United States Department of Agriculture

Soil Conservation Service

Agriculture Handbook 687

Stabilizing Coastal Sand Dunes in the Pacific Northwest

Cover: European beachgrass is the dominant plant for stabilizing frontal dunes in the Pacific Northwest.

Photo credits: All photographs were taken by Ron Nichols, public affairs specialist (former photographer), Soil Conservation Service, except for the black and white historic photographs.

August 1991

Stabilizing Coastal Sand Dunes in the Pacific Northwest

by Jack Carlson,[1] Frank Reckendorf,[2] and Wilbur Ternyik[3]

[1] Plant materials specialist, Soil Conservation Service, West National Technical Center, Portland, Oregon.
[2] Sedimentation geologist, Soil Conservation Service, West National Technical Center, Portland, Oregon.
[3] Former plant materials technician, Soil Conservation Service, Plant Materials Nursery at Warrenton, Oregon; current nurseryman and private consultant, Wave Beachgrass Nursery, Florence, Oregon.

European beachgrass.

Contents

List of Tables

Introduction

Extent and Location of Dunes

The Pacific Northwest Coast is defined as the area from Cape Mendocino, California, to the Strait of Juan de Fuca, Washington. This area has a similar climate, vegetation, soil, and geology, as well as similar variation in wind and wave action.

Many types of sand dunes and sand spits, which make up 250,000 acres of the Pacific Northwest coast, provide exceptional recreational opportunities as well as rich habitat areas for wildlife. Of the total dune area, about 26,000 acres are dunes with essentially no vegetation; and of these, nearly 5,000 acres are "active" dunes that threaten competing land uses. Active dunes, so called because they lack a stabilizing plant cover and are subject to extensive movement by wind action, advance onto forests, lakes, stream channels, roads, railroads, estuaries, and agricultural land. Every year several hundred acres of vegetated dune land are disturbed, mainly as a result of human activity, and become new active dunes.

Landowners and community planners face the challenge of selecting a dune stabilization plan that protects adjoining property and natural resources yet preserves sufficient open, active dune land for public recreation, aesthetics, and scientific purposes. To assist them, this publication draws upon the more than 50 years of infield dune management experience of the U.S. Department of Agriculture's Soil Conservation Service (SCS). It reviews fundamental dune-building processes, describes how to plan a dune-control program, and explains the mechanical aids, plants, and planting techniques for dune stabilization.

The recommendations in this publication apply specifically to the dune lands in the Pacific Northwest. Some of the plants, however, have been grown successfully as far north as Vancouver Island, Canada, and as far south as Morrow Bay, California. (See appendix I for common and scientific plant names used in this publication.)

Typical dune development in early stages of natural revegetation.

Residential and resort development are common on stabilized dunes, but vegetative cover must be maintained and managed to minimize sand deposition and damage to buildings. Building in beachgrass vegetation on or near foredunes is considerably more risky than further inland on much older stabilized dunes.

Formation of Dunes

Coastal dune formation is determined by four factors: wind action, wave action, vegetation, and source of sand. The two immediate sources of dune sand particles are the erosion of coastal formations exposed to wave attack, and sediment load from rivers. Ocean currents move sand from eroding headlands, and from the mouths of rivers, to where there are indentations in the coastline. As sand is deposited on beaches, it is exposed at low tide, dries quickly, is caught by the wind, and is carried inland. Along the Pacific coast there is almost always a moderate wind. At times the wind approaches hurricane force. High-velocity winds move enormous amounts of sand inland.

After a winter storm, rivers and streams carry a heavy load of sediments from the upper watershed. This sand is combined with that derived from storm waves attacking sea cliffs, dunes, and spits. These storms provide a seasonal near-shore sand supply, whereas lower-energy waves and currents, which occur more on a continual basis, transport the near-shore sand to beaches and tidal inlets (Peterson et al., 1982).

Waves reaching the coast generate longshore currents in the near-shore area that are important in the movement of sand along the beach and in beach erosion. When waves break at an angle to the shoreline, they generate a current that flows parallel to the shoreline (Komer 1976). This current, together with the waves, produces a transport of sand along the beach known as littoral drift (Komer 1979). Winds and associated waves arrive from the southwest during winter months and from the northwest during the summer months. As a result, littoral drift changes direction from season to season.

Recent work (Chesser and Peterson 1987) based on physiographic and mineralogic analysis indicates that there are at least 17 major littoral cells along the Pacific Northwest coast. Their preliminary results indicate longshore transport is bounded by major headlands and is highly correlated to the prevailing wave approach angle. They also concluded that episodic events may overshadow seasonal cycles of transport.

Dunes form and reform naturally or from human activities. Concentrated wind channels frequently create blowouts, or areas where wind removes existing vegetation.

Sand deposited on the beach is blown inland and trapped by European beachgrass, creating a frontal foredune. Without the introduced beachgrass, the native landscape typically would be more open and hummocky. The foredune has enabled greater development and use of the coastal zone.

The three largest littoral cells are associated with the three largest rivers—the Columbia, the Umpqua, and the Eel (Chesser and Peterson 1987). Therefore, it is no surprise that some of the largest dune areas occur in areas near these major rivers. Jetty construction on the Pacific Northwest coast also has a major effect on littoral sand drift and accumulation. Sand accumulates on both the north and south sides of jetties from the seasonally reversing waves. Embankments, formerly at the mouth of rivers, are filled with sand. This sand accumulation can be quite fast, such as behind the south jetty of the Columbia River. Between 1885 and the 1930's, a prograding beach developed in this area, resulting in 3,000 acres of open, active sand dunes.

Vegetation is a major factor affecting dune formation. Along a barren shore, dunes are oriented transversely or obliquely to the wind, depending on the existing wind regime. Prior to 1900, native coastal dune plants altered a barren dune area by generally making it hummocky in appearance. However, since then, introduced European beachgrass has been the primary pioneer species on newly deposited sand.

Plants establish and advance along the beach to the normal tide line, where they are halted by tide action. The stiff, coarse stems decrease the velocity of the surface wind and trap the sand. Thus, instead of a hummocky landscape or a series of transverse and oblique ridges of barren sand, a grassy foredune develops parallel to the coastline (Cooper 1958). The greatest amount of sand movement along the North Pacific coast takes place during the high-velocity winter wind storms. At this time sand engulfs the foredune vegetation. During the spring and summer, however, vegetation grows up through the sand and forms a lush growth. This is covered again the next winter, and a continuous sand ridge, built layer by layer, extending without interruption, and parallel to the coastline, results. The lands lying to the leeward of the foredune are protected from the scouring action of the sand-laden wind and a dense sod or forest cover eventually develops.

If sand is deposited more rapidly than it is blown inland, the beach line will build oceanward. The vegetation will advance to a new storm tideline, and a new foredune will be formed oceanward from the old foredune. Incoming sand will be deposited on the new foredune, and the old foredune will become vegetated by plants better suited to stable conditions.

This typical dune-building and dune-stabilizing process can easily be disrupted, however, by disturbance of the vegetal cover. When vegetation thins and sand is exposed, the wind lifts and carries it until vegetation or some artificial barrier causes it to deposit. Scouring often results in a blowout, a widening gap of open sand that can move a considerable distance inland. From such occurrences, a large active dune area may develop. Anything that destroys the vegetal cover furthers the development of active dunes. Active dunes may move for long distances over a flat plain before they are finally dissipated or stabilized.

Human activity has a profound effect on coastal dune areas, directly or indirectly accelerating or renewing dune activity. Fire can cause large active dune areas to form, both on the coast and inland. Destruction of recently stabilized dunes by fire exposes sand directly to the wind.

Further inland, fire can destroy the humus that has accumulated from hundreds of years of plant growth. This humus is the layer of decaying organic material that overlies the gray dune sand. The accumulation of organic matter on stabilized dunes over time enables further plant succession and an environment conducive to a greater variety of land uses. Fire can destabilize a dune management area quickly, and prevention is a primary concern.

In the past, overgrazing by livestock has been a significant cause of active dunes. Repeated trailing by livestock cuts through vegetation and the thin topsoil to the sand below, causing blowouts.

As stated previously, jetties, such as the ones built at the mouth of the Columbia River, have contributed to active dune formation. The south jetty built at the mouth of the Columbia River extends 7 miles to the sea, and the north jetty extends 3 miles. Construction of the jetties has scoured the main river channel, and much of the scoured sand has been deposited north and south of the mouth of the river. A low-lying sand flat south of the river has built oceanward, with its maximum width near the jetty. It extends several miles southward and gradually narrows until it meets the old beach line.

Ordinarily, a beach builds oceanward so gradually that vegetation keeps pace. Thus, the sand is stabilized as rapidly as it is deposited. In the case of the wide plain to the south of the Columbia River jetty, the beach line built oceanward too rapidly for the vegetation to keep pace. Occasional clumps of sand-stilling grasses washed onto the flat, took root, caught sand, and built up scattered hummocks. Generally, however, there was little vegetal cover to hold the sand. The prevailing winds moved the sand inward to form an extensive area of active sand movement. Similar problems have occurred in all cases where jetties have been built at the mouth of rivers on the North Pacific coast.

Construction of jetties usually results in the movement of the beach seaward. Note the advance of a new foredune from the old one at the mouth of the Siuslaw River near Florence, Oregon.

Recreational vehicles have become a major cause of active dunes in recent years. Motorcycle and other dune traffic easily destroy beachgrass and associated vegetation. Blowouts sprout quickly, and a large dune area can become active again.

Other causes of active dune processes include road construction, wearing of trails, regrading for building sites, and cultivation. In general, any destruction of the vegetal cover in an area of sandy soil is likely to start sand movement. The unprotected site starts as a blowout, which increases in size. Controlling an unwanted large blowout can be very expensive.

The Need for Selective Stabilization of Dunes

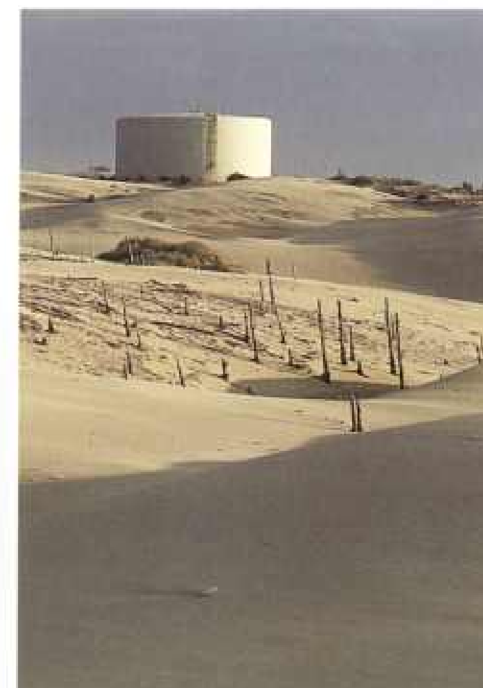
Dune stabilization is needed to:

1. Protect other natural features, such as lakes, wetlands, forests, and estuarine habitats along coastlines;
2. Protect improvements, such as highways, parks, shipping channels, and urban development;
3. Create sheltered wetland habitat or upland habitat for wildlife;
4. Provide needed beach access for recreational use; and
5. Overcome hazardous situations.

Yet, there also is considerable public demand for unstabilized, active, open dunes. This became apparent with the public comments on plans for the Oregon Dunes National Recreation Area and Oregon's Coastal Zone Management plans during the seventies. The public voiced their desire for open dune areas left in their natural state for recreational and scientific purposes. Plans, therefore, provide for hiking, dune buggies, photography, and camping areas such as Umpqua Scenic Area south of Winchester Bay and other dunelands left in their natural state. Underscoring the preference for open dunes, more than 40 percent of all visits to the Oregon Dunes National Recreational Area are to open sand areas.

Movement of large sand dunes affects human activity in coastal zones. Here a community must weigh the costs of maintaining a navigational channel and the benefits derived from preserving open dune areas.

Large parabolic dunes can move several hundred feet per year, invading spruce forests and encroaching upon highways, freshwater lakes, commercial developments, and other planned land uses.



Here a city water supply tower foundation must be protected from scour and undercutting.

Planning a Dune Control Program

The necessary balance between open, uncontrolled dune movement and selective stabilization is only achieved through sound planning and management, and usually requires considerable infield dune management experience. Such experience acquired over 50 years along the Pacific Northwest coast has caused a gradual shift from planting 99 percent of a problem area to smaller plantings that afford adequate protection of significant resources. A summary of the type of sand dune stabilization work that has been done on the West coast during the past 50 years is presented in Reckendorf et al. (1985, 1987).

Land Use

Recreation is the main land use that allows appreciable areas of active dunes. Size of the recreation area determines how much should be stabilized and how much should be left open. Active dunes left open should be slow moving, have room to move, and have a sand supply that can be controlled. Buffer strips of tall trees are useful for slowing the advance of dunes. Dune movement must also be predictable, and this depends on a thorough knowledge of dune history in the area, dune formation mechanics, and wind conditions. As active dunes encroach on incompatible land uses, they must be stabilized and new active dunes opened up elsewhere on the recreation area. The alternatives are to remove sand from the adjacent land or to sacrifice the adjacent land use to recreational purposes.

Very large, open active dune areas that have existed naturally since before the coast was settled have high potential for recreation and scientific study. They are made compatible with adjacent land uses by the use of adequate buffer zones to slow the movement of sand inland.

Urban Land. Residential and industrial development cannot coexist with open dunes unless land users are willing to pay for sand removal and tolerate sand deposition and abrasion. Houses often are constructed on sand spits; on, into, and behind foredunes; and on older stabilized dunes. In all cases, the surrounding area should at least be stabilized with beachgrass. Sand deposition on floors and sills is still a problem in areas stabilized with beachgrass, but less where older woody vegetation has become established. Clearing wooded areas for construction on dune sand can interrupt moisture availability and inadvertently kill adjacent trees. Urban development on stabilized dunes is much riskier than further inland.

Beachgrass is planted on the far dune to slow its encroachment inland towards a lake and other developments.

Community Services. Utility rights-of-way, highways, airports, ship channels, and other similar uses do not tolerate great accumulation of sand. Highway cuts and fills, as well as rights-of-way, almost always have to be stabilized. Waterways must be well buffered by vegetation on both banks to prevent clogging.

Woodland. Commercial or private woodlots are only possible in well-stabilized areas, well away from sand deposition and protected from wind blast, which shapes coastal trees into odd picturesque forms. Soil moisture balances are fragile on dune sand and can be upset by improper timber management. Loss of soil moisture can result in blowouts.

Wildlife Habitat. This land use can be primary or secondary. It also is the most compatible with recreation use, if the area is large enough to permit adequately diverse vegetation and fresh water. A mixture of forest, shrublands, grassy areas, and open dunes in combination with marsh habitat on deflation plains is the most desirable habitat for coastal wildlife. Recreation use can sharply reduce various animal populations, particularly with off-road vehicle traffic and high-density camping or day use, but tradeoffs are made either way, depending on which use has priority.

Cropland and pasture usually are not recommended uses for dune areas. These uses are limited to areas where the water table is high.

This strategically placed beachgrass planting in an open dune area will help to control sand movement into a lake that has high recreational value.

Cranberries are the most commonly cultivated crop. Cultivation on dune sand requires wind protection and is feasible only on a small scale. Pastures must be properly grazed to ensure that humus layers are not destroyed. Agriculture is impossible on open active dunes.

If an undeveloped site has active dunes, the owner or operator may stabilize it to permit residential or commercial use. The operator also may work with adjacent landowners to control dunes, or land use ordinances may require that certain areas be permanently stabilized to permit land uses that are not compatible with active dunes. Where complete stabilization is necessary, a dune treatment plan is relatively simple and follows the procedure outlined later in this publication. If active dunes are planned for recreation or natural areas, the land manager must consider controlling the sand supply, the area to be occupied by the dune, the direction of dune movement, buffer vegetation, eventual stabilization of the dune, and alternate dune sites. Vegetation is used to control open sand supply and build buffer strips. Adjacent areas that are not to remain active are stabilized with vegetation.

Dune Management Areas

Ternyik (1979b) recommends dividing dune land into dune management areas. Delineation of these areas follows significant natural or artificial boundaries that prevent dune movement. The boundaries may include lakes, rivers, channels, concentrated urban developments, and highways. By comprehensively considering an entire dune management area, local planners can recommend suitable land uses. Management areas can include several land uses, and it is important to ensure that all are compatible. Also within dune management areas are three dune landforms (Crook 1979) which must be considered to integrate elements of a dune control plan.

The type of dune landform determines how a dune is stabilized with vegetation:

1. **Foredune Area.** The barrier ridge of sand immediately above the high tide line and paralleling the beach is the foredune (Reckendorf 1975 and Crook 1979). It can be divided into the frontal section facing the ocean, the top surface, and the lee side (side protected from the wind). If no foredune is present, the area from the high tide line back 200 feet is considered the foredune area. This area is the one most affected by direct ocean sand supply.

Foredunes are subject to wave attack, severe winds, and constant sand movement and, therefore, are stabilized primarily with pioneer dunegrasses. The front and top of the foredune are vegetated to dunegrasses exclusively, whereas the more protected lee side can be planted to secondary grasses, legumes, and woody plants in addition to dunegrasses.

Beach sand movement and wave attack keep frontal areas in a constant pioneering stage. Vegetation on the foredune will prevent sand movement inland but will not stop erosion caused by wave attack. Therefore, if a beach over the long term is degrading, the foredune eventually may be destroyed by wave erosion. Severe storms or an abrupt cutoff of beach sand supply may also result in the destruction of a foredune by wave action.

Natural foredunes are created by sand-stilling dunegrasses. Blowouts in foredunes occur when the grass cover is disturbed, opening a wind tunnel for further sand movement inland. Foredunes can be created mechanically using sand fences and then vegetated.

High planting densities are required for dunegrasses on the front and top of foredunes. High fertilizer rates also are necessary for plants to establish rapidly and withstand the severe conditions. Plantings require periodic refertilization for at least 2 years to maintain a vigorous cover.

Recreational use continues to increase.

Afterwards, stands usually thrive on nutrients provided by the continuous supply of windblown sand. The lee side of the foredune is less intensively planted to dunegrasses. Secondary legume seedings or woody plantings provide fire protection between the high-fuel-volume dunegrasses and inland areas.

Parallel ridge dunes are vegetated foredunes that have been supplanted by new foredunes to the ocean side. These ridges and other stabilized areas are surface-stabilized dunes that have a weakly developed topsoil layer. The degree of soil development depends on how long the dune has been stable. Recently stabilized dunes are more fragile than those with a mature forest canopy. All surface-stabilized dunes can be destabilized if vegetation is destroyed and the dune mantle subjected to wind. Some residential developments have encountered problems during lot clearing when duff and humus layers are removed, killing large areas of tall trees that rely heavily on these layers for moisture and nutrients. If developments occur close to wind corridors, blowouts can occur even in wooded areas.

2. **Interdune areas.** Adjacent to the foredune's lee side are flat areas called deflation plains (Reckendorf 1975 and Crook 1979). These interdune areas are scoured down to the water table and are seasonally wet. Deflation plains usually support marsh plants and are valuable habitat for waterfowl. Most sites are seasonally wet and can be planted to cereals for waterfowl or to wet-tolerant pasture species for big game. In a few cases, especially where sand or dredge spoils are deposited, marsh creation may be required in the reclamation plan.

Interdune areas also may be hummocky, with islands of sand partially stabilized by dunegrasses. These areas are not easily vegetated without shaping and grading to eliminate the hummocks or to make them fit the contour of the land. Hummocky interdune areas have high recreational value and so revegetation may be undesirable. If necessary, leveled hummocks are stabilized to dunegrasses.

Deflation plains can be rapidly invaded by woody plants, particularly Hooker willow, which some land users may not want. Pasture grasses and legumes drill-seeded on the deflation plain can retard willow invasion.

3. **Interior Dune Areas.** This zone is the farthest inland, usually adjacent to headlands, and contains several types of dunes (Crook 1979). These dunes may be unvegetated or vegetated older dunes. Interior dune areas are not subject to appreciable ocean sand supply. They may be active dunes of low transverse ridges or massive oblique ridges, which are characteristic in open unvegetated areas; or they may be blowouts in vegetated areas, which can result sometimes in a giant trough ending in a large accumulation of sand on a previously vegetated area. These giant troughs are called parabola dunes and often are fed by oblique ridge dunes.

Interior dunes are stabilized initially to dunegrasses, similar to treatment of foredunes. Large open dune areas are easier to stabilize than small blowouts on stabilized dunes, because large open areas can be more easily shaped without damaging adjacent vegetation.

Secondary plantings into established dunegrasses provide more permanent control. Plantings may be herbaceous grasses and legumes, woody shrubs, trees, or combinations. These plantings should emphasize fire retardance, wildlife habitat, and improved stabilization. Because inner dunes do not receive salt spray, certain landscape ornamentals can be grown if cared for properly.

Wildlife habitat plantings should be a mixture of forest, shrubland, and open grassy areas. Some open sand may even be desirable. Older stabilized dunes with a weakly developed soil profile are fragile environments even if covered by tall trees and thick underbrush. Disturbance of the plant cover and thin topsoil can be catastrophic because most roots usually are concentrated near the top duff layer to capture moisture and nutrients that have accumulated.

Dunes that have been stable for hundreds or thousands of years have a deep, well-developed soil profile and are not classified as dune sand in soil survey reports. These soils are also underlain with moderately cemented sand. Blowouts are rare on these soils, but deep road cuts and excavations expose the underlying uncemented sands to blowing.

An example of damage to an older stabilized dune area occurred on a golf course in Oregon. The course contained stabilized dunes that separated the fairways. These dunes had a dense cover of salal, huckleberry, and 40-foot shore pine. Because players often lost golf balls in the dense cover, the owner removed all the brushy species and left the beautiful stand of pine trees. However, all the pine trees died during the first summer because removing the ground cover increased the loss of water through evaporation.

Rather than leave the ground bare, the owner could have used bark mulch to cover the area. Placement of bark mulch 3 or 4 inches thick can prevent massive water loss. In all cases, changes to older, stabilized areas should be carefully planned and thought out before they are undertaken.

Before disturbing a site, the stabilization team may examine root profiles to determine where roots are distributed in the soil or sand and to identify trouble spots to be avoided when grading. Root profiles are core samples taken on a grid superimposed over the site. Actual disturbance must be kept to a minimum and the area disturbed should be mulched heavily with 3 to 4 inches of bark dust immediately after disturbance.

Also most important is the effect of depth of disturbance on the existing vegetation. A deep cut on sloping land may drain the water table and source of moisture for shrubs and trees upslope. Woody plants usually have an extensive feeder root system in the top foot of the soil. However, large roots also penetrate deep into the sand to the top of the ground water table; therefore, plants survive seasonal dry periods. Disturbing the top surface layer or lowering the water table can be the two activities having the most destabilizing effect on older vegetated dunes.

Care must be taken to avoid creating wind tunnels during construction or other activity on tree-covered dunes. Tunnels could result in serious blowouts, which can be difficult and expensive to repair. Dunegrass can stabilize blowouts. However, establishing dunegrass may be difficult along the edges where competition and shading from the adjacent woody vegetation may be the most extensive.

The dune management area concept has been used successfully by the U.S. Army Corps of Engineers (1974) to manage dredge spoil disposal and stabilization along Oregon's coast. The Warrenton Soil and Water Conservation District, formed to control dune formation and movement on the Clatsop Plains, uses this concept also. The district delineated two zones and tailored ordinance restrictions to each (Reckendorf 1975 and Reckendorf et al. 1985). More than 3,000 acres were stabilized in a large-scale effort during the thirties and forties. It has been the most successful dune management program to date on the Pacific coast and one of the most successful in the world.

Site Investigation

Site investigation reports, proposed by Ternyik (1979a), help the planner and the landowner answer key questions about dune management: How does stabilizing this site fit into the planning objectives of the dune management area? What effect will the work have on adjacent land? What are the physical and biological

Agricultural use of interior, older stabilized dunes is decreasing.

conditions in the area? Is maintenance feasible and practical?

Appendix II is a checklist adapted for site investigation on the Oregon coast (Nelson 1976). Help in site investigation is available from local soil and water conservation districts, other local agencies, and consultants.

An effective stabilization plan mimics and accelerates the natural process of plant establishment on sand dunes. Planting sand-stilling grasses imitates the natural invasion of pioneer species on the dune. One of three naturally occurring dunegrasses is used as the pioneer.

As the dune is stabilized by the initial plantings, other grasses, herbs, and legumes can be introduced to increase the content of organic matter in the top sand layer. More permanent woody plants are established in the humus of the stabilized dune and can volunteer from surrounding forest areas as the natural process of succession takes over.

Maintenance

As important as forethought in planning a stabilization project is maintenance of the plant cover. Maintenance involves more than completing all phases of establishment of a new planting. Also essential are human and vehicular traffic control, adequate fire control measures, and revegetating disturbed or thinned-out areas even in old, well-established plantings.

The best way to spot trouble is to check the project systematically three or four times a year and after each major occurrence of high wind. Maintaining a sand dune takes commitment to realize a return on the investment.

The six steps required to stabilize an active dune permanently are:

1. **Prepare the site.** This step may entail the use of temporary mulches, blankets, and sand-trapping fences; grading the site to conform it to the landscape; and minimizing the effects of wind on the proposed planting.

2. **Plant sand-stilling dunegrasses.** This is by far the most dramatic, visible step.

3. **Maintain dunegrass stands.** Replanting and fertilizing are the primary tools for maintaining an even vegetal cover. Temporary mechanical aids may be useful.

4. **Plant secondary grasses, legumes, shrubs, or trees.** Usually done 2 years after planting, this step greatly accelerates the stabilization of the dune. If secondary plantings are not made, dunegrass must be fertilized continually to maintain adequate stands and dune cover until succession introduces secondary species.

5. **Maintain secondary plantings.** Low-vigor spots mean that any vegetation, including dunegrass, will not protect the site for long. They must be fertilized and, if a small blowout has occurred, must be replanted as well.

6. **Incorporate landscape plantings.** Ornamental or general landscape plantings for homesites, parks, roadways, and other uses are common on stabilized dunes. Such plantings are expensive and may require expensive maintenance, particularly irrigation, mulching, pruning, fertilizing, mowing, fencing, and weed control. These plantings usually are incidental to dune control but eventually are made for the most prevalent land uses on stabilized dune land. Such plantings must take into account the unique nutrient, wind, moisture, and salinity conditions on stabilized dunes, as well as the consequences of leaving any area devoid of vegetation.

Fenced walkways often are useful in planted areas that are highly susceptible to scour and blowouts. They can also reduce maintenance costs.

Sand-Stilling Dunegrasses for Initial Stabilization

Species

Beach or dunegrasses are the most widely useful sand-stilling plants for initial plantings on coastal areas. These grasses should be native or well suited to the area in which they are planted. When the proper species are planted correctly, they are effective even against high-velocity winds heavily laden with sand. They are successful because (1) their coarse stems protect the surface against scouring; (2) they grow rapidly up through heavy deposits of sand, as much as 2 feet or more in a single season; (3) their stems multiply rapidly from underground nodes, forming large clumps; and (4) they develop extensive root systems and, in some cases, horizontal underground stems capable of growing into unvegetated areas and producing new clumps.

Initial stabilization of moving sand in the Pacific Northwest has been accomplished largely through the use of three sand-stilling grasses: European beachgrass, American beachgrass, and American dunegrass.

European beachgrass is the most widely used, primarily because its production costs are much lower, it transplants easily, and it has more vigorous top growth. Except for special uses that require American beachgrass or American dunegrass, European beachgrass should be used for initially stabilizing active dunes.

European beachgrass forms a tight cover where fertility is maintained by continual sand deposition. Healthy plants produce rhizomes up to 40 feet long in a single year.

European beachgrass has naturalized on the Pacific coast since it was introduced from Europe in the late 19th century to control sand dunes. It has coarse, stiff stems and tough leaves that resist sand blasting. Four different types occur naturally: Tall, coarse, and bunchy; tall, coarse, and creeping; short, fine, and bunchy; and short, fine, and creeping.

The best type for foredunes is tall, coarse, and creeping, although the other forms could be used, depending on the purpose. Tillering can vary from 10 to 120 per culm per year. The strain commonly used commercially tillers at a 40:1 rate.

European beachgrass requires a continuous supply of sand to provide nutrients, promote tillering and rhizome development, and maintain stands. Unless fertilized, plants receiving no new sand die out and are replaced by succeeding vegetation. European beachgrass produces numerous seedheads, a feature that has accelerated its naturalization along the Pacific coast and created the typical foredune landform so prevalent. However, direct seedings are not practical because seedlings develop too slowly to permit adequate ground cover in most cases.

American beachgrass, native to the Atlantic coast, is occasionally used to repair blowouts because of its ability to establish quickly and resist the border effect of competing vegetation.

Native American dunegrass has wider leaves and a darker lime-green color than European beachgrass. It can form complete cover on large foredune areas; however, it is more difficult to establish and usually increases through natural reseeding.

Despite variation within the species, there are no cultivars of European beachgrass and few commercial sources. Buyers usually should specify the tall, coarse, creeping type for most jobs.

American beachgrass use is limited to patching small blowouts and rarely for planting foredunes. It is strongly rhizomatous and competes well with European beachgrass. Newly planted American culms readily establish adjacent to well-developed European stands, primarily because of rapid rhizome development. Some American strains can produce close to 400 feet of rhizomes per plant per year, nearly 10 times as much as the better European strains.

American beachgrass persists where continual sand supply provides nutrients and is less likely than European beachgrass to survive when sand no longer accumulates. Although this plant is strongly rhizomatous, leaves and stems grow less rapidly than the European variety; therefore, American beachgrass does not control sand movement as well.

American beachgrass is native to the Atlantic coast and Great Lakes area. 'Cape,' a cultivar released by the Cape May (New Jersey) Plant Materials Center in 1971, originates from Cape Cod, Massachusetts, and performs well on the Pacific coast. However, it remains dormant longer than naturalized stands, creating a greater fire hazard. 'Hatteras,' a cultivar from North Carolina, may have shorter dormancy, but is untested on the Pacific coast. Naturalized tall, coarse, creeping strains are the source for nearly all plantings of American beachgrass in the Northwest. Naturalized stands are scarce and scattered along the Pacific coast, limited primarily to old planting sites. Commercial quantities therefore, are limited. American beachgrass is four times more costly to produce than European.

American dunegrass, previously the least planted of the three dunegrasses, is the only native dunegrass of the Pacific coast. Its main drawback is its low transplant survival, usually 25 percent or less, whereas 98 percent is essential for complete cover. In the past, plantings of this species have been limited to foredune areas, where it is found naturally. It also needs continuous sand supply to maintain stands and is less adapted than the beachgrasses to sites farther inland. Large natural stands are found in Clatsop County, Oregon, between Seaside and Warrenton, particularly near Sunset Beach. They seem to be increasing in recent years, supplanting European beachgrass. American dunegrass has wider leaves than the beachgrasses and often has an attractive lime green appearance, hence one of its common names, sea lyme-grass.

American dunegrass has increased in prevalence within foredune plant communities during recent years, particularly along the northern Oregon coast. It is often seen invading open sites and supplanting European beachgrass as the dominant vegetation.

American dunegrass must be transplanted while dormant to achieve the best establishment. This limits flexibility in planting, harvesting, and storing culms. Despite these limitations, interest in its use has increased in the past decade. Consideration should be given to including at least small amounts in mixture with European beachgrass.

Natural populations of American dunegrass on the Pacific coast have more pubescent seed heads and culms than the very closely related beach wildrye found along coastlines throughout the hemisphere at northern latitudes. These coastal dunegrasses are related to robust inland wildryes such as basin wildrye and Asiatic species, giant wildrye and altai wildrye. American dunegrass is known to hybridize with native inland creeping wildrye, forming smaller plants with finer leaves. Perhaps there are traits within this group of plants that can help overcome the obstacles to greater use of American dunegrass on the Pacific coast.

American dunegrass seedheads usually contain few viable seeds. This is an obligate cross-pollinating species and, since large colonies may consist of a single plant, low seed set is not surprising. Some populations have been found to have good seed set, undoubtedly due to the presence of many individuals. Plantings should include vegetative material from several sources to increase seed production.

Unsuitable Plants

Most of the native or naturalized colonizing plants abundant on coastal dunes in the Northwest are not alone satisfactory for controlling sand movement. Many have unwanted growth characteristics, are shortlived, and can be fire hazards. The most common of these plants are presented in table 1. Many invade naturally into beachgrass plantings and add some diversity and additional stability. But, unless specialized landscaping of small protected areas is desired, or an open, hummocky appearance is desired, planting of these species does not justify the expense.

Table 1.—Plants not recommended for controlling sand movement in coastal dune areas

Common Name	Problem
Baltic rush	Insufficient ground cover in winter
Beach knotweed	Hummocking, caused by taproot
Beach silver-top	Hummocking, caused by taproot
Big headed sedge	Insufficient ground cover in winter
Dune morning glory	Hummocking, caused by taproot
Sand verbena	Hummocking, caused by taproot
Seashore tansy	Insufficient ground cover in winter
Silver beach-weed	Hummocking, caused by taproot

When To Plant Sand-Stilling Grasses

European and American beachgrass and American dunegrass should be planted when temperatures are between 32 and 60 °F. No planting should be done unless moisture is found within a depth of 3 inches of the dune surface. Most plantings are made during the cool, wet months from late fall through early spring (November 1 to April 15).

Proper temperature is critical. Work done by Brown (1942) at the Warrenton Project indicates erratic survival rates if temperature exceeds 60 °F within a 72-hour period after planting. The effect of warm temperatures late in the planting season can be somewhat minimized by planting at night. All transplanting stock is either stored at 35 °F or shade frames are placed 12 inches above the tops of heeled-in culm bundles. If plantings must be made during warm daytime temperatures, then each bundle of beachgrass is dipped in water to keep it from drying out during the planting process. To ensure success and minimize planting costs, select planting dates well before warm spring days or well after cool fall temperatures have set in.

Planting is not done during freeze periods. Therefore, November, February, and March usually are the best months to plant.

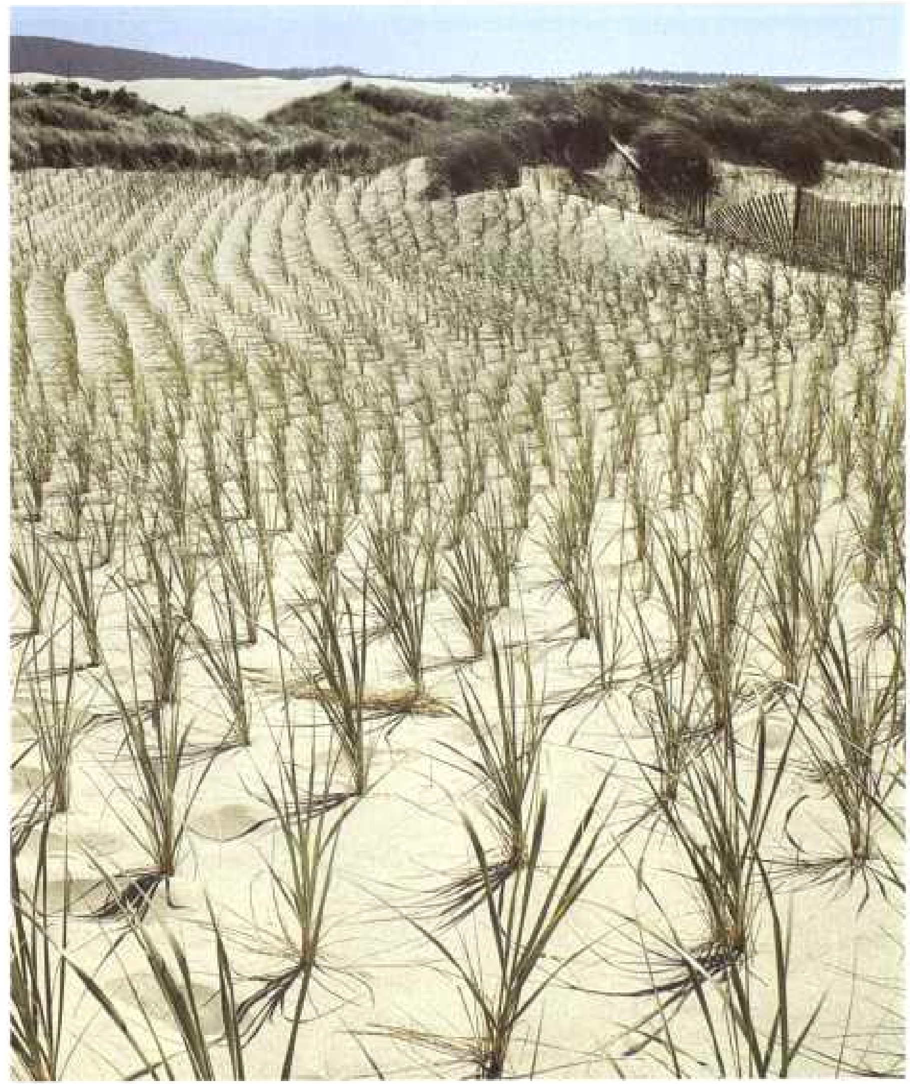
Plantings are usually successful during cool weather in these 3 months, even without precipitation for prolonged periods. Low-lying sites that are moist into early summer may be planted more safely later in middle to late spring than the higher, drier sites.

Plantings for the construction of foredunes should be made in the early spring after danger from severe storms is over. Plantings made earlier can be destroyed by very high tides. Plantings made early in spring establish themselves before the warm weather and grow rapidly as new sand accumulates on the dune throughout the season. A good planting may accumulate as much as 2 feet of sand annually.

Areas that are subject to winter submergence should be planted in the spring as the water level recedes. Plantings that have not experienced one growing season fail to withstand extended submergence without damage.

Planting Stock

Commercial beachgrass stock may be obtained from nurseries or natural stands of proper age and quality. Nursery stock is dug at 2 years, and thus is designated "2-0" stock. Most natural stands will not produce quality stock; it is only



Shown here is a properly spaced planting of European beachgrass about 4 months after planting.

Beachgrass nursery stock usually originates from fertilized, relatively open, young stands where plants have room to grow and produce large, healthy culms.

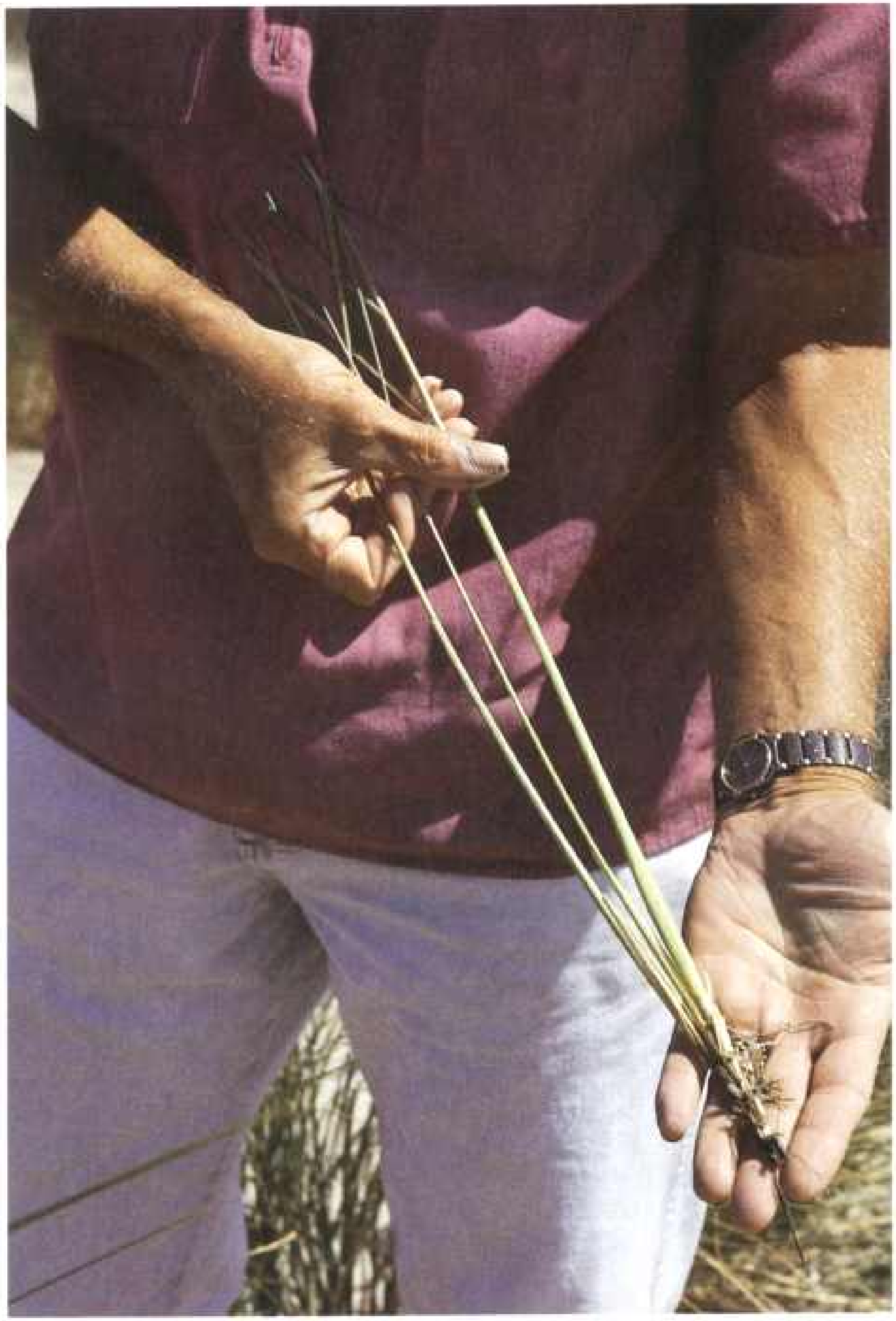
where new sand deposits on existing grass are fertilized that quality stock is produced. This results in 1-0 (1-year-old) stock from plants buried the previous season. Quality planting stock consists of young, vigorous, live culms with one to three root nodes and a minimum of old, dead material. It is not possible to dig old stands because of the excessive cost of removing old dead parts of individual plants. Because of varying growing depths caused by new windblown sand deposits, no specific digging depth is recommended. The grass should be dug at a depth that will ensure that all culms have one to three live root nodes remaining.

After being dug, grass is shaken free of sand, dead trash is cleaned from culms, and the hill or clump is broken into small bunches. Underground stems are broken back to one or two nodes. For convenience in stock accounting and handling, culms are tied into bundles of 10 pounds. After tying, the tops of the stock are cut back with an ax until the overall length is about 20 inches. This gets rid of long leaves that offer more surface for moisture loss and that are subject to wind agitation that could loosen the planted stem from the sand.

In nurseries, stock can be dug each year if given an annual application of fertilizer. When properly fertilized, a new crop will come up from underground stems or rootstalks. Nursery areas can be 95 percent dug without damage to the vegetative cover. New culms quickly regenerate from rhizomes.

Stock is harvested during the planting season. Stock should be collected during the cool, wet months from late fall through early spring (November 1 to April 15), when the plant is most nearly dormant. American dunegrass must be harvested when completely dormant. Dormant stock will have the greatest amount of stored energy and will, therefore, be more vigorous than culms from plants that are actively growing. The beachgrasses (European and American), however, will survive whether or not they are dormant, as long as the stock is harvested and planted in cool weather.

Storing of grass stock is confined to "heeling-in" on the nursery or planting site. It is important when heeling-in to keep the beds narrow, not over two bundles wide, in order to avoid heating of the grass. Bundles should be buried in the trench to a depth of approximately one-half their length, and sand firmed around them. The grass should not be heeled-in where water will stand on the bed as this will cause decomposition of the basal buds of the stem. The heeling-in bed should be a well-drained, damp trench with the roots (nodes) covered to a depth of at least 8 inches. Stock should not be held in heeling-in beds for more than 2 weeks. If



A three-culm propagule is approximately 20 inches long.

planting is late in the season, then either shade frames over the heel-in beds or artificial cold storage at 35 °F is recommended.

Tools for Planting

The most widely used tool for handplanting of beachgrass is the D-handle tile spade with an 18-inch blade. This can be thrust directly to a depth of 12 inches into the sand and provides the best hole that can be achieved for easy planting of the beachgrass culms. Planters normally make several hundred holes with this tool before planting.

Steep slopes must be planted by hand. However, on the less sloping areas, transplanting machines have been used with success since I960 for larger plantings of 5 acres or more from Santa Maria, California, to Westport, Washington (Ternyik 1979b).

The planting machines now used for large plantings are modified, commercial row crop transplanting machines. The planting shoe was redesigned to get the 12-inch depths specified for beachgrass plantings. Pulling these machines are small, crawler type tractors equipped with a rear-mounted hydraulic hitch. Two machines are now used behind each tractor, with four people on the machines. This combination will allow five people (including driver) to plant from 1 to 3 acres per day, depending on the conditions at the site. The primary conditions determining planting speed are weather, degree of slope, and type of sand.

Methods of Planting

Beachgrasses should be planted to a depth of 12 inches and the sand compacted to remove air around the roots and stem nodes. The top of the plant should be upright and extend approximately 8 inches above the ground.

Handplanting requires wet sand, otherwise holes are not open and the planters break the stock trying to force it into a closed hole. This results in high plant mortality. Transplanting machines can plant through 6 inches of dry sand. As a last resort, irrigation also can prepare a dry dune for planting.

For most sites along the Pacific coast, a hill spacing of 18 inches, with three culms per hill is sufficient. On sites exposed to more severe weathering, in areas surrounded by particularly valuable property, or on steep slopes or sand sea cliffs, closer planting with hill spacing approximately 12 inches and up to five culms per hill is needed. Well-protected sites can be stabilized by wider-than-normal spacings. A summary of planting rates that were found to be successful on the

A

A beachgrass hand-planting operation includes (a) opening a 12-inch-deep hole in wet sand with a tile spade, (b) placing a beachgrass propagule in the hole and leaving an 8-inch top, and (c) tamping sand around the propagule with the heel of a boot.

B

C

Clatsop Plains area are given in table 2. True economy in planting is achieved when hill spacing and the number of culms per hill are adjusted to the onsite conditions.

Fertilizing the Plantings

All planted areas should be fertilized with coarse-particle ammonium sulfate commercial fertilizer (N-P-K 21-0-0). This formulation should be applied at a rate of 42 pounds of available nitrogen per acre (200 pounds) during a period of light wind and steady rain. Rain is needed to thoroughly dissolve the fertilizer—a minimum of 4 hours of light rain or 2 hours of a downpour. If this is not done, fertilizer granules will be transported by winds, resulting in uneven distribution. Experience and weather forecasts are vital to ensure that the fertilizer is dissolved shortly after broadcasting. Irrigation may be substituted for rain, but usually is costly.

If the forward slope is steep or if sand sea cliffs have been planted, fertilizer must be applied immediately after planting so that it can be caught in the footprints left by the planting operation. If not, the fertilizer will filter to the bottom of the slope as the sand dries and no growth will occur on upper slopes. It is recommended that fertilizer application on these steep banks be

Until adequate tree growth results, beachgrass must be fertilized or interseeded with legumes to maintain adequate cover. Here a small bare area has appeared.

doubled to 400 pounds of N-P-K 21-0-0 per acre. If necessary, irrigate lightly and long enough to dissolve the fertilizer.

In cases where planting stock is scarce, the use of fertilizer on plantings with wider-than-normal spacing may be cheaper than deferring planting until more stock becomes available.

Followup fertilization on established plantings is best done on the Pacific coast dunes when the most rapid spring growth begins. In Washington, this is April 1 to April 15; in Oregon, it is March 1 to April 1; and in California, it is February 15 to March 1. There is usually plenty of moisture at these times and this permits the fertilizer to penetrate to the grass root system.

Most fertilizer is applied by hand, out of buckets, or with hand-operated cyclone type spreaders. This is because newly planted beachgrass is severely damaged by tractor-mounted spreaders. Two-year-old, well-established beachgrass plantings can be fertilized with tractor-mounted spreaders with little damage. Fertilizer usually is not spread by airplane unless the almost ever-present winds, which tend to drift the fertilizer, are absent.

This site needs fertilizer to maintain adequate cover.

Maintaining Dunegrass Stands

In this initial stage of dune stabilization it is important to develop and maintain an even vegetal cover that is devoid of breaks until secondary or permanent cover is established. Some maintenance is usually necessary because of poor hill survival, excessively wide spacing, or failure to plant all exposed areas. This requires temporary brush mats in summer and prompt replanting in the winter. American beachgrass is the most satisfactory plant for such repair work because it competes better than European beachgrass with surrounding European beachgrass systems (McLaughlin and Brown 1942).

Table 2.—Hill spacing and culms per hill for European beachgrass

	High-intensity stabilization		Moderate-intensity stabilization	
Site conditions	Spacing	Culms	Spacing	Culms
	Inches	*Number*	*Inches*	*Number*
Steep slopes				
Windward				
Dry	12 by 12	3	18 by 18	5
Moist	18 by 18	5	18 by 18	3
Leeward				
Dry	18 by 18	5	18 by 18	3
Moist	18 by 18	3	24 by 24	5
Flat areas				
Exposed to high winds				
Dry	18 by 18	5	18 by 18	3
Moist	18 by 18	5	18 by 18	3
Exposed to moderate winds				
Dry	18 by 18	3	18 by 18	5
Moist	18 by 18	5	24 by 24	5
Irregular topography				
Exposed to high winds				
Dry	12 by 12	5	18 by 18	5
Moist	18 by 18	5	18 by 18	3
Exposed to moderate winds				
Dry	18 by 18	5	18 by 18	3
Moist	18 by 18	5	18 by 18	3

Table 2.—Hill spacing and culms per hill for European beachgrass (Continued)

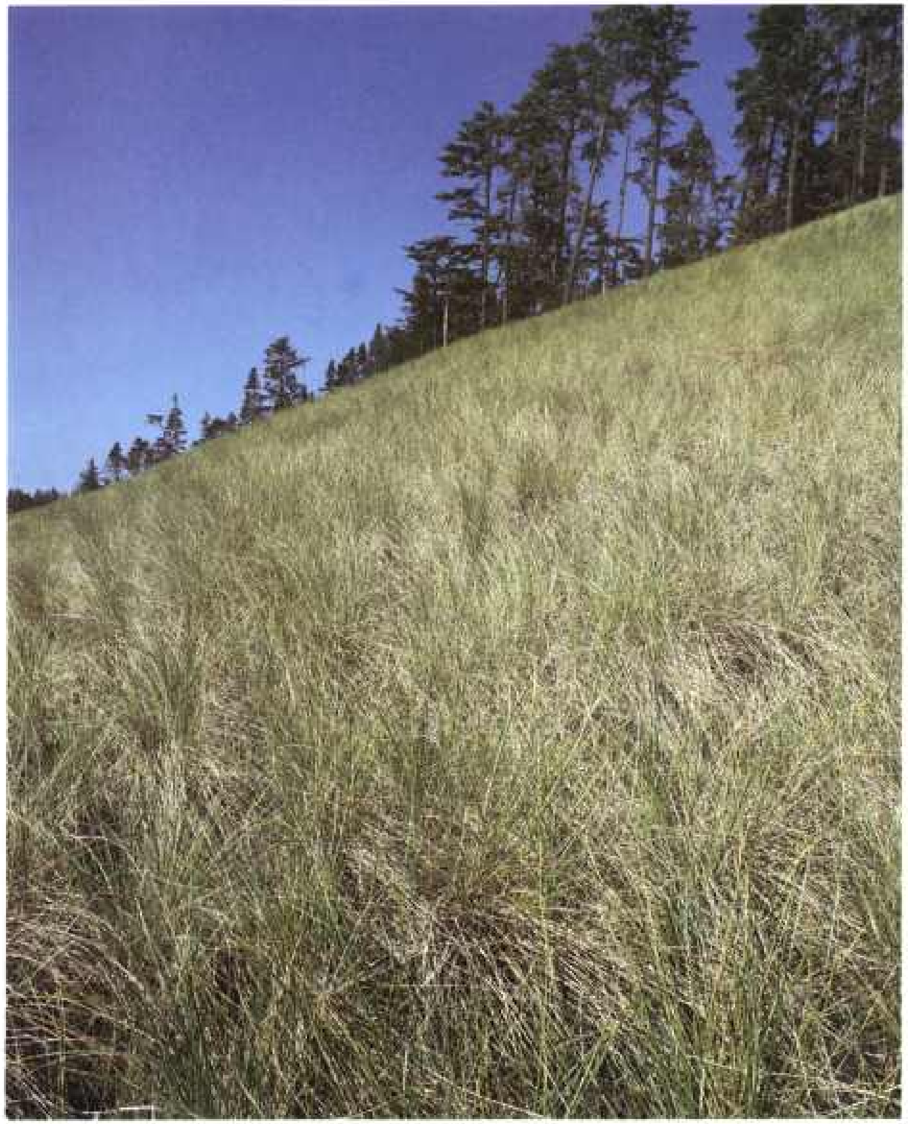
Site conditions	High-intensity stabilization		Moderate-intensity stabilization	
	Spacing	Culms	Spacing	Culms
	Inches	*Number*	*Inches*	*Number*
Valuable property				
Exposed to high winds				
Dry	12 by 12	5	12 by 12	3
Moist	12 by 12	3	18 by 18	5
Exposed to moderate winds				
Dry	12 by 12	3	18 by 18	5
Moist	12 by 12	3	18 by 18	5
Foredune*				
Windward face	18 by 18	3	-	-
Leeward face	18 by 18	5	-	-
Top	12 by 12	5	-	-

*All foredune areas are planted using the high-intensity approach.

Well-timed fertilization early in fall or in spring increases growth of low-vigor spots. A new planting should be checked at least monthly and after each major wind event to determine maintenance needs. A second-year planting should be inspected at least every other month.

Establishing and Maintaining a Source of Beachgrass

Unlike east coast nursery operations, where beachgrass is grown in cultivated fields, on the west coast it is grown in open sand. Carefully selected nursery sites are picked where



This large roadside cut and fill planting of European beachgrass near North Bend, Oregon, must be fertilized or interseeded with legumes to maintain adequate cover.

Above, vehicular and foot traffic should be controlled to protect beachgrass plantings that cannot withstand repeated trampling. Right, Douglas-fir and sitka spruce stumps can be used to protect plantings.

a continuing incoming sand supply is present. If new sand does not cover the nursery area, then a 3-year digging period is maximum. After the third season on such sites, the grass fails to meet specified size. One 100-acre planting will require 6 million culms of beachgrass. Therefore, identification of adequate-quality planting stock is essential. One commercial nursery in Florence, Oregon, maintains a 10- to 12-million in-field inventory of European beachgrass and 100,000 culm in-ground supply of American beachgrass and American dunegrass. The primary factor in nursery production is the ability to maintain vigorous, clean stands of grass requiring a minimum of cleaning during the digging process.

Permanent Cover

Shore lupine is a legume that often invades infertile sites where beachgrass has declined and sand deposition is not excessive. It is a prolific reseeder.

The main sand-stilling plants—European and American beachgrass and American dunegrass—begin to lose some of their vigor after a few years and it may be difficult to maintain cover. Dead stalks accumulate in the new growth, and some plants die. This causes the planted area to become patchy with open sand areas. Before this stage, it is advisable to ensure the development of a permanent cover by seeding longer lived grasses and legumes or by transplanting woody plants.

Species

Legumes help overcome the nitrogen deficiency of sandy soils, and thus help stimulate the growth of the grasses. Several species of legumes can be used. The most common are lupine, beach pea, perennial pea, and vetch.

Seashore lupine is a low-growing legume native to the dunes of the Northern Pacific coast. Its seeds germinate readily and the plants usually set a crop of seed the first season. In places, lupine develops so rapidly that it soon forms almost solid cover among the European beachgrass culms.

Purple beachpea is a fire-resistant legume and an excellent choice to seed into established beachgrass. It fixes nitrogen from the air and releases it for use by beachgrass.

Seashore lupine is short lived; thick initial stands steadily decline and seldom last 5 years. But, having increased the organic matter content and fertility of the soil, this plant leaves the ground surface in a condition suitable for establishing more permanent vegetation.

Purple beach pea produces more biomass than seashore lupine and is very fire resistant, an important factor to consider when interplanting beachgrass. It is slower to establish but more persistent, forming a thick viny growth. Stands usually are not fully developed until the third or fourth year after seeding. Seed and foliage are valuable to wildlife for food and cover. Beach pea, although not native, is found naturally along the coast from Alaska to California.

Unfortunately, seashore lupine and beach pea are not commercially available on a regular basis, and seed must be hand collected. This limits their use. Testing is underway to select and release cultivars of seashore lupine and purple beach pea for commercial production.

Recent evaluations at Ocean Shores, Washington, have compared the relative vigor of several commercially available legumes in areas stabilized with beachgrass. Perennial pea, pine lupine, and hairy vetch show the most promise as alternatives to seashore lupine and beach pea for large-scale seedings.

Perennial pea is slow in developing but persistent, with characteristics similar to beach pea. It is commonly found along roadsides farther inland, but can be established in beachgrass, though with less reliability.

Pine lupine is a robust, short-lived perennial native common to the coastal mountains of the Pacific Northwest. 'Hederma,' an improved cultivar, has shown promise on dredge spoils and stabilized coastal dunes.

Hairy vetch is a vigorous sprawling annual that reseeds sporadically, but can be used as a short-term planting to increase fertility. It is readily available commercially.

Scotch broom is a naturalized leguminous shrub. It is a vigorous and upright plant, reaching 6 feet, and offers resistance to fire in beachgrass plantings. Direct seedings are only sporadically successful but the plant should be transplanted. Scotch broom provides good wildlife food and cover and early wind protection for permanent tree and shrub plantings. However, scotch broom is considered by many to be an undesirable weed, particularly inland from coastal areas, where it may spread by seed to invade disturbed sites usually low in fertility and marginal for plant growth. Although it has many desirable characteristics and has been used extensively in the past, scotch broom seldom is interplanted into beachgrass-stabilized dunes today.

Tree lupine is a native leguminous shrub adapted to stabilized dunes

This mixture of beachpea and American dunegrass provides a cover that will not burn.

south of Newport, Oregon. It grows rapidly, gives excellent ground cover, and provides abundant litter for aiding fertility, but it may freeze out during severe winters. Plants can be found as far north as the central Washington coast, but losses resulting from freezing are more frequent in the northern reaches. Stands can be established by direct seeding, producing 4-foot plants after 2 years. Transplants have not been reliably established. Seed usually is not available commercially and must be hand collected.

Among native long-lived grasses that have been successfully seeded into initial dunegrass plantings are seashore bluegrass and red fescue. Seashore bluegrass withstands some sand deposition and survives under difficult conditions. It spreads rapidly by seed and by rhizomes that take root to form new plants. It is well suited to seeding, along with seashore lupine, into initial plantings of European or American beachgrass. Seashore bluegrass is not widely used because there is no commercial production and seed must be collected by hand. During the 1940's, a limited amount of seed from cultivated fields was produced on a trial basis near Astoria, Oregon. This species never advanced beyond this stage, giving way to red fescue, which could be readily supplied through the turfgrass trade.

Red fescue survives well in sand that is almost entirely stilled, but it cannot withstand sand deposition as well as seashore bluegrass. Nevertheless, fescue is widely used and covers large areas of coastal dunes, especially on drier sites. 'Clatsop' is a cultivar that was developed for sand dune seedings, but has not been produced for several years. Creeping red fescue, a rhizomatous form, is commercially available. 'Illahee' and 'Rainier' are adapted northwestern cultivars that can be used for permanent cover on sand dunes.

Tetraploid perennial ryegrass recently has been tested on sand dunes and dredge spoils. This species should form only a small percentage of a seed mixture because it may crowd out other species. It can be considered for quick short-lived cover while other, more persistent species develop. It has been seeded successfully alone for goose pasture on dredge spoils.

Another grass that has performed well recently on sandy dredge spoils is tall wheatgrass, which is very robust and tolerates saline conditions. Further testing may prove its adaptability on sand dunes.

Shrubs, in addition to the two woody legumes above, and trees can be successfully established in 2-year-old beachgrass/dunegrass stands. Shore pine is a small native tree that naturally invades newly stabilized dunes and can form dense thickets on deflation plains. It also is very easy to establish by transplanting and has been used extensively for permanent cover. After initial establishment, shore pine normally grows 2 feet per year on good sites. At the present time, shore pine is the most commonly used species for secondary stabilization.

Coyote brush is a native long-lived shrub that is transplanted into beachgrass plantings along the southern Oregon and northern California coasts. It forms a mounding cover. Prostrate to upright forms are available in the nursery trade. Container transplants are cuttings grown from male plants.

Other native woody plants can be used for permanent cover, particularly on wet sites. Red alder fixes nitrogen, grows rapidly, and gives way to climax species. It often volunteers naturally around deflation plains. However, high-velocity winds cause branch tips to burn back, limiting red alder's effectiveness in exposed areas. Hooker willow invades permanently wet sites. Its pliable stems and mounding habit also enable it to catch sand effectively. Plantings are easily established from hardwood cuttings stuck in permanently moist ground.

Oregon crabapple is native to the Pacific coast along riverbanks and lake shores. It is a long-lived tree that grows to 20 feet but in extreme wind can form a dense mat low to the ground. Fruits are readily eaten by birds.

Seashore bluegrass, a native perennial grass, can be interseeded in combination with legumes into beachgrass.

Autumn olive is an introduced shrub that has shown promise in recent tests on dunes stabilized by beachgrass. Although not a legume, it fixes its own nitrogen, and in the fall it produces an abundant crop of red berries that are relished by birds. The 'Elsberry' variety grows 6 to 8 feet high and to twice as wide, and appears to be well adapted to Pacific coast conditions.

Native Seed Harvest

Beach pea and lupine seed should be collected by hand because the seeds do not all ripen at the same time and natural stands usually are not of uniform density for economical mechanical harvesting. Pea moth infestations often destroy ripening seeds in both species. Pods should be collected after the seeds have begun to show a mottled color but before the pods dry and open. The pods should be spread on a canvas sheet to dry in the sun. They may also be dried by slight artificial heat. Seeds shatter out as the pods dry and open.

Collecting seeds of native grasses, such as seashore bluegrass, is laborious and expensive. On small lots it is easiest to strip the seed heads by hand or to clip them with a hand sickle. Occasional pure stands, covering a relatively large area, can be harvested with a mowing machine or a small combine. Seed is processed with conventional air-screen cleaners.

Planting Times and Seed Mixtures for Grasses and Legumes

It is best to defer permanent cover plantings until initial beachgrass plantings are 2 years old. The period when these plantings should be made will vary greatly under different conditions. However, it should not be delayed much after the sand is stilled, for two reasons: (1) vegetative competition from the initial plantings soon becomes too keen; and (2) as stands of beachgrass get older, sand can dry to a greater depth than young grasses and legume seedlings can tolerate.

Seeding may be done in the fall or early in the spring. Fall is preferred because legumes and grasses seeded in the spring often fail to germinate until the next fall. This is usually because of hard-seeded legumes or the lack of moisture.

The suggested seed mixture for drier sites is:

Species	Cultivar	Pounds/Acre
Seashore lupine	Native collection	5
Seashore bluegrass	Native collection	5
Purple beach pea	Native collection	20
Creeping red fescue	'Illahee,' 'Rainier'	12

Up to 30 pounds per acre of tree lupine may be added to this mixture.

If the lupine, bluegrass, and beach pea are not available, an alternate mixture of seed normally available on the commercial market can be used as follows:

Species	Cultivar	Pounds/Acre
Creeping red fescue	'Illahee,' 'Rainier'	12
Tetraploid perennial ryegrass	Locally adapted	3
Pine lupine	'Hederma'	20
Perennial pea	Commercial-common	20

Sand dune plant communities contain a diverse array of native and indigenous forbs, ground covers, and herbs. Shown here are beach morning glory (above top), sand knotweed (above, bottom), and wild strawberry (right). These plants generally do not have growth forms or root systems that enable them to be primary stabilization plants. Their presence as understory plants should be encouraged.

Substitutes include tree lupine for pine lupine or perennial pea, or hairy vetch for pine lupine. Both should be seeded at 20 to 30 pounds per acre.

Seeding Methods

Drill all seeds in order to cover them and to ensure uniform distribution. Rice hulls (obtained from California) should be used as a seed carrier to ensure even seeding through the drill when the mixture contains both large and small seeds. In irregular, rough areas the seeds should be broadcast. When seed is broadcast, mulching by clipping existing vegetation or by scattering straw or similar material greatly increases the chances for a successful even stand. All permanent seedings should be fertilized with 40 pounds of nitrogen and 80 pounds each of phosphorus and potassium per acre at the time of planting.

Fire Control

Care should be taken to plan for vegetative firebreaks in a woody habitat. Purple beach pea or scotch broom are green at the peak of fire season, and both are nitrogen-producing legumes, so grass cover mixed with them also tends to be green during this period. Racing fires seldom burn more than a few feet into either species.

Firebreak plantings should consist of interplanting beachgrass in 50-foot-wide bands interseeded with purple beach pea, at 20 lb/acre, or scotch broom, transplanted on 3-foot centers. Purple beach pea is well worth the expense of seed collection because of its superior fire-suppressing qualities. This legume also does not leave a large, lasting dry residue when it dies down in the fall.

Beachgrass will burn easily during the drier summer months, particularly older stands with a high percentage of dead stubble and chaff. Burns are common near parking lots and along roads.

Beachgrass plantings behind the foredune usually are planted to native shore pine. When the plantings are sufficiently tall and dense, they moderate wind velocities at the ground surface and control sand movement.

Shrubs and trees adapted to duneland immediately behind the foredune must be resistant to burning by wind. Shown here are shore pine, Oregon myrtle, and scotch broom. They are formed by the wind and conform to the landscape.

Woody Plantings

Shore pine usually is planted on 8-foot centers, between December and February after beachgrass plantings are 2 years old. It becomes the dominant vegetation after 10 to 12 years.

In most instances, woody plantings are made in place of permanent grass-legume seedings rather than in combination with them. Either way is acceptable, although combination plantings may result in thinner stands of woody plants. Often, it may be desirable to alternate herbaceous with woody plantings to increase diversity and create more edge for wildlife habitat.

Coyote brush, used from southern Oregon southward, transplants readily but is slower growing and therefore should be spaced closer together. It provides a low 2 1/2- to 3-foot high cover that supplants beachgrass in the interdune area and behind foredunes.

Besides providing a more stable cover, woody plantings also can "correct" uneven topography, reducing wind turbulence and eliminating wind tunnels. Both shore pine and scotch broom are resistant to wind. Shore pine especially becomes wind formed, conforming to the landscape.

Climax species such as sitka spruce and western hemlock are not planted on stabilized dunes because they volunteer readily into shore pine plantations. Douglas fir, although found naturally in some stabilized dune areas, is only marginally adapted. It tends to become wind damaged rather than wind formed.

Planting Methods

Shore pine, coyote brush, Oregon crabapple, and most other species are easily grown in nurseries. All stock should meet American Nursery Association's standards. All except shore pine should be planted as 1-0 seedlings to keep costs of large-scale mass plantings down. Shore pine should be 2-0 stock. Plantings from wildlings are not recommended because it is very difficult to dig up a sufficient root mass necessary for a high rate of transplant survival.

Broadleaf woody species should be 12 inches in height when transplanted. If taller, the tops are subject to wind burn during their establishment period. The minimum diameter of woody plants should be one-eighth of an inch measured at 1 inch above the root collar. Diameters of one-fourth of an inch are preferred because these plants will withstand more severe site conditions. All tips should be clipped back to about 12 inches in order to make planting easier.

The minimum-maximum range in height for shore pine or other conifers is 6 to 12 inches. The most convenient size for planting is 8 to 10 inches. Larger stock may be clipped to the desired height without detrimental effects if it meets all other specifications. Minimum diameter at the root collar is one-eighth of an inch; maximum diameter should be no more than three-eighths of an inch or the stock becomes oversized and hard to plant. The root system should be well branched and have many fibrous feeder roots. Broken roots should be trimmed.

It is essential that all broadleaf and coniferous stock meet minimum specifications, be dormant, and be free from disease and insect pests.

Stock from a distant nursery usually comes in some type of bale. If the weather is not too warm and the bales are kept in the shade, the stock is often so well packed that it can be kept in the bales for a week. However, it must be checked closely for signs of drying or exposure to damaging heat.

Under most conditions, stock should be removed from the bale and placed in "heel-in" beds in a shady place under moist conditions. When "heeling-in," the soil should be firmly packed about the roots, which should be kept straight. Soil around the roots should be higher than the ground line.

The tool used for planting most stock is the D-handle tile spade, which is the same tool used in beachgrass planting. When planting, soil should be firmly packed around the roots to prevent air pockets. Woody plants should be set in the ground to the same depth as they were in the nursery. This is especially important for coniferous stock because such species are intolerant of being buried to an appreciable depth. Willows, however, can be planted deeper in the field than in the nursery.

Roots must be kept moist and out of wind and sun. In the field, the stock should be kept moist and wrapped in burlap in a pail or in special carrying trays.

Most transplanting must be done from December to February, when plants are dormant, to optimize survival. Survival rate during this period has often been uniformly higher than 90 percent (Brown and Hafenrichter, 1962). Slow release fertilizer in each transplanting hole can boost initial plant growth.

Fire, rodents, and humans are the principal hazards to successful plantings of woody vegetation. Fire lanes through shore pine plantings are essential. Mice, beaver, and rabbits can easily damage young plantings but can be controlled, if necessary, with baits or other approved means. Vacationers and others frequenting recreation areas must be prevented from digging plants, creating fire hazards, and indiscriminately trampling and trailing.

Trees or other woody species should not be planted in the area immediately adjacent to open sand areas. In such areas, continually incoming windblown sand will kill them.

Maintenance

Fertilizer application of 100 pounds per acre of 16-16-16 N-P-K is recommended, as needed, to maintain stand vigor and growth of grasses and legumes. Managers should be ready each fall and spring to spot-fertilize weak areas as they are found during routine followup checks. Stand failures should be reseeded. Woody plantings seldom need fertilizer or other maintenance unless to increase their landscape value. Transplant failures should be replanted.

Temporary Mechanical Aids

Where applicable, suitable aids include sand fences, brush matting, oil, and wire netting, bark mulch, grass mats, rock gravel, clay, stone or concrete, and logs.

An important use of mechanical aids is to catch sand and shape dunes for future stabilization.

Sand fencing is perhaps the most common temporary stabilization method. It has been used on the Pacific coast to temporarily control large, windblown movements of sand from open dune areas or recently disturbed areas. Sand fences have also been used to create foredunes or to fill beaches.

Sand fences can be used in two important ways:

1. When located at right angles to the prevailing winds, they cause temporary deposition of sand.

2. When set at a tangent to the prevailing winds, they direct sand-laden wind and may, in some instances, result in a desired intensification of scouring.

Fence material ranges from individual pickets 1 to 4 inches wide to a wire and lath snow fence. The fences are most effective when placed in two parallel rows about 30 feet apart. Proper positioning is critical, because improperly placed fences can cause inundation of areas needing protection.

Supports for the fences should be installed by using heavy duty steel posts 6 feet long, driven into the sand 8 feet apart. The end posts should be anchored in three directions. The fence wire should be firmly attached to each post at the top, middle, and bottom.

Picket-type fences were used to build the foredune on the Clatsop Plains dune area. Two parallel lines of fence, 30 feet apart, were used to create the proper and stable conformation of this dune. The fences were made of pickets 4 feet tall, 4 inches wide, and three-fourths of an inch thick. It was essential to keep the top of the fence even so that the resulting dune would have an even crest. Unevenness of topography causes wind agitation around the high spots, which is detrimental to the success of the structure.

In some cases, fences have been used to raise roadbeds across soft, wet, deflation plains where equipment could not be used to do the job. The correct distance between fences depends on the size of sand particles and the mean wind velocity. When fences are spaced too far apart, two separate dune crests form. This is not desirable. When the fences are too close together, or a single fence is used, the result is a sharp crest that is difficult to establish to vegetation. Proper spacing of the fences results in the formation of a broad-based dune with a single, gently rounded crest.

Sand fences are the most common temporary mechanical aids in a dune stabilization system.

Fences should be used with caution. In some cases, fences 4 feet high, placed 30 feet apart across prevailing winds have filled in within 1 week. The lee side of such a fence will sometimes have 50 feet of sloping sand from accretion. Because of the rapid results achieved with fences, it is recommended that they be used only under the direction of experienced advisors.

Movable sand fences and brush barricades have been constructed for some control projects. The movable fences are similar to the old "A" style snow fence. Brush barricades can be constructed by weaving brush into wire and fastening them to posts at 10- to 12-foot intervals, or by digging a trench and burying the ends of the brush to form a dense barricade with the upper tip leaning away from the prevailing wind.

Fences and brush barricades are only temporary sand-stilling measures. They may be used to check the progress of sand only until it can be covered with the vegetation essential for permanent control.

Brush matting has been an accepted temporary measure since the early days of dune stabilization. It stops sand blowing, serves as a temporary check to further scouring, and acts as a mulch.

The brush, which can be reject material from coastal greenery trade, is laid flat on the ground. A second row is laid to partly overlap the first, shinglewise. On steep banks, the brush may be staked down and further secured by wire.

Matting is successful only if combined with a followup planting or a seeding of sand-stilling grasses or shrubs. In practice, it has been found very difficult to obtain a uniform stand of vegetation in this manner. Spots not fully protected by the permanent species can be scoured by the wind as the mat deteriorates.

Asphalt oil is used as a stabilizer on cut slopes associated with highway or railroad construction. It is strictly a temporary measure and is easily destroyed by human or animal activity. Also, it is unsightly, costly, and can make it difficult to establish permanent plant cover.

At The Dalles, in interior Oregon, attempts were made to stabilize a 100-acre active dune using oil. After two attempts and several years' time lapse, the oil coating deteriorated and the dune area doubled in size. It was later totally covered with an expensive gravel blanket. Failure at any portion of an oil-treated area can result in rough, uneven terrain. This results in increased cost of followup stabilization.

Chicken wire netting is normally used to hold down either brush or straw matting on steep slopes. Wire can be used during the summer, when vegetative planting efforts are not feasible. It is also an effective method for obtaining immediate relief from wind erosion. The wire must be laced together and staked down at 10-foot intervals to be effective.

In recent years, fir or hemlock bark has been used for temporary stabilization. Bark is expensive, but it is much more tolerant of foot traffic than rock and is attractive. It also prevents loss of moisture from the underlying sand. Bark is available in several sizes, ranging from coarse bark rock to finely ground mulch. Bark rock should be used in areas of strong wind exposure, and bark mulch should be used in back or protected areas.

In using bark:

A. The entire area to be treated must be covered, particularly along the windward edge. Bare spots will scour and may cause a complete blowout.

B. The bark should be at least 5 feet from all wooden structures, as it can pose a significant fire hazard.

C. Unperforated plastic sheeting should not be placed beneath bark, for two reasons. First, bark is buoyant and the heavy winter rains will displace it. Second, bark will slide down a plastic sheet on a slope, especially in the rain.

A straw mat or ryegrass straw can be placed on the ground surface on a calm day with no wind. On large areas, the straw is punched into the sand with a sheepfoot roller or large farm disc. On cut banks, or areas of extreme wind exposure, wire netting may be used to secure the straw. Permanent grasses and legumes can be seeded directly into the straw cover in the fall.

Rock or gravel can be used to prevent wind scouring, but in areas of heavy rainfall it is easily buried. It can, however, serve as a firebreak in residential areas, as it will not ignite from a carelessly thrown cigarette.

Clay is used to bind the sand and prevent wind erosion. This is costly and likely to have a very temporary beneficial effect.

Seawalls of stone or concrete can prevent sand from moving inland. If the source of the sand is extensive, however, dunes big enough to inundate the seawall will soon develop.

Beach logs can be used for stabilization. The weight of the logs prevents natural slumping on slopes, but if large voids exist between the logs, vegetation should be planted.

Landscape Plants for Stabilized Dunes

Once coastal sand dunes are stabilized with primary and secondary vegetation, certain land uses, such as urban development or recreation, may demand more intensive landscaping of the stabilized area. If sufficient organic matter, fertilizer, mulch, and supplemental water are provided, most plants adapted for landscaping of inland coastal sites, such as rhododendrons and azaleas, can be grown on stabilized dunes. However, these amendments in the amounts required can be very expensive to apply and maintain on coarse dune sand. There are some species, mostly natives, that can be found on older stabilized dunes, that are preferred landscaping choices.

Ground Covers

Shrub species in this group are decumbent, creeping, or low and dense. They are long lived and fire resistant.

Salal is a decumbent evergreen shrub that roots at the nodes, spreads rapidly, and forms a dense mat on the surface of the soil. It is widely distributed along the coast and grows in dense shade and partial sun. It is wind resistant. Salal grows best on well-drained sites but can be used where the soil is wet but not ponded. Seedlings are easy to grow from seed, and they transplant readily. Aside from making an ideal ground cover under climax trees, salal has utilitarian values. The fruit can be used for jelly and as food for game birds, and the foliage is valued for florist greenery.

Kinnikinnick (also called bearberry) is a creeping evergreen shrub that roots at the nodes and makes a good ground cover in partial shade, especially at the edges of open areas in tree plantings. It requires well-drained sites but, once established, spreads rapidly. Planting stock can be grown from seed but is easily obtained from cuttings. The fruit of kinnikinnick provides food for wildlife.

Douglas spiraea, or hardhack, makes a low, dense thicket on the poorly drained swampy areas within the dune area. It is a long-lived deciduous shrub, is very resistant to fire, and produces enough sprouts to completely cover the area. It will not tolerate shading. Plantings can be made with nursery-grown seedlings, but, as coastal dune areas become stabilized, it quickly volunteers on wet sites if plants are growing near the area.

Coyote brush, described earlier, also is a useful ground cover for more intensive landscaping.

Medium Shrubs

Shrubs in this group should be shade tolerant, evergreen, long lived, and fire resistant.

Evergreen huckleberry occurs naturally as an understory in forest vegetation on stabilized dunes on the coast. It is easily established with nursery-grown stock and attains a height of 4 to 5 feet in about 5 years. Well-drained sites are required for good establishment and optimum growth. This shrub produces good crops of edible berries that are used both for human consumption and as food for wildlife.

Pacific wax myrtle can be used on sites that are intermittently wet or have a high water table. It is best adapted to the southern half of the northern Pacific coast. Foliage is glossy, attractive, and wind resistant. Fruits are purplish nutlets and used by birds.

Scotch broom and autumn olive, described earlier, can be used for landscaping, as well as stabilization plantings. Both fix their own nitrogen and require less maintenance than typical landscape species. There are many ornamental varieties of scotch broom, providing a wide choice of flower colors.

Evergreen blackberry is exceptionally well adapted to the dune areas along the northern Pacific coast. It is a vigorous, spiny, decumbent evergreen shrub that produces abundant crops of edible fruit. Because of the growth characteristics and the spines, evergreen blackberry can be used to prevent indiscriminate traffic into areas planted to permanent trees. This plant is easy to establish from seedlings or crown divisions and is long lived. Some consider it to be too weedy.

Native salmonberry and thimbleberry volunteer and grow naturally as erect border plants on both well-drained and poorly drained sites. They provide food and shelter for upland game birds and are lightly browsed by deer. Twinberry honeysuckle, a viny shrub, is similar to these two shrubs in adaptation, establishment, and use.

Trees

Shore pine, described earlier, is an excellent landscaping choice for a conifer in coastal areas. Oregon crabapple is also an attractive small deciduous tree.

Four native timber species also can be planted on landscaped, stabilized dunes, but generally require mature, well-stabilized sites for optimum performance. They are Sitka spruce, which tolerates strong winds and wind forms in exposed areas; western hemlock; western red cedar; and Douglas fir, which probably is the least desirable of the four for landscaping on dunes because it is susceptible to wind damage.

The species described above represent the best-performing of over 50 native and introduced woody plants which have been evaluated in a long-term adaptation test plot trial near Astoria, Oregon. This test plot trial, established in the late 1930's, can still be visited today by contacting the local Soil Conservation Service office.

Marsh Habitats for Wet Interdune Areas

Description

Deflation plains, created when the wind-blown beach sand supply is cut off by foredune development and sand on the lee side is scoured down to the water table, usually revegetate naturally in a relatively short period to marsh plants. Common invaders include slough sedge, rushes, Pacific silverweed, and numerous other forbs. However, since deflation plains often are formed during the building of a foredune with beachgrasses, they usually are planted as well to suitable cover or improved waterfowl food.

Species and Mixtures

A standard seed mixture for deflation plains consists of a cereal grain and common pasture species:

Species	Cultivar	Pounds/Acre
Barley	Locally adapted	100 (2 bushels)
Tetraploid ryegrass	Locally adapted	5
Tall fescue	'Alta,' 'Fawn'	20
Birdsfoot trefoil	'Kalo,' 'Cascade,' 'Viking,' 'Empire'	4
Big trefoil	'Marshfield'	2

Barley and tetraploid ryegrass germinate and develop very rapidly following seeding. Tall fescue and trefoils are more persistent, will begin to take over during the second year, and can provide a long-lasting cover.

Where maximum waterfowl food is desired, deflation plains can be annually seeded to barley at 100 pounds (2 bushels) per acre and fertilized with at least 60 pounds per acre N-P-K, usually 15-15-15 or similar analysis. Barley is the preferred cereal grain because of its greater tolerance to salty or brackish conditions.

Increasingly, deflation plains or other coastal areas that are tidally influenced are established to prime native marsh habitat. Such plantings may be part of a mitigation of lost estuarine plant communities resulting from dredge spoil deposition,

Deflation plain wetlands and estuaries are extremely valuable for waterfowl and other forms of wildlife. Their conservation and reclamation are high priorities in most coastal community plans.

harbor development, or other activity. A generalized intertidal coastal marsh (Boss 1981) in the Pacific Northwest consists of three zones: low marsh, high marsh, and transition (to upland) zones. Indicator plants for the low marsh are arrow grass, pickleweed, and lyngby sedge. High marsh indicators include saltwort, tufted hairgrass, and creeping spike rush. Transition zone species include Pacific silverweed, redtop, and Baltic rush.

Despite the large number of marsh plants that are prevalent, only a few species to date have been successfully established in revegetation

Creeping spike rush is another useful fresh water marsh species. It is easily established and quickly forms a good cover.

projects. The following recommendations are based on testing by Ternyik (1980) for sites along bays and rivers that are tidally influenced:

Low Marsh: Lyngby sedge

High Marsh: Slough sedge
Tussock
Sharp-fruited rush
Tufted hairgrass
Creeping spike rush

All marsh plants are transplanted rather than seeded. The recommended species are dug from their natural habitat. Dug plants are separated into 4 to 7 culm sprigs; tops are cut back to 8 inches and roots to 6 inches. Processed sprigs are stored in ventilated plastic containers placed in holes dug in the upper one-third of the tidal range. Plants should not be stored longer than 7 days. Dry roots or broken stems result in low survival, so plants in this condition should be rejected.

Sprigs are planted on 18-inch centers with rows offset and parallel to the water's edge. Planting depth is 6 inches, but a hole is dug deep enough to prevent J rooting and backfilled firmly to prevent floatouts. A planted sprig should be upright with the top 8 inches above ground.

Planting occurs after tidal waters have been off the surface for 1 hour. Temperatures during planting must be below 65°F and above freezing. Machine planters are rarely used but are feasible if care is exercised not to destroy the benthic community.

Slough sedge is one of several important wetland species that can be easily established in a marsh reclamation project.

Interest is building for creating artificial tidal mudflats that support eelgrass in mitigating the loss of these environments elsewhere.

Hooker willow quickly invades deflation plains and is considered somewhat weedy by many. However, its tough, pliable stems make it valuable for plantings along coastal streams, and it can withstand sand deposition.

Cover for Dredge Spoils

Ship channel dredging is an ongoing activity in major rivers emptying into the ocean along the Pacific Northwest coast. Dredge spoils usually are placed on undredged portions of the river, often in estuarine zones, and can cover large areas. Left to revegetate naturally, wind erosion causes the coarse-textured spoil to migrate from the site. Artificial revegetation usually is necessary.

Approach

If shaped properly, a dredge spoil can be turned into marsh habitat, a stabilized upland site, or a mixture of the two. Marsh plants should be planted in intertidal zones as described in the previous section.

Upland sites are stabilized using the species and techniques for treating sand dunes described earlier with some modifications. Beachgrasses should be planted on areas that are subject to severe blowing. For instance, dredge spoil islands on the Columbia River often are planted to beachgrass along the windward, western edge toward the ocean, to trap sand blowing inland.

Because the "beach" along dredge spoil islands is usually degrading, wave action encroaches on the protective beachgrass strip. Therefore, the beachgrass strip should be wide enough and may need to be planted further inland until permanent vegetation becomes established.

Small dredge spoils may be planted entirely to beachgrass, but larger areas usually are direct seeded to permanent grasses and legumes on a prepared seedbed, except for the protective beachgrass strip around the edges.

Species

Many of the same species used for sand dune seedings can be used for upland dredge spoil sites. Recent tests have shown that tall wheatgrass and sickle-keeled lupine are especially well suited for upland dredge spoil seedings. Tall wheatgrass has excellent seedling vigor, and is tall, robust, and salt tolerant, with good wildlife cover value.

Pine lupine also has excellent seedling vigor, is robust, and provides large amounts of nitrogen to the sterile dredge material. 'Hederma,' a recent cultivar, has performed very well on several dredge spoil sites from Coos Bay, Oregon, to Ocean Shores, Washington.

Mixtures

Upland dredge spoil sites should be seeded to the following seed mixture:

Species	Cultivar	Pounds/Acre
Tall wheatgrass	'Largo'	20
Creeping red fescue	'Illahee,' 'Rainier'	8
Pine lupine	'Hederma'	20

If tall wheatgrass is unavailable, tetraploid ryegrass may be substituted at 10 pounds per acre. Creeping red fescue is readily available. Hairy vetch, tree lupine, or perennial pea may be substituted for pine lupine in order of decreasing preference.

Marsh creation recommendations should be followed where dredge spoils are formed to support wetland habitats. Woody plants, if desired, are those recommended previously for dune plantings.

Seedings should be drilled whenever possible. However, barging seeding equipment to dredge spoil islands may not be feasible and seed must be broadcast. If so, seeding rates should be increased by 50 percent as the chance of failure is substantially greater.

Seedings are best done in the late summer or fall, September 1 through October 15, but are possible in the early spring, March 1 through April 15. Fertilizer is essential at time of planting at a 40-80-80 N-P-K rate. If the legumes establish successfully, followup fertilization may not be necessary. Sites subject to severe blowing should be mulched with cereal straw or, as a last resort, grass hay which usually contains large amounts of weed seed. Straw mulch should be punched into the spoil with suitable equipment.

Case History: Warrenton Dune Control Project

The most complete and extensive dune control project along the west coast of the United States is the Warrenton Dune Control Project on the Clatsop Plains (Warrenton Dune SWCD, 1970). In 1935, more than 3,000 acres of active, moving sand dunes in the northwest corner of Clatsop County, Oregon, at the mouth of the Columbia River, were threatening adjoining farmland, forests, lakes used for recreation, and navigational channels.

Beach erosion, aggradation, and dune formation are nothing new or unique to the Pacific Northwest coastline. Hanson (1947) suggests that there has been very little permanent stabilization of the coastline in the past 6,000 years when the coastline reached its current level following the last ice age. Prior to settling by humans, fire was a major cause of disturbance and contributed to the cyclic pattern of dune formation and stabilization by vegetation. Shore pine is a prominent species that has adapted through time to constant coastal dune disturbance and stabilization process.

Fire has been increasingly controlled since humans have inhabited the coastline. However, logging, cultivation, grazing, jetty construction, and other activities have significantly affected beach sand supply and dune formation. A combination of these factors caused the formation of extensive, active, moving dunes on the Clatsop Plains in 1935.

Prior to 1885, a 20-foot-deep ship channel was maintained at the mouth of the Columbia River through the sand bars that formed as sand was carried down the river. After 1885, jetties were constructed, eventually extending 7 miles on the south and 3 miles on the north side of the river. By 1935, the river channel had scoured to a depth of more than 45 feet, depositing sand along the coast on both sides of the mouth. To the south, a low-lying sand flat was formed one-half mile wide at the jetty gradually narrowing and extending down the beach several miles. These jetties were one main source of sand that created the dunes and their movement that reached critical levels in 1935.

If beaches are formed gradually, natural vegetation often keeps pace helping to build littoral dunes that reduce dune activity inland. In the case of the Clatsop Plains, the beach by the jetty increased too rapidly for vegetation to keep pace, although European beachgrass had been

On the left is a plank road that led to the Peter Iredale Shipwreck in 1937. On the right the same location 52 years after it was planted to beachgrass and shore pine (Clatsop County, Oregon).

naturalized in the area for 30 years. As a result, there was a huge sand supply for massive dune formation inland that threatened the established land uses along the coast.

The other major cause of the sand dune problem on the Clatsop Plains was overgrazing. Widespread grazing by cattle, horses, and sheep in the early 1900's created trails in the stabilized dune sand, causing blowouts. By 1935, an estimated 40 million cubic yards of sand had blown inland from the old foredune that extended from the mouth of the Columbia River to Tillamook Head. The foredune was almost completely destroyed.

In 1935, landowners and the Clatsop County government decided to stabilize the 3,000 acres of active sand dunes and return the land to more productive use. The first work was accomplished by the Civilian Conservation Corps (CCC). Twenty-three miles of sand fences were installed and all open sand areas were planted to European beachgrass. The foredune was completely reestablished. In the less erosive areas behind the foredune, grasses and legumes were seeded into the beachgrass for permanent cover. Native shore pine and scotch broom were extensively planted over the entire area. Essentially the same procedures described previously in this publication were used to complete the project. In fact, the experience gained during this project provides the basis for most recommendations today.

By 1941, most of the 3,000 acres had been stabilized, at least initially. In that year the Warrenton Dune Soil and Water Conservation District, a local unit of government, was formed by area landowners to provide for wise land use and development of the stabilized area. The district, with technical assistance from the Soil Conservation Service, administered further planting projects and provided for maintenance of the planted dunes. Because of the original severity of the dune activity prior to 1935, the district established an ordinance to enforce proper land use for the area. The ordinance remains in effect today.

Specifications

Specifications for Contracts

Written specifications are developed for most of the larger stabilization jobs and are required when governmental agencies are involved, no matter the size. Specifications are tailored to the specific job, but must contain certain elements. Following are the recommended specification outlines for vegetative practices:

Dunegrass planting for initial stabilization
Scope of work
Site preparation including mechanical aids
Type, source, and quality of planting stock
Digging, stripping, and trimming method
Storage method
Transportation and handling
Planting method
Fertilizer application
Inspection and replanting
Measurement and payment

Grass-legume seeding for permanent stabilization, including dredge spoil or deflation plain seedings
Scope of work
Seed quality
Seed mixture
Seeding method
Fertilizer application
Inspection and reseeding
Measurement and payment

Woody planting for permanent stabilization
Scope of work
Species, type, and quality of planting stock
Transportation and handling
Planting method
Fertilizer application
Inspection and replanting
Measurement and payment

Landscape plantings
Scope of work
Site preparation
Species, type, and quality of planting stock
Transportation and handling
Topsoil mixture and amendments
Planting method
Mulch
Irrigation
Inspection and replanting
Measurement and payment

Marsh habitat planting
Scope of work
Site preparation
Type, source, and quality of planting stock
Digging and trimming method
Storage method
Transportation and handling
Planting method
Fertilizer application
Inspection and replanting
Measurement and payment

Contracting representatives responsible for inspecting plantings should check no less than 5 percent of the area treated. Except for very large jobs, a much larger percentage of the area is usually inspected for compliance with the specifications. Generally, plantings can tolerate a 10-percent transplanting or stand failure unless failure is concentrated in one or two locations within the planting. Failures between 5 and 10 percent should be reflected in a corresponding reduction in payment to the contractor. Failures greater than 10 percent must be replanted by the contractor.

Labor and Equipment Requirements

Hours of labor and equipment use vary with site conditions and density of planting. However, table 3 provides some general outputs for various tasks.

Summary of Recommended Plant Material

Table 4 summarizes plant species recommended in preceding chapters by ecological type, planting stock, adaptation to dune area, availability, planting rate, and season. Table 5 provides numbers of transplants needed for various plant spacings.

Table 3.—Time requirements or work rates for three types of dune stabilization tasks

Type of work	Spacing	Rate
Plant dunegrasses (or marsh plants)	12 inches	320 hr/acre 136 hills/hr
	18 inches	128 hr/acre 150 hills/hr
	24 inches	72 hr/acre 150 hills/hr
Seed grasses and legumes into dunegrasses, or on deflation plains or dredge spoils, with a 6-foot drill.		2.5 hr/acre (labor) 1.2 hr/acre (equipment)
Plant woody seedling transplants on stabilized dune area.		100 plants/hr
	3 by 3 ft	49 hr/acre
	6 by 6 ft	12 hr/acre
	8 by 8 ft	7 hr/acre
	12 by 12 ft	3 hr/acre

Table 4.—Basic recommended plant material for dune stabilization

		Planting Stock						Adaptation					Availability	Planting Rate	Planting Season
Species	Type	BR	B&B	Seed	1-0	2-0	Size	FD	MH	OS	SD	DS			
Grasses															
European beachgrass	IS	x				x	20"	x		x		x	CA	18"x18"	Nov. 15-Mar. 15
American beachgrass	IS	x				x	20"	x		x			CA	18"x18"	Nov. 15-Mar. 15
American dunegrass	IS	x				x	20"	x					CA	18"x18"	Nov. 15-Mar. 15
Creeping red fescue	PC			x							x	x	CA	12 lb/acre	Sept. or Apr.-June
Seashore bluegrass	PC			x							x	x	FC	5 lb/acre	Sept. or Apr.-June
Tall wheatgrass	PC			x							x	x	CA	20 lb/acre	Sept. or Apr.-June
Tetraploid ryegrass	PC			x							x	x	CA	3 lb/acre	Sept. or Apr.-June
Barley	IS			x			x						CA	100 lb/acre	Sept. or Apr.-June
Tall fescue	PC			x			x						CA	10-20 lb/acre	Sept. or Apr.-June
Legumes															
Hairy vetch	PC			x							x	x	CA	20 lb/acre	Sept. or Apr.-June
Perennial pea	PC			x							x	x	CA	20 lb/acre	Sept. or Apr.-June

*Abbreviations defined on page 47.

Table 4.—Basic recommended plant material for dune stabilization (Continued)

		Planting Stock						Adaptation					Availability	Planting Rate	Planting Season
Species	Type	BR	B&B	Seed	1-0	2-0	Size	FD	MH	OS	SD	DS			
Purple beachpea	PC			x							x	x	FC	20 lb/acre	Apr.-June
Seashore lupine	PC			x							x	x	FC	51 lb/acre	Sept. or Apr.-June
Pine lupine	PC			x							x	x	CA	20 lb/acre	Sept. or Apr.-June
Tree lupine	PC			x							x	x	FC	30 lb/acre	Apr.-June
Birdsfoot trefoil	PC	x							x				CA	41 lb/acre	Sept. or Apr.-June
Big trefoil	PC	x							x				CA	21 lb/acre	Sept. or Apr.-June
Marsh															
Creeping spike rush	HM	x					12"		x				FC	18"x18"	Apr.-July
Lyngby sedge	LM	x					12"		x				FC	18"x18"	Apr.-July
Sharp-fruited rush	HM	x					12"		x				FC	18"x18"	Apr.-July
Slough sedge	HM	x					12"		x				FC	18"x18"	Apr.-July
Tufted hairgrass	HM	x					12"		x				FC	18"x18"	Apr.-July
Tussock	HM	x					14"		x				FC	18"x18"	Apr.-July

**Abbreviations defined on page 47.*

Table 4.—Basic recommended plant material for dune stabilization (Continued)

Species	Type	Planting Stock						Adaptation					Availability	Planting Rate	Planting Season
		BR	B&B	Seed	1-0	2-0	Size	FD	MH	OS	SD	DS			
Woody															
Autumn olive	PC	x			x	x	12" (6')				x	x	CA	6'x6'	Dec.-Mar.
Kinnikinnick	L					x	1 gal (1')				x		CA	3'x3'	Dec.-Feb.
Coyote brush	PC	x			x		1 gal (2')				x	x	CA	3'x3'	Dec.-Feb.
Douglas spiraea	L	x			x		1 gal (5')				x		CA	3'x3'	Dec.-Mar.
Evergreen blackberry	L	x			x		1 gal		x		x		CA	6'x6'	Dec.-Feb.
Evergreen huckleberry	L	x					1 gal (5')				x		CA	3'x3'	Dec.-Feb.
Oregon crabapple	PC		x		x	x	1 gal (15')			x	x		CA	6'x6'	Dec.-Feb.
Red alder	PC	x				x	12" (60')				x	x	CA	8'x8'	Dec.-Feb.
Salal	L					x	1 gal (4')				x	x	CA	3'x3'	Dec.-Feb.
Hooker willow	PC	x			x		18" (10')		x				FC	3'x3'	Nov.-Apr.
Salmonberry	L				x		12" (6')				x		CA	6'x6'	Dec.-Feb.
Scotch broom	PC	x			x		12" (6')				x	x	CA	8'x8'	Dec.-Mar.
Shore pine	PC	x	x			x	12" (50')				x	x	CA	8'x8'	Dec.-Feb.
Sitka spruce	L	x	x			x	12" (80')				x		CA	8'x8'	Dec.-Feb.
Pacific wax myrtle	L		x			x	1 gal (10')				x	x	CA	8'x8'	Dec.-Feb.
Western hemlock	L	x	x			x	1 gal (80')				x		CA	8'x8'	Dec.-Feb.

**Abbreviations defined on page 47.*

Abbreviations for Table 4

B&B	-	balled and burlapped
BR	-	bare root stock
CA	-	commercially available
DS	-	open sandy dredge spoils
FC	-	field collection
FD	-	foredune or frontal areas
HM	-	high marsh
IS	-	colonizer-initial stabilizer
1-O	-	1-year-old seedling
2-O	-	2-year-old seedling
L	-	landscape plant
LM	-	low marsh
MH	-	deflation plain, wet inter-dune, or marsh habitat
OS	-	open sand dunes including blowouts
PC	-	permanent cover
SD	-	stabilized dunes and spoils container size
Size	-	height or container size

Table 5.—Transplants needed with varied space requirements

Transplant Type	Spacing	1,000 sq.ft.	1 Acre	100 Acres
Beachgrass				
3 culms/hill	12" x 12"	3,004	130,680	13,068,000
3 culms/hill	18" x 18"	1,335	58,080	5,808,000
3 culms/hill	24" x 24"	751	32,670	3,267,000
3 culms/hill	30" x 30"	480	20,880	2,088,000
5 culms/hill	12" x 12"	5,006	217,800	21,780,000
Woody species				
1 transplant/hill	3' x 3'	111	5,840	584,000
1 transplant/hill	6' x 6'	28	1,210	121,000
1 transplant/hill	8' x 8'	16	680	68,000
1 transplant/hill	12' x 12'	7	302	30,200

Note: A word of caution—always order 3 percent more to offset heavy planting.

Literature Cited

Boss, T.R. 1981. Intertidal Salt Marshes of Oregon. Oregon State Univ. Ext. Serv. Marine Advisory Program. SG 63. 7 pp.

Brown, R.L. and A.L. Hafenrichter. 1948. Factors Influencing the Production and Use of Beachgrass and Dunegrass Clones for Erosion Control: Effect of Date and Planting, Journal of the American Society of Agronomy, 40(6):512-521.

Brown, R.L. and A.L. Hafenrichter. 1962. Stabilizing Sand Dunes on the Pacific Coast with Woody Plants. U.S. Department of Agriculture, Soil Conservation Service, Miscellaneous Publication No. 892. 18 pp.

Chesser, S.A. and C. Peterson. 1987. Littoral Cells of the Pacific Northwest Coast. Coastal Zone 87 Specialty Conference, New Orleans, Louisiana. 2: pp. 1346-1360.

Cooper, W.S. 1958. Coastal Sand Dunes of Oregon and Washington. Geologic Society of America - Memoir 72, New York, N.Y. 169 pp.

Crook, C.S. 1979. A System of Classifying and Identifying Oregon's Coastal Beaches and Dunes. *In* Oregon Coastal Zone Management Association, Inc., Beach and Dunes Handbook for the Oregon Coasts, OCZMA, Newport, Oregon. 91 pp.

Hafenrichter, A.L. 1967. Lassoing the West's Rampaging Sand Dunes. 1967 Yearbook of Agriculture, pp. 317-321.

Hansen, H.P. 1947. Postglacial Forest Succession, Climate, and Chronology in the Pacific Northwest. Trans. of the Amer. Philosophical Soc. 27: 1-130.

Komar, P.D. 1976. Beach Processes and Sedimentation. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 429 pp.

Komar, P.D. 1979. Physical Processes and Geologic Hazards on the Oregon Coast. *In* Oregon Coastal Zone Management Association, Inc., Beaches and Dunes Handbook for the Oregon Coast, OCZMA, Newport, Oregon. 72 pp.

McLaughlin, W.T. and R.L. Brown. 1942. Controlling Coastal Sand Dunes in the Pacific Northwest. U.S. Department of Agriculture, Washington, D.C. Circular No. 660. 46 pp.

Munz, P.A. 1964. Shore Wildflowers of California, Oregon, and Washington. University of California Press, Berkeley, California. 122 pp.

Nelson, W.T. 1976. Geologic and Engineering Geology Guidelines - City of San Jose. California Geology, November. pp. 249-251.

Peterson, C., K. Scherdegger, and P.D. Komar. 1982. Sand Disposal Patterns in an Active Margin Estuary of the Northwestern U.S. as Indicated by Sand Composition, Texture and Bedforms. Marine Geology. 50: pp. 77-96.

Reckendorf, F., D. Leach, R. Baum, and J. Carlson. 1985. Stabilization of Sand Dunes in Oregon. Agricultural History. 59: pp. 260-268.

Reckendorf, F., D. Leach, R. Baum, and J. Carlson. 1987. Stabilization of West Coast Sand Dunes. Coastal Zone 87. WW Div/ASCE. Seattle, Washington. 2: pp. 1328-1342.

Ternyik, W.E. 1979a. Beach and Dune Implementation Techniques: Site Investigation Reports.
Beaches and Dunes Handbook for the Oregon Coast, OCZMA. 27 pp.

Ternyik, W.E. 1979b. Dune Stabilization and Restoration Methods and Criteria. *In* Oregon Coastal Zone Management Association, Inc. Beaches and Dunes Handbook for the Oregon Coast, OCZMA. 40 pp.

Ternyik, W.E. 1980. Salt Marsh Creation in the Pacific Northwest: Criteria, Planting Techniques, and Costs in Rehabilitation and Creation of Selected Coastal Habitats: Proceedings of a Workshop. U.S. Fish and Wildlife Service, Washington, D.C. FWS/OBSI-80/27. pp. 25-27.

U.S. Army Corps of Engineers, Portland District. 1974. Coastal Reconnaissance Study: Oregon and Washington. Battelle Pacific Northwest Laboratories, Richland, Washington. 478 pp.

U.S. Soil Conservation Service and Oregon Coastal Conservation and Development Commission. 1975. Beaches and Dunes of the Oregon Coast. U.S. Department of Agriculture, Soil Conservation Service, Portland, Oregon. 161 pp.

Warrenton Dune SWCD. 1970. Thirty-Five Years of Progress: 1935-1970. U.S. Department of Agriculture, Soil Conservation Service, Portland, Oregon. 16 pp.

Weideman, A.M., L.J. Dennis, and F.H. Smith. 1969. Plants of the Oregon Coastal Dunes. Oregon State University Book Stores, Corvallis, Oregon. 117 pp.

Weideman, A.M. 1984. The Ecology of Pacific Northwest Coastal Sand Dunes: A Community Profile. FWS/OBS-84/04. 130 pp.

Glossary

active dune — A dune with little or no vegetal cover, and which is subject to movement by the action of the wind.

benthic — A plant or animal living in or on the bottom of a body of water.

blowout — A scoured out gap in vegetation caused by wind-blown sand; wind-blown sand buries and kills vegetal cover.

climax species — In any given region there is a succession of plant species toward a type adapted to withstand even the extremes of local climate. Climax vegetation is relatively stable.

clone — Several attached culms.

culm — Single-jointed stem of a grass.

deflation plain — A flat area of sand that is normally east of the foredune and scoured by the wind down to the summertime water table.

foredune — The dune closest to the high-tide line that extends parallel to the beach. The foredune can be divided into three sections: the frontal area (closest to water); the top surface; and the lee or reverse slope (back side).

heeling in — A technique for storing plant stock in temporary plantings as in a nursery.

inner or open dune area — Open areas of actively blowing sand no longer receiving sand from ocean beaches.

pioneer or colonizer — The first few plants to establish themselves in an area.

prograding — A coastal area which is increasing in shoreline area, through the addition of sand or other sediment, at the expense of the area occupied by the sea.

retrograding — A coastal area that is eroding. The shoreline opposite of a prograding shoreline.

stable dune — A dune that changes slowly over time. Stable dunes have adequate vegetal cover and this protects against the blowing of a massive amount of sand off the dune.

subclimax species — Species of plants that will be replaced by others in succession.

succession — A sequence of vegetal changes whereby one type replaces another until a climax species or group of species is reached.

volunteer species — Native plant species whose seed invades natural or artificially stabilized areas of sand.

wet interdune — Areas of sand between dunes that are subject to seasonal flooding or periodic tidal area flooding, but not affected by the beach sand supply.

wind formed — Plants that bend, over time, with the wind without suffering serious damage.

wind tip — Wind blows down vegetation or bends it to the point of destruction.

Appendix I

Common and Scientific Plant Names Used in This Publication

Recommended Plants

Grasses:

American beachgrass — *Ammophila breviligulata* Fern.
American dunegrass — *Leymus mollis* (Trin.) Pilger
Barley — *Hordeum vulgare* L.
European beachgrass — *Ammophila arenaria* [L.] Link.
Seashore bluegrass — *Poa macrantha* Vasey
Tall fescue — *Festuca arundinacea* Schreb.
Tall wheatgrass — *Thinopyrum ponticum* (Podp.) Barkw. & D.R. Dewey
Tufted hairgrass — *Deschampsia cespitosa* [L.] Beauv.

Sedges/Rushes:

Creeping spike rush — *Eleocharis palustris* [L.] Roem. and Schult.
Lyngby sedge — *Carex lyngbyei* Hornem.
Sharp-fruited rush — *Juncus acuminatus* Mich X.
Slough sedge — *Carex obnupta* L.H. Bailey
Tussock — *Juncus effusus* L.

Legumes:

Big trefoil — *Lotus uliginosus* Schkuhr.
Birdsfoot trefoil — *Lotus corniculatus* L.
Hairy vetch — *Vicia villosa* Roth.
Perennial pea — *Lathyrus latifolius* L.
Purple beach pea — *Lathyrus japonicus* Willd.
Seashore lupine — *Lupinus littoralis* Dougl.
Tree lupine — *Lupinus arboreus* Sims.

Woody Plants:

Autumn olive — *Elaeagnus umbellata* Thunb.
Bearberry — *Arctostaphylos uva-ursi* [L.] Spreng.
Coyote brush — *Baccharis pilularis* DC
Douglas-fir — *Pseudotsuga menziesii* [Mirb.] Franco.
Douglas spiraea or hardhack — *Spiraea douglasii* Hook.
Evergreen blackberry — *Rubus laciniatus* Willd.
Evergreen huckleberry — *Vaccinium ovatum* Pursh.
Hooker willow — *Salix hookerana* Barr.
Kinnikinnick — *Arctostaphylos uva-ursi* [L.] Spreng.
Oregon crabapple — *Malus fusca* [Raf.] Schn.
Pacific wax myrtle — *Myrica californica* Cham.
Red alder — *Alnus rubra* Bong.
Salal — *Gaultheria shallon* Pursh.
Salmonberry — *Rubus spectabilis* Pursh.
Scotch broom — *Cytisus scoparius* [L.] Link.
Shore pine — *Pinus contorta* Loud.
Sitka spruce — *Picea sitchensis* [Bong.] Carr.
Thimbleberry — *Rubus parviflorus* Nutt.
Twinberry honeysuckle — *Lonicera involucrata* [Rich.] Banks.
Western hemlock — *Tsuga heterophylla* [Raf] Satg.
Western redcedar — *Thuja plicata* Donn.

Other Plants Listed

Altai wildrye — *Leymus augustus* (Trin.) Pilger
Arrowgrass — *Triglochin maritimum* L.
Baltic rush — *Juncus balticus* Willd.
Basin wildrye — *Leymus cinereus* (Scribn. & Merr.) Love
Beach knotweed — *Polygonum paronychia* C&S
Beach silver-top — *Glehnia leiocarpa* Math.
Beach wildrye — *Leymus arenarius* (L.) Hochst.
Big headed sedge — *Carex macrocephala* Willd.
Creeping wildrye — *Leymus triticoides* (Buck.) Pilger
Dune morning glory — *Convolvulus soldanella* L.
Giant wildrye — *Leymus racemosus*
Gorse — *Ulex europaeus* L.
Pacific silverweed — *Potentilla anserina,* subsp. *pacifica* (T. Howell) Rousi
Pickleweed — *Salicornia virginica* L.
Redtop — *Agrostis alba* L.
Saltwort — *Glaux maritima* L.
Sand verbena — *Abronia latifolia* Esch.
Seashore tansy —*Tanacetum camphoratum* Less.
Silver weed — *Franseria chamissonis* Less.

Appendix II

Beaches and Dunes Site Investigation Checklist
(Excerpted from Nelson 1976)

Location:

1. Local Zoning Regulations
   Does the proposed development site plan conform to city or county zoning regulations regarding setback lines and other code provisions? (Contact the city or county engineer for details.)
   ☐ Yes ☐ No

2. Comprehensive Plan Setback Line or Destination
   a. Has a Coastal Construction Setback Line (CCSBL) been adopted for this county or city? (Ask the county or city engineer.)
   ☐ Yes ☐ No

   b. Is the proposed site seaward of the CCSBL?
   ☐ Yes ☐ No

   c. If the proposed site is seaward of the CCSBL, has application for a variance or exception been made to the planning commission having jurisdiction?
   ☐ Yes ☐ No

3. Identified Hazardous Conditions
   a. Has any portion of the property been identified as being affected by any potential or existing geological hazard? (Contact county or city planning departments for information published by the State department of agriculture, Soil Conservation Service, U.S. Geological Survey, U.S. Army Corps of Engineers, and other government agencies.)
   ☐ Yes ☐ No

   b. Are any of the following identified hazards present?
   1. Active foredune
      ☐ Yes ☐ No
   2. Water erosion
      ☐ Yes ☐ No
   3. Wave undercutting or wave overtopping
      ☐ Yes ☐ No
   4. Flooding
      ☐ Yes ☐ No
   5. Wind erosion, scour
      ☐ Yes ☐ No
   6. Landslide or slough activity
      ☐ Yes ☐ No

   c. Are there records of these hazards ever being present on the site?
   ☐ Yes ☐ No

4. Existing Site Vegetation
   a. Does the vegetation on the site adequately protect against soil erosion from wind and surface water runoff?
   ☐ Yes ☐ No

   b. Does the condition of vegetation constitute a possible fire hazard or contributing factor to slide potential? (If answer is "yes," full details and possible remedies will be required.)
   ☐ Yes ☐ No

5. Fish and Wildlife Habitat
   a. Does the site contain any identified rare or endangered species or unique habitat (feeding, nesting, or resting)?
   ☐ Yes ☐ No

   b. Will any significant habitat be adversely affected by the development? (Contact State fish and wildlife department or county and city planning staffs for inventory data.)
   ☐ Yes ☐ No

6. Historical and Archaeological Sites
   Are there any identified historical or archaeological sites within the area proposed for development? (Contact local planning office.)
   ☐ Yes ☐ No

7. Flood Plain Elevation
   a. Does the elevation of the 100-year flood plain or storm tide exceed the existing ground elevation at the site? (Contact the Federal Insurance Administration, city or county planning departments for information on 100-year flood plain. Site elevations can be identified by local registered surveyor.)
   ☐ Yes ☐ No

   b. Will the lowest habitable floor of the proposed development be raised above the top of the highest predicted storm-wave cresting on the 100-year flood or storm tide?
   ☐ Yes ☐ No

8. Condition of Adjoining and Nearby Areas

Are any of the following natural hazards present on adjoining or nearby properties that would pose a threat to this site?

a. Open dunes

☐ Yes ☐ No

b. Active foredunes

☐ Yes ☐ No

c. Storm runoff erosion

☐ Yes ☐ No

d. Wave undercutting or wave overtopping

☐ Yes ☐ No

e. Slide areas

☐ Yes ☐ No

f. Combustible vegetative cover (Contact county and city planning staffs for local hazard information.)

☐ Yes ☐ No

9. Development Effects

a. Will there be adverse offsite effects as a result of this development?

☐ Yes ☐ No

b. Identify possible problem type:

1. Increased wind exposure

☐ Yes ☐ No

2. Open sand movement

☐ Yes ☐ No

3. Vegetative destruction

☐ Yes ☐ No

4. Increased water erosion (storm runoff, driftwood removal, reduction of foredune, etc.)

☐ Yes ☐ No

5. Increased slide potential

☐ Yes ☐ No

6. Effect on aquifer

☐ Yes ☐ No

c. Has landform capability (density, slope failure, ground water, vegetation, etc.) been a consideration in preparing the development proposal?

☐ Yes ☐ No

d. Will there be social and economic benefits from the proposed development?

☐ Yes ☐ No

e. Identified benefits:

1. New jobs

☐ Yes ☐ No

2. Increased tax base

☐ Yes ☐ No

3. Improved fish and wildlife habitat

☐ Yes ☐ No

4. Public access

☐ Yes ☐ No

5. Housing needs

☐ Yes ☐ No

6. Recreation potential

☐ Yes ☐ No

7. Dune stabilization (protection of other features)

☐ Yes ☐ No

8. Other

10. Proposed Design

a. Has a site map been submitted showing in detail exact location of proposed structures?

☐ Yes ☐ No

b. Have detailed plans showing structure foundations been submitted?

☐ Yes ☐ No

c. Have detailed plans and specifications for the placement of protective structures been submitted if need is indicated?

☐ Yes ☐ No

d. Has a plan for interim stabilization, permanent revegetation, and vegetation maintenance been submitted?

☐ Yes ☐ No

e. Is the area currently being used by the following?

1. Off-road vehicles

☐ Yes ☐ No

2. Motorcycles

☐ Yes ☐ No

3. Horses

☐ Yes ☐ No

f. Has a plan been developed to control or prohibit the use of off-road vehicles, motorcycles, and horses?

☐ Yes ☐ No

11. Oregon Land Conservation and Development Commission (LCDC) Coastal Goal Requirements

a. Have you read the LCDC goals affecting the site? (Contact LCDC city or county office for copies of goals.)

☐ Yes ☐ No

b. Have you identified any possible conflicts between the proposed development and the goals or acknowledged comprehensive plan? (If so, list them and contact local planning staff for possible resolution.)

☐ Yes ☐ No

c. Have all Federal and State agency requirements for consistency been met? (Contact local planning office.)

☐ Yes ☐ No

d. Has applicant or investigator determined that the development proposal is compatible with the LCDC beaches and dunes goal and other appropriate statewide land use planning laws?

☐ Yes ☐ No