TERRAIN SENSITIVITY OF OREGON COASTAL SAND AREAS

by

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I went down to the Sea
Bearing a garland of words
To honor the Sea and the Night
The Wind and the Stars
And forgot them in my passion for sea shells

- Mason Williams

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ABSTRACT

Based on a pilot study completed near Heceta Beach, Oregon, guidelines have been proposed for the development of Oregon coastal sand areas. The guidelines, in the form of performance standards are designed with respect to the variability of coastal sand areas. Landscape units and vegetation associations were grouped to reflect similar areas of environmental sensitivity. Performance standards are then proposed for the resulting sensitivity classes. In this way, flexibility has been incorporated into the report to allow for any differences between the study site and other coastal sand areas. The performance standards are also designed to provide planning officials with the capability of modifying the criteria to fit their specific location.

TERRAIN SENSITIVITY OF OREGON COASTAL SAND AREAS

INTRODUCTION

Since the passage of the federal Coastal Zone Management Act of 1972, a number of states have established agencies to deal with coastal zone problems. The Oregon Coastal Conservation and Development Commission (OCC&DC) was created by the state legislature (ORS 191.140) in 1971 for the purpose of developing "a proposed comprehensive plan for the preservation and development of the natural resources of the coastal zone..." After their four year life span, the OCC&DC recognized the need for maintaining the values and uses of Oregon coastal sand areas by "assuring that public and private uses do not exceed the carrying capacity of these areas."[1] OCC&DC further outlined necessary actions to be taken with respect to their policy statement. One action specifically requested was the establishment of planning criteria for sand areas.

The Land Conservation and Development Commission (LCDC), after incorporating the recommendations of OCC&DC into their planning process, put forth a set of goals for the coastal zone designed "to reduce the hazard to human life and property from natural or man-induced actions associated with these areas." LCDC also called for comprehensive plans which would "describe and identify the various types of beach and dune areas...; and designate management units and priorities of use consistent with the physical capabilities and limitations (of sand areas)..."[2]

Historically, Euclidean zoning has been used for planning as a land use control technique. Euclidean zoning is a technique which zones parcels of land for uses, typically commercial, industrial, and residential (with modifiers such as light, heavy, or moderate). In traditional zoning actions, any single zoned areas will contain a number of terrain types; each with its own constraints to development. In this way, some landscape types will have more restrictions placed upon them than necessary and other landscape types will not be adequately protected.

In numerous cases along the Oregon coast, homes have been built in morphologically unstable environments. These houses have satisfied the jurisdictional zoning requirements, but have been ruined by the action of physical processes. The Salishan spit is a prime example of this. The spit was zoned for residential use and all of the houses conformed to the local requirements. Unfortunately, the spit is an area which is susceptible to extreme energy conditions and many of the homes were destroyed in the Columbus Day storm of 1964. Obviously, the Salishan spit should never have been zoned for residential use.

Many other examples of imprudent zoning and development are found along the coast. One needs only to observe the homes built on or into the foredunes for evidence of this. In many cases, sand is actively being scoured from the foundations of these houses, and transported inland. Home owners have fruitlessly tried to halt the inland transport of sand with sand fences and other traps. In more potentially serious situations, the ocean processes are rapidly eroding the sand in front of some houses. There have been instances where homes have been washed into the sea by large waves, during the passage of storms.[3] Some home owners have tried to prevent or delay this inevitable end by placing riprap or gravel abutments at the base of their bluffs. This has often proven to be an unsuccessful procedure. Ocean waves either destroy the abutment and carry away the sand bluff in front of the home or they focus erosional forces upon some nearby unprotected parcel of land. Once an adjacent sand areas is eroded, it is a short time before erosional forces act to negate the effects of the riprap by scouring the sand bluffs from the side.

In all cases, large quantities of capital and property are lost each year because of development in essentially unstable areas. One way to reduce this loss of property is to require structures to be placed only in stable environments. Traditional zoning techniques have not accounted for differing land capabilities in the coastal zone. A method for environmentally sound planning in coastal sand areas is needed.

This paper will propose a method for land planning based on the physical characteristics of coastal sand areas. Physical constraints to development of landscapes provide the rationale for use of this method to determine the suitability of an area for development. In this manner, the development of coastal sand areas will be based on the capability of landscape units to accommodate structures, instead of being based on subjective political or economic boundaries. By placing restrictions on development of morphologically unstable areas, more capital and property will be saved and less will be wasted. In this manner, the public is spared the cost of relief funds and the burden is placed on the individual. Basing planning criteria on the physical properties of coastal sand areas may also ensure that areas which are suitable for development are not zoned for non-use.

The proximity and severity of the landscape units to physical processes, the chemical environment (susceptibility of ground water to pollution), and the biological state of the landscape units are used to determine the terrain sensitivity, or suitability, for development. Thus, planners can prohibit development in areas of severe physical processes (overwash, tidal flooding, wind erosion, wave erosion, mass wasting, or flood prone areas); in areas with unsuitable hydrologic conditions (areas of seasonal standing water); or in areas with sparse or fragile vegetation (which holds the sand in place).

This rationale for planning has an advantage over traditional approaches in that it allows flexibility in developmental plans. Planning based on physical properties will outline restrictions on development and mitigating measures which must be taken in order to build. There are no restrictions placed on type of development or use of the structure. In this way, flexibility is incorporated in the planning design and the community can use the land in any manner which does not surpass the capabilities of the land.

METHODOLOGY

Maps, aerial photographs, and field observations were used to identify a study area which would be representative of Oregon coastal sand areas. The area from the Siuslaw River to Lily Lake (Fig. 1) was chosen because of its diversity of landforms and vegetation. This area was also chosen because it has undisturbed areas in the Siuslaw National Forest and altered areas in the town of Heceta Beach.

Stereo coverage of U-2 high flight color infrared photographs was used in the investigation. The photographs (Flight 127, Photos 0261, 0262, 0263) were taken in July

Figure 1. Location of Study Area
Source: USGS Topographic Map

1973, at a scale of 1:30,000. A pantograph was used to trace identifiable landscape units from the photographs, thereby enlarging the scale to 1:12,000.

Landscape units and corresponding vegetation associations were delineated from the photographs. Field observations were then carried out on a series of parallel west to east transects, traversing all landscape units. Sand samples were obtained and analyzed, soil strength was obtained by penetrometer readings, the depth to ground water was determined by use of resistivity apparatus, and the vegetation was keyed out for all of the transects. A list of vegetation may be found in Table 1.

U-2 high flight color infrared photographs were used to delineate the spatial extent of landscape units and vegetation associations, as described earlier. In addition, the U-2 CIR photos were very helpful in delineating areas which have standing water on a seasonal basis. Depths to ground water were then deciphered for each landscape unit with the use of resistivity apparatus and visual observation in the field. By correlating depth to ground water with landscape units, as well as vegetation, topographic influences can be taken into account.

The depth to the water table varies within each landscape unit and some researchers feel it is possible to determine these variations by noting the plant species present. K.W. Newman in his study, "The Relation of Time and the Water

TABLE 1. VEGETATION AT HECETA BEACH - SPECIES LIST

Trees:	
Picea sitchensis	Sitka spruce
Pinus contorta	coast pine
Pseudotsuga menziesii	Douglas fir
Thuja plicata	western redcedar
Shrubs:	
Alnus rubra	red alder
Salix hookeriana	coast willow
Myrica californica	western wax myrtle
Cytisus scoparius	Scotch broom
Ulex europaeus	gorse
Arctostaphylos columbiana	hairy manzanita
Arctostaphylos uva-ursi	Kinnikinnic
Gaultheria shallon	salal
Ledum glandulosum	Pacific Labrador tea
Rhododendron macrophyllum	western rhododendron
Vaccinium ovatum	evergreen huckleberry
Herbs:	
Pteridium aquilinum	western bracken fern
Struthiopteris spicant	deer-fern
Agrostis palustris	creeping bent-grass
Ammophila arenaria	European beach-grass
Elymus mollis	American dunegrass
Carex obnupta	slough sedge
Juncus lesueurii	salt rush
Juncus bufonius	toad rush
Sisyrinchium californicum	golden-eyed grass
Fragaria chiloensis	coast strawberry
Potentilla pacifica	Pacific silverweed
Lathyrus japonicus	beach pea
Lupinus littoralis	seashore lupine
Glaux maritima	sea milkwort
Achillea millefolium	yarrow
Tanacetum camphoratum	seaside tansy
Hypochoeris radicata	false dandelion

Source: Franklin, Jerry F. and C.T. Dyrness, Natural Vegetation of Oregon and Washington (Portland: U.S.D.A., 1973.

Table to Plant Distribution on Deflation Plains along the Central Oregon Coast," proposed indicator species to determine depth of ground water.[4] Studies have been undertaken which utilize indicator plants to determine both quality and depth to ground water, the depth being estimated from the known penetration of the rooted species present.[5]

K.W. Newman, in his studies in coastal sand and wetland areas, looked at twenty-seven species in terms of their relative occurrence, based on successional stage and depth to water table. Ten of his listed species were also identified in the Heceta Beach study area, enabling predictions of depth to water table to within ten centimeters, as calibrated by drillings with a soil auger.

Once the landscape units were mapped, it became necessary to decipher the depth to ground water for each unit by field testing, using the Soil Test, Inc. resistivity meter. The resistivity varies for differing earth materials, but the Heceta Beach dune sheet is composed of relatively homogeneous materials. Therefore, the amount and salinity of ground water become the important factors. Specifically, resistivity decreases for an increasing water content and decreases at a faster rate for an increasing salinity of ground water. Using the Wenner arrangement of electrodes, resistivity (ρ) = $2\pi AR$, where A is the spacing between electrodes and R is the resistance in ohm-feet which is read directly from the meter. The electrode spacing is the significant factor.

> The results of 34,000 resistivity soundings and over 4,000 correlation borings have indicated that the electrode spacing |A| is equal to the depth of investigation.[6]

The resistivity reading is a weighted average of all resistivities in a given volume and greater emphasis is given to readings at small spacings (i.e. shallower depths). The apparatus has a lower limit of reliability, however, which is about two feet. Data in these high water table areas were gathered by visual observation in the field, as well as by using Newman's plant indicators.[7]

These field observations, combined with the photographic evidence, were used to compile a map of the area showing landscape units and vegetation associations. Additionally, a cross profile of the area was developed. The plan view map and the cross profile were then utilized in the determination of sensitivity classes. The vegetation type, soil strength, depth to ground water, steepness of slopes, and proximity to the ocean were examined for each landscape unit. Sensitivity classes were then arranged and superimposed on the base map. Performance standards were then developed from the environmental characteristics of each sensitivity class. A complete discussion of this follows in a later chapter.

DESCRIPTION OF COASTAL SAND AREAS

The enlarged U-2 high flight infrared photographs were used to draw a base map of areas of similar photo characteristics. The photographs were then viewed in stereo to observe the relative relief of the similar photo units. By comparing and contrasting the base map drawn from mono vision with the photos viewed stereoscopically, landscape units were delineated and drawn.

Landscape units are defined herein to be landforms consisting of homogeneous characteristics which are distinct from the characteristics of other landforms. The three meter resolution unit of the color infrared photographs set the minimum size limit for discernible characteristics within landscape units. Because of this factor and a need for landscape units of a practical size, a typical landscape unit might contain several sets of landforms. For instance, the landscape unit called the foredunes actually consists of a series of parallel ridges of sand with their corresponding troughs. However, since all ridges have the same relative position with respect to the entire study area and they all react similarly to energy changes, they are all classified as one landscape unit.

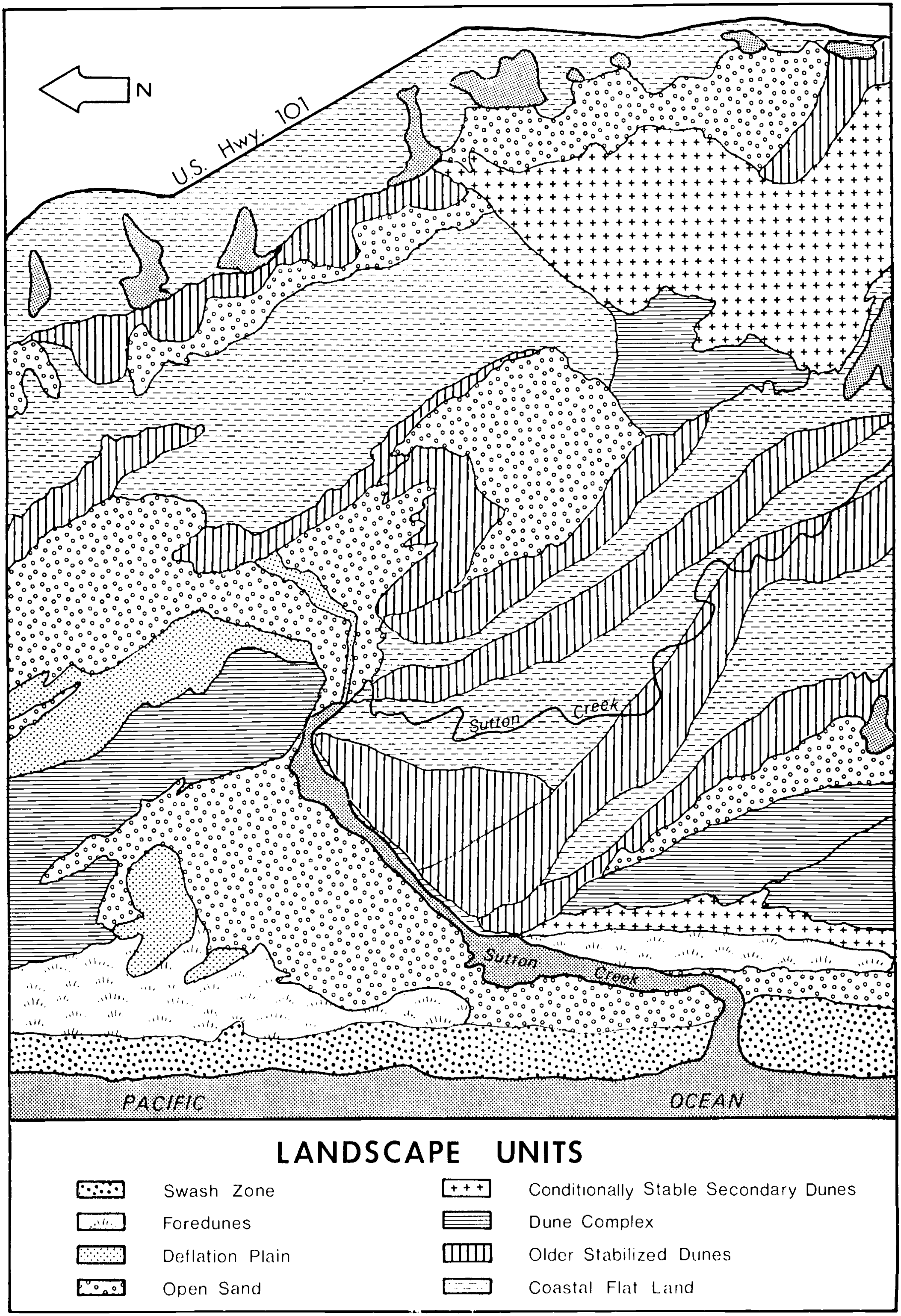
Nine landscape units were identified from the photos. The swash zone, foredunes, conditionally stable secondary dunes, deflation plains, interdunal wetlands, open sand, older stabilized dunes, dune complex, and coastal flat lands were the landforms designated as landscape units. Soil strength in each landscape unit was measured by use of a soil penetrometer. In each landscape unit the soil strength was negligible, which shows that the surface is unconsolidated sand in each class. The size of separate, but equivalent, landscape units varied little throughout the study area. A map of the landscape units is shown in figure 2.

Swash Zone

The swash zone is the most seaward landscape unit dealt with in this study. The swash zone is defined to be that area which is periodically covered and uncovered by the tides and waves. Driftlogs are deposited at the upper limit of the swash zone, which corresponds to the beginning of the foredunes. In some overwash areas driftlogs are deposited behind the foredunes, but generally they are found at the base of the foredunes which helps stabilize the dunes. Driftlogs were found to have a mode diameter of 0.5 to one meter with a maximum diameter of two meters. The width of the swash zone is approximately thirty meters.

Foredunes

Foredunes are those sand dunes which exist at the sea-land interface located at the inland extent of the swash zone. Foredunes provide a ridge of sand acting as


N
U.S. Hwy. 101
Sutton Creek
Sutton Creek
PACIFIC OCEAN
LANDSCAPE UNITS
Swash Zone
Foredunes
Deflation Plain
Open Sand
Conditionally Stable Secondary Dunes
Dune Complex
Older Stabilized Dunes
Coastal Flat Land

a barrier against ocean waves. They have originated as low accumulations of wave transported sediment which have gradually been built up to large deposits of sand. The great amount of sediment being supplied to the foredunes inhibits the growth of all but the hardiest vegetation. Thus this landscape unit is predominately a beach grass community. The ephemeral nature of beach grasses promotes rapid sand movement on the foredunes during the winter. One study has shown that the foredunes have greater than fifteen percent open sand patches on the crests of the foredunes in the summer and over forty percent open sand areas during the winter months.[8]

The sparse vegetation cover during the winter months, combined with extreme energy conditions, cause rapid morphological changes on this landscape unit. High winds cause frequent blowouts or depressions in the foredunes which transport sand inland. Extreme wave conditions create overwash areas. In the overwash areas observed the foredunes were denuded to base level and the dune material was transported inland. Extreme energy conditions also tend to steepen the seaward side of the foredunes while depositing driftwood at the base of the dunes. This driftwood in turn has a tendency to reduce wave energy and the resultant erosion at the foredune base.

Generally, the foredunes are about ten meters high with a seaward slope of nine degrees. The foredunes were actually a series of dunes with crests and troughs aligned with the predominate wind direction of 320^{o}. The width of this landscape unit is considered to be the distance from the front of the seaward most facing dune to the inland extent of the last foredune. This distance was thirty meters. The relative relief in the foredunes, excepting large blowouts, was determined to be three meters.

The foredunes are characterized by an *Ammophila arenaria* - *Fragaria chiloensis* vegetation association. *A. arenaria* (european beach grass) is the dominant species in the foredunes. It exists primarily on the crests of the dunes and also on the upper dune slopes (Fig. 3). *Fragaria chiloensis* (coast strawberry) is associated with *A. arenaria* and exists as understory on the windward dune slopes. *F. chiloensis* also occurs alone on the leeward side of the dune slopes.

Also on the leeward dune slopes some *Lathyrus japonicus* (beach pea) was found. The more inland dunes in the foredune complex showed a larger species diversity than did the most seaward foredune. *Lupinus littoralis* (shore lupine) is found in the troughs of the secondary and tertiary systems of dunes. *Elymus mollis* (American dune grass) also occurs on the more inland dunes.

Where humans have artificially stabilized the active foredunes a number of grasses and shrubs may be found. Coast strawberry, pearly everlasting, false dandelion, yarrow, seaside tansy, seashore lupine, purple beach pea,

Figure 3. *A. arenaria* on Foredune Crest.
Source: Madeline Hall

salal, and tree lupine are some of the types of plants which have been introduced to encourage foredune stabilization.

From the resistivity apparatus readings, depth to ground water in the foredunes was found to extend to four meters from the highest dune crest. A visual check of water table depth was made by observing the wetlands in the troughs of some of the more inland foredunes. It is difficult to predict the location of the saline interface, but a break in the resistivity curve suggests a depth of six meters.

It is highly probably that the water in the foredunes is quite brackish. Because sea water intrusion acts in a porous medium with a similar fluid, dispersion and diffusion processes act to mix the salt and fresh waters. Thus, there is no distinct interface between the salt and fresh water, rather it is a zone of transition. The thickness of the zone is highly variable, dependent upon rate of ground water pumping, rate of fresh water recharge, and the height of sea level. Flow within the zone of transition varies on a vertical gradient. In the upper reaches of the transition zone, the flow is similar to the fresh water seaward flow. Seaward flow in the transition flow approaches zero on the lower fringe of the zone. Throughout the transition zone, there is an upward diffusion of salt water (Fig. 4).[9]

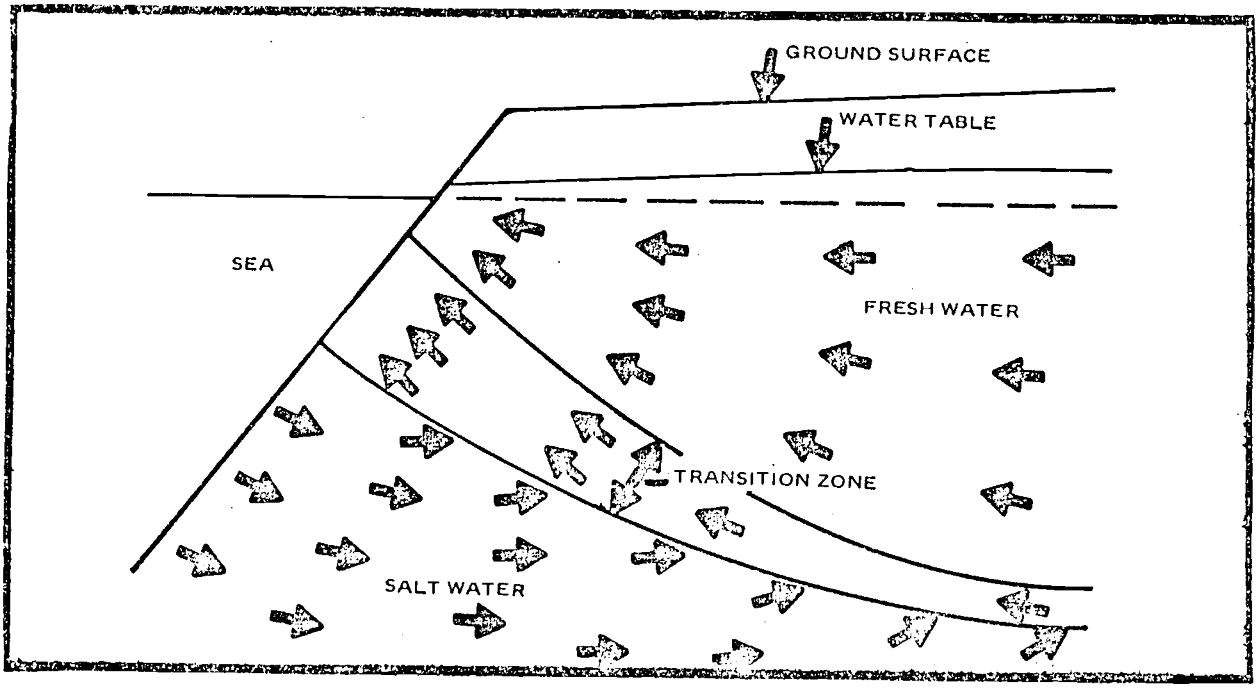


Figure 4. Ground Water Flow at Salt-Fresh Water Interface. Source: US EPA, Identification and Control of Pollution from Salt Water Intrusion.

Conditionally Stable Secondary Dunes

Conditionally stable secondary dunes are those dunes which have ceased migrating because of the growth of vegetation along the dune crests. Secondary dunes, which are located inland of the foredunes have some grasses and shrubs naturally occurring on the dune crests, but are devoid of vegetation in the dune trough (Fig. 5). These sand landscape units could easily become active sand types given a minimal disturbance of the vegetation cover. Consequently these areas are the most sensitive to terrain alteration.

Conditionally stable secondary dunes did not seem to have distinct distributions, however, they did seem to be aligned with the predominate wind direction. These dunes which have the same shape and relative size as the foredunes, have numerous blowouts and breaches in the dune crests.

The vegetation on the conditionally stable secondary dunes consists of an A. arenaria - F. chiloensis association with a number of other shrubs and grasses (Fig. 6). A. arenaria and F. chiloensis are found on the dune crests, with L. littoralis in the dune troughs. Salix hookeriana (coast willow) and Alnus rubra (red alder) are found as shrubs on the leeward flanks of the dunes. Pinus contorta (shore pine) and Picea sitchensis (sitka spruce) are also found in shrub form on the leeward slopes of the dunes. Juncus lesueurii (salt rush) is also found near the troughs of the conditionally stable secondary dunes.

The ground water is close to the surface in the conditionally stable secondary dunes. Resistivity readings indicated a ground water table one to one and one-half meters below the surface. Because of the intense developmental pressures on the secondary dunes and the shallow depth to ground water, this landscape unit is highly

Figure 5. A. arenaria Covers the Dune Crests in the Conditionally Stable Secondary Dunes
Source: Madeline Hall

Figure 6. Conditionally Stable Secondary Dunes with Dune Complex in the Background
Source: Dick Marston

susceptible to water contamination. If the conditionally stable secondary dunes exist near the foredunes, ground water pumping may cause an inland movement of the saline wedge. Continued pumping or an increase in number of wells will consequently contaminate water supplies by increasing salinities. Where coastal aquifers are over pumped or ground water recharge is reduced by construction activities, the ground water level is lowered. This reduction of fresh water flow allows the parabolic saline wedge to move inland.

> Because of the high salt content of sea water, as little as two percent of it mixed with fresh ground water can make that portion of the aquifer unusable in relation to the U.S. Public Health Service drinking water standard for total dissolved solids.[10]

Salt water intrusion can be retarded in cases where confined aquifers are found by moving wells further inland. This creates a larger seaward hydraulic gradient (Fig. 7).[11]

In addition to a hazard related to the migration of the saline wedge, the shallow depth to the ground water may pose a problem. In some areas of this landscape unit, ground water contamination from septic tanks is a potentially severe problem. If too many septic tanks are placed close to the water table, sewage may be released into the ground water. The result would be a contamination of ground water.

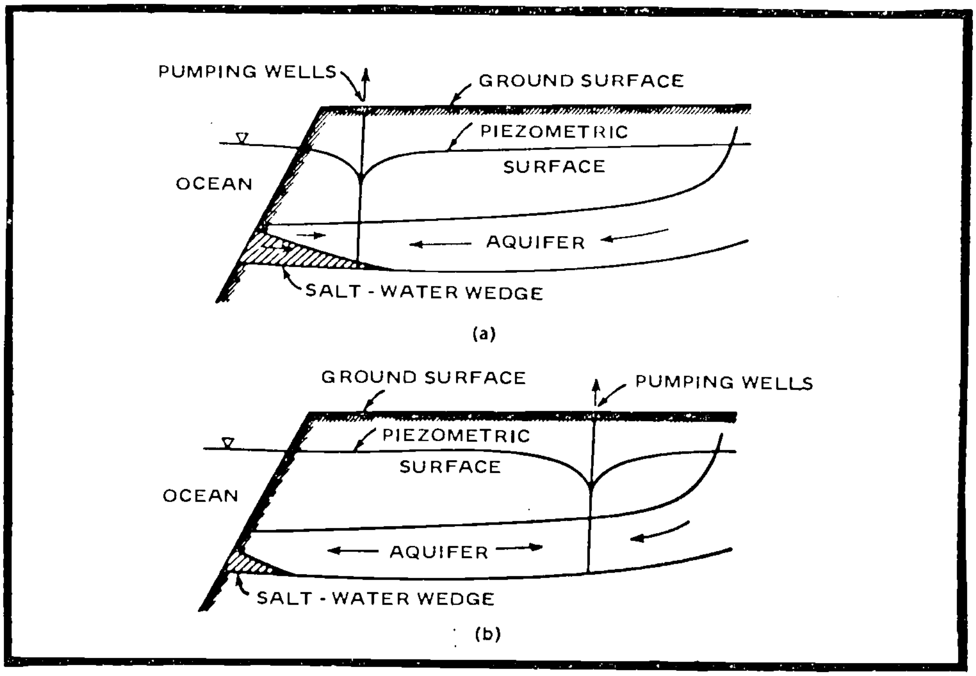


Figure 7. Control of Salt Water Intrusion in a Confined Aquifer by Relocating Wells from Point a to Point b.
Source: US EPA, Identification and Control of Pollution from Salt Water Intrusion.

Wet Interdune

This unit encompasses the constantly inundated areas of the coastal regime and the small areas between ridges of the dune complex which are covered by water for most of the year. The larger wet areas which are water covered the entire year existed in the older, more stabilized parts of the study site. Many of these areas were actively fed by small streams draining the overflow from the larger lakes. The most common occurrence of the wet interdune mapping unit was the area between dune ridges in the dune complex landscape unit (Fig. 8). These wet interdunal areas remain at least partially covered with water for the majority of the year. When the standing water does evaporate, the surface remains moist, indicating a high ground water level. These areas are covered by rushes, sedges, willows, alders, evergreen huckleberry, and salal. In the winter time the wet interdunes were often more than one meter deep, having a width of up to five meters and a length sometimes on the order of hundreds of meters.

Figure 8. A Wet Interdune in the Dune Complex During the Short Dry Season.
Source: Madeline Hall

The vegetation of the wet interdune mapping unit is similar to those areas of standing water in the dune complex. Commonly associated with the wet interdune areas is *Carex obnupta* (slough sedge) and *Juncus bufonius* (toad rush). *Salix hookeriana* (coast willow) and *Pinus contorta* (coast pine) are found on the fringes of the wet areas, along with *Gaultheria shallon* (salal).

The wet interdune, by its very nature, is a landscape unit characterized by a shallow water table or standing water on a seasonal basis, but with more available water and a greater vegetation density than the deflation plain. The wet interdune will usually have at least six months of standing water in the winter months with the water table not exceeding a depth of fifteen centimeters in the summer season.[12]

Dune Complex

The dune complex mapping unit is employed to encompass landscape units occurring in areas too small to be delineated at the scale used in mapping. These landscape units occurred in definite association, however, so they are combined into one mapping unit. The dune complex consists of the landscape units conditionally stable secondary dunes, deflation plains, and the wet interdune. In the dune complex the photos and the fieldwork showed a series of low ridges two to three meters high covered with dense vegetation separated by interdunal wetlands and small deflation plains (Fig. 9). The vegetation found on the ridges included small pines, some spruce, and other plants indicative of relatively stable sand conditions. The interdunal wetlands remain covered with water for the majority of the year and are densely inhabited by grasses and rushes plus larger vegetation such as coast willow. The deflation plains in this mapping unit are small, seasonally wet and dry, and are covered by short grasses.

The dune complex unit was an extensive area with a width of up to four hundred meters and a length of one thousand meters. The ridges and swales are aligned northwest to southeast, as were all other vegetated landforms. This landscape unit showed the most diversity, both between landform shapes and vegetation species.

Figure 9. A Small Deflation Plain in the Dune Complex
Source: Madeline Hall

The dune complex is characterized by five vegetation associations. Found in the dune complex were: A. arenaria - F. chiloensis, J. lesueurii - L. littoralis, C. obnupta - Potentilla pacifica, S. hookeriana - A. rubra, and P. contorta - P. sitchensis. The european beach grass - coast strawberry vegetation association was found in the leeward side of the first set of dunes. In the troughs of the first set of dunes the salt rush - seashore lupine association was recognized. Slough sedge - pacific silverweed was the association most commonly found in the small deflation plains of the dune complex. Also found here were Hypochaeris radicata (false dandelion) and Tanacetum camphoratum (seaside tansy).

Coast willow and red alder were found on the lower ridges of the dune complex. Coast pine coexists with coast willow and red alder to form a dense barrier of vegetation. Also on the lower ridges were evergreen huckleberry, western wax myrtle and salal. The higher ridges within the dune complex had coast pine and sitka spruce.

The height of the ground water in the dune complex fluctuates seasonally and is variable within the system of ridges and swales. Under the dune ridges, the depth to ground water may be greater than one meter in the summer, while the small deflation plains may be covered with standing water. This close proximity to the water table makes this landscape unit highly susceptible to water contamination.

Deflation Plain

The deflation plain mapping unit is defined to be a large open area which is wet in the winter and dry in the summer. This large area is sparsely covered by small rushes and grasses. Winter standing water may be as deep as one meter in the center of the deflation plain. In the summer, winds actively scour sand from the dry deflation plains and transport it to the open sand areas (Fig. 10). Often the deflation plain will be scoured to the height of the water table, eventually stabilizing the sand surface.

This interaction between the wind and dry deflation plains is the basis for active sand transport inland of the swash zone. The deflation plain acts as a sediment source for the open sand areas observed at the study site. The deflation plains are approximately sixty to seventy meters long by thirty to forty meters wide, although some deflation plains are considerably smaller and provide minimum sand supplies. Also included in the deflation plain mapping unit are the few very large blowouts which exist in the older stabilized dunes. These blowouts are twenty-five meters by forty meters.

The deflation plain is sparsely covered with grasses. The vegetation groups found were the *J. lesueurii* - *L. littoralis* association and the *A. arenaria* - *F. chiloensis* - *L. littoralis* association. The salt rush and seashore lupine plants were

Figure 10. Deflation Plains Provide a Sediment Source for Open Sand Areas.
Source: Dick Marston

found in the flat areas, predominately on the fringes of the deflation plain. European beach grass, coast strawberry, and seashore lupine were found coexisting on the occasional hummocks found within the deflation plain.

The seasonal standing water in this landscape unit generally precludes the placement of any static structure on the ground. Certain seasonal structures may be placed without harm to the environment or the structure, as long as adequate precautions are taken. Ground water in the summer season is immediately below the surface and is extremely susceptible to contamination.

Open Sand

The open sand landscape unit consists of large regions of active sand dunes, which are predominately active parabolic dunes. Active parabolic dunes require three criteria for development. For parabolic dunes of any size to originate, a stabilized surface creating a concentration of wind must be present and there must be a unidirectional wind. It is evident from the photographs that all three criteria are satisfied at the study site.

Deflation plains, scoured by the wind in the summer, provide an adequate sediment supply. In addition, the small creeks running through the area provide sand for wind transport. The larger deflation plains and thus the larger open sand areas, occurred on the lee side of a stable landscape unit, the dune complex. The wind energy is concentrated on the deflation plains because of the high capacity and high competence of the wind flowing over the dune complex.

The active sand dunes are climbing the large (25m) older stabilized dune ridges. This steady climb, ending in a precipitation ridge, causes the dunes to encroach upon the forests and lakes inland from the older stabilized dunes (Fig. 11).

Figure 11. Active Sand Movement Ending in a Precipitation Ridge Encroaching Upon a Mature Forest. Source: Dick Marston

In most areas the dune migration is quite rapid. For example, it has been calculated that sand dunes are migrating into Cleawox Lake (just south of the study site) at the rate of five meters per year.[13] In some areas dune stabilization programs are in progress. These areas show on the photos as linear striations in the sand which are light in color.

The continuous movement of sand in the open sand areas does not allow vegetation to become established. The moving sand, plus the large depth to ground water, makes the open sand areas devoid of vegetation. Ground water depth on a precipitation ridge was found to be about eight meters, as determined by the resistivity apparatus.

Older Stabilized Dunes

The landscape unit labeled older stabilized dunes was quite obvious when viewing the air photos in stereo. The older stabilized dunes were aligned in a northwest to southeast direction or parallel to the other dunes in the study site. The vertical relief of these dunes is quite large, with most of them having an elevation of twenty-five meters or greater. The slopes of these dunes ranged from twenty to twenty-six degrees on the seaward side and from eighteen to twenty-seven degrees on the leeward side.

These dunes were covered with dense vegetation, often with moderately old stands of forest. Most of the older stabilized dunes are being actively covered by migrating sand dunes. Photo evidence indicated that these landscape units had vegetation types similar to the adjacent mountain front areas, with smaller tree sizes and a less dense forest canopy. This vegetation is composed of the trees *P. sitchensis* and *P. contorta*, with an understory of *G. shallon*, *V. ovatum*, and *M. californica*. The sitka spruce is the dominant tree in the older stabilized dunes and is considered to be the mature climax forest of the dune area. A number of large blowouts exist in the older stabilized dune landscape unit. These blowouts were twenty-five meters by forty meters and are presently being scoured further (Fig. 12). These blowouts are difficult to artificially stabilize (Fig. 13).

Coastal Flat Land

This landscape unit was included to distinguish those areas which seemed to have little relief on the photos but were heavily vegetated. Large homogenous areas were covered by brush and woody species. The forest species showed shore pine, sitka spruce, red alder, western red cedar, western hemlock, and some Douglas fir. Many smaller shrubs provide a dense thicket of understory for this landscape unit.

Field work revealed the formation of a true soil profile in the flat coastal land. Large amounts of detrital organic material encourage the formation of soil. This

Figure 12: A Large Blowout in the Older Stabilized Dunes.
Source: Dick Marston

Figure 13. An Attempt to Stabilize the Blowout Seen in Figure 12.
Source: Dick Marston

landscape unit can be considered to be the most stable of all those observed at the study site, but the advancement of open sand into these areas indicates that one cannot consider the flat coastal land to have a long term stabilization.

Resistivity readings were taken to determine the depth to ground water in the coastal flat land. The depth to ground water was shown to be about three meters. However, standing water was observed in a number of swamp-like areas in the coastal flat land. These were probably the result of flooding from the numerous small streams in the area. Any construction in these areas should be done with respect to possible seasonal flooding.

SENSITIVITY CLASSES AND PERFORMANCE STANDARDS

Discussion

In recent years county planners have realized the necessity for observing certain precautions when building in the coastal zone. This report has shown that the physical hazards associated with rapid landscape (morphological) change exist relatively far inland. Wherever sand is exposed to the action of wind, there will be rapid and severe alterations of the landscape. This dynamic situation, coupled with the susceptibility of a high ground water table to contamination, creates an extremely fragile and sensitive environment. An imbalance in one aspect of the equilibrium condition will result in a rapid morphological response.

In order to minimize the possible adverse change which would take place by artificial alteration of the coastal sand environment, five terrain sensitivity classes have been delineated for the Oregon coastal environment and developmental or performance standards for each of the sensitivity classes have been proposed. This classification system with correlating performance standards is designed to provide the appropriate planning commission with the information necessary to establish stringent land use controls between sensitivity classes while permitting flexibility of development within each sensitivity class (landscape type). For example, a planner could prohibit development of the deflation plain while allowing a certain flexibility of land use in the older stabilized dunes.

The idea of performance standards for land usage is rapidly becoming of interest to many planners. Recently, performance controls for sensitive lands have been developed for the U.S. Environmental Protection Agency.[14]

The concept of performance standards is one which deals with the effect of a development on the physical setting. This emphasis on effect rather than use (as in traditional zoning) permits a large degree of flexibility for both the planning body and the potential developer. The developer has a range of choices for development of the land, as long as the performance criteria are met. The planners provide latitude for development while ensuring that there will be no usage which would be detrimental to the natural environment. In this manner, performance standards can be established to provide a general framework for development of coastal sand areas or they can be used to alleviate specific problems arising in certain critical sand areas. A treatise on performance standards may be obtained by writing to the O.S.U. Extension Service.[15]

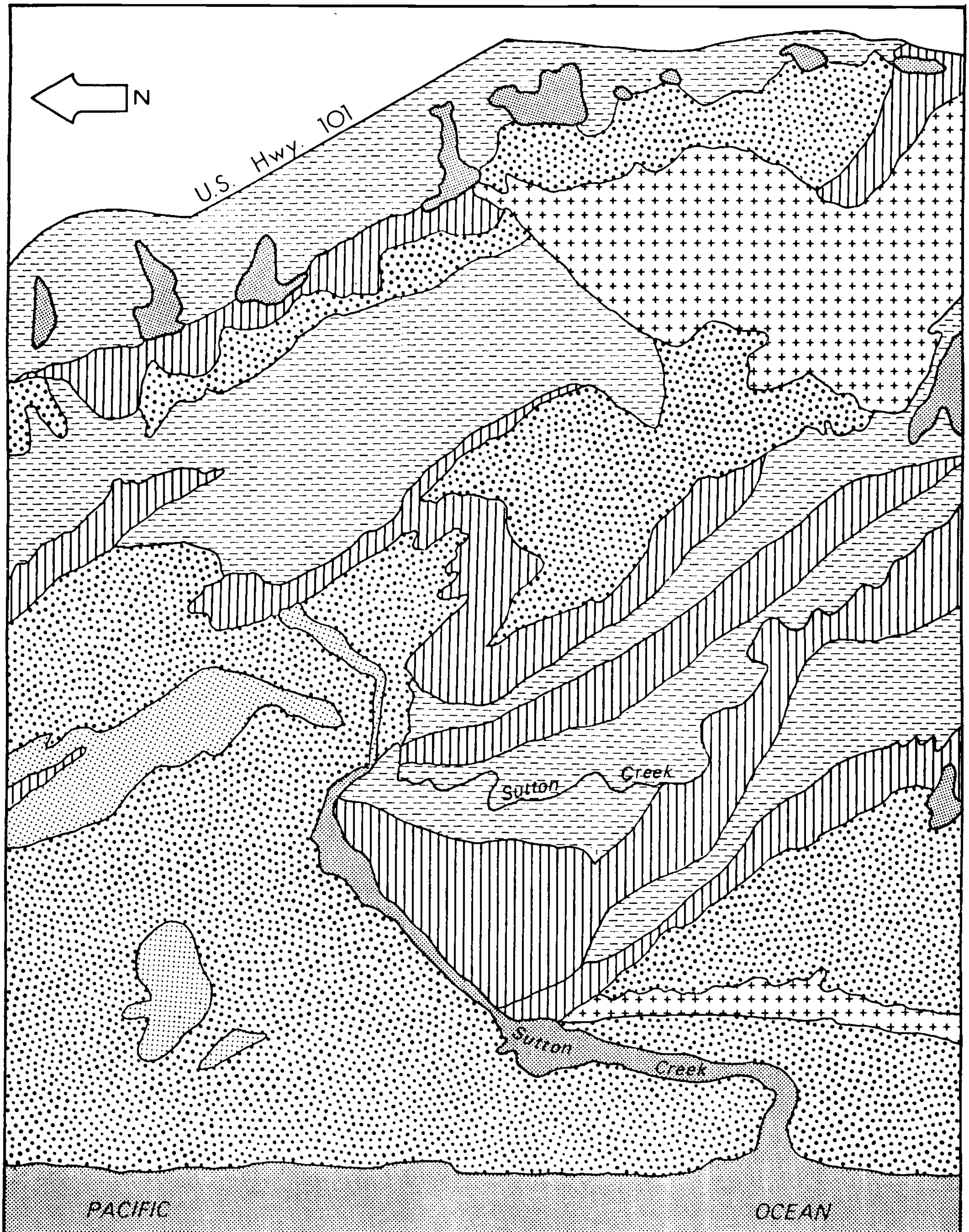
The sensitivity classes are delineated by the relative effects of physical processes on landscape units and vegetation. For example, an area covered only sparsely by grasses, with active sand movement, would be put into a sensitivity class with other fragile sand areas which are characterized by rapid sand movement. This sensitivity class would have a set of characteristic problems which would hinder or inhibit development. The performance standards would reflect the problems of this sensitivity class. Areas with less rapid physical response to processes would be placed in a different sensitivity class. Performance standards for development would be based on the problems inherent to the particular sensitivity class in question.

The magnitude of effects of physical processes differentiates sensitivity classes. The response of the terrain to five factors is used to transform differing magnitudes of processes to discrete sensitivity classes. The five factors are:

1. Terrain alteration impact. That is, what is the response of the environment to the construction of a structure;
2. water quality susceptibility. What is the water regime of the area? Does it fluctuate above and below the surface or is it sufficiently protected from the possibility of water contamination;
3. road impact;
4. off-road vehicle impact. Would the advent of off-road vehicles have a large or a minor effect on the environment; and
5. vegetation sensitivity. In other words, is the area in question amenable to fast and successful revegetation efforts?

The potential effects of physical processes associated with those five variables provide the framework for the establishment of sensitivity classes. Five such sensitivity classes have been determined for Oregon coastal sand areas. A map of sensitivity classes is shown in figure 14.

Each sensitivity class has a different set of environmental problems. This is where the concept of performance standards comes into prominence. Each sensitivity class



SENSITIVITY CLASSES

I

II

III

IV

V

0 1000

Feet

will contain its own characteristic set of performance standards to deal with the specific environmental problems of that class.

For instance, in a sand landscape unit with a high ground water table there is a large potential for water pollution from septic tank outflow. This landscape unit will be grouped with other landscapes with potential water pollution problems to form a sensitivity class. One performance standard for this particular sensitivity class would be the requirement of piped out sewage, or chemical toilets, to prevent ground water contamination.

If this performance standard is satisfied, and all other performance standards are met, then the area is suitable for artificial alteration. That is, development is possible. Note that the performance standards relate to the impact of a proposed development on a site and not to the type of development. This emphasis on effect rather than use (as in traditional zoning) permits a large degree of flexibility for both the planning body and the potential developer.

In this manner, planners can establish guidelines for development based on the inherent environmental properties of a relatively homogenous area. This will eliminate the problem of a structure meeting jurisdictional or traditional zoning requirements, yet causing adverse environmental impact. A typical coastal sand cross profile is shown in figure 15 with sensitivity classes and the five variables which delineate the sensitivity classes.

Class I

The Class I sensitivity class comprises those areas which are extremely sensitive to physical processes. Mass wasting, overwash by storm surges, shifting seasonal water tables, sparse vegetation, and rapid sand movement by wind are characteristic of this sensitivity class. Problems associated with one or more of these processes occur in the landscape units defined as the swash zone, the foredune, the dune complex, and the open sand areas. Because of the magnitude of effects of the processes on the landscape the following performance standards are proposed for the Class I sensitivity class:

1. Structures should not be permitted. The surface is constantly changing and is not suited for a rigid structure.
2. There should be no disposal of sewage in the landscape units which exist in this sensitivity class. With seasonal fluctuations in ground water levels this sensitivity class is very susceptible to water contamination.
3. The area should remain free of either paved or unpaved roads. Roads would disrupt the vegetation and would be quickly covered with sand. An exception

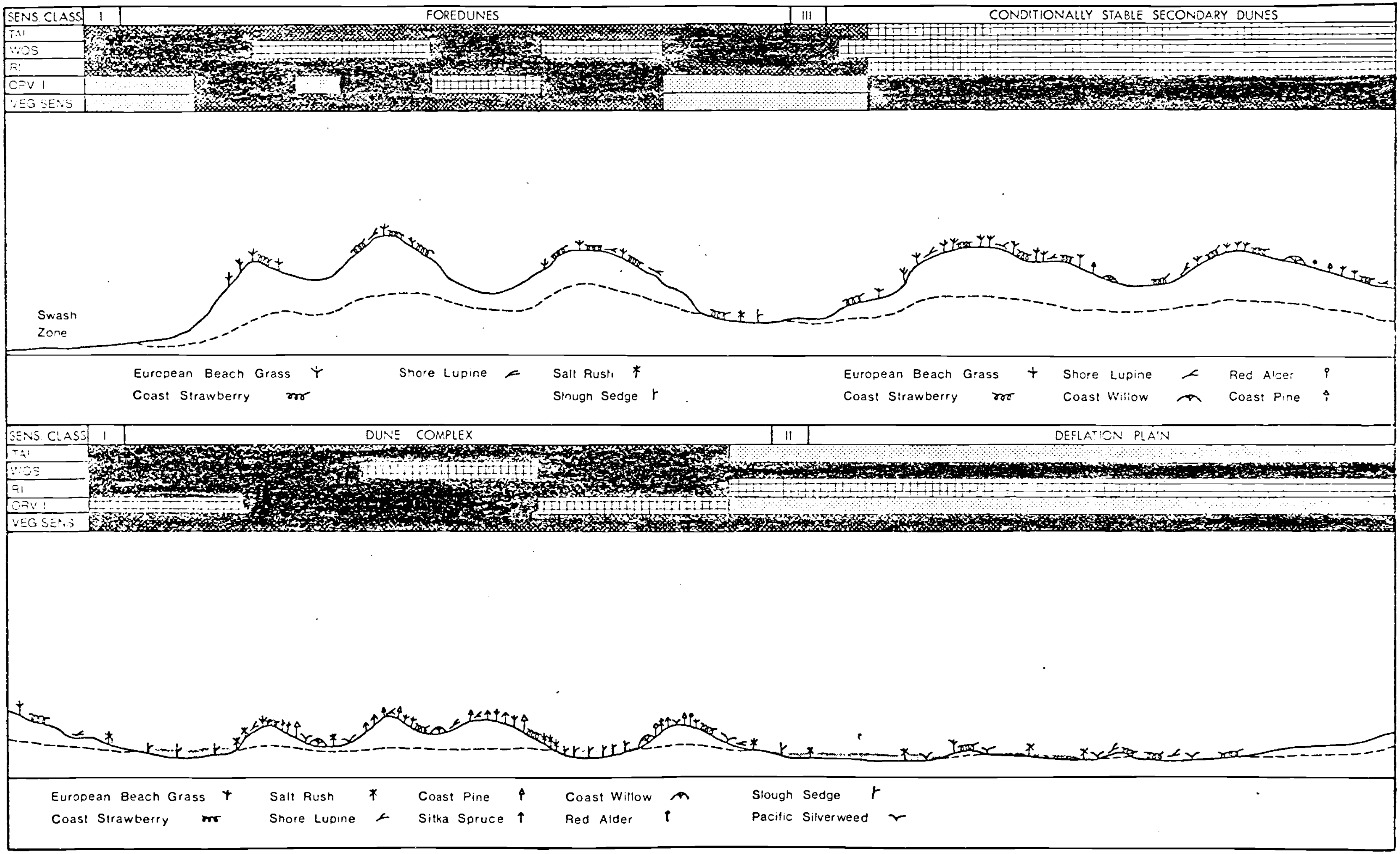
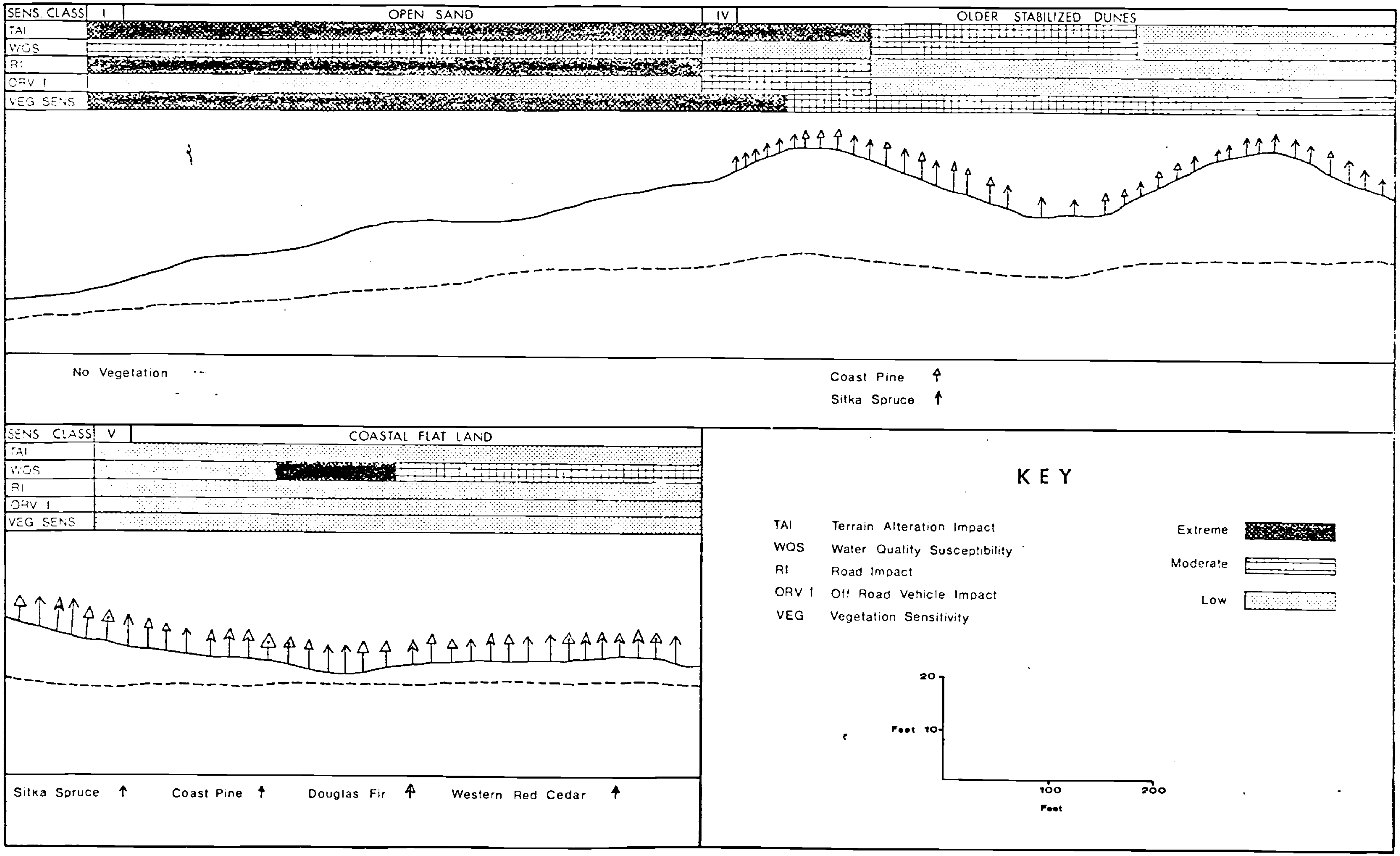


Figure 15. Generalized Cross Profile of Active Sand Areas.



SENS. CLASS
I
OPEN SAND
IV
OLDER STABILIZED DUNES
TAI
WQS
RI
ORV I
VEG SENS
No Vegetation
Coast Pine
Sitka Spruce
SENS. CLASS
V
COASTAL FLAT LAND
TAI
WQS
RI
ORV I
VEG SENS
Sitka Spruce
Coast Pine
Douglas Fir
Western Red Cedar
KEY
TAI Terrain Alteration Impact
WQS Water Quality Susceptibility
RI Road Impact
ORV I Off Road Vehicle Impact
VEG Vegetation Sensitivity
Extreme
Moderate
Low
20
Feet 10
100
200
Feet

to this would be those roads, preferably unpaved, which would provide access for off-road vehicles. Access roads should be carefully designed; they can provide paths of rapid sand movement (Fig. 16).

4. Off-road vehicles should be permitted in the non-vegetated areas of the landscape units of this class. Since the terrain is open sand, off-road vehicles would not be detrimental to the environment, as long as they meet state or local standards of acceptable noise level, air quality, and safety criteria.
5. Vegetation should not be removed or altered. The vegetation is extremely sensitive to landscape change and it is difficult to revegetate. Terrain and vegetation recovery is slow following alteration.

Class II

Class II is designed for those landscape units with water tables which fluctuate above and below the land surface. The landscape units are the deflation plain and the wet interdune. The following standards are proposed for the Class II sensitivity class:

1. Permanent structures should not be permitted. Structures would be subject to flooding at certain times of the year and sand movement at other times.

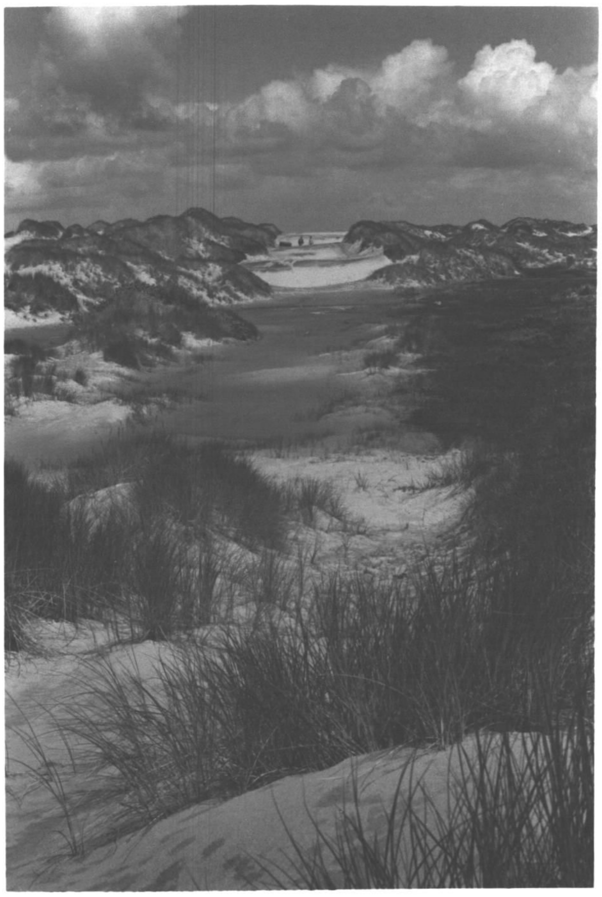


Figure 16. Active Parabolic Dunes Moving Through an ORV Access Road.
Source: Dick Marston

2. There should be no disposal of sewage in these landscape units. With the high water level, the areas are subject to water contamination.
3. There should be no paved roads in the deflation plain or wet interdune. The paved roads would interrupt the flow of sediment and would be rapidly covered with sand. Unpaved, gravel roads are permissible because they do not hinder the natural flow of sand.
4. Off-road vehicles are acceptable for use in these landscape units as long as they meet local standards.
5. Vegetation is highly sensitive but is not important to the stability of coastal sand areas.

Class III

Class III consists of moderately sensitive areas such as the conditionally stable secondary dunes landscape unit. The dunes are stabilized by grasses and low shrubs and trees. The initial stages of soil development are evident, especially on the crests of the dunes. The dunes, however, could revert to active sand movement if excessive removal of the vegetation occurs. Coastal planners must be aware of this fact, for the conditionally stable dunes are under intense developmental pressures. In light of this the following performance standards are proposed:

1. There should only be a few structures per acre allowed in this landscape unit. Local planners

should establish density requirements based on their particular site situation. It is recommended that density requirements be based on a number of criteria such as percent impermeable surface (to permit ground water recharge and flow of sand), floor area ratio (to limit size of structure to ensure adequate wind flow to transport sand), landscape area (to ensure adequate amounts of vegetation to keep the dune stable), and a minimum distance between buildings (again to ensure adequate wind flow). An example of density standards for the study area of Heceta Beach would be:

-- no more than 5 percent impermeable surface allowed.

-- a floor area ratio no greater than 0.025 (floor area/lot size).

-- 85 percent of the area should be left natural.

-- a minimum distance of 30 meters between structures.

It is extremely important that minimal disturbance of vegetation occur during construction of the structures.

2. Septic tanks should not be allowed in the moderately sensitive class. Piped out sewage or chemical toilets are permissible; this will prevent possible water contamination of the shallow water table.

3. Paved roads or gravelled roads are acceptable as long as adequate filter or buffer strips have been established on the side of the road. The buffer strips reduce the possibility of dune migration from paving the sand surface.
4. Off-road vehicles should be restricted from use in the conditionally stable dunes. Off-road vehicles would remove the vegetation and subject the area to active sand migration, with severe landscape changes resulting.
5. The vegetation is extremely sensitive and revegetation must be required immediately upon removal of plants. As little vegetation as possible should be removed.

Class IV

The Class IV areas generally have a thin layer of soil with larger trees and shrubs existing. The rate of sand transport is relatively low and there is little landscape change yearly. Removal of large amounts of vegetation could lead to active sand migration and in some cases enormous blowouts have been observed (Fig. 12). Generally, however, the surface is stable. The older stabilized dune landscape unit is characteristic of this sensitivity class and there are large stands of sitka spruce and shore pine. The following performance standards are proposed for Class IV:

1. A moderate density of structures is permissible, again based on the particular location. This is to ensure adequate transportation of sand by wind. An example of density standards based on the Heceta Beach study area would be:
   - -- No more than 15 percent impermeable surface (about three houses per acre) if sewage is piped out or chemical toilets are used. No more than 10 percent impermeable surface (about two houses per acre) if septic tanks are used (where permissible). The difference stems from the greater potential for contamination of ground water if septic tanks are used.
   - -- A floor area ratio no greater than 0.032.
   - -- 85 percent of the land should remain in a natural state.
   - -- a minimum distance of 23 meters between buildings.
2. Sewage disposal systems to follow local guidelines.
3. Paved roads are acceptable.
4. Off-road vehicles are acceptable subject to local controls.
5. Vegetation is stable given adequate wind breaks. Extensive revegetation is feasible and should be required after alteration.

Class V

Class V was established to recognize those areas such as the coastal flat land which are the least vulnerable to, and furthest removed from, coastal processes. There is generally a true soil profile, adequate supplies of fresh water, and very stable vegetation. The major problem existing in these areas is one of water quality. The following standards are proposed for Class V:

1. Density of housing should not exceed the carrying capacity of the land. This should be determined locally. An example of possible density standards for Heceta Beach is:
   - -- No more than 20 percent impermeable surface if sewage is piped out or a chemical toilet system is used. No more than 15 percent impermeable surface in areas where septic tanks are permitted. This ensures adequate ground water recharge and minimizes chance of ground water contamination.
   - -- A floor area ratio no greater than 0.064.
   - -- 75 percent of the land surface should remain in a natural state.
   - -- Cluster development is permissible if desirable.
   - -- There should be a minimum distance of 15 meters between buildings.

2. Sewage disposal should follow local guidelines. Contamination of ground water remains a serious problem, as often the ground water table is near the surface.
3. Paved and unpaved roads are acceptable.
4. Off-road vehicles are acceptable subject to local controls.
5. Vegetation is stable, adequate soil is present, and no specific guidelines need to be established.

SUMMARY

The coastal sand areas of Oregon contain a number of different landscape types. These landscape units have varying degrees of terrain stability. Terrain stability is dependent upon the amount of vegetation present, the proximity and exposure to erosional forces, and the depth to ground water. Some of the landscape units are more sensitive than others to physical processes, thus making them less stable. In the foredunes, for example, a slight alteration of the vegetation on the dunes will cause a rapid change in dune configuration. The same relative amount of vegetation removed in less sensitive (more stable) areas, such as the older stabilized dunes, will not cause such a dramatic change.

Because sand areas react quickly to terrain alteration, there are limitations to development of these areas. There are a number of places along the Oregon coastline where these limitations have been ignored, however. Many houses have been built in extremely sensitive sand areas. The result of this action has been a loss of houses and property. Many homes are currently in jeopardy and may be lost as erosional forces continue to act in high energy areas.

To ensure the safety of property and the health of people, protective guidelines for development must be adopted. This report has proposed guidelines for development of coastal sand areas which would protect ground water quality and prevent the building of structures in unstable areas. Landscape units with similar responses to terrain alteration were grouped to form sensitivity classes, which were subsequently mapped. Performance standards for each sensitivity class were then proposed, thus providing guidelines for development of coastal sand areas. These performance standards are flexible enough so they are applicable to all Oregon coastal sand areas. They are also designed with enough flexibility to allow for various types of structures within a landscape unit. The performance standards are sufficiently stringent, however, to prevent the destruction of property and of Oregon's beautiful coastal realm. It is imperative that planners act to prevent unwise development in the sensitive coastal sand areas.

FOOTNOTES

1. Oregon Coastal Conservation and Development Commission, Final Report, 1975 (Florence, OCC&DC, 1975), p. 118.

2. Land Conservation and Development Commission, Draft Land Use Planning Goals and Guidelines for the Coastal Zone (Salem, Oregon, LCDC, 1976), p. 8.

3. For information on recent losses of property, the reader is referred to James E. Stembridge, Shoreline Changes and Physiographic Hazards of the Oregon Coast (Ph.D. dissertation, University of Oregon, Eugene, Oregon, 1975).

4. K.W. Newman, The Relation of Time and the Water Table to Plant Distribution on Deflation Plains along the Central Oregon Coast (Masters thesis, Oregon State University, Corvallis, Oregon, 1974), pp. 8-10.

5. Helen L. Cannon, "The Use of Plant Indicators in Ground Water Surveys, Geologic Mapping, and Mineral Prospecting," Taxonomy, vol. 20 (1971), p. 230.

6. Soil Test, Inc., Earth Resistivity Manual (Evanston, Illinois, Soil Test, Inc., 1968), p. 5.

7. Material dealing with the methodology of vegetation analysis and ground water analysis comes from an unpublished research paper by Madeline J. Hall, Richard A. Marston, and Richard M. Starr.

8. Oregon Coastal Conservation and Development Commission, Beaches and Dunes of the Oregon Coast (Florence, Oregon: OCC&DC, 1974), p. 46.

9. United States Environmental Protection Agency, Identification and Control of Pollution from Salt Water Intrusion (U.S. Government Printing Office, Washington, D.C., 1973), p. 32.

10. United States Environmental Protection Agency, op. cit., footnote 9, p. 4.

11. United States Environmental Protection Agency, op. cit., footnote 9, p. 33.

12. A.M. Wiedemann, Contributions to the Plant Ecology of the Coastal Sand Dunes (Ph.D. dissertation, Oregon State University, Corvallis, Oregon, 1973), p. 35.

13. State of Oregon, Department of Geology and Mineral Industries, Environmental Geology of Coastal Lane County, Oregon (Portland, State of Oregon, 1974), p. 30.

14. Charles Thurow, William Toner, and Duncan Erleyn, "Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators," Planning Advisory Service Report #307, 308, a publication of ASPO (U.S. Government Printing Office, Washington, D.C., 1975).

15. Oregon State University Extension Service, Corvallis, Oregon, 97331.

BIBLIOGRAPHY

Cannon, Helen L., "The Use of Plant Indicators in Ground Water Surveys, Geologic Mapping, and Mineral Prospecting," Taxonomy 20 (1971).

Land Conservation and Development Commission, Draft Land Use Planning Goals and Guidelines for the Coastal Zone, Salem, Oregon, LCDC, 1976.

Newman, K.W., The Relation of Time and the Water Table to Plant Distribution on Deflation Plains along the Central Oregon Coast, Masters thesis, Oregon State University, Corvallis, Oregon, 1974.

Oregon Coastal Conservation and Development Commission, Beaches and Dunes of the Oregon Coast, Florence, Oregon, OCC&DC, 1974.

Oregon Coastal Conservation and Development Commission, Final Report, 1975, Florence, Oregon, OCC&DC, 1975.

Soil Test, Inc., Earth Resistivity Manual, Evanston, Illinois, Soil Test, Inc., 1968.

State of Oregon, Department of Geology and Mineral Industries, Environmental Geology of Coastal Lane County, Oregon, Portland, State of Oregon, 1974.

Stembridge, James E., Shoreline Changes and Physiographic Hazards of the Oregon Coast, Ph.D. dissertation, University of Oregon, Eugene, Oregon, 1975.

Thurow, Charles, William Toner, and Duncan Erleyn, "Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators," Planning Advisory Service Report #307, 308, a publication of ASPO, U.S. Government Printing Office, Washington, D.C., 1975.

United States Environmental Protection Agency, Identification and Control of Pollution from Salt Water Intrusion, U.S. Government Printing Office, Washington, D.C., 1973.