BULLETIN 81

ENVIRONMENTAL GEOLOGY
of
LINCOLN COUNTY, OREGON

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

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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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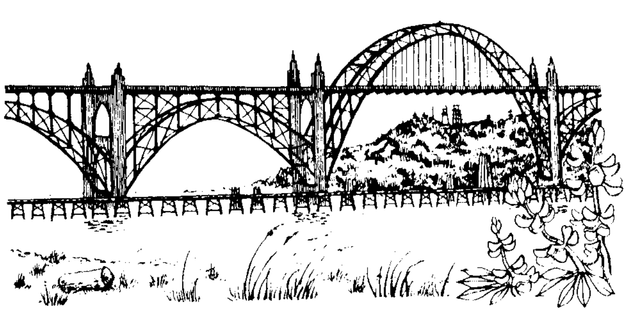
LINCOLN, BENTON, LINN COUNTIES

September 1973

Newport's Front Street on Yoquina Bay in 1900. (Courtesy of Lincoln County Historical Society)



PLANNING DEPARTMENT

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FOREWORD

The demand for recreational development has increased all along the Oregon Coast in recent years, but it has been particularly intensified in Lincoln County, owing to the proximity of major population centers in the Willamette Valley.

Along with increased recreational demands has come the need for more land. The upswing of the economy, the high market value of land, and the resulting increase in tax assessments have created pressures to utilize property which previously was considered best suited for timber growing and agriculture. Neither developers nor purchasers are always fully aware that much of this property, because of adverse geologic or soil conditions, is unsuited for development.

Examples of poor site selection for development are numerous and highly visible in Lincoln County. They occur along the ocean front, along river banks, and in view locations. All of these are prime building sites in terms of recreational or aesthetic value, but unfortunately such land is often subject to erosion, landslides, floods, or other serious geologic hazards. As a result, major financial losses accrue to individuals, corporations, and government agencies involved with such lands--all because of lack of public awareness of these hazards or because development on such areas is not regulated.

This study provides a wealth of much-needed information on the geologic conditions of Lincoln County, and it should be of great benefit to many persons concerned with land usage. For example, County officials can use it to adopt proper zoning, issue building permits, and evaluate development plans. Consulting geologists and engineers can use the information for preliminary studies at particular sites. Developers can plan improvements with the knowledge of potential geologic problems to be encountered. And private citizens can become aware of geologic hazards inherent in the type of property being considered for investment.

It is only through the application of information such as this report provides that safe, efficient, and objective land development can take place in Lincoln County.

Lynn Steiger
County Planner

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ENVIRONMENTAL GEOLOGY OF LINCOLN COUNTY, OREGON

INTRODUCTION

Purpose and Scope of Report

Development along the Oregon Coast is reaching the proportions of a "land rush." The rapidly growing demand for coastal, river-front, and view properties has resulted in increased use of geologically hazardous terrain; without strong building controls, the result could be disaster. The hundreds of coastal homes and properties lost or damaged in the recent past, such as Bayocean, Jumpoff Joe, Salishan, Kiwanda Spit, and numerous isolated localities are insignificant compared with what might happen under the present trend of development unless adequate building controls are instituted.

This investigation was initiated by Lincoln County to assure that in the future all potential geologic problems will be recognized and heeded by those concerned with land use planning and zoning. The resulting report and maps are designed to provide geologic information for use by county and city officials, planners, developers, engineers, and private citizens.

It should be emphasized that this study is general in its scope. It delineates broad areas where hazardous geologic conditions may exist, but it is not sufficiently detailed for localized site evaluation and many unsafe areas may occur that are too small to fall within the content of the report or the scale of the maps. Development of a particular site should proceed only after a careful, detailed evaluation is made of its geologic and engineering characteristics.

Numerous examples of poor development practices can readily be seen in Lincoln County. In nearly every instance, financial losses have accrued to the developer and the general public. Unfortunately, some of the major losses have had to be borne by purchasers of property within a development.

It is hoped that the availability of geologic hazard information in this report and the accompanying interpretive maps will help reduce substantially these losses in future projects.

Responsibility of Government Regarding Geologic Hazards

The experiences of local governments in California are summarized here to show how geologically hazardous conditions can perpetrate law suits against a county and cause it to be responsible for damages. It has been determined through the California courts that the issuance of construction permits by a governmental agency for land development implies that no dangerous or seriously damaging conditions will occur as a result of such construction or in relation to the presence of the development.

In a court case between Sheffet and Los Angeles County (Los Angeles Superior Court Case No. 32487), the court ruled that the county was responsible and must pay damages caused by water and mud flowing from a 12-lot subdivision above the plaintiff's property. In its decision, the District Court of appeals declared: "... where a public entity approved plans for a subdivision including a drainage system, and there is damage to an adjacent property as a result of those improvements, the public entity, not the subdivider, is liable. The fact that the work is performed by the contractor, subdivider, or private owner does not necessarily exonerate the public agency if [they] follow the plans and specifications furnished or approved by the public agency.

"When the work thus planned, specified, or authorized results in injury to adjacent property, the liability is upon the public agency under its obligation to compensate for the damage resulting from the exercise of its governmental power."

The Sheffet decision was upheld by Superior Court Judge William Fox of Pasadena, California. In addition, the County's petition for a rehearing was refused by the State Supreme Court. Refusal to rehear the case by the Supreme Court establishes a judicial precedent.

In brief, the Sheffet decision places the responsibility on the permit-granting agency. These agencies, it appears, are now faced with the necessity of obtaining adequate information on hazardous conditions for the protection of both the local government and the unwary public, who tend to minimize or ignore these hazards until the casualty occurs.

Construction by County Public Works Departments can also result in liability. The Los Angeles Superior Court (Case No. 684595) ruled that road building by Los Angeles County had triggered further damaging landslides in the Palos Verdes Hills and that the County must pay damages of approximately $6 million.

Many California counties now retain geologists for staff consultants as well as to review development plans and make on-site inspections. Certain counties, prompted by lawsuits, unscrupulous developers, and a series of major disasters brought about by both the building boom and a lack of control, have enacted ordinances requiring that developers hire engineers and geologists to examine development proposals and recommend safe design construction. If geologic hazards are indicated, the county then requires a geologic report prepared by a certified engineering geologist and a professional registered engineer. Plans for adequately handling construction problems are submitted for county approval, and inspection is continued during construction.

The cost of geologic reports and construction surveillance is minimal on a per unit basis for multi-lot developments and can be considered an inexpensive form of insurance. The value of having such studies has been made apparent in California (Slosson, 1969). During the torrential rainfall of 1969, almost $6.5 million damage was done to approximately 1,400 sites. Sites upon which no geology and engineering was required had a 10.4 percent failure, sites with soils engineering and limited geology and grading regulations had 1.3 percent failure, and those constructed under new grading codes requiring engineering and engineering geology during design and construction had a failure of only 0.15 percent.

The use of hazardous ground by developers and the need to protect the general public from loss is necessitating the formulation of local and statewide regulations in the nation. It is recommended that such legislation be considered in Oregon.

An initial step in this direction has been achieved in Senate Bill 100 passed in 1973 by the Oregon Legislature. The bill creates and authorizes a Department of Land Conservation and Development to promulgate and implement state-wide planning goals and to adopt comprehensive plans and ordinances for zoning and subdivision.

It makes each county, through its governing body, responsible for coordinating all planning activities affecting land uses within the county, including cities, special districts, and state agencies, to insure an integrated comprehensive plan for the entire area of the county, but it excludes cities of more than 300,000 population (Portland).

Activities of state-wide significance include the planning and siting of public transportation facilities, public sewerage systems, water-supply systems, solid-waste disposal facilities, and public schools.

In preparing and adopting state-wide planning goals and guidelines, the newly created department will give consideration to a number of areas and activities, including estuarine areas, tide marsh and wetland areas, beaches, dunes, coastal headlands and related areas, flood plains, and areas of geologic hazard, so as to protect life and property where floods, landslides, and other natural disasters might occur. It also recommends that any land use plan or zoning, subdivision or other ordinance adopted by a county shall take into consideration lands that are, can, or should be utilized for sources or processing of mineral aggregates.

Application of the Study by County Planners

Planning offices have assumed an increasingly larger function in recent years by attempting to provide the public with information on the characteristics of the land, but this service can be performed only to the extent that planning commission members and staff are sufficiently informed.

To facilitate the application of these engineering geology studies by the planning staff, a planning interpretation has been included with this document (Appendix E). By using the planning interpretation and the geologic hazards maps of this study, the planning commission and staff can advise developers about particular land problems which may exist on their property. The planning personnel can also require that the developers employ an experienced professional engineering geologist or a registered soils engineer, or both if warranted, to perform a site analysis. Such an analysis will determine the feasibility of the proposed development and provide guidelines for corrective engineering design and construction.

It becomes the responsibility of the county personnel and county-retained consultants to review the proposals and construction procedures and to require any necessary changes before approving the development plans.

Previous Work

Previous geologic mapping in Lincoln County includes studies in the Newport-Waldport area by Vokes and others (1949), the coastal area north of Cape Foulweather by Snavely and Vokes (1949), the Marys Peak and Alsea quadrangles by Baldwin (1955), and the Newport area by Snavely and others (1969, 1972a, 1972b, 1972c). The geologic map by Wells and Peck (1961) covers the entire County on a reconnaissance level. Topical studies have been conducted on the coastal dune areas (Cooper, 1958), the Tyee Formation (Snavely and Wagner, 1961), and the Siletz River Volcanics (Snavely and others, 1968). Coastal erosion is discussed by North and Byrne (1965), and the U.S. Army Corps of Engineers (1971a, 1971b).

The preliminary bedrock geologic maps of the Cape Foulweather and Euchre Mountain quadrangles (Snavely and others, 1972a), the Yaquina and Toledo quadrangles (Snavely and others, 1972c), and the Waldport and Tidewater quadrangles (Snavely and others, 1972b) cover the major area of the study and were used exclusively for information on bedrock outcrops and geologic structure for this report.

Sources of Data

The bedrock geology shown on the accompanying geologic maps was taken from the work of Parke D. Snavely, Norman S. MacLeod, Holly Wagner, and Weldon Rau of the U. S. Geological Survey. Distribution of the Quaternary units also shown on the geologic map was constructed from published and unpublished data and from additional field mapping by the authors. Sand dunes were studied and mapped by Frank Reckendorf (U.S.D.A., Soils Conservation Service, personal communication). Logs of water wells and petroleum exploration wells and exploratory drilling records of governmental agencies and private consulting firms were the source of considerable additional geologic information for the study.

Investigation of soils has included the mapping of soil variations in the field by the U.S.D.A. Soils Conservation Service and the study of published and unpublished information. Laboratory test data presented in the text provide additional information on the properties and behavior of the various soils and geologic units. The information was obtained from the Oregon State Highway Division; the office of the State Engineer; the U.S.D.A., Soil Conservation Service; the U. S. Forest Service; the U. S. Department of Transportation; Portland and Seattle District offices of U. S. Army, Corps of Engineers; and with the help of city planners, county planners, county sanitarian, county engineer, and personnel of private consulting firms.

The geologic hazards maps show landslides and areas subject to flooding. Other hazards discussed in the study include near-surface ground water, areas of compressible clay and soft organic soils, and destructive shoreline processes. Knowledge of these geologic problems was obtained through field studies and interviews with city, county, and state personnel, as well as private citizens. In addition, much of the detailed flood data was accumulated through personal interviews with innumerable local residents.

Although the authors collaborated in the preparation of much of this report, certain subjects are largely the responsibility of one person: description of geologic units is by John Beaulieu; the discussion of aggregate and jettystone by Herbert Schlicker, ground water by Gordon Olcott, oil and gas possibilities by Vernon Newton, and economic land uses by Jean Randall; the engineering section is by Herbert Schlicker, flooding by Gordon Olcott, and earthquakes by Robert Deacon. A special section on planning, by Lynn Steiger and Herbert Schlicker, comprises Appendix E.

Acknowledgments

The authors would like to acknowledge the many persons and organizations who have contributed to the report.

For assistance and support: the Lincoln County Board of Commissioners, County Planning Commission, County Planner and staff, State office of Local Government Relations, and the Council of Governments District Four.

We would especially mention Al Couper, Executive Secretary of the Council of Governments, for his help in preparation of the progress reports; Jean Randall, Assistant Planner, for preparation of the section entitled "Economic land uses"; and Vernon C. Newton, State Department of Geology and Mineral Industries, for the section "Oil and gas possibilities."

The Tertiary geology of the County was prepared by U. S. Geological Survey geologists Parke D. Snavely, Jr., Norman McCleod, Holly Wagner, and Weldon Rau, who graciously placed their maps on open file in order to make them available for this study prior to publication by the U. S. Geological Survey. References to Tertiary geology in Lincoln County should give credit to the U. S. Geological Survey open-file geologic maps as listed in the bibliography of this report.

Frank Reckendorf, U.S.D.A., Soil Conservation Service, helped in mapping the sand dunes.

Wesley G. Bruer, State Geologist and Chief of the California Division of Mines and Geology, reviewed part of this report and made helpful suggestions.

Ronald McReary, U.R.E.C.A. Inc., and Robert Dodge, Portland District, U.S. Army Corps of Engineers, provided data and gave assistance concerning jettystone. Data concerning rock quarries and soils were provided by Elmer Ostling of Yachats; Joseph P. Rohleder, geologist with the U.S. Forest Service; Lloyd Woolfe and Robert Forrester of the Oregon Highway Division.

Ground-water information was contributed by John R. Gurton, County Extension agent; Ted Swensen, Sanitarian; Ed Loftquist, Water Resources Coordinator; and Aline Miller, County Assessor's office, all of Lincoln County; Chet Olcott, Central Lincoln P. U. D.; Dick Bowers of Agate Beach, Wilber Day of Roads End, Kenneth Bach of Kernville, and Lester Folts of Lincoln City.

Engineering reports were supplied by Walter Wright of Shannon and Wilson; Kenneth Robbins and Irving Olsen of Dames and Moore; Georgia Pacific Corp.; Cascadia Lumber Co.; Port of Newport; Surftides Condominium Development; Yaquina Development Corp.; Marion A. Craft of the Oregon Highway Division, and D. H. Gosgen, U. S. Army Corps of Engineers. Soil tests were furnished by Fred Yarborough and Clarence Gregg of the Oregon Highway Division and Albert Petska of the State Engineer's office.

Cliff Gray of the California Division of Mines and Geology furnished data concerning court cases involving geologic hazards. Information on flooding came from Pete Wright of the County Road Department; Arthur Bensell, Mayor of Siletz; Joe Steere, County Engineer; Mike Miller, Lincoln County Commissioner; Tim Miller, Siletz River Valley resident; Donald Biggs and Brad Jeffreys of Lincoln City. James Hawley, William de Pew, and Gerald Burdwell provided information on tsunamis. Kenneth Kauffman, former Lincoln County Sanitarian, provided a detailed history of septic tank problems in the County, and Paul Brookhyser, Lincoln County Planning Department, provided data concerning flood insurance.

Soils maps and laboratory data provided by Melvin Rigdon of the U. S. D. A., Soils Conservation Service were greatly appreciated and used extensively in the report and maps.

Aerial photographs were loaned by Gary Potter, Oregon Highway Division. Don Leach, U. S. D. A., Soils Conservation Service of Astoria, provided publications on sand dune stabilization. Photographs were supplied by Wally McClung of Portland, Glen Edenfield of Newport, the Capital Journal of Salem, Pacific Studio of Newport, and the Lincoln County Historical Society.

Cartography and drafting was performed by Steven Renoud, Lynne Lawson, and William Pokorny of the State Department of Geology and Mineral Industries, and by Paul Oltman, Lincoln County Planning Department. Greg Paul photographed and processed the major portion of pictures.

Margaret Steere, Staff Geologist, was responsible for technical editing of the manuscript and was assisted in the copy editing by Carol Brookhyser; Ruthie Pavlat did copy preparation.

GEOGRAPHY

Location and Extent of Area

The study area includes all of Lincoln County (Figure 1). Its northern boundary lies near the Salmon River and Cascade Head at about 45° 2' latitude; its irregular eastern boundary follows roughly the crest of the Coast Range; its southern boundary is near Cape Perpetua south of Yachats River at about 44° 17' latitude. Its western boundary is the Pacific Ocean. The County is approximately 50 miles long, 15 to 25 miles wide, and has a total areal extent of 998 square miles.

Lincoln County is serviced by U. S. Highway 101 along the Coast and U. S. Highway 20 east of Newport. State Highway 18 extends eastward from Otis and State Highway 34 eastward from Waldport; State Highway 229 follows the lower Siletz River. Numerous county and city roads serve the coastal margin, and logging roads provide unpaved access to the mountain areas. The Southern Pacific Railroad connects the Newport area with Corvallis and the central Willamette Valley to the east.

The study area is covered by all or parts of the Hebo, Grand Ronde, Cape Foulweather, Euchre Mountain, Valsetz, Yaquina, Toledo, Marys Peak, Waldport, Tidewater, and Alsea quadrangles (see index map, Figure 1).

Population Trends

According to the U. S. Census, the population of permanent residents in Lincoln County in 1970 was 25,755. Over half of the County's population lived within incorporated cities, including Newport (5,180), Lincoln City (4,198), Toledo (2,818), Waldport (700), Siletz (596), and Yachats (441). Outside these communities the population is concentrated primarily along the coast and secondarily along the narrow valleys of the Salmon, Siletz, Yaquina, and Alsea Rivers.

Table 1. Permanent population of municipalities

	1960	1970	Percent change
Agate Beach Division	7,594	7,310	- 3.7
Newport	5,344	5,188	- 2.9
Delake Division	4,790	6,228	+30.0
Lincoln City	-----	4,198	-----
Depoe Bay Division	1,068	1,271	+19.0
Eddyville Division	956	820	-14.2
Siletz Division	1,369	1,283	- 6.3
Siletz City	583	596	+ 2.2
Toledo Division	5,445	4,936	- 9.3
Toledo City	3,053	2,818	- 7.7
Waldport Division	3,413	3,907	+14.5
Waldport City	667	700	+ 4.9
Yachats	-----	441	-----

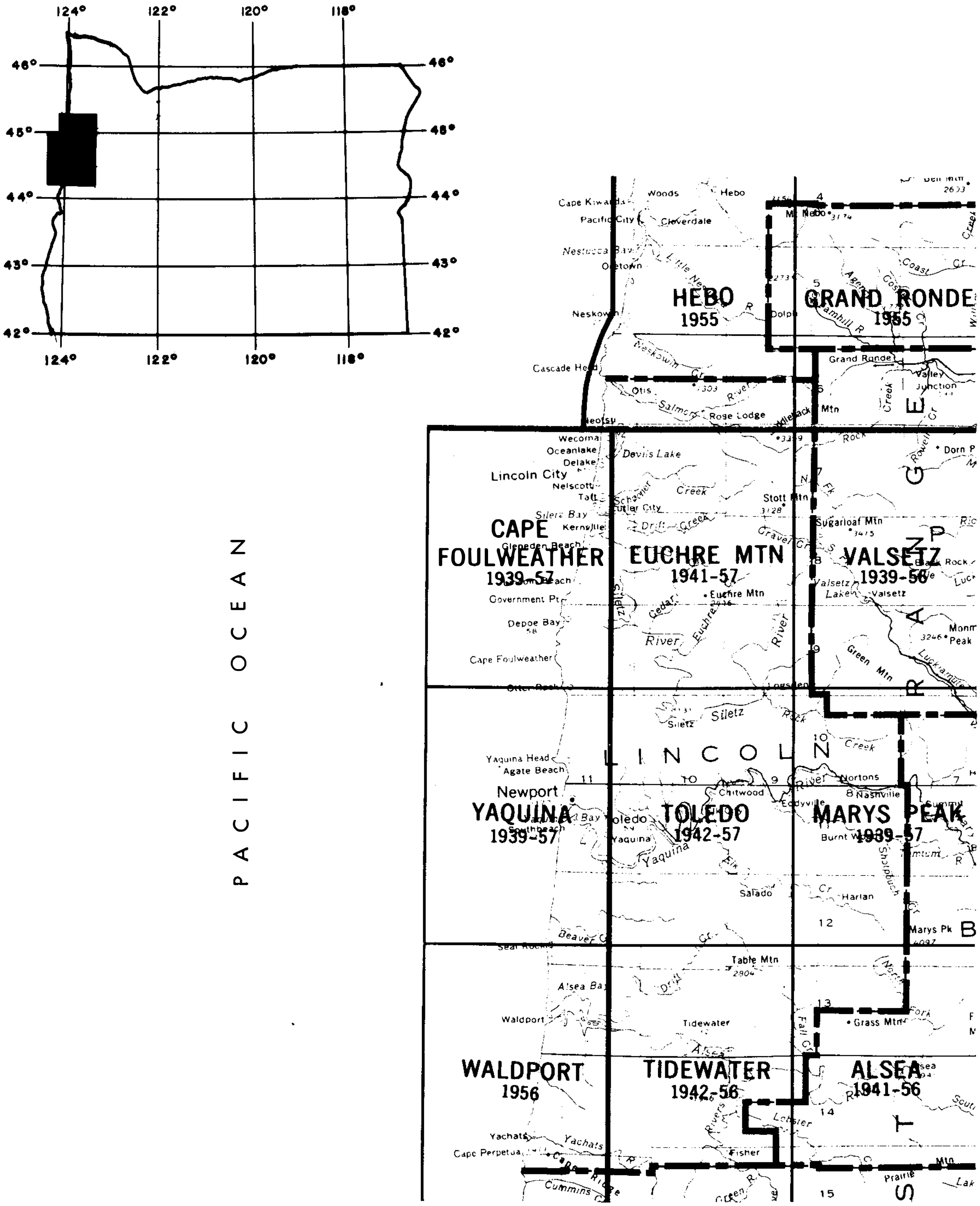


Figure 1. Index map of Lincoln County showing quadrangle map coverage.

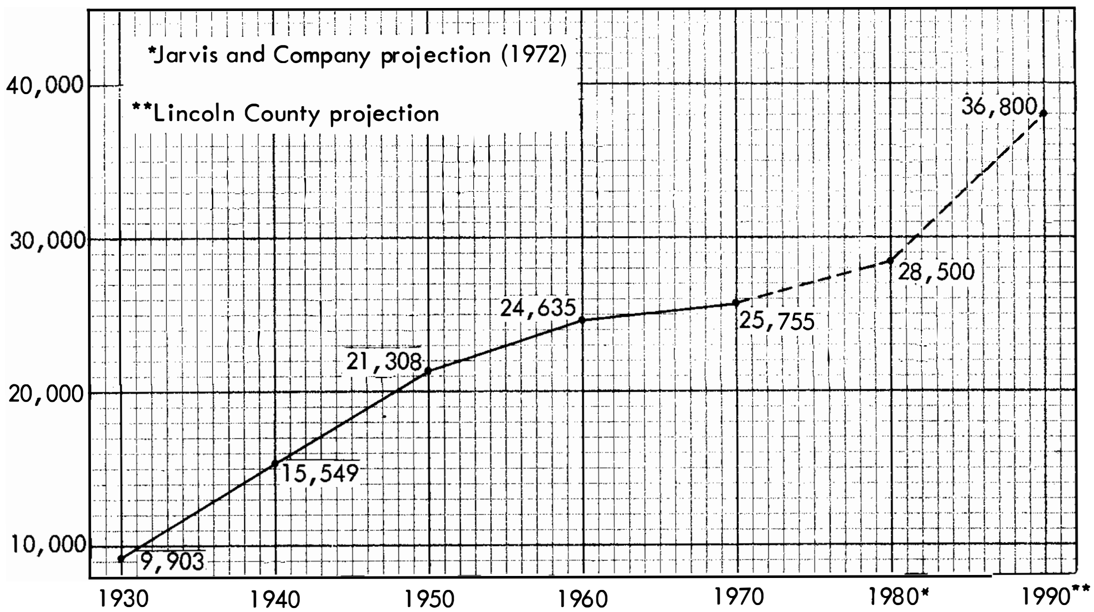


Figure 2. Population Trends in Lincoln County

As shown in Figure 2, the rate of increase of population in Lincoln County has diminished in recent years. Projections by Jack Jarvis and Co. and the Lincoln County Planning Department, however, point to a marked increase in the future (Figure 2).

The trend in population for individual municipalities of Lincoln County in the last decade vary considerably, as shown in Table 1. Generally the county-wide trend is away from the interior and towards the coast. Toledo, Siletz, and Eddyville registered declines between 1960 and 1970, whereas Waldport, Depoe Bay, and Delake registered increases. Newport showed a slight decline, which resulted from population movement toward new housing developments outside the city limits. A trend toward rapid urbanization of the north coastal part of the County is evident.

Superposed on the trends in permanent population is the effect of non-tourist summertime residents. Table 2 was prepared using vacant housing in April as a basis for estimating potential peak resident population in the summertime. The coastal areas receive most of the impact of summertime residents.

In addition, the tourist population has a considerable impact on the County. Tourists occupying motels, hotels, trailer camps, and campgrounds are not included in the above estimates, although they number in the thousands at any one time in the summer months.

Table 2. Summertime population

	Vacant housing in April	Additional population in summer	Estimated summer peak population
Lincoln County	3,014	9,042	34,797
Lincoln City	727	2,181	6,379
Siletz	10	30	626
Newport	257	771	5,979
Toledo	88	264	3,082
Waldport	19	57	757
Yachats	90	270	711

Climate and Vegetation

The climate of Lincoln County is moist, marine, and temperate. Precipitation ranges from 60 to 90 inches along the coast to as much as 180 inches in some parts of the Coast Range. Average rainfall in most inland areas ranges from 80 to 100 inches. At Cape Perpetua and adjacent inland areas, average rainfall exceeds 100 inches. Throughout the County, approximately 80 percent of the annual rainfall comes between October and March. Most precipitation occurs from winter storms, some lasting several days. The monthly precipitation for Newport is listed in Table 3.

Table 3. Average monthly precipitation at Newport

Month	Precipitation (inches)
January	10.01
February	8.38
March	8.38
April	4.16
May	2.93
June	2.39
July	0.81
August	0.92
September	2.31
October	6.12
November	8.80
December	11.02

Temperatures in the interior parts of Lincoln County seldom drop to zero in the winter and seldom exceed 100° in the summer. Conditions along the coast are generally more moderate. The average January temperature for Newport is 43.7° and the average July temperature is 57.6°. For the County as a whole, the average minimum temperature for January is 30° to 40° and the average July minimum is 50° to 55°. The low of -11°, recorded at Depoe Bay in December of 1972, was unprecedented in recorded history; the previous all-time low for that city was 10°.

In Lincoln County, summer winds are gentle out of the northwest and winter winds are gusty out of the southwest. Average wind velocities range from 15 to 25 miles per hour, but winter gusts of up to 100 miles per hour have been reported.

Conifers dominate the woody vegetation in Lincoln County. Near the coast and in mature stands the forests are composed mainly of shade-resistant varieties such as Western hemlock (*Tsuga heterophylla*). Inland nearer the crest of the Coast Range and in youthful stands the predominant species is Douglas fir (*Pseudotsuga menziesii*). Commonly associated species include Western hemlock and Western red cedar (*Thuja plicata*).

Topography

Lincoln County lies on the western flank of the Coast Range. The region is characterized by rugged mountains with steep-sided stream valleys in the uplands, by narrow flood plains in the interior, and by bays with spits, narrow sandy beaches, and bold headlands along the coast. The major drainages are the Siletz, Alsea, and Yaquina Rivers, which have cut steep and narrow valleys across the Coast Range to empty into small bays.

Coastal margin

Most of the coast is bordered by marine terraces, which typically range from 50 to 100 feet above mean sea level (msl), but locally are up to 200 feet. The terraces form vertical bluffs along the coast and extend as much as a mile inland. The continuity of coastal terraces is broken by bold headlands at Cascade Head, Cape Foulweather-Otter Crest, Yaquina Head, and Cape Perpetua. Small bays at the mouths of the Alsea, Yaquina, and Siletz Rivers are a mile or so in width and extend inland for 3 to 4 miles; they cover areas of 2 to 5 square miles. Narrow tidal flats occur near sea level along the bays.

The headlands rise abruptly from sea level on the coast to elevations of 400 to 700 feet. Cascade Head fronts the sea with a nearly vertical bluff of 400 feet, Cape Foulweather has cliffs 300 to 500 feet in height, and Cape Perpetua has steep slopes up to 700 feet in height.

Uplands

Uplands extend from the eastern boundaries of the terraces, headlands, and bays to the eastern part of the County and include the mountainous terrain of the area. Near the coast, the mountains have moderately rounded to elongate slopes with elevations of 200 to 300 feet. Easterly, the terrain becomes steep with narrow rugged ridge crests 500 to 700 feet above stream valleys, with elevations ranging from 1500 to 2000 feet msl. Ridges are randomly oriented, but some follow strong northwest-southeast trends (strike ridges). Igneous rocks underlie the higher peaks, which include (from north to south): Bald Mtn., elev. 2,890 feet; Saddleback Mtn., elev. 3,359 feet; Stott Mtn., elev. 3,128 feet; Deadwood Mtn., elev. 1,439 feet; Euchre Mtn., elev. 2,446 feet; Diamond Peak, elev. 2,453 feet; Table Mtn., elev. 2,804 feet; and Cannibal Mtn., elev. 1,946 feet.

Topographic irregularities on slopes in the upland area are the result of ancient landslides. The landslide areas are characterized by flatter slopes, irregular mounds and swales, ponds, randomly oriented closed depressions, and youthful drainage that contrasts with the older established stream patterns.

Drainage

The Siletz, Yaquina, and Alsea Rivers, the major streams of the area, originate near the crest of the Coast Range and flow westward through steep-sided canyons to their bays. Meander patterns indicate that these streams were established prior to the uplift of the Coast Range. Other significant streams are the Salmon River at the north edge of the County and the Yachats River in the southern part of the County. Smaller streams which reach the ocean include Drift Creek, Schooner Creek, Spencer Creek, Big Creek, and Beaver Creek.

The drainage pattern of the area is predominately dendritic with local areas of parallel drainage and entrenched meanders along the major streams.

Devils Lake, just east of Lincoln City, is a natural impoundment of water. The lake is approximately half a mile wide and extends northwesterly for approximately 3 miles. The origin of the depression is unclear. The depression was apparently developed as a stream valley, but present streams in the upper reaches of the lake are too small to account for it. The only nearby stream that seems to have the capacity to erode such a valley is the Salmon River to the north, which flows westerly to the coast. Possibly the valley occupied by Devils Lake is an abandoned channel of the Salmon River. Ancient landslides at the head of the lake may have diverted the stream to its present course.

Economic Land Uses

Lincoln County has traditionally had a natural-resource economy; the primary activities include agriculture, fishing and fish processing, lumbering and forest products, and recreation and tourism.

Shifts in employment distribution among various sectors of the economy indicate recreation and tourism is growing in importance while the other traditional industries, agriculture, lumbering and forest products, are declining.

Agriculture

Lincoln County was originally settled by homesteaders who farmed at the headwaters of the coastal streams, in the river valleys, and finally on the coastal plains. Farming, ranching, and dairying were once the primary economic activities in the County, but it has become increasingly difficult for a farmer to base his livelihood on farming alone because of increasing operational expenses and land costs inflated by recreational demands.

The County agricultural extension agent has estimated that only 25 percent of the land in the County suitable for agriculture is being used for that purpose. In 1964, 68,378 acres, or 10.8 percent of the total land area, were in farm production; in 1969 this had decreased to 47,390 acres, or 7.5 percent. Most of the farmland in the County is classified as woodland or pastureland.

Although total acreage decreased, total product revenue increased from $912,428 ($8,773 per family) in 1964 to $1,591,799 ($13,841 per family) in 1969. This is attributable partially to the shift to more specialized production, such as nurseries, tree farms, and berry farms.

Successful farming operations in the County are primarily those of long-time residents who own their land and condition the soil. Because of the high acidity and low nutrient content of the soils in many areas, preparation for production may be as high as $150 per acre.

Commercial fishing and fish processing

The majority of fishing activity in the County is centered around Yaquina Bay and Depoe Bay. Yaquina Bay ranks third among Oregon fishing ports; Astoria, 140 miles to the north, is the leading port, and Charleston, 100 miles to the south, ranks second. Altogether these three fishing ports account for at least 85 percent of the total commercial landings in Oregon.

The major fish and shellfish landed in Lincoln County are albacore, salmon, flatfish (flounder and sole), rock fish (including ocean perch), Dungeness crab, and shrimp. Dungeness crab and coho and Chinook salmon are considered to be fished at or near maximum levels with current fishing technology and methods.

An estimated 675 commercial fishing boats currently operate out of Yaquina Bay. About 275 of these are large vessels that operate on a full-time basis and participate in several fisheries during the year. About 400 are smaller boats used for part-time salmon fishing. A significant part of the catch is processed outside the County, including about 90 percent of the salmon and albacore and 30 percent of the crab. Most of the shrimp and bottom fish are processed locally.

The growth of the fishing industry in Lincoln County is limited by the available resources, the number of vessels the support facilities can handle, and the ability of processors to handle the production.

Lumbering and forest products

The forest products industry is the most extensive user of land in Lincoln County. It is estimated that more than 90 percent of the County is suitable for growing timber, with a productive capacity of over 1,000 board feet per acre per year or better. Timber lands are also used for outdoor recreation, watershed protection, and forage and habitat for wildlife.

The major species grown for timber production are softwoods including Douglas fir, Western hemlock, Sitka spruce, Lodgepole pine, and Western red cedar. Douglas fir is the principal species with a 60- to 80-year cycle. The most abundant hardwood species is Alder, with a 20-year cycle. Although Alder is not generally grown for production, good stands are frequently harvested for manufacture of furniture. Alder and other hardwoods will soon be used locally in the manufacture of kraft paper.

After a 10-year decline in timber production, the County is experiencing an increase in log harvest largely owing to national demand for new construction. There are 12 wood processors in the County; one major plant producing studs, paperboard, and plywood employs about 950 people.

Recreation and tourism

The Pacific Ocean, rugged coastline, sandy beaches, numerous clear streams and rivers, and scenic mountains make Lincoln County a major recreational area of the Pacific Northwest. Although there is little statistical information on the overall extent and character of recreation and tourism, there is little doubt that it will continue to be an important element in the economy of the County.

The tourist and recreational demand is oriented towards such activities as sightseeing, swimming, boating, sport fishing, picnicking, camping, and non-facility activities such as hiking, hunting, and nature study. These activities generate demands for overnight accommodations, restaurants, gift shops, marine exhibits, dry and wet moorage facilities, charter boat services, equipment and repair establishments, and other supporting activities.

The majority of tourist use occurs within four months, June through September, with July and August the peak season. Efforts are under way to make tourism a year-round activity, particularly through attracting the convention trade.

The number of annual recreational visitors to Lincoln County is projected to increase by 74 percent in the next decade as income levels and leisure time increase. This could result in the conversion of the entire coastal area from current uses to recreation-centered industries.

Photo 1. Cape Foulweather from Devils Punch Bowl in early 1900's. (Courtesy of Pacific Studio, Newport)

STRATIGRAPHIC TIME CHART FOR TERTIARY UNITS

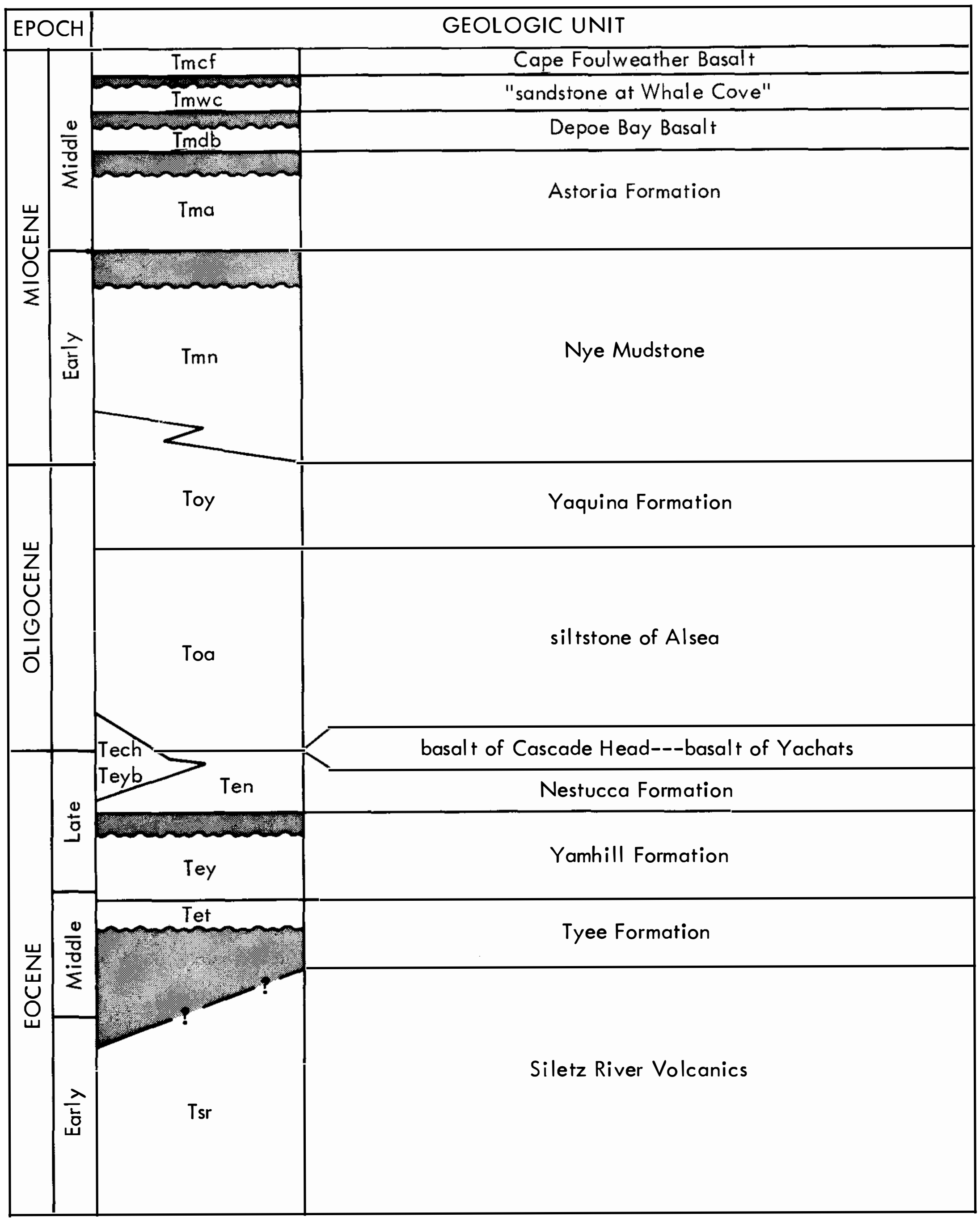


Figure 3. Chart showing the stratigraphic positions, map symbols, and relative ages of the bedrock formations in Lincoln County.

GEOLOGY

Summary of Geologic Units

Indurated rock units ranging in age from early Eocene through middle Miocene and unconsolidated deposits of Quaternary age underlie the project area (Figure 3). The consolidated units total more than 40,000 feet in composite thickness and include submarine and subaerial basaltic flows, breccia, tuff, marine siltstone, clayey siltstone, sandstone and intrusive rock. The two most extensive Tertiary bedrock units are the Siletz River Volcanics (Tsr), and the Tyee Formation (Tet). Most of the other units can be grouped on the basis of their engineering characteristics into five categories: siltstones, sandstones, basalts, intrusive rocks, and surficial deposits. All but the surficial deposits are of Tertiary age.

Siletz River Volcanics (Tsr)

The Siletz River Volcanics consists of a lower unit of basalt flows and breccias similar to that of the undifferentiated floor of the present-day Pacific Ocean, overlain in places by partly subaerial basalts such as those exposed at Ball Mountain (Snavely and others, 1968). Exposures in the study area are contiguous with the type section of Snavely and Baldwin (1948) and form a horseshoe-shaped outcrop in the southern Hebo, Euchre Mountain, and Valsetz quadrangles covering approximately 125 square miles.

The thickness of the Siletz River Volcanics is not well established. The unit is surrounded by younger units and the base is not exposed. Snavely and others (1968), however, estimate a thickness of up to 10,000 feet for the unit in areas of former volcanic centers.

Fine-grained to porphyritic basaltic flow rock, pillow basalts, well-cemented zeolitized massive lapilli tuffs and tuff breccias are the most common rock types. Vesicular to amygdaloidal textures are characteristic. The dominant minerals include labradorite, augite, titaniferous magnetite, and glass. Augite is the most common phenocryst.

Interbedded with the volcanic rocks are appreciable thicknesses of dark greenish-gray tuffaceous siltstone and sandstone with minor amounts of shale.

In places the volcanic rocks are dominated by pyroclastic materials, as at Ball Mountain a short distance inland from Cutler City, where the rocks include alkalic basaltic flows and abundant tuff and breccia. These rocks are interpreted to represent seamounts extruded during the latter stages of Siletz River deposition (Snavely and others, 1969).

Available data indicate an early Eocene to possible early middle Eocene age for the Siletz River Volcanics. Baldwin (1955) documents a lower Umpqua, lower Capay, Crescent age for the upper part of the unit on the basis of fossils found in the Kings Valley Siltstone member to the east. Snavely and others (1969) present foraminiferal lists which correspond to lower and middle Eocene stages. The profound environmental changes indicated by the lithology of the overlying Tyee Formation signify an appreciable unconformity or period of erosion and nondeposition following the deposition of the Siletz River Volcanics.

Weathering of the volcanic rocks yields a thin, reddish-brown clay soil on steep slopes and thicker soils on saddles, flattish hilltops, and spurs. Breakdown of the rocks causes colluvium (talus) to accumulate downslope. Weathering of the interbedded siltstone, sandstone, and shale produces shaly claystone having spheroidal pattern; dark manganese staining occurs along some of the fracture surfaces.

Tyee Formation (Tet)

The Tyee Formation consists of up to 6,000 feet of alternating sandstone and siltstone beds. It is the most widespread unit in central and southern Lincoln County and forms a continuous exposure covering almost 600 square miles in the Alsea, Tidewater, Marys Peak, Toledo, and Euchre Mountain quadrangles. The Tyee Formation defined by Diller (1898) was mapped as the Burpee Formation in southern Lincoln County by Vokes and others (1949). The name Tyee was extended to the Newport area by Snavely and

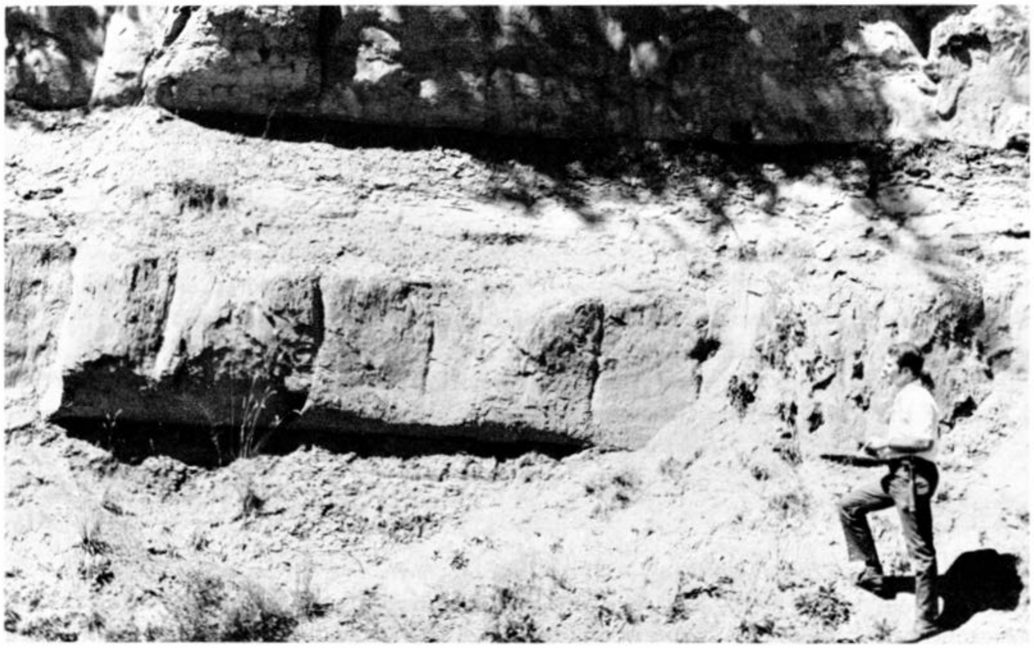
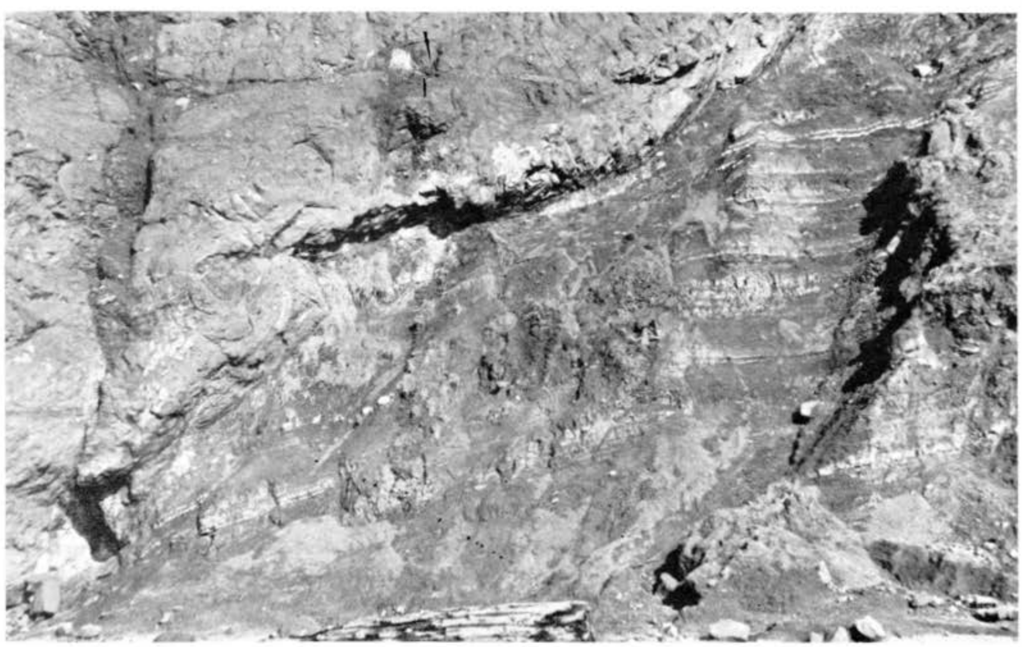


Photo 2. Graded bedding in Tyee Formation showing sharp contact below sandstone layers and gradational contact above.

Photo 3. Yamhill Formation exposed in roadcut on Highway 101 near the Lincoln-Tillamook County line. Note characteristic slope ravel in talus deposits at base of cut.

Photo 4. Nestucca Formation in high cliff north of Roads End. Small basalt dikes cut across bedding.

Photo 5. Basalt breccia (upper left) in probable fault contact with Nestucca Formation (lower right) in headland north of Roads End.



others (1969), and the Euchre Mountain and southern Hebo quadrangles by Snavely and Vokes (1949). Isolated blocks of Tyee down-faulted into the Siletz River Volcanics are preserved near Euchre Mountain and Lambert Point.

Sandstone beds of the Tyee Formation range from hard and well indurated to semi-friable and poorly consolidated. They consist predominantly of micaceous, arkosic, medium-grained sandstone. The alternating siltstone beds are softer and contain abundant plant debris in places. Lateral persistence of individual sandstone beds and other related features indicate emplacement by turbidity currents on the sea floor. Sole markings indicate a northerly direction of transport (Snavely and others, 1964b). The unit represents a series of coalescing submarine fans which spread northward from a topographic high at the site of the present-day Klamath Mountains.

Steep canyons cut in the resistant sandstone characterize much of the topography developed on the Tyee Formation. The lower-most Tyee strata exposed in the eastern part of the County consist of 2- to 15-foot thick sandstone interbedded with very thin layers of siltstone. Elsewhere the sandstone interbeds average 5 feet in thickness and are separated by nearly equal thicknesses of siltstone.

Foraminifera (small fossil shells) recovered from the basal and top siltstone units of the Tyee Formation and from finer grained interbeds throughout the unit indicate a middle Eocene age. The fossils give a remarkably consistent age determination, suggesting rapid deposition. The stratigraphic position of the Tyee Formation farther to the south also indicates that the precise age of the unit is probably late middle Eocene. The Tyee Formation in Lincoln County is conformably overlain by rocks assigned to the Yamhill Formation by Snavely and others (1969).

The Tyee Formation weathers to silty and sandy soils. In general, the soil cover is thin owing to the prevalence of steep slopes from which the soil is easily eroded. Locally, thick colluvial deposits are present at the base of slopes.

Tertiary siltstones

The four siltstone units are grouped together in recognition of their common engineering properties. They include the late Eocene Yamhill (Tey) and Nestucca (Ten) Formations, the early to middle Oligocene siltstone of Alsea (Toa), and the early Miocene Nye Mudstone (Tmn). The Oligocene Yaquina Formation (sandstone) lying stratigraphically between the Nye Mudstone and the older siltstone units is discussed later.

Yamhill Formation (Tey): The Yamhill Formation consists of several thousand feet of indurated, massive to thin-bedded clayey siltstone with minor interbeds of arkosic, basaltic, and glauconitic sandstone. Exposures are located near Lincoln City, north of Toledo, and at scattered localities beneath younger silts in the northeastern corner of the Euchre Mountain quadrangle. The rocks were previously mapped as part of the lower Toledo Formation (Vokes and others, 1949) in the south coastal area and as part of the Nestucca Formation in the north coastal area (Snavely and Vokes, 1949).

Foraminifera in the Yamhill Formation indicate a middle Eocene to upper Eocene age (Snavely and others, 1969). The Yamhill Formation is conformable over the Tyee Formation and is unconformably overlain by the younger Nestucca Formation. Weathering of the Yamhill rocks produces a light-colored clayey soil that is prone to sliding on moderate to steep slopes.

Nestucca Formation (Ten): The Nestucca Formation consists of 800 to 5,000 feet of indurated thin-bedded tuffaceous clayey siltstone and subordinate amounts of ash and interbedded arkosic, basaltic, and glauconitic sandstone. Small sandstone dikes and sills are common in the upper part of the section. Exposures of the Nestucca Formation are located at Lincoln City, in the Toledo area, and south of Yaquina Bay. It was previously mapped as part of the lower Toledo Formation in the south coastal area by Vokes and others (1949).

Foraminifera in the Nestucca Formation are of upper Eocene age (Snavely and others, 1969). The Nestucca Formation onlaps Yamhill, Tyee, and Siletz River strata and is less deformed than the underlying units. An unconformity is interpreted to separate the Yamhill and the Nestucca Formations (Snavely and others, 1969). Weathering produces a light-colored clay-rich soil that is prone to sliding.

Siltstone of Alsea (Toa): Massive, fine-grained indurated sedimentary rock of Oligocene age in the Newport and Waldport areas is referred to informally as the "siltstone of Alsea"(Toa) by Snavely and others (1969). The unit is particularly well-exposed at Alsea Bay and forms a 1-mile-wide band which extends northward past Toledo to the mouth of the Siletz River. The exposures were originally included in the upper part of the Toledo Formation by Vokes and others (1949).

The siltstone of Alsea is 1,500 feet thick at Yaquina Bay and is predominately a massive, tuffaceous siltstone with subordinate fine-grained sandstone. Concretions are common. Excellent exposures in the bluffs along the bay at Waldport include beds of tuff, tuffaceous siltstone, and mudflow breccia.

At Yachats and a short distance inland, the massive siltstone passes laterally and downsection into firmly cemented, thick-bedded, basaltic sandstones which grade downward into poorly sorted basaltic conglomerates. These coarse sedimentary rocks, about 250 feet thick, occupy the base of the Oligocene section.

The siltstone of Alsea overlies the Nestucca Formation in the central parts of the County and late Eocene volcanic rocks in the southern part of the County. On the basis of microfossils recovered at numerous localities an Oligocene age is interpreted for the siltstone (Snavely and others, 1969).

Nye Mudstone (Tmn): The Nye Mudstone was defined by Schenck (1927) and was later mapped in southern Lincoln County by Vokes and others (1949) and central Lincoln County by Snavely and others (1969). The unit is exposed along the sea cliffs and coastal creeks of the southern Yaquina quadrangle and extends 8 miles north of Yaquina Bay, where it is onlapped by the Astoria Formation inland from Cape Foulweather. Excellent exposures are located in the bluffs along the north side of Yaquina Bay. In the northern part of the County, the Nye Mudstone is exposed for 5 miles from Siletz Bay southward to a prominent bend in the Siletz River inland from Depoe Bay.

The Nye Mudstone is 4,400 feet thick at Yaquina Bay and thins to 500 feet $4\frac{1}{2}$ miles north of the Bay (Snavely and others, 1969).

The unit consists of indurated, massive to indistinctly bedded clayey siltstone rich in organic matter. Thin calcareous lenses and sandstone interbeds are common low in the section and large concretions are present in the upper parts of the unit. Fresh samples at an outcrop on the north side of Yaquina Bay emit a petroliferous odor when broken.

Talus deposits of shaly rubble are common along steep cuts in the Nye Mudstone. Iron staining emphasizes the close jointing in slightly weathered outcrops, and clay-rich soil prone to sliding is characteristic of the deeply weathered terrain.

On the basis of a thorough investigation of foraminiferal samples recovered from throughout the Nye section, Snavely and others (1964a) conclude that the unit is entirely of early Miocene age. The Nye Mudstone is conformable over the Yaquina Formation and unconformable beneath the Astoria Formation.

Tertiary basalts

Four basaltic units are grouped together in recognition of their common engineering properties. They include Eocene basalt at Cascade Head (Tech), Eocene basalt at Yachats (Teyb), the Miocene Depoe Bay Basalt (Tmdb), and the Miocene Cape Foulweather Basalt (Tmcf).

Basalt of Yachats (Teyb) and basalt of Cascade Head (Tech): Late Eocene volcanic rock of basaltic composition forms the headlands south of Yachats (Teyb) and at Cascade Head (Tech) in northernmost Lincoln County. The total areal extent of these units is approximately 30 square miles. They were included in the Nestucca Formation by Snavely and others (1969).

Volcanic rocks at Cape Perpetua are 2,000 feet thick and consist of basaltic flows, breccia, and lapilli tuff. Flows are generally 10 to 20 feet thick; oxidized zones indicate subaerial extrusion. Plagioclase is the most common phenocryst. Dike rocks are generally basaltic but range to dacites locally.

The volcanic rocks at Cascade Head consist primarily of fine-grained to glassy basaltic breccias and lapilli tuffs with intercalated siltstone. Scattered phenocrysts consist of plagioclase, augite, and olivine. Weathering of these rocks produces a thin granular soil on steep slopes and thin clay-bearing, reddish residual soils elsewhere.

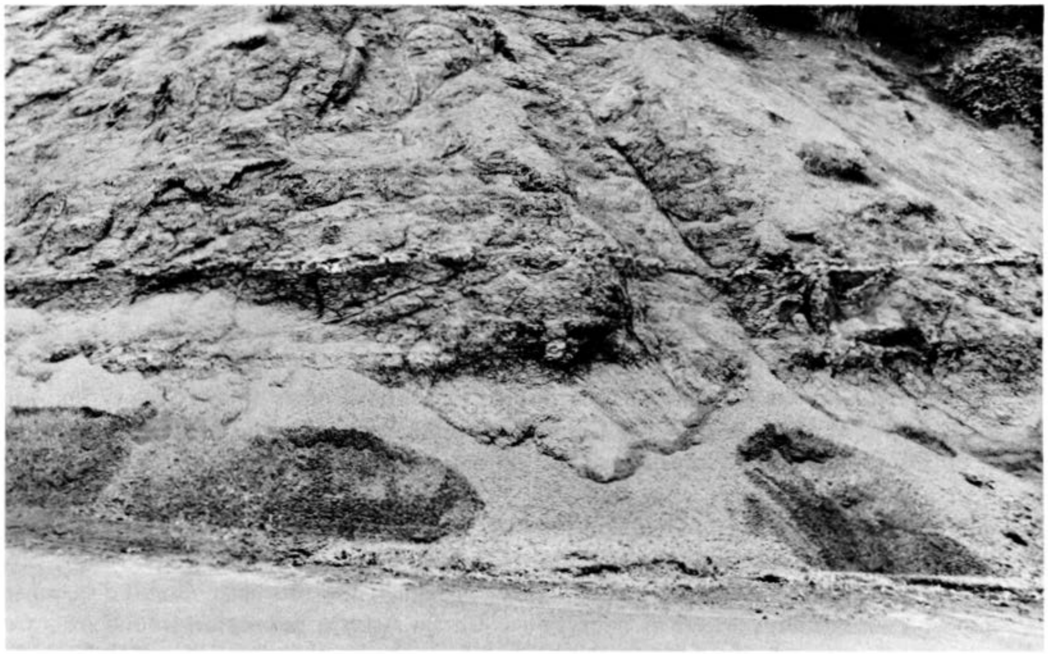


Photo 6. Siltstone of Alsea exposed on Yaquina Bay road at junction with Hidden Valley road near Toledo.

Photo 7. Nye Mudstone on Yaquina Bay road showing characteristic ravelling that produces talus at foot of cuts. Light-colored beds about 1 foot thick are limy concretions.

Photo 8. Headland north of Roads End composed of basalt of Cascade Head and volcanic sediments. Note large landslide in area of sediments not fronted by basaltic rock.

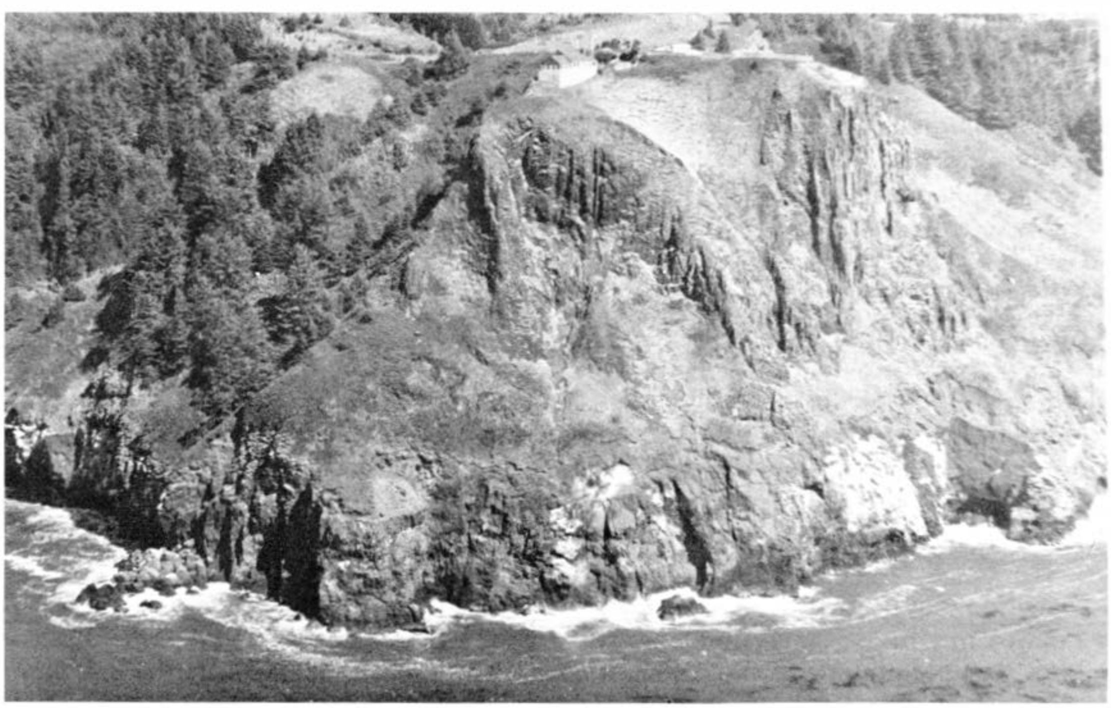


Photo 9. Massive basalt headland at Cape Foulweather resists erosion by the sea.

The stratigraphic position of the basalt at Yachats over the Nestucca Formation and beneath the Oligocene siltstone of Alsea indicates an uppermost Eocene age for the unit. A similar age is inferred for the basalt at Cascade Head.

Depoe Bay Basalt (Tmdb): Snavely and others (1969) referred informally to exposures of middle Miocene basalt in the Depoe Bay area which unconformably overlie the Astoria Formation and which underlie the "sandstone of Whale Cove" as the "basalt of Depoe Bay." Subsequently the unit was elevated to formational status (Snavely and others, 1973) as the Depoe Bay Basalt. Exposures extend about a mile north and south of Depoe Bay and are less than 2 square miles in area.

At Depoe Bay the unit consists of approximately 75 feet of submarine basalt, which is made up of basaltic pillows up to 4 feet in diameter set in a matrix of orange-brown plagonitized basaltic glass. A short distance to the south the pillows pass laterally into a subaerial flow of columnar, jointed, medium- to dark-gray, fine-grained basalt. Numerous dikes and sills in the immediate vicinity attest to the local origin of the unit.

Volcanic rocks of similar age and lithology are exposed to the north at Cape Lookout, Cape Meares, and Tillamook Head. All are equivalent petrochemically to the Yakima Basalt of Waters (1961) in eastern Oregon. Stratigraphic relationships in Lincoln County indicate a middle Miocene (Saucesian) or younger age for the Depoe Bay Basalt, and foraminifera recovered from sediments associated with similar volcanic rocks at Cape Meares indicate a middle Miocene (Relizian) age.

Cape Foulweather Basalt (Tmcf): The basalts and related rocks which form the headlands at Cape Foulweather and which overlie the "sandstone of Whale Cove" at Depoe Bay and Government Point are referred to as the Cape Foulweather Basalt (Tmcf). They were originally referred to informally as the "basalts of Cape Foulweather" by Snavely and others (1969). Total areal extent of the unit is approximately 3 square miles.

The unit consists mainly of basaltic breccias and water-laid fragmental rocks; pillow lavas and massive flows are subordinate. Much of the unit was extruded subaerially. The peripheral water-laid breccias such as those at Government Point probably represent material eroded off the growing volcanic center. The numerous feeder dikes surrounding Cape Foulweather indicate a local origin for the unit.

The Cape Foulweather Basalt is lithologically similar to some of the basalts to the north at Cape Lookout and Ecola State Park. Scattered yellowish plagioclase phenocrysts are distinctive (Snavely and others, 1969). The unit is petrochemically similar to the late Yakima basalt flow of Waters (1961) in eastern Oregon (Snavely and others, 1973).

The Cape Foulweather Basalt unconformably overlaps the "sandstone of Whale Cove," the Depoe Bay Basalt, and the Astoria Formation. A middle Miocene (Relizian) or younger age is inferred for the unit (Snavely and others, 1969).

Tertiary sandstones

Three sandstone units of middle Tertiary age are grouped together in recognition of their common engineering properties. They include the Oligocene and earliest Miocene Yaquina Formation, the middle Miocene Astoria Formation, and "sandstone of Whale Cove." The Yaquina Formation lies stratigraphically between the siltstone of Alsea and the Nye Mudstone. The Astoria Formation and the "sandstone of Whale Cove" are separated by the Cape Foulweather Basalt.

Yaquina Formation (Toy): The Yaquina Formation consists of deltaic sedimentary rock up to 2,000 feet thick. It is exposed in a band 1 to 5 miles wide from Siletz Bay southward through the uplands immediately west of Toledo to the coastal parts of the Waldport quadrangle south of Waldport. The unit was first discussed by the firm of Harrison and Eaton in 1920 and was subsequently treated by Snavely and Vokes (1949) in the northern part of the County and by Vokes and others (1949) in the southern part of the County. Most recent mapping was done by Snavely and others (1969; 1972a, b, c).

The Yaquina Formation exhibits a diverse lithology. It consists of micaceous, tuffaceous, arkosic sandstone that is hard but locally friable, massive to well bedded and cross bedded; pebbly sandstone; conglomerate; massive tuffaceous siltstone; and coaly deposits. Cut and fill structures, ash horizons,

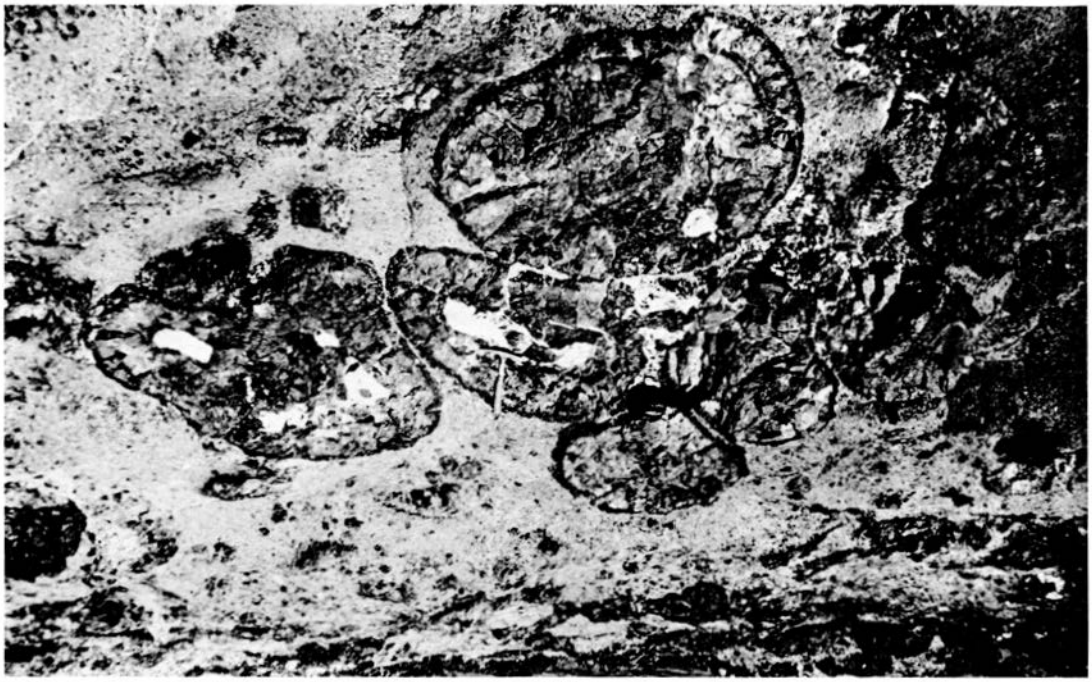


Photo 10. Pillow breccia in basalt of Depoe Bay exposed adjacent to Highway 101. Pillows formed by sudden cooling of lava entering the sea. (Photo from Snavely and MacLeod, 1971)

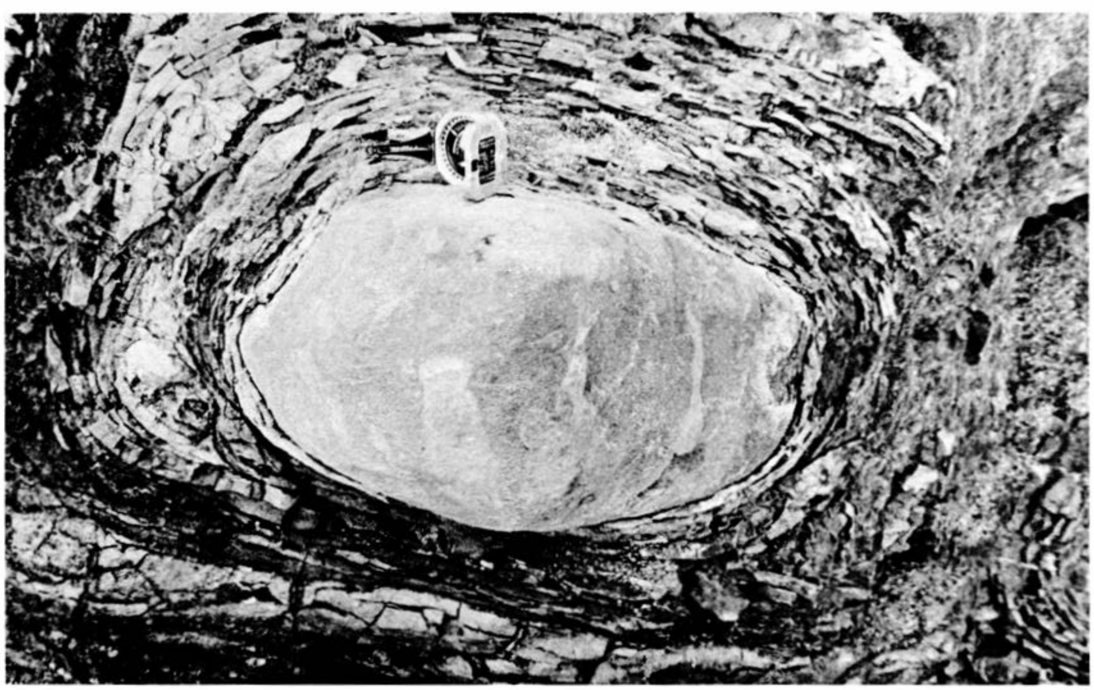


Photo 11. Spheroidal weathering of sandy part of "siltstone of Alsea" near Yachats; core of unweathered sandstone surrounded by weathered rock.

Photo 12. Well-bedded sandstone of Yaquina Formation exposed along Yaquina Bay road east of Newport.

Photo 13. Massive, irregular jointing in sandstone of Yaquina Formation on Yaquina Bay road east of Newport.

Photo 14. Hard sandstone layer in Astoria Formation at Beverly Beach; weathering and erosion of jointed rock has produced this mosaic pattern.

Photo 15. Fossil bed exposed in sea cliff of Astoria Formation near Beverly Beach State Park. Locality attracts many tourists.

pumiceous fragments, and silicic volconic fragments ore noted locally. Thicknesses range from less than 1,000 feet at Beaver Creek north of Alsea Boy and at Siletz Boy to 1,700 feet at Yoquino Boy, and 2,000 feet inland from Cope Foulweother (Snavely and others, 1969). Weathering produces sandy soils which ore less prone to sliding than the soils of the adjacent Alsea and Nye units.

Gross lithology, thickness patterns, and fossil types indicate that the Yoquino Formation was laid down as a large delta. Its thickest port is in central Lincoln County and it thins to the north and to the south, (Snavely and others. 1969). The unit is rich in megafossils near Kernville at Siletz Boy and at Beaver Creek in the southern Yoquino quadrangle.

The Yoquino Formation conformably overlies the siltstone of Alsea and is conformably overlain by the Nye Mudstone. To the north and south it posses laterally into fine-grained sediments assigned to these units. Megafossils and microfossils indicote late Oligocene age for much of the unit, but earliest Miocene age for the upper port of the unit.

Astoria Formation (Tmo): The Astoria Formation consists of a variety of nearshore marine sandstones and subordinate siltstones of middle Miocene age which overlie the Nye Formation and which underlie the middle Miocene volcanic rocks at Depoe Bay. Although the lithologies are distinct from the dominant claystones of the type section of the Astoria Formation of Howe (1926) at Astoria, application of the term "Astoria" to sands in the Oregon mid-coast region is well established. Previous studies in Lincoln County include those of Weaver (1937), Vokes and others (1949), Moore (1963), and Snavely and others (1964a; 1964b; 1969). The Astoria Formation crops out locally at Jumpoff Joe and at the Yoquino Bay lighthouse in Newport and at Beverly Beach in the northern Yoquino quadrangle. Farther north larger exposures extend 2 miles inland from near Depoe Bay. Exposures of the unit would be more extensive were it not for a mantling of younger terrace deposits (Qmt) along much of the coast of central Lincoln County.

The Astoria Formation consists primarily of hard massive, olive-gray, fine- to medium-grained, micaceous, arkosic sandstone and interbedded dark-gray, carbonaceous siltstone. In the Depoe Boy area where the total section is exposed, the Astoria Formation is approximately 2,000 feet thick. About 500 feet of strata representing the bose of the section crops out to the south at Beverly Beach.

Ledge-forming calcareous sandstone interbeds, basaltic sandstone interbeds,and beds rich in megafossils are common low in the section. Locally light yellow-gray waterlaid tuff beds of ondesitic and docitic composition stand out as prominent ribs. The formation as a whole becomes coarser grained and more massive in the upper port of the section. The unit weathers to produce sandy to clayey soils which ore subject to local sliding, especially where unfavorable dips occur in steep slopes.

The Astoria Formation rests unconformably on the Nye Mudstone. At Jumpoff Joe near Newport an angular contact of about 3° can be observed between the two units. Regionally the Astoria Formation onlops the Nye Formation between Yoquina Boy and Depoe Boy. Megafossils recovered from the Astoria Formation indicate a middle Miocene age and foraminifera recovered from the unit indicate a Saucesian age.

"Sandstone of Whale Cove" (Tmwc): Exposures of thick-bedded, semi-friable sandstone overlying the Depoe Bay Basalt are referred to informally as the "sandstone of Whale Cove" by Snavely and others (1969). The unit is restricted to the sea cliffs in the Depoe Bay and Whale Cove area and is mantled by a thin cover of marine terrace sand.

The "sandstone of Whale Cove" consists of 200 to 300 feet of massive to thick-bedded, medium- to fine-grained, arkosic sandstone and thin-bedded, carbonaceous, very fine-grained sandstone and siltstone. Cross bedding, cut and fill structures, and slump features indicate deposition in a shallow water environment. The unit is unconformable beneath the terrace sands and the Cape Foulweather Basalt, and it rests upon the Depoe Bay Basalt with slight unconformity (Snavely and others, 1969).

Tertiary intrusive rocks (Tib, Tis, Tig, Tic)

Intrusive rocks representing at least three major episodes of igneous activity form a wide variety of dikes and sills in Lincoln County. Much of the intrusive rock of late Eocene and middle Miocene age can be related to contemporaneous volcanic rock units. Large middle Oligocene sills and dikes in the Euchre Mountain quadrangle, however are local intrusions unrelated to extrusive volcanic activity.

Late Eocene basaltic dikes (Tib) are common in the Waldport, Marys Peak, and Alsea quadrangles and probably represent feeders for late Eocene volcanism similar to that preserved along the coast. The dikes generally are thin and elongate. One series of colinear dike segments in the Marys Peak quadrangle is 7 miles long.

Swarms of middle Miocene basaltic dike rocks (Tib) are present throughout much of the Cape Foulweather and Yaquina quadrangles. The intrusions are fine grained, slightly porphyritic in places, and are massive to columnar jointed. Dikes cutting strata as young as middle Miocene are probably of the same origin as the nearby middle Miocene basaltic accumulations at Cape Foulweather and Depoe Bay. Farther south at Seal Rocks, middle Miocene basaltic sills intruding the westerly dipping Yaquina Formation form small rocky headlands.

Light-colored, fine-grained dikes, small stocks, and sills of nepheline syenite (Tis) are exposed at Blodgett Peak in the Waldport quadrangle, and a nepheline syenite sill approximately 300 feet thick occurs on Table Mountain in the Tidewater quadrangle. The Blodgett Peak syenite consists of 50 percent albite microlaths, 10 to 15 percent each of albite, nepheline, and analcite, 5 to 10 percent aegirine, 3 to 5 percent olivine and opaques, and 1 to 2 percent riebeckite, according to Snavely and others (1969). These rocks are believed to be late Eocene in age.

Large sills of granophyric gabbro (Tig) intruded the Siletz River Volcanics at Euchre Mountain and Lambert Point and the Tyee Formation and late Eocene sedimentary rocks at Stotts Mountain in the Euchre Mountain quadrangle in Lincoln County. The rock consists of dense, fresh gabbro made up of olivine, ferro-augite, and quartz-feldspar intergrowths. Strong differentiation, however, has produced a variety of aplitic dikes near the tops of the sills. Geologic relationships suggest a late Eocene or younger age for the intrusions. Radiometric age dates at Lambert Point reveal an age of approximately 30 million years (middle Oligocene) (MacLeod, 1969).

Intrusions of camptonite (Tic) and related alkalic rocks are present between the Siletz and Salmon Rivers and at Cougar Mountain 24 miles northeast of Newport. Camptonite is an alkalic, iron-rich dike rock consisting of hornblende, augite, and plagioclase. At Cougar Mountain it is a porphyritic, medium-gray rock consisting of black, stubby crystals of randomly oriented alkali-rich hornblende set in a fine-grained gray groundmass. The camptonite is late Eocene to earlymost Oligocene in age.

Quaternary marine terrace deposits and old dune sands (Qmt)

Flat-lying marine terrace deposits, overlain in places by semiconsolidated dune sand, form a discontinuous series of coastal exposures along the entire length of Lincoln County. The deposits mantle wave-cut benches on tilted Tertiary strata. The marine terrace deposits are predominantly massive, fine- to medium-grained, friable sandstone of beach origin with thin interbeds of siltstone. Horizons of pebbles are common low in the section and old dune sands commonly overlie the deposits. Although rock types are remarkably similar to parts of the Astoria Formation, distinction from that unit can be made on the basis of geomorphology, horizontal attitude, and comparative lack of induration of the terrace deposits.

Marine terrace deposits range in thickness from 50 feet or more in the Lincoln City area to 20 feet or less in the Waldport quadrangle. Elevations of the upper surfaces range from less than 80 feet above mean sea level in the Waldport quadrangle to 100 feet at Lincoln City, and 150 to 200 feet immediately south of Yaquina Bay.

Weathering of the marine terrace deposits develops a sandy soil a few feet thick. Along the coastal margin, ocean erosion has produced nearly vertical cliffs in the terrace deposits by undercutting and subsequent rockfall. At intermittent breaks in the sea cliffs, the marine terrace deposits form stable slopes covered with vegetation.

The age of the marine terrace deposits has not been definitely established, but their elevated positions indicate that they are correlative with marine terrace deposits in the Coos Bay area for which a late Pliocene or early Pleistocene age have been interpreted (Baldwin, 1964). A molluscan fauna collected near the base of the deposits at Hinton Point (SE$\frac{1}{4}$ sec. 16, T. 16 S., R. 11 W.) on the south side of Yaquina Bay by P. D. Snavely, Jr., and W. O. Addicott, both of the U. S. Geological Survey, indicate a Pleistocene age (written communication, 1973).

Old stabilized dune sands overlie the marine terrace deposits in much of Lincoln City and Newport. They extend south from Newport through the Waldport area and thin out a few miles north of Yachats.

Photo 16. Sandstone beds of Astoria Formation overlain by marine terrace sediments (upper third of photo) at Beverly Beach.

Photo 17. Seaward dipping beds of the Astoria Formation overlain by flat-lying marine terrace deposits near Jumpoff Joe.

The topography of the old dune sand areas has been modified, but north-trending hills and swales are common. The dune sands are massive cross bedded, fine grained, friable to locally cemented with iron oxide; old soil profiles are common in the upper section. The deposits range in thickness from a few feet to more than 20 feet and commonly average 10 to 15 feet.

Unconsolidated surficial deposits

In many places, the older units of Lincoln County are mantled with thin, unconsolidated Holocene (recent) deposits. These include alluvium on terraces (Qtg) along the major streams, the flood-plain deposits (Qal) nearer the mouths of the major streams, the sand which makes up the beaches, spits, and active dunes (s) along the coast, and the mud and silt on tidal flats (tf) within bays and estuaries.

Terrace and flood-plain alluvium (Qtg, Qal): Alluvial terraces (Qtg) border the Yachats River, the Alsea River, Five Rivers, Drift Creek, Beaver Creek, the Yaquina River, Elk Creek, the Siletz River, the Salmon River, and numerous smaller rivers and tributaries. The terraces seldom exceed 1,000 feet in width, except along the Siletz River where they are a mile or more wide.

Alluvial terraces were formed when rivers cut downward through flood-plain deposits. As downward and lateral erosion within the valley produced a younger stream channel at a lower level, the elevated flood plain was left behind as a terrace along the sides of the valley.

The composition and texture of the terrace deposits depends on the type of bedrock available for erosion and redeposition and the ability of the stream to carry it. In the southern half of the County, where the terrain is developed mainly on Tyee Formation, the terrace alluvium is predominantly sand and silt with minor amounts of clay and thin pebbly interbeds. In contrast, the terrace deposits along the Siletz and the Salmon Rivers are characterized by abundant cobble and boulder gravel beds. Terrace alluvium adjoining Alsea, Yaquina, and Siletz Bays contains significant amounts of interbedded organic matter and clay as well as sand and silt.

Flood-plain alluvium (Qal) consists predominantly of mixtures of sand, silt, clay, and organic matter underlain in the upper reaches by gravel. The soils in the lower end of the flood plains are fine grained, consisting of sandy silt (ss), clayey silt (cs) and silty clay (sc) with local areas of peat (pt). The flood-plain gravel deposits occur mainly in the upper areas of the Salmon, Siletz, Alsea, and Yachats Rivers. The thickness of the flood-plain deposits ranges from 10 feet or less to about 40 feet.

Beach sand and primary dunes (s): Beach and primary dune sand along the coast consists of unconsolidated, fine- to medium-grained sand with occasional layers of peat. Because the sand is generally loosely consolidated, it is extremely susceptible to wave and wind erosion. The erosional characteristics of the sand are discussed in greater detail under "Geologic Hazards."

Sand is present intermittently along the length of the Lincoln County coastline as a series of narrow beaches. It is also present as a series of larger deposits near Alsea Bay, at the mouth of Beaver Creek, immediately south of Yaquina Bay, at Siletz spit, and south of Salmon River. According to Cooper (1958), the migrating sands were responsible for diverting the mouth of the Yaquina River northward a mile or more at Yaquina Bay. Old time residents of Siletz Bay report that the base of the spit at Siletz Bay covers the former channel of the Siletz River. Countless logs scattered over the surface of parts of the Siletz spit indicate that the area is subject to extreme wave action and possible overtopping at times. Buried logs in Siletz spit with sawed ends indicate that much of the present spit probably developed after logging began in the Siletz River drainage in the early 1900's.

Tidal-flat soils (tf): Tidal flats are located at the mouth of the Salmon River, the east end of Siletz Bay, parts of Yaquina Bay, and inland along the lower reaches of the Yaquina and Alsea Rivers. Most of the tidal flats consist of fine sand and clayey silt with intercalated organic matter and intercalated layers of peat.

Locally, peat and organic soils form deposits where a slow steady rise in sea level has induced a continued steady growth of sphagnum moss and other plants. Peat deposits may also occur in the subsurface below younger sediments. Pronounced compressibility of the organic soils makes them sensitive sites for construction.

Structural Geology

Lincoln County is located on the west flank of the Coast Range geanticline, a complex structural high with a predominant northerly trend but containing strong northeast-trending structural elements. The Siletz River Volcanics, the oldest rocks of the area, form the core of northeast-trending anticlinal highs in the northeast part of the County. Younger rocks of the Yamhill and Nestucca Formations flank the high to the west and northwest and Tyee strata flank it on the south and east. The central part of the mountainous terrain contains broad northeast-trending anticlines in the Tyee Formation. Attitudes are moderate with dips generally ranging from 5 to 15°. In the western part of the County, bedrock formations younger than the Tyee Formation form north-trending outcrop bands and generally dip at moderate angles to the west.

Faulting in the bedrock units is extensive. Snavely and others (1972a, b, c,) indicate a county-wide complex of northwest- and northeast-trending normal faults. Large vertical displacements are indicated on some faults mapped in the central and southern parts of the County. Other mapped faults reveal little vertical movement, but may have considerable horizontal displacement. The length of most faults is less than 10 miles.

Faulting is present in all of the bedrock units. Some faults terminate within a formation and others terminate at the boundary of a formation, indicating that faulting took place during more than one period of deformation. The youngest unit involved in faulting is the upper Miocene (± 20 m.y. old) Cape Foulweather Basalt. No faulting is noted in the marine terrace deposits, which range in age from late Pliocene to early Pleistocene, indicating that fault movement is older than 0.5 million years. Elevated marine terrace deposits and entrenched channels of the major rivers provide evidence for uplift of the coastal region in Holocene time.

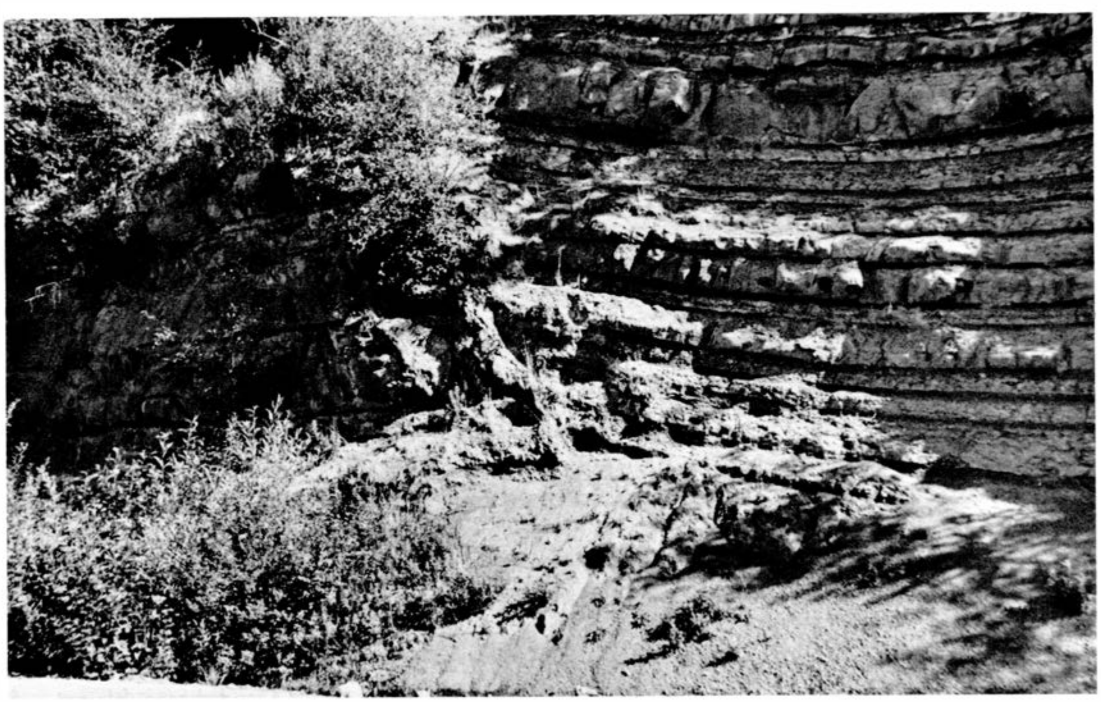


Photo 18. Small fault of local extent in Tyee Formation exposed along Siletz River road. Movement along fault plane has offset the bedding.

ECONOMIC MINERAL RESOURCES

Construction Aggregate

Construction aggregate (sand, gravel, and crushed rock) is the basic ingredient for concrete and a vital commodity, especially in growth areas such as the coastal counties of Oregon. Concrete is used for highways, streets, sidewalks, curbs, foundations, buildings, bridges, and numerous other construction purposes. According to Huntzicker (1970), every new housing unit generates a need for 176 cubic yards of concrete. Aside from that used for the house itself, concrete is required for the roads, utilities, schools, and public buildings that will be needed to serve the growing community.

The direct relationship between population growth and aggregate consumption makes it imperative that local government observe proper planning and zoning to assure the availability of this resource for present and future needs.

County requirements

Records from the U. S. Bureau of Mines indicate the use of aggregate in Lincoln County increased from 270,000 tons in 1960 to about 400,000 tons in 1970. During this period the County's population had increased from 24,635 to only 25,755; therefore, the per capita use increased from 10.8 tons to 15.3 tons per year. A higher average per capita use for the ten year period (21.1 tons) was due in part to several years of extensive road construction in the County during the middle 60's.

Population growth in the County can be expected to continue, although per capita usage should remain about the same. Construction related to tourist facilities and housing starts are expected to increase. Since most forest road systems are near completion, forest road construction should decrease in the future; however, rock will be needed for maintenance.

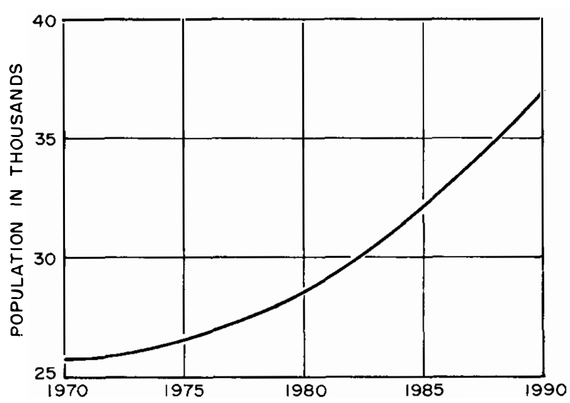
Using 15 tons per capita and the projected population curve (Figure 4-A), the annual use of aggregate in the County is projected to the year 1990. The curve (Figure 4-B) shows that in 1975 about 400,000 tons will be used, in 1980 about 425,000, in 1985 about 475,000 tons, and in 1990 approximately 550,000 tons. The cumulative production curve (Figure 4-C) indicates the total amounts which will have been used by specific future dates, or the amount by which the present total reserves will have been depleted. Beginning with 1970, about 2 million tons will have been used by 1975, 4 million by 1980, 6.2 million by 1990.

County resources

Because of the limited supply of sand and gravel in Lincoln County, crushed quarry rock is the major source of aggregate. Known large bodies of igneous rock suitable for sustained commercial production of aggregate are limited to about six areas, as follows: Widow Creek quarry on Salmon River; Devils Lake Crushing operation at Lincoln City; Agate Beach quarry, Yaquina Head quarries, and the state-owned Iron Mountain quarry near Agate Beach; and Eckman quarries near Waldport. Selective mining is necessary at all of these quarries because of variable rock quality. The lower-quality rock unsuited for concrete aggregate can be used for road base and embankment.

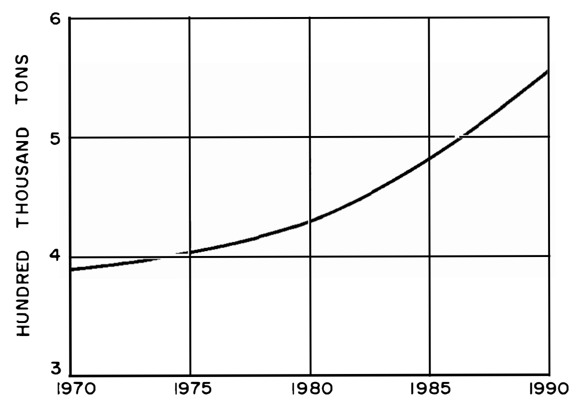
Although other rock bodies suitable for aggregate may exist in Lincoln County, their extent and value are not known at this time. New sites will probably be remote from population centers and thus will require high-cost development and longer haul routes. It may become necessary to use small rock bodies of limited quantity and short life.

The need to keep the present quarries operating is obvious when the effects of using alternate sources are considered. The upper Siletz River area appears to be the only established gravel source, but the quantity is limited and is obtained at the expense of destroying scarce agricultural land. Barging gravel from a distant source is a possibility but will result in increased cost.



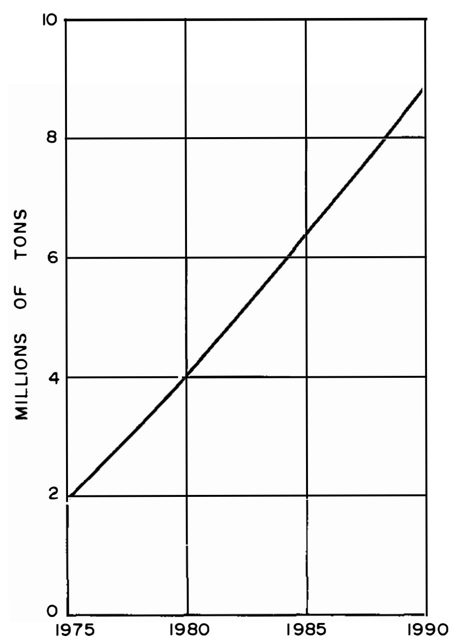
POPULATION GROWTH CURVE

4 A



ANNUAL PRODUCTION CURVE

4 B



CUMULATIVE REQUIREMENT FOR AGGREGATE

4 C

Figure 4. Projected curves for population growth and aggregate needs to the year 1990.

Photo 19. Basalt quarry (No. 33) at Agate Beach. The rock is one of the major sources of crushed aggregate in Lincoln County.

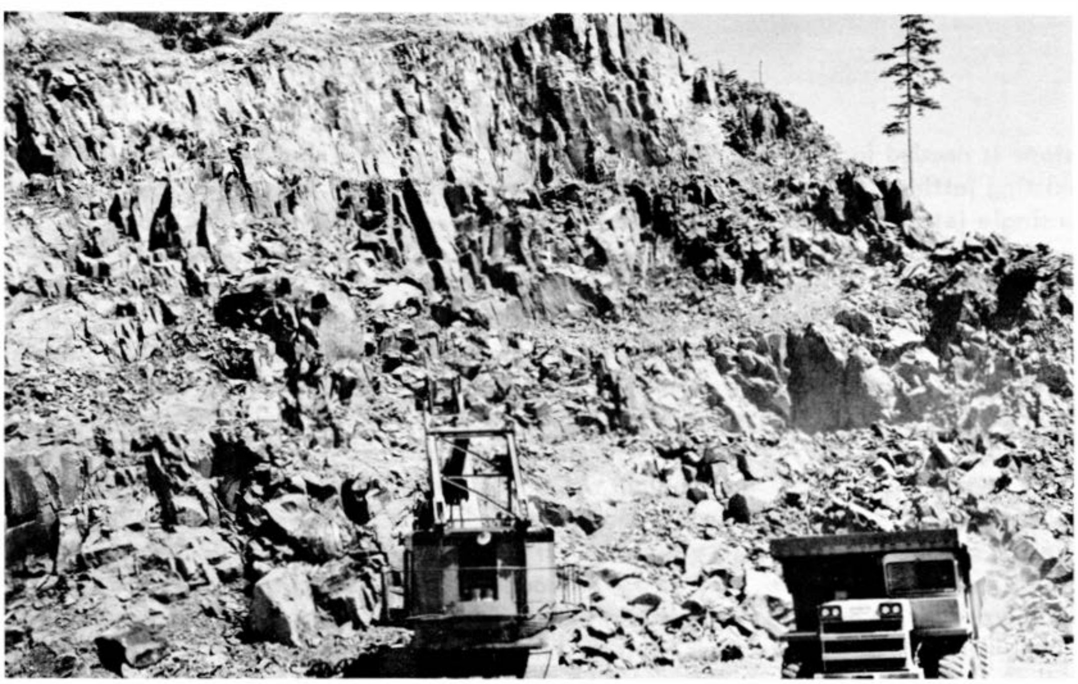


Photo 20. Calkins quarry (No. 24). Rock was quarried to extend the Yaquina Bay jetties.

The most likely areas to search for new sources of igneous rock for aggregate are as follows: in the vicinity of Euchre Mountain; at Lambert Point; adjacent to the Calkins quarry #24; the sill in sec. 21, T. 10 S., R. 11 W., about $1\frac{1}{2}$ miles northeast of Agate Beach; and in the Yachats basalt in the southern part of the County.

Quarries and gravel pits in Lincoln County are listed in Appendix A together with laboratory data and comments. The list includes quarries which have been depleted, abandoned, or are too small or remote to be economic except for local projects. Quarries in sandstone of the Tyee Formation are also listed even though the rock quality falls below present-day specifications for aggregate or jetty rock and is no longer used. Inclusion of these unusable quarries in this report should help to eliminate future time-consuming evaluation of the sites.

Nepheline Syenite

Nepheline syenite, a somewhat rare type of igneous rock, occurs in Lincoln County at Table Mountain and at Blodgett Peak. The Table Mountain rock is 300 feet thick, covers about 1 square mile, and has little overburden. It is estimated to contain 700 million tons of recoverable syenite.

Syenites in other parts of the nation have been used as a flux in making glass, but the Oregon material is not suitable for this purpose because of the iron content, which produces a dirty-brown discoloration. Beneficiation tests by the Bureau of Mines (Harris, 1962) did not remove the iron; however, the syenite could be used in the manufacture of rock wool.

Because of its neutral grey color, the syenite could also be used for roofing granules. The main factor that limits exploitation of the Lincoln County syenite for that purpose is its great distance from the principal U. S. markets. A roofing-granule plant large enough to be economically feasible would have to produce quantities in excess of the western market alone. Whether local and State interests could promote such an industry would depend upon results of a feasibility study by manufacturing and marketing experts. A plant of this magnitude could have a large impact on the economy of the County.

Lincoln County's nepheline syenite has been used successfully for jetty rock and is a potential source for future supply, as discussed below.

Jettystone

Jettystone is needed for the construction of new jetties and for maintenance, rebuilding, and extension of existing jetties. Several classes of stone are used in jetty construction and the quantities of each used on a single jetty will vary; the total often exceeds several million tons. Armor stone (class A) is placed on the outside surface of the jetty to resist the force of the largest storm waves. The interior of the jetty is built of smaller stone (classes B and C) and rubble.

The size of individual stones used in jetty construction is based on a number of considerations: unit weight of the rock, maximum expected wave height, method of placement on the jetty, and side-slope angle of the jetty. In addition, the sizes used are influenced by the maximum weight of material which can be quarried and handled with available equipment.

It is not economically feasible to make every jetty resistant to storm-wave damage. For example, to withstand the maximum expected wave height of 25 feet common to Oregon, class A select stone of 170 pounds per cubic foot would need to weigh 58,000 pounds each (Kidby and Price, 1965).

Early in the construction of the jetty at Yaquina Bay, sandstone from the Tyee Formation, quarried about 4 miles southeast of Toledo, was used. Although large stones could be quarried, they were too soft to withstand erosion. In order to prohibit continued use of this sandstone in jetty construction, U. S. Army Corps of Engineers introduced standards for jettystone which require the stone to have a unit weight greater than 160 lb/ft^3, (Table 4). Since Tyee sandstone weighs less than the minimum allowable, it can no longer be used, but unfortunately at least two other sources of igneous rock were also eliminated by this requirement.

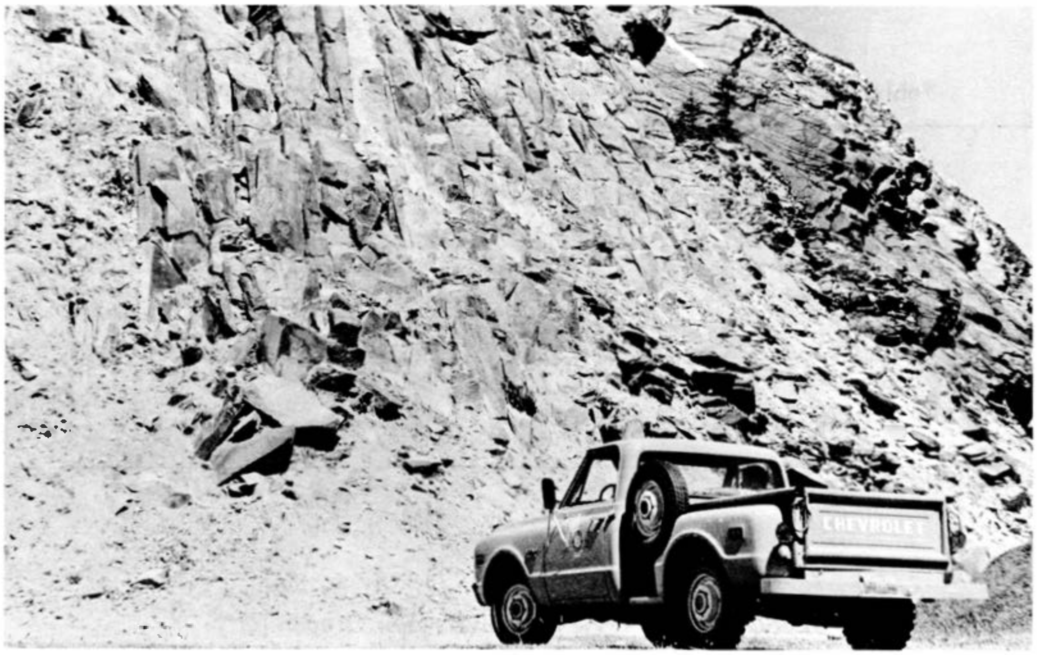


Photo 21. Nepheline syenite at Blodgett Peak (quarry No. 57) formerly quarried for construction of Newport jetty.

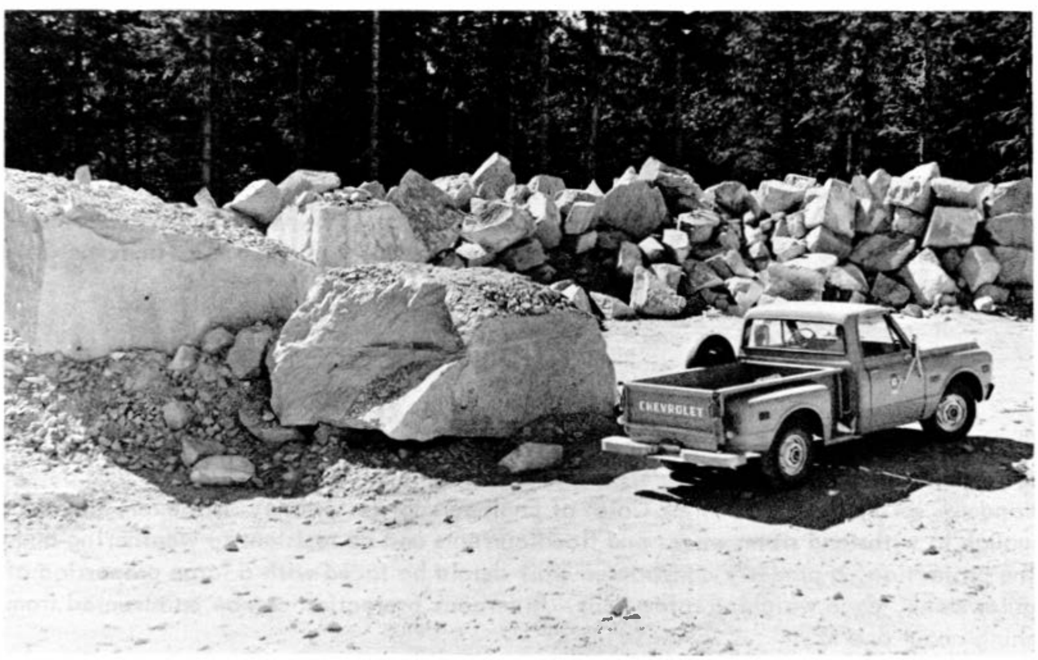


Photo 22. Thick sill of nepheline syenite on Table Mountain produces large blocks of rock (quarry No. 49).

Table 4. U. S. Army Corps of Engineers requirements for jettystone

Unit wt. of stone lb/ft^3	Select Class A Minimum Weight (tons)	Class A Min. wt. (tons)	Class B Min. wt. (tons)	Class C Min. wt. (pounds)
*160	27.8	15.2	7.6	500
165	24.8	13.5	6.8	500
170	22.0	12.0	6.0	500
175	19.8	10.8	5.4	500
180	17.8	9.7	4.9	500

*160 lb/ft^3 is minimum allowable

Approximate percentages of each class of stone used on a major Oregon jetty:

Class A stone - not less than 40 percent
Class C stone - not more than 17 percent
Class B stone - remainder

Most quarrying operations in Coast Range basalt and gabbro have been unsuccessful in producing jettystone because of close jointing in the rock. Even in apparently suitable rock, some operators produce an abundance of sizes too small to be used because they loosen big volumes of rock with a large "coyote" charge which fractures it extensively. An alternative method would be to do selective drilling and shooting.

Nepheline syenite at Table Mountain and at Blodgett Peak would appear to be suitable for jettystone, and in fact that from Blodgett Peak had been used on the Yaquina Bay jetty. The rock on Table Mountain has exceptionally wide jointing, and proper quarrying should produce the sizes needed for jetty construction and in sufficient amount to be economical; should future jetty work be required at Yaquina Bay, this stone should be considered as a possible local source of rock. Since most contracts involve several million tons of rock at prices approaching $15 a ton in today's market, use of local rock should reduce costs and be good for the economy of the County. Most recent work on the jetty utilized rock from the Calkins quarry on Cedar Creek in the Siletz River drainage.

Riprap

Selective quarrying of Cape Foulweather, Depoe Bay and Yachats basalts, and Siletz River Volcanics will produce rock of adequate quality for shoreline and riverbank protection. These uses do not require the rigid standards set by the U. S. Army Corps of Engineers for jettystone. However, the stone should be large enough to withstand storm waves and flood currents and be resistant to weathering and erosion. For shoreline protection, a properly constructed wall should be faced with a large proportion of individually placed angular stone, each weighing a few tons. Riverbank protection can be constructed from smaller stone weighing about one ton.

Oil and Gas Possibilities

Oil and gas exploration in Lincoln County to date has been limited to three shallow wildcats drilled onshore (Table 5) and two deep tests drilled on the bordering continental shelf (Table 6). Tertiary marine sedimentary rocks probably extend to a depth of 10,000 feet in the onshore area of Lincoln County and reach a depth in excess of 15,000 feet offshore (Braislin and others, 1971). Folding and faulting of the sedimentary rocks in Tertiary time have provided the necessary structural elements for entrapment of hydrocarbons. Gas shows have been fairly common in water wells and in the few oil drillings in the coastal region of Oregon (Table 7.)

In general, the coastal geology of Oregon has been somewhat discouraging to oil exploration firms because of the abundance of volcanic rocks in much of the geologic section. Sediments derived from volcanic rocks yield considerable amounts of fine, clayey material. Sands of Miocene, Oligocene, and Eocene age are present in Lincoln County, and some are the clean arkosic type that have good reservoir characteristics.

Offshore exploration

A total of 16 oil companies took part in oil and gas explorations along the Oregon coast from 1961 to 1969. Eleven of these companies joined forces to drill 8 test wells, one located as far as 30 miles offshore. It is estimated that the companies spent $60 million during the 8-year period, but no discoveries were made. They did determine that the sedimentary section extends to a depth of more than 12,000 feet. No records, other than those of the Pan American well offshore from Bandon, have been released to the public. It has been reported from several sources, however, that the companies were discouraged by the thick shale sections encountered and lack of sand beds in the 8 holes.

Recent studies by W. W. Rau (Washington Division of Mines and Geology) in northwestern Washington may offer an explanation for these thick-shale occurrences. Dr. Rau has investigated what he believes to be a shale intrusion in northwestern Washington, more specifically a piercement body (diapir) intruding Miocene sediments (personal communication, 1973). Since the oil companies very likely drilled seismic highs offshore, some of the drilling may have been in shale piercement domes (diapirs). Sand beds are sometimes found off the flanks of these structures, such as in the Gulf Coast region.

Snavely and others (1969) describes the Yaquina Formation as originating as a broad submarine fan from a shoreline 4 or 5 miles north of Yaquina Bay. This delta formed a constructional high upon which the Nye Mudstone and the Astoria Formation onlapped. Large deltas are known to be good oil and gas producing prospects, as many oil fields have been found in such a depositional environment. The continental shelf bordering Lincoln County and the central Newport embayment appear to offer the best prospects for commercial production in western Oregon.

Onshore prospects

Possibilities for finding petroleum onshore in Lincoln County are probably less than for finding it offshore. Unconformities in marine sediments are prime targets and in Lincoln County unconformities probably exist in the late Eocene formations and between the middle and early Eocene formations. More than 5,000 feet of marine sediment is believed to be present in Lincoln County as suggested by gravity studies and exposures of lower Eocene marine rocks in the eastern part of the County. A section of marine rocks ranging from Miocene age through lower Eocene age probably exists in the Newport embayment.

There are, nevertheless, some areas onshore that bear more investigation and possibly warrant drilling a deep hole if closures can be found.

Table 5. Oil and gas exploration in Lincoln County, Oregon

Company	Well Name	Location	Date	Total Depth	Remarks
Oregon Oil & Gas Company	Roberts No. 1	NE¼ sec. 25 T.10S.,R.8W	1958	2630'	Hit saltwater flow at 2400' FT2389 - 2569. Recovered 810' rise of gassy mud. IP 190 psi. FP 380 psi HP 1300 psi. Salinity 535 grains per gallon. FT 2158 - 2178. Recovered 1880' rise slightly gassy mud and saltwater. IP 210 psi FP 985 psi. HP 1200 psi Salinity 765 grains per gallon. FT 1739 - 1817. Recovered 1495' total rise; 995' of mud and 500' of gassy saltwater. Pressure recorder failed. Salinity not tested. FT 1531 - 1550. Recovered 220' rise of mud. Pressure recorder failed. FT 1152 - 1232. Fair blow, gas surfaced in 12 minutes died after ½ hour. Recovered 1025' rise of gassy mud and saltwater. IP 225 psi. FP 210 psi. HP 685 psi. Salinity 295 grains per gallon. Gas sample (see Table 7)
	FORMATION TESTS				
Pacific Coast Oil Development Co.	?	SE¼ sec. 25 T.13S.,R.12W	1919	1175'	Encountered small amount of gas at 900'. Reportedly burned with a 6' flame (Smith, 1924).
?	?	Drilled in sand dunes north of Waldport	Before 1926	?	(Smith, 1924)
Petroliferous shale	-	Outcrop east of Newport sec. 10 T.11S.,R.11W			Petroliferous shale of the Nye Formation (Braislin and others, 1971)
Johnson Lumber Company	Water well	NE¼ sec. 18, T.11S.,R.10W	1948	1900'	Hit a strong flow of gas at 1330'. (Dept. file)

Table 6. Offshore wells

Company	Well Name	Federal OCS No.	Bonus Price paid	Location	Total Depth	Remarks
Standard, Union Oil and Pan American Oil Companies	Grebe No. 1	PO 93	$350,000	16 miles off-shore from Waldport	10,010'	No data released thus far. Drilled on Federal lands.
Standard and Union Oil Companies	Nautilus No. 1	PO 103	$1.5 million	10 miles off-shore from Siletz Bay	12,285'	No data released thus far. Drilled on Federal OCS lands.

Table 7. Gas analyses

Company	Well Name	Zone Sampled	CH_4	N_2	Heavy Fractions	CO_2	O_2
Oregon Oil and Gas Co.	Roberts No. 1	1152 - 1232'	55.89%	43-71%	0%	0%	0.40%
Oregon Oil and Gas Co.	Roberts No. 1	2158 - 2178'	56.50%	42-99%	0%	.08%	0.43%

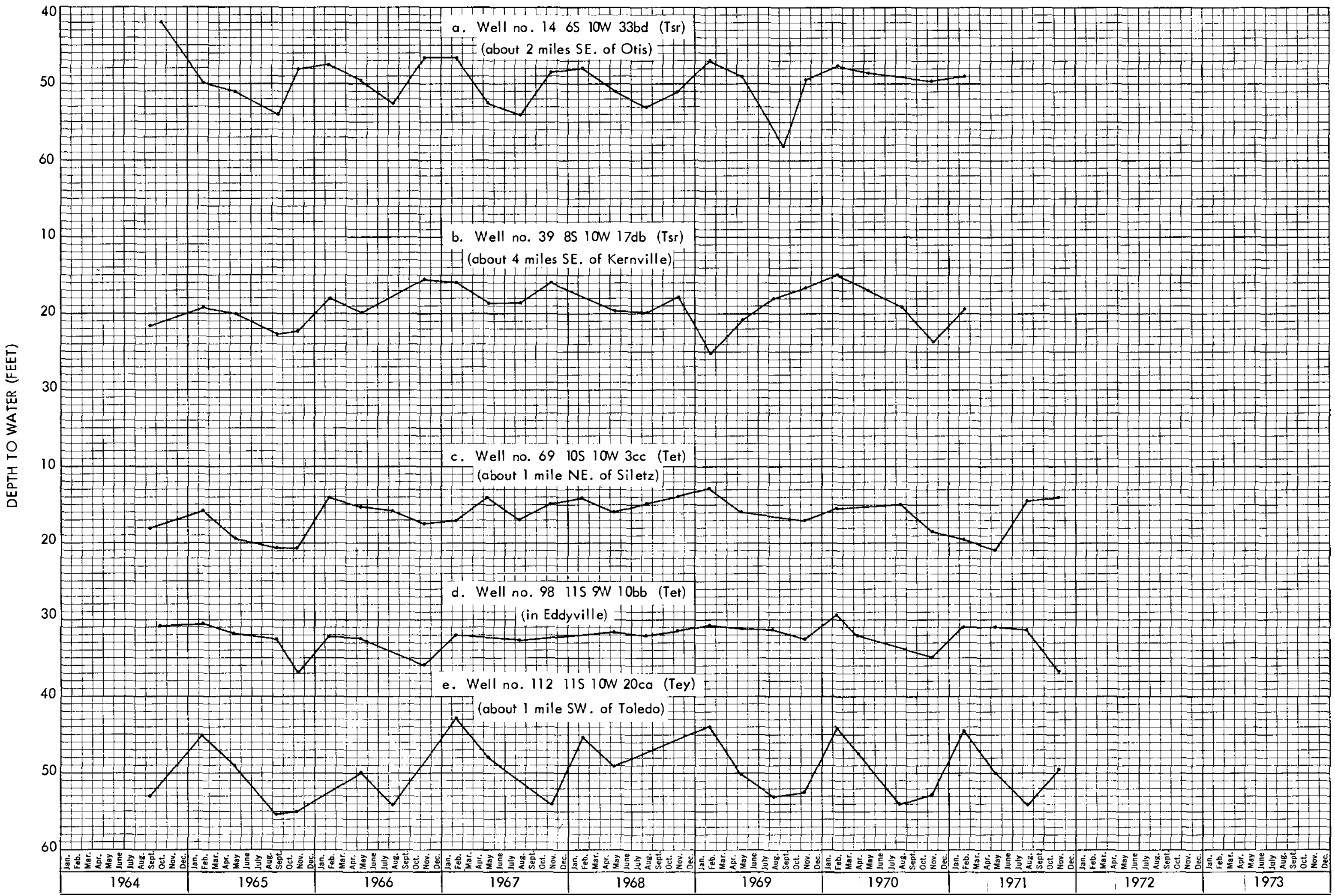


Figure 5. Hydrographs of five observation wells in Lincoln County.

GROUND WATER RESOURCES

General Characteristics of Ground Water

Ground water is the subsurface water that occurs in the zone of saturation, so named because all the voids in the rock materials are filled with water. The top of the zone, called the water table, roughly conforms to the land surface topography and may vary from zero at valley streams to several hundred feet or more below ridge tops; impervious rock determines the bottom of the zone. The water table fluctuates in response to recharge and discharge of the aquifer (any water-bearing rock formation), generally caused by the seasonal changes in precipitation. Between the water table and the land surface is the zone of aeration.

The availability of ground water to wells depends on the porosity and permeability of the geologic formations and their capacity to absorb, store, and transmit water. A continuing supply of ground water also requires a favorable climate to recharge the aquifer at an adequate rate.

Recharge of ground water occurs when rain infiltrates the zone of aeration and, after fulfilling soil and plant moisture deficiencies, percolates downward to the water table. The downward movement depends primarily on the porosity and permeability of the transmitting soil and rock units. Streams are also an important source of recharge, depending on the elevation of the water table. Artificial recharge is practiced by pumping water directly into the aquifer or by providing large impoundment basins from which the water percolates downward to the aquifer.

Discharge of ground water occurs when ground water moves down-gradient toward and along the major surface drainage features to points of exit, such as seeps, springs, streams, and swamps. Naturally discharged ground water provides much of the base flow to surface streams during the dry season. Water wells serve as an artificial means of discharge.

Ground water is "confined" if the permeable water-bearing zone is overlain by or sandwiched between impermeable, confining layers such as clay or shale. When a well penetrates a zone of confined ground water, the water rises in the well to a level higher than where it was encountered. The imaginary surface coinciding with the level to which the confined water will rise in wells that tap the same confined aquifer is called the piezometric surface. Such water is referred to as artesian water.

Perched water is unconfined ground water separated from an underlying main body of ground water by a zone of impermeable rock. Perched water is generally held in local, discontinuous depressions or in local permeable zones above the main water table. Such water may be seasonal and quickly pumped dry in wells; however, the larger bodies of perched water serve as important sources of domestic stock water in many areas of Lincoln County.

Observation of ground-water levels

The staff of the State Engineer monitors and records the ground-water levels throughout the State by means of observation wells. Five such wells are maintained in Lincoln County, all of which recover their summer declines during the winter months. No long-term trend of ground-water decline has been detected. The hydrographs and locations of the observation wells are shown in Figure 5.

Types of aquifers

In general an aquifer is any water-bearing rock formation, or more specifically, "it is a body of rock that contains sufficient saturated permeable material to conduct ground water and to yield economically significant quantities of ground water to wells and springs" (A.G.I. Glossary of Geology). Aquifers differ according to the geologic units in which they occur. The principal types of aquifers in Lincoln County are as follows:

Sedimentary rocks: Ground water aquifers in Tertiary sedimentary rock units occur principally in the fractures, joints, and bedding planes, and rarely in the intergranular pore spaces separating the rock grains. These voids are so narrow or minute that the molecular attraction on a droplet of water prevents it from being released to migrate; therefore, both the porosity (percentage of rock occupied by voids) and permeability (capacity of rock to transmit fluids) of these rocks is low, as is their ground-water potential. The Quaternary marine terrace sediments contain permeable sand layers that have intergranular pore spaces suitable for ground-water storage in some areas.

Volcanic rocks: Aquifers in volcanic rocks are generally limited to joints and fractures, brecciated zones, and sedimentary interbeds. The potential for ground water is dependent upon the structure of the rock units.

Unconsolidated rocks: Aquifers in unconsolidated rocks are unconfined and free to move. In flood-plain areas, aquifers may have good ground-water potential, provided the water does not drain from them. Along the coast line, ground water can be seen escaping in numerous places at the contact of terrace and dune deposits with underlying impermeable bedrock units.

Availability of Ground Water

The greater part of Lincoln County is underlain by fine-grained sedimentary and volcanic rocks of low porosity and permeability. Ground-water resources, therefore, are generally poor except for the marine terraces and possibly some dune-sand areas bordering the coast which could yield substantial quantities of water. Some alluvial terrace and flood-plain deposits bordering streams serve as fair aquifers. Although the wells in most areas yield sufficient water for domestic purposes, the quality sometimes requires treatment to be made potable.

Data from 190 water well logs were analyzed in partial preparation of this report. The log data are summarized in Appendix B "Water well log data," Appendix C "Geologic formation water-well yield summary," and Appendix D "Quadrangle map water-well yield summary." All of the wells are located by number on the engineering geology maps accompanying the report.

Well locations in this report are designated according to official systems for the rectangular subdivision of public lands. The numbers and letters indicate the location of the well by township, range, section and position within the section, in that order. The method of well location is graphically illustrated below:

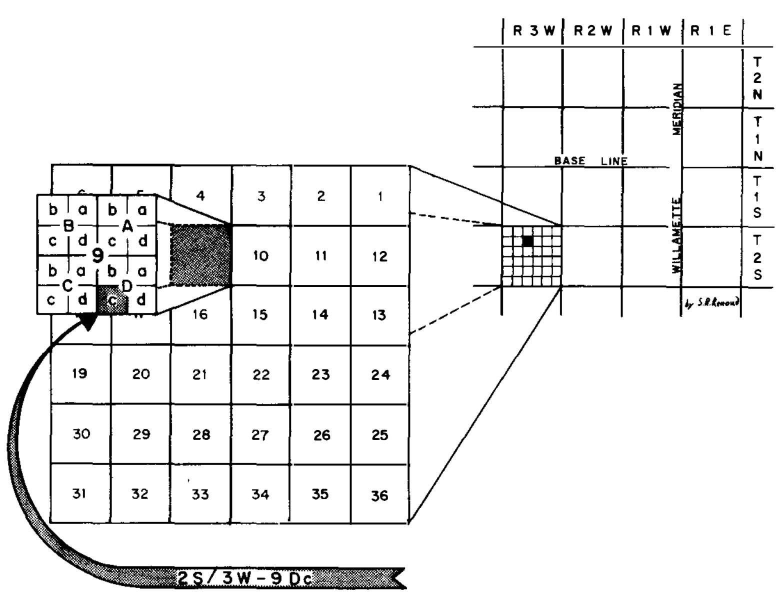


Table 8-a. Chemical analyses of well water

(In parts per million)

	Well Numbers 12	29	46	142
Location	6S 10W 33 ab	6S 11W 35cb	8S 11W 21cd	12S 8W 8ca
Date of analysis	2/6/72	1/15/71	6/19/72	10/13/63
Formation	Siletz River Volcanics	Nestucca	Marine Terraces	Tyee
Map symbol	(Tsr)	(Ten)	(Qmt)	(Tet)
Temperature °F	N.A.	49°	N.A.	N.A.
Chemical constituents				
Aluminum (Al)	< 0.01	0.2	0.01	N.A.
Arsenic (As)	< 0.001	< 0.001	< 0.005	N.A.
Calcium (Ca)	20.0	1.1	4.5	N.A.
Iron (Fe)	0.12	0.44	0.04	0.0
Magnesium (Mg)	0.5	0.8	3.4	N.A.
Manganese (Mn)	0.02	0.004	< 0.03	0.0
Potassium (K)	< 0.2	7.2	2.5	N.A.
Silica (SiO_2)	22.0	47.1	7.1	N.A.
Sodium (Na)	46.0	35.0	25.6	28.8
Bicarbonate (HCO_3)	60.0	3.5	N.A.	N.A.
Chloride (Cl)	23.0	19.2	44.6	0.8
Fluoride (F)	0.85	0.04	0.03	N.A.
Sulfate (SO_4)	54.0	38.9	11.2	9.6
Total dissolved solids	182.	378.	117.	N.A.
Hardness as $CaCO_3$	N.A.	6.1	25.4	N.A.
Conductance (Microhms at 25° C)	N.A.	N.A.	226.	N.A.
pH	9.4	7.4	5.5	8.6

Note:
< denotes "less than"
N.A. denotes "not available"

Table 8-b. Drillers' logs of wells in Table 8-a

	Thickness feet	Depth feet
Well No. 12 (6S 10W 33ab) Casey Jones Well Drilling Co., Nov. 1971		
Quaternary deposits		
Top soil	1	1
Red brown clay	13	14
Tertiary rocks		
Hard gray sandstone	53	67
Tan sandstone	17	84
Blue-gray sandstone	75	159
Fractured gray sandstone	39	198
Hard blue-gray sandstone	32	230
Well No. 29 (6S 11W 35cb) Charles Panschow Drilling Co., Jan. 1971		
Quaternary deposits		
Dark top soil	3	3
Yellow sand and clay	25	28
Red sand and clay	12	40
Dark soil	15	55
Red sand and clay	3	58
Tertiary rocks		
Black lava rock	8	66
Black lava rock, shale and clay	3	69
Shale	22	91
Gray shale and clay	43	134
Gray shale	27	161
Gray shale and clay	23	184
Water bearing		(181)
Gray shale and clay	42	226
Well No. 46 (8S 11W 21cd) Driller's log not available		
Well No. 142 (12S 8W 8ca) G. A. Pruitt Drilling Co., Aug. 1962		
Quaternary deposits		
Soil	5	5
Yellow sandy clay	7	12
Tertiary rocks		
Gray sandstone	24	36
Broken blue claystone	4	40
Blue sandstone	32	72
Blue claystone	8	80
Broken gray sandstone, water layer	8	88

Water Quality

The quality of ground water in Lincoln County varies considerably, depending on the type of geologic formation (Table 8-a and b). In general, the water in the alluvium, dune sand, and terrace deposits is good; that in the marine sediments is often high in iron, sulfur, and chloride compounds; and that in the volcanic rocks is good. Most of the ground water in the County is potable, having satisfactory odor, taste, color, and temperature.

Although ground water characteristically contains more dissolved solids than does surface water, it is generally preferable owing to its usually lower temperature, freedom from radio-active fallout and other air pollutants, and consistency of chemical and physical properties. Iron, sulfur, and chlorides of sodium, calcium, and magnesium are the principal undesirable elements in ground water in the County (Table 9). The fact that contamination from human and animal wastes is minimal attests to the efficiency of properly sealed wells. Treatment of the water for removal of the contaminants is relatively simple and inexpensive.

One major retail company sells water-conditioning and softenting units ranging from $115 to $335. The units are capable, with the proper filters, of neutralizing acidic or alkaline water, and removing iron, clay, silt, sand, dirt, and tastes or odors including those of chlorine, swamps, and the "rotten egg" smell of hydrogen sulfide. Additional filters are available for multiple duty. The type of purifying equipment required is determined by a free laboratory analysis of the water. Maintenance of the equipment is nominal.

Wells tapping the marine sediments commonly yield water containing dissolved iron released by the chemical breakdown of iron-bearing rocks during weathering.

The presence of sulfur in ground water is caused in large part by anaerobic bacteria, a group of micro-organisms that grows in and receives its oxygen from decaying organic matter. The bacteria produce sulfur, which combines with hydrogen from decaying plants to form hydrogen sulfide gas, readily recognized by its "rotten-egg" odor. Chloride or saline water is frequently encountered in marine sediments in which sea water was trapped at the time the sediments were deposited. High mineral concentrations also occur when ground water remains in contact with mineral-bearing rocks for long periods and is not diluted or flushed out by downward percolating ground water.

Water temperatures, as reported in 69 of the 190 well logs reviewed, ranged from 46° F. to 55° F. and averaged 51°F. The close similarity of the well-water temperature to that of the mean annual air temperature (51.4° F. at Newport) indicates that the downward infiltration of ground water in Lincoln County is shallow, a factor directly attributable to the impermeable nature of the geologic formations underlying the region.

Ground water in the County is generally soft because of the near-absence of calcium and magnesium in the rocks. Hardness is caused almost entirely by compounds of these minerals. The U.S. Geological Survey classifies hardness according to the amount of calcium carbonate or its equivalent that would be formed if the water were evaporated, as:

Parts per million	Class	Requiring treatment
0- 60	Soft	Unnecessary for most purposes
61-120	Moderately hard	High pressure steam boilers, some industrial processes
121-180	Hard	Laundries and industries
180-plus	Very hard	Most purposes

The balance between acids and alkalies in water, determined by the pH value or hydrogen-ion concentration, is very important because of its effect on both organic and inorganic matter. The pH values and hardness classifications for the four chemical analyses shown in Table 8-a are:

Well log no.	12	29	46	142
Hardness	N.A.	Soft	Soft	Soft
pH value	9.4	7.4	5.5	8.6

Water with a pH of 7.0 is neutral, above 7.0 is alkaline, and below 7.0 is acidic. A pH range of 6 to 8 is common for natural fresh water. Wells yielding acidic water cause corrosive problems in pipes and boilers. Many wells in Lincoln County are known to cause this problem.

Table 9. Summary of nine wells in Lincoln County having poor-quality water

Well No.	Location	Formation and	Symbol	Reason for poor quality
43	8S 10W 20cd	Tyee	(Tet)	Iron
67	10S 10W 1ab	Tyee	(Tet)	Chloride *
81	10S 10W 33db	Yamhill	(Tey)	Hydrogen sulfide
82	10S 10W 36aa	Tyee	(Tet)	Iron, hydrogen sulfide
87	10S 11W 30aa	Astoria	(Tma)	Septic tank contamination
108	11S 10W 18aa	Yamhill	(Tey)	Chloride, hydrogen sulfide
109	11S 10W 18ab	Yamhill	(Tey)	Chloride, hydrogen sulfide
142	12S 8W 8ca	Tyee	(Tet)	Chloride
157	13S 10W 33bb	Tyee	(Tet)	Chloride

* Chlorides of Na, Ca, or Mg

Drinking water standards recommended by the U. S. Public Health Service in 1962 are:

Chemical constituent	Recommended limit (ppm)	Maximum allowable (ppm)
Alkyl benzene sulfonate	0.5	--
Arsenic	0.01	0.05
Chloride	250.0	--
Copper	1.0	--
Fluoride	0.8 - 1.7*	1.6 - 3.4*
Iron	0.3	--
Lead	---	0.05
Manganese	0.05	--
Nitrate**	45.0	--
Sulfate	250.0	--
Dissolved solids	500.0	--

* Varies inversely with mean annual temperature.

** The public is warned of the potential danger of using the water for infant feeding when the nitrate content is in excess of the listed concentration.

Water Use

The availability of ground water in the County is indicated by a summary of the water use of the 190 wells reviewed. The one well (no. 175) drilled for irrigation was for a golf course south of Waldport, but its yield diminished to the extent that water had to be obtained elsewhere. The 75-foot deep well yielded 45 gpm with 30 feet of drawdown when it was bailer tested in 1969.

Nine wells had been drilled for municipal purposes, but only two (no. 23 and 46) are now operating. Two of the wells (no. 85 and 88) were dry, four wells (no. 45, 52, 84 and 86) were abandoned due to inadequate yield, and one well (no. 87) was abandoned due to contamination from septic tanks. Two of the three wells drilled for industrial purposes (no. 108 and 109) were dry, although saline water was struck. These two wells, drilled at the C. D. Johnson Lumber Company mill at Toledo, reached depths of 975 feet and 1,900 feet, respectively.

Water well yield summaries in Appendix C and D indicate that ground-water supplies in the County are generally adequate for domestic use.

A breakdown of the proposed use of the 190 wells is as follows:

Proposed use:	Domestic	Municipal	Recreation	Industrial	School	Fish	Irrigation
Total wells:	165	9	8	3	3	1	1

Occurrence of Ground Water in Geologic Units

Since the geology of the region controls in large part the occurrence, movement, quantity, and quality of ground water, the various rock formations in the County are described for the purpose of stating their water-yielding capabilities. Units having similar lithologic characteristics are grouped together.

Terrace and flood-plain alluvium (Qal)

Lithology: Alluvial terrace and flood-plain deposits bordering the streams are composed of boulders, cobbles, gravel, sand, silt and clay. Terraces are former flood plains left at an elevated position by the down-cutting stream. Flood plains are usually mantled by several feet of fine-grained sediments left by receding high waters. The thickness and composition of the deposits depend on the availability of rock debris, the quantity and velocity of water transporting it, the area available for deposition, and conditions conducive to accretion without stream erosion. The width of the alluvial deposits seldom exceeds 1,000 feet except along the Siletz River where some deposits approximate 1 mile.

Characteristics: The more porous and permeable strata or lenses within the alluvial deposits readily accept large quantities of precipitation as well as runoff from valley slopes and infiltration from streams. Those units situated below the water table generally form good aquifers. Water, however, drains readily from the deposits situated above the water table, unless clay strata provide an impermeable layer to create perched water conditions.

Quality: Ground water from these deposits, exclusive of tidewater areas, is satisfactory for most uses. Because the deposits are generally thin, particular care must be taken to properly seal wells against such contamination sources as livestock and other farm animals, fertilizers, insecticides, detergents and human wastes. State law requires that cased wells be at least 50 feet from a septic tank or cesspool and that uncased wells be a minimum of 100 feet away.

Yield summary and potential areas: The two wells producing from these alluvial deposits, (nos. 41 and 70 in Appendix B), yield 12 and 4 gpm, respectively.

Much of the terrace and flood plain area along the County's five major rivers and larger creeks has potential for ground water. Terraces that abut long hill slopes receive the precipitation runoff and ground-water flow therefrom and form aquifers that yield adequate ground-water supplies for domestic use throughout the year. The Siletz River, from the vicinity of Logsden downstream, has potential ground-water sources adjacent to its banks. Much of the Alsea River area likewise has ground-water potential.

Dune sand (s)

Although only one well log pertaining strictly to dune-sand deposits is known to be available, mention is here made of the deposits, including their ground-water capability and potential. The lone well (no. 129), located on a dune hill at South Beach State Park, went dry in 1970 when nearby lakes dried up.

Lithology: The sand is unconsolidated, fine-to medium-grained, well-sorted, and moderately to highly porous and permeable. The sand grains are mostly quartz and feldspar with lesser amounts of magnetite, mica, and rock fragments.

Characteristics: Dunes are formed by wind erosion of beach sands and deposition landward. Most dune deposits are less than 100 feet thick. Those of sufficient thickness and width absorb and store large quantities of fresh water.

Quality: In areas free of contamination, ground water in dune deposits is usually potable, of good chemical quality, and suitable for most purposes. The water is odorless, has a satisfactory color and taste, and a temperature approximating the mean annual air temperature. Wells near lakes or marshy areas, however, may have objectionable odor, taste, or color caused by decaying organic matter. Water having a combined content of iron and manganese in excess of 0.3 ppm (parts per million) is considered objectionable for domestic and public supply use by the U. S. Public Health Service. Such water may cause yellowish or reddish stains on plumbing fixtures, cooking utensils, and laundry, but can be treated at nominal cost. The ground water in some of the dune-sand areas may be acidic and thus corrosive to iron pipes.

It is important that wells withdrawing considerable ground water from the dune deposits be located and monitored to avoid sea-water infiltration. This is accomplished by maintaining a water table several feet above sea level so that the natural hydrostatic pressure and seaward movement of the fresh water holds back the sea water.

Yield summary and potential areas: Dune sand deposits occur at the Salmon River mouth area, the Siletz spit west of Siletz Bay, the South Beach area south of Yaquina Bay, the Beaver Creek mouth area, and the Hidden Lake to Alsea Bay area west of U. S. Highway 101. Most of the dunes are quite thin except for those near Hidden Lake, which rise more than 100 feet above sea level. The thicker portions of the deposits, with the possible exceptions of the narrow part of Siletz spit and the Beaver Creek dune area, are probably capable of yielding water in sufficient quantities for domestic purposes. The dunes are well-suited for shallow sand-point wells of low capacity, provided the area can be kept free of contamination. This problem becomes greater with the increasing housing and recreational activities in dune areas.

The potential of large dune sand aquifers is reviewed by Hampton (1963) in a study of the coastal dune area near Florence in Lane County. The report estimates that 48 inches of the 55 inches of annual recharge water that drains from the 18-square-mile dune study area is available to wells, which indicates that about 2.3 million gallons per day per square mile is available for withdrawal in that area.

The youth camp at the mouth of the Salmon River obtains its supplemental or emergency water supply from a shallow well in the dunes north of the dwelling areas. These dunes are capable of considerable ground-water storage and withdrawal.

The sand dune area west of U.S. Highway 101 extending nearly 3 miles from Driftwood Beach Wayside south to Alsea Bay probably contains the largest supply of ground water in dunes in Lincoln County. The dunes have appreciable thickness and areal extent, and in large part are bounded by small lakes abutting their east flanks. Within this area, the dune deposits situated between Hidden and Lotus Lakes should be able to sustain wells of considerable production. Unfortunately, however, much of the ground water is suspect, if not unfit for domestic purposes, due to the rapidly increasing habitation and use of septic tanks in much of the dune area.

Marine terrace deposits and old dune sand (Qmt)

Lithology: Marine terraces extend along most of the Lincoln County coastline, reaching inland a mile and a half in the Devils Lake, Yaquina Bay, and Waldport Bay areas. The terraces vary in composition, depending on the sediments deposited by the ocean or by rivers in the bays. They consist of semi-consolidated, fine-grained sand, silt, clay, and occasional pebble lenses. Old dune sand deposits are composed of massive, cross-bedded, friable sand.

Characteristics: The deposits are, for the most part, porous and permeable and where sufficiently thick and saturated could sustain relatively high-yield wells.

Quality: Water derived from marine terraces is generally of good quality. Any connate or saline water that was trapped in the interstices between the rock grains during deposition has been flushed by the heavy rainfall. Wells yielding water having an iron concentration exceeding 0.3 parts per million can be treated by relatively simple and inexpensive equipment.

The chemical analysis of well no. 46, located in the Lincoln Beach area and serving as an emergency supply for the Kernville, Gleneden Beach, and Lincoln Beach Water District is shown in Table 8-a.

Yield summary and potential areas: The 15 wells producing from marine terraces listed in Table 10 range in yield from 3 to 60 gpm and average 19 gpm. This is the highest average yield of any of the geologic formations described in this report. The 60 gpm well, no. 128 in Table 10, is located in South Beach State Park and is the second largest producer of the 190 well logs reviewed. Its yield probably could be increased by lengthening its 10-foot intake screen.

Other high-producing wells in these deposits are no. 35 in the Devils Lake area, which bailer-tested at 24 gpm, and no. 46 in the Lincoln Beach area, estimated to yield at least 30 gpm.

Table 10. Summation of the 15 wells tapping the marine terrace sediments (Qmt)

Well No.*	Yield gpm	Draw-down feet	Static water level feet	Depth feet	Location and remarks
35	24	30	34	95	Lincoln City, near D River
46	30	N.A.	60	107	North part Lincoln Beach, municipal
47	10	90	30	133	South part Lincoln Beach
55	23	20	10	223	Near Otter Crest, condominium
56	8	72	18	200	Otter Rock
57	12**	10	30	84	Otter Rock
126	3	20	19	30	East of South Beach
127	12	10	6	24	O.S.U. Marine Science Center
128	60**	35	15	96	South Beach State Park
135	18	8	14	38	East of Holiday Beach
147	8**	4	30	55	East of Holiday Beach
148	7	10	N.A.	40	North of coastal Beaver Creek
174	15	5	8	30	Alsea River, near Eckman Slough
175	45	30	26	75	Golf course south of Waldport
176	8	20	35	63	Crest View Drive south of Waldport

* Well numbers are plotted on the geologic maps accompanying the report and are listed with additional data in Appendix B.

** Well test-pumped.

The yield range and average and the depth range and average of the 15 wells reviewed in Table 10 are as follows:

Yield range	Yield average	Depth range	Depth average
3-60 gpm	19 gpm	24' - 223'	86'

The marine terrace deposits offer the best potential for development of ground water by wells, especially where the deposits extend below sea level. Because the elevation of the Tertiary bedrock surface beneath the terrace deposits is highly irregular and often well above sea level, the depth of wells will vary; in areas where the bedrock surface is encountered above the water table, no water will be produced from the terrace deposits.

"Sandstone of Whale Cove" (Tmwc), Astoria (Tma), and Yaquina (Toy) Formations

Lithology: Although differing stratigraphically, these three rock units are sufficiently similar in composition that their water-bearing capabilities are comparable. The units consist primarily of fine- to coarse-grained massive sandstone, in part tuffaceous and pebbly, and generally thin-bedded siltstone, in part tuffaceous and carbonaceous.

The "sandstone of Whale Cove" having minor thin siltstone interbeds, is exposed in two relatively small areas at Whale Cove and Depoe Bay. The Astoria Formation crops out from Gleneden Beach to Yaquina Bay. The Yaquina Formation contains interbeds of conglomerate and minor low-rank coal deposits, and is exposed from Siletz Bay to Seal Rock.

Characteristics: The tight texture or compactness of the fine-grained rock particles forming these three formations precludes any but minor infiltration of precipitation and storage of ground water. The chance penetration by the wells into fracture or joint zones down which water has percolated and collected offers the best potential.

Quality: Although only well no. 87 of the 14 well logs reviewed for these formations shows water quality problems, it is known that other wells in the formations yield iron, sulfur, or saline water in concentrations requiring treatment to be potable. Well no. 87, drilled in the Astoria Formation, was abandoned due to septic tank contamination.

Yield summary and potential areas: The 14 well logs, summarized in Table 11, range in yield from zero to 20 gpm and average 5 gpm. The two dry wells are no. 88 at Agate Beach, tapping the Astoria Formation to a depth of 159 feet, and no. 133, near Flesher Slough on the Yaquina River, tapping the Yaquina Formation to a depth of 230 feet.

The "sandstone of Whale Cove" (Tmwc) is tapped by well no. 53 that yields 4 gpm with an 18-foot drawdown in a 32-foot well. The well casing extends to 26 feet and is not perforated. Perforating the casing would no doubt increase the yield, although 4 gpm is usually sufficient for domestic use. Detailed mapping might indicate areas where a well could be drilled into the underlying Depoe Bay Basalt in the vicinity of faulting where a higher yield could be obtained. However, the area of outcrop is small and barely significant in terms of total possible yield.

The four wells listed as tapping the Astoria Formation (Tma) range in yield from a dry hole to 10 gpm, for an average of 5 gpm. Only one of the four wells, no. 83, is satisfactory for use. It is a domestic well that yielded 8 gpm with 47 feet of drawdown in an 83-foot well. The other three wells, numbers 52, 87, and 88, were drilled for the Agate Beach Water District but were abandoned due to lack of sufficient yield and to contamination from septic tanks.

The Astoria Formation has no predictable potential for good ground water. Although four wells are insufficient to make an accurate estimate of water yield, the general lack of permeability, and the possible contamination from iron, sulfur, and saline water, make the drilling of a moderately good well in the formation unlikely. Most domestic water sources in this area are therefore springs and large-diameter dug wells.

The nine wells listed in Table 11 as tapping the Yaquina Formation (Toy) likewise indicate poor ground-water potential. They range in yield from a dry hole to 20 gpm and average 6 gpm. Well depths range from 67 feet to 230 feet, averaging 124 feet. The deepest well, no. 133, is dry. Most domestic sources of water, as for the two prior-described formations in this group, are springs and large-diameter dug wells.

Table 11. Summation of 14 wells tapping the three sandstone units

Well No.*	Yield gpm	Draw-down feet	Static Water Level feet	Depth feet	Location
			"Sandstone of Whale Cove" (Tmwc)		
53	4	18	14	32	½ mi. S. of Depoe Bay
			Astoria Formation (Tma)		
52**	3	485	15	500	¼ mi. NE. of Depoe Bay
83	8	47	23	83	1 mi. N. of Agate Beach
87**	10	2	35	101	At Agate Beach
88**	Dry	-	-	159	At Agate Beach
			Yaquina Formation (Toy)		
117	8	Unknown	32	67	3 mi. NW. of Toledo
130	20	18	37	100	¼ mi. S. of Yaquina
131	3	128	70	200	½ mi. S. of Yaquina
132	3.5	Unknown	18	123	1 mi. S. of Yaquina
133	Dry	-	-	230	1 mi. S. of Yaquina
134	2	Total	15	90	At Winant on Yaquina River
137	7	73	22	95	2 mi. E. of Holiday Beach
149	4	Unknown	55	109	At Seal Rock
150	4	Total	8	103	At Seal Rock

* Well numbers are plotted on the geologic maps accompanying the report and are listed with additional data in Appendix B.

** Well drilled for municipal use but abandoned due to inadequate yield or contamination.

A summation showing the yield range and average, and the depth range and average, of the 14 wells drilled in the three units and listed in Table 11 follows:

Formation	No. of wells	Yield range	Yield average	Depth range	Depth Average
"Sandstone of Whale Cove" (Tmwc)	1	4 gpm	4 gpm	32'	32'
Astoria (Tma)	4	0-10 gpm	5 gpm	83' - 500'	211'
Yaquina (Toy)	9	0-20 gpm	6 gpm	67' - 230'	124'

Cape Foulweather Basalt (Tmcf), Depoe Bay Basalt (Tmdb), and basalt of Yachats (Teyb)

Lithology: The Cape Foulweather Basalt, Depoe Bay Basalt, and basalt of Yachats are composed mainly of flow breccias, tuff beds, and basalt flows. Because of their generally comparable lithology, they have similar water-bearing characteristics and are therefore discussed together.

Characteristics: The Depoe Bay and Cape Foulweather formations are of limited extent and therefore have only local significance as a source of ground water. The basalt of Yachats occupies a considerably larger area. Production from basalt is related to jointing, fracturing, interflow zones, and faulting. Dense, fine-grained, underlying sediments could prevent the escape downward of water and thereby aid in the accumulation of ground water in the porous areas of the basalt body.

These units are fine to medium grained, very dense to open and brecciated, and form the headlands that have more successfully resisted the erosional forces of water and wind than have the adjacent softer rocks.

Quality: Water from these units is of excellent quality as there is little mineralization present.

Yield summary and potential areas: One well log is listed in Appendix B for each of these three formations, which collectively yield an average of 8 gpm.

The Cape Foulweather formation well (no. 85), drilled to 31 feet, was dry. The Depoe Bay formation well (no. 48), 63 feet deep, yielded 15 gpm with 46 feet of drawdown, and the Yachats basalt well (no. 189), 84 feet deep, yielded 9 gpm with 80 feet of drawdown. The specific capacity (gallons per minute yield per foot of drawdown) of these wells is very low.

As a whole, these formations have a poor ground-water potential. A well tapping a porous area containing abundant water would be a matter of chance.

Nye (Tmn), Alsea (Toa), Nestucca (Ten), and Yamhill (Tey) Formations

Lithology: These four formations consist of massive to thin-bedded clayey mudstone and siltstone and very fine-grained sandstone with tuffaceous interbeds and localized concretions. Their water-bearing characteristics are similar.

Characteristics: Like other marine sedimentary rocks in Lincoln County, these formations are impermeable to the extent that most precipitation is rejected and very little infiltration and storage of ground water occurs. Any movement of ground water would most likely be along fracture or bedding planes.

Excellent exposures of the Nye Mudstone occur along the north side of Yaquina Bay where a thickness of 4,400 feet has been measured. The major exposures are located both north and south of Yaquina and Siletz Bays.

Quality: Ground water produced from these formations generally requires some form of treatment for iron, sulfur or its alteration product hydrogen sulfide, or for salinity. A domestic well, no. 81, north of Toledo produced hydrogen sulfide from a depth of 96 feet. Two deep industrial wells in Toledo, no. 108, drilled to 975 feet, and no. 109, 1,900 feet deep, yielded saline water and hydrogen sulfide from several zones. All three wells tap the Yamhill Formation (Tey).

The chemical analysis of well no. 29, tapping the Nestucca Formation (Ten) and serving a housing development in the Roads End area north of Lincoln City, is shown in Table 8-a. The water quality of this well is good except for an iron concentration of 0.44 parts per million, 0.14 more than the maximum level recommended by the U. S. Public Health Service for public and private use.

Yield summary and potential areas: The 66 wells listed in Appendix C for these units range in yield from zero to 50 gpm and average 9 gpm. Eight of the wells are dry, as shown in the following listing:

Dry well no.	Formation	Well depth	Location
3	Yamhill (Tey)	199'	Near Otis Junction
27	Yamhill (Tey)	118'	Near Roads End
31	Yamhill (Tey)	161'	Near Neotsu
108	Yamhill (Tey)	975'	In Toledo
109	Yamhill (Tey)	1,900'	In Toledo
120	Nye (Tmn)	200'	East of Newport
121	Nye (Tmn)	301'	East of Newport
165	Nestucca (Ten)	245'	Near Bayview by Alsea Bay

Further evidence of the low ground-water yield of the Nye Mudstone formation is the large drawdown of several wells tapping it. Well no. 119 in Newport yielded 2 gpm with 197 feet of drawdown in a 200-foot well, well no. 123 east of Newport yielded 2.5 gpm with 245 feet of drawdown in a 365-foot well, and well no. 136 located east of Holiday Beach, 4 miles south of Newport, yielded 9 gpm with 244 feet of drawdown in a 253-foot well (Table 12).

Table 12. Summation of 11 wells tapping the Nye Mudstone

Well No.*	Yield	Draw-down	Static water level	Depth	
	gpm	feet	feet	feet	Location and Remarks
84	15**	120	17	250	Agate Beach, inadequate for mun. use
86	9	65	114	179	Agate Beach, inadequate for mun. use
118	12	24	9	48	One-half mile east of Newport
119	2	197	6	200	In Newport, domestic use
120	Dry	-	-	200	One mile east of Newport
121	Dry	-	-	301	One-half mile east of Newport
122	16	10	30	80	Just east of Newport on St. Hwy. 20
123	2.5	245	120	365	1½ miles east of Newport
124	5	50	23	65	One mile east of Newport
125	3	Unknown	40	100	One mile east of Newport
136	9	244	30	253	One mile east of Holiday Beach

* Well numbers are plotted on the geologic maps accompanying the report and are listed with additional data in Appendix B.
** Well test-pumped.

A summary of 66 wells drilled into the four formations is as follows:

Formation		No. of wells	Yield range	Yield average	Depth range	Depth average
Nye	(Tmn)	11	0 - 16 gpm	7 gpm	48' - 365'	186'
Alsea	(Toa)	15	1 - 24 gpm	8 gpm	42' - 325'	114'
Nestucca	(Ten)	17	0 - 50 gpm	13 gpm	45' - 250'	144'
Yamhill	(Tey)	23	0 - 30 gpm	8 gpm	32' - 1,900'	113' *

* The two industrial wells of 975 feet and 1,900 feet are excluded to give a more representative average.

A ground-water observation well, no. 112, tapping the Yamhill Formation is located in a bend of the Yaquina River one mile south of Toledo. The hydrograph showing the ground-water fluctuations of this and four other wells is shown in Figure 5.

Tyee Formation (Tet)

Lithology: The Tyee Formation is the most widespread rock unit in the County. It underlies about 600 square miles, principally in the central and southeastern portions, and attains a thickness of up to 6,000 feet. The formation consists principally of alternating beds of fine-grained sandstone 2 to 10 feet thick and beds of siltstone commonly 1 to 3 feet thick.

Characteristics: For the most part, the Tyee is impermeable and rejects the infiltration of precipitation and therefore has little capability for storing ground water. Wells producing appreciable quantities from the Tyee have generally tapped fracture or bedding-plane zones.

Quality: Although poor quality water is recorded on only 5 of the 71 well logs of the Tyee Formation, it can be assumed that considerably more have poor-quality water. However, the water from most of these wells can be treated and made potable.

Saline water was encountered at 280 to 332 feet in well no. 67 located three miles east of Siletz, at 80 to 88 feet in well no. 142 at Harlan, and at 30 to 32 feet in well no. 157 at Little Albany.

Iron in well no. 43 near Mack Landing on the Siletz River was sealed off at 94 feet.

Hydrogen sulfide gas was present in well no. 82, two miles north of Toledo. This well also had a high iron concentration. Hydrogen sulfide in wells is particularly prevalent in the area generally bounded by Eddyville, Nashville, Burnt Woods, and Harlan. Some residents, rather than use the water, obtain supplies from springs.

The chemical analysis of well no. 142 drilled for school use at Harlan is shown in Table 8-a. The well was abandoned because of the high pH value of 8.6, making the water excessively alkaline and distasteful.

Yield summary and potential areas: The 71 wells listed in Appendix C for this formation range in yield from 0 to 50 gpm and average 10 gpm. Data on six of the wells reported dry are as follows:

Dry well no.	Well depth	Location
59	73'	At Nashville
115	100'	Two miles south of Toledo
138	115'	Three miles south of Toledo
143	94'	One mile east of Harlan
180	206'	At Blackberry Campground on Alsea River
190	148'	At Fisher

Two observation wells, an 85-foot domestic well at Siletz (no. 69), and a 70-foot school well at Eddyville (no. 98), monitor ground water conditions in those areas. Neither well registers an annual water-table fluctuation exceeding 6.5 feet, a nominal change. The hydrographs of these and other observation wells are shown in Figure 5.

The 12 highest yielding wells, producing from 20 to 50 gpm, are scattered throughout the formation from the Siletz River to the Yachats River and from near Waldport to near Burnt Woods (Table 13.)

The yield range and average and the depth range and average of the 71 wells reviewed are as follows:

Yield range	Yield average	Depth range	Depth average
0 - 50 gpm	10 gpm	35' - 332'	103'

Table 13. Summary of the 12 highest-yielding wells tapping the Tyee Formation

Well No.*	Yield gpm	Draw-down feet	Static water level feet	Depth feet	Location
42	25**	5	19	42	On Siletz River, near Mack Landing
43	20	94	11	125	On Siletz River, near Mack Landing
58	30	18	20	65	On Yaquina River, west of Nashville
60	20	Total	15	45	Near Rock Creek, SE.of Logsden
97	40	73	19	100	One-half mile east of Burnt Woods
152	20	Unknown	35	70	On Alsea River, near Hellion Rapids
156	20	40	17	66	On Alsea River, near Little Albany
168	50	145	10	155	On Drift Creek, near Alsea River
169	30	22	6	52	On Alsea River, 1 mi. E. of Drift Cr.
179	25	21	29	61	On Alsea River, east of Stoney Mtn.
184	38	195	40	290	On Five Rivers, north of Fisher
187	27**	28	6	135	On Yachats River, near grange hall

* Well numbers are plotted on the geologic maps accompanying the report, and are listed with additional data in Appendix B.
** Well test-pumped.

Siletz River Volcanics (Tsr)

Lithology: The principal rock types of this formation are basaltic pillow lavas, flows, tuff breccia, and mudflow breccia with interbeds of siltstone, sandstone, and conglomerate.

Characteristics: Precipitation readily infiltrates the fracture zones and the contact zones between the individual lava flows of the formation. Porous areas therefore may store significant quantities of ground water locally, but large reservoirs are unlikely. The formation has not been adequately tested by the drilling of water wells because much of it is remote from centers of population.

Quality: Ground water from this formation is generally of good quality with little, if any, treatment required. The chemical analysis of well no. 12, supplying a housing development on the north side of the Salmon River between Otis and Rose Lodge, is shown in Table 8-a. The water has a very alkaline pH value of 9.4, requiring the water to be treated.

Yield summary and potential areas: The 18 wells listed in Appendix C for this formation range in yield from 0 to 120 gpm and average 11 gpm. The three highest yielding wells in the formation for which logs are available, no. 10 producing 43 gpm, no. 12 with 120 gpm, and no. 14 with 33 gpm, are located in a small rectangular area spanning the Salmon River 1½ miles east of Otis Junction.

Well no. 12 is the largest producer of the 190 wells reviewed for this study. One dry well, no. 9, was reported in the formation. It is 355 feet deep and is located one mile southeast of Otis Junction. Well data are summarized in Table 14.

Two domestic wells serve as observation wells for the State Engineer. Well no. 14, near the Salmon River 1½ miles southeast of Otis Junction, is 215 feet deep and registers an annual maximum water-table fluctuation of 9 feet. Well no. 39, located along the Siletz River 3 miles east of Kernville, is 118 feet deep and registers an annual maximum water-table fluctuation of 10 feet. The hydrographs of these and other observation wells are shown in Figure 5.

Table 14. Summation of 18 wells tapping the Siletz River Volcanics

Well No.*	Yield gpm	Draw-down feet	Static water level feet	Depth feet	Location
1	0.5	40	13	68	1 mi. NE. of Rose Lodge on Salmon River
2	8	20	14	46	1 mi. NE. of Rose Lodge on Salmon River
9	Dry	--	--	355	1 mi. SE. of Otis Junction on Salmon River
10	43	177	11	220	1 mi. SE. of Otis Junction on Salmon River
11	8	150	18	200	½ mi. SE. of Otis Junction on Salmon River
12**	120	185	25	230	2 mi. E. of Otis Junction on Salmon River
13	1	80	12	120	1½ mi. E. of Otis Junction on Salmon River
14	33	150	51	215	1½ mi. SE. of Otis Junction on Salmon River
15	11	35	14	49	1½ mi. SW. of Rose Lodge on Salmon River
16	7	35	22	67	1 mi. SW. of Rose Lodge on Salmon River
17	15	83	21	120	½ mi. NE. of Rose Lodge on Salmon River
18	3	109	12	118	At Rose Lodge on Salmon River
19	8	40	8	65	½ mi. SW. of Rose Lodge on Salmon River
20	10	12	28	44	½ mi. S. of Rose Lodge on Slick Rock Creek
33	9	90	6	110	At Schooner Creek Campground
37	7	19	18	41	At North Creek Campground
38	12	20	--	210	3½ mi. SE. of Kernville on Siletz River
39	10	--	21	118	3½ mi. SE. of Kernville on Siletz River

* Well numbers are plotted on the geologic maps accompanying the report and are listed with additional data in Appendix B

** Chemical analysis of water quality is shown in Table 8-a. Well test-pumped; excluded from yield and depth summary to obtain more realistic figures.

The yield range and average and the depth range and average of 17 producing wells reviewed in Table 14 are as follows:

Yield range	Yield average	Depth range	Depth average
0 - 43 gpm	11 gpm	41' - 355'	127'

Construction and Development of Wells

Wells must be properly constructed and developed in order to operate efficiently and economically. This assures a maximum yield of water at the best quality obtainable at the site.

State law requires that drilled wells have unperforated steel casing sealed to at least 18 feet below the land surface to prevent surface contamination from entering the well. Dug wells greater than 12 feet in depth must have a watertight surface curbing extending to a depth of 18 feet, or to within 3 feet of the bottom of the well in wells ranging from 12 to 21 feet in depth.

Wells cased their entire depth must be at least 50 feet from a septic tank, disposal field, seepage beds, seepage pits, or cesspool. Wells not cased their entire depth, or springs, cisterns, and community or public sources of water must be at least 100 feet from such sites of contamination; irrigation wells must be 50 feet away.

State law requires that well logs of all water wells, detailing pertinent ground-water data, be filed by the well contractor with the office of the State Engineer. The data are available to the public from the U.S. Geological Survey in Portland and the State Engineer's office in Salem.

Wells drilled in unconsolidated materials, such as alluvium (Qal), dune sand (s), or the marine terrace deposits (Qmt), have greater yields when equipped with a properly designed well screen surrounded by an envelope of coarse sand or gravel. The envelope permits use of a screen having larger slots which admit the water at a faster rate and at a much reduced head loss. Where the unconsolidated sediments are too fine to develop a natural gravel pack around the well screen, the well diameter may be drilled large enough to permit the artificial introduction of course sand or gravel. Although more costly, this type of construction can more than justify itself in increased production. The use of well screens is not feasible in consolidated rock formations.

Proper well development may increase the yield of a well by 25 to 50 percent and prolong its life considerably. This is best accomplished by surging, whereby water is violently forced in and out of the well screen to draw the fine material into the well and thus increase the permeability adjacent to the well. Other less efficient methods include pumping at progressively higher rates than planned in regular service and backwashing in which the pump is alternately started and stopped to produce sudden changes in the pressure head in the well.

Redevelopment of a well may become necessary after a period of time due to the packing of fine material into the intake area or the encrustation of mineral matter on the well screen and on the rock particles around the screen. Encrustation is most severe in wells that pump hard water and is principally caused by the carbonates of calcium, magnesium, and less frequently, iron. These minerals are removed by surging the well with diluted hydrochloric acid or a strong detergent, or less effectively, with dry ice.

ENGINEERING CHARACTERISTICS OF GEOLOGIC UNITS

Each geologic unit described in this section is delineated on the maps accompanying this report and briefly summarized in the map legend. See "Summary of Geologic Units" pages 13 to 27 for a more detailed description of the geology. This section deals primarily with the engineering aspects of each unit and provides information on slope stability, ease of excavation, foundation support capability, use in embankments, and other characteristics which should be considered in using these materials (Table 15). The plasticity index ranges for the soils associated with each geologic unit is charted (Figure 6). Laboratory and soils classification data were obtained from the State Highway Department, U. S. D. A., Soils Conservation Service, U. S. Department of Transportation and the U. S. Forest Service, Siuslaw National Forest.

Siletz River Volcanics (Tsr)

The Siletz River Volcanics, the oldest geologic formation exposed in Lincoln County, crops out in an area of about 125 square miles in the northern part of the County. It is composed of lavas, breccias, and interbedded volcanic sediments. The topography developed in this unit is steep and mountainous.

Part of the lavas were ejected onto the sea floor, forming accumulations of poorly cemented broken angular fragments of basalt, termed breccias. At times, some areas built up above the sea, forming volcanic islands. Lavas which poured out on these islands cooled to form dense hard basalt or fractured to produce breccias and basaltic sandstones. Erosion of the islands, together with volcanic ash falls, produced flanking deposits of tuffaceous siltstone.

The relative abundance of each of these rock types varies from place to place depending upon the location of volcanic centers, the depth of the sea at the time the deposits were laid down, and the distance from land. Thus the Siletz River Volcanics should be considered a complex unit, and its engineering properties vary accordingly.

A soil profile has developed through weathering of the rock together with the addition of organic matter produced by vegetation. The steepest slopes are bare or have a very thin soil cover. On gently and moderately sloping areas soil depths are 3 to 4 feet; on flat or concave surfaces the combination of weathered rock and soils can total as much as 30 feet.

The following soil classifications and laboratory data are based on two samples:

SOIL CLASSIFICATION

AASHO	Unified	Textural
A-4, A-6	ML-CL	Clayey silt

RANGE OF LABORATORY DATA

Gradation	Atterberg Limits	
Percent passing 200	Liquid Limit	Plasticity Index
65-85	30-40	5-15

Engineering in areas of Siletz River Volcanics will need to consider the rock types at each locality. Dense basalt requires drilling and blasting; it is generally suitable for road metal. Breccia contains considerable clay and soft minerals and usually is not difficult to rip. It will make embankment material if the size range is uniform but generally is fair to poor as base rock and unsuitable for paving rock.

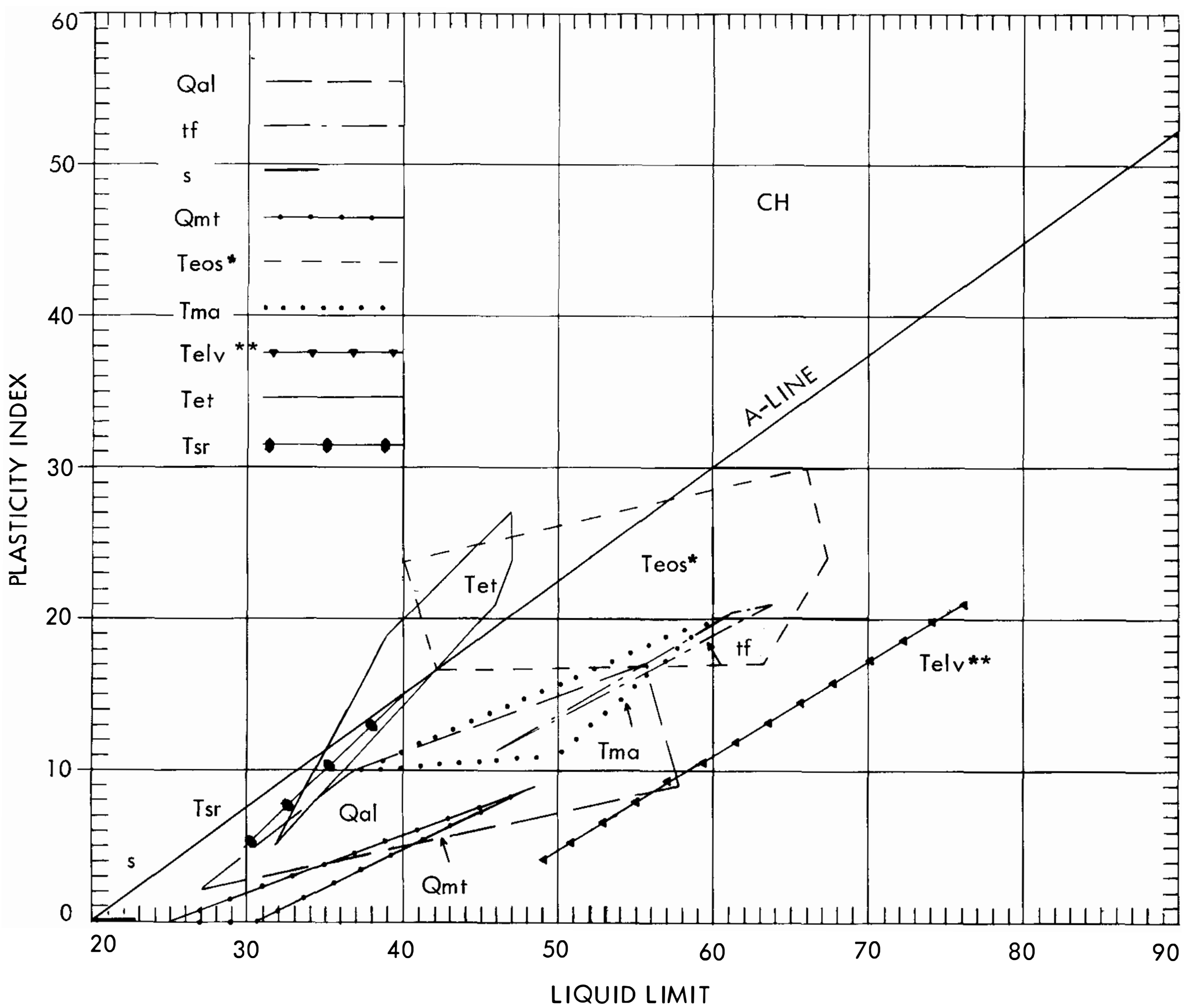
Table 15. Soil classification, laboratory test data,

	Geologic Unit	Tsr Siletz River Volcanics	Tet Tyee Formation	Telv Late Eocene Volcanics	Tey, Ten, Toa, Tmn Siltstones of Tertiary Age
	Number of Samples	2	3	2	7
Soil Classification	AASHO Unified Textural	A-4,A-6 ML-CL Clayey silt	A-6,A-7 ML-CL Clayey silt & Silty clay	A-5,A-7-6 ML-MH Clayey silt	A-7-5,A-7-6 ML-CL-MH Clayey silt Silty clay
Screen Analysis	Percent passing 4 10 40 200	80-100 75- 95 70- 95 65- 85	91-100 90-100 86- 99 53- 91	96-100 92-100 85- 98 68- 92	91-100 86-100 78- 99 65- 97
Hydrometer Analysis	Percent sand silt clay		7- 55 31- 51 18- 50	21- 41 32- 43 23- 35	3- 32 22- 43 28- 63
Shear Strength	Internal Friction ø Coehesion P.S.I. C		6- 18 4- 23	9- 13 11- 14	6- 14 7- 21
Atterberg Limits	Liquid Limit Plasticity Index	30- 40 5- 15	32- 47 5- 27	49- 76 4- 21	40- 63 17- 30
Proctor Density (Harvard Miniature)	Optimum Moisture Dry Density		16- 25 97-109	44- 45 74- 76	21- 38 80-104
Modified from Casagrande Soil Charts	Foundation Rating Shrink and Swell Internal Drainage Dry Strength Slope Stability Permeability m/hr.	Low on sediments Moderate Fair Low to moderate Low to moderate 0.6 - 2.0	Moderate Low-Moderate Poor Moderate Moderate	Low High Poor Moderate Low to moderate	Low High Poor Low to moderate Low
Uses for	Septic tank drainfield Source of ground water Embankment material	Poor Moderate to good Variable	Poor Low yield Fair	Poor Moderate yield Variable	Poor to very poor Poor yield Fair to poor

* Slight discrepancies between text data and the following tabulations are due to variations in samples tested.

and performance data for the geologic units*

Toy, Tma, Tmwc Sandstones of Tertiary Age	Qmt Quaternary Marine Terraces	s Stabilized Dune Sand	tf Tidal Flat	Qal Alluvial Deposits Terraces and Flood Plains
2	5	4	3	8
A-6 MH Sandy clay	A-2, A-5 ML Sandy clayey silt	A-2,A-3,A-4 SM Fine sand	A-7,A-8 ML-MH-OH-PT Peat Organic -clayey silt	A-7 ML-MH-CL Clayey silt
100 100 85-100 60- 95	100 90-100 95 20- 75	100 85-100 55- 99 0- 45	100 100 95- 99 90- 97	100 100 90- 99 75- 95
	30- 95 5- 35 0- 25	99 1 0	4 61 35	24- 49 33- 58 15- 26
	14- 38 4- 7	32- 37 0	19 9	50- 60 10- 20
36- 50 10- 20	15- 25 0- 4	20- 33 0	46- 64 11- 21	25- 58 11- 30
19- 23 100-105	18- 34 82-104	5- 17 99-109	33 86	21- 43 73-104
Moderate to good Low Fair Moderate Moderate 0.63 –2.0	Poor to moderate Low to moderate Poor to moderate Low Low to moderate 0.6 - 6.0	Moderate Low Excessive Low Low 0.2 - 0.6	Very poor Moderate to high Poor Low Low 0.6 - 2.0	Moderate Low to moderate Low to moderate Moderate Moderate 0.6 - 2.0
Fair to poor Moderate Fair	Fair to poor Fair to good Fair to good	No Fair to excellent Good if confined	No Poor Very poor	Variable Fair to good Fair to good



* Siltstones of Tertiary age (Ten, Tey, Toa, Tmn)
** Late Eocene Volcanics (Teyb, Tech)

Figure 6. Plasticity index ranges for soil associated with geologic units.

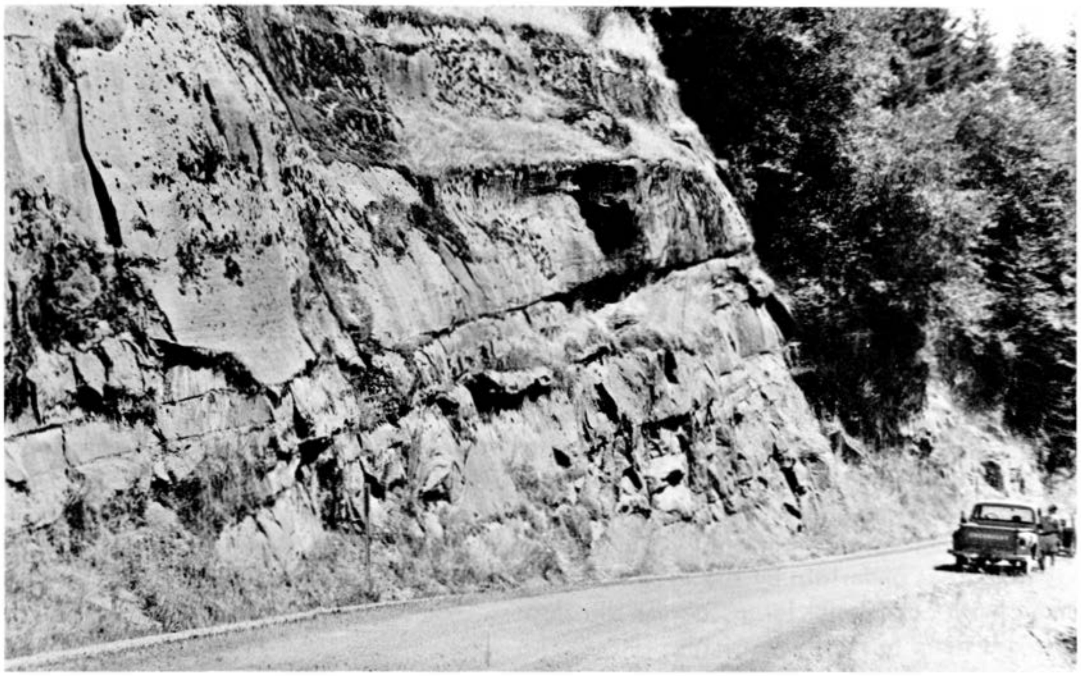


Photo 23. Lower part of Tyee Formation with alternating thick sandstone beds and thin siltstone beds.

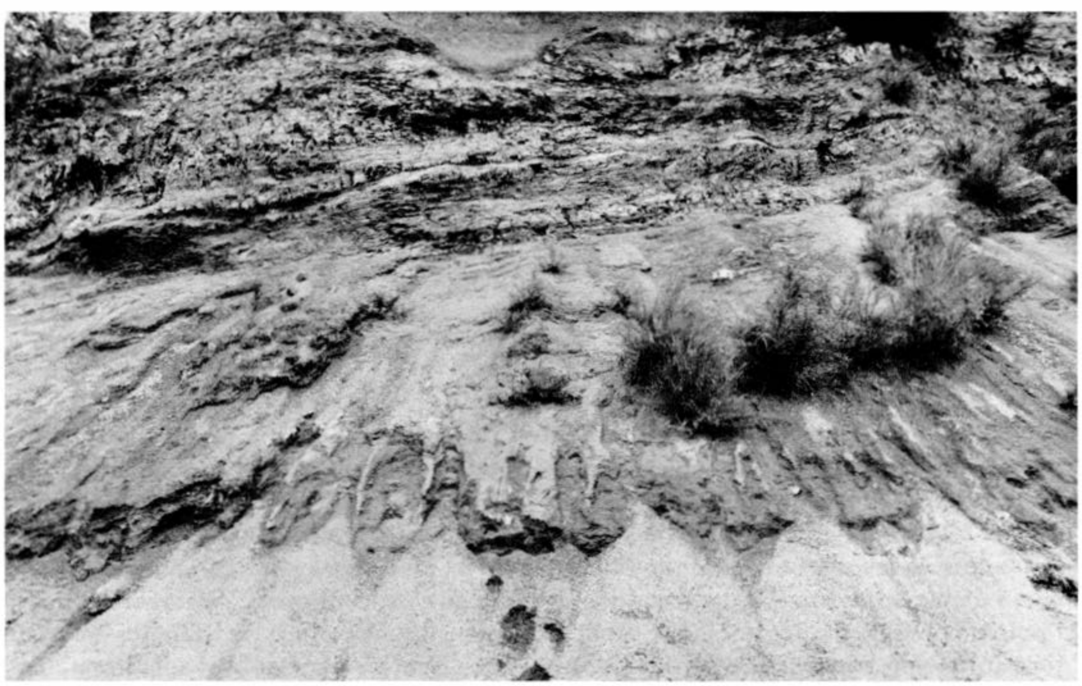


Photo 24. Nestucca Formation exposed at Yocum Point; rock weathers rapidly and forms abundant talus at base of slopes.

Tuffaceous siltstone can be easily excavated and can be used in carefully engineered and contructed embankments.

Cut slopes in the basalt and breccias will stand vertically; however, the siltstone beds tend to erode rapidly. Weathered sediments are weak and unstable in steep slopes, especially where the beds dip downslope.

The basalt and breccias of the Siletz River Volcanics are permeable through fractures; however, the sediments are slowly permeable to impermeable.

Tyee Formation (Tet)

The Tyee Formation is the most extensive rock unit exposed in Lincoln County. It crops out south and west of Stott Mountain and northward to the Tillamook County line. Except for a 4- to 5-mile wide coastal strip, it covers the southern part of the County from about 5 miles north of Siletz.

The Tyee Formation is composed of alternating beds of sandstone and siltstone. The sandstone is hard, gray, micaceous and arkosic in layers from 1 to 5 or more feet thick. The siltstone is dark brown to black, containing considerable plant fragments, in layers 6 inches to 2 feet thick. The sandstone is resistant to weathering, and areas underlain by the Tyee Formation are typically mountainous. The ridge tops are gently rounded with occasional large, gentle dip slopes. Where stream erosion has been active, the canyon walls are steep to nearly vertical.

Soil developed on the dip slopes and on the flatter ridge tops ranges from a few inches to 4 or 5 feet thick and is generally composed of silt and sand. The thicker soils contain an upper humic zone and a clayey substratum. The steep areas are usually devoid of soil. The following soil classification and labratory data are based on six samples taken from the well-developed older fine-grained soils:

SOIL CLASSIFICATION

AASHO	Unified	Textural
A-4, A-7-6	ML - CL	Clayey silt - silty clay Silty sandstone

RANGE OF LABORATORY DATA

Gradation	Atterberg Limits		Proctor Density (Harvard Miniature)	
Percent Passing 200	Liquid Limit	Plasticity Index	Optimum Moisture (Percent)	Dry Density lb./cubic feet
53 - 91	32-47	5-27	16-25	97-109

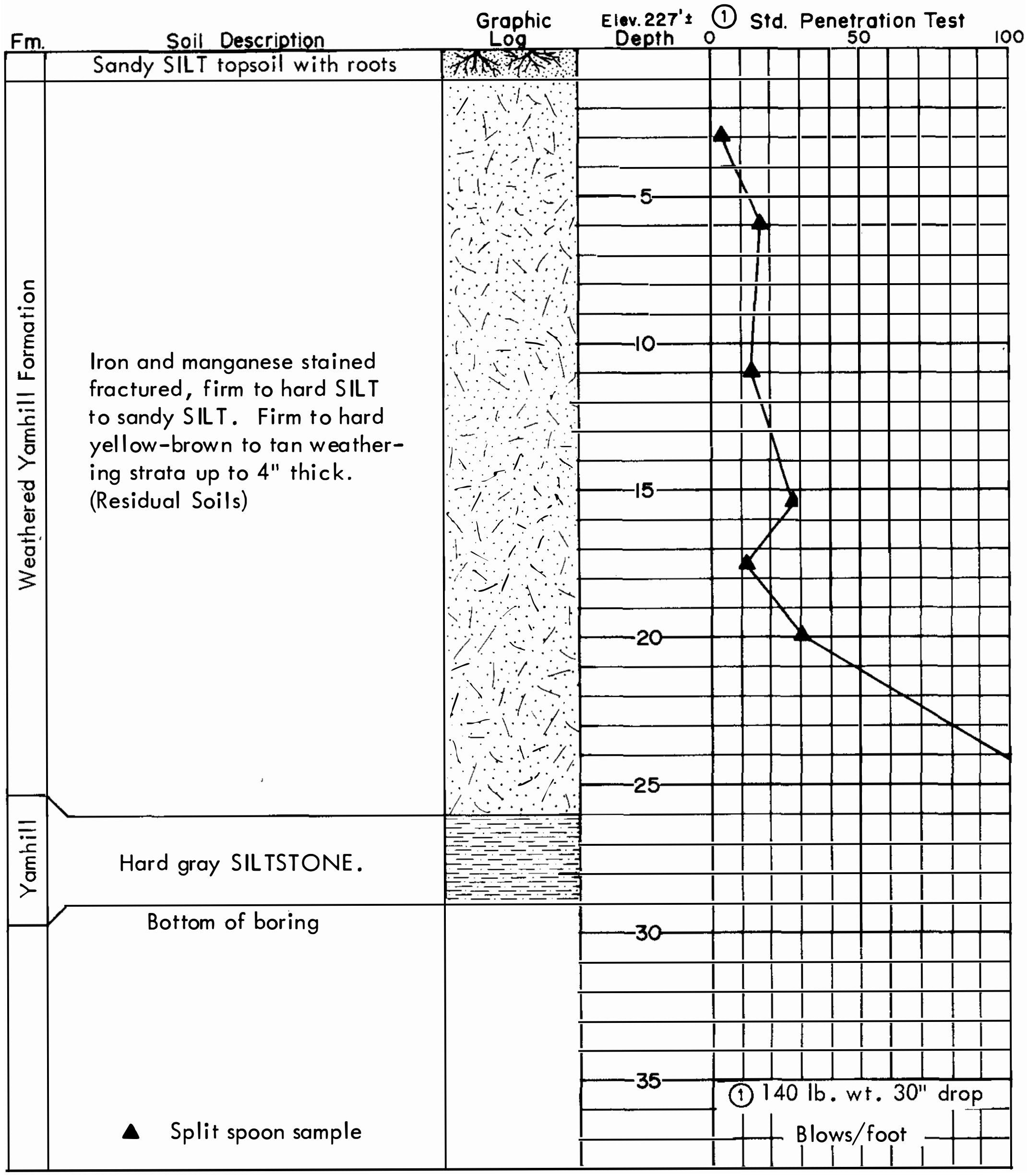
Excavation of the Tyee Formation generally requires drilling and blasting where the sandstone beds are thick and unweathered. Beds less than 2 feet thick can be ripped by heavy equipment. When blasting is required, large-diameter auger holes loaded with ammonium nitrate are most effective. Much of the energy of the blasting is absorbed by the sandstone and results are frequently erratic.

The use of excessive amounts of large sandstone blocks in an embankment can pose problems in compaction because of the voids created between the individual chunks of rock. Weathering and failure at the contact points between the large blocks cause settlement to take place at irregular intervals for long periods of time following construction of the embankment. Smaller fragments of sandstone, up to a foot or so in diameter, can be broken down and effectively compacted by construction equipment.

Permeability is low for both in-place Tyee and in properly compacted embankments.

Cut slopes stand vertically in areas where the beds are flat lying or dip away from the cut. Where the beds dip toward the cut at about 15 degrees or more, the hard sandstone layers may slide into the road.

Large areas of Tyee rocks have become involved in landslides where the sandstone layers parallel a slope of about 20 degrees or more. Generally the slope failure has resulted from stream erosion, which



Data from Shannon and Wilson, Inc.

Figure 7. Boring log of residual soils overlying the Yamhill Formation, Lincoln City area.

has allowed the Tyee rocks to fail along bedding planes. Landslides are also likely in places where the Tyee is underlain by less competent sediments in the Siletz River Volcanics. Many of the landslides are old and probably occurred when the stream gradients were steeper and downcutting more rapid during a lowering of sea level in late Pleistocene time.

In flat areas, or where the sandstone beds are nearly horizontal, the Tyee Formation will support heavy foundation loads. Soil and weathered rock must be removed and foundations adequately designed, however.

Road construction involving excavations in terrain underlain by the Tyee Formation should take into account the dip of the beds and also the areas of landslide, especially where recent movement is indicated. Although soils developed from Tyee rocks have good internal drainage and construction characteristics, they could fail in cuts where support has been removed downslope. Thick soils in relatively flat areas can perform adequately for septic tank drain fields in a rural-density population.

Tertiary siltstones (Ten, Tey, Toa, Tmn)

Four formations composed primarily of siltstone crop out in Lincoln County. They range in age from late Eocene through lower Miocene and in order of oldest to youngest are: the Yamhill Formation (Tey), Nestucca Formation (Ten), siltstone of Alsea (Toa), and Nye Mudstone (Tmn). They are adjacent stratigraphically except for the Nye, which is separated from the three lower siltstone formations by the Yaquina Formation, a sandstone unit. The siltstones are exposed extensively along the coast from about Yachats northward to the County line. The outcrop widens from a mile or so at each end to about 8 miles wide east of Newport. The Yaquina Formation occurs within the outcrop pattern of the siltstone units east of Newport.

The topography of the siltstones ranges from moderately steep to low rounded foot slopes often modified by ancient landslides and soil creep.

The siltstones are thin bedded to massive and contain thin limestone lenses and concretions. The Nye is often iron-stained in weathered outcrops. Fine- to medium-grained sandstone layers occur within the Yamhill, Nestucca, and Alsea rocks. Soils developed on the siltstones are usually thick, except for the areas of steep slope where soils are thin to absent. The upper 1 to 2 feet of soil is a sandy, clayey silt. It is underlain by about 3 feet of silty clay, which grades downward through a mixture of silty clay containing broken fragments of bedrock to in-place bedrock. Two boring logs of weathered Yamhill Formation are shown in Figures 7 and 8.

The following data represent the results of analysis from nine soil samples:

SOIL CLASSIFICATION

AASHO	Unified	Textural
A-7-5, A-7-6	ML-CL-MH	Clayey silt, silty clay

RANGE OF LABORATORY DATA

Gradation	Atterberg Limits		Proctor Density (Harvard Miniature)	
Percent Passing 200	Liquid Limit	Plasticity Index	Optimum Moisture (Percent)	Dry Density lb./cubic feet
61-98	40-67	17-30	21-38	80-104

The siltstones are easily excavated by construction equipment, and in most areas of unweathered rock the cut slopes stand on 1 to 1, horizontal to vertical. Cuts in which the bedding dips towards the excavation at about 15 degrees or more are apt to fail by material sliding along weak zones developed in the bedding planes. Where bedding planes dip into the hillside, cuts will stand steeply and will rarely fail by landsliding, providing the cut is not more than about 50 feet high.

Embankments made from this unit will need to be placed at very near optimum moisture content. The high silt content of the Nye Mudstone makes it sensitive to small moisture changes. The units containing

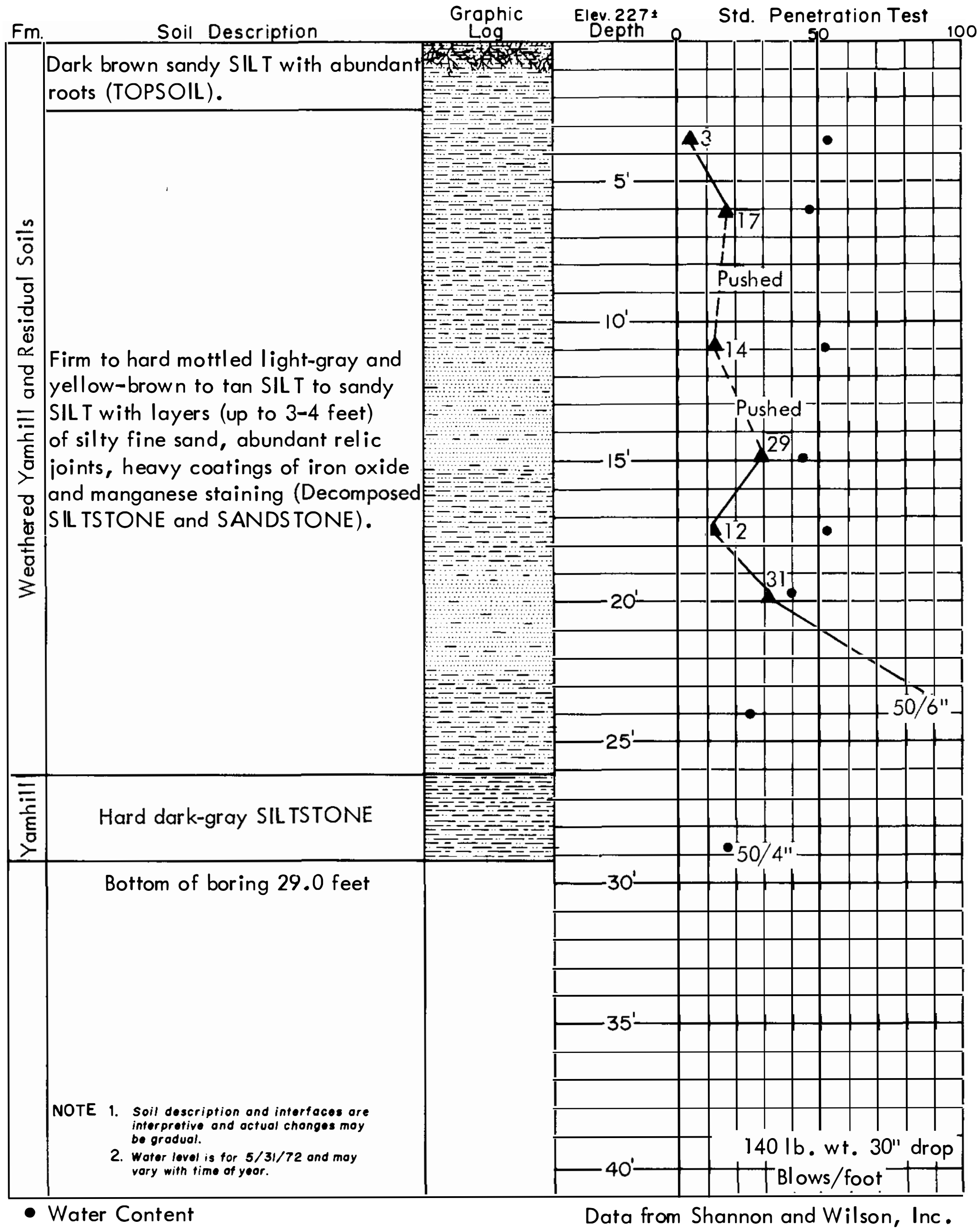


Figure 8. Boring log of residual soils and siltstone of Yamhill Formation, Lincoln City water supply reservoir.

considerable amounts of weathered volcanic ash have a high shrink and swell ratio relative to changes in moisture content. Embankments of this material need to be properly compacted to prevent moisture from gaining access to the swelling clays.

Erosion of embankment slopes by heavy rains can be lessened by planting certain types of vegetation and by installing curbs and catch basins or ditches to carry the runoff on exceptionally long fills. Natural slopes may be ancient landslides, some of which have been so modified that they no longer are readily recognizable as landslides. The slopes in old landslides are subject to failure if during construction they are over-steepened, overloaded, or if the drainage is modified appreciably. Slopes which are roughly parallel to the bedding will be especially subject to landslides in cut sections.

The foundation characteristics of this unit are poor. Light foundation loads will require normal precautions to assure satisfactory performance; heavy foundation loads will require detailed investigations to determine the depth of weathering, the structure, and the load-carrying capacity of the bedrock.

Because of the low permeability and high winter precipitation, drain fields and septic tanks will be inoperative much of the year, although in certain areas of very low population density, septic tanks may operate properly.

Tertiary sandstones (Toy, Tma, Tmwc)

Three formations composed dominantly of sandstone are exposed in western Lincoln County. They comprise the Yaquina and Astoria Formations and the "sandstone at Whale Cove."

The Yaquina Formation (Toy) of Oligocene age crops out in an arcuate pattern extending northeast from the coastline at Seal Rock, inland to about three miles east of Newport, and then trends northwesterly to the coast at Gleneden Beach. It is composed of massive to well cross-bedded, micaceous, tuffaceous, arkosic sandstone, pebbly sandstone and conglomerate, and layers of massive tuffaceous siltstone having local thin seams of low-grade coal.

The Astoria Formation of Miocene age crops out along the seacoast in the Newport area and is exposed extensively along the shoreline from Agate Beach to Gleneden Beach. It is composed of massive olive-gray, fine- to medium-grained micaceous, arkosic sandstone interbedded with carbonaceous siltstone.

"Sandstone at Whale Cove" is exposed in sea cliffs at Whale Cove and immediately north of Depoe Bay. It is a thickly bedded, friable, medium- to fine-grained arkosic sandstone with thin layers of siltstone. It contains cross bedding, cut-and-fill structures, and slump features.

Adjacent to the coastline, the sandstone units occur in flat wave-cut terraces and gently sloping or moderately rounded topography. To the east in the mountains the topography developed on the sandstones is moderately steep.

The laboratory data and soil classifications are based on two samples considered to be most typical of weathered rock and soil developed from the sandstone units.

SOIL CLASSIFICATION

AASHO	Unified	Textural
A-4, A-7	ML, MH	Sandy clayey silt, silty clay

LABORATORY SUMMARY

Proctor Density (Harvard Miniature)		Sieve Analysis				Atterberg Limits	
Optimum Moisture Percent	Dry Density lb./cubic feet	Percent Passing Screen 4	10	40	200	Liquid Limit	Plasticity Index
19-23	95-105	100	100	88-100	60-95	36-50	10-20

Landslides are common where the slopes have been steepened by erosion. This is especially true in exposures of the Astoria Formation along the coastline, where the unit is underlain by the Nye Mudstone, as at Jumpoff Joe in Newport. From Newport northward, the Astoria beds dip seaward from 10 to 25 degrees.

Bedding plane failures are numerous in the bluffs at the back of the beach. There, wave erosion continually removes the support from the foot of the slopes. These problems will be discussed in greater detail later in this report.

For the most part, the sandstones can be excavated by construction equipment without blasting. Although there are strata of fairly clean sand, they will become mixed with silty and clayey layers during excavation and the material will have the characteristics of a finer-grained (clayey silt) sediment. With good moisture control and proper compactive effort, satisfactory embankments can be built.

The maximum height and slope angle of stable cut slopes will vary, depending upon the type of material, structure of the beds, and degree of weathering. Best results will be in unweathered, nearly flat-lying rocks having few fractures and joint planes. Most problems will occur in weathered, fractured rock and where the beds dip toward the excavation. Site conditions should be determined before cut slopes are designed. Areas of old landslides are potentially unstable and will cause problems for a construction project.

Foundation characteristics of the sandstone units vary considerably, depending upon the type of material, dip of the beds, and the nature and slope of the topography. Where foundations are placed in weathered, downslope-dipping strata which lack toe support or in an area of active erosion, failure could occur by sliding of the foundations only or by involvement of a large part of the slope.

Impermeable layers alternating with highly permeable strata are not satisfactory for drain fields. Effluents will flow along the top of an impermeable layer in the direction of dip and emerge at the surface on a steep slope adjacent to the beach or a stream canyon. In some places, contaminated water could enter an aquifer being tapped by wells in the local area.

Tertiary basalts (Teyb, Tmdb, Tmcf, Tech)

Four basalt units are discussed as a group. In geographic sequence from south to north, they are the basalt of Yachats (Teyb), the Depoe Bay Basalt (Tmdb), the Cape Foulweather Basalt (Tmcf), and the basalt of Cascade Head (Tech).

The basalt of Yachats covers about 30 square miles and extends from Eckman Slough, east of Waldport, south to the vicinity of Yachats and Cape Perpetua, where it forms the prominent headlands along the coast. It is composed in part of dense fine-grained material, some having a large percentage of coarse crystals, some with numerous rounded cavities a few millimeters to a centimeter in diameter which in places are filled with secondary minerals. Much of the lava is highly fractured and cemented by a weathered glassy matrix. Basaltic sandstone and lapilli tuff weathered to a dark orange-brown, coarse, granular material is common in the vicinity of Yachats.

The Depoe Bay Basalt covers only about 2 square miles. It is composed mainly of pillow basalt, which formed where lava flowed into water and congealed in ovate blobs several feet in diameter. Cooling of the pillows formed brownish glassy surfaces and radiating internal fractures. A short distance south of Depoe Bay, where the lavas apparently did not flow into water, the basalt is columnar jointed.

The Cape Foulweather Basalt covers about 3 square miles and forms the headlands at the Cape. It is composed primarily of breccias and water-laid fragmental rocks; however, pillow lavas and columnar-jointed flows are locally present.

The Cascade Head basalt, centered north of the Salmon River in Tillamook County, barely extends into the northern coastal area of Lincoln County. It is composed of basalts intruded into Eocene sediments. The more resistant basaltic materials form prominent headlands immediately south of Salmon River.

Eash of the four basalt units has been intruded by dikes of basalt; in the Yachats area small camptonite and dacite dikes are present also.

South of Yachats and at Cape Foulweather the volcanics form massive headlands standing in steep cliffs up to elevations of about 500 feet above sea level. In the vicinity of Yachats, Whale Cove, and Depoe Bay, volcanic rocks occur in low terraces overlain by a thin veneer of sediments (Qmt).

Except for steep headlands and areas overlain by marine terraces, soils have developed directly upon the volcanics. The soils are usually about 3 feet thick, but in swales and flat upland areas they can be as thick as 5 feet and the underlying rock may be weathered to depths of 10 feet or more.

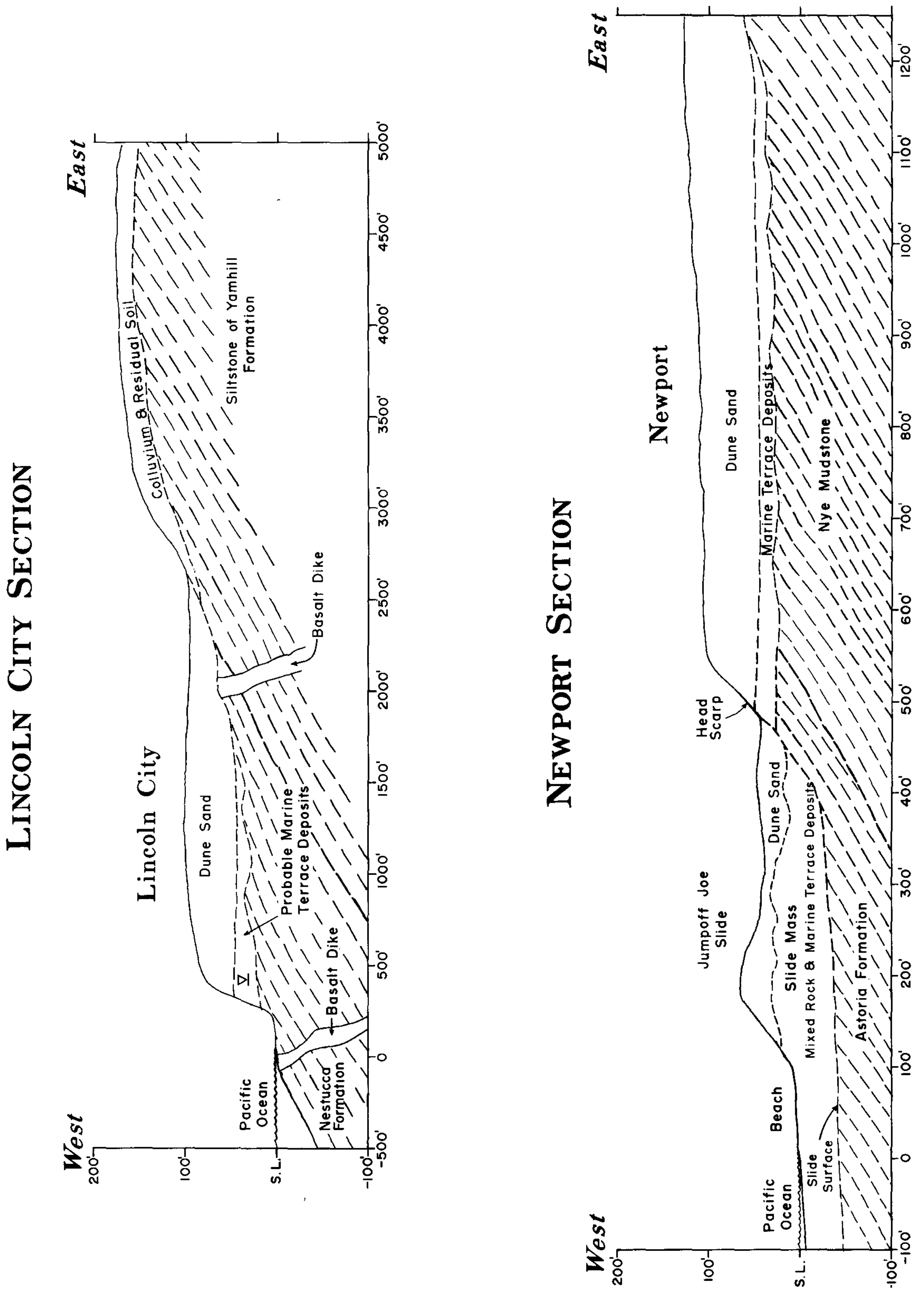


Figure 9. Cross sections showing the types of materials underlying the Lincoln City and Newport areas.

The following laboratory data and soil classifications are characteristic of the soils developed on the Tertiary basalts:

SOIL CLASSIFICATIONS

AASHO	Unified	Textural
A-5, A-7	ML, MH	Clayey silt

LABORATORY SUMMARY
(2 samples)

Gradation in Percent			Sieve Analysis Percent Passing Screen				Atterberg Limits	
Sand	Silt	Clay	4	10	40	200	Liquid Limit	Plasticity Index
21-41	32-43	23-35	96-100	92-100	85-98	86-92	49-76	4-21

The engineering characteristics are variable, depending upon the type of material, topography, and degree of weathering. The hard, dense rock can be used for road metal and riprap; however, good and poor rock often occur together in a single quarry face and mining must be selective in order to produce satisfactory material. Quarry rock is discussed in the section "Economic Mineral Resources."

Excavation of the weathered breccias and lapilli tuffs can be made with normal construction equipment; however, pillow lavas and columnar-and massive-jointed lavas require drilling and blasting.

Cut slopes in weathered pyroclastics will generally stand steeply, about one vertical to one horizontal, providing the upper highly weathered rock and soil zones are sloped on about two to one.

Embankments made from soils and highly weathered volcanic material must be placed at near optimum moisture content and well compacted. Partially weathered granular material will make satisfactory embankments; however, erosion of the embankment slopes could be a problem unless surface water is directed to a natural drainage channel. Planting of suitable cover is recommended on embankment and cut slopes.

Landslides occur mainly on the sides of deep valleys, such as the Yachats River valley, where weathering has been extensive and sliding is old but recurrent. Other areas of landslide are generally where underlying rocks have failed.

Marine terrace deposits and old dune sands (Qmt)

Marine terraces, mostly overlain by old dunes, are present along much of Lincoln County's shoreline between the rocky headlands and are the foundation for most of the County's coastal development (Figure 9).

The marine terraces represent ancient elevated beaches. The deposits are composed predominantly of sand, but also contain layers of gravel, clayey sand, clay and silt, and occasional lenses of peat. Thin impermeable layers of iron-cemented hardpan occur near the surface. Paleo soil horizons lie at various depths within the terrace deposits. The deposits are flat-lying and range in thickness from less than 20 feet south of Waldport to more than 50 feet in places to the north. They rest on the beveled Tertiary marine sedimentary rocks, and the contact may be exposed in sea cliffs from the beach level to as high as 50 feet.

Although the marine terrace deposits are semi-consolidated and fairly stable, the occasional incompetent layers of fine-grained soils, organic soils, and peat in the subsurface can cause stability problems. If these materials are within the sphere of load influence, they will settle unpredictably. The foundation characteristics of these soils can be determined only by drilling and soil testing. A log of a boring penetrating marine terrace deposits beneath dune sand is shown in Figure 10.

Areas with a slightly concave surface usually have impermeable clay and organic soils at the surface, high water table, and poor drainage. Septic tanks are usually ineffective, and without proper storm drainage and sewer installations even low-density development is impractical.

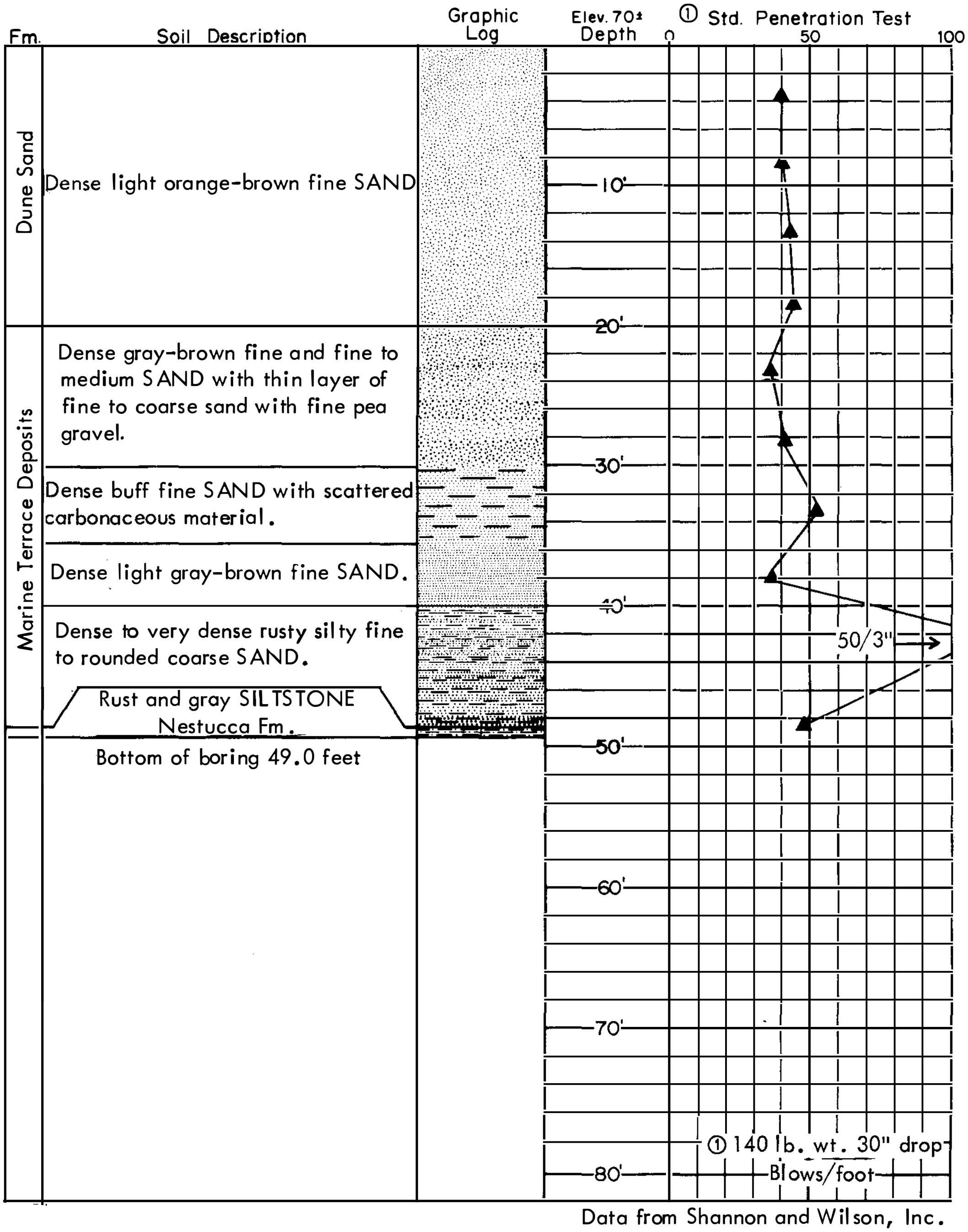
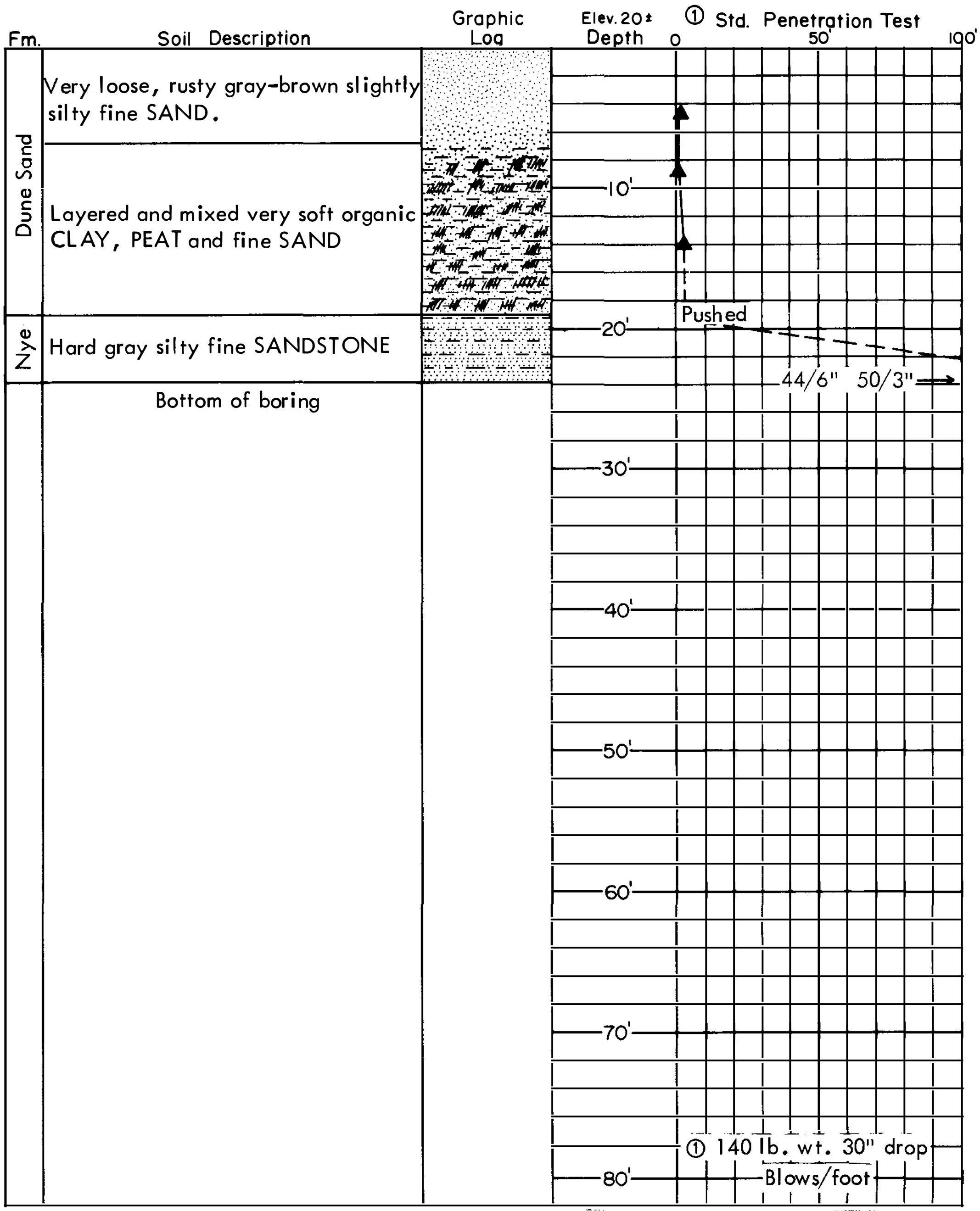


Figure 10. Boring log of dune sand and marine terrace deposits at Lincoln Beach.



Data from Shannon and Wilson, Inc.

Figure 11. Boring log of dune sand overlying soft peat at Lincoln Beach.

Photo 25. Marine terrace conglomerate just north of Yachats.

Photo 26. Tidal flat of Salmon River with small boat harbor.

When terrace soils become permeated by solutions containing soaps, detergents, water softeners, and other substances found in septic-tank-effluent oxidation ponds, sanitary land fills, and other waste-disposal facilities, the result is an increased soil sensitivity and reduction of strength (White and Bremser, 1966). Soils saturated for years by effluents may, under certain conditions, settle under buildings or start landslides. The continued use of septic tanks and effluent evaporation ponds or lagoons should be considered relative to earth stability.

The old dune sands overlying the terrace deposits have developed a soil horizon 2 to 3 feet thick which normally supports a thick vegetative cover. Although stabilized, the sand is unconsolidated and therefore easily excavated. Removal of the soil and plant cover will expose the sand to erosion and transport by the wind, causing sand build-up in unwanted areas such as city streets, driveways, and lawns.

Old dune sand underlies the Nelscott-Taft area of Lincoln City, the Newport-South Beach area, the large stretch of coast north of Waldport, and much of the area between Yachats and Waldport. The areas occupied by the old, stabilized dunes have a characteristic rolling topography.

The loose consolidation of the dune-sand soils and lack of lateral support may result in settlement from moderate foundation loads; therefore, only light foundation loads on spread footings are recommended. For moderate to heavy structures, foundation piling or large mat foundation may be required; its design should be based on subsurface exploration and soil testing. Three boring logs of dune sand are shown in Figures 11, 12, and 13.

The dune sand is relatively clean and can be washed and screened if the intended use requires it.

The following soil classifications and laboratory data for the dune sands are from information prepared by the U.S.D.A. Soils Conservation Service:

SOIL CLASSIFICATIONS

AASHO	Unified System	Textural
A-2, A-5	ML-SM	Sandy silt

RANGE OF LABORATORY DATA

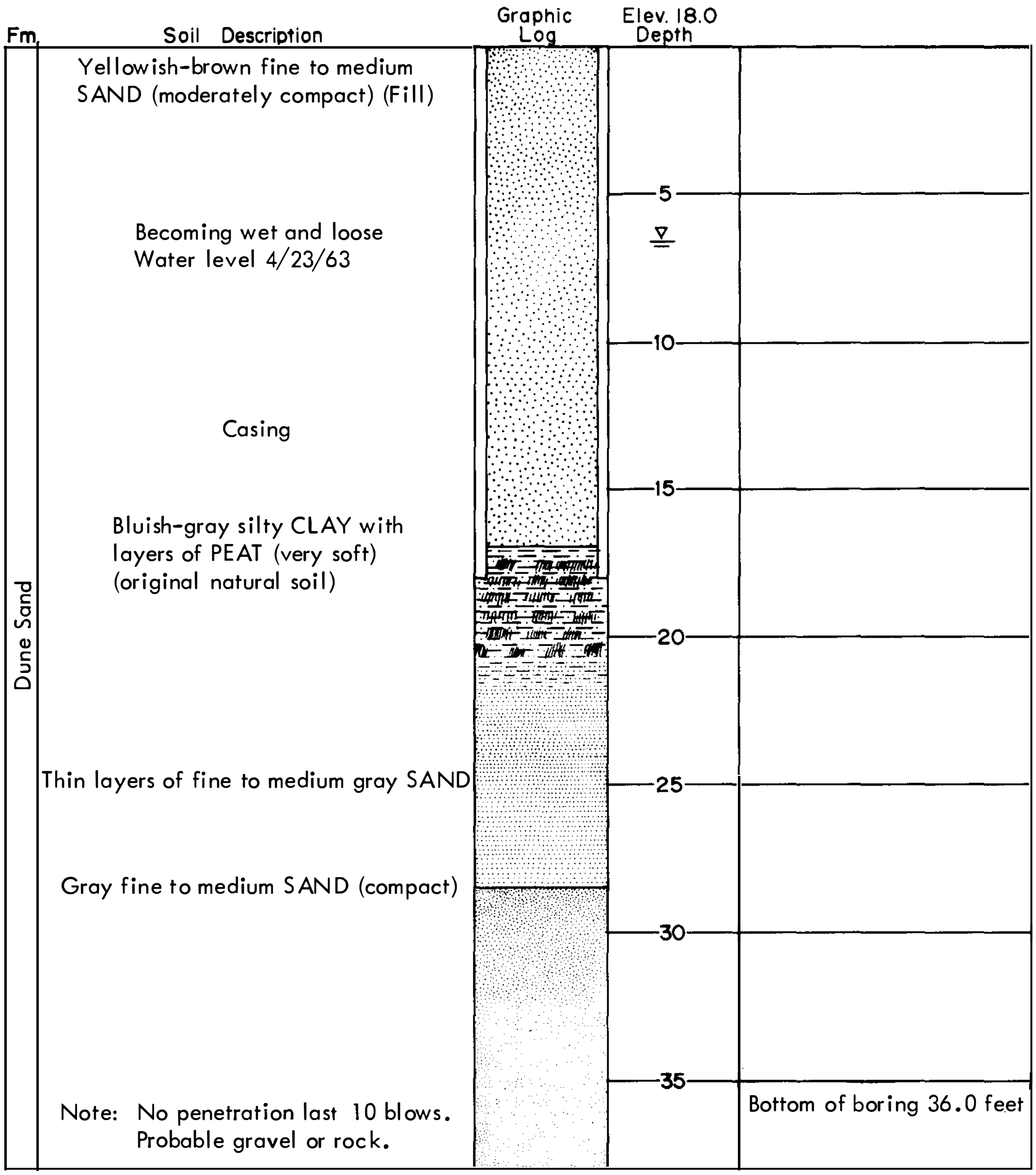
Sieve Analysis Percent Passing Screen 4	10	40	200	Atterberg Limits Liquid Limit	Plasticity Index	Permeability in./hr.
100	90-100	60-95	20-75	15-25	0-4	0.6 - 6.0

Severe problems of erosion involve the marine terrace deposits and old dune sands along the sea-cliff areas of Lincoln County. During high tides and storms, pounding waves erode the base of the cliffs; above the reach of the waves, wind and blowing rain and sand are the active agents of erosion. Gullying of the sea cliff by surface run-off during heavy rains contributes to the erosion problems.

Measurements of erosion rates indicate that marine terraces normally retreat from 6 inches to about $1\frac{1}{2}$ feet in a single year. However, if undercutting by wave erosion oversteepens the sea cliff and causes landsliding, as much as 15 or 20 feet of the cliff can drop off. Where annual erosion is about 1 foot per year and landsliding occurs every 10 or 15 years, the sea cliff can retreat at least 2 feet per year over a long period.

Landslides are most common where the bedrock underlying the marine terrace deposits is composed of soft sedimentary layers that dip seaward 15 degrees or more, as do the Nye Mudstone and the Astoria Formation in the Newport area. Terrace recession at Newport has averaged between $1\frac{1}{2}$ and 8 feet annually. See the section on "Geologic Hazards" for more detail on the landslides in the Jumpoff Joe area of Newport.

Construction on the terraces should be located where erosion and landsliding will not endanger the buildings within the time span of their planned purpose. The removal of vegetation in preparing the ground for a multi-unit development should be followed immediately by construction; otherwise, erosion and water saturation could produce excessive runoff along the cliff areas and induce slope instability and accelerate erosion.



(Data from Dames and Moore)

Figure 12. Boring log of dune sand at Taft (Lincoln City).

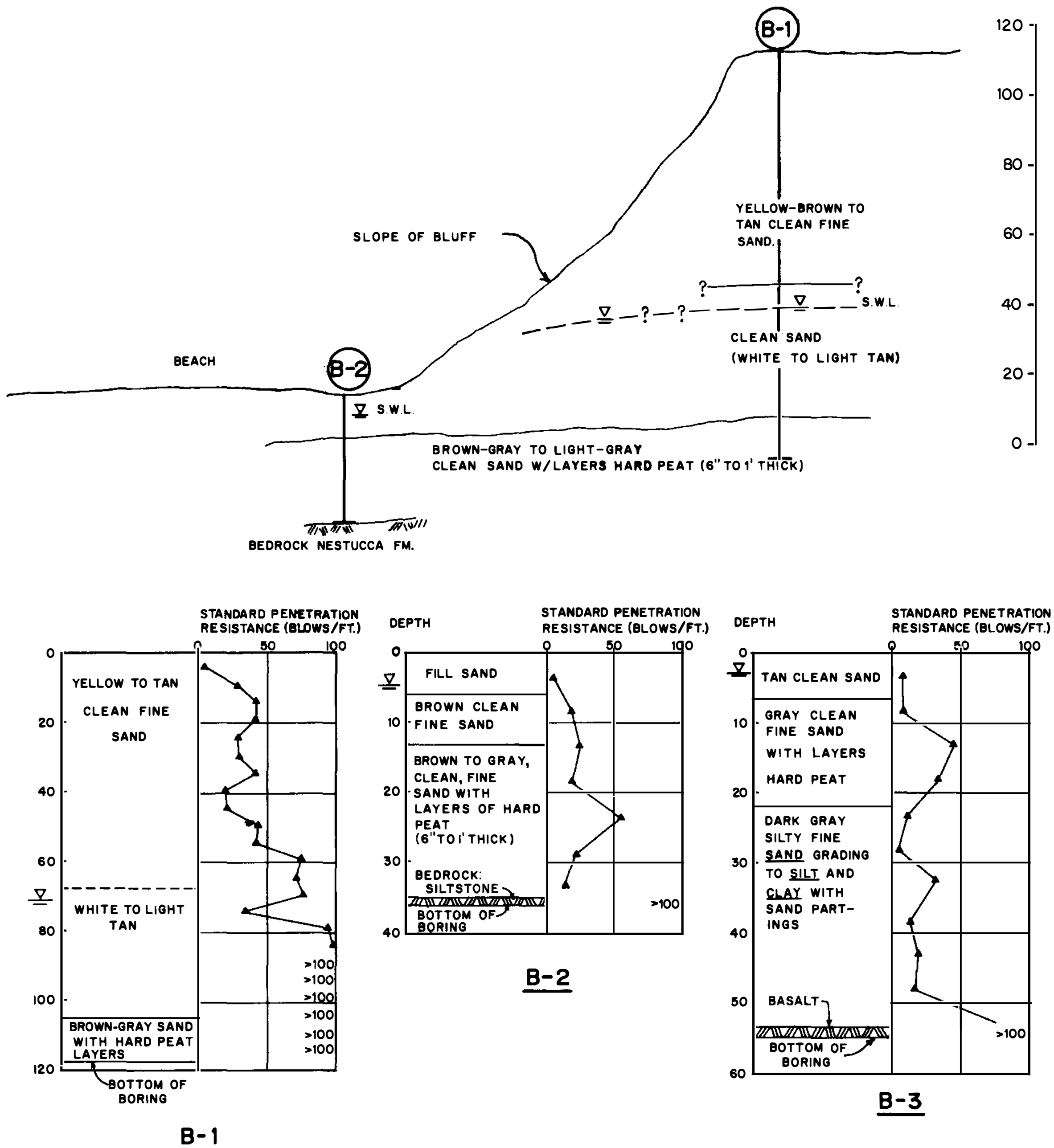


Figure 13. Boring logs and cross section of dune sand at Taft Heights (Lincoln City).

River terrace and flood-plain alluvium (Qal)

The alluvium occurs on the flat to gently sloping land in the valleys of the major streams and their tributaries. The unit includes soils of the river bottom land and the uplifted river terraces. The major alluvial deposits in Lincoln County occur along the Siletz, Alsea, Yaquina, and Salmon Rivers. Smaller deposits occur along Schooner, Drift, and Beaver Creeks and the Yachats River.

The alluvial deposits are predominantly silt, sand, and gravel; clay, organic soil, and peat may also be present in variable amounts. The predominance of any one of the constituents depends upon the relative abundance of igneous rocks versus sedimentary rocks in the drainage area, the stream gradient, and the configuration of the valley. Gravel can be expected to be at or near the surface in the upstream part of the valley, and to be under a thickening cover of sand and silt downstream. Gravel may be absent in the subsurface from about tidewater to the mouth of the stream. Gravel is more common in the larger valleys of the northern part of the County.

The thickness of the alluvial deposits ranges from about 45 feet at the mouths of the major streams to as little as 8 or 10 feet at the upper ends of the larger valleys and in the smaller stream valleys. Three boring logs of alluvial deposits are shown in Figures 14, 15, and 16.

The following soil classifications and laboratory data are based on six samples of alluvial soils:

SOIL CLASSIFICATION

AASHO	Unified	Textural
A-4, A-7-5	ML-MH	Sandy silt-clayey silt

LABORATORY ANALYSIS

Gradation in Percent			Sieve Analysis Percent Passing Screen				Atterberg Limits	
Sand	Silt	Clay	4	10	40	200	Liquid Limit	Plasticity Index
24-49	33-58	15-26	89-100	84-100	72-99	24-85	27-58	2-17

The flood plains are subject to inundation, and the lower terraces flood occasionally. Although the upper terraces rarely flood, the water table may rise to within a few feet of the surface during the wet season. During flooding, erosion occurs along the stream banks, and sand and silt are deposited on the flood plains.

Flood-plain uses should be limited to such purposes as agriculture, recreation, or gravel removal, provided the use is in agreement with the County's long-range comprehensive plans.

In areas where the upper terraces make attractive sites for housing development, strong consideration should be given to the requirement for a sewer system. The seasonal high water table and the possibility of water contamination will preclude the extensive use of septic tanks. The water level on the upper terraces can be lowered somewhat by tiling.

Valley alluvium on flood plains has low foundation strength. Structures built on the flood plain should be designed for light foundation loads and be able to withstand flooding. Heavy structures could be located on flood plains if dense gravel or bedrock in the subsurface could be reached by means of spread footings or piling.

Weak foundation soils characteristic of the valley alluvium will consolidate under the weight of a roadbed embankment producing an uneven grade. Often the settlement will be slow and the full effects not apparent for a year or more. The amount of settlement which will occur can be determined by subsurface sampling and laboratory testing, with an analysis performed by a soils engineer.

Tidal flats (tf)

Tidal flats are composed of fine-grained sediments deposited in the brackish water interface between sea water in the bays and estuaries and fresh water brought down by major rivers. Tidal flats occur near

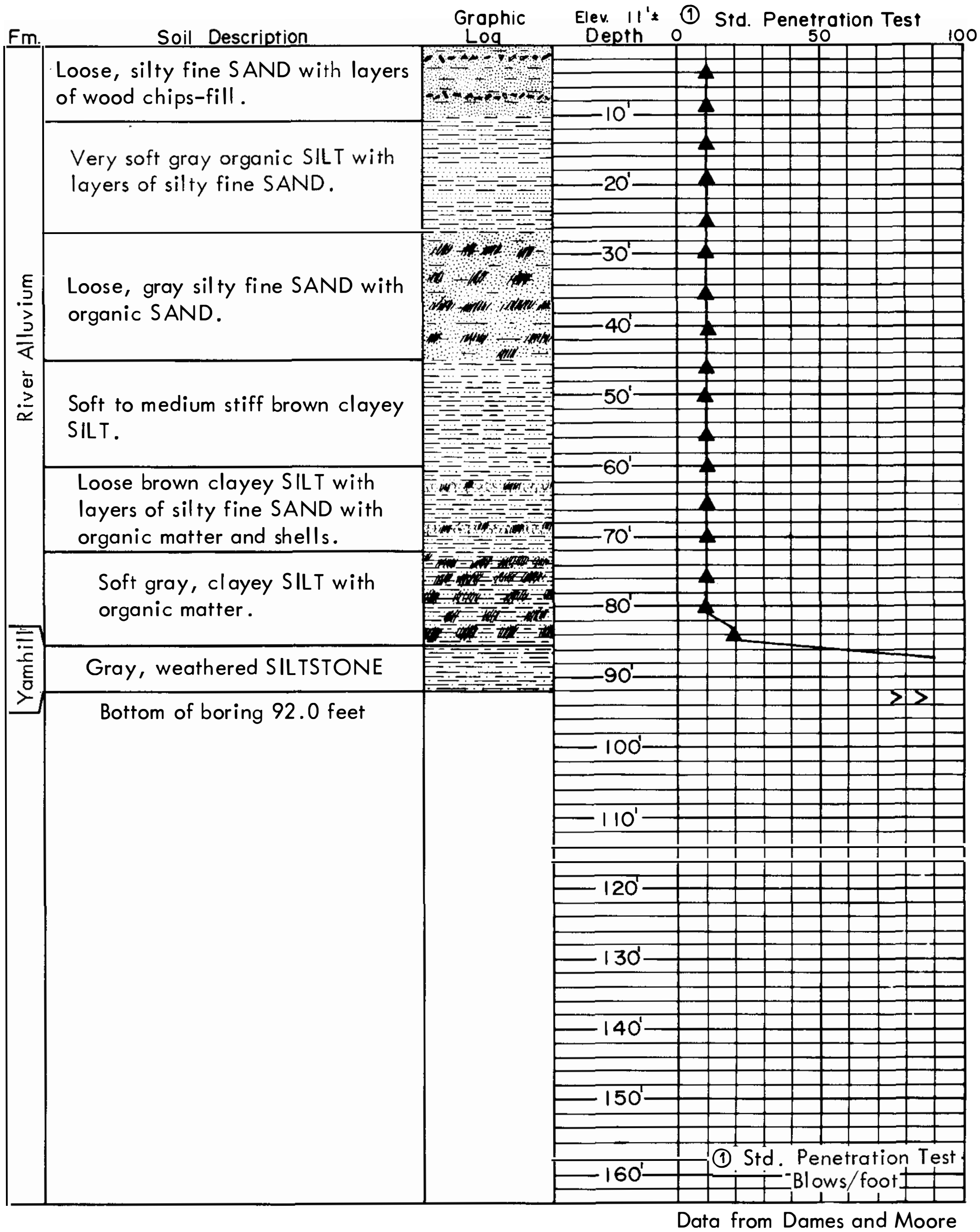


Figure 14. Boring log of Yaquina River alluvium, Toledo area.

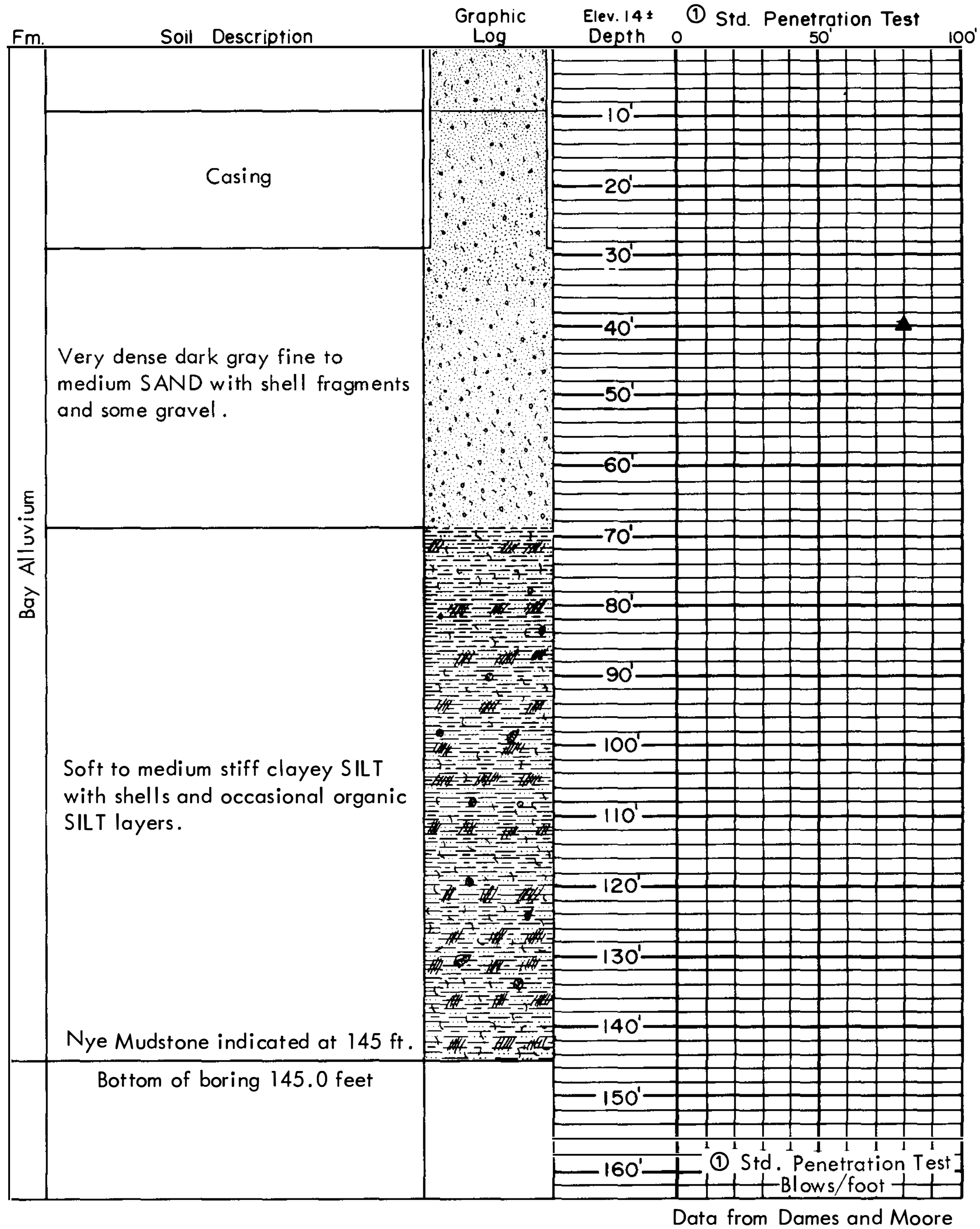
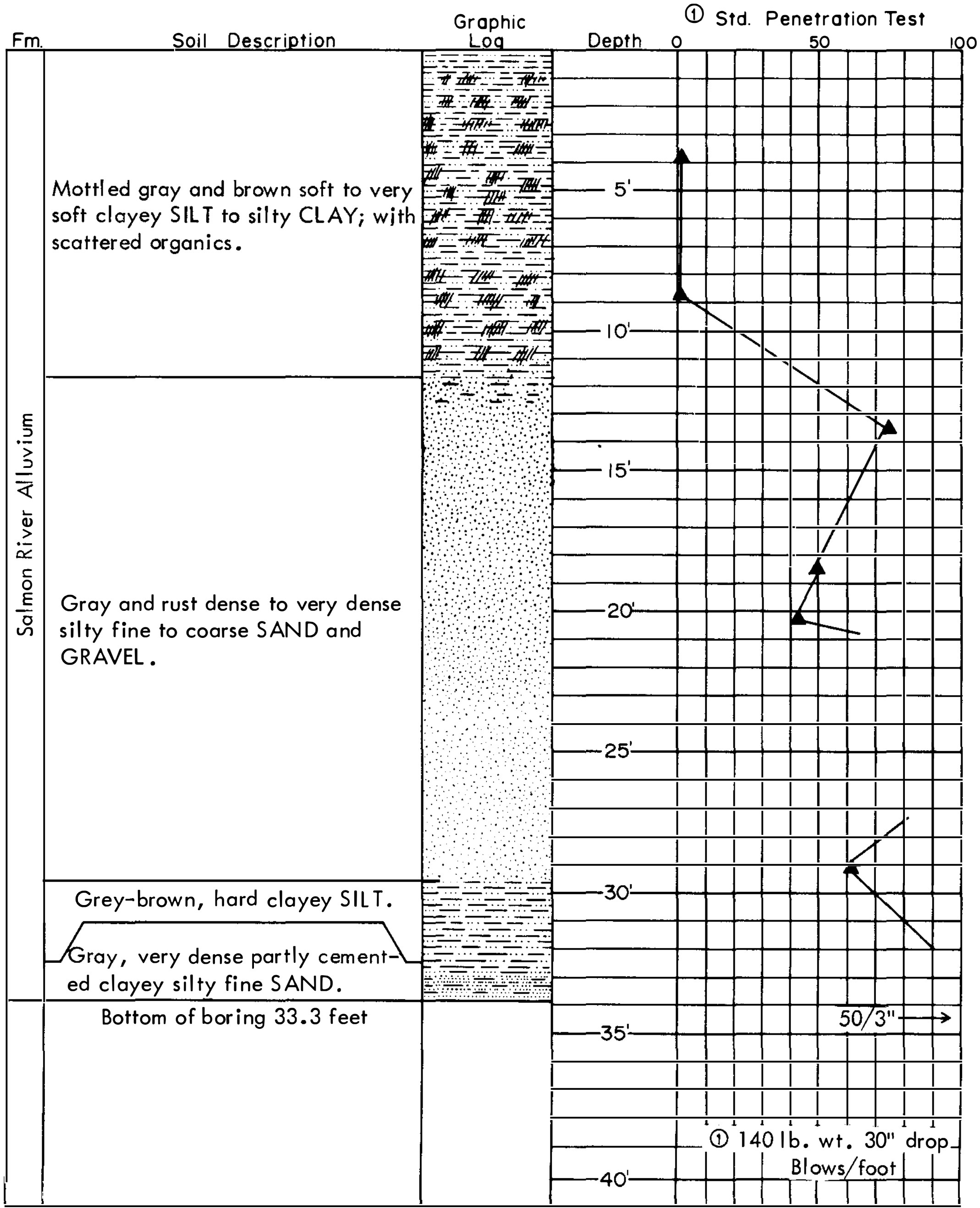


Figure 15. Boring log of bay alluvium, South Beach dock, Newport area.



Data from Shannon and Wilson, Inc.

Figure 16. Boring log of Salmon River alluvium at Pixie Land.

the mouths of the Salmon, Siletz, Yaquina, Alsea, and Yachats Rivers. In some areas they are inundated daily by the tides and in other areas only by abnormally high tides or storm-borne tides. During periods of heavy run-off and stream flooding, tidal flats receive considerable amounts of silt. Tidal currents bring in large amounts of sand from the ocean. Sometimes large waves washing across sandspits carry large amounts of sand into the bays and tidal flats. Sand-dune areas also contribute wind-borne sand. Some sections of the tidal flats are marshy and promote the growth of vegetation including peat moss.

In general, tidal flat materials are a mixture of fine river-borne sediments, beach sand, and organic matter in proportions depending upon proximity to the various sources of material. More typical is the organic silty clay which the following samples represent:

SOIL CLASSIFICATIONS

AASHO	Unified	Textural
A-7, A-8	ML - MH- OH - PT	Clayey silt, silty clay Organic soils and peat

LABORATORY SUMMARY
(3 samples)

Gradation in Percent			Sieve Analysis Percent Passing Screen				Atterberg Limits	
Sand	Silt	Clay	4	10	40	200	Liquid Limit	Plasticity Index
4	61	35	100	100	95-99	90-97	46-64	11-21

In cross section, a typical tidal-flat deposit consists of sandy, clayey silt and peat about 6 inches thick overlying a variable but usually thick layer of silty clay containing lenses of sand and peat.

The use of tidal flats for construction is limited because of frequent inundation and the presence of thick compressible soils. Areas not flooded by tides have a high water table and poor drainage. The use of these areas for drain fields is not recommended. The performance of sewage lagoons built in tidal flats is questionable; however, some have been constructed in tidal flats elsewhere in Oregon. Their performance and effect on the environment should be evaluated before more such construction is allowed.

Foundation characteristics for any kind of spread footing are such that settlement will be excessive and uneven. Even moderately heavy structures should be placed on piling. If the deposits are thin, end-bearing piling resting on bedrock can be used, but for thick deposits friction-bearing piles will perform satisfactorily.

Roads built over tidal flats must necessarily be placed on several feet of embankment in order to be above tide and flood-water elevations. The weight of such an embankment, although low, is sufficient to cause considerable differential settlement and give the road a roller-coaster effect. The low permeability of the tidal muds will cause settlement to take place over a long period of time. Moderately high embankments may cause the foundation soils to fail by shearing.

Soils and foundation engineers can, where necessary, examine the foundation soils and recommend construction of sand drains, counterweight, preloading, piling, or some other method to assure satisfactory results.

GEOLOGIC HAZARDS

Landslides

Landslides occur in a mass of sloping soil or rock when the shearing stress exceeds the shearing strength. Such slope failures develop naturally through several processes: erosion undermines and oversteepens the slope; excessive rainfall increases the weight of the material in the slope; weathering decreases soil strength; and ground water leaches the elements that act as soil and rock binders.

Landslides can move rapidly, slowly, or intermittently depending upon the influence of the factors causing the instability. They may begin slowly and increase in velocity, or they may begin abruptly and decrease in velocity. Large landslides may continue to creep or move intermittently for many years.

Initial failure of a slope generally produces tension cracks in the ground. As movement continues, the cracks widen. Thick soil will tear apart and a small linear depression may form parallel to the crack. The types of landslides differ depending upon factors such as slope angle, depth to bedrock, and type of material involved in sliding. The various types of slides are discussed below.

Time tends to modify and obscure the surface features produced by the landslide. The tilted and bent trees are replaced by a new growth of straight and vertical trees, the drainage is reestablished, and sag ponds are drained. Ancient landslides may be recognized, however, by subtle differences in the morphology of the terrain. Gently sloping, rolling topography, the displacement of strata, and the deranged structure of the bedding all give evidence of a prehistoric landslide.

In Lincoln County much of the geologic terrain is susceptible to landsliding. Inland, where the topography is mountainous and streams cut deep canyons with steep slopes, several rock sequences, especially the siltstone and claystone formations, weather to produce residual soils and thick colluvium which fail when oversaturated by moisture or undercut by erosion. Along the coast, the sea cliffs composed of these rocks as well as unconsolidated terrace soils are constantly undercut by high tides and storm waves. Steep terrain, weak rock materials, high rainfall, weathering, and erosion combine to produce extensive slope failure throughout Lincoln County.

Investigations of landslides in Lincoln County was largely reconnaissance in scope, except in selective areas along the coast where more detailed site inspection was done. Landslide areas were identified by geologic field studies, by stereo viewing of aerial photographs of the entire area, and by study of topographic maps. In addition, automobile and foot traverses and air reconnaissance were conducted to study specific problems and to substantiate information developed by the other methods.

Classification of landslides

Landslides in Lincoln County can be classified according to age: (1) ancient landslides (no historical movement, probably several hundred years old); (2) recent landslides (historic movement but no current active movement); and (3) active landslides. They can also be classified according to five general types: (1) rotational slump slides in cohesive materials, (2) debris slides and mudflows in granular materials and cohesive soils, (3) bedding plane failures in rock units, (4) sloughing of vertical slopes, and (5) soil creep.

Rotational slump slides: This term refers to slump masses which move downslope on a curved basal slip plane and contain numerous back-tilted blocks. The resulting topography is hummocky, and some of the depressions fill up with water to form sag ponds and small lakes.

Rotational slump slides commonly occur in the thick residual soils that develop through weathering of the fine-grained sedimentary rocks of the Yamhill, Nestucca, Alsea, and Yaquina Formations. They also occur in more localized areas of the Tyee Formation and in unconsolidated marine terrace deposits.

Debris slides: Debris slides occur on steep slopes covered with granular rock fragments and soil; they tend to develop rapidly during heavy rainfall. Debris slides are easily reactivated by natural or man-made alterations in slope, water content, or surface runoff.

Photo 27. Landslide in roadcut of Highway 101 north of Salmon River. Headscarp of slide can be seen in background. Slide is in residual soils and weathered siltstone of Yamhill Formation.

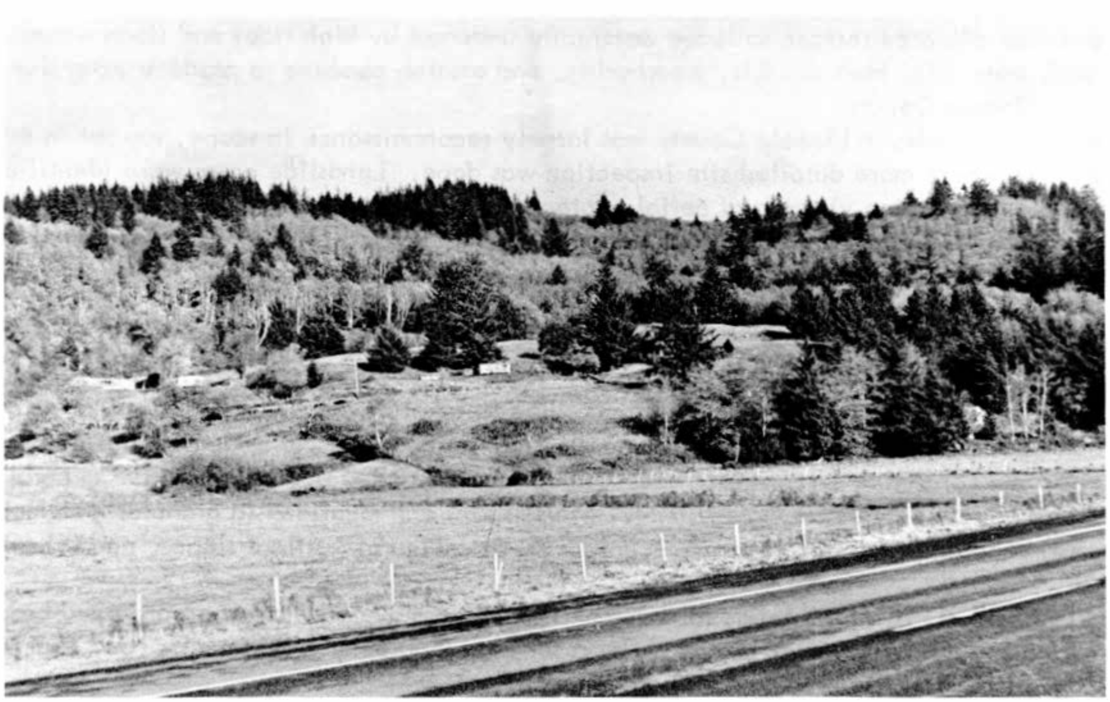


Photo 28. Topography characteristic of an old landslide in Yamhill Formation north of Salmon River on west side of Highway 101.

Photo 29. Large boulder from Siletz River Volcanics loosened during winter rains of 1973 rolled onto Siletz River Road at Fun River.

Photo 30. Seaward-dipping Astoria Formation between Agate Beach and Beverly Beach State Pork causes extensive sliding of marine terrace sediments.

Bedding-plane slides: Bedding-plane slides occur where the bedding of rock units slopes toward a bluff, stream canyon, or man-made cut. Movement generally occurs along the water-saturated contact of the overlying material and the bedding plane when lateral support is removed by either erosion or excavation. Similar failures also occur on low-angle surfaces of slopes in residual soil or in the underlying weathered rock zone when shearing forces exceed shearing resistance.

In Lincoln County, bedding-plane failure occurs in coastal cliffs where siltstone and claystone beds of the Nestucca, Astoria, and Nye units dip toward the beach. Failure occurs at the water-saturated contact of marine-terrace deposits and the weathered bedrock unit. Inland from the coast, bedding-plane slides are characteristic of the Tyee Formation.

Sloughing of steep slopes: Sloughing of steep slopes is a slow but continuous process of slope retreat. It involves dune sand and marine terrace deposits in bluffs facing the ocean and soil or weathered rock along steep-sided stream canyons. Erosion is the primary cause of sloughing, but freezing and thawing of soils are contributing factors.

Soil creep: Soil creep is mass downslope movement of soils at an imperceptible rate. Typical soil creep is nearly continuous at a rate of about 1 foot in 10 years (Terzaghi, 1950). Although soil creep areas have not been differentiated in this study, they occur on hillsides in some localities. They can be an important factor in long-term slope stability, since they can render a structure totally useless.

Summary of landslides along the coast

Coastal landslides occur principally in the bluffs of the marine terraces and rarely in the volcanic headlands in Lincoln County. The general areas of coastal slides are described, but no attempt is made to analyze in detail any specific landslide. Further geologic and engineering studies will be required to determine the nature of slide areas, their potential for future movement (either naturally or as a result of proposed construction), possible damage to property or structures, and the method and effectiveness of slide correction. Coastal landslide areas from north to south are as follows:

Cascade Head landslide: North and Byrne (1965) indicate debris and slump landslides in volcanic rocks and associated sediments in six small embayments at Cascade Head. The largest landslide, according to North and Byrne, involves some 20 acres of pasture land that slumped into the sea in 1934.

Coastal terrace landslides: From Roads End to Lincoln Beach significant slump failures occur in the coastal terrace. The terrace is composed of elevated marine terrace deposits overlain in places by older stabilized dune sand. The deposits are soft to friable and are easily eroded. Some of the larger active slumps in the bluffs near Roads End just south of Cascade Head have caused damage to property. Sloughing is common in the steep and unstable slopes between Wecoma Beach and the mouth of Siletz Bay and on the south side of Siletz Bay to Fogarty Creek.

At Otter Crest, active slump failure occurs both north and south of the Devils Punch Bowl. From Otter Rock south to Yaquina Head, sloughing and slump failures are numerous along the bluff and occasionally threaten to undermine developed property. Bedrock strata of the Nye Mudstone and Astoria Formation underlie the terraces in this area and provide saturated surfaces along which sliding occurs. Large slump failures on both the north and south sides of Yaquina Head in the community of Agate Beach have damaged private property.

The Jumpoff Joe landslide at Newport is a classic example of a detached mass sliding on a seaward-dipping bedding plane. Both north and south of Jumpoff Joe, the heads of slides have moved landward several hundred feet and have cut off roads, damaged or destroyed houses, and disrupted the ground surface. The latest large movement, occurring in 1942 and 1943, involved a crescent-shaped section about 200 feet wide and 1,000 feet long (Allen and Lowry, 1943). More than 16 acres of land have been involved in the Jumpoff Joe slide area (North and Byrne, 1965).

South of Yaquina Bay, between Henderson Creek and Grant Creek, a large slump mass described by North and Byrne (1965) is 300 yards long and 200 yards wide. Present investigations indicate active slope movement onto the beach, but houses above the headscarp have not yet been affected by headward development

Photo 31. Landslides in sea cliffs at Roods End caused by undermining of weak soils by wove erosion. Remains of house foundation still visible at head of slide in sea cliff near center of photo.

Photo 32. Close-up of same area from beach showing slide that destroyed o house.

Photo 33. Eroding terrace in north Lincoln City occupied by motels and houses. Erosion will eventually undermine foundations unless protected.

Photo 34. High marine terraces in Lincoln County show effects of active bluff erosion.

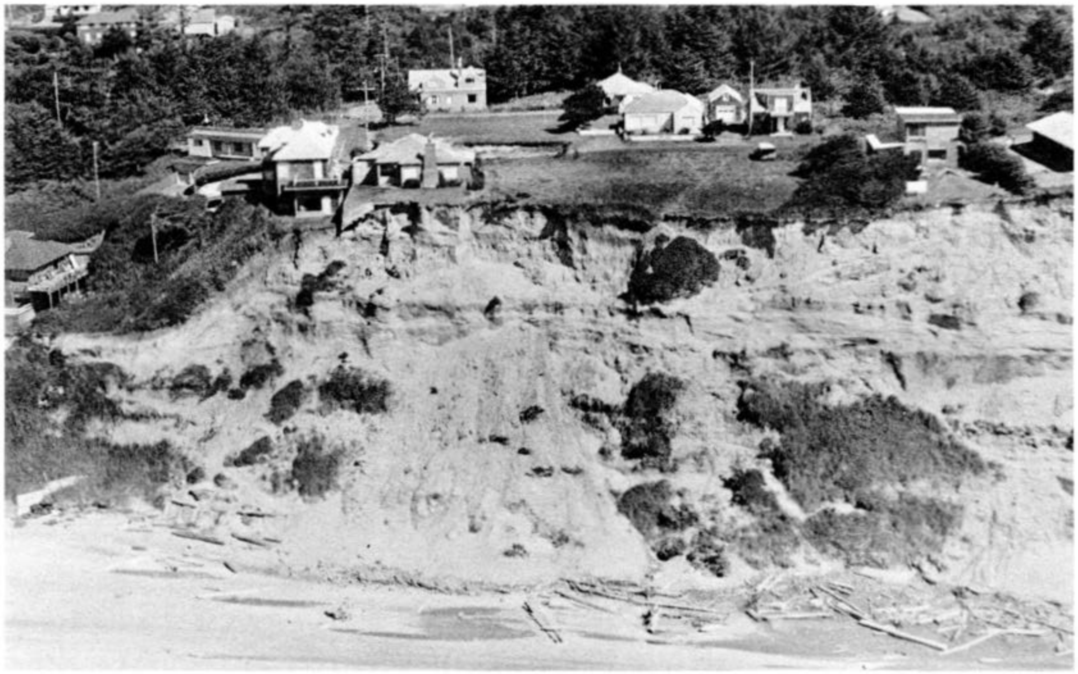


Photo 35. Houses built on old dune sand on marine terrace in Lincoln City. Wave erosion at base of cliffs removes support for upper part. Note patio foundation exposed by erosion.

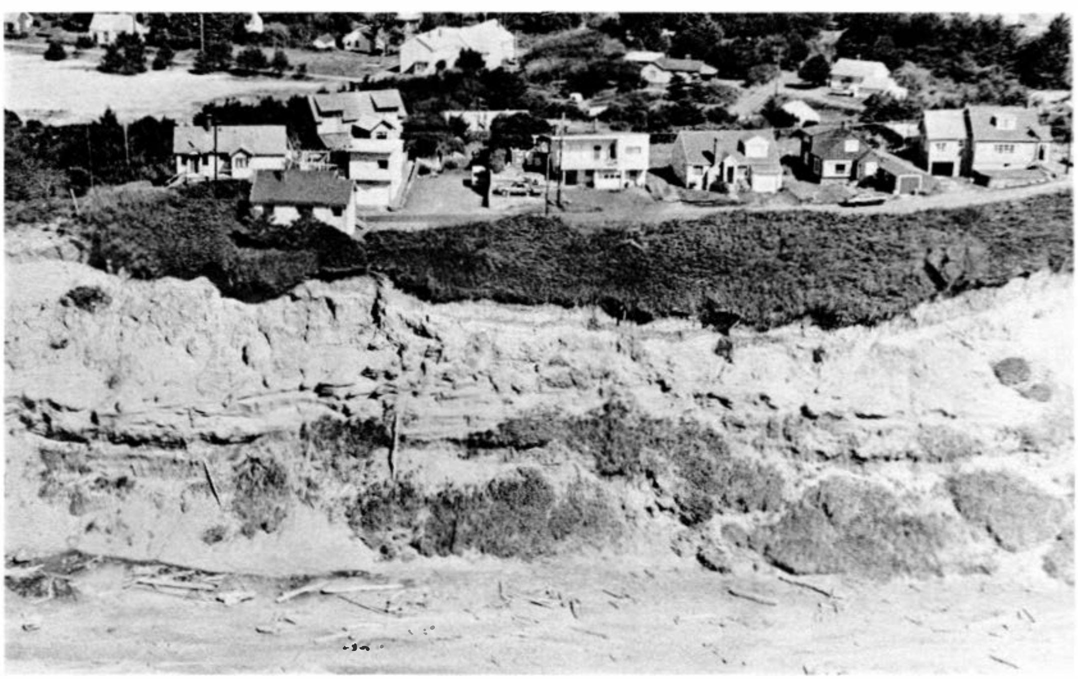


Photo 36. Overhanging mat of soil and vegetation ready to drop off characterizes the continual sea-cliff retreat in Lincoln County.

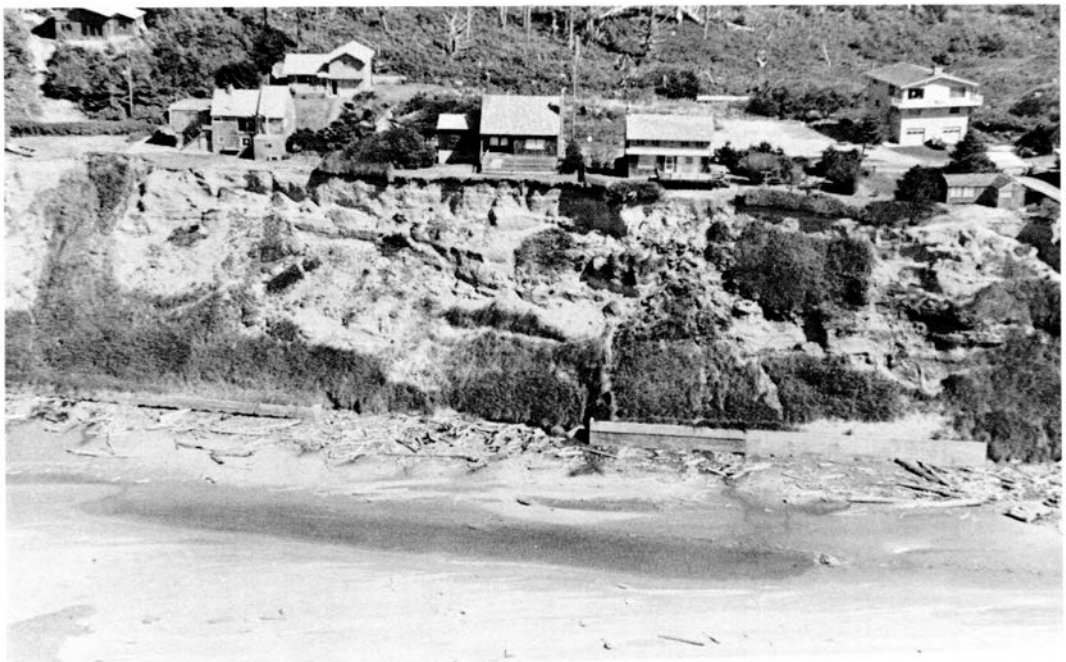


Photo 37. Short sections of concrete sea wall protect lower slopes of sea cliff from wave erosion, but are ineffective for upper, oversteepened portion.

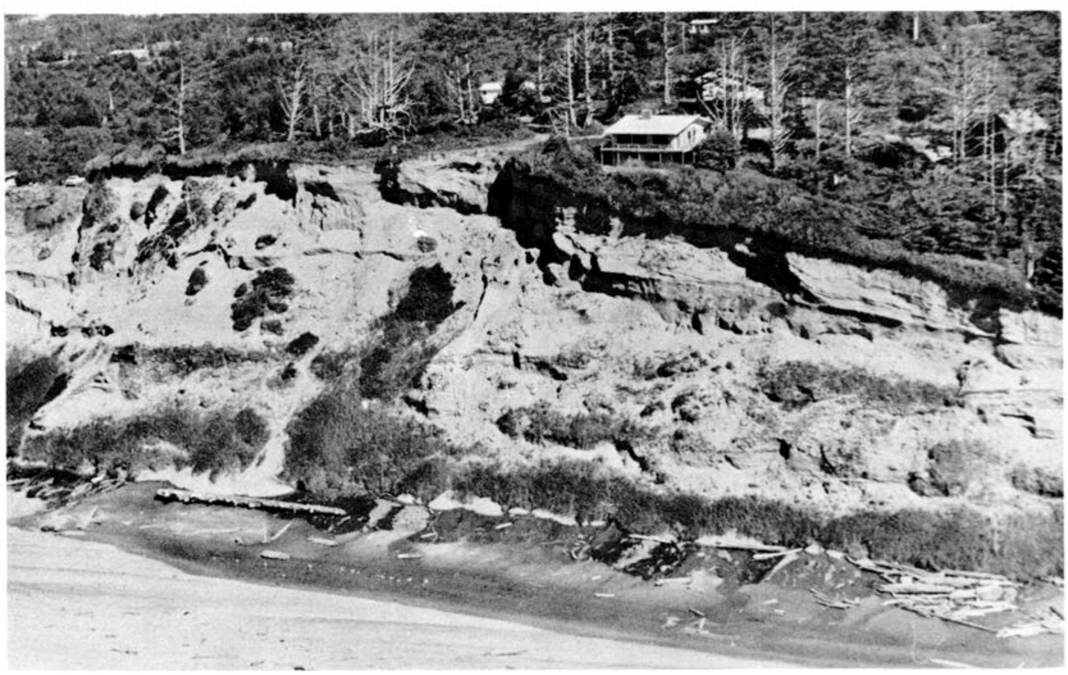


Photo 38. Wave erosion at base of high sea cliff is continually destroying the property along its margin.

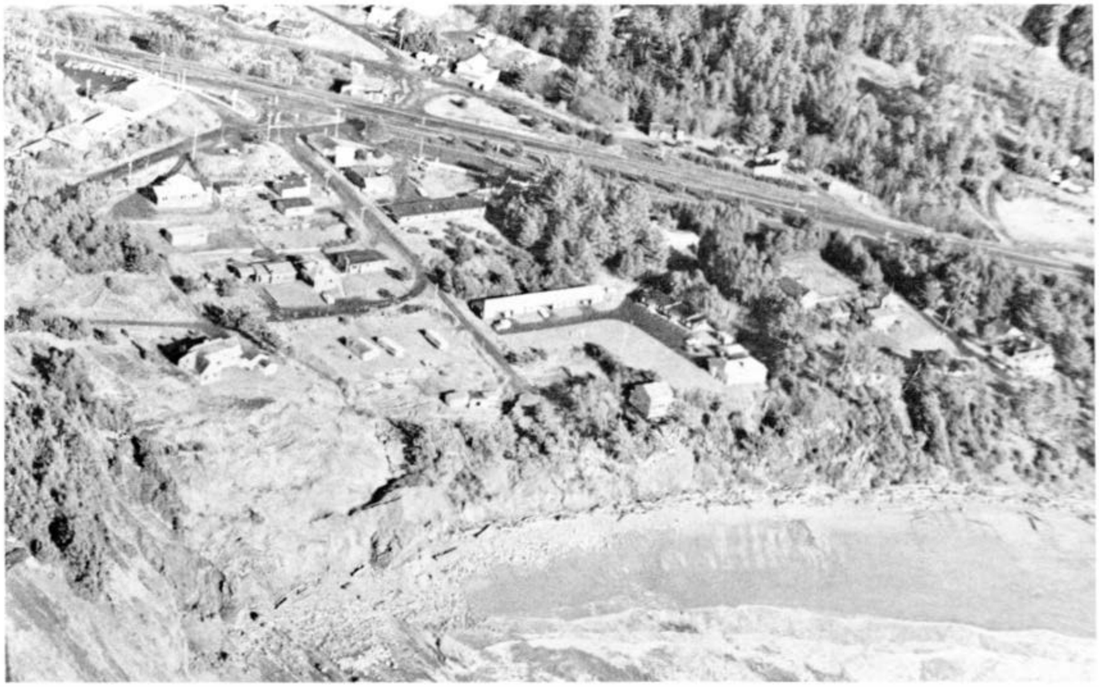


Photo 39. Active landslide at Agate Beach, lower left of photo, has severely damaged house and forced abandonment. Ground movement continues.

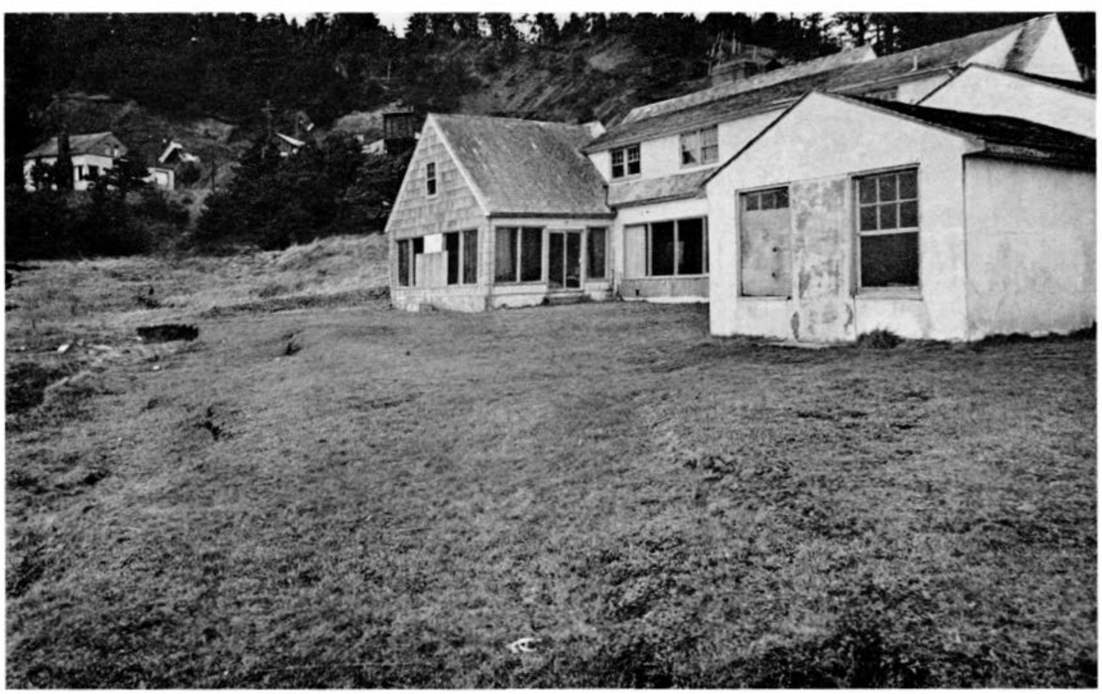


Photo 40. Close-up of house in above photo. Foundation destroyed by break in ground surface visible in right-center of photo. Breaks in ground at left of photo are headscarps of the active landslide.

Photo 41. Typical example of terrace retreat where thick mat of vegetation curls over cliff undermined by wave and wind erosion.

Photo 42. Building in center of photo severely damaged when caught in active landslide at Agate Beach. Ground disruption continues.

Photo 43. Active landslide at Spring Street just north of Jumpoff Joe in Newport creates a jumble of unstable ground involving many acres of land.

Photo 44. Close-up of part of the large landslide scarp exposed behind house on Spring Street. Extensive damage to house began in 1961 and slide mass continues to be unstable.

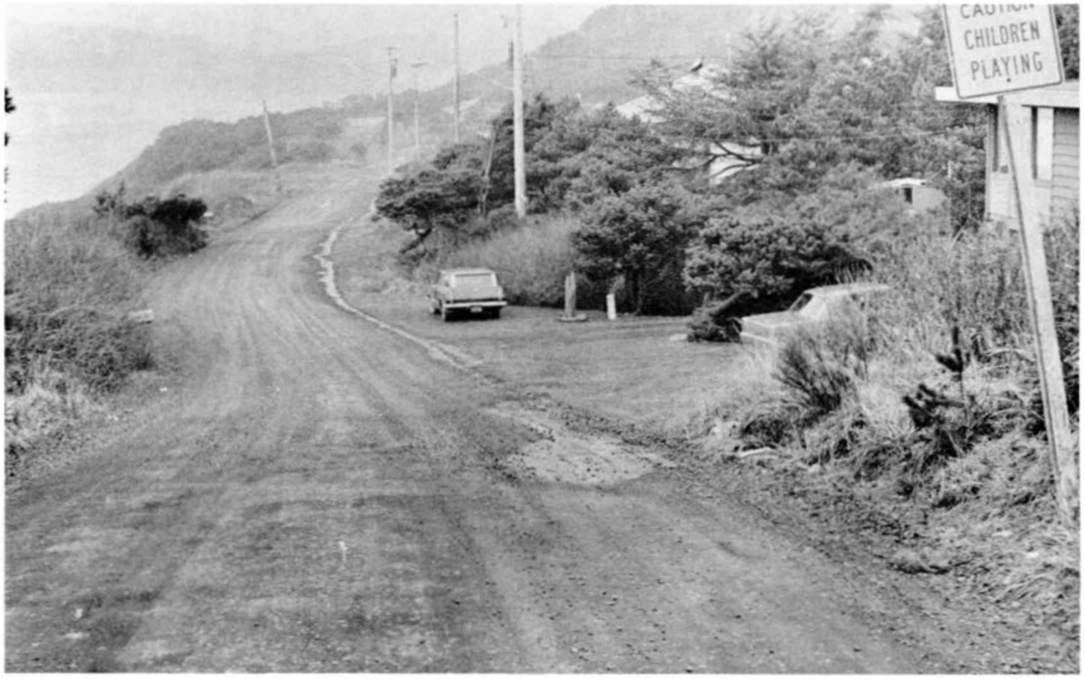


Photo 45. Spring Street dislocated by landslide movement. Water flowing down right side of street comes from spring, indicating the disturbed subsurface drainage of the landslide mass.

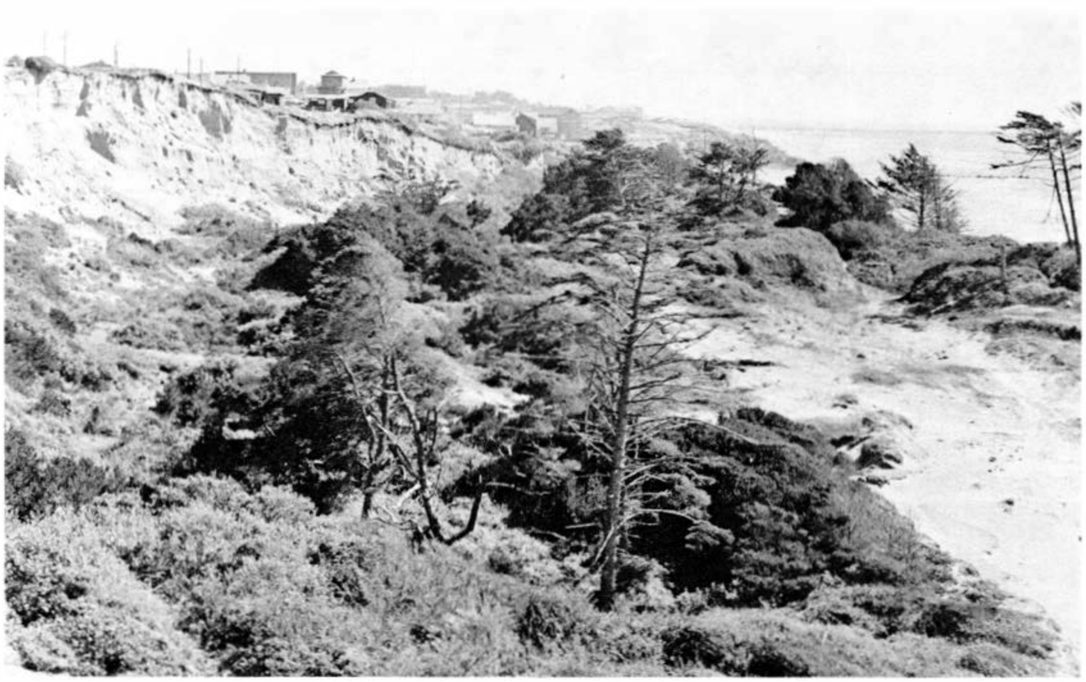


Photo 46. Jumpoff Joe landslide in Newport began in 1922, but major displacement occurred in 1942. A number of houses were situated on the down-dropped block of land.

Photo 47. Large landslide in marine terrace south of Yaquina Bay. Note semicircular headscarp along top of terrace with jumbled ground and tilted trees below.

Photo 48. Vertical escarpment near Yachats characteristic of active erosion of marine terrace.

of the slide. Numerous other types of slump failure and sloughing occur locally in the coastal terrace from Grant Creek to Alsea Bay.

South of Alsea Bay to Yachats the terrace is low; however, the soft terrace sands and overlying dunes can be attacked by ocean waves and actively eroded. Just north of Yachats, thin terrace deposits are underlain by basalt, which retards the rate of erosion considerably. At Yachats and to the south, where resistant basalt forms the slopes and headlands, erosion is minor. Terrace deposits overlying the basalt are thin and largely protected from wave erosion by the resistant basalt.

Summary of landslides in the upland areas

Large landslide slump failures are present in the upland areas of Lincoln County. They are most abundant in formations younger than the Tyee, particularly in the fine-grained units such as the Yamhill, Alsea, and Nestucca Formations and the Nye Mudstone. The predominantly sandstone strata of the Yaquina and Astoria Formations are less vulnerable to sliding in this area.

In the northern part of the County, large areas of ancient slump failure are present in the major drainage systems such as Schooner Creek, Drift Creek, Siletz River, the interior drainage in the hills between the Siletz and Yaquina Bays, and Devils Lake. From Yaquina Bay to Alsea Bay, landslides occur on the slopes of stream valleys, largely in the siltstone of Alsea. South of Alsea Bay, slump failures are locally present in the siltstone of Alsea and in weathered basalt of Yachats.

Most of the upland mountainous area of the County is underlain by relatively competent, resistant Tyee sandstone and basaltic and gabbroic intrusive rock. Locally on steep side slopes, residual soils, colluvium, and weathered rock will slide when saturated. Such landslides are generally tear-shaped masses which occur in bowl-like valleys tributary to major streams as well as on steep side slopes of the larger streams. Bedding-plane slides are common in the Tyee Formation, and range in size from small, or less than 10 acres, to massive hillside failure of more than 2 square miles. Large hillside slides in Tyee Formation are present south of Toledo in parts of secs. 29, 30, 31, T. 11 S., R. 10 W., on the north slope of Scott Mountain in parts of secs. 27, 28, 29, 32 and 33, T. 13 S., R. 9 W., and in the upper reaches of the Salmon River valley in the northwest part of the County.

It is emphasized here that many potentially unstable areas may exist in the upland areas of Lincoln County that are not shown on the map. For this reason, preliminary site investigations should be made to discover the possibility of slope problems prior to modifying slope or drainage for a construction project.

Catastrophic landslides

Catastrophic landslides are sudden or short-term movements of masses of material that create immediate danger to people or structures. For example, mudflows or slump-type landslides can move rapidly down slopes, block roads, crush buildings, and destroy power lines, bridges, and dams. A landslide moving into an already filled reservoir can cause overflow of the spillway and possible dam failure. Large blocks of land occupied by houses can move, tip, and break up. In 1951, a highway fill just east of Newport became liquid during heavy rains and formed a mudflow which destroyed an occupied house, fortunately without harm to the residents.

In some places, landslides of the past have moved into or across existing stream valleys. Probably the movement was slow and the stream was able to maintain its channel. However, there is always the possibility that some future landslide could temporarily dam a stream, impound the water, and then suddenly release it to the flood-plain areas downstream. Such potentially endangered areas include the following: the flood plain of the Salmon River from Rose Lodge east to the County border; on Big Creek in the NE$\frac{1}{4}$ of sec. 6, T. 8 S., R. 10 W., and the SW$\frac{1}{4}$, sec. 31, T. 9 S., R. 8 W., on the south side of the Alsea River flood plain in the N$\frac{1}{2}$ sec. 9 and south edge of sec. 4, T. 14 S., R. 9 W.; and in the flood plain of the Yachats River in the S$\frac{1}{2}$ of sec. 33, T. 14 S., R. 12 W.

There are a number of places along the coastal terrace of Lincoln County where houses have been destroyed by failure of the sea cliff; the slides at Jumpoff Joe are striking examples. In many places today, houses on the marine terrace situated within a few feet of the sea cliff could be involved in sudden slope failure. Because so much of Lincoln County's development is along the margin of the marine terrace where soft soil and weathered rock is being undermined by erosion at a rapid rate, catastrophic landslides are a serious potential hazard.

Photo 49. Embankment failure in recently constructed highway 1 mile east of Newport caused by impaired drainage of Nye Mudstone at base of fill.

Photo 50. House destroyed when newly constructed highway embankment become saturated and flowed rapidly down a small gully. (Photo by Glen Edenfield, Newport)

Soft Compressible Soils

Soils which settle unevenly under light to moderate foundation loads may be of several categories. The most critical of these is peat. Peat contains a large percentage of organic matter, mostly fibers, and is spongy and lightweight. It is usually water saturated and frequently under load will consolidate to less than 50 percent of its original volume. Peat occurs at the surface in swampy areas where the water table is rising slowly enough to allow the vegetation to remain and grow without being submerged. These conditions prevail along the margins of bays, estuaries, and mouths of streams in conjunction with a rising sea level or a subsiding seacoast. The build-up of a dune blocking the entry of a small stream to the sea will cause a rise in water level and promote the growth of peat. Shifting sands can cover the peat and form a buried horizon of compressible soils. Recent and old dune areas should be thoroughly investigated for buried peat soils if the site is to serve as a foundation for a structure.

Soft compressible soils can be several tens of feet thick in bays such as Siletz, Yaquina, and Alsea, and thinner in smaller bays such as Salmon River, Drift, Schooner, and Beaver Creeks. These bay soils are composed of clays mixed with sand, silt, and organic material and are subject to flowage under foundation loads such as road fills or foundation mats. In addition to excessive uneven settlement, the soil can fail by shearing under heavy embankment loads, causing an elevated ridge to form parallel to the toe of the embankment. Counterweights should be designed to prevent pressure build-up and shearing, and, if more rapid settlement is desired, sand drains can be installed to drain off water forced out during the consolidation of the soil.

Fine-grained alluvial soils deposited in the tidal areas of the major flood plains can contain layers of soft soils. Roads built on these areas will settle unevenly and produce an undulating grade. Subsurface investigations are needed to determine the extent of such material and the engineering design necessary to minimize the extent of the uneven settlement.

High Water Table

High water table in this section refers to near-surface ground water which can present a problem to land development and engineering construction. Near-surface ground water may be due to perched water, springs, hillside seepage, natural swampy areas, or soils that become saturated during and following periods of high rainfall.

Tidal flats and swamps in the lower flood-plain areas are characteristically wet year round. Higher terraces in the stream valleys may have a high water table, except during the late summer following a long, dry season. Much of the water in these areas has migrated downslope into the adjacent terraces from the hillside colluvial soils.

Marine terraces are usually composed of fine granular materials, somewhat permeable but with thin horizontal strata of impermeable soils which effectively restrict the downward percolation of water. Since the strata are essentially horizontal, any minor downwarping may produce a closed basin capable of holding water at or near the surface.

Sand dune areas are noted for containing significant amounts of ground water. Since fresh water is lighter than sea water, the water table remains above sea level and rises landward by hydraulic gradient. In interdune areas, the water table will be slightly below the ground surface or exposed in the form of lakes or ponds.

A high near-surface water table poses many engineering and development problems. Hydrostatic water pressure can force empty fuel storage tanks out of the ground and buckle and fracture swimming pools and basement floors. Highwater table causes septic tanks to overflow and the effluent to run out on the surface, possibly contaminating surface streams. The sides of deep excavations are subject to cave-in from weak saturated soils under hydrostatic pressure.

In areas where the water table has seasonal fluctuations, the maximum water elevations should be considered in the planning and design of engineering structures. The most common method to prevent pressure build-up is by installing gravel mats and tile prior to the placement of storage tanks or concrete slabs.

Stream Flooding

This portion of the report provides general information on the flood potential of streams in Lincoln County, including data on the major floods of past years. Because data on the December 1964 - January 1965 stream floods are by far the most complete and detailed, this flood period is the most fully discussed. The flood-prone areas are graphically shown on the geologic hazards maps accompanying the report.

The flood study, made during the winter of late 1972, is of a reconnaissance level because of the small scale of U. S. Geological Survey 15-minute quadrangle maps (1 inch to the mile) and large contour intervals (50 to 80 feet). Data on the boundaries of maximum recorded flooding, as well as other areas now believed susceptible to flooding, were compiled from flood maps by the U. S. Geological Survey (1969), U.S. Army Corps of Engineers (1971c), U.S.D.A. Soil Conservation Service (1972), and from data developed during this investigation, which included aerial photo interpretation, interviews with numerous residents, and extensive field checking along the streams. Additional information was obtained from the Lincoln County Planning Department and other local governmental agencies.

Causes of stream flooding

Floods are the result of various combinations of heavy rainfall, melting snow, steep topography, low bedrock permeability, landslides, extensive flood plains, log jams, and high ocean tides driven inland by the strong westerly winds of storms at sea. The partial blocking of stream mouths by sand, such as at Beaver Creek is another cause of flooding. Man-made structures (with the exception of dams and dikes) that slow or confine flood flows add to the flood potential. Forest fires and clear-cut logging practices cause increased runoff of precipitation into stream systems and augment flood conditions.

Occurrence and frequency of stream flooding

Stream flooding is an annual problem in Lincoln County and often occurs more than once a year. Flooding is most likely to occur during the November to February heavy precipitation period, with December and January generally experiencing the larger floods. Floods are rare in October or March.

Gage stations that measure elevation and rate of discharge of flood waters are located on the Siletz River (at river mile 42½) and on the Alsea River (at river mile 17). Of the ten largest floods listed for the Siletz River, four occurred in December and two in January, with other months receiving one or no floods, whereas the Alsea River recorded its largest floods three times in December and six in January (Table 16).

Flood hydrographs (Figure 17) show that coastal streams respond quickly to heavy rainfall and that runoff is rapid with peaks of short duration except during the larger floods. Precipitation ranges from 60 inches per year at Newport to 200 inches annually in the North Fork Siletz River area in the northeast corner of the County where elevations reach 3,128 feet at Stott Mountain.

Two of the larger floods of record on the Siletz and Alsea Rivers are designated by the U.S. Geological Survey as "8-year" and "28-year" floods (Table 17), based on records of past floods. Because flood occurrences are erratic, these designations are more a measure of magnitude of a possible flood than they are a measure of an expected time interval.

Control of stream flooding

Although levees or dikes have been built in the lower reaches of the Salmon, Siletz, Yaquina, and Alsea Rivers flood plains for local flood control, no flood-control storage reservoirs have been built to retard flood waters. It is unlikely that such protective structures will be considered for the Oregon coast streams, at least during the near future, because the cost-ratio factor is uneconomic for the expected benefits derived. This concept may change with the considerable increase in the number of homes, many of them year-round residences, that are appearing along the County's five major rivers and numerous streams.

For the present, major flood protection in the County must be in the form of flood-plain management having strictly enforced, adequate flood-plain zoning and building regulations.

Extent of stream flooding

Flooding is most extensive in the tidewater areas of the streams. Whenever westerly storm winds and high tides coincide with heavy runoff, upstream discharge of flood water is impeded and damage is particularly widespread and severe. Damage is compounded by the concentration of many homes and commercial structures on the flat low-lying flood plains and along estuaries, for the most part within the tidewater zone in Lincoln County.

An indication of the extent of tidewater area subject to possible flooding is the following listing (from north to south) of the river mileage representing the respective heads of tidewater:

a. Salmon River	5 miles	d. Elk Creek	3 miles
b. Siletz River	$22\frac{1}{2}$ miles	e. Alsea River	12 miles
c. Yaquina River	19 miles	f. Yachats River	$1\frac{1}{2}$ miles

The gentle topographic gradient through which much of the Siletz River flows, from above Logsden to the ocean, has caused the river to build long reaches of flood plain. For this reason, the Siletz River floods more acreage above tidewater than any other Lincoln County stream.

Flood of 1921

The largest recorded flood in Lincoln County occurred on the Siletz River on November 20, 1921 (Table 16). The flood had a peak discharge of approximately 54,600 cubic feet per second (cfs) at river mile 10, as determined by the U. S. Army Corps of Engineers (D.H. Basgen, written communication Aug. 18, 1972).

Newspaper accounts report that unprecedented rainfall for several days caused the Siletz River to rise 32 feet above the low-water mark in three days. Severe floods were also reported on the Yaquina, Alsea, and Yachats Rivers and on various creeks. Telephone and telegraph lines were down, roads were blocked by slides and washed-out bridges. The entire county was isolated by the 1921 storm.

Perhaps the 1921 flood is best known for the controversy arising from the opening of the headgate in the millpond dam at Valsetz to prevent flooding there of the town and sawmill. The dam, made of logs, held fast. Down-stream residents claimed that opening the gate materially increased the flood waters on the Siletz River, and the issue was taken to court as Arthur C. Crawford vs. Cobb and Mitchell Lumber Co. The Oregon Supreme Court sustained the Circuit Court's decision and ruled in favor of the plaintiff. Twenty-seven claimants filed for damages totaling $118,517. Lincoln County's claim of $73,640 for six bridges and associated losses was the largest filed.

Floods of 1964-1965

Christmas week 1964 and the last week of January 1965 witnessed the most widespread and devastating flooding in the state's history. The two periods of general flooding were produced by an unusual combination of meteorological events that in coastal areas culminated in severe storms December 19-23 and January 21-31. Lincoln County was one of the many hard hit. State and Federal officials declared the entire state a major disaster area. No other catastrophe in Oregon has been as great.

Although coastal streams are rarely above flood stage for more than 2 days, the long duration of the storms caused many streams to exceed flood stage for 3 to 4 days. At the height of the flooding, many small coastal streams and tributary creeks, some too small to warrant map recognition, turned into rivers of mud, rocks, and log debris. A summary of the maximum flows and discharges for the 1964-1965 and prior floods in the County is shown in Table 17.

December 1964

Flood stages were exceeded on all coastal streams during the December 1964 flood, with maximum stages occurring on December 21 and 22. Record floods occurred on the Yaquina and Alsea Rivers, with the Siletz River registering its sixth largest flood of record. The crest flow of the Alsea River was gaged

Table 16. Ten largest floods of record, Siletz and Alsea Rivers, in order of magnitude*

SILETZ RIVER near Mack Landing (at river mile 10)				ALSEA RIVER near Tidewater, Oregon (at river mile 12)		
Date of Crest	Elevation Ft.,M.S.L. 1/	Discharge C. F. S. 2/	Order of Magnitude	Date of Crest	Elevation Ft., M.S.L.	Discharge C. F. S.
Nov. 20, 1921	28.1	54,600	1	Dec. 22, 1964	76.2	41,800
Mar. 31, 1931	26.2	45,600	2	Jan. 21, 1972	74.6	37,100
Jan. 28, 1965	25.6	43,100	3	Dec. 21, 1955	72.6	32,200
Nov. 25, 1927	25.1	41,100	4	Jan. 28, 1965	72.1	30,800
Jan. 20, 1972	24.9	40,900	5	Jan. 20, 1964	71.0	28,200
Dec. 22, 1964	24.7	39,900	6	Jan. 4, 1956	70.8	27,900
Feb. 17, 1949	24.4	38,800	7	Jan. 7, 1948	70.7	27,800
Dec. 6, 1933	24.2	38,400	8	Dec. 15, 1946	70.2	26,400
Dec. 15, 1946	24.0	37,500	9	Feb. 17, 1949	70.2	26,400
Dec. 27, 1937	23.5	36,100	10	Jan. 18, 1953	70.0	26,100

* U.S. Army Corps of Engineers, "Special flood plain information," 1972.
1/ Elevations are from discharge curve.
2/ Discharges for river mile 10 were estimated from the gaging station at river mile 42½ near Siletz.

Table 17. Summary of maximum flows and discharges for 1964-1965 and prior floods for six streams in Lincoln County*

		Maximum Known Prior Flood				Maximum Dec. '64 and Jan. '65			
								Discharge	
Stream and Place of Determination	Drainage Area (Sq. mi)	Period of Record	Date	Gage Height (feet)	Discharge (cfs)	Date	Gage Height (feet)	(cfs)	Recurrence Interval (years)
Slick Rock Cr. near Rose Lodge	8.33					1/27/65		795	
Drift Creek near Taft	38					1/27/65		4,530	
Siletz River at Siletz	202	1905-12 1924-64 1921	 2/17/49 11/20/21	 25.17 31.60 1/	 37,000 40,800	 12/22/64 1/28/65	 25.74 27.32	 29,800 32,200	 8
Big Creek near Newport	2.66					1/28/65		203	
Alsea River near Tidewater	334	1939-64	11/24/60 2/ 3/90	24.02 29.50 2/	32,800	12/22/64 1/28/65	27.44 23.26	41,800 30,800	28
Yachats River near Yachats	39					1/28/65		5,430	

* U.S.G.S. W.S.P. 1866-A and B, 1971 and 1970.
1/ Different datum site then used.
2/ Based on floodmark (Feb.3, 1890) shown by long-time resident.

Photo 51. Flood waters in December 1972 cover Coyote Rock Trailer Park on Siletz River.

Photo 52. Flood waters reach edge of Siletz River Road about half a mile east of Highway 101.

at 41,800 cubic feet per second (cfs) on December 22 at 6:30 p.m., the highest in 36 years of record, and that of the Siletz River at 39,900 cfs, also on December 22, at 1:30 p.m. (Table 16). Flood hydrographs of the Siletz and Alsea Rivers for the December 1964 flood are shown in Figure 17. Discharges in the small coastal basins generally were not unusually high during the December flood.

Floodwaters inundated low-lying pasture lands and farms, forced closure of schools, curtailed or temporarily terminated many business activities, closed all major roads, downed communication lines, and isolated Lincoln County. Millions of tons of logs and other debris were swept out of the rivers to wash ashore on the beaches.

Salmon River to Siletz River: In the northern part of the County, the Salmon River and its tributaries closed travel in the Otis Junction area and along State Highway 18. Schooner Creek flooded the trailer court and school area of the Taft portion of Lincoln City, as well as the houses on the flood plain along Schooner Creek road. Drift Creek flooded extensively. The Siletz River flooded several homes at Siletz and washed several away near Kernville.

Yaquina River: High water on the Yaquina River washed away a loading dock and, augmented by the record 10-foot tides, nearly overtopped the docks along the Newport waterfront. Basements were flooded in low-lying areas. The oysters in a number of commercial beds in upper Yaquina Bay and lower Yaquina River were killed by siltation. Upstream at Toledo several lumber mills were flooded, and the municipal water supply from the Siletz River and Mill Creek was cut off. During this critical period the local radio station, KTDO, went off the air because of high water. The community of Elk City was flooded.

Alsea River: The Alsea River flooded or destroyed 80 to 90 houses and cabins from Tidewater to Waldport; 25 to 30 houseboats were lost. Resort communities situated on the flood plain were flooded; Little Albany, at river mile $7\frac{1}{2}$, was the most severely damaged. Serious sewage problems developed, and there was a shortage of potable water. At the mouth of the river, the Waldport waterfront was damaged by the high water.

January 1965

Precipitation in Lincoln County during the January 1965 storm was considerably more prolonged and greater than that during the December 1964 storm. Newport recorded 8.2 inches of rain during the December 19-23 storm, and 15.0 inches during the January 21-31 storm. Many coastal streams continued to be high into early February. This is illustrated by the discharge hydrograph of the Alsea River for the period December 16, 1964 through February 15, 1965 (Figure 18). The Siletz River registered its third largest flood of record, cresting at 43,100 cfs on January 28, whereas on the same date the Alsea River registered its fourth largest flood of record by cresting at 30,800 cfs (Table 16).

Salmon River to Drift Creek: At Otis, rainfall registered 7.44 inches on January 28 to worsen the already flooding Salmon River and its tributaries. Some of the communities making up Lincoln City faced critical water shortages due to flooded pumping stations and broken mains. To the south, Depoe Bay experienced similar difficulties. At Cutler City, Drift Creek was higher than during the December flood.

Siletz River: During the January 1965 flood, the Siletz River was over its banks for 3 days. The river rose at an average rate of 0.7 foot per hour, with a maximum rate of 1 foot per hour, for a 24-hour period, and then crested on January 28, according to the U.S. Army Corps of Engineers. Rainfall at Siletz was 5.37 inches on January 27, 5.25 inches on January 28, and then diminished to 1.25 inches on January 29.

Residents at Logsden stated that the January flood was much higher than the December flood. The Corps of Engineers estimated that the January flood was about 2 feet lower than the record flood of November 1921.

The Corps, in a release titled "Special Flood Plain Information, Siletz River," states:

"During major floods, main channel velocities would range from 3 to more than 6 feet per second. Velocities over the flood plain would vary widely, depending on location, topography, and

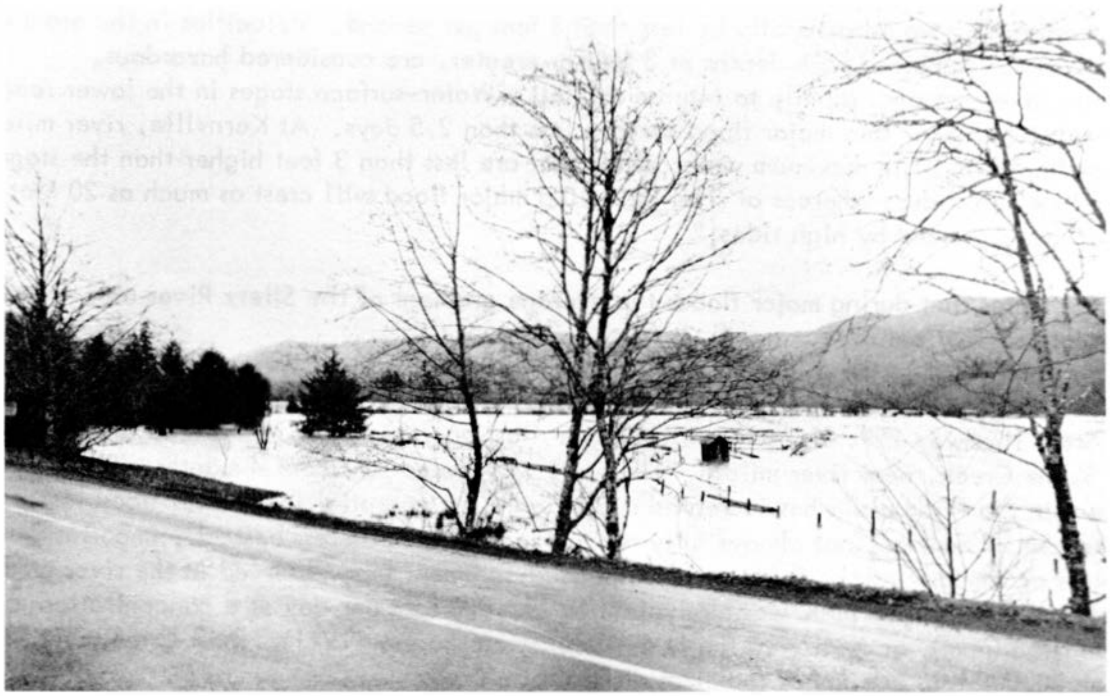


Photo 53. Flood plain of Siletz River covered by water during December 1972 flood.

Photo 54. Landfill on flood plain of Siletz River nearly topped by December 1972 flood.

vegetation, but would generally be less than 3 feet per second. Velocities in the order of 3 feet per second, combined with depths of 3 feet or greater, are considered hazardous.
"Siletz River responds rapidly to intense rainfall. Water-surface stages in the lower reach can rise from low water to a major flood crest in less than 2.5 days. At Kernville, river mile 0.5, major floods result in maximum water levels that are less than 3 feet higher than the stage produced by high tides, whereas at river mile 10 a major flood will crest as much as 20 feet above the stages produced by high tides."

The Corps states that during major floods the average gradient of the Siletz River along the lower 10 miles is about 1.7 feet per mile.

The high flood flows in the Siletz River in January 1965 swept away homes, barns, trailer houses, docks, and boats. A logjam formed against the bridge at Kernville, and damage to roads and highways was extensive. State Highway 229, along the Siletz River, lost approximately half a mile of roadway and its bridge at Skunk Creek, near river mile 6. The route was closed for about 4 months. Since 1965, new development in the flood plain has increased appreciably the potential for greater flood losses.

Another form of damage, not always fully recognized but nonetheless basically important, was the sediment loss accompanying the flood. The suspended-sediment load observed in the river at the Siletz gage 5 hours after the flood peak was equivalent to 102,000 tons per day at a concentration of 1,260 parts per million (ppm), according to the U.S. Geological Survey (1971). Drift Creek near Taft carried a very high 30,000 tons per day of sediment at maximum flow.

Depoe Bay: To the south at Depoe Bay, North Depoe Bay Creek washed out Collins Road and stranded a dozen families in the area.

Yaquina River: At Newport, dockside loading areas in Yaquina Bay were so silted by the January 1965 flood that dredging was required to clear the channels. High tides of 8.3 feet on January 29, driven higher by storm winds, continued the critical flooding along the coast.

At Toledo, 9 inches of rain fell in a 42-hour period. Water flooded the Arcadia district in the northwest part of town, causing the evacuation of some dwellings and businesses. The city was again without a municipal water supply because of a flooded pumping station and broken mains. Mill Creek, a municipal water-supply source for Toledo, had a peak discharge of 609 cfs on January 27.

At Elk City, flood water isolated the community and was reported 18 inches above the floor of the grocery store which stands approximately $3\frac{1}{2}$ feet above street level. A Coast Guard boat was used in evacuation work in the Elk City area. The three roads out of Harlan were closed by flood waters and the sawmill community isolated. Flood waters at Eddyville isolated the community and flooded several homes.

Alsea River: The late January storm of 1965 caused extreme flood flows in the lower Alsea River and on many small coastal streams. Numerous families were evacuated as State Highway 20 was closed. The discharge hydrograph for the Alsea River near the community of Tidewater for the period December 16 - February 15 is shown in Figure 18. Sediment transport was particularly heavy in the Alsea River basin as shown by comprehensive studies made of three small streams in the headwater areas of Drift Creek, tributary to the Alsea. During the flood period January 27-29 the combined sediment load of Deer Creek, Flynn Creek, and Needle Branch totaled 1,642 tons from a combined drainage area of 2.22 square miles, more than 90 percent of the total suspended load for the entire prior 6-year period. During the flood period the maximum daily sediment concentration for the three streams totaled 4,137 parts per million. Graphs illustrating the suspended-sediment concentration, and the load and stream discharge in Deer Creek for the periods December 20-30 and January 25 - February 4, are shown in Figure 19.

Yachats River: Similar transport observations near the January 1965 flood peak in the Yachats River near Yachats indicated a suspended-sediment load of 21,200 tons per day at a concentration of 1,450 parts per million. The other coastal streams also carried large quantities of sediment for short periods during the flood peaks. A summary of the maximum suspended-sediment concentrations and loads for various streams in the County during the 1964-1965 floods is shown in Table 18.

Photo 55. Houses built on flood plain of Siletz River can expect flood problems several times yearly. Photo taken during December 1972 flood.

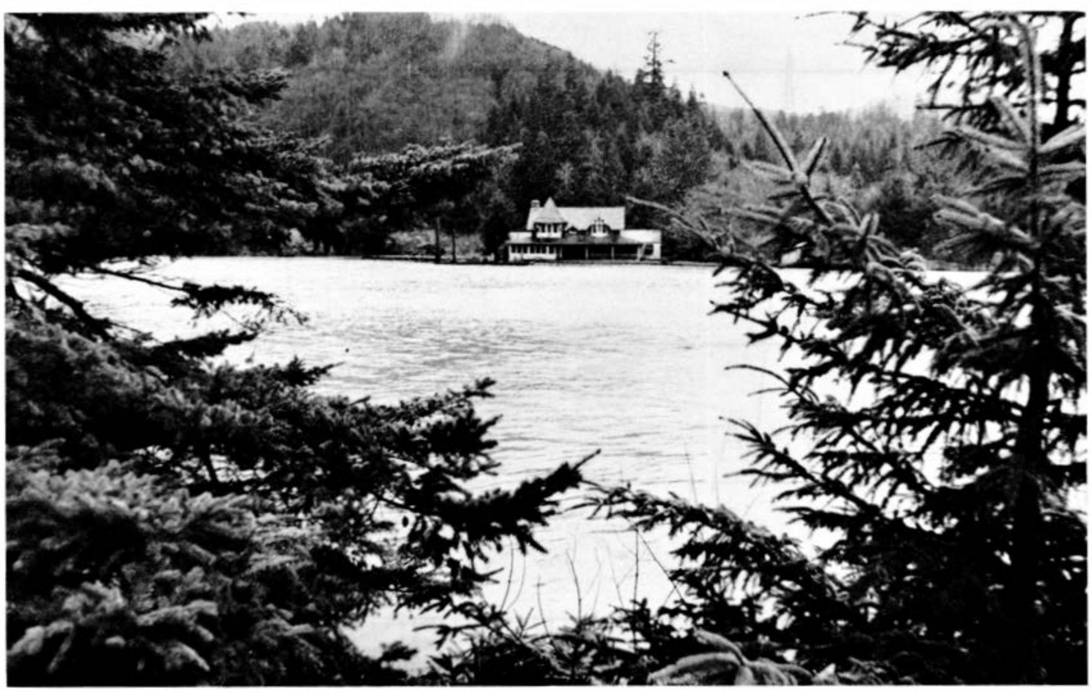


Photo 56. Flood waters of December 1972 rose to level of "Movie House" porch on Siletz River.

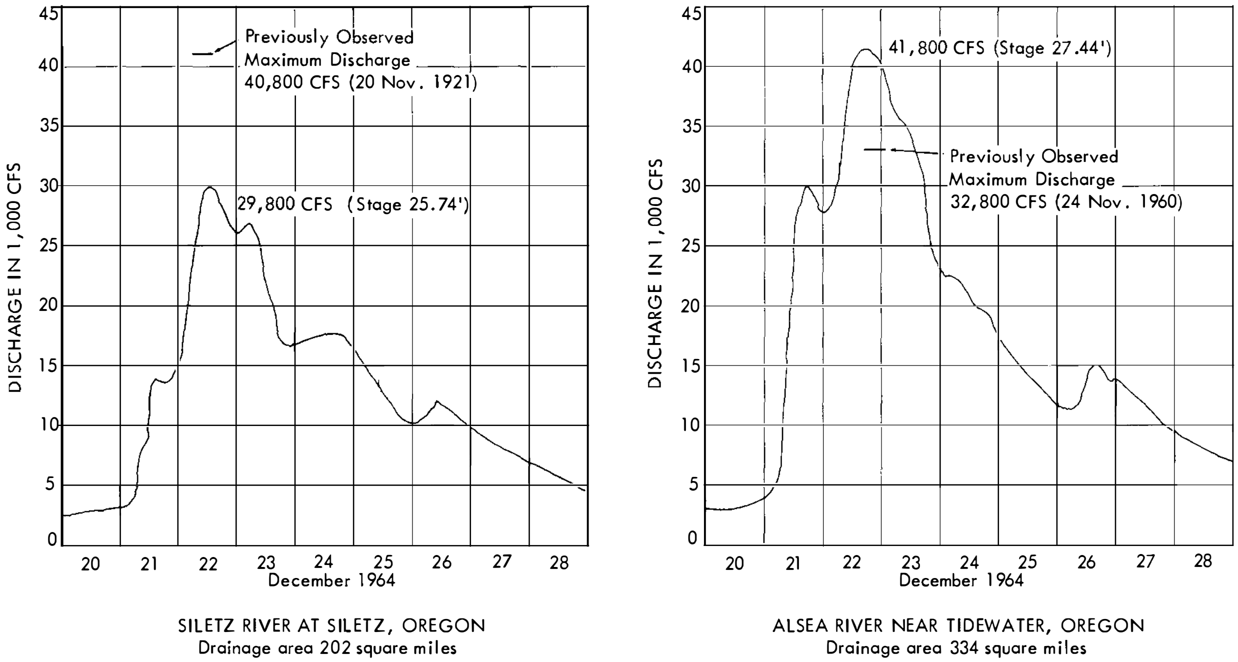


Figure 17. Flood hydrographs, Siletz and Alsea Rivers for December 1964.

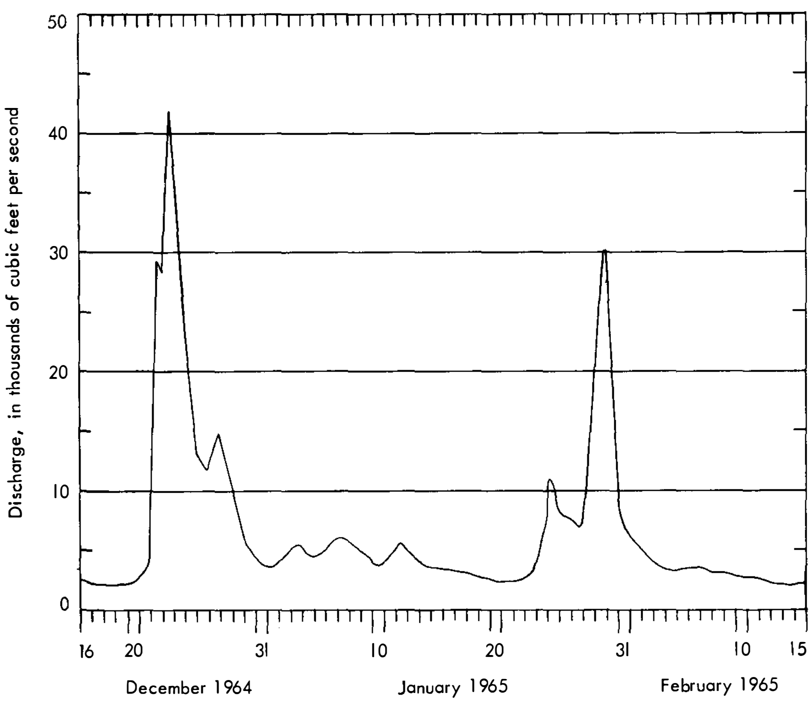


Figure 18. Discharge hydrograph for Alsea River, Dec. 16, 1964 - Feb. 15, 1965.

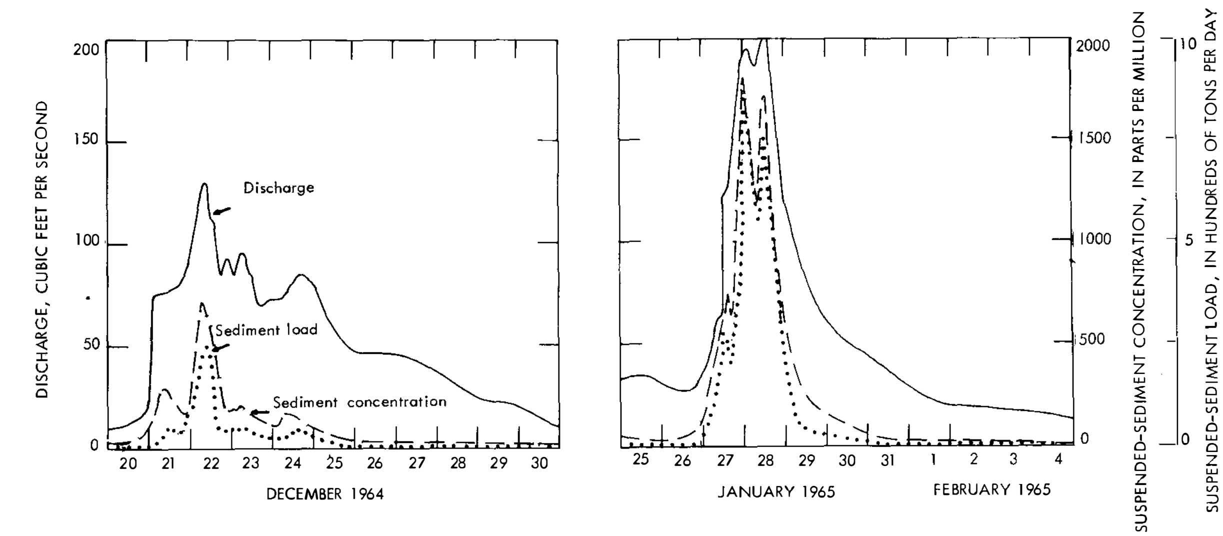


Figure 19. Suspended sediment concentration and load and stream discharge in Deer Creek, Dec. 20-30, 1964 and Jan. 25 - Feb. 4, 1965.

Flood damage, 1964-1965

Few areas in Lincoln County were left unscathed by the December 1964-January 1965 floods. Raging streams damaged homes, farm buildings, recreation property, docks, moorages, boats, summer cottages, industrial facilities, municipal water systems, public buildings, roads, and bridges; eroded banks and fields; silted channels and oyster beds; drowned wildlife and stock; and swept away valuable logs. Considerable damage to pastureland was caused by the deposition of tansy ragwort and other noxious weeds.

The giant logs stranded on the mud flats of Siletz Bay, particularly in the area west of Kernville known as Snag Alley, graphically attest to the ravages of these and past floods.

The siltation of farmland, considered for its general, long-range effect, was believed to be more beneficial than detrimental by the County Extension Agent and the Soil Conservation Service District Conservationist. Although a farmer may be temporarily out of production because of siltation, the build-up of his land is beneficial.

The forest products industry in Lincoln County was particulary hard hit by the floods. This is in part shown in Table 19 which presents damages incurred along the Siletz, Yaquina, and Alsea Rivers by the 1964-65 floods.

Flood of 1972

The month of January 1972 experienced two periods of major flooding, January 11-12 and 20-21. Storms dropped four inches of rain in 24 hours on much of the County on January 11, to be followed a week later by a 6-inch snowfall on January 18 and a 9-foot ocean tide blown higher by storm winds on January 21. The U. S. Army Corps of Engineers list a peak flow for the Siletz River of 40,900 cfs on January 20, and a peak flow for the Alsea River of 37,100 cfs on January 21 (Table 16). Of the largest floods on record for the Alsea, the 1972 flood ranks second; for the Siletz, the 1972 is the fifth in magnitude. No other rivers in Lincoln County have gaging stations.

Damages caused by the January 11-12 flood were estimated at $848,000 by the State Emergency Services Division and the Federal Office of Emergency Preparedness. Road and bridge restoration costs were estimated at $126,500 (Oregonian, 1/19/72). Major damage having been done by the first flood, it is believed that the January 20-21 flood did not add greatly to the monetary loss. President Nixon declared the County a national disaster area.

The following information about the two periods of flooding is summarized from the Newport News Times (1-13-72 and 1-27-72):

Table 18. Summary of maximum suspended-sediment concentrations and loads for 1964-1965 floods in Lincoln County *

Stream and Place of Determination	Drainage Area (sq. mi.)	Maximum Sediment Concentration ppm	Date	Maximum Daily Sediment Load tons	Percent Sediment by Size: Clay <.004mm	Silt .004-.062mm	Sand .062-1.00mm
Slick Rock Creek near Rose Lodge	8.33	138	1/27/65	296	21	33	46
Drift Creek near Taft	38	2,430	1/27/65	29,700	23	44	33
Siletz River at Siletz	202	1,260	1/28/65	102,000	31	46	23
Big Creek near Newport	2.66	752	1/28/65	412	--	--	--
Yachats River near Yachats	39	1,450	1/28/65	21,200	21	45	34

* U.S.G.S. W.S.P. 1866-A and B, 1971 and 1970.

Table 19. Flood damage in Lincoln County, December 1964 and January 1965 in thousands of dollars *

Stream Basin	Agri-cultural	Resi-dential	Commercial & Industrial	Trans-portation	Util-ities	Public Works	Channel Improvement	Emergency Relief	Total
Siletz River	82	78	49	166	0	14	0	2	391
Yaquina River	50	14	147	41	0	1	1	1	255
Alsea River	86	213	48	123	0	20	0	2	492
Grand total	218	305	244	330	0	35	1	5	1,138

* U.S.G.S. W.S.P. 1866-A, 1971

Siletz River: During the first period of flooding the Siletz River registered a high of 25.7 feet at the river gage 1 mile east of Siletz. The river fell to 18.2 feet at 8:00 a.m. the following day, showing the fast runoff characteristic of coastal streams. State Highway 229 was closed by high water about 10 miles above Kernville.

During the second flood period, the Siletz River crested at 24.6 feet, nearly a foot lower than the first flood, but flooding was worse below tidewater because of a 9-foot tide blown higher by storm winds.

Yaquina River: Elk City was isolated by both periods of flooding. High water in the Depot Slough area of Toledo flooded across old State Highway 20 and entered business buildings and dwellings in the Arcadia district. The Eddyville-Nashville road was closed by high water and slides.

During the second flood period, Toledo's water supplies from Mill Creek and Siletz River were so muddied that drinking water had to be supplied by Oregon National Guard tank trucks.

Alsea River: During the first period of flooding the Alsea River at the community of Tidewater (river mile $8\frac{1}{2}$) reportedly rose from $7\frac{1}{2}$ feet on the morning of January 11 to 15.8 feet the following morning and crested at about 20 feet that afternoon or evening.

During the second flood period on the Alsea, flooding was greater and extended from highway milepost 3 to head of tidewater (river mile 12). The river peaked at 25.5 feet at the Mike Bayer Campground (river mile 18) on January 21. All of the housing developments and some resorts and campgrounds on the flood plains of the Alsea River were flooded. A huge amount of debris floated out of the mouth of the Alsea River and drifted south, coming ashore on the beaches near Yachats.

Ocean Flooding

Causes of ocean flooding

Ocean flooding is unpredictable and may occur at any time throughout the year. Dr. June Pattullo, Oregon State University oceanographer, attributes this phenomenon to varying combinations of factors such as high tides, low barometric pressure, changes in ocean currents, winds, and storms. Sustained winds of gale force over a long reach of ocean can cause even a moderate 6- or 7-foot tide to build up high enough to be destructive when pushed on shore.

The commonest cause of flooding is wind that keeps the water piled up against the coast to produce storm waves and additive waves, as discussed below. Another cause of ocean flooding is the tsunami, a sea wave generated by seismic activity on the ocean floor.

Storm waves

Storm waves are large sea waves caused primarily by wind pushing the ocean onto low coasts not ordinarily subject to inundation. The waves have no relation to the tide brought about by gravitational forces except that the two may combine. The wind causing the waves is of gale (39-54 mph) to hurricane (exceeding 75 mph) force. Their size is proportional to the velocity, the duration, and the distance the wind blows across the sea.

On January 3, 1939, one of the greatest ocean floodings in history occurred when windswept high tides caused extensive damage over much of coastal Oregon.

On December 2 and 3, 1967, the entire Lincoln County coastline was battered by unusually destructive storm waves. The waves were generated by the accumulative effect of prolonged 50 mph southwesterly winds gusting to 65 mph, and tides exceeding 10 or 11 feet, the highest of the year.

Beaches everywhere were cluttered with logs and debris. The Newport area escaped severe damage, but logs were hurled onto the Nye Beach turnaround. High tides flowed over the new landfill at South Beach, but caused little damage. North of Newport, Beverly Beach State Park sustained $1,500 damage from logs floated into Spencer Creek. South of Newport, high waves did $4,700 damage to Ona Beach, Beachside, and Yachats State Parks. Large logs were washed through Ona Beach State Park, across U.S. Highway 101, and up Beaver Creek.

In the Waldport area logs and debris were washed over highways and seawalls, and much of Old Town Waldport was inundated with several feet of water. Water covered the road at the Lint Slough dike, and surged into several homes. "Old timers" said some areas were flooded that they had never seen flood.

Additive waves

Additive waves are potentially destructive sea waves that may occur under normally moderate conditions. Such waves are wind-formed by smaller waves building upon one another or by the coalescing of two or more waves moving at oblique angles from different storm areas. These built-up or multiple waves are the so-called "killer" or "freak" waves because they give no warning. The waves form regularly at sea even in mild winds, and there is always a statistical chance of their reaching shore, where great damage may result. Ships at sea have been sunk by such waves.

On February 19, 1973, a high tide of 8.7 feet was augmented by a rough sea, and "freak" waves struck several areas along the Oregon Coast at approximately the same time of day. The waves knocked one person unconscious on the beach at D River in Lincoln City, washed another off the rocks at Cape Kiwanda in Tillamook County, and broke over cars parked on the beach at Cannon Beach in Clatsop County. Fortunately there were no fatalities.

An eye-witness described the wave at Lincoln City as appearing no larger than the other large waves running that day, but that this particular wave was followed immediately by an unbreaking mound or swell of water. It was this additive force that gave the wave the impetus to run high onto the beach.

Tsunami waves (pronounced "soo-nóm-ee")

Volcanic or seismic activity in the Pacific Basin can generate shock waves that travel at great speeds (up to 600 miles per hour) and can cause catastrophic destruction in the coastal areas. These sea waves, or tsunamis, are imperceptible in the open sea, having wave lengths often in excess of 100 miles and amplitudes of only a foot or so. In coastal areas, however, the energy is concentrated by progressively shallower water, creating large waves, some as much as 100 feet in height, as the water continues to pile upon itself. Great damage along beaches and estuaries can result.

Tsunamis almost always involve more than one wave. Occasionally up to 9 or 10 waves over a period of several hours are involved. One of the middle waves is usually the largest. It is a matter of record that some tsunamis are immediately preceded by an anomalous rising or lowering of sea level.

The velocity of tsunami waves is controlled by the depth of the ocean, therefore, their arrival times at various points can be predicted once the generating area has been located from seismograph reports. No reliable system is yet available for predicting the height of tsunami waves or their effect on the various types of shorelines and estuaries. Oregon's wide continental shelf and generally high and rugged coastline with protruding headlands act to dissipate considerably the speed and impact of the waves. However, the location of most of the populace in low-lying areas and along estuaries makes the potential for tsunami damage high.

The largest recorded tsunami wave to hit the Oregon Coast occurred about midnight March 27, and early morning of March 28, 1964 (Schatz and others, 1964). This tsunami was generated about 6 hours earlier (5:36 p.m., Alaska Time) by a submarine earthquake in the North Pacific Ocean, 80 miles southeast of Anchorage. The quake (known as the Good Friday Earthquake of Alaska) caused waves to move the length of the Pacific Coast, doing catastrophic damage to some ports, particularly along the Alaskan Coast and at Crescent City, California.

Persons in the Newport area who witnessed the tsunami reported unusual churning of the ocean, followed by a huge wave that broke high and tossed logs like matchsticks. A second wave carried the logs far out to sea and exposed the ocean floor for an unusually long distance, then was followed by a wave of fairly normal size. Some of the reported effects of the tsunami wave in Lincoln County were logs and driftwood washed onto beaches, across highways in low areas, and into motel units. Some docks were washed out and a lumber barge torn from its moorings. An oyster grower in Yaquina Bay reported loss of oyster beds by wave scouring and siltation. Four tsunami waves were observed traversing Yaquina Bay, causing floating logs to change course abruptly. Several miles up the Yaquina River one witness described the water level as going down "as though a plug had been pulled," leaving the river a narrow stream until the next tsunami wave surge.

Although Lincoln County escaped the coastal onslaught with little damage in terms of monetary loss, tragically four children sleeping on the beach at Beverly Beach State Park were drowned.

Referring to the Good Friday tsunami, Dr. Peter Dehlinger, professor of geophysics at Oregon State University, stated: "Predicting the possibility of another wave such as this is impossible. The only thing we have to go on is past experience. It is known that this was the most severe wave to hit the Oregon Coast in recorded history. There is no reason to expect that such waves should become any more frequent. However, no one can say for sure it won't happen again."

The tide recorder at the Oregon State University Marine Science Center at Newport has recorded three tsunamis, all minor, since installation of the instrument in January 1967. One series of waves, lasting nearly two days, was generated 10 hours earlier by a strong earthquake off northern Japan. The waves were small and caused no serious damage. It was determined that these waves traveled about 670 feet per second, or 460 miles per hour, before slowing as they entered the shallow coastal waters.

A tsunami warning system is maintained by the National Ocean Survey at its observatories in Honolulu, Hawaii, Palmer, Alaska, and Newport, Washington. Alerts are transmitted from the Honolulu station to all participating nations. The primary receiving station for the west coast of the contiguous United States is located at the San Francisco International Airport which notifies the coastal states for general distribution. The chain of communication for Oregon proceeds as follows: State Department of Emergency Services or State Police headquarters in Salem, County Departments of Emergency Services, County Sheriff's Departments, local police and fire departments, and other local emergency personnel. Lincoln County's various police units are each responsible for patrolling a designated portion of the coastline.

The Environmental Science Services Administration of the U. S. Department of Commerce gives the following 10 safety rules for coastal residents regarding tsunamis:

1. All earthquakes do not cause tsunamis, but many do. When you hear that an earthquake has occurred, stand by for a tsunami emergency.

2. An earthquake in your area is a natural tsunami warning. Do not stay in low-lying coastal areas after a local earthquake.

3. A tsunami is not a single wave, but a series of waves. Stay out of danger areas until an "all clear" is issued by competent authority.

4. Approaching tsunamis are sometimes heralded by a noticeable rise or fall of coastal water. This is nature's tsunami warning and should be heeded.

5. A small tsunami at one beach can be a giant a few miles away. Don't let the modest size of one make you lose respect for all.

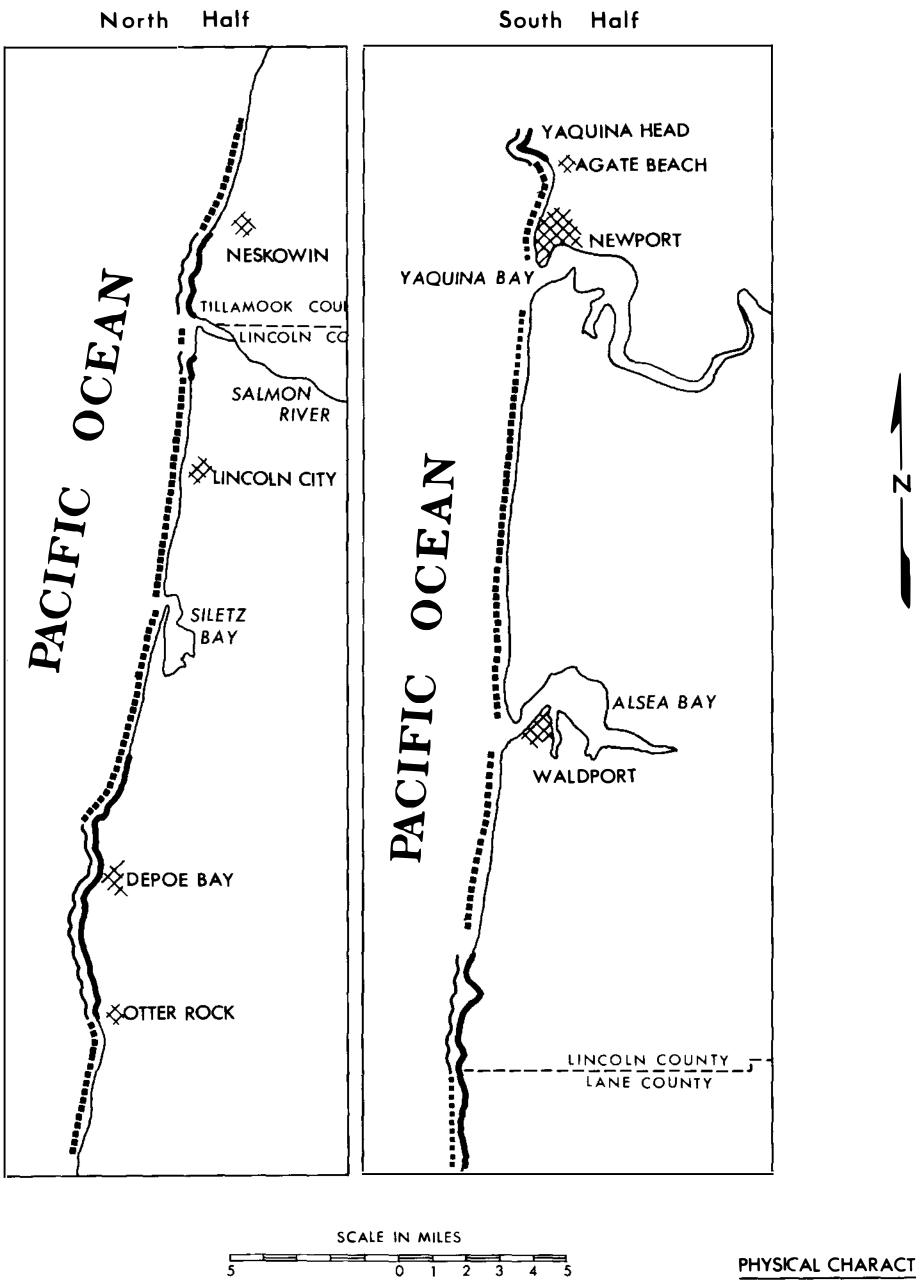
6. The National Tsunami Warning Center does not issue false alarms. When a warning is issued, a tsunami exists.

7. All tsunamis - like hurricanes - are potentially dangerous, even though they may not damage every coastline they strike.

8. Never go down to the beach to watch for a tsunami. When you can see the wave you are too close to escape it.

9. Sooner or later, tsunamis visit every coastline in the Pacific. Warnings apply to you if you live in any Pacific coastal area.

10. During a tsunami emergency, give your local emergency organizations your fullest cooperation.



NATIONAL SHORELINE STUDY

PHYSICAL CHARACTERISTICS AND HISTORICAL SHORE CHANGES

U.S. Army Engr. Division, North Pacific Aug. 1971
Redrafted by
DOGAMI Aug. 1973

PHYSICAL CHARACTERISTICS	(Landward)
SHORELINE WITH BEACH	No Symbol
SHORELINE WITHOUT BEACH	▬

HISTORICAL SHORE CHANGES	(Seaward)
CRITICAL EROSION	■■■■■■■
NON-CRITICAL EROSION	~~~
NO EROSION	No Symbol

Figure 20. Shoreline map of Lincoln County.

Transient Shorelines

The beaches, spits, headlands, and estuaries of coastal Lincoln County represent a natural balance between the interrelated processes of wave erosion, longshore drift, river transport of sediments, and landsliding. Beaches and spits are particularly sensitive to the migration of sand up and down the coast; marine terraces are sensitive, in turn, to the condition of the beaches protecting them from the sea. Headlands owe their presence to the relative hardness of the rocks of which they are composed, and estuaries record the world-wide rise in sea level of the last 20,000 years.

The features of the coastal strip are the result of a complex interplay of many processes with innumerable local variations. It is emphasized that the processes are continuing and that the coastal area, probably more than any other area, is subject to continuing change, be it natural or man-induced. Proper land-use management in these areas is needed to insure that future developments are intelligently keyed to the geologic conditions so as to minimize future losses.

Beach areas

Approximately 70 percent of the coastline of Lincoln County is made up of beaches. These include Lincoln Beach, Wecoma Beach, and Gleneden Beach in the Cape Foulweather quadrangle; the coastline between Otter Rock and Yaquina Head, and between Yaquina Head and Beaver Creek in the Yaquina quadrangle; and the strip between Seal Rocks and Yachats in the Waldport quadrangle (see Figure 20). Because beach areas span so much of Lincoln County coastline, an understanding of the processes which govern their formation and destruction is critically needed.

Beach areas represent a balance between erosion and deposition and constitute a natural protection of the inland areas from the ravages of the sea. Offshore bars trip the waves, shallow slopes dissipate their energy, and the flat back-beach areas normally above high tide accommodate most storm activity. The dunes, products of wind-blown beach sand, constitute a final protection against exceptionally high storm waves and tides.

Wind waves: Waves generated by the wind are instrumental in determining the profile and local configuration of beaches. In response to seasonal storm activity, the beaches undergo cyclic variation in their form. In general, steep intense winter waves erode the beach, cutting into dune areas, whereas the gentler summer waves bring in sand, restoring the beaches to their former shape. Larger, unrecognized cycles and non-cyclic phenomena (such as tsunamis, discussed under "Ocean Flooding") also are important factors in beach stability.

Longshore drift: Longshore drift is the term applied to the direction of movement of sand along the coast as a result of tidal and wave action. Little is known of the longshore drift of the central Oregon coast. It is generally concluded, however, that the gentle northerly currents of long duration of the summer months dominate the brisk southerly currents of short duration during the winter months to give a net drift towards the south. Wind and swell movements (Kulm and Byrne, 1966), patterns of sedimentation adjacent to jetties (U.S. Army Corps of Engineers, 1971 a, b; Schlicker and others, 1972), and the presence of the south-flowing Japanese Current off the coast are consistent with this interpretation.

The presence of offsetting currents does not necessarily diminish the problems introduced by longshore drift. In fact, the operation of two-current systems introduces a hazard to the beaches which is doubly difficult to control. A consideration of this factor is discussed under "Topography" below.

Topography: Inlets and headlands which interrupt beach areas are significant to beach stability because they influence the supply of sand delivered to beaches by longshore currents. Tidal currents flowing in and out of inlets, such as estuaries, carry drifting sand seaward and temporarily remove it from the beach system.

In the undisturbed state, the effect of removing sand at inlets is balanced by longshore drift, and a series of bars and shallows insures that enough sand passes the inlet to supply the beaches farther along the coast. Man, however, can interrupt this balance by dredging the channel or constructing jetties.

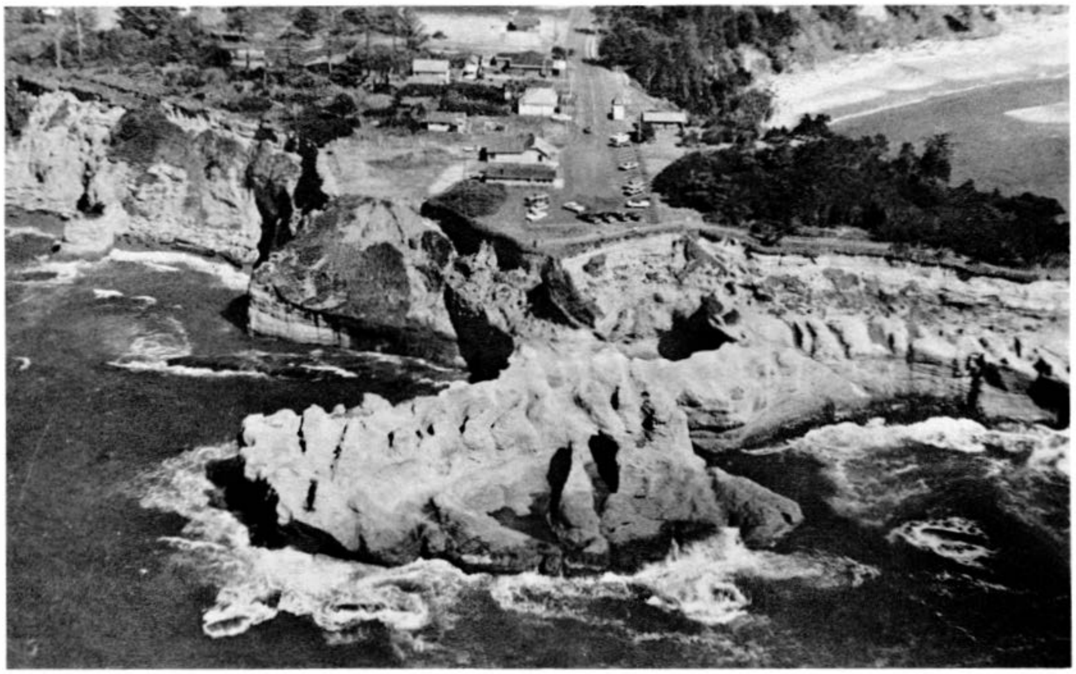


Photo 57. Devils Punch Bowl State Park at Otter Rock, a marine terrace on a sandstone headland. Wave erosion removes terrace sediments foster than the sandstone, continually reducing the margins of the park area.

Photo 58. Close-up of Devils Punch Bowl area. Erosion has removed former stairway access to the Punch Bowl on right. Remains of old walkway projects from cliff at left.

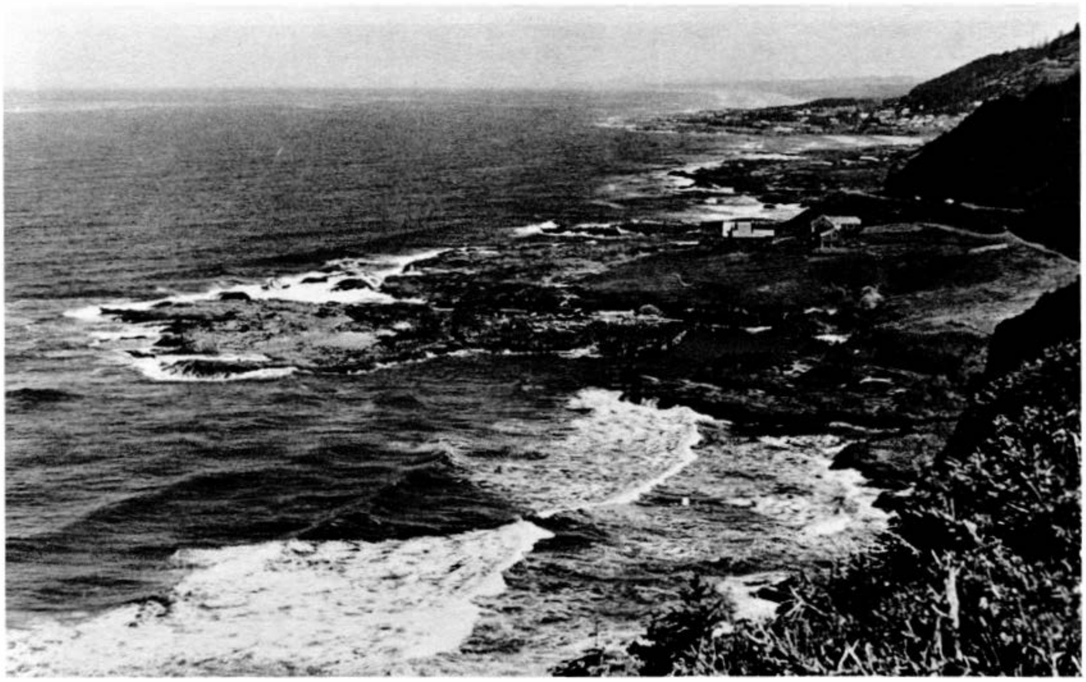


Photo 59. Wave-cut terraces on resistant basalt breccia at Cape Foulweather extend seaward. Basaltic rock is much slower to erode than sedimentary rock.

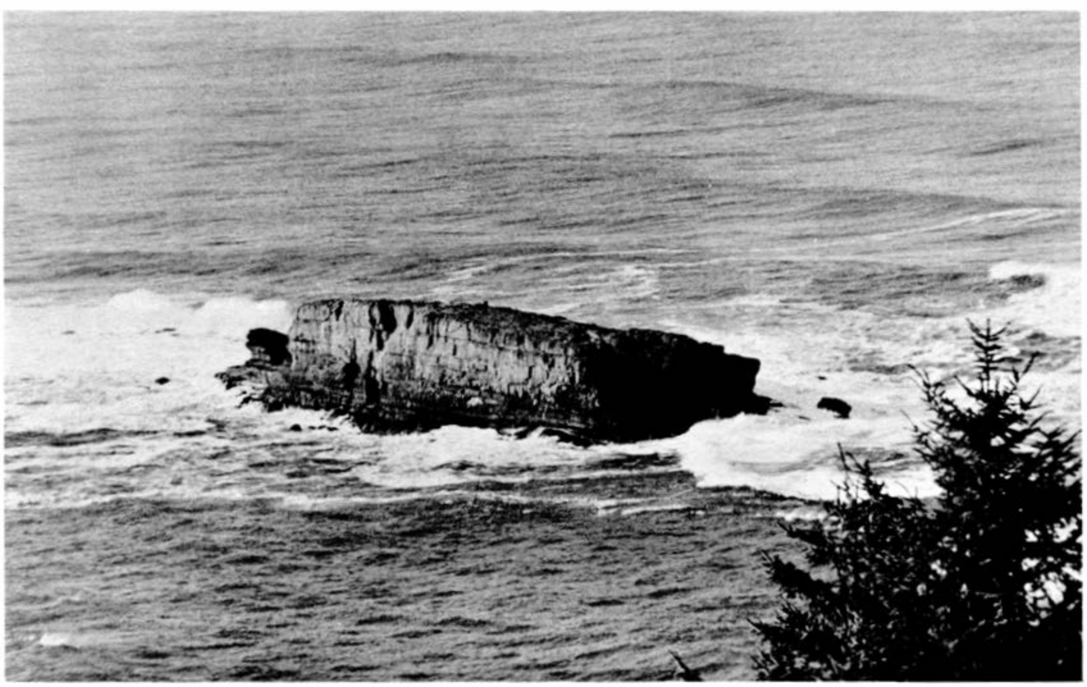


Photo 60. Basalt sea stack offshore from Cape Foulweather was once part of the headland. Erosion of less resistant rock between has left this isolated remnant.

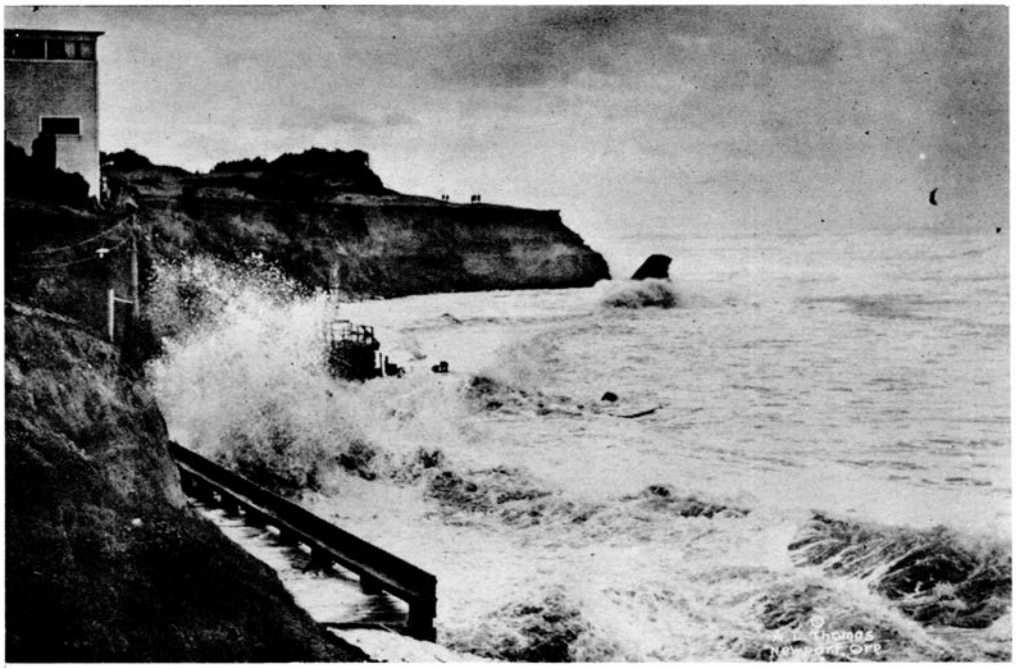


Photo 61. Nye Beach coastline about 1900. Photo taken from natatorium during storm at sea. (Courtesy of Lincoln County Historical Society)

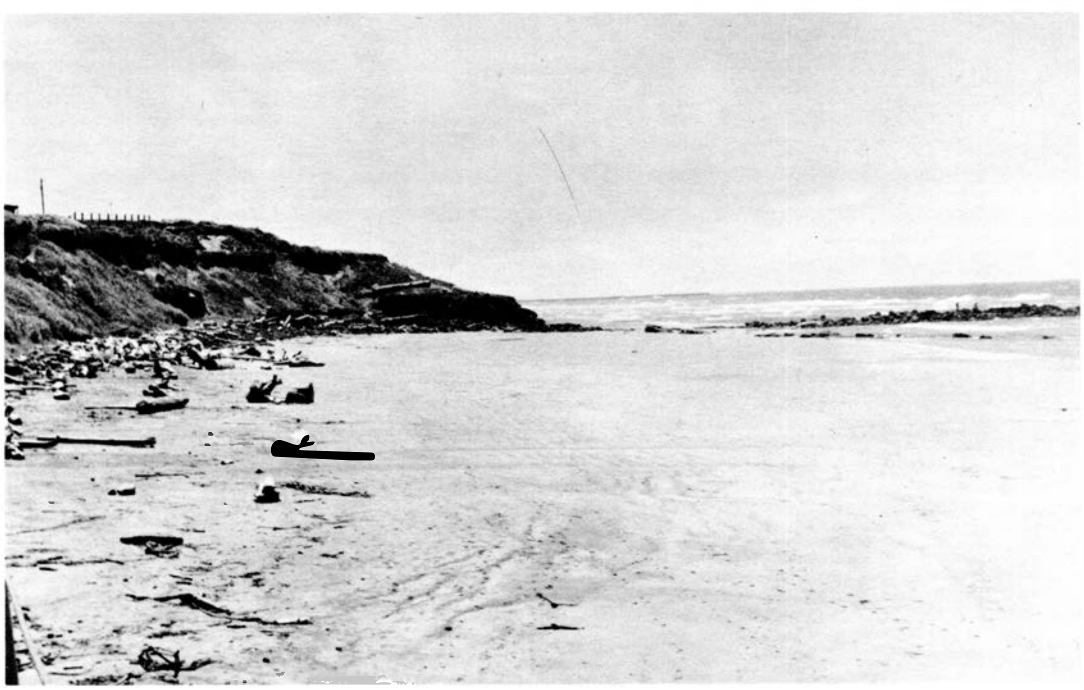


Photo 62. Photo taken from approximately same location in 1973 shows amount of recession of small headland and its terrace platform.

The result very commonly is the starving of beaches of sand and increased beach erosion. Bayocean at the mouth of Tillamook Bay is a case in point (Schlicker and others, 1972). Any proposed modifications of the shoreline should take into consideration the sand budget of adjacent beach areas. Large-scale removal of sand from the beaches should be discouraged in most instances.

Jetty construction or dredging operations will block sand migration both to the north and to the south and could conceivably contribute to beach instability in both areas. It is not uncommon elsewhere in coastal regions for beach sand to be transported by pipeline or barge from points of accumulation across dredged inlets to points of depletion on the other side. Modification of the coastal topography must proceed only after rigorous investigations of potential hazards are made and adequate provisions are made to preserve the flow of sand.

Sandspits and dunes

A sandspit is a point of land that projects from a beach and cliff area into an open body of water, usually between a bay and the ocean. Spits are a special class of beaches and are subject to the same processes, including longshore drift and wave and wind action. Most sand spits along the Oregon coast are topped by dunes, which become progressively lower and less stable toward the end of the spit.

Siletz Bay spit, projecting northward from the south shore of Siletz Bay and occupied by a part of Salishan, is the most notable sandspit in Lincoln County. Other spits include those at Yaquina and Alsea Bays.

The spit at Siletz Bay is undergoing critical sea erosion on its seaward side and is subject to a variety of other geologic hazards as well. Trough blowouts of its dunes are developing where the vegetative cover is insufficient. Most of the spit conceivably could be topped by high storm waves or tsunami waves. The scattered logs throughout much of the dune areas on the outer spit attest to the potential danger of storm waves.

Long-term residents of the area report that during the early 1900's the Siletz River passed through a channel at about the center of the spit. That channel subsequently became plugged with logs and sand, diverting the river northward. It is probable that the low spit has been breached at various places in the past.

During the high winter and spring tides of 1973, parts of the Siletz spit were attacked by the sea and in some places eroded back 75 feet or more. At least one house fell into the sea and the emergency placing of riprap was needed to preserve several others. The precise cause of the erosion has not been definitely identified, although the dominating factors probably included storm severity, the lateral migration of coastal landforms (a phenomenon discussed at length by Sonu, 1973), and natural variations in sand supplied by longshore currents and by the Siletz River.

A team of experts, including U. S. Army Corps of Engineers personnel, dispatched to the site at the request of Governor McCall concluded that at the present time parts of the spit are unsuitable for permanent construction. Properly engineered riprap and seawalls could conceivably stabilize the spit.

The dunes on the spit at the mouth of Yaquina Bay have undergone a relatively complex history and are presently stable in most areas. According to Cooper (1958), the deposits of sand south of the Bay fill the old channel of the Yaquina River and generally are stabilized by vegetation. The dune sand underlying parts of Newport was effectively cut off from its source of supply when the Yaquina River assumed its present course and it, too, is stable. As in all dune areas, preservation of the vegetative cover is recommended, especially in the dune fields south of Yaquina Bay. Excavation into stabilized dunes could expose loose sand to the wind and could initiate further dune activity.

At Alsea Bay, a blunt spit projects southward from the north bank into the estuary. With the exception of the foredune, all dunes on the spit were bulldozed flat for housing development. Preservation of the foredune and vegetation is essential to minimize wind erosion. Presently coastal erosion is critical on the seaward side. Wind erosion along the major dune axis is indicated by the centralized absence of vegetation and by the presence of half-buried trees on the landward side of the dune complex. Construction in the dune area could be hazardous. Leveling of dunes, especially foredunes, is contrary to presently accepted practices of dune management.

Because spits are subject to the same processes as beaches, they, too, must be regarded as transient features of a highly sensitive nature. Any major operations which interfere with the coastal sand budget could destroy parts or all of them. These include dredging of inlets and offshore bars, the construction of

Photo 63. Some of the houses built on the low dunes of Siletz spit. Photo taken in fall of 1972 before severe erosion of spit by winter storms.

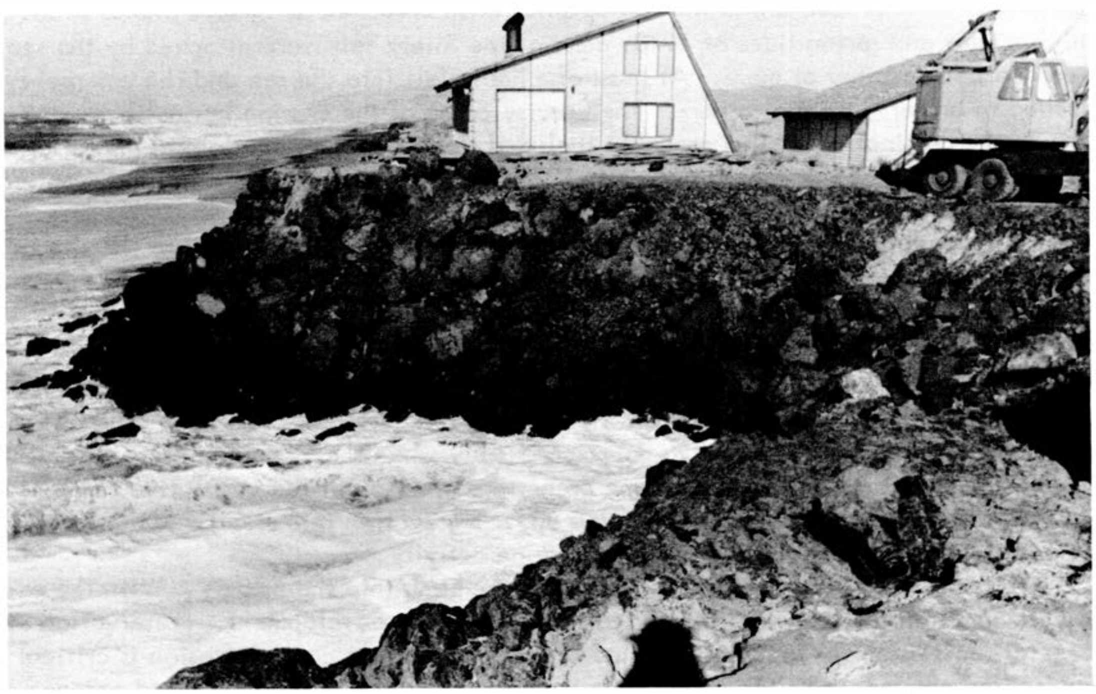


Photo 64. Close-up showing house on left side of above photo where riprap placed earlier at front of house was not sufficient to withstand later storms. Erosion continued to remove sand exposed at either end, requiring additional riprap.

Photo 65. Close-up of house on right side of Photo 63 showing riprap placed to protect property from further storm-wave damage in December 1972.

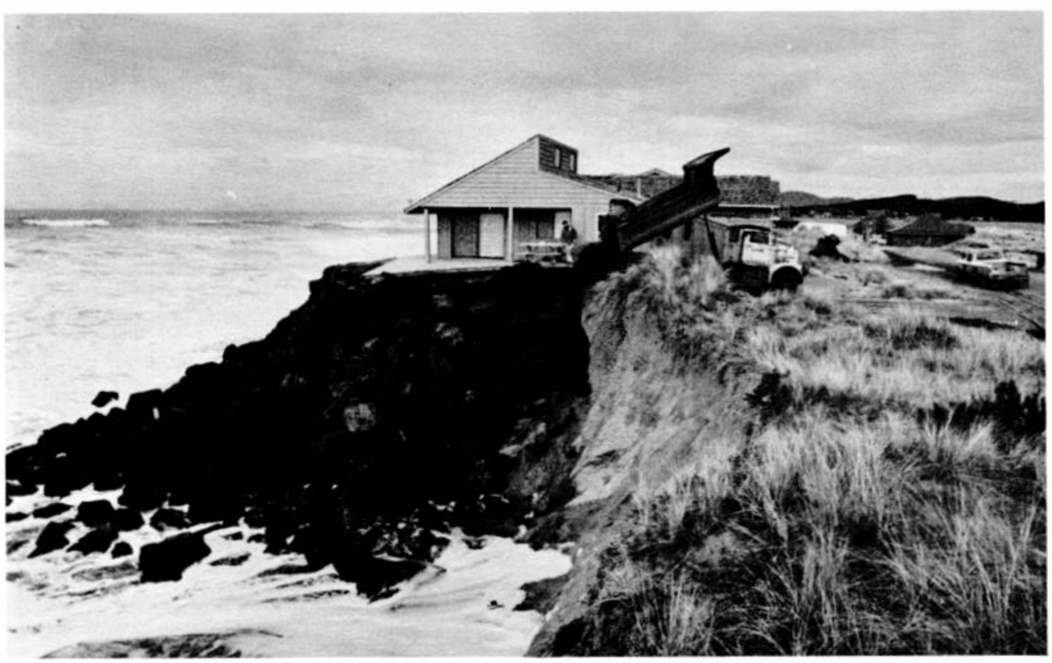


Photo 66. Same house as above after continued storms in January 1973 gouged out sand beyond the terminous of the riprap. Waves have already removed some of the basalt chunks used for riprap. See Photo 84, page 134, showing additional 1973 erosion.

Photo 67. View looking south at Siletz spit showing erosion of inner margin of dune and masses of driftwood deposited by high seas.

Photo 68. Logs scattered on Siletz spit indicate the level reached by recent storm waves. Photo taken during summer of 1972.

Photo 69. Dune grass planted to stabilize sand is no defense against the might of the ocean, which has eroded the dune, exposing buried logs carried in by previous storms.

Photo 70. Sawed logs buried under dune sands on Siletz spit indicate that burial postdates 1910, when logging began in upper Siletz River area.

Photo 71. All that remained of a house under construction on Siletz spit after winter storm waves destroyed it in 1973. (Photo by Lloyd E. Woolfe, Oregon Highway Department)

Photo 72. Even riprap placed along a lot frontage failed to prevent wave erosion of dune sand. Evidently at this site erosion worked behind riprap boulders.

promontories such as jetties, and the removal of vegetation. Indirectly, the overdraw of ground water could also lead to destruction by inducing salt water encroachment into the tap root areas of the trees which grow on the dunes in many areas.

Alternatively, development of the coastal strip should not be flatly condemned. Proper jetty construction and dredging, for instance, have contributed to the economic well-being of the Yaquina Bay area. Likewise, proper management of the ground water in the Clatsop dunes area to the north (Schlicker and others, 1972) is regarded as a realistic goal and an asset in the future development of that part of Clatsop County. It is emphasized, therefore, that what is needed in the beach and spit areas is a basic understanding of the processes that are operating and an appreciation of the magnitude of these processes in planning for future development. In evaluating specific projects, more detailed studies may be required.

Marine terraces

Marine terraces are elevated flat surfaces representing erosion or deposition by the sea along a former shoreline. Their present level may be a result of uplift, variations in absolute sea level, or both. A few terraces in Lincoln County are developed upon basaltic bedrock, as at Depoe Bay, Yaquina Head, and at Yachats. These areas are treated under the discussion of headlands below.

Elsewhere in the County, marine terraces are developed on bedrock of siltstone and sandstone, and the deposits are composed of semi-consolidated sand, clay, and gravel locally mantled by dune sand. Marine terraces generally lie immediately inland from beach areas and are present from Wecoma Beach to Lincoln Beach in the Cape Foulweather quadrangle, from Devils Punch Bowl to Seal Rocks (excluding Yaquina Head) in the Yaquina quadrangle, and from Seal Rocks to Yachats in the Waldport quadrangle. Elevations of terraces developed on sedimentary bedrock vary from 10 to 100 feet above sea level.

The seaward margins of the marine terraces are undergoing critical erosion as storm waves seasonally undercut the soft sediments and initiate a variety of landslides. Thus much of the terrace margin is unsuitable for development unless proper precautions are taken (see previous section on "Landslides").

The history of Jumpoff Joe, a small headland composed of sandstone overlain by terrace material, in north Newport points out the critical erosion of the terrace areas. Between 1880 and 1960, Jumpoff Joe was reduced progressively from a headland with a cave, to a headland with a tunnel, to a sea stack, and finally to a pile of rubble on the beach. In 80 years the headland and the terrace upon it retreated 167 feet (Shepard and Wanless, 1971) to give an average retreat of 2 feet per year.

With the headland thus reduced, the terrace to the north and south became increasingly subject to undercutting by the sea. Some of the most extensive terrace failures are immediately north of Jumpoff Joe. North and Byrne (1965) document between 35 and 490 feet of terrace retreat in northern Newport from 1902 to 1964 and between 40 and 220 feet of terrace retreat in southern Newport from 1912 to 1964. Average annual rates of retreat in this area have ranged between half a foot and 8 feet (Figure 21).

Since the beaches that front the terraces offer the only protection from the sea, it follows that whatever affects the stability of the beaches, be it dredging or jetty construction, also affects the terraces. Modifications of the coastal topography must proceed only after adequate geological engineering investigations are conducted.

As a general rule, the terraces with the narrowest beaches, the steepest slopes, and no exposed underlying bedrock are the most susceptible to undercutting and erosion. For these terraces, rates of retreat averaging several feet per year can be expected. For other terraces protected by wide beaches and underlain by exposures of bedrock, lesser rates of retreat are likely. Between Jumpoff Joe and Otter Rock, where bedrock dips up to 18° toward the west, massive slides are actively affecting large parts of the terraces, rendering them unsuitable for permanent development.

Headlands

Bold, natural promontories, or headlands, are formed in regions of coastal retreat where relatively resistant rock erodes more slowly than the adjacent terrain. The major headlands of Lincoln County consist of Eocene and Miocene volcanic and intrusive rock and include Cape Perpetua, Seal Rocks, Yaquina Head, and masses of volcanic rocks from Cape Foulweather to Government Point.

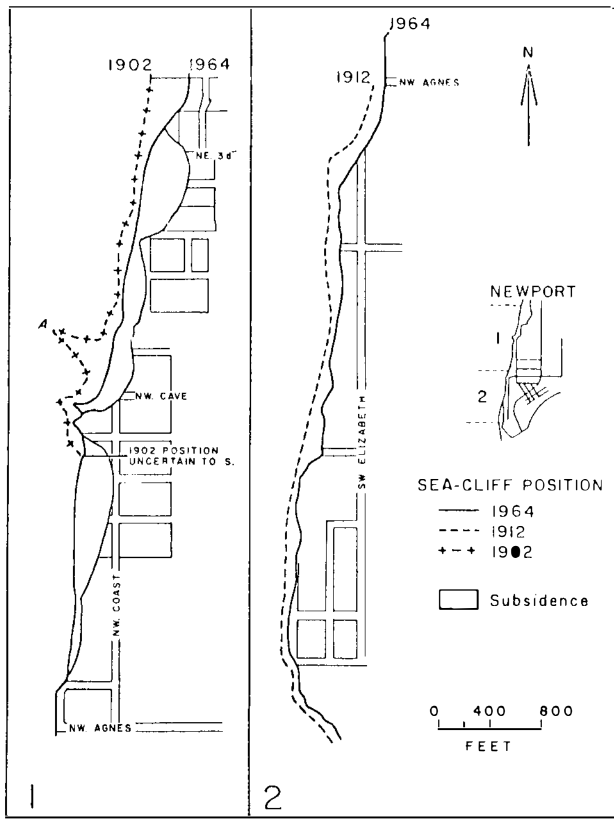


Figure 21. Coastal retreat at Newport , 1902-1964 and 1912-1964
(North and Byrne, 1965).

Although the volcanic headland areas are undergoing erosion, rockfall, and rockslide, the rate of retreat is negligible in most areas. Building on these headlands is not hazardous if the structures are placed sufficiently far back from the edge of the cliffs. Headlands in this category include Cape Perpetua, parts of Yaquina Head, and most of the Cape Foulweather area.

As waves approach the shoreline they are refracted towards areas of shallower water. In effect, they are concentrated on the headlands. In times of storm, rising tide, or high waves, dangers along the shore are most pronounced and beachcombers and boaters should avoid these areas. To the north at Cape Kiwanda 14 lives have been lost in the last 15 years by people unaware of the dangers posed by the headland areas.

Estuaries

The major rivers flowing through coastal Lincoln County from the Coast Range to the sea have been drowned by the post-Pleistocene rise in sea level to form estuaries. The Siletz, Yaquina, and Alsea Rivers empty into broad, partially alluviated bays; the valley of Beaver Creek is filled with sediment to form marshes; and the channel of Yachats Creek is uplifted to produce a series of alluvial terraces. In the northern part of the County the dendritic shoreline of Devils Lake suggests a former course of the lower Salmon River.

With the geologically recent rise in sea level, the gradients of the various streams were reduced and the capacities of the streams to carry sediment were diminished. Consequently the lower valleys became alluviated. Presently water depths are shallow and sediment thicknesses are great, probably exceeding 100 feet in places. As deposition and marsh growth have interacted, deposits of organic soil have developed

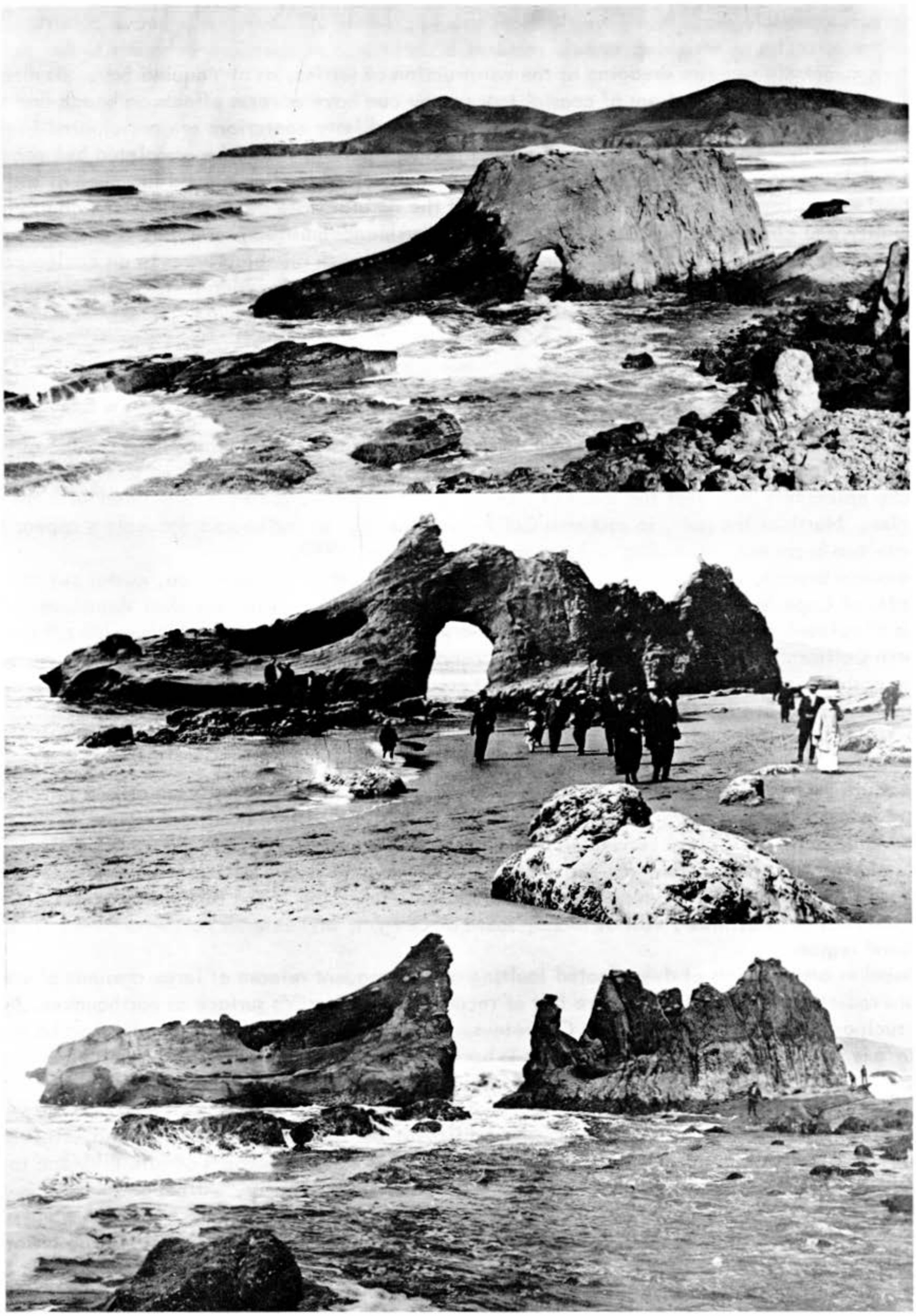


Photo 73. Jumpoff Joe in three stages of erosion: in 1900 (top), marine terrace remnant has a small arch; in 1913 (middle), surface eroded and arch enlarged; in 1926 (bottom), arch gone and outer rock an isolated sea stack. (Photos courtesy of Pacific Studio, Newport)

and are now present both at the surface and in the subsurface (see "Soft Compressible Soils", page 94). In the bay areas, adequate subsurface investigations should precede all moderate to heavy construction.

Use of the estuaries by seagoing vessels requires maintenance of adequate channels to the open sea. This in turn commonly requires dredging or the construction of jetties, as at Yaquina Bay. As discussed previously, however, modifications of coastal topography can have adverse effects on beach and terrace stability. It is recommended, therefore, that if dredging and jetty operations are anticipated in the future development of other estuaries, adequate engineering investigations should be completed beforehand.

The warm brackish waters of the estuaries constitute the major breeding ground for much of the marine life of the Oregon coastal area. It is imperative that the natural state be preserved as much as possible. Water quality and circulation must be maintained and marshlands must be preserved. Indiscriminate landfills and the introduction of pollution are not compatible with such an objective. In an ecological sense, the estuaries are among the most sensitive areas in Oregon and a continuation of in-depth studies is needed before proceeding with construction in these areas.

Earthquakes

Earthquakes in western North America are believed to be caused by the interacting motion of two large lithospheric plates, the North American Plate and the Pacific Plate. Off the Gulf of California, earthquake epicenters show that the locus of interaction of these two plates is associated with the East Pacific rise. North of the gulf, in southern California, the loci of earthquake epicenters appear to divide into two branches, according to Barazangi and Dorman, (1969).

The western branch, associated with the San Andreas fault system in California, passes out to sea in the vicinity of Cape Mendocino. Between Cape Mendocino and the northern end of Vancouver Island, the locus of epicenters is associated with the ridge-rise-transform fault system which exists off the coasts of northern California, Oregon, Washington, and Vancouver Island. From south to north the system comprises the eastern end of the Mendocino (or Gorda) escarpment, Gorda ridge, the Blanco fracture zone, Juan de Fuca ridge, Sovaco fracture zone, Explorer ridge, and the Queen Charlotte-Fairweather fault system. The Fairweather fault system and an associated major fault, the Denali fault, extend into southern Alaska.

The eastern branch of epicenters is less well defined, appearing as a broad zone or belt extending northward through Nevada, Utah, Wyoming, and Montana. The eastern earthquake zone either ends in northern Montana or is diffusely connected to the earthquake activity in the Puget Sound region. Oregon and parts of Washington and Idaho appear to be a relatively quiet island between the two zones of plate interaction. The major strain release associated with the interaction of the two plates occurs off the coast of the Pacific Northwest, east of Idaho, south of Oregon, and extends north-northwest from the Puget Sound region.

Earthquakes are products of deep-seated faulting and subsequent release of large amounts of energy. Vibrations radiating from the fracture are felt or recorded at the earth's surface as earthquakes. In some places, such as the San Andreas Fault in California, the fault producing the earthquake can be mapped at the surface, but in many instances the fault is buried (concealed) and cannot be observed at the surface. In Lincoln County, faults are numerous in the bedrock units. Snavely and others (1972 a, b, c) indicate a complex system of northwest- and northeast-trending normal faults, some of which have large vertical displacements. The age of faulting is not well established, but the youngest bedrock unit involved is late Miocene (15 m.y.). No faulting is present in the marine terrace deposits of late Pliocene to early Pleistocene, indicating that fault movement is at least older than 0.5 m.y. Although faulting is extensive in the County, no master earthquake-producing fault system is indicated.

Earthquake summaries by Berg and Baker (1963) and Couch and Lowell (1971) provide the historical earthquake data for Lincoln County. The data indicate that the recorded seismic history extends back only some 70 years to the late 1800's (Table 20). During this period seven earthquakes were reported: four at Newport with intensity ratings (Modified Mercalli) of IV; one at Waldport, intensity rating IV; one at Seal Rock, intensity rating III; and one at Alsea, intensity rating III (see Table 21 for Mercalli scale ratings).

Couch and Lowell (1971) have summarized information on seismic energy release in the entire Coast Range physiographic province of western Oregon. They report the seismic energy release for a 100-year period (1870-1970) as 6.4×10^{16} ergs per year, which they computed as approximately equivalent to one magnitude 5.0 earthquake (MMV) each decade. This compares with 2.6×10^{17} ergs per year for the same period at Portland, and an approximate earthquake level of one magnitude 4.8 (MMV) earthquake each year or one magnitude 5.2 (MMV-VI) each decade.

Couch and Deacon (1972) have attempted to evaluate the maximum level of seismicity to be expected in BPA service area (Oregon, Washington, Idaho, and western Montana). These studies indicate that for the Newport area a maximum intensity of VIII to IX could be produced from a distant earthquake epicenter near Port Orford. These studies also indicate that distant earthquakes, such as in the Gorda Basin off the southwest Oregon coast, could produce intensities of between VI and VII. Ground motion during earthquakes, from nearby earthquake epicenters as well as distant earthquakes, can affect not only buildings, bridges, and similar structures but also areas of potential land subsidence and landslides. Granular soils, especially thick sections of loose, saturated sand and gravel, will consolidate and subside as a result of shaking ground motion. Because subsidence is usually uneven, buildings on such ground may be tipped or destroyed. In regions of moderate to high relief with unstable slopes and saturated ground conditions (such as most of Lincoln County during winter and spring months), earthquake vibrations could start massive slope failure. In addition, fluid response in saturated lowlands soils could result in liquifaction as downslope flow, even on gentle slopes.

Table 20. List of earthquakes in the Lincoln County area *

Year	Date	Location	Intensity (Modified Mercalli)	Remarks
1897	January 26	Newport	IV	
1902	June 14	Newport	IV	
1916	January 4	Newport	IV	
1928	September 4	Newport (44.7° N-124.1° W)	IV	Felt for radius of 10 miles
1940	May 25	Waldport	IV	Felt at Toledo and Depoe Bay; small objects were moved at Waldport
1941	October 19	Seal Rock	III	
1957	March 22	Alsea	III	

* Data from Berg and Baker, 1963

Table 21. Modified Mercalli intensity scale
(Simplified for this report)

Scale degree	Effects on persons	Effects on structures	Other effects	Rossi-Forel equivalent	Equivalent shallow magnitude (Richter scale)
I	Not felt except by few under favorable circumstances			I	
II	Felt by few at rest		Delicately suspended objects swing	I-II	2.5
III	Felt noticeably indoors		Duration estimated	III	
IV	Felt generally indoors		Cars rocked, windows rattled	IV-V	3.5
V	Felt generally	Some plaster falls	Dishes, windows broken, pendulum clocks stop	V-VI	
VI	Felt by all, many frightened	Chimneys, plaster damaged	Furniture moved, objects upset	VI-VII	
VII	Everyone runs outdoors, felt in moving cars	Moderate damage		VIII	5.5
VIII	General alarm	Very destructive and general damage to weak structures. Little damage to well-built structures.	Monuments, walls down, furniture overturned. Sand and mud ejected. Changes in well-water levels.	VIII-IX	6
IX	Panic	Total destruction weak structures, considerable damage well-built structures.	Foundations damaged, underground pipes broken.	IX	
X	Panic	Masonry and frame structures commonly destroyed. Only best buildings survive.	Ground badly cracked, rails bent. Water slopped over banks.		
XI	Panic	Few buildings survive	Broad fissures, fault scarps. Underground pipes out of service	X	8.0
XII	Panic	Total destruction	Acceleration exceeds gravity. Waves seen in ground. Lines of sight and level distorted, objects thrown in air.		8.5

SUMMARY AND RECOMMENDATIONS

The geologic and climatic environment of Lincoln County is attended by a variety of natural hazards that have the potential for creating serious problems involving property and, possibly, lives. On the other hand, an understanding of these hazards and a sensible approach to coping with them in the planning stages of development can eliminate much of the grief that might otherwise transpire.

The information and recommendations in this report are presented as basic guidelines for the County so that planning and development can proceed in such a way as to avoid the losses induced by geologically hazardous conditions. It must be emphasized that the report is general in scope, delineating only broad areas where hazardous geologic conditions exist. Local sites should be evaluated by qualified geologists and soils engineers responsible to the County or cities in order to protect the individual land owners and investors. Developers of problem areas should be required to employ qualified consultants.

The following discussion reviews the areas in Lincoln County that are subject to geologic hazards and suggests ways these problems can be avoided or corrected. The report also reviews the available mineral resources needed for continued growth of the County.

Areas Subject to Geologic Hazards

Marine terraces

Most of the coastal communities and recreational developments of Lincoln County are situated on the marine terraces. These elevated platforms, representing former strandlines of the sea, extend the full length of the County, interrupted only by headlands and bays. The terrace materials consist of weakly cemented sand, silt, and pebbly sand which are overlain in many areas by old, fairly stable dunes. Bedrock beneath the terrace and dune sediments is tilted sharply seaward and is exposed in sea cliffs in some places.

The margins of these terrace areas adjacent to the ocean are attractive places to build, and many small beach cottages, permanent homes, condominiums, and motels occupy these locations. Unfortunately the sea cliffs at the terrace margins are slowly but continually receding. Wave erosion during storms and high tides undermines the cliffs, while rain, wind, and frost loosen the upper portions; as a result, masses of terrace material slip seaward at unpredictable rates and in unexpected places.

In general, marine terrace margins can be expected to retreat from 6 inches to 1 foot per year; however, in certain areas, recession can average more than 10 feet per year. In some locations, erosion may not be evident for a decade and then 10 or 15 feet of the cliff may drop off in a single season. Occasionally very large areas involving a number of acres of land may slide seaward, such as in the Jumpoff Joe area of Newport.

Excessive slippage along terrace margins is due to sliding of weakened, water-saturated bedrock along its seaward-tilted bedding planes. Of course, the overlying terrace sediments move with it. Particularly vulnerable to bedding-plane failure is the Nye Mudstone in the Newport area. This type of movement may have vertical and horizontal components of only 2 feet to as much as 50 feet. At first the surface of the slide block is not disrupted, but it is generally back-tilted, or rotated down, on the landward side. Water often accumulates in a sag pond at the back of the slide.

The surface of these slump areas may range from 50 to 100 feet wide and from 200 to 1,000 feet long. To the untrained eye, such apparently level areas of ocean frontage might appear to be desirable building sites. Unfortunately, however, these areas are extremely unstable since the ground surface must adjust to constant wave erosion at the toe of the slide. In a short time, the entire slump block can be eroded away. During the limited life of the slump block, home owners will be plagued with continual problems of settlement, such as cracks in walls, jammed doors and windows, and water- and sewer-line difficulties.

Photo 74. Motel unit safely situated back from edge of eroding marine terrace north of San Marine.

Photo 75. Resistant bedrock underlies marine terrace at this site near Yachats impeding erosion of the thin layer of terrace sands.

Photo 76. Sea wall at Roods End, consisting of large concrete blocks with weep holes to relieve hydrostatic pressure behind them, provides protection from wove erosion. Sloped bonk covered by vegetation prevents seo-cliff recession.

Photo 77. Sea walls and riprop protect some ports of low terrace in Lincoln City. High unprotected terrace to right of photo suffers from extensive wove erosion

Photo 78. Sea walls stabilize some sections of Lincoln City's coastal terraces, while other sections are exposed to wave erosion.

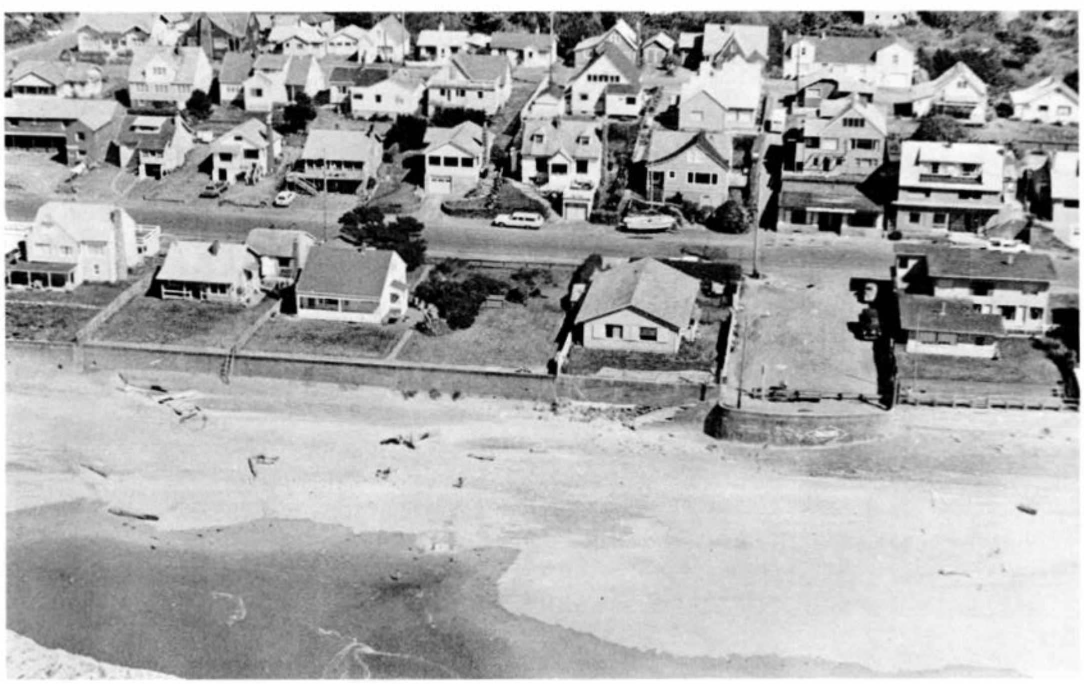


Photo 79. Sea walls in this part of Lincoln City are effective in protecting houses and property on low terrace from wave erosion.

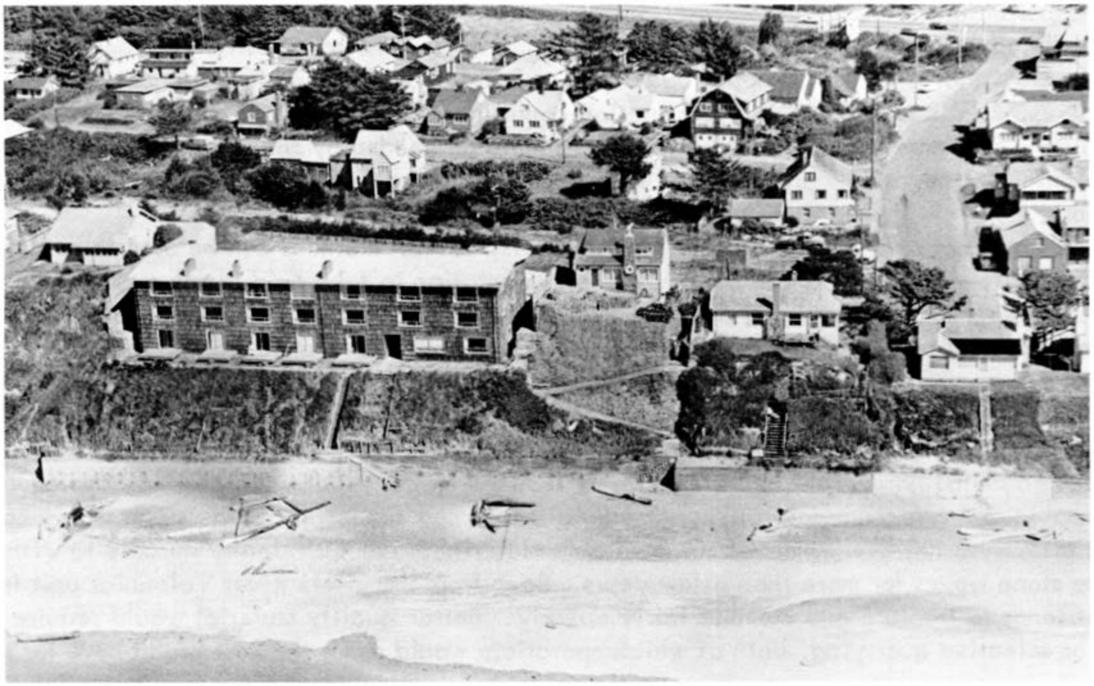


Photo 80. Concrete sea wall and sloped and planted terrace bluff provide excellent protection from storm-wave erosion for these buildings in Lincoln City.

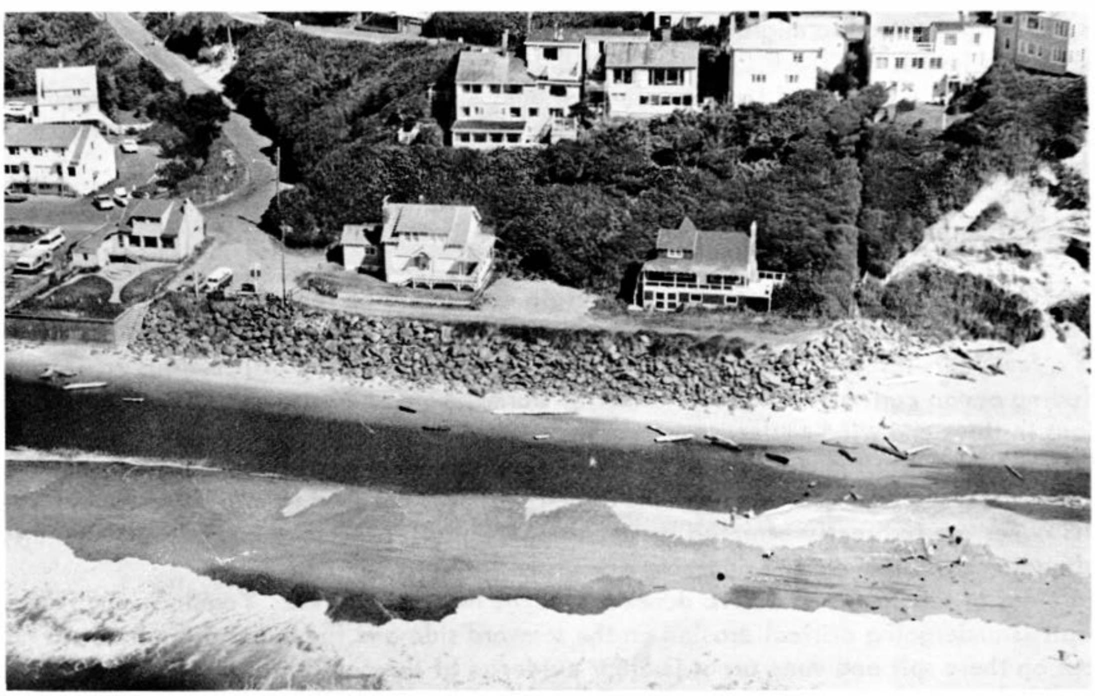


Photo 81. Riprap and concrete sea walls are effective in preventing wave erosion; however, riprap, although less expensive to install, is less resistant and requires periodic repair.

In locating structures on ocean-front portions of terraces, the rate of retreat and the possibility of extensive cliff failure should be considered in order to determine the safe position for buildings. Where erosion averages 1 foot per year, a house built 30 feet from the edge could lose foundation support within 30 years and eventually be destroyed. Destruction could come much sooner if a large mass of sea cliff should drop off. The possibility of such serious loss should be heeded by the intended purchaser, and a careful preliminary study of the property and its past history of erosion should be made before investing in such land.

Where sliding is not excessive along the terrace bluffs, several methods can be used to retard recession. Shaping the cliff to slope at an angle that will allow vegetation to take hold is one method, but this must be done at the expense of valuable land on the flat surface of the terrace. Another method is to preserve the cliff face by hanging wire fencing or woven lath over it to retain vegetation and to slow erosion. An alternative is to gunnite the entire surface; however, weep holes must be left to relieve hydrostatic pressure. Septic tank drainage and water from roof and storm drains should not be allowed to exit on the terrace slopes.

Wave erosion at the base of the sea cliff can be reduced by construction of properly designed seawalls. The most durable and effective seawalls are made of reinforced concrete. Large stone riprap can be moderately effective; however, most of the available material is not sufficiently durable to withstand pounding by storm waves for more than a few years. Rock from the Siletz River Volcanics unit is often used, but it tends to fracture and crumble fairly quickly. Better quality material would require either long hauls or selective quarrying, both of which operations would make the cost prohibitive for property owners.

Old dune areas

In certain areas, such as at Nelscott and Taft, large old sand dunes have developed a thick soil profile and have remained stable for many years. However, the need for easily excavated fill material and the preparation of ground for building sites has led to the removal of the stabilizing soil layer and has exposed loose sand. If these exposed areas are not immediately stabilized, the wind will soon erode basins and troughs, causing the sand to migrate to adjacent housing areas where it can cover driveways, sidewalks, streets, and lawns.

Where stabilized soil is removed from a deposit of dune sand capable of blowing, the sand should be covered promptly with topsoil and planted. If the exposed area is to be used for a building, construction should begin as soon as practical after excavation.

Sandspits and active dunes

Sandspits and their active dunes are of recent origin and should be regarded as relatively temporary features. Some parts of the spits and dunes are built up quickly by water and wind and destroyed by the same agents a few years later. Their instability results from the interplay of numerous environmental factors including ocean currents, size and number of storms, volume of stream sediment entering the ocean, and variations in tides and wind patterns.

Other factors that affect the stability of spits and dunes are man-made operations. Removal of vegetation, especially from the low foredune near the beach, exposes the sand to erosion and wind transport. The spits and dunes are indirectly affected by operations that alter the sand budget, such as jetty construction, dredging of estuaries, and damming of rivers.

The main areas of sandspits and active dunes are at the mouths of Siletz, Yaquina, and Alsea Bays. The Siletz spit is undergoing critical erosion on the seaward side and the dunes are subject to blowouts. Stranded logs on these spit and dune areas is clear evidence of the potential for overtopping by storm waves during high tides, or by tsunami and additive waves. That the low dune parts of sandspits close to the ocean are unfit as sites for permanent construction is now well known. Such areas that are already developed could possibly be protected from further erosion by properly engineered riprap or seawalls.

Preservation of vegetation on the dunes south of Yaquina Bay is recommended since excavation into loose sand could initiate further dune migration. All dunes on the Alsea Bay spit, except the foredune, have been bulldozed for housing development. It is essential that the foredune be preserved. Construction in this dune area could be hazardous.

Photo 82. Low, vegetated dunes on spit at mouth of Salmon River are retained in natural state by YWCA Camp Westwind. Low dune areas of this type are unsuited for permanent structures.

Photo 83. Well-developed foredune south of Gleneden provides protection for interior forested dunes and should not be disturbed. Note logs left by high tides and storm waves.

Photo 84. Salishan's development on Siletz spit was severely eroded by winter storms of 1972-73 and required repeated placement of riprap to save houses and property from total destruction. (Photo by Gerry Lewin, Capital Journal)

Hillside development areas

Where housing density is, or eventually will be, less than 5 acres per dwelling, hillside construction should be done in accordance with strict engineering design based on detailed geologic information. Landslide areas should be avoided.

Development of hillside properties has a considerable adverse effect on slope stability. Whenever material is excavated from a side hill, it results in a steeper than natural slope. Material excavated from the cut is usually placed immediately downslope to provide a nearly horizontal area for a yard or garden. Both operations create instability by oversteepening and adding weight to the slope.

Most hillside housing developments progress gradually and without the benefit of sewerage. By the time the development is complete, nearly half of the ground surface is covered by buildings, streets, driveways, and sidewalks, preventing normal infiltration of precipitation. Not only will the total rainfall be concentrated in small areas, but additional water will build up from septic-tank drainage, roof drains, and lawn sprinkling, causing possible oversaturation of downslope soils and eventual slope failure involving large sections of the total hillside area.

Nearly all aspects of hillside land development combine to create slope instability unless the entire construction project is properly engineered. It should be emphasized that slope failure may occur 5 or 10 years after the start of the development, by which time the developer may have divested himself of interest and responsibility.

Inland mountainous areas

Construction inland from the coast of Lincoln County usually involves steep topography along the valleys of the major rivers and smaller streams. (Flood-plain development and its associated hazards is discussed under "Flood-prone areas" below.) Since the early days of settlement in Lincoln County, these valleys have provided the best access inland from the ocean. As a result, farms, small towns, roads, and highways have followed them. Logging roads have penetrated far into the mountainous areas along the steep walls of the smaller tributary streams, and some of these roads have come into permanent use.

The valleys were excavated by streams to great depth during the ice ages of the Pleistocene when sea levels were considerably lowered. Melting of ice during interglacial episodes caused a rise in sea level and gradual drowning and silting up of the lower reaches of the valleys. Meandering streams now impinge on the steep walls, removing support of the weathered rock and soil mantle and causing new landslides and renewed movement of old slide masses. Man-made cuts for road construction, basement excavations, and other purposes have the same effect on the potentially unstable soil and rock.

Alteration of active slide areas should be avoided if at all possible. If roads cannot be located elsewhere, the slide should be thoroughly examined and stabilized within the economic limits allowable. Treatment could involve subsurface drainage of the toe, protection of the toe from stream erosion where necessary, placement of a designed buttress, and the re-routing of surface water from the main body of the landslide mass. The roadways should be designed so that no material is removed from the toe of the slide. If possible, a free-draining fill across the toe area should be constructed so that water will not accumulate in this and upslope areas.

Rural dwellings and farm buildings should not be built in areas of landslide or soil creep where recent movement is indicated by open cracks, bare scarps, active erosion at the toe of the slope, or bent or tipped trees. Rolling or hummocky topography which has apparently remained stable for a number of years and which exhibits none of the previously described indicators of active movement could be built upon, providing the slope and drainage is not altered so as to decrease the slope stability.

All possible geologic hazards should be recognized and satisfactory solutions determined prior to any construction. If correction will be uneconomical, the project should be abandoned. To ignore a geologic hazard is to invite disaster.

Flood-prone areas

Stream flooding: Flooding of the coastal lowlands in Lincoln County is an annual menace, occurring several times in some years. Major floods causing extensive damage have occurred at least ten times

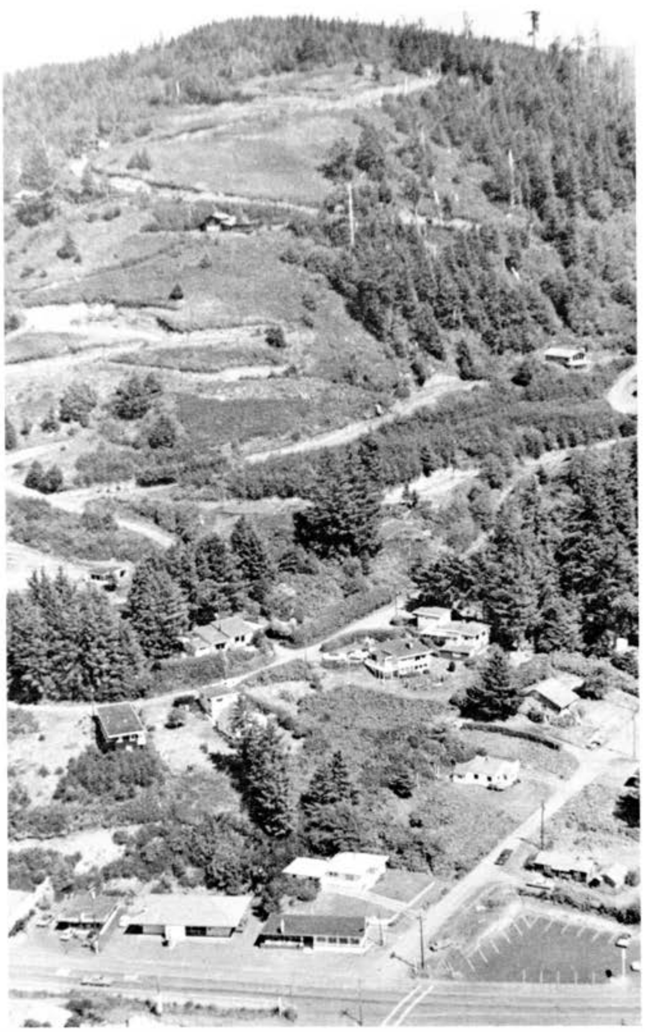


Photo 85. Kozy Acres, a development northeast of Alsea Bay, is situated on topography produced by an ancient landslide. Drainage, excavations, and embankments will need to be rigidly controlled.

Photo 86. Homesite development on steep hillside at Yachats must be planned carefully to prevent slope failure in weathered volcanic rock and soils that mantle bedrock.

Photo 87. Building pads stairstepped on hillside in Waldport. Such development will require control of surface drainage to prevent erosion and landsliding. Embankments must be properly compacted and have adequate subsurface drainage.

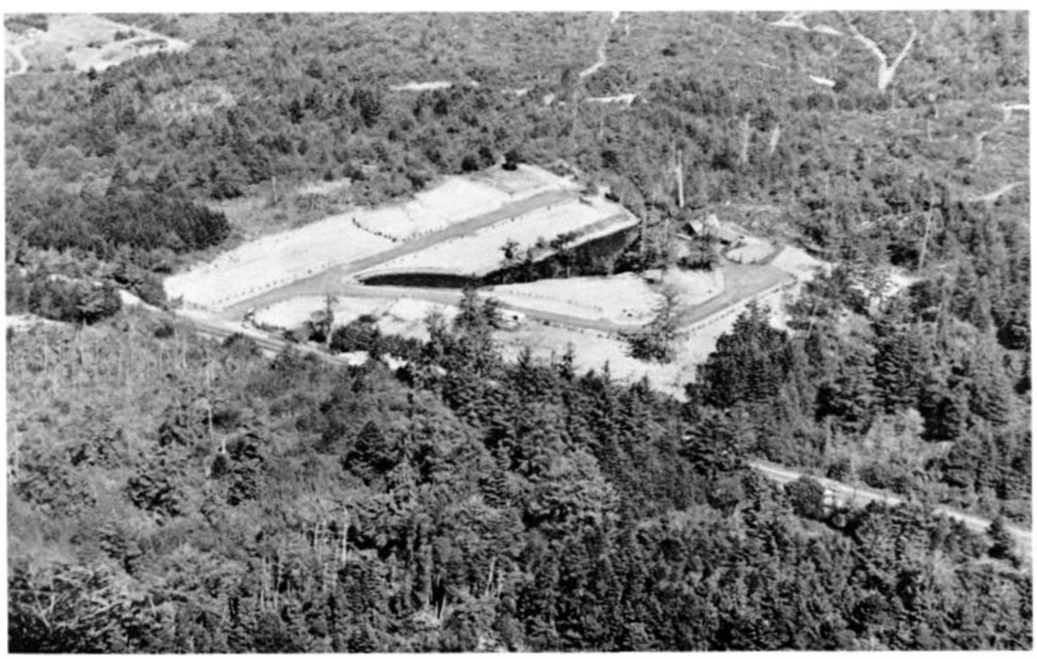


Photo 88. Trailer-site development around Hidden Lake in stabilized dune area north of Waldport. Such installations need sewage treatment to prevent ground-water contamination.

Photo 89. Little Cove Creek condominium north of Newport built on low terrace susceptible to dangers of high tides and storm waves.

Photo 90. Close-up of above photo showing abundance of driftwood carried into cove area by combined high tide and storm waves.

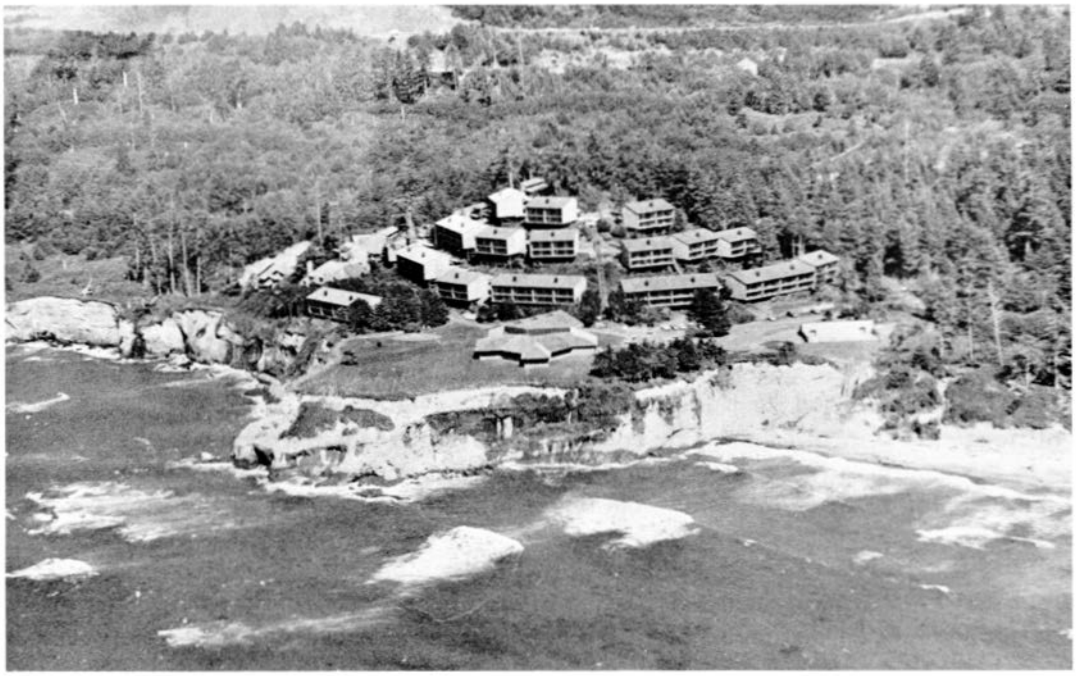


Photo 91. Inn at Otter Crest complex at Cape Foulweather. Upper buildings are situated on basaltic rock. Restaurant is on eroding marine terrace. Erosion is accelerated by landsliding of terrace sediments on seaward dipping sandstone beds.

Photo 92. Inn at Spanish Head condominium near Taft. The lower floor is highly vulnerable to the force of storm waves and driven logs.

since 1921, generally in December or January, but some have been as early as November 20 or as late as March 31. The interval between major floods has been from 1 year to as long as 15 years, with the average just over 5 years.

Floods are always associated with periods of heavy rainfall, especially after the ground has been soaked to near capacity or after the ground has been deeply frozen. Snow melt can add considerably to the flood intensity. Near the mouths of streams, flooding can be markedly increased by high tides resulting from strong onshore winds during severe winter storms.

Destructive flooding by streams occurred in Lincoln County during the winters of 1921, 1931, 1964-65, and 1972. Summarized briefly here, the high water inundated the flood plains of all the major streams. Houses, barns, and livestock were lost; bridges, sections of railroad, and boat docks were swept away; logs and debris from inland were carried out to sea and lodged on distant beaches; residential and business areas of some communities were under water, as were also some resorts; highways throughout the County were blocked by floodwaters and landslides. During the 1964-65 floods, the entire County was isolated.

Control of flooding in Lincoln County by construction of flood-control dams appears to be extremely unlikely due to the configuration of the stream valleys relative to the cost and effectiveness of a reservoir. Levees and dikes can offer some protection from floods in the lower reaches of the streams where the tidal effect is pronounced.

The severity of floods in Lincoln County together with the infeasability of adequate flood control structures points out that flood control measures must be in the form of flood-plain zoning regulations. Delineation of flood-prone areas on the environmental hazard maps accompanying this report should be adequate for determining areas that need to be zoned.

Development on flood-prone land should be limited to boat docks, fishing enterprises, and other water-oriented activities. Less susceptible areas might be suitable for trailer and camp sites that are vacated during winter flood periods. Farm houses, barns, and other permanent farm-related structures in flood-plain areas should be placed where high water will not damage buildings or contents; elevated roadways should be planned where necessary. Subdivisions for permanent homes should be prohibited on flood-prone land.

Marginal areas already developed should be covered by flood insurance. In order to alleviate flood damage costs, the Lincoln County Board of Commissioners has obtained authorization (February 16, 1973) for federally subsidized insurance through the National Flood Insurance Program of the Department of Housing and Urban Development (HUD). To become eligible for the insurance, the County was required to adopt land-use standards intended to reduce the potential for flood damage. Flood insurance is now available to residents in the unincorporated areas of Lincoln County and the residents of Lincoln City. Other incorporated cities in the County can qualify for the flood insurance by adopting the required land-use standards.

The insurance is available for all buildings existing prior to the authorization date and for their contents; buildings constructed after that date can be insured provided the first floor is at least one foot above the height of the greatest known flood in the area and that all construction within flood-plain areas be made in accordance with floodproofing procedures. A Flood Hazard Boundary Map showing flood-plain areas, to be prepared jointly by the County, the U.S.D.A. Soil Conservation Service, the U.S. Army Corps of Engineers, and the U.S. Geological Survey, will determine eligibility and insurance rates for subsequent new construction.

Flood-plain zoning and strict construction criteria are imperative if the annual flood loss is to be reduced. Selected publications on flood-plain zoning regulations and building recommendations are listed in the bibliography. (Bureau of Governmental Research and Services, 1971; Center for Urban Studies, 1967; Goddard, 1971; Office of Emergency Preparedness, 1972; Oregon State Water Resources Board, 1970a, 1970b; Reckendorf, 1968; Sheaffer, 1967; Shepard, 1971; U.S. Department of Housing and Urban Development, 1972; U.S. Geological Survey, 1967; U.S. Water Resources Council, 1971)

It is essential that local government, the land developer, real estate agent, builder, and prospective lot-buyer become aware of areas of potential flooding before committing themselves to developing the property.

Ocean flooding: Ocean flooding is unpredictable and can occur any time of the year. Its causes include storms at sea, strong westerly winds, tidal forces, and large unusual waves. Large unusual waves, although of short duration, can be very destructive. They include tsunamis caused by earthquakes on the sea floor and additive waves created when the crests of several in-phase waves are superimposed and reach the shore simultaneously.

In the past 33 years, wind and high tides have twice caused excessive flood damage along Oregon's coast. A third destructive wave was a tsunami resulting from the Alaska "Good Friday" earthquake of 1964; smaller seismic waves have occurred since that time. Although there is no accurate method of predicting the frequency and magnitude of ocean flooding, the occurrence of three damaging floods in 33 years suggests an average of about once every 10 years. Similar waves in the future will probably be even more destructive because of the greatly increased construction of residences, motels, and condominiums at or just above the normal high-tide line. The presence of logs above normal high-tide level is clear evidence of the elevations the sea can reach.

This report recommends that maximum wave elevations be determined from past experience and from data developed by oceanographers and seismologists, and that siting of future structures be based on such criteria.

Mineral Resources

Crushed rock, sand, and gravel

Crushed rock, sand, and gravel are needed for construction of roads, highways, streets, sidewalks, buildings, bridges, sewage- and water-treatment plants, and reservoir spillways.

Lincoln County, at present, requires about 400,000 tons of rock aggregate per year and this will increase to 480,000 tons per year by 1985. About six million tons of rock will have been used between 1972 and 1985. It is doubtful that the presently known commercial sites will be able to fulfill that need.

In order to delay this anticipated shortage, the present commercial quarries should be allowed to expand operations to remove the available rock at their sites. The sites should be quarried according to a reclamation plan which will leave the ground in a usable condition. Quarries may have future value as building sites, reservoirs, or sanitary landfills.

As the local supplies decline, crushed rock will need to be imported. Other sources inland do not appear to be adequate; therefore, barging of gravel from the upper Columbia River or elsewhere may be required.

Jettystone and riprap

Jettystone and riprap require a durable stone that consistently breaks in large, angular pieces and is resistant to abrasion and weathering. In the early days, jetty construction at Yaquina Bay utilized the Tyee sandstone. Although this rock produced stones of sufficient size, the rock was not durable and the jetty disintegrated. Later syenite was used from Blodgett Peak south of Waldport. This rock was apparently satisfactory, as much of it can still be seen in the jetty at Yaquina Bay. In order to exclude the Tyee sandstone from consideration by contractors, the U. S. Corps of Engineers raised the specific gravity requirement for jettystone to 160 lbs. per cubic foot; however, this also eliminated the syenite from consideration. Basalt jettystone has been produced locally in limited quantities. Present jetty construction along the coast utilizes rock barged from Camas, Washington.

It is recommended that the specifications for jettystone be reviewed to determine if syenite from either Blodgett Peak or Table Mountain can be used on future projects in Lincoln County.

Rock suitable for riprap to protect ocean-front property and stream banks is available locally from some of the basalt units. In the northern half of the County, basaltic tuff and basalt breccia are quarried from the Siletz River Volcanics unit. Although large pieces of rock can be obtained, much of it breaks down fairly rapidly. The basalt breccia, if well cemented, is the most satisfactory local material for shoreline protection.

Ground-water Resources

Ground-water resources are poor in much of inland Lincoln County because of the low porosity and low permeability of the bedrock units. However, the marine terrace deposits and certain dune-sand areas bordering the coast could yield substantial quantities of water. Some alluvial-terrace and flood-plain deposits bordering the streams serve as fair aquifers. Although the wells in most areas yield sufficient water for domestic purposes, the quality sometimes requires treatment to be made potable.

Photo 93. Small basaltic headland north of Roads End will probably become an isolated sea stack as erosion progresses into softer marine sediments behind it.

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Photo 94. Lincoln County coast has always had its attractions. Photo taken in early 1900's shows Cape Foulweather in background and a sea stack removed long ago by erosion. (Photo courtesy of Pacific Studio, Newport)

APPENDIX

APPENDIX A
ROCK QUARRIES AND GRAVEL PITS

No.	Location T	R	S	Owner or operator	Q/GP*	Type of material	Formation	Abrasion % Loss
1	6S	9W	22	Longview Fibre Co.	Q	Basalt	Tsr	
2	6S	9W	26	Murphy Logging Co.	Q	Gabbro sill	Tig	17.2
3	6S	10W	19	Elmer Calkins	Q	Diced basalt	Tech	18.1
4	6S	10W	21		Q		Tsr	
5	6S	10W	25	New Widow Creek Quarry	Q	Pillow basalt & breccia	Tsr	
6	6S	10W	25	Old Widow Creek Quarry	Q	Pillow basalt & breccia	Tsr	
	6S	11W	12 13	M & M Crushing	Q	Diced basalt	Tech	
7	6S	11W	25	Frazer Ranch	Q	Weathered basalt	Tsr	24.5
8	6S	11W	26		Q	Basalt	Tech	10.9
9	6S	11W	35		Q	Basalt	Tech	
10	7S	9W	17	B.L.M. Lindsey Ridge	Q	Basalt sill	Tib	14.6
11	7S	10W	11	Minski Ranch	Q	Camptonite intrusive	Tic	19.8
12	7S	10W	27	U.S.F.S. Cougar Mtn.	Q	Camptonite sill	Tic	14.1
13	7S	11W	23	Devils Lake Crushing	Q	Camptonite dike	Tic	16.7
14	8S	10W	5				Tsr	
15	8S	10W	7	M.E. Kauffman	Q		Tsr	
16	8S	10W	8		Q		Tsr	
17	8S	10W	20	Publishers Paper	Q	Camptonite dike	Tic	13.4
18	8S	10W	25	Boise Cascade	Q		Tsr	19.7
19	8S	11W	1	Publishers Paper	Q	Basaltic tuff breccia	Tsr	
20	8S	11W	12	M.E. Kauffman	Q	Basalt & breccia	Tsr	18.4
21	8S	11W	14	Ocean Lake Sand & Gravel	Q	Basalt intrusive	Tib	13.6
22	8S	11W	34		Q	Basalt dike	Tib	
23	9S	10W	3		Q	Basalt	Tsr	

* Q, quarry; GP, gravel pit; P, prospect - rock exposed

Specific Gravity	Na_2SO_4 % loss	Quality	Quantity	Use	Remarks
		Unknown	Unknown	Logging roads	Location approximate
2.88	17.2	Unknown	Unknown	Logging roads	Large sill-possibly other sites in area
2.88		Good	Unknown	Roads & concrete aggregate	
		Poor	Unknown	Fill	
		Variable	Medium	Road construction	Selective quarrying required to produce good quality rock.
		Variable	Small	Road construction	Abandoned (Edge of highway, no plant site)
		Reported good	Unknown	Base & surface	North of mapped area
2.78		Poor	Small	Fill	
2.71	0.2	Good	Small	Road Construction	Probably unavailable (Located in housing area)
		Unknown	Small	Unknown	Probably unavailable (Located in housing area)
		Good	Reported large	Logging roads	Sill 200' thick - remote for commercial use
2.66	Excessive	Poor	Small	Logging roads	Rock highly weathered
2.57		Marginal	Unknown	Logging roads	Only rock available locally
		Variable	Unknown	Commercial	Large commercial supplier - future supplies uncertain
		Unknown	Unknown	Logging roads	
		Marginal	Unknown	Commercial	
		Marginal	Unknown	Commercial	
		Marginal	Small	Logging roads	Private
	Excessive	Marginal	Unknown	Logging roads	Location not checked
		Poor	Small	Riprap	Unsuitable for road construction; private
2.66	Excessive	Poor	Unknown	Fill	
2.88	0.8	Good	Large	Commercial	Major commercial rock producer in area
		Good	Small	Logging roads	
		Poor	Unknown	Logging roads	

ROCK QUARRIES AND GRAVEL PITS, continued

No.	Location T	R	S	Owner or operator	Q/GP*	Type of material	Formation	Abrasion % Loss
24	9S	10W	4	Calkins Quarry (Macco)	Q	Gabbro sill	Tig	15.1
25	9S	11W	3		Q	Basalt intrusive	Tib	
26	9S	11W	4		Q	Basalt intrusive	Tib	
27	9S	11W	9		Q	Basalt intrusive	Tib	
28	9S	11W	20		Q	Basalt intrusive	Tmcf	
29	9S	11W	29		Q	Basalt intrusive	Tmcf	
30	10S	8W	7	Fish Hatchery Quarry	Q	Basalt sill	Tib	
31	10S	10W	10	Siletz River Gravel Pit	GP	River gravel	Qal	18.1
32	10S	11W	20	Iron Mtn. Quarry	Q	Basalt plug	Tib	
33	10S	11W	20	Agate Beach Quarry	Q	Basalt sill & breccia	Tmcf	14.1
34	10S	11W	29	Yaquina Head Quarries	Q	Submarine basalt	Tmcf	15.8
35	11S	8W	18				Tib	
36	11S	9W	16	Baber Mtn.	P	Basalt sill	Tig	25.4
37	11S	9W	17	W.O.W. Lumber Co.	Q	Gabbro sill	Tig	
38	11S	10W	26		Q	Tyee sandstone	Tet	
39	12S	8W	5		Q			
40	12S	8W	8	Harlan Quarry	Q	Basalt dike	Tib	
41	12S	8W	24	Gates Quarry	Q		Tib	
42	12S	9W	1		Q	Basalt dike	Tib	
43	12S	10W	11		Q	Tyee sandstone	Tet	
44	12S	11W	14		Q	Tyee sandstone	Tet	
45	13S	8W	7		Q	Basalt	Tib	
46	13S	9W	1	Georgia Pacific	Q	Basalt	Tib	
47	13S	9W	26		Q	Tyee sandstone	Tet	

* Q, quarry; GP, gravel pit; P, prospect – rock exposed

Specific Gravity	Na_2SO_4 % loss	Quality	Quantity	Use	Remarks
2.75		Good	Large	Jettystone	Used on Newport jettys
		Good	Small	Logging road	
		Good	Small	Logging road	
		Good	Small	Logging road	
		Good	Small	Road construction	Abandoned Adjacent to old Otter Crest Hwy
		Good	Small	Road construction	
		Marginal	Small	Road construction	Adjacent to road - limited area for plant site
2.86	2.1	Good	Small	Commercial	In river flood plain - several pits in vicinity
		Good	Medium	Road construction	Mostly mined out - State Highway use only
2.82	15.8	Variable	Medium	Commercial	Large producer
2.89	7.8	Variable	Medium	Commercial	Large producer
			Small	Logging roads	Depleted and abandoned
2.82		Marginal	Unknown	Prospect not developed	Some Tyee overburden - access road inadequate
		Marginal	Small	Logging roads	Excessive overburden of Tyee sandstone
		Poor		Abandoned	Formerly used for dimension stone, unsatisfactory quality
		Unknown	Small	Road construction	Depleted
		Good	Small	Road construction	Depleted
		Reported good	Unknown	Commercial	Location approximate
		Unknown	Small	Road construction	Depleted & abandoned
		Poor			Abandoned
		Poor		Unknown	Abandoned
		Unknown	Small	Road construction	
		Unknown	Unknown	Logging roads	
				Unknown	Abandoned

ROCK QUARRIES AND GRAVEL PITS, continued

No.	Location T	R	S	Owner or operator	Q/GP*	Type of material	Formation	Abrasion % Loss
48	13S	9W	31	Hellion Rapids Quarry	Q	Basalt dike	Tib	
49	13S	10W	1	Table Mtn. Quarry	Q	Nepheline syenite sill	Tis	19.0
50	13S	10W	34	Lee Barklay	Q	Basalt dike	Tib	
51	13S	10W	35		Q	Basalt dike	Tib	
52	13S	10W	36		Q	Basalt dike	Tib	
53	13S	11W	33	Eckman Creek	Q	Submarine flows & intrusive	Teyb	20.1
54	14S	9W	3	Bear Creek	Q	Basalt dike	Tib	
55	14S	9W	4	Wolf Creek	Q	Basalt dike	Tib	21.6
56	14S	9W	18	Five Rivers	Q	Tyee sandstone	Tet	
57	14S	11W	18	Blodgett Peak	Q	Nepheline syenite	Tis	24.6
58	14S	12W	25	Yachats Quarry	Q	Basalt dike	Teyb	17.6
59	15S	10W	29	Klickitat Quarry	Q	Basalt dike	Tib	
60	17S	12W	10	Berry Creek Quarry	Q	Submarine basalt	Teyb	

* Q, quarry; GP, gravel pit; P, prospect - rock exposed

Specific Gravity	Na_2SO_4 % Loss	Quality	Quantity	Use	Remarks
		Unknown	Depleted	Road construction	Abandoned
2.57	1.0	Marginal	Large	Logging roads	Breaks large - produces dusty roads - reported O.K. for oil
		Unknown	Reported small	Commercial	
		Unknown	Depleted	Road construction	Abandoned
		Unknown	Unknown	Road construction	Abandoned
2.84	Mod-erate	Variable	Large	Commercial	Major aggregate source
			Depleted	Road construction	Abandoned
	Low	Good	Medium	Commercial	Presently being developed
			Abandoned	Formerly for jettystone	Unsatisfactory quality
2.64	2.7	Marginal	Large	Base rock	Formerly used as jettystone at Yaquina Bay
2.88	Low	Variable	Small	Crushed rock	Remaining rock poor quality
		Good	Unknown	Logging roads	Located in Lane County
		Reported marginal	Unknown	Commercial	Being re-opened

APPENDIX B

WATER WELL LOG DATA

No. on Map	Well Location T. R. S. ¼/¼	Yield gpm	Draw-down feet	Depth to Static Water Level feet	Depth to Static Water Level date	Well Depth feet	Well Diameter inches	Water-bearing Zone(s) geologic formation**	Water-bearing Zone(s) rock type	Water-bearing Zone(s) thickness feet	Bedrock depth to top feet	Temp-erature °F	Water use
1	6S 10W 25cb	0.5	40	13	8/63	68	6	Tsr	Ss	31	7	48	Dom
2	25cd	8	20	14	8/63	46	6	Tsr	Ss	14	14	49	Dom
3	29bb	Dry	--	--	(6/69)	199	6	Tey	--	--	10	--	(Dom)
4	30ac	9	20	7	4/60	40	6	Tey	Slt	12+	18	--	Dom
5	30cb	10	14	6	5/64	32	6	Tey	G	3	16	49	Dom
6	31bc	10	49	50	9/71	155	6	Tey	Slt	15	17	52	Dom
7	31cb	2.5*	35	115	7/65	155	6	Tey	Slt	1	28	--	Dom
8	31dc	10*	52	32	8/64	103	6	Tey	Ba	42+	54	--	Dom
9	32ab	Dry	--	--	(3/72)	355	8	Tsr	--	--	11	--	(Dom)
10	32ad	43	177	11	3/72	220	8	Tsr	Ss	--	13	--	Dom
11	32ba	8	150	18	2/71	200	4	Tsr	Ba	--	16	53	Dom
12	33ab	120*	185	25	2/72	230	6	Tsr	Ss	--	14	--	Dom[a]
13	33bb	1	80	12	4/60	120	6	Tsr	Slt	83+	17	--	Dom
14	33bd	33	150	51	8/64	215	6	Tsr	Ba	--	15	--	Dom°
15	34cc	11	35	14	7/58	49	6	Tsr	Slt	3	30	--	Dom
16	34dc	7	35	22	3/60	67	6	Tsr	Ss	24+	12	--	Dom
17	35aa	15	83	21	7/71	120	6	Tsr	Slt	--	23	51	Dom
18	35ab	3	109	12	5/67	118	6	Tsr	Slt	7	92	49	Dom
19	35bc	8	40	8	12/63	65	6	Tsr	Ss	28+	18	49	Dom
20	35db	10	12	28	1/58	44	4	Tsr	Slt	8	14	--	Dom
21	6S 11W 23ab	6	115	14	4/68	145	6	Ten	Slt	--	18	54	Dom
22	24bd	26	91	9	5/71	221	6	Ten	C&G	--	209	50	Dom
23	26cc	12*	82	51	2/70	135	6	Ten	Slt	--	14	49	Mun
24	26dc	47*	101	19	7/65	150	6	Ten	Slt	116+	34	--	Dom
25	34dd	8*	30	50	8/68	219	6	Ten	Ss	1	97	49	Dom
26	35aa	25*	18	36	7/65	170	-	Tey	Slt	10+	27	--	Dom
27	35ac	Dry	--	--	(7/65)	118	-	Tey	--	--	36	--	(Dom)
28	35bb	50*	17	83	7/65	120	6	Ten	Slt	30	97	--	Dom

* pump test made; ** see text; + more than one aquifer; a chemical analyses in text; °observation well

Abbreviations: Ba, basalt; C, clay; C&G, clay and gravel; C&S, clay and sand; C&Slt, clay and silt; Dom, domestic; Fish, OSU Marine Science Ctr.; G, gravel; G&Slt, gravel and silt; Ind, industrial; Irr, irrigation; Mun, municipal; Rec, recreation; Rock, no rock type stated on log; S, sand; Sch, school; S&G, sand and gravel; Slt, silt; Ss, sandstone

WATER WELL LOG DATA, Continued

No. on Map	Well Location T. R. S. ¼/¼	Yield gpm	Draw-down feet	Depth to Static Water level feet	Depth to Static Water level date	Well Depth feet	Well Diameter inches	Water-bearing Zone(s) geologic formation**	Water-bearing Zone(s) rock type	Water-bearing Zone(s) thickness feet	Bedrock depth to top feet	Temp-erature °F	Water use
29	6S 11W 35cb	20*	101	44	1/71	226	8	Ten	Slt	3	58	49	Dom[a]
30	36ac	7*	24	31	8/64	136	6	Tey	Slt	--	28	--	Dom
31	36bd	Dry	--	--	(7/63)	161	6	Tey	--	--	50	--	(Dom)
32	36ca	30	110	40	8/70	158	6	Tey	Slt	--	2	--	Dom
33	7S 10W 21cb	9	90	6	6/65	110	6	Tsr	Ba	--	18	53	Rec
34	7S 11W 11ca	5	90	25	7/71	150	5	Tey	Slt	--	50	52	Dom
35	15ac	24	30	34	7/68	95	6	Qmt	S&G	69+	73	50	Dom
36	25ac	3	48	1	4/59	74	6	Ten	Rock	10	28	--	Dom
37	8S 10W 4da	7	19	18	8/68	41	6	Tsr	Slt	--	14	--	Rec
38	8dc	12	20	--	(11/70)	210	5	Tsr	Ba	--	60	52	Dom
39	17db	10	--	21	9/64	118	--	Tsr	Ss	--	--	--	Dom°
40	19da	5	Total	17	3/69	125	6	Tet	S&G	27	62	--	Dom
41	19dc	12	20	11	3/62	80	6	Qal	S&G	14	--	--	Dom
42	20cb	25*	5	19	3/71	42	8	Tet	Ss	21+	26	48	Dom
43	20cd	20	94	11	11/70	125	6	Tet	Rock	--	87	52	Dom
		(Log data is for deepening well from 82 to 125 feet. Water containing iron minerals cased off to 94 feet.)											
44	31cd	1	105	28	9/69	138	6	Ten	Slt	--	0	--	Dom
45	8S 11W 2cd	6	80	136	9/64	200	8	Toa	Rock	22	73	--	Mun
		(Well abandoned due to inadequate yield.)											
46	21cd	30	--	60	'55	107	8	Qmt	--	--	--	--	Mun[a]
47	28ca	10	90	30	5/68	133	6	Qmt	Slt	--	0	--	Dom
48	32db	15	46	15	8/56	63	6	Tmdb	Ss	11	7	--	Dom
49	36da	4	127	28	7/71	155	6	Ten	Ss	--	44	--	Dom
50	9S 9W 28cb	6	Total	31	9/71	52	6	Tet	Slt	21	30	--	Dom
51	9S 10W 7bc	15	55	22	7/70	77	6	Ten	Ss	7	26	--	Dom
52	9S 11W 5dd	3	485	15	5/71	500	6	Tma	Slt	--	8	54	Mun
		(Well abandoned due to inadequate yield.)											
53	8cd	4	18	14	9/66	32	6	Tmwc	Rock	8	24	--	Dom
54	12ad	6	38	22	11/66	60	6	Toa	Ss	--	8	--	Dom
55	32ba	23	20	10	10/70	223	10	Qmt	Slt	46+	129	49	Dom
56	32db	8	72	18	5/66	200	6	Qmt	Slt	5	52	50	Ind

*pump test made; **see text; +more than one aquifer; [a]chemical analyses in text; °observation well

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WATER WELL LOG DATA, continued

No. on Map	Well Location T. R. S. ¼/¼	Yield gpm	Draw-down feet	Depth to Static Water Level feet	Depth to Static Water Level date	Well Depth feet	Well Diameter inches	Water-bearing Zone(s) geologic formation**	Water-bearing Zone(s) rock type	Water-bearing Zone(s) thickness feet	Bedrock depth to top feet	Temp-erature °F	Water use
57	9S 11W 32dc	12*	10	30	10/63	84	6	Qmt	Slt	19	65	50	Dom
58	10S 8W 32ac	30	18	20	7/68	65	6	Tet	Slt	26+	17	53	Dom
59	36cd	Dry	--	--	(7/62)	73	8	Tet	--	--	16	--	(Dom)
60	10S 9W 2cb	20	Total	15	10/71	45	6	Tet	Ss	8	16	--	Dom
61	4ba	3	90	40	9/67	135	6	Tet	Slt	--	13	--	Dom
62	6bc	5	60	11	3/68	100	6	Tet	Ba	--	12	52	Dom
63	19cb	7	10	25	8/56	37	6	Tet	Rock	--	27	49	Dom
64	29cc	4	35	25	7/58	72	6	Tet	Ss	3	25	52	Dom
65	31da	4	60	30	8/69	95	6	Tet	Ss	--	16	--	Dom
66	35cd	10	30	10	5/67	61	6	Tet	Slt	6	33	--	Dom
67	10S 10W 1ab	15*	Total	40	10/67	332	6	Tet	Slt	52	40	--	Dom
		(Saline water encountered at 280-332 feet)											
68	2dc	4	Total	22	5/71	69	6	Tet	Slt	31	--	--	Dom
69	3cc	5	--	17	7/61	85	6	Tet	Slt	--	17	--	Dom°
70	4cc	4	25	10	7/62	31	6	Qal	Slt	--	27	--	Dom
71	9ab	0.5	165	50	9/70	215	6	Tet	Slt	--	13	--	Dom
72	17aa	20	35	9	5/60	66	6	Tey	Slt	11	29	--	Dom
73	17ab	5	120	30	8/71	150	6	Tey	Ss	--	31	--	Dom
74	19dc	9	56	24	4/67	83	6	Toa	Ss	12	16	52	Dom
75	25aa	1.5	Total	28	4/64	76	6	Tet	Ss	2	0	--	Dom
76	27ca	4	70	20	5/62	110	6	Tet	G	--	5	--	Dom
77	30ab	11	22	9	7/65	42	6	Toa	Slt	12	0	--	Dom
78	32ac	8	6	20	9/62	51	6	Ten	S	8	5	--	Dom
79	32dc	4	35	6	10/62	42	6	Tey	G	7	5	--	Dom
80	33cd	1	45	12	10/62	80	6	Tey	Slt	--	5	--	Dom
81	33db	2	Total	8	5/65	96	6	Tey	Slt	10	0	--	Dom
		(Well abandoned due to poor yield and hydrogen sulfide gas at 96 feet)											
82	36aa	8	26	6	4/64	50	6	Tet	Slt	4	10	--	Dom
		(Iron and hydrogen sulfide gas present)											
83	10S 11W 20bc	8	47	23	3/59	83	6	Tma	Rock	17	18	--	Dom
84	29ba	15*	120	17	2/64	250	6	Tmn	Slt	185+	59	55	Mun
		(Well abandoned due to inadequate yield)											
85	29bb	Dry	--	--	(5/58)	31	6	Tmcf	--	--	31	--	(Mun)

*pump test made; **see text; +more than one aquifer; [a]chemical analyses in text; °observation well

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WATER WELL LOG DATA, Continued

No. on Map	Well Location T. R. S. ¼/¼	Yield gpm	Draw-down feet	Depth to Static Water Level feet	Depth to Static Water Level date	Well Depth feet	Well Diameter inches	Water-bearing Zone(s) geologic formation**	Water-bearing Zone(s) rock type	Water-bearing Zone(s) thickness feet	Bedrock depth to top feet	Temperature °F	Water use
86	10S 11W 29dd	9	65	114	5/65	179	10	Tmn	Slt	--	18	48	Mun
		(Well abandoned due to inadequate yield)											
87	30aa	10	2	35	5/58	101	6	Tma	S	15	--	--	Mun
		(Well abandoned due to contamination by septic tanks)											
88	30aa	Dry	--	--	(11/58)	159	6	Tma	--	--	3	--	(Mun)
89	11S 8W 2ba	4	80	14	1/68	100	6	Tet	Slt	14+	17	53	Dom
90	4ab	4	74	16	8/66	94	6	Tet	Slt	--	23	53	Dom
91	12ba	6	100	25	8/71	125	6	Tet	Slt	--	27	52	Dom
92	13cd	4	--	--	(7/56)	65	5	Tet	Slt	37	17	--	Dom
93	15ba	5	35	14	3/63	54	6	Tet	Slt	20+	8	48	Dom
94	17ab	10	36	12	8/63	63	6	Tet	Ss	--	28	51	Dom
95	18aa	4	88	19	11/71	110	6	Tet	Slt	27	26	--	Dom
96	24ba	5	--	--	(7/56)	69	5	Tet	Slt	39	22	--	Dom
97	24bd	40	73	19	6/71	100	6	Tet	Ss	37	14	--	Dom
98	11S 9W 10bb	10	29	29	8/57	70	8	Tet	Ss	10	45	46	Sch°
99	10cd	1.5	70	8	2/69	85	6	Tet	Ss	48	35	53	Dom
100	11cb	3	50	33	7/65	83	6	Tet	Rock	--	29	--	Dom
101	13bd	8	11	20	10/56	35	6	Tet	Ss	4	24	--	Dom
102	11S 10W 5dc	8	25	48	5/59	100	6	Tey	Ss	5	21	--	Dom
103	6dc	2	50	10	5/62	60	6	Toa	Slt	--	3	--	Dom
104	7ad	8	Total	12	6/63	45	6	Ten	Slt	7	38	--	Dom
105	8bd	5	36	27	11/62	54	6	Tey	Slt	--	4	--	Dom
106	9ad	2	87	17	12/67	105	6	Tet	Ss	--	28	--	Dom
107	14bb	8	68	12	7/71	80	6	Tet	Ss	--	21	--	Rec
108	18aa	Dry	--	--	(3/48)	975	10	Tey	--	--	67	--	(Ind)
		(Well abandoned due to poor yield, saline water at 60-67 feet and 450 feet, and hydrogen sulfide gas at 720 feet)											
109	18ab	Dry	--	--	(10/48)	1900	10	Tey	--	--	--	--	(Ind)
		(Well abandoned due to poor yield, saline water at 60-65 feet and hydrogen sulfide gas at 335 and 1330 feet)											
110	19cd	24	0	28	8/58	42	6	Toa	Slt	8	34	51	Dom
111	19db	1.5	230	20	1/68	250	6	Ten	Slt	--	80	53	Dom
112	20ca	25	8	50	9/62	87	6	Tey	Slt	17	30	--	Dom°

*pump test made; ** see text; +more than one aquifer; ᵃchemical analyses in text; °observation well

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WATER WELL LOG DATA, Continued

No. on Map	Well Location T. R. S. ¼/¼	Yield gpm	Draw-down feet	Depth to Static Water Level feet	Depth to Static Water Level date	Well Depth feet	Well Diameter inches	Water-bearing Zone(s) geologic formation**	Water-bearing Zone(s) rock type	Water-bearing Zone(s) thickness feet	Bedrock depth to top feet	Temp-erature °F	Water use
113	11S 10W 20cd	9	--	59	6/61	120	6	Tey	Slt	--	24	--	Dom
114	20dd	10	20	1	1/69	100	6	Tet	Ss	--	33	52	Dom
115	29cb	Dry	--	--	(9/62)	100	6	Tet	--	--	50	--	(Dom)
116	30aa	3	70	30	8/68	100	6	Ten	Ss	--	40	53	Dom
117	11S 11W 2bb	8	--	32	9/62	67	6	Toy	Slt	--	5	--	Dom
118	4dc	12	24	9	10/69	48	6	Tmn	Slt	4	1	--	Dom
119	5dc	2	197	6	9/66	200	6	Tmn	Ss	13	2	50	Dom
120	9aa	Dry	--	--	(9/68)	200	6	Tmn	--	--	35	--	(Dom)
121	9ab	Dry	--	--	(2/70)	301	6	Tmn	--	--	98	--	(Dom)
122	9ba	16	10	30	10/63	80	6	Tmn	C	28	72	49	Dom
123	10ac	2.5	245	120	4/71	365	6	Tmn	Ss	--	29	--	Dom
124	10bb	5	50	23	8/62	65	6	Tmn	G	10	5	--	Dom
125	10bc	3	--	40	--	100	6	Tmn	Ss	--	39	--	Dom
126	16dc	3	20	19	7/62	30	6	Qmt	Slt	--	--	--	Dom
127	17aa	12	10	6	3/68	24	6	Qmt	S	4	--	50	Fish
128	20bc	60*	35	15	4/71	96	6	Qmt	S	26+	--	--	Rec
129	20cb	25*	5	50	6/69	94	6	s	S	10	--	--	Rec
130	22db	20	18	37	6/59	100	6	Toy	Slt	8	44	--	Dom
131	22dc	3	128	70	9/66	200	6	Toy	Ss	31	1	50	Dom
132	27aa	3.5	--	18	6/59	123	6	Toy	Ss	--	16	--	Dom
133	27bd	Dry	--	--	(7/62)	230	--	Toy	--	--	18	--	(Dom)
134	27dd	2	Total	15	3/65	90	6	Toy	Slt	2	12	--	Dom
135	31da	18	8	14	11/71	38	6	Qmt	S	5	36	--	Dom
136	32da	9	244	30	4/70	253	6	Tmn	C&Slt	--	95	50	Dom
137	33cd	7	73	22	9/71	95	6	Toy	Slt	--	36	--	Dom
138	36da	Dry	--	--	'60	115	6	Tet	--	--	12	--	(Dom)
139	12S 8W 4ab	7	43	19	3/63	80	6	Tet	Slt	--	40	48	Dom
140	7ca	3	45	28	10/60	76	6	Tet	Ss	--	12	--	Dom
141	8bd	7	--	20	4/57	100	6	Tet	Slt	34	0	--	Dom
142	8ca	16	56	16	8/62	88	8	Tet	Ss	8	12	--	Sch[a]
		(Well abandoned due to saline water at 80-88 feet)											
143	8dd	Dry	--	--	(9/60)	94	6	Tet	--	--	29	--	(Dom)

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WATER WELL LOG DATA, Continued

No. on Map	Well Location T. R. S. ¼/¼	Yield gpm	Draw-down feet	Depth to Static Water Level feet	Depth to Static Water Level date	Well Depth feet	Well Diameter inches	Water-bearing Zone(s) geologic formation**	Water-bearing Zone(s) rock type	Water-bearing Zone(s) thickness feet	Bedrock depth to top feet	Temp-erature °F	Water use
144	12S 9W 12ad	8	--	--	5/58	90	6	Tet	Slt	--	18	--	Dom
145	13ba	7	60	7	5/68	78	6	Tet	Slt	46+	17	--	Dom
146	12S 11W 4aa	3	37	33	11/65	70	6	Toa	Slt	--	4	--	Dom
147	6aa	8*	4	30	6/64	55	6	Qmt	S	19	47	--	Dom
148	18bb	7	10	--	7/60	40	6	Qmt	Ss	--	32	--	Dom
149	12S 12W 25aa	4	--	55	6/60	109	6	Toy	Ss	--	60	--	Dom
150	25dd	4	Total	8	5/60	103	6	Toy	Slt	6+	24	--	Dom
151	13S 9W 30dd	16	37	24	8/70	71	6	Tet	Slt	5	0	--	Dom
152	31bc	20	--	35	7/61	70	6	Tet	Ss	--	26	--	Dom
153	31cc	4	56	28	4/65	104	6	Tet	Ss	--	22	50	Rec
154	13S 10W 27dd	6	44	25	3/69	75	6	Tet	Ss	36+	16	55	Dom
155	30dd	15	--	1	10/58	68	6	Tet	Ss	--	43	--	Dom
156	32ac	20	40	17	8/64	66	6	Tet	Ss	--	50	--	Dom
157	33bb	14	38	12	9/64	64	6	Tet	Rock	4	52	53	Dom
		(Saline water cased off at 30-32 feet)											
158	34ca	7*	56	24	4/64	138	6	Tet	Slt	18	25	50	Dom
159	35ad	2	--	23	1/61	75	6	Tet	Ss	--	20	--	Dom
160	13S 11W 7dc	1	234	90	12/71	325	6	Toa	C&S	50	60	52	Dom
161	7dc	20	80	25	7/71	130	6	Toa	Ss	25	80	51	Dom
162	9ba	3	104	86	4/70	203	6	Toa	Slt	--	45	52	Dom
163	9bb	7	4	48	7/69	60	6	Toa	Slt	4	48	53	Dom
164	9bc	4*	Total	75	7/70	93	6	Toa	Slt	3	22	--	Dom
165	10cc	Dry	--	--	(6/70)	245	--	Ten	--	--	17	--	(Dom)
166	16ac	8	30	14	1/67	86	6	Toa	Slt	--	38	52	Dom
167	16bc	10	120	60	11/69	199	6	Toa	Ss	5	143	53	Dom
168	22bb	50	145	10	4/71	155	6	Tet	Ss	53	25	52	Dom
169	26bd	30	22	6	4/63	52	6	Tet	Ss	--	37	52	Dom
170	27ac	4	318	2	6/70	320	6	Tet	Slt	10	33	51	Dom
171	27ac	12	85	15	6/70	100	6	Tet	Ss	5	50	52	Dom
172	27bd	1.5	87	42	6/70	130	6	Tet	Slt	43	14	--	Dom

*pump test made; **see text; + more than one aquifer; [a]chemical analyses in text; °observation well

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WATER WELL LOG DATA, Continued

No. on Map	Well Location T. R. S. ¼/¼	Yield gpm	Draw-down feet	Depth to Static Water Level feet	Depth to Static Water Level date	Well Depth feet	Well Diameter inches	Water-bearing Zone(s) geologic formation**	Water-bearing Zone(s) rock type	Water-bearing Zone(s) thickness feet	Bedrock depth to top feet	Temp-erature °F	Water use
173	13S 11W 28ab	15	80	20	6/70	100	6	Ten	S	15	28	52	Dom
174	28ad	15	5	8	9/60	30	6	Qmt	G	13	--	--	Dom
175	30bd	45	30	26	4/69	75	12	Qmt	G&Slt	31+	25	53	Irr
176	31ba	8	20	35	8/67	63	6	Qmt	S	14	0	--	Dom
177	14S 9W 1bb	10	103	14	7/71	155	6	Tet	Ss	--	19	--	Dom
178	2cd	5	20	18	12/55	50	6	Tet	Ss	9	32	--	Dom
179	4cc	25	21	29	5/56	61	6	Tet	Ss	3	20	54	Dom
180	7bb	Dry	--	--	(6/68)	206	6	Tet	--	--	30	--	(Rec)
181	14S 10W 8bd	19	4	17	3/65	61	6	Tet	Ss	--	8	50	Rec
182	12dd	3	50	31	4/69	85	6	Tet	Ss	25+	21	53	Dom
183	13db	5*	100	8	8/69	213	10	Tet	Ss	--	78	50	Dom
184	25bd	38	195	40	10/71	290	6	Tet	Ss	--	14	--	Dom
185	14S 11W 5bb	6	20	30	8/60	50	6	Toa	Slt	--	38	--	Dom
186	32cd	13*	1	14	4/65	64	6	Tet	Ss	--	23	48	Dom
187	34ca	27*	28	6	6/70	135	6	Tet	Slt	--	87	--	Dom
188	35ac	3	--	14	3/72	150	6	Tet	Ss	--	4	49	Dom
189	14S 12W 22dd	9	80	--	(6/56)	84	6	Teyb	Rock	--	6	--	Dom
190	15S 10W 1da	Dry	--	--	(7/62)	148	8	Tet	--	--	20	--	(Sch)

*pump test made; **see text; +more than one aquifer; [a]chemical analyses in text; °observation well

Abbreviations: Ba, basalt; C, clay; C&G, clay and gravel; C&S, clay and sand; C&Slt, clay and silt; Dom, domestic; Fish, OSU Marine Science Ctr.; G, gravel; G&Slt, gravel and silt; Ind, industrial; Irr, irrigation; Mun, municipal; Rec, recreation; Rock, no rock type stated on log; S, sand; Sch, school; S&G, sand and gravel; Slt, silt; Ss, sandstone

APPENDIX C
GEOLOGIC FORMATION WELL-YIELD SUMMARY

Geologic formation	No. of well logs	Yield range gpm	Yield average gpm	Poor quality water	Dry well	4 or less gpm	5 to 9 gpm	10 to 24 gpm	25 to 99 gpm	100 or more gpm	Observation well	Chemical analysis
Qal	2	4-12	8	0	0	1	0	1	0	0	0	1
s	1	-	25	0	0	0	0	0	1	0	0	0
Qmt	15	3-60	19	0	0	1	4	7	3	0	0	0
Tmwc, Tma, Toy	14	0-20	5	1	2	7	3	2	0	0	0	0
Tmcf, Tmdb, Teyb	3	0-15	8	0	1	0	1	1	0	0	0	0
Tmn, Toa, Ten, Tey	66	0-50	9	3	8	17	20	15	6	0	1	1
Tet	71	0-50	10	5	6	21	19	17	8	0	2	1
Tsr	18	0-120	11*	0	1	3	6	5	2	1	2	1
TOTAL	190	0-120	10**	9	18	50	53	48	20	1	5	4

* A high-yield 120 gpm well is excluded to obtain a more realistic yield average for this formation.

** Average yield (10 gpm) obtained by dividing number of well logs (190) into gpm produced (1,918) during well tests. Figure may be high due to inaccuracy of testing method (bailer rather than pump) used for 168 of the 190 wells.

Data source: State Engineers' Office, Salem, water well logs

APPENDIX D
QUADRANGLE MAP WELL-YIELD SUMMARY

Quadrangle	No. of well logs	Yield range gpm	Yield average gpm	Poor water quality	Dry well	4 or less gpm	5 to 9 gpm	10 to 24 gpm	25 to 99 gpm	100 or more gpm	Observation well	Chemical analysis
Hebo	32	0-120	13*	0	4	4	8	8	7	1	1	2
Euchre Mtn.	15	1-25	9	1	0	3	6	5	1	0	1	0
Cape Foulweather	8	3-30	14	0	0	2	1	4	1	0	0	1
Marys Peak	19	0-40	9	1	2	5	8	2	2	0	0	1
Toledo	43	0-25	7	5	4	17	13	8	1	0	3	0
Yaquina	32	0-60	9	1	5	9	8	8	2	0	0	0
Alsea	2	5-10	8	0	0	0	1	1	0	0	0	0
Tidewater	19	0-38	13	1	2	4	3	6	4	0	0	0
Waldport	20	0-50	12	0	1	6	5	6	2	0	0	0
TOTAL	190	0-120	10**	9	18	50	53	48	20	1	5	4

* A high yield 120 gpm well is excluded to obtain a more realistic yield average for this formation.

** Average yield (10 gpm) obtained by dividing number of well logs (190) into gpm produced (1,918) during well tests. Figure may be high due to inaccuracy of testing method (bailer rather than pump) used for 168 of the 190 wells.

Data source: State Engineer's Office, Salem, water well logs

APPENDIX E

PLANNING AND GEOLOGY

by Lynn Steiger and Herbert G. Schlicker

Land use planning to promote public health, safety, and general welfare is the responsibility of governmental agencies. Each of these human elements is in some way related to the geologic conditions of the County. Therefore, an effective plan of development must consider the possible geologic hazards.

The land use plan is a document prepared to provide guidance for the orderly growth of a community. It indicates the land uses suitable and desirable for each area for the foreseeable future. The zoning ordinance is one of the legal documents used to implement the land use plan. The accompanying geological report provides the basic information needed to make recommendations for land use.

For planning purposes, Lincoln County has been divided into three major regions: 1) the north County region, 2) the central County region, and 3) the south County region. The north County region is subdivided into five planning areas: Salmon River, Lincoln City, Kernville-Siletz, Depoe Bay-Gleneden Beach, and Siletz-Logsden. The central County region comprises the Newport planning area, the Yaquina River planning area, the Toledo planning area, and the Seal Rock planning area. The south County region comprises the Waldport planning area, the Alsea River planning area, San Marine-Waconda Beach planning area, and Yachats planning area. A map showing the general outline of the planning areas appears on pages 164-165.

Geologic conditions in any one planning area must serve as the basis for determining the proper use of the land. Problems encountered in land development will depend on many factors, such as type of bedrock, condition of the soils, and susceptibility of areas to landsliding, erosion, and flooding. When these problems are understood, they can sometimes be rectified. As examples: low wet ground can be tiled; hillside excavations can be limited in depth to avoid creating landslides; and sewerage systems can be installed where poor drainage would prevent use of septic tanks. In other words, certain types of ground that would ordinarily be classified as unsuitable can be used under appropriate engineering applications.

Summary of Geologic Units

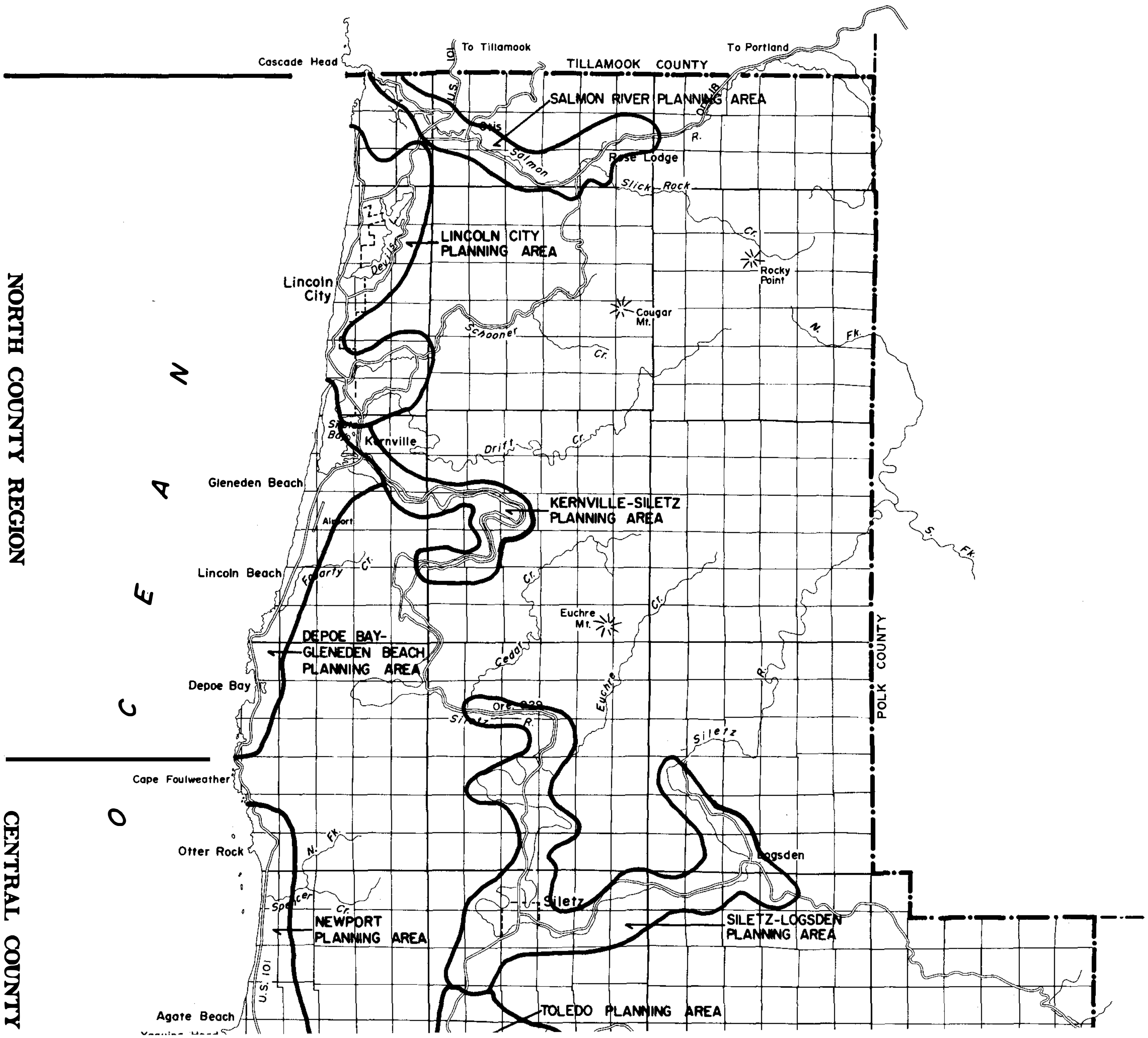
The following is a summary of the character and distribution of the various geologic units that make up the foundations of Lincoln County. The problems inherent in these units are briefly reviewed. For more detailed information, the text of the bulletin should be consulted and the geologic and hazard maps used for a visual concept.

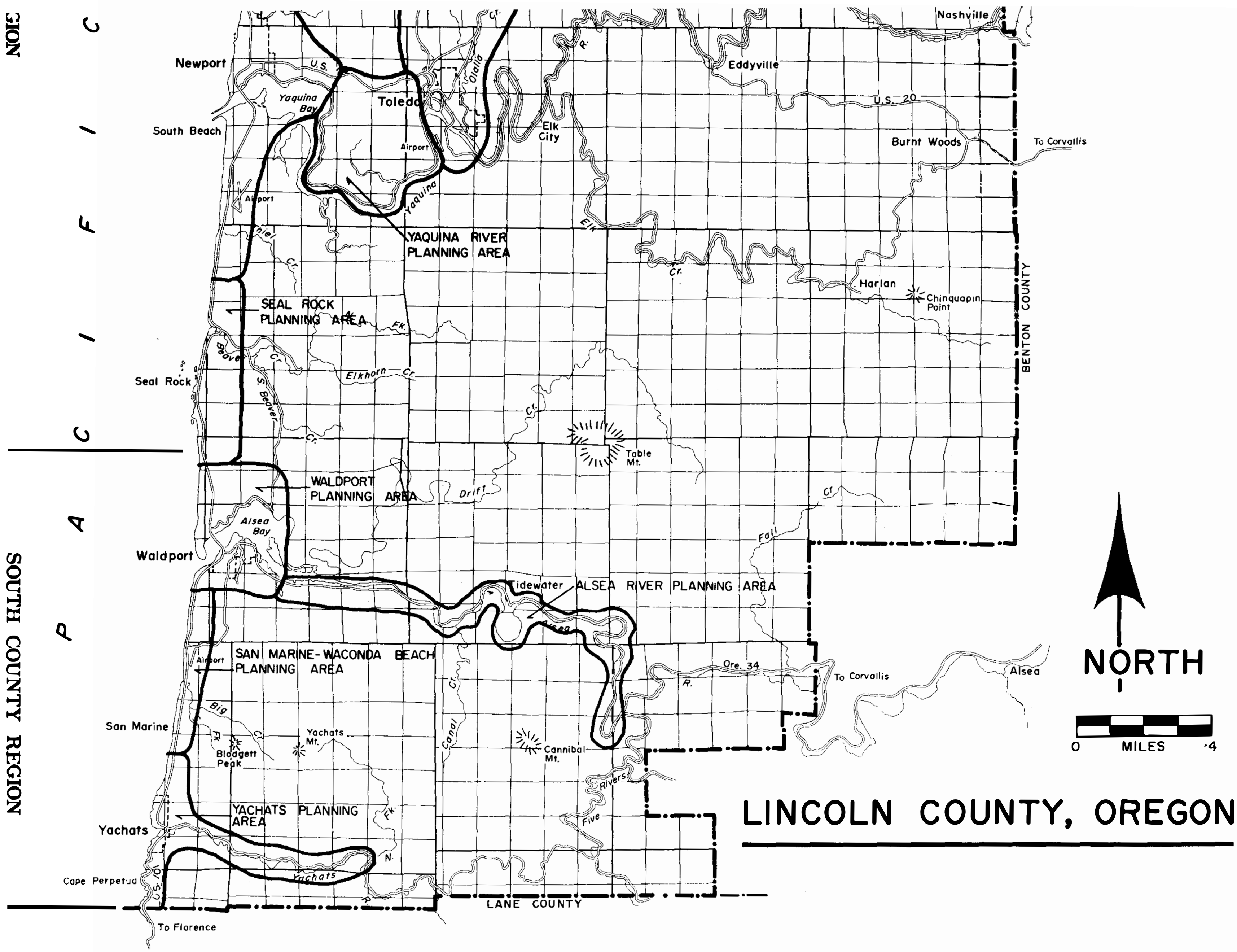
Siletz River Volcanics

The oldest bedrock unit occupies the mountainous northeastern part of the County. Known as the Siletz River Volcanics, it is composed of lava flows, pillow basalts, breccias, and thick sections of interbedded volcanic sediments. Much of the unit is deeply weathered and in steep terrain. Its interbedded sediments are mostly volcanic ash which is susceptible to landslide and erosion. Development in areas of Siletz River Volcanics is mainly along the Salmon River Valley east of Otis Junction and along the Siletz River Valley east of Kernville. Elsewhere, areas underlain by these rocks are remote and undeveloped with the exception of logging enterprises.

Basaltic headlands

Along the coast of Lincoln County masses of basaltic rock form bold headlands, as at Cape Perpetua, Cape Foulweather, and Cascade Head. These rocks are in most places resistant to erosion and slope failure but they present problems for development because of steep, mountainous terrain, high cost of road construction, and expense of sewerage installation. Such areas are by-passed for major development.


NORTH COUNTY REGION
CENTRAL COUNTY
O C E A N
To Tillamook
To Portland
TILLAMOOK COUNTY
Cascade Head
U.S. 101
SALMON RIVER PLANNING AREA
Otis
Salmon
R.
Rose Lodge
Slick Rock
Cr.
Rocky Point
LINCOLN CITY PLANNING AREA
Devils
Lincoln City
Cougar Mt.
Schooner
Cr.
N. Fk.
Siletz Bay
Kernville
Drift
Cr.
Gleneden Beach
KERNVILLE-SILETZ PLANNING AREA
Allegany
S. Fk.
Lincoln Beach
Fogarty
Cr.
Euchre Mt.
Cr.
DEPOE BAY-GLENEDEN BEACH PLANNING AREA
Cedar
Euchre
Cr.
R.
POLK COUNTY
Depoe Bay
Ore. 229
Siletz
R.
Siletz
Cape Foulweather
Otter Rock
N. Fk.
Logsden
Spencer
Cr.
Siletz
NEWPORT PLANNING AREA
SILETZ-LOGSDEN PLANNING AREA
U.S. 101
Agate Beach
TOLEDO PLANNING AREA


SOUTH COUNTY REGION
P A C I F I C
LINCOLN COUNTY, OREGON
NORTH
0 MILES 4
Newport
South Beach
Yaquina Bay
Toledo
Airport
Elk City
Eddyville
Nashville
U.S. 20
Burnt Woods
To Corvallis
YAQUINA RIVER PLANNING AREA
SEAL ROCK PLANNING AREA
Seal Rock
Elkhorn Cr.
Harlan
Chinquapin Point
BENTON COUNTY
Table Mt.
WALDPORT PLANNING AREA
Alsea Bay
Waldport
Drift Cr.
Fall Cr.
Tidewater
ALSEA RIVER PLANNING AREA
SAN MARINE-WACONDA BEACH PLANNING AREA
Ore. 34
To Corvallis
Alsea
San Marine
Big Cr.
Yachats Mt.
Blodgett Peak
Canal Cr.
Cannibal Mt.
Five Rivers
YACHATS PLANNING AREA
Yachats
Cape Perpetua
Yachats R.
LANE COUNTY
To Florence

Tyee Formation

The most widespread bedrock formation is the Tyee, which underlies the mountainous area of southeast Lincoln County. Because the formation is composed of massive sandstone beds interlayered with less competent beds of shale, problems in slope stability occur on steep terrain where bedding dips toward the valleys. Development in the Tyee Formation is generally limited to roads, which extend east from the coast into the back country along the major river valleys.

Tertiary siltstone units

Fine-grained sedimentary rocks, including siltstone, shale, and mudstone, crop out in the hills immediately east of the coast in a northerly trending band ranging from 2 to 8 miles wide. Several rapidly developing areas on these rock units are encountering problems: impermeability of the rocks, unstable slopes, excessive erosion, lack of good ground water, high water table in the lower slopes and colluvial soils, and a tendency for the rock to ravel and produce talus in road cuts.

Marine terrace deposits

Marine terraces parallel the beaches of Lincoln County and extend inland from the coast as much as a mile in some places. Most of the County's development is situated on these terraces.

The terrace sediments and overlying old dune sands exposed in sea cliffs are subject to undercutting by storm waves, and landslides are common. Even without landsliding, the sea cliffs are eroded back about a foot each year.

Developments on the sand dune areas usually encounter excessive permeability; however, in some areas layers of iron-cemented hardpan prevent downward percolation. When the soil and vegetation are removed from the dunes, exposing loose sand, wind can cause sand to migrate to other areas. Foundations in loose sand will settle under moderate loads.

Septic tanks in terrace and dune materials can create problems, particularly in the more densely populated areas, because effluent percolates downward to the water table or exits along the sea cliffs onto the beaches. Where impermeable layers are present in the terrace and dune deposits, septic tanks will not drain properly and effluent and other water will stand at the surface, creating a health problem. Clay soil tends to develop in the depressions on the marine terrace and dune deposits, resulting in extremely slow drainage. Such areas generally have a high water table.

Tidal flat soils

Tidal flat soils which form in drowned valleys are common to all of the major streams and estuaries along the coast in Lincoln County. Tidal muds are soft and compressible. They often contain layers of peat. These soils are very weak, and foundations for roadbeds or buildings will settle excessively. The areas are subject to flooding during ocean storms or during periods of heavy runoff, and major floods occur when storms and high tides occur simultaneously. Development along the estuaries is limited to marine recreational and marine industry. Structures in these areas must be built to withstand the effects of flooding and have adequate foundation design.

Sandspits and active dunes

Siletz, Yaquina, and Alsea Rivers have well-developed sandspits and dunes at their mouths. These low transient features are suitable only for seasonal recreational activities since they are highly vulnerable to erosion by wind and storm waves. The abundance of sawed driftwood incorporated into the spits and low dunes is a good indication that high tides and storm waves have carried them there in fairly recent time.

North County Region

Salmon River planning area

The segment of the planning area west of 101 and north of Three Rocks Road is shown on the land use plan and zoning maps as suitable for low-density residential development. Conditions limiting development in this area are seasonal high water table, inadequate soils for subsurface sewage disposal, and slopes greater than 30 percent with a potential for landslide and erosion.

The lowlands adjacent to the Salmon River are subject to flooding, even in some diked areas. The alluvial soils along Salmon River east of Otis Junction have moderate limitations for roads, construction and maintenance, moderate foundation loads, and subsurface sewage disposal. This area has been zoned for recreation residential land uses. The steeper ground adjacent to the river lowlands, extending east to Panther and Slick Rock Creek, has also been zoned recreation residential.

The comprehensive land use plan indicates two commercial areas along Salmon River. The first extends from Highway 101 east to Otis Junction, between Oregon Highway 18 and the river. The second is located north of Oregon Highway 18 and east of Slick Rock Creek. Limitation to development in the first area is due to danger of flooding. In both areas, buildings requiring substantial foundation loads should not be constructed without a study of the soil conditions.

Lincoln City planning area

This area includes three unincorporated areas. These are along Highway 101 between Cutler City and Taft, along the West Devils Lake Road, and the Roads End vicinity and adjacent watershed.

Within the incorporated area of Lincoln City, most of the land is on marine terrace overlain by old sand dunes. Problems normally affecting septic tanks in rapidly draining or poorly draining areas is not of concern here because of the installation of a public sewerage system.

Major problems occur on the marine terraces because of erosion by storm waves. The sea cliffs are eroded at a rate which sometimes exceeds 1 foot per year. Therefore, buildings on the terrace should be located far enough from the terrace escarpment to be free of possible damage from erosion or landslide within the expected life of the structure. In the sand dune area, excavations and leveling for building sites usually remove stabilizing vegetation and soil, exposing loose sand to wind transport. The sand should be stabilized as soon as possible after such excavations are made. The practice of leveling large areas for buildings or parking lots and leaving them unstabilized for months creates a distinct hazard to adjacent areas which receive drifted sand accumulations.

The area around Devils Lake and northward to the Salmon River is underlain by siltstone and associated clay soils. This area has rather heavy demand for urbanization; however, the soils are not suitable for use of septic tanks. Therefore, before development continues, a sewerage system must be installed. There are also problems of excessive erosion because of the heavy runoff in the areas underlain by impermeable soils on steep slopes. Landslides can also be initiated where large or excessively steep excavations are made. The lower slopes adjacent to the lake have a seasonal high water table.

Siltstones and clay soils are present in the bedrock east of Highway 101 between Taft and Kernville and on the sides of the valleys of Drift Creek and Schooner Creek. These areas have limitations similar to those surrounding Devils Lake. The lowlands west of Highway 101 in Cutler City and in Taft are underlain by tidal-flat soils. These soils are relatively compressible, and excessive settlement of roads and building foundations will require subsurface investigations for foundation design.

Kernville-Siletz and Siletz-Logsden planning areas

The tidal flats adjacent to the lower end of the Siletz River present problems for highway construction because of uneven settlement in the soft, compressible soils and frequent flooding. Development in the valley area upstream from Kernville is limited by high water table, flooding, and soft compressible soils. The wide alluvial terraces in the upstream region are satisfactory for agricultural purposes, but flooding is a potential hazard for other uses such as residential or road construction.

The upland area immediately east of Highway 101 is composed of siltstone. Farther east along the Siletz River, the uplands are underlain by Siletz River Volcanics and, in the vicinity of Siletz, by Tyee sandstone. The steep slopes in these rocks are subject to landsliding, and many areas along the river valley have been indicated as landslide topography. Anyone building on such terrain should be aware of the possibility of a high water table and unstable slopes.

The flood plain east of Kernville is designated on the land use plan as recreation residential and zoned marine residential. Much of the unincorporated land upstream from the influence of tide and from Siletz east to Logsden is zoned and is expected to remain rural residential and agricultural. The high areas underlain by Siletz River Volcanics and Tyee Formation are designated as forest land; problems of slope stability relative to road construction should be considered.

Depoe Bay-Gleneden Beach planning area

The area from Depoe Bay north to Boiler Bay is underlain by basalt and basalt breccia. Farther north the Gleneden area is underlain by marine terraces, and in some places, the terraces are overlain by dune sand partly covered by dense vegetation and thick soil. The use of septic tanks throughout the Depoe Bay and Gleneden Beach area is not recommended and can be tolerated only where the density of development is extremely low. Before more intense development can proceed, a sewerage system should be installed.

The continued development of land on the Siletz spit will likely encounter more of the severe erosion problems which have occurred for the past several years. The marine terraces to the south have also been eroding back by wave action, and landslides have occurred in some places. Some parts of the marine terraces have a high seasonal water table.

Central County Region

Newport planning area

The Newport planning area extends from Cape Foulweather to South Beach south of Yaquina Bay. Except for the basaltic headlands at Cape Foulweather and at Yaquina Head, the area is underlain by marine sediments capped by marine terrace sediments and sand dunes. At Cape Foulweather the basalt cliffs rise steeply from the beach for several hundred feet. Erosion is not a factor in the basalt headlands, but immediately to the south toward Otter Rock unstable slopes and marine terraces are eroding back at various rates. Just north of Otter Rock, the head of a small active landslide extends several hundred feet back from the beach. Although erosion at Otter Rock in the vicinity of the Devils Punch Bowl is relatively slow, it has progressed about 10 feet in the last 20 to 30 years. Just south of the Devils Punch Bowl, a slide extends from the beach to the Devils Punch Bowl Road.

In the community of Otter Rock, the water table on the marine terrace stands high much of the year and septic tanks do not drain properly. Before development proceeds in this area, a sewer system will be necessary.

Coastal erosion and landslides are extensive from Otter Rock southward to Yaquina Head. Here the abundance of landslides is due to the steep seaward dip of the underlying bedrock. Problems are especially apparent where highway fills have been placed across canyons or small valleys. Repairs are required annually in these areas. Sliding extends east of the highway, and in some areas the power lines require frequent repair and realignment.

There are large landslides on both the north and south sides of Yaquina Head. The landslide on the south side has made several buildings unusable. In Agate Beach, subsurface drainage is restricted and a public sewerage system is necessary before additional developments are made.

In the vicinity of Jumpoff Joe in Newport, the sea coast has retreated as much as several hundred feet since the turn of the century. A number of homes have been destroyed or badly damaged in recent years as a result of landslides in this area. Before any additional shoreline areas are developed, the stability of the slope should be studied by soil engineers and geologists. Often an apparently stable slope can be reactivated by the addition of houses and streets.

From Nye Beach southward to Yaquina Bay the shoreline is being eroded by storm waves. People considering building structures on these cliffs should be aware that the cliffs are eroding back about one foot per year, and erosion could be much more severe if landslides occur. The practice of placing embankments over steep vegetated slopes is extremely hazardous because the vegetation will decompose to produce a slip plain at the interface between the embankment and the original ground.

East of the shoreline in Newport from about Nye Beach south to the bay, the marine terraces are overlain by loose dune sand. These sands are stabilized where covered by vegetation; however, where the vegetation has been removed or none has grown, the sand is exposed to erosion and transport by the wind. Frequently during high winds, the sand can be observed drifting across streets and into properties adjacent to the street.

Just east of Newport, in the vicinity of McClean Point, much of the slope has been affected by landslides. Development in this area should proceed with great caution. The making of steep cuts, removal of toe support, the additional weight of embankments on the upper slopes, and the addition of moisture from the developments, including subsurface sewage disposal, all add to the instability of the slope. Serious problems can arise, especially following periods of extremely heavy rainfall. Developments in this area could suffer serious slope problems unless the slopes and embankments are properly constructed and a public sewerage system is installed.

The area south of Yaquina Bay from Highway 101 eastward as far south as Henderson Creek is subject to seasonal high water table. Before development reaches a greater density, a public sewerage system should be installed. A high water table creates problems for foundations of structures, and in some areas the water will stand at the surface after a heavy rainfall.

Yaquina River planning area

The Yaquina River planning area extends eastward from McClean Point to Hidden Valley just west of Toledo. This area is underlain by highly weathered, impermeable marine bedrock which is subject to slope failure, especially where cuts are made. Development in these areas is presently limited to rural densities by the steepness of slope, the weakness of the weathered rock and soil horizons, and the susceptibility to landslide, together with problems of subsurface sewage disposal.

Toledo planning area

This area includes the urbanizing land around Toledo and portions of Depoe and Ollala Creek Valleys. Most of the area which is being urbanized is either on steep slopes having a potential for landslide or lowlands adjacent to the valleys which have a high water table and weak foundation soils. Present zoning in most of the area allows for maximum one unit per acre; however, development could conceivably become denser with the installation of a subsurface sewerage system. Some of the steep areas within the city limits of Toledo are old landslides. All steep slopes and landslide topography should be examined before deep cuts are allowed, otherwise sliding could occur. Certain platted streets within the city limits have not been constructed because of the steep topography. Development in these areas should be limited. Development is not practical in many of the areas adjacent to the city until a public sewerage system and a water supply have been installed.

Most of the area south of the Yaquina River and to the west is landslide topography. Land development and road-building activities could easily reactivate erosion and landsliding, consequently home sites in this area should be adequately studied and the density of development should be kept low.

Seal Rock planning area

The Seal Rock planning area extends north from Collins Creek to Lost Creek. The area is composed of a narrow band of marine terrace overlain by dune sand bounded on the west by the Pacific Ocean and on the east by upland areas. Development is occuring mostly on the marine terrace. Much of the upland area is owned by timber producers and not available for development. The marine terraces are undergoing erosion by the sea and many areas of slope failure occur along the escarpments adjacent to the beach. Where shallow enclosed basins are present on the surface of the marine terrace, a clay soil has developed, and the water table stands near the surface most of the year. Before development can attain a higher density, it will be necessary to install drainage and a public sewerage system. Homes built along the edge of the sea cliffs are subject to the damage by landslide and erosion and, therefore, adequate setbacks should be required.

The Beaver Creek area is subject to flooding; therefore, any development or structures in the flood plain should be designed to withstand this hazard. Since the slopes adjacent to Beaver Creek are generally unstable, land use along the creek should be continued as natural resources and rural residential.

South County Region

Waldport planning area

Marine terraces occupy most of the coastal land in the Waldport area. The terrace margins are retreating at the rate of about a foot a year. Here, as elsewhere on marine terraces, setbacks for structures will be necessary to assure that they are not prematurely damaged by landslide or erosion. Where terraces are overlain by sand, subsurface sewage disposal is limited, especially in the upland areas and along steep slopes. Low lying areas within Waldport have a seasonal high water table, and where urban renewal will result in heavier foundation loads, foundation studies should be made.

The large sand spit development just north of Alsea Bay will require a sewerage system, and it is anticipated there will be continual problems with drifting sand and possible future erosion along the shoreline like that at Siletz Spit. These problems should be considered in the construction and location of buildings and roads. Sand spits are also a possible source for ground water unless contaminated by the use of septic tanks. East and north of Alsea Bay the lands are either hilly uplands or low tidal-flat soils. The lowlands are subject to floods both by river and by high tides. The use of septic tanks and problems in foundation settlement are common to the tidal flat areas whereas erosion and impermeable soils as well as landslides affect the hillside properties.

South of the bay and west of Highway 101, much of the land is underlain by sand dunes and terraces. Problems associated with this area are wave erosion and, where steep cuts are made, sloughing of the sand. A public sewerage system is necessary for development in this area.

Alsea River planning area

The Alsea River planning area extends east from Eckman Slough to the confluence of the Alsea River with Five Rivers. Immediately east of Eckman Slough the bedrock is siltstone; the remainder of the planning area is underlain by Tyee sandstone. Most of the developing areas along the river are in alluvial terrace deposits. The low terraces are subject to flooding, and development should be designed accordingly. The upper terraces seldom or never flood, and foundation characteristics of the terraces are generally good for light to moderate structures. Erosion of the stream bank is a problem in some areas and should be investigated before structures are placed adjacent to the river.

In the upland areas underlain by siltstone, the rock is impermeable as well as subject to landsliding; therefore, steep cuts or very high cuts are not recommended. The use of septic tanks will require large drain fields and low density housing. Most of the terrain underlain by the Tyee sandstone is mountainous with steep-sided canyons. The very large landslides have occurred where the dip of the sandstone beds is roughly parallel to the slope of the ground. Road cuts or other excavations made into this sandstone could cause slides where the beds dip toward the open cut.

On alluvial terraces which slope away from the river, low lying areas with a high water table and an impermeable clayey soils near the surface can be improved by draining. The use of the land along the river should be continued as recreation residential in the western part and agricultural and farm forest to the east.

San Marine-Waconda Beach planning area

The San Marine-Waconda Beach planning area is a marine terrace overlain by dune sand. The terraces are low, ranging from 20 to about 30 feet in height and are subject to wave erosion. Sometimes during the wet season the water table is slightly above the ground surface.

In many places, the upper surface of the terrace is overlain by a blue, impermeable clay which makes septic tanks inoperative. Other areas have an impermeable hardpan layer; if septic tanks are used, effluent may exit on the surface farther downslope. Where septic tanks have been operating for a long period of time, the sand becomes impregnated with organic materials from the effluent and slowly becomes impermeable. These problems are most apparent where the density exceeds about one unit for each 5 acres.

Flooding occurs along Big Creek and landslides are common in the adjacent uplands.

Yachats planning area

The Yachats planning area is underlain by basalt, except for the northern portion, which is underlain by basaltic sandstone and gravelly sandstone. Much of the low area along Highway 101 is overlain by a thin cover of soil composed of sand and gravel. Since the soils overlying the basalt and sandstone are thin, they quickly become saturated by rainfall and septic tank effluent. Problems in development in these areas are a seasonal high water table and low permeability.

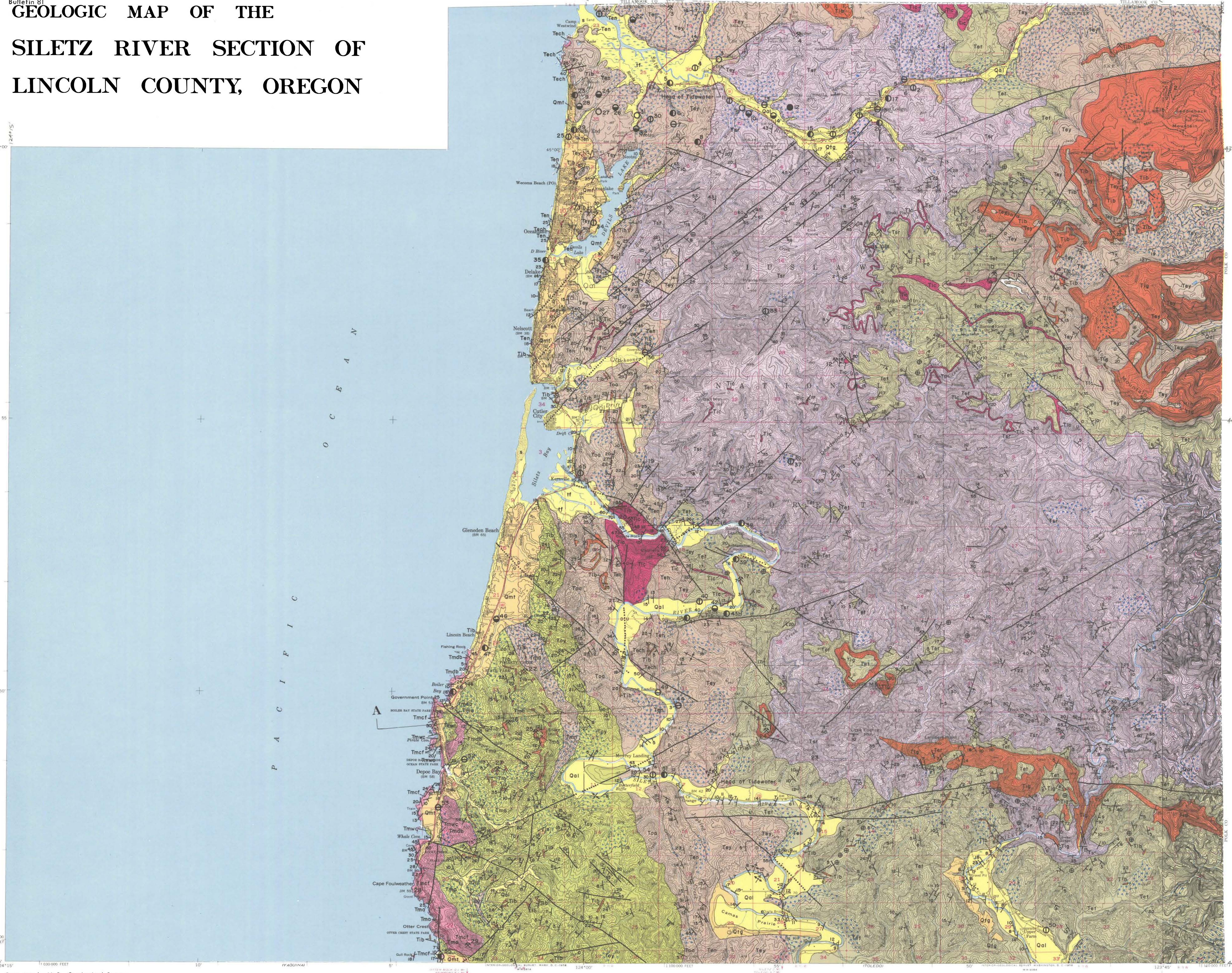
The steeply to moderately sloping land east of Highway 101 and north of Yachats is composed of weathered basaltic sandstone and breccia. Although in some areas the rock is impermeable, in others permeability is greater and the use of septic tanks appears to be possible for low density housing. Relatively impermeable soils on the steeper volcanic terrain in the foothills to the east have moderate to severe limitations for road or street construction and subsurface sewage disposal.

Alluvial soils along the flood plains of the Yachats River are somewhat better drained; however, there is a seasonal high water table in the alluvial soils. Before development reaches a higher density in the Yachats planning area, a subsurface sewerage system should be installed. The location of structures along the shoreline should consider the continual erosion of the marine terrace, and setbacks should be sufficient to prevent damage. In the steeper terrain where road construction has caused the removal of vegetation, the impermeable soils and the rapid runoff will subject the area to excessive erosion.

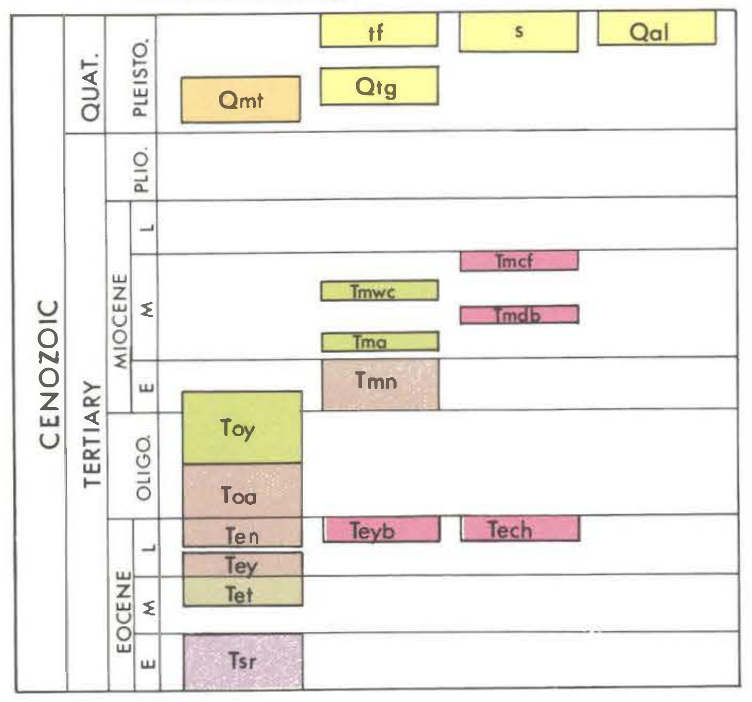
The Yachats River area east of Yachats has land suitable for low density development. Before density can be increased, a subsurface sewerage system will be required. The steeper slopes adjacent to the river have frequently been involved in landslide. Here, excavations for road or building construction might initiate additional landslides.

GEOLOGIC MAP OF THE SILETZ RIVER SECTION OF LINCOLN COUNTY, OREGON

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



STRATIGRAPHIC TIME CHART



EXPLANATION

Unconsolidated surficial units

Qal — *Alluvial bottom land deposits composed primarily of silt, sand, and gravel.*

s — *Unconsolidated fine- to medium-grained beach and dune sand.*

tf — *Flat-lying deposits of saturated fine sand and clayey silt (tidal flats) at or near sea level.*

Qtg — *Terrace deposits composed primarily of alluvial gravel, sand, and silt.*

Stratigraphic units

Qmt — Marine terrace deposits
up to 75 feet of semi-consolidated uplifted beach sand overlain locally by fine-grained dune deposits. Lenses of gravel are present in places.

Sandstone of Middle Tertiary Age

Tmwc — Sandstone of Whale Cove
fine- to coarse-grained massive to thick-bedded arkosic sandstone and thin-bedded micaceous carbonaceous siltstone; sandstone commonly shows cross-bedding, large scale load casts, convolute bedding and slump structures.

Tma — Astoria Formation
massive to thin-bedded, very fine- to medium-grained micaceous and carbonaceous arkosic sandstone and siltstone; commonly fossiliferous; locally contains calcareous concretions and dacitic ash beds.

Toy — Yaquina Formation
thick- to thin-bedded sandstone, conglomerate, and tuffaceous siltstone with thick glauconitic sandstone beds; sandstone is fine- to coarse-grained and shows cross-bedding, foreset bedding, and scour and fill structures. Conglomerate contains abundant pumice clasts.

Basalt of Tertiary Age

Tmcf — Cape Foulweather Basalt
flows, extrusive breccia, tuff breccia, and lapilli tuff composed of slightly porphyritic, glassy or fine- to medium-grained basalt; intrusive rocks within the flow and breccia sequence not differentiated.

Tmdb — Depoe Bay Basalt
isolated pillow breccia, pillow flows, extrusive breccia and columnar-jointed subaerial flows of glassy or fine- to medium-grained equigranular basalt. Some dikes and sills are not differentiated.

Teyb — Basalt of Yachats
subaerial porphyritic basalt and basaltic andesite flows, 10 to 20 feet thick, with flow breccias in the upper and lower parts of the flow units; commonly displays irregular jointing; includes pillow basalt, basaltic conglomerates, and basaltic sandstone in northern part of outcrop area.

Tech — Basalt of Cascade Head
basalt breccia and lapilli tuff with minor interbedded siltstone; the basalt is glassy to fine-grained and contains scattered phenocrysts of plagioclase, augite, and olivine.

Siltstone of Tertiary Age

Tmn — Nye Mudstone
massive to indistinctly bedded, gray, clayey siltstone and very fine-grained sandstone; contains sandstone interbeds near the base and calcareous concretions in places.

Toa — Siltstone of Alsea
massive- to thick-bedded fossiliferous tuffaceous siltstone and very fine-grained sandstone; locally concretionary and with glauconitic sandstone and pumice and ash interbeds.

Ten — Nestucca Formation
thin-bedded tuffaceous siltstone and sandstone with ash and glauconitic sandstone interbeds; contains some sandstone dikes and sills in siltstone within the upper parts of the unit; thick-bedded arkosic sandstone occurs in places near the base.

Tey — Yamhill Formation
massive to thin-bedded concretionary siltstone with thin interbeds of arkosic sandstone.

Other stratigraphic units

Tet — Tyee Formation
rythmically bedded sandstone and siltstone; sandstone is medium-grained, micaceous, and arkosic and forms beds 1 to 15 feet thick; siltstone is micaceous and contains organic matter locally; turbidite structures are widespread.

Tsr — Siletz River Volcanic Series
pillow flows, isolated pillow breccia, mudflow breccia, tuff breccia, fine to medium tuff conglomerate, basaltic sandstone and siltstone make up this unit; intrusive feeders are not differentiated on the map; basaltic rocks range in composition from tholeiitic to alkalic with minor more mafic variants.

Intrusive rocks

Tib — Intrusive basalt
includes feeder dikes for the Cape Foulweather and Depoe Bay Formations, and the basalt at Yachats and Cascade Head; porphyritic in places.

Tig — Gabbro
inclined sheets, sills and dikes of massive gabbro composed largely of plagioclase, ferroaugite, iron-rich olivine, and intergrowths of quartz and alkali feldspar; includes related mafic pegmatites.

Tis — Nepheline Syenite
sills, small stocks, and dikes of very fine- to medium-grained trachytic, equigranular to porphyritic nepheline syenite; very hard and coarsely jointed in places.

Tiyd — Dacite and Rhyodacite
dikes intruding the basalt of Yachats.

Tic — Camptonite and related alkalic intrusive rocks
camptonite occurs as glassy to fine-grained locally porphyritic intrusive rock and locally as zeolite-cemented tuff breccia.

GEOLOGIC SYMBOLS

Faults
Dotted where concealed

Folds
Syncline — Dotted where concealed
Anticline — Dotted where concealed

Contacts
Dotted where concealed

Strike and dip of beds
Attitudes
Horizontal beds

Landslide topography

Mines

Base map by U.S. Geological Survey and Army Map Service 1955–57

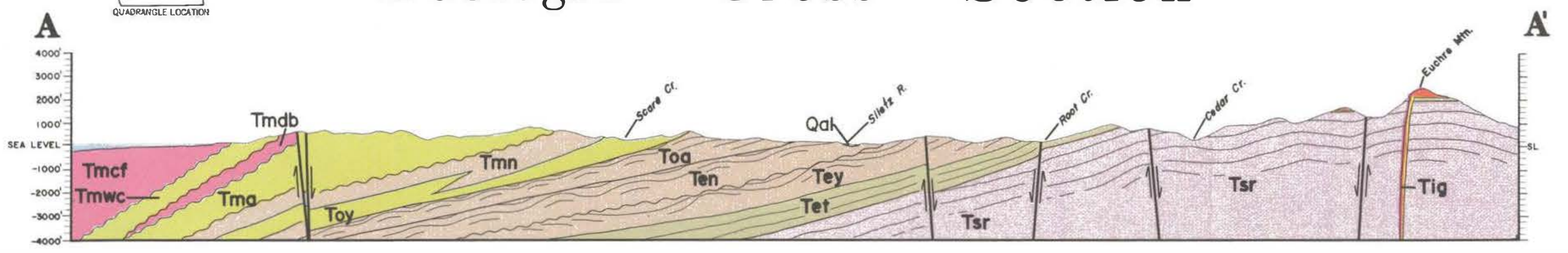
Polyconic projection 1927
North American datum

APPROXIMATE MEAN DECLINATION, 1957

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

Geologic Cross Section



Water wells

Dry
<5
5 to 10
10 to 25
25 to 100
>100

Water yield in gallons per minute
(Numbers on map refer to numbers of wells in text)

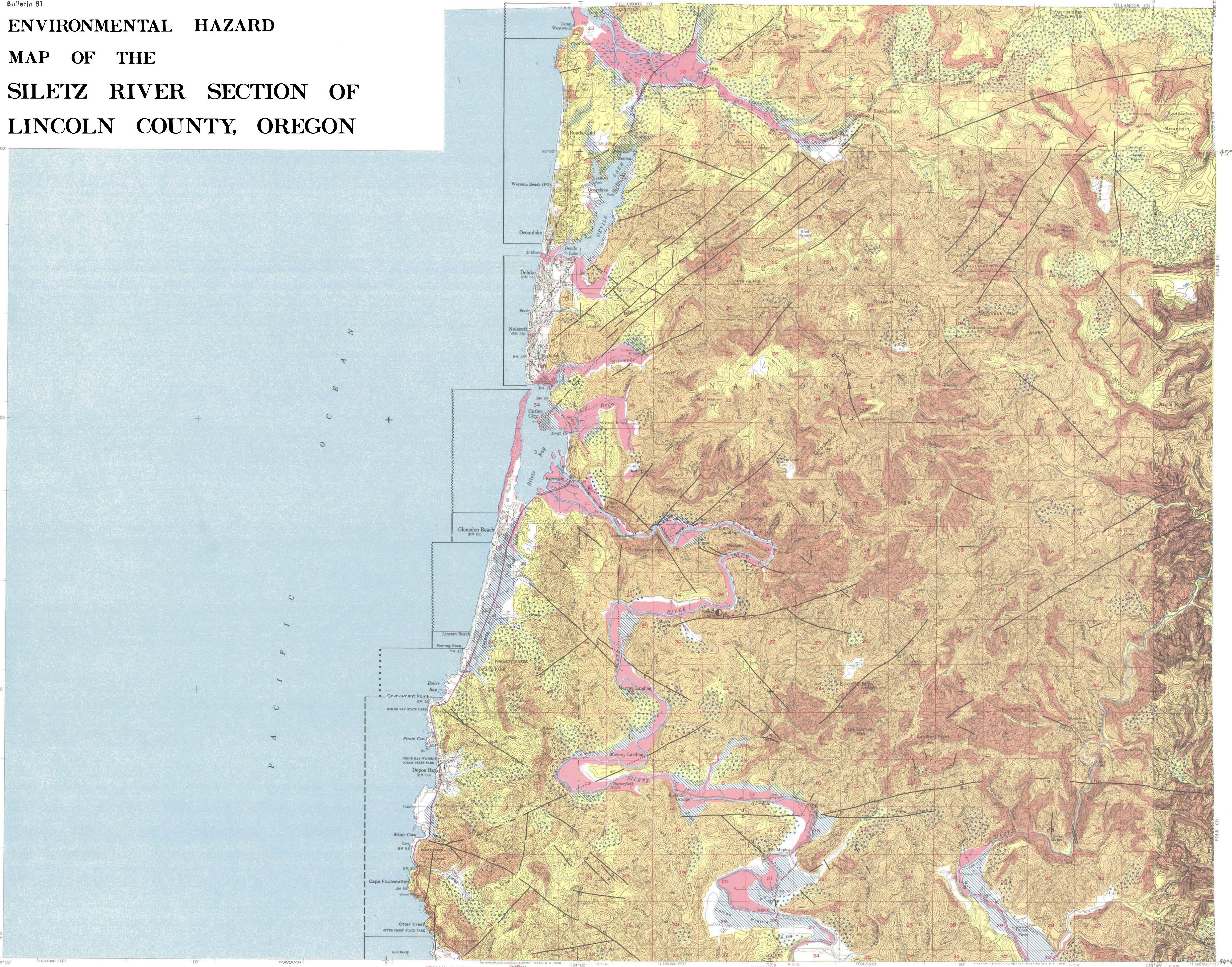
Bedrock Geology by P. D. Snavely, N. S. MacLeod and H. C. Wagner

Surficial Geology by H. G. Schlicker, R. J. Deacon G. W. Olcott and J. D. Beaulieu

Cartograph by S. R. Renoud, E. M. Lawson P. K. Oltman and W. H. Pokorny

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

ENVIRONMENTAL HAZARD MAP OF THE SILETZ RIVER SECTION OF LINCOLN COUNTY, OREGON



EXPLANATION

Fault
Dotted where concealed

Flood area

High ground-water table

Landslide topography

75 C

Nonpotable water well
(containing iron (Fe); chloride (Cl); hydrogen sulfide (H_2S); septic tank contamination (C))

Coastal Erosion

Erosion of thin marine terraces over basalt

Critical erosion of marine terraces and sediments

Critical erosion of sand spits and dune areas

Non-critical erosion of basalt headlands

Slope

0% to 10%
10% to 25%
25% to 50%
>50%

Base map by U.S. Geological Survey and Army Map Service 1955-57

Polyconic projection 1927
North American datum

APPROXIMATE MEAN DECLINATION, 1957

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 50 FEET
DATUM IS MEAN SEA LEVEL
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 6 FEET

OREGON
QUADRANGLE LOCATION

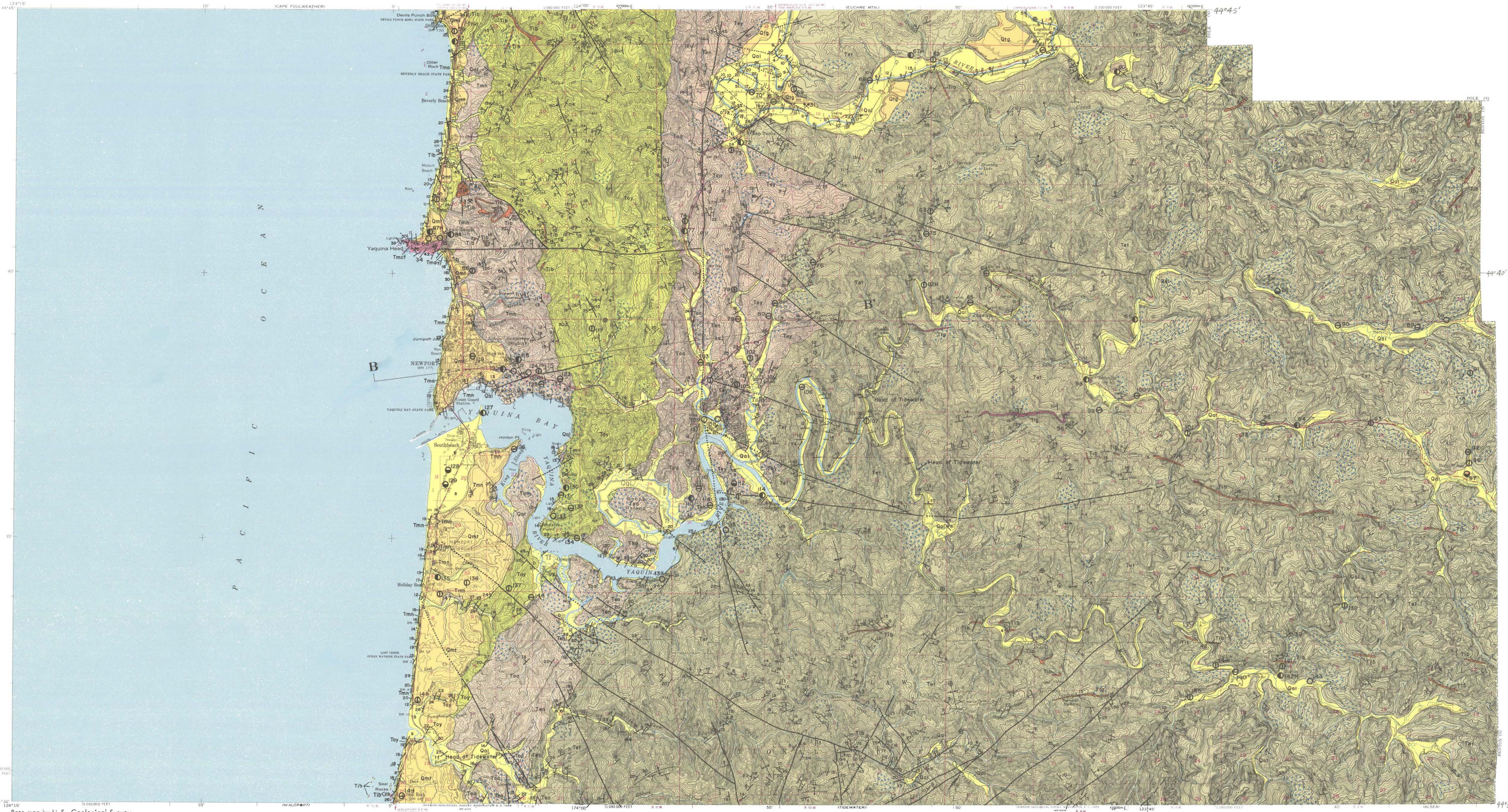
Cartograph by S. R. Renoud, E. M. Lawson
P. K. Oltman and W. H. Pohorny

Environmental Hazards by H. G. Schlicker, R. J. Deacon
G. W. Olcott and J. D. Beaulieu

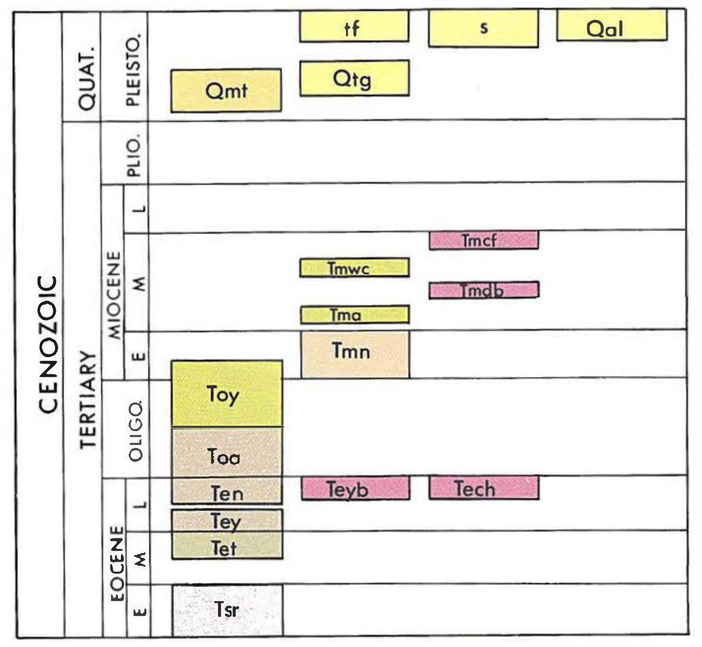
GEOLOGIC MAP OF THE
YAQUINA RIVER SECTION OF LINCOLN COUNTY, OREGON

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

Plate 5



STRATIGRAPHIC TIME CHART



EXPLANATION

Unconsolidated surficial units

Qal *Alluvial bottom land deposits composed primarily of silt, sand, and gravel.*

s *Unconsolidated fine- to medium-grained beach and dune sand.*

tf *Flat-lying deposits of saturated fine sand and clayey silt (tidal flats) at or near sea level.*

Qtg *Terrace deposits composed primarily of alluvial gravel, sand, and silt.*

Stratigraphic units

Qmt Marine terrace deposits
up to 75 feet of semi-consolidated uplifted beach sand overlain locally by fine-grained dune deposits. Lenses of gravel are present in places.

Sandstone of Middle Tertiary Age

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thin-bedded tuffaceous siltstone and sandstone with ash and glauconitic sandstone interbeds; contains some sandstone dikes and sills in siltstone within the upper parts of the unit; thick-bedded arkosic sandstone occurs in places near the base.

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Faults
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Anticline
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Contacts
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Strike and dip of beds

Attitudes

Horizontal beds

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Mines

Water wells

Dry
<5
5 to 10
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Water yield in gallons per minute
(Numbers on map refer to numbers of wells in text)

Base map by U.S. Geological Survey
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Polyconic projection 1927 North American datum

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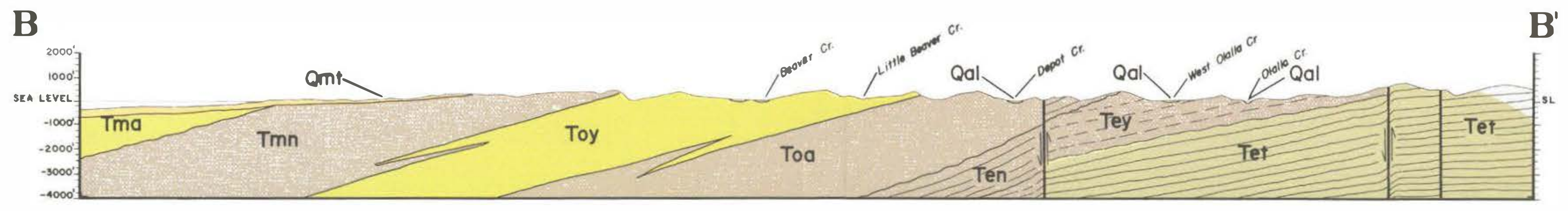
SCALE 1:62500

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

Geologic Cross Section



ENVIRONMENTAL HAZARD MAP OF THE
YAQUINA RIVER SECTION OF LINCOLN COUNTY, OREGON

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

EXPLANATION

Fault
Dotted where concealed

Flood area

High ground-water table

Landslide topography

75 C

Nonpotable water well
(containing iron (Fe); chloride (Cl); hydrogen sulfide (H_2S); septic tank contamination (C))

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Erosion of thin marine terraces over basalt

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Environmental Hazards by *H. G. Schlicker, R. J. Deacon G. W. Olcott and J. D. Beaulieu*

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GEOLOGIC MAP OF THE
ALSEA RIVER SECTION OF LINCOLN COUNTY, OREGON

Plate 1

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

Base map by U.S. Geological Survey
and Army Map Service 1956

Polyconic projection 1927 North American datum

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CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

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Syncline
Dotted where concealed

Folds

Anticline
Dotted where concealed

Contacts
Dotted where concealed

Strike and dip of beds

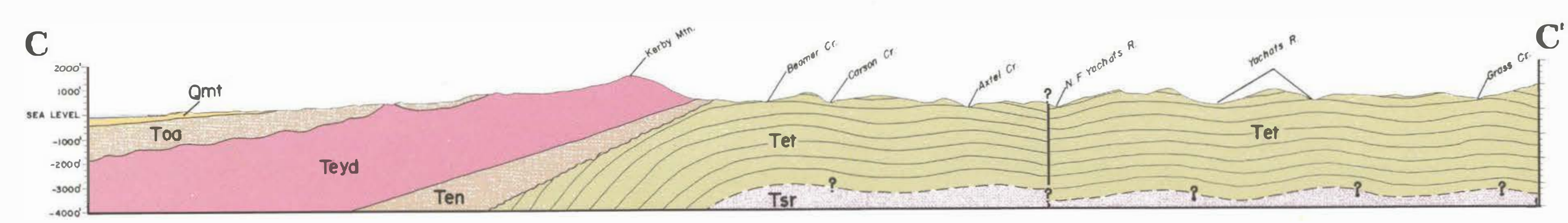
Attitudes

Horizontal beds

Landslide topography

Mines

Geologic Cross Section



Bedrock Geology by P. D. Snavely, N. S. MacLeod and H. C. Wagner

Surficial Geology by H. G. Schlicher, R. J. Deacon G. W. Olcott and J. D. Beaulieu

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Plate 2

ENVIRONMENTAL HAZARD MAP OF THE
ALSEA RIVER SECTION OF LINCOLN COUNTY, OREGON

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

EXPLANATION

Fault
Dotted where concealed

Flood area

High ground-water table

Landslide topography

Nonpotable water well
(containing iron (Fe); chloride (Cl); hydrogen sulfide (H_2S); septic tank contamination (C))

Coastal Erosion

Erosion of thin marine terraces over basalt

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10% to 25%

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>50%

Environmental Hazards by H. G. Schlicker, R. J. Deacon, G. W. Olcott and J. D. Beaulieu

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CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

APPROXIMATE MEAN DECLINATION, 1955

QUADRANGLE LOCATION