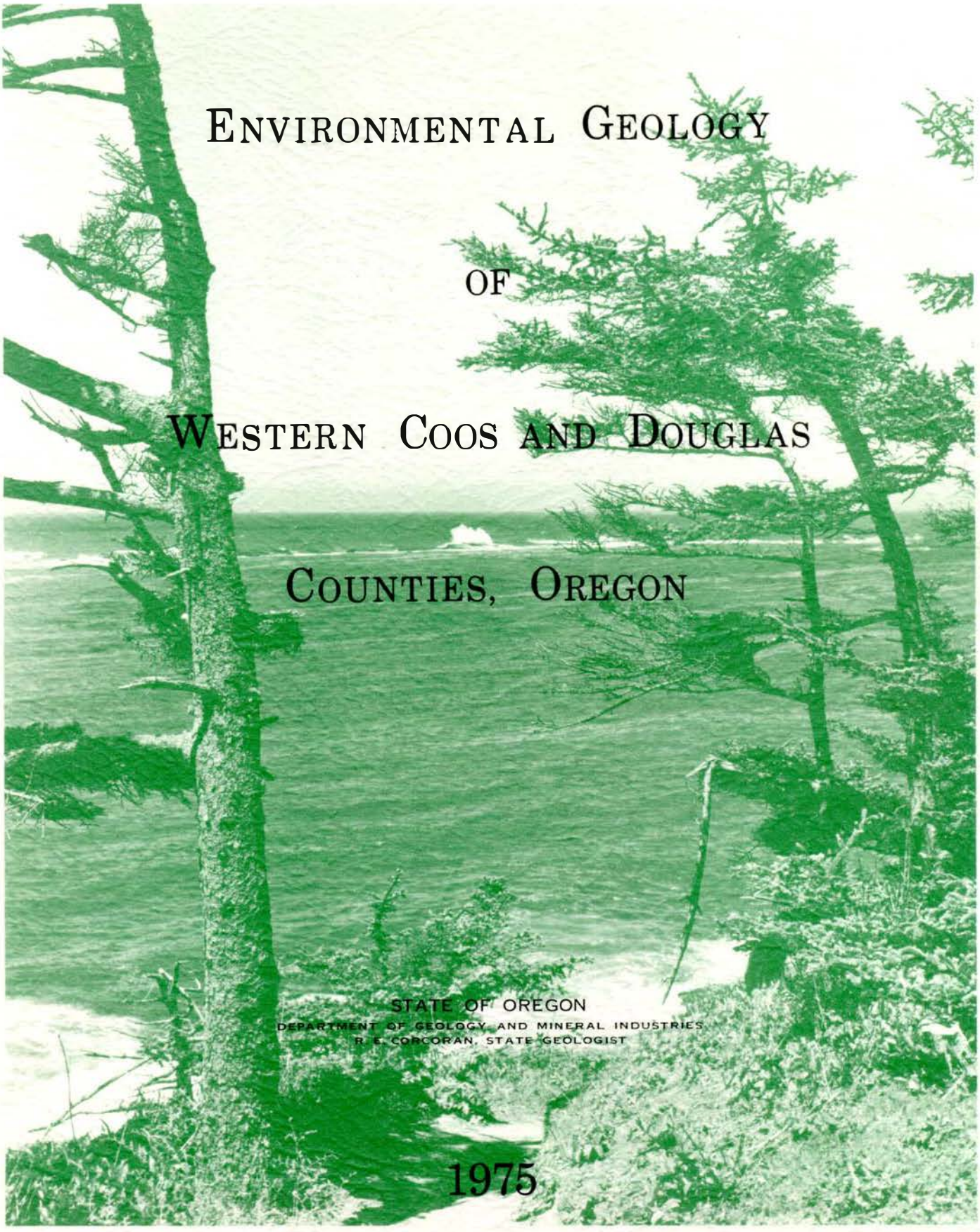


Environmental Geology of Western Coos and Douglas Counties, Oregon

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

1975

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1069 State Office Building, Portland, Oregon 97201

BULLETIN 87

ENVIRONMENTAL GEOLOGY OF WESTERN COOS AND DOUGLAS COUNTIES, OREGON

John D. Beaulieu
Oregon Department of Geology and Mineral Industries
and
Paul W. Hughes, Consulting Geologist

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The preparation of the Douglas County parts of this report was financed in part through a project development grant under the Coastal Zone Management Act of 1972 administered by the Office of Coastal Zone Management of the National Oceanic and Atmospheric Administration



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R. E. Corcoran

1975



DOUGLAS COUNTY

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COURTHOUSE ROSEBURG, OR 97470 503/672-3311

- July 1975 -

The Board of Commissioners of Douglas County anticipates that this report on geological hazards of the coastal portion of Douglas County will be a valuable tool in its land use planning, conservation and development.

BOARD OF COUNTY COMMISSIONERS
OF DOUGLAS COUNTY, OREGON

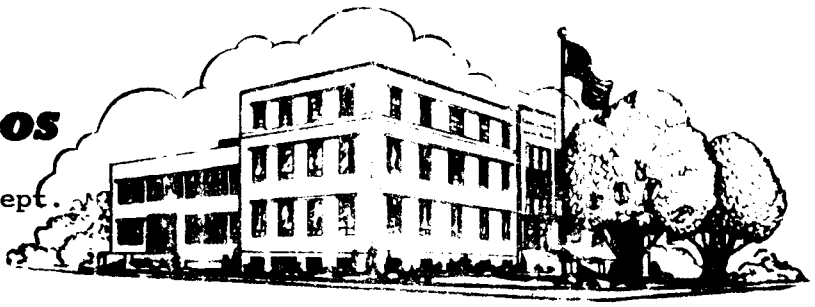
L. W. Michaels, Chairman

John T. Truett, Commissioner

Ray E. Doerner, Commissioner

County of Coos

Planning & Programing Dept.
Courthouse
Coquille, Oregon 97423
Telephone: 396-3121
267-7009



FOREWORD

In the past few years residential and other land development has spread from the more easily worked and accessible sites to areas further from established roads into the steep hilly lands of the county. This has happened partly because the more level and easily developed land, which is free from flood hazards, is being used up or is increasing in price making the more remote and lower priced land attractive to the buyer. In addition the growing desire among many people for rural isolation and agricultural space to be more self-sufficient has led to the development of land away from older settled areas. Because of the steepness of most of this type of land, the nature of the soils and underlying rock, and heavy rainfall, much of this land is subject to landslides, erosion, and other serious geologic hazards.

The information in this report which furnishes the basic data required to make determinations about the feasibility and safety of developing land, with respect to geologic hazards, will provide much needed information for Coos County land buyers to use in making choices. As comprehensive planning and zoning programs proceed the other environmental geology portions of this report, as well as the hazard data, will aid the county and its citizens in developing better informed land use planning decisions for the future.

Real estate purchase and development for individuals, corporations or governmental agencies involves a major financial investment for one, and all of those concerned. The protection of these investments from major losses by avoiding foreseeable geologic hazards will be a major goal of county land use programs.

The cooperative efforts of local, state, and federal governments in compiling and publishing this report for the use of the general public and planning officials have provided a good start toward this end.

COOS COUNTY BOARD OF COMMISSIONERS

Chairman

Commissioner

Commissioner

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- Coos Bay
- Coquille
- Empire
- Goodwin Peak and Scottsburg (in part)
- Powers and Sitkum (in part)
- Reedsport
- Siltcoos Lake

Geologic hazards maps of following quadrangles:
- Bandon and part of Langlois
- Coos Bay
- Coquille
- Empire
- Goodwin Peak and Scottsburg (in part)
- Powers and Sitkum (in part)
- Reedsport
- Siltcoos Lake

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ENVIRONMENTAL GEOLOGY
of
WESTERN COOS AND DOUGLAS COUNTIES, OREGON

INTRODUCTION

Purpose

Responsible land use planning and land management require an adequate data base with regard to the limitations and capabilities of the land. Providing the maximum amount of practical information to the greatest number of users in western Coos and Douglas Counties is the purpose of this study.

The need for systematic and reliable information about geologic hazards is gaining wider recognition by State officials, County officials, planners, developers, engineers, and private citizens. Senate Bill 100, passed by the Oregon Legislature in 1973, created a Land Conservation and Development Commission for the purpose of implementing state-wide planning goals. Technical information of the sort provided in this bulletin is essential to the success of that and similar efforts on State and local level in Oregon.

Legal trends in recent years have been toward placing increasing responsibilities on permit-granting agencies. In California, recently, a County road project initiated a landslide, and runoff from a County-approved subdivision adversely affected neighboring property. In both cases, liability was placed upon the County (Schlicker and others, 1973). The information provided in this bulletin will enable Coos and Douglas County personnel to evaluate and plan future development more effectively.

Acknowledgments

The authors greatly appreciate the cooperation and help given by many individuals and organizations in the preparation of this report. The investigation of Coos County was funded in part by a grant of $20,000 from the Western Environmental Geology Branch of the U. S. Geological Survey, and the investigation of western Douglas County was funded in part by a grant for $10,000 from the U. S. Office of Coastal Zone Management through the Oregon Coastal Conservation and Development Commission. Special thanks are extended to Dr. M. Clark Blake, Jr. of the U. S. Geological Survey and Grant J. Ross of the Oregon Coastal Conservation and Development Commission for their efforts in securing these funds. Additional funds included $5,000 provided by Coos County, $1,500 by Douglas County, and $12,800 provided as in-kind services by the State of Oregon Department of Geology and Mineral Industries.

The assistance of Robert L. Gerdes (Planning Director, Coos County), Richard D. Reynolds (Planning Director, Douglas County), Clair Silvernale (Soils Scientist, Douglas County), and Berl Oar (flood specialist, Douglas County) was invaluable. Agencies supplying major assistance included the U. S. Geological Survey (Portland Office), the U. S. Soils and Conservation Service (Coquille office), and the Office of the State Engineer. Photographs were provided by the Coos Bay World, the Reedsport Courier, and the Oregon State Highway Department.

The authors also wish to thank the staff members of the State of Oregon Department of Geology and Mineral Industries who helped in the project. Steven R. Renoud did the cartographic preparations of the maps for printing; Ruth E. Pavlat typed the camera-copy text, Carol Brookhyser edited the manuscript, and Margaret L. Steere edited the manuscript and did the layout.

Previous Work and Sources of Data

This report is a comprehensive and systematic treatment of the geology and geologic hazards of western Coos and Douglas Counties. It is broader in scope than any previous investigations in the area and treats many topics never before studied on a regional basis in the area. It is part of an on-going program of basic geologic hazards research in Oregon being conducted by the Oregon Department of Geology and Mineral Industries.

Major recent investigations in the study area include bedrock geologic mapping and mineral resource cataloguing in Coos County by Baldwin and others (1973), mineral resource cataloguing in Douglas County by Ramp (1972), and a ground-water investigation in the Coos-Umpqua dunes by Robison (1973). Other landmark studies include an investigation of the coal resources of the Coos Bay area by Allen and Baldwin (1944), and an investigation of dunes processes by Cooper (1958). Data on recent flooding are compiled on a continuing basis by the U. S. Geological Survey. Offshore structures and tectonism are presently being investigated by personnel of the U. S. Geological Survey and Oregon State University and by other individuals. Soils properties and use limitations are under investigation by the U. S. Soils Conservation Service.

A complete listing of all data sources used in this study is given in the bibliography. Much data and information used in this report was developed outside the study area and these references are also listed. References of special significance to particular topics are cited in the appropriate parts of the text.

Implementation

General

A land use planner is any person or body of persons who use or manage the land with foresight regarding the characteristics of the land. In addition to county and city planners, land use planners should include developers, policy formulators on the national, state, and local level, large land holders, architects, engineers, and the general public.

This bulletin provides planners in western Coos and Douglas Counties with the necessary information to make valid decisions. It is a synthesis of present thought regarding the geologic conditions and geologic hazards of the region. The material is reconnaissance in nature, however, and is subject to further refinement or revision based upon on-site investigations or more rigorous study.

The matrices and tables interrelate the various hazards and systematically present information about them. The text is an elaboration of the tables and is thoroughly cross referenced. The net result is a hazards analysis which proceeds through various levels of detail from map to tables to text and references. Organized in this way, the report has a potential for a wide variety of uses as discussed below.

Site evaluations

Proper use of this document in preliminary site evaluations is shown diagrammatically on the flow chart in Figure 1.

Land use suitability analysis

Data provided in this bulletin and on the accompanying maps can be used to develop sets of generalized overlay maps to aid in land use suitability analyses. To be valid, however, such maps should ideally meet three specifications:

(1) The maps should be prepared for one type of development or for sets of closely related types of development. Because the physical requirements for unrelated types of land use differ considerably, single maps depicting land use suitability for numerous types of use are commonly too generalized.

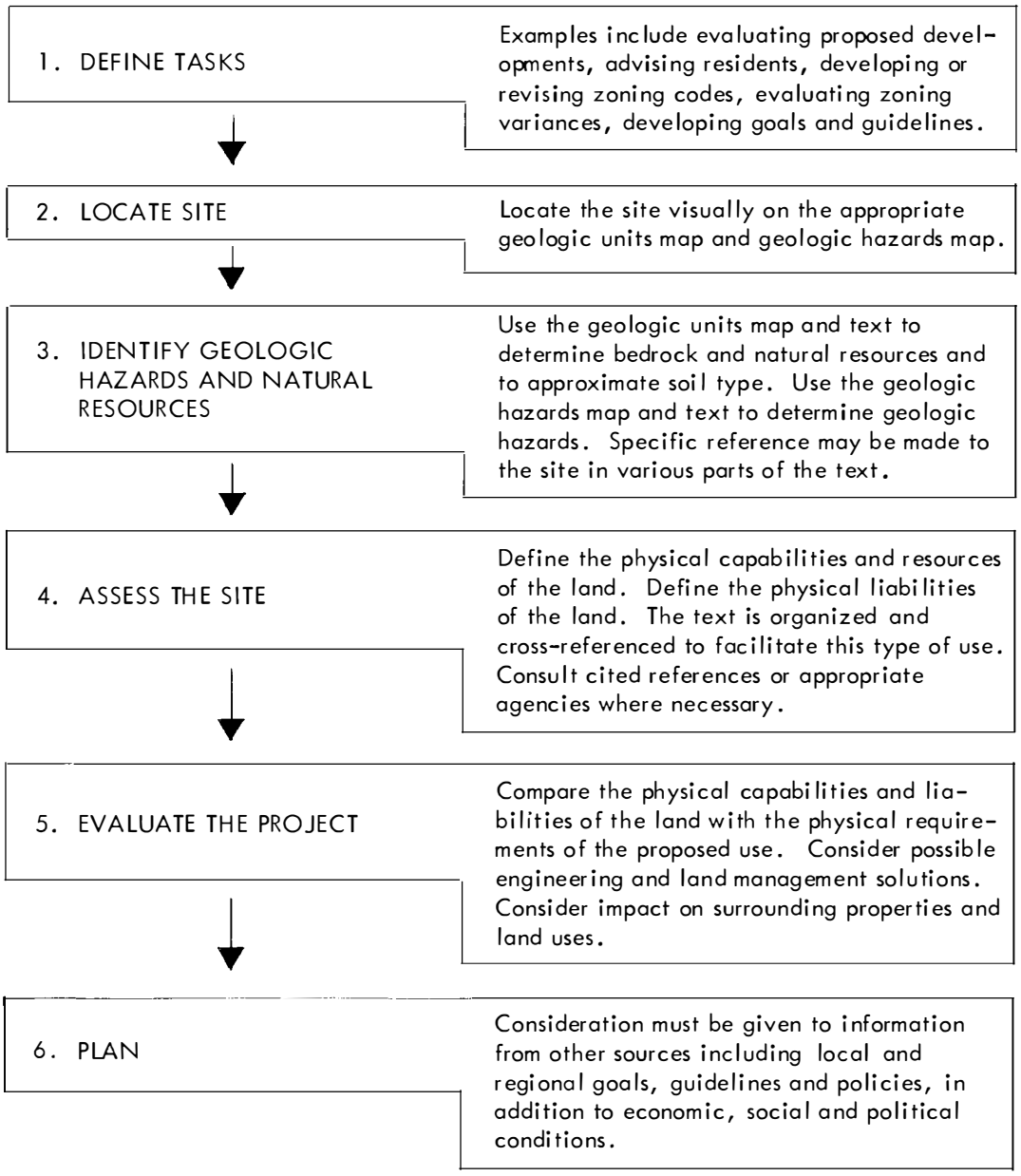


Figure 1. Suggested use of this bulletin in site evaluations.

(2) Suitability categories described in the map legends must be realistic. This requires thorough knowledge of 1) the information presented in the text, 2) the specific requirements of the land use under consideration and 3) the types of engineering solutions available. Assignment of arbitrary values to the various hazards is unrealistic.

(3) Scale must be properly appreciated. On the map scale used in this publication, conclusions must be viewed as a first approximation of on-site conditions, and provisions must be made for more detailed study.

Regionalization of data

On the county and city level, specialists commonly possess detailed information on specific sites or in their respective fields of expertise but do not have readily at their disposal a mechanism for synthesizing and interrelating their observations. Thus, an individual may have records of septic tank failures, but may not have adequate means of evaluating common characteristics or distribution of the failures. This bulletin, by interrelating geologic units, soils, slopes, landforms, and hazards, provides the specialist with the necessary tools to regionalize his observations and to make preliminary assessments of new areas for which no detailed data are available. It also informs the specialist of additional land characteristics about which he might otherwise be unaware.

Policy formulation

Used in conjunction with a set of realistic goals, this publication can be invaluable in formulating land-use policies on the local and regional level. Such policies should represent a coordinated effort on the part of government agencies of various levels, should consider all significant geologic hazards, and should make provisions for local conditions as revealed by on-site evaluations. Although policies are designed to protect the public, they should not be based on over-reactions arising from inadequate information regarding the magnitude of given hazards.

GEOGRAPHY

Location and Extent

The study area encompasses the western half of Coos County and the northwesternmost corner of Douglas County (Figure 2). It is bounded on the west by the Pacific Ocean, on the north by Lane County, and on the south by Curry County. The irregular eastern boundary follows the edges of topographic maps or section lines selected to incorporate inland valley areas.

Parts or all of 11 topographic quadrangle maps are included. Total areal extent of the study area is approximately 1,400 square miles. Access is provided by U. S. Highway 101 along the Coast, State Highway 38 along the Umpqua River, and State Highway 42 along the Middle Fork of the Coquille River. Numerous unnumbered county roads extend up other stream valleys, and private roads provide access to the more remote upland areas.

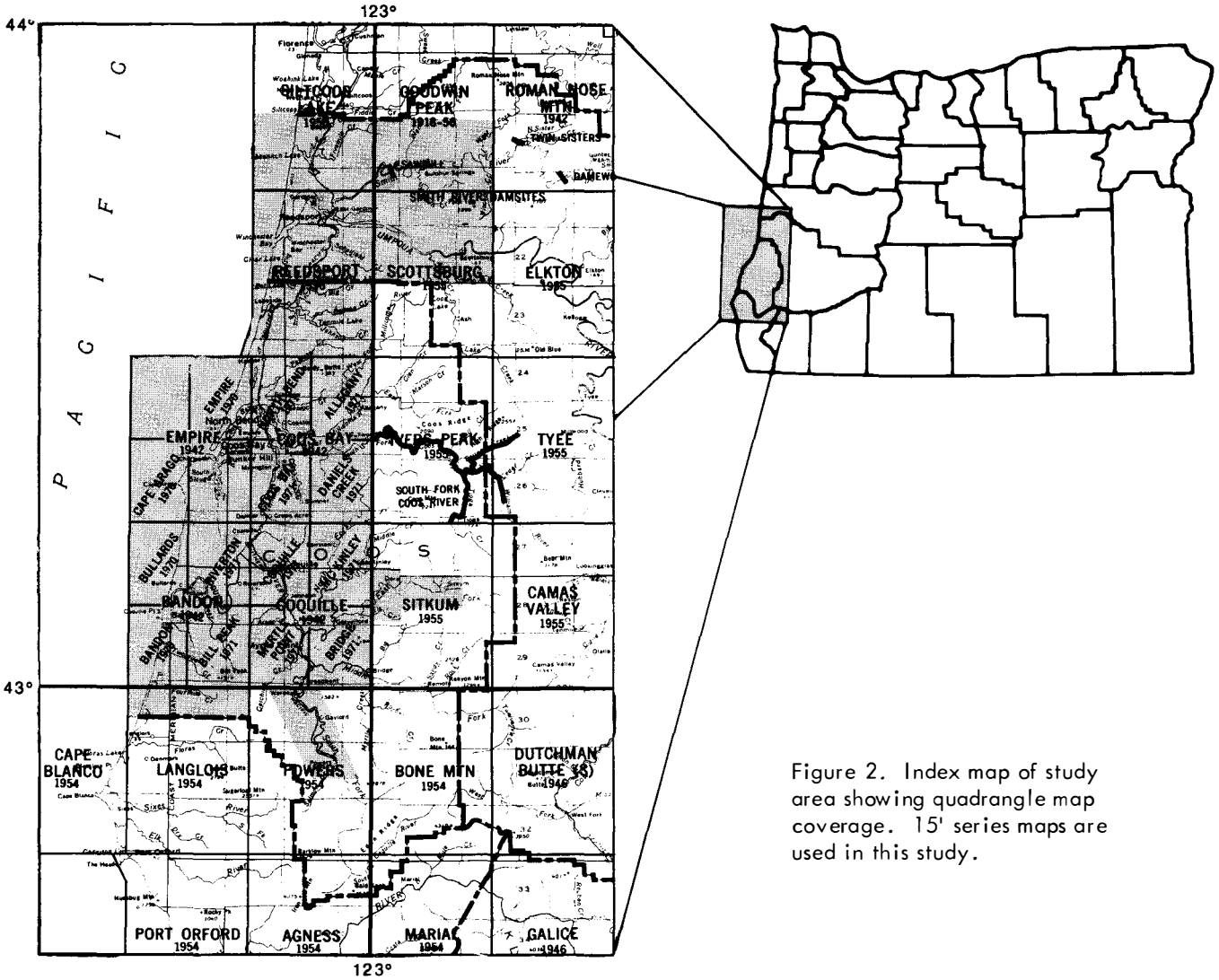


Figure 2. Index map of study area showing quadrangle map coverage. 15' series maps are used in this study.

Climate

The climate of the study area is moist and temperate owing to the prevailing westerlies and the proximity of the Pacific Ocean. Winters are cool and wet and summers are warm and dry with intermittent rain. Temperature data are summarized on Table 1a.

Rainfall varies from approximately 60 inches along the Coast to as much as 100 inches on the slopes of the more rugged interior uplands in eastern parts of the study area. Annual rainfall is 60 inches at North Bend and 77 inches at Reedsport. More than 10 inches of rain fall in December and January at North Bend, and more than 10 inches of rain fall in November, December, January, and February at Reedsport. Measurable precipitation falls in North Bend on about 160 days out of the year. Precipitation extremes for the Coos Bay-North Bend area are summarized on Table 1b. Between December 19 and 23, 1964, 8.1 inches of rain fell in North Bend, and 13.2 inches of rain fell in Powers.

Table 1a. Temperature data for western Coos and Douglas Counties

	Statistic	Coos Bay-North Bend	Reedsport
January	Mean	45°	44°
	Mean maximum	52	50
	Mean Minimum	37	37
	High	74	67
	Low	16	15
August	Mean	60	60
	Mean maximum	69	70
	Mean minimum	51	51
	High	90*	97
	Low	38	41

* June extreme is 100°

Table 1b. Weather extremes for Coos Bay-North Bend area

wettest month	22.7	inches	November, 1973
driest year	43	inches	1936
wettest year	91	inches	1937
wettest 24 hours	5.25	inches	Dec. 9-10, 1968
greatest snowfall	16	inches	Jan. 25-26, 1969
greatest wind velocity	130	knots*	Oct. 12, 1962

* Recorded on the Coast

Summer winds are characterized by steady moderate breezes from the north and northwest averaging 17 miles per hour. Winter winds consist of steady offshore breezes from the south and southeast and occasional strong onshore gales from the southwest. Average winter wind velocity is 15 miles per hour; maximum wind velocities, however, far exceed those of the summer (see Table 1b). Autumn and spring winds are transitional between those of winter and summer and are a mix of both.

Daily weather records including wind data are maintained by the U. S. Weather Bureau at North Bend and also by the U. S. Naval Air Force Base in North Bend. Data for the period 1915 to 1933 are available through the Portland Office of the U. S. Army Corps of Engineers and are summarized in Fleming (1955). Additional wind data are summarized by Cooper (1958). Wind patterns are instrumental in determining the form and distribution of dunes (see Wind Erosion and Deposition) and are the driving force behind nearshore ocean currents (see Coastal Erosion and Deposition).

Ocean Currents

Offshore ocean currents vary with the seasons, depth, and wind direction. Surface currents respond primarily to immediate wind direction (see Climate) and flow from south to north in the winter and north to south in the summer. At a depth of 60 meters a northerly component is more dominant; currents are northerly in the winter and also in the summer when sea breezes from the north abate (Oregon State University, 1968). Acting in harmony, tides, winds, and currents can produce surface currents with velocities as great as 3 to 4 knots. Average velocities, however, are approximately 0.25 knots.

Nearshore currents are more complex owing to the impact of bathymetry, topography, and other factors on wind and ocean currents. Longshore drift is generated by wave action and is particularly significant to the transport of sand along the shore (see Coastal Erosion and Deposition). Sediment transported in one direction by longshore drift may adopt new directions of transport as it is carried out to sea through regions with different current characteristics at depth. The carrying capacity of currents at depth is discussed briefly under Coastal Erosion and Deposition. Currents in estuaries are discussed under Geology of Estuaries.

Topography

The landforms of western Coos and Douglas Counties are grouped into three major categories: uplands, terraces, and lowlands. The characteristics of each are products of the interaction between the materials which underlie them, the processes that formed them, and the processes that presently are acting upon them. Each landform is characterized by a unique association of rock type, soils, and processes (geologic hazards) as summarized on Table 2. A knowledge of landform is fundamental to the regional understanding of geologic hazards.

The hills and mountains of the study area comprise the uplands. Elevations vary from sea level at base of sea cliffs to greater than 2,000 feet in the interior. Relief is generally less than 1,000 feet. Slopes vary from gentle to vertical.

Terraces consist of wave-cut surfaces with marine deposits along the coast and dissected remnants of elevated flood plains along major streams. Marine terraces form flat coastal expanses and ridge caps and are generally less than 500 feet in elevation. A notable exception is the marine terrace at Blue Ridge which is approximately 1,600 feet high. Fluvial (river) terraces are restricted to the lower walls of drainages and are generally less than 100 feet above present-day flood plains and streamways.

Lowland landforms include flood plains, marsh, tidal flats, dunes, beaches, and deflation plains. Major lowland geographic areas are the Coos Bay dunes and the estuaries of the Umpqua, Coos, and Coquille Rivers. Elevations are generally 20 feet or less but are greater along the inland reaches of alluvial valleys and on larger sand dunes. Slopes are very low with the exception of those developed on sand dunes.

Table 2. Landforms of western Coos and Douglas Counties, Oregon

Landform		Features	Major rock types[1]	Soils[2]	Current processes and hazards[3]
UPLANDS	Steep	Hill and mountain slope with regional slopes greater than 50 percent; also headlands	Sandstone, Siltstone and Basalt of Tertiary Age, and Rocks of Pre-Tertiary Age	Loam, silty clay loam, and silty clay of Bohannen, Orford, Templeton, Dement, Winema, Millicoma, Peavine, Honeygrove, and Blackly series	Severe erosion, flash flooding, rapid mass movement
	Moderate to gentle	Hills with regional slopes generally less than 50 percent	Sandstone and Siltstone of Tertiary Age, and Rocks of Pre-Tertiary Age		Slow to rapid mass movement, moderate erosion
TERRACES	Marine	Elevated, flat, ocean-cut surfaces; deposits of marine material or wind-blown sand	Marine sand, silt, and mud; vegetated wind-blown sand usually with soil development	Silt loam, sandy loam, and silty clay loam of Coos Bay, Bullards, Blacklock, Bandon, and Chetco series	Ponding and poor drainage locally, failure in deep cuts; hazards generally minimal
	Fluvial (river)	Dissected, flat remnants of former flood plains along major streams	Sand, silts, and gravels deposited by major streams and rivers; semi-consolidated	Silty loam, silty clay loam, and silty clay of Salander, Chetco, Lint, and Knappa series	Ponding and poor drainage locally, failure in deep cuts, stream-bank erosion; hazards minimal
LOWLANDS	Flood plain	Flat river deposits subject to flooding; also channel deposits	Sands, silts, and gravels deposited by rivers and streams	Silty loam, silty clay loam, and silty clay of Nehalem, Gardiner, Nestucca, and Brenner series	Flooding, ponding, stream-bank erosion, low foundation strength, possible liquefaction
	Marsh	Poorly drained, vegetated, flat wetlands of estuaries and dunes	Marsh and peat with fine-grained sediments	Silty loam, silty clay loam, silty clay and peat of Coquille, Clatsop, Brallier, and Langlois series	Ocean and stream flooding, low bearing strength, possible liquefaction
	Tidal flat	Unvegetated mudflats lying within the tidal zone	Sand, silt, and clay of complex estuarine origin	Peat and silty clay of Clatsop series; also sand, silt, and clay	Ocean flooding, low to variable bearing strength
	Dunes; beaches; deflation plains	Mounds of wind-blown sand; sloping sand adjacent to the ocean; wind-swept flats eroded to summer water table	Stable sand, unstable sand, beach sand, and deflation-plain sand	Sand and fine sand of Westport series, Active dunes, Beaches; peat and silty clay of Coquille and Clatsop series	Wind erosion and deposition, coastal erosion and deposition, high ground water, possible liquefaction locally

[1]See Bedrock Geologic Units and Surficial Geologic Units in text.
[2]See Soils in text.
[3]See Geologic Hazards in text.

Population

The major communities of Coos County and their 1972 populations are Coos Bay (13,320), North Bend (8,685), Coquille (4,300), Myrtle Point (2,595), Bandon (1,895), Eastside (1,490), and Powers (835). Population data for the County as a whole are summarized in Table 3. Periods of maximum growth coincide with times of maximum timber output. Between 1960 and 1965, population declined 4.6 percent. General trends are for increased urbanization at the expense of rural development. Between 1950 and 1960, urban population increased 65 percent, from 15,845 to 25,993, and between 1960 and 1970 it increased 11 percent, to 28,967. Between 1950 and 1960, rural population increased 10 percent, from 26,420 to 28,962, and between 1960 and 1970 it decreased 5 percent to 27,548. Between 1960 and 1970, net migration out of the County was 4,606 and natural increase was 6,166, to give a net gain of 1,560.

The major population centers of western Douglas County are Reedsport (4,039), the Tenmile area (2,559), Gardiner, and Scottsburg. Historic populations and projected trends for Reedsport are summarized on Table 4. In addition, combined urban and rural projections for the coastal area indicate increases of about 20 percent per decade through 1990 (Douglas County Planning Dept., 1973).

Table 3. Population of Coos County

Year	Population	Change (%)
1900	10,324	
1910	17,959	72
1920	22,257	24
1930	28,373	28
1940	32,466	14
1950	42,265	30
1960	54,955	30
1970	56,515	3

Table 4. Population of Reedsport

Year	Population	Change (%)
1920	850	
1930	1,178	39
1940	1,421	21
1950	2,288	61
1960	2,998	31
1970	4,039	35
1980 *	5,142	27
1990 *	6,170	25

* Projections by the Douglas County Planning Dept. based upon historic trends, projected employment and service trends, and other projections, including those of Pacific Northwest Bell and BPA.

Land Use

Historically, land use in western Coos and Douglas Counties has been closely related to landform. The flood plain of the Umpqua River has been the site of industrial, commercial, residential, and agricultural development. On the more frequently flooded flood plains of the Coos and Coquille Rivers, development has been largely restricted to pastureland and other agricultural uses. The Coos-Umpqua dunes area is used primarily for recreational purposes but is also the site of ground-water withdrawal and local industry in the Coos Bay area. The physical setting of estuarine borderlands has favored intensive development.

Marine and river terraces have been the sites of industrial, residential, and commercial development in the Reedsport, Coos Bay, and Bandon areas. Terraces of the interior are the sites of communities such as Scottsburg, Myrtle Point, and Coquille. Agricultural development includes cranberry bogs in south coastal Coos County and pastureland along major streams. Future, more intense development of the terraces is favored by the relative lack of physical constraints but will require increasing management with regard to ponding, ground-water contamination, and waste disposal.

Dominant land uses of the uplands are forestry, mining (including quarry operations), recreation, limited agriculture, and scattered residential development. In the future, residential development will spread to the gentler uplands surrounding developing urban centers on the lowlands and terraces. Transportation and communication facilities traverse a wide variety of upland terrains.

Although population and economy have historically fluctuated with logging activity, recent and future diversification into retail and wholesale trade, education, business services, and tourism will lead to increased urbanization. Additional demands will be placed on the land in and around urban centers and in new areas of growth. Management and education on all levels of government and private enterprise will be needed to minimize the existing and potential problems inherent in the three categories of landforms: erosion and mass movement in the uplands; ponding, ground-water contamination, and erosion on the terraces; and a variety of hazards on the lowlands, such as stream and ocean flooding, wind erosion and deposition of sand, unfavorable ground response during possible earthquakes, and tsunami danger to recreationists along the Coast.

ENGINEERING GEOLOGY

Classification of Geologic Units

A geologic unit is any rock type which may be distinguished from others and mapped on the basis of grain size, composition, bedding, distribution, age, or other physical properties. As shown on Table 5, each geologic unit is related in a general way to a basic category of landform. Recognition of landform is a key consideration in making preliminary identifications of geologic units.

Bedrock geologic units of consolidated material (firmly cemented when fresh) underlie the uplands and sea cliffs. Major rock types include sandstone, siltstone, and basalt. Each bedrock geologic unit recognized in this study may comprise several stratigraphic units (geologic formations). For example, the Sandstone of Tertiary Age is composed of all or parts of seven stratigraphic units (Roseburg, Tyee, Flournoy, Lookingglass, Coaledo, Tunnel Point, and Empire Formations). The formations have various stratigraphic positions and ages, but are treated collectively because of their similar engineering characteristics.

Semi-consolidated to unconsolidated (can be crumbled by hand) surficial deposits underlie a variety of lowland and terrace landforms. Subdivisions are based upon the specific environments of deposition and type of material. For example, terraces of both marine and nonmarine origin are recognized, and each exhibits a somewhat unique lithology.

The ages of the bedrock units range from approximately 140 million years for the Rocks of Pre-Tertiary Age to less than 10 million years for the youngest Tertiary formation (Empire Formation) as shown on Figure 3. The surficial units are probably all less than 2 million years old with the bulk of them less than 100,000 years old. Soils developed on the various bedrock and surficial geologic units are relatively young.

Bedrock Geologic Units

General

Four major bedrock geologic units are recognized: the Sandstone of Tertiary Age, the Siltstone of Tertiary Age, the Basalt of Tertiary Age, and the Rocks of Pre-Tertiary Age. The general geology and engineering properties of each bedrock unit are summarized below and the distribution in time of the stratigraphic units of which they are composed is shown on Figure 3. The general sequence of geologic events which produced the various stratigraphic units consisted of 1) compression and deep seated deformation during marine deposition to give the Otter Point Formation, 2) continued marine deposition, volcanism, and shallow, compressive deformation to give the Roseburg Formation, 3) regional marine deposition to give the middle Eocene sandstone and siltstone units, 4) local marine downwarp and deposition in the Coos Bay area to give the late Eocene through Pliocene units, and 5) regional uplift and fluctuations of sea level to produce the surficial geologic units discussed in the next section.

Sandstone of Tertiary Age

The Sandstone of Tertiary Age consists of all consolidated bedrock units of sedimentary origin composed primarily of sandstone. These include the Roseburg, Lookingglass, Flournoy, Tyee, Tunnel Point, Empire, and upper and lower Coaledo Formations. Unconformities (time gaps) separate all stratigraphic sandstone units.

Geology: Various geologic aspects of the six major stratigraphic units making up the Sandstone of Tertiary Age are summarized on Table 6. More detailed descriptions are available for exposures in Coos County in Baldwin and others (1973). Many of the units are very similar in terms of rock type, and final

Table 5. Classification of geologic units in western Coos and Douglas Counties, Oregon

Type of unit	Landform	Environment of formation	Rock type	Geologic unit name (this report)	Stratigraphic or topographic setting
Bedrock geologic units (consolidated)	Upland and sea cliff	Sedimentary	Sandstone with minor siltstone	Sandstone of Tertiary Age	Sedimentary rock of the Roseburg Fm. and bulk of Tyee, Flournoy, Lookingglass, upper and lower Coaledo, Tunnel Point, and Empire Formations
			Siltstone with minor sandstone	Siltstone of Tertiary Age	Parts of the above plus Bastendorff, middle Coaledo, and Elkton Formations
		Volc.	Basalt	Basalt of Tertiary Age	Basalt of the Roseburg Formation
		Variable	Sheared volcanic and sedimentary rocks; chert, blueschist	Rock of Pre-Tertiary Age	Otter Point Formation, Humbug Mountain Conglomerate, Galice Formation
Surficial geologic units (unconsolidated and semiconsolidated)	Terrace	Marine	Sandstone siltstone mudstone	Quaternary marine terrace deposits	Elevated, flat-lying deposits on wave-cut platforms or benches
		River	Gravel, sand, silt and mud	Quaternary fluvial terrace deposits	Elevated, flat-lying remnants of flood plains and estuary wetlands
	Lowland	Wind	Fine- to medium-grained sand	Stable sand	Sand protected by vegetative cover in dunes and non-dune areas
				Unstable dune sand	Unvegetated sand in large dunes
				Deflation plain and beach sand	Unvegetated sand in flat-lying interdune areas and in beaches
		Water	Organic material plus sediments	Marsh and peat	Frequently inundated poorly drained wetland
			Silt, clay, and sand	Tidal flats	Unvegetated tidelands of estuaries
			Sand, silt, gravel	Quaternary alluvium	Flood plains of major streams
			Variable	Fill and spoils	Lowland encroachments of man into wetlands

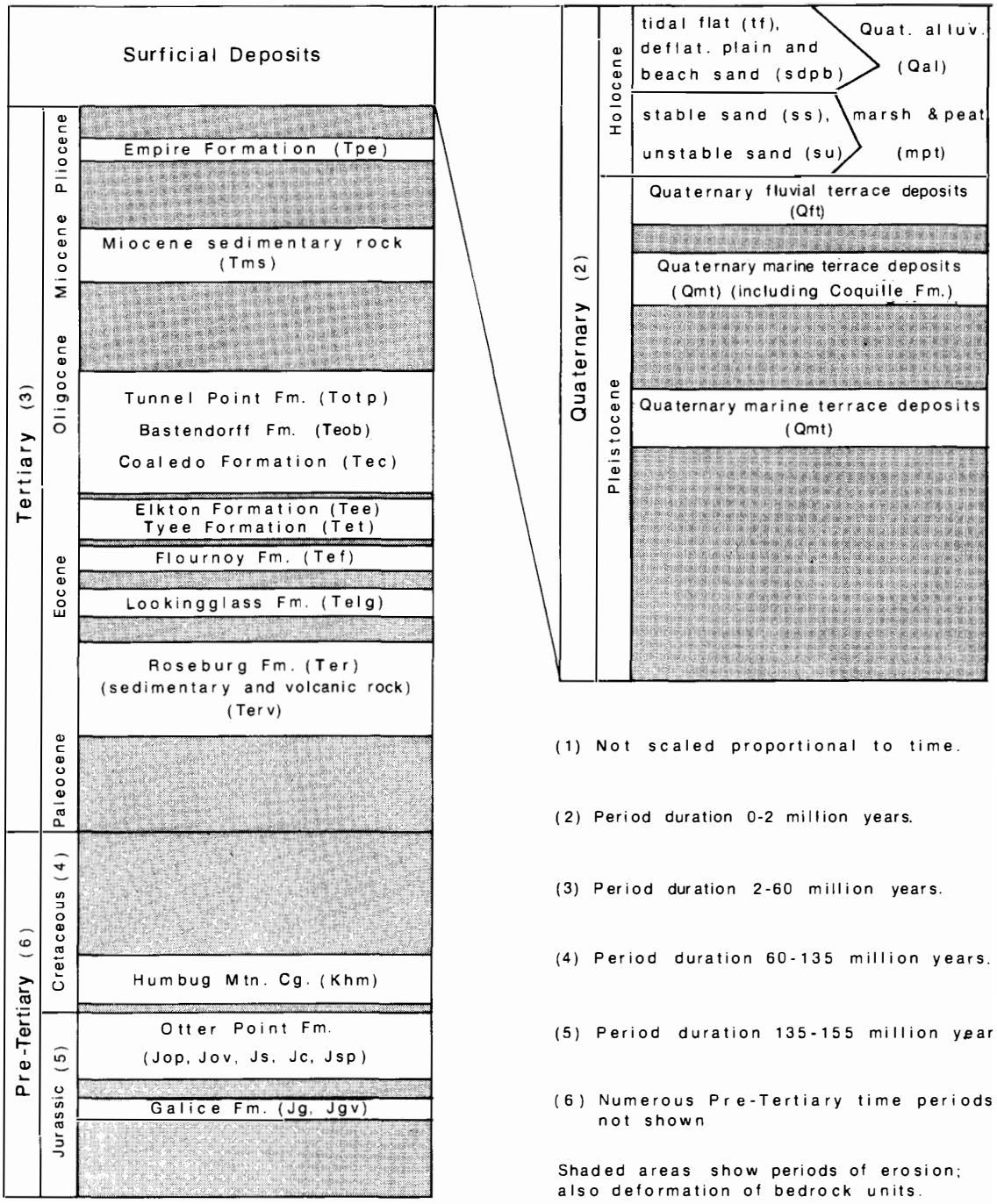


Figure 3. Time distribution[1] of stratigraphic and surficial geologic units.

distinction between them was not possible until the completion of regional mapping (Baldwin and others, 1973) which emphasized their stratigraphic relationships.

Sedimentary rocks of the Roseburg Formation are interbedded with submarine basalts, here included in the Basalts of Tertiary Age. Age of the base of the unit is uncertain but is probably Paleocene. The sedimentary rocks of the Roseburg Formation were deposited upon a crumpling sea floor at the close of Klamath Mountains deformation and are structurally distinct from the younger sedimentary units.

The Lookingglass Formation, in contrast to the Roseburg Formation, is gently deformed along north-south structures. Regionally the eastern and southern extents of the Lookingglass Formation consist of shallow-water deltaic deposits which represent the margins of the basin of deposition. Structural and paleogeographic trends in the Flournoy Formation of Coos County are similar to those of the Lookingglass Formation.

East of the study area the Tyee Formation occupies a synclinal depression along the crest of the Coast Range. Deposition in a northward deepening basin is interpreted on the basis of regional sediment studies (Snavely and others, 1964), and Baldwin (1974) interprets a northeasterly trending shoreline between Roseburg and Agness.

Differentiation of the Tyee Formation from the Flournoy is increasingly difficult to the north as stratigraphic distinctions between the two units become less well defined. The contact indicated in Douglas County is a continuation of the contact in Coos County (Baldwin and others, 1973). It is based upon regional dips and on the apparent greater drainage densities (evident in aerial photographs) in rocks mapped as Flournoy as opposed to Tyee. Also, the presence of Elkton Formation near Elkton indicates that rocks in that area are significantly younger than exposures near Reedsport. Although mapping in this study is inadequate for final interpretation it does correspond with smaller scale reconnaissance revisions of geologic mapping in the Coast Range of Oregon by Baldwin (1975).

The Coaledo Formation is more restricted in distribution than other Eocene sandstone units and is noted for extensive deposits of strandline coal in the Coos Bay area (see Mineral Resources). Folds within the Coaledo Formation are more intense than those of older Eocene units in the surrounding area. The degree of deformation of the Coaledo Formation and the original limited extent of the unit as shown by the coal deposits indicate local basining of the Coos Bay area as early as the late Eocene. Marine Miocene rocks present in Coos Bay at Fossil Point, Oligocene sandstones (Tunnel Point Formation) at Tunnel Point, and the Pliocene Empire Formation exposed along South Slough suggest continued basining in the area throughout the Tertiary.

The marine Miocene rocks in Coos Bay and the Tunnel Point Formation are of very limited extent and are not included on Table 6. The units are included on the stratigraphic time chart, however. The general engineering properties do not differ appreciably from the other stratigraphic units in the Sandstone of Tertiary Age.

Engineering geology: Lithology of the Sandstone of Tertiary Age varies with position in the stratigraphic section (Table 6) and with geographic location. The Roseburg, Lookingglass, Flournoy, and Tyee Formations are progressively more silty in their upper parts, where they resemble the Siltstones of Tertiary Age in terms of their engineering properties. The Roseburg Formation is sheared in places and is thin-bedded in contrast to the thicker bedding of the Flournoy and Tyee Formations, both of which have beds of sandstone well over 10 feet thick. Bedding thicknesses of the Coaledo are variable with sandstone interbeds thickest in the upper and lower parts. The middle Coaledo is included in the Siltstone of Tertiary Age. The Empire and Tunnel Point Formations consist primarily of thick-bedded sandstone.

Depth of weathering and soil development vary with topography. Shallow weathering horizons and thin soils predominate in the steeper sloping upland areas where streams are in their youthful stages of development. Uplands along the Coast are underlain by sandstones with varying depths of weathering depending upon bedding, jointing, slope, and rate of erosion. Soils developed on the Sandstone of Tertiary Age include loamy sand, sandy loam, silty loam, and silty clay loam (see Soils).

Geologic hazards associated with the Sandstone of Tertiary Age include high ground water in areas of thick mass movement (see Mass Movement; High Ground Water and Ponding), rapid runoff and flash flooding (see Stream Flooding), and mass movement. Major types of mass movement are debris flow and rapid earthflow in the steeper uplands and moderately rapid earthflow on the moderately sloping terrain (see Mass Movement). The potential exists for slide generation on steep saturated slopes by earthquake

Table 6. Geology of the Sandstone of Tertiary Age

Unit	Surface distribution	Rock type and bedding	Structure	Age and stratigraphy	Origin
Roseburg Fm.	Coquille drainage north of the Klamath Mtns., south of Blue Ridge, and within 25 miles of the Coast	Several thousand feet of thin-bedded sandstone and siltstone interbeds of approximately equal proportions	Highly deformed with regional faulting, tight folding, and shearing	Paleocene and early Eocene; unconformable over Pre-Tertiary bedrock	Deep submarine
Lookingglass Fm.	Isolated exposures in middle and upper Coquille drainage (also east of study area)	Several thousand feet of rhythmically bedded sandstone and siltstone; sandstone hard locally; siltstone dominant high in section	Gently to moderately folded; local faulting	Early to middle Eocene; unconformable over older units	Variable submarine depths; marginal deltaic
Flournoy Fm.	Uplands north of Coos Bay and in western Douglas County	Several thousand feet of rhythmically bedded sandstone and minor siltstone; sandstone thick locally and hard; siltstone dominant high in the section	Gently folded; a few minor faults	Middle Eocene; unconformable over older units	Variable submarine depths; marginal deltaic
Tyee Fm.	Interior uplands of western Douglas County; large areas out of study area	Thousands of feet of thick-bedded sandstone and minor rhythmically bedded siltstone	Gently folded, jointed	Middle Eocene; unconformable over older units; relation with Flournoy unclear	Submarine deepest to north; marginal deltaic
Coaledo Fm. (upper, lower, and undiff.)	Coastal uplands from Tenmile Lake to lower Coquille drainage	Coarse to fine-grained, cross-bedded, deltaic sandstone and minor siltstone	Moderately to tightly folded with steep dips locally	Late Eocene; unconformable over older units	Local marine basin
Empire Fm.	South Slough area, particularly west side	Thick sandstone beds with very minor siltstone	Moderately to gently dipping	Pliocene; unconformable over older units	Shallow marine basin

activity in the winter months (see Earthquakes). The sharply alternating beds of hard sandstone and softer siltstone favor bedding-plane slides where beds tilt into artificial cuts or areas of active erosion.

Ease of excavation varies with degree of weathering and thickness of sandstone interbeds. Where thick, fresh sandstone is exposed, blasting is required. Where large sandstone blocks are used in fill, continued settling over protracted periods of time can be expected as point boundaries adjust to the load.

Permeability is very low except along prominent joints, faults, bedding planes, and localized areas of pervasive weathering or low cementation. Ground-water production is low (see Ground Water). The potential for runoff is very high, especially in regions of steep slopes and thin soils. Because the soils are not aggregated, the erosion potential is also high (see Stream Erosion and Deposition).

Potential use of terrain underlain by the Sandstone of Tertiary Age is limited in many areas by steep slopes and associated hazards and is generally restricted to sparse residential development, well-managed forestry, and open space. Where slopes are moderate, more intensive uses are possible. Septic tanks are not feasible in the bedrock, but are compatible with the textures of many of the soils, provided soil depth is sufficient (see Soils). The tightness of the rocks is compatible with landfills, but slopes are generally prohibitive. Foundation strength varies from moderate to high. Natural resources of the unit include fill material, stream riprap, coal in some areas, and possible undiscovered oil at depth.

Siltstone of Tertiary Age

The Siltstone of Tertiary Age consists of all consolidated-bedrock Tertiary units of sedimentary origin composed primarily of siltstone. These include the Elkton Formation, the middle member of the Coaledo Formation, and the Bastendorff Formation. In addition, those parts of the Sandstone of Tertiary Age (generally, the upper parts of formations) which are rich in siltstone exhibit the engineering properties of the siltstones discussed in this section. Although these exposures are ideally treated in this section, present mapping does not permit their specific delineation on the geologic map.

Geology: Various aspects of the geology of the stratigraphic units included in this unit are summarized on Table 7. More detailed discussions of the geology of the units is provided by Baldwin and others (1973). Because large parts of the sandstone units discussed in the previous section are essentially siltstone, data provided in this section also apply to parts of those units.

The Elkton Formation consists of several thousand feet of clayey siltstone with minor interbeds of sandstone. Exposures are restricted to the Elkton area in the Umpqua River drainage and the Sacchi Beach area south of Coos Bay. Present interpretations of the Sacchi Beach exposures indicate that they may actually be a part of the Flournoy Formation (Baldwin, 1975), thus underscoring the need to distinguish between siltstone and sandstone in assessing the engineering properties of exposures mapped as Sandstone of Tertiary Age.

The Elkton Formation is gently folded and locally faulted and is uppermost middle Eocene in age. Because of its fine grain size and gradational contact upwards into deltaic and strandline deposits (Baldwin, 1974), the unit is thought to represent shallow-water deposition under shoaling conditions. The Elkton Formation grades downsection into the deeper-water Tyee Formation.

The middle Coaledo Formation in the Coos Bay area is a siltstone lying between the sandier upper and lower members of the Coaledo Formation. The unit is late Eocene in age (Figure 3) and locally displays steep dips. The middle Coaledo Formation represents relatively deep-water deposition which occurred at the peak of the marine transgression that produced the Coaledo Formation in the Coos Bay area. Recent interpretations of the fauna indicate lower neritic to upper bathyal depths (Rooth, 1974). Although water depths of greater than 600 feet are suggested by literal interpretations of these terms, shallower depths are possible. The Coos Bay area is a unique structural situation (see Structure), and rigorous application of bathymetric terminology may not be appropriate.

The Bastendorff Formation consists of approximately 3,000 feet of shale and siltstone with a thin sandstone interbed (50 feet) in the middle of the section. The unit is restricted to the axes of major synclines in the Coos Bay area. Most recent studies of the planktonic fauna indicate restriction to the late Eocene (Rooth, 1974). Earlier studies included the upper part of the unit in the lowermost Oligocene. Deposition deep in the bathyal zone is interpreted by Rooth (1974), although the precise meaning of this term in the Coos Bay area is still uncertain.

Table 7. Engineering geology of bedrock geologic units, Coos and Douglas Counties, Oregon

Unit	Formation Name and symbol[1]	Rock type	Structure and bedding	Soils[2]	Associated hazards	Resources	Additional land use suitability characteristics[3]
Sandstone of Tertiary Age	Empire (Tpe) Miocene sed. (Tms) Tunnel Point (Totp) Coaledo, upper (Tecu) Coaledo, lower (Tecl) Coaledo, part (Tec) Tyee (Tet) Flournoy (Tef) Lookingglass (Telg) Roseburg (Ter)	Hard, thick to thin-bedded sandstone with minor siltstone	Rhythmic to deltaic bedding; gentle to moderate dips, jointed and faulted locally	Loamy sand and sandy loam; very thin soils on steeper slopes and with abrupt transition to bedrock	Rapid erosion, flash flooding, rapid mass movement, stream-bank erosion	Coal, fill material, possible oil, low groundwater yield (less than 5 gpm), stream riprap	Good to very good foundation, rippable to needs blasting, locally permeable along joints and faults, very limited waste disposal potential, use limited by steep slopes and associated hazards in many areas; sparse development, well-managed forestry, open space, low density subdivision in places, moderate density in areas of gentle slope
Siltstone of Tertiary Age	Bastendorff (Teob) Coaledo, middle (Tecm) Coaledo, part (Tec) Elkton (Tee)	Soft to moderately hard siltstone and shale with minor sandstone	Same as above, but much finer jointing	Silty loam and silty clay loam; very thin locally even on gentle slopes	Rapid erosion, mass movement, stream erosion	Limited use potential, ground-water yield less than 5 gpm; poor fill	Good to fair foundation, rippable, impermeable, very limited waste disposal potential, use limited by slopes and associated hazards; moderate density housing on gentle slopes
Basalt of Tertiary Age	Roseburg (Terv)	Dense to rubbly basalt	Massive, thick, variable stratigraphic position	Silty clay loam, silt loam; extremely variable in thickness	Flash flood, mass movement	Fill, riprap, road metal, quarry rock, ground-water yield less than 5 gpm	Good to excellent foundation characteristics, requires blasting, impermeable, poor waste disposal, development limited by slopes and associated hazards, and cost of excavation
Rocks of Pre-Tertiary Age	Humbug Mtn. Conglomerate (Khm) Otter Point (Jop, Jov, Js, Jc, Jsp) Galice (Jg, Jgv)	Sandstone & conglomerate Shearedsediment. rock, pods of schist and crumpled beds of chert, also altered volc. rock	Bedded rocks, unsheared Pervasively sheared with intact knockers of schist or chert	Silty loam, silty clay loam, rubbly locally; extreme variability	Mass movement (locally deep and slow), stream-bank erosion, slope erosion	Limited use potential, ground-water yield less than 5 gpm generally, schist for jetty stone and riprap locally	Extreme variability of rock type, limited use potential, highly variable foundation ratings, mass movement precludes most economic permanent development except sparse housing in stable areas, variable logging potential; active stream-bank erosion along major streams; grazing, forestry, sparse settlement

[1]See stratigraphic time chart and map legends for age and distribution.
[2]See Soils Section for characteristics of soils and use limitations.
[3]Applicable to bedrock, as opposed to soils (discussed elsewhere).

Engineering geology: The siltstones and shales of this unit are interbedded with sandstone over large areas. The result is a wide range of engineering properties that can be properly assessed only by on-site observation where specific localized decisions are required.

Where siltstone is the predominant rock type over large areas, a characteristic low-lying, rolling topography is developed. Deep weathering produces silty loam and silty clay loam soils (see Soils). In the more steeply sloping upland areas where siltstone is interbedded with more abundant sandstone, soils are thinner and coarser textured.

On moderate slopes, high plasticity, shrink-swell processes, and other cyclic soil phenomena produce abundant, slow earthflows (see Mass Movement). The potential for slope failures in artificial cuts is high. Drainage is poor, especially in areas of irregular topography. Erosion potential varies from moderate to low in areas of thin, well-structured soils to very high in areas of unprotected disaggregated soils such as at construction sites.

The Siltstone of Tertiary Age is excavated with moderate difficulty, but makes very poor fill material owing to the high plasticity and low shear resistance. Permeability is low and runoff is high in regions of thin soils. Ground-water yields are very low (see Ground Water).

The unit is characterized by fair to good foundation strength, depending upon the degree of weathering, and can support moderate to high density housing on gentle slopes where other hazards are minimal. Potential for landfill waste disposal is good on gentle slopes. Resource potential of the unit is minimal.

Basalt of Tertiary Age

The Basalt of Tertiary Age consists of all the Tertiary eruptive basalt and associated intrusive basalt in the study area. It is mapped as basalt of the Roseburg Formation and is discussed in detail by Baldwin and others (1973) and Baldwin (1974).

Geology: The Basalt of Tertiary Age is distributed as a series of isolated patches in the valleys east of Coos Bay and in the middle Coquille drainage to the south. The largest exposures are those at Old Blue and three miles southeast of Coquille. Total areal extent of the unit is approximately 30 square miles.

An exploratory oil well in Davis Slough encountered greater than 5,000 feet of basalt without penetrating the bottom of the unit (Baldwin and others, 1973). The basalt consists of fine-grained submarine pillow basalts and breccias with varying degrees of alteration. Secondary minerals include zeolites and chlorite and are concentrated along joints and other structures. Exposures of coarser-grained more dense and less altered basalt such as that in the Hillstrom quarry on Kentuck Slough probably is of intrusive origin.

Individual exposures of the basalt tend to be located on the axes of northeast trending anticlines and commonly are fault-bounded on at least one side. Internal structures are difficult to define regionally. Jointing is variable, but generally is too closely spaced to permit quarrying for jettystone (see Mineral Resources). Some faults are noted locally. The basalt is not folded and apparently was deformed or displaced as a unit rather than being deformed internally.

Paleocene microfossils have been recovered from sedimentary interbeds in the basalt on the south side of Sugarloaf Mountain (Baldwin, 1965). The basalt is interbedded with the lower part of the Roseburg Formation, and its base is not exposed. The unit represents localized centers of submarine volcanism during the deposition of Roseburg sedimentary strata in the early Tertiary.

Engineering geology: The Basalt of Tertiary Age consists of variably altered submarine breccias and pillow lavas. Engineering properties and potential uses are determined by conditions at the specific site in question. Locally, limestone lenses are present stratigraphically above the basalt, as in the northeast quarter of section 35 near the fork of the Coos River.

Depth of weathering and soil development (see Soils) is highly variable. Bare slopes and rubbly soil characterize steep terrain, and reddish-brown silt loams varying in thickness from 0 to 20 feet are present on the gentler slopes. Soil mantles exposed in quarries indicate, however, that soil thickness varies considerably over very short distances even in areas where slope is constant.

Excavation requires blasting, and the unit is a good source of fill material as discussed below. Steeper slopes are subject to rockfall (see Mass Movement) and rapid runoff (see Stream Flooding). Local earthflows

are common in areas of thick soil on moderate slopes. The basalt constitutes firm ground in terms of earthquake response and provides relatively safe construction sites in this regard.

Permeability of the basalt is very low except locally along major joints, and ground-water production is negligible. Erosion hazard and runoff potential are high on moderate to steep slopes.

Foundation strength is very high. Blasting is required for the installation of underground facilities or for the construction of roads in cuts. Waste disposal potential is minimal. Landfills in abandoned quarries generally are not advisable, although specific on-site studies are required for a final determination. The very low infiltration rates would cause a near-surface accumulation of runoff and precipitation, which in turn would spill over into surrounding areas. Where water could penetrate along joints, effluent attenuation would be minimal owning to the tightness of the bedrock. In contrast, suitable soils and bedrock units expose much larger surface areas of material to effluent and provide more effective treatment.

Septic tank installations should be restricted to the soil zone (see Soils). In view of the extreme range of soil type and thickness of this unit, the need for on-site examination of potential building sites is particularly acute.

Long-range land use planning should consider the resource potential of this unit to assure that valuable sources of quarry stone are not lost through improper development. The basalt provides good-grade road metal and also is used for fill and base rock. Through controlled blasting and stockpiling of large blocks, the basalt also can serve as a limited source of jettystone.

Rocks of Pre-Tertiary Age

The Rocks of Pre-Tertiary Age consist primarily of a diverse assemblage of sheared sandstone and siltstone, volcanic rock, contorted chert, and blueschist termed the Otter Point Formation. Also included are small exposures of bedded conglomerate and sandstone (Humbug Mountain Conglomerate) and bedded siltstone and volcanic rock (Galice Formation) in the extreme southern part of the mapped area south of Powers. The three formations are discussed in more detail by Baldwin and others (1973).

Geology: The Otter Point Formation is restricted to exposures along the South Fork of the Coquille River between Myrtle Point and Powers and to coastal and upland exposures south of Bandon. Outside the study area, the unit flanks the periphery of the Klamath Mountains and extends down the Curry County coastline into California, where it is equated with the Franciscan Assemblage (Ghent and Coleman, 1973).

The Otter Point Formation is a complex structural association of highly varied rocks of diverse origin and is commonly referred to as a melange in reference to its shearing, or an ophiolite in reference to its composition. Pervasive shearing and regional faulting along northeasterly trending faults obscure bedding, and no meaningful estimate of stratigraphic thickness is available.

Exposures of sheared sedimentary rock are dominant in the study area. Rhythmic bedding of sandstone and siltstone evident in fresh exposures in Curry County (Dott, 1971) indicate a turbidity origin for this part of the Otter Point Formation. A multitude of calcite-filled hairline fractures characterize fresh samples.

Scattered in moderately sloping terrain of sheared sedimentary rock are isolated subequant pods of harder, more resistent bedrock (Figure 4) consisting of altered volcanic rock, contorted reddish and gray chert, and blueschist (a foliate rock consisting in part of glaucophane). Although local structures in the pods, such as tight folding of the chert, cannot be extended regionally, they do reflect the intense deformation of the Otter Point Formation as a whole (see Structure).

Other rock types included in the Rocks of Pre-Tertiary Age include small patches of serpentine in Otter Point terrain, a small exposure of bedded conglomerate and sandstone assigned to the Humbug Mountain Conglomerate by Baldwin and others (1973), and a small exposure of hard, bedded siltstone assigned to the Galice Formation. The serpentine was probably injected into the Otter Point Formation along associated faults after the Otter Point was sheared into position. The Humbug Mountain Conglomerate represents Cretaceous deposition on a sea floor of Otter Point rocks. The Galice Formation represents deposition on the sea floor in pre-Otter Point times.



Figure 4. Otter Point terrain consists of moderate slopes with scattered blocks of steeper more resistant bedrock.

The Otter Point Formation is thought to represent Mesozoic sea-floor and island-arc rocks (Coleman, 1972) that were thrust beneath the continental crust by sea-floor spreading (see Structure). Fossils recovered from the unit out of the study area indicate a late Jurassic age (Dott, 1971). Radiometric age determinations for blueschist pods within the unit ore generally consistent with this interpretation, but do yield scattered pods of older age for which the origin is still uncertain (see Structure). Extensive uplift and erosion have brought these deep-seated rocks to the surface.

Engineering: From the standpoint of engineering, the most significant feature of the Rocks of Pre-Tertiary Age is the extreme variability of rock type and consequently the extreme variability of engineering properties. Although sedimentary rocks are by far the dominant rock type, the specific types of sedimentary rocks and the degree of faulting or shearing vary considerably depending upon location.

Deep weathering and soil development are facilitated by the extensive shearing of much of the sedimentory rock. Soils include silty loam and silty clay loam on gentle to moderate slopes and rubble around the edges and downslope of many of the larger pods of harder bedrock.

Earthflow characterizes the bulk of Otter Point terrain and occurs on slopes as gentle as 20 percent. Although the large tectonic pods discussed above resemble landslide blocks in some respects, they differ in their great size relative to the depth and type of mass movement and in the fact that suitable source topography for the blocks upslope is not present. The irregular topography of the Otter Point Formation, therefore, is the result of both tectonic history and present mass movement.

Mass movement is the most pronounced where active stream erosion impinges on moderate slopes. Construction in these areas is difficult. For example, future widening, straightening, or rerouting of the road to Powers may easily initiate additional sliding and should proceed only after careful route selection and engineering review.

Additional hazards include rockfall on steeper slopes of unsheared bedrock, possible liquefaction on moderate slopes during blasting or earthquake activity, and erosion of unprotected soils.

Rocks of Pre-Tertiary Age are excavated with moderate to great difficulty, and blasting is required in areas of relatively intack bedrock. Excavatability of the unit varies with the degree of shearing and is often difficult to predict accurately beforehand. Much of the rock provides adequate fill for most construction projects, although the plasticity of weathered soils may be unacceptable.

Permeability of the soils is moderate to slow and permeability of the bedrock is generally very low owing to the recementation of the many fractures by clay, calcite, and other materials. Runoff is moderate to high depending upon slope, and ground-water potential is low.

Owing to the extensive development of earthflows on moderate slopes and the unacceptable steepness of slopes developed on unsheared terrain, the potential land uses of the Pre-Tertiary terrain is limited to low intensity uses such as grazing, controlled logging, and open space. Potential for septic tanks varies considerably and must be determined on a site-by-site basis. Scattered low-density housing is a possibility in areas of minimal slide hazard, adequate drainage, and acceptable shrink-swell properties.

Greenstone is quarried locally from the Otter Point Formation outside the study area. Tupper Rock, a blueschist pod near Bandon, was quarried for jettystone for the south jetty at Bandon in the early 1900's. Recemented chert of suitable quality can be used for building or ornamental stone.

Surficial Geologic Units

General

Nine surficial geologic units are recognized. They are 1) Quaternary marine terrace deposits, 2) Quaternary fluvial (river) terrace deposits, 3) Quaternary alluvium, 4) marsh and peat, 5) deflation plain and beach sand, 6) tidal flat, 7) stable sand, 8) unstable dune sand, and 9) fill and spoils. Surficial geologic units are semi-consolidated to unconsolidated deposits that formed by relatively recent processes and that mantle older bedrock units and structures. Surficial geologic units differ from soils in that they are the product of depositional processes and not of weathering.

The general geology and engineering properties of the nine surficial geologic units are summarized on Tables 8 and 9 respectively, and the relative ages of deposition are summarized schematically on Figure 3. The marine terraces are the remnants of past sea floor elevated by recent uplift, and the river terraces are the dissected remnants of prior flood plains. The various sand deposits were laid down relatively recently as rising sea level moved the coastline inland (see Coastal Erosion and Deposition). Thickness of the deposits is nearly 200 feet in some coastal areas and thins to extinction in the upper reaches of sloughs. Total thickness does not reflect the total rise in sea level because erosion has removed the original coastline.

Quaternary marine terrace deposits (Qmt)

Geology: This unit is composed of marine and related deposits that have been uplifted to form broad horizontal surfaces along the coast and flat ridge crests farther inland. Elevations vary from a few tens of feet in the Coos Bay area to approximately 1,600 feet on Blue Ridge. Rock types include basal surf-zone sands and gravels, compact horizontal layers of silt and fine-grained sand, river deposits of coarse sand and conglomerate, and a widespread mantling of unconsolidated medium-grained beach sand and finer-grained wind-blown sand. Total thickness ranges from a few feet to 100 feet or more locally.

River deposits located in the subsurface between Whiskey Run and Cut Creek represent the course of the Coquille River during the last interglacial period, approximately 100,000 to 200,000 years ago. Similar deposits are reported in the Coos-Umpqua dune sheet near Coos Bay (Robison, 1973). Baldwin (1964) assigns the deposits near Bandon to the Coquille Formation and correlates them with other elevated river deposits of similar setting along the Oregon Coast.

Beach deposits of this unit consist of flat expanses of medium-grained, horizontally bedded sand. Wind-blown deposits consist of cross-bedded, fine-grained dune sand. Basically, the dune sand of this unit differs from stable sand (ss) in that it rests upon marine terrace deposits. In many areas, however, this distinction cannot be made. All dune sand not involved in the last episode of dune advance (Cooper, 1958) is included in the Quaternary marine terrace unit. The better developed soil profile and location far removed from areas of unstable sand distinguish the dune sand of the terraces from that of the stable

Table 8. Geology of surficial geologic units

Unit	Distribution	Material and bedding	Age	Origin
Quaternary marine terrace (Qmt)	Flat coastal uplands mantled with marine deposits	Compact, horizontally bedded, deeply weathered silt, sand, and clay; pan development locally	Middle to late Quaternary; highest erraces may be Pleistocene	Coastal deposits uplifted by tectonism
Quaternary fluvial terrace (Qft)	Dissected former flood plains "elevated" above present flood plains	Sand, silt, clay, and gravel depending upon source; cross-bedded	Late Quaternary	Prior flood plain "elevated" by downcutting
Quaternary alluvium (Qal)	Flood plains of rivers and major streams	Sand, silt, clay, and gravel depending upon environment and source; cross-bedded	Holocene to late Pleistocene at depth	River deposits laid down in flood stage
Marsh and peat (mpt)	Estuarine and interdune wetlands with vegetative cover; under dunes and Qal	Horizontally bedded sand, silt, and clay, rich in organic material	Holocene; surface deposits to the present	Sediment entrapment by vegetation in higher tidal areas
Deflation plain and beach sand (sdpb)	Wind-swept areas exposed to the water table inland from the foredune; beaches	Fine- to medium-grained sand, indistinct cross-bedding, horizontal soil horizons associated with water table locally	Variable depending upon conditions; still changing; Holocene	Lag deposits in wind erosion areas and coastal deposition
Tidal flat (tf)	Estuarine wetlands located within the range of normal tidal fluctuations	Horizontally bedded sand, silt, clay, and organic material	Holocene; surface deposits to the present	Ocean and river sediment winnowed by tidal action
Stable sand (ss)	Forested dunes and vegetated interdune areas; foredunes	Fine-grained sand with indistinct cross-bedding	Late Holocene depending on protective cover	Wind-blown sand with natural cover
Unstable sand (su)	Large dunes inland from deflation plains; transverse dune fields	Fine-grained sand with indistinct cross-bedding	Variable depending upon conditions; still changing; Holocene	Wind-blown sand in big dunes and with no cover
Fill and spoils (fs)	Marginal to wetlands, road fill in the uplands and other dissected terrains	Dredge spoils, solid waste, sand, silt, clay, sawdust and woodchips; dumped	Historic, generally less than 50 years	Man-made

Table 9. Engineering geology of surficial geologic units

Unit	Soil[1]	Hazards[2]	Resources	Additional land use suitability characteristics
Quaternary marine terrace (Qmt)	Silt loam, silty clay loam, sandy loam, sand, silt	Ocean erosion, stream-bank erosion	Suitable for development; minimal hazards over large areas	Thin locally, poor drainage in places, failure in deep cuts
Quaternary fluvial terrace (Qft)	Silty loam, silty clay loam	Ponding, high water table, stream-bank erosion	Sand and gravel; ground water; agricultural land	Surface textures commonly much finer than those at depth, very thin locally
Quaternary alluvium (Qal)	Sandy and loamy sand, silty loam, silty clay loam	Flooding, ponding, settling, siltation, high ground water	Sand and gravel, fill material, ground water, agricultural land	Surface textures commonly much finer than those at depth, variable waste disposal potential, caving
Marsh and peat (mpt)	Silty loam, silty clay, muck	Liquefaction, settling, flooding, high ground water	Wildlife	Extremely variable soil conditions, caving
Deflation plain sand and beaches (sdpb)	Sand	Wind erosion, wind deposition, high water table, tidal and ground-water flooding	High ground water potential, shell fish, wildlife	Poor foundation strength, caving, highly variable soil conditions, minimal waste disposal
Tidal flat (tf)	Silty clay, loam, peat	Ocean flooding, liquefaction, settling	Shell fish, wildlife	May underlie dunes in the subsurface; caving; fill may have regional adverse impact on biota
Stable sand (ss)	Sand with surficial humus, loamy sand	Wind erosion, ocean and ground-water flooding, ground-water pollution	Fill material, ground water	May overlie compressible soils, high wind-erosion potential, restricted waste disposal potential
Unstable sand (su)	Sand	Wind deposition, wind erosion, ocean flooding, ground-water pollution	Fill material	May overlie compressible soils, may contain pan deposits at depth, minimal waste disposal
Fill and spoils (fs)	Variable	Settling, sliding, flooding, liquefaction	New land for development	Hazards result from poor fill selection, poor placement, and insufficient consideration of substrate properties

[1] See Soils.

[2] See appropriate parts of text.

sand unit (ss). The Dune sand of the terraces is probably Wisconsin in age.

The marine terraces are of complex origin and vary in age from an estimated 2 million years at Blue Ridge (Baldwin and others, 1973) to approximately 30,000 years, as determined by radiocarbon age dates, along the seaward edge of the Whisky Run Terrace (Richard Kent, PP&L, oral communication, 1975). The latter deposits probably were laid down during an interstadal rise in sea level during the late Pleistocene, as described by Curray (1965). The bulk of the terraces probably are last interglacial (Sangamon), or approximately 100,000 years old.

Engineering geology: The flat upper surface of the terrace deposits inhibits erosion and promotes deep weathering. Soils include silt loam and silty clay loam over finer-grained older material, and sandy loam, sand, and silt over some of the more recent wind-blown deposits (see Soils). In the soil horizons and at depth, iron-cemented pans are developed locally (see Soils).

Geologic hazards are primarily concentrated along the edges of the terrace deposits and include ocean erosion (see Coastal Erosion and Deposition), stream-bank erosion (see Stream Erosion and Deposition), and caving in deep excavations (see Mass Movement). Along terraced coastal headlands, ground-water movement along the base of the terrace deposits commonly promotes sloughing of the surficial material even in areas where the coastal erosion rate is minimal.

Permeability ranges from high for many of the surficial beach deposits and wind-blown deposits to moderate or low for the finer-grained marine deposits at depth. Permeability of the Coquille Formation is favorable and for the areas of pan development is very low. Ground-water potential varies accordingly, but is generally moderate.

Potential for waste disposal is variable depending on local ground-water conditions, the nature of the proposed waste-disposal techniques, and the type of terrace deposits present at the proposed site. Landfills in the Whisky Run terrace area are successful in spite of the moderate permeability because of the low water table and relative isolation. Septic tanks in soils developed on wind-blown sand may fail, however, owing to the greater grain size and high permeability of the unweathered dune sand beneath the soil horizon. Decisions for potential waste disposal in the Quaternary marine terrace unit (Qmt) are highly complex and require on-site examination.

The Quaternary marine terraces have a high potential for future development because of their characteristic low slopes and good drainage. The terrace material is excavated with little difficulty and is suited to use as fill material. In places, specialized uses have developed in response to unusual local conditions. Where black sands are concentrated, mining operations have left large excavations now utilized in part for landfills. Where near-surface impermeable pans are present, cranberry bogs have been constructed.

Quaternary fluvial terrace deposits (Qft)

Geology: Alluvial terraces are formed when continued uplift of the land prompts the stream to cut downward through its flood-plain deposits to form a new flood plain at a lower elevation. The dissected and fragmented remnants of the former flood plain are then seen as terraces along the sides of the valley (Figure 5). Quaternary fluvial terrace deposits are developed locally in the middle and upper reaches of all the major rivers of the study area.

The terrace deposits consist of sand and silt along the Coos River, Millicoma River, and middle drainage of the Coquille River, and of sand, silt, and gravel along the Umpqua River and in the upper reaches of the Coquille River. Distribution of gravel is a function of the nature of the source area and not solely of stream gradient. Many of the tributaries of the Millicoma River exhibit very steep gradients but are not associated with gravel because the watersheds are underlain entirely by sandstone and siltstone.

Terrace thicknesses vary from approximately 30 feet in the lower reaches of major rivers to a few feet in the upper reaches of the Coquille River. Characteristically the upper few feet of the terrace deposits are finer grained than deposits at greater depths. The fluvial terraces are younger than the marine terraces on overlooking ridge crests and are probably very late Pleistocene in age.

Engineering geology: The fluvial terrace deposits form flat, poorly to moderately drained landforms above the present-day flood plains. Soils consist of silty loams and silty clay loams (see Soils). Major



Figure 5. Fluvial terraces in the middle reaches of the Coquille River. Foreground terrace is younger than background terrace.

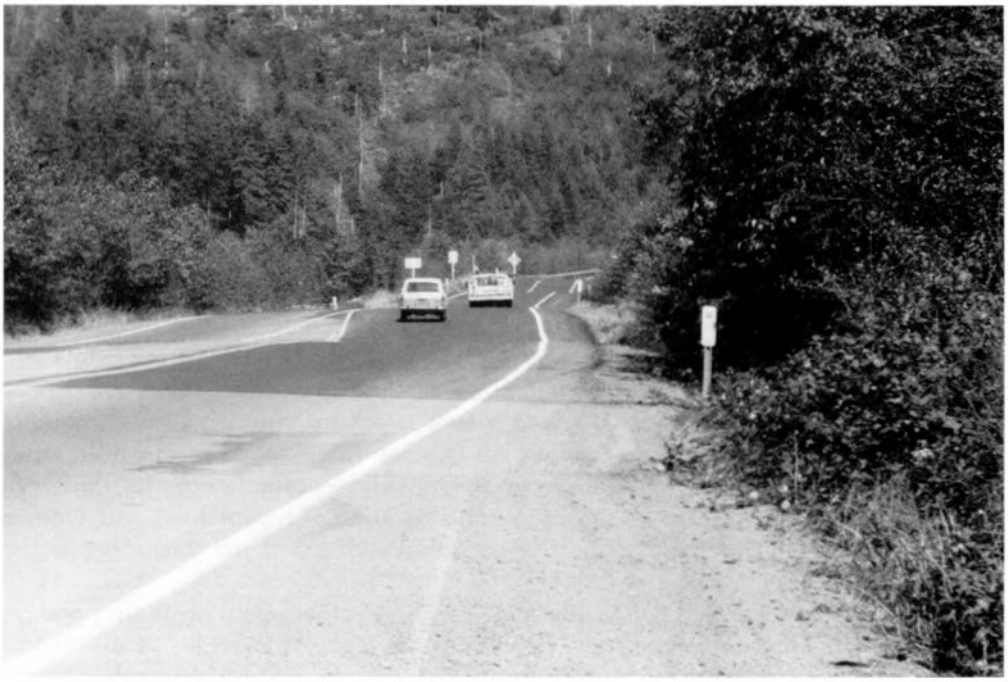


Figure 6. Compressible horizons of peat underlie the highway along Davis Slough; note the dips and swales.

hazards include ponding, high ground water, and stream-bank erosion along the edges. Where terrace deposits are thin, the characteristics of the underlying bedrock are significant and must be considered in all engineering projects.

The terrace deposits are easily excavated and are moderately to well suited for use as fill. Although ground-water production and subsurface permeability are moderate, infiltration is commonly slow owing to mantling deposits of silt and clay. The terrace deposits are well suited to development since there are flat landforms and minimal hazards over large areas. The communities of Coquille, Myrtle Point, Reedsport and Scottsburg are situated in part or entirely on terraces. Where upland streams spill onto poorly defined channels on terraces, local flooding is a distinct hazard, as in the area surrounding Arago in the middle Coquille drainage. Mineral resources include local high-grade deposits of sand and gravel.

Quaternary alluvium (Qal)

Geology: Unconsolidated deposits of poorly sorted gravel, sand, silt, and clay in the flood plains and channels of major rivers and streams is assigned to the Quaternary alluvium. Thicknesses vary from a few feet in the upland valleys to greater than 100 feet in some estuarine areas. Gravel and sand predominate in the Umpqua River drainage and the middle and upper reaches of the Coquille River. Elsewhere gravel is lacking owing to the weathering properties of the sandstone and siltstone that underlie the other watersheds. Flash-flood deposits consist in part of coarse sandstone rubble.

The Quaternary alluvium of major flood plains consists of three types of sediment: 1) sand and silt in levees lining present-day stream channels, 2) cross-bedded sand and silt behind levees, and 3) a surficial layer of silt and clay, rich in organic matter, behind the levees. The levees formed when rapidly moving flood waters spilled over the channel banks and dropped the coarsest sediment nearest the stream. The cross-bedded sand and silt represent former courses of the stream channel in the valleys. The surficial fine-grained sediment over the channel deposits was laid down relatively recently by quieter flood waters on the flood plain away from the main river channel.

The Quaternary alluvium occupies channels cut into the youngest marine terraces, for which an age of less than 200,000 years has been inferred (see Quaternary marine terrace deposits). In addition, the lower reaches of the major streams are adjusted to present sea level. An age of less than 20,000 years can be inferred for alluvium in these areas (see Coastal Erosion and Deposition). The relative age of the alluvium of the interior is less certain, but obviously is less than that of the river terraces, for which a late Pleistocene age is inferred.

Engineering geology: Soils developed upon the Quaternary alluvium are complex and are the result of weathering, flood-plain deposition, and plant growth. They include silty loams, silty clay loams, and silts with varying organic contents. Soils on the levees grade downward into coarser material (see Soils), and surface soil in the depressions behind levees grades downward into finer-grained soil profiles at depth (see Soils). Interbeds of varying grain size and peat are common.

The levees retard drainage, and the main geologic hazards include ponding of rainwater as well as stream flooding. Although ditches and drainageways are maintained in much of the alluvium, ponding persists through the summer months in many areas. Other hazards include siltation (see Stream Erosion and Deposition), high ground water, and settling of ground under structures.

The Quaternary alluvium is easily excavated but is prone to caving, especially in saturated areas. Suitability for use as fill ranges from low for the clay-rich peaty deposits to high for the sandy gravels of the upper Coquille River. Infiltration and drainage are a function of topography, soil type, and location of the water table. Generally the ground is wet or saturated year round and ground-water production is good.

The Quaternary alluvium is best suited to agricultural and other open-space uses and generally should not be considered for permanent development. Because of the high water table, septic tanks and other forms of waste disposal are not recommended. In addition to ground water and highly productive soil, resources include sand and gravel locally.

Marsh and peat (mpt)

Geology: Wetland deposits rich in organic matter and exposed at the surface are assigned to marsh and peat (mpt). Marsh and peat are widely distributed and are present around the edges of estuaries and interdune lakes and along sloughs. As alluviation and dune migration spread into new areas, the marshes are buried under a variety of surficial units. Consequently, the subsurface distribution of the marsh and peat is far greater than the surface distribution and must be considered in dealing with these other units. Areas of present-day marsh and peat development are recognized on the basis of abundant vegetation, low-lying and saturated ground, and sinuous drainage.

Units which may include interbeds of peat are the Quaternary alluvium, tidal flats, Quaternary fluvial terrace deposits, and Quaternary marine terrace deposits. Units which may overlie the peat include stable sand and unstable sand. The distribution of peat in these units is determined by on-site subsurface investigations and cannot be accurately predicted beforehand.

Engineering geology: Soils associated with marsh and peat include silt loam, silty clay loam, and clay with varying amounts of organic content (see Soils). Geologic hazards include high ground water, flooding, and caving in deep excavations. Under light to moderate loads, the spongy to fibrous material making up peaty soils compresses and expels water to produce hazardous settling over prolonged periods of time. Highway 101 along Davis Slough south of Coos Bay was constructed on peaty and marshy material and has experienced severe differential settling (Figure 6). An additional hazard in areas of larger fills and developments is that of spreading of unconsolidated material laterally in the subsurface in response to the increased load. Impacts may include soils dislocations and the actual formation of ridges and mounds alongside the original development.

Where necessary, the severe restrictions posed by the soil conditions associated with marshy ground can commonly be overcome by any of a variety of engineering techniques including 1) excavation and backfilling with more suitable material, 2) preloading, 3) the use of piling or spread footing, 4) drain construction to accommodate migrating subsurface water mobilized by the additional load, 5) and the use of counterweights to control soil adjustments adjacent to such large construction projects as elevated highway fills. For small structures, the use of fill needed to avoid projected flooding may be sufficient to overcome the settling problem. Where peat is present in the subsurface, the extent of the hazard can be accurately determined only by subsurface study.

Deflation plain and beach sand (sdpb)

Geology: Deflation plains are broad, low-lying regions within the dune areas which serve as sources of sand for the large inland dunes. Commonly the deflation plains are situated immediately inland from the foredune. They are characterized by either widespread fields of low transverse dunes (see Wind Erosion and Deposition) or flat areas eroded to the level of the summer water table. In the winter a rise in the water table produces lakes and marshes.

Beaches are the primary source of all sand for the dune fields and are discussed in detail under Coastal Erosion and Deposition. The beaches and deflation plains consist primarily of fine- to medium-grained unconsolidated sand. Because the deflation plains also are associated with marsh development, they commonly are underlain by interbeds of peaty material. As shown by well-log data, areas of present-day dunes may also be underlain by horizons of peaty material representing former deflation basins and interdunal lakes.

The beaches and deflation plains are sources of wind-blown sand for larger dunes. Because they are adjusted to present-day sea level (see Coastal Erosion and Deposition), a maximum age of 5,000 years is inferred for them. Deflation-plain deposits in the subsurface are probably considerably younger than 20,000 years.

Engineering geology: In addition to sand, the deflation plains also are associated with silty clay and peat. Geologic hazards may include ocean flooding, possible liquefaction during moderate to strong earthquakes, differential settling, and caving of excavations. High water table prohibits most forms of waste disposal in the marshy deflation plains. Where transverse dunes are developed, the continual shifting

of the landscape and other aspects of wind erosion and deposition constitute serious difficulties to most forms of development. Deflation plains are delicate features representing a balance between sand supplied and removed by the wind. Where foredunes have been established, the diminished sand supply has resulted in enlargement of the deflation plain (see Wind Erosion and Deposition).

Resources of the deflation plain include wildlife and high ground-water potential; resources of the beach include sand and shellfish. Part of the deflation plain on North Spit (Coos Bay) has been utilized as an industrial waste lagoon. The site is isolated from water wells and is monitored on a regular basis. The foredune between the lagoon and the beach is probably an adequate defense against storm-surge erosion and tsunamis (see Coastal Erosion and Deposition).

Tidal flats (tf)

Geology: Tidal flats are deposits of silt, clay, and sand situated within the range of normal tidal fluctuations (mean high and mean low water) in the estuaries and other coastal areas. Tidal-flat material is also located in the subsurface beneath dunes, near the mouths of major rivers, and beneath Quaternary alluvium along the inner boundaries of estuaries. Silt and mud predominate, but sand is common in areas of moderate current activity such as at the mouths of streams and in ebb channels. It also predominates in regions downwind from spits and dune accumulations near the mouths of major rivers.

Thicknesses vary from greater than 100 feet near the Coast to a few feet or less in the inland areas. Distribution and thickness of tidal-flat deposits beneath dunes and alluvium are uncertain. Scattered water wells on North Spit west of Coos Bay penetrate a total thickness of greater than 200 feet of unconsolidated material, much of which probably is tidal-flat material. This figure is unusual, however, and thicknesses within the present-day bays probably do not exceed 100 feet and generally are probably less. Near Empire, bedrock is mantled by only 30 to 40 feet of tidal-flat material.

Engineering geology: Because the tidal flats are continually reworked by tidal action, they are mantled by no true soils. Grain-size distributions are equivalent to silty clay, loam, and sand, however. Geologic hazards include caving of excavations, possible liquefaction during earthquakes (see Earthquakes), and differential settling; tsunami potential, tidal flooding, and storm surge (see Coastal Flooding). Peaty horizons and compressive clay are common in the subsurface of tidal-flat areas.

Major resources include wildlife, shell fish, and a thriving biotic community. Land use potential under natural conditions is severely restricted, and the impact of extensive fills may be substantial (see Geology of Estuaries). Septic tanks and landfills are unacceptable. Construction of bridges, docks, and other structures for water-dependent uses should be preceded by adequate engineering studies to assess the foundation characteristics of the site. Hazards associated with subsurface peat must be considered in evaluating the site (see Marsh and peat (mpt)). Hazardous conditions can be overcome by a variety of engineering techniques including placement of proper fill material, the use of end-bearing piles where tidal-flat deposits are thin, and the use of friction piling where deposits are relatively thick.

Stable sand (ss)

Geology: Stable sand includes 1) all stable dunes not located on marine terraces, 2) interdune areas with a well-developed vegetative cover, and 3) the foredunes situated between the beaches and the deflation plains immediately inland. The foredunes are artificial features which have developed subsequent to the introduction of European dune grass to the Oregon Coast in the 1920's and 1930's.

Stable sand does not include vegetated dune sand that overlies marine terraces (see Quaternary marine terrace deposits) from which it is distinguished on the basis of topographic setting and relative degree of soil development. Stable sand is closely related to present systems of sand movement, whereas eolian sand on the marine terraces is a product of past systems of sand movement by the wind.

Stable sand consists primarily of fine-grained unconsolidated sand, but also includes marine sand, clay, tidal-flat material, and peaty horizons to depths of 80 to 150 feet. The sand is not totally eolian. Its complex origin can be best understood by envisaging present-day dunes migrating inland over forest, Quaternary alluvium, marsh, and lake deposits. As defined, most of the stable sand is a product of the last rise in sea level, which occurred during the past 20,000 years.

Engineering geology: Soils developed on stable sand generally consist of loamy sand and fine sand and are finer grained than the parent material at depth. In areas of high water table, impermeable pans of iron-cemented sand are developed at shallow depths in the soil or at greater depths in the parent material (see Soils). True soils are not present on the foredunes.

Where vegetation is removed, wind erosion and deposition may be initiated. Where prolonged periods of construction are anticipated in sensitive areas, temporary means of sand stabilization in exposed areas should be considered. Foundation strength is variable depending upon the type of material in the subsurface. For moderate to large structures, detailed subsurface investigations are recommended. In regions of high water table, liquefaction may accompany moderate to high earthquake activity or wide fluctuations in the water table.

Foredunes constitute artificial obstructions where beaches formerly merged almost imperceptibly with deflation plains and dunes inland. As such, they absorb storm waves which previously were dissipated over much larger areas. They therefore are subject to catastrophic erosion during severe storms (see Coastal Erosion). Damage to foredunes by tsunamis, however, can be expected to be relatively low owing to the limited number of waves involved.

Excavations in the foredune open avenues for sand migration and can accelerate wind deposition of sand inland. In addition, structures placed in the excavations can act to inhibit sand migration in a more local sense and can be expected to be plagued by undesirable sand deposition as well.

Resource potential of stable sand includes ground water and wildlife. Ground-water pollution can be minimized by strict control of waste disposal. In areas of soil development, examination of the coarser, more permeable parent material is necessary to accurately assess waste-disposal potential.

Unstable dune sand (su)

Geology: This unit includes those parts of all large dunes that are not protected from the wind by vegetative cover. Oblique dunes and parabolic dunes (see Wind Erosion and Deposition) are the most common dune forms. Small transverse dunes are included in the discussion of deflation plain and beach sand (sdpb).

Wind-blown sand from beaches and deflation plains is deposited on the active dunes. Migration rates of the dunes vary from a few inches to several feet per year (see Wind Erosion and Deposition) depending largely upon the extent of the source area. Active dunes situated inland from broad deflation plains and transverse dune fields advance the most rapidly.

With the recent development of foredunes, the supply of sand delivered from the beach to the deflation plains has been reduced over large areas. Consequently the amount of sand reaching the windward face of the large transverse and oblique dunes (see Wind Erosion and Deposition) also has decreased and the dunes no longer are in equilibrium. As the dune sand migrates inland there is less additional sand to replace it, and the deflation plains are widening. Ultimately, active dunes as we now know them could disappear from much of the coastal area.

Engineering geology: Active dune forms represent a balanced response of the terrain to present wind patterns, vegetative cover, and sand supply. Changes in any one of these can initiate unexpected changes in the pattern of wind deposition. For instance, structures or excavations placed in areas of wind erosion can promote local wind deposition detrimental to the development. For further discussion see Wind Erosion and Deposition.

Owing to very high infiltration rates and permeabilities, runoff is very low and ground-water potential is excellent in active dune areas. During the rainy season it is not uncommon for ground water to emerge at the surface between steeper dune faces and to produce localized quicksand conditions. The ground water is easily contaminated and the use of septic tanks and other forms of waste disposal is generally not recommended.

Active dunes display low to moderate foundation strength and may overlie peaty material in the subsurface (see Marsh and peat (mpt)). Resources include ground water and foundary sand. Use of the sand for fill under heavy structures in flood-prone areas is not recommended owing to potential liquefaction when saturated. Stabilization of active dunes should be preceded by a thorough investigation of all possible consequences.



Figure 7. Fill placed in southeast Saunders Lake (Reedsport quadrangle) is suited for light structures.



Figure 8. Continual fill failure of Highway 101 on the Coos-Douglas County line may be traced to improper selection of fill material.

Fill and spoils (fs)

Description: The term fill refers to all materials placed on the land surface to create new land or for the disposal of waste. Fill materials include sand, silt, mud, sawdust, wood chips, mixed rock and soil debris, solid waste, and dredge spoils. Most fills are located in the regions bordering estuaries and streams (see Estuaries). Other examples of fill include stream and channel crossings for major roads and sidehill base material for logging roads.

Geologic hazards: Geologic hazards associated with fills are determined by the type c fill material used, the location of the fill, and the techniques used in placing the fill. Poorly engineered fill projects are subject to a wide variety of difficulties, whereas proper engineering and site location minimizes hazard potential.

Sawdust and wood chips constitute a large percentage of the fill used in downtown Coos Bay. If large structures are anticipated, the engineering properties of the fill material and any long-term changes it may undergo should be considered. In areas underlain by eolian sand units, sand is often used for fill. Care should be exercised to assure that the engineering properties of the fill are consistent with the requirements of the project. Of particular concern also is the practice of creating housing lots by pushing sand from cuts into topographic lows (Figure 7). In the uplands where blasting may produce large blocks of sandstone for fill, the larger blocks should be broken down to minimize the risk of long-term irregular settling. In weathered terrain, fine-grained soils should not be used for deep fills. Use of clay-rich fill may be the cause of continued settling on the Coast Highway at the Coos-Douglas County line (Figure 8). Fill placed on drainage sewers in Reedsport has led to sagging and ineffective runoff control over the years.

Numerous topographic and geologic settings are unsuited to indiscriminate use of fill material. Steep, impermeable slopes such as those common in the interior uplands are potential sites of road failure if adequate drainage and proper engineering are not provided. Areas of peaty soil or ground-water discharge are potential sites of differential settling. Small drainages, especially in urbanizing areas, should not be indiscriminately filled. Winter runoff passing through the fill from upslope can lead to basement flooding or settling.

Various techniques can be employed to bring the engineering properties of the fill material or the fill location within acceptable limits. These include proper packing of fill material, placing of fill material under proper moisture conditions, and the installation of adequate surface and subsurface drains. Along streams and rivers, fill material can be fronted with riprap or other protective facings including natural vegetation where appropriate.

Large-scale fill projects also impact the biotic community, and in critical areas this factor should be considered. In estuaries, for example, large-scale landfill operations and spoils disposal operations can modify circulation and displace wildlife (see Geology of Estuaries). Dredging operations also may release toxic material locked up in the sediments and can modify the grain-size distribution of the surface sediments.

Soils

General

Unconsolidated mineral material at the Earth's surface formed in place by weathering over a period of time and differing from the material from which it is derived is termed soil. This definition is less restrictive than that employed by many agronomists, who limit soil to material capable of supporting plant growth, and it is more restrictive than that of many soils scientists who include depositional surficial units as soil (see Surficial Geologic Units). The definition is consistent with the methods of sampling (limited to the upper 5 or 6 feet) employed by the U. S. Soil Conservation Service, and it emphasizes the unique characteristics of the weathered zone.

Weathering processes of the Earth's surface include chemical breakdown of minerals, chemical reconstitution to form new minerals, physical disintegration, and leaching. Specific processes are governed by the nature of the parent material, topographic setting, climate, biologic activity, and time. Because

physical and chemical conditions vary vertically within the soil, horizons of differing composition and texture are developed. The upper, or A, horizon is the zone of leaching and clay removal. It is the zone of maximum organic activity and may be the site of removal of iron, carbonate, or other materials.

The middle, or B, horizon is the zone of accumulation of suspended material derived from the A horizon. Accordingly, this horizon is characterized by relatively high concentrations of silicated clay minerals, iron, and other materials removed from the A horizon. Basically, the underlying C horizon consists of partially weathered and decomposed parent material.

Some environments such as flood plains, wetlands, and dune areas are the sites of continuing deposition rather than uninterrupted penetrative weathering. The unconsolidated material may extend to relatively great depths and is treated as surficial geologic units in this study. It is treated as soil by the U. S. Soil Conservation Service.

Systems of soils classification

The National Cooperative Soils Survey of the U. S. Department of Agriculture adopted the Seventh Approximation System of Soils Classification in 1965. In it soils of the nation are grouped into order (based on regional climate), suborder (based on physical setting), group (uniformity and types of horizons), subgroup (gradations between horizons), families (broad textural and compositional features related to plant growth potential), series (parent material and genetic horizons), and type (based on surface texture) (see Appendix A). At the top of the scheme, soils of coastal Oregon are called Utisols on the basis of the moist temperate climate. At the bottom of the scheme, local soils are named according to soil profiles and surface textures. For instance, Blacklock fine sandy loams are characterized by a distinct soil profile and by fine sandy loam at the surface. Field recognition of soil textures is summarized in Appendix B.

All soils mapping is conducted using the system of classification adopted by the U. S. Department of Agriculture. Two other major systems of classification include the Unified Soils Classification (Appendix C) used by the U. S. Army Corps of Engineers and the AASHO (American Association of State Highway Officials) System (Appendix D) used by the U. S. Bureau of Reclamation and other government agencies. Comparison of the particle-size boundaries employed by the three systems is given in Appendix E. General equivalence of soils categories in the three systems are included in Tables 10 through 15.

The U. S. Department of Agriculture system of soils classification is based primarily on grain-size distribution and lends itself well to regional mapping. The Unified System is more rigorous and places emphasis on the engineering properties of the soil, including plasticity index (a measure of the water content at which the soil behaves as a plastic), liquid limit (a measure of the water content at which the soil behaves as a liquid), and organic content. The AASHO System is used to classify soils according to those properties that affect use in highway construction and maintenance.

Soils properties and uses

Tables 10 through 15 summarize the properties and uses of the soils of western Coos and Douglas Counties as furnished by the U. S. Soil Conservation Service. Data on properties are collected from the upper 5 or 6 feet of the earth and are not directly applicable to material at greater depths. Statements regarding processes and use potential are generalized. Proper site evaluation requires an assessment of bedrock and surficial geology (see Bedrock Geologic Units and Surficial Geologic Units), geologic processes (see Geologic Hazards), and mineral wealth (see Natural Resources), in addition to a consideration of soils (this section).

Distribution

The soils of western Coos and Douglas Counties are the acidic and leached products of weathering in a moist temperate climate under coniferous cover. As shown on Tables 10 through 15, soil development is closely related to landform and parent material.

The upland soils are characterized by moderate to rapid runoff, moderate to extreme erosion hazard, variable liquid limit, variable plastic limit, moderate to high corrosivity, and low to moderate shrink-swell potential. The A horizons are dominated by silty loams and the B horizons are generally silty clay. On

Table 10. Upland soils - properties, Coos and Douglas Counties, Oregon

Soil environment	U.S.D.A. system	Unified	AASHO	Perm. (in/hr)	Runoff	Erosion hazard	Liquid limit	Plastic limit	pH	Corrosivity		Shrink-swell potential
										Steel	Concrete	
Sandstone	Bohannen gravelly loam	SM	A-4	2.0-6.3	Medium to rapid	Mod. to severe			4.5-5.5	Low		Low
Sandstone and siltstone	Orford											
	0-22" silty clay loam	ML	A-4	.6-2.0	Medium	Moderate	35-40	5-10	5.0-			
	22-59" silty clay	CL	A-7	.2-0.6	to	to	41-50	15-25	5.6	High	Mod.	Moderate
	59-70" gravelly silty clay loam	GM	A-2-4	.6-2.0	rapid	severe	35-40	5-10				
	Templeton					Moderate						
	0-15" silt loam	ML	A-4	.6-2.0	Medium	to very	25-35	2-10	5.6-	Mod.	Mod.	Low to
	15-42" silty clay loam	CL	A-6	.2-0.6	to rapid	severe	35-40	11-15	6.0			moderate
	Dement											
	0-7" silt loam	ML	A-4 to	.6-2.0	Slow to	Slight to	25-30	1-5	5.0-	Mod.	Mod.	Low to
	7-45" silty clay loam		A-7	.2-0.6	rapid	severe	41-50	15-20	6.5			moderate
Sandstone and shale	Winema				Medium	Moderate						
	0-21" silt loam	ML	A-4	.6-2.0	to rapid	to	30-40	7-10	4.5-	High	High	Low to
	21-60" silty clay	ML	A-7	.2-0.6	(>12%)	severe	40-50	10-15	5.0			moderate
Siltstone and sandstone	Millicoma				Medium	Moderate						
	0-8" loam	ML	A-4	.6-2.0	to rapid	to	25-30	Non-	6.1-	Mod.	Low	Low
	8-35" gravelly loam	GM	A-2	.6-2.0	(>30%)	severe		plastic	6.5			
Siltstone	Orford				Medium	Moderate						
	0-28" silty clay loam	CL	A-7	.2-0.6	to rapid (>30%)	to severe	41-50	15-25	5.0-5.5	High	Mod.	Moderate
Siltstone and shale	Peavine				Medium	Moderate						
	0-10" silty clay loam	ML	A-7	.2-0.6	to rapid	to	45-55	15-20	4.5-	High	High	Low to
	10-36" silty clay	MH	A-7	.2-0.6	(>30%)	severe	60-85	30-45	6.0			moderate
Sed. rocks and basalt	Honeygrove				Medium	Slight to			4.5-			
	0-60" clay	MH	A-4	.2-0.6	to rapid	moderate			6.5	High		Moderate
Basalt and sandstone	Blachly					Moderate						
	0-6" silty clay loam	MH	A-5	.6-2.0	Medium	to very	50-65	5-10	4.5-	High	High	Low to
	6-60" silty clay	MH	A-7	.2-0.6	to rapid	severe	50-65	10-25	5.0			moderate
Siltstone and shale	Trask											
	0-8" shaly loam	ML	A-4	2.0-6.0	Slow to	Moderate	25-30	NP-5	4.5-		High	Low
	8-28" shaly silt loam	ML	A-2, A-1		rapid	to high	25-30	NP-5	5.0			
Sedimentary rock	Astoria											
	0-19" silty loam	ML	A-4	.6-2.0	Moderate	Moderate	NP	NP	4.5-			Low
	19-50" silty clay	MH	A-7	.6-2.0	to	to	50-60	11-20	5.0	High	High	Moderate
	50-68" silty clay loam	MH	A-7	.6-2.0	rapid	severe	50-60	11-20				Low

Table 11. Upland soils - uses, Coos and Douglas Counties, Oregon

Soil environment	U.S.D.A. system	Unified	AASHO	Construction use	Septic tank	Sewage lagoon	Sanitary landfill	Comments and present use
Sandstone	Bohannen gravelly loam	SM	A-4	Not suitable for aggregate; suitable for local roads on gentle slopes	Severe, steep slopes, shallow bedrock	Steep slopes, high permeability	Not suitable	Mainly used for timber production
Sandstone and siltstone	Orford 0-22" silty clayloam 22-59" silty clay 59-70 gravelly silty clay loam	ML CL GM	A-4 A-7 A-2-4	Not suitable for aggregate; may be used as fill or excavated on gentle slopes	Severe, steep slopes, low permeability	Acceptable on gentle slopes	Acceptable on gentle to moderate slopes	Timber production, recreation, water supply, wildlife
	Templeton 0-15" silt loam 15-42" silty clay lm.	ML CL	A-4 A-6	Not suitable source of sand or gravel; suitable for levees, fill on gentle to mod. slopes	Suitable on gentle slopes	Acceptable on gentle slopes	Suitable on gentle slopes w/thick soil	Woodland, recreation, and wildlife
	Dement 0-7" silt loam 7-45" silty clay loam	ML	A-4 to A-7	Not suitable for aggregate or construction except on gentle slopes	Acceptable where slope, thickness and perm. allow	Possibly suitable on gentle slopes	Limited by thin soils	Timber, forage crops, recreation, wildlife, and urban development
Sandstone and shale	Winema 0-21" silt loam 21-60" silty clay	ML ML	A-4 A-7	Good topsoil, not suitable for aggregate; base for roads and reservoirs	Severe where perm. is low or slopes high	Severe on steep slopes	Acceptable on gentle slopes	Pastures, homesites, water supply, and wildlife
Siltstone and sandstone	Millicoma 0-8" loam 8-35" gravelly loam	ML GM	A-4 A-2	Not suitable for sand or gravel; suitable const. sites on mod. to gentle slopes	Limited by steep slopes, thin soils	Limited by thin soils and steep slopes	Unsuitable on thin soils, steep slopes	Timber, recreation, and wildlife
Siltstone	Orford 0-28" silty clay loam	CL	A-7	Not suitable for construction or road base	Limited by steep slopes, thin soils	Limited to areas of low slopes	Not suitable - thin soils	Timber, recreation, wildlife, water supply
Siltstone and shale	Peavine 0-10" silty clay loam 10-36" silty clay	ML MH	A-7 A-7	Not suitable for construction	Severe - low permeability and thin soils	Not suitable	Not suitable - thin soils	Grains, pastures, orchards, homesites, timber, recreation
Sed. rocks and basalt	Honeygrove 0-60" clay	MH	A-4	Suitable for light structures on moderate slopes	Severe - low permeability	Acceptable on mod. slopes	Acceptable	Timber production
Basalt and sandstone	Blachly 0-6" silty clay loam 6-60" silty clay	MH MH	A-5 A-7	Not suitable for aggregate; suitable for local road base on moderate slopes	Severe - low permeability	Limited by steep slopes	Limited by slopes	Timber, water supply, and wildlife
Siltstone and shale	Trask 0-8" shaly loam 8-28" shaly silt loam 28" shaly silt loam	ML ML	A-4 A-2,A-1	Generally not suitable; suitable for dwellings on gentle slopes	Severe limitations due to bedrock	Not suited	Not suitable owing to slopes	Timber production, recreation, water supply, wildlife
Sedimentary rock	Astoria 0-19" silty loam 19-50" silty clay 50-68" silty clay lm.	ML MH MH	A-4 A-7 A-7	Suitable for local roads, road fill, and small buildings locally	Limited suitability	Suitable on gentle slopes	Not suitable - slopes and depth to bedrock	Used for woodland, pasture, recreation, and water supply

Table 12. Terrace soils - properties, Coos and Douglas Counties, Oregon

Soil environment	U.S.D.A. system	Unified	AASHO	Perm. (in/hr)	Runoff	Erosion hazard	Liquid limit	Plastic limit	pH	Corrosivity		Shrink-swell potential
										Steel	Concrete	
Marine terrace	Coos Bay											
	0-12" silt loam	ML	A-4	0.6-2.0	Slow to rapid	Slight to severe	25-30	0-5	5.6-6.0	Mod.	Low	Low
	12-34" silty clay loam	ML					30-40	5-10				
	Bullards											
	0-38" sandy loam	SM	A-2-4	0.6-2.0	Slow to rapid	Slight to severe		Non-plastic	5.6-6.0	Mod.	Low	Low
	38-60" sand	SP-SM	A-2-3	2.0-6.0								
Marine and eolian terrace	Blacklock											
	0-22" fine sandy loam	SM	A-4	0.6-2.0	Slow to moderate	Slight		Non-plastic	5.0-6.0	High	Low	Low
	22-32" loamy sand	(pan)										
	32-60" loamy fine sand	SM	A-2	2.0-6.0								
	Bandon											
	0-17" sandy loam	SM	A-2	0.6-2.0	Slow to moderate	Slight to moderate	15-25	0-5	5.6-6.5	Low-mod.	Low	Low
	17-30" loamy fine sand	(pan)		.06-2.0								
	30-50" loamy fine sand	SM-SP	A-2	2.0-6.0				Non-plastic				
River terrace	Salander											
	0-53" silt loam and silty clay loam	ML	A-4	0.6-2.0	Slow to rapid	Slight to severe	30-40	5-10	5.2-5.8	Mod.	Low	Low
	Knappa											
	0-68" silt loam and silty clay loam	CL	A-6	0.6-2.0	Slow	Slight	30-40	10-15	4.5-5.0	Mod.	High	Low
	Lint											
	0-60" silty clay loam	ML	A-5	0.6-2.0	Medium	Moderate	40-50	5-10	5.0-5.5	High	High	Moderate
Low marine terraces and deltas	Chetco											
	0-12" silty loam	ML	A-4	0.6-2.0	Very slow	Slight	30-40	5-10	5.1-6.1	Mod.	Mod.	Mod. to high
	12-54" silty clay	ML	A-7	0.06-.2			41-50	15-20				
	54-60" clay	MH	A-7	$<.06$			50-60	20-25				

Table 13. Terrace soils - uses, Coos and Douglas Counties, Oregon

Soil environment	U.S.D.A. system	Unified	AASHO	Construction use	Septic tank	Sewage lagoon	Sanitary landfill	Comments and present use
Marine terrace	Coos Bay 0-12" silt loam 12-34" silty clay loam	ML ML	A-4	Base for light structures and road beds	Limited by low permeability	Limited by slope	Limited by slope	Timber, water supply, urban development, recreation
	Bullards 0-38" sandy loam 38-60" sand	SM SP-SM	A-2-4 A-2-3	Suitable for light structures, roadfill, and sand supply	Suitable on gentle slopes	Not suitable, rapid percolation	Not suitable, rapid percolation	Wildlife, recreation, homesites, pasture, timber
Marine and eolian terrace	Blacklock 0-22" fine sandy loam 22-32" loamy sand 32-60" loamy fine sand	SM (pan) SM	A-4 A-2	Suitable as sand source at depth, poorly drained	Not suitable	Not suitable	Not suitable	Cranberry bogs, pasture, wildlife, timber, recreation
	Bandon 0-17" sandy loam 17-30" loamy fine sand 30-50" loamy fine sand	SM (pan) SM-SP	A-2 A-2	Suitable for light structures where slopes permit	Suitable if pan is ripped	Not suitable, high percolation rates	Not suitable, high percolation rates	Homesites, water supply, recreation, specialty crops, timber
River terrace	Salander 0-53" silt loam and silty clay loam	ML	A-4	Suitable for local roads and light structures where slopes permit	Suitable on lower slopes	Suitable on gentle slopes	Suitable on gentle to mod. slopes	Timber, recreation, wildlife
	Knappa 0-68" silt loam and silty clay loam	CL	A-6	Suitable as base for roads, light structures; also shallow excavations and embankment material	Suitable on gentle slopes (12%)	Suitable on slopes less than 7%	Suitable	Used mainly for hay and pasture; also for homesites and timber production
	Lint 0-60" silty clay loam	ML	A-5	Suitable as a base for roads and light structures; also for shallow excavations and for embankment material	Suitable on slopes less than 12%	Suitable on slopes less than 7%	Suitable	Used mainly for hay, pasture, homesites, and timber production
Low Marine terraces and deltas	Chetco 0-12" silty loam 12-54" silty clay 54-60" clay	ML ML MH	A-4 A-7 A-7	Not suitable for most construction owing to flood conditions	Poor drainage	High water table	High water table	Pasture and wildlife

Table 14. Lowland soils - properties, Coos and Douglas Counties, Oregon

Soil nviron-ment	U.S.D.A. system	Unified	AASHO	Perm. (in/hr)	Runoff	Erosion hazard	Liquid limit	Plastic limit	pH	Corrosivity		Shrink-swell potential
										Steel	Concrete	
Stable dune	Netarts and Westport 0-60" fine sand	SM	A-2	>20.0	Slow	Severe		Non-plastic	5.1-6.0	Low	Low	Low
Unstable dune	Active dunes 0-72" fine sand	SM-SP	A-2	6.0-20.0	Slow	Severe		Non-plastic	4.6-5.0	Very low	Low	Low
Marsh	Coquille 0-13" silt loam 13-40" silty clay loam 40-60" silty clay	ML CL CL-CH	A-4 A-6 A-7	0.6-0.2 0.2-0.6 0.06-.2	Slow to ponded	Slight	30-35 30-40 45-55	5-10 12-20 25-35	4.5-5.0	High	Low to moderate	Low to moderate
Marsh and tidal flat	Clatsop 0-6" peat 6-36" silty clay	Pt MH	A-8 A-7	0.6-0.2 <.06	Slow to ponded	Slight	50-60	15-20	4.5-6.5	High	Low to moderate	Low to moderate
Peat	Brallier 0-60" peat or muck	Pt	A-8	0.6-2.0	Slow to ponded	Slight		Non-plastic	4.1-6.5	Very high	Moderate	Moderate
Quaternary alluvium	Nehalem 0-17" Silty loam 17-60" silty clay loam	ML ML-CL	A-4 A-6	0.6-2.0 0.6-2.0	Slow	Slight to severe	25-35 30-40	5-10 10-15	4.6-5.5	Mod.	Low	Low
	Gardiner 0-8" sandy loam 8-56" loamy fine sand 30-60" sand and gravel	SM,ML SM GP,SM	A-4 A-2 A-1	0.2-0.6 6.0-20 6.0-20	Slow	Slight to severe		Non-plastic	5.1-6.2	Mod. to low	Low	Low
	Nestucca 0-14" silt loam 14-41" silty clay loam 41-60" silty clay	ML CL CL	A-4 A-6 A-7	0.6-2.0 0.2-0.6 0.2-0.6	Slow to ponded	Low	25-35 35-40 40-50	5-10 15-20 20-25	4.5-5.5	High	Moderate to high	Low to moderate
	Brenner 0-21" silty clay loam 21-52" silty clay	CL CL,CH	A-6 A-7	0.6-2.0 0.06-.2	Slow to ponded	Slight	25-40 41-55	11-20 20-30	5.1-6.0	Very high	Low to moderate	Low to moderate
Mixed marine and fluvial	Langlois 0-28" silty clay loam 28-52" silty clay	CL CH	A-6 A-7	0.2-0.6 .2	Very slow	Slight	35-40 50-60	15-20 25-30	5.5-6.0	High	Moderate	Moderate
Beaches	0-72" fine sand or sand	SM,SP, SM	A-2	6.0-20	Slow	Severe		Non-plastic		High	High	Low

Table 15. Lowland soils – uses, Coos and Douglas Counties, Oregon

Soil environment	U.S.D.A. system	Unified	AASHO	Construction use	Septic tank	Sewage lagoon	Sanitary landfill	Comments and present use
Stable dune	Netarts and Westport 0-60" fine sand	SM	A-2	Will support light structures; use limited by hazards	Acceptable on some gentle slopes	Not suitable	Not suitable	Homesites, wildlife, and recreation
Unstable dune	Active dunes 0-72" fine sand	SM-SP	A-2	Source of sand, not suitable for structures	Not suitable	Not suitable	Not suitable	Wildlife and recreation
Marsh	Coquille 0-13" silt loam 13-40" silty clay loam 40-60" silty clay	ML CL CL-CH	A-4 A-6 A-7	Not suited owing to low bearing strength and other hazards	Not suitable	Not suitable	Not suitable	Pasture, crops, wildlife, and recreation
Marsh and tidal flat	Clatsop 0-6" peat 6-36" silty clay	Pt MH	A-8 A-7	Not suited owing to geologic hazards	Not suitable	Not suitable	Not suitable	Pasture and wildlife
Peat	Brallier 0-60" peat or muck	Pt	A-8	Not suitable, bearing strength and hazards	Not suitable	Not suitable	Not suitable	Pasture and wildlife
Quaternary alluvium	Nehalem 0-17" silty loam 17-60" silty clay loam	ML ML-CL	A-4 A-6	Local roads, embankment material; flooding	Suitable where no flooding	Suitable where no flooding	Suitable where no flooding	Hay and pasture
	Gardiner 0-8" sandy loam 8-56" loamy fine sand 30-60" sand & gravel	SM,ML SM GP,SM	A-4 A-2 A-1	Suitable for local road base; source of gravel; flooding	Generally not suitable	Not suitable – flooding	Not suitable – flooding	Hay and pasture
	Nestucca 0-14" silt loam 14-41" silty clay loam 4-60" silty clay	ML CL CL	A-4 A-6 A-7	Suitable in part for embankments, dikes and levees	Not suitable	Not suitable – flooding	Not suitable – flooding	Pasture and forage crops
	Brenner 0-21" silty clay loam 21-52" silty clay	CL CL,CH	A-6 A-7	Not suitable owing to flooding hazards	Poorly drained, low permeability	Not suitable – high water table	Not suitable – flooding	Pasture, hay and wildlife
Mixed marine and fluvial	Langlois 0-28" silty clay loam 28-52" silty clay	CL CH	A-6 A-7	Not suitable owing to flooding hazards	Poorly drained, low permeability	Not suitable – high water table	Not suitable – high water table	Pasture and wildlife
Beaches	0-72" fine sand or sand	SM,SP, SM	A-2	Source of sand; not suited to construction	Not suitable	Not suitable	Not suitable	Beach recreation

steeper slopes of sandstone bedrock, a rubbly C horizon of bedrock debris is present at shallow depths. The high clay content of the B horizon and the presence of impermeable bedrock at shallow depths contribute to the low infiltration rates. Soil thicknesses are variable. Recent mapping shows Millicoma and Templeton soils where Astoria and Trask soils were mapped in earlier studies. All four of these soil series are summarized on Tables 10 and 11.

The terrace soils are characterized by slow to moderate runoff, slight to moderate erosion potential with high erosion potential on steep slopes, variable liquid limit, variable plastic limit, variable corrosivity, and low to moderate shrink-swell potential. Soils over fine-grained marine deposits and river deposits have clay-rich B horizons, whereas soils developed over eolian or beach sand grade downward from loams into sandier horizons. River terrace soils along the Umpqua and Coquille Rivers overlie deposits of sand and gravelly sand. Terrace material along other drainages is finer grained, being restricted to silts, clays, and sands.

Because of the flat upper surfaces of the terraces, erosion has been minimal over large areas and weathering has proceeded to relatively great depths. In places, the bedrock beneath the terrace deposits also has been weathered significantly so that its engineering properties are modified. Failures in deep cuts result where the reduced shearing strength is not accommodated (see Mass Movement). Infiltration rates are moderate, with the exception of Blacklock sandy loams and the Bandon silty loams for which low infiltration rates and high runoff or ponding are characteristic. Impermeable iron-cemented horizons in the subsurface formed as iron was leached from the A horizon by organic acids and was redeposited in the B horizon in response to differing soil conditions.

Many of the lowland soils recognized by the U. S. Soil Conservation Service have no soil horizons and are the products of ongoing deposition rather than weathering. Examples include beaches and wetlands. The lowland soils exhibit extreme variability both vertically and laterally. For example, included in the Quaternary alluvium are levee deposits and flat flood-plain deposits. At depth the loamy soils of the levees pass into permeable sand deposits, whereas the silty flat deposits pass downward into a clay-rich B horizon of low permeability. At greater depths a wide variety of materials may be encountered (see Quaternary alluvium).

The various sand units are generally characterized by high infiltration rates and low slope erosion. Where sand deposits are thin, however, overland flow can produce gullying or stream-bank erosion. The low-lying lowland soils, including peat, marsh, tidal flats, and parts of the Quaternary alluvium, generally are flat-lying and are situated in regions of high water table. They are characterized by low infiltration rates and ponding. Some depressions in the sandy units, such as interdune marsh, have developed impermeable iron-rich soil horizons similar to those of the terrace sands.

The lowland soils vary from nonplastic in the sands to moderate plasticity in some of the clay-rich horizons of the alluvium. Corrosivity varies from moderate to high and shrink-swell potential varies from low to moderate.

Structural and Tectonic Setting

General

Structural interpretations of the study area include reconnaissance geologic mapping of Coos County (Baldwin and others, 1973) and a more detailed investigation of the Coos Bay area (Allen and Baldwin, 1944) made in connection with a study of the coal fields. Little new structural data of regional significance was developed in the present study. Structural data for western Douglas County is more limited than that for western Coos County, and the distribution of certain rock units is still not fully understood (see discussion of Tyee Formation under Bedrock Geologic Units).

Since its launching on July 23, 1972, the Earth Resources Technology Satellite (ERTS-1) has maintained a 560-mile orbit and has transmitted a wealth of observational data to Earth for computor processing into photo-like imagery. Examination of these images on a scale of 1:250,000 substantiates on a tentative basis the structures defined in previous on-the-ground investigations. Detailed, more systematic study is needed, however, to fully utilize this new source of data and to provide further refinements in our understanding of the structure of the study area.

Knowledge of structure enables the geologist to 1) assess the distribution of mineral resources (see Mineral Resources) 2) assess the potential for earthquake activity, 3) map the distribution of rock units, and 4) assess more accurately the distribution of geologic hazards.

Five broad regions of structural significance are recognized in this discussion: 1) the Pacific Basin and continental shelf, 2) the northern Klamath Mountains in southern Coos County, 3) the western Coast Range, which makes up the bulk of Coos and Douglas Counties, 4) the Coos Bay Synclinorium, a region of complex folding throughout the Tertiary, and 5) coastal terraces and sea cliffs, features in which faulting is detected with relative ease.

Pacific Basin and continental shelf

According to the plate tectonic theory, the crust and upper mantle of the Earth are subdivided into a series of semi-independent slabs or plates, each of which is moving laterally in response to deeper seated activity within the earth. Boundaries between the plates are sites of 1) sea floor rises in areas of divergence, 2) trenches or related features in areas of convergence, or 3) transform faults in zones of parallel movement.

In the northeastern Pacific Basin, a relatively complex border zone has developed between the Pacific Plate on the west and the North American Plate on the east (Figure 9). As the Pacific Plate moves north relative to the North American Plate, a right lateral component of movement is experienced along the various faults and rises which separate the two plates. Off the coast of Oregon these include the Mendocino Escarpment, the Gorda Rise, the Blanco Fracture Zone, and the Juan de Fuca Rise.

The structures are the locus of considerable tectonism. High heat flow is reported along the rises (Dehlinger, 1969). Greatest seismic activity is located along the transform faults, and most epicenters are fairly shallow (Northrop and others, 1968). Right lateral fault plane solutions characterize both the Blanco and Mendocino fracture zones (Tobin and Sykes, 1968), and rates of displacement are several cm per year (Atwater, 1970). Seismic data also indicate a series of right lateral epicenters radiating northwestward into the Gorda Plate from the juncture of the San Andreas Fault and the Mendocino Escarpment.

The most intense earthquakes on record for the study area originated on the Mendocino Escarpment within 200 miles of the coast of California (see Earthquakes). Although this observation is consistent with the general tectonic model of the region, more data are needed for a complete assessment of potential seismic activity, and investigations continue. Silver (1971) recently defined a large subsea fault off the coast of Oregon with a displacement of 70 kilometers. He interprets cessation of activity along the fault approximately 500,000 years ago.

Major structures of the continental shelf include 1) the Coquille Bank, a north-south doubly plunging anticline off the south Coos County Coast, and 2) an unnamed large north-south-trending basin between Cape Blanco and the Coquille Bank which is filled with extensive Miocene and Pliocene sediments. Other structural features include unconformities, faults, and folds similar to those on shore (McKay, 1969).

A buried channel of the Coquille River is situated northwest of the present-day Coquille River and is filled with sediments similar to those of the Coquille Formation on shore (see Quaternary marine terrace deposits). An ancient bed of the Coos River underlies the dunes northwest of Coos Bay (Robison, 1973). A short distance off the coast of Cape Arago, upfolded bedrock is exposed on the sea floor. Farther north, bedrock units of the continental shelf are mantled by unconsolidated deposits of Quaternary age.

Northern Klamath Mountains

The northern Klamath Mountains in the study area are characterized by 1) northeasterly trending compressive structures including thrust faults, 2) block faulting, 3) widespread distribution of the pervasively sheared Otter Point Formation, and 4) scattered local basins or downwarps with rocks assigned to the Tertiary Lookingglass Formation. The structures are products of late Mesozoic and early Tertiary tectonic episodes and are not a measure of present-day seismicity. Present uplift is the product of deep-seated isostatic processes and, on the basis of currect information, does not appear to be concentrated along major faults at the Earth's surface. Recorded seismic activity in the Klamath Mountains is very low (see Earthquakes).

Blueschist pods within the Otter Point Formation are dated at 130 million years (Coleman, 1972). The blueschists and related rocks may be the metamorphic equivalents of the Galice and Dothan Formations

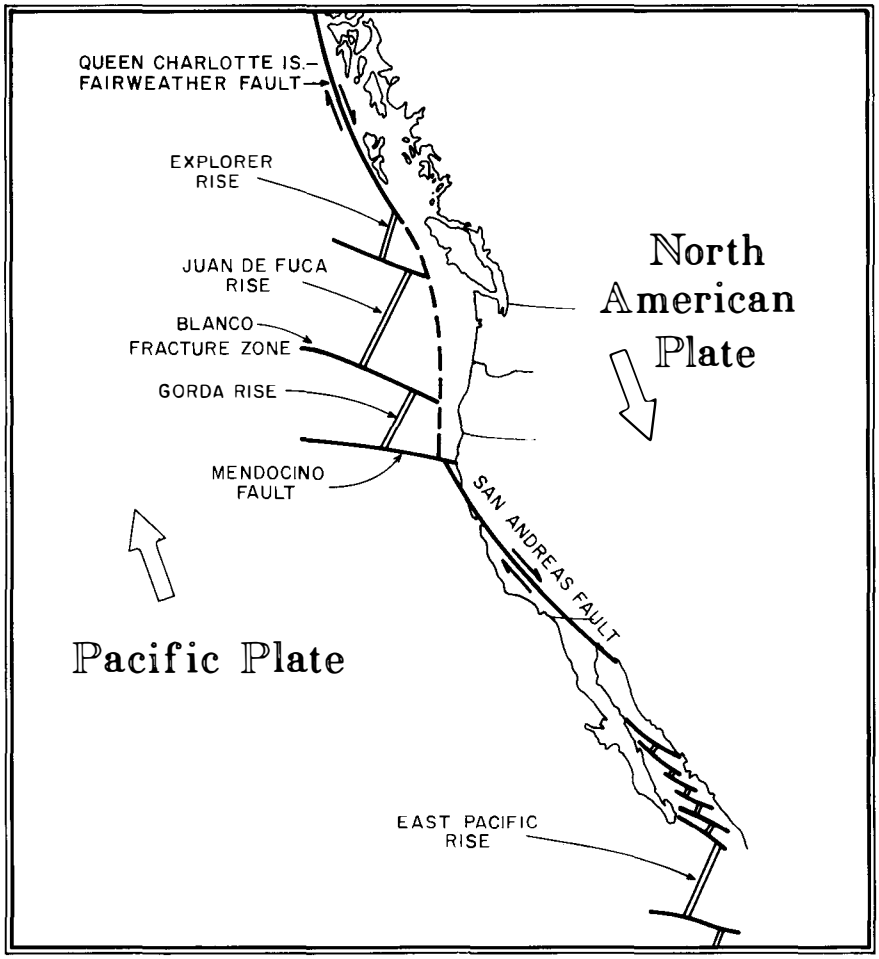


Figure 9. Major structures off the Coast of North America.

(Coleman, 1972) and may have been introduced into the Otter Point Formation during Late Jurassic subduction or Late Cretaceous thrust faulting. In Curry County the Colebrooke Schist, a unit similar in composition to the blueschist pods, overlies rocks of Cretaceous age.

Recent evidence indicates that thrusting continued into the early Eocene. The Roseburg Formation displays southeasterly thrusting and is characterized by tight, isoclinal folding overturned to the southeast. Baldwin and Lent (1972) postulate that at one locality the Colebrooke Schist lies structurally above rocks of Eocene age. Tertiary strata containing blueschist pebbles in Curry County originally mapped as Umpqua Formation (Coleman, 1972) have subsequently been mapped as Lookingglass Formation (Baldwin, 1974). An upper age limit of thrusting of middle Eocene rather than Late Cretaceous is indicated.

Scattered higher grade, older (approximately 150 million years) blueschist pods in the Otter Point Formation are apparently unrelated to the Galice or Dothan Formations and are of uncertain origin. Perhaps they represent deep-seated metamorphism of undefined rocks along the continental margin (Coleman and Lanphere, 1971) or beneath a sea-floor rise as postulated by Dudley (1972) for some similar rocks in California. Blocks of the blueschist were then incorporated into the younger Otter Point Formation during subduction of that unit or during later thrusting in the Late Cretaceous (Coleman and Lanphere, 1971).

Coast Range

The western Coast Range is characterized by gentle north-south folds and scattered faults (Figure 10). Little detail is available and delineation of structures is difficult owing to the uniformity of rock types. A small anticline and syncline are indicated east of Reedsport. The Elkton Formation east of Scottsburg occupies the axis of a broad syncline trending along the crest of the Coast Range. The contact between the Tyee and Flournoy Formations in the Umpqua drainage is speculative (see discussion of Tyee Formation), and structural interpretations of the area are subject to revision.

With the exception of the Coos Bay area, the youngest sediments in the Coast Range portion of this investigation are Eocene. Consequently, accurate determination of upper age limits on the faulting in the Coast Range is not possible. It is doubtful, however, that the mapped faults are younger than Eocene. There is no evidence of present activity.



Figure 10. Plane of a small unmapped fault exposed in quarry along Middle Fork of the Coquille River (SW¼ sec. 20, T. 29 S., R. 11 W.).

Coos Bay Synclinorium

The Coos Bay Synclinorium is an area of crustal weakness centered at Coos Bay and contains numerous small synclines and anticlines. It has been the locus of repeated deposition throughout the Tertiary, as shown by the original local distribution of the Coaledo Formation (late Eocene), Tunnel Point Formation (Oligocene), Miocene sedimentary rocks, Empire Formation (Pliocene), and numerous marine terraces. Structures are more intense than in most parts of the Coast Range, and dips approach vertical in places.

Allen and Baldwin (1944) mapped 17 folds and 9 faults in the Coos Bay area. Major downwarps include the South Slough Syncline, in which South Slough is located, and a syncline under Isthmus Slough. The Westport Arch between South Slough and Isthmus Slough underlies the uplands south of Coos Bay. Structures shown on the geology maps were taken from mapping by Baldwin in Baldwin and others (1973).

Coastal terraces and sea cliffs

Excellent exposures along sea cliffs and flat upper surfaces of marine terraces provide excellent opportunities for detecting faults and other structures. Possible Quaternary faulting has been described or inferred at several localities along the south Coos County coastline. Although detailed study is beyond the scope of this investigation, the localities are described briefly below.

A small offset of approximately 10 feet (vertical) of bedrock, terrace deposits, and the terrace surface is noted at Yoakam Point north of Cape Arago. Baldwin (1966) interprets the feature as a bedding plane slip fault within a synclinal fold. As such it may be restricted to shallow depths rather than a deep-seated structure and may not be capable of producing large earthquakes. Consistent with this interpretation is the extremely low seismicity of the area and the predominance of folding in the Coos Bay area.

Several offsets of Eocene bedrock are mapped along the face of the Whisky Run terrace north of Bandon, and faulting of the terrace material is a distinct possibility. Baldwin (1975, oral communication) maintains, however, that the faulting is restricted to bedrock. Offsets in terrace deposits in a quarry north of Bandon ($NW\frac{1}{4}$,$SW\frac{1}{4}$, sec. 17, T. 28 S., R. 14 W.) are interpreted as possible faults by Janda (1975, written communication), but may represent settling features related to the late Pleistocene fluctuations of sea level.

The level of the terrace south of Sunset Beach is approximately 20 feet higher than the level of the terrace behind the beach. Janda (1975, written communication) infers that faulting in the Bay and inland is a possible explanation. Small offsets in sandstone ribs immediately offshore can be inferred from aerial photographs.

Preliminary study of ERTS imagery indicates that a prominent linear extends from Chickamine mine (placer) in South Slough southeasterly along the east side of the Coquille Valley, past Coquille and Myrtle Point, into the Klamath Mountains. A northwestward projection of the linear trend passes out to sea in the Cape Arago-Bastendorff Beach area. The linear is not evident in the Quaternary units.

The fault-like features at Sunset Beach and Yoakam Point are not clearly understood. They may represent local displacements in folds, as suggested by Baldwin (1966) for those at Yoakam Point, or they may represent large-scale settling or surficial faulting along older zones of structural weakness. In view of the low seismicity interpreted for the region at the present time, the features do not appear to be deep-seated structures capable of producing large earthquakes. Major concern should be for local displacements and low foundation strengths rather than severe tectonic activity. For large projects, additional study is necessary.

MINERAL RESOURCES

The study area has limited metallic and non-metallic mineral resources, excellent ground-water potential in some of the dunes areas, and poorly defined but modest fuel resources. More detailed discussion of the mineral resources of Douglas and Coos Counties is available in Bulletins 64, 75, and 80 of the State of Oregon Department of Geology and Mineral Industries.

Metallic Mineral Resources

Black sands

Black sand deposits are concentrates of heavy minerals (usually dark in color) in wave- and current-deposited sediments on marine terraces, on beaches, and on submerged Holocene shorelines out to sea. The deposits have a complex origin involving erosion from inland areas, deposition in Tertiary sedimentary units, and Quaternary erosion and redeposition. Deposits closely associated with present-day streams probably have not undergone a second cycle of erosion and deposition.

Minerals in black sands deposits contain iron, chromium, and minor gold, titanium, zirconium, platinum, and garnet. Reserves are not accurately defined and are now under investigation by the United States Geological Survey and the Oregon State University School of Oceanography. Offshore research reveals a deposit of black sand about 7 miles from the Coast midway between the Coquille River and Cape Arago. The deposit is approximately 3 miles long and 1 mile wide and is situated at a depth of 10 to 20 fathoms. Maximum percentage of heavy minerals in recovered samples is 17 percent. The deposit is smaller and lower in grade than other submerged black-sand deposits off the coast of Curry County.

Onshore deposits are concentrated on the marine terraces in the Bandon area. One estimate places the reserves of chromite ore in concentrations greater than 5 percent at 1,913,000 long tons (Ramp, in Baldwin and others, 1973). Production from the black sands began at Whisky Run Creek in 1852. In the succeeding two decades, approximately $100,000 worth of gold was recovered from this claim. Between 1903 and 1929 a total of 804 ounces of gold and $1,707 worth of platinum was recovered from the Whisky Run-Bullards area. In World War II (1943), 46,500 tons of semi-finished chromite (35%) was recovered and stockpiled at Coquille.

Chromium is a strategic and critical commodity used for a variety of purposes including metallurgy, transportation, construction, and machinery manufacturing. In view of the low domestic production and the international trend towards nationalization of mineral resources, the remaining deposits of black sand in the Coos County coastal area may someday become economic. In addition, continuing investigations may uncover additional deposits.

Gold and silver

Several small mines and prospects for gold and silver are located in the Powers area and to the south. The majority of the mines are placer operations in tributaries of the South Fork of the Coquille River. Production over the years has been negligible. Lode operations are associated with Mesozoic intrusions of diorite into the Pre-Tertiary Galice Formation (Rocks of Pre-Tertiary Age). Salmon Mountain mine, located at an elevation of approximately 3,000 feet 10 miles south of Powers, produced between $75,000 and $100,000 worth of gold between 1885 and 1936. Increased prospecting can be expected in the future with the greatly increased price in gold.

Copper

All four copper occurrences in Coos County lie outside the study area and are located in Pre-Tertiary terrain. The Bolivar mine, 15 miles southeast of Powers, produced 300 tons of ore. Other prospects south of Powers report no production.

Manganese

Small manganese prospects are associated with marine chert deposits in the Otter Point Formation of southern Coos County. The deposits are localized and widely scattered, and there are no significant reserves. Secondary enrichment by weathering is common. The McAdams mine, 5 miles inland from the coast, on the Coos-Curry County line, produced 100 to 150 tons of ore during World Wars I and II.

Nonmetallic Mineral Resources

Silica sand

The large size, accessibility, and relatively high quality of the sand deposits in the Coos-Umpqua dunes area are favorable to the production of silica sand. The sand is remarkably uniform in grain size and is significantly lower in iron content than the beach and dune sands of more marginal quality along the Oregon Coast north of Heceta Head.

Mineralogic analysis of a sample taken near Hauser showed 32 percent quartz, 38 percent feldspar, 13 percent chert, 13 percent agate, and a small percentage of rock fragments and dark, heavy minerals such as magnetite. A chemical analysis of a sample taken near Rogers showed a silica content of 82.4 percent and an iron oxide content of 0.75 percent. The remainder consisted of oxides of aluminum, titanium, calcium, magnesium, sodium, and potassium.

According to Carter and others (1964) the sand is suited to use in the foundry, sand blasting, fillers, and ceramics industries. With magnetic separation and acid leaching of the iron oxides, the sand is also suitable for the manufacture of certain types of glass. The relatively high content of alumina limits uses for certain types of glass.

Limestone

A small limestone lens is located immediately west of the confluence of the Coos and Millicoma Rivers in section 35, T. 25 S., R. 12 W. approximately 8 miles east of Coos Bay. Analyses of calcite content average about 80 percent, and one source estimates total reserves at about 80,000 tons (Ramp in Baldwin and others, 1973). The deposit overlies flows of Roseburg basalt and represents a reef deposit that formed in Eocene times on top of a subsea volcanic landform. Conceivably, similar deposits may someday be discovered associated with other exposures of Roseburg basalt.

Limestone deposits of this type in western Oregon are generally small, and future discoveries, if any, will be localized. The limestone is medium grade and is best suited to use as fertilizer. Historically, some of the limestone in the above deposits has been used locally for mortar.

Clay

Economic deposits of clay can form either by alluvial deposition in regions of low current activity or by deep penetrative weathering on flat landforms (see Soils). In Coos County, clay of alluvial origin was used for the manufacture of brick and tile in the Myrtle Point area at the turn of the century. In the 1930's the Coos Bay Brick and Tile Manufacturing Company operated in Marshfield (now Coos Bay).

Peat

Peat consists of partially decomposed vegetative material and is generally formed in wetlands. In the study area it is present in many of the lowland surficial geologic units (see Geologic Maps; Surficial Geologic Units - marsh and peat). Formerly used as a fuel, peat is now being sought elsewhere in the country as a soil conditioner, a horticultural commodity, and in a limited quantity for blending with by-products of the sugar industry for cattle feed. The quality and potential uses of peat deposits of western Oregon have not been investigated.

Construction Materials

Crushed stone is used for construction of highways, and broken stone is used for jetty construction and riprap. Sand and gravel are used in the construction of highways, streets, roads, foundations, and many other types of structures. For every housing start, approximately 175 cubic yards of concrete is needed for the individual structure and for the numerous other projects it generates, including streets, sewers, schools, libraries, shopping centers, and industrial facilities.

Coos County is deficient in gravel and high-quality rock for concrete aggregate. Western Douglas County is rich in this commodity and exports large quantities to Coos County. Rock suitable for roadfill, base material, and surfacing is in adequate supply in Coos County, but is generally lacking in western Douglas County with the exception of hard sandstone which is used for local road repair in the Smith River drainage. Estimates of future needs for various construction materials given below are based on very limited data.

Crushed and broken stone

The U. S. Bureau of Mines reported that in 1969 a total of 309,000 tons of stone was used in Coos County; more complete records of the State of Oregon Department of Geology and Mineral Industries indicate a production total of 680,000 tons in 1969 and 728,035 tons in 1973. Assuming a slow rate of population growth (see Population) and continued consumption at the rate of ten tons per year per capita, a total of approximately 20 million tons of crushed and broken stone will be needed in the study area by the year 2000. This is equivalent to a pit 2,000 feet on a side and 50 feet deep.

Large, active operations near major lines of transportation are summarized in Table 16. Generalized information on dormant sites and areas of favorable geology can be inferred from the geologic map or by reference to Baldwin and others (1973). Detailed information on quarry operations of all sizes can be obtained from the Mined Land Reclamation Division of the State of Oregon Department of Geology and Mineral Industries.

Quarry stone has certain advantages and disadvantages compared to stream gravel. It makes a better base for paved surfaces and is better suited to construction of oiled and macadamized roads. Where jointing is coarse, it is suited to use as riprap for riverbank protection. It is not well suited to use as concrete aggregate and is more costly to produce than sand and gravel. Jettystone can be derived from some occurrences of marine basalt and blueschist by stockpiling larger boulders or by employing specialized blasting techniques to minimize shattering. Two Coos Bay Timber Operators' quarries in the middle reaches of Kentuck Slough have good potential for jettystone production (Jerry Gray, oral communication 1975).

Quarries in Coos County are located primarily in basalt and associated intrusives (Basalt of Tertiary Age) along Kentuck Creek and southeast of Coquille and in the blueschist of the Otter Point Formation in the Bridge area. Several small sandstone quarries in the northern part of the County and in western Douglas County were developed in the past when specifications for road material were less rigid.

A blueschist outcrop on Baker Creek southwest of Broadbent and immediately outside the study area produced 100,000 tons of jetty rock in 1962-1963 for the Coos Bay south jetty. A total of 35,000 tons of jetty stone for jetty construction at the mouth of the Coquille River was removed from Tupper Rock between 1884 and 1916. Tupper Rock at Bandon was originally over 100 feet high. Most quarry stone of the Coast Range fails to meet size and density requirements for jetty stone (Schlicker and others, 1973). The sandstone of the Coast Range is prone to excessive abrasion, and the basalt generally is too closely jointed to produce Class A armor rock (9.7 to 27.8 tons) in the necessary quantities.

Standards for riprap are less rigid, and thick-bedded sandstone and marine basalt are generally suitable. Large blocks capable of withstanding storm waves are required for shoreline protection; for riverbank protection smaller stones can be used.

Table 16. Major quarry operators in western Coos County

Operator	Location	Comments
Coos Bay Timber Operators		
Koosrock	sec. 27, T. 25 S., R. 12 W.	Marine basalt with 4-6 feet overburden
Kenstone	sec. 26, T. 24 S., R. 12 W.	Marine basalt with 20 feet overburden
Kenrock	sec. 3, T. 25 S., R. 12 W.	Marine basalt with 18 feet overburden
Coos County Highway		
Enegren	sec. 27, T. 25 S., R. 12 W.	Marine basalt
Kuhnert	sec. 3, T. 25 S., R. 12 W.	Marine basalt
Morris	sec. 29, T. 29 S., R. 12 W.	Marine basalt
Hervey	sec. 10, T. 28 S., R. 12 W.	Marine basalt
Johnson Rock Products	sec. 3, T. 25 S., R. 12 W.	Marine basalt
Kincheloe Quarry	sec. 36, T. 29 S., R. 12 W.	Blueschist
Norway Rock Products	sec. 30, T. 28 S., R. 12 W.	Marine basalt with 3-5 feet overburden
Oregon State Highway Dept.		
Baker Creek	sec. 17, T. 31 S., R. 12 W.	Blueschist
Myrtle Creek	sec. 16, T. 30 S., R. 11 W.	Blueschist

Sand and gravel

Consumption of sand and gravel in western Coos County is approximately 400,000 tons annually, the majority of which is trucked in from the Reedsport area. No specific consumption figures are available for western Douglas County. Assuming a slow rate of population growth and continued annual consumption of 7 tons per capita, a total of 12 million tons of sand and gravel will be needed in western Coos and Douglas Counties by the year 2000.

In western Douglas County the Umpqua River Navigation Company (by far the largest producer) is under contract to maintain channels, side channels, and turning basins in the lower 10 miles of the Umpqua River. This operation produced 388,908 tons of sand and gravel in 1973.

Sand and gravel in the bed of the Umpqua River is replenished by stream action and constitutes a renewable resource. Specific figures on the annual rate of resupply are not available, but the total probably does not greatly exceed the average annual amount being dredged from the river.

The U. S. Bureau of Mines reports that sand and gravel production in Coos County was 140,000 tons in 1969 and 181,596 tons in 1973. Most production is from small operations in the middle reaches of the Coquille drainage and from operations in the terraces around Bandon. Sand and gravel is recovered from the bed of the Coquille River during low water and is stockpiled for use during the rest of the year. It, too, constitutes a renewable resource.

Bedrock of other drainages in the study area does not produce coarse sediment, and bedloads of these streams consist of sand, silt, and clay.

The sand and gravel on the marine terrace near Bandon is situated near the base of the deposit and is overlain by 20 feet of finer grained overburden. Size distribution of the gravel limits potential uses, and the overburden may preclude economic recovery of much of the deposit (Gray and Ramp, in Baldwin and others, 1973). The deposits are part of the Coquille Formation (see Surficial Geologic Units - Quaternary marine terrace deposits).

Many temporary sand pits of varying size have been excavated in the dunes of western Coos and Douglas Counties. Use of some of the sand for glass and manufacturing purposes has been studied by the U. S. Bureau of Mines (see Silica Sand). Excavation of eolian sand on terraces is primarily to level terrain for urban use. The sand is used locally for fill.

Planning considerations

The demand for quarry stone, sand, and gravel in western Coos and Douglas Counties will probably increase slowly during the next few decades. If highway construction is undertaken, however, demand for these products will increase sharply. Major sources of supply will continue to be the channels of the Umpqua and Coquille Rivers and outcrops of Tertiary basalt. Although Basalts of Tertiary Age underlie approximately 30 square miles in Coos County, the supply of economic stone is restricted owing to the isolation, thick overburden, and long steep slopes of many of the exposures.

The production of aggregate is esthetically unpleasing in terms of noise, stream turbidity, dust, and disturbance of the land. Location near communities is required, however, owing to high hauling costs and natural distribution. For economic reasons it is imperative that urban growth be prevented from sprawling indiscriminately over future sources of supply. Likewise, zoning ordinances, zoning variances, and other planning decisions should not arbitrarily discriminate against the aggregate industry.

The aggregate industry and society are best served by the implementation of multiple use and sequential land use policies. Visual and acoustic screening can minimize the adverse esthetic impacts of gravel and quarry operations. Abandoned pits can serve as sites for houses, landfills, or other structures, depending upon overall physical and cultural setting. Reclamation of mining claims is overseen by the Mined Land Reclamation Division of the State of Oregon Department of Geology and Mineral Industries.

Fuel

Oil and gas

The formation of recoverable oil or gas in nature requires 1) the accumulation of carbonaceous material in fine-grained source beds, 2) the presence of coarser-grained porous reservoir rock upstructure, and 3) a structural or stratigraphic trap to confine the migrating oil or gas in the reservoir rock. Many of the most productive oil fields of the world are associated with basins having a history of rapid deposition and subsidence. The weight of the sediments accumulating in the center of the basin in the geologic past squeezed the oil into the reservoir rock, where it was trapped by surrounding structures.

In the Tertiary section of the study area, conditions necessary for the formation of oil are generally favorable. Siltstone and sandstones are potential source and reservoir rocks respectively, and the region has a geologic history of basining, especially in the Coos Bay area. Factors that locally may inhibit the formation of recoverable oil include the low organic content of the siltstones, the small size of the basin, low permeability of the sandstone, and poor spatial relationships between the source rocks and the reservoir rocks. Exploration in the region is still in its infancy and accurate determination of the oil and gas potential is not currently possible. Reports of gas and oil shows are included in many of the logs for exploratory wells in the Coos Bay area (Table 17).

Table 17. Holes drilled for oil and gas in Coos County

Company	Well Name	Location	Date	Depth Drilled	Remarks
Coast Oil Co. (deepened by Fat Elk Oil Co.)	Well No. 1	Coquille area NE¼SE¼ sec.10, T.28S., 13 W.	1929-1934	2526'	Cable tools. A thin oil-bearing sand reported at 1585' and gassy salt water at 1745'.
Coast Oil Co.	Well No. 2	Coquille area NE¼SW¼ sec.10, T.28S., 13 W.	1939	2255'	Cable tools. A good gas flow reported at 1170'.
Coast Oil Co.	Well No. 3	Coquille area SW¼SE¼ sec. 10, T.28S., 13 W.	1939	1640'	Cable tools. Reported to be a small gas well.
Coast Oil Co.	Well No. 4	Coquille area SW¼SE¼ sec. 10, T. 28S., 13 W.	1939	1640'	Cable tools. Hit flowing salt water.
Coast Oil Co.	Rhoades-Menasha No. 1	Westport Arch NE¼SE¼ sec. 32, T.26S., 13 W.	1938	1365'	Cable tools. Reported shows of gas and numerous coal layers.
Libby Mine area	Pitch Coal occurrence	Westport Arch Approx.sec. 3 or 4, T.26S., 13 W.	1920	--	Pitch coal found in fractures of coal. This is a form of asphalt.
Oregon Coastal Corp.	J.Coy No. 1	Bandon area NW¼ sec. 4, T.29S., 14W. 330' S.of N.line & 330' E.of W. line	1953	1894'	Rotary. No oil or gas shows reported.
Pacific Petrol Co. (J.B.Ewell)	Morrison No. 1	Bandon area S½NW¼ sec. 28, T.28S., 14 W.	1936-1937	2282'	Claimed enough gas was encountered to fire the boiler.
Pan American Petroleum Corp.	OCS P-0112	Bandon area Tract 102	1967	6146'	Gas show at 5400' in tight sandstone.
Phillips Petrol.Co.	Dobbyns No. 1	Coos Bay area SW¼ sec.28, T.26S., 13 W. 330'S.&330' E.from W¼ cor.	1943-1944	6941'	Gas sand on electric log at 1040'. Submarine basalt at 2300'.
Sunset Oil Co. (J.B.Ewell)	Bandon	Bandon area Sec.4, T.29S., 14 W.	1944	1089'	Rotary. No information.
Warren, E.M.	Coos County No. 1-7	Coquille area SE¼sec.7, T.27S., 13 W. 450'N. of S. line &2200' W. of E. line	1963	6337'	Rotary. Traces of gas and oil. Bottomed in Coaledo Formation.
West Shore Oil Co.	?	Bandon area NW¼ sec. 23, T.30 S., 14W.	1913-1919	1400'+	No information.

The West Shore Oil Company drilled the first oil and gas well in Coos County in 1919 near the town of Bandon. No production was reported in the well nor has significant production been reported in 10 other wildcat wells drilled during the following 40 years in the County. Coast Oil Company, however, encountered strong gas shows in 2 of its holes drilled $2\frac{1}{2}$ miles southwest of Coquille along Fat Elk Creek. A hole near Bandon drilled by Pacific Petroleum Company in 1941 reportedly yielded enough gas to fire the engine boiler.

The Coos Bay Synclinorium (see Structure) is promising from the standpoint of rock type, thickness, structure, and geologic history. At least 10,000 feet of folded siltstones and sandstones may underlie the region. Phillips Petroleum Company drilled on the Westport Arch south of Coos Bay, between South Slough and Isthmus Slough, but encountered submarine basalt at a depth of 2,300 feet. The electric logs indicated the presence of a 10-foot gas sand at 1,040 feet, but no tests were made. Another well drilled $3\frac{1}{2}$ miles to the southwest in 1963 by E. M. Warren and Associates penetrated over 6,000 feet of Coaledo Formation. Several gas and oil shows were found in the Warren well, but the rock was too fine grained to produce commercial amounts of petroleum.

Upper Coaledo is exposed along the crest of a narrow anticline between Isthmus Slough and Catching Slough. Although more section is available here than in the anticline to the west, no drilling has been done on this structure. Faulting and gentle plunging to the south provide closure in this direction. The structure extends 7 miles and has a width of 1 to 2 miles.

The geologic history of the continental shelf is similar to that of the mainland. Recently the shelf has become subject to systematic investigation by oil companies (Figure 11), the U. S. Geological Survey, and the Department of Oceanography at Oregon State University. Research has included geophysical investigations and sediment sampling. McKay (1969) has tentatively correlated offshore bedrock units defined by their seismic properties to bedrock units exposed onshore. Major structures include the Coquille Bank (see Structure), the southern part of the Heceta Bank, and a large linear basin between Bandon and Cape Blanco that is filled with a thick Miocene to Pliocene section. Generally, the late Tertiary section is thicker and more extensive on the shelf than onshore, a feature which contributes to the attractiveness of the shelf in terms of oil potential.

Only four of the eleven tracts offered for lease in the "Bandon Block" in 1964 were leased. Pan American and its partners drilled to a depth of 6,146 feet and bottomed in Tyee Formation in 1967 (Baldwin and others, 1973). A good gas show was encountered at 5,400 feet in a 60-foot sandstone, but the bed was too tight to yield commercial amounts.

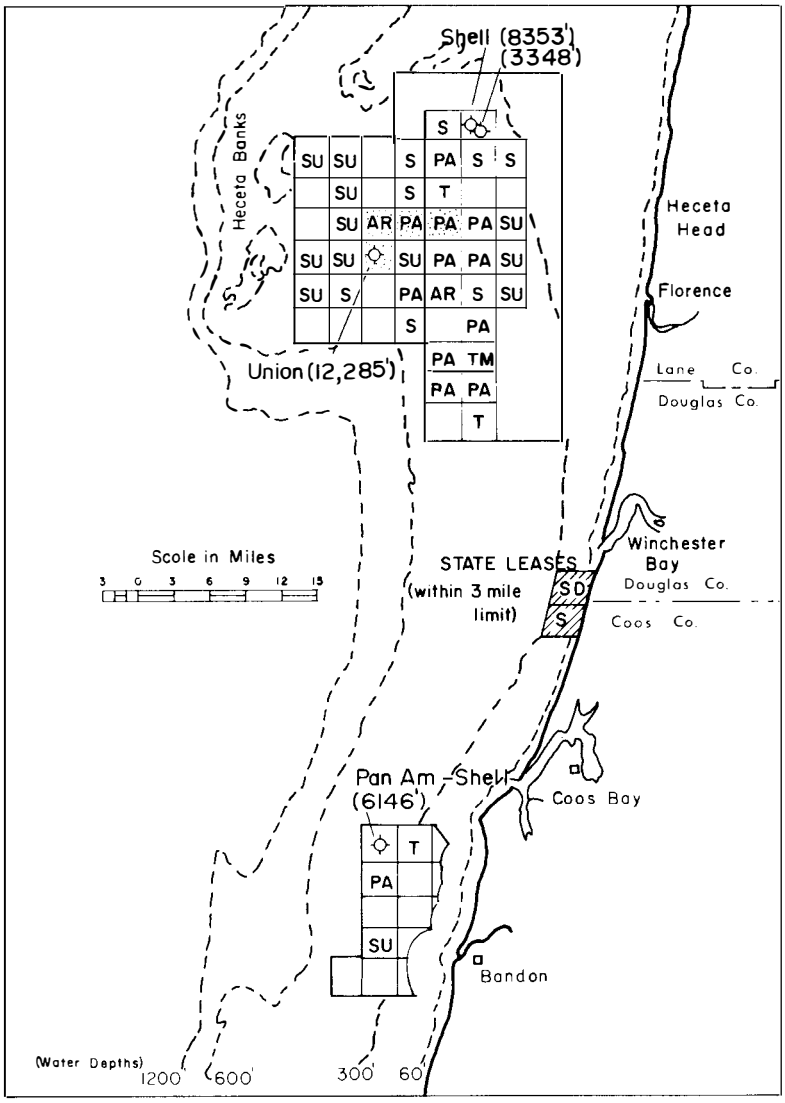
Approximately 1,100 square miles of shelf lands offshore from Coos County remain unexplored for oil and gas. Prospects are considered to be good for the area, and it is considered to be one of the best for petroleum exploration in western Oregon. Similar potential is interpreted for the southern part of the Heceta Bank off the coast of Douglas County. No exploratory wells have been drilled onshore in western Douglas County.

Coal

Coal in the Coos Bay area was commercially mined from 1854 to the close of World War II. Production totaled 3 million tons and peaked at 111,540 tons in 1904 when the Beaver Hill Mine was in full operation. The seams are most abundant in the upper member of the Coaledo Formation (a late Eocene deltaic deposit), but also occur in the lower and middle members. Land overlying the coal is in private, city, County, State, and Federal ownership. The coal fields were studied intensively by Allen and Baldwin (1944) and are currently being reinvestigated by the State of Oregon Department of Geology and Mineral Industries.

The coal has an average heating value of slightly less than 10,000 BTU per pound and contains 17 percent moisture, 8 percent ash, and 1 percent or less of sulfur. It is subbituminous in grade. Analyses of numerous samples from various localities in several mines are summarized by Allen and Baldwin (1944). Additional tests are desirable at the present time to evaluate the coal in terms of present technology.

A total of approximately one billion tons of coal (not all economically recoverable) may be present in the Coos Bay area. This is equivalent to a 40-inch seam underlying the total extent of the Coaledo Formation. However, all grades of coal at all depths and in all thicknesses of seams are considered in the calculation (Mason and Erwin, 1955), and much of the coal can never be mined. Minable coal under present economic and technologic conditions is considerably less and totals about 60 million tons. Depths of less



Atlantic-Richfield . . . . AR
Pan American Petrol. Group . PA
Shell Oil Co. . . . . S
Standard Oil . . . . . SD
Standard Oil and Union Oil . . . SU
Texaco, Inc. and Mobil Oil . . . TM
Texaco, Atlantic-Richfield, Mobil T
[Stippled areas indicate cancelled Federal leases, and lined areas show state leases.]

Figure 11. Deep wells and leases off the southwest Oregon Coast.

than 1,500 feet, seams greater than 30 inches thick, and dips of less than 45° are used in arriving at this estimate (Hughes, oral communication, 1975). To the southeast at Eden Ridge, Pacific Power and Light owns an additional 50 million tons of reserves. The coal at this remote locality is higher in heat value and occurs in thicker and more gently dipping seams, but lies under a considerable overburden and is extensively faulted.

The proven reserves (60 million tons) in the Coos Bay area are small and account for only one out of every 25,000 tons of proven reserves of medium- to low-grade coal in the United States. The coal reserves of the United States include 430 billion tons of subbituminous coal, 450 billion tons of lignite, and 671 billion tons of bituminous coal. In addition, there are an estimated 1.3 trillion tons of unmapped reserves within the limits of economic recovery (Hunter, 1970). With the recent great increases in the price of oil, marginal deposits that were considered uneconomic in 1968 now may be considered economic. Thus, these figures have undoubtedly increased considerably since they were made.

The coal reserves of Coos County are not suited to large-scale coal gasification under present technology. An average-sized plant producing 250 billion Btu's per day would exhaust the entire reserve in 6 years, assuming 50 percent recovery. Smaller plants keyed to local industry may be feasible, however, in view of escalating energy costs nationwide.

Water requirements also place restrictions on development. In a typical coal gasification plant, projected water needs vary from 7,000 to 30,000 gallons per minute depending upon water quality and the extent of recycling (Davis and Wood, 1974). This compares with a present rate of ground-water production in the dunes of 3,000 gallons per minute (see Groundwater), and minimum streamflows of 5,400 gallons per minute on the South Fork and 5,850 gallons per minute on the North Fork of the Coquille. Average flows during low months are 14,360 and 24,680 gallons per minute respectively (Oregon Water Resources Board, 1963).

Potential future use of the coal for power is local and small in scale. For development to proceed, several obstacles will have to be overcome, including overlapping ownership, economic constraints, and the need for supporting transportation and water systems. Environmental considerations in the Coos Bay area include air and water pollution and use restrictions in the South Slough Sanctuary which limit possible future mining to certain areas and under strict conditions.

Ground Water

General

Ground water is water that fills the open spaces in rock and soil beneath the land surface. The top of the zone of saturation, called the water table, conforms in a general way with topography, so that it is relatively near the surface in depressions and is situated at greater depths along ridges. Porosity and permeability are key considerations in determining the capability of geologic materials to hold and transmit ground water.

Porosity is the percentage of open spaces per unit volume. Open spaces include pore spaces (opening between grains), fractures, and joints. The size, number, and arrangement of these open spaces is dependent upon the shape, size, mineral constituents, and arrangement of the particles that make up the soil or rock, as well as the composition, alteration, and deformation of the rock or soil.

Permeability is the capacity to transmit water and is dependent upon porosity, the size of the pore spaces, and the degree of interconnection between the pore spaces. "The coefficient of permeability is the rate of flow (gallons per day) through a square foot of cross section, under a hydraulic gradient of 100 percent at a temperature of 60° F." (Tolman, 1937). Materials such as sand with relatively large interconnected pore spaces are very permeable and have high capacities. In contrast, jointed bedrock may have high transmitting potentials locally, but may have very low holding capacities.

In areas where the geologic materials are both porous and permeable and where hydraulic gradient is sufficient to generate flow, the ground water is in constant motion. Precipitation is absorbed into the soil, percolates downward to the water table, and flows slowly down-gradient to a point of discharge. This type of ground-water system can produce water with fairly constant chemical characteristics and low temperature and is generally a highly desirable resource. Because of local and regional variations in

geologic conditions, however, ground-water quality and availability vary considerably with location in the study area.

Water-well records are on file at the Office of the State Engineer in Salem and in the Portland Office of the U. S. Geological Survey. Published reports dealing with the ground water of the study area include Robison (1973), Oregon Water Resources Board (1963), and Brown and Newcomb (1963).

Distribution

Ground water is most abundant in the Coos-Umpqua dune sheet north of Coos Bay, where well yields of several hundred gallons per minute are common (Figure 12). Yields in the terrace units and alluvium are a few tens of gallons per minute, and yields in the bedrock units are very low, seldom exceeding 5 gallons per minute. Drawdowns are small in the dunes and great on the terraces and in bedrock. Ground-water distribution in the bedrock is sporadic. Depths to producing ground-water horizons in all areas are generally less than 200 feet and many wells are less than 100 feet deep.

Lowlands: The Coos-Umpqua dune sheet consists of 80 to 150 feet of fine- to medium-grained unconsolidated sand (see Surficial Geologic Units) and constitutes the largest source of ground water in the study area. Presently, in the southern part of the dunes area, 18 wells with yields averaging 200 gallons per minute are producing approximately 4 million gallons of water per day for industrial and domestic uses. The water is under the control of the Coos Bay-North Bend Water Board. Farther north the only ground-water production from the dunes is for local use at campgrounds.

Precipitation averages 62 inches per year regionally. Runoff is between 12 and 18 inches annually and evapotranspiration averages 8 inches annually. Recharge (net 38 inches per year) is primarily by precipitation regionally, but in places includes local runoff from upland drainages. Discharge approximately equals recharge and is by pumping and subsurface outflow into the Pacific Ocean. Vertical permeability is two orders of magnitude less than horizontal permeability, and depression cones during pumping are virtually nonexistent. Instead, withdrawal is accompanied by small lowerings of the water table over large areas. Lake and stream levels are related directly to the level of the water table. During the wet winter months, lake levels rise at rates of about 2 feet per month, and during the dry summer months, lake levels lower at rates of about 1 foot per month. Lake levels fluctuate 3 to 6 feet during the year.

Excessive rates of ground-water withdrawal in the future could lead to 1) reduction of subsurface discharge into the ocean, 2) induced saltwater intrusion along the coast, or 3) lowering of lake levels beyond acceptable limits. Although ground-water withdrawal may generate only minor changes in the level of the water table, much of the terrain of the dunes may be sensitive to these minor changes. Included are shallow lakes, marshes, and deflation plains. Most recent estimates place the upper limit of ground-water production at about 15 million gallons per day (Robison, 1973) and recommend monitoring for salt-water intrusion along the coastline.

Within the Coos and Coquille flood plains, surficial material consists of silts, clays, and sands with low permeabilities and poor drainage. Surface ponding occurs many times during the year. Potential yields are generally small to moderate and wells are easily contaminated. The aerial extent of alluvium in the Umpqua drainage is insignificant in terms of potential ground-water production. Along the Smith River the alluvium yields water sufficient for rural domestic demand.

Terraces: Marine terraces form flat coastal exposures from half a mile to 5 miles wide along the coast of Coos County and are underlain by semiconsolidated sand and silt with local pebbly horizons. Producing wells are generally adequate for domestic purposes (Table 18). Recharge is primarily by direct precipitation, and discharge is along the sea cliffs or into local streams. Infiltration is retarded in many areas by iron pans in the soil profile or by layers of low permeability material at greater depths. Wells may be easily contaminated in regions of surficial ponding. Favorable topography will continue to encourage rural and urban development of the marine terraces, and increasing demands on the ground-water resources can be anticipated.

Fluvial terrace deposits along the Coos, Coquille, and Umpqua Rivers consist of sand, silt, clay, and gravel and provide adequate ground water for scattered domestic needs especially in the interior of Coos County. Ground water is generally available at shallow depths. In agricultural areas, contamination is a distinct possibility, especially if there is surficial ponding.

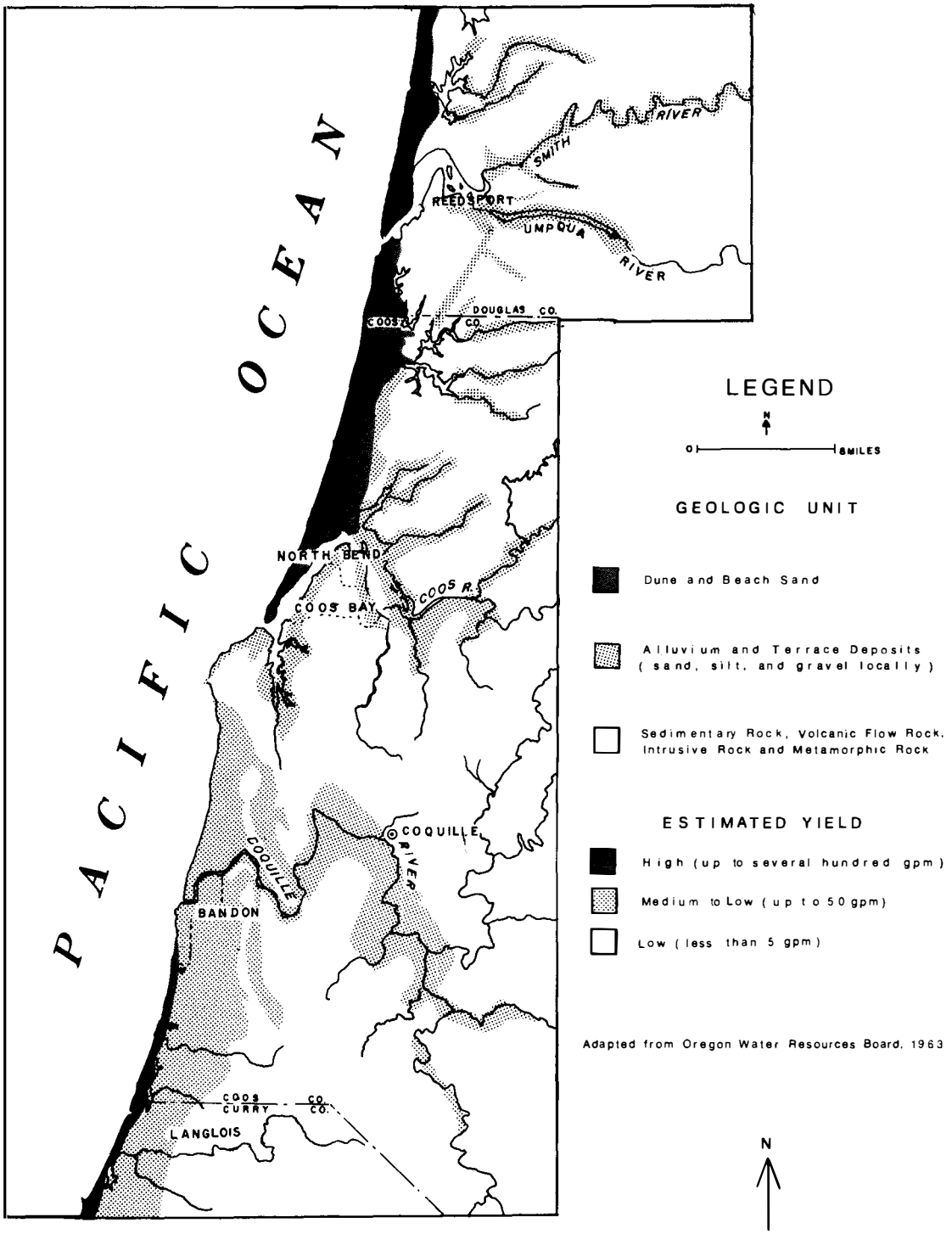


Figure 12. Ground-water distribution in western Coos and Douglas Counties.

Table 18. Representative water wells in western Coos and Douglas Counties, Oregon

Location[1] (unconfirmed)	Owner	Year	Topographic unit	Geologic unit	Material	Depth (ft)	Casing	Finish	Water depth and date	Yield (gpm)	Drawdown	Specific capacity[2]
Sec.9, T.22S. R. 9 W.	Koehster	1972	Uplands	Elkton	Sandstone	110	6" to 63'	-	60'(9/1/72)	7	40	0.17
Sec.31,T.22S. R. 12 W.	Pearson	1974	Uplands.	Flournoy	Sandstone	105	6" to 28'	-	60' (1974)	20	15	1.3
Sec.17,T.23S. R. 12 W.	Ziemienczuk	1973	Uplands	Coaledo	Sandstone with coal	175	6" to 40'	Open hole	60'(5/23/73)	4	111	0.36
Sec.13,T.23S. R. 13 W.	Dunes Mobile Ranch	1964	Lowland-dunes	Sand	Dune sand	42	6" to 32'	5 5/8" screen 32'-42'	4'(1/9/74)	43	27	1.6
Sec.26,T.24S. R. 11 W.	Farmer,T.	1965	Uplands	Flournoy	Sandstone and shale	119	6' to 24'	Open hole	16'(4/30/65) salt water at 112'	200	Total in 1 hr.	-
Sec.11dbb,T.24S R. 13 W.	North Bend Jr. High	1966	Terrace-marine	Qmt	Sand?	183	6" to 89'	Screen to 151'?	52'(2/25/66)	20	30	0.67
Sec.33adb,T.24S R. 13 W.	PP&L	1960	Lowland-dunes	Sand	Sand	152	10" to 66' 8" 120' to 141'	8" no.10 screen 63'-110' no.12 to 120'	15'(9/29/60)	572	33	17.2
Sec.29c,T.25S. R. 12 W.	Justrom Stromme Realtors	1969	Uplands	Coaledo	Sandstone and claystone	360	-	Abandoned	100'(4/2/69)	3	360	0.08
Sec.21dc,T.27S. R. 14 W.	Strictland	1973	Terrace-marine	Qmt	Coarse sand	54	6" to 77'	6" to .008 slot scr. 51'-77'	30'(6/16/73)	15	Total in 1 hr.	-
Sec.18aa,T.28S. R. 13 W.	Kane, E.	1973	Uplands	upper Coaledo	Sandstone	143	6" to 50'	Slotted 25'-45'	30'(11/2/73)	2	Total in 1 hr.	-
Sec.8,T.29S. R. 14 W.	Loftin, R.	1972	Terrace-marine	Qmt	Sandstone	77	6" to 73'	6" to .008 slot scr. 72'-77'	45', aquifer at 72' (1972)	15	Total in 1 hr.	-
Sec.6ab,T.30S. R. 14 W.	Crane, E.	1969	Uplands	Otter Point	Fine sand	48	6" to 43'	6" to .008 slot scr. 43'-47'	33'(7/15/69)	8	6	1.3
Sec.34bb,T.27S. R. 12 W.	Rose, L.	1972	Fluvial terrace	Roseburg at depth	Alluvium over shale	12, 30	40" conc. 18' to total dep.	Open	1'(10/27/72)	9	0	-

[1] The U.S. Geological Survey system of locating wells is explained in Appendix F.

[2] Specific capacity is yield (gpm) divided by drawdown (feet); it is a more accurate measure of well productivity than is yield.

Table 19-a. Chemical analyses of water from lakes and production wells, Coos-Umpqua dunes area (from Robison, 1973)

Sample no.	Local designation	Well number	Total interval of screen or perforations (depth in (feet)	Date of collection	Milligrams per liter														Specific conductance, micromhos @ 25°C	pH	Temperature	
					Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness, as $CaCO_3$			°C	°F
1	Beale Lake			12/15/55	1.6	0.06	1.2	1.2	9.6	0.9	7	0	1.3	15	0.1	0.1	0.01	37	8	66	6.5	--	--
2	Horsfall Lake			9/18/70	.0	.06	1.7	1.9	14	2.2	0	0	10	25	.1	1.2	--	56	12	126	7.2	--	--
3	Bluebill Lake			9/18/70	1	.50	1.9	1.7	19	2.8	7	0	7.8	33	.0	.5	--	70	12	135	7.1	--	--
4	Well 44	24S/13W-32abd	87-185	10/28/70	30	1.0	22	11	17	8.7	143	0	2.8	23	.1	.1	--	190	100	292	7.6	13	55
5	46	24S/13W-32dcb	80-180	10/31/70	24	.02	27	20	18	--	189	0	7.5	28	.1	.3	--	220	150	373	7.9	12	53
6	(47, 48, 49)			8/ 8/58	23	2.5	33	3.4	9.7	4.9	110	0	2.9	16	.0	.1	--	150	95	--	7.6	--	--
7	48	24S/13W-33dbc	82-134	4/ 7/59	20	2.4	31	4.9	12	6.0	120	0	3.0	18	.0	.0	--	160	97	--	7.8	--	--
8	49	24S/13W-33acd	78-130	7/17/70	22	2.6	23	3.4	9.6	3.5	90	0	4.2	14	.1	.8	--	130	72	190	7.7	13	55
9	55	24S/13W-27bbd	53-97	10/ 4/70	31	.05	26	6.8	19	--	124	0	1.0	27	--	.3	--	170	93	280	7.8	14	57
10	56	24S/13W-22ccd	58-100	7/16/70	--	4.1	--	--	--	--	--	--	--	27	--	--	--	--	--	324	--	--	--
11	57	24S/13W-22cac	58-100	6/18/70	36	.90	40	7.7	21	5.7	164	0	.0	34	.1	3.0	--	230	130	360	7.9	14	57
12	58	24S/13W-22bdc	63-111	6/18/70	30	6.6	36	5.0	22	4.3	142	0	.0	33	.1	2.9	--	210	110	323	7.7	13	55

Uplands: The uplands comprise the largest physiographic unit of the study area and are generally underlain by a thin mantle of soil over indurated bedrock of sandstone, siltstone, or basalt. Permeability is very low and ground-water yield to wells is very small (Table 18 and Figure 12), rarely exceeding a few gallons per minute. Many wells drilled in the uplands are dry. The coal mines of the Coos Bay area were basically dry during their operation. Recharge and ground-water motion, where present, is generally along prominent bedding planes, joints, and faults. Discharge is into streams downslope. Ground-water potential is sporadic, and drawdown is commonly excessive owing to the low holding capacity of the strata.

Quality

Water quality data for some of the wells in the Coos-Umpqua dunes area is tabulated in Table 19a. Drinking water standards defined by the U. S. Public Health Service (1962) is provided in Table 19b. Virtually all of the ground water of the study area contains some iron, and some wells yield water with iron contents above the acceptable limits for drinking water. Other mineral constituents do not appear to be a problem.

Ground water derived from lowland areas with peaty horizons in the subsurface is sometimes acidic and may possess offensive odors. In areas of ponding and poor well construction, bacterial contamination may be introduced into the ground-water supply resulting in outbreaks of hepatitis (see Planning Considerations). A study by the Coos County Health Department in 1961 revealed that 52 percent of the ground-water wells surveyed and 78 percent of the springs surveyed failed to meet adopted standards. Septic-tank effluent and surficial water from fertilized fields or pasture land may also introduce nitrate into the ground water in regions of poor well design or location. Young infants are particularly sensitive to this type of water pollution.

Table 19-b. Drinking-water standards defined by the U.S. Public Health Service, 1962

Constituent	Recommended limit ppm	Maximum allowable limit ppm
Fe (Iron)	0.3	--
Mn (Manganese)	0.05	--
SO_4 (Sulfate)	250.0	--
Cl (Chloride)	250.0	--
Fl (Fluoride)	0.8-1.7	1.6-3.4[1]
NO_3 (Nitrate)	45.0	--
As (Arsenic)	0.01	0.05
Dissolved solids	500.0	--

[1] Varies inversely with mean annual temperature

Planning considerations

Management of the ground-water resource should be directed towards the multiple goal of 1) maximizing the use of the resource, 2) minimizing the adverse effects of withdrawal, and 3) maintaining or improving the quality of the ground water. In the dunes area, continued monitoring of the ground-water level and the position of the saltwater interface in the subsurface is recommended (Robison, 1973) to assure efficient well operation, to avoid well interference, and to maintain an esthetically pleasing natural area. Methods of maximizing the availability of ground water include 1) seasonally adjusting the rate of production, 2) damming the outlets of streams flowing through the dunes areas, 3) artificially recharging lakes in the dunes during periods of excess production, and 4) pumping ground water from shallow depths in the area of subsurface discharge along the Coast.

The proper spacing, construction, and location of wells are overseen by the Department of Environmental Quality, the State Engineer, and County officials. The danger of overwithdrawal or contamination will be of increasing concern in the study area as development continues. Infectious hepatitis commonly occurs after the first periods of heavy rain in western Coos and Douglas Counties in areas of unsewered clustered developments such as Lakeside, Greenacres, and Charleston. It is postulated that during the rainy season perched and ponded water on the terraces moves laterally at shallow depths to enter the deeper water table along improperly sealed or constructed well casings or other avenues. Bacteria derived from septic tanks and pasture land travels with the water to enter sources of domestic water.

GEOLOGIC HAZARDS

A geologic hazard is any geologic process or condition which may be hazardous to man or may be a threat to his activities. In this section are discussed stream and ocean flooding, high ground water, mass movement, stream erosion and deposition, coastal erosion and deposition, wind erosion and deposition, and earthquake potential. Landform is basic to an understanding of geologic hazards and is emphasized throughout the discussion.

Development in regions of geologic hazard should be restricted to those forms of land use that are either compatible with the conditions or that can be engineered to provide an adequate level of safety. The accompanying Geologic Hazards Maps delineate areas of existing or potential risk.

Stream Flooding

General

A stream flood is a temporary rise in streamflow resulting in bank overflow and the inundation of adjacent lowlands (Table 20). Various subdivisions of flood areas include the flood plain (subject to inundation by larger floods), the floodway (stream channels or channels that convey fast-moving water), and floodway fringe (area of the flood plain outside the floodway, but subject to periodic flooding). In the lower reaches of streams having low gradients and natural levees such as the Coos, Coquille, and Umpqua Rivers, the floodway fringe and the flood plain are more or less synonymous.

The Corps of Engineers, the U.S. Soil Conservation Service, and the U.S. Geological Survey, by using various computer models, delineate areas subject to flooding. The programs are used to produce flood maps for a variety of desired frequencies. An Intermediate Regional Flood (also referred to as the 100-year flood) is the flood having a 1 percent probability of occurring in any given year. Flooding indicated for the lower Umpqua and Smith Rivers (see Geologic Hazards Maps of Reedsport, Goodwin Peak, Siltcoos Lake, and Scottsburg quadrangles) is a Preliminary Intermediate Regional Flood and is based on preliminary data developed by the U.S. Geological Survey and Douglas County.

In the absence of statistical models, maps showing past flooding can be assembled using flood records, high-water marks, interviews, newspaper accounts, and aerial and surface photographs. Such data are the basis of the Maximum Observed Historic Flood indicated for most of the valleys of Coos County (see Geologic Hazards Maps of Coos Bay, Coquille, Langlois, Bandon and Powers quadrangles). The period of observation is approximately 100 years. The indicated flood differs from the Intermediate Regional Flood because it is not based on a rigorous statistical treatment of flood data. It is, rather, a composite of many historic floods of undetermined frequency.

For areas in which there is little or no recorded data, flood-prone regions can be deduced from topography, landforms, soils, vegetation patterns, and other natural features. Information of this sort is generalized and constitutes the basis for the delineation of flood-prone areas of northwestern Coos and western Douglas Counties (see Geologic Hazards Maps of Siltcoos Lake and Reesport quadrangles).

In many upland areas, reaches of streams having little or no flood plain are the sites of an additional type of flooding characterized by rapid streamflow and catastrophic erosion and deposition. For lack of a better term these floods are termed flash floods. They are most prevalent in the steep interior uplands where regional slopes exceed 50 percent and relief is moderate to high (1,000 feet or more). They occur during intense frontal and adiabatic rainfall. Extreme conditions of erosion and deposition associated with flash floods impose severe restrictions on roads, fills, and bridges (see Stream Erosion and Deposition).

Causes

Stream flooding in coastal Coos and Douglas Counties is the result of high rainfall (see Climate) on moderately sloping to steeply sloping terrain (see Topography and Geologic Hazards Maps) with low rates

Table 20. Flooding of western Coos and Douglas Counties, Oregon

Type	Variety	Distribution	Causes	Impact	Recommendations
Stream	Flash flood	Interior uplands with regional slopes 50% or greater and moderate to high relief	Steep slopes, low infiltration rates, heavy rainfall	Minimal bank overflow owing to lack of flood plain; channel scouring and streambank erosion	Limits on development through zoning, proper engineering of necessary structures, proper land management
	Lowland stream flood	Flood plains of streams and other wetland areas, no sophisticated computor models available for Coos County	Same as flash flood in headwaters; channel obstructions and effects of ocean flooding in lowlands	Wide variety of structural damage and water damage, siltation of cropland, safety and health hazards, disruption of transportation	Controlled development through proper zoning, building codes, subdivision regulations; flood insurance, effective dissemination of information, construction of dikes and levees
Ocean	Tidal flooding	Low-lying coastal areas including beaches and marsh, highest tide 6 feet above msl	Daily and seasonal tidal variations	Aggravates stream flooding, salt water inundation, inundates immature high marsh, covers mature high marsh	Incorporate into models of stream flooding, appropriate zoning and policies, construction of tide gates
	Storm surge	Same as tidal flooding and additive to it; winter and spring; highest recorded storm surge 4.3 feet not counting waves	Wind and low atmospheric pressure elevate local sea level, waves additional	Same as tidal flooding and additive to it; also includes severe wave erosion in places; water levels 4-5 feet above mature high marsh possible	Incorporate into models of stream flooding; appropriate zoning and policies; tide gates; short range prediction and warnings
	Tsunami (Seismic sea wave)	Same as other ocean flooding, but can inundate greater areas; amplitude of 15 feet possible, local runup undefined; dissipation in estuaries, amplification along headlands	Large magnitude regional earthquakes with vertical displacement (e.g. Aleutians); attenuation is a function of distance	Loss of life to unwary beachcombers, clammers, and campers at low elevations; damage to moorings and other low-elevation structures; salt water inundation	Same as tidal and storm surge flooding; also, a well-coordinated, thorough and effective warning system to all coastal areas
Ground water	Ponding	Floodway fringe, behind levees, depressions, wetlands, interdune areas	Low infiltration rates in topographically confined areas	Flotation, caving, compressible soils, flooding, waste disposal malfunctions	Restricted development through proper zoning, subdivision regulations, policies and review processes;
	High ground water	Same as ponding, also includes areas of groundwater discharge	Accumulation of surface water or intersection of ground surface with water table	Same as ponding; also includes settling, unfavorable shrink-swell, and liquefaction during earthquakes	Proper engineering and construction of necessary and approved structures

of infiltration (see Engineering Geology). As the rapidly moving stream water is delivered downstream to flat-lying lowlands, the reduced velocity leads to flooding of adjacent areas. Commonly, ocean flooding (see Ocean Flooding) further aggravates the flooding. Acts of man which may also aggravate flooding include channel fills and modifications (which require permits from the U. S. Army Corps of Engineers or the State Land Board) and construction in the floodway (which is undergoing increasing regulation on the State and local level).

Land use also can influence flooding by altering surface-water residence times and infiltration rates. In a recent study on part of Long Island, New York, urbanization of open land was shown to increase the volume of direct runoff by factors of 1.1 to 4.6, depending upon local conditions. Peak runoff increased by a factor of 3 (Seaburn, 1969). A similar study of the Colma Creek drainage in California revealed a doubling of storm runoff but no change in peak flow (Knott, 1973). A variety of modeling procedures is available for predicting runoff patterns in areas of changing land use (Rantz, 1971).

The impact of logging on stream flooding appears to be minimal. Studies in the Alsea drainage (Harris, 1973) and the H. J. Andrews Experimental Forest (Rothacker, 1970a) show no increase in peak flows after clear-cut logging. These conclusions are based on the selection of a 95-percent level of confidence in their graphical comparisons, however, and a selection of a 67-percent level of confidence might yield different conclusions. Also, little attention has been given to the actual volume of storm-generated runoff (as opposed to peak flow) and the manner of its conveyance through lowland areas. Also, increased siltation downstream and the possible impacts on lowland flooding are in need of more study.

A beneficial impact of logging is increased streamflow during the dry summer months when consumption is at its peak. Removal of conifers has been shown to reduce summer evapotranspiration by approximately 18 inches in the H. J. Andrews Experimental Forest (Rothacker, 1970a). As a result, summer streamflow after logging increased by about 30 percent (Moore, 1966). In regions of dryer climate, thinner soils, and less uniform conifer cover than in the H. J. Andrews Experimental Forest, the impact of logging on annual evapotranspiration is probably less than 18 inches.

Distribution

Coos County: The Coos River basin covers 729 square miles and has an annual runoff of 2,500,000 acre feet. Annual precipitation is 83 inches. The Coquille River basin covers 1,094 square miles and has an annual runoff of 2,500,000 acre feet also. Annual precipitation varies from 60 inches along the Coast to greater than 100 inches east of Powers and averages 66 inches.

Extreme high and low discharges for various parts of the two drainages are listed on Table 21. High winter flows are a product of steep slopes and low infiltration rates, and low summer flows result primarily from the very low ground-water storage capacities of the bedrock in the uplands.

Water elevations for the calculated 100-year flood for the Coquille basin are indicated on Table 22. The figures are approximate and were derived from a stream profile developed by the U. S. Army Corps of Engineers (1972). Actual mapping of the 100-year flood is not yet available. Because tidewater extends inland to Allegany on the Coos River, similar data are not available for the Coos basin.

On the Coquille River, bankfull discharge between Bear and Lampa Creeks is 18,000 cfs. A discharge of this magnitude is possible once every three years on the North, South, East, and Middle Forks of the Coquille River. Moreover, the combined total discharge of any two forks exceeds 18,000 cfs every year, and river banks in the lower reaches of the drainage are overtopped about three times each year (U. S. Army Corps of Engineers, 1972).

At Coquille, bankfull discharge is at gage height 16.0 (9.6 feet msl). At gage height 17.5 (11.1 msl), flooding of the lowlands begins along the South Fork near Catching Creek. At gage height 20.5 (14.1 msl), the flood plains between Myrtle Point and Norway are flooded. Downstream from Coquille, most of the river bottom is higher than the surrounding lowlands behind the levees owing to siltation of the channels. For this reason, post-flood drainage is inhibited, and the use of floodgates is not possible. Prior to agricultural development, much of the lower valley was characterized by marsh growth and prolonged ponding.

Douglas County: The Umpqua River basin covers 4,560 square miles and has an annual runoff which varies from 2.2 million to 9 million acre feet. Approximately 80 percent of the watershed lies upstream from Elkton, and consequently only a small portion of it lies within the study area. The drainage of the Smith River covers 346 square miles.

Table 21. Extreme discharges at selected stream gaging stations, Coos County, Oregon[1]

Gaging station and water years of record	Minimum discharge		Maximum discharge	
	cfs[2]	Month	cfs[2]	Month
Coquille River basin[3]				
South Fork above Panther Creek near Illahee 1957-1965	1.0	Oct. 1961	8,830	Dec. 1964
South Fork near Illahee 1957-1965	1.6	Oct. 1961	12,000	Dec. 1964
South Fork at Powers 1917-1926, 1930-1965	12	Oct. 1961 Sept. 1939	48,900	Dec. 1964
North Fork near Fairview 1964-1965	4.6	Sept. 1965	4,660	Jan. 1965
North Fork near Myrtle Point 1930-1946, 1963-1965	13	Sept. 1965	38,400	Dec. 1964
Middle Fork near Bridge 1930-1931	1.0	each year	4,430	April 1929
Middle Fork near Myrtle Point 1931-1946	1.0	July 1931	31,800	Oct. 1924
Coos River basin				
West Fork Millicoma near Allegany 1955-1965	1.8	Sept. 1965	8,100	Nov. 1960
Tenmile Creek near Lakeside 1958-1965	1.4	Oct. 1961 Sept. 1965	3,330	Dec. 1964

[1]Table modified from Oregon Water Resources Board, 1963.

[2]1 cubic foot per second (cfs) equals approximately 450 gallons per minute (gpm).

[3]Discharge at the Coquille River below Myrtle Point is not calculated owing to tidal influence. Estimated discharge of Coquille during 1964 flood was 120,000 cfs.



Figure 13. Flooding of the Cape Arago Road, Coquille Valley, during the 1964 flood. (Photo courtesy of The World)



Figure 14. Flooding of the Coquille River at Coquille during the 1964 flood. (Photo courtesy of The World)

Table 22. Water elevations of the 100-year flood in the Coquille River basin[1]

Location	River mile	Approximate low water elevation (feet) msl	100-year flood elevation (feet) msl
Coquille River			
Bandon	0.1	varies with tide	8
Riverton Ferry	16.4	varies with tide	22
Coquille	24.6	varies with tide	24[2]
South Fork			
Mouth of N. Fork	36.3	1.5	36.5
Myrtle Point	37.4	2	41[3]
Mouth of Middle Fork	41.0	4	42
Broadbent	46.2	12	48
Powers	64.5	200	222
North Fork			
Mouth of East Fork	9.1	13	37
Middle Creek	18.8	51	88
Evans Creek	25.8	105	147
Middle Fork			
Myrtle Creek	8.8	111	118
Frenchie Creek	13.8	160	166

[1] Table adapted from U.S. Army Corps of Engineers, 1972

[2] 23 msl for 1890 flood; 21.1 msl for 1964 flood

[3] 46.75 msl for 1964 flood



Figure 15. Extensive flooding of the Coquille Valley two miles north of Coquille during the 1964 flood. (Photo courtesy of The World)



Figure 16. Flooding of the old Coquille-Bandon Road near Coquille during the 1974 flood. (Photo courtesy The World)



Figure 17. Flooding of Coquille during the 1974 flood. (Photo courtesy The World)



Figure 18. Shallow flooding at Coquille during the 1974 flood. (Photo courtesy The World)

Extreme high discharge of the Umpqua River gaged at Elkton was 265,000 cfs during the December 1964 flood. Extreme low discharge was 640 cfs on July 18, 1926. Extremely low summer discharges into the estuary are not as common as in other coastal estuaries owing to the moderating influence of the great size of the drainage basin and the summer runoff from the Cascade Range.

The distribution of the Preliminary Intermediate Regional Flood (100-year flood) was derived from detailed contour maps (1" equals 400 feet) and preliminary flood-water elevations data supplied by the Portland Office of the U. S. Geological Survey. Level of the 100-year flood is approximately 9.3 feet above mean sea level at The Point and 11 feet above mean sea level at the U. S. Highway 101 bridge north of Reedsport. Although the figures are subject to revision, they are adequate for the map scale used in this study.

Impact

Flooding destroys structures through current action, siltation, and water damage. It inflicts losses on agricultural land by scouring topsoil, eroding stream banks, silting cropland, and killing livestock. It threatens citizens by isolating dwellings, damaging property, disrupting transportation, and polluting or disrupting water supplies.

Coos County: The December 1964 flood was the greatest flood on record in Coos County in this century (Figures 13, 14, 15). Total damage in the Coquille basin was $3.1 million and included $1.44 million to agricultural land, $868,000 to industrial property, $178,000 to transportation, and $323,000 to channel improvements. Total damage in the Coos basin was $1.2 million.

At Myrtle Point, the South Fork of the Coquille River crested at 46.8 feet above mean sea level, nearly 10 feet above flood stage and approximately 5 feet above the level of the Intermediate Regional Flood. At Coquille the flood crested at 21.1 feet (msl) and water averaged 15 feet deep on the flood plain. This compares with a crest of 23 feet (msl) for the largest flood on record in that area in 1890 and a crest of 24 feet (msl) for the Intermediate Regional Flood. Calculated recurrence frequencies for 1964 discharges vary considerably in the County and also include frequencies of 4 years on the North Fork at Fairview, 10 years on the West Fork of the Millicoma near Allegany, 12 years on Gettys Creek near Myrtle Point, and 17 years on Tenmile Creek near Lakeside (Waananen and others, 1971).

Specific damage during the flood of 1964 included destruction of logging roads and bridges in the uplands, flooding of the sewage treatment plant at Myrtle Point, and forced evacuation of numerous residences at Myrtle Point. The community of Coquille was isolated from Coos Bay by 3 feet of water over the road at a point 4 miles west of Coquille. Downstream two plywood plants were flooded to depths of 4 feet and numerous houses and pastures were damaged. In the Coos Bay area large sediment deposits restricted shipping and dockside loading in the Bay and several tide boxes and tide gates were damaged.

The January 1974 flood resulted in $28,000 damage along the North Fork of the Coquille, $109,000 along the South Fork of the Coquille, and $173,000 along the lower reaches of the Coquille River. The flood crested at 17.6 feet (msl) (gage height 24 feet) and inundated large lowland areas (Figures 16-19). It was the third largest flood since the 1955 flood, which crested at 37 feet near Myrtle Point.

Projections by the Oregon Water Resources Board (1972) show that annual flood damage in the Coos River basin will rise to $250,000 in 1980, $384,000 in the year 2000, and $582,000 in the year 2020. Figures for the Coquille basin are $642,000 in 1980, $997,000 in the year 2000 and $1,496,000 in the year 2020. Figures are in 1965 dollars and assume continued development with no flood control.

Douglas County: The flood of December 1964 was the greatest flood on official record for the Umpqua basin. Peak discharge was 265,000 cfs at Elkton compared to a peak discharge of 218,000 cfs for the largest previous flood in 1955. The 1964 flood is approximately equivalent to the Intermediate Regional Flood in the study area.

Damage during the 1964 flood in the Reedsport area totaled $4 million to $5 million. Water levels averaged 4 feet in much of northern Reedsport (Figures 20, 21, 22), and in places waters approached the eaves of buildings. Flooding of the community was the result of overtopped dikes (Harris and Williams, 1971) and piping of water through muskrat holes in the dikes. Maintenance requirements for the reconstructed dikes call for total removal of vegetation to alleviate the muskrat problem.



Figure 19. Flooding of agricultural land near Coquille during the 1974 flood. (Photo courtesy The World)



Figure 20. Flooding of the Reedsport commercial district in the 1964 flood. (Photo courtesy The Courier)



Figure 21. Flooding of residential district in Reedsport in the 1964 flood. (Photo courtesy The Courier)



Figure 22. Flooding of a shopping district in Reedsport during the 1964 flood. (Photo courtesy The Courier)

Upstream at Scottsburg the flood crested at 45.8 feet on the south side of the highway bridge and flowed over that side of the bridge. Many homes were flooded; when flood waters receded, approximately 15 homes had been washed away. Two miles upstream at Wells Creek, waters crested at 54.8 feet and flooded several structures. Downstream, flood waters covered parts of the Loon Lake Road, the Deans Creek Road, and the Smith River Road, and rose to the level of the Scholfield Creek Road in some places.

Recommendations

On the State level, assistance in developing flood-plain management plans is provided by the Oregon Water Resources Board, and broad policies are formulated by the Land Conservation and Development Commission. Numerous Federal agencies also assist in dealing with flood hazards, as discussed below.

Structural means of water storage or retention such as dams, levees, and dikes do not appear to be feasible methods of flood control in western Coos County. Effective flood control by water storage would require a total capacity of 530,000 acre feet in the Coquille River drainage. Loss of arable land, damage to fish runs, and topographic restraints make this alternative unfeasible at the present time (U. S. Army Corps of Engineers, 1972). Levee construction would greatly reduce bank storage and would require a channel level of 40 feet at Coquille to accommodate a flood equivalent to that of 1964. This is nearly 20 feet above the level of the 1964 flood. Channel improvements required to significantly alleviate flooding would be expensive to maintain and would involve destruction of natural levees.

Existing structures for flood control in western Douglas County include levees along the lower reaches of the Umpqua and Smith Rivers to provide protection from 25-year floods, and a dike around north Reedsport to provide protection from the 100-year flood. There is no flood protection for Gardiner, and parts of the community are frequently flooded by ocean and stream flooding.

The U. S. Soil Conservation Service administers the Watershed Protection and Flood Protection Act of 1954 and provides technical assistance for channel protection and other flood-related projects.

Declaration of a flooded area as a disaster area by the Governor allows the release of funds for the restoration of public facilities, river-bank repair, and low-interest loans to individuals and small businesses. Assistance of this type is coordinated by the Office of Emergency Preparedness, the State Emergency Services Center, and local officials.

Emergency preparedness includes flood forecasting and flood warning by the National Weather Service River Forecast Center in Portland. Flood fighting by local personnel is commonly supplemented by the U. S. Army Corps of Engineers and is coordinated by the State Emergency Operations Center. The Flood Insurance Act of 1968 is administered by the U. S. Department of Housing and Urban Development with the assistance of the State Water Resources Board and provides flood insurance to individuals and businesses in regulated developments.

Zoning codes regulate regional land use and can be written to restrict land use in various parts of the flood plain. Subdivision codes can require disclosure statements, flood warning signs, and construction practices compatible with flood potential. Building codes often regulate floor elevations and provide for waterproofing, anchoring, and other appropriate construction standards.

Ocean Flooding

General

Ocean flooding is the inundation of lowland areas by salt water owing to tidal action, storm surge, or tsunami (see Table 20). Landforms subject to ocean flooding include beaches, marshes, coastal lowlands, and low-lying interdune areas. The highest predicted tide is approximately 6 feet above mean sea level. The highest probable storm surge is 4 to 7 feet above prevailing tidal elevations. The highest probable tsunami is approximately 14 feet high in the mouths of estuaries and slightly higher on the beaches. Because tidal flooding occurs daily, the effect of high tides is superposed on that of storm surges or tsunamis in determining the impact of those phenomena. The simultaneous occurrence of an extreme storm surge and an extreme tsunami is considered highly improbable and is not investigated.

Tidal flooding

Causes: Tides are the periodic rises and falls of sea level which occur approximately two times per day. Tides are primarily caused by the permanent development of two bulges of water in the oceans formed in response to the gravitational attraction of the Moon. On the side of the Earth facing the Moon, the gravity of the Moon attracts the water to form a bulge, and on the side opposite the Moon a similar bulge is formed owing to centrifugal acceleration. The Sun exerts a similar effect on the Earth's oceans, but to a lesser extent. The net result is a secondary set of tides superposed on those of the Moon. When the tides of the Sun and the Moon coincide (approximately bimonthly), observed tides are additive, giving extreme tides called spring tides. During other alignments the tides tend to cancel to various extents, giving less extreme tidal situations. When the Earth, Sun, and Moon form a right angle, cancellation is the greatest and gentle neap tides result.

Other major factors of tidal generation include 1) the variations in the distance of the Earth to the Moon, 2) the variations in the distance of the Earth to the Sun, 3) the declination of the Earth's orbit around the Sun with the equator, and 4) the declination of the Moon's orbit with the Earth's equator. In all, several dozen major and several hundred minor periodicities affect tides. The physical configurations of the various ocean basins and shorelines also are factors which contribute measurably to tidal levels.

Tidal elevations: Tidal elevations at specific localities vary with the relative influence of the various tidal periodicities, the characteristics of the basin, and time. In the Pacific Ocean, daily high tides and daily low tides are not equal. Thus, a higher high tide and a lower high tide, and a higher low tide and a lower low tide are recognized. Various tidal elevations relevant to nautical charting, coastal engineering, and navigation are illustrated on Table 23.

Mean lower low water is arbitrarily defined as '0' and is the base level of all other tidal elevations. Mean low water marks the boundary between submerged land and tidal flats. Mean sea level is based upon observations taken over a number of years and serves as the datum base for topographic maps produced by the U. S. Geological Survey. Mean sea level varies with location, but along the Oregon Coast is generally 4 feet above mean lower low water. Knowledge of mean sea level is required to interrelate land elevations and tidal elevations. Thus, an 8 foot tide is only about 4 feet above mean sea level.

Mean high water is the average of all observed high tides and for the Oregon Coast is approximately $3\frac{1}{2}$ feet above mean sea level. Mean higher high water is generally less than a foot above mean high water. Both are approximately equivalent to the ground elevation of mature marshes with well-defined drainage.

The highest predicted tides flood the highest marshes, and the highest observed tides (prevailing high tide plus storm surge) inundate the marshes and may flood other low-lying areas. According to Table 23, the highest tide in Yaquina Bay during the observation period was 12.6 feet, or nearly 5 feet above mean high water (the level of high marshes). Over considerably longer periods of time, maximum observed tides at the mouth of the Umpqua River and at Lincoln City were about 13 feet, and adoption of this figure for the study area is reasonable.

Impact and recommendations: Tidal action inundates tidal flats and marshes, enhances estuarine circulation (see Geology of Estuaries), aids navigation, controls sedimentation and deposition, and supports a complex of biologic activity in the Oregon coastal zone. All construction and fills in the tidal zone should proceed on the basis of careful planning and are subject to policy statements formulated by the Oregon Coastal Conservation and Development Commission. Permits are issued by the State Land Board and the U. S. Army Corps of Engineers. Hazards associated with tidal flooding are discussed in detail under Storm surge.

Storm surge

General: Storm surge is the rise of sea level above predicted tide levels owing to low barometric pressure and wind. Local factors influencing the magnitude of storm surge also include bottom gradient, shore slope, position of the coast relative to the storm center, and harbor configuration.

Table 23. Representative tidal elevations of the Oregon Coast[1]

Elevation (feet)	Tidal term[2]	Description
14.5	Extreme high tide	Highest projected tide that can occur and is the sum of the highest predicted tide and the highest observed storm surge. Very long recurrence intervals are assumed. It is the level used by engineers for the design of harbor structures.
12.6	Highest measured tide	Highest tide measured on the tide staff.
10.3	Highest predicted tide	Highest tide predicted by the tide tables. Storm surges and other climatic factors are not considered.
8.4	Mean higher high water	Average height of the highest high tides observed over a specific time interval. Time intervals are selected on the basis of the moon's many cycles and the degree of refinement required. This plane is used by the National Ocean Service to reference navigational clearances.
7.6	Mean high water	The average of all observed high tides. It is the boundary between tideland and "upland," the land generally at or above the level of mature high marsh.
4.6	Mean tide level	A level midway between mean high water and mean low water. The difference between mean tide level and local mean sea level reflects asymmetry between local high and low tides.
4.5	Local mean sea level	The local average height of the water surface for all stages of the tide.
4.1	Mean sea level	A regional datum based on observations taken over a number of years on the West Coast of the United States and Canada. It is the reference for elevations on U.S. Geological Survey topographic maps.
1.5	Mean low water	The average of all observed low tides. It is the boundary between tideland and submerged land.
0.0	Mean lower low water	The average height of the lower low tides.
-2.9	Lowest predicted tide	The lowest tide predicted on the tide tables.
-3.1	Lowest measured tide	The lowest tide actually measured on the tide staff.
-3.5	Extreme low tide	The lowest estimated tide that can occur.

[1] Specific figures are based on 6 years of tide observations at the Oregon State University Marine Science Center dock on Yaquina Bay. Values vary from estuary to estuary, within an estuary, and with the interval of observation.
The above figures are good approximations for values in the study area.

[2] Adapted from Oregon Division of State Lands (1973).

The low barometric pressures which accompany storm activity induce sea level to rise slightly at a rate of approximately 1 centimeter per millimeter drop in pressure (approximately 1 foot per inch in mercury). The maximum possible storm surge resulting directly from fluctuations in barometric pressure is about 3 feet.

Wave "set-up" is the retarded return of waves to the sea owing to wind friction. Set-up is approximately 10 to 20 percent of wave height in extreme storms (Fairbridge, 1966). Thus, in regions where winter storm waves are commonly 20 feet high near shore, as along the Oregon Coast (U.S. Naval Oceanographic Office, 1966), set-ups along beaches may approach 2 to 4 feet. Within bays where tidal gages are generally located, however, wave set-ups are much less and recorded storm surges are therefore less.

Magnitude: Along the Atlantic seaboard and the Gulf coastal zone, storm surges as high as 9 to 12 feet have been recorded over large areas. At Pass Christian, Mississippi, Hurricane Camille delivered a 25-foot storm surge in 1961. The city is situated at the narrow head of a wide-mouthed bay that faced directly into the storm. Along the Oregon Coast, storm surges generally are less than a foot and probably do not exceed 4 to 7 feet, depending on local conditions. During a 45-year observation period, the highest observed tide was 3.8 feet above mean higher high water (U. S. Army Corps of Engineers, 1973). During a 6-year observation period at the Oregon State University Marine Science Center in Yaquina Bay, the highest observed storm surge was 4.2 feet. Both observations were made at locations with minimal wave set-up.

Extreme high tide is the sum of the highest predicted tide and the highest observed storm surge. It is used as a reference for coastal engineering and has a very long recurrence interval. Using data developed for Yaquina Bay, an extreme high tide of approximately 14 feet (10 feet msl) can be tentatively adopted for the study area.

Impact: Ocean flooding caused by high tides and storm surges is common in the winter and results in considerable lowland flooding (Figure 23). The rise in sea level hinders stream drainage, further contributing to inland flood hazards. Because elevated base level (level of prevailing seas) rather than siltation is a major cause of flooding, dredging and channel modifications cannot alleviate the situation in the lower reaches of many coastal streams. Storm surges also allow waves to pass unbroken over coastal bars to directly attack beach and dune areas (see Coastal Erosion and Deposition).

On January 3 and 4, 1939 heavy seas inflicted considerable damage on the Sunset Inn located in wooded lowlands immediately inland from Sunset Beach. Breakers 4 feet high were reported around the walls of the Inn, and three cabins nearby were washed from their foundations (Coos Bay Times).

On January 5, 1939, a second storm surge, superposed upon an 8.5 foot tide and possibly upon the swells of the first storm, destroyed six of 15 cabins at Sunset Inn, covered parts of South Broadway Street in Coos Bay, and lapped water against some of the lower lying stores in Charleston. One large wave broke over the tip of the Coos Spit and sent water into South Slough, damaging moorings and spreading water 500 yards inland from the normal high water mark at the Coos Head CCC Camp. The road to the Coast Guard Station at Charleston was also damaged.

Recommendations: Ocean flooding by storm surge and high tides can be predicted on the basis of tidal tables and weather predictions. Planning measures for long-range protection should include provisions for public disclosure of hazardous areas. During the summer months, the many low-lying coves and beach areas are deceptively peaceful, as the example of the ill-fated Sunset Inn illustrates. Because storm surge and stream flooding often coincide, storm surge should be considered in all models of stream flooding.

Tsunami

General: Tsunami is the term applied to waves generated at sea by large earthquakes or particularly violent submarine volcanic eruptions. Tsunamis are difficult to detect at sea, having wave lengths of a hundred miles or more and amplitudes seldom exceeding a foot or so. Velocity of the waves is determined by the depth of the ocean and approaches 450 miles per hour in parts of the Pacific Ocean.

As tsunamis approach land, the shallower depths cause the water to pile upon itself, thus increasing the amplitude. In some of the coastal inlets of Japan, tsunamis greater than 80 feet high have been generated



Figure 23. Logs scattered on Bandon Spit indicate level of recent ocean flooding. (Photo courtesy Oregon Highway Division)

by local seismic activity. The largest tsunamis on record, an estimated 120 feet high, occurred on the coastal lowlands of Java during the eruption of Krakatoa in 1883. The height of any given tsunami at any given locality is determined by 1) the magnitude of the disturbance generating the tsunami, 2) attenuation, 3) bathymetry, and 4) run-up.

Magnitude of the disturbance: Most tsunamis are generated by seismic activity. Factors favoring the generation of destructive tsunamis include a magnitude 7.5 earthquake on the Richter Scale, a shallow focus, a large area of displacement, and vertical displacement along the active fault. Strike-slip faulting (horizontal displacement) generally does not generate tsunamis.

Wilson and Torum (1972) relate the maximum height of tsunamis to the magnitude of the earthquakes which produced them. Data were collected for tsunamis at points within 500 miles of their respective epicenters. Their equation shows that for earthquakes of Richter magnitude 8.7 (the largest possible quake) the largest probable tsunami anywhere in the world is approximately 100 feet in height. Similarly, quakes of magnitudes less than 6.7 on the Richter Scale are shown to generate tsunamis of 3 feet in height or less, which probably would have little or no effect on structures. The above determinations are statistical, however, and are generalized in that they do not consider peculiarities of individual future tsunamis.

Attenuation: As waves move away from their point of origin, they diminish in size (attenuate) owing to friction, dispersion, and other factors. Where the mechanics of generation of a particular tsunami favor propagation in one direction over another, the propagation is said to be directional, and wave height is inversely proportional to the square root of the distance (a tsunami a distance 2x from origin is $1/\sqrt{2}$ as high as at point x) (Wiegel, 1969). Where propagation favors no direction over another, it is said to be nondirectional, and wave height is inversely proportional to the distance (a tsunami at distance 2x from origin is $\frac{1}{2}$ as high as at point x) (Wiegel, 1969). The Alaska earthquake of 1964 produced a directional wave toward the eastern and southern margins of the Pacific Ocean and is analyzed by Li-San and Divoky (1972). In contrast to the destructive waves delivered to the West Coast of the United States (see Impact), the tsunami reaching the coast of Japan was generally only 1 to 2 feet high. Likewise, the Tokachi-oki earthquake of May 16, 1968 in Japan, which registered 7.8 on the Richter Scale, delivered a tsunami only 6 inches high on the Oregon Coast (Pattullo and others, 1968).

Bathymetry: Much of the impact of tsunamis is determined by the extent to which the water piles upon itself as the tsunami approaches shore. This, in turn, is determined by subsea bathymetry in the deep sea, on the continental shelf, and nearshore. Along the Oregon Coast, possible shoaling areas include the gentle shelf off the coast of Clatsop County, the Heceta Bank off the central Oregon Coast, and Coquille Bank off the coast of southern Coos County. Too little information is available to determine the extent to which these low-water areas amplify or dissipate tsunamis. Likewise the effect of the subsea canyons is also undefined.

Topographic features of more local extent along the coast of Douglas and Coos Counties also influence the impact of tsunamis. Generally, the tsunamis tend to concentrate on the headlands and to disperse in the estuaries. Dispersion results from the narrow, shallow entrances, the extensive marshes, and the winding lower reaches of the estuaries. In other parts of the world, wide, deep harbor entrances are known to amplify tsunamis.

Run-up: Run-up is that elevation on land that a tsunami may reach and is measured relative to prevailing sea level at the time of the tsunami. For instance, a tsunami with a 10-foot run-up occurring at the time of an 8-foot tide would reach an elevation of 18 feet above mean lower low water. (Tides are measured relative to mean lower low water.) In Oregon this is approximately 14 feet above mean sea level.

Run-up is determined by local bathymetry and topography, angle of incidence, bottom slope, bottom permeability in shallow areas, and by the nature of the material underlying the lowland areas. Generally, run-up is 1 to $1\frac{1}{2}$ times wave height (Wilson and Torum, 1972), but may approach 2 times wave height under ideal conditions (Torum, 1972). Along the coast of Coos and Douglas Counties, run-up is probably equivalent to H (height of the tsunami as it breaks nearshore) along the headlands, and greater than H along the coves and beaches. In the estuaries, where the tsunamis tend to dissipate, the

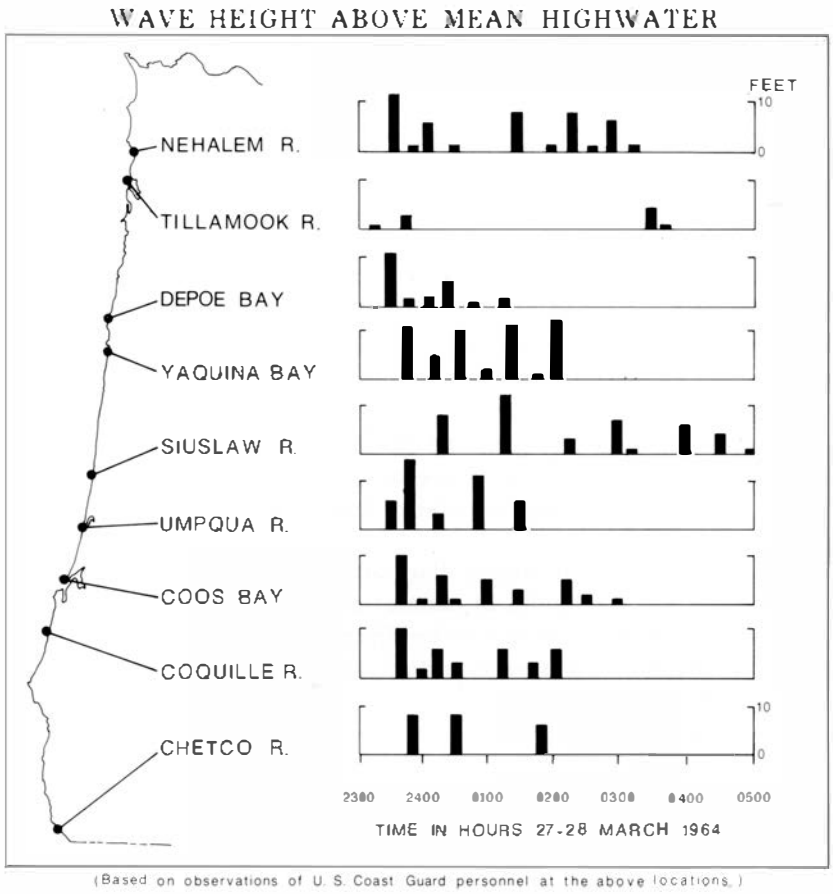


Figure 24. Wave heights of the 1964 tsunami above mean high water. (from Schatz, Curl and Burt, 1964)



Figure 25. Salvage operations of a small craft at Charleston after the 1964 tsunami. (Photo courtesy The World)

run-up is measured relative to the wave height in the estuary rather than along the coast. Run-up is probably less than local H owing to the damping effects of the marsh. The impact, however, may be disproportionately high owing to the great extent and the very low elevations of much of the estuary borderlands.

Impact: Potential damage by tsunamis includes flooding of tidelands and peripheral marshes and lowlands, damage to moorings and vessels, and injury or drowning of persons on beaches, in isolated coves, and on low-lying terrain. This latter impact is particularly significant in view of increased tourism and extensive beachcombing and clamming along coastal Coos and Douglas Counties.

The Good Friday Alaska earthquake of March 27, 1964 satisfied all requirements for the generation of a destructive tsunami along the Oregon Coast. It registered 8.3 to 8.6 on the Richter Scale and involved vertical displacements of regional extent in the nearest zone of tectonic convergence, a factor which favors the generation of destructive tsunamis (Isaaks and others, 1968). In contrast, vertical faulting in the sea-floor rise systems off the coast of Oregon involves more local displacements of lesser magnitude (maximum Richter magnitude 6.8) in a region of tectonic divergence rather than convergence. Faulting on the Mendocino Escarpment to the southwest is primarily strike-slip (see Structural and Tectonic Setting) and generally does not generate tsunamis. The tsunami generated by the Alaska quake coincided with high spring tides and exhibited directional propagation towards the Oregon Coast. Although data are limited, it is a fairly accurate indicator of potential damage along the coast of Coos and Douglas Counties from tsunamis originating in the northeast Pacific.

Total damage along the Oregon Coast amounted to $700,000 and four drownings. Losses would have been considerably greater had the tsunami arrived during a period of heavy tourist use rather than late at night in March. Wave heights of 4 to 14 feet above prevailing mean high water (Figure 24) were recorded in Oregon, and a wave greater than 20 feet high was recorded in Crescent City, California. There, analysis of tidal gage data has revealed a 100-year recurrence frequency for tsunamis of that size. Downtown Bandon was temporarily flooded, and at Charleston several boats were sunk (Figure 25) or beached (Figure 26), and damage to docks totalled $7,000. At Sunset Bay the picnic grounds were flooded (Figure 27), and a waterline 3 feet deep was later observed in the restroom of the park facility. Owing to dissipation within the Coos Bay estuary, no damage was noted upstream from Charleston, and at North Bend the only evidence of the tsunami was the recording of tides at slightly greater than predicted levels.

Because tsunamis deliver waves over a period of several hours, conservative estimates of the maximum probable tsunami for the study area must assume that the tsunami will be superposed upon mean high water (approximately $7\frac{1}{2}$ feet above mean lower low water and 3 feet above mean sea level). Remarkably, the tsunami generated by the Good Friday earthquake in Alaska occurred during high spring tides. Using the Good Friday tsunami, therefore, as an approximate measure of the highest probable tsunami, inundation by tsunamis to elevations of 17 feet above mean sea level in some coastal areas of the study area should be expected. Run-ups to elevations of 25 feet are possible in some beach areas.

General impacts may include 1) catastrophic flooding of beaches, 2) minor foredune erosion, 3) salt-water flooding of coastal lowlands and interdune areas, and 4) marshland flooding near the mouths of estuaries. Superposition of tsunamis and extreme high tides (highest predicted tide and highest observed storm surge) is extremely improbable and is not considered in this investigation.

Recommendations: The greatest threat of tsunamis is loss of life to individuals such as clammers, hunters, beachcombers, and beach campers in low-lying areas such as beaches, tidal flats, and marshes. It is imperative, therefore, that local warning procedures be efficient and comprehensive. Tsunamis are detected by the Seismic Sea-Wave Warning System at the Environmental Sciences Services Administration stationed in Honolulu. Warnings are relayed first to the Oregon State Emergency Services Office and then to county and city personnel along the Coast. A tsunami watch means that conditions conducive to the generation of a tsunami have occurred. A tsunami warning means that an actual tsunami has been observed.

Once a tsunami warning has been received by local officials it must be relayed to the populace by radio and TV announcements and through the effective use of the beach patrol. Because many isolated coastal areas and coves may also be occupied, use of helicopters and other low-flying craft should be considered. The public should be informed that tsunamis involve many waves over a period of several hours.



Figure 26. A small croft beached near Charleston after the 1964 tsunami. (Photo courtesy The World)



Figure 27. Damage to the picnic grounds at Sunset Beach by the 1964 tsunami. (Photo courtesy The World)

The first wave is often preceded by a pronounced withdrawal of the sea that may lure the unwary observer to his death. Moreover, tsunami warnings should not go unheeded merely because the area escaped damage during a previous tsunami warning.

High Ground Water and Ponding

General

A water table situated high enough to have an adverse effect on a selected activity of man is termed high ground water. It is recognized on the basis of well-log data and surficial and soil features such as marshy ground, the presence of reeds or marsh grass, extremely flat topography or depressions, high organic content in the soil, and black to blue-gray soil mottling. Ponding is the local accumulation of runoff or rain water and is due to low slopes, topographic restrictions, or low permeability of the underlying soil or bedrock. It constitutes a special case of high ground water in the sense that it represents perched water conditions in which the water table lies above the surface of the ground. Ponding is recognized by the same features as those of high ground water.

In the study area, high ground water and ponding are most common on lowland and terrace landforms, especially on flood plains and fluvial terraces where overland flow is impounded by natural or artificial levees. Lakes and marshes in the Coos-Umpqua dune sheet are also areas of high water table. Quicksand conditions and slumping in some dune areas are products of high ground water.

Impact

High ground water or ponding can lead to 1) flooding of basements, underpasses, and other subsurface facilities, 2) flotation or damage to buoyant structures such as pipelines, tanks, swimming pools, newly installed septic tanks, and basements, (3) differential settling of large to moderate-sized structures, and 4) complications in the installation of underground facilities. Included is the danger of caving during excavation.

Other problems include the possibility of shrink-swell related damage (see Soils) as the soil responds to rising and falling of the water table, liquefaction phenomena during earthquakes (see Earthquakes), and threats to water quality in areas of waste disposal. Hepatitis may occur in areas where agricultural runoff or septic-tank effluent pollutes surface or near-surface water that later flows into domestic ground-water wells (see Ground Water). Septic-tank installations and other methods of waste disposal are overseen by the Department of Environmental Quality.

Recommendations

Engineering studies for large structures generally take high ground water or ponding into consideration, but housing developers and individual homebuilders sometimes fail to do so. Of special concern is the practice of covering drainage areas with fill during the summer months to produce additional land for development. During the wet winter months, when subsurface flow saturates the fill material, severe ground-water flooding can result.

Engineering solutions for dealing with ground-water flooding include the installation of drainage tiles beneath and around subsurface structures, construction on piling, and implementation of safety provisions against caving during excavation. In regions of particularly severe hazard, seasonal construction may be necessary.

In areas of regional commercial or residential development, such as shopping centers or high-density subdivisions, infiltration rates are greatly reduced. Flooding will result if the added runoff is not handled adequately. Gentle slopes can be constructed to elevate individual structures and to direct runoff to gutters and drains. Provisions should also be made to assure that the disposed runoff does not adversely effect adjacent land use.

Sump pumps and drain tiles are often used to handle severe leaking of basements in regions of high infiltration or high ground water. Where problems are less severe, sealants may be applied to either the interior or the exterior of the foundation wall (Consumer Reports, July, 1974).

Moss Movement

General

Moss movement is the movement of rock or soil material downslope in response to gravity. As summarized on Table 24, various kinds of moss movement ore recognized on the basis of 1) type of movement, 2) rote of movement, 3) type of material, and 4) water content. Treatment of specific instances of moss movement must be keyed to these parameters. Hence, in a general way the recognition of the type of moss movement is a fundamental step in dealing with moss-movement hazards (see Recommendations).

Rockfall is the rapid or extremely rapid movement of rock down steep slopes. It is most prevalent in the steeper uplands and along sea cliffs and occurs in terrain of Sandstone of Tertiary Age or Basalt of Tertiary Age. Areas of rockfall ore characterized by talus flanking steep cliffs. Vegetation commonly masks the tolus.

Debris flow is the very rapid movement of saturated soil and rock material down steep slopes (Figure 28). It is most prevalent where thin soils overlie Sandstone and Siltstone of Tertiary Age on regional slopes of approximately 100 percent (45° slope) or greater. Debris flow commonly forms linear slurry-like deposits in steep canyons and differs from rockfall in that saturated soil material predominates rather than rocks.

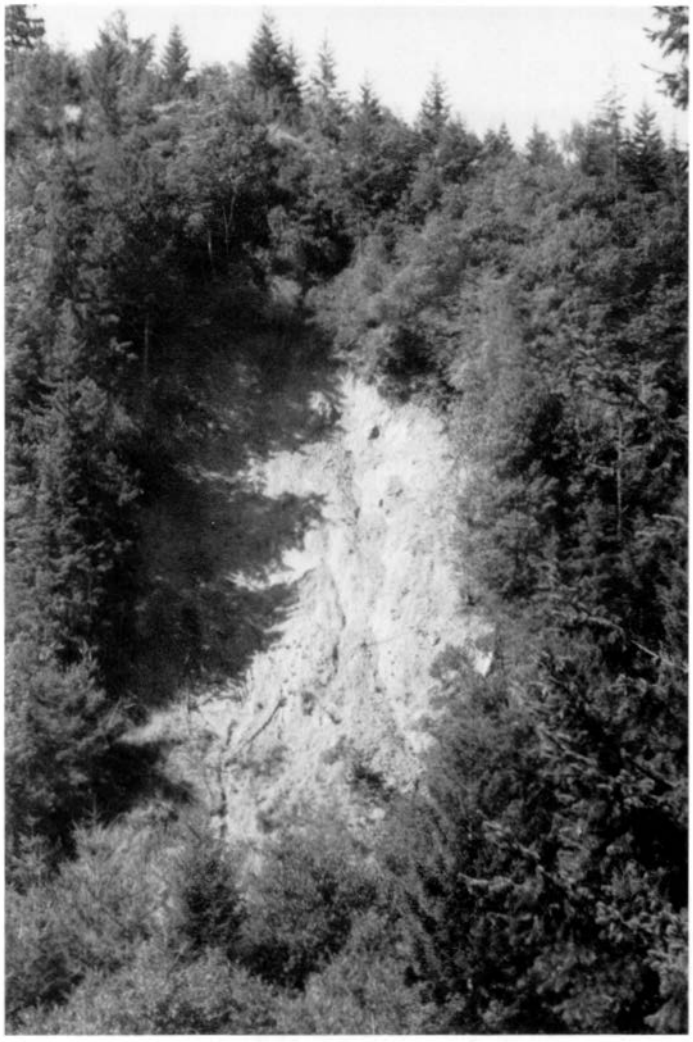


Figure 28. Shallow debris flow on a steep slope. Slide is typical of mass movement along South Fork of Coquille River, where stream-bank erosion undercuts steep slopes.

Earthflow is similar to debris flow in its viscous flow of soil and rock material but is less rapid and occurs on gentler slopes. It also penetrates to greater depths. Earthflow is most prevalent in moderately sloping upland areas underlain by sheared Rocks of Pre-Tertiary Age and sheared to deeply weathered Sandstone and Siltstone of Tertiary Age. High silt and sand content of the soil and moderately steep slopes favor more rapid movement, and gentler slopes richer in clay favor slower rates of movement. Under natural conditions, earthflow occurs on slopes as gentle as 20 percent in terrain underlain by Rocks of Pre-Tertiary Age and 30 percent in terrain underlain by Sandstone of Tertiary Age.

Slump is the downslope rotational movement of soil or rock material along a few slide surfaces. It characterizes the upslope portions of earthflow terrain and its distribution, therefore, is similar to that of earthflow. Movement is generally rapid to moderately rapid and is preceded by the development of cracks in the ground where the slip plane intersects the ground surface.

Earthflow and slump terrain is interpreted on the basis of a reconnaissance observation of the features listed in the appropriate columns of Table 24. Field studies, aerial photographs, topographic maps, and geologic maps were used to outline these areas on the Hazards Maps. Rockfall and debris flow terrain is determined primarily on the basis of slope and rock type and secondarily on the basis of scattered observations.

Causes

Mass movement occurs where the downslope component of gravity exceeds the shear resistance. In areas where slides are undesirable, therefore, the octivities of man should be controlled to assure that the downslope component of gravity is minimized and that the shear resistance is maximized or at least maintained.

Downslope gravity component: Weight of the soil column is increased by the improper placing of fill for road construction or construction sites. Increased water content resulting from seasonal precipitation or disrupted drainage patterns has the same effect. Debris flows and earthflows often result. It is doubtful, however, whether the increased soil moisture associated with logging has an impact on slope stability. Slides generally occur in the winter when soils, even under forest cover, are saturated. Other factors discussed below are probably more significant in logged areas.

Models of slope failure presuppose that the weight of the soil column is perpendicular to the Earth's surface. Where nearby blasting is a factor, a horizontal acceleration is introduced along with the acceleration of gravity, and the net result is to produce an inclined direction of acceleration for the soil column. In effect, the slope is increased and failure may result. For more distant blasts and for earthquakes of the magnitude possible in the study area, the effect of a reoriented acceleration is probably secondary to the impact of ground shaking on soil cohesion as discussed below.

Shear resistance: An increase of pore pressure acts to reduce internal friction and thereby to reduce shear resistance. Water accumulating in the soil and acting against an impermeable zone tends to buoy the soil particles upward and to reduce the component of gravitational attraction acting against the slope. Debris flows involving thin soils overlying impermeable bedrock and earthflows on gentler slopes can be attributed in part to increased pore pressure.

Cohesion, the bonding attraction of soil particles, can be reduced by shrink-swell phenomena, frost wedging, blasting or seismic activity with associated liquefaction (see Earthquakes), and variations in moisture content in the soil. The impact of moisture content varies with soil type (Figure 29). For example, small increases in moisture content may actually promote bonding in fine silts, whereas slightly greater amounts of moisture may promote liquid response. Clays, on the other hand, may accomodate large quantities of water before reaching their liquid limit but deform plastically over long periods of time with lesser water contents. Much of the earthflow terrain on moderate to gentle slopes is the result of long-term plastic deformation of cohesive soils. More rapid earthflows on steeper soils are in part the result of saturation of more silty soils and the consequent loss of cohesion along critical horizons.

Other factors which contribute to shear resistance include independent means of support and the distribution of soil on the slope. Root support by trees is now recognized as a primary agent of slope stability in forested areas (Figure 30). Most slides in logged over areas (excluding those associated with road construction) are attributed to the loss of root support through decay after logging. Removal of the toe of slide areas or soil from near the base of a moderate slope can initiate sliding by reducing shear resistance. Toe removal is often the result of improperly designed cuts (Figure 31) or of stream-bank erosion (Figure 32).



Figure 29. Water seeps (dark areas) in a slide moss near Powers; major couse of sliding was stream-bonk erosion nearby.



Figure 30. Shallow eorthflow on a moderate slope initiated by the removal of trees.

Table 24. Classification of mass movement

Type	Movement	Material	Water content	Topography	Additional characteristics
Rockfall and minor rockslide	Extremely rapid to very rapid falls and slides	Blocks and boulders of bedrock	Low to moderate	Near vertical slopes in steep interior uplands, also steep sea cliffs	Vertical slopes with jointed or bedded bedrock exposures; unvegetated talus, other signs of recent activity
Debris flow (includes mudflow)	Very rapid viscous flow	Rock and soil in varying proportions	Generally high; can be low where movement caused by undercutting	Upland slopes of approximately 100%[1] slopes or greater	Linear to elongate slurry-like deposits in steep channels or on steep slopes; debris commonly gullied and sparsely vegetated
Rapid earthflow	Rapid viscous flow along innumerable surfaces of failure	Fresh to weathered bedrock	Low to moderate	Steep high valley walls of interior uplands	Steep, high headscarp, irregular rubbly topography, irregular drainage
				Gentle to moderate slopes with stream-bank erosion or deep roadcuts	Sag ponds, irregular soil distribution, bowed and tilted trees, reduced slope relative to rest of slope
		Weathered bedrock and soil	Moderate to high	Slopes of approximately 50 to 100% in uplands and along sea cliffs	Same as above, but commonly does not involve bedrock; extent and depth commonly less, and distinguishing features commonly more subdued
Slow earthflow	Slow to moderate viscous flow (includes soil creep)	Plastic soil and deeply weathered bedrock	High	Deeply weathered moderate slopes (20-50%) of the uplands with plastic soils or deeply weathered and sheared bedrock	Same features as above, but much more subtle owing to reduced rates of movement (as little as a few inches per year); subdued topography, disordered soil in cuts, trees bowed downslope; high clay content typical
Slump	Slow to rapid movement on a basal plane	Bedrock or soil	Moderate to high	Upslope margins of earthflows; also soil failures on moderate slopes	Rotational movement on a curved basal slip plane, well-pronounced headscarp, reduced slope, disrupted drainage

[1]Percent slope is ratio of vertical distance to horizontal distance



Figure 31. Failure of deep roadcut in deeply weathered material along Highway 101 between Bandon and Coos Bay (sec. 25, T. 27 S., R. 13 W.).



Figure 32. Slide along county road in Catching Slough inlet influenced by stream-bank erosion during the 1974 flood. (Photo courtesy The World)

Distribution

Mass movement is most prevalent in the uplands and along sea cliffs. Small unmapped slides occur along the edges of terraces, along smaller streams and gullies, and on moderately steep slopes of local extent. Within each landform the specific type of sliding is related to slope. Very steep slopes (greater than 100 percent regionally and near vertical locally) favor rockfall and rockslide; moderate slopes (between 50 and 100 percent) favor debris flows and rapid earthflows; and gentle slopes (20 to 50 percent) favor slow earthflow in areas of shearing or clay-rich soils.

Uplands: Mass movement in areas of Rocks of Pre-Tertiary Age in southern Coos County is dominated by slow to rapid earthflow. Conditions conducive to sliding include 1) pervasive shearing of the bedrock (see Structure and Tectonic Setting), 2) moderate slopes, 3) undercutting by vigorous stream-bank erosion along major streams, and 4) diverse rock types, each with its specific slope stability requirements. Rapid to slow earthflow occurs on slopes between 20 and 50 percent, and isolated rockfalls occur on steeper canyon walls.

Mass movement in terrain underlain by Sandstone of Tertiary Age varies with structure, rock type, and topographic setting. In inland Coos and Douglas Counties, deep stream dissection favors rapid erosion, and soils are generally thin over impermeable bedrock. Debris flows and rapid earthflows characterize the steeper slopes and rockfall predominates along vertical ledges. In the Coquille drainage, where pervasive shearing and regional faulting favor deep weathering, slow earthflow on moderate slopes is the dominant mass movement, especially in areas underlain by thick siltstone interbeds of the Roseburg and Bateman Formations.

Large deep slides penetrate to great depths in bedrock (Sandstone of Tertiary Age) at several localities in the interior uplands including Sitkum, Loon Lake, and the area around Scottsburg on the Umpqua River. At Sitkum a large slide mass covering several square miles blocked the East Fork of the Coquille River in prehistoric times and promoted stream deposition upstream to give the alluvial valley upon which Sitkum is now located. Apparently stream-bank erosion undercut the bedrock slope to such a depth that the strength of the bedrock was no longer sufficient to support the weight of the mountain. A thick siltstone interbed probably was the locus of sliding. A similar origin is interpreted for the Loon Lake slide in the Umpqua drainage and for the massive slides near Scottsburg. Regional dips measured near Scottsburg demonstrate that slide movement is generally concentrated along bedding planes. Depths of the Sitkum and Loon Lake slides probably exceed several hundred feet. The slide masses are characterized by very irregular topography and consist in part of large disoriented blocks of bedrock, many the size of houses.

Sea cliffs: Pronounced undercutting by wave action is the driving mechanism of mass movement along sea cliffs in much the same manner as stream-bank erosion is the driving mechanism of much of the more active mass movement in the uplands. Slide material is removed quickly and major types of sliding are those associated with steep slopes such as rockfall, debris flows, and rapid earthflow (see Coastal Erosion).

Flat landforms: Marine terraces, river terraces, river alluvium, and gentle slopes on bedrock are subject to minimal erosion and consequently may be deeply weathered. Interbeds of peaty material, high water table, and low degrees of consolidation also contribute to the characteristic low shear strengths of these materials. Deep artificial cuts for roads and other developments may produce slides. Examples include the slump-earthflow along Highway 101 southeast of South Slough near the head of Talbot Creek and the earthflow along the Oregon Coast Highway near the mouth of China Creek 3 miles northwest of Coquille. In the latter slide, a 100-foot cut with a benched slope of approximately 80 percent was reduced to a 40 percent slope by slumping. Limits for slope ratios or cut height generally can be calculated beforehand using basic soils information as summarized by Krynine and Judd (1957).

Impact

Debris flows and rapid earthflows remove valuable soil, promote slope erosion, and clog stream channels (see Stream Erosion and Deposition). In addition, they can destroy a variety of structures including highways, pipelines, logging roads, and houses. Large earthflows on steep slopes may move fast enough to kill persons standing in their path. Rockfalls pose dangers to hikers and even motorists in mountainous

areas and to beachcombers at the base of sea cliffs. In addition, hiking trails along the crests of sea cliffs are equally dangerous in that slumping of soils or terrace deposits may occur at any time (see Coastal Erosion).

Slow earthflows with rates of movement as small as a few inches to a few feet per year are particularly bothersome because they are usually difficult to recognize (see Table 24), and their effects are commonly not experienced for a considerable time after development has been completed. Thus, gradual movement may slowly crack foundations, destroy structures, and warp linear features such as pipelines and roads. Variable soil and ground-water conditions produced by the sliding may lead to differential settling, ground-water flooding, and septic-tank failure.

Areas of prehistoric deep failure may exhibit variable foundation strength, variable soil conditions, and poor drainage. Recent sliding along gullies and along steeper slopes within these slide areas is unrelated to the original failures and is local and surficial in comparison.

Recommendations

Type and density of land use in mass-movement areas should be controlled by zoning regulations which key development to the actual potential of the land. Detailed landslide mapping for regions of potential urban growth is recommended. Areas of active sliding should be avoided for most types of land use.

Four basic engineering techniques are available for the treatment of specific slides. They are 1) unloading the head of the slide, 2) loading or controlling the toe of the slide with buttresses or retaining walls, 3) removing water from the slide or controlling infiltration, and 4) shifting the surface of failure to greater depths with any of a variety of structures. The specific causes of the individual slide should be determined and the method of treatment should be selected and adjusted to fit the problem. To prevent the initiation of new slides on slopes of no prior sliding, basic grading practices such as those outlined in the Uniform Building Code should be followed.

Specific methods of dealing with rockfall or rockslide potential in areas of steep slope may also include 1) controlling blasting where vibrations may initiate sliding, 2) screening or scraping of slopes where there is danger to motorists or other persons below, 3) constructing of properly engineered retaining walls at the foot of active talus where rolling rocks may present a hazard, 4) placing warning signs at particularly critical localities along roads, hiking trails, or beach areas, and 5) grouting of jointed cliffs where justified.

Specific methods of dealing with debris flow and earthflow may also include 1) cutting logging roads into bedrock where fill is not suitable, 2) adjusting logging techniques to the requirements of the terrain, 3) controlling blasting where liquefaction might initiate sliding, 4) controlling stream-bank erosion where it undercuts slopes, and 5) controlling drainage. On many of the slower-moving slides, cyclic soil phenomena such as shrink-swell or frost heaving are dominant factors in sliding, and proper drainage would do much to alleviate the situation.

In extremely critical areas, where the cost is justified, a variety of equipment can be employed to monitor pore pressure, rotation, slope noise (Blake and others, 1974), and slope extension. During the slide season, when maintenance and repair work is anticipated, the slide areas should first be examined upslope for signs of continued activity, such as the development of extension cracks. Observations should continue throughout the maintenance program. Maintenance work is not recommended during storm activity. Occasionally, a small slide at the base of a slope is followed by a much larger slope failure. An example is the slide of January 1974 near Canyonville, which claimed nine lives.

All cuts may potentially oversteepen slopes and should be carefully evaluated in terms of jointing, weathering, bedding, heterogeneous lithology, and other factors to assure that the critical slope is not exceeded. On flat landforms, reduction of shear strength by penetrative weathering is of particular concern. All fills should be adequately engineered also and should be constructed of material capable of withstanding projected stresses (see Surficial Geologic Units - Fill and spoils).

Stream Erosion and Deposition

General

Stream erosion includes slope erosion, stream-bank erosion, and scouring by flash floods. Downstream from sites of erosion, deposition is induced by changes in stream parameters (velocity, discharge, width, depth, load, and channel roughness) which reduce the carrying capacity of the stream. Examples include deposition on the inner parts of meanders, behind obstacles, and on flood plains. The distribution, causes, rates, impacts, and methods of treatment of the various types of stream erosion and deposition are summarized in Table 25.

Slope Erosion

Slope erosion is the regional erosion which occurs on slopes rather than in the well-defined channels in the valleys between them. It includes sheet wash (the uniform removal of soil without the development of conspicuous channels), rill erosion (the removal of soil by cutting numerous small but conspicuous rivulets), and gully erosion (the removal of soil by the formation of channels on a slope).

Sandy and fine sandy soils are the most susceptible to slope erosion. Coarser materials are less easily transported by rills. Finer-grained, clay-rich materials are generally more cohesive and cluster to form larger particles (called peds), which resist erosion. Organic matter tends to reduce soil erodibility. High permeabilities also reduce soil erodibility by removing runoff otherwise available for transport of soil material. Where soils are thin the nature of the underlying bedrock is also significant. Detailed treatment of the above factors for many soil types is available through the U. S. Soil Conservation Service.

Other factors influencing slope erosion include annual rainfall intensity, slope length, and slope gradient. Generally the slope erosion per unit area on moderate to steep slopes increases with the square of the slope intensity (expressed in percent)(Young and Mutchler, 1969) and with the square root of the slope length (Young and Mutchler, 1969). Thus erosion per unit area on a slope of two unit lengths is 1.4 times the erosion on a slope of one unit length.

Aspects of land use which influence slope erosion include removal of vegetation, soil disturbance, alteration of slopes, modification of drainage patterns, and conservation practices. A recent study shows that intensive agriculture and construction associated with urbanization may increase sediment yields by 65 to 85 times (Knott, 1973). After the initial cuts, fills, and landscaping associated with intense urbanization are stabilized, sediment yields decrease markedly.

Yorke and Davis (1971) document a 90-fold increase in sediment yield in a small Maryland watershed during conversion from pasture and woodland to townhouses. The physical parameters of the site were similar to parts of coastal Coos and Douglas Counties and included a low slope of 1.3 percent, an annual rainfall of 41 inches per year, and predominately silty loam soils.

Rigorous analysis of all the above factors (U. S. D. A. Soil and Conservation Service, 1972) is required to properly assess slope erosion potential. A casual survey of gullying, for example, is inadequate and may lead to inaccurate results. Thus, on steep bedrock slopes, gullies are poorly developed (Figure 33) and erosion potential is very high. Road fills in such areas should be carefully located and properly engineered. Likewise, on gently sloping terraces, gullies are few and soils are very thick. Artificial changes in the landscape may induce considerable erosion locally in spite of the natural topography which suggests only a minimal potential for erosion. Land use can lead to significant erosion in both the uplands and coastal terraces regardless of the dissimilarities in topography, soil thickness, and regional slope.

In rural residential areas, modifications of the landscape are considerably less than for rapidly urbanizing areas and are spread over longer periods of time. Sediment yields are correspondingly less and are most closely related to road construction. Regions developed for open-space use, such as parks and watershed preserves, undergo the smallest increases in sediment yield.

The impact of logging on sediment yield varies greatly with the area involved, the techniques involved, and the extent of road construction. On an experimental site in the Cascades where conservation was not practiced sediment yields increased by a factor of 67 after clear-cut logging and slash burning (Dyrness, 1969). Similar results are cited for an analogous study in California (Anderson, 1971). In the Needle Branch

Table 25. Stream erosion and deposition

Type	Material and landform	Process	Factors and causes	Rate	Impact	Treatment
Channel scour and deposition by flash floods	Upland streams with little or no flood plains and scoured in bedrock, in particular the hard Tertiary sandstone of the interior uplands	Erosion	High precipitation, impermeable bedrock, steep slopes and stream gradients, moderate to high relief	Sufficient to remove all available soil and boulder cover	Scouring to bedrock, removal of vegetation, road destruction, clogging of culverts, and damage to manmade structures	Proper road engineering, large culverts over channels, log cribbing for fill, maintenance of vegetation
		Deposition	Reduction of carrying capacity of the stream generally through abruptly reduced gradient at base of slope	Extremely rapid	Buries roads and clogs culverts, blocks channels, buries property	Minimize upslope scouring by above methods, avoidance of areas, periodic maintenance
Slope gullying and downslope deposition; also rills and sheetwash	Moderate to steep upland slopes and long gentle slopes of the uplands, terraces, and other coastal areas	Erosion	Favored by silty to sandy soil of low cohesion, steep and/or long slopes, lack of surface protection	Slow to very rapid depending on slope, and soil properties	Removal of soil, reduction of productivity and infiltration capacity, increases runoff, damage landscaping	Maintain vegetative cover, seasonal construction in critical areas, properly handle increased runoff from altered land use
		Deposition	Reduction of gradient at base or lower concave part of eroding slope	Variable depending upon local factors	Siltation of crops and lawns, clogs storm sewers, damage to landscaping	Minimize upslope gullying by above methods, settling ponds in noncritical areas, flush sewer lines, properly engineer land use
Stream-bank erosion and channel deposition	Unconsolidated floodplain material of the coastal lowlands and dune sand where crossed by streams from the interior	Erosion	Hydraulic friction and meandering, discharge greater than stream mean	Slow under natural conditions; rapid near improper stream use	Undercut structures, destroys farmlands, alters channel characteristics	Revetments, riprap, and stream-bank vegetation, bar and snag removal, channel dredging, and control of channel use
		Deposition	Local changes in stream regimen including natural and man-made obstructions, reduction in discharge, increased load upstream, etc.	Variable depending on local conditions and upstream conditions	Hinders navigation, redirects currents toward other banks, promotes marsh development in estuaries	Minimize upstream erosion, dredging of channels, proper engineering of channel and estuarine use

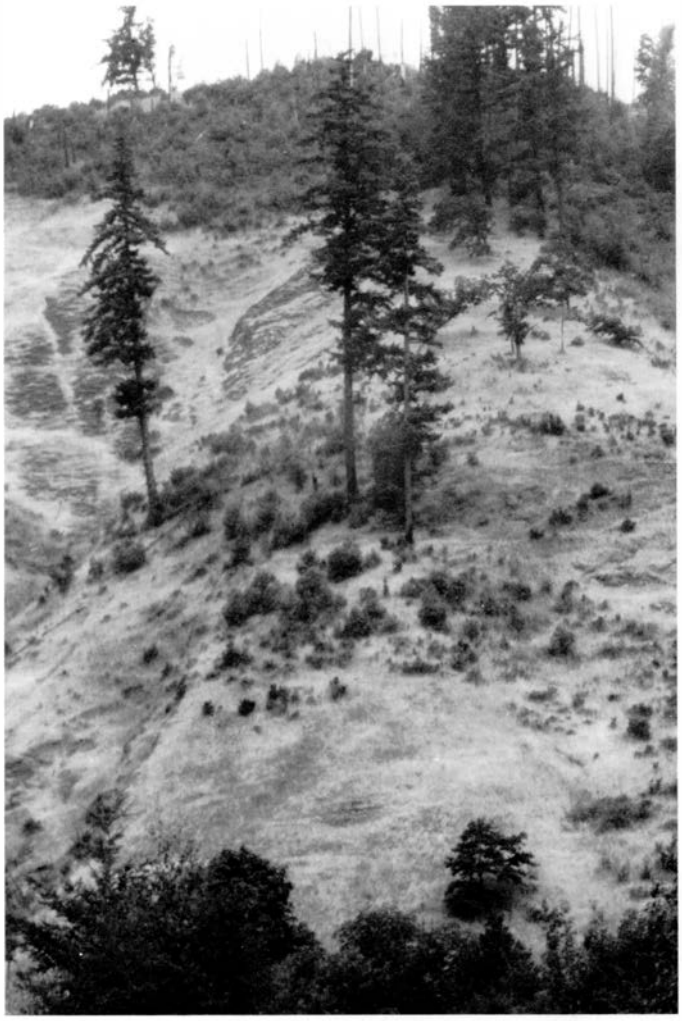


Figure 33. Unchanneled slope erosion exposes bore bedrock on parts of this slope near Powers.

watershed of the Alsea drainage, post-clearcut sediment yields for the year after logging were six times the pre-logging mean (7-year observation period) (Harris, 1971; Harris and Williams, 1971). Present logging regulations on the State and Federal level are designed to reduce erosion to acceptable amounts (see Recommendations).

Flash-flood scour and stream-bank erosion

A flash flood is a torrent of high-velocity water flowing down a narrow stream channel and having a high potential for stream-bed and stream-bonk erosion (see Stream Flooding). Recent flash flooding is easily recognized on the basis of unvegetoted, coarse stream-bed deposits and scattered debris (Figures 34 and 35). Where vegetation has reclaimed the channel, recognition of flash-flood potential is based on indirect features such as steep side slopes, steep gradients, impermeable bedrock, and the absence of a flood plain. In the study area, most flash-flood channels are restricted to upland areas having a local relief of 1,000 feet or greater. In areas of less relief, local discharge is not sufficient to generate floods of catastrophic nature.

Stream-bonk erosion is the loss of land by bank caving along the courses of established streams and rivers. It occurs as the streams assume sinuous or meandering courses, especially during times of flooding. Stream-bonk erosion is most common along flood plains and at the bose of river terraces or large landslides in the uplands. Stream-bonk erosion is characterized by steep river bonks overlooking deeper water ports



Figure 34. Logs and debris flushed down a flash-flood channel north of Allegany on the West Fork of the Millicoma River.



Figure 35. Some locality as Figure 34; note that boulders and sand clog the old stream channel to the level of the top of the log jam. Culverts under roads with settings such as this may be ill advised (see text).

of stream channels on the outer side of meanders. The inner edges of meanders are generally shallow and characterized by gravel bars or other deposits (Figure 36).

Stream-bank erosion is noted on most of the sharper turns of the Coquille (Figure 37), Coos, and Umpqua Rivers. Along the Coquille River, the stream-bank erosion undercuts terraces in bedrock and initiates mass movement in the uplands (see Mass Movement). The rates of erosion are relatively slow, but the impacts are considerable where upland topography limits development and road construction to near-stream corridors.

As the rapidly flowing flood waters from the uplands spill into the low-gradient reaches of the Coquille and Coos Rivers, carrying capacity is diminished, and much of the sediment load is deposited in the channel. In addition, flood waters rising over the banks and spreading into the lowlands deposit more sediment along the banks and on the flood plains. Since the last Ice Age, natural channel siltation and levee development has elevated rivers to the extent that water elevations in the channels of the lower Coquille River are now near or above that of the surrounding flood plain even during times of moderate or low flow.

Superposed on natural siltation is the possibility that changing land use in the past 100 years has increased the rate of sedimentation. Dicken (1961) attributes rapidly accelerated marsh growth north of Bandon near the mouth of the Coquille River to increased siltation due to logging and forest fires. Alternatively, it can be argued that the rapid spread of marsh is a natural result of estuarine sedimentation following large-scale changes in the course of the lower Coquille River in recent times (see Geology of Estuaries).

Impact and recommendations

Slope erosion removes valuable topsoil, and slope deposition clogs drains, clogs sewers, and silts lawns. Where allowed to continue to the point of gully formation, these processes damage landscaping and result in more rapid runoff of surface water. In clear cuts and areas of forest fires, the contribution of sediment to larger streams may have considerable impact downstream.

Slope erosion and deposition can be minimized by proper planning and management. Roads in the uplands should be located on benches, ridge tops, and gentle slopes rather than on steep hill sides or in narrow canyon bottoms. Vegetation removal and soil disturbances should be kept to a minimum during construction. Where new land uses will measurably affect infiltration rates, adequate provisions should be made to handle runoff. It may be desirable or necessary to develop erodibility maps prior to construction. Other techniques to minimize erosion and deposition include the use of buffer strips and settling ponds along drainages and the application of protective ground cover such as mulch, asphalt spray, plastic sheets, sod, or jute matting in critical areas.

Flash-flood damage in the uplands includes road and bridge washouts. These totaled several hundred thousand dollars in the 1964 flood alone. Where flash-flood channels spill into flat terrain, rubble and debris fans may quickly bury roads and clog culverts. In these areas periodic road maintenance and clearing often proves more economical than culvert repair and clearing.

Where residential construction is anticipated, provisions should be made to assure that no development is allowed in the actual flash-flood channel and that bridge abutments and channel crossings do not significantly alter streamflow. Road fills should be discouraged in areas of flash-flood scour and rapid streamflow. Where necessary, road fills should be cribbed or composed of riprap of adequate size to prevent erosion. Channel crossings in sidehills should be constructed with adequate culverts, and periodic maintenance should be performed to assure that the culverts are not blocked with debris.

Stream-bank erosion initiates landslides, undercuts roads, and destroys structures. It undercuts levees during times of flooding, resulting in regional flooding of some lowland areas. On a smaller scale, the placing of improperly designed fills along ephemeral streams in the summer is often followed in the winter by costly damage from erosion associated with storm runoff.

Sedimentation damages fresh water habitats, increases the cost of water treatment, and leads to excessive wear in pumps and sprinklers. It contributes to marsh growth and siltation in estuaries. For example, during the 1964 flood, sedimentation hindered navigation and dockside loading in Coos Bay. Siltation in the middle and lower reaches of stream channels raises river levels and contributes to flooding. Upstream sedimentation produces bars of gravel, sand, or silt, and directs currents against opposite stream banks, leading to further erosion.

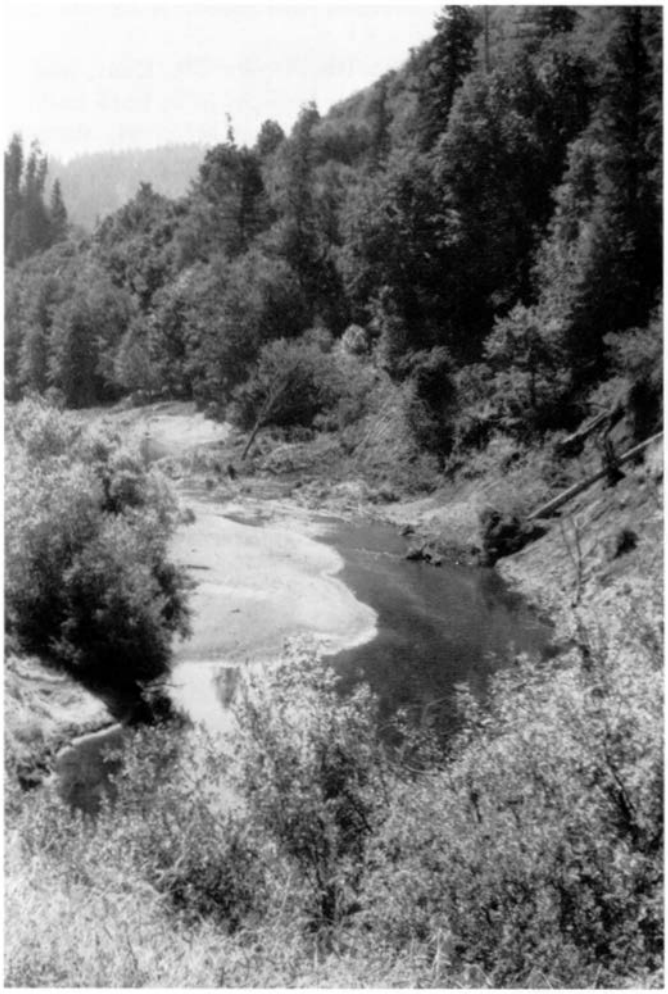


Figure 36. Stream-bonk erosion, landsliding, and bar development on the Middle Fork of the Coquille River west of Bridge.

Figure 37. Stream-bank erosion and sliding necessitate major road repairs north of Powers on the South Fork of the Coquille River.



The impact of stream-bank erosion on structures can be minimized by avoiding building near the outer bends of meanders and by adequately reinforcing critical areas with riprap. Regional straightening of streams is not a viable solution to stream-bank erosion in most instances because it tends to increase gradient and thereby to increase channel erosion and erosion downstream.

Other methods of minimizing stream erosion and sedimentation include proper land management, the removal of logjams and snags in channels, and dredging. In the study area, dredging of the lower reaches of major streams probably would not be beneficial in terms of flooding owing to the influence of ocean flooding (see Ocean Flooding). Likewise dredging in the middle reaches of streams would probably not measurably reduce flooding, except in carefully selected areas, owing to specific channel requirements (see Stream Flooding). Terrain modifications in areas of changing land use such as urbanization should proceed only after the maximum probable runoff has been accommodated in the management plan.

Various governmental agencies are involved in the control of erosion and sedimentation. The U. S. Forest Service conducts hydrologic studies and investigates erosion and sedimentation resulting from forest practices on Federal lands. The Oregon State University Department of Forestry has an ongoing program of investigating erosion, sedimentation, and streamflow related to various forest practices. The State Department of Forestry regulates forest use through the implementation of the Forest Practices Act of 1971.

The U. S. Soil Conservation Service maps soils and advises local officials, and local Soil and Water Conservation Districts conduct surveys and promote conservation by managing Federal and State projects within their boundaries. The U. S. Army Corps of Engineers constructs and finances levees and performs other channel protection and modification functions.

Coastal Erosion and Deposition

General

Patterns of coastal erosion and deposition are controlled by tectonic uplift, worldwide fluctuations in sea level, bedrock hardness, structure, sediment grain size, and distribution and relative significance of sediment sources such as rivers. In Coos County terrace levels provide clues to the rate of tectonic uplift. The elevation (1,600) and probable age (2 million years) of Blue Ridge suggests a rate of uplift of one inch per thousand years. Lower terraces for which radiometric age dates are available (see Surficial Geologic Units - Quaternary marine terrace deposits) are within the range of recent eustatic changes in sea level and cannot be used to approximate rates of uplift. The elevation of the Bandon terrace of Sangamon Age (100,000 years) possibly is also due in large part to a significantly higher stand of sea level.

Changes in sea level induced by the growth and retreat of continental glaciers during the Ice Age were relatively rapid. Submerged terraces off the coast of Coos and Curry Counties at depths of 300, 210, 150, and 60 feet (Oregon State University, 1967) probably formed during the final retreat of the glaciers. Sea level has risen approximately 400 feet during the past 15,000 to 20,000 years (Curray, 1965; Milliman and Emery, 1968). An average rise of sea level of one foot every 70 years is indicated. Because glacially induced rises in sea level are much more rapid than tectonic uplift it is possible to have flooded river mouths along the rising coastline of southwest Oregon.

The lowest submerged terrace (300 feet below present sea level) is located 10 nautical miles off the coast of Curry County, indicating an average rate of coastal retreat of 3 feet per year. Because sea level has remained relatively stable for the past 5,000 years (Curray, 1965), the present rate of regional coastal erosion is considerably less.

Wave refraction concentrates energy on the headlands (Figure 38) and disperses it in the coves. The universal pattern of coastal retreat is one of planation to give a linear coastline of retreat as the headlands are attacked and the coves are aggraded. Various aspects of headland and beach erosion in the study area are summarized on Table 26.

Headland erosion

Regional coastal erosion rates along the headlands vary from less than one inch per year to several inches per year depending upon bedrock, structure, topographic setting, and other factors. Superposed on regional averages are local, more sporadic phenomena resulting from local conditions.



Figure 38. Storm waves at Cape Arago. (Photo courtesy The World)

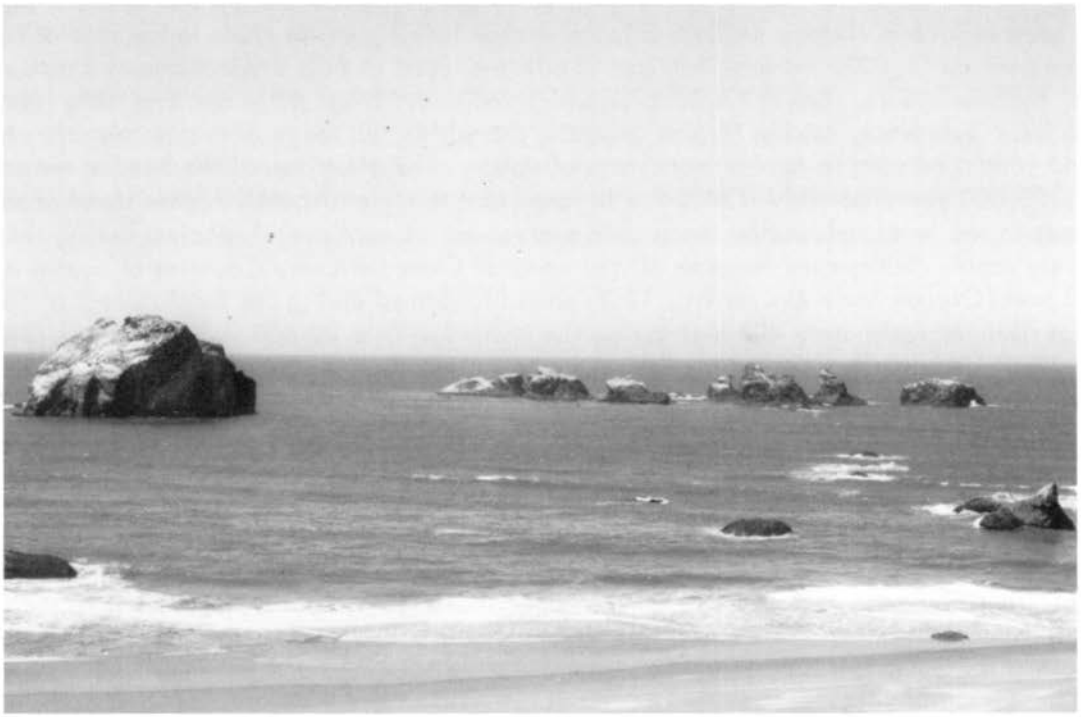


Figure 39. Face Rock at Bandon is one of many sea stacks marking the position of the former shoreline.

Table 26. Summary table of coastal erosion, Coos and Douglas Counties, Oregon

Regional landform	Material	Local landform	Characteristics	Approximate rate of erosion	Major causes and mechanisms[1]
Headlands	Heterogeneous Pre-Tertiary bedrock	Sea stacks and irregular headlands (Bandon)	Numerous steep stacks with irregular coastline, variable surficial terrace deposits and variable beach development	Extremely slow, little to no change in past 100 years in many areas; local slides of surficial material and bedrock rockfall, however	Refracted waves attacking headlands, coastal retreat along joints and bedding planes, rockfall and slumping and sliding of unconsolidated surficial material
	Tertiary sandstone and minor siltstone	Rugged headlands and coves controlled by bedding and jointing (Cape Arago)	Irregular coast following joints and bedding, headlands and coves, vertical cliffs, and no beach	Very slow, few inches per year or less on average; sporadic blockfall or sliding of mantle material may remove 10' or more in one episode, however	Refracted waves attacking headlands, coastal retreat along bedding planes and joints, rockfall and sliding and slumping of unconsolidated surficial material
	Tertiary siltstone and minor sandstone	Straight cliffed shoreline (Twomile Creek)	Set back from rugged sandstone headlands, thin, narrow beach with little or no berm	Estimated few inches per year average; less sporadic than above owing to finer jointing and uniform lithology	Attack by waves passing over beach during ocean flooding (see Ocean Flooding), orderly retreat of near-vertical cliffs
Beaches[1]	Fine- to medium-grained unconsolidated beach and wind-deposited sand	Drift beach and dunes (Coos dune field)	Thick deposits, large dunes inland, smoothly convex toward shore, oriented at angle to wave fronts, adequate sediment source	Negligible, but with local undercutting of dunes at times. Rapid erosion possible through artificial changes in beach equilibrium	Episodic and local removal of beach and dune material during high tides and/or storms; under natural conditions the loss is usually short-lived
		Semi-starved drift beach (New River area)	Thin deposits, dunes few or lacking; smoothly arcuate to straight, oriented at slight angle to waves; limited sediment source	Negligible under present conditions, little change in historic times, moderate to rapid erosion possible through man's actions	Episodic and local removal of beach material by storm waves and/or high tides; subsequent constructive waves generally restore beach
		Swash beach (Sunset Beach)	Strongly convex toward shore, oriented parallel to oncoming waves, between headlands, limited sediment source, no dunes	Slow, less than adjacent headlands (rapid erosion during initial stages of cove development or minor changes in sea level)	Advance of sea along topographic depressions and jointed bedrock. Once established, cove beach little eroded as long as sea level and adjacent headlands persist

[1] See also Table 27



Figure 40. Bedrock headlands at Bandon are undergoing very slow rates of coastal retreat. (Photo courtesy Oregon Highway Division)

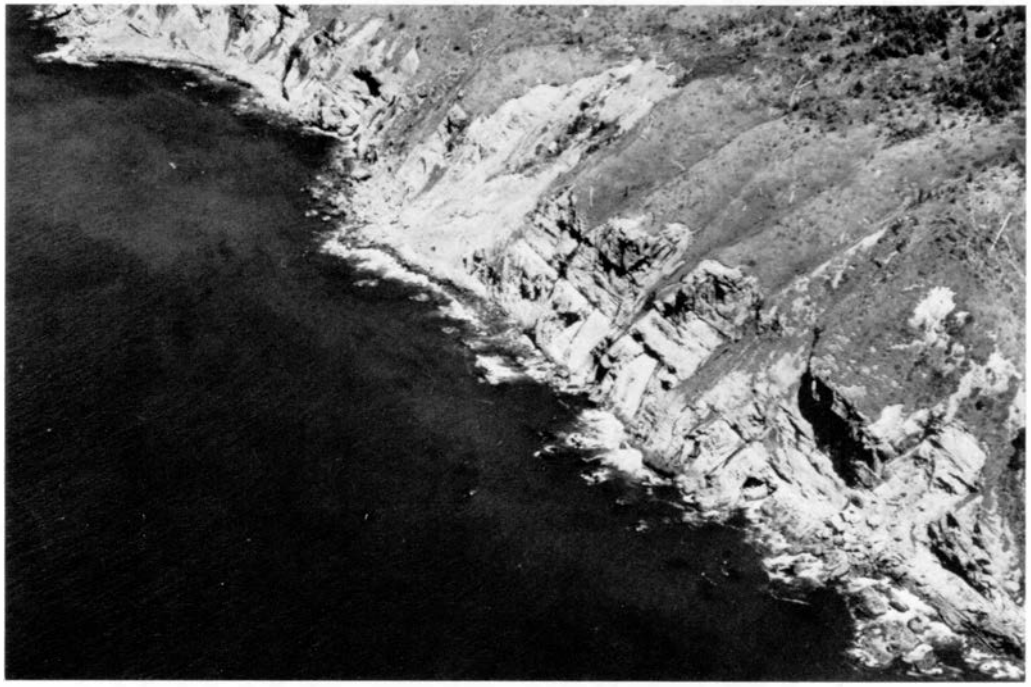


Figure 41. Earthflows and debris flows cause rapid and sporadic coastal retreat immediately south of Cape Arago. (Photo courtesy Ore. Hwy. Division)

Pre-Tertiary bedrock: Near Bandon in southern Coos County irregular headlands and sea stacks (Figure 39) are composed of heterogeneous, hard, Pre-Tertiary bedrock. Erosion is directed along structural weakness such as shear zones, faults, and zones of relatively soft bedrock. Regionally, the rate of erosion is extremely slow, and in some areas there has been little or no change for the past 100 years. At Bandon, for example, old dwellings perched on steep faces of sea cliffs remain undamaged to the present day (Figure 40). In other places, such as at the Bandon Viewpoint, slides and noticeable erosion of weaker bedrock and overlying terrace material are apparent. Generally the rate of erosion in the Pre-Tertiary bedrock is less than one inch per year to almost negligible, but locally it is considerably greater.

Tertiary sandstone: The Cape Arago Headlands of central Coos County are composed of regularly interbedded sandstone and minor siltstone and are characterized by the uniform development of prominent headlands and semi-circular coves. Erosion is concentrated along siltstone interbeds and joints and includes blockfall, terrace slump, and slope erosion.

Comparison of recent shoreline with photographs taken 70 years ago shows little or no regional change at Ocean Shores. On-site examination, however, reveals recent blockfall and hazardous overhangs involving local retreats of 10 feet or more. At Cape Arago a sea cave extending thirty feet into the cliff is the cause of surficial sliding upslope and illustrates the role of structure in localizing coastal retreat. Regional rates of headland erosion probably do not exceed a few inches per year, but random retreats in areas of weakness or undercutting may exceed several tens of feet (Figure 41) at one time, especially during winter storms. Retreat of siltstone cliffs within coves is somewhat more rapid and may approach 1 inch per season through the action of rain alone. A possible maximum rate of siltstone cliff retreat of 1 foot per year is suggested by examination of original surveyors maps of the South Cove area made in 1889.

Examination of man-made structures at Coos Head suggest a retreat of the massive sandstone cliffs of between 2 and 10 feet locally in the past 30 years. Where terrace material overlies impermeable bedrock, saturation during the winter months favors slumping that extends locally landward for a distance as much as twice the thickness of the deposit.

Tertiary siltstone and minor sandstone: South of Cape Arago are developed headlands in Tertiary siltstone that are characterized by straight cliffed shorelines (Figures 42, 43) fronted by narrow low beaches. The headlands are attacked by winter storm waves passing over the beach, and cliff retreat is uniform and regular compared to that of the sandstone headlands. The rate of retreat is difficult to assess but probably approaches several inches per year in places. In similar rocks of similar setting, Mathiot (1973) measured retreats averaging 4.7 inches per year to the north in Lincoln County. The eroding headlands constitute a major source of material for the Bandon Beach to the south.

Recommendations: Coastal erosion rates, sporadic blockfall, and terrace slumping should be considered in the location of all developments along headlands. Erosion rates can be derived from the study of sequential maps and photographs, examination of County and city records, interviews, on-site inspection and monitoring, and landform analysis. Factors to be considered in landform analysis include distribution of vegetation, types of mass movement, degree of beach protection, bedding, and the presence of structural weaknesses such as joints and faults.

Setbacks are most critical in areas of overhang, steep landward dips, and thick terrace deposits overlooking steep cliffs. Individual failures in terrace deposits are somewhat independent of coastal erosion rates and are a function of saturation and thickness of the deposit. Because of headland erosion, parts of coastal hiking trails are now located dangerously near the edge of sea cliffs and should be relocated.

Beaches

A beach is a sloping zone of unconsolidated material situated between the ocean and other landforms, such as terraces, uplands, sea cliffs, and dunes. Deposits tossed by storm waves to the backside of beaches are called berms. Beaches in the study area consist of fine- to medium-grained sand (0.125 to 0.5 mm) (Twenhofel, 1946) and are coarser grained than nearshore sediments within a few miles of land (Kulm and others, 1975). The beaches include a prominent drift beach (Coos-Umpqua Beach), a semi-starved beach (New River area), and several swash beaches (Sunset Beach, North Cove, South Cove). Characteristics of the various types of beaches and the hazards associated with them are summarized on Table 26.



Figure 42. Retreat of a siltstone headland at Merchants Beach is prompted by close jointing and minimal protection by the beach.



Figure 43. Retreat of siltstone headlands at Merchants Beach is hastened by local slumping.

The formation of a beach requires a source of sediment and is controlled primarily by longshore drift, topographic setting, and climatic activity as summarized on Table 27. Variations in these determine the form of a given beach, and changes in any one of these can affect the stability of a given beach through time. An understanding of these parameters is fundamental in assessing probable beach adjustments (instability) that may arise through the activities of man (see Recommendations).

Source: The major source of sediment in the study area is the Umpqua River, which crosses the center of the Coos-Umpqua beach. Numerous more local drainages are now blocked with beach sand and dunes (Siltcoos Lake and Tenmile Lake). Recent studies (Kulm and others, 1975) suggest that very fine-grained sand and finer material escape the sediment traps of the estuaries (see Geology of Estuaries) and enter the surf zone, where they are available for beach or dune development. Coarser-grained material may also escape the estuary during severe floods or strong ebb tides. Volumes of sediment carried by the Umpqua, Coquille, and Coos Rivers annually are 564,000 tons, 100,000 tons, and 72,000 tons respectively. Some of the coarser material of the beaches probably was also derived from the shelf and was transported inland by surf action along a retreating coastline during the Holocene rise in sea level (Kulm and others, 1975). The headlands south of Coos Bay probably supply less than 60,000 tons of sediment per year (assuming 3 inches annual retreat, 100 foot cliffs, 6 miles of coastline, and 2 tons per cubic yard). The bulk of this material is too fine grained for beach development. Recent studies show that a significant portion of the coarse material of the surf zone is actually reworked shelf material (Kulm and others, 1975).

Beaches in the coves south of Coos Bay derive sediment from local headland erosion, slope wash, and local drainages, such as Big Creek at Sunset Beach (Figure 44). Sediment supplies are limited and beaches are narrow and thin (Figure 45) compared to the well-fed drift beaches to the north (Figure 46). Longshore drift is a very minor factor in sediment supply.

Major sources of sediment for Sacchi Beach, Agate Beach, Merchants Beach, and Bandon Spit are the sandstone headlands of Coaledo Formation at Cape Arago and the sands of Whisky Run terrace. Using heavy mineral analysis, Rottman (1972) demonstrated that the terrace sands were derived in large part from Coaledo bedrock. The present-day beach sands, therefore, are probably also being derived from that source. The fine grain size of the dune and beach sands north of Bandon also is consistent with a Coaledo source. Sacchi Beach, Agate Beach, and Merchants Beach are removed from large sources of sediment and therefore are narrow and have poorly developed berms.

Sources of sediment south of Bandon include local drainages such as Crooked, China, Twomile, and Fourmile Creeks. Possibly some sediment from the Coquille River is carried southward around the Bandon headlands by longshore drift. The total supply of sediment is modest, and the beaches are narrow and backed by lagoons (Figure 47). Uplift keeps pace with deposition, and a broad marine terrace with a sand mantle has developed. Owing to the limited supply of sand, dunes are poorly developed and the beaches are termed semi-starved.

Longshore drift: Longshore drift is the transport of sand along the coastline by the action of waves and currents. As waves impinge obliquely on the coastline, sand is transported down the Coast in the breaker zone. At greater depths, waves touch bottom at a depth equal to half the distance between crests, and they transport sediment if the energy supply (determined in part by wave height) is sufficient. Currents also can transport sediment in deeper water but little data about them are available for the Oregon Coast. Generally, significant longshore drift appears to be restricted to depths less than 60 feet (U. S. Army Corps of Engineers, 1973), although evidence for some transport at greater depths is available (Kulm and others, 1975). Longshore drift along the Oregon Coast is northerly in the winter and southerly in the summer. On the middle and outer shelf, evidence suggests a minor net transport to the north (Kulm and others, 1975).

A study off the coast of Newport revealed mean velocities of 13 to 27 centimeters per second at depths of 20 to 75 meters at various times of the year. Kulm and others (1975) record velocities of 30 centimeters per second at depths of 36 meters in calm weather and 75 centimeters per second at a depth of 50 meters in severe storms. Very fine sand is transported at depths of 90 to 200 meters off the Oregon Coast, depending on local conditions. Relationships between current velocities, particle size, and transport processes are summarized in Figure 48.

Oscillatory ripple marks indicating bottom agitation but minimal transport have been photographed at depths of 612 feet, but generally are restricted to depths of less than 300 feet (Komar and others, 1973). Sand is the dominant bottom material at depths less than 200 to 300 feet (Oregon State University, 1967). At greater depths muddy sand and mud predominate.



Figure 44. Sunset Beach is a typical cove or swash beach characterized by wave approach parallel to the shore.



Figure 45. Sand for Sunset Beach is supplied by local drainage and headland erosion; note Big Creek in the lower left. (Photo courtesy Oregon Highway Division)

Table 27. Factors of beach equilibrium in coastal Coos and Douglas Counties, Oregon[1]

	Location	Source of sediment	Longshore drift	Geomorphic setting	Acts of man
Drift beach	Coos Bay to Florence and the Bandon Spit area	Major streams from the interior including Umpqua River, Coos River, and Coquille River. Contributions from coastal erosion are secondary and small with the exception of Bandon Spit area.	Moderate and uniform construction waves and currents impinge from the northwest. Choppy, severe, sporadic destructional waves and currents impinge from the southwest in winter.	Seasonal and long-term migration of rhythmic topography (see text) including beach cusps and offshore bars may affect local beach and dune stability. Lateral migration of streams and reduction of headlands affect beach stability	Jetty construction blocks longshore drift, causing sediment starvation downdrift and sediment accumulation updrift; specific situations often complex. Excavation interrupts sand supply to downdrift beaches if conducted in the zone of effective longshore drift (active beach and berm and offshore). May promote coastal erosion. Dredging interrupts longshore drift, causing sediment starvation downdrift.
Semi-starved drift beach	New River area in southern Coos County	Drainages of more local extent including Davis, Fourmile, and Twomile Creeks. Coastal erosion minimal, but of possible local significance.	Same as above but a more limited supply of sand. Local variations owing to drift impedence by headlands and channels.		
Swash beach	South Cove, North Cove, Sunset Beach, Bastendorff Beach, and others	Small local streams flowing into coves such as Big Creek at Sunset Beach. Headland erosion variable, but generally small.	Generally not of significance as a source of beach sediment. Waves impinge on beach parallel to the shore	Generally stable as long as headlands persist. Sensitive to small changes in sea level.	Activities affecting longshore drift generally exert minimal impact. Indirect impacts may result from inland land use of regional extent. Uses affecting sediment supply are most critical.

[1] Elements of climate having short- and long-term influences on beach stability include large storms, series of large storms, cyclic climatic activity induced by sunspot activity and other astronomic phenomena, and long-range climatic variations which alter sea level (see Coastal Erosion and Deposition - General).



Figure 46. The Coos-Umpqua Beach is △ a drift beach with abundant sand supplied by regional drainages (see text).

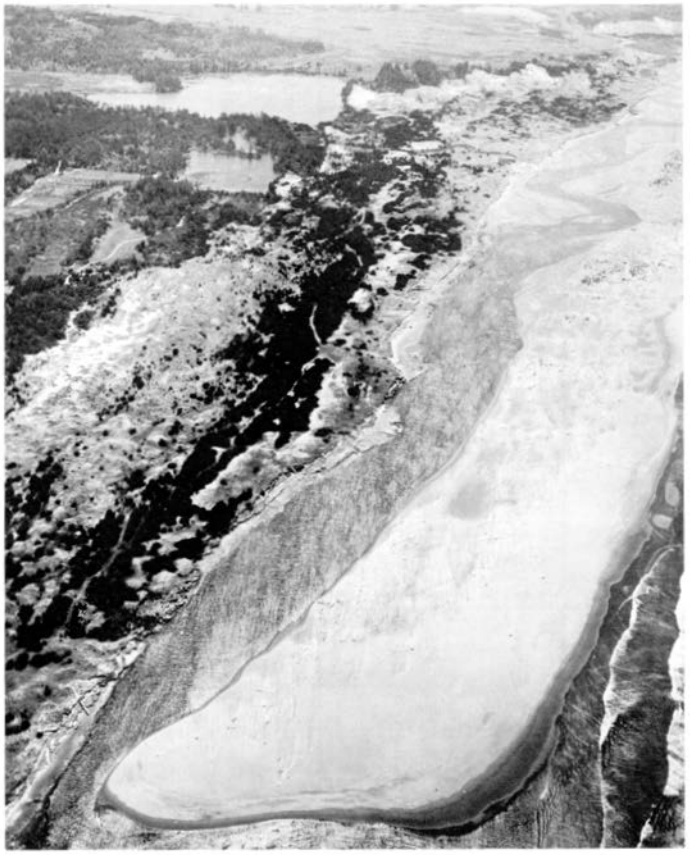


Figure 47. Beaches at New River are ◁ semi-starved drift beaches with modest supplies of sand delivered from local drainages. (Photo courtesy Oregon Highway Div.)

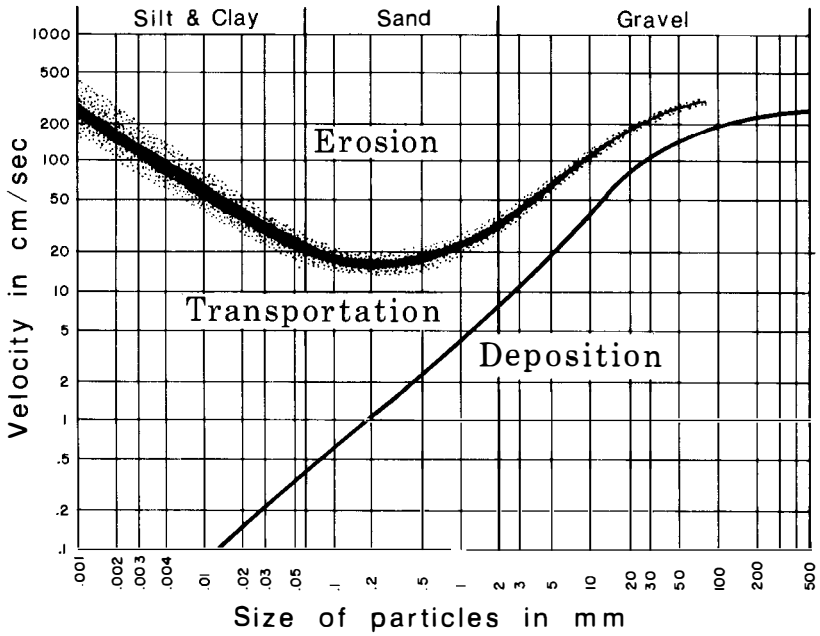


Figure 48. Erosion and deposition plotted as a function of particle size and current velocity. (after Dunbar and Rodgers, 1957)

Topography: Topographic features having a bearing on beach stability include the presence or absence of headlands, the migration of rhythmic topography (see below), and other factors. Where two headlands are present, swash beaches may develop between them owing to wave refraction. Where one headland is present, numerous types of beaches are possible depending upon the balance of other factors. Changes in the extent of headlands or jetties near beaches generally impacts beach stability.

Rhythmic topography along a beach refers to the systematic development of landforms such as bars, rip channels, points, and beach cusps. Under favorable circumstances, these are developed in a regular and repeated pattern along the Coast. As coastal hydraulics change with the seasons or with longer-term climatic or tidal variations, these features migrate in concert up and down the beach, subjecting specific localities to alternating conditions of stability and instability (Sonu, 1973).

Other topographic features of significance to beach stability include modifications of terrain which may influence the supply of sediment. These include dredging, excavations in the littoral zone, lateral migration of streams crossing beaches, and variations in coastal erosion rates of headlands.

Weather: Summer swells are characterized by long wave length and uniform size. They transport sand in the beach zone and are responsible for beach construction. Winter waves, in contrast, are short and choppy and have a destructive influence on coastal beaches and at shallow depths. Summer swells generally are from the northwest and winter waves generally are from the southwest, especially during gales. Bascom (1951) determined that for Pacific Coast beaches a wave height to length ratio of 0.03 was the cutoff point between constructive waves at lower values and destructive waves at higher values.

Long-term fluctuations in the weather may influence the balance between constructive waves and destructive waves and also may influence long-term migration patterns of rhythmic topography. Although the specific pattern is unclear, recent research clearly demonstrates that short-term and long-term cyclic climatic fluctuations are a reality and that the earth is entering a period of significant climatic change. In terms of present planning efforts and development, however, the impact will probably be negligible in the study area. Foredunes and spits are the most susceptible to climatically induced changes in beach stability.

Historic changes: The Coos-Umpqua dune field and beach constitute one of the most stable stretches of the Oregon Coast. There has been little natural change in this area in the past 100 years, with the exception of wind erosion and deposition inland (see Wind Erosion and Deposition) and lateral migration of the lower reaches of Tenmile Creek.

Artificial changes have occurred at all sites of jetty construction (for dates of construction see Geology of Estuaries). At the mouth of the Umpqua River, the north spit has grown seaward along the north jetty, and the south shore has undergone complex erosion and deposition along the south and middle jetties. Generally, deposition has occurred between the south and middle jetty, and erosion has occurred north of the south jetty where it is not fronted by the middle jetty (see Reedsport quadrangle).

The north spit at Coos Bay has widened at its southern end to meet the north jetty, and a wide beach (Bastendorff Beach) has developed south of the south jetty. Prior to construction of the jetties, the outlet from the estuary was characterized by a migrating breaker zone about 200 feet wide and 10 feet deep (Fleming, 1955).

Swash beaches in the Cape Arago area are relatively stable, with the exception of seasonal losses of sand through winter storm activity. Couched between prominent headlands, they will persist as long as the headlands remain. Sunset Beach, located at the mouth of a fault-controlled drainage, is a typical swash beach, being minimally dependent on longshore drift for its modest supply of sand. Tree roots anchored to bedrock in the cove suggest a former more seaward shoreline in the not-too-distant past. At the time the trees were growing, the site where they are now located probably resembled the present day park site situated a short distance inland. When the trees grew they probably were rooted in fresh water perched above salt water at depth. Thus, the presence of the roots below present-day sea level does not necessarily indicate recent fluctuations of sea level.

Bandon Beach, situated north of the Coquille River, consists of fine sand derived from siltstone headlands to the north. Little natural change is noted along the beach and coastal retreat is probably closely tied to the rate of retreat of Fivemile Point. To the south, the spit is anchored by the north jetty. Beach growth has occurred behind both north and south jetties.

The Blacklock-Bandon Beach, situated south of Bandon, represents a growing beach ridge in an area of modest sand supply. Over most of its extent, the beach is separated from the inland sand and terraces by a narrow lagoonal river (New River) which empties near its northern end (see Figure 47). Major changes include the migration of the mouth of the river from section 15 in 1879 to section 3, $1\frac{1}{2}$ miles to the north, at a later time. New Lake formed sometime in the late 1800's when beach sand and logs dammed the river mouth. Marsh growth and alluviation has reduced the lake to its present size, which is considerably less than its original extent.

Recommendations

The carrying capacity of waves is significantly altered by modifications of bathymetry, coastal topography, longshore drift, or climate. Recognition of problem areas rests fundamentally on one's viewing of the coastline as a system of sediment transport in equilibrium and in viewing changes in any of the above factors in terms of their potential effect on the carrying capacity of the waves or the supply of sediment available to the beaches.

Geologic investigations should precede all development in areas subject to coastal erosion and deposition. Goals, the magnitude and probability of hazard, and economics largely determine the nature of the investigation and the method of treatment. In beach areas, provisions should be made to assure that modified patterns of erosion and deposition lie within acceptable limits. Development on the foredune is potentially very hazardous.

In headland areas without beaches, most engineering solutions are uneconomical. The most effective methods of dealing with coastal erosion consist of adequate setback of new structures or relocation of previously constructed structures. Coastal erosion rates in these areas can be estimated on the basis of historic records, on-site monitoring, or landform analysis. Treatment of coastal erosion in beach areas involves a wide variety of techniques as summarized on Table 28. Final selection is based on the specific purpose of the project and the cost and impacts of the choices available.

Adverse impacts of coastal erosion and deposition commonly can be minimized through proper engineering. For example, starvation of beaches adjacent to jetties can be reduced through beach nourishment,

Table 28. Engineering treatment of coastal erosion

Treatment	Purpose	Cost	Impact and other limitations
Beach nourishment	Mitigate erosion losses on beaches by storms or other short-term activity	Relatively low	Impact on borrow area; requires on-going program if applied to areas with long-term threats of erosion
Dune stabilization	Reduce flooding or catastrophic shore regression; also, to minimize wind erosion	Relatively low	May starve inland dune areas leading to deflation and reduction of esthetic appeal
Breakwater	Protect shore areas from wave erosion	Moderate	Not suitable in deep water; promotes local deposition behind the structure and may lead to downdrift beach starvation
Jetty	Stabilize inlets and channels and mitigate large-scale erosion; promote large-scale deposition	High	Induces large-scale erosion or deposition of adjacent beach areas; benefits must outweigh costs
Sea walls, revetments, and bulkheads	Protect high-value structures on cliffs or dunes	Variable with design	Unattractive, limited beach access; must be designed to prevent undercutting or flanking; access to suitable construction material often a limiting factor
Groins	Maintain or increase sand supply on beach at a particular site	Moderate to high	Promotes downdrift erosion if too long; not suited to beach areas with steep gradients
Relocate	Save structure from probable undercutting	Variable	Space availability; moving skill required

sediment bypassing, or modified design. The impacts of groins can be reduced by placing limits on their length, and the impact of jetties can in some instances be reduced by developing designs which maximize the natural bypassing of sediments (Silvester, 1974-b). Similarly, dredging costs can be reduced through the integration of wave technology into project designs.

Wind Erosion and Deposition

General

The transport of sand by wind in the Oregon coastal zone is favored by the abundant supply of sand delivered to the beaches by the surf (see Coastal Erosion and Deposition), the absence of protective vegetation over large areas, and the persistence of moderate to strong winds during much of the year (see Geography). Major dune areas include the Oregon Dunes National Monument inland from the Coos-Umpqua beach, the Bandon spit area, and the New River area. Dunes in the latter two regions are poorly developed owing to the more limited supply of sand.

Dunes

Generally where sand is in large supply in coastal areas a well-developed beach and seasonally fluctuating berm are developed. Inland, deflation plains supply sand to growing dunes farther downwind. In the study area, this general pattern is modified by two additional features. First, the particular balance of opposed seasonal winds, vegetation, and sand supply has led to a unique development of linear dunes (oblique dunes) oriented east-west oblique to both the northwest summer winds and the southwest winter gales and located inland from the more typical transverse dune system (Figure 49). Second, the introduction of European dune grass along the berm has resulted in the development of a stable and growing foredune along the back of the beach which traps most of the sand that formerly was blown inland to the deflation plain. The location, shape, and relief of the various dune landforms are summarized on Table 29.

The dune system is a balanced and interrelated mechanism of sand transport and deposition. In recent years, the capture of blowing sand by the foredune has resulted in a sand deficit in the deflation plain, which consequently has grown at the expense of the transverse dune system. Farther inland the oblique dunes may also be decaying, as sand delivered to the precipitation ridge from the windward side is not replaced by sufficient sand from the diminishing transverse dunes. The long-term fate of the dunes is unclear, and it is suggested that further large-scale stabilization not be conducted without an assessment of long-term impact on the esthetics of dune systems.

Historic changes

Dicken (1961) documents numerous fires along the Oregon Coast in the mid 1800's. Undoubtedly many of these fires released large amounts of sand to redistribution by the wind. The coniferous cover of the eolian sand on the terraces north of Cut Creek (north of Bandon) were logged off prior to placer mining days. The region is now covered by a thick growth of almost impenetrable gorse, a plant tolerant of acid sandy soil and characterized by thorns, a massive root system, and vigorous growth. The lower Bandon spit was an expanse of open sand in 1887 but now is covered over large areas by scattered grass. The Bandon fire of 1936 destroyed a small stand of conifers on the lower extremity of the spit.

During the past 50 years the trend in the Coos-Umpqua dune field has been towards stabilization as European beach grass has spread to give an ever-growing foredune between the beach and the deflation plain (see Dunes). On a more local scale, the construction of jetties has promoted accretion and dune growth at the mouth of the Coos River and mixed erosion and deposition at the mouth of the Umpqua River (see Coastal Erosion and Deposition). In the New Lake area south of Bandon, the lateral shifting of stream outlets has produced extensive lakes, marshes, and alluvial environments inland (see Coastal Erosion and Deposition).

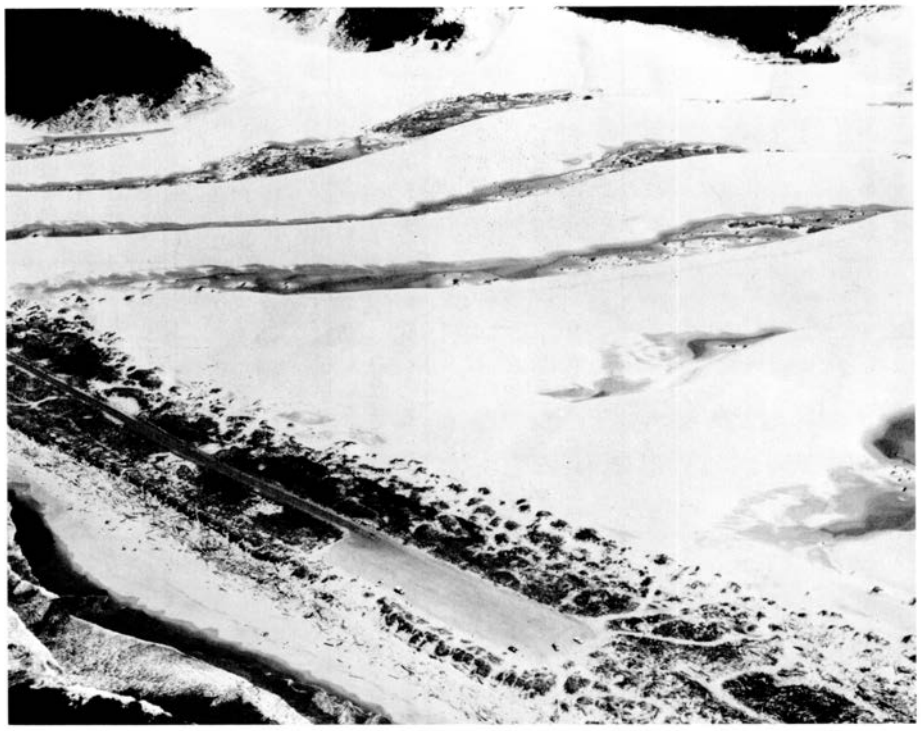


Figure 49. Oblique dunes immediately south of the mouth of the Umpqua River. (Photo courtesy Oregon Highway Division)



Figure 50. Steep dunes south of Bandon exposed to strong winds are stabilized by sturdy vegetative cover.

Table 29. Summary table of dune landforms, Coos and Douglas Counties, Oregon

Description	Foredune	Deflation plain	Transverse dune	Oblique dune	Precipitation ridge	Parabolic dune
Location (for plan view see topographic maps)	Along back of beach	Landward of foredune in wide dune areas	Between deflation plain and oblique dunes or uplands	Landward from extensive transverse systems	Eastern extremity of oblique dune systems or parabolic dunes	Blowouts from precipitation ridges of oblique systems
						
Shape and orientation	Elongate parallel to the shore; no steep slip face[1]	Large flat depressions to the water table; devoid of dunes with exception of isolated hummocks	Sinuous dunes oriented perpendicular to the summer winds	Elongate dunes oblique to winter and summer winds; usually asymmetric to the north	Parallels the wind obstruction; steep slip face[1] landward	Sharply convex landward; steep slip face[1]
Relief	25 feet or less	very low and flat	5-15 feet high	200 feet or more (increasing in height landward)	Controlled by relief of obstructions	Same as oblique
Rate of movement	Stationary, but grow through time	Stationary, but enlarging in recent years owing to deficit in sand budget	Obliterated or greatly subdued by winter storms	Stationary with seasonal fluctuations of form	Varies with size and shape of dune, extent of source area and vegetative cover; 2'/year north of Bandon; 2-6'/year west of Eel Lake (1945-1951); 6-17½'/year near Florence (Lane County)	
Comments	Initiated and maintained by European beach grass introduced in 1930's	Deficit sand budget and recent growth attributed to sand capture by foredune	Favored by abundant sand and strong winds; extent diminishing as deflation plain expands	Sand supplied by transverse dunes; origin obscure	Sand deposition promoted by obstructions, usually forest	Blowouts in precipitation ridge usually occur at breaks in the vegetation

[1]The leeward side of a dune where sand is deposited by the wind

Impact

Sand deposition is promoted where natural or man-made obstructions divert or slow the wind, causing it to lose its carrying capacity. The result can be the burial or partial burial of roads, lawns, agricultural land, or parking lots. In urban areas where excavations expose old dune deposits, sand blown into the streets can clog storm sewers during heavy rains. In coastal areas where houses or condominiums are constructed in regions of wind-blown sand, local adjustments in wind patterns can result in partial burial of structures.

Locations in the path of advancing precipitation ridges and parabolic dunes are particularly vulnerable. Rates of advance vary with the size, shape, and location of the dune and also with the extent and degree of cover of the source of sand. Between 1945 and 1951, dunes west of Eel Lake advanced at rates of 2 to 6 feet per year (Cooper, 1958). A small inland dune on the Bandon spit advanced 30 feet between 1945 and 1960 (Dicken, 1961). Near Florence, in Lane County, rates of advance of 6 to 17½ feet per year have been observed at some of the larger dunes with very large source areas. Because dunes migrate, deposits of sand commonly obscure deposits of peat and compressible soil in the subsurface (see Engineering Geology).

Over long periods of time migrating dunes can block streams and rivers flowing to the sea if discharge is insufficient to flush the channel. Where large amounts of sand are involved, large lakes may result, as seen at the Tenmile Lakes area. Where sand supply is more limited, only small local streams are impounded, as in the New Lake area.

Blowing sand abrades surfaces of cars, houses, and other man-made objects. The irritation factor of blowing sand should be considered in the location of camping facilities and other similar land uses. Where vegetation is removed by fire, logging, or overgrazing, wind erosion may remove soil horizons necessary for revegetation.

Recommendations

Wind erosion is best controlled by the maintenance, establishment, or protection of vegetation in critical areas (Figure 50). The establishment of a permanent vegetative cover ideally involves a succession of plants ranging from sand-binding grasses through shrubs and thickets to stands of pine, spruce, western hemlock or Douglas fir. Expertise in the field is available through the U. S. Soil Conservation Service and is summarized by Brown and Hafenrichter (1962).

Protection of vegetation in critical areas includes limited access by vehicles and pedestrian traffic and effective fire protection and fire fighting. Expanses of gorse, such as that north of Cut Creek, are particularly susceptible to fire.

Adverse impacts of sand deposition can be minimized by restricting developments and terrain modifications in regions of blowing sand and by promoting deposition in noncritical areas with fencing, plantings, or other means. Engineering investigations in dune areas should include a consideration of blowing sand, and prospective developers and buyers should be informed of the hazard. The foredune is especially sensitive to terrain modifications.

Earthquakes

General

The shaking of the Earth's surface which accompanies the release of energy at depth is called an earthquake. Associated with the release are displacements along planar surfaces called faults. The specific location of the displacement within the Earth is called the focus and the geographic location above the focus on the Earth's surface is called the epicenter. The crustal structure and tectonic behavior of the northwestern United States is very complex (see Structural and Tectonic Setting) and the historic record is short. Knowledge of future tectonic activity and earthquake potential is incomplete.

Classification of earthquakes

Intensity and magnitude are measures of the energy released by an earthquake. On the Modified Mercalli Intensity Scale, observations of the effects of the quake on the Earth's surface serve as indicators of its relative severity. Determinations made in this way are subject to inaccuracies owing to the distance from the epicenter, the nature of the subsurface where the observations are being made, and the subjectivity of the viewer. The Mercalli scale tends to be imprecise for these reasons. It is widely used, however, owing to its universal applicability and no need for equipment. Also, the gathering of numerous observations allows the identification and elimination of inconsistent and inaccurate data.

The Richter scale is based on recordings from seismometers rooted in bedrock. It gives a more direct measure of energy release during an earthquake and is less subject to errors through local variations of the subsurface. Instead of indicating "Intensity" with Roman numerals as used in the Mercalli scale, the Richter scale indicates "magnitude" with decimal numbers (Table 30) on a logarithmic scale. Each digit represents a 10-fold increase in the amplitude of the seismic waves and a 31-fold increase in the amount of energy released. Thus, an earthquake of magnitude 5.0 is 31 times greater than an earthquake of magnitude 4.0 and produces seismic waves with an amplitude 10 times greater than those of the magnitude 4.0 quake. The scale ranges from less than 1 for small quakes to slightly less than 9 for the largest possible quake.

To convert observations on the Mercalli scale to magnitudes on the Richter scale, several equations are available, including:

$$M_B = 2/3\ I + 1 \qquad \text{(Gutenberg and Richter, 1965)}$$

$$m = 0.43\ I + 2.9 \qquad \text{(Stacey, 1969)}$$

M values are the Richter magnitudes and I values are the Mercalli Intensities. The relationship defined by Stacey is based upon shallow quakes and is particularly applicable to quakes originating off the southwest Oregon Coast.

Earthquake severity

Earthquake hazard is determined by the magnitude of probable earthquakes, distance to the epicenter, ground response, and the type of construction. An analysis of these factors for the study area is given below.

Magnitude: No epicenters have been recorded in western Douglas or Coos Counties for over 100 years. A small quake occurred off the coast of Douglas County in 1938 (see Table 31). There have been no epicenters in the Klamath Mountains for over 20 years (Couch and Lowell, 1971). The historic seismicity of the study area is traced primarily to activity in the Gorda Basin (see Structural and Tectonic Setting) as summarized by Couch and others (1974). Small offsets on coastal terraces are probably not the result of deep-seated tectonic activity (see Structural and Tectonic Setting) but are in need of more thorough study for proper evaluation.

The earthquake potential for the study area varies from minor in the northern and central areas to moderate and possibly major in the southern and Coos Bay areas. Earthquakes of Mercalli Intensities V to VII respectively are indicated. Couch and Deacan (1972) determined that the recurrence interval of an earthquake of magnitude 8.0 in the Gorda Basin was approximately 130 years. Quakes as great as Richter 7.3 have been recorded off the coast of northern California along the Mendocino Escarpment and as great as 6.6 have been recorded on land. Vibrations generated by quakes in this area have affected the southern and central Oregon coast. In addition, large quakes in the Puget Sound area have been felt with moderate Intensities in the study area.

Distance: As seismic waves are radiated through the Earth from the point of origin (focus) they are attenuated (diminished with distance) as a function of dispersion, friction, depth, bedrock structure, and propagational properties of the seismic waves in question. For areas of moderate earthquake hazard from external sources, such as the study area, attenuation is a critical factor in determining the possible severity of future earthquakes.

Table 30. Scale of earthquake Intensities*

Mercalli Intensity	Description of effects	Equivalent Richter magnitude
I	Instrumental: detected only by seismographs	
II	Feeble: noticed only by sensitive people	3.5 to 4.2
III	Slight: like the vibrations from a passing truck; felt by people at rest, especially on upper floors	
IV	Moderate: felt by people walking; swaying of loose objects, including standing vehicles	4.3 to 4.8
V	Rather Strong: felt generally, most sleepers awakened and bells ring	
VI	Strong: trees sway and all suspended objects swing; damage by overturning and falling of loose objects	4.9 to 5.4
VII	Very Strong: general alarm; walls crack; plaster falls	5.5 to 6.1
VIII	Destructive: car drivers seriously disturbed, masonry fissured, chimneys fall; poorly constructed buildings damaged	6.2 to 6.9
IX	Ruinous: some houses collapse where ground begins to crack, and pipes break open	
X	Disastrous: ground cracks badly; many buildings destroyed; railroad lines bent; landslides on steep slopes	7.0 to 7.3
XI	Very Disastrous: few buildings remain standing; bridges destroyed; all services disrupted; large landslides and floods	7.4 to 8.1
XII	Catastrophic: total destruction; objects thrown into the air; ground rises and falls in waves	Max. recorded 8.9

* After Holmes (1965)

A review of records for past earthquakes (Table 31) shows that a quake of Mercalli X along the Mendocino Escarpment attenuated to a quake of Mercalli V in the Coos Bay area. A similar quake farther out to sea was felt over a much smaller area on land. Assuming similar attenuation properties for the largest possible quake along the Mendocino Escarpment, a maximum possible future quake of Mercalli VII can be tentatively assigned to the Coos Bay area (see Impact).

It is emphasized, however, that the data are extremely limited and that no two quakes attenuate in exactly the same way. Ideally, mathematical modeling would supply a much more reliable estimate of the earthquake potential of the study area. Although no such studies have been conducted for the area, attenuation curves have been prepared as part of a much larger study by Couch and Deacon (1972). Their predicted intensities, which are considerably higher than those given above, are believed by the authors of this report to be inconsistent with the historic record and to be based on insufficient local data.

Table 31. Summary of earthquake data for Coos and Douglas Counties, Oregon

Date	Magnitude and Intensity	Location	Local impact	Comments
1873 (Nov. 22)	Uncertain	Uncertain	Not available	VIII in Port Orford (Curry County) where chimneys were toppled. Incomplete records on location of epicenter.
1922 (Jan. 31)	7.6,7.3 I = X (calculated)	150 - 200 miles off coast of Cape Mendocino on Mendocino Escarpment	V in Coos Bay where sleepers were awakened, furniture creaked, buildings swayed, and rumbling was heard. No damage.	In view of more recent construction in less favorable areas, observed intensity of such a quake today would probably be higher locally.
1923 (Jan. 22)	7.2 I = X (calculated)	40 miles off coast of Cape Mendocino on Mendocino Escarpment	Not observed in Coos Bay-North Bend area. Intensity VI at Eureka is the highest onshore intensity on record.	Microfilmed copies of Coos Bay Times have no mention of local shocks, although notation is made of slight tremors near Sacramento.
1938 (May 28)	I=V or less	Short distance off the coast of Douglas County	IV in North Bend, trees and brush sway at Gardiner, felt throughout much of study area; not observed in other parts.	Coverage in local newspapers was minimal, suggesting that Intensity IV observations were localized to regions, persons, or structures of high sensitivity.
1954 (Dec. 21)	6.6 I - VII	Between Eureka and Arcata onshore (Calif.)	IV in parts of Coos Bay area	VI at Brookings. Attenuation is less than that for quakes at sea owing possibly to a deeper focus or to structural setting.
Future	8.0 determined graphically I = XI, XII (calculated)	Mendocino Escarpment nearshore is assumed	VII assuming attentuation similar to that of the 1922 quake. Local impact will vary with ground conditions (Table 32).	Rough estimates only. Available attentuation curves (Couch and Deacon, 1972) postulate greater impacts, but may not be applicable (see text). Historic onshore quakes have less attentuation, but are of lower magnitude.

Acceleration and ground response: The impact of an earthquake is directly related to ground acceleration and to the specific response of the ground to that acceleration. Housner (1965) has shown that for earthquakes of magnitude 8.0, accelerations greater than 0.10 g (1 g equals the acceleration of gravity) are unlikely at distances greater than 80 miles. Thus, for all quakes originating in the vicinity of Cape Mendocino and the Mendocino Escarpment, it is tentatively concluded that none will produce ground accelerations greater than 0.10 g in the study area.

Ground response is a function of several factors including the nature of the bedrock, the nature of the soil, the slope of the ground, and the water content of unconsolidated geologic units. There are several types of ground-water response. Elastic response occurs in material in which there is no damping and in which component particles maintain the same position relative to one another during the quake. Elastic response is almost universal during small quakes and is most common in consolidated bedrock and dry semi-consolidated surficial units (terrace deposits) during moderate earthquakes.

Where competent bedrock units occupy precarious positions on hillsides and are detached in moderate to strong quakes, the response is said to be brittle. Brittle response is possible in the steeply sloping sandstone terrain of the interior and along the headlands (see Mass Movement).

Clay-rich soils and weathered bedrock with appreciable immobile water on moderate to steep slopes may deform plastically in response to seismic activity to produce slow to rapid earthflow. Such response is termed viscous response and may occur in the clay and silty clays overlying weathered finer-grained Tertiary bedrock units such as the Bateman Formation and the middle Coaledo Formation.

Fine-grained granular soils with high water content may undergo a total loss of strength upon repeated application of forces to give fluid response or liquefaction. Basically, liquefaction occurs when seismic shaking causes a reorientation of sediment grain into a more compact arrangement. During the time of reorientation, the load normally borne by grain contacts is transferred to the pore water, reducing the shear strength tremendously and resulting in viscous behavior. Saturated clay-free sediments such as silt, sand, and gravel are most apt to undergo liquefaction.

In the lowlands, loss of structural support through liquefaction may occur in areas of fill, alluvium, tidal flats, marsh, and sand. Sand mobilized at depth may emerge at the surface as rises or ridges. Of particular concern are the urban areas of Coos Bay, North Bend, and Reedsport lying on fill material over estuarine sediments. On moderately steep to very steep slopes of the uplands, debris flows and earthflows may develop in saturated granular soils during the wet winter months or on the poorly drained parts of ancient landslides.

Type of construction: Damage to structures by earthquakes is closely related to the size of the construction, the nature of the frame and floor suspension, and the presence or absence of facing. Generally, small wood frame buildings of three stories or less are the most resistant to earthquake damage. Earthquake resistance is progressively less for larger buildings with frames of steel, reinforced concrete, wood, unreinforced concrete, and brick. Constructions of unreinforced adobe, hollow concrete block, and hollow clay tiles are the least resistant and may collapse in moderate shakes (Mercalli VII). Facings of unreinforced masonry, brick, or concrete block are relatively susceptible to damage.

Recent investigations show that for very thick soils (several hundred feet) wave lengths of seismic waves approximate the natural wave lengths of buildings greater than 10 stories in height. Damaging resonance can result where the natural period of vibration of a building is similar to that of the ground on which it rests. For thinner deposits of 30 to 100 meters in thickness, similar to that of much of the Oregon estuaries, fundamental periods of vibration are similar to those of buildings five to nine stories high (Nichols and Buchanan-Banks, 1974). Although these figures are preliminary and general, they illustrate the varying responses of different types of constructions to seismic input in different geologic settings.

Impact

The historic impact of earthquakes in the study area is summarized on Table 31. Local records of the 1873 quake, which was felt with an Intensity of VIII in Port Orford, are not available for Coos or Douglas Counties. An earthquake of magnitude 7.2 and calculated Intensity X occurred 40 miles off the coast of Cape Mendocino in 1922 and was felt with an Intensity of V in Coos Bay, but caused no damage.

An earthquake with a magnitude of 7.3 which occurred 150 to 200 miles off the coast of Cape Mendocino the following year was not felt in Coos Bay. Maximum observed Intensity on record was VI in Eureka, California.

With a few preliminary assumptions it is possible to arrive at a tentative estimate of the maximum probable earthquake to be expected in the Coos Bay area. In view of past seismicity, it is assumed that a largest possible quake of magnitude 8.0 (Couch and Deacon, 1972) will occur in the Gorda Basin. It is further assumed that the quake will occur nearshore on the Mendocino Escarpment, the most active structure in the region (see Earthquakes - magnitude). With attenuation similar to that of the 1922 quake, an earthquake of Mercalli VII is calculated for the Coos Bay area; the shock farther north would be correspondingly less. Maximum Intensities of Mercalli V-VI probably will not be exceeded at Reedsport.

The impact of a Mercalli VII quake varies with the type of construction and the location and is summarized on Table 32. For firm ground (marine and fluvial terrace deposits, gentle upland slopes on bedrock or thin soil), negligible damage will occur in buildings of good construction and slight to moderate damage will occur in buildings of ordinary construction. Considerable damage may occur to poorly constructed buildings. On solid bedrock (gently sloping basalt or well-indurated sandstone) damage will be negligible; however, slopes on these units are commonly moderate to steep and landslide damage is a primary concern. In areas of unstable materials (granular soils such as tidal flats, some alluvium, sand), wave amplification may generate considerable damage even to specially designed structures. Liquefaction poses an additional hazard in areas of high ground water.

Recommendations

Western Coos and Douglas Counties are regions of moderate urbanization and low-rise construction in which earthquake danger is primarily a function of external seismicity and local ground conditions. Zoning regulations, building codes, and policies should proceed toward the multiple goal of 1) promoting construction design capable of withstanding potential earthquake activity, 2) directing the location of critical structures to solid or firm bedrock, 3) assuring the safety of individuals in structures of high occupancy (office buildings and schools), and 4) assuring the continued operation of critical structures such as hospitals in the event of an earthquake.

Although presently available data allow generalized policies and goals, the formulation of specific regulations requires additional technical information including more detailed information on earthquake attenuation, thickness and saturation of surficial deposits, and specific responses of surficial deposits to shaking.

With increasing urbanization, the trend will be towards construction of higher buildings in the core areas of the major communities and of industrial facilities on spoil areas in the estuaries. Proper design of larger new structures is especially critical in the Coos Bay, North Bend, and Reedsport areas.

In the absence of local seismic data, adoption of the relevant provisions of the Uniform Building Code is recommended. Section 2314 specifies broad building requirements to accommodate base shear during an earthquake. Factors considered in the calculations include 1) type of frame and structure, 2) structural elements of the building including facing, walls and ceilings, 3) the fundamental period of vibration of the building, 4) the weight of the building. Specifications are broad and generalized, and figures used in the calculations are derived from tables or simple equations.

Earthquake risk is also incorporated into the calculations. The study area is designated as Zone 1 in the north (for which earthquakes of Mercalli Intensity V and VII can be expected) and borderline Zone 2 in the extreme south (for which earthquakes of Mercalli Intensity VII can be expected. Although this figure corresponds in general to that determined on Table 31 for the Coos Bay area, the Uniform Building Code as it is now formulated does not take into consideration ground response (see Table 32). It also does not take into consideration the interaction of specific structures with specific ground responses, thus further underscoring the need for local study.

The Uniform Building Code also discusses chimney anchorage and reinforcement (Section 3704), anchorage of walls (Section 2313), elevator construction, standby power facilities, and electrical and fire-fighting installations in high rise structures (Section 1806 k).

Table 32. Impact and recommendations for earthquake of Intensity VII, Coos and Douglas Counties, Oregon

Setting	Description	Impact	Recommendations
'firm ground'	Type of ground for which official Intensity observations are accepted. Not specifically defined, but firmer than saturated fill, and less firm than solid bedrock. Includes flat, well-drained soils and gravels, etc.	VII - negligible damage in buildings of good design and construction. Considerable damage in poorly built or designed structures. Slight to moderate damage in ordinary buildings.	Authorize a seismic ground response study if large structures are anticipated or if urbanization begins to spread farther into the saturated tidal and coastal areas. Require that earthquake accelerations be incorporated into the designs of large or high-risk structures. Generally small wood frame structures of three or less stories are very stable whereas structures of greater heights with unreinforced concrete or masonry are more susceptible to damage. Zoning, if desired, should proceed toward the goals of proper location of structures out of high-risk areas, the proper construction of structures, and the minimizing of risk to the populace. Thus, greatest restrictions should be placed on large structures of high occupancy and critical need, such as multi-story schools, hospitals, and office buildings.
'solid ground'	Not specifically defined but includes basaltic bedrock and firm, hard, well-indurated strata such as thick sandstone sections. Also presupposes gentle slopes or flat ground.	VI or less - furniture is moved, loose plaster falls; some chimneys are damaged.	
'unstable ground'	Not specifically defined but no doubt includes granular soils, saturated ground, and soil on steep slopes subject to sliding.	VIII or greater - damage slight to considerable even in specially designed structures. Great damage to collapse in poorly designed structures. Some well-built wooden structures destroyed with I = X or greater.	

Table 33. A classification of estuary wetlands, Coos and Douglas Counties, Oregon

Name	Definition	Description	Processes
Fillable submerged land	Submerged land lying below the level of mean low water (+1.5 feet) and less than 6 feet (-4.5 feet) below mean low water. Potential for being filled for dry land use.	Shallow bottoms of most estuaries exclusive of main channels. Substrate of sand, silt, mud, or clay.	Vigorous water mixing; biotic activity; a near balance of erosion and deposition under natural conditions.
Tidal flats	Flat-lying land between mean low water (1.5 feet) and mean high water (7.5 feet). Potential for being filled for dry land use. Noted for profuse biotic activity.	Extensive mudflats at low tides in the marginal and shallow parts of estuaries. Includes eelgrass wetlands in areas of moderate current activity and low sediment supply. Substrate of sand, silt, or mud.	Daily tidal flooding; vigorous mixing of water except in some marginal areas; slow vertical accumulation of sediment.
Low tidal marsh	Land similar to upper tidal flats above local mean sea level (4.5 feet) and below mature marsh, but characterized by gentle slopes to higher ground and isolated islands of arrow grass or marsh.	Margins of estuaries and mouths of sloughs where slow deposition is favored by low currents and by sediment entrapment in vegetation. Flocculation of clays may also be a significant factor in deposition. Silt and clay.	Daily tidal flooding; diffuse drainage; incipient sediment entrapment in vegetation; potential for rapid marsh development.
Mature tidal marsh	Deeply channeled marsh sharply elevated a few feet above most tidal flats; approximately at the level of mean high water or slightly higher.	Shore areas bordering tidelands and characterized by a level upper marsh surface dissected with deep interconnected ditches, channels, and potholes near the tidelands. In upper slough areas channels are less well developed.	Supplies bulk of nutrients to estuarine biotic community; inundated by higher tides to depths of several feet during severe storms; sediment entrapment.
Diked salt marsh	Similar to mature tidal marsh, but diked and modified to give level ground generally for agricultural purposes.	Marginal wetland areas of sloughs bordered by dikes, levees, and tide gates. Fresh water vegetation has replaced brackish water vegetation.	Isolation from estuarine system; advance of nonsalt vegetation; fresh water dominance.

GEOLOGY OF ESTUARIES

General

Estuaries are drowned river mouths formed by a relative rise of sea level. They are generally characterized by tidal influence and a mixing of salt and fresh water. The major estuaries of the study area are the lower reaches of the Coos and Coquille Rivers in Coos County and the lower Umpqua River in western Douglas County.

Major geologic processes in the estuaries include ocean flooding, sedimentation, and water mixing. Similar to most estuaries of the West Coast of North America, the estuaries of the study area are characterized by vigorous tidal currents, abundant sand and sediment supply, and relatively rapid alluviation and marsh development. Silt and clay predominate around the margins of the estuaries and fine- to medium-grained sand is abundant in the main channels.

Estuaries are centers of organic activity and support a complex interlocking web of plant and animal life which includes phytoplankton algae (microscopic plants), eel grass, zooplankton (microscopic animals), crustaceans, clams, worms, and predators (fish). The physical setting and relatively protected waters invite harbor use by man, and the resource potential and favorable geography of the surrounding areas favor development.

Through time, the biotic community of an estuary has become adjusted to the particular salinity, nutrient, and temperature levels associated with circulation as it occurs under natural conditions. Poorly planned or improperly located obstructions can have adverse impacts on these delicate balances and can initiate undesirable biologic and physical side effects including stagnation. To date, very little is known concerning the tolerances of estuarine biota to outside influence. Water mixing and pollution dispersion in estuaries are reviewed by Dyer (1973).

The various parts of estuaries have different physical requirements and settings (Table 33) and perform different functions. Particularly sensitive to changes in currents are the isolated sloughs with low levels of fresh water input from the surrounding watershed. Current activity is low and even small changes in them can exert significant impact. Marshlands provide most of the organic material for estuaries, and the maintenance of access between them and the rest of the estuary is essential for the health of the entire system. Eel grass tidal flats provide protection for a wide variety of sea life but require waters of high salinity and low turbidity. Increased fresh-water flow or storage of log booms over them are incompatible with their biologic resource values.

Geologic Processes of Estuaries

Circulation

General: Circulation and water mixing within the estuary is promoted by the opposing forces of outflowing fresh water and incoming tidal water. In addition, in two-layer systems where fresh water flows out over marine water, the greater density of the marine water generates landward currents along the bottom of the estuary. Fluctuations in the degree of circulation are controlled largely by variations in the tides, stream flow, and storm or low stream-flow phenomena, but also are greatly influenced by the activities of man. Mixing is closely linked to the seasons, with the most thorough mixing occurring in the winter and the least mixing occurring in the summer.

Mixed water and two-layer, or wedge, systems dominate in Oregon estuaries including those of the study area. Two-layer systems involve seaward-moving fresh water near the surface and inland moving marine water at depth. A zone of diffusion between the two layers continually skims marine water from the leading edge of the lower system (salt water wedge). Size, shape, and position of the salt water wedge at depth is dependent on the shape of the estuary and the nature of the currents.

Diffusion is the dominate mixing action during gentle current action. Turbulence is dominate during rapid incoming tides or rapid runoff. During particularly severe winter storms, salt water may surge inland over the less dense fresh water, causing an inversion. The resulting convective action produces thorough mixing which yields well-oxygenated waters beneficial to biotic activity. During particularly high runoff two-layer systems are developed in which fresh water flows seaward over incoming marine water at depth.

Activities of man

Man can exert significant influence on the circulation of an estuary either intentionally or inadvertently by 1) modifying the flow of fresh water into the estuary, 2) modifying the flow of salt water into the estuary, or 3) restricting currents within the estuary. The impact of specific projects is difficult to assess and varies with the nature and location of each project. Likewise, the tolerance of various parts of the estuary to change also is poorly understood. The potential impacts discussed below should be regarded as rational possibilities and are not necessarily intended as established fact in specific situations.

Man can increase fresh water runoff locally either by diverting streamflow to new locations or by decreasing infiltration rates through modified land use such as urbanization. Biologic areas with tolerance only for high salinity waters, such as eel grass, may be adversely affected. Although it has been demonstrated that logging increases summer streamflow (see Stream Flooding), it is doubtful that this activity has adverse effects on the estuary. Increased streamflow along established channels in the summertime probably would be beneficial to the circulation of the estuary.

Man can decrease fresh-water streamflow into the estuary by diverting streams to a variety of uses including agriculture, industry, or mining. Flood-control projects also can greatly modify fresh-water input into the estuary. During the summer months, the decreased fresh-water influence in the estuary could produce greatly modified current action and increased salinity. It is doubtful whether properly managed flood-control structures would exert adverse impacts, however. A reduction of excessive winter runoff probably would be beneficial.

Salt-water circulation in the estuary is generally enhanced by channel dredging. The impact in terms of mixing is generally favorable, although adverse effects associated with spoils disposal and other aspects of dredging are also noted (see Estuaries-Sedimentation). In a very real sense, the dredging counteracts the long-range process of alluviation which threatens the vitality of the estuary. Where current action is minimal, however, stagnation "sinks" may develop.

Currents within estuaries are commonly modified or restricted by dikes, fills, or spoils disposal. Impacts vary with the extent of the project and may include 1) burial of the local benthic community, 2) elimination of sloughs or inlets, or 3) reduction of the biologic productivity of the estuary. Fluctuations in the fisheries resource on the continental shelf can be traced in part to changes in the estuaries. Fills also can isolate estuarine marshlands from the rest of the estuary, thus limiting food supply for the remainder of the biotic community. If unchecked for a long enough period of time the practice of fill placement in the estuaries can lead to elimination of much of the estuary including sloughs and secondary bays.

Deposition

General: Sedimentation within estuaries is complex and includes settling of wind-blown sands (see Wind Erosion and Deposition) near the active parts of spits, deltaic and related deposition near major streams, clay flocculation and settling in sloughs and marshes, deposition by littoral drift near bay mouths, and upstream transport of marine sediments by marine water flowing into the estuary, sometimes for considerable distances (Kulm and others, 1975).

Because the circulation of the estuaries is dominated by mixed or two-layered systems during most of the year, bedload material coarser than very fine-grained sand is generally deposited near the mouths of inflowing streams and along major channels in the estuary. Although ebb tides and extreme storms may periodically flush some of this material to the surf zone, Oregon estuaries are generally regarded as sediment traps for fine-grained sand and coarser material (Kulm and others, 1975). Large volumes of finer-grained material do escape the estuaries, however.

Where inflowing ocean currents are statistically balanced by outgoing tidal and river currents, mean flow approaches zero and deposition is promoted. This region is termed the nodal point and is the site of shoaling. Owing to relatively efficient outgoing currents, shoaling in the Oregon estuaries is generally located very near the mouths of the estuaries or even a short distance out to sea, as at the mouths of the Coquille and the Umpqua Rivers.

Deposition within the estuaries produces a natural sequence of landform development which proceeds from submerged land successively through tidal flats, tidal marsh, and meadow. Vegetation of the marshes efficiently entraps sediment so that ground elevations of marshes generally are a foot or more above the immediately surrounding tidelands (Table 33). In quiet brackish waters, such as sloughs, clay flocculation by positive ions in the salt water is now recognized as a major contributor of sediment.

Activities of man: The filling of estuaries by sediments is a natural and irreversible process. Man can modify the rate of filling in several ways including 1) increasing or decreasing the supply of sediment from the watershed, 2) increasing or decreasing the supply of sediment from the coastal zone, and 3) modifying depositional patterns within the estuary.

Improper land use, including poor logging practices and excessive soil disturbances during construction of various projects, greatly increases mass movement and sediment yields to streams. As the sediments move seaward they account for increased rates of sedimentation in the estuaries. Although no quantitative data are available, poor logging practices in past years are blamed for much of the sedimentation of the estuaries (U. S. Department of the Interior, 1971; Dicken, 1961). Various techniques and policies available to minimize slope erosion in areas of timber harvest are discussed under Stream Erosion and Deposition.

Jetty construction at the mouths of estuaries greatly reduces the quantities of sediment delivered to the bay by longshore drift and tidal action by promoting beach deposition on the adjacent coastlines (see Coastal Erosion and Deposition). The impact of dredging, however, is variable, depending upon the hydraulics of the particular estuary. Where shallow bay mouths are enlarged by dredging, as along the Oregon Coast, more efficient ebb tides and estuary flushing are generally experienced. Dredging inside the estuary may increase circulation and lead to increased dispersion of pollutants and increased shellfish production. Alternatively, dredged areas may develop into localized sinks characterized by a buildup of organic material and the development of toxic reducing conditions. Additional impacts of dredging include sediment sorting during slurry disposal, increased turbidity and consequent siltation, and the release of a variety of materials previously locked in sediment including sulfides, hydrocarbons, insecticides, and possibly heavy metals. The increased oxygen demand associated with dredging is largely of chemical rather than biologic origin.

Improperly placed fills and dikes can impact on circulation patterns, which in turn can affect patterns of deposition. Bridges rather than fills should be constructed where roads or railroads cross established channels in the estuary. Fills for new land have the least impact on estuaries if located on high marsh and meadows rather than on tide flats or other low-lying landforms.

Coos Bay Estuary

Coos Bay covers 12,380 acres and is primarily tidal flats (6,200 acres), tidal marsh (2,738 acres), and eel grass tidelands (1,400 acres). The watershed draining into the Bay covers 820 square miles. Annual sediment discharge into the Bay is estimated at 72,000 tons (Percy and others, 1974). Head of tidewater is at Dellwood on the South Fork of the Coos River and at Allegany on the Millicoma River. Average depth of the Bay is 5 feet below mean sea level.

Most parts of the Bay have partly to well-mixed water during most of the year. Salt-water inversion occurs during many winter storms (Burt and Queen, 1957). Salinity is highest in the summer months. Tidal mixing is the least effective in areas far removed from main tidal channels, such as the middle and upper reaches of sloughs. The capacity to accommodate pollution is the least around the edges of sloughs draining local watersheds. Stagnation and low oxygen levels have been reported in Isthmus Slough.

Current velocity data for Coos Bay are limited. Percy and others (1974) report maximum ebb and flood currents of 7 knots and 3.5 knots respectively. Side channel readings taken from a dock near the mouth of the Bay ranged from 0.2 to 2.7 knots for ebb tides and 0.2 to 1.1 knots for flood tides in a study

Table 34. Modifications to Coos Bay estuary, U.S. Army Corps of Engineers[1]

Modification	Location	Dimensions			Status
		Depth[2]	Width	Length	
North jetty	Entrance				1929 completed; 1940 reconstructed
South jetty	Entrance				1970 repair started; 1942, 1962, 1963 reconstructed and rehabilitated
Breakwater	Charleston				
Bulkhead	Charleston				
Turning basin	Opposite Coalbank Slough	30 feet	600 feet	1,000 feet	
Turning basin	At city of North Bend	30 feet	600 feet	1,000 feet	
Anchorage basin	Outer part of mile 3.5	30 feet	600 feet	2,000 feet	
Anchorage basin	Coos Bay near mile 7	30 feet	600 feet	2,000 feet	
Mooring basin	Charleston		900 feet	900 feet	1956 small boat basin completed
Channel	Entrance	40 feet	suitable	1 mile	1952 completed
Channel	Entrance to mouth of Isthmus Slough	30 feet	300 feet	15 miles	1937 dredged to 24 feet; 1951 channel completed to 30 feet
Channel (Isthmus Slough)	Isthmus Slough to Millington	22 feet	150 feet	3 miles	
Connecting channel	Coos Bay main channel to Charleston	10 feet	150 feet		1956 completed
Channel extension	In South Slough to highway bridge	10 feet	150 feet		1970 completed
Channel	Coos Bay to Allegany on Millicoma River	5 feet	50 feet	13.8 miles	1966 improvements
Channel	To Dellwood on the South Fork, Coos River	5 feet	50 feet	15 miles	1966 improvements
Channel	Dellwood to mile 14.7 of South Fork, Coos River	3 feet	50 feet	0.7 miles	1966 improvements

[1] Adapted from Percy and others, 1974.

[2] Depth is in reference to mean lower low water; see Table 23.

cited by Fleming (1955). Additional readings token from the Boy entrance during jetty construction revealed maximum mid-channel velocities greater than 3.5 knots. Current velocities recorded in 1912 near the proposed Willomette Pacific Railway Bridge were as great as 2.25 knots during flood tide and 2.5 knots during ebb tide. Bottom currents greater than 0.5 knots (approximately 20 cm/sec) (see Figure 48) ore capable of eroding and transporting fine sand. Seaward of North Bend, bottom material is primarily sand and shells; to the east, silt, fine sand, and mud predominate.

Land use in the Coos Boy area includes timber harvesting, fish harvesting, and processing, urbanization, strip commercial development, scattered ogriculture, residentiol development, moderate industry, and shipping. Approximately 85 percent of the watershed is commercial forest. The Millicomo River and numerous sloughs ore devoted largely to log storage. Coos Boy is a deep-water port with 30-foot channels, numerous lorge turning basins, and scattered boat romps. The most intensely developed port of the Boy is the south shore.

Prior to channel dredging and jetty construction, the mouth of Coos Bay consisted of a channel 200 feet wide and 10 feet deep. The location of the mouth fluctuated seasonally over a distance of several thousand feet. Near the community of Coos Boy the channel was only 50 feet wide and 6 feet deep. Subsequent projects (Table 34) hove produced the present deep-water harbor and undoubtedly hove affected current activity and depositional patterns. The old channel at the delta of the Coos River east of the marsh islands northeast of Eastport is reportedly filling with sediments at the present time. A new channel dredged to join the Coos River and the Marshfield channel immediately north of Eastport has redirected currents away from the old channel. Marsh growth in the general region of the mouth of the Coos River into Coos Boy has been rapid in recent years (Dicken, 1961).

Linear fills in estuaries con hove severe impact on estuarine waters. The impact of the roodfill leading north post Haynes Inlet and west to North Spit from Russell Point has been minimized by the construction of bridges over main tidal channels. The precise long-range effects of the fills, however, are unknown.

Diking has claimed 2,000 acres of tideland for agriculture (Figure 51), and fill has produced 1,500 acres of new land for development in the Bay since 1920 (see Figure 52). Major projects include industrial

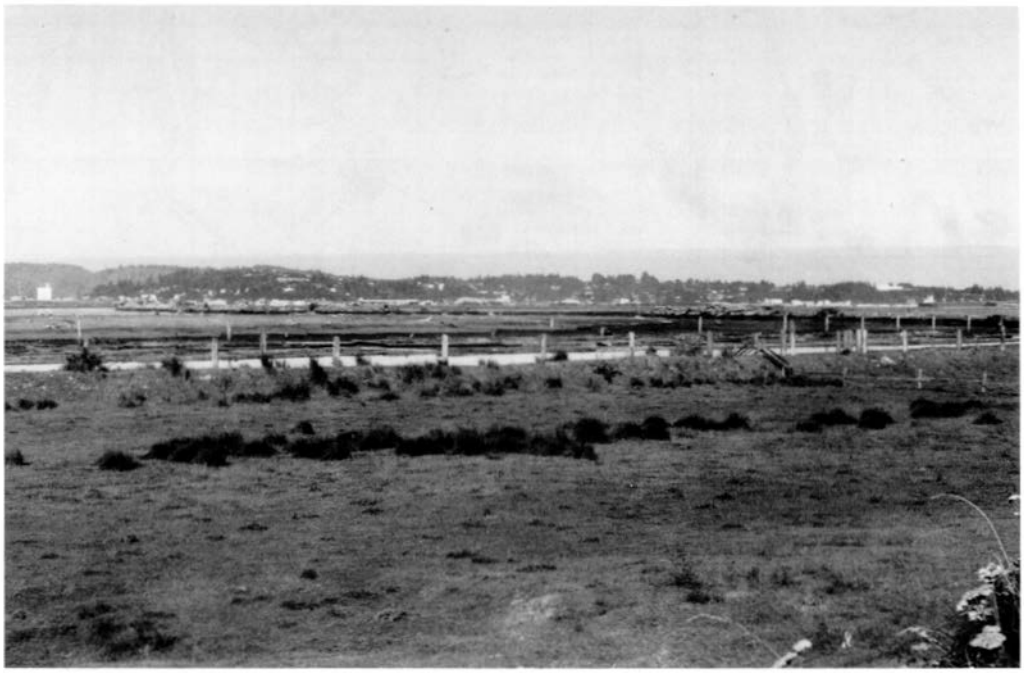


Figure 51. Lost wetlands through diking and fill placement.

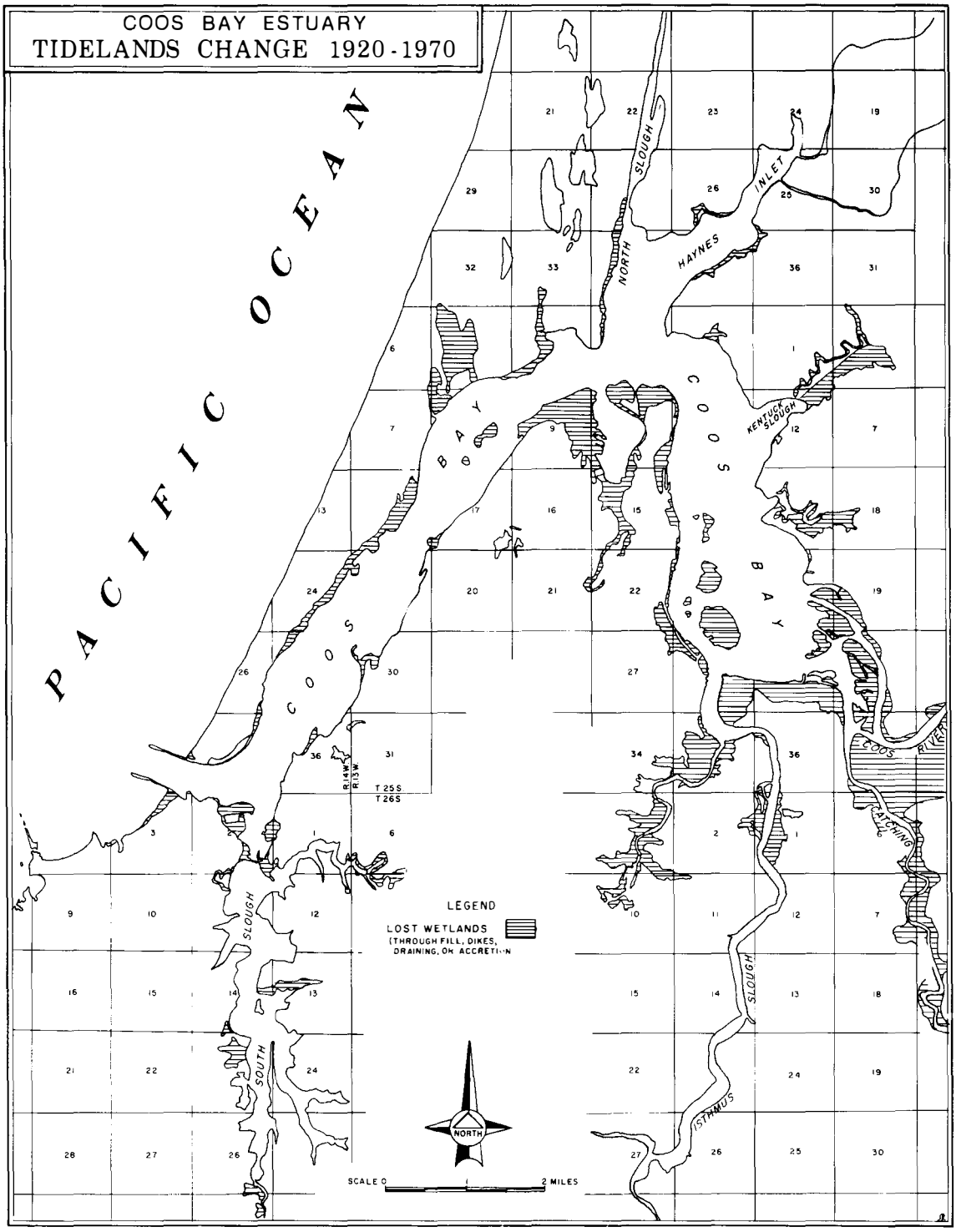


Figure 52. Diking for agricultural land has reduced the size of the Coos Bay estuary.



Figure 53. Marsh growth at the mouth of Kentuck Slough has accelerated in recent years possibly owing to man's influence (see text).



Figure 54. High tide in South Slough covers pristine tidal flats.

fill at the mouths of Isthmus and Coalbank Sloughs, in the area north of Eastside, and at the mouths of Coos and Catching Sloughs. Fill at the mouth of Pony Slough underlies the airport constructed in World War II. Fill continues to be placed in the area of Pony Slough for residential and commercial development.

The tidegate at Kentuck Slough allowed the conversion of high marsh to agricultural land, but also reduced current action and promoted sediment deposition. With the cessation of tidal flushing, flocculated clays have been allowed to accumulate in the immediate area. Between 1939 and 1961, the marsh at the mouth of Kentuck Slough doubled in size (Dicken, 1961), and it is still growing (Figure 53).

North Slough and Haynes Slough in the north Coos Bay area consist of relatively unchanged tidal marsh, and South Slough south of Charleston remains as relatively pristine tidal flats (Figure 54); however, fills are present at the mouth of the slough at Charleston, and diked agricultural land occupies several of the inlets of South Slough. The area has been proposed as an estuarine sanctuary by OCC&DC and the National Oceanic and Atmospheric Administration.

Coquille River Estuary

The estuary of the Coquille River covers 771 acres and consists primarily of tidal flats (301 acres) and tidal marsh (373 acres). The Coquille watershed extends over an area of 2,390 square miles. Sediment discharge into the bay is approximately 100,000 tons per year (Percy and others, 1974). Head of tidewater is located at Myrtle Point and the average depth of the estuary is 7 feet below mean sea level. Waters are partly to well-mixed year round. Salinity is highest during times of low streamflow in the late summer.

Land use around the estuary includes lumber processing, local commercial developments at Bandon, boat ramps, scattered residential and urban development, and agriculture (primarily cranberries and livestock). Harbor improvements include a channel dredged to a depth of 13 feet, two jetties (Table 35), and a small boat basin.

Table 35. Modifications of Coquille Bay estuary by U.S. Army Corps of Engineers*

Modification	Location	Dimensions			Status
		Depth	Width	Length	
North Jetty	Entrance			3,450 feet	1908 completed 1942 reconstructed 1951 extended 1956 repaired
South Jetty	Entrance			2,700 feet	1908 completed 1954 repaired
Channel	Entrance	13 feet below mean lower low water	Suitable	1.3 miles	1933 completed

* Adapted from Percy and others, 1974

The most significant change in the estuary of the Coquille River in historic times has been the rapid spread of marshlands along the east bank north of Bandon. Prior to 1895 most of the marsh (see Geologic Map) did not exist. Since that time, the marsh has spread at rates up to 70 feet per year, although it has slowed considerably in recent years (Dicken, 1961).

The marsh occupies the inner bend of a meander, formerly an area of slack water. The brackish water site was ideal for deposition of flocculated clays and other fine-grained sediments. The slack-water area probably formed when the Coquille River cut westward into the easily eroded spit, leaving its former channel. It is unknown when the river shifted to its present position. Available records (Dicken, 1961) show that the river has not changed course since 1887.

Formation of the marsh is here attributed to a sequence of natural events which included 1) a shift of the main channel of the river westward to produce slack-water conditions along the old channel, 2) regional shallowing along the east bank as a result of sedimentation, and 3) rapid lateral spreading of marsh as a result of sediment entrapment.

Logging and forest fires in the watershed undoubtedly contributed to the sediment supply but probably were not a major factor in the formation of the marsh as postulated by Dicken (1961). Before the marsh began to spread, shallow tidelands developed in the slack water as a natural result of hydraulic conditions and at a time prior to man's influence in the hinterland. Likewise the rapid spread of the marsh is explained primarily in terms of sediment entrapment by vegetation rather than a greatly increased sediment supply.

Umpqua River Estuary

The Umpqua River estuary covers 6,830 acres, of which approximately 1,500 are tideland marsh and the remainder submerged land. The river system drains an area of 4,500 square miles. The head of tidewater is at Scottsburg on the Umpqua River and at river mile 28.5 on the Smith River. Sediment discharge into the bay is estimated at 564,000 tons per year (Percy and others, 1974). Average depth of the bay is 15 feet below mean sea level.

Waters are partly to well mixed throughout the year with a prominent salt-water wedge common in January and February. Shoaling and cross currents are a major concern in the bay and are analyzed in a computor program developed by the U. S. Army Corps of Engineers (Technical Report H-70-6). Another program developed by the Washington State Institute of Technology (Bulletin 265) models pollution potential. Summertime salinities are lower than in most other estuaries, owing to melting snows in the headwaters of the Umpqua River in the Cascade Range.

Industrial development near the bay includes lumber processing at Gardiner, fish processing at Winchester Bay, a lumber mill on Scholfield Creek, and sand and gravel dredging up the Umpqua River (see Mineral Resources). Other types of land use include commercial and residential development at Reedsport, sports fishing, clamming, and agriculture (grazing and small farms). Harbor improvements (Table 36) include jetties at the river mouth, a 22-foot deep channel to Reedsport, and side channels to Winchester Bay, Gardiner, part of Scholfield Creek, and 21 miles up the Smith River.

Major physical changes in the estuary in historic times are the joint result of spoils disposal and natural marsh growth. Levees, dikes, and fill have been used to elevate much of Bolon Island above the range of tidal influence. The southeasterly upstream extension of Steamboat Island has formed since 1885 largely as a result of natural marsh development. Various other parts of the island, especially the northern end, are composed of dredge spoils, and the island is mapped as fill and spoils (see Geologic Map).

Leeds Island on the south bank of the Umpqua River is now connected to the mainland by levees and spoils. According to Dicken (1961), the site of the commercial district of Reedsport was high salt marsh in 1885 and owes its present elevation to fill. Various geologic hazards that should be considered in the further development of this and similar areas are discussed under Marsh and Peat (Surficial Geologic Units) and Earthquakes.

At the present time, most active marsh growth appears to be on the western edge of The Point, a short distance northwest of Reedsport, where tidal marsh accretion and channel development are noted by Dicken (1961).

The physical makeup and future development of the Umpqua River estuary is currently being intensively and systematically investigated by the Umpqua River Study Group. Topics of consideration include soils limitations, slopes, hydraulics, land use, and spoils disposal.

Table 36. Modifications to Umpqua River estuary, U.S. Army Corps of Engineers[1]

Modification	Location	Dimensions			Status
		Depth[2]	Width	Length	
North jetty	Entrance			8,000 feet	1940 completed
South jetty	Entrance			4,200 feet	1938 extension completed; 1963 rehabilitated
Training jetty	Inside south entrance			5,500 feet	1951 completed
Turning basin	Reedsport	22 feet	600 feet	1,000 feet	
Mooring and turning basin	Winchester Bay	12 feet	175 feet	300 feet	
Turning basin	Gardiner	22 feet	500 feet	800 feet	
Passing basin	Mile 16 on Smith River near North Fork				1957 completed
Channel	Entrance	26 feet			Completed
Channel	Entrance to Reedsport	22 feet	200 feet	11 miles	1941 completed
Side channel	Main channel to docks at Winchester Bay	12 feet	100 feet		
Channel	Scholfield Creek from confluence with Umpqua River	12 feet	100 feet	2 miles	
Channel	Smith River mouth to North Fork	6 feet	100 feet	16 miles	1957 completed
Channel	Smith River from North Fork to Sulphur Springs	4 feet	75 feet	5 miles	1957 completed
Side channel	Main channel to Gardiner	22 feet	200 feet		

[1] Adapted from Percy and others, 1974.

[2] Depth is in reference to mean lower low water, see Table 23.

SUMMARY

Use of Bulletin

This bulletin provides planners in western Coos and Douglas Counties with the necessary information and guidelines to make valid land-use planning decisions. It is a comprehensive and systematic synthesis of present thought regarding hazardous geologic conditions and mineral resources of the region. The information is general and reconnaissance in nature, however, and is subject to further refinement based upon more rigorous study.

The report proceeds through various levels of detail from map to tables to text and references. Organized in this way, the report has a potential for a wide variety of uses including preliminary site evaluations, land use suitability analyses, regionalization of data, and policy formulation.

Geographic Setting of Study Area

The study area encompasses the western half of Coos County and the northwestern tip of Douglas County and covers approximately 1,400 square miles. The climate is moist temperate with summer breezes from the northwest and winter gales from the southwest. Ocean currents are complex but generally are in response to the winds.

Landforms include categories of uplands, terraces, and lowlands. Each is the product of specific geomorphic processes acting upon specific materials. Landforms can be used to deduce a first approximation of hazardous geologic conditions.

The population of Coos County was 56,515 in 1970 and that of Reedsport in western Douglas County was 4,039. Data indicate modest increases in the future with the trend towards urbanization. Construction of more efficient transportation links to the Roseburg area would modify the projections upward.

Engineering Geology

Three types of geologic units are recognized: 1) bedrock geologic units of consolidated material, 2) surficial geologic units of semi-consolidated to unconsolidated sedimentary Pleistocene deposits, and 3) soils, the products of weathering. Soils overlie both the bedrock and surficial geologic units.

Bedrock geologic units include all or parts of 12 stratigraphic units grouped into four major categories: Sandstone of Tertiary Age, Siltstone of Tertiary Age, Basalt of Tertiary Age, and Rocks of Pre-Tertiary Age. Local use limitations in the bedrock geologic units generally are dominated by degradational hazards such as mass movement and erosion, and related conditions such as thin soils.

Surficial geologic units include 9 units: fill and spoils, stable sand, unstable sand, deflation plain sand and beach sand, tidal flats, marsh and peat, Quaternary alluvium, Quaternary fluvial terrace deposits, and marine terrace deposits. Local use limitations generally are dominated by aggradational and weathering hazards including flooding, ponding, high ground water, and deposition. Related engineering conditions include low bearing strength and potential liquefaction during earthquakes.

Soils are leached and acidic and are grouped into three major categories: upland soils, terrace soils, and lowland soils. Upland soils are characterized by steep slopes, rapid runoff, rapid erosion and silty loam to silty clay textures. Gentle slopes and deep weathering are typical of terrace soils; however, clay-rich horizons or thin iron pans impede infiltration locally. Bank failure in deep cuts is a little appreciated hazard. Lowland soils occupy regions of stream flooding, ocean flooding, and wind erosion and deposition. Where depositional processes are dominant, lowland soils are indistinguishable from the surficial geologic units they overlie. The engineering properties of the upper 5 feet of these units are discussed under soils.

Mineral Resources

The study area is characterized by limited metallic and non-metallic resources, high ground-water potential in dune areas, and poorly defined but modest fuel potential. Construction materials appear to be in adequate supply.

Metallic mineral resources

Black sands deposits contain gold and chromite and consist of small relatively low-grade deposits offshore and scattered deposits onshore with long but sporadic histories of small-scale production. Investigations of the deposits continue. Several small prospects for gold (placer and lode) are located in the South Coquille drainage. Increased prospecting can be expected in future years. Copper and manganese prospects also are located in southern Coos County.

Nonmetallic mineral resources

The Coos-Umpqua dunes area is favorable to the production of silica sand in terms of its size, accessibility, and quality. Potential for certain types of glass and for foundry sand has been demonstrated. Small limestone deposits suitable for agricultural use may overlie the Basalt of Tertiary Age locally. One deposit east of Coos Bay was mined for mortar on a very limited basis. Other nonmetallic mineral resources of undefined utility include clay and peat.

Construction materials

Coos County is deficient in gravel and high-quality rock for concrete aggregate and imports large volumes of these commodities from the Reedsport area. Sand and gravel are mined primarily from the bed of the lower Umpqua River, with subordinate activity in the middle and upper reaches of the Coquille River, and from marine terrace deposits near Bandon. Quarry stone in adequate supply for local riprap, road construction, and some jetty construction has been produced from Basalt of Tertiary Age and from blueschist pods of the Rocks of Pre-Tertiary Age. Providing an adequate supply of construction materials for future use will require a well-informed balancing of esthetic desires and material needs. Well-managed mining and sequential or multiple land use are recommended.

Ground water

Ground water is most abundant in the Coos-Umpqua dune sheet; yields of several hundred gallons per minute are common, and present daily production approximates 4 million gallons. A total of about 15 million gallons per day could probably be withdrawn without adverse consequences to lake levels, water quality, or well efficiency. Ground-water potential of terraces and other lowland areas is generally less than a few tens of gallons per minute and use is restricted to scattered domestic use. Ground-water potential of the uplands is very low. Increased monitoring and management will be needed to assure the most beneficial and efficient use of the ground-water resource in the future.

Fuel

The Tertiary geologic history of the study area is generally favorable for the generation of oil and gas, but low bedrock permeabilities and other geologic conditions have operated against its accumulation in commercial quantities in many of the more promising structures. Exploration has been extremely limited, however, and the possibility of future discoveries is very real. Offshore, thick sections of Miocene to Pliocene age strata between Bandon and Cape Blanco and older strata forming an anticlinal structure at Coquille Bank are particularly promising.

Approximately one billion tons of coal (not all economically minable) of subbituminous grade underlie the Coos Bay area. Of this, only 60 million tons are minable with present technology and under present

economic conditions. Similar reserves underlie Eden Ridge to the southeast. The resource is only of local significance when compared with the extensive coal reserves of the midwest and east. Future development of the resource will probably be for local needs and may involve application of new technologies, such as in-place coal gasification.

Geologic Hazards

Geologic hazards present at various times in various parts of the study area include stream flooding, ocean flooding, high ground water, ponding, mass movement, stream erosion and deposition, coastal erosion and deposition, and moderate earthquake potential.

Stream flooding

Flash flooding is restricted to steeply sloping upland areas with high relief. The major impact is from channel scour and stream-bank erosion, which damage roads, bridges, and other structures. Major recommendations include limits on development in critical areas and provisions for proper engineering of necessary structures.

Lowland stream flooding is common on the flood plains of the major streams and results in structural damage, water damage, siltation, and hazards to health. Protective and remedial measures may include appropriate zoning ordinances and building codes, insurance programs, disclosure policies, and flood prevention construction such as dikes and levees.

Ocean flooding

Tidal flooding occurs two times daily and affects tidal flats, low-lying beaches, and marsh to an elevation of approximately 6 feet above mean sea level. It aggravates stream flooding in coastal areas and should be integrated into all flooding models.

Storm surge is caused by low atmospheric pressure and wind, and is additive to tidal flooding. Maximum observed storm surge on the Oregon Coast is slightly greater than 4 feet above the level of predicted tides in an area of minimal wave set-up. When extreme storm surges are superposed on high tides, inundation of mature marshes by several feet of water and flooding of low fill placed in lowlands is possible.

Tsunamis (seismic sea waves) generally are small and rare occurrences, but the evaluation of the historic record indicates possible amplitudes of 15 feet. Hazards are greatest to unwary beachcombers and tourists in low-lying coastal areas. A well-coordinated and thorough warning system is recommended. In the study area, tsunamis are concentrated on the headlands and are dissipated in the estuaries.

High ground water and ponding

High ground water and ponding are common in flat-lying lowland areas with low infiltration rates, such as flood plains and wetlands. Engineering difficulties include flotation, failure of waste disposal systems, caving of excavations, low bearing strength, and unfavorable shrink-swell properties. A variety of engineering practices and regulations are recommended.

Mass movement

Mass movement on steep slopes is dominated by rockfall, debris flow, and rapid earthflow; mass movement on more deeply weathered moderate slopes includes slump and slow to moderately rapid earthflow. Impacts of mass movement are varied and may include personal injury and immediate or long-term destruction of property and buildings. Controlled development and engineering techniques keyed to the specific causes of particular slides are recommended for areas prone to mass movement.

Stream erosion and deposition

Stream erosion includes stream-bank erosion of unconsolidated materials in the lowlands and of bedrock in steep valleys, channel scour in upland areas, and sheet wash, rill erosion, and gullying on moderately to steeply sloping hillsides. Impacts are varied and may include loss of topsoil and damage to roads and other structures. Deposition in areas downslope can clog drainages and sewers, bury lawns, and hinder navigation. Recommendations include proper land management on a regional level and appropriate engineering practices on a local level. The U. S. D. A. Soils Conservation Service provides technical assistance for many erosion problems.

Coastal erosion and deposition

Coastal erosion of headlands averages a few inches per year or less, but may exceed 10 feet or more at any one time and place as a function of rock type and structure. Prevention of coastline retreat in headlands of coastal Coos County are not economic, and adequate setbacks are recommended for future developments.

Beaches in the study area are generally stable under present conditions. Future changes in sediment supply and wave dynamics resulting from natural or man-made causes could initiate erosion or deposition. Jetty construction, dredging, beach excavations, and groin construction are acts of man with potential impact on beach stability. Natural processes with impact on beach stability include cyclic changes in climatic activity, storms, migration of rhythmic topography, and others. Impact of all developments having an influence on longshore drift should be evaluated prior to construction. Engineering treatments of beach instability vary with local conditions and goals.

Wind erosion and deposition

The dunes between Coos Bay and Heceta Head form a complex system of landforms which owe their origin primarily to a balanced interplay of wind erosion and deposition. Changes in any part of the system can lead to secondary changes in others. Thus, the growth of the foredune induced by the introduction of dune grass has been at the expense of dunes farther inland. As a consequence, the deflation plain areas are presently growing in size.

Dune migration blocks streams, buries structures, and occurs at rates of up to several feet per year. Management should include provisions for protecting vegetation in the dunes and for limiting development to areas of low hazard potential. Long-range impacts should be evaluated for all projects of regional extent including foredune stabilization.

Earthquake potential

No epicenters have been recorded in western Coos and western Douglas Counties for over 100 years. However, earthquake hazard is moderate owing to the high seismicity of the Mendocino Escarpment and related structures off the coast of northern California. Seismic activity in that area can be expected to produce earthquakes with observed Mercalli Intensities as high as VII in the southern parts of the study area. In regions of thick, saturated soils, Intensities could be even greater owing to amplification of seismic waves and to liquefaction.

Zoning regulations, building codes, and policies should proceed toward the multiple goal of 1) promoting construction design capable of withstanding potential earthquake activity, 2) directing the location of critical structures to solid or firm bedrock, 3) assuring the safety of individuals in structures of high occupancy, and 4) the continued operation of hospitals in a disaster. In lieu of additional technical information, adoption of the relevant provisions of the Uniform Building Code is recommended.

Estuaries

Estuaries are drowned river mouths formed by a rise of sea level relative to the land and are characterized by a tidal influence and by mixing of fresh and salt water. Estuaries are nodes of organic activity and are sites of complex interaction of numerous geomorphic processes including ocean and stream flooding, sedimentation, and water mixing.

Man can exert significant influence on the circulation and deposition patterns of an estuary by 1) modifying the flow of fresh water into the estuary, 2) modifying the flow of salt water into the estuary, and 3) restricting or modifying currents within the estuary. Activities of man requiring thorough study include the placing of fills, the construction and extension of jetties, dam construction, and various types of regional land use such as logging in the interior and urbanization near the estuary.

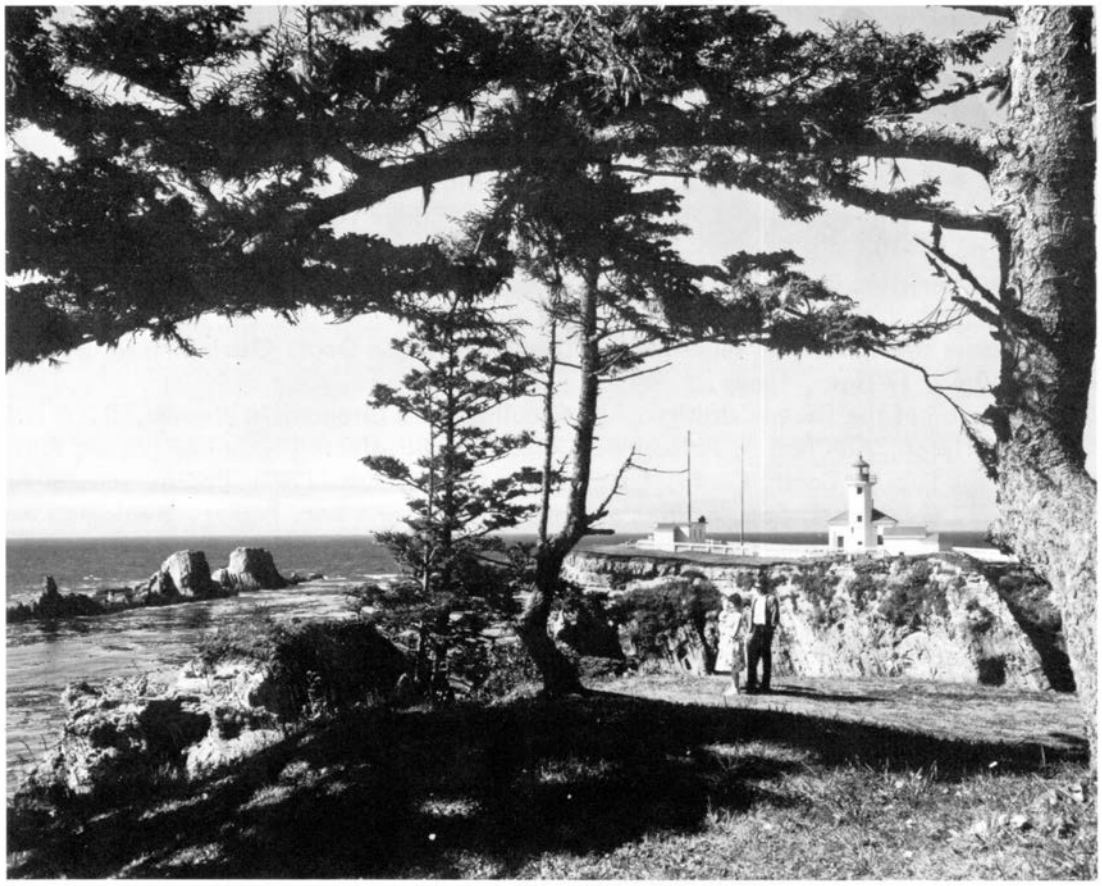


Figure 55. Cape Arago Lighthouse near Sunset Bay State Park. (Photo courtesy Oregon Highway Division)

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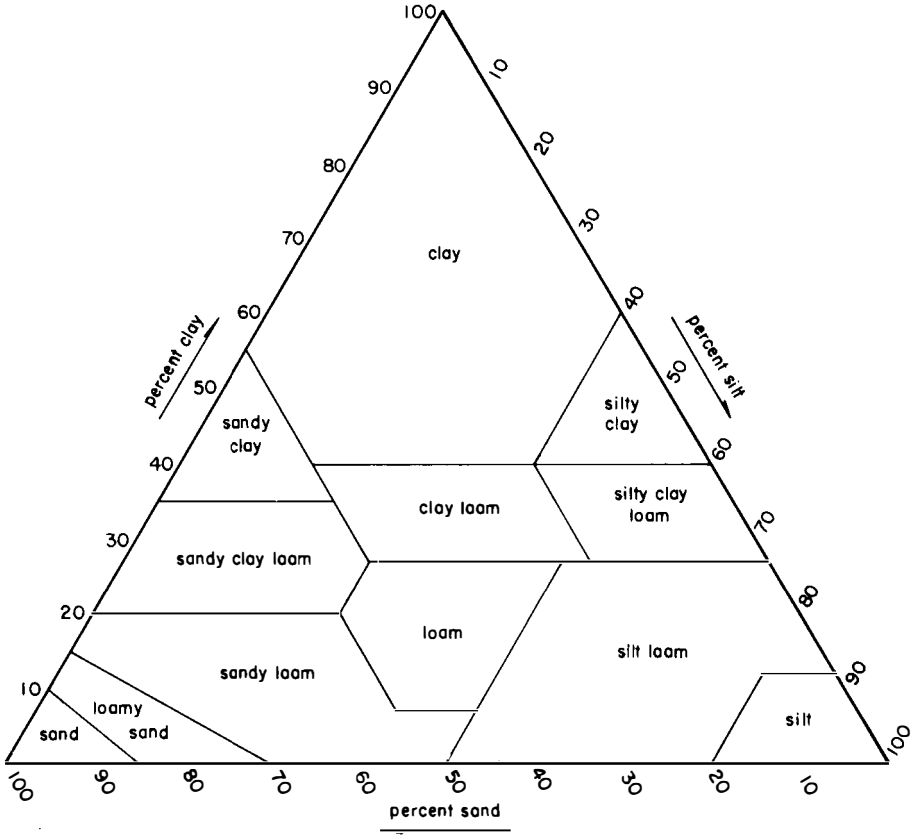
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APPENDIX

APPENDIX A. GUIDE FOR THE TEXTURAL CLASSIFICATION OF SOILS



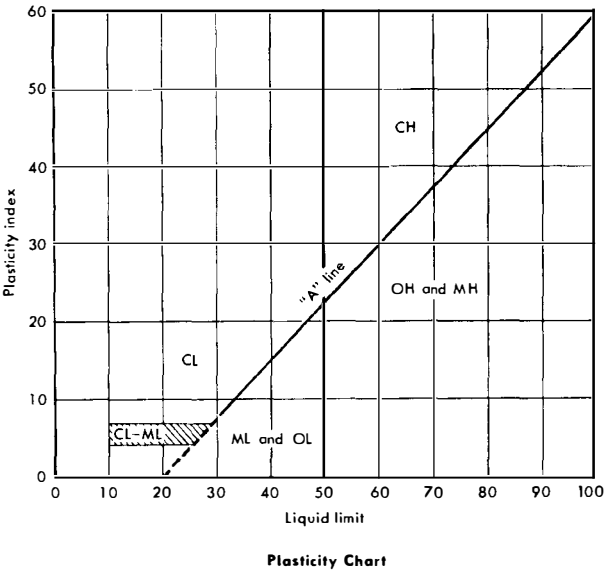
APPENDIX B. FIELD RECOGNITION OF SOIL TEXTURES[1]

Soil type	Dry pressure	Dry feel	Dry breaking strength	Moist pressure	Moist feel	½" - 1' wide 1/8" thick Moist plasticity (ribbon)	Moist 2"+ long plasticity (wire) 1/8"	Moist shaking	Moist shine
Sand	Fall apart w/release pressure	Individual grains seen and felt	Collapse on touch	Hold shape w/o pressure, crumble when touched	Individual grains seen and felt	Will not ribbon	Will not wire	Rapid reaction	No shine
Sandy loam	Fall apart w/release pressure	Individual grains appear dirty	Crumbles w/ slight finger pressure	Weak cast, careful handling	Individual grains appear dirty	Will not ribbon	Will not wire	Moderately rapid reaction	No shine
Loam	Weak cast careful handling	Gritty, floury feel	Crumbles w/ moderate finger pressure	Cast freely handled; thrown short distance	Gritty, smooth slick	Very weak ribbon, broken appearance	Very weak wire in broken segments	Moderate reaction	Faint dull shine
Silt loam	Cast withstands handling freely	Soft and floury	Crumbles w/ considerable finger pressure	Cast holds shape when thrown, none sticks to target	Smooth, slick w/ some stickiness	Ribbon, broken appearance	Weak wire easily broken	Moderately slow reaction	Dull shine
Clay loam	Cast can be dropped	Slightly hard, little grittiness	Crumbles w/considerable finger pressure, can be powdered	Cast withstands handling, some sticks to target	Smooth slightly sticky w/some grittiness	Ribbon barely sustains weight	Wire sustains weight	Slow reaction	Prominent dull shine
Silty clay loam	Cast thrown moderate speed	Moderately hard, no grittiness	Crumbles w/high finger pressure, powdered w/ difficulty	Cast resists breaking, stick to target, can be removed	Smooth, sticky feel, some plasticity	Ribbon sustains weight and careful handling	Wire sustains weight and withstands gentle shaking	Very slow reaction	Faint shine
Silty clay	Cast thrown fast speed	Hard, no grittiness	Can be broken, difficult to powder	Cast difficult to remove from target	Smooth sticky plastic, faint fingerprints visible	Ribbon withstands considerable movement and deformation	Wire can withstand considerable shaking and rolling	No reaction	Shine
Clay	Cast only broken w/ hammer	Very hard, no grittiness	Broken w/difficulty, cannot be powdered	Cast scraped off target	Smooth very sticky, plastic fingerprints visible	Long thin ribbon	Wire can withstand shaking, rolling, bending; 1/16"	No reaction	Bright shine

[1] U.S. Soils Conservation Service.

APPENDIX C. UNIFIED SOIL CLASSIFICATION SYSTEM

Major divisions			Group symbols	Typical names	Laboratory classification criteria	
Coarse-grained soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5 per cent ..... GW, GP, SW, SP; More than 12 per cent ..... GM, GC, SM, SC; 5 to 12 per cent ..... Borderline cases requiring dual symbols**	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW
		Gravels with fines (Appreciable amount of fines)	GM* d	Silty gravels, gravel-sand-silt mixtures		Atterburg limits below "A" line or P.I. less than 4
			GM* u			Atterburg limits above "A" line with P.I. greater than 7
			GC	Clayey gravels, gravel-sand-clay mixtures		Above "A" line with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3
			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW
		Sands with fines (Appreciable amount of fines)	SM* d	Silty sands, sand-silt mixtures		Atterburg limits below "A" line or P.I. less than 4
			SM* u			Atterburg limits above "A" line with P.I. greater than 7
			SC	Clayey sands, sand-clay mixtures		Limits plotting in hatched zone with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols.
Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			OL	Organic silts and organic silty clays of low plasticity		
	Silts and clays (Liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			CH	Inorganic clays of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity, organic silts		
	Highly organic soils		Pt	Peat and other highly organic soils		



Plasticity Chart

*Division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is based on Atterburg limits; suffix d used when L.L. is 28 or less and the P.I. is 6 or less; the suffix u used when L.L. is greater than 28.

**Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example: GW-GC well-graded gravel sand mixture with clay binder.

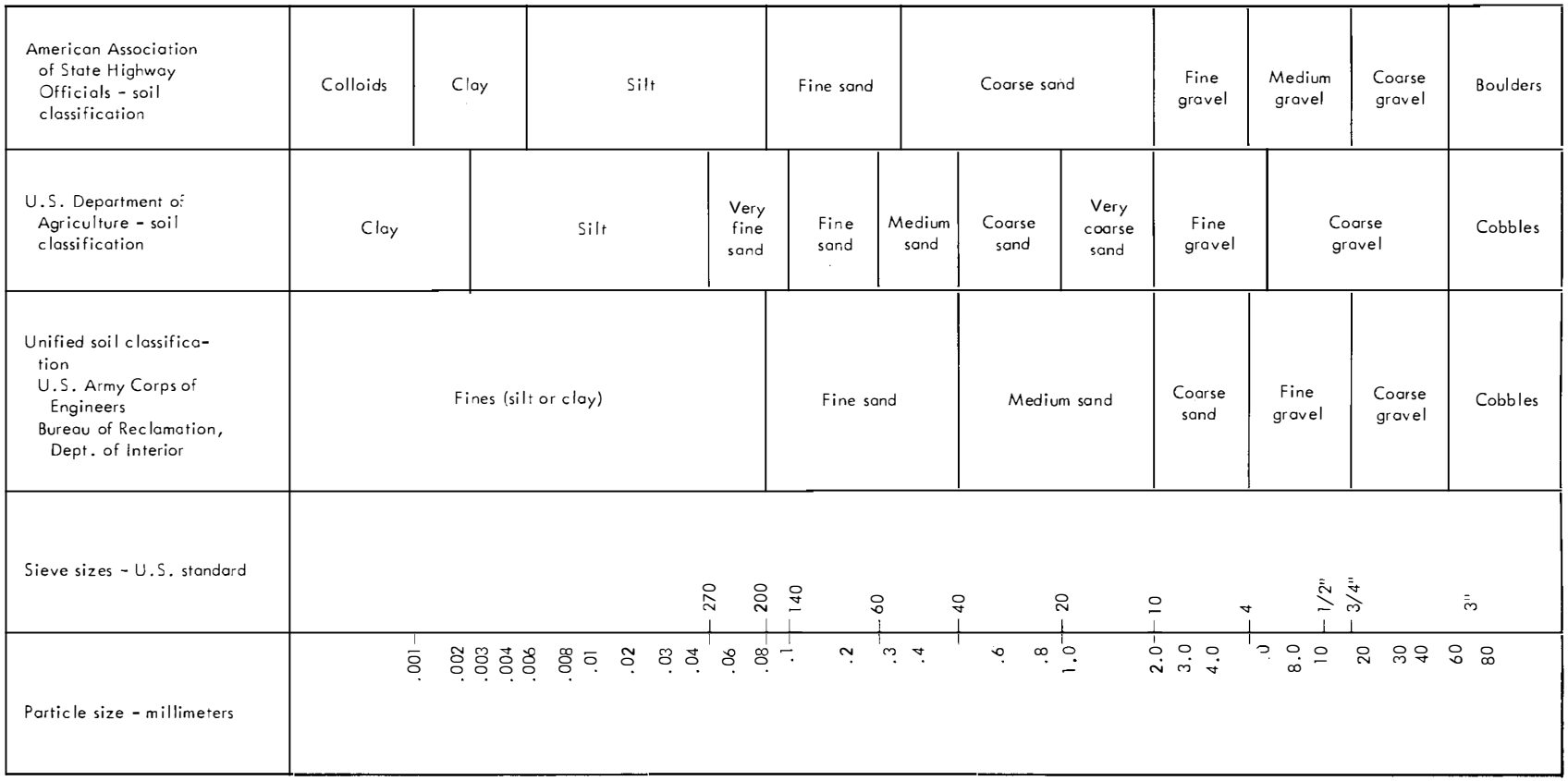
Reprinted from PCA Soil Primer

APPENDIX D. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS (AASHO) SOILS CLASSIFICATION

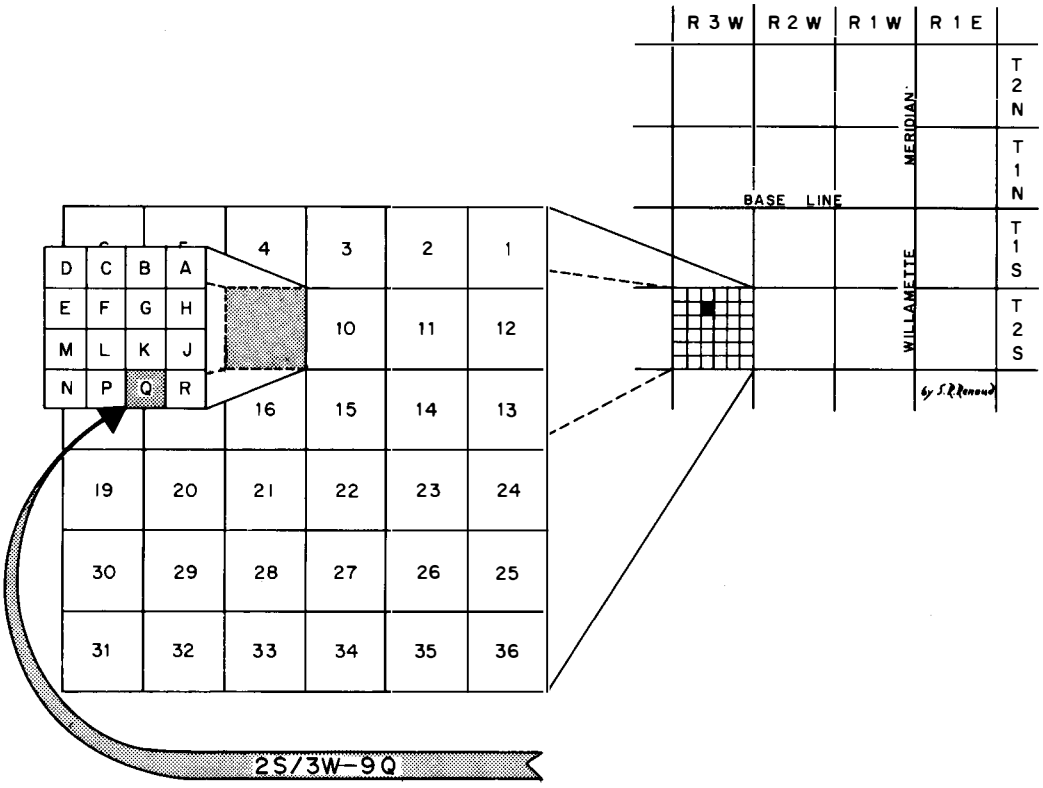
General classification			Group symbols	Grain size (sieve)	Atterburg limits for fraction passing No. 40		
					Liquid limit	Plasticity index*	
Granular materials Less than 35% is smaller than No. 200 sieve	Stone fragments gravel and sand	A-1	A-1-a	50% max. passes No. 10 30% max. passes No. 40 15% max. passes No. 200		Less than 6	Good to excellent subgrade
			A-1-6	50% max. passes No. 40 25% max. passes No. 200			
	Fine sand	A-3	A-3	50% min. passes No. 40 10% max. passes No. 200		N.P.	
	Silty or clayey gravel and sand	A-2	A-2-4	35% max. passes No. 200	Less than 40	Less than 10	
			A-2-5		Greater than 40	Less than 10	
			A-2-6		Less than 40	Greater than 10	
			A-2-7		Greater than 40	Greater than 10	
Silt-clay materials More than 35% is smaller than No. 200 sieve	Silty soils	A-4	A-4	Greater than 35% passes No. 200	Less than 40	Less than 10	Poor to fair subgrade
		A-5	A-5		Greater than 40	Less than 10	
	Clayey soils	A-6	A-6		Less than 40	Greater than 10	
		A-7	A-7-5 and A-7-6		Greater than 40	Greater than 10	

*The difference between liquid limit and plastic limit; the range of water content through which the soil behaves plasticly.

APPENDIX E. COMPARISON OF THREE SYSTEMS OF PARTICLE-SIZE CLASSIFICATION



APPENDIX F. WATER-WELL NUMBERING SYSTEM



Wells are designated by symbols that indicate location according to the rectangular subdivision of public lands. Thus, in the above example:

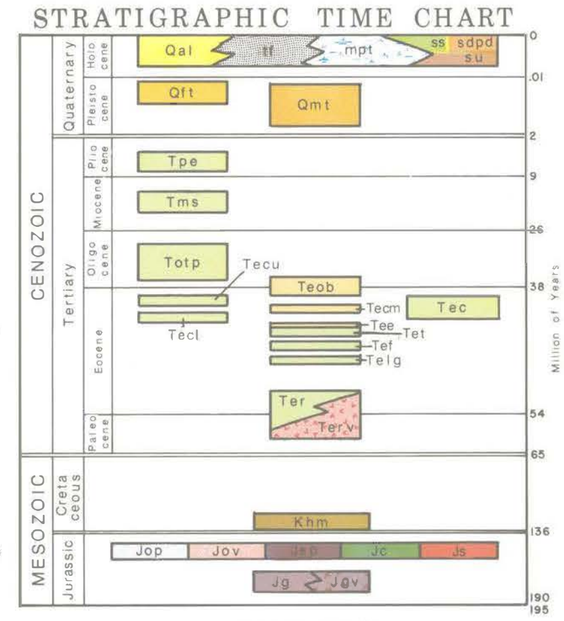
2S refers to Township 2 south
3W refers to Range 3 west
9 refers to Section 9
Q refers to tract Q

GEOLOGIC MAP
of the
BANDON & part of LANGLOIS QUADRAGLES
OREGON

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST



STRATIGRAPHIC TIME CHART



EXPLANATION

Surficial Geologic Units

fs — fill and spoils: *Sand, silt, gravel, sawdust, wood chips, dredge spoils, and other material placed in wetland areas and on slopes for disposal or to provide space for development; adequate foundation strength for small structures if properly placed; nature of substrate variable and includes compressible soils locally; hazards include flooding, differential settling, and amplification of seismic waves in areas of thick estuarine fill.*

ss — stable sand: *Unconsolidated fine- to medium-grained dune sand protected from wind erosion by natural or artificially introduced vegetation; thickness up to 200 feet in large dune fields, much thinner south of Bandon; ground-water production high; hazards include stream erosion, high ground water, ground-water pollution, overwithdrawal of ground water, and ocean flooding at low elevations; unit may overlie organic soils and ancient soil horizons with other properties; does not include stable sand overlying Qmt.*

su — nstable dune sand: *Unconsolidated fine- to medium-grained sand of large dunes not protected from wind erosion by vegetation; thickness, hazards and ground-water potential similar to those of stable sand; also wind erosion and wind deposition, especially in excavations or around structures; unit may overlie compressible soils or other ancient soil horizons.*

sdpb — deflation plain and beach sand: *Unconsolidated fine- to medium-grained sand of beaches, flat-lying interdune areas and transverse dune fields; thickness, hazards, and ground-water potential similar to those of stable sand; possible presence of iron-pan layers at shallow depths; possible extreme variability vertically in permeability and degree of consolidation; preservation of vegetative cover dependent on water table.*

tf — tidal flat: *Unconsolidated mud, silt, clay, and sand in the tidal zone of estuaries and other coastal wetlands; sediments compacted or high in organic material locally; hazards may also include amplification of seismic waves and ocean flooding; may be present beneath some dune sands.*

mpf — marsh and peat: *Unconsolidated organic soils of silt, clay, and sand in estuarine and fresh-water wetland areas; characterized by abundant vegetation, ponding, or high water table, hazards also include low foundation strength and stream or ocean flooding; organic soils may be present in the subsurface beneath other alluvial units or dune sands.*

Qal — Quaternary alluvium: *Unconsolidated deposits of sand, silt, clay, and mud in the flood plains of major streams draining sandstone and siltstone terrain, and gravel, sand, and silt along the middle and upper reaches of rivers draining Pre-Tertiary or volcanic terrain; grain size typically increases with depth; ground-water production moderate; associated with fresh water marsh and peat in places; hazards include stream-bank erosion, ponding, high ground water, flooding, siltation, and compressible soils locally.*

Qft — Quaternary fluvial terrace deposits: *Unconsolidated to semi-consolidated flat-lying and elevated deposits of river alluvium overlooking present stream valleys (Quaternary alluvium) and situated above the present levels of flooding; also includes fine-grained terrace deposits of estuarine origin; grain-size distributions similar to those of Quaternary alluvium and estuarine deposits: moderate ground-water production; hazards include ponding, local high ground water, and stream-bank erosion.*

Qmt — Quaternary marine terrace deposits: *Unconsolidated to semi-consolidated flat-lying and elevated marine deposits of sand, silt, clay and gravel locally; thicknesses vary from 10 to 50 feet, but locally are as little as 2 to 3 feet; elevations range from a few feet to several hundred feet near Coos Bay to almost 2,000 feet farther inland; ground-water production low to moderate; hazards may include headland erosion, stream-bank erosion, poor drainage, failure in deep cuts, and others, but generally are negligible; coastal Qmt mantled by stable dune sand.*

Bedrock Geologic Units

Sandstone of Tertiary Age

Tpe — Empire Formation (Pliocene): *Thickly bedded, hard, marine sandstone with minor thin interbeds of siltstone; impermeable, firm foundations; mantled with loamy sand, sandy loam, and silty loam; hazards include rockfall in coastal cliffs and variable erosion and mass movement; limited in distribution to the South Slough area.*

Tms — Miocene sedimentary rocks: *Calcareous, medium-grained, hard, gray sandstone exposed at Pigeon Point and recovered from nearby dredgings; indicates shallow depth to bedroch in southern extremities of entrance of Coos Bay estuary.*

Totp — Tunnel Point Formation (Oligocene): *Coarse- to fine-grained tuffaceous sandstone and minor siltstone exposed only at Tunnel Point near the entrance to Coos Bay; subject to slow headland erosion prior to the development of Bastendorff Beach.*

Tecu Tecl — Coaledo Formation, upper and lower members (late Eocene): *Coarse- to fine-grained, hard, deltaic sandstone with interbeds of softer siltstone; well-developed bedding; conglomerate and coal beds present locally with more extensive coal deposits at depth; overlain by loamy sand, sandy loam and silty loam; low permeability and ground water potential; hazards may include slow to sporadic headland erosion locally and earthflow in deep cuts; flooding in coal mines minimal.*

Tec — Coaledo Formation, undifferentiated (late Eocene): *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in sandstone content; lithology and hazards similar to that of the upper and lower Coaledo Formation; precise distribution determined by on-site inspection.*

Tet — Tyee Formation (middle Eocene): *Thick sequence of rhythmically bedded, hard sandstone and minor siltstone; coal-bearing at Eden Ridge; impermeable, but with moderate infiltration along joints and faults; very low ground-water potential; mantled with sandy loam and silty loam soils that locally are very thin; hazards include flash flooding, erosion, rapid earthflow, and debris flows.*

Tef — Flournoy Formation (middle Eocene): *Lithology and soils similar to those of the Tyee Formation except for increased siltstone content high in the section; mantled by sandy loam and silty loam; hazards and ground-water potential similar to those of the Tyee Formation.*

Telg — Lookingglass Formation (middle Eocene): *Lithology, ground-water potential, and hazards similar to those of the Tyee Formation, but thinner bedded and conglomeratic near the base locally; mantled by sandy loam and silty loam.*

Ter — Roseburg Formation — sedimentary rocks (lower Eocene and older): *Rhythmically bedded hard sandstone and siltstone; low permeability and low ground-water potential; faulted and sheared in southern Coos County to produce extensive mass movement terrain and subdued topography; mantled by silt loam and loamy sand; hazards include mass movement, erosion, and variable foundation conditions.*

Siltstone of Tertiary Age

Teob — Bastendorff Formation (late Eocene and early Oligocene): *Thinly bedded shale and siltstone confined to the South Slough, Isthmus Slough and Catching Creek areas; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow mass movement, and failures in deep cuts.*

Tecm — Coaledo Formation — middle member (late Eocene): *Thinly bedded siltstone with minor sandstone interbeds; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow headland erosion, and local mass movement.*

Tec — Coaledo Formation — undifferentiated (late Eocene): *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in siltstone content; lithology and hazards similar to those of the middle member of the Coaledo Formation; precise distribution determined by on-site inspection.*

Tee — Elkton Formation (middle Eocene): *Thinly bedded siltstone with minor sandstone interbeds; mantled with silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion and mass movement.*

Basalt of Tertiary Age

Terv — Roseburg Formation — basalt (early Eocene): *Marine basalt of variable lithology including pillow basalt, basaltic breccia and intrusive basalt; hardness, jointing, alteration, and potential use variable; widespread low-grade alteration; interfingers with sedimentary rock of the Roseburg Formation; mantled by silty clay loam and silty loam a few inches to several tens of feet in thickness; hazards include rapid erosion and mass movement.*

Rocks of Pre-Tertiary Age

Khm — Humbug Mountain Conglomerate (early Cretaceous): *Small exposure of bedded conglomerate and sandstone.*

Jop Jov Js Jc Jsp — Otter Point Formation (Jurassic): *A tectonically sheared assemblage of rocks including pervasively sheared sedimentary rocks (Jop) now prone to regional mass movement and subordinate amounts of sheared to intact volcanic rock (Jov), isolated blocks of thinly bedded lightly folded chert (Jc), exposures of serpentinite (Jsp), and isolated blocks of resistant blueschist (Js), a medium-grade metamorphic rock. Soil types, thicknesses, and properties highly variable; major hazards include mass movement, slope erosion, stream-bank erosion, and variable bearing strength.*

Jgv Jg — Galice Formation (Jurassic): *Limited exposures of volcanic rock and bedded siltstone.*

Geologic Symbols

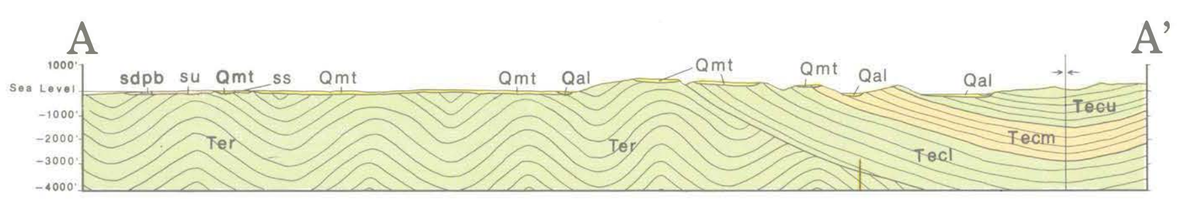
Contacts — Faults
Folds — Syncline — Anticline
Attitudes — Strike and dip of Beds and flows — Horizontal beds and flows

Research for this map sponsored in part by the U.S. Geological Survey, Department of the Interior, under USGS Grant No. 14-08-0001-G-135.

Cartography by S. R. Renoud 1975

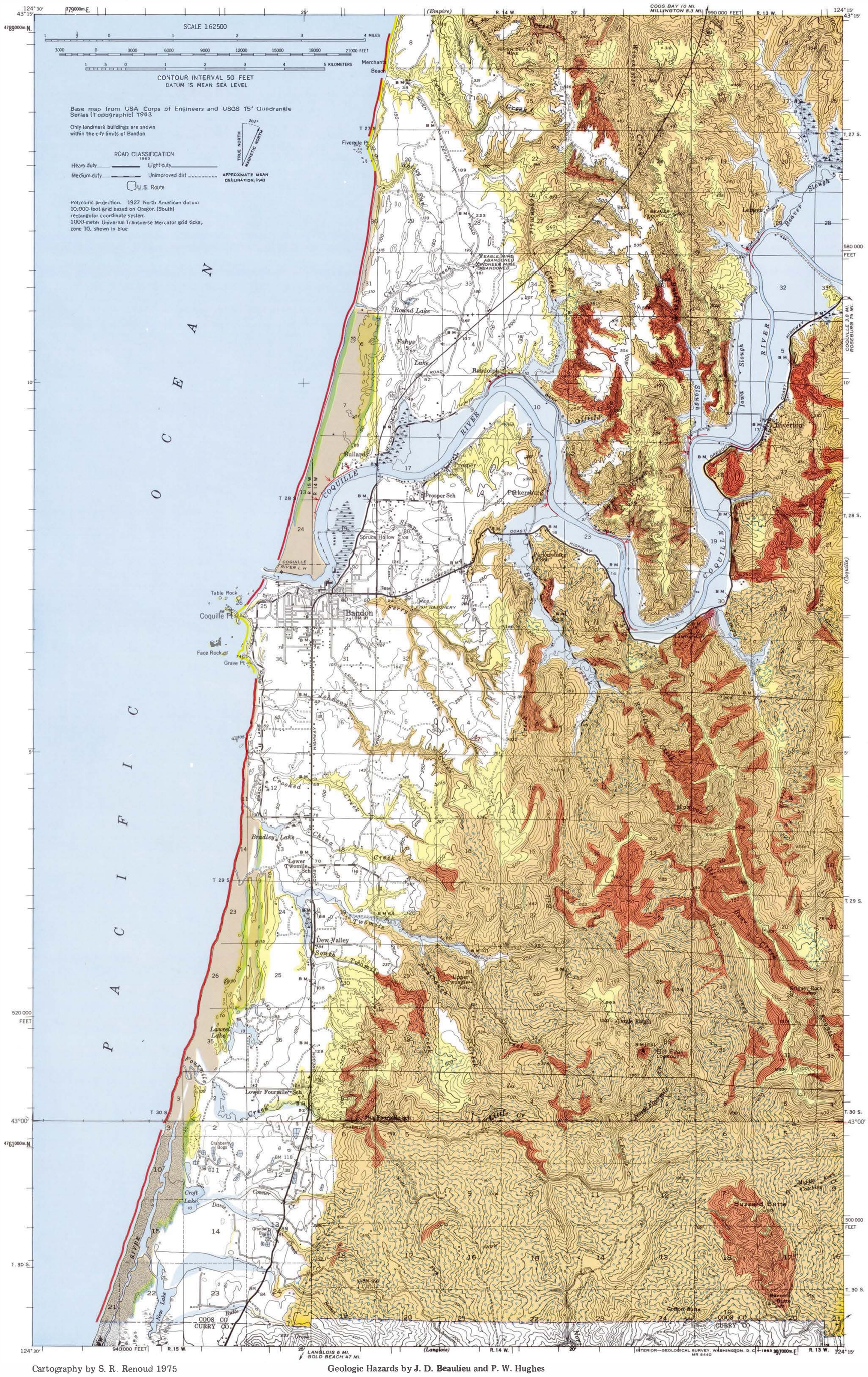
Surficial Geology by J. D. Beaulieu
Bedrock Geology by E. M. Baldwin 1973

Geologic Cross Section



GEOLOGIC HAZARD MAP
of the
BANDON & part of LANGLOIS QUADRAGLES
OREGON

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EXPLANATION

(Boundaries are approximate; statements are general; site-specific decisions require on-site inspection.)

Regional Slope

0 - 5% — *0-15% slopes locally; landforms include beaches, flood plains and other wetlands, fluvial and marine terraces; hazards include flooding, erosion, deposition, ponding, high ground water, compressible soils, and possible amplification of earthquake vibrations; land use potential excellent to good in areas of minimal hazards.*

5 - 15% — *Local slopes to 50% and 100% in some dunes areas; landforms include dunes, marine terraces, and gentle uplands; hazards include negligible to moderate erosion and deposition by stream, wind, and wave depending on setting; land use potential is excellent to good in regions of minimal or controllable hazards.*

15 - 30% — *Up to 50% slopes locally; landforms include parts of terraces, coastal uplands, and some valleys; hazards include moderate to rapid erosion on slopes and along streams and slow to rapid earthflow; land use potential is variable and is generally restricted to low-density residential use, forestry and other low-intensity development.*

30 - 50% — *Greater than 50% slopes locally; landforms include uplands and some small valleys in more gently sloping terrain; hazards include moderate to rapid erosion, earthflow, and debris slides; land use potential is generally limited to sparse development and forestry.*

> 50% — *50% to vertical locally; landforms include uplands of the interior and sea cliffs; hazards include extreme erosion, rapid earthflow, debris flow, rockslide, and rockfall; land use potential restricted to well-managed logging and open space.*

Flooding

Preliminary Intermediate Regional (100-year) Flood: *Extent of flood (determined from preliminary data developed by the U.S. Geological Survey and Douglas County) having a 1 percent probability of occurring in any given year. Levees at Reedsport provide protection from the 100-year flood. Other levees in the lower Umpqua and Smith Rivers provide protection for 25-year floods.*

Flood Prone Areas: *Areas subject to flood hazard approximately equivalent to the Intermediate Regional Flood based on topography and scattered observations; differs from Intermediate Regional Flood in the absence of gage data and rigorous statistical treatment; also, based on little empirical data relative to the Maximum Composite Flood.*

Composite Maximum Historical Flood: *Areas that are known to have experienced flooding in the past but for which no sophisticated computer modeling is available; based on field observations, extensive personal interviews, and other investigations by the U.S. Soils Conservation Service, and also on data provided by the U.S.G.S., the U.S. Army Corps of Engineers, and the Oregon Water Resources Board. Period of observation approximately 100 years.*

Major Flash Flood: *Small- to medium-sized stream channels situated in areas of moderate to steep slope, moderate to high relief, and low permeability, for which catastrophic streamflows have a high probability of occurrence; characterized by narrow canyons, coarse, poorly sorted stream-bed deposits and the absence of a flood plain; permanent structures not feasible with the exception of properly engineered roads.*

Potential Ocean Flooding: *Low-lying coastal areas, marshes, and contiguous wetlands subject to tidal flooding, storm-surge flooding, and tsunami inundation; highest possible tides are approximately 6 feet above mean sea level; storm surges may add 4 feet to this, exclusive of wave action. Tsunamis with amplitudes of 15 feet are possible and may have runups to elevations of 20-25 feet above concurrent water level. Major impact concentrates on headlands, coves, beaches, and spit extremities; dissipation in the estuaries.*

Erosion and Deposition

Regional Wind Erosion: *Deflation basins, windward sides of unstable dunes, beaches, and other areas of exposed sand not protected by vegetation; promoted by over-grazing, removal of protective cover, lowering of interdune water tables, and rapid deposition along the coastline; prevented by preserving or restoring compatible vegetation.*

Wind Deposition: *Sand deposition on the windward side of active dunes; rates vary from a few inches to a few feet per year depending on dune size, protective cover, extent of source area, and local wind conditions; prevented by stabilizing source area, proper location of projects, and proper planning.*

Potential Beach Erosion and Deposition: *Areas for which jetty construction, beach excavations, channel dredging, spoil disposal, and other artificial changes will initiate future beach erosion and/or deposition; extent of impact varies with size of project; beach areas presently stabilized with exception of seasonal variations.*

Headland Erosion: *Removal of headlands by waves; extremely slow in Pre-Tertiary terrain, sporadic to slow in Sandstone of Tertiary Age, and uniform and slow (several inches per year maximum) in Siltstone of Tertiary Age; no viable means of prevention; impact minimized by proper setback of structures.*

Critical Stream Bank Erosion: *Undercutting and caving of river and stream-bank material by stream action; restricted primarily to flood plains except in upper reaches of large rivers; characterized by location on river bends, bar growth on opposite bank, and relatively deep water near shore; passes upstream into flash-flood channels and downstream into estuarine deposition. Properly engineered riprap provides local correction.*

Mass Movement

Earthflow and Slump Topography: *Terrain characterized by such features as irregular topography, moderate slopes, irregular drainage, irregular soil distribution, and occasionally features of recent movement including tension cracks and bowed trees (depending upon type, depth, and time of failure); generally restricted to the soil zone but also bedrock in sheared or deeply weathered terrain; hazards include ground movement, variable foundation strength, caving in excavations, poor drainage, and others. Excavations, stream-bank erosion, fills, drainage modifications, removal of vegetation, and use of drain fields and septic tanks may reactivate or accelerate sliding. On-site inspection recommended prior to development.*

Deep Bedrock Failure: *Areas of deep bedrock failure initiated by prolonged stream-bank erosion over extended periods of time in the geologic past; restricted to sandstone terrain in the interior uplands; presently inactive with the exception of localized areas within the slides; major hazards include variations in drainage, soil conditions, and foundation strength.*

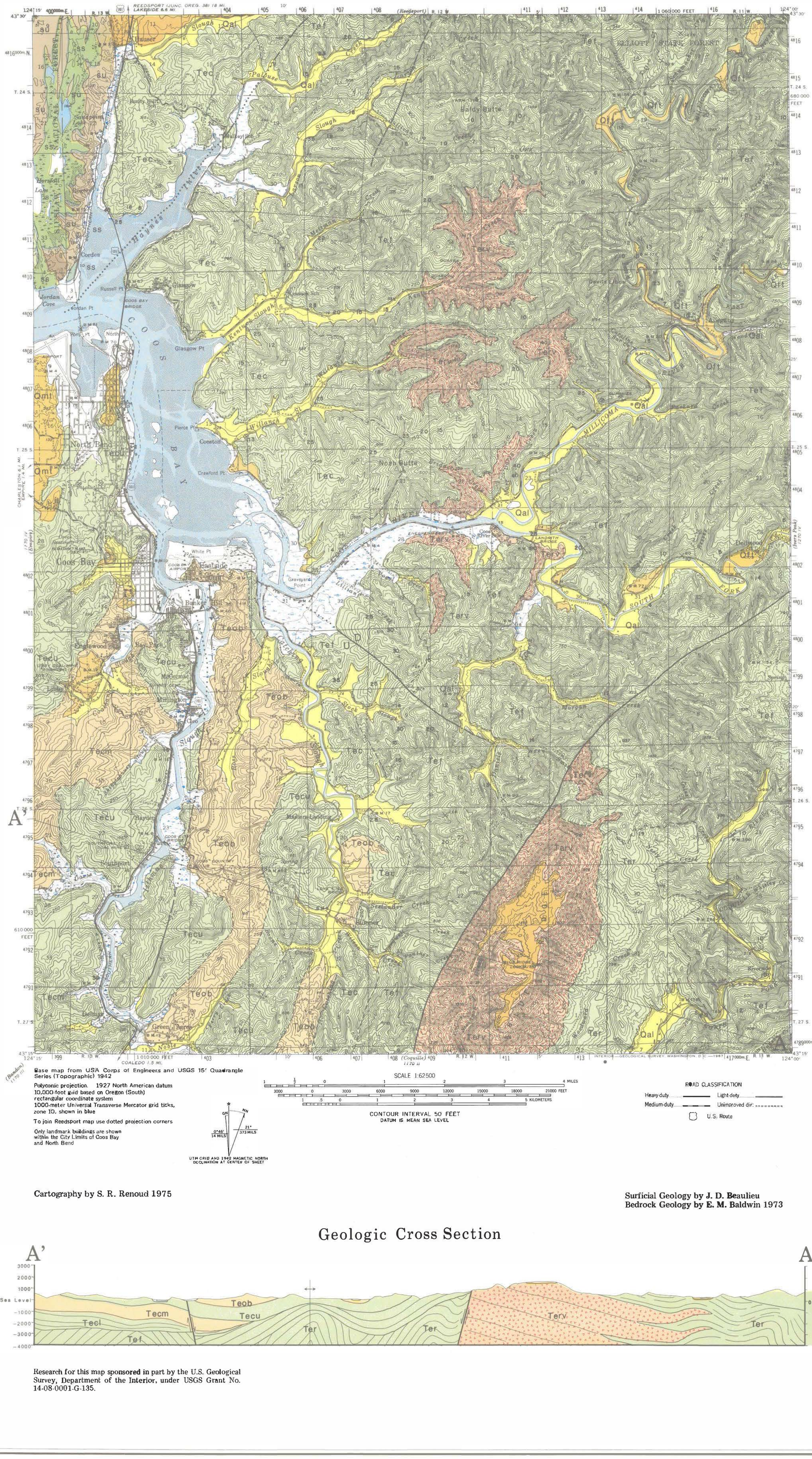
Rockfall and Debris Flow Terrain: *Areas with slopes greater than 50% regionally are subject to rapid and shallow mass movement such as debris flow, rock slide, and rock-fall. Recent large individual debris flows are indicated with arrows. The specific location of individual mass movements is a function of rock and soil characteristics, weathering history, vegetative cover, and present land use. Treatment includes retaining walls, preservation of vegetative cover, drainage control, screening of critical slopes, and proper engineering of all construction, especially roadcuts and fills.*

Cartography by S. R. Renoud 1975

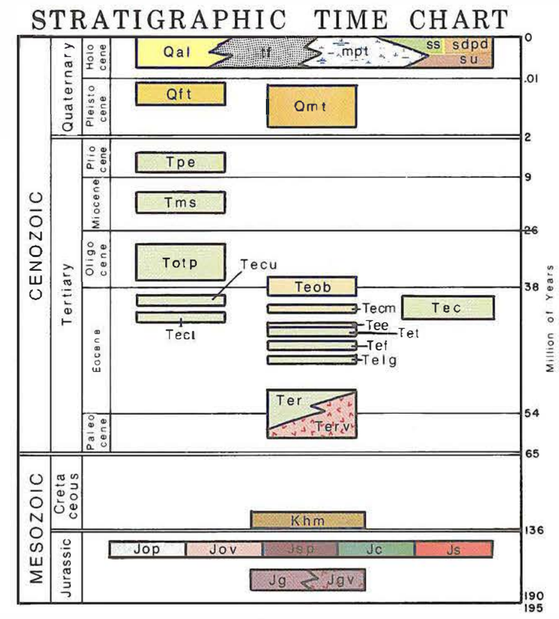
Geologic Hazards by J. D. Beaulieu and P. W. Hughes

GEOLOGIC MAP
of the
COOS BAY QUADRANGLE
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STRATIGRAPHIC TIME CHART



EXPLANATION

Surficial Geologic Units

fs — **fill and spoils:** *Sand, silt, gravel, sawdust, wood chips, dredge spoils, and other material placed in wetland areas and on slopes for disposal or to provide space for development; adequate foundation strength for small structures if properly placed; nature of substrate variable and includes compressible soils locally; hazards include flooding, differential settling, and amplification of seismic waves in areas of thick estuarine fill.*

ss — **stable sand:** *Unconsolidated fine- to medium-grained dune sand protected from wind erosion by natural or artificially introduced vegetation; thickness up to 200 feet in large dune fields, much thinner south of Bandon; ground-water production high; hazards include stream erosion, high ground water, ground-water pollution, overwithdrawal of ground water, and ocean flooding at low elevations; unit may overlie organic soils and ancient soil horizons with other properties; does not include stable sand overlying Qmt.*

su — **unstable dune sand:** *Unconsolidated fine- to medium-grained sand of large dunes not protected from wind erosion by vegetation; thickness, hazards and ground-water potential similar to those of stable sand; also wind erosion and wind deposition, especially in excavations or around structures; unit may overlie compressible soils or other ancient soil horizons.*

sdpb — **deflation plain and beach sand:** *Unconsolidated fine- to medium-grained sand of beaches, flat-lying interdune areas and transverse dune fields; thickness, hazards, and ground-water potential similar to those of stable sand; possible presence of iron-pan layers at shallow depths; possible extreme variability vertically in permeability and degree of consolidation; preservation of vegetative cover dependent on water table.*

tf — **tidal flat:** *Unconsolidated mud, silt, clay, and sand in the tidal zone of estuaries and other coastal wetlands; sediments compacted or high in organic material locally; hazards may also include amplification of seismic waves and ocean flooding; may be present beneath some dune sands.*

mpt — **marsh and peat:** *Unconsolidated organic soils of silt, clay, and sand in estuarine and fresh-water wetland areas; characterized by abundant vegetation, ponding, or high water table, hazards also include low foundation strength and stream or ocean flooding; organic soils may be present in the subsurface beneath other alluvial units or dune sands.*

Qal — **Quaternary alluvium:** *Unconsolidated deposits of sand, silt, clay, and mud in the flood plains of major streams draining sandstone and siltstone terrain, and gravel, sand, and silt along the middle and upper reaches of rivers draining Pre-Tertiary or volcanic terrain; grain size typically increases with depth; ground-water production moderate; associated with fresh water marsh and peat in places; hazards include stream-bank erosion, ponding, high ground water, flooding, siltation, and compressible soils locally.*

Qft — **Quaternary fluvial terrace deposits:** *Unconsolidated to semi-consolidated flat-lying and elevated deposits of river alluvium overlooking present stream valleys (Quaternary alluvium) and situated above the present levels of flooding; also includes fine-grained terrace deposits of estuarine origin; grain-size distributions similar to those of Quaternary alluvium and estuarine deposits; moderate ground-water production; hazards include ponding, local high ground water, and stream-bank erosion.*

Qmt — **Quaternary marine terrace deposits:** *Unconsolidated to semi-consolidated flat-lying and elevated marine deposits of sand, silt, clay and gravel locally; thicknesses vary from 10 to 50 feet, but locally are as little as 3 to 3 feet; elevations range from a few feet to several hundred feet near Coos Bay to almost 2,000 feet farther inland; ground-water production low to moderate; hazards may include headland erosion, stream-bank erosion, poor drainage, failure in deep cuts, and others, but generally are negligible; coastal Qmt mantled by stable dune sand.*

Bedrock Geologic Units

Sandstone of Tertiary Age

Tpe — **Empire Formation (Pliocene):** *Thickly bedded, hard, marine sandstone with minor thin interbeds of siltstone; impermeable, firm foundations; mantled with loamy sand, sandy loam, and silty loam; hazards include rockfall in coastal cliffs and variable erosion and mass movement; limited in distribution to the South Slough area.*

Tms — **Miocene sedimentary rocks:** *Calcareous, medium-grained, hard, gray sandstone exposed at Pigeon Point and recovered from nearby dredgings; indicates shallow depth to bedrock in southern extremities of entrance of Coos Bay estuary.*

Totp — **Tunnel Point Formation (Oligocene):** *Coarse- to fine-grained tuffaceous sandstone and minor siltstone exposed only at Tunnel Point near the entrance to Coos Bay; subject to slow headland erosion prior to the development of Bastendorff Beach.*

Tecu Tecl — **Coaledo Formation, upper and lower members (late Eocene):** *Coarse- to fine-grained, hard, deltaic sandstone with interbeds of softer siltstone; well-developed bedding; conglomerate and coal beds present locally with more extensive coal deposits at depth; overlain by loamy sand, sandy loam and silty loam; low permeability and ground water potential; hazards may include slow to sporadic headland erosion locally and earthflow in deep cuts; flooding in coal mines minimal.*

Tec — **Coaledo Formation, undifferentiated (late Eocene):** *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in sandstone content; lithology and hazards similar to that of the upper and lower Coaledo Formation; precise distribution determined by on-site inspection.*

Tet — **Tyee Formation (middle Eocene):** *Thick sequence of rhythmically bedded, hard sandstone and minor siltstone; coal-bearing at Eden Ridge; impermeable, but with moderate infiltration along joints and faults; very low ground-water potential; mantled with sandy loam and silty loam soils that locally are very thin; hazards include flash flooding, erosion, rapid earthflow, and debris flows.*

Tef — **Flournoy Formation (middle Eocene):** *Lithology and soils similar to those of the Tyee Formation except for increased siltstone content high in the section; mantled by sandy loam and silty loam; hazards and ground-water potential similar to those of the Tyee Formation.*

Telg — **Lookingglass Formation (middle Eocene):** *Lithology, ground-water potential, and hazards similar to those of the Tyee Formation, but thinner bedded and conglomeratic near the base locally; mantled by sandy loam and silty loam.*

Ter — **Roseburg Formation — sedimentary rocks (lower Eocene and older):** *Rhythmically bedded hard sandstone and siltstone; low permeability and low ground-water potential; faulted and sheared in southern Coos County to produce extensive mass movement terrain and subdued topography; mantled by silt loam and loamy sand; hazards include mass movement, erosion, and variable foundation conditions.*

Siltstone of Tertiary Age

Teob — **Bastendorff Formation (late Eocene and early Oligocene):** *Thinly bedded shale and siltstone confined to the South Slough, Isthmus Slough and Catching Creek areas; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow mass movement, and failures in deep cuts.*

Tecm — **Coaledo Formation — middle member (late Eocene):** *Thinly bedded siltstone with minor sandstone interbeds; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow headland erosion, and local mass movement.*

Tec — **Coaledo Formation — undifferentiated (late Eocene):** *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in siltstone content; lithology and hazards similar to those of the middle member of the Coaledo Formation; precise distribution determined by on-site inspection.*

Tee — **Elkton Formation (middle Eocene):** *Thinly bedded siltstone with minor sandstone interbeds; mantled with silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion and mass movement.*

Basalt of Tertiary Age

Terv — **Roseburg Formation — basalt (early Eocene):** *Marine basalt of variable lithology including pillow basalt, basaltic breccia and intrusive basalt; hardness, jointing, alteration, and potential use variable; widespread low-grade alteration; interfingers with sedimentary rock of the Roseburg Formation; mantled by silty clay loam and silty loam a few inches to several tens of feet in thickness; hazards include rapid erosion and mass movement.*

Rocks of Pre-Tertiary Age

Khm — **Humbug Mountain Conglomerate (early Cretaceous):** *Small exposure of bedded conglomerate and sandstone.*

Jop Jov Js Jc — **Otter Point Formation (Jurassic):** *A tectonically sheared assemblage of rocks including pervasively sheared sedimentary rocks (Jsp) now prone to regional mass movement and subordinate amounts of sheared to intact volcanic rock (Jov), isolated blocks of thinly bedded tightly folded chert (Jc), exposures of serpentinite (Jsp), and isolated blocks of resistant blueschist (Js), a medium-grade metamorphic rock. Soil types, thicknesses, and properties highly variable; major hazards include mass movement, slope erosion, stream-bank erosion, and variable bearing strength.*

Jgv Jg — **Galice Formation (Jurassic):** *Limited exposures of volcanic rock and bedded siltstone.*

Geologic Symbols

Contacts — Faults — Folds — Syncline — Anticline — Attitudes — Strike and dip of Beds and flows — Horizontal bed and flows

Geologic Cross Section

Base map from USA Corps of Engineers and USGS 15′ Quadrangle Series (Topographic) 1942

Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon (South) rectangular coordinate system
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

To join Reedsport map use dotted projection corners

Only landmark buildings are shown within the City Limits of Coos Bay and North Bend

SCALE 1:62500

1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1942 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
GN MN
0°46′ 14 MILS
21° 373 MILS

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dir:
U.S. Route

Cartography by S. R. Renoud 1975

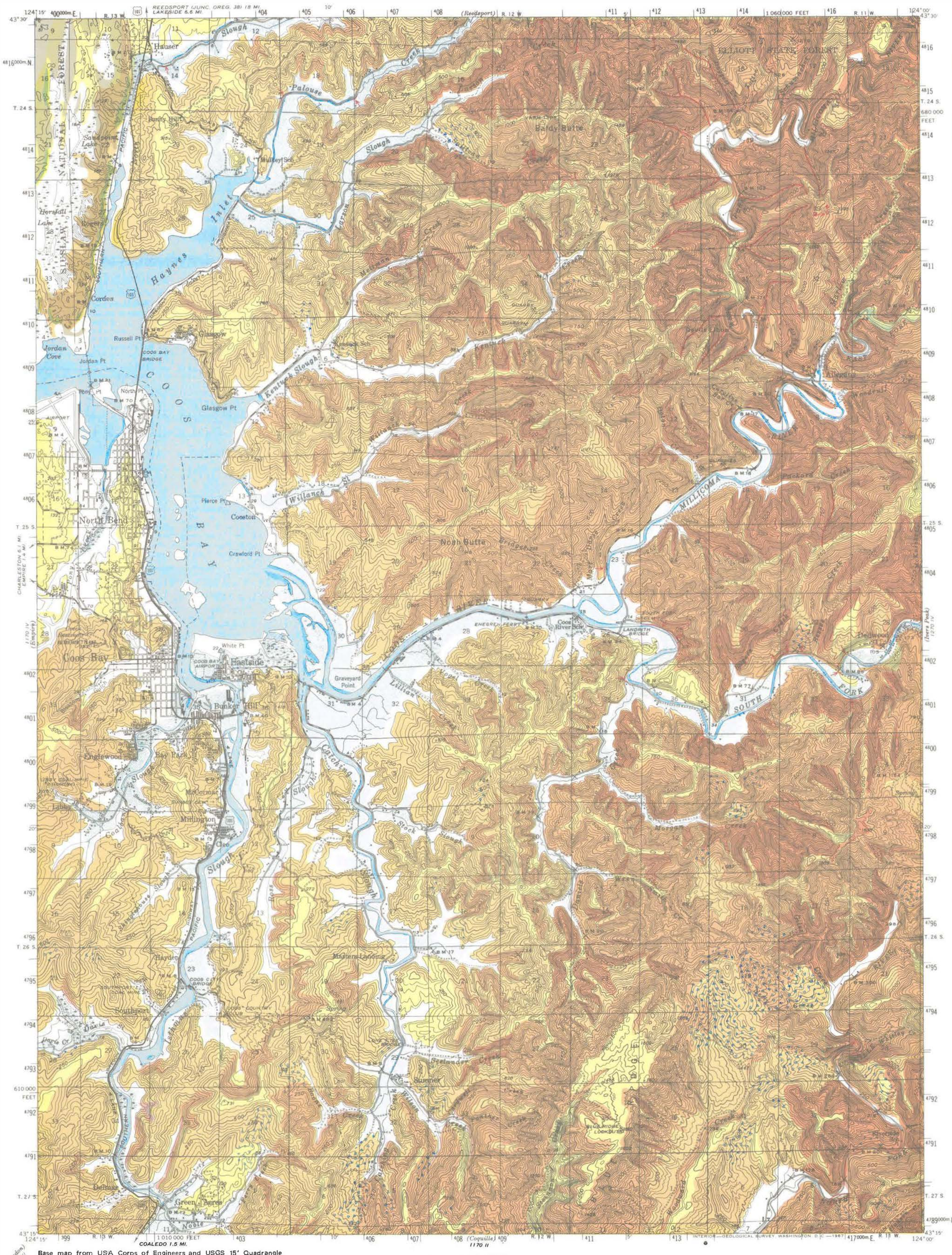
Surficial Geology by J. D. Beaulieu
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Research for this map sponsored in part by the U.S. Geological Survey, Department of the Interior, under USGS Grant No. 14-08-0001-G-135.

COALEDO 1.5 MI. — INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1967

GEOLOGIC HAZARD MAP
of the
COOS BAY QUADRANGLE
OREGON

STATE OF OREGON
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INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1967

EXPLANATION

(Boundaries are approximate; statements are general; site-specific decisions require on-site inspection.)

Regional Slope

0 - 5% — *0-15% slopes locally; landforms include beaches, flood plains and other wetlands, fluvial and marine terraces; hazards include flooding, erosion, deposition, ponding, high ground water, compressible soils, and possible amplification of earthquake vibrations; land use potential excellent to good in areas of minimal hazards.*

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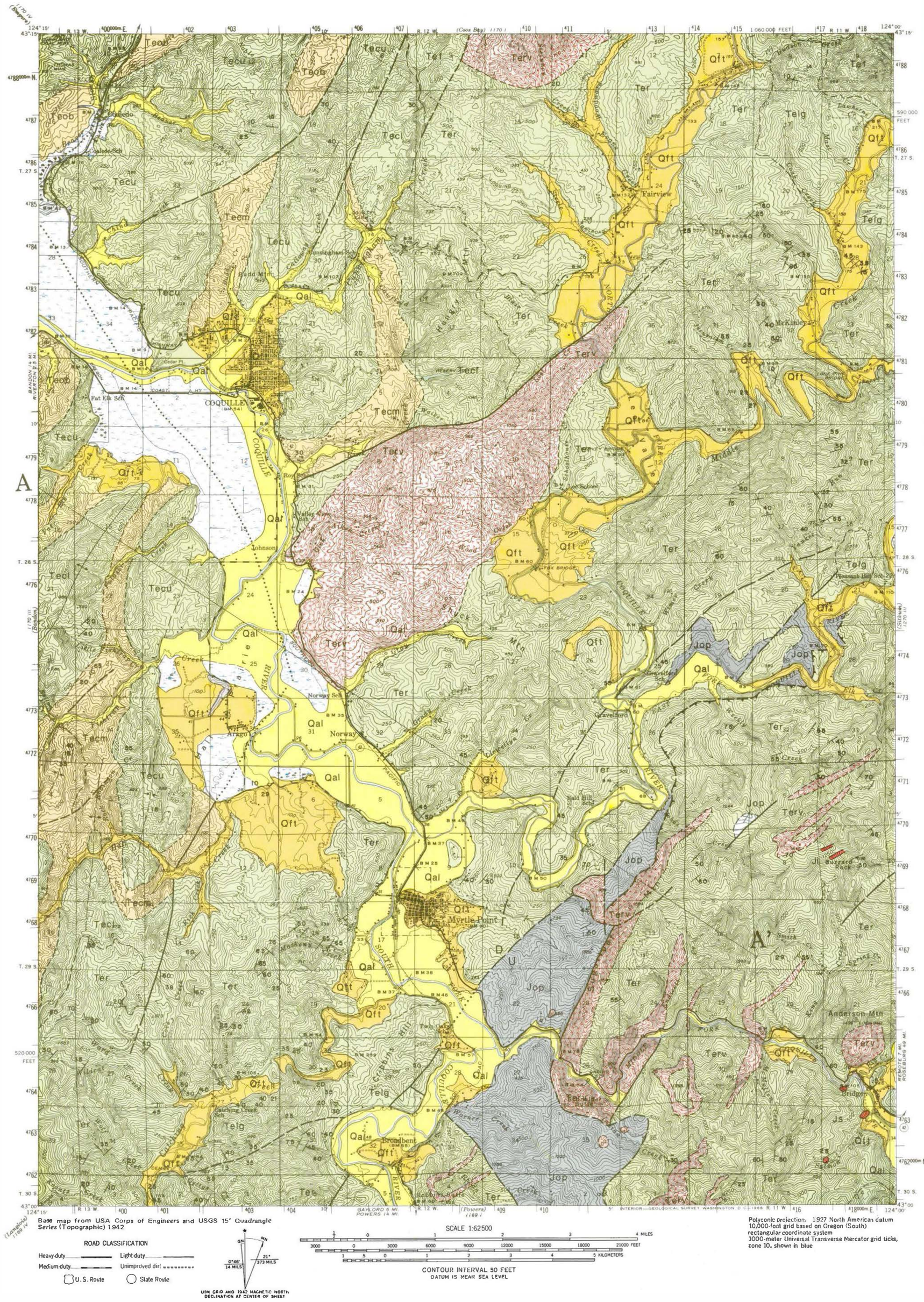
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Cartography by S. R. Renoud 1975

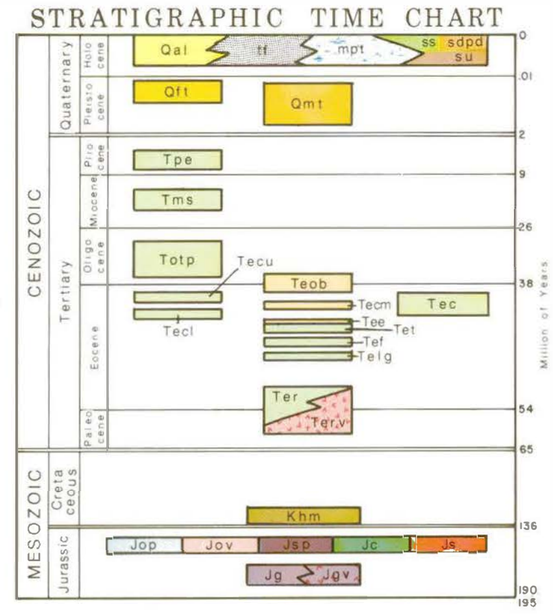
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STRATIGRAPHIC TIME CHART



EXPLANATION

Surficial Geologic Units

fs — **fill and spoils:** *Sand, silt, gravel, sawdust, wood chips, dredge spoils, and other material placed in wetland areas and on slopes for disposal or to provide space for development; adequate foundation strength for small structures if property placed; nature of substrate variable and includes compressible soils locally; hazards include flooding, differential settling, and amplification of seismic waves in areas of thick estuarine fill.*

ss — **stable sand:** *Unconsolidated fine- to medium-grained dune sand protected from wind erosion by natural or artificially introduced vegetation; thickness up to 200 feet in large dune fields, much thinner south of Bandon; ground-water production high; hazards include stream erosion, high ground water, ground-water pollution, overwithdrawal of ground water, and ocean flooding at low elevations; unit may overlie organic soils and ancient soil horizons with other properties; does not include stable sand overlying Qmt.*

su — **unstable dune sand:** *Unconsolidated fine- to medium-grained sand of large dunes not protected from wind erosion by vegetation; thickness, hazards and ground-water potential similar to those of stable sand; also wind erosion and wind deposition, especially in excavations or around structures; unit may overlie compressible soils or other ancient soil horizons.*

sdpb — **deflation plain and beach sand:** *Unconsolidated fine- to medium-grained sand of beaches, flat-lying interdune areas and transverse dune fields; thickness, hazards, and ground-water potential similar to those of stable sand; possible presence of iron-pan layers at shallow depths; possible extreme variability vertically in permeability and degree of consolidation; preservation of vegetative cover dependent on water table.*

tf — **tidal flat:** *Unconsolidated mud, silt, clay, and sand in the tidal zone of estuaries and other coastal wetlands; sediments compacted or high in organic material locally; hazards may also include amplification of seismic waves and ocean flooding; may be present beneath some dune sands.*

mpt — **marsh and peat:** *Unconsolidated organic soils of silt, clay, and sand in estuarine and fresh-water wetland areas; characterized by abundant vegetation, ponding, or high water table, hazards also include low foundation strength and stream or ocean flooding; organic soils may be present in the subsurface beneath other alluvial units or dune sands.*

Qal — **Quaternary alluvium:** *Unconsolidated deposits of sand, silt, clay, and mud in the flood plains of major streams draining sandstone and siltstone terrain, and gravel, sand, and silt along the middle and upper reaches of rivers draining Pre-Tertiary or volcanic terrain; grain size typically increases with depth; ground-water production moderate; associated with fresh water marsh and peat in places; hazards include stream-bank erosion, ponding, high ground water, flooding, siltation, and compressible soils locally.*

Qft — **Quaternary fluvial terrace deposits:** *Unconsolidated to semi-consolidated flat-lying and elevated deposits of river alluvium overlooking present stream valleys (Quaternary alluvium) and situated above the present levels of flooding; also includes fine-grained terrace deposits of estuarine origin; grain-size distributions similar to those of Quaternary alluvium and estuarine deposits; moderate ground-water production; hazards include ponding, local high ground water, and stream-bank erosion.*

Qmt — **Quaternary marine terrace deposits:** *Unconsolidated to semi-consolidated flat-lying and elevated marine deposits of sand, silt, clay and gravel locally; thicknesses vary from 10 to 50 feet, but locally are as little as 2 to 3 feet; elevations range from a few feet to several hundred feet near Coos Bay to almost 2,000 feet farther inland; ground-water production low to moderate; hazards may include headland erosion, stream-bank erosion, poor drainage, failure in deep cuts, and others, but generally are negligible; coastal Qmt mantled by stable dune sand.*

Bedrock Geologic Units

Sandstone of Tertiary Age

Tpe — **Empire Formation (Pliocene):** *Thickly bedded, hard, marine sandstone with minor thin interbeds of siltstone; impermeable, firm foundations; mantled with loamy sand, sandy loam, and silty loam; hazards include rockfall in coastal cliffs and variable erosion and mass movement; limited in distribution to the South Slough area.*

Tms — **Miocene sedimentary rocks:** *Calcareous, medium-grained, hard, gray sandstone exposed at Pigeon Point and recovered from nearby dredgings; indicates shallow depth to bedroch in southern extremities of entrance of Coos Bay estuary.*

Totp — **Tunnel Point Formation (Oligocene):** *Coarse- to fine-grained tuffaceous sandstone and minor siltstone exposed only at Tunnel Point near the entrance to Coos Bay; subject to slow headland erosion prior to the development of Bastendorff Beach.*

Tecu Tecl — **Coaledo Formation, upper and lower members (late Eocene):** *Coarse- to fine-grained, hard, deltaic sandstone with interbeds of softer siltstone; well-developed bedding; conglomerate and coal beds present locally with more extensive coal deposits at depth; overlain by loamy sand, sandy loam and silty loam; low permeability and ground water potential; hazards may include slow to sporadic headland erosion locally and earthflow in deep cuts; flooding in coal mines minimal.*

Tec — **Coaledo Formation, undifferentiated (late Eocene):** *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in sandstone content; lithology and hazards similar to that of the upper and lower Coaledo Formation; precise distribution determined by on-site inspection.*

Tet — **Tyee Formation (middle Eocene):** *Thick sequence of rhythmically bedded, hard sandstone and minor siltstone; coal-bearing at Eden Ridge; impermeable, but with moderate infiltration along joints and faults; very low ground-water potential; mantled with sandy loam and silty loam soils that locally are very thin; hazards include flash flooding, erosion, rapid earthflow, and debris flows.*

Tef — **Flournoy Formation (middle Eocene):** *Lithology and soils similar to those of the Tyee Formation except for increased siltstone content high in the section; mantled by sandy loam and silty loam; hazards and ground-water potential similar to those of the Tyee Formation.*

Telg — **Lookingglass Formation (middle Eocene):** *Lithology, ground-water potential, and hazards similar to those of the Tyee Formation, but thinner bedded and conglomeratic near the base locally; mantled by sandy loam and silty loam.*

Ter — **Roseburg Formation — sedimentary rocks (lower Eocene and older):** *Rhythmically bedded hard sandstone and siltstone; low permeability and low ground-water potential; faulted and sheared in southern Coos County to produce extensive mass movement terrain and subdued topography; mantled by silt loam and loamy sand; hazards include mass movement, erosion, and variable foundation conditions.*

Siltstone of Tertiary Age

Teob — **Bastendorff Formation (late Eocene and early Oligocene):** *Thinly bedded shale and siltstone confined to the South Slough, Isthmus Slough and Calching Creek areas; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow mass movement, and failures in deep cuts.*

Tecm — **Coaledo Formation — middle member (late Eocene):** *Thinly bedded siltstone with minor sandstone interbeds; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow headland erosion, and local mass movement.*

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Tee — **Elkton Formation (middle Eocene):** *Thinly bedded siltstone with minor sandstone interbeds; mantled with silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion and mass movement.*

Basalt of Tertiary Age

Terv — **Roseburg Formation — basalt (early Eocene):** *Marine basalt of variable lithology including pillow basalt, basaltic breccia and intrusive basalt; hardness, jointing, alteration, and potential use variable; widespread low-grade alteration; interfingers with sedimentary rock of the Roseburg Formation; mantled by silty clay loam and silty loam a few inches to several lens of feet in thickness; hazards include rapid erosion and mass movement.*

Rocks of Pre-Tertiary Age

Khm — **Humbug Mountain Conglomerate (early Cretaceous):** *Small exposure of bedded conglomerate and sandstone.*

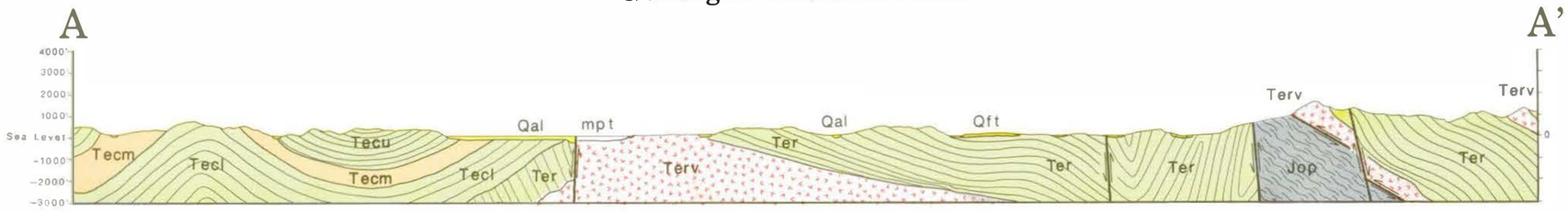
Jop — **Otter Point Formation (Jurassic):** *A tectonically sheared assemblage of rocks including pervasively sheared sedimentary rocks (Jop) now prone to regional mass movement and subordinate amounts of sheared to intact volcanic rock (Jov), isolated blocks of thinly bedded tightly folded chert (Jc), exposures of serpentinite (Jsp), and isolated blocks of resistant blueschist (Js), a medium-grade metamorphic rock. Soil types, thicknesses, and properties highly variable; major hazards include mass movement, slope erosion, stream-bank erosion, and variable bearing strength.*

Jgv Jg — **Galice Formation (Jurassic):** *Limited exposures of volcanic rock and bedded siltstone.*

Geologic Symbols

Contacts — Faults
Syncline — Anticline
Folds
Attitudes
Strike and dip of Beds and flows — Horizontal bed and flows

Geologic Cross Section



Base map from USA Corps of Engineers and USGS 15' Quadrangle Series (Topographic) 1942

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UTM GRID AND 1942 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:62500

CONTOUR INTERVAL 50 FEET
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Polyconic projection. 1927 North American datum
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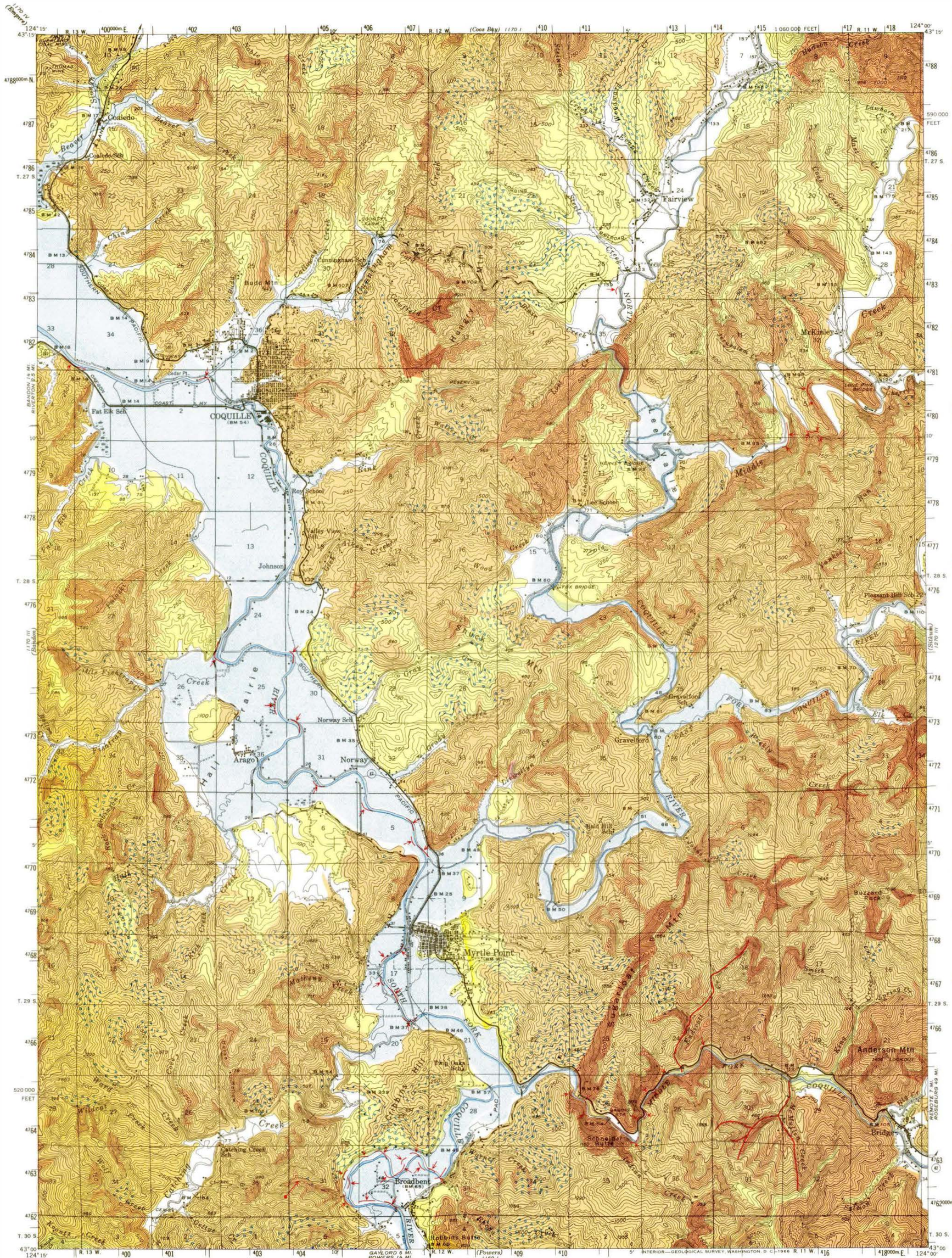
Cartography by S. R. Renoud : 975

Surficial Geology by J.D. Beaulieu
Bedrock Geology by E. M. Baldwin 1973

Research for this map sponsored in part by the U.S. Geological Survey, Department of the Interior, under USGS Grant No. 14-08-0001-G-135.

GEOLOGIC HAZARD MAP
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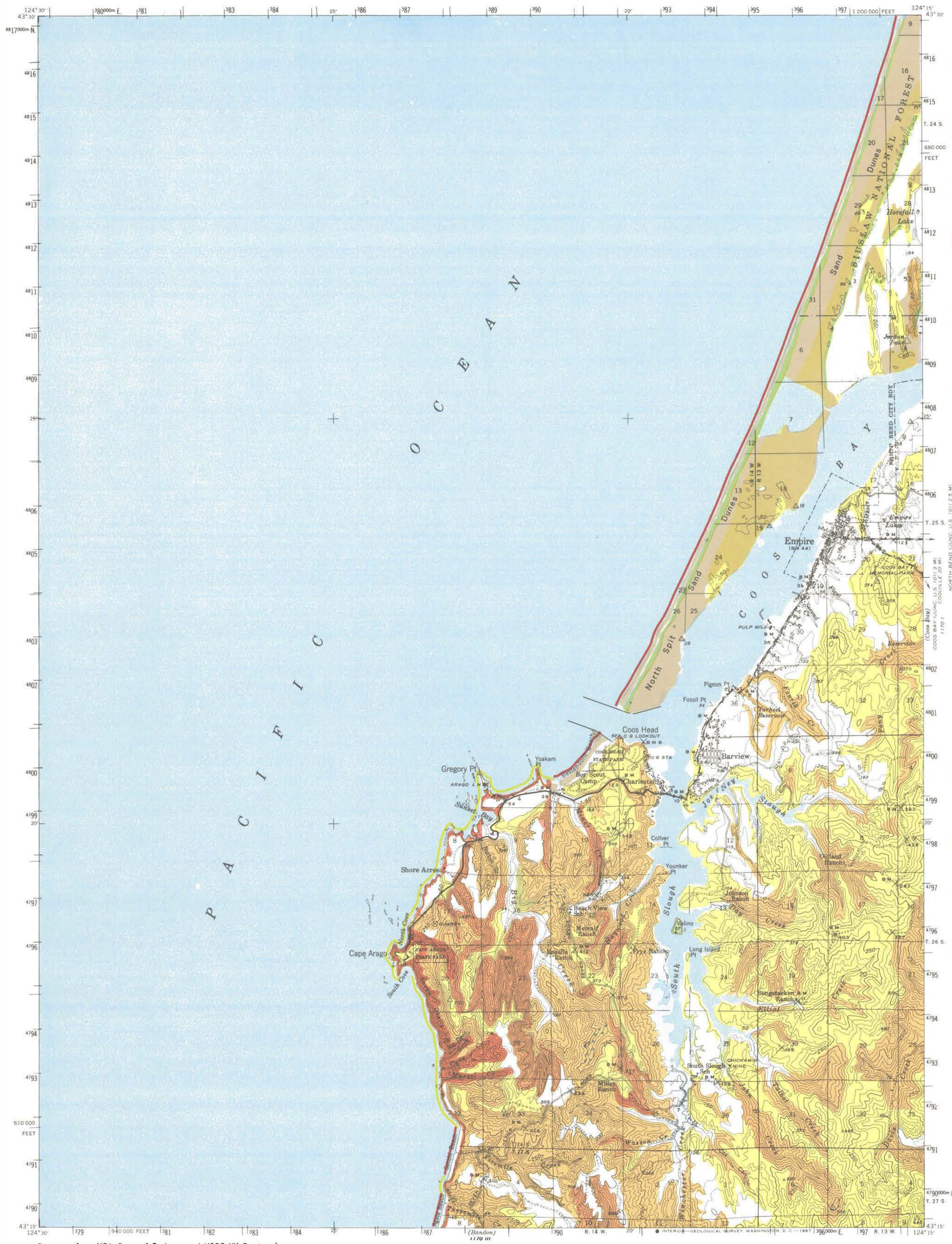
GEOLOGIC MAP
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EMPIRE QUADRANGLE
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STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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PACIFIC OCEAN
COOS BAY
Coos Head
Cape Arago
Gregory Pt
Shore Acres
Empire
Barview
North Spit
Sand Dunes
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Tecl
Tecm
Teob
Tpe
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To join Reedsport map use dotted projection corner

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Mass Movement

Earthflow and Slump Topography: *Terrain characterized by such features as irregular topography, moderate slopes, irregular drainage, irregular soil distribution, and occasionally features of recent movement including tension cracks and bowed trees (depending upon type, depth, and time of failure); generally restricted to the soil zone but also bedrock in sheared or deeply weathered terrain; hazards include ground movement, variable foundation strength, caving in excavations, poor drainage, and others. Excavations, stream-bank erosion, fills, drainage modifications, removal of vegetation, and use of drain fields and septic tanks may reactivate or accelerate sliding. On-site inspection recommended prior to development.*

Deep Bedrock Failure: *Areas of deep bedrock failure initiated by prolonged stream-bank erosion over extended periods of time in the geologic past; restricted to sandstone terrain in the interior uplands; presently inactive with the exception of localized areas within the slides; major hazards include variations in drainage, soil conditions, and foundation strength.*

Rockfall and Debris Flow Terrain: *Areas with slopes greater than 50% regionally are subject to rapid and shallow mass movement such as debris flow, rock slide, and rock-fall. Recent large individual debris flows are indicated with arrows. The specific location of individual mass movements is a function of rock and soil characteristics, weathering history, vegetative cover, and present land use. Treatment includes retaining walls, preservation of vegetative cover, drainage control, screening of critical slopes, and proper engineering of all construction, especially roadcuts and fills.*

Cartography by S. R. Renoud 1975

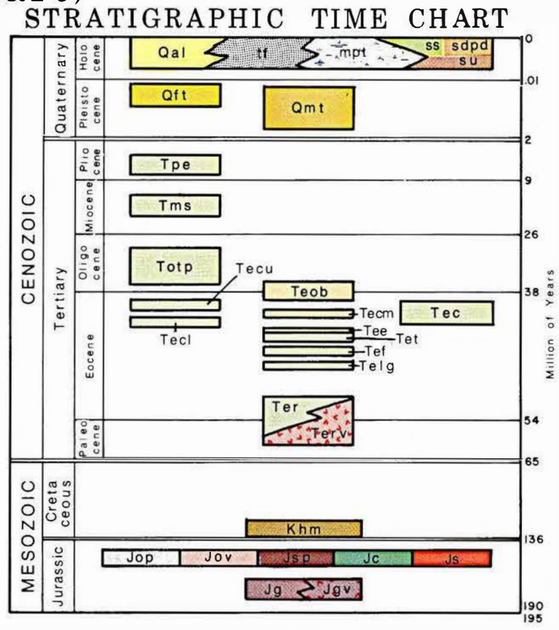
Geologic Hazards by J. D. Beaulieu and P. W. Hughes

GEOLOGIC MAP
of the
GOODWIN PEAK & SCOTTSBURG QUADRANGLES (in part)
OREGON

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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STRATIGRAPHIC TIME CHART



EXPLANATION

Surficial Geologic Units

fs — **fill and spoils:** *Sand, silt, gravel, sawdust, wood chips, dredge spoils, and other material placed in wetland areas and on slopes for disposal or to provide space for development; adequate foundation strength for small structures if properly placed; nature of substrate variable and includes compressible soils locally; hazards include flooding, differential settling, and amplification of seismic waves in areas of thick estuarine fill.*

ss — **stable sand:** *Unconsolidated fine- to medium-grained dune sand protected from wind erosion by natural or artifically introduced vegetation; thickness up to 200 feet in large dune fields, much thinner south of Bandon; ground-water production high; hazards include stream erosion, high ground water, ground-water pollution, overwithdrawal of ground water, and ocean flooding at low elevations; unit may overlie organic soils and ancient soil horizons with other properties; does not include stable sand overlying Qmt.*

su — **unstable dune sand:** *Unconsolidated fine- to medium-grained sand of large dunes not protected from wind erosion by vegetation; thickness, hazards and ground-water potential similar to those of stable sand, also wind erosion and wind deposition, especially in excavations or around structures; unit may overlie compressible soils or other ancient soil horizons.*

sdpb — **deflation plain and beach sand:** *Unconsolidated fine- to medium-grained sand of beaches, flat-lying interdune areas and transverse dune fields; thickness, hazards, and ground-water potential similar to those of stable sand; possible presence of iron-pan layers at shallow depths; possible extreme variability vertically in permeability and degree of consolidation; preservation of vegetative cover dependent on water table.*

tf — **tidal flat:** *Unconsolidated mud, silt, clay, and sand in the tidal zone of estuaries and other coastal wetlands; sediments compacted or high in organic material locally; hazards may also include amplification of seismic waves and ocean flooding; may be present beneath some dune sands.*

mpt — **marsh and peat:** *Unconsolidated organic soils of silt, clay, and sand in estuarine and fresh-water wetland areas; characterized by abundant vegetation, ponding, or high water table, hazards also include low foundation strength and stream or ocean flooding; organic soils may be present in the subsurface beneath other alluvial units or dune sands.*

Qal — **Quaternary alluvium:** *Unconsolidated deposits of sand, silt, clay, and mud in the flood plains of major streams draining sandstone and siltstone terrain, and gravel, sand, and silt along the middle and upper reaches of rivers draining Pre-Tertiary or volcanic terrain; grain size typically increases with depth; ground-water production moderate; associated with fresh water marsh and peat in places; hazards include stream-bank erosion, ponding, high ground water, flooding, siltation, and compressible soils locally.*

Qft — **Quaternary fluvial terrace deposits:** *Unconsolidated to semi-consolidated flat-lying and elevated deposits of river alluvium overlooking present stream valleys (Quaternary alluvium) and situated above the present levels of flooding; also includes fine-grained terrace deposits of estuarine origin; grain-size distributions similar to those of Quaternary alluvium and estuarine deposits; moderate ground-water production; hazards include ponding, local high ground water, and stream-bank erosion.*

Qmt — **Quaternary marine terrace deposits:** *Unconsolidated to semi-consolidated flat-lying and elevated marine deposits of sand, silt, clay and gravel locally; thickness ev vary from 10 to 50 feet, but locally are as little as 2 to 3 feet; elevations range from a few feet to several hundred feet near Coos Bay to almost 2,000 feet farther inland; ground-water production low to moderate; hazards may include headland erosion, stream-bank erosion, poor drainage, failure in deep cuts, and others, but generally are negligible; coastal Qmt mantled by stable dune sand.*

Bedrock Geologic Units

Sandstone of Tertiary Age

Tpe — **Empire Formation (Pliocene):** *Thickly bedded, hard, marine sandstone with minor thin interbeds of siltstone; impermeable, firm foundations; mantled with loamy sand, sandy loam, and silty loam; hazards include rockfall in coastal cliffs and variable erosion and mass movement; limited in distribution to the South Slough area.*

Tms — **Miocene sedimentary rocks:** *Calcareous, medium-grained, hard, gray sandstone exposed at Pigeon Point and recovered from nearby dredgings; indicates shallow depth to bedrock in southern extremities of entrance of Coos Bay estuary.*

Totp — **Tunnel Point Formation (Oligocene):** *Coarse- to fine-grained tuffaceous sandstone and minor siltstone exposed only at Tunnel Point near the entrance to Coos Bay; subject to slow headland erosion prior to the development of Bastendorff Beach.*

Tecu Tecl — **Coaledo Formation, upper and lower members (late Eocene):** *Coarse- to fine-grained, hard, deltaic sandstone with interbeds of softer siltstone; well-developed bedding; conglomerate and coal beds present locally with more extensive coal deposits at depth; overlain by loamy sand, sandy loam and silty loam; low permeability and ground water potential; hazards may include slow to sporadic headland erosion locally and earthflow in deep cuts; flooding in coal mines minimal.*

Tec — **Coaledo Formation, undifferentiated (late Eocene):** *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in sandstone content; lithology and hazards similar to that of the upper and lower Coaledo Formation; precise distribution determined by on-site inspection.*

Tet — **Tyee Formation (middle Eocene):** *Thick sequence of rhythmically bedded, hard sandstone and minor siltstone; coal-bearing at Eden Ridge; impermeable, but with moderate infiltration along joints and faults; very low ground-water potential; mantled with sandy loam and silty loam soils that locally are very thin; hazards include flash flooding, erosion, rapid earthflow, and debris flows.*

Tef — **Flournoy Formation (middle Eocene):** *Lithology and soils similar to those of the Tyee Formation except for increased siltstone content high in the section; mantled by sandy loam and silty loam; hazards and ground-water potential similar to those of the Tyee Formation.*

Telg — **Lookingglass Formation (middle Eocene):** *Lithology, ground-water potential, and hazards similar to those of the Tyee Formation, but thinner bedded and conglomeratic near the base locally; mantled by sandy loam and silty loam.*

Ter — **Roseburg Formation — sedimentary rocks (lower Eocene and older):** *Rhythmically bedded hard sandstone and siltstone; low permeability and low ground-water potential; faulted and sheared in southern Coos County to produce extensive mass movement terrain and subdued topography; mantled by silt loam and loamy sand; hazards include mass movement, erosion, and variable foundation conditions.*

Siltstone of Tertiary Age

Teob — **Bastendorff Formation (late Eocene and early Oligocene):** *Thinly bedded shale and siltstone confined to the South Slough, Isthmus Slough and Catching Creek areas; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow mass movement, and failures in deep cuts.*

Tecm — **Coaledo Formation — middle member (late Eocene):** *Thinly bedded siltstone with minor sandstone interbeds; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow headland erosion, and local mass movement.*

Tec — **Coaledo Formation — undifferentiated (late Eocene):** *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in siltstone content; lithology and hazards similar to those of the middle member of the Coaledo Formation; precise distribution determined by on-site inspection.*

Tee — **Elkton Formation (middle Eocene):** *Thinly bedded siltstone with minor sandstone interbeds, mantled with silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion and mass movement.*

Basalt of Tertiary Age

Terv — **Roseburg Formation — basalt (early Eocene):** *Marine basalt of variable lithology including pillow basalt, basaltic breecia and intrusive basalt; hardness, jointing, alteration, and potential use variable; widespread low-grade alteration; interfingers with sedimentary rock of the Rosebug Formation; mantled by silty clay loam and silty loam a few inches to several tens of feet in thickness; hazards include rapid erosion and mass movement.*

Rocks of Pre-Tertiary Age

Khm — **Humbug Mountain Conglomerate (early Cretaceous):** *Small exposure of bedded conglomerate and sandstone.*

Jop Jov Jsp Jc Js — **Otter Point Formation (Jurassic):** *A tectonically sheared assemblage of rocks including pervasively sheared sedimentary rocks (Jop) now prone to regional mass movement and subordinate amounts of sheared to intact volcanic rock (Jov), isolated blocks of thinly bedded tightly folded chert (Jc), exposures of serpentinite (Jsp), and isolated blocks of resistant blueschist (Js), a medium-grade metamorphic rock. Soil types, thicknesses, and properties highly variable; major hazards include mass movement, slope erosion, stream-bank erosion, and variable bearing strength.*

Jgv Jg — **Galice Formation (Jurassic):** *Limited exposures of volcanic rock and bedded siltstone.*

Geologic Symbols

Contacts — Faults
Folds
Syncline — Anticline
Attitudes
Strike and dip of Beds and flows — Horizontal bed and flows

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SCALE 1:62500

1 ½ 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

20° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1955
43°35′ 123°55′

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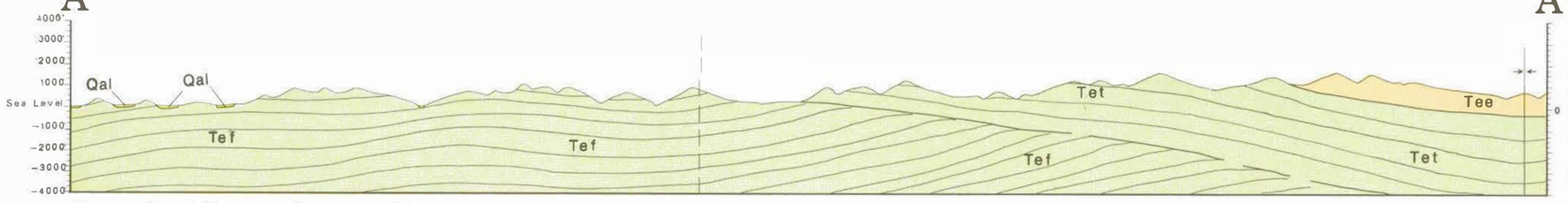
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Medium-duty — Light-duty
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OREGON
QUADRANGLE LOCATION

Cartography by S. R. Renoud 1975

Surficial Geology by J.D. Beaulieu
Bedrock Geology by E. M. Baldwin 1973

Geologic Cross Section



The preparation of this map was financed in part through a project development grant under the Coastal Zone Management Act of 1972 administered by the Office of Coastal Zone Management of the National Oceanic and Atmospheric Administration.

GEOLOGIC HAZARD MAP
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OREGON

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Control by USGS and USC&GS

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3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

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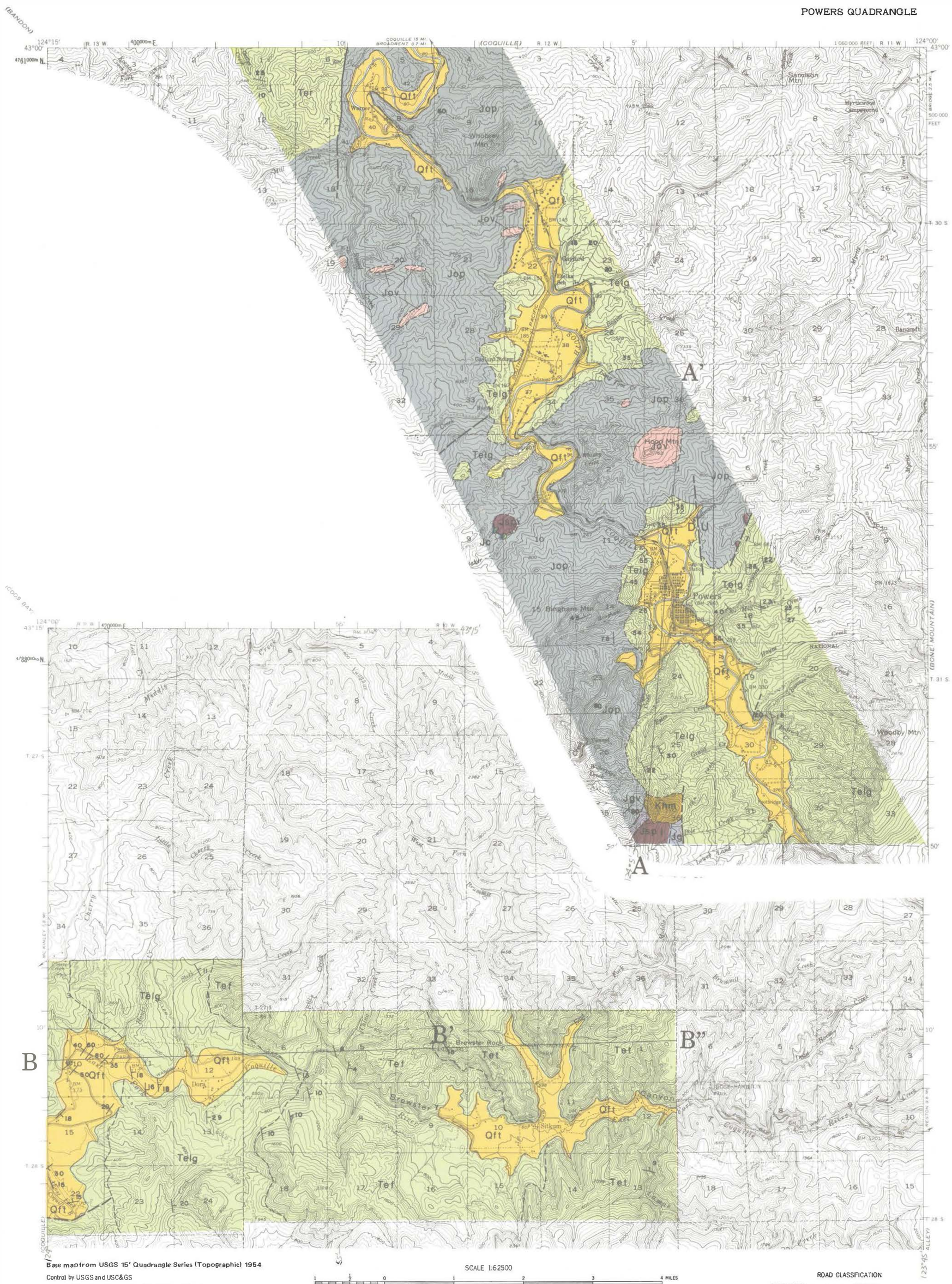
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GEOLOGIC MAP
of the
POWERS & SITKUM QUADRANGLES (in part)
OREGON

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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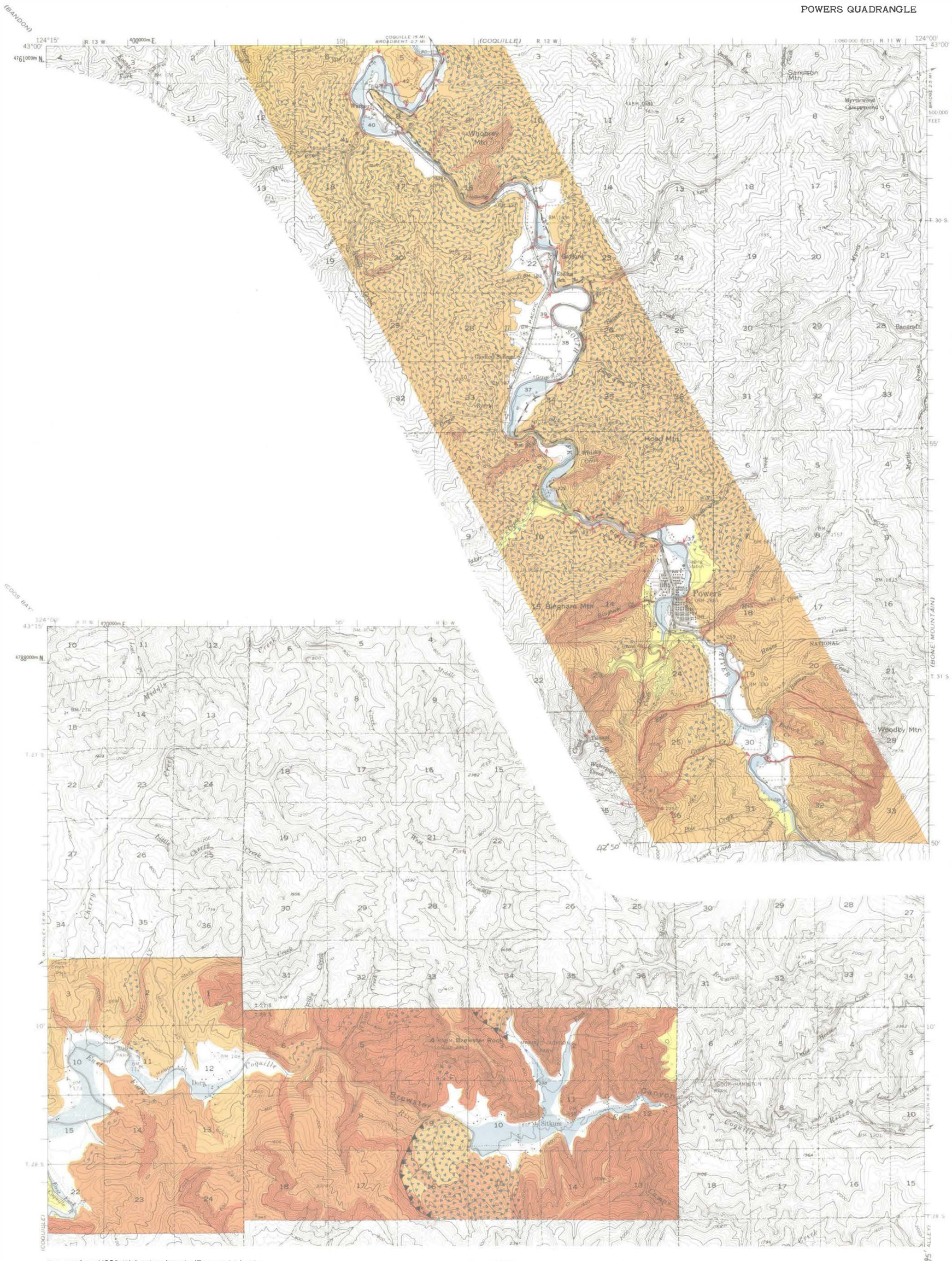
POWERS QUADRANGLE


(BANDON)
124°15'
43°00'
R. 13 W.
400000m E.
4761000m N.
COQUILLE 15 MI.
BROADBENT 07 MI.
(COQUILLE)
R. 12 W.
124°00'
R. 11 W.
1060000 FEET
Qft
Qmt
Jop
Jov
Jsp
Jc
Js
Jg
Jgv
Khm
Telg
Tef
Tet
Tecl
Tecm
Tee
Tec
Teob
Totp
Tms
Tpe
Ter
Terv
Qal
tf
mpt
ss sdpd su
Whobrey Mtn.
Samtson Mtn.
Myrtlewood Campground
Woodby Mtn
Hood Mtn
Powers
Bunghars Mtn
Gaylord Bridge
Footbridge
Bancroft
Myrtle Creek
Middle Creek
Cherry Creek
Fork
Lower Land
Trumbull
Hubbard
Hall
Hansen
Hanscom
Hanscomb
Park
Mill
Creek
Ranch
Gravel Pit
Water Tank
Dump
Ridge
Mountain
Canyon
Brewster Rock
Brewster River
Coquille River
Sitkum
Powers
Footbridge
Bancroft

GEOLOGIC HAZARD MAP *of the* POWERS & SITKUM QUADRANGLES (in part) OREGON

STATE OF OREGON
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POWERS QUADRANGLE



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OREGON
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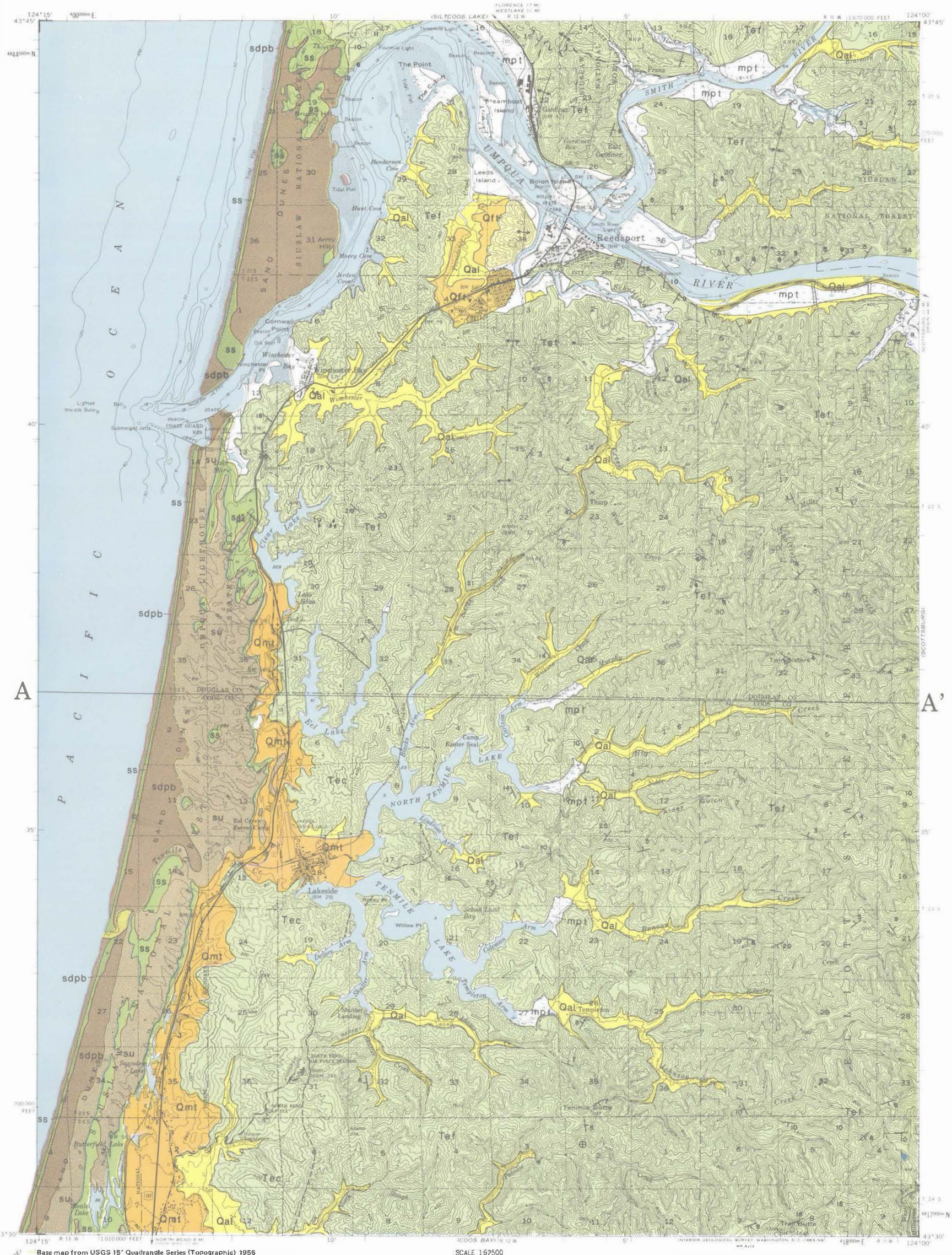
Rockfall and Debris Flow Terrain: *Areas with slopes greater than 50% regionally are subject to rapid and shallow mass movement such as debris flow, rock slide, and rock-fall. Recent large individual debris flows are indicated with arrows. The specific location of individual mass movements is a function of rock and soil characteristics, weathering history, vegetative cover, and present land use. Treatment includes retaining walls, preservation of vegetative cover, drainage control, screening of critical slopes, and proper engineering of all construction, especially roadcuts and fills.*

Cartography by S. R. Renoud 1975

Geologic Hazards by J. D. Beaulieu and P. W. Hughes

GEOLOGIC MAP
of the
REEDSPORT QUADRANGLE
OREGON

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST



Base map from USGS 15′ Quadrangle Series (Topographic) 1956
Control by USGS and USC&GS
Mapped 1919 and 1921, remapped 1956
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1954. Field check 1956
Hydrography compiled from USC&GS chart 6004 (1955)
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue
Dashed land lines indicate approximate locations
Unchecked elevations are shown in brown

SCALE 1:62500

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES IN FEET – DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 5 FEET

APPROXIMATE MEAN DECLINATION, 1956

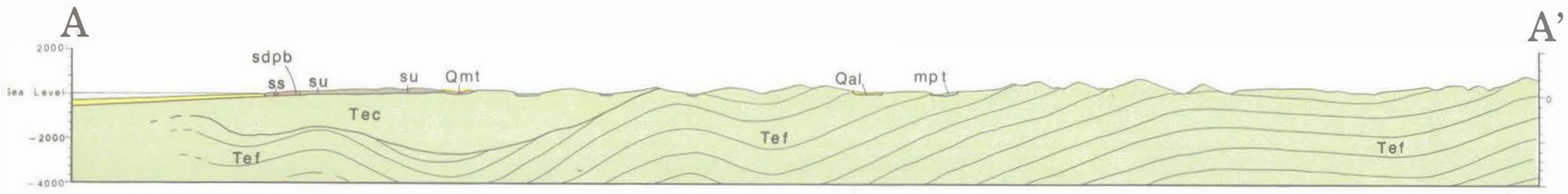
ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U.S. Route — State Route

OREGON
QUADRANGLE LOCATION

Cartography by S. R. Renoud 1975

Surficial Geology by J.D. Beaulieu
Bedrock Geology by E. M. Baldwin 1973

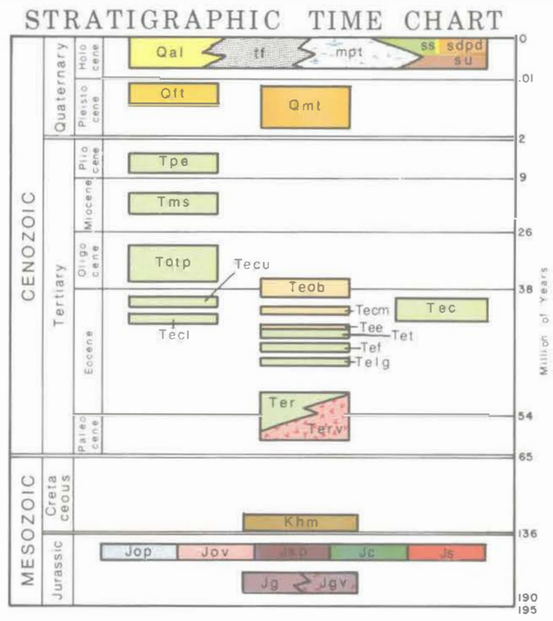
Geologic Cross Section



The Coos County portion of this map's research was sponsored in part by the U.S. Geological Survey, Department of the Interior, under USGS Grant No. 14-08-0001-G-135.

The Douglas County portion of this map was financed in part through a project development grant under the Coastal Zone Management Act of 1972 administered by the Office of Coastal Zone Management of the National Oceanic and Atmospheric Administration.

STRATIGRAPHIC TIME CHART



EXPLANATION

Surficial Geologic Units

fs — fill and spoils: *Sand, silt, gravel, sawdust, wood chips, dredge spoils, and other material placed in wetland areas and on slopes for disposal or to provide space for development; adequate foundation strength for small structures if properly placed; nature of substrate variable and includes compressible soils locally; hazards include flooding, differential settling, and amplification of seismic waves in areas of thick estuarine fill.*

ss — stable sand: *Unconsolidated fine- to medium-grained dune sand protected from wind erosion by natural or artifically introduced vegetation; thickness up to 200 feet in large dune fields, much thinner south of Bandon; ground-water production high; hazards include stream erosion, high ground water, ground-water pollution, overwithdrawal of ground water, and ocean flooding at low elevations; unit may overlie organic soils and ancient soil horizons with other properties; does not include stable sand overlying Qmt.*

su — unstable dune sand: *Unconsolidated fine- to medium-grained sand of large dunes not protected from wind erosion by vegetation; thickness, hazards and ground-water potential similar to those of stable sand; also wind erosion and wind deposition, especially in excavations or around structures; unit may overlie compressible soils or other ancient soil horizons.*

sdpb — deflation plain and beach sand: *Unconsolidated fine- to medium-grained sand of beaches, flat-lying interdune areas and transverse dune fields; thickness, hazards, and ground-water potential similar to those of stable sand; possible presence of iron-pan layers at shallow depths; possible extreme variability vertically in permeability and degree of consolidation; preservation of vegetative cover dependent on water table.*

tf — tidal flat: *Unconsolidated mud, silt, clay, and sand in the tidal zone of estuaries and other coastal wetlands; sediments compacted or high in organic material locally; hazards may also include amplifiealion of seismic waves and ocean flooding; may be present beneath some dune sands.*

mpt — marsh and peat: *Unconsolidated organic soils of silt, clay, and sand in estuarine and fresh-water wetland areas; characterized by abundant vegetation, ponding, or high water table, hazards also include low foundation strength and stream or ocean flooding; organic soils may be present in the subsurface beneath other alluvial units or dune sands.*

Qal — Quaternary alluvium: *Unconsolidated deposits of sand, silt, clay, and mud in the flood plains of maior streams draining sandstone and siltstone terrain, and gravel, sand, and silt along the middle and upper reaches of rivers draining Pre-Tertiary or volcanic terrain; grain size typically increases with depth; ground-water production moderate; associated with fresh water marsh and peat in places; hazards include stream-bank erosion, ponding, high ground water, flooding, siltation, and compressible soils locally.*

Qft — Quaternary fluvial terrace deposits: *Unconsolidated to semi-consolidated flat-lying and elevated deposits of river alluvium overlooking present stream valleys (Quaternary alluvium) and situated above the present levels of flooding; also includes fine-grained terrace deposits of estuarine origin; grain-size distributions similar to those of Quaternary alluvium and estuarine deposits; moderate ground-water production; hazards include ponding, local high ground water, and stream-bank erosion.*

Qmt — Quaternary marine terrace deposits: *Unconsolidated to semi-consolidated flat-lying and elevated marine deposits of sand, silt, clay and gravel locally; thicknesses vary from 10 to 50 feet, but locally are as little as 2 to 3 feet; elevations range from a few feet to several hundred feet near Coos Bay to almost 2,000 feet farther inland; ground-water production low to moderate; hazards may include headland erosion, stream-bank erosion, poor drainage, failure in deep cuts, and others, but generally are negligible; coastal Qmt mantled by stable dune sand.*

Bedrock Geologic Units

Sandstone of Tertiary Age

Tpe — Empire Formation (Pliocene): *Thickly bedded, hard, marine sandstone with minor thin interbeds of siltstone; impermeable, firm foundations; mantled with loamy sand, sandy loam, and silty loam; hazards include rockfall in coastal cliffs and variable erosion and mass movement; limited in distribution to the South Slough area.*

Tms — Miocene sedimentary rocks: *Calcareous, medium-grained, hard, gray sandstone exposed at Pigeon Point and recovered from nearby dredgings; indicates shallow depth to bedrock in southern extremities of entrance of Coos Bay estuary.*

Totp — Tunnel Point Formation (Oligocene): *Coarse- to fine-grained tuffaceous sandstone and minor siltstone exposed only at Tunnel Point near the entrance to Coos Bay; subject to slow headland erosion prior to the development of Bastendorff Beach.*

Tecu Tecl — Coaledo Formation, upper and lower members (late Eocene): *Coarse- to fine-grained, hard, deltaic sandstone with interbeds of softer siltstone; well-developed bedding; conglomerate and coal beds present locally with more extensive coal deposits at depth; overlain by loamy sand, sandy loam and silty loam; low permeability and ground water potential; hazards may include slow to sporadic headland erosion locally and earthflow in deep cuts; flooding in coal mines minimal.*

Tec — Coaledo Formation, undifferentiated (late Eocene): *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in sandstone content; lithology and hazards similar to that of the upper and lower Coaledo Formation; precise distribution determined by on-site inspection.*

Tef — Tyee Formation (middle Eocene): *Thick sequence of rhythmically bedded, hard sandstone and minor siltstone; coal-bearing at Eden Ridge; impermeable, but with moderate infiltration along joints and faults; very low ground-water potential; mantled with sandy loam and silty loam soils that locally are very thin; hazards include flash flooding, erosion, rapid earthflow, and debris flows.*

Tef — Flournoy Formation (middle Eocene): *Lithology and soils similar to those of the Tyee Formation except for increased siltstone content high in the section; mantled by sandy loam and silty loam; hazards and ground-water potential similar to those of the Tyee Formation.*

Telg — Lookingglass Formation (middle Eocene): *Lithology, ground-water potential, and hazards similar to those of the Tyee Formation, but thinner bedded and conglomeratic near the base locally; mantled by sandy loam and silty loam.*

Ter — Roseburg Formation — sedimentary rocks (lower Eocene and older): *Rhythmically bedded hard sandstone and siltstone; low permeability and low ground-water potential; faulted and sheared in southern Coos County to produce extensive mass movement terrain and subdued topography; mantled by silt loam and loamy sand; hazards include mass movement, erosion, and variable foundation conditions.*

Siltstone of Tertiary Age

Teob — Bastendorff Formation (late Eocene and early Oligocene): *Thinly bedded shale and siltstone confined to the South Slough, Isthmus Slough and Catching Creek areas; mantled by silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion, slow mass movement, and failures in deep cuts.*

Tecm — Coaledo Formation — middle member (late Eocene): *Thinly bedded siltstone with minor sandstone interbeds; mantled by silty loam and silty clay loam, very low permeability and ground-water potential; hazards include erosion, slow headland erosion, and local mass movement.*

Tec — Coaledo Formation — undifferentiated (late Eocene): *Parts of the undifferentiated Coaledo terrain of the east Coos Bay area high in siltstone content; lithology and hazards similar to those of the middle member of the Coaledo Formation; precise distribution determined by on-site inspection.*

Tee — Elkton Formation (middle Eocene): *Thinly bedded siltstone with minor sandstone interbeds; mantled with silty loam and silty clay loam; very low permeability and ground-water potential; hazards include erosion and mass movement.*

Basalt of Tertiary Age

Terv — Roseburg Formation — basalt (early Eocene): *Marine basalt of variable lithology including pillow basalt, basaltic breccia and intrusive basalt; hardness, jointing, alteration, and potential use variable; widespread low-grade alteration; interfingers with sedimentary rock of the Roseburg Formation; mantled by silty clay loam and silty loam a few inches to several tens of feet in thickness; hazards include rapid erosion and mass movement.*

Rocks of Pre-Tertiary Age

Khm — Humbug Mountain Conglomerate (early Cretaceous): *Small exposure of bedded conglomerate and sandstone.*

Jop Jov Js Jc — Otter Point Formation (Jurassic): *A tectonically sheared assemblage of rocks including pervasively sheared sedimentary rocks (Jop) now prone to regional mass movement and subordinate amounts of sheared to intact volcanic rock (Jov), isolated blocks of thinly bedded tightly folded chert (Jc), exposures of serpentinite (Jsp), and isolated blocks of resistant blueschist (Js), a medium-grade metamorphic rock. Soil types, thicknesses, and properties highly variable; major hazards include mass movement, slope erosion, stream-bank erosion, and variable bearing strength.*

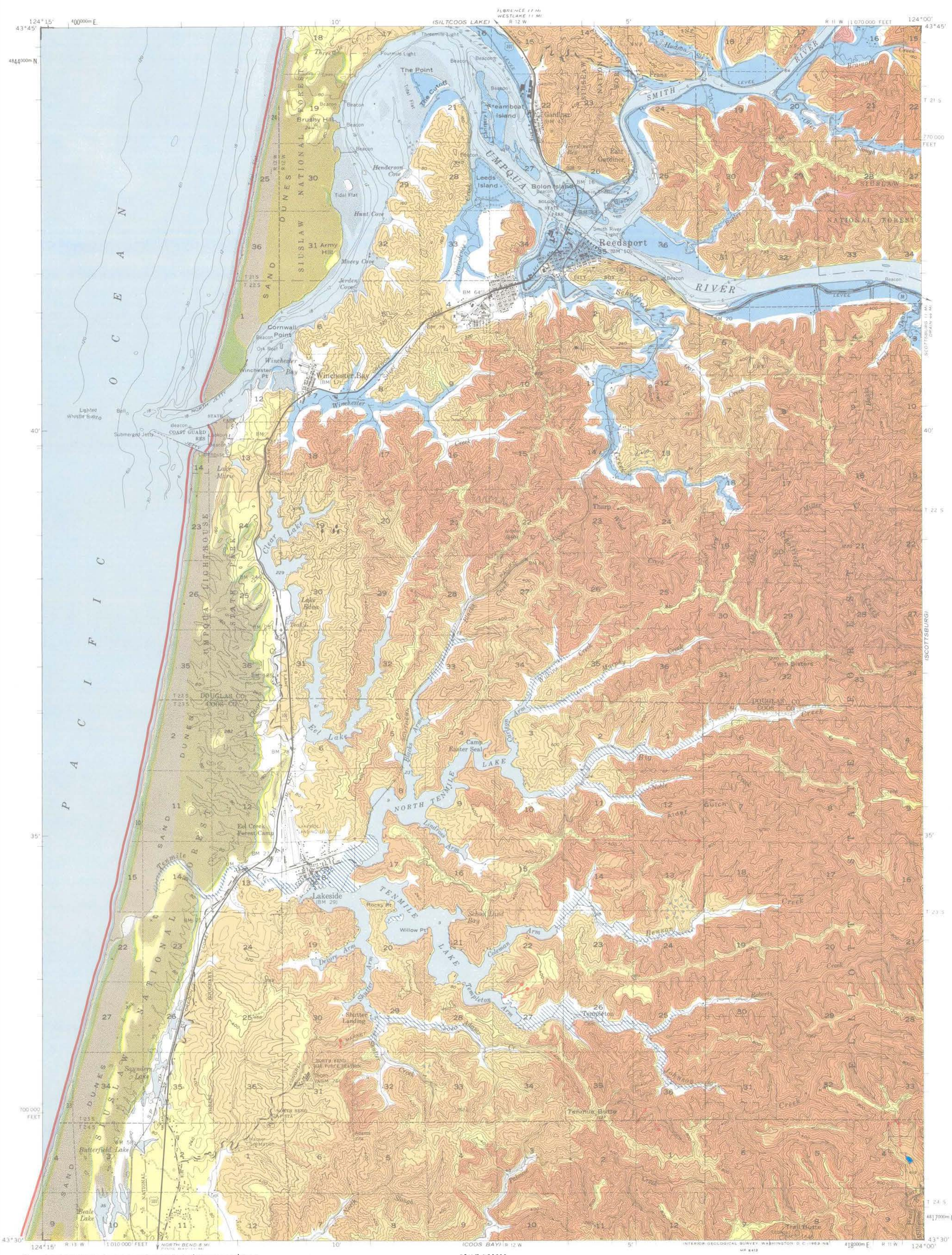
Jgv Jg — Galice Formation (Jurassic): *Limited exposures of volcanic rock and bedded siltstone.*

Geologic Symbols

Contacts — Faults
Folds
Syncline — Anticline
Attitudes
Strike and dip of Beds and flows — Horizontal bed and flows

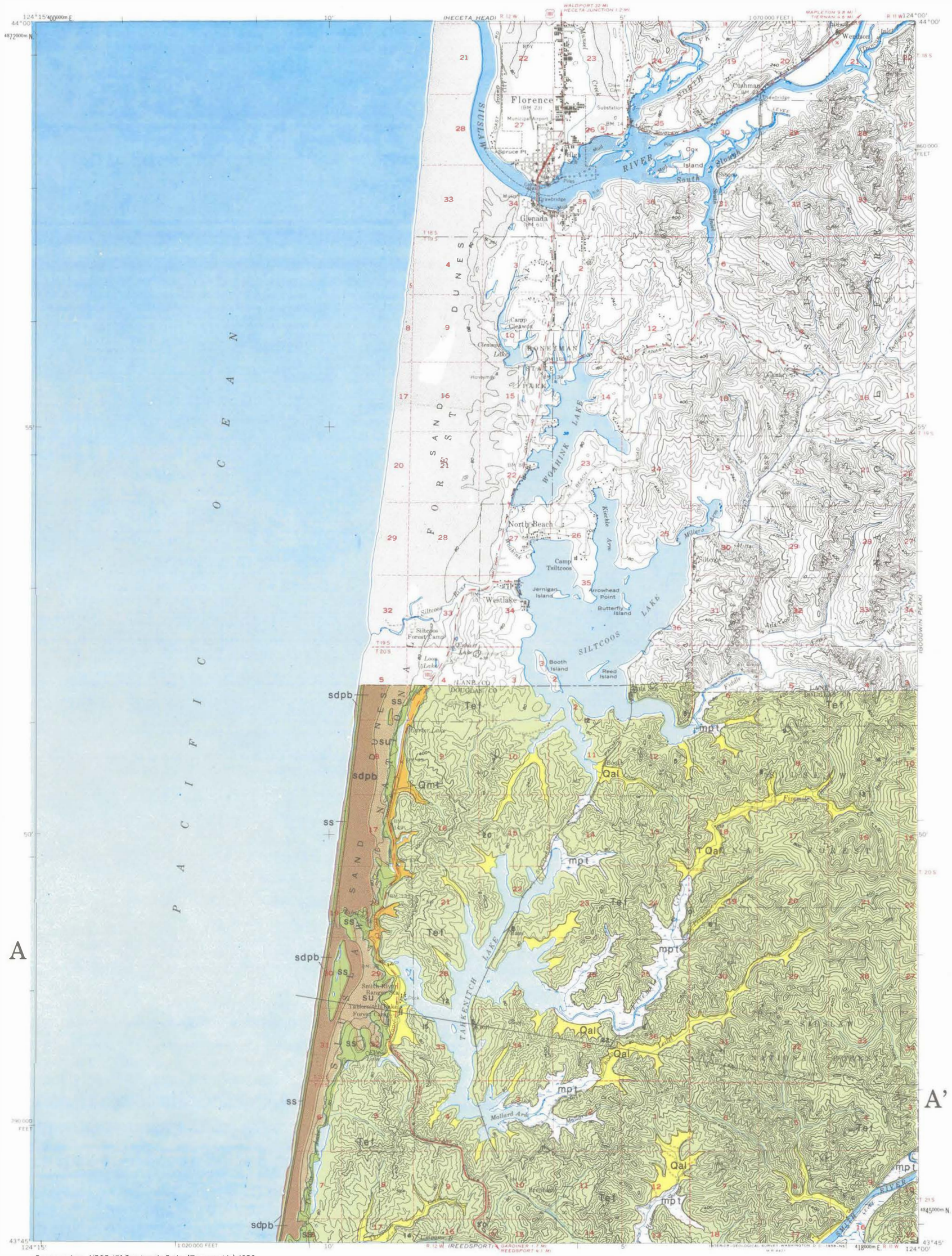
GEOLOGIC HAZARD MAP
of the
REEDSPORT QUADRANGLE
OREGON

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST

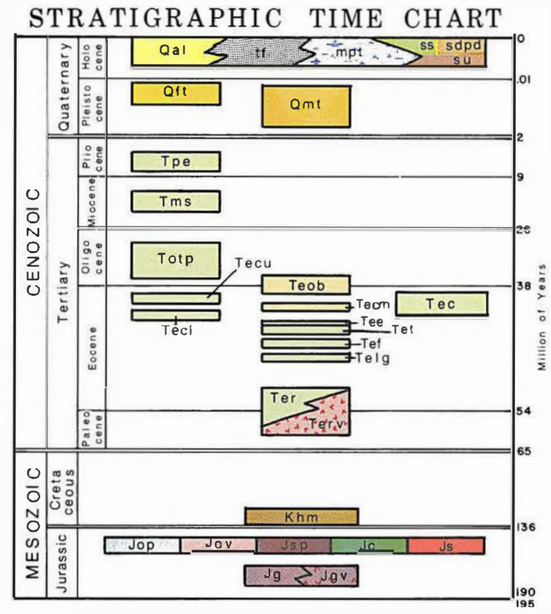

PACIFIC OCEAN
SIUSLAW NATIONAL FOREST
SAND DUNES
UMPQUA LIGHTHOUSE STATE PARK
SMITH RIVER
UMPQUA RIVER
SIUSLAW RIVER
TENMILE LAKES
Winchester Bay
Reedsport
Lakeside
Gardiner
Scottsburg
Coos Bay
Empire
The Point
Cutoff
Steamboat Island
Leeds Island
Bolon Island
Brushy Hill
Henderson Cove
Hunt Cove
Tidal Flat
31 Army Hill
Mosey Cove
Jerden Cove
Cornwall Point
Oak Reef
Lighted Whistle Buoy
Bell
Submerged Jetty
Lake Marie
Clear Lake
Lake Eden
Teal L.
Eel Lake
Eel Creek Forest Camp
Tenmile Creek
Camp Easter Seal
Rocky Pt.
Willow Pt.
School Land Bay
Delory Arm
Shutter Arm
Templeton Arm
Coleman Arm
Lindross Arm
Butterfield Lake
Saunders Lake
Beale Lake
Tenmile Butte
Twin Blisters
Noble Gulch
Big Creek
Hudson Creek
Franz Creek
Braman Creek
Miller Creek
Thurp Creek
Roberts Creek
Johnson Creek
Murphy Creek
Ash Swamp
Threemile Light
Fourmile Light
Beacon
Tidal Flat
Levee
Jetty
Coast Guard Res
Lighthouse
Radio Towers
Boundary
Fence
Trail
Ferry
Pipeline
Ab.
Sch.
Ch.
Ruins
Mine
Quarry
Tank
Windmill
Spring
Well
Cem.
Ranger Station
Forest Camp
Lookout
Landing
Boat Ramp
Fish Hatchery
Air Force Station
Radar Dome
Tacan
Hangar
Runway
Taxiway
Apron
Helipad
Control Tower
Terminal
Hangar
Fuel
Wind Cone
Beacon
Light
Buoy
Dock
Pier
Wharf
Jetty
Levee
Dam
Bridge
Ferry
Pipeline
Power Line
Tower
Pole
Fence
Boundary
Trail
Road

GEOLOGIC MAP
of the
SILTCOOS LAKE QUADRANGLE
OREGON

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST



STRATIGRAPHIC TIME CHART



EXPLANATION

Surficial Geologic Units

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Rocks of Pre-Tertiary Age

Khm — Humbug Mountain Conglomerate (early Cretaceous): *Small exposure of bedded conglomerate and sandstone.*

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Jgv Jg — Galice Formation (Jurassic): *Limited exposures of volcanic rock and bedded siltstone.*

Geologic Symbols

Contacts — Faults

Syncline — Folds — Anticline

Strike and dip of Beds and flows — Attitudes — Horizontal beds and flows

Base map from USGS 15' Quadrangle Series (Topographic) 1956

Control by USGS and USC&GS

Mapped 1918, remapped 1956

Topography from aerial photographs by multiplex methods
Aerial photographs taken 1954. Field check 1956

Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

Red tint indicates areas in which only landmark buildings are shown

Dashed land lines indicate approximate locations

21° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1956

1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 5 FEET

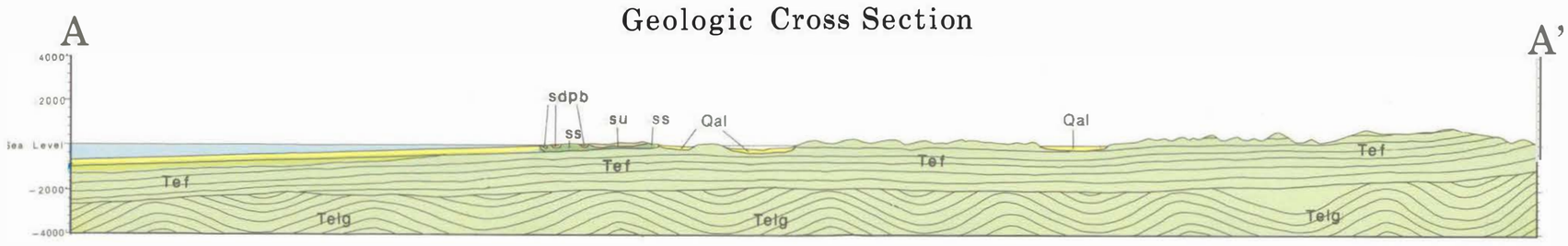
OREGON
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dir.
U.S. Route — State Route

Cartography by S. R. Renoud 1975

Surficial Geology by J. D. Beaulieu
Bedrock Geology by E. M. Baldwin 1973

Geologic Cross Section



The preparation of this map was financed in part through a project development grant under the Coastal Zone Management Act of 1972 administered by the Office of Coastal Zone Management of the National Oceanic and Atmospheric Administration.

GEOLOGIC HAZARD MAP
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SILTCOOS LAKE QUADRANGLE
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APPROXIMATE MEAN DECLINATION, 1956 — TRUE NORTH, MAGNETIC NORTH, 21°

1 ½ 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETERS

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OREGON
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U.S. Route — State Route

INTERIOR—GEOLOGICAL SURVEY WASHINGTON, D. C.—1958—NS

EXPLANATION

(Boundaries are approximate: statements are general: site-specific decisions require on-site inspection.)

Regional Slope

0 - 5% — *0-15% slopes locally; landforms include beaches, flood plains and other wetlands, fluvial and marine terraces; hazards include flooding, erosion, deposition, ponding, high ground water, compressible soils, and possible amplification of earthquake vibrations; land use potential excellent to good in areas of minimal hazards.*

5 - 15% — *Local slopes to 50% and 100% in some dunes areas; landforms include dunes, marine terraces, and gentle uplands; hazards include negligible to moderate erosion and deposition by stream, wind, and wave depending on setting; land use potential is excellent to good in regions of minimal or controllable hazards.*

15 - 30% — *Up to 50% slopes locally; landforms include parts of terraces, coastal uplands, and some valleys; hazards include moderate to rapid erosion on slopes and along streams and slow to rapid earthflow; land use potential is variable and is generally restricted to low-density residential use, forestry and other low-intensity development.*

30 - 50% — *Greater than 50% slopes locally; landforms include uplands and some small valleys in more gently sloping terrain; hazards include moderate to rapid erosion, earthflow, and debris slides; land use potential is generally limited to sparse development and forestry.*

>50% — *50% to vertical locally; landforms include uplands of the interior and sea cliffs; hazards include extreme erosion, rapid earthflow, debris flow, rockslide, and rockfall; land use potential restricted to well-managed logging and open space.*

Flooding

Preliminary Intermediate Regional (100-year) Flood: *Extent of flood (determined from preliminary data developed by the U.S. Geological Survey and Douglas County) having a 1 percent probability of occurring in any given year. Levees at Reedsport provide protection from the 100-year flood. Other levees in the lower Umpqua and Smith Rivers provide protection for 25-year floods.*

Flood Prone Areas: *Areas subject to flood hazard approximately equivalent to the Intermediate Regional Flood based on topography and scattered observations; differs from Intermediate Regional Flood in the absence of gage data and rigorous statistical treatment; also, based on little empirical data relative to the Maximum Composite Flood.*

Composite Maximum Historical Flood: *Areas that are known to have experienced flooding in the past but for which no sophisticated computer modeling is available; based on field observations, extensive personal interviews, and other investigations by the U.S. Soils Conservation Service, and also on data provided by the U.S.G.S., the U.S. Army Corps of Engineers, and the Oregon Water Resources Board. Period of observation approximately 100 years.*

Major Flash Flood: *Small- to medium-sized stream channels situated in areas of moderate to steep slope, moderate to high relief, and low permeability, for which catastrophic streamflows have a high probability of occurrence; characterized by narrow canyons, coarse, poorly sorted stream-bed deposits and the absence of a flood plain; permanent structures not feasible with the exception of properly engineered roads.*

Potential Ocean Flooding: *Low-lying coastal areas, marshes, and contiguous wetlands subject to tidal flooding, storm-surge flooding, and tsunami inundation; highest possible tides are approximately 6 feet above mean sea level; storm surges may add 4 feet to this, exclusive of wave action. Tsunamis with amplitudes of 15 feet are possible and may have runups to elevations of 20-25 feet above concurrent water level. Major impact concentrates on headlands, coves, beaches, and spit extremities; dissipation in the estuaries.*

Erosion and Deposition

Regional Wind Erosion: *Deflation basins, windward sides of unstable dunes, beaches, and other areas of exposed sand not protected by vegetation; promoted by over-grazing, removal of protective cover, lowering of interdune water tables, and rapid deposition along the coastline; prevented by preserving or restoring compatible vegetation.*

Wind Deposition: *Sand deposition on the windward side of active dunes; rates vary from a few inches to a few feet per year depending on dune size, protective cover, extent of source area, and local wind conditions; prevented by stabilizing source area, proper location of projects, and proper planning.*

Potential Beach Erosion and Deposition: *Areas for which jetty construction, beach excavations, channel dredging, spoil disposal, and other artificial changes will initiate future beach erosion and/or deposition; extent of impact varies with size of project; beach areas presently stabilized with exception of seasonal variations.*

Headland Erosion: *Removal of headlands by waves; extremely slow in Pre-Tertiary terrain, sporadic to slow in Sandstone of Tertiary Age, and uniform and slow (several inches per year maximum) in Siltstone of Tertiary Age; no viable means of prevention; impact minimized by proper setback of structures.*

Critical Stream Bank Erosion: *Undercutting and caving of river and stream-bank material by stream action; restricted primarily to flood plains except in upper reaches of large rivers; characterized by location on river bends, bar growth on opposite bank, and relatively deep water near shore; passes upstream into flash-flood channels and downstream into estuarine deposition. Properly engineered riprap provides local correction.*

Mass Movement

Earthflow and Slump Topography: *Terrain characterized by such features as irregular topography, moderate slopes, irregular drainage, irregular soil distribution, and occasionally features of recent movement including tension cracks and bowed trees (depending upon type, depth, and time of failure); generally restricted to the soil zone but also bedrock in sheared or deeply weathered terrain; hazards include ground movement, variable foundation strength, caving in excavations, poor drainage, and others. Excavations, stream-bank erosion, fills, drainage modifications, removal of vegetation, and use of drain fields and septic tanks may reactivate or accelerate sliding. On-site inspection recommended prior to development.*

Deep Bedrock Failure: *Areas of deep bedrock failure initiated by prolonged stream-bank erosion over extended periods of time in the geologic past; restricted to sandstone terrain in the interior uplands; presently inactive with the exception of localized areas within the slides; major hazards include variations in drainage, soil conditions, and foundation strength.*

Rockfall and Debris Flow Terrain: *Areas with slopes greater than 50% regionally are subject to rapid and shallow mass movement such as debris flow, rock slide, and rock-fall. Recent large individual debris flows are indicated with arrows. The specific location of individual mass movements is a function of rock and soil characteristics, weathering history, vegetative cover, and present land use. Treatment includes retaining walls, preservation of vegetative cover, drainage control, screening of critical slopes, and proper engineering of all construction, especially roadcuts and fills.*

Cartography by S. R. Renoud 1975

Geologic Hazards by J. D. Beaulieu and P. W. Hughes