90%	61%	99%	96%	95%	Total Obs: 1107	
	Overall Accuracy									

Table 22. Summary of Map Accuracy of the Mariana Archipelago based on the new classification scheme

Map Category	Overall Accuracy	Tau
Major Structure	98.7%	0.98
Detailed Structure	92.6%	0.92
Major Cover	87.8%	.086
Detailed Cover	80.9%	0.80

Table 23. GIS area analysis for the structural component of coral reef habitats of Guam

Coral Reef Structure Type	Area (km^2)	% of Total Reef Area
Pavement	45.0	43.0
Spur and Groove	7.0	6.7
Individual Patch Reef	0.4	0.4
Aggregate Patch Reef	1.4	1.3
Aggregated Reef	16.0	15.3
Rock/Boulder	0.6	0.6
Rubble	0.8	0.8
Scattered Coral and Rock in Unconsolidated Sediment	0.4	0.4
Total Coral Reef and Hard Bottom	**71.7**	**68.5**
Sand	32.3	31.9
Mud	0.6	0.6
Total Unconsolidated Sediment	**32.9**	**31.5**
Total Coral Reef Area	**104.5**	**100**

Table 24. GIS area analysis for the biological cover component of coral reef habitats of Guam

Coral Reef Biological Cover Type	Area (km^2)	% of Area
Coral	25.4	24.3
Seagrass	3.7	3.5
Macroalgae	16.8	16.1
Coralline Algae	3.8	3.6
Turf	25.6	24.5
Emergent Vegetation	0.2	0.2
Uncolonized	28.9	27.7
Total Coral Reef Area	**104.5**	**100**

Table 25. GIS area analysis for the structural component of coral reef habitats of the southern islands of CNMI

Coral Reef Structure Type	Area (km^2)	% of Total Reef Area
Pavement	55.0	35.3
Spur and Groove	13.7	8.6
Individual Patch Reef	0.2	0.1
Aggregated Patch Reef	13.5	8.5
Aggregate Reef	9.3	5.9
Rock/Boulder	0.3	0.2
Rubble	2.0	1.3
Scattered Coral and Rock in Unconsolidated Sediment	1.3	0.8
Pavement with Sand Channels	15.3	**9.0**
Total Coral Reef and Hard Bottom	**110.6**	**69.7**
Sand	48.1	30.3
Mud	.02	0.01
Total Unconsolidated Sediment	**48.1**	**30.3**
Total Coral Reef Area	**158.7**	**100**

Table 26. GIS area analysis for the biological cover component of coral reef habitats of the southern islands of CNMI

Coral Reef Biological Cover Type	Area (km^2)	% of Area
Coral	47.7	30.0
Seagrass	6.7	4.2
Macroalgae	18.5	11.8
Coralline Algae	22.2	14.4
Turf	24.4	15.4
Uncolonized	39.2	24.7
Total Coral Reef Area	**158.7**	**100**

Table 27. GIS area analysis for the structural component of coral reef habitats of the northern islands of CNMI

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

Table 28. GIS area analysis of the biological cover component of coral reef habitats of the northern islands of CNMI

Coral Reef Biological Cover Type	Area (km^2)	% of Area
Coral	24.3	53.6
Macroalgae	1.1	2.4
Coralline Algae	9.2	20.3
Turf	7.2	15.9
Uncolonized	3.5	7.7
Total Coral Reef Area	**45.3**	**100**

4.2.7 Training for Local Staff

All training goals that were specified in the proposal for this work have been completed. A custom syllabus was created to combine “hands on” lecture and field exercises to transfer the methods used in field data acquisition and accuracy assessment of these map products. Training sessions were conducted on Saipan and Guam and in each case the information that was included in the program was tailored to the needs and guidance of local interests. On Saipan, 9 staff from the Department of Environmental Quality and the Coastal Resources Management teams attended the training. On Guam, 11 participants representing the Bureau of Statistics and Planning, The Department of Aquatic and Wildlife Resources and the University of Guam participated in the training. (Figures 10 and 11).

Figure 10. Scanned copy of the attendance sheet for the Benthic Habitat Mapping Training for Saipan

Attendance Sheet

Benthic Habitat Mapping Training for Saipan

Name	Affiliation	Phone Number	email
PETER HOUK	DEQ	664-8504	deq.biologist@saipan.com
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Julie Manibusan	CRM	664-8306	

Figure 11. Scanned copy of the attendance sheet for the Benthic Habitat Mapping Training for Guam

Attendance Sheet

Benthic Habitat Mapping Training for Guam

Name	Affiliation	Email
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5. Discussion

During this work, modifications were made to the classification scheme resulting from comments and suggestions received by local coral biologists and reef managers. The most significant change was the revision of the classifications scheme into a two layer scheme with one layer representing the geomorphologic structure of the reef and the second representing the biological cover. As the structure of the reef is typically monotypic, a hierarchy of classes is not required to determine the class type. However, as the biological cover is typically characterized by a complex community with many classes represented with in a single benthic habitat characterization survey area, a hierarchy was established. This hierarchy was created based on the interests and recommendations of the coral reef management community (Section 2.1). It is recognized that the classes at the top of the hierarchy are therefore more likely to be encountered than those at levels lower in the scheme. As a result, the high coralline algae cover classes are often not well represented in an accuracy assessment data set as either macro algae or coral is nearly always present and takes priority over this class.

It was also observed that some classes are poorly represented in certain regions whereas others are strongly represented. In areas where a class is poorly represented, the objective of conducting 25 assessments per class may not be feasible. For example, sea grass was not encountered in The American Samoa and Northern Islands of CNMI regions but was abundant in the Guam and Southern Islands of CNMI regions. Volcanic rock was not encountered in the Southern Islands of CNMI but was encountered elsewhere. Furthermore, some classes were not encountered in any of the regions. The structure classified as “Pavement with Sand Channels” was not encountered in any test area.

Power analysis was conducted on accuracy assessment tests for the Main Eight Hawaiian Islands and sampling frequency was derived. It was determined that 25 samples per class yield a 95% confidence of the accuracy of these map products. This analysis was conducted on a class by class basis and the results indicated that some classes do not require as robust of a sample set due to the very high accuracy of the interpretation of that class from the remotely sensed imagery. Examples include emergent vegetation and Land. As a result, fewer samples were collected in these. Both classes have historically been mapped at 100% accuracy in both user and producer accuracy.

The process of determining the thematic accuracy of a map includes identifying the correct determinations and examining the incorrect determinations to establish their suitability to be used in the assessment. When an accuracy assessment field survey is conducted on a feature that is smaller than the MMU it is not used in the accuracy determination. When a survey is conducted in an area that can not be classified due to environmental conditions such as surf, turbidity or cloud cover, it is also not used in the assessment. These conditions occur rarely. In the American Samoa accuracy assessment, 651 benthic characterizations were conducted of which 643 were used to determine the accuracy of the maps prepared on the first classification scheme. Furthermore, in American Samoa, much of the field data was collected prior to the decision to upgrade the classification scheme to the two layered system. As the new classification scheme required information that was not included in benthic assessments conducted to establish thematic accuracy on the old scheme, this data set was further reviewed to identify the samples where benthic habitat content was suitable to determine the habitat class of the new scheme. Six hundred and thirteen of the 643 classes used in the accuracy assessment on the old scheme were used in the assessment of accuracy of the maps delivered using the new system. In the data set collected for the Mariana Archipelago, all but 6 of the 1113 characterizations for the Mariana Archipelago were used. Five of these were collected in areas where surf obscured the bottom and one was not used due to a minimum mapping conflict. All other data was included in the assessment of the thematic accuracy of these products.

6. List of Products Delivered

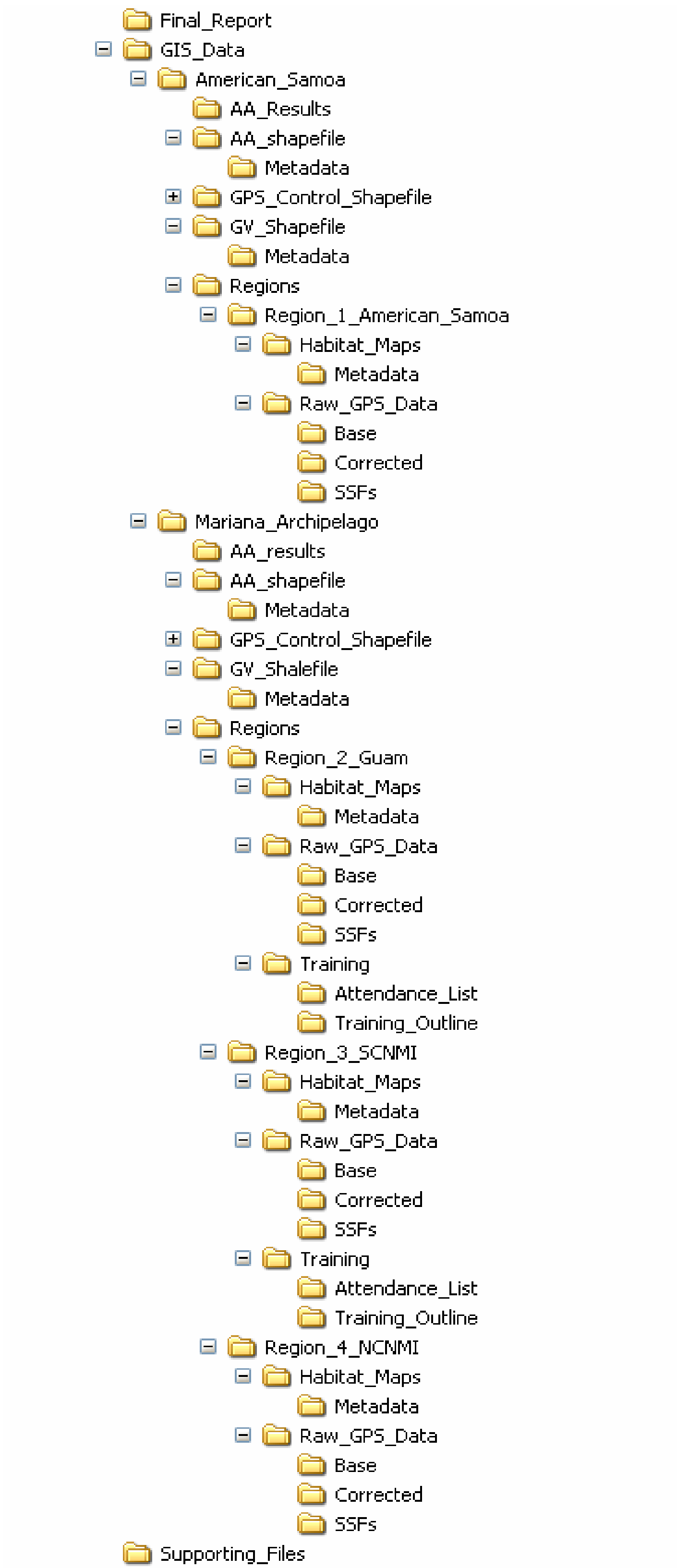
Nine contract line items were agreed on for this work (Table 29). All work has been completed.

Table 29. Contract line items that have been delivered during this tenure

Completion of Contract Line Items		
CLIN	**Description**	**Level of Completion**
0001A	American Samoa Draft Map	Complete
0001B	Guam Draft Map	Complete
0001C	Southern CNMI Draft Map	Complete
0001D	Northern CNMI Draft Map	Complete
0002A	Saipan Training	Complete
0002B	Guam Training	Complete
0003A	Final Deliverables	Complete
0003B	Final Map Products	Complete
0003C	Final Training Product	Complete

This final delivery includes all components requested in the scope of work for this contract. The digital deliverables are organized on the CD ROM that is included with this package (Figure 11). Original field notes for all four regions are also included and are bundled by region.

Figure 12. File structure of deliverables on CD ROM



7. Deviations from Contract Requirements

All contract line item numbers have been completed on time and on budget. During this work, two contract modifications were executed. The first combined the accuracy assessment of regions 2, 3 and 4 into a single process. This modification was accommodated during this work. The second modification expanded the number of test areas and islands to be surveyed for accuracy and ground validation data to include the Island of Rota. Our survey team modified its logistics plan and surveyed this test area during the month of July, 2003.

No deviations have been made from contract requirements.

8. References

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