Spatial aspects of the Diu and Daman coastal spits

Dr. N.L. Dongre

Keywords: Irregular long shore. Shingle. Enabled vegetation. off shore relief. Tidal banks. Trapped. Autocorrelation. Constant refraction. Refracted waves. Various Sub routines. Superabundance.

Abstract: the **analysis of form in geomorphology can have several purposes and can be carried out in many different ways. The examples of Diu and Daman coastal spit that have been considered briefly are concerned with aspects of coastal spit formation. They are intended to illustrate how form can be related to process, and to the development of the feature through time. The first method of form analysis is directly related to time, via trend analysis of the changing dimensions of the spit over a period of nearly two decades. The trends can be used to relate the changes on the foreshore to the accretion on the spit, thus suggesting processes by which the material reaches the spit. Problems of autocorrelation in time series cause some complications, when processes are related to time and care must be used, not to draw false conclusions from correlations of this type. In the example cited independent evidence reduces this danger. The second example is aimed to**

express more accurately the form of a spit, which is one of its important spatial characteristics, by a curve fitting technique. The logarithmic spiral curve fits the spit shape closely at some periods, and increasingly so through time. The best fit obtained are for the 2008 and 2009 outlines of the spit crest. This suggests that now the spit has deeper water off its distal tip one set of long waves can influence its form so that its whole outline is closely approximated by a single spiral. The degree of curvature is probably a function of the length of waves to which it has become adjusted. The more open curvature of may 2009 be the effect of less refracted waves than those that formed the outline in 2008 , when the distal curvature is quite strong. The very tight curvatures of former years are probably due to small waves from another quarter, when the water at the end of the spit was very shallow. The third example is concerned with simulation of spit formation. A computer program is based on a number of subroutines that simulated four individual wave types as well as other factors. These variables are thought to be responsible for the distinctive form of Daman complex recurved spit. The computer model produced a spit very similar in outline to the real spit, when the optimum range of random numbers are allocated to the different subroutines, and when the depth and refraction conditions are simulated optimally. These last two variables are found to be particularly important in the optimum simulation of the spit.

Geomorphologic features are more amenable to spatial analysis than others, in that they occur in large numbers and can be represented as point patterns. Others, however, occur as individuals and each must be studied on its own merits. A large drumlin field exemplifies the first situation, while coastal spits fall into the second category. Each spit must be considered individually, although the operation of processes common to them all can often be recognized in the form of spits in general. They are all formed by waves and usually respond in a similar way to similar processes. (King C.A.M.1972) Spits have another characteristic that makes their analysis rewarding. They develop very rapidly and changes in form can be recorded over short time intervals. This rapid speed of development means that both time and space can be introduced into the analysis of spit forms.

This contribution aims to describe methods of studying the form of spits over both time and space. In the first section trends in the development of the spit at Diu point in Arabian Sea (Figure: 1) are considered, as an example of simple time-series analysis. In the second section the form of the spit at one point in time is investigated by curve fitting methods. In the final section both time and form are considered together in a simulation model of Daman coast Spit in Arabian Sea (Figure: 2). The simulation model allows prediction by extrapolation, and thus enables changes in form to be considered over time both in the past and future. Some general points concerning spit development should be made before the examples are cited. The relative abundance and complexity of spits around the coasts of the India and world at present, is the result of the immaturity of all coastlines.(Chandra Mohan 1996) It is only at most about 4000 year since sea level attained close to its present height along the stable coasts of the world, following the rapid flandrian transgression, during which sea level rose by nearly 100 m during the previous 15,000 years.(Horace Gardiner1973) Thus modern spits have had at most a few thousand years to form.

Figure: 1. The Spits at Diu point; A dot in the Arabian Sea (Google earth Photography)

Figure: 2 Daman Coast Spits in Arabian Sea (Google earth Photography)

Another result of the very large and recent fluctuations of sea level has been the creation of an intricate coastline in Western coast of India. River incision and deposition at times of low Sea level provided an uneven surface across which the sea has risen

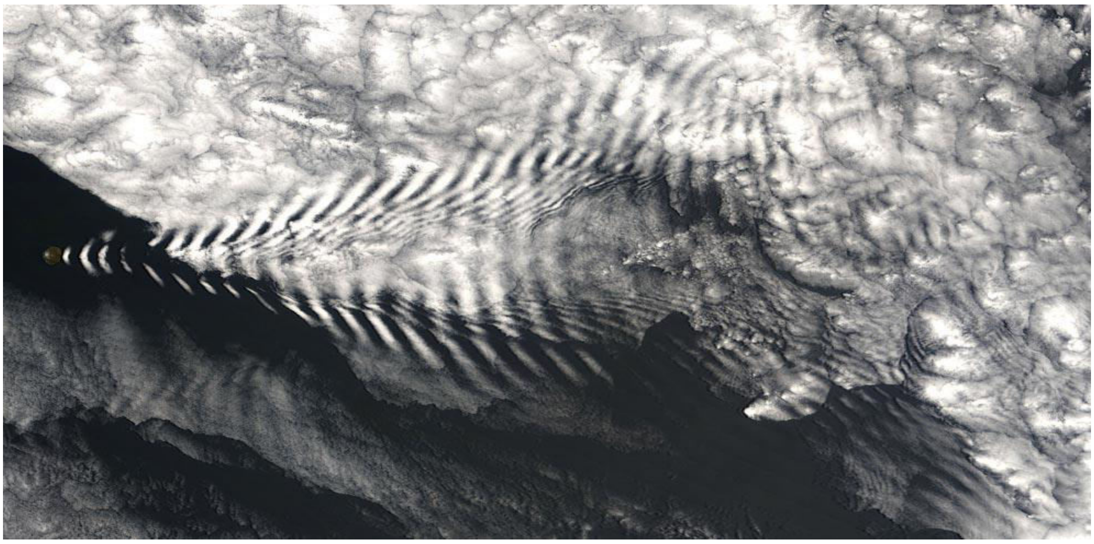

Figure: 3 the wave pattern in association with the Coastal outlines (Google earth Photography)

Spits are most likely to form where the coastline is irregular, and their form will also be more complex as a result.(Helen M 2008) Where the coastline is irregular alongshore movement of material will be unlikely to be uniform, and spits will form in those areas where more material is reaching a stretch of coast than is leaving it. (Robin and levoy 2007). Such areas will be determined by the wave pattern in association with the coastal outline. (Figure: 3) In some areas the tidal streams also play an important part.(Andrew D. Ashton, A. brad Murray and Ryan Uttlewood 2007). Of the two areas exemplified, the Diu coast is influenced both by the tide and the waves,(Figure:4) while Daman coast Spit is probably influenced more by the waves than the tide (Figure.5), although the latter does play a part. In both areas the position of the spit is influenced by the form of the coast, as each spit prolongs the direction of the mainland coast where his turns abruptly inland. (Figure: 6) The features are, however, of very different ages, although both are fairly small.

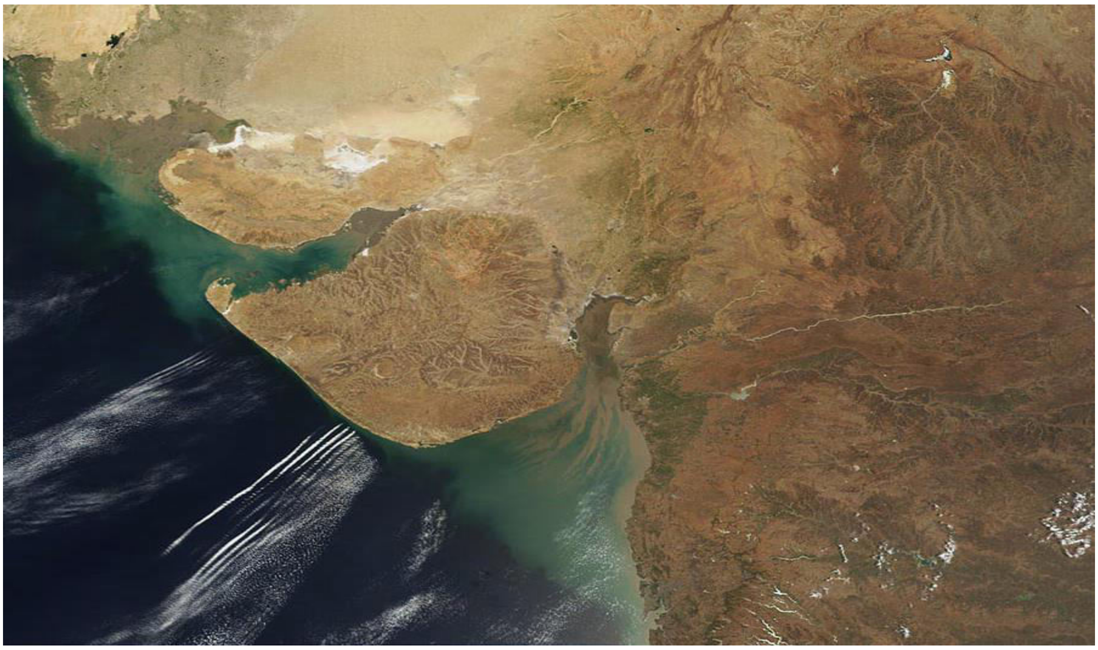

Figure: 4 The Diu Spit is influenced more by the waves than tide and prolonged the direction of the main land coast where it turns abruptly in land (Google earth Photography)

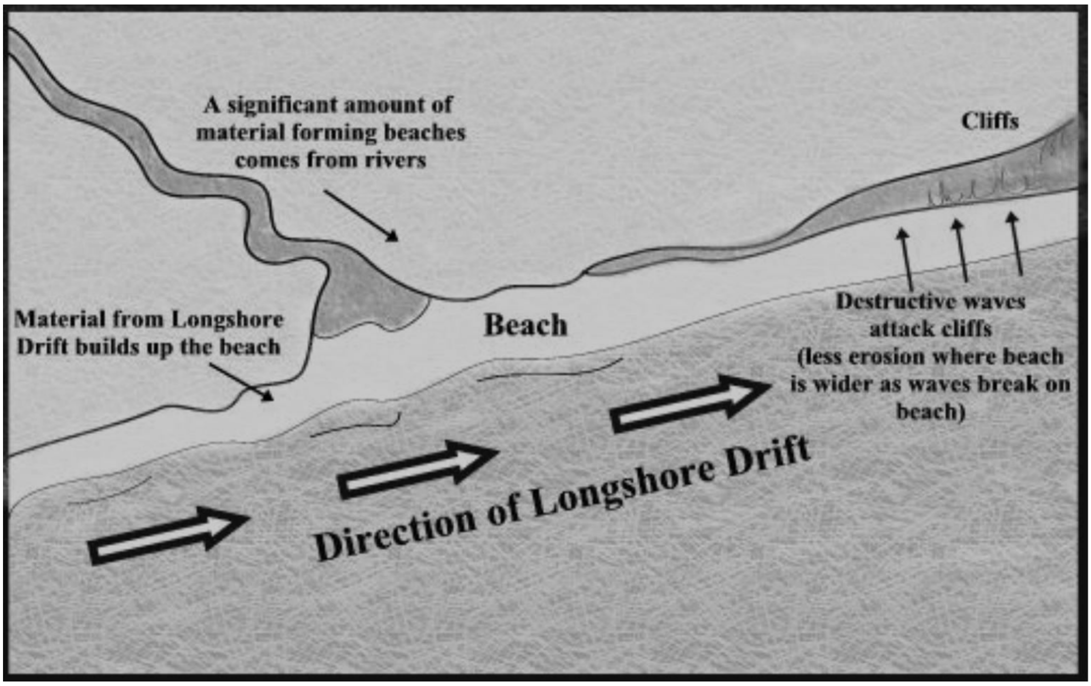

Figure: 5 The Spit continue to grow outwards joining land to an offshore Island

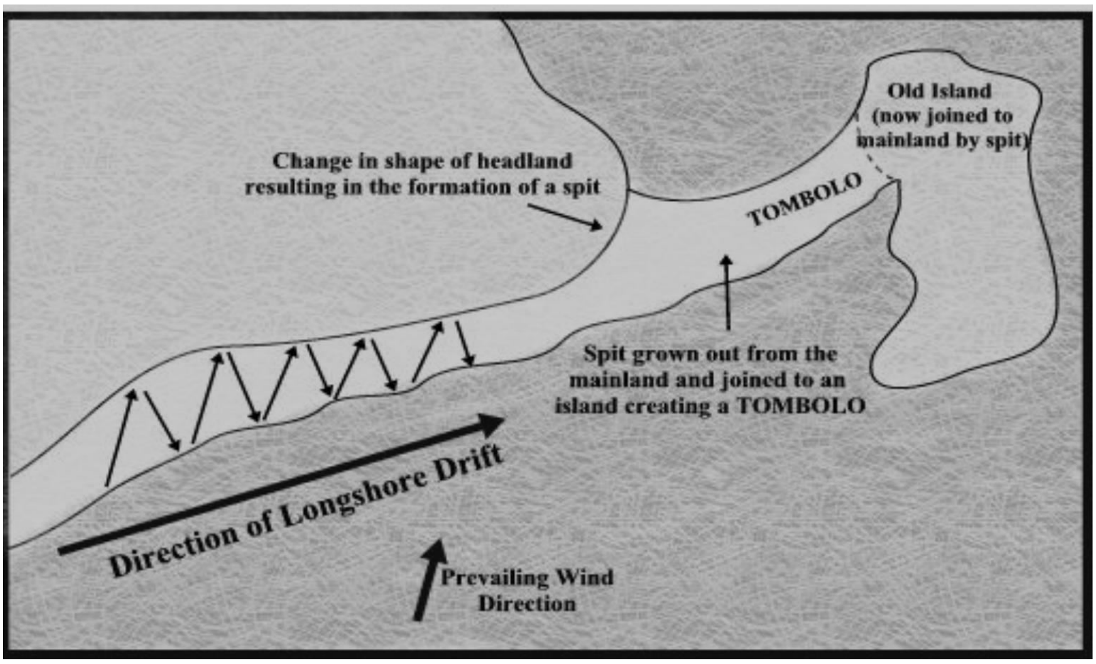

Figure: 6 C changes in prevailing wind direction often causes the end of the Spits to become hooked

The spit at Diu Point can only have been forming since1942, when it was initiated by a storm, which truncated the old marsh and dune deposits,(Figure:7) driving the latter over the former. The spit developed from the angle of the coast at Diu Point (Figure: 8) Its development has been studied in repeated surveys at roughly annual intervals since1991. It is dependent for its growth on material supplied from the west along the shore. By wave action (Figure: 8) Changes that are taking place on the beach to the west are relevant, therefore, in analyzing the growth of the spit (Chandra Mohan P 1996).

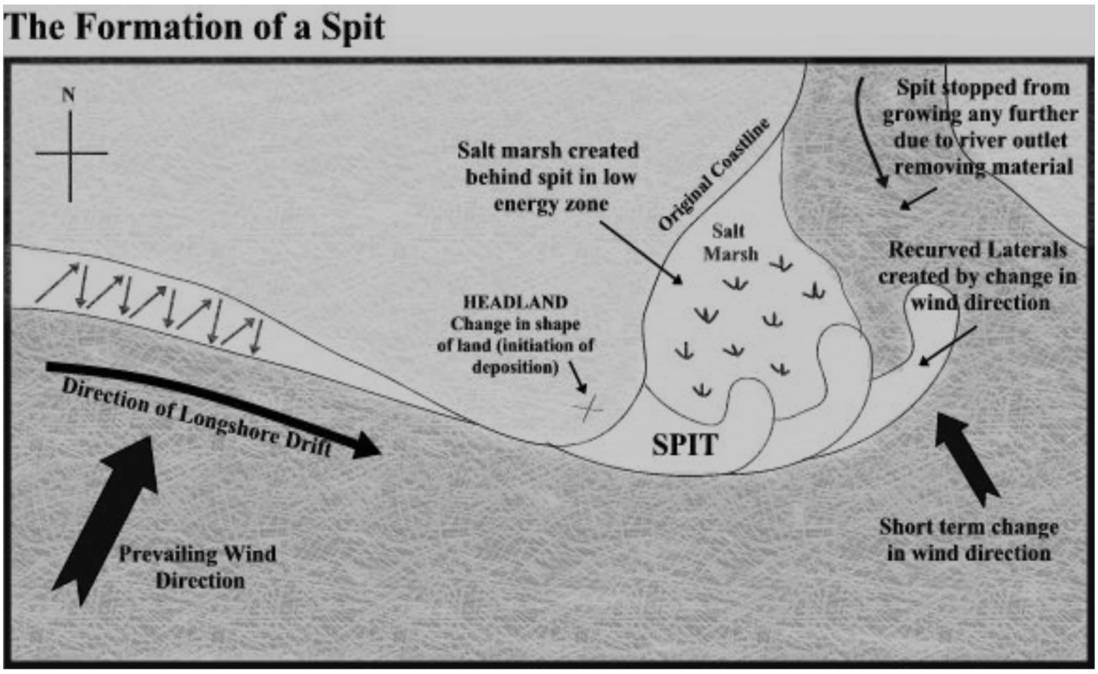

Figure: 7 Spits are long narrow ridges of sand and shingle which project from the coastline into the sea

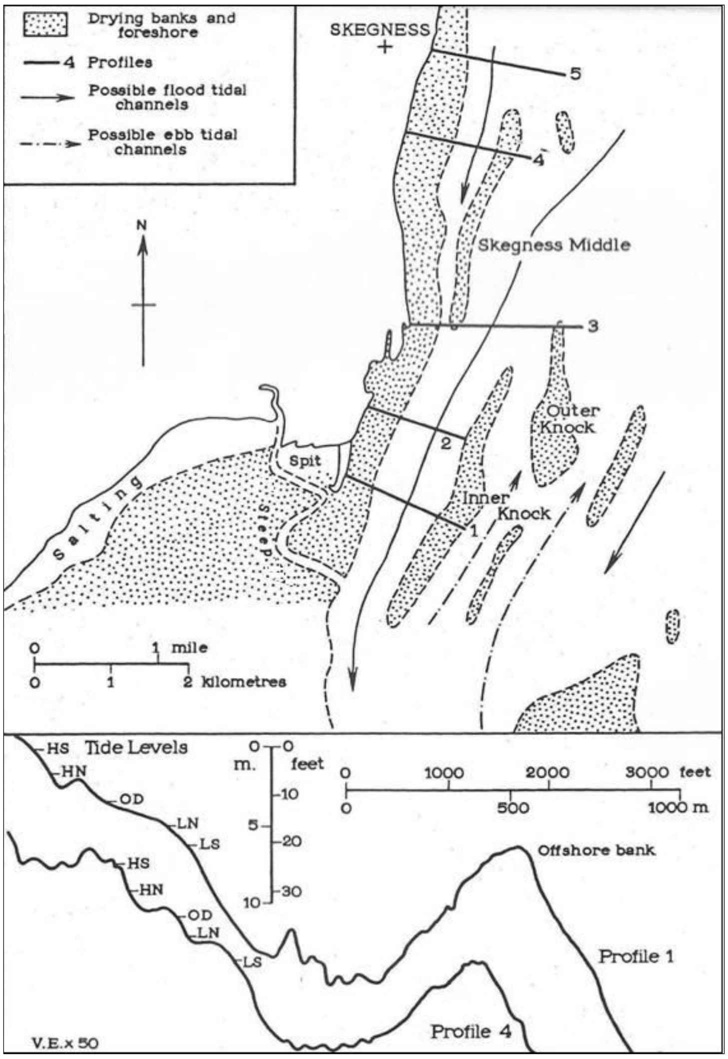

Figure: 8 Location of Profiles and the Spit at Diu point, Arabian Sea

Figure: 9 Goghla point: A sheltered parts of the coastlines and transported material is deposited to form a beach.

Where the movement is predominantly in one direction along a coast, as it is on the Diu, Arabian sea coast, the up-drift beaches supply the down-drift ones.(Figure:9) The situation here is such that it can lead to cyclic development of coastal features. (Chamal S.,Maurya D.M. and Rai Rachna 2003). In the Diu point area, accretion is taking place to the west of the spit and material that should reach the spit is being increasingly absorbed further west, or diverted along the beach at too low a level, to build the spit up further. The spit may therefore decline in time and a new one will form further offshore, (Figure:10) as has happened in the past. (Boer G de1964) The present spit lies further seaward than one which formerly prolonged the earlier line of dunes to the north of the mature marsh A reverse cyclic procedure, associated with coastal erosion and inland transference of successive spits, has been established for Goghla Point at the mouth of the Chassi River to the west.(Figure:11)

Spit changes over time

The spit is a small feature, only just over 350 *meter* long when it was first surveyed in 1991. It consists of sand with some shingle, and at times has a recurved narrow distal end, which is very mobile, while its proximal end is lower and flatter. At high tide the distal end often forms an island as the tide washes across the low root area of the spit. Detailed measurements reveal that the spit has in general been increasing in length, area and volume. The increases in length have been rather variable although the growth in volume has been more regular. The trend equations indicate the rate of change of the different dimensions. The increase in area has been slow above 10 ft. Indicating that the spit has gained material mainly by an increase in height and length. The increase in height has enabled vegetation to renew its foothold on the spit, a process that further aids the up growth of the spit, by trapping sand blown on to the spit. The maximum difference between the trend line and the actual volume of accretion is $22.8 \times 1000\,\mathrm{ft}^3$, a value less than the mean annual increment of $24 - 4\,x\,1000\,\mathrm{ft}^3$ over the period from1991 to 2009. The supply of material is regular. Sediment is carried by waves eastwards along the beach from the area of accretion to the west. Much of this material is brought into the area by tidal streams, which have formed a complex off shore relief of tidal banks and channels. The offshore relief has a twofold influence on beach accretion. (Schwartz M.L., Fabbri P and Scott Willace R 1987) It directs the tidal streams along the channels, allowing the flood stream residual, (Figure: 12) in the channel nearest the shore, to carry material up on to the lower foreshore a short distance to the west of the spit. The banks also shelter the beach from destructive waves, (Figure: 13) and ensure that some of the sand moving into the area along the coast from the west is trapped in this zone. (Figure: 14) The material is forming a growing ness of accumulation just east of Skegness a few Kilometers west of the spit.

Figure: 10 Diu Spits are formed along the irregular coast line and movement of material is unlikely uniform. Diu Spit is a result of more material and wave pattern is determined by the coastal outline.

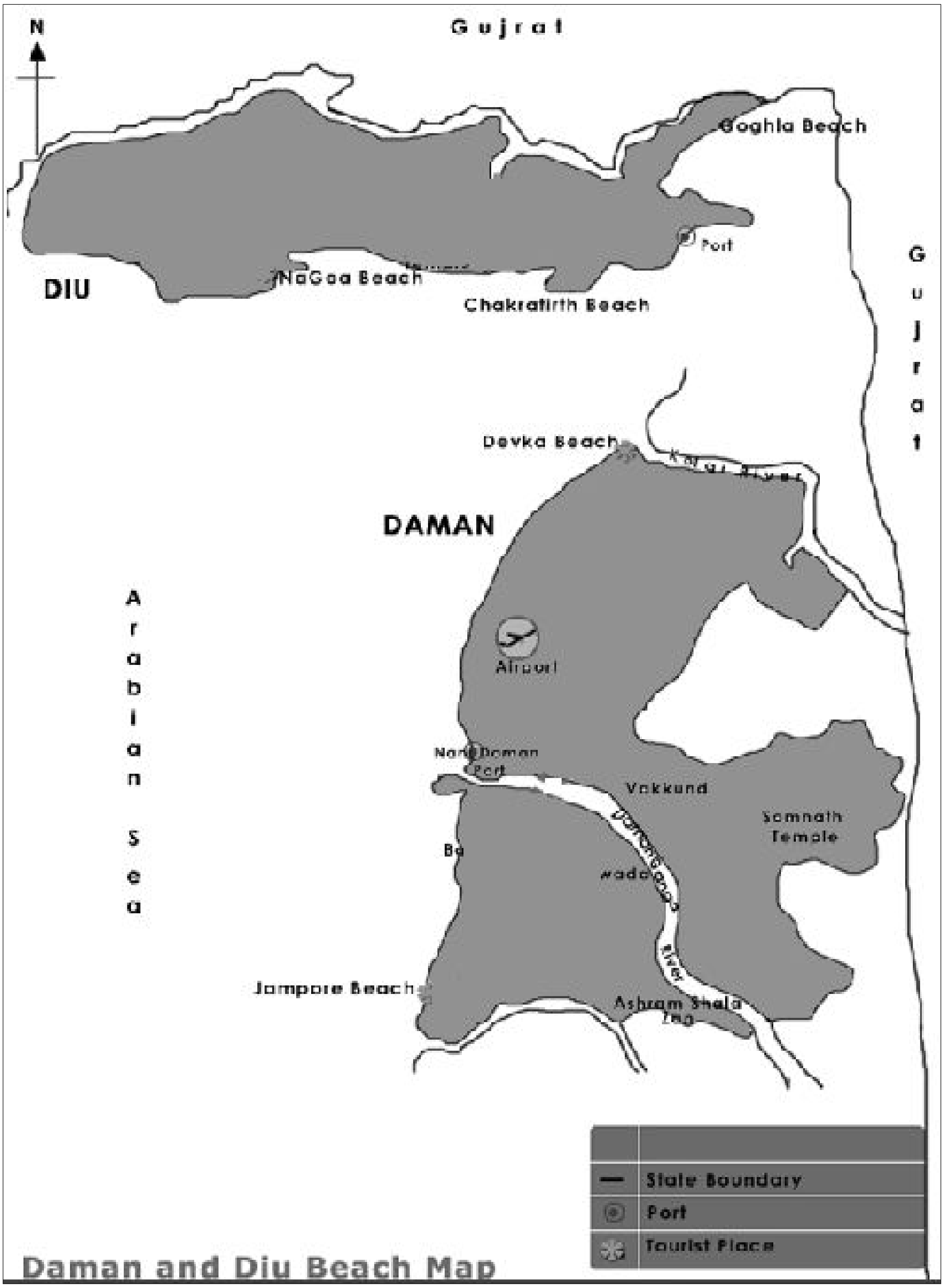

Figure: 11 Geographical locations: Diu and Daman

Growth. The trend for the volume of the spit above 10 ft O.D. is given by $Y = 310 + 24.4\,X$ for the period $1991 - 2009$ The value 310 gives the volume in the middle of the period of observation, 2000, in 1000_s ft^3, while 24.4 is the mean annual addition of material in the same units. Y is the volume and X is the year.

Figure: 12 Tidal streams, which have formed a complex offshore relief of tidal banks and channels. The offshore relief has a twofold influence on beach accretion. It directs the tidal streams along the channels, allowing the flood stream residual.

Over the period $1992 - 2008$ the spit increased in length at the $10 - \text{ft}$ level by a mean amount of 30 ft/year, as the trend equation is $Y = 686 + 30X$, where 686 ft represents the mean length from a fixed position. The trends for the other one-foot contours are respectively: $11\text{ ft} - Y = 525 + 40X$, $12\text{ ft} - Y = 383 + 47.5X$, for $1992 - 2008$. The values of the coefficients indicate that the higher contours have grown in length more rapidly, thus steepening the distal end. The trend equations for the areas are:

$$Above\ 10\text{ ft} - Y = 259 + 1.56X \text{ Above } 11\text{ft} - Y = 139 + 8.07X$$
$$Above\ 12\text{ ft} - Y = 62.3 + 9.9X, \text{for the period } 1991 - 2009.$$

These equations show that the maximum increase in area took place at the higher levels, with little increase at the 10-f't level. Only 1560 ft2 were added each year at 10 ft, compared with 8070 ft^2 at 11 ft and 9900 ft^2 at 12 ft.

The material that increased the volume and height to the spit has come from the west and has been added to the uppermost part of the foreshore, (Figure: 15) as the mean high spring tide level is $10 - 9$ ft. The process by which sediment moves to the spit is related to wave drift along the long, assisted by tidal streams, which have a due easterly direction at high storm (Figure: 16 and Figure: 10)

Figure: 13 the banks also shelter the beach from destructive waves.

Figure:14 Diu Spit in the Arabian sea, with arrows indicating the directions of Long shore drifting, determined by local exposure to wind-generated waves. (Google earth Photography)

Figure: 15 Banks also shelter the beach from destructive waves

The upper foreshore is, therefore, only influenced by easterly. Flowing tidal streams. The importance of material derived from the west in the build-up of the spit can be assessed quantitatively by relating the accretion on the spit, in terms of its volume, to the accretion on the foreshore in the area both to the west and immediately in front of it. Three profiles have been surveyed over a long period of time across the foreshore in this area. Profile 1 lies immediately in front of the spit. Profile 4 lies 5 kilomeeter further west, just east of Skegness and profile 1 lies about 800 *meeter* west of profile 1 and the spit (Figure:8). The annual mean change of volume on these profiles has been measured by recording the net loss and gain between surveys over a unit width of beach, and constructing trend equations for the results. The trend equations, for the three profiles are as follows:

Profile $1Y = -1 + 43.42\,X,$ Profile $2\,Y = 826 + 114.68\,X,$
Profile $4\,Y\ =\ 1504\ +\ 190.7I\,X$ for the period $1993 - 2009.$
Values are in $50\ _{s}ft2/ft$

Figure: 16 shaping of a recurved spit where sand or shingle delivered by long shore drifting, resulting from obligor wave action

The results Show that profile1, immediately in front of the spit, has gained the least material, and in fact over the whole period the constant of the equation is slightly negative. The coefficient is positive, because the slow and steady loss of sand between 1993 and 2005 was changed to a net gain over the period $2005 - 2009$. Over the period $1992 - 2005$ the trend coefficient was negative. The changes on profiles 2 and 4 are very different and show a rapid rate of accretion, which is considerably higher at profile 4 than at profile 2, amounting respectively to an annual gain of 100.71 and 114.68 in the same units.

There is, therefore, material accumulating and available to the west to build up the spit, but it is not so easy to show conclusively that the material moves east to the spit. The pattern of ridge movement, however, indicates a regular westerly transference of material. The ridges are closely associated with the accretion, as shown by the correlation of ridge height with accretion. (King 1970)As the ridges increase in-height, so the volume of accretion increases. The accretion explains 80% of the variation in ridge size, when the Profiles are controlled by its analysis of covariance. The cause of the higher ridges on profile 4 is the coarser material on his part of the beach. The sequence of surveys shows that the ridges move steadily landwards on each profile.

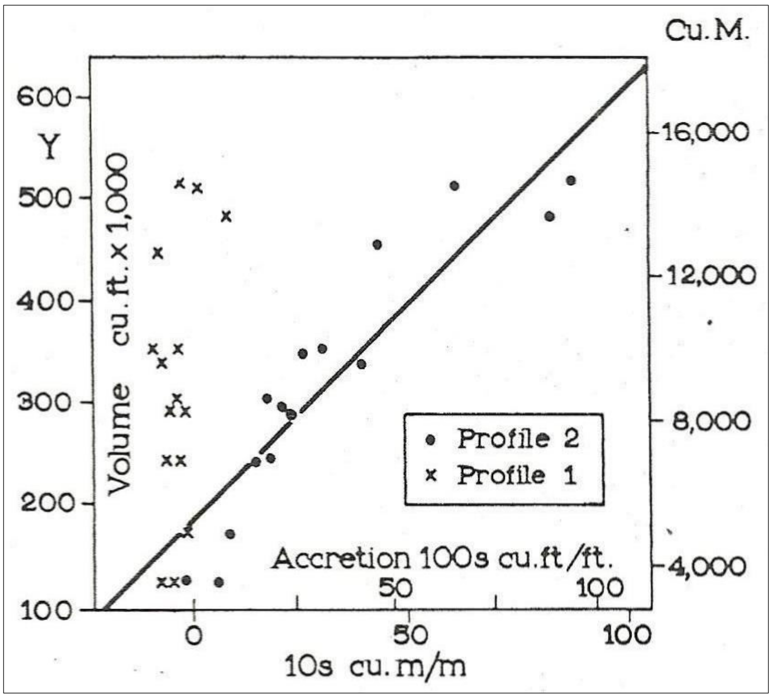

Figure: 17 Correlation of accretion on profile 1 and 2 with changes in the volume of the Spit.

This movement results from the bodily transfer of the ridges eastwards by the pushing of sand over their crests by the waves. The ridges move inwards on each profile because they diverge slightly from the shore wards, in response to the direction of approach of the long refracted swells from south and west-north, the direction of maximum felch The level of the foreshore at which the maximum amount of sand move therefore, is related to the position of the ridges on the beach at any one time.

The relationship between accretion on profile 1 and profile 2 and the increase in the volume of the spit above 11 ft O.D. is shown in (Figure: 17) The graph shows that there is a close correlation between the accretion profile 2 and the spit volume but there is no relation between the changes on the foreshore in front of the spit and the increase in spit volume The correlation between accretion on profile 2 and the spit volume $0-90$. Because both variables may be related to similar changes over time in this instance, the correlation may be spurious and it does not necessarily indicate a causal relationship between the variables. A test for autocorrelation of time series shows that in fact both sets of values are highly significantly auto correlated. The value for accretion on profile 2 is 0.0192 and for spit volume is 0.00145. Both values are far below the 99% significance level of 0.84 for $n = 10$. The time series are thus positively auto correlated, and the individual values cannot be considered independent.

In this area, however, where easterly sediment transfer can be demonstrated by ridge movement, it is likely that the relationship is causal. The lack of relationship between accretion on profile 1 and the spit volume indicates that the sand moving west moves only along the upper foreshore to build up the spit. This may be due to lack of wave action on the foreshore in front of the spit because an offshore bank protects it from the waves when the tide falls only a short distance down the beach. At high water, when sand movement must take place, the water depths offshore will be greatest and waves, therefore, less refracted, so that long shore drift can take place most effectively. The waves will also be higher. The tidal streams in addition give a net movement south, especially near the high water level.

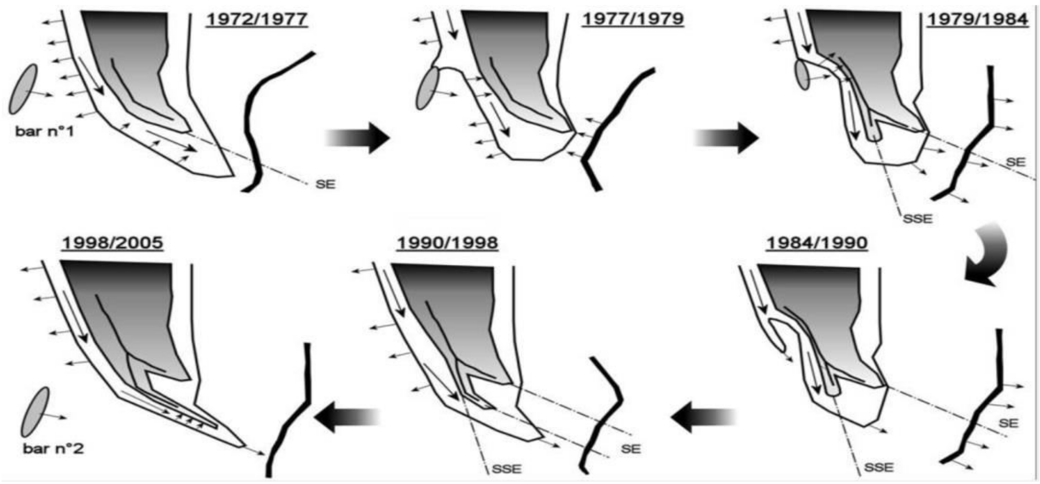

Figure:18 The spit migrates to the south and its distal end exhibits various spit recurve. The Diu area, extent ending more than 4 kilometers off shore its northerner part exhibits numerous swash bars which are absent in its southern part.

Figure:19 Conceptual model of Daman spit evolution which present the formation of hook spit after migration and weld of swash bar with upper beach. (Google earth Photography)

Spit form

The outline of the spit has changed during the period of annual surveys (Figure:18) from 1972 to 2005. Sometimes the spit has been relatively straight, while at others it has been hooked (Figure: 19) A method of assessing the form of the beach outline has been developed by Yasso (1964). It has been applied to the outline of the crest of the Diu point. A geometrical form that fits the equilibrium beach outline, in situations where one dominant wave type can form a fairly constant refraction pattern, is the logarithmic spiral. The beach must be free to align itself parallel to the direction from which the refracted waves reach the foreshore this situation applies to spits that are wave-formed features and hence reflect the pattern of wave approach. The spit at Diu Point is built by the long, constructive refracted swells that come from a easterly early quarter. This significance in terms of ridge alignment and spit nourishment has already been considered. They also are important in determining the shape of the spit outline.

The logarithmic spiral has an increasing radius of curvature away from its initial point, which represents the distal point of the spit (Figure: 20). This is usually recurved shore wards as the waves become refracted around the distal end. The equation for a logarithmic spiral is where the length of the radius vector and is the angle of the vector from some. Convenient datum direction. The angle X is the spiral angle. It is the angle between the radius vector and the tangent to the spiral curve at that point. For any one logarithmic spiral it is a constant, and for curves fitted to beach outlines it normally varies between 30 and 90 degrees.

One problem in fitting spirals to beach outline is to establish the optimum center from which the spiral best fits the beach outline. The exponential form of the spiral equation $r = e^{\theta \cot a,}$, can be written in logarithmic form, $\log_{10} r = \theta \cot \propto \log_e,\ or\ log_{\ e}\, r = \theta\ cot\ \propto$. $Cot\ \propto$ is a constant for any one spiral curve.

Figure: 20 The beach must be free to align itself parallel to the direction from which the refracted waves reach the foreshore. (Google earth Photography)

The linear relationship between log r and θ must be optimized. The relationship between log r and θ can be expressed as $\log_e r = a\theta + b$, where a is the slope of the regression line and b is the regression constant. The value of r and θ vary with the origin of the spiral. The highest value of, the correlation coefficient, can be found from repeated trials centers, and the mean squared difference can be reduced to a minimum in the same way.

The method was used to fit the best spiral form to the 2009 outline of the spit, when it had a well-developed recurved form. Repeated trials revealed a point at which the value of r was 0.9980, and the mean squared error was 0.031. another point had a correlation of

0.9970 and a mean squared error of 0.029. The spiral curves drawn from these two points are entered in (Figure: 21) which shows the outline of the spit for comparison. The spiral angle was 48.4 and 38.5 for the two curves. The angle increases as the spiral starting point moves away from the distal tip of the spit, because the tangent becomes more nearly normal to the vector as the centre moves away from the distal tip.

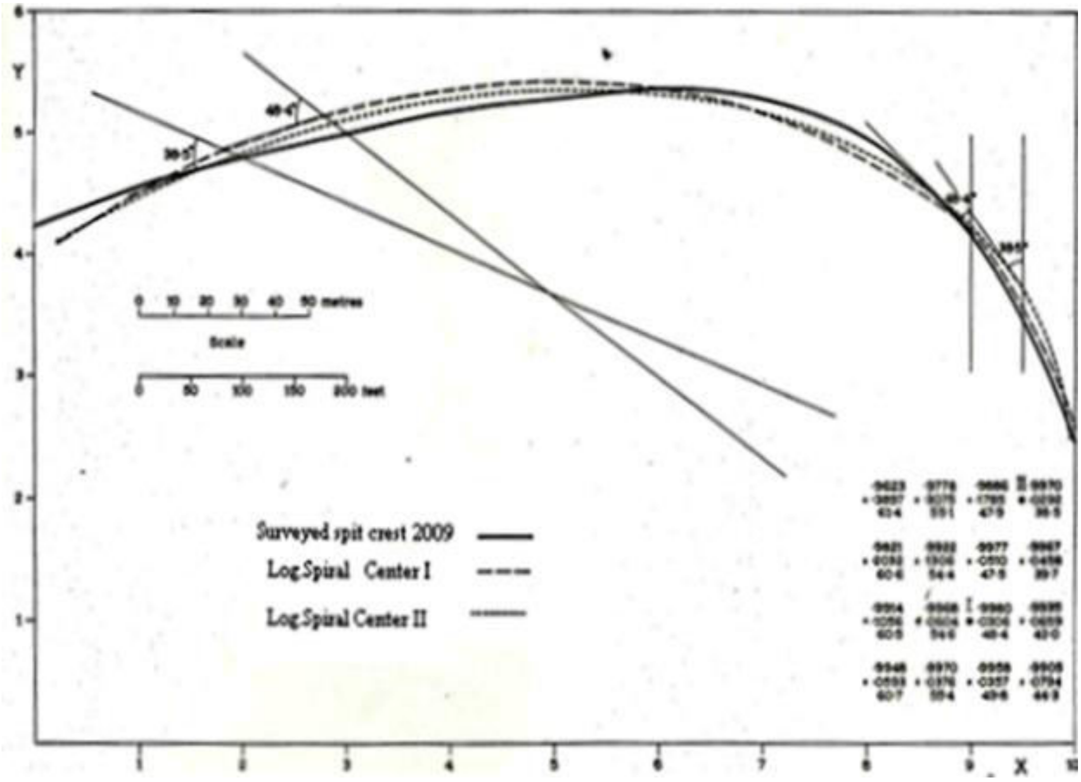

Figure.21 Logarithmic spirals compared with the Daman point Spit outline of 2009.the upper of each set gives the correlation coefficient between r and $\emptyset$, the middle figure gives the mean squared difference and the lower .

The fitting of the spiral from a number of centers is facilitated if a computer program is used, and one was written by Mather P. M. to perform the necessary calculations in this instance.

The spit in 2009 showed a close approximation to the logarithmic spiral form, as it had a well-developed recurved end at this time. The high value of and low value of the mean squared error shows that the form was well developed. The close approximation suggests that prior to the survey; long waves from the west had been acting to drive material along the spit. This is shown by the increase in length between 2008 and 2009, an increase that followed three years during which the length had been reduced. The reduction was partly due to the cutting of the River Steeping across the beach just east of the spit. The elongation of the spit was achieved by the addition of the recurve to the narrow and steep distal tip of the spit. As the spit has grown, it has been moved by the waves increasingly inland over the marsh deposits accumulating in its lee. This movement means that refraction has pushed the distal tip further to the north. As a result the distal curvature has increased, because refraction has become greater as the spit has moved north (Figure: 22) The horizontal movement of the spit crest has amounted to more than 200 ft (60 in) at a point 1000 ft (300 $meeter$) from the longest distal tip in 2004, while the tip itself has moved even further. The outline of the spit has not always shown a good spiral fit. Curves have been fitted for the years 2000,2002,2007,2009 and 2007. In 2000 the spit was straight with only a minor and tight recurve, which was not of log spiral form, in view of the relatively low values of the correlation coefficient obtained, the best being 0.970. By 2002 a large recurve had formed but the degree of curvature was again excessive. The distal tip lay parallel to the outer part of the spit.(Figure:23) The values for the correlation coefficient were also low in 2006, when the spit was almost straight, with no recurve at all. By 2007 a small tight recurve had formed, very similar to that of 2000. A larger recurve had formed by 2009, but again the spiral fit was not very close, because the spiral did not bend round enough near the tip.(Fig:24) A correlation of 0.9823 was obtained, however, showing a fair relationship between the curve and the spiral. The 2007 curve had straightened out somewhat from the best fit of 2007, but the log spiral form was reasonably well maintained, with a maximum correlation of 0.9951 and a mean squared error of 0.029, values only marginally less good than those for 2009.

Figure:22 The process carries into the sea and sand is deposited here along the beach. Over the time this material builds up and a bank of it forms stretching out to sea the mass of sand is known as a Diu Spit (Google earth Photography)

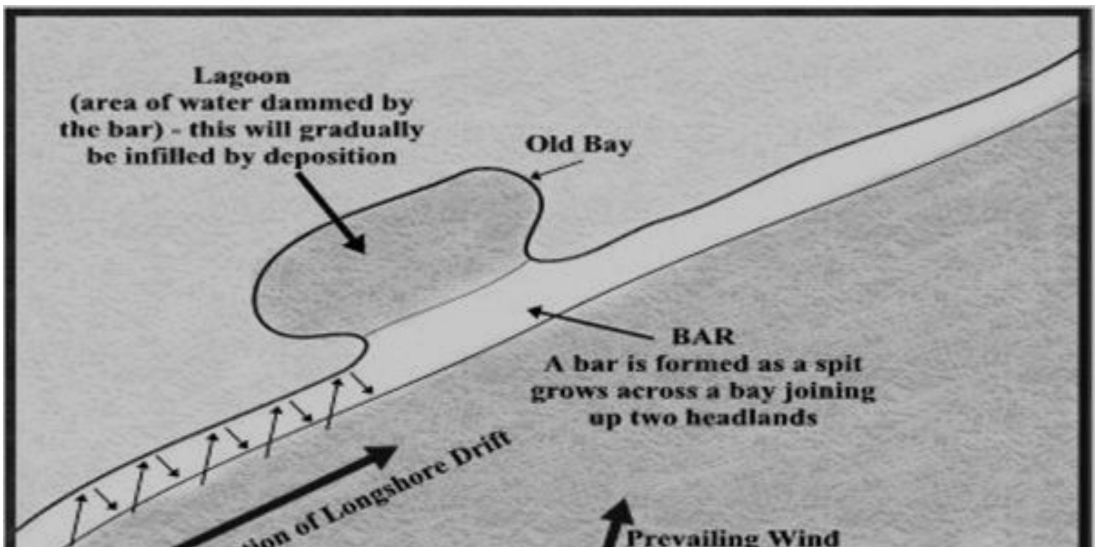

Figure: 23 The formation of a Spit due to change in the direction of coastline

Figure: 24 Aerial photographs of Daman spit

The results suggest tentatively that the spit is now reaching a stage where it is almost in equilibrium with the long waves that form it, and has become adjusted to their refracted form. This has been achieved by the movement of the spit westwards over the marsh so that the alignment now reflects the pattern of the refracted swell more closely than it did in the early years of the last decade. Since 2005 it has had a much steeper distal end, (Figure: 25) which would allow more effective waves to reach it at high tide, and hence to form a spiral of rather more regular form.

The very tight recurve characteristic of the spit outlines analysed in the earlier years were formed when only very short waves could reach the distal part of the spit. These short waves would come from the east or south-east. They would not be related to the long ones that formed the main line of the spit. The lack of good fit along the whole of the spit outline would have been related to the operations of two different wave types. A good fit is only possible when the whole spit reflects one wave throughout its length. This can occur when the water round the tip is steep enough to allow the long waves coming from the south-west to be refracted round it to form one complete logarithmic spiral (Figure: 26).

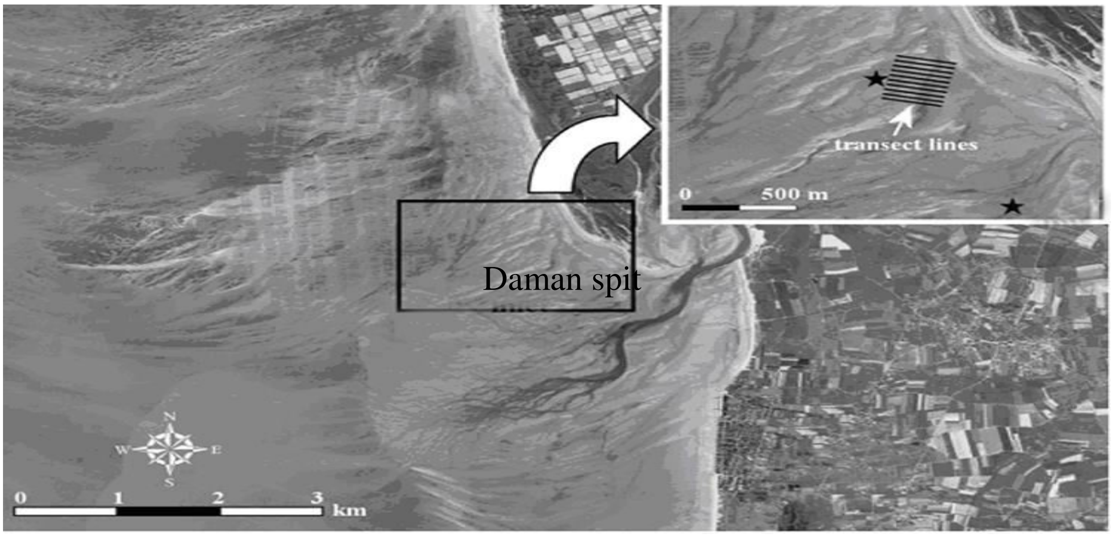

Figure: 25 Daman case studies: dynamic of swash bar and hook spit formation in mega tidal environment. These very dynamic system have a largest spatial impart on adjacent shoreline changes

Changes of spit form over time - simulation model

Some spits have a form that is determined by the action of several distinct wave types. Daman spit in Arabian sea provides an example of a complex recurved spit of this type (Figure: 17). A computer simulation model has been developed to study the processes that are responsible for the spit form and to predict its possible future development.(Figure:26) The details of the program and of its application to the study of the spit form is based on the study photo of (Google earth Photography) . Only a brief summary of the most essential elements of the study are given to exemplify the possibilities of this type of model. The shingle spit is 2 kilomeeter long and it consists of one main ridge, which has a large curve leading up to the distal point. There are a series of recurved ridges that join the main ridge at an acute angle, and which become more numerous and longer towards its distal end, as shown in (Figure. 27). The spit is largely supplied by shingle from the west, brought into the area by waves with a northerly component by beach drifting The main spit crest is built up by storm waves, which approach from the direction of maximum fetch to the north. The waves from south-north or south-west are short, owing to the shelter of the Daman coast and these move shingle around the distal tip on to the recurves. The recurve ridges are built up by waves from the north-west coming down the solent. Apart from the different wave types that influence the form of the spit, it is controlled also by the increasing depth offshore, which has the effect of slowing down its easterly growth. This factor increases the number and length of recurves towards the distal end of the spit. The other process of importance is the refraction of the long waves, which determine the alignment of the main ridge. This factor determines the curvature of the spit. All these variables have been incorporated in the computer simulation model. The simulated spit is built up element by element on a 50 by 60 matrix. Random numbers determine the order in which the subroutines that represent the different wave types are called. In addition the depth and refraction factors are added to the subroutine that simulates the operation of easterly waves. The depth factor operates by fixing a column at which the depth function changes from linear to exponential, and another column where depth becomes infinite, thus fixing a limit to spit growth. It operates through selection of random numbers that make the elongation of the spit by waves from the west less likely. The refraction factor operates by allowing the spit to move up the matrix if the random number selected lies within a specified range, which can be modified in the data input. It is thus possible to test various proportions of different wave types, variations in the depth pattern and in the operation of refraction. Different initial random numbers from which the others are derived allow the effect of varying -the order of operation of the subroutines to be tested.

Figure: 26 Fault line is the result of immaturity of coastline

The results of a number of tests indicate that the initial random number does not affect the form of the spit very much, thus leading to the conclusion that the order in which the different types of wave operate is not important in determining the form of the spit. Tests to determine the effect of different proportions of the various subroutines showed that, when there was a superabundance of westerly waves, the spit became too long and insufficient recurves formed. when too many south-east or north-east waves operated too many recurves were created. The optimum proportions agreed closely with recorded wind frequencies, if allowance was made for wasting many westerly wave random numbers by the depth and refraction factors. (Figure: 27) The optimum values for the depth factors were found by testing a variety of possible values. The best-lit spit was formed when the increase of depth was linear to column.35 and exponential to column 55. By comparison with the chart of the area, these values can be related to the true spit by means of a scale of 10 columns of the matrix to 0.5 kilomeeter in reality. This would place the depth changes at 1.7 kilomeeter and 2.7 kilomeeter from the root of the spit. In fact the depth increases linearly to a point 2.1 kilometer from the root and then more rapidly to 2.6 kilomeeter at the tip of the spit. At this point the depth increases very quickly to 57 m only 350 m from the distal tip. The depth is 12 $meeter$ at the first point and 20 m at the second. The values simulated are, therefore, realistic. The correct simulation of the depth pattern is very important in producing a good approximation of the real spit in the computer model. If the depth is too shallow not enough recurves form, while if it is too great too many occur too close to the spit root in the model.

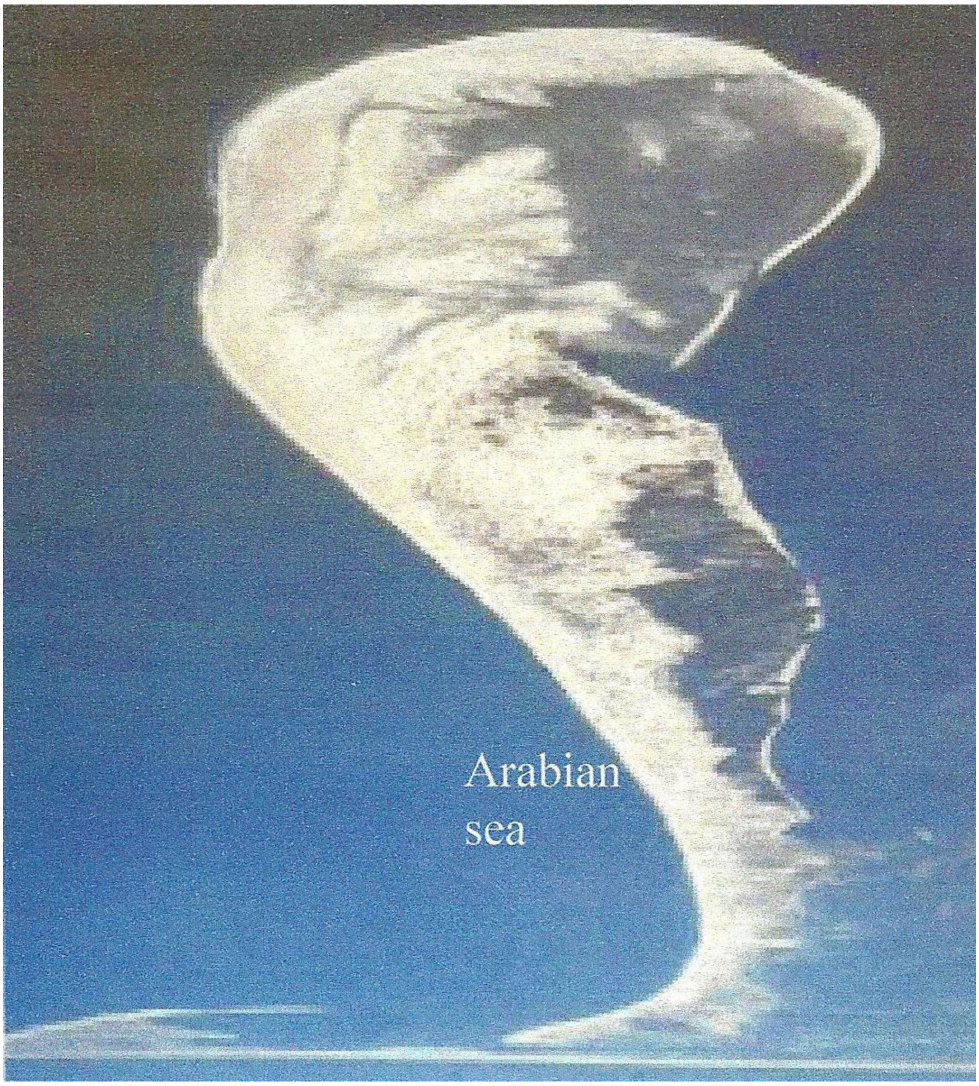

Figure :27 Conceptual model of Spit evolution which presents the formation of hook Spit migration and weld of swash bar with the beach.

The curvature of the main line of the spit is influenced by the refraction of the storm waves, coming from the south-west, which build up the main part of the spit. The refraction in turn is influenced by the offshore relief. The presence of the Shingles Shoal is important in this respect. At present the shoal is situated off the proximal two-thirds of the spit. It retards the waves approaching this part of the spit, but they can advance faster at the distal end of the spit where the offshore depths are greater, hence producing the bend of the spit. The waves coming from the south-west thus are refracted to approach more from the south in the distal part of the spit. The refraction factor simulates changes in the position of the shoal water area. When the refraction factor is low, the shoal and deep water areas are represented as being further west. When it is high the shoal area is represented as being continuous, thus preventing waves from swinging round in deep water to approach from further south. The intermediate value that gave the best curvature represents the shoal in its correct position relative to the real spit. The effect of changes in the position of the shoal could thus be simulated by varying the refraction factor.

The standard simulated spit compares very well with the outline of the real spit, indicating that the optimum values for the input variables have been adequately established. These values can also be shown to be realistic when they are compared with the controlling variables that determine the form of the real spit. The future growth of the spit may be suggested by continuing the development beyond the stage of best fit. More recurves were built at the distal end of the spit. The great length of some of these is not, however, realistic. This is due to the omission of some essential controls from the model. No allowance has been made for the growth of marsh behind the spit, for instance. The value of such models depends, therefore, on the correct simulation of reality. In view of the great simplification of the situation in this model, which in reality is highly complex, the results are remarkably consistent. Their application must, however, be treated with caution. Nevertheless such simulation models do provide a useful means of rapidly testing a large number of different conditions and controls, once the computer program has been made operational.

References

Andrew D.Ashton,A Brad Murray and Ryan Little Wood(2007) Conference proceeding paper on coastal sediment(on Internet).

Boer, G.De (1964) Spurn Head: Its history and evolution; Transactions of the Institute of British Geographers 34, 71-89.

Chandra Mohan P.(1996)Shoreline dynamics of Indian coast : National Institute of Oceanography Dronapaul Panjim Goa.

Chemyal S.,Maurya D.M. Rai Rachna 2003 Fluvial system of the drylands of western India A synthesis of late Quaternary environmental and tectonic changes Quaternary international volume 104 issue

Helen M.(2008)The Geomorphology of Farewell Spit and its Sensitivity to Sea Level Rise.

King C.A.M.(1972) Some spatial aspects of the analyses of coastal spits (ed:R.J.Charley)Methuen.

King, C.A.M. and McCullagh, M. J. (1971) A simulation model of a complex recurved spit; Journal of Geology 79, 22-37.

McCullagh, M. J. (1970) Changes in the spit at Gibraltar Point, Lincolnshire, 1951-1969; East Midland Geographer 5 (1 and 2), 33 and 44, 19-30.

McCullagh, M. J. and King C.A.M. (1970) Spitsym, a Fortran IV Computer program for spit simulation; Kansas Computer Contribution No. 50, 20p.

Robin and Levoy (2007)The very dynamic system have a large spatial impact on adjacent shoreline Oliver Manfert(On Internet).

Yasso, W.E. (1964) Geometry and development of spit-bar shorelines at Horseshoe Cove, Sandy Hook, New Jersey; Office of Naval Research, Geographical Branch, Task No. 388-657, Contract Nonr 266(68) Technical Report No. 5, Department of Geology, Columbia University, 166p