BULLETIN 84

TEXT



Environmental Geology of Western Linn County, Oregon

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

1974

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

BULLETIN 84

ENVIRONMENTAL GEOLOGY
of
WESTERN LINN COUNTY, OREGON

John D. Beaulieu
Oregon Department of Geology and Mineral Industries
Paul W. Hughes and R. Kent Mathiot
Hughes and Associates, Consulting Geologists

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CONTENTS

INTRODUCTION ---------- 1
Purpose ---------- 1
Previous work ---------- 1
Implementation ---------- 2
Acknowledgments ---------- 2

GEOGRAPHY ---------- 5
Location and extent of area ---------- 5
Climate and vegetation ---------- 5
Topography ---------- 5
Population ---------- 7

GEOLOGY ---------- 9
Geologic units ---------- 9
Summary ---------- 9
Little Butte Formation ---------- 9
Columbia River Basalt ---------- 13
Sardine Formation ---------- 16
Cascades Formation ---------- 20
Tertiary intrusive rock ---------- 20
Quaternary upper terrace ---------- 23
Quaternary middle terrace ---------- 23
Quaternary lower terrace ---------- 23
Willamette silts ---------- 25
Quaternary alluvium ---------- 26
Geologic structure ---------- 26
Faults ---------- 26
Folds ---------- 28

ENGINEERING GEOLOGY ---------- 29
Engineering characteristics of geologic units ---------- 29
Little Butte Formation ---------- 29
Columbia River Basalt ---------- 32
Sardine Formation ---------- 32
Cascades Formation ---------- 32
Tertiary intrusive rock ---------- 32
Quaternary upper terrace ---------- 33
Quaternary middle terrace ---------- 33
Quaternary lower terrace ---------- 33
Willamette Silts ---------- 34
Quaternary alluvium ---------- 34
Soils of the Willamette Valley ---------- 34
Soils classification ---------- 35
Clay and silty clay ---------- 37
Clay loam and silty clay loam ---------- 37
Loam and silty loam ---------- 37
Sand and sandy loam ---------- 37
Gravelly loam ---------- 38

GEOLOGIC HAZARDS ---------- 83
General discussion ---------- 39
Slope ---------- 39
Class 1 slopes ---------- 39
Class 2 slopes ---------- 39
Class 3 slopes ---------- 43
Class 4 slopes ---------- 43
Class 5 slopes ---------- 43
Flooding ---------- 47
Definitions ---------- 47
Causes ---------- 47
Distribution ---------- 47
Impact ---------- 47
Planning measures ---------- 51
Ponding and high ground water ---------- 53
Definitions and causes ---------- 53
Recognition and distribution ---------- 53
Impact ---------- 53
Planning measures ---------- 53
Stream-bank erosion ---------- 56
Definition and recognition ---------- 56
Causes ---------- 56
Distribution ---------- 58
Willamette River ---------- 58
South Santiam River ---------- 58
Santiam River and North Santiam River ---------- 59
Calapooia River ---------- 59
Muddy Creek, Thomas Creek, Crabtree Creek ---------- 59
Impact ---------- 60
Planning measures ---------- 60
Mass movement ---------- 61
Definitions ---------- 61
Mass-movement topography ---------- 62
Definition and causes ---------- 62
Distribution ---------- 62
Impact ---------- 66
Planning measures ---------- 66
Failure on steep slopes ---------- 66
Definitions ---------- 66
Distribution ---------- 67
Impact ---------- 67
Planning measures ---------- 67
Flash flooding ---------- 69
Definitions and causes ---------- 69
Distribution ---------- 69
Impact ---------- 69
Planning measures ---------- 69
Tectonic hazards ---------- 75
Volcanism ---------- 75
Earthquake potential ---------- 75
Natural resources ---------- 79
Construction materials ---------- 79
Sand and gravel ---------- 79
Quarry stone ---------- 82

GEOLOGIC HAZARDS, continued
Natural Resources, continued
Ground water ---------- 85
Occurrence ---------- 85
Hydrology ---------- 87
Quality ---------- 87
Planning considerations ---------- 90
Oil and gas ---------- 91
Gold and silver ---------- 92
Coal ---------- 92

SUMMARY ---------- 93

BIBLIOGRAPHY ---------- 97

APPENDIX ---------- 103
A. Unified soil classification system ---------- 105
B. American Association of State Highway Officials soils classification ---------- 106
C. Comparison of three systems of particle-size classification -- 107
D. Construction materials operations in western Linn County --- 108
E. Water-well numbering system ---------- 113
F. Drillers' logs of representative wells ---------- 114

ILLUSTRATIONS

Figures

1. Implementation flow chart showing use of bulletin in planning process ---------- 3
2. Index map of western Linn County showing quadrangle map coverage ---------- 4
3. Average precipitation and evaporation at Albany, Oregon ---------- 6
4. Looking southwest from Green Peter Mountain across moderately hilly terrain ---------- 6
5. Maximum population projections for Linn County and Albany ---------- 8
6. Medium population projections for Linn County and Albany ---------- 8
7. Stratigraphic time chart for western Linn County ---------- 10
8. Andesitic tuffs and breccias of the Little Butte Formation exposed on Shot Pouch Butte ---- 11
9. Well-indurated tuffs of Little Butte Formation exposed on Moss Butte ---------- 11
10. Tuffs of Little Butte Formation are composed of small fragments from volcanic activity ---- 12
11. Varicolored fine-grained tuffs and ash of Little Butte Formation on Brush Creek Road ----- 12
12. Massive beds of marine sandstone exposed at elevation of 1,000 feet on Washburn Butte --- 13
13. Columnar jointing is well developed in dense basalts of Little Butte Formation on Wiley Creek 14
14. Some of the Little Butte basalts have platy jointing ---------- 14
15. Ward Butte is one of many resistant accumulations of basaltic flow and vent rock ------- 15
16. Quarry at Saddle Butte exposes basaltic dike rock, flow rock, and breccia ---------- 15
17. Flat-topped ridges of Columbia River Basalt overlook lower lying terrace deposits near Scio 17
18. Quarry operations at Hale Butte indicate hill is mainly Columbia River Basalt ---------- 17
19. Thick flow of Columbia River Basalt at Marks Ridge displays classic thin columnar jointing in the entablature and thicker columnar jointing in colonnade ---------- 18
20. Exposures of Sardine Formation along North Santiam River form steep slopes with thin soil -- 18
21. Massive andesitic flow rock of Sardine Formation forms steep cliffs on Green Mountain ---- 19
22. Base of Cascades Formation on Snow Peak includes thin flows of light-gray massive flow rock and intercalated fine-grained tuffs and breccias ---------- 19
23. Steep canyon on Snow Peak exposes the core of the ancient volcano ---------- 21
24. Large boulder of porphyritic andesite assigned to the Cascades Formation ---------- 21
25. Coarsely jointed columnar basalt forms large intrusion in Little Butte Formation -------- 22
26. Radiometric age of large diorite intrusion at Detroit Dam is inconsistent with stratigraphy -- 22
27. Low-lying terraces on Thomas Creek are assigned to Quaternary lower terrace unit ------ 24
28. Willamette Silts overlie most of the floor of Willamette Valley ---------- 24
29. Subsurface geologic map of western Linn County ---------- 27
30. Soil overlying basaltic intrusions in Little Butte Formation is very thin ---------- 31
31. Differential settling caused structural damage to foundation of house ---------- 31
32. Guide for the textural classification of soils ---------- 35
33. The Powell Hills are gently sloping and well-suited to many forms of development ------ 42
34. Gently sloping terrain on basaltic bedrock in uplands area is stable ---------- 42
35. Roadcuts in gently sloping weathered clay soils of Little Butte Formation are prone to failure 44
36. Thin soils characterize Class 3 slopes underlain by basaltic bedrock ---------- 44
37. Small slides are common along roads cut into Class 3 slopes ---------- 46
38. Scar of a recent landslide controlled by jointing in partly weathered Little Butte tuffs ---- 46
39. Aerial view two miles west of Albany showing distribution of 1964 flood ---------- 48
40. Flooding of central Lebanon during December 1964 ---------- 48
41. Flooding of the Calapooia flood plain during the flood of December 1964 ---------- 49
42. Standing flood waters can cause considerable damage to homes and their contents ------- 49
43. Still water in the floodway fringe can cause crop damage through siltation ---------- 50
44. Flood waters of January 1974 immediately east of Highway 99E at Oak Creek --------- 50

Figures, continued

45. Flood waters of the Calapooia flood plain in January 1974 ---------- 52
46. Because of local ponding, this brige is essential in the winter months ---------- 52
47. Clumps of reed grass are indicators of potential winter ponding and high water table ----- 54
48. Area of slack flood water will be an area of ponding when streamflow subsides --------- 54
49. Disrupted drainage and decreased runoff in areas of urbanization can cause ponding ------ 55
50. Features of a river meander ---------- 55
51. Revetment on the south bank of the South Santiam River ---------- 57
52. Active streambank erosion along South Fork of the Santiam River ---------- 57
53. Gravel bar deflects streamflow against south bank of the South Santiam River ---------- 59
54. Tilted trees and irregular topography indicate active sliding along Crabtree Creek Road --- 63
55. A basalt scarp overlooking hummocky landslide topography ---------- 63
56. Irregular to hummocky topography characterizes mass-movement areas surrounding Ward Butte 64
57. Mass-movement topography and tilted trees near Ward and Lone Pine Buttes ---------- 64
58. Recent sliding has downdropped a large section of road at Shot Pouch Butte ---------- 65
59. Massive failure in clay-rich tuff of Little Butte Formation on Brush Creek Road --------- 65
60. Drainage trenches and pipes used to eliminate water from slide mass along Brush Creek Road - 67
61. Removal of vegetation prompted shallow mudflow along Wiley Creek ---------- 68
62. Rockfall and rock slide deliver large blocks of rock to valley bottom of Wiley Creek ----- 68
63. Upper Wiley Creek displays many flash-flood features ---------- 70
64. Channel of Bigs Creek at confluence with Calapooia River ---------- 71
65. Vegetation has partially obscured this unnamed flash-flood channel 3 miles from Bigs Creek - 71
66. Steep slopes and impermeable bedrock contribute to flash-flood potential of North Santiam River area ---------- 72
67. Repeated road washouts at this crossing along upper McDowell Creek prompted installation of oversized culvert ---------- 73
68. Small unmappable gullies in steeply sloping areas are subject to flash flooding --------- 73
69. Debris removed from Calapooia River Road at mouth of Bigs Creek ---------- 74
70. Debris for delta was eroded from burned area since completion of Big Cliff Dam --------- 74
71. State of Oregon seismic risk map ---------- 77
72. Projected annual consumption of sand and gravel ---------- 78
73. Cumulative curve of sand and gravel consumption ---------- 78
74. Diamond Hill quarry yields rock of variable quality and is isolated from high demand areas - 82
75. Large quantities of high-quality rock are available at Marks Ridge ---------- 83
76. Shot Pouch Butte supplied riprap for Foster Dam ---------- 83
77. Ridgeway Butte quarry is a small source of rock for local road maintenance ---------- 84
78. Sheety jointing at Sodaville quarry makes the rock well suited for use as road rock ------ 84

Tables

1. Population of major communities of Linn County, 1900-1970 ---------- 8
2. Summary of engineering properties of geologic units ---------- 30
3. Soil use classification for the Willamette Valley of western Linn County ---------- 36
4. Summary of lowland hazards ---------- 40
5. Summary of upland hazards ---------- 41
6. Summary of slope hazards ---------- 45
7. Discharge of major streams ---------- 51
8. Mass-movement terminology ---------- 61
9. Scale of earthquake intensities ---------- 76
10. Seismic events in the central Willamette Valley ---------- 77
11. Construction materials in Linn County ---------- 80
12. Sand and gravel production in Linn County ---------- 81
13. Stone production in Linn County ---------- 81
14. Characteristics of representative wells in western Linn County ---------- 86
15. Chemical anlyses of representative ground-water aquifers, western Linn County -------- 88
16. Drinking water standards defined by U.S. Public Health Service ---------- 90
17. Oil and gas test wells in Linn County ---------- 91
18. Landforms and associated hazards ---------- 93

Maps in folder

Geology of:
- Albany quadrangle
- Brownsville quadrangle
- Cascadia quadrangle
- Halsey quadrangle
- Lebanon quadrangle
- Quartzville quadrangle
- Snow Peak quadrangle
- Sweet Home quadrangle
- Portions of the Eugene, Lyons, Marcola, and Stayton quadrangles

Geologic hazards of:
- Albany quadrangle
- Brownsville quadrangle
- Cascadia quadrangle
- Halsey quadrangle
- Lebanon quadrangle
- Quartzville quadrangle
- Snow Peak quadrangle
- Sweet Home quadrangle
- Portions of the Eugene, Lyons, Marcola, and Stayton quadrangles

Textural soils of:
- Albany quadrangle
- Halsey quadrangle
- Lebanon quadrangle
- Portions of the Eugene and Stayton quadrangles

ENVIRONMENTAL GEOLOGY OF WESTERN LINN COUNTY, OREGON

INTRODUCTION

Purpose

As development continues, private citizens, engineers, developers, planners, county, and state officials are recognizing the need for information about geologic hazards. A knowledge of geologic hazards promotes safe, economical decisions and efficient planning, both of which pay long-range dividends. It is the purpose of this study to delineate and evaluate the geologic hazards of western Linn County. It is the further purpose of this study to place the hazards into proper perspective so that knowledge of them may better serve the planning process.

Senate Bill 100, passed in 1973 by the Oregon Legislature, creates a Department of Land Conservation and Development for the purposes of implementing state-wide planning goals and adopting comprehensive plans for zoning and subdivision. The bill also makes each county responsible for coordinating all planning activities affecting land uses within the county. This bulletin will be a valuable aid to Linn County personnel in responding realistically to this and similar directives.

Legal trends in recent years have been toward the courts placing increasing responsibilities on permit granting agencies. In California recently, a county road project initiated a landslide and a county-approved subdivision later adversely affected neighboring property. In both cases, liability was placed upon the county (Schlicker and others, 1973). The information provided in this bulletin will enable Linn County personnel to avoid such difficulties by evaluating and planning future development more accurately.

Previous Work

Earlier geologic studies in western Linn County include geologic investigations along the North Santiam River (Thayer, 1936, 1939), in the Lebanon quadrangle (Felts, 1936; Allison and Felts, 1956), in the Stayton quadrangle (O'Neill, 1939), in the Albany quadrangle (Allison, 1953), the northwest Marcola quadrangle (Bristow, 1959), in the southwest quarter of the Brownsville quadrangle (Hauck, 1962), and in western Detroit Reservoir area (Pungrassami, 1969). Peck and others (1964) included the foothills of western Linn County in a regional geology study of the Western Cascades of Oregon.

Mineral resource studies include a general survey of mining activities by the Oregon Department of Geology and Mineral Industries (1951), ground water investigations by Piper (1942) and Helm (1968), and a study of subsurface geology and oil-producing potential by Newton (1969).

Soil investigations include those by Kocher and others (1924) and Balster and Parsons (1969). Geophysical studies include a gravity study for the State of Oregon (Thiruvathukal and others, 1970) and an aeromagnetic study of the Lebanon quadrangle (Bromery, 1962). Topical studies include investigations of ice-rafted erratics in the Willamette Valley (Allison, 1935), fossil leaves near Scio (Sanborn, 1947), and fossil wood near Holley (Gregory, 1968).

Various governmental agencies in the County continue to produce data pertinent to environmental and hazards investigations. These include the U. S. Army Corps of Engineers (stream-bank erosion and flooding), the U. S. Soils Conservation Service, the State Engineer (ground water), the State Highway Department (engineering data) and the U. S. Geological Survey (ground water).

Implementation

The recommended use of this bulletin by the planner or other persons in the planning process is outlined in Figure 1. The planner must first clearly define the problem and determine its precise location. This involves accurately locating the site of proposed construction or outlining a larger area for general study and listing the physical requirements of the proposed project or plan.

The planner must then consult the geologic map, the hazards map, and, where appropriate, the soils map (Willamette Valley area) to determine the rock unit, the geologic hazards, and the soil conditions. These features are briefly discussed in the map legends and are treated in more detail in the text. To assist the planner, the text emphasizes the recognition, impact, and treatment of hazards and is thoroughly cross-referenced. For areas in which no hazard is specifically indicated, it is suggested that the hazards of surrounding areas of similar character be studied to fully assess the potential problems.

After studying the maps and reading the appropriate parts of the text, the planner must assess the overall impact of geology on the proposed development or plan. Where appropriate he must also consider the influence of development on local geologic processes. Both may involve requests for more geologic input from appropriate personnel (developers, County road builders, State and Federal agencies) or the use of sophisticated planning techniques (overlay maps).

Finally, the planner must integrate the knowledge of geologic impact with input from other disciplines and with broad community goals and guidelines to arrive at a final decision. This may include a commitment to preserve mineral resources or to protect ground water from contamination or overuse. Therefore, natural resources are also discussed in the text.

This study is reconnaissance in nature; boundaries on the maps are approximate and conclusions in the text are general. For final decisions regarding the precise impact of geologic hazards on specific areas, on-site investigations are necessary. This bulletin is a planning tool and should not be regarded as the final word in individual problems. Thus, the problem-solving process (Figure 1) may involve requests for more information as discussed above.

Acknowledgements

The authors greatly appreciate the cooperation and help given by many agencies and individuals in the preparation of this report. Special thanks are extended to Al Couper, Executive Secretary of the District 4 Council of Governments, for his administrative assistance and constructive criticism. The efforts of Lee Christiansen, former County Planner for Linn County, were instrumental in initiating the project. Bernard Gilkison, Linn County Planner, and other personnel of the Linn County Planning office were very helpful and provided drafting assistance and numerous other services.

The office of the State Engineer participated in discussions and field conferences relating to landfills and provided valuable ground-water data. Discussions with personnel of the State Water Resources Board in the early stages of the project also are appreciated.

Soils information provided by the Tangent office of the U. S. Soils Conservation Service was helpful. The U. S. Army Corps of Engineers provided data on flooding, bedrock engineering, and revetments. The Portland office of the U. S. Geological Survey provided ground-water data and information regarding erosion in the Willamette Basin.

Information on local problems concerning soils, landfills, and septic tanks was provided by the engineering offices of the cities of Sweet Home, Lebanon, Albany, and Brownsville, and by Scio city government personnel.

The authors also wish to express appreciation to the staff members of the Oregon Department of Geology and Mineral Industries for their help in preparing this report for publication. Steve Renoud and Bill Pokorny did the drafting and cartography. Margaret Steere and Carol Brookhyser edited the manuscript. Typing of the final draft was by Ruth Pavlat. Data on aggregate production was provided by Jerry Gray of the Mined Land Reclamation Division in Albany, and Greg Paul, student at Portland State University, did most of the photography and prepared most of the prints.

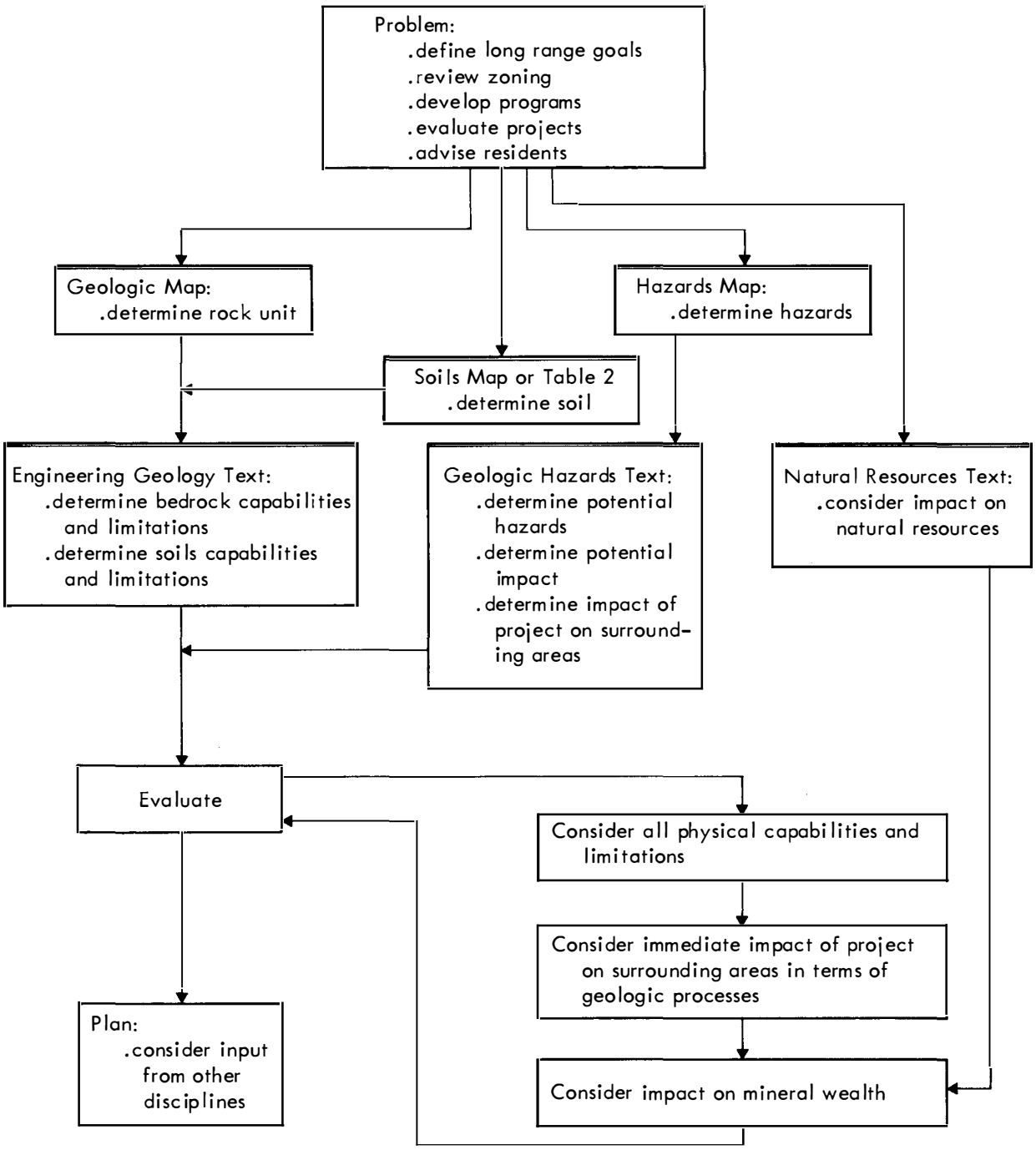
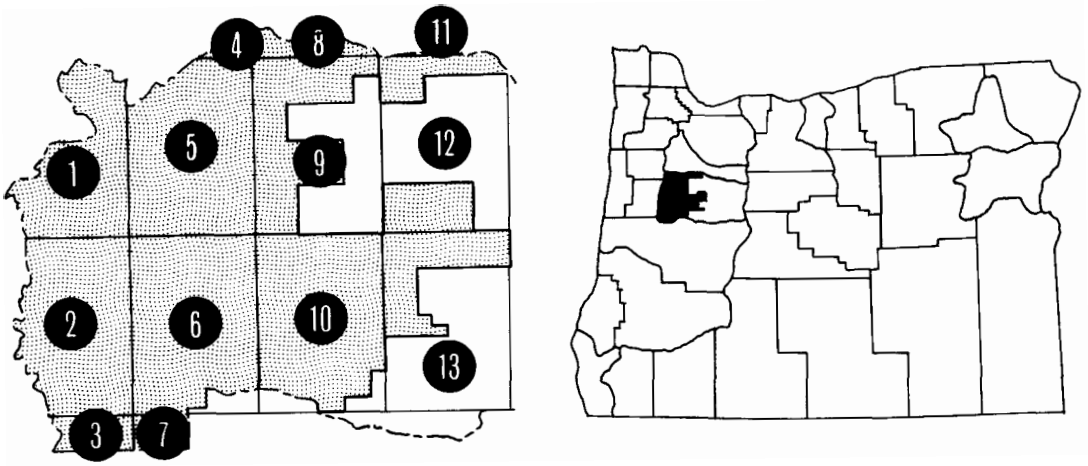


Figure 1. Implementation flow chart showing how the various parts of this bulletin should be used in the planning process.



Area included in this study

1 Albany quadrangle

1 Halsey quadrangle

3 Eugene quadrangle

4 Stayton quadrangle

3 Lebanon quadrangle

6 Brownsville quadrangle

1 Marcola quadrangle

3 Lyons quadrangle

6 Snow Peak quadrangle

10 Sweet Home quadrangle

11 Mill City quadrangle

12 Quartzville quadrangle

11 Cascadia quadrangle

Figure 2. Index map of western Linn County showing quadrangle map coverage.

GEOGRAPHY

Location and Extent of Area

Linn County extends from the center of the Willamette Valley eastward to the crest of the Cascade Range. The Santiam and North Santiam Rivers constitute the northern boundary and the Willamette River makes up the western boundary. Bordering counties are Marion County on the north, Benton County on the west, Lane County on the south, and Deschutes County on the east.

The study area (Figure 2) includes the Willamette Valley and the foothills of the Western Cascades eastward to an irregular boundary defined on the basis of National Forest landholdings, river valleys, and access. The area of investigation covers approximately 1,300 square miles and includes all the land to which the County planning process must address itself. Some small areas of National Forest land lie within the boundaries of the study area. Thirteen topographic quadrangles are involved (see Figure 2).

Several thousand miles of access road are present in the study area. They include Interstate 5, U. S. Highway 99 East, and numerous County and private roads in the Willamette Valley. U. S. Highway 20, State Highway 226, and State Highway 228 provide access along the South Santiam, North Santiam, and lower Calapooia Rivers respectively. Numerous other unnumbered roads extend up all the major valleys, and private roads and logging roads provide access to the more remote areas of the foothills.

Climate and Vegetation

The climate of western Linn County is temperate owing to strong marine influences and is characterized by dry warm summers and mild wet winters. Towards the east, in the foothills of the Western Cascades, more extreme conditions prevail.

Temperatures typically vary between 20° and 100° during the year. The record high was 104° in 1926 and the record low was -15° in 1919. The January and July average temperatures for Albany are 39° and 67° respectively.

Annual precipitation varies from 40 inches in the central parts of the Willamette Valley to 80 inches at the higher elevations and in the eastern extremities of the interior valleys. Precipitation for most of the foothills area is between 40 and 60 inches annually. Average annual precipitation at Albany is 39 inches.

The seasonal variation of precipitation and potential evaporation is shown in Figure 3. Moisture surpluses during the winter months promote flooding and ponding in flatland areas. The overall warm moist conditions promote deep chemical weathering, a process which favors the development of thick, clay-rich soils. The warm dry summers are partly responsible for the extensive red coloration of the soils.

Land cover of western Linn County is characterized by timber of the Douglas-fir association in the uplands and farming in the lowlands and the Willamette Valley. The Douglas-fir association consists of Douglas-fir with subordinate Western hemlock, Western redcedar, and Grand fir. Also present are Bigleaf and Vine maple.

Willamette Valley crops include rye grass, wheat, barley, oats, corn, and hay. Poorly drained and easily flooded areas are devoted largely to grazing.

Topography

The landforms of western Linn County include the Willamette Valley, the foothills and mountains of the Western Cascades, and the numerous stream and river valleys which cut into the Western Cascades. The shape and characteristics of each are products of the rocks that underlie them and the processes that are acting upon them.

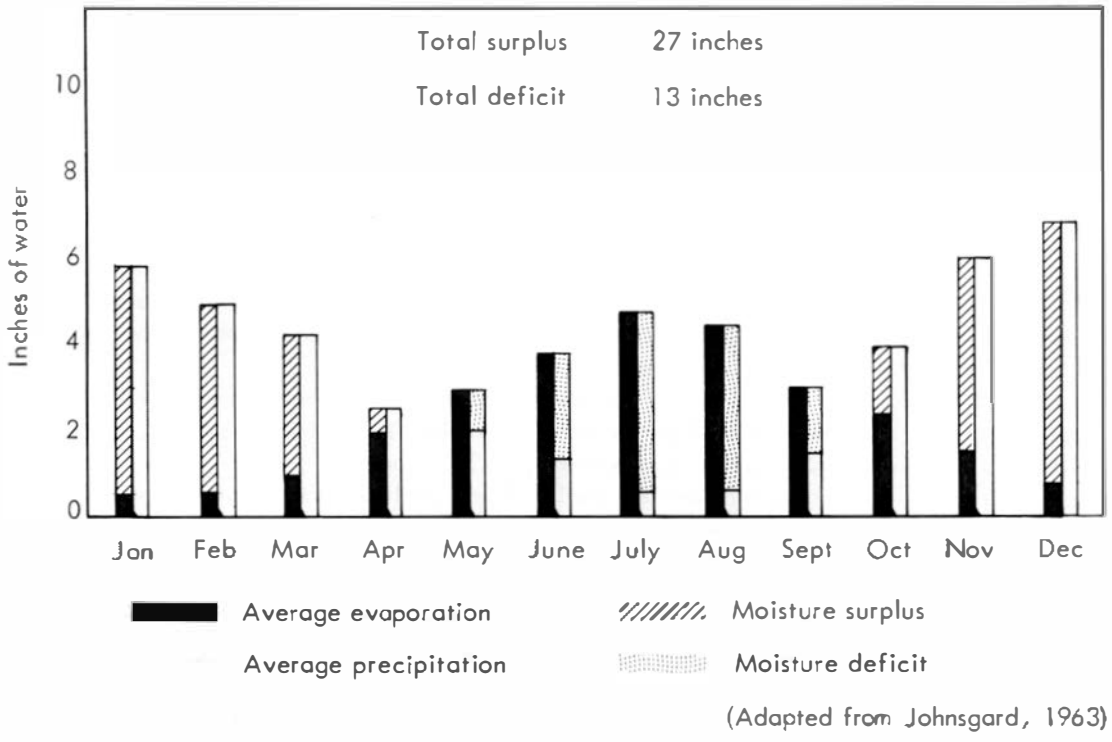


Figure 3. Average precipitation and evaporation at Albany, Oregon. A moisture surplus is indicated for winter months.



Figure 4. Looking southwest from Green Peter Mountain across moderately hilly terrain underlain by mid-Tertiary tuffs and breccias; Foster Reservoir in middle distance.

The Willamette Valley in western Linn County is 10 to 15 miles wide and varies in elevation from approximately 190 feet on the flood plains north of Albany to 350 feet on gently sloping valley deposits along the Lane-Linn County line to the south. The valley is extremely flat and was formed by the Willamette River as it meandered back and forth over its ever enlarging flood plain. Other rivers and creeks in the valley include the North and South Santiam Rivers, Lake Creek, Muddy Creek, Oak Creek, and the Calapooia River.

The hills and mountains which make up the foothills of the Western Cascades have diverse origins. Snow Peak is the highest mountain (4,298 feet) and is the eroded remnant of a Plio-Pleistocene volcano. At slightly lower elevations, Green Peter (3,977 feet), High Deck (3,566 feet), and Farmers Butte (3,610 feet) are erosional remnants of a once extensive sheet of Pliocene volcanic flow rock. The flow rock caps a lower, more gentle terrain composed of more easily eroded mid-Tertiary tuffs and breccias (Little Butte Formation) (see Figure 4). Basaltic intrusions and flows interbedded with the tuffs form local peaks at Shot Pouch Butte, Moss Butte, Washburn Butte, Lone Pine Butte, and Peterson Butte. A short distance to the west where erosion has completely removed the softer tuffs the remaining basaltic rock forms prominent isolated buttes (i. e., Saddle Butte and Ward Butte) in the Willamette Valley. In northern Linn County, resistant middle Miocene flow rock (Columbia River Basalt) caps numerous ridges underlain by less resistant bedrock.

The major streams of the foothills, including the North and South Santiam Rivers, Thomas Creek, Crabtree Creek and the Calapooia River, in their lower reaches cross flat-lying valley alluvium. Regional uplift and concurrent downcutting have produced a series of terraces in the alluvium in the northern part of the County. Farther east toward their headwaters, the streams are more youthful and no flood plains are present. Instead, the valleys are characterized by steep narrow canyons.

Population

The 1970 population of Linn County was 71,194 persons according to the 1970 census. The population of Albany, the major urban center, was 18,181. The populations of the eleven largest communities from 1900 through 1970 are shown on Table 1. Albany, Harrisburg, Lebanon, and Sweet Home have shown the most rapid population growth over the years. Albany, with its centralized location in the Willamette Valley and its continually diversifying economic base, will exert growing influence on the surrounding Valley in future years.

The District 4 Council of Governments (1973) presents two sets of projections for future populations in Linn County. The maximum population projection (Figure 5) is obtained by extending historical growth on a logarithmic rate of increase. Using this method, the population of Linn County is shown to increase by almost 80 percent to 128,000 by the year 2000. This is an annual growth rate of almost 2 percent.

More conservative estimates are obtained by integrating recent population growth trends into the calculations. Assuming that after 1975 the rate of population growth decreases by 0.1 percent per year until an average growth rate of 1 percent is achieved, the projections shown on Figure 6 are obtained. By the year 2000, the population of Linn County will increase from the present population of 71,914 to 106,000. This represents an average annual growth rate of 1.6 percent.

Urban areas will grow more rapidly according to the projections. On the median growth curve (Figure 6) Albany will grow to a population of 37,900, an average annual growth rate of 3.6 percent.

In view of national population trends in recent years (rate of growth in 1973 was 0.7%) and the likelihood of economic slowdown in future years, the conservative projection (Figure 6) of future population growth is probably more accurate. Data such as that provided by Figure 6 are useful for estimating the demand for nontransportable resources (ground water) and resources of low transportability (gravel, sand, and crushed rock).

Table 1. Population of major communities of Linn County 1900 to 1970

	1900	1910	1920	1930	1940	1950	1960	1970
Albany	3,149	4,275	4,840	5,325	5,654	10,115	12,926	18,181
Brownsville	698	919	763	746	784	1,175	875	1,034
Halsey	294	337	339	300	305	388	404	467
Harrisburg	502	453	573	575	622	862	939	1,311
Lebanon	922	1,820	1,805	1,851	2,729	5,873	5,858	6,636
Lyons	----	----	----	----	----	----	463	645
Mill City	----	----	----	----	----	1,792	1,289	1,451
Scio	346	295	300	258	351	448	441	447
Sodaville	178	110	72	77	99	157	145	125
Sweet Home	----	202	175	189	1,090	3,603	3,353	3,799
Waterloo	59	83	82	----	----	----	151	186

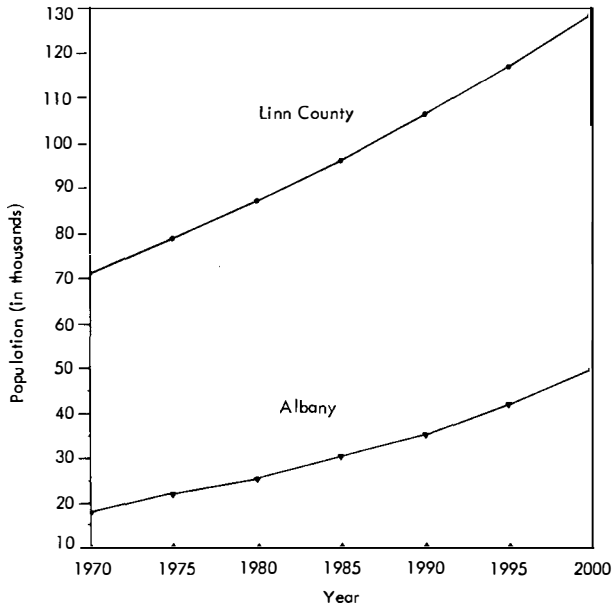


Figure 5. Maximum population projections for Linn County and Albany. High estimates of population growth obtained by extending historical growth on a logarithmic rate of increase (data from District 4 Council of Governments, 1973).

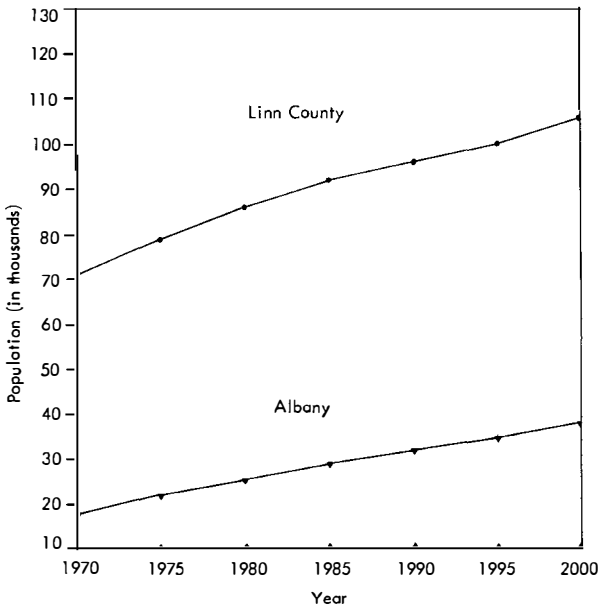


Figure 6. Median population projections for Linn County and Albany. Median estimates of population growth obtained by assuming that a trend to a 1 percent growth rate will be achieved gradually after 1975 (data from District 4 Council of Governments, 1973).

GEOLOGY

Geologic Units

Summary

Bedrock geologic units in western Linn County total approximately 15,000 feet in composite thickness and include (Figure 7) 10,000 feet of Oligocene to early Miocene dacitic to andesitic breccias and tuffs and associated basaltic accumulations (Little Butte Formation, Tolb), several hundred feet of middle Miocene flow-on-flow basalt (Columbia River Basalt, Tcr), 1,500 feet of late Miocene to early Pliocene massive to platy hypersthene andesite flow rock and breccia (Sardine Formation, Tps), and up to 3,000 feet of late Pliocene to Pleistocene andesite flow rock and breccias (Cascades Formation, Qtv). Thick sequences of Oligocene marine sandstone of the Eugene Formation are present in the subsurface of the Willamette Valley. Where interbeds of marine sandstone are present in the Little Butte Formation, the symbol Tlbe is used in this study.

Five surficial geologic deposits of Pleistocene age mantle the bedrock units in the Willamette Valley and adjoining valley and foothill areas. In order of decreasing age, they are upper, middle, and lower terraces (Qtu, Qtm, Qtl), lacustrine silts and clays (Willamette Silt, Qws) and Quaternary alluvium (Qal).

Intrusive rocks (Ti) include basaltic feeder dikes and plugs for parts of the Little Butte Formation and a plug for accumulations of Cascades Formation andesite and basalt at Snow Peak.

Little Butte Formation (Tolb, Tlbe)

The Little Butte Volcanic Series was defined by Wells (1956) in the Medford quadrangle and was later extended to include all the Oligocene to early Miocene volcanic rocks of the Western Cascades by Peck and others (1964). In western Linn County, the unit includes the Mehama volcanics of Thayer (1939) and the Berlin volcanics of Felts (1936). As mapped in this study, the formation also includes interbeds of marine sandstone equivalent to the Eugene Formation of Smith (1924).

The Little Butte Formation is the most extensive bedrock unit in the study area. It is exposed throughout the foothills of the Western Cascades in central Linn County with the exception of parts of the North Santiam, Thomas Creek, and Crabtree Creek drainages, where it is buried under younger volcanic strata. The marine equivalent of the lower and middle Little Butte Formation underlies Quaternary alluvial fill in the Willamette Valley.

Present mapping in the Sweet Home quadrangle represents a significant revision of the work of Peck and others (1964). Terrain mapped as Sardine Formation by them along ridge crests overlooking the Calapooia River and surrounding Green Peter Mountain is here included in the Little Butte Formation because of the abundance of tuffs, dark basalts, and clay soils on gentle slopes.

The Little Butte Formation is an association of dacitic to andesitic pyroclastic rocks and dense, dark basaltic flow rock having an approximate maximum thickness of 10,000 feet. The pyroclastic rocks include coarse greenish to buff breccias in the Middle Santiam, South Santiam, and Calapooia drainages, and a variety of finer grained lapilli tuffs, ash deposits (Figures 8-11), and continental volcaniclastic sandstone toward the west away from the axis of volcanism.

Bordering the Willamette Valley, beds of quartzo-feldspathic marine sandstone (Figure 12) equivalent to the Eugene Formation are interbedded with the lower and middle parts of the Little Butte Formation. Areas in which these interbeds are known to occur are mapped as Tlbe.

The basalts of the Little Butte Formation represent local volcanic accumulations, intracanyon flows, dikes, and sills contemporaneous with the more silicic volcanism which produced the tuffs and breccias. The basalt is dark, dense, and zeolitic and displays columnar (Figure 13), blocky, and occasionally platy jointing (Figure 14). It is fine- to very coarse-grained and phenocrysts of pyroxene are common.

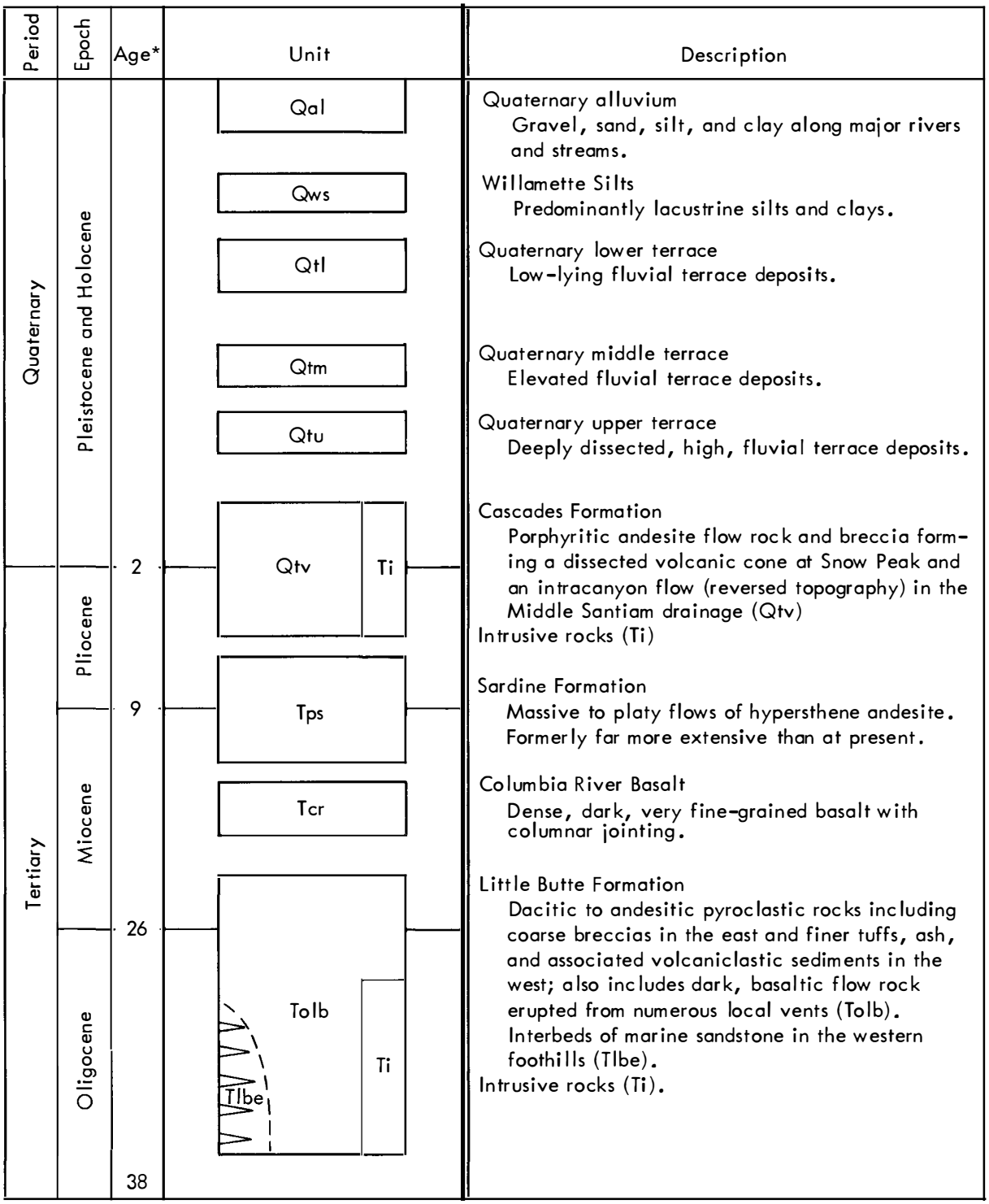


Figure 7. Stratigraphic time chart for western Linn County.

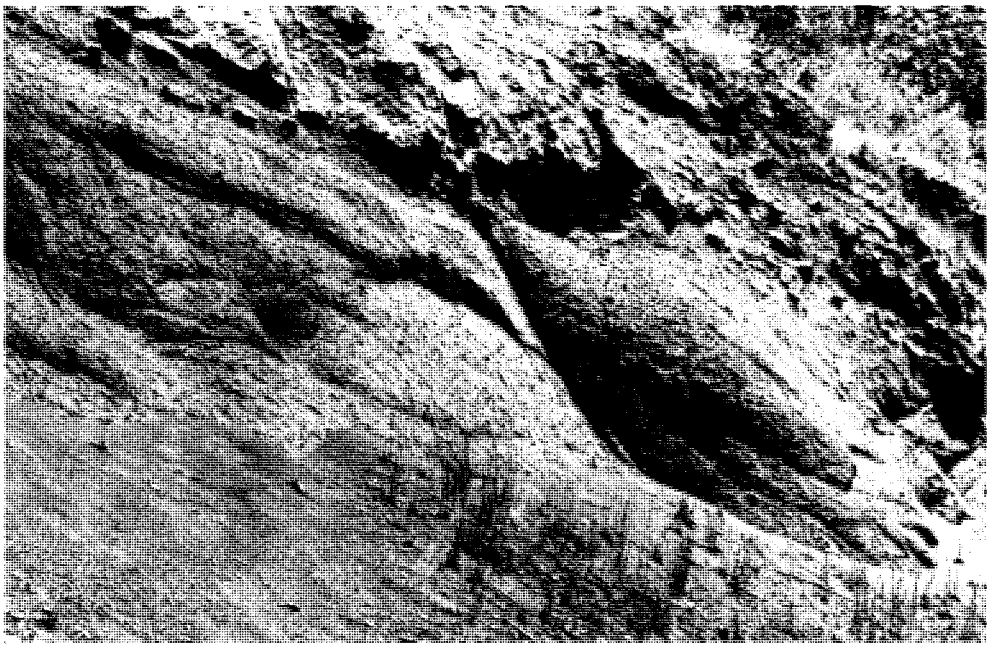


Figure 8. Andesitic tuffs and breccias of the Little Butte Formation exposed on the lower slopes of Shot Pouch Butte (eastern Sweet Home quadrangle).

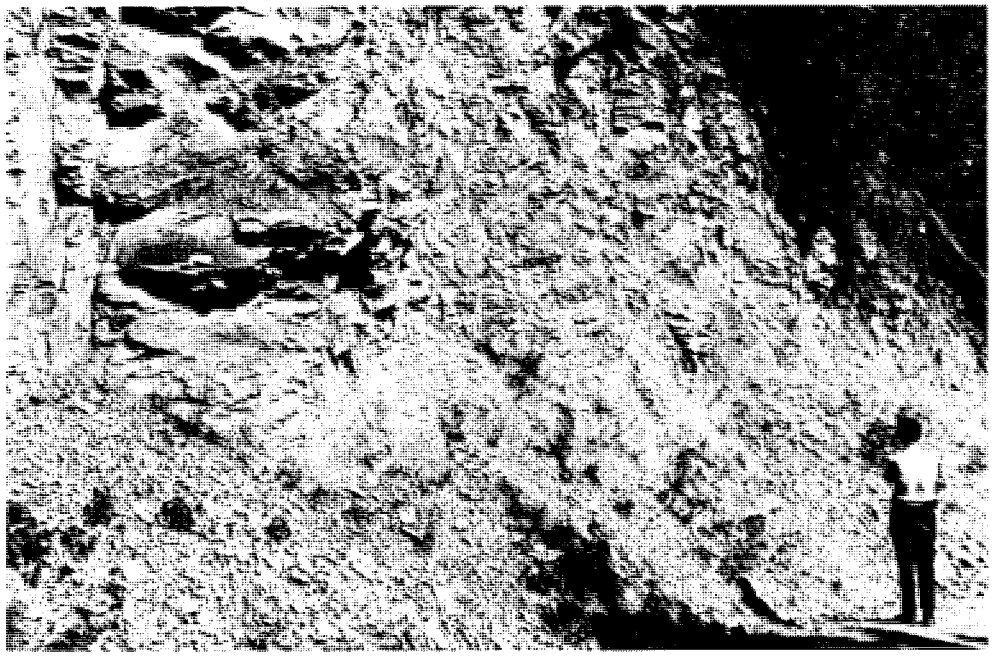
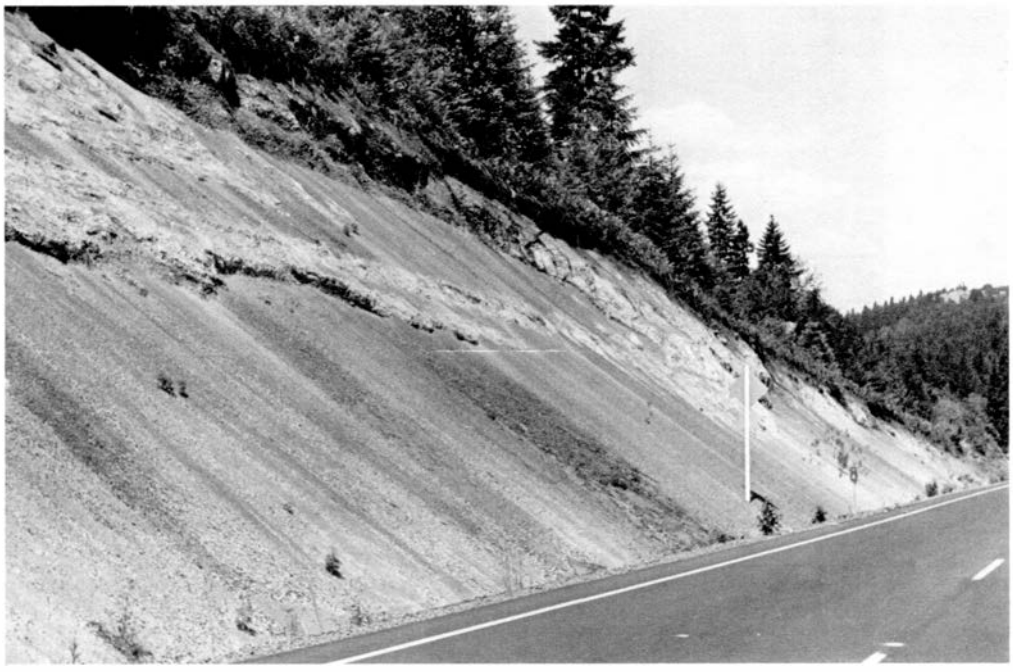


Figure 9. Well-indurated tuffs of the Little Butte Formation exposed on the south slope of Moss Butte (eastern Sweet Home quadrangle).



Figure 10. Tuffs of the Little Butte Formation are composed of innumerable small fragments that were blasted into the air by volcanic activity.

Figure 11. Varicolored fine-grained tuffs and ash of the Little Butte Formation are well-exposed on the Brush Creek Road south of Crawfordsville (southern Brownsville quadrangle).



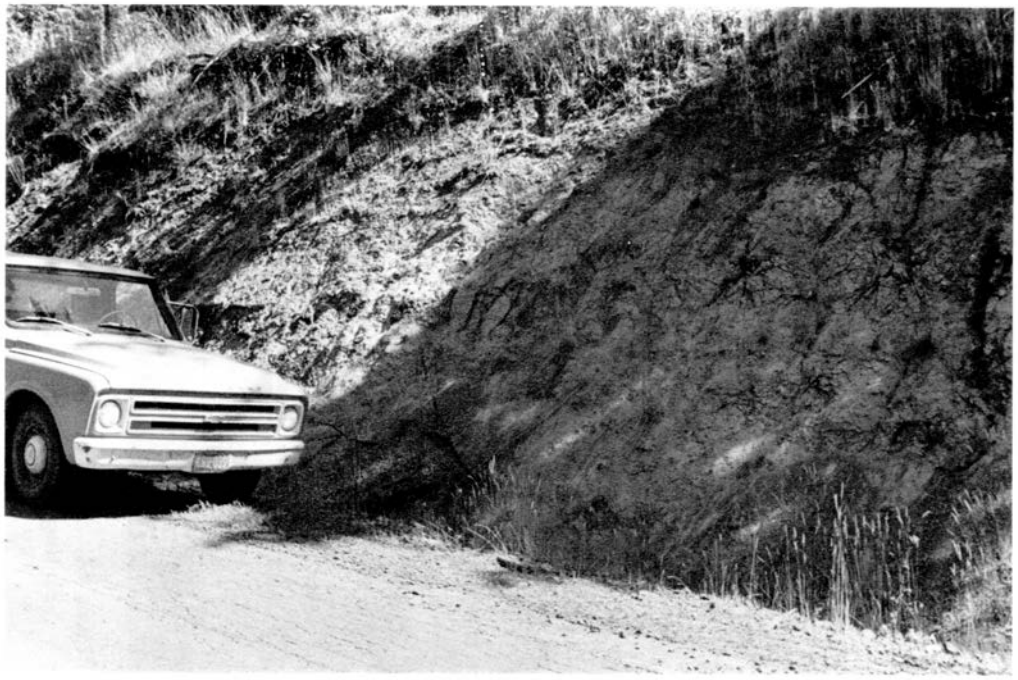


Figure 12. Massive beds of marine sandstone are exposed at an elevation of 1,000 feet on the southeast slope of Washburn Butte (western Brownsville quadrangle).

Poor exposures preclude the differentiation of intrusive and extrusive rocks and the differentiation of basaltic flow rock and pyroclastic rock.

Differential erosion has produced numerous residual basaltic buttes along the eastern edge of the Willamette Valley by removal of the softer enclosing tuffs and sediments (Figure 15). Characteristically the buttes consist of a poorly defined core of dike rock flanked with softer flow rock and basaltic tuffs and breccias (Figure 16). Peterson Butte, Lone Pine Butte, Washburn Butte and Indian Head are resistant basaltic knobs that have yet to be totally isolated from the foothills by erosion.

Accumulations of capping flow rock at Bald Mountain, Cougar Ridge, and Horse Mountain are basaltic to andesitic in composition and represent a relatively late stage of Little Butte volcanism. Dense, dark basalt near Foster Reservoir was mapped as Columbia River Basalt by Peck and others (1964) but is here included in the Little Butte Formation on the basis of lithologic, stratigraphic, and geochemical data (see Columbia River Basalt).

The Little Butte Formation is assigned an early Oligocene through early Miocene age on the basis of stratigraphic position and fossil leaves by Peck and others (1964). The unit overlies Eocene volcanic rock to the south and is unconformable beneath the middle Miocene Columbia River Basalt. Fossil leaves collected from the unit include middle Oligocene leaves at Knox Butte, late Oligocene to early Miocene leaves at Franklin Butte (Scio flora of Sanborn, 1947), and numerous other mid-Tertiary collections (Peck and others, 1964). Molluscan fossils recovered from marine interbeds indicate a middle Oligocene age at Peterson Butte (Allison and Felts, 1956), and an Oligocene age at the juncture of the South and the North Santiam Rivers (Allison, 1953).

Weathering of the Little Butte Formation produces rubbly looms over the basaltic rocks and deep clay soils over the tuffs on gentle slopes. Deep soil and bedrock failures typify much of the breccia and tuff.

Columbia River Basalt (Tcr)

Russell (1893) first used the term Columbia lava in central Washington and modified the term to Columbia River lava in a later study in Idaho (Russell, 1901). The unit was restricted to lavas of

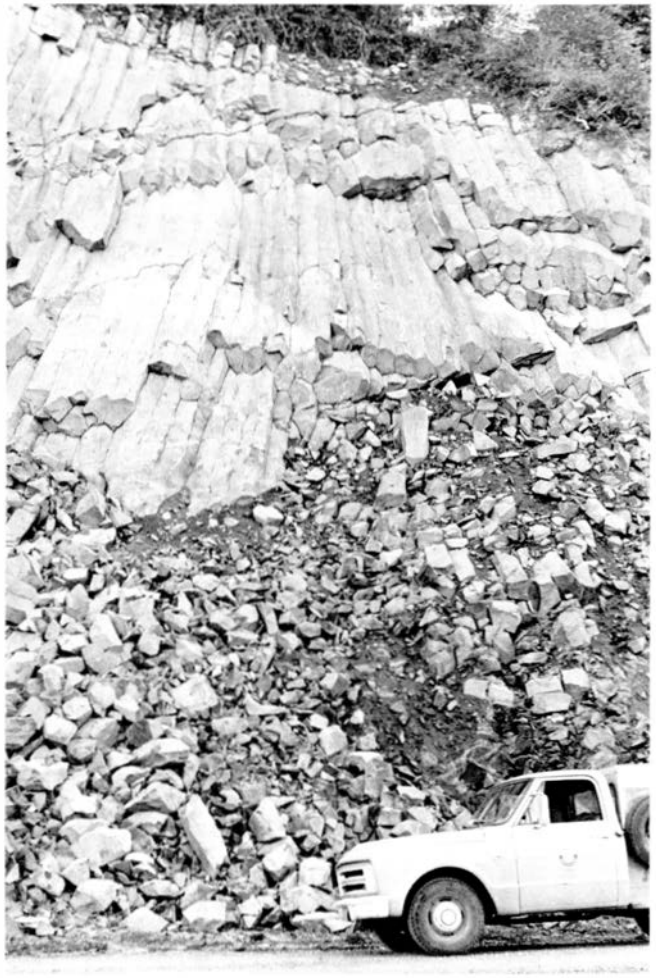


Figure 13. Columnar jointing is well developed in the dense basalts of the Little Butte Formation along Wiley Creek (east central Sweet Home quadrangle).



Figure 14. Some of the Little Butte basalts have platy jointing (quarry in N.E.¼ Sec. 7, T. 12 S., R. 4 W. three miles east of Lebanon).

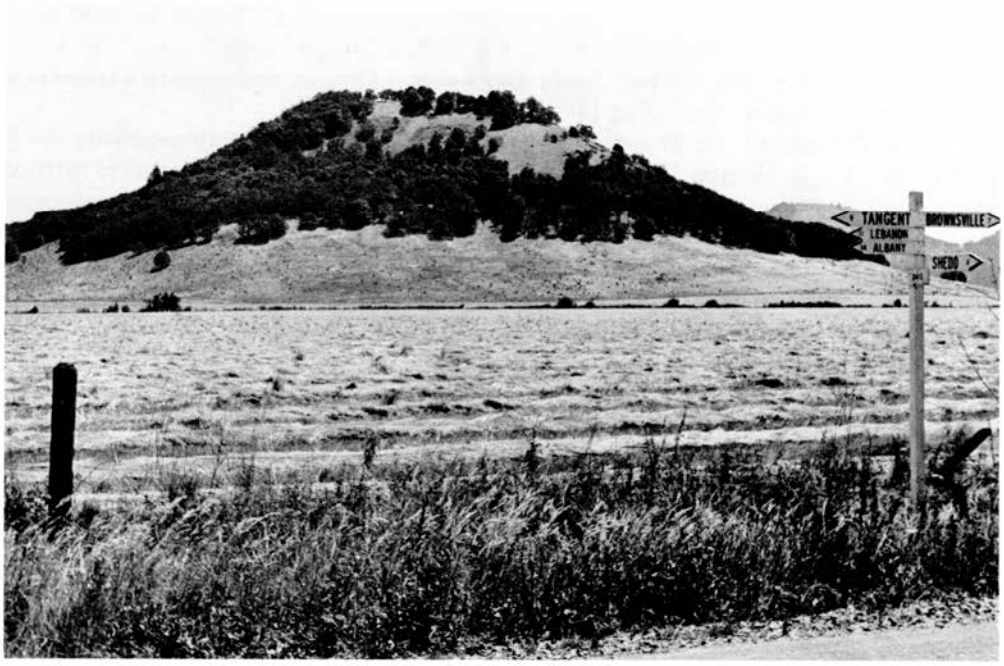


Figure 15. Ward Butte is one of many resistant accumulations of basaltic flow and vent rock along the eastern edge of the Willomette Volley (northeastern Halsey quadrangle).

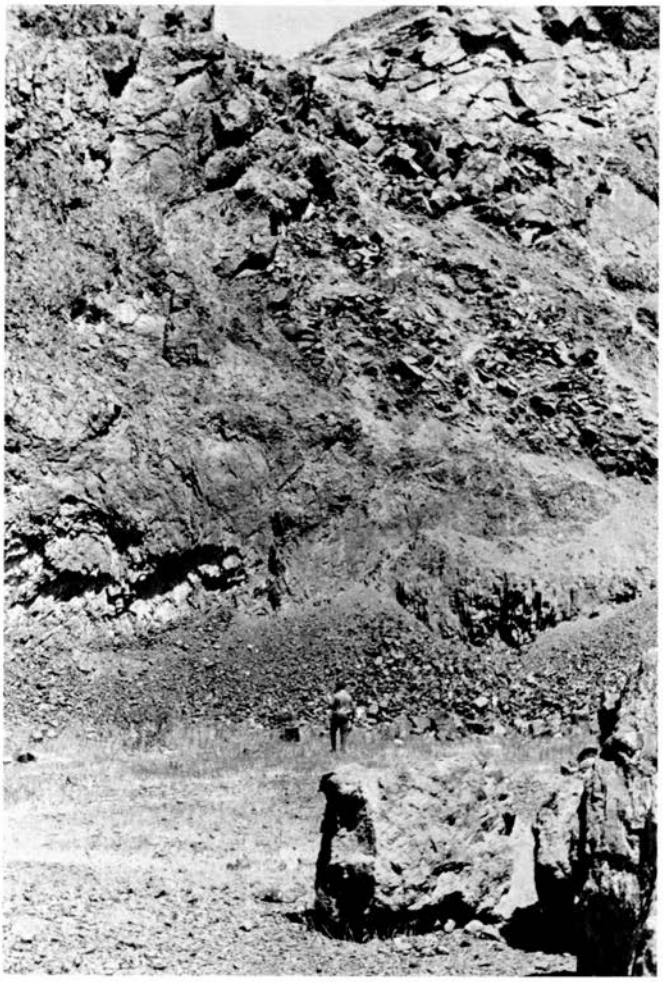


Figure 16. The quarry at Saddle Butte exposes basaltic dike rock, flow rock, and breccia (northeastern Holsey quodrongle).

post-John Day and pre-Mascall (late Miocene) age in central Oregon by Merriam (1901). Waters (1961) subdivided the unit into two formations, the Picture Gorge Formation and the Yakima Basalt. Peck and others (1964) traced the Yakima Basalt into western Oregon and mapped exposures of the unit in parts of the Western Cascades, including Linn County.

The Columbia River Basalt forms gently sloping flat-topped ridges along the North Santiam River and Thomas Creek (Figure 17) in northern Linn County and occurs as several resistant, low-lying hills immediately northeast of Albany (Figure 18). In addition, a thick, elongate intracanyon flow of dense basalt at Marks Ridge immediately north of Sweet Home (Figure 19) is also assigned to the unit.

The Columbia River Basalt is a dense, dark gray to black, tholeiitic basalt. Small scattered phenocrysts of plagioclase and olivine are present in places, but phenocrysts of pyroxene are very rare. Columnar jointing is well developed locally (Figure 19). At Knox Butte, phenocrysts of plagioclase are particularly large, approaching 5mm in length.

Numerous basaltic exposures in the Sweet Home area mapped as Columbia River Basalt by Peck and others (1964) are here included in the Little Butte Formation. They contain abundant pyroxene phenocrysts and occur stratigraphically below dacitic tuffs assigned to the Little Butte. Geochemical analysis of the trace element composition of the prominent roadside outcrop on Route 20 south of Foster Reservoir shows the basalt to be quite distinct from any of the Columbia River types east of the Cascades (Nathan and Fruchter, 1974).

The Columbia River Basalt is unconformable above the Little Butte Formation and occurs stratigraphically beneath the Sardine Formation. Radiometric age determinations from elsewhere in the state indicate an age of approximately 15 million years (middle Miocene) for the Yakima Basalt Formation of the Columbia River Basalt Group.

The Columbia River Basalt weathers to reddish-brown rubbly loam soils in the North Santiam drainage. At Marks Ridge weathering is variable. In places, the basalt is leached to a depth of 20 feet to produce a light-gray crumbly regolith with scattered spheroids of more resistant bedrock; elsewhere fresh bedrock is exposed at the surface.

Sardine Formation (Tps)

As defined by Peck and others (1964), the Sardine Formation includes all the volcanic and volcaniclastic units of post-Columbia River and pre-Cascades Formation age in the Western Cascades of Oregon. The formation is not to be confused with the Sardine Series of Thayer (1936) which was a generalized term applied to what are now parts of the Little Butte Formation as well as the Sardine Formation.

The Sardine Formation is a thick remnant caprock on the higher ridges of south central Linn County at Farmers Butte, High Deck, and Green Peter Mountain. The most extensive exposures form uniform slopes and steep ridges extending from the north side of Snow Peak northeastward along the North Santiam River to Detroit Dam (Figure 20).

The Sardine Formation in the study area consists of a maximum of approximately 1,500 to 2,000 feet of hypersthene andesite flow rock and minor andesitic breccias. At Farmers Butte, thick massive flows of porphyritic andesite are hard and form steep cliffs (Figure 21). At High Deck, the formation consists of porphyritic andesite flow rock near the base, platy andesite in the middle, and very fine-grained andesite and minor basalt near the top. Exposures at Green Peter Mountain consist of andesitic and basaltic flow rock and represent the southernmost tip of a much larger exposure extending northeastward out of the mapped area.

In the drainage of the North Santiam River, the Sardine Formation is dominated by steep slopes of andesitic flow rock, but also includes tuffs and breccias. Pungrassami (1969) recognizes a lower tuff and flow unit, a middle breccia unit, and an upper platy andesite flow unit in the Detroit Dam area. Farther north, breccias are more abundant in the Sardine Formation (Peck and others, 1964).

The Sardine Formation overlies the Columbia River Basalt and underlies the Cascades Formation. Late Miocene to early Pliocene leaves have been recovered from rocks assigned to the unit about the periphery of the Western Cascades north of Linn County (Peck and others, 1964). No leaf fossils have been recovered from the unit in the interior of the range (Wheeler and Mallory, 1970).

A lead-alpha age determination on zircon recovered from a diorite intrusion at Detroit Dam indicated an age of 25$\pm$ 10 million years (Peck and others, 1964). Jaffe and others (1959) report a lead-alpha age of 23 million years for zircon recovered from "late Miocene rocks" in Marion County 8 miles north of



Figure 17. Flat-topped ridges of Columbia River Basalt overlook lower terrace deposits northeast of Scio (northeastern Lebanon quadrangle).

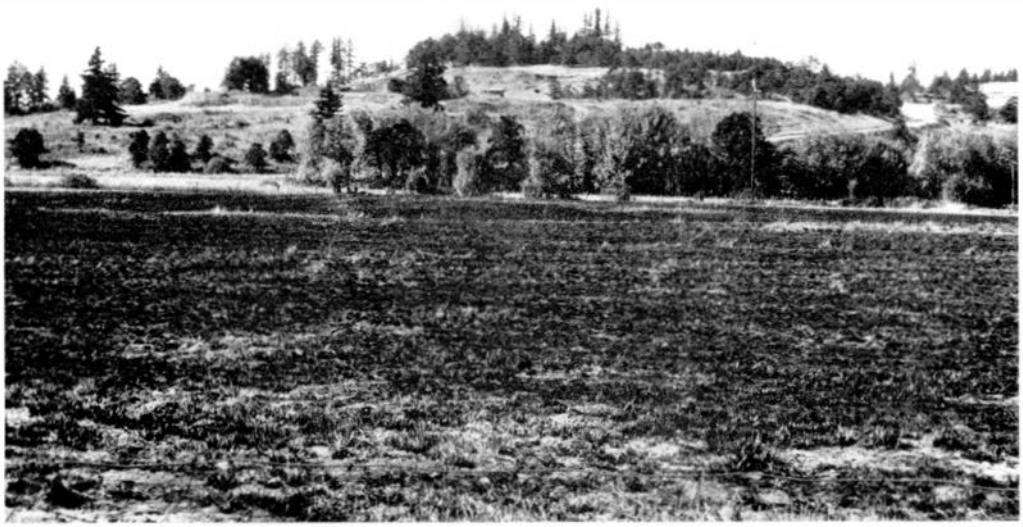


Figure 18. Extensive quarry operations at Hole Butte indicate that the hill is composed largely of Columbia River Basalt (northern Albany quadrangle).

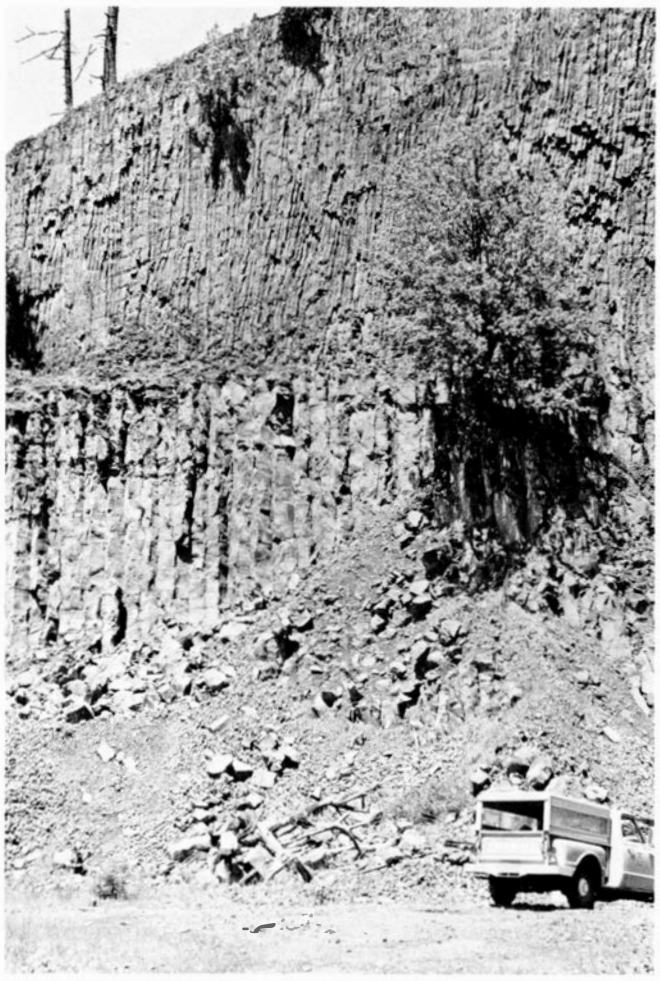
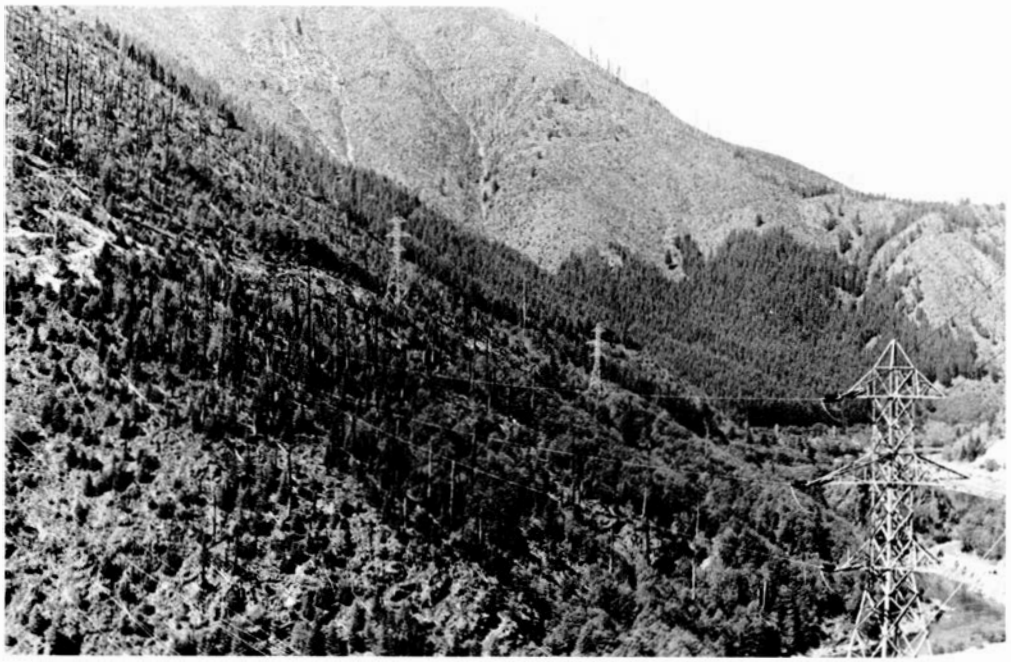


Figure 19. Thick flow of Columbia River Basalt at Marks Ridge displays classic thin columnar jointing in the entablature (upper zone) and thicker columnar jointing in the colonnade (lower zone) (northwestern Sweet Home quadrangle).

Figure 20. Exposures of Sardine Formation along the North Santiam River form steep slopes with a thin soil cover (northeastern Quartzville quadrangle).



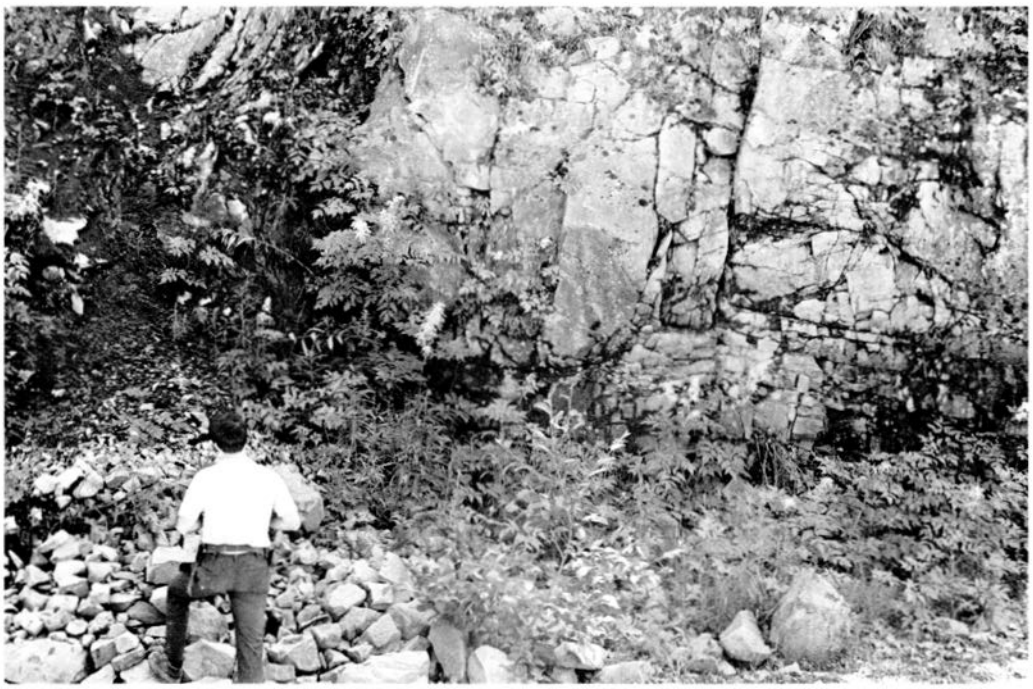


Figure 21. Massive ondesitic flow rock of the Sardine Formation forms steep cliffs on the northwestern side of Green Mountain (Formers Butte) in the southern Sweet Home quadrangle.

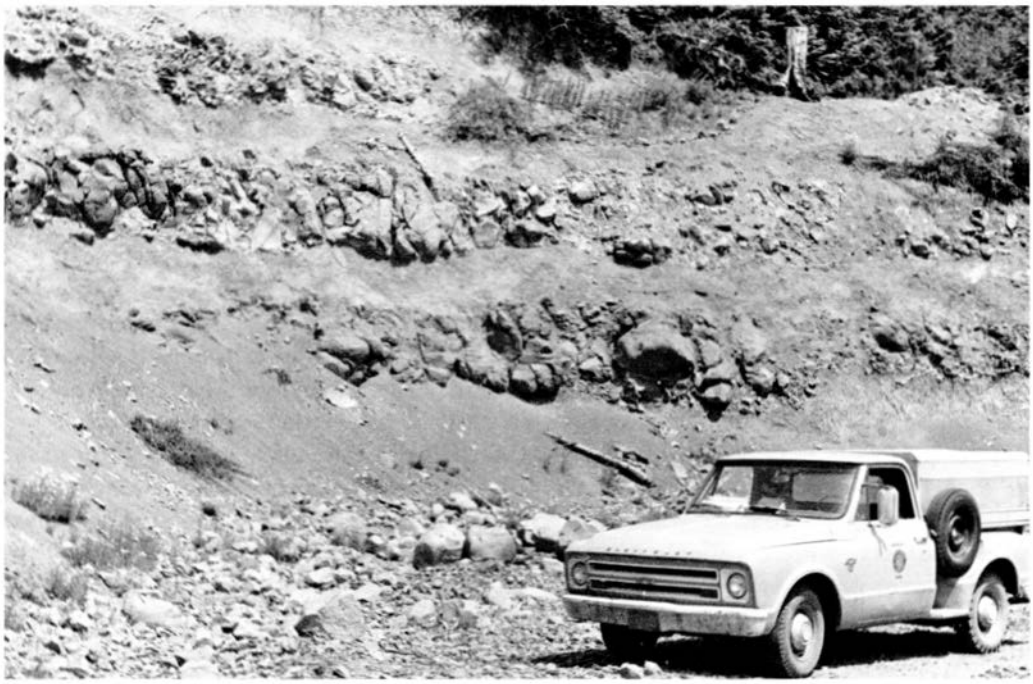


Figure 22. The bose of the Cascades Formation on the south slopes of Snow Peak includes thin flows of light-gray massive flow rock and intercalated fine-grained tuffs and breccias (central Snow Peak quadrangle).

Detroit Dam. The accepted late Miocene to Pliocene age of the stratigraphic units involved suggests that the absolute ages provided by the lead-alpha methods are in error. The great half-life of the lead isotope involved and the small amounts of lead in the samples may be sources of error. Jaffe (written communication, 1973) maintains, however, that the ages are correct.

Recently McBirney and Sutter (1974) released potassium argon dates of 15.5, 15.9, and 16.7 million years for andesite flow rock, andesite dike rock, and basaltic flow rock respectively in rocks mapped as Sardine Formation north of Detroit Reservoir. These ages lie midway between the age of the base of the Sardine Formation and the age of the top of the Little Butte Formation as presented by Peck and others (1964). Clearly, the stratigraphy of the interior of the Western Cascades is poorly understood.

Rocks of the Sardine Formation characteristically form steep slopes. Hazards include flash flooding and steep-slope failure. On ridge crests and other gentle slopes, thin rubbly reddish-brown silty loam soils are common.

Cascades Formation (Qtr)

The Cascades Formation was defined near the Columbia River Gorge by Williams (1916). Subsequently, equivalent rocks to the south have been referred to as Cascade Andesite, Cascan Formation, Cascade Formation, High Cascades Lavas and Plio-Pleistocene lavas by numerous writers. Recent studies have shown the Cascades Formation of parts of the Western Cascades to be considerably older than the prominent vents of the High Cascades (Wise, 1969).

At Snow Peak the Cascades Formation consists of up to 3,000 feet of massive, light- to medium-gray andesite flow rock and breccia with minor basalt (Figure 22). A deep canyon carved in the north side of Snow Peak exposes the feeder plugs and numerous smaller dikes of the ancient volcano (Figure 23).

Farther to the east, massive light-gray andesite flows form a protective caprock on the ridge between Quartzville Creek and the Middle Santiam River. The accumulation is interpreted as a series of intra-canyon flows which have become a ridge top as the rapidly downcutting streams have removed the softer tuffs and breccias which surround them. A rubbly regolith with large andesite boulders typifies much of the upper surface of the flows. Much of the andesite is coarsely porphyritic and vesicular, and in places closely resembles Cascades Formation flow rock near the base of Mount Hood, situated 75 miles to the northeast (Figure 24).

The Cascades Formation is unconformable over the Sardine Formation and is deeply dissected. A late Pliocene to Pleistocene age is assigned to the unit. Hazards include rockfall and flash flooding in the steeper canyons. At Rocky Top, massive bedrock failures in the underlying Little Butte Formation are undercutting the Cascades Formation on steep slopes.

Tertiary intrusive rock (Ti)

Tertiary intrusive rock includes numerous basaltic plugs and dikes of Oligocene to early Miocene age which fed the basaltic vents of the Little Butte Formation and the late Pliocene to Pleistocene plug which fed the Cascades Formation at Snow Peak. Within Little Butte terrain only the largest intrusions are mapped. These include those at Washburn Butte, Lone Pine Butte, and Shot Pouch Butte (Figure 25). The presence of innumerable smaller intrusions within parts of the Little Butte Formation is indicated by the irregular, lumpy topography south of Lebanon, the riffles in the South Santiam River east of Lebanon, and the dike rock in the cores of the buttes located in the eastern part of the Willamette Valley.

The plug at Snow Peak consists of massive andesite and basalt. The texture of the basalt shows many resorption features, which probably were formed through recrystallization brought about by repeated passage of lava through the vent (Peck and others, 1964). A diorite intrusion at Detroit Dam (Figure 26), immediately east of the study area on the North Santiam River, penetrates the Sardine Formation and is probably Pliocene in age (see Sardine Formation). Nowhere in western Linn County are feeder dikes exposed for the Columbia River Basalt.



Figure 23. A steep canyon on the north side of Snow Peak exposes the core of the ancient volcano; steep slopes on the right and in the center background are intrusive plugs (central Snow Peak quadrangle).



Figure 24. Lorge boulder of porphyritic andesite assigned to the Cascades Formation; the hand specimen recovered from the Cascades Formation near Mount Hood is remarkably similar (southern Quartzville quadrangle).



Figure 25. Coarsely jointed columnar basalt forms a large pluglike intrusion into the Little Butte Formation at Shot Pouch Butte (eastern Sweet Home quadrangle).

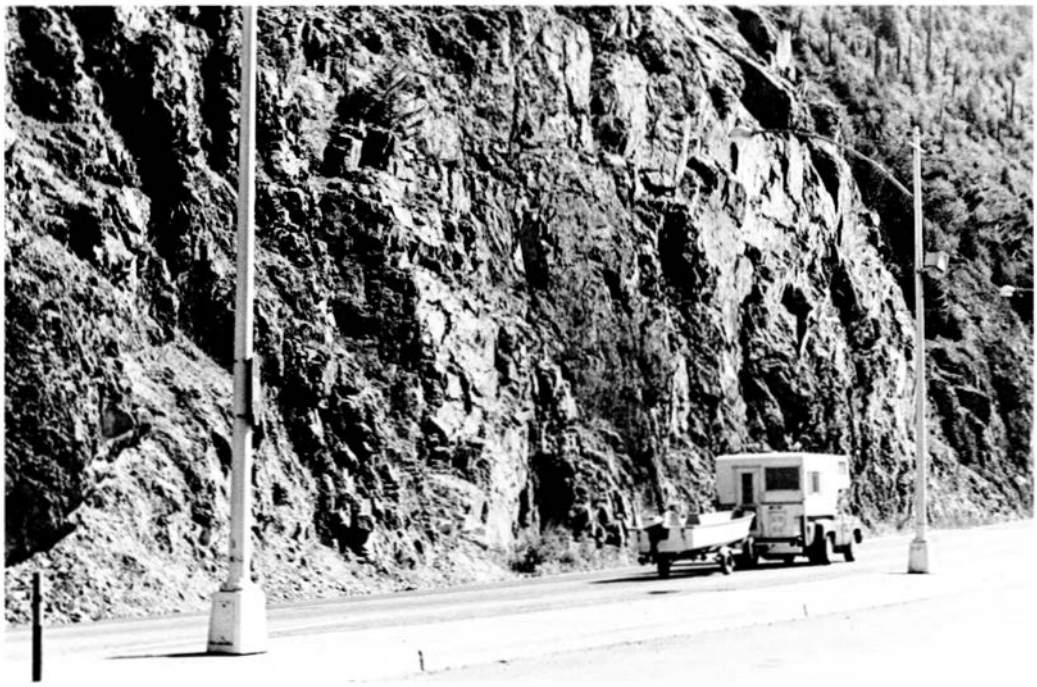


Figure 26. The radiometric age of the large diorite intrusion at Detroit Dam is inconsistent with the identity of the stratigraphic units involved (see Sardine Formation in text).

Quaternary upper terrace (Qtu)

The Quaternary upper terrace deposits consist of a deeply dissected, elevated gravel fan in the east central Lebanon and the west central Snow Peak quadrangles, and an elevated terrace surface immediately southeast of Hardscrabble Mountain northeast of Albany. The terrace unit is equivalent to the Lacomb gravels of Allison (1953) and Allison and Felts (1956).

The upper terrace lies 100 to 200 feet above the level of nearby alluvial stream valleys and has a maximum elevation of 864 feet east of Lacomb. It consists of very coarse to pebbly fluvial gravels, sands, and silts. Boulders up to 2 feet in diameter are common at the eastern apex of the fan. The deposit mantles bedrock units and probably does not exceed 100 to 150 feet in thickness.

The elevated topographic position, advanced degree of dissection, and deep weathering suggest an early Pleistocene age for the unit (Allison and Felts, 1956). Soils include clay loams in the west and silty clay loams in the east.

Quaternary middle terrace (Qtm)

The Quaternary middle terrace deposits consist of flat-lying, moderately elevated pebble gravels, sands, and silts of fluvial origin which lie below the upper terraces (Qtu) and which lie above the lowermost terrace level (Qtl). They include the Leffler gravels of Thayer (1939) near Stayton and equivalent terrace levels farther upstream along the North Santiam River. Also included are the Leffler gravels of Allison (1953) in the Albany quadrangle and the Leffler gravels of Allison and Felts (1956) in the Lebanon quadrangle.

Elevation of the terrace gravels varies from 300 feet in the west to 500 feet locally in the east. Thickness seldom exceeds 20 to 30 feet. The deposits consist of moderately to deeply weathered gravels, sands, and silts.

In well-drained regions, reddish-brown silty loam soils up to several feet thick are developed on the middle terrace gravels. In areas of exceptionally flat terrain and poor drainage, clay-rich soils develop. North of Scio, coarse gravels are weathered to soft clay soils to a depth of 10 to 20 feet. Individual boulders are distinguishable on the basis of color, but are as soft as the surrounding matrix and can be easily cut with a knife.

The middle terrace deposits are intermediate in elevation and in degree of stream dissection between the lower and upper terrace deposits. A middle Pleistocene age is inferred. Thayer (1939) correlates his Leffler gravels in the North Santiam basin (Qmt of this report) with poorly sorted gravels, which he terms the Mill City Glacial Moraine. He infers a Kansan age for the moraine.

Quaternary lower terrace (Qtl)

The Quaternary lower terrace consists of low-lying fluvial gravels overlooking Quaternary alluvium along the lower reaches of the North and South Santiam Rivers. The unit also includes all the subsurface gravels of the Willamette Valley which are overlain by Willamette Silt (Qws) and isolated patches of low-lying terrace gravel along many of the foothill streams (Figure 27). The unit includes the Linn gravels of Allison (1953) in the Albany quadrangle and of Allison and Felts (1956) in the Lebanon quadrangle.

The lower terrace lies above the level of flooding and is characterized by numerous subdued meander scars unlike the smoother areas underlain by Willamette Silt. In places distinction of this unit is difficult and must be based on subtle drainage patterns or soil type. Between Lebanon and Albany, topographic contours on the Willamette Silt are inflected toward the northeast as they enter lower terrace terrain. In addition, stream channels in the lower terrace gravel between Albany and Lebanon trend northwest, whereas streams in the Willamette Silt to the west trend in a more westerly direction. Soils developed on the lower terrace surface are dominated by sands and gravels unlike the silt and clays of the Willamette Silt.

The lower terrace deposits consist of moderately to well-rounded granule pebble gravels and sands of fluvial origin. Average thickness in the east appears to be 20 to 30 feet, primarily on the basis of topographic expression (Allison, 1953). To the west in the more central portions of the valley, average thickness of the alluvial fill including the overlying Willamette Silt is approximately 70 feet (Piper, 1942).



Figure 27. Low-lying terraces in the middle reaches of Thomas Creek are assigned to the Quaternary lower terrace unit (northern Snow Peak quadrangle).

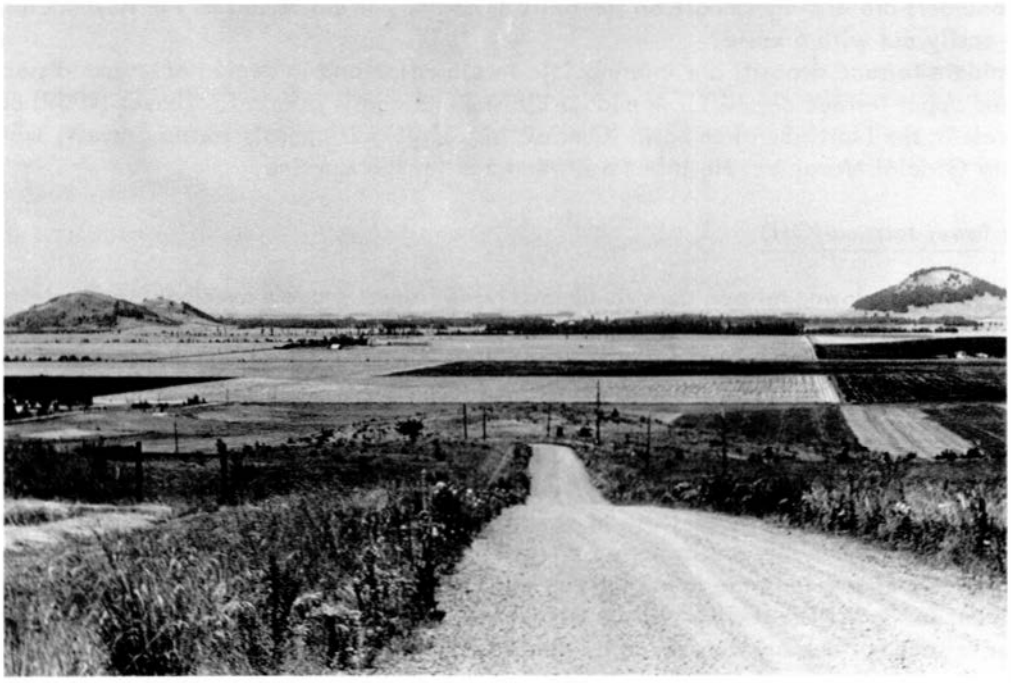


Figure 28. The Willamette Silts overlie most of the floor of the Willamette Valley (looking north from Powell Hills at Saddle Butte on the left and Ward Butte on the right, northeast Halsey quadrangle).

The Porter No. 1 well near Halsey penetrated 80 feet of alluvial fill before reaching bedrock (Newton, 1969). Approximately 200 to 230 feet of alluvial fill is present near Junction City, and similar thicknesses are present at other localized areas (Frank, oral communication, 1974), but these appear to exceed the thickness found in most of the valley (Piper, 1942). Piper (1942) points out that the elevation of the upper surface of bedrock near Junction City is 40 feet lower than the elevation of bedrock in parts of the Albany area, a feature which suggests irregular variations in the alluvial thicknesses of the valley and which supports the concept of continuing deformation in the valley.

On the basis of relative topographic position, degree of dissection, elevation, and stratigraphic position beneath the Willamette Silt, a late Pleistocene (possibly early Wisconsin or Illinoian) age is postulated for the lower terrace gravels (Allison and Felts, 1956).

Willamette Silts (Qws)

In 1935, Allison described numerous ice-rafted erratics in the Willamette Valley, and in 1953 he proposed the name Willamette Silts for all "the parallel-bedded sheets of silt and associated materials that cover the greater part of the Willamette Valley lowland." Subsequently, Baldwin (1964) assigned the lower silts to his late Pleistocene lakebeds for which he inferred an eustatic origin. For the surficial veneer of silts and erratics, he inferred a glacial meltwater origin. Glenn (1965) described numerous soil horizons within the Willamette Silts of the northern Willamette Valley and postulated a series of at least 40 floods resulting from glacial melting to account for the deposition of the silts as discussed below.

In Linn County, the Willamette Silts are located on the flat-lying floor (Figure 28) of the Willamette Valley west of the South Santiam River. At least 27 localities of glacial erratics have been reported in the County (Allison, 1935). Maximum elevation of the deposit is 350 feet, although the distribution of erratics throughout the valley shows that lake elevation at times of maximum flooding approached 400 feet (Allison and Felts, 1956). East of the South Santiam River, Allison and Felts (1956) mapped Willamette Silts on lower terrace levels (their Linn gravels and Qtl of this study). In this study, the silty veneer is regarded as too thin and patchy to be mapped. In addition, Balster and Parsons (1969) note that many of the soils overlying the terraces are too coarse to be regarded as Willamette Silts.

At Irish Bend along the Willamette River west of Halsey, the type section of the Willamette Silts consists of massive to thinly bedded admixtures of silt and clay. Between 6 and 13 feet below the surface the sediment is a micaceous, quartz and feldspar-rich silt that is faintly bedded. Overlying the silt and separated from it by a soil horizon is a 6-foot layer of gray silt and clay. Although Balster and Parsons (1969) do not consider the upper silts and clays to be part of the Willamette Silts, they are here considered to be part of that unit. The erratics which typify the concept of Willamette Silts in Linn County occur at or near the ground surface in Linn County.

The Willamette Silts range from 0 to approximately 30 feet in thickness. In the northern part of the County, numerous stream valleys with a relief of 15 feet do not penetrate to the base of the unit. In the southern half of the County, lower terrace gravels are within 5 to 10 feet of the surface. Samples taken from scattered hand auger holes by Balster and Parsons (1969) indicate an average thickness of approximately 15 to 20 feet. The total thickness at Irish Bend is 13 feet.

The number and thickness of beds in the Willamette Silts increases northward toward Albany (Balster and Parsons, 1969). At Albany the unit thins markedly. Farther north between Albany and Portland, the Willamette Silts approach 100 feet in thickness and include rippled and cross-bedded sands in addition to silts and clays (Glenn, 1965). Heavy-mineral studies in the northern Willamette Vally (Glenn, 1965) and the composition of erratics throughout the Willamette Valley (Allison, 1935, 1953) indicate a Columbia River source for the sediments.

The Willamette Silts vary in age from approximately 18,000 years to 100,000 years. Peat deposits overlying the Willamette Silt in the Labish Channel north of the study area have been dated at 11,000$\pm$ 230 years, and alluvial gravels beneath the silts are older than the age range of the carbon-14 dating method (greater than 37,000 years) (Glenn, 1965). The Willamette Silts of the northern Willamette Valley overlie a terrace along Mill Creek in the North Santiam drainage which is equivalent to the lower terrace (Qtl) of this report and the Linn gravels of Allison (1953). This is the same stratigraphic position as is occupied by the Willamette Silts of Linn County; the two deposits are stratigraphically equivalent and inferences regarding the origin of one can be applied to the other.

Allison (1953) and Glenn (1965) state that glacial meltwater cascading down the Columbia River was temporarily ponded in the Willamette Valley, where it deposited silt and erratics upon the alluvial fill. On the basis of numerous soil horizons within the Willamette Silts, Glenn (1965) postulates that at least 40 floods were involved in the deposition of the silts. The absence of shoreline deltas, beaches, and locally derived sediments implies rapid deposition over a short period of time. Ice age floods which could have delivered the sediments are described by Bretz (1969). The oldest occurred about 100,000 years ago (Bretz, 1969), and the most recent about 18,000 to 20,000 years ago (Richmond and others, 1965). The last flood (Spokane Flood) was the largest.

Baldwin (1964) postulates that the lower parts of the Willamette Silts were laid down in lakebeds generated during the last interglacial rise of sea level. The speed of deposition as inferred from the lack of shoreline features, the high elevation of much of the silt, and the presence of erratics as much as 30 feet below the surface (Allison, 1935) do not appear to be compatible with this theory.

Quaternary alluvium (Qal)

Unconsolidated deposits of poorly sorted gravel, sand, silt, and clay which occupy the flood plains of the major streams are assigned to the Quaternary alluvium. Exposures along the Willamette River are several miles wide southwest of Albany and are dominated by lenticular gravels and sands. Silt mantles much of the flood plain away from the main channel. Thickness of the Quaternary alluvium varies from a feather edge to approximately 30 feet. A maximum thickness of 42 feet of alluvium is present in a well near Corvallis (Piper, 1942).

The flood plains of the North and South Santiam Rivers are floored with gravel, sand, and silt. Farther east in the foothills, the major valley floors are mantled with coarse cobble gravels and sands, and organic fine-grained soils are present in the marshy areas of poor drainage.

Muddy Creek, the Calapooia River, and numerous smaller creeks of the Willamette Valley are lined with alluvium consisting primarily of silt and clay. These deposits are generally thin, probably not exceeding 5 to 10 feet.

The Quaternary alluvium occupies stream valleys which are undercutting deposits of Willamette Silts (Qws), and the alluvium clearly postdates that unit. An age of less than 20,000 years is assigned to the Quaternary alluvium.

Geologic processes associated with the Quaternary alluvium include flooding and stream-bank erosion. Ground-water production is good except in areas of high silt or clay content.

Geologic Structure

Interpretations of the geologic structure of western Linn County are based on published maps, reconnaissance mapping, regional gravity data, limited aeromagnetic data, and the logs of four deep exploratory oil wells. The structure is that of a regional east-dipping monocline modified locally by gentle folds and by numerous possible faults.

Marine sedimentary rock of Eocene through middle Oligocene age is present in the subsurface of the Willamette Valley and nonmarine strata of Oligocene to Pleistocene age are present in the Western Cascades. Dips are gentle to the east; the base of the Oligocene section dives to relatively great depths in that direction (Figure 29). Consistent with this structural interpretation, gravity decreases uniformly from west to east, indicating greater crustal thicknesses under the Cascades (Berg and Thiruvathukal, 1967).

Faults

A fault is a surface or zone of rock fracture along which there has been displacement. In reconnaissance mapping, large faults are determined on the basis of recognizable rock displacement, significant topographic lineations, and shear zones. Using these criteria, no definite faults were mapped in this study. No shear zones were seen; topographic lineations were attributed to phenomena other than faulting, and apparent local offsets of rock units were interpreted in terms of the irregularities of continental

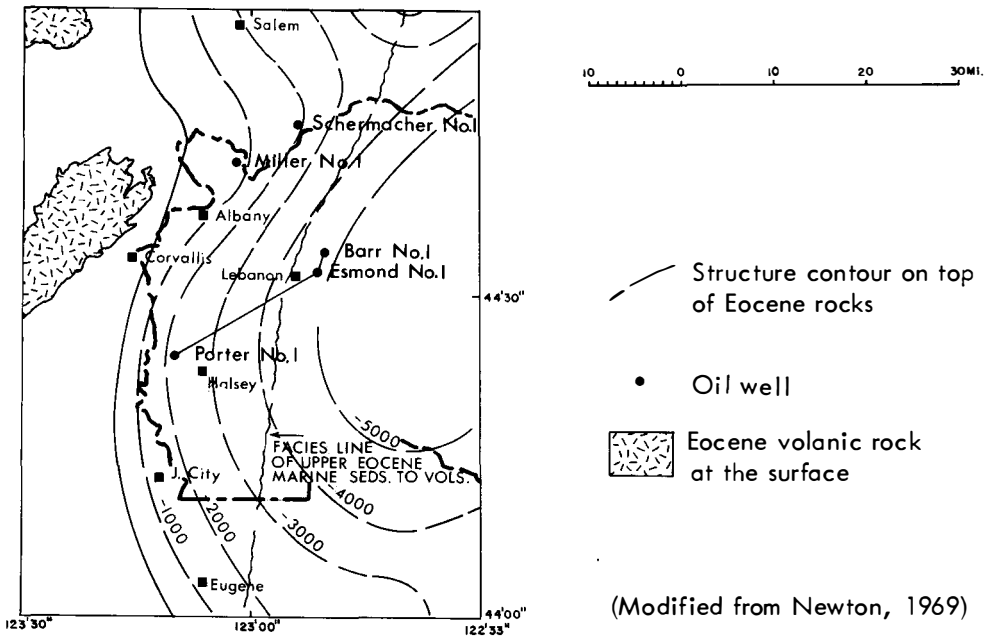


Figure 29. Subsurface geologic map of western Linn County.

deposition on irregular terrain. In addition, thick vegetative cover, extensive alluvial fill, and deep weathering in many areas preclude the recognition of faults.

Although no definite faults are recognized in this study, it should not be concluded that there are no faults. Seismic data reveals at least three earthquake epicenters in the County (see Geologic Hazards: Seismicity). More detailed study in the future may show many of the lineations within the County to be faults. Several of the more significant possible faults described in the literature are discussed below.

"Willamette Valley fault": Lewis (1950) described the mid-Tertiary rocks of the Eugene quadrangle and noted that the persistent easterly dips indicated an unusually thick section. To account for the great apparent thickness, he postulated that a prominent north-trending fault along the east side of the Willamette Valley had upthrown rocks to the east. No direct field evidence for the fault was described.

In western Linn County, persistent easterly dips also suggest a very thick column of Eocene to early Miocene rocks. It is doubtful, however, that a major north-trending fault is present in the subsurface of the eastern edge of the Willamette Valley. Well data show that the upper surface of the Eocene rocks dives uniformly to the east at least as far east as Lebanon (Newton, 1969), several miles beyond the most likely positions of the hypothetical fault. Aeromagnetic data (Bromery, 1962) and gravity data (Berg and Thiruvathukal, 1967) show no evidence for a major fault. Although part of the eastern margin of the Coast Range is recognized as a fault (Bromery and Snavely, 1964), there are no gravity anomalies uniquely associated with the rest of the Willamette Valley (Thiruvathukal and others, 1970).

The great apparent thickness of the Oligocene section in western Oregon (8,000 feet of Eugene Formation and 10,000 feet of Little Butte Formation) can be explained in terms of a broad regional downwarp along the axis of the Cascade Range. This interpretation is consistent with present geophysical data and deep-well information. It is concluded that there is no major faulting along the eastern edge of the Willamette Valley.

Other faults: On the state map of western Oregon (Wells and Peck, 1961), six northerly trending faults are shown in western Linn County. Two major colinear faults 5 miles west of Sweet Home are mapped on the basis of topographic lineations and the abrupt termination of the Columbia River Basalt unit. Remapping reveals the basalt to be Little Butte rather than Columbia River Basalt. Lineations alone are not regarded as sufficient evidence to define faults, and they are not shown on the geologic map.

The other four faults shown on the state map of western Oregon (Wells and Peck, 1961) are south of Sodaville in a north-trending valley and at Indian Head (eastern Halsey and western Brownsville quadrangles). No evidence was acquired in this study to either support or refute the presence of these faults. If the faults are present, they are probably local features of little significance in terms of hazards to most types of development.

A northwest-trending magnetic anomaly northeast of Lebanon near Golden Valley School is described by Bromery (1962). The anomaly passes southeastward along the steep hillside slope and is colinear with the valley of Hamilton Creek. Bramery postulates a fault along the anomaly. It seems likely, however, that the steep topography of the hillside best explains the aeromagnetic patterns. Magnetic isapleths along Hamilton Creek trend northeasterly in marked contrast with those to be expected from the proposed fault. Colinearity of the Hamilton Creek Valley and the steep slope to the northwest is probably coincidental.

Linears: High altitude photography recently made available by the Earth Resources Technology Satellite (ERTS) provides geologists with an additional tool useful in mapping faults. The synoptic views provided by the imagery provide an excellent opportunity for selecting significant lineations of possible fault origin on the earth's surface. Such lineations are called linears (Short and Lowman, 1973); on-the-spot field checking is required to determine whether the linears are actual faults or if they represent man-made objects, vegetation patterns, optical illusions, or spurious alignments of diverse ground features.

Brief preliminary investigation of small-scale imagery revealed 24 major linears in western Linn County (Robert Lawrence, written communication, 1973). Field examination showed most of the linears to be erosional escarpments along terraces and cliffs. Many others were relatively straight stretches along mountain canyons. Although some of the linears may represent faults, no field evidence was gathered in the course of this reconnaissance study to allow them to be mapped as faults. The value of high-altitude imagery will no doubt increase in the future, however, and more detailed studies are needed.

Folds

Folds are generally recognized on the basis of measured attitudes and outcrop patterns. In this study, measured attitudes are relatively scarce and random. Although they do indicate a regional easterly dip throughout the County, they are not sufficient for the delination of more local structural features. Outcrop patterns provide most of the basis for the folds recognized in this study.

The hills and buttes northeast of Albany are surrounded by surficial alluvial deposits suggesting upwarp. Alternatively, the hills could be remnants left behind as the softer surrounding bedrock was removed by river erosion. They are composed of Columbia River Basalt and are similar to Hungry Hill, Franklin Butte, and Prospect Mountain to the east for which no folding is inferred.

South of Lebanon, the western edge of the Western Cascades is underlain by marine sandstone. Outcrop patterns of the sandstone southward through Brownsville and Indian Head Mountain suggest an anticline with a north-trending axis. An exploratory oil well (Esmond #1) on the extended axis of the structure northeast of Lebanon had gas shows and oil fluorescence at depths between 2,780 and 3,990 feet. Alternatively, greater appreciation of facies changes and more detailed mapping could negate the possibility of a fold.

Bald Mountain, Cougar Ridge, and Horse Rock in the southern Brownsville quadrangle are capped with flow rock believed to be high in the Little Butte section. Towards the northeast an isolated exposure of Columbia River Basalt is mapped at Marks Ridge north of Sweet Home, and a tongue of Sardine rocks trending northeast out of the mapped area is exposed at Green Peter Mountain. Downwarp can account for the local preservation of these relatively young exposures. A synclinal axis is indicated on the geologic maps.

Minor folding may also occur within the Willamette Valley. Piper (1942) notes that the elevation of the upper surface of bedrock is 40 feet lower at Junction City than where the Willamette narrows near Albany. For the Willamette River to have maintained a northerly course, gentle basining and alluviation would have been required in the Junction City area during the Quaternary. In addition, the series of terraces in northern Linn County suggest uplift in that area.

ENGINEERING GEOLOGY

Engineering Characteristics of Geologic Units

The variety of rock types and the various degradational processes in western Linn County have produced ground conditions displaying a wide range of engineering properties. It is imperative that man's activities be keyed to these engineering conditions as well as to the active geologic processes discussed under Geologic Hazards.

The following discussion is regional in its approach and generalized in its conclusions. It is intended for planning purposes and in no way supplants rigorous on-site investigations required for individual developments. Rather, it provides the planner with a guide to some of the problems to be considered in such investigations and in the general planning process.

The engineering properties of the various rock units are summarized on Table 2. In the text, various parts of the Geologic Hazards Section are referred to where appropriate. Following the discussion of individual rock units is a more detailed discussion of soils of the Willamette Valley.

Little Butte Formation (Tolb, Tlbe)

The Little Butte Formation consists of 10,000 to 15,000 feet of continental volcanic and volcaniclastic strata including flow basalt, breccias of basaltic and andesitic composition, tuff, ash, and tuffaceous sandstones. Along the western margin of the foothills, interbeds of feldspathic marine sandstone are interbedded with the more prevalent nonmarine strata. The Little Butte Formation underlies most of the foothills area of western Linn County. Because the lithology of the unit is highly variable, its engineering properties are very complex.

Basalts of the Little Butte Formation include flows and unmapped intrusions. The basalt is more resistant to weathering than the surrounding tuffs and forms steep resistant ledges or localized knobs as in the mountainous region north and east of Brownsville (Figure 30). Soils overlying the basalt are thin and consist of rubbly loam. Land uses relying on moderate permeability for septic tanks and ground-water production are not recommended in most regions of Little Butte basalt. Locally, however, deep weathering on gentle slopes produces acceptable soil conditions. Foundation stability is generally very good, but excavations into the bedrock require blasting.

The breccias and tuffs of the Little Butte Formation are weathered to thick clay loam and silty clay loam soils in the gently to moderately sloping parts of most of the foothills, but they form steep fresh exposures in the canyons of rapidly downcutting streams in the interior (e.g. upper Middle Santiam River). Ground-water production data are incomplete, but low yields can be expected (see Natural Resources: Ground Water). In addition, water quality is poor in places.

The tuffs and breccias of the Little Butte Formation are capable of supporting large structures if properly engineered and located. Green Peter Dam is situated on tuffs and basalts of the Little Butte Formation. In regions of very low slopes and deep weathering, however, the high clay content of the thick soil profile poses severe engineering difficulties. On gently sloping terrain, moderately sized structures such as houses generally show no foundation difficulties.

Special problems associated with the breccias and tuffs of the Little Butte Formation include the possibility of landslides on gentle to moderate slopes (see Mass Movement: Mass Movement Topography), caving in deep excavations, and rockfall and other types of steep-slope failure in the unweathered outcrops. The pervasive jointing and local faulting of the tuffs contribute to the last hazard.

Other engineering difficulties include the extreme variability of rock types within the Little Butte both laterally and with depth. Locally, runoff is irregular where ground water must pass over and around resistant knobs of basalt and is temporarily impounded in regions of more gently sloping tuff. Here development of thick clay soils and perched water produces severe engineering difficulties. As a general rule, well-drained areas are characterized by red soils and orderly topography, whereas the poorly drained, problem areas are characterized by variable slopes and locally by yellow or gray soils.

Table 2. Summary of engineering properties of geologic units

Bedrock units	Rock type	Degradational processes	Soils	Estimated ground-water production	Foundation stability	Special problems
Little Butte Formation (Tolb)	Flow basalts	Rock fall, erosion (slow)	Rubble, loam	Probably low	Variable depending on bedrock and topography	Mass movement Steep slopes Pervasive jointing Extreme variability Local ponding
	Breccia and tuffs	Mass movement Chemical weathering Erosion	Clay loam Silty clay loam	Probably low		
	Sandstone	Erosion Mass movement	Sand and sandy clay	Very high locally variable quality		
Columbia River Basalt (Tcr)	Flow-on-flow basalt	Chemical weathering	Rubbly loam	Low to high	Good	Bedding and jointing Undercutting on steep slopes
Sardine Formation (Tps)	Flow rock and breccia	Erosion (slow)	Rubbly loam	Low to moderate	Good	Jointing in places Steep slopes
Cascades Formation (Qtv)	Flow rock	Erosion (slow)	Rubbly loam	Probably low	Fair to good	Rugged topography Variability of interbedded rock units
	Breccia	Mass movement	Rubbly loam	Moderate to low		
Upper terrace (Qtu)*	Sand, gravel, and silt	Erosion and chemical weathering	Gravel, sandy loam	Moderate	Good	Variable lithology
Middle terrace (Qtm)*	Sand, gravel, and silt	Chemical weathering	Loam, silty loam	Moderate	Poor to good	Ponding locally, variable lithology
Lower terrace (Qtl)*	Gravel, sand and silt	Chemical weathering	Loam, silty loam	Moderate	Poor to good	Extreme variability of rock types
Willamette Silts (Qws)*	Silty clay and clayey silt	Chemical weathering	Loam, silty loam clay loam	Wells penetrate to underlying units	Poor to good	Ponding, high ground water, poor drainage Stream-bank erosion
Quaternary alluvium (Qal)*	Gravel, sand silt	Erosion	Gravel, silty loam	High in gravels	Poor to good	Flooding Compressible soils Stream-bank erosion
Intrusive rock (Ti)	Dense basalt	Steep slope failure	Rubble	Very low	Good	Peripheral mass movement

*See Soils of the Willamette Valley, p. 34



Figure 30. Soil overlying basaltic intrusions in the Little Butte Formation is very thin; note the gentle slopes developed on this particular intrusion (3 miles northeast of Brownsville).



Figure 31. Differential settling has caused structural damage to the foundation of this house; it is constructed partly on compressible soils.

The marine sandstone interbeds in the westernmost exposures of the Little Butte Formation are generally well-sorted and clean. They are semi-consolidated over most of their extent and are generally covered with vegetation. Sand weathered from them is present in recent roadcuts or is inferred on the basis of abundant sand in gullies along logging roads. Stripping of vegetation in areas underlain by the marine sandstone can lead to severe erosion in areas of gentle slopes and to erosion and mass movement in areas of moderate to steep slopes. Ground-water production from the marine sandstone is very high in places (see Natural Resources: Ground Water).

Columbia River Basalt (Tcr)

The Columbia River Basalt consists of numerous flows of dark, dense basalt. It caps many of the ridges in the north-central part of the County and underlies several of the isolated hills northeast of Albany, including Knox Butte, Hardscrabble Hill, and Hale Butte. In addition, Marks Ridge immediately north of Sweet Home is interpreted to be underlain by Columbia River Basalt.

In most areas the upper surface of the Columbia River Basalt is relatively smooth and gently sloping. Drainage is generally good and weathering produces reddish loam and rubbly loam soils. Locally, however, as on parts of the north side of Marks Ridge, leaching proceeds to a depth of 20 feet or more, producing a light-colored punky regolith. The Columbia River Basalt is characterized by moderate to high yields of high-quality ground water (see Natural Resources: Ground Water).

The Columbia River Basalt provides a good foundation for most structures and is generally free of hazards. Drainage is good, ponding is rare, and mass movement is minimal except in regions of undercutting (see Mass Movement: Mass Movement Topography). Soils and slopes are generally consistent with septic tank use and drainfields. Locally, however, the soils are very thin and require alternative methods of waste disposal. Because blasting is commonly required for excavation, development costs may be prohibitive.

Sardine Formation (Tps)

The Sardine Formation consists primarily of platy to massive andesite flow rock and forms resistant ridges and upland areas in the interior of the foothills. Significant exposures include Farmers Ridge, High Deck, much of the northern slope of Snow Peak, and the ridge crests overlooking the middle reaches of the North Santiam River. Hard unweathered tuffs make up much of the unit in the Detroit Reservoir area. The unit is characterized by moderate to steep bedrock slopes and thin rubbly soils. Little is known of its ground-water potential, although it is probably low.

Much of the terrain underlain by the Sardine Formation is not suited to residential development. Although the unit consists primarily of flow rock similar in many respects to the Columbia River Basalt, the steep slopes and thin rubbly soils are prohibitive to development. Moderately sloping areas, such as parts of the north side of Snow Peak, may offer some potential, however. Special problems associated with the Sardine Formation include steep-slope failures, undercutting of slopes by mass movement within the underlying Little Butte Formation, and thin soils.

Cascades Formation (Qtv)

The Cascades Formation consists of massive flow rock and interbedded breccias. It makes up the bulk of Snow Peak and caps Rocky Top and contiguous ridges in the upper reaches of the Middle Santiam River in the interior. Terrain underlain by the Cascades Formation is generally rugged and associated hazards include steep-slope failure, flash flooding, and undercutting by massive failures in the underlying Little Butte Formation.

Weathering produces rubbly soils and loams. Soil types and thicknesses are highly variable, depending upon parent bedrock and local topography. Little is known of the ground-water potential of the unit.

Tertiary intrusive rock (Ti)

Only the larger intrusions are shown on the geologic map; these include the dense basaltic intrusions into the Little Butte Formation at Shot Pouch Butte, Washburn Butte, and Lone Pine Butte, and the basaltic

and andesitic plug that makes up the core of Snow Peak and which fed the Cascades Formation. Innumerable smaller intrusions are present throughout the Little Butte Formation.

Hazardous conditions associated with the intrusions include steep-slope failures, rapid runoff, peripheral landslides in regions of undercutting, and thin soils. In the Lone Pine Butte-Washburn Butte area north of Brownsville, steep slopes and mass movement must be considered in future developments. Elsewhere in the Little Butte Formation, the possible presence of thin soils and impermeable bedrock associated with smaller unmapped intrusions must be considered in all planning.

Quaternary upper terrace (Qtu)

The upper terrace consists of a gently sloping fan of fluvial gravel, sand, and silt lapping against the foothills of the Western Cascades in the Lacomb area, and of several scattered high terrace levels of presumably similar age elsewhere in central Linn County. Boulders, gravel, and sand are most common in the east, and sand and silt with occasional pebbles or gravel beds characterize deposits in the west. Owing to their elevated position in the present landscape, the terraces are being rapidly eroded by streams. This facilitates ground-water migration and produces well-drained soils. Ponding and high ground water are rare.

Ground-water production is moderate and foundation stability is good. Mass movement, flooding, and other geologic hazards are minimal except along some of the major streams. The unit is generally well suited to most forms of development. Soils are thick and excavation is relatively easy. The uncontrolled proliferation of septic tanks in regions of ground-water recharge could contaminate ground water in areas of high permeability. To date no hydrologic models and few chemical analyses of ground water are available. Little is known of the subsurface aquifers.

Quaternary middle terrace (Qtm)

The middle terrace includes strips of flat-lying fluvial deposits along the edges of major stream valleys overlooking lower terrace deposits in north-central Linn County. The deposits vary greatly in composition both laterally and vertically and include gravel, sand, silt, and clay. Chemical weathering proceeds to great depths in places to produce clays, loams, and silty loams (see Geology and Soils Maps). In some areas drainage on the terraces is greatly impeded by the very low slopes, and ponding and high water table are common during the wet season. Ground-water yield is moderate to good (see Natural Resources: Ground Water) and foundation stability is variable, depending in large part on degree of weathering.

The main problems to future residential development arise primarily from the poor drainage and related phenomena of the middle terrace. Clay-rich soils produced by rapid chemical decay lead to septic tank failures in many areas, and poor drainage produces many of the problems associated with ponding (see Geologic Hazards: Ponding). In a broader sense the need to coordinate waste disposal (septic tanks, landfills) with ground-water production requires detailed investigations, ground-water sampling and monitoring, and solid policy decisions on the State and local level (see Soils of the Willamette Valley).

Quaternary lower terrace (Qtl)

The lower terrace includes broad lowland areas lying above the flood plain but not covered by the Willamette Silts. The terrace material is of fluvial origin and varies greatly in composition both laterally and vertically. It consists of lenticular bodies of sand, silt, and gravel (see Geology and Soils Maps) and shows very little weathering owing to its relative youthfulness.

Hazards in the lower terrace level derive mainly from its topographic position and expression and include ponding, high water table, and local flooding. The unit is a good water producer, is easily excavated, and occupies regions for which extensive development in future years is anticipated. Problems arising from conflicting land use are treated under Natural Resources (Sand and gravel, Ground Water) and Soils of the Willamette Valley. To properly deal with these problems in critical areas, detailed soil surveys, resource analyses, and hydrologic models are needed. Ground-water contamination through the excessive use of septic tanks is a significant hazard.

Willamette Silts (Qws)

The Willamette Silts consists of up to 30 feet of flat-lying silt and clay which mantle older fluvial deposits in the Willamette Valley. The unit is a unique lacustrine deposit (see Geology) and should not be viewed as typical alluvium in an engineering sense.

Dominant processes acting upon the Willamette Silts include ponding, slow circulation of high ground water, and chemical weathering. The soils commonly are gray or black. Regionally they exhibit a clay-rich horizon a few feet below the surface resulting from downward movement of soluble or suspended material by ground-water percolation. Thus the extensive silty looms indicated on the soils maps are somewhat misleading in that clay-rich soils are present at shallow depths (see Soils of the Willamette Valley).

Special problems associated with the Willamette Silts include those associated with ponding, high ground water and poor drainage (see appropriate sections). Caving should be anticipated and guarded against in all deep excavations. As with the middle terrace level, clay-rich horizons in the soil can cause septic tank failures (see Soils of the Willamette Valley).

Ground-water wells in areas underlain by the Willamette Silts tap coarser fluvial deposits beneath the Willamette Silts. The mantling silts and clays are characterized by perched water and poor drainage during the winter months.

A special problem associated with the Willamette Silts is the loss of land along streams and rivers through stream-bank erosion (see Geologic Hazards: Stream-bank Erosion). The volume of land lost by stream-bank erosion in recent years is surprisingly high; the economic losses associated with the hazard can be catastrophic for the individual landowner.

Quaternary alluvium (Qal)

Flood-plain deposits along rivers and major streams make up the Quaternary alluvium. It consists of a maximum of a few tens of feet of gravel, sand, and silt along the major rivers and is dominated by clay and clay-rich silts along the smaller streams which flow over the Willamette Silts and the various surficial terrace deposits to the east (see Soils Map and Soils of the Willamette Valley).

The major hazards in the Quaternary alluvium include ponding, high ground-water table, flooding, and stream-bank erosion (see appropriate sections). The unit is easily excavated. Ground-water production is very good, especially in the gravels (see Natural Resources: Ground Water).

Special problems in the Quaternary alluvium derive primarily from its low topographic position and variable lithology. Flooding and high ground water can cause septic tanks and landfills to fail. Under extreme conditions, pollution of surface waters and streams is a potential hazard. The clay-rich soils along the smaller streams and in the alluvium of the rivers and larger streams locally contain significant amounts of organic material. Organic soils are compressible and are not suitable for supporting structural foundations. Improper engineering of buildings in areas of organic soil will lead to differential settling and considerable damage (Figure 31). Roads constructed over compressible soils settle unevenly to produce an unstable and often dangerously irregular grade.

Soils of the Willamette Valley

A soil can be defined as an unconsolidated mantle of earth material either derived from underlying bedrock or transported to its present position by natural processes. The soils of the Willamette Valley are river, lake, and possibly wind deposited and thus are transported soils. Although there is considerable overlap between the concepts of soils and surficial geologic units as discussed above, in soils the emphasis is on climate, topography, vegetation, and time, as well as parent material. Emphasis also is focused on the uppermost few feet of the deposit where chemical and other changes induced by weathering are most pronounced.

Information presented in this section and on the soils maps is intended for regional planning use and for preliminary evaluations of specific sites. Rather than supplanting on-site investigations, the

purpose of this section is to provide guidance concerning the types of soil conditions present and to point out situations where more detailed studies should be made.

Soils classification

The U. S. Department of Agriculture system of soils classification adopted in this study (Figure 32) is based on grain-size distribution. The textural soils in western Linn County include 1) clay and silty clay, 2) clay loam and silty clay loam, 3) loam and silty loam, 4) sand and sandy loam, and 5) gravelly loam. Suitability of the five soil types for various land uses is summarized in Table 3.

Also shown in Table 3, columns 2 and 3, are the corresponding designations of the soils classes used in this report in two other more rigorous systems of classification, the Unified Soil Classification (see Appendix A) and the American Association of State Highway Officials Soils Classification (AASHO) (see Appendix B). The Unified Scale is employed by the U. S. Army Corps of Engineers, the U. S. Army, the U. S. Bureau of Reclamation, and the Department of Interior.

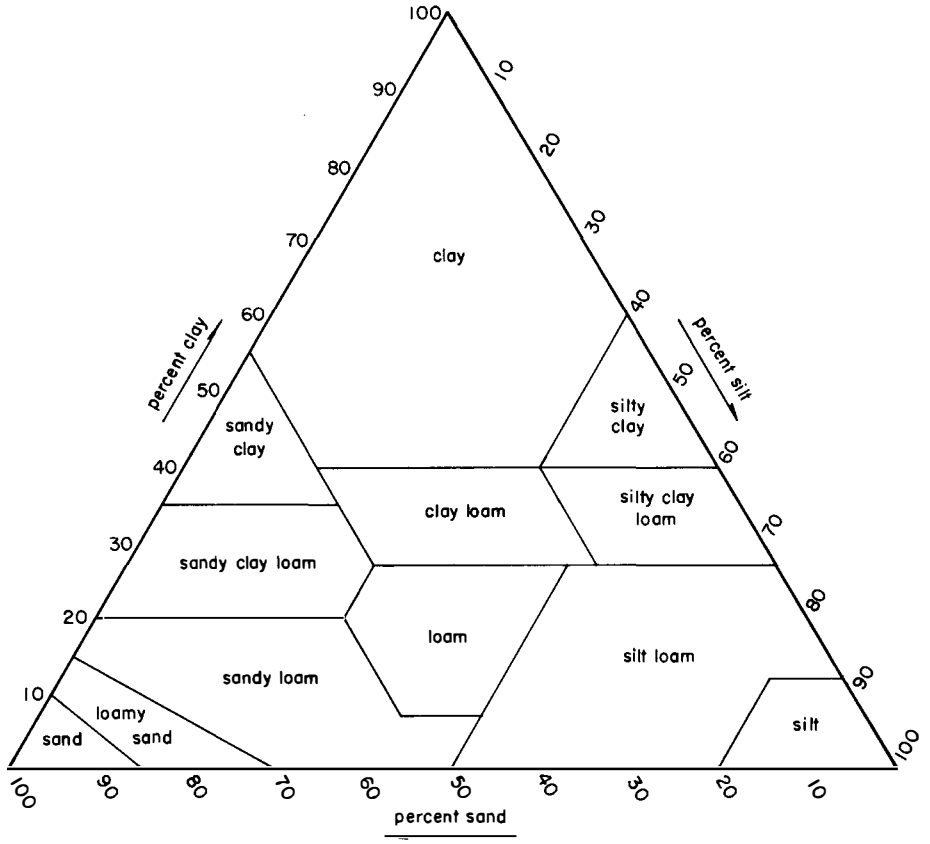


Figure 32. Guide for the textural classification of soils.

Table 3. Soil use classification for the Willamette Valley of western Linn County

Soils nomenclature					Waste disposal			
Department of Agriculture	Unified*	AASHO**	Topography	General construction use	Septic tank leach fields	Sewage lagoons	Sanitary landfills	Comments
Clay and silty clay	MH or CH	A-7	Generally occupies depressions and drainage ways	Not suitable for construction due to poor drainage, flooding, compressible deposits, moderate to high shrink-swell potential	Not acceptable, very low infiltration rates, flooding potential high	Not acceptable in low areas where flooding potential and high ground water exist	Not acceptable in areas susceptible to flooding	
Clay loam and silty clay loam	ML or C	A-6 to A-7	Undulating to level bottom lands and basinlike areas, gentle sloping alluvial fans; in eastern Lebanon quadrangle occupies large upland areas	Limited use to unacceptable dependent upon topographic position, high water table, shrink-swell potential and moderate to low shear strength	Not acceptable in areas subject to flooding or high water tables. Acceptable in upland areas of moderate infiltration rates	Acceptable in soils of low permeability not in contact with ground water and not subject to flooding	Acceptable in upland areas in soils of low permeability where ground water pollution is not likely	Soil is prominent on slopes and uplands east of South Fork of Santiam River and adjacent to North Fork of Santiam River
Loam and silty loam	ML or C	A-4 to A-7	Level, gently sloping to concave surfaces. Primary soil type of terrain between drainage ways	Poor surface drainage and high water tables in winter and spring restrict use. In other areas construction is limited to acceptable	Unacceptable in low permeability and high water table areas. Acceptable in other areas	Restricted in permeable areas or where in contact with water table. Some slope stability problems when soil saturated	Limited due to high water table and poor surface drainage	The predominate soil type in the valley area. Primarily located between drainage ways
Sand and sandy loam	SM	A-1	Found in drainage ways and terrace slopes, or on slopes below bedrock exposures	Acceptable on terrace slopes and slopes below bedrock outcrops. Limited in areas prone to flooding	Generally not acceptable in areas of rapid infiltration where ground water pollution is likely	Generally not acceptable due to rapid infiltration or in areas of flooding potential	Poor to not acceptable due to flooding or potential groundwater pollution	Exception to rule in topographic position are linear, trending gravel deposits between Lebanon and Albany
Gravelly loam	GM SM GP	thru A-7						

*See Table 4
**See Table 5

Because the three soils classifications are based upon physical soil parameters pertinent to land use, it is desirable that the planner have a general understanding of the relationships between them. The most basic parameter is the grain-size distribution within the soil (texture). This parameter is of most interest in regional investigations including most aspects of land use planning. Within the three systems of classification, the arbitrary boundary lines between respective textural classes are somewhat independent (Appendix C). Subclasses are established within the Unified and AASHO Scales primarily on the basis of the Atterburg limits. These include the liquid limit (water content needed to impart liquid behavior to the soil) and plastic limit (water content needed to impart plastic behavior to the soil). Study of the two systems (Appendices A and B) shows that arbitrary boundaries between subclasses in the two units differ. Atterburg limits are of significance primarily to the engineering aspects of individual projects.

Clay and silty clay

The clays and silty clays of western Linn County occur almost exclusively in the drainageways and depressions of smaller streams. The few minor exceptions where these deposits occur on alluvial terraces or in gentle interfluves of the Willamette Valley involve low-energy environments of local ponding. Clays and silty clays comprise approximately 15 percent of the surface soils in the valley areas of western Linn County and are among the youngest soil groups.

The clay deposits are dark gray, bluish-gray, to dark brown and are commonly mottled yellow or bluish-gray, reflecting reducing to alternating reducing and oxidizing conditions. As shown in Table 3, Appendix A, and Appendix B, these soils are generally not suitable for building sites, waste disposal, septic tanks, or general construction owing to high flood potential, high ground water, poor foundation properties, and high clay content. Their use is limited primarily to agriculture.

Clay loam and silty clay loam

These soil types occur primarily as flat to undulating bottomlands of major drainageways, as linear exposures on terraces between drainageways such as the lower terrace deposit (Qtl) between Lebanon and Albany, and as residual mantle over Little Butte tuffs in the uplands. The soil is reddish-brown in the well-drained uplands and yellowish-brown to brown in the lowlands. Mottling is generally absent, indicating constancy of oxidizing conditions.

Between Albany and Lebanon, drainage of much of the clay loam and silty clay loam is poor. Over a period of years the physical properties of this soil have changed where agricultural practices have promoted the use of lime to improve its quality. Further, the use of agricultural drain tile has changed the near-surface relationship between the water table and the soil; water tables are lower in tiled areas.

Loam and silty loam

Loam and silty loam make up 45 percent of all the soil types in the valley area and comprise the largest soil unit. They are derived primarily from the Willamette Silts and form a dark-brown to gray terrace mantle between drainageways. The topography is generally flat to slightly depressed and surface drainage poor. Owing to the recency of deposition of the parent Willamette Silts, the soil is young; surficial loams indicated on the map are underlain by a clay-rich horizon a few feet beneath the surface.

Physical properties of loam and silty loam are summarized in Table 3 and under the appropriate headings in Appendices A and B. Loam and silty loam form a fair subgrade and are subject to high water table and ponding. Potential for waste disposal sites is limited. Septic tanks commonly fail owing to the poor drainage and the shallow clay-rich horizons. Soil treatment and installation of drainage tiles are acceptable engineering solutions in areas of appropriate topography.

Sand and sandy loam

Sand and sandy loam soils form discontinuous deposits along the undulating alluvial deposits of the major streams including the Willamette, Calapooia, Santiam, North Santiam, and South Santiam Rivers. The soils are dark in color and commonly are interbedded with beds of gravel.

Physical properties of the sand and sandy loams are summarized in Table 3 and under the appropriate headings in Appendices A and B. Foundation strength is generally good and permeability is voriable. In areas of relatively rapid infiltration, ground water is threatened, and septic tanks, sewage lagoons and sanitary landfills are generally not feasible or should be allowed only with appropriate restrictions based upon adequate on-site investigations. Ground-water contamination through unwise land use should be avoided (see Natural Resources: Ground Water). Associated hazards such as flooding should be considered in all evaluations.

Gravelly loam

The gravelly loam soils occur as recent alluvial deposits, as discontinuous lenses in the lower terrace unit (Qtl) between Lebanon and Albany, and as thin stony residuum surrounding isolated buttes and flanking the foothills. Engineering properties are summarized in Table 3 and under the appropriate headings in Appendices A and B.

Alluvial gravelly loams form good foundations, but are of restricted use owing to the relatively high flood potential. Use for waste disposal is limited also because of flood potential and generally high permeabilities. Gravelly loams in the lower terrace (Qtl) between Lebanon and Albany are well-suited to development, but are also limited in their waste disposal capacities. Locally, however, high silt and clay contents of the matrix produce relatively low permeabilities. Future potential for sand and gravel production should be considered and land use planning should include reservation of high quality gravels in the gravelly loam (see Natural Resources: Sand and gravel) to meet future construction needs.

Stony loams surrounding isolated buttes in the eastern Willamette Valley and situated along the valley periphery are generally very thin and reflect the characteristics of the underlying bedrock. Foundation strengths are generally high, but permeability and waste disposal potential are very low. The engineering properties of residual stony loams should be evaluated largely on the basis of the underlying bedrock.

GEOLOGIC HAZARDS

General Discussion

The geologic hazards of western Linn County include all the active natural processes which tend to modify the landscape in a geologic sense and which pose problems of stability or safety from the standpoint of development. In the low sloping areas of the Willamette Valley and its tributaries, the geologic hazards are chiefly flooding, stream-bank erosion, high water table, and ponding (Table 4). Hazards in the foothills areas are mass movement and flash flooding (Table 5). Volcanic activity and earthquake potential are minimal, but require consideration under special conditions. Engineering conditions of the ground also constitute geologic hazards if improperly handled; these are discussed under Engineering Geology.

Locations of hazards indicated on the geologic maps should be regarded as approximate, and interpretations presented in the text should be regarded as general. This is a reconnaissance study intended for use as a planning tool and for pinpointing subjects of concern for more local studies. Individual on-site investigations are required to determine the presence or absence of hazards on specific parcels of land.

Slope

The slope of the land represents nature's balanced response to the interaction of rock type, weathering, mass movement, and erosion at a particular site. A consideration of slope (see Table 6) is very important in the planning process because many geologic hazards are directly or indirectly related to slope. Five classes of slope are depicted on the hazards map and are discussed below.

Class 1 slopes (0-10 percent)

Class 1 slopes are widespread throughout the Willamette Valley and larger flood plains leading into the foothills of the Western Cascades. Class 1 slopes are also developed on older terraces and on flat ridge crests overlying Columbia River Basalt in the north-central part of the County.

Natural processes dominant on Class 1 slopes include chemical weathering, flooding, ponding of rainwater, and high water table. With the exception of chemical weathering, these are discussed in detail under the appropriate headings in the Geologic Hazards section of this bulletin. Chemical weathering produces a clay-rich soil horizon at shallow depth (see Engineering Geology: Willamette Silts).

In areas where flooding and related hazards are not a factor, Class 1 slopes are generally well-suited to most forms of development. Such areas include many of the buttes, ridge crests, and broad slopes underlain by Columbia River Basalt in the northern part of the County. Also included are large parts of the various terraces with the exception of gentle depressions where ponding is a factor.

In the Willamette Valley and other areas of very low slope, significant drainage problems can arise at large scale development sites. Where subdivisions, parking lots, and similar projects with extensive impervious surfaces are anticipated, adequate provisions for greatly increased runoff should be required. Much of the flooding difficulties experienced in urban areas not subject to stream overflow can be traced to inadequate handling of runoff.

Class 2 slopes (>10-25 percent)

Class 2 slopes characterize parts of the older terraces, much of the Columbia River Basalt terrain in northern Linn County, and scattered patches of the Little Butte Formation. Natural processes acting upon the slopes include variable chemical weathering, erosion in unprotected areas, and mass movement (see Geologic Hazards: Mass Movement Topography). Class 2 slopes are generally well drained except for localized patches of lower slope too small to be shown on the hazards map.

Table 4. Summary of lowland hazards

Hazard	Characteristics	Impact	Preventive, remedial, and planning measures
1% flood Standard project flood	Determined by U.S. Army Corps of Engineers on basis of probabilistic analysis of rainfall data, basin analyses, and field survey including assessments of local topography and structures	Damages resulting from standing water, current action and siltation	Discourage future incompatible use of flood plains through appropriate zoning ordinances and public information and education programs, possibly including the placing of warning signs; implementation of the Federal flood-plain insurance program; floodproofing of present structures; construction of levees and dikes in critical areas; close coordination of flood forecasting, flood fighting, and evacuation services
Estimated flood area	Crude projections of 1% flood and STP floods based primarily on topography		
Stream-bank erosion	Location on outer bend of curves, deep water near shore, growing bar on opposite bank, history of undercutting inferred from older maps and aerial photos; also inferred on basis of stream plan and knowledge of dynamics of stream meandering	Total destruction of structures and loss of land through undercutting and erosion	Discourage future construction in areas subject to stream-bank erosion through appropriate zoning ordinances or other restrictions; construction of stream-bank protective structures such as revetments in critical areas of active erosion or where present structures or farmland are threatened (large-scale correction of entire channels is not feasible)
Revetment	Man-made erosion protective devices	May direct erosion to points farther downstream	Proper engineering and planning prior to construction; realization that meandering often flanks revetment structures
High water table	Ground water at or near ground surface, especially during wet season; position during dry season highly misleading	Contamination from septic tanks and landfills; damage to basements, underground tanks, and swimming pools	In areas of high water table, restrict incompatible developments through appropriate zoning ordinances and building regulations or require adequate engineering and construction, such as the installation of drainage tile
Ponding of rainwater	Low regional slopes and gentle localized depressions in areas of low permeability (clay and clay loam); depressions particularly evident in aerial photographs	Localized flooding; also polluted runoff in areas of landfills and septic tanks	Restrictions on construction; require properly engineered terrain modifications such as the placing of fill; on-site investigations required to determine the potential for ponding in specific areas
Adverse soil conditions; see Table 3	Clay-rich soils and compressible soils high in organic matter	Septic tank and leach field failure	On-site soil investigations for septic tanks, leach fields, and large construction projects

Class 2 slopes underlain by basaltic bedrock are well suited to most forms of development. The Powell Hills area immediately northwest of Brownsville (Figure 33) and isolated small valley areas in the interior (Figure 34) are included in this category. The elevated sloping nature of the ground surface generally insures against flooding and other lowland hazards.

Hazards in Class 2 slope terrain generally involve regions underlain by tuffaceous bedrock or regions of steeper slope in the Class 2 category (>15 percent). Where weathering has proceeded to depth in non-basaltic bedrock, clay-rich soils are produced. Cuts in this material may lead to failure over large areas (Figure 35). Associated hazards may include low foundation strength, poor drainage, and low permeability. To determine the suitability of Class 2 slopes to a particular form of development requires on-site evaluation. To a large extent, the nature of the planned development determines the thoroughness of the evaluation.

An additional hazard in Class 2 slope terrain is the threat of erosion or gullying in areas stripped of vegetation. Generally the threat is not great, but to avoid initiating erosion in areas of steeper slope, care should be exercised in any logging, large scale development, or landscaping.

Table 5. Summary of upland hazards

Hazard	Characteristics	Potential impact	Preventive, remedial, and planning measures
Mass movement topography	Irregular to hummocky terrain, moderate slopes (Class 2 and 3), irregular drainage, sag ponds, cracked ground, bowed trees	Structural damage through future movement or uneven settling, caving in excavations, poor drainage	Require on-site investigation and/or detailed engineering investigations prior to development; strict adherence to grading codes; limitations on excavations, drainage alterations, removal of vegetation and septic tanks or drain fields
Steep slope failure	Include rapid runoff, rockslides, rockfalls, debris slides, mudflows, and earthflow on Class 4 and 5 slopes	Rapid erosion, structural damage, road failure	Require on-site investigation and/or detailed engineering investigations prior to development; strict adherence to grading codes; preservation of natural vegetation where possible
Flash flooding	Small to medium-sized stream channels, moderate to steep gradients and side slopes, no flood plain, coarse stream-bed deposits, thin soils, impervious bedrock	Total destruction of structures; road washouts	Prohibit construction at or near stream level in flash-flood channels; assure adequate engineering of all road and path crossings

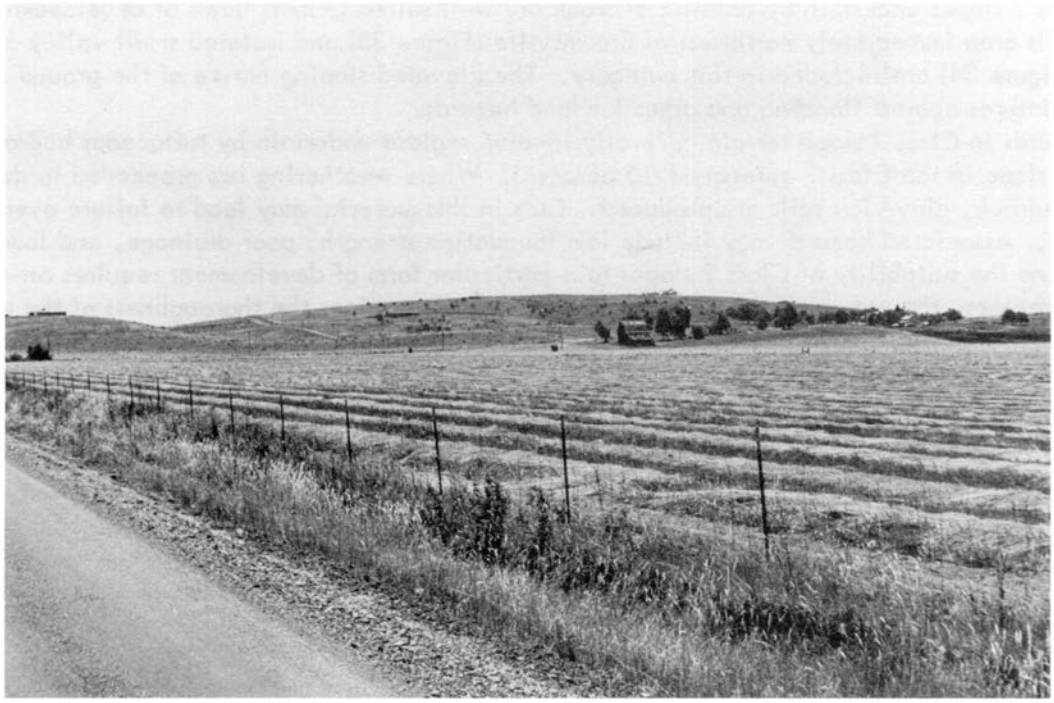


Figure 33. The Powell Hills immediately northwest of Brownsville are gently sloping and well suited to many forms of development.



Figure 34. Gently sloping terrain on basaltic bedrock in the uplands area is stable (5 miles south of Brownsville).

Class 3 slopes (>25-50 percent)

Class 3 slopes are restricted to the uplands and are developed on the Little Butte Formation, the Sardine Formation, the Columbia River Basalt, and the Cascades Formation. Natural processes include chemical weathering, erosion, and mass movement (see Geologic Hazards: Mass Movement Topography). The relative significance of chemical weathering and erosion varies with topographic setting and rock type. Tuffs of the Little Butte weather quickly to form thick clay soils, whereas volcanic flow rock weathers very slowly to produce thin soils (Figure 36) threatened by rapid runoff.

Overloading and oversteepening slopes can initiate landslides in previously stable Class 3 slope terrain (Figures 37 and 38). Deep roadcuts and other excavations are particularly susceptible to failure in deeply weathered tuffs of the Little Butte Formation. Septic tank effluent may emerge at the surface on hillsides if units are improperly placed with regard to terrain and soil permeability. Stripping of natural vegetation can lead to severe gullying (see Geologic Hazards: Flash Flooding).

Under extreme conditions of rainfall or of freezing and thawing, steep Class 3 slopes assumed to be stable can fail, producing rapid, deep, catastrophic landslides. An example is the Canyonville slide of 1974 which claimed nine lives in Douglas County. When slides occur, repair and maintenance operations should not be initiated until the storm passes and until a qualified engineering geologist or soils engineer outlines protective measures and pronounces the area safe.

Class 3 terrain is suited to open-space use, properly engineered road construction, and low-density residential development in places. On-site evaluation should be required for all large developments. Although proper engineering may offer solutions to most potential problems of stability, permeability, runoff, and gullying, cost may be prohibitive.

Class 4 slopes (>50-75 percent)

Class 4 slopes are developed on exposures of unweathered resistant bedrock and are most common along escarpments assigned to the Sardine Formation, in canyons carved into the Cascades Formation, and along headscarps where Columbia River Basalt overlies softer bedrock of the Little Butte Formation. Rapid runoff, erosion (see Geologic Hazards: Flash Flooding), rockslide and rockfall (see Geologic Hazards: Failures on Steep Slopes) are the most common degradational processes.

Class 4 slopes are subject to shallow failures in areas of undercutting and to severe gullying in regions stripped of vegetation (see Geologic Hazards: Flash Flooding). Septic tank effluent will surface downslope and septic tanks are not recommended. Improperly engineered road fills commonly fail. Under extreme weather conditions deep catastrophic slides or mudslides may occur (see Class 3 slopes).

Losses through natural hazards on Class 4 slopes can be minimized through restrictive zoning, preliminary detailed on-site investigation, proper grading practices (e.g., those set forth in the Uniform Building Code), and proper engineering of all developments.

Class 5 slopes (>75 percent)

Class 5 slopes are developed on exposures of unweathered, resistant bedrock, and their distribution is similar to that of Class 4 slopes. Major hazards include gullying, flash flooding (see Geologic Hazards: Flash Flooding), rockfall, and mudslides (see Geologic Hazards: Failure on Steep Slopes).

Class 5 slopes are ill-suited to most forms of development. Road fills commonly fail and most roads are notched into the bedrock. Rapid runoff can easily lead to road washouts.



Figure 35. Roodcuts in gently sloping weathered cloy soils of the Little Butte Formotion ore prone to failure in places (Brush Creek Rood south of Crawfordsville).



Figure 36. Thin soils characterize Closs 3 slopes underlain by basaltic bedrock (Horse Mountain area south of Brownsville).

Table 6. Summary of slope hazards

Slope	Natural processes	Potential disastrous impact	Remedial, preventive, and planning measures
1 (0-10%)	Chemical weathering; no slope-initiated hazards; other hazards include flooding, ponding, high water table, and clay soils	Poor drainage; ponding and high water table can cause flooding, septic tank failure, basement cracking, floating of underground storage tanks and water table pollution from waste disposal leachate; increased runoff in flat urbanized areas can cause flooding	Promote developments compatible with geologic conditions through proper zoning ordinances; require detailed geologic and engineering studies for developments in areas of potential problems; require adequate solutions to anticipated hazards (i.e., fill, levees, proper drainage facilities)
2 (>10-25%)	Moderate chemical weathering and slight erosion under natural conditions; some mass wasting on steeper slopes	Initiation of slides through overloading and oversteepening of slopes (especially in areas of mass movement topography); gullying in areas stripped of natural vegetative cover; structural damage in areas of low foundation stability (see Landslides)	Promote developments compatible with geologic conditions through proper zoning ordinances; require detailed geologic and engineering studies for large developments; strict adherence to grading regulations in the Uniform Building Code
3 (>25-50%)	Chemical weathering and erosion; also mass wasting including earthflow, mudflow, and creep; gullying in areas stripped of natural vegetation	Initiation of slides through overloading and oversteepening of slopes (see Mass movement topography); gullying on unprotected slopes; caving of excavations; emergence of septic tank effluent, etc. on hillsides; road failure; structural damage in places	Promote developments compatible with geologic conditions through proper zoning ordinances; require detailed geologic and engineering studies for large developments; advise all developers of potential hazards; strict adherence to grading regulations in the Uniform Building Code
4 (>50-75%)	Erosion, rapid runoff, shallow slides, and deep slides in bedrock under extreme conditions	Initiation of slides through overloading and oversteepening of slopes; pronounced gullying in areas unprotected by vegetation; road washouts in areas of flash floods and improper engineering; emergence of septic tank effluent on hillsides; failure of improperly placed fill	Limit development through adequate zoning ordinances; strict adherence to the grading regulations in the Uniform Building Code; engineering investigations for all development; adequately sized road culverts at stream crossings
5 (>75%)	Rapid runoff and erosion; rockfall, rock slide and mudflows	Initiation of slides through undercutting or indiscriminant blasting; extreme gullying in unprotected areas; road washouts in areas of flash floods and improper engineering; emergence of septic tank effluent; failure of improperly placed fill	Restrictive zoning ordinances; require appropriate engineering studies for all types of development; strict adherence to the grading code; preserve natural vegetation to greatest extent possible; adequately sized culverts



Figure 37. Small slides are common along roads cut into Class 3 slopes.

Figure 38. Scar of a recent landslide controlled by jointing in partly weathered tuffs of Little Butte Formation.



Flooding

Definitions

The inundation of a region by flowing water derived from a stream or a river is a flood. Agencies involved in rigorous flood delineation studies include the U. S. Army Corps of Engineers, the U. S. Geological Survey, and the Oregon State Water Resources Board. Published reports of these agencies (see Bibliography) were used in the construction of the maps.

The Intermediate Regional Flood (also referred to as the 100-year flood) is the flood having a 1 percent probability of happening in any given year. The Standard Project Flood is the flood that would occur under the most severe hydrologic and meteorologic conditions that reasonably can be expected.The Standard Project Flood is larger than the Intermediate Regional Flood and represents the reasonable upper limit of flooding.

In areas for which no information was available, a third flood designation, Estimated Flood Area, was interpreted on the basis of topography, geologic units, scattered aerial photographic coverage, and extrapolation from known floods. Additional studies should be conducted to assess flood potential more accurately in areas of estimated flooding. Such studies include a consideration of sounding data, photogrammetric interpretations, flow data, stream gradient, and channel roughness (Bailey and Ray, 1966).

Causes

Flooding in western Linn County is a result of high runoff from the upper Willamette Basin or from Linn County watersheds brought about by intense cyclonic rain storms, rapid snow melt, or both. Also contributing to flooding are low infiltration rates resulting from rock type, saturated soil, or frozen ground. Locally, improper watershed management or land use practices can aggravate flooding. An additional factor contributing to flooding in the Willamette Valley is the extremely low gradient of the streams there as compared to typical gradients in the foothills and mountain watersheds.

Distribution

All rivers and major streams of lowland western Linn County undergo significant flooding. These include the Willamette (Figure 39), Santiam, North Santiam, South Santiam (Figure 40), and Calapooia (Figure 41) Rivers and Thomas, Crabtree, Beaver, Oak, Muddy, and Lake Creeks. Discharge data of the major streams is summarized in Table 7. Flooding of the upland streams is discussed under "Flash Flooding" (see Geologic Hazards: Flash Flooding).

Owing to the moderate climate, flooding is a winter occurrence restricted to the period from October through April. December and January are the most critical months. Several floods can occur in any given year.

Impact

Past flooding in Linn County has caused damage resulting in hundreds of thousands of dollars in losses annually and total losses amounting to millions of dollars. Flooding destroys structures through current action, siltation, and water damage (Figure 42). It inflicts losses on agriculture by scouring topsoil, removing acreage through meanderings (see Geologic Hazards: Stream-bank Erosion), silting cropland (Figure 43), and killing livestock. It threatens citizens by isolating dwellings, damaging property, disrupting transportation (Figures 44 and 45), and polluting or disrupting water supplies. Flooding constitutes the greatest geologic hazard in western Linn County.

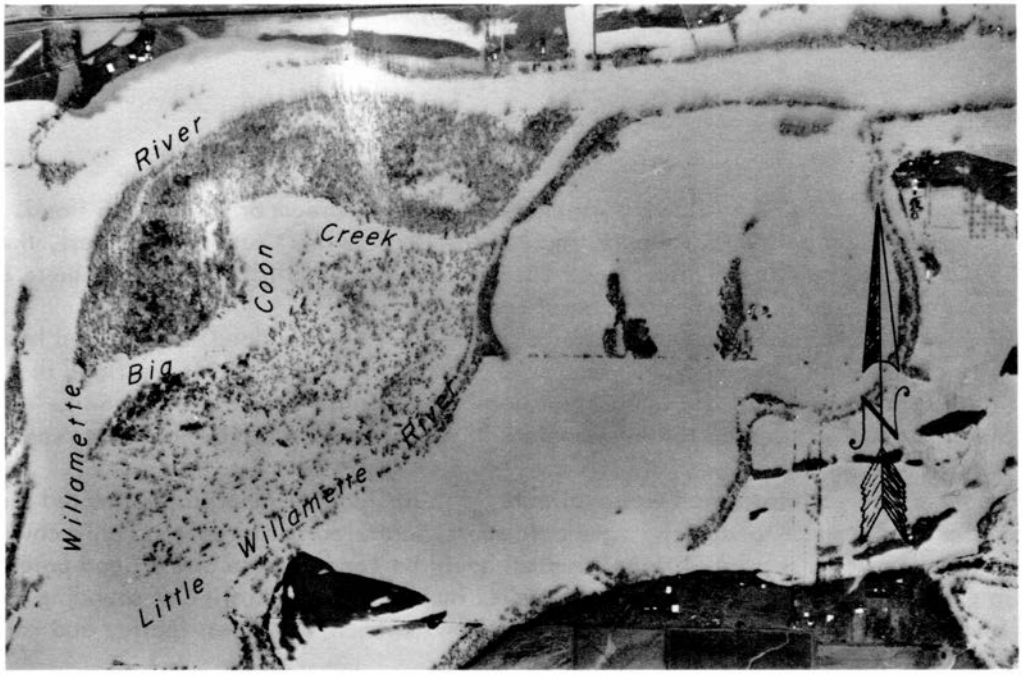


Figure 39. Aerial view 2 miles west of Albany showing the distribution of the 1964 flood.



Figure 40. Flooding of central Lebanon during the flood of December 1964.



Figure 41. Flooding of the Colopooio flood plain 3 miles northwest of Saddle Butte in the Willomette Volley during the flood of December 1964 (dimensions of area approximately 1 mile by 1½ miles).



Figure 42. Standing flood waters con cause considero ble damage to homes and their contents (east of Highway 99E at Oak Creek, half o mile south of Albany).



Figure 43. Still water in the floodway fringe can cause considerable crop damage through siltation (looking northwest of Riverside Drive, 2½ miles southwest of Albany).



Figure 44. Flood waters of January 1974 immediately east of Highway 99E at Oak Creek, half a mile south of Albany.

Planning measures

Federal dam construction has considerably reduced discharge of the Willamette River in the past few decades. Projects include the Cottage Grove (1942), Dorena (1949), Lookout Point (1953), Hills Creek (1961), Cougar (1963), and Smith River (1963) Reservoirs in the headwaters of the Willamette River. The flood of December 24, 1964 discharged 186,000 cfs at Albany, considerably less than the 226,000 cfs figure (Table 7) for the flood of 1881. The South Santiam River and other rivers unregulated by dams in 1964 registered their greatest floods in 1964. Discharge of the North Santiam River at Niagara on December 26, 1964 was 19,300 cfs as compared to 63,200 cfs (Table 7) during the flood of 1909. Regulation by the Detroit Dam (completed 1953) significantly reduced flooding. In the South Santiam drainage Green Peter and Foster Dams were put into operation in 1967.

Table 7. Discharge of major streams

River	Observation period	Average discharge	Maximum discharge	Minimum discharge
Willamette (at Albany)	1894-1965	14,490	226,000 (Jan.14, 1881)	1,840 (Sept.1, 1940)
Willamette (at Harrisburg)	1944-1965	12,730	210,000 (Dec.29, 1945)	1,990 (Oct.30, 1944)
Santiam (at Jefferson)	1905-1916 1939-1965	7,840	197,000 (Dec.22, 1964)	260 (Aug, Sept, 1940)
South Santiam (at Waterloo)	1905-1911 1923-1965	2,910	95,200 (Dec.22, 1964)	96 (Sept.1, 1940)
South Santiam (Cascadia)	1935-1965	826	27,600 (Dec.22, 1964)	23 (Dec.1, 1936)
North Santiam (Niagara)	1908-1920 1938-1965	2,339	63,200 (Nov.22, 1909)	430 (Sept.23, 1915)
Calapooia (Albany)	1940-1965	929	32,700 (Dec.22, 1955)	4 (Oct. 7, 1952)
Calapooia (Holley)	1935-1965	450	12,600 (Dec.22, 1964)	13 (Sept. 8, 1940)
Thomas Creek (Scio)	1962-1965	------	16,700 (Dec. 22, 1964)	14 (Sept.24, 1965)
Crabtree Creek (Crabtree)	1963-1965	------	8,410 (Jan.28, 1965)	15 (Aug.4, 1965)
Wiley Creek (Foster)	1947-1965	227	8,370 (Dec. 22, 1964)	6 (Nov. 26, 1952)



Figure 45. Flood waters of the Colopooio flood plain in January 1974 (looking east from Ookville Rood 3 miles southwest of Albany).

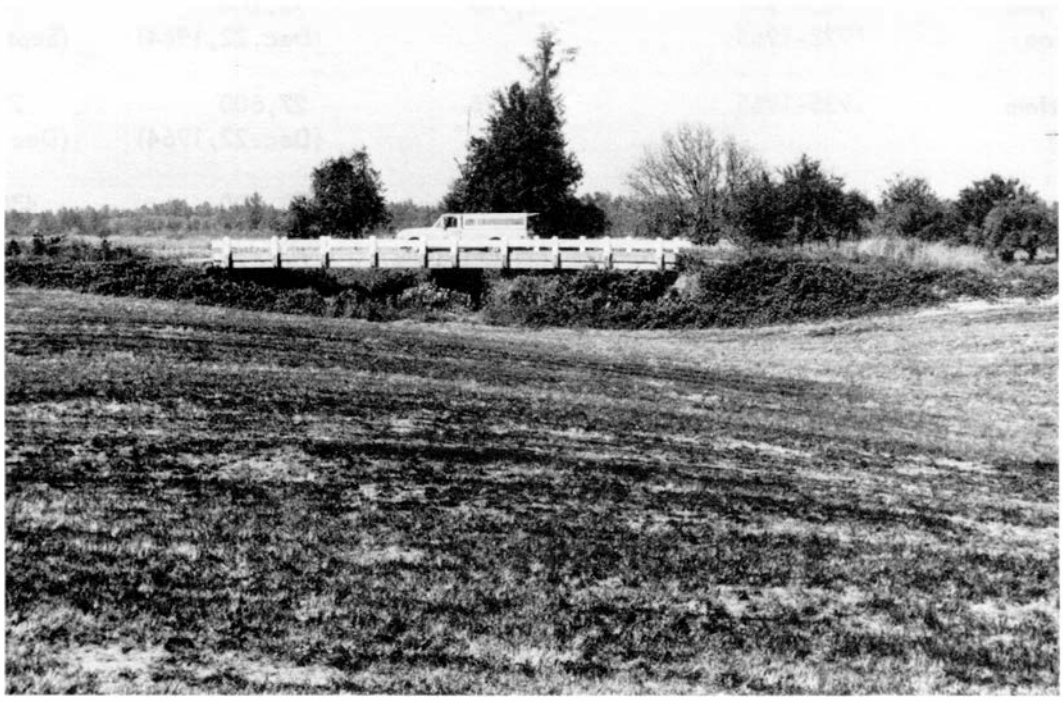


Figure 46. Because of local ponding, this bridge is essential in the winter months (west of the South Sontiom River near the mouth of Crabtree Creek).

On the more local level, flood damage can be reduced through the use of realistic zoning codes, subdivision regulations, and building codes. Floodway uses should be restricted primarily to open space use such as agriculture, parks, golf courses, and parking facilities. Obstructions created by bridge abutments, roads, and large structures often impound water leading to increased flooding upstream. Regulations in the floodway fringe should include guidelines for floor elevations, storage restrictions, waterproofing, and anchoring of structures. Water supply facilities should be protected from contamination, and sewage treatment plants should be designed to prevent pollution during flooding. The Oregon State Water Resources Board provides assistance in formulating development guidelines and in implementing the Flood Insurance Act of 1968. The U. S. Army Corps of Engineers is participating in an extensive revetment and diking program in the Willamette Valley and has the capabilities to delineate floodway and floodway fringe areas.

Flood forecasting is performed by the U. S. Department of Commerce National Weather Service River Forecast Center in Portland, Oregon. Flood fighting, such as diking, riprapping, and sandbagging, is performed by local personnel supplemented by the U. S. Army Corps of Engineers and coordinated by the State Emergency Operations Center. Evacuations are conducted by local personnel and the National Guard.

After a major flood region is declared a disaster area, Federal assistance is available in the form of grants for restoring public facilities, loans to individuals and small businesses, and funding to repair river and creek channels. Assistance of this type is coordinated by the Office of Emergency Preparedness, the State Emergency Services Division, and local officials.

Ponding and High Ground Water

Definition and causes

Ponding refers to the local accumulation of rainwater on the surface of the ground or to rising ground water which actually has surfaced. High ground water refers to near-surface ground water which can present a problem to land development and engineering construction. Ponding and high ground water result from springs, perched water conditions, high regional water table, or excessive rainfall.

Recognition and distribution

Ponding is restricted primarily to localized depressions in areas of low slope (Figure 46). Additional distinguishing features may include black, organic soil, clay soils, and the abundance of coarse grasses and reeds (Figure 47). High water table is a general winter condition over much of the Willamette Valley. On-site investigations are needed to assess the capabilities and liabilities of individual parcels of land and these hazards are not specifically indicated on the geologic hazards maps. Many areas of the floodway fringe are subject to ponding or high water table when the flood subsides (Figure 48).

Impact

The presence of water at or near the ground surface has produced adverse soil conditions over large areas of the Willamette Valley; a clay-rich zone a short distance below the surface in immature soils greatly restricts the use of septic tanks. Compressible soils in areas of ponding and marsh growth provide inadequate foundations for large structures. High water content can promote caving in deep excavations.

Buoyancy associated with high ground-water table can crack basements, lift swimming pools out of the ground, and cause underground storage tanks and septic tanks to surface. Septic tank effluent may be forced to the surface where it may pollute nearby streams. Gravel pits and other excavations fill with water during the rainy season; future uses should be planned with this in mind.

Planning measures

In areas of low slope, engineering investigations for large-scale construction and development projects should include an assessment of the ponding or high water-table hazard. Emphasis should be



Figure 47. Clumps of reed grass are indicators of potential winter ponding and high water table; in the summer the lake will disappear (looking northwest from Oakville Road 2 miles southwest of Albany).



Figure 48. Area of slack flood water (floodway fringe) that will be an area of ponding when streamflow subsides (2 miles north of Crabtree on Crabtree Creek).

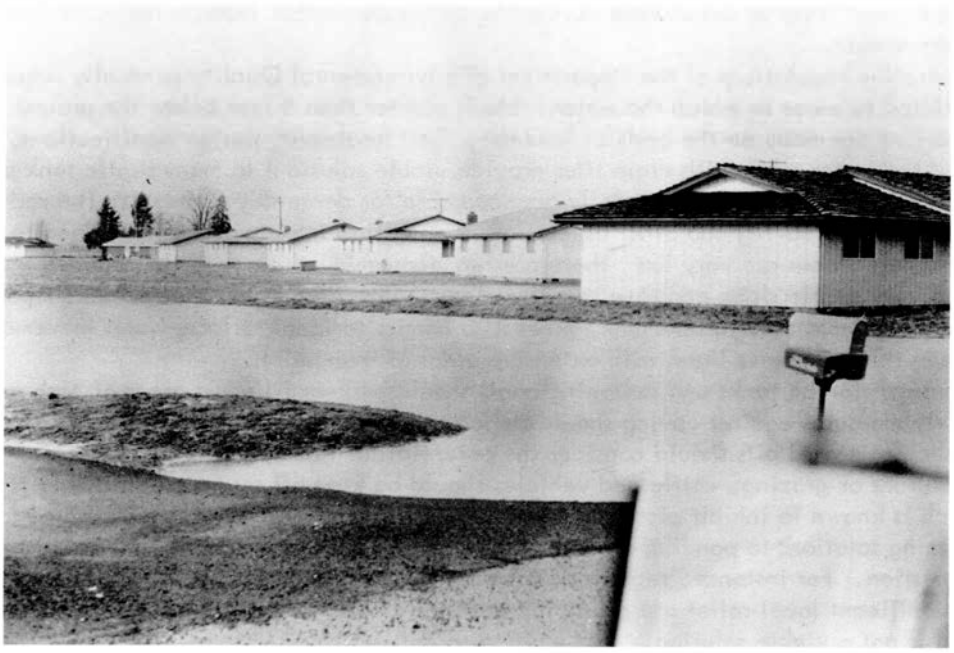


Figure 49. Disrupted drainage and decreased runoff in areas of urbanization can cause ponding during the winter months (Ranchero Acres 3 miles southeast of Albany).

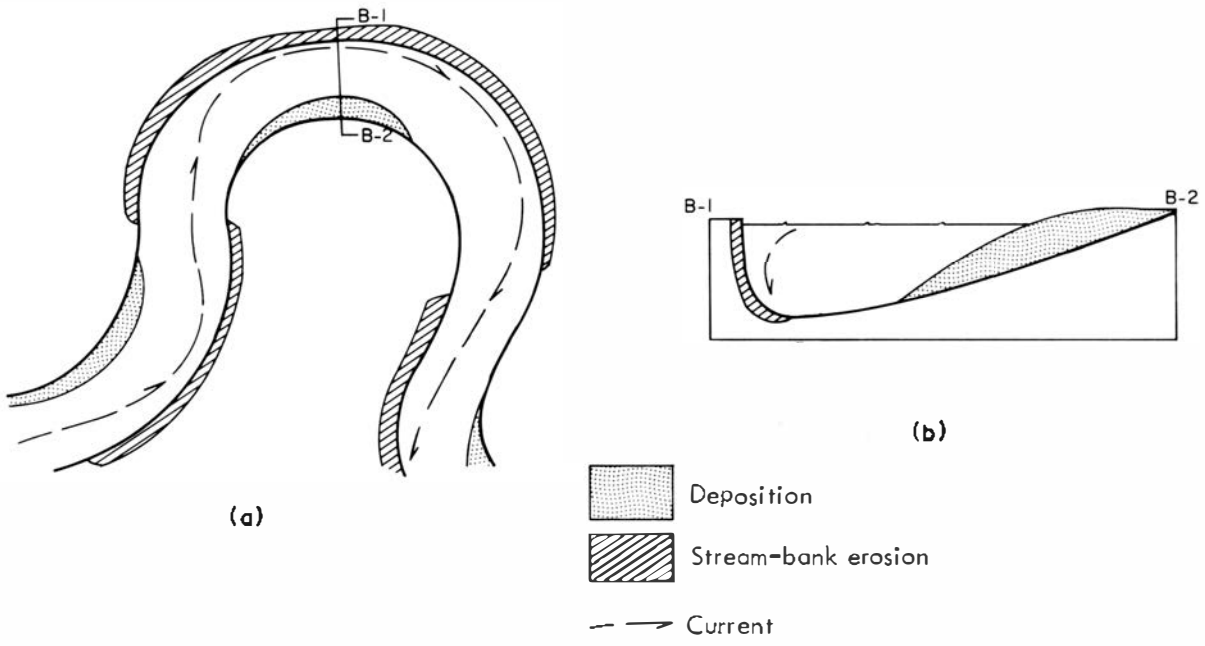


Figure 50. Features of a river meander: a. Plan view showing areas of stream-bank erosion and bar deposition; b. Section showing relative water depths and dominant processes.

placed on the highest level of occurrence during the wet season rather than on the lower levels representative of the dry season.

Administrative regulations of the Department of Environmental Quality generally require that septic tanks be restricted to areas in which the water table is greater than 6 feet below the ground surface. Limited exceptions are made on the basis of land use. Soil treatment, design modifications, and control of the level of the water table with drain tiles provide viable solutions to many septic tank problems.

Areas of critical ponding are generally unacceptable for dense development. The reduction of infiltration arising from paving and other aspects of urbanization increase runoff and lead to local flooding (Figure 49). Where slopes are very low, there are few economic solutions to the problem.

Areas of very gentle slope and slow runoff are particularly prone to local ponding through the interference of man. Interstate 5, for example, presents a barrier to local surface-water movement. During the rainy season the freeway is lined with extensive areas of inundation.

Underground storage tanks and swimming pools should be kept filled in areas of high ground water. Adequate safety measures against caving should be followed in all excavations. Reclamation plans for excavations such as gravel pits should consider the potential for flooding by ground water or runoff. In areas of agriculture or grazing, cattle and vehicles should be kept off saturated ground to prevent compaction, which is known to inhibit plant growth.

Engineering solutions to ponding and high ground water must be keyed to the specific conditions of the area in question. For instance, regions of apparent ponding in large depressions or in depressions bordered by significant local relief are commonly areas of ground-water discharge. For these areas, the placing of fill is not a viable solution.

The impact of ponding and high ground-water table in western Linn County is complex in nature and regional in extent. Future damage can be reduced through the use of realistic zoning ordinances and building codes. Such regulations should make allowances for workable engineering solutions to specific problems.

Stream-bank Erosion

Definition and recognition

Stream-bank erosion is the loss of land by stream action. It occurs through the scouring by flash floods in most of the upland areas (see Geologic Hazards: Flash Flooding), as local soil fall (bank caving) in the upper flood plains of the major streams and along the large flood plains of the various streams and rivers in the Willamette Valley, where it is the most critical. Meandering, the tendency of some streams to assume sinuous courses, is the underlying cause of stream-bank erosion in the flood plains.

Meander-generated erosion is characterized by a steep bank on one side of the river associated with a sand or gravel bar on the opposite side (Figure 50). Areas of critical stream-bank erosion are also identified by studying sequential sets of aerial photographs and topographic maps which show changes in stream pattern with time. But to assess properly any particular locality, it is necessary to make on-site inspections and interview residents and appropriate government personnel.

Considerable research in recent years has revealed that the ideal shape of a meandering channel is that of a series of smooth accentuated S-shaped curves (Leopold and Langbein, 1966). Thus, straight stretches and relatively sharp turns in streams prone to meandering are signposts of future adjustments through bar deposition and bank erosion. The radius of curvature of an ideal meander bend generally is two to three times the width of the stream (Bagnold, 1960; Leopold and Wolman, 1960).

Causes

The fundamental cause of meandering in streams is not completely understood. Gorycki (1973) demonstrates that the friction of moving water over a surface generates sinuous currents which, in turn, are responsible for sinuous stream patterns (meanders) under the proper conditions of gradient and discharge. Of more immediate concern to the planner than hydraulic friction, however, are factors subject to at least partial human control such as discharge, bar growth, revetment construction, and zoning practices. These provide local relief to stream-bank erosion and are discussed under "Planning Measures" below.



Figure 51. Revetment on the south bank of the South Santiam River, 1½ miles upstream from the juncture with the North Santiam River (looking downstream).



Figure 52. Active stream-bank erosion along the South Santiam River; same location as Figure 51, only looking upstream. Continued meandering of the stream has flanked the upstream end of the revetment.

Distribution

The relative threat of stream-bank erosion varies with the discharge of the streams. Large-scale channel changes have occurred along the Willamette, South Santiam, and North Santiam Rivers in recent years. The Calapooia River and Muddy Creek are characterized by numerous smaller scale channel changes. Dangers along Thomas and Crabtree Creeks are minimal in most places but do require consideration in planning. Smaller creeks such as Oak Creek and Lake Creek show no significant stream-bank erosion or channel changes in the past few decades.

Willamette River: The meandering course of the Willamette River has undergone considerable change since the County line was established along it in 1847. Relatively recent changes are evident in aerial photographs and topographic maps. At present, extensive revetments control much of the course of the river.

Revetments at Harrisburg protect the city from critical stream-bank erosion. Three miles downstream on the Benton County side of the river, Morgan Island separates a revetment from the present river channel. This channel change in conjunction with bar growth on the east bank immediately downstream is causing stream-bank erosion on the west bank in the west Morgan Island area. Farther downstream extensive revetments guard the concave river banks of meanders from erosion.

West of the Lake Creek School at Irish Bend, the Willamette River makes a right angle turn against the east bank. The situation is highly unstable. Continued undercutting at Irish Bend may cause the river to migrate beyond (flank) the south end of the revetment on the Linn County side of the river. Alternatively, catastrophic truncation of the meander bend would result in accelerated meandering and stream-bank erosion immediately downstream beyond the north end of the revetment (see Geologic Hazards Map: Halsey quadrangle). The time scale of these events cannot be determined.

At Hoacum Island, one mile south of Peoria, a sharp meander bend has been truncated since 1957. Revetments placed to stabilize the new channel direct it obliquely at the river bank. Stream-bank erosion is a threat in this area.

West of Albany extensive riprap has been placed along the outer bends of five successive meanders. Although the meander configurations and revetments are stable, their effect is to transmit erosive potential downstream. Thus, the Big Coon Creek area (section 10) immediately downstream from the Little Willamette revetment has undergone considerable scouring since the revetment was installed in 1943. Stream turbulence is eroding the streambank locally above the north end of the revetment as well.

Farther downstream, high-intensity use areas such as the Albany riverfront are protected by revetments, but stream-bank erosion is not generally critical. The channel of the Willamette River in this reach has undergone no significant changes since the County line was established.

South Santiam River: Comparison of the 1957 topographic maps with 1970 aerial photographs reveals several large-scale channel changes along the South Santiam River in recent years. Meander bends in the vicinity of Griggs have shown considerable adjustments and now are partly protected by revetments. The channel presently exhibits sharp turns and relatively straight stretches and future flanking of the present revetments is a possibility.

The channel of the South Santiam River immediately upstream from the Sanderson Bridge is unstable. Major patterns of erosion, deposition, and streamflow have occurred in recent years and are continuing at the present time. At least two revetments are now located far from the river. A third revetment along the river is in danger of being flanked on its upstream end. Numerous large point bars on either side of the river and several islands in the river indicate the potential for significant channel changes in the near future.

Downstream from the Sanderson Bridge channel engineering has produced several straight stretches separated by abrupt turns, one of which approximates 90 degrees. The revetments have been designed to accommodate future channel adjustments. However, the undissipated erosive potential is now being transmitted downstream to create additional areas of stream-bank erosion.

Down stream from the mouth of Crabtree Creek the course of the South Santiam River is relatively straight and is controlled locally by revetments. As the river continues to modify its channel, flanking action around the ends of the revetments will occur (Figures 51 and 52). The rate of stream migration can be rapid (Figure 53). In places revetments have already been isolated from the river channel by bar growth.



Figure 53. Grovel bar deflects streomflow against the south bonk of the South Sontiom River; the south bonk was located at the area of the brushy point bar (center) a few years ago (some location as Figures 51 and 52).

Sontiom River and North Sontiom River: Stream-bonk erosion along the North Sontiom River is restricted primarily to the region downstream from Stayton. West of Kingston, channel changes within the post 15 years hove produced a double channel, indicative of high erosion potential. Revetments protect the stream bonk in some critical areas. A short distance downstream the channel makes a right angle turn to the west. Here truncation of the meander bend on the north side of the river or critical erosion of the south bonk ore possible.

West of Shelburn the Wiseman Island-McKinney Bottom region of the North Sontiom River is undergoing rapid stream-bonk erosion. Numerous meanders ore developing in a former straight stretch of the river. Although most of the area lies within Marion County, Linn County also will be affected by some of the changes. A few miles downstream in the Greens Bridge area, a brood curve in the river may undergo similar modifications in the future.

Downstream from the confluence of the North and South Sontiom Rivers, the meanders of the Sontiom River are lorge in accordance with the larger discharge. The position of the County line indicates that the meanders hove formed since 1847. The radii of curvature, uniform shape, and sizes of the meanders appear to be ideal, but future modifications ore a certainty. Revetments protect some areas from stream-bonk erosion. Farther downstream the river channel is characterized by recently developed straight stretches and truncations of meanders.

Colopooio River: Numerous stream-channel modifications hove occurred on the Colopooio River and numerous sites of future stream-bonk erosion are identified on the geologic hazards mop. Consistent with the relatively low discharge of the stream, the meanders ore considerably smaller than those on the aforementioned rivers. Accordingly the threats of future stream-bonk erosion ore more localized and more economically treated.

Most stream-bank erosion in recent years has been concentrated in the Brownsville, Saddle Butte, Powell Hills, and Tangent areas. Revetments protect critical areas in the Brownsville district. Downstream protective measures are minimal and the stream is allowed to meander unobstructed. This undoubtedly has resulted in considerable losses to individual farmers.

Muddy Creek, Thomas Creek, and Crabtree Creek: Muddy Creek is characterized by large sweeping curves and by smaller localized meanders. Discharge is not sufficient to initiate true meanders in most places. Locally, however, stream-bank erosion is critical and must be considered in the planning process. Thomas and Crabtree Creeks have slightly higher discharges and exhibit considerably more stream-bank erosion. Smaller creeks, such as Oak Creek and Lake Creek, do not meander.

Impact

Stream-bank erosion can lead to property loss, the destruction of roads, buildings, and bridge abutments, and financial ruin for the private citizen. As flood waters flow over sharp meanders, scouring can destroy farmland; truncation of the meander curve can isolate large parcels of land. Areas of bar growth are commonly the sites of heated property-line disputes.

Planning measures

Owing to the large number of variables and uncertainties involved, it is not possible to delineate broad areas of probable future meandering in a reconnaissance investigation. Instead, only areas of stream-bank erosion are indicated. Engineering investigations for all projects near areas of stream-bank erosion should include a consideration of the future potential for catastrophic erosion, meandering, and meander truncation.

As part of such considerations, the interdependence of various stream parameters such as discharge, load, gradient, velocity, channel roughness, and stream geometry should be appreciated. A change in any one of the parameters will initiate compensatory changes in the others. Thus channel straightening increases stream gradient, which in turn increases both stream velocity and stream-bank erosion downstream.

The recent completion of Green Peter, Foster, and Detroit Dams will reduce discharges of the North and South Santiam Rivers during flooding. As a result, the rivers will have less energy and stream-bank erosion downstream should decrease.

Regional channel straightening generally does not provide a viable solution to meandering. Instead, the increased gradient would accelerate stream-bed erosion, which in turn would lower the base level of tributary streams. Gullying of valuable farmland and undercutting of all riverside structures could result (Ruhe, 1971).

The piecemeal placing of revetments preserves many of the streams' natural parameters and provides a more viable and economic solution. In certain areas, however, flood waters occasionally top the revetments on their upstream end. A false sense of security arising from scattered revetments in an incompletely treated area could prove disastrous.

In areas of high intensity use and critical concern, revetments can be profitably complimented by other forms of channel engineering. Dredging and bar removal, for example, can provide renewable supplies of sand and gravel while also maintaining the river channel.

The impact of mining of bar deposits varies with location according to local conditions and goals. Two examples illustrate this point. Immediately downstream from Mill Creek on the South Santiam River northeast of Albany, the river is very unstable. Revetments placed several years ago are now far from the river and recently placed revetments now are in the process of being flanked as the river channel continues to migrate. In this stretch of the river, bar removal would function as a stabilizer and would retard river migration. The rate of flanking action would be reduced or halted, and streamflow would be directed at the revetments. Stream-bank erosion would be minimized and the overall impact of mining probably would be beneficial.

At other locations along the river where channel changes have been minimal in recent years, the river is temporarily stable. Mining of sand or gravel in these areas possibly would result in increased stream velocities or shifted current positions. The impact possibly would include increased rates of stream-bank erosion for short distances downstream.

Mass Movement

Definitions

Mass movement is the slow or rapid, natural or artificially induced movement of rock, soil, or fill downslope in response to gravity. In western Linn County, the major geologic types of mass movement include earthflow, slump, rockslide, rockfall, and mudflow (see Table 8). Basically earthflow involves flow movement along innumerable slip surfaces above a planar basal slip surface, and slump involves rotational movement of a large block of earth above a curved basal slip plane. Slumped areas generally lie immediately upslope from earthflow areas in regions of mass movement topography. Rockfall and rockslide involve the movement of rock debris down steep slopes, and mudflows involve the rapid movement of mudlike slurries down steep canyons.

Mudslide is a term defined statutorally by the National Flood Insurance Act of 1968. It is "a general and temporary movement down a slope of a mass of rock, soil, or artificial fill, or a combination of these

Table 8. Mass movement terminology

Type	Characteristics	Distribution
Earthflow	Irregular, subdued terrain, tilted trees, cracked ground, sag ponds, irregular drainage; flow-type movement, planar basal slip surface.	Most common on Class 2 and Class 3 slopes in Little Butte tuffs.
Slump	Hummocky terrain, backtilted trees, irregular drainage, sag ponds, rotational movement on curved basal slip plane.	Occupies upslope parts of earthflow areas.
Rockslide	Talus and rubbly veneer moving rapidly downslope; poorly sorted mantle of unconsolidated debris produced by such action.	Class 4 and Class 5 slopes generally underlain by flow rock.
Rockfall	Actual free fall of rock material through the air.	Steep Class 5 slopes.
Mudflow	Rapid movement of a mudlike slurry down steep canyons; called debris flow if rocks and other debris are abundant in the mud.	Class 4 and Class 5 slopes with adequate soil cover.
Mudslide	A general and temporary movement of rock, soil, fill, or combinations of these downslope caused or precipitated by the accumulation of water on or under the ground; incorporated in National Flood Insurance Act of 1968.	May include earthflow, slump, rockslide, rockfall, and mudflow, provided necessary conditions are met (see text).

caused or precipitated by the accumulation of water on or under the ground." Under the proper conditions, mudslide-prone areas are covered under the National Flood Insurance Act. A mudslide-prone area is an area whose slope, history, geology, soil, bedrock structure, and climate indicate a potential for mudslides.

In this study, Class 4 and Class 5 slopes and areas of mass movement topography qualify in a general sense as mudslide-prone areas. More detailed investigations of these areas would be required, however, for them to be incorporated in any flood insurance program. It is emphasized also that claims for mass movement damage would be honored only if sliding was rapid, water induced, and of general distribution. Some types of earthflow and slump would not be covered under the National Flood Insurance Act.

Mass movement topography

Definition and causes: Mass movement topography is terrain for which prior mass movement is inferred primarily on the basis of topographic expression. Factors considered include features visible on aerial photographs, contour-line pattern and distribution on topographic quadrangle maps, slope, rock type, and such local features as irregular topography, disordered drainage, sag ponds, tilted trees (Figure 54), and scarps (Figure 55).

Factors contributing to mass movement include climate, rock type, slope, and natural or artificial changes in any of these. The moist moderate climate of the study area promotes deep chemical weathering which, in turn, breaks down the rock, increases pore pressures, and decreases the shear strength. Rocks which weather to clay-rich soils are the least stable and the most prone to failure. The Little Butte Formation (Tolb) is particularly high in ash, a component which weathers to clay.

Under extreme conditions catastrophic earthflows, such as the one which recently claimed nine lives near Canyonville (Douglas County), can occur. These conditions include heavy rains over a prolonged period of time followed first by a long freeze and then by a quick thaw with more heavy rains. Corrective action on deep, rapid slides of this sort should not be undertaken until after the extreme weather conditions pass and after a qualified soils engineer or engineering geologist pronounces the operation to be safe.

Under less extreme conditions earthflow and slump in areas of mass movement topography vary in rate from rapid to imperceptibly slow. Most movements are fairly rapid. Those movements which are imperceptibly slow and which extend over prolonged periods of time do not correspond to the definition of mudslide in the National Flood Insurance Act of 1968 and would not be covered under the program. They are, nevertheless, a hazard.

Distribution: Mass Movement topography is restricted primarily to Little Butte terrain and breccias of the Cascades Formation. In places mass movement undercuts Columbia River Basalt or involves thick soils developed on that unit. It is restricted to slopes of greater than 15 percent and generally less than 50 percent (Class 2 and Class 3). It is on these slopes that weathering and failure proceed to depths great enough for the results to be visible in a reconnaissance investigation such as this. On steeper slopes, shallower types of mass movement occur (see Failure on Steep Slopes below).

In north central Linn County, massive slope failures are present on the sides of Hungry Hill, Rogers Mountain, McCully Mountain, and other high ridges leading eastward towards Detroit Dam. Characteristically the slides are developed in the tuffs of the Little Butte Formation and undercut more competent strata along the crests, forming pronounced headscarps. Depth of failure is great below the larger headscarps, and landslide features are well-developed in places (Figure 55). On the lower flanks of Snow Peak, breccias of the Cascades Formation are undergoing mass movement; on the south side of the mountain along Crabtree Creek, rapid downcutting is initiating a series of active slides.

Numerous scattered patches of mass movement topography are mapped in the region bounded by Lebanon, Brownsville, and Sweet Home. Sliding is restricted to thick soils and tuffs of the Little Butte Formation. Ridge crests and knobby peaks are underlain by basaltic intrusions or the remnants of intracanyon flows. The isolated mounds underlain by the basalt are stable and are probably in place. Their size, high topographic position, and probable intrusive origin together with the absence of large-scale active undercutting preclude a slide origin for them. The relatively large intrusions at Ward Butte and Lone Pine Butte are surrounded by deep slope failures (Figures 56 and 57).



Figure 54. Tilted trees and irregular topography indicate active sliding along the Crabtree Creek Road leading to Snow Peak Camp.



Figure 55. A basalt scarp overlooking hummocky landslide topography 3 miles northeast of Jordan.

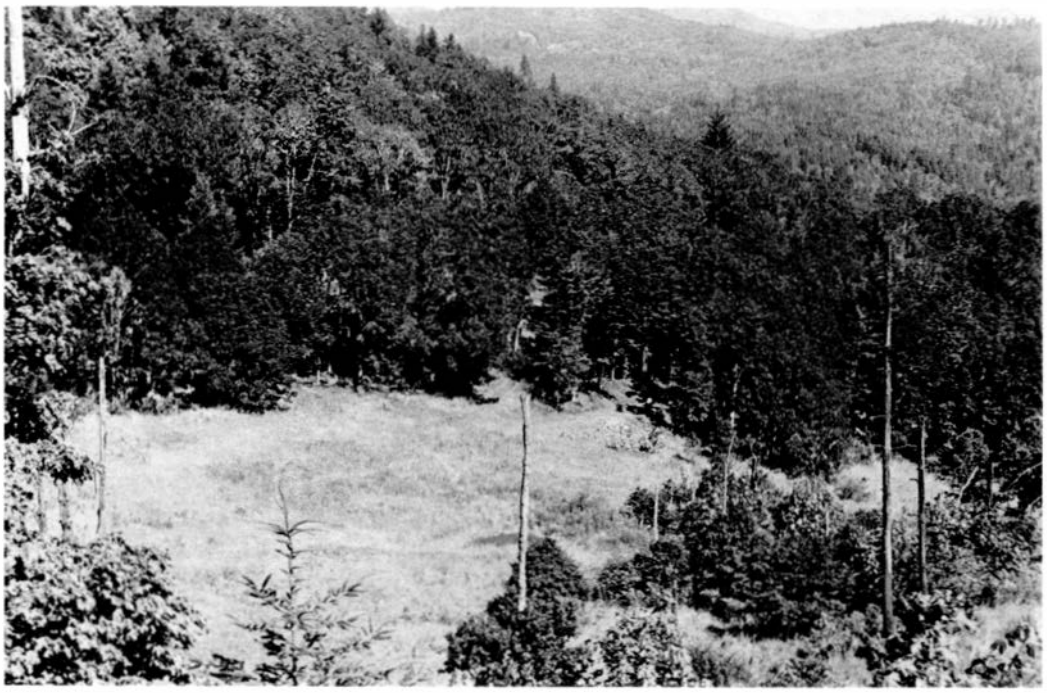


Figure 56. Irregular to hummocky topography characterizes the mass movement surrounding Ward Butte; note the sag pond.



Figure 57. Mass movement topography and tilted trees near Ward and Lone Pine Buttes.

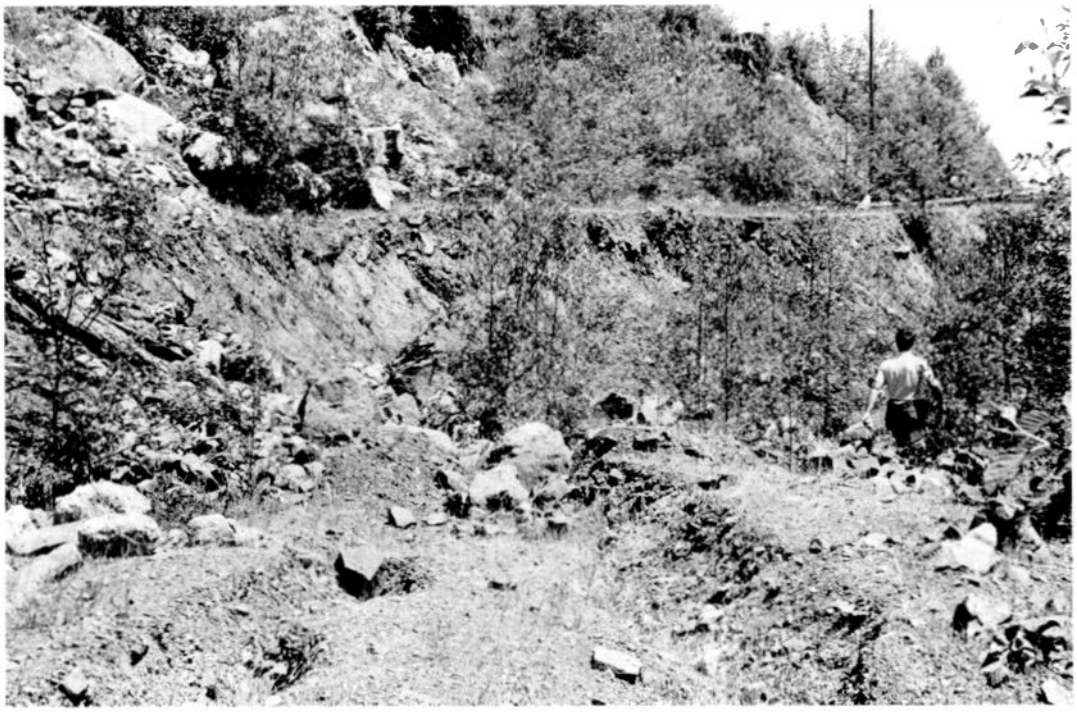


Figure 58. Recent sliding has downdropped a large section of road at Shot Pouch Butte.



Figure 59. Massive failure in gently sloping clay-rich tuff of the Little Butte Formation on Brush Creek Road south of Crawfordsville.

Mass movement topography is common in the middle and upper reaches of the South Santiam River east of Sweet Home. Deep failures are common where slides undercut resistant caprocks as at Marks Ridge, Green Peter, and Shot Pouch Butte (Figure 58). Many of the slide areas are active and all are restricted to Little Butte terrain.

The high ridges of the Calapooia drainage and points to the south overlook large areas of mass movement topography. Smaller regions of mass movement are present on the sides of smaller ridges and hills. Along Brush Creek Road, numerous slides are developed in gently sloping terrain along recent road-cuts (Figures 35 and 59).

Impact: Damage to structuresmay occur in regions of mass movement topography through continued slide movement, uneven settling, or a variety of related processes. Cuts, fills, and changes of the ground-water budget through use of septic tanks or improper handling of runoff are common factors in reinitiated slide activity.

Several areas of mass movement topography in western Linn County are zoned for possible residential or other large-scale development. These include some of the slopes south of Lyons, the north side of Rogers Mountain, the Ward Butte area north of Brownsville, the slopes east of Lebanon, the valley areas of the Calapooia drainage, and the lower slopes of Mount Tom in the extreme southern part of the County. Without proper planning, considerable structural damage could occur in these areas in future years.

The major impact of mass movement in areas of logging include various types of road and cut-bank failure and the contribution of huge volumes of debris and sediment to streams. Repeated failures on the upper Crabtree Creek Road leading to Snow Peak Camp are a case in point.

Planning measures: Developments in areas of mass movement topography may include large-scale construction, subdivisions, piecemeal home building in areas of rapid growth, and home building in isolated areas. In all instances, the grading standards of the Uniform Building Code should be strictly adhered to.

In regions of rapid piecemeal growth, progressive covering of the ground surface with buildings and roads leads to critical runoff difficulties if drainage is not handled adequately. Sumps commonly develop in unused areas, and this, in addition to increased infiltration from drain fields, septic tank use, and lawn sprinkling, can lead to eventual slope failure. For areas of poorly coordinated rapid growth, full implementation of the National Flood Insurance Act is recommended. Also, density regulations and provisions for proper handling of runoff and septic tank use should be spelled out in the zoning code.

For areas of large-scale construction, landfills, roads, and well-coordinated development such as subdivisions, on-site investigations should be required prior to development. Because this study is of reconnaissance nature and because many areas within regions of mass movement topography are stable, investigation may show that further action is unnecessary. If, however, the inspection reveals potential hazards at the site, detailed engineering studies should be required. The stability problems should be discussed, and the manner in which they will be handled should be described in detail. Engineering solutions are available for many slide problems (Figure 60).

Failure on steep slopes

Definitions: Types of land failure on steep slopes (Class 4 and Class 5) include rockfall, rockslide, and shallow earthflow or mudflow (Table 8). Unlike deep failures, such as those involved in mass movement topography, failures on steep slopes do not penetrate to great depths. Consequently they are not readily delineated in reconnaissance studies such as this. Instead, slope maps are used to define general areas especially prone to these forms of mass movement.

Most earthflows and mudflows on steep slopes are general in distribution, water induced, and rapid. Hence they conform to the concept of mudslide (Table 8) in the National Flood Insurance Act of 1968. Many rockslides and rockfalls are induced by causes other than those related to water; consequently many of them would not be covered under the National Flood Insurance Act.



Figure 60. Drainage trenches and pipes are used to eliminate water from a slide mass along Brush Creek Road.

Distribution: Failures on steep slopes are by definition restricted to slopes greater than 50 percent (Class 4 and Class 5). They ore most common along the upper reaches of the Colapooio, Middle Sontiom, and North Sontiom Rivers and along major creeks such as Wiley Creek and Neal Creek. Geologically, steep-slope failures ore concentrated along escarpments of Sardine Formation, Columbia River Basalt, Little Butte Formation, and in youthful canyons cut in the Little Butte Formation (Figures 61 and 62).

Impact: Failures on steep slopes ore traceable to the some causes as failures in regions of moss movement topography (see Moss Movement: Moss Movement Topography). Man-induced causes of steep failures include undercutting steep slopes, placing of excessive fill, indiscriminant blasting, improper handling of runoff in areas of construction, removal of vegetation on steep slopes, and diversion of streams against steep canyon walls with poorly engineered volley-bottom roods.

Planning Measures: Most regions of Closs 4 and Closs 5 slopes are restricted to tree harvesting and directly related activities. Roods in these areas should be properly located and engineered to ovoid slope failure through slope overloading, oversteepening, indiscriminont blasting, improper handling of runoff, or improper placement of fill.

Regions mopped as steep slopes for which possible residential use is allowed in the zoning code include some of the slopes west of Lyons, a few lower volley areas near Cascadia, and port of West Point Hill in the extreme southern port of the County. As the County and the U. S. Forest Service continue to trade parcels of land, other areas may be included in this list in the future. On-site inspections should precede development in these areas, and detailed engineering studies should be required for lorge developments to assure that all potential hazards ore accommodated. For areas of particular concern, implementation of the Notional Flood Insurance Act is recommended. Every attempt should be mode to preserve the natural vegetation where feasible to prevent gullying and shallow landslides and mudflows.



Figure 61. Removal of vegetation prompted this shallow mudflow along Wiley Creek southeast of Sweet Home; slope is approximately 60 percent.

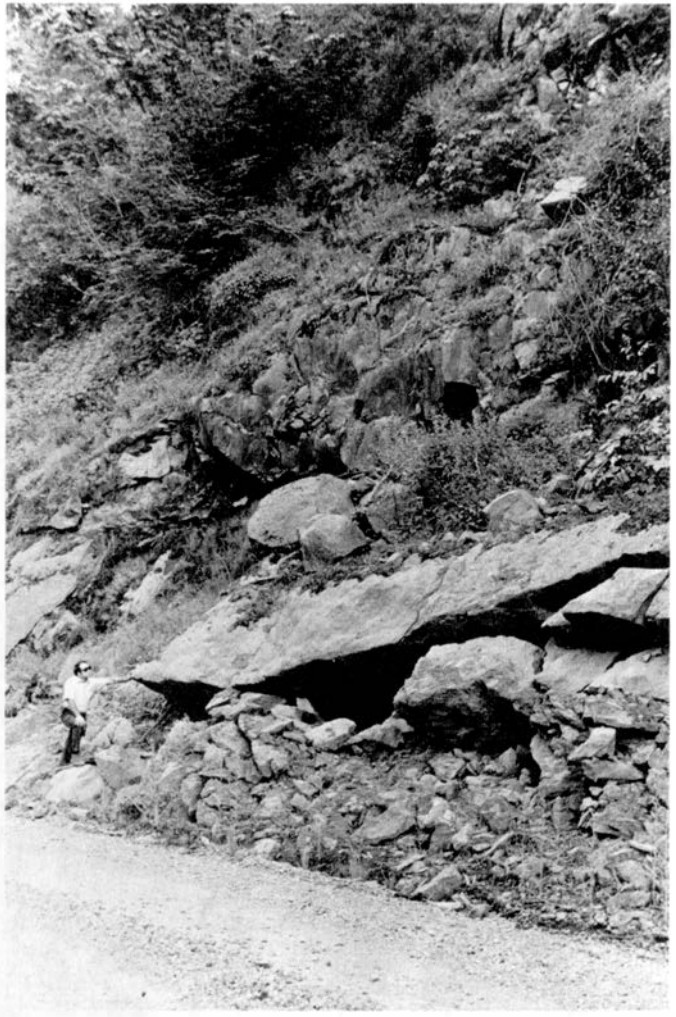


Figure 62. Rockfall and rock slide deliver large blocks of rock to the valley bottom of Wiley Creek; oversteepening of slopes such as this can be dangerous.

Flash Flooding

Definitions and causes

A flash flood is a sudden torrent of a relatively great volume of water flowing down a stream channel. Load potential of the water is so great that boulders, logs, and other debris are commonly incorporated into the streamflow. Recent flash flooding is easily recognized on the basis of the unvegetated, very coarse stream-bed deposits and other scattered lateral debris (Figures 63 and 64).

In areas where vegetation has reclaimed the channel (Figure 65), recognition is based upon more indirect features. These include steep side slopes, steep gradients, impermeable bedrock, and the absence of a flood plain (Figure 66). In western Linn County, flash-flood channels are generally less than a few miles in length.

Distribution

Flash-flood channels are most common in the upper reaches of the North Santiam, Middle Santiam, and Calapooia Rivers and also along Wiley Creek, upper McDowell Creek, Upper Roaring River, and other streams flowing off Snow Peak.

Impact

Flash floods are among the potentially more destructive geologic hazards in western Linn County. Fortunately flash-flood channels are local and easily delineated. Potential damage from flash floods includes road washouts and partial or total destruction of other structures.

Most flash-flood regions are dedicated to timber harvesting and other low-intensity uses. However, residential development is provided for in the zoning code along flash-flood channels in the Mill City area and in the upper reaches of the Calapooia River.

Planning measures

Roads should be properly designed to withstand flash flooding. This includes the use of adequately sized and placed riprap and culverts (Figure 67). In most areas, provisions should also be made to assure that culverts do not become clogged with debris. In particularly critical areas, debris screens are sometimes used (Figure 68). In some areas, especially at marked breaks in slope, the accumulation of debris during flooding is unmanageable, and road crews clear the road after flooding subsides (Figure 69). This approach is economic and reasonable where road washouts are not a threat (bottomland of the Calapooia River), but it is generally not acceptable on sloping areas where fills are used. Where stream channels consist of bedrock with very little gravel, considerable scouring can be inferred; in these areas log cribbing may be required to retain fill placed in the channel (parts of upper Crabtree Creek).

Where residential construction is anticipated, provisions should be made to assure that no development is allowed in the actual flash-flood channel and that bridge abutments and similar structures do not significantly alter stream flow. Implementation of the Flood Insurance Act is recommended. This will require compliance with all the provisions of the act and, possibly, more detailed mapping of given flash-flood areas by appropriate personnel.

Were it not for the vegetation of the uplands area, the flash-flood danger would be far greater. Where fires have removed this protective cover from steep slopes, the impact of erosion is particularly evident. At Big Cliff Reservoir, sizable deltas have formed at the mouths of creeks draining burned-over areas (Figure 70). To avoid gullying and severe erosion losses, proper landscaping and protection of vegetation are needed for all developments in flash-flood and steeply sloping areas.



Figure 63. Upper Wiley Creek (Sweet Home quadrangle) displays many flash-flood features; note the steep slopes, eroded hillsides, bouldery bedload, logs and other side-channel debris, and the channel scoured in bedrock. As stream-bed erosion is not possible, increases in discharge are accommodated primarily by hazardous increases in stream velocity.



Figure 64. Channel of Bigs Creek at confluence with the Calapooia River after recent flash flooding (south central Sweet Home quadrangle).



Figure 65. Vegetation has partially obscured this unnamed flash-flood channel 3 miles downstream from Bigs Creek on the Calapooia River.



Figure 66. Steep slopes and impermeable bedrock contribute to the flash-flood potential of the upper North Santiam River area.



Figure 67. Repeated road washouts at this crossing along upper McDowell Creek (northern Sweet Home quadrangle) prompted the installation of this seemingly oversized culvert.



Figure 68. Small unmappable gullies in steeply sloping areas are subject to flash flooding; note the debris screen.



Figure 69. Debris beside Calopooio River Rood at the mouth of Bigs Creek was removed from rood by mointenonce crews.

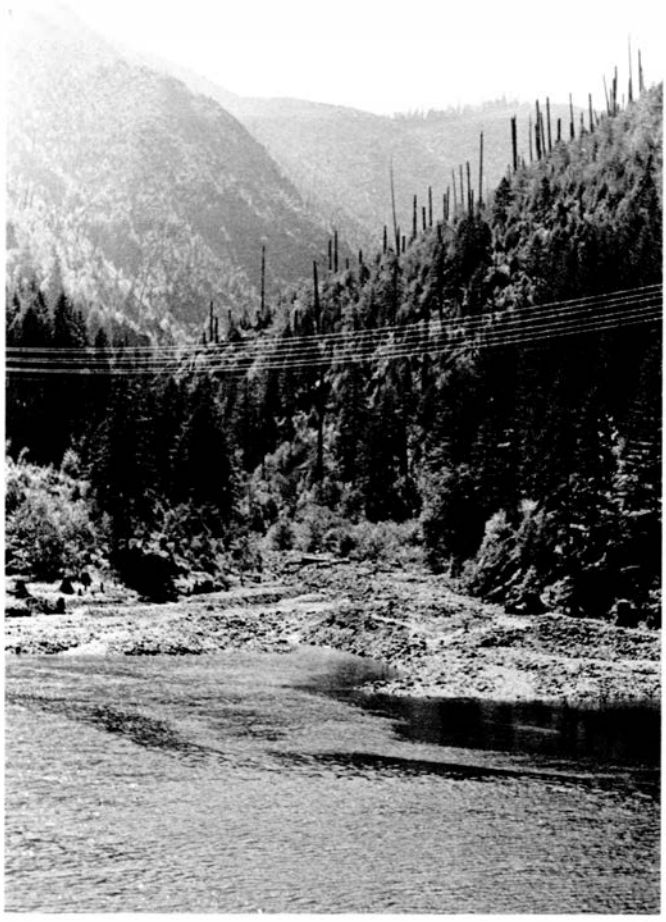


Figure 70. Debris for this delta has been eroded and delivered from the burned area since the completion of Big Cliff Dam.

Tectonic Hazards

The West Coast of North America is situated in the Circum-Pacific "ring of fire", a band of high volcanic and seismic activity which encircles the Pacific Basin. The crustal structure and tectonic behavior of the northwestern United States are very complex and the historic record is short. With the limited knowledge available to us at the present time, it is impossible to predict future tectonic activity with any degree of precision. Oregon appears to be seismically less active than neighboring Washington and California. Recent regional structural interpretations suggest that major active structures bypass most of the State.

Volcanism

The Western Cascades document intermittent volcanism for the past 40 million years. In the study area several thousand cubic miles of flow rock and pyroclastics were ejected during Oligocene and early Miocene times. After a period of local quiescence during which the Columbia River Basalt flowed into the area from the north, renewed volcanism produced the Sardine Formation and the Cascades Formation at Snow Peak and Rocky Top. Numerous local eruptions over the past few thousand years in the High Cascades of eastern Linn County and nearby areas are described by Taylor (1965), and historical volcanic events on Mounts St. Helens, Hood, and Lassen are discussed by Folsom (1970).

Future volcanic activity in Linn County is possible in view of the duration and continuity of the past record. However, the extent of the volcanism probably would be local and the impact on western Linn County would probably be negligible. Currently personnel from the U. S. Geological Survey are initiating reconnaissance geophysical investigations of the Cascade Range including parts of Oregon to assess more accurately the probability of future volcanic activity.

Earthquake potential

The shaking of the earth's surface which accompanies the release of energy at depth is called an earthquake. Associated with the release are displacements of rock along planar surfaces called faults. The specific location of the displacement within the earth is called the focus and the geographic location above the focus on the earth's surface is called the epicenter.

Intensity and magnitude are indirect measures of the total energy released by an earthquake. In using the Modified Mercalli Intensity Scale (Table 9), observations of the effects of the quake serve as an indicator of its relative severity. Determinations made in this way are subject to inaccuracies owing to the distance from the epicenter and to the nature of the subsurface where the observations are being made. The Mercalli Scale tends to be imprecise for these reasons. It is widely used, however, owing to its universal applicability and the need for no equipment. Also, the gathering of numerous observations tends to rule out subjective errors and local variations.

The Richter Scale is based on recordings from seismometers rooted in bedrock. It gives a more direct measure of energy release during an earthquake and is less subject to errors through local variations of subsurface than is the Mercalli Scale. Instead of indicating "intensity" with Roman numerals as used in the Mercalli Scale, the Richter Scale indicates "magnitude" with decimal numbers (Table 9) on a logarithmic scale. Each digit represents a 10-fold increase in the amplitude of the seismic waves and a 31-fold increase in the amount of energy released. Hence, an earthquake of magnitude 5 is 31 times greater than an earthquake of magnitude 4. The scale ranges from less than 1 for small quakes to slightly less than 9 for the largest possible quake.

A seismic risk map for the State of Oregon (Figure 71) shows Linn County to lie in Zone 2, an area for which quakes with intensities as high as VII on the Mercalli Scale are possible. Quakes of this intensity are capable of cracking walls. With saturated ground conditions, such as are common in much of the Willamette Valley during the winter months, the damage to structures could be considerably greater if fluid response (liquifaction) were to occur. Initiation of destructive landslides in the foothills also is a possibility.

The central Willamette Valley area has been the site of at least eight earthquakes since 1891 (Table 10). Epicenters for the quakes are only approximate. The faults are not evident in reconnaissance mapping procedures and may not extend to the earth's surface. The largest quake had an intensity of VI, which corresponds roughly to an acceleration of 0.03 g.

Failure to map definite faults on the reconnaissance geologic map (see Geology: Geologic Structure) and the scanty record of historic earthquake activity in western Linn County should not be interpreted to indicate little or no seismic risk in the area. The response of saturated ground and sloping terrain to moderate seismic shock is in need of more investigation. In addition, highly sensitive developments such as nuclear reactors require a level of inquiry far more rigorous than that provided here. The general conclusions advanced here should in no way prejudice the findings of more involved studies in the future.

Table 9. Scale of earthquake intensities*

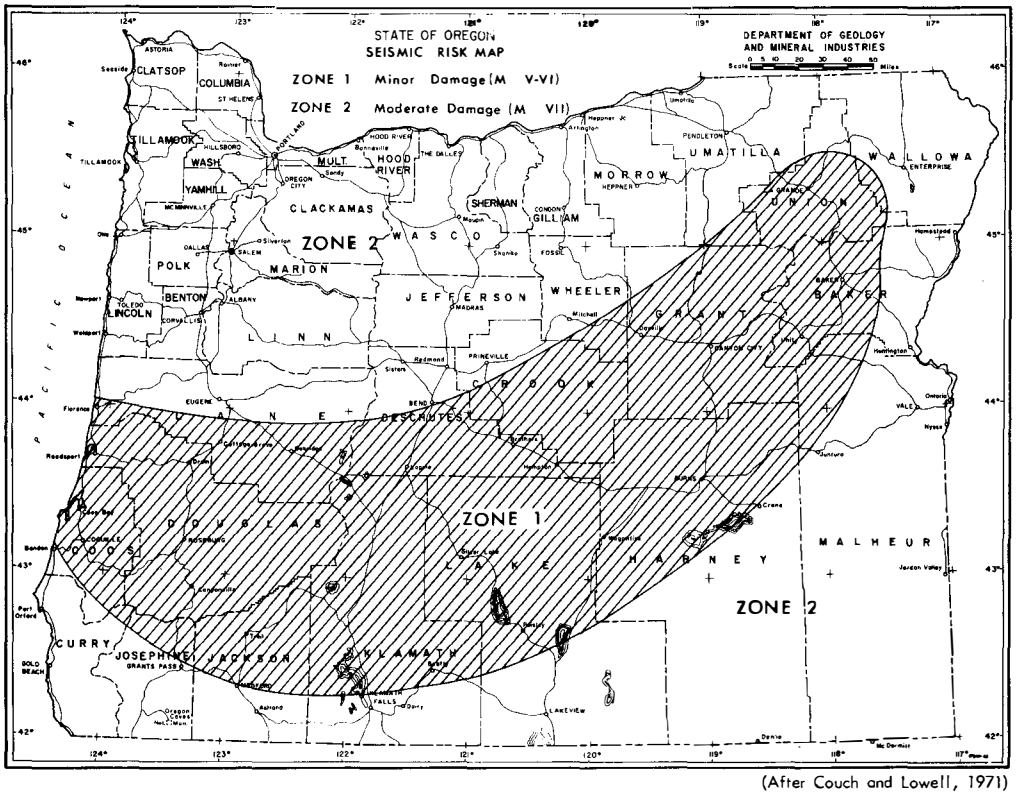
Mercalli Intensity	Description of effects	Equivalent Richter magnitude
I	Instrumental: detected only by seismographs	
II	Feeble: noticed only by sensitive people	3.5 to 4.2
III	Slight: like the vibrations from a passing truck; felt by people at rest, especially on upper floors	
IV	Moderate: felt by people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

* After Holmes (1965)

Table 10. Seismic events in the Central Willamette Valley Region

Date	Location of epicenter (approximate)	Intensity (Mercalli)
Sept. 16, 1891	Salem	IV
April 2, 1896	McMinnville	VI
Dec. 15, 1920	Cascadia	III
Feb. 25, 1921	Cascadia	V
May 12, 1942	Corvallis	V
March 5, 1944	Dallas	III
March 5, 1944	Dallas	V
Nov. 16, 1957	Salem	VI
Aug. 18, 1961	Albany	III - IV

Adapted from Berg and Baker, 1963



(After Couch and Lowell, 1971)

Figure 71. State of Oregon seismic risk map.

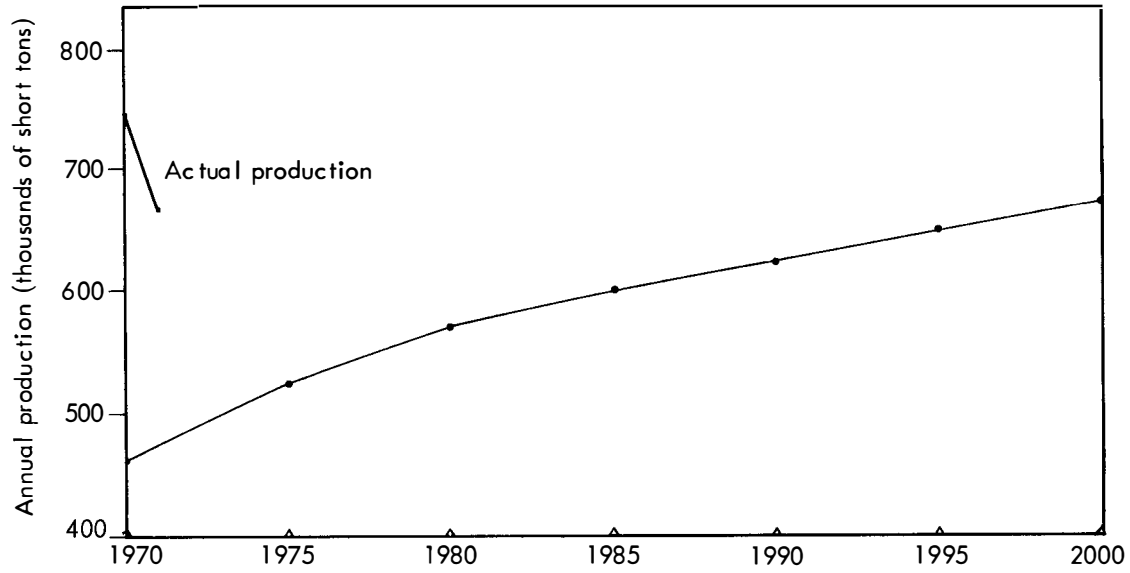


Figure 72. Projected annual consumption of sand and gravel based on population trends shown in Figures 5 and 6 and assuming consumption of 6.5 tons per capita per year. Actual production for years 1970 and 1971 is also shown.

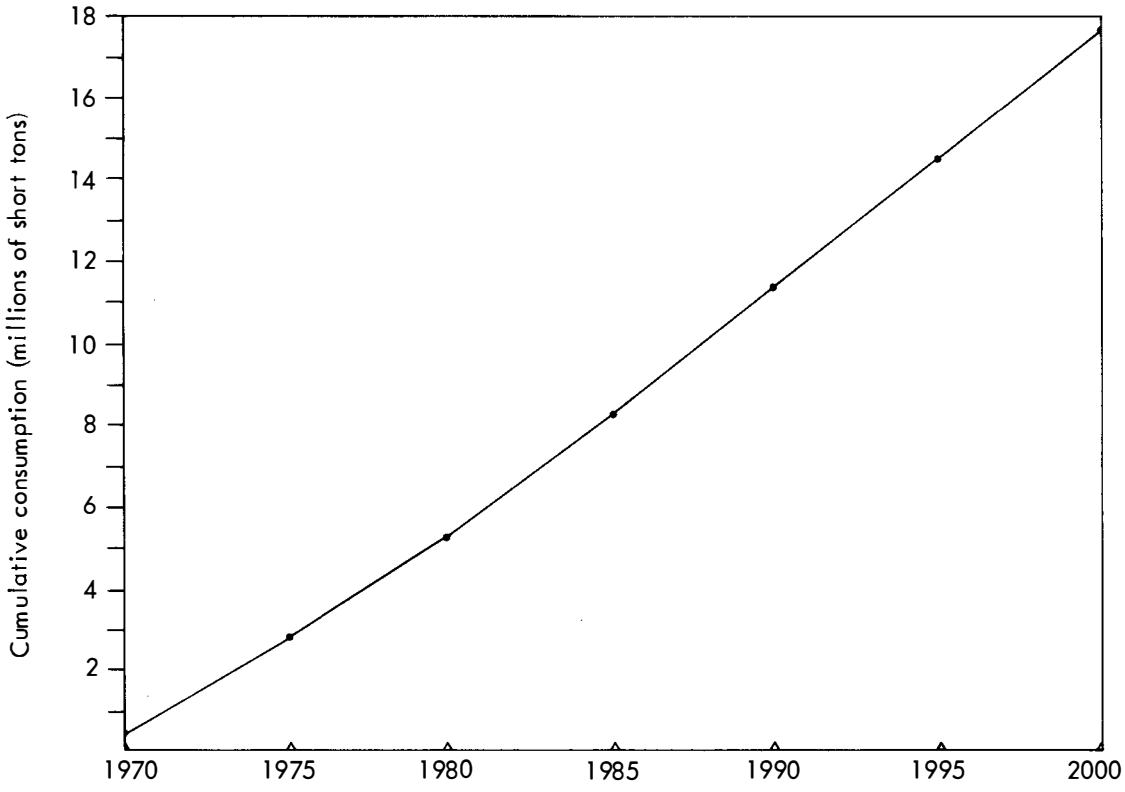


Figure 73. Cumulative curve of sand and gravel consumption based on population trends shown in Figures 5 and 6 and assuming consumption of 6.5 tons per capita per year.

NATURAL RESOURCES

Mineral resources of present economic value in western Linn County are primarily construction materials, which grossed $1,237,000 in 1970, and ground water. From a historical standpoint, the gold and silver production of the Quartzville mining district is of interest as are the thin presently uneconomic coal seams of the Jordan Valley. Future exploration in the Willamette Valley may reveal economic reserves of oil and gas.

Construction Materials

Sand, gravel, and crushed rock are important factors in the development of any community. These materials are used in the making of concrete, asphalt, riprap, and select fill and are used in the construction of dams, roads, bridges, buildings, revetments, and houses. It is estimated that for every housing unit started, a total of 176 cubic yards of concrete is needed for the individual structure and for the numerous other projects it generates including streets, sewers, schools, libraries, shopping centers, and industrial facilities.

More than 70 pits and quarries (see Appendix D) in a variety of rock units (Table 11) are in operation or have operated in the past in western Linn County. Production of sand and gravel peaked at 1,882,000 tons in 1965 and averaged approximately 700,000 tons annually for the period 1960 to 1970 (Table 12). Stone production from quarries peaked at 1,787,042 tons in 1966 and averaged approximately 630,000 tons annually for the period 1960 to 1970 (Table 13). Production in recent years has declined considerably with the completion of dam construction.

Average per capita consumption of sand and gravel for the period 1960 to 1970 was approximately 11 tons per year and that for quarry stone was about 10 tons per year. Both figures are regarded as higher than normal, owing to extensive road and dam construction during the decade. In addition, the population grew from 54,300 in 1960 to 71,914 in 1970 for an average annual increase of approximately 3 percent. As the growth rate declines in the future, per capita consumption of construction materials should also decrease since there is a direct relationship between consumption of sand, gravel, and crushed rock and the rate of population growth of a given area.

Sand and gravel

Sand and gravel occur as lenticular bodies along present and former courses of major rivers. The deposits are generally high in quality and if unweathered are suitable for use as aggregate. Pits are concentrated in the Quaternary alluvium (Qal) and lower terrace unit (Qtl) in the areas surrounding Albany, Lebanon, and Sweet Home. The large volumes of aggregate needed for the construction industry and the economic aspects of transport preclude hauling distances of greater than 15 or 20 miles.

Using the population data developed on Figure 6 and assuming a conservative consumption rate of 6.5 tons per capita per year (Schlicker, 1969), total production of sand and gravel in the County will approach 700,000 tons per year by the year 2000 (Figure 72). Cumulative consumption between 1970 and 2000 will be about 18,000,000 tons (Figure 73). This is equivalent to a pit 25 feet deep, half a mile wide, and 2 miles long. If annual per capita consumption should continue at the present rate (11 tons) cumulative consumption will exceed 30,000,000 tons by the year 2000.

Future sources of sand and gravel will include the Quaternary alluvium (Qal), the lower terrace (Qtl), and parts of the Willamette Valley where only a thin mantle of Willamette Silts overlies fluvial gravels. The soils map (pocket) delineates areas known to be underlain by gravelly soil in the valley areas of western Linn County. Further studies by governmental or private agencies are needed to survey in detail the distribution of marketable sand and gravel in areas of gravelly soil and beneath the Willamette Silts. In addition to gross reserves, such studies should investigate rock and sand quality, zoning restrictions, ownership, and other factors which tend to limit the quantity of marketable product. Presently there are no precise estimates of the sand and gravel reserves of western Linn County.

Accessibility of adequate sand and gravel in the alluvium and lower terraces must be assured for future years. It is these units that contain the bulk of high-quality construction material needed for concrete aggregate. Few, if any, rock quarries can meet the necessary specifications, and the higher terrace gravels are too weathered.

Urban growth must not be allowed to sprawl indiscriminately over future sources of supply. Likewise, zoning ordinances, zoning variances, and other planning decisions should not arbitrarily discriminate against the aggregate industry. Consideration should be given to the possibility of periodically mining sand and gravel from the more rapidly growing bars in the major drainages. River-bed sites such as these constitute renewable sources for what is considered elsewhere to be a nonrenewable resource. Bar excavation also might minimize local stream-bank erosion in certain areas (see Geologic Hazards: Stream-bank Erosion).

Table 11. Construction materials in Linn County

Unit	Useful materials	Transportation factor	Quality	Quantity	Uses and comments
Quaternary alluvium (Qal)	Hard gravel and fresh sand	Near urban centers	Very good	Large	Ill-advised political decisions may severely restrict supply; used for concrete aggregate and construction
Willamette Silts (Qws)	None	--	--	--	Accessible gravel and sand of Qtl unit may be near surface locally
Lower terrace (Qtl)	Gravel and sand	Near urban centers	Good	Large	Largely untapped; urbanization is covering large reserves; used for concrete aggregate and construction
Middle terrace (Qtm)	Sand and gravel	Semi-isolated	Poor - deeply weathered	Small	Deep weathering and small proportions of gravel preclude development
Upper terrace (Qtu)	Sand and gravel	Semi-isolated	Fair - weathered	Small	Untapped; weathering and isolation are prohibitive
Sardine Formation (Tps)	Quarry stone	Isolated	Variable	Large	Small local quarries for mountain road construction
Columbia River Basalt (Tcr)	Quarry stone	Near urban centers	Good	Large	Large well-located reserves; used for road construction; some possibly suitable for aggregate
Little Butte Formation (Tolb)	Quarry stone	Isolated	Variable	Large	Diffuse, poorly defined exposures; used locally for road rock on mountain roads
Intrusive rock (Ti)	Quarry stone	Isolated	Good	Large	Suitable for road rock, riprap, and dam construction; isolated from Willamette Valley

Table 12. Sand and gravel production in Linn County

Year	Opera-tors	Commercial S/tons	Commercial Value	Non-commercial S/tons	Non-commercial Value	Total S/tons	Total Value
1940-1949 Total		2,462,274	$1,779,527	174,578	$ 91,287	2,636,852	$1,870,814
1950	7	183,448	133,751	-	-	183,448	133,751
1951	2	100,424	101,256	-	-	100,424	101,256
1952	5	100,374	108,041	-	-	100,374	108,041
1953	7	326,320	255,830	141,530	34,960	467,850	290,790
1954	14	416,991	453,823	82,350	8,175	499,341	461,998
1955	13	428,628	413,253	211,800	109,000	640,428	522,253
1956	9	292,710	284,087	124,427	51,791	417,137	335,878
1957	9	320,100	310,193	282,070	205,335	602,170	515,528
1958	10	304,671	323,260	49,049	43,953	353,720	367,213
1959	9	230,220	214,874	1,484,800	1,816,373	1,715,020	2,031,247
Total		2,703,886	$2,598,368	2,376,026	$2,269,587	5,079,912	$4,867,955
1960	7	110,168	$ 120,700	185,641	$ 98,187	295,809	$ 218,887
1961	9	183,250	194,872	150,901	172,544	334,151	367,416
1962	12	362,715	375,397	104,687	116,252	467,402	491,649
1963	14	434,785	473,515	286,189	349,486	720,974	823,001
1964	12	434,000	454,000	270,000	344,000	704,000	798,000
1965	13	733,000	807,000	1,149,000	1,775,000	1,882,000	2,582,000
1966	13	718,000	796,000	445,000	482,000	1,163,000	1,278,000
1967	8	339,000	315,000	20,000	46,000	359,000	361,000
1968	6	283,000	293,000	65,000	65,000	348,000	358,000
1969		601,000	688,000	151,000	282,000	752,000	970,000
Total		4,198,918	$4,517,484	2,827,418	$3,730,469	7,026,336	$8,247,953
1970		664,000	$ 738,000	75,000	$ 337,000	739,000	$1,075,000
1971		678,000	760,000	2,000	9,000	680,000	769,000

Table 13. Stone production in Linn County

Year	Opera-tors	Commercial S/tons	Commercial Value	Non-commercial S/tons	Non-commercial Value	Total S/tons	Total Value
1940-1949 Total		303,663	$ 353,172	310,126	$ 248,898	613,789	$ 602,070
1950	2	49,846	49,846	33,526	41,908	83,372	91,754
1951	1	51,500	51,500	-	-	51,500	51,500
1952	3	105,805	179,653	-	-	105,805	179,653
1953		-	-	-	-	-	-
1954	2	-	-	62,182	61,936	62,182	61,936
1955	4	3,400	4,250	60,867	56,042	64,267	60,292
1956	8	89,756	108,863	129,099	169,191	218,855	278,054
1957	7	50,991	58,866	134,776	141,456	185,767	200,322
1958	8	45,912	32,640	133,963	114,122	179,875	146,762
1959	8	726,824	487,328	43,292	44,078	770,116	531,406
Total		1,124,034	$ 972,946	597,705	$ 628,733	1,721,739	$1,601,679
1960	5	290,600	$ 196,897	45,640	$ 40,800	336,240	$ 237,697
1961	5	---------- Confidential ----------				571,924	460,428
1962	9	109,806	97,882	863,171	472,521	972,977	570,403
1963	8	61,311	80,137	757,630	555,081	818,941	635,218
1964	9	74,933	86,761	383,028	297,626	457,961	384,387
1965	9	123,088	137,188	657,641	530,948	780,729	668,136
1966	7	---------- Confidential ----------				1,787,042	2,112,086
1967	7	78,661	93,396	46,764	80,000	125,425	173,396
1968						255,076	251,026
1969						233,472	179,080
Total						6,339,787	$5,671,857
1970	8					176,351	$ 162,868
1971	4					Confidential	63,944

Quarry stone

Quarry stone has certain advantages and disadvantages compared to stream gravel. It makes a better base for paved surfaces and is better suited to the construction of oiled and macadamized roads. Where jointing is moderately coarse, it is well-suited as riprap for riverbank protection. It is generally not well-suited to use as concrete aggregate and it is more costly to produce than sand and gravel. Much of the available quarry stone in western Linn County is relatively isolated compared to most of the deposits of sand and gravel.

In western Linn County, quarry rock is produced from the Columbia River Basalt (Tcr), the Little Butte Formation (Tolb), the Sardine Formation (Tps), and Tertiary intrusive rock (Ti) (Table 10). Although the supply of quarry stone is very large, depth of overburden, quality of stone, degree of weathering, and isolation place economic restrictions on development in many instances (Figure 74).

Quarries in the Columbia River Basalt produce stone suitable for use in road construction and riprap. In addition, selective mining of the Hale Butte quarry may produce rock suitable for use as concrete aggregate (J. J. Gray, oral communication, 1973). Outcrops are concentrated in the northern part of the County. An isolated exposure at Marks Ridge (Figure 75) provides a future source of stone for the Sweet Home area. Presently it cannot compete economically with local deposits of sand and gravel.

Stone from the Little Butte Formation and related intrusives has been used in road and dam construction. Coarsely jointed stone at Shot Pouch Butte (Figure 76) was used in the construction of Foster Dam. Isolated erosional remnants of Little Butte basalt in the Willamette Valley southeast of Lebanon are quarried for road metal. The deposits consist of dike rock, flow rock, and basaltic breccia; the quality of stone derived from them varies considerably. The area bounded by Lebanon, Sweet Home, and Brownsville is characterized by innumerable knobs of basaltic dike and flow rock. Quarries there are generally small and aimed at local road maintenance (Figure 77). However, a few of the larger deposits are in commercial operation (Figure 78).

Exposures of Sardine Formation are relatively isolated, being restricted to the higher upland areas near Snow Peak and at Bald Peter, High Deck, and Farmers Butte. Quarry stone production is restricted to small operations for maintenance of mountain roads. Quality is variable.



Figure 74. The Diamond Hill quarry (Sec. 1, T. 15 S., R. 3W.) yields rock of variable quality and is isolated from areas of high demand.

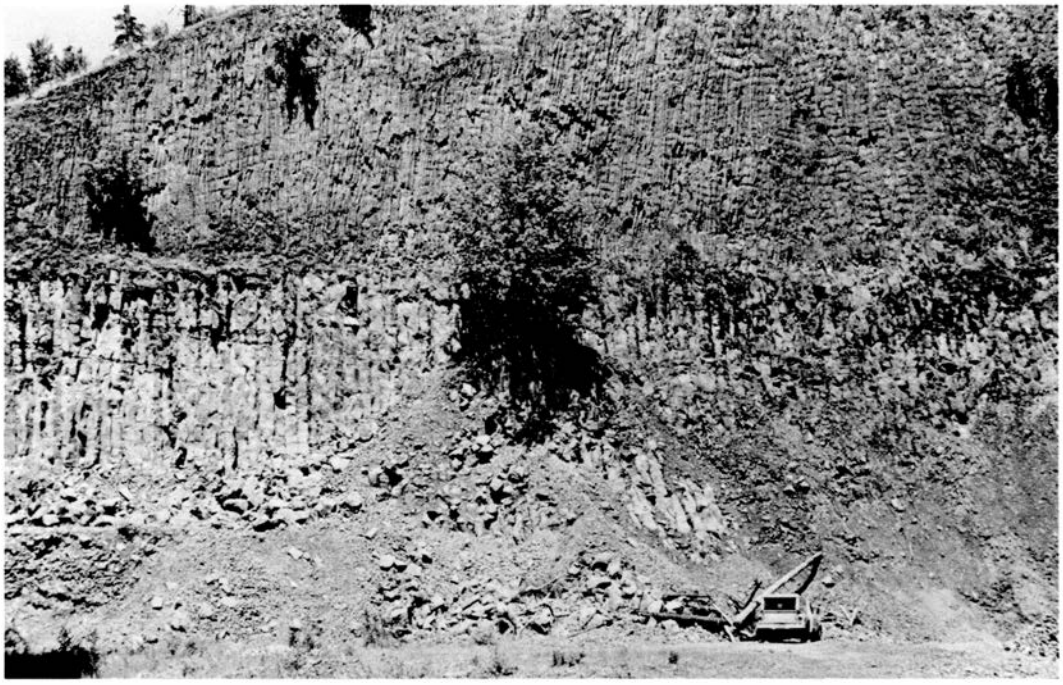


Figure 75. Large quantities of high-quality rock are available at Marks Ridge.

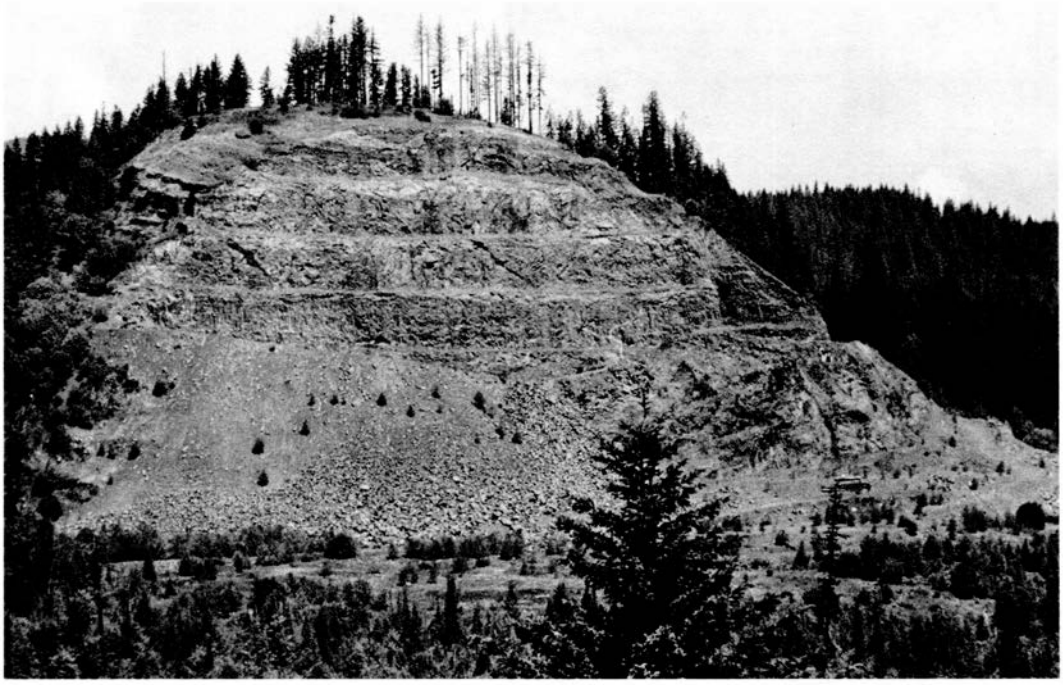


Figure 76. Shot Pouch Butte supplied riprap for Foster Dam.

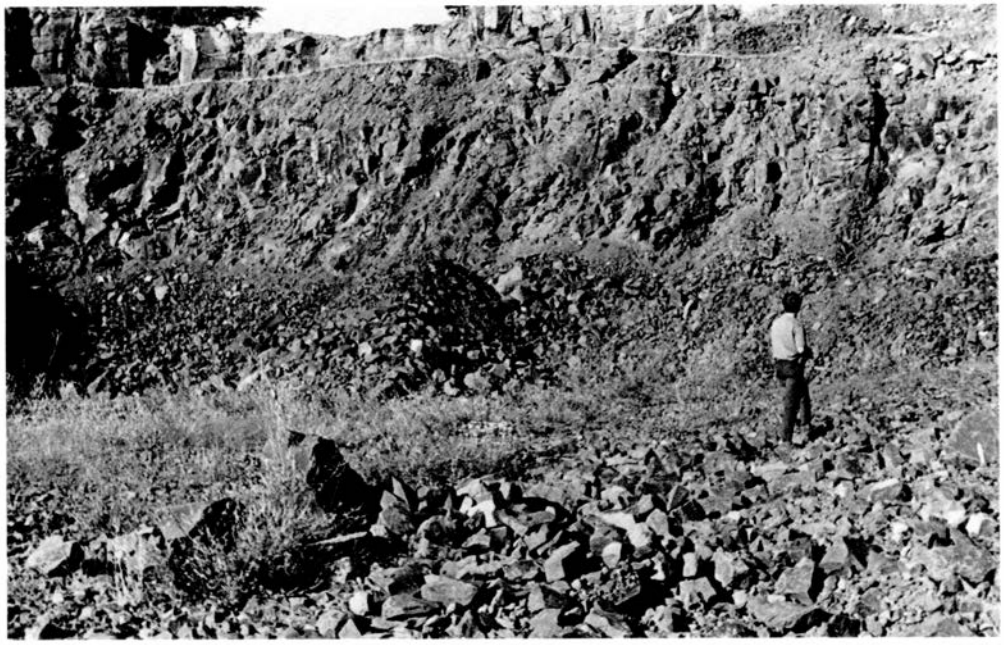


Figure 77. The Ridgeway Butte quarry (Sec. 13, T. 12 S., R. 2 W.) is a small source of rock for local road maintenance.

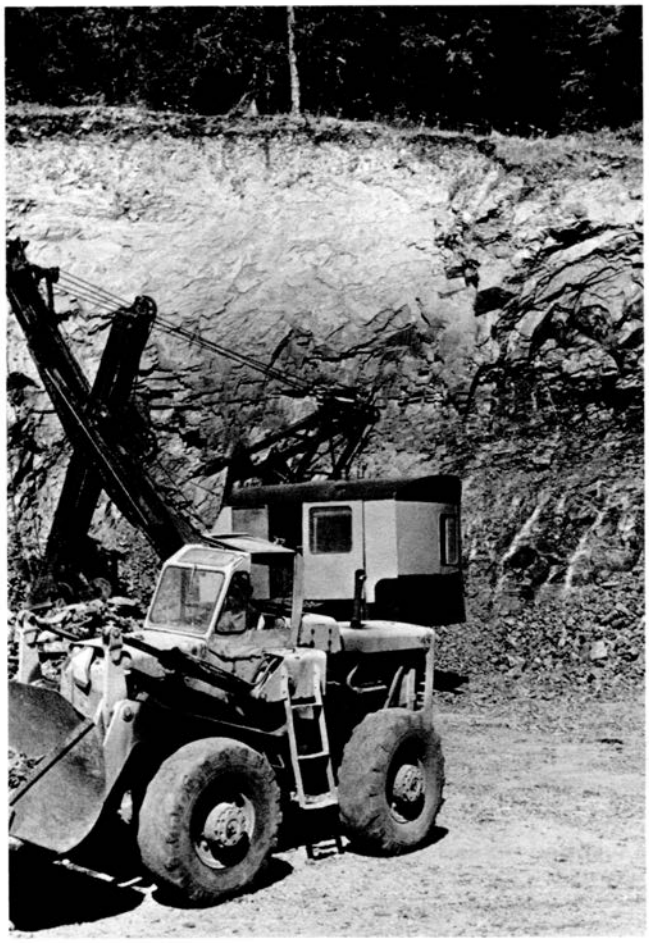


Figure 78. Sheety jointing at the Sodaville quarry (Sec. 1, T. 14 S., R. 2 W.) makes the rock well suited to use as rood rock.

Ground Water

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

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

Permeability is the capacity to transmit water and is dependent upon the porosity, the size of the pore spaces, the degree of interconnection between the pore spaces and the hydraulic gradient. Materials such as sand with relatively large interconnected pore spaces are very permeable and have high capacities. In contrast, jointed flow rock commonly has high permeability but low holding capacity.

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

Utilization of ground-water supplies has been a key factor in the continuing agricultural, industrial, and residential development of the western portion of Linn County. Information concerning the occurrence, quality, and quantity of this resource is obtained primarily from the observation and recording of water-well data. Well records are on file at the State Engineer's Office in Salem, and in the Portland office of the U. S. Geological Survey. In addition, the well data for various sections of the County are available in report form (Piper, 1942; Helm, 1968; Frank and Johnson, 1972), and additional reports are in preparation (F. J. Frank, oral communication, 1974). Persons seeking information on a specific site should research the well records available for the site area or consult a ground-water geologist.

Occurrence

The primary sources of ground water in the study area are the unconsolidated Quaternary alluvial deposits which cover the valley floors of the major rivers and their tributaries (Table 14). Lesser amounts of water are drawn locally from the Tertiary sedimentary and volcanic rocks that underlie the alluvium and form the foothills of the Cascade Mountains. In places, the Columbia River Basalt is highly productive. Logs of representative wells are given in Appendix F.

The most productive units are situated in the Quaternary alluvium (Qal) and the Quaternary lower terrace deposits (Qtl) in the Willamette Valley and in the lower reaches of the North and South Forks of the Santiam Rivers. Upstream from Stayton on the North Fork and Lebanon on the South Fork, the recent alluvial deposits are not extensive enough to produce the high yields characteristic of many of the wells situated downstream. The Quaternary alluvium and lower terrace deposits consist of sand and gravel with varying amounts of silt, and have an average thickness of 50 feet. Thicknesses of several hundred feet are inferred locally, however. Wells which extend only a few feet below the water table commonly produce large volumes of water.

The Quaternary alluvium (Qal) which forms the flood plains of the smaller streams in the study area (e.g., Calapooia River, Muddy Creek, Oak Creek, Thomas Creek) contains high percentages of silt and clay and is less permeable than the coarser deposits of the larger rivers. Shallow wells situated in these deposits commonly yield a few tens of gallons per minute, but performance is variable depending upon location. Wells drilled to underlying alluvium at greater depths are not affected.

The large expanses of valley floor between the major channels in the Willamette Valley are underlain by a few tens of feet of Willamette Silts (Qws) which, in turn, overlie coarser unconsolidated alluvium equivalent to the various terrace levels. In these areas, wells penetrate the silts (Qws) to producing horizons in the underlying gravels. Although the gravels generally exhibit high permeability, low permeabilities are noted in areas (defined roughly by Piper, 1942) of high silt and clay content. Thickness of the older alluvium in the Willamette Valley averages 70 feet (Piper, 1942) but varies considerably owing to local relief and bedrock topography and structure.

Consolidated bedrock in the study area consists of marine and nonmarine sedimentary rocks (interbeds in the Little Butte Formation) and a wide variety of volcanic rocks (Little Butte Formation, Columbia River Basalt, Sardine Formation, Cascades Formation). Sedimentary rocks underlie the alluvium of the valley floor and crop out in the foothills. Ground-water movement is limited to fracture zones and to discontinuous interbeds or lenses of relatively permeable sandstone. Wells tapping these aquifers commonly yield only a few tens of gallons or less per minute. Potential production of relatively thick permeable interbeds such as those north of Brownsville may be somewhat greater.

Within volcanic rocks, scoriaceous or rubbly layers, buried soil horizons, and highly fractured or jointed zones can act as aquifers. Within the Little Butte Formation, these zones are discontinuous and yields are very low. A few wells in the Columbia River Basalt in the north central part of the County, however, are producing several hundred gallons per minute (Table 14). The gentle westerly dips, flow-on-flow structure, and regional continuity of the Columbia River Basalt are ideal for the production of ground water.

Table 14. Characteristics of representative wells in western Linn County
(Data shown in feet unless otherwise noted)

Well location number*	Owner	Year completed	Depth	Depth of Casing	Finish	Water bearing zones: Depth to top	Thickness	Character of material	Altitude	Water level: Feet	Water level: Date	Performance: Yield (gpm)	Performance: Drawdown	Use
9S/1W-13D1	Salem	1939	60	60		16	3	Gravel Qal	466	12	--	1775	--	Public supply
10S/2W-8N2	W. Upstad	1957	21	21	Perforated 15-20'	17	4	Gravel and sand Qal	253	14	8/22/57	450	1.5	Irrigation
10S/2W-19Q2	N. Bradley	1966	22	22	Perforated 18-22'	15 19	1 3	Gravel and sand Qal	230	5	5/22/66	300	1.5	Irrigation
12S/4W-6P1	W. Homlin	1961	35	35	Perforated 26-35'	20	15	Gravel Qal	220	17	9/18/70	475	9.5	Irrigation
12S/3W-7E1	Tangent	Pre-1928	45	36-40	Screen at base	42	3	Gravel Qtl	245	11	8/2/28	30	--	Public supply
11S/3W-17F2	J. Anderson	1960	70	66	Perforated 32-38' and 58-64'	29	37	Sand and gravel Qtl	226	15	11/?/65	40	0.5	Domestic & irrigation
9S/1W-14Q1	J. Fery	1964	326	19	Open bottom	57	269	Basalt Tcr	550	3	3/19/64	600	62	Irrigation
10S/1W-4J1	C. Limbeck	1957	139	4	Open bottom	90 110 124 133	12 2 8 4	Basalt Tcr	675	48	12/13/57	10	All	Domestic and stock
13S/2E-36Q1	U.S. Forest Service	1958	100	36	Open bottom	54	46	Tuff Tolb	795	7.5	3/19/58	32	82.5	Domestic
10S/3W-15P1	G. Miller	1965	70	50	Open bottom	51	19	Sandstone Tolb	465	0	1/3/66	19	All	Domestic
10S/3W-20K1	E. Chawning	1959	150	150	Perforated 105-110' 120-126' 142-148'	105	45	Sandy clay Tolb	227	27.7	8/20/65	30	4	Domestic

*See Appendix F
Data from Frank and Johnsan, 1972; and Helm, 1968.

Hydrology

Recharge of ground water occurs directly from precipitation on the alluvium or bedrock and involves absorption at points where aquifers are exposed as well as lateral movement along the aquifer. If the aquifer recharge area is small or covered by materials of low permeability (clay soils or solid bedrock), recharge of ground water may be a very slow process. In Quaternary alluvium near major streams, subsurface replenishment allows very high yields.

Surface water and ground water in the study area are closely related. Well-level and streamflow records indicate that surface- and ground-water fluctuations in both are directly related to the amount of precipitation. During the rainy winter and spring months, ground-water and stream levels increase, and during the dry summer and autumn months, ground-water and stream levels decrease. During the dry months, more water is being removed from the ground-water system by streamflow than is being replaced by precipitation or surface runoff. Surface-water levels during the dry months are maintained primarily by the discharge of ground water into the streams and rivers.

Ground water in the Quaternary alluvium is unconfined and free to flow in a down-gradient direction. Throughout most of the Willamette Valley of western Linn County (Piper, 1942), the ground water moves away from the foothills of the Cascades in a westerly direction and then flows north-northwest until it is discharged into the Willamette River or one of its tributaries. Local variations in the regional flow pattern occur as a function of local topography. At points of discharge into streams, ground water flows at right angles to the stream channel. Along the edges of terraces or along other breaks in slope, flow is perpendicular to the hillside.

Monitoring by personnel from the office of the State Engineer and the U. S. Geological Survey shows that in western Linn County the water table in the unconsolidated deposits is replenished by winter and spring rains in spite of considerable pumping during the summer and fall months. A lowering of the water table in the Columbia River Basalt in the north central part of the County has been noted over a period of several years, however, suggesting that more water is being withdrawn from this aquifer than is replaced by natural recharge.

Quality

Water-quality data from well samples by the State Engineer's office and the U. S. Geological Survey is summarized on Table 15. Water-quality standards proposed by the U. S. Public Health Service are shown in Table 16. Water derived from the alluvial deposits is generally high in quality and is suitable for most agricultural, industrial, and domestic uses. Locally, however, iron content in water derived from the alluvium is high enough to require treatment prior to use. It is postulated that the high iron content results from tapping of low-quality connate water originating in the underlying bedrock. Most occurrences of iron-rich water in wells are in shallow alluvium near the foothills.

Wells producing water from the Little Butte Formation vary considerably in quality. "Soda springs" are noted at several locations in the foothills, and mineral springs near Cascadia were used for medicinal purposes for many years (Department files; Wagner, 1959). Water is soft to moderately hard and is frequently high in iron, salts, and dissolved solids. Although no wells with excessive arsenic are noted in Linn County, Goldblatt and others (1963) list several dozen high arsenic wells in Lane County in rocks equivalent to the Little Butte Formation. Arsenic poisoning through ground water is very rare, but when it does occur, leads to numerous physical maladies of the nerves, skin, stomach, blood, and other parts of the body.

Wells tapping marine interbeds beneath the alluvium in the Willamette Valley locally are high in mineral content, resulting from the influx of dissolved solids or connate water. Content of dissolved solids is commonly greater than 1,000 parts per million. In places the connate water percolates upward into the valley alluvium to contaminate shallower wells. Water derived from the Columbia River Basalt is generally of good quality although iron content is moderately high in places.

Table 15. Chemical analyses of representative

Well location number*	Water-bearing material	Date of collection	Parts per million										
			SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl
9S/1W-13D1	Gravel Qal	6/14/51	17	0.03	--	4.9	1.1	3.2	2.6	31	0	17	1.0
10S/2W-8N2	Gravel and sand Qal	5/18/66	20	0.01	--	7.4	2.5	3.3	0.4	32	0	3.8	1.5
10S/2W-19Q2	Gravel and sand Qal	6/24/66	24	0.04	--	21	7.2	7.0	0.9	62	0	18	5.5
12S/4W-6P1	Gravel Qal	7/23/71	42	0.03	0	21	11	11	0.6	87	0	15	12
11S/3W-17F2	Gravel Qtl	6/17/66	33	0.37	--	33	17	14	1.0	213	0	1.4	4.5
12S/3W-7E1	Sand and gravel Qtl	4/18/29	35	0.08	--	31	18	14	1.1	193	0	2.1	13
9S/1W-14Q1	Basalt Tcr	6/23/66	45	0.48	--	5.7	3.6	9.9	1.3	60	0	2.8	1.0
10S/1W-4J1	Basalt Tcr	5/25/66	23	0.01	--	4.9	3.0	7.8	1.0	25	0	1.2	10
13S/2E-36Q1	Tuff Tolb	3/16/65	34	1.6	--	80	17	257	2.6	443	0	43	300
10S/3W-15P1	Sandstone Tolb	5/25/66	35	13	--	2.9	2.1	7.9	1.1	16	0	0.8	11
10S/3W-20K1	Sandstone Tolb	6/17/66	37	0.79	--	13	7.7	10	1.3	80	0	14	7.0

*See Appendix F
Testing laboratory - U.S. Geological Survey, Portland

ground-water aquifers in western Linn County

Parts per million															
NO_3	ASN	Ortho ASP	PO_4	B	As	Calculated dissolved solids	Solid residue on evaporation	$CaCO_3$ hardness	Non-carbonate hardness	Hardness Ca, Mg	Sodium absorption ratio	Specific conductance at 25°C	Temperature °F	pH
0.1	--	--	--	--	--	47	45	17	0	--	0.3	54.4	64	7.3
4.3	--	--	0.14	0.01	0.00	59	--	29	3	--	0.3	76	50	6.6
23	--	--	0.03	0.09	0.00	138	--	82	31	--	0.3	210	52	6.6
--	5.8	0.2	--	0.06	0.003	181	--	--	26	72	0.5	246	58	7.2
0.2	--	--	0.81	0.11	0.00	210	--	152	0	--	0.5	330	56	7.5
3.8	--	--	--	--	--	213	204	151	--	--	0.5	--	52	7.9
0.1	--	--	0.50	0.03	0.00	101	--	29	0	--	0.9	102	56	7.5
8.8	--	--	0.13	0.0	0.00	72	--	24	4	--	0.7	96	54	6.8
0.0	--	--	13	2.4	0.12	956	965	270	0	--	6.4	1670	52	7.0
1.4	--	--	1.2	0.02	0.00	72	--	16	3	--	1	74	55	5.3
0.0	--	--	0.05	0.05	0.00	129	--	64	0.0	--	0.5	0.7	56	6.9

Table 16. Drinking water standards defined by the U.S. Public Health Service, 1962

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

* Varies inversely with mean annual temperature

Planning considerations

The preservation of the high quality of present sources of ground water and the availability of additional supplies in the future are essential to the growth of western Linn County. Of primary concern, therefore, is the prevention of pollution of the ground-water supply. Such factors as sewage, industrial wastes, street runoff, solid waste leachates, irrigation return water, or other potential pollutants must be closely controlled to assure that they are not allowed to percolate into the soil in regions of ground-water recharge. The widespread distribution of permeable sands and gravels in the more rapidly developing parts of Linn County make this problem particularly acute.

A potential environmental problem of regional importance ironically arises from the abundant supply of ground water. Whereas many city or county governments elsewhere limit the boundaries of growth by limiting the extension of the municipal water supply, no such constraints exist in western Linn County. Instead, developers are able to supply water to developments almost regardless of location because of the abundant ground water. The result is a more random pattern of development than would otherwise be possible. In areas of permeable soil, the discharge of sewage and other pollutants is detrimental to ground-water quality. High bacteria counts and high concentrations of phosphate and salts have been reported in well water taken from in and around urban and suburban areas in the Willamette Valley.

Restrictions on further septic-tank installations should be formulated for areas in which ground-water pollution is a problem. Realistic regulations require increased well monitoring, detailed soils data, knowledge of infiltration rates, and input by qualified personnel. Results from individual studies in problem areas might include additional density zoning ordinances. Generally speaking, septic-tank use in regions of dense development leads to environmental problems especially if water needs are supplied by individual wells.

A related problem involves the annual fluctuation in the level of the water table. Over large areas of the Willamette Valley, the water table rises to within a few feet of the ground surface or actually discharges into topographic lows during the winter months. Under these conditions, septic tanks may fail and effluent may actually emerge at the surface. Water wells and surface drainage may become polluted. The level of the water table must be considered in issuing septic-tank permits. Engineering solutions are available for many problem areas.

In addition to pollution problems associated with regions of ground-water recharge or ground-water withdrawal, there also are potential problems associated with regions of ground-water discharge. In sloping areas, for example, septic tanks and landfills can be the source of unacceptable surface-water pollution if surfacing ground water is allowed to bring effluent or leachate to the surface.

Oil and Gas

The formation of recoverable oil requires the presence of fine-grained carbonaceous source beds laid down in a rapidly subsiding basin, a coarser reservoir rock situated upstructure, and rapid deposition. As sediments are piled into the center of the basin, the oil is squeezed into the permeable sands where it is trapped by variations of lithology or structure.

The Willamette Valley is underlain by 8,000 feet of interbedded coarse and fine sedimentary rock (Eugene Formation). The record of four exploratory wells in western Linn County is summarized in Table 17. Gas shows, oil shows, and high salt-water pressure in permeable zones underscore the possibility of future production in the area. In a region such as the Willamette Valley, detailed geophysical study should precede actual drilling.

Table 17. Oil and gas test wells in Linn County, Oregon

Name	Location	Depth	Remarks
Barr 1	NW¼ sec. 31, T. 11 S., R. 1 W.	4,529'	Gas and oil shows at 4,300' in Eugene Formation equivalent; production tests disappointing - little gas, no oil; mechanical difficulties may have been responsible.
Esmond 1	SW¼ sec. 7, T. 12 S., R. 1 W.	8,603'	Gas shows and oil fluorescence; strong gas kick at 3,990; high salt-water pressures at 7,060; oil and gas production tests disappointing - sealing effect of drilling mud may have been responsible.
Miller 1	SE¼ sec. 10, T. 10 S., R. 3 W.	4,951'	Bottomed in late Eocene volcanic rock associated with porous sands saturated with salt water; located on possible anticlinal structure; penetration of volcanics into underlying sediments recommended.
Porter 1	NE¼ sec. 27, T. 13 S., R. 4 W.	8,470'	Gas shows between 3,800 and 5,200 feet; strong gas shows in places; high salt-water pressure at 5,080 feet. Drilled on a structure located by seismic means.

Gold and Silver

The Quartzville mining district, situated 40 miles east of Albany and a short distance east of the study area (T. 11 S., R. 4 E., and part of T. 12 S., R. 4 E.), produced gold (8,557 oz.), silver (2,920 oz.), lead, zinc, and copper before operations ceased in the 1890's. Approximately 25 mines, mine groups, and claims are located in the area.

Mining was disorganized, with no systematic cross-cutting. With the increasing price of gold it may now be economic for a firm to reenter the area and to scientifically assess the potential production of the area with modern technology.

Coal

Although the coal localities of Linn County are not of economic quality, the numerous seams reported in water-well logs and exposed on steep slopes in Thomas, Bilyeu, and Neal Creeks (secs. 2, 4, 8, 9, 10, 12, 16, T. 10 S., R. 1 E) are of general interest. A coal seam situated half a mile due east of Jordan on the south side of Thomas Creek was used for a blacksmith shop in the early 1900's. It is no longer locatable.

The coal occurs as small discontinuous lenses of lignite in subaerial volcanic and volcaniclastic rocks of the Little Butte Formation (Tolb). Its poor quality and limited extent precludes development.

SUMMARY

This bulletin is intended as a guide for the planner. It will be of use to all those dealing directly or indirectly with the physical characteristics of the land. The geology maps, geologic hazards maps, and soils maps show the regional distribution of the numerous hazards, bedrock units, and soils that are summarized in Table 18. The content, emphasis, and organization of the text are designed to provide the maximum assistance to the planner in effectively evaluating proposals in terms of the capabilities and liabilities of the land.

Table 18. Landforms and associated hazards

Landform	Associated hazards	Areas of high hazard potential	Areas of low hazard potential
Flat valley land	Flooding and stream-bank erosion along rivers and major streams; poor drainage, ponding, high ground water, poor soil conditions in local depressions; variable soil conditions on gentle rises	Flood plain west of Albany	High interfluves, gentle rises, and sloping regions near the mountain front
Isolated valley hills	Erosion, gullying, thin soils and local mass movement on steep slopes; minimal problems on gentler slopes	Peterson Butte, flanks of Knox Butte	Powell Hills, crests of Knox Butte, Hardscrabble Hill
Terraces	Poor drainage, ponding, high ground water, poor soils in local depressions or broad flat areas; erosion, gullying, local ground water discharge on steep side slopes; compressible soils locally on surficial alluvium	Middle terrace level underlain by poor soils (near Brewster and Draperville)	Upper terrace near Lacomb, parts of lower and middle terrace levels
Upland slopes	Deep weathering and thick clay soils on many gentle to moderate slopes; irregular drainage and highly variable lithology; mass movement, gullying and poor drainage on moderate slopes; shallow failures, flash flooding, erosion, and thin soils on steep slopes	Mass movement topography; steep slopes, such as those along Middle Santiam River; deeply weathered gentle slopes as along Brush Creek Road	Middle slopes on north side of Snow Peak; gentle slopes in Columbia River Basalt south of Kingston; most gentle slopes

In approximate order of decreasing importance, the active geologic hazards of western Linn County include flooding and related ponding and high ground water, stream-bank erosion, mass movement, flash flooding and erosion, and tectonism. Passive geologic hazards include the engineering properties of the ground and soils such as high organic or clay content, permeability, foundation strength, soil thickness, and soil texture. The success or failure of septic tanks, landfills, drain fields, and foundations are largely dependent on how these and other static ground conditions are handled.

FLOODING is a winter occurrence leading to many thousands of dollars worth of damage annually along the rivers and major streams. Methods of dealing with flooding include dam, levee, and dike construction, zoning codes, building regulations, flood forecasting, and implementation of the Flood Insurance Act. More accurate determinations of flood potential are needed in less populated areas. Delineations of floodways and floodway fringes in areas of current and future development are recommended.

PONDING AND HIGH GROUND WATER are regional winter hazards in low sloping areas. The damage arising from the resulting buoyancy and poor runoff on septic tanks, buried tanks, basements, and subdivisions can be avoided through comprehensive zoning ordinances and proper engineering. The potential for ponding or high ground water exists in all flat-lying areas. On-site investigations are needed to assess specific projects.

STREAM-BANK EROSION caused by river meandering is a prime concern to landholders along the South Santiam and Willamette Rivers. It also occurs along many lesser rivers and streams. Plans to protect the riverbank must recognize the need of the river to meander. Owing to the complex interrelationships between the velocity, gradient, load, and other parameters of stream regimen, short-sighted projects aimed at rigidly controlling stream-bank erosion could prove disastrous. Presently, the placing of riprap at critical localities and possibly zoning appear to be the most realistic economic means of minimizing losses through stream-bank erosion.

MASS MOVEMENT in regions of mass-movement topography can cause structural damage either rapidly or gradually over extended periods of time. Losses are often accentuated by improper land use or lack of engineering. Engineering studies are recommended for all large projects. Zoning ordinances are an effective means of controlling land use in critical areas. Continued adherence to the grading code is recommended.

FAILURES ON STEEP SLOPES are of secondary concern to the County planner because most steep slope areas lie in regions zoned exclusively for logging and related activities. However, such failures do contribute significant sediment and debris to streams and could cause damage in lower areas. Proper road engineering and construction can be attained in these areas by strict adherence to the grading code. In contemplating zoning changes, the severe limitations of steep slope areas should be considered.

FLASH FLOODS and erosion in upland areas can cause local catastrophic damages to structures and roads. Construction should be severely restricted in and along flash-flood channels, and culverts of adequate size should be required for all road construction. Loose fill along logging roads is particularly susceptible to flash-flood erosion.

SLOPE designations of the hazards map should be considered as guides for potential hazards in assessing land liabilities. Thus, although specific hazards are not shown over large areas, a variety of hazards may develop in the future if the land is mismanaged. For example, flat-lying areas are subject to ponding, flooding, or high ground water if drainage is impaired or improperly handled. Mass movement can occur on moderate slopes if poorly engineered cuts are made. Gullying, flash flooding, and erosion also can be generated on moderate to steep slopes through improper land use.

The largest probable EARTHQUAKE in western Linn County would register VII on the Mercalli Scale. Of the eight earthquakes observed in the central Willamette Valley since 1891, the largest was a Mercalli VI shock. For seismically sensitive structures such as nuclear reactors detailed earthquake studies are required. Potential VOLCANISM in western Linn County is negligible.

Cumulative SAND AND GRAVEL consumption by the year 2000 will range from 18 to 30 million tons. Appropriate zoning may be required to preserve adequate reserves in the Quaternary alluvium and Quaternary lower terrace, which produce the highest quality aggregate. QUARRY STONE is derived primarily from Columbia River Basalt, but also locally from basaltic intrusions in the Little Butte Formation.

The highest producing wells of GROUND WATER are located in the Quaternary alluvium and the Quaternary lower terrace deposits. Future planning must include a sophisticated understanding of the influence of geology on ground water so that this resource can be used most effectively and so that it will not become polluted or otherwise damaged.

Statements in the text are general and should not be construed as the final work on specific projects or parcels of land. The types of land use being considered in large part determine the actual magnitude of the hazards in question. Likewise, the feasibility of a particular project in a hazardous area is determined largely by the corrective measures to be employed. By being aware of the distribution, impact, and possible treatments of hazards, the planner will be better able to direct future growth.

BIBLIOGRAPHY

Abed, G. T., 1965, Flood plain management policy: Oregon Department of Commerce, Willamette Basin Land Use Study, Background paper no. 7, 30 p.

Allison, I. S., 1935, Glacial erratics in Willamette Valley, Oregon: Geol. Soc. America Bull., v. 46, no. 6, p. 615-632, 1 fig., 3 plates.

_____, 1953, Geology of the Albany quadrangle, Oregon: Oregon Dept. Geol. and Mineral Indus., Bull. 37, 18 p.

Allison, I. S., and Felts, W. M., 1956, Reconnaissance geologic map of the Lebanon quadrangle: Oregon Dept. Geol. and Mineral Indus. map.

Bagnold, R. A., 1960, Some aspects of the shape of river meanders: U.S. Geol. Survey P.P. 282-E, p. 135-144.

Bailey, J. F., and Ray, H. A., 1966, Definition of stage-discharge relation in natural channels by step-backwater analysis: U.S. Geol. Survey W.S.P. 1869-A, 24 p.

Baldwin, E. M., 1959, Geology of Oregon: Ann Arbor, Mich., Edwards Bros., Inc., 136 p.

_____, 1964, Geology of Oregon [2nd ed.]: Ann Arbor, Mich., Edwards Bros., Inc., 165 p.

Balster, C. A., and Parsons, R. B., 1968, Geomorphology and soils, Willamette Valley, Oregon: Corvallis, Oregon State Univ., Agri. Exp. Stn., Spec. Rpt. 265, 31 p.

_____ and _____, 1969, Late Pleistocene stratigraphy, southern Willamette Valley, Oregon: Northwest Sci., v. 43, no. 3, p. 116-129.

Barlow, J. L., 1955, The geology of the central third of the Lyons quadrangle: Univ. Oregon master's thesis, 79 p., unpub.

Battelle Pacific Northwest Laboratories, 1973, Oregon, areas of environmental concern: Richland, Wash. 104 p.

Beattie, J. A., 1962, Ground surfaces and soils in the Willamette Valley, Oregon: Oregon State Univ., doctoral dissert., 100 p., unpub.

Beaulieu, J. D., 1971, Structure of the Oregon Cascades: Ore Bin, v. 33, no. 8, p. 160-163.

_____, 1971b, Geologic formations of western Oregon: Oregon Dept. Geol. and Mineral Indus., Bull. 70, 72 p.

Berg, J. W., and Baker, C. D., 1963, Oregon earthquakes 1841-1958: Bull. Seismol. Soc. America, v. 53, no. 1, p. 95-108.

Berg, J. W., Thiruvathukal, J. V., 1967, Regional gravity of Oregon: Ore Bin, v. 29, no. 6, p. 120-126.

Berggren, W. A., 1973, The Pliocene time scale: calibration of planktonic foraminiferal and calcareous nannoplankton zones: Nature, v. 243, June 15, p. 391-396.

Bloom, A. L., 1969, The surface of the earth: Englewood Cliffs, N.J., Prentice-Hall, Inc., 152 p.

Bouma, J., Ziebell, W. A., Walker, W. G., Olcott, P. G., McCoy, E., and Hole, F. D., 1972, Soil absorption of septic tank effluent: Wisconsin Geol. and Nat. Hist. Survey IC 20, 235 p.

Bretz, J. H., 1923, Glacial drainage of the Columbia Plateau: Geol. Soc. America Bull. v. 34, p. 573-608.

_____, 1969, The Lake Missoula floods and the channelled scablands: Jour. Geol. v. 77, no. 5, p. 505-543, 2 plates, 10 figs., 2 tables.

Bretz, J. H., Smith, H. T. V., and Neff, G. E., 1956, Channelled scabland of Washington, new data and interpretations: Geol. Soc. America Bull. v. 67, no. 8, p. 957-1049.

Bristow, M. M., 1959, The geology of the northwestern third of the Marcola quadrangle, Oregon: Univ. Oregon master's thesis, 70 p., unpub.

Bromery, R. W., 1962, Geologic interpretations of the aeromagnetic map of the Lebanon quadrangle, Linn and Marion Counties, Oregon: U.S. Geol. Survey, Geophys. Inv. Map GP-212.

Bromery, R. W., and Snavely, P. D., Jr., 1964, Geologic interpretation of reconnaissance gravity and aeromagnetic surveys in northwestern Oregon: U.S. Geol. Survey Bull. 1181, p. N1-N13.

Chinnery, M. A., 1969, Earthquake magnitude and source parameters: Bull. Seismol. Soc. America, v. 59, no. 5, p. 1969-1982.

Coates, D. R. (ed.), 1971, Environmental geomorphology; Geomorphology Symposia Series, First, Proc.: Binghamton, N. Y., State University of New York, 262 p.

Compton, R. R., 1967, Manual of field geology: New York, John Wiley and Sons, Inc., 378 p.

Corcoran, R. E., and Libbey, F. W., 1956, Ferruginous bauxite deposits in the Salem Hills, Marion County, Oregon: Oregon Dept. Geol. and Mineral Indus. Bull. 46, 53 p.

Couch, R. W., and Lowell, R. P., 1971, Earthquakes and seismic energy release in Oregon: Ore Bin, v. 33, no. 4, p. 61-84.

Crandell, D. R., 1967, The glacial history of western Washington and Oregon, in Quaternary of the United States, Wright, H. E., Jr., and Frey, D. G. (eds.): Princeton, N. J., Princeton University Press, p. 341-354.

Croft, A. R., and Adams, J. A., 1950, Landslides and sedimentation in the North Fork of the Ogden River, May 1949: Ogden, Utah, Intermountain Forest and Range Exp. Stn., U.S. Forest Service Res. Paper INT-21.

District 4 Council of Governments, 1973, Statistical data base, a report by Oregon District 4 Council of Governments covering Linn, Benton, and Lincoln Counties: Corvallis, Oregon.

Dyrness, C. T., 1967, Mass soil movements in the H. J. Andrews Experimental Forest: Pacific Northwest Forest and Range Exp. Stn., U.S. Forest Service Res. Paper PNW-42, 12 p.

_____, 1969, Hydrologic properties of soils on three small watersheds in the Western Cascades of Oregon: Pacific Northwest Range Exp. Stn., U.S. Forest Service Res. Note PNW-111, 17 p.

Eckel, E. B., 1958, Landslides and engineering practice: Washington, D. C., Highway Research Board, Spec. Rpt. no. 29, 232 p.

Emerson, J. W., 1972, Channelization, a case study in man and his environment, in McKenzie, G. D., and Utgard, R. O. (eds.), Man and his physical environment: Minneapolis, Minn., Burgess Publishing Co., p. 61-63.

Environmental Quality Commission, 1973, Proposed rules pertaining to standards for subsurface sewage disposal: Portland, Oregon, November, 95 p.

Eppley, R. A., 1965, Earthquake history of the United States, Part I, Stronger earthquakes of the United States: U.S. Coast and Geod. Survey, Publ. 41-1, (revised edition through 1963), 120 p; originally published 1938.

Evernden, J. R., and Evernden, R. K. S., 1970, The Cenozoic time scale: Geol. Soc. America Spec. Paper 124, p. 71-90.

Evernden, J. R., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Am. Jour. Sci., v. 262, p. 145-198.

Felts, W. M., 1936, The geology of the Lebanon quadrangle, Oregon: Oregon State College master's thesis, 83 p., unpub.

Flawn, P. T., 1970, Environmental geology, conservation, land use planning, and resource management: New York, Harper and Row, 313 p.

Folsom, M. M., 1970, Volcanic eruptions - the pioneers attitude on the Pacific Coast from 1800 to 1875: Ore Bin, v. 32, no. 4, p. 61-71.

Frank, F. J., 1973, Ground water in the Eugene-Springfield area, southern Willamette Valley, Oregon: U.S. Geol. Survey W.S.P. 2018, 65 p., 3 plates, 12 figs.

Frank, F. J., and Johnson, N. A., 1972, Ground-water data in the Corvallis-Albany area, central Willamette Valley, Oregon: Oregon State Engineer, Ground-water Rpt. no. 17, 46 p.

Fredriksen, R. L., 1970, Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds: Portland, Ore., Pacific Northwest Forest and Range Exp. Stn., U.S. Forest Service Res. Paper PNW-104, 15 p.

_____, 1971, Comparative water quality - natural and disturbed streams, in Proceedings of a Symposium, Forest Land Uses and Stream Environment: Oregon State Univ., p. 125-136.

Glenn, J. L., 1965, Late Quaternary sedimentation and geologic history of the north Willamette Valley, Oregon: Oregon State Univ. doctoral dissert. 231 p., unpub.

Goldblatt, E. L., Van Denburgh, A. S., and Marsland, R. A., 1963, The unusual and widespread occurrence of arsenic in well waters of Lane County, Oregon: Eugene, Ore., Lane County Public Health and Sanitation Dept., 24 p.

Gorycki, M. A., 1973, Hydraulic drag: a meander generating mechanism: Geol. Soc. America Bull., v. 84, no. 2, p. 175-186, 16 figs.

Gottfried, David, Jaffe, H. W., and Senftle, F. E., 1959, Evaluation of the lead-alpha (Larsen) method for determining ages of igneous rocks: U.S. Geol. Survey Bull. 1097-A, 63 p., 6 figs., 22 tables.

Gray, D. H., 1969, Effects of clear cutting on the stability of natural slopes: Univ. of Mich. Dept. of Civil Engineering, Progress Rpt., 67 p.

Gregory, Irene, 1968, The fossil woods near Holley in the Sweet Home Petrified Forest, Linn County, Oregon: Ore Bin, v. 30, no. 4, p. 57-76, 9 figs.

Grim, R. E., 1950, Application of mineralogy to soil mechanics: Urbana, Ill., State Geological Survey, 21 p.

Gutenberg, B., and Richter, C. F., 1965, Seismicity of the earth and associated phenomena: New York, Hafner Publishing Co., 310 p.

Hackett, J. E., 1968, Geologic factors in community development at Naperville, Illinois: Illinois State Geological Survey Environ. Geol. Notes no. 22.

Halstead, P. N., 1955, The geology of the northern third of the Lyons quadrangle, Oregon: Univ. Oregon master's thesis, 87 p., unpub.

Harper, H. E., 1946, Geology of the Molalla quadrangle: Oregon State Univ. master's thesis, 26 p., unpub.

Harris, D. D., 1973, Hydrologic changes after clearcut logging in a small Oregon coastal watershed: U.S. Geol. Survey Jour. Research vol. 1, no. 4, p. 487-491.

Hauck, S. M., 1962, Geology of the southwest quarter of the Brownsville quadrangle, Oregon: Univ. Oregon master's thesis, 82 p., unpub.

Helm, D. C., 1968, Records of wells, water levels, and chemical quality of water in the Lower Santiam River Basin, middle Willamette Valley, Oregon: Oregon State Engineer, Ground-water Rpt. 13,186 p.

Hickman, C. J. S., 1969, The Oligocene marine molluscan fauna of the Eugene Formation in Oregon: Univ. Oregon master's thesis, 1968. [Also: Eugene, Oregon, Mus. Nat. Hist. Bull. 16, 112 p., 14 plates, 4 tables, 4 figs., 1969.]

Highway Research Board, Committee on Landslide Investigations (Eckel, E. B., ed.), 1958, Landslides and engineering practice: Highway Research Board Spec. Rpt. 29, NAS-NRC Publ. 544, 232 p.

Holmes, Arthur, 1965, Principles of physical geology: New York, Ronald Press Co., 1288 p.

Hughes, G. M., Landon, R. A., and Farvolden, R. N., 1971, Hydrogeology of solid waste disposal sites in northeastern Illinois: Washington, D. C., Supt. of Documents, U.S. Govt. Printing Off., Solid Waste Mgmt. Ser. SW-12d, 154 p.

Jaffe, H. W., Gottfried, David, Waring, C. L., and Worthing, H. W., 1959, Lead-alpha age determination of accessory minerals of igneous rocks (1953-1957): U.S. Geol. Survey Bull. 1097-B, 148 p.

Johnsgard, G. A., 1963, Temperature and water balance for Oregon weather stations: Oregon State Univ. Agr. Exp. Stn. Spec. Rpt. 150.

Kocher, A. E., Carpenter, E. J., Harper, W. G., Torgerson, E. F., and Stephenson, R. E., 1924, Soil survey of Linn County, Oregon: U. S. Dept. Agriculture no. 25, 72 p.

Krynine, D. P., and Judd, W. R., 1957, Principles of engineering geology and geotechnics: New York, McGraw-Hill Co., 730 p.

Laursen, J. M., and Hammond, P. E., 1973, Radiometric ages of Oregon and Washington through June, 1972: Portland State Univ., 57 p., open-file rpt.

Lawrence Halprin and Associates, 1972, The Willamette Valley choices for the future: Willamette Valley Environmental Protection and Development Planning Council, 118 p.

Leopold, L. B., and Langbein, W. B., 1966, River meanders: Sci. American, v. 214, no. 6, p. 60-70.

Leopold, L. B., and Wolman, M. G., 1957, River channel patterns, braided, meandering and straight: U.S. Geol. Survey P. P. 282-B, p. 39-85, 42 figs., 6 tables.

_____ and _____, 1960, River meanders: Geol. Soc. America Bull., v. 71, no. 6, p. 769-797, 7 figs.

Lewis, R. Q., 1950, The geology of the southern Coburg Hills including the Springfield-Goshen area: Univ. Oregon master's thesis, 56 p., unpub.

Libbey, F. W., Lowry, W. D., and Mason, R. S., 1945, Ferruginous bauxite deposits in northwestern Oregon: Oregon Dept. Geol. and Mineral Indus. Bull. 29, 97 p.

Lowry, W. D., and Baldwin, E. M., 1952, Late Cenozoic geology of the lower Columbia River Valley, Oregon and Washington: Geol. Soc. America Bull., v. 63, no. 1, p. 1-24, 3 figs., 2 plates.

Mackin, J. H., 1948, Concept of the graded stream: Geol. Soc. America Bull., v. 59, no. 5, p. 463-512.
Mader, G. G., and Crowder, D. F., 1970, An experiment in using geology for city planning - the experience of the small community of Portola Valley, California, in Environmental Planning and Geology: U.S. Dept. of Housing and Urban Dev., p. 176-189.
McBirney, A. R., 1968, Petrochemistry of the Cascade andesite volcanoes, in Andesite Conference Guidebook: Oregon Dept. Geol. and Mineral Indus. Bull. 62, p. 101-107.
McBirney, A. R., and Sutter, John, 1974, New radiometric age determinations in the Western Cascades: talk presented at Oregon Acad. Sci., Feb. 23, Lane Community College, Eugene, Oregon.
McComas, M. R., Hinkley, K. C., and Kempton, J. P., 1969, Coordinated mapping of geology and soils for land-use planning: Illinois State Geol. Survey, Environ. Geol. Notes no. 29, 11 p.
McGauhey, P. H., and Krone, R. B., 1967, Soil mantle as a wastewater treatment system: Berkeley, Univ. of Calif., SERL Rpt. no. 67-11, 201 p.
Merriam, J. C., 1901, A contribution to the geology of the John Day Basin, Oregon: Univ. Calif., Dept. Geol. Sci. Bull., v. 2, p. 269-314.
Nathan, Simon, and Fruchter, J. S., 1974, Geochemical and paleomagnetic stratigraphy of the Picture Gorge and Yakima Basalts (Columbia River Group) in central Oregon: Geol. Soc. America Bull., v. 85, no. 1, p. 63-76, 9 figs.
Newton, V. C., Jr., 1969, Subsurface geology of the lower Columbia and Willamette Basins, Oregon: Oregon Dept. Geol. and Mineral Indus. Oil and Gas Inv. 2, 12 figs.,7 plates, 121 p.
O'Neill, T. F., 1939, The geology of the Stayton quadrangle, Oregon: Oregon State College master's thesis, 83 p., unpub.
Oregon Department of Geology and Mineral Industries, 1951, Oregon metal mines handbook, northwestern Oregon: Oregon Dept. Geol. and Mineral Indus. Bull. 14-D, p. 95-111.
Oregon State University Extension Service, 1967, Planning for tomorrow in Linn County, Oregon: Albany, Oregon, Albany Printing Co., 48 p.
Oregon State Water Resources Board, 1963, Middle Willamette River Basin: Salem, Ore., 138 p.
_____, 1969, Oregon's long-range requirements for water: Salem, Ore., 397 p., appendices I through VII.
_____, 1971, Flood plain management for Oregon cities and counties: Salem, Ore. 24 p.
_____, 1972, Oregon's flood plains: Salem, Ore., 39 p.
Parizek, R. R., Kardos, L. T., Sopper, W. E., Myers, E. A., Davis, D. E., Farrell, M. A., and Nesbitt, J. B., 1967, Waste water renovation and conservation: University Park, Penn., Pennsylvania State Univ., study no. 23, 71 p.
Peck, D. L., 1960, Geologic reconnaissance of the Western Cascades in Oregon north of latitude 43°: Harvard Univ. doctoral dissert., 232 p., unpub.
Peck, D. L., Griggs, A. B., Schlicker, H. G., Wells, F. G., and Dole, H. M., 1964, Geology of the central and northern parts of the Western Cascades: U.S. Geol. Survey P.P. 449, 56 p.
Peck, D. L., Wolfe, J. A., and Griggs, A. B., 1970, "Remarks on the paper 'Oregon Cascades in relation to Cenozoic stratigraphy' by Wheeler, H. B., and Mallory, V. S.," in Columbia River Basalt Symposium, 2nd, Eastern Washington State College, Cheney, Proc.: Cheney, Eastern Washington State College Press, p. 125-130.
Peck, R. B., Hanson, W. E., and Thornburn, T. H., 1954, Foundation engineering: New York, John Wiley and Sons, 410 p.
Piper, A. M., 1942, Groundwater resources of the Willamette Valley, Oregon: U.S. Geol. Survey W.S.P. 890, 194 p.
Portland Cement Association, 1950, PCA soil primer: 33 West Grand Ave., Chicago, Ill., 76 p.
Pungrassami, T., 1969, Geology of the western Detroit Reservoir area, Quartzville, and Detroit quadrangles, Linn and Marion Counties, Oregon: Oregon State Univ. master's thesis, 76 p., unpub.
Richmond, G. M., Fryxell, Roald, Neff, G. F., Weis, P. L., 1965, The Cordilleran ice sheet of the northern Rocky Mountains, and related Quaternary history of the Columbia Plateau, in Quaternary of the United States: Princeton, N.J., Princeton University Press, p. 231-242.
Richter, C. F., 1958, Elementary seismology: San Francisco, W. H. Freeman and Co., 768 p.
Robinson, G. W., 1935, Soils, their origin, constitution, and classification: London, Thomas Murby & Co., 442 p.

Rothacher, J. S., Dyrness, C. T., and Fredriksen, R. L., 1967, Hydrologic and related characteristics of three small watersheds in the Oregon Cascades: Pacific Northwest Forest and Range Exp. Stn., U.S. Forest Service, Misc. Stn. Rpt., 54 p.

Ruhe, R. V., 1971, Stream regimen and man's manipulations, in Coates, D. R. (ed.), Environmental geomorphology; Geomorphology Symposia Series, First, Proc.: Binghamton, N.Y., State University of New York, 262 p.

Russell, I. C., 1893, A geological reconnaissance in central Washington: U.S. Geol. Survey Bull. 108, 108 p.

_____, 1901, Geology and water resources of Nez Perce County, Idaho: U.S. Geol. Survey W.S.P. 53 and 54, 141 p.

Sanborn, Ethel, 1947, The Scio Flora of western Oregon: Oregon State College Mono., Stud. in Geol., no. 4, 47 p., 9 plates.

Schlicker, H. G., 1969, Sand and gravel, in Mineral and water resources of Oregon: Oregon Dept. Geol. and Mineral Indus. Bull. 64, in coop. with U.S. Geol. Survey, p. 233-237.

Schlicker, H. G., and Deacon, R. J., 1967, Engineering geology of the Tualatin Valley region, Oregon: Oregon Dept. Geol. and Mineral Indus. Bull. 60, 103 p., 45 figs., 5 tables, 4 plates.

Schlicker, H. G., and Dole, H. M., 1957, Reconnaissance geology of the Marcola, Leaburg, and Lowell quadrangles, Oregon: Ore Bin, v. 19, no. 7, p. 57-62.

Schumm, S. A., 1967, Meander wavelength of alluvial rivers: Science, v. 157, no. 3796, p. 1549-1550.

Sheaffer, J. R., Von Boehm, Berndt, and Hackett, J. E., 1963, Refuse disposal needs and practices in northeastern Illinois: Chicago, Northeastern Illinois Planning Commission, 71 p.

Short, N. M., and Lowman, P. D., Jr., 1973, Earth observations from space; outlook for geological sciences: Greenbelt, Md., Goddard Space Flight Center, Rpt. no. X-650-73-316, 115 p.

Smith, W. D., 1924, Petroleum possibilities of western Oregon: Economic Geol., v. 19, p. 455-465.

Snavely, P. D., Jr., MacLeod, N. S., and Wagner, H. C., 1973, Miocene tholeiitic basalts of coastal Oregon and Washington and their relations to coeval basalts of the Columbia Plateau: Geol. Soc. America Bull., v. 84, no. 2, p. 387-424, 16 figs.

Staples, L. W., 1965, Engineering geology of the Carmen Smith diversion tunnel, Linn Co., Oregon [abs.]: Geol. Soc. America Spec. Paper 82, p. 280.

Stevens, C. G., 1953, Soil surveys for land development: Rome, Italy, Food and Agriculture Organization of the United Nations, study no. 20, 110 p.

Swanston, D. N., 1970, Principle soil movement processes influenced by roadbuilding, logging, and fire, in Proceedings of a Symposium, Forest land uses and stream environment: Oregon State Univ.

_____, 1971, Judging impact and damage of timber harvesting to forest soils in mountainous regions of western North America: Corvallis, Oregon, Western Reforestation Coordinating Committee, Western Forestry and Conservation Assoc., 7 p.

Taylor, E. M., 1965, Recent volcanism between Three Fingered Jack and North Sister, Oregon Cascade Range: Ore Bin, v. 27, no. 7, p. 121-147.

_____, 1968, Roadside geology, Santiam and McKenzie Pass Highway, Oregon, in Andesite Conference Guidebook: Oregon Dept. Geol. and Mineral Indus. Bull. 62, p. 3-33.

Terzaghi, Karl and Peck, R. B., 1948, Soil mechanics in engineering practice: New York, John Wiley and Sons, 566 p.

Thayer, T. P., 1936, Structure of the North Santiam River section of the Cascade Mountains in Oregon: Jour. Geol. v. 44, no. 6, p. 701-716.

_____, 1937, Petrology of the Later Tertiary and Quaternary rocks of the north central Cascade Mountains in Oregon, with notes on similar rocks in western Nevada: Geol. Soc. America Bull., v. 48, no. 11, p. 1611-1651.

_____, 1939, Geology of the Salem Hills and North Santiam River Basin, Oregon: Oregon Dept. Geol. and Minerals Indus. Bull. 15, 40 p.

Thiruvathukal, J. V., Berg, J. W., Jr., 1966, Gravity measurement program in Oregon: Ore Bin, v. 28, no. 4, p. 69-75.

Thiruvathukal, J. V., Berg, J. W., Jr., and Heinrichs, D. F., 1970, Regional gravity of Oregon: Geol. Soc. America Bull., v. 81, no. 3, p. 725-738.

Todd, D. K. (ed.), 1970, The water encyclopedia: Port Washington, N.Y., Water Information Ctr., 559 p.

Turner, D. L., 1970, Potassium-argon dating of Pacific Coast Miocene foraminiferal stages: Geol. Soc. America Spec. Paper 124, p. 91-129.

U.S. Army Corps of Engineers, 1967, Guidelines for reducing flood damages: Vicksburg, Miss., Mississipi River Commission, 9 p.

_____, 1971, Floodplain information, Willamette River, Calapooia River, Oak Creek, Albany, Oregon: Portland District, 54 p., June.

_____, 1972, Floodplain information, Willamette River, Harrisburg, Oregon: Portland District, 33 p., Dec.

_____, 1973, Floodplain information, South Santiam River, Lebanon, Oregon: Portland District, 30 p., June.

U.S. Department of Agriculture, 1961, Handbook on soils: Washington, D. C., U.S. Dept. Agr. Forest Service Handbook, 372 p.

U.S. Department of Housing and Urban Development, 1970, Environmental planning and geology; Symposium on engineering geology in the urban environment, Proc.: Washington, D. C., Supt. of Documents, U.S. Govt. Printing Off., 204 p.

U.S. Geological Survey, 1949, Interpreting ground conditions from geologic maps: U.S. Geol. Survey Circ. 46, 10 p.

_____, 1958, Compilation of records of surface waters of the United States through September 1950; Part 14. Pacific Slope Basins in Oregon and lower Columbia River Basin: U.S. Geol. Survey W.S.P. 1318, 550 p.

_____, 1971, Surface water supply of the United States, 1961-65; Part 14. Pacific Slope Basins in Oregon and lower Columbia River Basin: U.S. Geol. Survey W.S.P. 1935, 957 p.

_____, 1972, Surface water supply of the United States 1966-1970; Part 14. Pacific Slope Basins in Oregon and lower Columbia River Basin: U.S. Geol. Survey W.S.P. 2135, p. 280-309.

U.S. Public Health Service, 1963, Manual of septic tank practice: Washington, D.C., U.S. Dept. of Health, Educ., and Welfare, 93 p.

Waanenen, A. O., Harris, D. D., and Williams, R. C., 1970, Floods of December 1964 and January 1965 in the western states; Part 2. Streamflow and sediment data: U.S. Geol. Survey W.S.P. 1866-B.

_____, 1971, Floods of December 1964 and January 1965 in the far western states: U.S. Geol. Survey W.S.P. 1866-A, 265 p.

Wagner, N. S., 1959, Natural sources of carbon dioxide in Oregon: Ore Bin, v. 21, no. 11, p. 103-113.

Waters, A. C., 1961, Stratigraphic and lithologic variations in the Columbia River Basalt: Am. Jour. Sci., v. 259, no. 8, p. 583-611.

Wells, F. G., 1956, Geology of the Medford quadrangle, Oregon-California: U.S. Geol. Survey Map GQ-89.

Wells, F. G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geol. Survey Map I-325.

Wheeler, H. E., and Mallory, V. S., 1970, Oregon Cascades in relation to Cenozoic stratigraphy, in Columbia River Basalt Symposium, 2nd, Eastern Washington State College, Cheney, Proc.: Cheney, Eastern Wash. State College Press, p. 97-124.

White, G. F., 1964, Floodplain adjustments and regulations, in Handbook of applied hydrology: New York, McGraw-Hill, Chapter 25, p. 112-124.

White, W. A., and Kyriazis, M. K., 1968, Effects of waste effluents on the plasticity of earth materials: Ill. State Geol. Survey Environ. Geol. Notes, no. 23.

Williams, I. A., 1916, Columbia River Gorge; its geologic history as interpreted from the Columbia River Highway, in Mineral Resources of Oregon: Oregon Bur. Mines Geol., v. 2, no. 3, p. 66-77.

Williams, R. E., and Wallace, A. T., 1970, Hydrogeological aspects of the selection of refuse disposal sites in Idaho: Idaho Bur. Mines and Geol., Pamph. 145, 31 p.

Wise, W. S., 1969, Geology and petrology of the Mount Hood area - a study of High Cascade volcanism: Geol. Soc. America Bull., v. 80, no. 6, p. 969-1006.

Wood, H. O., Heck, N. H., and Eppley, R. A., 1966, Earthquake history of the United States; Part II. Stronger earthquakes of California and western Nevada: U.S. Coast and Geod. Survey, Pub. 41-1, (revised through 1963), 48 p., illus., tables.

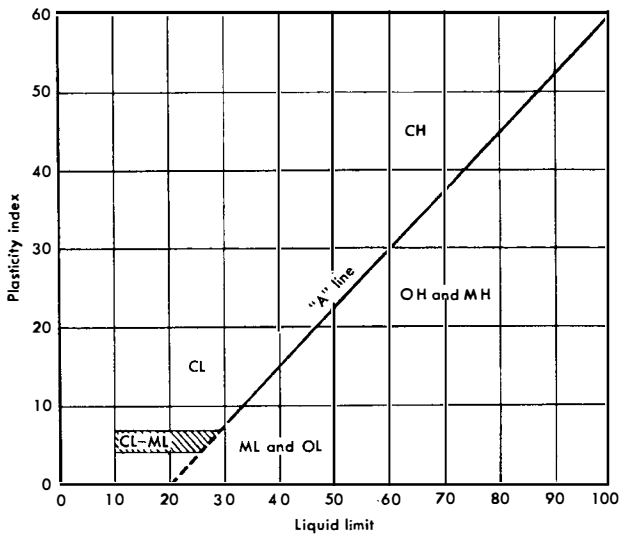
APPENDIX

APPENDIX A

Unified Soil Classification System

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

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:
Less than 5 per cent ..... GW, GP, SW, SP
More than 12 per cent ..... GM, GC, SM, SC
5 to 12 per cent ..... *Borderline* cases requiring dual symbols**



Plasticity Chart

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

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

Reprinted from PCA Soil Primer

APPENDIX B

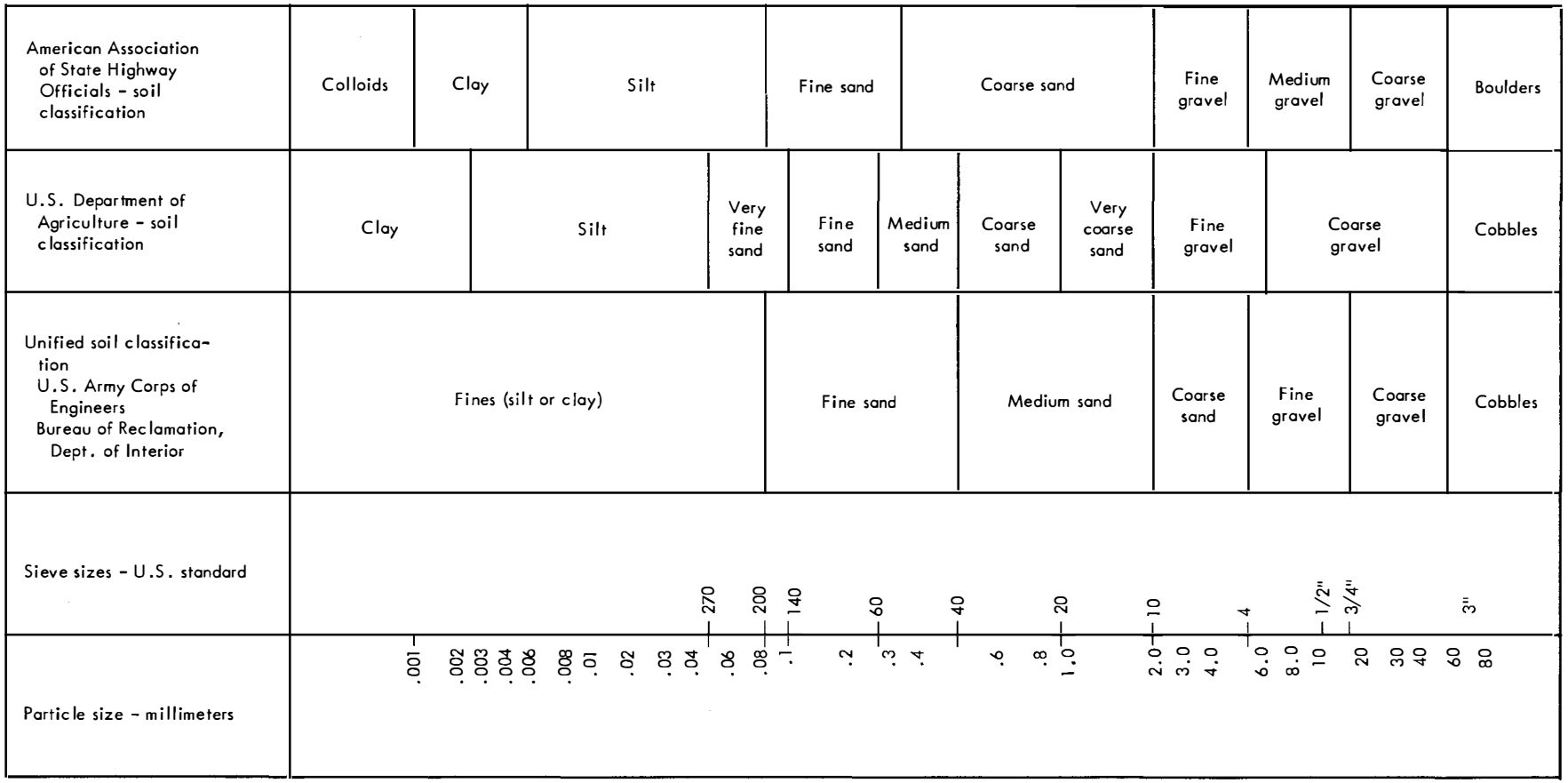
AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS
SOILS CLASSIFICATION (AASHO)

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

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

APPENDIX C

COMPARISON OF THREE SYSTEMS OF PARTICLE-SIZE CLASSIFICATION



APPENDIX D

CONSTRUCTION MATERIALS OPERATIONS IN WESTERN LINN COUNTY

Albany Rock Products M.O. Salmon, Sr., President	gravel	Sec. 10, T. 11 S., R. 3 W. 2 miles east of Albany
Howard Atkeson	gravel	Sec. 21, T. 11 S., R. 4 W. 5½ miles southwest of Albany
Builders Supply Co. Office Manager	gravel	Sec. 2, T. 12 S., R. 5 W. 1 mile east of Corvallis
Orris Carnegie	gravel	Sec. 20, T. 11 S., R. 4 W. 4 miles southwest of Albany
Geraldine F. or Richard D. Downer Richard Downer	gravel, sand, rock	Secs. 25 & 30, T. 10 S., Rs. 1 & 2 W.
Govro Rock Quarry and Plant L.W. Govro, operator	rock	Secs. 9,10,15,16, T. 10 S., R. 3 W. 2 miles west of Jefferson, Oregon
Floyd Grahm Construction Co. Margaret Grahm, Sec.-treas.	riprap rock	Sec. 16, T. 12 S., R. 1 W. 6 miles southeast of Lebanon, Oregon
Lauren Karstens	dirt, sand, gravel	Sec. 16, T. 11 S., R. 4 W.
Harvey A. Larsen Harvey A. Larsen, Owner		Sec. 7, T. 11 S., R. 1 W. 2 miles north of Lacomb, Oregon
Brock Pit Gordon B. Wallace, Asst. Engr.	quarry rock	Secs. 5 & 3, T. 10 S., R. 1 E. 1½ miles northeast of Scio
Cook Pit Gordon B. Wallace, Asst. Engr.	gravel	Sec. 6, T. 10 S., R. 3 W. 8 miles north of Albany, Oregon
Lebanon Dump Gordon B. Wallace, Asst. Engr.	gravel	Sec. 1, T. 12 S., R. 2 W. 2 miles northeast of Lebanon
Cormier Pit Gordon B. Wallace, Asst. Engr.	quarry rock	Sec. 13, T. 13 S., R. 1 W. 3½ miles northwest of Sweet Home
Sanderson Br. Gordon B. Wallace, Asst. Engr.	gravel	Sec. 10, T. 11 S., R. 2 W. 1½ miles west of Crabtree
Linn County, Oregon Gordon B. Wallace, Asst. Engr.	quarry rock	Sec. 7, T. 10 S., R. 1 W. 1½ miles northwest of Scio
Linn County, Oregon Gordon B. Wallace, Asst. Engr.	quarry rock	Sec. 26, T. 13 S., R. 1 W. 2½ miles northwest of Sweet Home

CONSTRUCTION MATERIALS OPERATIONS IN WESTERN LINN COUNTY, continued

Linn County, Oregon Gordon B. Wallace, Asst. Engr.	quarry rock	Sec. 9, T. 13 S., R. 3 W. 5 miles northwest of Brownsville
Linn County, Oregon Gordon B. Wallace, Asst. Engr.	quarry rock	Sec. 24, T. 14 S., R. 2 W. 2½ miles southwest of Crawfordsville
Linn County, Oregon Gordon B. Wallace, Asst. Engr.	gravel	Sec. 31, T. 10 S., R. 1 W. 4 miles south of Scio
Linn County, Oregon Gordon B. Wallace, Asst. Engr.	river gravel	Secs. 7 & 18, T. 10 S., R. 2 W.
Morse Brothers, Inc. R. H.Bellinger , Office Mgr.	sand & gravel	Sec. 10, T. 11 S., R. 2 W.
Morse Brothers, Inc. R. H. Bellinger, Office Mgr.	sand & gravel	Sec. 10, T. 11 S., R. 2 W.
Morse Brothers, Inc. R. H. Bellinger, Office Mgr.	sand & gravel	Sec. 10, T. 11 S., R. 2 W.
Morse Brothers, Inc. #3 W. Moore, V. President	gravel	Sec. 31, T. 13 S., R. 4 W.
Morse Brothers, Inc. R. H. Bellinger, Office Mgr.	gravel	Secs. 30 & 25, T. 13 S., R. 4 W. 10 miles north of Harrisburg
Morse Brothers, Inc. J. Morse, President	rock	E½ sec.11, T. 12 S., R. 2W. Lebanon, Oregon
Morse Brothers, Inc. R. H. Bellinger, Office Mgr.	sand & gravel	Sec. 28, T. 13 S., R. 1 E. Sweet Home, Oregon
Morse Brothers, Inc. R. H. Bellinger, Office Mgr.		Sec. 6, T. 14 S., R. 2 W. 1 mile east of Brownsville
Morse Brothers, Inc. Office Mgr.	gravel	Secs. 1,2,11,12, T. 12 S., R. 2 W. 1 mile northeast of Lebanon
Morse Brothers, Inc. R. H. Bellinger, Office Mgr.		Sec. 6, T. 13 S., R. 2 E. 3 miles northeast of Foster
Morse Brothers, Inc., Office Manager	gravel	Secs. 35 & 36, T. 13 S., R. 3 W. 1 mile west of Brownsville
Morse Brothers, Inc. Office Mgr.	gravel	Sec. 9, T. 15 S., R. 4 W. ¼ mile north of Harrisburg
Morse Brothers, Inc. Office Manager	gravel	Sec. 5, T. 15 S., R. 4 W. 2 miles north of Harrisburg

CONSTRUCTION MATERIALS OPERATIONS IN WESTERN LINN COUNTY, continued

Morse Brothers, Inc. W. Moore, V. President	gravel	Secs. 13 & 18, T. 14 S., Rs. 5 & 4 W.
Morse Brothers, Inc., McNutt, Office Manager	gravel	Sec 16, T. 15 S., R. 4 W. 1 mile south of Harrisburg
Morse Brothers, Inc. R. H. Bellinger, Office Mgr.	pit-run gravel	Sec. 36, T. 13 S., R. 3 W.
Morse Brothers, Inc., Office Manager	gravel	Secs. 13 & 14, T. 12 S., R. 2 W. 2 miles east of Lebanon
Morse Brothers, Inc., R. H. Bellinger, Office Mgr.	gravel	Secs. 11 & 14, T. 12 S., R. 2 W. 1 mile east of Lebanon
Morse Brothers, Inc. R. H. Bellinger, Office Mgr.	gravel	Secs. 13 & 18, T. 14 S., R. 4 W. 8 miles north of Harrisburg
Morse Brothers, Pine Grove Office Manager	gravel	Sec. 30, T. 13 S., R. 4 W. 10 miles north of Harrisburg
Morse Brothers Office Manager	quarry rock	Sec. 13, T. 12 S., R. 2 W. 2 miles east of Lebanon
Morse Brothers Office Manager	gravel	Secs. 28 & 29, T. 13 S., R. 1 E. 2 miles east of Sweet Home
Morse Brothers R. H. Bellinger, Office Mgr.	sand & gravel	Sec. 29, T. 13 S., R. 1 E.
N. Santiam Sand & Gravel, Inc. F. A. LuLay, Pres.	sand & gravel	Secs. 34 & 35, T. 9 S., R. 3 E. Gates, Oregon
North Santiam Sand & Gravel, Inc.	sand & gravel	Sec. 19, T. 9 S., R. 2 E. Lyons, Oregon
North Santiam Sand & Gravel, Inc. F. A. LuLay, Pres. & Mgr.	sand & gravel	Sec. 14, T. 9 S., R. 1 W. 1 mile southeast of Stayton
North Santiam Sand & Gravel, Inc. Ralph Morgs, Office Mgr.	sand & gravel	Sec. 15, T. 9 S., R. 1 W. $\frac{1}{2}$ mile south of Stayton
North Santiam Sand & Gravel, Inc. J. Morgan, Sec.	sand & gravel	Secs. 14, 15, & 22, T. 9 S., R. 1 W. $\frac{1}{2}$ mile south of Stayton
Oregon State Highway Division Don Trout, Design Office Mgr.	soil	Secs. 21 & 28, T. 14 S., R. 3 W. $6\frac{1}{2}$ miles southeast of Halsey
Oregon State Highway Division Donald Trout, Design Engr.		Sec. 28, T. 14 S., R. 3 W. $7\frac{1}{2}$ miles southeast of Halsey

CONSTRUCTION MATERIALS OPERATIONS IN WESTERN LINN COUNTY, continued

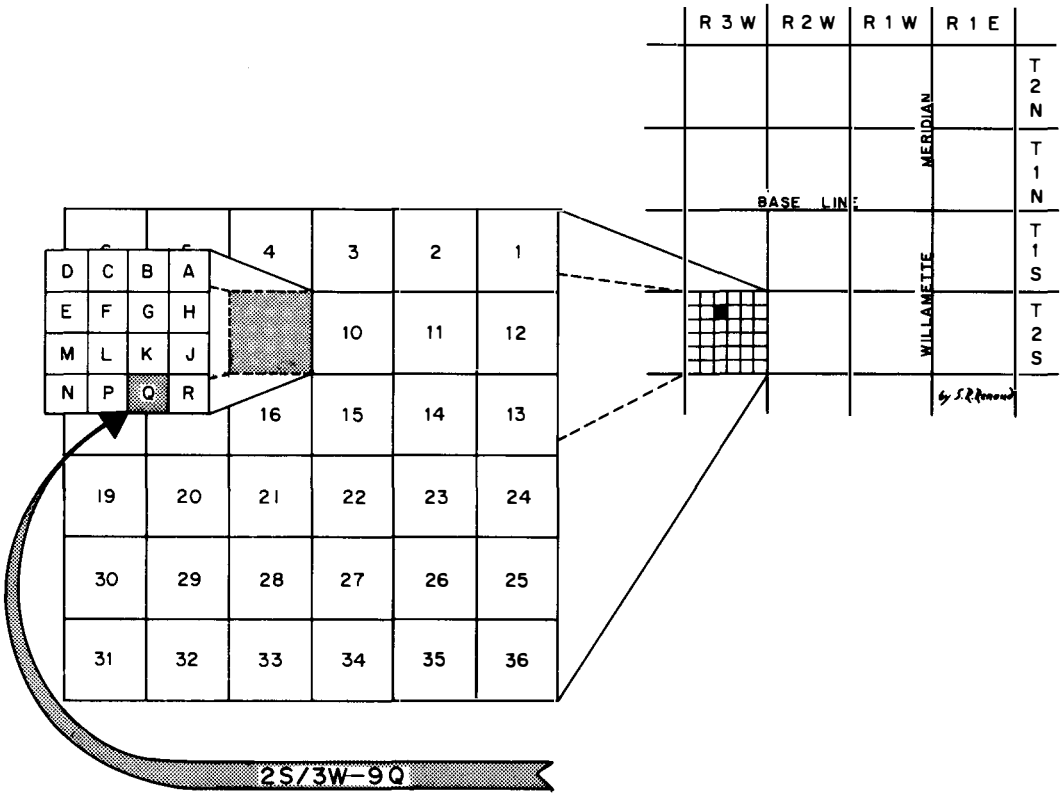
Oregon State Highway Division Donald Trout, Design Engr.	volcanic cinders	Sec. 15, T. 13 S., R. 7 E. 25 miles west of Sisters
Oregon State Highway Division Frank Hall, Design Engr.	river gravel	Sec. 10, T. 11 S., R. 2 W.
Pioneer Concrete Company Kenneth Howard		Sec. 6, T. 14 S., R. 2 W. $\frac{1}{4}$ mile east of Brownsville
Pioneer Concrete Company Kenneth Howard, Owner	river rock	Sec. 6, T. 14 S., R. 2 W.
Albany Rock Prod., Inc. M.O. Salmon & Sons, Inc. M.O. Salmon Sr., Pres.	gravel & dirt	Sec. 10, T. 11 S., R. 2 W. $1\frac{1}{2}$ miles west of Crabtree, Oregon
Cox Quarry Mack Slate, Jr., Owner	rock - "shale"	Sec. 22, T. 10 S., R. 3 W. $1\frac{1}{2}$ miles northeast of Western Kraft
Shedd Quarry Mack M. Slate, Jr.	rock - "shale"	Sec. 27, T. 13 S., R. 3 W. 6 miles southeast of Shedd, Oregon
Millard & Lavera Smith, DBA Smith Sand & Gravel Millard Smith, Owner & Mgr.	gravel	Secs. 2 & 11, T. 10 S., R. 3 E. $1\frac{1}{4}$ miles west of Jefferson
Smith Sand & Gravel Millard Smith, Owner	bar run	Sec. 11, T. 10 S., R. 3 W. $\frac{1}{2}$ mile northwest of Jefferson
Smith & Sons, Sand & Gravel Fred Smith	pit-run rock	Sec. DLC #37, T. 13 S., R. 3 W. 2 miles north of Brownsville
South Santiam Water Control Dist. (2) Francis E. Bradley	rock, sand, gravel	Secs. 25 & 30, T. 10 S., Rs. 2 W. & 3 W.
Willamette Western Corp. Frank Hall, Design Engr.	gravel	Secs. 9 & 10, T. 11 S., R. 2 W.
H. Kim Wood & Jeraldine Wood H. Kim Wood, Owner	gravel	Sec. 4, T. 11 S., R. 2 W. $2\frac{1}{2}$ miles northwest of Crabtree
Mari Linn Pit and Plant (Aero Linn Sand & Gravel) Mr. Marion Towery, Mgr.	sand & gravel	Sec. 4, T. 10 S., R. 3 W.
Albany Rock Pit & Plant Albany Rock Products Company M.O. Salmon Sr. Pres.	sand & gravel	Sec. 10, T. 11 S., R. 3 W.
Cedar Lumber, Inc. Don Walker		Sec. 27(?), T. 9 S.(?), R. 2 E.(?)

CONSTRUCTION MATERIALS OPERATIONS IN WESTERN LINN COUNTY, continued

Collins Pit Collins Sand & Gravel Elmer Collins		Sec. 32, T. 11 S., R. 2 W. 2 miles northwest of Lebanon
Gate, R. G.		Sec. 8, T. 12 S., R. 4 W.
Albert L. Gregory Mrs. A. L. Gregory	gravel	Sec. 31, T. 11 S., R. 4 W. 2 miles east of Corvallis
Hub City Concrete Co. Plant Thomas Jackson, Mgr.	sand & gravel	Sec. 5, T. 11 S., R. 3 W.
Jefferson Sand & Gravel Co. Jerry Jones, Owner & Mgr.		Sec. 11, T. 10 S., R. 3 W. $\frac{1}{2}$ mile southeast of Jefferson Located off Hard Scrabble Hill Road
Morse Brothers, Crocker Pit R. H. Bellinger, Office Mgr.	sand & gravel	Secs. 28 & 29, T. 13 S., R. 1 E. Outskirts of Sweet Home
Morse Brothers, Jensen Pit & Plant R. H. Bellinger, Office Mgr.	sand & gravel	Sec. 5, T. 15 S., R. 4 W.
Kenneth Howard DBA Pioneer Concrete Co. Ken Howard		Sec. 6, T. 14 S., R. 2 W. $\frac{1}{4}$ mile from main road east of Brownsville
Kenneth Howard DBA Pioneer Concrete Co. Ken Howard		3 miles south of Brownsville
Northern Pit, Mack M. Slate, Jr.		3 miles east of Brownsville
Mack M. Slate, Jr.		3 miles southwest of Scio
Smith Sand and Gravel Millard Smith, Owner	bar run	Sec. 11, T. 10 S., R. 3 W. $\frac{1}{2}$ mile northwest of Jefferson
Smith Sand & Gravel Co. Manning pit Millard Smith, Owner	sand & gravel	Sec. 30, T. 13 S., R. 2 W. 2 miles north of Brownsville
TOMCO, Inc. Edwin J. Malloy		Sec. 33, T. 13 S., R. 3 E.
U. S. Plywood (Forest Resource Dept) Tom Lackey		
Willamette Quarries, Inc. Bond Butte Quarry Ralph Stubblefield, Pres.	traprock	Sec. 33, T. 14 S., R. 3 W.
H. Kim Wood	river-run rock	Sec. 4, T. 11 S., R. 2 W. 2 miles west of Crabtree

APPENDIX E

WATER-WELL NUMBERING SYSTEM



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

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

APPENDIX F

DRILLERS' LOGS OF REPRESENTATIVE WELLS

QUATERNARY ALLUVIUM

Well No.	Materials	Thickness (feet)	Depth (feet)
9S 1W	Gravel and sand, loose	6	6
13 D1	Gravel, tight, cemented	10	16
	Gravel, loose, water-bearing	3	19
	Gravel, cemented	7	26
	Gravel, loose, water-bearing	2	28
	Gravel, dirty, fairly loose	7	35
	Gravel, cemented, and boulders	25	60
	Salem City Water Department. Altitude 466 ft. Drilled by R. J. Strasser Drilling Co., 1939 Casing: 16-in. to 60 ft.		
10S 2W	Soil and sand	4	4
8 N2	Gravel	5	9
	Basalt Boulders	8	17
	Gravel and sand, water-bearing	4	21
	William Uppstad. Altitude 253 ft. Drilled by Ace Drilling Co., 1957 Casing: 10-in. to 21 ft. perforated 15-20 ft.		
10S 2W	Soil, sandy	8	8
19 Q2	Gravel, cemented	5	13
	Gravel, silted "packed"	2	15
	Gravel, rounded, and sand, loose, water-bearing	1	16
	Clay and gravel	3	19
	Gravel, rounded, and sand, water-bearing	3	22
	Sand, silted, packed	-	22
	N. D. Bradley. Altitude 230 ft. Drilled by Pete Tolmasoff Well Drilling, 1966 Casing: 10-in. to 22 ft., perforated 18-22 ft.		
12S 4W	Loam, sandy	10	10
6 P1	Gravel and sand	5	15
(6 cdb)	Gravel	8	23
	Gravel, coarse	12	35
	Willard Hamlin. Altitude 220 ft. Drilled by Raymond C. Gellatly & Ronald S. Witham Well Drilling, 1961 Casing: 10-in. diam to 35 ft., perforated 25-36 ft.		

DRILLERS' LOGS OF REPRESENTATIVE WELLS, continued

LOWER TERRACE DEPOSITS (BENEATH WILLAMETTE SILTS)

Well No.	Materials	Thickness (feet)	Depth (feet)
11S 3W	Clay	29	29
17 F2	Sand and gravel	37	66
	Clay, blue	4	70
	J. T. Anderson. Altitude 226 ft. Drilled by Hamilton Drilling Co., 1960 Casing: 6-in. to 66 ft., perforated 32-38 ft., 58-64 ft.		
12S 3W	Soil	20	20
7 E1	"Hardpan"	11	31
	Gravel, with clayey gravel, water-bearing (small yield)	4	35
	"Hardpan" (cemented gravel)	7	42
	Gravel, water-bearing (larger yield)	3	45
	City of Tangent. Altitude 245 ft. Driven by W. A. Slate, prior to 1928 Casing: $1\frac{1}{4}$ in to 36 or 40 ft., screen at base		
	COLUMBIA RIVER BASALT		
9S 1W	Soil	2	2
14 Q1	Clay, orange	6	8
	Boulders	2	10
	Basalt, very hard	47	57
	"Old land surface", (red clay)	3	60
	Basalt, gray	18	78
	Volcanic ash, blue, and "old land surface"	$6\frac{1}{2}$	$84\frac{1}{2}$
	Basalt	$15\frac{1}{2}$	100
	Basalt, angled fractures	80	180
	Basalt, very hard	20	200
	"old land surface" (red clay)	5	205
	Basalt, vesicular "honeycombed"	10	215
	Basalt, hard	9	224
	Basalt, vesicular, "honeycombed"	3	227
	Basalt, hard	$5\frac{1}{2}$	$232\frac{1}{2}$
	Basalt, vesicular, "honeycombed"	$1\frac{1}{2}$	234
	Basalt, hard	2	236
	Basalt, vesicular, "honeycombed"	2	238
	Basalt, hard	47	285
	Basalt,"broken" very hard	30	315
	Basalt, very hard, crevices on angle	11	326

DRILLERS' LOGS OF REPRESENTATIVE WELLS, continued

COLUMBIA RIVER BASALT, continued

Well No.	Materials	Thickness (feet)	Depth (feet)
9S 1W 14 Q1 (continued)	John Fery. Altitude 550 ft. Drilled by Miller-Robinson Well Drilling, 1964 Casing: 10-in. to 19½ ft., unperforated		
10S 1W 4 J1	Soil	2	2
	"Bedrock" hard	22	24
	Shale, blue, soft	11	35
	Shale and black sand	15	50
	Basalt, hard	5	55
	Shale, sandy	5	60
	Basalt, dark, hard, seamy	30	90
	Basalt, hard, seamy, and boulder	12	102
	Shale, dark, soft	3	105
	Shale, blue	2	107
	Shale, dark, "broken" and wood	2	109
	"Rock", black hard	1	110
	Basalt, seamy	2	112
	Basalt	9	121
	Basalt, hard	3	124
	Basalt, hard, seamy	8	132
	Shale, dark, hard	1	133
	Sand, black	4	137
	Basalt, black, hard	2	139
	Carl Limbeck. Altitude 675 ft. Drilled by Edward Beagley, 1957 Casing: 6-in. to 4 ft., unperforated.		

LITTLE BUTTE FORMATION - SANDSTONE INTERBEDS

13S 2E 36 Q1	Loam	4½	4½
	Gravel and boulders, with yellow-brown clay pressed in, water at 11-17 ft.	14	18½
	Ash, volcanic, light brown, weathered	1½	20
	Ash, volcanic, very light-gray	5	25
	Ash, volcanic, lavender	5	30
	Ash, volcanic, light-gray	5	35
	Tuffstone, lavender, firm	8	43
	Tuffstone, lavender and green, softer	11	54
	Tuffstone, lavender, firm	5	59
	Tuffstone, beige	41	100
	U. S. Forest Service. Altitude 795 ft. Drilled by Harry A. Robinson, 1958 Casing: 8-in. to 36 ft., unperforated.		

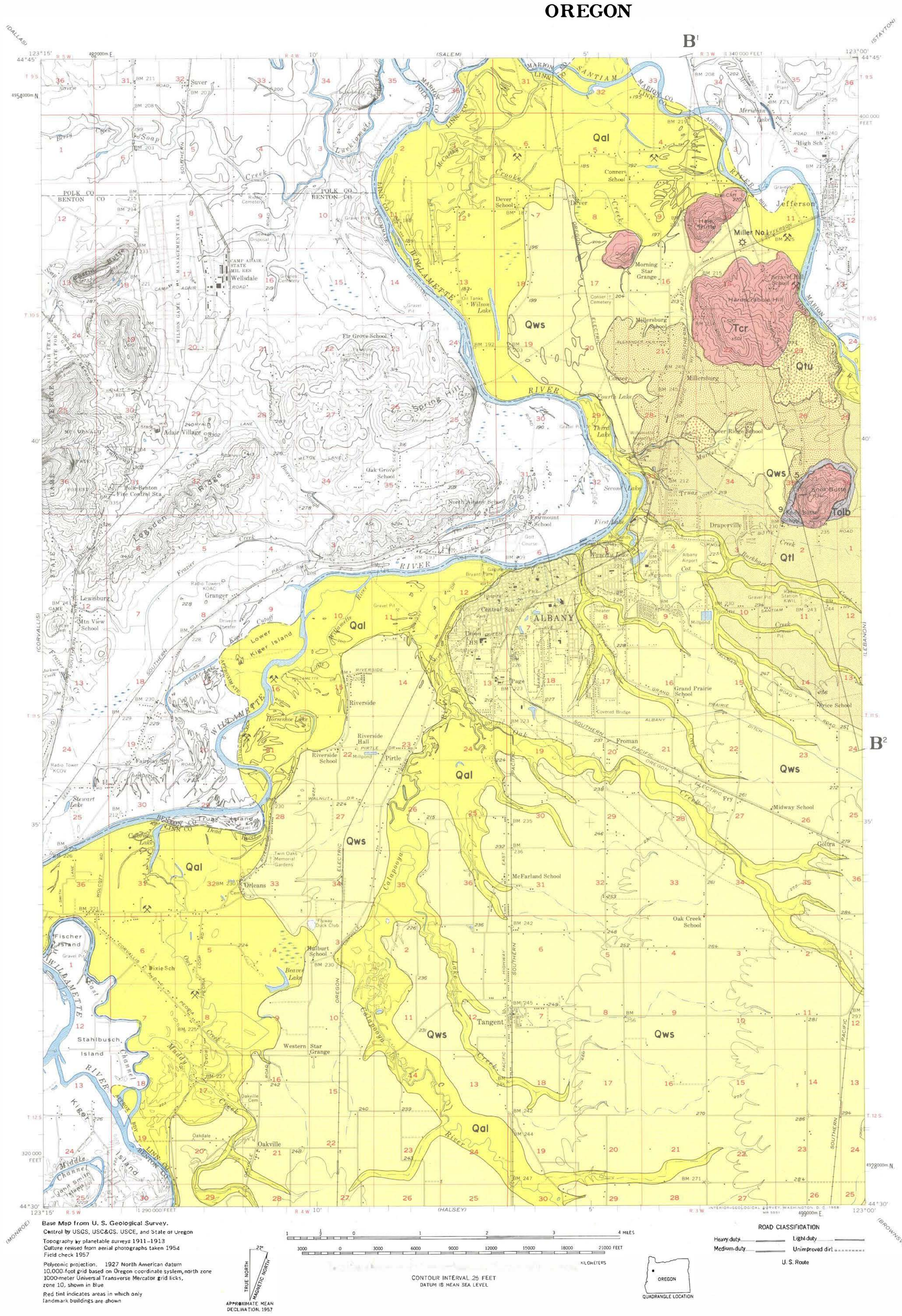
DRILLERS' LOGS OF REPRESENTATIVE WELLS, continued

LITTLE BUTTE FORMATION - SANDSTONE INTERBEDS, continued

Well No.	Materials	Thickness (feet)	Depth (feet)
10S 3W	Soil	1½	1½
15 P1	Clay, yellow, sticky	26½	28
	Clay, gray, very sticky	19	47
	Sandstone, dark-gray, very hard	4	51
	Sandstone, yellow	19	70
	G. K. Miller. Altitude 465 ft. Drilled by Willamette Irrigation & Equipment Co., 1965 Casing: 8-in. to 50 ft., unperforated.		
10S 3W	Clay	26	26
20 K1	Sand and clay	19	45
	Sand	1	46
	Clay, sandy	100	146
	Clay, blue	4	150
	Eldon Chowning. Altitude 227 ft. Drilled by Hamilton Drilling Co., 1959 Casing: 6-in. to 150 ft., perforated 105-110 ft., 120-126 ft., 142-148 ft.		

GEOLOGIC MAP
of the
ALBANY QUADRANGLE
OREGON

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



Base Map from U. S. Geological Survey.
Control by USGS, USC&GS, USCE, and State of Oregon
Topography by planetable surveys 1911–1913
Culture revised from aerial photographs taken 1954
Field check 1957
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
1000-meter Universal Transverse Mercator grid licks, zone 10, shown in blue
Red tint indicates areas in which only landmark buildings are shown

APPROXIMATE MEAN DECLINATION, 1957

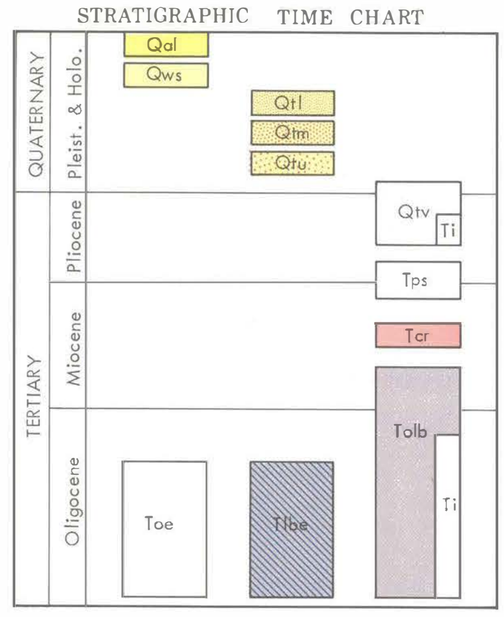
CONTOUR INTERVAL 25 FEET
DATUM IS MEAN SEA LEVEL

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U. S. Route

OREGON
QUADRANGLE LOCATION

INTERIOR-GEOLOGICAL SURVEY, WASHINGTON, D. C. 1958
MR 5551

STRATIGRAPHIC TIME CHART



Surficial Deposits

Qal — Quaternary alluvium:
A few tens of feet of gravel, sand, and silt along major streams, and thin veneers of silt and clay lining the smaller streams of the Willamette Valley. Hazards include flooding, stream meandering, and siltation.

Qws — Willamette silts:
Up to 20 to 30 feet of faintly bedded, quartzo-fetdspathic silts, silty clays, and clays of lacustrine and glacial flood-water origin. Surficial erratics and heavy minerals indicate Columbia River source. Carbon-14 dating reveals an age of 19,000 to 34,000+ years. Hazards include poor drainage, ponding, and low permeability in places.

Qtl — Quaternary lower terrace:
A maximum of 50 feet of fluvial pebble gravel, sand, and clay, along the South Santiam River, in the subsurface of the Willamette Valley and in the larger valleys of the foothills area. Also includes terrace gravels along the smaller streams. Equivalent in part to the Linn gravels of Allison (1953). Early Wisconsin or Illinoisian (late Pleistocene) in age. Poor drainage, ponding, and high water table locally.

Qtm — Quaternary middle terrace:
Moderately dissected deposits of pebble gravel, sand, silt, and clay of fluvial origin overlooking younger lower terraces (Qtl). Equivalent in part to the Leffler gravels of Allison (1953). Elevations vary from 245 feet in west to 500 feet in east. Kansan (middle Pleistocene) in age. Deep weathering produces clay-rich soils.

Qtu — Quaternary upper terrace:
Deeply dissected remnants of a high, level gravel fan equivalent to the Lacomb gravels of Allison (1953). Maximum thickness 100 to 150 feet. Maximum elevation 365 feet. Early Pleistocene in age.

Stratigraphic Units

Qtv — Cascades formation:
Light- to medium-gray porphyritic flow andesite, basalt, and breccias forming a deeply dissected cone at Snow Peak and an intracanyon flow with reversed topography in the middle Santiam drainage. Maximum thickness approximately 3,000 feet. Late Pliocene to early Pleistocene in age. Hazards include steep slopes, rockfall, and flash floods.

Tps — Sardine formation:
Up to 1,500 feet of massive to platy hypersthene andesite and basalt unconformable beneath the Cascades Formation and overlying Columbia River Basalt. Late Miocene to early Pliocene in age. Hazards include flash flooding and rockfall.

Tcr — Columbia River Basalt
Several hundred feet of dense, dark, very fine-grained flow basalt capping the ridges of northern Linn County. Also includes basalt of Marks Ridge. Columnar jointing is universal. Plagioclase phenocrysts are present locally; pyroxene phenocrysts are absent or very rare. Middle Miocene in age. Weathers to a red loamy soil. Undercut by massive slides on steep slopes.

Tolb, Tlbe — Little Butte Formation:
Approximately 10,000 feet of dacitic to andesitic pyroclastic rocks and dense, dark, basaltic flow rock. The pyroclastics are coarsest in the drainage of the middle Santiam and include breccias, tuffs, and ash. Interbeds of continental volcaniclastic sediments are common towards the west.
The basaltic flow rock was erupted from many sources. The numerous buttes of the eastern Willamette Valley represent the exhumed remnants of some of the vents. Scattered small pyroxene phenocrysts typify the basalt.
Parts of the unit (Tlbe) in the west contain interbeds of massive, marine, quartzo-fetdspathic sandstone equivalent to the Eugene Formation (Toe) reported in well logs in the Willamette Valley.
Age of the formation is early Oligocene through early Miocene as shown by stratigraphic position and leaf fossils.
Hazards include flash floods in the interior, massive landsliding, and thick clay soils.

Toe

Ti — Intrusive rock:
Mappable bodies of intrusive basaltic rock within the Little Butte Formation. No feeders for other units are recognized.

Geologic Symbols

Contacts
Rock — Surficial

Folds
Anticline — Syncline

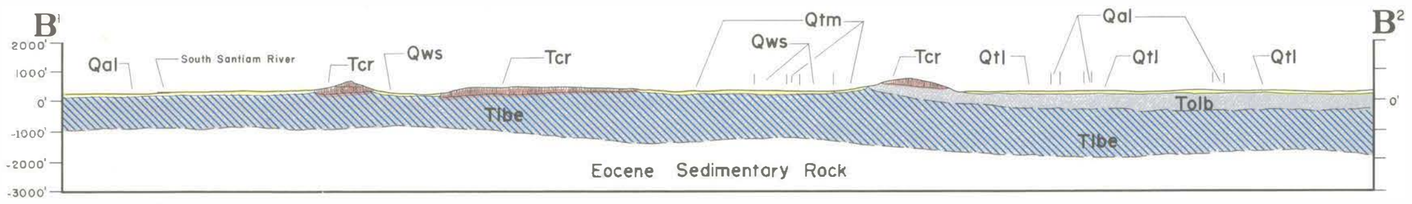
Attitudes
Strike and dip of Beds and flows — Horizontal beds and flows

Exploratory Oil Wells
Show of Oil — Dry Hole — Show of Gas

Mines and Quarries

Sand and Gravel Pits

Geologic Cross Section

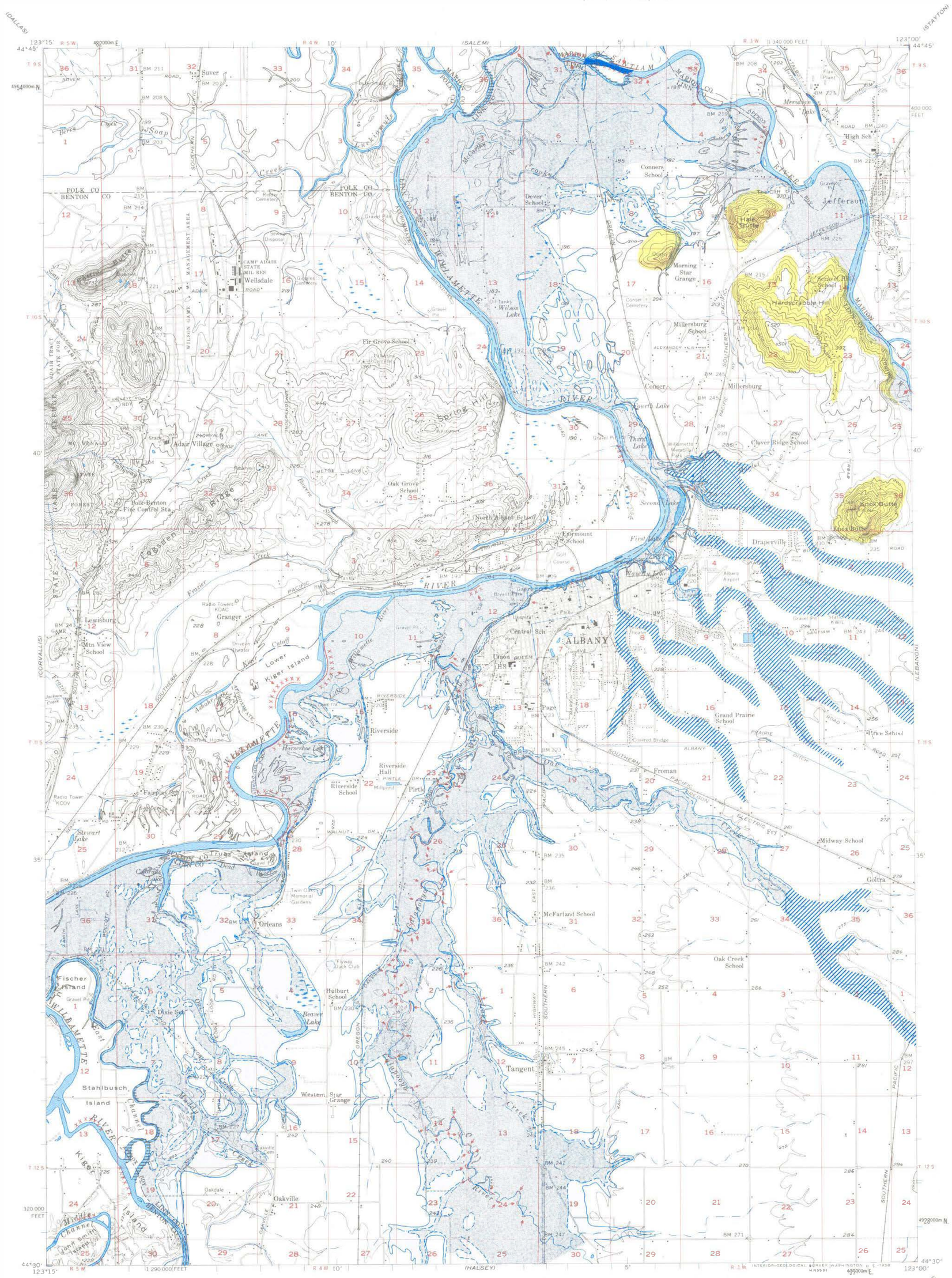


Geology by J. D. Beaulieu

Cartography by S. R. Renoud and W. H. Pokorny 1974

GEOLOGIC HAZARDS MAP
of the
ALBANY QUADRANGLE
OREGON

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



Base Map from U. S. Geological Survey.
Control by USGS, USC&GS, USCE, and State of Oregon
Topography by planetable surveys 1911-1913
Culture revised from aerial photographs taken 1954
Field check 1957
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue
Red tint indicates areas in which only landmark buildings are shown

21° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1957

1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETERS
CONTOUR INTERVAL 25 FEET
DATUM IS MEAN SEA LEVEL

OREGON
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty — Light-duty —
Medium-duty — Unimproved dirt - - - - - -
U.S. Route

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

Cartography by S. R. Renoud and W. H. Pokorny 1974

EXPLANATION

Slope

0-10% — *Willamette Valley lowlands, flood plains of major streams, terrace deposits, and isolated upland areas; hazards may include flooding in drainageways, ponding in depressions, high water table, and poor soils (see Soils map for Willamette Valley area); septic tanks, drain fields, basements, buried tanks, and swimming pools not feasible in many areas; suited to agriculture, industry, recreation, and residential use where hazards are minimal.*

10-25% — *Gentle sloping upland areas, parts of older dissected terraces, and stream channels in the Willamette Valley; chemical weathering predominates in uplands; hazards minimal over Columbia River Basalt; thick clay soils and mass movement in parts of Little Butte Formation; clay soils in Willamette Valley (see Soils map); deep cuts require proper engineering in much of the Little Butte; suited to low density residential development and similar uses.*

25-50% — *Extensive hillslope areas in uplands; includes areas of thick clay soil and mass movement topography in weathered parts of the Little Butte Formation in the lower foothills, thick loam soils overlying stable bedrock in areas underlain by Sardine and Cascades Formations, and some talus along ridges of Columbia River Basalt and fresh exposures of Little Butte Formation; hazards variable; fills, cuts, septic tanks, and deep excavations not feasible or require special engineering in places; suited locally to low-density, highly regulated, properly engineered use, also open space and forestry.*

50-75% — *Exposures of solid bedrock of all volcanic units and thin slopes of steeper talus locally; rapid erosion and minimal chemical weathering and soil formation; hazards include rapid runoff, rockslides, thin debris slides, and flash flooding; potential for development small; cuts and fills for road construction require proper engineering; houses and septic tanks generally not feasible; preservation of vegetative cover needed to minimize erosion.*

>75% — *Steep bedrock slopes in areas of youthful topography; rapid erosion with little chemical weathering; hazards include rockfall, rockslide, thin debris slides, mudflow, and flash flooding; little potential for development; cuts and fills difficult.*

Lowlands

Intermediate Regional Flood: *Flood (determined by U.S. Army Corps of Engineers) having a 1 percent probability of occurring in any given year. Preventive action includes zoning restrictions on incompatible developments, education of the public, implementation of Federal flood plain insurance program, floodproofing of present structures, and the construction of levees and dikes.*

Standard Project Flood: *Extent of flood (determined by U.S. Army Corps of Engineers) which would be produced under the most extreme hydrologic and meteorologic conditions possible, excluding extremely rare combinations; areas outside this boundary are not subject to flooding through stream overflow, but may be subject to localized ponding of rainwater.*

Estimated possible flooding: *Areas probably subject to flooding but for which no detailed study has been made.*

Stream bank erosion: *Underculting and caving of river and stream banks commonly accompanied by large scale migration of the river channel; generally characterized by location on the outer bends of sharp curves, bar growth on the opposite bank, and deep water near shore; also inferred on basis of history of past migration, geometry of stream plan, and general knowledge of stream meandering; properly engineered riprap provides local correction for critical areas; other solutions may include zoning, restrictions on construction within given distances of stream bank, and possibly removing sand and gravel from critical bars.*

Abandoned channel: *Length of river or stream channel abandoned through catastrophic channel changes during flooding; commonly the site of stagnation, progressive siltation, marsh growth, and compressible soils; restricted to past and present flood plains of larger rivers, such as Willamette and South Santiam; useful in determining meander history and potential for future stream migration.*

Channel change: *Location of present stream channel acquired by recent progressive meandering through stream bank erosion or truncation of meander bends during floods.*

Taken from U.S.G.S. 7½' Topographic Maps dated 1969 and 1970 and aerial photographs dated 1970. Revisions do not meet National Map Accuracy Standards.

Revetment: *Riprap placed to control stream bank erosion; may lead to increased rates of erosion short distances downstream.*

Uplands

Mass movement topography: *Earthflow terrain characterized locally by irregular to hummocky topography, moderate slopes, irregular drainage, displaced soil, and features of recent movement including cracked ground and bowed trees; failure restricted to soil zone (10 to 30 feet) generally, but penetrates to bedrock in parts of Little Butte Formation, especially below escarpments of resistant cap rock; hazards may include potential for ground movement, poor foundation strength, caving in excavations, and poor drainage; excavations, drainage modifications, removal of vegetation, and use of septic tanks and drain fields may reactivate sliding; on-site investigation recommended for most development; suited to low-density housing in places.*

Headscarp: *Steep slopes of intact bedrock marking the upper limit of a deep slide mass downslope; hazards and limitations are those of shallow failure discussed below.*

Failure on steep slopes (see slopes 4,5): *Hazards include rapid runoff, rockslides, thin debris slides, earthflows and mudflows; frequency of occurrence highest for greatest slopes; steep slopes with thin soil cover particularly sensitive to excavation, placement of fills, and removal of vegetation; potential for development in many areas negligible.*

Flash flood channels: *Small to medium-sized stream channels situated in areas of moderate to steep slope and low permeability; characterized by steep, narrow canyons, lack of flood plain, and very coarse, poorly sorted stream bed deposits; permanent structures generally not feasible; large culverts required under roads crossing channels.*

TEXTURAL SOILS MAP
of the
ALBANY QUADRANGLE
OREGON

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



EXPLANATION

Clay and silty clay: *Severe construction limitations in places because of poor drainage, compressibility, and location in flood prone areas; generally not acceptable for septic tanks owing to low infiltration rates.*

Clay loam and silty clay loam: *Limited use as a function of local topography, water table, and engineering properties; septic tanks, sewage disposal, and landfills acceptable in areas of favorable topography, water table, and permeability.*

Loam and silty loam: *Restricted use in Willamette Valley because of poor drainage and high water table; septic tanks and sewage disposal acceptable in regions of appropriate permeability and water table.*

Sandy and sandy loam: *Acceptable for most construction; generally not acceptable for septic tanks, leach fields, sewage disposal, and landfills owing to rapid infiltration.*

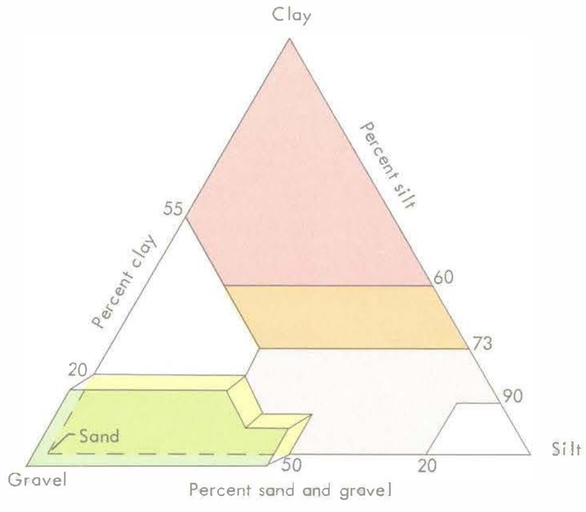
Gravelly and stony loam: *Same as sand and sandy loam above.*

Soils by P. W. Hughes

Cartography by S. R. Renoud and W. H. Pokorny 1974

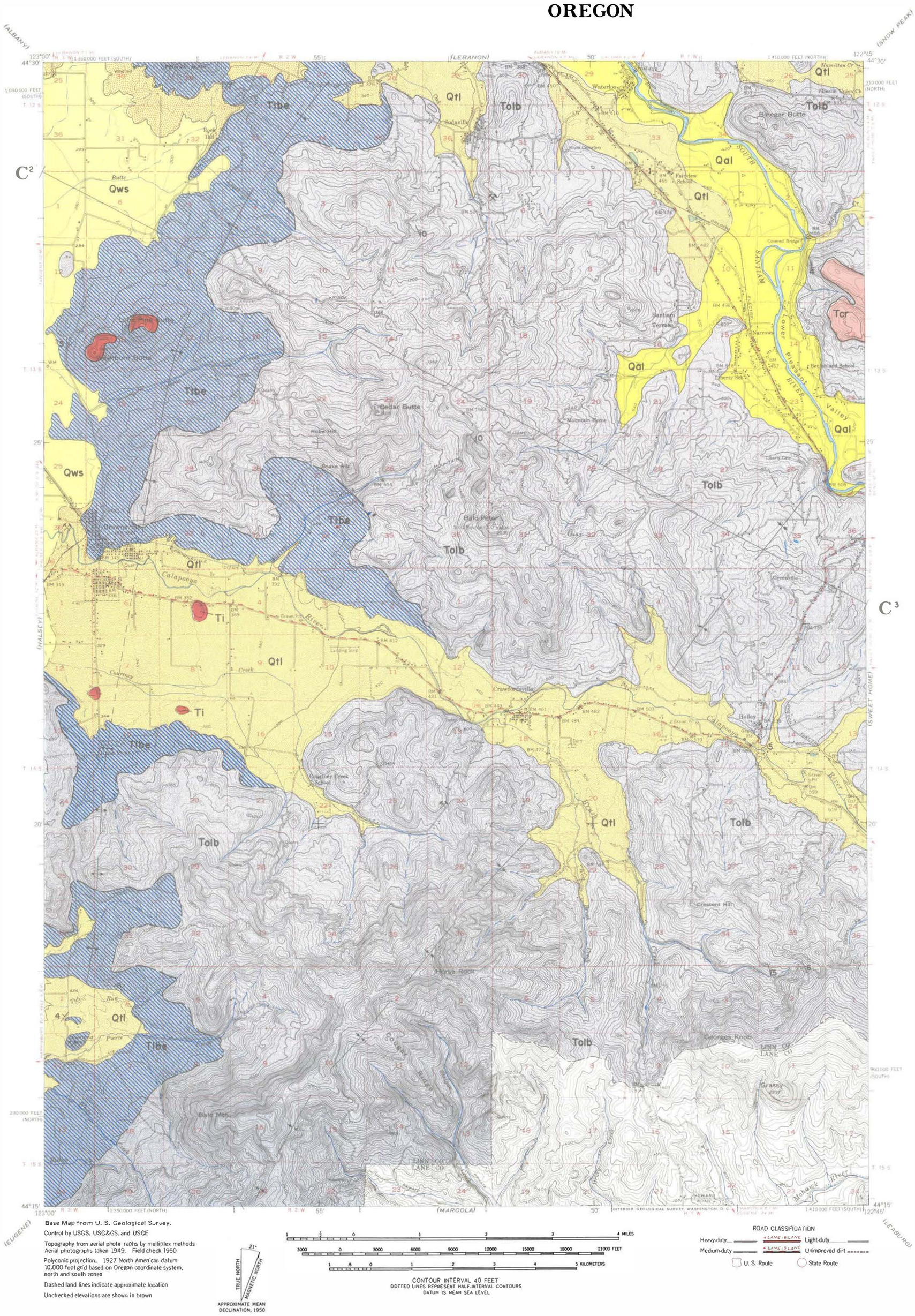
Soil Classification Diagram

Soils are unconsolidated mixtures of clay, silt, sand, and gravel; textural terminology is based on the relative abundance of these components.

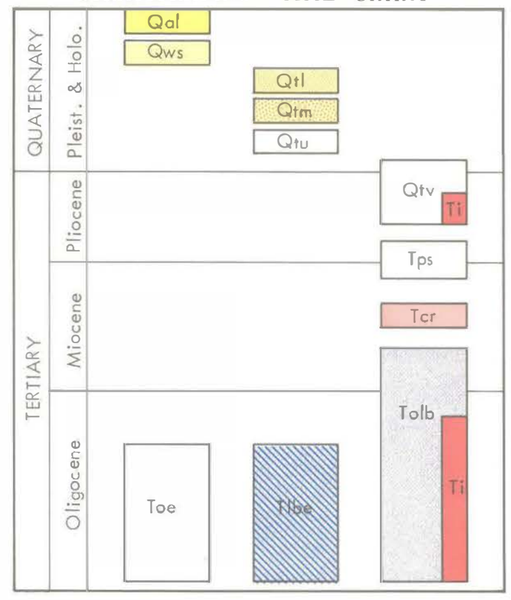


GEOLOGIC MAP
of the
BROWNSVILLE QUADRANGLE
OREGON

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



STRATIGRAPHIC TIME CHART



Surficial Deposits

Qal — **Quaternary alluvium:**

A few tens of feet of gravel, sand, and silt along major streams, and thin veneers of silt and clay lining the smaller streams of the Willamette Valley. Hazards include flooding, stream meandering, and siltation.

Qws — **Willamette silts:**

Up to 20 to 30 feet of faintly bedded, quartzo-feldspathic silts, silty clays, and clays of lacustrine and glacial flood-water origin. Surficial erratics and heavy minerals indicate Columbia River source. Carbon-14 dating reveals an age of 19,000 to 34,000+ years. Hazards include poor drainage, ponding, and low permeability in places.

Qtl — **Quaternary lower terrace:**

A maximum of 50 feet of fluvial pebble gravel, sand, and clay, along the South Santiam River, in the subsurface of the Willamette Valley and in the larger valleys of the foothills area. Also includes terrace gravels along the smaller streams. Equivalent in part to the Linn gravels of Allison (1953), Early Wisconsin or Illinoisan (late Pleistocene) in age. Poor drainage, ponding, and high water table locally.

Qtm — **Quaternary middle terrace:**

Modemtely dissected deposits of pebble gravel, sand, silt, and clay of fluvial origin overlooking younger lower terraces (Qtl). Equivalent in part to the Leffler gravels of Allison (1953). Elevations vary from 245 feet in west to 500 feet in east. Kansan (middle Pleistocene) in age. Deep weathering produces clay-rich soils.

Qtu — **Quaternary upper terrace:**

Deeply dissected remnants of a high, level gravel fan equivalent to the Lacomb gravels of Allison (1953). Maximum thickness 100 to 150 feet. Maximum elevation 865 feet. Early Pleistocene in age.

Stratigraphic Units

Qtv — **Cascades formation:**

Light- to medium-gray porphyritic flow andesite, basalt, and breccias forming a deeply dissected cone at Snow Peak and an intracanyon flow with reversed topography in the middle Santiam drainage. Maximum thickness approximately 3,000 feet. Late Pliocene to early Pleistocene in age. Hazards include steep slopes, rockfall, and flash floods.

Tps — **Sardine formation:**

Up to 1,500 feet of massive to platy hypersthene andesite and basalt unconformable beneath the Cascades Formation and overlying Columbia River Basalt. Late Miocene to early Pliocene in age. Hazards include flash flooding and rockfall.

Tcr — **Columbia River Basalt**

Several hundred feet of dense, dark, very fine-grained flow basalt capping the ridges of northern Linn County. Also includes basalt of Marks Ridge. Columnar jointing is universal. Plagioclase phenocrysts are present locally; pyroxene phenocrysts are absent or very rare. Middle Miocene in age. Weathers to a red loamy soil. Underlain by massive slides on steep slopes.

Tolb / **Tibe** — **Little Butte Formation:**

Approximately 10,000 feet of dacitic to andesitic pyroclastic rocks and dense, dark, basaltic flow rock. The pyroclastics are coarsest in the drainage of the middle Santiam and include breccias, tuffs, and ash. Interbeds of continental volcaniclastic sediments are common towards the west.

The basaltic flow rock was erupted from many sources. The numerous buttes of the eastern Willamette Valley represent the exhumed summits of some of the vents. Scattered small pyroxene phenocrysts typify the basalt.

Parts of the unit (Tibe) in the west contain interbeds of massive, marine, quartzo-feldspathic sandstone equivalent to the Eugene Formation (Toe) reported in well logs in the Willamette Valley.

Age of the formation is early Oligocene through early Miocene as shown by stratigraphic position and leaf fossils.

Hazards include flash floods in the interior, massive landsliding, and thick clay soils.

Toe — **Eugene Formation:**

Marine, quartzo-feldspathic sandstone equivalent to the Little Butte Formation (Tibe) reported in well logs in the Willamette Valley.

Age of the formation is early Oligocene through early Miocene as shown by stratigraphic position and leaf fossils.

Hazards include flash floods in the interior, massive landsliding, and thick clay soils.

Ti — **Intrusive rock:**

Mappable bodies of intrusive basaltic rock within the Little Butte Formation. No feeders for other units are recognized.

Geologic Symbols

Contacts
Rock — Surficial

Folds
Anticline — Syncline

Attitudes
Strike and dip of Beds and flows — Horizontal bed and flows

Exploratory Oil Wells
Show of Oil — Dry Hole — Show of Gas

Mines and Quarries

Base Map from U. S. Geological Survey.
Control by USGS, USC&GS, and USCE
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1949. Field check 1950
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north and south zones
Dashed land lines indicate approximate location
Unchecked elevations are shown in brown

APPROXIMATE MEAN DECLINATION, 1950 — TRUE NORTH, MAGNETIC NORTH, 21°

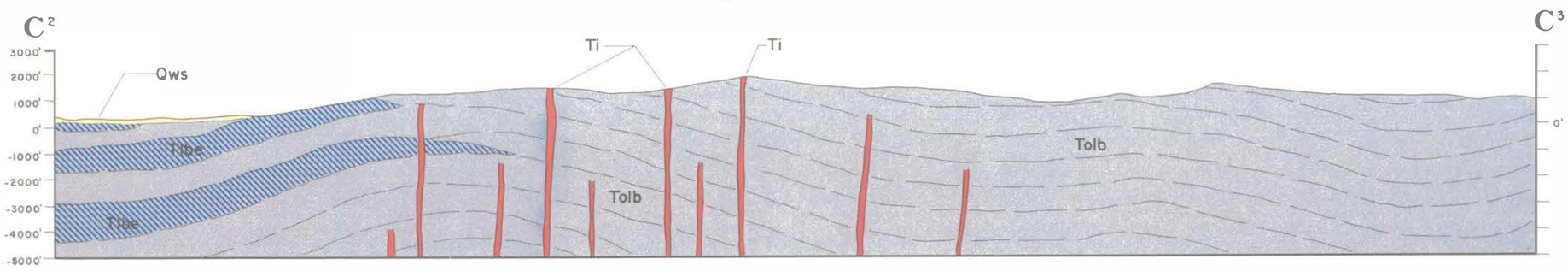
1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT HALF-INTERVAL CONTOURS
DATUM IS MEAN SEA LEVEL

ROAD CLASSIFICATION
Heavy-duty — 4 LANE | 6 LANE — Light-duty
Medium-duty — 4 LANE | 6 LANE — Unimproved dirt
U. S. Route — State Route

INTERIOR GEOLOGICAL SURVEY, WASHINGTON, D. C.

Geologic Cross Section

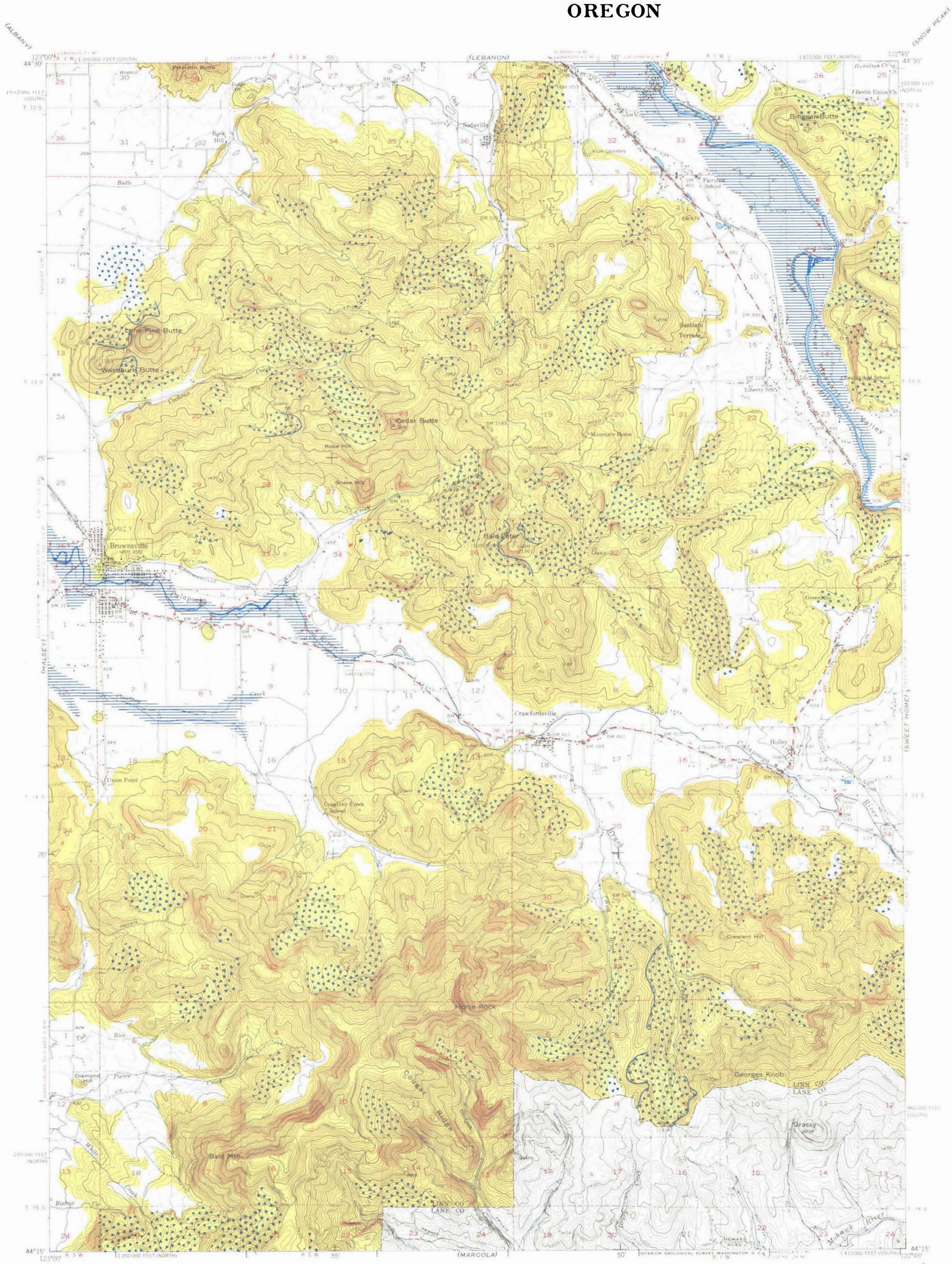


Geology by J. D. Beaulieu

Cartography by S. R. Renoud and W. H. Pokorny 1974

GEOLOGIC HAZARDS MAP
of the
BROWNSVILLE QUADRANGLE
OREGON

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



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

Cartography by S. R. Renoud and W. H. Pokorny 1974

EXPLANATION

Slope

0-10% — *Willamette Valley lowlands, flood plains of major streams, terrace deposits, and isolated upland areas; hazards may include flooding in drainageways, ponding in depressions, high water table, and poor soils (see Soils map for Willamette Valley area); septic tanks, drain fields, basements, buried tanks, and swimming pools not feasible in many areas; suited to agriculture, industry, recreation, and residential use where hazards are minimal.*

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50-75% — *Exposures of solid bedrock of all volcanic units and thin slopes of sleeper talus locally; rapid erosion and minimal chemical weathering and soil formation; hazards include rapid runoff, rockslides, thin debris slides, and flash flooding; potential for development small; cuts and fills for road construction require proper engineering; houses and septic tanks generally not feasible; preservation of vegetative cover needed lo minimize erosion.*

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Lowlands

Intermediate Regional Flood: *Flood (determined by U.S. Army Corps of Engineers) having a 1 percent probability of occurring in any given year. Preventive action includes zoning restrictions on incompatible developments, education of the public, implementation of Federal flood plain insurance program, floodproofing of present structures, and the construction of levees and dikes.*

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Taken from U.S.G.S. 7½' Topographic Maps dated 1969 and 1970 and aerial photographs dated 1970. Revisions do not meet National Map Accuracy Standards.

Revetment: *Riprap placed to control stream banl: erosion; may lead to increased rates of erosion short distances downstream.*

Uplands

Mass movement topography: *Earthflow terrain characterized locally by irregular to hummocky topography, moderate slopes, irregular drainage, displaced soil, and features of recent movement including cracked ground and bowed trees; failure restricted to soil zone (10 to 30 feel) generally, but penetrates to bedrock in parts of Little Butte Formation, especially below escarpments of resistanl cap rock; hazards may include potential for ground movement, poor foundalion strength, caving in excavations, and poor drainage; excavations, drainage modifications, removal of vegetation, and use of septic lanks and drain fields may reactivate sliding; on-site investigation recommended for most development; suited to low-density housing in places.*

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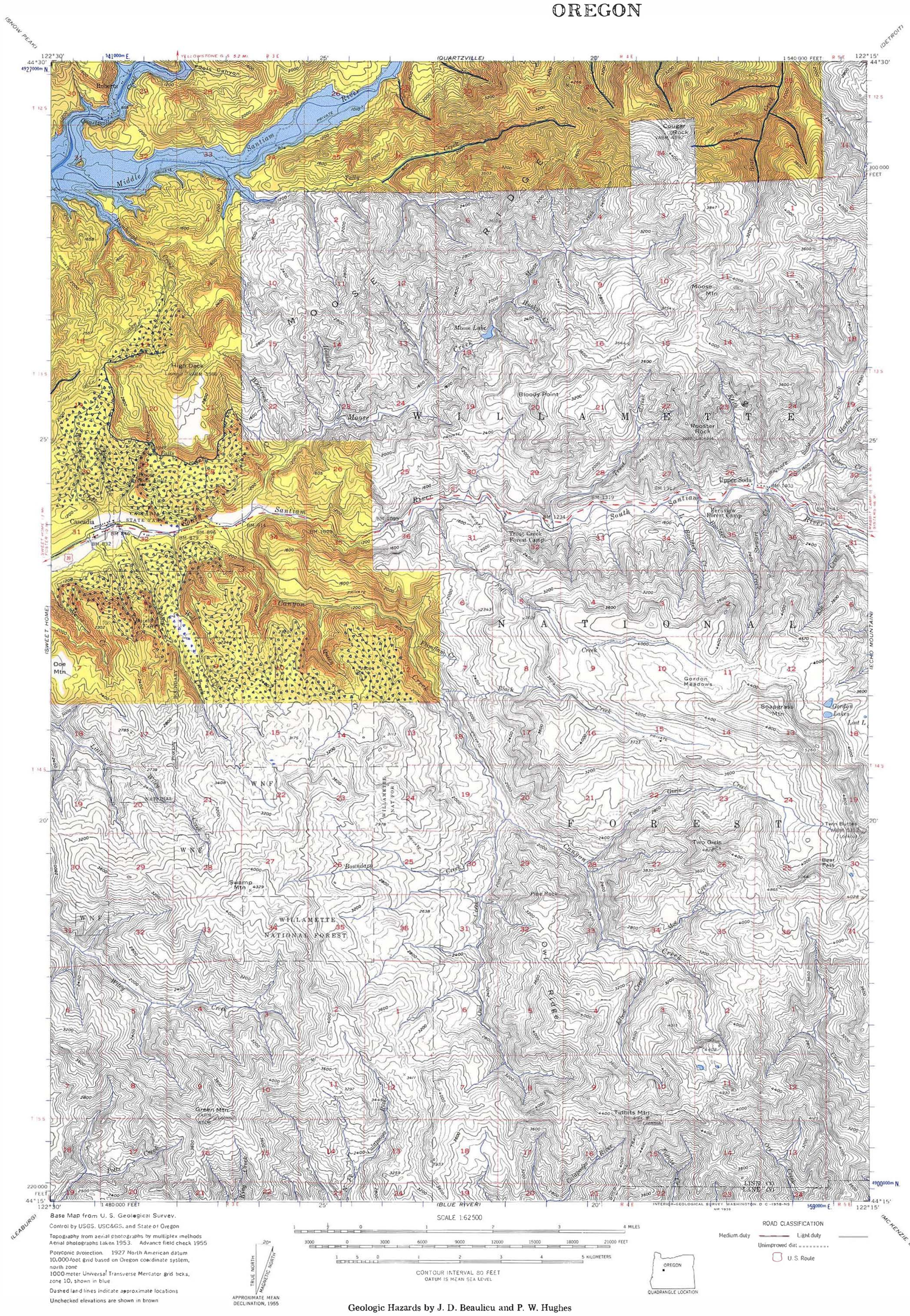
GEOLOGIC MAP
of the
CASCADIA QUADRANGLE
OREGON

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


B5
B4
Tolb
Tps
Tp
Qtl
Tolb
Tolb
Tolb

GEOLOGIC HAZARDS MAP
of the
CASCADIA QUADRANGLE
OREGON

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



Base Map from U. S. Geological Survey.

Control by USGS, USC&GS, and State of Oregon

Topography from aerial photographs by multiplex methods
Aerial photographs taken 1953. Advance field check 1955

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

Dashed land lines indicate approximate locations

Unchecked elevations are shown in brown

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

Cartography by S. R. Renoud and W. H. Pokorny 1974

EXPLANATION

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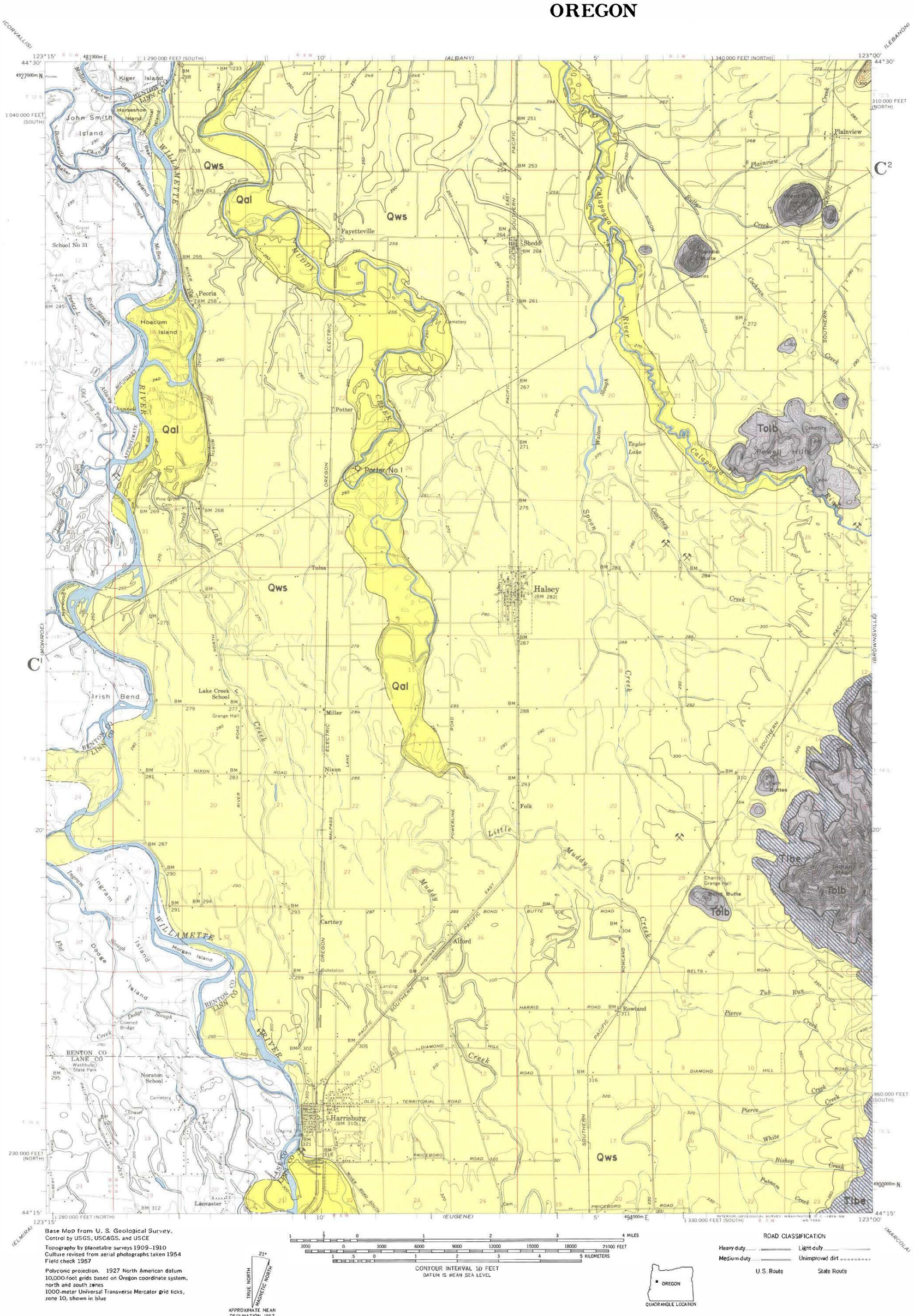
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GEOLOGIC MAP
of the
HALSEY QUADRANGLE
OREGON

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



Base Map from U. S. Geological Survey.
Control by USGS, USC&GS, and USCE

Topography by planetable surveys 1909–1910
Culture revised from aerial photographs taken 1954
Field check 1957

Polyconic projection. 1927 North American datum
10,000-foot grids based on Oregon coordinate system, north and south zones
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

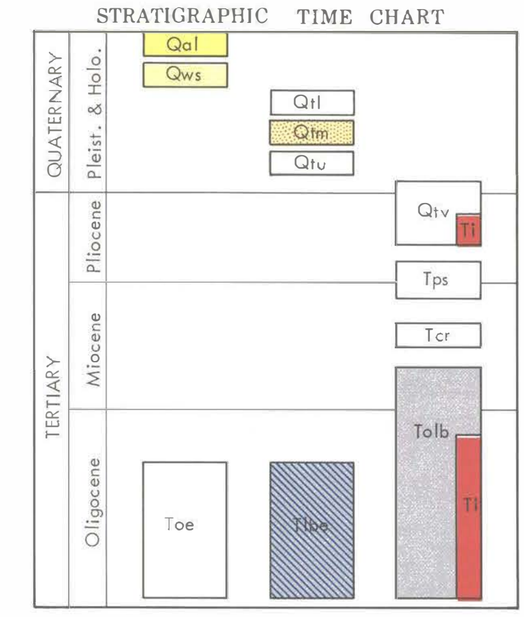
APPROXIMATE MEAN DECLINATION, 1957

OREGON
QUADRANGLE LOCATION

ROAD CLASSIFICATION

Heavy-duty	Light-duty
Medium-duty	Unimproved dirt
U.S. Route	State Route

STRATIGRAPHIC TIME CHART



Surficial Deposits

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A few tens of feet of gravel, sand, and silt along major streams, and thin veneers of silt and clay lining the smaller streams of the Willamette Valley. Hazards include flooding, stream meandering, and siltation.

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Up to 20 to 30 feet of faintly bedded, quartzo-feldspathic silts, silty clays, and clays of lacustrine and glacial flood-water origin. Surficial aerates and heavy minerals indicate Columbia River source. Carbon-14 dating reveals an age of 19,000 to 34,000+ years. Hazards include poor drainage, ponding, and low permeability in places.

Qtl — **Quaternary lower terrace:**
A maximum of 50 feet of fluvial pebble gravel, sand, and clay, along the South Santiam River, in the subsurface of the Willamette Valley and in the larger valleys of the foothills area. Also includes terrace gravels along the smaller streams. Equivalent in part to the Linn gravels of Allison (1953). Early Wisconsin or Illinoisian (late Pleistocene) in age. Poor drainage, ponding, and high water table locally.

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Moderately dissected deposits of pebble gravel, sand, silt, and clay of fluvial origin overlooking younger lower terraces (Qtl). Equivalent in part to the Leffler gravels of Allison (1953). Elevations vary from 245 feet in west to 500 feet in east. Kansan (middle Pleistocene) in age. Deep weathering produces clay-rich soils.

Qtu — **Quaternary upper terrace:**
Deeply dissected remnants of a high, level gravel fan equivalent to the Lacomb gravels of Allison (1953). Maximum thickness 100 to 150 feet. Maximum elevation 865 feet. Early Pleistocene in age.

Stratigraphic Units

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Light- to medium-gray porphyritic flow andesite, basalt, and breccias forming a deeply dissected cone at Snow Peak and an intracanyon flow with reversed topography in the middle Santiam drainage. Maximum thickness approximately 3,000 feet. Late Pliocene to early Pleistocene in age. Hazards include steep slopes, rockfall, and flash floods.

Tps — **Sardine formation:**
Up to 1,500 feet of massive to platy hypersthene andesite and basalt unconformable beneath the Cascades Formation and overlying Columbia River Basalt. Late Miocene to early Pliocene in age. Hazards include flash flooding and rockfall.

Tcr — **Columbia River Basalt**
Several hundred feet of dense, dark, very fine-grained flow basalt capping the ridges of northern Linn County. Also includes basalt of Marks Ridge. Columnar jointing is universal. Plagioclase phenocrysts are present locally; pyroxene phenocrysts are absent or very rare. Middle Miocene in age. Weathers to a red loamy soil. Undercut by massive slides on steep slopes.

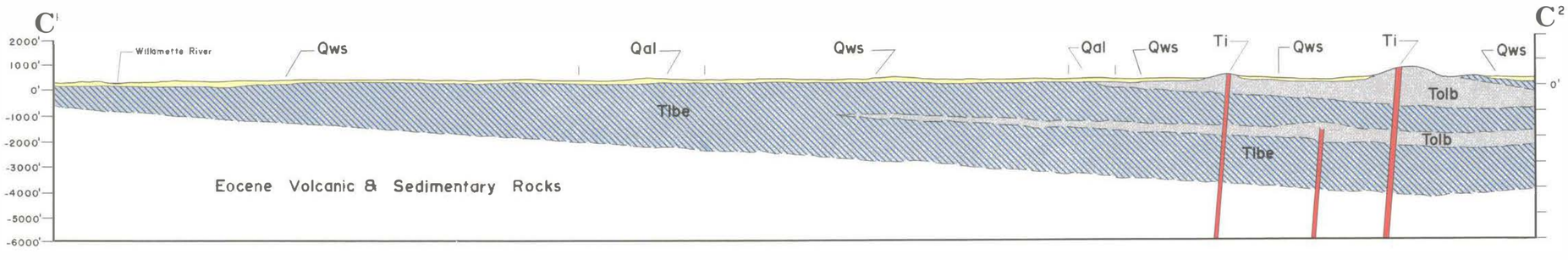
Tolb, Tibe — **Little Butte Formation:**
Approximately 10,000 feet of dacitic to andesitic pyroclastic rocks and dense, dark, basaltic flow rock. The pyroclastics are coarsest in the drainage of the middle Santiam and include breccias, luffs, and ash. Interbeds of continental volcaniclastic sediments are common towards the west.
The basaltic flow rock was erupted from many sources. The numerous buttes of the eastern Willamette Valley represent the exhumed remnants of some of the vents. Scattered small pyroxene phenocrysts typify the basalt.
Parts of the unit (Tibe) in the west contain interbeds of massive, marine, quartzo-feldspathic sandstone equivalent to the Eugene Formation (Toe) reported in well logs in the Willamette Valley.
Age of the formation is early Oligocene through early Miocene as shown by stratigraphic position and leaf fossils.
Hazards include flash floods in the interior, massive landsliding, and thick clay soils.

Toe — **Intrusive rock:**
Mappable bodies of intrusive basaltic rock within the Little Butte Formation. No feeders for other units are recognized.

Geologic Symbols

Contacts: Rock; Surficial
Folds: Anticline; Syncline
Attitudes: Strike and dip of Beds and flows; Horizontal beds and flows
Exploratory Oil Wells: Show of Oil; Dry Hole; Show of Gas; Mines and Quarries

Geologic Cross Section

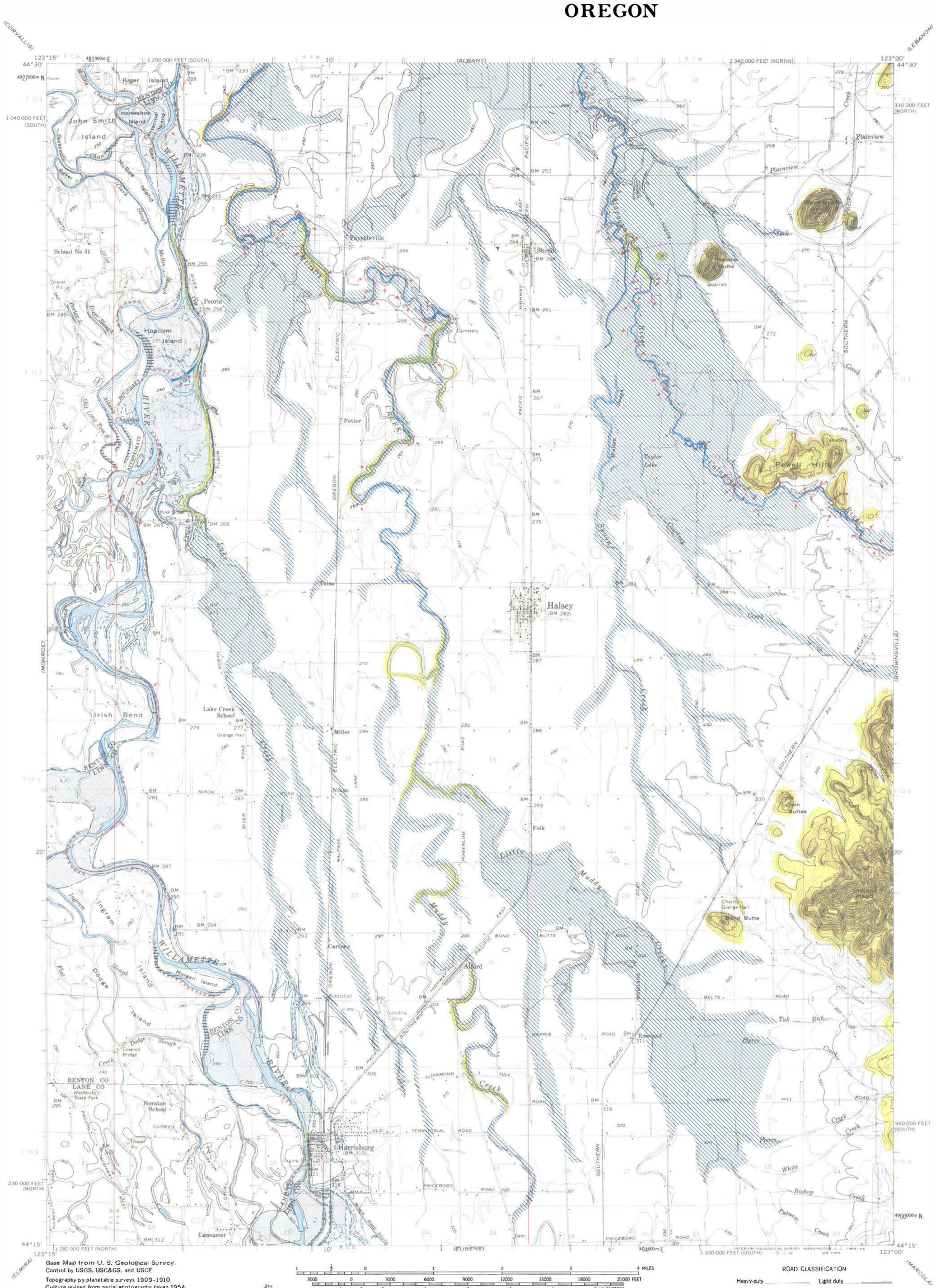


Geology by J. D. Beaulieu

Cartography by S. R. Renoud and W. H. Pokorny 1974

GEOLOGIC HAZARDS MAP
of the
HALSEY QUADRANGLE
OREGON

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



Base Map from U. S. Geological Survey.
Control by USGS, USC&GS, and USCE
Topography by planetable surveys 1909–1910
Culture revised from aerial photographs taken 1954
Field check 1957

Polyconic projection. 1927 North American datum
10,000-foot grids based on Oregon coordinate system, north and south zones
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

APPROXIMATE MEAN DECLINATION, 1957
21°
TRUE NORTH
MAGNETIC NORTH

1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 5 0 1 2 3 4 5 KILOMETERS
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

OREGON
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U. S. Route — State Route

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

Cartography by S. R. Renoud
and W. H. Pokorny 1974

EXPLANATION

Slope

0-10% — *Willamette Valley lowlands, flood plains of major streams, terrace deposits, and isolated upland areas; hazards may include flooding in drainageways, ponding in depressions, high water table, and poor soils (see Soils map for Willamette Valley area); septic tanks, drain fields, basements, buried tanks, and swimming pools not feasible in many areas; suited to agriculture, industry, recreation, and residential use where hazards are minimal.*

10-25% — *Gentle sloping upland areas, parts of older dissected terraces, and stream channels in the Willamette Valley; chemical weathering predominates in uplands; hazards minimal over Columbia River Basalt; thick clay soils and mass movement in parts of Little Butte Formation; clay soils in Willamette Valley (see Soils map); deep cuts require proper engineering in much of the Little Butte; suited to low density residential development and similar uses.*

25-50% — *Extensive hillslope areas in uplands; includes areas of thick clay soil and mass movement topography in weathered parts of the Little Butte Formation in the lower foothills, thick loam soils overlying stable bedrock in areas underlain by Sardine and Cascades Formations, and some talus along ridges of Columbia River Basalt and fresh exposures of Little Butte Formation; hazards variable; fills, cuts, septic tanks, and deep excavations not feasible or require special engineering in places; suited locally to low-density, highly regulated, properly engineered use, also open space and forestry.*

50-75% — *Exposures of solid bedrock of all volcanic units and thin slopes of sleeper talus locally; rapid erosion and minimal chemical weathering and soil formation; hazards include rapid runoff, rockslides, thin debris slides, and flash flooding; potential for development small; cuts and fills for road construction require proper engineering; houses and septic tanks generally not feasible; preservation of vegetative cover needed to minimize erosion.*

>75% — *Steep bedrock slopes in areas of youthful topography; rapid erosion with little chemical weathering; hazards include rockfall, rockslide, thin debris slides, mudflow, and flash flooding; little potential for development; cuts and fills difficult.*

Lowlands

Intermediate Regional Flood: *Flood (determined by U.S. Army Corps of Engineers) having a 1 percent probability of occurring in any given year. Preventive action includes zoning restrictions on incompatible developments, education of the public, implementation of Federal flood plain insurance program, floodproofing of present structures, and the construction of levees and dikes.*

Standard Project Flood: *Extent of flood (determined by U.S. Army Corps of Engineers) which would be produced under the most extreme hydrologic and meteorologic conditions possible, excluding extremely rare combinations; areas outside this boundary are not subject to flooding through stream overflow, but may be subject to localized ponding of rainwater.*

Estimated possible flooding: *Areas probably subject to flooding but for which no detailed study has been made.*

Stream bank erosion: *Undercutting and caving of river and stream banks commonly accompanied by large scale migration of the river channel; generally characterized by location on the outer bends of sharp curves, bar growth on the opposite bank, and deep water near shore; also inferred on basis of history of past migration, geometry of stream plan, and general knowledge of stream meandering; properly engineered riprap provides local correction for critical areas; other solutions may include zoning, restrictions on construction within given distances of stream bank, and possibly removing sand and gravel from critical bars.*

Abandoned channel: *Length of river or stream channel abandoned through catastrophic channel changes during flooding; commonly the site of stagnation, progressive sillation, marsh growth, and compressible soils; restricted to past and present flood plains of larger rivers, such as Willamette and South Santiam; useful in determining meander history and potential for future stream migration.*

Channel change: *Location of present stream channel acquired by recent progressive meandering through stream bank erosion or truncation of meander bends during floods.*

Taken from U.S.G.S. 7½' Topographic Maps dated 1969 and 1970 and aerial photographs dated 1970. Revisions do not meet National Map Accuracy Standards.

Revetment: *Riprap placed to control stream bank erosion; may lead to increased rates of erosion short distances downstream.*

Uplands

Mass movement topography: *Earthflow terrain characterized locally by irregular to hummocky topography, moderate slopes, irregular drainage, displaced soil, and features of recent movement including cracked ground and bowed trees; failure restricted to soil zone (10 to 30 feet) generally, but penetrates to bedrock in parts of Little Butte Formation, especially below escarpments of resistant cap rock; hazards may include potential for ground movement, poor foundation strength, caving in excavations, and poor drainage; excavations, drainage modifications, removal of vegetation, and use of septic tanks and drain fields may reactivate sliding; on-site investigation recommended for most development; suited to low-density housing in places.*

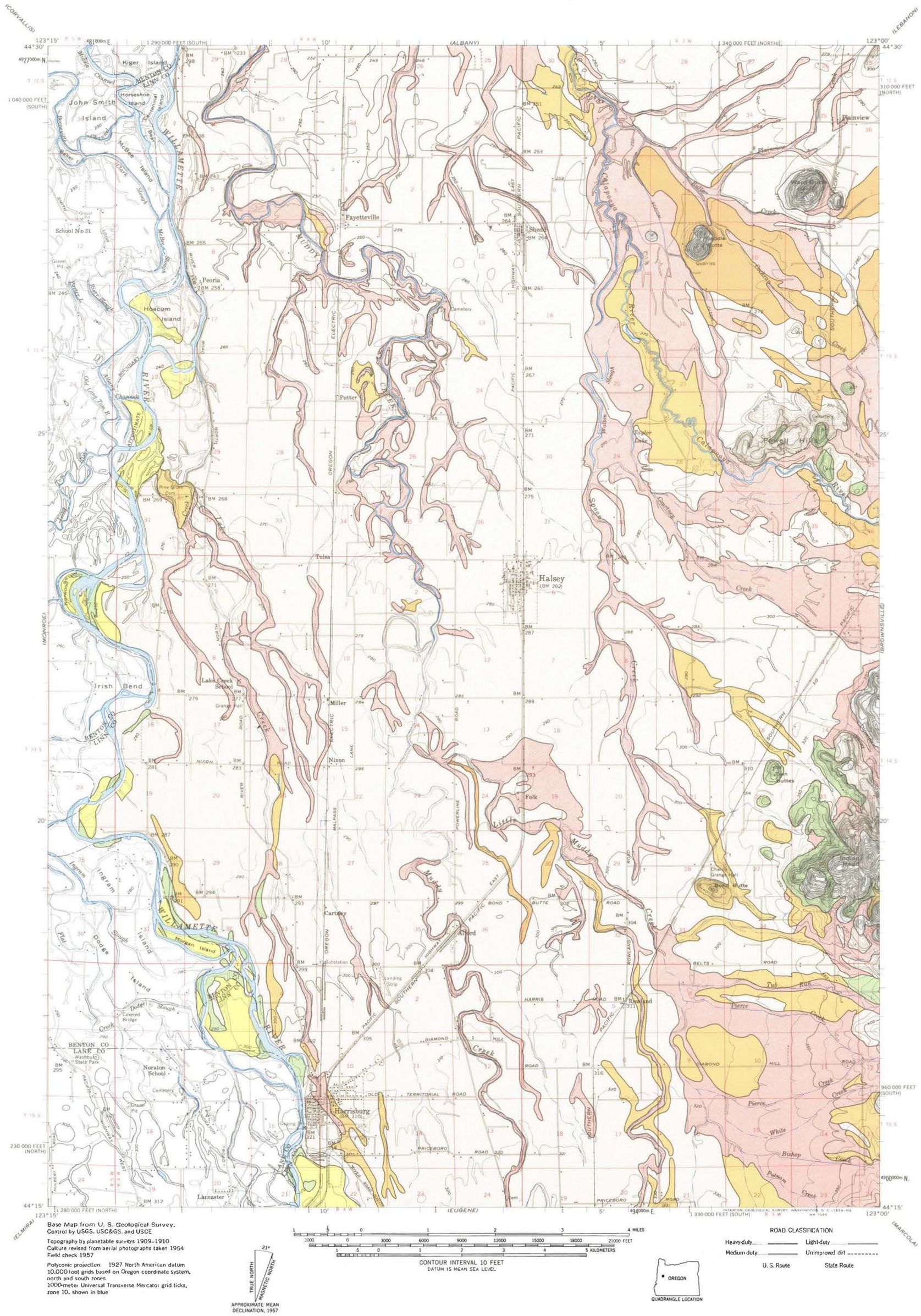
Headscarp: *Steep slopes of intact bedrock marking the upper limit of a deep slide mass downslope; hazards and limitations are those of shallow failure discussed below.*

Failure on steep slopes (see slopes 4,5): *Hazards include rapid runoff, rockslides, thin debris slides, earthflows and mudflows; frequency of occurrence highest for greatest slopes; steep slopes with thin soil cover particularly sensitive to excavation, placement of fills, and removal of vegetation; potential for development in many areas negligible.*

Flash flood channels: *Small to medium-sized stream channels situated in areas of moderate to steep slope and low permeability; characterized by steep, narrow canyons, lack of flood plain, and very coarse, poorly sorted stream bed deposits; permanent structures generally not feasible; large culverts required under roads crossing channels.*

TEXTURAL SOILS MAP
of the
HALSEY QUADRANGLE
OREGON

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



EXPLANATION

Clay and silty clay: *Severe construction limitations in places because of poor drainage, compressibility, and location in flood prone areas; generally not acceptable for septic tanks owing to low infillralion rates.*

Clay loam and silty clay loam: *Limited use as a function of local topography, water table, and engineering properties; septic tanks, sewage disposal, and landfills acceptable in areas of favorable topography, water table, and permeability.*

Loam and silty loam: *Restricted use in Willamelte Valley because of poor drainage and high water table; septic tanks and sewage disposal acceptable in regions of appropriate permeability and water table.*

Sandy and sandy loam: *Acceptable for most construction; generally not acceptable for septic tanks, leach fields, sewage disposal, and landfills owing to rapid infiltralion.*

Gravelly and stony loam: *Same as sand and sandy loam above.*

Stony mountainous land: *variable; see Geologic Hazards maps.*

Soils by **P. W. Hughes**

Cartography by S. R. Renoud and W. H. Pokorny 1974

Base Map from U. S. Geological Survey.
Control by USGS, USC&GS, and USCE

Topography by planetable surveys 1909–1910
Culture revised from aerial photographs taken 1954
Field check 1957

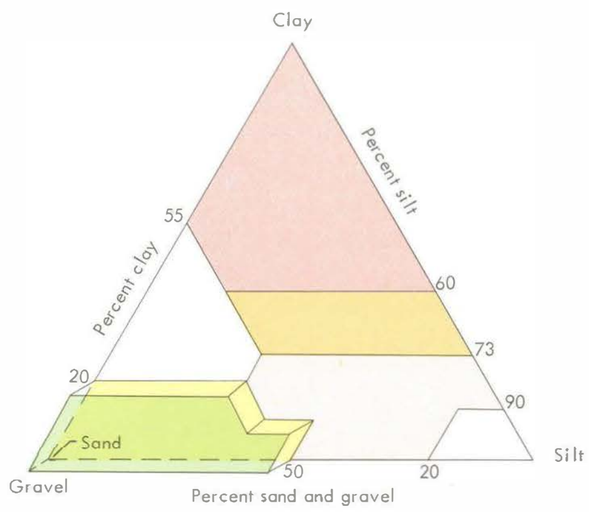
Polyconic projection. 1927 North American datum
10,000-foot grids based on Oregon coordinate system, north and south zones
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

ROAD CLASSIFICATION

Heavy-duty	Light-duty
Medium-duty	Unimproved dirt
U. S. Route	State Route

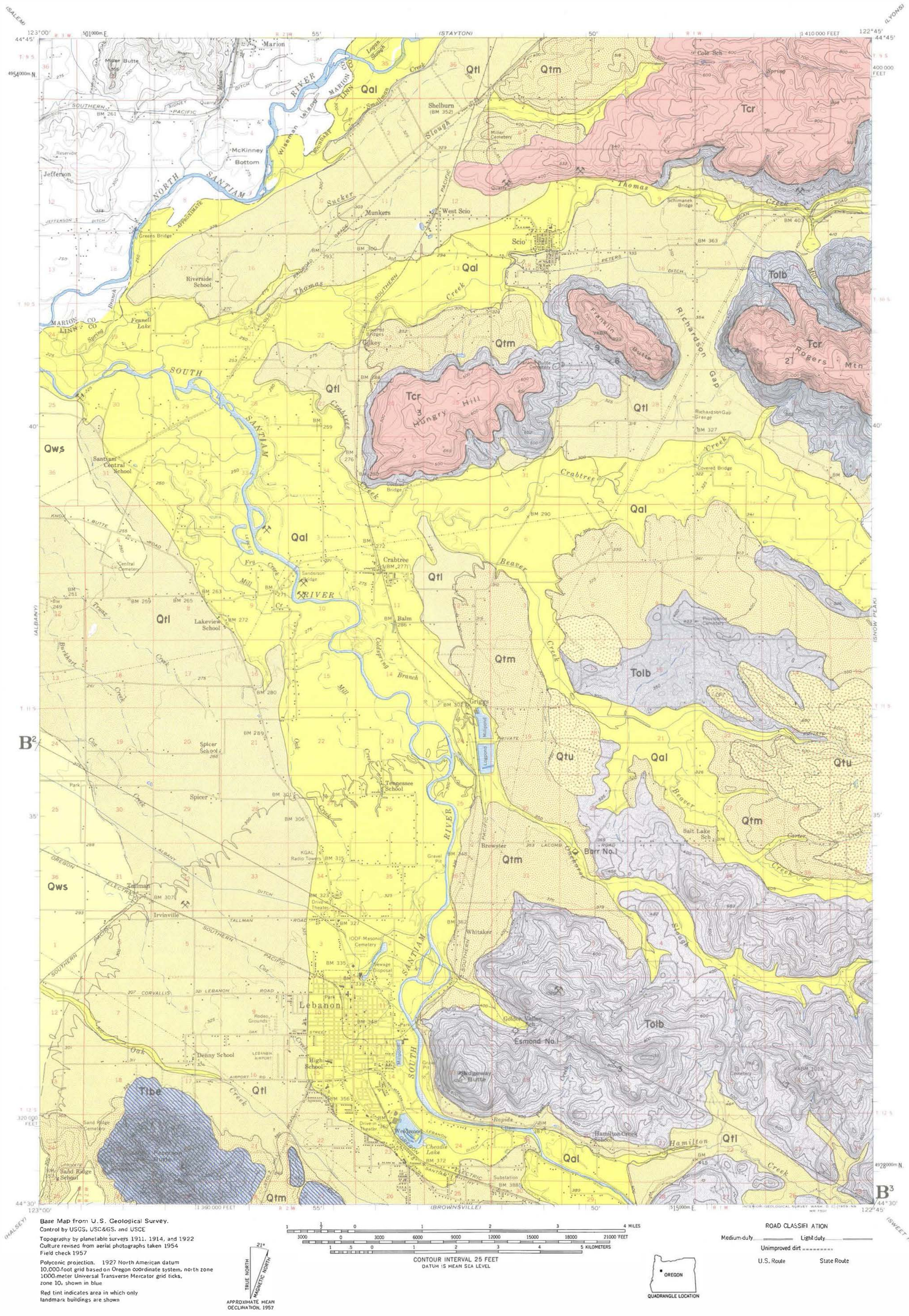
Soil Classification Diagram

Soils are unconsolidated mixtures of clay, silt, sand, and gravel; textural terminology is based on the relative abundance of these components.



GEOLOGIC MAP
of the
LEBANON QUADRANGLE
OREGON

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



Base Map from U.S. Geological Survey.
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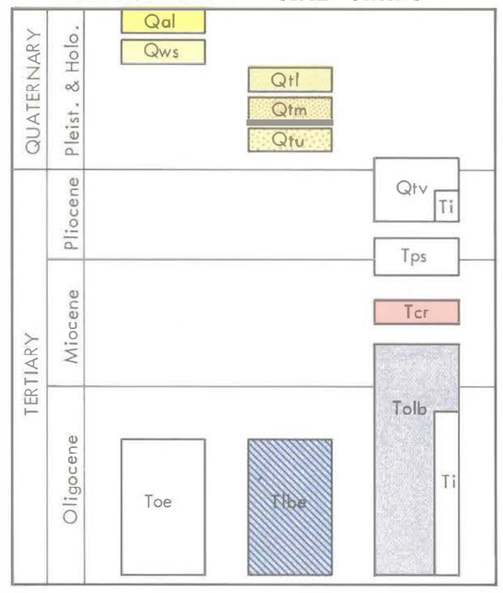
APPROXIMATE MEAN DECLINATION, 1957

CONTOUR INTERVAL 25 FEET
DATUM IS MEAN SEA LEVEL

ROAD CLASSIFICATION
Medium-duty — Light-duty
Unimproved dirt
U.S. Route — State Route

QUADRANGLE LOCATION

STRATIGRAPHIC TIME CHART



Surficial Deposits

Qal — **Quaternary alluvium:**

A few tens of feet of gravel, sand, and silt along major streams, and thin veneers of silt and clay lining the smaller streams of the Willamette Valley. Hazards include flooding, stream meandering, and siltation.

Qws — **Willamette silts:**

Up to 20 to 30 feet of faintly bedded, quartzo-feldspathic silts, silty clays, and clays of lacustrine and glacial flood-water origin. Surficial erratics and heavy minerals indicate Columbia River source. Carbon-14 dating reveals an age of 19,000 to 34,000+ years. Hazards include poor drainage, ponding, and low permeability in places.

Qtl — **Quaternary lower terrace:**

A maximum of 50 feet of fluvial pebble gravel, sand, and clay, along the South Santiam River, in the subsurface of the Willamette Valley and in the larger valleys of the foothills area. Also includes terrace gravels along the smaller streams. Equivalent in part to the Linn gravels of Allison (1953). Early Wisconsin or Illinoisian (late Pleistocene) in age. Poor drainage, ponding, and high water table locally.

Qtm — **Quaternary middle terrace:**

Moderately dissected deposits of pebble gravel, sand, silt, and clay of fluvial origin overlooking younger lower terraces (Qtl). Equivalent in part to the Leffler gravels of Allison (1953). Elevations vary from 245 feet in west to 500 feet in east. Kansan (middle Pleistocene) in age. Deep weathering produces clay-rich soils.

Qtu — **Quaternary upper terrace:**

Deeply dissected remnants of a high, level gravel fan equivalent to the Laeomb gravels of Allison (1953). Maximum thickness 100 to 150 feet. Maximum elevation 865 feet. Early Pleistocene in age.

Stratigraphic Units

Qtv — **Cascades formation:**

Light- to medium-gray porphyritic flow andesite, basalt, and breccias forming a deeply dissected cone at Snow Peak and an intracanyon flow with reversed topography in the middle Santiam drainage. Maximum thickness approximately 3,000 feet. Late Pliocene to early Pleistocene in age. Hazards include steep slopes, rockfall, and flash floods.

Tps — **Sardine formation:**

Up to 1,500 feet of massive to platy hypersthene andesite and basalt unconformable beneath the Cascades Formation and overlying Columbia River Basalt. Late Miocene to early Pliocene in age. Hazards include flash flooding and rockfall.

Tcr — **Columbia River Basalt**

Several hundred feet of dense, dark, very fine-grained flow basalt capping the ridges of northern Linn County. Also includes basalt of Marks Ridge. Columnar jointing is universal. Plagioclase phenocrysts are present locally; pyroxene phenocrysts are absent or very rare. Middle Miocene in age. Weathers to a red loamy soil. Undercut by massive slides on steep slopes.

Tolb — **Little Butte Formation:**

Approximately 10,000 feet of dacitic to andesitic pyroclastic rocks and dense, dark, basaltic flow rock. The pyroclastics are coarsest in the drainage of the middle Santiam and include breccias, tuffs, and ash. Interbeds of continental volcaniclastic sediments are common towards the west.

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Age of the formation is early Oligocene through early Miocene as shown by stratigraphic position and leaf fossils.

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Ti — **Intrusive rock:**

Mappable bodies of intrusive basaltic rock within the Little Butte Formation. No feeders for other units are recognized.

Geologic Symbols

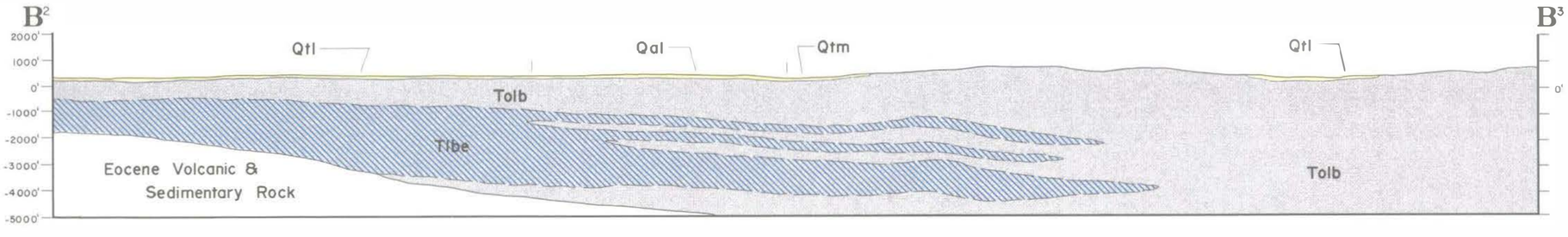
Contacts
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Folds
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Attitudes
Strike and dip of Beds and flows — Horizontal beds and flows

Exploratory Oil Wells
Show of Oil — Dry Hole — Show of Gas
Mines and Quarries

Geologic Cross Section

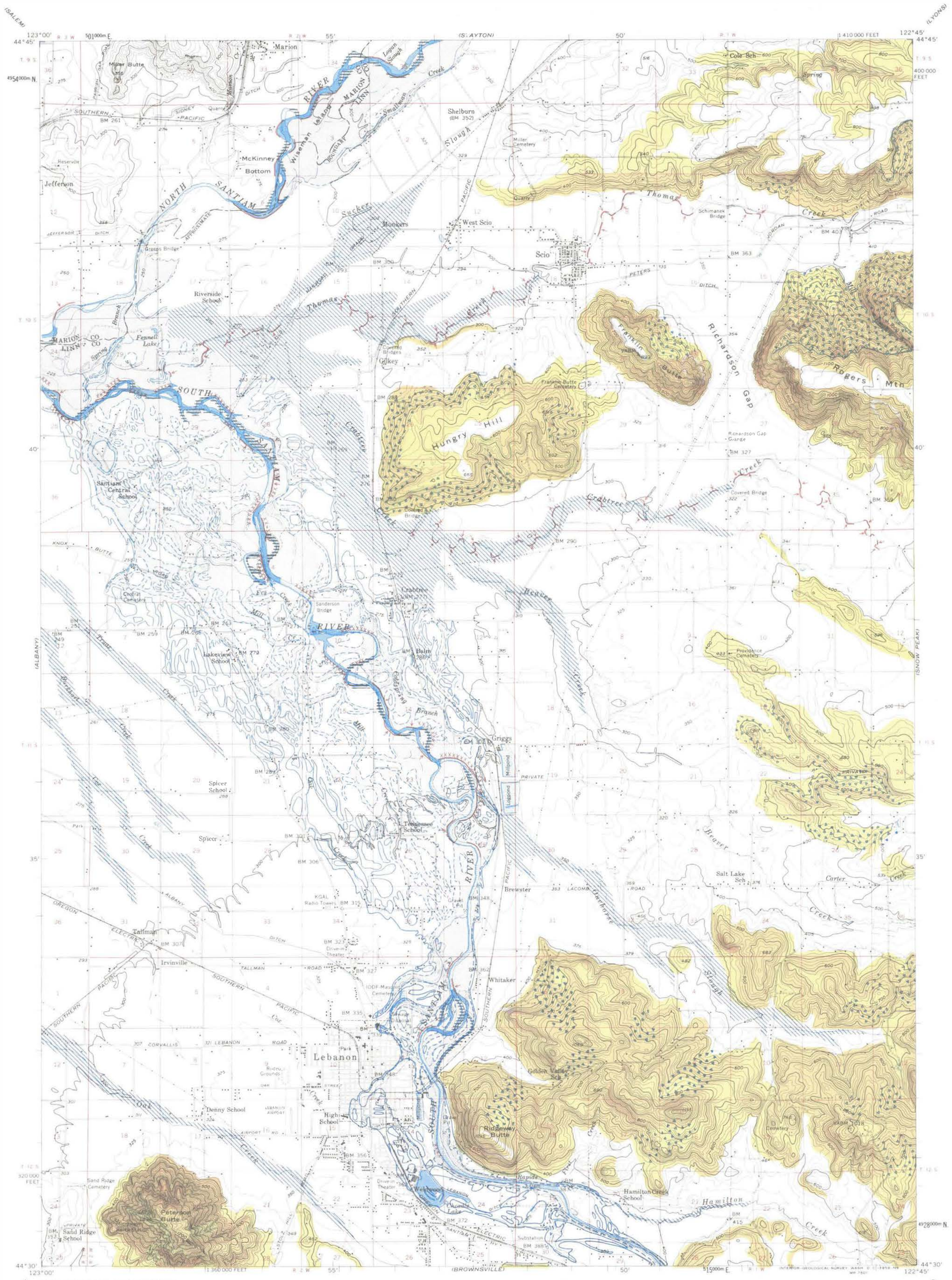


Geology by J. D. Beaulieu

Cartography by S. R. Renoud and W. H. Pokorny 1974

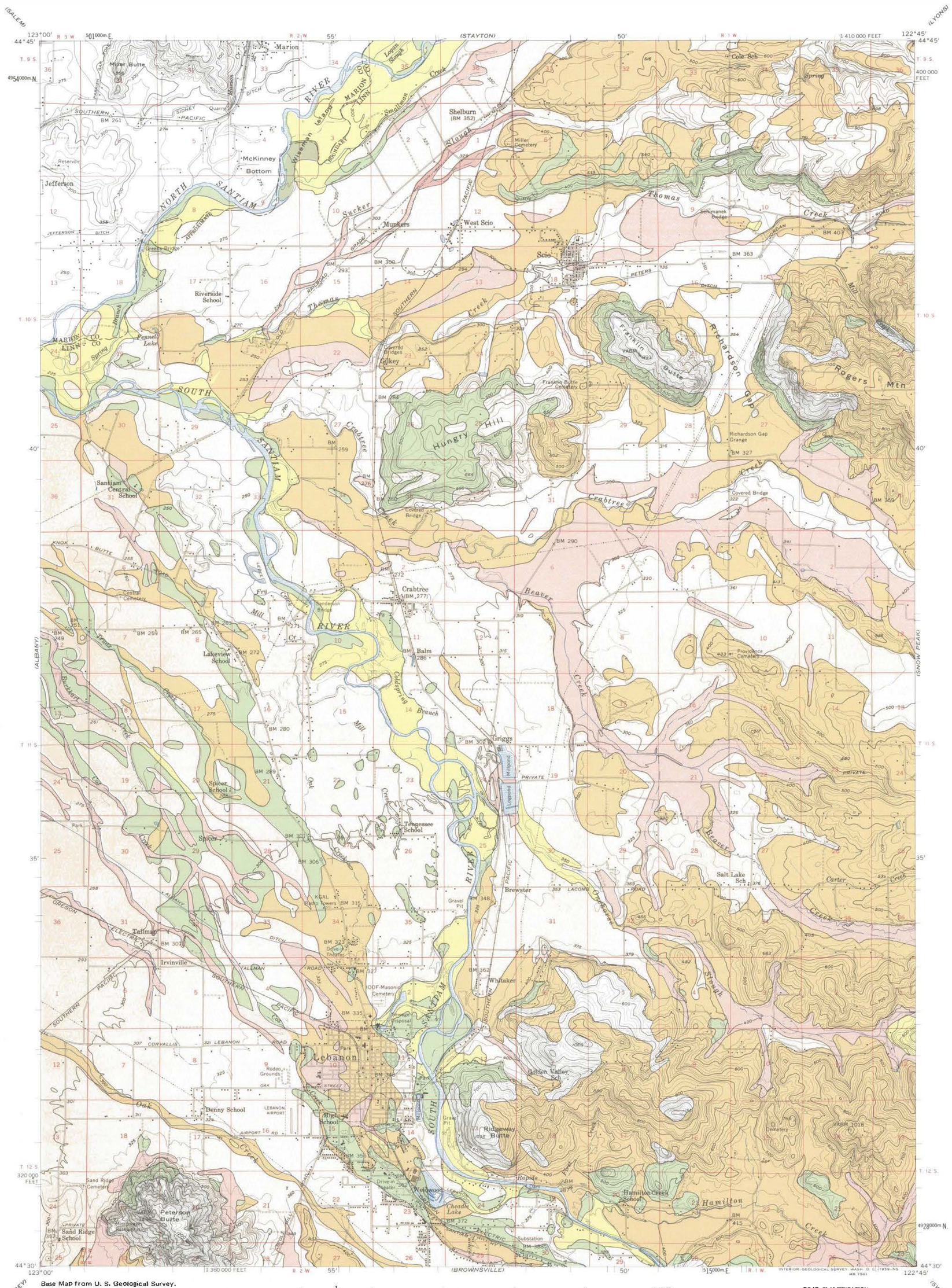
GEOLOGIC HAZARDS MAP
of the
LEBANON QUADRANGLE
OREGON

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


(SALEM)
(S. AYTON)
(LYONS)
(ALBANY)
(SNOW PEAK)
(HALSEY)
(BROWNSVILLE)
(SWEET HOME)
123°00'
122°45'
44°45'
44°30'
501 000m E.
495 4000m N.
515 000m E.
492 8000m N.
1 410 000 FEET
1 400 000 FEET
1 360 000 FEET
320 000 FEET
Marion
Miller Butte
Logan Slough
Swalhalem Creek
Shelburn (BM 352)
Cole Sch
Spring
Miller Cemetery
McKinney Bottom
Jefferson
Heservoir
Sucker Creek
Hookers
West Scio
Scio
Schimanek Bridge
Thomas Creek
Riverside School
Fennell Lake
Gilkey
Franklin Butte
Franklin Butte Cemetery
Richardson Gap
Richardson Gap Grange
Rogers Mtn
Hungry Hill
Santiam Central School
Crabtree
Crabtree Creek
Covered Bridge
Sanderson Bridge
Central Cemetery
Lakeview School
Providence Cemetery
Calapooia Branch
Briggs
Millpond
Lodgepond
Spicer School
Spicer
Twogreases School
Brewster
KGAL Radio Towers
Salt Lake Sch
Carter Creek
Tallman
Irvinville
Whitaker
Lebanon
Golden Valley Sch
Denny School
High School
Ridgeway Butte
Oak Creek
Sand Ridge Cemetery
Peterson Butte
Sand Ridge School
Webwood
Rapids
Hamilton Creek School
Hamilton Creek
Substation
Cemetery
Grain Elevator
Gravel Pit
Drive-in Theater
Riding Grounds
Lebanon Airport
Covered Bridge
Bridge
Ferry
Mill
Millpond
Lodgepond
Cr.
Creek
River
Branch
Slough
Ditch
Road
Pacific
Southern Pacific
Santiam Electric
Lacomb Overhead
Private
Jordan
Peters
Knox Butte
Albany
Corvallis
Lebanon Road
Tallman Road
Oregon
Electric
Jefferson Ditch
Marion Ditch
Thomas Creek Ditch
Peters Ditch
Jordan Ditch
Calapooia Ditch
Mill Ditch
Burkhart Creek
Oak Creek
Cedar Creek
Park Creek
Crabtree Creek
Beaver Creek
Carter Creek
Hamilton Creek
Quarry
Cemetery
Bridges
Gravel Pit
Millpond
Lodgepond
Substation
Driveway
Theater
Riding Grounds
Airport
Airport Rd.
Private
Road
Ditch
Creek
River
Branch
Slough
Pacific
Southern Pacific
Santiam Electric
Lacomb Overhead

TEXTURAL SOILS MAP
of the
LEBANON QUADRANGLE
OREGON

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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EXPLANATION

Clay and silty clay: *Severe construction limitations in places because of poor drainage, compressibility, and location in flood prone areas; generally not acceptable for septic tanks owing to low infiltration rates.*

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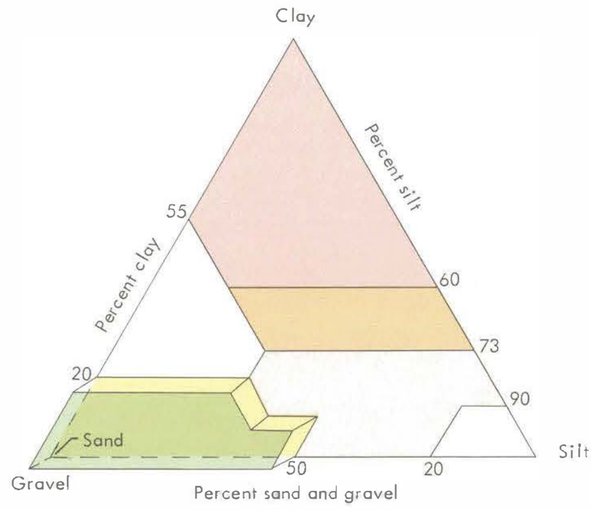
Stony mountainous land: *variable; see Geologic Hazards maps.*

Soils by P. W. Hughes

Cartography by S. R. Renoud and W. H. Pokorny 1974

Soil Classification Diagram

Soils are unconsolidated mixtures of clay, silt, sand, and gravel; textural terminology is based on the relative abundance of these components.



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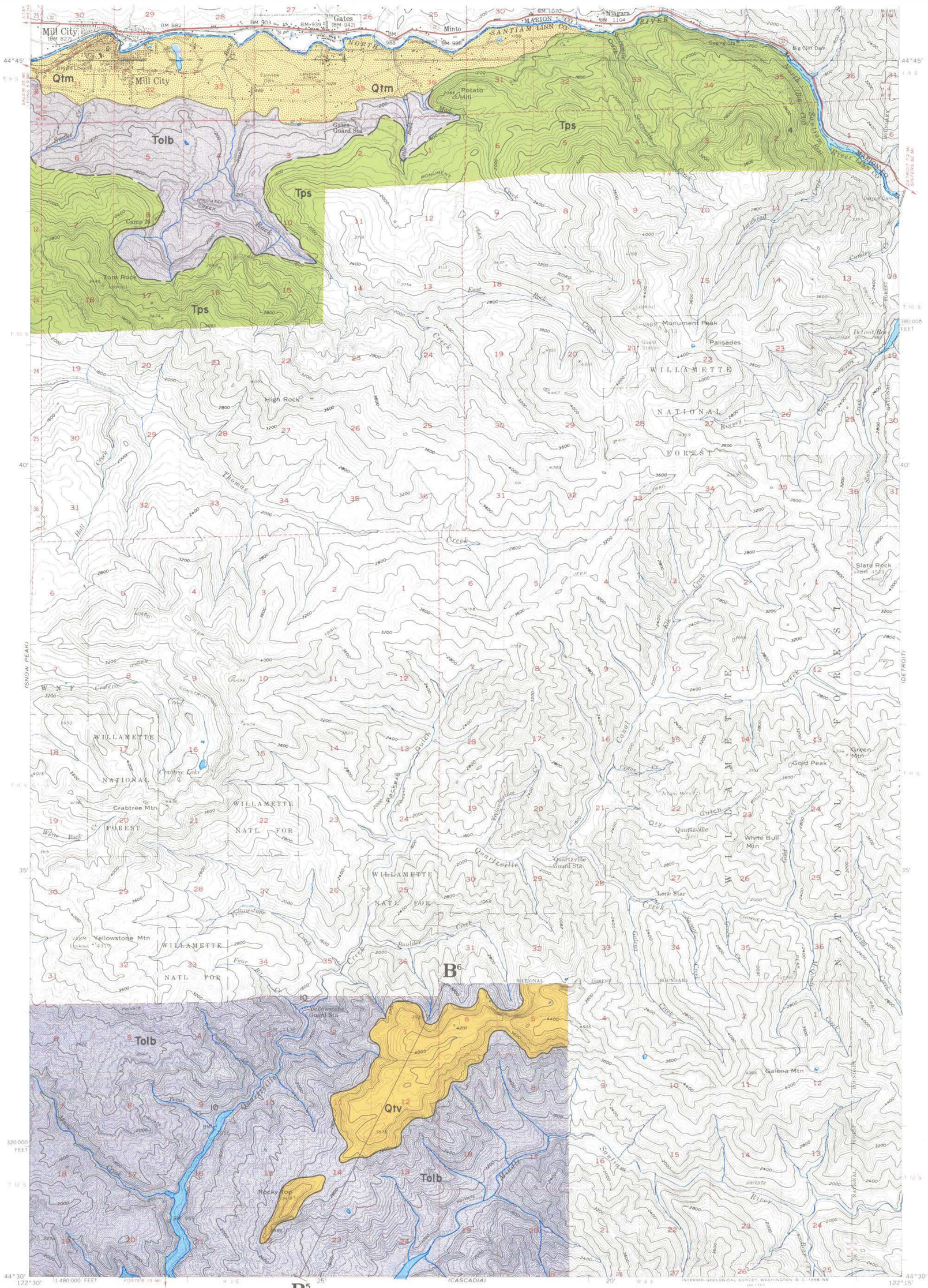
OREGON
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Medium-duty ——— Light-duty ———
Unimproved dirt - - - - - -
U.S. Route State Route

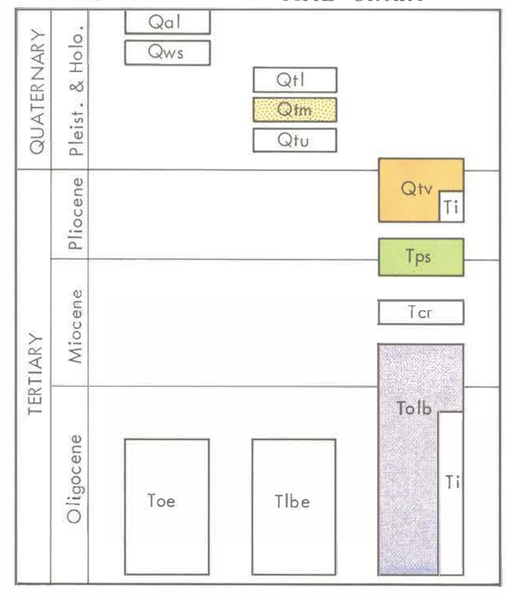
INTERIOR-GEOLOGICAL SURVEY, WASH., D. C.—1959—NS
MR 7501

GEOLOGIC MAP
of the
QUARTZVILLE QUADRANGLE
OREGON

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



STRATIGRAPHIC TIME CHART



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Tolb — Little Butte Formation:
Approximately 10,000 feet of dacitic to andesitic pyroclastic rocks and dense, dark, basaltic flow rock. The pyroclastics are coarsest in the drainage of the middle Santiam and include breccias, tuffs, and ash. Interbeds of continental volcaniclastic sediments are common towards the west.

The basaltic flow rock was erupted from many sources. The numerous buttes of the eastern Willamette Valley represent the exhumed remnants of some of the vents. Scattered small pyroxene phenocrysts typify the basalt.

Parts of the unit (Tlbe) in the west contain interbeds of massive, marine, quartzo-feldspathic sandstone equivalent to the Eugene Formation (Toe) reported in well logs in the Willamette Valley.

Age of the formation is early Oligocene through early Miocene as shown by stratigraphic position and leaf fossils.

Hazards include flash floods in the interior, massive landsliding, and thick clay soils.

Toe — see Tlbe

Ti — Intrusive rock:
Mappable bodies of intrusive basaltic rock within the Little Butte Formation. No feeders for other units are recognized.

Geologic Symbols

Contacts: Rock; Surficial

Folds: Anticline; Syncline

Attitudes: Strike and dip of beds and flows; Horizontal beds and flows

Exploratory Oil Wells: Show of Oil; Dry Hole; Show of Gas

Mines and Quarries

Base Map from U.S. Geological Survey.
Control by USGS, USC&GS and USCE
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1953. Field check 1955–56
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue
Dashed land lines indicate approximate locations
Unchecked elevations are shown in brown

SCALE 1:62500
1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 5 0 1 2 3 4 5 KILOMETERS
CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

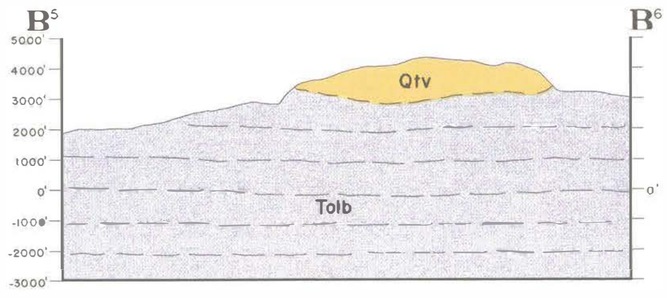
APPROXIMATE MEAN DECLINATION, 1956
20½° EAST
TRUE NORTH
MAGNETIC NORTH

ROAD CLASSIFICATION
Heavy-duty
Medium-duty
Light-duty
Unimproved dirt
State Route

OREGON
QUADRANGLE LOCATION

INTERIOR-GEOLOGICAL SURVEY, WASHINGTON, D. C.-1958-NS

Geologic Cross Section

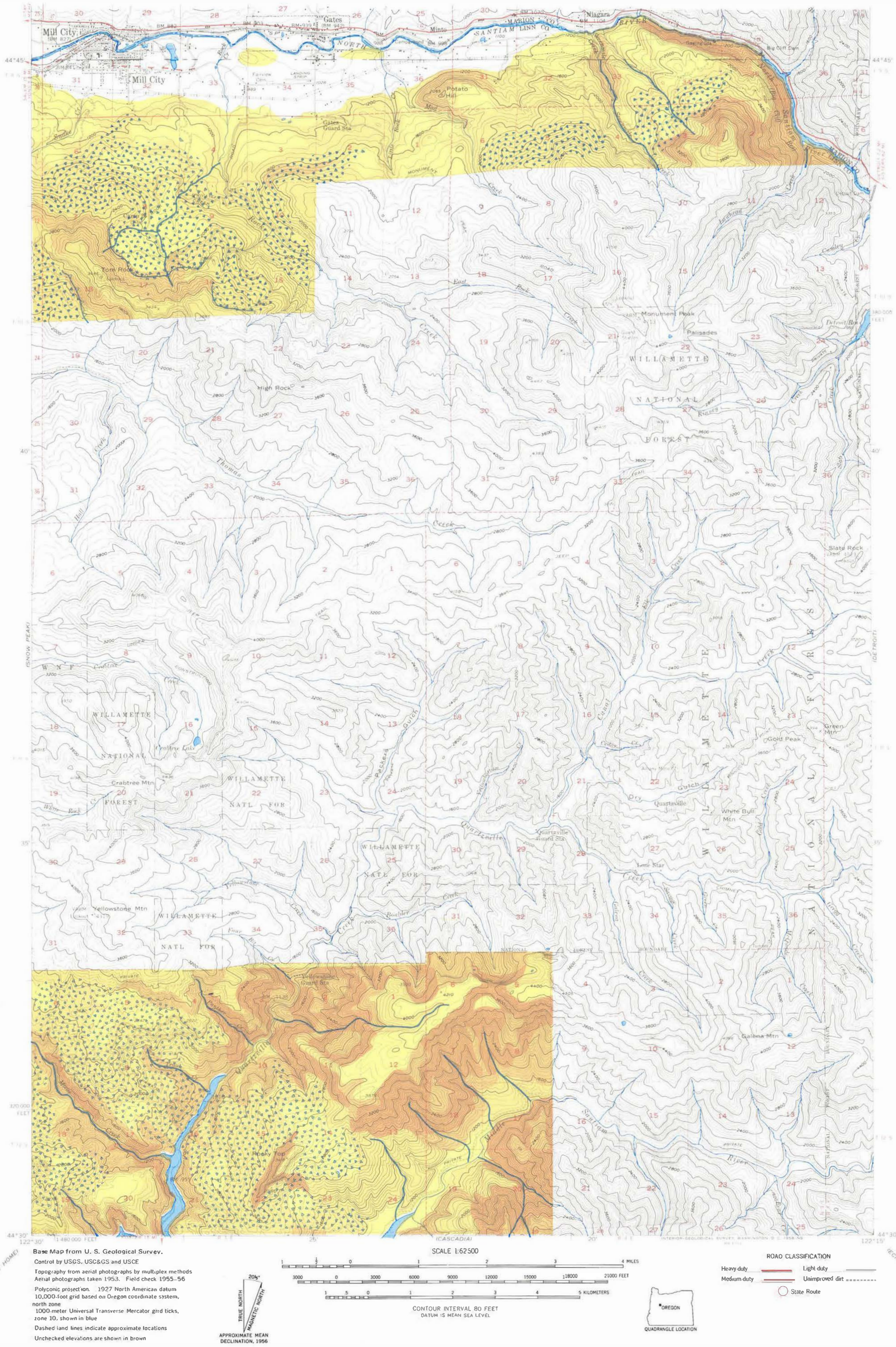


Geology by J. D. Beaulieu

Cartography by S. R. Renoud and W. H. Pokorny 1974

GEOLOGIC HAZARDS MAP
of the
QUARTZVILLE QUADRANGLE
OREGON

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



EXPLANATION

Slope

0-10% — *Willamette Valley lowlands, flood plains of major streams, terrace deposits, and isolated upland areas; hazards may include flooding in drainageways, ponding in depressions, high water table, and poor soils (see Soils map for Willamette Valley area); septic tanks, drain fields, basements, buried tanks, and swimming pools not feasible in many areas; suited to agriculture, industry, recreation, and residential use where hazards are minimal.*

10-25% — *Gentle sloping upland areas, parts of older dissected terraces, and stream channels in the Willamette Valley; chemical weathering predominates in uplands; hazards minimal over Columbia River Basalt; thick clay soils and mass movement in parts of Little Butte Formation; clay soils in Willamette Valley (see Soils map); deep cuts require proper engineering in much of the Little Butte; suited to low density residential development and similar uses.*

25-50% — *Extensive hillslope areas in uplands; includes areas of thick clay soil and mass movement topography in weathered parts of the Lillie Bulte Formation in the lower foothills, thick loam soils overlying slable bedrock in areas underlain by Sardine and Cascades Formations, and some talus along ridges of Columbia River Basalt and fresh exposures of Little Butte Formation; hazards variable; fills. cuts, septic tanks, and deep excavations not feasible or require special engineering in places; suited locally to low-density, highly regulated, properly engineered use, also open space and forestry.*

50-75% — *Exposures of solid bedrock of all volcanic units and thin slopes of steeper talus locally; rapid erosion and minimal chemical weathering and soil formation; hazards include rapid runoff, rockslides, thin debris slides, and flash flooding; potential for development small; cuts and fills for road construction require proper engineering; houses and septic tanks generally not feasible; preservation of vegetative cover needed to minimize erosion.*

> 75% — *Steep bedrock slopes in areas of youthful topography; rapid erosion with little chemical weathering; hazards include rockfall, rockslide, thin debris slides, mudflow, and flash flooding; little potential for development; cuts and fills difficult.*

Lowlands

Intermediate Regional Flood: *Flood (determined by U.S. Army Corps of Engineers) having a 1 percent probability of occurring in any given year. Preventive action includes zoning restrictions on incompatible developments, education of the public, implementation of Federal flood plain insurance program, floodproofing of present structures, and the construction of levees and dikes.*

Standard Project Flood: *Extent of flood (determined by U.S. Army Corps of Engineers) which would be produced under the most extreme hydrologic and meteorologic conditions possible, excluding extremely rare combinations; areas outside this boundary are not subject to flooding through stream overflow, but may be subject to localized ponding of rainwater.*

Estimated possible flooding: *Areas probably subject to flooding but for which no detailed study has been made.*

Stream bank erosion: *Undercutting and caving of river and stream banks commonly accompanied by large scale migration of the river channel; generally characterized by location on the outer bends of sharp curves, bar growth on the opposite bank, and deep water near shore; also inferred on basis of history of past migration, geometry of stream plan, and general knowledge of stream meandering; properly engineered riprap provides local correction for critical areas; other solutions may include zoning, restrictions on construction within given distances of stream bank, and possibly removing sand and gravel from critical bars.*

Abandoned channel: *Length of river or stream channel abandoned through catastrophic channel changes during flooding; commonly the site of stagnation, progressive siltation, marsh growth, and compressible soils; restricted to past and present flood plains of larger rivers, such as Willamette and South Santiam; useful in determining meander history and potential for future stream migration.*

Channel change: *Location of present stream channel acquired by recent progressive meandering through stream bank erosion or truncation of meander bends during floods.*

Taken from U.S.G.S. 7½' Topographic Maps dated 1969 and 1970 and aerial photographs dated 1970. Revisions do not meet National Map Accuracy Standards.

Revetment: *Riprap placed to control stream bank erosion; may lead to increased rates of erosion short distances downstream.*

Uplands

Mass movement topography: *Earthflow terrain characterized locally by irregular to hummocky topography, moderate slopes, irregular drainage, displaced soil, and features of recent movement including cracked ground and bowed trees; failure restricted to soil zone (10 to 30, feet) generally, but penetrates to bedrock in parts of Little Butte Formation, especially below escarpments of resistant cap rock; hazards may include potential for ground movement, poor foundation strength, caving in excavations, and poor drainage; excavations, drainage modifications, removal of vegetation, and use of septic tanks and drain fields may reactivate sliding; on-site investigation recommended for most development; suited to low-density housing in places.*

Headscarp: *Steep slopes of intact bedrock marking the upper limit of a deep slide mass downslope; hazards and limitations are those of shallow failure discussed below.*

Failure on steep slopes (see slopes 4,5): *Hazards include rapid runoff, rockslides, thin debris slides, earthflows and mudflows; frequency of occurrence highest for greatest slopes; steep slopes with thin soil cover particularly sensitive to excavation, placement of fills, and removal of vegetation; potential for development in many areas negligible.*

Flash flood channels: *Small to medium-sized stream channels situated in areas of moderate to steep slope and low permeability; characterized by steep, narrow canyons, lack of flood plain, and very coarse, poorly sorted stream bed deposits; permanent structures generally not feasible, large culverts required under roads crossing channels.*

Base Map from U. S. Geological Survey.
Control by USGS, USC&GS and USCE
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1953. Field check 1955-56
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue
Dashed land lines indicate approximate locations
Unchecked elevations are shown in brown

SCALE 1:62500
1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 5 0 1 2 3 4 5 KILOMETERS
CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

APPROXIMATE MEAN DECLINATION, 1956
20½° EAST
TRUE NORTH
MAGNETIC NORTH

OREGON
QUADRANGLE LOCATION

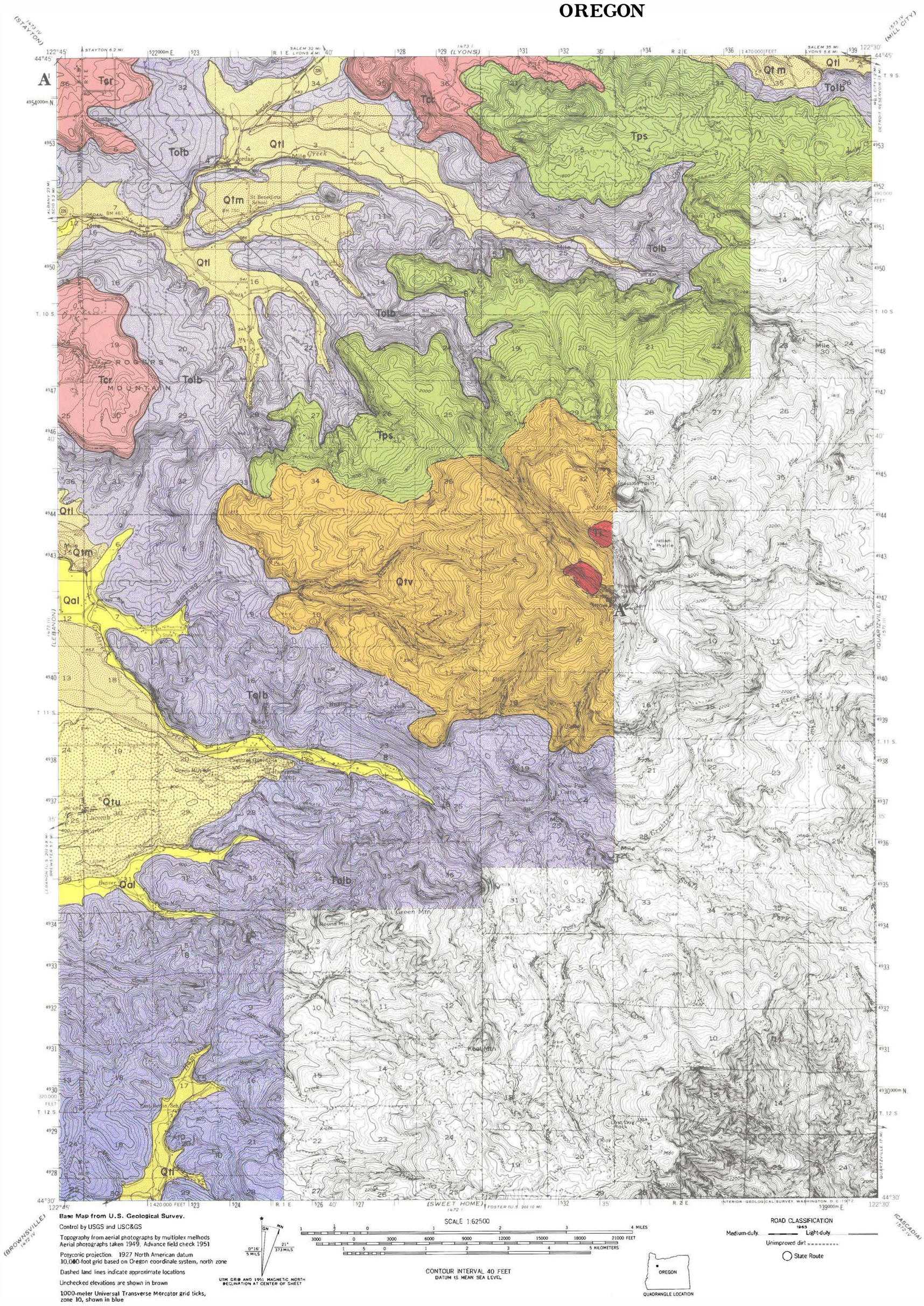
ROAD CLASSIFICATION
Heavy-duty
Medium-duty
Light-duty
Unimproved dirt
State Route

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

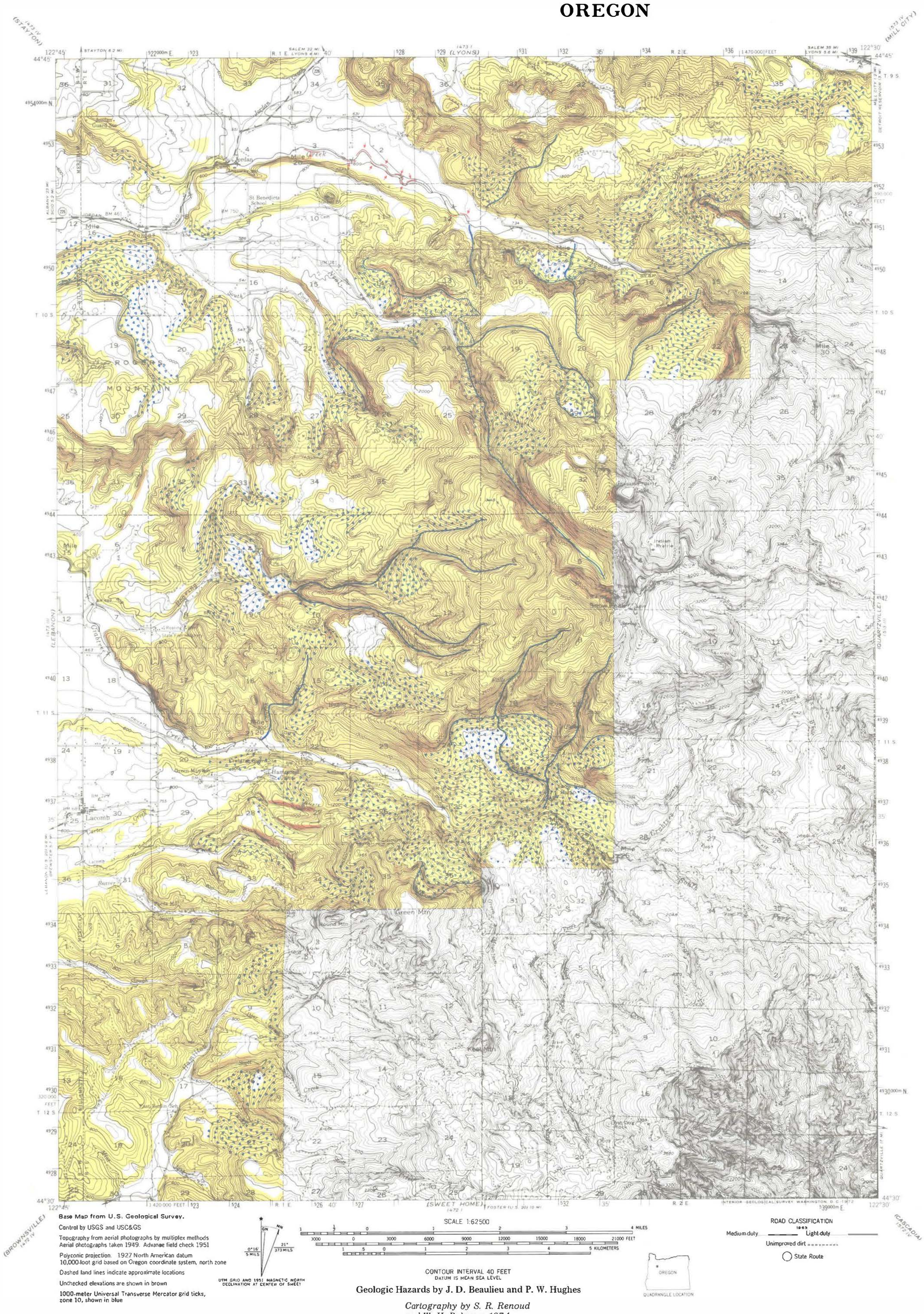
Cartography by S. R. Renoud and W. H. Pokorny 1974

GEOLOGIC MAP
of the
SNOW PEAK QUADRANGLE
OREGON

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

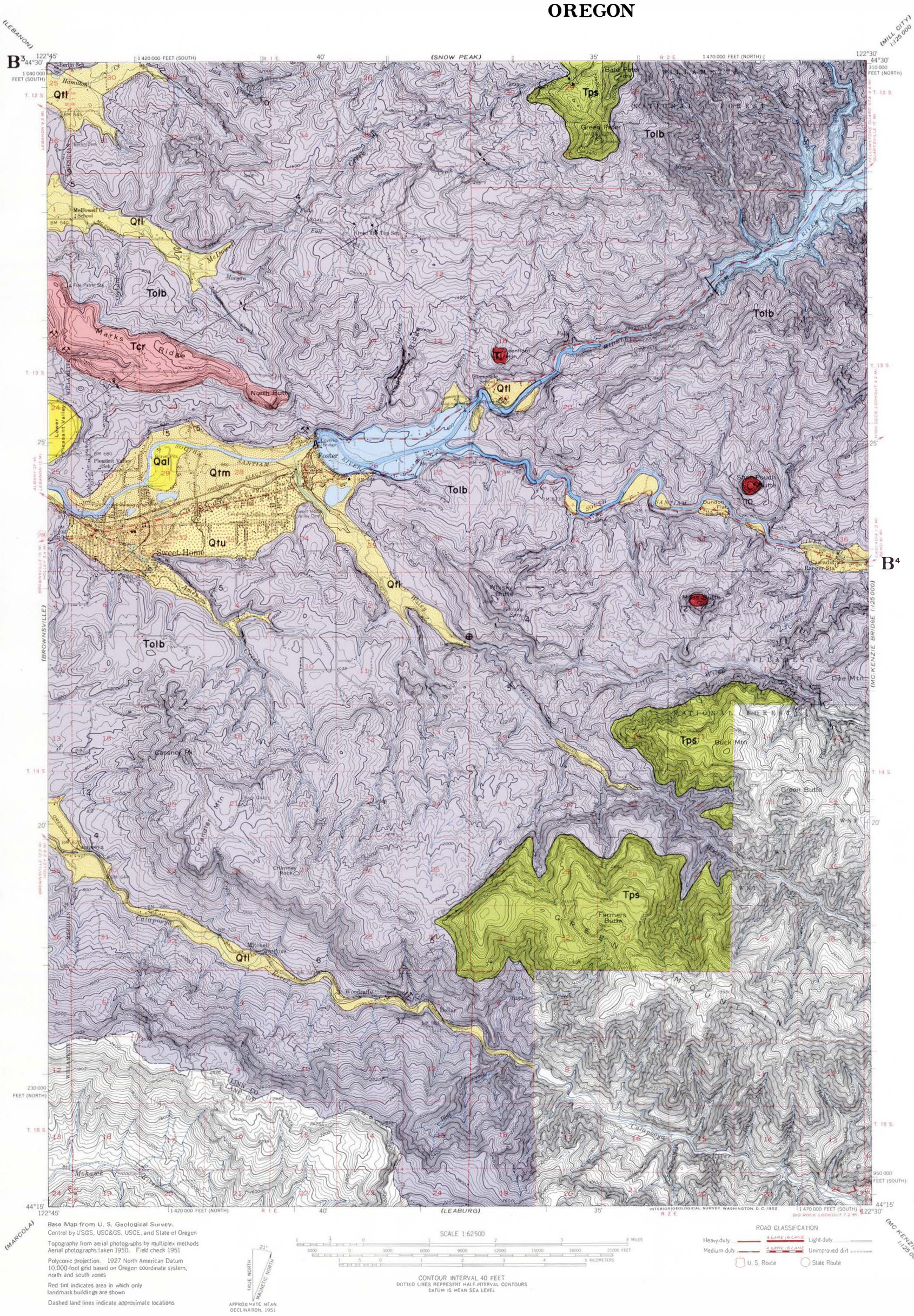

A
A'
Tcr
Tolb
Tps
Qtv
Qtm
Qtl
Qal
Qtu
Ti
Toe
Tlbe
ROGERS MOUNTAIN
Jordan Creek
Mile Creek
South Santiam River
Green Mtn
Round Mtn
Indian Prairie
Lacomb
Beaver Creek
Hamilton Creek
Hogg Rock
Snow Peak Camp
St. Benedicts School
Jordan Dam
Jordan Guard Station
Peterson Guard Station
Hamilton Camp
East Benton Sch.
Lost Dog Rock
Thirty Three Prairie
Indian Prairie
Mile Prairie
Green Mtn Trail
Mile Trail
Mile Creek Trail
Mile Ridge
Mile Creek
Mile Creek Ridge
Mile Creek Rock
Mile Creek Rock
Mile Creek Rock

GEOLOGIC HAZARDS MAP
of the
SNOW PEAK QUADRANGLE
OREGON

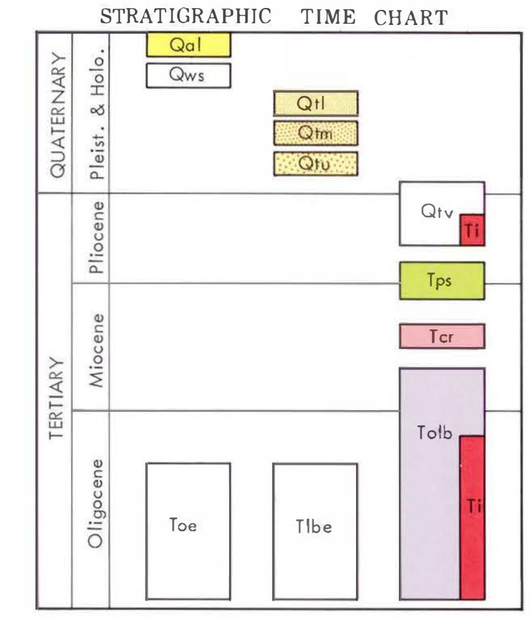

(STAYTON) 1473 IV
(MILL CITY) 1473 IV
122°45'
122°30'
44°45'
44°30'
R. 1 E.
R. 2 E.
T. 9 S.
T. 10 S.
T. 11 S.
T. 12 S.
STAYTON 6.2 MI.
SALEM 32 MI.
LYONS 4 MI.
SALEM 35 MI.
LYONS 5.6 MI.
MILL CITY 12 MI.
DETROIT RESERVOIR 13 MI.
ALBANY 23 MI.
LEBANON 12 MI.
(LYONS) 1473 I
(SWEET HOME) 1472 I
(LEBANON) 1472 IV
(BROWNSVILLE) 1472 IV
(QUARTZVILLE) 1571 IV
(CASCADIA) 1572 IV
FOSTER (U.S. 20) 10 MI.
420 000 FEET
1 470 000 FEET
522 000m E.
539 000m E.
4954 000m N.
4930 000m N.
320 000 FEET
Jordan
Mile Creek
St Benedicta School
Thomas
South Fork
ROGERS MOUNTAIN
Lacomb
Green Mtn
Round Mtn
Indian Prairie
Hungry Creek
Gradner
Hamilton Creek
Hoover
Quartzville
Foster
Lacomb
Butter
Green-Myrtle
Hamilton Creek
Hoosing Forest
State Fish Hatchery
Gradner
Quartzville
East Butte Sch.
Foster
Sweet Home
Mile
Creek
Slough
Ditch
Canal
Dam
Camp
Ranch
Cem
Sch
BM 461
BM 750
BM 1281
BM 1710
BM 1763
BM 1767
BM 1768
BM 1769
BM 1770
BM 1771
BM 1772
BM 1773
BM 1774
BM 1775
BM 1776
BM 1777
BM 1778
BM 1779
BM 1780
BM 1781
BM 1782
BM 1783
BM 1784
BM 1785
BM 1786
BM

GEOLOGIC MAP
of the
SWEET HOME QUADRANGLE
OREGON

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



STRATIGRAPHIC TIME CHART



Surficial Deposits

Qal — Quaternary alluvium:

A few tens of feet of gravel, sand, and silt along major streams, and thin veneers of silt and clay lining the smaller streams of the Willamette Valley. Hazards include flooding, stream meandering, and siltation.

Qws — Willamette silts:

Up to 20 to 30 feet of faintly bedded, quartzo-feldspathic silts, silty clays, and clays of lacustrine and glacial flood-water origin. Surficial erratics and heavy minerals indicate Columbia River source. Carbon-14 dating reveals an age of 19,000 to 34,000+ years. Hazards include poor drainage, ponding, and low permeability in places.

Qtl — Quaternary lower terrace:

A maximum of 50 feet of fluvial pebble gravel, sand, and clay, along the South Santiam River, in the subsurface of the Willamette Valley and in the larger valleys of the foothills area. Also includes terrace gravels along the smaller streams. Equivalent in part to the Linn gravels of Allison (1953). Early Wisconsin or Illinoisian (late Pleistocene) in age. Poor drainage, ponding, and high water table locally.

Qtm — Quaternary middle terrace:

Moderately dissected deposits of pebble gravel, sand, silt, and clay of fluvial origin overlooking younger lower terraces (Qtl). Equivalent in part to the Leffler gravels of Allison (1953). Elevations vary from 245 feet in west to 500 feet in east. Kansan (middle Pleistocene) in age. Deep weathering produces clay-rich soils.

Qtu — Quaternary upper terrace:

Deeply dissected remnants of a high, level gravel fan equivalent to the Lacomb gravels of Allison (1953). Maximum thickness 100 to 150 feet. Maximum elevation 865 feet. Early Pleistocene in age.

Stratigraphic Units

Qtv — Cascades formation:

Light- to medium-gray porphyritic flow andesite, basalt, and breccias forming a deeply dissected cone at Snow Peak and an intracanyon flow with reversed topography in the middle Santiam drainage. Maximum thickness approximately 3,000 feet. Late Pliocene to early Pleistocene in age. Hazards include steep slopes, rockfall, and flash floods.

Tps — Sardine formation:

Up to 1,500 feet of massive to platy hypersthene andesite and basalt unconformable beneath the Cascades Formation and overlying Columbia River Basalt. Late Miocene to early Pliocene in age. Hazards include flash flooding and rockfall.

Tcr — Columbia River Basalt

Several hundred feet of dense, dark, very fine-grained flow basalt capping the ridges of northern Linn County. Also includes basalt of Marks Ridge. Columnar jointing is universal. Plagioclase phenocrysts are present locally; pyroxene phenocrysts are absent or very rare. Middle Miocene in age. Weathers to a red loamy soil. Undercut by massive slides on steep slopes.

Tolb / **Tlbe** — Little Butte Formation:

Approximately 10,000 feet of dacitic to andesitic pyroclastic rocks and dense, dark, basaltic flow rock. The pyroclastics are coarsest in the drainage of the middle Santiam and include breccias, tuffs, and ash. Interbeds of continental volcaniclastic sediments are common towards the west.

The basaltic flow rock was erupted from many sources. The numerous buttes of the eastern Willamette Valley represent the exhumed remnants of some of the vents. Scattered small pyroxene phenocrysts typify the basalt.

Parts of the unit (Tlbe) in the west contain interbeds of massive, marine, quartzo-feldspathic sandstone equivalent to the Eugene Formation (Toe) reported in well logs in the Willamette Valley.

Age of the formation is early Oligocene through early Miocene as shown by stratigraphic position and leaf fossils.

Hazards include flash floods in the interior, massive landsliding, and thick clay soils.

Toe —

Ti — Intrusive rock:

Mappable bodies of intrusive basaltic rock within the Little Butte Formation. No feeders for other units are recognized.

Geologic Symbols

Contacts: Rock; Surficial

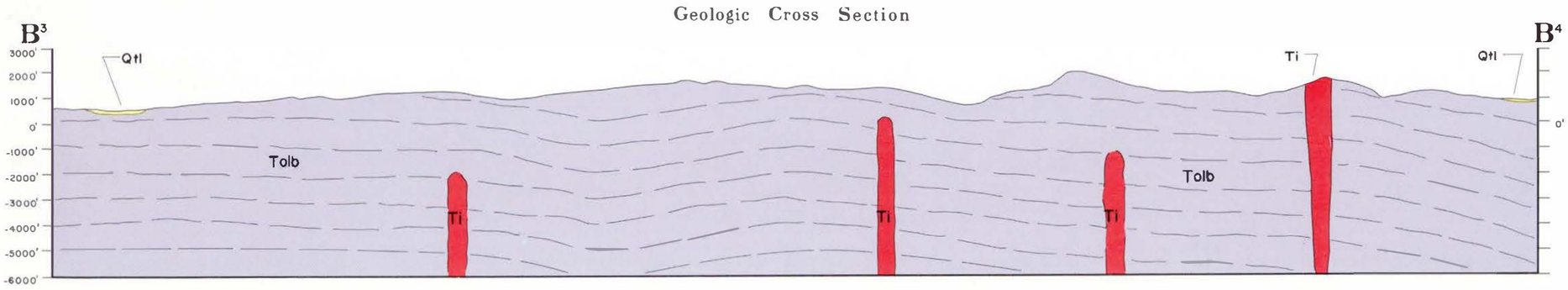
Folds: Anticline; Syncline

Attitudes: Strike and dip of Beds and flows; Horizontal beds and flows

Exploratory Oil Wells: Show of Oil; Dry Hole; Show of Gas

Mines and Quarries

Geologic Cross Section

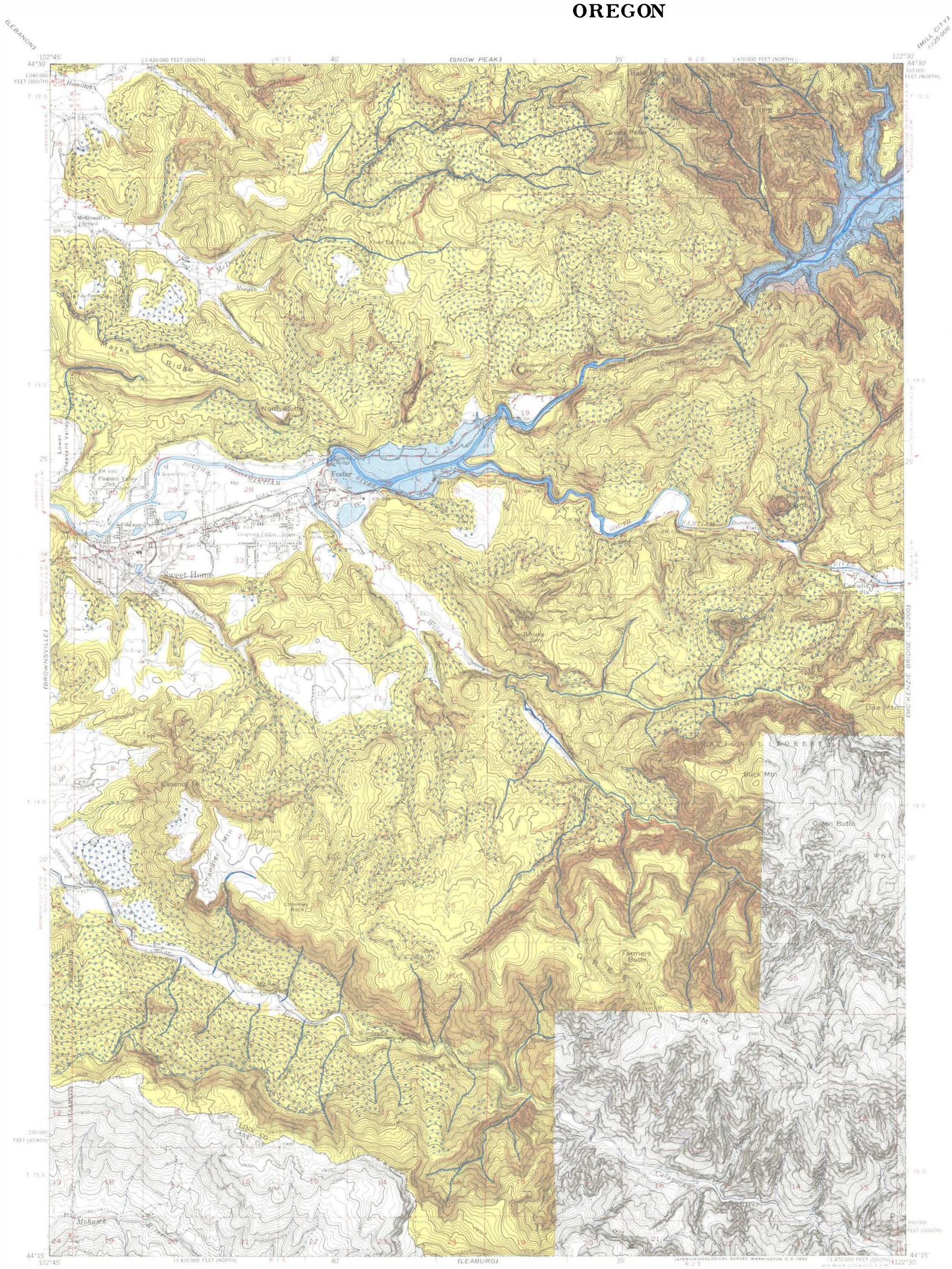


Geology by J. D. Beaulieu

Cartography by S. R. Renoud and W. H. Pokorny 1974

GEOLOGIC HAZARDS MAP
of the
SWEET HOME QUADRANGLE
OREGON

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



EXPLANATION

Slope

0-10% — *Willamette Valley lowlands, flood plains of major streams, terrace deposits, and isolated upland areas; hazards may include flooding in drainageways, ponding in depressions, high water table, and poor soils (see Soils map for Willamette Valley area); septic tanks, drain fields, basements, buried tanks, and swimming pools not feasible in many areas; suited to agriculture, industry, recreation, and residential use where hazards are minimal.*

10-25% — *Gentle sloping upland areas, parts of older dissected terraces, and stream channels in the Willamette Valley; chemical weathering predominates in uplands; hazards minimal over Columbia River Basalt; thick clay soils and mass movement in parts of Lillie Butte Formation; clay soils in Willamette Valley (see Soils map); deep cuts require proper engineering in much of the Lillie Butte; suited to low density residential development and similar uses.*

25-50% — *Extensive hillslope areas in uplands; includes areas of thick clay soil and mass movement topography in weathered parts of the Lillie Butte Formation in the lower foothills, thick loam soils overlying stable bedrock in areas underlain by Sardine and Cascades Formations, and some talus along ridges of Columbia River Basalt and fresh exposures of Lillie Butte Formation; hazards variable; fills, cuts, septic tanks, and deep excavations not feasible or require special engineering in places; suited locally to low-density, highly regulated, properly engineered use, also open space and forestry.*

50-75% — *Exposures of solid bedrock of all volcanic units and thin slopes of steeper talus locally; rapid erosion and minimal chemical weathering and soil formation; hazards include rapid runoff, rockslides, thin debris slides, and flash flooding; potential for development small; cuts and fills for road construction require proper engineering; houses and septic tanks generally not feasible; preservation of vegetative cover needed to minimize erosion.*

> 75% — *Steep bedrock slopes in areas of youthful topography; rapid erosion with little chemical weathering; hazards include rockfall, rockslide, thin debris slides, mudflow, and flash flooding; little potential for development; cuts and fills difficult.*

Lowlands

Intermediate Regional Flood: *Flood (determined by U.S. Army Corps of Engineers) having a 1 percent probability of occurring in any given year. Preventive action includes zoning restrictions on incompatible developments, education of the public, implementation of Federal flood plain insurance program, floodproofing of present structures, and the construction of levees and dikes.*

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Abandoned channel: *Length of river or stream channel abandoned through catastrophic channel changes during flooding; commonly the site of stagnation, progressive siltation, marsh growth, and compressible soils; restricted to past and present flood plains of larger rivers, such as Willamette and South Santiam; useful in determining meander history and potential for future stream migration.*

Channel change: *Location of present stream channel acquired by recent progressive meandering through stream bank erosion or truncation of meander bends during floods.*

Taken from U.S.G.S. 7½' Topographic Maps dated 1969 and 1970 and aerial photographs dated 1970. Revisions do not meet National Map Accuracy Standards.

Revetment: *Riprap placed to control stream bank erosion; may lead to increased rates of erosion short distances downstream.*

Uplands

Mass movement topography: *Earthflow terrain characterized locally by irregular to hummocky topography, moderate slopes, irregular drainage, displaced soil, and features of recent movement including cracked ground and bowed trees; failure restricted to soil zone (10 to 30 feet) generally, but penetrates to bedrock in parts of Little Butte Formation, especially below escarpments of resistant cap rock; hazards may include potential for ground movement, poor foundation strength, caving in excavations, and poor drainage; excavations, drainage modifications, removal of vegetation, and use of septic tanks and drain fields may reactivate sliding; on-site investigation recommended for most development; suited to low-density housing in places.*

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Failure on steep slopes (see slopes 4,5): *Hazards include rapid runoff, rockslides, thin debris slides, earthflows and mudflows; frequency of occurrence highest for greatest slopes; steep slopes with thin soil cover particularly sensitive to excavation, placement of fills, and removal of vegetation; potential for development in many areas negligible.*

Flash flood channels: *Small to medium-sized stream channels situated in areas of moderate to steep slope and low permeability; characterized by steep, narrow canyons, lack of flood plain, and very coarse, poorly sorted stream bed deposits; permanent structures generally not feasible; large culverts required under roads crossing channels.*

Base Map from U. S. Geological Survey.
Control by USGS, USC&GS, USCE, and State of Oregon
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1950. Field check 1951
Polyconic projection. 1927 North American Datum
10,000-foot grid based on Oregon coordinate system, north and south zones
Red tint indicates area in which only landmark buildings are shown
Dashed land lines indicate approximate locations

21° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1951

SCALE 1:62500
1 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 5 0 1 2 3 4 5 KILOMETERS
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT HALF-INTERVAL CONTOURS
DATUM IS MEAN SEA LEVEL

ROAD CLASSIFICATION
Heavy-duty — 4 LANE; 6 LANE
Medium-duty — 4 LANE; 6 LANE
Light-duty
Unimproved dirt
U.S. Route
State Route

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

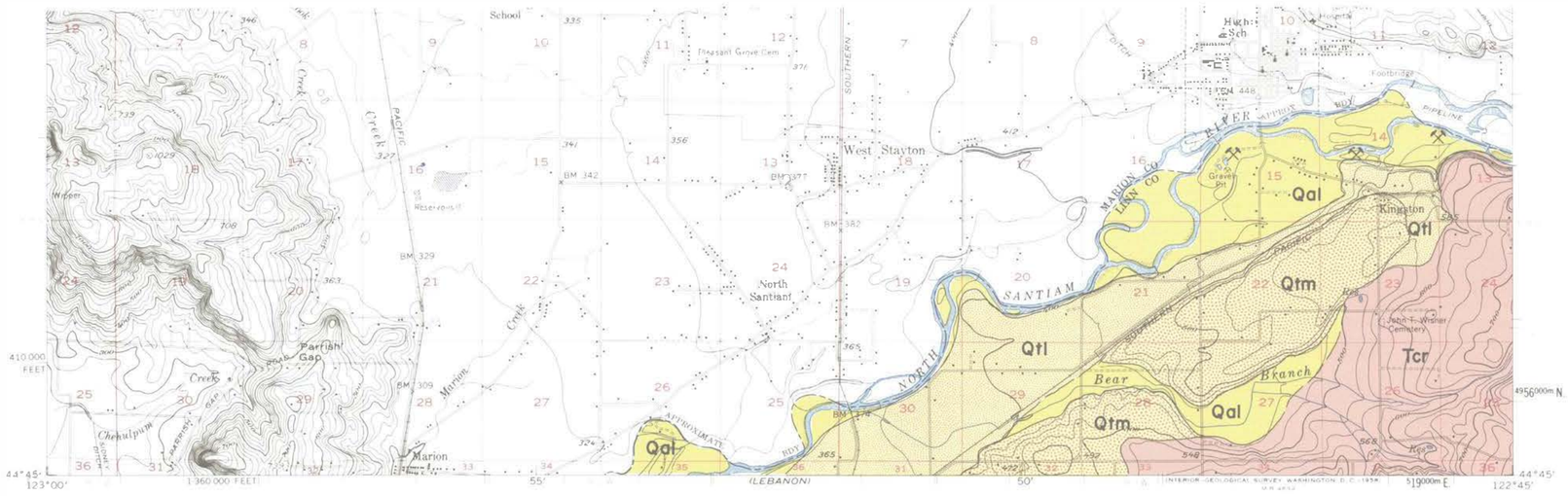
Cartography by S. R. Renoud and W. H. Pokorny 1974

Bulletin 84

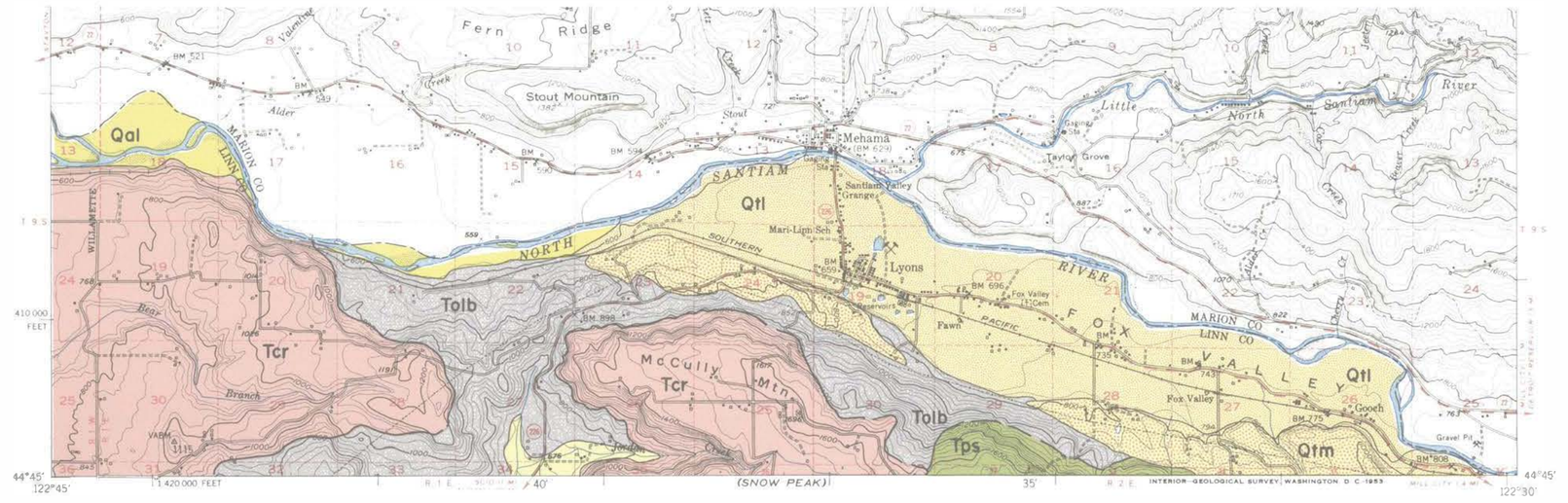
GEOLOGIC MAP
of parts of the
STAYTON, LYONS, MARCOLA & EUGENE QUADRANGLES
OREGON

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

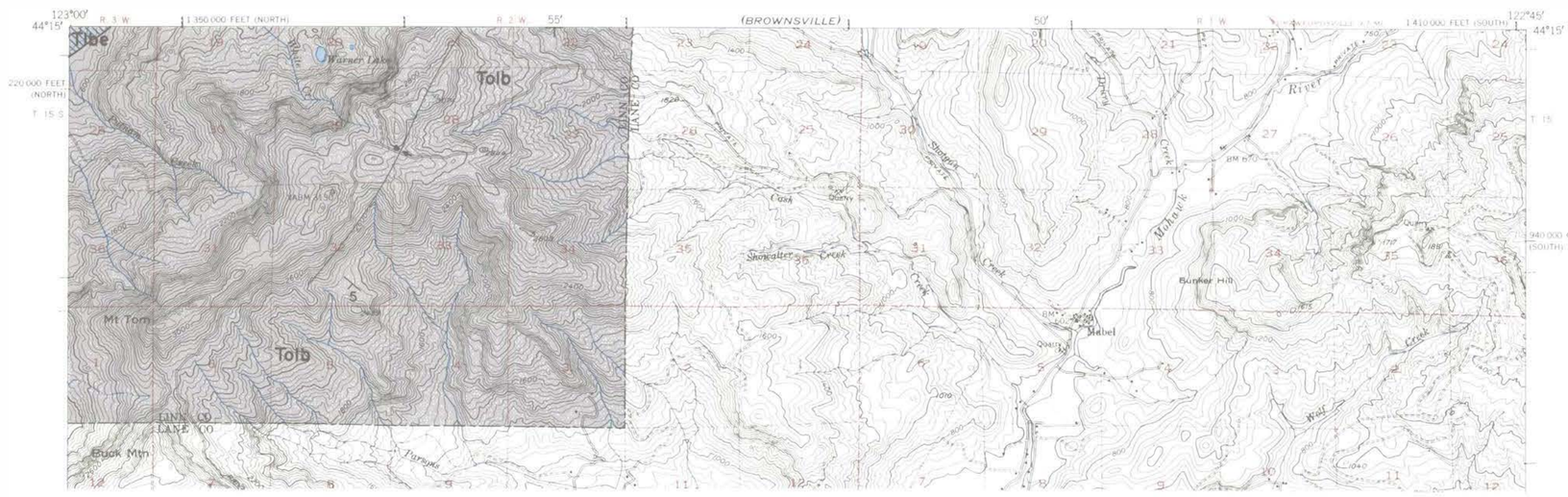
STAYTON



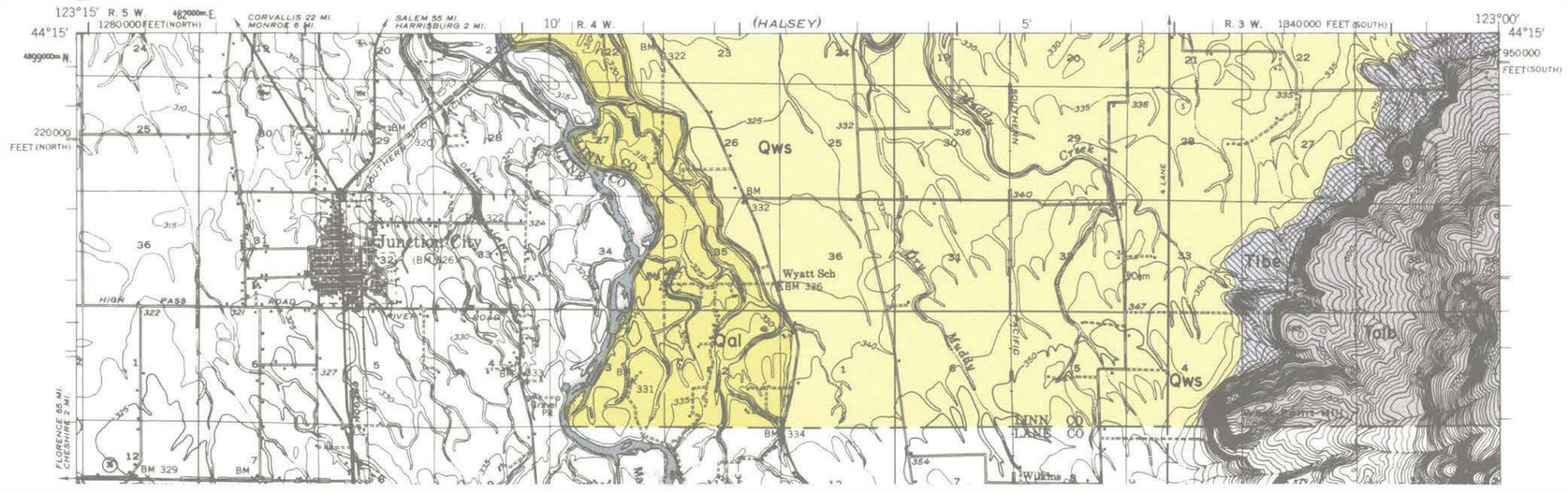
LYONS



MARCOLA



EUGENE



Base Map from U. S. Geological Survey.

Topography by planetable surveys 1942
Culture revised from aerial photographs taken 1952
Field check 1956

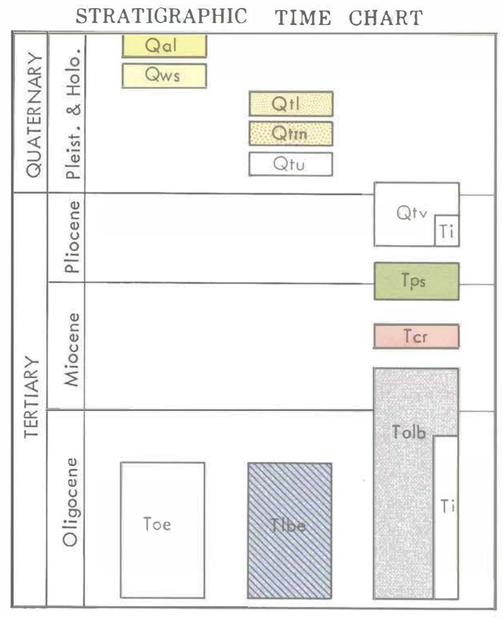
Polyconic projection. 1927 North American datum
10,000-foot grids based on Oregon coordinate system, north and south zones
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

APPROXIMATE MEAN DECLINATION, 1956

SCALE 1:62500

ROAD CLASSIFICATION
Heavy duty — Light duty
Medium duty — Unimproved dirt

STRATIGRAPHIC TIME CHART



Surficial Deposits

Qal — **Quaternary alluvium:**
A few lens of feet of gravel, sand, and silt along major streams, and thin veneers of silt and clay lining the smaller streams of the Willamette Valley. Hazards include flooding, stream meandering, and siltation.

Qws — **Willamette silts:**
Up to 20 to 30 feet of faintly bedded, quartzo-feldspathic silts, silty clays, and clays of lacustrine and glacial flood-water origin. Surficial erratics and heavy minerals indicate Columbia River source. Carbon-14 dating reveals an age of 19,000 to 34,000+ years. Hazards include poor drainage, ponding, and low permeability in places.

Qtl — **Quaternary lower terrace:**
A maximum of 50 feet of fluvial pebble gravel, sand, and clay, along the South Santiam River, in the subsurface of the Willamette Valley and in the larger valleys of the foothills area. Also includes terrace gravels along the smaller streams. Equivalent in part to the Linn gravels of Allison (1953). Early Wisconsin or Illinoisian (late Pleistocene) in age. Poor drainage, ponding, and high water table locally.

Qtm — **Quaternary middle terrace:**
Moderately dissected deposits of pebble gravel, sand, silt, and clay of fluvial origin overlooking younger lower terraces (Qtl). Equivalent in part to the Leffler gravels of Allison (1953). Elevations vary from 245 feet in west to 500 feet in east. Kansan (middle Pleistocene) in age. Deep weathering produces clay-rich soils.

Qtu — **Quaternary upper terrace:**
Deeply dissected remnants of a high level gravel fan equivalent to the Lacomb gravels of Allison (1953). Maximum thickness 100 to 150 feet. Maximum elevation 865 feet, Early Pleistocene in age.

Stratigraphic Units

Qtv — **Cascades formation:**
Light- to medium-gray porphyritic flow andesite, basalt, and breccias forming a deeply dissected cone at Snow Peak and an intracanyon flow with reversed topography in the middle Santiam drainage. Maximum thickness approximately 3,000 feet. Late Pliocene to early Pleistocene in age. Hazards include steep slopes, rockfall, and flash floods.

Tps — **Sardine formation:**
Up to 1,500 feet of massive to platy hypersthene andesite and basalt unconformable beneath the Cascades Formation and overlying Columbia River Basalt. Late Miocene to early Pliocene in age. Hazards include flash flooding and rockfall.

Tcr — **Columbia River Basalt**
Several hundred feet of dense, dark, very fine-grained flow basalt capping the ridges of northern Linn County. Also includes basalt of Marks Ridge. Columnar jointing is universal. Plagioclase phenocrysts are present locally; pyroxene phenocrysts are absent or very rare. Middle Miocene in age. Weathers to a red loamy soil. Undercut by massive slides on steep slopes.

Tolb / **Tlbe** — **Little Butte Formation:**
Approximately 10,000 feet of dacitic to andesitic pyroclastic rocks and dense, dark, basaltic flow rock. The pyroclastics are coarsest in the drainage of the middle Santiam and include breccias, tuffs, and ash. Interbeds of continental volcaniclastic sediments are common towards the west.
The basaltic flow rock was erupted from many sources. The numerous buttes of the eastern Willamette Valley represent the exhumed remnants of some of the vents. Scattered small pyroxene phenocrysts typify the basalt.
Parts of the unit (Tlbe) in the west contain interbeds of massive, marine, quartzo-feldspathic sandstone equivalent to the Eugene Formation (Toe) reported in welllogs in the Willamette Valley.
Age of the formation is early Oligocene through early Miocene as shown by stratigraphic position and leaf fossils.
Hazards include flash floods in the interior, massive landsliding, and thick clay soils.

Toe — **Eugene Formation:**
Marine, quartzo-feldspathic sandstone and siltstone, commonly micaceous and carbonaceous. Contains abundant fossil plants and marine invertebrates. Thickness 1,000 feet. Early Oligocene in age. Hazards include landsliding and thick clay soils.

Ti — **Intrusive rock:**
Mappable bodies of intrusive basaltic rock within the Little Butte Formation. No feeders for other units are recognized.

Geologic Symbols

Contacts: Rock; Surficial
Folds: Anticline; Syncline
Attitudes: Strike and dip of Beds and flows; Horizontal beds and flows
Exploratory Oil Wells: Show of Oil; Dry Hole; Show of Gas
Mines and Quarries

Geology by J. D. Beaulieu

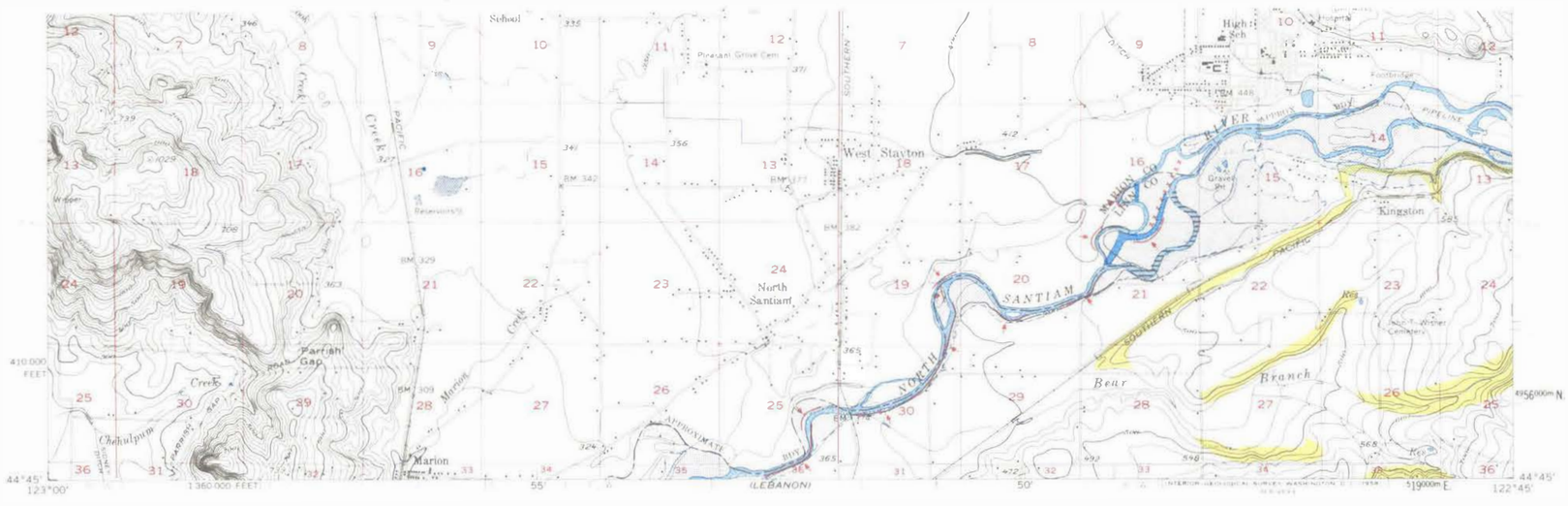
Cartography by S. R. Renoud and W. H. Pokorny 1974

Bulletin 84

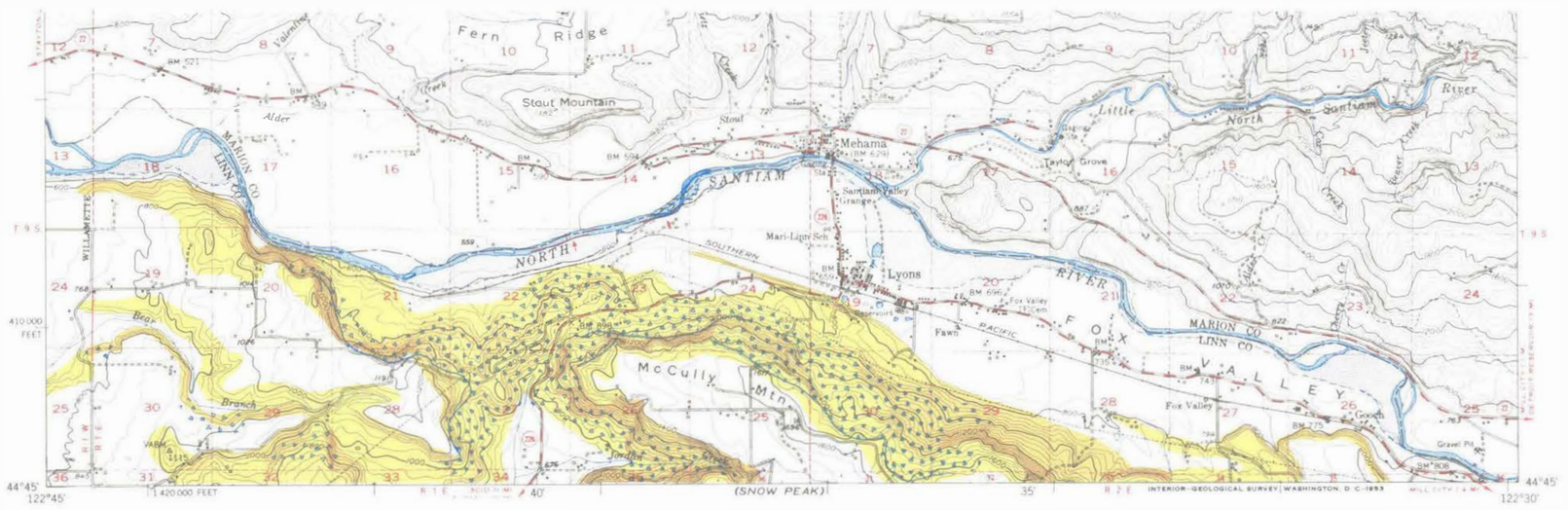
GEOLOGIC HAZARDS MAPS
of parts of the
STAYTON, LYONS, MARCOLA & EUGENE QUADRANGLES
OREGON

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

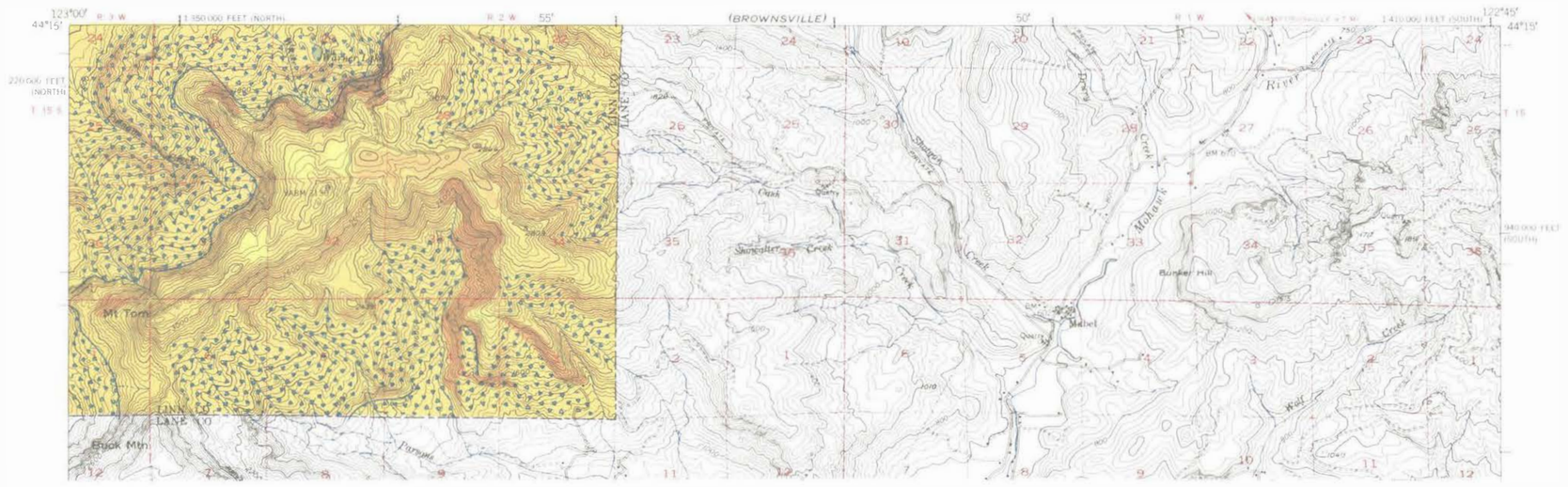
STAYTON



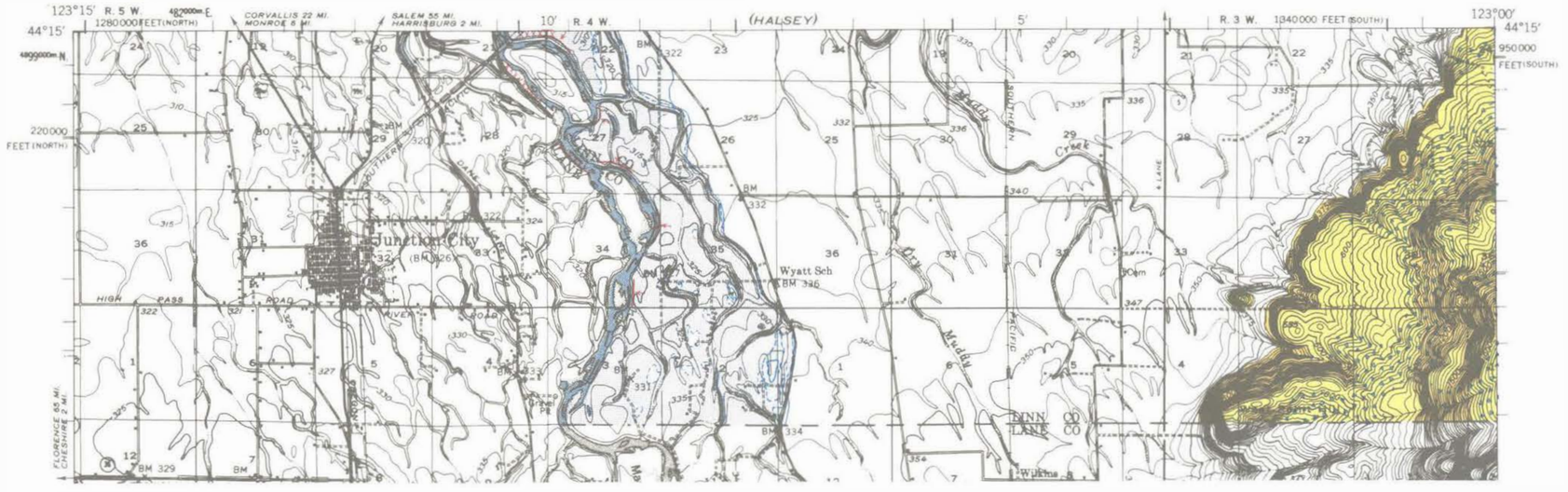
LYONS



MARCOLA



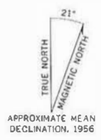
EUGENE



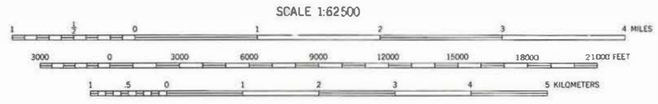
Base Map from U. S. Geological Survey.

Topography by plantetable surveys 1942
Culture revised from aerial photographs taken 1952
Field check 1956

Polyconic projection. 1927 North American datum
10,000-foot grids based on Oregon coordinate system, north and south zones
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue



SCALE 1:62500



ROAD CLASSIFICATION

Heavy-duty
Medium-duty
Light-duty
Unimproved dirt

EXPLANATION

Slope

0-10% — *Willamette Valley lowlands, flood plains of major streams, terrace deposits, and isolated upland areas; hazards may include flooding in drainageways, ponding in depressions, high water table, and poor soils (see Soils map for Willamette Valley area); septic tanks, drain fields, basements, buried tanks, and swimming pools not feasible in many areas; suited to agriculture, industry, recreation, and residential use where hazards are minimal.*

10-25% — *Gentle sloping upland areas, parts of older dissected terraces, and stream channels in the Willamette Valley; chemical weathering predominates in uplands; hazards minimal over Columbia River Basalt; thick clay soils and mass movement in parts of Little Butte Formation; clay soils in Willamette Valley (see Soils map); deep cuts require proper engineering in much of the Little Butte; suited to low density residential development and similar uses.*

25-50% — *Extensive hillslope areas in uplands; includes areas of thick clay soil and mass movement topography in weathered parts of the Little Butte Formation in the lower foothills, thick loam soils overlying stable bedrock in areas underlain by Sardine and Cascades Formations, and some talus along ridges of Columbia River Basalt and fresh exposures of Little Butte Formation; hazards variable; fills, cuts, septic tanks, and deep excavations not feasible or require special engineering in places; suited locally to low-density, highly regulated, properly engineered use, also open space and forestry.*

50-75% — *Exposures of solid bedrock of all volcanic units and thin slopes of sleeper talus locally; rapid erosion and minimal chemical weathering and soil formation; hazards include rapid runoff, rockslides, thin debris slides, and flash flooding; potential for development small; cuts and fills for road construction require proper engineering; houses and septic tanks generally not feasible; preservation of vegetative cover needed to minimize erosion.*

>75% — *Sleep bedrock slopes in areas of youthful topography; rapid erosion with little chemical weathering; hazards include rockfall, rockslide, thin debris slides, mudflow, and flash flooding; little potential for development; cuts and fills difficult.*

Lowlands

Intermediate Regional Flood: *Flood (determined by U.S. Army Corps of Engineers) having a 1 percent probability of occurring in any given year. Preventive action includes zoning restrictions on incompatible developments, education of the public, implementation of Federal flood plain insurance program, floodproofing of present structures, and the construction of levees and dikes.*

Standard Project Flood: *Extent of flood (determined by U.S. Army Corps of Engineers) which would be produced under the most extreme hydrologic and meteorologic conditions possible, excluding extremely rare combinations; areas outside this boundary are not subject to flooding through stream overflow, but may be subject to localized ponding of rainwater.*

Estimated possible flooding: *Areas probably subject to flooding but for which no detailed study has been made.*

Stream bank erosion: *Underculting and caving of river and stream banks commonly accompanied by large scale migration of the river channel; generally characterized by location on the outer bends of sharp curves, bar growth on the opposite bank, and deep water near shore; also inferred on basis of history of past migration, geometry of stream plan, and general knowledge of stream meandering; properly engineered riprap provides local correction for critical areas; other solutions may include zoning, restrictions on construction within given distances of stream bank, and possibly removing sand and gravel from critical bars.*

Abandoned channel: *Length of river or stream channel abandoned through catastrophic channel changes during flooding; commonly the site of stagnation, progressive siltation, marsh growth, and compressible soils; restricted to past and present flood plains of larger rivers, such as Willamette and South Santiam; useful in determining meander history and potential for future stream migration.*

Channel change: *Location of present stream channel acquired by recent progressive meandering through stream bank erosion or truncation of meander bends during floods.*

Taken from U.S.G.S. 7½' Topographic Maps dated 1969 and 1970 and aerial photographs dated 1970. Revisions do not meet National Map Accuracy Standards.

Revetment: *Riprap placed to control stream bank erosion; may lead to increased rates of erosion short distances downstream.*

Uplands

Mass movement topography: *Earthflow terrain characterized locally by irregular to hummocky topography, moderate slopes, irregular drainage, displaced soil, and features of recent movement including cracked ground and bowed trees; failure restricted to soil zone (10 to 30 feet) generally, but penetrates to bedrock in parts of Little Butte Formation, especially below escarpments of resistant cap rock; hazards may include potential for ground movement, poor foundation strength, caving in excavations, and poor drainage; excavations, drainage modifications, removal of vegetation, and use of septic tanks and drain fields may reactivate sliding; on-site investigation recommended for most development; suited to low-density housing in places.*

Headscarp: *Steep slopes of intact bedrock marking the upper limit of a deep slide mass downslope; hazards and limitations are those of shallow failure discussed below.*

Failure on steep slopes (see slopes 4,5): *Hazards include rapid runoff, rockslides, thin debris slides, earthflows and mudflows; frequency of occurrence highest for greatest slopes; steep slopes with thin soil cover particularly sensitive to excavation, placement of fills, and removal of vegetation; potential for development in many areas negligible.*

Flash flood channels: *Small to medium-sized stream channels situated in areas of moderate to steep slope and low permeability; characterized by steep, narrow canyons, lack of flood plain, and very coarse, poorly sorted stream bed deposits; permanent structures generally not feasible; large culverts required under roads crossing channels.*

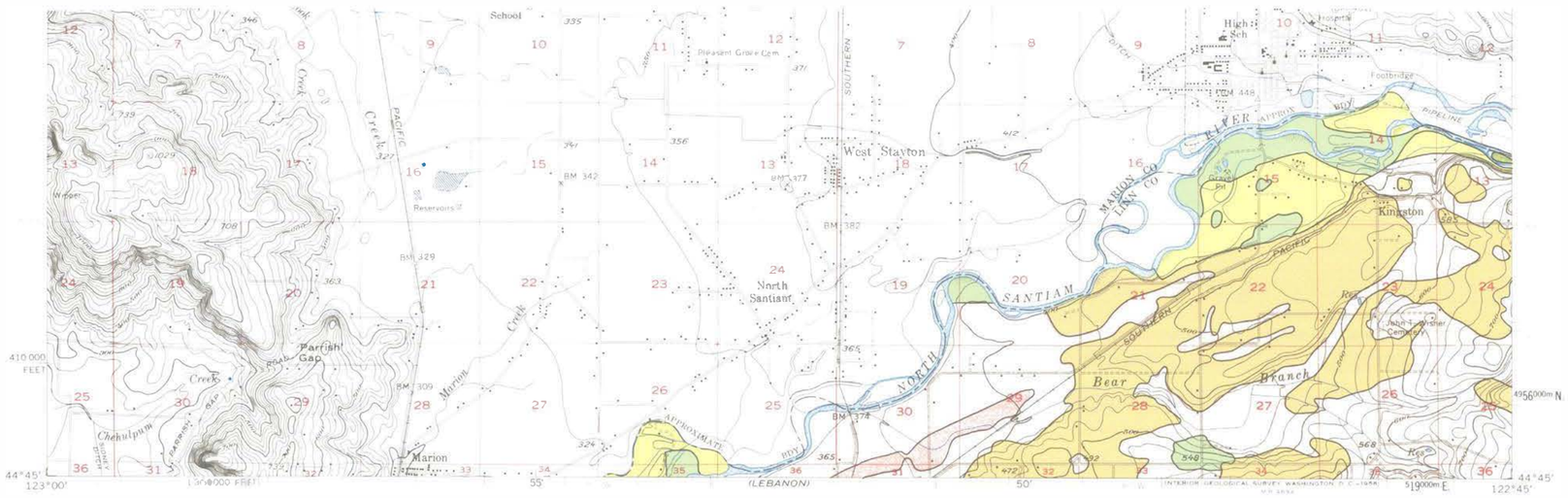
Geologic Hazards by J. D. Beaulieu and P. W. Hughes

Cartography by S. R. Renoud and W. H. Pokorny 1974

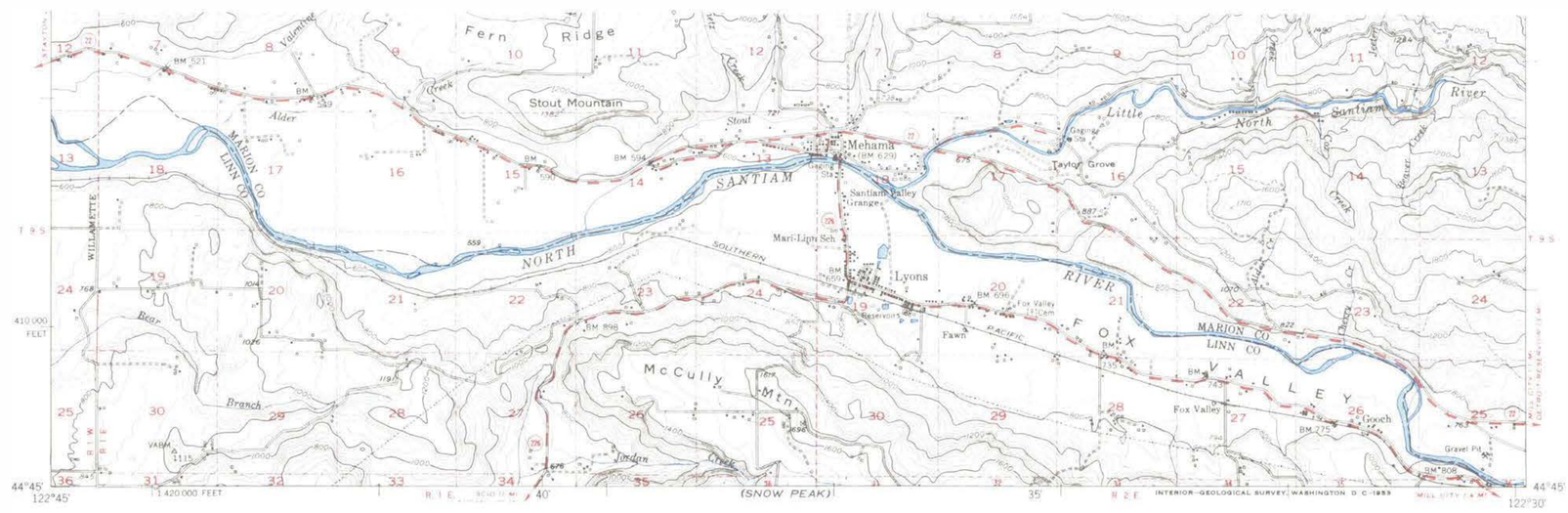
TEXTURAL SOILS MAPS
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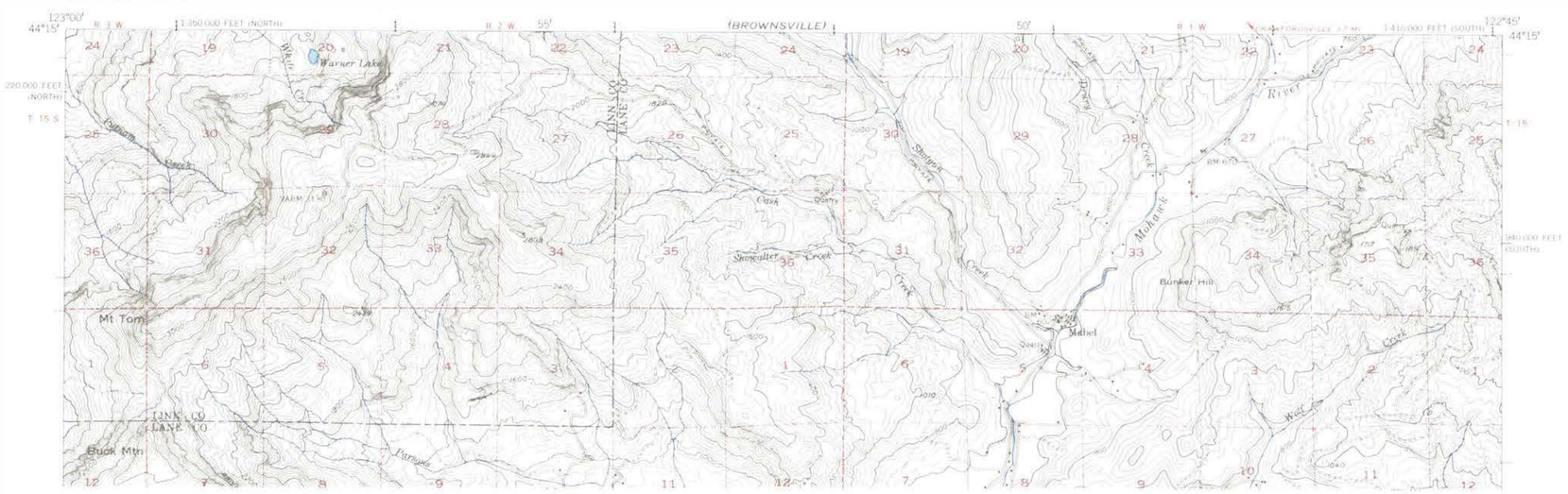
STAYTON



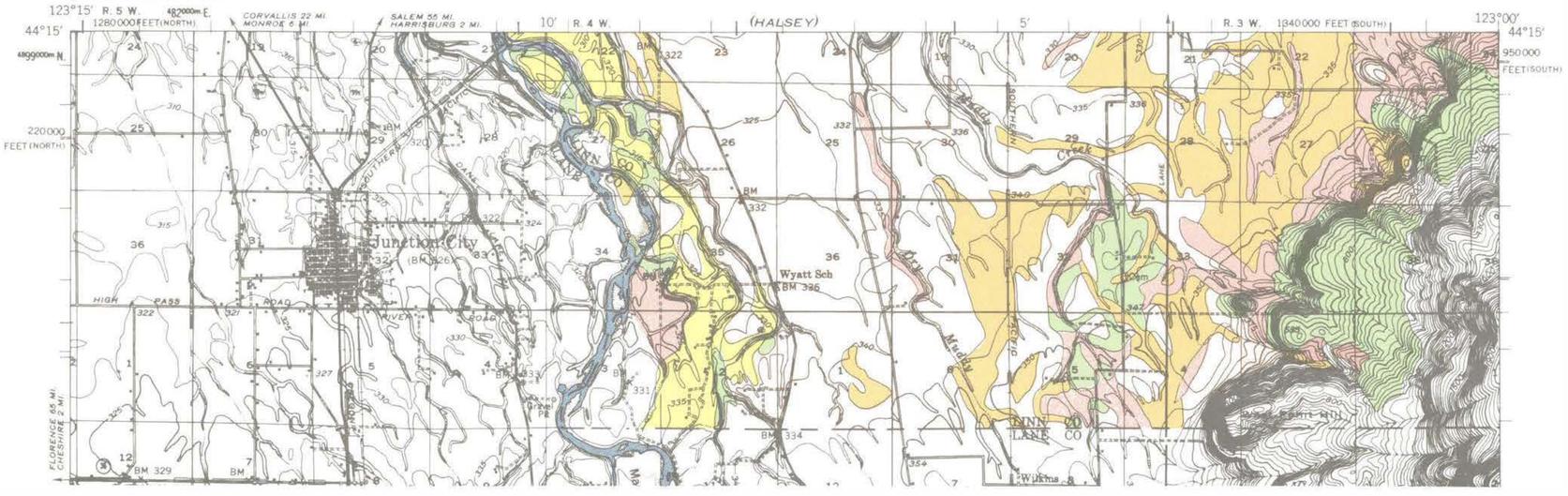
LYONS



MARCOLA



EUGENE



EXPLANATION

Clay and silty clay: *Severe construction limitations in places because of poor drainage, compressibility, and location in flood prone areas; generally not acceptable for septic tanks owing to low infiltration rates.*

Clay loam and silty clay loam: *Limited use as a function of local topography, water table, and engineering properties; septic tanks, sewage disposal, and landfills acceptable in areas of favorable topography, water table, and permeability.*

Loam and silty loam: *Restricted use in Willamette Valley because of poor drainage and high water table; septic tanks and sewage disposal acceptable in regions of appropriate permeability and water table.*

Sandy and sandy loam: *Acceptable for most construction; generally not acceptable for septic tanks, leach fields, sewage disposal, and landfills owing to rapid infiltration.*

Gravelly and stony loam: *Same as sand and sandy loam above.*

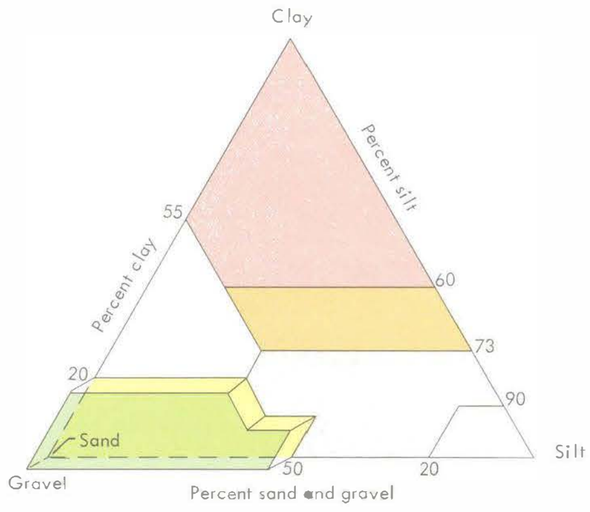
Stony mountainous land: *variable; see Geologic Hazards maps.*

Soils by P. W. Hughes

Cartography by S. R. Renoud and W. H. Pokorny 1974

Soil Classification Diagram

Soils are unconsolidated mixtures of clay, sill, sand, and gravel; textural terminology is based on the relative abundance of these components.



— Base Map from U. S. Geological Survey. —

Topography by plantetable surveys 1942
Culture revised from aerial photographs taken 1952
Field check 1956

Polyconic projection. 1927 North American datum
10,000-foot grids based on Oregon coordinate system, north and south zones
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

APPROXIMATE MEAN DECLINATION, 1956

SCALE 1:62500

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