INVESTIGATING TIME SERIES SHORELINE CHANGES BY INTEGRATION OF REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS

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ABSTRACT

INVESTIGATING TIME SERIES SHORELINE CHANGES BY REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS

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Spatial analyses of shoreline recession and accretion, and future shoreline position predictions in coastal countries have considerable importance due to engineering, planning, management and environmental concerns. In spite of this importance, there are only a few studies in Turkey.

The aim of this thesis are to determine the shoreline rate-of-change of Büyük Menderes Delta, by geographical information systems for the last fifty-year period, in order to approximate future shoreline position of Büyük Menderes Delta shoreline, and to evaluate appropriate models while predicting the future shoreline position.

To achieve the purpose of the study time series shoreline position data is extracted from three sets of topographic maps belonging to 1954-1957, 1977-1978 and 1993 aerial photographs and two sets of high resolution satellite imageries (January 2002 Ikonos, August 2004 QuickBird). Then “Coastal” script of TNTMips, which uses some statistical shoreline analyses methods, that are End Point Rate (EPR), Average of Rates (AOR), Linear Regression (LR) and Jackknifing (JK) is edited so that it can locate the future shoreline positions on the map. Suitable baselines are created and appropriate transect intervals are decided to analyze the shoreline. Finally, some additional analyses that are Backward Analysis and Oscillation Analysis are done to obtain most suitable future shoreline position with rate-of-changes. The results showed that, shorelines having different geomorphologic characteristics needed to be analyzed separately and the linear methods to model the future shoreline position differ from one geomorphologic region to another.

Keywords: Delta progradation, shoreline rate-of-change analysis, shoreline prediction methods, Büyük Menderes, Geographic Information Systems.

ÖZ

ZAMAN SERİSİ KIYI ÇİZGİSİ DEĞİŞİMLERİNİN UZAKTAN ALGILAMA VE COĞRAFİ BİLGİ SİSTEMLERİ KULLANILARAK İNCELENMESİ

FULAT, İhsan Alper
Yüksek Lisans, Jeodezi ve Coğrafi Bilgi Teknolojileri Ana Bilim Dalı
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Kıyı ülkelerinde kıyı şeridi ilerlemesi ve gerilemesinin mekansal analizi ve gelecek kıyı şeridi pozisyon tahmini mühendislik, planlama, yönetim ve çevre konularında büyük önem taşımaktadır. Buna rağmen bu tür çalışmalar ülkemizde kısıtlı sayıda, kalmaktadır

Bu tezin amacı Büyük Menderes Deltası kıyı çizgisinin son elli yıllık değişim hızını coğrafi bilgi sistemleri kullanarak hesaplamak, Büyük Menderes Deltası kıyı çizgisinin gelecekteki kıyı çizgisi pozisyonunu tahmin etmek ve gelecek kıyı çizgisi pozisyonunu modelleyebilmek için uygun yöntemleri değerlendirmektir.

Bu amaca ulaşabilmek için, 1954-1957, 1977-1978 ve 1993 hava fotoğraflarından üretilmiş üç setlik topografik haritadan ve iki setlik uydu (Ikonos Ocak 2002, QuickBird Ağustos 2004) görüntüsünden zaman serisi kıyı çizgisi pozisyon verisi çıkarılmıştır. Daha sonra TNTMips programının End Point Rate (EPR), Average of Rates (AOR), Doğrusal Regresyon (LR) ve Jackknifing (JK) gibi istatistiksel kıyı şeridi analizi yöntemleri kullanan "Coastal" yazılımı, gelecek kıyı pozisyonlarını gösterecek şekilde değiştirilmiştir. Son olarak değişim miktarları ile en uygun "gelecek kıyı çizgisi pozisyonu"nu elde etmek amacıyla Geri Analiz ve Osilasyon Analizi gibi başka analizler de yapılmıştır. Sonuçlar farklı jeomorfolojik özelliklere sahip kıyı çizgilerinin ayrı ayrı analiz edilmesi gerektiğini ve uygun doğrusal analiz yöntemlerinin Farklı jeomorfolojik özelliklere sahip kıyıları modellemek için farklı istatistiksel yöntemler önerilmiştir.

Anahtar Kelimeler: Deltanın ilerlemesi, kıyı çizgisi değişim analizi, kıyı çizgisi tahmin yöntemleri, Büyük Menderes, Coğrafi Bilgi Sistemleri

To My Family

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INTRODUCTION

1.1. Purpose and Scope

Spatial analysis of shoreline recession and accretion, and future shoreline position predictions in coastal countries have considerable importance for engineering studies (Süzen and Özhan, 2003), economic resources, insurance industry (ex: Evaluation of erosion hazards, April 2000, prepared for FEMA by The Heinz Center), planning and management problems, biological and ecological studies and wildlife protection. “General impacts from the rapid expansion of unplanned coastal activities include: alteration and loss of coastal habitats; increased erosion, sedimentation and pollution; dramatic changes in vegetation cover; deteriorating water quality; loss of traditional public access to the coast; rising land prices and property taxes; displacement of traditional coastal activities and livelihoods; and shifting demographics of coastal communities” (Coastal Zone Planning in Nova Scotia – Policy Backgrounder RCIP Rural Policy Forum – February 17-19, 2005*).* In spite of the importance of the shoreline change analysis studies, there are only a few studies in Turkey such as Çetin et al. (1999) Süzen and Özhan (2003), Süzen and Rojay (2005).

For thousands of years, South-Western Anatolian lands had been serving as a settlement area and especially as an *emporium*. Many harbor cities like Ephesus, Heracleia, Miletos and Priene are constructed in South-Western Anatolia. These harbor cities are now seen apart from the present shoreline. Actually Miletus and Priene started to loose their importance’s as coastal trade centers by the end of the Roman Era (personal communication, Erciyas (2005). This results from the sediment accumulation brought by Büyük Menderes and Küçük Menderes Rivers. In Figure 1.1 the ancient (archaeological) shorelines and harbor cities relative to the study area are presented.

Figure 1.1. Location Map of the study area within the Aydın province, and the ancient shorelines and antiques harbor cities (1.Ion-Hellenistic Era (~8thCentury BC-133BC) 2.Roman Era (133BC-~4thCentury) 3.End of Old Ages) (modified from Kraft et al., 1981).

The aim of this thesis is to determine the shoreline rate-of-change of Büyük Menderes Delta, by Geographical Information Systems for last fifty-year period and to approximate future shoreline position. In order to reach this goal, data from different sources and periods are utilized to prepare time series shoreline position data. A baseline is created behind all the shorelines representing the general trend. Then, transects (line segments vertical to the baseline) crosscutting all the shorelines are created in order to measure the distance between the successive shorelines. These measured distances represent how the shoreline is changing through time (Danforth and Thieler, 1992; Thieler et al., 2003). By analyzing these values with some statistical methods like Linear Regression (LR), End Point Rate (EPR), Jackknifing (JK), Average of Rates (AOR), the future position of the shoreline along these transects with minimum, average and maximum values are determined (Dolan et al., 1991; Danforth and Thieler, 1992; Fenster et al., 1993; Thieler et al., 2000; Moore and Griggs, 2002; Süzen and Özhan, 2003; Thieler et al 2003). After the determination of the future position of the shoreline with all possible statistical methods and different baselines presenting the shore, the most possible and more reliable case, according to estimated accuracies and according to general trend of the shore, is chosen.

While selecting the study area, it is taken into account that there exist different geomorphologic features (such as sand barriers and moving inlets), accretion (at present delta mouth) and recession (at previous delta mouth) at the shoreline. So Büyük Menderes Delta, where the topographic maps and aerial photographs are available, is chosen as the study area as it contains lagoons with moving inlets, lakes and swamps, an old delta mouth, and the present newly forming delta mouth. The channel mouth clastics are transported by the waves and longshore currents to form coastal barrier islands and bars, which result in the formation of these lagoons, lakes and swamps. The lagoons are Karine Lagoon (or Dil Lake), Tuzla Lake, Mavi Lake, Kokar Lake, Akköy Fishery and their locations can be seen in Figure 1.2. As the lagoons are very shallow in depth (~1m) (field observations) and have fresh water supply (Republic of Turkey Ministry of Environment and Forestry, 2005), the area (especially Karine Lagoon) is one of the important fisheries of the Aegean region and a very valuable bird habitat (~208 species) (Ministry Of Culture And Tourism, Büyük Menderes Basin, 2005). Thus to carry out a shoreline change analysis and future shoreline prediction are very crucial on the shoreline of Büyük Menderes Delta.

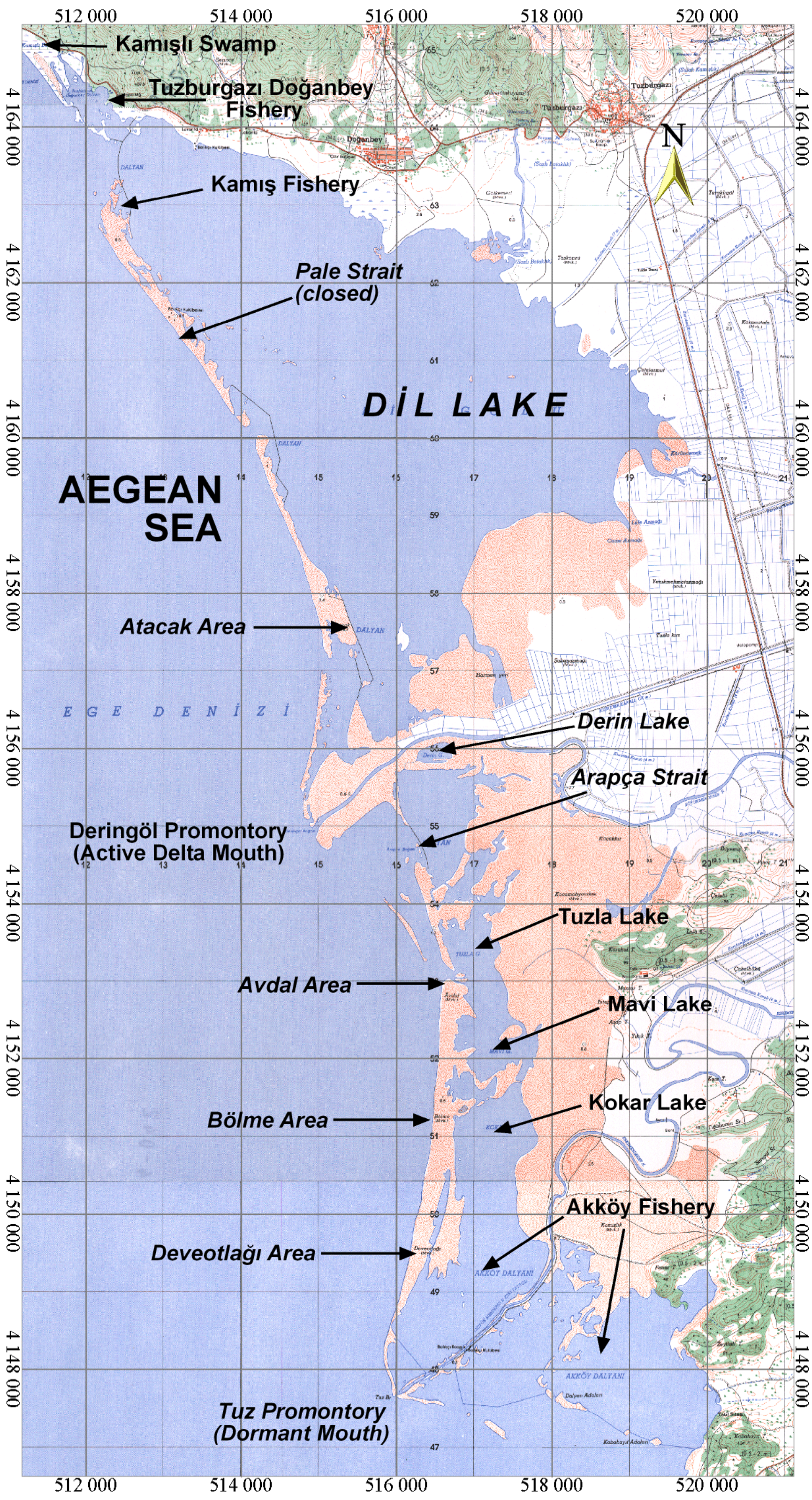

Figure 1.2. Important geographic locations of Büyük Menderes Delta.

1.2. Geographical Setting of the Study Area

Büyük Menderes Delta is at the lower reaches of the Büyük Menderes Basin. Its aerial extent is about 600km^2. At the southern reaches of the delta there are abandoned meandering channels and flood basins (Aksu et al., 1987 and field observations). By the construction of irrigation canal network (back from 1960's) (Aksu et al., 1987) the flow regime of the river is regulated and the present delta mouth is being formed by a single channel (field observation). Büyük Menderes River drains a basin of 23.889km^2 with an average annual discharge of 90 m^{3}s^{-1} (UNESCO, 1969) and the annual sediment yield is about 8.5 million tones (Kılınç, 1981). There are many human influences in the study area and in the catchment area of the Büyük Menderes River. Figure 1.3 is showing the catchment area limits and locations of some of the dams in the catchment area.

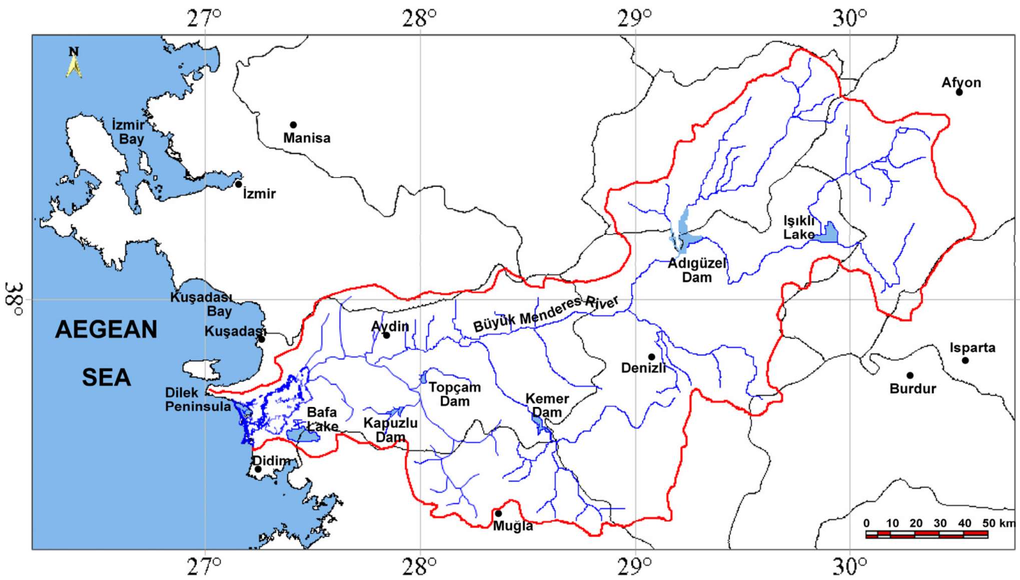

Figure 1.3. The catchment area limits (red in color), locations of some of the dams constructed in the catchment area of Büyük Menderes River, and some important lakes and locations.

There are several numbers of dams in the catchment area. The names and the dates of construction of the dams are Kemer Dam (1958), Topçam Dam (1984), Mumcular Dam (1989), Adıgüzel Dam (1989), Yaylakavak Dam (1996) and Gökpınar Dam

(2003). However, the influences of those dams are not important as they are build at the (far) upper reaches of the river. At least it can be sad that the influences of the dams are not important relative to the influence of the huge irrigation channel network on the delta, because the direction of the river flow is changed from its original direction by the construction of the channels. Between 1957 and 1977 the river was originally flowing and reaching the sea by two natural river channel, one at the southern part of the study area forming the previous delta mouth Tuz Promontory and the other at the middle parts of the area forming the new active delta mouth Deringöl Promontory. At those times, the irrigation channel network was started to be build. After 1980's, the irrigation channel construction is excessively increased but the natural channels were active also. While entering to 1990's, the southern channel was inactive by the influence of the excessively increased irrigation network channels in the area. This channel is started to be used only as an irrigation channel. The other channel located in the middle is still active at its original place but also used as an irrigation channel time to time for the huge cotton fields located at both sides of it. The enormous development of the irrigation network channels covering the flood plain of the delta (Figure 1.3) in time and the positions of the river channels can be examined in the figures below (Figure 1.4, 5, 6).

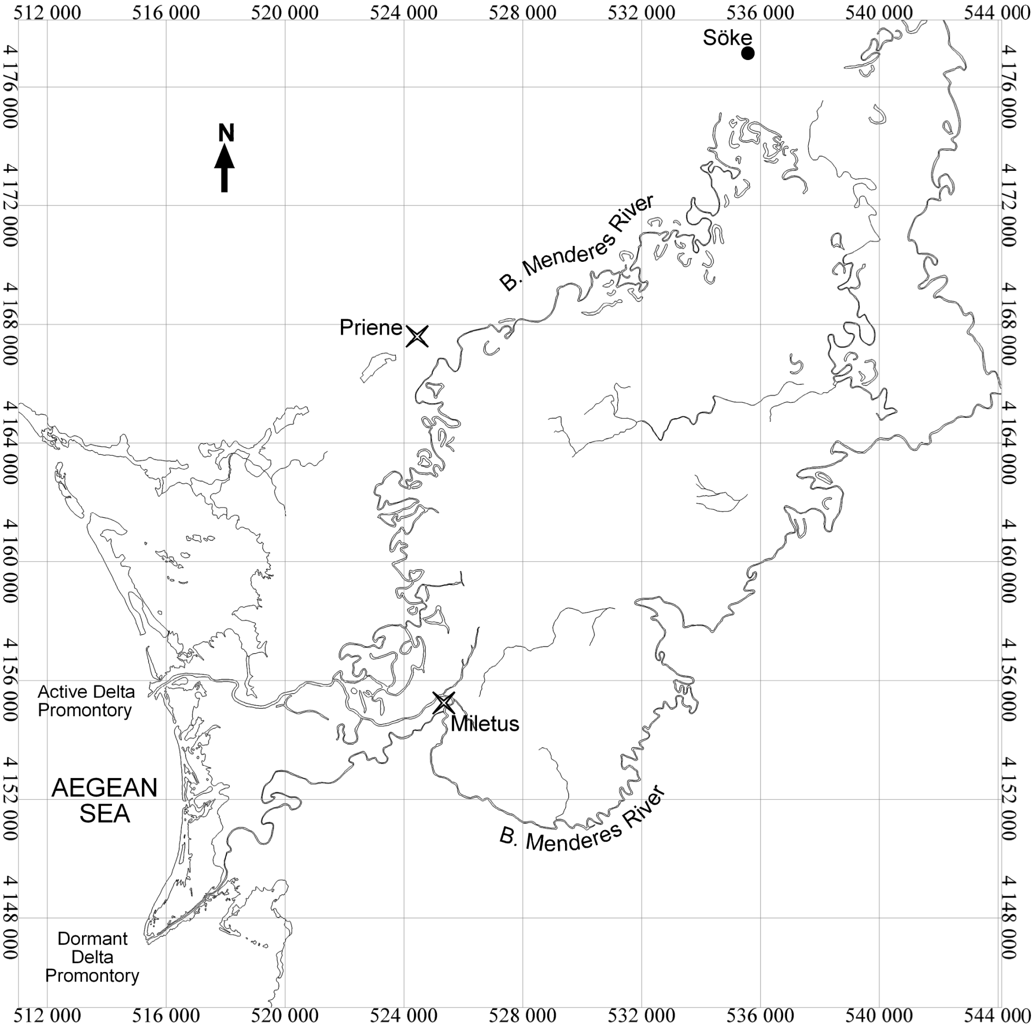

Figure 1.4. The position of the natural river channels and the active delta promontory in 1957.

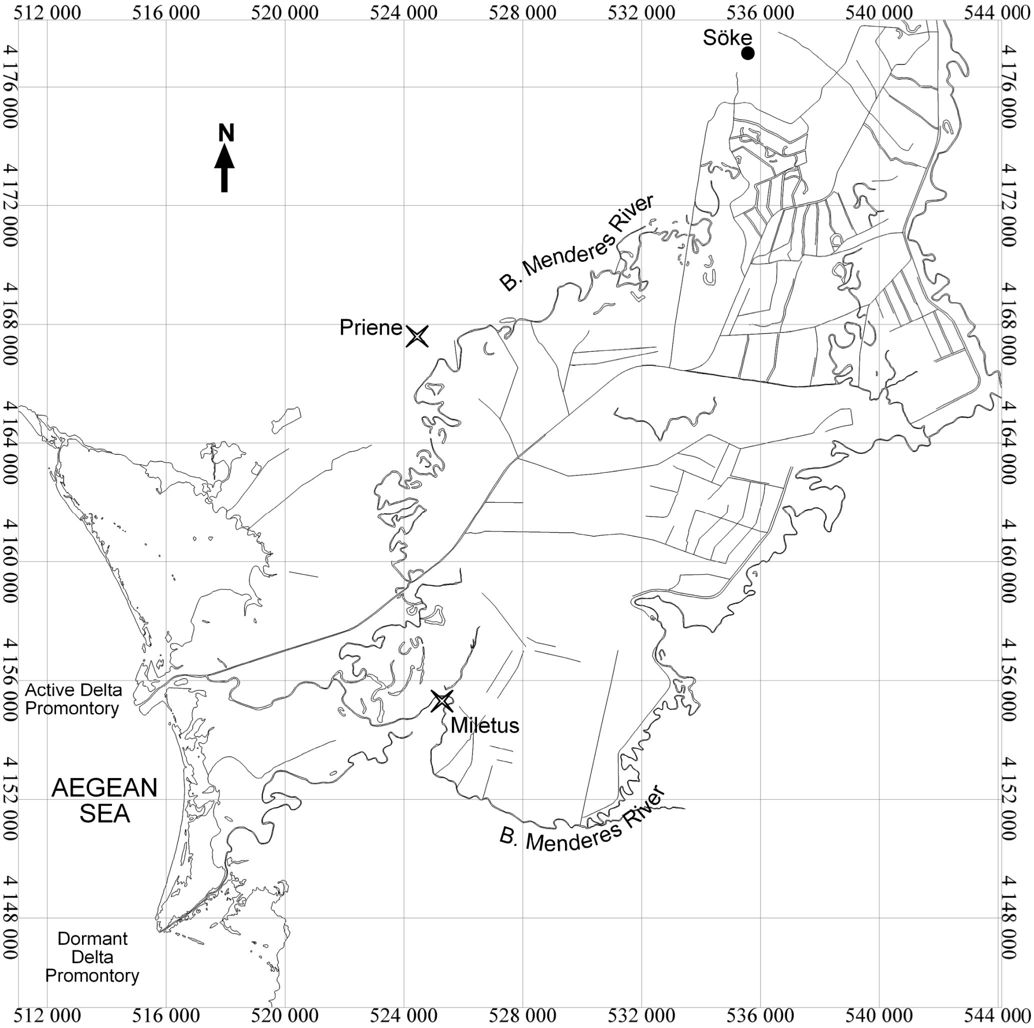

Figure 1.5. The position of the natural river channels and the active delta promontory in 1977. The two natural river channels are still active but irrigation channel network is started to be constructed.

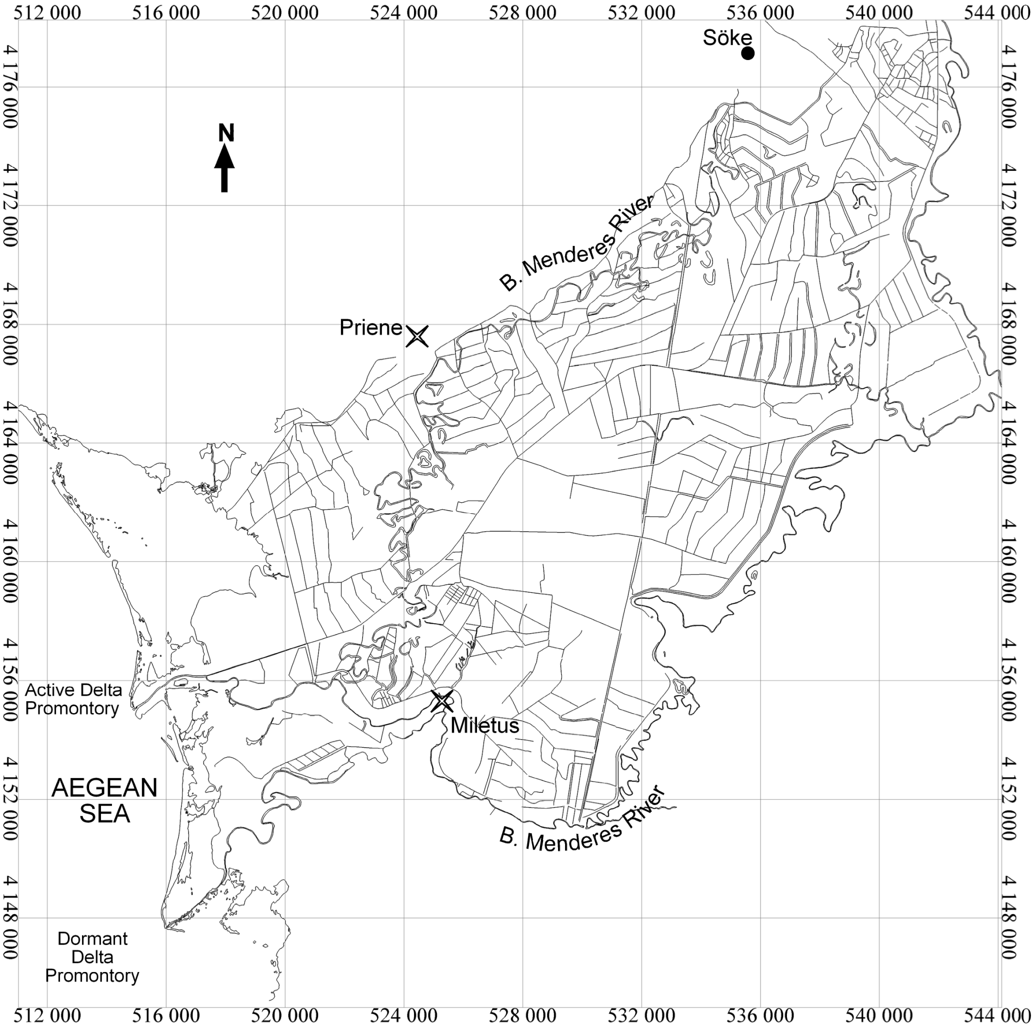

Figure 1.6. The position of the natural river channels and the active delta mouth in 1993. The southern channel is not active and irrigation channel network construction is continuing.

1.3. Organization of the Thesis

The main body of this thesis is organized in six chapters. The first chapter introduces the purpose and scope of the thesis, the geographical setting of the area, and the organization of the thesis.

The second chapter starts with a general background of deltas including coastal terminology, the shape of a deltaic shoreline and factors affecting the shape of the deltaic shoreline. Then shoreline rate of change analysis, long term and short term changes of the shores and their importance and usage is explained. Further more, the change analyses of shorelines and the selected method to use in this thesis is explained. Finally, the statistical methods to compute the rate of change values are discussed in this chapter.

The third chapter contains the data preparations, and the fourth chapter contains the analyses carried out in the thesis.

In the fifth chapter, the results of the analyses are presented and discussed.

The sixth chapter contains the conclusion of this thesis. References cited and the Appendices are the last sections of the thesis.

CHAPTER 2

SHORELINE RATE-OF-CHANGE ANALYSES

2.1. General Background about Deltas

Rivers delivering huge amount of water and sediment yield to the coast derived from surface run-off and erosion extensively in drainage basins, results in the formation of deltas. As the velocity of river flow diminishes on entering a larger open body of water, the deposition of fluvial sediments takes place in and around river mouths (Morgan, 1970). When the rate of sediment accumulation at the river mouth exceeds the rate, at which sediment is eroded and dispersed by waves and currents, deltas form (Bird, 2003). Graduation from coarser (sand) material to finer silt and clay downstream along channels is a common feature of most of the deltaic sediments (Morgan, 1970).

Necessary terminology in order to ease the understanding of coastal areas is given in Appendix 1.

2.1.1. Shape of a Delta

The size and shape of a delta depends partly on the pattern and rate of sediment yield, on the configuration of coasts and near shore bathymetry of the water body (open sea, *golf, lagoon*, lake) into which it has grown, and partly on the effects of waves and *current*s on accumulating sediment.

Many deltas can be characterized as wave-, river-, tide-dominated, and combination of all of these.

- **River-dominated deltas:** the type of delta where the river effect is dominant beside the wave and current effects. This type of delta builds delta lobes out into the sea (Figure 2.1). To identify river-dominated deltas, one should look for thin fingers of the delta protruding into the basin. It also helps to consider if the delta is located in a protected area, away from strong currents or waves.

- **Wave-dominated deltas** forms where river dump in to the sea in areas of significant wave build up. The waves constantly rework the delta front. The sediments are carried off down the longshore drift direction. This causes the delta to have a more cuspate shape and smooth shoreline characteristics (Figure 2.1). The shoreline downdrift of the river mouth may have much better developed and extensive beaches and even sandy spits can form in the down drift direction.
- **Tide-dominated deltas** generally forms where river mouths hit the sea in areas affected by large tidal ranges, the delta shape can be extensively reshaped by the twice a day flood and ebb tidal currents moving in and out of the river mouth. This usually happens in bays and estuaries where the river mouth is protected from much wave activity. Wide lobes of land growing perpendicular to the coast are the main shoreline characteristics of the tide-dominated deltas (Figure 2.1).

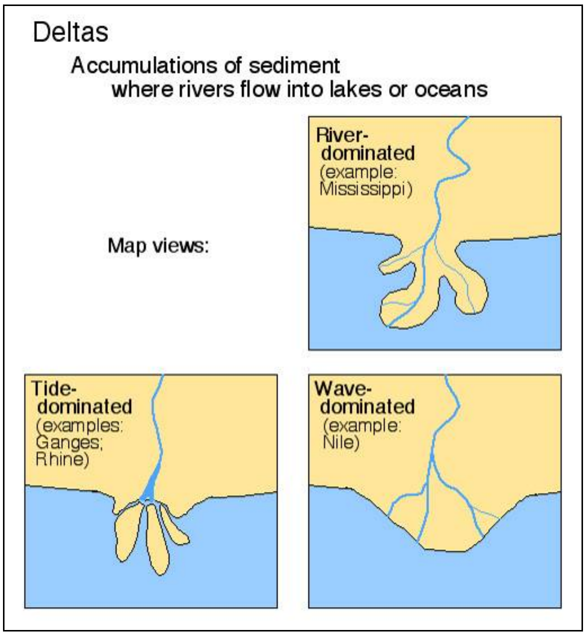

Figure 2.1. Types of deltas according to their shapes (University of Georgia, 2005).

Besides the wave, river and tide are the main shaping processes of deltas, still there are some other factors affecting the shape of deltaic shoreline:

Waves - If wave action is the dominant process, the delta is called wave-dominated delta. These types of deltas will be of smoother and cuspate shape (ex: Ebro delta, Mediterranean coast of Spain, Çarşamba Delta or Büyük Menderes delta with cuspate outline and sandy shoreline, with bordering beaches prolonged as *spits* by wave that come in from the north west and break obliquely). The sediments are newly deposited and sorted by wave action and sandy beaches and spits are formed. If wave action is stronger, the shape will be lobate.

Tides - although deltas are best formed in the microtidal coasts, they are also formed where the tide rises and falls about even up to 4.5 meters. Because of tide action, the delta shape is irregular rather than cuspate (the Mahakan Delta, Indonesia).

Sediment budget - The branching digitate shape of the deltas is formed at low energy wave action is present, and the fluvial sediment supply is abundant (ex: Mississippi delta).

Velocity of discharge and near-shore water depth - prograding deltas are generally seen at shallow near-shore water depths where the fluvial sediments are dispersed rapidly in the form of *jetties*. In the opposite, delta growth is slower where near-shore water is deep or where a submarine canyon is present.

Bathymetry **-** delta profile - if the near-shore profile is concave and the incident wave energy is strong, the shape of the delta is lobate (ex: Nile delta). Also the prograding (i.e. seaward moving) deltas have generally a convex sea-floor profile where as retrograding (i.e. landward moving) deltas have concave sea-floor profiles. Bathymetry is directly related both with the bedrock morphology and some of the other parameters explained in this subsection, such as waves, sediment budget, tectonic activity, etc.

Longshore sediment transport **-** near shore currents - they can move the fine-grained sediment supplied by the river along the coast. Growth of a protruding (i.e. extending out) delta can be prevented. Muddy flats and sandy (fine-grained) beaches can be formed by these currents.

Storms - the short-term impacts are directly affecting the shape of the deltas and the shoreline.

Climate - it directly affects the amount of water, sediment type and budget of the river, the weather characteristics, so the wind, waves, storms, longshore currents

Tectonic activity - it directly affects the relative height of the land towards the sea so the sediment characteristics can also be changed beside the subsided part of the delta.

The human activities and disasters - the sediment yield so the progradation of the delta can be accelerated by deforestation, or unwise cultivation leading to rapid erosion, or mining activities in the river catchment. Alternatively, the erosion rate can be increased by diminishing the sediment yield by a construction of dam upstream in its catchment (as dramatically seen at Nile delta and Yeşilırmak Delta).

Diversion of the river mouth - followed by the erosion of the former delta and the building of a new one (ex: Büyük Menderes River, Ceyhan River and Yeşilırmak River).

2.2. Shoreline Rate-of-Change Analysis

One of the important research subjects of coastal geomorphology studies is to determine the rate-of-change of coast, water level and the moving direction of the shoreline, then by making use of these informations predicting the future shoreline position. There are many factors affecting the shoreline rate-of-change, such as bathymetry, shoreface, sea level fluctuations, sand budget, alongshore sediment transport and tectonic activity. Shoreline change models are very important for engineering studies, planning and management projects. Thus, choosing proper data and appropriate statistical methods is crucial.

The long term and short-term variations are the most important issues to be known by the researchers in analyzing shoreline changes. Because appropriate data type, mapping techniques and statistical analyses methods should be different in short term and long term changes of shorelines.

Generally short-term variation is introduced over periods ranging from days to seasons whereas long-term variations (the rise in sea level, the shift in natural sediment supply) occur over periods of decades to centuries and produce the more predictable trends (Dolan et al., 1991). The Figure 2.2 shows a cyclic, long-term accretion trend of a shoreline that could result to a wrong prediction when there is insufficient shoreline position data and when the selected statistical method is not appropriate.

“Changes which occur along sandy shoreline over short periods of time are often cyclic. “ (Dolan et al., 1991). Shoreline analyses based on such short-term data will not give accurate results in long-term estimates (Dolan et al., 1991) (Figure 2.2). As it is observed in Figure 2.2, the size of sample domain is very important, such that without the knowledge of cyclic behavior of this coast it is very easy to make wrong estimates. However, trend dependent linear estimates with larger confidence intervals are capable of estimating well.

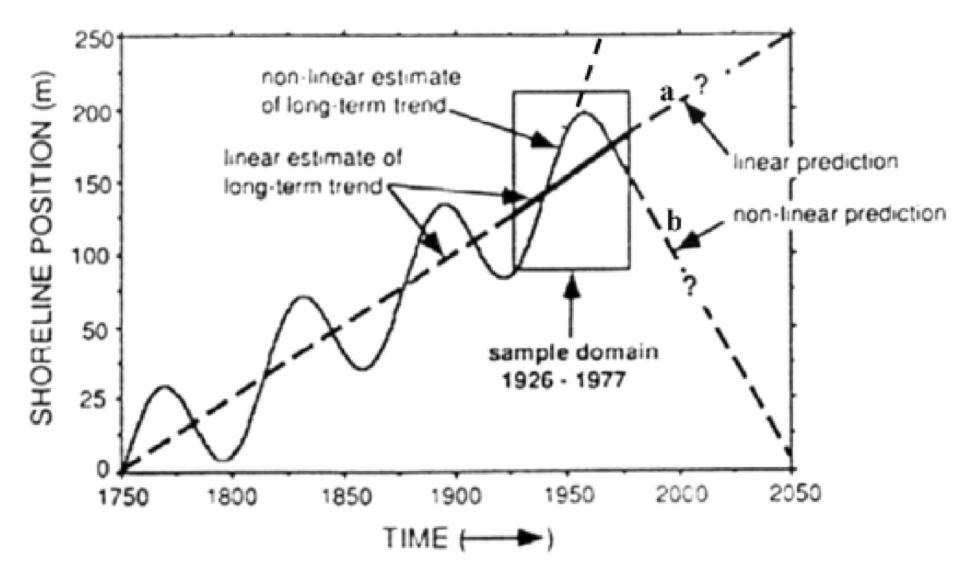

Figure 2.2. Hypothetical plot showing a cyclic, long-term accretion trend. In this case, a quadratic fit would be a more fitting curve but it could result a worse prediction than a linear fit (Dolan et al., 1991). **“a”** is the linear fit that will result to an accreting shoreline which fits the real trend of the shoreline, whereas **“b”** is a non-linear fit that could result to a wrong prediction.

Future shoreline position predictions have considerable importance for human health and economy. Because of this reason, to model the long-term trend of the shoreline and the short-term impacts accurately, is the main goal of the time series shoreline change analyses where it is critical to obtain the data properly and accurately. Short-term (less than some decades) shoreline position predictions and the prediction of the regeneration process of the shore after a storm impact are also very important for planning purposes. It is obvious that such analyses need frequently collected data from the area of interest. On the other side, for the prediction of long term (more than some decades) shoreline position, the data must be collected over a long term period of time with the records of the events that occurred in that period of time. In this way, it is possible to predict and model short-term fluctuations and regeneration processes of the shoreline, and the real long-term trend of the shoreline. The long-term trend of a shoreline and the short-term fluctuations and regeneration process are studied in Douglas et al. (1998). When doing the linear regression analysis of the shoreline position it is useful to obtain some extra information about the coast. The most important information is the storms impacting the shoreline, the magnitudes and number of the impacts, the date, so the position before and just after the storms and the regeneration process (time) of the shoreline. If the linear regression analysis is done without elimination of the data just after the storm, which the shore is in the regeneration process, the long-term shoreline position predictions, confidence intervals and error margins will probably be wrong. So the linear regression analyses will only be reliable after eliminating these “wrong or noise data”. Those after-storm data could be used to generate safety buffer zones after the analyses (Douglas and Crowell, 2000). Nevertheless, Galgano (1998), Galgano et al. (1998) and Zhang (1998) showed that linear regression analyses will be an appropriate method for shorelines unaffected by inlets or engineered changes and it is not applicable at the delta mouths (Douglas and Crowell,2000).

Morton (1974), Dolan et al. (1978), Leatherman(1982), Anders and Byrnes (1991) and Crowell et al. (1991) mentioned about the accuracy of the data, the accuracy of the rate-of-change of the shoreline and the accuracy of the future shoreline position predictions. Furthermore the ability to handle the data for both short and long term shoreline change analyses are compared in Morton (1979), Dolan et al. (1991), Crowell et al. (1993) and Fenster et al. (1993).

The accuracy of the analysis directly depends on the accuracy of the data used for the analyses and the estimated error of the analyses. If the data used for the analyses contain errors more than a pre-defined threshold value, and cannot be corrected, then these data should not be used in the analyses (Crowell et al., 1991). In addition, Walton (1998) proposed to use Least Squares Filtering Method in the cases where the data is numerous and when it is hard to eliminate the errored ones (outlier data), to separate the real and meaningful data from the errored data (outlier data) and to have more reliable results.

“The precision with which estimates of shoreline rates-of-change reflect actual changes and predict future changes is dependent on: 1) the accuracy achieved in collecting shoreline position data, 2) the temporal variability of the shoreline movement, 3) the number of measurements used in the computation, 4) the proximity of the observations to actual changes in the trend, 5) the period of time between measurements, 6) the total time span of the record, and 7) the method used to calculate the rate“ (Dolan et al., 1991).

An important point that should be considered in the analyses is that, the calculated distances of shoreline movement should not be smaller than or equal to the estimated error margins for the analysis. And the future shoreline position estimates should cover at most the half the period of time comprised by the whole data (If the time coverage of the data is 50 years, one can only make a prediction for at most 25 years) (Douglas, 1991).

2.3. Shoreline Mapping and Change Analyses Methods, Constraints and Trends

Shoreline can be defined in many ways but the high water level is generally preferred as an indicator to define the shoreline because it could easily be identified both in the field and from low altitude oblique air photos. A change in gray tones can be seen from the air photos due to the moisture content of the sand. The line of demarcation that separates the wet sand from the dry sand is the high water level demonstrating the strict change in gray tones (Figure 2.3). The high water level is seasonally variable. These changes in the shoreline can cause inaccuracies in shoreline change analyses. In order to prevent these types of bias, the shoreline data must be derived from air photos taken at the same periods of the year (preferably in summer because of the atmospheric conditions).

It is necessary to pay attention to have the same projection system while using topographic maps from different times. If the geographic datum is not known, it is necessary to georeference the maps from minimum four ground control points. It is also important not to use old topographic maps that are not protected properly. Such maps can be torn, folded, or unevenly shrunk because of moisture or wetness.

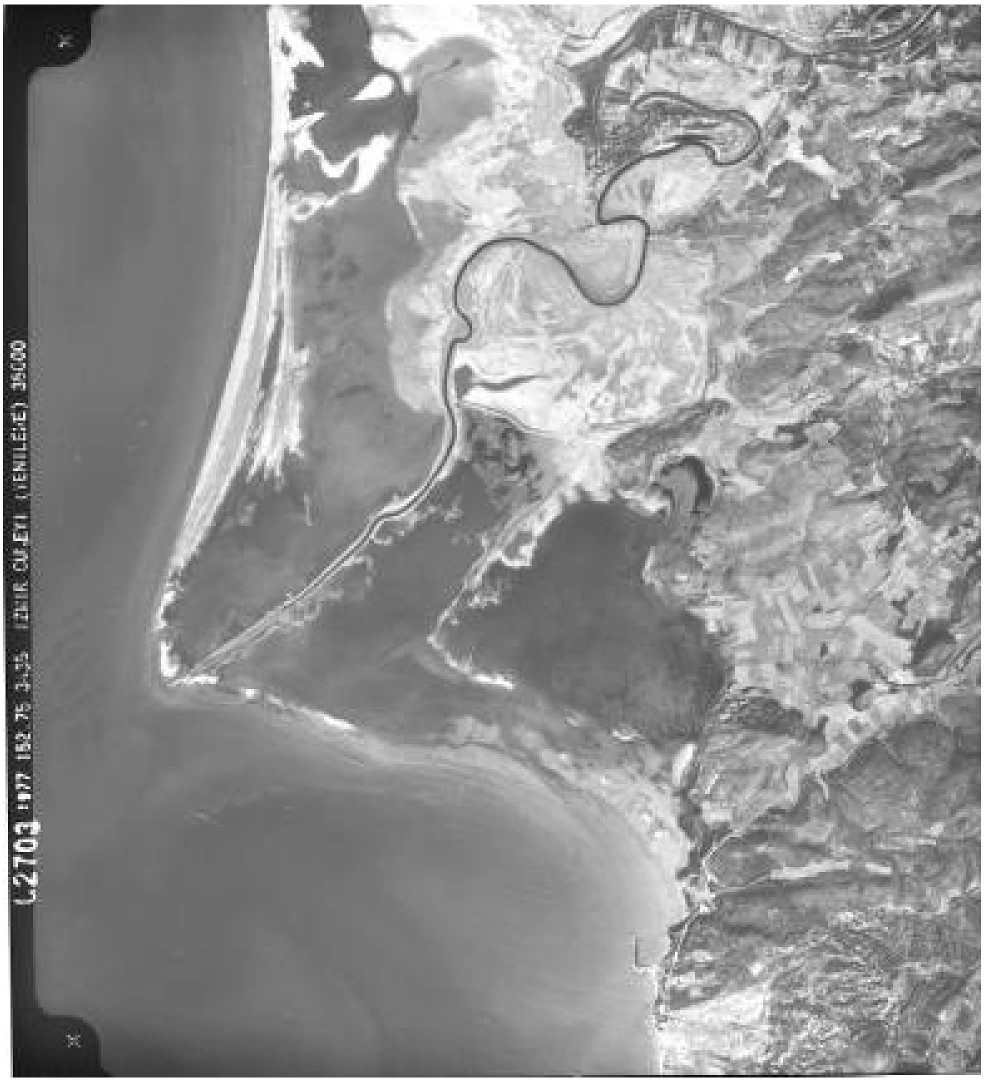

Figure 2.3. Aerial photograph showing the southernmost part of the study area taken in 1977 (scale=1/35.000). Note that the high water line can be distinguished by a distinct change in gray tones (dark colors indicate wet areas and light colors indicate dry sand along the shoreline).

In addition, the systematic and non-systematic errors must have been corrected or minimized in the air photos. The types of errors can be listed as follows:

- Tilt (Scale Differences within Photo)
- Scale Difference between Photos
- Relief Displacement
- Radial Lens Distortion

It must be taken into account that the shoreline is extracted from mean high water level (MHWL) in the NOS T-sheets (National Ocean Service Topographic Survey Sheets in US) or topographic base maps, results in some errors in the position of the shoreline. Although there is no distinct difference and margin of error between the MHWL and the high water level (HWL), Shalowitz (1964), Dolan et al. (1980), Anders and Byrnes (1991), Crowell et al. (1991), Thieler and Danforth (1994), Douglass and Crowell (2000), Moore (2000) and Moore and Griggs (2002) carried out detailed studies on the difference and the error margins between HWL and MHWL and the correction or minimization of these errors, and to get the same errors (magnitude, margins, standards) at different data sets. It should be remembered that the HWL extracted from air photos is still more subjective (image analysts and air photo quality dependent) than the HWL extracted from field studies. After the correction or minimization of these types of error, the shoreline analyses, the rate-of-change calculations and the future predictions of the shoreline position will be more accurate. Now, developing image enhancement techniques allow us to analyze the air photos easily and differentiate the high water lines so that the shoreline can be extracted accurately as demonstrated in Shoshany and Degani (1992). Detailed studies on evaluation of the archive data in the system and the potential use of air photos in time series shoreline change analyses are carried out by Anders and Byrnes (1991), Crowell et al. (1991) and Jimenez et al. (1997).

An excellent summary of shoreline mapping techniques and change analyses methods is done by Moore (1998 and 2000) and discussed in this thesis as follows:

Point Measurements Method is based on calculating the distances of the shoreline from the objects whose positions are known on air photos of different periods. Then the distance between the successive shorelines are divided to the time span between the two shorelines. This method is proposed by Stafford (1971). The drawback of this method is that the systematic and non-systematic errors of air photos are not corrected but enhanced by using only the central regions of the photos when the distortions are kept at minimum. Another drawback is the lack of accuracy assessment of this method, and this method cannot produce a continuous representation of the shoreline.

Orthogonal Grid Mapping System (OGMS) is based on creating based maps of 1/5.000 by photoenlargement technique from 1/24.000 topographic maps while orienting them having long axis parallel to shoreline. Following this air photos are rescaled to 1/5.000 by using a projecting light table. The base maps and air photos of different periods are superimposed and HWL of different periods are traced onto an overlay. A rectangular grid is traced on them in order to calculate the differences of the successive shorelines. Then the distance between two successive shorelines is divided by the time span between two shorelines. This method cannot go further in tracing shoreline from closely spaced points hence it is still not representing the shoreline continuously. The errors of air photos and 1/24.000 quadrangles are also preserved in the analysis. This method is proposed by Dolan et al. (1978), Dolan et al. (1979) and Dolan et al. (1980) and discussed in Leatherman (1983). The difference of this method from point measurements is that there exist no need to have control points whose coordinates are known and the analysis is done on orthogonal grids. However, in the point measurement method, there exist points whose coordinates are known and the analyses of shoreline rate-of-change could only be done by the use of these points. Therefore, point measurement method is not applicable for a deltaic shoreline where there are few available control points. On the other hand, the potential of OGM is still under debate as the change can be quantified but it cannot be tied down to earth coordinates as the source data is not orthorectified.

When the ground control points are used to rectify the air photos, this time the method is called ***Stereo Zoom Transfer Scope***. This method is proposed by Fisher and Simpson (1979). It is very similar to OGMS (where 100m. interval records are used to map in a computer), however the shoreline is mapped continuously with hand traced record. This method still cannot remove the errors of air photos, as it does not orthorectify the aerial photos.

Then the ***"Metric Mapping"*** method is proposed by Leatherman (1983) and developed by Clow and Leatherman (1984), which is based on removing the radial and tilt displacement of air photos by using primary and secondary control points. The primary control points are the geographic coordinates of labeled grid marks on topographic base maps. Secondary control points are the features identifiable on both topographic base maps and air photos. After tracing the shoreline and plotting the control points with known coordinates on air photos, in order to remove the errors in them, and bring them to the same scale a Fortran IV "space resection program" is computed. Finally, shoreline map is plotted by "MESH" program that adjusts the junctions between the adjacent photos. This method also does not create a continuous shoreline.

In addition to ZTS and OGMS, ***"Zoom Transfer Scope and GIS"*** method makes use of a GIS software to bring all photos and topographic base maps to a common projection, coordinate system, horizontal datum and ellipsoid. All the photographic errors are preserved and it does not create a continuous shoreline. This method is developed by McBride et al. (1991).

When the air photos are scanned with a scanner, rectified with control points and digitized on screen, this method is called ***"GIS strategy"*** in Hilland et al. (1993) and Byrnes and Hilland (1994). The change of shoreline is analyzed by an **Automated Shoreline Analysis Program (ASAP)** which uses several statistical analysis methods and accuracy assessments. Since a scanner is used, it is more accurate than ZTS Method but the accuracy of the scanner is under debate. Same errors coming with rectification of photos from maps are preserved like in the other methods.

In addition to Metric Mapping Method, ***Digital Shoreline Mapping and Analyses Systems (DSMS/DSAS)*** method includes also fiducials and camera calibration data in order to minimize the photographic errors with a **General Integrated Analytical Triangulation Method (GIANT)** program which also tie all the photos together. Then DSMS is used to compute the geographic position of the shoreline and DSAS is used to calculate the shoreline rate-of-change. Then the data from DSAS is used in a GIS software to get the output on a plotting device. The advantage of this technique is that it gives more accurate results than the other methods; hence, it allows correcting the photogrammetric errors. This method is proposed by Thieler and Danforth (1994a and 1994b).

In addition to DSMS/DSAS, “***Softcopy Photogrammetry and GIS”*** method contains photogrammetric software and photogrammetric scanner, to give results that are more accurate. This method is proposed by Fisher and Overton (1994) and Moore (1998). In this method, an orthophoto mosaic is generated by a Digital Elevation Model (DEM) and triangulated images. The shoreline is digitized on screen from orthophoto mosaic for all sets of photos. Then a DSAS is used like in previous method to calculate the rate-of-change. The advantage of DSMS/DSAS and Softcopy Photogrammetry and GIS methods is that they require fewer points to rectify the air photos.

In this thesis, shoreline position data obtained from different periods and sources, such as topographic maps, air photos, satellite images and GPS measurements, are utilized to prepare time series shoreline position data. After the correction, rectification and conversion of the sources to the same projection, coordinate system, horizontal datum, and ellipsoid, the shorelines of different periods are digitized and overlaid in a GIS software. A baseline is created behind all the shoreline positions, preferably representing the general trend of all the shorelines. Then, a digital shoreline analysis system is processed. This can be either an extension of a GIS software or a standalone program. The “Coastal” script of TNTMips is selected to analyze the shoreline digitally. It produces transects (with a user defined separation interval and with a specified length) perpendicular to the defined baseline, and crosscutting all the historic and present shorelines, in order to measure the distance between the successive shorelines. These values are analyzed with the statistical methods (Linear Regression (LR), End Point Rate (EPR), Jackknifing (JK) and Average of Rates (AOR)) to determine the shoreline rate-of-change and the future position of the shoreline along these transects (Dolan et al., 1991; Danforth and Thieler, 1992; Fenster et al., 1993; Thieler et al., 2000; Moore and Griggs, 2002; Thieler et al., 2003; Süzen and Özhan, 2003). The maximum, minimum and the average values of the results are also determined. A negative rate-of-change value on a transect show that there is an erosion on the shore whereas a positive rate-of-change value indicates an accretion on the transect. The Figure 2.4 shows an hypothetical shoreline analysis.

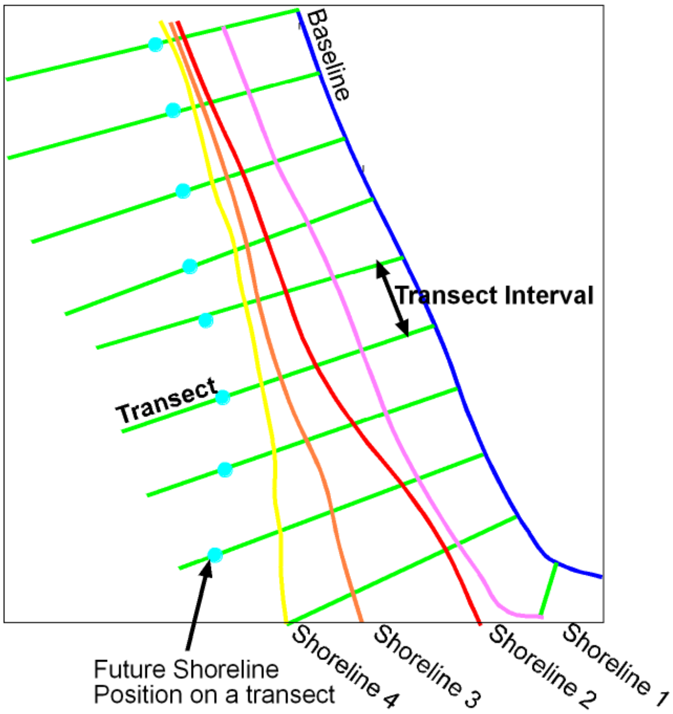

Figure 2.4. Hypothetical shoreline analysis. Blue nodes are the future positions of the shoreline along the transects (green color) after the analyses is computed.

It is important to get recent data, in extracting time series shorelines, besides the archive data. It is possible to use high-resolution satellite images in such analyses (Süzen and Özhan, 2003); however due to their high costs it is not efficient to use them for regional mapping purposes. It is recommended to use GPS as an alternative source to get the current shoreline position data beside remote sensing techniques (Morton et al., 1993).

The Differential GPS (DGPS), which gives results in mm scale, is a very time–consuming technique, as it requires dense point measurements on the other hand handheld GPS's resolution is restricted between 3-15m. In addition to these quantitative remote sensing studies and global positioning system measurements, the bathymetry can also be used as an indirect parameter, in order to visualize the sea bottom and to have ideas about future deposition places (Gorman et al., 1998).

Until now, mapping and analysis techniques for shoreline changes using shoreline position data are discussed. The shoreline change analyses can also be done using “water level change data” which are more spread over a wide period of time according to other types of data. As they are collected frequently over a wide period, they can be used to predict future shoreline position for both short and long-term periods. The Linear Regression (LR) Method is much more successful among the other statistical methods used for long-term (30+ years) future shoreline position prediction for such data (Crowell et al., 1997).

In shoreline change analyses, the data derived by calculating sediment budget, can also be used besides the water level change data and the shoreline position data. The factors that should be considered are geographic position of the area, incoming sediment amount, dynamics of the region (wave, wind, overflow characteristics, directions, heights, and periods of them, sediment movement directions), tides and water level changes (Aubie and Tastet, 2000).

In literature, several studies are undertaken to calculate the rate of shoreline change, to determine the future shoreline position and error proportions and to acquire the appropriate data for the analysis and how to classify the acquired data. These analyses are done by using various data sets such as bathymetry and shore profiles, water level changes, incoming and outgoing sediment amounts, sediment transfer along the shoreline and time series shoreline positions. Beside these data, some other factors can be used to reach to more reliable results and estimates. These factors include; 1) natural events occurring at the interested coast (such as storms), 2) the response of the coast to these events, the regeneration and reaching the equilibrium state processes, 3) the engineering structures that might affect the results of the analysis (e.g.: dams) at the interested area, and 4) similar events, processes and structures and studies and their results (if there exist) about these factors at the vicinity of the area of interest. The statistical methods that will be used in the analyses can be changed according to the quality, quantity and type of the shoreline position data used and in order to stay in the estimated error margin and the confidence interval.

2.4. Statistical Methods Used for Calculating Shoreline Rates-of-Change

The values obtained from the shoreline position data used are analyzed using some statistical methods such as End Point Rate (EPR), Average of Rates (AOR), Linear Regression (LR), Jackknifing (JK), Minimum Description of Length (MDL) Criterion and future positions of the points of measurements are predicted.

All methods used to calculate shoreline rates-of-change involve measuring the differences between shoreline positions through time. Rate-of-change is expressed in terms of distance of change per year.

2.4.1. End Point Rate (EPR)

This most commonly used method is based on the calculation of the distance of total shoreline movement (usually the earliest and the latest points) divided by the time elapsed between the measurements. If several shoreline positions are available, combinations of EPRs can be calculated. The major advantages of the EPR method are the ease of computation and its widespread use. However, when data available in the record are not used in the analysis, important trends or changes in trend may not be detected or incorporated into the results. (Dolan et al., 1991)

2.4.2. Linear Regression (LR)

If the amount of data used is not sufficient and if their changes in time are constant or not much variable then, the LR method will be a good choice to use in the analyses. This simple and easy approach, which is based on the accepted statistical concepts calculate a best fit line, using Least Squares, through the entire sample of shoreline position (Figure 2.5). However, this approach has some problems when the shoreline positions are clustered (some dates will have more influence on the regression than others will).

Some advantages of this method can be listed as:

- all data points are used and the effects of spurious data are reduced
- Popular, easily understood statistical analysis tool
- a number of summary and related statistical techniques are available to test and measure the quality of straight-line fit and estimate the variance of the data (Kleinbaum and Kupper,1978 is cited in Crowell et al., 1997)

2.4.3. Jackknifing (JK)

Efron (1982) proposed an approach, which is an adaptation of LR, using all possible combinations of LRs given by omitting one point at each iteration. The slopes of each regression line are then averaged to give an estimate of the long-term trend. Unlike LR the results are influenced less by data clusters, and the influence of extreme data are reduced. However, the amount of computation is a problem for this technique (Dolan et al., 1991). “When temporal variability is small the rates computed by LR method approximate to those computed by JK method.” (Dolan et al., 1991).

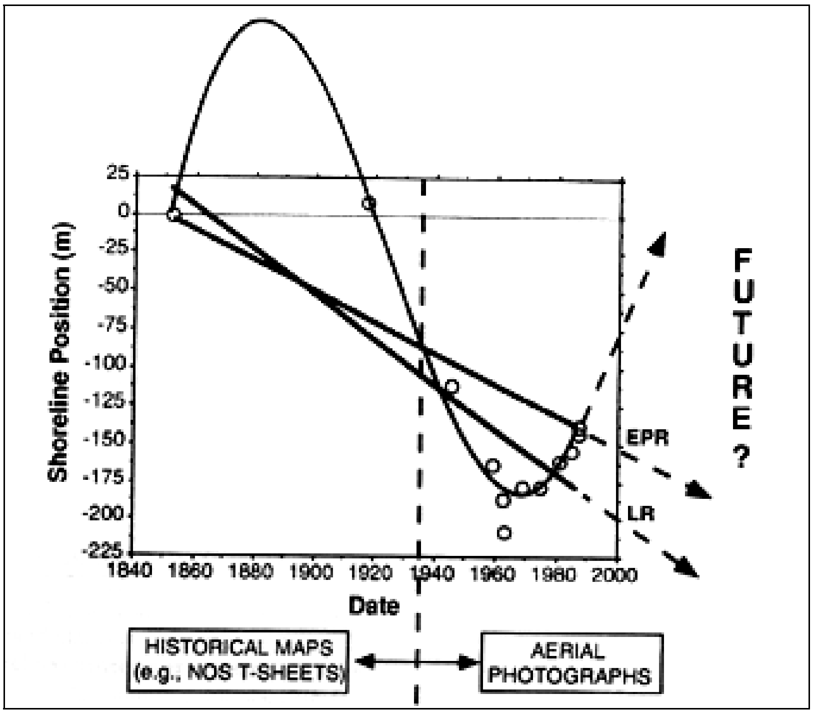

Figure 2.5. Hypothetical graphs showing the difference in magnitude and directions of trend between EPR, LR and higher order statistical method while predicting shoreline position along a transect (Fenster et al., 1993).

2.4.4. Average of Rates (AOR)

Foster and Savage (1989) proposed a method with which individual EPRs are calculated from the shoreline position data when more than two shoreline positions are available. They developed an equation incorporating the accuracy of the shoreline position data and the magnitude of the rate-of-change to determine if any EPR meets a minimum time criterion (T_{min}). T_{min} is represented by the following formula (Equation 2.1):

$$T_{\min} = \frac{\sqrt{(E_1^2 + E_2^2\ )}}{R_1} \qquad \text{Equation 2.1}$$

where E_1 and E_2 are the measurement errors in the first and second point respectively and R_1 is the EPR of the longest time span for a particular transect. The estimates of data accuracy for E_1 and E_2 are ±6.25m for map data, ±6.1m for photographs, and ±3.1m for surveyed points (Foster and Savage, 1989). All EPRs that survive the time span requirement (*survival data*) are considered long-term rates, which will then be averaged to provide a more reliable estimate of the actual shoreline rate-of-change. Foster and Savage (1989) primarily use this approach to predict future changes based on the most recent trend of shoreline change. In addition to using all survived data, this method is sensitive to substantial shifts in trends and data variability and, therefore, filters short term variability. However, there is not a computational norm for modeling the minimum time span equation (Dolan et al., 1991). In addition, Foster and Savage (1989) recommend using AOR in combination with the EPR and LR as method of verification, and they do not recommend AOR as a general computational model. "The spatial distribution of the rates produced by the AOR method is more variable than those produced by the other three methods (EPR, LR, and JK)." (Dolan et al., 1991).

Therefore, *the survival data* from AOR method may probably provide a more reliable result, by using them to have a best-fit line in linear regression method. Furthermore, having different data sources among different periods would hamper the availability of survival data; hence, the data will become incomparable.

It should be mentioned that AOR should not be confused with mean. That is, AOR is the Average of Rates of all the EPRs calculated by taking the position data in pairs for all data set, but not the averages of the results calculated by the three other statistical methods.

2.4.5. Minimum Description Length (MDL) Criterion

The real geomorphologic events are generally very complex. If there exist powerful storms and the sea level fluctuations are frequent in short and long term periods the linear methods will not be efficient to model the geomorphologic events. The use of non-linear methods will be more appropriate for such areas. To model these kinds of conditions Fenster et al. (1993) developed MDL criterion method and Fenster and Dolan (1994) compared this method to linear methods such as EPR and LR.

Fenster et al., (1993) proposed a type of complexity-penalty model that is used to determine straight or curved line (polynomial) that best fits the data set. This method is called Minimum Description Length (MDL) Criterion (of Rissanen, 1989) and it is a more complex method than LR method. It controls whether the precision of the model is increasing while the degree of the model is increasing. Steps are reviewed in Fenster et al. (1993) and Crowell et al. (1997).

Several linear and non-linear statistical methods are discussed above. However, it must be taken into account that “predictions are not necessarily improved by using non-linear methods, and in many cases may be enhanced by linear methods.”(Dolan et al., 1991). Higher order fits will be better for future shoreline position predictions, if there is no or minimal background noise and no apparent cyclic events in the data. Except the cases where short term shoreline changes can be documented as a real change in long term trend, using linear methods will be more appropriate to represent long term shoreline changes (Dolan et al., 1991).

CHAPTER 3

DATA PREPARATION

In order to establish the time series shorelines of Büyük Menderes river delta different data sets have been used to extract the shorelines of three different periods. These are topographic base maps and satellite images that had been used by the permission of TUBITAK project 103Y134. With the help of the extracted shorelines, suitable baselines and series of transect necessary for the shoreline rate-of-change analyses are generated.

3.1. Topographic maps

The shorelines are extracted from 1/25.000 scaled topographic maps that are obtained from archives General Command of Mapping, Turkish Army. Three different sets of different periods of three different map sheets are used in the study (Table 3.1).

Table 3.1. The properties of topographical base maps used in the study.

Production date	Identity and scale	Map sheets
1963	Topographic map of 1:25.000 scale	M18d2, M18d3, N18a2
1980	Topographic map of 1:25.000 scale	M18d2, M18d3, N18a2
1996	Topographic map of 1:25.000 scale	M18d2, M18d3, N18a2

These topographical maps are scanned in 8-bit gray scale tiff format to differentiate the features better on the topographic maps while digitizing process of the shorelines. Then the topographic maps are imported to TNTMips editable format, which is rvc format, to use the data in a geographic information system. The raster images in the GIS are registered by using at least four ground control points read from UTM graticules. For the registration process, the 35th zone (E 24 to E 30) of Universal Transverse Mercator projection system is used. The datum is European 1950-Mean and the ellipsoid is International 1909/1924 / Hayford 1910. The root mean square errors of all these maps are calculated and presented on Table 3.2. The analyses are based on the source date of aerial photographs but they are called in the thesis as 1960 period, 1980 period and 1996 period. Although only 4 points with affine transformation is supposed to be adequate for transformation, the maps were gathered from archives in not very good shape; hence, in some maps 12 control points were used to register. The registered three quadrangles are then clipped from their edges in order to put them together seamlessly, so to cover all the interested study features in the study area. The study features are the seaward shorelines along the sand barriers and barrier islands formed at both the North and the South of the Büyük Menderes Delta's present mouth and the seaward shoreline formed by the previous mouth of the delta. The digital shoreline map of each set is extracted by digitizing from the digital topographical maps (Figure 3.1, Figure 3.2 and Figure 3.3).

Table 3.2. The RMS Error Values of the Topographic Maps.

Map sheet	Source AP date	Printing Date	RMS error (xy/m)	Source AP date	Printing Date	RMS error (xy/m)	Source AP date	Printing Date	RMS error (xy/m)
M18d2	1957	1963	1,96	1977	1980	1,51	1993	1996	1,94
M18d3	1957	1963	1,65	1977	1980	1,18	1993	1996	1,92
N18a2	1957	1963	2,28	1977	1980	0,41	1993	1996	2,55

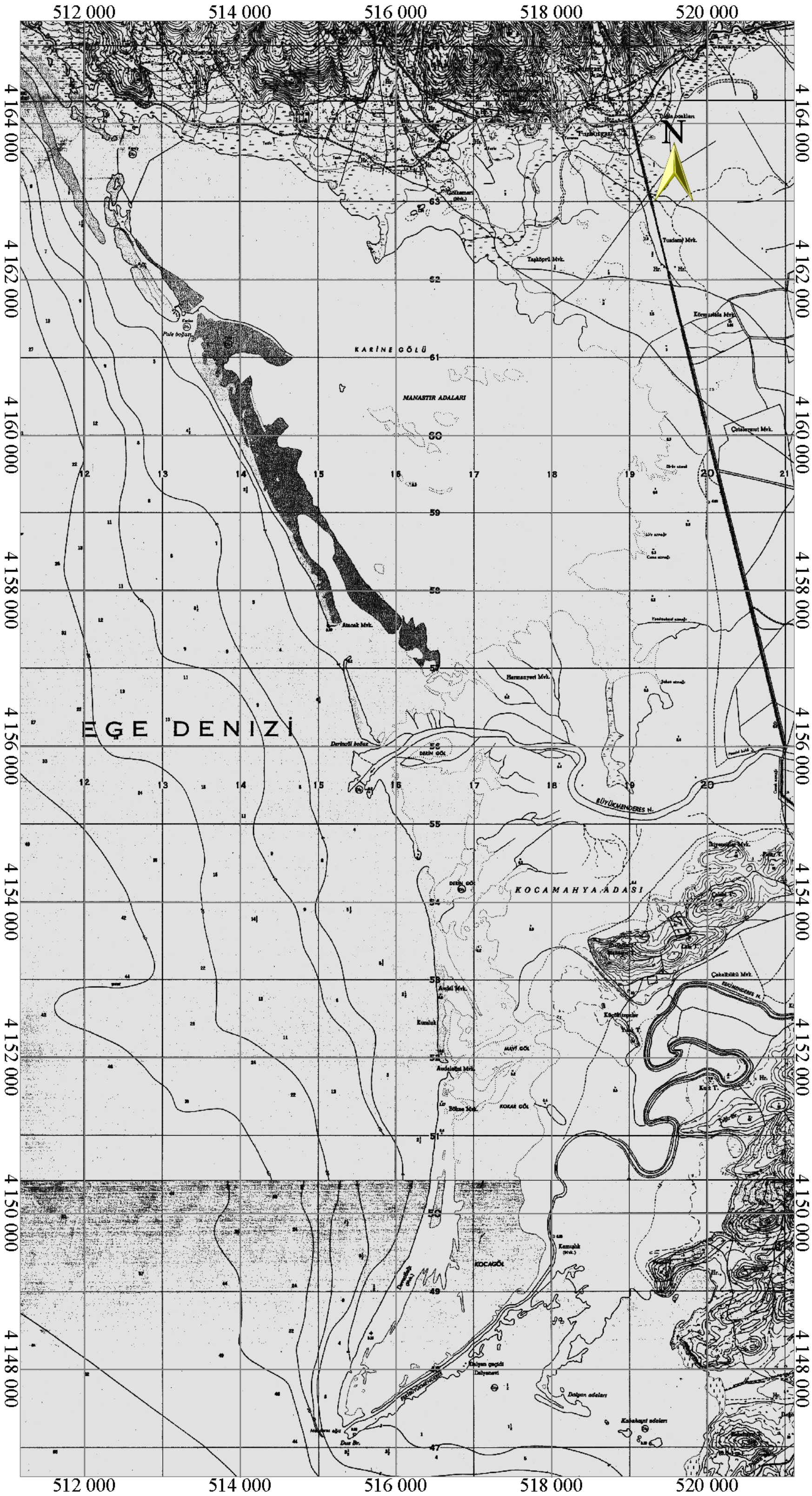

Figure 3.1. Topographic map of quadrangles M18d2, M18d3, and N18a2 (1960 period).

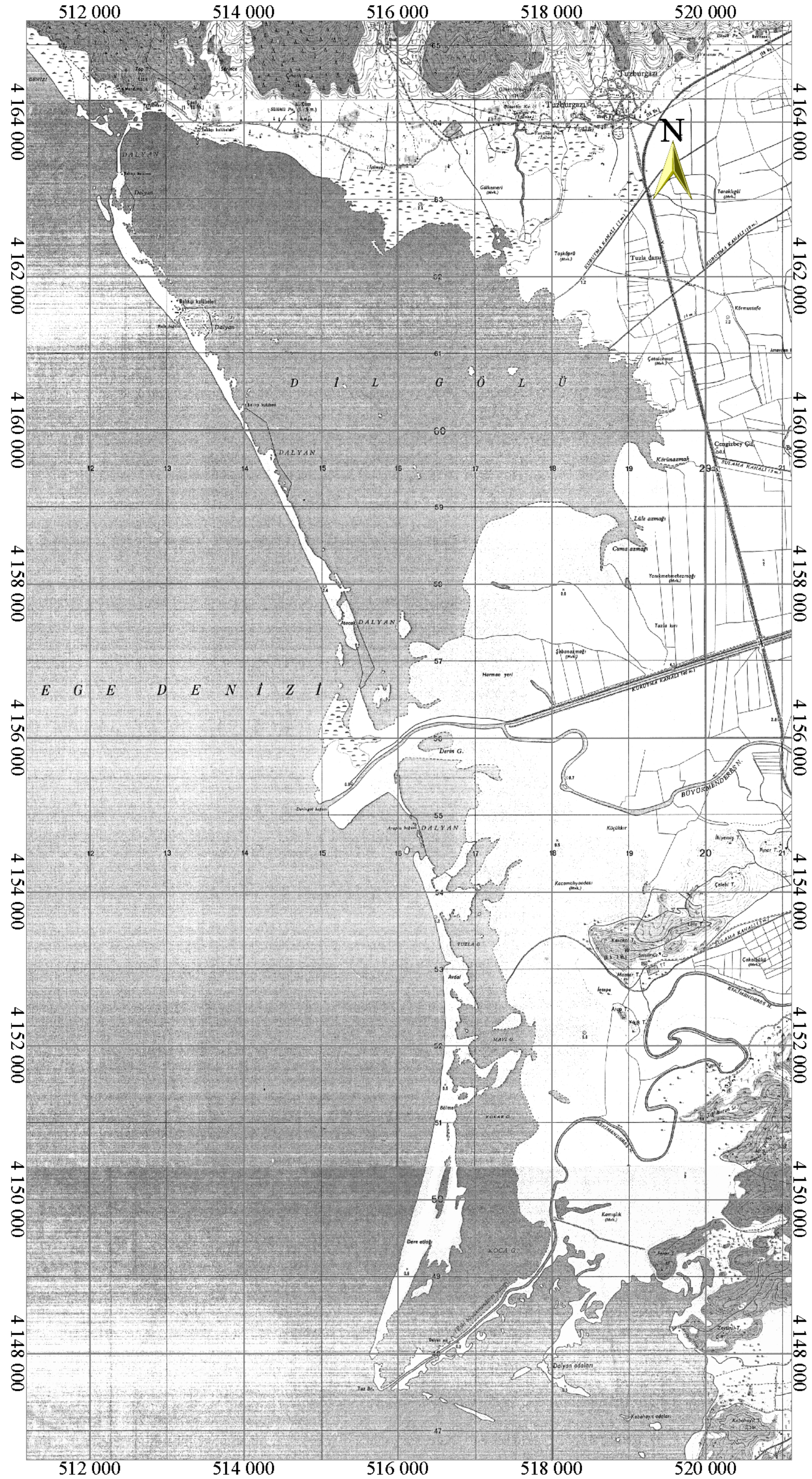

Figure 3.2. Topographic map of quadrangles M18d2, M18d3, and N18a2 (1980 period).

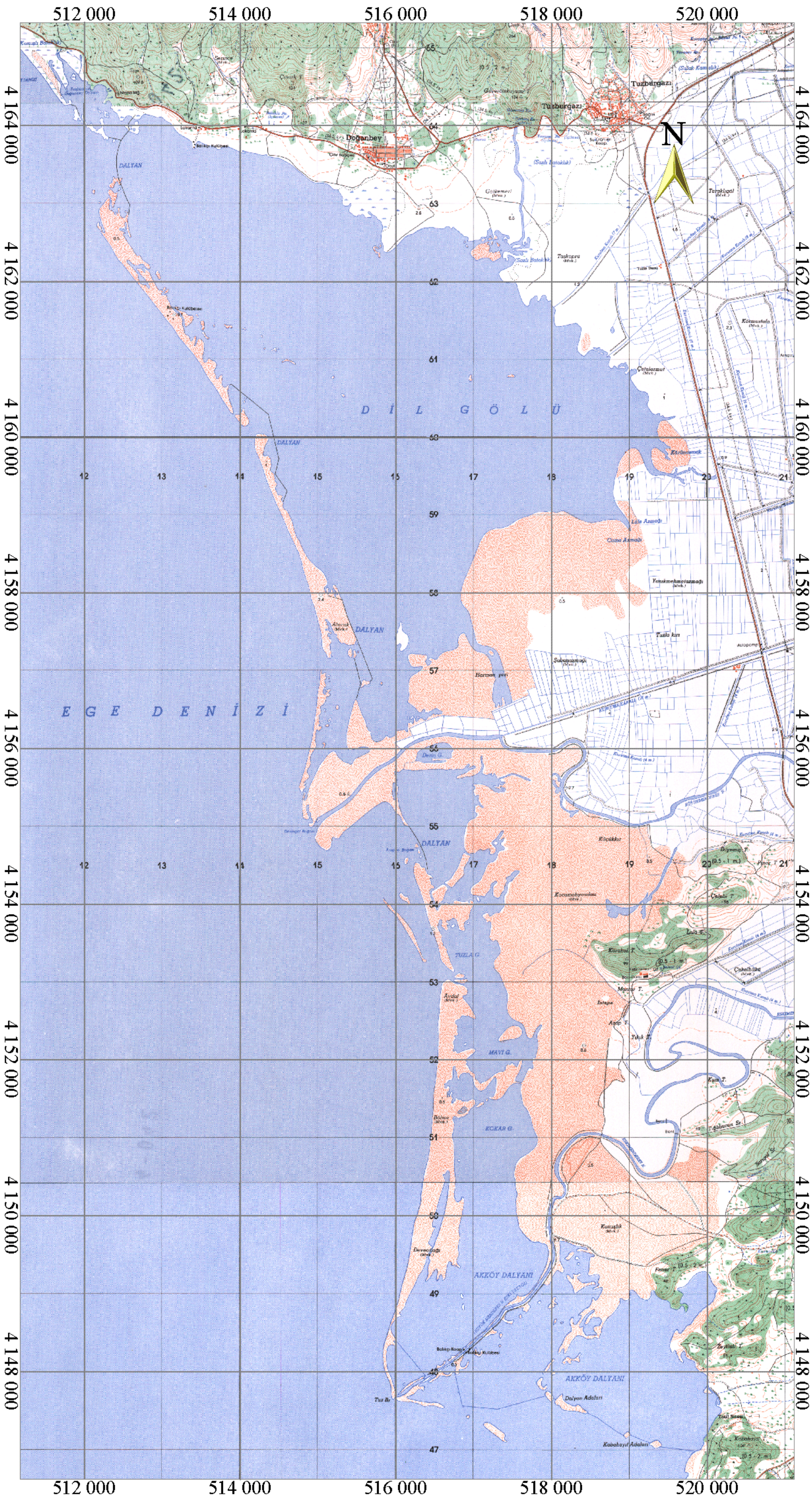

Figure 3.3. Topographic map of quadrangles M18d2, M18d3, and N18a2 (1996 period).

3.2. Satellite images

Using January 2002 Ikonos satellite imagery and August 2004 QuickBird satellite imagery covering the study features in the study area (the area covered by the quadrangles M18d2, M18d3, N18a2) two more periods of shoreline data are extracted. The Ikonos Imagery covering the study area is composed of 11726 columns and 19569 rows. The cell size is 1 meter and the extents are from 4165330N-513220E to 4145746N-524951E. The QuickBird imagery covering the study area is composed of 25984 columns and 33328 rows. The cell size of the imagery is 0.62 meters. The extents of the imagery are from 4166111N-510327E to 4146110N-525920E. The projection system is Universal Transverse Mercator. The zone is 35th zone (E 24 to E 30). The datum is European 1950-Mean and the ellipsoid is International 1909/1924 / Hayford 1910. The satellite imagery of tiff format is imported to TNTMips editable format, which is rvc format, to use the data in a geographic information system. The geometric accuracy of the image is tested via randomly selected control points and it is found to be quite inaccurate. Therefore, 10 ground control points have been collected from the field, in addition to the 75 points that have been collected by detailed GPS survey at every 250 meters of the shoreline from the July 2004 grain size sampling field campaign. The resultant cumulative RMS was found to be 2.5 meters. The seaward shorelines of sand barriers and barrier islands are extracted manually, from the mean high water line (MHWL) defined as the boundary of the sea and the sand barriers, where the gray tones change distinctively from black to white. The satellite imageries covering the area are given in Figures 3.4 and 3.5).

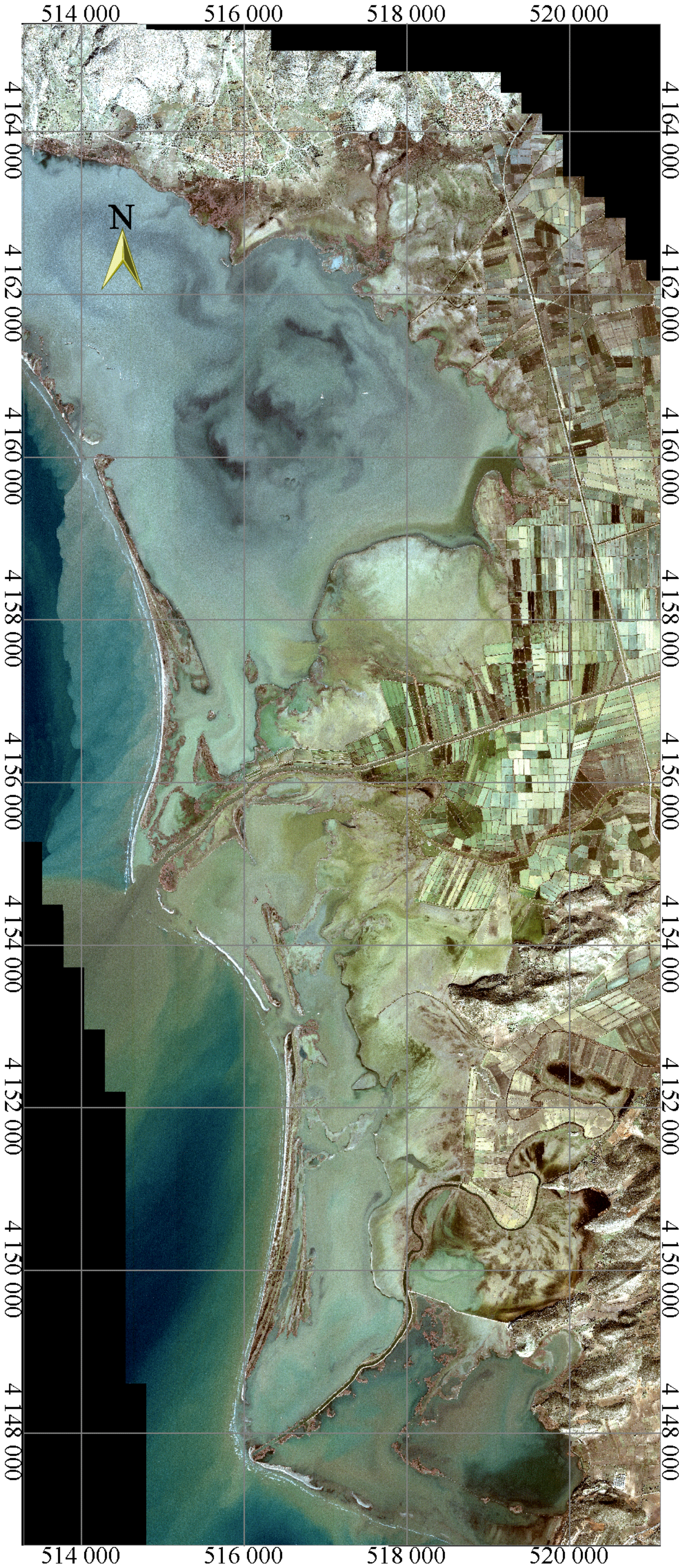

Figure 3.4. Ikonos satellite imagery covering the study area (January 2002).

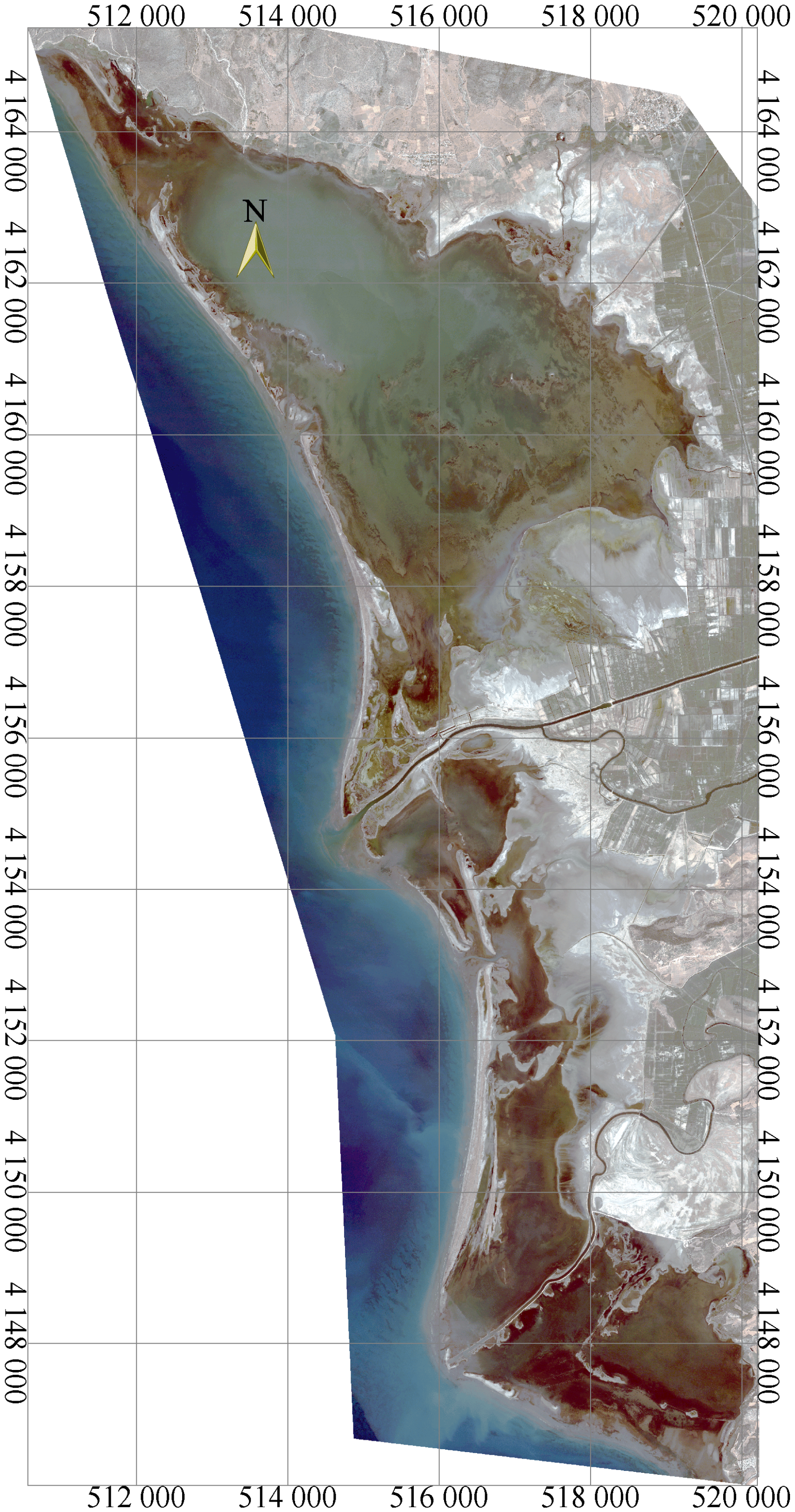

Figure 3.5. QuickBird satellite imagery covering the study area (August 2004).

3.3. Time series shorelines of Büyük Menderes River Delta

The land and water boundaries (including land and sea, land and lagoon, land and lake and boundaries of inlets) are digitized from 1/25.000 scaled topographic maps of 1960, 1980, 1996, January 2002 Ikonos Imagery and August 2004 QuickBird Imagery. Then, only the shoreline of the Aegean Sea (the most seaward boundary Büyük Menderes Delta) is extracted in order to minimize the possible errors in rate-of-change calculation processes. Important points to be mentioned in this extraction process are that, transects should pass only the latest position of the shoreline in a period, and the shorelines of the inlets and lagoons will give wrong points of measurement that directly affect the rates-of-change. An example of a shoreline extraction process is given in Figure 3.6. The separate shorelines and the cumulative view can be seen below in Figure 3.7, 8, 9, 10, 11.

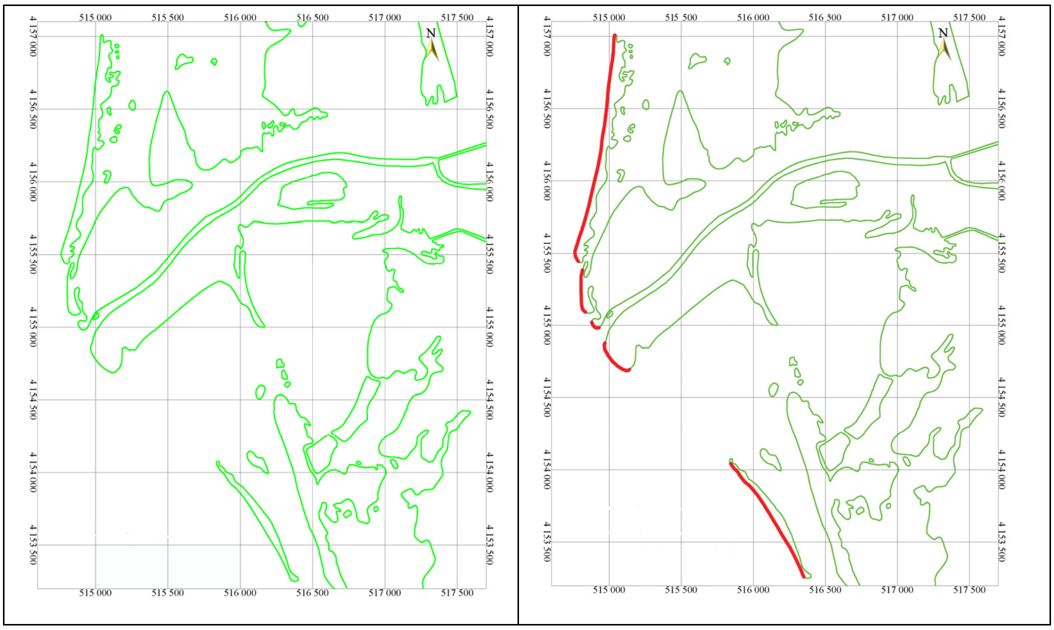

Figure 3.6. The extracted sea shoreline from 1/25.000 topographic map.

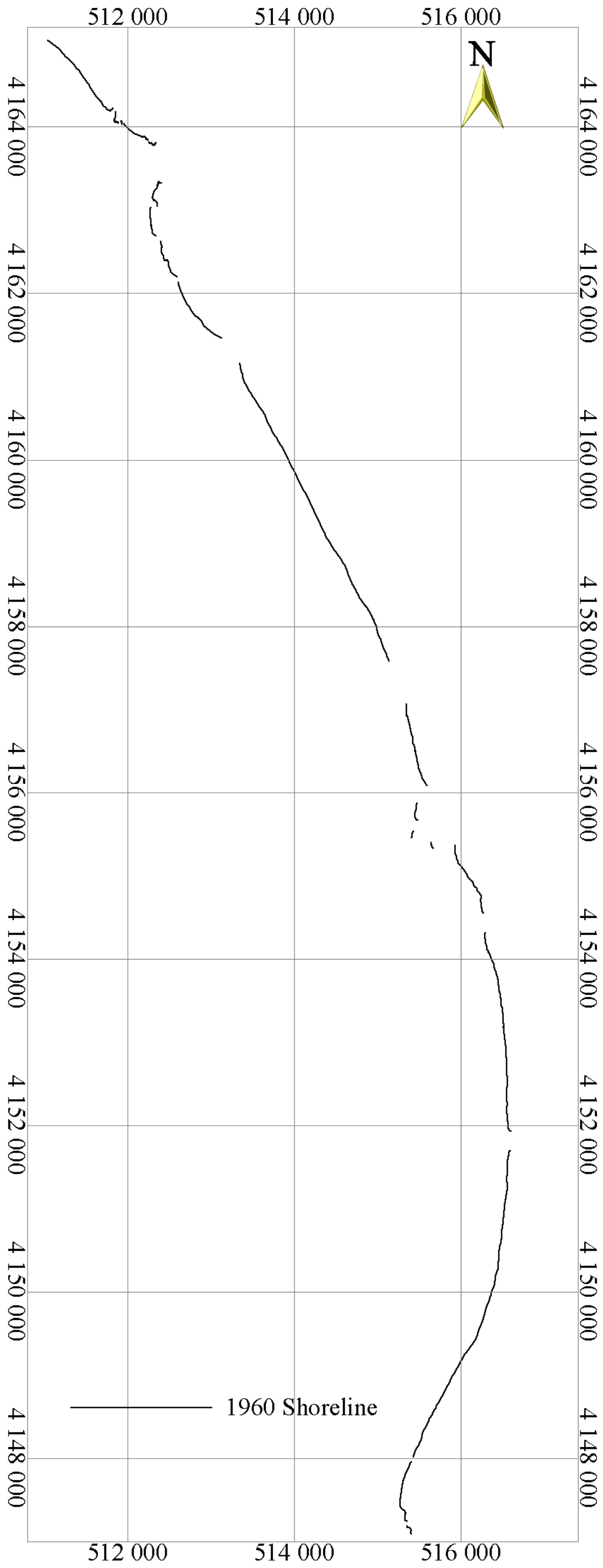

Figure 3.7. The shoreline extracted from 1/25.000 topographic map of 1960.

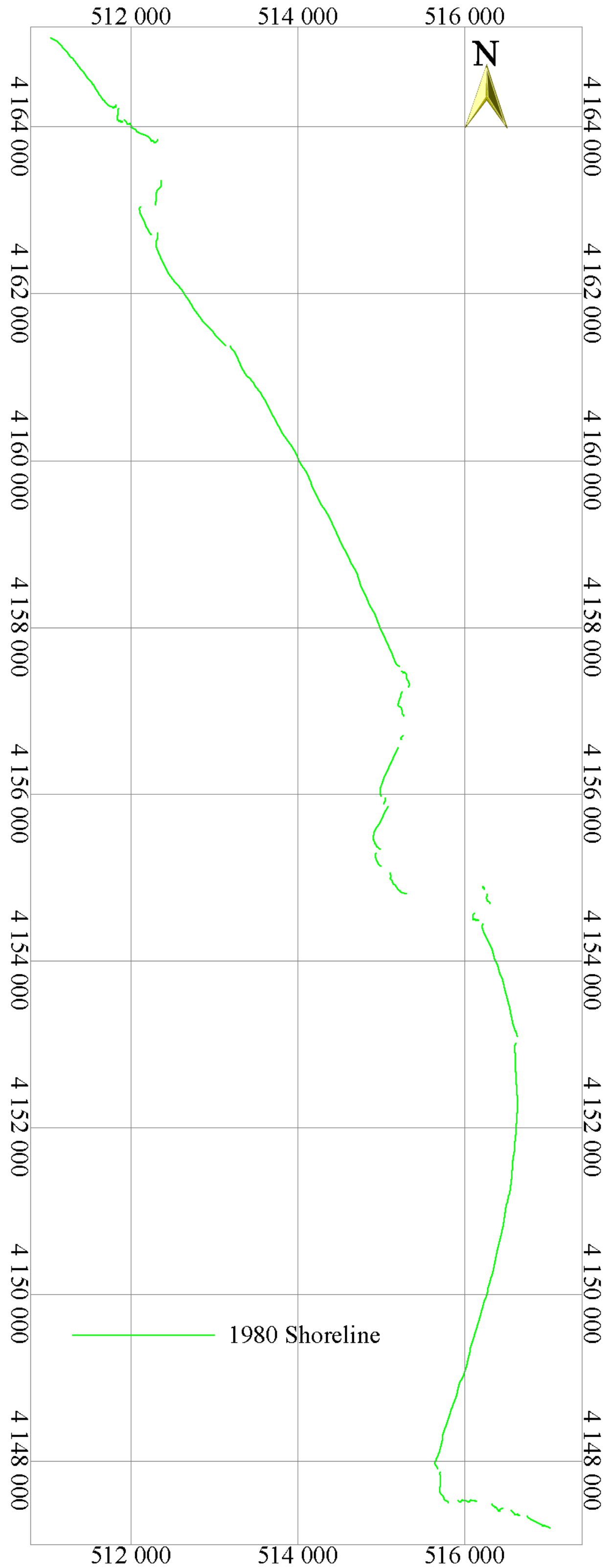

Figure 3.8. The shoreline extracted from 1/25.000 topographic map of 1980.

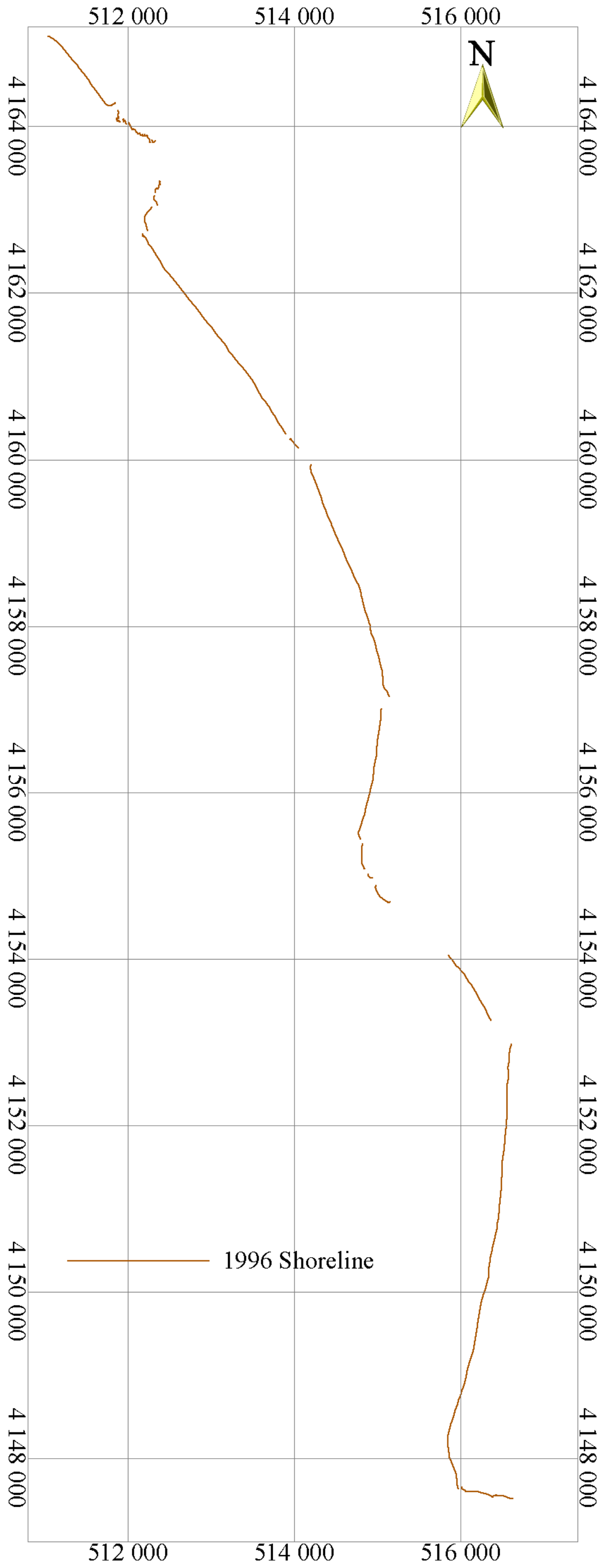

Figure 3.9. The shoreline extracted from 1/25.000 topographic map of 1996.

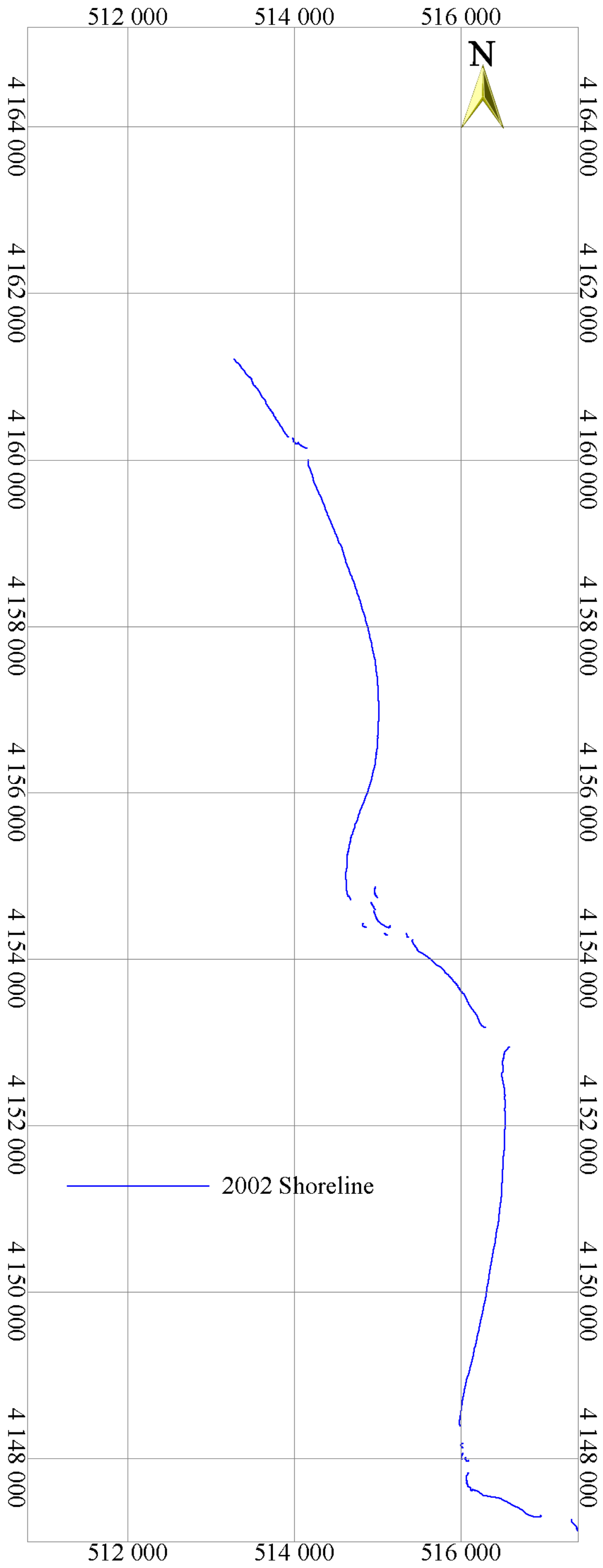

Figure 3.10. The shoreline extracted from January 2002 Ikonos satellite imagery.

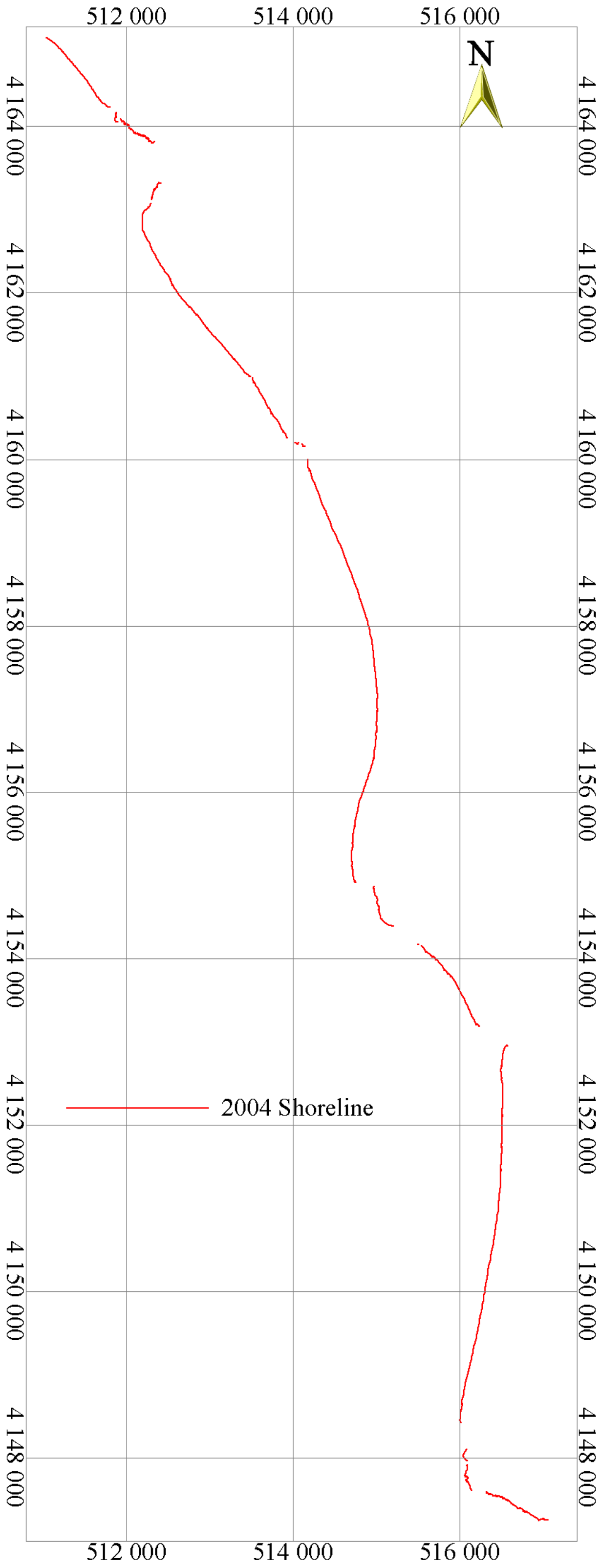

Figure 3.11. The shoreline extracted from August 2004 Quickbird satellite imagery.

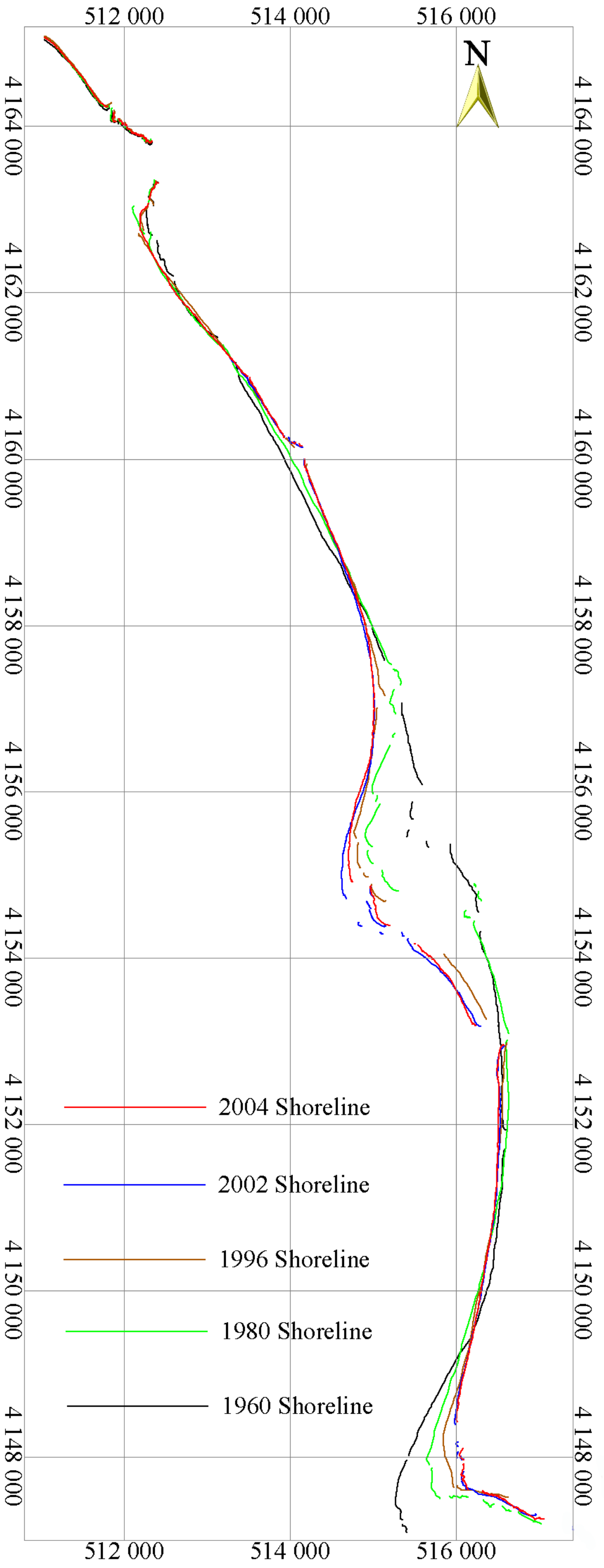

Figure 3.12. The shorelines of five different periods used in the analyses.

3.4. Baselines and Transects

For the calculation of the shoreline rate-of-change, and for the prediction of the future shoreline position, another necessary data (besides the extracted shorelines) to be created is the baseline. The baseline is one of the most important components of the shoreline rate-of-change analyses. They are imaginary shorelines that should be created behind (either landward side or seaward side) all the shorelines that will be included in the analyses. The baselines should carefully be drawn and smoothed considering the general trend and trend changes of the analyzed shorelines, since the shape and relative location of the baseline(s) to the shoreline(s) directly impacts the rate calculations.

Büyük Menderes Delta shoreline shows different type of geomorphology and needed to be separated into regions. The Five major baselines are drawn in order to represent the general trend of the Büyük Menderes Delta shoreline. The general regions can be examined in the following figure (Figure 3.13), and the details of the shorelines and the belonging baselines can be examined in figures 3.14-15-16-17 and 3.18.

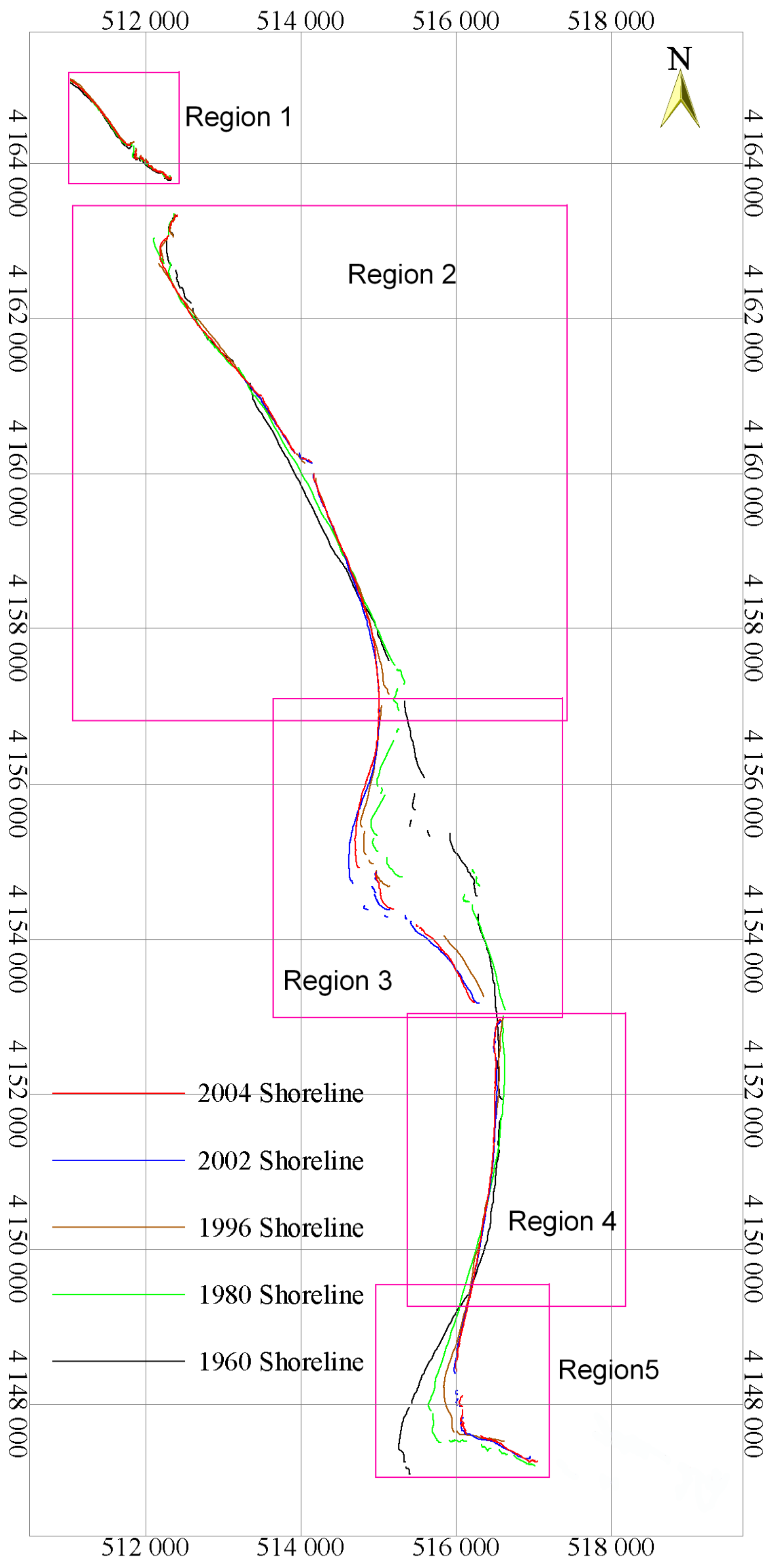

Figure 3.13. Regions of Büyük Menderes Delta shoreline analyzed separately.

“MajorBL1” starts in “Kamışlı Swamp” at the south of Dilek Peninsula, passes through Tuzburgazı Doğanbey Fishery and, ends at the northwest parts of Dil Lake. It has a length of 1749.8m with a direction of NorthWest-SouthEast (Figure 3.14).

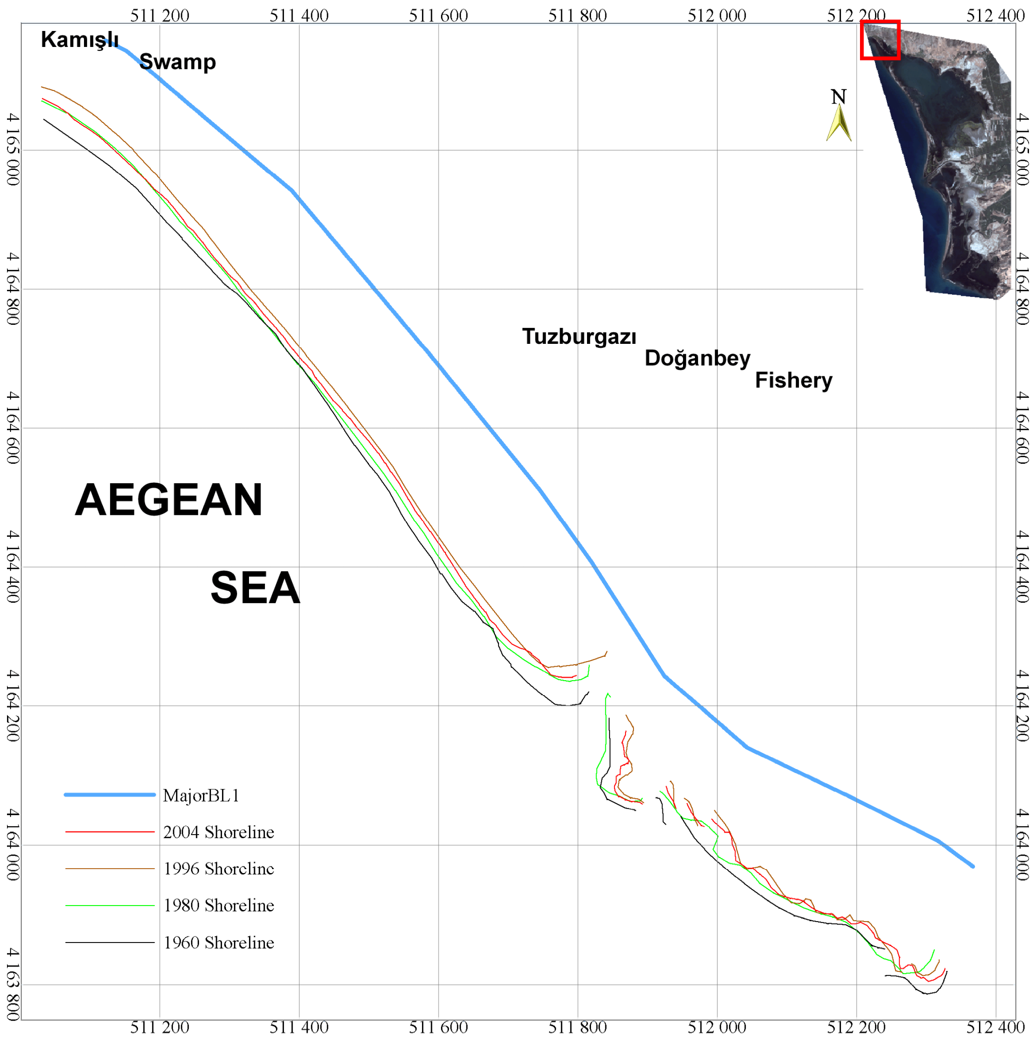

Figure 3.14. Close view of the northernmost part of the shorelines and the representative baseline “MajorBL1” at the study area (Region 1 in Figure 3.13).

“MajorBL2” starts at the south of Kamiş Fishery at the northwestern parts of Dil Lake passes through Pale Strait and ends at the south of Atacak Area at the north of the present delta mouth. It has a length of 7099.3m with a NorthNorthWest-SouthSouthEast direction (Figure 3.15).

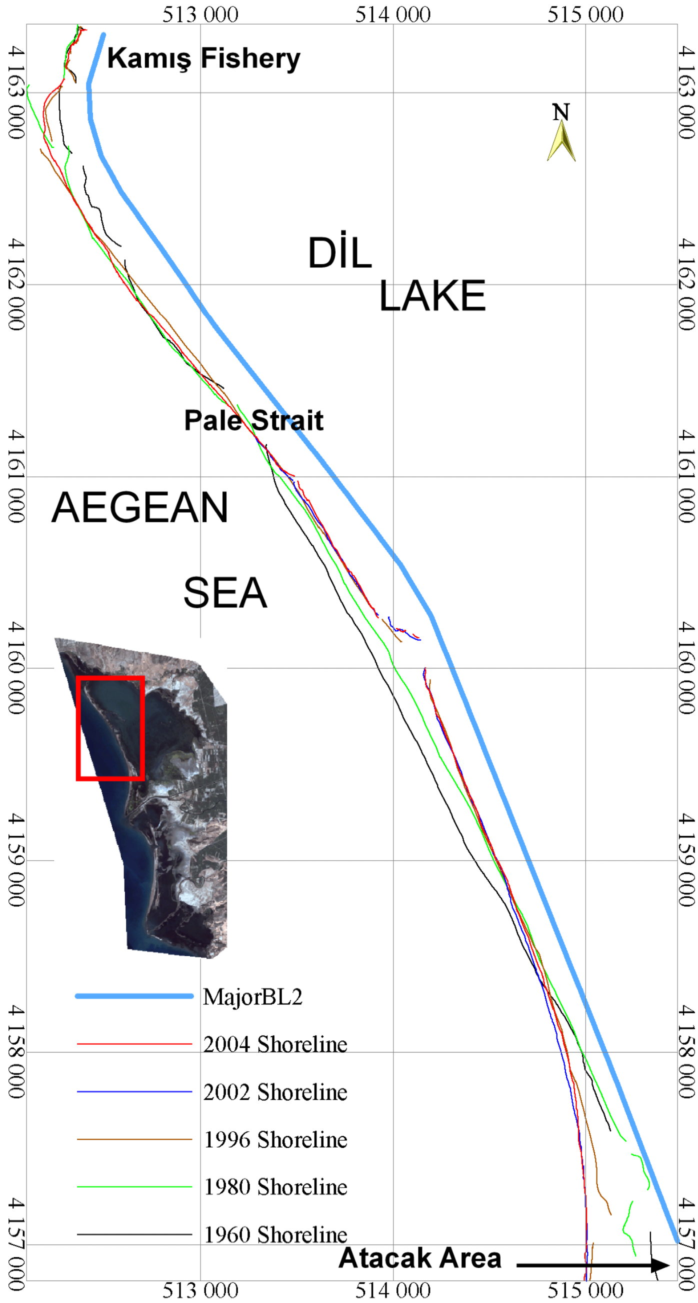

Figure 3.15. Close view of the northern parts of shorelines and the representative baseline “MajorBL2” at the study area (Region 2 in Figure 3.13).

“MajorBL3” starts at the south of Atacak Area at the north of the present delta mouth, passes through the present channel of Büyük Menderes River, Deringöl, Arapça Strait and Tuzla Lake respectively, and ends at Avdal Area. It has a length of 4173.8m with a NorthNorthWest-SouthSouthEast direction (Figure 3.16).

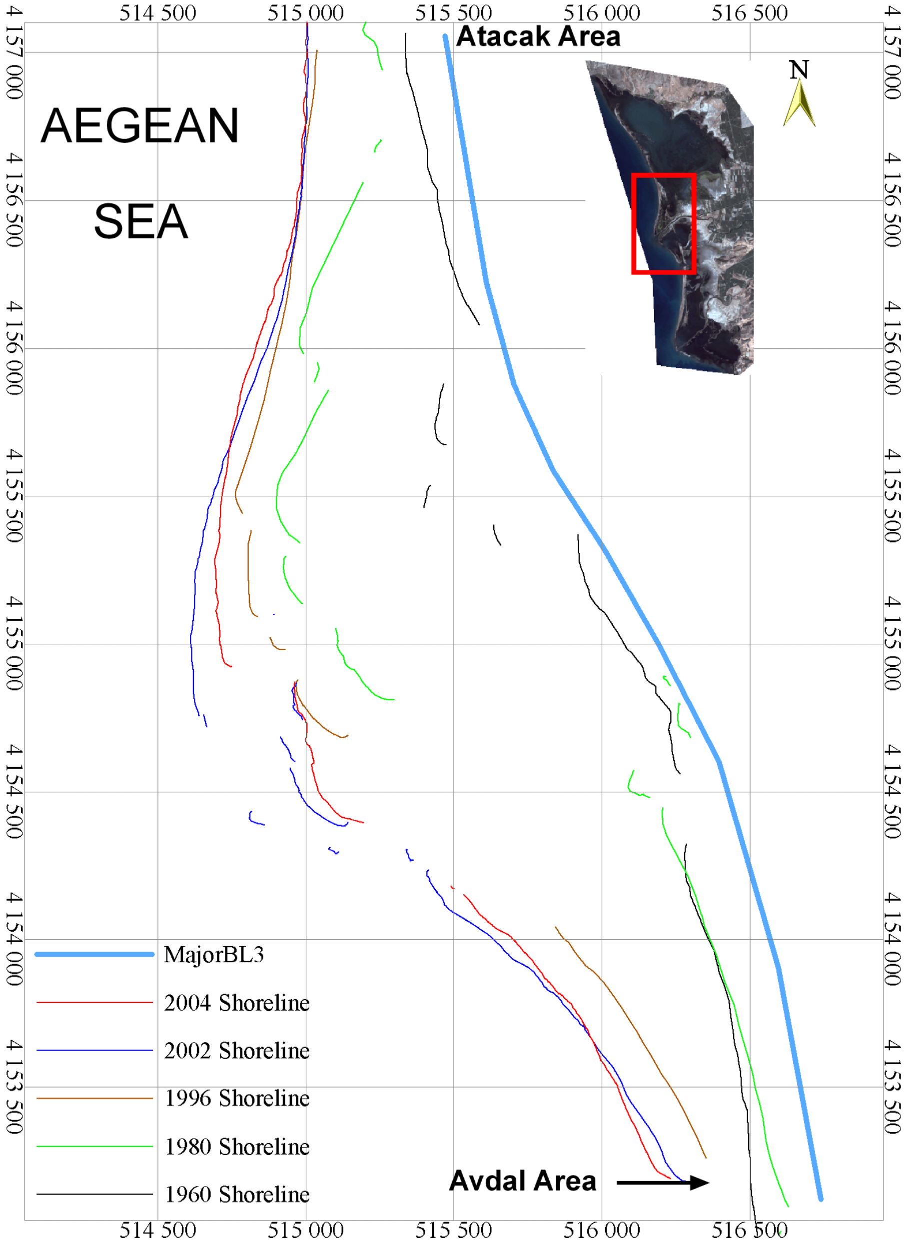

Figure 3.16. Close view of the shorelines at the present mouth of the delta and the representative baseline “MajorBL3” at the study area (Region 3 in Figure 3.13).

MajorBL4 starts at Avdal Area passes through Mavi Lake, Avdalağzı Area, Bölme Area, Kokar Lake respectively and ends at Deveotlağı Area. It has a length of 3608.5m with a North-South direction (Figure 3.17).

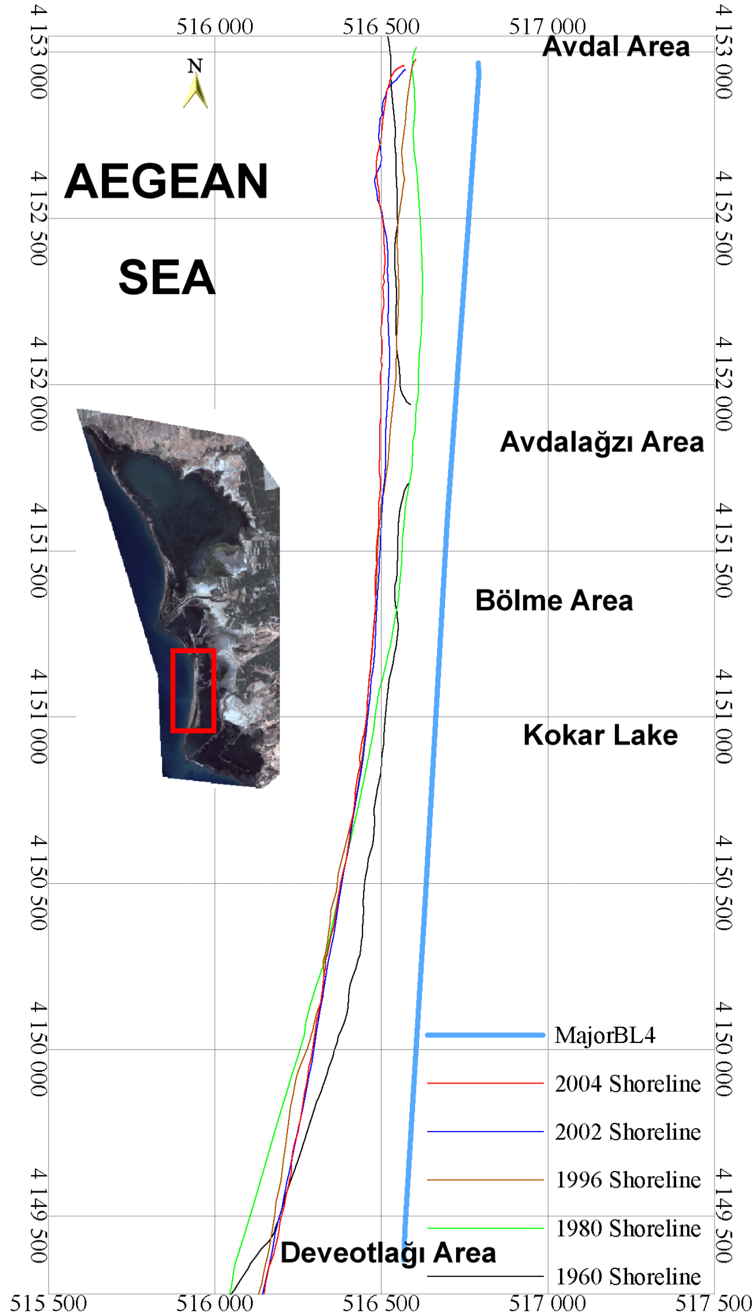

Figure 3.17. Close view of the southern parts of shorelines and the representative baseline “MajorBL4” at the study area (Region 4 in Figure 3.13).

MajorBL5 starts at Deveotlağı Area, passes through Akköy Fishery, previous channel of Büyük Menderes River respectively and ends at the barrier islands just at south of the oldest river channel. It has a length of 2269.3m with a curvilinear form that start with a North-South direction and turns into a NorthWest-SouthEast direction (Figure 3.18).

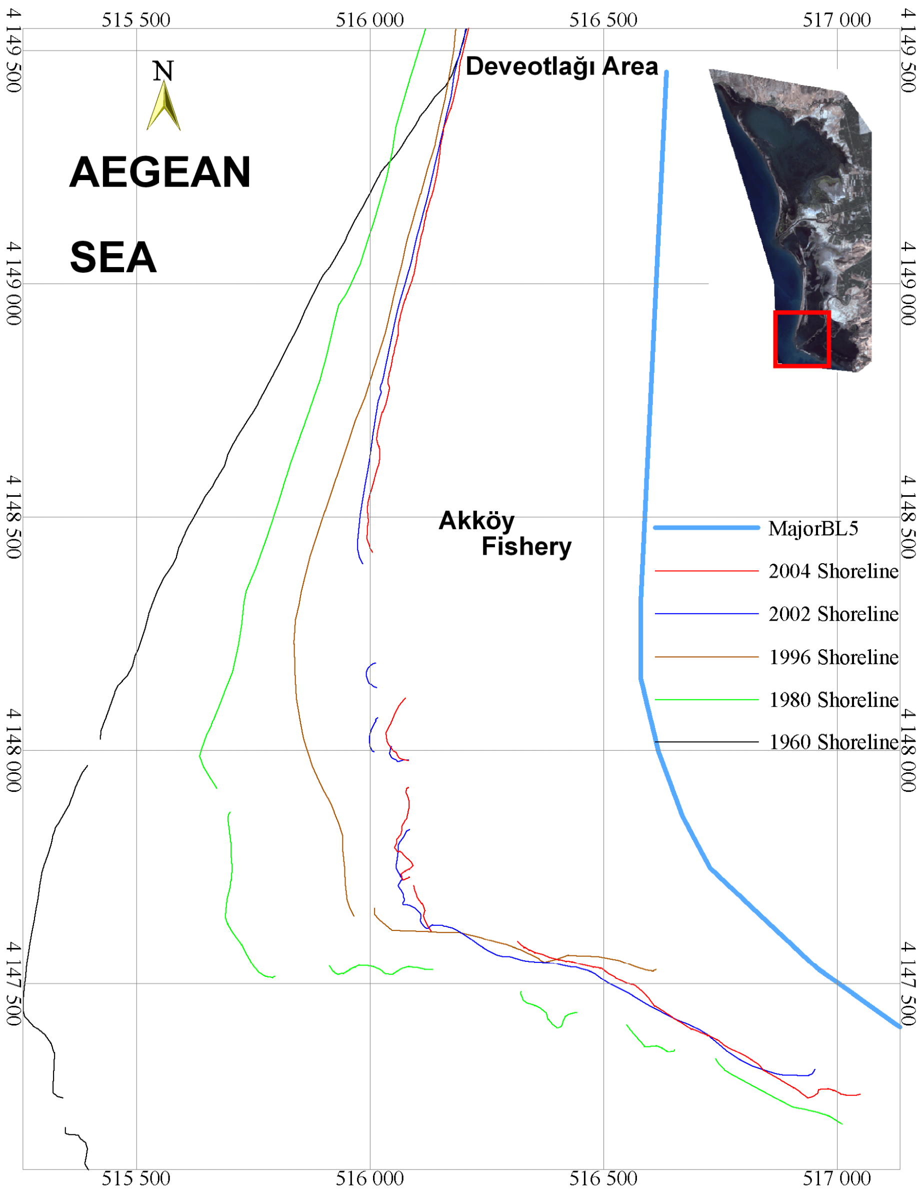

Figure 3.18. Close view of the southernmost part (previous mouth of the delta) of shorelines and the representative baseline "MajorBL5" at the study area (Region 5 in Figure 3.13).

The major trends and the suitable baselines are presented at the figures 3.14-15-16-17-18. However, the major baselines and also the transect intervals are insufficient to represent the local trends and moving (accretion and recession) directions of the shorelines at the present and previous delta mouths, as they are not simple to define with a single line. In order to catch the local changes in shoreline positions, at some places where the shorelines possess a very complex outline, baseline is drawn in smaller discrete segments in order to represent the shoreline more accurately. Therefore, the MajorBL1, MajorBL2, MajorBL3, MajorBL4 and MajorBL5 are segmented into SubBL11-12-13, SubBL21, SubBL31-32-33-34-35-36, SubBL41 and SubBL51-52-53 respectively (Figure 3.19-20-21-22-23). The length and orientation of the sub-baselines are determined by the length and orientation of the oldest or the youngest and smallest shoreline segments in the complex areas. The accretion and recession directions of the shorelines at those areas are also taken into account while deciding the directions of the sub-baselines. The lengths and directions of the sub-baselines can be seen on the table 3.3. An important point to be mentioned here is that, although the direction of a sub-baseline is identical to the major-baseline (ex: SubBL41-MajorBL4 and SubBL52-MajorBL5), the transect intervals are not the same. The major-baseline have larger transect intervals than the sub-baselines in order to not use excessive amount of point of measurements.

Table 3.3. The lengths and the directions of the sub-baselines used for the analyses.

	Length (m)	Direction		Length (m)	Direction
subBL11	95	007N	subBL34	855	321N
subBL12	79	325N	subBL35	334	348N
subBL13	30	060N	subBL36	428	006N
subBL21	195	323N	subBL41	236	003N
subBL31	210	007N	subBL51	135	000N
subBL32	98	000N	subBL52	310	343N
subBL33	97	315N	subBL53	99	325N

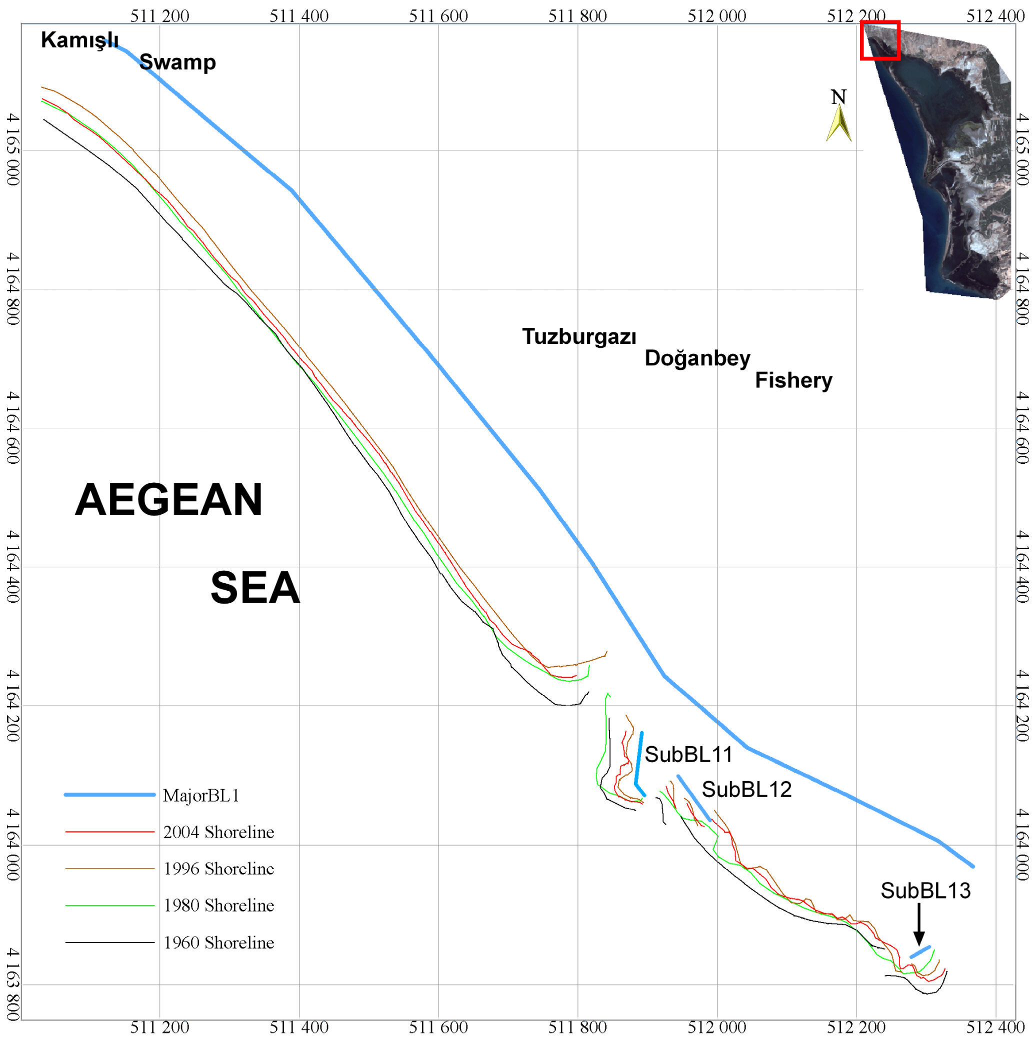

Figure 3.19. Close view of the shorelines and the representative sub-baselines for the MajorBL1.

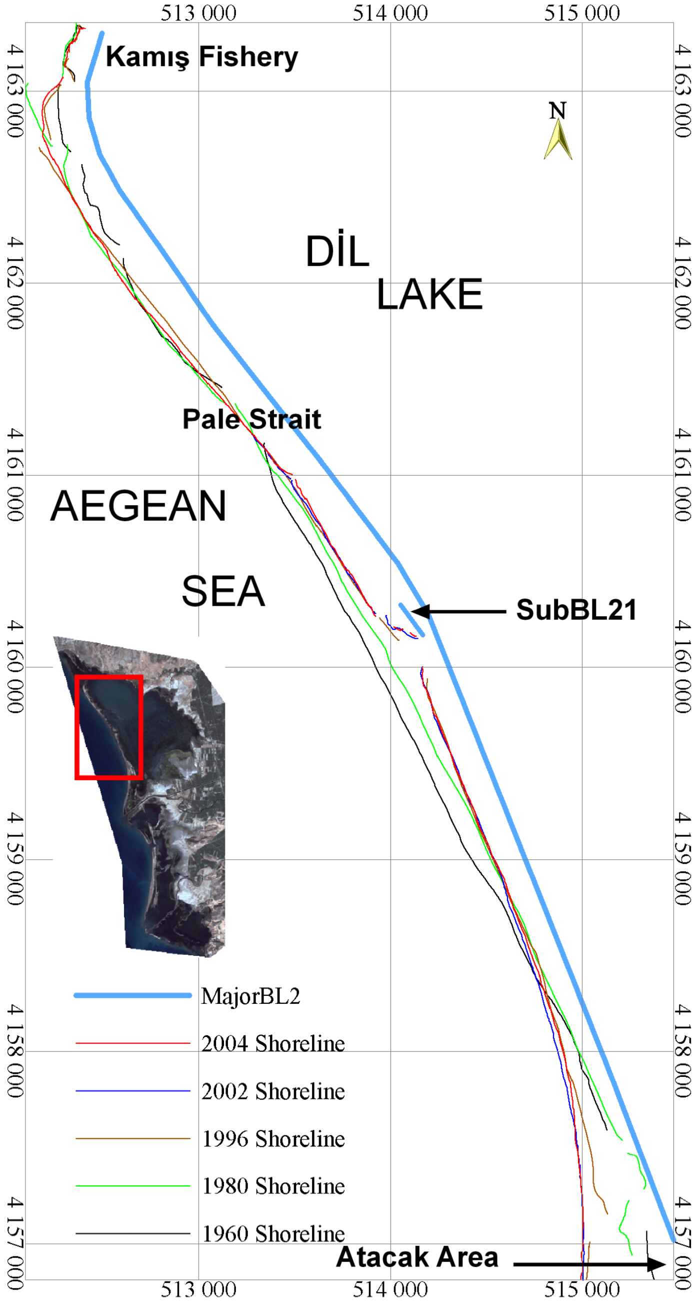

Figure 3.20. Close view of the shorelines and the representative sub-baselines for the MajorBL2.

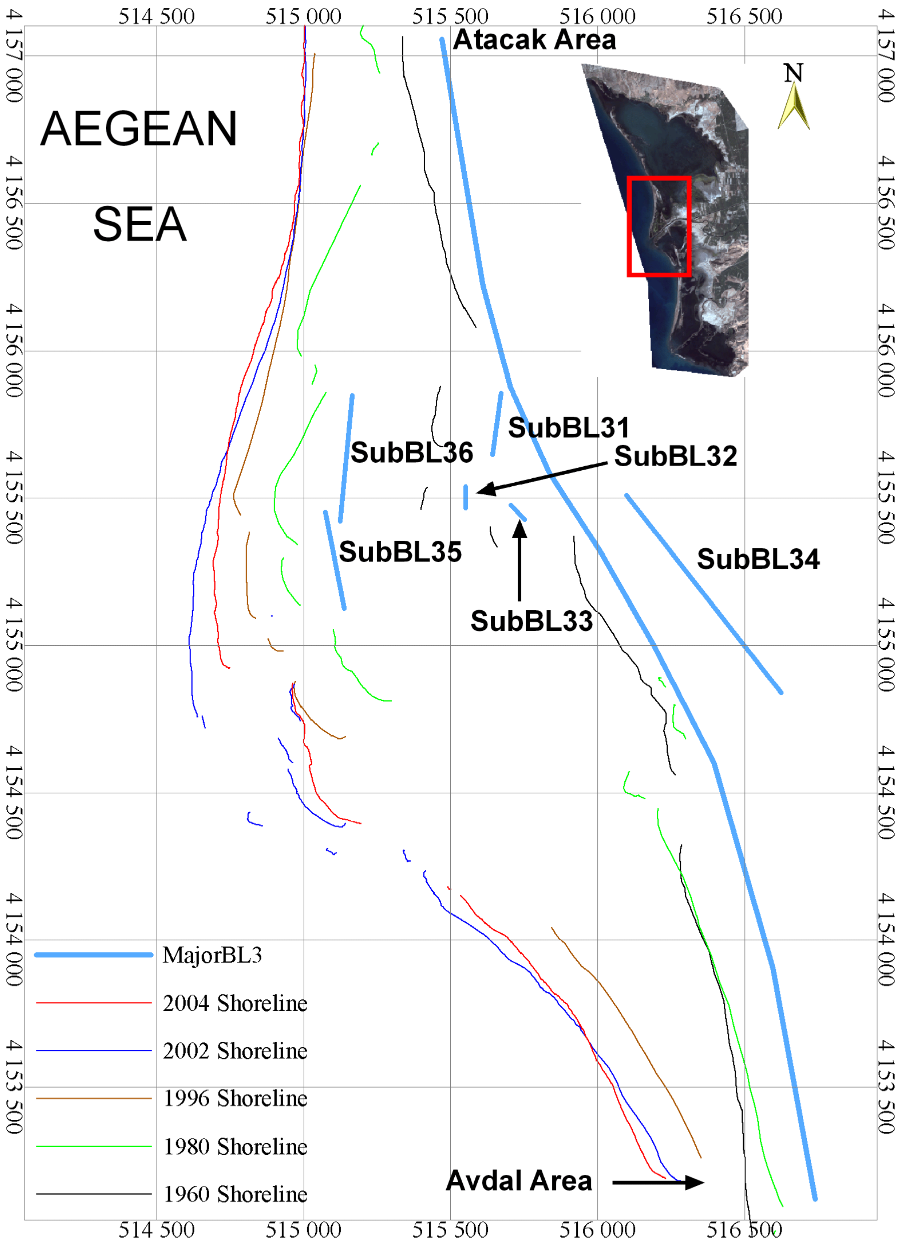

Figure 3.21. Close view of the shorelines and the representative sub-baselines for the MajorBL3.

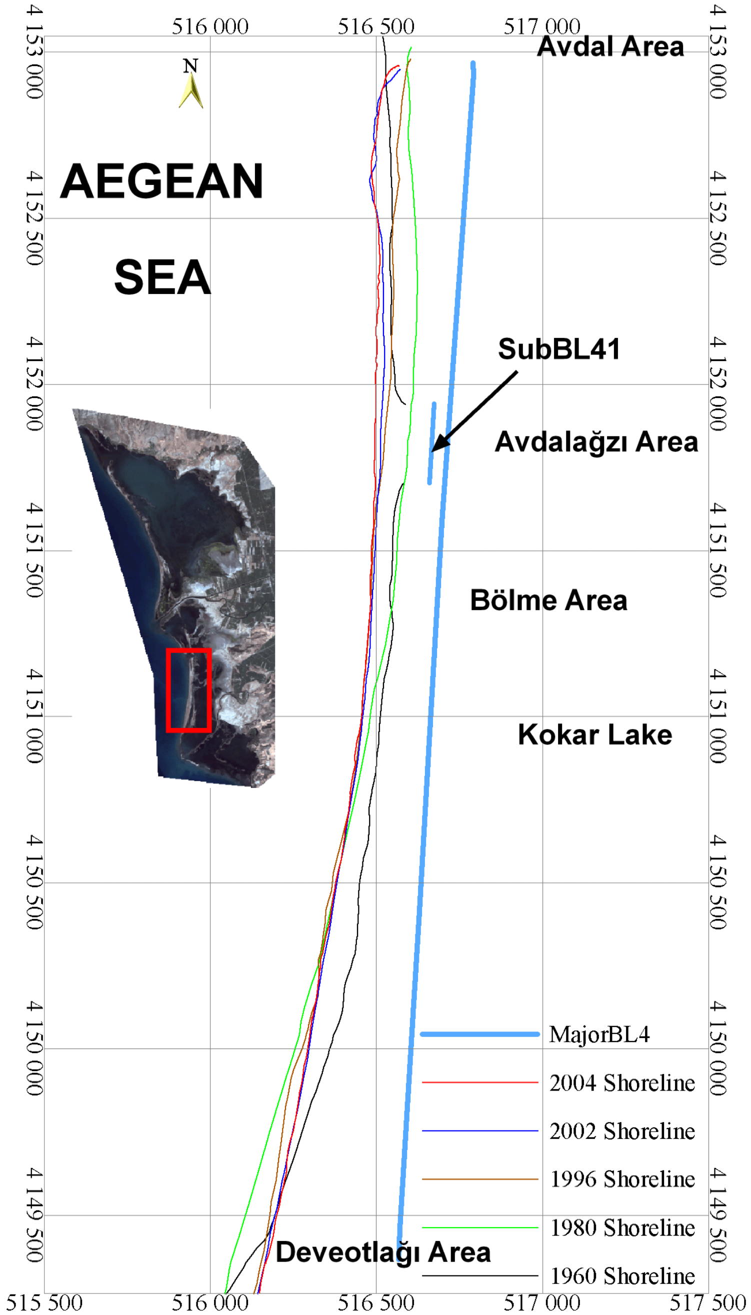

Figure 3.22. Close view of the shorelines and the representative sub-baselines for the MajorBL4.

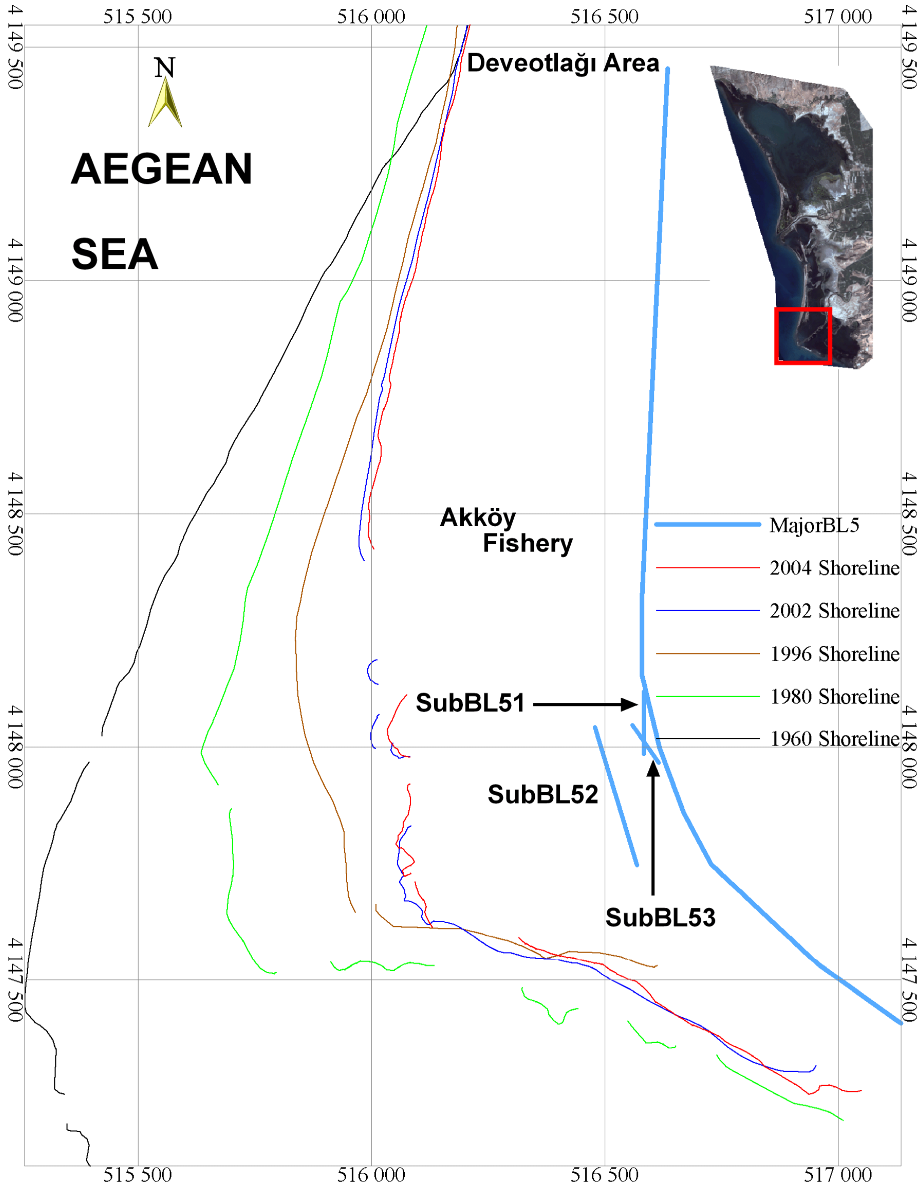

Figure 3.23. Close view of the shorelines and the representative sub-baselines for the MajorBL5.

The rate-of-change analysis is then built on "transects". Transects are the lines that are drawn perpendicular to the baselines. The important trend changes should be covered by the baselines so that the general accretion and recession directions should fit the transect directions at the changing shore. Transects are generated at user specified intervals (D) along the baselines. The length of transects (L) should be as long as they crosscut all the shorelines that are in the analyses and locate the future shoreline. To provide those conditions the interval of transects are selected between 10m to 100m and the length of transects are selected between 100m to 2500m, changing from region to region. To avoid excessive rate-of-change data, the trends of the shorelines are considered visually, so that the uniformly changing shores are analyzed with large interval of transects and the non-uniformly changing shores are analyzed with closely spaced transects. Besides the characteristics of the shorelines, also the length of the sub-baselines and the shoreline segments covered by those sub-baselines are taken into account to decide the transect interval and the transect lengths. That is, If the length of the sub-baseline is between 100 m and 200 m, then the transect interval is selected as 10, 20 or 25 meters in order to catch the sub-changes in trends at those shoreline segments (Figure 3.24).

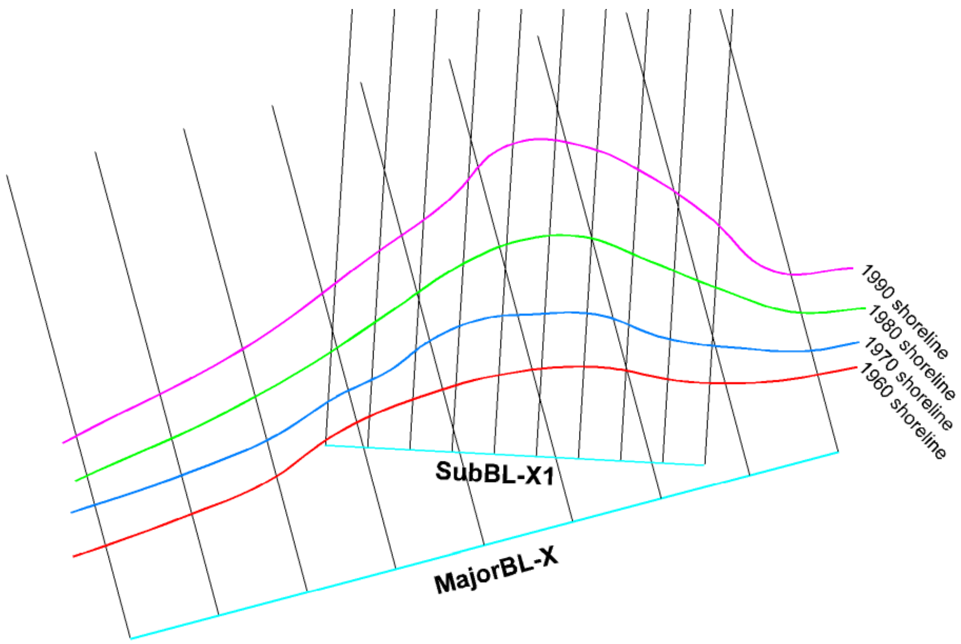

Figure 3.24. Hypothetical figure showing the changing baseline direction and transect interval in order to catch the trends of the shoreline.

CHAPTER 4

ANALYSES

After the preparation of all available data, four different statistical methods are used for the calculations of shoreline rates-of-change, which are End Point Rate (EPR), Average of Rates (AOR), Linear Regression (LR) and Jackknifing (JK). All methods involve measuring the differences between shoreline positions through time. Rates are expressed in terms of distance of change per year (m/yr). The outputs are produced by those four methods and the future shoreline position data are then compared to select the most suitable and meaningful one in coherence with the general trend of the shoreline to obtain the best representative prediction results.

The shoreline data extracted from the 1:25000 topographic maps of the years 1960, 1980, 1996, the satellite imageries of January 2002 and August 2004 of the study area and the suitable baselines that are mentioned in the third chapter are used in the analyses after importing to TNTMips editable format. For the analyses, a script of TNTMips called "coastal", which calculates the rate-of-changes for each baseline positions, is used.

Coastal is a script that uses the interested shorelines and the most suitable baselines as an input data. The transect length and the interval of transects (in meter) are then entered as other inputs for the analyses. The rates-of-change are then calculated, with necessary equations, on transects crosscutting the shorelines. Each pair of successive shorelines is analyzed separately on each transect. The result of the analyses are the transect numbers and the belonging rates that are EPR, AOR, LR, JK, the standard deviations and the variances. An example of the script's result is given in Table 4.1.

Table 4.1. Example of the statistical results obtained after computation of the script.

Transect	EPR	Mean	StdDev	Variance	Regression	Jackknife
1	-5.70	-5.61	1.47	2.16	-5.74	-5.61
2	-4.37	-4.39	0.30	0.09	-4.36	-4.39
3	-4.06	-4.08	0.23	0.06	-4.05	-4.08
4	-3.77	-3.80	0.38	0.14	-3.76	-3.80
5	-2.64	-2.67	0.49	0.24	-2.62	-2.67
6	-2.78	-2.80	0.31	0.10	-2.77	-2.80
7	-2.69	-2.49	1.12	1.26	-2.82	-2.78
8	-2.75	-2.59	0.92	0.84	-2.87	-2.84
9	-2.73	-2.63	0.60	0.36	-2.81	-2.79
10	-2.60	-2.51	0.44	0.19	-2.65	-2.63
11	-2.24	-2.04	0.94	0.88	-2.33	-2.28
12	-2.07	-1.86	0.99	0.97	-2.17	-2.11
13	-2.12	-1.97	0.69	0.48	-2.19	-2.14
14	-2.05	-1.85	0.83	0.69	-2.12	-2.06
15	-2.16	-2.01	0.53	0.29	-2.14	-2.05
16	-2.24	-2.08	0.76	0.58	-2.14	-2.02
17	-2.31	-2.14	0.89	0.79	-2.18	-2.05
18	-2.38	-2.22	0.92	0.84	-2.25	-2.11
19	-2.51	-2.39	0.85	0.73	-2.38	-2.26
20	-2.47	-2.35	0.52	0.27	-2.41	-2.32
21	-2.45	-2.39	0.36	0.13	-2.40	-2.35

Although at each transect the rates-of-change are calculated by the “coastal” script, it is insufficient to predict the future shoreline positions, which is the main purpose of this study. To overcome this problem the script is edited so that it can calculate the future shoreline positions for each transect and can plot the position of the future shoreline as point data on the transects. The edited script requires selecting the desired statistical method and the time span (in years) for the asked future position. A “final” editing on the script is also done to have the minimums, means and the maximums of the calculated rates by the four statistical methods and to plot them again as point data. The need of those editing are explained later in the future chapters (see Ch4 and Ch5). The “Coastal” script and the edited script are given in Appendix 2.

4.1. End Point Rate (EPR)

The End Point Rate method is the most common and the simplest method based on the calculation of the distance of total shoreline movement (usually the earliest and the latest points) divided by the time elapsed between the measurements (i.e. 1957-2004). The script uses the equation below for the EPR calculations (Equation 4.1).

$$EPR = \frac{(d_1 - d_0)}{(t_1 - t_0)} \quad \text{, in m/year} \qquad \text{(Equation 4.1)}$$

An End Point Rate is calculated separately for each transect and the future shoreline position is located on those transects. An example of a calculation of the EPR on an arbitrary transect of a baseline is plotted as given in Figure 4.1. The rate-of-change vs. transect number plot of an example MajorBL3 is given in Figure 4.2.

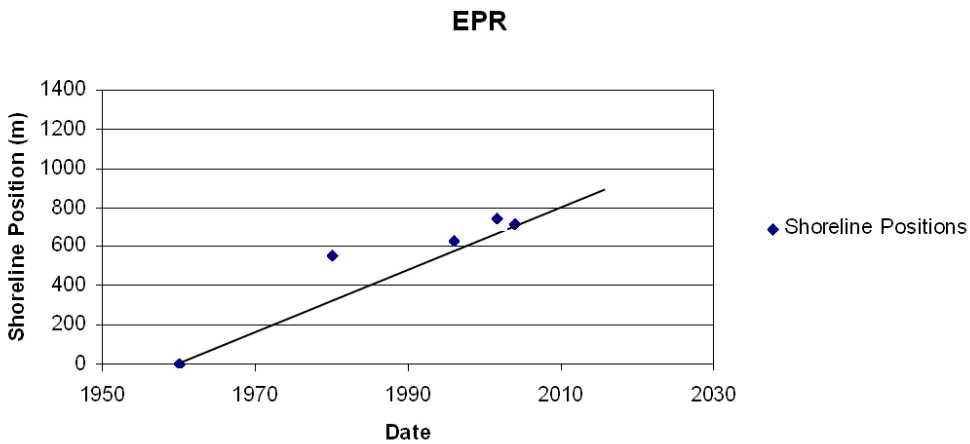

Figure 4.1. Example of EPR calculation on a transect of a baseline.

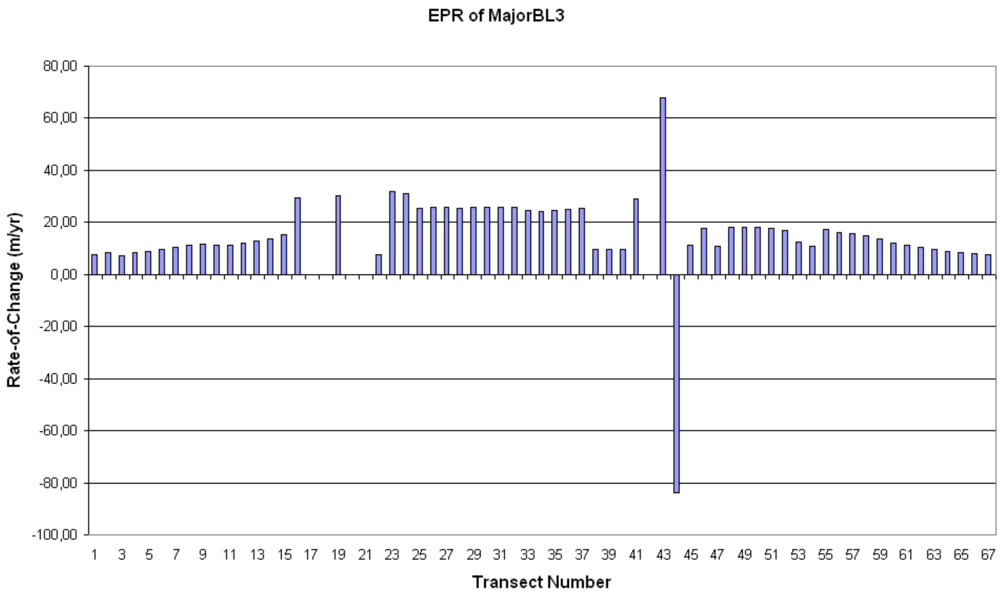

Figure 4.2. EPR values (in m/yr) of MajorBL3.

The total EPR frequency of the same baseline is given below (Figure 4.3) on a histogram. The frequency histograms are prepared after eliminating the transects with no record. That are transects that do not cross at least two of the ancient shorelines. The total number of transects decreased to 62 from 67 for MajorBL3 (Figure 4.4).

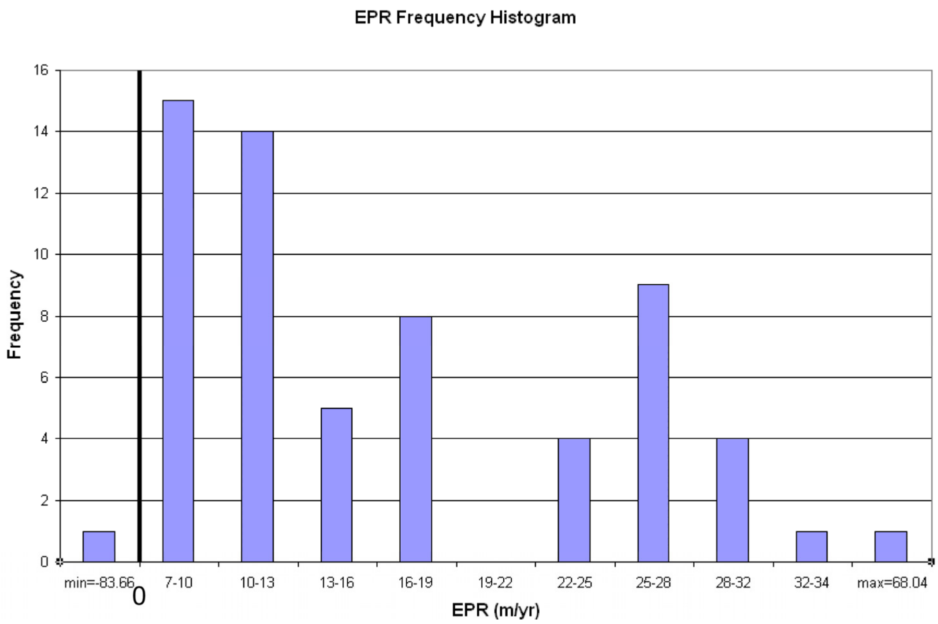

Figure 4.3. The total EPR frequency histogram of MajorBL3.

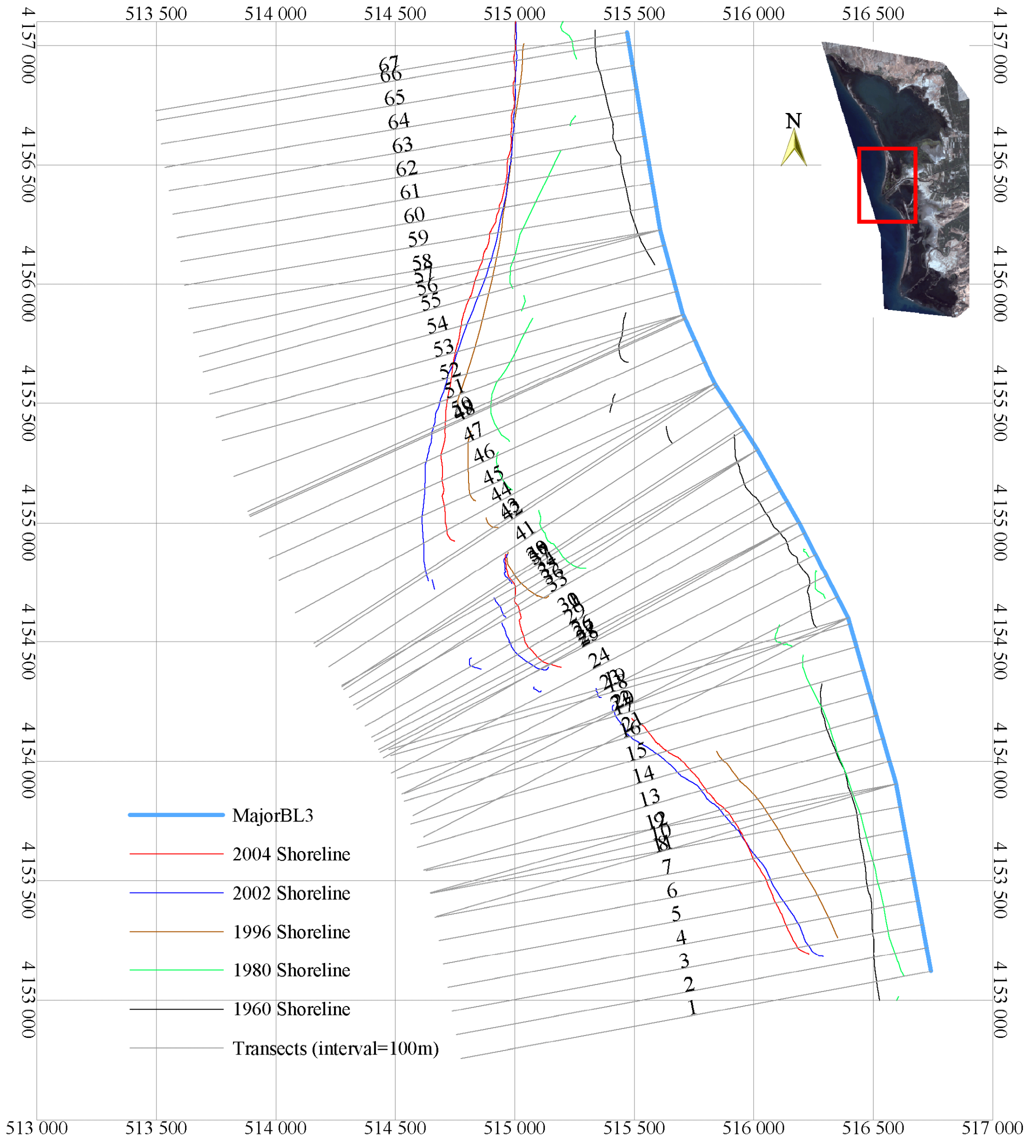

Figure 4.4. The transects computed on the baseline "MajorBL3", the transect numbers and the location map of MajorBL3 on the study area. The total number of transects is 67 for this baseline and the transect interval is 100m.

4.2. Average of Rates (AOR)

In Average of Rates method, proposed by Foster and Savage (1989), individual EPRs are calculated from the shoreline position data when more than two shoreline positions are present. The equation incorporates the accuracy of the shoreline position data and the magnitude of the rate-of-change to determine if any EPR meets a minimum time criterion (T_{min}).

T_{min} is represented by the following formula (Equation 4.2):

$$T_{\min} = \frac{\sqrt{(E_1^2 + E_2^2\ )}}{R_1} \qquad \text{(Equation 4.2)}$$

AORates are calculated separately for each transect and the future shoreline position is located on those transects. An example of a calculation of the AOR on a transect of a baseline is plotted as given in Figure 4.5. The rate-of-change calculated by AOR method versus transect number plot of a local example MajorBL3 is given in Figure 4.6.

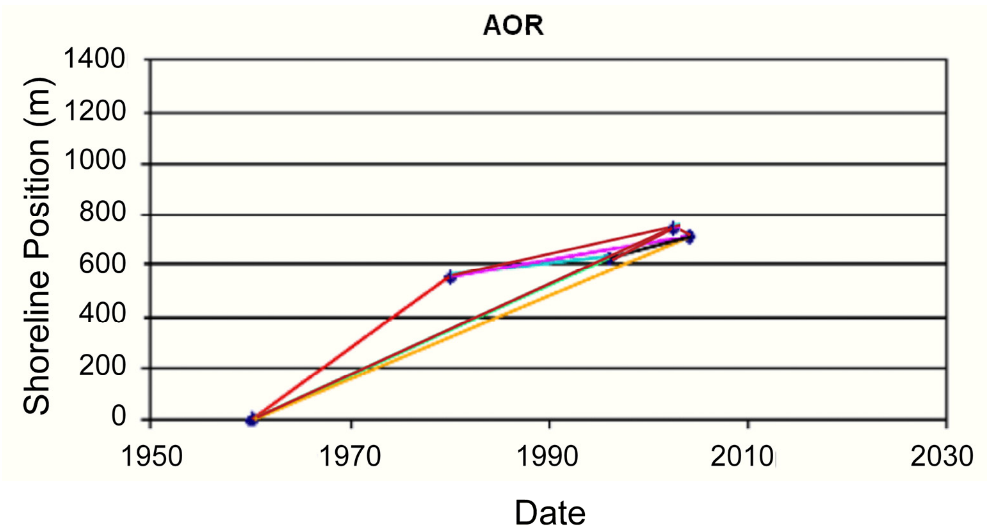

Figure 4.5. Example of AOR calculation on a transect of a baseline.

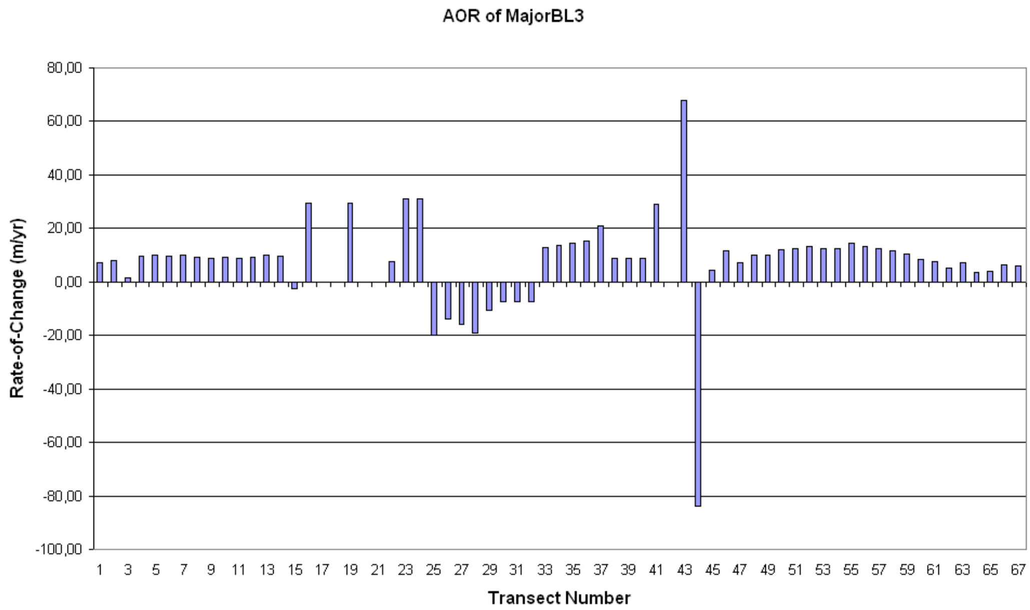

Figure 4.6. AOR values (in m/yr) of MajorBL3.

The AOR frequency of the same baseline is given below (Figure 4.7) on a histogram.

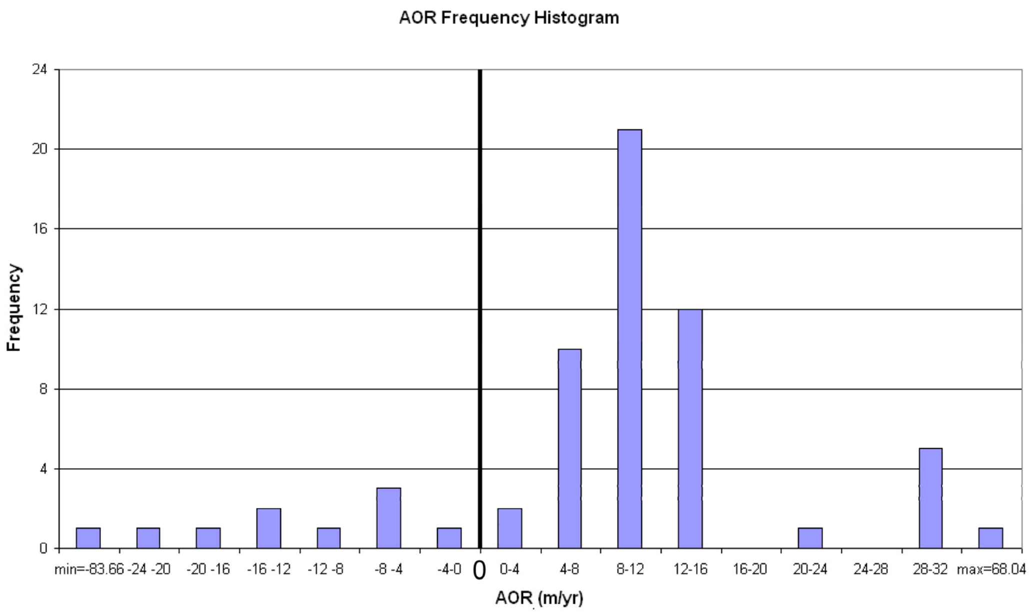

Figure 4.7. The AOR frequency histogram of MajorBL3.

4.3. Linear Regression (LR)

LR method is a more suitable method to use in the analyses when there is insufficient amount of shoreline position data and if the changes of the shorelines are constant or not much variable. This simple and easy approach calculates a best-fit line through the entire sample of shoreline position.

This method uses the entire data as input (for this case: 1960, 1980, 1996, 2002 and the 2004 shoreline position data) for the analyses.

A Linear Regression is calculated separately for each transect and the future shoreline position is located as a point on the transects. An example of a calculation of the LR on a transect of a baseline is plotted as given in Figure 4.8.

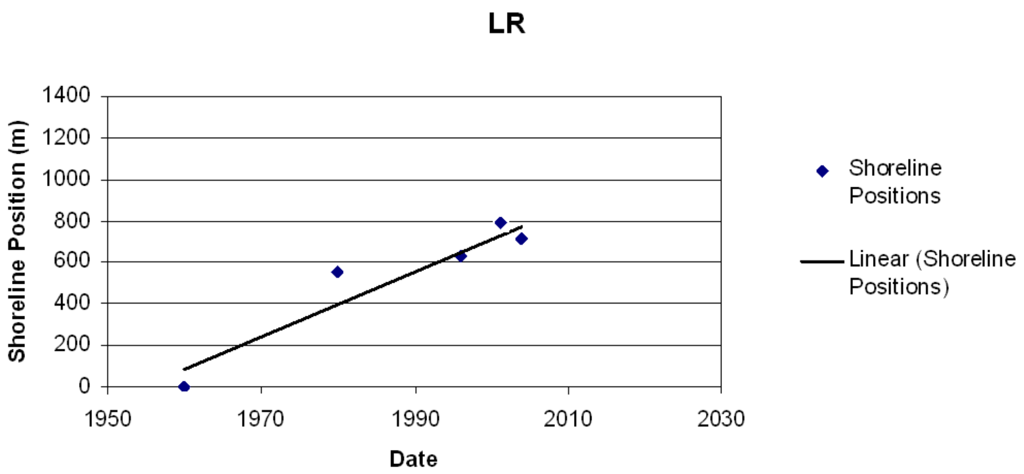

Figure 4.8. Example of LR calculation on a transect of a baseline.

The general formula of Linear Regression is explained below:
The best fit line associated with the n points (x1, y1), (x2, y2), . . . , (xn, yn) has the form

y = mx + b, where

$$slope = m = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^y}$$

$$\text{int}\,ercept = b = \frac{\sum y - m(\sum x)}{n}$$

Here, Σmeans "the sum of." Thus

Σxy = sum of products = x1y1 + x2y2 + . . . + xnyn

Σx = sum of x-values = x1 + x2 + . . . + xn

Σy = sum of y-values = y1 + y2 + . . . + yn

Σx2 = sum of squares of x-values = x12 + x22+ . . . + xn2

The rate-of-change vs. transect number plot computed by LR method of a local example MajorBL3 is given in Figure 4.9.

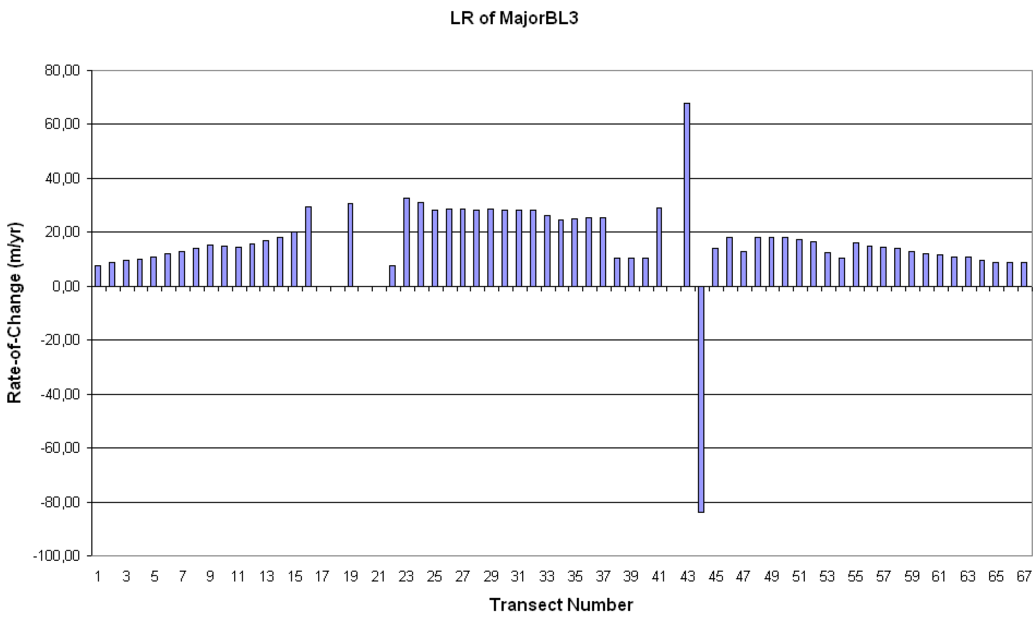

Figure 4.9. LR values (in m/yr) of MajorBL3.

The LR frequency of the same baseline is given below (Figure 4.10) on a histogram.

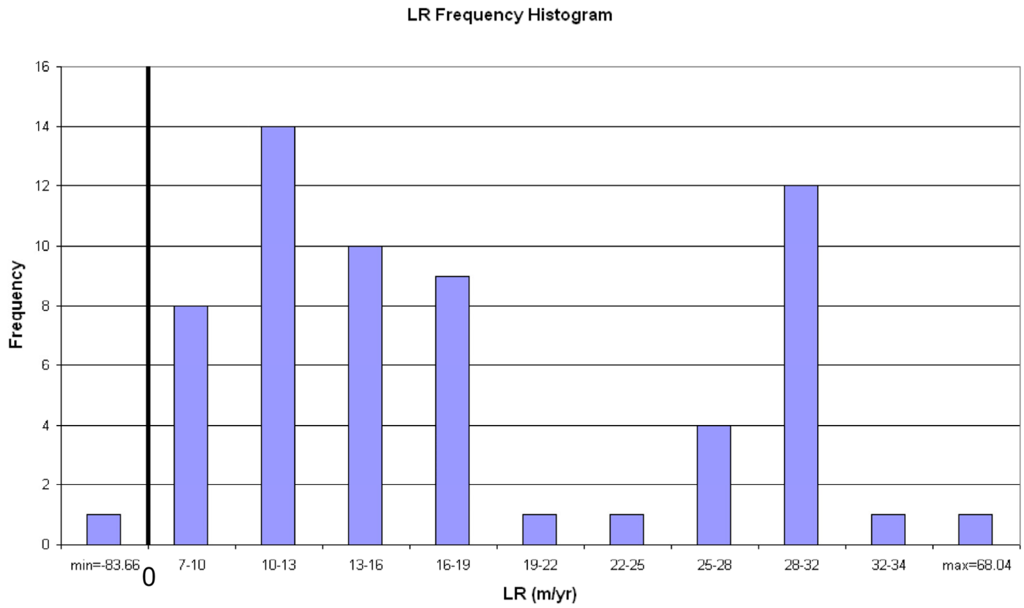

Figure 4.10. The LR frequency histogram of MajorBL3.

4.4. Jackknifing (JK)

JK approach, proposed by Efron (1982), is an adaptation of LR, which uses all possible combinations of LRs by omitting one data point at each iteration cycle. The average of slopes of each regression line is calculated to estimate the long term trend.

A maximum of ten different regression lines is used for the JK rate calculations by omitting one shoreline data point at each iteration for each baseline.

JK rates are calculated separately for each transect and the future shoreline position is located on those transects. An example of a calculation of the JK on a transect of a baseline is plotted as given in Figure 4.11. The rate-of-change calculated by JK method versus transect number plot of a local example MajorBL3 is given in Figure 4.12.

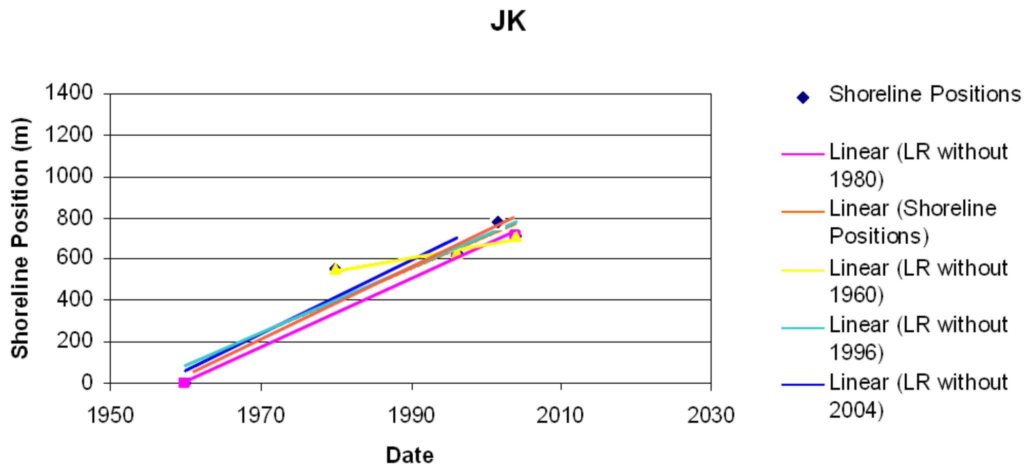

Figure 4.11. Example of JK calculation on a transect of a baseline.

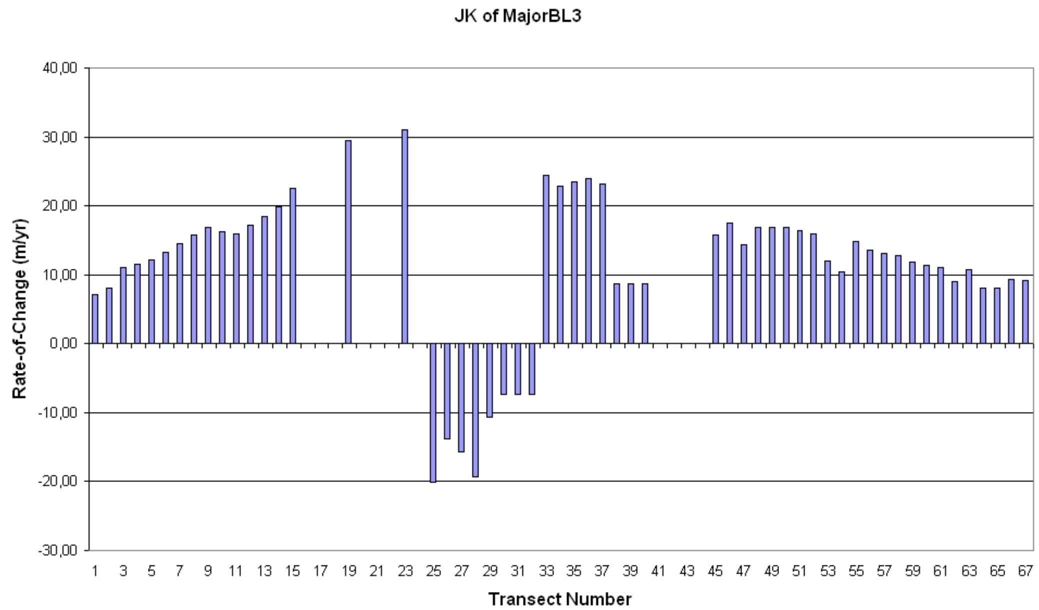

Figure 4.12. JK values (in m/yr) of MajorBL3.

The LR frequency of the same baseline is given below (Figure 4.13) on a histogram.

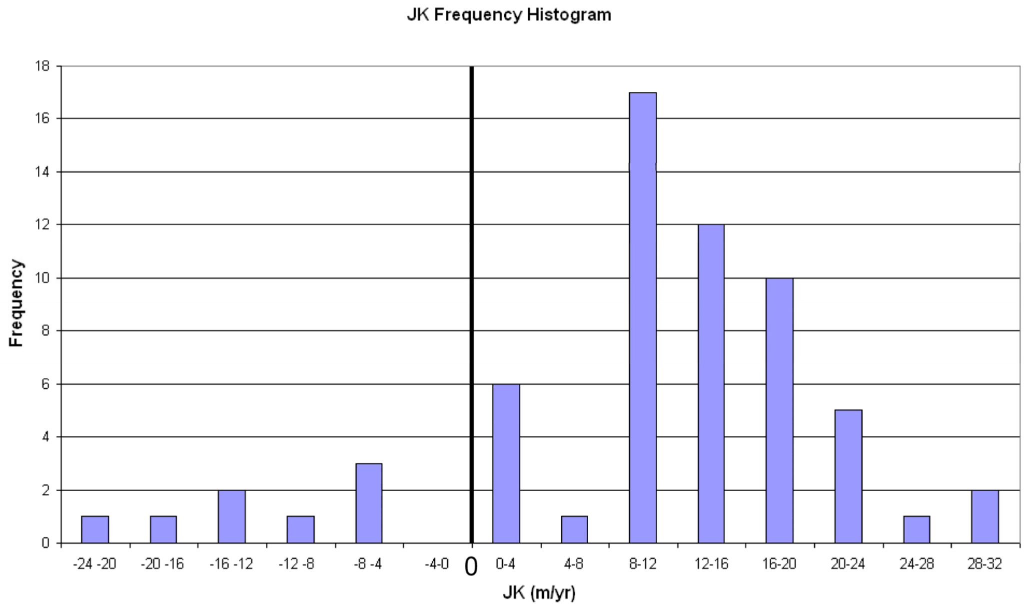

Figure 4.13. The JK frequency histogram of MajorBL3.

4.5. Positional Analyses - for future shoreline mapping

The results of the statistical analyses explained above can be examined in chapter 5.1. The future shoreline approximation of the year 2024 is done and plotted as points on the transects for each statistical method. The 2024 shoreline is than manually drawn, separately for each statistical method, on screen by analyzing the general trend of the previous shorelines that are entered as inputs for this approximation (which are 1960, 1980, 1996, 2002 and 2004 shorelines) (ch5.1. figures.5.1, 2, 3, 4).

4.6. Oscillation Analyses - limits of a buffer zone

In order to have a general idea of the final future shoreline position (that is 2024 shoreline position of the B. Menderes Delta) the minimum, mean and the maximum changes (of the four methods) on each transect are also analyzed and plotted as “minimum shoreline”, “mean shoreline” and the “maximum shoreline” (ch.5.2., figures 5.5, 6, 7). This will show the range (the limits) of oscillation of the 2024 shoreline. That is the 2024 shoreline is limited between the “minimum shoreline” and the “maximum shoreline”. The “minimum shoreline”, where the minimum rates-of-change are caught, can be defined also as the closest shoreline position to the latest shoreline (that is 2004 shoreline in this thesis), and the “maximum shoreline”, where the maximum rates-of-change are caught, can be defined as farthest shoreline position to the latest shoreline (2004 shoreline). The statistical method that will be chosen as the best method will be the method that gives the shoreline the most analogous (or similar or indistinguishable) to the “mean shoreline” (chapter 5.3 figure 5.6). It should be mentioned that the minimum shoreline and the maximum shoreline will not be one of the shorelines derived (or extracted or acquired) from the four statistical analyses, but they will cover some positional points from all methods.

4.7. Spatial Rate-of-Change Analyses - a Backward Analysis

After having all the four positions of the 2024 shoreline explained in the sections from 4.1 to 4.4, a backward analysis is needed to be done in order to “visualize” the rates-of-change at all over the area, as they are not plotted on the maps, although the positions are plotted. That is, only the point data extracted from all of the transects computed from all of the baselines in the area are connected, not by looking to the rates they have and to the transects or the baselines they belong, in order to form the 2024 shoreline. However, it is a very hard, long and possibly erroneous process to put all the rates to the belonging points manually, because the transect numbers of the points and belonging baselines cannot be utilized at the same time manually. So an automatized process was needed in order to have the rates without error and without consuming time. The reason behind this automatized “backward analysis” is that a shoreline in this thesis is created with more than one shoreline having different baselines and rates-of-change at complex areas. Beside this reason, it should be remembered that, at the areas, where more than one shoreline position data (so more than one rate-of-change for the same area) that are coming from transects of different baselines, the “right (true) vertex” to compose the shoreline so the “right rate-of-change” is selected by the shoreline specialist (or the analyst) only on the screen not only by looking the rates but also following the general trends. In addition, to visualize the changes will give the spatial distributions of the rates-of-change and mapping of the rates is necessary to classify the shoreline into segments as “stationary or immobile shoreline”, “accreting shoreline” and “receding or retrograding shoreline”, with the rate-of-change intervals. (Chapter 5.4., Fig. 5.7, 8, 9, 10).

The steps of this complex but useful automatized “backward analysis” can be explained as follows:

1- In order to do this backward analysis, first of all the shorelines (line vectors) had to be disintegrated into their original vertices that form those line vectors, whose transects were not interested while drawing the shoreline, by using a line-to-point conversion script.
2- After deriving the vertices forming the shorelines, all the transect data, belonging to separate baselines, for each statistical method are merged in order to have one transect database for one method.
3- Buffers are formed around the vertices in order to have polygons instead of vertices. Because the line-to-point intersection process was a very hard process because of the spurious accuracy of the GIS software used to compute all the shoreline analyses for this thesis, a more easy method, which is polygon to line intersection process, is chosen for the next steps. The diameter of the buffer zones is selected as 0.1m to minimize the possibility of more that one intersecting transects in one polygon.
4- The polygon vectors are then intersected with the merged transects (at step 2), that the original points lie on.

5- After the intersection process, an attribute transfer process is needed to transfer the rates of the intersecting transects to the vertices formed in step 1.
6- Statistical analyses and visual analyses of the points with the labels on are done to analyze the spatial and statistical distributions of the rates-of-change.
7- Finally, thematic mapping in order to have a shoreline rate-of-change classification. A flow chart may ease the understanding of this backward analysis and can be examined below in figure 4.14.

This process is repeated for each statistical method and the results can be examined in chapter 5.3. After the backward analyses, all the points forming the final shorelines belonging to each method are analyzed statistically as they are given as examples of MajorBL3 in the previous chapters (Chapters 4.1, 2, 3 and 4). With the help of rate frequency histograms, the Final EPR Shoreline, Final AOR Shoreline, Final LR Shoreline and Final JK Shoreline are discussed carefully again in chapter 5.3.

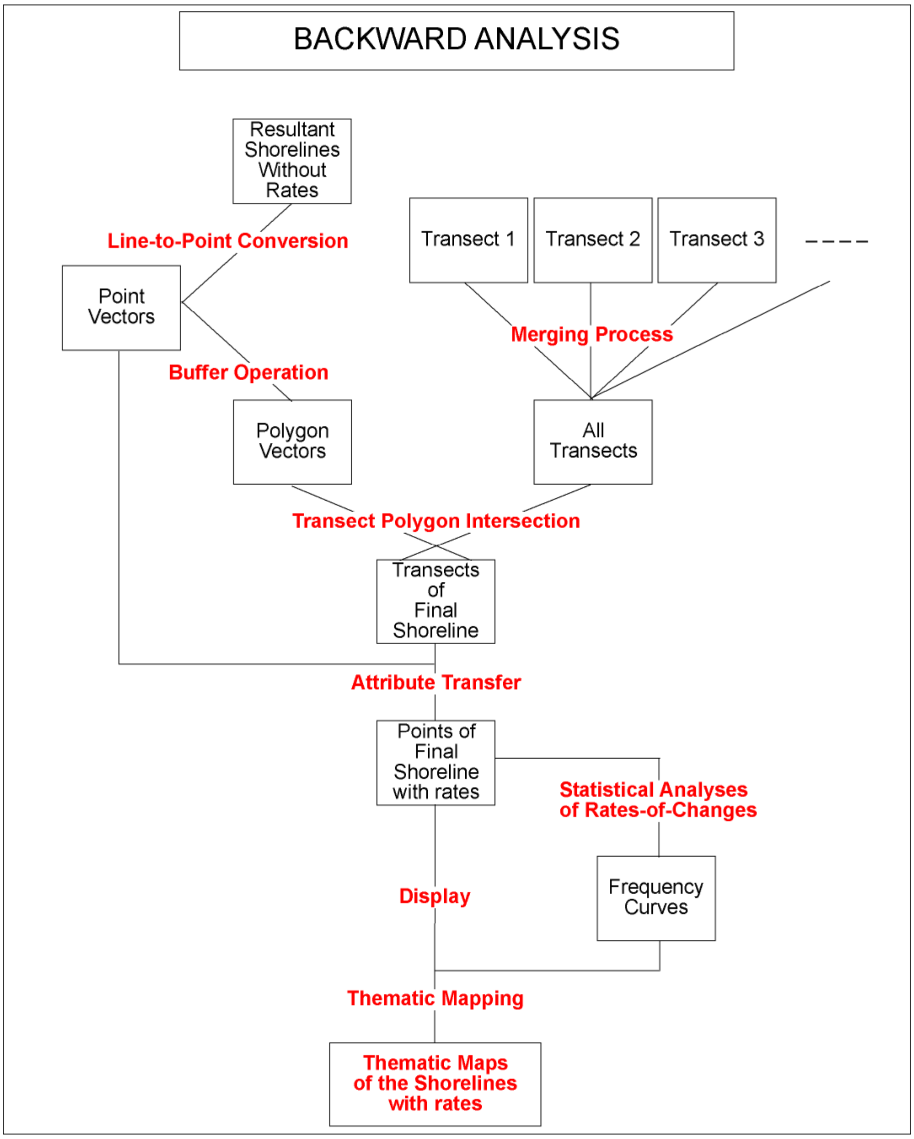

Figure 4.14. Flowchart showing the steps of the backward analysis.

CHAPTER 5

RESULTS AND DISCUSSION

The purpose of this study was to determine the shoreline rate-of-change of Büyük Menderes Delta for the last ~ 50-year period and to approximate future shoreline positions, by the integration of remote sensing and geographic information systems. Four types of statistical methods are applied to analyze the shoreline position data obtained by digitizing different types of data from different periods by using a number of baselines and transects of different lengths and different intervals, as explained in previous chapters (see chapters 3 and 4). The analyses are computed through a script, called "Coastal" after the necessary editing is done on that script.

5.1. Mapping

The results of the analyses are obtained as point data plotted on transects and as a transect database. The point data belonging to analyses of separate baselines representing the whole shoreline is than connected with line segments to have final position of the shorelines. This process is done separately and carefully for each statistical method as explained in section 4.5. The results of each analysis are shown in figures 5.1, 2, 3 and 4. The time span for the approximation of the future shoreline is taken as 20 years.

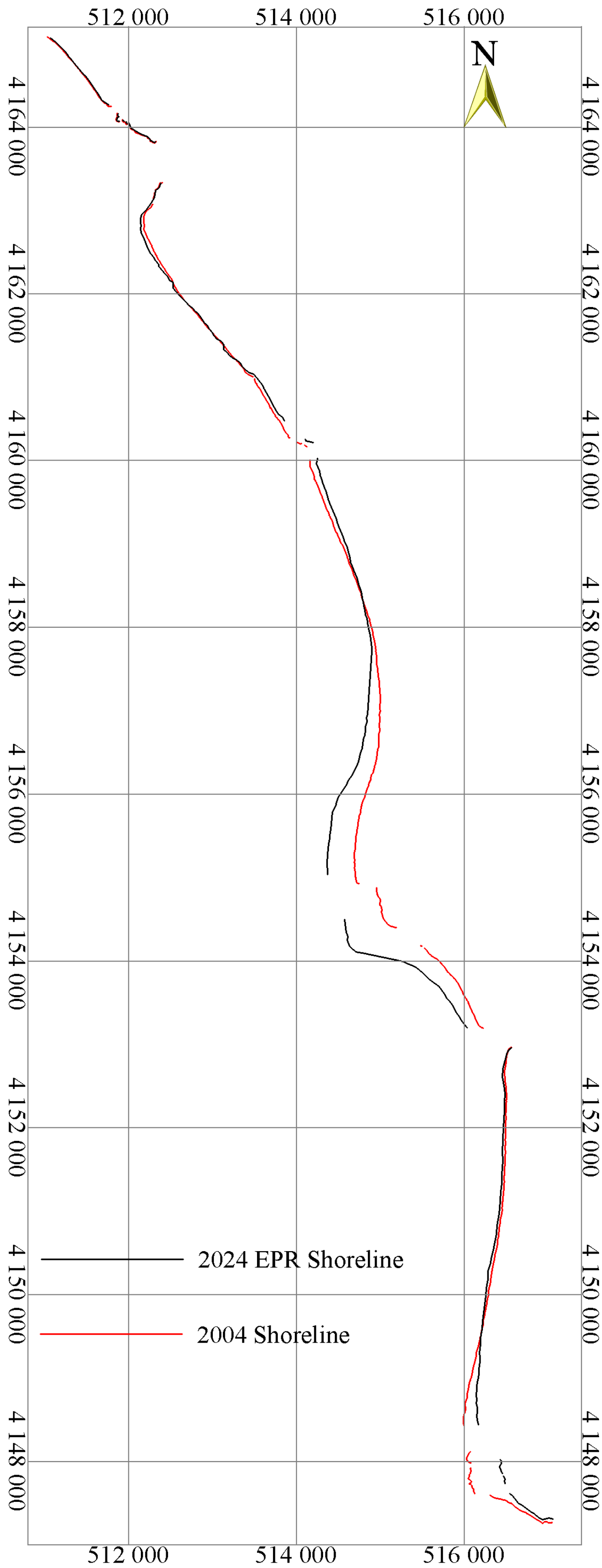

Figure 5.1. Position of the 2024 shoreline (computed by EPR method) with respect to 2004 shoreline.

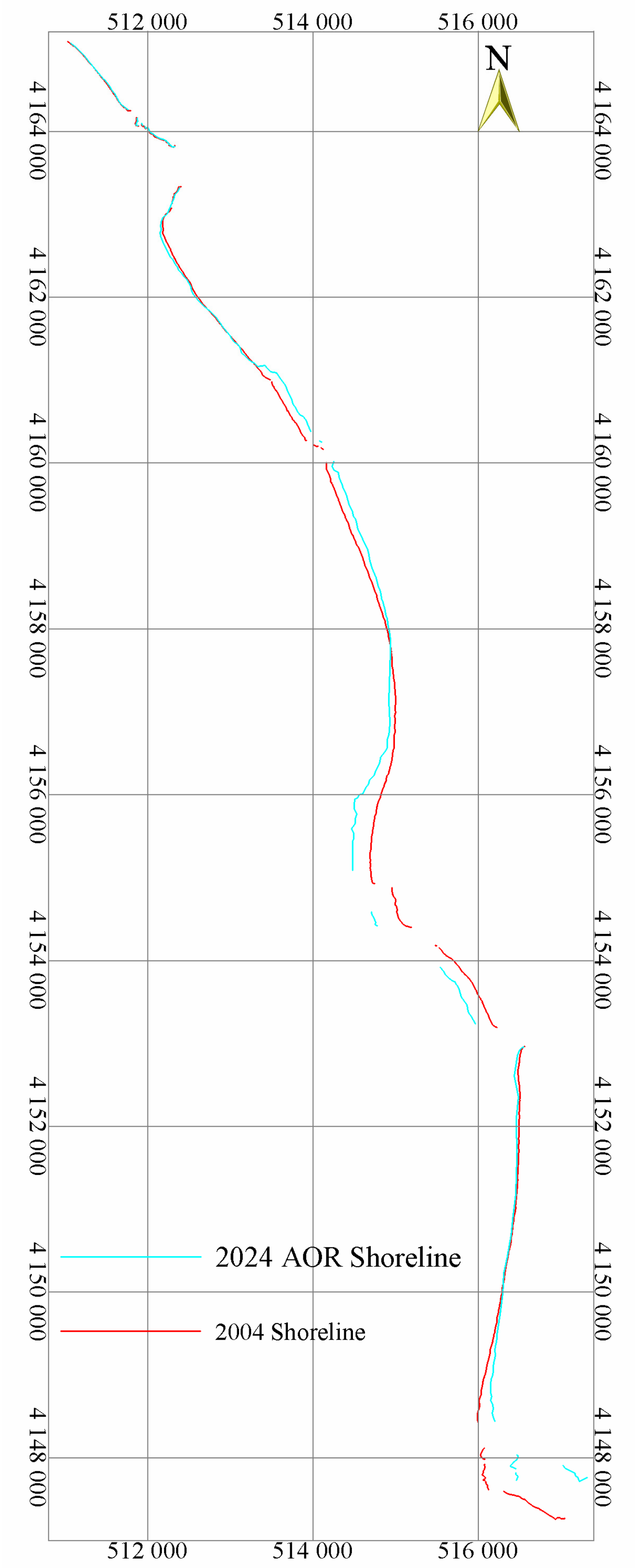

Figure 5.2. Position of the 2024 shoreline (computed by AOR method) with respect to 2004 shoreline.

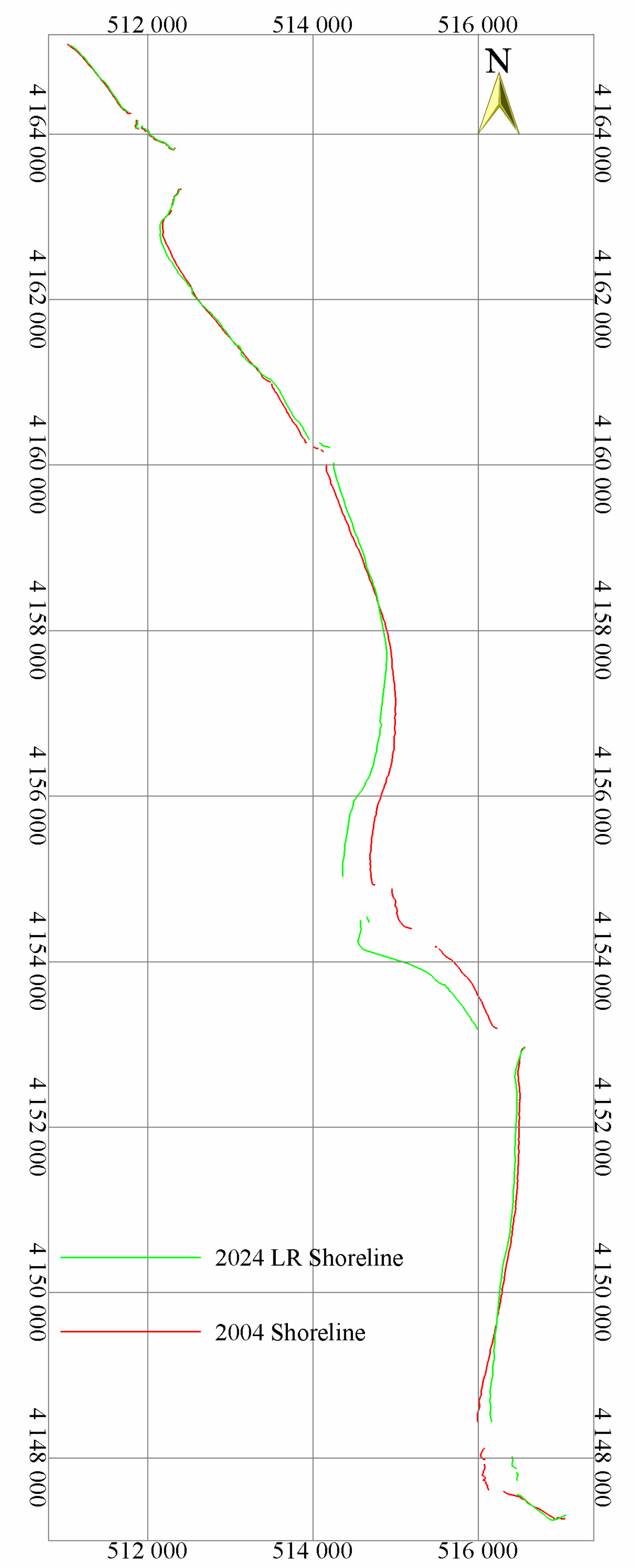

Figure 5.3. Position of the 2024 shoreline (computed by LR method) with respect to 2004 shoreline.

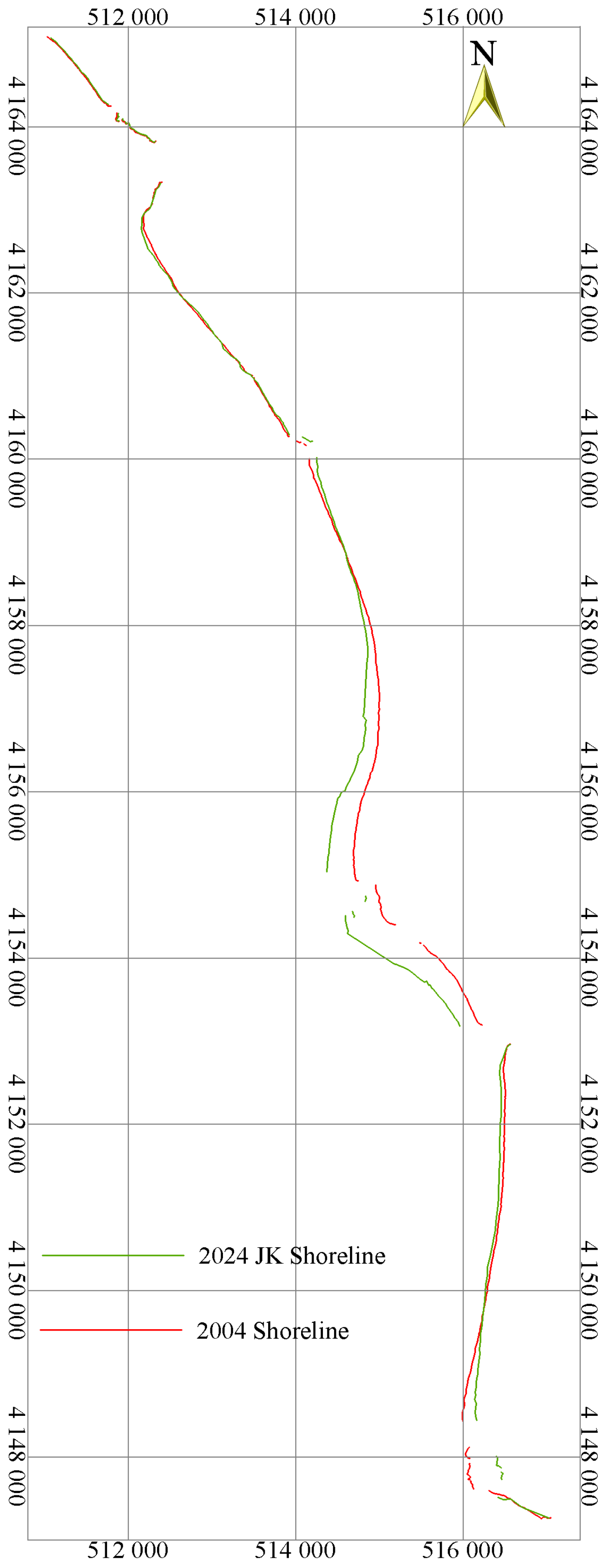

Figure 5.4. Position of the 2024 shoreline (computed by JK method) with respect to 2004 shoreline.

Like the other shoreline mapping methods as explained in Chapter 2.3, which could not give a continuous shoreline, this study also, could not give a continuous shoreline. The approximated future shoreline is nothing else than a shoreline formed of closely spaced (from 10 to 50m depending on the general trend of the previous shorelines) position data (points). However, the results are enhanced with the use of different baselines defining the previous shorelines. A hypothetical figure can make it easier to understand such a process (Figure 5.5).

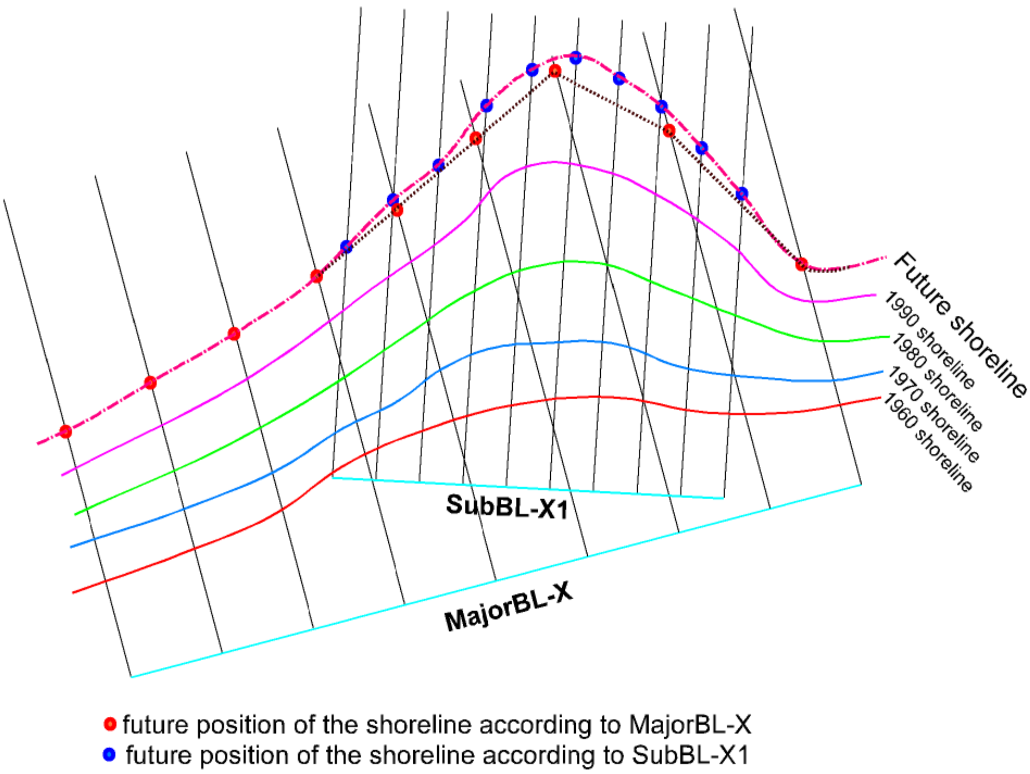

Figure 5.5. Hypothetical sketch of the future shoreline formed by connecting the closely spaced point data produced with different baselines, which defines the general trend of the previous shorelines.

The approximated shoreline is depending directly on the observations of the analyst. Although the result can be changed from one shoreline analyst to another, they will not be that different, because of some restrictions while connecting the points. First of all it must be remembered that the future shoreline should fit the general trend of the previous shorelines. They are directly depending on the dynamics that control the shape of the delta. Therefore, the wave and longshore current directions, bathymetry, if possible rate of change in sediment budget, have to be known by the analyst to have a general idea about the trend and possible trend changes. Secondly, the future shoreline should be as smooth as possible. Finally, it should be approximated in order to have a natural form without abnormalities.

5.2. Oscillation Analyses Results (min, mean, max)

As it is explained in chapter 4.6, the future shorelines approximated by the use of four methods, are analyzed visually and mathematically in order to have a general idea about where will be shoreline after 20-year time span and what are the limits of the oscillation of the shoreline, that is to have the answer the following questions:

- "What is the minimum and maximum change of the shoreline position on a transect?", and
- "Which is the appropriate statistical method to model such an area and to approximate the future shoreline position?"

In order to achieve the goal the script was edited as it is explained at the beginning of the Chapter 4 to have the minimum, maximum and mean rate-of-change values of the four statistical methods. After the rates are computed, they are plotted on the map. The points are again connected by making use of the four previous shorelines of each method, and of course by the use of the restrictions explained above in Chapter 5.1.

The answer for the first question can be found out by the "minimum shoreline" and the "maximum shoreline". The range of change of shoreline position is 609 m with a minimum change of 3 m at the long linear barriers extending at the north of the present delta mouth and a maximum change of 612 m at the southern parts of the previous delta mouth. If the ranges are grouped by the changing geomorphological characteristics of the shoreline, the north barriers have a range of 129 m of shoreline change (between 3 m and 132 m). The 132 m of difference between maximum shoreline and the minimum shoreline can be seen at the northern starting point of the new delta mouth. The maximum difference at the delta mouth (just at the south of delta) is 320 while the minimum difference is 32 m. The minimum difference is again ~3 m at the southern barriers and the maximum is 40 m. The minimum difference between the Minimum Shoreline and the Maximum Shoreline at the previous delta mouth is 10 m and the maximum difference is 612 m.

The answer for the second question will probably be the method that gives the most analogous shoreline to the "mean shoreline". The "minimum shoreline", the "maximum shoreline" and the "mean shoreline" can be examined in the Figure 5.6. The results and the answer for the second question will be discussed after chapter 5.3.

5.3. Backward Analysis Results

As it is explained in section 4.7, a backward analysis is done in order to visualize the spatial distribution of the rates-of-change. The backward analysis is done four times for each method and the resulting classified shoreline based on the rate-of-change per year can be examined at the following figures (Figure 5.7, 8, 9, 10). This analysis was necessary to have the rates on the maps with spatial relationships. This is also a necessary analysis for the future studies including management and protection that may be done in the area.

The "Minimum Shoreline", "Maximum Shoreline" are constructed from the positions of all the rates computed by EPR, AOR, LR and JK methods. And the "Mean Shoreline is the shoreline constructed by points having rates which are the arithmetic averages of all computed rates coming from EPR, AOR, LR and JK. The "mean shoreline" is used to visualize and find out only the answer to the "Which is the most appropriate method to model the dynamics of the B. Menderes Delta shoreline?"

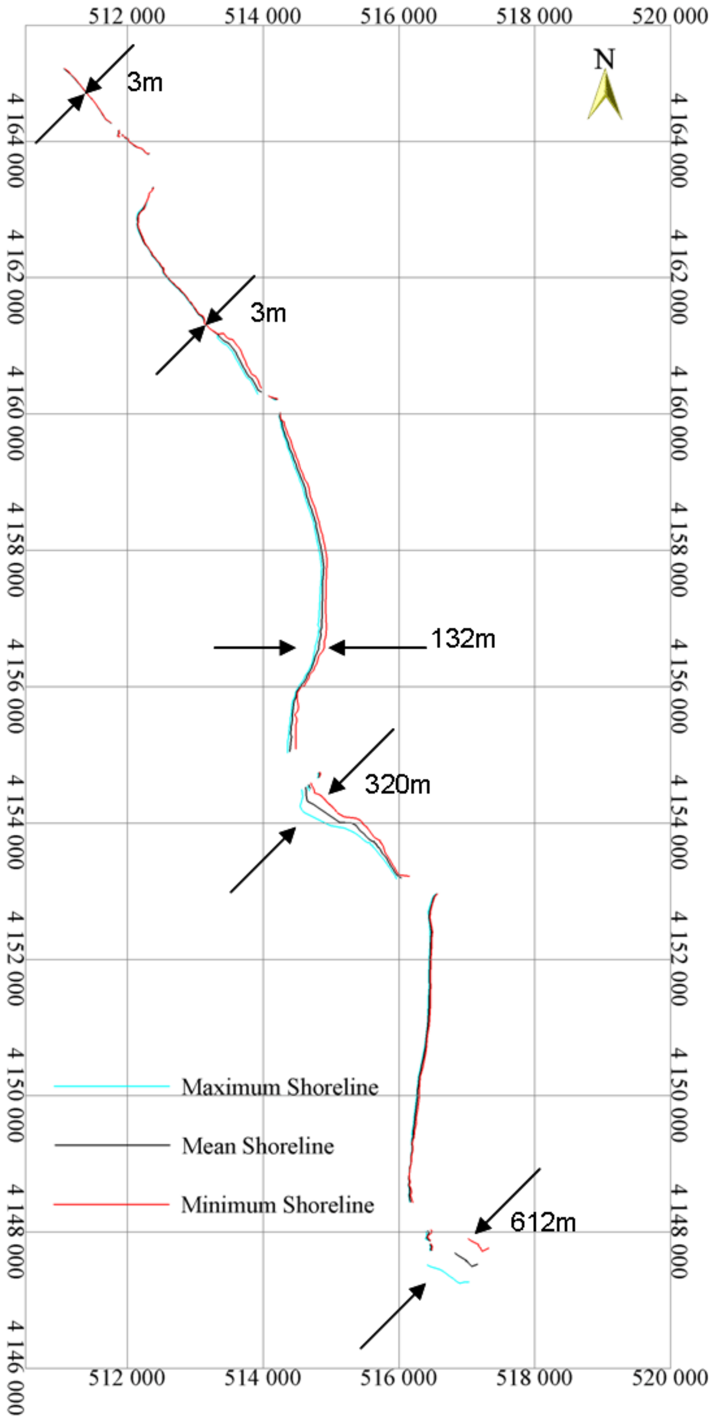

Figure 5.6. The “maximum shoreline”, “minimum shoreline” and “mean shoreline” of the year 2024. Note that the difference of the shorelines is resulted from the difference in statistical methods.

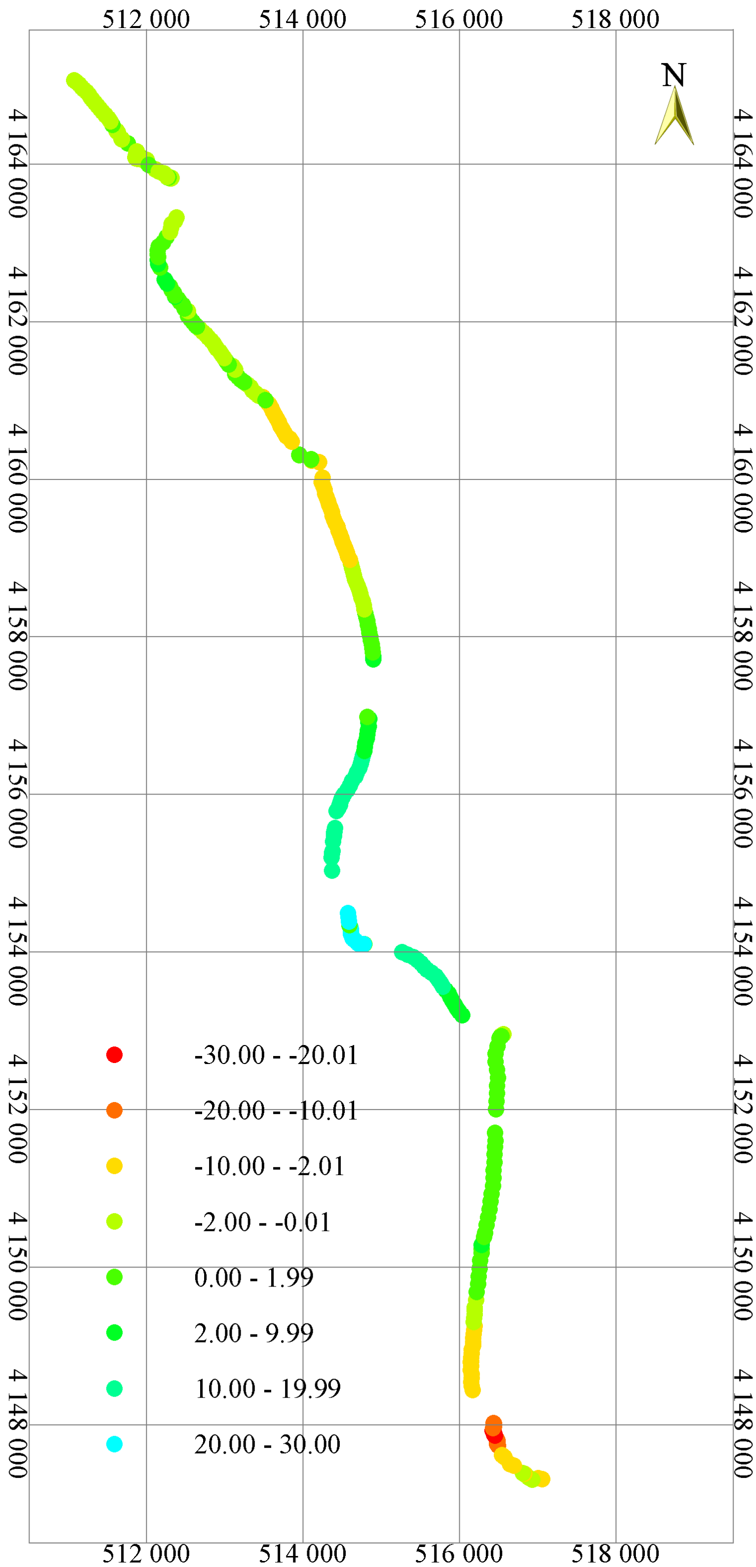

Figure 5.7. Spatial distributions of the rates-of-change (m/yr) of 2024 shoreline computed by EPR method.

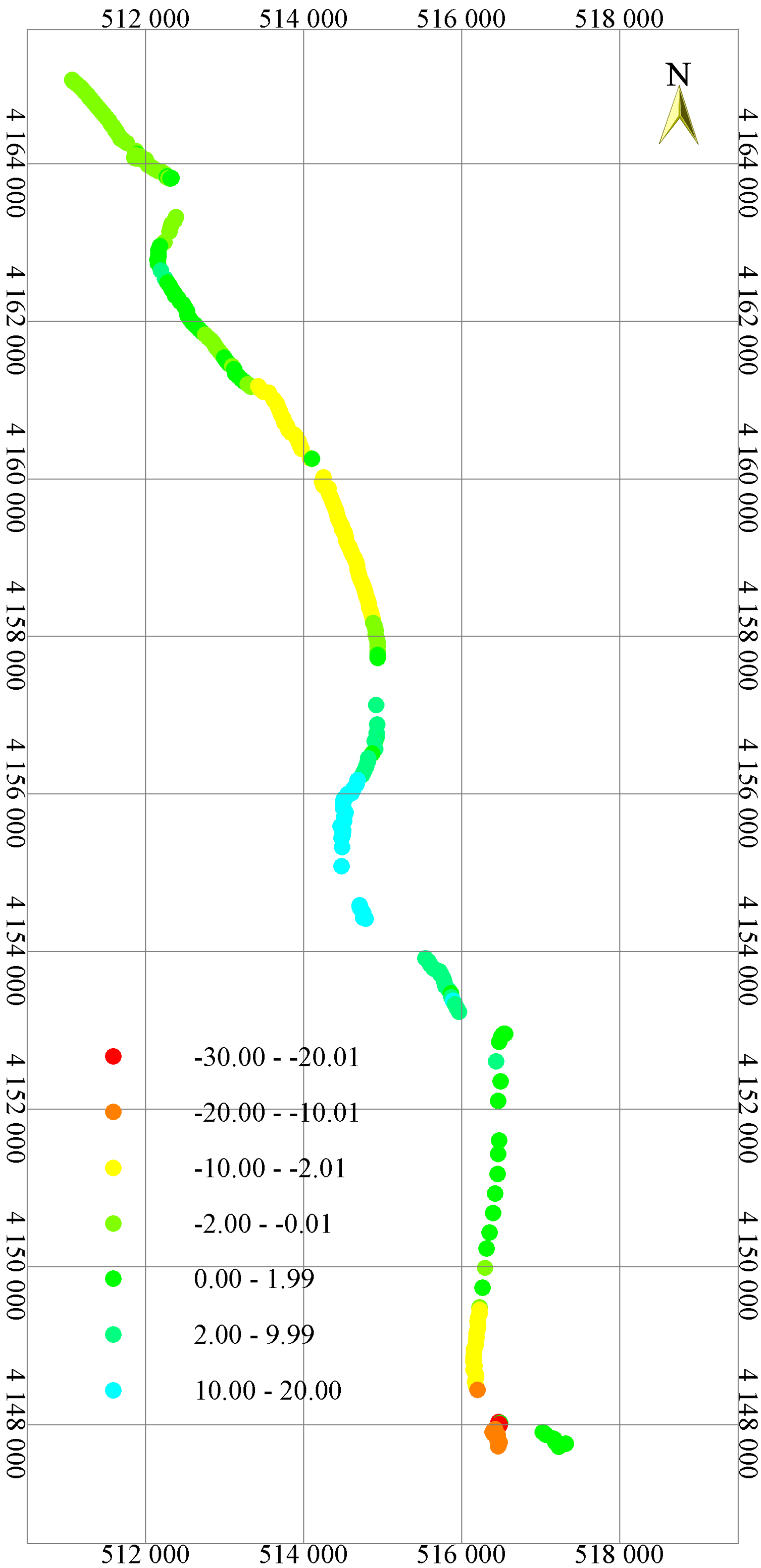

Figure 5.8. Spatial distributions of the rates-of-change (m/yr) of 2024 shoreline computed by AOR method.

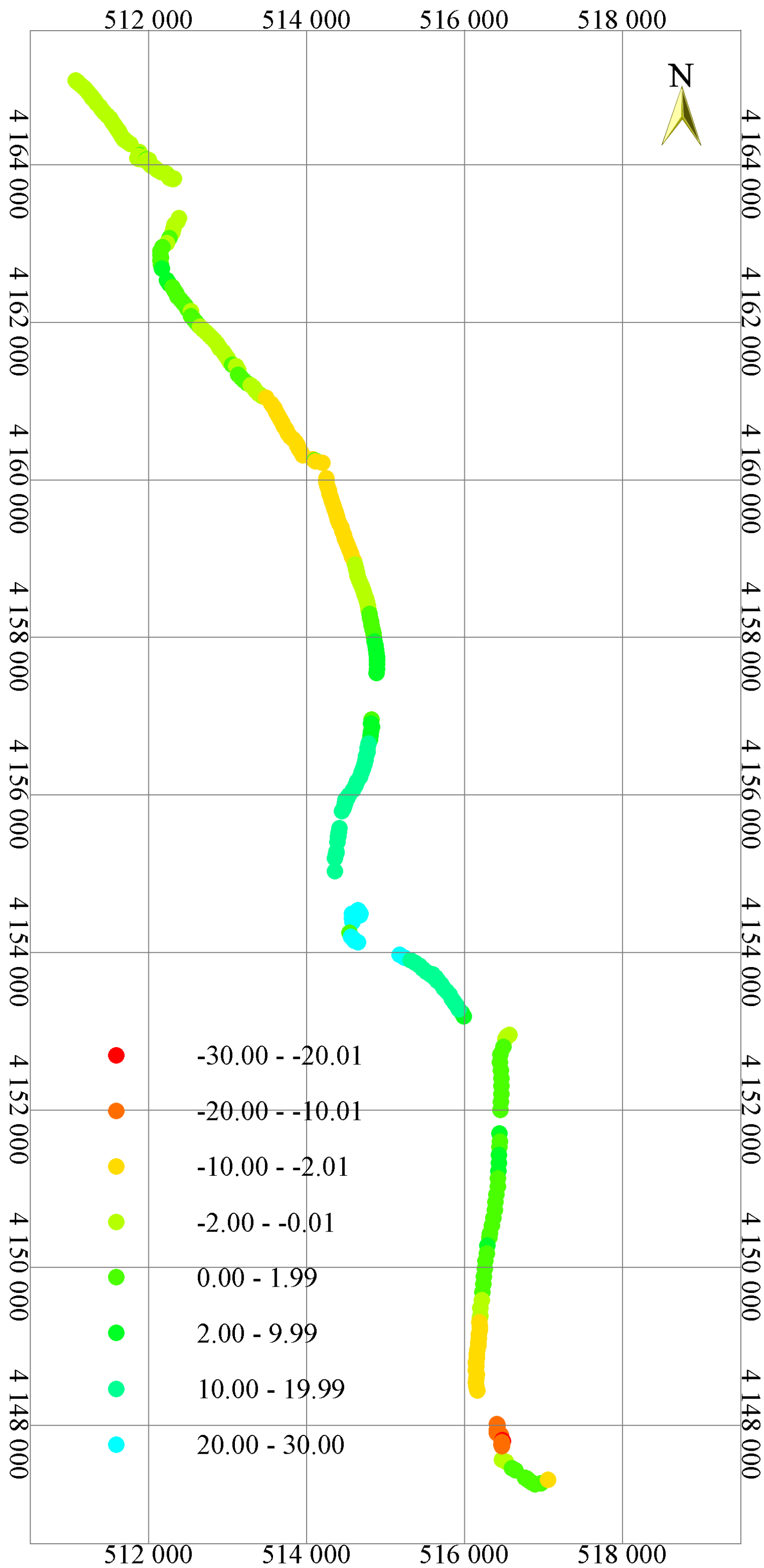

Figure 5.9. Spatial distributions of the rates-of-change (m/yr) of 2024 shoreline computed by LR method.

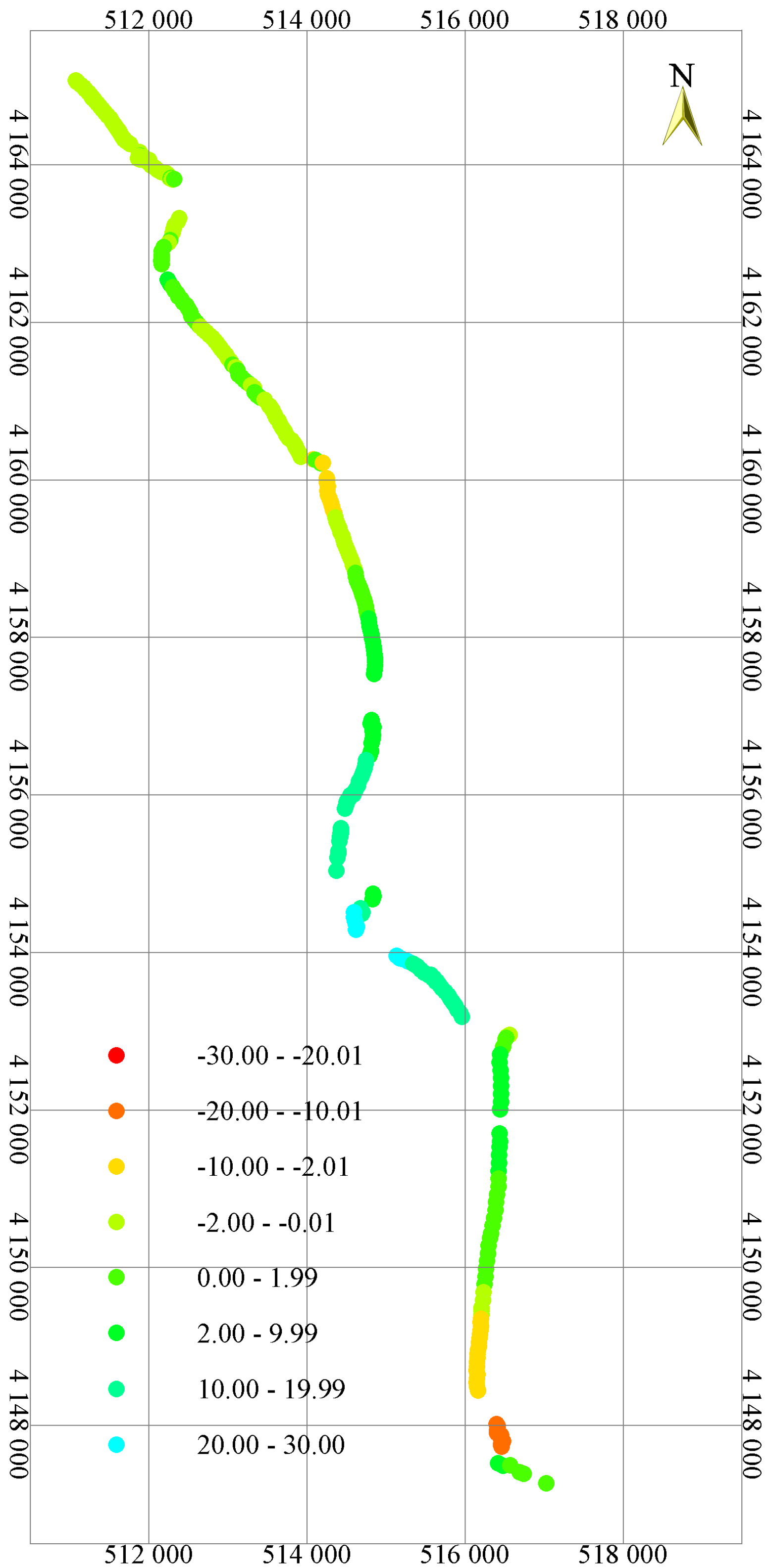

Figure 5.10. Spatial distributions of the rates-of-change (m/yr) of 2024 shoreline computed by JK method.

The EPR frequency histogram is presented in the Figure 5.11. A total number of 421 transects are located on the final EPR shoreline. The transect interval is changing between 10 m and 50 m and transect length is changing between 100 m and 2500 m.

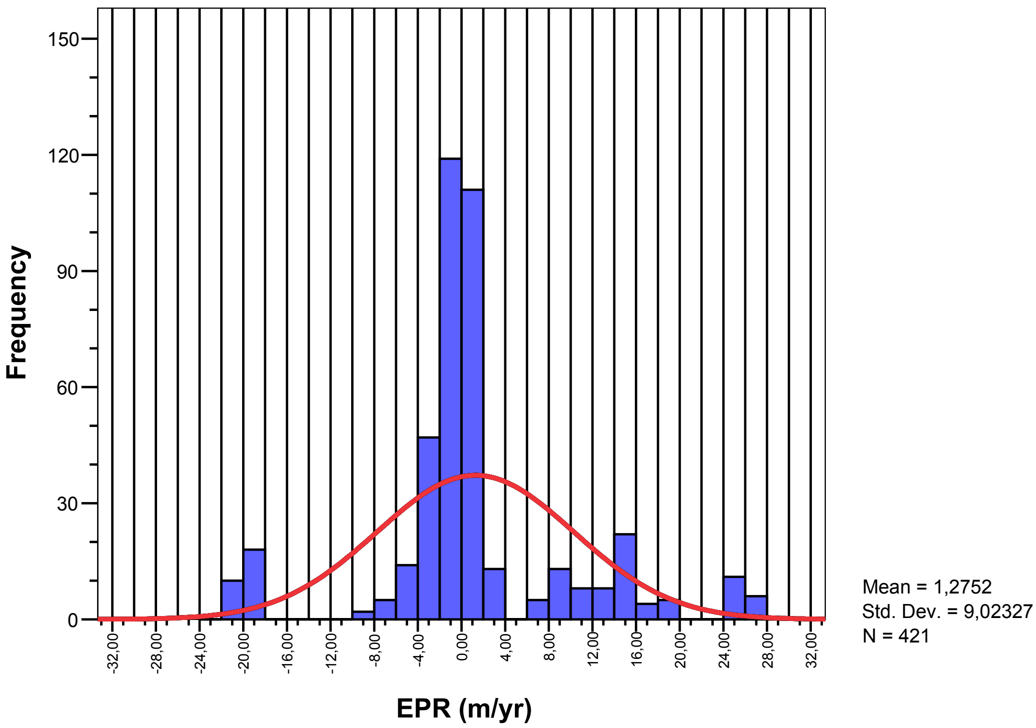

Figure 5.11. EPR frequency Histogram of 2024 Shoreline. Note that the total number of transects is 421 for this Final EPR shoreline.

As it is seen on the histogram, the maximum rate-of-change concentrations are between -2 m/yr and 2 m/yr. For EPR method, the mean of the rate-of-change values on transects, is 1.28 m/yr with a maximum rate-of-change of 26.17 m/yr and a minimum of -20.73 m/yr. With these results, one can say that the general trend of the shoreline is 1.28 m/yr of accretion. However, it must be taken into account that there is a total number of 38 transect that do not crosscut minimum two of the shorelines and because of that reason, the rate-of-change values are calculated as 0 m/yr. Also it must be taken into account that three of the shorelines are digitized from 1/25.000 scaled topographic maps that give an accuracy of ±6.25 m. the accuracy of the 2002 Ikonos imagery is ±0.25 m and the accuracy of 2004

QuickBird Imagery is ±0.15m. When the accuracies are summed up, it will give the accuracy of the source data in the best case as ±19.15 m (~±20 m). So the analysis done in between 1960 and 2004 with three 1/25000 topographic map, one Ikonos and one QuickBird Imagery can contain a cumulative error of about 40 m (~±20 m). If this 40 m of potential error is divided by the total time span used for prediction (2004-2024), which is 20 years, it will give us a rate of ±1 m/yr, hence so the rate-of-changes that are between -1 m/yr and +1 m/yr are debatable for 2024 Shoreline.

Unfortunately, the total number of transect on the Final 2024 EPR shoreline that have a rate-of-change value between -1 m/yr and 1 m/yr is 62 (38 of 0 m/yr). As a result, a new frequency histogram of rate-of-change values computed with EPR method is plotted by considering the constraints mentioned above. The new histogram is shown below in Figure 5.12. Either the eliminated rates between ±1 m/yr can be the result of the accuracy of the source data or they can represent a non-moving shoreline.

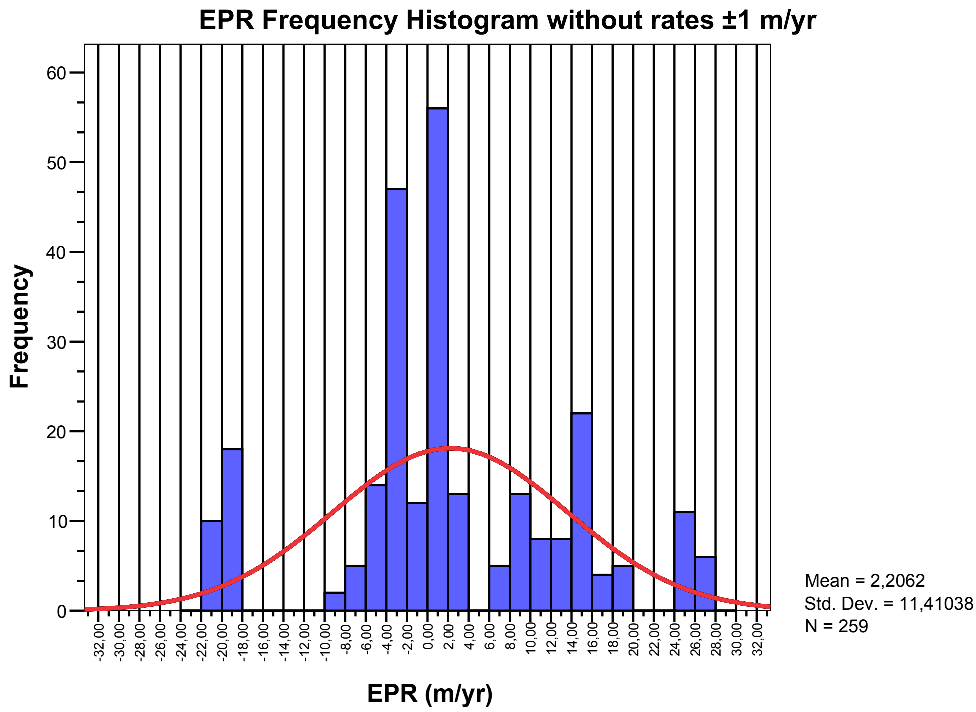

Figure 5.12. EPR Frequency Histogram of 2024 Shoreline eliminating the rates between -1 m/yr and 1 m/yr. Note that the total number of transects, after eliminating [-1, 1] interval, is 259.

As it is seen on the new histogram plotted according to limitations, the mean of rate-of-change values is 2.21 m/yr and rate-of-change values are generally clustered in between [-22 m/yr, -18 m/yr], [-6 m/yr, 4 m/yr], [8 m/yr, 10 m/yr], [14 m/yr, 16 m/yr] and [24 m/yr, 26 m/yr]. The accuracy of the rates is also ±1 m/yr for all the rates computed by each statistical method.

The general accretion and recession trends and the spatial distributions of these trends can also be examined on Figure 5.7. The accretion can be seen in light (bright) blue and bright green including the rate clusters mentioned above (8-16 m/yr and 24-26 m/yr) and the recession is represented (with a minus sign) by red color with rates including 22-18 m/yr. Transects that are showing considerable recession are at the previous mouth of the delta which is at the southern parts of the study area. The accretion trend can be seen at and around the present mouth of the delta, which is at middle parts of the area.

As it is seen on the next histogram (Figure 5.13) the maximum rate-of-change concentrations of the AOR method are the same with EPR method (-2.00 m/yr and 2 m/yr) (Figure 5.11).

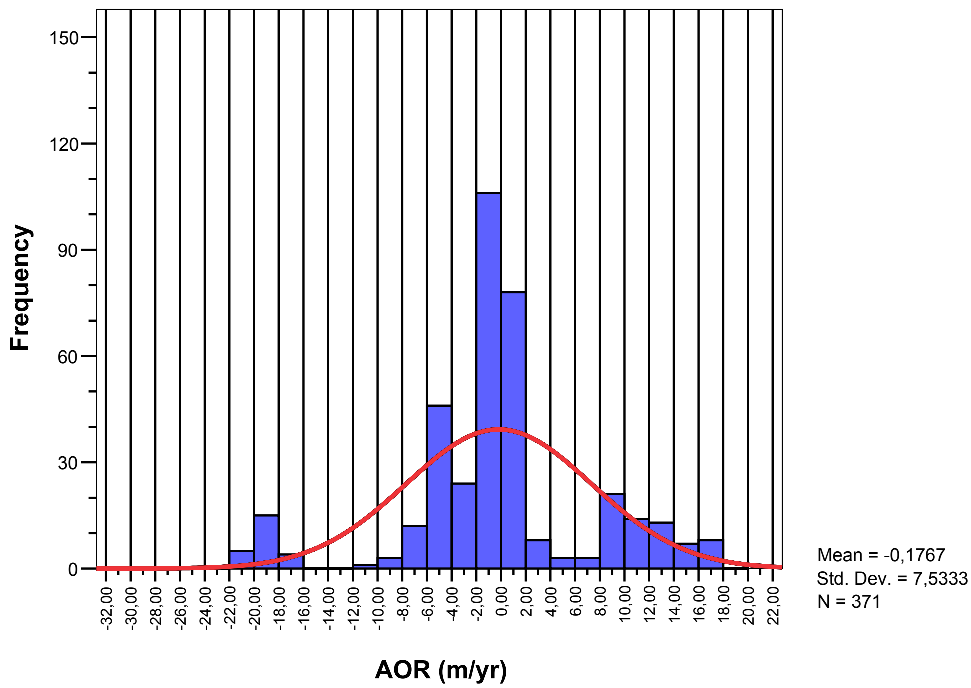

Figure 5.13. AOR Frequency Histogram of 2024 Shoreline. The total number of transects is 371 for this Final AOR Shoreline.

The mean rate-of-change value calculated by AOR method is -0.18 m/yr (which shows by its negative sign that the shoreline is in recession) with a maximum rate-of-change of 17.10 m/yr and a minimum of -21.12 m/yr. However, according to the constraints that are mentioned above for the case of EPR method are also valid for all the other methods. As a result new frequency histogram of rate-of-change values are prepared and given below in Figure 5.14.

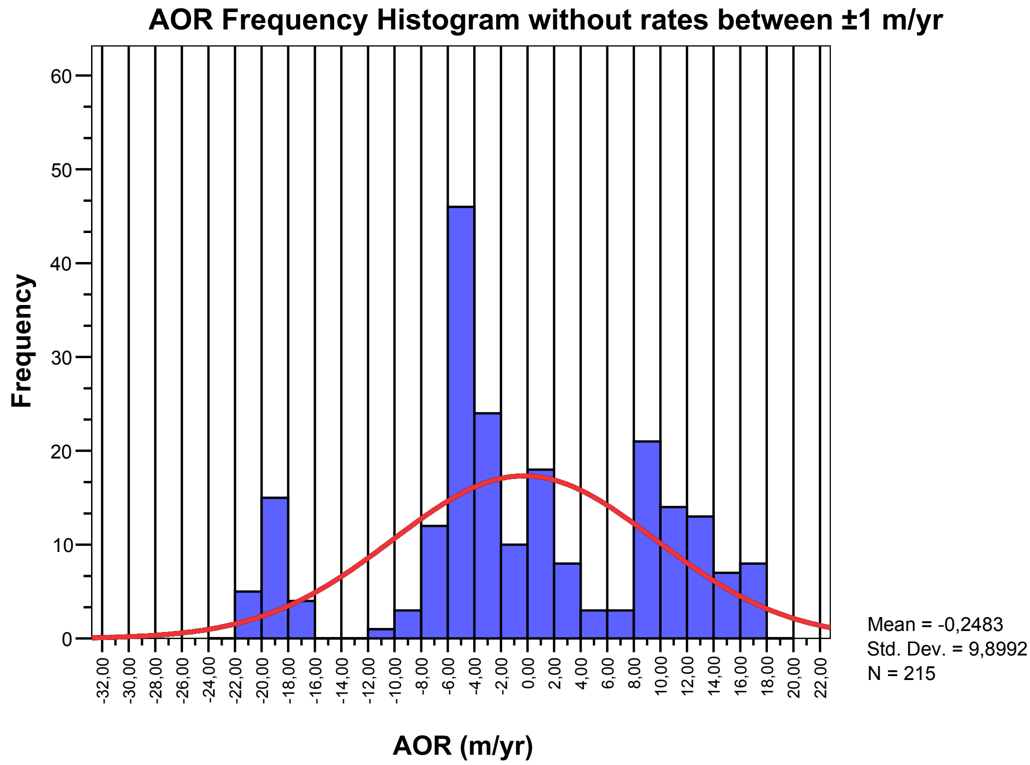

Figure 5.14. AOR Frequency Histogram of 2024 Shoreline after eliminating the rates between -1 m/yr and 1 m/yr.

As it is seen on the new histogram plotted by AOR method according to limitations, newly computed mean rate-of-change value is -0.25 m/yr. The rate-of-change values are generally clustered in between [-20 m/yr, -18 m/yr], [-8 m/yr, 2 m/yr] and [8 m/yr, 18 m/yr]. The general accretion and recession trends and their spatial distributions can also be examined on the spatial clusters in Figure 5.8. Shoreline is again showing considerable recession rates at the previous mouth and accretion rates at and around the present delta mouth.

It can be seen in the following figure (Figure 5.15) that the rate-of-change values are concentrated at the same interval (between -2 m/yr and 2 m/yr). The mean computed by LR method is 1.70 m/yr with a maximum rate-of-change of 28.58 m/yr and a minimum of -20.14 m/yr.

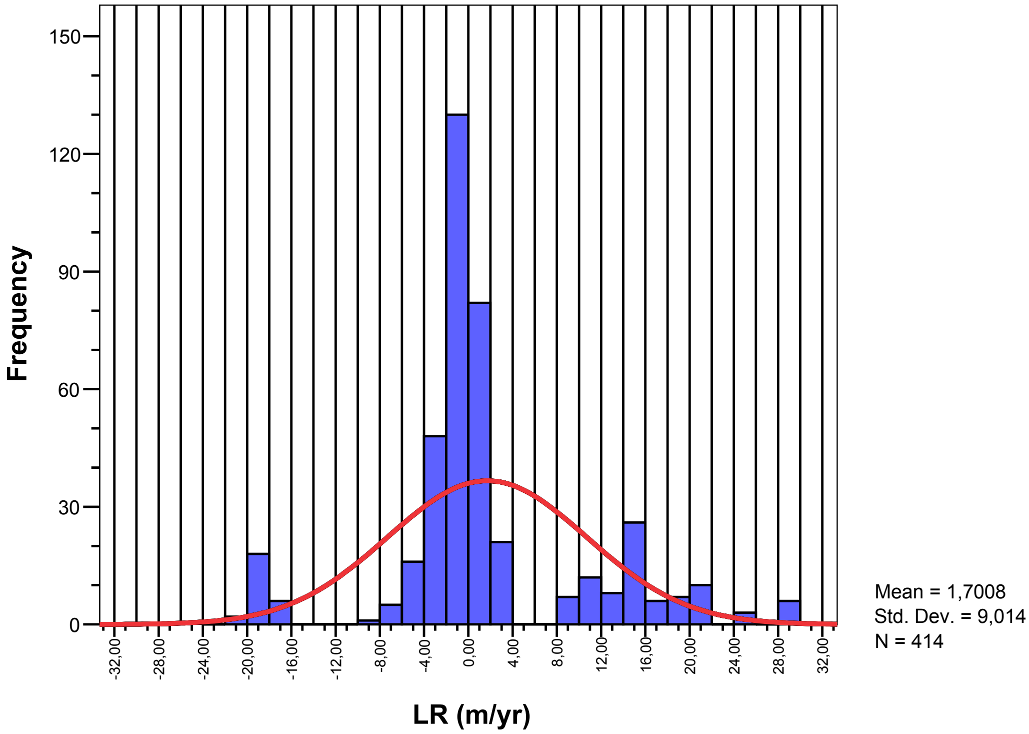

Figure 5.15. LR Frequency Histogram of 2024 Shoreline. The total number of transects is 414 for this Final LR shoreline.

According to the limitations, a new frequency histogram of LR rates is prepared and shown below in Figure 5.16.

On the new histogram there are a total number of 265 transects having the mean rate-of-change value of 2.85 m/yr. The rate-of-change values are generally clustered in between [-20 m/yr, -18 m/yr], [-6 m/yr, 4 m/yr], [10 m/yr, 12 m/yr], [14 m/yr, 16 m/yr] and [20 m/yr, 22 m/yr]. The spatial clusters in figure 5.9 can also be examined to have an idea about general accretion and recession trends and their spatial relationships.

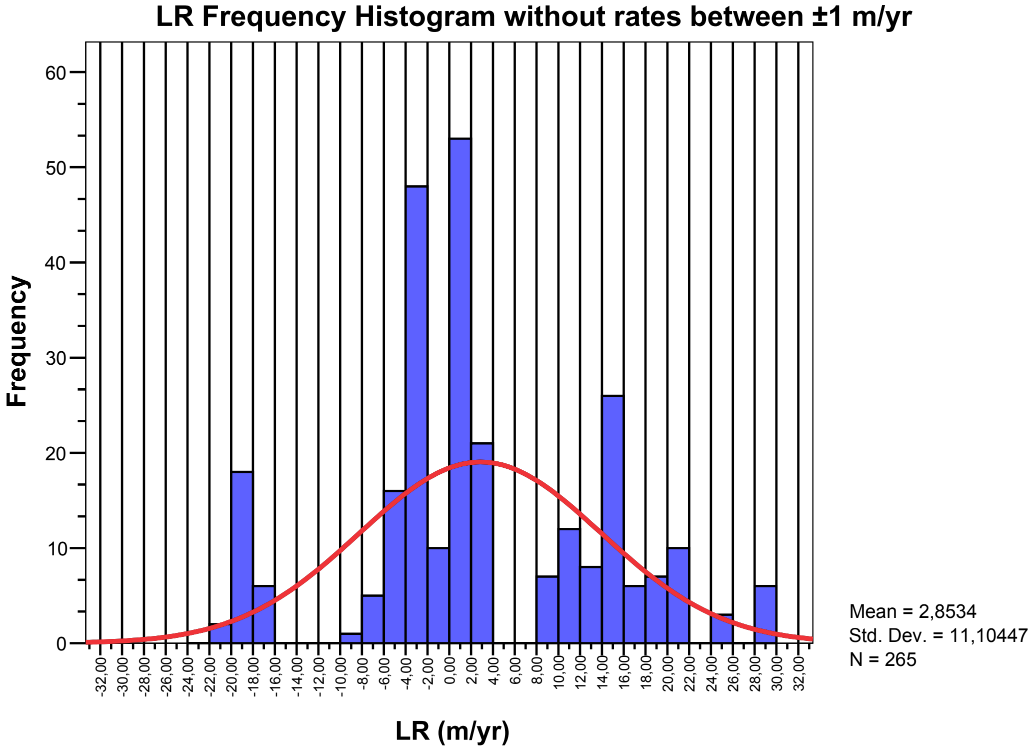

Figure 5.16. LR Frequency Histogram of 2024 Shoreline after eliminating the rates between -1 m/yr and 1 m/yr.

The JK frequency histogram (Figure 5.17) shows maximum rate-of-change concentrations again in between -2 m/yr and 2 m/yr. The mean value is 1.96 m/yr and the rates show a maximum of 25.72 m/yr and a minimum of -19.62 m/yr. After eliminating the values between -1 m/yr and 1 m/yr and the null values, a new frequency histogram is generated and presented below in Figure 5.18.

As it is seen on the new histogram plotted by JK method according to limitations, the survival transects (i.e. transects that satisfy the constraints) have a total number (N) of 182. The mean of rate-of-change values is 3.49 m/yr, and rate-of-change values are generally clustered in between [-20 m/yr, -16 m/yr], [-6 m/yr, 4 m/yr] and [10 m/yr, 20 m/yr]. The rate clusters can also be examined in figure 5.10.

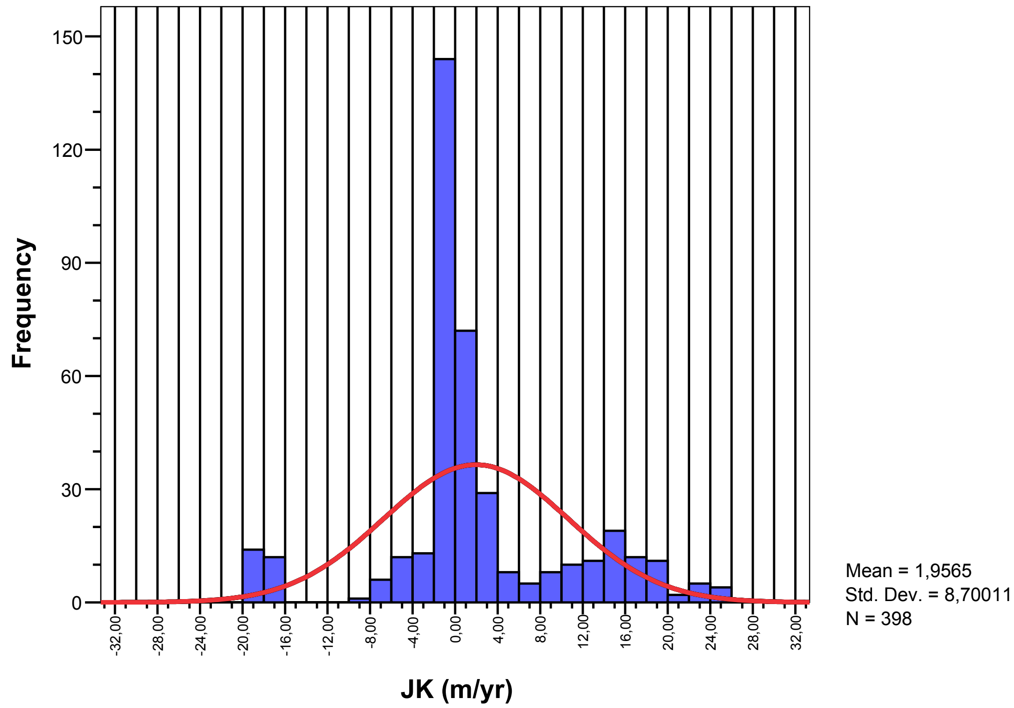

Figure 5.17. JK Frequency Histogram of 2024 Shoreline. The total number of transects is 398 for this Final JK shoreline.

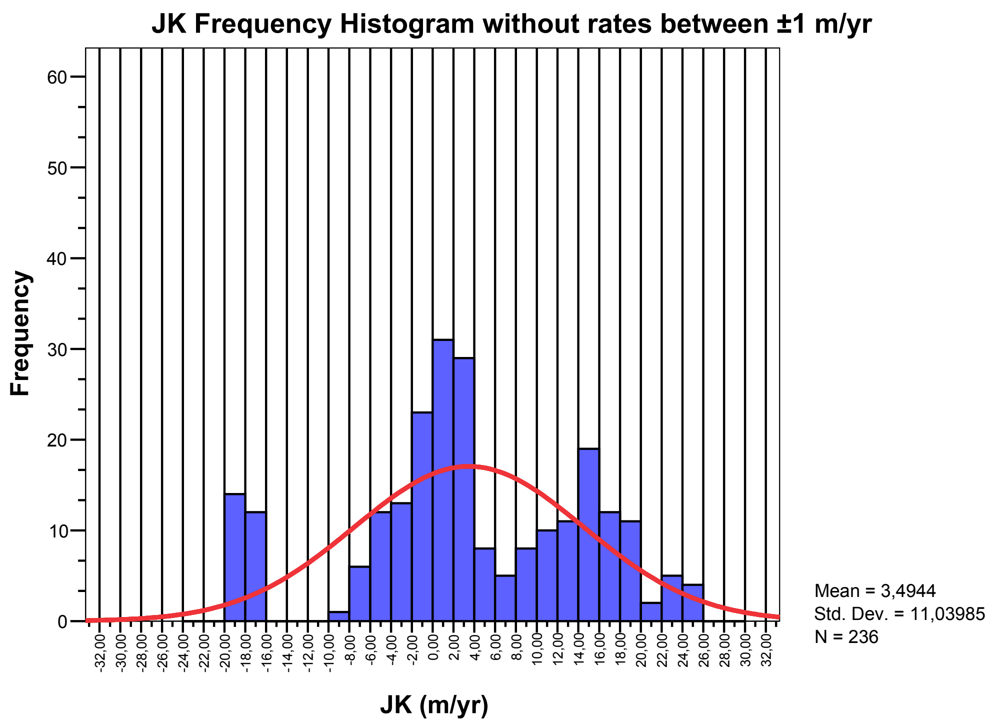

Figure 5.18. JK Frequency Histogram of 2024 Shoreline after eliminating the rates between -1 m/yr and 1 m/yr.

As a result of all the spatial and statistical analyses, the general accretion and recession rates and their spatial distributions are showing the same characteristics for all the four methods. Transects that are showing considerable **recession** are at the dormant mouth (southern promontory) of the delta with rates of **~20 m/yr**, which is a consistent result with the ~870 m of recession for this promontory from 1960 to 2004. The **accretion** trend can be seen at and around the present mouth (northern promontory) of the delta with rates of **~20 m/yr**, which is also a consistent result with the ~820 m of accretion for this promontory from 1960 period to today. These results show that the results of EPR method can be acceptable if the shorelines are analyzed generally.

While analyzing and comparing the results, both visually and statistically, it is find out that there is no a best method to choose, to model the **"whole area"**. Because there is not a distinguishable or comparable shoreline that fit the best to the "mean shoreline" that was mentioned before in Chapter 5.2. As it is mentioned before the resultant shoreline of the statistical analyses do follow sinusoidal paths (changing places locally with each other) on all over the area. The statistical results also did not point out a distinguishable and a more reliable method to choose at the **"whole area"**. The EPR, AOR, LR and JK methods helped only to find out the range of the shoreline with minimum, mean and maximum positions it can have in 2004.

The cause of the result "There is no a best statistical method to model whole of the B. Menderes Delta shoreline" can probably be the non-linearly changing rate of the shoreline. Although, the JK method was expected to be the "right method" from a mathematical point of view, because of the inconsistent position of the 2002 shoreline, as it do not fit the general trend of the shoreline in accreting present mouth (Figure 5.19), and as there exist lots of discontinuities in the whole area, JK did not show any proof neither visually nor statistically that it is more reliable than the other methods for the whole area.

It can also be said that the result "No single method is representing the whole area." was as expected result before the start of the analyses even when the area is selected as the study area. As it is mentioned before in Chapter 1 Büyük Menderes Delta Shoreline is selected because of its different and actively changing geomorphological features such as a newly forming prograding active delta, a retrograding delta with abrupt changes, relatively stable and linear barrier spits and barrier islands showing homogeneous trends.

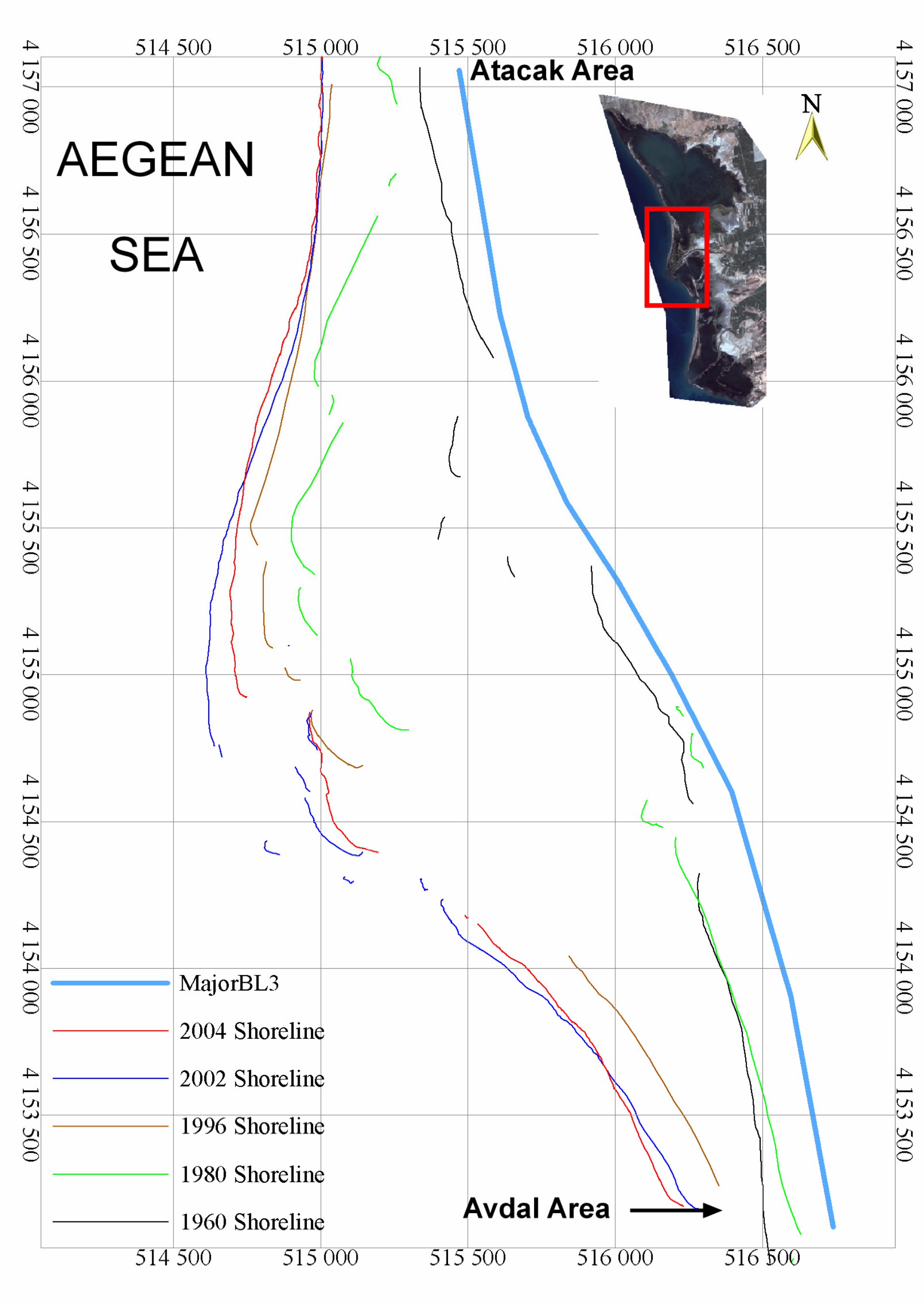

Figure 5.19. Figure showing the inconsistent position of the 2002 shoreline with respect to the general growing trend of the present delta promontory.

The main reason of the inconsistency of the 2002 shoreline is probably the date when Ikonos Imagery is taken. The Ikonos Imagery is a winter image where as the QuickBird Imagery and the air photos from where the topographic maps are prepared are taken in summer. As the sediment budget is increasing and as the wind and resultant wave activity is increasing in winter it was an expected inconsistency.

Finally, it is decided that it will be better to examine the shoreline not as a whole, but as individual geomorphologic divides as it is done while choosing the length and the positions of the major baselines explained in chapter 3.5.

For the area covered by MajorBL1 (Figure 3.13), the results computed by EPR method give the closest shoreline positions to the “Mean Shoreline”, where as LR and JK are giving the “Minimum Shoreline” and AOR is identical to “Maximum Shoreline”. So the northest part of the study area where the shoreline change rates are not exceeding 2±1 m/yr of recession (Figure 5.7, 8, 9, 10) and where the shorelines are parallel to each other and where they are linear the EPR method is suitable to model the area. It will be good to be mentioned that the area is not controlled by the waves controlling the whole area, it is a stable area and the sedimentation is caused especially from suspension (field observation and sieve analyses).

For the area covered by Major BL2 (Figure 3.14), the “Mean Shoreline” is representing the shorelines resulted from EPR and LR rates, AOR is identical again to Minimum Shoreline” and the “Maximum Shoreline” is represented by JK method. It can be said that visually there are not significant inconsistencies between the position of the shorelines at that area, and the area includes interchanging (or oscillating) positions of the almost linear shorelines that are almost parallel to each other with the rates-of-change that are in between 10±1 m/yr to -10±1 m/yr (Figures 5.7, 8, 9, 10). So the area can be represented by EPR or LR methods.

For the area covered by MajorBL3 (Figure 3.15) the shoreline represented by JK method is the most analogous shoreline to the “Mean Shoreline”. The EPR and LR rates are giving the maximum rates at the area and AOR is again giving the minimum rates. The rates-of change shows 2±1 m/yr to 30±1 m/yr of accretion (Figure 5.7, 8, 9, 10). It should be mentioned that the shoreline positions are not linear but doing smooth curves while the mouth of the delta is accreting in the control of dominant waves in the area. The data include the inconsistent position of January 2002 shoreline. Therefore, JK method will be an appropriate method to model such areas with such available data.

For the area covered by MajorBL4 (Figure 3.16), where the shorelines are linearly changing and similar to the shorelines covered by MajorBL2 (Figure 3.14), the shorelines computed by EPR and LR are generally analogous to the "Mean Shoreline". JK is giving generally the maximum and AOR is giving the minimum rates in the area. The rates-of-change are not so much in the area, as they are in between -10±1 m/yr and 10±1 m/yr (Figure 5.7, 8, 9, and 10). So the area can be represented by a linear estimation such as EPR or LR.

At the northern parts of the area covered by MajorBL5 (Figure 3.17), where the shorelines are smooth and where there are not so much inconsistencies and interchanging positions of the shorelines the EPR, LR and JK methods are giving very the close results to the "Mean Shoreline" and the "Maximum Shoreline" and AOR is giving the "Minimum Shoreline". At the south of the area (south of the previous mouth) the AOR is the Minimum Shoreline with a position very far (~600 m) to the results computed by JK, EPR and LR methods. JK, EPR and LR methods are forming the maximum shoreline in an interchanging manner. However, no method is giving a close result to the mean shoreline. The reason behind this is probably that the result of AOR is giving a very wrong result shifting the mean shoreline far away from the maximum shoreline.

It is also visually understood that AOR and JK method should not be used at the areas where there are lack of shoreline data or rather a non-continuous shoreline position data such as inlets and channels. This result can explain the non-trustable positional results of the shorelines created by AOR and JK methods at the south of the dormant delta mouth.

It should be mentioned again that, the "minimum shoreline" and the "maximum shoreline", derived from the four methods EPR, AOR, LR and JK, and the "mean shoreline" are the results of this thesis, with a rate-of-change of -2±1 m/yr at the most northern part, ~ -10±1 m/yr to ~+10±1 m/yr at the long, linear barrier islands and barrier spits extending both to the north and at the south of the present delta mouth. An average rate-of-change 2±1 m/yr to 30±1 m/yr of accretion are seen at the present delta mouth and 10±1 m/yr to 30±1 m/yr of recession are seen at the previous delta mouth. This result is given in the following figure having both the rates and appropriate method to model the area (Figure 5.20).

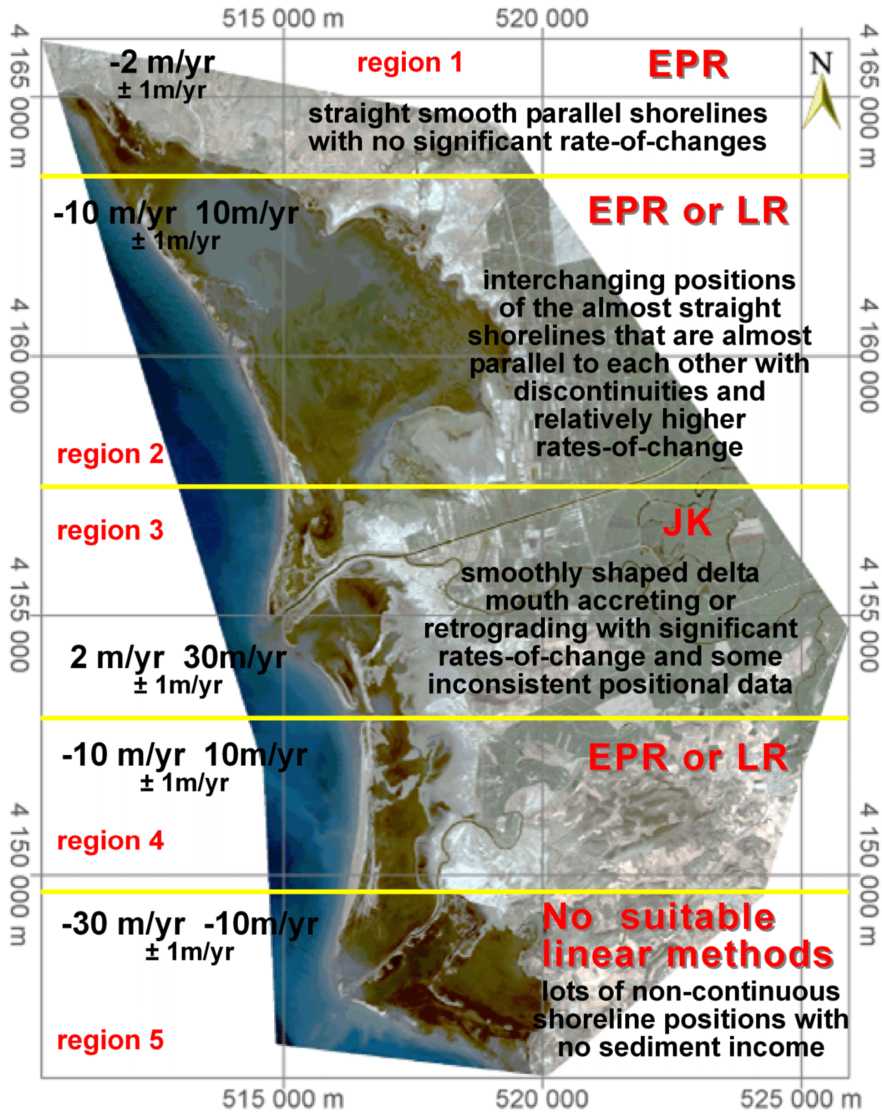

Figure 5.20. Final shoreline separated into five regions having different geomorphologic features, the appropriate statistical methods, and calculated shoreline rate-of-change intervals belonging to each region. Note that the rates and the geomorphologic characters are given independently.

The rates-of-change calculated at the barrier spits and barrier islands mean that those areas are stable areas as the accuracy of the data used for the analyses is limited by 40 m (or ±1 m/yr for a 20-year period). Another explanation for this result can also be that the rates-of-change calculated at those areas are erroneous because of the 12.5 m accuracy of the topographic maps. The errors may come from the scanning or digitizing process, or from original and old topographic maps. The measurements on screen showed that the movement from the first shoreline (1960 shoreline) to the last shoreline (2004 shoreline) was not exceeding the limit of 6.25 m at both directions. It probably means that those shorelines did not move actually, so the areas with rates-of-change between the accuracy limits can be considered as not moving (neither progressing nor retrograding) areas. Although those shorelines extending towards north and south directions did not make seaward or landward movement, they showed lateral (or alongshore) variations. Figure 5.21 is showing a very good example of this lateral variation. The circular areas on the topographic maps are pointing out a laterally moving inlet from its previous position in 1960 to the south to its recent position in 1996.

This process can be explained by analyzing the geomorphological properties of Büyük Menderes Delta Shoreline. Based on a general background about deltas given in chapter 2.1 it can be said that Büyük Menderes Delta is a wave-dominated delta. The shoreline is building up by the reworking of sediments by the waves coming from North-West and the resultant alongshore currents. The moving inlets to the south and the ongoing filling up process of the inlets (field study) can be the best proofs of the dominant waves and longshore currents (Figures 5.22). In addition, the extremely smooth, linear and long barrier spits and barrier islands, lobate shape of the present delta mouth without a digitate structure are the general geomorphological characteristics of a wave-dominated delta.

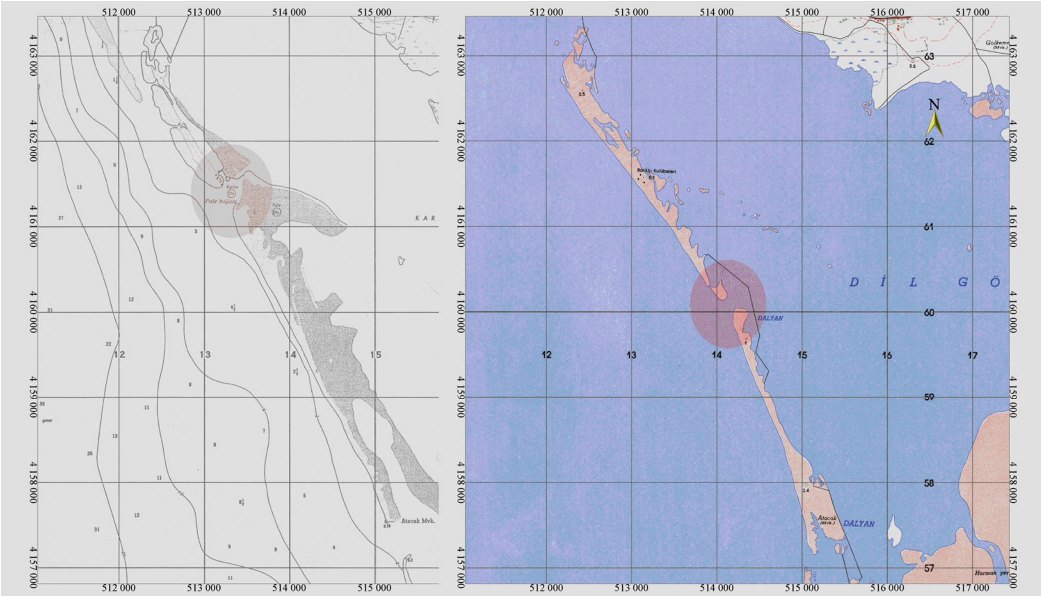

Figure 5.21. Lateral movement of an inlet from 1960 to 1996. Note that it is moved toward South by the waves coming generally from North-West and dominating the system.

Figure 5.22. Photograph in July 2004 from the northern sand spit showing an inlet opened artificially but filled up with sediments brought by the waves and longshore currents dominating the Büyük Menderes Delta Shoreline.

It is mentioned before that there is a seasonal variation of sediment discharge to from the river resulting to some inconsistencies between shoreline positions, such as shoreline 2002 in Figure 5.19. Another reason of this inconsistent position of 2002 shoreline is the artificial freshwater barriers. It is observed that there is no sediment discharge at the active delta promontory in summer, because the active delta channel is diverted to the large cotton fields covering the flood plain for irrigation purposes (July 2004 field study). However, in fall, the channel is reopened and returned to its original flow (October 2005 field study). The next three figures are showing the large cotton fields covering the flood plain (Figure 5.23), the barrier at Büyük Menderes River Channel (Figure 5.24) and the same river channel free of the artificial barrier (Figure 5.25).

Figure 5.23. Panoramic view of the large cotton fields covering the flood plain of Büyük Menderes Delta.

Figure 5.24. Panoramic view of the artificial barrier that blocks the sediment discharge of Büyük Menderes River. The river is diverted to the large cotton fields for irrigation purposes. Photos are taken in July 2004.

Figure 5.25. Panoramic view of Büyük Menderes River channel. Note that the artificial barrier shown in Figure 5.24 is not present. Photos are taken in October 2005.

Although there is a seasonal variation of the shorelines because of natural seasonal variation of sediment income and because of human influences, the winter and summer shoreline data are used for the 2024 shoreline position prediction. The main reason was by knowing this seasonal variation testing the statistical methods whether they will work or not in such areas with these kinds of data. Normally to have more reliable results, the data must cover seasonal variations. That is, the data should cover both summer and winter shoreline positions. However, it is not always possible to have such shoreline position data easily. So while doing the analyses, the seasonal variations resulting to inconsistent shoreline positions must be taken into account in areas like delta promontories that have considerable rate-of-changes. Fortunately, in the analyses, JK method was successful for the prediction of 2024 shoreline position of the northern delta promontory, because of its nature eliminating some of the errored and noisy data in the analyses.

CHAPTER 6

CONCLUSION

The purpose of this study is to determine the shoreline rate-of-change by the integration of remote sensing and geographic information systems and to approximate future shoreline positions. For this purpose, Büyük Menderes Delta Shoreline is selected as the study area. Having different geomorphological features such as sand barriers, barrier islands and moving inlets, active and old delta mouth and being an economically important area, Büyük Menderes Delta is an appropriate study area for this thesis. After obtaining the necessary data that are topographic maps, aerial photographs and satellite imageries from different periods, the shoreline position data is produced. The statistical methods that are applied to the shoreline position data to analyze the shoreline rate-of-change of the produced data sets are End Point Rate Method, Average of Rates Methods, Linear Regression Method and Jackknifing Method that are very widely used statistical methods in shoreline change analyses. The shorelines are analyzed by using a number of baselines and transects of different lengths and different interval, as explained in previous chapters. The analyses are computed through an edited version of a script, called “Coastal”. The original and the edited script are given respectively in Appendix 2 and Appendix 3.

After the determination of the future position of the shoreline with all possible statistical methods and suitable baselines, the most possible and more reliable cases, according to estimated accuracies and according to general trend of the shore, is chosen. This best output is still an expert dependent choice, and is directly dependent on the resolution of the shoreline data in both time and space.

The results of the selected statistical methods show approximately the same results both on the screen and in the analyses for each selected baselines. So the “Mean

Shoreline” is selected as the future shoreline. In addition, the “Minimum Shoreline” and the “Maximum Shoreline” are formed a buffer zone around this shoreline for management or protection problems.

It is concluded that:

1- At the areas where there are linear, smooth and parallel shorelines with not significant rates-of-change, EPR method is suitable to model the area.
2- At the areas including interchanging (or oscillating) positions of the almost linear shorelines that are almost parallel to each other with relatively higher rates-of-change the EPR or LR methods will be appropriate to model the area.
3- At the areas where a smoothly shaped delta mouth is accreting or retrograding with significant rates-of-change and there exist some inconsistent positional data, JK method will be appropriate to model the area.
4- At the areas with lots of non-continuous shoreline position data AOR and JK are not giving trustable results

As it is mentioned before Büyük Menderes Delta shoreline is affected by a very large irrigation channel network cowering the flood plain. In addition, there exist many inlets resulting in non-continuous shoreline especially at the delta promontory. Although Douglas and Crowell (2000) claimed that linear regression analysis is not appropriate to model such discontinuous shorelines, Jackknifing method, which is an adaptation of LR method, was found to be the most appropriate method to model these areas in this study. As also proposed by Walton (1998) that it is convenient to use least square filtering method in the cases where it is hard to eliminate the errored or noisy data.

As a result, a considerable **recession** changing from **~30 m/yr to ~10 m/yr (± 1 m/yr)** is seen at the dormant delta mouth Tuz Burnu at the southern reaches of the study features. On the other hands an **accretion** changing from **~30 m/yr to ~2m/yr (± 1 m/yr)** is can be seen at the present delta mouth Deringöl Strait at the middle parts of the study area. The long, linear sand spits and barrier islands extending towards north and south of the active delta mouth are showing rates-of-change between **-10 m/yr and 10 m/yr (± 1 m/yr)**. They are all controlled by the dominant wave action in the area. Whereas at the northern most part of the study area where the sedimentation is controlled by suspension, the rates-of-change are not exceeding **2 m/yr (± 1 m/yr)** of recession.

The results could be enhanced, by having more than five sets of data with higher accuracies and covering seasonal variations.

For the future researchers and further studies, including engineering, planning, management and protection studies in coastal areas, to establish a database containing more frequent shoreline positions with different seasonal packages will be very helpful and useful while analyzing short-term and long-term changes in trends of the shorelines and while approximating the future shoreline positions.

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APPENDIX 1

Coastal Terminology

Deltas, which are *alluvial deposits*, often in the shape of the Greek letter "delta" extending beyond the general trend of a *coastline*, are the features of *coastal zone*s. The ***coastal zone*** is formed by coastal waters and the adjacent *shore* lands which include the islands, transitional and inter-tidal areas, salt-marches, wetlands and beaches (Hicks, 1984). Whereas the line separating land and water is the ***shoreline***, which fluctuates as water rises and falls. In areas affected by tidal fluctuations, the line of contact is the mean high water line (MHWL).

Other major features of coastal terminology are explained below:

Alluvial deposits: Detrital material which is transported by a river and deposited at points along the floodplain of a river. Commonly composed of sands and gravels (Glossary of coastal terms, 2005).

Shore: That strip of ground bordering any body of water which is alternately exposed, or covered by tides and/or waves. A shore of unconsolidated material is usually called a beach (Glossary of coastal terms, 2005).

Beach is the zone between low-water line and the place where there are significant changes in material, or to the line of permanent vegetation (Ellis 1978). The region that extends from the sea inland to the first significant change in terrain features, with indefinite width is called ***coast*** (Ellis 1978). The seaward limit of a beach – unless otherwise specified – is the mean low water line. A beach includes foreshore and backshore. (Glossary of coastal terms, 2005).

Bar: An offshore ridge or mound of sand, gravel, or other unconsolidated material which is submerged (at least at high tide), especially at the mouth of a river or estuary, or lying parallel to, and a short distance from, the beach. (Glossary of coastal terms, 2005).

Barrier beach: A BAR essentially parallel to the shore, which has been built up so that its crest rises above the normal high water level. Also called barrier island and offshore barrier (Glossary of coastal terms, 2005). **Barrier island** is a detached portion of a barrier beach between two inlets (Glossary of coastal terms, 2005). **Barrier spit** is similar to a barrier island, only connected to the mainland (Glossary of coastal terms, 2005).

Spit: A long narrow accumulation of sand or shingle, lying generally in line with the coast, with one end attached to the land the other projecting into the sea or across the mouth of an estuary (Glossary of coastal terms, 2005).

Bathymetry: The measurement of depths of water in oceans, seas and lakes; also the information derived from such measurements (Glossary of coastal terms, 2005).

Lagoon: A shallow body of water, as a pond or lake, which usually has a shallow restricted INLET from the sea. (Glossary of coastal terms, 2005).

Current: (1) The flowing of water, or other liquid or gas. (2) That portion of a stream of water which is moving with a velocity much greater than the average or in which the progress of the water is principally concentrated. Currents can be classified in a number of different ways. Some important types include the following:

Periodic currents- due to the effect of the tides; such currents may be rotating rather than having a simple back and forth motion. The currents accompanying tides are known as *Tidal Currents*.

Temporary currents- due to seasonal winds.

P*ermanent* or *ocean* currents- constitute a part of the general ocean circulation. The term DRIFT CURRENT is often applied to a slow broad movement of the oceanic water.

N*earshore* currents - caused principally by waves breaking along a shore.

APPENDIX 2

Original Script

```
#########################################################
#
#	Transect and Rates SML script
#
#	Written 8 Mar 1998
#	David Williss
#	MicroImages, Inc
#
#	Based on a pair of DSAS programs.
#
#########################################################
#
#	Can be found at		http://www.microimages.com/sml/
#
#########################################################
#	Limits --
#		A few limits which are hard-coded.
#		Increase as necessary
#
numeric maxTrans = 10000;		# Maximum number of transects
numeric maxShores = 20;			# Maximum number of shoreline
vectors
#########################################################
#
#	Defaults --
#		These are initial default values.
#		They will be read out of the tntproc.ini file.  The
#		last parameter to IniReadNumber is the default value
#		to use if not found in the ini file
#
numeric transInterval, maxdist;
string outfilebase$;
transInterval = IniReadNumber("transect", "interval", 100);
maxdist = IniReadNumber("transect", "maxdist", 250);
outfilebase$ = FileNameGetPath(_context.Filename);
outfilebase$ = IniReadString("transect", "outfilebase", outfilebase$);

#########################################################
#
#	Global Variables
#
array numeric  transx[maxTrans];
array numeric transy[maxTrans];
array numeric transa[maxTrans];
```

```
numeric numtrans, numshores;
array numeric shorex[maxShores], shorey[maxShores];
array numeric vectdate[maxShores], juldate[maxShores], years[maxShores];
array numeric distToBase[maxShores], distFromShore1[maxShores],
years[maxShores];
array numeric basex[10], basey[10];  # Automatically resized anyway
class FILE locfile, julfile, distfile, ratefile;
class GRE_GROUP group;
class GRE_LAYER_VECTOR voverlay, layer;
class GRE_LAYER translayer;
class GRE_VIEW view;
class GRE_LAYER_RASTER bglayer;
class XmForm form;
class PUSHBUTTONITEM okItem, cancelItem;
class XmForm button_row;
class XmSeparator sep;
class PromptNum pinterval, pmaxdist;
class STATUSCONTEXT status;
class DATABASE database;
class DBTABLEINFO ratetable;
class DBFIELDINFO transfield, field;
class GRE_LAYERMANAGER controls;
class XmPushButton transButton;
vector Transects;
raster BackgroundRaster;
vector BaseLineVector;
string prompt$, fname$, name$, lastdate$;
numeric inode, year, month, date;
numeric line, numbasepts, flipbaseline;
numeric x1, y1, x2, y2;
numeric hits, misses, numint, sx, sy, rates;
##########################################################

proc DoTransSeg(x0,y0, x1,y1)
{
	local numeric theta, theta90, r, dx, dy, x, y, dist;

	dx = x1 - x0;
	dy = y1 - y0;
	theta = atan2(dy, dx); # Angle of this segment
	theta90 = theta + pi/2;			# angle perpendicular to segment
	dist = sqrt(dx*dx + dy*dy);
	for r = 0 to dist step transInterval {
		numtrans += 1;
		transx[numtrans] = x0 + r*cos(theta);
		transy[numtrans] = y0 + r*sin(theta);
		transa[numtrans] = theta90;
		}
	if (r != dist) {
		numtrans += 1;
		transx[numtrans] = x1;
```

```
                transy[numtrans] = y1;
                transa[numtrans] = theta90;
                }
        return;
  }

############################################################
#
#       Do the corner between two segments.
#               Segment A is from (x0,y0) to (x1,y1)
#               Segment B is from (x1,y1) to (x2,y2)
#
#       The transect from the end of segment A is already in the
#       list.  The transect from the beginning of B will be added
#       by DoTransSeg
#       Compute a transect at point (x1,y1) which bisects the
#       angle betweent the two transects.
#
proc DoCorner(x0,y0, x1,y1, x2,y2) {
        local numeric dxA, dxB, dyA, dyB, thetaA, thetaB, theta90A, theta90B,
theta90AB;

        dxA = x1 - x0;
        dyA = y1 - y0;
        dxB = x2 - x1;
        dyB = y2 - y1;
        thetaA = atan2(dyA, dxA);       # Angle of segment A
        thetaB = atan2(dyB, dxB);       # Angle of segment B
        theta90A = thetaA + pi/2;
        theta90B = thetaB + pi/2;
        # Angles greater than 2*pi screw up the bisection
        if (theta90A > 2 * pi) {
                theta90A -= 2 * pi;
                }
        if (theta90B > 2 * pi) {
                theta90B -= 2 * pi;
                }
        if (abs(theta90A - theta90B) > pi) {
                theta90A -= 2 * pi;     # Doesn't really matter which one we
subtract from
                }
        theta90AB = (theta90A + theta90B) / 2;
        numtrans += 1;

        transx[numtrans] = x1;
        transy[numtrans] = y1;
        transa[numtrans] = theta90AB;
        return;
        }

############################################################
```

```
#
#               Compute the endpoint rate dr/dt.
#               The dates are assumed to be julian dates
#               return value is in meters/year.
#
func EndPointRate(dist0, dist1, date0, date1) {
        return ((dist1 - dist0) / ((date1 - date0) / 365.25));
        }


#       Called when user closes layer controls.
#       Close the view window.  This will cause
#       the popdown callback to be called
proc cbQuit(class widget widget) {
        DialogClose(form);
        }

#       Called when the dialog actually pops down.  Free
#       and destroy everything.
proc cbPopdown(class widget widget) {
        ViewDestroy(view);
        GroupDestroy(group);
        DestroyWidget(form);
        Exit();
        }


#######################################################
#                                                 MAIN
#######################################################

#
#       Lets assume that the baseline vector contains lines whos
#       verticies are the segment points.
#
if (_context.ScriptIsRVCObject) {
        # Script is being run from an RVC file which has all the data it needs
        # This is for demo purposes
        OpenVector(BaseLineVector, _context.Filename, "BaseLine");
        numshores = OpenInputVectorList(ShoreVectorList,
                        _context.Filename, "_1844",
                        _context.Filename, "_1942",
                        _context.Filename, "_1976"
                        );
        }
else {
        GetInputVector(BaseLineVector);
        numshores = GetInputVectorList(ShoreVectorList, "Select shoreline
vectors in cronological order");
        }
```

```
class XmForm pform;
numeric cancel;

proc cbPromptsOK() {
	DialogClose(pform);
	cancel = 0;
	}

proc cbPromptsCancel() {
	DialogClose(pform);
	cancel = 1;
	}

proc PromptForValues() {
	pform = CreateModalFormDialog("Parameters");
	okItem = CreatePushButtonItem("OK", cbPromptsOK);
	cancelItem = CreatePushButtonItem("Cancel", cbPromptsCancel);
	button_row = CreateButtonRow(pform, okItem, cancelItem);
	button_row.BottomWidget = pform;

	sep = CreateHorizontalSeparator(pform);
	sep.LeftWidget = pform;
	sep.RightWidget = pform;
	sep.BottomWidget = button_row;

	pinterval = CreatePromptNum(pform, "Interval:", 5, 0, transInterval, 0);
	pinterval.BottomWidget = sep;

	pmaxdist = CreatePromptNum(pform, "Max Dist:", 5, 0, maxdist, 0);
	pmaxdist.BottomWidget = pinterval;
	AlignWidgets(pinterval.label, pmaxdist.label);

	DialogOpen(pform);
	DialogWaitForClose(pform);
	if (!cancel) {
		transInterval = pinterval.value;
		maxdist = pmaxdist.value;
		# Write them back out to the ini file for next time
		IniWriteNumber("transect", "interval", transInterval);
		IniWriteNumber("transect", "maxdist", maxdist);
		}
	DestroyWidget(pform);
	}

proc cbComputeTransects() {
	local i;

	PromptForValues();
	if (cancel) {
		return;
		}
```

```
	#--------------------------------------------------------------
	#	Prompt for output file location
	#		I'd like to make this use the standard get file
	#		dialog but I don't have that callable from within
	#		SML yet.
	#
	prompt$ = "Select output .loc file.  Other files will\n"
			+ "be created in the same directory by changing\n"
			+ "the file extention";
	GetOutputVector(Transects, "Network,VectorToolkit");
	fname$ = Transects.$info.Filename;
	#fname$ = GetOutputFileName(outfilebase$ + ".loc", prompt$, ".loc");
	outfilebase$ = FileNameGetPath(fname$) +
FileNameGetName(fname$);
	IniWriteString("transect", "outfilebase", outfilebase$);		# remember
it for next time

	#--------------------------------------------------------------
	#	Prompt operator for the dates of the shoreline vectors.
	#	Genreate the default by assuming the vector names are of
	#	the form _YYYY_MM
	#
	numeric j;
	for j = 1 to numshores {
		fname$ = GetObjectFileName(ShoreVectorList[j]);
		inode = GetObjectNumber(ShoreVectorList[j]);
		name$ = GetObjectName(fname$, inode);
		year = StrToNum(mid$(name$, 2, 4));
		month = StrToNum(mid$(name$, 7, 2));
		if (month < 1) month = 1;
		date = year * 10000 + month * 100 + 1;
		if (! _context.ScriptIsRVCObject) {
			# Don't bother prompting if this is only a demo.  Just
assume Jan 1
			prompt$ = "Enter date for vector " + name$ + " as
YYYYMMDD";
			date = PopupNum(prompt$, date);
			}
		vectdate[j] = DateToJulian(date);
		}


	status = StatusContextCreate(view.StatusHandle);
	#--------------------------------------------------------------
	#
	#	Initialize vector toolkit routines for intersection
	#	finding on the shoreline vectors
	#
	for j = 1 to numshores {
		status.Message = sprintf("Preparing vector %d for finding
intersections\n", j);
```

```
			VectorToolkitInit(ShoreVectorList[j]);
			}

		#------------------------------------------------------------
		#
		#	Compute the transects
		#
		numtrans = 0;
		clear();
		status.Message =  "Computing transects...";
		for line = 1 to NumVectorLines(BaseLineVector) {
			numbasepts = GetVectorLinePointList(BaseLineVector, basex, 
basey, line);
			if (flipbaseline) {
				for i = 1 to numbasepts - 1 {
					if (i > 1) {
						DoCorner(basex[i+1], basey[i+1], basex[i], 
basey[i], basex[i-1], basey[i-1]);
						}
					DoTransSeg(basex[i+1], basey[i+1], basex[i], 
basey[i]);
					}
				}
			else {
				for i = 1 to numbasepts - 1 {
					if (i > 1) {
						DoCorner(basex[i-1], basey[i-1], basex[i], 
basey[i], basex[i+1], basey[i+1]);
						}
					DoTransSeg(basex[i], basey[i], basex[i+1], 
basey[i+1]);
					}
				}
			}

		#------------------------------------------------------------
		#
		#	Create a vector object with the trancects so we can overlay them
		#	Would like to make this use network topology.  That way, 
transects
		#	which cross each other won't be broken up into multiple lines.  
This
		#	insures that transect 1000 is line 1000 and will make it easier to
		#	attach database records later
		#
		status.Message = "Creating transect vector...";
		#DeleteFile(outfilebase$ + ".rvc");
		#CreateVector(Transects, outfilebase$ + ".rvc", "Transects", "Generated 
by SML", "Network");
		for i = 1 to numtrans {
			StatusSetBar(status, i, numtrans);
```

```
		x1 = transx[i];
		y1 = transy[i];
		x2 = x1 + maxdist * cos(transa[i]);
		y2 = y1 + maxdist * sin(transa[i]);
		VectorAddTwoPointLine(Transects, x1, y1, x2, y2);
		}
	StatusSetBar(status);
	status.Message = "Updating transect vector topology...";
	CopySubobjects(BaseLineVector, Transects, "georef");
	VectorValidate(Transects);
	CloseVector(Transects);

	database = OpenVectorLineDatabase(Transects);
	ratetable = TableCreate(database, "Rates", "Erosion rates");
	ratetable.ImpliedAttachment = 1;
	transfield = TableAddFieldInteger(Transects.line.Rates, "Transect", 5);
	field = TableAddFieldFloat(Transects.line.Rates, "EPR", 8, 2);
	field.UnitType = "velocity";
	field.Units = "m/yr";
	field = TableAddFieldFloat(Transects.line.Rates, "Mean", 8, 2);
	field.UnitType = "velocity";
	field.Units = "m/yr";
	TableAddFieldFloat(Transects.line.Rates, "StdDev", 8, 2);
	TableAddFieldFloat(Transects.line.Rates, "Variance", 8, 2);
	TableAddFieldFloat(Transects.line.Rates, "Regression", 8, 2);
	TableAddFieldFloat(Transects.line.Rates, "Jackknife", 8, 2);

	if (! _context.ScriptIsRVCObject) {
		# Don't create text files for the demo version
		# If we don't open the files then fprintf or close,
		# SML is kind enough to just ignore us (C programs
		# die if we did that)
		julfile = fopen(outfilebase$ + ".jul", "w");
		distfile = fopen(outfilebase$ + ".dis", "w");
		ratefile = fopen(outfilebase$ + ".rat", "w");
		locfile = fopen(outfilebase$ + ".loc", "w");
		}

	status.Message = "Creating .loc file...";

	#------------------------------------------------------------
	#
	#	Output the .loc file
	#
	for i = 1 to numtrans {
		StatusSetBar(status, i, numtrans);
		fprintf(locfile, "%f,%f,%d\n", transx[i], transy[i], i);
		}


	#------------------------------------------------------------
```

```
	#	This is the biggie!  Find the intersections and compute
	#	the rates.
	#
	status.Message = "Finding shoreline-transect intersections";

	hits = 0;
	misses = 0;
	for i = 1 to numtrans {
		StatusSetBar(status, i, numtrans);

		#-------------------------------------------------------------
		# Find intersection of vector transx[i], transy[i], transa[i]
		# with each line.
		#
		#	Write the intersections to the .jul file.
		#
		#	Point to ask Randy: do you want this as one line per
transect like
		#	the original or one line per intersection as requested for
the .dis
		#	file?
		#
		numint = 0;
		for j = 1 to numshores {
			if (VectorLineRayIntersection(ShoreVectorList[j], transx[i],
transy[i], transa[i], maxdist, sx, sy)) {
				fprintf(julfile, "%4d %10.2f %10.2f %10.2f %10.2f
%7d\n", i, transx[i], transy[i], sx, sy, juldate[j]);
				numint += 1;
				shorex[numint] = sx;
				shorey[numint] = sy;
				distToBase[numint] = sqrt((transx[i] - sx) ^ 2 +
(transy[i] - sy) ^ 2);
				juldate[numint] = vectdate[j];
				}
			}
		if (numint) {
			hits += 1;
			}
		else {
			misses += 1;
			}

		#-------------------------------------------------------------
		#	Output the line in the .dist file
		#
		#	For each intersection, also compute the distance from this
		#	intersection and the first intersection, and also the
		#	difference in time (in years).  These will obviously be
		#	0 for the first intersection.
		#
```

```
		string thisdate$, lastdate;
		numeric lastdist = 0, delta;
		for j = 1 to numint {
			thisdate$ = DateToString(JulianToDate(juldate[j]),
"%m/%Y");
			if (j > 1) {
				delta = distToBase[j] - lastdist;
				fprintf(distfile, "%d,%s,%s,%f\n", i, lastdate$,
thisdate$, delta);
				}
			distFromShore1[j] = sqrt((shorex[j] - shorex[1])^2 +
(shorey[j] - shorey[1])^2);
			if (distToBase[1] > distToBase[j]) distFromShore1[j] = -
distFromShore1[j];
			years[j] = (juldate[j] - juldate[1]) / 365.25;

			lastdist = distToBase[j];
			lastdate$ = thisdate$;
			}

		#-----------------------------------------------------------
		#
		#	Compute endpoint rate
		#
		fprintf(ratefile, "%d,", i);		# transect number
		Transects.line[i].Rates.Transect = i;
		if (numint > 1) {
			numeric epr = EndPointRate(distToBase[numint],
distToBase[1], juldate[numint], juldate[1]);
			fprintf(ratefile, "%.2f", epr);
			Transects.line[i].Rates.EPR = epr;
			}

		#-----------------------------------------------------------
		#
		#	Compute average of rates.  Need at least 3 points to do
this
		#		This uses a feature of SML that's been there since
the beginning
		#		but I don't know if it's documented.  The rates
variable is set to
		#		the empty set ( { } ).  Then each endpoint rate is
computed and
		#		the is added to the set.  When the loops are done,
we have a set
		#		of all the rates, which can be passed to SetMean,
SetSD, SetVariance
		#		or any of the other Set functions.
		#
		numeric k;
		if (numint >= 2) {
```

```
			rates = {};
			for j = 1 to numint - 1 {
				for k = j+1 to numint {
					epr = EndPointRate(distToBase[j],
distToBase[k], juldate[j], juldate[k]);
					rates = rates + { epr };
					}
				}
			Transects.line[i].Rates.Mean = SetMean(rates);
			fprintf(ratefile, ",%.2f", SetMean(rates));
			if (numint > 2) {
				fprintf(ratefile, ",%.2f,%.2f", SetSD(rates),
SetVariance(rates));
				Transects.line[i].Rates.StdDev = SetSD(rates);
				Transects.line[i].Rates.Variance =
SetVariance(rates);
				}
			else {
				fprintf(ratefile, ",,");
				}
			}
		else {
			fprintf(ratefile, ",,,");
			}

		#------------------------------------------------------------
		#
		#	Standard linear regression.  Compute slope where x is
years and
		#	y is distance in meters.
		#
		numeric slope, intercept;
		if (numint > 1) {
			LinearRegression(years, distFromShore1, numint, slope,
intercept);
			fprintf(ratefile, ",%.2f", slope);
			Transects.line[i].Rates.Regression = slope;
			}
		else {
			fprintf(ratefile, ",");
			}

		#------------------------------------------------------------
		#
		#	Compute jackknife regression.   The jackknife regression
is the
		#		mean of the regression run numint times, each
time omitting
		#		one of the points.  The LinearRegression function
has an
```

```
		#		optional parameter that makes this easier.  The
parameter
		#		after the intercept tells it which point to ignore.
		#
		numeric sum;
		if (numint > 2) {
			sum = 0;
			for j = 1 to numint {
				LinearRegression(years, distFromShore1, numint,
slope, intercept, j);
				sum += slope;
				}
			fprintf(ratefile, ",%.2f", sum/numint);
			Transects.line[i].Rates.Jackknife = sum/numint;
			}
		else {
			fprintf(ratefile, ",");
			}

		fprintf(ratefile, "\n");
		}

	StatusSetBar(status); # Clear it
	status.Message = "Cleaning up...";

	for i = 1 to  numshores {
		CloseVector(ShoreVectorList[i]);
		}

	fclose(julfile);
	fclose(distfile);
	fclose(ratefile);
	fclose(locfile);
	StatusContextDestroy(status);

	if (voverlay) {
		LayerDestroy(voverlay);
		}
	voverlay = GroupQuickAddVectorVar(group, Transects);
	voverlay.Line.NormalStyle.Color.name = "blue";
	voverlay.Line.DataTip.Field = FieldGetInfoByName(Transects.line.Rates,
"Mean");
	ViewRedraw(view);
	}

############################################################
############################ MAIN ###########################
############################################################

	numeric height = .8 * _context.DisplayInfo.Height;
	numeric width = .75 * height;
```

```
	form = CreateFormDialog("Transect intersections");
	WidgetAddCallback(form.Shell.PopdownCallback, cbPopdown);

	group = DispCreate2DGroup();
	if (_context.ScriptIsRVCObject) {
		if (RasterExists(_context.Filename, "KENTIS")) {
			OpenRaster(BackgroundRaster, _context.Filename,
"KENTIS");
			bglayer = GroupQuickAddRasterVar(group,
BackgroundRaster);
			bglayer.ShowDataTips = 0;
			width = height * (BackgroundRaster.$info.NumCols /

BackgroundRaster.$info.NumLins);
			}
		}
	numeric i;
	for i = 1 to numshores {
		layer = GroupQuickAddVectorVar(group, ShoreVectorList[i]);
		}
	layer = GroupQuickAddVectorVar(group, BaseLineVector);
	layer.Line.NormalStyle.Color.name = "blue";

	view = GroupCreateView(group, form, "view", height, width);
	view.form.TopWidget = form;
	view.form.LeftWidget = form;
	view.form.RightWidget = form;
	view.form.BottomWidget = form;
	view.BackgroundColor.Red = 80;
	view.BackgroundColor.Green = 80;
	view.BackgroundColor.Blue = 80;
	ViewCreateSelectTool(view);
	ViewCreateMeasureTool(view);
	ViewAddStandardTools(view);
	ViewAddToolIcons(view);
	transButton = CreatePushButton(view.IconBar, "Create Transects");
	WidgetAddCallback(transButton.ActivateCallback,
cbComputeTransects);
	DialogOpen(form);
	controls = GroupOpenLayerManagerWindow(form, group);
	DispAddCallback(controls.CloseCallback, cbQuit);
	ViewRedraw(view);
	WaitForExit();
```

APPENDIX 3

Edited Script

```
##########################################################
#
#        Transect and Rates SML script
#
#        Written 8 Mar 1998
#        David Williss
#        MicroImages, Inc
#
#        Based on a pair of DSAS programs.
#
##########################################################
#
#    If You use this edited script, please cite it as follows:
#
#    Fulat, A., 2005, Investigating time series shoreline changes by integration of
#          Remote Sensing and Geographical Information Systems, M.Sc. Thesis,
#          Middle East Technical University, Turkey, 144 p.
##########################################################
#     Edited    Summer 2005
#
#             by (and very special thanks to) Adem Tunca
#                (Hat Coğrafi Bilgi Sistemleri A.Ş.)
#                (atunca@hatgis.com.tr)
#
#             by (and very special thanks to) Deniz Gerçek
#                (RS-GIS Lab. Geological Eng. Dept., METU, Turkey)
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#
#             by Alper Fulat
#                (RS-GIS Lab. Geological Eng. Dept., METU, Turkey)
#                (alperfulat@gmail.com)
#             (www.rsgis.metu.edu.tr)
#
#    Edited to find out especially the "future shoreline position",
#                    also the minimum, maximum and mean rates.
##########################################################
#        Limits --
#                A few limits which are hard-coded.
#                Increase as necessary
#
numeric maxTrans = 10000;            # Maximum number of transects
numeric maxShores = 20;                        # Maximum number of shoreline
vectors
##########################################################
```

```
#       Defaults --
#               These are initial default values.
#               They will be read out of the tntproc.ini file.  The
#               last parameter to IniReadNumber is the default value
#               to use if not found in the ini file
#
numeric transInterval, maxdist;
string outfilebase$;
transInterval = IniReadNumber("transect", "interval", 100);
maxdist = IniReadNumber("transect", "maxdist", 250);
outfilebase$ = FileNameGetPath(_context.Filename);
outfilebase$ = IniReadString("transect", "outfilebase", outfilebase$);

#######################################################
#
#       Global Variables
#
array numeric  transx[maxTrans];
array numeric transy[maxTrans];
array numeric transa[maxTrans];
numeric numtrans, numshores;
array numeric shorex[maxShores], shorey[maxShores];
array numeric vectdate[maxShores], juldate[maxShores], years[maxShores];
array numeric distToBase[maxShores], distFromShore1[maxShores],
years[maxShores];
array numeric basex[10], basey[10]; # Automatically resized anyway
class FILE locfile, julfile, distfile, ratefile;
class GRE_GROUP group;
class GRE_LAYER_VECTOR voverlay, layer;
class GRE_LAYER translayer;
class GRE_VIEW view;
class GRE_LAYER_RASTER bglayer;
class XmForm form;
class PUSHBUTTONITEM okItem, cancelItem;
class XmForm button_row;
class XmSeparator sep;
class PromptNum pinterval, pmaxdist;
class STATUSCONTEXT status;
class DATABASE database;
class DBTABLEINFO ratetable;
class DBFIELDINFO transfield, field;
class GRE_LAYERMANAGER controls;
class XmPushButton transButton;
vector Transects;
raster BackgroundRaster;
vector BaseLineVector;
string prompt$, fname$, name$, lastdate$;
numeric inode, year, month, date;
numeric line, numbasepts, flipbaseline;
numeric x1, y1, x2, y2;
```

```
numeric hits, misses, numint, sx, sy, rates;
##########################################################

proc DoTransSeg(x0,y0, x1,y1)
{
	local numeric theta, theta90, r, dx, dy, x, y, dist;

	dx = x1 - x0;
	dy = y1 - y0;
	theta = atan2(dy, dx); # Angle of this segment
	theta90 = theta + pi/2;				# angle perpendicular to
segment
	dist = sqrt(dx*dx + dy*dy);
	for r = 0 to dist step transInterval {
		numtrans += 1;
		transx[numtrans] = x0 + r*cos(theta);
		transy[numtrans] = y0 + r*sin(theta);
		transa[numtrans] = theta90;
		}
	if (r != dist) {
		numtrans += 1;
		transx[numtrans] = x1;
		transy[numtrans] = y1;
		transa[numtrans] = theta90;
		}
	return;
  }

##########################################################
#
#	Do the corner between two segments.
#		Segment A is from (x0,y0) to (x1,y1)
#		Segment B is from (x1,y1) to (x2,y2)
#
#	The transect from the end of segment A is already in the
#	list.  The transect from the beginning of B will be added
#	by DoTransSeg
#	Compute a transect at point (x1,y1) which bisects the
#	angle betweent the two transects.
#
proc DoCorner(x0,y0, x1,y1, x2,y2) {
	local numeric dxA, dxB, dyA, dyB, thetaA, thetaB, theta90A, theta90B,
theta90AB;

	dxA = x1 - x0;
	dyA = y1 - y0;
	dxB = x2 - x1;
	dyB = y2 - y1;
	thetaA = atan2(dyA, dxA);	# Angle of segment A
	thetaB = atan2(dyB, dxB);	# Angle of segment B
	theta90A = thetaA + pi/2;
```

```
	theta90B = thetaB + pi/2;
	# Angles greater than 2*pi screw up the bisection
	if (theta90A > 2 * pi) {
		theta90A -= 2 * pi;
		}
	if (theta90B > 2 * pi) {
		theta90B -= 2 * pi;
		}
	if (abs(theta90A - theta90B) > pi) {
		theta90A -= 2 * pi;	# Doesn't really matter which one we
subtract from
		}
	theta90AB = (theta90A + theta90B) / 2;
	numtrans += 1;

	transx[numtrans] = x1;
	transy[numtrans] = y1;
	transa[numtrans] = theta90AB;
	return;
	}

######################################################
#
#		Compute the endpoint rate dr/dt.
#		The dates are assumed to be julian dates
#		return value is in meters/year.
#
func EndPointRate(dist0, dist1, date0, date1) {
	return ((dist1 - dist0) / ((date1 - date0) / 365.25));
	}


#	Called when user closes layer controls.
#	Close the view window.  This will cause
#	the popdown callback to be called
proc cbQuit(class widget widget) {
	DialogClose(form);
	}

#	Called when the dialog actually pops down.  Free
#	and destroy everything.
proc cbPopdown(class widget widget) {
	ViewDestroy(view);
	GroupDestroy(group);
	DestroyWidget(form);
	Exit();
	}


#####################################################
#							MAIN
```

```
########################################################

#
#        Lets assume that the baseline vector contains lines whos
#        verticies are the segment points.
#
if (_context.ScriptIsRVCObject) {
         # Script is being run from an RVC file which has all the data it needs
         # This is for demo purposes
         OpenVector(BaseLineVector, _context.Filename, "BaseLine");
         numshores = OpenInputVectorList(ShoreVectorList,
                             _context.Filename, "_1844",
                             _context.Filename, "_1942",
                             _context.Filename, "_1976"
                             );
         }
else {
         GetInputVector(BaseLineVector);
         numshores = GetInputVectorList(ShoreVectorList, "Select shoreline
vectors in cronological order");
         }

class XmForm pform;
numeric cancel;

proc cbPromptsOK() {
         DialogClose(pform);
         cancel = 0;
         }

proc cbPromptsCancel() {
         DialogClose(pform);
         cancel = 1;
         }

proc PromptForValues() {
         pform = CreateModalFormDialog("Parameters");
         okItem = CreatePushButtonItem("OK", cbPromptsOK);
         cancelItem = CreatePushButtonItem("Cancel", cbPromptsCancel);
         button_row = CreateButtonRow(pform, okItem, cancelItem);
         button_row.BottomWidget = pform;

         sep = CreateHorizontalSeparator(pform);
         sep.LeftWidget = pform;
         sep.RightWidget = pform;
         sep.BottomWidget = button_row;

         pinterval = CreatePromptNum(pform, "Interval:", 5, 0, transInterval, 0);
         pinterval.BottomWidget = sep;

         pmaxdist = CreatePromptNum(pform, "Max Dist:", 5, 0, maxdist, 0);
```

```
	pmaxdist.BottomWidget = pinterval;
	AlignWidgets(pinterval.label, pmaxdist.label);

	DialogOpen(pform);
	DialogWaitForClose(pform);
	if (!cancel) {
		transInterval = pinterval.value;
		maxdist = pmaxdist.value;
		# Write them back out to the ini file for next time
		IniWriteNumber("transect", "interval", transInterval);
		IniWriteNumber("transect", "maxdist", maxdist);
		}
	DestroyWidget(pform);
	}

proc cbComputeTransects() {
	local i;

	PromptForValues();
	if (cancel) {
		return;
		}
	#-----------------------------------------------------------
	#	Prompt for output file location
	#		I'd like to make this use the standard get file
	#		dialog but I don't have that callable from within
	#		SML yet.
	#
	prompt$ = "Select output .loc file.  Other files will\n"
			+ "be created in the same directory by changing\n"
			+ "the file extention";
	GetOutputVector(Transects, "Network,VectorToolkit");
	fname$ = Transects.$info.Filename;
	#fname$ = GetOutputFileName(outfilebase$ + ".loc", prompt$, ".loc");
	outfilebase$ = FileNameGetPath(fname$) +
FileNameGetName(fname$);
	IniWriteString("transect", "outfilebase", outfilebase$);		# remember it
for next time

	#-----------------------------------------------------------
	#	Prompt operator for the dates of the shoreline vectors.
	#	Genreate the default by assuming the vector names are of
	#	the form _YYYY_MM
	#
	numeric j;
	for j = 1 to numshores {
		fname$ = GetObjectFileName(ShoreVectorList[j]);
		inode = GetObjectNumber(ShoreVectorList[j]);
		name$ = GetObjectName(fname$, inode);
		year = StrToNum(mid$(name$, 2, 4));
		month = StrToNum(mid$(name$, 7, 2));
```

```
			if (month < 1) month = 1;
			date = year * 10000 + month * 100 + 1;
			if (! _context.ScriptIsRVCObject) {
				# Don't bother prompting if this is only a demo.  Just
assume Jan 1
				prompt$ = "Enter date for vector " + name$ + " as
YYYYMMDD";
				date = PopupNum(prompt$, date);
				}
			vectdate[j] = DateToJulian(date);
			}


		status = StatusContextCreate(view.StatusHandle);
		#-----------------------------------------------------------
		#
		#	Initialize vector toolkit routines for intersection
		#	finding on the shoreline vectors
		#
		for j = 1 to numshores {
			status.Message = sprintf("Preparing vector %d for finding
intersections\n", j);
			VectorToolkitInit(ShoreVectorList[j]);
			}

		#-----------------------------------------------------------
		#
		#	Compute the transects
		#
		numtrans = 0;
		clear();
		status.Message =  "Computing transects...";
		for line = 1 to NumVectorLines(BaseLineVector) {
			numbasepts = GetVectorLinePointList(BaseLineVector, basex,
basey, line);
			if (flipbaseline) {
				for i = 1 to numbasepts - 1 {
					if (i > 1) {
						DoCorner(basex[i+1], basey[i+1], basex[i],
basey[i], basex[i-1], basey[i-1]);
						}
					DoTransSeg(basex[i+1], basey[i+1], basex[i],
basey[i]);
					}
				}
			else {
				for i = 1 to numbasepts - 1 {
					if (i > 1) {
						DoCorner(basex[i-1], basey[i-1], basex[i],
basey[i], basex[i+1], basey[i+1]);
						}
```

```
				DoTransSeg(basex[i], basey[i], basex[i+1],
basey[i+1]);
				}
			}
		}

	#-----------------------------------------------------------
	#
	#	Create a vector object with the trancects so we can overlay them
	#	Would like to make this use network topology.  That way,
transects
	#	which cross each other won't be broken up into multiple lines.
This
	#	insures that transect 1000 is line 1000 and will make it easier to
	#	attach database records later
	#
	status.Message = "Creating transect vector...";
	#DeleteFile(outfilebase$ + ".rvc");
	#CreateVector(Transects, outfilebase$ + ".rvc", "Transects", "Generated
by SML", "Network");
	for i = 1 to numtrans {
		StatusSetBar(status, i, numtrans);
		x1 = transx[i];
		y1 = transy[i];
		x2 = x1 + maxdist * cos(transa[i]);
		y2 = y1 + maxdist * sin(transa[i]);


#				numeric x3, y3;
#				x3 = transx[i] + (maxdist-(pinterval+200)) *
cos(transa[i]);
#				y3 = transy[i] + (maxdist-(pinterval+200)) *
sin(transa[i]);

#VectorAddPoint(Transects, x3, y3);











		VectorAddTwoPointLine(Transects, x1, y1, x2, y2);
		}
	StatusSetBar(status);
	status.Message = "Updating transect vector topology...";
	CopySubobjects(BaseLineVector, Transects, "georef");
	VectorValidate(Transects);
```

```
	CloseVector(Transects);

	database = OpenVectorLineDatabase(Transects);
	ratetable = TableCreate(database, "Rates", "Erosion rates");
	ratetable.ImpliedAttachment = 1;
	transfield = TableAddFieldInteger(Transects.line.Rates, "Transect", 5);
	field = TableAddFieldFloat(Transects.line.Rates, "EPR", 8, 2);
	field.UnitType = "velocity";
	field.Units = "m/yr";
	field = TableAddFieldFloat(Transects.line.Rates, "Mean", 8, 2);
	field.UnitType = "velocity";
	field.Units = "m/yr";
	TableAddFieldFloat(Transects.line.Rates, "StdDev", 8, 2);
	TableAddFieldFloat(Transects.line.Rates, "Variance", 8, 2);
	TableAddFieldFloat(Transects.line.Rates, "Regression", 8, 2);
	TableAddFieldFloat(Transects.line.Rates, "Jackknife", 8, 2);



#ADEM

	if (! _context.ScriptIsRVCObject) {
		# Don't create text files for the demo version
		# If we don't open the files then fprintf or close,
		# SML is kind enough to just ignore us (C programs
		# die if we did that)
		julfile = fopen(outfilebase$ + ".jul", "w");
		distfile = fopen(outfilebase$ + ".dis", "w");
		ratefile = fopen(outfilebase$ + ".rat", "w");
		locfile = fopen(outfilebase$ + ".loc", "w");
		}

	status.Message = "Creating .loc file...";

	#----------------------------------------------------------
	#
	#	Output the .loc file
	#
	for i = 1 to numtrans {
		StatusSetBar(status, i, numtrans);
		fprintf(locfile, "%f,%f,%d\n", transx[i], transy[i], i);
		}


	#----------------------------------------------------------
	#	This is the biggie!  Find the intersections and compute
	#	the rates.
	#
	status.Message = "Finding shoreline-transect intersections";

	hits = 0;
```

```
		misses = 0;
		for i = 1 to numtrans {
			StatusSetBar(status, i, numtrans);

			#------------------------------------------------------------
			# Find intersection of vector transx[i], transy[i], transa[i]
			# with each line.
			#
			#	Write the intersections to the .jul file.
			#
			#	Point to ask Randy: do you want this as one line per
transect like
			#	the original or one line per intersection as requested for
the .dis
			#	file?


#KESISIM
			numint = 0;
			for j = 1 to numshores {
				if (VectorLineRayIntersection(ShoreVectorList[j], transx[i],
transy[i], transa[i], maxdist, sx, sy)) {
					fprintf(julfile, "%4d %10.2f %10.2f %10.2f %10.2f
%7d\n", i, transx[i], transy[i], sx, sy, juldate[j]);
					numint += 1;
					shorex[numint] = sx;
					shorey[numint] = sy; #print (j, sx,sy)
					distToBase[numint] = sqrt((transx[i] - sx) ^ 2 +
(transy[i] - sy) ^ 2); #print(i,j, distToBase[numint])
					juldate[numint] = vectdate[j];
					}
				}
			if (numint) {
				hits += 1;
				}
			else {
				misses += 1;
				}

			#------------------------------------------------------------
			#	Output the line in the .dist file
			#
			#	For each intersection, also compute the distance from this
			#	intersection and the first intersection, and also the
			#	difference in time (in years).  These will obviously be
			#	0 for the first intersection.
			#
			string thisdate$, lastdate;
			numeric lastdist = 0, delta;
			for j = 1 to numint {
```

```
			thisdate$ = DateToString(JulianToDate(juldate[j]),
"%m/%Y");
			if (j > 1) {
				delta = distToBase[j] - lastdist;
				fprintf(distfile, "%d,%s,%s,%f\n", i, lastdate$,
thisdate$, delta);
				}
			distFromShore1[j] = sqrt((shorex[j] - shorex[1])^2 +
(shorey[j] - shorey[1])^2);
			if (distToBase[1] > distToBase[j]) distFromShore1[j] = -
distFromShore1[j];
			years[j] = (juldate[j] - juldate[1]) / 365.25;

			lastdist = distToBase[j];
			lastdate$ = thisdate$;
			}

		#------------------------------------------------------------
		#
		#	Compute endpoint rate
		#
		fprintf(ratefile, "%d,", i);		# transect number
		Transects.line[i].Rates.Transect = i;
		if (numint > 1) {
			numeric epr = EndPointRate(distToBase[numint],
distToBase[1], juldate[numint], juldate[1]);
			fprintf(ratefile, "%.2f", epr);
			Transects.line[i].Rates.EPR = epr;
			}

		#------------------------------------------------------------
		#
		#	Compute average of rates.  Need at least 3 points to do
this
		#		This uses a feature of SML that's been there since
the beginning
		#		but I don't know if it's documented.  The rates
variable is set to
		#		the empty set ( { } ).  Then each endpoint rate is
computed and
		#		the is added to the set.  When the loops are done,
we have a set
		#		of all the rates, which can be passed to SetMean,
SetSD, SetVariance
		#		or any of the other Set functions.
		#
		numeric k;
		if (numint >= 2) {
			rates = {};
			for j = 1 to numint - 1 {
				for k = j+1 to numint {
```

```
                                        epr = EndPointRate(distToBase[j],
distToBase[k], juldate[j], juldate[k]);
                                        rates = rates + { epr };
                                        }
                                }
                        Transects.line[i].Rates.Mean = SetMean(rates);
                        fprintf(ratefile, ",%.2f", SetMean(rates));
                        if (numint > 2) {
                                fprintf(ratefile, ",%.2f,%.2f", SetSD(rates),
SetVariance(rates));
                                Transects.line[i].Rates.StdDev = SetSD(rates);
                                Transects.line[i].Rates.Variance =
SetVariance(rates);
                                }
                        else {
                                fprintf(ratefile, ",,");
                                }
                        }
                else {
                        fprintf(ratefile, ",,,");
                        }

                #---------------------------------------------------------
                #
                #       Standard linear regression.  Compute slope where x is
years and
                #       y is distance in meters.
                #
                numeric slope, intercept;
                if (numint > 1) {
                        LinearRegression(years, distFromShore1, numint, slope,
intercept);
                        fprintf(ratefile, ",%.2f", slope);
                        Transects.line[i].Rates.Regression = slope;
                        }
                else {
                        fprintf(ratefile, ",");
                        }

                #---------------------------------------------------------
                #
                #       Compute jackknife regression.   The jackknife regression
is the
                #               mean of the regression run numint times, each
time omitting
                #               one of the points.  The LinearRegression function
has an
                #               optional parameter that makes this easier.  The
parameter
                #               after the intercept tells it which point to ignore.
                #
```

```
			numeric sum;
			if (numint > 2) {
				sum = 0;
				for j = 1 to numint {
					LinearRegression(years, distFromShore1, numint,
slope, intercept, j);
					sum += slope;
					}
				fprintf(ratefile, ",%.2f", sum/numint);
				Transects.line[i].Rates.Jackknife = sum/numint;
				}
			else {
				fprintf(ratefile, ",");
				}

			fprintf(ratefile, "\n");
			}

		StatusSetBar(status); # Clear it
		status.Message = "Cleaning up...";

		for i = 1 to  numshores {
			CloseVector(ShoreVectorList[i]);
			}

		fclose(julfile);
		fclose(distfile);
		fclose(ratefile);
		fclose(locfile);
		StatusContextDestroy(status);

		if (voverlay) {
			LayerDestroy(voverlay);
			}
		voverlay = GroupQuickAddVectorVar(group, Transects);
		voverlay.Line.NormalStyle.Color.name = "blue";
		voverlay.Line.DataTip.Field = FieldGetInfoByName(Transects.line.Rates,
"Mean");
		ViewRedraw(view);
		}

#################################################################
############################ MAIN ###########################
#################################################################

		numeric height = .8 * _context.DisplayInfo.Height;
		numeric width = .75 * height;
		form = CreateFormDialog("Transect intersections");
		WidgetAddCallback(form.Shell.PopdownCallback, cbPopdown);

		group = DispCreate2DGroup();
```

```
	if (_context.ScriptIsRVCObject) {
		if (RasterExists(_context.Filename, "KENTIS")) {
			OpenRaster(BackgroundRaster, _context.Filename,
"KENTIS");
			bglayer = GroupQuickAddRasterVar(group,
BackgroundRaster);
			bglayer.ShowDataTips = 0;
			width = height * (BackgroundRaster.$info.NumCols /

BackgroundRaster.$info.NumLins);
			}
		}
	numeric i;
	for i = 1 to numshores {
		layer = GroupQuickAddVectorVar(group, ShoreVectorList[i]);
		}
	layer = GroupQuickAddVectorVar(group, BaseLineVector);
	layer.Line.NormalStyle.Color.name = "blue";

	view = GroupCreateView(group, form, "view", height, width);
	view.form.TopWidget = form;
	view.form.LeftWidget = form;
	view.form.RightWidget = form;
	view.form.BottomWidget = form;
	view.BackgroundColor.Red = 80;
	view.BackgroundColor.Green = 80;
	view.BackgroundColor.Blue = 80;
	ViewCreateSelectTool(view);
	ViewCreateMeasureTool(view);
	ViewAddStandardTools(view);
	ViewAddToolIcons(view);
	transButton = CreatePushButton(view.IconBar, "Create Transects");
	WidgetAddCallback(transButton.ActivateCallback,
cbComputeTransects);

################################################################
#################
################################# edit ######### edit #########
edit############
################################################################
#################

#for i=1 to 4 {

proc cbFbutton() {
OpenVector(Vadem, "D:/sml/result.rvc", "Transects")
VectorToolkitInit(Vadem)
class DATABASE db_a;
db_a = OpenVectorLineDatabase(Vadem);

#PopupSelectTableField(db_a, t$, f$)
```

```
########################################################

#numofselfield=PopupSelectTableField(db_a, t$, f$)

#for i=1 to 4 {

################(numofselfield=number of selected field)---------------until
cancel

#PopupSelectTableField(db_a, t$, f$)


field1=PopupSelectTableField(db_a, t$, f1$)
field2=PopupSelectTableField(db_a, t$, f2$)
field3=PopupSelectTableField(db_a, t$, f3$)
field4=PopupSelectTableField(db_a, t$, f4$)


#t=table, f=field

########################################################
########################################################


class DBTABLEINFO t_info;
t_info = DatabaseGetTableInfo(db_a, t$);
}
#}

proc cbVbutton() {
numeric factor;
pop_num = PopupNum("FACTOR :", 1)


vector V_trans_adem;
OpenVector(V_trans_adem, "D:/sml/result.rvc", "Transects")
VectorToolkitInit(V_trans_adem)
OpenVector(V_shore_adem, "D:/sml/shorelines.rvc", "_2004kiyi")
VectorToolkitInit(V_shore_adem)

###############################################################
#####
for g = 1 to NumRecords(t_info){
numeric ekle_cikart;
ekle_cikart = SetMin(TableReadFieldNum(t_info, f1$, g),

# ekle_cikart = SetMax(TableReadFieldNum(t_info, f1$, g),

# ekle_cikart = SetMean(TableReadFieldNum(t_info, f1$, g),
```

```
TableReadFieldNum(t_info, f2$, g), TableReadFieldNum(t_info, f3$, g),
TableReadFieldNum(t_info, f4$, g));

print (ekle_cikart)
carpan = ekle_cikart * pop_num
print(carpan)

                    x1 = transx[g];
                    y1 = transy[g];

ClosestPointOnLine(V_trans_adem, g, x1, y1, x_desired, y_desired)
print(x_desired, y_desired)

VectorLineRayIntersection(V_shore_adem, x1, y1, transa[g], maxdist, x2_adem,
y2_adem)
print(x2_adem, y2_adem)

base2shore = sqrt(((x1 - x2_adem)^2) + ((y1 - y2_adem)^2));
#print (g, "----", base2shore)

#print (distToBase[4])

                                        numeric x3, y3
                                        x3 = x1 + (carpan+base2shore) * cos(transa[g]);
                                        y3 = y1 + (carpan+base2shore) * sin(transa[g]);

                              VectorAddPoint(Vadem, x3, y3);


}

}





          fieldbutton = CreatePushButton(view.IconBar, " Field Selection ");
          WidgetAddCallback(fieldbutton.ActivateCallback, cbFbutton);

          variablebutton = CreatePushButton(view.IconBar, " Enter X ");
          WidgetAddCallback(variablebutton.ActivateCallback, cbVbutton);

          DialogOpen(form);
          controls = GroupOpenLayerManagerWindow(form, group);
          DispAddCallback(controls.CloseCallback, cbQuit);
          ViewRedraw(view);
          WaitForExit();
```