Photogrammetry Techniques for Coastal Monitoring

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Abstract

Understanding and predicting coastal changes are crucial issues in coastal management and planning within the Caribbean and effectively the world. The on-going researches of collecting geospatial data using photogrammetry techniques with digital aerial photographs, goes a long way in helping to understand the long term behaviours of the natural environment and is particularly important. This research aims to highlight photogrammetry techniques to monitor coastal erosion over large areas. The digital aerial photographs used were acquired from the Survey and Mapping Department of the study area in the island of Providenciales, Turks and Caicos Islands in the years 2000, 2007 and 2012. This research will also aim to closely monitor the coastal processes and the geomorphology behaviour of the coastal area. ArcGIS software will be used in a workstation as a tool for analysis of geospatial data used in acquiring the data for examining the recurrent developments of integrated coastal zone management and the distribution of geospatial data. Further analysis will be conducted to examine the effect of coastal erosion on vegetation and property damage.

Acknowledgement

The journey for the last three years has been long, but all things must come to an end. The experiences and memories will stick with me for the rest of my life. As I finish writing, editing and reediting this research paper the reality of the last three years has not yet sunk in. Although the degree for this dissertation will be in my name this work belongs to many other persons that have supported me throughout this journey. The contributions made by various individuals, I would like to extend a heartfelt thank you for all of the support.

Firstly, I would like to recognize the Ministry of Education of the Turks & Caicos Islands Government for affording me the opportunity to further my studies in the area of Civil Engineering Surveying, I am very grateful for your support for the last two years financially. All of my training gained in the last three in BSc Civil Engineering Surveying will be a great benefit to the Government of Turks and Caicos Islands and indeed the people of the Turks and Caicos Islands.

It goes without saying, the hard work and dedication of the staff, members and lecturers of the school of Architectural, Computing and Engineering (ACE) at the University of East London. The Surveying programme is without a doubt the best program because of the following persons that I must make mention of, starting with Dr Brain Whiting, Mr Richard Latham and Mr Peter Lakin, but a special thanks to Dr Colm Johnson for taking the time to advise me throughout the process of my research and also to Ms Sharon Brown who is no longer with the program, I would like to thank you all for the advice, guidance and support that you gave to me over the last three years of my studies. All of you have made a positive contribution to my personal development for life and also to my career in surveying.

To all of the following agencies that supported me with all of the data that I needed for my research, Mr Demarco Williams, Mr James Fritz and Mr Leroy Charles at the Survey and Mapping Department in the Turks and Caicos Islands. Mrs Kathleen Wood and Mr Eric Salamanca at the Department of Environment and Maritime Affairs and to Mr Tony Sani at Sani International for the support and ensuring that I got all of the data in a timely manner to research it and be able to produce this dissertation, I am so indebted to you for the help.

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Author's Declaration

Photogrammetry for Techniques Coastal Monitoring

Gervin K. Simmons

The author makes the declaration that this dissertation is of the author's own work and that all research was done by author, except where otherwise, acknowledged, cited or referenced.

The body of this dissertation contains approximately 9021 words.

Signed……..

Date……..

Table of Contents

Acknowledgement 2

Author's Declaration 4

Chapter 1 7

Introduction 7

1.1 Photogrammetry 7

1.2 Photogrammetry Techniques for Coastal Monitoring 8

1.3 Coastal Monitoring 8

1.4 Case Study Area 9

1.5 Aims 10

1.6 Objectives 10

1.7 Methodology 11

Chapter 2 13

Literature Review 13

Background Research of Study Area 18

Chapter 3 23

3.1 Aerial Photogrammetry Monitoring Techniques 23

3.2 Terrestrial & Close-range Photogrammetry Monitoring Techniques 24

3.3 Coastal Processes 25

3.4 Coastal Geomorphological Processes 26

3.5 Erosion of Coastal Causes 26

3.6 Software & Data Management 28

Chapter 4 30

4.1 Data Collection 32

4.2 Data Results 33

4.3 Data Analysis 37

Chapter 5 42

5.1 Conclusions 42

5.2 Recommendations 43

References 45

Image References 48

Appendix 49

Appendix (A) 49

Appendix (B) 50

Appendix (C) 51

Chapter 1

Introduction

1.1 Photogrammetry

There are many proven techniques and methods that are used in geomatics in gathering geospatial data for analysis, but throughout the year's photogrammetry techniques have been one of the most proven methods in collecting data in a fast and convenient and cost effective way. The author in conducting this research of photogrammetry techniques for coastal monitoring will be using photogrammetry as the main subject and will highlight other methods and techniques in photogrammetry such as terrestrial or close-range photogrammetry. However, in geomatics there are different methods and techniques that are available for collecting geospatial data to help engineers in gaining information as mentioned. The process of obtaining data by aerial photographs with a camera that is typically airborne and also having a photograph taken from a ground based camera can be used as a source of gathering geospatial data to create two dimensional (2D) and three dimensional (3D) digital terrain models (DTM). Photogrammetry is the technique by which 2D or 3D objects are measured from photographs and it is the goal of photogrammetry to derive geometrical parameters of remote objects from photographs (Sesli, 2010). This process is done using mathematical formulae with perspectives which are applied to transformations, to determine the relationship between the positions of the given points on the photograph, this is called imagery coordination and the object coordinates X, Y, Z located on the ground (Sesli et al. 2006). The result of a Photogrammetric process produces coordinates of the required object point, topographical and thematical maps and rectified photographs (Sesli et al. 2006).

1.2 Photogrammetry Techniques for Coastal Monitoring

There are different classifications of photogrammetry which are specified based on the type of photography used and the purpose for which geospatial information and data is collected. These classifications include; aerial photogrammetry, terrestrial photogrammetry from laser scanning or airborne lidar and close range photogrammetry, used for emergency purposes amongst other things, where the photo is taken using a hand camera. The author will, however, use the aerial photogrammetry approach as the main basis for conducting the following research on Photogrammetry Techniques for Coastal Monitoring. These methods use large format imageries with ground coordinate information to effectively recreate the geometry of a location or position on the ground or on earth in a virtual environment (Matthews, 2008).

1.3 Coastal Monitoring

Coastal monitoring is the process by which understand the effects that the natural environment has on the behaviour of the coastal features through coastal and geomorphological processes, as well as on coastal erosion. There are different techniques in geomatics that are used in coastal monitoring to effectively predict changes in the shoreline. It is fair to say that photogrammetry is a method that is cost effective and a simple process of monitoring coastal erosion. The general behaviour of the boundary between the land and the shoreline often experiences movements in position over time as a result of external factors created by the natural environment and manmade activities. The shifts in the coastline that advances toward the ocean result in what is termed as accretion; whereas the shifts that advances away from the ocean causes erosion to the shoreline (Masle & Mayunga, 2000).

1.4 Case Study Area

The Caribbean is a tropical paradise of many islands having coastal lines of beautiful beaches. These coastlines experience hurricanes, heavy rain and thunder storms during the months of July to November, which is considered to be the hurricane season in the Caribbean region. This type of weather activity causes heavy coastal damage to the beaches and significant changes to the coastline all year round and for this reason, it is important to monitor the coast line, to ensure that the natural resource of the beaches which are vital to the tourism industry of most Caribbean countries is well protected and reinforced.

The Turks and Caicos Islands is one of those countries that rely heavily on its magnificent turquoise beaches to attract thousands of tourists and international investment from around the world to its shores. It is therefore, crucial to the Department of Environment and Coastal Resources to ensure that the beaches of the Turks and Caicos Islands are well protected, safe, and clean for future generations. The Department of Environment and Maritime Affairs embarked on conducting coastal monitoring programs on the beaches in the Turks and Caicos Islands. One of the locations monitored during the program is the main focus of this research. The approximate length and size of the shoreline for this research is about 2.1 miles. My choice of such a location within the Turks and Caicos Islands is that, this location has experienced significant changes in the last ten years. The research will detail the use of aerial images taken in three different years 2000, 2007 and 2012 in order to identify the changes in the coastal features of the location on the island of Providenciales in the Turks and Caicos Islands. The author will achieved this conducting an experiment set up by the author of using photogrammetry techniques and method of collecting geospatial data and managing that data in a GIS work station using ArcGIS. As additional research information, the effects of erosion on coastal properties or any vegetation and marine life damage in the area of Leeward

Point will be conducted as well. However, this is on-going research for the country of the Turks and Caicos Islands to ensure that the coastlines are well protected for the benefit of future generations.

1.5 Aims

The central aim of this research is to:

- Introduce aerial photogrammetry techniques as one of the main tools in collecting geospatial data and to briefly highlight the history of the Turks and Caicos Islands and the reason for selecting the location of monitoring coastal erosion.
- Through the literature review, highlighting the performance of different photogrammetry techniques as well as other techniques used in coastal monitoring.
- Analytically discuss the different techniques within photogrammetry, the causes of coastal erosion and the geomorphological and coastal processes within the environment that affect the coastline.
- Highlight the fundamental skills in using photogrammetry techniques and ArcGIS software as tools to collect data when creating 2D models to analyse and display coastal erosion on beach, vegetation and property.
- Gain new ideas, a better understanding, formulate new strategies and gain background knowledge from the recommendation of different coastal monitoring programmes in order to manage the coastal erosion problems.

1.6 Objectives

A number of objectives were identified to guide the author in effectively achieving the aims of this study. Those objectives are:

- To analytically discuss the use of the different photogrammetry techniques for coastal monitoring.
- To identify and discuss the main causes of coastal erosion of wind patterns, tidal level and land use practices.
- To analytically discuss coastal processes and the coastal geomorphological processes to better understand these aspects and how they relate to and affect coastal erosion.
- To gain skills in using different software development, such as ArcGIS 10.1 and DSAS 4.3, for the collection and management of geospatial data for the purpose of detecting changes in shoreline data.

1.7 Methodology

The author through this methodology will highlight the process by which all of the geospatial information needed to conduct this research is to be carried out. The method used for collecting data would be the aerial photogrammetry approach of obtaining aerial photographs from three different years from the Survey and Mapping Department within the Turks and Caicos Islands government, followed by survey, road network and property data.

The author used a Geographic Information System (GIS) workstation with software ArcGIS 10.1 Geographic Information System (GIS) and Digital Shoreline Analysis System (DSAS) software, to manage, collect data and conduct analysis of the geospatial data.

The author through collecting the spatial data will create a personal geodatabase to manage all data and within that database the author will create three different feature class files of the beach location, a shoreline, vegetation line and shoreline polygon of the study area and from those models, the author will compare the differences in results by conducting further analysis of the shoreline. The data will be collected using a digitize method, by manually

digitizing the data from the aerial photographs, within the ArcGIS and Geographic Information System to create each of the feature class spatial data.

The author will analyse each geospatial data within ArcGIS 10.1, by comparing the data within the attributable. The attributable of the shoreline, vegetation and the shoreline model contains statistical data of each layer. The author will display all measurements in meters, kilometers, square miles and square meters and the standard measurements.

The geospatial data collected will then be displayed in map form for the year of 2000, 2007 and 2012 to better present and highlight the changes in the coastal line of each feature class. The author will use this data to conduct a full analysis of the shoreline data, to better understand, which part of the beach has been affected and to display those analyses within this research to state what has changed between those time periods.

Chapter 2

Literature Review

This chapter is a presentation of the literature review of selected case studies that highlight the advantages of photogrammetry techniques for coastal monitoring and also summaries of abstract reports of work conducted on the location in question. This chapter will also highlight the methods used and the accuracy achieved using photogrammetry techniques, as well as the effectiveness of photogrammetry techniques for coastal monitoring.

There are many different techniques used in coastal monitoring, these include: remote sensing, Global Positioning System (GPS)/ Global Navigational Satellite System (GNSS) surveying and laser scanning that are all photogrammetry and terrestrial based systems, which have been used extensively for planning and managing changes in coastal features. Over the years photogrammetry techniques have been developed and used as a tool for surveying to assist in the analysing and processing of geospatial data. A number of case studies and research papers will support my theory on the use of photogrammetry techniques for coastal monitoring. The photogrammetry technique used in the selected case studies of (Sesli, 2010), (Masle and Mayunga 2001) and (Sesli et al. 2006) have all used and acknowledged the advantages of photogrammetry techniques as a cost effective way of collecting data for monitoring coastal erosion.

The (Sesil, 2010) study, effectively used photogrammetry techniques to map and monitor temporal erosion of the coastal line with digital photogrammetry aerial images from three different years over a large area, in achieving their objective, three aerial images from three different years were acquired from the department of General Command of Mapping.

Below shows a table of Technical specifications of images

Table 2.1

Date	Scale	Type	Obtained Agency & Institute
1935	1/35,000	Panchromatic	General Command of Mapping
1972	1/25,000	Panchromatic	General Command of Mapping
2006	1/35,000	Panchromatic	General Command of Mapping

The authors of this case study presented a case where photogrammetry techniques was used three different aerial images as a data source to detect coastal erosion over a large area of 70.74 ha and 95.32 ha of the Samsun Turkey coastal area. The authors achieved their objective of detecting changes of the coast line between 1935-1972 period of 95.32 ha and also discovered that the coastal lands in 1972-2006 period of 70.74 ha, significant changes occurred during the case study periods. The table above shows all the technical specifications of the images used in the case study. The hardware and software used in this study includes digital photogrammetric workstation (Z/I Imaging) for photogrammetry evaluation, ArcGIS 9.2 and AutoCAD.

The author of this case study has enhanced the ideas of my research by affectively highlighting the role of the photogrammetry process in detecting coastal erosion. The author, however, did not highlight much of the information on coastal processes in the study area, which would be very important to the research. The coastal geomorphology behaviour will consist of wind, tide and land use practices, these will be highlighted in the next case study conducted by (Masle and Mayunga, 2000).

The (Masle and Mayunga, 2000) study used similar methods of photogrammetry techniques to investigate coastal erosion effects of the town Dar Es Salaam, on the East coast of Africa in Tanzania, which was suffering from coastal soil erosion and pollution. The authors

acquired aerial photography taken between 1967 to 1992 of the Dar Es Salaam area to investigate the rate of erosion taking place on the coastline. As the authors in the previous case study, the authors of this case study also used GIS as a geospatial analysis tool to analyse the imagery data to detect the amount of soil erosion from the coastline.

Below shows a table of image Technical specifications

Table 1.2

Date	Scale
1967	1/12,500
1992	1/12,500

These images were taken in two different years, but were of the same scale, but the difference is that, the images taken in 1967 were taken at a (flight height of 800m; f= 152mm) (Masle and Mayunga, 2000), there were a number of ground control points established using classical methods in the year 1967, whereas the aerial image taken in 1992 used a (GPS) ‘’Global Positioning Systems’’ in the fly over. The authors also discuss the causes of coastal erosion, which relate to coastal geomorphology processes and its behaviours.

However, (Masle and Mayunga, 2000) only acquired two images in their study for Photogrammetry and GIS Technologies for Monitoring Coastal Erosion along the Dar Es Salaam Coastline. Their research further used aerial photogrammetry with Geographic Information System (GIS) as a tool to manage geospatial data and analyse aerial imagery data to detect the rate of coastal erosion, the coastal geomorphology behaviours and produce statistical analysis.

The author will further look at the case study of (Sesli et al. 2006). Their research on Monitoring Coastal Land Use Changes Using Digital Photogrammetry, a research conducted on the Black Sea coast of the town Trabzon, Turkey by using photogrammetry techniques to investigate coastal erosion using aerial images for the period 1973 and 2002. These images were obtained from the General Directorate of Forestry Ankara and the District Directorate of Forestry Trabzon. The study area in question was produced for different purposes during the periods of use in (1973 and 2002).

Below shows a table of images Technical specifications

Table 2.3

Date	Scale	Type	Purpose	Grid Photo #	Source
1973	1/23,000	Panchromatic	Revision of Topographical Maps	6986,6978, 6988,6989	District Directorate of Forestry (Trabzon).
2002	1/15,000	Colour Infrared	Forestry	4766,4765, 4764,4763, 4762,4761	General Directorate of Forestry (Ankara)

The imagery acquired, produced different qualities and scales as shown in the technical specifications table above and provided a good indication of coastal erosion of the study area. There were1:1000 scale topographical maps available to reference aerial images, by selecting time independent objects on the ground such as buildings or roads as control points, to establish the relationship between the object and the image space. However, their research

returned results during the 1973 and 2002 periods of 71.8 hectares of filling area and a further 7.5 hectares of coastal erosion through use of Z/I Imaging SSK Digital photogrammetric system work station and Microstation V8 from Bentley for CAD processing. However, the authors of this research did not collect much analysis of the study area, but showed a clear indication of photogrammetry techniques in their research.

The research conducted by (Buckley et al.2001), of the Synergy of GPS, Photogrammetry and Insar for Coastal Zone Monitoring was very different and quite unique in the method used for detecting coastal erosion. The authors used three different methods of Photogrammetry, Global Positioning System (GPS) and Insar techniques to acquire data for monitoring coastline changes. The authors achieved their objective of using these three techniques in which photogrammetry techniques were also used. A different data capturing technique for acquiring imagery data was used, by mounting a Kodak DCS 660 digital camera onto a Thruster microlight. The microlight flows at a height of 2000 feet (600m), the camera was set at ISO200 and f/4 with an exposure time of 1/400s. The camera was equipped with a 28mm Nikkor lens giving the approximate photo scale of 1:20,000. (Buckley et al.2001), were able to achieve 60% fore/aft that provides a ground pixel size of 0.20m and expected height precision of 0.35m (Light,2001). There were 54 ground control marks laid out with coordinates to conduct the aerial fly over. There were some 50 images taken to complete a stereo coverage of Filey Bay. Small format cameras have been used previously for aerial survey (Buckley et al.2001), this is a cost-effective solution for small-area surveys (Buckley et al.2001), However, the authors' findings have not revealed a lot of result analysis on the rate of change in the coastline, but have achieved their objective of comparing aerial photogrammetry with GPS and Insar acquisition techniques.

However, as the author conducting the research on Photogrammetry Techniques for Coastal Monitoring analysis through these four case studies conducted on coastal monitoring using photogrammetry techniques and also analysing result analyses collected by the authors in each case study to grasp a better understanding of the different methods and techniques used for collecting imagery data using photogrammetry techniques. The different applications, workstations and software platforms used in processing the data for analysis purposes in the case studies, prove helpful in this research. Through analysing these four case studies it is very clear that in each case study the authors could have added more depth to their research by revealing more data analysis on the coastal line changes, the authors, have, however, provided much data that helps to advance research in Photogrammetry Techniques For Coastal Monitoring.

Background Research of Study Area

The author has discovered reports revealing work conducted on the study area itself for the research on Photogrammetry Techniques for Coastal Monitoring. The summary report was obtained from the company Erickson Consulting Engineers Inc. (ECE) who conducted the research and engineering work along the East Grace Bay Beach and Pelican Point, Beach, a report of the Providenciales comprehensive beach management plan and Sand Source Investigation for Beach Nourishment of the area.

The author will highlight some of the key elements and objectives in the project that Erickson Consulting Engineers Inc. (ECE) sought to address. Through the report summary gathered and the investigation conducted by the author of this research, it was found that the East Grace Bay Beach at the southeast of the island, Pelican Point, Leeward going through Point at the northeast of the island and other areas along the coastline are experiencing signs of erosion. Using images with aerial photogrammetry techniques, the author further discovered

through the reports made by Erickson Consulting Engineers Inc. (ECE) a diagram revealing a plan showing the entire area of the beach condition and structure.

The diagram shows the layout and plan of the study area for the Providenciales comprehensive beach management plan, on the island of Providenciales, in the Turks and Caicos Islands. The plan further describes the study of coastal processes and causes of the sand deficits along the subject beach, it further shows an analysis of the inventory of the existing coastal structures and beach conditions and the proposed solutions based upon existing and planned projects currently under review by the government's agency Department of Environment and Maritime Affairs (DEMA). However, Erickson Consulting Engineers Inc. (ECE) recommended a beach monitoring program on an annual basis, to determine the project's performance.

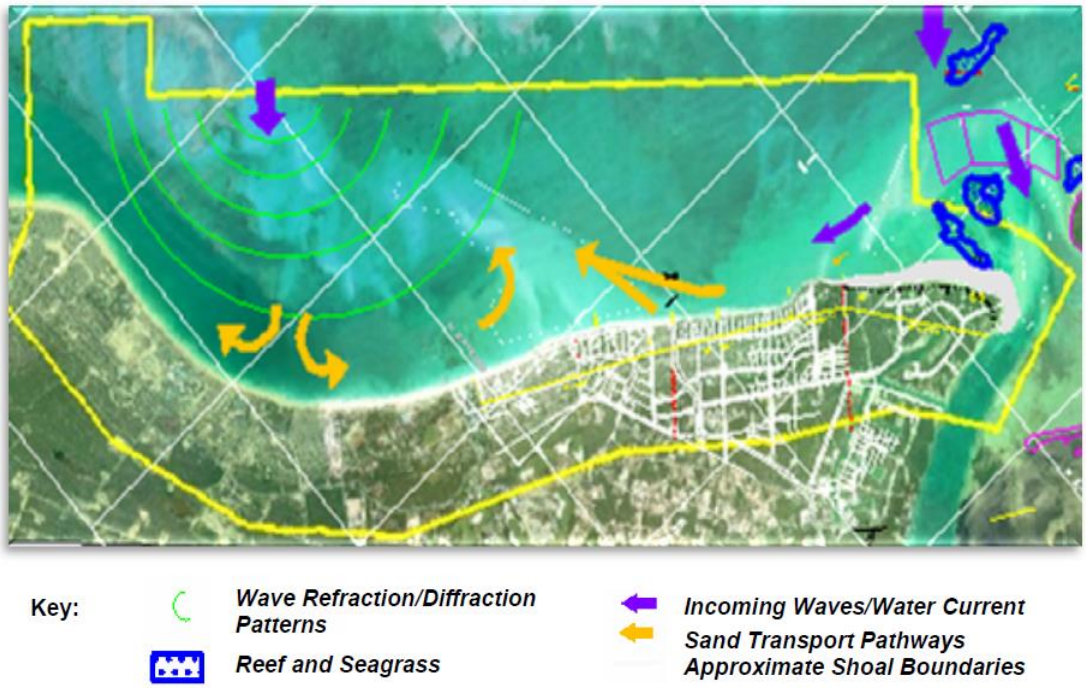

Figure 2.1 Providenciales Comprehensive Beach, Erickson Consulting Engineers Inc. (ECE) 2007

The diagram describes the beach erosion problem and recommendations made by Erickson Consulting Engineers Inc. (ECE) for a restoration project that is required to ameliorate the

beach damage in a consistent, comprehensive manner that will protect owner's beach front property along the shoreline from Emerald Beach to Grace Bay. The author further discovered reports made of the projects that were conducted by Erickson Consulting Engineers Inc. (ECE) of the Pelican Point Beach Restoration and East Grace Bay Beach. Below are some photos that were obtained showing the area before and after of each restoration project.

Figure 2.2, Pelican Point Beach Restoration, Erickson Consulting Engineers Inc. (ECE) (No Year)

The photo in figure 2.2 shows the beach restoration project of the Pelican Point Beach in progress. The beach restoration project took about 70,000 cubic yards to fill the eroded shoreline of the Pelican Point Beach. A tapered groin was constructed to reinforce the beach fill, as well as to help to reduce the long term loss in the beach. However, Erickson Consulting Engineers Inc. (ECE) faced a number of challenges on the Pelican Point Beach restoration project, where they came upon a piece of hard rocky land that caused a divergence

in the direction in sand movements or as called a nodal point. There was strong water currents created at the point, which scours the shoreline immediately adjacent to the shoreline point, which resulted in the beach experiencing great coastal erosion loss. ECE designed a T-head groin consisting of sand placement designed to hold the sandy beach in place, whereas there was no sandy beach historically existing in this area before.

Before

Figure 2.3

After

Figure 2.4

Pelican Point Beach Restoration, Erickson Consulting Engineers Inc. (ECE) (No Year)

8-Months Post Construction

Figure 2.5, Pelican Point Beach Restoration, Erickson Consulting Engineers Inc. (ECE) (No Year)

The photos in figure 2.3 shows the beach at Pelican Point before the restoration project, figure 2.4 shows the result of the finished project and figure 2.5, shows a photo of the Pelican

Point beach eight months after completion of the construction of the T-Head groin and restoration. This research however, ended where the East Grace Bay Beach restoration project begins. The ECE constructed and designed five T-head groins, on a one mile beach nourishment project. The project was designed to be completed in the two phases, with phase one completing in February 2008. The completion of phase one resulted in the placement of beach fills of 170,000 cubic feet of sand yards, along with one
of the five T-head groins being completed. The second phase was estimated to be completed for the year 2011/2012 and this would be on the basis of the monitoring program, which monitors the performance of the East Grace Bay Beach post construction.

The author has disclosed all literature, which relates to this research on Photogrammetry Techniques for Coastal Monitoring, by highlighting four case study research papers that used photogrammetry techniques with digital aerial photography to effectively monitor coastal erosion and effectively achieve analytical results from using geospatial data. The author also discovered through the review of the case studies that one research project has effectively highlighted the coastal processes as it relates to coastal monitoring. The author can now move forward from the background knowledge gained and build on all four of the case studies by using some of the same techniques and enhancing them by finding new techniques in gaining more data that will help with Photogrammetry Techniques for Coastal Monitoring. The author also did background research on the location for this research as well. The location of the beach is in the Leeward Settlement, ECE conducted a number of projects in the area, where there were signs of coastal erosion.

Chapter 3

This chapter highlights and briefly describes the various and most commonly used photogrammetry techniques. Each photogrammetry technique will be described within its respective area of use. The author will seek to highlight the different coastal processes, coastal geographical studies and causes of coastal erosion these are all elements that affect the coastline. Each element in this chapter is very crucial to the effects on coastal erosion and also the management of the effects of coastal erosion.

3.1 Aerial Photogrammetry Monitoring Techniques

There are a number of methods, of obtaining geospatial data using aerial photogrammetry techniques. Photogrammetry, being the art and science of obtaining precise mathematical measurements and three dimensional 3D data from two or more photographs, has different applications that are applied to aerial photogrammetry techniques (Matthews, 2008).The functions of each technique can be further broken down into different categories. These categories and applications have the unique ability to perform, depending on the number of the aerial images used and the size of the location or area being photographed. The aerial photogrammetry approach to directly determine coastal erosion through aerial photography is considered the most practical and cost effective method to conduct an aerial survey. Its method includes the use of large format imageries that take into account ground coordinate information to essentially recreate the geometry of a given location or position on the earth in a virtual environment (Matthews, 2008). The author however, found that aerial photographs can be obtained using an Unmanned Arial Vehicle (UAV). This is new to the field of surveying and is now the latest technology being used in photogrammetry. This method is has also been recently introduced to the geomatics industry of surveying and is considered to be what is termed as close-range aerial photogrammetry. This is where surveyors can obtain and

have at their disposal equipment that has the capability to take aerial photographs of a large area, but at the same time the UAV will fly low to the ground at low altitudes of about 500 to 1000 feet and will take more photographs of the area. As opposed to cases where an aircraft will take two or three photographs at a high altitude capturing a large area. Both methods are cost effective solutions in aerial photogrammetry and will reduce the time it takes to collect geospatial data.

3.2 Terrestrial & Close-range Photogrammetry Monitoring Techniques

The terrestrial and close-range photogrammetry techniques utilize a variety of platforms that are used to obtain geospatial data within photogrammetry. Traditional principles of aerial photogrammetry can also be applied to stereoscopic pictures taken from lower altitudes or from the ground (Matthews, 2008). They further share the same principles of traditional aerial photogrammetry which is applied to stereoscopic pictures, as the same basic principles apply to photographs taken from a camera mounted on a tripod, however terrestrial and suspended from a light sport aircraft flying at low levels taking aerial images, both types of non-traditional photogrammetry are referred to as close-range photogrammetry (CRP) (Matthews, 2008). Terrestrial base techniques also use GNSS and total station to obtain geospatial data for DTMs, but laser scanning has been developed as one of the most unique methods for coastal monitoring. This, however, is very costly and time consuming. Some of the key factors of successfully using long-range laser scanning is the accuracy of the horizontal and vertical positioning of the instrument and at least one other point, any errors in position is magnified in distance (Poulton et al, 2006). The most commonly used methods in terrestrial base techniques are levelling and total station of collecting measurements to interpolate changes in coastal features of the earth's surface, but GNSS and laser scanning having been recently developed, are now adopted in terrestrial coastal monitoring. Terrestrial

ground based and close-range techniques are descriptive terms used to refer to photos taken with an object to camera distance that is 300m which is about 1,000feet or less (Matthews, 2008). Terrestrial monitoring techniques do however, take a longer time to obtain geospatial data over a large area and the duration of the work flow is lengthy as well.

3.3 Coastal Processes

Longshore Drift Diagram

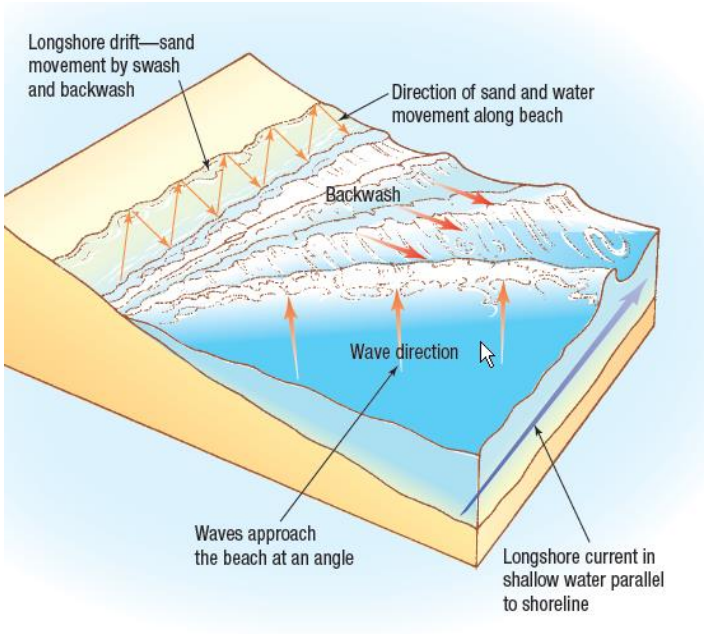

Figure 3.1 Geographical Processes Shaping the Coastal Environment, Cav's Geography Blog (2011)

Coastal processes are the effects of the waves on the shoreline, it interoperates with the effect the natural environment has on the shoreline, which the above diagram figure 3.1 shows an illustration of coastal processes. It depicts the longshore drift, which is the sand movement that is created by the swash and backwash highlighted in red point outward to the ocean away from the shoreline, it further shows the direction of the sand and the water movements along the shoreline with the orange line with arrow pointing up and down as it moves up and down the shoreline, the direction in which the waves move toward the beach. The waves approach

the shoreline at an angle and the longshore current shows water parallel to the shoreline. This diagram highlights the coastal process that takes place on the study area. It is clear from the above diagram that coastal processes do affect the shoreline and that natural environment of the area contributes to coastal erosion simple by the way it works.

3.4 Coastal Geomorphological Processes

The geomorphology studies help to interpolate the features of the earth surface that relates to the underwater geology. Coastal geomorphological behaviour relates to the landform features and the land forming processes essentially shaped by the atmospheric, terrestrial and marine processes that occur in the study area (Whitehouse et al, 2009). The geomorphological analyses study will help to provide a more conceptual picture of the coastal processes and the potential behaviour of the coastal system. The bedrock composition, which affects the potential rate of change in the coastal evolution and results, will be qualitative, rather than quantitative.

3.5 Causes of Coastal Erosion

There are three key elements in coastal erosion that can have short term affects or long term effects on coastal features. Those elements are wind, tide and land use practices. These will play a significant role in how the shoreline is affected by coastal erosion. The general behaviour of the boundary between land and water will experience a shift in position over a period of time as a result of external processes created by nature or by man's activities and behaviour (Masle and Mayunga, 2000). This is a fair and true statement as it relates to coastal management as it is very important in understanding each of the elements of coastal erosion whether by wind, tide or land use practices.

Wind Patterns

The Turks and Caicos Islands is geographical located in the Atlantic Ocean between 21o and 22o N and 71o and 72o 30” W, located in the middle of the Atlantic Ocean, brings a lot of wind activity, thunder storms and hurricanes as stated earlier. Wind helps to develop under water currents, bringing large waves to the shoreline as shown in figure 3.1. The Turks and Caicos Islands consists of six major islands West Caicos, Providenciales, North Caicos, Middle Caicos, East Caicos and South Caicos all of which are located in what is called the Caicos Bank. The islands of Grand Turk and Salt Cay are located in the smaller Turks Bank. This puts the location of the study area into perspective as the islands face the Atlantic Ocean in a northerly direction. The island of Providenciales lies in an east to west direction and the winds normally blow in from an easterly to westerly direction with forces of up to 20 to 80 mph from the Atlantic Ocean. Also located in a tropical high pressure zone that is prone to experience storms and hurricanes all year around, these weather patterns regularly bring winds that blow mainly from these directions and contribute to the geomorphological processes of the sea and coastal lines that create waves that can reach up to between 10 to 30 feet in height depending on whether the day is normal or there is a storm.

Tidal Levels

Tide level data is very critical in understanding the effects on coastal erosion in conducting this study. It was very difficult to obtain relevant date pertaining to tidal effect on the coastlines as it could have been useful and very helpful to such information on hand for the years 2000, 2007 and 2012. It would allow for a better understanding of tidal levels at the time of taking the aerial images and what if any affect it has on the coastline. The data can possibly verify whether there was a high tide when the aerial images were taken or if the images were taken at low tide and what affect if any would have been made on the coastline.

However, it is evident, that when there is a high tide there is a greater possibility that there will be effects of coastal erosion (Masele and Mayunga, 2000). The author understands that such information will help to prove the hypothesis in terms of understanding the effect of the tide on the shoreline around the time that the aerial image was taken.

Land Use Practices

The Turks and Caicos Islands, like other countries around the world heavily rely on the tourism industry as a form of their income. Surrounded by turquoise water, the beaches are also targets for on-going infrastructural development through the building of hotels and luxury homes along the shoreline. This type of practise will have a significant impact on the shoreline. Developments must be monitored closely to minimize the devastating effects of coastal erosion, as in the case of the study area, which has had shown signs of some beach erosion already. The ever increasing value of beach front property continues to grow every year as investors and local residents seek to enhance and secure their millions dollar investment in infrastructure a piece of beach front paradise in the Turks and Caicos Islands this makes the effects and the potential to have even greater coastal erosion on the beaches in TCI a growing source of concern for the TCI Government, to protect beaches from this looming environmental problem.

3.6 Software & Data Management

The author used ArcGIS 10.2 and DASA 4.3 software to effectively store and manage all geospatial data of the study area. The geospatial data and imagery were uploaded into ArcGIS where it was analysed for coastal erosion. ArcGIS is software that was developed from the 1980s by the company Esri for the purpose of managing geographic data or metadata in a geographic system the data that is managed in GIS called metadata, is data about data, which means data that contains information about data that is managed within a

Geographic Information System (GIS). A Geographic Information System (GIS) is a tool that integrates hardware, software and spatial data by capturing information, analysing information and displaying information in different forms and formats of geographically referenced information. It further allows users to understand geospatial data by visualizing, questioning, analysing and interpreting data to reveal the relationship, patterns and trends in the form of a map display, global positioning, reposts and charting. It is also a helpful tool in answering questions and problem solving because data can be handled in a way that it can quickly be understood and conveniently shared. This is a brief overview of explaining why ArcGIS and Geographic Information System (GIS) are effective tools and means of managing, storing and analysing data for the research of Photogrammetry Techniques for Coastal Monitoring.

Digital Shoreline Analysis System (DSAS) software was also used to monitor the rate of change of the shoreline. This software was developed in the early 1990's and is still undergoing continuous and albeit episodic refinement. The first version 1.0 was developed in 1992 and was written in C and Awk programming languages for users that used MapGrafix and Arcinfor geographic Information System programmes, however, the second version 2.0 was developed and written for ArcView 3.0 programme, followed by DSAS 3.0 which was written in VB. Net using Arc Objects and Object library for ArcGIS 9, but the author acquired the latest version DSAS 4.3 that is written for the last version of ArcGIS 10.2. The DSAS software is not standalone software you will already realize by now, but will require to be attached to an ArcGIS programme and computer software that calculates coastal changes, it can also help with positional changes to boundaries over timely period. This means, computerised calculations of line feature class data inserted into DSAS will generate statics analysis of the shoreline data. The author will have to achieve the objective by using Digital Shoreline Analysis System (DSAS) software in ArcGIS 10.2.

Chapter 4

The coastal study area is approximately 2.014 miles in length. Located in the Leeward Settlement, the shore line begins from the Leeward Going through Cut and finishes at Thomas Stubbs Point, which is to the east of Grace Bay Beach. The subject area has suffered signs of coastal erosion and is still undergoing changes and also underwent a restoration project by ECE. Recommendations were made for a monitoring program to be carried out on the beach on an on-going basis to annually to oversee the performance of the restoration project.

The author, however, acquired digital aerial photography from the years 2000, 2007 and 2012 to be used to further investigate the effects of coastal erosion. The data collected from the aerial images are taken from the author's geospatial data collection, with the use of ArcGIS and Digital Shoreline Analysis System to detect the rate of change in the shore line from each image. The author has also considered the spatial errors that relate to manually collecting geospatial data from digital photography and has accounted for those errors. In addition, geospatial data was collected and analysed using the used digital automated program, Digital Shoreline Analysis System (DASA) 4.3 software to compare the result taken manually using ArcGIS software.

The Digital Shoreline Analysis System (DASA) 4.3 program is not standalone software, this is software that is created and is required to be attached to ArcGIS 10.2 for the purpose of detecting and collecting geospatial data analyses on the rate of change in shore lines and is used in gathering statical analysis in decrementing the rate of change.

The digital images acquired by the author, were obtained from the Survey and Mapping Department, Turks and Caicos Islands Government and were already geo referenced to its

geographic location according to the islands' location, Providenciales Turks and Caicos Islands (B.W.I). The author also acquired cadastral survey data; consisting of the parcel, blocks, survey point, building and road layout of the study area.

The technical specification digital imagery of the spatial reference system is displayed in the table below.

Table 4.1

Providenciales, Turks & Caicos Islands B.W.I.			
Year	2000	2007	2012
Grid Photo	790_2410, 790_2415	790-2410, 790_2415	N/A
Spatial Reference	North American 1927 UTM Zone 18N		
Linear Unit	Meter (1.000000)		
Angular Unit	Degree (0.0174532925199433)		
false easting	50,000		
false northing	0		
Central Meridian	-75		
Scale Factor	0.9996		

The parcel, block, building and survey point spatial data of the study area were acquired to conduct additional analysis so as to understand how many properties were affected by the problem of coastal erosion. ArcGIS was used in creating a personal geodatabase to manage the data for the research. The author collected shoreline data, that was manually digitize from the digital imagery within ArcGIS and also automated shoreline data detected using Digital Shoreline Analysis System (DASA) with predefine shorelines to detect the rate of changes as

stated earlier in this research. All data was collected and manage in ArcGIS, 4.1. Data collection will be briefly described and displayed in the spatial data that was collected from each digital image.

4.1 Data Collection

The 2000, 2007 2012 imagery with spatial data of parcel, blocks, building and shore line data are displayed in the diagrams located in the appendix A, B and C. The shoreline imagery was collected by the author for analysis and the cadastral data was obtained by the author from the Survey and Mapping Department as mentioned earlier in this chapter. The shoreline data was collected from three different aerial images and was laid over the aerial imagery to analyse the imagery for coast line erosion. The author also created three maps of the study area that shows the layout of the beach beginning from the Leeward Going Through Cut and ending at the Thomas Stubbs Point, this area has been showing effects of coastal erosion, and it was the subject of a restoration project as mentioned in the literature review chapter of summary reports made by Erickson Consulting Engineers Inc. (ECE).

Study area Providenciales, Turks and Caicos Islands Cadastral Data

Table 4.2

Base Layers	2000	2007	2012
Blocks	✓	✓	✓
Parcel	✓	✓	✓
Building	✓	✓	✓
Shore Line	✓	✓	✓
Vegetation Line	✓	✓	✓
Beach Profile Shape	✓	✓	✓

Imagery Data	✓	✓	✓

The table above describes the base layer for each year used by the author with the collected data of shoreline, vegetation line and beach profile shape polygon feature. The author also created maps that are displayed in appendixes A, B and C showing all the data and labellings. The author used this data to conduct the analysis by analysing the data from each year respectively.

4.2 Data Results

The author through analysing the 2000, 2007 and 2012 imagery found a difference in shore and vegetation lines, it also shows that a number of properties were effected by coastal erosion in the 2000 and even up to 2007 where the beach in some areas has grown in size, but in 2012 the shore line grew even larger along the coast line of the study area. The table below will show the difference in the beach profile taken by the author in a polygon shape feature.

The statistical analysis of each shape polygon from 2000, 2007 and 2012 as shown in the above table clearly shows a difference in each respectively. The statistical data was acquired from the attribute table of each feature class layer and was inserted into excel, it was compared using square meters, which showed 41972.2 m^2 difference between 2000 and 2007, a difference of 50115.92 m2 between 2007 and 2012 and in 2000 and 2012 showed a difference of 92088.12.

The author further went on to compare, the 2000, 2007 and 2012 shoreline layer in terms of their lengths along the coast of the study area. The shoreline data was collected using the digitize method from the aerial images of the coast line near the water mark, This method of manually digitizing, was applied to the collection of the vegetation line data of 2000, 2007

and 2012, this was also compared between items of their lengths, however the author has kept in mind the geospatial errors contained within the data using this method. The shore line and vegetation line data is presented in the table below.

Further analysis was conducted of the study area to better understand which beach front property and other nearby properties were affected by the erosion problem. Beach front properties are high value investment assets to many individuals and countries, including the Turks and Caicos Islands. For this reason the properties that are affected my coastal erosion will cause the cost of these properties to go down. Manually digitized data analysis collected from digital Images.

Shoreline Shape Polygon

Table 4.3

Table showing Shoreline Shape Polygon			
Year	Shape	m^2	Sq. Miles
2000	Polygon	41250.83	0.02
2007	Polygon	83223.03	0.03
2012	Polygon	133338.95	0.05

The result in table 4.3 is taken from the shoreline shape polygon created by the author to better understand how much the beach has grown in size from 2000 to 2007 and 2012, which shows a clear indication of change. The shoreline shape polygon will be displayed on a map to highlight the change in the most critical areas by showing which areas have grown and which areas show changes in beach lost.

Table show shoreline Feature

Table 4.4

Table show shoreline Feature			
Year	Shape	Meters	Shoreline (km)
2000	Polyline ZM	3092.15	3.09
2007	Polyline ZM	3138.30	3.13
2012	Polyline ZM	3368.68	3.37

The result in table 4.4 presents the shoreline feature of the study area for the year 2000, 2007 and 2012. The table shows the difference in the shoreline lengths and it clearly shows some differences over the time periods. The author has also displayed the information in the table in a form of a map to better outline the differences in the shoreline. All maps will be displayed in the analysis, highlighting the critical areas of the shoreline.

Table Showing Vegetation Line Feature

Table 4.5

Table Showing Vegetation Line Feature			
Year	Shape	Meters	Shoreline (km)
2000	Polyline ZM	3033.43	3.03
2007	Polyline ZM	3044.81	3.04
2012	Polyline ZM	2953.37	2.95

This table shows the difference in the vegetation. This data was also digitized from each aerial image to identify the changes in the vegetation line. However, again the author will give an account for the error that will occur when using such techniques when obtaining

geospatial data from aerial images. The author will also display this information in map form to show critical areas of change.

Digital Shoreline Detect System (DSAS)

Shoreline Statistical Data Results

Table 4.6

Year	SCE	NSM	EPR	ECI	LRR	LSE	WLR	WSE	LMS
2000	4.2	4.2	0.35	0.24	0.34	0.59	0.34	0.29	0.35
2007	6.65	6.65	0.55	0.24	0.55	0.41	0.55	0.2	0.55
2012	2.41	2.41	0.2	0.24	0.2	0.35	0.2	0.17	0.19

The above table 4.6 shows statistical analysis from the DSAS software. The table shows Shoreline Change Envelope (SCE), Net shoreline Movement (NSM), End Point Rate (EPR), Confidence of End Point Rate (ECI), Linear Regression Rate (LRR), Standard Error of Linear Regression (LSE), Weighted Linear Regression Rate (WLR), Standard Error of Weighted Linear Regression (WSE) and Least Median of Squares (LMS). The author used DSAS to calculate the change for each element, but only the LRR and LSE of insert, because LRR Linear regression rate will show how difference the shoreline was moving between the each year and LSE standard error of linear clarifies the errors that were detected by DSAS in calculating the shoreline rates. This section is highlighted in red in the table, but further analysis will of the result in the analysis section.

4.3 Data Analysis

Table showing Shoreline Shape Polygon

Table 4.7

Difference in Changes		
Square Miles		
2000	2007	0.02
2000	2012	0.04
2007	2012	0.02

The author found it very critical to analyse each table of results that was collected from the experiment conducted for the research. The table above shows a clear indication of movement in the beach from the data collected. The year 2000 and 2007 showed a difference of 0.02 sq. miles, whereas between 2000 and 2012 showed a difference of 0.04 sq. miles and 2007 and 2012 showed a similar difference of 0.02 sq. miles as with 2000 and 2007. It is very clear that there was movement between each of the years, with 2000 and 2012 showing the largest difference of 0.04 sq. miles.

Table show shoreline Feature

Table 4.8

Difference in Changes		
Kilometers		
2000	2007	0.04
2000	2012	0.28

2007	2012	0.24

The author further compared the difference in the shoreline feature using the results from the table 4.8. The results reveal that from 2000 to 2007 a difference in shoreline length of 0.04 km, whereas between the years 2000 to 2012 there was a difference of 0.28 km and from 2007 to 2012 there was difference of 0.24 km. The author went on to compare the differences from 2000 to 2012 of 0.28 km and 2007 to 2012 of 0.24 km with a difference of about 0.04 km in the shoreline feature.

Table Showing Vegetation Line Feature

Table 4.9

Difference in Changes		
kilometers		
2000	2007	0.01
2000	2012	0.08
2007	2012	0.09

The results shown in table 4.9, is of the vegetation line feature, where there was very little difference in the vegetation line from 2000 to 2012 of 0.08 km and 2007 to 2012 of 0.09 km, with a difference of 0.01 km, but from 2000 to 2007 of 0.01 compare with the other results given showed and difference of 0.07 km, when with 2000 to 2012 and 0.08 km when compare with 2007 to 2012.

Digital Shoreline Detect System (DSAS)

Shoreline Statistical Data Results

Table 4.10

Linear Regression Rate		
Differences		
2000	2007	0.21
2000	2012	0.14
2007	2012	0.35

The author further analysis the results shown in table 4.10, which highlights the results, obtain form of the Digital Shoreline Detect System (DSAS). These are of the Linear Regression Rate (LRR), shows a difference of regression in the shoreline of 2000 to 2007 of 0.21, from 2000 to 2012 a difference of 0.14 and 2007 to 2012 there was difference of 0.35. However, from the analysis conduct, 2007 to 2012 showed the largest difference of 0.35 in linear regression rate. To further compare this data, 2000 to 2007 of 0.21 and 2000 to 2012 of 0.14, there is a difference of 0.07, where 2000 to2012 of 0.14 and 2007 to 2012 of 0.35 showed a difference of 0.21 of linear regression. However, the author seen some difference in the linear regression rate results.

Standard Error of Linear Regression

Table 4.11

Standard Error of Linear Regression		
Year	LRR	LSE

2000	0.34	0.59
2007	0.55	0.41
2012	0.2	0.35

The author further displayed the standard error of linear regression in table 4.11. The standard errors where obtained from the DSAS, when the linear regression rate where calculated. It shows a standard error of the results in 2000 of 0.59, whereas, 2007 showed LES of 0.41 and in the 2012 the LSE was 0.35. However, the author has mentioned throughout this research that there will be errors when collecting geospatial data.

Figure 4.1 2000 Imagery

Figure 4.2 2007 Imagery

Figure 4.3 2012 Imagery

The author through analysing the aerial images has discovered that one home was lost due to the coastal erosion problem along east Grace Bay Beach. The fig 4.1, 4.2 and 4.3 shows the house on the block and parcel number of 60904/254, 255, where there is clearly displayed in the aerial image of 2000 and in 2007 the home was deranged because of the coastal erosion. The author also analysed through the aerial photographs that most of the properties along the shoreline including the property in the displayed aerial image, are littoral boundary. Littoral is where the property boundary alias on the seashore and inland water. Littoral derived from the riparian, is where the owner property is on the bank of a watercourse and lake, where the boundary is located at the water side a lake.

Chapter 5

5.1 Conclusions

The author through this dissertation successfully demonstrated the ability of photogrammetry techniques for coastal monitoring, by conducting an experiment set by the author of collecting geospatial data using ArcGIS and DSAS in work station in creating 2D digital terrain models from aerial images from 2000, 2007 and 2012 of the shoreline of the study area in question. The author also, disclosed information from different case studies conducted on coastal erosion using photogrammetry techniques and also background review of the location ad the impact of coastal erosion of the shoreline of the study area. In this respect a GIS provides an effective tool to allow geospatial data from different sources to be stored, managed and transformed into the same reference system to be accessed when required (Masele at el 2000).

However, the author through conducting the experiments concluded that there were some differences in the shoreline of the geospatial data taken from the aerial images 2000, 2007 and 2012. The author also concluded that photogrammetry is still one of the most cost effective ways of collecting geospatial data and effectively used ArcGIS or GIS as a management tool of geospatial data. Photogrammetry has a great significance in terms of planning and managing activities (Sesli, 2010). It is important to plan and manage such activity, to ensure the maximum achievement of the experiment.

The demonstration of the ability of photogrammetry techniques in collecting geospatial data to create DTM in 2D or 3D for coastal monitoring and has showed that photogrammetry is an easy and cost effective way of conducting such experiments and research using photogrammetry with large aerial images in collecting geospatial data of a larger area. It is

perceived that using large scale aerial photos would enable the manufacture of large scale maps of high resolution satellite images will be preferred in other studies to be carried out with the purpose of following the temporal changes on the coastal line and coastal area (Sesli, 2012).

Furthermore, the author revealed the different behaviours that cause coastal erosion and gain a much better understanding of the different elements that causes coastal erosion. The author further concluded that the coastal processes or coastal geomorphological processes are indeed an important part of coastal management. The geomorphological elements of the beach, Seacliff and saltmarsh, which forms the basic building blocks of the coastal system, will also be constrained at the larger scale by the geological control (Whitehouse at el. 2009)

Therefore, in conclusion the author would have benefited from having more information about the coastal geomorphological study conducted on the study area. It would have been ever more beneficial to the author, if old aerial imagery were obtained of the study area, this would have given a more detailed analysis of the shoreline and the changes that took place over a longer period of time.

5.2 Recommendations

This section seeks to improve the standard of photogrammetry for coastal monitoring in collecting more geospatial data to conduct important analysis.

The author would strongly recommend that for future reference when conducting such a research one should ensure that all information is obtained to conduct the research of aerial images and that the geospatial data collected to create DTM collected from the aerial image are 2D and 3D. This will further improve the understanding of the effects lost of the shoreline using 3D DTMs in creating cross section models and collecting data of the beach profile.

Photogrammetry is a convenient, cost effective and easy method of conducting coastal monitoring programs due to that fact the lack of time and funds invested in this research of photogrammetry techniques for coastal monitoring, there could be further improvement by comparing photogrammetry with other terrestrial and close-range photogrammetry techniques.

Coastal processes and coastal geomorphological change are important elements in understanding what is happening with the shoreline and without these key elements it would be very difficult to conduct and carry out coastal monitoring program. However, this research would have benefited from having coastal geomorphological studies conduct on the study area, to better understand coastal erosion problem. The author would recommend that these elements be looked at closely in conducting any research for coastal monitoring, as other research and to a extent of conducting this research did not have much information on coastal processes and coastal geomorphological changes.

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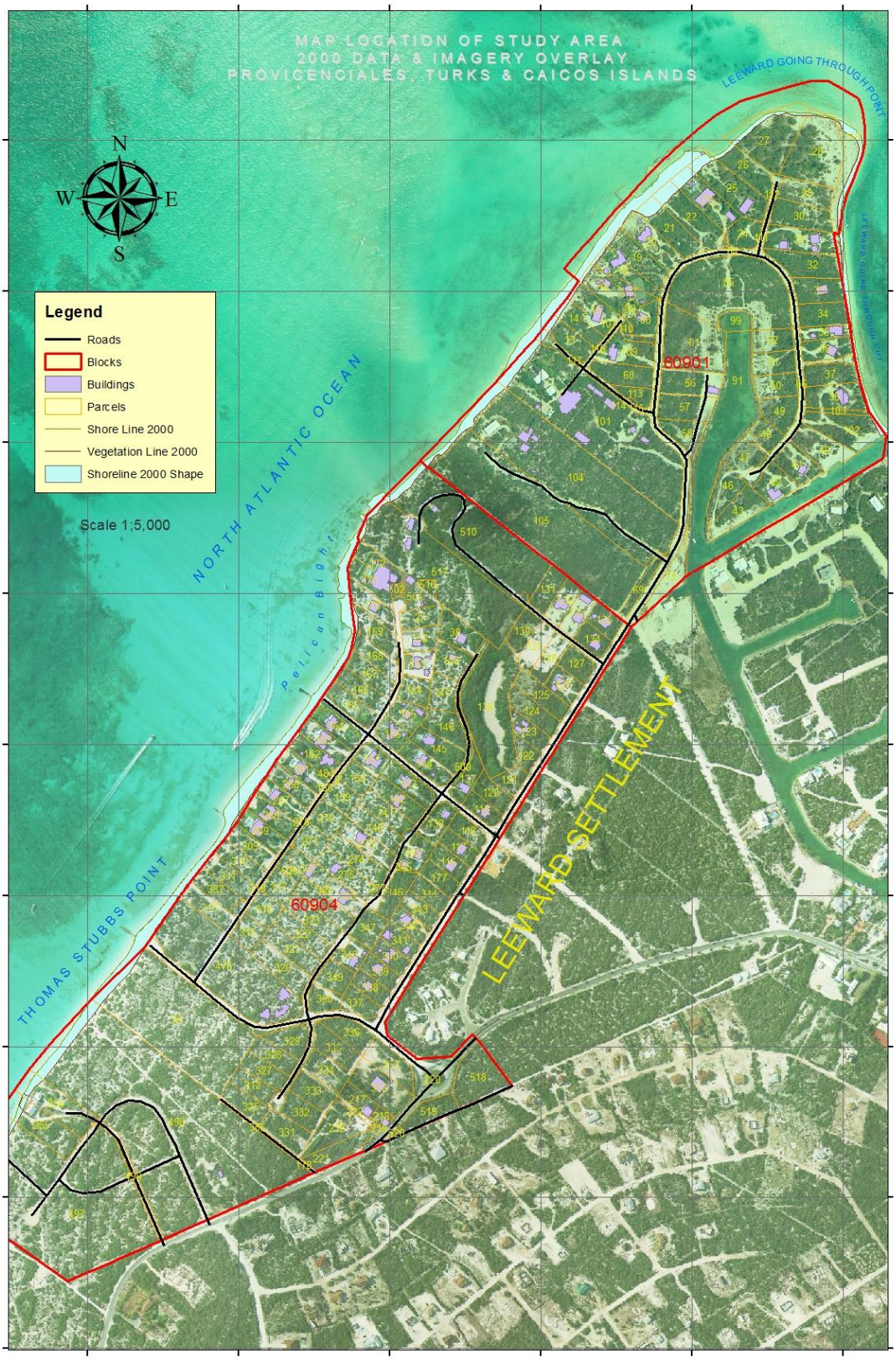
Appendix

Appendix (A)

Displays a layout, of 2000 imagery with geospatial data of the study area



Appendix (B)

Displays a layout, of 2007 imagery with geospatial data of the study area

Appendix (C)

Displays a layout, of 2012 imagery with geospatial data of the study area