A STUDY OF THE GEOMORPHOLOGICAL PROCESSES AT THE SILTCOOS FOREDUNE BREACHING EXPERIMENT SITE

by

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ABSTRACT. The focus of this study was to examine and record the physical changes brought about by the breaching of the Siltcoos Foredune. The origin of the dunes and the physical processes that operate there must be considered before effects due to the breach can be studied. A series of field observations then led to the quantitative analysis of wind and sand transport data. The examination of these figures show the differences in processes between the breach and two undisturbed control areas. The final areas of consideration were the possible rejuvenation of the interior dunes and the future of the breach area.

INTRODUCTION

Study Area

The study site is located within the Oregon Dunes National Recreation Area (NRA), 11 km south of Florence, Oregon. (Figure 1) More specifically, it is 1.3 km north of the parking lot at the end of the Siltcoos beach and dune access road. The area was created between February and June 1984, by the U.S. Forest Service and the Army Corps of Engineers. During that period, a section of the stabilized foredune and all associated vegetation was removed. Approximately 200 meters of the foredune was breached. The southern half was leveled to 1 m above mean sea level (m.s.l.). The remaining 100 m was left 3 m above m.s.l. The hummocky area between the foredune and the vegetated deflation plain was also leveled down to 1 m above m.s.l. The old deflation plain and its vegetation were undisturbed (Figure 2). On May 26th, 1984, the breach area was clear of all vegetation, logs, and debris that might impede

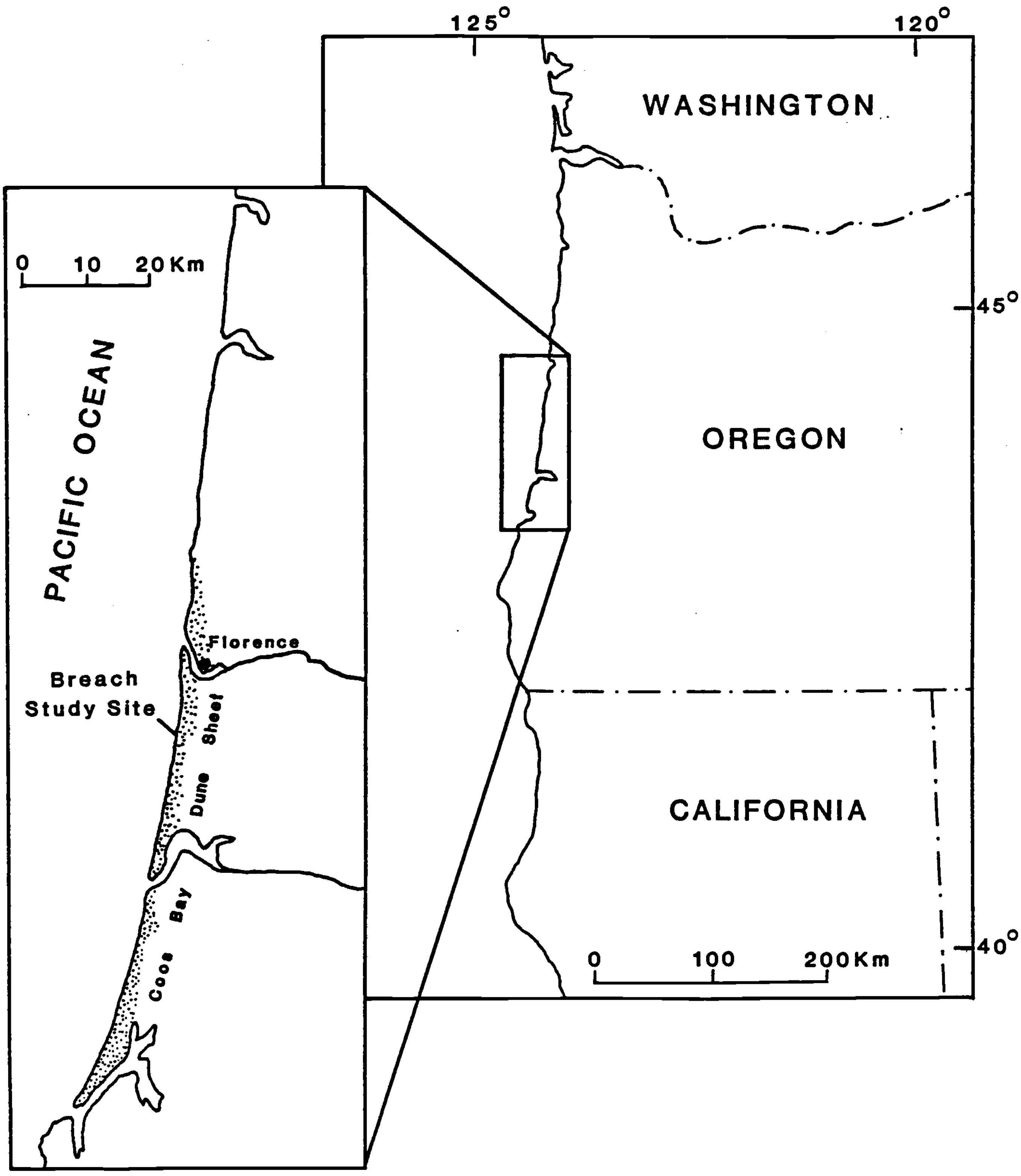

Fig. 1 General map of the Siltcoos foredune breach location
(source: Hunter 1983)

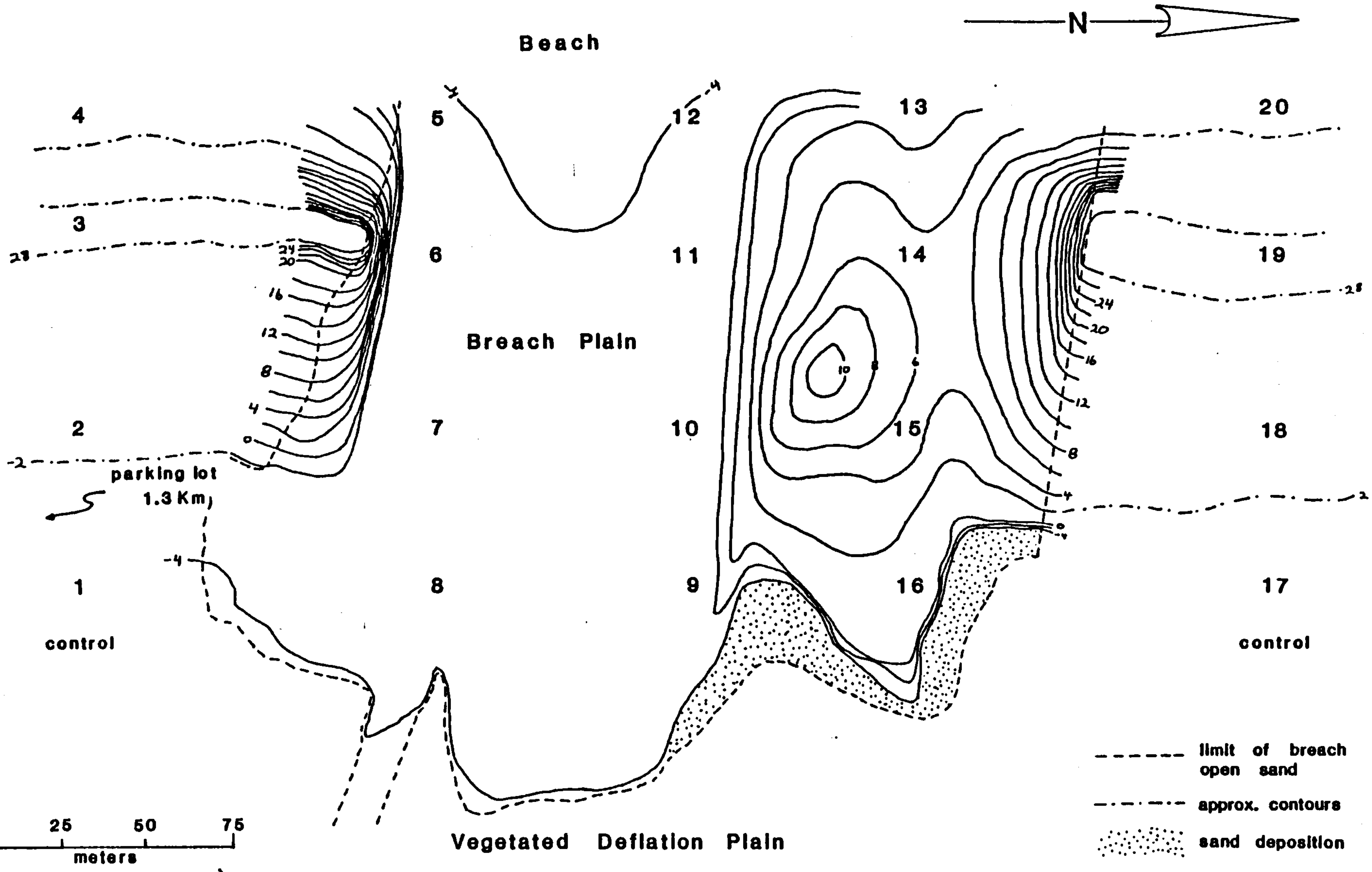

Fig. 2 Specific map of breach area showing; sand trap locations, control rows, sand deposition and extent of open sand. (source: E. Riegelmann, P. Costa, M. Thoma 1984)

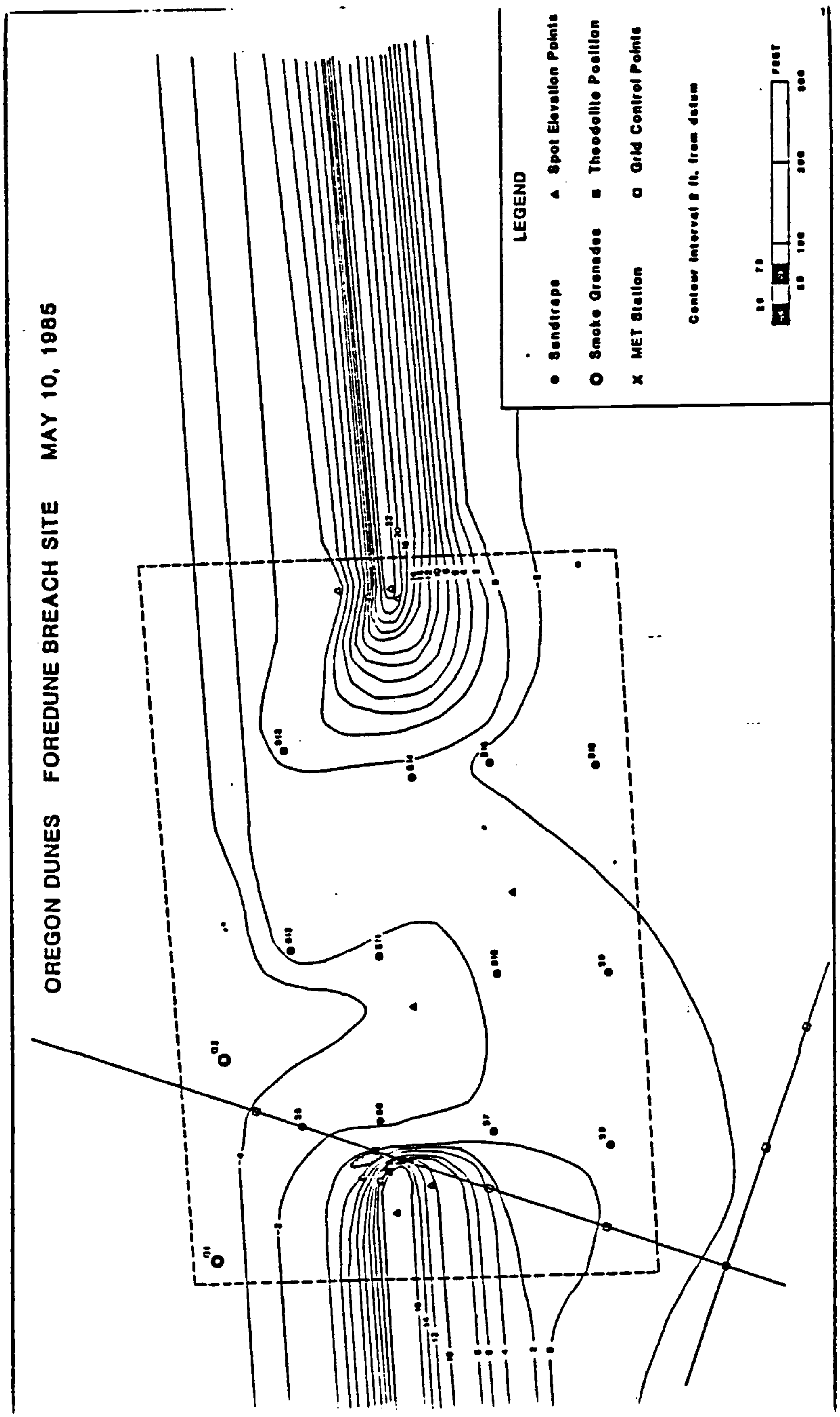

Fig. 3 Map of breach area May, 1985.
(source: OSU Geography Dept.)

sand movement. When the first observations were made on February 9th, 1985, a few large logs had been washed up at the southwest corner of the breach, a fair amount of debris had been washed into the breach, and little vegetation had been established. The configuration of the breach area remained constant for all observations.

Objectives

Before stating the objectives of the Forest Service and this study, it is necessary to examine a policy statement by the U.S.D.A. Soil Conservation Service:[1]

> State and local government shall allow breaching of foredunes only on a temporary basis for emergency purposes (e.g., fire control, cleaning up oil spills) and shall require that these foredunes be restored once the emergency passes, unless it is demonstrated that the social benefits of permanent breaching of the foredune exceed the social costs.

with this exemption:

> In the Dunes National Recreation Area, managed by the U.S. Forest Service, variance from this policy is necessary in order to maintain a continuing supply of sand to inland recreational areas.

The Forest Service objectives in breaching the foredune were to:

a) provide a generalized beach access for off-road vehicles (ORVS);

b) provide an area for breach effect and sand transport research.

The social benefits of increased beach access and the results of this study will hopefully outway the costs. As will be discussed later in this report, a breach of this magnitude will not contribute a significant amount of sand to inland dune areas.

The objectives for this study came from two basic areas: the unique situation provided by the breach, and the monitoring of sand movement during the winter months. I was interested in pursuing the latter, as all the previous actual measurements on the Oregon dunes had been made during summer wind patterns. The objectives of this study are to:

a) compare sand transport through the breach area with that of the undisturbed control areas;
b) compare wind speeds through the breach area with those of the control areas;
c) correlate wind speeds with sand transport;
d) investigate the possibility for renewal of sand supply to interior dune areas;
e) formulate hypothesis about the future possibilities for the breach.

This research should add to studies by Cooper (1958), Hunter (1983), and U.S.D.A. Soil Conservation Service (1974). It should be noted that this study is a possible beginning for a potentially longer and more in-depth project on the impacts of foredune breaching.

PHYSIOGRAPHIC SETTING

Physical Geography

The study area is located in the Coos Bay dune sheet. This dune area is 86 km long and is only broken by the mouths of the Siuslaw and Umpqua rivers. According to Cooper, "This is the most continous and widest of the dune areas and furnishes the most comprehensive display of forms and processes (on the Oregon coast)."[2] The dunes of the Oregon coast have come about largely due to the extreme fluctuations in sea level due to continental glaciation.

There have been two major episodes of sea level flucuations which have influenced existing features in coastal landscapes. During the Quaternary period, there was a period of great submergence followed by a period of slight emergence. Prior to submergence, there was a broad sloping plain that stretched for the entire length of the coast. This plain stretched beyond what would later become rocky headlands. Sand would have been readily transported up and down this plain and great dune fields likely existed. As the sea advanced, a series of terraces were formed and the shoreline became more irregular due to the differences in resistance to erosion. The drowned valleys of coastal rivers and streams, formed sand spits and bars at their mouths as sediments began to accumulate. Sand dunes migrated inland as the sea level rose. The moving dunes dammed small streams and created many lakes. Since the time of maximum submergence there has been a period of uplift of the coast, which is associated with a terrace at an elevation of 150 feet. In the past 3000 to 6000 years since maximum submergence, the shoreline has remained essentially stable.[3,4]

The immediate sources of sand for recharge in the dune sheets are wave erosion of rocky headlands and outflow from streams. Sediments eroded from headlands are transported both north and south of their points of origin depending on the season. During the winter, eroded material is carried northward by the Davidson current. In summer months sediments are generally carried southward by the California current. The importance of rivers to sediment accumulation is relative to their discharge. The Columbia is by far the most important in the Pacific Northwest with the Umpqua and Siuslaw being important to the study area. These rivers supply sand faster than the longshore currents can carry it along the coast. For this reason the dunes near the mouths of the rivers are correspondingly large. The beach sediments are generally eroded during the winter months and carried northward, while the summer waves tend to rebuild the beaches with sediment from the coastal rivers.[5,6] A detailed study of the origins and composition of Oregon's coastal sands, has been carried out by Twenhofel (1946).

Evolution of Landforms

Prior to 1930, foredune ridges did not exist, as we know them, on the Oregon coast. The area immediately inland from the beach was a low area of sand accumulation and copice dunes that was frequently overwashed by high tides. This overwashing provided sand and helped to limit vegetative growth in the area behind known as the deflation plain. The deflation plain, when dry, was the ultimate source of sand for the larger oblique dunes which lie further inland. The movement and encroachment of these dunes on man-made features became an important issue at that time.

During the thirties, the theory for halting dune movement involved two phases: (1) limit wind speed by forming stabilized foredunes and (2) reduce sand accretion from deflation plains by introducing vegetation. Stabilized foredunes have evolved largely from the plantation and/or natural dispersion of European beach grass (Ammophila arenaria). This grass, introduced from Europe in the late nineteenth century, was widely used on the Pacific coast by the Civilian Conservation Corps. It achieves its maximum growth in areas where the plant receives the maximum sand deposition. (Figure 4) The grass receives nutrients from the sand and is able to grow upward, extending its roots and shoots vertically. It is extremely competative and has forced out native species in the active sand zones.[7,8,9] In the deflation plain, Shore Pine (Pinus contorta), Coast Willow (Hooker iana) and Salt Rush (Juncus lesueuri) have been planted extensively to retard sand movement.

The sequence of landforms from west to east, in the study area, is a result of these stabilization projects. The area from the low tide zone to the storm line at the foot of the foredune is one of high energy. It is a place of constant change and also the source of sand for foredune building. As the volumetric studies showed, this is the area of most active sand transport. The stabilized foredune is second, with its cover of beach grass and its shear height (up to nine meters), efficiently restricting windspeeds and sand movement. The densely vegetated deflation plane lies directly behind it with little or no sand gained or lost. The area of active deflation lies east of the old deflation area. Finally, the large oblique dunes are to the east north east of the active deflation plain.

Climate

The climate for the Oregon coast according to the Koppen classification is Csb. To break down the classification, C is

Fig. 4 European Beach Grass with sand accumulation.

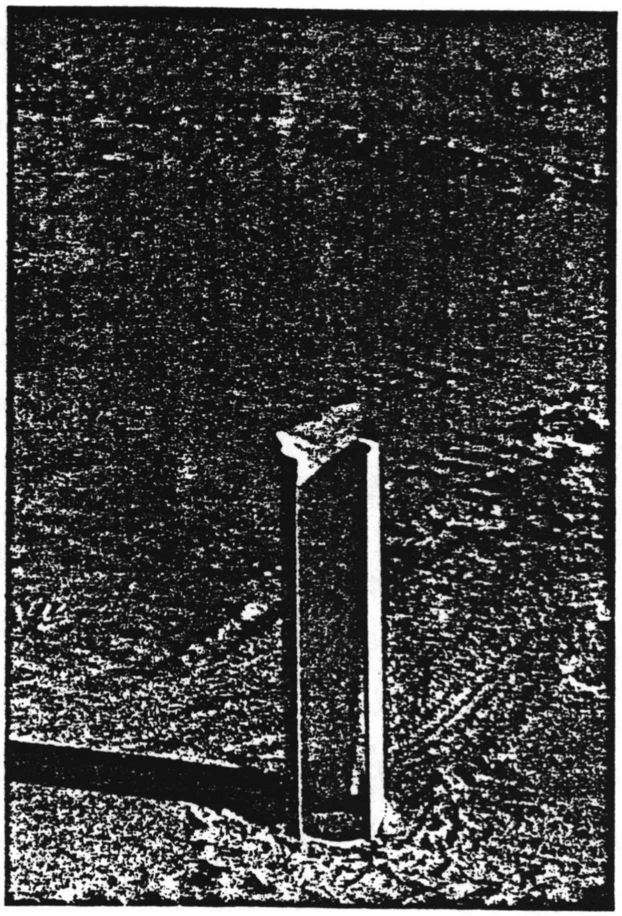

Fig. 5 Sand trap in place, ready to collect sand.

mesothermal, s is summer-dry and b is median temperature within C. Mean temperatures are mild with minor seasonal fluctuations. They range between 5 and 8.3 degrees celsius for January and between 14 and 16 degrees celsius for July. Precipitation is heaviest during the winter months (46% falls between December and February) and much less during the summer months (4% falls between June and August).[10] Fog cover during the summer helps to reduce the amount of moisture lost.

The most important climatic factor to consider when studying sand movement is the wind. Accurate long term wind data for the Oregon coast is almost non-existent. The station on the south jetty in Newport and monitored by the Oregon State University Marine Science Center is the only station located near the beach where it is open to unobstructed winds from all directions. As a general trend however, most stations show a south to southwest trend during the winter months and a north to northwest trend for the summer months. The sand-transporting winds in the summer generally reach speeds of 9 to 13 m/s. The sand-transporting winds of the remainder of the year are associated with storms and reach 13 to 22 m/s with occasional blows of hurricane force.[11] Hunter writes "The summer winds are for the most part dry northerlies and northwesterlies of moderate strength, whereas the most important winter winds are the strong southerlies and southwesterlies that accompany intense rainstorms."[12] During these storms only one-third of the potential sand transport actually takes place. However, these winter storm winds are still responsible for the majority of depositional features found in the dune areas. It is these winds also that will affect the breach area.

MATERIALS AND METHODS

Surface Wind Instrumentation

Surface wind was measured once each observation day at each sand trap location. A Weather Measure 3-cup anemometer was used at a height of 2 m above the ground surface for both wind speed and direction readings. This height was choosen to best indicate breach effects on local wind patterns and to provide a measure of convenience for the researcher. Limited time was the major factor in holding the readings to one per observation day. Future research should include a greater number of readings at the 2 m level and a permanent station near the breach area, at an approriate height.

Venturri Effect

The venturri effect (funneling of wind through a narrow gap), was observed in an experiment on May 11. On this day there was a moderate breeze (6-8 m/s) from the southwest. Two smoke grenades of different colors were placed on the beach. One was in the center of the breach and the other was near the southwest corner. The grenades were set off simultaneously and the smoke flowed for approximately one minute. Analysis of photographs from this experiment showed an angle of deflection of 35 degrees due to the breach. This means the wind is deviating from it's normal path by 35 degrees to funnel through the breach instead of over the foredune.

Sand Transport-Field Instrumentation

The construction, placement, and monitoring of the sand traps was the largest portion of this research. The traps were used to gather both saltation and bedload (surface creep). Design simplicity, collection efficiency, and minimal cost were the major considerations for the traps. These requirements were best met by a design suggested by Leatherman (1978):[13]

> The unit consists of a section of PVC pipe, with two slits cut in one end. The trap is buried so that the base of the slits is flush with the sand surface. One slit serves as a collection orifice, while the other is covered with 65 um screening to provide maximum flow-through of wind with little disruption of air flow and with little back pressure. All sand-sized material is collected in the inner sleeve (insert) of the sub-surface chamber...The collection chamber is filled with an insert of...pipe which rests flush with the base of the slits...The sand can be removed quickly by retrieving the tube (Figure 5,6).

This type of collector was found to be 80 percent efficient in wind tunnel experiments at Big Springs Experimental Wind Tunnel, Big Springs, Texas.[14] However, any collected data can only be approximate since the presence of any collector disturbs the natural surface flow of winds.

The traps were arrayed in a grid pattern through the breach area with five rows of four traps (Figure 2) The controls (rows one and five) were placed approximately 200 m north and south of the breach. Except for the beach locations, the traps in the control areas were surrounded by beach grass or other vegetation.

Only a few problems arose with the sand collection. Disturbance of

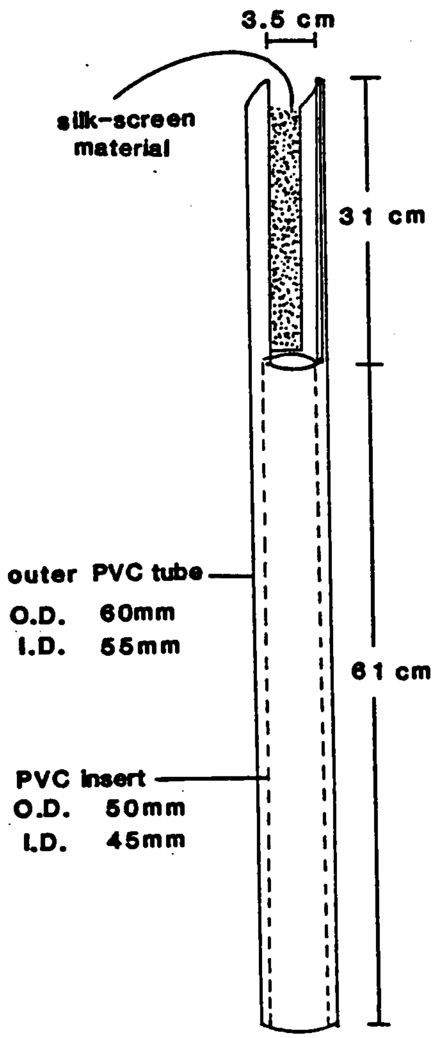

Fig. 6 Dimensions of Leatherman sand trap used in this study. (source: Marston 1984)

the sand surface near the traps is an unavoidable problem, and care should be used to minimize it. Curious persons and ORVs occassionally disturbed a site. Being visable and answering questions is the only solution for this. Finally, care should be taken when collecting sand so as not to rip out the bottom screen of the inserts.

Methods

The field observations were made on February 9, 10, 16, 17 and March 10, 1985. During this period seven sets of sand data and five sets of wind speed observations were compiled. Each day the sand traps were distributed and then opened when sand movement began. Each trap collected sand for a period of 1.5 hours. During this time the daily wind speed and direction readings were made. The contents of the PVC inserts were emptied into plastic bags, once the time had expired. On February 10 and 16, time allowed for a second sand transport measurement to be made.

The sand was returned to the Physical Laboratory at the Geography Department of Oregon State University for analysis. Volumetric measurements of the sand were made using a graduated cylinder. Simple graphics of average sand transport and wind speed were designed manually. The multiple regression and residual analysis of the data was carried out on an IBM Personal computer. Sand grain size was determined using a Tyler sand sieve.

RESULTS

Windspeed and Direction

The windspeeds and directions observed during the course of this research gave values that fit well with the norms suggest by both Cooper (1958) and Hunter (1983). They report for historical data, that January winds show generally a south to southwest vector, and an average velocity of 7 m/s.[16,17] The windspeeds varied between 2 m/s and 9 m/s for the results from all observations. The directional components varied from 0^{o} (north) to 100^{o} (south-east) with the average being 247^{o} (west-southwest). No east or northeasterly winds were recorded. During all observations, windspeeds remained below the threshold for sand movement until approximately 1:00 pm. From this time until about 5:00 pm windspeeds remained high enough to move a measurable amount of sand.

The spatial distribution of windspeed averages (Figure 7) show a definite breach effect. The four lowest readings come from the sites behind the undisturbed foredune (1,2,17,18). The corresponding locations in the breach (7,8,9,10,15,16) show significantly higher windspeeds. As expected the beach front (4,5,12,13,20) and dunetop (3,19) locations showed the highest average speeds. The result is a curve showing a general decrease in windspeed from beach front to the rear of the breach area. The readings from the breach area, however, certainly higher than those from undisturbed areas behind the foredune.

Volume of Sand Transported

Perhaps the most notable characteristic of the sand volume measurements was the large variances (Figure 8). The five beach front

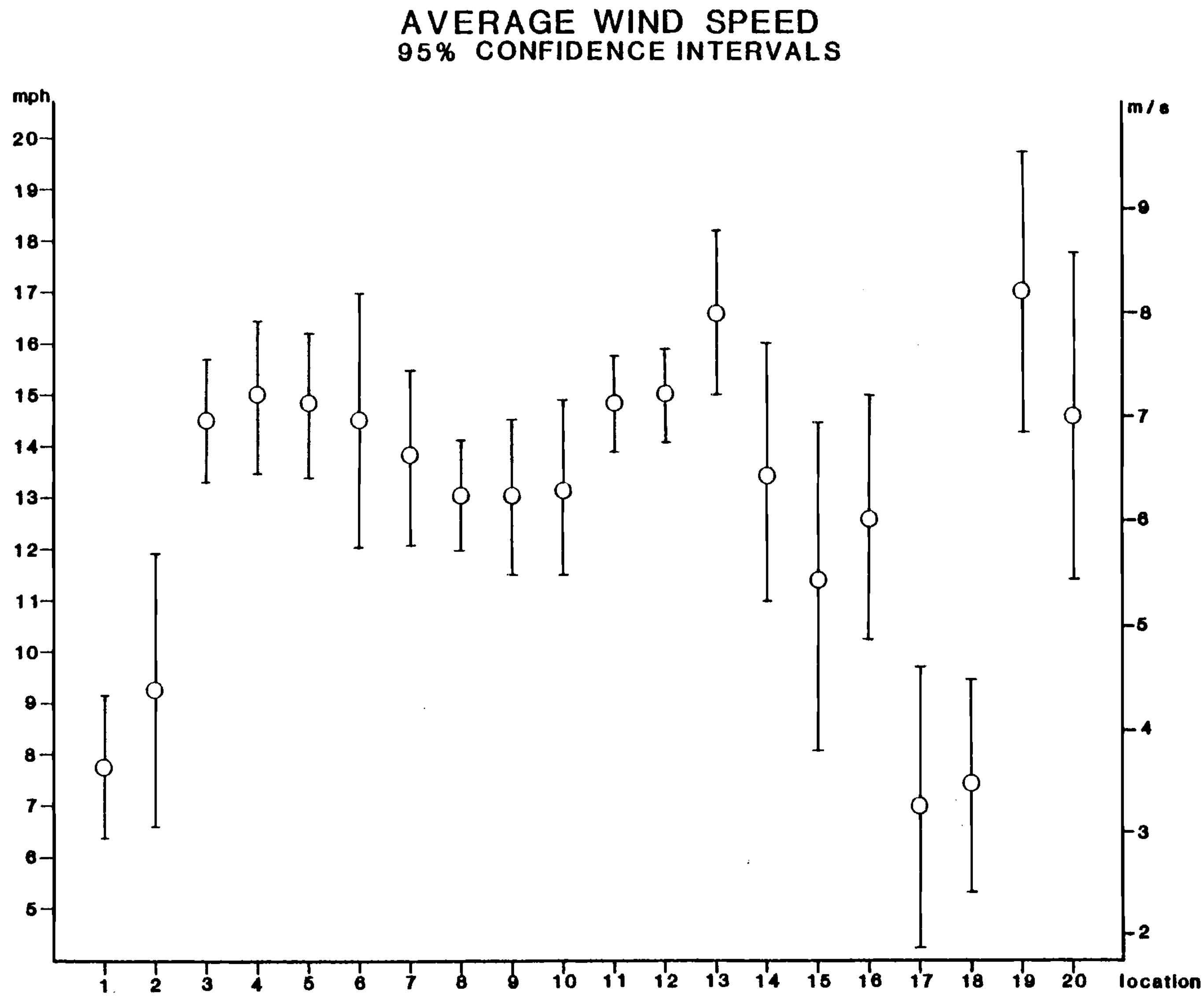

Fig. 7 Average wind speeds with 95% confidence intervals

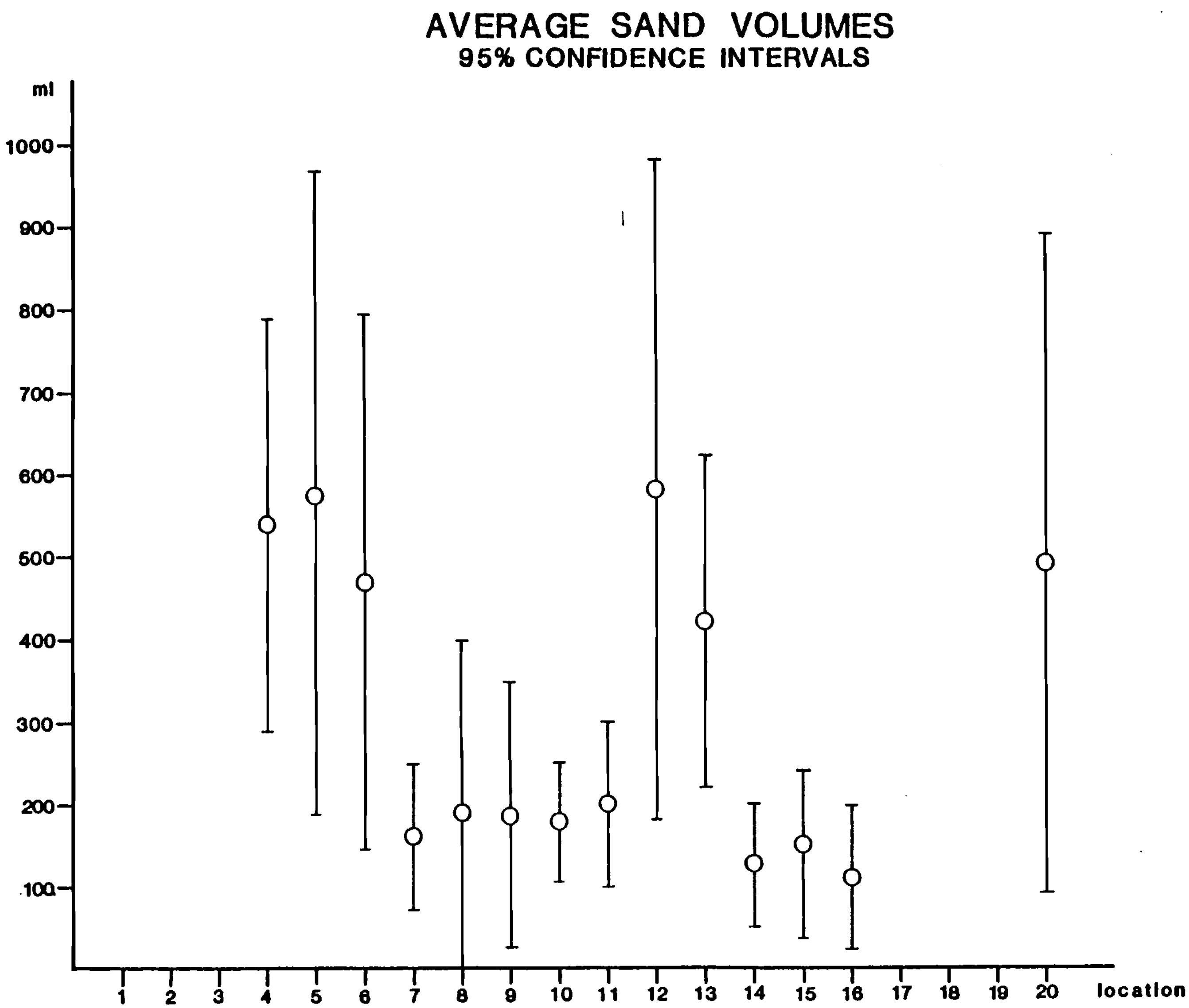

Fig. 8 Average sand volumes with 95% confidence intervals

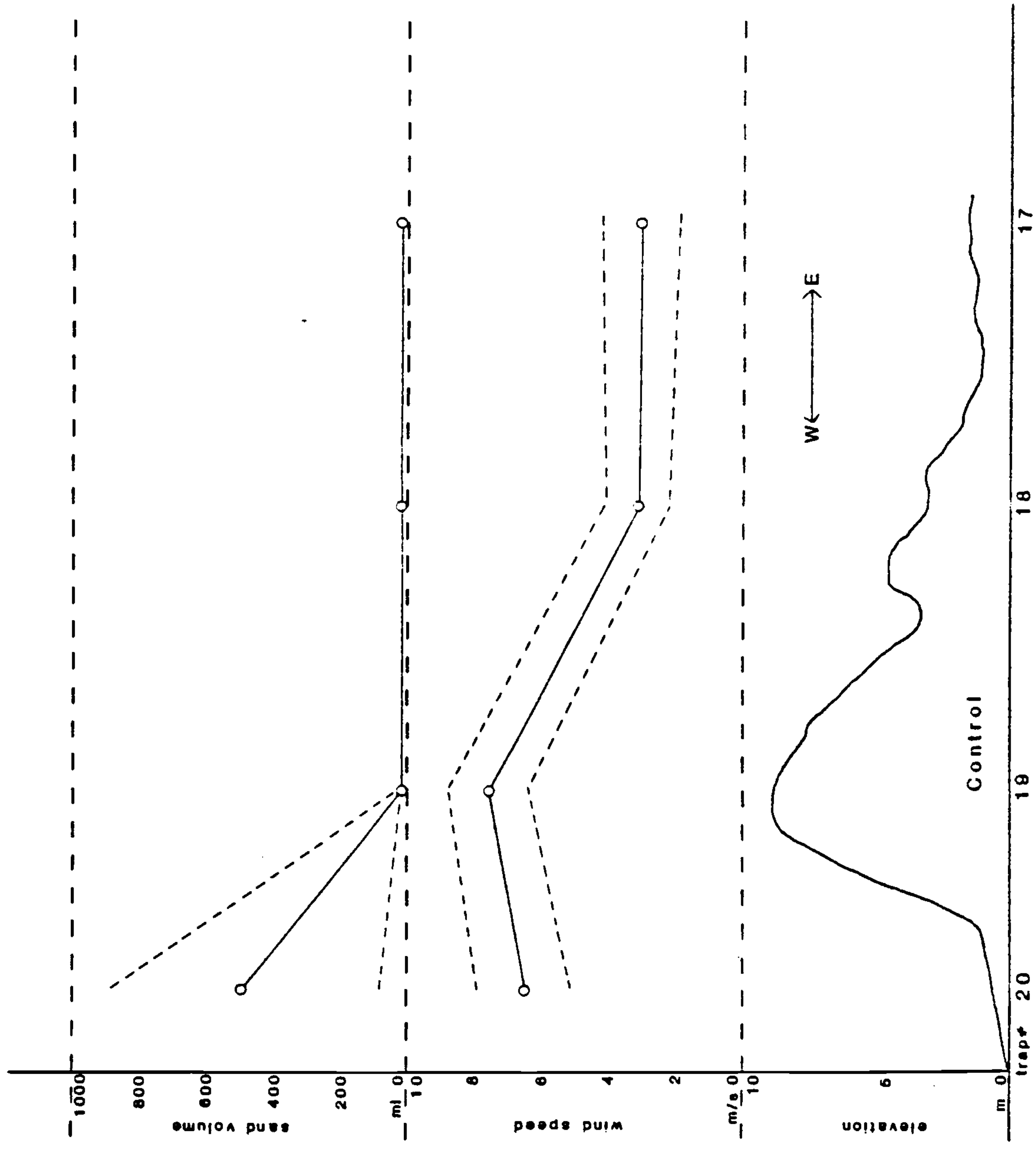

Fig. 9 Profile view of the north control row. (dashed lines represent limits of 95% confidence intervals)

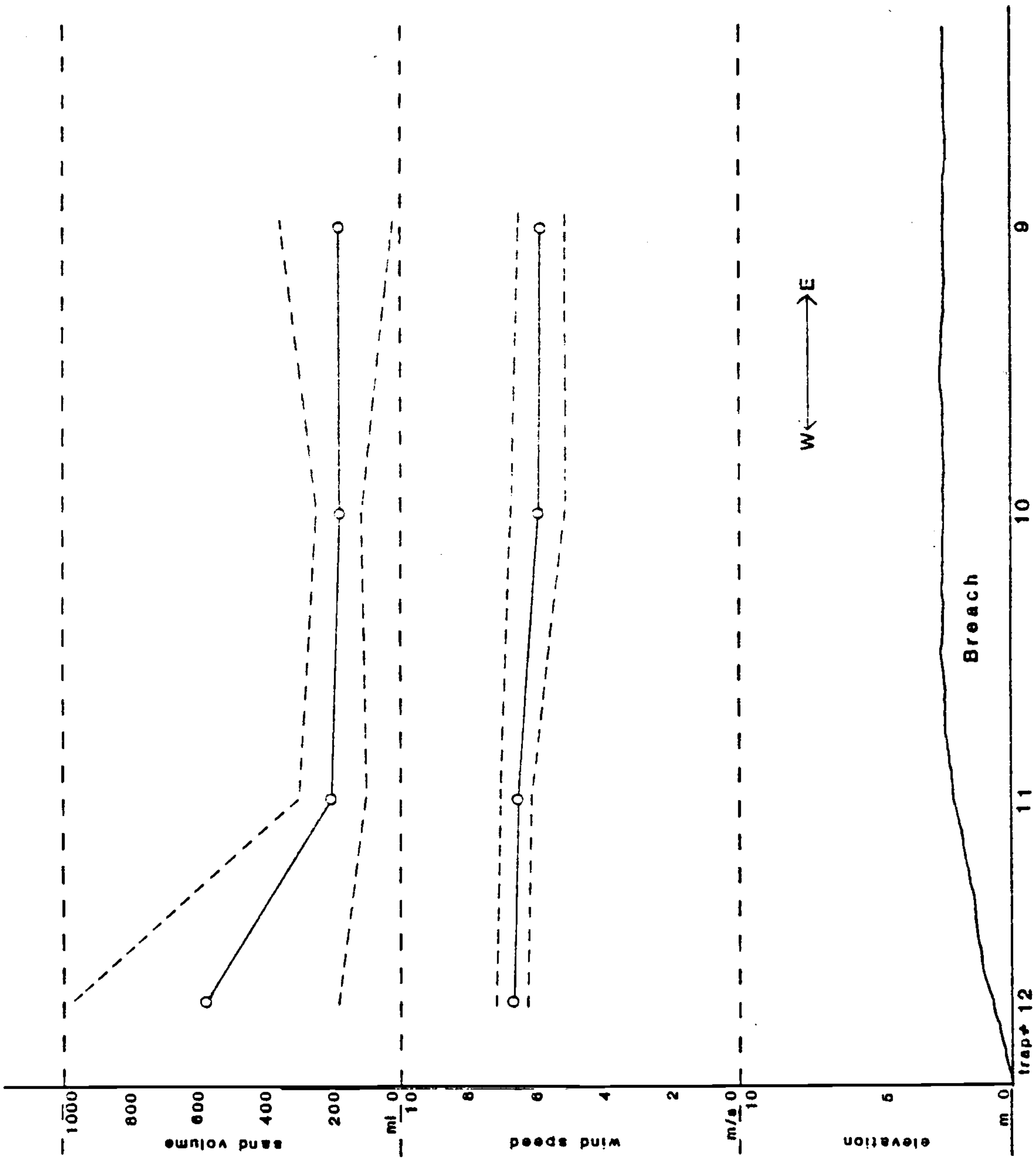

Fig. 10 Profile view of the middle breach row. (dashed lines represent limits of 95% confidence intervals)

locations and location six showed the largest variances. For the beach front sites, this can be attributed to: 1) differences in tide encroachment, 2) fluctuations of windspeed during the collection period, and 3) disturbance of individual traps. The variability of the readings from position six can be attributed to it's sensitivity to wind direction. The variability of the interior observations was generally smaller and is related to windspeed.

As with windspeeds, the volume of sand transported shows an effect due to the breach. The six traps showing no sand transport were located in vegetation on top of and behind the foredune in the control areas. The corresponding locations within the breach showed a moderate but fairly consistent amount of sand transport. The beach front locations indicated the area of greatest sand movement. The differences between the beach front and interior breach locations (except location six) show that little beach sand is actually carried through the breach. Sand from within the breach was responsible for the majority of the sand collected at the breach sites. The collector at location six was in a position to receive beach sand when the wind was from the southwest. With other wind directions it received the majority of its sand from the beach.

Correlation of Windspeed and Sand Movement

To make an accurate corr'eation of windspeeds and sand movement, a number of various physical properties of grain and fluid motion must be considered. Along with the discussion of these properties, Bagnold (1941) gives us this general formula "...sand flow...varies as the cube of the excess wind velocity over and above the constant threshold velocity at which the sand begins to move."[18] In all cases observed at the breach this general trend held. To make a more quantitative assumption about this correlation each reading was analysed using the Number Cruncher Statistical System.[19] The first step was to take the cube root of the sand volumes so the trends would be "straight line". Simple multiple regression and residual analysis was then carried out. Four of the collection periods showed correlation factors (R^2) greater than 0.50 (1.00 maximum) which, considering the nature of the experiments is reasonable. The other three showed factors less than 0.35 which can be attributed to problems with missing observations and high and low single observations with high leverage. The correlation factor when all the observations of sand volume and windspeeds are regressed together was 0.46. To increase these correlations a number of other variables would have to be introduced into the model. These variables would reach into areas outside the scope of this study. In general, when the variable of vegetation has been removed, an increase in windspeed showed a related increase in sand transport.

Grain Size and Sand Composition

The sand collected in the breach showed an average percentage of grain size that was very comparable to the observations in the same area by Twenhofel. (Table 1) This show that an average grain size is

	1/4 - 1/2 mm	1/8 - 1/4 mm	1/16 - 1/8 mm
Twenhofel	51.50	47.00	1.50
Breach Observations	48.27	50.78	.60

(Table 1)[20]

present and allows the assumptions for threshold velocity and wind speed/sand transport relations, given by Bagnold, to be used. The majority of the sand was composed of quartz. Through microscopic analysis the fine (1/16 - 1/8 mm) sand showed traces of other minerals including: Amethist, Garnet, Hornblende and Magnetite.

OTHER VARIABLES

Off-Road Vehicle Impacts

The study site is located in an extremely popular off-road vehicle (ORV) use area. The breach itself has provided a convenient and highly utilized beach access. It has also become the focus of a great deal of vehicle play. It was observed that on any one day nearly all ORVs in the dune area passed through the breach at least once. The ORVs will have a number of impacts on sand transport through the breach including:

1) Sand transport and compaction

   No quantitative studies have been conducted which confirm or deny an increase in either factor. However, during some sand collections the beach became so compacted from ORV use that no sand movement could take place.

2) Effects on vegetation

   According to Fowler (1978), "Unfortunately, the likelihood of vegetation damage from ORVs is high since few vehicle passes are needed to remove beach and dune vegetation."[15]

3) Removal of debris

   ORV use may restrict general distribution of logs and other debris within the breach as people attempt to keep favorite thoroughfares open. The magnitude of this will be determined by future NRA decisions.

The sheer number of ORVs using the breach throughout the year must also be taken into consideration when we consider their impacts. It is this researcher's opinion that the majority of the breach should be allowed to regenerate naturally with possibly a small corridor maintained for beach access. A more comprehensive study of ORV impacts on Oregon dune areas has been carried out by Fowler (1978).

Tide Encroachment and Storms

The lower (south) half of the breach is susceptible to frequent overwash by any tide that is slightly higher than normal. Salt water was observed well over half way through the lower area on December 9th. Whenever the sand is moist, the threshold velocity for movement is greatly increased. Even during normal tides the beach sand is wet 10 m higher here than the normal high tide line. This greatly affected sand movement with the 2 m/s to 9 m/s windspeed range observed. The differing moisture of the beach sand also was a factor in the large variances of sand volumes collected at the beach front locations.

Storm events will play a large part in the possible rebuilding of the foredune. During these events, large waves will be able to bring logs and other sizable debris into the central and back breach areas as well as the beach front. Once the logs are in place, sand accumulation will occur more rapidly. No significant storms occured during the observation period, but waves had obviously brought smaller debris through the low area and to the rear of the breach. A storm event of yearly magnitude would be adequate to begin the log/debris accumulation.

CONCLUSIONS

Control Versus Breach

The results gathered from this study indicate considerable difference between the control and breach areas. Windspeeds were consistently lower behind the undisturbed foredune than the readings in the rear of the breach. Dune top readings were greater than those through the breach mostly due to the extra height. Differences in beach front windspeeds (control and breach) showed little variations. Wind direction was steady throughout the breach, beach front and dune tops. Behind the dune, the direction trended parallel with the dune, when measureable. Overall, the breach has increased the wind flow to its immediate inland areas when compaired to the control sites.

Sand transport showed a more definitive trend towards the breach area. Differences in sand movement at the beach sites showed little variation due to the breach. The dune top and rear dune control sites showed almost no sand transport. The breach sites, however, virutally always showed some measurable sand movement. Some sand does move over the foredune and freshly blown sand was observed at the crest of the foredune. However, this movement was not of a magnitude to be measured by the sand traps used. Besides the physical reduction of windspeed by the foredune, vegetation played a major part in limiting sand movement. The beach grass effectively stilled the wind below 50 cm and therefore stopped most sand movement. It was observed that a definite increase in sand transport has occurred due to the breaching of the foredune.

Possible Effects on Interior Dunes

Although windspeeds and sand transport have increased due to the breaching of the foredune, the possibilities of it becoming a sand recharge area are low. The majority of the sand moving through the breach is deposited when it reaches the vegetated areas at the back of the breach. The large strip of Shore Pine and Coast Willow effectively shuts down sand movement through the old deflation area. It would take a breach of much larger magnitude to inundate this area with sand. The majority of the sand deposited on the beach and transported inland will most likely go to regeneration of the foredune itself.

The Future

The future of the breach lies in the hands of the NRA. If it is decided to maintain the breach area, little effective change will take place. This would not probably be feasible as a large amount of sand and debris would have to be removed each year. If allowed to follow a normal course of rejuvenation, a different series of events will take place. A normal winter with at least one strong storm surge will begin the process by depositing logs and debris in the lower breach area. This will limit ORV use and help form areas for sand deposition. Beach grass will then establish itself in these areas and sand collection will become greater. The entire breach will then become a hummocky area with more sand transported in the high traffic zones and sand deposited in the hummocks. Sand accumulation near the beach should be rapid, especially at the windward corners of the existing foredune. The rebuilding of the foredune will continue in this fashion with the beach grass becoming more and more of a factor. The breach will slowly become mostly a low spot in the foredune and then build itself back to its original height. An appropriate time estimate for the total rebuilding of the foredune would be five to seven years. A further long term study would be useful to examine the process of foredune building and the variables that effect it.

SUMMARY

The findings of this study indicate an effect on geomorphic processes has been created by the breaching of the foredune. The contrast between the results for the control areas and those from the breach is marked. The magnitude of the breach effect is still difficult to assess. With the length of the study period and the diversity of variables that will effect the breach little long term prediction can be made from the quantitative data. It should only be considered as being representative of the observation days. However, with the meger of qualitative observation, historical data and quantitative data sense we can give a reasonable prediction of events for the area. If left to its own processes, the breach should slowly rebuild itself to its original foredune height. During this rebuilding, little or no changes will take place in the vegetated deflation plain or any other areas inland from this foredune breach.

FOOTNOTES

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