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Assessment of Natural and Anthropogenic Environmental Effects in the Costal Areas between Abu Dhabi and Dubai – Application of Remote Sensing

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Assessment of natural and anthropogenic environmental effects in the costal areas between Abu Dhabi and Dubai – Application of Remote Sensing

By

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DEDICATION

In the Name of Allah, Most Gracious, Most Merciful

It is my pleasure to present my thesis as a gift to **my father** and **mother** in fulfillment of their long-awaited dream.

I hope that my research will be a strong incentive for me to serve my country, the Emirates, and to do my best to build up and develop this generous homeland.

Sultan M. Karrni,
2007

Acknowledgments

I would like to express my deep gratitude to His Royal Highness, President of United Arab Emirates **Sheikh Khalifa Bin Zayed Bin Sultan Al Nahyan**, for making available, to all U.A.E nationals, this exclusive an excellent opportunity to undertake a master degree in Environmental science. His personal interest in educating and developing his people has earned him the love that he truly deserves.

I want to thank the contributions of my supervisors: Professor Fadhil N. Sadooni, Dr. Salem Essa from the Geology Department, UAE University and Dr. Hussein Harahsheh, Global Scan, Dubai and to the memory of the late Dr. Hazem Katyia, the ex-coordinator of the Environmental Science program for his continuous care and consideration.

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Abstract

The present work represents an attempt to detect changes induced by both natural and anthropogenic activities to the coastal area extending between the cities of Abu Dhabi and Dubai, United Arab Emirates. This area is dominated by islands, bars, tidal channels and embayment regimes and flanked by coastal sabkhas that give way to the great sand dunes, which represent an extension of the Empty Quarter desert.

The area is also characterized by the existence of many aquatic systems such as coral reefs and the oolitic shoals around Abu Dhabi city. It was the site of many human activities in the pre-oil era, such as pearl diving.

During the last three decades, the study area has witnessed deep and widespread changes as part of the urbanization process that has impacted the whole United Arab Emirates. Examples of such activities include coastal modification, large scale construction, oil well drilling and many other similar activities, some of which are really big in scale. Such activities have affected significantly the components of the natural ecosystems as well as the physical and chemical properties of the area, including its geomorphology and topography.

In the study, some of these changes were traced and detected using remote sensing and direct visual observation, such as ground truthing where ever possible. The study focused on visual analysis mainly due to the scarcity of old data from the pre-oil era. However, wherever possible a quantitative approach was attempted when data was available.

Major changes in the studied area are in the form of large scale urbanization in residential, commercial and industrial development of both continental and aquatic environments. Some of these are of a drastic scale and have affected significantly the pristine environment.

These changes were detected and contrasted from the available images and then documented using ground photography. In some cases, vector layers were extracted and superimposed to give an idea about the extent of such changes.

Such studies are essential to document the baseline environmental and man-made environmental components and to trace changes over time. These studies should be part of the future coastal management in the United Arab Emirates.

جامعة الإمارات العربية المتحدة
عمادة الدراسات العليا
برنامج ماجستير علوم البيئة

تقييم التأثيرات البيئية الطبيعية والبشرية في المناطق الساحلية الممتدة بين أبوظبي ودبي باستعمال تقنية الاستشعار عن بعد.

رسالة مقدمة من الطالب

سلطان محمد عبد الرحمن أحمد كراني

رسالة مقدمة إلى
جامعة الإمارات العربية المتحدة
استكمالا لمتطلبات الحصول على درجة الماجستير في علوم البيئة

2007

CHAPTHER ONE

INTRODUCTION

1.1 Background

The United Arab Emirates (U.A.E) is considered one of the fastest developing countries in the Middle East, which has recorded good developments in the field of urban and industrial development during the last 30 years. His Highness Sheikh Zayed bin Sultan Al-Nahyan (God keep his soul in peace) and His Highness Sheikh Khalifa bin Zayed Al-Nahyan (President of U.A.E) have always placed their interest into the development of all the urban and industrial as well as other related fields giving the U.A.E an excellent development position between the other modern countries. The U.A.E has rapidly changed in a relatively short time. The main development activities that have happened are generally in the western coastal zone of the country. This is due to the location of the two main cities (Emirates) in the U.A.E; Abu Dhabi – the capital, and Dubai –the commercial city. Each emirate has its specific environmental and geomorphological properties. For example, Abu Dhabi is set on shallow sandy islands located between quiet tidal channels. On the other hand, Dubai is mostly plain sandy area with relatively low sand dunes.

The two cities and its concessions areas face very obvious and fast development and changes during the 1990s. The coastal area has a political, commercial and environmental importance. Therefore, it is necessary to study the area in more detail and identify exactly the changes that happened and the locations of the changes during the 1990s.

It has been noticed that it is difficult to study the whole area by field observation techniques only, because the study area is very large and many places are difficult to reach or visit. Furthermore, it is not practical to study the fast changes without using a tool to help us in that study. To this end, the idea of using satellite images available in the U.A.E University archive comes up to enable us in better understanding all the major changes that have happened in the areas mentioned. It is also noted that such a study is easier to conduct and is less cost to execute.

1.2 Objectives

The main objectiv[illegible] s[illegible]y [illegible]s [illegible] s [illegible] changes along the coastline between cities of Abu Dhabi and Dubai during the period between (1993-2000) using "Landsat" satellite images with relatively high spatial resolution (30 meters pixel size). The author aims to evaluate the use of satellite data in detecting natural or human-induced changes in the coastal zone area between the emirates of Abu Dhabi and Dubai (as shown in figure 1-1). The study should add more value on understanding the area of interest and may help in future researches studies. This study will focus on the benefit of using different techniques in satellite imagery processing to identify and detect the changes which may occur in the coastal zone area, specially in dry climates like the climate of the U.A.E.

The importance of the coastal zone between Abu Dhabi and Dubai has led the author to use different digital image processes to ensure that several methods have been used to obtain better results and more accurate detection of the changed locations. Furthermore, the study will try to assess the causes of the changes that have happened, either naturally or through human activity. Finally, the study should give the reader an idea of the positive or negative value of the changes detected in the coastal environment and predict the future environmental issues which may be related or expected.

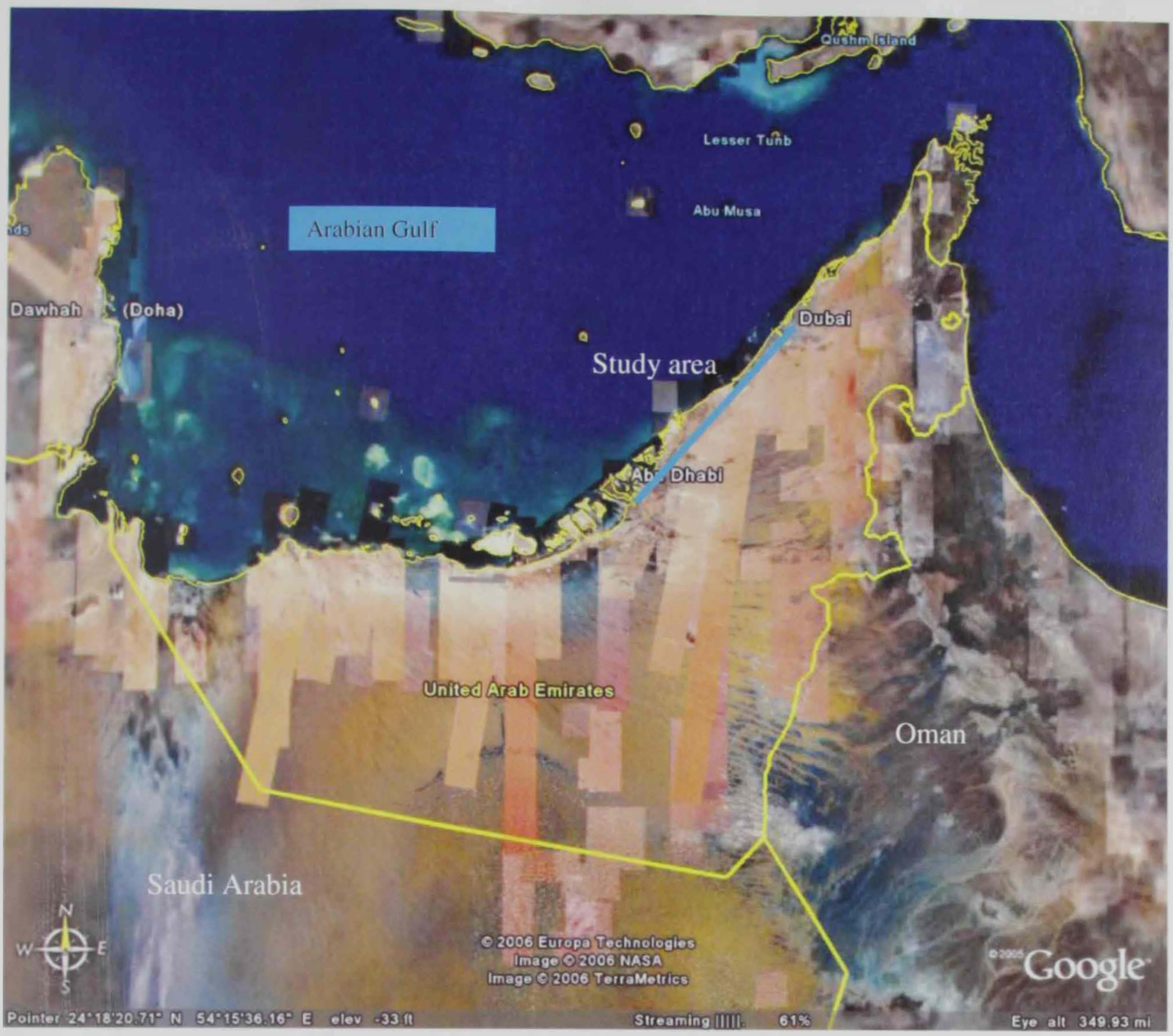


Figure 1-1. A Map of the United Arab Emirates showing the study area. Longitude = 54.37 degree, 55.37 degree.Latitude = 24.21 degree, 25.32 degree

1.3 Approach

As there are only limited studies conducted for various purposes on the study area as a whole or in the location within the study area identified, the author will review the literature and data from these studies. Then remote sensing data from the U.A.E University archive was used.

Two Landsat satellite images have been used mainly;

1- Landsat-5 image which has been captured in 1993

2- Landsat-7 image which has been captured in 2000

The images are georeferenced to the correct coordinate system, so that the comparison will be accurate. The E.R Mapper software is used to apply different methods of digital image processing.

The major changes were be verified by site visit to the locations and photographs were be used to record field findings. All the results were recorded and discussed. Conclusions were drawn from this study and then recommendations will be listed for future studies.

1.4 Scope of work

The scope of the study was limited to detect and delineate the major changes that have happened in the coastal zone between the cities of Abu Dhabi and Dubai during the period between 1993-2000, using available satellite imagery from the U.A.E University archive. This enabled the accurate identification of the major changes that have happened in that seven-year period. Also, the study used other digital image processing methods to identify/confirm the changes which may occur in the shallow zone and "sabkha" areas using established methods. The study focused mainly on the study of shoreline changes and urban/industrial development.

1.5 Thesis structure

This Thesis is presented in six chapters: -

1- Chapter one defines the purpose, objectives approach, and scope of work of this thesis.

2- Chapter two introduces the characteristics of the U.A.E in general and specifically the study area. The different aspects of the area have been covered such as history, climate, geomorphology, and human activities.

3- Chapter three presents the methodology of the thesis using Landsat image data. It shows the processing steps of this case study and how the images have been processed and interpreted.

4- Chapter four is the results from the digital image processing technique. It shows all the possible changes which have been found in the study area with the different processing methods.

5- Chapter five presents the classification method and the major results

6- Chapter six lists the summary and the main recommendations.

CHAPTER TWO

GENERAL SETTINGS

2.1 Introduction

The United Arab Emirates (U.A.E) covers an area of about 77700 km^2 with a total population of around 3.44 million in 2002. The U.A.E is located along the south-eastern side of the Arabian Peninsula, between 22^O50 and 26^O N. and between 51^O and 56^O25 E. Qatar, Saudi Arabia, and Oman are the countries sharing borders with the U.A.E, refer to figure 1-1. The total length of the coastline of the U.A.E is 700 kilometres - 600 km's along the Arabian Gulf and 100 km's along the Gulf of Oman (U.A.E year book, 2003).

Abu Dhabi:

Abu Dhabi is the capital Emirate of the "seven federation" United Arab Emirates. It is the largest of the Emirates in terms of area with about 400 kilometers of the total coastline. Abu Dhabi Island is surrounded by a number of large and important islands near the coast and near the offshore oil fields. (Barrault, 2000).

The area of the Abu Dhabi Emirate is 67,340 square kilometres which constitutes 86% of the total area of United Arab Emirates. Abu Dhabi city is an island, which is 8 kilometres wide and 14.5 kilometres long. More than 90% of the U.A.E's oil reserves are in Abu Dhabi. Abu Dhabi International Airport is located on the main land 35 kilometres away from Abu Dhabi City. Mina (Port) Zayed is the main shipping port of Abu Dhabi, and it is located in the north side of Abu Dhabi Island (U.A.E year book, 2003).

Dubai:

Dubai is considered as a great world business center between the East and the West. Dubai city is about 120 kilometers away in the north-east direction of Abu Dhabi city. Because Dubai is in one of the richest areas in the world, the capital of the Internet and economy, and one of the most pleasant places to liv [illegible] s for their regional offices in the Middle East.

The population of Dubai was 610,000 in 1993 and expected to rise to 2.1 million by 2010. In the past, Dubai depended on oil to build its infrastructure. Since oil reserves are depleting, Dubai has focused to base its economy on trade, transport, and tourism activity (Barrault, 2000).

The shoreline of the Dubai Emirate extends about 72 kilometres along the Arabian Gulf. Its area is of 3,885 square kilometres (5% of the total area of U.A.E). Dubai is separated by a narrow creek of 10 kilometres length. The southern section is called Bur Dubai, and the other section is called Deira. These two sections are connected by two main bridges, 'Al Maktoum' and 'Al Garhoud', and the main tunnel called 'Al Shindagha'. The largest industrial Free-Trade Zone is located in Jebel Ali which is 30 kilometres away from Dubai city. Dubai main ports are Mina (Port) Rashid, Hamria Terminal, and Jebel Ali which is the largest man made port in the world (U.A.E year book, 2003).

2.2 Historical Background

The U.A.E is located in the eastern side of Arabian Peninsula. In the early maps of the Greek geographer, Eratosthenes, who lived in the third century BC, it was mentioned that Arabia lies in the center of the Earth. The Strait of Hormuz is evident, but the Gulf coastline of the U.A.E. runs east west as a straight line as shown in figure 2-1, 2-2.

Figure 2-1: Early map (1680) of Arabia showing the gradual improvement in understanding the configuration of land and water boundaries (Atlas of the UAE, 1993)

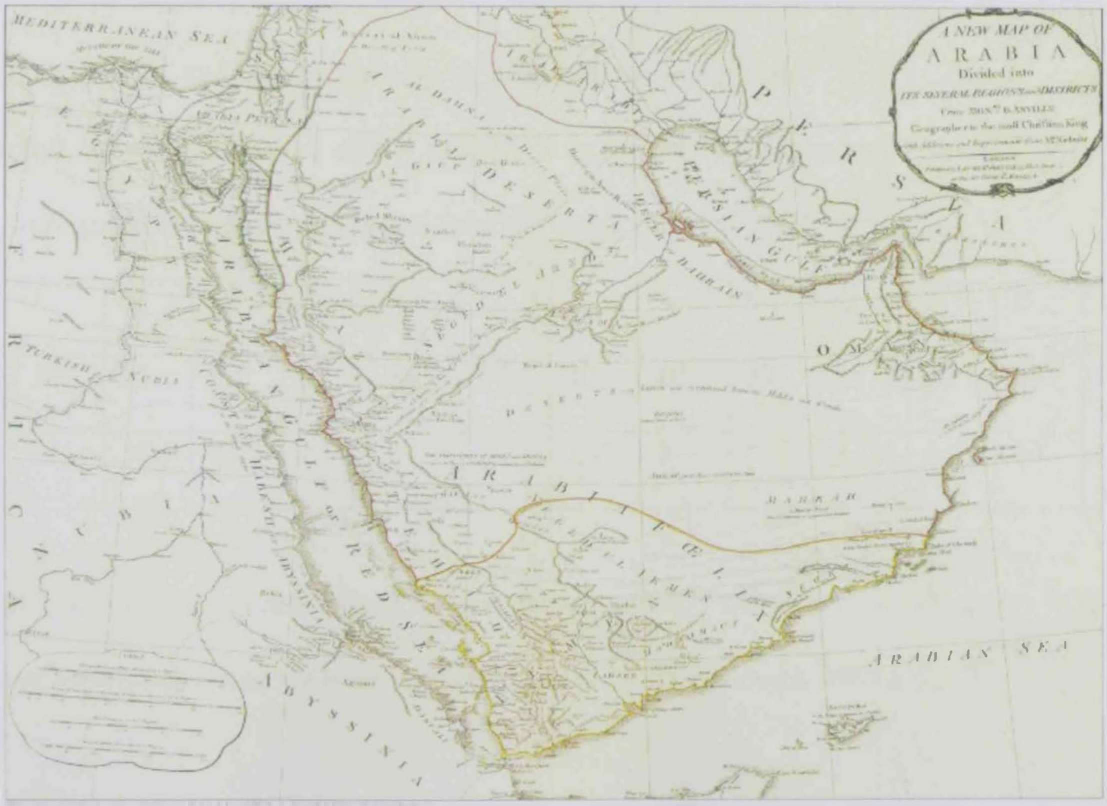


Figure 2-2: Hand coloured map that was drawn in 1794. It is clear that there was a better understanding of the topography and coastline during that time (Atlas of U.A.E, 1993)

The Arabian Gulf coastline was accurately mapped by the nineteenth century. During the seventies of the last century, the unification of the Emirates (1971) and the discovery of oil led to finalized surveys and maps clearly showing the boundaries and major features of the country (Atlas of U.A.E, 1993).

2.3 Climate

The U.A.E is an arid tropical country and is characterized by a desert type environment. The tropic of Cancer crosses its southern part. The country has two distinct seasons: a very long summer, which is hot with 30^{O} to 35^{O} C and a short unstable winter with temperature between 20^{O}-25^{O} C. The annual rainfall in the western parts is about 50 mm and is characteristically less than in the eastern mountain areas which enjoy typically 140mm rainfall (Atlas of U.A.E, 1993).

The United Arab Emirates is warm and sunny in winter, and hot and humid during summer. The minimum temperature recorded in the winter was in the desert at 5^{O} C. The temperatures in the summer can exceed 40^{O} C. Humidity percentages are higher in the coastal zone areas than inlands, and it may reach up to 90% in the summer time.

Rainfall is very rare. Most of the rainfall is in winter (February and March). Table 2-1 shows the averages of the temperatures and rainfall during the year 2003.

	J	F	M	A	M	J	J	A	S	O	N	D
^{O}C	24	25	29	33	38	39	40	40	39	35	30	26
mm	11	38	34	10	3	1	2	3	1	2	4	10

Table 2-1: Measurements taken from Bateen Airport in 2003 showing mean monthly maximum temperature and mean monthly rainfall (U.A.E year book, 2003).

The climate of Abu Dhabi is typically that of the desert. Winter is the season of rain and strong winds. In the spring the temperatures increase rapidly to the maximum temperature and may exceed up to 40^{O} C. Temperature decreases in the autumn, which is the most pleasant season in general. The highest temperature recorded was in the southwestern part of the Emirate in summer with a maximum of 50^{O} C. On the other hand, temperatures can fall to near freezing in the desert during winter. Humidity is high near the coastline and the sky over the whole U.A.E area is mostly cloud-free. These parameters have led to extremely high evaporation rates. Winds in the Emirate remain light for most of the year, but stronger winds can occur with the passage of weather system or squall lines and thunderstorms (Asborne, 1996).

Over 20 years the annual average was around 45 mm only and it was mostly between December and April. The absolute maximum temperature on the Arabian Gulf is around 49^{O}C and the mean annual relative humidity is over 60%-70% for Abu Dhabi. Foggy days with rising sand are common. As solar radiation is weak in the winter, it takes some time to burn off the fog. Advective fogs also occur when air of a high dew point over the sea moves land-ward where it is forced to rise over the cooler and denser desert air. Such fog blankets may extend inland for up to 100 kilometres. Dewfall is the only fairly regular source of moisture for plants, since fogs and rains are mostly restricted to the winter and spring months.

Two circulating pressure centers are causing the persistent summer wind "Shamal". These come from Iran – low one – and Saudi Arabia – high one – as shown in figure 2-3. Mean daily sunshine for the year is 10.3 hours (at the new Abu Dhabi Air-port) with a maximum daily mean of 11.4 hours in June and a daily mean of 8.4 hours in January (Western, 1989).

Figure 2-3 Dust storms: a common natural agent that shapes the landforms in desert regions.

2.4 Geomorphology

Most of the geomorphologic features of the country are composed of sandy dunes (plains) with maximum heights of between 150-250 m above sea level. Some mountain peaks may reach to 1500 meters and are restricted to mainly the eastern part of the country. The most significant valleys are Dibba, Al Bih and Ham [Atlas of the UAE, 1993].

The United Arab Emirates can be divided geomorphologically into three main regions (figure 2-4):

1- Internal Sand Dunes

2- Eastern mountain region

3- Coastal-marine region

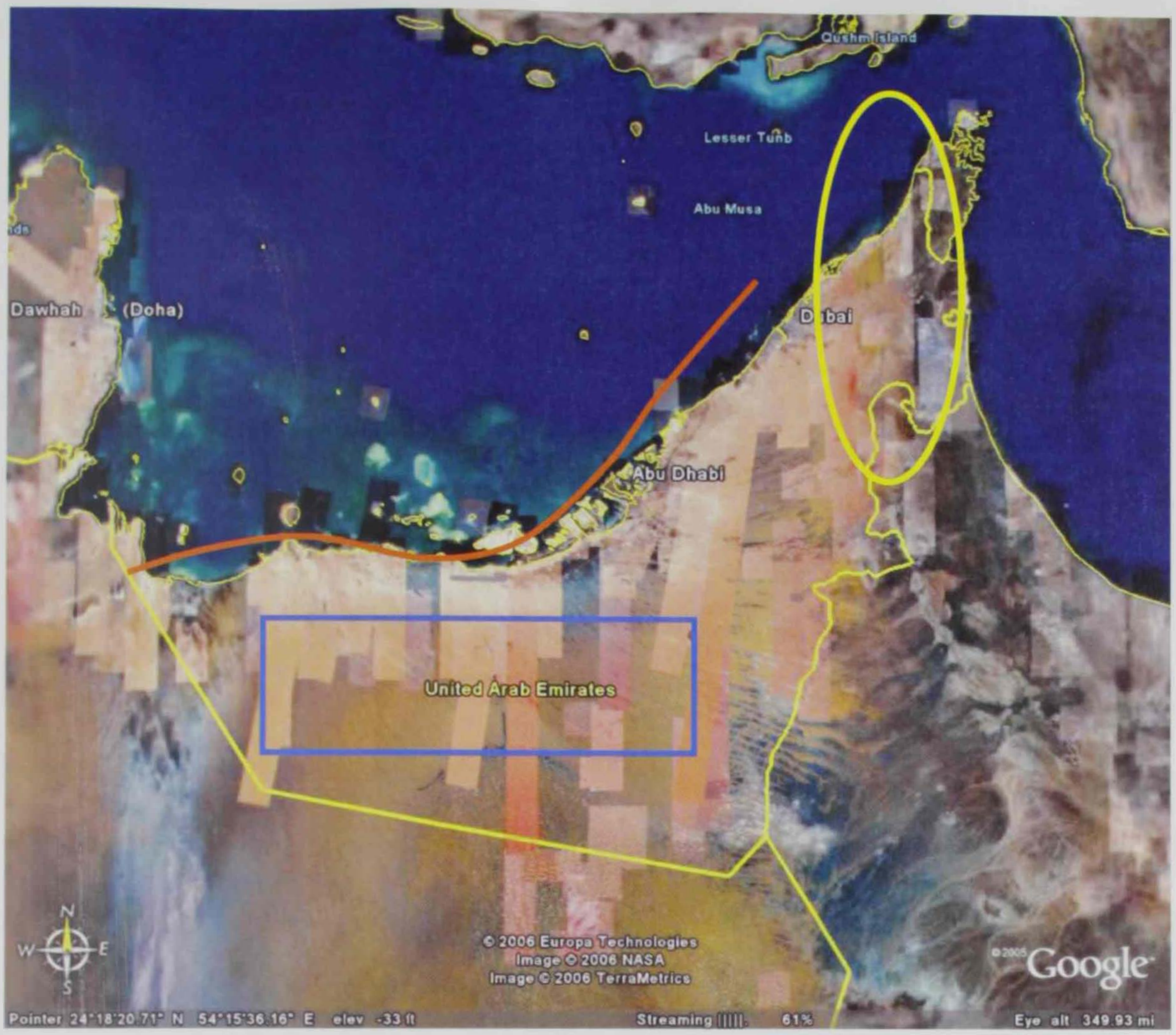


Figure 2-4: A satellite image showing the different Geomorphologic features in the U.A.E (Google Earth, 2006)

Mountain region

Coastal-marine region

Internal Sand dunes

Because the vegetation cover is rare, the main areas can be distinguished easily. The mountain region is located in the eastern side of the United Arab Emirates. In the southern side of the U.A.E. sand plains and sand dunes are the most significant features. These areas are part of the Empty Quarter Desert. In our study area – which is located in the western coastal area – shallow beaches and sabkhas are the main features found. It is difficult to draw a clear or sharp boundary between sabkhas and sand dunes in the image because both features have comparable visual properties and also the resolution is not enough to carry out such recognition.

The mountain zone in the U.A.E is located the northern part of the country, and it is a part of the Oman Mountains. It has a maximum N-S extent of 150 kilometres and an E-W extent of 50 kilometres. The maximum height of the mountains here is over 1500 meters above sea level. These are the result of an uplift process and thrusting, which took place over a period of 20 million years (Atlas of UAE, 1993).

The internal sand dune region covers about 80% of the whole area of the U.A.E. It is actually a part of the well-known sand sea "Ar Rub Al Khali". Sand dunes are a very dominant feature with some being about 200 meters in height in some areas.

The coastal-marine region lies along the Arabian Gulf and the Gulf of Oman. The region is characterized by complex features due to local tectonic movement and sea level changes. Three main features can be found in that region: Coastal inlets, islands, and sabkha plains. The largest island in the region is Abu Al Abyad (35 km's length, 12 km's width). This is shown in the figure 2-5.

Figure 2-5: Landsat-7 Satellite image showing Abu Dhabi island and Abu Al Abyad which is the largest island in the region (ADCO archive, 2000).

Coastal inlets are very common features in that region and it is divided into two groups: lagoons and estuaries. A lagoon is a body of shallow water between a barrier island and the shore (Dictionary of Geology, 1995). Estuaries are the lower courses of the wadis and they are covered by sea water, and they are not as obvious as much as lagoons (Atlas of U.A.E, 1993).

The geomorphology in the coastal zone area between the cities of Abu Dhabi and Dubai is mainly consisting of the following main features:

1- Coastal Sabkha:

Coastal sabkha is a broad, flat coastal area with a thin covering of saline deposits (NaCl). Sabhkas lie above the high tide mark and are not often covered by the sea.

2- Barrier Islands:

Abu Dhabi Island is a typical example of a barrier island in the study area. This type of an island acts as a barrier between the main land and the Gulf.

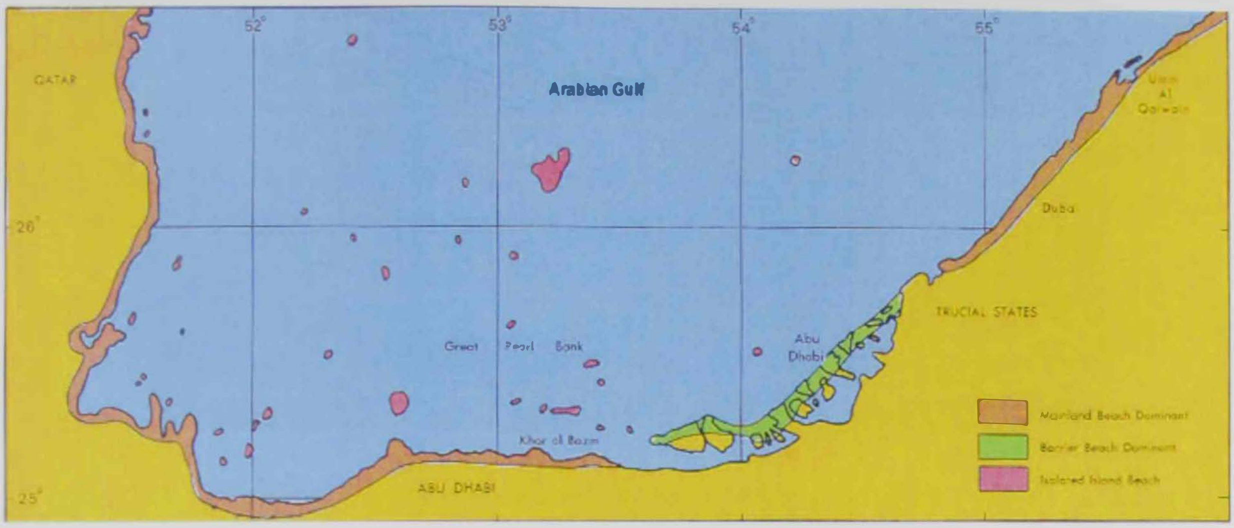


Figure 2-6: Western coastline of the UAE. It is clear that the coastline in Abu Dhabi is barrier beach dominant, but the coastal zone in Dubai is mainly land beach dominant (Shinn, 1983).

3- Tidal Flats and Channels:

Tidal flats and channels can be found as a shallow sea area between the barrier islands (see marine land forms).

Figure 2-7: Typical tidal channel as seen from space in the area of Abu Dhabi coastline (ADCO archive)

4- Sand Beaches:

The coastal zone close to Dubai city is characterized by long and narrow sandy beaches. It is common also to find similar beaches in many other places along the coastline in Abu Dhabi as well.

Figure 2-8: The area between Abu Dhabi and Dubai is covered by Recent carbonate sediments containing shell fragments (skeletal grains). The photo shows some of the grazing gastropods which has been found in Al Shahama area.

5- Small linear dunes:

The sand dunes extend to reach to the coastal zone due to the wind action and activity as shown in figure 2-9 (Atlas of the U.A.E, 1993).

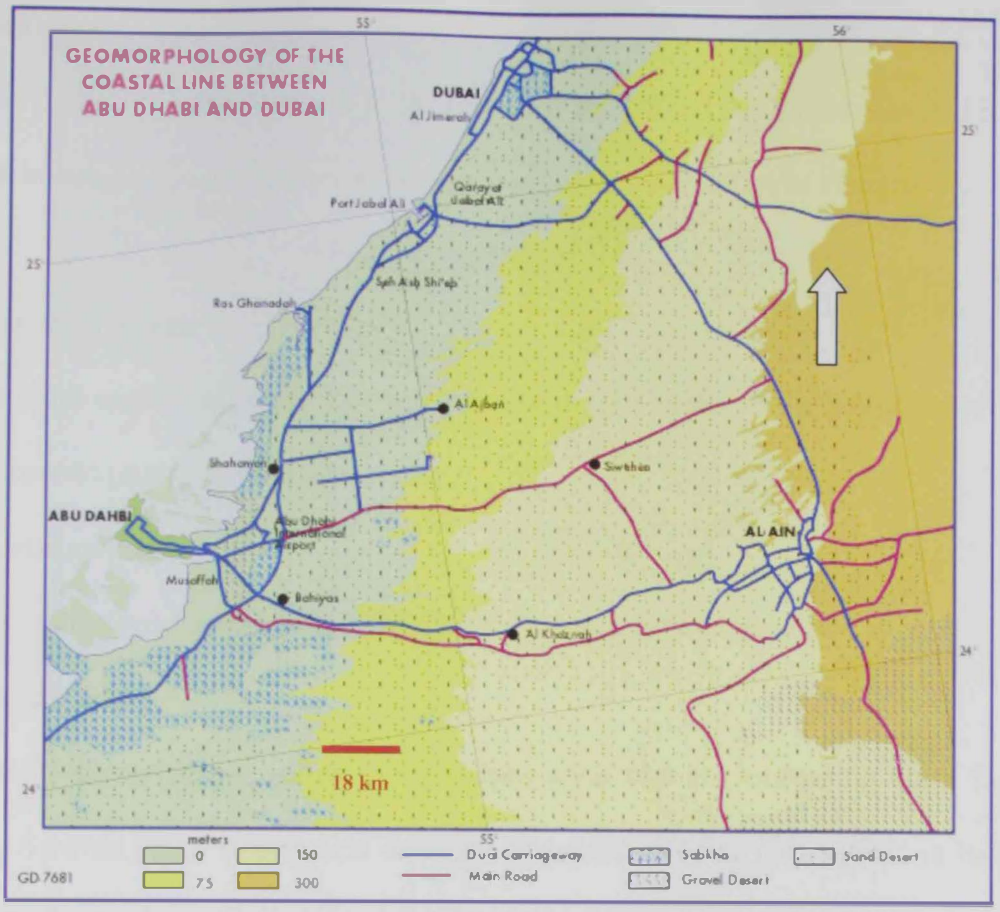


Figure 2-9: General geomorphology and topography in Abu Dhabi and some areas around including the main roads between the cities of Abu Dhabi, Dubai, and Al Ain (Atlas of the U.A.E, 1993)

2.5 Continental Landforms

Flat land covered with sand and sabkhas are the most common land forms of the studied area. This is shown in figure 2-10. The geomorphology become sandier and contains more gravel eastward. On the inland side of the study area there is a escarpment of Tertiary rocks where the elevation is not more than 75 meters above the sea level (Western, 1989).

Most of the area in the United Arab Emirates is covered by desert. Also, sabkha is a distinctive feature along the coastline, especially in the north and western region. The desert is composed of gravels and sand dunes [U.A.E year book, 2003].

In general, the desert in the U.A.E can be divided in to five different landforms:

2.5.1 Sand dunes

Sand dunes are very common in the desert of the United Arab Emirates and it may reach 200 meters in height. Quartz grains with some carbonates are the most dominant content of the dunes.

2.5.2 Inter-dune areas

Interdune areas vary from low scrub-covered sand drifts in the West to fluvial gravels close to Oman Mountains in the East.

2.5.3 Coastal sabkha

This feature has been already been discussed previously on page 14.

2.5.4 Inland sabkha

Inland sabkhas appear within the interdune areas and are located far away from the sea (landward). Sabkhat Matti is a typical example of inland sabkha. This sabkha is located in the western part of country and is considered to be the largest area of such type occupying low land region (figure 2-10). It extends inland from the coast for 120 kilometres, reaching a height of forty meters above sea level at its southern tip (Atlas of UAE, 1993).

Figure 2-10: Satellite image showing the geographical distribution of sabkhat Matti. Notice the extension of the sabkha inside the continent (ADCO archive, 2000)

2.5.5 Rock outcrops

Rocks exposed in Abu Dhabi regions belong to many types and ages. In the coastal area Cambro-Precambrian salt, Late Cretaceous shallow marine carbonates, and cherts are the most common rock types (Glennie, 1996).

2.6 Marine Landforms

The main features associated with the Arabian Gulf side of the U.A.E are: small sandy inlets, coral reefs, sea grass beds, mangrove stands, tidal channels, and sandy beaches. Maximum depth of seawater is not more than 31 meters with a narrow tidal range (0.5-1.5 meters). The maximum water temperature recorded in the Arabian Gulf was 33^{O} C and minimum temperature was 16^{O} C in the north.

The coastal zone between Abu Dhabi and Dubai cities is characterized by the presence of three tidal flat environments (figure 2-11). These are the supratidal, intertidal, and subtidal (Shinn, 1983).

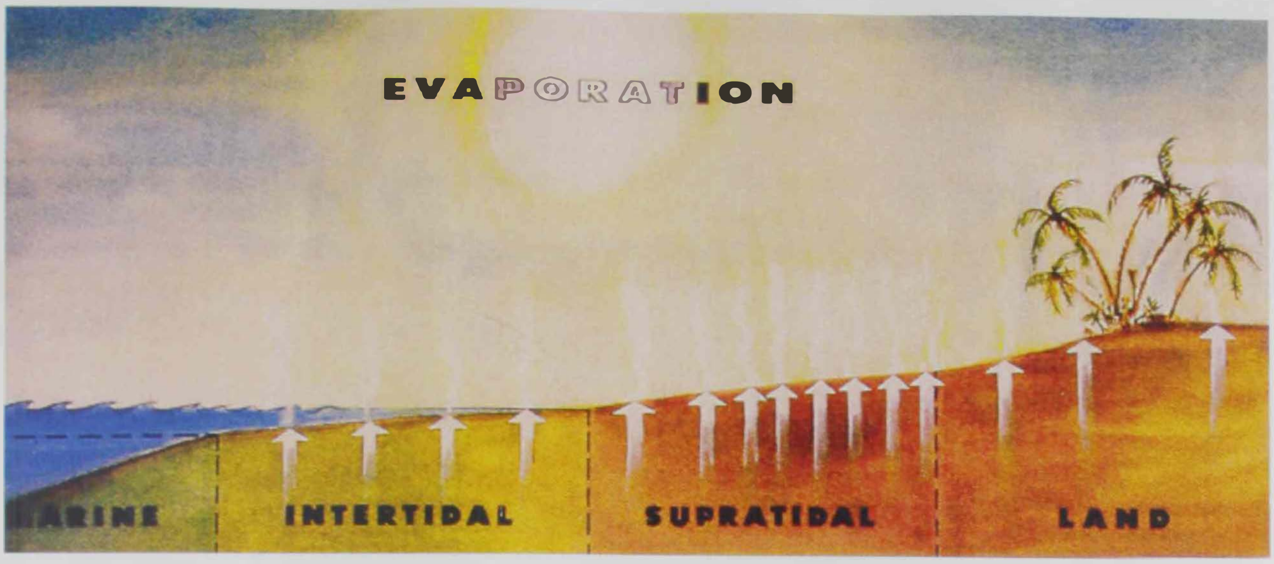


Figure 2-11: Subdivision of the main tidal flat of the Arabian Gulf region (Shinn, 1983)

2.6.1 Supratidal zone or Sabkha zone

In this zone the sediments deposits are above the normal high tide environment, and usually exposed to aerial conditions. It is flooded only by storm tides or during certain seasons during the year. Mud cracks caused by shrinkage of carbonate are the best-known sedimentary structure associated with the supratidal environments of the tidal flat. Salt deposits also cover the supratidal zone during summer time (Shinn, 1983).

2.6.2 Intertidal zone

This zone is located between the normal high and low tide. It is exposed to air one or two times a day depending on the tidal conditions and weather situation. Tidal channels separate many intertidal flat zones. This zone is characterized by the presence of algal mats and burrowing organisms in the upper part. The mid-to lower part of the intertidal zone is dominanted by burrowing crabs and grazing gastropods (figure 2-12) (Shinn, 1983). This zone contains many of the rare species which usually play an important role in the ecological system of the tidal zones.

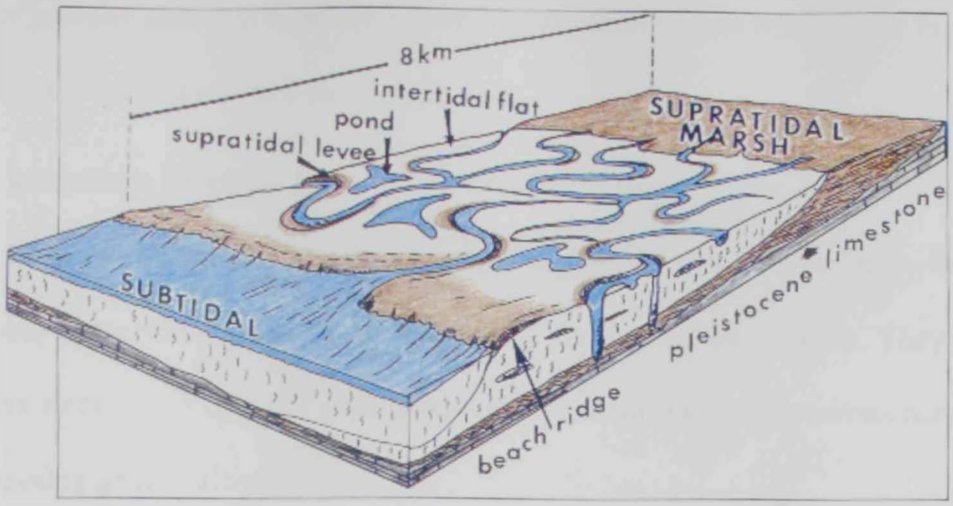
A major feature of the upper intertidal zone in the studied area is the mangrove stands. Mangrove is found in the intertidal zone. It is shrub capable of living in water of high salinity up to 60000 ppm. This tree has a great influence in stabilizing the coastal soil and prevents soil erosion by its aerial root. Also, it hosts many of the organisms such as birds, small fishes, and shrimps. Mangrove stands are characterized by high organic activity. They act as breeding grounds for many birds, fish and benthic organisms. There is a significant work that has been achieved to grow mangroves in many parts of the coastal areas of the country to minimize erosion and stabilize soils.

Figure 2-12: Under-water photo showing skeletal fragments deposited recently in shallow marine water. It indicates that carbonate deposition with organic skeletal grains is still on going today [ADCO Archive].

2.6.3 Subtidal zone

In this zone, the sediments are rarely exposed to air – e.g.: lagoon and tidal channels- (Figures 2-14 & 2-15). Depth ranges from 0 to 15 meters along the Arabian Gulf. The channels are filled usually with quartz and carbonate sand giving a channel sequence with more porous and permeable sediments. Most of the tidal channel ooids has been cemented under submarine conditions (Shinn, 1983).

Figure 2-13: Mangroves are the most dominant shrub in the shallow marine around and close to Abu Dhabi coastal zone (ADCO Archive).



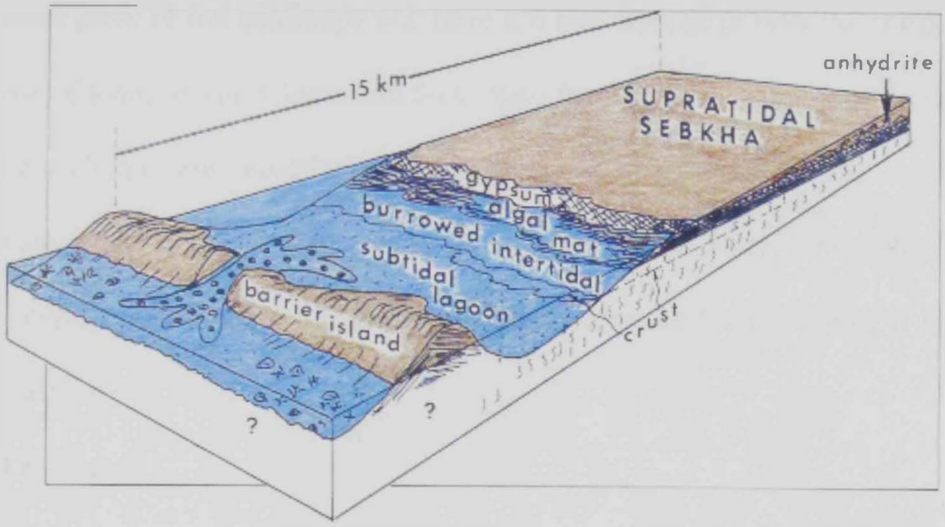


Figure 2-14 & 2-15: Block diagrams showing the different major depositional environments in the coastal area between Abu Dhabi and Dubai. The barriers are mainly composed of cerithid gastropods sands, ooids and scattered coral fragments (Shinn, 1983).

2.7 Soil groups

The major types/classes of soils present in the UAE are:

2.7.1 Entisols (from the Latin 'ent' – meaning recent):

Entisols display little or no evidence of soil development. They occur on steep-active-eroding slopes and have none of the diagnostic soil horizons. A sub-group of this soil is the torrifluvents. The torrifluvents are mostly deep, non-saline to moderately saline soils. Some are sandy or gravelly although most are loamy. They are not extensive but occur throughout the mountain and bahada areas of the U.A.E.

2.7.2 Inceptisols (from the Latin word inceptum, meaning beginning):

Inceptisols exhibit a relatively minor alteration of the parent material by soil forming processes. These soils do not occur extensively throughout the country. They are found in low, interdune areas where they are associated with the occurrence of numerous natural springs. These soils are often under cultivation.

The haplaquepts are poorly drained inceptisols. They are formed in deep, loamy deposits on the lower parts of the landscape and have a water table at or near the surface. Their texture is mainly one of loam or sandy loam and they range from slightly saline to strongly saline.

Eutrochrepts are inceptisols that are better drained than the haplaquespts. Eutrochrepts have a water table at a depth of seventy-five centimeters or more, unless they are drained. They form in deep loamy deposits and are mainly sandy loam or loam, ranging from slightly saline to strongly saline.

2.7.3 Aridisols:

Aridisols are soils that are dry and do not have moisture available over long periods of time for mesophytic plants (plants requiring moderate amounts of water). All of the aridisols in the U.A.E have an acidic moisture regime except for the salorthids, which occasionally have a high water table in addition to a salic horizon. Aridisols occur extensively throughout the country. The aridisols described in the soils map belong to the suborder orthids and can be divided into three groups: Calciorthids, gypsiorthids and salaorthids.

Calciorthids are aridisols in which secondary carbonates have accumulated from calcic horizons that has its upper boundary within one meter of the soil surface. They occur throughout the sedimentary succession where limestone and calcareous sandstone are common sources of calcium carbonate.

Gypsiorthids are aridisols that have a gypsic or petrogypsic horizon within one meter of the soil surface. Although gypsiorthids are scattered throughout the U.A.E they occur most extensively in the southeastern part of the country.

Salorthids are aridisols that have salic horizons. They are wet and strongly saline when they occur in basins where capillary rise and evapotranspiration concentrate salts into a salic horizon. The largest area of salorthids is in the Sabkhat Matti region in the western part of the country (Atlas of UAE, 1993). Table (2-2) summarizes the information presented in the previous sections.

Class	Sub-class	Description
Entisols	***Terripsamments***	- Formed in poorly graded sands. - Mostly non saline or slightly saline soils.
	Torrifluvents	- Formed in alluvial sediments. - Deep, non saline to moderately saline soils. - Most are loamy
	Torriorthents	- Formed in material which are resistant to weathering. - Shallow soils. - Loamy sands. - Range from non saline to saline soils.
Inceptisols	Haplaquepts	- Formed in deep, loamy deposits. - Slightly saline to strongly saline.
	Eutrochrepts	- Better drained than Haplaquepts.
Aridisols	Calciorthids	- Accumulated from calcic horizons. - Mostly calcareous. - Sandy to loamy. - Non saline to strongly saline.
	Gypsiorthids	- Have gypsic horizon.
	Salorthids	- Have salic horizons.

Table 2-2: Summary of the main soil types in the U.A.E.

2.8 Geology of the study area

The study area is geologically a part of the Arabian platform, which is a vast area to the east of the Arabian shield. The Arabian platform has accumulated a thick sequence of sedimentary rocks ranging in age from Cambrian (570 million years ago) to Recent. The platform has remained a tectonically stable area characterized by the persistence of lithofacies over great distances from Permian to Upper Cretaceous times. The surface geology is concealed under a cover of sand. In Abu Dhabi the oldest rocks known are exposed at Jebel Dhanna and in a number of islands located in the west of the area. These rocks have been brought to the surface as a result of salt tectonics. They consist of a mixture of shale, dolomites and volcanic and they are tentatively assigned a Cambrian age. The deepest horizon reached by the wells in the onshore belongs to the Khuff formation of Permian age (290 million years ago) [ADCO Library, 1987].

At the end of the ice age, the Gulf flooded and the dry sand was removed. As a result of continuous evaporation in the summer time, crystalline salt crust formed and calcium sulfate accumulates. That was the simple process of forming the coastal sabkhas in the region (Alsharhan and Kendall, 2001).

Sediments of the region of Abu Dhabi coastal zone land include: skeletal grains, non-skeletal grains, carbonate mud, non-carbonate minerals and organic materials. Lithofacies in the same area include: corals, oolitic sands, pellet aggregates, muds, molluskan sands, algal mats and evaporites (Alsharhan, 2002).

In terms of Hydrocarbon Occurrence in the study area, Arab Formation and Thamama Group (Upper Jurassic and Lower Cretaceous age) contain the principal oil reservoirs in Abu Dhabi. Other formations also have oil in Abu Dhabi like The Araej (Middle Jurassic), Mishrif (Middle Cretaceous) and the Simsima (Uppermost Cretaceous) (ADCO Library, 1987).

The sediments in the coastal zone between Abu Dhabi and Dubai are relatively recent (Holocene). Because of the accumulation of the sediments, sandy shoals and islands occurred between tidal channels. Oolites and coral reefs are the main component of the islands. Carbonate mud and pellets are accumulating as well. The importance of the tidal system in the coastal zone area of Abu Dhabi is that it can be used as a simulation model for better understanding some ancient carbonates/evaporates depositional and digenetic system and processes in the Upper Jurassic time [Kendall, 2004].

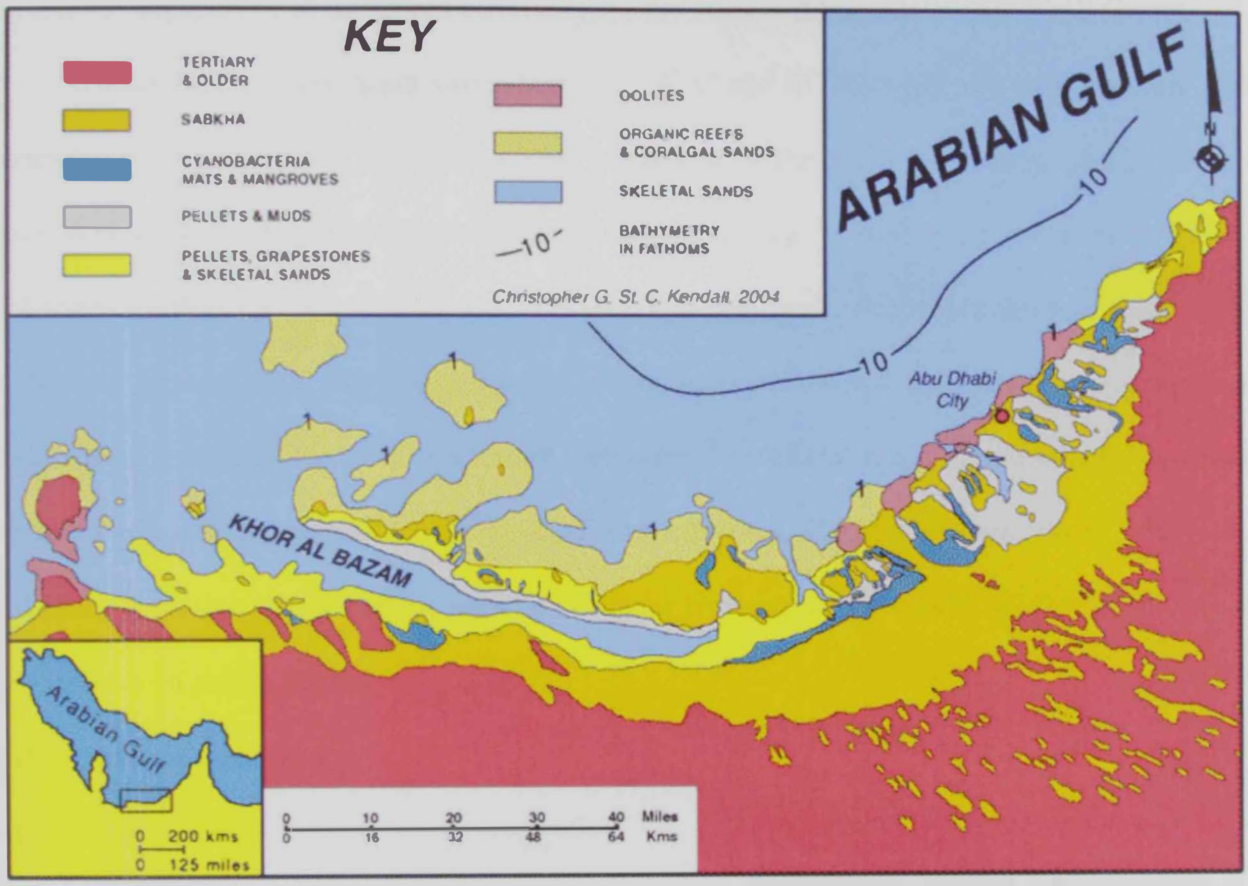


Figure 2-16: General facies in Abu Dhabi coastal area (Kendall, 2004)

2.9 Water Resources

Evapotranspiration causes the loose of about 72% of the annual rainfall and 50% of the remaining precipitation runs off directly into the sea. Another large portion of the rain goes into the ground. The fresh water which is consumed per year exceeds one billion cubic meters and 70% is not renewed.

Prior to the 1960s the amount of consumed water using traditional methods such as falajes and manual wells was balanced by natural renewal. More modern methods, using submersive and mechanical pumps to draw out large amounts of groundwater have resulted in receding quantity and quality of groundwater. In 1985, there were 70 rotary drills in use, yielding up to 4000 wells annually as well as many ordinary percussion drills, belonging to private drilling establishments, the official department of water and electricity, or the army drilling unit.

Groundwater temperature varies between 29^{O} C and 41^{O} C, while the hydrogen rate (pH) varies between 7 and 8.5. The flow from the mountains of the north feeds the plains in the west and it is characterized by high percentage of calcium elements. Sewage water treatment is the way that water aquifers can be protected from bacteria and chemicals. Pesticides and fertilizers can be controlled directly also. The protection of groundwater fields and their feeding regions from pollution is a national necessity. Basic and metamorphic rocks of the southern U.A.E Mountains are relatively rich in chrome, copper, nickel and iron ores. Contact of these rocks with water makes it imperative to monitor the presence of these elements in the waters because of the danger they impose on public health.

2.10 Human Activities

2.10.1 Pearl diving

Pearl diving is one of the most important historical jobs in U.A.E. People or divers were used to collect pearl – bearing oysters – from close shallow depth waters of the Arabian Gulf 4000 years ago until few years ago. This was carried out until the middle part of twenty century. Pearl diving played a great role in the economy of the people in the area. The Gulf pearl was sold by British, Persians and the Portuguese traders (Atlas of UAE, 1993).

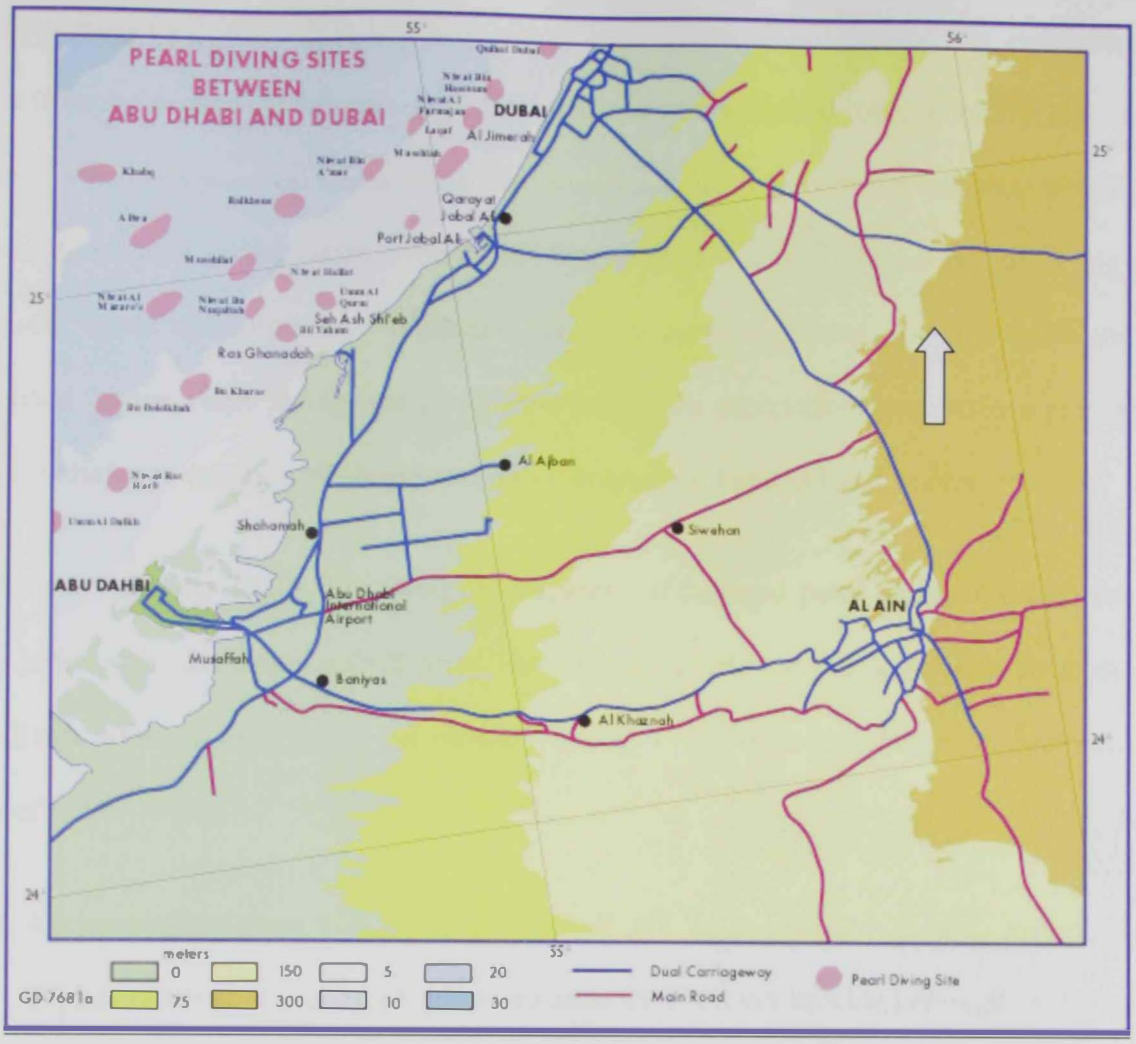


Figure 2-17: Pearl-diving sites in the sea region between Abu Dhabi and Dubai [Atlas of UAE, 1993]

The pearls themselves obtained from pearl oysters and occurred in the southern area of the Arabian Gulf. Pearls can be formed in different sizes and colors. Development of pearls is starting from a foreign body (ex: grain of sand) introduced to a shell, which is very important source of any pearl formation. It is not necessary to find pearls in all the shells. The diving season is during the hot summer months –from June until October-. This is because divers can swim and dive in warm seawater.

Before the large-scale decline of the industry during the 1950's large fleets of dhows would set sail at the beginning of summer. The following months would be spent anchored to the numerous pearling banks while teams of divers used centuries-old methods of collecting pearl oysters from the seabed. The divers, their feet in a loop of a weighted rope, would be lowered into the water where they would spend up to two minutes collecting between ten and twenty shells. After being brought to the surface, the divers would rest for a few minutes before diving again. The divers would make up to one hundred dives a day, spending a total of between two and three hours under water. Pearl diving was therefore a dangerous occupation, a situation which was not helped by the large numbers of sharks and jellyfish which inhabited local waters.

Starting from the 1930s, the rapid development of cultured pearl in Japan ended the pearl diving industry in the Arabian Gulf area. The cultured pearls are much cheaper, so most of the pearl divers went to work in the oil industry during 1960s with less dangerous and better pay [Atlas of UAE, 1993].

2.10.2 Archaeological sites

Studies of the stratigraphy of excavated sites have not yet provided enough evidence to fill the gaps which exist in the history of the United Arab Emirates. The sequences of the old Stone Ages are still unknown, and the eastern slopes of Jabal Hafit are the only places where sites have been found belonging to the Neolithic period.

Nothing has been found, so far, which indicates the existence of housing in the Fourth Millennium. The Jamdat Nasr culture began at the end of this millennium and lasted until the beginning of the Third Millennium. This culture is represented by a number of circular tombs at Hafit and Qarn Bint Saud, which house metal artifacts, earthenware and ornaments.

The third Millennium forms the golden era in the ancient history of the U.A.E. Excavations have shown the existence of rural civilizations depending on agriculture (particularly millet crops) and on industry (particularly copper mining). A number of settlements and circular tombs were excavated and the finds included flint, bronze, copper, stone and ceramic vessels of different color, designs and decorations. Archaeologists call this era the Culture of Um An Nar, after the important site which first displayed the features of this culture. It then seems to have spread to the rest of the country, as indicated by excavations at such places as Jabal Hafit, Al Hili and Ajman.

Excavations have shown that there were significant climatic changes at the beginning of the Second Millenium. A decrease in rainfall was responsible for the decline of agriculture and a return to the Bedouin lifestyle.

This situation continued throughout the Second Millennium, and it was not until the beginning of the First Millennium that urban life returned, both to Third Millennium sites and to new settlements. In these places, excavations have revealed the remains of settlements built of white mud bricks, and burial sites containing pottery made from different types of clay and of different colors, stone vessels and copper and bronze tools. Example of such sites are Ar Rumeilah, Al Hili and QamBint Saud (Al Ain), Ghanada (Abu Dhabi), Al Qises and Hatta (Dubai), Wadi Al Qor (Ras Al Khaimah), Qadfa (Fujairah), Milehah (Sharjah) and Tawi Ad Dur (Umm Al Quwain).

During the Hellenistic period, some sites maintained connections with commercial and trade routes between the Mediterranean regions and those of the Arabian Gulf. Evidence has been found in the form of pottery and coins from the period.

The region flourished during the Parthian and Sassanian periods. Excavations in Sabhkat Al Jurf have uncovered remains of citadels with four circular towers, which may belong to the Fourth Century A.D., particularly the region of Saput 2nd (310-279).

So far, no remains of the Early Islamic period (in which Islam arrived in the region) have been found. The Modern and Contemporary Islamic periods are represented by castles, fortresses, mosques and some ruined settlements, identified through their pottery [Atlas of UAE, 1993].

Excavations at the islamic site has been found between 1993 and 2001 on behalf of Dubai municipality in Jumeirah area. These consisted of two houses built of plastered beach rock. Doors and windows were decorated and arched. The houses phases could be dated to the 18th centuries. A small mosque was excavated also. It was built with the same rock used in the houses. It has been suggested that the mosque was built in the 10th century and remained in use untill the 18th century.

2.10.3 Modern land use

The study area underwent extensive urbanization during the last 30 years. These activities include wide-scale constructions, coastal modification, land reclamation, agriculture, tourism, and other industrial and commercial activities. These activities led to significant changes in the pristine environmental conditions such as wetland, mangrove, coastal landforms, and sand dune fields and produced serious environmental effects in these areas through time.

There has been obvious and heavy investment in the infrastructure of the U.A.E's towns and villages since 1950s until now. The main fields which were fully developed were; telecommunications, roads, airports, seaports, housing, sewage, water, and electricity.

Roads in U.A.E were built to access newly developed area and to improve traffic flow. Furthermore, high standard roads improved the quality of life in the country. Local governments take care of transport networks within the individual emirates [U.A.E year book, 2003].

Although, the United Arab Emirates is a small rich country, which have been developed rapidly, the environment cannot be ignored for the people of U.A.E. It is enough to mention here that the president of the United Arab Emirates and the ruler of Abu Dhabi said on the occasion of the U.A.E's first environment Day:

" ... We shall continue to work to protect our environment and our wild-life, as did our forefathers before us. It is a duty – and, if we fail, our children, rightly, will reproach us for squandering an essential part of their inheritance and of our heritage." HH Sheikh Zayed Bin Sultan Al Nahyan, 1998'.

The development of the economy in the U.A.E was associated with the discovery of oil and gas in Abu Dhabi in 1958. In 1962, oil was discovered also in Sharjah, Dubai and Ras Al Khaima. Furthermore, gas has been found in Umm Al Quwain as well. Rapid expansion all over the country was the result of the wealth accumulated due to revenues generated from oil and gas. This led to the growth of modern cultivation, constructions, industry, trade, transport, communications and many other fields in the whole country.

Only in those areas where man has a direct influence, as in towns, villages, farms, and beside roads, has there been any significant alteration to the desert environment in recent years. The effects of pumping out subsurface water still have to be fully evaluated though this does seem to be adversely affecting some perennials [WESTERN, 1989].

The first discovery of commercial oil was in Abu Dhabi emirate in 1958. The oil has been exported from Abu Dhabi since 1962 and in Dubai since 1969. Later, the federation of the seven emirates was formed on 2nd December 1971. The federation impacted positively on the U.A.E in terms of economics, culture, infrastructure, social life, and policy. Small towns became modern cities with the appearance of developed infrastructure like roads, ports, airports, water and electricity supplies, schools, and hospitals.

The investment in manufacturing with oil and gas took place in the governmental plan. The government of the United Arab Emirates developed the industry of refineries, fertilizer plants, and aluminium manufacture. The industrial establishment was mainly concentrated in both Abu Dhabi and Dubai. Other industrial activities include: petroleum products, chemicals, metal products, transport and electrical equipment, and recycling.

Cement factories, which were built by the local government, take the raw materials from local sources. The cement industry played a great role in the development of infrastructure buildings. Other industrial activities, such as concrete block manufacture, interlock, and tile factories, have been established recently and a portion of their production has been exported.

The Jebel Ali free zone, which is 30 kilometres away from Dubai city, is the oldest and largest Free Zone in the United Arab Emirates. It was established in 1985, and the area of the Free Zone is about 10,000 hectares. Trading is the main activity in the Free Zone with some heavy industrial activities and services. Jebel Ali Free Zone was built around the largest man-made port in the world. Modern management led to very well implemented environmental regulations [Ghanem, 2001].

Since the federation of the Emirates, the improvement and development of the road network system is under successful process. The development includes expanding of the previous roads to fit the increasing number of cars every day in the U.A.E. Also, building and constructing new roads continuos to cut the travel time between the cities.

Sea transport is one of the main goals that the government of the U.A.E is trying to develop and manage in a high quality system. About 15 commercial ports are working together all over the country to improve its services and expand its business [Ministry of Information and Culture, 1996].

CHAPTER THREE

IMAGE PROCESSING

The overall methodology adopted for the preparation of land use/ land cover maps and change analysis is shown in Figure 3-1. The image processing techniques adopted aimed to detect all the possible changes that happened between the times 1993 and 2000. Digital image pre-processing and processing techniques have been used for preparation of land use/ land cover maps from the multi-date satellite data. This includes geometric correction of satellite images, exploration of different possible image enhancement and classification procedures. Two methods of change detections were adopted; the direct visual comparison of enhanced data and the comparison between the classified images for different dates. ER MAPPER image processing software has been used for all image processing techniques.

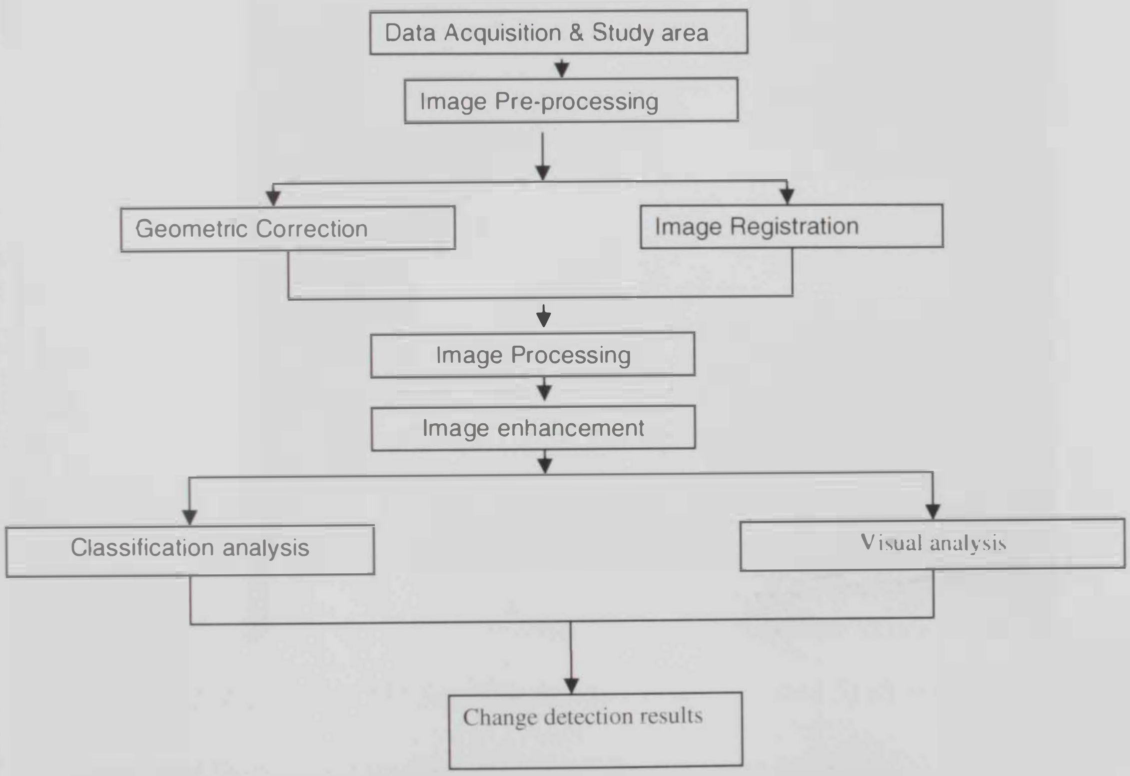


Figure 3-1: Flow chart of the methodology adapted in the thesis.

3.1 Data acquisition and study area

Two sets of images have been used in the thesis. The Landsat images were recovered from the United Arab Emirates University archive. The first image set have been captured in 1993 and the second in 2000. The satellite image of the area of 1993 has been pre-processed with the registration to a real coordinates in a topographic map. Then, the image of 2000 has been geometrically corrected with the registered image of 1993.

The first set of images was used in this study is Landsat -5 TM and was captured in 1993 (Figure 3-2). The second set is the Landsat –7 ETM that was captured during 2000 (Figure 3-3). The row of the whole image is 43 and the path is 160. Comparison between the two image sets enabled us to detect any changes - whether natural or anthropogenic - that happened in the area during the period 1993-2000.

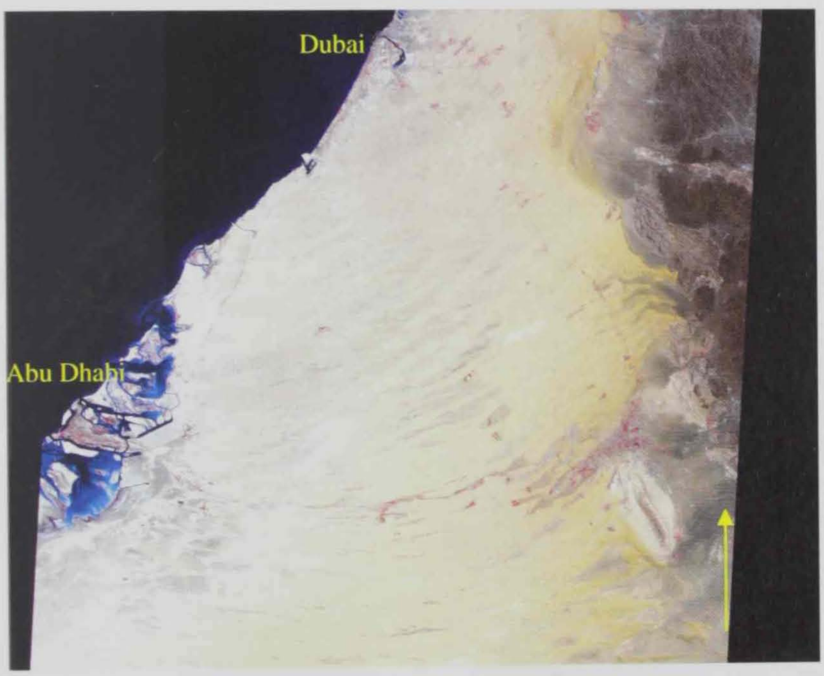


Figure 3-2: Landsat-5 TM Satellite Image (bands 3, 4 and 5) showing the area between Abu Dhabi and Dubai captured in 1993 (U.A.E University archive).

Figure 3-3: Landsat-7 ETM Satellite Image (bands 3, 4 and 5) showing the area between Abu Dhabi and Dubai captured in 2000 (U.A.E University archive).

3.2 Sub-division of study area

The image sets were divided into two sub-sets to facilitate the study. The first sub-set covers the coastal zone of Abu Dhabi (Figure 3-4 and 3-5). The second sector includes the coastal zone from Ras Ghantut area to Dubai city (Figures 3-6 and 3-7).

Figure 3-4: A satellite image (Landsat –5 TM) of Abu Dhabi city and Abu Dhabi N-E coastal zone area captured during 1993.

Figure 3-5: A satellite image (Landsat –7 ETM) of Abu Dhabi city and Abu Dhabi N-E coastal zone area captured during 2000.

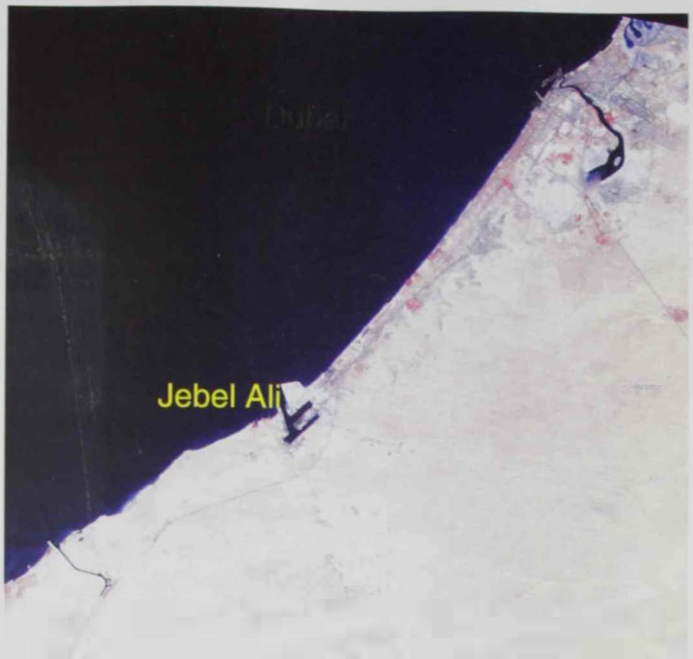


Figure 3-6: A satellite image (Landsat –5 TM) of Dubai city and coastal zone area captured during 1993. The distance between Jebel Ali and Dubai City is approximately 30 Kilometers.

Figure 3-7: A satellite image (Landsat –7 ETM) of Dubai city and coastal zone area captured during 2000.

	ABU DHABI (2000)	ABU DHABI (1993)	DUBAI (2000)	DUBAI (1993)
Data type	Raster	Raster	Raster	Raster
Geodetic datum	WGS 84	WGS 84	WGS 84	WGS 84
Map projection	UTM 40	UTM 40	UTM 40	UTM 40
Number of bands	8	6	8	6
Number of lines	1993	1993	1970	1970
Number of cells per line	1974	1974	2068	2068
Cell size X	30 meter	30 meter	30 meter	30 meter
Cell size Y	30 meter	30 meter	30 meter	30 meter

Table 3-1: Detailed properties of the studied images. The low resolution of the images is due to the large scale of the study area.

3.3 Image pre-processing: Image registration & Geometric correction

Pre-processing is needed before the primary analysis of the studied images. For this study it includes both image registration and geometric correction. This will register the previous image with another correct map or image.

All images contain geometric distortions of some kind. There are a large number of combinations of effects due to different kinds of platform instability, optical and mechanical distortions in the radiation-gathering set-up. Earth rotation beneath the platform and both parallax and scale effects resulting from topographic relief. Apart from the last two effects, these are amenable to quite simple corrections. Where precise information about platform attitude and track relative to the Earth's rotation is available, this can be built into automatic correction programmers. In Landsat images the correction for Earth rotation is simply a systematic line-by-line displacement of pixels, very much like giving a slant to the edges of a pack of cards.

At large scales the Earth's surface can be regarded as a plane on which the topography is superimposed. Rectification of an image essentially restores objects to their correct relative disposition in two-dimensional space as if they were all viewed from directly above. Small-scale images contain effects due to the Earth's curvature. They are projections of a spherical surface into two dimensions. All maps have similar distortions. However, different scales and different uses call for different kinds of projection such as stereographic, conical, cylindrical and more complex renditions. All aim to maintain a common scale over a whole map, a minimum of distortion, and a uniform representation of shapes and areas. Because maps are the stock-in-trade for all users of remotely sensed images, geometric manipulations of images attempt to register images to the map projection required for a particular project. Since most digital images consist of rectilinear arrays of DN for columns of pixels in rows of lines, rectification consists of a transformation from one set of Cartesian coordinates to another. In cartographic projections the spherical coordinates of points, expressed as latitude and longitude, do not confirm to a rectilinear array. Points must be expressed as a metric grid of eastings and northings. Sometimes a grid of this kind is an integral part of the map, as in the Universal Transverse Mercator (UTM) projection and other relatively modern projections. Where more archaic projections are found, a false grid must be used to register the image to the map.

All image distortions, except those caused by differences in surface elevation, can be removed by registration of a digital image to a map base. The process begins by identifying topographic or cultural features visible on both the image and the map. The map coordinates are assigned to the pixel and line coordinates of a number of these ground control points on the image. A very similar procedure can be used to register an image of one type to another.

Each new pixel in a rectified image must have a DN derived form those in the raw image assigned to it. As the new pixels are displaced relative to the raw array of DN, simply assigning the original DN of a shifted pixel will produce errors in the new image. The simplest means of allowing for this effect is to assign the DN of the nearest raw pixel to a pixel in the new array.

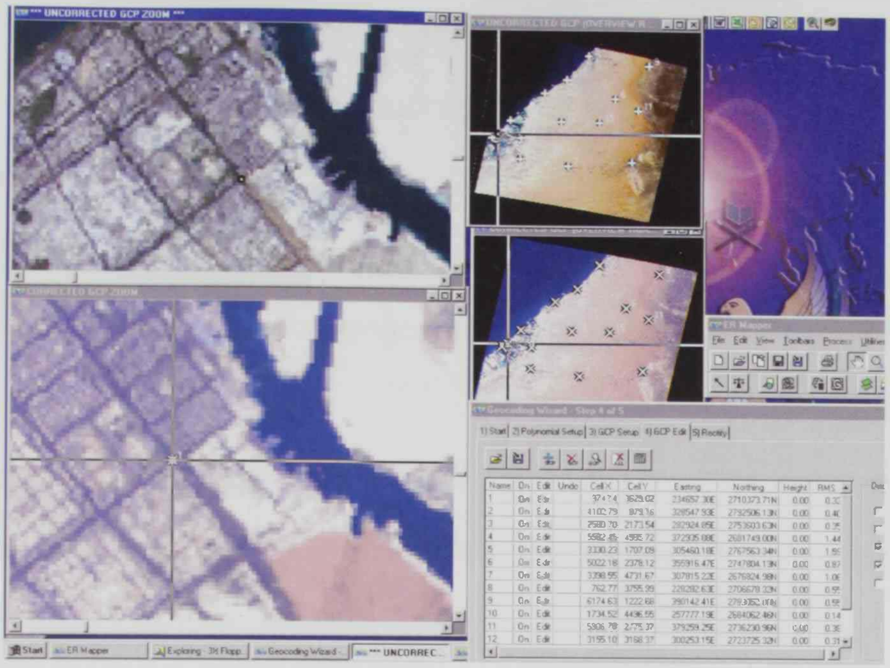
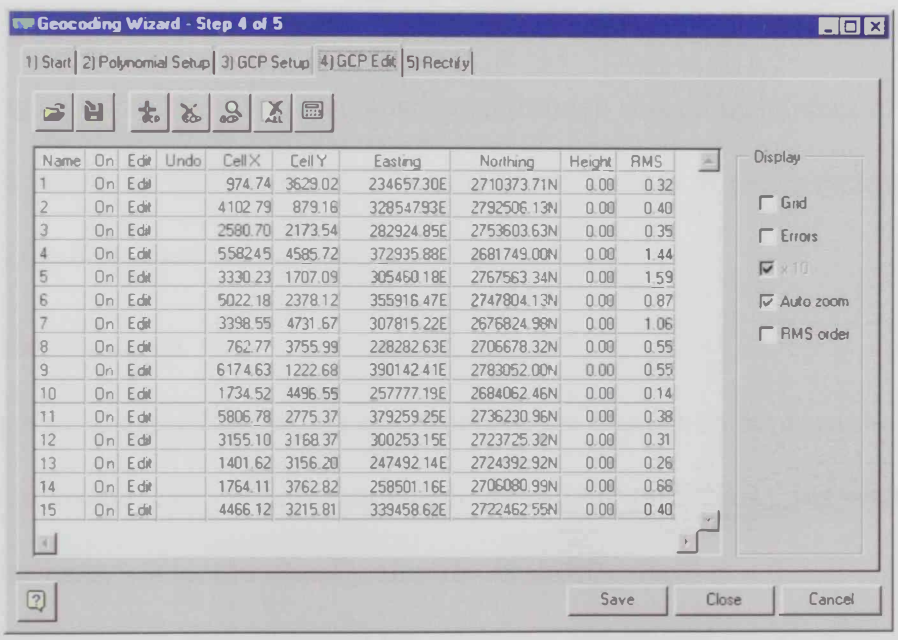


Figure 3-8: The selection of Ground Control Points.



Name	On	Edit	Undo	Cell X	Cell Y	Easting	Northing	Height	RMS
1	On	Edit		974.74	3629.02	234657.30E	2710373.71N	0.00	0.32
2	On	Edit		4102.79	879.16	328547.93E	2792506.13N	0.00	0.40
3	On	Edit		2580.70	2173.54	282924.85E	2753603.63N	0.00	0.35
4	On	Edit		5582.45	4585.72	372935.88E	2681749.00N	0.00	1.44
5	On	Edit		3330.23	1707.09	305460.18E	2767563.34N	0.00	1.59
6	On	Edit		5022.18	2378.12	355916.47E	2747804.13N	0.00	0.87
7	On	Edit		3398.55	4731.67	307815.22E	2676824.98N	0.00	1.06
8	On	Edit		762.77	3755.99	228282.63E	2706678.32N	0.00	0.55
9	On	Edit		6174.63	1222.68	390142.41E	2783052.00N	0.00	0.55
10	On	Edit		1734.52	4496.55	257777.19E	2684062.46N	0.00	0.14
11	On	Edit		5806.78	2775.37	379259.25E	2736230.96N	0.00	0.38
12	On	Edit		3155.10	3168.37	300253.15E	2723725.32N	0.00	0.31
13	On	Edit		1401.62	3156.20	247492.14E	2724392.92N	0.00	0.26
14	On	Edit		1764.11	3762.82	258501.16E	2706080.99N	0.00	0.66
15	On	Edit		4466.12	3215.81	339458.62E	2722462.55N	0.00	0.40

Figure 3-9: The geocoding wizard which shows the accuracy of geocoding (RMS values between 0 – 1.4)

The satellite image of the study area which has been captured in 1993 has been registered into the real world coordinates. The raw image has wrong coordinates and the correct map have been used to justify the satellite image of 1993. The satellite image of 2000 has been geometrically corrected with the registered image of 1993. These pre-processes ensure us to compare fairly both images together and to get more accurate justification with each other.

3.4 Image processing

Image interpretation is a translation of the image into information, or, derives useful information about an area from un-interpreted images we receive from remote sensing system (raw data).

To do an interpretation of an image for a specific area, some knowledge and experience must be required with the interpreter. If the interpretation has been applied in to unfamiliar regions, it will be necessarily to make a field trip and observation or get certain data from several references. For that reason, several field trips have been conducted to identify and ensure some of the different regional features within the study area which have been mentioned in this work.

The image interpretation has been conducted through several techniques of digital images processing. The following techniques have been conducted more to better understand the study area and extract the maximum information:

3.4.1 Image enhancement

The target of image enhancement is to improve the distinction between the features in the scene. Since the naked eye cannot distinguish the slight differences between the features, computer enhancement is a tool to visually amplify these differences.

3.4.2 Principal component analysis:

Principal component analysis is an efficient process for better observation in the shallow depth areas. It helps the interpreter to compare any changes between depositional environments. It is one of the digital image techniques which used to analyze two or more images. This technique has been used in the thesis because it is useful to compare the same depositional environment in two different times. Principal component analysis has been used also to help confirm what have been discovered in visual image interpretation. Furthermore, we can use this technique to add more understanding of the shallow marine environment.

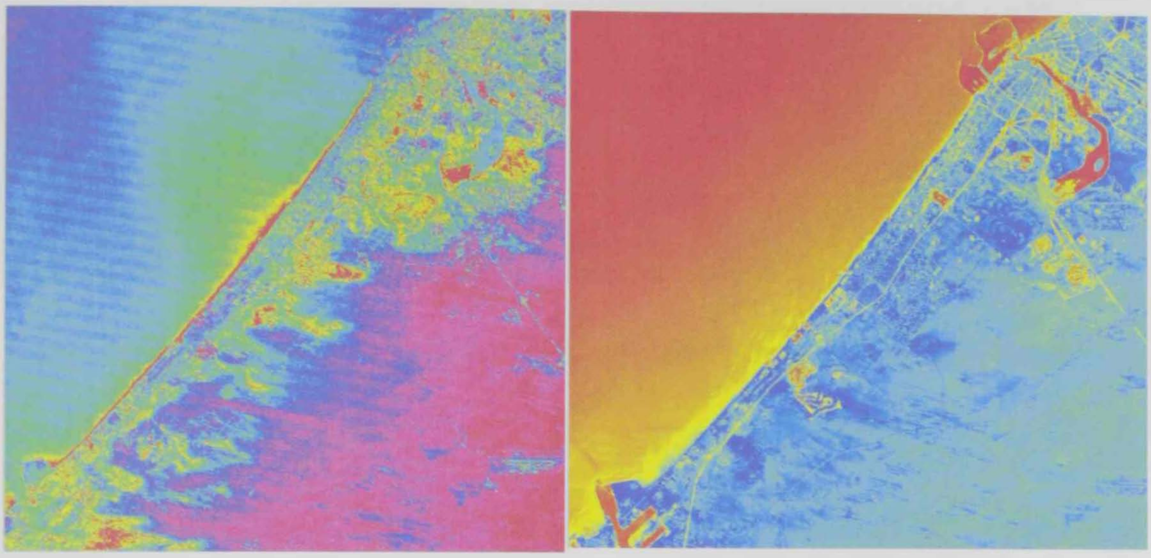


Figure 3-10: Processed images of Dubai area with principal component analysis.

3.4.3 Spatial filtering

High-pass filtering has been applied to enhance coastal-line and detect any major changes of the position of the coastline (Harahsheh, 2002). The figure below shows a sample of the Abu Dhabi area, where the sharp definition of coastal boundaries can be easily recognized.

Figure 3-11: High –pass filter of 1993 image and High –pass filter of 2000 image

3.4.4 Classification

Image classification is a digital process that sorts the pixels of an image into classes. The pixels are representing values in several spectral bands. Homogeneous pixels can be classified and formed for better image analysis and pattern recognition.

In this study, unsupervised image classification has been applied to the data of 1993 and the data of 2000. The reason to use unsupervised classification is the scarcity of field sample data. We followed exactly the same parameters for both years as, algorithms, number of classes, iteration. The results of classification are explained in the following chapter.

3.4.5 Overlay of multi-temporal data

This is a very important technique, which allowed us to detect and identify the changes that happened between two or three dates. After an accurate image to image registration, it is possible to overlay the different images of different dates. In this research we displayed the one band from the data of 1993 (band 5) with the same band form 2000 as false color composite (the third component was left blank). This technique allowed us to visualize the extent and location of changes that happened after 1993. The results will be explored in chapter four.

3.5 Change detection

The above mentioned digital image processing techniques were used to detect the environmental changes that occured in the study area. For the final results and the conclusions about the changes happened in the study area, we will use the following three techniques of change detection:

1. Visual interpretation
2. Overlay of multi temporal data
3. Classification of multi temporal data

Image enhancement, principal component analysis, and spatial filtering techniques were used carefully to help us in the visual interpretation step. In the following chapter explore all of these three techniques. We think all of these techniques are important and worth to be used, a conclusion will be made about the advantages and disadvantages of each technique.

CHAPTHER FOUR

CHANGE DETECTION

This chapter will review all the results of all the study field changes which have been detected between the period 1993 - 2000 based on different processing and interpretation techniques in the laboratory of Remote Sensing in the U.A.E University. All the areas, islands and other names have been taken from the image prepared by the United States Geological Survey, in cooperation with the National Drilling Company, Abu Dhabi, under the supervision of the Military Survey, UAE, and Armed Forces. The results of the three change detection techniques (Visual interpretation, Overlay of multi temporal data and Classification of multi temporal data) will be analyzed. The following chapter will conclude with a discussion of the results with some remarks about the development of the study area and the type of changes that were covered in this study.

4.1 Visual change detection

4.1.1 Abu Dhabi coastal zone

Figure 4-1 is a close up of Abu Dhabi Island that was captured during 1993 by Landsat-5 TM. Area A is the Eastern side of Abu Dhabi Island, known as "Al-Sadiaat" Island. The two entrances of Abu Dhabi Island are shown with yellow arrows. Area B is the "Musaffah" industrial area. The image shows clearly the main roads in the capital city in 1993. Note also the other shallow islands such as island which surrounds the main island.

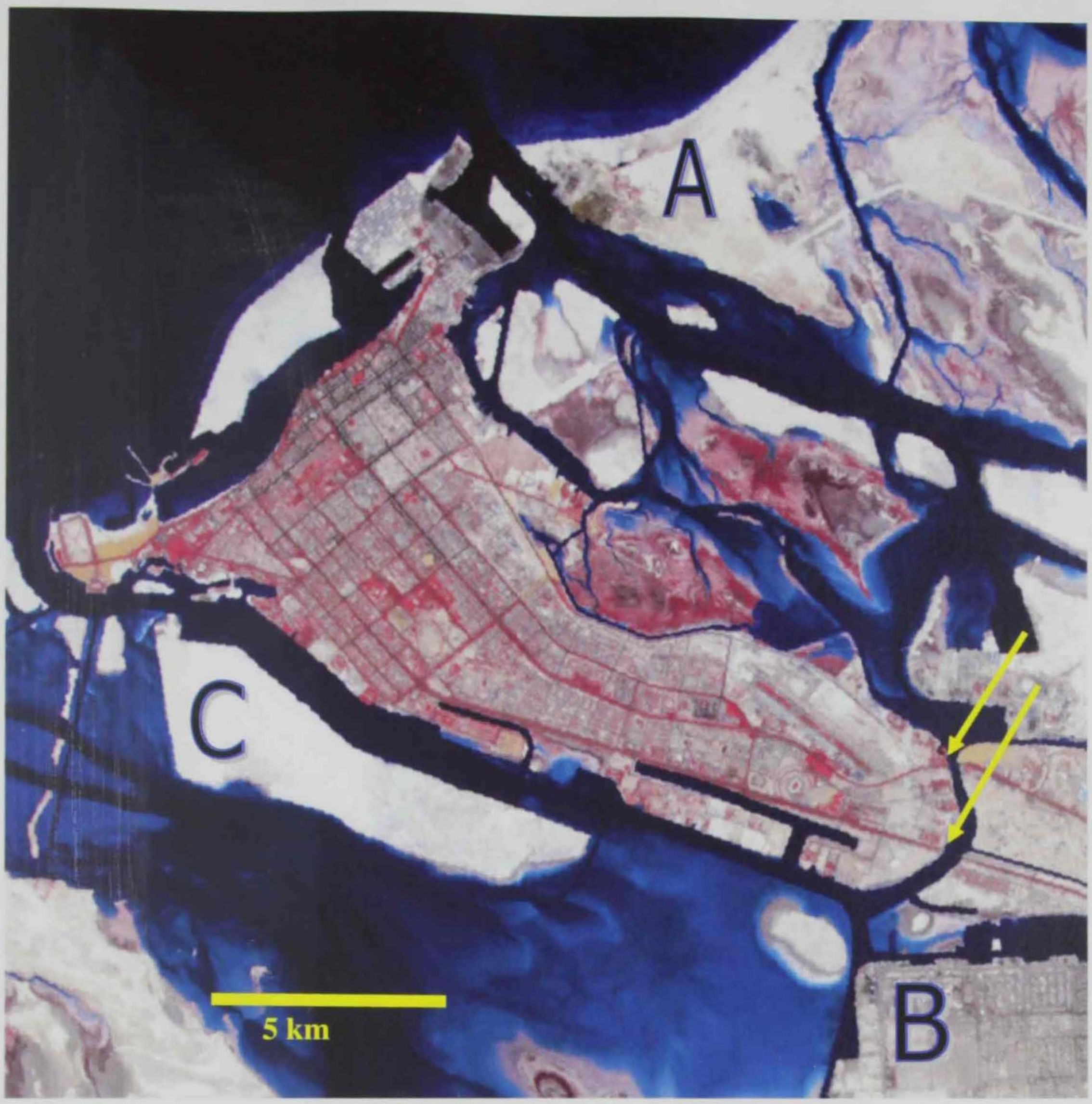


Figure 4-1: A close up of Abu Dhabi Island captured during 1993 by Landsat-5 TM.

Figure 4-2 is a close up of Abu Dhabi Island captured during 2000 by Landsat-7 ETM. Many major changes can be observed visually between figure 4-1 and figure 4-2, which covers the same area seven years later.

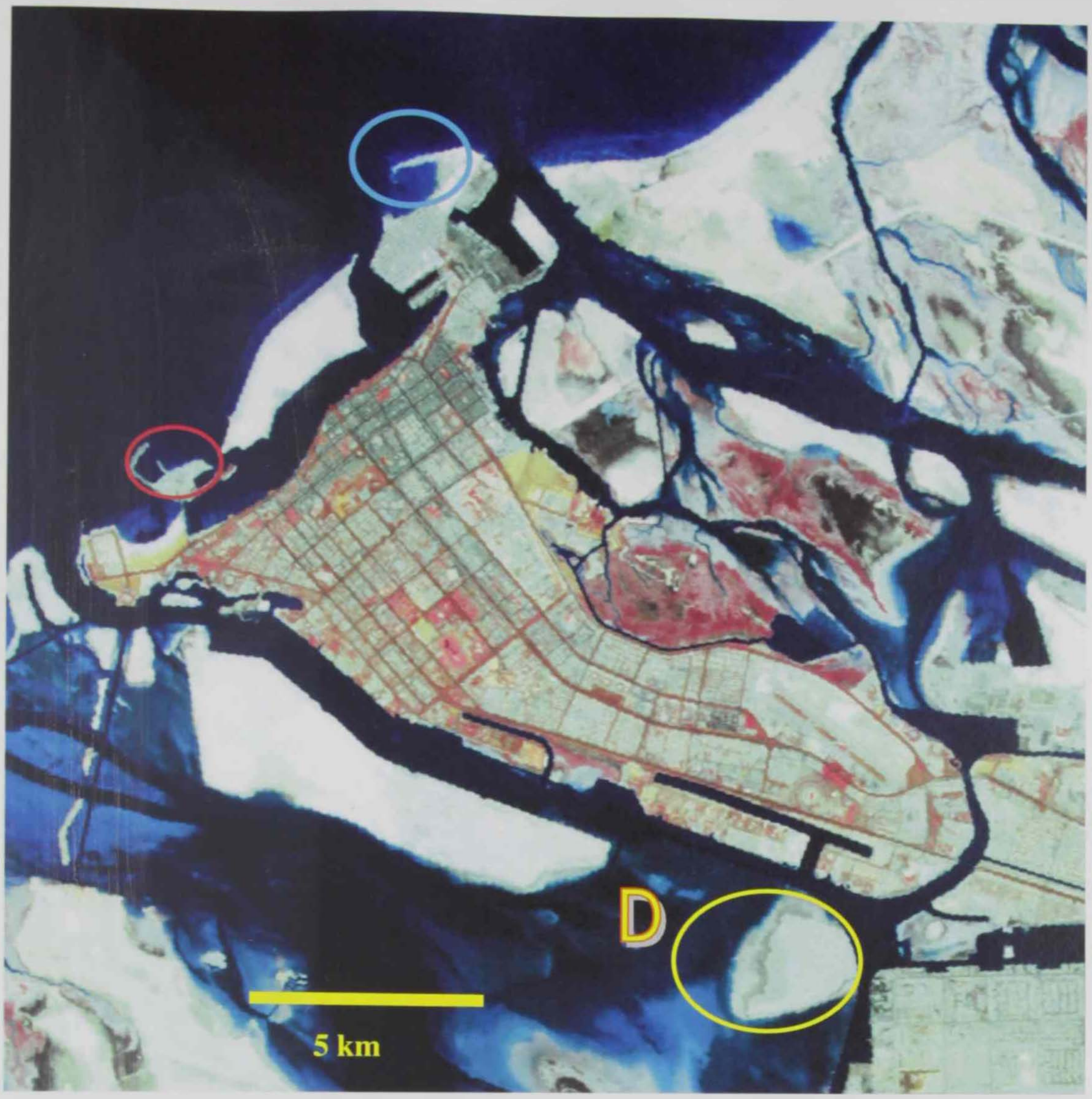


Figure 4-2: A close up of Abu Dhabi Island captured during 2000 by Landsat-7 ETM. The yellow circle shows increase in the small island in the south of Abu Dhabi main city. The red circle shows the land addition in the main sea breaker toward the west of Abu Dhabi city. Blue circle is the additional part of Zayed Port observed in the Satellite image captured in 2000.

One of the main changes is located in the southern part of Abu Dhabi Island. The yellow circle shows the increase in the island size that happened through the period between 1993 & 2000. The increase of sediments in this island is most probably due to the transport of the sediments from the bottom of the surrounding shallow waters. Benthic sediments have been removed from channels in the D area to increase the channels depth and thus allowing for bigger ships to enter the straight of the industrial area of "Musaffah" and to prevent any grounding of the ships.

Towards the western side of Abu Dhabi Island, the red circle marks the second change that happened, and it is again due to land reclamation activities. This area represents the main sea breaker of Abu Dhabi city. The area is very important because many tourist facilities are found in this area. Re-addition of the reclaimed island was due to many other market buildings and shopping facilities which have been built towards the beach.

Figure 4-3 has been taken toward the west in the area of the main sea breaker. It shows the new constructions that have started to appear on the reclaimed area.

Figure 4-3: In the western side of Abu Dhabi Island, new constructions have started to appear on the reclaimed area (2003).

As mentioned in Chapter Two, Mina (Port) Zayed is located in the Northern side of Abu Dhabi Island (city). The continuous development of the port led to an increase in the total area of the port and its facilities. The Port is surrounded by sea water. Thus, the reclamation of some areas in the sea was a matter of importance. The blue circle is the additional part of Zayed port observed in the Satellite image captured in 2000 (figure 4-2). A large and long sea breaker has been created in Zayed port to protect the reclaimed area from sea waves as shown in figure 4-4. There are lots of shops and markets built in this additional land since the project ended.

Figure 4-4: Large and long sea breaker has been created in Zayed Port for protection from sea waves. The photo is showing the main sea breaker in Zayed Port.

Figure 4-5 is a close up of an image of the northern side of Abu Dhabi. It is clear that huge areas represent shallow waters and sequence of typical tidal flats. The shallow islands such as E and F are not urbanized and it is difficult to move through these areas smoothly. Red arrows show some artificial channels which were already dug prior to 1993. In figure 4-6, the channels are extended further at areas close to the coastline.

Figure 4-5: A Landsat-5 TM satellite image of Abu Dhabi Island showing small islands in the northern side captured during 1993.

Figure 4-6 is representing the same area, but the image was captured in 2000 by Landsat-7 ETM. It is very interesting to see that some new islands appeared during the seven years (see red arrows in figure 4-6). The appearance of some of the islands is due to the increase of the bottom sediments within the seawater. Furthermore, we see the extension of new channels through the beach toward the north. These new channels are the completion of the network channels for the purpose of navigation in that area. The sediments in the bottom of these channels have been moved to the close shallow islands and have increase the amount of sediments in that area. Thus, it caused the appearance of new small islands and the connection of some big ones.

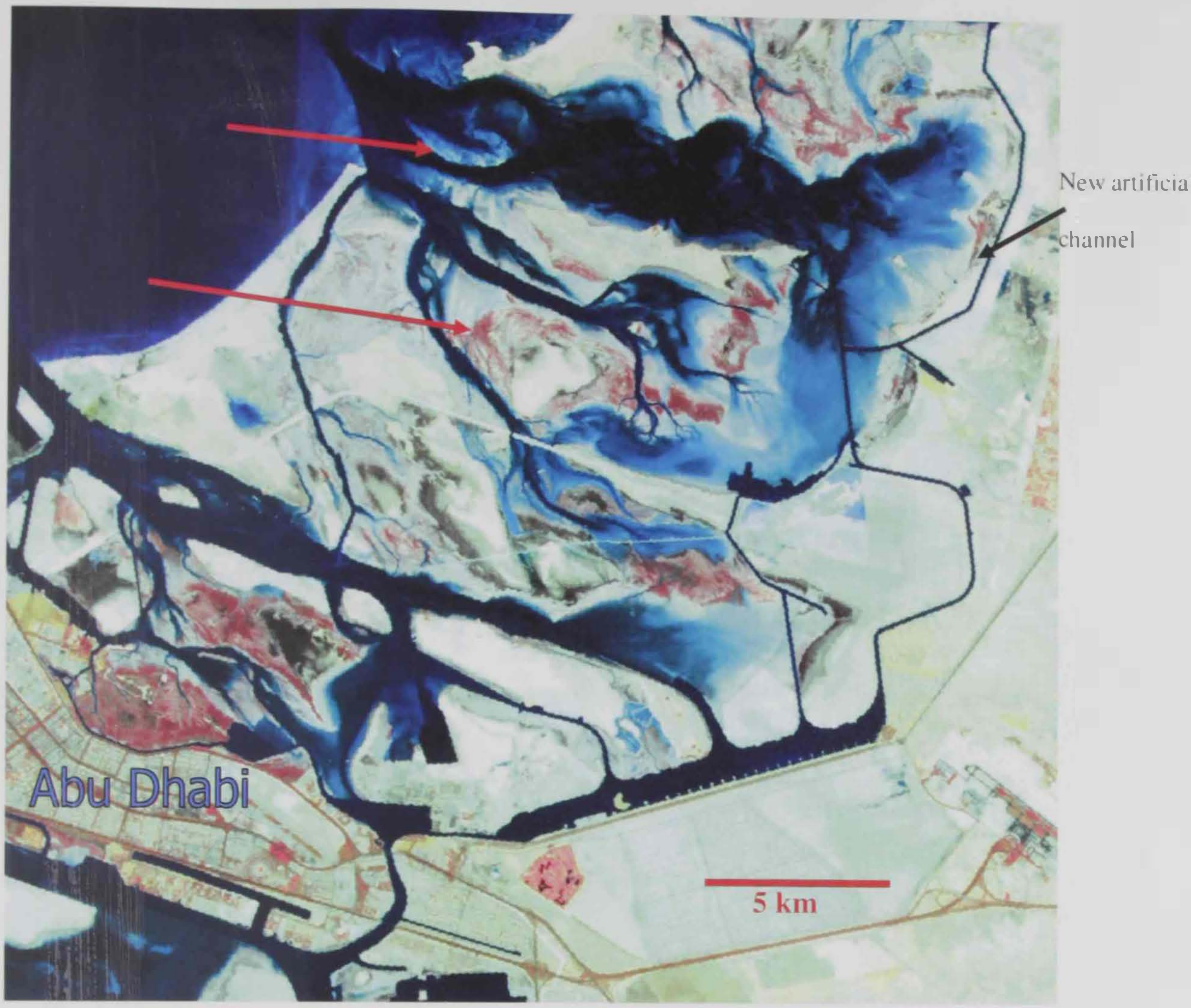


Figure 4-6: A Landsat –7 ETM satellite image of Abu Dhabi coastal zone area. Red arrows showing new islands appeared during the time 1993-2000.

Figure 4-7 is a close up of Al Raha Beach in 1993 which is 30 Kilometers away from Abu Dhabi City. The image was captured by Landsat-5 TM. The length of the whole beach is about 10 kilometers. The coastline along the beach was straight. Figure 4-8 shows a close up satellite image of the same area captured in 2000 by Landsat-7 ETM. The appearance of certain numbers of sea breakers is clear. This has caused a change in the geomorphology along the coastline (or the beach).

Figure 4-7: A close up of Al Raha Beach image captured in 1993 by Landsat-5 TM.

Figure 4-8: A close up Landsat-7 ETM image showing the sea breakers that appeared in the time for the period 1993-2000.

Figure 4-9 is a real example of one of the sea breakers which the government has built for the tourism purpose. The approximate length of the sea breaker is about 200 meters. It consists of hard igneous rocks that were brought from the northern emirates mountains.

Figure 4-9: This is an example of sea breakers along Al Raha Beach. It consists of hard igneous rocks that were delivered from the northern emirates mountains.

Abu Dhabi Golf Club is located very close to Al Raha Beach on the southern side of Al Raha Beach (figure 4-10). This club was built in 1993. Figure 4-11 is a close-up view of the location of Abu Dhabi Golf Club captured by Landsat-5 TM. Note that the location is directly to the east of Abu Dhabi Island. The reason for locating the club outside the main land (Abu Dhabi city) is to allow any extension of the vegetated area at the club in the future.

Figure 4-10: The location of Abu Dhabi Golf Club (close to Al Raha Beach).

Figure 4-11: A close up image of the area of the Abu Dhabi Golf Club at 1993 captured by Landsat-5 TM.

Figure 4-12 shows the Abu Dhabi Golf Club captured in 2000 by Landsat-7 ETM. Visually, we can detect how the cultivation of plants and grass has changed the color of the land. Also, we can determine easily the boundary of the club using a colour index. Black patches in the middle of the club represent the artificial lakes within the club itself.

Figure 4-12: A satellite image captured during 2000 by Landsat-7 ETM. Red color showing the boundary of Abu Dhabi Golf Club.

Figure 4-13 is a picture showing part of Abu Dhabi Golf Club area. It is clear that the green area has been cultivated all over the club. Artificial lakes are obvious at the right hand side of the photo.

Figure 4-13: Abu Dhabi Golf Club area. It is clear that the green area has been on a large scale

During the period of the study the development activity has increased huge areas of construction and housing in the Abu Dhabi Emirate. The building of new houses and settlements was very rapid, so this can be obviously one of the main changes which could be detected in figure 4-14. Figure 4-14 shows part of the new construction which have been built during the time 1993 and 2000. The image has been captured by Landsat-7 ETM in 2000 and it shows clearly the main road and/or high-way between Abu Dhabi and Dubai cities. Shallow beaches are located in the left side of the image.

A new big settlement has been built along the road for Abu Dhabi citizens, the "Al-Shahamah" area. The total length of "Al-Shahamah" is about 25 kilometers along the main road. Note that the settlement was located at a substantial distance from the supratidal zone to prevent future impacts on the foundations of new houses built in the Al Shahamah area.

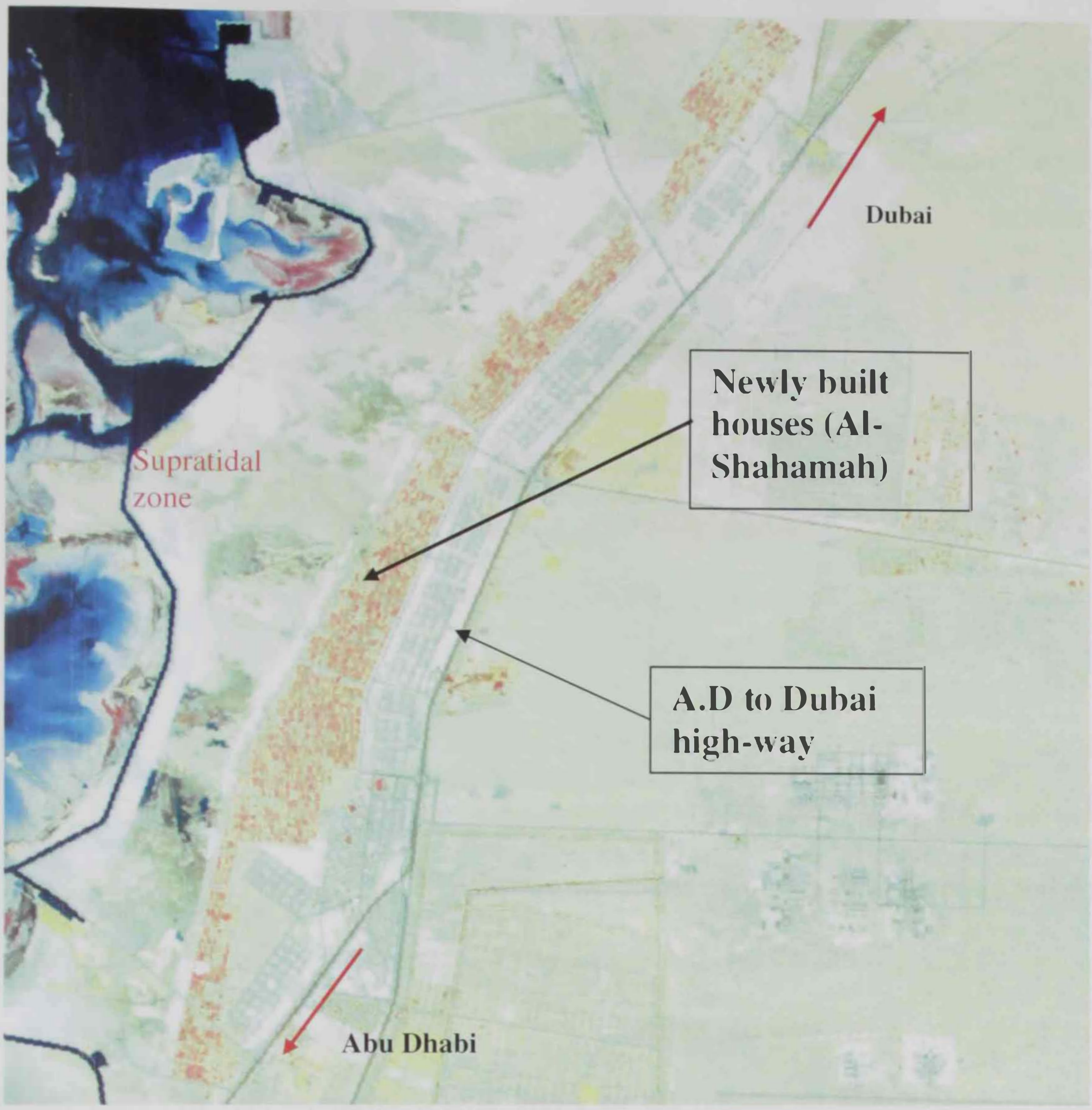


Figure 4-14: Landsat-7 ETM satellite image showing the Al Shahamah area in 2000. New houses in this recently developed area have been built. The total length of Al Shahamah is about 25 km along the high-way.

The new houses are being developed in the direction of the Dubai emirate. Figure 4-15 is a photo showing some of the modern houses in Al-Shahamah area built recently.

Figure 4-15: Al Shahamah area and the newly constructed houses.

Figure 4-16 is one of the important areas located in the coastal zone of the Abu Dhabi emirate. This image which has been taken by Landsat-5 TM in 1993 is for the area of "Ras-Ghanadah". The geomorphology of the area is characterized by a very shallow coast and consists of long subtidal channels. The importance of this area is that it hosts the water desalination plant to supply water to the new houses and is used for irrigation purposes. Thus, the government of Abu Dhabi had to reclaim /or create a huge and long sea breaker to protect the coastline from potential pollution that may come from the sea into the desalination stations section lines (such as oil spill pollution).

Figure 4-16: The area of Ras Ghanadah image captured by Landsat-5 TM during 1993 using bands 2, 3 and 4.

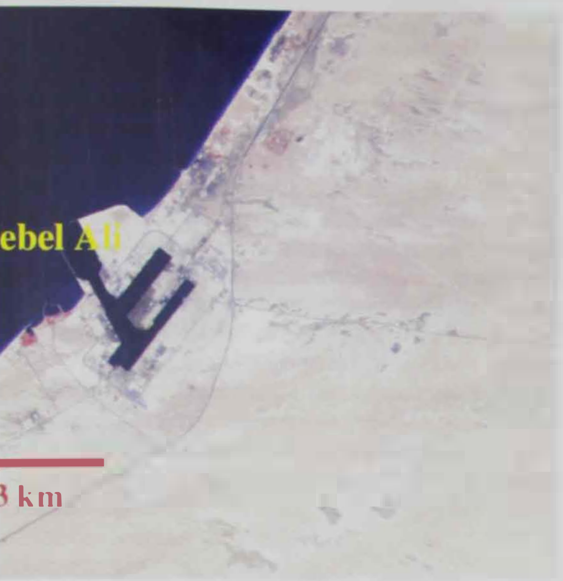
The circle shows a huge and long sea breaker (figure 4-17). The image was captured during 2000 by Landsat-7 ETM.

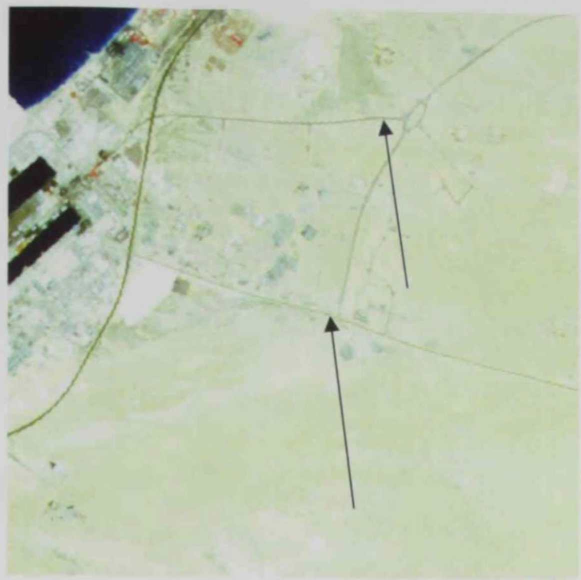
Figure 4-17: The area of Ras Ghanadah image captured by Landsat-7 ETM during 2000 using bands 2, 3 and 4.

4.1.2 Dubai coastal zone

The coastline of Dubai is almost a straight line and has less significant geomorphological changes through the period between 1993 and 2000. The most significant change is the construction of a new high-way connecting the Jebel Ali area with the southern side of Dubai city. The Emirates road was commissioned in the year 2000.

Figure 4-18 is a satellite image of Landsat-5 TM taken in 1993 when there was only one main road to Dubai. Figure 4-19 is a Landsat-7 ETM image captured in 2000. It is noted that there is no significant constructions yet around the newly constructed road. Figure 4-20 is an actual picture of Emirates road captured in 2002.





Figures 4-18 & 4-19: Satellite images of the outskirts of Dubai city showing the newly constructed Emirates road which has been completed during 2000 (black arrows). The left figure is showing the same area before the road construction.

Figure 4-20: Emirates road is one of the most significant changes that has happened in Dubai area during the time between 1993 & 2000. The road starts from Jebel Ali area and finishes in the border of Sharjah City.

Urbanization and settlement in Jebel Ali and the Jumerah area has increased due to large development properties that were needed in the Emirate of Dubai. Figure 4-21 is an image of the Jebel Ali industrial area captured in 1993 by Landsat-5 TM. Seven years later, the development of the area through warehouses, trading buildings, and economic facilities increased. Figure 4-22 shows some of the new areas which have been built recently close to the Jebel Ali industrial area (see arrows). Some of these facilities are close to the main road, as shown in figure 4-23.

Figure 4-21: A Landsat-5 TM satellite image showing Jebel Ali industrial area captured in 1993.

Figure 4-22: A Landsat-7 ETM satellite image showing Jebel Ali area and the port during 2000. Black arrows show the increased area of new buildings and facilities - mostly due to construction work.

Figure 4-23: Newly industrial and trading facilities have been built in the Jebel Ali Free Zone and Jabal Ali Port.

Dubai city is one of the most important cities that has increased its area of development and constructions since the 1970s. The development was mainly along Dubai creek (khor). Figure 4-24 is an image of Dubai city captured in 1993 by Landsat-5 TM. The northern-east side of the creek is called "Deira" and the other side of the creek is called "Bur Dubai". Port Rashid, Dubai International Airport and Jumerah are shown in figure 4-24.

Figure 4-24: Landsat-5 TM satellite image of Dubai City captured in 1993.

Landsat-7 ETM captured the city of Dubai in 2000 (figure 4-25). Comparison between this image and the previous leads us to discover many major changes that happened during the period between 1993 and 2000.

Figure 4-25: Landsat-7 ETM of Dubai City captured in 2000. It is clear that the Airport has been widely developed (black circle). Some other areas have been more cultivated (blue arrows). The red circle is showing an example of an area, which have been developed and built with new constructions.

Among the major changes are those that happened within the Dubai International Airport (black circle). The airport has been widely developed to increase its ability to handle more aircraft. Other parts of Dubai city have witnessed the construction of new houses, buildings, and market facilities. This phenomenon is clear in the area inside the red circle. Dubai Municipality has extended its efforts to cultivate some more areas during the period of 1993 and 2000. Blue arrows show some of the wide areas that have been cultivated in the city to form parks and gardens.

Comparisons between two satellite images of the Jumerah area in Dubai helped in detecting the major changes that happened during the seven year study period. The major changes that happened were: rapid urbanization and development in this particular area. Figure 4-26 shows the area of Jumerah in 1993 as a modern part of Dubai city. Jumerah received big tourist projects, renewal of infrastructure, and housing buildings in the last 20 years.

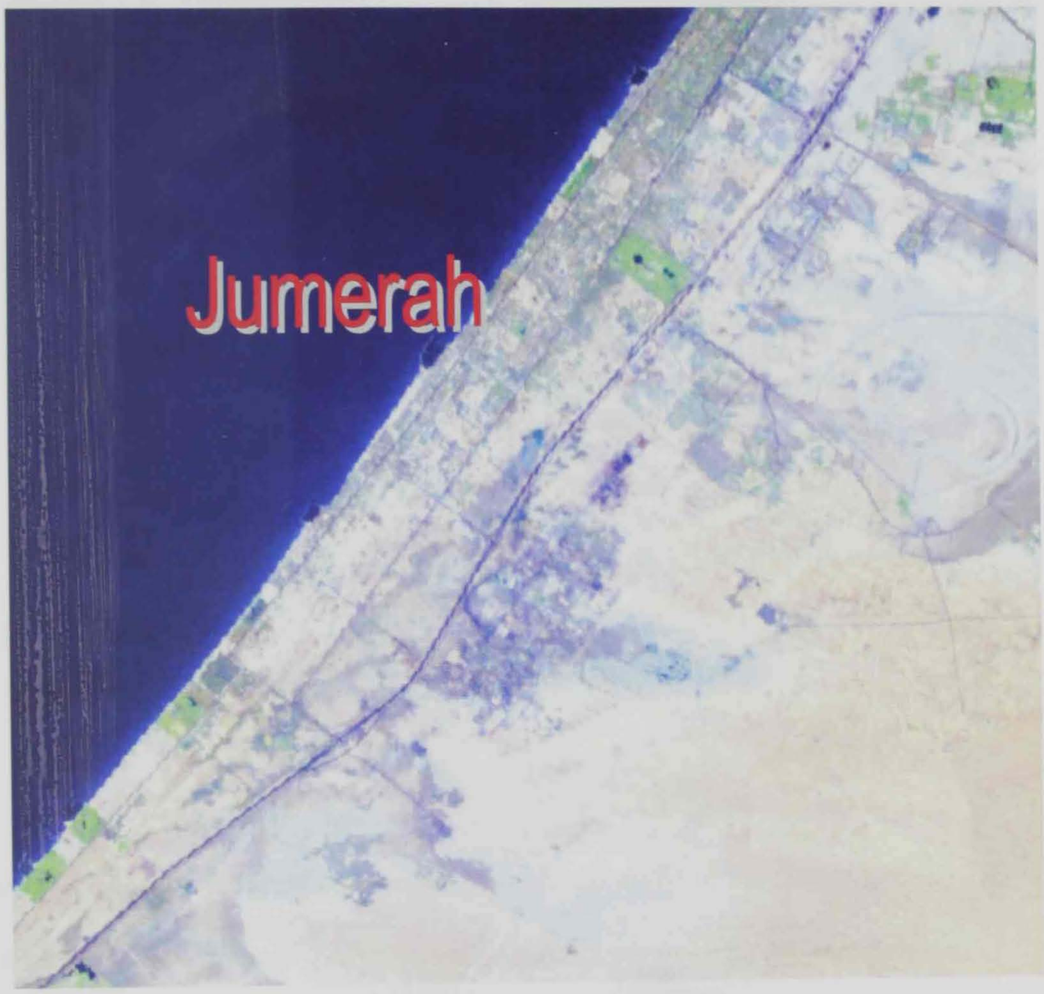


Figure 4-26: The Jumerah area, which is located between Jebel Ali Port and Dubai city. This image has been captured through Landsat-5 TM in 1993 using bands 2, 3 and 4.

Looking at figure 4-27, Landsat-7 ETM in 2000, we can detect two major changes that happened through the time period between 1993 and 2000. The black arrow in the figure shows the new constructions and facilities which were absent in the previous image. On the other hand, blue arrow shows an area which has been cultivated more widely than the past where the Safa Park located. The government of Dubai Emirate is trying to stabilize the urbanization development with less environmental effects by developing green parks and vegetation along the roads.

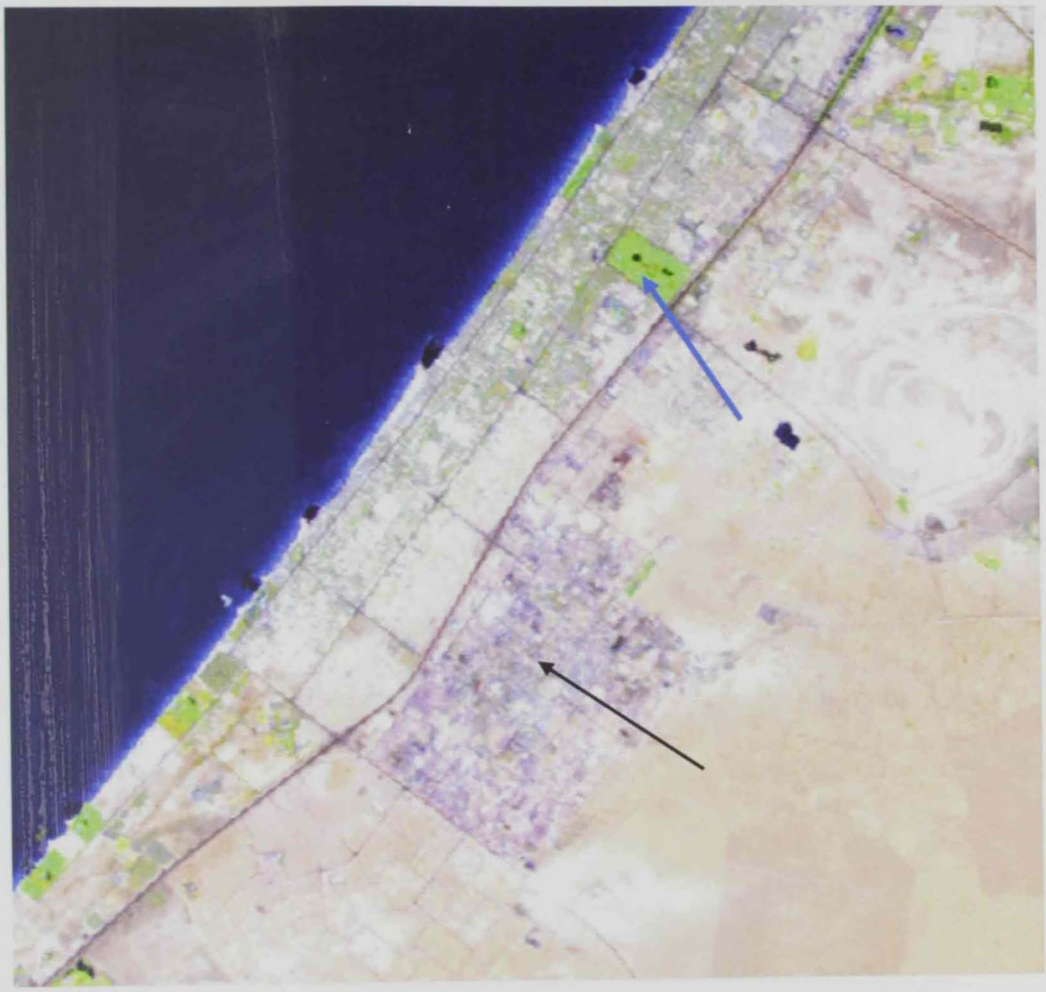


Figure 4-27: The same area captured by Landsat-7 ETM in 2000 using bands 2, 3 and 4. Black arrow shows the new constructions, which have been added through time. Blue arrows are showing the green areas, which have become more abundant in 2000 due to expansion of Safa Park area.

4.2 Overlay of multi-temporal data

Different techniques have been used to detect the changes that occurred in the study area of the coastal zone between the cities of Abu Dhabi and Dubai using two Landsat data sets in 1993 and 2000. This is to enhance our study and results, and also to prove the theories of changes found in some of the discovered areas. Furthermore, different techniques were used to maximize the detection of any possible changes that occurred during the mentioned time.

Using different colors in different images with the same band (band 5) enabled us to highlight the areas which have been "reclaimed" or removed in the study area through the study period. Starting from figure 4-28, which shows the far eastern side of Abu Dhabi island "Main sea breaker" and using such technique; it is easy to determine the amount of the land which has been reclaimed at this area, which is shown by red color. The surface of the new reclaimed area is 1,172,700 m^2, and assuming a 10m thickness, the estimated volume is 11,727,000 m^3 of the reclamation material. The Government of Abu Dhabi (Abu Dhabi Municipality) started to reclaim this area for the purpose of constructing new tourism facilities since 2000. Figure 4-29 is a photo showing an example of huge amount of earth used for these reclamation projects.

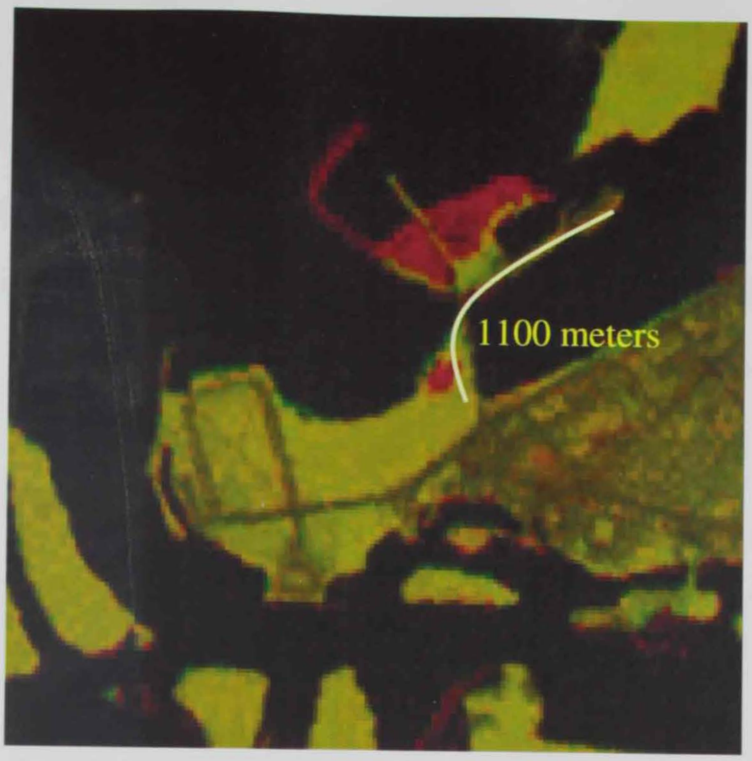


Figure 4-28: The main sea breaker in the western side of Abu Dhabi city. Red color indicates the additional land that has been reclaimed during the time between 1993-2000.

Figure 4-29: Huge amount of earth have been moved and transported to reclaim land from the sea in many parts of Abu Dhabi coastal area. The photo is showing an example of a huge pile of earth which is ready to use for reclamation purposes.

Abu Dhabi coastal zone is one of the shallow zones that faces many human activities of degrading channels through time. The government of Abu Dhabi initiated these channels for navigation purposes and for easy passage of boats through shallow coastal zones. Yellow arrows in figure 4-30 mark some parts of the new channels. The result of dredging the bottom of the sea sediments to near-by islands allowed these small islands to increase in area. In some other places, new shallow islands have merged since 1993. The blue arrow in figure 4-30 shows an example of a newly created island close to Jazirat Al Hel.

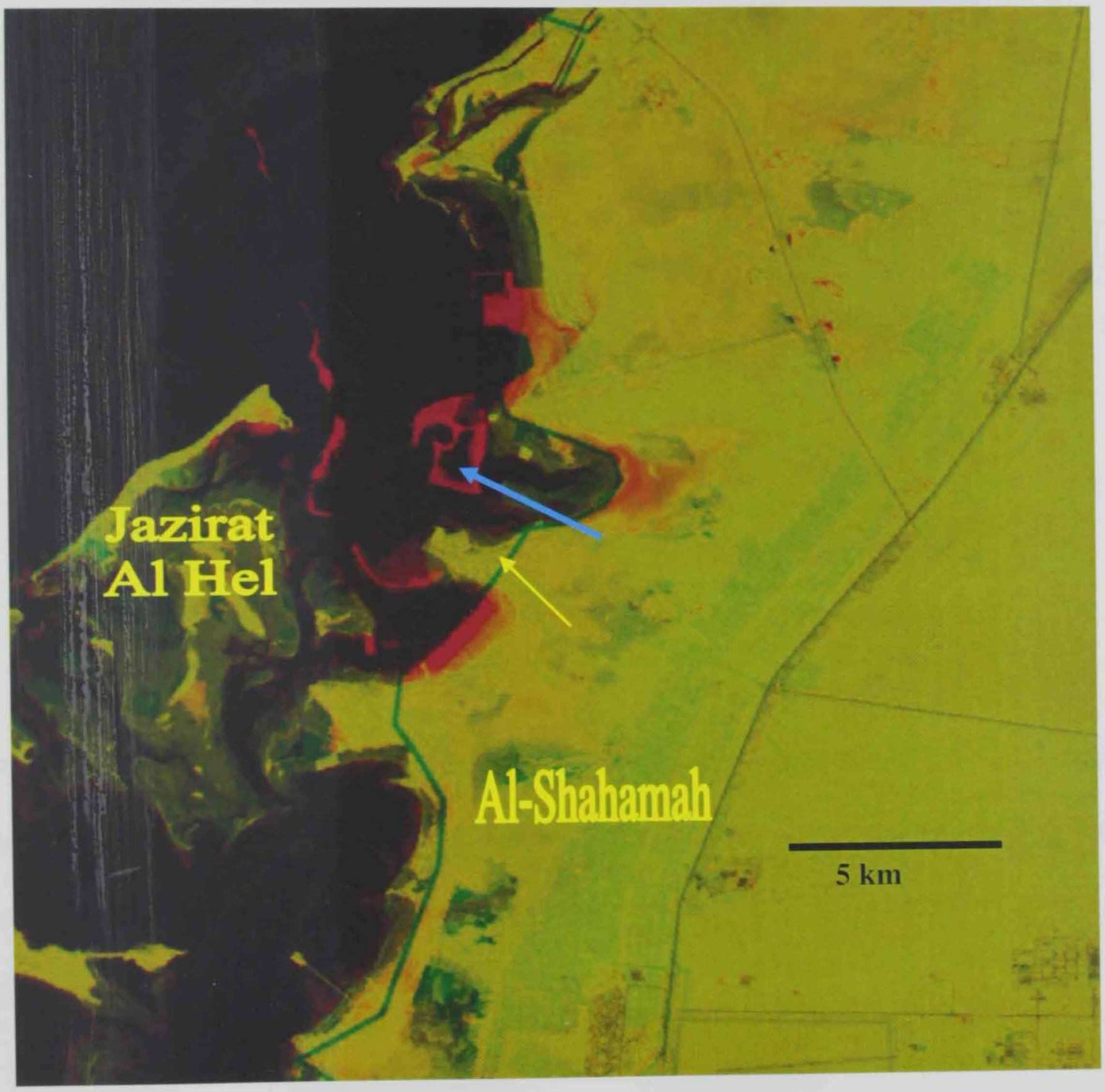


Figure 4-30: The new channels (see yellow arrows) and new small islands close to Jazirat Al Hel (see blue arrow).

Along 'Al Raha Beach', the change in the coastline is clear due to several sea breakers. Figure 4-31 shows some of the sea breakers which have been added all over the beach.

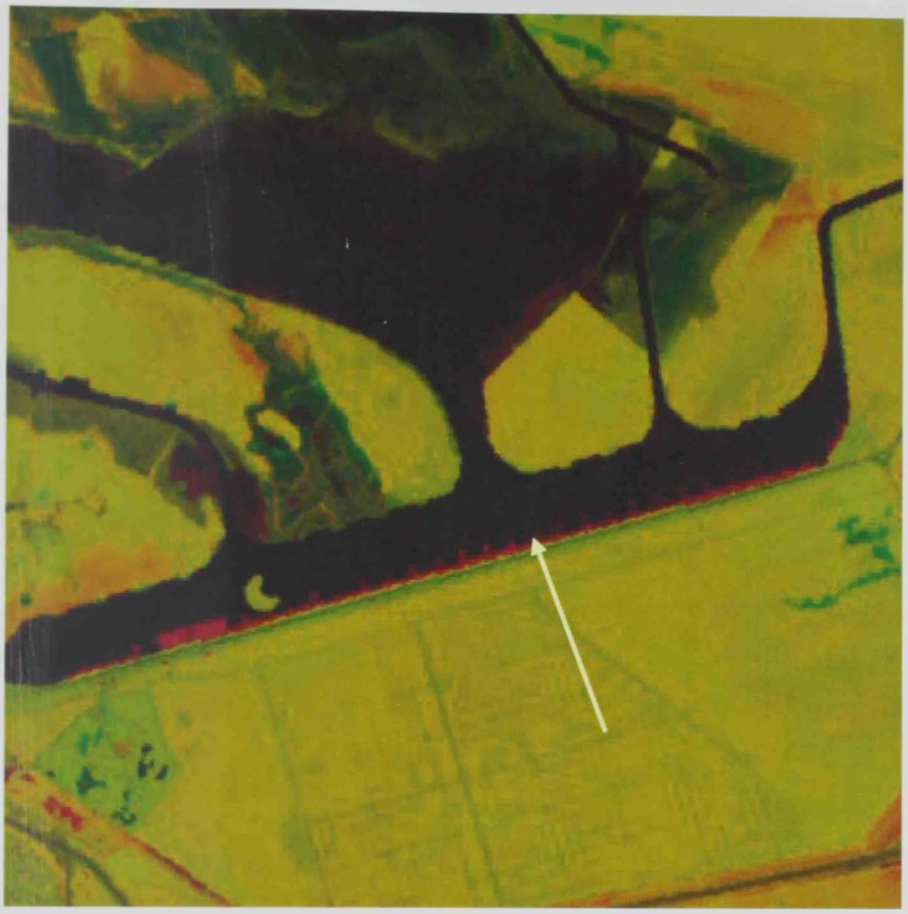


Figure 4-31: The yellow arrow shows the additions of sea breakers along Al Raha beach.

Figure 4-32 shows Ras Ghantut, which is located at the far end of Abu Dhabi Emirate before entering into Dubai Emirate. The red color indicates that during seven years some considerable amount of sediments have accumulated in the area shown in figure 4-32 (yellow arrow). This change was difficult to detect using visual image techniques.

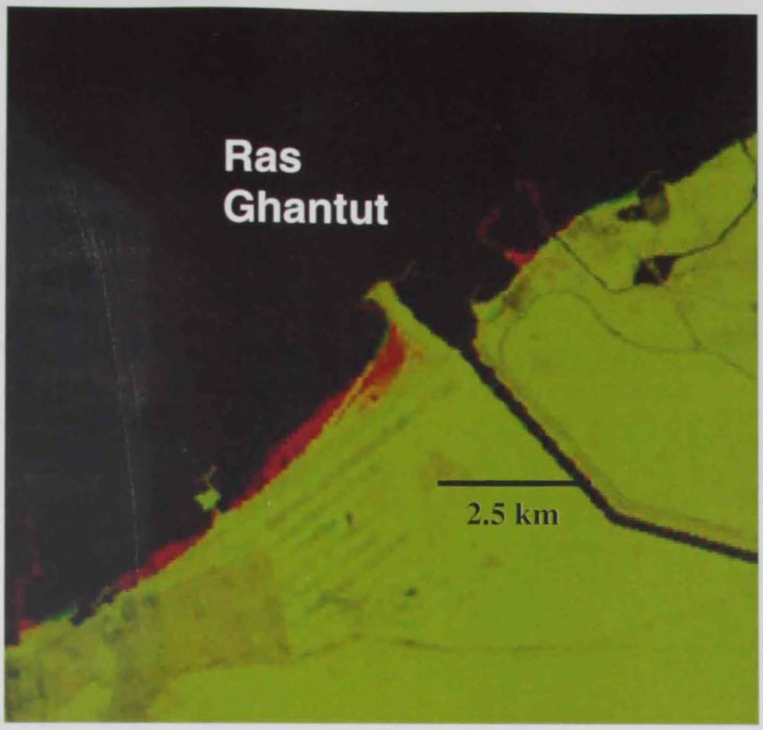


Figure 4-32: Additional land creation (red color) in Ras Ghantut

CHAPTER FIVE

CLASSIFICATION AND DISCUSSION

5.1 Classification

Major geomorphological features can be classified and sorted based on their properties shown in the digital images. That means that similar distinctive colours represent the same feature. The available images were classified using the unsupervised classification technique.

Unsupervised classification is used to sort out the relatively same features together into a certain color. It is used again for the area which cannot be classified –easily- into certain features using supervised classification.

The benefit of unsupervised classification is its ability to detect the changes that have occurred through the time period between 1993 and 2000. Colors in the classified images allow us to identify the extension of the features and their goemorphological or geographical distribution. Un-supervised classification has been used in this process due to many reasons. One of the main reasons is due to the un-accessible areas that lie in some parts of our study area in Abu Dhabi and Dubai. It was quite difficult to reach some areas because they are protected or belong to private proprieties. Furthermore, it is not possible to collect any data in 1993 and sort it into supervised classes. Finally, is was decided to use the unsupervised classification method to analyze the satellite images.

The features have been randomly classified into nine classes. Bands 2, 3, 4, and 5 were used for images, the image of 1993 and the image of 2000. We applied the same parameters of unsupervised classification to both images to get more logic and consistence comparison between the two period. The common parameters used are the band types and number, the iteration number, the classes, number, and we used the same algorithm iso-data. But we have to consider the limitation of the unsupervised classification in term of accuracy and reliability as we are not considering any actual data (ground truth) in the classification process. Although the classification results in many mix-classification feature, still the outcomes of this unsupervised classification could provide us with the general trend of geomorphologic and land feature changes.

Figure 5-1 present a classification analysis applied to an image of the Abu Dhabi coastal zone captured by Landsat-5 TM in 1993. The water surface is grouped into three classes; deep water and two types of tidal zones (shallow and deep), these are much less in depth than the sea water and the shallow tidal or inter tidal zone may consider part of the surrounding islands, which is relatively shallower than the sub tidal zone, as well we consider sub tidal a shallow sea water.

It is clear that many parts of the small islands are considered as "sabkha" or wet land as seen in the figure 5-1. Here again we found out three categories of wet land distinguished by the dominant and associated features such as mangrove, vegetation or urban.

The main-land shows many big economic developments (agriculture, industrial and urban). We can note the sharp changes from reclaimed (under construction) land in 1993 into agriculture and urban activities in 2000. A total of three categories are classified on the main-land; urban, reclaimed land and sand land or undeveloped land.

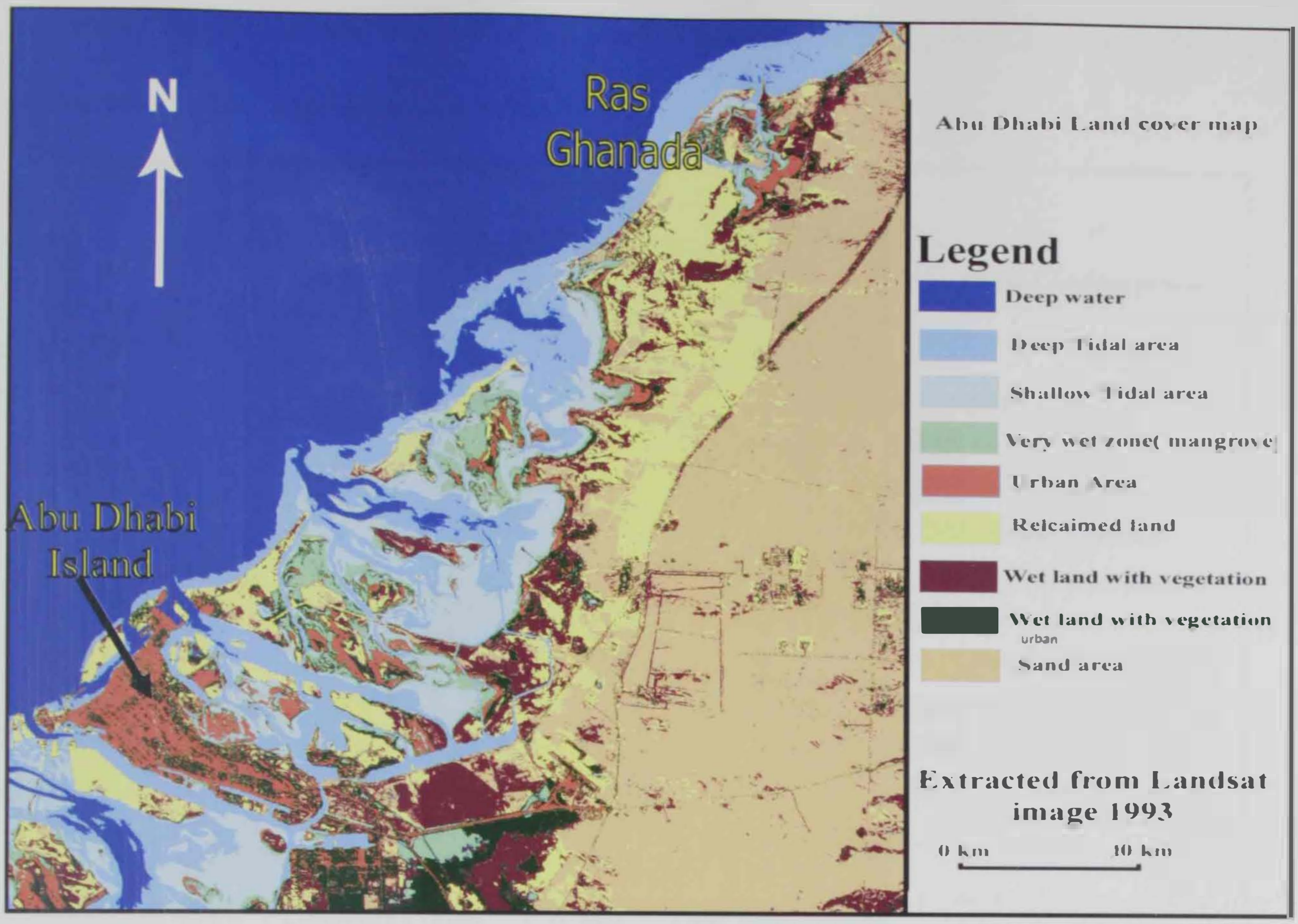


Figure 5-1: Classification analysis applied to image covering Abu Dhabi coastal zone area captured during 1993.

The most important feature that faced significant changes is the coastal zone area. The situation of the water depths has changed within seven years. In figure 5-2, it seems that many major changes happened and large areas of sub tidal or deep tidal zones became inter tidal zones. Black arrows show an example of some areas which become intertidal zones. The most important point here is to distinguish that the deep tidal zone is more abundant in the image of the Abu Dhabi area in 2000. We can't make a decisive conclusion about the reason behind this big change, but both the natural and anthropogenic factors are important and must be considered.

So we can conclude that the bottom depth has decreased through time. On the other hand, some small and narrow areas have increased in water depth due to human activities. This is clear in the southern area of Abu Dhabi Island where the government set a project to increase the depth of that area for the purpose of navigation.

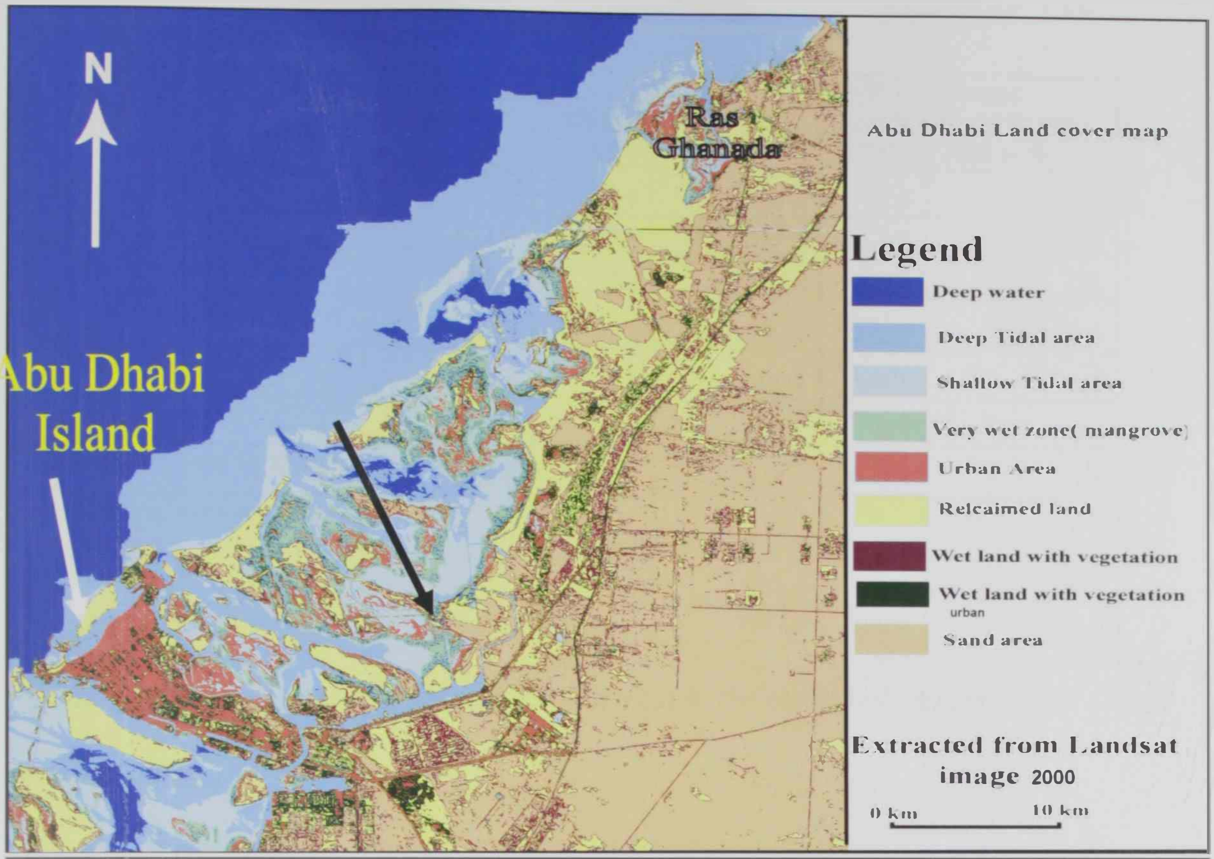


Figure 5-2: Classification analysis applied to image covering Abu Dhabi coastal zone area captured during 2000. Black arrow showing some areas, which became intertidal zones. Abundance of the light blue color is significant in 2000 more than in the classified image of Abu Dhabi in 1993.

Statistical analysis of the classified images of Abu Dhabi:

It is possible to follow up the distribution changes of different features during the time between 1993 and 2000, by calculating the percentage in each image and find out the change in percentage again. The results of classification statistics are as indicated in table 5.1.

From the table 5-1, it is clear that the coastal zone has undergone important changes during the seven years. That lead us to detect the change of the tidal zones around the coastal zone in Abu Dhabi. The increasing area of the subtidal and intertidal zones indicates that the sea level close to the shallow and small islands in Abu Dhabi is in a regression process.

	Area in Km^2 2000	Area % 2000	Area in Km^2 1993	Area% 1993	Change from1993 to 2000 in %
Deep water	952.9	26.9	1321.3	37.2	-10.4
Deep tidal	621.0	17.5	315.0	8.9	8.6
Shallow tidal	188.0	5.3	169.8	4.8	0.5
Very wet with mangrove	114.2	3.2	92.1	2.6	0.6
urban	134.4	3.8	109.2	3.1	0.7
Reclaimed land	414.2	11.7	310.1	8.7	2.9
Wet land with vegetation	205.4	5.8	258.2	7.3	-1.5
Wet land with vegetation & urban	107.7	3.0	147.8	4.2	-1.1
Sand and open land	810.2	22.8	824.4	23.2	-0.4
Total	3547.9	100.0	3547.9	100.0	0.0

Table 5-1: The percentage of the colors (features) in the classified images of Abu Dhabi coastal zone.

On the main-land we note the important change of the reclaimed land, which was under process for economic and social development, and within seven years about 100 Km^2 changed to reclaimed land for urban, infrastructure or agriculture activities. This means a large land area is changing and becoming developed as agriculture or urban sectors. This is also indicated by the decrease of sand land and wet land.

5.2 Detailed Examples: Local change detection, East Abu Dhabi

Among several studied examples, the following would serve as an example to show changes induced to the coastal area either by natural or anthropogenic factors:

Several corrected images were superimposed over each other. The images extended over the period 1972-2006, which is the period that witnessed the major changes in the studied area. The images vector layers have been extracted to show the gradual changes over time. These are shown in the figures 5-3; 5-4 and 5-5.

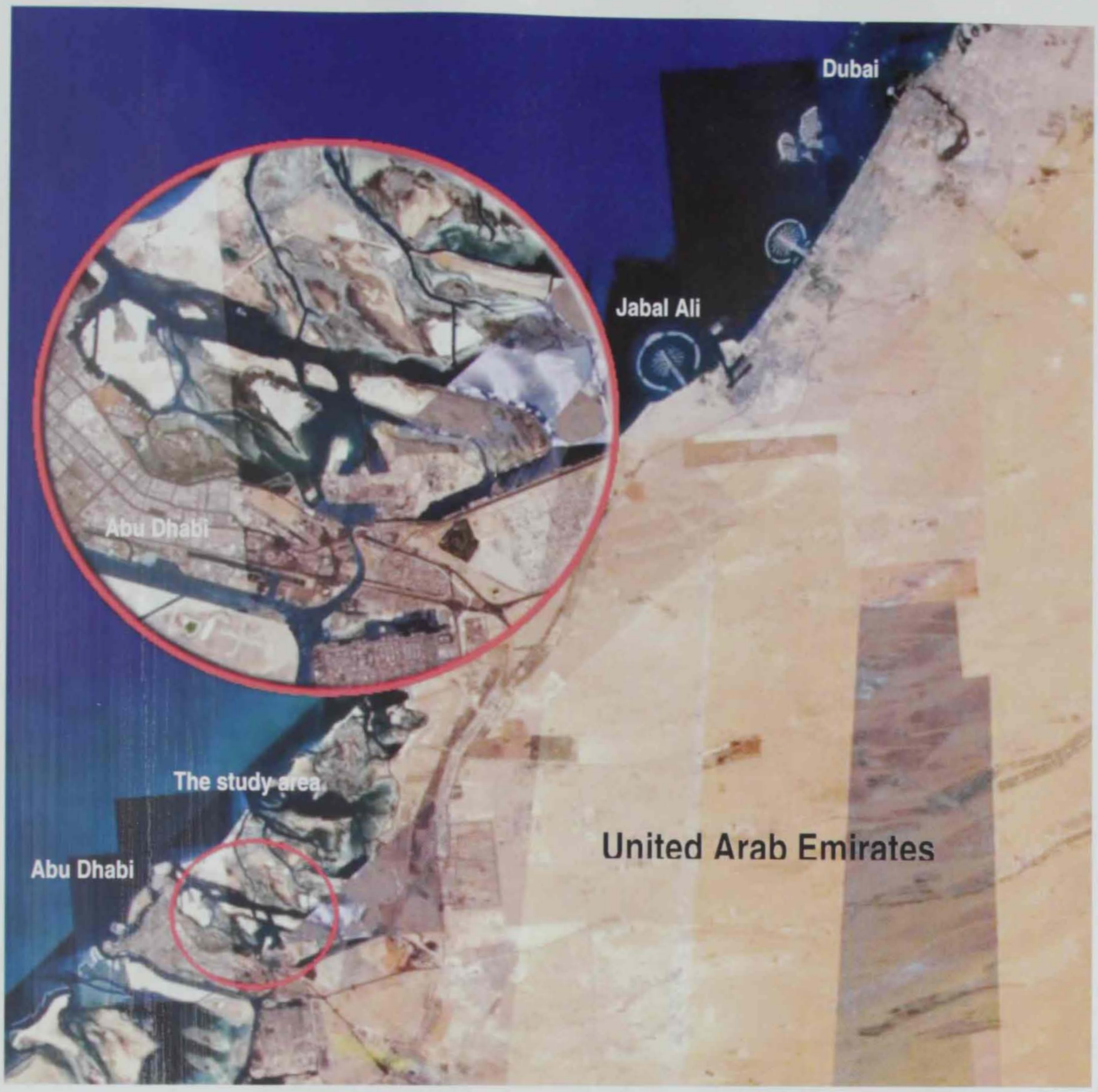


Figure 5-3: Location map of the coastal area between Dubai and Abu Dhabi showing the area under investigation.

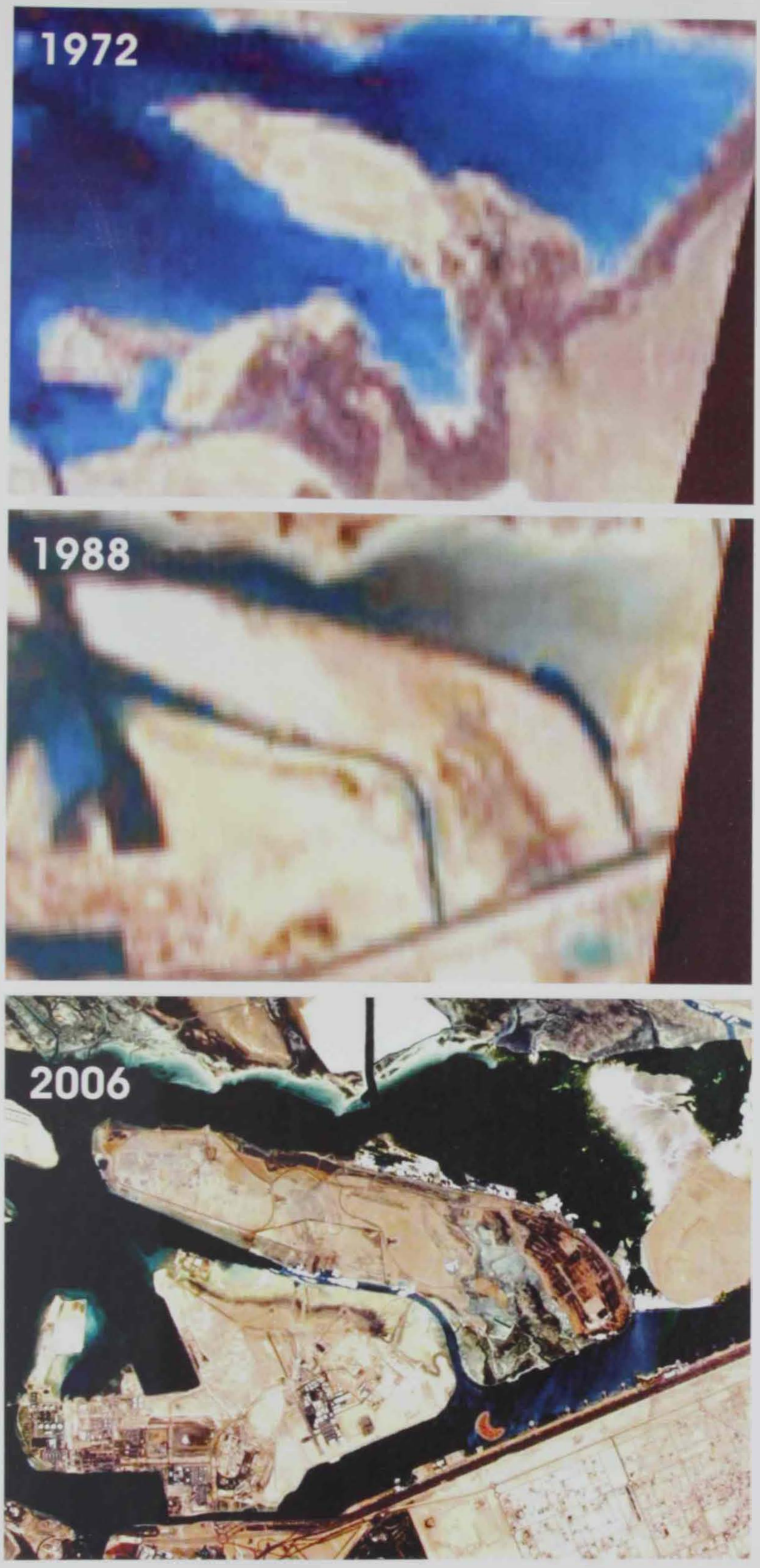


Figure 5-4: Change detection of the study area (1972-2006).

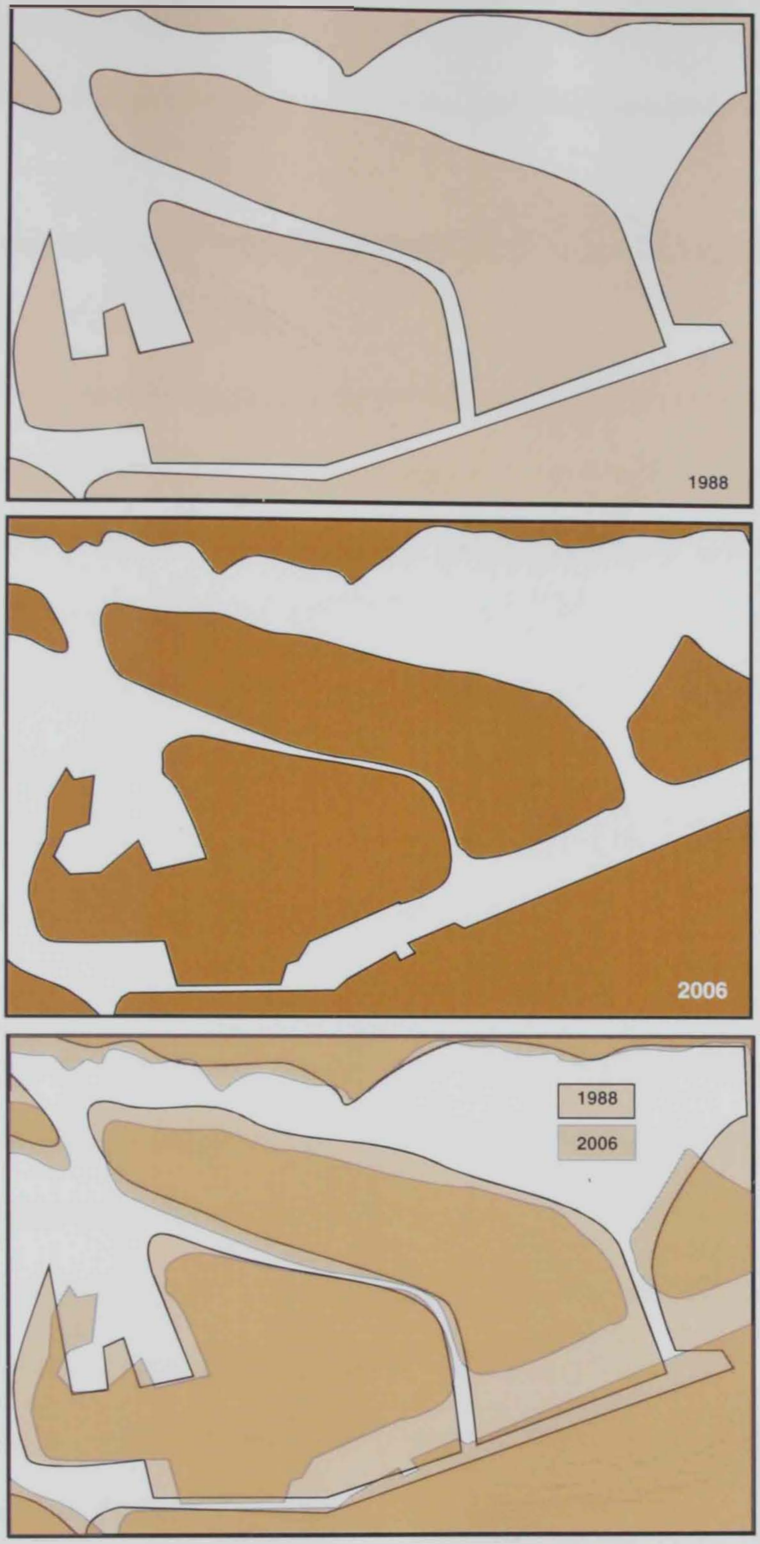


Figure 5-5: Change detection of the study area between 1988 and 2006.

Taking into consideration variations in the spatial resolution and the coarse resolution of the early images, there are several changes that can be detect and probably measured. Some of these changes are:

1. General "trimming" of the coastal area due to natural erosion and human activities such as the construction of seaport facilities.
2. The expansion of the island area at the top of the images. These are normally achieved through the process of sea reclamation and natural accumulation of sediments that are probably eroded from other places in the area due to the different hydrodynamic regimes prevailing in the studied area.
3. Expansion of the canal at the lower part of the images and the construction of several facilities on this canal.

The vectors illustrated in Fig. 5.5 contrast the major changes in the studied images for the period 1988-2006 that can be measured or studied further.

5.3 Discussion

The purpose of this research study is to explore the reliability of remote sensing technology to find out the important changes in terms of land use, land cover and land forms caused by natural and human factors, therefore two aspects of this research will be discussed.

First, the results of this methodology will give us idea about the reliability of remote sensing technology with its different techniques.

Second, the different types of image processing techniques employed will orient future researchers and consultant to adopt the proper remote sensing techniques to be taken in consideration in environmental studies.

Major results

We could conclude many results using remote sensing techniques employed and much new land use and land forms were identified, most of these features were identified by the direct visual interpretation on the screen, however overlay processes using different images (dates) with the same band (band 5) enable us to highlight the areas which have been "reclaimed" or removed in the study area through the study period. Hereafter we list the new and most important features detected.

1. One of the main changes is located in the southern part of Abu Dhabi Island. The increase of sediments in this island is most probably due to the transport of the sediments from the bottom of the surrounding shallow waters, and we can see that the benthic sediments have been removed from channels.
2. The western side of Abu Dhabi Island shows land reclamation activities. This area represents the main sea breaker of Abu Dhabi city. Re-addition of the reclaimed island was due to many other market buildings and shopping facilities which have been built towards the beach.
3. A new, large and long sea breaker has been created in Zayed port to protect the reclaimed area from sea waves.
4. Artificial channels, which were already dug prior to 1993, are extended further at areas close to the coastline.
5. Furthermore, we see the extension of new channels through the beach toward the north. These new channels are the completion of the network channels for the purpose of navigation in that area. The sediments in the bottom of these channels have been moved to the close shallow islands have increased the amount of sediment in that area. Thus, it caused the appearance of new small islands and connection of some big ones.

6. A new big settlement is built along the road for Abu Dhabi citizens, the "Al-Shahamah" area. The total length of "Al-Shahamah" is about 25 kilometers along the main road.
7. The area of "Ras-Ghanadah". The geomorphology of the area is characterized by a very shallow coast and consists of long subtidal channels. The government of Abu Dhabi had reclaimed a huge and long sea breaker to protect the coastline from potential pollution that may come from the sea into the desalination stations (such as oil spill pollution).
8. The coastline of Dubai is an almost straight line and has less significant geomorphological changes through the period between 1993 & 2000. The most significant change is the construction of a new high-way connecting Jebel Ali area with the southern side of Dubai city.
9. Images of 1993 & 2000 showed that urbanization and settlement in Jebel Ali and Jumerah area has increased due to large development properties that were needed in the Emirate of Dubai.
10. The most significant changes are those which happened within the Dubai International Airport. The airport has been widely developed to increase its ability of handling more aircraft. Other parts of Dubai city have witnessed the construction of new houses, buildings, and market facilities.
11. Dubai Municipality has extended its efforts to cultivate some more areas during the period of 1993 and 2000; this takes the form of parks and gardens.
12. Jumerah area in Dubai has undertaken major changes in the form of rapid urbanization and development (big tourist projects, renewal of infrastructure, and housing buildings)
13. The overlay technique helped us to identify and calculate the volume of reclaimed area in the eastern side of Abu Dhabi island "Main sea breaker".
14. The government of Abu Dhabi initiated navigation channels for easy passage of boats through shallow coastal zones. The result of dredging the bottom of the sea sediments to

near-by islands allowed these small islands to increase its area. In some other places, new shallow islands have merged since 1993, such as an example of a new created island close to Jazirat Al He. We used overlay techniques to show these new features around Abu Dhabi Island.

15. Based on the classification process, we could distinguish nine classes, three classes of surface water, three classes of wet land, and three classes of "main land".
16. The most important feature that faced significant changes is the coastal zone area.
17. The major changes happened on the large areas of sub tidal or deep tidal zones, which have become inter tidal zones.
18. We distinguished that the sub tidal zone is more abundant in the image of the Abu Dhabi area in 2000. So we can conclude that the bottom depth has decreased through time.
19. On the other hand, some small and narrow areas have increased in water depth due to the human activities. This is clear in the southern area of Abu Dhabi Island.
20. The results of classification statistics lead us to conclude that the sea level close to the shallow and small islands in Abu Dhabi is in a regression process.
21. on the main-land we note the important change of the reclaimed land, which was under process for economic and social development, this means a large land area is changing and becoming developed as agriculture or urban sectors. This is indicated by the decrease of sand land and wet land.

We conclude that many results of change were detected, and we can tell with confidence that the study area is undergoing dramatic changes, so careful planning development is required to preserve the environment and its different resources.

CHAPTER SIX

SUMMARY AND RECOMMENDATIONs

6.1 Summary

- United Arab Emirates (U.A.E) is located in the south-east side of the Arabian Gulf.
- The capital of the U.A.E – Abu Dhabi – is the largest Emirates, and Dubai is the city of economy and tourism.
- Regional maps have been developed and corrected through time.
- The U.A.E is a desert climate and characterized by hot weather, with rare natural vegetation
- The study area is characterized by presence of coastal sabkhas and sandy plains.
- Through out the history of the U.A.E, human impact have played a great role to effect on the geomorphology, vegetation, and the coastline in the study zone.
- Remote Sensing is a method/tool which has been used to approach the theory of change detection.
- Two satellite images from two different times have been used to detect all the possible changes that have happened through the time period between 1993 and 2000 in the coastal zone between the cities of Abu Dhabi and Dubai.
- Images has been processed and interpreted in different ways.
- Visual change detection, over-lays of multiple temporal data, principal component, classification, and special filtering are the methods which have been used to identify all the possible changes that have happened within 30 meters image resolution.
- Abu Dhabi Island has been expanded in its area due to continuous reclamation projects.
- Abu Dhabi Island has been expanded due to the dredging of the bottom shallow sea sediments.

- Artificial channels between the tidal flats caused appearance of come new shallow islands.
- Al Raha beach is a typical example of changing the geomorphology of the coastline because of the number of sea breakers which have been added over the beach.
- Large areas of vegetation have been added and cultivated due to tourism projects such as the Abu Dhabi Golf Club.
- Development of new housing, roads, and trading facilities are one of the largest factors that affected the area of study.
- Using different methods helped us to detect the maximum changes which happened within the 30 m resolution.
- The visual interpretation method gave more reliable results in this study, still the author believes that supervised classification is the best method of change detection because it gives us more accurate data for the coastal and land zones.

6.2 Recommendations

The Government of the United Arab Emirates is pushing all efforts and care to the environment on both the desert and marine sides. The coastal zone between Abu Dhabi and Dubai cities is one of the most important areas in the U.A.E which has faced obvious and major changes through time. Using satellite imagery data of that particular area leads us to the importance of studying the nature of the zone from different points of view. Days over days, the development of the infrastructure and facilities have increased rapidly. This development had a powerful and direct effect on the environmental elements in the area of the study. In fact, the development did not effect the environment negatively. It has had left positive fingerprints in some areas as some vegetation has been increased. Abu Dhabi and Dubai Governments did their best efforts to use the sabkhah's areas, since it was not able to be used a few years ago.

The thesis concentrates on the major changes that happened from the year 1993 to the beginning of the present century. It is our duty to mention that the time period after the year 2000 was full of changes and developments in the study area. For example, the coastline of Abu Dhabi has been changed due to more reclamation along the western coast of Abu Dhabi island. Furthermore, the Dubai government has added most of its buildings and facilities along the coastline towards the Abu Dhabi Emirate. From these points, it is necessary to build a data base which shows and controls the location, speed, and volume of the changes happening through time using higher resolution of satellite images.

Finally, it is possible to apply the methods used in this thesis on other areas in the U.A.E. to detect all the possible changes – either natural or made by human activities.

References:

Abu Dhabi Municipality and Town Planning, Green Process Landmarks, 1996.

ADCO PDD Technical Library, Reference: REP 1798, 1987.

ADMA-OPCO, A Preliminary Ecological Survey of the Coastline of Abu Dhabi, United Arab Emirates, July, 1982.

4- Alec W., Illustrated Dictionary of Geology, 1995.

5- Anthony K., GeoArabia, Pleistocene Carbonate Seif Dune and Their Role in the Development of Complex Past and Present Coastlines of the U.A.E., vol.3, No. 1, 1998.

6- Asborne P., Desert Ecology of Abu Dhabi, 1996.

7- Azab M. A. and Noor A. M., Change detection of the North Sinai coast by using remote sensing and geographic information system, 2004.

8- Cracknell A. P., Remote sensing techniques in estuaries and coastal zones – an update, International Journal of Remote Sensing, vol. 19, no. 3, 1999.

9- Dury S.A., Image Interpretation in Geology, 2nd edc, 1993.

10- E.R Mapper User Guide, Earth Resources Mapping PTY Limited L.T.D, September 1998.

11- Europa Technologies (Google Earth Image), 2006.

12- Ghanem S., Aspinall S., United Arab Emirates: A new perspective, 2001.

13- Glennie K.W., Desert Sedimentary Environment, ADCO PDD Technical Library, 1966.

14- Glennie K.W., Geology of Abu Dhabi, 1996.

15- Harahsheh H., Remote sensing Course, 2002.

16- Harahsheh H., Remote Sensing Technology and its Application – Course -, Department of Geology, Faculty of Science, United Arab Emirates University, 2000.

17- Hussein Q., Editors: David P., Hasan Al-N., Peter H., Archaeology of the United Arab Emirates, , Zayed Center for Heritage and History, 2001.

18- International Journal of Remote Sensing, Relation between river dynamics and coastal changes in Albania: An assessment integrating satellite imagery with historical data, vol. 20, no. 3, 1999.

19- James B. C., Introduction to Remote Sensing, 2nd edition, Virginia Polytechnic Institute and State University, Taylor and Francis, London, 1996.

20- JI C.Y., Qinhuo L., Danfeng S., Sheng W., Pei L., Xiaowen L., Monitoring urban expansion with remote sensing in China, International Journal of Remote Sensing, vol. 22, no. 8, 2001.

21- Kendall C.G. St. C., John D.D., & Venkat L., Alsharhan A.S. and Whittle G.L., Using Satellite Data & GIS in Geomorphological Mapping of Coastal Phenomena in an Arid Environment: Khor Al Bazam, U.A.E., Published in: Desertification in the Third Millennium. Edited by A. S. Alsharhan, W.W. Wood, A.S. Goudie, A. Fowler and E.M. Abdellatif, 2003.

22- Keven W., El Asmar H.M., Monitoring Changing position of coastline using Thematic Mapper imagery, an example from the Nile Delta, 1998.

23- Khawlie M., Awad M., Shaban A., Bou Kheir R., Abdallah C., Remote sensing for environmental protection of the eastern Mediterranean rugged mountains area, Lebanon, Journal of Photogrammetry & Remote Sensing, 2002.

24- Koch M., Geological controls of land degradation as detected by remote sensing: a case study in Los Monegrose, north-east Spain, International Journal of Remote Sensing, vol. 21, no. 3, 2000.

25- Kwarteng A.Y., Chavez P. S., Change detection study of Kuwait City and environs using multi-temporal Landsat Thematic Mapper data, International Journal of Remote Sensing, , vol. 19, no.9, 1998.

26- Madhavan B.B., Appraising the anatomy and spatial growth of the Bangkok Metropolitan area using a vegetation-impervious-soil model through remote sensing, Sachio Kubo, International Journal of Remote Sensing, vol. 22, no. 5, 2001.

27- Marycke J., The Green Guide of the Emirates, 1991.

28- Mas J.-F., Monitoring land-cover changes: a comparison of change detection techniques, International Journal of Remote Sensing, vol. 20, no. 1, 1999.

29- Michele Barrault, The United Arab Emirates, 2000.

30- Ministry of Information and Culture, The United Arab Emirates Hand Book, 1996.

31- Munyati C., Wetland change detection on the Kafue Flats, Zambia, by classification of a multitemporal remote sensing image dataset, International Journal of Remote Sensing, vol. 21, no. 9, 2000.

32- Nasr S., El-Raey M., An assessment of natural and human-induced changes along Hurghada and Ras Abu Soma coastal area, Red Sea, Egypt, H. I. El-Gamily, International Journal of Remote Sensing, , vol. 22, no. 15, 2001.

33- Peter J. M., Alastair R.H., Development of a systematic classification scheme of marine habitats of facilitates regional management and mapping of Caribbean coral reefs, Biological Conservation, 1999.

34- Peter A.S., Don G.B., Clyde H.M., Carbonate Depositional Environments, 1984.

35- Read J. M., Lam N. S-.N., Spatial methods for characterizing land cover and detecting land-cover changes for the tropics International Journal of Remote Sensing, vol. 23, no. 12, 2002.

36- Richard P., The U.A.E. The Business Traveler's, 2000.

37- Riley R. H., Phillips D. L., Schuft M. J., Garcia M. C., Resolution and error in measuring land-cover change: effects on estimating net carbon release from Mexican terrestrial ecosystems, International Journal of Remote Sensing, vol. 18, no. 1, 1997.

38- Ryznar R.M., Wagner T.W., Using remotely sensed imagery to detect urban change: viewing Detroit from space, American Planning Association. Journal of the American Planning Association, vol. 67, 2001.

39- Sabins F., Remote sensing – principles and interpretation, third edition, 1997.

40- Serneels S., Sadi M. Y., Lambin E. F., Land cover changes around a major east African wildlife reserve: the Mara Ecosystem (Kenya), International Journal of Remote Sensing, vol. 22, no. 17, 2001.

41- Shinn E., Carbonate Depositional Environments, Edited by: Peter A. Scholle, Don G. Bedont, Clyde H. Moore, page 171, 1983.

42- The National Atlas of the United Arab Emirates, U.A.E University, 1993.

43- Theobald D.M., GIS concepts and Arc GIS methods, first edition, Natural Resource Ecology Laboratory. Colorado State University, 2003.

44- The U.A.E ministry of information and Culture, United Arab Emirates, Year Book 2003.

45- Thomas M.L, Ralph W.K., Remote Sensing and Image Interpretation, 4th edition. 2000.

46- Valairat W., Promchit T., Boonrak P., Change Detection in Coastal Zone by Remote Sensing Technique, Land Development Department, Ministry of Agriculture and Cooperatives, Thailand, 1995.

47- Western A.R., The Flora of the United Arab Emirates -An Introduction-, 1989.

48- www.strata.geol.sc.edu

49- Xiuwan C., Using remote sensing and GIS to analyze land cover change and its impacts on regional sustainable development. International Journal of Remote Sensing, vol. 23, no. 1, 2002.

50- Zainal A. J. M., Monitoring Marine Ecological Changes on the East Coast of Bahrain with Landsat TM, 1993.