Environmental Geology of Western Linn County, Oregon

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

1974
ENVIRONMENTAL GEOLOGY

of

WESTERN LINN COUNTY, OREGON

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LINCOLN, BENTON, LINN COUNTIES

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STATE GEOLOGIST
R. E. Corcoran
1974
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- Portions of the Eugene, Lyons, Marcola, and Stayton quadrangles

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ENVIROMENTAL 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 Kacher 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.
INTRODUCTION

Problem:
- define long range goals
- review zoning
- develop programs
- evaluate projects
- advise residents

Geologic Map:
- determine rock unit

Hazards Map:
- determine hazards

Soils Map or Table 2:
- determine soil

Engineering Geology Text:
- determine bedrock capabilities and limitations
- determine soils capabilities and limitations

Geologic Hazards Text:
- determine potential hazards
- determine potential impact
- determine impact of project on surrounding areas

Natural Resources Text:
- consider impact on natural resources

Evaluate

Plan:
- consider input from other disciplines

Consider all physical capabilities and limitations

Consider immediate impact of project on surrounding areas in terms of geologic processes

Consider impact on mineral wealth

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

- Marcola quadrangle
- Albany quadrangle
- Halsey quadrangle
- Eugene quadrangle
- Stayton quadrangle
- Lebanon quadrangle
- Brownsville quadrangle
- Lyons quadrangle
- Snow Peak quadrangle
- Sweet Home quadrangle
- Mill City quadrangle
- Quartzville quadrangle
- 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

<table>
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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 quartz-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.
<table>
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<tr>
<th>Period</th>
<th>Epoch</th>
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<tr>
<td>Quaternary</td>
<td>Pleistocene and Holocene</td>
<td>2</td>
<td>Qtv</td>
<td>Cascades Formation&lt;br&gt;Porphyritic andesite flow rock and breccia forming a dissected volcanic cone at Snow Peak and an intracanyon flow (reversed topography) in the Middle Santiam drainage (Qtv)&lt;br&gt;Intrusive rocks (Ti)</td>
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<td>9</td>
<td>Tps</td>
<td>Sardine Formation&lt;br&gt;Massive to platy flows of hypersthene andesite. Formerly far more extensive than at present.</td>
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<td>Tcr</td>
<td>Columbia River Basalt&lt;br&gt;Dense, dark, very fine-grained basalt with columnar jointing.</td>
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<td>38</td>
<td>Tolb</td>
<td>Little Butte Formation&lt;br&gt;Dacitic to andesitic pyroclastic rocks including coarse breccias in the east and finer tuffs, ash, and associated volcanioclastic sediments in the west; also includes dark, basaltic flow rock erupted from numerous local vents (Tolb).&lt;br&gt;Interbeds of marine sandstone in the western foothills (Tibe).&lt;br&gt;Intrusive rocks (Ti).</td>
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*Millions of years

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 loams 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.1 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 Willamette Valley (northeastern Halsey quadrangle).

Figure 16. The quarry at Saddle Butte exposes basaltic dike rock, flow rock, and breccia (northeastern Halsey quadrangle).
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 volcanioclastic 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± 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 andesitic 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 base of the Cascades Formation on the south slopes of Snow Peak includes thin flows of light-gray massive flow rock and intercalated fine-grained flows 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 Pli-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. Large 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 QtI 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 Valley (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±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 (QtI) 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 (QaI)

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 Calapooya 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
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 Snively, 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. Re-mapping 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 Soda ville 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. Bromery postulates a fault along the anomaly. It seems likely, however, that the steep topography of the hillside best explains the aeromagnetic patterns. Magnetic isopleths along Hamilton Creek trend northeastier 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.

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

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

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

*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 interfluvies 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; superficial 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 variable. 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

Ge ne ral 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 stand-
point 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 inter-
pretations 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, weath-
ering, 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 weath-
ering 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 exten-
sive 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>
<thead>
<tr>
<th>Hazard</th>
<th>Characteristics</th>
<th>Impact</th>
<th>Preventive, remedial, and planning measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% flood</td>
<td>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</td>
<td>Damages resulting from standing water, current action and silting</td>
<td>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</td>
</tr>
<tr>
<td>Standard project flood</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated flood area</td>
<td>Crude projections of 1% flood and STP floods based primarily on topography</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stream-bank erosion</td>
<td>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</td>
<td>Total destruction of structures and loss of land through undercutting and erosion</td>
<td>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)</td>
</tr>
<tr>
<td>Revetment</td>
<td>Man-made erosion protective devices</td>
<td>May direct erosion to points farther downstream</td>
<td>Proper engineering and planning prior to construction; realization that meandering often flanks revetment structures</td>
</tr>
<tr>
<td>High water table</td>
<td>Ground water at or near ground surface, especially during wet season; position during dry season highly misleading</td>
<td>Contamination from septic tanks and landfills; damage to basements, underground tanks, and swimming pools</td>
<td>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</td>
</tr>
<tr>
<td>Ponding of rainwater</td>
<td>Low regional slopes and gentle localized depressions in areas of low permeability (clay and clay loam); depressions particularly evident in aerial photographs</td>
<td>Localized flooding; also polluted runoff in areas of landfills and septic tanks</td>
<td>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</td>
</tr>
<tr>
<td>Adverse soil conditions; see Table 3</td>
<td>Clay-rich soils and compressible soils high in organic matter</td>
<td>Septic tank and leach field failure</td>
<td>On-site soil investigations for septic tanks, leach fields, and large construction projects</td>
</tr>
</tbody>
</table>
Class 2 slopes underlain by basalitic 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>
<thead>
<tr>
<th>Hazard</th>
<th>Characteristics</th>
<th>Potential impact</th>
<th>Preventive, remedial, and planning measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass movement topography</td>
<td>Irregular to hummocky terrain, moderate slopes (Class 2 and 3), irregular drainage, sag ponds, cracked ground, bowed trees</td>
<td>Structural damage through future movement or uneven settling, caving in excavations, poor drainage</td>
<td>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</td>
</tr>
<tr>
<td>Steep slope failure</td>
<td>Include rapid run-off, rockslides, rockfalls, debris slides, mudflows, and earthflow on Class 4 and 5 slopes</td>
<td>Rapid erosion, structural damage, road failure</td>
<td>Require on-site investigation and/or detailed engineering investigations prior to development; strict adherence to grading codes; preservation of natural vegetation where possible</td>
</tr>
<tr>
<td>Flash flooding</td>
<td>Small to medium-sized stream channels, moderate to steep gradients and side slopes, no flood plain, coarse stream-bed deposits, thin soils, impervious bedrock</td>
<td>Total destruction of structures; road washouts</td>
<td>Prohibit construction at or near stream level in flash-flood channels; assure adequate engineering of all road and path crossings</td>
</tr>
</tbody>
</table>
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 headscarsps 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. Roadcuts in gently sloping weathered clay soils of the Little Butte Formation are prone to failure in places (Brush Creek Road south of Crawfordsville).

Figure 36. Thin soils characterize Class 3 slopes underlain by basaltic bedrock (Horse Mountain area south of Brownsville).
<table>
<thead>
<tr>
<th>Slope</th>
<th>Natural processes</th>
<th>Potential disastrous impact</th>
<th>Remedial, preventive, and planning measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (0-10%)</td>
<td>Chemical weathering; no slope-initiated hazards; other hazards include flooding, ponding, high water table, and clay soils</td>
<td>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 run-off in flat urbanized areas can cause flooding</td>
<td>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)</td>
</tr>
<tr>
<td>2 (&gt;10-25%)</td>
<td>Moderate chemical weathering and slight erosion under natural conditions; some mass wasting on steeper slopes</td>
<td>Initiation of slides through overloading and oversteepening of slopes (especially in areas of mass movement topography); gully ing in areas stripped of natural vegetation; structural damage in areas of low foundation stability (see Landslides)</td>
<td>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</td>
</tr>
<tr>
<td>3 (&gt;25-50%)</td>
<td>Chemical weathering and erosion; also mass wasting including earthflow, mudflow, and creep; gullying in areas stripped of natural vegetation</td>
<td>Initiation of slides through overloading and oversteepening of slopes (see Mass movement topography); gullies in unprotected slopes; caving of excavations; emergence of septic tank effluent, etc. on hillsides; road failure; structural damage in places</td>
<td>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</td>
</tr>
<tr>
<td>4 (&gt;50-75%)</td>
<td>Erosion, rapid runoff, shallow slides, and deep slides in bedrock under extreme conditions</td>
<td>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 hillside; failure of improperly placed culvert</td>
<td>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</td>
</tr>
<tr>
<td>5 (&gt;75%)</td>
<td>Rapid runoff and erosion; rockfall, rock slide and mudflows</td>
<td>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</td>
<td>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</td>
</tr>
</tbody>
</table>
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 Valley during the flood of December 1964 (dimensions of area approximately 1 mile by 1 1/2 miles).

Figure 42. Standing flood waters can cause considerable damage to homes and their contents (east of Highway 99E at Oak Creek, half a 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.
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

<table>
<thead>
<tr>
<th>River</th>
<th>Observation period</th>
<th>Average discharge</th>
<th>Maximum discharge</th>
<th>Minimum discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willamette (at Albany)</td>
<td>1894-1965</td>
<td>14,490</td>
<td>226,000</td>
<td>1,840 (Jan.14, 1881)</td>
</tr>
<tr>
<td>Willamette (at Harrisburg)</td>
<td>1944-1965</td>
<td>12,730</td>
<td>210,000</td>
<td>1,990 (Dec. 29, 1945)</td>
</tr>
<tr>
<td>Santiam (at Jefferson)</td>
<td>1905-1916</td>
<td>7,840</td>
<td>197,000</td>
<td>260 (Dec. 22, 1964)</td>
</tr>
<tr>
<td>South Santiam (at Waterloo)</td>
<td>1923-1965</td>
<td>2,910</td>
<td>95,200</td>
<td>96 (Dec. 22, 1964)</td>
</tr>
<tr>
<td>South Santiam (Cascadia)</td>
<td>1935-1965</td>
<td>826</td>
<td>27,600</td>
<td>23 (Dec. 22, 1964)</td>
</tr>
<tr>
<td>North Santiam (Niagara)</td>
<td>1908-1920</td>
<td>2,339</td>
<td>63,200</td>
<td>430 (Nov. 22, 1909)</td>
</tr>
<tr>
<td>Calapooia (Holley)</td>
<td>1935-1965</td>
<td>450</td>
<td>12,600</td>
<td>13 (Dec. 22, 1964)</td>
</tr>
<tr>
<td>Thomas Creek (Scio)</td>
<td>1962-1965</td>
<td>16,700</td>
<td>14 (Dec. 22, 1964)</td>
<td></td>
</tr>
<tr>
<td>Crabtree Creek (Crabtree)</td>
<td>1963-1965</td>
<td>8,410</td>
<td>15 (Jan. 28, 1965)</td>
<td></td>
</tr>
<tr>
<td>Wiley Creek (Foster)</td>
<td>1947-1965</td>
<td>227</td>
<td>8,370</td>
<td>6 (Dec. 22, 1964)</td>
</tr>
</tbody>
</table>
Figure 45. Flood waters of the Colopoio flood plain in January 1974 (looking east from Oakville Road 3 miles southwest of Albany).

Figure 46. Because of local ponding, this bridge is essential in the winter months (west of the South Santiam 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 undisipated erosive potential is now being transmitted downstream to create additional areas of stream-bank erosion.

Downstream 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.
Santiam River and North Santiam River: Stream-bank erosion along the North Santiam River is restricted primarily to the region downstream from Stayton. West of Kingston, channel changes within the past 15 years have produced a double channel, indicative of high erosion potential. Revetments protect the stream bank 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 bank are possible.

West of Shelburn the Wiseman Island-McKinney Bottom region of the North Santiam River is undergoing rapid stream-bank erosion. Numerous meanders are 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 broad curve in the river may undergo similar modifications in the future.

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

Colopooia River: Numerous stream-channel modifications have occurred on the Colopooia River and numerous sites of future stream-bank erosion are identified on the geologic hazards map. Consistent with the relatively low discharge of the stream, the meanders are considerably smaller than those on the aforementioned rivers. Accordingly the threats of future stream-bank erosion are 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 statutorily 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

<table>
<thead>
<tr>
<th>Type</th>
<th>Characteristics</th>
<th>Distribution</th>
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<tbody>
<tr>
<td>Earthflow</td>
<td>Irregular, subdued terrain, tilted trees, cracked ground, sag ponds, irregular drainage; flow-type movement, planar basal slip surface.</td>
<td>Most common on Class 2 and Class 3 slopes in Little Butte tuffs.</td>
</tr>
<tr>
<td>Slump</td>
<td>Hummocky terrain, backtilted trees, irregular drainage, sag ponds, rotational movement on curved basal slip plane.</td>
<td>Occupies upslope parts of earthflow areas.</td>
</tr>
<tr>
<td>Rockslide</td>
<td>Talus and rubbly veneer moving rapidly downslope; poorly sorted mantle of unconsolidated debris produced by such action.</td>
<td>Class 4 and Class 5 slopes generally underlain by flow rock.</td>
</tr>
<tr>
<td>Rockfall</td>
<td>Actual free fall of rock material through the air.</td>
<td>Steep Class 5 slopes.</td>
</tr>
<tr>
<td>Mudflow</td>
<td>Rapid movement of a mudlike slurry down steep canyons; called debris flow if rocks and other debris are abundant in the mud.</td>
<td>Class 4 and Class 5 slopes with adequate soil cover.</td>
</tr>
<tr>
<td>Mudslide</td>
<td>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.</td>
<td>May include earthflow, slump, rockslide, rockfall, and mudflow, provided necessary conditions are met (see text).</td>
</tr>
</tbody>
</table>
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 undercutts 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 headscarsps. Depth of failure is great below the larger headscarsps, 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 intra-canyon 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 structures may 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 groundwater 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.
Distribution: Failures on steep slopes are by definition restricted to slopes greater than 50 percent (Class 4 and Class 5). They are most common along the upper reaches of the Colopooio, Middle Santiam, and North Santiam Rivers and along major creeks such as Wiley Creek and Neal Creek. Geologically, steep-slope failures are 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 are traceable to the same causes as failures in regions of mass movement topography (see Mass Movement: Mass 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 valley-bottom roads.

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

Regions mapped 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 valley areas near Cascadia, and port of West Point Hill in the extreme southern part 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 large developments to assure that all potential hazards are accommodated. For areas of particular concern, implementation of the National Flood Insurance Act is recommended. Every attempt should be made 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; over-steepening 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 unrappable gullies in steeply sloping areas are subject to flash flooding; note the debris screen.
Figure 69. Debris beside Calopooia River Rood at the mouth of Bigs Creek was removed from rood by maintenance 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*

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

* After Holmes (1965)
Table 10. Seismic events in the Central Willamette Valley Region

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

Adapted from Berg and Baker, 1963

Figure 71. State of Oregon seismic risk map.

(After Couch and Lowell, 1971)
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

<table>
<thead>
<tr>
<th>Unit</th>
<th>Useful materials</th>
<th>Transportation factor</th>
<th>Quality</th>
<th>Quantity</th>
<th>Uses and comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Hard gravel and fresh sand</td>
<td>Neat urban centers</td>
<td>Very good</td>
<td>Large</td>
<td>Ill-advised political decisions may severely restrict supply; used for concrete aggregate and construction</td>
</tr>
<tr>
<td>Willamette Stills (Qws)</td>
<td>None</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Accessible gravel and sand of Qtl unit may be near surface locally</td>
</tr>
<tr>
<td>Lower terrace (Qt1)</td>
<td>Gravel and sand</td>
<td>Neat urban centers</td>
<td>Good</td>
<td>Large</td>
<td>Largely un-tapped; urbanization is covering large reserves; used for concrete aggregate and construction</td>
</tr>
<tr>
<td>Middle terrace (Qtm)</td>
<td>Sand and gravel</td>
<td>Semi-isolated</td>
<td>Poor - deeply weathered</td>
<td>Small</td>
<td>Deep weathering and small proportions of gravel preclude development</td>
</tr>
<tr>
<td>Upper terrace (Qtu)</td>
<td>Sand and gravel</td>
<td>Semi-isolated</td>
<td>Fair - weathered</td>
<td>Small</td>
<td>Untapped; weathering and isolation are prohibitive</td>
</tr>
<tr>
<td>Sardine Quarry Formation (Tps)</td>
<td>Quarry stone</td>
<td>Isolated</td>
<td>Variable</td>
<td>Large</td>
<td>Small local quarries for mountain road construction</td>
</tr>
<tr>
<td>Columbia River Basalt (Tcr)</td>
<td>Quarry stone</td>
<td>Neat urban centers</td>
<td>Good</td>
<td>Large</td>
<td>Large well-located reserves; used for road construction; some possibly suitable for aggregate</td>
</tr>
<tr>
<td>Little Butte Formation (Taib)</td>
<td>Quarry stone</td>
<td>Isolated</td>
<td>Variable</td>
<td>Large</td>
<td>Diffuse, poorly defined exposures; used locally for road rock on mountain roads</td>
</tr>
<tr>
<td>Intrusive rock (Tt)</td>
<td>Quarry stone</td>
<td>Isolated</td>
<td>Good</td>
<td>Large</td>
<td>Suitable for road rock, riprap, and dam construction; isolated from Willamette Valley</td>
</tr>
</tbody>
</table>
### Table 12. Sand and gravel production in Linn County

<table>
<thead>
<tr>
<th>Year</th>
<th>Commercial</th>
<th>Non-commercial</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S/tons</td>
<td>Value</td>
<td>S/tons</td>
</tr>
<tr>
<td>1940-1949</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1950</td>
<td></td>
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<td>1971</td>
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</table>

### Table 13. Stone production in Linn County

<table>
<thead>
<tr>
<th>Year</th>
<th>Commercial</th>
<th>Non-commercial</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S/tons</td>
<td>Value</td>
<td>S/tons</td>
</tr>
<tr>
<td>1940-1949</td>
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<tr>
<td>1950</td>
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<tr>
<td>1971</td>
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</tbody>
</table>

**Note:** Confidential data marked with [Confidential].
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 Willomette 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 Bold 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. 3 W.) 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 road 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 (Qt1) 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)

<table>
<thead>
<tr>
<th>Well location number*</th>
<th>Owner</th>
<th>Year completed</th>
<th>Depth</th>
<th>Casing Finish</th>
<th>Water bearing zones</th>
<th>Altitude</th>
<th>Water level</th>
<th>Performance</th>
<th>Yield</th>
<th>Drawdown</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>95/1W=13D1</td>
<td>Salem</td>
<td>1939</td>
<td>60</td>
<td>60</td>
<td>Gravel</td>
<td>466</td>
<td>12</td>
<td>--</td>
<td>1775</td>
<td>--</td>
<td>Public</td>
</tr>
<tr>
<td>105/2W-8H2</td>
<td>W. Upstad</td>
<td>1957</td>
<td>21</td>
<td>21</td>
<td>Perforated 15-20&quot;</td>
<td>17</td>
<td>4</td>
<td>Gravel</td>
<td>253</td>
<td>8/22/57</td>
<td>Irrigation</td>
</tr>
<tr>
<td>105/2W-19Q2</td>
<td>N. Bradley</td>
<td>1966</td>
<td>22</td>
<td>22</td>
<td>Perforated 18-22&quot;</td>
<td>15</td>
<td>1</td>
<td>Gravel</td>
<td>230</td>
<td>5/22/66</td>
<td>Irrigation</td>
</tr>
<tr>
<td>125/4W-6F1</td>
<td>W. Homlin</td>
<td>1961</td>
<td>35</td>
<td>35</td>
<td>Perforated 26-35&quot;</td>
<td>20</td>
<td>15</td>
<td>Gravel</td>
<td>220</td>
<td>9/18/70</td>
<td>Irrigation</td>
</tr>
<tr>
<td>125/3W-7E1</td>
<td>Tangent</td>
<td>Pre-1928</td>
<td>45</td>
<td>36-40</td>
<td>Screen at base</td>
<td>42</td>
<td>3</td>
<td>Gravel</td>
<td>245</td>
<td>8/2/28</td>
<td>Public supply</td>
</tr>
<tr>
<td>115/3W-17F2</td>
<td>J. Anderson</td>
<td>1960</td>
<td>70</td>
<td>66</td>
<td>Perforated 32-38&quot; and 58-64&quot;</td>
<td>29</td>
<td>37</td>
<td>Sand and gravel Qyl</td>
<td>226</td>
<td>11/1/65</td>
<td>Irrigation</td>
</tr>
<tr>
<td>95/1W=14Q1</td>
<td>J. Fery</td>
<td>1964</td>
<td>326</td>
<td>19</td>
<td>Open bottom</td>
<td>57</td>
<td>269</td>
<td>Basalt Tec</td>
<td>550</td>
<td>3/19/64</td>
<td>Irrigation</td>
</tr>
<tr>
<td>105/1W=4J1</td>
<td>C. Limbeck</td>
<td>1957</td>
<td>139</td>
<td>4</td>
<td>Open bottom</td>
<td>90</td>
<td>110</td>
<td>Basalt Tec</td>
<td>675</td>
<td>12/13/57</td>
<td>All Domestic</td>
</tr>
<tr>
<td>105/2L=36Q1</td>
<td>U.S. Forest Service</td>
<td>1958</td>
<td>100</td>
<td>36</td>
<td>Open bottom</td>
<td>54</td>
<td>46</td>
<td>Tuff Talb</td>
<td>795</td>
<td>3/19/58</td>
<td>Domestic</td>
</tr>
<tr>
<td>105/3W-15P1</td>
<td>G. Miller</td>
<td>1965</td>
<td>70</td>
<td>50</td>
<td>Open bottom</td>
<td>51</td>
<td>19</td>
<td>Sandstone Talb</td>
<td>465</td>
<td>1/3/66</td>
<td>All Domestic</td>
</tr>
<tr>
<td>105/3W-20K1</td>
<td>E. Chowning</td>
<td>1959</td>
<td>150</td>
<td>150</td>
<td>Perforated 105-110' 120-126' 142-148'</td>
<td>105</td>
<td>45</td>
<td>Sandy clay Talb</td>
<td>227</td>
<td>27.7 8/20/65</td>
<td>Domestic</td>
</tr>
</tbody>
</table>

*See Appendix F
Data from Frank and Johnson, 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 downslope 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

<table>
<thead>
<tr>
<th>Well location number*</th>
<th>Water-bearing material</th>
<th>Date of collection</th>
<th>SiO₂</th>
<th>Fe</th>
<th>Mn</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>HCO₃</th>
<th>CO₃</th>
<th>SO₄</th>
<th>Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>9S/1W-13D1</td>
<td>Gravel Qq1</td>
<td>6/14/51</td>
<td>17</td>
<td>0.03</td>
<td>--</td>
<td>4.9</td>
<td>1.1</td>
<td>3.2</td>
<td>2.6</td>
<td>31</td>
<td>0</td>
<td>17</td>
<td>1.0</td>
</tr>
<tr>
<td>10S/2W-8N2</td>
<td>Gravel and sand Qq1</td>
<td>5/18/66</td>
<td>20</td>
<td>0.01</td>
<td>--</td>
<td>7.4</td>
<td>2.5</td>
<td>3.3</td>
<td>0.4</td>
<td>32</td>
<td>0</td>
<td>3.8</td>
<td>1.5</td>
</tr>
<tr>
<td>10S/2W-19Q2</td>
<td>Gravel and sand Qq1</td>
<td>6/24/66</td>
<td>24</td>
<td>0.04</td>
<td>--</td>
<td>21</td>
<td>7.2</td>
<td>7.0</td>
<td>0.9</td>
<td>62</td>
<td>0</td>
<td>18</td>
<td>5.5</td>
</tr>
<tr>
<td>12S/4W-6P1</td>
<td>Gravel Qq1</td>
<td>7/23/71</td>
<td>42</td>
<td>0.03</td>
<td>0</td>
<td>21</td>
<td>11</td>
<td>11</td>
<td>0.6</td>
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<td>0</td>
<td>15</td>
<td>12</td>
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<tr>
<td>11S/3W-17T2</td>
<td>Gravel Qq1</td>
<td>6/17/66</td>
<td>33</td>
<td>0.37</td>
<td>--</td>
<td>33</td>
<td>17</td>
<td>14</td>
<td>1.0</td>
<td>213</td>
<td>0</td>
<td>1.4</td>
<td>4.5</td>
</tr>
<tr>
<td>12S/3W-7E1</td>
<td>Sand and gravel Qq1</td>
<td>4/18/29</td>
<td>35</td>
<td>0.08</td>
<td>--</td>
<td>31</td>
<td>18</td>
<td>14</td>
<td>1.1</td>
<td>193</td>
<td>0</td>
<td>2.1</td>
<td>13</td>
</tr>
<tr>
<td>9S/1W-14Q1</td>
<td>Basalt Tcr</td>
<td>6/23/66</td>
<td>45</td>
<td>0.48</td>
<td>--</td>
<td>5.7</td>
<td>3.6</td>
<td>9.9</td>
<td>1.3</td>
<td>60</td>
<td>0</td>
<td>2.8</td>
<td>1.0</td>
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<tr>
<td>10S/1W-4J1</td>
<td>Basalt Tcr</td>
<td>5/25/66</td>
<td>23</td>
<td>0.01</td>
<td>--</td>
<td>4.9</td>
<td>3.0</td>
<td>7.8</td>
<td>1.0</td>
<td>25</td>
<td>0</td>
<td>1.2</td>
<td>10</td>
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<td>13S/2E-36Q1</td>
<td>Tuff Tolb</td>
<td>3/16/65</td>
<td>34</td>
<td>1.6</td>
<td>--</td>
<td>80</td>
<td>17</td>
<td>257</td>
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<td>443</td>
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<td>43</td>
<td>300</td>
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<td>5/25/66</td>
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<td>--</td>
<td>2.9</td>
<td>2.1</td>
<td>7.9</td>
<td>1.1</td>
<td>16</td>
<td>0</td>
<td>0.8</td>
<td>11</td>
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<tr>
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<td>6/17/66</td>
<td>37</td>
<td>0.79</td>
<td>--</td>
<td>13</td>
<td>7.7</td>
<td>10</td>
<td>1.3</td>
<td>80</td>
<td>0</td>
<td>14</td>
<td>7.0</td>
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</tbody>
</table>

*See Appendix F  
Testing laboratory - U.S. Geological Survey, Portland
NATURAL RESOURCES - GROUND WATER

Ground-water aquifers in western Linn County

<table>
<thead>
<tr>
<th>NO₃</th>
<th>ASN</th>
<th>Ortho</th>
<th>ASP</th>
<th>PO₄</th>
<th>B</th>
<th>As</th>
<th>Calculated dissolved solids</th>
<th>Solid residue on evaporation</th>
<th>CaCO₃ hardness</th>
<th>Non-carbonate hardness</th>
<th>Hardness Ca, Mg</th>
<th>Sodium absorption ratio</th>
<th>Specific conductance at 25°C</th>
<th>Temperature °F</th>
<th>pH</th>
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<tbody>
<tr>
<td>0.1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<td>47</td>
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<td>82</td>
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<td>0.3</td>
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<td>--</td>
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<td>0.06</td>
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<td>--</td>
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<td>--</td>
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<td>151</td>
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<td>0.0</td>
<td>0.00</td>
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<td>--</td>
<td>24</td>
<td>4</td>
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<td>0.7</td>
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<td>54</td>
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<td>956</td>
<td>965</td>
<td>270</td>
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<td>--</td>
<td>6.4</td>
<td>1670</td>
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<td>0.00</td>
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<td>--</td>
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<td>3</td>
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<td>74</td>
<td>55</td>
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<td>0.05</td>
<td>0.05</td>
<td>0.00</td>
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<td>--</td>
<td>64</td>
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<td>0.5</td>
<td>0.7</td>
<td>56</td>
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Table 16. Drinking water standards defined by the U.S. Public Health Service, 1962

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<th>Constituent</th>
<th>Recommended limit ppm</th>
<th>Maximum allowable limit ppm</th>
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<tbody>
<tr>
<td>Fe (Iron)</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Mn (Manganese)</td>
<td>0.05</td>
<td>-</td>
</tr>
<tr>
<td>SO₄(Sulfate)</td>
<td>250.0</td>
<td>-</td>
</tr>
<tr>
<td>Cl (Chloride)</td>
<td>250.0</td>
<td>-</td>
</tr>
<tr>
<td>F (Fluoride)</td>
<td>0.8 - 1.7</td>
<td>1.6 - 3.4 *</td>
</tr>
<tr>
<td>NO₃ (Nitrate)</td>
<td>45.0</td>
<td>-</td>
</tr>
<tr>
<td>As (Arsenic)</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Dissolved solids</td>
<td>500.0</td>
<td>-</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Depth</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barr 1</td>
<td>NW 1/2 sec. 31, T. 11 S., R. 1 W.</td>
<td>4,529'</td>
<td>Gas and oil shows at 4,300' in Eugene Formation equivalent; production tests disappointing - little gas, no oil; mechanical difficulties may have been responsible.</td>
</tr>
<tr>
<td>Esmond 1</td>
<td>SW 1/2 sec. 7, T. 12 S., R. 1 W.</td>
<td>8,603'</td>
<td>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.</td>
</tr>
<tr>
<td>Miller 1</td>
<td>SE 1/4 sec. 10, T. 10 S., R. 3 W.</td>
<td>4,951'</td>
<td>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.</td>
</tr>
<tr>
<td>Porter 1</td>
<td>NE 1/4 sec. 27, T. 13 S., R. 4 W.</td>
<td>8,470'</td>
<td>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.</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Landform</th>
<th>Associated hazards</th>
<th>Areas of high hazard potential</th>
<th>Areas of low hazard potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat valley land</td>
<td>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</td>
<td>Flood plain west of Albany</td>
<td>High interfluves, gentle rises, and sloping regions near the mountain front</td>
</tr>
<tr>
<td>Isolated valley hills</td>
<td>Erosion, gullying, thin soils and local mass movement on steep slopes; minimal problems on gentler slopes</td>
<td>Peterson Butte, flanks of Knox Butte</td>
<td>Powell Hills, crests of Knox Butte, Hardscrabble Hill</td>
</tr>
<tr>
<td>Terraces</td>
<td>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</td>
<td>Middle terrace level underlain by poor soils (near Brewster and Draperville)</td>
<td>Upper terrace near Lacomb, parts of lower and middle terrace levels</td>
</tr>
<tr>
<td>Upland slopes</td>
<td>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</td>
<td>Mass movement topography; steep slopes, such as those along Middle Santiam River; deeply weathered gentle slopes as along Brush Creek Road</td>
<td>Middle slopes on north side of Snow Peak; gentle slopes in Columbia River Basalt south of Kingston; most gentle slopes</td>
</tr>
</tbody>
</table>

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.
POUNDING 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.
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APPENDIX
### Unified Soil Classification System

**Major divisions**

<table>
<thead>
<tr>
<th>Group symbols</th>
<th>Typical names</th>
<th>Laboratory classification criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW</td>
<td>Well-graded gravels, gravel-sand mixtures, little or no fines</td>
<td></td>
</tr>
<tr>
<td>GP</td>
<td>Poorly graded gravels, gravel-sand mixtures, little or no fines</td>
<td></td>
</tr>
<tr>
<td>GM*</td>
<td>Silty gravels, gravel-sand-silt mixtures</td>
<td></td>
</tr>
<tr>
<td>GC</td>
<td>Clayey gravels, gravel-sand-clay mixtures</td>
<td></td>
</tr>
<tr>
<td>SW</td>
<td>Well-graded sands, gravelly sands, little or no fines</td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>Poorly graded sands, gravelly sands, little or no fines</td>
<td></td>
</tr>
<tr>
<td>SM*</td>
<td>Silty sands, sand-silt mixtures</td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td>Clayey sands, sand-clay mixtures</td>
<td></td>
</tr>
<tr>
<td>ML</td>
<td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity</td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, clayey clays, lean clays</td>
<td></td>
</tr>
<tr>
<td>OL</td>
<td>Organic silts and organic silty clays of low plasticity</td>
<td></td>
</tr>
<tr>
<td>MH</td>
<td>Inorganic silts, micaceous or distomaceous fine sandy or silty soils, elastic silts</td>
<td></td>
</tr>
<tr>
<td>CH</td>
<td>Inorganic clays of high plasticity, fat clays</td>
<td></td>
</tr>
<tr>
<td>OH</td>
<td>Organic clays of medium to high plasticity, organic silts</td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>Peat and other highly organic soils</td>
<td></td>
</tr>
</tbody>
</table>

**Laboratory classification criteria**

- $C_g = \frac{D_{10}}{D_{90}}$ greater than 4; $C_s = \frac{(D_{10})^3}{D_{60} \times D_m}$ between 1 and 3
- Not meeting all gradation requirements for GW
- Atterberg limits below "A" line or P.L. less than 4
- Above "A" line with P.L. between 4 and 7 are borderline cases requiring use of dual symbols
- Atterberg limits above "A" line with P.L. greater than 7
- $C_g = \frac{D_{10}}{D_{90}}$ greater than 4; $C_s = \frac{(D_{10})^3}{D_{60} \times D_m}$ between 1 and 3
- Not meeting all gradation requirements for SW
- Atterberg limits below "A" line or P.L. less than 4
- Limits plotting in hatched zone with P.L. between 4 and 7 are borderline cases requiring use of dual symbols.

**Division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is based on Atterberg limits.**

**Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols.**

For example: GW-SC, well-graded gravel-sand mixtures with clay binder.

Reprinted from PCA Soil Primer
## APPENDIX B

**AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS**  
**SOILS CLASSIFICATION (AASHO)**

<table>
<thead>
<tr>
<th>General classification</th>
<th>Group symbols</th>
<th>Grain size (sieve)</th>
<th>Atterburg limits for fraction passing No. 40</th>
<th>Plasticity index*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granular materials</td>
<td></td>
<td></td>
<td>Liquid limit</td>
<td>Plasticity index</td>
</tr>
<tr>
<td>A-1</td>
<td>A-1-a</td>
<td>50% max. passes No. 10</td>
<td>Less than 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A-1-6</td>
<td>30% max. passes No. 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>15% max. passes No. 200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine sand</td>
<td>A-3</td>
<td>50% min. passes No. 40</td>
<td>N.P.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10% max. passes No. 200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silty or clayey gravel and sand</td>
<td>A-2-4</td>
<td>35% max. passes No. 200</td>
<td>Less than 40</td>
<td>Less than 10</td>
</tr>
<tr>
<td></td>
<td>A-2-5</td>
<td>Greater than 40</td>
<td>Greater than 10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A-2-6</td>
<td>Less than 40</td>
<td>Greater than 10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A-2-7</td>
<td>Greater than 40</td>
<td>Greater than 10</td>
<td></td>
</tr>
<tr>
<td>Clayey soils</td>
<td>A-4</td>
<td>Greater than 35% passes No. 200</td>
<td>Less than 40</td>
<td>Less than 10</td>
</tr>
<tr>
<td></td>
<td>A-5</td>
<td>Greater than 40</td>
<td>Less than 10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A-6</td>
<td>Less than 40</td>
<td>Greater than 10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A-7</td>
<td>Greater than 40</td>
<td>Greater than 10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A-7-5</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>A-7-6</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*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**

<table>
<thead>
<tr>
<th></th>
<th>Colloids</th>
<th>Clay</th>
<th>Silt</th>
<th>Fine sand</th>
<th>Coarse sand</th>
<th>Fine gravel</th>
<th>Medium gravel</th>
<th>Coarse gravel</th>
<th>Boulders</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>American Association</strong>&lt;br&gt;of State Highway&lt;br&gt;Officials - soil classification</td>
<td></td>
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</tr>
<tr>
<td><strong>U.S. Department of</strong>&lt;br&gt;Agriculture - soil classification</td>
<td></td>
<td>Clay</td>
<td>Silt</td>
<td>Fine sand</td>
<td>Medium sand</td>
<td>Coarse sand</td>
<td>Very coarse sand</td>
<td>Fine gravel</td>
<td>Coarse gravel</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Unified soil classification</strong>&lt;br&gt;U.S. Army Corps of Engineers&lt;br&gt;Bureau of Reclamation,&lt;br&gt;Dept. of Interior</td>
<td>Fines (silt or clay)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sieve sizes - U.S. standard</strong></td>
<td>.001</td>
<td>.002</td>
<td>.003</td>
<td>.004</td>
<td>.006</td>
<td>.008</td>
<td>.01</td>
<td>.02</td>
<td>.03</td>
</tr>
<tr>
<td><strong>Particle size - millimeters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>


### APPENDIX D

**CONSTRUCTION MATERIALS OPERATIONS IN WESTERN LINN COUNTY**

<table>
<thead>
<tr>
<th>Company</th>
<th>Material</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albany Rock Products</td>
<td>gravel</td>
<td>Sec. 10, T. 11 S., R. 3 W. 2 miles east of Albany</td>
</tr>
<tr>
<td>M.O. Salmon, Sr., President</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Howard Atkeson</td>
<td>gravel</td>
<td>Sec. 21, T. 11 S., R. 4 W. 5½ miles southwest of Albany</td>
</tr>
<tr>
<td>Builders Supply Co., Office Manager</td>
<td>gravel</td>
<td>Sec. 2, T. 12 S., R. 5 W. 1 mile east of Corvallis</td>
</tr>
<tr>
<td>Orris Carnegie</td>
<td>gravel</td>
<td>Sec. 20, T. 11 S., R. 4 W. 4 miles southwest of Albany</td>
</tr>
<tr>
<td>Geraldine F. or Richard D. Downer, Richard Downer</td>
<td>gravel, sand, rock</td>
<td>Secs. 25 &amp; 30, T. 10 S., Rs. 1 &amp; 2 W.</td>
</tr>
<tr>
<td>Govro Rock Quarry and Plant, L.W. Govro, operator</td>
<td>rock</td>
<td>Secs. 9, 10, 15, 16, T. 10 S., R. 3 W. 2 miles west of Jefferson, Oregon</td>
</tr>
<tr>
<td>Floyd Graham Construction Co., Margaret Graham, Sec.-treas.</td>
<td>riprap rock</td>
<td>Sec. 16, T. 12 S., R. 1 W. 6 miles southeast of Lebanon, Oregon</td>
</tr>
<tr>
<td>Lauren Karstens</td>
<td>dirt, sand, gravel</td>
<td>Sec. 16, T. 11 S., R. 4 W.</td>
</tr>
<tr>
<td>Harvey A. Larsen, Owner</td>
<td></td>
<td>Sec. 7, T. 11 S., R. 1 W. 2 miles north of Lacombe, Oregon</td>
</tr>
<tr>
<td>Brock Pit, Gordon B. Wallace, Asst. Engr.</td>
<td>quarry rock</td>
<td>Secs. 5 &amp; 3, T. 10 S., R. 1 E. 1½ miles northeast of Scio</td>
</tr>
<tr>
<td>Cook Pit, Gordon B. Wallace, Asst. Engr.</td>
<td>gravel</td>
<td>Sec. 6, T. 10 S., R. 3 W. 8 miles north of Albany, Oregon</td>
</tr>
<tr>
<td>Lebanon Dump, Gordon B. Wallace, Asst. Engr.</td>
<td>gravel</td>
<td>Sec. 1, T. 12 S., R. 2 W. 2 miles northeast of Lebanon</td>
</tr>
<tr>
<td>Cormier Pit, Gordon B. Wallace, Asst. Engr.</td>
<td>quarry rock</td>
<td>Sec. 13, T. 13 S., R. 1 W. 3½ miles northwest of Sweet Home</td>
</tr>
<tr>
<td>Sanderson Br., Gordon B. Wallace, Asst. Engr.</td>
<td>gravel</td>
<td>Sec. 10, T. 11 S., R. 2 W. 1½ miles west of Crabtree</td>
</tr>
<tr>
<td>Linn County, Oregon, Gordon B. Wallace, Asst. Engr.</td>
<td>quarry rock</td>
<td>Sec. 7, T. 10 S., R. 1 W. 1½ miles northwest of Scio</td>
</tr>
<tr>
<td>Linn County, Oregon, Gordon B. Wallace, Asst. Engr.</td>
<td>quarry rock</td>
<td>Sec. 26, T. 13 S., R. 1 W. 2½ miles northwest of Sweet Home</td>
</tr>
<tr>
<td>Site Description</td>
<td>Material</td>
<td>Section Numbers</td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Linn County, Oregon</td>
<td>quarry rock</td>
<td>Sec. 9, T. 13 S., R. 3 W.</td>
</tr>
<tr>
<td>Linn County, Oregon</td>
<td>quarry rock</td>
<td>Sec. 24, T. 14 S., R. 2 W.</td>
</tr>
<tr>
<td>Linn County, Oregon</td>
<td>gravel</td>
<td>Sec. 31, T. 10 S., R. 1 W.</td>
</tr>
<tr>
<td>Linn County, Oregon</td>
<td>river gravel</td>
<td>Secs. 7 &amp; 18, T. 10 S., R. 2 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>sand &amp; gravel</td>
<td>Sec. 10, T. 11 S., R. 2 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>sand &amp; gravel</td>
<td>Sec. 10, T. 11 S., R. 2 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc. #3</td>
<td>gravel</td>
<td>Sec. 31, T. 13 S., R. 4 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Secs. 30 &amp; 25, T. 13 S., R. 4 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>rock</td>
<td>E 1/2 sec. 11, T. 12 S., R. 2 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>sand &amp; gravel</td>
<td>Sec. 28, T. 13 S., R. 1 E.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Sec. 6, T. 14 S., R. 2 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Secs. 1, 2, 11, 12, T. 12 S., R. 2 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Sec. 6, T. 13 S., R. 2 E.</td>
</tr>
<tr>
<td>Morse Brothers, Inc., Office Manager</td>
<td>gravel</td>
<td>Secs. 35 &amp; 36, T. 13 S., R. 3 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Sec. 9, T. 15 S., R. 4 W.</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Sec. 5, T. 15 S., R. 4 W.</td>
</tr>
</tbody>
</table>
**ENVIRONMENTAL GEOLOGY OF WESTERN LINN COUNTY**

**CONSTRUCTION MATERIALS OPERATIONS IN WESTERN LINN COUNTY,** continued

<table>
<thead>
<tr>
<th>Company</th>
<th>Material</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Secs. 13 &amp; 18, T. 14 S., Rs. 5 &amp; 4 W.</td>
</tr>
<tr>
<td>W. Moore, V. President</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Sec 16, T. 15 S., R. 4 W.</td>
</tr>
<tr>
<td>McNutt, Office Manager</td>
<td></td>
<td>1 mile south of Harrisburg</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>pit-run gravel</td>
<td>Sec. 36, T. 13 S., R. 3 W.</td>
</tr>
<tr>
<td>R. H. Bellinger, Office Mgr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Secs. 13 &amp; 14, T. 12 S., R. 2 W.</td>
</tr>
<tr>
<td>Office Manager</td>
<td></td>
<td>2 miles east of Lebanon</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Secs. 11 &amp; 14, T. 12 S., R. 2 W.</td>
</tr>
<tr>
<td>R. H. Bellinger, Office Mgr.</td>
<td></td>
<td>1 mile east of Lebanon</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Secs. 13 &amp; 18, T. 14 S., R. 4 W.</td>
</tr>
<tr>
<td>R. H. Bellinger, Office Mgr.</td>
<td></td>
<td>8 miles north of Harrisburg</td>
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<tr>
<td>Morse Brothers, Pine Grove</td>
<td>gravel</td>
<td>Sec. 30, T. 13 S., R. 4 W.</td>
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<tr>
<td>Office Manager</td>
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<td>10 miles north of Harrisburg</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>quarry rock</td>
<td>Sec. 13, T. 12 S., R. 2 W.</td>
</tr>
<tr>
<td>Office Manager</td>
<td></td>
<td>2 miles east of Lebanon</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>gravel</td>
<td>Secs. 28 &amp; 29, T. 13 S., R. 1 E.</td>
</tr>
<tr>
<td>R. H. Bellinger, Office Mgr.</td>
<td></td>
<td>2 miles east of Sweet Home</td>
</tr>
<tr>
<td>Morse Brothers, Inc.</td>
<td>sand &amp; gravel</td>
<td>Sec. 29, T. 13 S., R. 1 E.</td>
</tr>
<tr>
<td>R. H. Bellinger, Office Mgr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N. Santiam Sand &amp; Gravel, Inc.</td>
<td>sand &amp; gravel</td>
<td>Secs. 34 &amp; 35, T. 9 S., R. 3 E.</td>
</tr>
<tr>
<td>F. A. LuLay, Pres.</td>
<td></td>
<td>Gates, Oregon</td>
</tr>
<tr>
<td>North Santiam Sand &amp; Gravel, Inc.</td>
<td>sand &amp; gravel</td>
<td>Sec. 19, T. 9 S., R. 2 E.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lyons, Oregon</td>
</tr>
<tr>
<td>North Santiam Sand &amp; Gravel, Inc.</td>
<td>sand &amp; gravel</td>
<td>Sec. 14, T. 9 S., R. 1 W.</td>
</tr>
<tr>
<td>F. A. LuLay, Pres. &amp; Mgr.</td>
<td></td>
<td>1 mile southeast of Stayton</td>
</tr>
<tr>
<td>North Santiam Sand &amp; Gravel, Inc.</td>
<td>sand &amp; gravel</td>
<td>Sec. 15, T. 9 S., R. 1 W.</td>
</tr>
<tr>
<td>Ralph Morgan, Office Mgr.</td>
<td></td>
<td>½ mile south of Stayton</td>
</tr>
<tr>
<td>North Santiam Sand &amp; Gravel, Inc.</td>
<td>sand &amp; gravel</td>
<td>Secs. 14, 15, &amp; 22, T. 9 S., R. 1 W.</td>
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<tr>
<td>J. Morgan, Sec.</td>
<td></td>
<td>½ mile south of Stayton</td>
</tr>
<tr>
<td>Oregon State Highway Division</td>
<td>soil</td>
<td>Secs. 21 &amp; 28, T. 14 S., R. 3 W.</td>
</tr>
<tr>
<td>Don Trout, Design Office Mgr.</td>
<td></td>
<td>6½ miles southeast of Halsey</td>
</tr>
<tr>
<td>Oregon State Highway Division</td>
<td></td>
<td>Sec. 28, T. 14 S., R. 3 W.</td>
</tr>
<tr>
<td>Donald Trout, Design Engr.</td>
<td></td>
<td>7½ miles southeast of Halsey</td>
</tr>
</tbody>
</table>
APPENDIX

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.
½ 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.
1½ miles west of Crabtree, Oregon

Cox Quarry
Mack Slate, Jr., Owner
rock - "shale" Sec. 22, T. 10 S., R. 3 W.
1½ 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 & Lavaer Smith, DBA Smith Sand & Gravel
Millard Smith, Owner & Mgr.
gravel Secs. 2 & 11, T. 10 S., R. 3 E.
1½ miles west of Jefferson

Smith Sand & Gravel
Millard Smith, Owner
bar run Sec. 11, T. 10 S., R. 3 W.
½ mile northwest of Jefferson

Smith & Sons, Sand & Gravel
Fred Smith
pit-run rock Sec. D.C. #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.
2½ 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.(?)
<table>
<thead>
<tr>
<th>Location</th>
<th>Name</th>
<th>Description</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec. 32, T. 11 S., R. 2 W.</td>
<td>Collins Pit</td>
<td>Sand &amp; Gravel</td>
<td>2 miles northwest of Lebanon</td>
</tr>
<tr>
<td>Sec. 8, T. 12 S., R. 4 W.</td>
<td>Gate, R. G.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 31, T. 11 S., R. 4 W.</td>
<td>Albert L. Gregory</td>
<td>Gravel</td>
<td>2 miles east of Corvallis</td>
</tr>
<tr>
<td>Sec. 5, T. 11 S., R. 3 W.</td>
<td>Hub City Concrete Co. Plant</td>
<td>Sand &amp; Gravel</td>
<td></td>
</tr>
<tr>
<td>Sec. 11, T. 10 S., R. 3 W.</td>
<td>Jerry Jones, Owner &amp; Mgr.</td>
<td>Jefferson Sand &amp; Gravel Co.</td>
<td>½ mile southeast of Jefferson</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Located off Hard Scrabble Hill Road</td>
<td></td>
</tr>
<tr>
<td>Secs. 28 &amp; 29, T. 13 S., R. 1 E.</td>
<td>Morse Brothers, Cracker Pit</td>
<td>Sand &amp; Gravel</td>
<td>Outskirts of Sweet Home</td>
</tr>
<tr>
<td></td>
<td>R. H. Bellinger, Office Mgr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 5, T. 15 S., R. 4 W.</td>
<td>Morse Brothers, Jensen Pit &amp; Plant</td>
<td>Sand &amp; Gravel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R. H. Bellinger, Office Mgr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 6, T. 14 S., R. 2 W.</td>
<td>Kenneth Howard DBA Pioneer Concrete Co.</td>
<td></td>
<td>½ mile from main road east of Brownsville</td>
</tr>
<tr>
<td></td>
<td>Ken Howard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 miles south of Brownsville</td>
<td>Kenneth Howard DBA Pioneer Concrete Co.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ken Howard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 miles east of Brownsville</td>
<td>Northern Pit,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mack M. Slate, Jr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 miles southwest of Scio</td>
<td>Mack M. Slate, Jr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 11, T. 10 S., R. 3 W.</td>
<td>Smith Sand and Gravel</td>
<td>Bar Run</td>
<td>½ mile northwest of Jefferson</td>
</tr>
<tr>
<td>Millard Smith, Owner</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 30, T. 13 S., R. 2 W.</td>
<td>Smith Sand &amp; Gravel Co.</td>
<td>Sand &amp; Gravel</td>
<td>2 miles north of Brownsville</td>
</tr>
<tr>
<td>Manning pit</td>
<td>Millard Smith, Owner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 33, T. 13 S., R. 3 E.</td>
<td>TOMCO, Inc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Edwin J. Malloy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 33, T. 14 S., R. 3 W.</td>
<td>U. S. Plywood (Forest Resource Dept)</td>
<td>Traprock</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tom Lackey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 miles southeast of Brownsville</td>
<td>Willamette Quarries, Inc.</td>
<td>Traprock</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Band Butte Quarry</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ralph Stubblefield, Pres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 4, T. 11 S., R. 2 W.</td>
<td>H. Kim Wood</td>
<td>River-run Rock</td>
<td>2 miles west of Crabtree</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Materials</th>
<th>Thickness (feet)</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9S 1W</td>
<td>Gravel and sand, loose</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>13 D1</td>
<td>Gravel, tight, cemented</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Gravel, loose, water-bearing</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Gravel, cemented</td>
<td>7</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Gravel, loose, water-bearing</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Gravel, dirty, fairly loose</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Gravel, cemented, and boulders</td>
<td>25</td>
<td>60</td>
</tr>
</tbody>
</table>

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           |

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           |

Casing: 10-in. diam to 35 ft., perforated 25-36 ft.
APPENDIX

DRILLERS' LOGS OF REPRESENTATIVE WELLS, continued

LOWER TERRACE DEPOSITS (BENEATH WILLAMETTE SILTS)

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Materials</th>
<th>Thickness (feet)</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11S 3W</td>
<td>Clay</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>17 F2</td>
<td>Sand and gravel</td>
<td>37</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Clay, blue</td>
<td>4</td>
<td>70</td>
</tr>
</tbody>
</table>

Casing: 6-in. to 66 ft., perforated 32-38 ft., 58-64 ft.

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Materials</th>
<th>Thickness (feet)</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12S 3W</td>
<td>Soil</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>7 E1</td>
<td>&quot;Hardpan&quot;</td>
<td>11</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Gravel, with clayey gravel, water-bearing (small yield)</td>
<td>4</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>&quot;Hardpan&quot; (cemented gravel)</td>
<td>7</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Gravel, water-bearing (larger yield)</td>
<td>3</td>
<td>45</td>
</tr>
</tbody>
</table>

City of Tangent, Altitude 245 ft.
Driven by W. A. Slate, prior to 1928
Casing: 1½ in to 36 or 40 ft., screen at base

COLUMBIA RIVER BASALT

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Materials</th>
<th>Thickness (feet)</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9S 1W</td>
<td>Soil</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>14 Q1</td>
<td>Clay, orange</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Boulders</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Basalt, very hard</td>
<td>47</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>&quot;Old land surface&quot;, (red clay)</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Basalt, gray</td>
<td>18</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>Volcanic ash, blue, and &quot;old land surface&quot;</td>
<td>6½</td>
<td>84½</td>
</tr>
<tr>
<td></td>
<td>Basalt</td>
<td>15½</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Basalt, angled fractures</td>
<td>80</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>Basalt, very hard</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>&quot;old land surface&quot; (red clay)</td>
<td>5</td>
<td>205</td>
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<tr>
<td></td>
<td>Basalt, vesicular &quot;honeycombed&quot;</td>
<td>10</td>
<td>215</td>
</tr>
<tr>
<td></td>
<td>Basalt, hard</td>
<td>9</td>
<td>224</td>
</tr>
<tr>
<td></td>
<td>Basalt, vesicular, &quot;honeycombed&quot;</td>
<td>3</td>
<td>227</td>
</tr>
<tr>
<td></td>
<td>Basalt, hard</td>
<td>5½</td>
<td>232½</td>
</tr>
<tr>
<td></td>
<td>Basalt, vesicular, &quot;honeycombed&quot;</td>
<td>1½</td>
<td>234</td>
</tr>
<tr>
<td></td>
<td>Basalt, hard</td>
<td>2</td>
<td>236</td>
</tr>
<tr>
<td></td>
<td>Basalt, vesicular, &quot;honeycombed&quot;</td>
<td>2</td>
<td>238</td>
</tr>
<tr>
<td></td>
<td>Basalt, hard</td>
<td>47</td>
<td>285</td>
</tr>
<tr>
<td></td>
<td>Basalt, &quot;broken&quot; very hard</td>
<td>30</td>
<td>315</td>
</tr>
<tr>
<td></td>
<td>Basalt, very hard, crevices on angle</td>
<td>11</td>
<td>326</td>
</tr>
</tbody>
</table>
### DRILLERS' LOGS OF REPRESENTATIVE WELLS, continued

#### COLUMBIA RIVER BASALT, continued

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Materials</th>
<th>Thickness (feet)</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9S 1W</td>
<td>John Fery. Altitude 550 ft.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 Q1</td>
<td>Drilled by Miller-Robinson Well Drilling, 1964</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(continued) Casing: 10-in. to 19(\frac{1}{2}) ft., unperforated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10S 1W</td>
<td>Soil</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4 J1</td>
<td>&quot;Bedrock&quot; hard</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Shale, blue, soft</td>
<td>11</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Shale and black sand</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Basalt, hard</td>
<td>5</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Shale, sandy</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Basalt, dark, hard, seamy</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Basalt, hard, seamy, and boulder</td>
<td>12</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>Shale, dark, soft</td>
<td>3</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>Shale, blue</td>
<td>2</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>Shale, dark, &quot;broken&quot; and wood</td>
<td>2</td>
<td>109</td>
</tr>
<tr>
<td></td>
<td>&quot;Rock&quot;, black hard</td>
<td>1</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>Basalt, seamy</td>
<td>2</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>Basalt</td>
<td>9</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>Basalt, hard</td>
<td>3</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td>Basalt, hard, seamy</td>
<td>8</td>
<td>132</td>
</tr>
<tr>
<td></td>
<td>Shale, dark, hard</td>
<td>1</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td>Sand, black</td>
<td>4</td>
<td>137</td>
</tr>
<tr>
<td></td>
<td>Basalt, black, hard</td>
<td>2</td>
<td>139</td>
</tr>
</tbody>
</table>

Carl Limbeck. Altitude 675 ft.
Drilled by Edward Beagley, 1957
Casing: 6-in. to 4 ft., unperforated.

#### LITTLE BUTTE FORMATION - SANDSTONE INTERBEDS

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Materials</th>
<th>Thickness (feet)</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>135 2E</td>
<td>Loam</td>
<td>4(\frac{1}{2})</td>
<td>4(\frac{1}{2})</td>
</tr>
<tr>
<td>36 Q1</td>
<td>Gravel and boulders, with yellow-brown clay pressed in, water at 11-17 ft.</td>
<td>14</td>
<td>18(\frac{1}{2})</td>
</tr>
<tr>
<td></td>
<td>Ash, volcanic, light brown, weathered</td>
<td>1(\frac{1}{2})</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Ash, volcanic, very light-gray</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Ash, volcanic, lavender</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Ash, volcanic, light-gray</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Tuffstone, lavender, firm</td>
<td>8</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Tuffstone, lavender and green, softer</td>
<td>11</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Tuffstone, lavender, firm</td>
<td>5</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Tuffstone, beige</td>
<td>41</td>
<td>100</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Materials</th>
<th>Thickness (feet)</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>105 3W</td>
<td>Soil</td>
<td>1 1/2</td>
<td>1 1/2</td>
</tr>
<tr>
<td>15 P1</td>
<td>Clay, yellow, sticky</td>
<td>26 1/2</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Clay, gray, very sticky</td>
<td>19</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Sandstone, dark-gray, very hard</td>
<td>4</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Sandstone, yellow</td>
<td>19</td>
<td>70</td>
</tr>
</tbody>
</table>

Casing: 8-in. to 50 ft., unperforated.

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Materials</th>
<th>Thickness (feet)</th>
<th>Depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>105 3W</td>
<td>Clay</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>20 K1</td>
<td>Sand and clay</td>
<td>19</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Sand</td>
<td>1</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Clay, sandy</td>
<td>100</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>Clay, blue</td>
<td>4</td>
<td>150</td>
</tr>
</tbody>
</table>

Eldon Chowning. Altitude 227 ft. Drilled by Hamilton Drilling Co., 1959
GEOLOGIC HAZARDS MAP of the
ALBANY QUADRANGLE
OREGON

EXPLANATION

0-10% Minimum risk of flooding. Very unlikely to be flooded in any given year. Small structures may be damaged by debris or mudflow. Treatments are not feasible near streams, and potential for ground movement is negligible.

10-25% Low risk of flooding. Structures may be damaged by debris, mudflow, flash flooding, or debris flow. Zoning restrictions on incompatible uses, preservation of open space and wildlife areas, and measures to control flood damage may be considered.

25-50% Moderate risk of flooding. Structures may be damaged by debris, mudflow, flash flooding, or debris flow. Zoning restrictions on incompatible uses, preservation of open space and wildlife areas, and measures to control flood damage may be considered.

50-75% High risk of flooding. Structures may be damaged by debris, mudflow, flash flooding, or debris flow. Zoning restrictions on incompatible uses, preservation of open space and wildlife areas, and measures to control flood damage may be considered.

75-100% Critical areas; other solutions may include zoning, restriction on construction within given distances of stream, riprap, and possibly removing sand and gravel from critical areas. High potential for ground movement, collapse, and land sliding.

OTHER SOLUTIONS

- Zoning may be used to control development in areas with high risk of flooding.
- Riprap may be placed to control stream bank erosion.
- Dredging may be used to control stream flow in areas with low risk of flooding.
- Land use restrictions may be implemented in areas with moderate risk of flooding.
- Flood control structures may be built in areas with critical risk of flooding.
- Vegetation may be preserved to minimize erosion.
- Agricultural practices may be implemented to reduce erosion.
- Permeable surfaces may be used to reduce runoff.
- Critical areas may be identified and mapped for future planning.
- Flood insurance may be required for structures in areas with critical risk of flooding.
- Floodplain management plans may be developed for areas with critical risk of flooding.
- Measures to prevent flooding may be implemented, such as levees, dams, and flood control structures.

FURTHER INFORMATION

- For more information on flood hazards, contact your local government or FEMA.
- For information on flood insurance, contact the Federal Emergency Management Agency.
- For information on floodplain management, contact your local planning department.
- For information on flood control structures, contact your local government.
- For information on vegetation management, contact your local government.
- For information on agricultural practices, contact your local government.
- For information on permeable surfaces, contact your local government.
- For information on critical areas, contact your local government.
- For information on flood insurance, contact your local government.
- For information on floodplain management plans, contact your local government.
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GEOLOGIC HAZARDS MAP
of the
BROWNSVILLE QUADRANGLE
OREGON

EXPLANATION

Intermediate Flood: 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 of which is defined as flooding channels and stream channel may be subject to localized flooding.

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 of which is defined as flooding channels and stream channel may be subject to localized flooding.

Floods are:

- True Floods: Floods that occur in channels due to a significant change in the size and position of the channel.
- Floods due to Poor Drainage: Floods that occur due to poor drainage conditions.
- Floods due to Urbanization: Floods that occur due to urbanization.
- Floods due to Natural Causes: Floods that occur due to natural causes (e.g., landslides, earthquakes).
- Floods due to Human Activities: Floods that occur due to human activities (e.g., dams, levees).

Partially Flooded: Areas that are partially flooded due to the above-mentioned causes.

Unflooded: Areas that are not flooded due to the above-mentioned causes.

Geologic Hazards Map by J. D. Broxter and P. W. Hughes
Cartography by H. E. Berns and M. R. Fosbery 1974

BROWNSVILLE QUADRANGLE
STATE OF OREGON
DEPARTMENT OF CONSERVATION AND FISHERS INDUSTRIES

GEOLOGIC HAZARDS MAP
of the
BROWNSVILLE QUADRANGLE
OREGON

EXPLANATION

I. Floods:

- Willamette Valley floods: Floods that occur in the Willamette Valley due to a significant change in the size and position of the channel.
- Floods due to Poor Drainage: Floods that occur due to poor drainage conditions.
- Floods due to Urbanization: Floods that occur due to urbanization.
- Floods due to Natural Causes: Floods that occur due to natural causes (e.g., landslides, earthquakes).
- Floods due to Human Activities: Floods that occur due to human activities (e.g., dams, levees).

Partially Flooded: Areas that are partially flooded due to the above-mentioned causes.

Unflooded: Areas that are not flooded due to the above-mentioned causes.

Geologic Hazards Map by J. D. Broxter and P. W. Hughes
Cartography by H. E. Berns and M. R. Fosbery 1974
GEOLOGIC MAP of the
HALSEY QUADRANGLE
OREGON

Geologic Cross Section

Geologic Symbol:

Contacts: Rock
Faults: Fault
Strikes and dips of Bedding and Shale
Expositional Oil Wells:
Dry Hole: Dry Hole
Show of Oil: Show of Oil
Wells and Quarters:

Geology by J. D. Brandreth
Cartography by S. R. Renoud and W. H. Pokorny 1974
GEOLeGIC HAZARDS MAP
of the
HALSEY QUADRANGLE
OREGON

STATE OF OREGON
DEPARTMENT OF GEOLeGIC AND MINERAL RESOURCES
W. S. HOSKINS, STATE GEOLOGIST

EXPLANATION

Topo Map

Wiltamette Valley floodplains; flood plains of major streams, terraces, and isolated upland areas; hazards may include flooding in development, governed by the development boundary (as indicated by the flood plain and existing structures). Occasionally, these areas may be part of Little Basal Formation, where landslides or other mass movements are possible during or after heavy rain.

Faults on steep slopes (see page 6.5). Hazards include rapid runout, rockslides, debris slides, earthflows, and mudflows. The hazard zone is characterized by steep slopes, mass movement, vegetation, and vegetation characteristics. The hazard zone is limited by the most extreme hydrologic and meteorologic conditions.

Failure on steep slopes (see page 6.5). Hazards include rapid runout, rockslides, debris slides, earthflows, and mudflows. The hazard zone is characterized by steep slopes, mass movement, vegetation, and vegetation characteristics. The hazard zone is limited by the most extreme hydrologic and meteorologic conditions.

Flash flood channels: Small to medium-sized stream channels, situated in areas of moderate to steep slopes and low permeability, characterized by rains, snowmelt, heavy floods, and heavy snowfall. The hazard zone is characterized by steep slopes, rapid flow, and potential for extensive damage.

Revised map: The map is revised to include new data and information, and to reflect recent developments and changes in the area. The map includes information such as topography, stream channels, and flood plains, and is updated to reflect the most recent hydrologic and meteorologic conditions.

Geologic Hazards by J. D. Bresnahan and P. W. Bagley
Cartography by H. E. Brennan and W. H. Folks, 1974

R.109

0-10%

10-25%

20-35%

30-40%

40-50%

50-60%

60-70%

70-80%

80-90%

90-100%

TEXTUAL SOILS MAP
of the
HALSEY QUADRANGLE
OREGON

EXPLANATION
Clay and silt: clay lenses construction limitations in places because of poor drainage, compressibility, and location in flood prone areas; generally not acceptable for septic tanks owing to slow 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.

Sand and sandy loam: acceptable for most construction, generally not acceptable for septic tanks, septic basins, 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. Polvruy 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
LEBANON QUADRANGLE
OREGON

Geologic Cross Section

Geologic Symbols

Contacts

Rock

Contact

Folds

Attitude

Horizontal hinge, and axes

Exploratory Oil Wells

Shore of US

Plane and dip of Beds and Folds

Exploratory Oil Wells

Dry Hole

Shore of Litte

Horizon and Structures

Geology by J. D. Beaudin
Cartography by D. R. Resourd and W. M. Poteray 1976
TEXTURAL SOILS MAP
of the
LEBANON QUADRANGLE
OREGON

EXPLANATION
- Clay and silt: poor construction limitations in places due to poor drainage, compressibility, and location in flood prone areas; not acceptable for septic tanks owing to low infiltration rates.
- Clay loam and silt loam: limited use as a function of local topography, water table, and engineering properties; generally acceptable for septic tanks, sewage disposal, and landfills.
- Loam and silt loam: restricted in Willamette Valley because of poor drainage and high water table; septic tanks and sewage disposal acceptable in areas of favorable topography, water table, and permeability.
- Sandy and stony loam: acceptable for most construction; generally not acceptable for septic tanks, leach fields, and landfills due to rapid infiltration.
- Gravelly and stony loam: same as sandy and stony loam above.
- Stony mountainous land: variable; see Geologic Hazards maps.

Soils by P. W. Hughes
Cartography by S. R. Renouf 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.

Clay
Silt
Sand
Gravel
Percent sand and gravel
Percent clay and silt
Percent sand, silt, and gravel

Soil Classification
- Clay: >50% clay
- Silt: >40% silt
- Sand: >30% sand
- Gravel: >30% gravel

MAP FOOTNOTES
Base map from U. S. Geological Survey: Shepperd, 1931; 1951, and 1962
Control by USGS, USC&GS, and USCE
Trophy by photoplot, 1911, 1914, and 1922
Culture based on aerial photographs taken 1954
Field check 1957

Polyconic projection, 1927 North American datum
10,000-foot grid base on Oregon coordinate system, north to west

1000-meter Universal Transverse Mercator grids, zone 10, shown in blue

Reprinted with permission of the Oregon Department of Geology and Mineral Industries.
**GEOLOGIC HAZARDS MAP of the QUARTZVILLE QUADRANGLE OREGON**

**EXPLANATION**

**Shake**

Wilmette Valley klipsetts, flood plains of major streams, terrace deposits, bedrock outcrops; hazards may include flooding in streams, gushing in depressions, and debris in upper reaches of drainage. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

**Gravitational sliding** hazards, parts of older alluvial terraces, and similar channels in the Wilmette Valley klipsetts, chemical weathering produces in uplands; hazards include erosion, mass movement, and failure. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

**Extended Wilglo areas in uplands** include areas of thick clays and sand and may experience liquefaction in areas underlain by unconsolidated deposits or bedrock. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

**Lowlands**

Intermediate Regional Flood: Floods (estimated by U.S. Army Corps of Engineers) occurring in any given year. Preventive action includes zoning regulations and inapplicable developments, evaluation of the public, implementation of Federal floodplain insurance program, and the construction of levees and floodwalls.

Regulated Project Flood: Floods (estimated by U.S. Army Corps of Engineers) which would be produced under the most extreme hydrologic and meteorologic conditions possible, excluding extreme low combinations, areas which would not be included in flooding through chance or man's fault, but may be subject to localized flooding of various types.

Estimated possible flooding areas probably subject to flooding but for which no statistical data has been made.

**Soil bank erosion**. Undercutting and erosion of soil and stream banks, commonly accompanied by landslides, mudslides, and debris flows. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

**Abandoned channel**. Length of river or stream channel abandoned through catastrophic channel changes during flooding; common on the site of migrations, progressive and recent. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

**Channel change**. Location of present stream channel as estimated by recent progressive movements through stream banks and floodplains. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

**Uplands**

Mass movement topography: Erosion of the upper surface of the soil, wind erosion, and deposition of sediments. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

**Failure on steep slopes** (slope >45°). Hazards include rapid flows, debris flows, and debris slides. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

**Flash flood channels**. Small, temporary streams that may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may be initiated by rainfall events, with or without a stream change, usually associated with poor drainage and steep slopes. Floods may also be associated with mudslides, debris flows, or failure on steep slopes in areas underlain by unconsolidated deposits or bedrock.

Geologic Hazards by J. D. Beaulieu and P. W. Hughes
Cartography by S. R. Reveau and W. H. Polenay 1974

**BASE MAP**

Quartzville Quadrangle, shown in blue, 1927 National American datum. Topographic map from aerial photography by multiple methods. 100-meter Universal Transverse Mercator grid ticks, based on Geologic Hazards Map, Oregon State University, 1974.
GEOLOGIC HAZARDS MAP
of the
SNOW PEAK QUADRANGLE
OREGON

EXPLANATION

Mass movement topography: Earthflow terrain characterized locally by gentle undulating topography, moderate slopes, visible changes in soil, and failures of resistant materials, especially calcite and clayey materials. Failure generally, but prominently, in parts of the Lillooet Butte Formation. Hazard may include potential for widespread, poor foundation strength, rapid reactivation, and poor resistance to erosion, deposition of debris, and development of erosion by recent progressive meandering along stream channels. Hazard potential small; cuts and fills (or future stream channels) do not pose a significant threat to flood plains or ground water. Use of septic systems and drain fields may be restricted. Other solutions may include zoning, restrictions on incompatible developments, etc.

Intermediate Regional Flood (modified by U.S. Army Corps of Engineers) with a 1% probability of occurrence in any given year. Preventive action includes bank reinforcement, riprap placement to control stream bank erosion, and construction of levees and dikes. Bank failures and channel changes can cause damage to structures and damage to agriculture, industry, recreation, and residential areas.

Lowlands

Standard Project Flood: Excess of flood (modified by U.S. Army Corps of Engineers) with a 1% probability of occurrence in any given year. Preventive action includes bank reinforcement, riprap placement to control stream bank erosion, and construction of levees and dikes. Bank failures and channel changes can cause damage to structures and damage to agriculture, industry, recreation, and residential areas.

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

Ground water: pictures (modified by U.S. Army Corps of Engineers) with a 1% probability of occurrence in any given year. Preventive action includes bank reinforcement, riprap placement to control stream bank erosion, and construction of levees and dikes. Bank failures and channel changes can cause damage to structures and damage to agriculture, industry, recreation, and residential areas.

Mass movement topography: Earthflow terrain characterized locally by gentle topography, moderate slopes, visible changes in soil, and failures of resistant materials, especially calcite and clayey materials. Failure generally, but prominently, in parts of the Lillooet Butte Formation. Hazard may include potential for widespread, poor foundation strength, rapid reactivation, and poor resistance to erosion, deposition of debris, and development of erosion by recent progressive meandering along stream channels. Hazard potential small; cuts and fills (or future stream channels) do not pose a significant threat to flood plains or ground water. Use of septic systems and drain fields may be restricted. Other solutions may include zoning, restrictions on incompatible developments, etc.

Intermediate Regional Flood (modified by U.S. Army Corps of Engineers) with a 1% probability of occurrence in any given year. Preventive action includes bank reinforcement, riprap placement to control stream bank erosion, and construction of levees and dikes. Bank failures and channel changes can cause damage to structures and damage to agriculture, industry, recreation, and residential areas.

Lowlands

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**GEOLOGIC HAZARDS MAP of the SWEET HOME QUADRANGLE OREGON**

**EXPLANATION**

Statewide:

- Willamette Valley backlands, flood plains of major streams, terraces, and alluvial fans, hazards may include flooding in springtime, resulting in depressional flow. High water levels, and poor soils (not Soil Map) may be hazardous in the Willamette Valley. Major flood plains, flood fans, and alluvial fans are not shown.

- Coastal areas, including coastal plains, are subject to storm surge, coastal erosion, and other coastal hazards.

- Aerial photography is provided at: 1:24,000 scale, 1950. Field check 1951.

- Oregon coordinate system.

**Scale**: 1:62,500

- Polyconic

- Oregon Ohio Quadrangle

1951

**METHODS**

- Oregon Geologic Map

1951

- Oregon Geologic Map

1951

- Oregon Geologic Map

1951

**STATE OF OREGON**

- DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

1974

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Culture revised from aeriel topography by ZOM Polysonic projection. North and South zones field checked 10,000 feet grid. Lyons photographs 1956, h0 west pl in blue and east red. Oregon coordinate system, North American Datum 1942, taken 1952 west tem. ticks. --­ --­

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EU GENE QUADRANGLES

SCALE 1:62500

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Geologic Symbols

Contact

Bedrock

Anticline

Folds

Syncline

Altitude

Horizontal beds and forms

Expositional Outcrops

Dry Site

Shore of Oil

Moss and Quartz

Geology by J. D. Beaulieu
Cartography by R. R. Hannus and W. R. Pohorsky 1974

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GEOLOGIC HAZARDS MAPS
of parts of the
STAYTON, LYONS, MARCOLA & EUENGE QUADRANGLES
OREGON

EXPLANATION

Bare Map from U.S. Geological Survey. Field check 1956
Polyconic projection 1927 North American datum
10,000-foot grids based on Oregon coordinate system,
aerial photographs taken 1952

Approximate Mean Declination, 1956

1:62500


Small- and medium-sized stream channels:
Small to medium-sized stream channels discurved through catastrophic channel changes during flooding; stream channel changed by channel migration, migration to opposite bank, and deep water near shore; also inferred location of present stream channel acquired from U.S. Army Corps of Engineers flood proofing program. Taken from U.S.G.S. 7 1/2" Topographic Maps dated 1969 and 1970 and aerial photographs dated 1970. Revisions do not meet National Map Accuracy Standards.

Abandoned channel: Length of river, or stream channel abandoned through catastrophic channel changes during flooding; stream channel made up of abandoned stream channel, and deep water near shore; also inferred location of present stream channel acquired from U.S. Army Corps of Engineers flood proofing program. Taken from U.S.G.S. 7 1/2" Topographic Maps dated 1969 and 1970 and aerial photographs dated 1970. Revisions do not meet National Map Accuracy Standards.

Baseline: Riprap placed to control stream bank erosion; may extend to increased area of erosion, but connections downstream.

Mass movement topography: Earthflows terrain characterized by irregular to symmetrical topography, irregular shapes, eroded drainage, displaced soil, and failure of mass movement causing abrupt ground and knoll structures. In general, but particularly in parts of Little Butte Formation, especially below unconformities of resistant cap rock, hazards may include potential for ground movement, poor foundation strength, danger to structures, and poor water quality. Earthflow terrain can be divided into six types: slip failure, knoll structures, and use of riprap; and zone little may contain of subaqueous, active investigation recommended for most development, except for low-density housing in places. Baseline: Riprap placed to control stream bank erosion; may extend to increased area of erosion, but connections downstream.

Runoff, rockslides, thin debris slides, earthflows, and mass movement topography in areas characterized by slope changes, and deep excavations not feasible or unsuitable engineering in much of the Lillie Butte Formation; hazards variable; fills, culs, septic tanks generally not feasible; preservation of vegetation, low-density, highly wooded residential development.

Flood (determined by U.S. Army Corps of Engineers) which would be produced under the most extreme hydrologic and meteorologic conditions. High-risk to life safety and property; not subject to federal flood plain management program. Undercutting and cutting of row and stream channel, local areas of moderate to steep slope and low relief; hazards include rapid erosion with little chemical weathering; hazards include reaction ranges, thin debris slides, earthflows, and flash flooding; potential for development small and fills for road construction require proper engineering, and seismic hazards generally not subject to federal flood plain management program, low density development in much of the Lillie Butte Formation; hazards minimal over Columbia River Basalt; clay soils and mass movement in parts of Little Butte Formation; hazards variable; fills, culs, septic tanks generally not feasible; preservation of vegetation, low-density, highly wooded residential development.

Flood (determined by U.S. Army Corps of Engineers) which would be produced under the most extreme hydrologic and meteorologic conditions. High-risk to life safety and property; not subject to federal flood plain management program. Undercutting and cutting of row and stream channel, local areas of moderate to steep slope and low relief; hazards include rapid erosion with little chemical weathering; hazards include reaction ranges, thin debris slides, earthflows, and flash flooding; potential for development small and fills for road construction require proper engineering, and seismic hazards generally not subject to federal flood plain management program, low density development in much of the Lillie Butte Formation; hazards minimal over Columbia River Basalt; clay soils and mass movement in parts of Little Butte Formation; hazards variable; fills, culs, septic tanks generally not feasible; preservation of vegetation, low-density, highly wooded residential development.
TEXTURAL SOILS MAPS of parts of the STAYTON & EUGENE QUADRANGLES OREGON

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 slow infiltration rates.

Clay loam and silty clay loam: Ground water varies from low in areas of favorable topography, water table, and permeability. Acceptable for sewage disposal and septic tanks.

Loamy and silt loam: Restricted use as a function of local topography, water table, and engineering properties; septic tanks and sewage disposal acceptable in areas of favorable topography and water table.

Sandy and sandy loam: Acceptable for most construction; generally not acceptable for septic tanks. Landfills acceptable in regions of appropriate permeability and water table.

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

Stony mountainous land:Variable; see Geologic Hazards maps.


Soil Classification Diagram

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