CHAPTER III

MATERIALS AND METHODS

Based on the theory of remote sension that can be used for the study on coral reef component distribution, this session explains the remotely sensed techniques which were used in the study.

3.1 Site Location

The reefs in The Gulf of Thailand are found around the offshore islands where the water is much clearer than the area close to the mainland. Around small islands reefs may be continuous but narrow, often no more than fifty meters in width (Sudara et al., 1989). The initial stages of reefs exist around some islands in the inner gulf. In the outer gulf, the reefs at large islands may have 500 meters or greater in width, for example Samui Island, Mak Island (Sudara et al., 1990).

Samui Islands, composed of more than 70 islands, the name followed the main island "Samui" which is the third biggest island in Thailand (Paw et al., 1985). This group comprises many islands located between Latitude $9^{\circ}15'$ to $10^{\circ}10'$ North and Longitude $99^{\circ}30'$ to $100^{\circ}10'$ East (Figure 7). This group has one of the sediment factors from the same source which is the run off along Ban Don Bay. The biggest runoff in this area is Tapi-Phum Duang river which flows out a big load of sediment approximately 9850 million m per year, this is the biggest sediment load in the southern region (JICA, 1985). Other runoffs, such as Khlong Takhian, Khlong Tha Tong, etc., flow out the sediment approximately 739 million m per year.

The reefs which can be found around these islands show the high percentage of living coral coverage in the eastern part of Samui, the southern and eastern part of Pha-ngan and the northern part of Rapp island, one of the islands in Tan group (Sudara et al., 1989). Those reefs are very big, approximately 300-500 meters in width and can be claimed as one of the biggest reefs in The Gulf of Thailand. The seagrass communities are also found in the reef flats

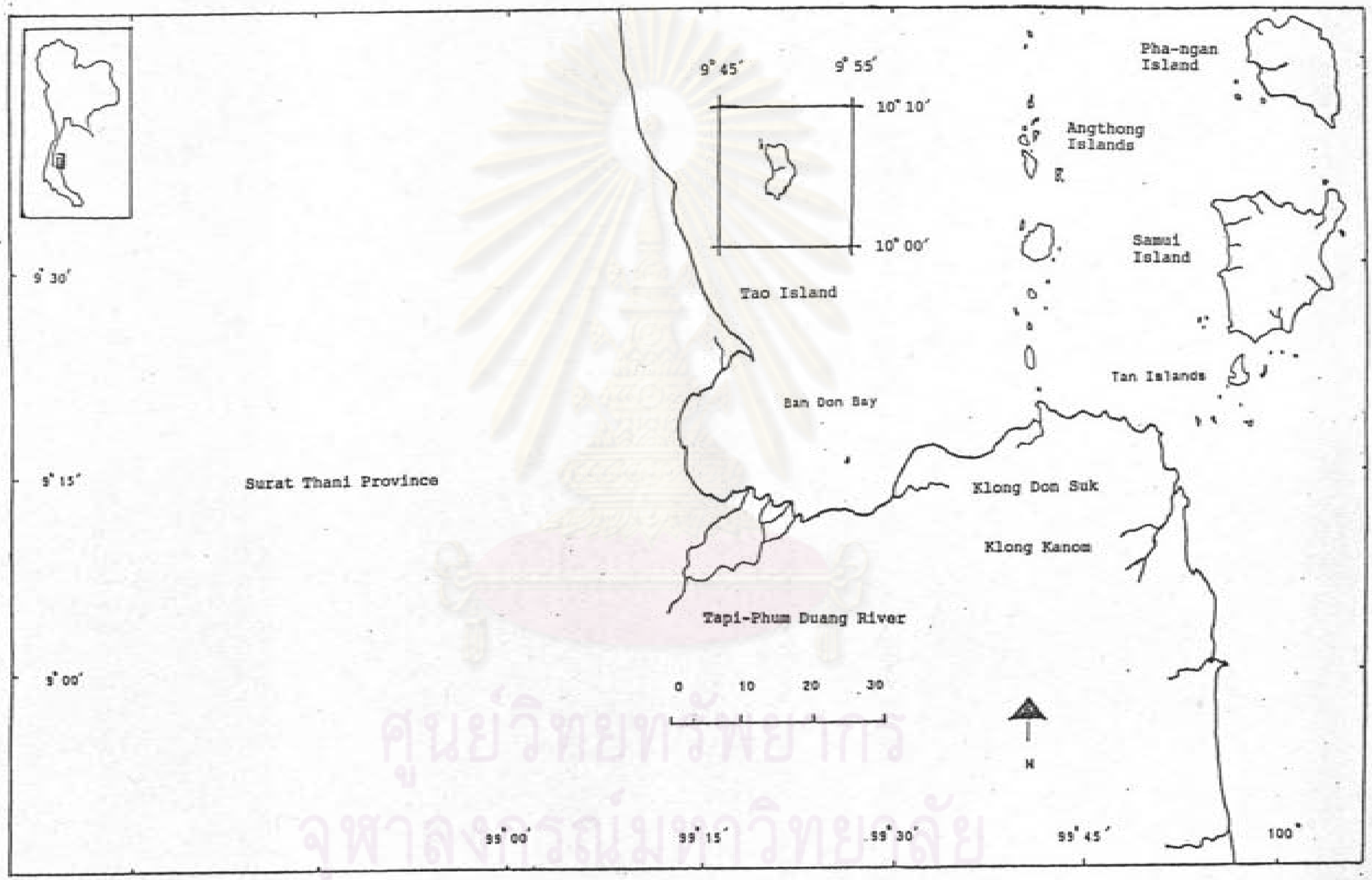

Figure 7. The Location of Samui and Its Surrounding Areas.

especially Mat Lang, Samui, and Nai Wog Bay, Pha-ngan island.

The tourist industry, one of major activities in this area, is rapidly developed because of many beautiful beaches, natural attractions and coral reefs. Tourism volume in Samui has experienced a radical surge. In 1980, there were only about 14,870 visitors, this increased to 33,155 in 1981 and in 1984, there were 142,320 visitors (Paw et al., 1988). For the visitors who have activities in reef area, it was predicted that in 1988 more than 30,000 tourists spent their time in the reef. The reef tourism revenue in 1988 was estimated to be 50 million baht (Sudara, Thamrongnavasawat and Patimanukaseam, 1989).

Many reefs in this area were destroyed by anchoring, coral blasting and construction of boat canals. Some reefs have the human impact from other sources such as the sediment problem. Few effects are clearly presented visually, the others which are the disregard effects change the reef process and they will cause the irregularity case in the reef and destroy the reef process.

Topographic map, tourist map and hydrographic map have different names of locations, and the same names are spelled in different ways. So this project follows the names of locations which are presented in the topographic map (Royal Thai Survey Department, 1973) because the topographic map is a base map rectifying the image. Figure 8 displays the names of locations in Samui Islands.

<u>Samui</u>:

25. Som and Lum Mu Noi Islands
26. Plai Laem Bay
27. Mai Kaen Cape
28. Sai Cape
29. Bang Po Bay
30. Yai Cape
31. Chon Krum Cape
32. Hin Khom Cape
33. Phangka Bay
34. Tong Tanod Bay
35. Sor Cape
36. Set Cape
37. Natian Island
38. Hin Ang Wang
39. Hau Thanon
40. Nan Cape
41. Chaweng Beach
42. Mat Lang Island
43. Samui Island

<u>Tan Island</u>:

44. Mat Sum Island
45. Tan Island
46. Tok Bay
47. Hin Mat Khong
48. Wang Nok Island
49. Wang Nai Island
50. Rapp Island

<u>Tao Island</u>:

1. Nang Yuan Island
2. Sai Lee Beach
3. Tao Island
4. Luk Bay

<u>Angthong</u>:

5. Wao Islands
6. Tai Plua Islands
7. Hin Dup Island
8. Sam Sua Island
9. Mae Ko Island
10. Wua Ta Lapp Island
11. Wua Te Island
12. Phaluai Island
13. Nok Thaphao Island

<u>Pha-ngan</u>:

14. Chalok Lam Bay
15. Mae Hat Beach
16. Hat Lat Beach
17. Hat Yau Beach
18. Wog Tom Bay
19. Nai Wog Bay
20. Tae Nai Island
21. Tae Nok Island
22. Ta Pan Noi
23. Pha-ngan Island
24. Talat Mai Beach

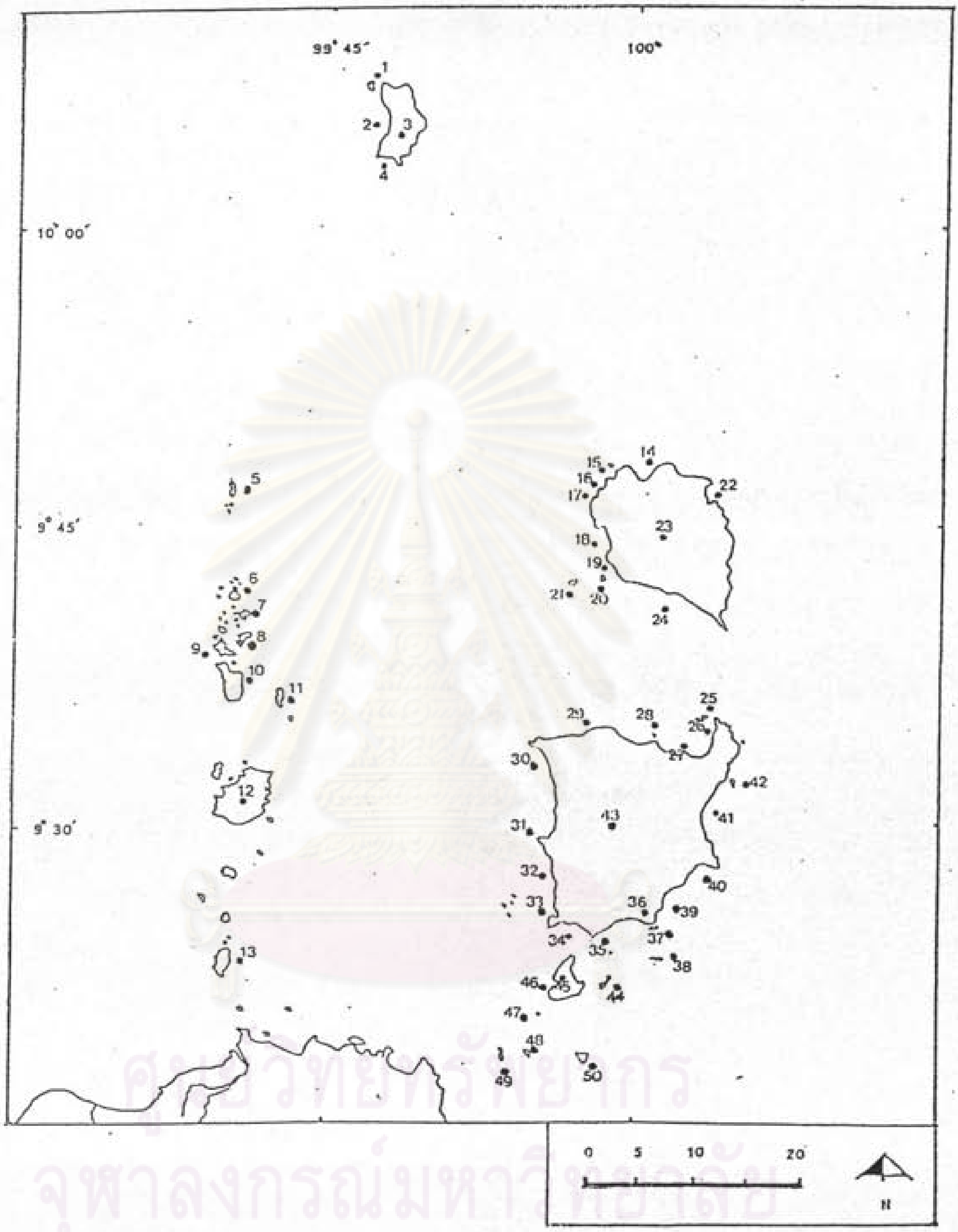

Figure 8. The Study Site Names.

According to many operations in this project, each study does not covers all the study site because it will take a lot of time. In each study the study site is selected suitable for developing a technique and reef study. The selected study sites are described as Table 2.

Study Site	Operation	Satellite Data
All Samui Islands	Image Enhancement	Landsat TM 28/10/88 17/1/89
Nai Wog Bay	Band Ratio, PCA	Landsat TM 28/10/88
Samui and Tan Islands	Intensive Reef Classification, Checking with Transect Ground Truthing	Landsat TM 28/10/88
Tao Islands, Pha-luai Islands	Reef Classification, Checking with Overall Reef Survey	SPOT XS 26/8/89
Pha-ngan Islands and Angthong Island	Normal Reef Classification, Checking with Overall Reef Survey	Landsat TM 17/1/89
All Samui Islands and Ban Don Bay	Sediment Density Slicing	Landsat TM 17/1/89
Eastern Part of Samui	Multi-Resolution Map	Landsat TM 28/10/88 SPOT PAN 14/1/89
Tan and Mat Sum Islands	Combined Reef and Depth Composite Image	Landsat TM 28/10/88
Tan Island	Perspective Three Dimensions Image	Landsat TM 28/10/88

Table 2. The Study Sites and The Operations in This Project.

3.2 Remote Sensing Studies on Reef

Using the remote sensing technique to study the reef in different areas must be carefully researched and customized for the general technique which can give the real data suitable the need of users in that reef. This idea is the main objective of this project, to develop the remotely sensed techniques and using the result for reef geomorphological, zonation and classification in Samui Islands.

As described, the radiation has the effects from surface roughness, surface orientation and scattering of atmosphere and water column. The first two factors can calibrate by the special program at the receiving station and in image processing system, the last consideration will be expanded with emphasizing on the reef operation. The artificial model of light coming through the reef is made to demonstrate the functions. There are three major factors which need to consider, atmosphere, sea and air interface and water absorption and sedimentation (Figure 9).

When light emitted from the sun shines through atmosphere which has the dust or others, light intensity is disturbed by scattering process. When light reaches water surface, some are reflect and the others are refracted. In water column the sediment, phytoplankton and depth is three major gradients that disturb the light intensity, then light reaches the reef substrate. The dissimilar substrate reflect the light in different frequencies. The reflected light passes the water and atmosphere with the same incidents before reaching the satellite scanner.

Although the light process has a lot of disturbance, there are several techniques to solve the problems. It is lucky that Samui Reefs are the fringing reefs which have most parts as the plane substrate except the reef slope. So the reef substrate will reflect the light with a low water disturbance. Though the reef slope, which is the important zone, has different depths, the reef slope in Samui Islands is narrow with 30-100 meters in width (Sudara et al., 1990) so this narrow zone has low effects.

3.3 microBRIAN System

From all reviewed information it recommends that the remote

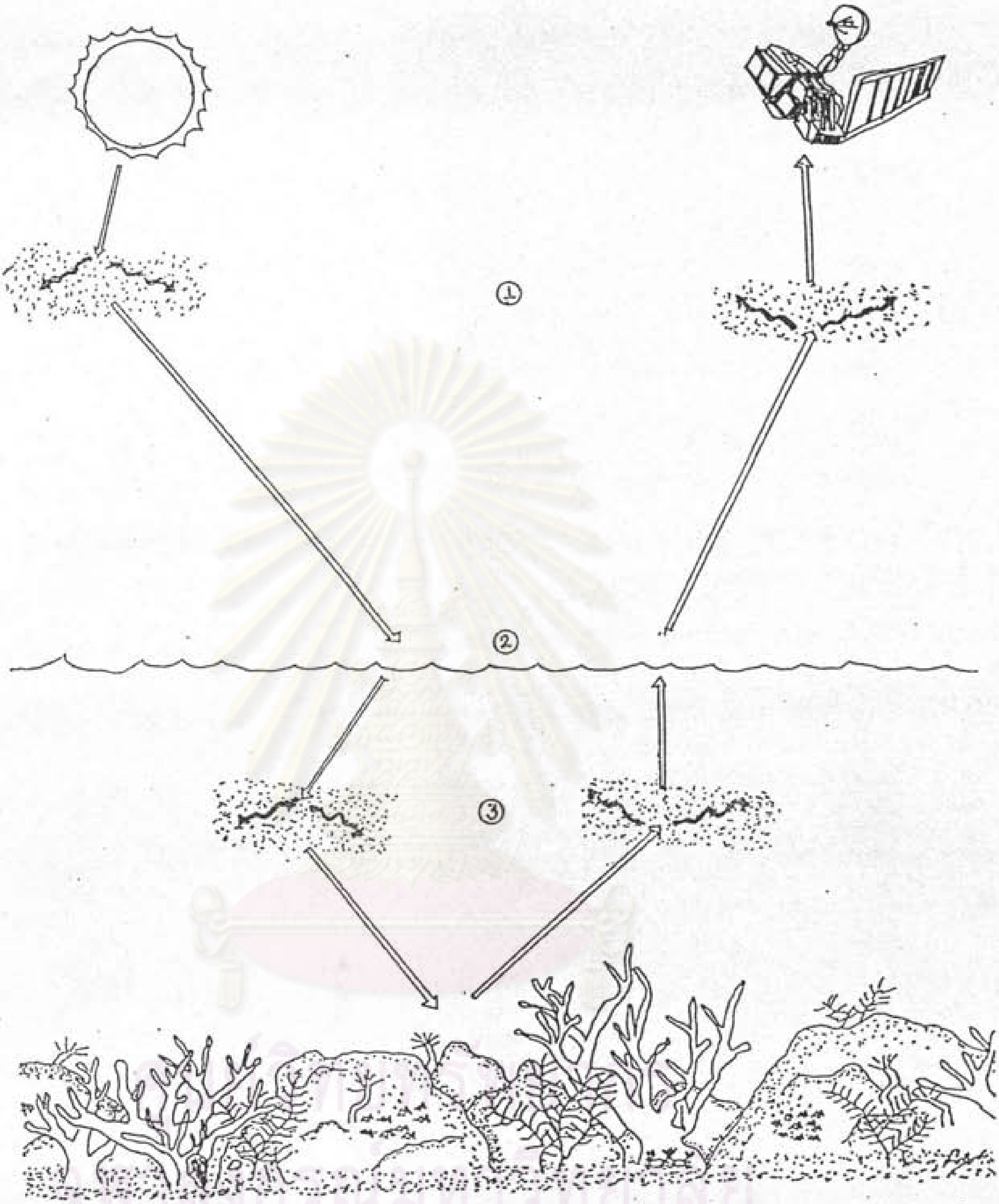

Figure 9. The Light Model in Remote Sensing Studies The Reef.

sensing studies on reefs at Samui Islands are possible to process. The digital image processing system which is used in this thesis is called as microBRIAN (Barrier Reef Image ANalysis) developed by CSIRO Division of water and land resource and MPA International Pty Ltd since 1979 (Harrison and Jupp, 1989). The system is implemented on microcomputer hardware and offers an extensive range of processing algorithms with special application to remotely sensed data. Appropriate verification stages are included in each processing sequence to ensure that derived results are valid within an acceptable range of accuracy. In addition to the standard image processing functions, specific application modules are provided in microBRIAN for modelling in valid landscapes .

The system that is used in this thesis has the joined equipments which are microcomputer unit (PC386 AT with 320 Megabyte Hard Disk and the monochrome monitor), EGA monitor, Ink-jet plotter, Printer and GCR Cachetape. The functions of this operation is illustrated as Figure 10, more information see BRIAN methodology and computer system in Jupp <u>et al.</u>, 1985; Harrison and Jupp, 1989,1990).

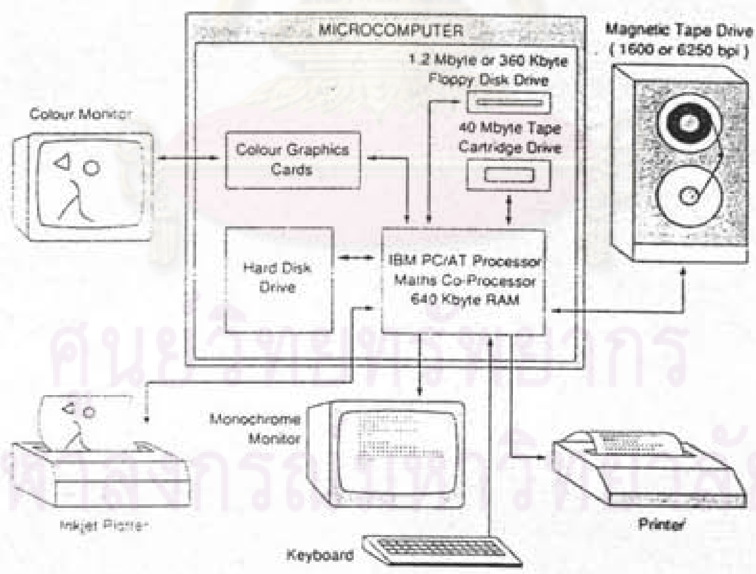

Figure 10. Hardwares Component of The microBRIAN System (Harrison and Jupp, 1989).

3.4 Digital Image Processing

The digital image processing is varied with many new methods developed in last few years, so they are the new theory to solve special research opinion. The example is Kauth-Thomas Greenness Transformation (Harrison and Jupp, 1990), it was produced to study the vegetation indices. microBRIAN has a special program to support the user in each study. However, the main function, such as classification, is still based on a standard theory which needs the user definition.

In this research, the process was run through both methods. A few special programs were selected to produce the image results, and they were carefully classified to select the suitable programs to be used in reef study. These simple methods were also reviewed for analyzing the special techniques. The methods which will be explained are the basic methods which have already been selected from many methods of microBRIAN. The methods include the image analysis, image classification and special techniques.

3.4.1 Image analysis

This session consists of image enhancement and operation. Image enhancement is a process for improving the display for visual identification and pre-product used in other processes. This is a part of image representation which is separated into linear stretching and non linear stretching enhancement. The operation is concerned with techniques commonly applied on one or more image channels to produce the new channel for the result (Harrison and Jupp, 1990).

3.4.1.1 Image Enhancement

The numeric value records in an image, which are called raster format, may be represented as a picture by associating each image value with an intensity colour on a display (Harrison and Jupp, 1990). While the image displayed with the computer manipulation of data values, a fundamental part of the image needs the visible interpretation to classify its.

The word "contrast" is related to the ability to differentiate a feature from its background which is important for the visual identification of the image. In an image processing, contrast enhancement can be conducted in many ways depending on the type of features being identified in an image. Based on the microBRIAN system (Harrison and Jupp, 1990) the contrast can be separated into two types, the overall image contrast or linear stretching and the selected feature image contrast or non linear stretching. The theory of this stretching simply explains that the linear stretching uses the histogram enhancement to highlight overall image. While the non linear stretching uses the interactive scene enhancement (mPIC) for contrasting some parts of the image.

The contrast in this study uses the linear stretching to improve the reef image, because the non linear stretching is more complex for use in the small reef. Another reason is the result from this process is used for the basic visual classification for a latter process, so it does not need the complexes stretching. The overall image enhancement is based on the theory that remote sensors are designed to detect the reflectance value in the wide range (0-255), so the data rarely cover the full range. To produce the best contrast of image representation, the user must find out the suitable range for the image, and each image has its own range. This problem can be solved by the histogram enhancement (Figure 11).

microBRIAN has two types of histogram enhancement, the automatic or 98% enhancement and the user defined enhancement. The 98% histogram enhancement may suit the process which needs to be quick and has the neighboring substrate features in the image. The program selects the data coverage from 1% to 99%, so the data at 0-1% and 99-100% are left. Harrison and Jupp (1990) suggested that the method can improve the pictorial image representation because the data range are narrow while the lost data is only two percent. However, this method may not suit enhancing small reefs, because the fringing reef is located between land and sea areas. The data are separated into two loops and 98% histogram enhancement cannot produce the high contrasted display. The data need to be separated from each other.

The technique for generating one image into two images is called as theme digitise imagery (mSPDIG). Based on the remotely sensed theory the reflectance values from infrared band is high on the land and low in the sea. So the land and sea themes are put in the program, and the program will separate this image into two images. Based on this theory, the reflectance values in the reef area are dissimilar from the land and sea areas. So in some images the process can separate the reef from other features. However, during high tide the reef is covered by water and it will disturb the reflectance values, so some images cannot be separated reef from water mass especially in the turbid area. In this case, the reef image can be isolated from the water image by the scene digitise image using cursor (mDIGIT).

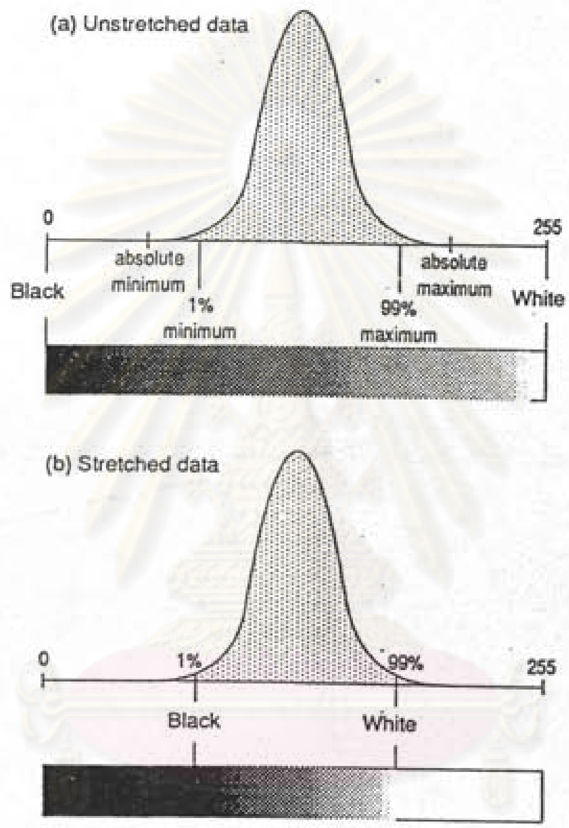

Figure 11. Histogram Stretching for Image Display (Modifies from Harrison and Jupp, 1990).

The reef imagery is represented by histogram enhancement. The image may display high contrast in overall image or only in some parts of the image. The problem comes from a variation of reef substrate which reflect the high range of spectral bands, so the reef has the high and low contrasting areas. Based on the theory of reflectance in the reef area, most reflectance values come from the bright substrate, for example sand (Thamrongnavasawat, 1990). If the 98% image enhancement is used, the major data are present as the sandy values, and the 2% of living coral or other important component values are lost. The image enhancement by user define can solve this problem.

Although the image enhancement is a useful tool for the study, colour is an important aspect of image presentation and interpretation. Discussion so far has referred to representing image data as shades of gray between black and white. Since the human eye is not particularly good at detecting gray shades, image data can be interpreted more easily if displayed as a range of different colours. The type and range of colours used to represent data values in a colour image will directly affect power visual interpretation of the data by enhancing or reducing our perception of its patterns and features. Various contrast enhancement transformations discussed above attempt to improve this displayed colour range.

Base on the colour theory, the colour composite imagery is formed by associating three different image channels with these three colour guns (Figure 12). One channel is displayed as a blue-scale, another as a green-scale and a third as a red-scale. The display device then effectively registers these three colour scales as though they were three transparencies being viewed in front of a uniform light source (Harrison and Jupp, 1990). The resulting composite colours of a pixel depend on its shades of red, green and blue in the individual channels. Usually each channel of a colour composite image is individually contrast enhanced to improve contrast in the displayed image.

If the colour image has been formed by simultaneously displaying a blue data channel (that is, recorded reflectance were in the wavelengths of the blue light) as a blue-scale (with shades of blue, instead of gray, representing the channel values), a green data channel as a green-scale and a red channel as a red-scale, it is referred to as a "true", "real" or "natural" colour composite (Harrison and Jupp, 1990). This should resember the actual colour of the scanned object. With remotely sensed data, the colours of a "true" colour composite image would be similar to those of the Earth's surfaces viewed from a high altitude aircraft. Any other 2mapping of the channels to be blue, green and red is called a "false" colour composite since features in the resultant colour image do not have their true colour.

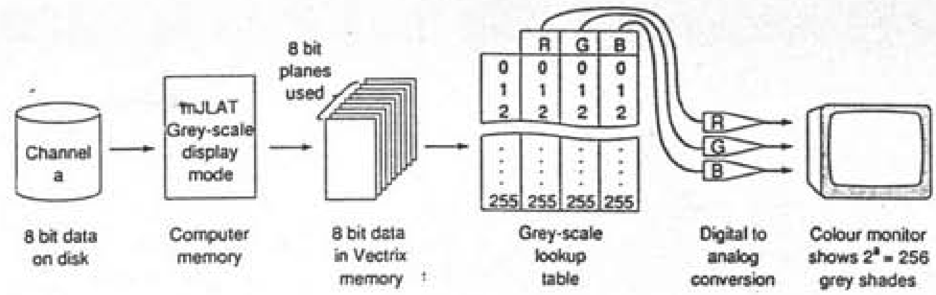

Figure 12. microBRIAN Gray-Scale Display Mode and The Additive Colour Mixing (Modifies from Harrison and Jupp, 1990).

The way to explain the displayed colour composite and reflectance data used in this project is the channel and band. Channel refers to three colour guns, and we use the position to present the channel, for example first position presents blue gun. Band refers to the reflectance band in remotely sensed data, for example TM has band 1 to 7, SPOT XS has band 1 to 3. The technical term used in this project, which is the same as used in the microBRIAN program, attempts to solve the problem in representing the colour composite image. For example the 1,4,3 colour composite image is the image display reflectance, band 1 as blue gun, band 4 as green gun and band 3 as red gun.

The image enhancement is the useful technique to classify and interpreting the display picture. However, the technique to get the nice result is based on the experience and the information from the study area.

3.4.1.2 Operation

Another process to improve the display is an operation which separates into linear and non linear operations.

i Linear Operation: This operation relies on matrix algebra and can implement simple rescaling for one or more channels (Harrison and Jupp, 1990). This operation comsists of many processes which microBRIAN has the special program to support them. However, in this project only principle component analysis (PCA) is used. The description will explain only PCA operation.

PCA involves a rotation of the original data to give new axis that minimizes the variance. Because TM data contain 6 bands (band 6 which is the thermal infrared is not used for this reef study), so the operation is very complex. The explanation of PCA starts from two channels. Figure 13 is a graph between channel 1 and 2 as X and Y axis. If the line of best fit is put through this data set, a variance is just the distance from each point to the line of best fit. If the line of best fit goes through all the data points then the variance will be zero. Departures from this increase the variance.

Where channels areas correlate, that is, one varies with the other. Hence if the axis are rotated the data can now be reduced to one axis, a requirement for a data is only located on the new axis which is called A axis. This A axis contains one hundred percent of the information and the variance is zero.

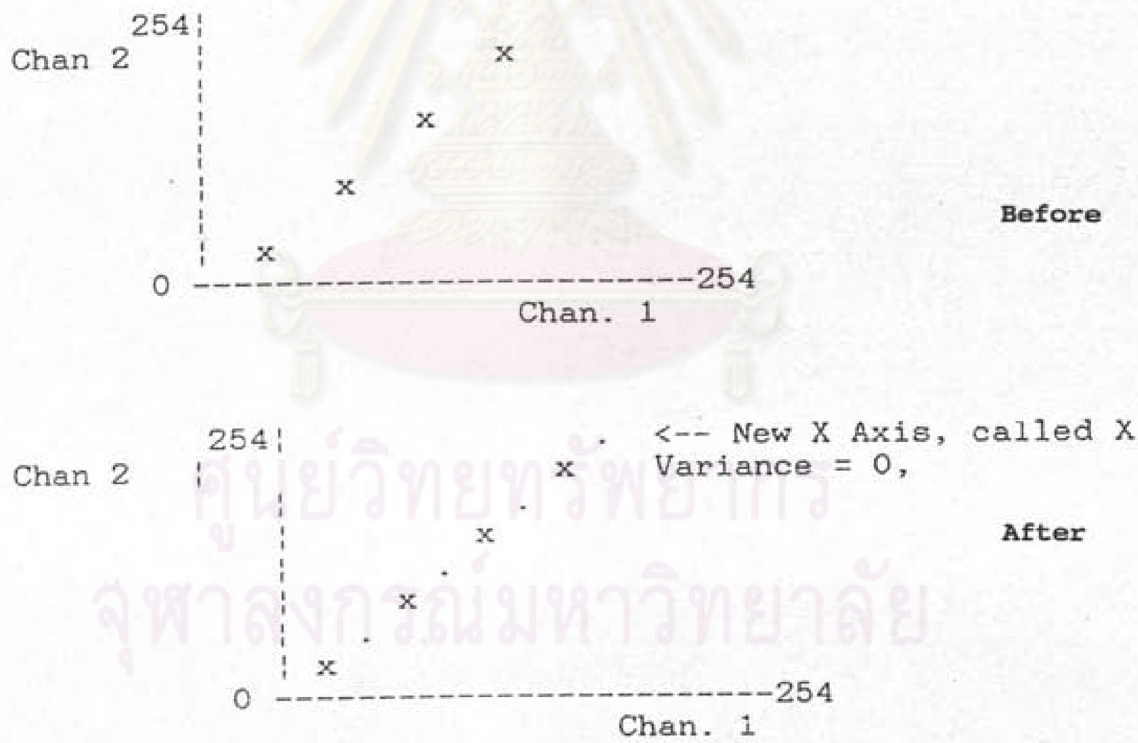

Figure 13. Graph Present The Data Before and After Operates with PCA.

So the PCA looks through the data which may be 4 or 6 dimensions (channels) and finds a line that produces the minimum variance or best fit. This line becomes the first PCA vector or simply PCA-1. The second axis is put at right angle to the first, again, in a plane that minimizes the variance. The third goes at right angle to this one and so on. The use of PCA's id twofold, that of data reduction and of feature isolation.

Most remotely sensed images contain some unnecessary information. For example, Landsat MSS 6 and MSS 7 contain similar data values since most ground cover types give similar responses in these two channels (Harrison and Jupp, 1990). When redundancies do occur in an image, it is possible to "remove" the duplicate information and rearrange the data in fewer channels. This data reduction operation is particularly relevant to geological applications where feature identification relies on visual 2interpretation of enhanced imagery.

This is useful when using TM data which has six channels. As the classification in microBRIAN can only handle four channels, PCA allows for the six channels to be reduced to four with little or no data loss.

Feature isolation comes from the result that when the axis is rotated, it is isolated to highlight certain features. For example PCA-1 is often called "brightness" because it tends to contain the very bright and dark areas of the image. PCA-2 is often called "greenness" because it seems to break things up on their greenness (Bainbridge, 1991). The high PCA's often contain the noise (an error in a data) so it can be a way of isolating the noise.

In microBRIAN version 2.31, PCA is applied to imagery using mGNPCA. This program has a very flexible range of options for adjusting channel variance. mGNPCA allows a principle component transformation to be applied, and the input function contains eight channels so it can receive all TM band. Furthermore, this program may process from two input images but this opportunity is not used in this study.

ii Non Linear Operation: Different from linear operation, the non linear operation is applied to pairs of channels in an image. This operation is a simple but effective transformation which commonly involves computing the ratio values between image channels. The implementation of this transformation involves dividing the value of a pixel in one channel by its value in a second channel and rescaling the result to the available image data range for all pixels in the image.

In microBRIAN, ratios may be computed in a variety of ways. The simple program is mRATIO which computes a simple ratio between pairs of channel (Harrison and Jupp, 1990; Figure 14). While the ration of image channels is a very simple computational operation, it is a very effective way of highlighting the differences between two channels. For example, healthy green vegetation (in the reef is seagrass) typically has high reflectance in near infrared and low reflectance in red wavelengths. Other image features may have either high near infrared and low red values so it becomes difficult to identify vegetation pixels using only one of these channels. However, dividing the near infrared channel value by the red channel value for each pixel in the image gives us a ratio result which is high for the vegetation pixels.

Using mRATIO, which is called band ratio in this project (Figure 14), the valuable process may provide for the vegetation in the reef area especially the separation of seagrass and macroalgae. The band ratio may be used for the identification of other reef features. This process needs the information from mTRAN to produce the productive result (mTRAN operation will describe in the special technique session). Other reviewed literatures can give ideas to process this operation in the reef area. Harrison and Jupp (1990) suggested that the ratios of various channels could be used to highlight differences in particular features of the Earth's surface.

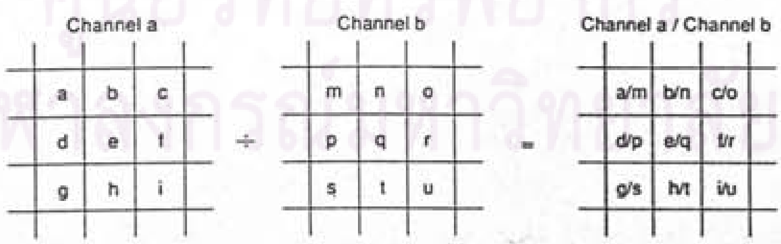

Figure 14. Operation of Simple Band Ratio (Modified from Harrison and Jupp, 1990).

The commonly used band ratios are:

- green/red: soil colour or water colour
- green/blue: water colour
- near infrared/red: vegetation with green foliage
- shortwave infrared: geological features.

The descriptions are very useful for the process. However, the ratios which are described use MSS data. Using TM data it needs a modification for the project objective.

An image analysis is the method which may be useful for many remotely sensed studies. However, this process is not widely used, because the process is quit complex and it needs the reef knowledge to identify the result. Recently, the unclassified process is starting to be increasingly studied but the projects still try to solve problems in the theory and equation detail (Gillespie et al., 1986; Rothery, 1987; Hyland, Lennon and Luck, 1988). So this project emphasizes on the technique using those methods to find out the valuable result for reef study.

3.4.2 Image classification

The image classification is commonly used for feature or pattern recognition and usually involves converting a continuous tone image to a thematic map. Similar to other image processes, the image classification for a particular interpretation task will depend on the nature of the application and the resolution of remotely sensed data. The different reef cover features radiate electromagnetic energy differently and are thus recorded as different spectral values in image data. The natural zonation in the reef makes the image data display the values in patches larger than individual pixels which are usually required in remote sensing analysis. So the remote sensing studies on the coral reef component distribution can use this technique for analyzing the reef features distribution.

According to the few projects operating on the classification of the reef features (Kuchler, 1985; Jubb et al., 1985) the remotely sensed data using in those projects is Landsat MSS which is different data characteristic from this project. The low resolution of MSS data may suit the Great Barrier Reef which has a wide reef area but it can not be used in the small reef at Samui Islands. However, the high resolution TM and SPOT data will give a lot of different reflectance value pixels which are hardly separated by the classification.

The classification in the reef is different from other classifications because this ecosystem is submerged and very complex. Any classification can get the result but the reasonable and valuable result for reef study need the carefully process to present the result as the objective planning. The remotely sensed theory and the reef knowledge suggest that the reef classification may concern the following;

- As coral reefs are usually covered by water (even in the low tide the coral tissue still have water), different depths with the same substrate will give distinctive reflectance values. The result is that any intensive analysis of coral reef data must include some sort of depth correction.
- Coral reefs are not simple structure but are three dimensional surfaces, though some reef flats can be considered to be two dimensions. The reef slope which is the living coral area has a three dimensional surface. The classification process in this area needs the supported information.
- The coral ecosystem is one of the most diverse areas. The satellite sensor effectively integrates all the diverse components into a set of pixels. The classification of the reef may separate the reef in many zones but the reef component distribution knowledge must cluster these classes into the zonation of the reef.
- The coral reef component distribution in each reef is different because the reef environments are dissimilar, especially the reefs in Thailand which comsist of many small islands so the island location and morphology cause the different environments.
- The components in one reef still have different relation levels in each groups. For example sand which has the high reflectance values may be isolated from each other, so the basic classification may identify this component area in many groups. However, in the reef component distribution sand is the minor interesting component so it needs to be identified as a big group. While the living coral and other organisms are the area of interest, the reflectance values from these features are very similar. So the classification may group them as one or two big groups which are not the direct objective.

The classification process can generate into two main operations, supervised and unsupervised classification. Harrison and Jupp (1989) explained a supervised classification as a procedure for classifying an image by a basis of representative training samples of known identity. They also suggested that the unsupervised classification was a classifying without the pre-define classes. However, there are two main problems that prohibit the using of supervised or unsupervised classification. These obstacles are:

- The reefs have the mixing components and they are always submerged so the ground data can not be surveyed covering all the reef area. The ground data for reef component distribution in Thailand is very insignificant so the well defined area for classification can not be run through. The image enhancement cannot clearly identify the submerged reef features, so the supervised process which needs to know all the component area in the reef is impossible to operate.
- The reef is composed of a lot of sand and dead coral groups which have the isolated reflectance values. The unsupervised process is purely run by the computer equation so the result will be composed of many classes that make the clustered class process rarely succeed.

The mixing classification is a process combining both classifications together. Starting with supervised process the reef components are carefully selected for the training area. After selecting the main reef component area the unsupervised process is operated to generate other reef areas which are left from the first process. This classification can solve the problems and give more reasonable data.

There are two important phenomena which are used in this study, Chi-square and percent of dissimilar. Chi-square is used in selecting the training set, one has a high Chi-square suggests that training set has a high variation of remotely sensed data. However, the low Chi-square does not mean that training set is good, because the low Chi-square demonstrates that the training set has the same substrate feature so other data cannot be grouped in this training set. Chi-square used in this process is varied depending on how important are reef features. For example, in the coral area Chi-square can be about 3 while the sandy area Chi-square may rise up to 5. Chi-square is used in other processes, for example the data analysis and inspection, similar to the classification. In each process Chi-square depends on how important are the features.

The percent of dissimilar is a technical word used in this project, this word comes from the dendrogram which is used for clustering the feature classes. The percent starts from 0-100% (Figure 15) demonstrating the similarity of those classes. The percent of dissimilar means in the opposite way, for example a percent in dendrogram is 10%, the percent of dissimilar is 90%. Using this method it is easier to understand the differences between feature classes. For example sand and coral has 80 percent of dissimilar while coral and dead coral has 60 percent of dissimilar, so dead coral and coral have a closer correlation than coral and sand. The percent of dissimilar is very useful in the clustering feature classes.

microBRIAN has many programs to support the classification, mTRAIN and mOVRLY are used for selecting the training set while mCLASS is used for classifying. mTAXON, mSUPER and mPAINT are used for clustering the features class, and mSMOOO and mFILLA are used for modifying the product (see Harrison and Jupp, 1990 for more details). This study dose not run the classification alone, but the results from other processes are required to develop the technique and find out the reasonable product.

3.4.3 Special Techniques

This session is separated from other digital image processing techniques because these techniques operate from the idea used in other processes. However, the processes are still the digital image processing. The special techniques in this project are mTRAN and sediment density slicing.

3.4.3.1 mTRAN Technique

The aim of first special technique is to develop the special program, mTRAN, for using with ground truthing result. However, when this program is resolved the useful result suggests that it can explain the remotely sensed aspect in the reef area, so developing the technique for this program is expanded to use as a tool in many image processes.

mTRAN program is not the program in microBRIAN, but it is developed by Bainbridge in 1990 for using with microBRIAN system. In microBRIAN version 2.31 there is mLOCAT program for calculating the result to employ with a ground truthing data. However, this program calculates the remotely sensed data only in one pixel so it difficult to examine with a transect ground truthing result. In 1990 Bainbridge developed mTRAN program to solve the problem and it is tested in this study (This program is not published yet).

mTRAN is a program which can calculate the remotely sensed data along the test line. The test line lays on the image using curser or keyboard, and a program will create histogram for remotely sensed data in each band along the pixels in transect line. The program is very useful for observing the variation of reflectance values along the test line. If a line lays overlap to the ground truthing line, the result will be practical for analyzing and checking the classification result.

According to the early creation of mTRAN, there is no information about this program. This program must be tested before being used in a project. After operating on a few varied component reefs, the result demonstrates that mTRAN can be used in three study objectives as follows:

- mTRAN operates in the reef which has a lot of information and the result is recorded for different substrate reflectance values. When this program operates in the unknown reef the first result can help to identify substrate covered unknown reef. This operation is very useful for image enhancement, visual identification and image classification.
- mTRAN can be used as a tool for reflectance study. In few projects the reflectometer is used for recording the variation of the spectral reflected from substrate. However this equipment is very expensive. If there is a fixed point in the reef and image, and there is a unique component area which is big enough for satisfying the reflectance values from a pixel come from one component, the mTRAN result can give a idea for identifying different substrate reflectance. This method is tested in Tao Island and the result will be explained in result session.
- mTRAN can use as its aim for checking classification data and a ground data. The tested result demonstrates that mTRAN fits with the new ground transect technique and the data can be easier to examine than using mLOCAT.

3.4.3.2 Digital Image Processing Step

From the unclassified and image classifications as described above, the digital image processing is run as follows:

1. Testing the technique and studying in detail for reflectance values in the known reef. mTRAN can be utilized as a tool to get more information.

2. Preparing the image by image analysiss, image enhancement, band ratio and principle component analysis can produce the result for visual identification. Furthermore, the products may be used as the image for image classification.

3. The classification operates on two remotely sensed data, TM and SPOT XS, TM data is used as a major source while SPOT data is tested in the small areas. The major results in this step are thematic reef image and developed technique for selecting training area and cluster feature classes.

4. The results from all methods are tested by ground truthing and mTRAN data, Chi-square is controlled not to be high in living coral and other important areas.

5. After correcting the products, the thematic reef images are used for studying the reef zonation and classification. The result measures the living coral and overall reef areas as products.

The different classified process follows the groud truthing, if the ground truthing is concentrated with a new survey technique, the result will consist of many classes. The reef thematic map can not be focused on any reef because the intensive ground truthing needs the long term operation, and it is not useful for the project that emphasizes on techniques.

3.4.3.2 Sediment Density Slicing

The simplest form of classification involves grouping ranges of consecutive values in a single image channel to represent different categories. In microBRIAN, mPAINT are flexible painting of gray channel imagery. This program contains a specialized display module different from mJLAT and it requires that images to be painted and displayed using this module.

After a grey scale image has been displayed, ranges of image values can be associated with a displayed colour. Painted values may be listed by class or colour, in microBRIAN version 2.31 the display colours are defined by number in the range 0-511 colour. The values in a single data channel are separated in many ranges, for example 0-10 is a lowest sediment theme, then 11-15 may be the medium sediment theme, etc
(Figure 16). In this study band 3 in TM data is used because the previous project (Tongsima, 1989 cited by Thamrongnavasawat, 1991) suggests that this channel suitable or water mass classification in this area.

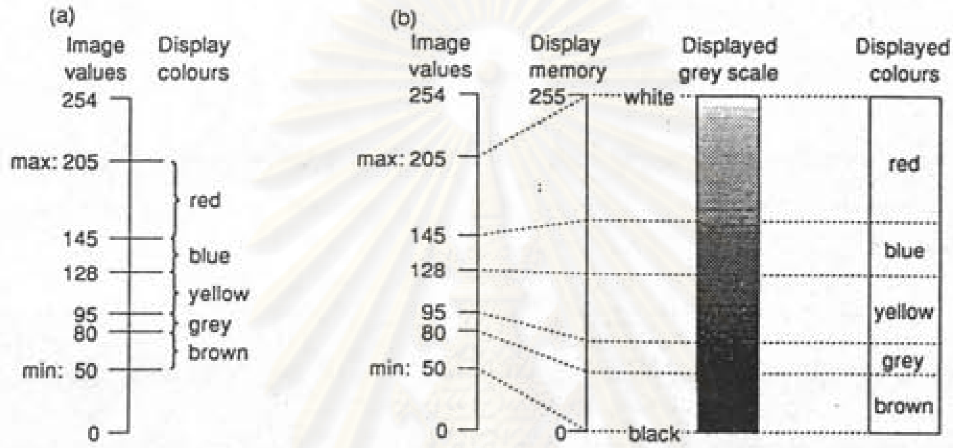

Figure 16. Sediment Density Slicing Process.

The ranges defined during painting may be recorded as a theme file, the latter defines each category on the basis of colour, so all values painted as a common colour are redefined to have the same output value. The classes may also be applied to the disk image and recorded as an output image. The painted colours can be considered as image categories or classes and summarized in a single channel. In this study channel 4 of the output image is the classification channel in which each is painted pixel in the image is given a class number associated with its painted colour and unpainted pixel are set the null value.

The sediment density slicing is used for labelling and aggregating classes in the mosaic model classification approach. The outcome may be used for visual identification of the sediment and water pattern or it can combine with other digital results such as thematic reef image to explain the effect of sediment corresponded with the reef component distribution.

3.5 Ground Truthing

This project emphasizes on developing the ground truthing because the zonation and size of reefs in Samui Islands are different from Great Barrier Reef which is a source for producing microBRIAN. This session separates into three parts, overall reef survey, ground positioning technique and ground truth transect method.

3.5.1 Overall Reef Survey

The overall reef survey in this study can generate in two parts, presurvey and postsurvey. Using Manta Tow method (Dartnall and Jones, 1986) and Horizontal Photography, which is developed from the land ground truthing, the general coral reef component distribution is reported as a presurvey for using in unclassified and image classifications. This presurvey is observed in a few reefs at different locations and the data are used for study in the others. Other sources of the data are reviewed from the projects that were surveyed in this area (Sudara et al., 1989, 1990).

The techniques are developed to suit the general reef data for remotely sensed studying because the previous methods emphasize only on some parts of the reef. Manta Tow survey which highlights on reef slope is developed to expand in the reef flat area, so this method must be done during the high tide. One Manta Tow is done along the reef slope while another is done in the outer reef flat. It must separates Manta tow sites because it can not run zig-zag across the reef edge. The percent coverage of reef components do not estimate only the living coral but also the dead coral and sand.

The horizontal photography started from the idea that visual identification and image classification need hard copies. There are two points for processing the horizontal photography, it requires a very low tide period and the high location to view the reef. The photograph must be taken overlaping each other so it can be attached more easily when the negatives are produced. One overall reef photograph must be taken to recognize the area.

The overall reef survey may be observed before the data processing or it may be overlooked after the data process is finished. However, it recommends that few reefs should be examined before the process and those sample sites should have enough background information.

3.5.2 <u>Ground Positioning Technique</u>

This technique was developed to solve the problems with reef size and equipment. The projects using microBRIAN were presented from other studies (Kuchler, 1985, Bainbridge and Reichelt, 1988) usually studying large size reefs. However, the reefs at Samui Islands are small so the technique was not matched with the study. Recently there is the high efficiency equipment for checking the ground position with very low error, this equipment is called Global Positioning System (GPS) but it will not be submitted in this study.

The developed technique should concern two items, the reasonable data which can be used in small reefs and the cheap and easy method which can be processed in the field work. The new technique result must be checked with the high resolution map, this project uses the result from multi-resolution map scale 1:25,000 to conform this method (this multi-resolution map will explain data integration).

The technique used the plastic sheet made in L shape for 5 plus 5 meters and laid it on the reef area in the same time as satellite passed. After laying the plastic sheet, the researcher will use the ground transect method to observe the reef area. The reflectance value of the plastic location will be higher than other closed pixels. When displaying the satellite data the bright pixel of the plastic sheet can be clearly observed in the image, and the field data which were recorded will be checked with the satellite data.

3.5.3 <u>Ground Transect Method</u>

According to Bainbridge and Reichelt (1988), the special ground truthing method for remote sensing studies on the reef is very insignificant. The technique was developed for survey in the reef, usually using the earlier coral reef survey technique which may not be suitable for remote sensing study. The new technique (Bainbridge and Reichelt, 1988) which was modified from Lifeform Benthic Line (Dartnall and Jones, 1986), is suitable for the wide reef which has a large component area. This method was tested in Samui Reefs and the result suggests that though it has a low error, the method cannot be processed in the small reef especially in the narrow living coral band. A new method must be developed for this project following three aims:

- The new method may modify from the previous reef survey method because it can be easier to process by the coral scientist.
- This method should report the component distribution in the overall reef area and sensitive enough to describe the component in each area with the resolution of TM data (900 square meters). The method should record the depth data along each area. The intersection reef component zone must be clearly presented.
- This method should operate with the program in microBRIAN for the easy checking process. It should locate the points in both image and field site.

The method from Lifeform Benthic Line (Dartnall and Jones, 1986) and Shore Transect Method (Sudara et al., 1988) was developed with the remotely sensed theory. The new method which is called "Ground Truthing Transect Method" can support those aims with a small group of researchers processing in a short time (half or one day depending on the reef size). However, the problem in this method is that the researcher should understand the reef zonation, remotely sensed theory and the reef surveying technique. This method should operate in the low tide period so the time may be one factor affecting this method.

This method should run as follows:

1. The study site should has a starting point which is the reef or shore location that is exactly located in the image. In the mixed component reef, the point from ground positioning technique may be located to make sure where is the exactly started point.

2. The field time should be in the same tide range as the remote sensing recorded (If it possible the tide should be low). The transect lines are laid in four directions and these lines may cover all reef components.

3. The researcher records the substrate component along the line with the depth every 30 meters. The area should cover approximately 30 meters in each site.

4. In the intersection zone the paralleled lines are laid 50 meters in each sites then the lifeform technique is used to report the percent coverage of reef component. The result is utilized for the linear regression for the graph so it can present the tended of the major component in the intersection area.

5. The area graph is made as the final product for this survey, then the result compares with mTRAN data and digital image processing results, they can present the checking and percent of conference interval in that areas.

3.6 Data Integration

The data integration is different from the other processes in this study because it is not a real remote sensing. Data integration can be explained as a tool for combining and presenting the data from many sources to one product. Recently a part of data integration is extensive service called Geographic Information System (GIS). Harrison and Jupp (1989) concluded that GIS was a data-handling and analysis system based on sets of spatial attributes. The data sets may be map-oriented, when they comprise qualitative attributes of an area recorded as lines, points and areas or image-oriented, when the data are quantitative attributes referring to cells in a rectangular grid.

microBRIAN also has the programs for data integration. However, the product is only presented in the land area (Jupp, 1990). This project developed the technique in microBRIAN data integration for using in the reef area. A prototype GIS starts with two data sources, remotely sensed data and ground data. The data integration for this study is separated into three items, the multi-resolution map, the combined reef and depth image and the perspective three dimensions view.

3.6.1 Multi-Resolution Map

This worthwhile method is commonly used in many urban projects which emphasize on the visual classification. However, in the reviewed reef projects this method was not already operated. The problem may come from the puzzle to combine different remotely sensed data (the problem will describe in a discussion session).

The multi-resolution is a map, it is not an image. The difference between map and image is that maps can locate the point with grid number and has a plane section. So this session will firstly demonstrate how to transform images to maps. Then the multi-resolution technique will be introduced.

3.6.1.1 Image Rectification

This session has introduced the concepts of geometric manipulation of imagery and describes a set of operations which is required to modify the scale or orientation of imagery before processing. Remotely sensed imagery contains a variety of geometric distortions which need to be accounted for before registering with different image source or map data (Harrison and Jupp, 1990).

The image rectification module in microBRIAN (mBARRY) implements a range of modules to account for known geometric distortions in satellite imagery as well as map projection models which compensate for the spatial inconsistencies between different map co-ordinate systems. These models can be used in conjunction with control point modelling techniques to achieve accurate registration between different images.

The maps used in this study are topographic maps from the Royal Thai Survey Department (1973) which are the highest resolution (1:50,000) map in this area. The map codes are 4927 I,IV and 4928 II,III. The rectification can be processed by selecting the ground control points (GCP) which are the points that display clearly in the image and can calculate the grid number in the map. The points in map are put in the program. Then the points in the imagery are processed to overlap with map points. The program will correct the distortion of the point in the image and produce the new imagery corresponded with the map.

This product can be rescaled and it may be different from the image resolution. However, it should be considered that even the new scale has a higher resolution, the result will still be the data in the earlier resolution so the new imagery just enlarge the pixel area to the new scale. For example, while the rectified Landsat TM imagery may be scaled to 10 meters pixel size, the data will still be recorded from the 30 meters pixel size. On the other hand, the effective rescaled product is used for the merged process which can produce the high resolution result.

3.6.1.2 Merged Process

After being rectified and rescaled the TM map to 10 meters pixel size, the result will have the pixel size matched with the SPOT Panchromatic data, so the merged process is an operation for making a mapped image result that has a resolution as SPOT imagery and the colour as TM imagery.

The first problem to combine these two image data is the lack of reviewed literature because the projects which have been done emphasize on the land area, and they used the combined SPOT Mss data with SPOT Panchromatic data. To solve this problem the technique was reviewed and tested with the SPOT data, then the processed TM data was done only in the eastern part of Samui Island because the SPOT result suggested that the process is very complex and needs a long term operation. This project aim is to develop the technique, so it does not require the result for overall study sites. The eastern part of Samui Island is the known area which has varied reef types so it is a suitable site for reef studying.

3.6.2 Combined Reef and Depth Process

In the latter session the remotely sensed data are combined with itself but in this process the remotely sensed data will be combined with the ground data. Before solving the technique there are two words which may be described for more understanding, raster and vector data format. Harrison and Jupp (1989) suggested that "raster" display device stored and displayed data as horizontal rows of uniform grid and picture pixels. While "vector" is the representation of points, lines and polygons (areas) on a map, or other spatial diagrams, by digitising their position co-ordinates, and recording associated values. Data in this format may be integrated with raster imagery in microBRIAN using programs in the mBRINT module. In the simple way the raster data is a ground data which can fix the location and the vector data is a remotely sensed format.

To combine the raster data with vector data the first step is to select the raster data which is important to the reef environment. This data should reference the grid number and they may have a high contrast or be located in the diverted area so the result will be easily identified. For example, if the tidal data is selected, the tidal range in Samui Islands is very similar to the others so the result has only a few zones which is very difficult to explain.

In this study the depth data is a raster data that combined with vector data. The study site is Tan Islands because this area has a different depth zones and it is a diverse area with the reef pattern and oceanographic process.

The first step is how to transform the raster data to vector data. This study will use SURFER program because it is a simple and reasonable program which everybody can operate it in a short time. However, in the technique there is a problem which will be explained in the result session.

The ASCII file transforms to microBRIAN vector file by mTRADE, data is stored in a single channel which can be displayed and painted to present the depth zone in a image. When displaying it with the remotely sensed data or thematic reef map the result is a combined reef and depth image. It is recommended that this process is a first real prototype GIS using in reef study in Thailand.

3.6.3 Perspective Three Dimensions Process

The perspective three dimension image is a useful product which can present the reef geomorphology, and it solves the problem for the reef scientists to understand the physical processes that affect the reef. It is recommended that this module, different form other artificial module, can present the real reef morphology in an image and it can put other factors affecting that area so other studies can use this module as a tool (Jupp, 1990). However, Samui Reefs are the small fringing reef so the process is very difficult to produce the perspective reef view.

This study selects the study site emphasizing on sea floor topography because it is big enough to explain the physical process in that area. Around Samui Islands, Tan Island is suitable for a study site because it is an isolated island with varied sea floor topography (reference from topographic and hydrographic maps). There are many reefs around this island and the reef patterns are different so they may be caused by the sea floor topography which controls the physical processes.

The programs in microBRIAN which be used in this operation are mMULTI to combined the height data which have already been transformed as described in a latter process and m3D to produce the perspective three dimensional images. Figure 17 displays the flow chart for this operation.

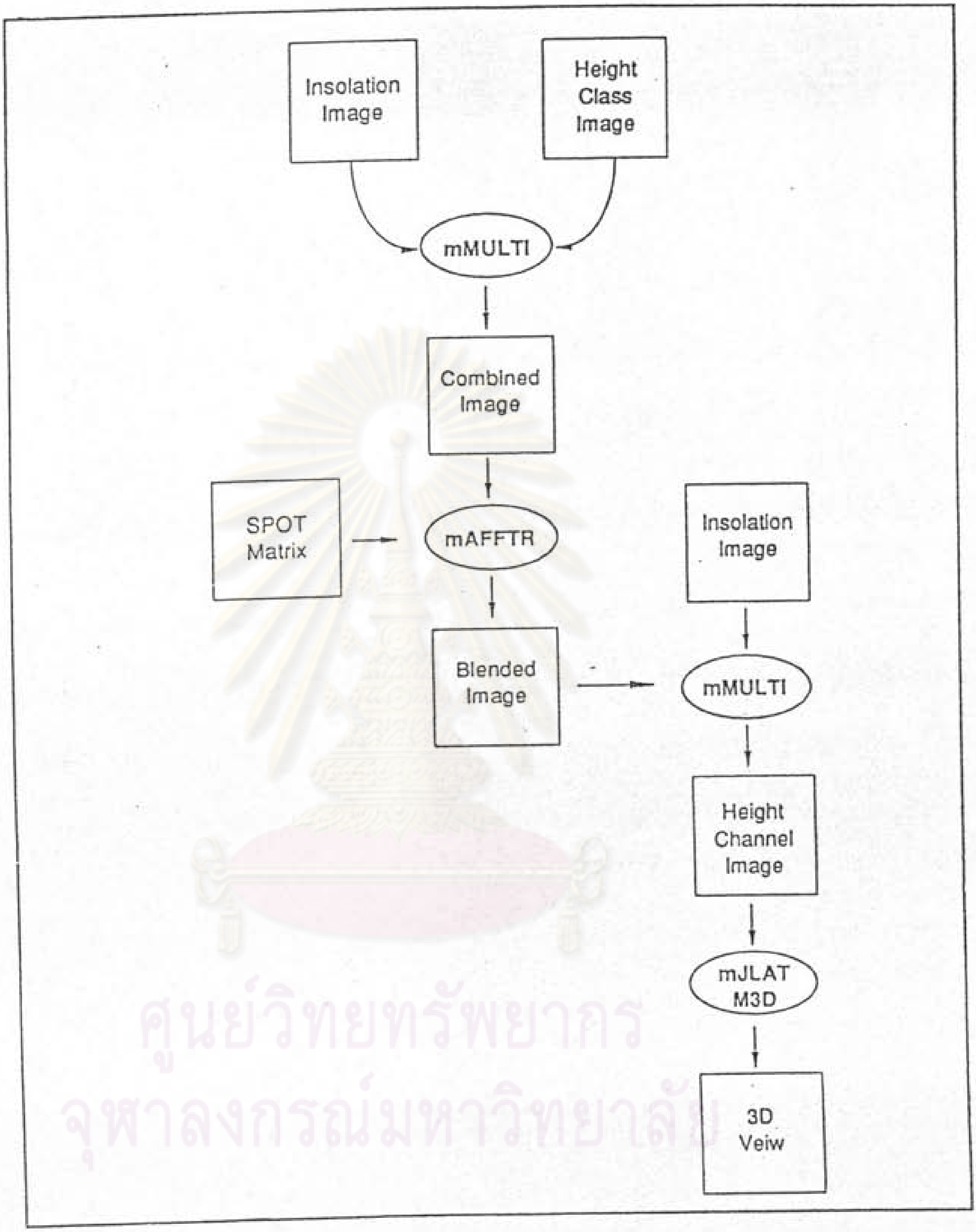

Figure 17. The Flowchart for Using Height Data and Topographic Themes to Produce a Three Dimensions Perspective Image (Modifies from Jupp, 1990)