SHALLOW WATER MAPPING APPLICATIONS USING SATELLITE REMOTE SENSING (SPOT) AT BIPI ISLAND, MANUS PROVINCE

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Abstract

SPOT data recorded from the French satellite is used to investigate water depth measurements in the Manus Province in the vicinity of the Sabben Island Group on the South West Coast of Manus. An exponential relationship between digital counts and water depths was observed and formulated to produce shallow water map based on measured water depth and GPS position. Sampled Shallow Water Maps SWM have been constructed at an appropriate cartographic requirement. Verification of the bathymetric result for this area was not possible at this stage due to constraints. Traditional Marine Ownership of the surrounding areas was also investigated.

1 Introduction

In the past ten years or so, remote sensing techniques have gradually been adopted as reliable tool for shallow water mapping and monitoring coral reef resources. This confidence has arisen from a number of factors such as positive ground verification by [4] and increased sensor resolution capabilities of the satellite. This article reports on a method devised to improve bathymetric image maps of relatively unknown and unsurveyed coral reef. The correlation between the image bathymetric map by Spot Satellite and actual depths has been reported by authors[1] & [2]. Theoretical aspects have been covered by authors [5] ,[6] &[7].

The present paper mainly discusses the remote sensing aspects of the investigation, the survey that was carried out and processing of the imagery using the Envi – Environment for Visual Images Version 2.0 software.

The general objective of the study is to assess appropriate procedures and methodologies on the coastal environmental conditions for Shallow Water Mapping on a territorially designate application, utilizing Satellite Imagery.

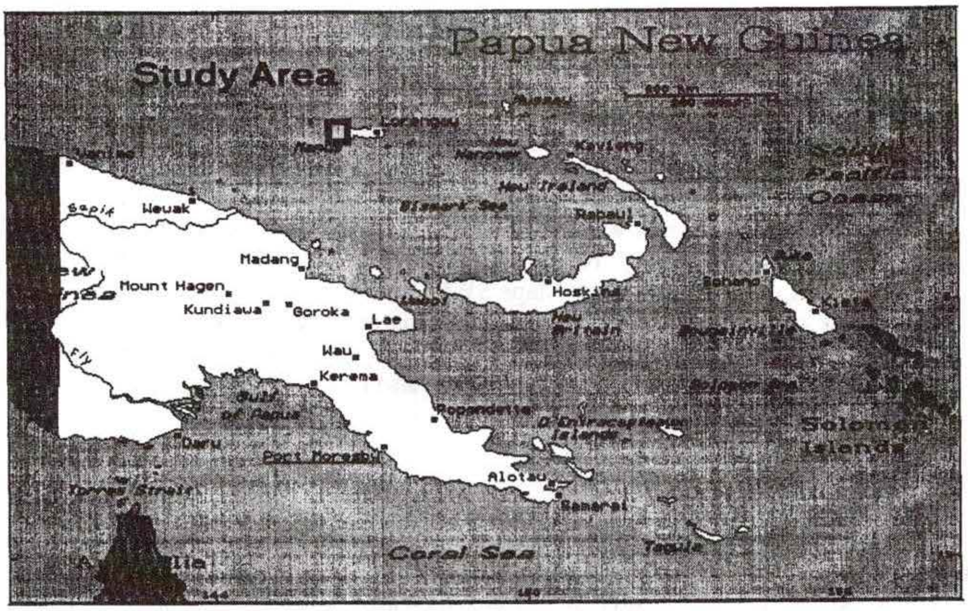
Specific objectives to investigate include 1) Study changes detection in the Shallow Water Mapping SWM and its impacts 2) Assess and develop a methodology for submerged reef mapping based on a specific Satellite capability; 3) Mapping and delineating specific traditional marine territoriality at an appropriate cartographic and satellite requirements.

2. Study area.

Manus Southwest Corner

The study area is located on the 146° 00' – 146° 30' East and 1° 55' – 2° 20' South, from the Northwest to South West corner of the Manus Island in the Admiralty Group, see ILLUSTRATION[1]. These areas are highly noticeable for its chain of barrier reef protecting numerous islands and the mainland. Navigation around this waters by overseas logging vessel operating in this areas were quite dangerous until in 1994 when the Royal Australian Navy surveyed the entrance to the logging site. Even now sporadic patches of submerged reefs that are too small to depict on the 1: 100,000 hydrographic chart can pose dangers to the unaccustomed sailors operating in these areas.

ILLUSTRATION 1: MAP OF PAPUA NEW GUINEA & STUDY AREA.



Bipi Island

Bipi Island with the population about eight hundred and whose inhabitants has the sole marine rights to the surrounding islands and reefs, comprises of three villages namely Masoh, Matahai and Kum. Indications during the survey at Bipi Island reflected the likelihood for possible fourteen different clans / sub-clan whose ownership range from the occupying reefs and islands around the Southwest corner of Manus island *see* FIGURE 1. Approximate locations of their claims are indicated in FIGURE2 below.

FIGURE1: EXISTING CLANS & FAMILY MARINE OWNERS

Number	Names	Class	Village
1	Masan	Clan	Mwasoh
2	Papipus	Clan	Mwasoh
3	Paihi	Clan	Kum
4	Samisih Sapon	Clan	Mwasoh
5	Samisih Paluwelan	Clan	Kum
6	Bipi Kopwasu	Clan	Mwasoh / Kum
7	Bipi Sapasamu	Clan	Kum
[redacted]			
9	Paidreh	Clan	Mwasoh
10	Natau	Clan	Kum
11	Suwawe'rch	Clan	Mwasoh
12	Kaheu / Soki	Clan	Kum
13	Pehelan.	Clan	Kum
14	Sotou (Kiteni)	Family	Matahai

The colloquial names of clan shown on the map and listed below are in local vernacular which may not be the Clan descendent names as such but generally referred to these areas for easy recognizant. The origin of the Silikou Clan with descendants' Sapanyandroh subclan is based at Matahai village. Only the Silikou Clan-hold will be taken up for study purposes.

For the purposes of this research and condition thereof to participate in the study of this particular clan, their descendent and their family members cannot be revealed in this study. Only graphical representation, FIGURE 3. will be portrayed to indicate ancestral stratification within the study area. Their full listing of the Original clans and sub-clan/members in this study area are separately tabled and kept only for reference.

FIGURE2. CLANS AND APPROXIMATE MARINE BOUNDARIES

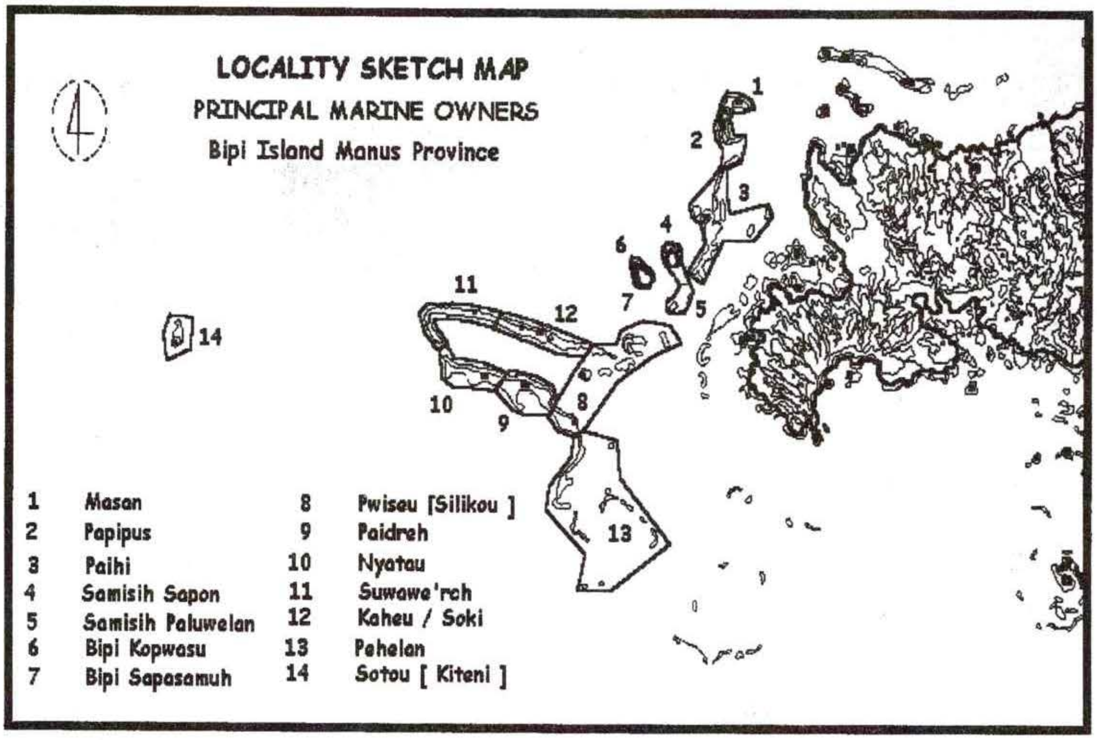
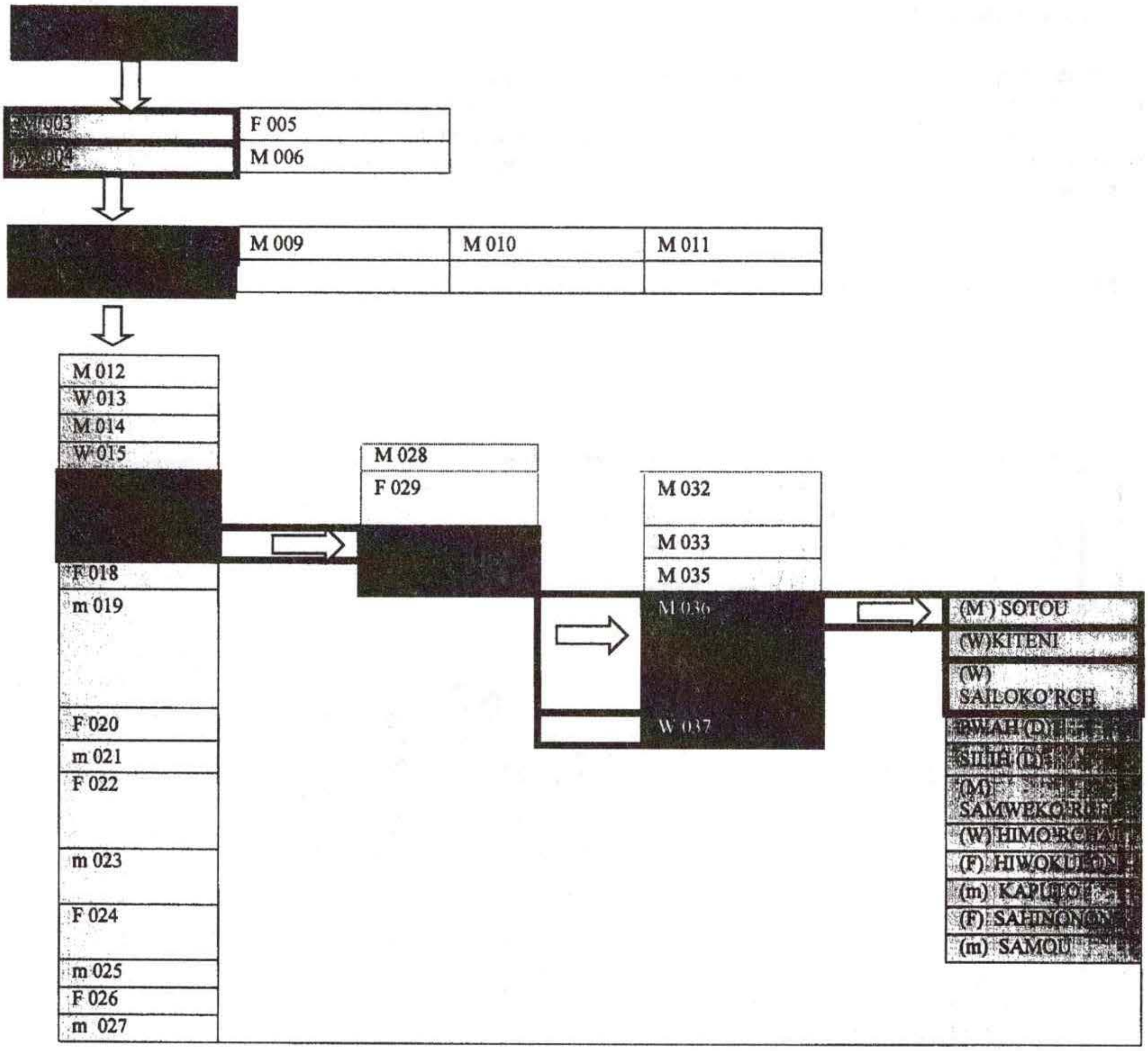


FIGURE : 3. GENEALOGICAL STRATIFICATION DATA OF SILIKOU CLAN.



NOTE : Gray shades indicates family groups
Colored shades indicates leadership roles

"F" represents sister of family member
"m " represents husband of a sister.
"W" represents Wife of a family member

3. Field Survey

Study area under the investigation basically on the Sabben Island Group comprising of three major patches of reefs and islands viz. – Yalak, Toh and Pwiseu Island. There are a number of submerged reefs belonging to same clan however these reefs are referred to as the one of the same patched of reefs.

The GPS Sokkia Spectrum Packer 3300 was used on the surrounding islands and reefs basically to enable the control network with the satellite data for the determination of the bathymetric maps. The GPS was used namely to establish the control for satellite imagery, obtain positions for depths measurements and define boundary locations/ positions

Depth measurement at various locations were recorded using an measuring device over the reefs and lagoon. These data then were used to provide and calibrate depths information in relation to the Spot data digital counts at the time of the satellite pass over the area.

The temporary tide gauge apparatus was established on Pwiseu Island. The datum for tidal predictions must be the same as the datum for the depth measurements, since the total depth of the water is found by the addition of the charted depth to the height of the tide. The times and heights of high and low water are tabulated for every day of the year in the Australian National Tide Tables

Sectional Surveys

This involves the longitudinal and cross-sectional surveys; the longitudinal section running approximately east – west direction on 299 degrees by the compass bearing, ranging from station 1 to the most westerly end of Paidreh Island. Intermediate points marked by floating coconuts at an interval of 200 meters were temporarily anchored to the bottom to indicate station points. Cross-section were done at point of change along the reef tops and the deep waters.

Surveys were conducted on the Toh Reef for both the Longitudinal and Cross-sectional runs for the comparison of the Satellite data. The same field data was used to calibrate the satellite data for the satellite imagery processing, *see* FIGURES 4 & 5.

FIGURE: 4. GPS POINTS OF LOCATION - LONGITUDINAL & CROSS-SECTIONS.

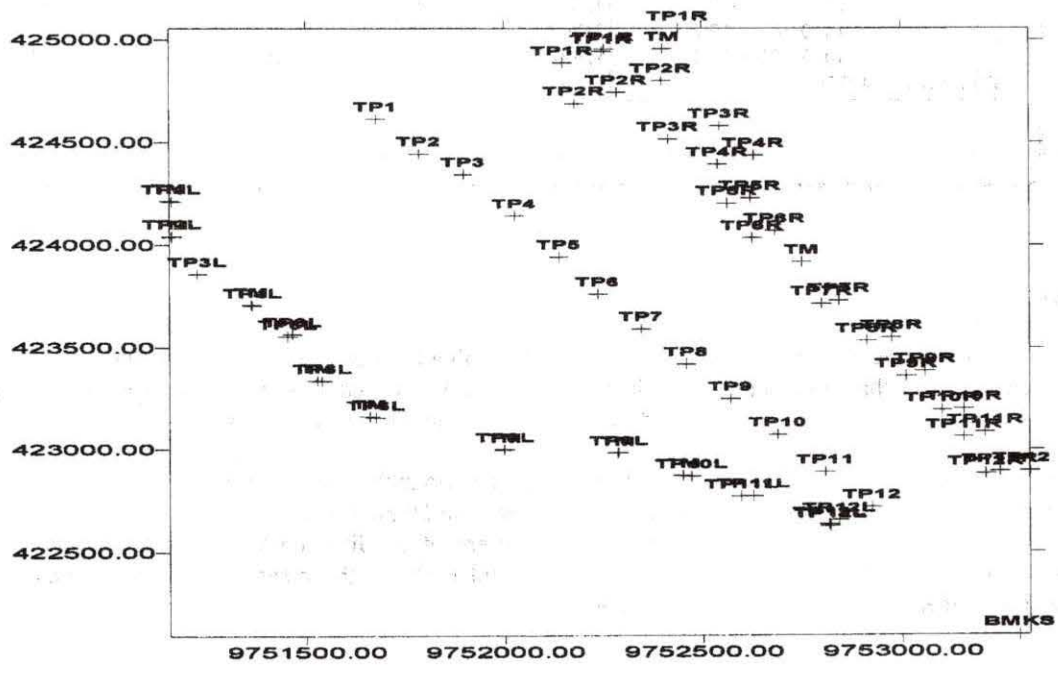


FIGURE 5: GPS SECTIONAL DATA

PART 'A'

NORTH	EAST	DEPTHS	*COMMENTS*
9751677.33	424613.804	-1.62	*TP1"*
9751785.66	424443.496	-2.1	*TP2"*
9751898	424343	-2	*TP3*
9752026	424143	-2.02	*TP4*
9752138	423943	-1.67	*TP5*
9752236.18	423762.969	-1.64	*TP6*
9752345.39	423594.031	-1.69	*TP7*
9752458.81	423421.587	-1.6	*TP8*
9752569.74	423252.506	-1.73	*TP9*
9752687.93	423075.558	-1.82	*TP10*
9752807.63	422889.014	-1.52	*TP11*
9752923.59	422716.11	-1.4	*TP12*
9753209.01	422879.976	-1.7	*TP12R*
9753244.58	422890.697	-6.1	*TP12R*
9753320.11	422894.471	-36.2	*TP12R*
9752841.77	422652.111	-1.73	*TP12L*
9752817.49	422631.895	-37.7	*TP12L*
9752820.37	422624.406	-36.7	*TP12L*
9752595.66	422768.546	-12.3	*TP11L*
9752626.65	422770.609	-1.7	*TP11L*
9753153.87	423065.653	-1.93	*TP11R*
9753207.79	423088.707	-15.5	*TP11R*
9753154.77	423203.186	-14.4	*TP10R*
9753099.53	423197.63	-2.12	*TP10R*
9753010.12	423364.098	-1.77	*TP9R*
9753056.53	423389.03	-17.2	*TP9R*
9752973.84	423552.541	-17.6	*TP8R*
9752911.67	423536.184	-1.89	*TP8R*
9752750	423920	-30	*TM*
9752798.64	423716.522	-1.8	*TP7R*
9752843.34	423730.809	-12.3	*TP7R*
9752682.25	424070.241	-10.5	*TP6R*
9752624.54	424035.623	-1.91	*TP6R*
9751465.15	423566.906	-1.5	*TP6L*

PART 'B'

NORTH	EAST	DEPTHS	COMMENTS
9751453.24	423555.144		TP6L
9752440.46	425057.724	-13.3	TP1R
9752400	424956	-40	TM
9752252.59	424955.488	-1.55	TP1R
9752247.16	424943.741	-11.1	TP1R
9752147.53	424887.092	-1.83	TP1R
9752178.22	424688.663	-1.65	TP2R
9752284.2	424742.839	-1.45	TP2R
9752397.23	424800.762	-8.6	TP2R
9752413.54	424515.477	-1.62	TP3R
9752544.17	424579.931	-1.67	TP3R
9752539.37	424392.151	-2.15	TP4R
9752561.69	424203.295	-1.92	TP5R
9752620.73	424228.848	-15.6	TP5R
9751157	424215	-30	TM
9751162.33	424211.221	-3.45	TP1L
9751161	424040	-45	TM
9751162.74	424041.947	-2.38	TP2L
9751225.88	423858.145	-2.05	TP3L
9751362	423710	-30	TM
9751365.27	423705.159	-2.28	TP4L
9751469.22	423550.805		TP5L
9751528	423341	-30	TM
9751540.16	423338.45	-2.15	TP6L
9751660	423165	-30	TM
9751675.44	423158.784	-2.3	TP6L
9751995	423009		TM
9752000	423000	-2.32	TP8L
9752275	422990		TM
9752286.82	422984.597	-2.25	TP9L
9752470.98	422866.969	-2.62	TP10L
9752450	422871	-30	TM
9753292.12	422098.989		BMKS

Depths Survey

Two methods of measurement were carried out to determine the depth of the water. Where the depths of the water was less than two meters, a graduated bamboo rod was used to measure the approximate depth of the water and finer measurement was made with the use of the pocket tape for final reading.

At spot points where the depth measured deeper then the two meter mark, a simple measuring gadget was used, *see* FIGURE 6 to measure the depth even greater than 50 meters. It consist of roll of thin thread and on the end is attached a sinker to enable the movement of the line quickly reaching the bottom. The movement of the thread goes through a spinning wheel enabling the measurement of the length of the thread to be measured to the nearest centimeter.

FIGURE 6: MEASUREMENTS TAKEN OUT AT SEA.

4. MAP CONSTRUCTION

Bathymetric model

There are two major approaches in making bathymetric modeling out of satellite data: physical approach which is supposed to take account of the whole of the parameters affecting the radiometry while the empirical approach, which is based on the points of known depth. This study will adopt the latter approach.

From the study area on the Toh reef, thirty-three points of known depths were measured and selected for the depth calibration. For each point, the depth measured was added to the predicted height of the tide during the satellite flight to obtain the height of water from the seabed. Pixel intensities (digital numbers) at each point were noted. A plot of pixel intensities versus water depths was constructed for all points as shown in FIGURE 7. From the regression analysis of the field data a simple equation of the following form $y = 0.1041x - 18.667$ was used to relate the water depth to the intensity in the band.

FIGURE 7: REGRESSION ANALYSIS DATA

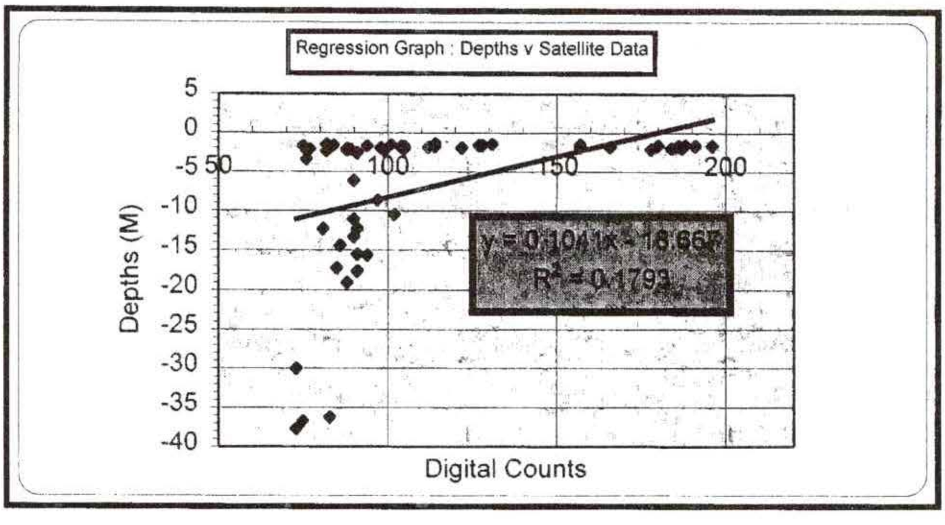
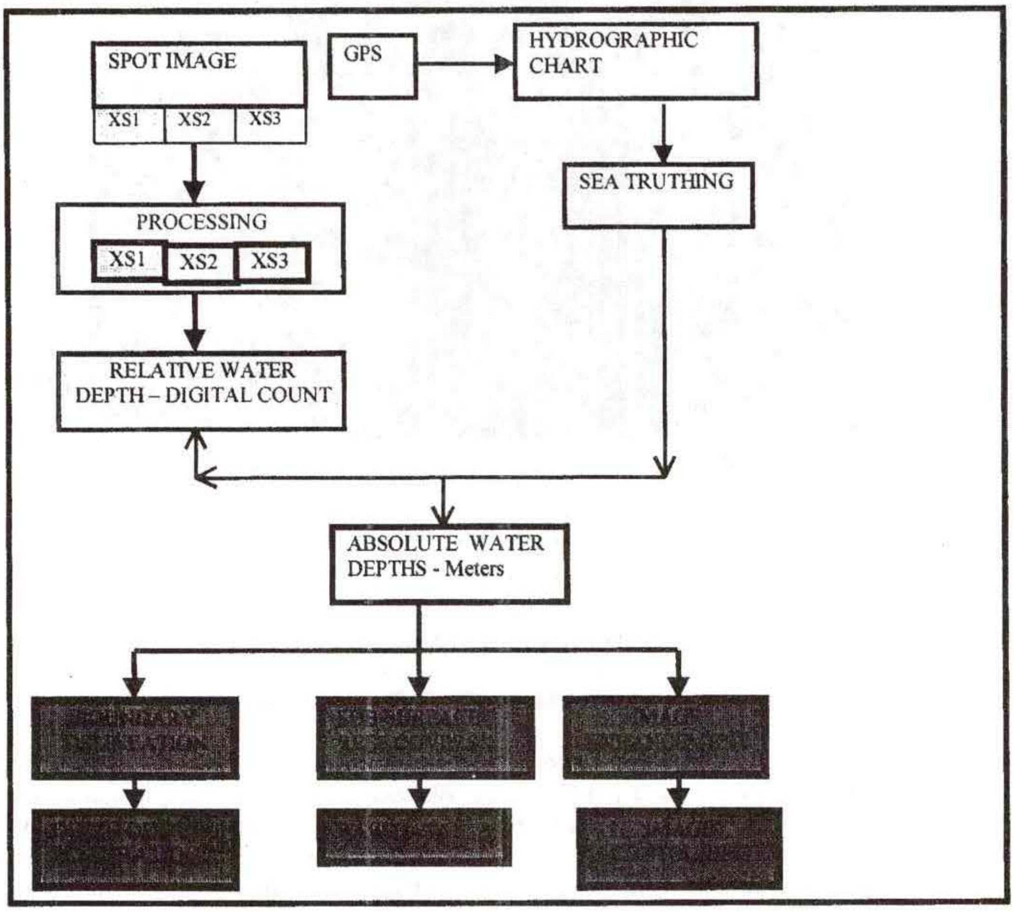


Image processing

The image processing applied here was the use of bands 1 and band 2 and applying the ratios band1/band2 resulted in the following to show through amongst the shallow waters features as coral sand coverage and coral structured features. The image processing procedure can be summarized in the following FIGURE 8.

FIGURE 8: FLOW-CHART- IMAGE PROCESSING PROCEDURES



Creation of SWM Maps

The SPOT scene generally appears to be cloud free except in patches between the mainland and the Bipi Island. Apparently, this area most likely contain patches of reefs undetected on the hydrographic chart (1:250,000) or topographic map (1:100,000) due to its small scale. During reconnaissance, this was obvious as clearly shown but the image with cloud cover, this cannot be detected.

Shallow Water Maps can contain a variety of map features depending on the client's requirement. It is envisaged to develop a variety of map types for differentiation that will in the end result in quality of marine environment maps. This study will envisage the following variety of maps to fulfill this requirement:

- Raw data map
- Enhancement map
- Improved Enhancement map

- Contour map
- Density Slicing
- Traditional marine Boundary

Raw Data Map

This map displays the image in the original form – no enhancement only rectification. The three bands raw data with composite RGB without other enhancement techniques does not look impressive on the face value. This means that even though features may not be distinguishable, however, all satellite data information are still intact. In this regard, the image in itself valuable to abstract information from, prior to other forms of image improvements *see* FIGURE 9, but hardly able to obtain any meaningful data.

Enhancement map

Improved Enhancement map

This map utilize not all Spot bands but band1and band2 only disregarding the third band due to its ability to absorbed water at this wavelength. Instead, the rationing of band1/band 2 provided the replacement.

Attempts made to investigate the possibility of improving the quality of the image displaying substrate features. The ratio of band1/band2 gave those features additional enhancement and contrast to the bottom features. Explanation to this ratio attempt is covered by author [3]

Following FIGURES 10 & FIGURE 11 below are indicates this point of view.

FIRUGE 10 Image Enhancement
FIGURE 11 Improved Image

Contour Maps

Envi contour image function image contouring enables a selected image band and generates contour lines on that image. There are other options available to create other definition such, spacing, contour intervals and other contouring characteristics.

- Other contour options include
- Default contour levels
- Edit contour levels
- Add contour levels

FIGURE12 Contour Maps of the area

Density Slicing Map

In Envi function color tables and density slicing allows both contrast stretching and the application of standard color tables (density slicing) to the data. The minimum and maximum values are entered and default values are automatically displayed. Options are available to alter or add information, *see* FIGURE13.

The merit here is that depths can be either in digital form or where depths have been converted from digital counts to relative depths this is also possible on the density slicing option.

FIGURE 9: RAW DATA IMAGE MAP

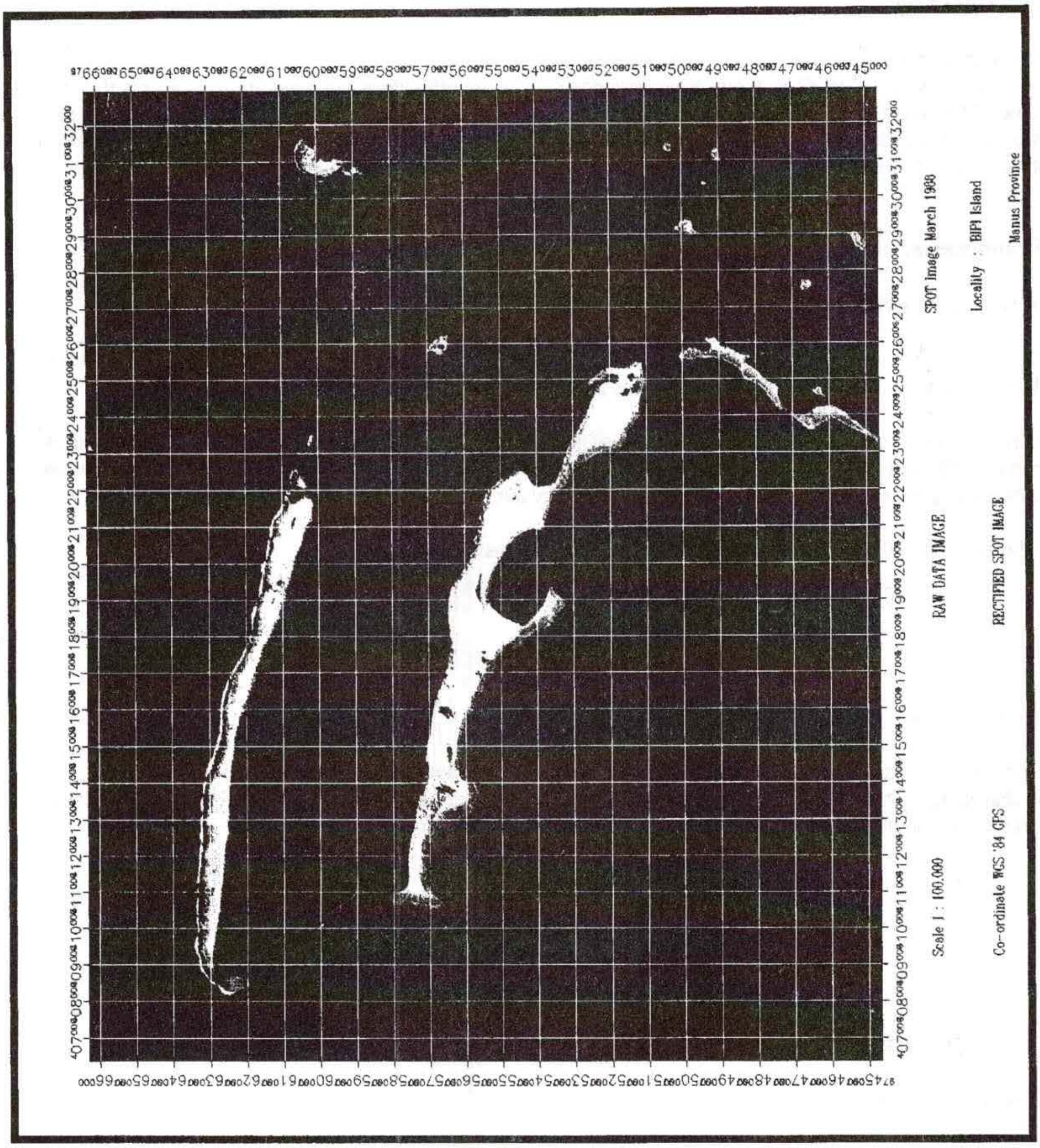
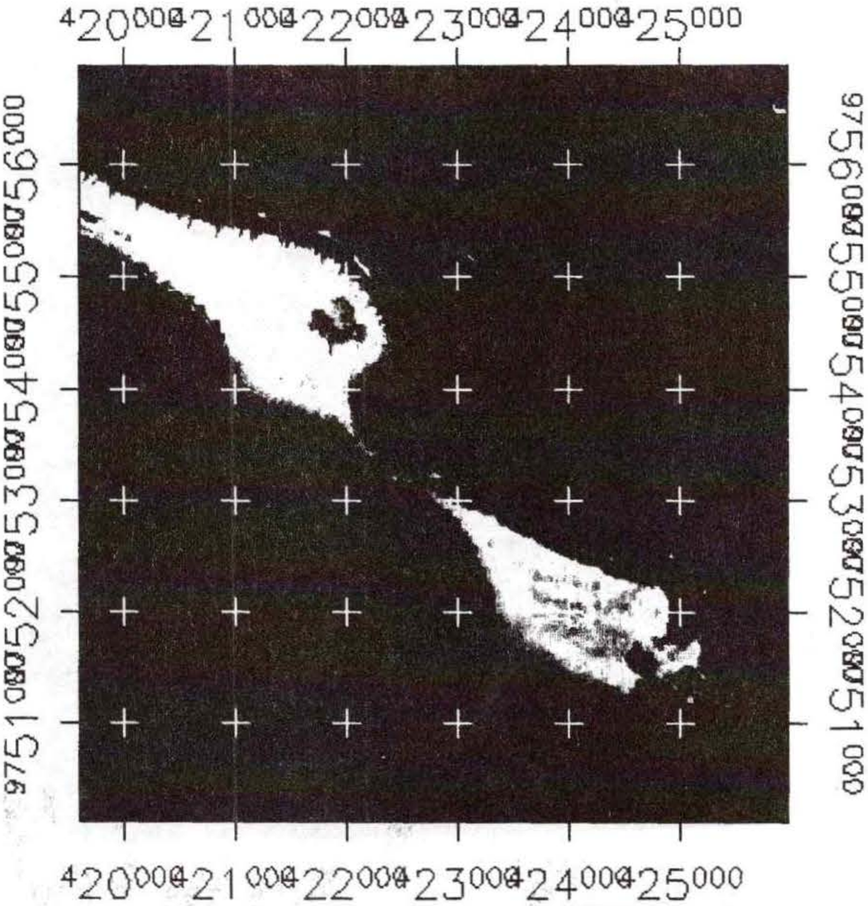


FIGURE 10 : SPOT IMAGE ENHANCEMENT MAP



scale : 1: 100,000
Enhanced SPOT Image
SPOT Image March 1988
Locality - BIPI Island - TOH Reef
Coordinate System - WGS1984 GPS
South West Coast Manus
Manus Province

FIGURE 11: SPOT IMAGE IMPROVED ENHANCEMENT

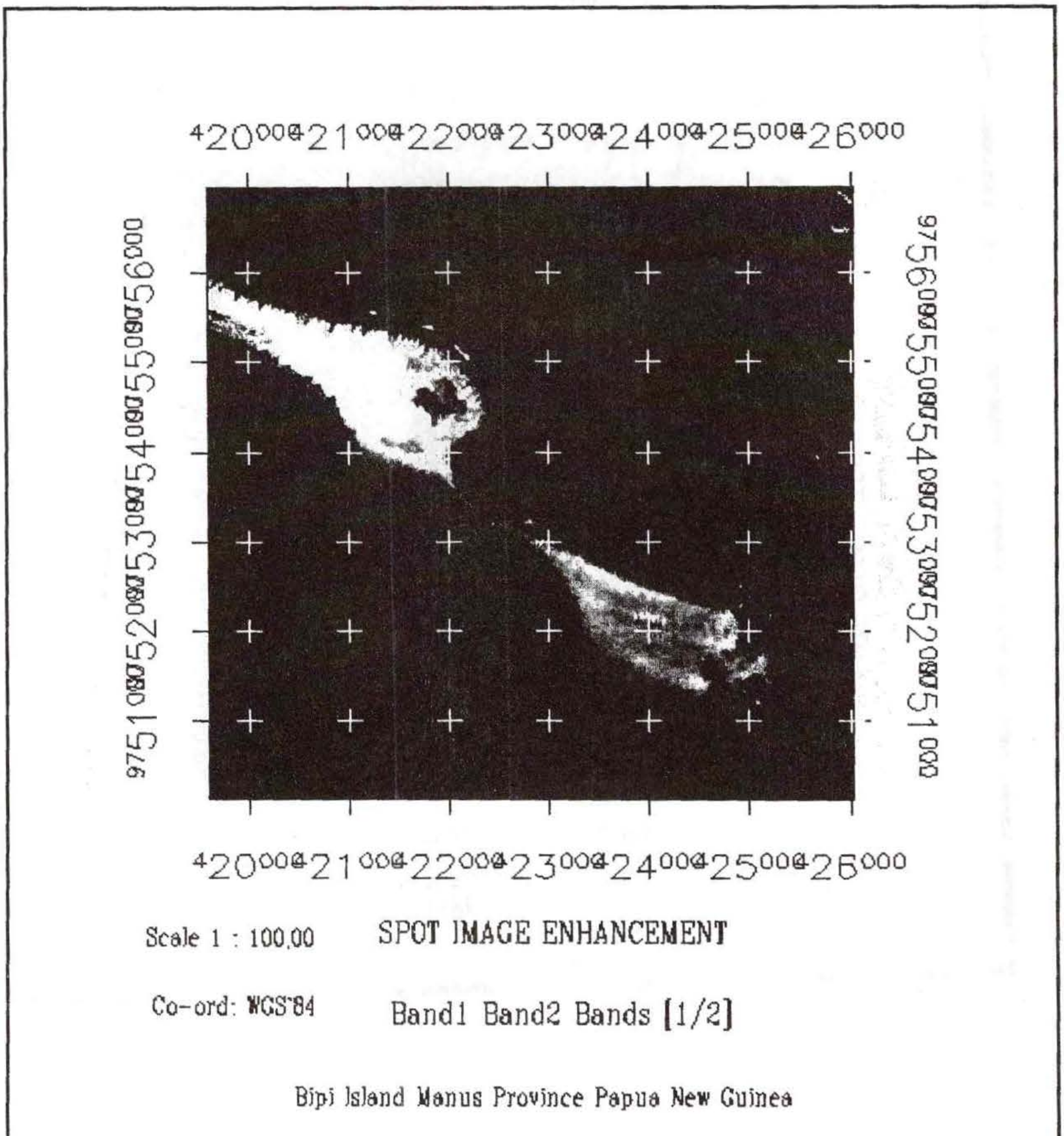


FIGURE 12: SPOT CONTOUR MAP

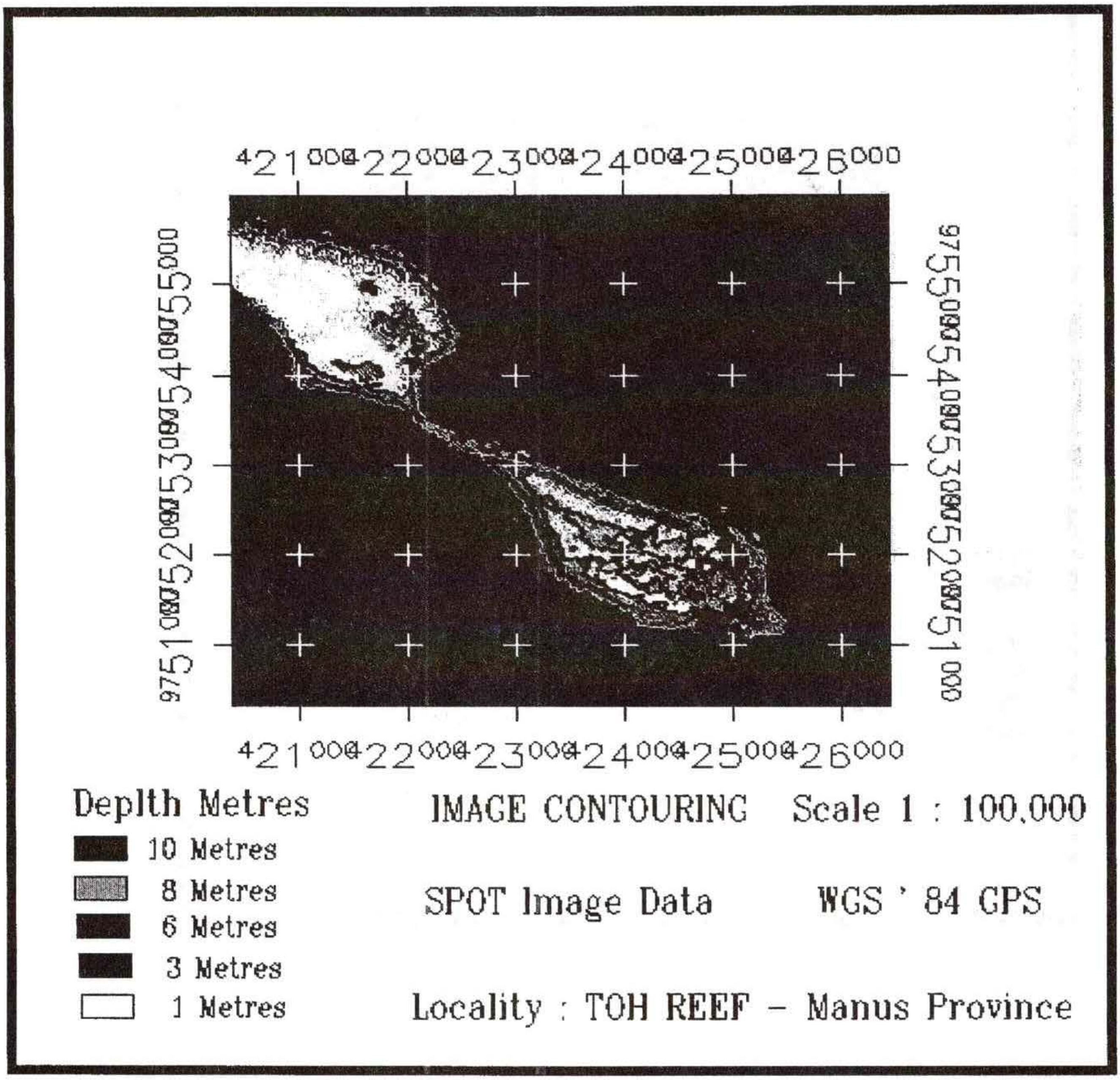
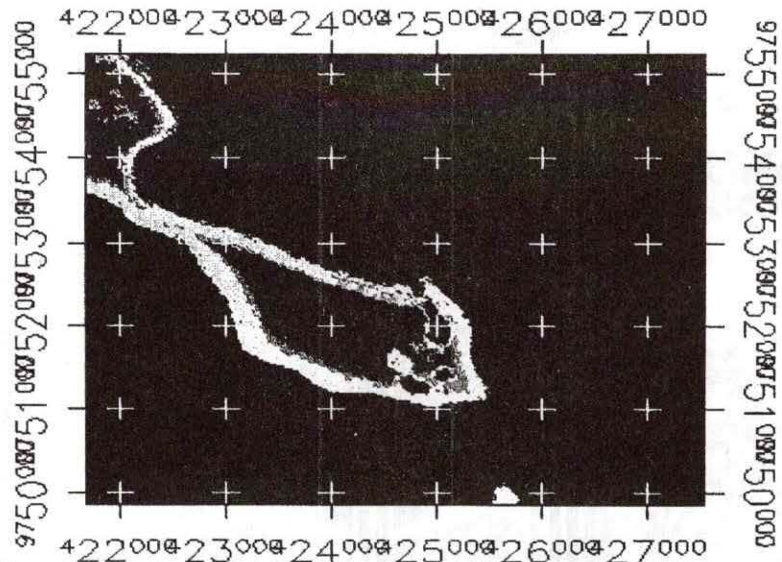


FIGURE 13: DENSITY SLICING INTERPOLATION



DEPTHS

>	-	10 M
10	-	7 M
7	-	4 M
4	-	2 M
2	-	0 M
0	-	2 M

DEPTH OF PENETRATION

DENSITY SLICING INTERPOLATION

BIPI ISLAND - TOH REEFS

SCALE 1 : 100,000

SPOT Image 1988

Co-ord : WGS'84 GPS

Traditional Marine Boundary Map.

This Map essentially aims to fulfil the notion the tradition marine ownership claims up to the depths and is defined by the sensitivity and the capability of the power of Spot Satellite resolution. This leads to the production of the Shallow Water Map with the follow contents:

- Enhanced image
- Contour Maps
- Registered
- Geomorphologic features

Band1, bands2 and the band1/band2 were used to produce enhanced Traditional Marine Boundary Map of the Silikou clanhold boundary to the depth of 10meter mark.

5. RESULTS AND OBSERVATIONS

Shallow water maps.

A coastal base map is a reference system with information about exiting features that may assist interested parties such as marine biologist, planners, engineers, scientists etc. for planning and management purposes. Satellite imagery provides helpful information about reef covers and reef morphology. Imageries of satellite origin can be used as reference base map for coastal management purposes.

Produced maps contain here have all been rectified, color composite selected, with the purpose to enhance, analyses and delineation of a hypothetical traditional marine boundaries. This study, to arrive with presentation of the final thematic maps investigated amongst other things such as types, functions, criteria for coastal maps; satellite applications for coastal environment and products of thematic maps for coastal areas.

The task to determine depth of penetration can be reliable depending on the accuracy of the known water data used to calibrate the fieldwork. In the event where accurate calibration data of the water depths are not available, assessment of the water depths can still be carried out. This involves calibration of the water of known depths against the satellite and hence absolute water depth can then be mapped.

The correlation coefficient for the depth analysis reported by Loubersac L., for 250,000 pixels in the Aitutaki Atoll after elimination of deep-water areas was 0.905. The result produced from the field analysis could not be verified then due to geographical reason but the author intend to pursue this research soon.

Future Trend

With the advent of new generation of satellite ILLUSTRATION[2] gives shallow water mapping a far more dimension to work on than the current stage of medium range resolution. However, the major question will need to be answered whether the higher resolution of satellite will overcome most of the current problems facing today will have to yet determine.

Given the future trend as shown by private sectors in providing visible/infrared high-resolutions spacecraft for scientific mapping, monitoring and research, to the coastal environment, will become a reality in the next decade or so.

ILLUSTRATION2: FUTURE SATELLITES OF HIGHER RESOLUTIONS

FUTURE - VISIBLE/INFRARED HIGH-RESOLUTION SPACECRAFT MILITARY, CIVIL, AND SCIENTIFIC MAPPING, MONITORING AND RESEARC URBAN, LAND, AGRICULTURAL, COASTAL AND CORAL REEF APPLICATION

SATELLITE	SPONSOR	SENSORS/COMMENTS	LAUNCH
SSTI/LEWIS	NASA/TRW	HIS(PAN), 5M RES	Jul-97
		HIS (384[MS] BANDS),30 RES	
		LEISA (ATMOS.GASES)	
EARLYBIRD	EARTH-WATCH	HRC(PAN),3M RES	
	(BALL-BROS.,KODAK & PARTN	WFC(3 BANDS), 15M RES, RUSSIAN	LAUNCH
SSTI/CLARK	NASA/CTA	HRC(PAN),3M RES.	EARLY-1998
	(COST OVERRUN PROBLEMS)	HFC(3 BANDS), 15M RES.	
		MAPS(ATMOS.GASES)	
CARTERRA-1	SPACE IMAGING	CRSS PAN, 1M RES (11KM FOV)	Dec-97
	EOSAT	CRSS MS(4 VIS BANDS), 4M RES	
QUICKBIRD	EARTH-WATCH	HRC(PAN), 1M RES	
	(BALL-BROS.,KODAK & PARTN	WFC(3 BANDS), 15M RES,	MID 1998
ORBVIEW-3	ORBITAL SCIENCES	PAN, 1 & 2 M, RES (8KM FOV)	
	CORP. AND SAMSUNG	MS (COLOR), 4 RES	1999 PAGASUS
ORBVIEW-4	ORBITAL SCIENCES	PAN, 1 & 2 M RES	
	CORP. AND PARTNERS	MS (COLOR) , 4 M RES	
		HIGH-RES SAR(?)	2001
EROS	GER CORPORATION	PAN, < 10M; MS (COLOR), 10M RES	2000 +
ALOS	Japan/NASDA	VSAR(L, VARIBLE OFF-NADAR)	2000+
		AVNIR-2 PAN(3BANDS, 2.5M RES35KM SWATH	
		AVNIR-2 MS(4BANDS, 10M RES, 70KM SWATH	

RESOLUTION IS 1-10M. OTHERS UNDER CONSIDERATION BY PRIVATE AND GOVERNMENT SECTORS

SOURCE: OCEAN & LAND SPACE MISSIONS DURING 1990'S AND BEYONG
OCEANSPACECRAFT – PATZERT/ VAN WOERT – 7 /16/97
JET PROPULSION LABORATORY
EMAIL: WPATZERT@PACIFIC.JPL.NASA.GOV

Conclusion Remarks

Using satellite imagery for mapping of near-shore areas has proven to be very valuable in many aspects.

This study, satellite information concerning abstracting satellite data and algorithmically create shallow water maps is of great importance to those in decision making and planning etc. The studied processes of map creation for a particular application, in coastal areas could gain very useful information from earth resources satellite.

There is a growing awareness among marine scientist of the value of remote sensing to their work. Only remote sensing can be able to cope fully with the related problems of delineation of reefs or even assessing reef productivity etc. It has been demonstrated that Spot data can provided a mapping base for the shallow water mapping, approximate bathymetry and a set of plans for the area of the Clans interest which expresses this potential.

Recommendations

To summarize I consider the use of satellite imagery for studies of the Shallow Water Mapping very appropriate.

The continuation of this case study leading to other thirteen existing locations in the Bipi region should proceed to complete the marine data base in that area. An inventory of various clans in the area with genealogical data base information, geographic and satellite information favors the use of a geographic information system GIS for this continued work.

The use of remote sensing should be considered for socio-economic assessment in areas as reef productivity, reef covers, trochus estimation in this area.

In terms of mapping of marine environment, latest satellite data of higher resolution such as the EarlyBird, QuickBird etc with 1 meter resolution needs to be investigated for mapping purposes.

As a follow up of this study into the shallow water mapping with a vast interest in the traditional marine ownership in the islands region in general, a study should be carried out to gauge its full potential and where appropriate, a study group be formed to monitor this interests.

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