FINAL REPORT

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SOME RECENT PHYSICAL CHANGES OF THE OREGON COAST

by

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SOME RECENT PHYSICAL CHANGES OF THE OREGON COAST

CHAPTER 1. DEFINITION OF THE AREA AND THE PROBLEMS

Samuel N. Dicken

At the time of white settlement, more than a century ago, most of the Oregon coast was retreating slowly while some sections, near the outlets of the large rivers, were advancing. The estuaries were filling and the coastal dunes were tending to become stabilized. Man's activities during the past century have tended to accelerate both erosion and deposition. The Indians burned small areas periodically but the white man logged, burned, and cultivated larger areas, thus increasing the sediment load of streams. Overgrazing down to the high-tide line changed the character of the backshore. During the last half-century man's structures, on and near the coast, have brought about striking changes. The natural changes are brought about by a number of interacting agents and materials - wind and waves, rain and sun, tide and currents, rock type and landform. Man's works have further complicated the problems and much more study will be necessary before the natural and human processes at work on the Oregon coast can be fully understood. Failure to understand them has cost hundreds of thousands of dollars in the past; in the future the amount will be measured in millions.

SCOPE AND PURPOSE

This report is concerned with some of the physical changes of the Oregon coast (from the California boundary to the Columbia River) which have occurred since settlement. More specifically, it includes changes of the beaches and the immediate backshore, of the active dunes near the shore, and of the estuaries. Some parts of the report are of a more general nature, in an effort to place the specific studies in the proper perspective. The time span, arbitrarily chosen, is the period since white settlement, a little more than a century. This is the time for which historical records are available to document the nature of the changes. The purpose of the report is to describe, measure, and explain some of the Oregon coast changes within the limitations of time and resources available. Special emphasis is placed on the beaches, dunes, and tidal marshes in the estuaries, where changes have occurred and are occurring. Many aspects of these three categories and many lines of investigation had to be left unstudied. It is hoped that the content of this report, as well as its shortcomings, will point out the need for further research.

SOURCES

A great variety of source materials is available for the study of coastal changes, some of it scattered in various libraries and unavoidably mixed up with records of little significance; some more readily available. The old topographic charts of the U. S. Coast and Geodetic Survey, some of them dating back to the 1850's, were very useful. Some of these charts were mapped by the use of a plane table on the scale of 1:10,000 and show the nature of the shoreline and the backshore in more detail than most present day maps. Comparison of these charts with recent aerial photographs has proved to be most rewarding. The old charts provide much specific information on the shore vegetation of the early days. Various editions of the Coast Pilot, first published in 1859, were most helpful; the most complete is the edition of 1889. U. S. Army Corps of Engineers reports from the late 19th century to the present have provided maps of historical interest and much useful information. Old ground photographs of the coast are available in quantity and comparison of these with very recent photographs has revealed many specific changes, especially in vegetation. Journals, diaries, and first-hand descriptions of early travelers have been quite helpful, as have the reports of many scientists who have studied special aspects of the Oregon coast. Interviews with local residents, who recall word by word accounts of early conditions, have often pointed up specific changes.

By far the most valuable source materials, however, are the aerial photographs of the Oregon coast. For many parts of the coast, good vertical coverage is available for the years 1939 and 1940; in a few cases aerial photographs are available for earlier years. Comparison of these with aerial photographs of 1960 and 1961 has given the most precise measure of changes in shoreline, landforms, and vegetation. Approximately 500 of these photographs were examined, many of them with stereoscope, in the course of this study. A few are reproduced in this report.

Field work carried out for the duration of this study, 15 months, supplied much additional information and the means of interpreting and evaluating the sources mentioned above. The field work was long enough to observe many specific changes and especially to isolate the purely seasonal variations which have

limited meaning. Measurements were made of slopes and beaches; beach profiles were mapped; samples of sand, rock, and plants were collected for laboratory analyses.

PRE-SETTLEMENT CONDITIONS

It is apparent that at the time of settlement the coast of Oregon was in a state of slow change. For approximately 6000 years the sea level has been relatively constant and during this time erosion and deposition have proceeded at a comparatively uniform rate. To be sure, storms and floods often caused an unusual amount of erosion and deposition within a short period of time but, considered in terms of centuries, it appears that conditions have been fairly uniform during the last 6000 years. There are those who will disagree with this statement. Some students of shorelines believe that a lowering of sea level occurred 400 or 500 years ago with the result that, in places, a two meter terrace has been formed. No clearcut evidence has come to the attention of the authors that this has occurred on the Oregon coast.

It appears that the beaches, the estuaries, and the dunes of the Oregon coast of 100 years ago were approaching an equilibrium. This does not mean that conditions were static; on the contrary, change was constant. Some of the changes were of an oscillatory nature, such as the changing in the spits and bars of the lower estuaries. It is a part of the natural process that the openings of the rivers in the coastal spits should shift from time to time. Some of these had more or less normal and regular cycles of change. The estuaries were filling, but the streams running across them were able to carry out most of the sediment that arrived at the upper end. The beaches were changing but within a slow pattern. As headlands were eroded, the attack of the waves and the supply of sand was changed; nevertheless, the beaches probably continued to have the same general form and position for many centuries. (It also appears that during the last 6000 years there has been no appreciable warping of the earth's crust along the Oregon coast to bring any part of it out of line with the rest. Warping must have occurred during the late Pleistocene, while sea level was rising, since some river beds, such as that of the Rogue River, appear to be higher than others. The tide, for example, reaches up the Rogue River only two or three miles, whereas it reaches 20 miles or more in the Coquille and the Umpqua rivers).

AGENTS OF CHANGE

On the Oregon coast the principal agents or elements of change are the waves, currents, tides, storms, wind, running water on the land - especially floods, and mass movements, such as slumping and landslides.

The waves are the cutting edge of the sea and the velocity and angle of attack of the waves represent the most important factor in changing the coastline. Currents and tides have their effect but the main function of the current is to transport some of the fine material disturbed by the waves. Storms are especially significant: one great storm will bring about more erosion than the normal action of the waves for many months, because the potent factor of the storm is the increased velocity and mass of the breaking waves.

On the land, wind plays an important role in carrying sand from the beaches to the dunes and beyond. Wind is an important agent in moving sand from the beaches to the dunes, even in wet weather. Running water also plays an important role, but since the rain generally falls on the Oregon coast in gentle drizzles rather than in downpours, there is ample opportunity for the water to soak in. As a result, many areas with steep slopes have no open stream channels but instead have rounded, dale-like forms and mass movement accounts for a very large part of the changes in the landforms.

Mass movements, especially slumping and landslides, are a normal feature of the Oregon coast. Landslides of great size and depth were developed long before the coming of man, but this is a form of erosion which is easily accelerated by the activities of man. Mass movements stem from two major factors - rock quality and climate. Weathered shale and serpentine are especially subject to mass movements. The climate contributes to landslides in two ways, one in the formation of very thick soil cover because of a deep penetration of weathering; in many cases landslides involve soil more than bedrock. The other factor, previously mentioned, is the long-continued gentle rains, which enable the soil and the upper weathered parts of the rock to become saturated; since the slopes are, in many cases, fairly steep, mass movements are frequent.

The effect of man on the Oregon coast has been, in general, to upset the delicate equilibrium which existed under nature. The activities of man - burning, logging, grazing, cultivating, and mining - have accelerated erosion, provided more sediment for the streams, and encouraged mass movements on steep slopes. Man's structures, especially jetties and breakwaters, together with roads and railroads near the coast, have also modified the natural forces. Especially noteworthy are jetties at the mouths of the rivers, for the purpose of improving navigation. The effect of these barriers has been to deny sand to certain parts of the coast and to accumulate the sand in other parts; in other words, acceleration of erosion has occurred in some places and increased deposition has occurred in other places. Inland occupation of western Oregon by man has increased the amount of sediment carried by the streams. Within the

memory of living residents, streams which were formerly clear for most of the year, except at flood stage, now carry much sediment all the year. This has tended to accelerate the filling of the estuaries and bays.

Prior to the coming of the white man to western Oregon, a little more than a century ago, the Indian occupation had already left some imprint upon the land. The Indians occupied the coastal areas of Oregon from the Columbia River to the California boundary; they were especially concentrated along the estuaries of the streams and other favorable fishing sites. The Indians depended mainly upon salmon for their food, but they were also dependent upon other sea foods and, to a certain extent, they hunted and gathered in the coastal areas. Periodic burning was common for the purpose of driving game, and also to improve grazing conditions in order to attract game. However, the impact of the Indians upon the land was relatively less than that of the white man.

EXPLORATION AND SETTLEMENT

The first explorations of the Oregon coast were by sea, and from these very little information has been derived about the nature of the shoreline itself. The early explorers, mostly Spaniards, Americans, and Britishers (Carey, 1922), learned to stay at some distance from the shore most of the time, because of fog, cloud, the rocky character of the shore, and the scarcity of harbors. The explorers, of course, examined the coast from a distance, often with the aid of telescopes, but their chief interest was the depth of water immediately offshore and the possibility of harbors. Consequently, the early maps showed a very generalized shoreline. Nevertheless, as time went on some specific knowledge of the inshore areas and some of the bays was obtained. Captain George Vancouver mapped the coastline from the middle Oregon coast northward into Washington and Vancouver Island in the years 1792-1794. Later, many small craft entered the bays and rivers. Unfortunately, much of the information derived from these voyages has been lost, since in most cases no written records were made. However, some of the information acquired by mariners was given, by word of mouth, to the field personnel of the U. S. Coast and Geodetic Survey and eventually found expression in their publications.

Before the careful examination of the coastline by the Coast and Geodetic Survey began in the 1850's, there had been several expeditions and observations by land travelers. The explorations of Lewis and Clark in the years 1805-1806 (Thwaites, 1905), David Douglas in 1826 (Royal Hort. Soc., 1914), Jedediah Smith in 1828 (Maloney, 1940), and Lieutenant Talbot in 1849 (Sec'y of War, 1850) are of particular interest. Specific references will be made to these and other travelers at various points in this report.

Settlement of the Oregon coast began in the northwest, apparently stimulated by the accounts of Lewis and Clark of the grasslands (Chapter 6). Many of the early settlers brought livestock with them and found that conditions were more favorable for pasture than for the cultivation of crops; however, this fact had to be learned by trial and error in different localities. In some areas, as in the Clatsop Plains, south of the Columbia River, the soils were too sandy and infertile; in other areas, the slopes were too steep. A decided handicap was the coolness, cloudiness, and fogginess of the summer period, which was, and is, unfavorable for many crops. Nevertheless, settlements were established at the most favorable places throughout the Oregon coastline during the period of 1840 to 1860; and these settlements have had a definite effect upon the physical changes of the Oregon coast. Especially noteworthy is the quick change-over from the Indian occupation to the white occupation. The white settlers immediately occupied the land most suitable for forage and grain production, in many cases, land previously occupied by Indians; the Indians were placed upon reservations at an early date. Forest fires became more numerous and probably more extensive than in the days of Indian occupation (Chapter 3); land was cleared, cultivated, and grazed; streams were diverted for placer mining; and many new trails and roads were established. The effect of the white occupation on the natural vegetation was immediately obvious; the effect on the beaches and estuaries was more difficult to evaluate.

CHAPTER 2. MATERIALS

Samuel N. Dicken

The nature of the changes of the Oregon coast depends upon a variety of materials, structures, and processes, ranging from sand beaches and sand dunes, through folded and faulted sediments, to highly resistant basalts (Baldwin, 1959). The distribution of these elements on the Oregon coast is uneven and the nature of the recent physical changes of the coast is related to this uneveness, both uneveness in distribution and in resistance, as well as to the force of the elements that are bringing about the changes.

Most of the Oregon coast is bordered by beaches, some of which are many miles in length and are limited on the shoreward side by sand dunes; other beaches lie at the foot of sea cliffs, which are composed of hard rock, or are adjacent to headlands. Beaches are discussed in detail in Chapter 5; it is sufficient to say here that the beaches represent material brought in by rivers or material derived from erosion of the backshore.

DUNES

Bordering the beaches on parts of the Oregon coast are extensive areas of both active and stabilized sand dunes (W. S. Cooper, 1958). The sand dunes are extensive on the northern part of the Oregon coast, particularly north of Coos Bay; south of Coos Bay the areas of dunes are small and scattered. The southern Oregon coast has many sea cliffs and headlands, making it difficult for sand to be blown inland in sufficient quantities to accumulate in the form of dunes. However, small dune deposits are to be noted at Pistol River, near Euchre Creek, in the Garrison Lake area north of Port Orford, and more extensive but thin deposits of dune sand on the wide terrace to the north of Cape Blanco. Some of the dunes along the Oregon coast are very old and have become stabilized and forested naturally in past centuries.

The most extensive dune areas, reaching north from Coos Bay to the Columbia River, are related to the softer sediments of the Coast Range, in contrast to the more resistant rock of the Klamath Mountains. These sediments have been more easily eroded by running water, wind, and sea, and thus have furnished large quantities of sand to form the dunes. Many of these dunes reach to a height of 200 feet or more above sea level. In general, the ones near the shore have been active in recent years, but during the last 20 years considerable planting of the dunes has been carried on, so that the active dune area has been diminished. In some areas, the sea has attacked and eroded the dunes, thus supplying the beaches with a large amount of sand. In other areas, as the Clatsop Plains of northwestern Oregon, the dune area is growing. The dune sand tends to move in from the northwest in summer and from the southwest in winter. Tongues of active dune sand in the form of long fingers are, in many cases, invading forest areas, frequently overriding old stabilized dunes. The dunes have played a major role in altering the drainage of the coastal area, especially by blocking the outlets of smaller streams and forming numerous lakes, or by changing the course of the streams.

ESTUARIES

In the low-lying areas of the Oregon coast, where large streams enter the sea, there are extensive deposits of estuarine materials - clay and silt mixed with varying amounts of sand. These estuaries have been developed by the eustatic rise in sea level and the subsequent partial filling of the stream valleys in the lower reaches by deposits from the rivers. In Nehalem, Tillamook, and Netarts bays and also in the lower courses of the Yaquina, Siuslaw, Umpqua, Coos, and Coquille rivers large estuarine deposits have been made; to the south of the Coquille River estuarine deposits are not extensive.

These estuarine deposits are produced by the inflow of the rivers into the bays and the reworking of the material by the tidal waters. Man's activities, such as logging and burning, have had considerable effect upon the rate of deposition. The diking of the lands adjacent to the estuarine streams in order to keep brackish water out of pastures and fields has contributed to the additional transport of sediment into the mud flats and undiked marshes, thereby filling the estuaries. During the last century the amount of silt carried by the streams has increased and thus the rate of filling has been accelerated. The general tendency is for the estuaries of the Oregon coast to fill up more and more completely as time passes (Chapter 7). The amount of change in the estuaries, however, varies widely; some have changed relatively little in the last 100 years.

MARINE TERRACES

Lying slightly higher than the estuaries, beaches, and lower dunes are extensive terrace deposits along the Oregon coast (Fig. 2.1). Although terrace deposits are found at elevations of several hundred feet in a few localities, for the purposes of this study, detailed descriptions are confined to the lower terraces which, in general, are not higher than 100 feet. Marine terraces are more extensive on the southern Oregon coast, south of Coos Bay, than they are on the northern Oregon coast. On the southern Oregon coast the terraces, which rise 50 feet or more above sea level, are underlain by resistant rock. Hence, the erosion of the terraces by the sea is less rapid than it is further north where the bedrock is weaker.

The marine terraces of the Oregon coast are, in some respects, the most important landforms involved in the recent changes. On the marine terraces lie most of the coastal towns, farms, and airports. Wherever possible the terraces are the preferred locations for roads and railroads. The terraces, in various stages of dissection, usually slope gently seaward but some have been warped enough to reverse this slope. The typical terrace has a smooth platform, the terrace deposits resting on an abrasion surface of bedrock. The backslope is usually modified by mass movements from above, the foreslope has often been destroyed or modified by the advancing sea.

J. S. Diller (1902) described the terraces of the southern Oregon coast and studied a section near Cape Blanco. Allen and Baldwin (1944:43-44) studied the terraces of the Coos Bay region and Baldwin (1959:30) discussed the terraces of the coast briefly in his Geology of Oregon. A. B. Griggs (1944:129-142) investigated the terraces on the southern Oregon coast with special reference to the deposits of chrome sands. Cooper (1958) gave some attention to terraces, since some of the sand dunes lie on top of old terraces. These scientists have been concerned with limited areas and specific problems and no complete correlation is available.

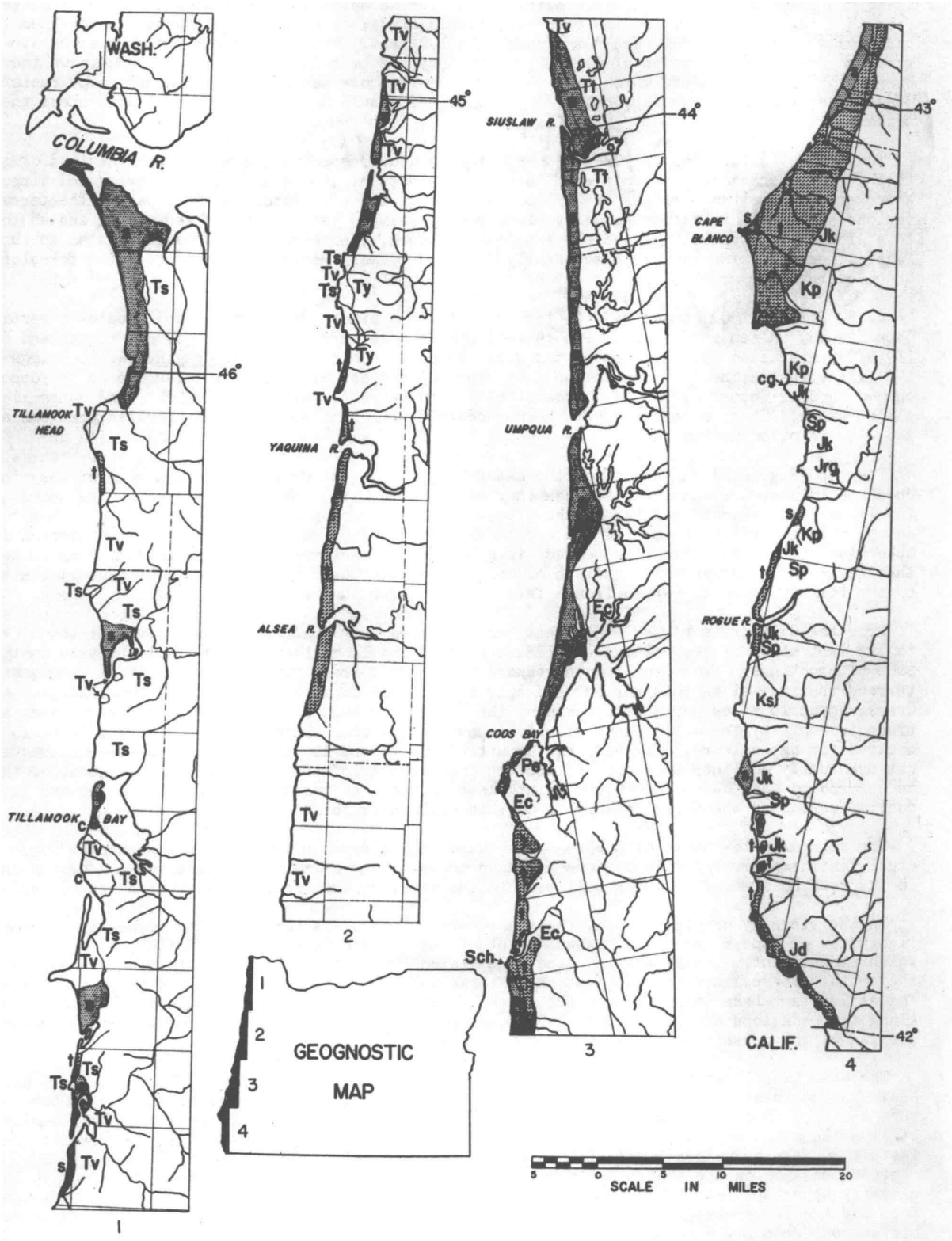
The map (Fig. 2.1) shows most of the major terraces of the Oregon coast and some of the minor ones. Undoubtedly some are not shown because they are covered with sand dunes or because the deposits and levels have not been identified in the steep, woody and brushy areas of parts of the Oregon coast. But enough data is available to give a general description of Oregon terraces. (In all cases, unless noted otherwise, the elevation of the terrace is given at the back surface of the terrace and, in some cases, the elevation of the abrasion surface or the contact with hard rock will also be given. The thickness of the terrace deposits varies from a few inches to more than 100 feet.)

From the California border the lowest terrace rises very gradually from 50 feet at the Winchuck River to 125 feet at Brookings. Above the 125 foot level small, higher benches are to be seen on the north side of Brookings. From Brookings northward the major terrace rises steeply with only fragments of the terrace showing, since this region is deeply and closely dissected by small stream valleys. At Thomas Creek, about 10 miles north of Brookings, the terrace reaches an elevation of about 300 feet and is represented only by fragments, some of which show up on aerial photographs because the level land has been cleared for agriculture. However, the amount of level land is very small. The terrace then levels out but eventually declines to about 125 feet in the vicinity of the Pistol River where most of the terrace is covered by sand dunes. At Crook Point, however, the sea has cleared away the dunes and terrace deposits, revealing the abrasion surface of this particular terrace.

For several miles north of Euchre Creek there is a stretch without terrace remnants. Here the principal landforms are landslides, some of which contain huge segments of solid rock. These have moved out to the sea and are sufficiently resistant to the waves so that small promontories are maintained.

In the vicinity of Cape Blanco, the major terrace reaches a maximum width of nearly five miles. At the lighthouse on Cape Blanco, the highest point of the terrace is 220 feet. Unlike the normal terrace, which slopes gently toward the sea, the Cape Blanco terrace is warped down to the northeast and also to the south. It declines to sea level near Floras Lake (about five miles to the northeast of Cape Blanco) and at Garrison Lake (six miles to the south of Cape Blanco) the elevation is slightly over 100 feet. Along the backslope of the terrace elevations are generally less than 200 feet. Associated with the warping of the terrace is an extensive offshore reef.

The Cape Blanco terrace is deeply dissected by the Sixes and Elk rivers which flow across it to the sea. The courses of these rivers are near sea level, although small riffles and rapids occur in the terrace section. North of Floras Lake the terrace dips below sea level for many miles; it declines somewhat at Fivemile Point and climbs again to nearly 100 feet at Cape Arago. Again there is a decline to approximately 30 feet above sea level at Coos Bay in the vicinity of Empire and South Slough. This terrace is represented also on the east side of the ridge in the towns of North Bend and Coos Bay with an elevation slightly above sea level; here the terrace has been modified by deposition from the Coos River. North of Coos Bay the terrace deposits have been eroded and, for a stretch of nearly 50 miles, dunes cover the backshore. Probably much of this dune coast is underlain by terrace deposits, some of which are below sea level, but the exact extent is not known. Further north a well-defined terrace at an elevation of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COLUMBIA R.
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GEOGNOSTIC MAP
SCALE IN MILES
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from 25 to 50 feet appears in the vicinity of Yachats and continues northward to Newport and beyond. Remnants of this terrace are to be seen further north, but to the north of Tillamook Bay terraces are almost completely absent. Instead, broad, rugged headlands alternate with stretches of dune sand.

The Oregon terraces are the result of numerous eustatic changes in sea level which have worked upon a slowly rising coastline. The old, high terraces are probably of late Pliocene age and the remaining terraces of Pleistocene age down to the latest one, which is perhaps late Pleistocene (Baldwin, 1959). However, the youngest well-developed terrace is too old to be dated by the carbon 14 method (Park Snavely, personal interview).

One of the problems which has interested the students of terraces is the occurrence, at many parts of the world's coastline, of a two-meter terrace. This implies that sea level has declined about two meters, more or less, during perhaps the last 400 to 500 years. The two-meter terrace is a controversial question and, in many cases, what appears to be the result of a reduction of sea level is actually just a platform cut by storm waves. At some points along the Oregon coast, particularly in the vicinity of Heceta Head, a rocky, two-meter "terrace" is very prominently developed. But examination of these sites indicates that this is actually the abrasion surface of an old terrace which is, at this point, slightly above sea level. The gravels and other terrace deposits on this old surface are very easily eroded by the storm waves. Hence, a two-meter "terrace" is developed.

BEDROCK

The bedrock on the Oregon coast (Fig. 2.1) ranges in age from Jurassic to Pleistocene and varies from highly resistant igneous and metamorphic rocks to very weak shales and serpentines. In general, the order of resistance ranges from intrusive basalts, flow basalts, graywackes, to massive sandstones, shales, and serpentines. In many cases, these bedrock materials, especially the harder ones, are overlain with terrace deposits or sand dunes.

Comparatively few formations make up most of the bedrock of the Oregon coast, although the rock material and the resistance within each formation varies from place to place. On the southern Oregon coast, one of the oldest of the sedimentary formations is the Dothan (Jd). This is made up predominantly of sandstones, usually medium-grained and massive, but with some layers of shale and siltstone. Occasionally there are interbedded lava flows which have higher resistance. The Dothan formation is most prevalent on the extreme southern Oregon coast in the vicinity of Brookings. The Rogue formation (Jrg) is mostly igneous, made up of massive, dark-gray lava flows, tuffs, and agglomerates. There are also some intrusive rocks in this formation. The Rogue formation has its greatest extent in the area of the Rogue River, inland from Gold Beach. It occurs on the coast between Euchre Creek and Brush Creek and also in the vicinity of Humbug Mountain.

The Knoxville formation (Jk) - generally equivalent to the Riddle formation - consists of dark-gray sandstone and some shale with conglomerate at the base. The Knoxville formation crops out at various places along the coast from Cape Ferrelo northward to Humbug Mountain and has a wide extent inland also. The Paskenta formation (Kp) - generally equivalent to the Days Creek formation - crops out in the vicinity of Euchre Creek; also in the area of Humbug Mountain and continues to Port Orford. It underlies a part of the wide terrace in the Cape Blanco region. Late Cretaceous beds (Ks) crop out widely in the area between Pistol River and Hunter Creek on the coast. They consist of relatively soft, khaki-colored, coarse-grained massive sandstones, together with some conglomerates. There are also black shales which are very weak. In spite of the weak appearance of the Cretaceous strata, it is fairly resistant, especially under certain attitude conditions. For example, Cape Sebastian which is composed of steeply dipping beds of Cretaceous sandstone, is a prominent headland on the Oregon coast.

Serpentine (Sp) occurs along the southern Oregon coast in a number of places, including Houstenader Creek, the vicinity of the Rogue River, and near Brush Creek. The serpentine, derived mainly from peridotite, is green to black in color but often weathers to a buff or rust color. Weathering penetrates

Fig. 2.1. Geognostic Map of the Oregon Coast. Stippled (s), dune sand, including active and stabilized dunes (cf. Fig. 6.1, which shows dune areas recently active); ruled (t), terrace deposits - sand, gravel, and cobbles. Special rock types: c, clay; cg, conglomerate; Sch, schist; Sp, serpentine. Formations: Pe, Empire; Ec, Coaledo; Tm, Keasey; Tn, Nestucca; Ts, Astoria; Tt, Tyee; Tv, volcanics; Ty, Yaquina; Kp, Paskenta; Ks, Cretaceous sediments; Jd, Dothan; Jk, Knoxville; Jrg, Rogue. (Compiled from various sources, including Baldwin (1959); Allen and Baldwin (1944); U. S. G. S. Oil and Gas Maps, Nos. 42, 88, 97, 186; Mineral Fuels Map No. 38.)

deeply into the serpentine and the upper portions are especially susceptible to mass movements. However, the serpentine is also weak internally and the larger landslides involve rock to a depth of 100 feet or more.

Between Cape Blanco and Heceta Head most of the outcrops of bedrock, appearing on or near the coast, are Tertiary sandstones, shales, and mudstones. From Sacchi Beach (Fig. 5.1) to a point 10 miles north of Coos Bay, the Coaledo (Ec) is the dominant formation, while the Tyee sandstone (Tt) is prevalent further north. The Tyee crops out in much of the central Oregon Coast Range and supplies large quantities of sand to the beaches. In the immediate vicinity of Coos Bay the sediments are folded in a series of anticlines and synclines with moderate faulting, all of which makes for abrupt changes in the character of the backshore (Allen and Baldwin, 1944).

From Heceta Head northward to Tillamook Head, Tertiary volcanics (Tv), mostly basalts and basalt breccias with associated tuffs and basaltic sandstones, play a dominant role in the detailed configuration of the coast. Intrusive masses also crop out, mostly basalts and gabbros. The harder phases of all the formations are represented by prominent headlands, while the weaker phases and the outcrops of sediments are associated with the bays and low-lying areas; in a few cases even the sediments are resistant enough to form headlands. The Nestucca formation (Tn) is largely tuffaceous siltstone and claystone with imbedded lenses of sandstone. It crops out in the vicinity of Nestucca Bay and also both to the north and south of the Salmon River. The Keasey formation (Tm) is made up of massive mudstones and siltstones that crop out north of the Nestucca River. The Yaquina formation (Ty) is mostly sandstone with interbedded tuffaceous siltstone. This formation occurs in the vicinity of Yaquina Bay and also in the Siletz River region. Because of its relative weakness, it does not usually appear in sea cliffs. The Astoria formation (Ts) is widespread along the northern Oregon coast from the vicinity of Astoria southward for 50 miles or more. It consists of sandstones, siltstones, and conglomerates.

STRUCTURES

The bedrock of the Oregon coast has undergone a variety of structural changes from gentle folding and warping to extensive movements along shear zones. North of Coos Bay, folding and faulting have been on a comparatively small scale; in many places, the sediments are of relatively low dip. Small faults and gentle folds, nevertheless, are responsible for abrupt changes in the backshore. Resistant headlands often end abruptly in faults; dikes, sills, or other resistant members sometimes control the direction of the shoreline for a short distance, or form reefs in shallow water.

South of Cape Blanco the older rocks of the Klamath Mountain region are folded and faulted in a more complex manner. Dips are generally steeper, faults are more common and of greater magnitude. Broad shear zones often mark abrupt changes in lithology, they are themselves less resistant than the bordering formations, and they are especially susceptible to mass movements. In the shear zones relatively small, resistant masses of schist, greenstone, and sandstone occur in rocky mounds or bosses, or they occur in sea stacks on the beaches. Specific mention of materials and structures are included in the detailed studies (Chapters 5, 6, and 7).

CHAPTER 3. AGENTS OF CHANGE

Samuel N. Dicken and Bill Hanneson

On the Oregon coast rain, wind, waves, gravity, and man are the most effective agents of change; temperature, currents, tides, soil water, and ground water play lesser or at least secondary roles. Man is a new agent; but, for more than a century he has burned, logged, cultivated, built, and dredged - all of which have upset the equilibrium of the natural processes. The following discussion of the agents of change applies mainly to a belt extending not more than five miles inland and lying between sea level and 1000 feet elevation. (Obviously, agents operating farther inland also affect the coast.)

CLIMATIC AGENTS

The Oregon coast has a humid west coast marine climate with moderate temperatures and high annual rainfall. The temperature range is small, reflecting the influence of the maritime air. Snow and freezing are rare. Newport, on the middle Oregon coast, is a representative station (Table 3.1).

TABLE 3.1*

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Ann
Av. T. in °F.	43.5	44.9	45.9	48.4	51.6	55.1	56.8	57.2	55.9	53.3	48.9	45.2	50.6
Av. R.F. in inches	10.20	8.37	7.24	4.94	3.80	2.50	0.77	0.79	2.94	5.01	10.57	10.28	67.41

* U. S. Weather Bureau.

In Thornthwaite's system (1948) the climate is perhumid mesothermal A B_4 r a' with no marked seasonal thermal concentration. There is little difference from north to south; in the north the evaporation is slightly higher, reflecting the higher latitude and the greater distance from the cold upwelling water off the northern California coast (Patton, 1956:129). The temperature conditions are conducive to the maintenance of a complete vegetation cover wherever other ecological factors, such as soil moisture, are favorable.

The moisture surplus-deficit, using Thornthwaite's (1948) calculations, has a short but marked summer minimum. This deficit appears to be important in the erosion and transport of sand, both in restricting plant growth and in drying the sand for eolian erosion. However, large quantities of sand are transported by wind in the wet season, even during heavy rains. The drying of sand in summer promotes movement at lower wind velocities.

Fog, common during the summer months, partially offsets the absence of rain, in so far as plant growth is concerned. It is particularly significant on the edges of the forest, but high humidity results in reduced evapotranspiration from all plants (Geiger, 1957:364-365). The ground-water table does fluctuate seasonally, being lowest in late summer. There is enough precipitation for a dense vegetation cover, since the moisture economy of most plants of the temperate world is adequate to overcome the summer deficit. The effects of the summer deficit are most pronounced on the dunes and terraces.

The winds of the Oregon coast blow generally from the north and northwest in the summer months, and from the south, southwest, or southeast during the winter. W. S. Cooper (1958:14-20) made a detailed study of the winds of the Oregon coast and summarized them as follows:

> In summer, onshore winds greatly predominate, and most of these are confined to the sector N.-NW.; they cover about one octant seaward from the trend of the coast. Winds within this sector have the greatest average velocity. Fall conditions are transitional; winds of the winter type appear in alternation with those of the summer type. In winter, offshore winds are most frequent but have low velocity, except for the gorge winds of the Columbia River. Onshore winds from south to southwest are relatively infrequent but have by far the greatest velocity; they are parallel to the coast or strike it at an acute angle. Spring

conditions are again transitional: N.-NW. winds reappear alternating with the gentle offshore breezes and high-velocity S.-SW. winds of winter.

Cooper noted the importance of the high velocity winds and his wind rose diagram is reproduced here (Fig. 3.1).

The removal, transport, and deposition of sand particles by the wind affect the morphology and plant growth of the sand dunes. Where the vegetation cover is sparse, the removal of sand from blowouts (zones of deflation) may result in the exposure and subsequent killing of plant roots. The continual impact of sand particles on plant stems and shoots, termed sand-blasting, may result in permanent damage or even death of the plants. Sand deposition results in the burial of vegetation unless plant growth is able to keep apace. Wind-shorn trees and shrubs on most oceanward bluffs and cliffs reveal the drying effect of the wind; wind action alone makes the Oregon littoral a rigorous plant habitat.

Most of the winds of the Oregon coast are related to the large extra-tropical cyclonic structures which move in from the Pacific Ocean. The centers of some of these storms move across the Gulf of Alaska, some directly into Oregon and Washington, and some into California. The points at which the storm centers reach the Pacific coast affect the direction of the winds and waves which strike the Oregon coast. The cyclones which originate near Japan and move eastward across the Pacific tend to enter the Gulf of Alaska, particularly in the summer season when the wind systems are shifted to the north; this means that the winds on the Oregon coast are likely to be north or northwesterly. When the storm center moves directly across the Oregon coast, the winds blow from the southwest and south and often reach hurricane force. Although the duration of these high velocity wind periods is not very great, they do generate some fairly high waves. In this situation waves may approach the Oregon coast from southwest to northwest, depending upon the exact location of the storm center. When storms move into California, the winds along the Oregon coast are from the north or east, and the sea is usually fairly calm with a low westerly swell.

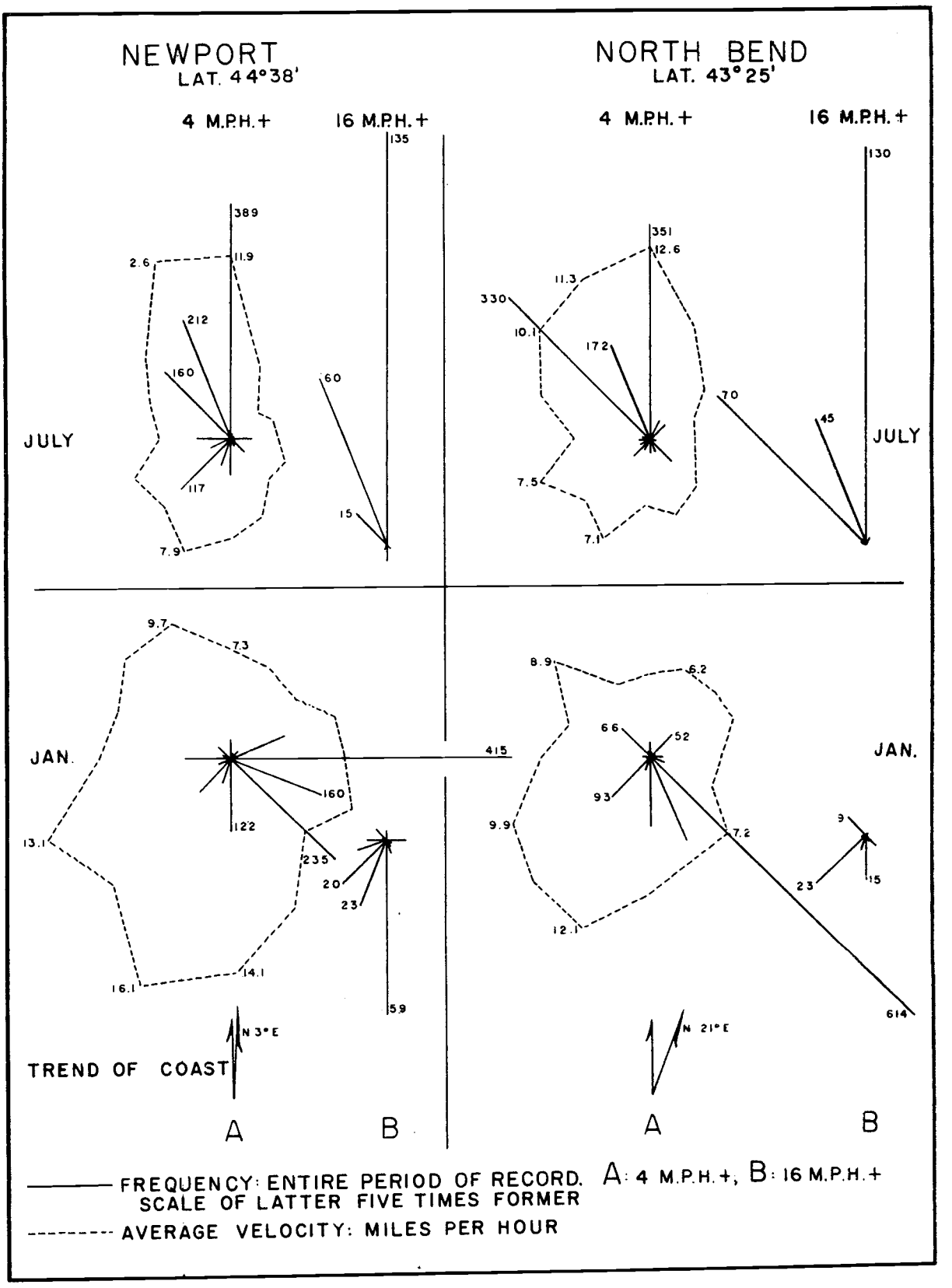
TIDES

Tides along the Oregon coast are moderate with the usual range of about seven feet above mean lower low water; the maximum range is from plus ten to minus two feet. One of the peculiarities of the tides of the west coast of the United States is the large difference in heights between the two high waters and the two low waters each day. Tides play an important part in changing the Oregon coast. The range of tide affects the character and width of the beaches. High tides are especially significant during storms when most severe erosion occurs on the backshore. Tides are also significant in the currents that are introduced into the estuaries. Tides reach up the estuaries of rivers to varying distances; for example, the tide reaches up the Columbia and Willamette rivers to Portland, approximately 97 miles, where it has a range of about one and one half feet. The tide continues up the Columbia River to Bonneville Dam above Vancouver, Washington. Tides extend up some of the other coastal rivers for distances of 20 to 25 miles. For instance, tidewater on the Siuslaw River reaches to Mapleton and on the Umpqua River to Scottsburg, 20 and 28 miles, respectively.

CURRENTS

The currents along the Oregon coast are not generally strong. A weak but fairly constant offshore current moves generally southward and has a width varying from 200 to 300 miles. The rate of movement is so slow that strong winds in the opposite direction may reverse the direction of the current on the surface. Near shore, a favorable combination of tide, wind, and ocean current will add up to a movement of three or four knots, but the average velocity is approximately 0.25 knots. Close to shore the currents are complicated and variable. Especially significant, from the standpoint of coast changes, are the longshore currents generated by waves. These currents vary from season to season, as previously suggested, and even vary from storm to storm. There is a strong northward drift in shallow water in the winter, particularly during severe storms. However, there is evidence that these storms carry sediment out into deep water and that probably southern currents pick up some of this sediment. More specific statements will be made concerning currents and tides in connection with local studies (Chapters 5,7).

Fig. 3.1. Wind direction and velocity at Newport and North Bend, Oregon. The diagram on the right side of each rectangle (B) shows the frequency of winds of 16 m.p.h. and greater. The predominant direction of these high velocity winds, which tend to generate the highest waves, is from the north and northwest in July, and from the south and southwest in January. (From W. S. Cooper, 1958:16).


NEWPORT
LAT. 44°38'
NORTH BEND
LAT. 43°25'
4 M.P.H.+
16 M.P.H.+
4 M.P.H.+
16 M.P.H.+
JULY
JULY
JAN.
JAN.
389
11.9
2.6
212
160
117
7.9
135
60
15
351
12.6
11.3
330
10.1
172
7.5
7.1
130
70
45
9.7
7.3
13.1
16.1
14.1
122
160
235
20
23
59
415
8.9
6.2
6.6
52
93
9.9
7.2
12.1
614
9
23
15
TREND OF COAST
N 3° E
N 21° E
A
B
A
B
FREQUENCY: ENTIRE PERIOD OF RECORD. SCALE OF LATTER FIVE TIMES FORMER
A: 4 M.P.H.+, B: 16 M.P.H.+
AVERAGE VELOCITY: MILES PER HOUR

WAVES

Wave studies along the Oregon coast have been limited to a few observational studies and a comparatively few hindcast studies. Nevertheless, the general character of the waves and swells - their direction, length, height, and period - is known. O'Brien (1951) reported on wave observations made at the Columbia River Light Vessel for the years 1933 to 1936. The ship was anchored about seven miles to the southwest of the Columbia River entrance in 198 feet of water. The dominant wave direction, expressed as percentage of total observations, was west (30 percent), followed by southwest (18.7 percent), northwest (16.5), and south (15 percent). This suggests that the dominant wave direction is from the west-southwest. O'Brien weighted the percentages in proportion to the square of the wave height (Fig. 3.2, inset). Thus the effective wave direction is more nearly from the southwest, a bearing of approximately 228 degrees. This fact is important in terms of the generation by waves of littoral currents and the transport of sand, especially in view of the variation in orientation of the Oregon beaches (Chapter 5). Measurements at the Columbia River Light ship showed that the longest waves (325 feet) and the highest (10.6 feet) occurred in December; the shortest waves (45 feet) and the lowest (1.2 feet) occurred in July.

Scripps Institution of Oceanography (Univ. of Calif., 1947) in a report, entitled "A Statistical Study of Wave Conditions at Five Open Sea Localities Along the California Coast", included one Oregon station (Lat. 42° 5' N., Long. 125° W., vicinity of Cape Blanco). It was concluded from this hindcast study (p.33) that, "the predominate wave direction for all seasons is from the northwest". However, the report further stated that "the preponderance of waves from the northwest increases ... from north to south". It appears from the wave-height-direction chart (Fig. 12) in the report that the dominant wave direction at the station near Cape Blanco is more nearly west-northwest.

A report prepared for the U. S. Army Corps of Engineers by the National Marine Consultants (May, 1961) includes two stations along the Oregon coast, one off the mouth of the Columbia River and another near Newport. This is a hindcast study with separate data for both swell and sea (Fig. 3.2). The data for Station 1, Toledo (near Newport), is presented in Table 3.2.

TABLE 3.2

AVERAGE DIRECTION FREQUENCY OF WAVES FOR 1956, 1957, 1958 (%)

	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE
JANUARY										
SWELL	- -	- -	14.6	36.0	41.1	39.4	15.4	11.6	0.6	- -
SEA	0.6	- -	4.2	2.5	3.8	3.3	10.8	13.0	22.6	6.5
JULY										
SWELL	- -	8.3	27.0	20.0	19.0	3.5	1.2	2.7	- -	- -
SEA	21.1	26.8	21.2	1.1	1.3	2.9	2.4	1.6	0.6	0.3

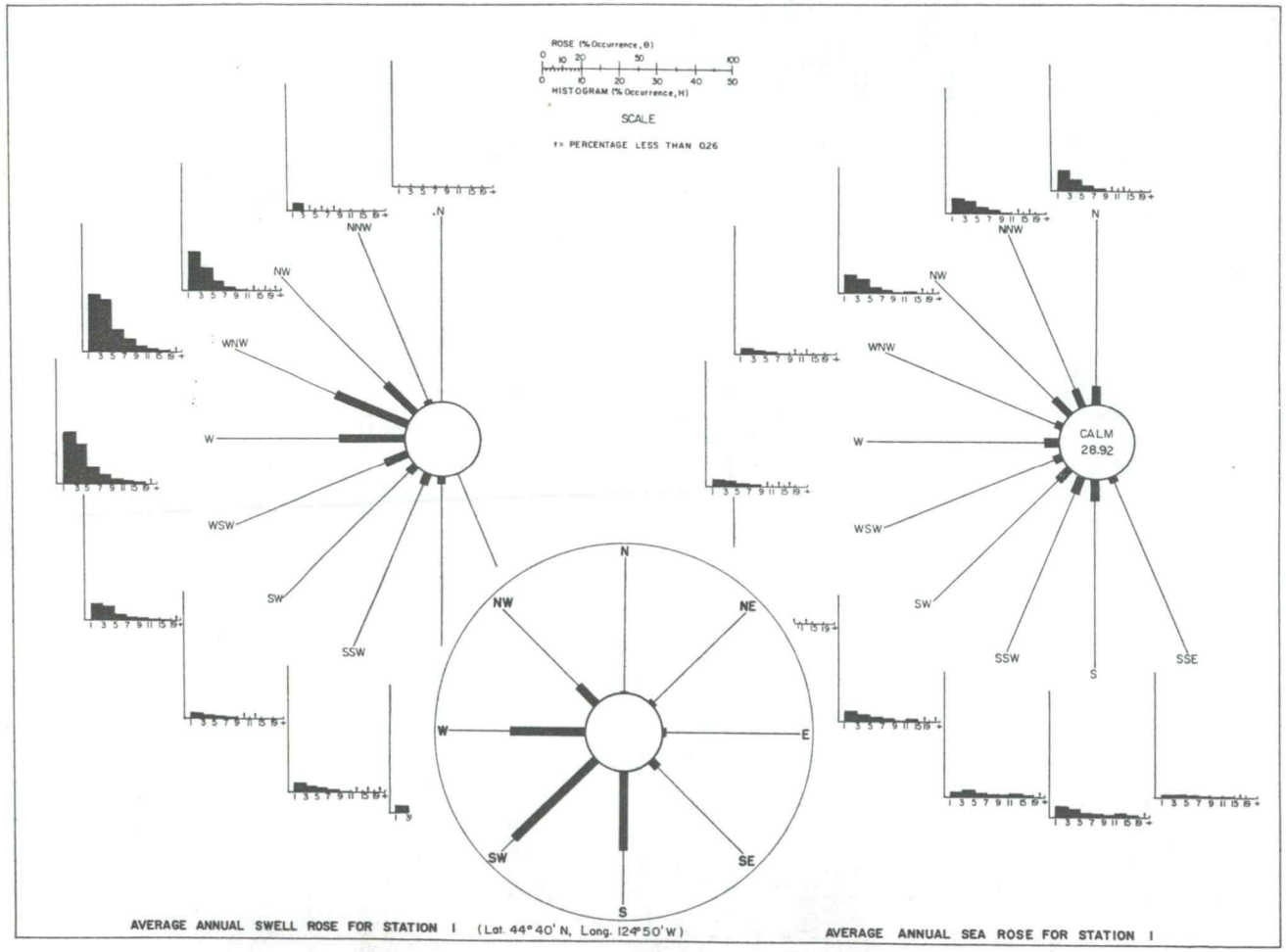
The results for the swell are fairly close to those of the Scripps Report, but the sea rose shows much more predominant south and southwest components. It is obvious from Table 3.2 that in January the predominant wave direction was west, while in July it was northwest. The tables in the National Marine Consultants Report indicate, however, that the waves are higher in the winter from the west and southwest than from the northwest.

Most observations of storms and storm damage along the Oregon coast indicate that southwest winter storms are the ones that do damage. The northwest winds of summer may create an effect of high velocity but the storm waves accompanying the northwest winds are not as high. This also is confirmed by the configuration of the beaches, many of which are skewed to the north. Tsunamis (tidal waves) are rare on the Oregon coast. Occasional large waves, probably of tectonic origin, have resulted in property damage but do not appear to have caused significant permanent changes.

THE IMPACT OF MAN

As noted briefly in Chapter 1, the advent of the white man on the Oregon coast more than a century ago upset the equilibrium of the natural forces. Of the many activities of man, burning, on the one hand, and the construction of jetties and dikes, on the other hand, have had the most far-reaching effects.

Fig. 3.2 Annual swell rose and sea rose for a station (Toledo) off Newport, Oregon. According to these hindcast values, the dominant swell direction is from the WNW, while the sea direction ranges from SSE to N. (From National Marine Consultants, 1961). The inset circle (data from O'Brien, 1951) gives the results of wave observations from the Columbia Light Ship, the values of which represent the frequencies observed times the square of the heights.



AVERAGE ANNUAL SWELL ROSE FOR STATION I (Lat. 44° 40' N, Long. 124° 50' W)

AVERAGE ANNUAL SEA ROSE FOR STATION I

Forest Fires

Fires set by Indians probably played a fairly important role in changing the landscape of the Oregon coast, prior to white settlement. (Fires set by lightning are rare in the coastal zone.) The Indians set fires to drive the game animals and also to make the browse more attractive to these animals. David Douglas (Royal Hort. Soc., 1914:214), the botanist, who traveled through western Oregon in 1826 believed that the Indians were responsible for the fires at that time. However, only small portions of the coast were occupied by Indians and it is likely that most of their fires were local in character.

By 1845 white settlers had occupied many areas of western Oregon, and the decade that followed was a time of extensive burning. Accounts of forest fires came from Indians, fur traders, and settlers (Morris, 1934:313). Some of the Oregon coast fires originated in the Willamette Valley; for example, in 1845 a fire, starting near Champoeg on the Willamette River, burned its way to the coast and covered a large area near the lower Nestucca River (Oregonian, 1894). In 1846 another great fire occurred, which burned from Tillamook Bay to Coos Bay (Horner, 1919), bringing death to many Indians and to thousands of game animals. According to William Smith, an Alsea Indian (Frachtenberg, 1920), a fire devastated the coast from the Siuslaw River to Coos Bay in 1850.

The widespread burning during this period - 1845 to 1850 - is confirmed in detail by the early topographic charts of the U. S. Coast and Geodetic Survey and by the observations in the Coast Pilot (Davidson, 1889). The charts have specific notations of burned timber and brush near the shore. Since the burned-over land today is soon covered with brush, it can be assumed that the early accounts of brush and grass on the Oregon coast are evidence that fires had recently occurred there.

When the forests were carefully mapped many years later (U. S. Forest Service, 1936), the age of the trees substantiated the early accounts of fire with few exceptions. Between 1845 and 1902, much of the coast from the Nehalem River to the Rogue River was burned, some sections more than once. One important effect of this burning was the subsequent increase in the extent of the Douglas fir forest (C. F. Cooper, 1961:151) over wide areas. The Douglas fir will not germinate in shade; the openings made by the fires enabled the seedlings to grow more readily. Other effects of these fires were accelerated stream erosion, an increased rate of estuary filling, and more pronounced mass movements. (Superficial mass movements are held in check by large trees; on some of these surfaces at present only scattered trees and brush are growing.)

Jetties

During the last 80 years jetties have been constructed on ten river entrances along the Oregon coast, causing immediate and obvious changes in the shoreline. In most cases rapid deposition occurred adjacent to the jetties both on the north and on the south, until the shoreline became adjusted to the new conditions. Some of the effects of the jetties were slow to appear. In a few cases, on beaches which were previously stable, erosion was observed a few years after jetty construction. On the Oregon coast jetty construction first began at the Yaquina and Coquille rivers in 1881 and has continued intermittently to the present. Many of the jetties required several years to complete; some have been extended and repaired from time to time. Table 3.3 lists the years in which construction started on these jetties.

TABLE 3.3*

	NORTH JETTY	SOUTH JETTY
CHETCO RIVER	1957 E	1957 D
ROGUE RIVER	1960 D	1959 D
COQUILLE RIVER	1892 D	1881 D
COOS BAY	1891 D	1924 D
UMPQUA RIVER	1917 D	1933 E
SIUSLAW RIVER	1892 D	1910 E
YAQUINA RIVER	1889 D-	1881 D+
TILLAMOOK BAY	1914 D+	---- E+
NEHALEM RIVER	1916 D-	1910 D+
COLUMBIA RIVER	1913 D	1885 D+

* D Deposition to the north of the north jetty and to the south of the south jetty.
E Erosion to the north of the north jetty and to the south of the south jetty.
\+ Rapid and extensive deposition or erosion.
\- Minimum deposition or erosion.
No south jetty was built for Tillamook Bay.

The most extensive deposition has occurred to the south of the Columbia River; the greatest erosion to the south of the Tillamook Bay entrance. Details of these jetties are discussed in Chapter 5.

Dikes

On the margins of the bays and estuaries, low earthen dikes have been constructed to keep the brackish water out of the pastures and fields. In the early days of settlement, many of these were constructed by the farm owners, using hand shovels and horse-drawn scoops; later power shovels were used. In recent years some of the dikes have been built by the U. S. Army Corps of Engineers and some have been built by independent drainage districts and by individuals. Drainage is usually provided by automatic tide gates, fed by open ditches. The general effect of the dikes has been to change the species composition and the shoreline on the margins of the bays and estuaries. Details of these estuarine changes are discussed in Chapter 7.

CHAPTER 4. CLASSIFICATION OF OREGON SHORELINES

Samuel N. Dicken

The simple classification of Oregon shorelines presented here is intended as an aid in understanding recent physical changes and is, therefore, mainly descriptive of the present forms rather than initial forms. It is assumed that the coast is one of submergence and that sea level has been constant, or nearly so, for the last 6000 years; furthermore, it is assumed that during this period no significant tectonic warping has occurred to bring about local changes in sea level. The classification is concerned with the foreshore and the backshore, and especially with the contact of these two zones, for this is the location of the most significant recent changes. The classification makes use of ideas from several more comprehensive classifications, including those of Cotton (1954), Guilcher (1958), Shepard (1948), and Valentin (1952).

GENERAL CLASSIFICATION OF OREGON SHORELINES

I. Advancing Shorelines

1. Prograding beaches

1j. Prograding beaches associated with jetty construction

2. Prograding estuarine deposits

3. Prograding by mass movement

II. Equilibrium Shorelines

(Including shorelines where evidence of retreat or advance is lacking)

III. Retreating Shorelines

1. Submergence only, little erosion or deposition

2. Eroding shorelines

(a) Bordered by dunes

(b) Bordered by terrace deposits, little or no hard rock

(c) Bordered by hard rock cliffs, no stacks

(d) Bordered by hard rock cliffs, numerous stacks

(e) Bordered by mass movement debris, little or no bedrock in place

The main divisions are based on the advance or retreat of the shoreline. On the Oregon coast prograding beaches (I-1) are few, limited to those areas where the supply of sediment, from streams or from wave erosion of weak deposits, is unusually large. The best example is Clatsop Beach immediately south of the Columbia River, which is advancing seaward at a fairly rapid rate. In addition, prograding has occurred, and is occurring, near jetties constructed at the entrances of various rivers and bays (I-1j); in the estuaries and lower courses of the rivers (Chapter 7), tidal marshes and mud flats are growing at the expense of open bay (I-2). A special kind of prograding (I-3) involves the seaward movement of landslides and rockslides, if the movement is faster than the waves can erode the material. This is a temporary sort of prograding, but it represents a process which has a significant effect on the character of some shorelines.

There is a temptation to omit equilibrium shorelines (II) from this classification. Probably no large part of the Oregon coast is in equilibrium. However, since portions of some shorelines are both prograding and retrograding, it follows that some short sections of shoreline are in equilibrium, at least tem-

porarily. In any event this category is effective in classifying those shorelines where evidence is lacking of either retreat or advance.

The general configuration of the Oregon coast is the direct result of submergence (III-1), and the invasion of a landscape fashioned by subaerial erosion. As sea level rose to its present height, river valleys were drowned and bays, such as Coos, Yaquina, and Tillamook, were formed, the resistant hills appearing as headlands. Since sea level has been nearly constant for the last 6000 years, submergence is not a direct factor in present processes.

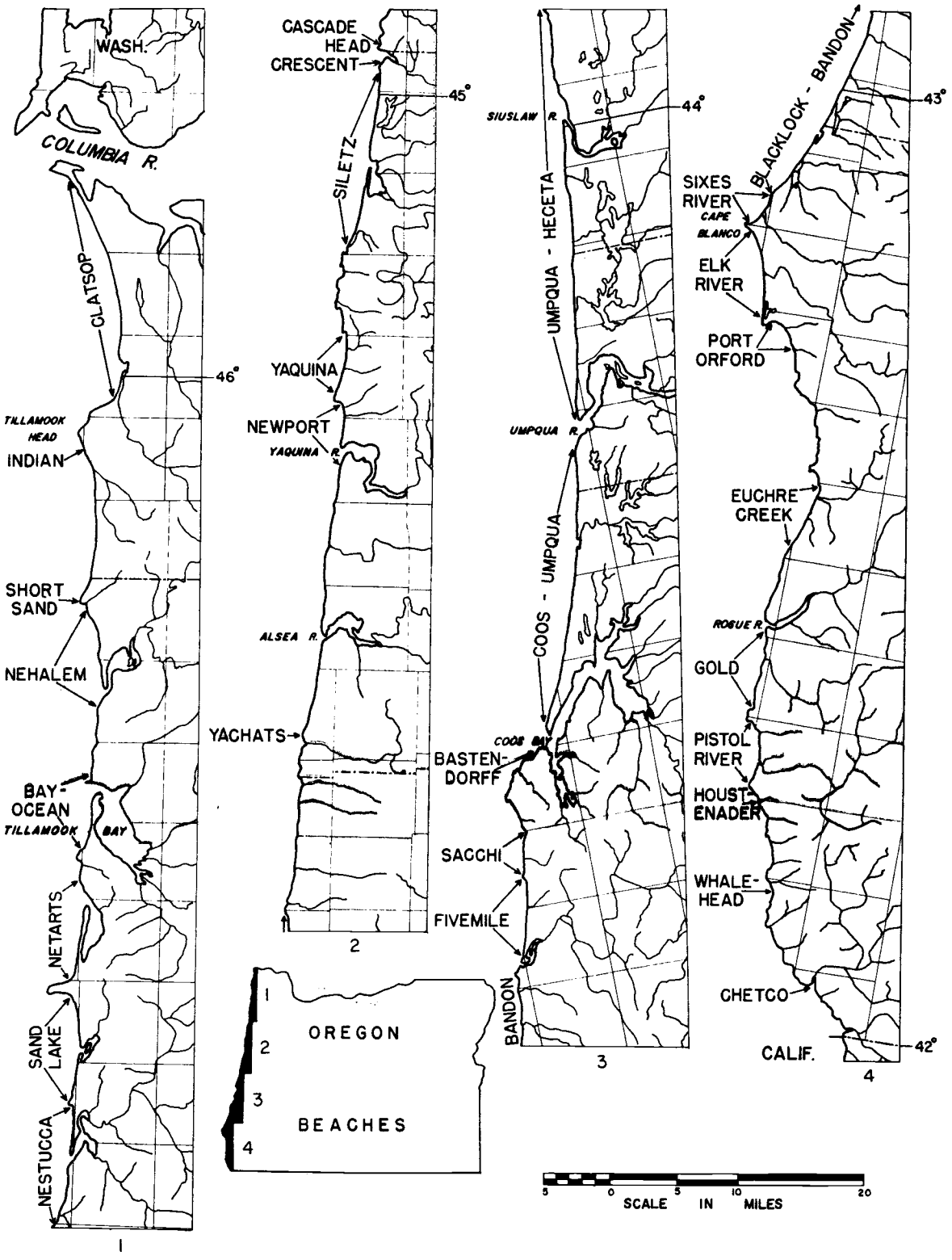
Much of the detailed character of the Oregon coast is due to retrogression under direct marine erosion, the type of erosion depending upon the materials and forms which the sea is attacking. This classification of eroding shorelines (III-2) is based upon this variety of materials and forms of the Oregon coast.

Type III-2a includes eroding shorelines which are flanked by dunes. The dunes themselves are subject to change under the influence of wind and vegetation. In many places this retrogression of the coast is at the expense of stabilized dunes which have been forest-covered for at least 200 years. Type III-2b includes coasts flanked by terrace deposits. Here the sea is cutting into old marine deposits of Pleistocene age which are readily eroded. This type occurs only where the abrasion platform of hard rock is near or below sea level. Where the abrasion platform is high up on the cliff another type (III-2c) is indicated.

Type III-2c includes eroding shorelines which are flanked by rocky cliffs. The cliffs may vary in hardness, in resistance to erosion, and in the rate of retrogression. They all have steep slopes, parts of which have formed along joint planes and may be vertical. A variation of this type, Type III-2d, results when the beach below the cliff is dotted with many stacks and small rocky islands.

Type III-2e is developed in mass movement debris. This is a type common on the Oregon coast; however, it has received little attention in coastal literature. One of the effects of mass movement is to bring large quantities of rock fragments to the beach. If these fragments are too large to be moved readily by the waves, a rocky shoreline results. This type is of special interest in a study of present changes, since deforestation of the backshore has accelerated mass movements.

The above classification can be applied, in a broad way, to include all of the Oregon shoreline; in terms of a general classification, it will be observed that several types are missing. For example, Oregon has no ria coast, in the usual meaning of the term; it has no coral coast; and it has no shoreline of volcanic accumulation. Restricted though it is, however, the classification is a broad one; more detailed classifications of beaches and estuaries are included in Chapters 5 and 7.


WASH.
COLUMBIA R.
CLATSOP
46°
TILLAMOOK HEAD
INDIAN
SHORT SAND
NEHALEM
BAY-OCEAN
TILLAMOOK BAY
NETARTS
SAND LAKE
NESTUCCA
1
CASCADE HEAD
CRESCENT
45°
SILETZ
YAQUINA
NEWPORT
YAQUINA R.
ALSEA R.
YACHATS
2
SIUSLAW R.
44°
UMPQUA - HECETA
UMPQUA R.
COOS - UMPQUA
COOS BAY
BASTEN-DORFF
SACCHI
FIVEMILE
BANDON
3
BLACKLOCK - BANDON
43°
SIXES RIVER
CAPE BLANCO
ELK RIVER
PORT ORFORD
EUCHRE CREEK
ROGUE R.
GOLD
PISTOL RIVER
HOUSTENADER
WHALE-HEAD
CHETCO
CALIF.
42°
4
OREGON
BEACHES
1
2
3
4
SCALE IN MILES
5
0
5
10
20

CHAPTER 5. CHANGES OF THE OREGON BEACHES

Samuel N. Dicken

The Oregon beaches occur as distinct units (Fig. 5.1), of varying length and shape, separated by rocky headlands, jetties, or other obstructions. Although few, if any, of the barriers block the longshore movement of sand entirely, they do form definite breaks in the shoreline. The beaches vary in length up to nearly 30 miles. The longest beach, originally extending more than 50 miles from Coos Head to Heceta Head, is now divided by the jetties at the entrance to the Umpqua River into two distinct beaches, the Coos-Umpqua Beach, 30 miles long, and the Umpqua-Heceta Beach, 23 miles long. Clatsop Beach, between the Columbia River and Tillamook Head, is 17 miles long and at least ten other beaches are more than five miles in length. On the other hand, many of the smaller beaches measure only a fraction of a mile. The average length of 30 beaches studied is 6.2 miles. All beach lengths herein are expressed as the chord distance in miles between the extreme ends at the high-tide line.

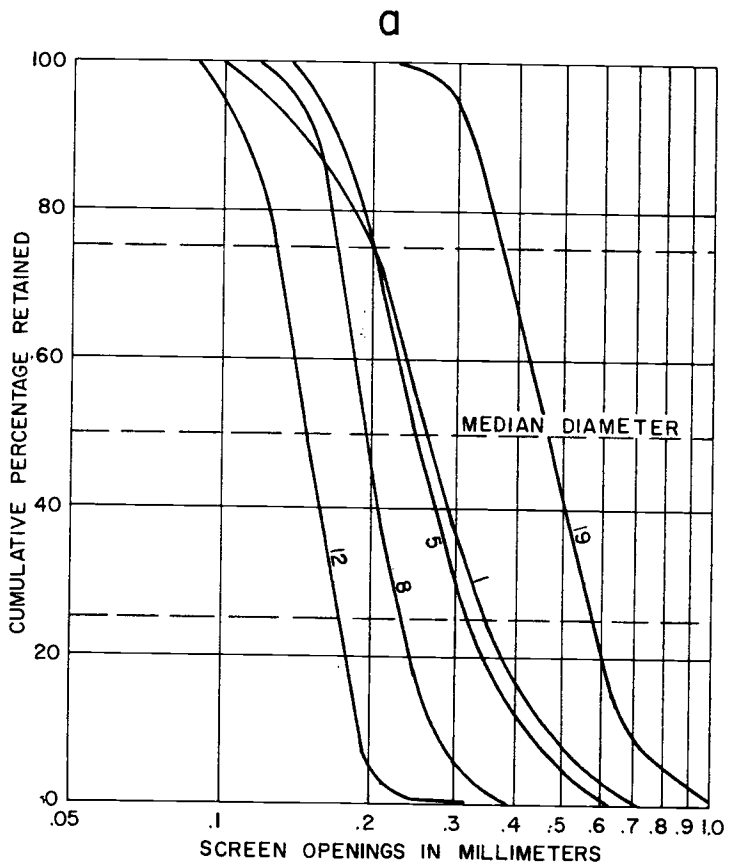
MATERIALS OF THE BEACHES

The materials of the Oregon beaches range from fine sand to large boulders and angular rock fragments. Small quantities of silt sometimes appear near the outlets of the rivers. The characteristic material is a fine sand with a median diameter of nearly 0.250 mm. (Fig. 5.2). About three fourths of each sand sample consists of angular to subangular quartz and feldspar; the remainder is made up of dark minerals, chiefly magnetite, chromite, and epidote. Well-rounded grains are common but not abundant. Some coarser sand is found on most beaches and on a few the median diameter is greater than 0.5 mm. Tables 5.1 and 5.2 show sieve analyses of sand samples from various beaches. Table 1 includes sand samples collected in 1960-1961 during the course of this study. Most of them were taken from the mid-point on the beach face. In addition, a number of analyses by Twenhofel (1946a and 1946 b) are listed in Table 2. These samples were collected in the summers of 1942 and 1943. All samples were processed with a Rotap apparatus but with different sieve openings; Twenhofel used the Wentworth system, whereas the Tyler system was used in this investigation. The results are fairly comparable, however.

Near rocky headlands the beaches are likely to include large, well-rounded cobbles and boulders, mixed with the sand, especially near the high-tide line. In some cases these large fragments have been carried two or three miles to the north of the headlands. At Bayocean, north of Cape Meares, and at Seaside, north of Tillamook Head, large quantities have been carried to the north. Boulders are also carried southward from the headlands, but to lesser distances. Grain size shows some correlation with the slope of the beaches, but the relation is by no means a simple one. Where the material is homogeneous, the finer sands are found on nearly level beaches and the coarse sands and gravel on the steeper slopes. On many beaches where thin layers of differing sizes occur, the correlation is not clear. The slope is also affected by the intensity of wave action (Bascom, 1951:871).

The sand, gravel, cobbles, and boulders of the beaches are derived from the land, either via the rivers, or by wave erosion of the shore. The large fragments are easily traced. They originate from the adjacent headlands and cliffs. Most of the sand comes from the rivers, although some is derived from the erosion of sandstone cliffs, terrace deposits, and sand dunes. Although bed load data is not available for the Oregon rivers, it is assumed that it is roughly proportional to the water discharge of the rivers. The discharge of the representative rivers which provide sand to the Oregon coast is as follows:

Fig. 5.1. Location of beaches described in Chapter 5. The extent of the longer beaches is shown by arrows. Local names are used in most cases; arbitrary names are used for some of the longer beaches and for a few of the shorter ones, for which no local names are available.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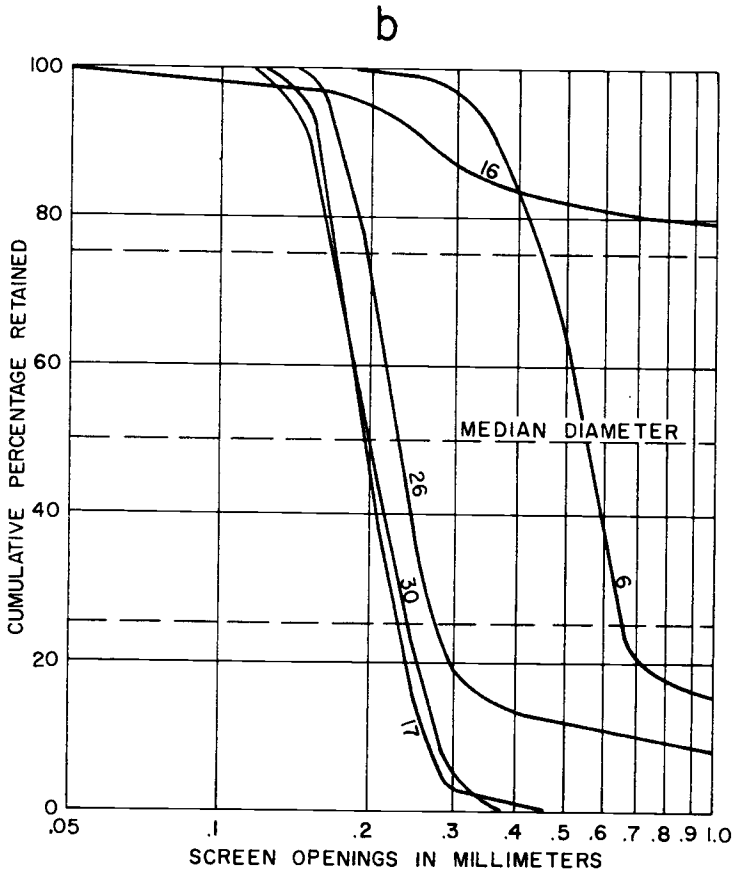
SCREEN OPENINGS IN MILLIMETERS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CUMULATIVE PERCENTAGE RETAINED
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SCREEN OPENINGS IN MILLIMETERS

River and Gauging Station	Drainage Area sq. mi.	Average Discharge cu. ft. per sec.	Peak Discharge cu. ft. per sec.
Columbia Bonneville	259,000	235,000	1,170,000
Nehalem Foss	667	2,646	....
Alsea Tidewater	334	1,529	....
Siuslaw	770	2,500	12,900
Umpqua Elkton	3,680	7,297	172,000
Rogue Grants Pass	2,420	3,353	91,500

(U. S. Geol. Survey, 1949, Water Supply Paper, No. 1080; Circulars Nos. 44 & 52.)

Discharge records are not available for the outlets of the rivers but this listing shows the dominant position of the Columbia River. Peak discharge records are probably more significant than the average flow in bringing about changes in the estuaries and beaches.

The movement of sand on the beach is complex. In general, the initial movement is generated by waves and the direction inshore is opposite the wave direction. On the Oregon coast this varies with the season; the predominant waves from the southwest in winter drive the sand to the northwest. However, this is merely the inshore movement of the sand; as the waves in the rip currents carry sand seaward, the sand is picked up by currents often in the form of eddies, and these currents may carry the sand in the opposite direction. On many of the Oregon beaches which are terminated by headlands, the movement of the sand is circular and, although inshore movement appears to be in one direction, the net effect may be just the opposite.

BEACH PROFILES

The Oregon beaches vary widely in slope from the gentlest, nearly one in 75, to the steepest, about one in 10. Generally, the fine sand beaches have a gentle slope. The most common profile includes a gentle, concave slope at the lower low-water line which increases toward the high-tide line - a concave slope which may be a steep 30 degrees at the berm. Shoreward from the berm ridge is usually a gentle back slope toward the inshore , often with a veneer of coarser sand, as finer material is removed by the wind. On many beaches no berm can be identified, on some beaches two berms are present. Below the low-water line two bars are often present, one at about minus 2 feet and another at minus 20 feet (Fig. 5.3).

On prograding beaches the profile is often simple and concave, increasing in steepness shoreward and passing without a definite break to the low, hummocky foredune. All prograding beaches are bordered by foredunes, but foredunes are found also at the foot of cliffs, especially during the summer season. The slopes are generally steeper on the ends of the beaches than in the middle. Cobbles often appear on the steep parts in winter, but may be covered with sand in the summer.

MAPS OF THE BEACHES

Nearly all of the Oregon beaches are curved inward, forming crescents of varying curvature, some approaching arcs of circles (Fig. 5.4 a. and b.). A few beaches are nearly straight or curved outward, due to unusual local conditions. The explanation of the curvature lies in the direction of the waves, as noted above. The waves tend to move the material along the shore and to orient the shore normal to the wave direction. Waves from the southwest drive the material northward, waves from the northwest drive the material southward. The north headlands tend to protect the northern part of the beach from the

Fig. 5.2. Size variation of beach sands. Most of the Oregon beaches are similar to Beaches 1 and 5; Beach 6 represents an unually coarse sand, while Beach 16 is an accumulation of coarse sand and gravel in pockets on a rocky shore.

TABLE 5.1

SIEVE ANALYSES OF SAND SAMPLES (%)
(Collected by Principal Investigator)

BEACH	greater than 1	0.71	0.50	0.35	0.297	0.246	0.210	0.149	less than 0.124	
1. CHETCO. Mid-point.	...	...	7.7	16.6	13.2	18.4	16.1	24.7	3.3	
2. WHALEHEAD. Inside middle stack; uniform to 1 ft.	...	...	9.3	21.7	18.3	21.4	14.5	13.6	1.2	
4. PISTOL RIVER. Upper mid-beach; midway Cape Sebastian and Pistol R; 1 in. coarse removed.	...	31.2	7.9	9.2	8.4	14.5	13.1	...	15.5	
5. GOLD. 150 yds. s. of s. jetty; upper beach face.	...	...	4.3	14.3	12.8	19.4	18.2	27.8	3.1	
6. EUCHRE CREEK (North). Southern end.	...	3.2	23.3	44.9	16.9	8.4	2.3	...	0.9	
8. ELK RIVER. Stack at Cape Blanco.	...	...	...	2.3	3.4	11.9	19.2	55.2	6.9	
									1.1	pan
10. BLACKLOCK-BANDON. 3 mi. s. of Bandon.	...	...	...	4.7	21.3	41.5	19.9	12.2	0.4	
12. SACCHI. Mid-point on foreslope.	...	...	...	0.04	0.06	0.30	2.5	45.7	30.4	
									20.9	pan
16. YACHATS (North).	...	...	...	3.2	6.2	18.1	22.8	45.9	3.3	
									0.5	pan
17. NEWPORT (at Jumpoff Joe).	...	...	...	1.8	1.5	11.9	22.8	57.6	4.2	
									0.2	pan
19. SILETZ (Gleneden). North end of cliffs.	0.3	8.0	...	73.4	13.8	3.8	0.5	...	0.1	
26a. BAYOCEAN. Low tide.	8.5	1.5	1.9	3.1	4.1	18.5	25.8	36.6	1.6	
26b. BAYOCEAN. Dune	...	...	...	1.0	1.0	9.5	23.8	60.0	4.3	
27. NEHALEM (at Manzanita).	...	...	...	0.5	2.4	22.7	40.8	33.4	0.2	
									0.02	pan
30. CLATSOP. 8 mi. n. of Gearhart; low tide.	...	...	...	1.3	4.3	17.4	22.3	47.3	6.2	
									1.2	pan

TABLE 5.2

SIEVE ANALYSES OF SAND SAMPLES (%)
(Twenhofel, 1946)

BEACH (mm)	greater than 2	1-2	½-1	¼-½	1/8-¼	1/16-1/8	less than 1/16
4. PISTOL RIVER. Forebeach at old placer mine, s. of Myers Creek, n. of Pistol River.	...	...	0.65	26.0	70.0	3.35	...
5. GOLD. Old placer mine, 1 mi. n. of Rogue R, low to middle forebeach, 8 in. channel sample.	...	trace	0.10	11.95	81.0	6.95	...
6. OPHIR (EUCHRE CREEK). Top of back beach, n. side, mouth of Euchre.	1.35	82.40	14.45	1.50	0.30	...	...
8. ELK RIVER. S. of southern placer mine, s. of Cape Blanco. Top of forebeach.	...	...	trace	25.45	69.35	5.20	...
10. BLACKLOCK-BANDON. Forebeach 4.5 to 5 mi. s. of Bandon.	...	...	0.80	85.90	13.15	0.15	...
12. SACCHI. N. of Fourmile Creek in cliff, 280 ft. elevation.	...	...	...	4.05	91.65	4.30	...
12. SACCHI. Front of forebeach at top, s. of mouth of Fivemile Creek.	...	...	...	1.95	93.80	4.25	...
14. COOS BAY (Coos-Umpqua). End of Coos Bay Coast Guard trail to spit, low tide level.	...	...	0.85	84.75	14.40	...	...
14. COOS BAY (Coos-Umpqua). 2 mi. n. of Coast Guard trail to spit, low tide level.	...	...	6.15	84.30	9.20	0.35	...
14. SAUNDERS LAKE (Coos-Umpqua). 1 mi. s. of Coast Guard trail, mid-tide level.	...	0.50	19.85	79.20	0.45	...	...
14. UMPQUA RIVER (Coos-Umpqua). 4 mi. s. of mouth of Umpqua R, high tide level.	...	...	...	87.40	12.60	...	...
14. UMPQUA RIVER (Coos-Umpqua). 1 mi. s. of mouth of Umpqua R, high tide level.	...	...	...	82.75	17.75	...	...
14. UMPQUA RIVER (Coos-Umpqua). S. side of mouth of Umpqua R., high tide level.	...	...	2.70	88.90	81.20	0.20	...
15. UMPQUA RIVER (Umpqua-Heceta). 1 mi. n. of end of Coast Guard trail, low tide level.	...	...	0.70	50.70	48.60	...	...
15. SIUSLAW RIVER (Umpqua-Heceta). N. of jetty on n. side of Siuslaw R., low tide level.	...	...	0.50	57.20	41.60	0.70	...
17. AGATE (Newport). S. end of black sand deposit, s. end of Agate Beach, about 2 mi. n. of Newport, s. of Big Creek, high tide level.	...	...	...	0.85	50.35	48.80	...
19. GLENEDEN (Siletz). High tide level.	0.50	4.85	38.70	54.70	1.20	...	...
19. SILETZ BAY. N. side of entrance, high tide level.	1.70	10.67	69.13	18.0	0.50	...	...
19. SILETZ BAY. 1 mi. n. of n. side of entrance, high tide level.	...	...	3.25	89.65	7.10	...	...
22. PACIFIC CITY (Nestucca). High tide level.	...	...	...	77.10	22.90	trace	...
23. CAPE LOOKOUT (Sand Lake). Back of beach at foot of cliff s. of Cape Lookout, high tide level.	...	...	...	12.48	61.44	26.08	...
27. MANZANITA (Nehalem). 1 mi. s. of village, high tide level.	...	...	...	15.05	84.95	trace	...
30. SEASIDE (Clatsop). End of Broadway, high tide level.	...	...	...	3.65	93.25	3.10	...
30. CLATSOP. Peter Iredale wreck, high tide level.	...	...	...	12.05	85.30	2.65	...
30. COLUMBIA RIVER (Clatsop). S. of s. jetty, low tide level.	...	...	...	30.50	68.50	1.0	...
30. COLUMBIA RIVER (Clatsop). S. of s. jetty, high tide level.	...	...	...	2.35	79.90	17.75	...

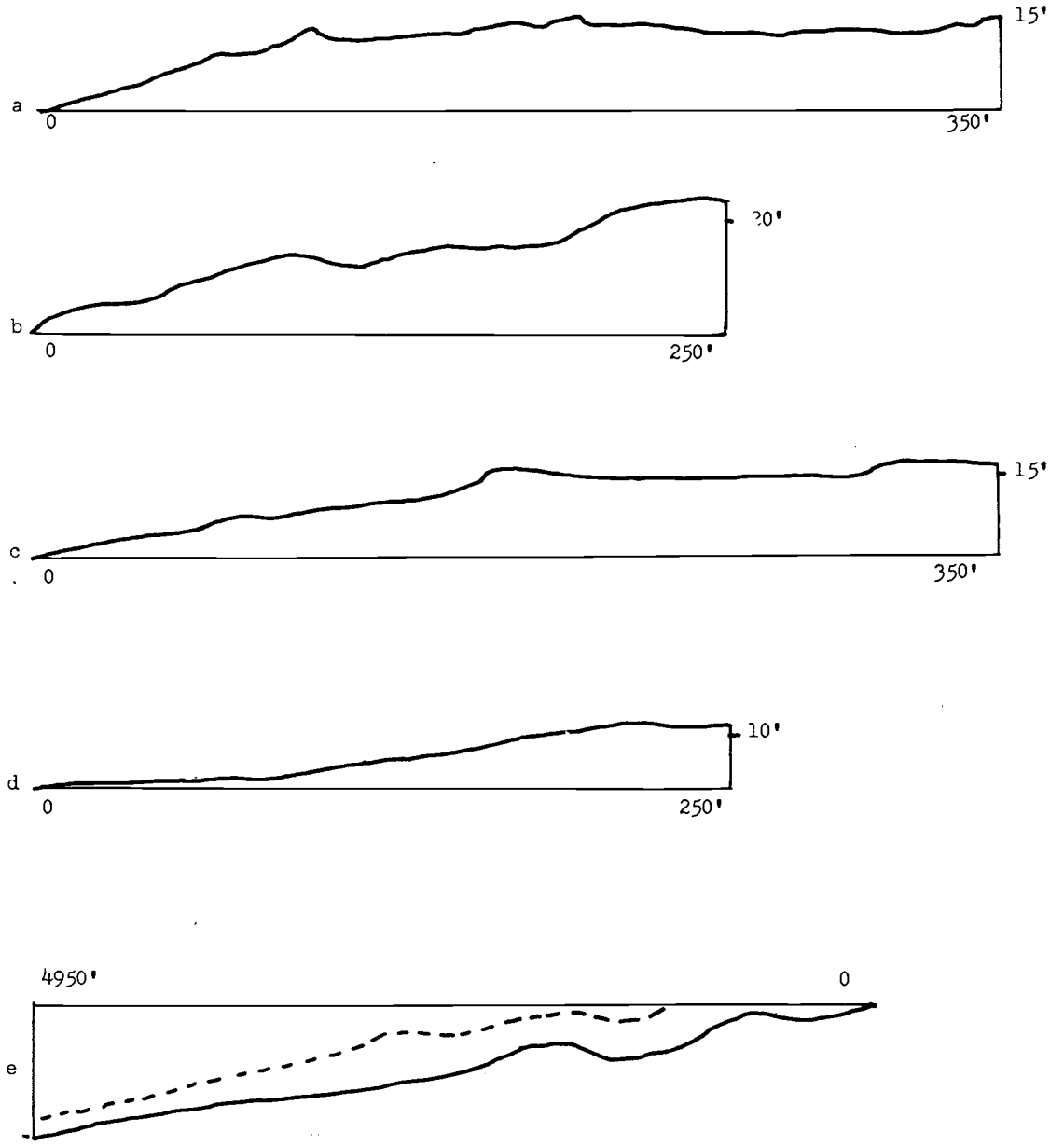


Fig. 5.3. Beach Profiles

a. Chetco Beach, Lat. 42° 1'.
b. Elk River Beach near Garrison Lake, Lat. 42° 46'. A steep gravelley beach.

c. Euchre Creek Beach, Lat. 42° 34'. An average beach.
d. Port Orford Beach, Lat. 42° 42'. An example of a smooth beach.
e. Profile at Bayocean Beach from mean lower low water level to a depth of 50'. (From U. S. Coast and Geodetic Survey Chart, 8370, 1957.) The dashed line shows the approximate profile in 1931.

northwest waves and the south headlands protect the southern portion of the beach from the southwest waves. Since the waves from the southwest are more effective, the curve of the beaches tends to be skewed to the north. Obviously, the orientation of the beach affects this factor. Most Oregon beaches run nearly north-south, but the orientation varies from 65 degrees to 310 degrees; in other words, from 50 degrees to west of north to 65 degrees to the east of north. About one half of the beaches studied are oriented between 350 degrees and 10 degrees. In most cases, the orientation of the beaches is related to the character of the shoreline, as developed by subaerial processes on rocks of unequal resistance, rather than to processes of marine erosion.

MEASUREMENTS OF THE BEACHES

Measurements were made of the chord length of the beaches (Fig. 5.3) after locating the end points in the field and on aerial photographs. The high-tide line was chosen as a line of reference, since the beach is usually steeper at this point and the probable error is less. At the mid-point of the chord a perpendicular was drawn to the shore. The ratio of the chord distance, C, to the perpendicular, P, gives a convenient index of curvature, C/P, which can be readily converted to radius of curvature by the formula: $R = \frac{C^2 + 4P^2}{8P}$. The subtended angle can be obtained by the formula: $\frac{C}{2P} = \cot \frac{0}{4}$.

The chord direction gives the orientation of the beach. An expression of skewness was obtained by measuring the areas on opposite sides of the perpendicular with a planimeter. The results of the measurements and computations are given in Table 5.3. This method, expressing the skewness as percent of the total area of the beach plan, tends to minimize the effect of irregularities on the beach line.

TABLE 5.3

BEACH	CHORD (mi.)	PERPENDICULAR (mi.)	C/P INDEX	SKEWNESS (percent)	ORIENTATION (degrees)
1. CHETCO	1.12	0.26	43.0	62N	310
2. WHALEHEAD	1.0	0.08	12.0		350
3. HOUSTENADER	0.62	0.056	11.0		350
4. PISTOL RIVER	4.7	0.5	9.2	57N	351
5. GOLD	6.7	0.35	19.2	55N	357
6. EUCHRE CREEK	5.58	0.35	16.0	60N	15
7. PORT ORFORD	1.9	0.3	6.5	57S	319
8. ELK RIVER	6.7	0.61	11.0	63N	340
9. SIXES RIVER	2.6	0.15	17.3	57S	32
10. BLACKLOCK-BANDON	14.9	0.8	18.5	50	13
11. FIVEMILE	7.5	0.35	21.4	51N	15
12. SACCHI	3.6				13
13. BASTENDORFF	0.95	0.17	5.5	52S	41
14. COOS-UMPQUA	22.9	0.9	25.4	50	16
15. UMPQUA-HECETA	29.7	0.4	74.0	52N	7
16. YACHATS	1.5				20
17. NEWPORT	3.1	0.3	10.3	69N	2
18. BEVERLY	4.7	0.3	15.5	56N	6
19. SILETZ	12.35	0.2	49.0	56S	9
20. CRESCENT	0.15	0.043	3.5		65
21. CASCADE HEAD	0.13				35
22. NESTUCCA	8.4	0.35	24.0	56N	6
23. SAND LAKE	7.9	0.55	14.3	57N	0
24. NETARTS	7.35	0.5	14.7	61N	1
25. SHORT (Cape Meares)	0.6				0
26. BAYOCEAN, OLD	3.4	0.09	37.6	66S	10
BAYOCEAN, NEW	3.9	0.23	17.0	53S	10
27. NEHALEM	11.25	0.6	18.7	58N	2
28. SHORT SAND	0.5				320
29. INDIAN	0.35	0.06	58.0		340
30. CLATSOP, OLD	15.5	1.02	15.2		352
CLATSOP, NEW	17.2	1.6	10.7	54S	349

The curvature of beaches has long been considered an important characteristic and, by some, a measure of maturity and stability. Hoyle and King (1958) set forth the essentials for stable beaches: (1) the beach must be supported at each end by barriers, such as headlands or jetties; (2) the beach must have a curved outline representing the arc of a circle with the angle subtended by the radii at the beach ends of 0.25 radians; (3) the slope of the beach must be in equilibrium; (4) the orientation of the beach must be established consistent with prevailing wave direction.

None of the Oregon beaches satisfy all four of these conditions. Most are bordered by headlands or jetties and some approach arcs of circles, but with great variation in the subtended angles. The prescribed angle, 0.25 radians, is equivalent to a C/P index of 15 which is approached by few Oregon beaches. The slope of the many beaches seems to approach equilibrium, in that there is little net gain or loss of sand, but this does not mean that the shoreline is stable. Where orientation is affected by the wave direction, the resulting beach line is not an arc of a circle, but is more nearly hyperbolic in form.

A number of factors tend to cause the beach to depart from the ideal characteristics listed above: the nature of the backshore and its resistance to erosion; sea stacks or rocky outcrops on the beach, which tend to affect the curve; and the presence of streams with a large bed load of sand. Although the effect of a large stream, such as the Umpqua River, does not affect the general trend of the coastline substantially, the very fact that it brings in a fairly large bed load affects the general curve of the beach. Since the outlet of the Umpqua River tends to lie across the middle of the long Coos-Heceta Beach, the effect is to reduce the degree of curvature of the beach, by supplying additional sand in the mid-section. The degree of curvature of the beach is also affected by the nature of the beach material. On the Oregon coast adjacent to the headlands, in many cases, there is coarse material on the beach including gravel, pebbles, and cobbles. But the effect of the larger particles near the headlands is to increase the curvature of the beach in this area.

NATURE OF BEACH CHANGES

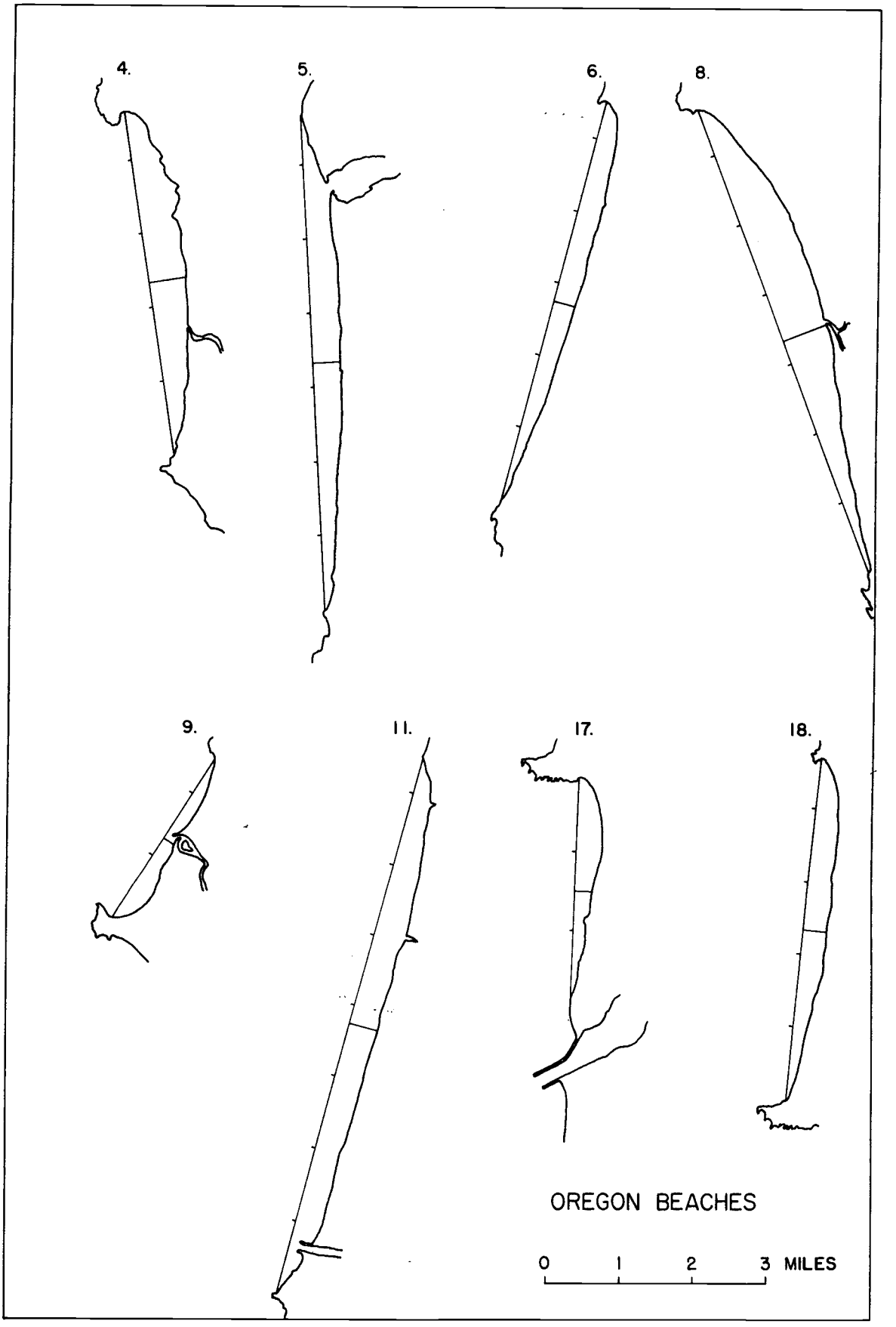
Changes of the Oregon beaches are both short term and long term. The seasonal changes, although not as pronounced as on many coasts, are observable in most localities. In summer the sand tends to build up on the beaches and in winter the net movement is toward deep water. Especially noticeable is the change at the outlets of the smaller streams. As the volume of these streams declines in summer, the beach sand, driven by the northwest waves, often closes the outlet, allowing the smaller volume of water to seep through the beach. In winter the stream overflows the beach and re-establishes its outlet, sometimes in a new location. Another cycle of change, which may extend over a period of several years, is the change in the outlets of the larger rivers. In such cases, the tendency is for a spit to build in one direction until the river has reached an extreme position against an obstruction, and then, in times of flood, the river breaks through the base of the spit and the process is repeated. The construction of jetties and dikes has halted this process on many of the Oregon beaches.

The long term changes of the Oregon beaches appear to be related to the recent rise in sea level and the slow adjustment to this condition. In general, the shoreline on the open sea is retrograding, and, at the same time, the large streams are bringing in enough sediment to fill in the bays and extend the spits. The beaches adjacent to the Columbia River, however, are prograding, as are the mud flats and tidal marshes in the estuaries. A state of dynamic stability on most Oregon beaches appears to be established, but the beaches and shorelines are by no means stable. Erosion of the headlands and sea cliffs is active, in some cases fairly rapid; as is the seaward growth of beaches and dunes in some localities.

The rates of erosion and deposition for the last century are, in some places, too slow to be measured satisfactorily, even though evidence of change is clear; in others, especially where the processes have been accelerated by man, excellent measurements are available. For example, the maximum rate of erosion observed at Bayocean, 1939-1960, was nearly 50 feet per year; the maximum deposition adjacent to the north jetty was about the same. In both cases the jetty is definitely involved and there is no reason to believe that these rates will continue for more than a few years. Under natural conditions the rates of erosion and deposition are on the order of one foot per year or less.

Measurement of the rates of erosion and deposition are difficult to make except in those localities where changes have been of great magnitude. Where shoreline changes during the last century have been

Fig. 5.4a. Outlines of Oregon beaches. For each beach a chord is drawn and a perpendicular erected at the mid-point. These outlines are the basis of the computations summarized in Table 5.3. Tick marks on the chords are at mile intervals. Numbers correspond to text descriptions of beaches: 4, Pistol River; 5, Gold; 6, Euchre Creek; 8, Elk River; 9, Sixes River; 11, Fivemile; 17, Newport; 18, Beverly. (See Fig. 5.1 for locations.)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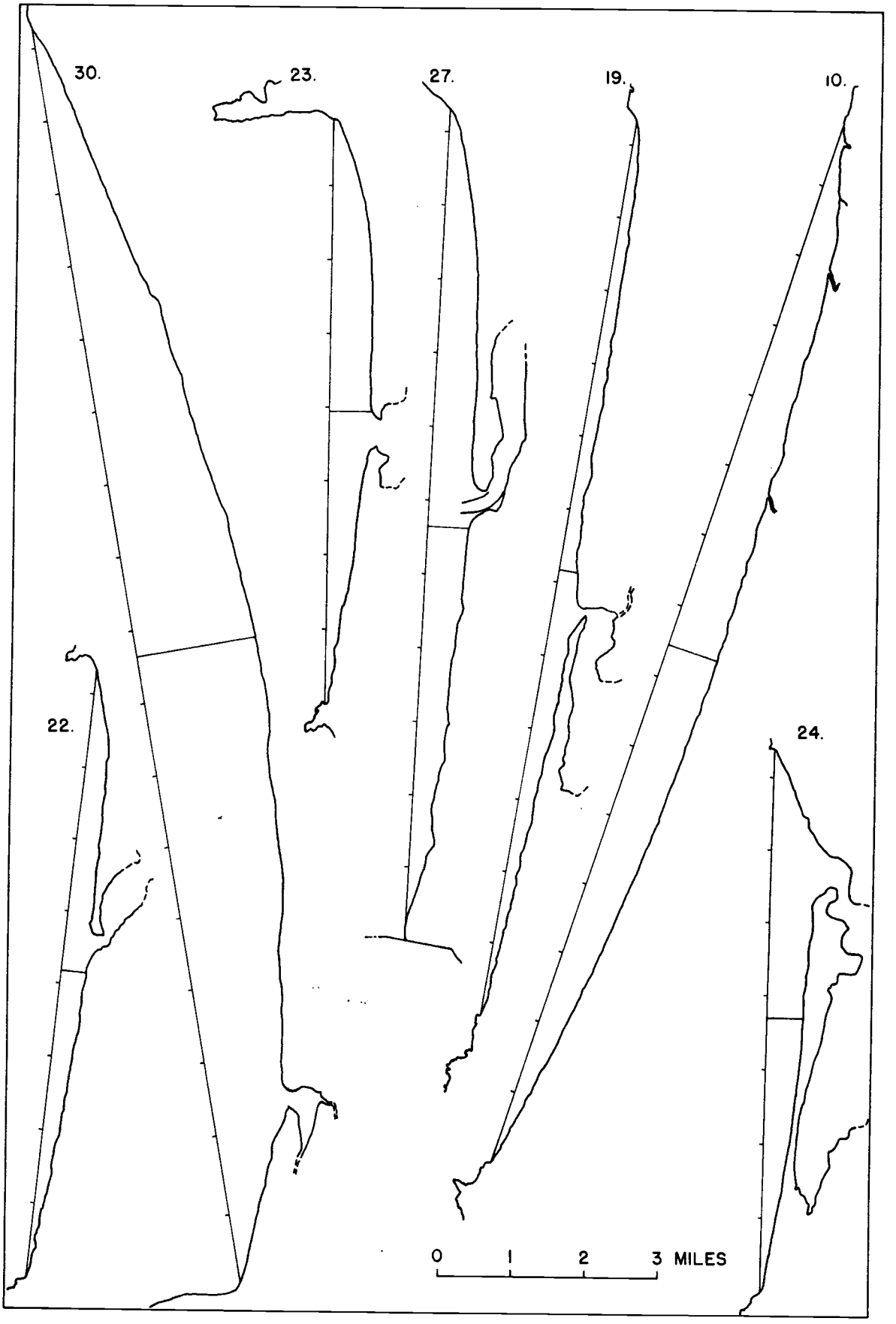
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50 feet or more, comparison of maps and charts give fairly reliable data. Where the rates are slower, comparison of ground photographs may indicate that changes have occurred, but reliable measurements are difficult to make. Measurements are further hindered by the lack of satisfactory reference points for many parts of the Oregon coast. Houses, roads, and fences close to the shore are not always reliable references where mass movements of the land are common. The rates of change, of course, vary from year to year so that short term measurements may not be typical. Where the rates of change are relatively slow, the vegetation gives a rough measure, especially on the sea cliffs or other steep slopes above the beaches. Bare cliffs indicate relatively rapid erosion; grassy cover, complete or in patches, suggests active but less rapid erosion; brush-covered slopes are fairly stable; tree-covered slopes are most stable. Such criteria have value only in sites protected from such hazards as fire, overgrazing, and landslides.

CLASSIFICATION OF OREGON BEACHES

This classification of Oregon beaches extends that of shoreline types discussed in Chapter 4. The main division is based on the size and shape of the materials. These are the rocky and the sandy beaches. Although gravel occurs on the Oregon beaches, it plays a minor role as compared with sand, and is, therefore, of limited classification value. The rocky beaches are either the result of landslides or of wave action on friable rocks; in each case the rock is derived from the immediate shore. Because of the variation in the rock formations, more than one type of beach is often found in a short stretch of the shoreline. To simplify the notation in the discussions to follow, the beach types are designated by single letters, A, B, C, D, E, and F.

A. Beaches bordered by active foredunes

B. Beaches bordered by stabilized dunes

C. Beaches bordered by sand and gravel terrace deposits

D. Beaches bordered by marine clays and muds

E. Beaches bordered by sea cliffs of resistant rocks

F. Beaches bordered by active landslides

GENERAL NATURE OF THE SHORELINE

A brief description of the **shoreline** is in order prior to the descriptions of the individual beaches. From the California boundary to Cape Blanco the shoreline is generally rugged with many short beaches, bordered by steep cliffs and bold headlands. Longer beaches are associated with marine terraces at each end of this sector and in the mid-section; where terraces are lacking, beaches are short. The average length of the beaches studied in this section is 3.2 miles.

From Cape Blanco to Heceta Head the character of the Oregon shoreline is markedly different. The beaches are longer, with gentler curvatures. Stacks and reefs are not as common as they are to the south, except at Coquille Point near Bandon and in the Cape Arago area. The Blacklock-Bandon Beach is developed upon a great sag in the 100-foot terrace, which is described in some detail for the Elk River Beach (8). The terrace platform, which is nearly 200 feet above sea level at Cape Blanco, drops off sharply to the north of Blacklock Point. At the north end of Floras Lake the terrace platform is nearly at sea level and, so far as the coastal areas are concerned, the terrace is not in evidence again until a point about three miles south of Bandon (W. S. Cooper, 1958). At Bandon the terrace platform rises from 60 to 80 feet above sea level and continues, with an interruption due to the Coquille River, northward as the Whisky Run terrace. It is not certain that the terrace at Bandon is the same one as noted at Cape Blanco, but the effects, so far as the beaches are concerned, are the same. The terrace deposits in this stretch, from Blacklock to Bandon, are composed largely of sand, some of it fine-grained; gravel is not common. North of Fivemile Point there is a very straight beach, unusual in some respects, parts of which are known locally as Merchants Beach, Agate Beach, and Sacchi Beach. Several short beaches occur in the Cape Arago-Coos Head area, but these are followed by the Coos-Umpqua Beach which is 22 miles long and the Umpqua-Heceta Beach which is 30 miles long. Actually, Coos-Umpqua and Umpqua-Heceta beaches could be con-

Fig. 5.4b. Outlines of Oregon beaches (a continuation of Fig. 5.4a). Numbers correspond to text descriptions of beaches: 10, Blacklock-Bandon; 19, Siletz; 22, Nestucca; 23, Sand Lake; 24, Netarts; 27, Nehalem; 30 Clatsop. (See Fig. 5.1 for locations.) Tick marks are at mile intervals with zero to the south.

sidered as one beach, with a total length of over 50 miles, if the slight protuberance provided by the jetties at the entrance to the Umpqua River is ignored. The average length of beaches studied in this section of the coast is 11.7 miles.

North of Heceta Head, to the Columbia River, both long and short beaches occur. The average length is 5.1 miles. There are some stacks and offshore islands, but these stacks are not nearly as numerous as they are off the southern Oregon coast. Several of the beaches, however, have a length of 10 miles or more, specifically Nehalem and Clatsop beaches. The chief differences of these various beaches are in the nature of the backshore, the orientation, the changes which have occurred in recent times, and the variations in sand supply.

CHANGES OF INDIVIDUAL BEACHES

In the following pages the changes which have occurred in 30 Oregon beaches since settlement are analyzed and described, in order, from south to north. Together, these beaches include substantially all of the conditions and processes involved in shoreline changes. All beaches and backshores show some changes; in some cases the record is clear and data are available to measure the amount and rate of the change; in other cases no quantitative measurements could be made. The beaches are numbered for ready reference and classified by letter (Page 29).

1. CHETCO BEACH (E)

Chetco Beach (Fig. 5.1) is located five miles north of the Oregon-California line where the Chetco River enters the sea. The beach is 1.12 miles long, the perpendicular at the mid-point is 0.26 of a mile, and the C/P ratio is 43 (Fig. 5.5). The shoreline has an orientation of 310 degrees and is skewed 62 percent north. The sharp curvature of the beach and the skewness may be related to the wide valley carved by the Chetco River, which enters the beach from the north.

The backshore consists of a steep bluff which is the eroded edge of a marine terrace, rising 60 feet above the beach. The bedrock is sandstone, striking 30 degrees, dipping steeply to the east. The sandstone is jointed in an irregular manner and the exposures tend to be ragged. The top 20 feet of the cliff is composed of terrace deposits - gravel and sand - sufficiently indurated to break off along vertical joints. The sea cliff is generally well-vegetated with a thick growth of grasses, shrubs, and trees. The beach willow, myrtle, alder, elderberry, and salal are found at various points. On the northern part of the bluff is a small stand of Sitka spruce.

The Chetco River, one of the smaller rivers of the Oregon coast, rises in the Klamath Mountains at an elevation of 4000 feet and flows, in general, southwesterly to the sea. For the last four or five miles of its course, it flows almost due south. The river drains an area of 365 square miles; most of this area is underlain by the Dothan formation which consists mainly of sandstone, shale, and siltstone with interbedded lava flows and serpentine. The region is forested, much of it with a thin growth of Douglas fir. The Chetco River has a distinct low-water stage in late summer, but it is able to maintain a channel across the bar. The river has tended to hug the right bank, but has, at times, broken through the spit at the extreme southern end of the beach. To the east of the river there was a small tidal marsh and estuary before the construction of the jetties and the harbor facilities.

Chetco Beach is divided by the river into two beaches, each with a distinct quality. Southeast of the river the beach is prograding. Near the jetty the sand has a median diameter of 0.222 mm., is angular to subangular, and includes fragments of igneous rocks in addition to the quartz and dark minerals. There are small quantities of gravel and small cobbles. A profile (Fig. 5.3), measured at the mid-point of the southern section of the beach, shows a width of 350 feet with berms at 60 and 90 feet from the mid-tide line. Cusps with steep, gravelly crests are spaced from 90 to 130 feet apart. Northwest of the river the beach is narrow and contains little sand. A thin layer of cobbles and gravel rests on bedrock. The amount of sand on this beach has varied with the changes in the outlet of the river; when the outlet was far to the south, more sand was deposited on the north beach.

All evidence points to a very slow rate of change on the beach and backshore prior to the construction of the jetties. Erosion was most rapid at the extreme ends of the beach, while the middle portion was stable enough to permit the growth of small trees and shrubs. Two jetties were completed in 1958, the

Fig. 5.5. Chetco Beach. In the upper photo, 1952, the chord and perpendicular are shown. (Oregon State Highway Dept.) In the lower photo, 1960, the effect of the jetty construction is indicated. (U. S. Corps of Engineers.) Note a slight difference in orientation and scale of the two photos.

north one is 800 feet long and the south one is 1660 feet long. The intervening channel was dredged to permit the entrance of barges and small craft. The main effect of the jetties on the beach is to build up sand on the south side of the river and to deny the sand to the north side. Another effect has been shoaling near the outer ends of the jetties. It is doubtful if the construction of the jetties will result in greatly accelerated erosion, since the jetties tend to protect the north beach from some of the effects of the south and southwest waves. Additional sand is accumulating on the south beach. During the winter of 1960-61, storms carried large quantities of driftwood and gravel from the north and piled it on the north jetty, some of it apparently entering the channel; a sag in the south jetty allowed sand and gravel to flow into the channel. The jetties and the harbor development are so important to the town of Brookings that it is planned to repair the jetties and re-dredge the channel from time to time. It is probable that the south jetty will be extended as more sand accumulates.

2. WHALEHEAD BEACH (E, F)

Whalehead Beach (Fig. 5.1; Fig. 5.6) is nine miles north of Chetco Beach. Whalehead Beach is modified in the northern section by a stack and a recurved section of the beach. This modification makes it unfeasible to measure the C/P ratio for the beach as a whole. The southern two thirds of the beach forms a normal crescent, one mile long, with a perpendicular distance of 0.28 of a mile and a C/P ratio of 12. The orientation of the whole beach is 350 degrees. The marine terrace rises above the beach to a height of 125 feet. On the north, the sea cliff is regular with a sharp edge at the top; on the south, the scarp consists of a series of slumps with an average slope of 40 degrees.

The beach face is made up mostly of fine sand, median 0.245 mm., with small quantities of gravel. The beach is broad in the north, narrow in the south; at the extreme southern end, some angular rock fragments derived from landslides are found. This asymmetry is related to the large stacks offshore, but near the beach, and to the protection afforded by Whalehead Point to the north. In the northern sector, the beach face slope averages 5.6 degrees. The berm is sharp and capped with gravel. Above the berm the slope is minus 2 degrees for 110 feet and then nearly level to the foot of the cliff. The flat part of the beach has a veneer of coarse sand.

Erosion of the backshore at Whalehead Beach is slow but more rapid than that of Chetco Beach. The sea cliff supports grass but very little brush and no trees. A measure of the rate of erosion is provided by a small building on the sea cliff which was constructed in 1923 for the purpose of reclaiming gold from the black sands of the beach. The building has been undermined by wave erosion and at this point the lower part of the sea cliff has receded 20 feet in 38 years. Reliable local testimony confirms the amount of recession. The probable rate of erosion for the sea cliff as a whole is 0.25 of a foot per year.

3. HOUSTENADER BEACH (F)

Houstenader Beach (Fig. 5.7), five miles north of Whalehead, is 0.62 of a mile long and has a perpendicular distance of 0.056 of a mile; the C/P index is 11. The orientation of the beach is zero degrees. The backshore is a complete landslide surface, reaching up to an elevation of more than 1200 feet. However, the land immediately back of the beach is comparatively low. The beach is made up of some sand and silt, plus many angular fragments of rock washed out of the landslide material.

In February, 1958, the slide above the beach moved, in places as much as 165 feet. This was reflected in a rise of the beach level of approximately 25 feet for a distance of one fourth mile. When studied in March, 1958, this upraised beach consisted of fragments of angular rock, plus some rounded cobbles, mud, sand, and silt; all of which was capped with large quantities of driftwood. The uplift diminished rapidly both to the south and to the north. Immediately above the beach a low ridge rises, which prior to the February, 1958, movement had an elevation of slightly more than 62 feet. In February, 1958, this ridge was uplifted to an elevation of 73 feet and moved seaward 25 feet. All of the backshore, including a landslide pond (Fig. 5.8) immediately behind the ridge, moved horizontally and vertically during the 10 days of activity (Fig. 5.7). The waves immediately attacked the upraised beach and by July, 1961, much of this beach had been removed. A highway engineer reports that the beach retreated 30 feet during one storm in April, 1958.

Fig. 5.6. Whalehead Beach. In the upper photo, 1958, the middle and northern section of the beach is shown, together with Whalehead Point and large stacks in the foreground (Oregon State Highway Dept). The lower photo, 1948, shows all of Whalehead Beach and a portion of Cape Ferrelo, lower right (Univ. of Calif., Hydraulic Eng. Lab.).

In view of the sliding nature of the backshore, it is difficult to estimate the rate of erosion for Houstenader Beach; in fact, for all beaches with a sliding backshore. Assuming that the sea stacks at some distance from the shore are relatively stable, comparison of the beach line of 1940 and that of 1953 from aerial photographs, suggests an erosion rate of about one foot per year. It is to be noted, however, that the mass movements are very irregular and that no recent record, other than the 1958 landslide, shows a large movement of this particular slide area. The nature of the terrain, however, indicates that mass movements are primarily responsible for the form of the land and the detailed configuration of the shoreline.

4. PISTOL RIVER BEACH (A, E, F)

Pistol River Beach extends from Crook Point to Hunters Cove, south of Cape Sebastian. This beach presents a very different character from the beaches to the south, which are associated with terraces. The backshore of Pistol River Beach is alternately sand dunes (partially stabilized) and landslide surfaces. Some terrace deposits appear at the southern end and also in the middle portion above a sea cliff, but they play a minor role. Pistol River Beach is 4.7 miles long and the orientation is 351. The perpendicular is 0.5 of a mile, giving a C/P index of 9.2; the skewness is 57N. Crook Point is a rocky headland with a fringe of rocky islands or stacks. A stack at Mile 0.25 allows the waves to attack this part of the beach at a different angle, more from the southwest, and thus gives a short, separate section of the beach a different orientation. A promontory on the beach corresponds to the position of the rocky stack. The major part of Crook Point is covered with terrace deposits. The terrace surface is approximately 125 feet and the abrasion surface of the rock is about 20 feet lower. Crook Point, itself, is a rocky pinnacle extending up to 168 feet. The margin of the point on the north side is steep-faced and very rugged. This portion of the backshore resembles that of Whalehead Beach.

From Crook Point northward to the Pistol River, the backshore consists of a belt of sand dunes, more or less active (Chapter 6). North of the Pistol River, the beach is flanked by a foreshore of terrace deposits above hard rock. At times the Pistol River flows northward, hugging the cliff; at other times the course changes, leaving a lagoon on this part of the beach. The terrace deposits north of the river lie at an elevation of about 180 feet and the abrasion surface is slightly over 100 feet. There is a low foredune, partially grassed-over, at the foot of the cliff, which is especially conspicuous to the north of the lagoon.

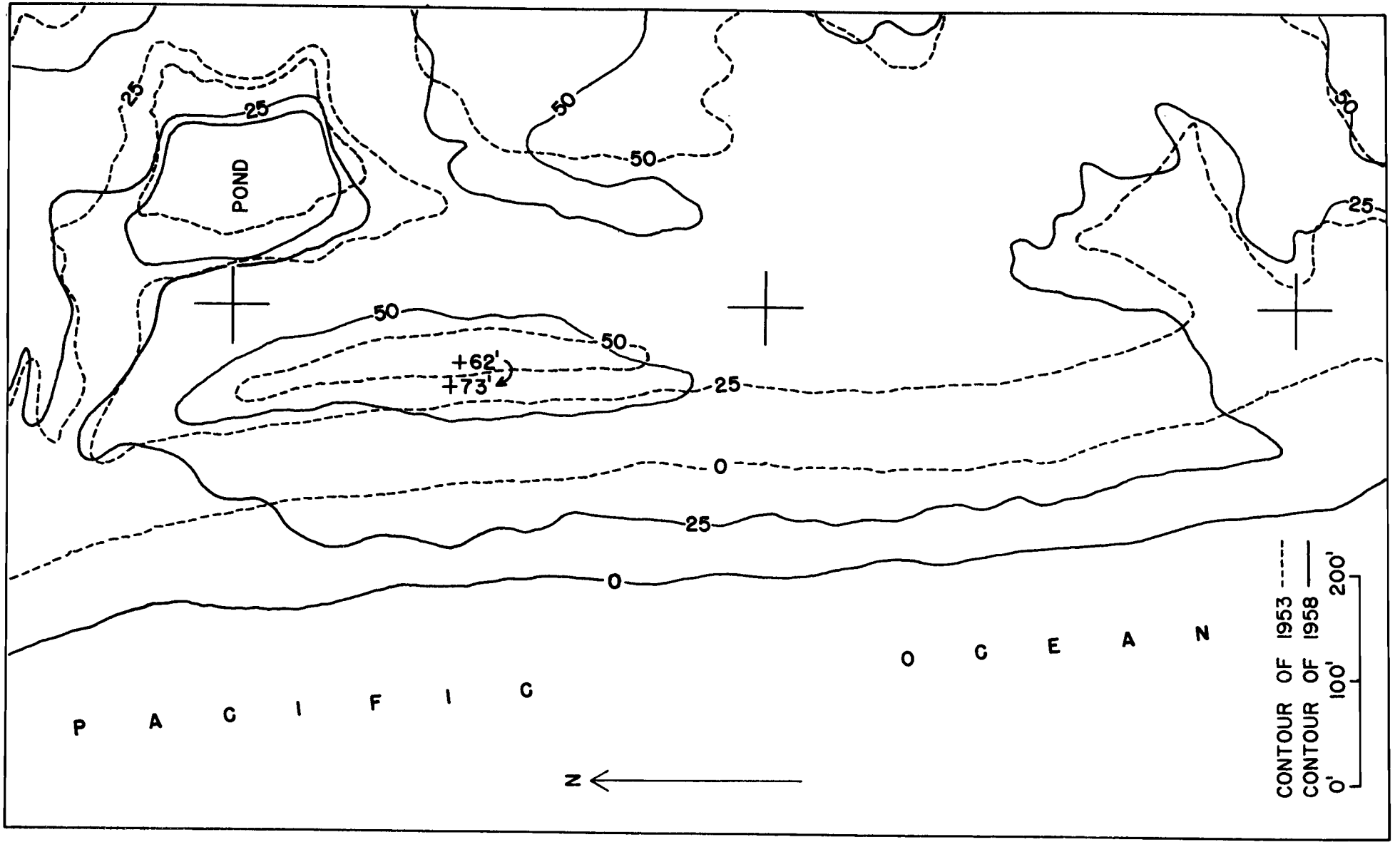
Near Myers Creek (Mile 3) a mass of resistant rock forms a promontory and also a large rocky stack. North of Myers Creek there are numerous rocks and stacks, some on the beach, others not even exposed but connected with the beach at low tide. Cape Sebastian, a rocky promontory at the northern end of Pistol River Beach, consists mainly of steeply dipping sandstones with a north-south strike. The backshore, especially of Hunters Cove, tends to slide easily even though hard rock is exposed in several places. The bedrock along this section of the beach is mainly shale and this tends to develop mass movements very readily.

Pistol River Beach is abundantly supplied with coarse sand; median grain size is 0.35 mm., both at the north and at the south ends. At the north, the sand is finer except for small, scattered patches, whereas the grain size on the southern part of the beach, near Crook Point, is definitely coarser.

A profile at the mid-point of Pistol River Beach, between Pistol River and Myers Creek, is as follows: At the water line, 10 feet below the berm crest on the upper beach slope, 7 degrees; just below the top of the berm, 22 degrees; at 60 feet, minus 3.6 degrees. The backslope is nearly uniform at this angle. At 120 feet the slope is zero degrees. At 330 feet driftwood, mixed with sand and rubble from the cliffs, appears. Then there are 50 feet of driftwood extending to the foredune, which is at the foot of the cliff and is covered with grass. The berm is very strikingly developed on the middle point of the beach and, at one point, has a distinct convex curve toward the sea. This is apparently not a temporary condition, since it shows in old photographs.

Changes of the Pistol River Beach include erosion of the stacks and bluffs, the building out of the beach seaward, and variations in the course of the Pistol River. According to Coast Survey Chart No.1588 of 1873, the outlet of the river was around the southern edge of Sheep Rock. This stack is a remnant of the terrace with the terrace deposits surmounting sandstone. The sandstone abrasion surface is 50 feet

Fig. 5.7. Contour Map of Houstenader Beach. The dashed lines indicate the 1953 contours, the solid lines indicate the 1958 contours. Note the seaward shift of the pond and the survey point on the crest of the ridge. (Oregon State Highway Dept. map. The location of this map is shown in Figure 5.8 and also in Figure 5.1).


POND
25
25
50
50
50
50
50
25
25
+62'
+73'
0
25
0
P A C I F I C
O C E A N
N
CONTOUR OF 1953 -----
CONTOUR OF 1958 ——
0'
100'
200'

above sea level. During the 89 years since Chart No. 1588 was drawn, the southern part of the stack has been cut back approximately 35 feet. Since the Pistol River at times washed against this stack on the southern end, some of this erosion may be due to lateral cutting by the river. The stacks adjacent to Myers Creek Point also show erosion, especially on their sharp promontories.

The northern part of the beach has built seaward to a maximum of 135 feet. The chart of 1873 shows a narrow beach between high-water and low-water lines. The present beach is very wide and flat, especially to the north and, although some of the increased width may be reflected in the erosion of the cliff, it is apparent that much more sand has piled up on the beach than previously existed. Furthermore, the low-water line on the beach is much more irregular now than formerly. It would appear that the high berms are of comparatively recent origin.

5. GOLD BEACH (C, E)

Gold Beach (Fig. 5.1; Fig. 5.9) extends from Cape Sebastian northward to the smooth promontory which is about one mile north of the Rogue River. Actually, the beach continues for two or three miles further north to Otter Point, but the promontory marks the end of the smooth curve of Gold Beach. Gold Beach is 6.7 miles long, has a perpendicular of 0.35, and a C/P index of 19.2; the orientation is 357 and the skewness is 55N. It is obvious from the data that Gold Beach has a gentler curve than most beaches of its length. The southern margin of the beach, adjacent to Cape Sebastian, is bordered by high cliffs with active mass movements. The cliff top is 400 feet above sea level; the elevation decreases to the north, as does the mass movement activity. In the mid-portion of the beach the backshore is a marine terrace, the top of which is about 160 feet above sea level with about one fourth of this elevation showing terrace deposits. At Hunter Creek, a prominent rocky stack stands out from the main cliff. This is represented on the old chart as a promontory on the beach, but at present no protuberance appears on the beach at the low-water line. North of Hunter Creek (Mile 3), the foreshore continues as a marine terrace but at a lower elevation. About one mile north of Hunter Creek the terrace has an elevation of 60 feet, about 20 feet of which is terrace sand and gravel. The bedrock is a resistant sandstone striking north 80 degrees east, dipping 46 degrees north. The lowest portion of the outcrop is a resistant conglomerate. Above the race track in the town of Gold Beach (Mile 5) the terrace has an elevation of only 50 feet; many of the streets and houses of the town are on this terrace.

Gold Beach is interrupted by the Rogue River which has an open channel the year around. The outlet of the river has been subject to considerable fluctuation. At times the river has clung close to the left bank, developing a long spit from the north. This condition, however, has been subject to frequent interruption and, in general, the outlet has been near the right bank. The spits which have developed north and south of the outlet have varied considerably, as the two illustrations show (Fig. 5.9). North of the Rogue River the backshore consists of a terrace at a lower level than that in the town of Gold Beach. The abrasion surface of the terrace does not show in this section, since it is completely buried in sand. However, a few large rocks occur on the beach and in very shallow water.

A beach profile was made about one fourth mile north of Hunter Creek on July 6, 1961. At the low-water line the beach face slope was 4.5 degrees; at 50 feet from the water line, 4.8 degrees; at 90 feet, 0.32 degrees, with mostly fine-grained, even sand. A strong wind slightly rippled the beach. Above 90 feet the beach contained some gravel and small cobbles; at 160 feet there was a newly-formed beach dune about two feet high and 12 feet wide, oriented north-south. At 250 feet the profile terminated in the foredune which is generally grassed over.

The foredune is in evidence throughout most of the beach south of the mid-point and extending to Cape Sebastian. The foredune is hummocky with an elevation of about 20 feet above the beach usually; the hummocks are frequently separated by stream channels coming from the adjacent terrace cliff. On the southern part of the beach, near Cape Sebastian, the stream channels through the foredune correspond with the cusps along the beach. These cusps are gentle, smooth, and rarely have sharp, angular separation ridges. The sand is fine with a median diameter of 0.246 mm. The beach north of the Rogue River (Fig. 5.10) is unique in that it has a reverse curve. Without any resistant rock showing in the vicinity, it is a little surprising that the sandy beach, with lower terrace deposits in the backshore, should present this convex curve toward the sea. It is to be noted, however, that the rock material inland is quite resistant and that seaward is the Rogue River Reef which protects this shoreline. Resistant rock is to be found on the bottom of the sea, even at shallow depths.

The most striking changes that have occurred in the Gold Beach area are those associated with the outlet of the Rogue River. As previously noted, the river has changed its course from time to time, espe-

Fig. 5.8. Houstenader Beach Area. The left photo was taken in 1952 and the right photo in 1958. The change in the configuration of the coast in the section near the pond is clearly shown (Oregon State Highway Dept.).

cially during floods. The Rogue is a tidal river, but the tide goes up stream only a few miles from the sea. The inference is that, as compared to other river valleys such as the Umpqua, the Gold Beach region has been warped upward somewhat, probably during Pleistocene time. The most recent changes of Gold Beach are those brought about by the construction of two jetties at the mouth of the Rogue River, to provide navigation facilities. The south jetty was completed in September, 1959, and the north jetty in September, 1960. The effect of the jetties has been to pile up sand on the beaches, both to the north and to the south of the jetties. These new accumulations of beach are triangular in shape. On the north, the additional sand thins out at a distance of about one mile north of the north jetty; the sand becomes thinner about the same distance south of the south jetty. The sand tends to extend out toward the end of both the north and the south jetties. In July, 1961, sand and gravel accumulated between the jetties on an inner beach which formerly represented a continuation of the north and south beaches. This sand and gravel is to be dredged out as the harbor facilities are completed.

6. EUCHRE CREEK BEACH (E, F)

Euchre Creek Beach (Fig. 5.1) begins five miles north of the Rogue River and extends northward for 5.58 miles. The perpendicular is 0.35 of a mile and the C/P index is 16; the orientation is 15 degrees and the skewness is 60N. Euchre Creek Beach is a smooth, gently curving beach with an abundance of sand, fairly coarse, and well-developed berms at the upper limit of the beach face. A profile of the northern section of Euchre Creek Beach, made on July 1, 1961, is shown in Figure 5.3. The crest of the berm has especially coarse sand but not at great depth. Beach stacks and promontories are responsible for small variations in the beach, but altogether this is a very regular beach with very little skewing and variation.

At the northern end of Euchre Creek Beach the backshore is steep with mass movements of some magnitude. Farther south the slopes are lower and gentler so that there is very little movement of material out onto the beach. Euchre Creek brings in a supply of sediment, meanders from side to side, and cuts away at the backshore, aided by storm waves and high tides. It has been necessary for the Oregon State Highway Department to construct groins along the beach in the area south of Euchre Creek in order to prevent damage to the new highway.

7. PORT ORFORD BEACH (F)

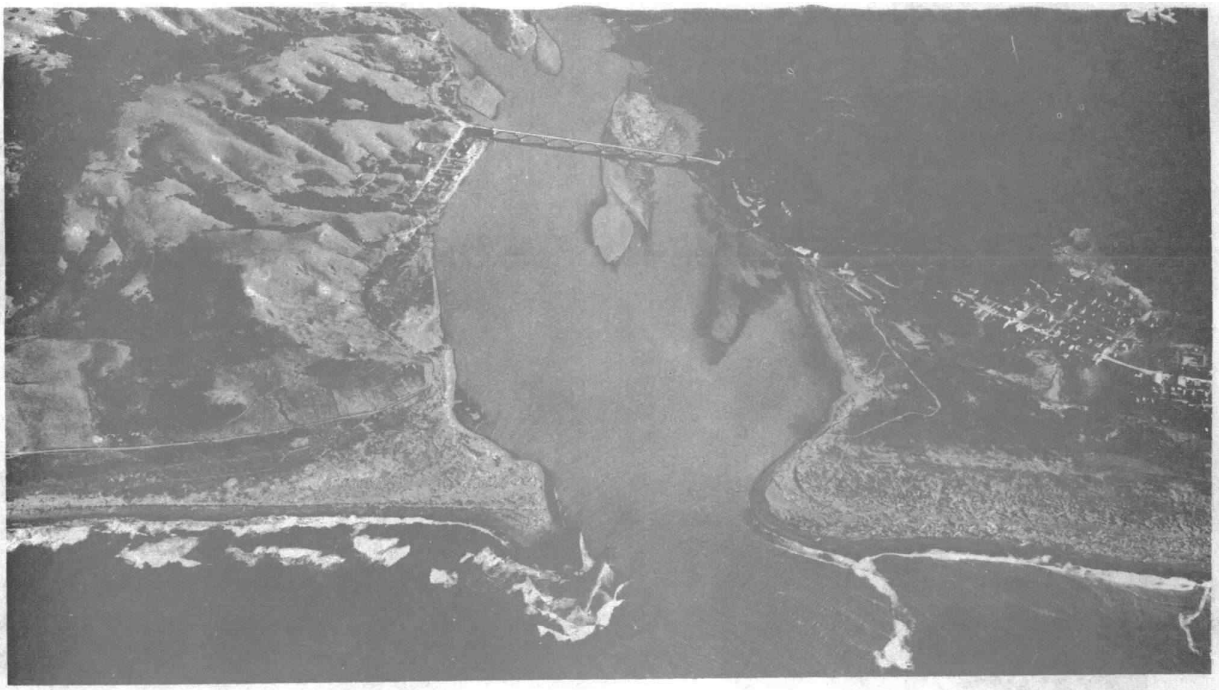
Port Orford Beach extends southward from Battle Rock, immediately south of the town of Port Orford, to Rocky Point where there is a definite break in the beach. This beach is 1.9 miles long and has a perpendicular distance of 0.3 of a mile. The C/P index is 6.5. The orientation is 319 degrees and the skewness is 57S. There are slight irregularities in the shoreline related to the concentration of sea stacks on the beach.

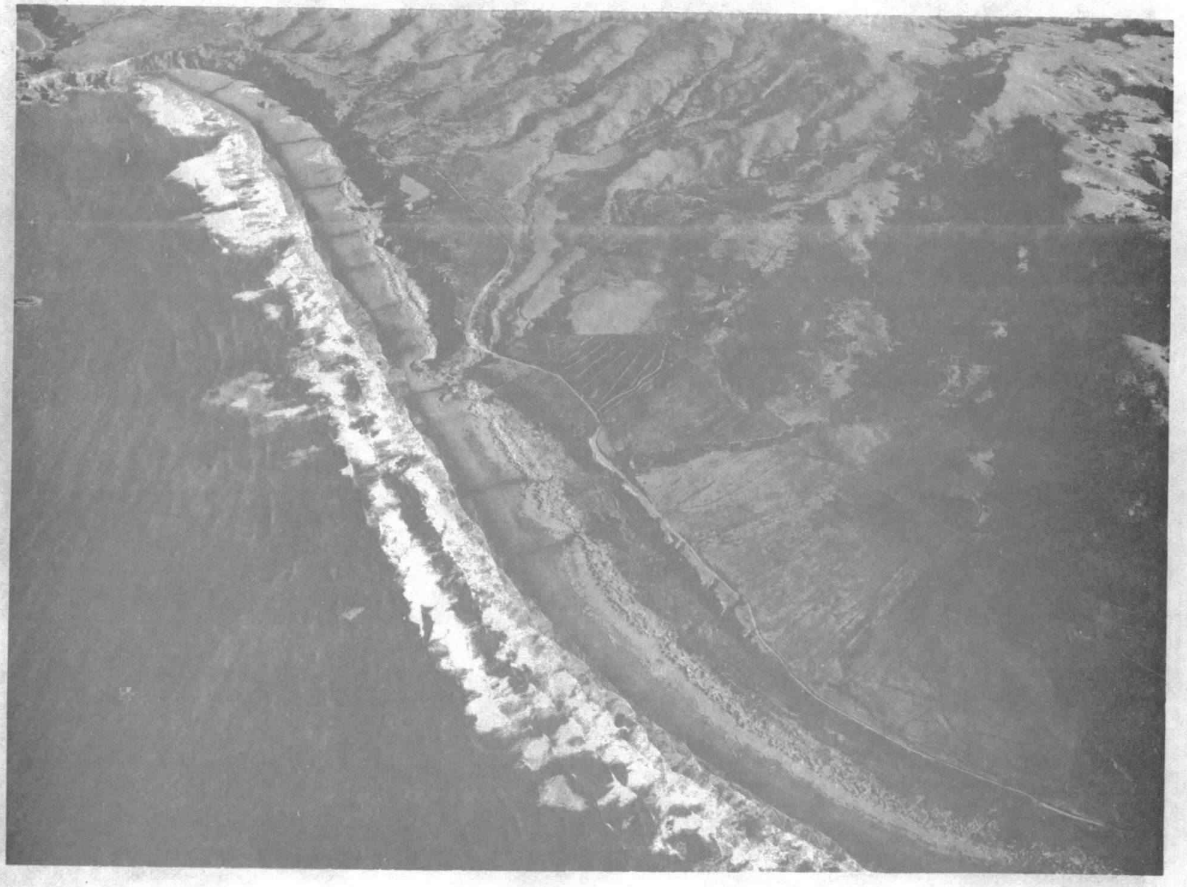
The backshore of Port Orford Beach is composed of terrace deposits which are resting on highly sheared and disturbed sediments and metasediments; some traces of serpentine also appear. Either due to the shearing or the general nature of the sediments (the terrace deposits in the vicinity of Port Orford contain large quantities of fine material, making them less porous and more subject to saturation and sliding), mass movements are quite common. It may be said that this backshore is fashioned by mass movements. From time to time landslides move out across the beach as far as the low-water line. The waves then gradually remove this debris back to the high-tide line. It is evident that this slide material sometimes reaches a depth of 25 feet or more on the beach, since remnants of the landslide debris are visible on the beach sea stacks. Mass movements have probably been accelerated by the construction of the new route of U. S. Highway 101, near the top of the sea cliff.

8. ELK RIVER BEACH (C, E)

Elk River Beach extends from the south side of Cape Blanco (Fig. 5.11) southward to the first rocky promontory to the north of Port Orford. The beach is 6.7 miles long and the perpendicular is 0.61; the C/P index is 11.0, the orientation is 340 degrees, and the skewness is 63N. The regularity of the beach

Fig. 5.9. Rogue River Entrance. The upper oblique photo was taken in 1948, the lower photo in 1952, to which the position of the recently constructed jetties has been added. The dotted line shows the prograding of the beaches adjacent to the jetties during 1959 and 1960. (Univ. of Calif., Hydraulic Eng. Lab. and Oregon State Highway Dept.)





is modified by one large stack near the northern end. The backshore of Elk River Beach is part of the warped terrace which occupies a wide zone on the coast in this area. The general level is 200 feet above sea level, but the terrace is warped downward to the northeast. However, this down-warping does not affect the level substantially along Elk River Beach. Near the north end of the beach the terrace deposits are thin, underlain by nearly 200 feet of sandstone, whereas on the southern end of the beach the hard rock is at or near sea level and is not generally exposed. On the southern end the terrace deposits themselves are nearly 150 feet thick. At the extreme northern end of the beach the rock is shale in a highly disturbed and faulted zone which lies immediately to the east of Cape Blanco. The effect of this shaly outcrop, with little or no terrace deposits on top, is to develop a gentler slope with mass movement characteristics. This slope is subject to fairly rapid erosion; and, not only do mass movements occur, but the slope is washed by running water. Small, well-developed alluvial fans appear from time to time at the top of the beach; these fans are removed by the waves during periods of high tide and storms, only to reappear again after heavy rains occur at lower tides.

It is worth noting that the slope on the north side of Cape Blanco, which is made up of material similar to that found on the slope south of Cape Blanco, is much gentler and well-vegetated; here, too, mass movement appears to be the principal erosional process. The more rapid erosion on the south side, plus the skewness of the beach, demonstrates the importance of the southwest waves to erosion, as contrasted to the west and northwest waves from which Cape Blanco affords some protection to Elk River Beach.

Indications are that the rate of erosion on the foreshore of Elk River Beach is relatively slow, since the slope of the sea cliff is grass covered. Two significant breaks occur in the sea cliff: one at the mouth of Elk River and the other halfway between Elk River and Cape Blanco. Elk River has carved a broad valley through the terrace by meandering back and forth; its outlet varies, but it is generally far to the north. This tendency of the river to seek an outlet near the north bank of the valley also suggests that the strongest movement of material in the foreshore zone is toward the northward. The second break, between Elk River and Cape Blanco, is partially filled with dune sand. Here and there on the top of the terrace there are shallow, more or less isolated dunes, naturally stabilized and covered with grasses, shrubs, and spruce trees. Garrison Lake, on the southern end of Elk River Beach, has been cut off from the sea, except for an occasional outlet close to the rocky headland at the south end of the beach. In this area the beach is developed on very coarse sand, with very steep slopes and well-developed cusps of approximately 500 feet in length.

It is worth noting that the Port Orford Reef, which lies to the west of Elk River Beach, is the most extensive on the Oregon coast. Shallow water, 18 feet or less, extends out for four miles in an irregular area to the west of Elk River outlet. The Port Orford Reef is connected to the Cape Blanco Reef; the latter does not extend quite so far from land but, nevertheless, covers a large area. If it is to be presumed that erosion of the terrace began at the outer limits of the reef at the time when sea level was stabilized, one must assume that the sea cliff has retreated some four miles in the last 6000 to 10,000 years. This would give an approximate rate of retreat of two feet per year. However, there is no indication that the present rate of erosion is that rapid; it is unlikely that the sea cliff has retreated approximately 200 feet since settlement began on the Oregon coast.

9. SIXES RIVER BEACH (F)

Sixes River Beach extends northward from the north side of Cape Blanco to Blacklock Point. The beach is 2.6 miles long and the perpendicular distance is 0.15 of a mile; the C/P index is 17.3, the orientation is 32, and the skewness is 57S. The orientation, plus the fact that the southern flank is protected by Cape Blanco, probably accounts for the skewness to the south. In the mid-section of the beach there is a protuberance which is protected by Castle Rock and a series of smaller stacks. It is at this point that the Sixes River most frequently crosses the beach. The river meanders back and forth along the beach in a limited distance. The backshore is, for the most part, shaly material similar to that found immediately south of Cape Blanco. This means that the slopes are hummocky, mass-movement slopes, in strong contrast to the steep sea cliffs which develop on sandstone south of Cape Blanco. A small sand dune has developed as a thin veneer on the terrace scarp to the south of the Sixes River. Sand blows up the dune to the terrace platform, 217 feet above sea level; this is one of the few instances in which sand is actively blowing in some quantity up a steep terrace scarp as high as 200 feet. The fact that the shale scarp is gentler than scarps in other areas along the Oregon coast, perhaps accounts for this phenomenon.

Fig. 5.10. Otter Point and Humbug Slide. Otter Point in the upper left marks the north end of the recurving beach immediately to the north of Rogue River. This protuberance is based upon resistant rock on land and a resistant reef seaward. There is erosion in the edge of the terrace at various points. The lower photo shows the large slide south of Humbug Mountain which extends into the sea and is able to maintain itself because of the large quantity of resistant rock fragments (Univ. of Calif., Hydraulic Eng. Lab., 1948)

10. BLACKLOCK-BANDON BEACH (A, E)

The Blacklock-Bandon Beach is 14.9 miles long and the perpendicular distance is 0.8 of a mile; the C/P index is 18.5, the orientation is 13 degrees, and the skewness of the beach is insignificant. This beach may be described in a series of units beginning at the south. From Blacklock Point for two miles northward, to a point opposite the middle of Floras Lake, the beach is a narrow cliff-base beach. The sandstones which make up the bedrock of the marine terrace break off in nearly vertical joints. Small streams and rills flow generally north and drop over the cliff into the sea as small waterfalls. The beach is exposed at low tide but completely covered by high tide. It is composed of medium sand, some of which is derived from the eroding rock face. The sandstone blocks which fall from the cliffs are soon broken up by the waves. This is the only part of the Blacklock-Bandon Beach which is suffering fairly rapid erosion; the stretches to the north are nearly stable. In the long, middle section of the beach (Miles 2 - 12), the beach is bordered by dunes. On the northern end of the beach, between China Creek (Mile 13) and Crooked Creek (Mile 14), hard rock again appears at low elevation (approximately 30 feet above sea level). This is sandstone and conglomerate, above which rise weathered, tan-colored terrace deposits.

Throughout the length of the Blacklock-Bandon Beach there is little evidence of rapid change. There is some erosion both at the north and south ends and, it may be presumed, in the middle section, although the evidence for this is less clear. Changes in the outlets of the streams crossing the beach can be noted, especially by comparison with the old charts. This is a lonely beach with very few habitations, except at the northern end, that may be used as a basis for measuring erosion.

11. FIVEMILE BEACH (C, E)

Five Mile Beach extends from Coquille Point, immediately south of the Coquille River, northward to Fivemile Point, a distance of 7.5 miles. The perpendicular distance is 0.35 of a mile and the C/P index is 21.4. The orientation is 15 degrees and the beach shows almost no skewness. The short jetties at the entrance to the Coquille River do not modify this beach substantially. Construction of the north jetty was begun in 1892 and completed in 1909 to a length of 1575 feet. It was extended 1875 feet between 1915 and 1916; and extended 750 feet in 1951. The south jetty was constructed between 1881 and 1901 to a length of 2700 feet. Repairs were made in 1951 and 1955. On the spit which has developed to the north of the Coquille River, the backshore is composed entirely of dune sand. On the northern half of the beach dune sand rests on top of the Whisky Run terrace which forms the backshore. Only at the extreme northern part - at Fivemile Point and slightly to the south - is hard rock encountered. The hard, steeply dipping sandstones and shales are at a sharp angle to the coast and are found in the beach as well as in Fivemile Point itself.

Fivemile Beach is broad and composed of exceptionally fine sand; coarse sand is rarely present and shallow quicksand has been reported in some places on the upper parts of the beach. Much of this sand appears to be derived from the Whisky Run terrace, via small streams. The sea cliff of the backshore is well-vegetated (Chapter 6) and shows only a minimal amount of erosion. Fivemile Point is eroding more rapidly, especially on the south side.

12. SACCHI BEACH (E)

Sacchi Beach which, for the purposes of this report, includes Merchant Beach and Agate Beach, extends 3.6 miles northward from Fivemile Point to Cape Arago. Except for one small headland faulted in the northern half, this beach is so straight that no C/P index nor skewness could be calculated. The orientation is 13 degrees. The backshore is composed of sandstone and shale dipping steeply to the east, overlain by deposits of the Pioneer terrace and, in part, by higher terraces. The backshore, most of it covered with shrubs and grasses, shows a minimal amount of erosion.

The explanation for the straightness of Sacchi Beach is not an easy one. Although the backshore is not especially resistant and the structure of the bedrock corresponds to the orientation in the southern portion, the most likely explanation seems to be the large amount of sand supplied from the terrace deposits by Twomile, Threemile, and Fivemile creeks which enter the beach. Twenhofel (Table 5.2) sampled Sacchi Beach and, at the same time, sampled the terrace deposits. The sand from the terrace deposits corresponded in size and angularity with those of the beach. The high proportion of black minerals in the sand confirms the fact that some of the sand on the beach is derived from the terrace deposits, which contain extensive layers of black sand (Griggs, 1945:146).

Fig. 5.11 Oblique photo of Cape Blanco, looking east. Erosion is much more severe on the south side resulting in a steeper profile. The neck of the peninsula is a shear zone developed in shale with some indications of serpentine. A portion of Elk River Beach is shown on the right and a portion of the Sixes River Beach on the left (Oregon State Highway Dept., 1958).

13. BASTENDORFF BEACH (E)

Bastendorff Beach (Fig. 5.12) near the entrance to Coos Bay, extends from Yoakam Point to the south jetty. It is 0.95 of a mile long, the perpendicular distance is 0.17 of a mile, and the C/P index is 5.5. The orientation is 41 degrees and the skewness is 52S. The characteristics of this beach changed after construction of the jetty. The backshore of Bastendorff Beach consists of massive, poorly-bedded Tunnel Point sandstone on the north end and the Bastendorff shale on the south end. These formations strike almost north and dip steeply, 60 to 70 degrees to the east. This steep dip and the jointing of the sandstone are responsible for the irregular, jagged backshore line at the north end of the beach. Before construction of the jetty, the beach was represented by only small beaches between the jutting promontories produced by erosion of the sandstone. These cliffs, honey-combed with sea caves, were being eroded fairly rapidly at the time of settlement.

The construction of the south jetty led to the entrapment of sand between Yoakam Point and the jetty so that the beach was built out 0.2 of a mile, on the average. This means that, except in times of very high tides and storms, the sea no longer comes up to the base of the cliff.

14. COOS-UMPQUA BEACH (A)

Coos-Umpqua Beach extends 22.9 miles from the north jetty at the entrance to Coos Bay to the south jetty at the entrance to the Umpqua River. The perpendicular is 0.9 of a mile, the C/P index is 25.4, and the orientation is 16 degrees. The skewness is too small to measure. Throughout its length this beach is broad and gently sloping; generally smooth without the complications of berms or other features. The upper beach shows wind drift and the development of a foredune throughout its length. The backshore consists entirely of dune sand. No outcrop of hard rock appears in the immediate vicinity of any part of the beach. The sand is fine-grained and even, characteristics referred to as a standard Oregon beach sand. The sand is composed largely of quartz, with some feldspar, and a small amount of dark minerals. Concentration of dark minerals was not observed on this coast. The zone of active dunes, to the east of the beach, is one half to two miles wide, but some parts of this dune area are stabilized and pine trees occur in small bands or clumps. There are also numerous lakes on the inner margin of the active dune area. The only stream of any size crossing the beach between Coos Bay and the Umpqua River is Ten Mile Creek which drains Ten Mile Lake. The creek crosses the beach in the north-middle portion in a meandering course which has changed frequently since settlement, due mostly to the movement of dune sand.

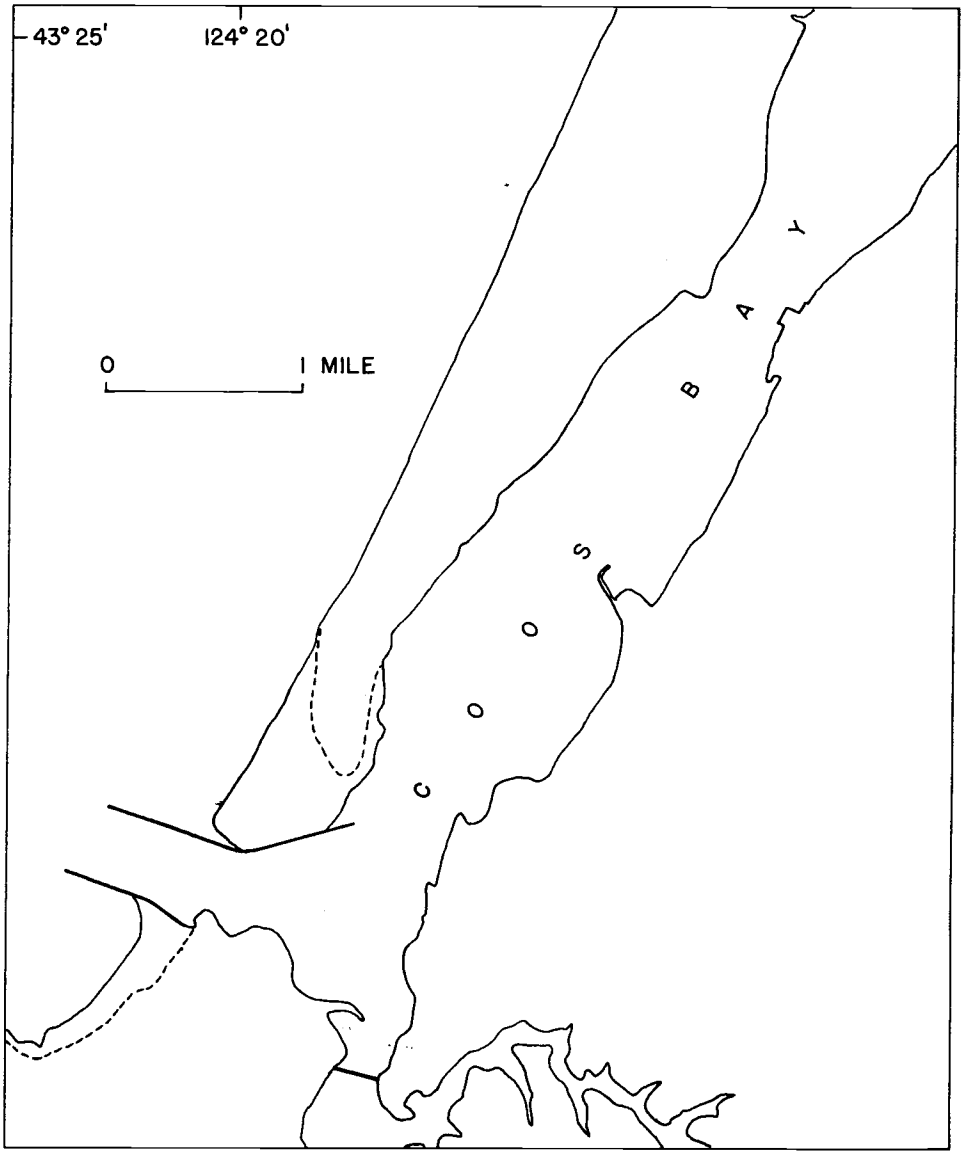
The construction of the jetties on the Coos and Umpqua entrances (Fig. 5.12; Fig. 5.13) changed the line of the beach slightly at each end. The north jetty of Coos Bay was constructed between 1891 and 1898 to a length of 9600 feet. It was extended 768 feet in 1931 and has been repaired as recently as 1958. The south jetty was constructed between 1924 and 1929 to a length of 4576 feet. The north jetty of the Umpqua River was constructed between 1917 and 1919 to a length of 3400 feet; it was extended 4600 feet between 1924 and 1931. The south jetty was completed in 1934 to a length of 2500 feet. It was extended 1700 feet between 1937 and 1939. The inner jetty (Training jetty) was constructed to a length of 5500 feet in 1951. North of the Coos north jetty the beach was built out slightly (Fig. 5.12) and south of the Umpqua south jetty there was some erosion (Fig. 5.13); it is to be noted, however, that even before the construction of the jetties, the Umpqua River represented a break point in the curvature of the beach.

15. UMPQUA-HECETA BEACH (A)

In a limited sense, the Umpqua-Heceta Beach represents a continuation of the Coos-Umpqua Beach. The length of the Umpqua-Heceta Beach, which extends northward from the Umpqua north jetty to Heceta Head, is 29.7 miles, with a perpendicular of only 0.4 of a mile, giving a C/P index of 74, the highest index of any long Oregon beach, unless straight line beaches such as Sacchi are included. The orientation is 7 degrees. The decreased curvature of the Umpqua-Heceta Beach to the north can be interpreted in terms of skewness for the whole beach (the combination of the two beaches, the Coos-Umpqua and the Umpqua-Heceta, which extend from Coos Bay to Heceta Head).

The backshore of the Umpqua-Heceta Beach is similar to that of the Coos-Umpqua Beach. A belt of more or less active dunes from one half to two miles wide is encountered, interspersed with lakes, forested areas, and grassy swales (Fig. 5.14). Many of these active dune areas are now in the process of being planted to dune grass and other plants (Chapter 6). Several streams cross this backshore belt to the

Fig. 5.12. Coos Bay Entrance, showing the prograding as a result of jetty construction. The prograded areas are stippled. Bastendorff Beach is shown in the lower left.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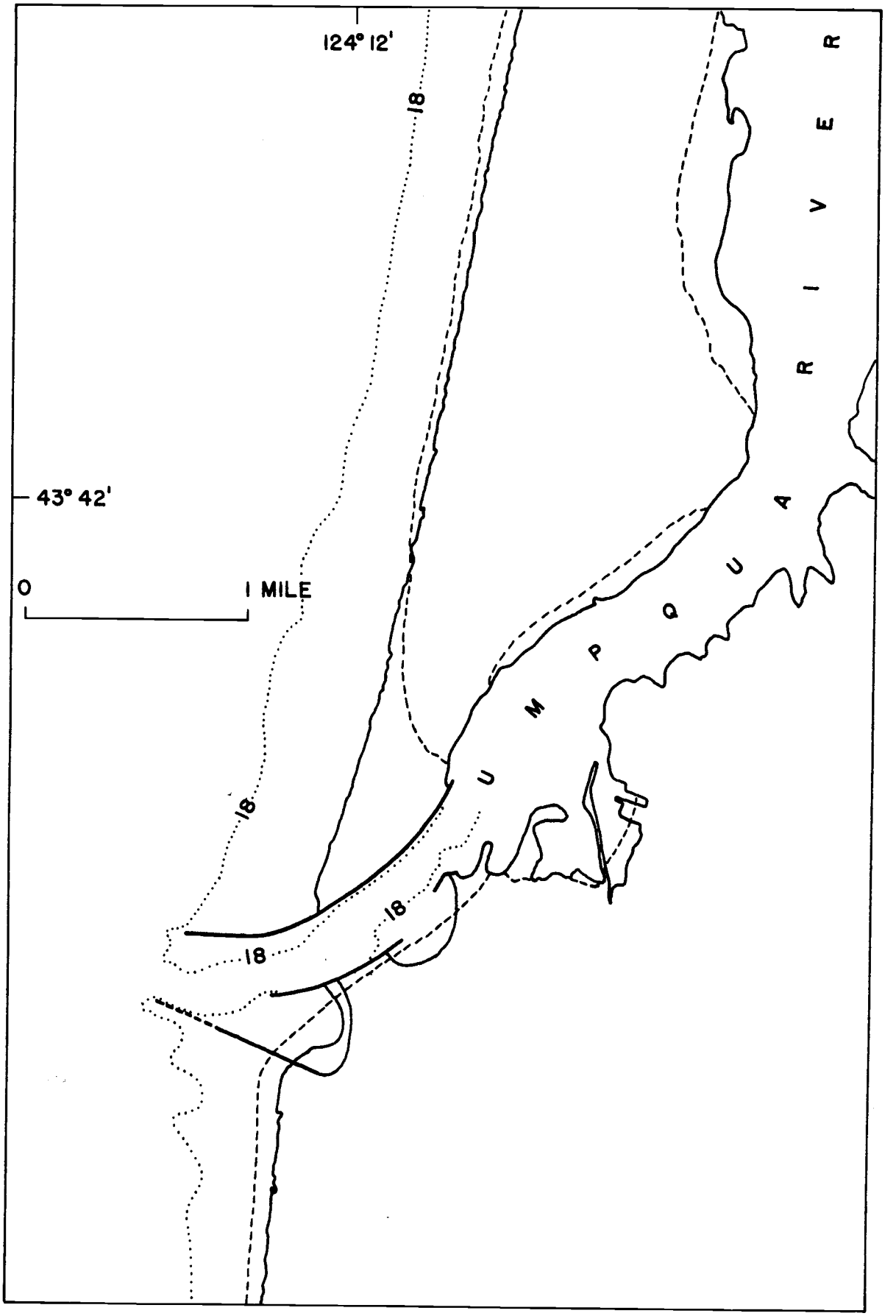
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UMPQUA RIVER

beach, of which the largest is the Siuslaw River. Others include Threemile Creek, Tahkenitch Creek, and Siltcoos River. The latter two drain lakes of considerable size. Of these streams, only the Siuslaw River has a marked effect upon the character of the Umpqua-Heceta Beach, and this largely because of the construction of the jetties (Fig. 5.15). The north jetty at the mouth of the Siuslaw River was constructed between 1892 and 1901 to a length of 1090 feet and extended 3750 feet between 1912 and 1917. Repairs were made in 1957. The south jetty was constructed between 1910 and 1917 to a length of 3945 feet.

The Umpqua-Heceta Beach is very uniform in character, similar to the Coos-Umpqua Beach. It is broad and gently sloped, without many distinguishing features. The upper beach usually shows the effect of wind erosion and there are often some small parallel accumulations of wind-blown sand. The foredune is well-marked and, in many places, it is partially grassed over. The planting of the foredune in some instances is natural. The sands are fine, consisting mainly of quartz and feldspar, with occasional small concentrations of black minerals.

The two beaches described above, Coos-Umpqua and Umpqua-Heceta, together make up a long stretch of broad, fine-grained sandy beach with a total length of 52.6 miles. The beaches appear to have changed very little in the last 100 years, except where jetties have been constructed at the Coos, Umpqua, and Siuslaw river entrances. These jetties have had only a local effect reaching, for the most part, a few miles to the north and less than that to the south of the jetties. Inside the jetties, or very near to them, the changes have been somewhat more spectacular, especially at Winchester Bay and in the small bay (Fig. 5.13) between the middle and south jetties of the Umpqua River. There is little evidence of either active prograding or retrograding on these two beaches. On the whole, this is the most stable part of the Oregon coast and, perhaps, this beach (Coos-Heceta) with its supply of sand from the three large rivers and many lesser streams, is in a state of near stability. The lack of permanent landmarks or reference points, however, leaves this statement open to some question.

16. THE YACHATS SHORELINE (E)

The Yachats shoreline (Fig. 5.16), extending a mile and one half north of the Yachats River and about three miles to the south, beyond Captain Cook Point, is rocky and uneven and cannot properly be called a beach. The bedrock consists of dense basalt and basaltic sandstones in the form of a bench 10 to 20 feet above sea level. Above the bedrock the terrace deposits vary in thickness up to 25 or 30 feet. In general, the terrace deposits consist of sand, black at the bottom with gravel, then 10 to 12 feet of buff-colored sand, and on the top a well-weathered dark soil profile containing clay and sand. The sandy deposits of the terrace cliffs along the Yachats shoreline are indurated sufficiently so that they stand up in vertical slopes along joint lines and erosion is brought about by falling away of large blocks along irregular joint lines. On the promontories these joints appear to be curved, giving a curved-wall aspect to the terrace cliff.

Viewed from the south in the vicinity of the Paddock Motel (one mile north of the Yachats River) the terrace appears to slope eastward slightly; however, it also slopes toward the south and the Yachats River. To the north of the town of Yachats the abrasion surface slowly rises but the terrace deposits thin out, so that the effect is an almost level bench along the shoreline; in most parts of the Yachats shoreline the terrace slopes toward the sea at an angle of approximately five degrees. The bedrock has deep indentations, or coves, cut in it by the waves and it is in these coves that erosion is most rapid. At low tide most of these coves show some coarse sand and gravel, known locally as smelt sand.

At the Adobe Motel the bedrock is mostly basaltic sandstone containing fossils, but with an appearance and character similar to that of the basalt. Coarse gravel occurs in the pockets with occasionally a thin veneer of medium sand on top. This last may be derived from the terrace cliffs. In this area the terrace deposits total only 12 feet in thickness, with coarse sand at the bottom, gray to buff in color, and with a conglomerate near the top.

The rate of erosion is uneven on the Yachats shoreline both in time and space. A single storm will cut back the terrace deposits a foot or more without substantially affecting the hard rock below. The most rapid erosion appears to be in the coves. Comparison of 1952 large scale aerial photographs with three ground measurements made in 1960, gives an average value of 0.5 of a foot per year but the whole of the Yachats shoreline is probably much less.

Fig. 5.13. Map showing shoreline changes at the entrance of the Umpqua River. Note the construction of three jetties. The dashed line represents the shoreline in 1885. The changes in shoreline in Winchester Bay are partly the result of the construction of a breakwater and of dredging for a small boat harbor. The 18-foot depth contour is shown by a dotted line.

One and one half miles north of the Yachats River the shoreline changes in character. The igneous rocks come to an end and a beach appears, which takes on a more normal beach aspect with a broad, nearly level stretch of fine sand and a terrace cliff about 20 feet high on the inner margin. This cliff is eroding rapidly in places; the erosion tends to attack weaknesses in the cliff and also the rounded projections, rather than to follow the pattern of coves and indentations similar to those farther south. Within the last 50 or 60 years erosion in this area has removed entirely the county road which formerly ran north-south along the top of the terrace but close to the edge (Fig. 5.16). Observations by Mr. William Brubaker (Personal interview) over a period of 30 years show the erosion on the terrace scarp to be approximately 15 feet, making a yearly average of 6 inches.

17. NEWPORT BEACH (E, F)

Newport Beach extends approximately 3.1 miles from the north jetty of Yaquina Bay to Yaquina Head (Fig. 5.17). The perpendicular distance is 0.3 of a mile, the C/P index is 10.3, the orientation is 2 degrees, and the skewness is 69N. However, South Beach (south of the south jetty) also is included in this description in order to discuss the changes which have occurred at the entrance of Yaquina Bay.

Newport Beach proper is sometimes separated into Nye Beach on the south and Agate Beach on the north, according to local usage. The beach itself is a broad, gently sloping, fine sand beach, interspersed with reefs and ridges of sandstone which, however, do not stand up prominently above the beach sand. Here and there are cobbles but, in general, the beach has uniform fine sand. Above the beach rise the steep cliffs of the marine terrace on which a large part of the city of Newport rests (Baldwin, 1950). The terrace is fairly broad in the southern portion but narrows to a remnant to the north; it ends against the south face of Yaquina Head - an igneous, rocky promontory. At the base of the cliffs, in most places, there are outcrops of Astoria sandstone and Nye mudstone, the latter a thick, massive layer of mud consolidated sufficiently to resist the sea to some extent. These formations dip to the westward 8 to 16 degrees; the Astoria formation outcrops for only a part of the beach area especially on the southern end; to the north, erosion has progressed far enough to eliminate the Astoria formation from parts of the cliff. Overlying the truncated beds of the Astoria sandstone and Nye mudstone are the terrace deposits, generally designated as Elk River. These consist largely of sand with some gravel and account for about one third to one half of the height of the terrace. The top of the terrace, coated with a thin veneer of dune sand, is generally flat except where eroded by a few stream valleys or broken down by slumping or slump faulting along the cliff.

The most striking feature of the backshore of Newport Beach is the extensive slump faulting which makes the area more susceptible to erosion by storm waves. Altogether, a large amount of flat terrace land has slumped into the sea during the last 100 years. The topographic chart of 1868, contour interval 20 feet, indicates clearly by hachures the scarps of these slump faults. The scarps are too high above sea level to be simple sea cliffs. The general outline of all of these slump faults is curvilinear. One lies immediately north of the north jetty and extends for about one fourth mile; the scarp elevation is between 40 and 60 feet and appears on the old chart as a trench running out to sea on both ends. Another scarp is shown on the chart at the foot of the present Olive Street in Newport. The crack of this slump also is shown clearly in early photographs. A third scarp with a sharp curve is indicated to the north of Jumpoff Joe Point, which is near the west end of Cave Street. Jumpoff Joe has now practically disappeared; only a few rocks remain at low tide.

The slumping obviously affects rocks below sea level and yet the movements are not tetonic in character. Although the slumps occur all along Newport Beach, the nature of the beach outline indicates that they are not all part of one fault. The most active of these faults, in recent years, is the one that lies to the south of Jumpoff Joe Point. This area began to move in 1942; the movement being in the nature of a great slump with a mass approximately two blocks in width and one quarter of a mile in length, moving seaward and rotating slightly toward the land. The area had previously been built up with houses, streets, power lines, and sewage facilities. Some of the houses still remain, although unoccupied, and

Fig. 5.14. Dunes at Florence and at Clear Lake. The upper photo shows a section of the dunes immediately to the west of Florence on the Siuslaw River. The general movement of the sand is northward into the river, thus interfering with navigation. Much of this area has been planted to dune grass, broom, and pine since this photograph was taken. The darker band immediately inland from the foredune is a low-lying, wet area including some quicksand. A part of this is naturally vegetated. The lower photo shows the dunes a few miles to the south, in the vicinity of Clear Lake. Here the dunes are advancing into the forest as fingers of sand, moving generally northward. Clear Lake is the result of the blocking of a stream by advancing sand (Univ. of Calif., Hydraulic Eng. Lab., 1948).

give a key to the amount of movement and also to the amount of tilting. Although several of the houses were reconditioned by new foundations, one house, which still exists, apparently was not treated thus. The floor and foundation of this house at present dip five degrees to the east. This general tilting of the block to the northeast is confirmed also by the attitude of some of the large spruce trees which moved down with the block. One effect of the movement has been to push the base of the sea cliff outward and subject it to more rapid wave erosion. Erosion is cutting rapidly at the outer scarp of this block and within the last 10 years it has cut approximately 25 feet from the face of the scarp. Another effect has been rapid erosion on the new scarp at the top of the terrace.

The construction and extension of the jetties at the outlet of Yaquina Bay have probably had little effect upon Newport Beach except near the jetties. The jetties were completed in 1896 and included two high-tide jetties, the north one 2300 feet and the south one 3748 feet in length. These jetties were subsequently extended; the north jetty 1400 feet in the years 1921 to 1925 and 1400 feet in 1925 and the south jetty 2200 feet between 1919 and 1922. In 1903 a reef, which lay 2000 feet seaward of the existing jetties, was removed. In 1919 the jetties were again restored and extended and a 20-foot channel was dredged. In 1937 there was another extension of 1000 feet to the north jetty and the 20-foot channel was re-dredged. The effect of the jetties has been to build up sand on the south beach extensively and to build up sand on the north side of the north jetty very little. This difference is, perhaps, related to the direction of the jetties, which extend southwestward from the entrance. Sand moving from the north tends to spill around the north jetty and to accumulate to the south of the south jetty.

18. BEVERLY BEACH (E)

Beverly Beach extends from Yaquina Head northward to Otter Rock. The beach is 4.7 miles long, has a perpendicular of 0.3 of a mile, a C/P index of 15.5, and an orientation of 6 degrees. The skewness is 56N. The beach is very similar to Newport Beach as far as sand, slope, and profile are concerned. The beach is sharply delimited both at the north and south ends by faults. The south end is bordered by the volcanic rocks of Yaquina Head and the north end by the Yaquina sandstone which is represented by a resistant promontory.

The backshore of Beverly Beach is similar to that of Newport Beach in terms of formations. The Astoria sandstone has a broader outcrop on Beverly Beach but dips seaward at angles from 10 to 24 degrees. It is underlain by Nye mudstone. The backshore of Beverly Beach, however, presents an interesting contrast to that of Newport Beach. In spite of similar structures, there is a much more regular, stabilized backshore with very little slumping of large masses.

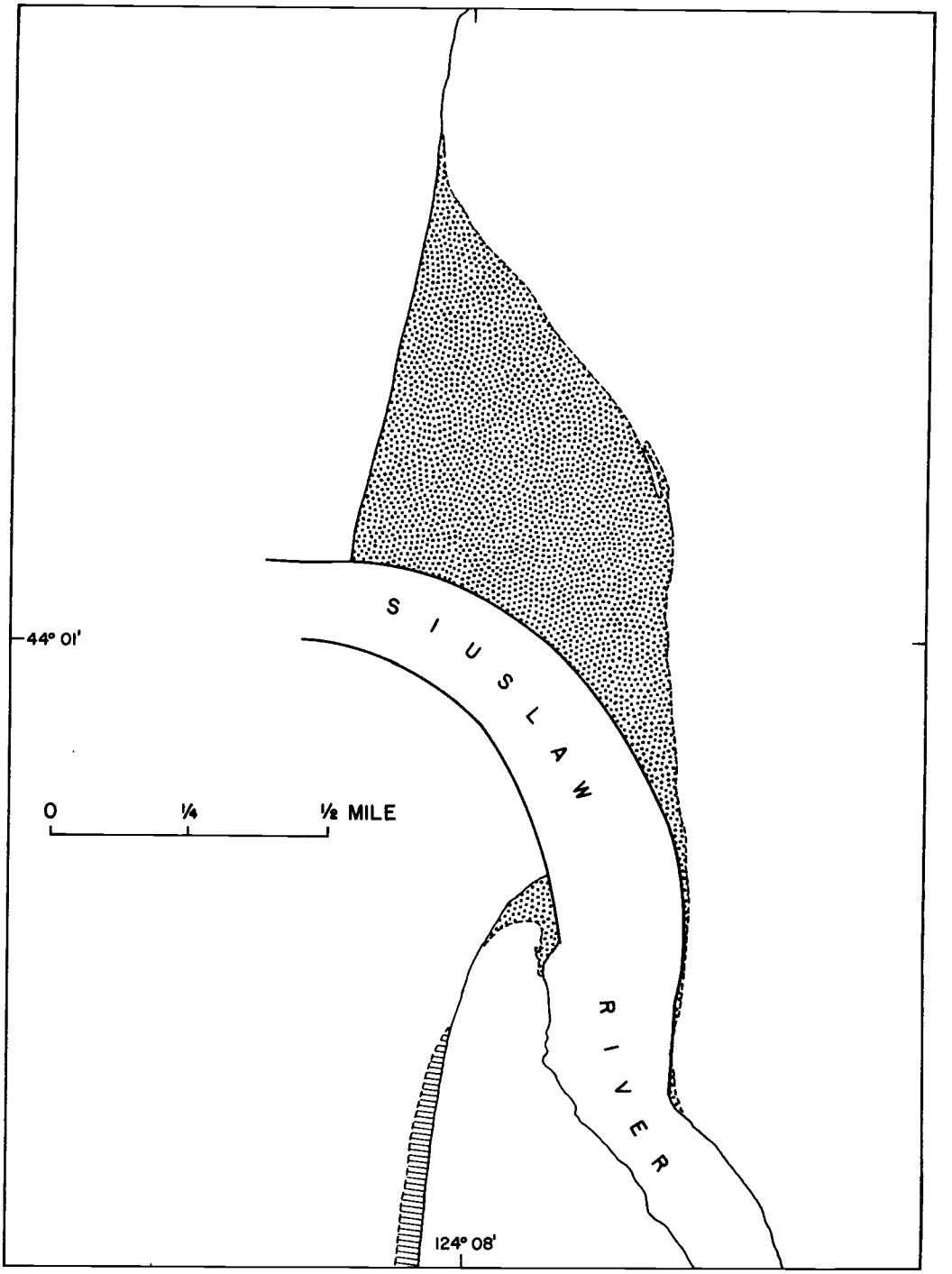
19. SILETZ BEACH (A, C, E)

Siletz Beach extends from Fishing Rock, north of Government Point, to Roads End Headland, north of the outlet of the Siletz River. Parts of the beach are variously known as Lincoln Beach, Gleneden Beach, and Wecoma Beach. The beach is 12.35 miles long, has a mid-point perpendicular of 0.25 of a mile, and the C/P index is 49. The beach is skewed 56 percent south and the orientation is 9 degrees. The skewness of the beach may be related to the lower resistance of the shoreline on the south, especially to the low, dune-covered spit bordering Siletz Bay, rather than to the dominant wave direction. The heaviest erosion on the beach appears at the north end where there is the characteristic sharp curve to the beach.

The beach varies greatly in composition. In the south the sands are coarse; a sample collected on Gleneden Beach (Mile 3) at mid-tide has a median diameter of 0.51 mm. This corresponds to a sample collected by Twenhofel at the high-tide line with a median diameter of 0.49 mm. The sand on the northern part of the beach is finer, medium to fine, comparable to a standard Oregon beach sand. The southern beach, especially, shows a great many irregularities; cusps are common, berms occur on the beach at the high-tide line, and there is a well-developed bar at approximately sea level. Between the bar and the beach proper, there are prominent runnels.

The backshore of the beach consists mainly of thick, sandy terrace deposits, overlain in the southern portion by stabilized dunes. On the spit and also somewhat to the south of the spit are dunes of more recent origin. The spit itself is almost bare, but a part of the active dunes at its base have been stabilized within the last 10 years. Hard rock is encountered in the headlands and at a few points on the beach. Basalts and basaltic sandstones make up the headlands, both to the north and the south, and the limits of the beach are marked by faults. At the north end of the beach there is a short but steep outcrop of the Nestucca formation, which consists of siltstones with interbedded sandstones dipping north-

Fig. 5.15. Map of the Siuslaw River Entrance showing prograding and erosion. The stippled area represents prograding following the construction of the jetties. The ruled areas in the lower part of the photo represent erosion. The south jetty is scheduled for repair and extension in 1961.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ward and northwestward. The Nestucca formation includes clastic dikes of basaltic material cutting across the bedding planes. This slope is being eroded fairly rapidly and is entirely bare of vegetation; however, the material falls off in even layers, more or less at right angles to the bedding, and does not show evidences of slumping.

Changes in the backshore of Siletz Beach have ranged from slight to moderate. The changes generally have been too small to be measured from comparison of aerial photographs, but an indication of the changes is revealed by the type of vegetation on the sea cliff. From the southern end, at Fishing Rock, to the town of Gleneden, approximately three miles, the sea cliff is well-vegetated with shrubs, indicating slight erosion. Northward from Gleneden (town) to the end of the sea cliff, a distance of one mile, the cliff is nearly bare. It is less vegetated now than it was in 1939. From this point northward, the sea waves are eroding the dunes. It is difficult to note the amount of erosion, but it appears that the cliff formed in the foredune has been pushed back slightly in the last 20 years. North of the outlet of the Siletz River and in the town of Taft (Mile 6) the erosion appears to have been a little greater. Measurements on the 1939 and 1958 aerial photographs reveal a retrograding of 6 to 10 feet for those years. This comparison calls for measurement in terms of hundredths of inches and is not entirely satisfactory. However, it can be noted that the detailed configuration at the top of the sea cliff has changed noticeably during the last 20 years. North of Taft the elevations of the sea cliff and the terrace decline to 10 or 20 feet above sea level. Immediately north of the D River (Mile 9), an outcrop of intrusive rocks on the beach protects the sea cliff which is completely vegetated. Further north at Nelscott several buildings near the beach have been damaged severely by storms in the past 20 years. North of Oceanlake (Mile 9.5) the terrace again rises and shows patches of vegetation, as well as patches of bare sand and gravel. In summary it may be said that erosion at Siletz Beach is greatest at the middle portion and northern end, least at the southern end and in scattered areas where there is some protection from the full force of the waves.

20. CRESCENT BEACH (E, F) and 21. CASCADE HEAD BEACH (F)

Two small beaches (Fig. 5.18), Crescent Beach and Cascade Head Beach, lie on opposite sides of the Salmon River but not adjacent to the river and represent different phases of landslide or mass movement beaches. Crescent Beach is one half mile north of Roads End Headland. It is only 0.15 of a mile long with a perpendicular distance of 0.043 of a mile, a C/P index of 3.5, and an orientation of 65 degrees. The beach, crescent-shaped and almost entirely landlocked, is supplied with sand - by wind and water action - and with some fragments of rock derived from small landslides in the basaltic rock and from the Nestucca formation.

Cascade Head Beach (Fig. 5.18), on the southwestern flank of the headland, is bordered by steep landslides and, as a result, the beach is composed mostly of rock fragments brought down from the slides and has only a limited supply of sand. The beach is 0.13 of a mile long but, because of the irregularities, it is not feasible to measure perpendicular distance, C/P index, or skewness. The orientation of Cascade Head Beach is 35 degrees. The backshore is entirely in basalt and basaltic sandstones. Mass movements have been very active in recent years, perhaps related to the clearing of the forest on its slopes. At the time the early surveys were made, the headland was completely forested down to the top of the sea cliff. It is now in grassland, for the most part, although the northern portion of the backshore is cut-over forest land. The movement of material downslope has kicked up a toe of the slide and formed a small pond, similar to that described at Houstenader Beach, but with much steeper slopes. On the middle and northern portions of Cascade Head Beach the slide debris ends in a cliff, approximately 50 feet in height, which is constantly being attacked by the waves; as the material is removed from the toe of the slide, there is further mass movement.

22. NESTUCCA BEACH (Kiwanda Beach) (A,E)

Nestucca Beach extends from Cascade Head northward to Cape Kiwanda. The beach is 8.4 miles long, has a perpendicular distance of 0.35 of a mile, and a C/P index of 24; the orientation is 6 degrees and the skewness is 56 percent north. The beach is broad and, particularly in the south, composed of coarse sand. The immediate backshore is made up of dunes. At the southern end of the beach the interior backshore is a sea cliff based upon sedimentary and igneous rocks of the Nestucca formation. Various zones of intru-

Fig. 5.16. Otter Crest with Yaquina Beach in the distance. Erosion is more rapid on the northern exposures than on the southern ones, probably due to the structure. Note the strike of the sedimentary beds in the lower right (Oregon State Highway Dept., 1958). The lower vertical photo shows a portion of the shoreline immediately north of the town of Yachats. The terrace is being eroded in spite of the protection of the bedrock. Scale 1:4800 (Corps of Engineers, 1952).

sive and flow igneous rock are exposed in the cliff. On the extreme northern end of Nestucca Beach, the interior backshore is made up of sedimentary deposits plastered over with high dunes. Cape Kiwanda, although of soft Astoria sandstone, is, nevertheless, resistant to erosion and has shown very little change in recent years.

Except for dune activity, there has been little change in Nestucca Beach or, for that matter, in the lower river and bay since settlement. The active dune area has extended all the way from Cascade Head to Cape Kiwanda, but has been especially noticeable on the northern end, from Nestucca Bay to Cape Kiwanda. It is apparent that at some time in the past the Nestucca River cut through the narrow spit, but this has not occurred in historic time. Nestucca Beach is one of the most stable of the Oregon beaches. Throughout the area the sea cliff of the interior backshore is well-vegetated with shrubs and small trees and shows little signs of erosion. The broad beach and the belt of dunes apparently protect the cliff from erosion by the waves. Although the north spit (Mile 5) shows some erosion by waves, there is no indication that this amount is enough to be measured and it probably varies with the season. During the strong southwest storms of winter the beach diminishes but it builds up again in summer.

It is evident that sand from the northern portion of the beach has moved northward under the force of the wind and invaded the high forested country, since tongues of dunes are to be seen today and also show on the old charts. On the north side of Cape Kiwanda there is evidence that some sand also moves in from the north in the summer and, particularly in one trough, it appears that the sand moves southward in the summer and northward in the winter. Sand is also invading the forest at the southern end of the beach.

23. SAND LAKE BEACH (A, B, E, F)

Sand Lake Beach extends from Cape Kiwanda to Cape Lookout (Fig. 5.19). It is 7.9 miles long and has a perpendicular of 0.55 of a mile, giving a C/P index of 14.3. The orientation is zero degrees and the skewness is 57 percent north. The name - Sand Lake - is misleading; the body of water actually is an estuary fed by a small stream, Sand Creek. Formerly Sand Lake probably also received the waters of Tillamook River. The estuary represents a broad embayment, flooded at high tide, the margins of which are covered with dunes, both active and stabilized.

The beach in the vicinity of the lake is broad, of medium to fine sand, and has a well-developed bar. The southern one third of Sand Lake Beach is flanked by a low terrace in front of which beach sand, mixed with driftwood, has accumulated. The entire Sand Lake Beach shows very little erosion except at the southern end near Cape Kiwanda. In this area a fresh sea cliff is exposed, revealing a basalt sill; parts of the backshore show active mass movement. At the low-tide level tree trunks and branches are exposed.

24. NETARTS BEACH (A, D, E)

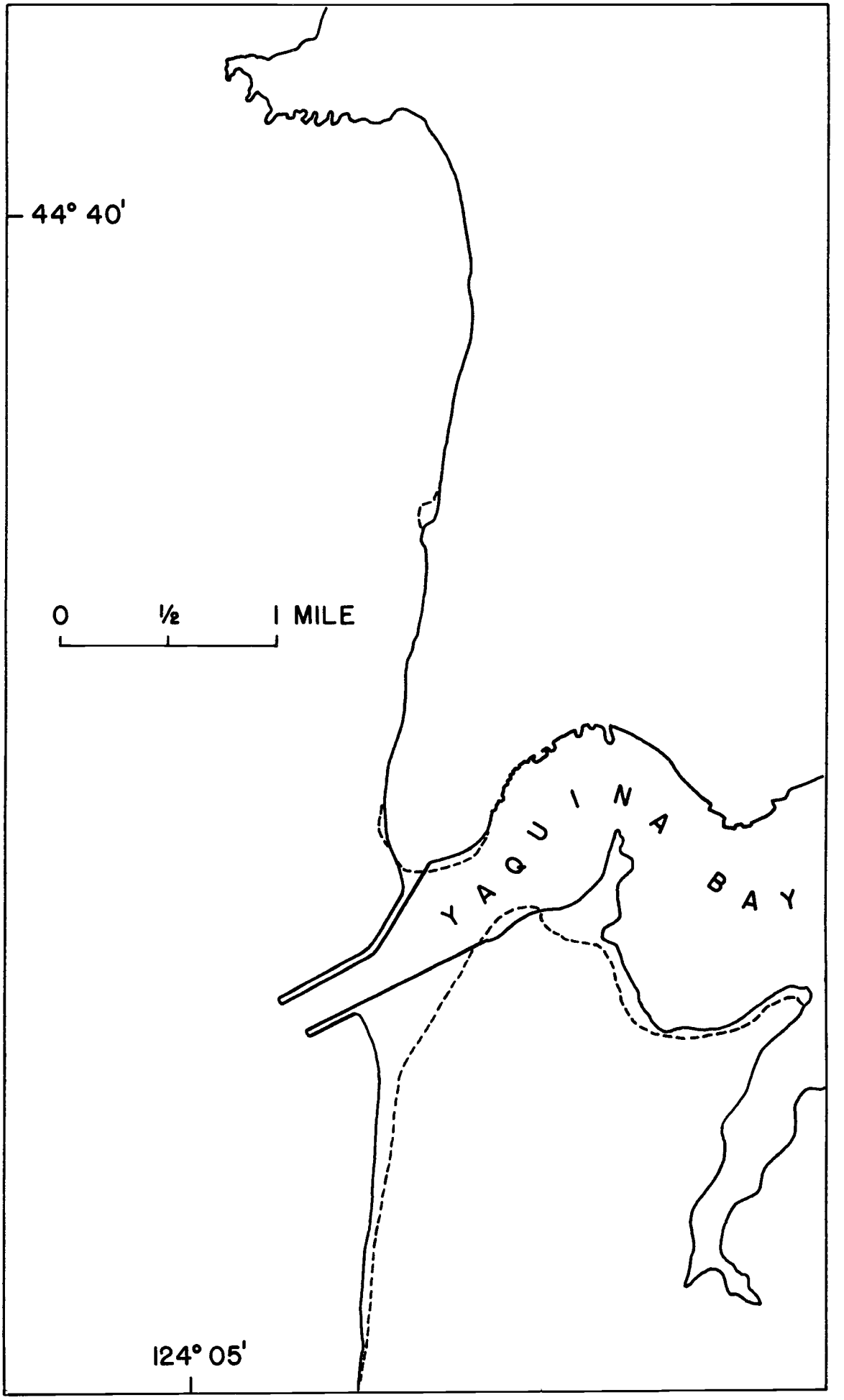
Netarts Beach (Fig. 5.4) which lies between Cape Lookout and Maxwell Point, south of Cape Meares, is interrupted by the outlet of Netarts Bay. The beach is 7.35 miles long and has a perpendicular of 0.5 of a mile. The C/P index is 14.7, the orientation is one degree, and the skewness is 61N. Although Maxwell Point marks the northern end of the beach, it does not extend seaward far enough to interrupt the movement of sand.

From the southern limit of the town of Oceanside (Mile 7) northward to Maxwell Point, the beach is bordered by a terrace approximately 25 feet above sea level and there is a higher terrace at 200 feet. The extent of the terrace along the shore is quite limited and is succeeded, to the south of Oceanside, by dune sand which is plastered as a thin veneer on basaltic cliffs. These cliffs extend to the outlet of Netarts Bay with some minor modifications. On the north side of the entrance to the bay marine clay forms a resistant layer on the beach. Above the clay in an embayment in the sea cliff there is a small area of active sand dunes.

Netarts Bay is a shallow, elongated body of water which is gradually filling with sediment. It has no major stream flowing into it, but there is sufficient movement of sediment to produce large areas of sand and mud at low tide. Several years ago Jackson Creek, which formerly flowed directly to the ocean, was diverted into the bay with the purpose of providing more water, apparently with little effect.

The bay is bordered on the west by a long sand spit, nearly five miles in length, very narrow in the middle portion, but widening to the north, where apparently, as the sandspit was forming, several recurved

Fig. 5.17. Map of the entrance to Yaquina Bay with Newport Beach to the north. Prograding as a result of the jetty construction shows and also an indication of erosion to the north.


44° 40'
0
1/2
1 MILE
YAQUINA BAY
124° 05'

spits were developed. No part of the spit reaches an elevation of over 50 feet. It is evident that the sea has broken through the spit in past times and there is local testimony of this. The break-through occurred in the narrow neck of the spit (Mile 2) about three miles north of Cape Lookout. There is no record of break-throughs during the last 20 years. The vegetation cover on the spit varies from bare sand areas on the north with no vegetation to stands of large Sitka spruce on the south. In the middle of the spit there is a large area of beach pines and dune grass; in intermediate locations dune grass is wide-spread. Dunes, thickly covered with grass, form the southern part of the spit. This dune grass was planted in 1950, after the area had been acquired as a state park. The planting of the dunes has probably resulted in some accumulation of sand as it is blown in from the beach.

The northern part of the beach, from Maxwell Point southward, consists of large cobbles which continue almost to the outlet of Netarts Bay while decreasing in volume and size. These cobbles appear to have a protecting effect on the beach, since little active erosion occurs on the terrace face. However, immediately north of the entrance to Netarts Bay, where cobbles are missing, there is some active erosion.

Erosion on Netarts Beach is minimal. It is greatest on the north (at the south edge of Maxwell Point) and on the south (at the northern extremity of the cliffs forming Cape Lookout). These areas are attacked by the waves in a manner previously described. The waves tend to impinge upon the north and south faces of the headlands and to concentrate their effects in the corners between the headlands and the beaches. Even here the erosion is not excessive. Erosion also occurs to the north of the bay outlet (Mile 6). This erosion which affects the dunes and causes minor slumping, has apparently been going on for some time. Photographs taken 40 years ago show mild slumping but not sufficient to completely break the vegetation cover of the dune slope.

25. SHORT BEACH (Cape Meares) (E)

Short Beach, immediately south of Cape Meares and north of Maxwell Point, is too rocky and irregular for measurements of curvature and skewness. It is 0.6 of a mile long and is almost entirely devoid of sand. The slope of the beach is generally more than 10 degrees and shows many short, irregular cusps. The backshore consists of nearly vertical basaltic cliffs, 50 to 100 feet high. Almost all of the backshore is actively eroding, especially in the areas where large-scale slumps have moved out onto the beach. This beach is significant in connection with the erosion processes which are occurring on Bayocean Beach to the north; very little of the sand which moves southward from Bayocean finds its way to Short Beach. In general, it appears that sand by-passes headlands but, in some cases, is lost in deep water and does not return to the adjacent beaches.

26. BAYOCEAN BEACH AND KINCHELOE BEACH (B, D)

A continuous recurving beach extends nearly five miles north from Cape Meares along the spit which separates Tillamook Bay from the ocean (Fig. 5.1; Fig. 5.20). On the north end of the spit the beach has advanced a maximum of 600 feet since 1939, while to the south the retreat has been nearly 1000 feet. The southern four miles, curved inward and eroding, is Bayocean Beach; the northern section, curving outward and prograding is Kincheloe Beach. The present Bayocean Beach is 3.9 miles long, with a perpendicular distance of 0.23 of a mile, a C/P index of 17 and an orientation of 10 degrees. The beach shows a slight skewness to the south.

Bayocean Beach Forty Years Ago

Forty years ago Bayocean Beach was 3.4 miles long with a perpendicular distance of 0.09 of a mile and a C/P index of 37.6. The orientation was 10 degrees and the skewness was 66S. It was a broad, sandy beach with a gentle slope. There were two bars, one near low water and the other, an outer bar, at a distance of about 300 feet from the high-tide line and at a depth of minus 20 feet. Most of the beach consisted of medium-grained sand but some pebbles and cobbles appeared on the upper beach in winter.

Fig. 5.18. Cascade Head and Crescent Beach. The upper photo shows Cascade Head and the entrance to Salmon River. The small beach on the left shows the effect of landslides; the immediate backshore of the beach is a cliff of landslide debris. The lower vertical photo shows Crescent Beach (not to be confused with Crescent Beach, Ecola Park) and other small crescent areas; also the effect of landslides on the backshore. Cascade Head Beach has a much higher backshore than Crescent Beach and, therefore, shows much greater landslide activity. (Univ. of Calif., Hydraulic Eng. Lab., 1948 and U. S. Corps of Engineers, 1939).

Above the beach the steep face of the backshore was cut in the old stabilized dunes, which formed the spit. It is apparent that these dunes, which rose to a height of 140 feet and had a maximum width of one half of a mile, had been stabilized for at least 200 years, probably longer, and that they were eroding very slowly. In a few places old stream channels had cut through the spit and allowed sand to be blown toward the bay. As shown in old photographs (Fig. 5.21), the slope, approximately 30 degrees, was vegetated with Sitka spruce trees (many of them more than 100 years old), beach pines, and an understory of various shrubs (Chapter 6). Small hummocky active beach dunes occurred at the foot of the slope. Well-boring records of these old dunes indicate that sand and gravel reaches to depths of at least 20 feet below sea level. In recent times a bed of cobbles four feet thick has been exposed by erosion at the base of the old dunes. On the southern part of the beach (Mile 0 to 1), the backshore consisted of a 20-foot terrace composed mainly of marine clays resting on sandstone. Once the erosion was accelerated, there were no resistant materials in the backshore to check the erosion. One can only conclude that prior to the acceleration of erosion forty years ago, the broad beach acted as a cushion protecting the spit from the full effect of the waves.

Construction of the jetty north of the entrance to Tillamook Bay, begun in 1914 and completed in 1933, apparently had a profound effect on Bayocean Beach. One obvious effect of the jetty construction was the accumulation of sand on the north side (Watseco Beach) (Fig. 5.20). There is good circumstantial evidence that the construction of the jetty also triggered the erosion of Bayocean Beach by denying sand to the beach. This is borne out by the fact that soundings made after the construction of the jetty revealed a loss of sand from the submerged portion of the beach, within the 10 fathom line. Furthermore, in similar situations in various parts of the world the construction of jetties or breakwaters has led to erosion of the adjacent beaches.

Erosion at Bayocean Resort

In 1906-1907 an extensive resort, known as Bayocean (Mile 2), was developed on the stabilized dunes at Bayocean Beach. The resort included three hotels, a large natatorium, numerous houses and cottages, together with several miles of paved streets and roads. Photographs taken from about 1910 to 1915 provide a good pictorial record of what the peninsula was like before erosion was accelerated. From the records of erosion which are fairly well documented in the early stages and very well represented by aerial photographs in the later stages, it is evident that erosion began some time after the construction of the jetty, probably between 1920 and 1925. At first the rate of erosion was slow and scarcely noticed. By 1935, however, the rate of erosion had increased and the results had been observed by many people.

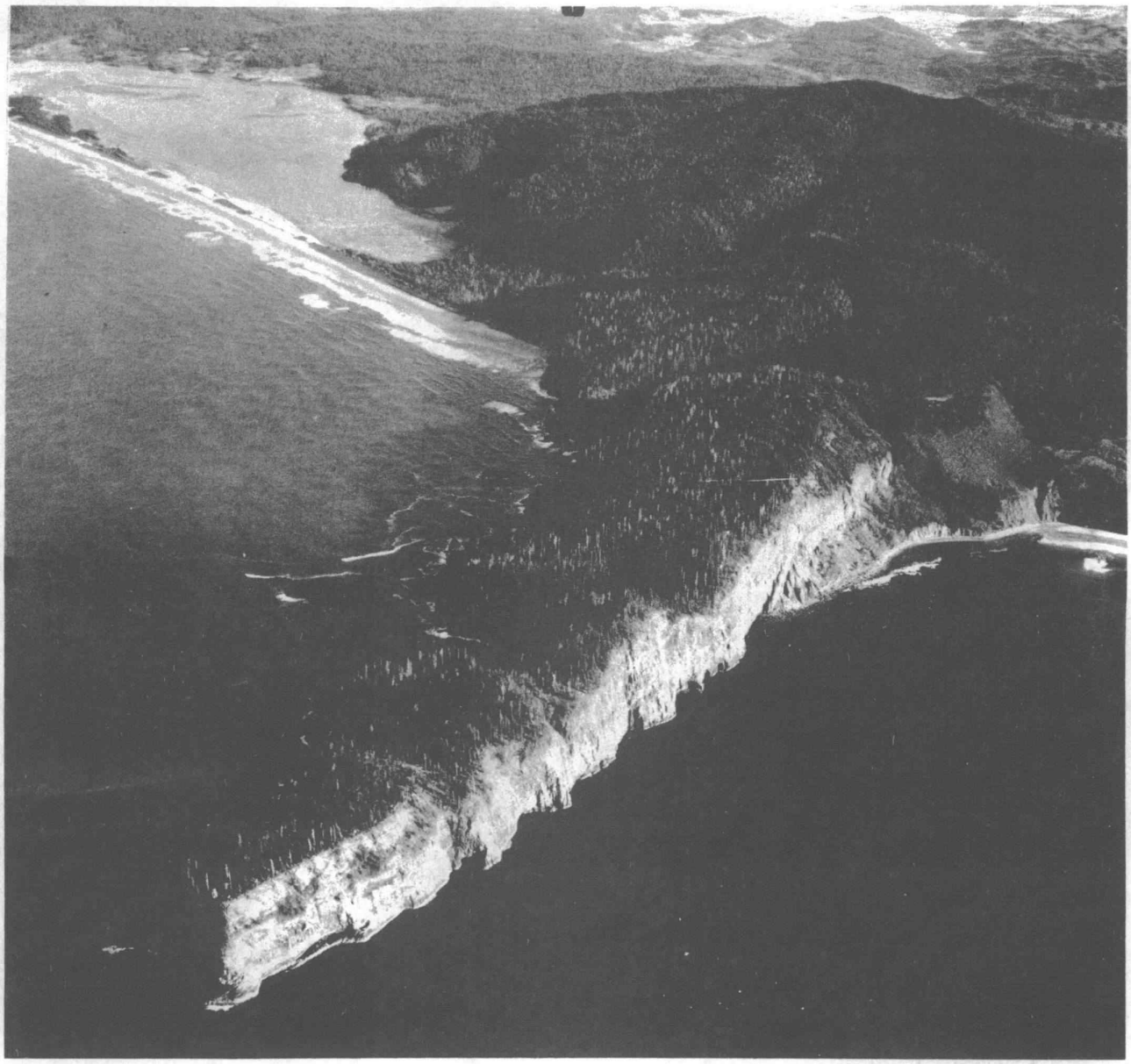
The first measurement of erosion was begun in 1926 by a Mr. Williams who lived on a small bench in the dunes at an elevation of about 50 feet. He drove stakes near the top of the slope on his property and observed, over a period of six years (1926-1932), an average rate of erosion of about one foot per year. It should be stressed, of course, that most of the erosion occurred and still occurs during periods of heavy storms and high tide; erosion also is uneven from month to month and from year to year. In 1932, due to a heavy storm, the waves broke through the spit and severely damaged the natatorium (Fig. 5.22). Mr. Williams took further measurements from 1932 to 1933 which indicated a rate of erosion of six feet per year. Erosion was accelerated in the period between 1933 and 1939 according to local testimony and old photographs. In 1939 vertical aerial photographs of the region were made and the spit has been re-photographed at intervals and, in the last two or three years, it has been photographed twice a year. In the period from 1939 to 1944 the rate of erosion was about 16 feet per year, whereas for the whole period from 1939 to 1960 the rate of erosion averages about 50 feet per year.

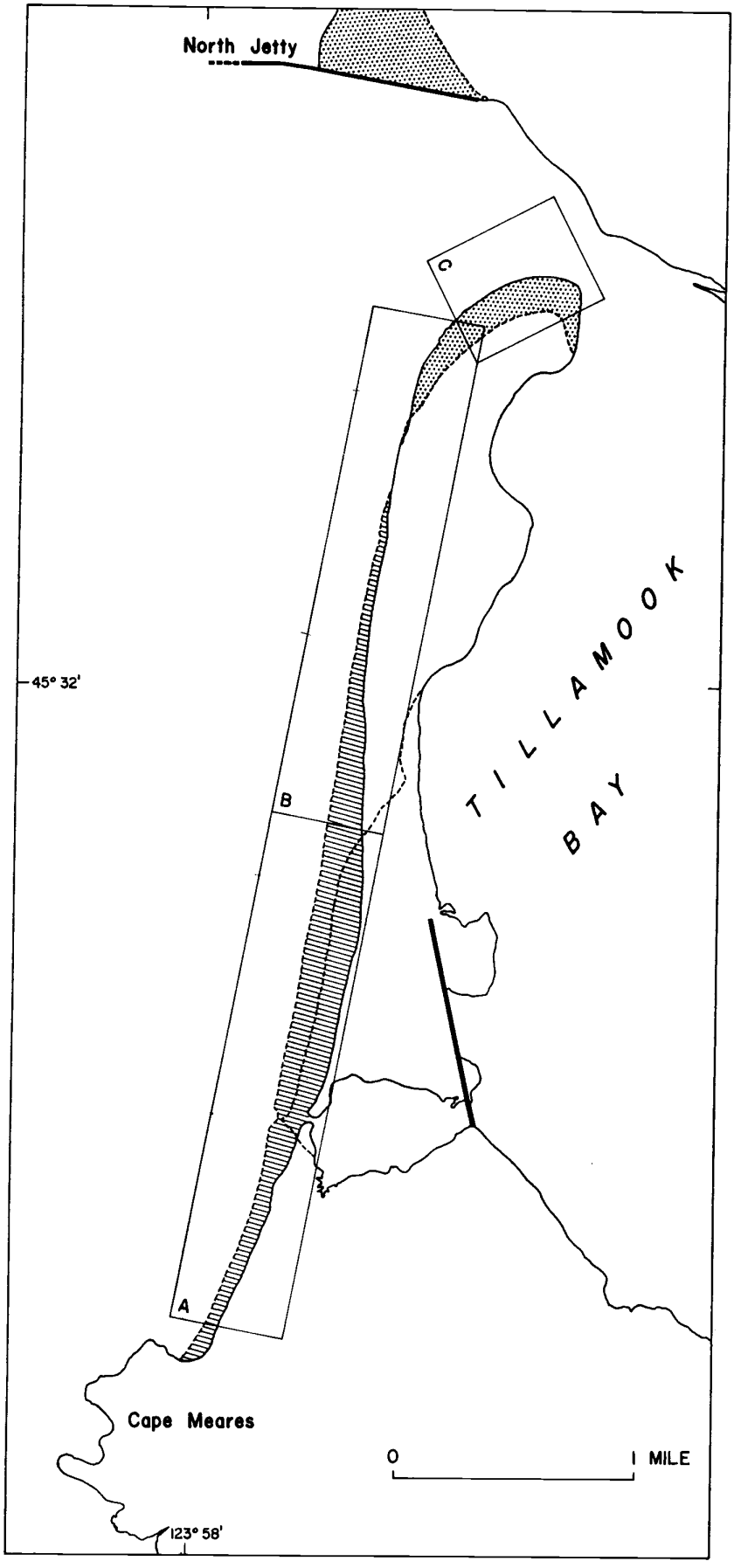
In 1952 erosion reached a point at which the combination of a severe storm and a high tide, caused a mile-long break through the spit (Mile 2 to 3) and large amounts of beach sand moved into the bay. The break was closed in 1955-1956 by the construction of a dike. Erosion of the beach continues, however, on the newly formed shoreline.

Erosion of the Southern End of Bayocean Beach

On the southern end of Bayocean Beach (Mile 0 to 1) the sea cliff is composed of marine clay of which there are two layers, the lower one being dark-gray, peaty, and mucky in character, and the upper one having a light-yellowish color. Both of these clays are highly plastic, can be molded in the hands, but, nevertheless, present a rubbery surface more resistant to the action of the waves than that presented by the dunes. These marine clays appear to be of Coquille age and were probably deposited in a bay or bays during the third interglacial stage (Baldwin, Personal interview). Beginning at Mile 0.5 and extending

Fig. 5.19. Oblique photo of Cape Lookout and a portion of Netarts Beach, upper left. Cape Lookout shows severe erosion on the south side, less on the north side. The northern end of Sand Lake Beach is shown on the right (Univ. of Calif., Hydraulic Eng. Lab., 1948).




North Jetty
C
B
A
45° 32'
TILLAMOOK
BAY
Cape Meares
0
1 MILE
123° 58'

southward to Cape Meares, the clays are overlain with angular slide rock with a mixture of mud derived from Cape Meares. This layer of slide material becomes thicker to the south. This material is especially susceptible to attack by the waves and is also affected by landslides. Whereas the area to the north of the mid-point above the beach is a flat terrace developed on marine clays, the land to the south is hummocked with landslides, some of which near the cliff are quite active. Near Cape Meares cliff (north side) there is an outcropping of sandstone dipping gently to the south. This massive sandstone outcrop extends out to sea to the low-tide level and presumably beyond. Overlying the sandstone is a light-gray mudstone which appears especially at the very base of the cliff of Cape Meares. Since 1939 the maximum retreat of the sea cliff has been approximately 500 feet on the southern part of Bayocean Beach. It is somewhat less at the extreme southern end, about 320 feet, causing a slight increase in the curvature of the beach. In a period of 22 years, the average retreat of the sea cliff is approximately 23 feet per year.

All along the southern end of Bayocean Beach (Mile 0 to 1), at the upper level, is a thick deposit of very large cobbles and boulders overlying the marine clays. Very little gravel is to be seen, except in the extreme southern end where some pebble or shingle surfaces occur on the beach. The cobbles are especially abundant on the middle and northern portions of this section (Mile 1); during severe storms these cobbles serve as tools by which the waves erode and break up the sea cliff. Against ordinary waves the cobbles form a protecting layer. There is an almost complete absence of sand in this area (Mile 0 to 1), which indicates a changed condition in recent years. It is presumed that this lack of sand is associated with the construction of the jetty and especially with the breakthrough into Tillamook Bay, which carried much sand away from this beach. The acceleration of erosion at the southern end of Bayocean Beach (Mile 0 to 1) did not attract early attention, although probably by 1922 there was some noticeable acceleration. The local people mark 1933 as the year when accelerated erosion began. (This is also the year when the extension to the jetty was constructed.) In more recent years the rate of erosion has increased.

For the past several years aerial photographs have been available for various years which, by comparison with land marks, such as houses, streets, and individual trees, make it possible to determine the rate of erosion quite sharply. Specifically, during the winter of 1960-1961 the retreat on Pacific Avenue in Cape Meares (town) was 75 feet. Actually, most of this retreat occurred between September, 1960, and April, 1961.

Comparison of the Charts

The U. S. Coast and Geodetic Survey prepared the first chart of the Bayocean area for publication in 1867. The chart has been revised and republished at intervals including 1908, 1923, 1931, 1943, and 1957 editions. Each revision shows some changes in the peninsula. On the 1867 chart soundings are shown only for Tillamook Bay and the entrance, together with the margin of the sea to the north of the entrance; no depths are shown on the west side of Bayocean Peninsula. The outline of the peninsula is clearly indicated by trees along the inner margin of the southern portion and one small group of trees in the north-central portion. The 1908 chart shows depth contours with intervals of 5, 10, and 20 feet along the west shore as well as in the channel entrance and the bay. West of Bayocean Peninsula the 20-foot contour is approximately one half mile from the shoreline. One half mile west of the 20-foot contour the depth drops to 40 feet or more. The next chart was published in 1923, six years after the construction of the first portion of the north jetty. It shows the changes relating to the north jetty, including the prograding of the shoreline on the north side. The soundings in the bay were copied from the 1908 chart.

The 1931 chart shows some changes in the peninsula; the southern portion (Mile 1) is narrower; a sand bar is indicated on the northwest side (Mile 4.5); and there are some changes in the 20-foot depth contour along the west side; in general, it is closer to the shoreline than previously. The chart also shows some depths of over 50 feet, lying approximately one half mile west of the 20-foot contour, about one mile out from shore. The 1943 chart shows several new features, including further accumulation of sand on Watseco Beach to the north of the north jetty and the building up of a sand bar to the northwest of Kincheloe Point. At this time the extreme end of the north jetty was deteriorating somewhat under the action of the waves. Although the 1943 chart does not show it, aerial photographs taken in 1939 indicate a breakthrough of the sea in a narrow channel at Mile 1.

Fig. 5.20. A map of Bayocean Beach showing the erosion (horizontal ruling) and the prograding (stippled areas). These changes occurred after the construction of the north jetty. The dike shown on the bay side was constructed to heal a breakthrough at this point. The prograded area lying between the dashed line and Tillamook Bay is not stippled. The rectangles, A, B, and C refer to the detailed shoreline changes shown in Figure 5.23. The tick marks between A and C indicate miles, measured northward from Cape Meares. The dashed line offshore represents the 20-foot contour in 1931; the solid line represents the same contour in 1957.

The 1957 hydrographic chart No. 8370 shows the extent of the 1952 breakthrough of the ocean, extending approximately from the beach cove area northward (Mile 1 to 2). The ocean broke through in a broad front, pushing sand and silt into the bay and, in effect, pushing the southern part of the peninsula to the east. This was accompanied by very active erosion north and south of the breakthrough, involving the destruction of parts of the dunes, the forest, and Bayocean Resort. The chart also shows the new dike which was constructed in 1955-1956 northward from Biggs Point (also called Pitcher Point). The 1957 chart shows detailed new soundings to the west at Bayocean Beach, and it is evident that changes have occurred. The amount of the offshore change is indicated by the shift in the 20-foot contour, from 1931 to 1957 (Fig. 5.20). The greatest change occurred on the southern margin of Bayocean Beach, where the average shift was approximately 1200 feet, comparable to the amount of erosion of the backshore.

The most striking contrast is between the charts of 1931 and 1957, suggesting that the greatest changes occurred after the completion of the north jetty in 1933 to a length of 5700 feet. The changes from 1917 to 1927 were neither so spectacular nor so concisely mapped. The charts reveal that shortly after 1931 the ocean, which had been eroding the west side of the peninsula, broke through in four places. Three of these breakthroughs were near the base of the peninsula (Fig. 5.20) and are referred to as Wash 1, Wash 2, and Wash 3. The fourth broke through the southern part of the Bayocean Resort and is referred to as Natatorium Gap.

Comparison of 1939 and 1960 Aerial Photographs

Comparison of the aerial photographs for 1939 and 1960 reveal clearly many of the changes in the shoreline (Fig. 5.23) and backshore, also changes in vegetation, roads, and houses. Both sets of photographs were made for the U. S. Corps of Engineers approximately at low tide. The scales are 10,200 and 7700 respectively.

The 1939 aerial photographs show that considerable damage already had been done to the roadway between Cape Meares (town) and Bayocean Resort. The road had been broken and possibly filled with sand immediately north of the turn from Cape Meares (town), but was still in use. At the breakthrough opposite Biggs Point (Mile 1), the road had dropped down into the break which had no water in it at the time the photographs were taken, and continued along the bay beach as an irregular road. A straight road existed along the inner beach at this time. At several points on Bayocean Beach (Miles 2, 3), the photographs show that severe damage had occurred. One or two houses were hanging over the actively eroding dune cliff. North of Bayocean Resort (Mile 3) the paved road along the high dune was broken in several places and parts of it had fallen down the cliff to the beach. The Tillamook Bay margin of the Bayocean Peninsula is shown on the 1939 aerial photographs as being fairly stable. The area was vegetated down to the high-tide line, except in the northern part which, in general, always had very limited vegetation. Small clumps of vegetation, indicating a northwest-southeast orientation of the dune humps, together with smaller patches of vegetation in the low-lying areas between the hummocks are visible (Chapter 6).

The 1960 aerial photographs of Bayocean Beach indicate further active erosion in the area. These photographs reveal that the most spectacular changes in this area since 1939 have been the erosion and the removal of a large part of Bayocean Peninsula north of Biggs Lagoon. The southern-middle, wooded part of the peninsula was removed completely for a distance of nearly two miles and, in its place, there is a low accumulation of sand, slightly above the high-tide line.

Measurements on the aerial photographs indicate that the amount of erosion has varied from place to place on Bayocean Beach (Fig. 5.23). For example, a comparison of the 1939 and 1960 aerial photographs shows that at the end of Second Street in Cape Meares (town) (Mile 0.2) the low cliff has been removed for a distance of approximately 320 feet, whereas in the Bayocean Resort area (Mile 3) the retreat, measured at the foot of the talus slope or angle of repose, is over 1000 feet. From this point northward, the amount of erosion has decreased. About one mile north of Bayocean Resort the forested dunes give way to a low, bushy and grassy vegetation cover (Chapter 6) indicating recently stabilized dunes; toward the northern end of the peninsula the amount of erosion decreases to practically zero; and at Kincheloe Point the beach is prograding.

Fig. 5.21. Bayocean Beach. The upper photo looking generally southward toward Cape Meares was taken in 1910. It shows the cliff face above the beach, well-vegetated with grasses, shrubs, and small but fairly old spruce trees (Angelus Studio Collection, Univ. of Oregon). The lower photo, taken in 1940 from the same point, looking in the opposite direction, shows the effect of erosion in changing the face of the cliff (Wilbur Greenup).

KINCHELOE BEACH

As Bayocean Beach eroded, Kincheloe Beach to the north (Mile 4.5) progressively prograded. At present the inner margin of the beach has a steep ridge of sand mixed with driftwood (Chapter 6). Apparently some of the material removed from Bayocean accumulated on Kincheloe Beach, since it is protected by the north jetty, and supplied with sediment from Tillamook Bay streams and from the dredging of the channel on the north side of the outlet to Tillamook Bay. Although the comparison of the charts and photographs shows that Kincheloe Point varied in outline from time to time, most of the prograding has occurred since 1933. The prograded strip is one mile long and has a maximum width of 700 feet on the northern flank of Kincheloe Point.

27. NEHALEM BEACH (B, E)

Nehalem Beach reaches from the north jetty of Tillamook Bay to Neahkahnie Mountain (Fig. 5.24). The beach is 11.25 miles long, has a perpendicular distance of 0.6 of a mile, and a C/P index of 18.7. The skewness is 58 percent north and the orientation is 2 degrees. Various parts of Nehalem Beach have local names, beginning on the south with Watseco and including Rockaway, Manhattan, Nedonna, Sunset, and Neahkahnie. Nehalem Beach resembles Nestucca Beach in many ways, but several differences are noted. The Nehalem River is much larger than the Nestucca River and brings in much more sediment. Furthermore, the dune area to the north of the Nehalem outlet is more stabilized, since some of these dunes were stabilized in prehistoric time. Nehalem Beach is a broad, sandy beach of medium-grain size. It is a standard beach as far as the sand is concerned. However, at the north end of the beach there is an unusually large accumulation of rock fragments, including huge, angular blocks of basalt from Neahkahnie Mountain; farther south there are cobbles, large and small, in various stages of roundness and grading down to pebble and gravel size on the beach. The gravel can be seen on the upper beach in the winter season as far south as Mile 9.

The backshore of the southern part of Nehalem Beach is based upon the Astoria sandstone with here and there small massive outcrops of basalt. One basaltic outcrop occurs just south of the old mouth of the Nehalem River near Nedonna Beach (Mile 5). Another outcrop occurs just inside the entrance to Nehalem Bay, opposite Mile 6. On the north end of the beach, near Mile 11 (Neahkahnie Beach), hard rock again appears in the slope of Neahkahnie Mountain, including Astoria sandstone and, a little farther north, basalt. Otherwise the backshore consists of dunes, some old and stabilized, others young and active until recent times. Within the last 10 years nearly all of the active dunes have been planted and controlled.

Changes in the Shoreline

It is apparent from old records that at several points on Nehalem Beach there was retrograding at the time of settlement. The old charts show active slumping just above the beach near the present town of Neahkahnie Beach. The greatest changes, however, have been brought about by the construction of the jetties at the entrances to Nehalem and Tillamook bays. At the southern end of Nehalem Beach (Watseco Beach) there has been local prograding as a result of the construction of the north jetty to Tillamook Bay (as previously noted in connection with Bayocean Beach). The effect of the jetties at the entrance to Nehalem Bay is less spectacular. The north jetty was constructed in the period from 1916 to 1919 to a length of 3285 feet; the south jetty from 1910 to 1916 to a total distance of 4950 feet. Both of these jetties have suffered from storm damage and also from settling and for many years no repairs have been made. Since the sea has cut through the base of the north jetty, removed a part of it, and has access to the river both behind and to the north of the jetty, the effect of the north jetty on Nehalem Beach has been minimized. The south jetty, although settling somewhat and suffering damage on the outer edge, has, nevertheless, had a permanent effect upon the shoreline. It has caused extensive prograding; measurements on aerial photographs from 1939 to 1960 reveal a growth of 140 feet seaward. It is not certain whether the erosion which is occurring in the vicinity of Manhattan and Rockaway (Miles 3 and 4) is related to these jetties or not. However, the jetties have fixed the position of the Nehalem River outlet, so that further migration has not occurred.

Fig. 5.22. An oblique view of Bayocean Spit looking southward, showing the extent of the breakthrough. The position of the shoreline on the ocean side in 1939 is shown, approximately, by the dotted line. The recently constructed dike, upper left, is emphasized by a black line (Oregon State Highway Dept., 1961).

Comparison of Aerial Photographs for 1939 and 1960

The aerial photograph coverage which is available for Nehalem Beach includes the entire beach for 1939 and all except the area from Mile 2 to Mile 5 for 1960. The 1960 aerial photographs for the southern part of the beach have a scale of 1:7700, whereas the scales for 1939 for the entire beach and for 1960 for the northern section of the beach are respectively 1:10,200 and 1:15,000. Comparative measurements for the two years, 1939 and 1960, reveal the following changes: at Mile 0, at the north jetty of Tillamook Bay, the beach has prograded 1200 feet (it has prograded 0.7 of a mile since the construction of the jetty); at Mile 4.8 there is prograding, not easily measurable, perhaps 10 feet; at Mile 5.5, which is influenced by the construction of the jetties at the Nehalem River, the prograding is 140 feet (the total since the construction of the south jetty for this portion of the beach is approximately 3000 feet); at Mile 6, immediately north of the Nehalem north jetty, the shoreline is approximately the same for the two years (prior to 1939, however, there was prograding before the damage to the north jetty occurred); at Mile 10.3 retrograding is 5 feet; at Mile 11 retrograding is 6 feet; and at Mile 11.3 retrograding is evident, on the order of 10 feet for the 21 year period. In summary it may be stated that Nehalem Beach is prograding at the south end and to the south of the Nehalem south jetty, otherwise there has been a slow retrograding which is measurable in some areas and obvious, but not easily measurable, in other areas.

28. SHORT SAND BEACH (E)

Short Sand Beach lies in Smuggler Cove between Neahkahnie Mountain and Cape Falcon. The beach is in a pocket of sedimentary rock in the massive igneous rock of this broad headland (Cape Falcon and Neahkahnie Mountain). The beach is 0.5 of a mile long, irregular in outline, and has an orientation of 320 degrees; no satisfactory measurement of the C/P index nor skewness could be made. The beach is slightly curved in an irregular manner, but the general outline seems to be related to the variable resistance of the bedrock in the sea cliff.

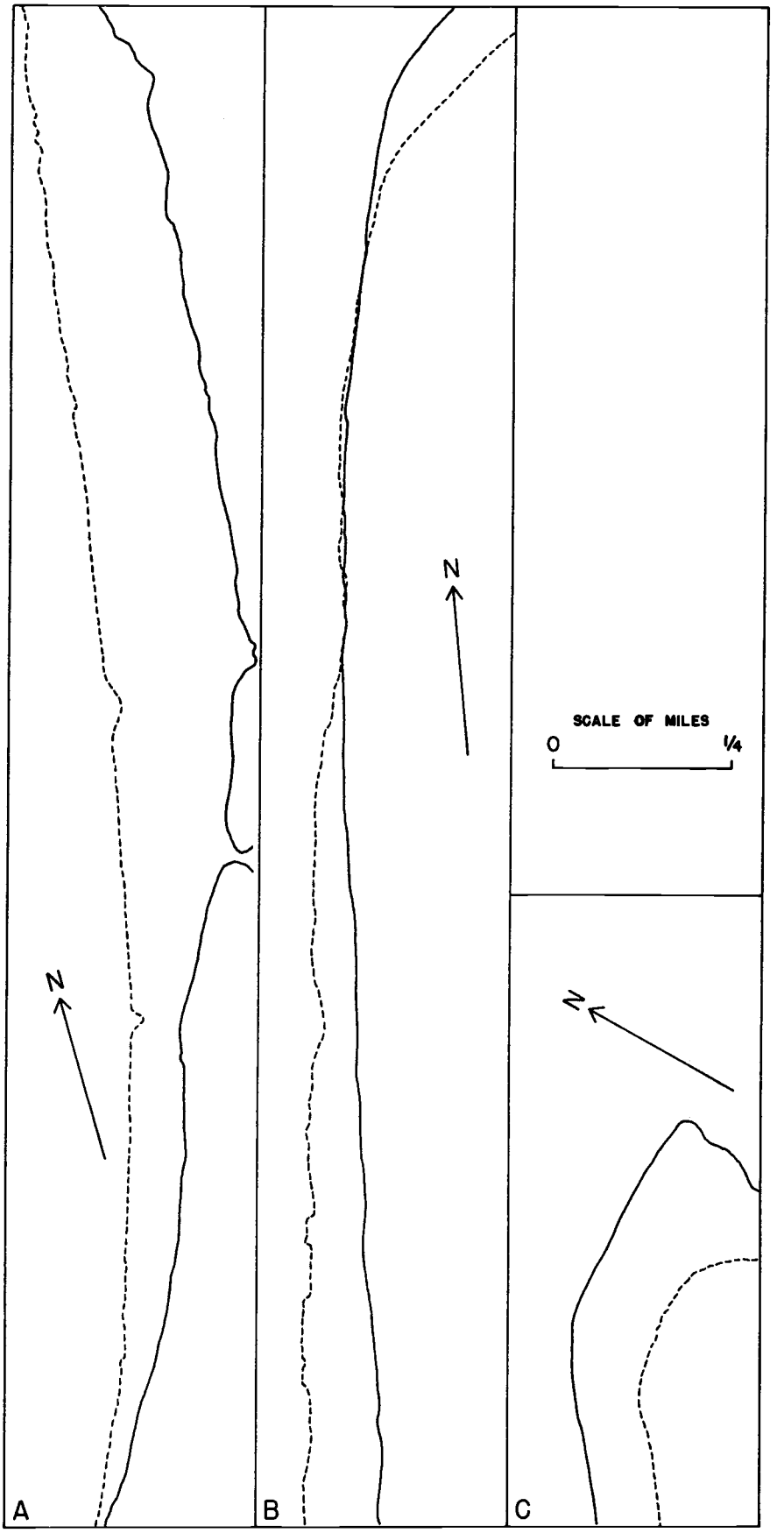
The beach has a small quantity of fine sand which varies somewhat with the season. Were it not for the protected location of the beach, erosion would probably be more active on the sea cliff. However, the beach is protected from northwest and westerly winds and is open only to the southwest. Erosion of the backshore is active on the north end of the beach and just south of the middle section, otherwise the sea cliff back of the beach is well-vegetated. The character of this beach suggests that if a beach is sufficiently protected by headlands, a large supply of sand is not necessary to keep erosion to a minimum.

29. INDIAN BEACH AND ECOLA PARK (F)

Indian Beach (Fig. 5.25) lies between the south margin of the igneous mass of Tillamook Head (immediately to the south of Indian Point) and Bald Point. Indian Beach is 0.35 of a mile long, has a perpendicular of 0.06 of a mile, a C/P index of 58, and an orientation of 340 degrees. The beach is skewed very slightly to the south, not enough to be measured. The beach has a fair supply of sand on the north, but is composed mostly of rock fragments mixed with sand and gravel on the south side. The backshore consists of a steep bluff in the tertiary shales and sandstones and is very subject to mass movements. As the sea cuts at the base of the cliff the material moves down, either in fall-offs from the steep cliff or in larger slides that come from higher up the slope. In February, 1961, an unusually active slide involved the Ecola Park Headquarters and picnic grounds (Schlicker, 1961), making it necessary to close the park to visitors. The area affected is 3000 feet long and about 1000 feet wide (Fig. 5.25). Starting at an elevation of approximately 240 feet, the slide moved seaward in a narrowing band with a maximum horizontal displacement of about 100 feet. Some of the debris moved to the small beach and into the sea. Large trees including Sitka spruce, some of which were four feet in diameter, were toppled and carried along with the slide (Fig. 5.26). This slide has been active in a moderate way in recent years. Trees have been tilted, roads and trails fractured and offset, sag ponds formed and subsequently drained. Movement invariably follows periods of heavy and long-continued rain.

The shoreline both to the north and south shows evidence of other slides, some of which have been active in recent years. The configuration of the coast is affected, the toes of the slides forming small promontories where the debris contains quantities of resistant rock fragments. Other slide areas, with smaller and weaker rock fragments are represented by indentations in the shoreline. The character of the beaches is also affected; the beaches in the vicinity of Bald Point are covered with angular rock fragments.

Fig. 5.23. Detailed map of shoreline changes at Bayocean between 1939 and 1960, traced from aerial photographs. The dashed line shows the shoreline in 1939, the full line shows the shoreline in 1960. Only the ocean shoreline is shown in these maps (see Fig. 5.20).


N
A
N
B
SCALE OF MILES
0
1/4
N
C

30. CLATSOP BEACH (A, B)

Clatsop Beach is located on the northern Oregon coast between Tillamook Head and the Columbia River (Fig. 5.27; Fig. 6.2). The beach is 17.2 miles long, has a perpendicular of 1.6 miles, a C/P index of 10.7, and an orientation of 349 degrees. The skewness is 54 percent south. The old Clatsop Beach was 15.5 miles long, had a perpendicular of 1.02 miles, a C/P index of 15.2, and an orientation of 352. Parts of Clatsop Beach are known locally as Columbia Beach, Sunset Beach, and Seaside Beach. It is the most uniform of all the Oregon beaches. Throughout its entire length the character of the sand, the slope of the beach, and other characteristics are remarkably consistent.

Tillamook Head, at the southern end of Clatsop Beach, is made up of tertiary volcanic rocks, mostly basalt, and of conglomerates, mostly sandstones and shales of the Astoria formation. The western extremity of Tillamook Head is composed of basalt which gives the headland its characteristic shape. The basalt is also the principal source of the cobbles which are found along the southern sector of Clatsop Beach. The beach area, from Seaside (Mile 1.2) northward, is bordered on the east by a broad belt of dunes consisting, for the most part, of old foredunes and intervening valleys. To the east of the dunes are the low hills of the Coast Range, rising usually to a few hundred feet in elevation and based upon the Astoria formation. Clatsop Beach is limited on the north by the Columbia River and, more specifically at the present time, by the south jetty. The only break in the entire length of the beach from Tillamook Head to the south jetty is provided by Necanicum River (Mile 2).

Description of the Beach

The curvature of Clatsop Beach for the 17 miles of its length is a gentle arc, which approaches an arc of a circle. The northern part has been modified by the south jetty so that, in effect, the beach has barriers at both ends, whereas previously there was a barrier only at the south end. The radius of curvature for the arc is approximately 24 miles. At the extreme southern end of the beach (Mile 0), on the flanks of Tillamook Head, the beach has a steep, cobble slope, with some large boulders ranging up to three feet in diameter. Even at low tide no sand is visible. Above the cobble zone is a terrace made up of smaller cobbles, which is covered at the present time with spruce trees and shrubs. It is evident that, in times of storms, some driftwood is thrown up onto this bench but ordinarily it is not damaged much by waves, since the trees have grown there for approximately 100 years. At Mile 1, the cobbles are large, up to three feet in diameter, but average about two feet in diameter. From the top of the cobble zone to the low-tide level, the cobbles are of nearly uniform size. At low tide, sand is usually exposed, although this may not be true every year. The houses on the terrace above have required protection from the waves in recent years. Rock material from a nearby quarry has been added in the form of a dike. This built-up zone extends for one half of a mile from the corner northward.

The cobble zone fades out rapidly to the north of Mile 1. Not only is there a decreasing amount of cobbles, but they are of smaller size. It is well known that cobbles extend to Mile 2 underneath the beach sand. Old photographs (1910?) show a continuous zone of cobbles on the upper beach from Tillamook Head to the Necanicum River (Mile 0 to 2.2). Local citizens testify that sand has been slowly accumulating for the past 50 years. At Mile 2, the wide beach supplies a large amount of sand which is blowing in on the houses and streets in the northern sector of Seaside. From time to time the dune hummocks, which develop on the upper beach from the blowing sand, are bull-dozed into a level condition so that the sand is distributed over a wider area. Board fences have been built to hold back the sand, with little success. Along the beach front at Seaside, for a distance of two miles, is a concrete wall, rising about three feet above a paved promenade. This serves to keep out some of the sand which would otherwise blow in. Sand accumulates on the seaward side of the wall in the form of low, hummocky dunes, some of which have been stabilized by planting dune grass and shore pine.

The outlet of Necanicum River and its tributary, Neawanna Creek, occupy a meander zone between Seaside and Gearhart. The channels change frequently since they are invaded by the tide. Both of these streams are short and carry a limited amount of sediment. Necanicum River carries considerable sand and is bordered by sand flats, similar in character to the beach, whereas Neawanna Creek brings in mud and is bordered by mud flats at low tide. A few years ago a rock dike was constructed on the left bank of the Necanicum River with the intention of controlling meanders. This wall was battered by waves at high tide and has been largely destroyed; however, a remnant still protects the northern end of the Seaside spit.

Fig. 5.24. Nehalem Spit looking northward toward Neahkahnie Mountain. Portions of the north and south jetties are shown. The north jetty has deteriorated and the sea enters to the north of it, thus restoring the spit in this area to something like its original condition (Oregon State Highway Dept., 1958).

To the north of Necanicum River for approximately 9 miles (Miles 3 to 12) the beach is remarkably uniform. It is very difficult to distinguish one part from another. At the low-tide line the beach is nearly flat. The slope gradually increases toward the berm which is indistinct. Water-borne sand gradually changes to wind-borne sand and small, hummocky dunes make up the upper beach level. This is a prograding beach and growing fairly rapidly. Comparison of aerial photographs even a few years apart, such as the 1948 and 1960 photographs, shows a substantial growth westward, both of the dummocky dune area and the beach. Inland from the berm there is a foredune with a remarkably uniform crest at an elevation of approximately 25 feet. Beyond this, to the east, is a larger dune which is generally asymmetrical with a gentle, hummocky slope on the west and a steep slope on the east. The western margin of the foredune is difficult to pinpoint. The eastern margin, however, is sharp.

A little farther to the north (Mile 13) the character of the berm changes. The slope from the beach to the dunes is a little steeper, and yet it is evident that this is formed of depositional material little disturbed by the waves. Northward, however, in the vicinity of Fort Stevens Park (Mile 14), there is a more abrupt change. The berm and foredune show definite erosive wave action and from this point to the south jetty on Clatsop Spit this is generally true. There may be some deposition at times and the cliff cut by the waves may be temporary, but the beach near the south jetty of the Columbia River does not show distinct evidence of prograding. The beach sands include a higher percentage of the dark, heavy minerals.

Throughout the length of Clatsop Beach, from Tillamook Head to Clatsop Spit, driftwood, most of which is the result of logging in the hinterland, plays a fairly important role. Where driftwood is abundant, it is an important factor in the character of the upper beach, since it resists erosion by the waves. It, perhaps, has a part also in the accumulation of sand on a prograding coast. Within the city limits of Seaside driftwood mixed with cobbles forms a part of the upper berm. The waves throw the large logs to extreme levels during storm periods. From the mouth of the Necanicum River (Mile 2.5) northward to Mile 12, however, driftwood plays a minor role. The scattered logs cause small hummocks on the upper part of the beach, and even on the low dunes. Driftwood is frequently seen buried in the dunes that are now being eroded by the waves.

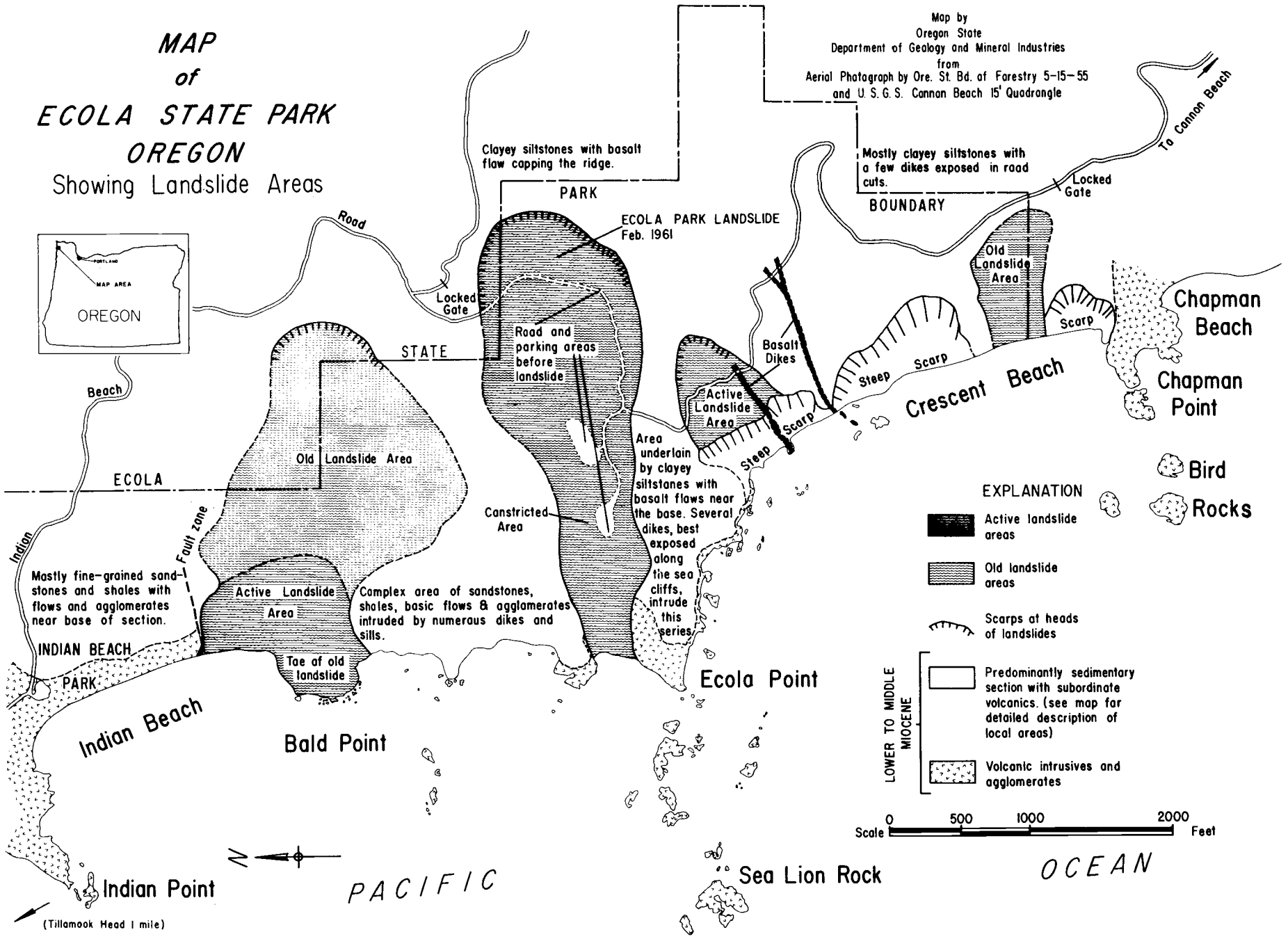
Changes in Clatsop Beach

Clatsop Beach is, and has been for at least the last century, a prograding beach. The earliest chart which shows the northern part of the beach in any detail, is that of Captain James Alden (1854). This chart shows a number of soundings and indicates that a shoal, called Clatsop Spit, had developed to the north of Point Adams for a distance of one and a half miles. This, in part, is the area in which the south jetty was later constructed. There were also shoals further to the north, between Point Adams and Cape Disappointment, on the north outlet of the Columbia River. Two main channels of the river are shown, one to the north of Clatsop Spit and the other immediately to the south of Cape Disappointment, on the Washington side of the Columbia River. This chart also shows the position of Sand Island as slightly nearer Point Adams than Cape Disappointment. Even in 1854 the island was in the process of migrating northward and now is near Cape Disappointment, having moved northwestward approximately five miles. Undoubtedly, the large supply of sand provided by the Columbia River is the major factor in making Clatsop Beach a prograding coast, while most of the Oregon beaches are retrograding.

The topographic chart of 1868, on a scale of 1:10,000, shows no substantial change in the shoreline as compared to the 1854 chart. However, the detailed topography suggests a prograding beach with a belt of hummocky sand dunes and without any definite break at the berm.

The construction of the jetties did, however, change the nature of Clatsop Beach at the northern end and, perhaps, throughout its entire length to Tillamook Head. The south jetty was constructed in the period between 1885 and 1896 to a length of approximately 7 miles and the north jetty from 1913 to 1917, to a length of approximately 2½ miles. Dredging was undertaken also to open a deeper channel to the Columbia River, but it is doubtful if this dredging had a profound effect upon the beach. The jetties, however, trapped the sand to the north and south, respectively, and built out spits to the northwest and to the southwest, so that Clatsop Spit now extends about two miles to the northwest of the old shoreline of 1854. The effect of the south jetty was to convert the convex shoreline of Point Adams into the concave

Fig. 5.25. Map of Ecola State Park showing recent and older landslides. Indian Point and Chapman Point are fairly stable, but the shoreline between has moved at various times during the last century. It is important to note the difference between the sea cliffs (steep scarps) and the more extensive landslide areas (Oregon State Dept. of Geology and Mineral Industries, 1961).


MAP
of
ECOLA STATE PARK
OREGON
Showing Landslide Areas
Map by
Oregon State
Department of Geology and Mineral Industries
from
Aerial Photograph by Ore. St. Bd. of Forestry 5-15-55
and U. S. G. S. Cannon Beach 15' Quadrangle
OREGON
MAP AREA
Road
Beach
Indian
Clayey siltstones with basalt flow capping the ridge.
PARK
STATE
ECOLA
Locked Gate
ECOLA PARK LANDSLIDE
Feb. 1961
Road and parking areas before landslide
Mostly clayey siltstones with a few dikes exposed in road cuts.
BOUNDARY
Locked Gate
To Cannon Beach
Old Landslide Area
Scarp
Chapman Beach
Chapman Point
Basalt Dikes
Active Landslide Area
Steep Scarp
Crescent Beach
Area underlain by clayey siltstones with basalt flows near the base. Several dikes, best exposed along the sea cliffs, intrude this series.
Old Landslide Area
Constricted Area
Fault zone
Mostly fine-grained sandstones and shales with flows and agglomerates near base of section.
Active Landslide Area
Complex area of sandstones, shales, basic flows & agglomerates intruded by numerous dikes and sills.
Toe of old landslide
INDIAN BEACH
PARK
Indian Beach
Bald Point
Ecola Point
Bird Rocks
Sea Lion Rock
Indian Point
(Tillamook Head 1 mile)
PACIFIC
OCEAN
EXPLANATION
Active landslide areas
Old landslide areas
Scarps at heads of landslides
LOWER TO MIDDLE MIOCENE
Predominantly sedimentary section with subordinate volcanics. (see map for detailed description of local areas)
Volcanic intrusives and agglomerates
Scale 0 500 1000 2000 Feet

crescent of the characteristic beach. There was undoubtedly an acceleration in the prograding on the north end of Clatsop Beach and possibly on the middle section, although comparison of the shoreline of 1868 with that of 1960 shows that this prograding diminishes to the south. There is no indication that at any point on Clatsop Beach any serious retrogression resulted from the construction of the jetties. During heavy storms there was some erosion, of course, but sand removed in winter was restored in summer. Although it has been reported that prograding has stopped on this beach, there is considerable evidence that this is not the case. A comparison of aerial photographs for 1944 with those of 1960 for Clatsop Beach shows a definite growth of approximately 500 feet at Mile 14.

In general it may be said that Clatsop Beach, from Tillamook Head to the south jetty of the Columbia River, has prograded consistently for the last century, excepting only the extreme northern part which may have retrograded slightly in the last decade. The amount of prograding is greatest at the north, amounting to nearly one mile to the west of Point Adams (Mile 16). Southward the amount of prograding decreases gradually to nearly zero at the south end of the beach.

Erosion has occurred at the south jetty, extending about one mile to the southward. In the last 15 or 20 years the contour of this shoreline has changed from a concave outward to a nearly straight line. Actually, there has been very little erosion of the beach, although more of the south jetty is exposed on the south side at low tide. The high-tide line at present consists of a steep cliff showing considerable wave erosion. It is evident, however, that a mile or more to the south of the south jetty accretion has been more important than erosion in recent years. In the next chapter, changes in the vegetation of the dunes adjacent to Clatsop Beach are discussed.

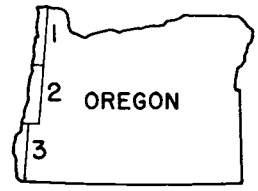
Fig. 5.26. An oblique view of Ecola Park looking west, showing the landslide of 1961, outlined by a dashed line. One effect of this slide was to change the character of the beach, upper right (Oregon State Highway Dept.).

Fig. 5.27. Overlapping vertical pictures of Clatsop Beach at Gearhart. The upper photo, 1960, the lower, 1948. The photos are matched at the house, shown by the circle. The position of the berm is indicated by arrows on the respective pictures. Note that the 1960 photo is slightly smaller in scale, tending to minimize the apparent change in shoreline (U. S. Corps of Engineers).

SAND DUNE AREAS OF THE OREGON COAST

Dunes

(2) Stabilization Plantings (See Table I)



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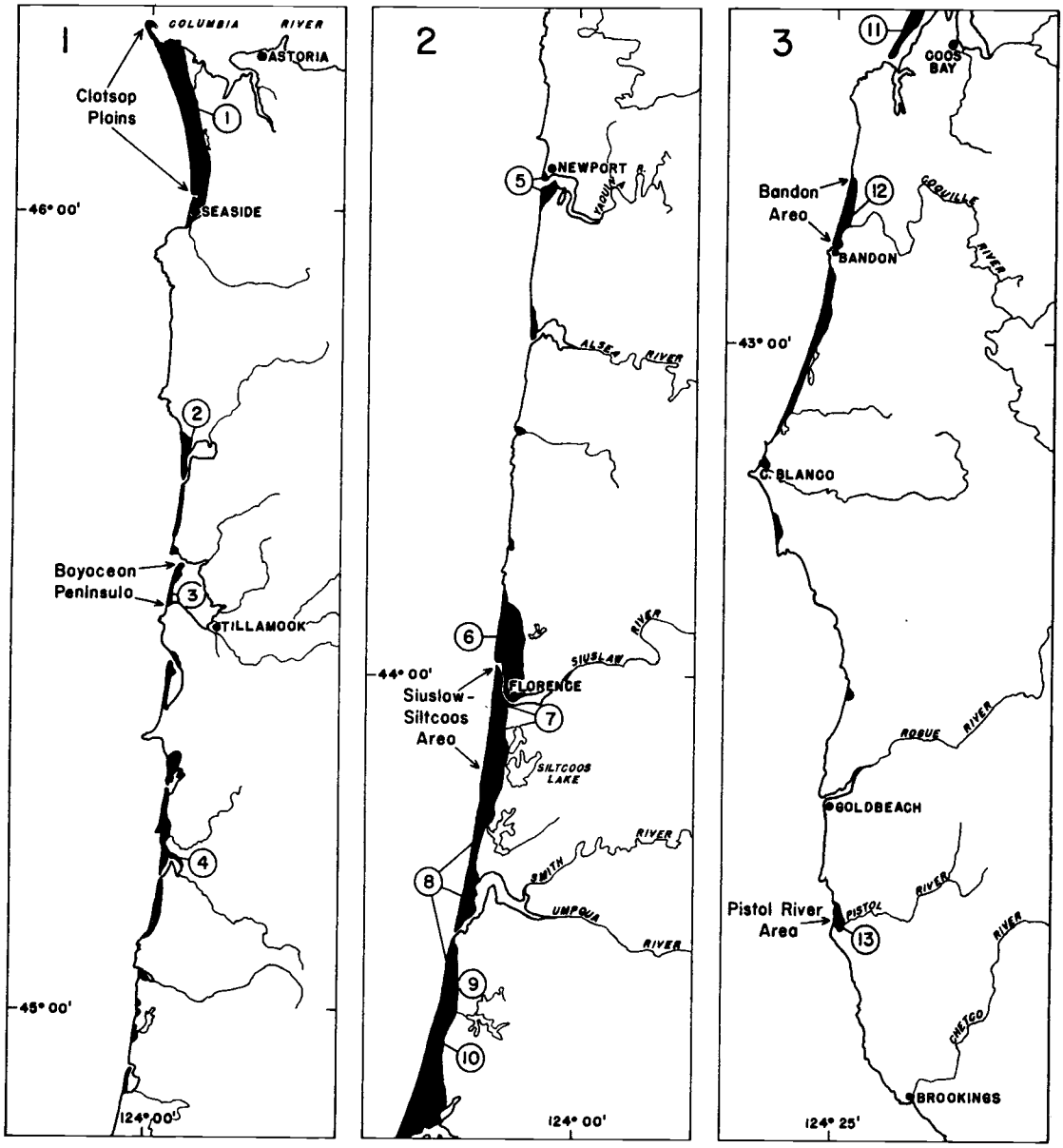
MILES



CHAPTER 6. VEGETATION CHANGES OF THE OREGON COASTAL DUNES*

Bill Hanneson

The distribution of the surface cover and floristic composition of the vegetation on the Oregon coast have been markedly altered since initial white settlement 120 years ago. In this discussion, the influence of white man in altering the vegetation on the Oregon sand dunes is documented and the processes through which man changes the vegetation are studied. Biotic succession and changes wrought by natural phenomenon (exclusive of man) are not studied in detail; nor have changes associated with Indian occupance been considered intensively.

The sand dunes of coastal Oregon form a discontinuous strip fronting the Pacific Ocean, separated by headlands of resistant material (Fig. 6.1). Between the Columbia and the Coquille rivers are the larger dune masses, and emphasis was accordingly placed on this portion of the coast. Five dune localities were selected for detailed study: the Clatsop Plains, Bayocean Peninsula, the Siuslaw-Siltcoos Area, the Bandon Area, and the Pistol River Area (Fig. 6.1). The plant names used are those of Morton E. Peck (1961 rev. ed.).

The historical approach is used in reconstructing the surface cover from the early literature and maps, and in tracing through time the evolution of the present landscape. The maps presented use general categories, in keeping with the available historical documents, thereby making past and present maps comparable. Since elements of the physical environment circumscribe which introduced species acclimatize and naturalize, a survey of some of the environmental factors precedes the detailed studies. The evidence indicates that man, through actions both deliberate and accidental, has played a major role in altering the surface cover of the Oregon dunes.

The dominant type of change in recent years has been the result of stabilization plantings. These plantings have been important in altering both the areal distribution of the general surface cover types and the floristic composition of the vegetation on the dunes. Table 6.1 lists the major plantings, based on interviews with local residents and conservationists, of both indigenous and exotic plant species.

* Presented to the Department of Geography and the Graduate School of the University of Oregon in partial fulfillment of the requirements for the degree of Master of Science.

Fig. 6.1. Sand dunes of the Oregon coast, based on W. S. Cooper (1958). Significant portions of all these dune areas have been active during the past 100 years.

TABLE 6.1

MAJOR STABILIZATION PLANTINGS ON THE OREGON DUNES

	LOCATION*	YEARS	APPROX. ACREAGE
1.	Clatsop Plains	1934-1944	3000
2.	Nehalem Area	1956	100
3.	Bayocean Peninsula (neck of the spit)	1958	75
4.	Pacific City (Sand Lake)	1940	150
5.	Newport Area	1930	10-20
6.	Mercer Lake	1936	40
7.	Siuslaw River to Tenmile Creek	1948-1961	800
8.	Between Coos Bay and Florence	1910-1916	50
9.	Clear Lake	1933-1934	30
10.	Reedsport (15 miles south)	1934-1935	100
11.	Coos Bay Spit	1926-1928	40
12.	Bandon Area	1934-1940	10
13.	Pistol River Area	pre-1920 onward	40

* Numbers refer to Fig. 6.1

ENVIRONMENT

The environment of the dunes is a major factor in determining which introduced plants can survive outside the protected habitats provided by man. The elements of the environment serve as a background against which to analyze the influence of man as an agent of vegetation change. The climatic regime of the Oregon coast is discussed in Chapter 3. The sand areas of Oregon's coast may be considered as a "district" within the hierarchy of regions as outlined by the American Association of Geographers (Whittlesey, 1954:49). Parent material, surface configuration, and, to some extent, indigenous vegetation differentiate the dune sites from the surrounding habitats. Although the parent material, sand, varies in particle size and mineral content from one dune area to the next (Twenhofel, 1946b:56-57), the differences, for the purposes of this study, were not considered significant.

The disjunct sand areas, however, show differences of form and structure that are apparent from field study. These differences appear to be based on varying influences of the physical elements of sand deposition and erosion; that is, upon waves, wind, sand, and vegetation. Four dune forms may be distinguished on the Oregon coast and, since an example of each is presented, it is pertinent to describe each type.

The Clatsop Plains exhibit features of a prograding shoreline (W. S. Cooper, 1958:3) with a series of ridges parallel to the shoreline. The rate of progradation has been particularly rapid since construction of the jetties on the Columbia River. The ridges are wall dunes (Passarge, 1920:347), and many of them are without breaks for several miles. Streams flowing parallel to the coastal front and elongated lakes are common features within this dune complex.

The Coos Bay-Heceta Head dune region, of which the area between the Siuslaw and Siltcoos rivers is typical, is the most extensive of the Oregon dune masses. Features of this area include broad (up to 75 yards), hummocky foredunes, and massive interior sand accumulations. Oregon's largest areas of active sand are on the Coos Bay dune sheet. The streams and lakes of this broad sand mass show the effect of encroaching dune sand, with the streams having right-angle turns in their courses and the shallow lakes often bounded on one side by active slip-face slopes. The drainage features in this locality exhibit little of the parallel pattern characteristic of the Clatsop Plains.

Bayocean Peninsula and the southern portion of the Bandon Area display features common to most of the smaller sand dune areas on the Oregon coast, such as Nehalem, Sand Lake, Nestucca, and Pistol River. Smaller dune sites have many of the features associated with the Siuslaw-Siltcoos Area, but on a smaller scale. Limited in individual extent, these dunes are irregularly spaced along the coast and are associated with the outlets of smaller rivers and streams.

The northern portion of the Bandon Area has perched dunes which rest on marine terraces that are elevated above sea level. This area is marked by a wave-cut cliff of nearly 100 feet facing the ocean.

Within all these dune complexes, a number of habitat sites exist. The differentiation of these sites is based on three of the ecological variables associated with relief: exposure, ground-water level, and

elevation. These sites or ecological niches provide a variety of habitats for plant colonization. Four general niches may be distinguished, most or all of which appear within each of the study areas considered.

The foredune is the sand ridge adjacent to the ocean front and exposed to the rigorous physical environment associated with the interaction of wave and wind. The foredune may be attacked by storm waves and in some instances displays a slope at or near the angle of repose for sand. This site appears to be the most severe dune environment for plants.

The interior ridges, which vary in elevation from 40 to over 200 feet above sea level, provide a less severe habitat for plants. These ridges, often stabilized by a thick growth of shrub and coniferous timber, generally have a low ground-water level following the short dry summer season. This is partially offset by fog drip, by capillarity, and by the mositure economy of the plants involved.

The sand flats are broad, gently undulating expanses of sand that are located between ridges but are at a higher elevation than the swales. These flats were often the location of initial white settlement in those areas where the sand flats maintained a growth of vegetation palatable to livestock.

The swales, which like the sand flats are inter-ridge features, are distinguished by their high-water table. These areas often become marshes during the winter months. Stream channels and lakes are associated with the swales, which occupy the lowest elevations within the dune complex.

It is apparent from the above that there exists a variety in dune form along the Oregon coast, but that certain ecological niches are found within all the dune types. The differentiation of these four sites allows some comparison of the different study areas.

Indigenous Vegetation

Dr. Leroy Detling (Personal interview, October, 1960) of the University of Oregon Herbarium has suggested some indigenous plant indicators. Dividing them into three groups, the lists are based on the successional stage of the dune plant community, using the terms early, middle-aged, and mature. These lists of indicators are, as the name implies, suggestive rather than exhaustive. The three groups of species are applicable to the foredunes (except for the mature species), the interior ridges, and the sand flats. They are not applicable to the swales, since these sites represent an unique habitat within all the dune complexes.

The plants of the early dune communities represent the primary or pioneer successional trend in the establishment of permanent vegetation. The indigenous species that can invade an area of bare sand are:

Lupinus littoralis Dougl.	seashore lupine
Abronia latifolia Esch.	yellow sand verbena
Elymus mollis Trin.	sea lyme-grass
Festuca rubra L.	red fescue
Poa confinis Vas.	dune bluegrass
Poa macrantha Vas.	seashore bluegrass
Glehnia leiocarpa Math.	beach silver-top

The degree of success which these and other pioneer plants have is determined by a great number of variable factors, ranging from the frequency of high velocity winds to the amount of precipitation. The length of time necessary before secondary species can invade the area is determined by the same type of variables, but most often edaphic conditions appear to determine the rate of vegetational succession.

Most of the species of the middle-aged dune communities are shrubs:

Arctostaphylos Uva-ursi (L.) Spreng.	kinnikinnick
Lonicera involucrata (Rich.) Banks.	black twin-berry
Gaultheria shallon Pursh.	salal
Pinus contorta Loud.	shore pine

Of these, kinnikinnick is by far the most common plant indicator of the secondary stage of dune succession. Both the shore pine and the salal, if present at this stage, will be noticeably smaller and less well-developed than those appearing in the mature dune communities.

The following are the most common plants of the mature dune communities, the spruce generally appearing late in the successional evolution:

Pinus contorta Loud.	shore pine
Gaultheria shallon Pursh.	salal
Vaccinium ovatum Pursh.	shot huckleberry
Rhododendron macrophyllum G. Don.	western rhododendron
Picea sitchensis (Bong.) Carr.	Sitka spruce

It is important to note that the dating of dunes by the age of the pine and spruce trees which exist on them will give only a minimum age. Several factors influence the development of a receptive seed bed; time, during which organic material is added to the sand, appears to be the most significant factor.

The vegetated swales, with their hydroseres, are unique among the dune sites in both species composition and successional stages. Rushes, sedges, willows (*Salix* spp.) and shore pine (*Pinus contorta* Loud.) are the most common members of the swale communities. Red alder (*Alnus oregona* Nutt.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) are found in the more advanced stages of plant succession. Sand does not blow out of the unvegetated swales except during the late summer.

W. S. Cooper, in discussing the native plants of the Washington-Oregon coast (1958:67), states that, "A small number of native species qualify to some extent," (as "potential sand-binding plants"), "none of them being outstandingly effective." Field observation indicated that areas composed strictly of indigenous species are restricted to a few small areas of forest land. Judging from the extensive tracts of stabilized dunes in the 19th century, certain plants must have been effective agents of stabilization. The following hypothetical processes may explain these stabilized areas.

The dune areas which are elevated or situated to the interior offer less severe environments for the establishment of a vegetation cover. These areas could have been seeded from the interior, the vegetation advancing from east to west.

On the lower dune areas that are more exposed to wind and wave action, the most probable site for plant invasion would be in the swales and in the areas that are on the far side of the broad swales away from the blowing sand in summer (for most sites this would be to the southeast). Although no conclusive evidence of such a process was found, one area (the Bandon Area) displayed this type of growth but both exotic and indigenous species were involved.

Migration of Introduced Plants

In Table 6.2 are listed some of the most common introduced plants found on the Oregon dunes. Some of these plants are naturalized on the dunes, growing in areas little disturbed by humans. There is historical evidence indicating that the first three species listed were intentionally introduced. The others may be either accidental or purposeful introductions.

TABLE 6.2

COMMON EXOTIC PLANTS OF THE DUNES

COMMON NAME	SCIENTIFIC NAME
European beach grass	*Ammophila arenaria* (L.) Link.
Scotch broom	*Cytisus scoparius* (L.) Link.
Gorse	*Ulex europaeus* L.
Foxglove	*Digitalis purpurea* L.
Fireweed	*Erechtites* Raf. spp.
Hawkbit	*Leontodon* L. spp.
False dandelion	*Hypochaeris radicata* L.
Himalayan blackberry	*Rubus procerus* Muell.

The processes through which these plants have become established are several. Some were probably introduced originally with seed and livestock of the early settlers, others in the ballast and cargo of ships. Of the hundreds of viable seeds that were introduced, only a few species became naturalized and were able

to compete with indigenous species outside the protected habitats provided by human activity.

Dispersion, following original introduction and establishment, occurred through both the physiological adaptations of the plants and human agency. Undoubtedly original establishment was dependent on the availability of disturbed sites. With acclimatization, dispersion was possible through environmental and physiological means. Seeds of some, such as the Himalayan blackberry, are eaten by birds and dispersed over large areas. The ability of the introduced blackberry to hybridize with related indigenous species has resulted in further extension. European beach grass has reportedly been dispersed by wave action (Personal interviews, J. Walker and Mrs. C. Evans). Most commonly, however, European beach grass has been planted by humans and reproduced by root shoots. Many of the weeds, such as false dandelion and hawkbit, have been dispersed by wind after initial introduction.

The exotic species found on the dunes are an important and an integral part of the present floral landscape. Their present extent is in part the result of human disturbance, but the dearth of indigenous sand-binding species has reduced competition.

THE CLATSOP PLAINS

The Clatsop Plains border the Pacific Ocean from the mouth of the Columbia River southward to the mouth of the Necanicum River. The eastern margins are the Clatsop Ridge upland and the northern portion of the Skipanon River. This area, approximately 14 miles long from north to south and from one and one half to three miles wide, is characterized by long sand ridges and swales lying parallel to the ocean front. Drainage and vegetation are markedly influenced by this ridge-swale pattern of the dunes.

Historical Geography

William Clark, of the Lewis and Clark Expedition, included in his journal a descriptive comment on the area between Fort Clatsop (located to the east of the Skipanon River) and the Pacific Ocean:

> The Sea Coast is about 7 Miles distant Nearly West about 5 miles of the distance through a thick wood with reveens hills and Swamps the land, rich black moald 2 miles in a open wavering Sandy prarie, ridge runing parrelal to the river, covered with Green Grass. (Thwaites ed., 1904-1905, Vol. III:277).

Written on December 10, 1805, the quotation describes the hummocky nature of the dunes and the extensive, undulating grass prairie. Another portion of the area, in the vicinity of Point Adams, was described by David Douglas (Royal Hort. Soc., 1914:103) in the spring of 1825. He spoke of the land being "... low and many places swampy." It is apparent from the above two quotations that several ecological niches existed within the area prior to settlement by whites.

Following settlement of the area in 1840, several descriptions appeared which are more detailed than the earlier accounts. James Dana, geologist of the Charles Wilkes Expedition, left a description which gives some indication of the width of the grassland:

> The <u>first</u> of the ridges is a fourth of a mile from the sea, and ten to fifteen feet high. The <u>second</u>, three-fourths of a mile back of the first, and twenty to twenty-five feet high; the <u>third</u>, one and one-fourth miles from the second, and fifteen or eighteen feet above the sea. The prairie plain extends for a mile back of these ridges, and then becomes densely wooded... (Dana, 1849:667).

George Wilkes, an early traveler through the area, described the prairie as "... two miles long by three miles wide." (Wilkes, 1846:136). The width ascribed to the prairie by both Dana and Wilkes is comparable, if one assumes that the oceanward ridges were grass covered. The length assigned to the prairie by Wilkes is unaccountably shorter than the length inferred from other sources.

In 1859, George Davidson, as a member of the U. S. Coast Survey Team, described the area more completely than any preceding writer:

> Two miles northward of Tillamook Head commences a peculiar line of low sandy ridges, running parallel to the beach towards Point Adams, and appearing like huge sand waves covered with grass and fern. Between some of them run small creeks, whilst behind the country is low, swampy and covered with wood and an almost impenetrable undergrowth ...

Point Adams is low and sandy, covered with bushes and trees to the line of sand beach and low dunes; ... (U. S. Coast Survey, 1859:387).

Three types of surface cover - grassland, swamp, and woodland - appear to be the categories used by the early travelers in describing the landscape of the Clatsop Plains. Shrub growth, so apparent on the Plains today, seems to have been restricted to the stand borders and as an understory in the wooded areas (Thwaites ed., 1904-1905, Vol. IV:19-21; Royal Hort. Soc., 1914:104). It is possible to reconstruct some of the dominant species of the above general categories from more recent literature and from the present vegetation cover.

The grassland, extending inland from the ocean front, may be divided into two areas on the basis of exposure. The foredune, the most halophytic site, undoubtedly contained dune grass (Elymus arenarius L. var. villosus Mey.) (Cooper, 1958:125). Other species might well have been large-headed sedge (Carex macrocephala Willd.), yellow sand verbena (Abronia latifolia Esch.), and coast strawberry (Fragaria chiloensis L. Duch.). The interior portion of the grassland is thought to have contained reed grass (Calamagrostis inexpansa Gray), hair grass (Deschampsia caespitosa L. Beauv.), blue wild rye (Elymus glaucus Buckl.), red fescue (Festuca rubra L.), and bent grasses (Agrostis spp.) (R. L. Brown: Cooper, 1958:125). It should be noted that all of the above species which are thought to have existed on the interior prairie are palatable to livestock (U. S. Forest Service, 1937:G1-G56).

The swamps of the Clatsop Plains, lying along the margins of the Columbia River and in the swales between the dunes, were dominated by tree species. Those most common in these moist sites were red alder, willow, and Sitka spruce. Along the banks of Neacoxie Creek, the stumps of spruce trees of over 250 years of age are not uncommon.

Shore pine, Sitka spruce, and Douglas fir (Pseudotsuga Menziesii(Mirb.) Franco) appear to have been the dominant surface cover of the interior dunes. The coniferous forests of the Pacific Coast have a dense understory of shrub and fern growth. Meriwether Lewis commented on the shot huckleberry (Vaccinium spp.) and kinnikinnick (Thwaites ed., 1904-1905, IV:19-21), and David Douglas described the site of salal (Royal Hort. Soc., 1914:104). These species are now commonly found both as an understory in the coniferous forest and on the stand border.

Changes in the Vegetation

To study the history of the Clatsop Plains in terms of the botanical data available, the 120 years of white occupance are divided into three periods: (1) the initial period, from 1840 to 1915, marked by increasing settlement and the introduction of the greatest number of exotic species; (2) the second period, from 1915 to 1934, marked by activation of large areas of sand; and (3) the recent period, from 1934 to the present, marked by man's plantings on large tracts of former grassland. These periods are arbitrary divisions, for some overlap does exist. They represent not only periods of changing surface cover but also periods of changing attitudes on the part of the residents of the Clatsop Plains.

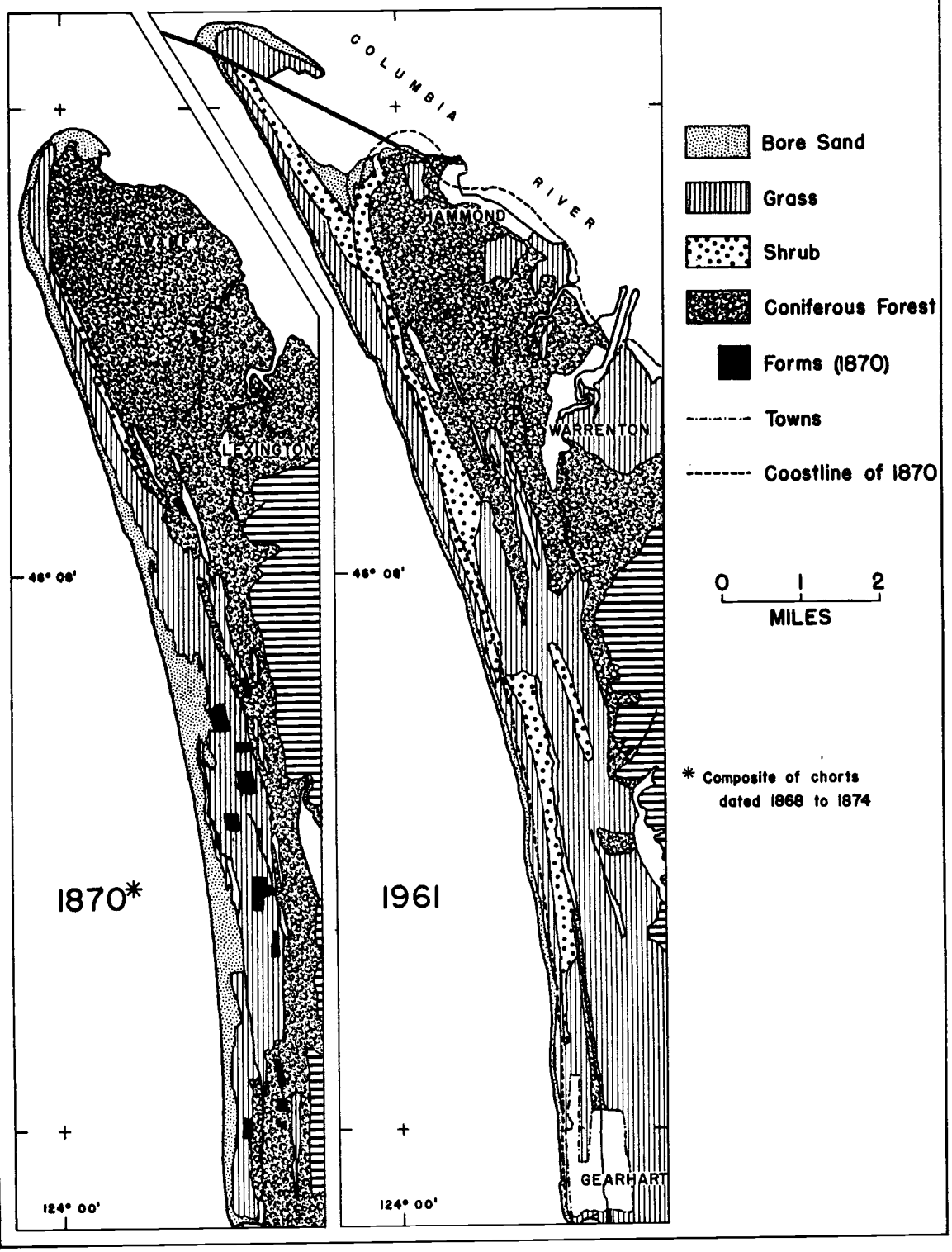
The map of early surface cover (Fig. 6.2) is generalized from charts of the U. S. Coast Survey, dated between 1868 and 1874, on which surface cover categories were distinguished. It is apparent that by the time the charts were drawn, several changes had occurred since white settlement: land was being tilled, portions of the grassland were being grazed, and towns had begun to develop.

Initial Period (1840-1915)

The availability of grassland for grazing, the availability of timber for construction, and the proximity of the port of Astoria were all factors in the early settlement of the Clatsop Plains. Plant introductions of an economic nature associated with this initial period include wheat, corn, oats, potatoes, and barley (Miller, 1958:202). More numerous were the flowers, shrubs, and trees introduced by settlers for their yards and garden plots. Probably many of the domesticated plants of the temperate world were tried for either aesthetic or economic reasons. Inasmuch as accidental introductions of plants are

Fig. 6.2. Maps of the Clatsop Plains surface cover, 1870* and 1961. The map of 1870 is based on U. S. Coast Survey Charts of 1868 and 1874, original scale 1:10,000. The 1961 map, configuration modified from U. S. G. S. topographic sheet Astoria, original scale 1:62,500. Vegetation from 1958 and 1960 aerial photographs, scale approximately 1:20,000, and from field observations.

CLATSOP PLAINS SURFACE COVER-1870* and 1961



thought to exceed deliberate introductions (Bates, 1956:793), we can assume that these would add another large group of exotic species.

Records of some of the purposefully introduced plants indicate that they became acclimatized to such an extent that they were able to compete outside the yards and gardens. The significance of these introductions can be seen by taking a few specific examples.

1. In 1871, the city of Astoria passed a law prohibiting the discarding of foxglove (Digitalis purpurea L.) since it was spreading to hayfields (Miller, 1958:204). When dry, this plant is poisonous to livestock. Commonly found along the coast, foxglove was originally introduced from Europe, either as an ornamental or as a medicinal herb.

2. The cranberry (Vaccinium Oxycoccus L.) was introduced to the Clatsop Plains in the 1890's (Miller, 1958:208) from Coos County. It was planted in the bogs formed by the drainage of some of the small lakes bordering the Skipanon River (Seaside Signal: Jan. 25, 1912). The cranberry is reported to have escaped cultivation and to be established in sphagnum bogs along the Oregon coast (Peck, 1961:596).

3. Scotch broom (Cytisus scoparius L.) has a documented history, both as to its introduction and uses. Historians have differed concerning the location and date of first introduction on the Pacific Coast (Pollard, 1957:34), which suggests that Scotch broom may represent an instance of multiple introduction. It is known that William Hobson, an early resident on the Clatsop Plains, sold seed to the United States Government in 1882, the seed to be used to stabilize an area of drifting sand on the Fort Stevens Military Reserve. This plant, introduced originally as an ornamental, has become both an important economic plant and a troublesome weed. It is a conspicuous member of the roadside and fence row plant communities throughout western Washington and Oregon. The importance of Scotch broom as a stabilization agent of the dunes warrants consideration of this plant as one of the most significant plant introductions to Oregon's littoral. Further consideration will be given below to the role of broom in dune stabilization.

In addition to plant introductions, other activities were effective in altering the vegetation during this early period of white occupance. The major economic activity of the early settlers was the rearing of livestock. Of 24 farms in Clatsop County in 1850, 23 were raising livestock, and the largest numbers of these animals were on the Clatsop Plains (Miller, 1958:202). The basis of this grazing was the extensive grassland on the western margin of the Clatsop Plains.

The development of small towns on the Clatsop Plains, originally associated with rural commercial and social activities and, more recently, with recreation, also resulted in significant changes in the surface cover. Gearhart (1960 population, 725), Warrenton (1960 population, 1717), and Hammond (1960 population, 480) (U. S. Bur. of the Census, 1961) are the three towns situated within the Clatsop Plains area. All were founded during this early period.

A quite different but no less significant change in the surface cover was produced by the construction of the south jetty on the Columbia River, commencing in 1885. Accelerated sand accretion to the southward resulted in a progradation of the shoreline. The rapidity of accretion combined with the relative dearth of sand-binding plants on the Pacific Coast resulted in a mass of sand with little or no vegetal cover. This accumulation of unstabilized sand was to play an important role in the decades following 1910.

Second Period (1915-1934)

Two factors for which man was responsible were influential in affecting the extensive erosion characteristic of the second period of human occupance. One was the aforementioned sand accumulation, southward of the jetty, ideally located for eolian transport by the dry summer winds which blow mostly from northwest to southeast. The other factor was the denuded grassland surface wrought by overgrazing.

As population increased in the late 19th and early 20th centuries, grazing became overgrazing and, with the resultant loss of the binding agency of plants, the surface was subject to blowouts by the least disturbance. The thin soil, said to average between five and six inches deep (Dana, 1849:668), was compacted by trailing cattle to form still more blowouts. These scour areas increased in dimensions and eventually the sand mass was advancing eastward. The location of the mass of bare sand to the north of the former prairie aggravated conditions. By 1935, 3000 acres of mobile sand were destroying homes, roads, soil, and forest in their migration inland (McLaughlin and Brown, 1942:5).

Recent Period (1934-1961)

In 1934, the U. S. Soil Conservation Service began action to halt the advancing sand. This action marks the beginning of the period of man-induced plant succession. The result has been a man-made plant community based, to a large extent, on exotic species. A major portion of the area, still termed a grassland, contains few of the species found at the time of white settlement (Fig. 6.3). Several introduced plants were tried, but most of these were abandoned as impractical for stabilization purposes. The development of stable sand surfaces is dependent on the growth of primary sand-binding species and the development of a soil to allow establishment of more advanced plants for permanent stabilization. To create a stable surface, the U. S. Soil Conservation Service developed a three-stage program of planting.

1. European beach grass (Ammophila arenaria (L.) Link.) and, to a lesser extent, American beach grass (Ammophila breviligulata Fern.) have been used to bind the bare sand surfaces. European beach grass has a long history as a sand-binding plant in northwestern Europe (Passarge, 1920:360). Its ability to survive sand-blasting and sand-burial and its rapid development of an extensive root system make it ideal for this purpose. In recent years it has spread along the Oregon coast and appears to be naturalized to the environmental conditions. American beach grass, a native of eastern North America, is of almost equal merit, but its use has been more limited on the Pacific Coast (R. L. Brown, Personal interview, April, 1961). The two species are now major components of the grassland area in the western portion of the Clatsop Plains.

2. After initial stabilization of the sand surfaces, Scotch broom has been used as an agent of nitrogen fixation. Not readily browsed by herbivores, it provides organic litter aiding in soil development (McLaughlin and Brown, 1942:5). This exotic species appears naturalized, occurring in apparently undisturbed sites along the coast. Scotch broom is also a frequent invader of disturbed areas, such as roadsides and abandoned pasture lands and in these areas has all the characteristics of a weed.

3. For the final stage in dune control, an indigenous tree species, shore pine, has been planted on the Clatsop Plains. Shore pine is adapted to sandy soils and high winds. In recent years, Sitka spruce has been naturally seeding on the dunes. Originally, the U. S. Soil Conservation Service planted young spruce, but it was noted that until edaphic conditions had progressed to a more mature stage, the growth of the spruce was negligible (R. L. Brown, Personal interview, April, 1961).

It is evident from the above that the Clatsop Plains have undergone considerable change in vegetation during the past 120 years. The vegetation changes which have occurred reflect, in part, a changing attitude on the part of the inhabitants. During the early years there was exploitation of the grassland for economic gain. Faced with the loss of that resource, there has, in more recent years, been an increasing attitude of conservation. Present land use within the area is directed by the supervisors of the Warrenton Dune Soil Conservation District, and is restricted to activities which promote conservation rather than destruction of the surface cover.

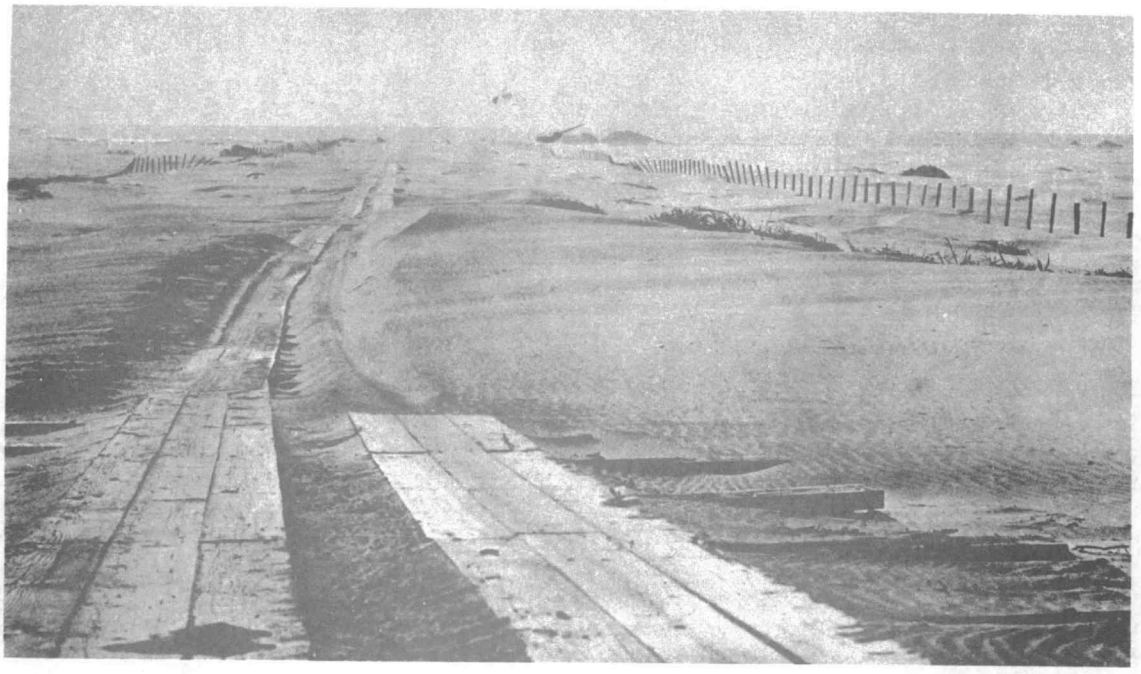
BAYOCEAN PENINSULA

Bayocean Peninsula extends three and one half miles northward from Cape Meares along the western margin of Tillamook Bay. At the present time, this spit is connected to the mainland by a man-made dike which extends about one mile north from Biggs Point (Fig. 6.4). Prior to a breakthrough in 1952, caused by storm actions, and previous inundations dating back to 1939 (Orcutt, 1951:233), the connection was by a long, narrow neck of sand west of Tillamook Bay.

The northern portion of the spit (Kincheloe Point) (Fig. 6.5) is marked by a low, hummocky foredune with a broad sand flat to the interior. On the bay side of the spit are several vegetated hummocks, the major axes of which trend northwest-southeast. The mid-section of the spit has a high foredune, the remnant of a former interior ridge, and a complex of vegetated ridges and swales, trending generally northwest-southeast, east of the foredune. One large trough extends almost across the spit and cuts through the stable dunes. Indications of this trough are apparent on the chart of 1887. The southernmost portion of the spit is a sand flat that has a sparse grass cover. An embryo foredune is apparent on some portions of this southern section.

Historical Geography

Since most early references to the vegetation of Bayocean Peninsula were written 20 years after initial white settlement, it is difficult to reconstruct conclusively the vegetation of some portions of the spit. However, some of the early vegetation of the spit can be reconstructed from the present age of the trees and available historical descriptions.



The settlement of Bayocean Peninsula has been relatively recent; the southern portion (or neck) of the spit was filed on in 1867 by Webley Hauxhurst, and it was not until 1883 that the northern portion of the spit was filed on (Fed. Works Agency, 1940:18). No record of activities of these individuals in altering the surface cover was found, although Hauxhurst is known to have maintained a farm (Fed. Works Agency, 1940:18).

The first post office established on the spit was called Barnegat, presumably on property of the original Hauxhurst claim. In 1906, this post office was replaced by the establishment, one mile north, of the Bayocean Post Office (McArthur, 1952:34-35). At this time, a group of Portland men embarked on the sale of lots on the spit and advertised the development of a large resort. By 1912, the community had a natatorium and a large hotel. A railroad, between Portland and Tillamook, was completed in 1912, largely under the impetus of the hoped-for tourist business. On June 22, 1912, the resort was officially opened, but its success was short-lived, possibly because of the lack of a road around Tillamook Bay to Bayocean. In 1917, the developing corporation was declared bankrupt (Fed. Works Agency, 1940:18). The brief, but spectacular rise of the Bayocean resort was followed by a long, slow decline. The permanent residents carried on a modest tourist trade. In 1927, when the road around the bay was built, a revival was hoped for, but the economic depression of the 1930's curtailed further development of the resort town.

Changes in the Vegetation

The history of Bayocean Peninsula, and its relationship to the surface cover, is dominated by two human actions. The first of these was the establishment of the town of Bayocean with the grandiose scheme of a resort development. The second was the construction of the north jetty of Tillamook Bay with the disastrous consequences associated with it (Chapter 5). In the first case, man has influenced vegetation changes by disturbance of the habitat and introduction of plants, and, in the second case, man has influenced vegetation change by the erosion and deposition of sand attributable to the jetty.

In 1889, George Davidson described Bayocean Peninsula in the Pacific Coast Pilot:

> The peninsula is narrow and bordered by a broad, low-water sand beach. It is formed of low sand hills, partly grass-covered, for two miles from the Cape, and then widens to half a mile for the distance of a little over one mile. As this widening is reached the sand hills are about forty or fifty feet high, and are grass-covered. Behind them on the bay shore are open groves of spruce trees which show seaward over the dunes.
>
> At the northern end of the sand dunes, which is named Kincheloe Point, is the entrance to the bay, ... (1889:437).

The above description is essentially the same data as appears on the map of early surface cover (Fig. 6.4).

Today several exotic plant species are apparent on the dunes and although many of them might have grown spontaneously, their chances of survival were enhanced by the disturbance associated with the development of the town. Blackberries, both evergreen (Rubus laciniatus Willd.) and Himalayan (R. procerus Muell.) are seen growing over the remnants of old buildings and old roads. A large cypress (Cupressus spp.), introduced for aesthetic purposes, grows in a former yard. The common lawn weeds, summer dandelion (Hypochaeris radicata L.) and hawkbit (Leontodon spp.), are apparent over much of Bayocean Peninsula. On the northern portion of the spit, gorse (Ulex europaeus L.) is growing, along with several clumps of Scotch broom. Neither of the latter appear to be planted.

Fig. 6.3. The changing surface cover of the Clatsop Plains since 1935. The upper photo shows the area west of Coffenbury Lake as it appeared in 1935. Much of the area shown is associated with progradation of the shoreline since construction of the jetty in 1885. The middle photo, taken in the summer of 1944, shows few areas of bare sand. The grass planting of the late 1930's and early 1940's produced stabilized sand surface. The dominant vegetation is European beach grass. The lower photo shows the same area in the summer of 1956. (Note that this photo is at a smaller scale than the two above). Scotch broom, planted to the interior, now appears as a spontaneous growth in this oceanward portion of the Clatsop Plains (U. S. Soil Conservation Service).

On the southern portion of the spit about 75 acres of sand, most of which was deposited after the storm breakthrough of 1952, was leveled and planted with European beach grass (Fig. 6.5) in 1958. This was followed in 1959 with a planting of Scotch broom, shore pine, and Sitka spruce (W. E. Ternyik, Personal interview; June, 1961).

The records failed to indicate any grass planting on the northern end of the spit. Some European beach grass may have been planted during the 1940's however, judging from the linear growth pattern. The shore pine that are sparsely scattered, particularly on the eastern margins, appear to be spontaneous growth. The vegetation of the entire northern portion of the spit appears to have been less disturbed than the central and southern portions.

The influence of white man on the surface cover of Bayocean Peninsula has been, for the most part, through indirect actions. It is important to note that almost 10 years after the abandonment of the peninsula by permanent residents, few of the total number of exotic plant species, which were undoubtedly introduced, remain in evidence. Those that are there are the common exotic plants of the Oregon dunes and represent the most naturalized species (Table 6.2). The recent grass, shrub, and tree planting for stabilization on the southern portion, necessitated by changes caused by the presence of the Tillamook Bay jetty, is the only direct action taken by man effecting recent vegetation changes.

SIUSLAW-SILTCOOS AREA

Extending from Heceta Head southward to Coos Bay is the largest dune mass of the Oregon coast, generally called the Coos Bay dune sheet. Two large rivers, the Siuslaw and the Umpqua, cross this dune complex, and the most varied array of dune features on the Oregon coast may be seen within it. Illustrating some of these dune features is the area between the mouths of the Siuslaw and Siltcoos rivers (the latter a small stream draining a dune-bound lake). The interior margin of the Siuslaw-Siltcoos Area was placed, arbitrarily, to coincide with the edge of W. S. Cooper's study area, about one and one half miles east of the Pacific Ocean.

The relief of the area between the Siuslaw and Siltcoos rivers consists of a broad, hummocky foredune with a long interior swale in the western portion. Towards the eastern margin, high sand islands covered with coniferous trees and an understory of shrubs stand above the lower dunes. Several dune-bound lakes, such as Cleawox and Woahink, and the coniferous forest form the eastern margin.

Historical Geography

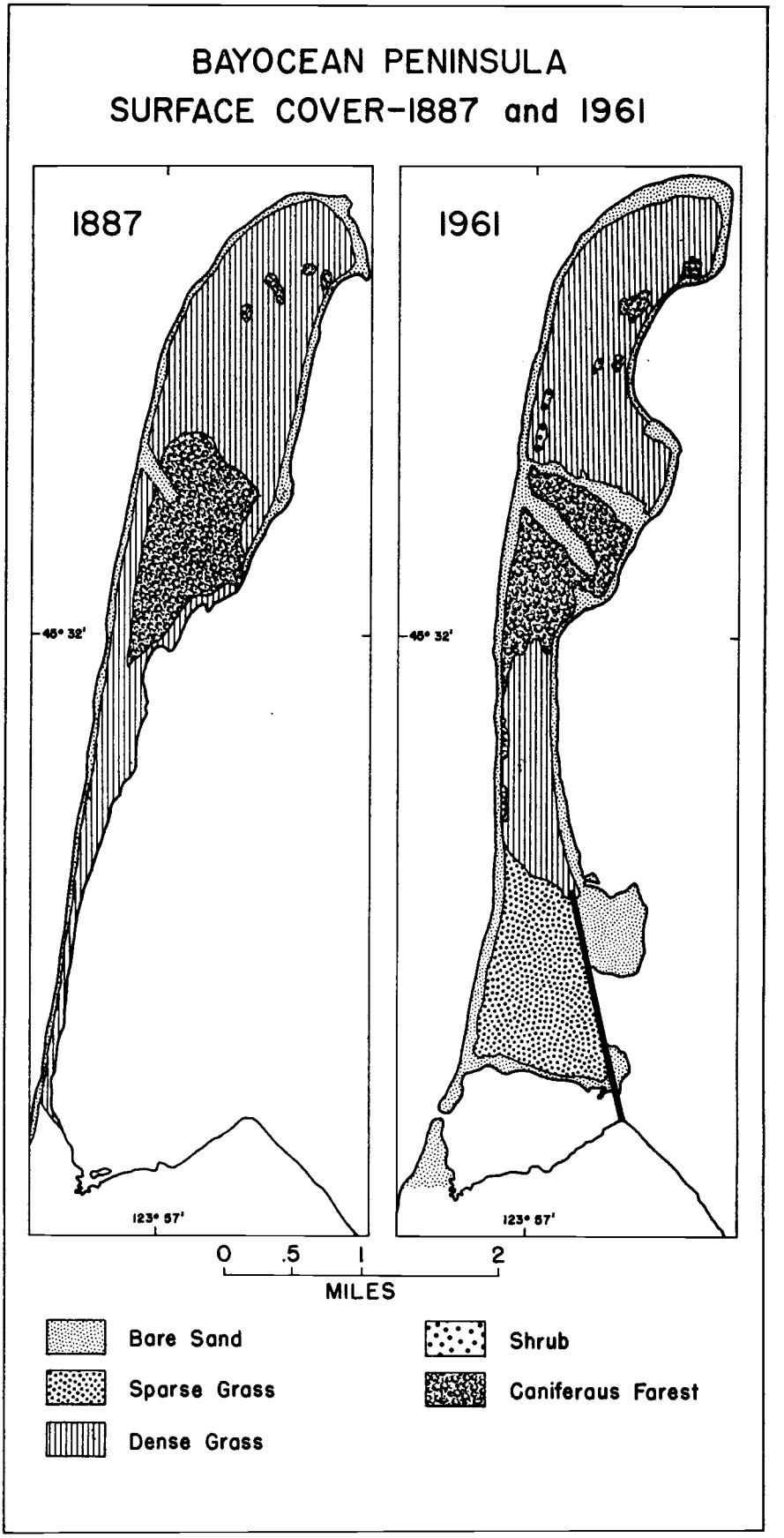
The map of the surface cover of the Siuslaw-Siltcoos Area in 1887 (Fig. 6.6) is a tracing from the U. S. Coast and Geodetic Survey Chart of that year, the earliest source located. Activity by white man before that date is quite probable. The map indicates a barren surface dotted with a few islands of vegetated hummocks. This chart is very similar to the map of 1940 (Fig. 6.6) which is from Cooper (1958:88).

In 1889, George Davidson described the area between the Umpqua and Siuslaw rivers in general terms:

> ... for two or three miles the high sand dunes, forming the north point of the Umpquah, stretch a mile inshore, and then follows a succession of high sand ridges densely covered with forest which comes down close to the shore for several miles.
>
> .....
>
> Along this part of the coast the shore is a low, sandy beach with sand dunes, and behind the sand dunes low wooded ridges rising to three hundred and five hundred and forty feet within a mile or a mile and a half. Behind the lagoons, which are one and a half miles inland, there are high wooded hills (1889:405).

Writing specifically of the shoreline between the Siuslaw and the Siltcoos rivers, he says:

Fig. 6.4. Maps of Bayocean Peninsula surface cover, 1887 and 1961. The 1887 map is based on charts dated 1867 and 1887 with the surface cover based on Davidson's (1889) description and indications of vegetation on the charts. The map of 1961 is modified from the U. S. Coast and Geodetic Chart of Tillamook Bay. Surface cover is based on aerial photographs of 1958 and 1960 (scale approximately 1:20,000) and field observations.


BAYOCEAN PENINSULA
SURFACE COVER-1887 and 1961
1887
1961
46° 32'
46° 32'
123° 57'
123° 57'
0 .5 1 2
MILES
Bare Sand
Sparse Grass
Dense Grass
Shrub
Coniferous Forest

> North of the Tsiltkoos River, the sand dunes reach over one mile inland, and then commence the pine woods on low hills ...
>
> For two miles south of the mouth of the Siuslaw River there is a peninsula half a mile wide separating the Siuslaw from the ocean. It is a waste of bare sand dunes terminating in a sandy point forming the south side of the entrance to the river. (1889:405-406).

The extensive area of active sand was an early concern to the officials of the Siuslaw National Forest. In 1905, P. S. Rice (1951:9) was sent by the U. S. Forest Service to the Umpqua River to bring back willow cuttings. These cuttings were planted in a futile attempt to still the moving sand. The failure of these plantings is related to the unique conditions under which willow grows on the sand dune areas. It often appears as the only vegetation growing on the lee slope of an advancing dune. Its survival in this peculiar ecological niche is dependent on two factors. The first is the availability of moisture; the second, a limited amount of annual sand deposition. If the plant has a good start in a moist (swale) site, a dune advancing from the windward may bury the original roots with more than 50 feet of sand. The ability of the plant to send up new shoots from the branches, and to transport water a considerable vertical distance, give it the appearance of an early invader of active dunes.

After a brief reconnaissance of the dune area for the Siuslaw National Forezt, T. T. Munger (1910:7-8) wrote a short description of the area listing what he thought were the principal causes of dune activation. He thought that fire, grazing, and timber cutting (in order of importance) were the major causes of active dunes. He found evidence of fires but did not date their occurrences.

In his description of the region, Munger also presents reasons in support of an earlier, greater extent of forest:

> There are numerous indications that formerly a much larger proportion of the present sand-hill region was forested than is at present; in many places is found a little island of trees, clearly the remnant of a large forest, surrounded by a barren waste of sand, often with all the sand cut away from around it to a depth of 50-75 feet; in other places are found sticking up in the sand on the windward side of a dune the tops of dead trees which are relics of forests long ago buried by an advancing dune and now uncovered. Furthermore, the present living forest comes in some places to within ¼ mile of the ocean and there is no apparent reason why it should not come this close everywhere, and there are indications that it once did come this close to the beach throughout the region. (Munger, 1910:6).

The "several islands of trees" are apparent on all three maps of surface cover (Fig. 6.6). The ravine, which often partially or entirely surrounds them, is a function of sand precipitation when the velocity of the sand-carrying wind is decreased by the presence (to the leeward) of the high hill. In part, then, these islands of vegetated dunes protect themselves from sand burial. While visiting the area, Munger planted some exotic tree species. This accounts for the few cluster pine (Pinus pinaster Ait.) now growing in the area (Fig. 6.6).

W. G. Morris (1934:328-329), in a more recently published study of forest fires, states that 1868 was a particularly bad year for coastal fires and refers to one that year south of Heceta Head. A fire might have been instrumental in the development of this extensive tract of bare sand.

On the map of 1940 (Fig. 6.6), two separate dune plantings appear. The first planting followed construction of the south jetty of the Siuslaw River, when a limited area of European beach grass was planted. The second, to the north of the mouth of the Siltcoos River, was a planting by the Siuslaw National Forest authorities during the 1930's in an attempt to keep the mouth of the Siltcoos River from shifting or being closed.

It is apparent from a comparison of the maps in Figure 6.6 that the major changes in surface cover since 1887 have been during the last 20 years. These changes are the result of a cooperative, comprehensive dune-planting scheme, presently the largest on the Oregon coast.

Fig. 6.5. Oblique view of Bayocean Peninsula, looking northward. The linear pattern of vegetation on the southern portion of the spit is the result of the grass, herbaceous legume, and tree planting begun in 1958. Photo taken April 8, 1961 (Oregon State Dept. of Highways).

Changes in the Vegetation

The work program of the Siuslaw Soil Conservation District commenced in 1948 and by 1961 had planted about 700 acres within the area. The Siuslaw Soil Conservation District is a cooperative, volunteer organization of the major landowners (Bureau of Land Management, Lane County, Siuslaw National Forest, and the State of Oregon) working under the direction of the U. S. Soil Conservation Service. The U. S. Soil Conservation Service, using the techniques and knowledge gained from experience on the Clatsop Plains, divided the region into small planting areas. This enabled planting to be done piecemeal on a priority basis. The major objective was to halt sand deposition into the Siuslaw River, the dune-bound lakes to the south (Cleawox and several unnamed, smaller ones), and the Siltcoos River. This is being accomplished by planting the source areas of sand and the areas of most active deposition. Future plans do not call for the planting of the entire area, however, for as the source of the moving sand becomes vegetated, plant invasion will undoubtedly gradually stabilize the adjacent areas.

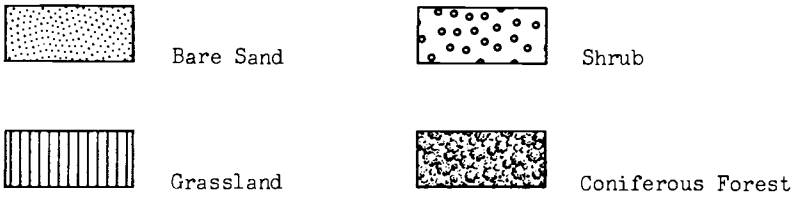
Although the entire stabilization project uses many of the ideas of the Clatsop Plains project, some differences do exist, both in techniques and in species. In the Siuslaw-Siltcoos Area, machine planting has replaced the hand planting of the Clatsop Plains, and areas of uneven terrain are often mechanically smoothed for machine planting. All the species used in the Siuslaw-Siltcoos Area were chosen from those formerly experimented with on the Clatsop Plains. (Others, also experimented with on the Clatsop Plains, were not used because of the lack or high cost of planting stock or because of a personal preference.)

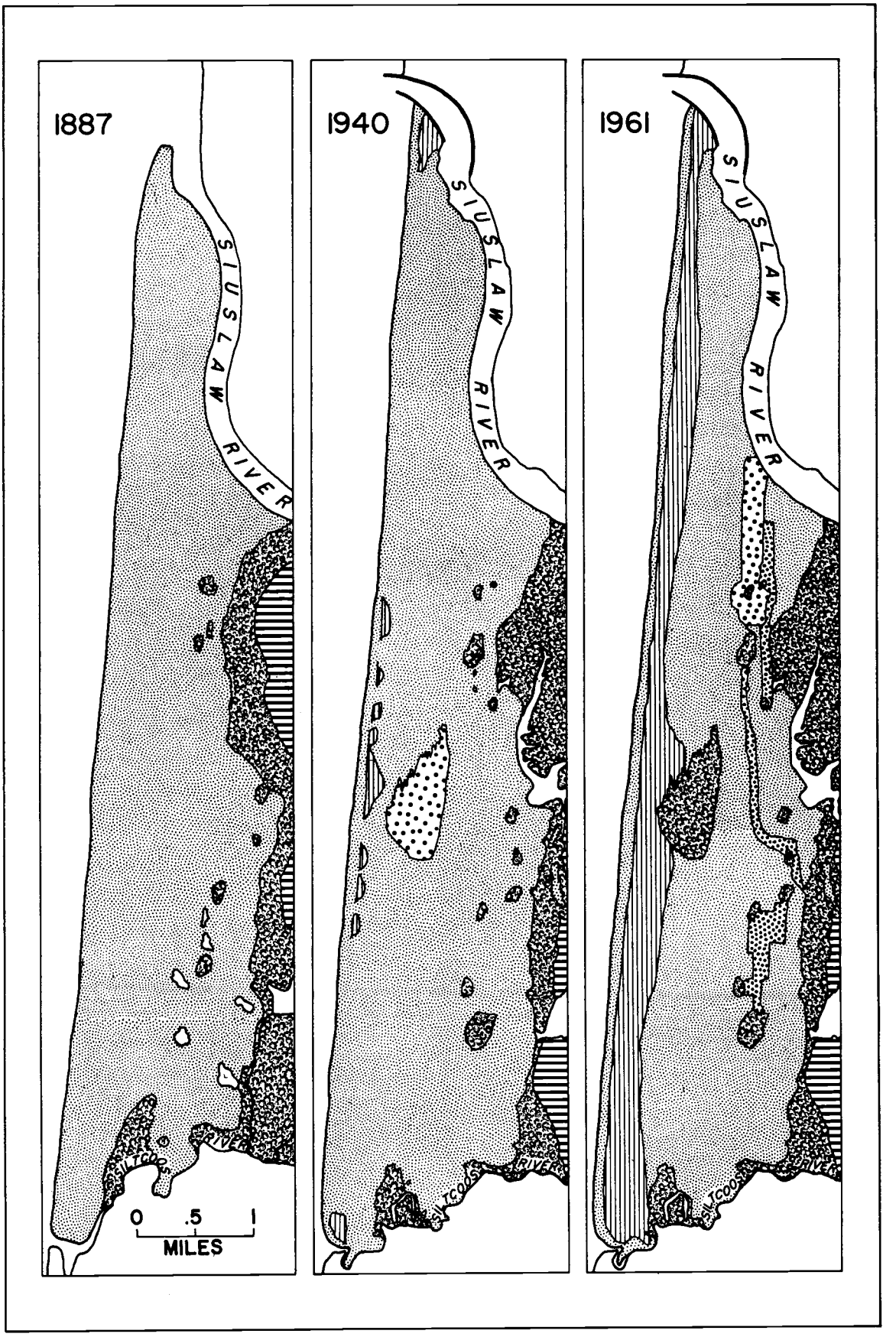
Most of the species used in the Siuslaw District can be associated with definite ecological niches. The following group contains the most common planted species and their associated sites. In the swales, the most common planted species is Lotus major (Lotus formosissimus Greene.), a native. Other species planted in the swales are creeping red fescue and alta fescue, a hybrid. On the foredune, a mixed seeding of purple beach pea (Lathyrus japonicus Willd.) and European beach grass has been used, with the former particularly apparent on the lee slopes. Over the interior dunes and sand flats, the European beach grass is dominant. Plantings of American beach grass have been restricted to blowout areas and to sites where European beach grass has failed to become established. American beach grass is a desirable species but it is difficult to raise as nursery stock and, therefore, expensive as a stabilization species (W. E. Ternyik, Personal interview; June, 1961).

Later plantings were Scotch broom, tree lupine (Lupinus arboreus Sims.) and shore pine. Tree lupine, a native shrub, is found in scattered locations along the Oregon coast, particularly southward. The map of present surface cover (Fig. 6.6) has the recent stabilization plantings sketched in from field observation.

One exotic plant which was introduced to Siltcoos and Tahkenitch lakes, south and east of the Siuslaw-Siltcoos Area, warrants inclusion on the basis of the effect it might have had if allowed to develop unchecked. In 1946, W. E. Pitney, senior biologist for the Oregon State Game Commission, conducted a survey to map the extent and to suggest possible means of eradication of Brazilian waterweed (Elodea densa Planch.) (Edwards, Oregonian, Jan. 19, 1947). This surface weed, which became troublesome about 1942, is thought to have been introduced in 1936 or 1937. One danger of this weed is the rate at which it deposits litter on the bottom of lakes; sometimes as much as two feet per year. Pitney estimated that within four years of 1947, the lakes might " ... be so choked as to forbid passage by motor or rowboat". Chemical sprays were found effective in the control of the waterweed and since 1949 little has been heard about it.

Fig. 6.6. Maps of the Siuslaw-Siltcoos Area surface cover, 1887, 1940, and 1961. The map of 1887 is based on the U. S. Coast and Geodetic Survey Chart of 1887 (#1811), original scale 1:40,000. The 1940 map is based on Cooper (1958). The 1961 map is based on aerial photographs of 1961, approximate scale 1:20,000, and field observations.




1887
SIUSLAW RIVER
SILTCOOS RIVER
0 .5 1
MILES
1940
SIUSLAW RIVER
SILTCOOS RIVER
1961
SIUSLAW RIVER
SILTCOOS RIVER

Within the Siuslaw-Siltcoos Area most of the changes in surface cover influenced by white man have occurred during the past 13 years. Prior to 1887, changes may have occurred but no documentation was found in the historical material. The evidence of fire, noted by Munger, may date into the prehistory of the area, as there is evidence in descriptions of other Oregon coastal areas of fire scars that antedate white contact. The presence of exposed soil horizons further indicates that vegetation was once more extensive than appears on the map of 1887.

The proponents of a Dunes National Park that would include much of the area between the Siuslaw and Umpqua rivers should be aware that the present stabilization plantings will eventually result in the development of vegetation on much of the bare sand beyond these limits.

THE BANDON AREA

The Bandon Area, as defined herein, extends north from the mouth of the Coquille River to Whisky Run. This coastal area, about six miles long, and one third to one and one half miles wide, is bordered on the north and east by terrace deposits and on the southeast by the Coquille River and its associated alluvial deposits. Cut Creek, a small stream, crosses the dune mass and divides the area into a northern and a southern section.

The northern portion is higher, having an oceanward cliff of about 70 feet that is partially vegetated. Behind this is a series of small ridges that are obscured by the thick growth of gorse. This area is a perched dune, underlain by a marine terrace, the surface of which is above sea level. The area south of Cut Creek has a hummocky, low foredune, up to 120 feet wide. The interior portion has a broad sand flat with one well-defined swale. The sand flat is dotted with numerous grass-covered hummocks. East of the sand flat is a high sand dune which in the past buried a coniferous forest. The rate of eastward advance by the dune appears to be slowing down due to a small amount of grass planted in the source area of sand to the west, and to a surprisingly large amount of spontaneous growth.

Historical Geography

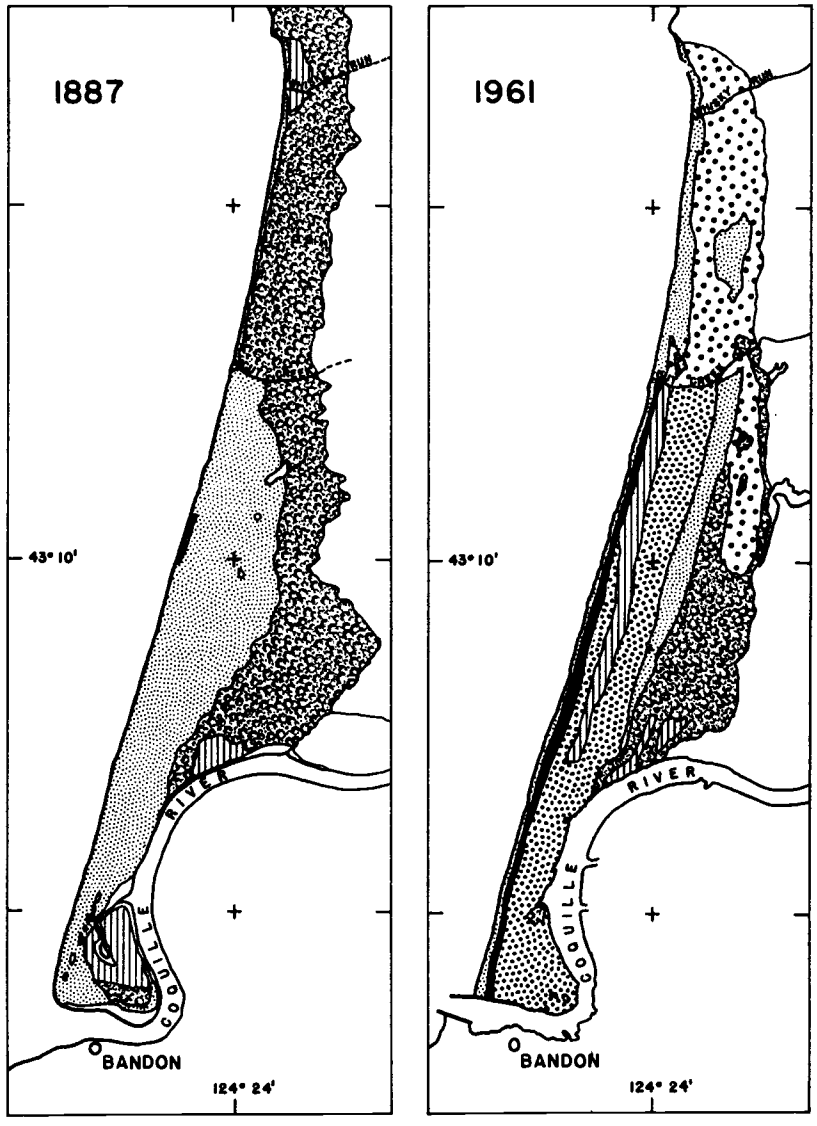
The map of early vegetation cover of the Bandon Area (Fig. 6.7) is based on the chart of the U. S. Coast and Geodetic Survey of 1887. Prior to 1887, however, gold-mining activities and homesteading had done much to alter the vegetation cover. The gold mining was near the mouth of Whisky Run and the homesteading was south of Cut Creek.

The first written accounts of the area north of Cut Creek deal with the gold mining and the town of Randolph, which was the center of operations from 1852 to 1885 (Scholfield, 1854: Unpublished letters). Storm waves in the winter of 1855-1856 denuded the beach of much of the black sand;the following spring many of the miners went south to the Sixes River area (Wells, 1856:595). Shortly thereafter the town of Randolph was abandoned, and the name applied to a community on the Coquille River (McArthur, 1952:505), about four miles inland from its mouth. Since the miners of Whisky Run apparently cut timber for buildings and equipment from the nearby coniferous forest, by 1907 the north bank of the stream was only grass-covered with scattered clumps of brush. This area presumably supported timber prior to the gold-mining era.

The western portion of the area between Cut Creek and the Coquille River was filed on in 1857 by John Hamblock. He described this area as an open prairie, the grass everywhere knee-high. About 20 years after settlement, a large portion of the dunes was denuded (Mrs. C. Evans, Personal interview, July, 1961). The cause or causes of the activation of the sand are not fully known, but one factor that undoubtedly aided was the removal of the grass by the grazing of cattle and sheep. Mr. Hamblock sold portions of the sand areas to the U. S. Government (for a lighthouse) and to the Port of Bandon.

The map of surface cover in 1887 (Fig. 6.7) shows the clearing in the vicinity of Whisky Run and the active sand area to the south. Also shown is the clearing of the Hamblock farm on the Coquille River and on the eastern margin of his claim.

Fig. 6.7. Maps of the Bandon Area surface cover, 1887 and 1961. The map of 1887 is based on the U. S. Coast and Geodetic Survey Chart of 1887 (#1813), original scale 1:40,000. The map of 1961 is modified from the U. S. G. S. topographic sheet, Bandon, with vegetation from aerial photographs (scale approximately 1:20,000) and from field observation.



BANDON AREA

SURFACE COVER-1887 and 1961

Bare Sand

Sparse Grass

Foredune Grass

Dense Grass

Shrub

Coniferous Forest

0 .5 1 2

MILES

In the Pacific Coast Pilot of 1889, George Davidson describes the area north of the Coquille River:

> The north point (at the mouth of the Coquille River) is a long, low, narrow spit of dreary sand dunes covered with heavy drift logs. (1889:389).
>
> For four miles north of the river there is a sandy beach backed by sand dunes that stretch from one-half to one mile to the edge of the forest. (1889:392).
>
> From the mouth of the Coquille River to this cape the first four or five miles of the coast-line, to Whiskey Run, is bordered by low, rolling, auriferous sand and gravel hills, covered with thin soil and a scanty growth of grass and scattering trees. (1889:393).

We may conclude from the above that the vegetation of the Bandon Area had undergone some changes prior to 1887. The processes of change here are better documented than in the other sample areas. Continued human disturbance has altered the vegetation during more recent years.

Changes in the Vegetation

George Bennett, who settled near the present town of Bandon in 1873, introduced gorse from Ireland (Turner, 1947:22). He planted two, 12-foot hedgerows of gorse that by 1949 was estimated to cover 25,000 acres in western Oregon and Washington (Hill, 1949:1). Gorse has been one of the most costly and troublesome weeds to eradicate in Oregon. In the northwestern portion of the Bandon Area, gorse is the dominant vegetation.

The former coniferous forest cover on the perched dune area is now marked only by the burned stumps and snags standing in the gorse. Logging probably preceded the burning in this section. The burning of the area allowed the establishment of the heliophytic gorse. Along the banks of Whisky Run, the gorse became dense shortly after 1910 (Mrs. C. Evans, Personal interview, July, 1961). Areas of bare sand, clearly visible in the 1954 aerial photographs, are being encroached upon, as the gorse invades their margins.

This area of gorse is a fire hazard to the surrounding vegetation since it is 2.5 to 4.0 percent oil by weight (Hill, 1949:2). It spreads into burned, logged, or abandoned areas and forms a complete, impenetrable cover within a few years. Though not restricted to the sand dunes, it appears well adapted to the sandy areas, and is tolerant to some salt spray. Certain characteristics aid in its propagation and ability to maintain a dominant ecological position. These include vigorous plant growth; tolerance to high acidity of the soil; sharp spines, that are avoided by animals; a massive root system; and seeds that have a long period of viability and which are able to withstand the effects of fire (Hill, 1949:2-7), (Oregonian, May 10, 1946). It is not shade tolerant, and this enables trees to invade the margins of gorse infested areas. In the Bandon Area, any forest advancement from the east is unnoticeable, perhaps because of the youth of the coniferous forest, which is second growth.

From a comparison of the two maps in Figure 6.7, it is apparent that stabilization has occurred south of Cut Creek, particularly on the interior portion. The dominant species of the hummocks and on the interior ridge is now European beach grass. Local residents state that the first appearance of this beach grass was in the 1920's when plants were washed ashore (Mrs. C. Evans and L. Felsheim, Personal interviews, July, 1961). The first growth was on the foredune while later growth came in on the hummocks and interior ridge. Sometime between 1934 and 1940, 10 acres of beach grass were planted near the Coquille River Lighthouse. The local residents have done some planting in recent years on the southern portion of the interior ridge. This planting covered less than 10 acres.

The removal of most of the forest on the southern end of the dune mass (Fig. 6.7) is the result of the 1936 Bandon fire. This is one of the few locations where this fire spread north of the Coquille River. Starting on September 25, the fire spread south from Bandon under the influence of the northwest winds. The forest remnants are stunted and no regrowth is apparent.

The interior ridge has, since 1945, advanced about 30 feet eastward in the area just north of the Coquille River (A. Evans, Personal interview, April, 1961). Earlier advances are apparent from the exhumed forest, now located on the west side of this interior ridge. East of the ridge the vegetation is shore pine and Sitka spruce with a few Port Orford cedar (Chamaecyparis Lawsonia Parl.), all of which is second growth timber, except for a few older spruce trees near the river. A sample of 15 trees indicated that the stand had a varied age structure. The trees sampled had between 10 and 62 growth rings, the average being 48 rings. Several small, young trees were present, but were not included in the sample. These findings indicate that this area has been cleared and regrowth begun since white settlement.

The swale, immediately to the east of the foredune (Fig. 6.7), contains a few stunted shore pines all under 10 years of age, and some small willows. The vegetation of the swale is dominated, however, by sedges (Carex spp.) and grasses. In early July, the area is still soggy underfoot, a condition that probably lasts through July or until the moisture deficit of summer dries the area. Some introduced plants, such as hawkbit, summer dandelion, and clovers (Trifolium spp.) are present in the swale area and on the margins. The most frequently encountered exotic plant south of Cut Creek is, however, European beach grass.

The extension of vegetation from the swale appears to be most dense on the south and east margins. Although both exotic and indigenous species are involved, this extension leads to the conclusion that the stabilization of dunes may progress outward from the swales in the direction of the prevailing summer winds (in this case, south and east of the swale).

The vegetation in the Bandon Area has been greatly influenced by human activities, beginning in the 1850's. The northern portion has undergone two distinct phases, the first being the removal of the original forest cover, thought to have been shore pine and Sitka spruce, through clearing and burning. The second phase has been the establishment of a complete cover of gorse in the western portion. The southern part of this sample area has been grazed since 1857. Changes in the Bandon Area are associated with logging, burning, overgrazing, and the introduction of several exotic plants.

THE PISTOL RIVER AREA

The southernmost dune area studied extends northward from Crook Point to Hunters Cove, its greatest extent lying between Crook Point and the Pistol River. North of Pistol River, the sand forms a narrow strip between the ocean and the hard rock of the interior. South of the Pistol River, the dunes become wider, reaching a maximum width of one and one half miles near Crook Point. The major ridges of the dunes trend northwest-southeast (parallel to the coast), but superimposed are several small ridges at right angles to this trend line. The sand mass has its highest elevations to the south near Crook Point.

Historical Geography

The Pistol River Area drew little attention in the early chronicles of the Oregon coast. The first settlers were apparently the Crook family who homesteaded the area in 1864 and who operated a cattle and sheep ranch (Dodge, 1898:26). In subsequent years more settlers arrived and by the late 19th and early 20th centuries, serious denudation of the grassland had begun. In the decade between 1900 and 1910, active sand threatened the grazing land of the Walker family. Mr. J. Walker, Sr. commenced one of the earliest known dune planting projects on the Oregon coast and one of the few large plantings undertaken privately. Clones of European beach grass were ordered from San Francisco and set out on the Walker property, south of the Pistol River, in the cool winter months (Mr. J. Walker, Sr., Personal interview, August, 1961).

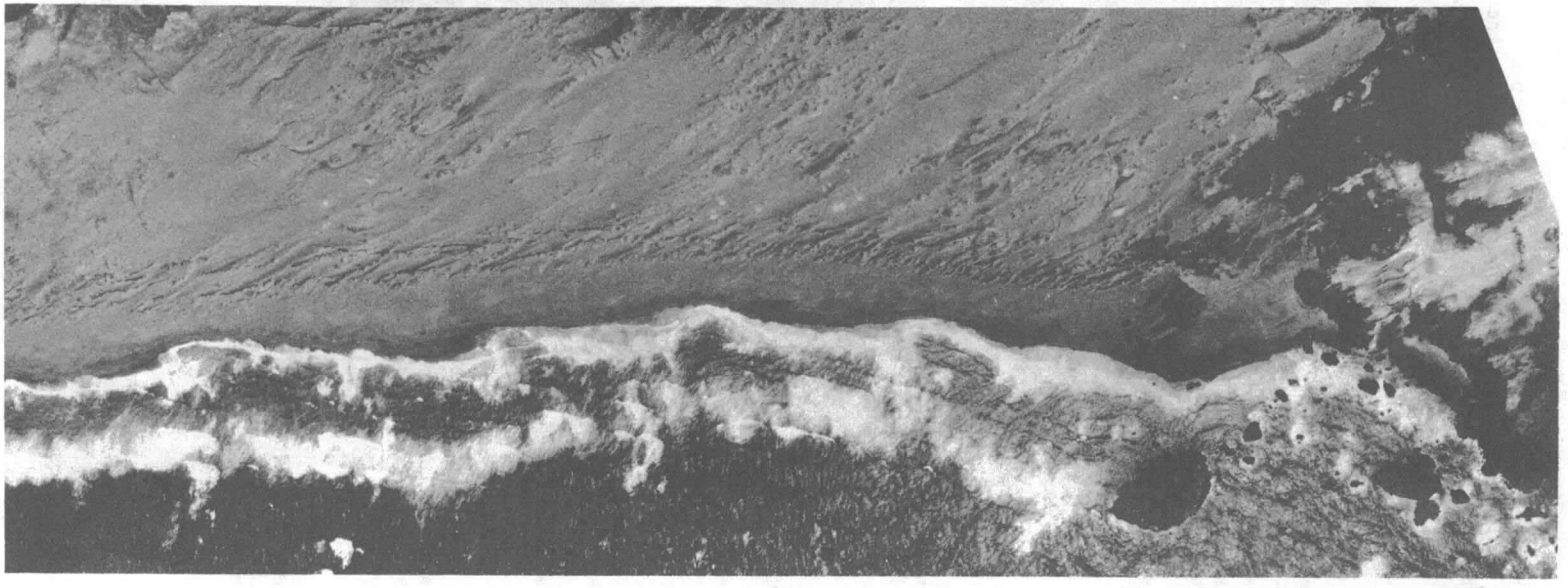
Changes in the Vegetation

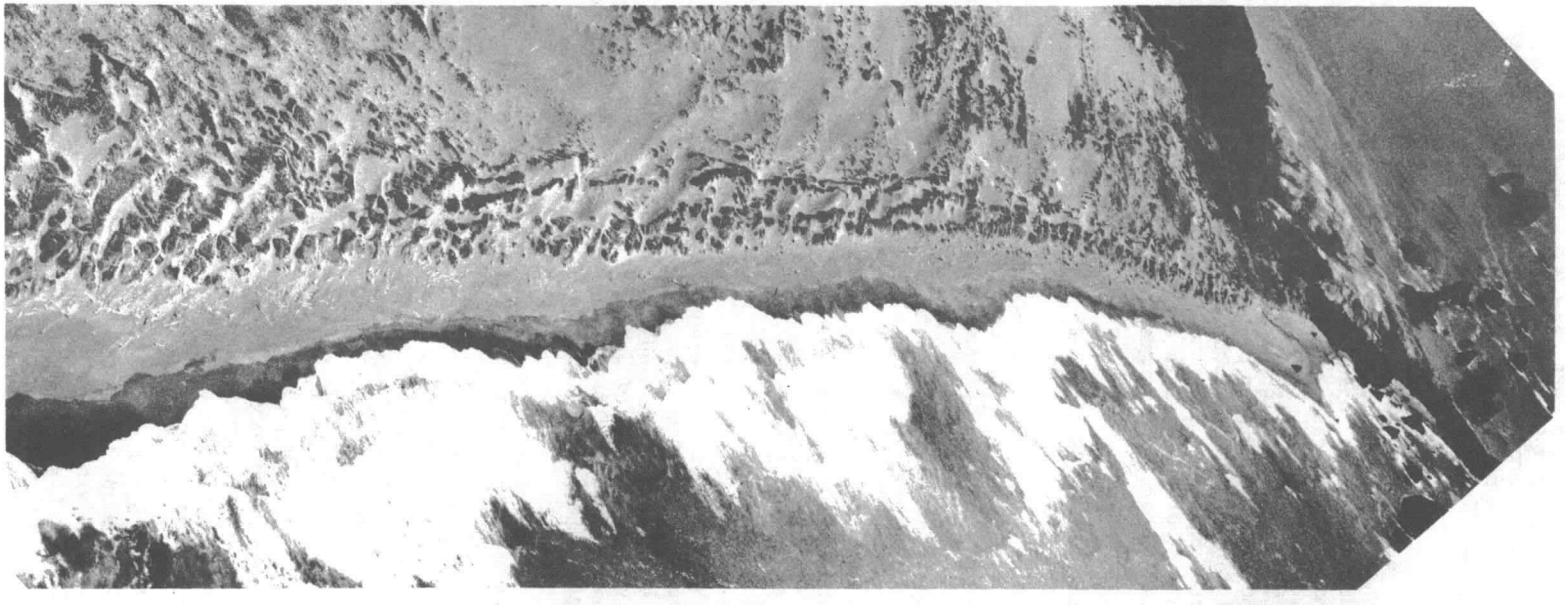
The planting of European beach grass has continued intermittently up to the present. Much of the interior portion of the dune area is now stabilized, while more recent plantings on the oceanward portion have been supplemented by spontaneous growth of beach grass. The grass has reproduced by root shoots and by the transfer of viable portions of the plant by environmental processes. None of the beach grass north of the outlet of the Pistol River is thought to have been planted (Mr. J. Walker, Jr., Personal interview, August, 1961).

On much of the interior portion of the dune area yellow tree lupine, an indigenous herbaceous legume, has started growing. This species apparently fills the same ecological niche as Scotch broom has in the stabilization plantings considered previously. Nitrogen fixation and the deposition of humus may result in the establishment of woody plants. However, the grazing of sheep, which has continued to the present, may preclude any tree growth.

Figure 6.8 shows the development of vegetation on the oceanward portions of the area between 1952 and 1959. The spontaneous growth of European beach grass produces a hummocky surface as sand is precipitated out of the wind and deposited around the individual grass clones. This is particularly apparent wherever individual plants have come up at some distance apart. There has been almost no development of sand flats within the area.

The change in land ownership which will accompany present highway construction will result in the State of Oregon becoming responsible for the maintenance of vegetation on much of the dune area. Having





the area under the control of one authority with financial resources available, should make it possible to extend the work started by private citizens.

SUMMARY

The five areas studied show that man has indeed played a major role in altering the surface cover of the Oregon dunes during the past 120 years. Two types of change can be distinguished. The first has been in the floristic composition of the dunes through the introduction of exotic plants. The second change is in the areal distribution of the major surface cover types, such as bare sand, grassland, and shrub, under the direct and indirect influence of man. A summary of the influence of plant introductions, followed by a brief resume of the processes that have influenced the areal distribution, reveals the impact of human actions on the vegetation of the sand dunes studied.

The introduction of exotic plants was contemporaneous with the settlement of the Oregon coast. Some exotic species were introduced purposefully, for economic or ornamental reasons. More numerous were the accidental introductions of weeds. Some of these plants seem naturalized and have filled ecological niches in the plant communities of the Oregon dunes. Most of the alien plants, however, are associated with disturbed habitats of gardens, roadsides, and fence rows.

Several economic activities of the past and present residents of the dunes have been particularly influential in effecting vegetation change. In at least two areas (the Clatsop Plains and the Bandon Area) overgrazing has wrought changes in the surface cover, through the denudation of former grasslands. Logging, clearing, and burning of the former coniferous forest in the Bandon Area has effected change through its disruption of the habitat. Such disruption on the perched dunes has resulted in the establishment of an exotic shrub, gorse. A fire played an important part in changing the vegetation of the Siuslaw-Siltcoos Area, but may antedate white contact.

Urbanization has been a significant factor in the evolution of the present surface cover of the Clatsop Plains. Bayocean Peninsula has been altered through urbanization in the past and is now undergoing change following abandonment of the town of Bayocean. Of the total number of introduced plants, only the most naturalized species remain in quantity on the spit.

The construction of the jetties at the mouths of rivers and bays has had startling effects on the surface cover of some of the Oregon dunes. This, in conjunction with the overgrazing described above, was instrumental in the development of a 3000 acre waste of bare sand on the Clatsop Plains by the 1930's. Construction of the Tillamook Bay jetty resulted in eventual erosion and deposition at various locations along Bayocean Peninsula. Portions of the coniferous forest were undermined and washed to sea, while elsewhere on the spit sand deposition resulted in the development of low sand flats. The jetties of the Siuslaw and Coquille rivers have been relatively insignificant in causing vegetation change: the difference seems dependent on local conditions of littoral sand transport.

The relative importance of man's influence in activating the sand prior to 1930 cannot be accurately determined without a full and detailed consideration of environmental factors. This study does reveal, however, that man's actions were significant in the activation of the sand dune areas. Since the 1930's, the most important changes on the Oregon dunes that have been influenced by man are the stabilization plantings. These plantings have used both native and exotic grasses, herbaceous legumes and trees with evident success. In every area studied, planting has been done to halt wind erosion of active sand.

Fig. 6.8. The area south of the Pistol River. The vertical aerial photograph on the left, taken in July 1952, shows the oceanward portion of the Pistol River dunes. The top of the photograph (showing the margins of Crook Point) is south. No vegetation is apparent on the dune surface. On the right is a low, oblique photograph of the same area taken in May, 1959, showing the development of patches of vegetation, most of which is European beach grass. This is spontaneous growth, resulting from planting to the interior. By 1961, the vegetation had become much thicker (Oregon State Highway Dept.).

CHAPTER 7. SHORELINE AND VEGETATION CHANGES OF THE ESTUARIES

Carl L. Johannessen

INTRODUCTION

The processes of vegetation change and the historical location of the margins of the tidal marshes are investigated and compared in six estuaries of the Oregon coast. From south to north they are: Coquille Estuary, Coos Bay, Umpqua Estuary, Alsea Estuary, Tillamook Bay, and Nehalem Bay. The purpose of this research is to determine whether consistent changes have occurred and continue to occur in the shorelines of these estuaries. The tidal marsh lands provide the most dynamic element along the shorelines in these river valleys, which were flooded in the last great rise of the sea level 6000 to 12,000 years ago. In several locations during the last century the borders of the estuaries have been mapped; the lines drawn of these borders represented the bay side of the marsh land, therefore, historical research on the phenomena of the expansion of the marsh is made possible. Apparently a condition of relatively slow change had been reached during Indian times because it appears that since the coming of Europeans the process of filling of estuaries has been greatly accelerated. In order to measure the changes in the shorelines and understand more about the processes involved, detailed studies of the advance of tidal marsh vegetation are presented.

An attempt is made here to design the research on vegetation so that the independent variable or factors of the environment are relatively constant when comparisons of the marshes are made. In such a study the climate, barriers to dispersal of seed, degree and aspect of slope, parent material, time since disturbance, and management of the land by man would ideally be about the same from one study area to another. If one restricts the study of the tidal marshes to those that are non-diked and regularly inundated by tidal waters, then man's direct activities are limited to occasionally dumping dredge spoil in a few spots or defiling the water with pollutants. Indirectly, activities that affect the watershed will influence the estuaries by modifying the sediment in the river, but the processes are of an entirely different type in comparison to diking or draining a marsh. The observations on vegetation are restricted to the lower estuaries that are strongly influenced by maritime air that blows across them from the Pacific Ocean. A general lack of barriers to the movement of seeds of the marsh plants in this section of the coast is indicated by the similarity of the flora from one estuary to another. Since the bays are under the influence of the tide, the broad mud flats and marshes normally have very low gradients of slope. Exceptions to this develop where there are breaks in slope on the marshes, caused by erosion or by a recent colonization of formerly unoccupied mud flats. In some places the recent colonization may have taken place on bare mud flats, one to three feet lower in elevation than the adjacent mature marsh; nevertheless, the broad surfaces are very close to horizontal.

Complications arise when the other variables are considered. The substratum or parent material on which plants grow is all alluvium, to be sure, but the alluvial material is highly segregated into deposits of clay that are carried by the tide into backwater areas or among the marsh plants; the gravels and coarse sands, at the other extreme, are deposited directly by the streams and rivers where the gradient of the stream channel changes rapidly. The mud flats of the central portion of the bays and estuaries are found to have a high sand content, whereas the older and higher tidal marsh islands that developed on that sand commonly have a high clay content. This indicates that the process of island building in the estuaries varies from the period of time when sandy alluvium is deposited on mud flats, at elevations below the level where vegetation starts to grow, to the period of time when the deposition of silts and clays occurs on higher and older marshes. As a result, comparisons of vegetation associations and their successional sequences need to be segregated on this basis and studied separately. However, as a practical matter in the study of the advance of shorelines, the sandy parent material made up over 90 percent of the surface being colonized.

The factor of time varies from time zero (and the sprouting of the primary invaders on the mud flats) to a period of 96 years for historical information of the Oregon coast. It is now possible to compare the marshes that are very recent, to those that are 22 to 96 years old, throughout the estuaries. At the time the field work was being carried out, the discovery that it was possible (through the use of photo interpretation) to determine those portions of higher marshes that are older than historical record, had not been realized. They could now be examined separately, for they are distinctive in appearance on the aerial photographs. The major emphasis in the study on succession of marsh vegetation presented here is on the youngest sequences, usually less than 22 years, because this time period was the interval between the 1939 and 1961 aerial photographs, and field work. Consequently, the discussion of the ecology and succession of the plants compares these young colonies with colonies of similar age wherever they occur in the study area.

The height of the former margins of all the marshes that are shown on the old 19th century Coast Survey charts are near the maximum height of tidal marshes observable today. In addition, some of the areas that were open mud flats in the period when the first charts were drawn are now nearly as high as the older marshes. Most of the recently invaded mud flats are at a lower elevation than the high marshes and the only exceptions are those areas of marsh that have developed on deposits in the deltas from the dumping of veritable mud flows in the margin of the bay.

The variability in elevation of the marshes causes differences in the salinity of water to which the plants are subjected. However, in addition to elevation, other factors influence the salinity level in soil, such as seasonal changes in the volume of fresh water in the river and the shape of the river channel or bay. If the estuary or river channel is broad and relatively shallow, more mixing occurs than if the wedge of salt water is restricted to a narrow and deep channel (Burt and McAlister, 1959).

The field and laboratory work for the study of the tidal marshes and their shorelines took place in the summer of 1961. Aerial photographs taken in 1939 are compared with the most recent aerial photographs available (1954, 1960, or 1961); the recent photographs are field checked for the latest distributions when possible. This method has allowed the construction of maps illustrating the differences in shoreline that have developed in the last 22 years. Photographic interpretation of these estuaries soon indicated that certain types of images or patterns, such as circular colonies of marsh plants on otherwise bare mud flats, can be used to indicate areas in which the vegetation change was most rapid. Also, the more stable shorelines can be differentiated by their tendency to be linear and sharp, and have steep sides when viewed with the stereoscope.

Plants are collected frequently in the field so that if fine distinctions between species are present, they may be discovered in the laboratory where microscopes and other equipment enable close inspection. Plant identification and classification is based on information in the books by the following authorities: Peck (1961), Mason (1957), Hitchcock et. al (1955), Abrams (1923-1960), Hitchcock (1950), and Steward et. al. (1960), and by comparisons with the herbarium materials at the University of Oregon.

Problems that Remain Partially Solved

Many problems have been raised in the course of this study and several are presented in this introductory section so the reader may be able to consider them and their possible solutions along with the descriptive data recorded here. Since returning from the field, where the major emphasis in the observations was directed toward the fringe of vegetation actively colonizing the mud flats, it has become increasingly clear that several additional investigations could profitably be carried out on the older and higher marshes. The floral composition of the high marshes is more diverse and the soil texture is much less diverse than conditions in the pioneer colonies where a single species, at one time dominant, may be virtually replaced as the accretion of sediment raises the elevation of the marsh. Initially the alluvium that is colonized may vary in texture from gravel to clay, whereas, the islands have consistently heavy soils, high in clay content. A detailed census of the flora of the high marshes is not part of this report, although the dominant species are noted. Such a census could be conducted to determine the affect of a greater range of age of the site on the flora, while the other environmental factors are relatively constant.

Probably the most fascinating landforms of the tidal marsh are the old shorelines of the bays and estuaries which commonly show up as stream channels in the current landscape. The fact that present stream channels mark the old margins, for all the estuaries examined for which 19th century maps were available, implies that more of the marshes had steep, high banks in the old days in comparison to the modern condition of many new, low, broad areas of marsh bordering the water. The steep, nearly vertical banks are unlikely situations to allow a homogenous fusion of new and old marsh surfaces with no break in relief. No doubt a few of the old marsh edges had more gradual slopes; for this reason a perfect, one to one correlation between old shoreline and modern stream channels is lacking, but the relative amount of primary colonization taking place must have been very much less in the old days. Steers (1946, 1954) has suggested that the tidal streams, typical of English marshes, are probably the result of the maintenance of the bed of the streams at a nearly constant elevation while the marsh rises beside them. In England, Steers did not have the rapid changes in culture that have occurred in Oregon with the displacement of the Indians by the Europeans and the concomitant changes in the cycle of erosion and deposition; therefore, he apparently did not consider using these tidal stream channels as historical markers.

Often the tidal stream channels in the marshes can be used to mark former boundaries of the marsh, quite precisely, once the typical appearance is recognized through the study of the old charts and modern aerial photographs. (Now that the technique of interpretation has been mastered it should be possible to predict the mid 19th century shorelines in those estuaries for which we have no records.) Some of the areas in which tidal creeks are found along the former margins are: the northern and central margin of the former, much narrower mainland marsh on the Coquille Estuary (Fig. 7.5); the islands near the outlet of the Coos River into Coos Bay (Fig. 7.13); the central western shore of Cannery Island; the northern

and southern sides of the old islands in The Point; the new little island at the northwestern corner of the mainland at The Cutoff. An older shoreline farther to the west and south than the one on the 1885 map (U. S. Coast and Geod. Sur., Umpqua) can be inferred from modern aerial photographs in conjunction with the 1885 map and stream patterns (Fig. 7.14). Other examples are found in the delta regions of the Wilson and Kilchis rivers in Tillamook Bay (Fig. 7.19) and several places in the Nehalem marshes (Fig. 7.21). In almost all cases these marsh creeks, which mark old boundaries of the marsh, primarily drain the marsh rather than transport water from the mainland to the sea.

The variety of Sitka spruce (Picea sitchensis) called tideland spruce is commonly found farther out on the tide flats than any other tree, except an occasional (three percent) western hemlock (Tsuga heterophylla). Most of the shrubs that are tolerant of salt spray, and usually occur on the sand dunes, may be found growing out of the same logs with the conifers. The species of shrubs most often seen include Gaultheria shallon (salal) and Vaccinium sp. (huckleberry). The Douglas fir (Pseudotsuga menziesii), and shore pine (Pinus contorta) are not found on old logs in the marshes in comparable positions to those of the spruce. A detailed comparison between the morphology of tideland spruce and the Sitka spruce could be made at some future date in order to determine whether or not varietal standing should be given to the tideland form. However, from a cursory examination it would appear that morphological differences are too small for a varietal designation.

Since the tideland spruce does invade the marshes, or at least does grow on logs on the marshes, the question of the sensitivity of the spruce to salt concentrations is obviously raised (Fig. 7.1). Perhaps it is simply more tolerant of salt than the other conifers or possibly the logs on which they grow hold them out of contact with brackish waters, even in times of flood tide. After all, when the rivers run full and overflow their normal banks in the delta regions, there may be so much fresh water that the usual saline wedge in the estuary is effectively washed out to sea. It would be interesting to know what species of logs are colonized, but perhaps the physical condition of the wood is the most important feature. Often the logs, on which young trees five to ten years old are growing, have a thick bark that may trap rain water. The old and well-weathered logs that are so pithy that they can hold large quantities of water also are colonized by spruce. The larger and more mature tideland spruce trees are concentrated on older and higher marshes, often times above the normal high tide zone, but on the flood plain. Some are so old that they no longer have any evidence of a seed-bed log. After having raised several questions about habitat of the spruce, some environmental factor not observable in the summer may be the critical one. It is tentatively suggested that the frequency and magnitude of the floods in the estuary are most likely the controlling factor in the presence of the spruce on the marshes. High floods in combination with high tides may be expected to float the logs lying on the marshes, probably overturn them and thus destroy tideland spruce seedlings that had a start on the logs. There comes a time, of course, when the spruce will have driven its roots down into the soil below the log, or when the log may have been decayed or partially buried as the result of the deposit of alluvium around it, to the point where it will no longer float.

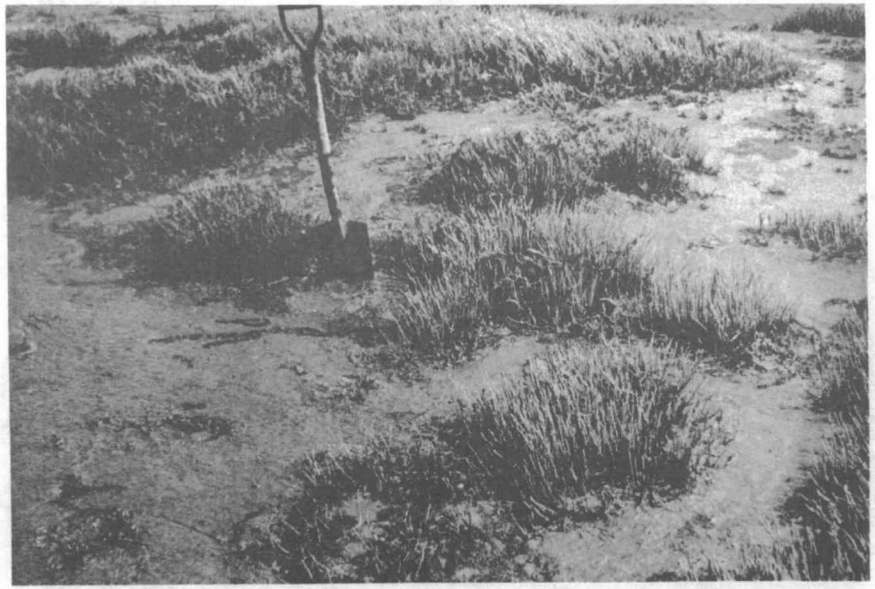
Once the mainland marshes reach a height at which alluvium from the main river is no longer being deposited in large quantities, presumably, the smaller creeks and rivulets spread their subaerial alluvial fans on the old marsh and a full compliment of forest trees invade the land. Perhaps a closer examination of the boundaries between forest and marsh would reveal the rate of advance of the forests, too. It will be much slower than the rate for the advance of low marsh. It is suggested that these problems and their tentative solutions be kept in mind as the discussions on vegetation change in the tidal marshes and the resultant changes in the position of the margin of the estuaries are presented, sequentially, by individual river systems.

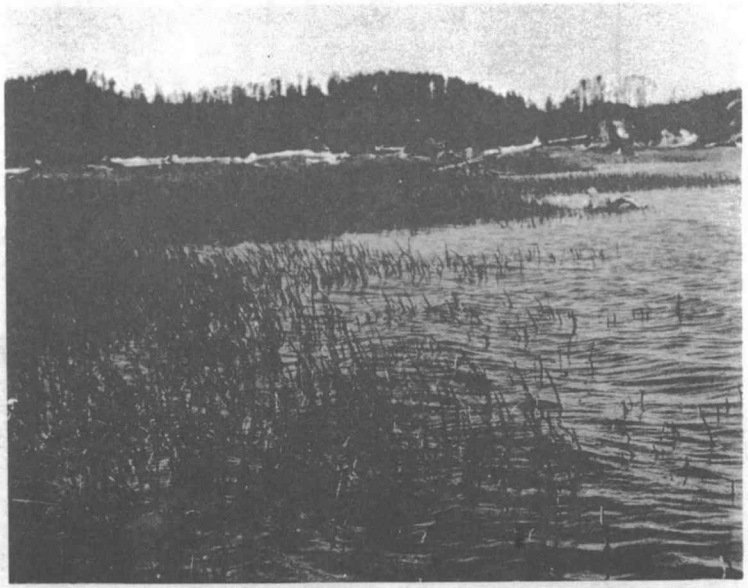
Fig. 7.1. Upper left. Tideland spruce, salal, and huckleberry on log in tidal marsh of Siletz Bay.

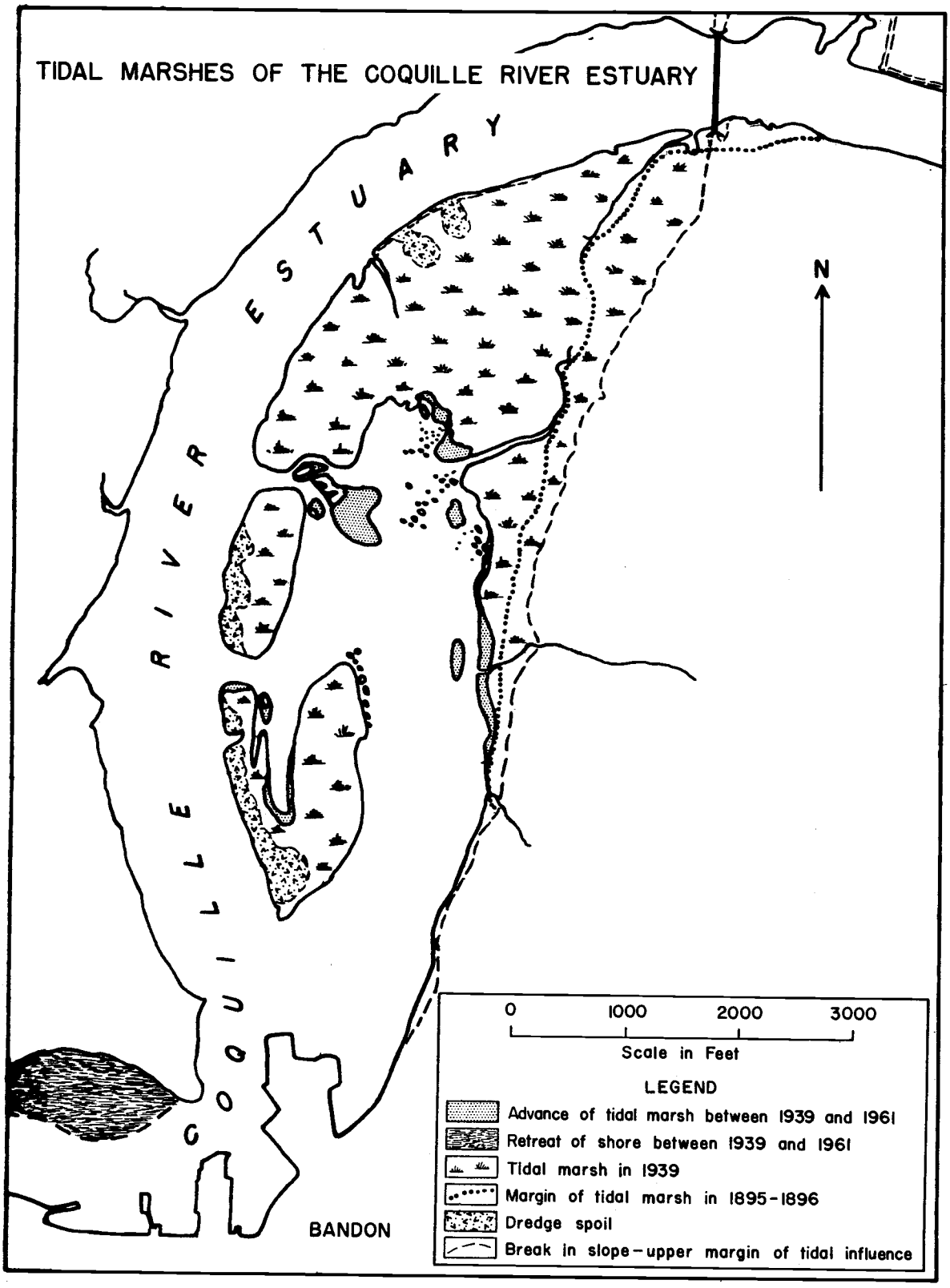
Fig. 7.2. Upper right. Primary invasion of circular colonies of Triglochin maritima on mud flats in Coquille Estuary.

Fig. 7.3. Lower left. Primary invasion of circular colonies of Salicornia ambigua that soon fuse to form a closed marsh cover, in Coquille Estuary.

Fig. 7.4. Lower right. Primary invasion of Scirpus americanus on a broad, sinuous front on the east side of Coquille Estuary, north of Bandon.






TIDAL MARSHES OF THE COQUILLE RIVER ESTUARY
COQUILLE RIVER ESTUARY
N
BANDON
0
1000
2000
3000
Scale in Feet
LEGEND
Advance of tidal marsh between 1939 and 1961
Retreat of shore between 1939 and 1961
Tidal marsh in 1939
Margin of tidal marsh in 1895-1896
Dredge spoil
Break in slope-upper margin of tidal influence

COQUILLE ESTUARY

The bay at the mouth of the Coquille River north of Bandon is about two miles long and three quarters of a mile wide at high tide. The river drains an area of 1070 square miles and is affected by tides 35 to 36 miles upstream from the mouth. The watershed is covered mainly by Douglas fir, red cedar, Port Orford cedar, spruce, and hemlock on the hills and on the pasture lands of the flat alluvial deposits in the valley (U. S. House of Rep., 1942a:7). Sufficient disturbance from fire and logging has occurred in the Coquille watershed that the forest is now predominantly closely-spaced second growth instead of possessing the park-like appearance it had 60 to 100 years ago. The most disastrous fire, in terms of loss of personal property, occurred in 1936 when the town of Bandon was destroyed (Chapter 6).

Floods, caused by heavy rainfall in extensive areas of logged and burned-over lands, formerly left many residents of the Coquille River Valley marooned on their farms. In recent years the roads have been raised and new access highways have been built to alleviate the effects of the floods, as far as the people are concerned; but the river has continued to carry the silts and sands down into the estuary and has filled in large areas of the estuary since 1885.

The most destructive flood in the early days of settlement, according to the U. S. Army Corps of Engineers (U. S. House of Rep., 1942a:9), occurred in February 1890, with a discharge of about 100,000 cubic feet per second at Coquille, 24 miles upstream. Other major floods have occurred at about ten year intervals throughout the record (U. S. House of Rep., 1942a:9). Stream flow data for the South Fork of the Coquille River near Powers indicates that during the period from 1916 to 1926, and the period from 1928 to 1959, the maximum flow occurred in December of 1945, but the volume of 30,500 cubic feet per second at Powers is not really comparable with the volume at Coquille of 100,000 cubic feet per second, because of the disparity in the watershed area (U. S. Geol. Sur., 1960:261).

In the headwaters of the Coquille basin an annual precipitation of about 90 to 100 inches is expected. Since the extremes of precipitation and temperature are more likely to indicate a limiting condition for plant growth than any other kind of value readily available in the climatic records of the area, these records are given to help assess the relative stress that the plants must endure from the climatic portion of the environmental factors. In the Bandon area for the period 1931 to 1952 precipitation maxima of 82 inches in 1950 and 72 inches in 1937 were received; minima in precipitation of 37 inches in 1939, and 39 inches in 1935 and 1936, were recorded. Minimum temperature for ten years of record at Bandon was 15 degrees F. in January and a maximum temperature of 93 degrees F. obtained in June (91 degrees F. in September) (U. S. Weather Bur., 1956). (For purposes of this report the maximum and minimum temperatures for the period 1931 to 1952 are given without specific year of occurrence, since this information is not readily available in the climatic summary.)

The highest tides in the Bandon reach of the Coquille River are about six feet above mean sea level and the mean, lower low tides are about four feet below mean sea level, giving a range of 10 feet (U. S. House of Rep., 1942a:17).

Shoreline Changes of Coquille Estuary

The most extensive, non-diked tidal marsh on the Coquille River is situated immediately north of Bandon on the east side of the big curve in the river (Fig. 7.5). This tidal marsh has not always been as large as it is now. The main channel of the river has held the same general bed ever since the 1887 hydrologic chart was drawn, at which time the bay was devoid of marsh except for a narrow ribbon along the straight mainland shore. The margin of the old and high marsh shown in the 1888 chart is marked on the modern landscape either by a declivity of one to two feet down to recently expanding marsh in the southern section, or by a tidal stream channel about four or five feet deep, below the level of the marsh. This condition of stream channel obtains in the northern portion of the marsh and no significant difference in elevation is observable on the two sides of the channel, between the newer and older marsh. Apparently, the process that raises the elevation of a marsh, has an upper limit beyond which additional increase in elevation due to deposition from tidal and flood waters is very slow. It is obvious, from the large amount of driftwood and logs, that flood water does thoroughly inundate all of the high marsh and must deposit some sediment on the surface, but perhaps it is the almost daily deposit of smaller amounts of debris brought in on normal tides that contributes most to the increase in elevation of marsh land.

In 1910 the United States Congress " ... provided for a river channel 100 feet wide, ten feet deep between Bandon (Mile 1) and Riverton (Mile 16) and nine feet deep thence to Coquille (Mile 24), ..." (U. S. House of Rep., 1940:7). The dredge spoil was probably dumped along the margin of the channel and augmented two small islands of marsh vegetation that had developed between 1887 and 1907 on the broad mud

Fig. 7.5. Tidal Marshes of the Coquille Estuary.

flats of the river (U. S. Coast and Geod. Surv., 1887a; U. S. House of Rep., 1907). The low-tide line on the eastern margin of the river channel in the 1916 map probably indicates the site where the spoil was dumped (Fig. 7.7).

The 1887 chart shows tidal marsh vegetation only on the extreme eastern fringe of the mud flats by the channel and the location of this margin is shown by a large dotted line on Figure 7.5. Toward the mainland in back of this fringe is a forest of spruce, alder, and hemlock, 30 to 70 years old. The map drawn in 1912 by the U. S. Army, Corps of Engineers, shows two small islands in the lower estuary, not present in 1887 (Fig. 7.6); these may have been the result of the dumping of dredge spoil. By 1916, when another map was drawn, the mainland marsh had begun to extend from the northeast and, therefore, indicates a gradual expansion of the tidal marsh area rather than a unitary change of scene (Fig. 7.7).

The rate of advance of the margin of the tidal marsh between 1887 and 1916 was about 70 feet per year for a total of 1500 feet and about the same amount and rate of expansion took place between 1916 and 1939. Since then the rate has been much slower, more on the order of four or five feet per year. The small island that shows up in the 1912 map (Fig. 7.6) and on the 1939 aerial photographs is omitted on the 1916 map (Fig. 7.7); this indicates a certain limitation to the reliability of the 1916 map but does not detract from its general usefulness in gaining insight into the type and rate of advance of the mainland marsh. The changes in the islands in mid-bay have been much slower than those to the northeast of the estuary. Some of this change, no doubt, has been the result of the deposition of dredge spoil beside the main channel of the Coquille River in the period just after 1910. However, much natural sedimentation has also occurred.

Vegetation of Coquille Estuary

The most frequently encountered plants in the primary succession on the mud flats of the Coquille Estuary are Triglochin maritima (seaside arrow-grass), Salicornia ambigua (woody glasswort), Spergularia marina (salt-marsh sand spurry), and Scirpus americanus (three-square) (Table 7.1). The first two species occur as circular colonies in the otherwise bare mud flats (Fig. 7.2; Fig. 7.3). Commonly these species extend rhizomes into the surrounding mud at about the same rate in all directions, and by the time the clumps have grown to about three or four feet in diameter, the process has continued long enough so that the colonies begin to coalesce, form elliptical patches, and then a complete cover develops. The islets in the middle of the bay are distinctive by their high proportion of S. ambigua. With the exception of Zosterna marina (eel grass) which is a limp aquatic (prostrate when the tide is out) and not a marsh plant, the Spergularia marina grows farther out on the mud flats than any other erect marsh plant, and grows at the lowest elevation. The individual plants of Zosterna marina typically are widely spaced and do not form a dense mat of vegetation as do all the others.

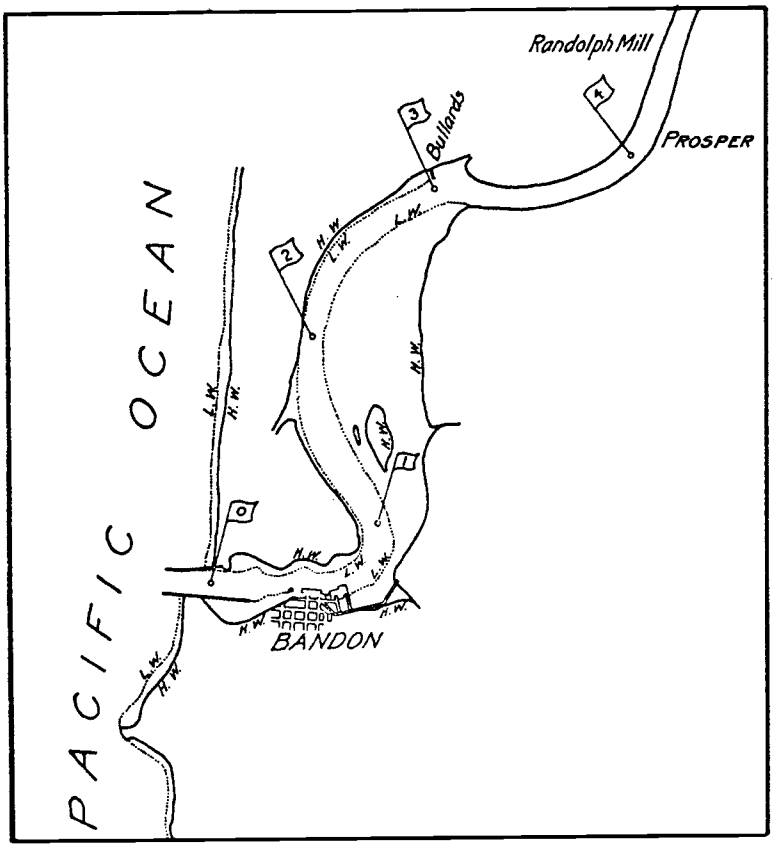
Scirpus americanus is advancing on a broad, sinuous front along the central eastern margin of the bay as a nearly pure, single-species stand (Fig. 7.4). Since the latter area is contiguous to the mainland, the salt concentration may be somewhat reduced by runoff from the land, but this is doubtful. The substratum of silty sand is about the same here as elsewhere on the mud flats, so this can hardly account for the differences in the species composition between the central-eastern and northeastern side of the bay.

In the northeastern end of the bay the S. americanus marsh forms a sharp boundary with the Salicornia ambigua because the intergrading zone on flat relief is less than a dozen yards wide. Only a few circular colonies of T. maritima (from the typical Salicornia marsh association) grow among the S. americanus and then they only grow in this northern border zone between the two marsh types. The Salicornia marsh is expanding its coverage on the lower mud flats in the northeastern end of the bay and consists of Distichlis spicata (saltgrass), T. maritima, and the yellow-flowered composite, Jaumea carnosa (jaumea).

On the lower elevations of the river channel side of the large southern island, Salicornia ambigua grows as a primary succession species in elliptical clumps from six inches to four feet in diameter. The rate of coalescence is such that by the time the clumps are about four feet in diameter they fuse and a complete cover is developed.

Fig. 7.6. Upper. 1912 Sketch Map of Shorelines in the Coquille Estuary (U. S. House of Rep., 1913).

Fig. 7.7. Lower. 1916 Sketch Map of Shorelines in the Coquille Estuary (U. S. House of Rep., 1917b).


Randolph Mill
Bullards
PROSPER
PACIFIC OCEAN
BANDON
H.W.
L.W.

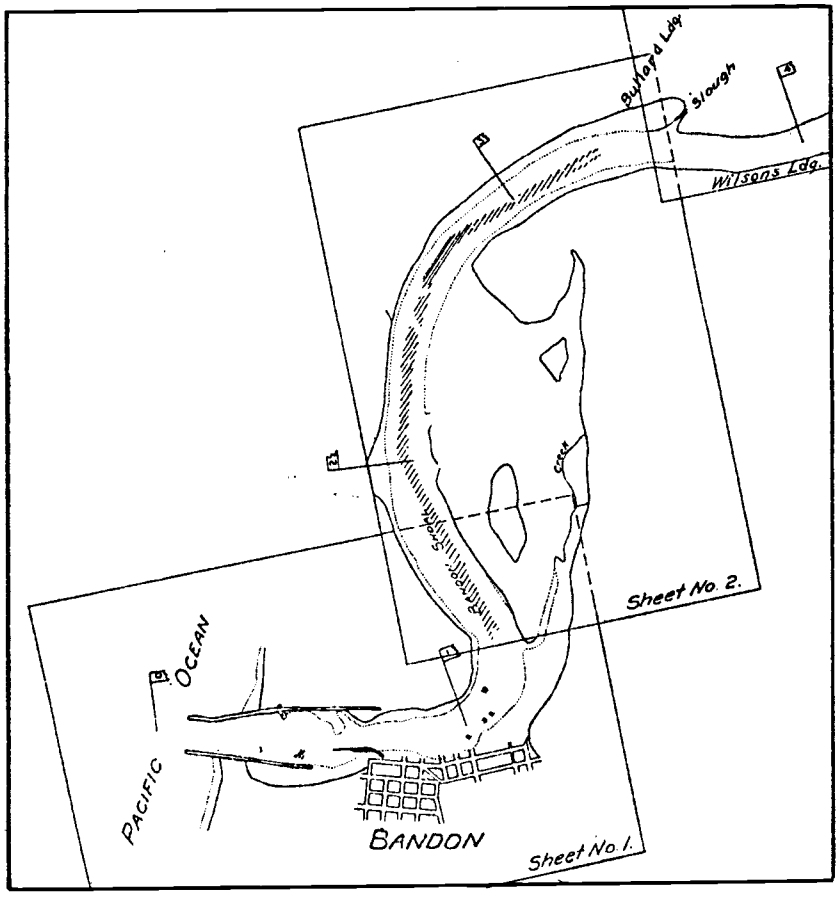

Bullard's Ldg
Slough
Wilsons Ldg.
Sheet No. 2.
OCEAN
PACIFIC
BANDON
Sheet No. 1.

TABLE 7.1*

LOWER COQUILLE ESTUARY

SPECIES COMPOSITION OF TIDAL MARSH FLORA (%)

SITUATION / SPECIES	*Agrostis alba*	*Carex lyngbyei*	*Deschampsia caespitosa*	*Distichlis spicata*	*Jaumea carnosa*	*Juncus effusus*	*Salicornia ambigua*	*Scirpus americanus*	*Spergularia*	*Triglochin maritima*
1. Intermediate elevation, old marsh about 1000 feet south, southwest of bridge over river.	25	50	10		5		10			
2. Low, old marsh at same location as above.							40	30		30
3. Intermediate elevation, old marsh about 2000 feet southwest of bridge over river.	35		5	20	5	5	20			
4. High, old marsh near river channel about 2000 feet southwest of bridge over river.				30	30		40			
5. Low, new marsh at river's edge at same location as above.				40			60			
6. Low, new marsh on mainland one mile north, northeast of Bandon.								80		20
7. Low, old marsh on mainland side of bay north of the above location 3700 feet southwest of bridge (silty sand).		5 (in clumps)		25	20		40			10
8. High, old marsh at the above location.			X (Dominant)							
9. Low, new marsh north and west of drainage slough on northeastern side of bay 3500 feet southwest of bridge.		15			35		40			5
10. Low, old marsh 150 feet to north of site #9.				20	30		30			20

TABLE 7.1 (cont.)

LOWER COQUILLE ESTUARY

SPECIES COMPOSITION OF TIDAL MARSH FLORA (%)

SITUATION	*Agrostis alba*	*Carex lyngbyei*	*Deschampsia caespitosa*	*Distichlis spicata*	*Jaumea carnosa*	*Juncus effusus*	*Salicornia ambigua*	*Scirpus americanus*	*Spergularia*	*Triglochin maritima*	Others
11. Low, new marsh 200 feet north northwest of site #9.							30	20		50	
12. Circular and elliptical colonies of primary succession at northwestern end of bay.							40			60	
13. Primary succession at bay side of mouth of most northerly entrance into bay.							50		50		
14. Intermediate elevation, old marsh of central portion of large northern island one mile southwest of bridge.			12	20	10		40			18	
15. Low, new marsh on northwestern side of embayment in center of large southern island.							60			35	5
16. High, old marsh in center of former small island now joined to large southern island.			40	20			20				20
17. Low, new marsh at southern end of embayment in center of large southern island.			T	40			40			20	
18. Low, new marsh at southern tip of large southern island.							90			10	
19. High, old marsh at center of large southern island.			25	20	15		40				
20. Low, old marsh at eastern edge of large southern island.					20		60			20	

* Table 7 is a record of estimations made in localized situations on the marsh; a sufficient number of records are presented to suggest the diversity that is typical.

In situations a foot or so above the level of the primary succession, just described, Carex lyngbyei (Lyngbye's sedge) commonly assumes dominance (Fig. 7.8). In this location it is exposed to less salt water inundation, since the freshest water is always on top of the incoming tide. Its distribution at lower elevations, which are comparable to elevations in which S. americanus is found, are restricted to the marshes at the mouths of creeks that enter the bay from the mainland. Agrostis alba, fittingly called red top because of its reddish-purple inflorescence, occurs over large areas of the northern portions of the marsh often in association with C. lyngbyei at what might be called an intermediate elevation in the marsh.

The higher elevations of the marsh are dominated by Deschampsia caespitosa (tufted hair-grass), which stands taller than all other of the herbaceous material and gives the marsh as beautiful a character as the grass fields that wave with the nearly constant breezes that blow across the flat plain. On these higher marshes the numerous seedlings of tideland spruce (Picea sitchensis) found on driftwood logs in the marshes farther to the north are absent on the marshes of the Coquille Estuary, even though large numbers of logs are available for colonization.

In summary, the plants of the lower marsh include S. ambigua, S. americanus, and T. maritima, and D. spicata as the most widespread species, while J. carnosa is found in some, but not all, of the low marshes; it is also found in the high marshes. In the intermediate elevations in the tidal marsh C. lyngbyei and A. alba are dominant while D. caespitosa is the tallest and most abundant species of the highest marsh.

COOS BAY

Coos Bay (Fig. 5.1) is about 14 to 15 miles long and from one half to one and a half miles in width at high tide; the channels are 300 to 1500 feet wide at low tide. Of the seven rivers and sloughs that enter the bay, the Coos River is the largest with its two branches - the Millicoma River and the South Fork - and its watershed of 420 square miles. The Millicoma and South Fork divide 5.3 miles above the mouth of the Coos River at Coos Bay. The total drainage basin for Coos Bay is estimated to be 820 square miles (U. S. Sen., 1946:6) and includes Haynes Slough, Kentuck Slough, Coos River, Catching Slough, Isthmus Slough, Pony Slough, and South Slough.

Information on the tides is summarized in the U. S. Army, Corps of Engineers reports as follows: "Tides near the mouth of Coos River have a mean range of 5.6 feet and an extreme range of about 10 feet. Tidal effect extends up the Millicoma River as far as Allegany, 8.5 miles above its mouth, and up the South Fork to just above the settlement of Dellwood, 9.4 miles above its mouth". (U. S. Sen., 1948:5). In the lower reaches of Coos Bay the tidal range is seven feet on the average and 11 feet during extreme conditions.

During the period of record from 1931 to 1952, precipitation at North Bend, on Coos Bay, has varied from an annual total of 43 inches in 1936 to 91 inches in 1937. The lowest temperature recorded at North Bend over 21 years of record was 17 degrees F. in December; the highest was 96 degrees F. in July (U. S. Weather Bur., 1956).

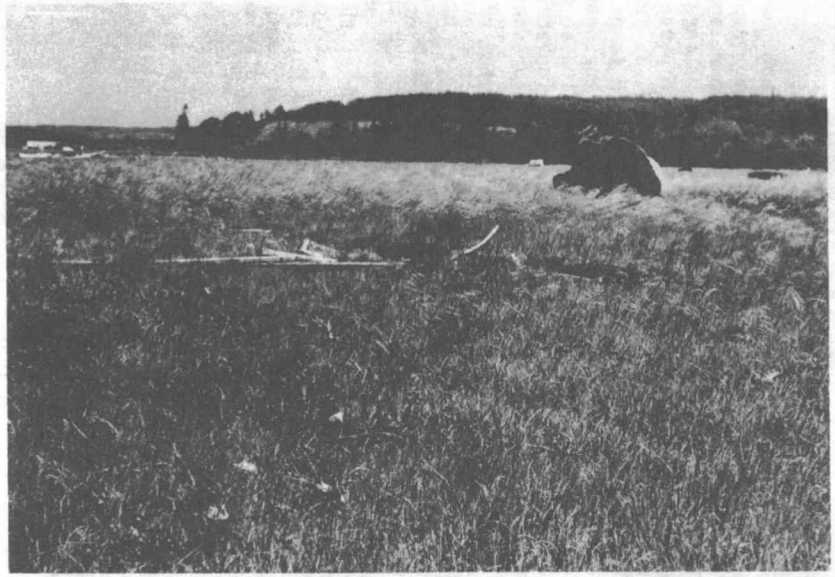
The seven main streams and rivers that enter Coos Bay drain a " ... basin ranging from low foothills to peaks of 3000 feet above sea level, is heavily timbered with several species of conifers, the principal commercial varieties being Douglas fir, spruce, and Port Orford cedar ... Along the lower reaches on the South Fork and Millicoma River a considerable growth of myrtlewood exists." (U. S. Sen., 1948a:6). Practically all the low, flat, formerly marshy land along the borders of the rivers has been diked by local interests and supplies pasturage for the many dairy farms in the area.

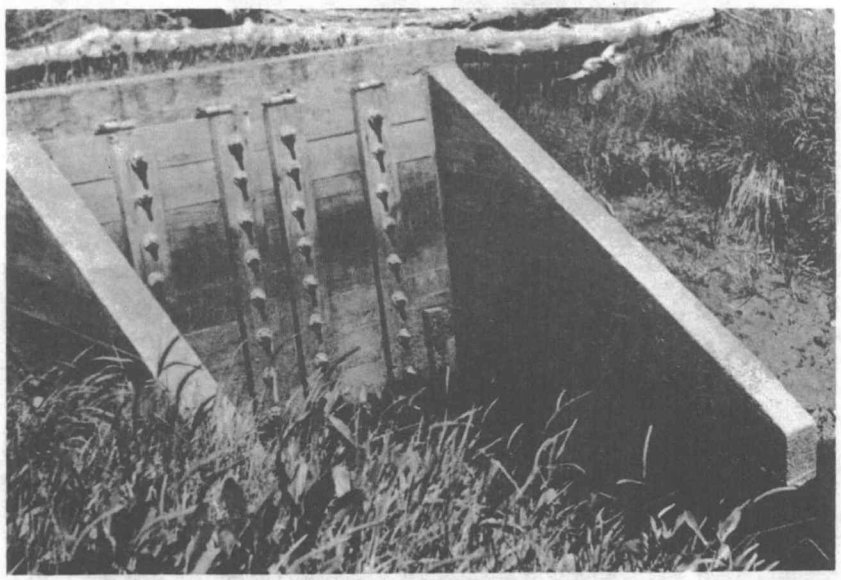
Fig. 7.8. Upper left. Carex lyngbyei in foreground with higher marsh and Deschampsia caespitosa in distance, Coquille Estuary.

Fig. 7.9. Upper right. Old high tidal marsh at low tide, showing the steep-sided banks that have been eroded in the North Channel of the Alsea Estuary; Douglas fir and Sitka spruce on mainland to north.

Fig. 7.10. Lower left. Edge of tidal marsh where Scirpus americanus is advancing at the lower level, at the same time that the higher and older marsh, dominated by Deschampsia caespitosa, is being undercut by erosion and is caving off. Distichlis spicata has invaded the mud that has caved off from the higher marsh. Shepard's Point, Alsea Bay.

Fig. 7.11. Lower right. Tide gate on the bay side of the north shore of the Alsea Estuary.





Shoreline Changes of Coos Bay

Of the Coos Bay tidal marshes that were investigated, Kentuck Slough revealed the most recent and rapid change (Fig. 7.12). Dikes were built many years ago along the upper portion of the slough. An extension of the dikes down the south margin of the slough and the construction of a bridge (with suitable tide gate) and a road levee across the slough at about the midway point have changed the flow of stream and tide. A semi-fluid mud has been flocculated in the bay water and laid down in the "barrow ditch" dug in the mud flat during the construction of the levees. The old mud flat has been built up slightly and tidal marsh vegetation is rapidly invading. The amount of marsh in the slough has doubled in the last 22 years according to a resident (Millard Miller, Personal interview). The long, thin, marsh-covered islands on one side of the channel in Kentuck Slough (Fig. 7.12) are typical of mounds of earth left when channels are deepened and are similar to the series of finger-like islands that extend into South Slough where log-holding ponds were dredged on the western side of the slough.

Only small changes are observable from a study of the charts of the delta of the Coos River in the last 20 years, but if the recent charts (U. S. Coast and Geod. Sur., Coos Bay, 1959) are compared with maps of 1889 and 1890 (U. S. Coast and Geod. Sur., Coos Bay,) then an increase in the tidal marsh is demonstrable on the southeast side of the bay; a decrease can be noted on the southwest side, as a result of the spread of urbanization onto the former marsh (Fig. 7.13). (The Coos Bay area is the only one for which current aerial photographs are not used as the basis for the maps in this chapter, instead the U. S. Coast and Geodetic Survey hydrographic chart of the bay for 1959 is used, corrected by field observation where possible.) This is much the same condition as is observed in the estuary of the Umpqua River.

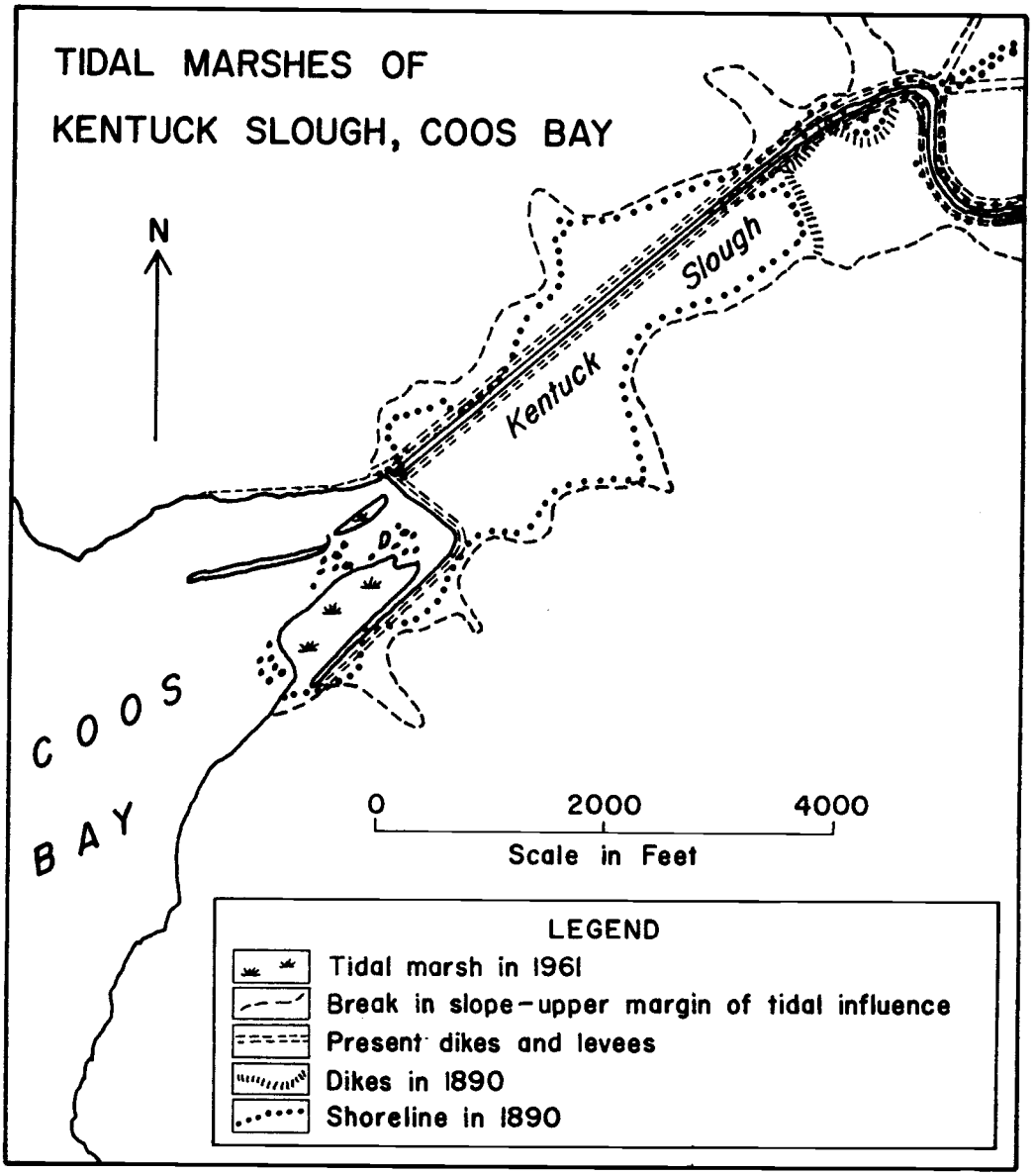
The increase in marsh has taken place on the opposite side of these islands from the deep river channel, which at that time in the early 20th century, was east of the marsh islands, although now the channel is reported to be filling because a cutoff was dredged to join the Marshfield Channel diverting the major flow from the old channel. The islands have increased about 50 percent since 1890.

In 1890 the mud flats adjacent to, but northwest of, Eastside (across the channel from the city of Coos Bay) had a narrow belt of marsh (Fig. 7.13). The remainder of the mud flats were two or three feet above mean sea level and bare. Dikes had been constructed by 1890 on the marsh north of Eastside and along the north bank of the Coos River out from Graveyard Point and had blocked off a former narrow channel of the Coos River. The land south of Coos River, opposite Graveyard Point, was not diked and was marsh.

Several piles of dredge spoil have been deposited on the marshes and mud flats of Coos Bay, but the largest deposit is a broad, flat surface directly opposite the city of Coos Bay. High dikes have been built to hold the mud dredged out of the channel. In one place the surface of the land has been raised more than 25 feet and many acres of dry land have been created. This is land that technically belongs to the State of Oregon, although the Harbor Commission must provide dumping grounds - usually on state land - for the spoil that will accumulate when channels and turning basins are deepened by the U. S. Army, Corps of Engineers. This kind of reclamation of the mud flats and tidal marshes may be expected to continue for many years, as the rivers bring in mud and dredges lift it out. The tendency of the engineers to dredge with ships that carry the spoil out into the ocean for dumping will probably be modified as the pressure for industrial sites and an airport places a higher premium on newly-made flat land. The shallow portions of the bay may be expected to be changed to dry land. An airport already has been created at Pony Point on the west side of Pony Slough in the northwestern side of the city of North Bend. The southern portion of the slough has been reclaimed to provide a shopping center.

Those portions of the city of Coos Bay and Bunker Hill that are near sea level have been reclaimed from a large marsh that borders Isthmus Slough, Coal Bank Slough to the west, and the slough through the middle of what is now the city of Coos Bay (Fig. 7.13). It is of interest to note that it was the business community of Coos Bay and the industrial companies of Bunker Hill that paid for the filling of these marsh lands. It is possible, in some places, to delimit the extent of the former marsh fairly well by the margin of the residential districts around the central business district. The city of Coos Bay in 1890 already occupied some of the low lands that may be assumed to have been marsh at an earlier time; however, no maps have been found that show the limits of the marsh in that situation before the city was started.

Fig. 7.12. Tidal Marshes of Kentuck Slough, Coos Bay.


TIDAL MARSHES OF
KENTUCK SLOUGH, COOS BAY
N
Kentuck
Slough
COOS
BAY
0
2000
4000
Scale in Feet
LEGEND
Tidal marsh in 1961
Break in slope-upper margin of tidal influence
Present dikes and levees
Dikes in 1890
Shoreline in 1890

Vegetation of Coos Bay

The vegetation of the areas of new marshlands in the Coos Bay area will be described by regions, starting with Kentuck Slough on the northeast side of the bay. The 1890 charts of the slough show a dike across most of the slough about one half of a mile east of the present highway-levee and tide gate that have been placed across the slough. An area of new marsh is developing on formerly open mud flat to the west of this new levee in much the same way as it did after the construction of the first dikes over 70 years ago. The eastern edge of this new tidal marsh is made up of Triglochin maritima colonies. Salicornia ambigua forms the bank cover for the more mature or higher islets on top of which Carex lynbgyei is is the most abundant plant and Deschampsia caespitosa the tallest species. The Triglochin maritima continues as an important plant in the interior of the marsh, too, because it is highly dissected by drainage channels. However, if it continues to occupy the bottom of the channels, they will surely fill up and the islets will fuse into one large marsh. On the southwestern extreme of the tidal marsh, fronting the open bay, the circular colonies of T. maritima are again dominant with S. ambigua invading only after the colonies become more mature and rise above the level of the mud flat. The plants of the marshes on the islands in the delta of the Coos River, as it empties into the bay, are dominated by D. caespitosa across the broad flats of the islands and C. lyngbyei on their depressions and wetter margins.

Three estimates were made of the species composition in the marsh on the western side of Pony Slough, adjacent to the area reclaimed from mud flats and marsh for the construction of the North Bend airport. The marsh is not extending itself rapidly across mud flats, for there are no primary, circular colonies along its edge, but it is probably slowly filling in the higher mud flats and the area of the slough, disrupted by the construction of the airport. From an ecological viewpoint most of this marsh is invaded by brackish water during normal high tide, for it is relatively low and very nearly level. In this situation Salicornia ambigua consistently provides the most abundant plant material with Distichlis spicata, Carex lyngbyei, Triglochin maritima, and Deschampsia caespitosa in decreasing order of abundance (Table 7.2). Deschampsia caespitosa is perhaps somewhat overestimated due to its growth habit, which allows it to grow taller than the other species; this may distort its abundance. Eel grass is abundant in South Slough and occasionally present on the mud flats on the northernmost side of the bay.

TABLE 7.2

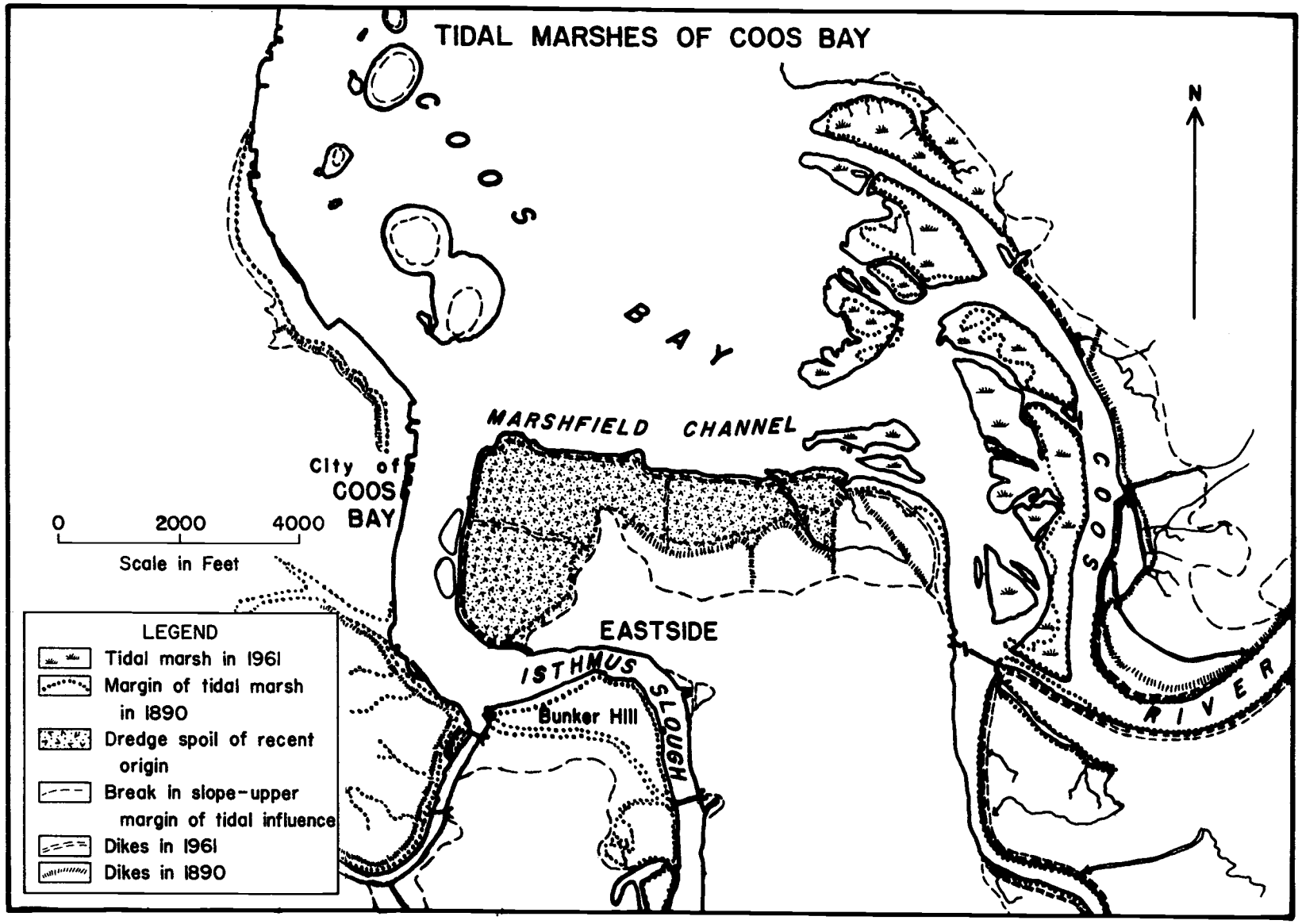
PONY SLOUGH

SPECIES COMPOSITION OF TIDAL MARSH FLORA (%)

	Agrostis alba	Carex lyngbyei	Deschampsia caespitosa	Salicornia ambigua	Scirpus americanus	Triglochin maritima
Northwest margin Pony Slough, east of airport	Trace	5	5	30	45	15
South of above site, 300 yards		25	5	25	30	15
Southern end of marsh on western side, south of above site, 700 yards		20	5	30	45	

The presence of Baccharis pilularis var. consanguinea (coyote-brush), as a shrub (8 to 12 feet tall) on the margin of Pony Slough, is an interesting variant of shoreline shrubs. This variety is not seen farther north, although its distribution is reported to extend to Tillamook Bay (Abrams, 1960:386). It is found along the Coquille Estuary in the dryland margins of the marshes and is prevalent in the flora of the hills on the seaward slope farther south in Oregon and in California.

Fig. 7.13. Tidal Marshes of Coos Bay


TIDAL MARSHES OF COOS BAY
COOS BAY
N
MARSHFIELD CHANNEL
City of COOS BAY
0 2000 4000
Scale in Feet
EASTSIDE
ISTHMUS SLOUGH
Bunker Hill
COOS RIVER
LEGEND
Tidal marsh in 1961
Margin of tidal marsh in 1890
Dredge spoil of recent origin
Break in slope-upper margin of tidal influence
Dikes in 1961
Dikes in 1890

UMPQUA RIVER ESTUARY

The Umpqua River has a total length of 111 miles and a watershed of 4550 square miles, most of which is in rugged timbered country. Its drainage system is, therefore, the largest of all the estuaries analyzed in this tidal marsh study. Tidal influence extends upstream for 28 miles to the head of navigation at Scottsburg. Dikes or relatively high flood plains limit the unmodified, tidal marsh vegetation to the estuarine islands or to the narrow strips along the margin of the estuary in the lower 13 to 14 miles. "From the town of Reedsport to the mouth, 11.5 miles, the river is developed as a deep-draft harbor, and in the tidal estuary has a width ranging from 2,000 to 6,500 feet." (U. S. Sen., 1949:8). The channel depth is maintained at 22 feet (U. S. Sen., 1949:11). The Smith River, a tributary of the Umpqua, has a meandering course about 70 miles long, with a drainage area of 364 square miles. It joins the Umpqua River near the town of Reedsport (Fig. 5.1).

The watersheds of these two rivers are heavily wooded with fir, spruce, and cedar. The lumbering industry dominates the commercial activity of the area that is adjacent to Reedsport. However, in the Smith River drainage, at least, the forest is principally new growth timber that has come in since the area was devastated by forest fires about 100 years ago (U. S. Sen., 1947:6). The extent to which such fires affected the rate of filling of the estuary with silt is not known specifically, but surely the process must have accelerated the rate at which the new mud flats and tidal marshes developed.

Many log rafts are towed up and down the navigable reaches of the Umpqua River and ocean-going ships come up the estuary as far as Reedsport. In addition to the dredging necessary to keep the channel open for the deep vessels, the margins of the tidal marshes are affected by the waves, created by the ships, the large numbers of small craft, and sport fishing boats that have increased with the construction of enlarged harbor facilities at Winchester Bay.

In the eleven years of complete records for Reedsport the annual precipitation varied from a minimum of 56 inches to a maximum of 92 inches. The "Elkton 2 W" rain gauge, 35 miles upstream from Reedsport, has a complete record for 14 years in the period from 1931 to 1952, and the average annual value of precipitation is 50 inches, with an extreme range of 31 to 74 inches. In the upper drainage the precipitation has an annual average of 32.6 inches over the period 1931 to 1952. At Reedsport during a 13 year period the lowest temperature recorded was 15 degrees F. and the highest was 97 degrees F.

The tidal range at the mouth of the Umpqua River is about 6.9 feet on the average and the extreme range is 11 to 12.5 feet during fall and winter floods (U. S. Sen., 1942:4; 1949:9). The lower 23 miles of the Smith River is a tidal estuary with an average between higher high and lower low tide of 7 feet at its mouth, 11.5 miles inland from the ocean.

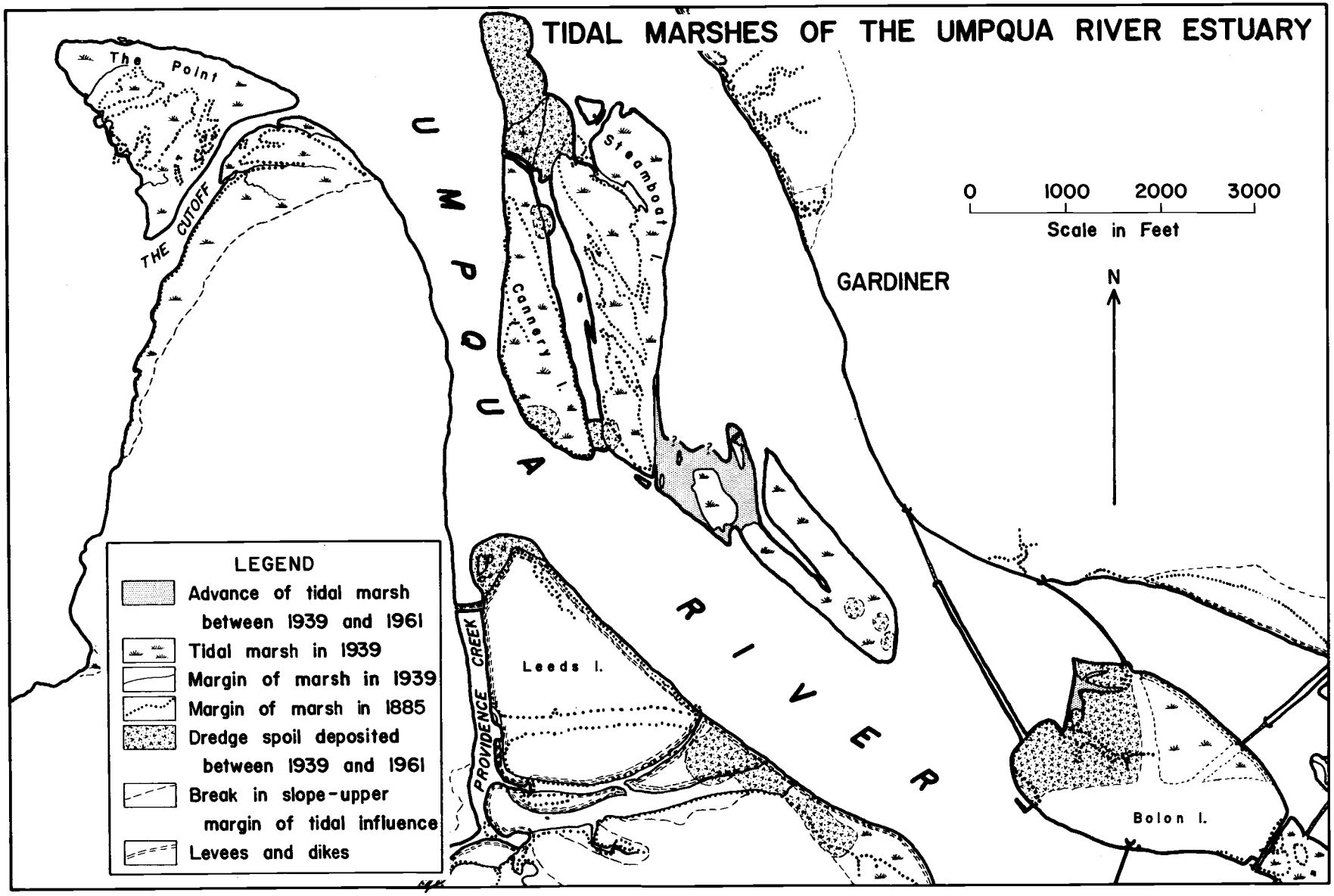
Shoreline Changes of the Umpqua Estuary

The major changes in the shoreline of the estuary of the Umpqua River are best illustrated by close observations of the maps of the area (Fig. 7.14). By 1939 an island appeared between Bolon Island and Steamboat Island that was not present in 1885. Four small circular areas on the 1939 aerial photographs of this island indicate that some dredge spoil had been dumped here prior to 1939. However, the general aspect of the island in the 1939 aerial photographs gives the impression of a natural development. At least one of these appears to have more spoil added since 1939. In the 22 years since 1939 the new island has joined with Steamboat Island by a process of natural sedimentation.

Diking and dumping of dredge spoil in the last 15 years have caused large differences in the shorelines and in the appearance of the vegetation of this estuary. The dikes especially in the Leeds Island area have allowed desalinization and drainage of the soil to occur, and improved pastures have been the result. In 1885 there were three islands in the vicinity of Leeds Island (U. S. Coast and Geod. Sur., Topography, Umpqua R., 1885). An additional island developed by 1939 and now "Leeds Island" is connected to the mainland by levees and extensive deposits of dredge spoil. All of the spoil dumps, as shown on the map (Fig. 7.14), are raised well above any influence of the tide and are covered with European dune grass and shrubs to the exclusion of the marsh flora. On the north end of Cannery Island sufficient dredge spoil has been dumped to cover up the northern fourth of the island and extend dry land out on the former mud flat.

U. S. Highway 101 was built across Bolon Island in 1949 and 1950 and, in the process of dumping the dredged material for the causeway, the owner of the island paid to have the land on both sides of the highway filled also. This left a small slough on the northwest corner that has subsequently filled up naturally with tidal marsh vegetation.

Fig. 7.14. Tidal Marshes of the Umpqua Estuary.


TIDAL MARSHES OF THE UMPQUA RIVER ESTUARY
The Point
THE CUTOFF
UMPQUA RIVER
Steamboat I.
Cannery I.
GARDINER
0 1000 2000 3000
Scale in Feet
N
Leeds I.
PROVIDENCE CREEK
Bolon I.
LEGEND
Advance of tidal marsh between 1939 and 1961
Tidal marsh in 1939
Margin of marsh in 1939
Margin of marsh in 1885
Dredge spoil deposited between 1939 and 1961
Break in slope-upper margin of tidal influence
Levees and dikes

Gardiner City was a thriving lumber town in 1885 at the time the U. S. Coast and Geodetic Survey made their topographic survey of the area and it remains active in the same enterprise. The site of Reedsport was truly a reedy port as illustrated on the 1885 chart (Fig. 7.15). (Curiously enough the port was not named after the reeds that bordered the river, but for Alfred W. Reed, a local resident. The name, Reedsport, was first applied in 1900.) The changes wrought at Reedsport are well illustrated by a comparison of the old chart with the aerial photographs taken in 1954 (Fig. 7.16). The symbols on the 1885 chart indicate that the island and adjacent mainland, where Reedsport is now situated, were covered with a tidal marsh. An occasional spruce tree grew on the marsh and alders were along a part of the border of the slough. That Reedsport is built upon a former tidal marsh can be determined by the tactile experience of standing on a downtown street corner and feeling the ground jiggle as a truck passes.

The process of island building observable at The Point (Fig. 7.14) indicates that accretion of tidal marsh takes place by the development of an island or long peninsula, near the former margin of the marsh, but with a shallow channel between the new and old marsh. Subsequently, the shallow channel gradually may partially fill in with sediment. In several situations, at least, the coincidence of the margin of the marsh vegetation in 1885 and the existence of a tidal channel or slough within the present tidal marsh indicates that this process must operate part of the time.

Vegetation of the Umpqua Estuary

The most abundant primary invader on the northeastern side of the mainland in the region of The Point in the Umpqua Estuary is Scirpus americanus. Salicornia ambigua is restricted in its distribution to a few small strips of shoreline in the channel called The Cutoff because most of the banks here rise about three feet in a vertical and sometimes overhanging cliff. As a result, the space for primary invaders in The Cutoff is much restricted. On the eastern margin of the mainland south of The Cutoff, the slope of the soil is gentle and Scirpus americanus is extending the vegetated zone toward, but not reaching, the domain of the clams and shrimp in the adjacent mud flat.

With a one foot rise in elevation Scirpus americanus is joined by Distichlis spicata as the dominant vegetation. A foot higher on the slope Agrostis alba is associated with Distichlis spicata; the former is the most abundant and the S. americanus is absent. At higher sites Agrostis alba and Juncus balticus each form about 40 percent of the cover with Potentilla pacifica (Pacific silver weed), Elymus triticoides (alkali rye-grass), Carex lyngbyei, Hordeum nodosum, Trifolium pratense, and Deschampsia caespitosa each contributing less than five percent of the cover. The existence of Trifolium pratense, which is the introduced red clover, and the low concentration of Deschampsia caespitosa, which is the usual dominant in this habitat, may be attributed to the grazing by beef cattle that are kept on this non-diked pasture during the summer months. (Hordeum nodosum is better named Hordeum brachyantherum.)

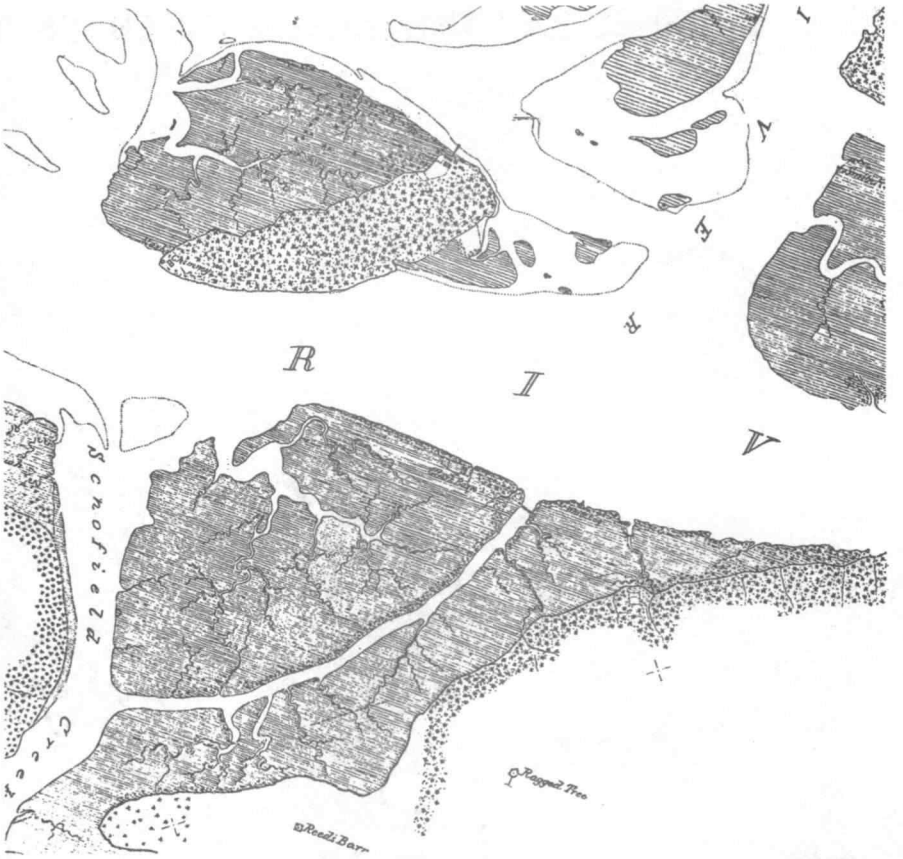
The vegetation around the margin of the island called The Point consists of about 50 percent Agrostis alba, 25 percent Juncus balticus (Baltic rush), about 5 percent Carex lyngbyei, and about 20 percent of less numerous species including Deschampsia caespitosa.

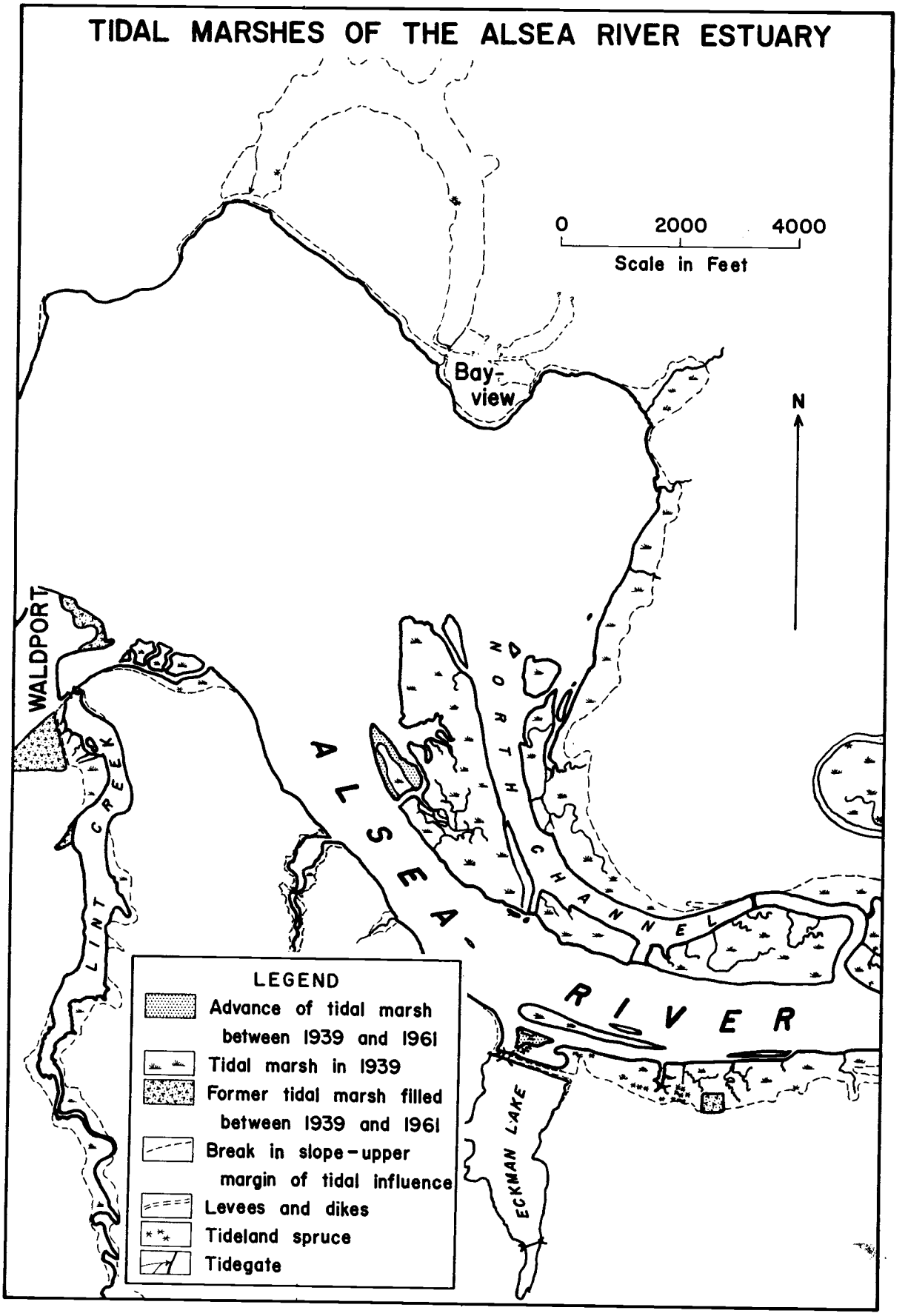
An older and darker marsh can be seen on the 1939 aerial photographs of the mainland south and west of The Cutoff and probably represents the margin of the marsh when Europeans came. By 1885 the two lobes of marsh, shown on Figure 7.14 by the large dotted line, were added and by 1939 an additional tiny island had been built. The major expansions of marsh seem to have come about by non-uniform deposition. They were probably associated with comparable shifts of the border of the marsh in The Point, the island to the north of The Cutoff, since the photographs indicate at least three stages of expansion of marshy land making up The Point.

The most abundant species along the lower margin of the north side of The Point are Salicornia ambigua, 55 percent and Jaumea carnosa, 35 percent; about 10 percent of the vegetation is made up of Scirpus cernuus (low club rush), S. americanus, and Plantago sp. (probably P. maritima) in decreasing frequency. At elevations of 18 to 20 inches above the lowest plants Agrostis alba is the dominant, about 60 percent, D. spicata, 20 percent, J. carnosa, 10 percent, and other species 10 percent. Scirpus americanus is once again found on the outer and saltier margin of the marsh while C. lyngbyei grows in slough-like depressions, two feet deep, in the interior of the island where the concentration of the salt probably is somewhat reduced.

Fig. 7.15. 1885 Topographic Map by the U. S. Coast and Geodetic Survey of tidal marshes of the Umpqua Estuary. To be compared with the aerial photograph below.

Fig. 7.16. 1954 Aerial Photograph by the U. S. Army, Corps of Engineers, of Reedsport and Bolon Island, showing the degree of urbanization on the marshland.


Reed Barr
Ragged Tree
Scrofield
Creek
R I V E R


TIDAL MARSHES OF THE ALSEA RIVER ESTUARY
0
2000
4000
Scale in Feet
N
Bay-view
WALDPORT
LINT CREEK
NORTH CHANNEL
ALSEA RIVER
ECKMAN LAKE
LEGEND
Advance of tidal marsh between 1939 and 1961
Tidal marsh in 1939
Former tidal marsh filled between 1939 and 1961
Break in slope-upper margin of tidal influence
Levees and dikes
Tideland spruce
Tidegate

In the middle of the river opposite Gardiner several small islands have joined and some vegetation change may be noted. Although the elevated point of land formed from dredge spoil at the northern end of Cannery Island and the other mounds of spoil on the islands in the estuary are not marshland, it should be noted that they have become vegetated with Ammophila arenaria (European beach grass) in the last decade. The marsh at an intermediate elevation on the southeastern extension of Steamboat Island, an area absent in 1885, is clothed at present with about 70 percent Carex lyngbyei, 20 percent Agrostis alba, and the remaining 10 percent includes Elymus triticoides, Scirpus acutus (viscid bulrush) which stands 8 feet tall, Hordeum brachyantherum (meadow barley), and a few other species with low concentrations.

In general, the banks on most of the margins of the marshes are steep and have a two to four foot vertical rise, which leaves little chance for pioneer colonization because the mud flats are too far under water at high tide. With the exception of the expansion of the marsh at the southern end of Steamboat Island, the vegetation is relatively stable at present. For example, very few circles of primary invading species are found on mud flats exposed at low tide.

ALSEA ESTUARY

The bay in the vicinity of Waldport is one half to one and a half miles wide at high tide and the deep water channel is 5 to 15 feet deep at lower low tide (Fig. 7.17). Above Waldport the main channel of the Alsea River was only one or two feet deep at lower low water in 1914 (U. S. House of Rep., 1915:6), although it must be considerably deeper now since the north channel of the river has been blocked off by three dams and all the flow is directed through the south channel. This has concentrated the flow, probably deepened the channel in the center of the stream, and deposited sediment on the south bank. The residents had hoped the south bank would become steeper through erosion, which would have made docking their recreation boats an easier task.

The estuary has never been developed as an ocean port; it is used only by fishing boats and other boats with a draft of less than 8 feet, due to the shallow bar at the mouth of the bay. The average range from higher high to lower low tide at the mouth of the river is about 7 feet (U. S. House of Rep., 1915:5). It is probable that in times of flood the greatest deposits are made on the tidal marshes. Between 1939 and 1959 the maximum discharge of 32,200 cubic feet per second occurred on December 21, 1955, at a time when the stream gauge height showed 23.8 feet. The maximum stage known is approximately 29.5 feet on or about February 3, 1890, which is based on a floodmark shown by an old resident (U. S. Geol. Sur., 1960:225). On the basis of estimates of area above the stream gauging station on the Alsea River by the U. S. Geological Survey (1959:225) and the number of sections counted on the U. S. Topographic map for the area below the stream-gauging station, the area of this watershed is about 450 square miles.

The abundant timber resource, instead of being processed locally and shipped from this estuary, is moved by truck north, south, and east to loading points. According to the Forest Service(1944), much of the Douglas fir, cedar, and hemlock now growing on the Alsea watershed is the result of regrowth since the 1846 or 1847 forest fires that swept the Coast Range.

Tidal marsh vegetation in significant quantities extends along the estuary of the Alsea River for about 8 or 9 miles from the mouth. The additional 5 or 6 miles of estuary, to the head of tide (about two miles east of the Tidewater post office), has relatively steep banks and the river terraces have "estuarine" waters on them during maximum floods only; hence there is no problem of high salt concentrations in the pastures on the terrace.

The only weather records for the lower Alsea River are those taken three miles northeast of Tidewater, upstream, 11 miles east of Waldport. The precipitation averaged 93.2 inches in 10 years of records that are complete between 1940 and 1952, with extreme values of 118.4 inches in 1950 and 76.3 inches in 1952. The lowest temperature recorded in 11 years of record was 8 degrees F. in the month of January and the highest temperature was 105 degrees F. Such extreme temperatures probably do not obtain at Waldport.

Shoreline Changes of the Alsea Estuary

Relatively few changes in the shoreline due to natural accretion have occurred (Fig. 7.18). The marsh vegetation on one small island in the center of the river has extended into the tidal sloughs that formerly drained the island, and the area in front of the levee at Eckman Lake is also one of the most important areas of expansion of tidal marsh vegetation since 1939. The southern and western shorelines of the islands are obviously retreating slowly because they have steep sides, four to six feet high, and are bare of vegetation; about five percent of the margin has caved off the islands and the sections of sod

Fig. 7.17. Tidal Marshes of the Alsea Estuary.

and mud lie at the base of the banks. The marsh sod lies in the water at high tide and is eventually washed away. At times the patches of sod may come to rest on formerly bare mud flats and serve as a focal point for colonization by some of the marsh species that are more tolerant of salt than the original species found in the sod of the higher marsh, for the tolerant forms are given a chance to establish themselves while the mud is held together in a clump. This process is also observable at Nehalem, Tillamook, and Siletz bays. The marshes are built up with varve-like layers of clay and silts. When the weaker material washes away as the waves undercut the margins of the marsh, shallow, natural terraces form on the steep banks. The texture of the soil exposed in these banks could be investigated more fully to gain an insight into conditions at the time the marshes were being built.

The major modification of shoreline and drainage characteristics in the Alsea Estuary has been the result of human activities. During the summer of 1961, ditches were being cut with a bucket dredge in several places along the south shore of the estuary. These ditches, from 10 to 15 feet wide, were being dug to provide landings for small craft, and to provide mud for raising the level of the land, so that some use could be made of the land during times of high water in the winter; the ditches also drain the tidal marsh during the summer to allow better utilization as livestock pasturage.

Dredge spoil and dry fill have been used to create dry land where once mud flats and tidal marshes existed. Sea walls of stone rubble have been constructed around the bay shore of Waldport. On the northeastern corner of town near the small boat basin, a sandy mud flat behind the dike has been filled and leveled. A quarry next to the small area of fill (Fig. 7.17) on Lint Slough was used to fill that area of the slough and also to fill the triangular plot on the east side of Waldport, shown on Figure 7.17. Dry fill was also used to raise the rectangular area on the southern shore of Alsea River near Drift Creek; a hillside across the highway was used to change the marsh to a trailer park.

The diking and the installation of tide gates in two places on the north shore has allowed the utilization of an old ox-bow meander for pasturage (Fig. 7.11). On the south side of the river old dikes have served to protect some pasturage, especially east of the region where Drift Creek empties into the Alsea River.

The highway bridge across the old Eckman Slough was converted into a solid-fill levee with two units for regulating water drainage through this levee in 1958. The fresh-water level is now controlled by an overflow spillway under the road and a low,level, manually operated, drainage culvert capable of draining the lake at low tide. Today Eckman Lake is an important recreation spot, providing facilities for boating, water skiing, and swimming. As a consequence of the change in movement of tidal waters and the lack of a scouring action at the mouth of the old slough, the portion of the old slough on the river side of the levee is one of the places where natural accretion of mud and tidal marsh is most rapid. Colonies of Triglochin maritima are sprouting on the mud and once established allow other species to invade the soil.

Several marshy islands have developed in the middle of the Alsea Estuary, north and east of which, formerly, the North Channel of the river carried a considerable volume of water until the flow from the river was blocked by the construction of three dams. The location of the dam in the North Channel between the eastern island and the mainland was determined by the availability of rock from a cliff at the edge of the river. Two dams or, more properly, impediments to stream flow have been built of piling and junk, such as logs and automobile bodies; all of this has trapped enough sediment to stop stream flow from the South Channel to the North Channel. The dams have produced a backwater slough out of the former North Channel, and now this provides a huge trap for migrating salmon, which are subsequently slaughtered by seals in the bay. It is unfortunate that a hard rock wing or deflection jetty could not have been built upstream from the most easterly of these three entrances to the North Channel, so as to concentrate the flow in the South Channel, but retain an outlet for the salmon. Eventually, it may be presumed, "North Channel Slough" will fill in with detritus sufficiently to reduce the volume of tidal water and remove the rapid stream flow on ebb tide that now attracts the salmon.

Vegetation of the Alsea Estuary

The plants that are the primary invaders of the tidal flats of the Alsea Estuary are Triglochin maritima, Salicornia ambigua, and Scirpus americanus. Of these Triglochin maritima is the most frequently encountered plant on the main bay; it is growing in exposed situations, such as the northern end of the northernmost islands in the estuary, the islets along the south shore of the estuary east of Lint Slough, the rapidly filling region at the mouth of the former Eckman Slough (now a backwater created when the slough was dammed), and the northernmost shore of the estuary. Salicornia ambigua is most abundant along the marshy margins of the backwater sloughs, such as Lint Slough and two other little sloughs between Lint and Eckman sloughs. Scirpus americanus is found at slightly higher elevations, by two or three inches, than Triglochin maritima when they occur together on the extreme northern shore of the estuary.

Fig. 7.18. 1914 Hydrographic Chart by the U. S. Army, Corps of Engineers, of the Alsea Estuary, emphasizing the similarity of conditions 47 years ago.

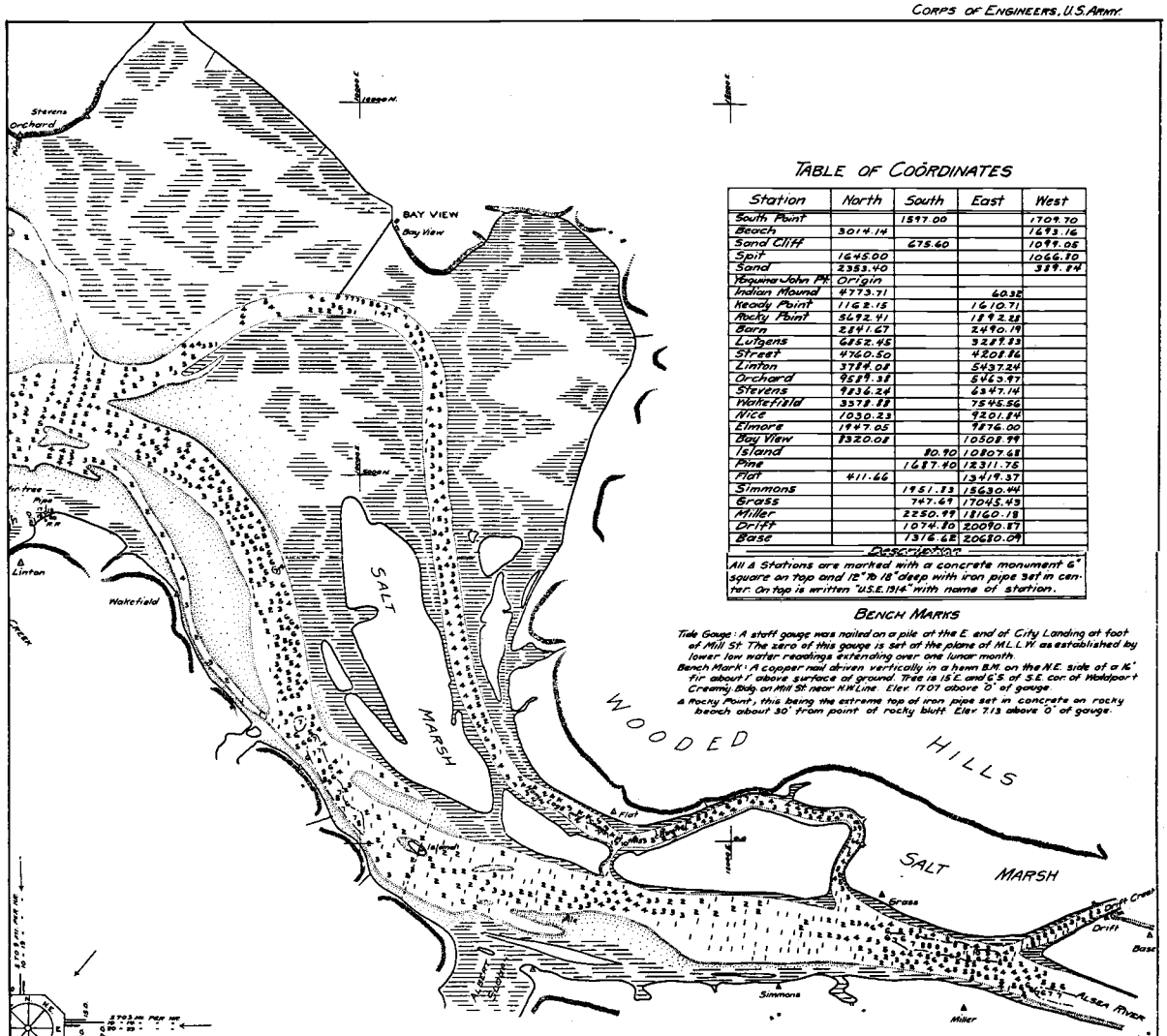


TABLE OF COÖRDINATES

Station	North	South	East	West
South Point		1597.00		1709.70
Beach	3014.14			1693.16
Sand Cliff		675.60		1099.05
Spit	1645.00			1066.10
Sand	2383.40			339.84
Higgins John Pt.	Origin			
Indian Mound	4773.71		60.32	
Heady Point	1162.15		1610.71	
Rocky Point	5492.41		1892.28	
Barn	2841.67		2490.19	
Lutgens	6852.45		3229.83	
Street	4760.50		4208.86	
Linton	3784.08		5437.24	
Orchard	9589.38		5463.47	
Stevens	9836.24		6347.14	
Waldfield	3378.88		7545.56	
Nice	1030.23		9201.84	
Elmore	1997.05		9876.00	
Bay View	9320.08		10508.99	
Island		80.90	10807.68	
Pine		1687.40	12311.75	
Flat	411.66		13419.37	
Simmons		1951.83	15630.44	
Grass		747.69	17045.43	
Miller		2250.99	18160.18	
Drift		1074.10	20090.87	
Base		1376.68	20680.09	

Description

All A Stations are marked with a concrete monument 6" square on top and 12" to 18" deep with iron pipe set in center. On top is written "U.S.E. 1914" with name of station.

BENCH MARKS

Tide Gauge: A staff gauge was nailed on a pile at the E. end of City Landing at foot of Mill St. The zero of this gauge is set at the plane of M.L.L.W. as established by lower low water readings extending over one lunar month.

Bench Mark: A copper nail driven vertically in a hemlock B.M. on the N.E. side of a 16" fir about 1' above surface of ground. Tree is 15 E. and 6 S. of S.E. cor. of Waldport Creamy. Bldg. on Mill St. near N.W. Line. Elev. 17.07 above "0" of gauge.

▲ Rocky Point, this being the extreme top of iron pipe set in concrete on rocky beach about 30' from point of rocky bluff. Elev. 7.13 above "0" of gauge.

Diagram

U.S. Weather Bureau of wind velocities at the mouth June 30, 1913 and is characteristic of the whole by arrows

12 0 20 40 60 DAYS

0 100 MILES PER HOUR

ALSEA BAY, OREGON.

ENTRANCE TO MOUTH OF DRIFT CREEK.

SURVEYED JULY—AUG. 1914.

UNDER THE DIRECTION OF

MAJOR J. J. MORROW,

Corps of Engineers, U.S.A.

J. S. POLHEMUS, ASS'T. ENGR.

C. R. Wright, Surveyor.

Scale

1000 0 1000 2000 3000 FT.

U.S. Engineer Office, First District,
Portland, Ore., Dec. 26, 1914.

Approved: Jay J. Morrow
Corps of Engineers, U.S.A.

To accompany report of Dec. 26, 1914
to the Chief of Engineers.

LEGEND

Soundings are expressed in feet and indicate the depth at Mean Lower Low Water.

The 6' contours are shown thus

" 12' " " " "

" 18' " " " "

" 24' " " " "

Proposed jetties are shown thus

—Walter P. Stewart, Col.—

On the northern shore at Bayview, the intermediate elevation marsh has a species composition made up of 60 percent Scirpus americanus, 15 percent Salicornia ambigua, 10 percent Distichlis spicata, 5 percent Triglochin maritima, and 10 percent Deschampsia caespitosa. The latter is restricted to higher sites in this elongated marsh at the toe of the cliff of Shepard's Point (where the railroad used to interconnect Waldport and land across the bay). Carex lyngbyei is the most prevalent species along the northwest of Bayview shore, above a belt of Scirpus americanus. Flood tossed logs form a tangle of driftwood above the level of the Carex lyngbyei.

Several tideland spruce are growing on the higher marshes of the estuary where they germinated on old, rotten or bark-covered logs. These logs are deposited naturally at periods of high flood when all the non-diked marsh lands of the estuary are under water. The occurrence of such violent floods is not too frequent on the Alsea River, since the little seedlings are commonly six to seven years old; they could hardly reach this age if every year or two these great logs on the marshes were floated and over-turned.

TILLAMOOK BAY

Tillamook Bay is six miles long and up to three miles wide. The five rivers that empty into the bay have a combined drainage area of 574 square miles. At the southeast end of the bay the Kilchis and Wilson rivers have tidal marshes in their delta regions (Fig. 7.19). These marshes have been expanding rapidly in recent years (primarily as a result of the deposit of river-borne sand), although a part of the sediment - silts and clays - may have been deposited in their delta regions. This is especially true in the case of the Wilson River, as a result of the redistribution of material in the bay by the tides (Einstein, et. al., 1961). The description of the economy and landform of the Tillamook region has been well summarized by the U. S. Army, Corps of Engineers, as follows:

> At the southeast end of Tillamook Bay, the merging valleys of the Kilchis, Wilson, Trask, and Tillamook Rivers form a broad alluvial plain on which is located the heaviest concentration of large dairy farms within Tillamook County. The lower portion of the plain, nearest the bay, contains a network of waterways formed by the river channels and by numerous branching sloughs. Within this portion of the plain, five organized drainage districts cover a total area of 2,754 acres. Considerable bank protection and levee construction has (have) been done within this area by private interests, county forces, and by relief agencies (U. S. Sen., 1954:8).

Along the shoreline of Tillamook Bay, 23 miles of levees had been constructed by 1952; these have been extended and raised since then. The dikes hold out the normal high tides but serious floods are still a potential problem during periods of heavy winter and spring runoff.

The extremes of annual precipitation in the city of Tillamook during the period 1933 to 1952 were 130.29 inches maximum in 1933 and 64.62 inches minimum in 1935, with an average value of 88.58 inches. The extremes of temperature recorded in this vicinity were 101 degrees F. in June and 0 degrees F. in December over the 19 years. Continuous records of floods in the Tillamook Bay drainage are available only from 1931 to 1959, and of these the greatest flood was that of December 1933. In a six day period, 16.58 inches of rain was recorded in Tillamook, with a maximum 24-hour rainfall of 3.88 inches. Nearly 10,000 acres of land were inundated as a result (U. S. Sen., 1954:10). The flood following the devastating forest fire of 1933 (the Tillamook Burn) caused a great amount of sediment to be carried down onto the delta region; white sands at the mouth of the Kilchis River can be seen on the 1939 aerial photographs (Fig. 7.19). "Precipitation records at Tillamook over the period of record indicate that similar floods probably occurred in 1897 and 1914." (U. S. Sen., 1954:10). The estimated peak discharge from the Wilson River was 30,000 second feet and 20,000 second feet for the Trask River, the only two rivers with gauging stations.

About 240,000 acres of Douglas fir, hemlock, spruce, and cedar forest in the Kilchis, Wilson, and Trask watershed were destroyed in the Tillamook Burn of 1933; 50,000 acres were burned in 1939, and 65,000 acres in 1945. Some of the 1939 and 1945 fires took place in the area of regrowth of the earlier fire. This aggravated the sedimentation problems and the Kilchis River, at least, has changed its course several times in its delta region, as a result of the great amount of sand that has been dropped (Fig.7.20)

Tidal range at the entrance of Tillamook Bay from mean lower low to mean higher high water is 7½ feet, and the extreme range is about 13½ feet (U. S. Sen., 1954:6). In the vicinity of Tillamook the tidal range from mean higher high to mean lower low is 6.6 feet with an estimated maximum range of 15 feet (Table 7.3).

Fig. 7.19. 1939 aerial photograph by the U. S. Army, Corps of Engineers, of the delta of the Kilchis River.

6.01

TABLE 7.3

TIDE PLANE	BARVIEW (Mile 0.0)	GARIBALDI (Mile 1.5)	TILLAMOOK-HOQUARTEN SLOUGH (Mile 10.0)
PERIOD OF OBSERVATION	JULY-NOVEMBER 1933	MAY 1933-APRIL 1934	SEPTEMBER-NOVEMBER 1933
Highest tide (est.)	+7.0	+7.2	+9.3
Mean higher high water	+3.47	+3.56	+3.86
Mean high water	+2.77	+2.86	+3.16
Half-tide level	-0.08	+0.06	+0.56
Mean low water	-2.93	-2.74	-2.04
Mean lower low water	-4.03	-3.84	-2.74
Lowest tide (est.)	-7.0	-7.3	-5.7

(U. S. Sen., 1954:11).

The Miami River flows into the northeastern side of Tillamook Bay (Fig. 7.21). It is a relatively small river and no data is available on conditions of stream flow, though tidal fluctuations near its outlet at Garibaldi have an average range from mean higher high to mean lower low water of seven feet and a maximum estimated range of 14½ feet.

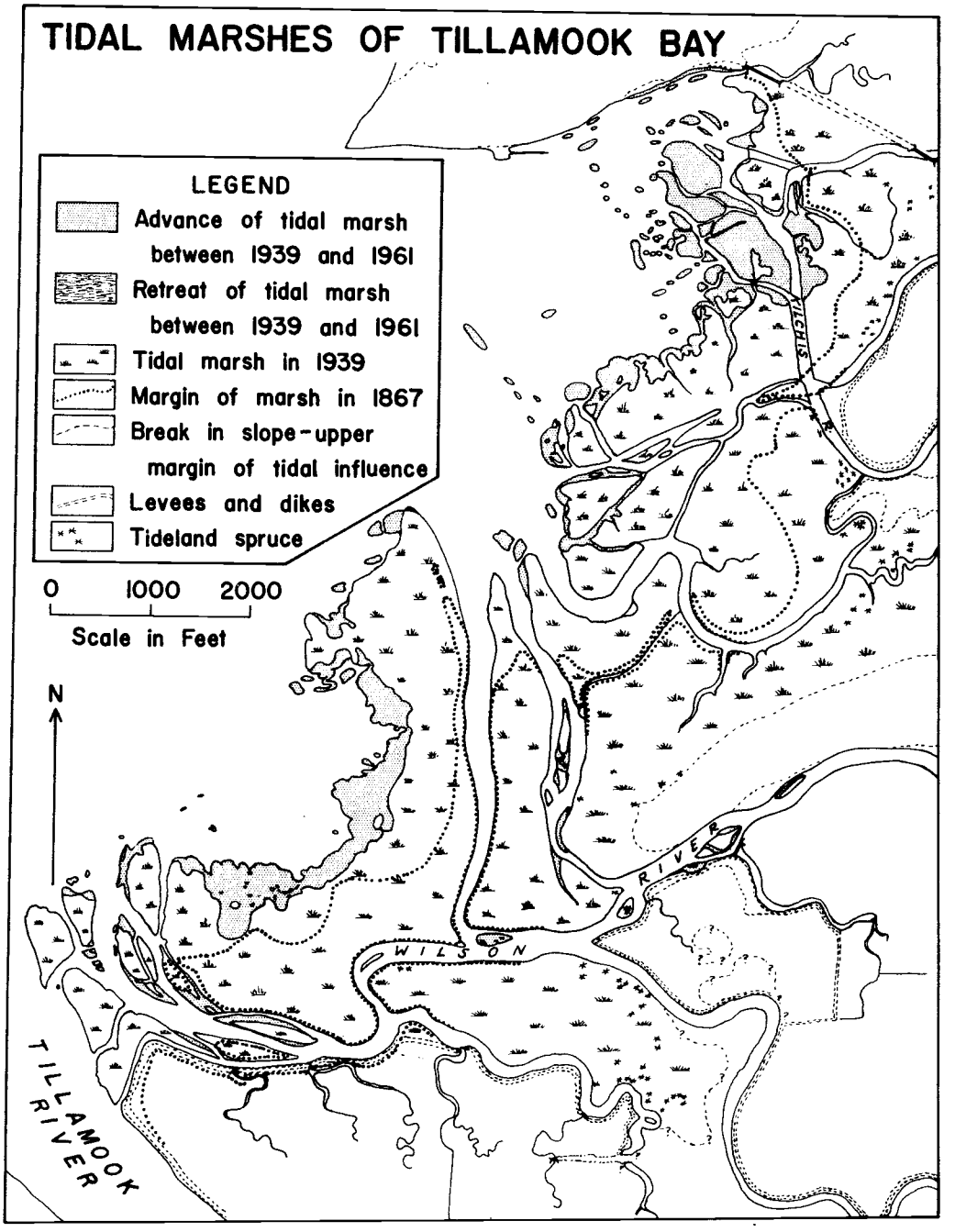
Shoreline Changes of Tillamook Bay

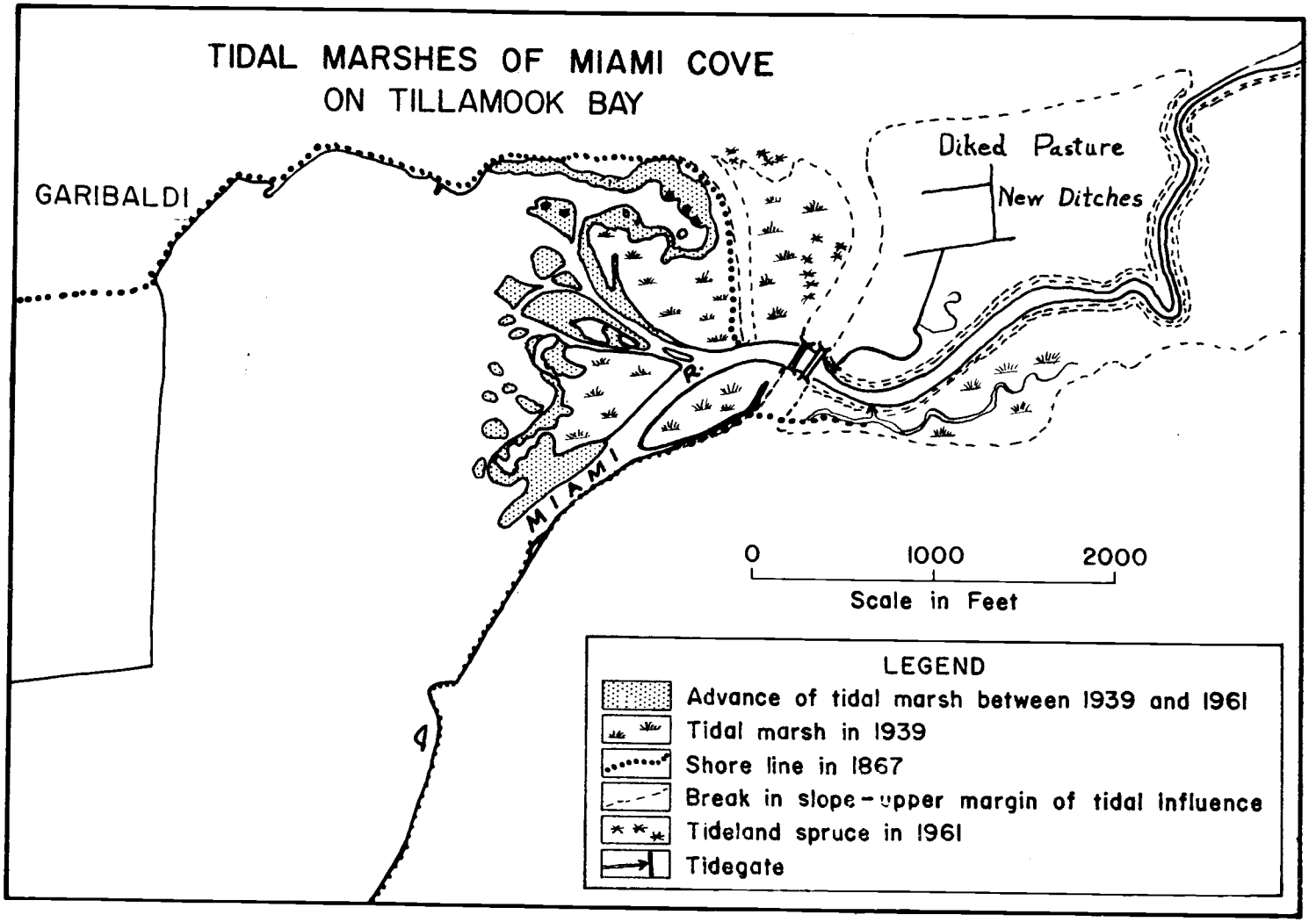
By taking a broad view of depositional features in Tillamook Bay, the largest of the bays considered in this report, the sediment of quaternary origin has been deposited in four valleys that have now fused into one deltaic front in the southern end of the bay, across which pour the waters of the Kilchis, Wilson, and Tillamook rivers together with a tributary of the Tillamook River, the Trask River. These river systems are divided by ridges of indurated conglomerate of a similar textural composition. The toes of the ridges to the north of the Kilchis River and north of the Wilson River both have a sharp rise of five to eight feet and indicate that the bay waters have truncated the seaward extension of the ridges at a time when they were unprotected by marsh. Kilchis Point is still unprotected by marsh, although a wide sandy flat may serve the purpose of protecting the toe of the ridge now. The slope of these ridges is fairly straight with a gradient of 15 to 20 feet per mile up to an elevation of 60 or 70 feet at the foothills. They appear to be the remnants of old alluvial fans or aprons truncated by streams with rejuvenated load-carrying capacity during some period of tectonic uplift of the Coast Range or because of a low sea stand, but now sediments from the streams are once again filling in the bay around the ridges. Because of the surface slope and the large size of the gravels and occasional cobbles, it is likely that these old terraces were laid down subaerially. At present gravels and cobbles of a comparable size are found on the flats of the Kilchis River delta at a distance of less than 100 yards from the margin of the marsh vegetation; the slope of the present river bed is about 10 feet per mile. The slope of the Wilson River for some distance upstream, by comparison, is two to three feet per mile.

The rapid advance of tidal marsh vegetation in the deltas of the Kilchis and Wilson rivers is a direct result of the great amount of silt carried down by these two rivers (Fig. 7.20). (The various changes in the southern portion of the bay have gone unrecorded on the U. S. Coast and Geodetic hydrologic charts of Tillamook Bay since 1867. The Coast and Geodetic Survey has decided to bring their charts up to date.) The white deposit, which shows in the 1939 Corps of Engineers aerial photographs of the Kilchis River, indicates the location of the sands, silts and cobbles dumped down stream when a cut off was dredged across a peninsula of marsh (Fig. 7.19). The cut off shortened the Kilchis River by two thousand feet but caused considerable silting and subsequent marsh growth in that eastern embayment of Tillamook Bay. The white deposits have since become brown due to silts and organic debris and are partially vegetated. The Wilson River Valley is much longer and broader and, therefore, sediments have more chance to be deposited over the greater flood plain and also one of the distributaries empties into the bay in such a way as to have its load removed by the Tillamook River. The net result is a different type of delta formation on the Wilson River for there have been no large deposits of white sand here as there were on the Kilchis River. However, the broad surfaces of the mud flats of both deltas are now characterized by similar brown, silty sands and silt loams.

It should be emphasized that the delta region of these two rivers has filled considerably during the era of the Europeans. From 1867 to 1939 the accretion to the tidal marsh resulted in a shoreline advance of 500 to 1500 feet (about 14 feet per year on the average); in the last 22 years the margin has extended

Fig. 7.20. Tidal Marshes of Tillamook Bay.


TIDAL MARSHES OF TILLAMOOK BAY
LEGEND
Advance of tidal marsh between 1939 and 1961
Retreat of tidal marsh between 1939 and 1961
Tidal marsh in 1939
Margin of marsh in 1867
Break in slope-upper margin of tidal influence
Levees and dikes
Tideland spruce
0 1000 2000
Scale in Feet
N
TILLAMOOK RIVER
WILSON RIVER
KILCHIS R.


TIDAL MARSHES OF MIAMI COVE
ON TILLAMOOK BAY
GARIBALDI
Diked Pasture
New Ditches
MIAMI
0
1000
2000
Scale in Feet
LEGEND
Advance of tidal marsh between 1939 and 1961
Tidal marsh in 1939
Shore line in 1867
Break in slope - upper margin of tidal influence
Tideland spruce in 1961
Tidegate

200 feet on the average (about nine feet per year) across formerly bare mud flats. Therefore, the rates have been roughly the same and it may be assumed that the process will continue. As the marsh expands it may be assumed also that dikes will be built and extended, and that material dredged from the sloughs and stream channels, to maintain channels for boats, will be used to create dry land of high value.

By photographic interpretation it is possible to differentiate the marshes of 1867 from the more recent additions to the tidal marshes of Tillamook Bay (U. S. Coast Survey, Tillamook Bay, 1867). This border line is shown by a large dotted line on Figure 7.20. The older marshes appear darker in tone and often have a lightly shaded zone at their perimeter (Fig. 7.19). Since this interpretation was not confirmed until the later stages of the analysis, no field check has been made to determine exactly the floral composition of these older marshes. The 1867 borderline of the tidal marshes is discernible on aerial photographs of the deltas of the Wilson and Kilchis rivers. This indicates that a major change in the processes of accretion to tidal marshes occurred subsequently to 1867, since there is nothing comparable to the old borderline in the deposits and marshes that have developed subsequently.

The site of the first big deposit laid down after the 1867 map was drawn was to the south of the westerly extension of the channel of the Kilchis River. This deposit filled the embayment in the islands to the south by 1892 (U. S. House of Rep., 1892) as shown on the map of the U. S. Army, Corps of Engineers. By 1914 islands had formed on the north side of this same channel, to the west of the old mouth of the Kilchis River (Whitney Co., map, 1914). The Kilchis River bypassed a longer route to the bay, which it had formerly built, and flowed due north, from the 1920's to the 1950's; during this period it kept a channel open fairly close to the mainland of Kilchis Point. The heavy load of silt and sand carried by the river has filled in a relatively large area of the bay in this northern location. In the last two or three years the Kilchis River has been entering the bay through a more central distributary and has once again caused a shift in the site of major deposition of sand and silt.

Observations on the margins of Tillamook Bay reveal the fact that the population density of the bay is very closely related to the elevation of the ground. The city of Tillamook, for instance, is situated on one of the indurate gravel ridges discussed earlier. The large elevational differences on the southeast side of the bay are closely related to these old gravel ridges. Other marshes around the bay have also undergone considerable expansion such as in the delta of the Miami River near Garibaldi (Fig. 7.21), which has extended out into the bay 1000 to 1400 feet since 1867 when the first detailed map was drawn. Considerable disturbance of the waters and muds of Miami Bay has resulted from the continual activity in the log ponds of the lumber mill at Garibaldi. The specific effects of this disturbance are unknown.

When the ocean broke through Bayocean Peninsula in 1952, large quantities of sand and boulders were washed into the bay. About one third of the extensive oyster beds were covered and ruined (U. S. Sen., 1954:15); for a time the surges from ocean waves did damage to property, houseboats, and pilings along the margin of the bay. The ocean waves have ceased now that the levee has been constructed across the opening but the oyster beds that were covered remain a loss. In the future, the broad sand flats will be colonized by tidal marsh vegetation after the sands of the peninsula become better stabilized. As it is now, clouds of blown sand, 6 to 10 feet high, were observed (in the summer of 1961) moving across the flat spit and out over the shallow water for a distance of 15 to 25 feet. This amount and rate of accretion of sand may have been atypical, but if not, would account for the present lack of vegetation along the margin of the peninsula.

Vegetation of Tillamook Bay

The most abundant primary invaders in the delta of the Kilchis River are Carex lyngbyei and Scirpus americanus. These two species comprise over 95 percent of the little circular colonies and sinuous margins of the larger islands that have developed in the last 22 years (Fig. 7.20). Carex lyngbyei is frequently the species in the circular colonies out on the sandy mud flats and along the margin of the islands, whereas Scirpus americanus most commonly serves to join the little colonies to the larger islands. A third plant, Scirpus robusta, has its main distribution in a nearly pure stand along the mainland in the vicinity of the railroad bridge to the northeast beside the old channel of the Kilchis River (Fig. 7.19). The soil here has a much higher content of clay and smaller amount of sand on the north side of the old channel, in comparison to the main mud flats of Tillamook Bay.

Several of the larger and higher islands in the delta of the Kilchis River have been deposited relatively recently and rapidly, since the soil profile is likely to have a six inch layer of brown, coarse sand overlying two or three inches of black, stinking woodchips or leaf remains, under which are apt to be interbedded layers two to four inches thick of black and brown sands. The top six-inch layer of

Fig. 7.21. Tidal Marshes of Miami Cove, Tillamook Bay.

coarse sand apparently was deposited in a very short time because it appears completely homogeneous and has resulted in unusual islets in the delta. They are high enough that Deschampsia caespitosa, a grass that usually occupies only the old, mature marshland, is colonizing the otherwise bare sand now and has occupied most of the region of the "white deposit" of 22 years ago. Probably the sand islands are sufficiently elevated that the salt concentration has never reached a value that was too high for Deschampsia caespitosa to grow. The surface of these higher delta islands is somewhat uneven, as might be expected from their rapid deposition, and Carex lyngbyei often forms an important component of the flora in slightly lower and wetter sites in juxtaposition with Deschampsia caespitosa.

The circular clumps of primary colonization at the western-most mouth of the Wilson River consist of Triglochin maritima, whereas, in general, the expansion of the marsh between the mouths of the distributaries of the Wilson River, has occurred on a broad sinuous front rather than by the agglomeration of small islands into larger ones by sand burial, as has been the case in the delta of the Kilchis River.

NEHALEM BAY

The Nehalem Bay is about five miles in length and the greatest width is a mile and a half on the downstream side of Dean's Point (Fig. 7.22). The point is composed of hard rock running parallel to the river and deflects the river into a wide curve. A mile square embayment is the only large area of tidal marsh in the estuary; other embayments have been diked and drained.

The Nehalem River follows a circuitous course of over 100 miles and drains an area of about 862 square miles. Most of this area is timbered with Douglas fir, cedar, spruce, and hemlock, although a dense, shrub cover now grows on the areas affected by the northern extension of the Tillamook Burn in 1933. Extensive logging and milling operations in the forest, no doubt, have increased the load of sediment carried by the river (U. S. House of Rep., 1942b:7). The precipitation records from nearby stations indicate that on the average the coast, in the vicinity of the Nehalem River, received approximately 85 inches of rain per year and the mountains, in the vicinity, somewhat over 100 inches. The bottom land in both the upper and lower portions of the river is used in agricultural pursuits of which dairying is predominant. In those areas where saltwater inundation would be a problem, the lowlands have been diked with the exception of the islands and tidal marshes in Nehalem Bay below the town of Wheeler. Tidal influences extend nine miles inland, but flooding of large flat areas as a result of normal tides now extends only six miles upstream.

Information on the tidal conditions is summarized by the U. S. Army, Corps of Engineers as follows:

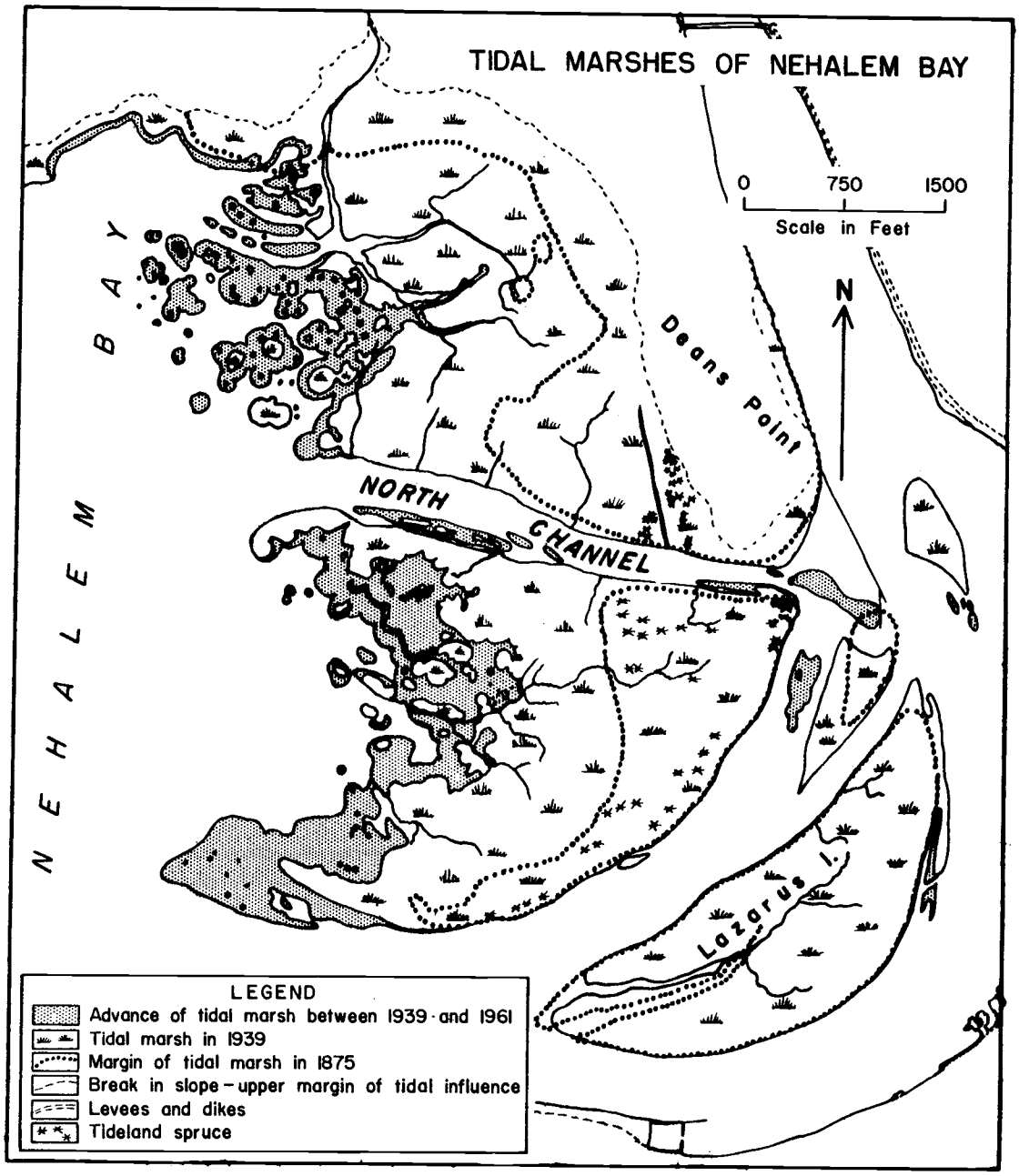
> The range of tide at Nehalem, from mean lower low water to mean higher high water, is 7.2 feet. The higher tides rise to about 9.5 feet above mean lower low water, while the highest tide known was recorded at Wheeler, January 3, 1939, at 11.7 feet above mean lower low water. In its lower reach, the river is about 200 feet in width with a depth of 7 or 8 feet at low water. (U. S. House of Rep., 1942b:6).

Shoreline Changes of Nehalem Bay

The increases in the areal extent of the tidal marshes in Nehalem Bay are large. The broad area of mud flats provides a sensitive instrument for measuring accretion of sediments or tectonic uplift. An inch or two difference in elevation would make it possible for the tidal marsh vegetation to extend many feet into what had been mud flats. By a comparison of the map (Fig. 7.22) and the earliest U. S. Coast Survey chart(1875) of Nehalem Bay (Fig. 7.23), the shoreline, defined as the beginning of densely-spaced vascular plants, has expanded rapidly at the expense of the bay since 1875. In the period between 1875 and 1939 the margin of the tidal marsh moved 1200 feet across the bay, an average of approximately 18 feet per year. Since 1939, the margin has moved 600 feet or about 27 feet per year. Lazarus Island, however, has not changed appreciably in the last 22 years and only slightly since 1875.

The 1875 chart shows two types of marsh in the Dean's Point area (Fig. 7.23). The symbolization on the outer marsh, drawn with less sharpness of detail, is in a position that indicates it must have been a new low tidal marsh. The outline of the other marsh indicates it was probably a higher, drier, and more mature marsh. The 1875 margins of the oldest marsh are visible as a distinct line on the marsh in the 1939 and 1960 aerial photographs; these are currently marked by windrows of old logs (Fig. 7.24).

Fig. 7.22. Tidal Marshes of Nehalem Bay


TIDAL MARSHES OF NEHALEM BAY
0
750
1500
Scale in Feet
N
NEHALEM BAY
NORTH CHANNEL
Deans Point
Lazarus I.
LEGEND
Advance of tidal marsh between 1939 and 1961
Tidal marsh in 1939
Margin of tidal marsh in 1875
Break in slope – upper margin of tidal influence
Levees and dikes
Tideland spruce

The somewhat darker tones on the aerial photographs denoting the high old marsh indicates that it has a distinctive flora, either because of different species, which is most likely, or because of a denser growth on the drier sites.

Vegetation of Nehalem Bay

The most numerous species of the tidal marshes undergoing rapid change at lower elevations in Nehalem Bay are Scirpus robusta, Carex lyngbyei, and Triglochin maritima. Scirpus americanus and Salicornia ambigua were not encountered along the western margin of the marsh shown in Figure 7.22, although they are a normal component of the comparable tidal marsh flora farther south in Oregon. However, Salicornia ambigua, at least, is found in a backwater on the south shore of Nehalem Bay where the bay water has a limited access through a culvert under the railroad embankment. Scirpus robusta is usually found on the edge of the marsh next to the open bay or mud flat. It is possible to identify most of the present-day colonies in the 1939 aerial photographs, for they have expanded concentrically around their original center and fused to form distinctively-shaped marsh islands, in a manner similar to that of a sparse population of mold on an agar plate. Occasionally, the vegetated center of these expanding islets of Scirpus robusta has died out and the bared root stalks are left exposed in the mud. It appears as if some of the soil, trapped by the growing colony, has been removed from the dead center of the islets. That sand and silt are eroded from portions of the mud flats at times is demonstrated by the fact that beds of dead, soft-shelled mud clams can be seen with the shells in a vertical position exposed in the mud. Whether the two processes are related, however, is somewhat doubtful.

Other species also form circular colonies on the open mud flats. Carex lyngbyei is a primary invader of the mud flats on the north side of the north channel, which passes through the marsh; Carex lyngbyei is also found in the northern-most portion of the bay along the borders of the fresh-water creeks that enter the marsh. The tendency of C. lyngbyei to be in positions with lower salinity contents than the species of Scirpus or Salicornia is demonstrated by its habitat on the larger island south of Dean's Point and south of the north channel. Here C. lyngbyei grows on slightly higher ground than the band of S. robusta which, in turn, is generally higher than many small clumps of Triglochin maritima in the lowest and saltiest sites. Deschampsia caespitosa dominates the higher and older marsh from the oldest sites in the east to a line roughly comparable to the edge of the closed marsh in 1939. Therefore, on the basis of the appearance of the vegetation in the 1939 aerial photographs, D. caespitosa is now growing on sites that only 22 years ago were occupied by S. robusta.

The highest marsh land is the oldest and it is on this surface that virtually all the tideland spruce are growing. The spruce on the small piece of old marsh to the west of the southern end of Dean's Point were present in 1939, but have been cut down since then, perhaps at the same time the straight drainage channel was excavated. The spruce are shown on Figure 7.22 to emphasize the character of the marsh and the "undisturbed" distribution of the spruce.

CLASSIFICATION OF MARGINS OF THE ESTUARIES

For the purpose of estuarine research, the shoreline is defined as the margin of the land that has a dense enough vascular vegetation to be seen in the aerial photographs. Whether the shoreline is advancing or retreating may be determined by historical studies of old maps and photographs in comparison with the modern scene. The relative position of the margin and type of vegetation at various times in the past, in comparison to the present, is indicative of the rising or lowering of the mud flats adjacent to the margin of the tidal marshes. The classification of margins of the estuaries that is proposed is a simplified system including the categories listed in Table 7.4.

Fig. 7.23. 1874 Hydrographic Chart of Nehalem Bay.


U.S. COAST SURVEY
Carlile P Patterson Supdt
SECTION XI
COAST OF OREGON
BETWEEN
Latitudes 45° 38' and 45° 45'
INCLUDING
MOUTH OF NEHALEM RIVER
Surveyed
August 25 to September 11
1873
J. J. Gilbert
Supdt. U.S. Coast Survey
Desoly
Wooded
Point
Lighter
Nehalem River
Mount

TABLE 7.4

CLASSIFICATION OF MARGINS OF THE ESTUARIES

I. Advancing margin of marsh into estuary

1. Prograding margins

1a. Prograding margins associated with building of dikes and dumping of dredge spoil

II. Retreating margin of marsh

1. Eroding estuarine deposits along main channels

1a. Retreating margins as a result of excavation by man

III. Simultaneous advancing and retreating of marsh at different elevations in the same location

IV. Near equilibrium of shorelines in estuaries (where bed of main river is steep and close to shore)

Advancing Margin of Marsh into Estuary

Where deposits have been built up sufficiently to allow plants to grow and are stable enough to let them remain, the margins of the tidal marshes have been prograding. Prograding may take the form of a thin line of plants, circular colonies, or broad belts of primary succession vegetation that are trapping sediment, depending on the rate of accretion and the initial depth of water. Where the water is deep, the expansion of vegetation has been small; where the bay is shallow, small clumps of invader species usually establish themselves in circular colonies and, gradually, the marsh fills in around them until a virtually complete cover exists. At times the advance of the shoreline has been on a long, sinuous front.

The older margins of the mainland and island marshes often have a steep embankment of about one foot from the older, higher marshes to a lower level on which the rapid advance of the marsh is taking place (I-1). However, where the advance of the marsh has been long-continued, the gradient of slope of the marsh surface may be very gentle. Bare mud flats in the middle of bays seem to be building up very slowly in the large estuaries. The delta regions of the streams entering the bays, however, sometimes show a very rapid increase in elevation, as if sandy mud-flows had been sluiced into the margin of the bay. The "high" deposits that result from these mud-flows may be colonized initially by plants typical of the high marshes.

Another phenomena that causes the mud flats to build up in addition to those factors of entrapment by vegetation is the small mollusks' and crustaceans' pumping of sediment-laden waters through their digestive tracts and excreting inorganic soil particles which build small mounds, as much as three to four inches high, on the otherwise smooth mud flats.

Man-made modifications, such as dikes, levees, and road beds (I-1a), all present new shores on the estuaries and usually involve extensions of land at the expense of the water surface. The estuarine region of the Oregon coast has been extensively changed by human action. However, the necessary data, for instance, for the reconstruction of the history of diking, is very difficult to obtain because it has not been assembled by public agencies in the past. Dredge spoil has been used in large quantities in a few places to change marsh and mud flat to dry land.

Retreating Margins of the Marsh

Retrograding shorelines (II-1) are less usual than prograding ones and the processes are generally much slower in operation. The rate of retreat is slow enough that it is difficult to measure on the aerial photographs available, although it certainly is occurring because great chunks of marsh sod from

Fig. 7.24. 1939 aerial photograph by the U. S. Army, Corps of Engineers, of Dean's Point and the north channel through the marshes in Nehalem Bay.


4918

five to fifteen feet long and from one to two and one half feet wide can be seen caved off of high, and formerly undercut banks. Often five percent of the margin of the tidal marsh on the islands or mainland along the main river channels show this caving-in process. Natural changes in the meanders of the rivers in their deltas occasionally cut a channel through a marsh, presumably during a period of flood.

People have excavated channels in the marshes (II-1a) at an ever increasing rate for use as docking facilities and for draining the marshes (with or without tide gates). The value of flat lands near the water is increasing and, because of this, more capital can be expended to modify the natural endowments of the beautiful shoreline sites.

Simultaneous Advancing and Retreating of Marsh

The advance of the primary colonies occasionally may take place on the seaward side of an area where the higher marsh is being undercut and the bank is caving (III). It is as if both prograding and retrograding were taking place at the same time. This condition was found south of The Cutoff in the Umpqua Estuary, on the northern side of Alsea Bay near Bayview, and on an island in the middle of Siletz Bay. However, in all of these places where this dual process occurs, the lengths of the shoreline involved are relatively small, between 10 and 50 yards.

Near Equilibrium Shorelines

Where the bed of a main channel of a river is steep and close to shore the processes of erosion are in some temporary equilibrium with those of deposition, and colonization by plants is very difficult (IV). When, in addition, the shore is of an indurate parent material, little change may take place for long periods of time. Another condition of stability is induced when a channel of the river is used for navigation and is dredged to maintain the depth and position of the bed.

The classification of the estuarine margins proposed here is merely a summarization of the types of shorelines, which are likely to be encountered. The processes that operate to fill in the estuary with sediment prior to its becoming vegetated are left for the engineers to solve. It is definitely established that the vegetation, once started, can greatly accelerate the accretion process and induce changes in the shoreline.

THE MATERIALS AND TEXTURES OF THE ESTUARINE DEPOSITS

The materials of the mud flats and soil of the marshes may also be classified in broad categories on the basis of size of particle: gravel, sand, silt, clay. The estuaries and their constituent sloughs tend to fill up with sediment in two different ways. The gravels, sand, and silt carried down by streams in suspension or as bed load is deposited where the stream changes gradient and decreases its speed and, consequently, its carrying power. The colloidal material remains in the water until it is flocculated by the salts in the brackish water of the bay. The floc is dropped whenever the water stops moving; this occurs during the slack period of high tide for an hour or two, or it may occur within flooded marshes where the water is slowed by the great number of plant parts. The colloidal fraction (clay) in any given deposit may come from some other stream elsewhere in the bay, or it may be stirred up from the mud flats by winds and waves during the summer when incoming fresh water and sediment is at a minimum (Einstein, et. al., 1961).

When a floc of this type is deposited in a nearly pure form, the high water content incorporated with the clay results in a material that will support very little weight. If this deposit is deep, it may be quite treacherous for human travel, since a person wearing normal-size boots sinks into the floc. The material clings so tightly that a vacuum is created at the bottom of the hole when an attempt is made to pull out of the clay. If the material is sufficiently deep, as in Kentuck Inlet, Coos Bay, it is possible to become mired down so that a person cannot extricate himself without assistance. Lint Slough on Alsea Bay is well calculated to catch people, too. This soft "quick mud" is found in most of the drainage channels within the marshes and along the margins of the islands and mainland where rapid invasion of the marsh flora is not taking place. At times plants grow in the "quick mud", but whether they germinated in it or were covered over has not been determined in the field.

The texture of the great majority of the materials of the mud flats by contrast is usually a coarse sand with only small amounts of silt and even less clay in the summer time. The usual sandy deposit often packs tightly enough that footprints are only an inch or so deep. A distinctive variant occasionally is encountered in which the sandy surface of about the same texture has a very fluffy structure and one sinks into the sand three or four inches. Presumably, this fluffiness is induced by the deposit of flocculated clays, which stick the particles of sand together in an open structure, at the same time that the sand is brought in by the moving waters.

SUMMARY

Studies of the colonization and succession of vegetation on the mud flats of the estuaries of the Oregon coast assist in understanding the vegetation associations of the tideland marshes and the processes of sedimentation that build up land in the estuaries. Vegetation changes on the marshes are investigated in the following estuaries: Coquille, Coos, Umpqua, Alsea, Tillamook, and Nehalem. The study of the colonization of the mud flats leads directly to an analysis of the historical location of the margins of these tidal marshes through their position on old charts, maps, and aerial photographs taken in 1939 and the present. Field work carried out in the summer of 1961 is the basis for the descriptions of the plants and their locations.

The recent colonization is in an ecological habitat that allows, at any given elevation in the estuary, comparisons to be made between the marsh vegetation of the several river estuaries. The climate is maritime and relatively similar in all six estuaries; the slope is nearly flat over those areas that are rapidly being colonized; the parent material is usually a silty sand at the time that large scale colonization of the mud flats occurs, although in the bottoms of the large and small sloughs with water movement fairly well restricted to gentle tidal fluctuations and also where steep banks, five or six feet high, form the margin of the marsh, the parent material is usually much higher in clay content; a general lack of barriers to the movement of seeds of the marsh plants in this section of the coast is indicated by the similarity of floras from one estuary to another; the time factor of 22 years of marsh expansion is used for comparative purposes in the analysis of the vegetation; but, in addition, such longer time periods as are available from early charts are used for comparisons of the relative position of estuarine margins.

By using a time period of 22 years or less for the age of the marsh association that is studied intensively, the detailed description of the vegetation is directed to those areas of primary colonization of the mud flats. The presence of many circular colonies on otherwise bare mud flats is a sure sign of rapid expansion of the tidal marsh in the northern as well as the southern estuaries. Where the colonization is taking place on a long, homogeneous, and sinuous front the evidence of rapid colonization is not as readily seen on a stereo-pair of aerial photographs, although the change is readily observable with a historical sequence of photographs. Suggestions of rapid change by this latter type of colonization are available in the field with the observations of a nearly pure stand of Scirpus sp. or Carex sp. that have their rhizomes extending out into the unvegetated mud. The extent of the older tidal marsh area, as documented on the older charts and maps, allows inferences to be drawn on the successional sequences in the flora, their rapid change, and on the rate of sedimentation of each particular estuary.

The following species are the ones most frequently found in the estuaries and illustrate the successional process on mud flats from their initial colonization to high, mature, tidal marshes. Perhaps the most distinctive primary invader is Triglochin maritima as it is found in exposed sites at the lowest elevations in all the estuaries under consideration. Because of its strong tendency to proliferate by vegetative reproduction, it forms dense, circular or elliptical clumps often times several yards out on the mud in front of any other marsh plants. Salicornia ambigua grows as a major component of the lower, saltier flats of the marshes particularly in the south, whereas in the north it stabilizes banks at similar low elevations but it is not involved in the colonization of great stretches of mud flats. In the southern five of the estuaries Scirpus americanus is abundant in the somewhat less exposed sites, but grows at the same elevation as far as tide level is concerned as the two preceding species. A species with similar ecological characteristics, Scirpus robusta, flourishes in the sandy flats of Nehalem Bay and is found on the deposits of a watery clay - quick mud - in Tillamook Bay on the mainland border of the delta of the Kilchis River. Carex lyngbyei occurs in less saline habitats than Scirpus americanus or S. robusta, and is commonly associated with the upper and interior margins of their distribution, although where fresh-water streams traverse the marshes C. lyngbyei grows along their banks as far out on the mud flats as Scirpus americanus, for example. At various sites each of the preceding plants develop the circular colonies typical of single species that are expanding relatively rapidly on the mud flats. In other places these same species may occupy a broad belt which results in a coalescence of the circular colonies into a closed marsh cover.

Distichlis spicata is closely associated with Salicornia ambigua throughout its range and, similarly, it is more prevalent in the southern estuaries and much restricted in the two northern bays. Although D. spicata is rarely a primary invader on the mud flats, it rapidly invades the stands of S. ambigua at elevations that are built up very little from those that obtained at the time of their initial colonization.

The following group of species grows at intermediate or high elevations in the tidal marshes, usually in association with several other species and not in pure stands as often occurs with the primary invaders. In the southern estuaries Jaumea carnosa is an important subdominant in the tidal marshes at both the intermediate and higher elevations. At the higher elevations the plant associations become more diversified with Deschampsia caespitosa as the most universal and usually the tallest plant. Its mature panicles give the marsh its visual character, when viewed from a distance, as they wave above the other species such as Potentilla pacifica, Agrostis alba, Hordeum nodosum, Juncus balticus, J. effusus, and

many more.

The ways in which the mud flats gradually build up are many and varied; even though the clay fraction may be washed out of the sediments during the summer period of low stream flow with its attendant small sediment load, the larger grains of sand accumulate slowly on the main flats of the estuaries. A little burrowing shrimp builds up mounds three to four inches high on the mud flats, as a result of its continually pumping sediment-laden waters through its digestive tract. Once established at the lowest possible elevation, where they are inundated almost daily by the brackish tidal waters, the plants speed the process of trapping additional sediment, usually with a higher clay content than the sandy mud flats. The tidal marsh increases in elevation relatively rapidly as a result of this entrapment. Certain tidal marshes show considerable expansion during the last 22 years and particularly during the last 70 to 90 years.

Due to the availability of 19th century maps and modern aerial photographs, and the maps made from them, a record of change is available in all the estuaries studied, although in the Alsea Estuary the marshes have not expanded appreciably. However, for the Alsea Estuary there is only one 19th century map, 1887, and it only shows the tip of the island region of the estuary; this tip was very nearly the same as it is at present. It is unlikely that the upper regions of the estuary could have been much smaller in the past than now. The lack of more extensive changes in the Alsea Estuary is not readily explainable, for extensive mud flats exposed at low tide have been present since at least 1914. Why they have not been colonized and additional sediments trapped remains an unsolved problem that should prove fascinating at a future time. Differences in land use, geology, landform, and fire history are all likely causes.

The earliest map found for any of the marsh borders of the six estuaries, considered here, is one of Tillamook Bay in 1867. The aerial photographs taken in 1939 and also in 1960 of Tillamook Bay show differences in tone in a part of the photographs of the marsh far back from the present-day margin. The outline of this margin is practically the same as the shoreline of 1867. A similar pre-European margin of the marsh is found to be present in the following places: along the eastern margin of the bay above Bandon on the Coquille Estuary; southwest of The Cutoff in the Umpqua Estuary; probably most of the high islands and high mainland marsh in Alsea Estuary; and the mainland south of Dean's Point and the eastern side of the island across North Channel in Nehalem Bay. The modern aerial photographs show a somewhat darker tone for the pre-European, mid-19th century marshes than is shown for the more recent marshes. In addition, rows of driftwood logs sometimes mark the boundary of these old shorelines. Often, in the modern scene, tidal stream channels are found in positions that mark this old boundary, too. The fairly high correlation between tidal streams and the mid-19th century margins suggests that relatively little colonization was taking place at the time that the Europeans arrived; it also suggests that the edges of the marshes were probably steep, because, by reasoning from the analogy of the modern scene, in those areas of most active colonization, the boundary line of the marsh at any given date is very transitory. A small change in elevation of the mud flats makes a great difference in the chance for colonization.

APPENDIX A

U.S.G.S.TOPOGRAPHIC MAPS
(In order N. to S.)

Scale 1:62,500

Astoria (Corps of Engineers)
Cannon Beach
Nehalem
Tillamook
Hebo
Cape Foulweather
Euchre Mt
Yaquina
Waldport
Heceta Head
Siltcoos Lake
Reedsport
Empire
Coos Bay
Bandon
Cape Blanco
Langlois
Port Orford
Gold Beach
Cape Ferrelo
Mt Emily

Scale 1:31,250

Clatsop Spit
Warrenton
Gearhart
Tillamook Head

U. S. COAST & GEODETIC SURVEY

Harbor Charts

No.	Title	Scale
5896	Pyramid Point to Cape Sebastian	1:40,000
5951	Cape Sebastian to Humbug Mountain	1:40,000
5952	Port Orford to Cape Blanco	1:40,000
5971	Coquille River Entrance	1:10,000
5984	Coos Bay	1:20,000
6004	Umpqua River - Pacific Ocean to Reedsport	1:20,000
6023	Siuslaw River	1:20,000
6055	Yaquina Bay and River	1:10,000
	Continuation of Yaquina Bay	1:25,000
6056	Approaches to Yaquina Bay	1:50,000
	Depoe Bay	1:10,000
6112	Tillamook Bay	1:20,000
6122	Nehalem River	1:20,000
6151	Columbia River - Pacific Ocean to Harrington Point	1:40,000

U. S. COAST & GEODETIC SURVEY

Old Topographic Surveys*

No.	Date	Scale
T-1381a	1874	1:10,000
T-1381b	1874	1:10,000
T-1382a	1874	1:10,000
T-1382b	1874	1:10,000
T-1416a	1875	1:10,000
T-1416b	1875	1:10,000
T-1417	1875	1:10,000
T-1529	1883	1:10,000
T-1776	1887	1:40,000
T-1778	1887	1:40,000
T-1086	1863	1:10,000
T-1757	1882-83-85	1:10,000
T-1769	1886	1:10,000
T-1809	1887	1:40,000
T-1810	1887	1:40,000
T-1811	1887	1:40,000
T-1876	1888	1:10,000
T-1877	1888	1:10,000
T-1971	1889	1:10,000
T-1130	1869	1:10,000
T-1131	1869	1:10,000
T-1227	1870	1:10,000
T-1260	1871	1:10,000
T-1317	1872	1:10,000
T-1588	1873	1:10,000
T-1812	1887	1:40,000
T-1813	1887	1:40,000
T-1862	1888	1:40,000
T-2460	1890	1:10,000

* Out of print. Photo copies can be obtained from U. S. C. & G. S., Washington, D. C.

APPENDIX B

SCIENTIFIC AND COMMON NAMES OF PLANT SPECIES

Abronia latifolia Esch. - Yellow abronia
Agrostis alba L. - Redtop
Alnus oregona Nutt. - Red alder
Ammophila arenaria (L.) Link. - European beach grass
Ammophila breviligulata Fern. - American beach grass
Arctostaphylos uva-ursi (L.) Spreng. - Kinnikinnick
Baccharis pilularis DC var. consanguinea (DC.) Kuntze - Coyote-brush
Calamagrostis inexpansa Gray var. robusta (Vas.) Stebb. - Reed-grass
Carex lyngbyei Hornem - Lyngbye's sedge
Carex macrocephala Willd. - Large-headed sedge
Chamaecyparis lawsoniana Parl. - Port Orford cedar
Cupressus (Spp) - Cypress
Cytisus scoparius (L.) Link. - Scotch broom
Deschampsia caespitosa (L) Beauv. - Tufted hair-grass
Digitalis purpurea L. - Foxglove
Distichlis spicata (L.) Greene. - Saltgrass
Elodea densa Planch. - Brazilian or South American waterweed
Elymus glaucus Buckl. - Blue wild rye or western rye grass
Elymus mollis Trin. - Sea lyme-grass
Elymus triticoides Buckl. - Alkali rye-grass
Festuca rubra L. - Red fescue
Fragaria chiloensis (L.) Duch. - Coast strawberry
Gaultheria shallon Pursh. - Salal
Hordeum brachyantherum - Meadow barley
Hypochaeris radicata L. - Summer dandelion or Hairy cat's ears
Jaumea carnosa (Less.) Gray. - Jaumea
Juncus balticus Willd. - Baltic rush
Juncus effusus L. - Common rush
Lathyrus japonicus Willd. var glaber (Ser.) Fern. - Purple beach pea
Leontodon - Hawkbit
Lotus formosissimus Greene - Lotus major or seaside lotus
Lupinus arboreus Sims. - Tree lupine
Picea sitchensis (Bong.) Carr - Sitka spruce or Tideland spruce
Pinus contorta Loud. - Shore pine
Pinus pinaster Ait. - Cluster pine
Plantago maritima L. - Seaside plantain
Potentilla pacifica How. - Pacific silver weed
Pseudotsuga menziesii (Mirb.) Franco. - Douglas fir
Rubus laciniatus Willd. - Evergreen blackberry
Rubus procerus Muell. - Himalaya berry
Salicornia ambigua Michx. - Woody glasswort
Salix - Willows
Scirpus acutus Muhl. - Viscid bulrush
Scirpus americanus Pers. - Three-square
Scirpus cernuus Vahl. - Low club-rush
Scirpus robusta -
Spergularia marina (L.) Griseb. - Salt-marsh sand spurry
Triglochin maritima L. - Seaside arrow-grass
Trifolium pratense L. - Red clover
Tsuga heterophylla (Raf.) Sarg. - Western hemlock
Ulex europaeus L. - Gorse
Umbellularia californica (H & A.) Nutt. - California laurel
Vaccinium L. - Huckleberry
Vaccinium ovatum Pursh. - Shot huckleberry
Vaccinium oxycoccus L. - Cranberry
Zostera marina L. var. stenophylla Asch. & Graeb. - Eel-grass

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