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Environmental Geology of the Marquam Hill Area

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December 13, 1973

ENVIRONMENTAL GEOLOGY
OF THE
MARQUAM HILL AREA

by
ROGER ALAN REDFERN

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
EARTH SCIENCE

Portland State University
1973

AN ABSTRACT OF THE THESIS OF Roger Alan Redfern for the
Master of Science in Earth Science presented December 13, 1973

Title: Environmental Geology of the Marquam Hill Area

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:



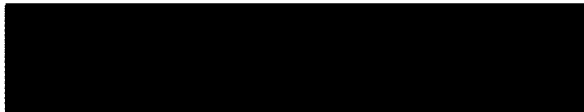
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This work on Marquam Hill area in Portland, a relatively undeveloped urban hillside area, is a pilot study in which environmental factors are evaluated quantitatively in order to delineate limitations on development. The study was undertaken at the request of and in cooperation with the City of Portland Planning Commission and with the State of Oregon Department of Geology and Mineral Industries. Factors considered include various aspects of the land, vegetation and attitudes of inhabitants. Findings are not

intended to satisfy need for individual site studies by qualified experts but should show where that expertise is needed.

Field data were collected on site by observations, borings, personal interviews and by geophysical surveys; laboratory tests were made on soil samples; studies were compiled of topographic maps and aerial photographs; and pertinent data from available previous works were incorporated. Data were integrated into a series of environmental factor maps including ground slope, bedrock and soil, bedrock structure, soil thickness, ground stability, hydrology, and vegetation.

Land use constraints and environmental limitations were defined using U.S. Department of Agriculture, Soil Conservation Service, soil suitability and limitations criteria as a guide. Mapped geologic and environmental constraints were overlaid with the mapped soil criteria to identify areas by limitations. An interpretive map and chart show that most of the study area is moderately to severely limited for most land uses. Some small areas can be considered as slightly limited, but the majority of these are already developed.

The constraints are so severe that most of the area should be left in open space. The major recommendation is that any development must be carefully controlled, utilizing stringent grading codes (such as Chapter 70 of the Uniform Building Code) and professional expertise to assure the

safety and environmental compatibility of the site. It is suggested that planned unit development, in the form of clustered or low- to medium-rise structures would optimize design for natural conditions, siting locations, and residential density least affecting the surrounding, naturally vegetated, hazardous slopes.

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1. Ground slope
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4. Ground stability and hydrology
5. Vegetation

INTRODUCTION

At the request of the City of Portland Planning Commission and the State of Oregon Department of Geology and Mineral Industries an investigation was conducted of the physical values and limitations of an area herein called the Marquam Hill area.

Location and setting

The Marquam Hill area, as shown in figure 1, is located in southwest Portland along the east flank of the Tualatin Mountains (locally and herein called the Portland Hills). The study area is bounded on the north by S. W. Patton and Broadway Drive, on the east by S. W. Barbur Boulevard, on the west by the 825 foot elevation as shown on topographic maps, and on the south by an arbitrary line.

The Portland Hills are composed of a bedrock of basalt which has apparently been uplifted by folding and faulting to form the Tualatin Valley on the west and the Portland valley (Willamette Valley) on the east. These two valleys have bedrock basements composed of basalt overlain by valley fill of mostly river-transported sediments (alluvium). The basalt bedrock of the Portland Hills is rarely exposed. It is mostly covered by soils of probable wind-blown origin and soils derived from deep weathering of the basalt.

Purpose and scope of study

It was the purpose of this study to supply data on the physical environment of the Marquam Hill area that would be pertinent to planning and development of that area. In accordance with this perspective, the study has concentrated on defining the natural limitations of the land to development by man; this is part of what is now being called environmental geology.

The study was concerned with defining general areas in which particular environmental geologic problems or limitations are recognized or anticipated. The report is not intended to replace actual site evaluations by qualified experts, but rather to serve as a guide for land-use planning and to encourage site evaluations under chapter 70 of the Uniform Building Code (appendix A) in areas which are hazardous or limited in use-potential.

Previous work and sources of data

Geologic investigations and mapping covering the study area have been conducted on a regional basis by Warren, Norbistrath, and Grivetti (1945), Peck (1961), and Lowry and Baldwin (1952). Geologic mapping and study of the Portland area has been conducted by Treasher (1942) and Trimble (1963). Schlicker and Deacon (1967) studied and mapped the engineering geology of the Tualatin Valley including part of the Tualatin Mountains north of the study area. Other previous investigations related to the study are credited in the text where they are cited.



Figure 1. Location map, Marquam Hill area, Portland, Oregon.

The majority of the data collected and reported herein was obtained by the investigators and assistants of this study. Existing reports helped to guide the field investigations and analyses and supplied the basic foundation from which this study has developed. Water-well logs from the files of the U. S. Geologic Survey's Water Resources Branch in Portland provided some information on the subsurface conditions of the general area.

Methods of study, evaluation, and interpretation

The interpretation of environmental data for planning involved three general steps: detailed mapping and study, evaluation, and interpretation.

Detailed surficial mapping and subsurface studies, supported by laboratory analyses and aerial photo interpretation, were performed to differentiate and characterize all geologic, soil and vegetation units. More than three months and 800 man hours were necessary to complete the information accumulation. Information collected in the field included distribution of vegetation, soil, and rock units; descriptions of the surficial material, vegetation, and landforms; detailed sampling of all deposits; and delineation of areas of instability. Subsurface information was obtained from water-well records in adjoining areas, roadcuts, selected borings, and seismic refraction surveys. These studies produced the following maps: (1) ground slope, (2) bedrock and soil, (3) bedrock structure and soil thickness, (4) ground stability and hydrology, and (5) vegetation.

After the detailed surficial and subsurface investigation was accomplished, all geologic and soil units were evaluated in terms of their engineering and hydrologic properties on the basis of field observations, laboratory analysis and classification, and previous investigations. The vegetation units were evaluated on the basis of age, type, condition, and successional placement.

Information developed to this point was then used to prepare an interpretive map in which areas were graded on the number of limitations to potential land uses. This map was constructed by overlaying the individual physical factor maps which present limitations to specific developments or uses of the earth materials. Most of the basic factors utilized are defined by the Soil Conservation Service and are included in Appendix B of this report. The basic factors include soil classification, texture, drainage, thickness and permeability, ground slope, and depth to water table. Where appropriate, other factors such as soil instability and vegetation are overlaid with the basic soils overlays.

Eight sections of this report describe the information accumulated. The sections cover: (1) ground slope, (2) bedrock and soil, (3) bedrock structure, (4) seismicity, (5) soil thickness, (6) ground stability, (7) hydrology, and (8) vegetation. Following these discussions are sections devoted to interpretations and recommendations.

Acknowledgements

The investigation was organized and conducted by the author under the supervision of Dr. Leonard Palmer with the assistance of the following persons:

Donald Baggs and Kent Mathiot contributed to the field mapping and material sampling. Paul White accumulated most of the seismic data. Christiana Stachelrodt investigated and reported on the vegetation. She also authored a paper on a survey of the attitude of the Marquam Hill area residents toward land development and their knowledge of potential geologic hazards (see Appendix H). Steve Bowers, Ace Bush, Pam Paetzhold, and Cheryl Wilgus assisted the investigators in field and laboratory work.

George Otte, Soil Conservation Service field representative, mapped the soil units and reported on their properties and characteristics.

The Oregon Department of Geology and Mineral Industries furnished financial assistance and performed general review, editing, typing for camera copy, and cartographic work.

GROUND SLOPE

Slope maps are used by engineers, soil scientists, geologists, geographers, and others for interpreting underlying rock structure, subsurface and surficial earth processes, soil formation, and other factors. Practical applications of slope maps include: determining excavation equipment limitations, soil-use limitations, landslide-prone areas, watershed management, forest management, and many more aspects pertinent to land planning and development.

Methods

The ground slope map of the Marquam Hill area was constructed from detailed, 1:2400 topographic maps supplied by the Portland Planning Commission for this study. The ratio of vertical elevation differences to horizontal distances determines the percent slope when the horizontal distance is corrected to 100 (ie. 10 feet vertical to 50 feet horizontal = 20 percent slope).

The slope map (map 1) depicts areas of the land surface which have slopes within certain ranges. Lines separating shaded areas on the map correspond to isopleths or lines of equal slope. Steeper slopes are shown with progressively darker shades of grey; steeper slopes present progressively greater limitations to man's activities, both constructional and recreational.

Findings and evaluations

Ground slope can be a major limiting factor in land use and development. In general, gently sloping areas (less than 15 percent) can be developed with few problems if reasonable grading and excavation practices are applied. Gently sloping ridge crests and spurs in the area are well defined on the slope map by map units showing less than 33 percent slope. They also correlate well with the areas of residence, parks, small retail outlets, and institutions that exist in the study area. Slopes from 15 percent to 33 percent have been developed with some subsequent land failure.

Slopes steeper than 33 percent occupy the majority of the study area; these slopes are situated on the sides of youthful stream canyons. Initial evaluation of the slope map based on field observations indicates that the moderately steep slopes (15 percent to 67 percent) generally have thick soil with at least the upper soil mass actively moving downslope at rates varying from slow (soil creep) to rapid (landslides and mudflows). Steep slope areas (greater than 67 percent) are generally associated with shallow bedrock. Soil overlying the bedrock on these steep slopes is actively moving downslope at varying rates.

BEDROCK AND SOIL

Surficial mapping in the Marquam Hill area includes both bedrock geologic units exposed at the surface and soil units defined by the Soil Conservation Service. Geologic maps by Trimble (1963) and Treasher (1942) show that bedrock units in the study area consisted of basalt called the Columbia River Basalt, conglomerate* of the Troutdale Formation, silts of possible wind-transported origin (loess*), and waterlaid deposits consisting of fine sand and silt. Boring Lava, not previously mapped in the study area, is also present.

Methods

Soil and rock exposures as shown on map 2 were classified and were examined for structure, relative stability, degree of weathering, and thickness. Unconsolidated sediments and soils were studied by field classification and laboratory analysis. Samples were obtained with the aid of hand and portable power augers (figure 2). Seismic surveys with a portable seismic timer (Soiltest Model MD-3) supplemented the identifications.

* Defined in the glossary - Appendix C.



Figure 2. Highly portable power auger used for soil exploration to depths as much as 40 feet; supplied by Oregon Department of Geology and Mineral Industries.

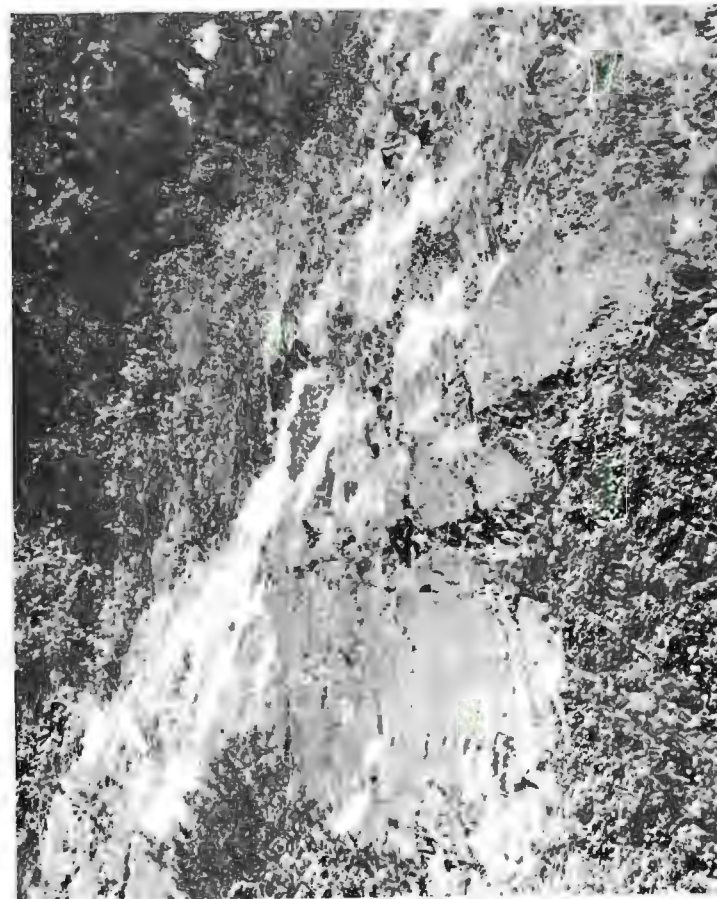


Figure 3. Columnar (bottom) and closely spaced (top) jointing in basalt have different stability and excavational characteristics.

The two flow basalts in the study area were similar in overall engineering properties, and are therefore not differentiated on the maps. Some volcanic materials around Council Crest appear to have different engineering properties and will be treated separately below.

Descriptions of units with occurrences, engineering properties, and characteristics are summarized below. More detailed geologic descriptions can be found in Trimble (1963), Lowry and Baldwin (1952), and other works noted above.

Findings and evaluations

Columbia River Basalt

(Columbia River Basalt is the bedrock which forms most of the Portland Hills. The basalt is exposed in scattered outcrops but throughout most of the area it is covered by soils and sediments averaging about 15 feet thick. Power auger borings indicate that in some eastern parts of the area the basalt is covered by more than 42 feet of sediment.)

The Columbia River Basalt is composed of numerous lava flows lying one sheet upon another. The entire mass of basalts has been uplifted to form the Portland Hills. Fracturing and breaking of the rock mass has occurred but the fractures, or faults, are not well exposed for observation and study.

Consistent variations within individual lava flows, however, are quite well known and have an important effect upon the way the land will respond to excavation, grading, and slope stability. An individual flow may contain the following layers (see figure 3): (1) an underlying soil, (2) a basal columnar jointed basalt, (3) a zone of closely spaced jointing with open cavities (vesicles), (4) an upper columnar jointed basalt, and (5) an overlying soil.)

Soil and sediments between flows of basalt are common and are seen outside the area of this study. Interlayer soils can form weak planes in the rock mass. A landslide 1/2 mile long occurred on such a soil in the Freeway cut at West Linn (about 4.8 miles along the south-southeast extension of the West Hills). No hazardous soil layers have been located between flows in the study area, but the potential for major landsliding is present. Careful exploration including deep borings should be required for major structures such as high-density residential facilities or public buildings to be built on the basalt.

Columnar jointed basalt is created by cooling of the hot molten lava forming columns approximately perpendicular to the top and bottom of the flow. The basalt columns range from several inches to several feet in diameter. Massive columns may form cliffs from which rockfalls occur. Large columns form stable foundations but are commonly difficult to excavate.

Basalt with closely spaced jointing and open cavities (vesicles) is generally more easily excavated. Where such basalts are weathered, unstable and failing ground can be expected on slopes steeper than 15 percent (figure 4).

The Columbia River Basalt is normally excellent foundation material, and has few limitations for use. However, Schlicker and Deacon (1967) recommend that before a site is developed on Columbia River Basalt, consideration should be given to "the slope and thickness of the rock, nature of the overlying and underlying formations, geologic structure, and degree of weathering and jointing."

Though limitations to land development depend largely on the sum of all site conditions, some generalizations can be made. Septic systems may not be possible where the basalt is overlain by impermeable soil or thin soil because of potential ground water pollution and surface leakage of the effluent. Excavation in relatively unweathered basalt usually requires explosives except for the vesicular or closely jointed zones which can often be ripped* with proper equipment. Weathered basalt excavation may require ripping and/or removal of large unweathered blocks of basalt.

Boring Lava

Boring Lava overlies the Columbia River Basalt in the Council Crest area. Distribution of these lava flows and relief suggest that Council Crest is the probable site of the source vent for the Boring Lava found in the study area. The lava is exposed in several locations, but it usually underlies silty soils and sediments up to 18 feet or more thick. Jointing in these lavas is usually widely spaced, and weathering in some localities outside the study area has produced residual boulders over 5 feet in diameter.

* Defined in the glossary - Appendix C

The Boring Lava is generally like the Columbia River Basalt in providing good foundations and few limitations. Excavation of the basalt and removal of boulders are exceptions to this generalization. Occasional deposits of weakly consolidated volcanic ash and cinders, which overlie or are interbedded with the flows, are sometimes found near Boring source vents. These ash and cinder deposits may contribute to landslides in basalt at Council Crest. Lava tubes or cinder pockets in Boring Lava caused million-dollar foundation problems in the St. Vincent Hospital construction in 1970. Careful and numerous foundation borings and tests are required in Boring Lava because of the irregularity of rock units near volcanic eruptions.

Conglomerate

Two widely separated deposits of moderately well-cemented sands and gravels (conglomerate) were found, one of which was mapped by Treasher (1942) as Troutdale Formation (Figure 5). These deposits do not resemble the Troutdale in all respects, but stratigraphically* and within the objectives of this study the gravels can be considered equivalent to the Troutdale. The extent of the gravels is probably greater than shown on the map but is masked by soil cover.

Because of the limited extent of the conglomerate and the scarcity of information on its properties, very little can be said at this time about its response to use. Field examination of the conglomerates and the relative stability of the outcrops indicates that this unit may present few limitations to development. However, serious landsliding and damage to structures has occurred on this type of unit near the old St. Vincent Hospital. Excavation in weathered portions of the conglomerate is thought to be possible by ripping, but excavation in the unweathered conglomerate may require explosives. Field observations indicate that heavy structural loads may cause differential settlement or failure along joints, faults, or contacts with other formations. Before any development begins on this unit, detailed engineering geologic studies should be conducted to determine the extent, engineering properties, and geologic structure of the rock unit, as well as the nature and relationship of the overlying and underlying formations.

Weathered basalt soil

Alteration of the basalts by weathering has resulted in a layer of clayey soils up to several feet in thickness that is exposed in the study area in small irregular patches. Exploratory borings indicate that this unit occurs beneath the Portland Hills Silt unit in some of the area. The thickness of these soils is highly variable and in some localities, especially in stream valleys, it is completely absent or very thin due to erosion.

Weathering of the Columbia River Basalt generally results in a red to brown residual product of thoroughly decomposed, earthy, untransported rock (saprolite) in which the relic textures, structures, and mineral outlines are discernable (Trimble, 1963). Complete decomposition results in a clayey soil with the clay mineral halloysite predominating.

Weathering of the Boring Lava results in a similar red clayey soil up to 15 feet thick that retains none of the original character of the parent rock. As noted above, widely spaced jointing (columnar and massive) may result in large residual boulders of the lavas suspended in the clayey soil.

Soils developed in situ on the basalts have been classified mostly as low plastic clays (CL), but they range up to highly plastic clays (CH) on the Unified Soils Classification System (see Appendix D). In many steep slope areas a mixture of basaltic soils and loess soils (see unnamed soil series) results in a clayey silt soil (ML) and (ML-CL). (Note: When two symbols are shown in this manner, it means that the soil falls on the classification on or near the boundary between the two classes and the properties of the soil are intermediate between the two classes.)

The majority of these basaltic soils (CL and ML-CL) have a poor to good rating for foundations and other urban uses. Relative shear strength is low to moderate, ease of compaction control is fair to good, and compressibility is moderate. Internal drainage is poor to impervious. There is a slight to moderate limitation due to shrinkage and expansion of the soils through wet and dry cycles. Dry strength is slight to moderate. Frost heave potential is moderate to severe. (Schlicker and Deacon, 1967; U.S. Department of the Interior, 1963; U. S. Federal Housing Administration, 1959).

Portland Hills Silt

A blanket of silty sediment overlies other geologic units above elevations of approximately 200 feet throughout most of the area. Thickness of the silt averages about 15 feet in the study area, and

* Defined in the glossary - Appendix C.



Figure 4. Landslide in moderately weathered basalt on Northwood Avenue, an unimproved and undeveloped street.



Figure 5. An unusual occurrence of quartzite-free conglomerate on S.W. Fairmount Boulevard at an elevation above 900 feet near the crest of the Portland Hills.

thicknesses in excess of 42 feet are known in the eastern portion of the area. The silts are uniform, geologically structureless, yellow-brown to buff sandy silt and clayey silt with occasional well-rounded pebbles. These silts have been called Quaternary loess by Trimble (1963), Portland Hills Silt by Lowry and Baldwin (1952), and Upland Silt by Schlicker and Deacon (1967); Portland Hills Silt is probably the most widely used name for this unit.

The silts range on the Unified Soil Classification from clayey silt to silty clay (ML to CL) with a borderline classification of ML-CL being predominant in the area. Samples from power auger holes indicate that the silts increase in clay content with increasing depth (Appendix E). A representative well log would show surficial soils of nearly pure silt (ML). With increasing depth the soils become clayey silts (ML and ML-CL), and towards the bottom of a silt deposit the soils are classified as silty clays (CL). Several well logs indicate that this representative profile is not present everywhere, but a general increase in clay content with depth was encountered in the majority of the holes drilled. It is thought that this clay distribution profile in undisturbed soils is due to weathering of some of the silt constituents near the surface to clays which are transported downward in the soil by groundwater to accumulate at depth.

Soil series: Three soil series developed in the Portland Hills Silt have been mapped and evaluated by George Otte of the Soil Conservation Service (SCS), (Table 1). The results of the soil survey are quoted below, supplemented by field and laboratory findings and evaluations.

The bedrock geologic and soils map shows the location and extent of each kind of soil in the Marquam Hill area (map 2).

Methods: Holes were dug with a shovel or soil auger so that the soil profile could be examined. The soil profile is composed of one or more natural layers or horizons. It extends from the surface down into the parent material that has not been changed much by leaching or by the action of plant roots. A maximum of five feet in depth was examined in the area. The nature and sequence of the horizons in each soil profile were compared with known kinds of soils outside the Marquam Hill area that have been classified and named according to nationwide, uniform procedures. Soils that have profiles almost alike make up a soil series. Except for different texture in the surface layer, all soils of one series have major horizons that are similar in thickness, arrangement, and other important characteristics. Each soil series is named for a town or other geographic feature near the place where a soil of that series was first observed and mapped. Two soil series, the Cascade and Goble, have been named. The third soil series has not had a name assigned to it.

Cascade soil series: The Cascade series consists of somewhat poorly drained, silt loam soils formed in loess-like material over mixed, old alluvium. They are on smooth or rolling convex long slopes and ridge tops on the uplands. The surface soil is dark brown silt loam about 17 inches thick. The upper subsoil is dark brown silt loam about 7 inches thick. It is underlain by a very firm, brittle, and mottled silt loam 3 or more feet thick. The depth to fragipan* ranges from 20 to 30 inches. The permeability is slow. The surface runoff is slow to rapid, and erosion hazard ranges from slight to high. Total available water-holding capacity is 9 to 12 inches. The soil is used mainly for small grain, grass seed, hay and pasture and some berries. Other uses include homesites, wildlife, recreation, woodland, and water supply.

The majority of the soils in this unit range on the Unified Soil Classification System from ML to ML-CL. Soils of this range can be expected to have a moderate shear strength, to be impervious, and to have fair to poor internal drainage. There is a medium to high susceptibility to frost action because of a high water table and high capillary rise of moisture in this soil. Shrinkage and expansion is only slight with variation in the water content. The silts have a slight to moderate dry strength and are fairly stable at low moisture contents. At higher moisture contents the silts become unstable and spongy. (Schlicker and Deacon, 1967; U.S. Department of the Interior, 1963; U.S. Federal Housing Administration, 1959).

Goble soil series: The Goble series consists of well or moderately well drained, silt loam over silty clay loam soils formed on loess-like material on the uplands. It is on gently sloping to rough mountainous topography. The surface layer is very dark grayish-brown silt loam about

* Defined in the glossary - Appendix C.

TABLE 1. Soil Conservation Service
Engineering Interpretations

Estimated Chemical and Physical Properties

Soil Series	Depth from surface of typical profile	Classification			Over 3" (per-cent)	Percent of material passing sieve				Permeability (inches per hr.)	Available Water Capacity (inches per inch of soil)	Soil reaction (pH)	Shrink swell potential	Corrosivity Uncoated steel
		USDA Texture	Unified	AASHO		#4	#10	#40	#200					
Cascade	0-17"	Silt Loam	ML	A4	0	100	95-100	90-100	70-90	.63-2.0	.19-.21	5.6-6.0	Low	Moderate
	17-24"	Silt Loam	ML-CL	A4	0	100	95-100	90-100	70-90	.2-.63	.19-.21	5.2-5.6	Low	High
	24-60"	Silt Loam	ML-CL	A4	0	100	95-100	90-100	70-95	.06-0.2	.19-.21	5.2-5.6	Low	High
Goble	0-14"	Silt Loam	ML	A4	0	100	95-100	90-100	70-90	.63-2.0	.19-.21	5.2-5.6	Low	Moderate
	14-37"	Silty Clay Loam	ML-CL	A-6	0	100	100	95-100	85-95	.63-2.0	.19-.21	5.2-5.6	Mod.	High
	37-60"	Silty Clay Loam	ML-CL	A-6	0	100	100	95-100	85-95	.06-0.2	.19-.21	4.8-5.2	Mod.	High
Unnamed	0-36"	Silt Loam	ML	A-4	0	90	90-95	80-95	65-85	.63-2.0	.19-.21	5.6-6.0	Low	Moderate
	36"	Basalt			10	95								

14 inches thick. The upper subsoil is dark brown, firm, silty clay loam about 23 inches thick. It is underlain by a firm, brittle, distinctly mottled fragipan more than a foot thick. Depth to bedrock is over 60 inches. Permeability is moderate above and slow within the fragipan. Surface runoff is medium to rapid. Erosion hazard is moderate to severe. Total available water holding capacity is 11 to 13 inches. The soil is used mainly for timber production, but some areas have been cleared and are used for small grain, berries, hay and pasture. Other uses include homesites, recreation, wildlife, and water supply.

The majority of the Goble soils have been classified as ranging from ML-CL to CL. These soils can be expected to have a low to medium shear strength, a moderate compressibility, and fair to good compaction characteristics. The internal drainage characteristic is impervious. A moderate shrinkage-expansion is also expected. The dry strength is medium to high (Schlicker and Deacon, 1967; U.S. Department of the Interior, 1963; U.S. Federal Housing Administration, 1959).

Unnamed soil series: The unnamed series consists of well-drained silt-loam soils formed in mixed loess-like material, old alluvium material and residuum material from basalt rock. These soils occur on smooth, low hills with convex, long slopes, and on ridge tops and canyon sides on all exposures. The surface layer is dark reddish-brown silt loam about 9 inches thick. The subsoil is dark reddish-brown silt loam about 29 inches thick. The substratum is basalt. The depth to bedrock ranges from 20 to 40 inches. Pebble and stone content ranges from 10 to 35 percent in the subsoil layer. The permeability is moderate. Surface runoff is rapid. Erosion hazard is severe. Total available water-holding capacity is 3.5 to 8 inches. The soils are used mainly for timber. Other uses include wildlife, recreation homesites and water supply.

Soils of the unnamed series are classified as mostly ML and ML-CL. The same soil properties can be expected with this series as noted for the Cascade soil series.

Made land: The Made land and urban areas consist of a variety of soil and rubble material that has accumulated during the construction of houses, parking lots, streets, large buildings, etc. The soil has been so altered that its original profile cannot be determined.

General characteristics of Portland Hills Silt: All of the Portland Hills Silt unit has the following characteristics as summarized from Schlicker and Deacon (1967):

When compacted the silts require close moisture control for a fill of moderate strength and compressibility, which limits grading and excavation in this unit during much of the year in Portland. Portland Hills Silt is capable of supporting light to moderately heavy structures with spread footings at shallow depth. The structure must be able to tolerate a small amount of settlement. Heavy structural loads or construction that cannot tolerate settlement could be built with the load on the underlying basalt.

Slopes in Portland Hills Silt tend to be unstable. Natural mudflows and landslides have been observed mostly on slopes in excess of 15 percent. Failure has occurred on slopes of less than 15 percent, as well as greater, where the toe of a slope has been excavated, where a load has been placed on a slope, and/or where the sediments have been oversaturated.

Small septic tank drainfields are possible in the silt soils, but other considerations such as water table depth and slope usually preclude absorption of water and effluent. Septic fields for large installations are considered nearly impossible with present techniques.

Alluvium

A deposit of unconsolidated, light-brown to buff sandy clayey silt, thought to be Willamette Silt was mapped along the eastern margin of the map at elevations below 250 feet. Small lenses of pebbly sands and clays probably exist within the unit but are not exposed in the map area. The exact thickness of the unit is not known but thicknesses of up to 50 feet are known elsewhere in the Willamette Valley. The soils near the surface have been leached by ground water and the leached clays have accumulated in layers at shallow depths.

The engineering classification (ML), the characteristics, and the properties of these silts are almost identical to those of the Portland Hills Silt - Cascade series; therefore no further discussion is included here.

BEDROCK STRUCTURE

Columbia River Basalt flows over 700 feet thick have been folded into a broad arch (anticline*) that trends about 40 to 50 degrees west of north (N 40-50° W) and have probably been faulted at the base of both the northeast and southwest flanks (Schlicker and Deacon, 1967; Balsillie and Benson, 1971). There is a need for analysis of bedrock structure based on the premise that active faults do exist in the area and may be a hazard to development. Inclined layers of bedrock exposed by natural erosion, faulting, and/or by man's excavational activities, may result in block glide failures (Figure 6). Bedrock structure in the Marquam Hill is shown on map 3.

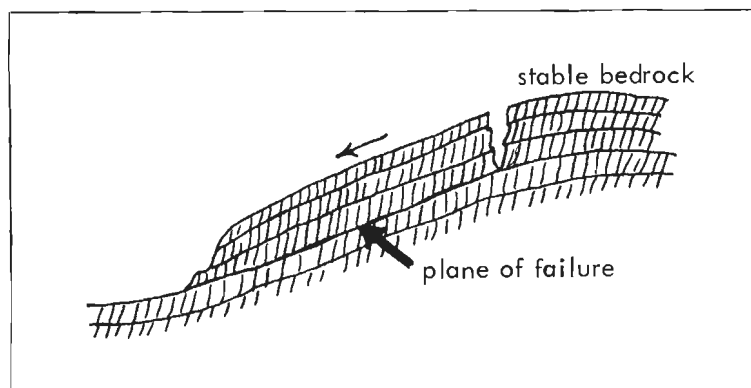


Figure 6. Diagrammatic cross section of a block glide failure in which inclined layers of bedrock break away from stable areas and move downslope under the force of gravity. Similar in concept to the "West Linn landslide" in the southern Portland Hills.

Methods

Columbia River Basalt bedrock exposures in the study area were explored for dip of the basalt flows by direct measurement and by an indirect method first used in Portland by Balsillie and Benson (1971). Exposures were also examined for indications of faulting such as fault gouge*, slickensides*, and visible displacement of flow surfaces. Where a fault was identified in exposures, the fault zone trend was measured directly. Where direct measurement was not possible, related landforms were used to deduce the trend.

An analysis of linear landform elements was made on the study-area topographic map to evaluate alignments for structural significance. Linear landforms plotted on map 3 include straight stream segments, ridgecrests, and linear breaks in slope angle. These alignments commonly mark zones in the basalt bedrock that are more easily eroded or weathered than the surrounding rock. Differential weathering and erosion most often creates linear landforms along faults, joints, and bedding.

* Defined in the glossary - Appendix C.

Findings and evaluations

The cross section on map 3 shows the general structure of the study area from Council Crest through the site of the University of Oregon Medical School. The cross section is based on surface outcrops, measurements of dips, and previous investigations in the Portland Hills. The overall structure is that of an asymmetrical anticline. In the Portland Hills north of the study area dip measurements by Balsillie and Benson (1971) indicate a small syncline* on the east flank of the anticline. This syncline does not appear to extend into the Marquam Hill area, although a flattening of the dip may represent a continuation of it. As can be seen on the cross section, the anticlinal shape of the bedrock has been complicated by faults.

Four fault zones were positively identified in the study area (map 3). Two faults near Duniway Park trend approximately due north with nearly vertical fault planes. One of these fault zones is shown in figure 7. A third north-trending fault was identified near Council Crest but no dip measurements on the fault plane were possible. The fourth fault zone trends approximately west and dips approximately 55 degrees to the north. Figure 8 shows an exposure of this last fault zone with three distinct fault planes separating areas of highly fractured basalt. Displacements on the first two faults are on the order of a few feet. The last two faults may have displacements of a few tens of feet at most. Comparison of these fault trends with the mapped lineations on map 3 indicates that there may be more faults in the area approximately parallel (en echelon) to the known faults.

No direct evidence was found for the structural controls of the strong northwest lineation orientations. However, a large amount of indirect evidence for a northwesterly structural or fault zone has been accumulated in recent years. The origin of the linear eastern front of the Portland Hills, which trends northwest, has been debated for a long time. Trimble (1963) concluded that there was insufficient evidence of a major fault. But, Diller (1915), Schlicker and Deacon (1967), Balsillie and Benson (1971), and Schmela and Palmer (1972) have favored the fault interpretation. First-motion* studies of Portland earthquakes conducted by Dehlinger and Berg (1962), Westphal (1962), Dehlinger and others (1963), Schlicker and others (1964), and Heinrichs and Pietrafesa (1968) support, at least in part, one or more northwesterly trending faults in the Portland area.

In summary, at least minor faults are known to exist in the Portland Hills and in the Marquam Hill area in particular. The west- and north-trending fault zones identified in this study are shown on map 3. Where evidence suggests the presence of other faults or fault zones parallel with these trends, they are mapped as inferred faults. All of the northwesterly faults or fault zones are mapped as inferred, including the portion of the controversial Portland Hills fault which is thought to extend through the eastern portion of the study area.

Dipping lava flows on the flanks of the Portland Hills pose a problem for development. The stability of these flows has been questioned since the development of a massive block-glide failure near West Linn, Oregon during construction of Interstate 205. This slide occurred in a southern extension of the Portland Hills where Columbia River Basalt flows dip northeastward only a few degrees and are underlain by an interflow layer of clayey sediments only a few inches thick. The slide failure occurred after roadcut excavation had removed support at the toe of an ancient landslide.

Structural conditions similar to these at West Linn exist in the Marquam Hill area. The Columbia River Basalt flows in the study area dip northeasterly at angles up to 15 degrees. Toes of several flows have been exposed by natural erosion and possibly by faulting, as shown in the cross section. Although no direct observations of interflow sediments were made in the study area, samples of clayey soils similar to those at West Linn were obtained in three power auger test drill holes. Therefore, the possibility of this type of failure must not be overlooked in the Marquam Hill area.

* Defined in the glossary - Appendix C.



Figure 7. A nearly vertical, north-trending fault (indicated by dashed line) with minor displacement near Duniway Park.



Figure 8. Part of a wide, west-trending, zone of normal faulting in a road cut on S.W. Terwilliger Boulevard. Note the three distinct fault planes separating highly fractured and weathered basalt.

SEISMICITY

"Oregon lies within the circum-Pacific belt of crustal instability along with California and Washington, both of which have recorded violent shocks in recent years. Since Oregon is a tectonically active state, consideration of the effects of earthquakes is necessary in all design and construction, particularly for schools, churches, and public buildings.

Prediction of earthquakes is a subject of great interest to many investigators; however, the difficulties to be overcome in this worthy pursuit are staggering. Such predictions may very well prove to be beyond the capability of man. Records indicate that where earthquakes have occurred in the past they will probably recur, and that the intensity of the recurrence can be much greater than that of previous quakes. The probability that an earthquake will recur increases proportionally as time elapses."

(Schlicker, Deacon, and Twelker, 1964)

Methods

A careful review and analysis was conducted of existing information on earthquakes in the Portland area. Historical earthquakes are reviewed to indicate the probability for future earthquakes and the magnitude to be expected; known and inferred faults in the study area are studied in relation to known earthquakes because of the possibility of differential ground displacement across the fault zones; and the response of the various geologic units to earthquake vibration is considered.

Findings and evaluations

History

The Portland area, like most of the Western United States and other countries on the Pacific rim, has felt the effects of earthquakes. Since 1841, there have been 52 earthquakes reported or recorded within an approximate 25 kilometer radius of Portland (see Table 2). Apparently the seismicity of the Portland area is considerably higher than that of Oregon as a whole although this may in part reflect population distribution. In addition, study of earthquake energy release shows that the rate of seismic energy release in the Portland area has increased about tenfold since 1950 (Couch and others, 1968).

Known and inferred faults

The tectonic map of Portland (Figure 9) shows a number of faults. Probably of greatest concern is the major inferred Portland Hills fault, which trends northwest along the eastern base of the Portland Hills. Although ground breakage has not been recorded, strong geomorphic, structural, and seismic evidence supports the existence of this fault (Balsillie and Benson, 1971; Schmela and Palmer, 1972). Epicenter* and focus* determinations along with source motion* information indicate that the November, 1962; January, 1968; and May, 1968 earthquakes may have occurred along a common fault or fault zone which coincides with the inferred Portland Hills fault (Couch and others, 1968). This information indicates that the fault is probably active, and that it is responsible, at least in part, for the tremors in the Portland area.

The activity of other faults in Portland and the Marquam Hill area is virtually unknown due partially to rapid weathering and erosion. It is known, however, that any historically active fault will probably have recurring seismic activity, and that any historically inactive fault may be reactivated.

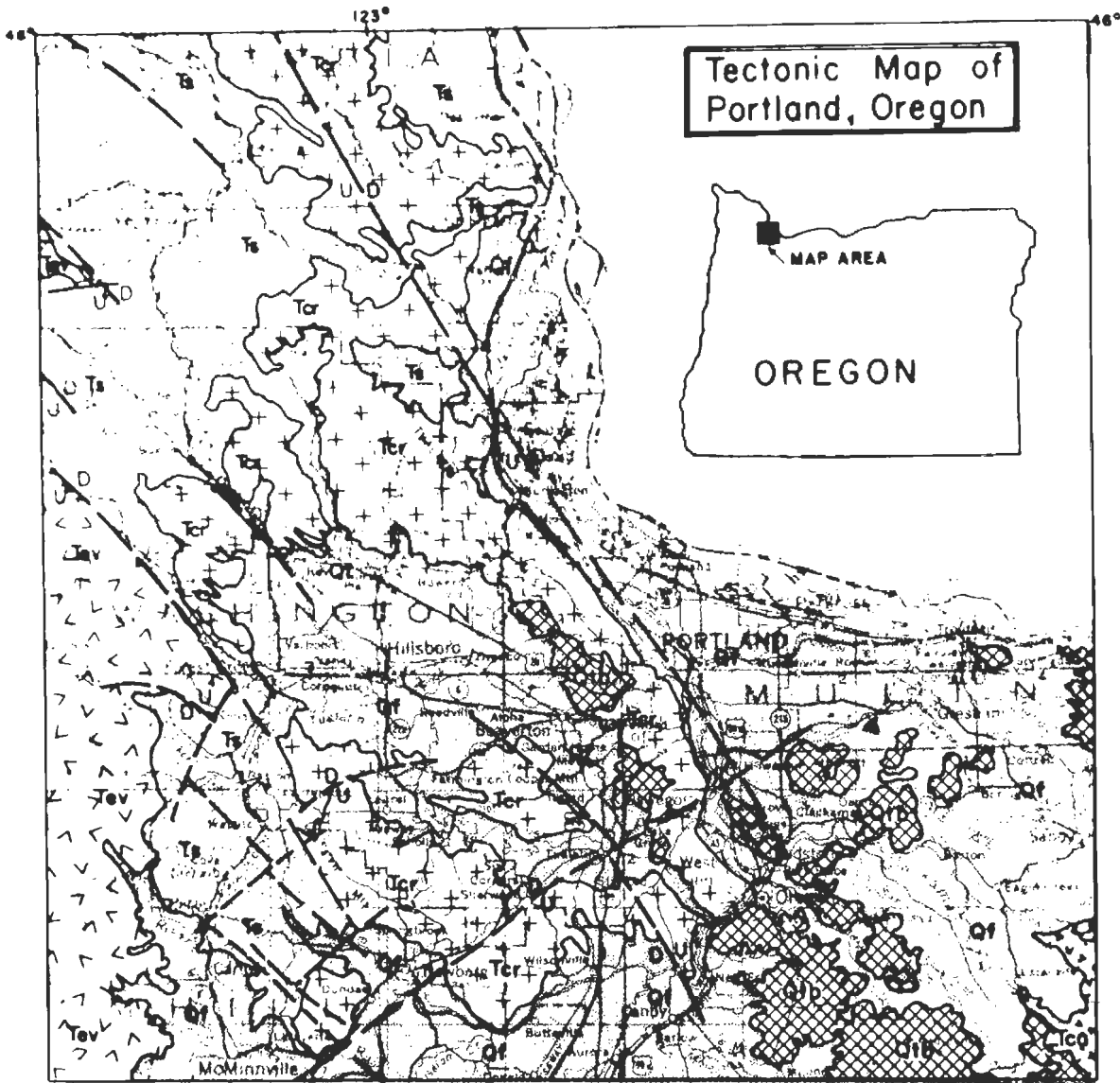
Earthquake potential

Earthquake hazard planning includes consideration of the location, frequency, and severity of probable seismic events and surficial displacement across faults. Present technology does not permit reliable predictions of the timing of earthquake events. We can make a careful study of the geologic







* Defined in the glossary - Appendix C.

TABLE 2. Documented earthquakes since 1841 within 25 kilometers of Portland

Date	Location	Intensity (Modified Mercalli)	Number of Shocks
1841	Vancouver	V	1
1870	Vancouver	III	1
1877	Portland	III	1
1879	Portland	IV	1
1882	Portland	III	1
1883	Portland	VII	2
1884	Portland	IV	1
1885	Portland	II - III	3
1892	Portland	VI	1
1898	Portland	III	1
1904	Portland	IV	1
1904	Portland	- -	1
1904	Portland	- -	1
1907	Portland	III	1
1909	Portland	IV	1
1910	Portland	III	1
1910	Portland	IV	1
1914	Portland	IV	1
1914	Portland	III	1
1915	Portland	V	1
1918	Portland	III	1
1920	Portland	III	1
1921	Portland	II - III	7
1921	Portland	IV	1
1922	Portland	IV	1
1922	Portland - Vancouver	III	1
1924	Brush Prairie, Wash.	IV	1
1932	Portland - Lakeview, Wash.	V	1
1933	Portland - Lakeview, Wash.	III	1
1939	Portland	III	1
1939	Portland	III	1
1941	Portland	VI	1
1942	Portland	V	1
1948	Burton, Oregon	IV	1
1951	Portland	III	1
1953	Portland	VI	1
1957	Portland	III	1
1958	Portland	II	1
1961	N. W. of Portland	VI	1
1961	Portland	V	1
1961	N. W. of Portland	IV	1
1962	Portland	VII	1
1963	Portland	IV	1
1964	N. W. of Vancouver	V	1
1968	Portland	IV	1
1968	Portland	IV	1
1969	Near Vancouver	IV	1
1970	W. of Portland	IV	1
1972	Portland	III	1



EXPLANATION

-  Valley fill
-  Boring Lavas
-  Cascade Andesite
-  Columbia River Basalt
-  Eocene and Oligocene marine sediments
-  Mid-Eocene volcanics, rocks, and sediments



Base map from U.S.G.S.

Figure 9. Tectonic map of Portland (Schlicker, Deacon, and Twelker, 1964).

conditions and the past earthquake and fault history of the area and develop reasonable predictions. Thus, the Portland area can expect earthquakes in the future, at least comparable to a repeat of the November, 1962 earthquake (intensity VII on the modified Mercalli scale) with a maximum acceleration of 12 percent of gravity. Building design should be based on this minimum.

Ground response

The ground response to earthquakes will vary depending on soil depth and soil and rock type. Schlicker and others (1964) have described five of the most important types of responses that geologic units in the Portland area may experience. These reactions are: (1) elastic, (2) fluid, (3) brittle, (4) viscous or visco-elastic, and (5) granular.

Elastic response: Columbia River Basalt, Boring Lava, and the conglomerate unit may be expected to respond elastically to earthquake ground motion. This type of response occurs in bedrock formations in which damping does not play an important part and in which the component particles maintain the same relative position.

"Reports on previous earthquakes in this and other areas indicate that structures founded in bedrock are not severely disturbed by quakes whose epicenters are more than 50 miles distant. In the event of an extremely violent earthquake in the near vicinity, however, the maximum lateral accelerations may be unleashed on structures founded on competent bedrock."
(Schlicker and Deacon, 1967)

Fluid response: Alluvial silt and Portland Hills Silt if saturated may be expected to respond in a fluid manner to earthquake vibrations. That is to say, they may undergo total loss of strength upon repeated application of forces. If a liquified soil is confined, structures may sink into the formation, and if it is unconfined the material may flow in mass movement. On steep slopes these failures can be both rapid and disastrous.

Brittle response: A brittle response to earthquake vibration is usually expressed by detachment and rapid movement of portions of relatively competent units occupying precarious positions on hillsides. Relatively well indurated Portland Hills Silt and deeply weathered and unweathered portions of the Columbia River Basalt may be expected to have a brittle response. Joints, interflow zones, fault zones, and other weaknesses in the units may contribute to failure and may be of great importance in individual localities.

Viscous or visco-elastic response: A viscous or visco-elastic response can be expected for cohesive materials, like the clayey portions of the Portland Hills Silt and weathered basalt soil, which have the following general properties: (1) low mobility of pore water; (2) ability to deform plastically under shear stresses of low to moderate order; (3) inability to undergo sudden changes in volume; and (4) a "rubber-like" response to dynamic loads. Existing landslide areas with more or less continuous earth movements, such as those in the Marquam Hill area shown on map 4, will probably respond in a viscous or visco-elastic manner. It is not expected that the landslide masses would move rapidly and catastrophically, but existing slides would continue moving, possibly at an increased rate. Probably more important, areas of marginal stability may begin landsliding and old relatively inactive slides may be reactivated, creating a hazard for or damaging structures on these areas.

Very little is known about the amplification or damping of ground motion in viscous or visco-elastic materials, but it is believed that these fine-grained materials have a tendency to magnify small or moderate earthquake vibration, whereas severe motion tends to be damped out by this same material.

Granular response: There are no loose, cohesionless sand and gravel geologic units in the Marquam Hill study area which are expected to respond in a granular manner. But, where these units do exist, structures founded in them may differentially settle because of densification under vibratory loading. Some alluvial materials in the major river valleys can be expected to respond in this manner.

(SOIL THICKNESS)

Soil thickness or depth to bedrock can be a limiting factor in development of an area. Thin soil over bedrock presents extra expense for excavation, and thick soil areas, as in the hills of Portland, often have stability problems.

Methods

Soil thicknesses in the Marquam Hill area were determined by several methods. Hand augering at soil sampling localities, power augering, and observations at rock outcrop localities yielded direct observations of the soil thickness. A Soiltest MD-3 seismic timer gave indirect, acoustic refraction determinations of soil thickness. Thicknesses determined by the hand and power augers and the seismic timer are shown on the soil thickness map (map 3) in circles. Bedrock outcrop localities are shown as black areas.

Findings and evaluations

In mapping the soil thickness, the 5-foot contour interval was chosen because it is accepted as minimal for many excavations and effluent disposal. See Appendix B for detailed soil thickness limitations to development.

Soil thickness is a critical factor in relative land stability, such as landsliding and differential settlement. Soil that is 5 feet or less in thickness is not immune to instabilities, but the scale of landslides in thin soil can generally be considered as only minor. Therefore, map areas with less than 5 feet of soil have reduced land instability potential.

Accuracy of soil thickness shown on the map is subject to two main variables: (1) depth to bedrock can vary considerably over short distances from the test site, and (2) depth to bedrock can be misinterpreted in places where the auger meets rocky material that is assumed to be bedrock but is actually not in place. Such material includes stringers of rocks up to a foot in diameter situated 1 or 2 feet above bedrock, talus (accumulations of rock fragments), and colluvium (rock and soil) that have moved downslope under the influence of gravity. Therefore, the soil thicknesses as mapped must be considered minimum.

GROUND STABILITY

There are numerous landslides in the Portland Hills in and around the study area. Many of the slides have been caused by man, and have occurred where Portland Hills Silt and residual clay soils have failed through oversteepening or overloading of slopes, where there has been removal of lateral and toe support, and where over-saturation has occurred (Figure 10). Many other land failures, however, have occurred under natural conditions, emphasizing the precarious balance of stability that exists in the steep hillside area.

Portland landslide damage is more common than is generally realized due to time gaps between movements and the relatively small number of people directly affected by any one slide. Public utility and road damage in Portland can amount to as much as one-third of a million dollars per year, plus uncounted damage to private properties (Schlicker, 1956).

Because of the possibility of public and private loss due to land failure subsequent to uncontrolled development, a high priority was given to mapping of ground stability in the study area (map 4).

Methods

Landslides were located primarily through field identification after careful examination of the aerial photos and detailed topographic maps. Recognition and identification of features such as unusual



Figure 10. A landslide in Portland Hills Silt near the University of Oregon Medical School.

(hummocky) topography, flattened slopes, and disordered drainage on the photos and map preceded field identification of landslides. All active and inactive landslides identified are shown on the stability map in dark and medium grey, respectively. Not all landslides in the area have been mapped, however, because of the limitations of the study.

Landslides questionably identified and areas of potential slippage are shown in a lighter grey. Some areas of irregular topography appear to be ancient landslides, but erosion and soil creep subsequent to sliding has precluded absolute identification. Areas showing slow but extensive movement of the land (soil creep), high moisture content in the soil, and loosely consolidated soil are mapped as potential landslides.

Generalized areas in which numerous landslides and extensive soil creep were noted are mapped in light grey to indicate the strong potential for further movement.

Findings and evaluations

More than 150 landslides involving almost 10 percent of the land in the study area are identified. They range in size from 200 to more than 500,000 square feet. Land slippage has occurred on almost all slopes, soil thicknesses and soil types. The greatest majority of slides, however, have occurred on slopes steeper than 15 percent on Portland Hills Silt and basaltic soils greater than 5 feet thick. Because of the widespread natural instability, uncontrolled alteration of the land in the study area greatly increases the potential for new, renewed, or increased landsliding.

HYDROLOGY

An investigation of the hydrology of the Marquam Hill area was conducted to determine the nature and extent of the ground water and to indicate what changes in the surface and ground water could be expected with urban or suburban development. Existing literature and well logs from the files of the U. S. Geologic Survey indicated the nature of the regional ground water table. Field mapping and soils information from the Soil Conservation Service, as well as field work by the investigators, yielded general information on near-surface water tables.

Methods

Field investigations conducted from February to May, 1972 by the field representative of the Soil Conservation Service and the investigators included hand and power auger drilling and observation of water table elevations, as well as observations and mapping of springs, seeps, and streams.

A series of stream peak discharge estimates was made for two small watersheds in the study area to indicate the relative magnitude of changes to be expected if the amount of exposed ground surface and/or vegetation is reduced by man's activities and impermeable roads and buildings (Table 3). The data supplied from the charts of the Hydrology Branch of the Soil Conservation Service is based on the area of the watersheds, the storm distribution for the coastal side of the Cascade Mountains, the basic hydrologic soil group, and the steepness of slopes in the watershed areas. The watersheds used for examples are shown on map 4.

Findings and evaluations

Even though the hydrologic information acquired during this investigation was limited, some general conclusions and guidelines were obtainable.

The regional water table appears to be slightly above the elevation of the adjacent Willamette River and of little consequence to the Marquam Hill area.

The Cascade soil series, as outlined in map 2, develops a seasonal perched water table over an impervious fragipan during the winter months. The depth to this water table can be as little as a few inches and as much as 30 inches. Because of its shallow character, the water table presents limitations to development of dwellings, especially those with basements, septic tank absorption fields, sanitary landfills, and other excavations. This water table is generally shallowest near stream valleys and at the downslope edges of the Cascade soil series, especially where a break in slope coincides with the soil unit boundary. It is important to note that along this boundary the soil is likely to be more saturated and more steeply sloping, increasing the possibility of landsliding. In fact, about 60 percent of the known landslides in the study area occur near or on the mapped boundary of the Cascade series.

The Goble soil series has randomly located perched water bodies, but the majority of the area in this soil unit presents no high water-table limitations.

Study of surface hydrology indicates the relative changes that can be expected with alteration of the existing watersheds (Table 3). Two almost undeveloped watersheds of 110 and 280 acres were used for examples (map 4). Exact information was not available on the probable annual storm discharges, but 24-hour rainfall rates of 3, 6, and 10 inches have been used. The 3-inch, 24-hour rainfall represents approximately a 10- to 15-year storm frequency.

These estimates indicate that for heavy rainfall on the Marquam Hill area, increases in stream peak discharge, and possibly flooding, can be expected where naturally vegetated watersheds are disturbed or developed. Vegetation disturbance increases stream discharge because: (1) There is less vegetation to intercept and allow evaporation of part of the precipitation, and, (2) there will be less infiltration of rain into the soil because of: (a) compaction of exposed soil by rain drops and man's activities reducing the permeability and the infiltration capacity of the soil, (b) disturbance and eventual loss of the layer of decaying organic material will discourage the beneficial activities of burrowing insects and animals, and (c) surface runoff will not be impeded by vegetative obstacles.

TABLE 3. Peak rates of discharge for small watersheds
 Type 1A storm distribution (coastal side of Cascade Mountains)
 Based on hydrologic soil group C - steep slopes (16 percent)

110 acre watershed

24 hour Rainfall	Undisturbed Natural Condition	Young Second Growth and Brush	Residential Low density	Residential Medium Density
3 inches	16 cfs	22 cfs	33 cfs	37 cfs
6 inches	57 cfs	67 cfs	83 cfs	87 cfs
10 inches	123 cfs	137 cfs	157 cfs	161 cfs

280 acre watershed

24 hour Rainfall	Undisturbed Natural Condition	Young Second Growth and Brush	Residential Low Density	Residential Medium Density
3 inches	37 cfs	48 cfs	72 cfs	81 cfs
6 inches	125 cfs	150 cfs	186 cfs	196 cfs
10 inches	276 cfs	305 cfs	345 cfs	352 cfs

Based on data from:

U.S. Department of Agriculture
 Soil Conservation Service
 Engineering Division - Hydrology
 Branch
 3-15-71

Because of the increased surface and stream runoff resulting from vegetation disturbance or removal, increases in erosion and siltation can also be expected. Increased surface runoff will allow greater rivulet formation and gullying, and increased streamflow will result in greater erosion of stream channel and banks. It is probable that this erosion would generate landsliding adjacent to the streams because of oversteepening and removal of supporting soil.

Table 3 further indicates the predicted increase in peak discharge as a result of residential land development. Normally, the clearing and grading practices of land development will produce the same problems previously outlined for vegetation disturbance. But in addition, the construction of impermeable roads and buildings will prevent infiltration and result in increased surface runoff and stream discharge. Impermeable structures will often localize the water collected on and around them, thereby concentrating and increasing erosion potential. Also, poor drainage around developments may allow ponding of surface runoff. All of the above changes can result in greater landslide potential in marginally stable and unstable areas, and in greater siltation, erosion, and flood hazard.

Localized flooding in the canyons could result from increased stream discharge by: (1) Backup of water behind inadequate culverts, (2) blockage of culverts with debris carried by the increased runoff, and (3) landslide blockage of streamways.

VEGETATION

Major types of vegetation in the Marquam Hill area were classified and mapped to supplement and support geologic data on land instability and to provide a semiquantitative evaluation of vegetation as a natural resource. Particular efforts were made: (1) to determine the relative stability of the forested slopes in the Marquam Hill area using vegetation indicators and (2) to explore the effects of vegetation disturbance on land stability. It is possible to make some general proposals concerning development and vegetation removal practices on various site types.

Gross removal of vegetation has been noted as a major contributing cause of land instability on the slopes of the Portland Hills. Under natural forest cover roots help keep the soil mass intact. The exposed biomass reduces damaging rain drop impact and, by plant interception and evapotranspiration*, limits the precipitation reaching and saturating the soil mass.

The forested parts of the Marquam Hill area are viewed by most area residents to be of major aesthetic value (Appendix H).

Methods

The first stage of the vegetation analysis consisted of outlining major tree groups from stereographic aerial photographs. The forest groups outlined were (1) deciduous, (2) mixed-predominately deciduous, (3) coniferous, (4) mixed-predominately coniferous, (5) rather evenly mixed deciduous and coniferous, (6) mixed in patches, and (7) scrub-brush. These mapped groups were then investigated on the ground with attention to: (1) predominant upper, middle, and lower story vegetation types; (2) approximate age and relative condition of the vegetation (density of growth, straightness of trunks, etc.); (3) angle of ground slope; (4) soil type and condition (moisture content, hummocky ground, past and present slide activity, etc.); and (5) any other apparent characteristics (evidence of logging, fires, etc.).

Map 5 developed from this study shows the areal distribution of the vegetation, approximate rates of vegetation renewal (regeneration rates), and relative stability values. The regeneration and stability values were generated on the basis of the natural succession of plant types from a barren area to a climax forest.

Forests consist of dynamic plant communities which reflect the changing factors of their environment. Communities replace one another in a natural succession until the environment is prepared for the natural climax vegetation of the area. In either a formerly barren site or a recently cleared forest, early pioneer species are rapid growing flowering plants and weeds which give way in a few years to a dominance of shrubs and seedlings. In the final stage the trees of the forest reappear. In each stage, plant communities

* Defined in the glossary - Appendix C.

go through several successions and may endure many years before the beginning of the next stage. Under favorable conditions a few centuries or less may be required for the regrowth of climax forests in the northern Willamette Valley. However, such unfavorable local conditions as boggy or unstable soil could cause continued maintenance of a successional community for an indefinite period of time.

Botanical indicators of relative land stability were investigated to supplement and improve geologic stability interpretations. Some indicators of instability are (1) curved tree trunks, (2) maintenance of successional populations, (3) recent dying of climax populations and ingrowth of successional trees, (4) inordinant number of tilting and fallen trees, and (5) scarcity of vegetation.

Curved tree trunks are usually caused by the downslope movement of the top portion of a soil mass (mass wasting or soil creep). The tree is moved downslope a short distance and leans somewhat downslope from vertical. If the movement and resultant root damage is not fatal to the tree, it will usually begin to grow in a vertical direction and acquire a bend in the lower trunk (see Figures 11 and 12).

Continued maintenance of deciduous trees or sudden ingrowth of deciduous trees in a conifer forest in the Pacific Northwest indicates a disturbance of some kind has taken place which is not allowing the climax coniferous forest to evolve. A major disturbance may be due to fire, logging, or unstable soil. Deciduous trees are evidence of such disturbance because they are often the pioneer forest species in a burned or logged site and they can more successfully survive the damaging effects of instability than the climax species of conifers. Both fire and logging alone cause some measure of surface instability.

Findings and evaluations

Although one must exert caution when placing man's taxonomically organized constraints upon the forest, the community types mapped in the study area will here be outlined and described (refer to map 5).

Coniferous trees

Climax forest species in the northern Willamette Valley are considered to be Western Red Cedar (*Thuja plicata*), and Western Hemlock (*Tsuga heterophylla*). Coniferous forests in the study area consist of these climax species associated with varying proportions of subclimax Douglas Fir (*Pseudotsuga menziesii*). Larger populations of Douglas Fir indicate a more hostile environment or more recent disturbance than a full climax forest area. Average height of the larger climax individuals usually range between 70 and 100 feet, indicating they are probably 60 to 150 or more years old. Rate of growth varies from species to species and, within a specie, from one site to another. For this reason regeneration rates cannot be pinpointed, but for these conifer forest communities, including all stages of successional growth, they are estimated to be from 200 to 400 years.

The presence of climax or near-climax forests may indicate, if not relative stability, at least an absence of vigorous disturbance in the recent past (200 to 400 years).

In the Marquam Hill area the lower story in the conifer community is most often composed of Swordfern (*Polystichum minitum*), Oregon Grape (*Berberis nervos*) with minor components of Oregon oxalis (*Oxalis oregonan*) and Skunk Cabbage (*Lysechitum americanum*). According to Franklin and Dyrness in Vegetation of Oregon and Washington (1969) this is a typical "moist site" community composition.

Mixed - predominantly coniferous trees

Mixed, mainly coniferous forests are generally composed of many of the same species as the closed coniferous community. Major differences include the absence of Skunk Cabbage and decrease of the Swordfern component in the lower story and an increase in Douglas Fir as compared to Western Red Cedar and Western Hemlock. In addition, this forest community includes the successional deciduous species of Red Alder (*Alnus rubra*), and Big Leaf Maple (*Acer macrophyllum*) in the upper or secondary stories. Additional deciduous species in the shrub story include Cascara Buckthorn (*Rhamnus purshiana*) and Vine Maple (*Acer circinatum*).

These forests, particularly because of their increased composition of successional species, may be regarded as either younger, more recently disturbed, or possessing less favorable conditions for the growth and maintenance of climax forests. Regeneration rates for these communities are presumably less than the closed coniferous forests and have been placed at approximately 150 to 300 years.

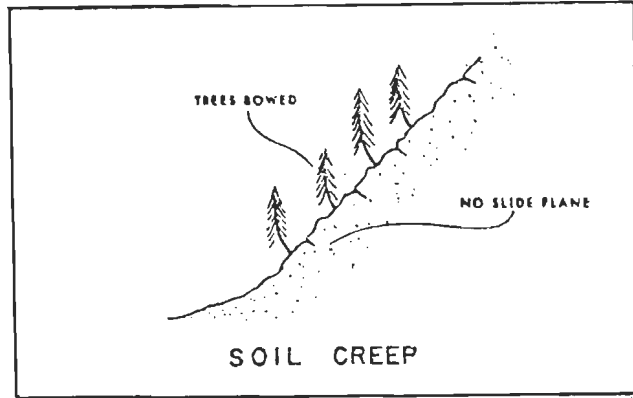


Figure 11. Diagram of soil creep shows the effect of this movement on the growth of trees. (Schlicker, 1956)

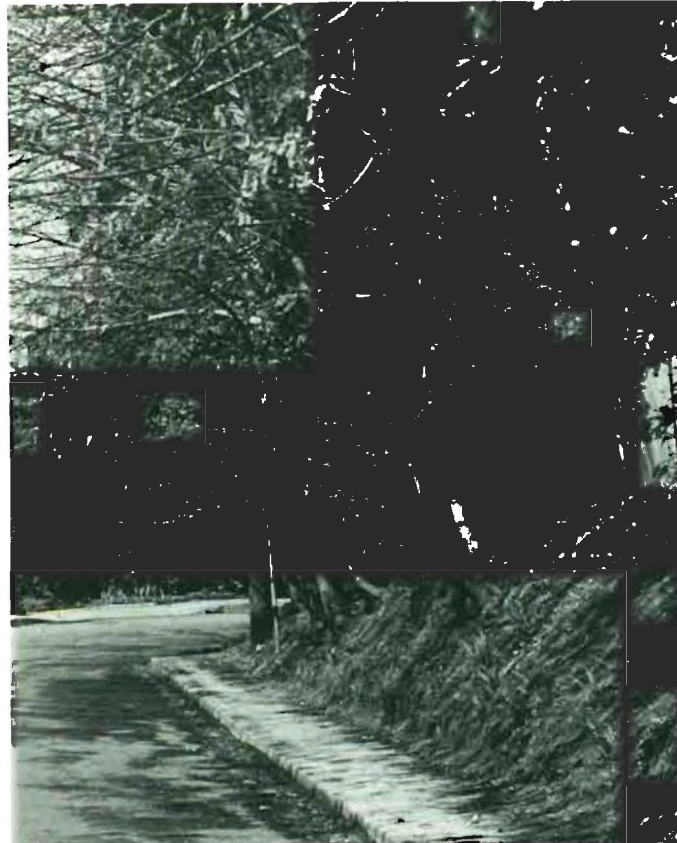


Figure 12. Bowed trees on a soil creep slope. Note also the diminished width of sidewalk.

Deciduous trees:

The earliest trees which appear in forest regeneration are deciduous. Most of the deciduous forests in the Marquam Hill area consist of Red Alder and Big Leaf Maple in the upper story (averaging 60 to 70 feet). A lower shrub story is generally composed of mixtures of Vine Maple, Cascara Buckthorn, Elderberry (*Sambucus glauca*), California Hazel (*Corylus cornuta californica*), and Pacific Dogwood (*Cornus nuttallii*). In most deciduous communities the species are rather well mixed, containing inclusions of most of these deciduous species. There are also a few younger or less stable communities which largely consist of relatively even-aged stands of Red Alder and occasional minor communities of Vine Maple. Both deciduous and coniferous communities usually include a floor cover of Swordfern and mosses.

Regeneration rates for the older, well-developed deciduous communities could range from 70 to 200 years. The younger Red Alder forests are probably 40 to 70 years or more old, depending on specific environmental conditions. Under stable conditions regeneration rates for the Red Alder forest would be approximately 40 to 50 years. If, however, at least the upper layers of the soil are unstable, the Red Alder forest could replace itself for a long period of time, because the later successional species are less able to survive the effects of downslope movement. Even if later successional species begin to inhabit a site which is not totally favorable for their growth they may eventually die out and the earlier succession will reappear, in this case the Red Alder forest. When the rate of succession is not definite within a community it can be helpful to look for other signs of instability. If the soil is spongy and has a hummocky topography, as in many areas around Marquam Hill, or if lower trunks of any forest species display varying degrees of bending it may be assumed that some movement is taking place.

Mixed - predominantly deciduous trees:

The mixed forest with a dominance of deciduous trees is quite similar to the mixed coniferous forest, but with a higher population of deciduous trees. Principally it is either slightly younger than the mixed coniferous forests and/or slightly less stable.

Scrub brush:

In the Marquam Hill area, most sites which contain only shrubs and other scrub vegetation have been quite recently disturbed. If there is sufficient soil available, even a very steep slope will generally support at least some deciduous, if not coniferous, forest growth. Although much of the study area is steeply sloping, there is a fairly deep soil mantle in most places. Most bedrock outcrops are associated with man's activities, such as road building, and only a very small portion of the undeveloped land in the study area is covered with scrub vegetation.

Summary:

The vast majority of the vegetation on the undeveloped slopes of the Marquam Hill study area is composed of forests in various successional stages of growth. In some areas these forests inhibit the obvious effects of inherently unstable soil. Other parts of the forests have characteristics which may or may not indicate downslope movement. Individual site studies of greater detail are required in order to delineate the type and magnitude of the effect of developments proposed within the boundaries of this study.

Generalized proposals regarding development in the Marquam Hill area include:

- (1) At all sites proposed for development an in-depth impact evaluation should be conducted to determine the stability of the soil and the amount of development (i.e. excavation, vegetation removal, etc.) which the site can accommodate without causing land instability problems.
- (2) At sites where development is feasible, only a bare minimum of disturbance of existing natural conditions should be allowed. Any clearing which already exists, and is found to be usable for the proposed project should be developed, rather than clearing a second area. The vegetation on these sites should be cleared only for proposed building and access to it, leaving as much of the site forested as feasible for both aesthetic and safety purposes.

INTERPRETATIONS

This section is divided into two parts covering first, direct interpretations drawn from information presented in the previous sections, and second, limitations and suitabilities of the land and the earth materials to specific uses presented in the form of an interpretive map.

Direct Interpretations

Interpretations and land use limitations identified in the information sections of this project are summarized and restated here.

1. The majority of slopes in the study area are moderately steep to steep.
2. Moderately steep slopes (approximately 15 percent to 67 percent) appear to define areas of greater than 5 feet of soil and colluvium.
3. Steep slope areas (greater than 67 percent) appear to be associated with shallow bedrock.
4. Rock fall of basalt bedrock may occur in near vertical exposures.
5. Excavation in relatively unweathered basalt and conglomerate bedrock may require extensive effort such as explosives.
6. Excavation in weathered and closely jointed basalts and conglomerate bedrock may only require ripping.
7. Weathered, jointed basalts can fail as landslides on moderately steep and steep slopes, especially where disturbed by excavation.
8. Septic systems are not recommended where the basalt bedrock is overlain by thin or impermeable soils.
9. Council Crest is probably the location of the source vent for the Boring Lava found in the area.
10. Excavation of weathered Boring Lava around Council Crest may require the removal of large boulders.
11. Interbedded, weathered ash and cinder deposits appear to contribute to landslide activity near Council Crest.
12. If heavy structural loads are placed on the conglomerate, without appropriate engineering design, differential settlement or failure could occur along joints, faults, or formational contacts.
13. Weathered basalt soils:
 - General rating for use - poor to good
 - Relative shear strength - low to moderate
 - Compaction control - fair to good
 - Compressibility - moderate
 - Internal drainage - poor to impervious
 - Shrinkage and expansion - slight to moderate
 - Dry strength - slight to moderate
 - Frost heave potential - moderate to severe
14. Portland Hills Silt - Cascade and unnamed soil series:
 - Permeability - slow
 - Surface runoff - slow to rapid (depending on slope and vegetation)
 - Erosion hazard - slight to high (depending on slope and vegetation)
 - Waterholding capacity - 9 to 12 inches
 - Shear strength - moderate
 - Internal drainage - fair to poor
 - Susceptability to frost action - medium to high
 - Shrinkage and expansion - slight
 - Dry strength - slight to moderate
 - Relative stability - Dry - fairly stable
 - Wet - unstable and "spongy"

15. Portland Hills Silt – Goble soil series:
 Permeability – moderate above the fragipan
 – slow within the fragipan
 Surface runoff – medium to rapid (depending on slope and vegetation)
 Erosion hazard – moderate to severe (depending on slope and vegetation)
 Waterholding capacity – 11 to 13 inches
 Shear strength – low to moderate
 Compressibility – moderate
 Compaction characteristics – fair to good
 Internal drainage – impervious
 Shrinkage and expansion – moderate
 Dry strength – medium to high
16. Portland Hills Silt and Alluvium generally increase in clay content with increasing depth.
17. The Portland Hills Silt and Alluvium can support light to moderately heavy structures with a small amount of settlement.
18. In unsatisfactory soil areas heavy structural loads or construction that cannot tolerate settlement could be founded on the underlying basalt.
19. Where slopes exceed approximately 15 percent, Portland Hills Silt usually displays soil creep, landsliding, and other signs of instability.
20. Failure of previously stable Portland Hills Silt usually occurs during the winter, where the toe of a slope has been excavated, where a load has been placed on a slope, or where the sediments have been oversaturated.
21. Only small septic tank drainfields are possible in Portland Hills Silt and Alluvium where other factors do not limit their development.
22. The overall structural form of the bedrock in the study area is an asymmetrical anticline.
23. Structural conditions of the bedrock in the study area are similar to those at a block glide landslide area near West Linn, Oregon.
24. There have been 52 recorded earthquakes within 25 kilometers of Portland since 1841.
25. The seismic activity in the Portland area is apparently greater than that of Oregon as a whole.
26. The rate of seismic energy release in the Portland area has increased about ten-fold since 1950.
27. Ground response to earthquakes varies with the local conditions, but four general responses may be expected. They are: (1) Elastic response – Columbia River Basalt, Boring Lava, and the conglomerate unit; (2) fluid response – saturated Portland Hills Silt and Alluvium; (3) brittle response – well indurated Portland Hills Silt and Columbia River Basalt; (4) viscous or visco-elastic response – clayey portions of the Portland Hills Silt and weathered basalt soil.
28. Excavation in soils mapped as being less than 5 feet thick can be hindered by residual boulders and massive bedrock.
29. Soil greater than 5 feet thick can fail in large enough masses to be a threat to life and property.
30. The depth to bedrock can vary considerably within a short horizontal distance.
31. Landsliding is extensive in the study area (approximately 10 percent of the area).
32. Disturbance of the land in most of the study area presents a strong possibility of renewed and increased landslide activity.
33. A majority of landslides in the area correlate with the mapped boundary of the Cascade soil series.
34. In Cascade soil areas a shallow perched water table during the winter limits excavations and some land uses.
35. Scattered perched water tables in the Goble soil series could limit some land uses.
36. Increased stream discharges and possibly flooding are indicated if the naturally vegetated areas are disturbed and/or developed.
37. Increased erosion, landsliding, and stream siltation is indicated for areas of vegetation disturbance and/or development.
38. The following vegetation classifications mapped in the study area are arranged as indicators of relative land stability assuming no previous disturbance by man or recent fires. The approximate regeneration rates (resource renewal rates) for the vegetation types are also tabulated.

<u>Classification</u>	<u>Stability indicator</u>	<u>Renewal Rates</u>
Coniferous	Most stable areas	200 - 400 years
Mixed - predominately coniferous	↓	150 - 300 years
Mixed - predominately deciduous		less than 300 years
Deciduous Red Alder	Least stable areas	40 - 200 years 40 - 70 years
Scrub brush	Recently disturbed	

Limitations and Suitabilities

Using the Soil Conservation Service's soil suitability and soil limitation criteria (Appendix B) as a guide, overlays of the basic maps were made to identify areas by the total number and types of limitations. The basic maps are (1) ground slope, (2) bedrock and soils, (3) bedrock structure and soil thickness, (4) ground stability and hydrology, (5) vegetation.

The basic soil map rates the severity of limitations to development of the three soil series by different combinations of the following soil characteristics: (1) Unified Soils Classification, (2) shrink-swell potential, (3) frost heave potential, (4) natural or compacted soil drainage or wetness, (5) depth to seasonal water table, (6) surface texture, (7) moisture supplying capacity, (8) permeability, (9) moist consistency, and (10) thickness of material.

The ground-slope map was used to rate the severity of limitations to development created by different ranges of slopes and erosion hazards. The erosion hazard in a vegetated area of one soil type is almost directly related to the ground slope. The slope ranges mapped and those recommended by the Soil Conservation Service differ slightly for some of the interpretation maps. The slope difference in most cases is less than 3 percent but a few are as much as 5 percent. The significance of these differences is minimal because a large amount of the area affected is already developed, and the actual amount of area affected is estimated to be less than 1 percent of the total study area. The slope ranges were chosen to fit, as closely as possible, the Soil Conservation Services criteria with a minimum of maps.

Limitations caused by soil thickness, bedrock depth, rockiness, and coarse fragments in the soil were overlaid using the soil thickness map.

When appropriate as a limitation, the vegetation map values are included with the other basic factors.

When a land use being considered may cause or increase instabilities or may be located on unstable areas, the stability map is included in the overlay analysis.

Other limiting factors which are rated as only slight for all of the study area are not mapped or used in the computation of total limitations (i.e. stoniness class, woodland site class, and others).

RECOMMENDATIONS

This investigation has shown that the Marquam Hill area is severely limited in potential land uses. There is a tendency among the investigators to recommend many of the most severely limited areas to non-use or open space, because of the potential for economical and physical loss by both the developer and the public.

Discussions with planners, architects, engineers, soil scientists, and geologists acquainted with the

Marquam Hill area have indicated that economical and safe urban developments would probably be cluster or condominium types of planned unit developments. Most of the investigators agree that these types of developments would allow a capability for maximum site investigation, development design for hazards and limitations, and density least affecting the surrounding naturally vegetated, instability-prone slopes. Even these developments may not be feasible in much of the area.

It is our opinion, however, that if the following recommendations are implemented and chapter 70 of the Uniform Building Code is fully utilized, losses can be minimized or completely eliminated by either avoidance of hazardous sites or careful planning and design of developments to accommodate the limitations and prevent hazards.

If the recommendations are not followed, the presently undeveloped areas should be left undeveloped or developed only after detailed investigation and analysis by competent professional persons such as engineering geologists, environmental geologists, and/or soil engineers. There are almost no sites remaining in the study area which can be indiscriminately developed.

Control Procedures

It is recommended that control be exercised over all phases of development (i.e. vegetation clearing, grading, excavation, foundation design, building practices, etc.). The type of control necessary and available through chapter 70 is well explained below by the Association of Engineering Geologists as quoted from the special publication "Geology and Urban Development" (Association of Engineering Geologists, 1965):

CONTROL PROCEDURES FOR GRADING OPERATIONS

Control over grading operations must be exercised to prevent aggravating or creating the types of geologic hazards and problems previously discussed. Control procedures in the form of grading codes administered by local governing bodies have been established in an attempt to eliminate such problems, but even the most effective regulations will usually minimize hazards rather than eliminate them. Agency control at several stages of a grading development is essential so that oversights and omissions can be corrected.

The governing agency should have an experienced soils engineer and an engineering geologist on the staff. If such technical assistance is not available, even the most rigorous codes will be only partially effective. If sufficient building and safety work is not available for their full-time employment, other departments may be able to make use of their services. For example, engineering geologists in the Los Angeles County Engineer's Department serve as advisors to various divisions in that Department as well as to the Road Department.

Tentative Map: The first and probably the most important phase of control for tracts involves the review of the tentative map prior to the advisory agency's approval. It is here that the basic feasibility of the tract is evaluated. A careful review at this stage can avoid many problems. For this reason, in hilly areas, rough grading plans should be submitted with the tentative map to prove the feasibility of development.

If geologic problems are likely, a geologic report should be required prior to approval of the tentative map. Knowledge of geologic factors is fundamental to good engineering design, and it is imperative that any geologic problems present be considered early in the design stage.

A number of geologic conditions can affect tract design:

1. Adversely oriented bedding planes, joints, or faults may require special grading design.
2. Thick sections of poorly consolidated material may necessitate special foundations or sewage disposal systems.

3. The presence of existing landslides may require removal by grading, buttressing with special stabilization devices, or elimination as usable areas.

Certain problems indicated in the geologic report may require that consulting soils engineers analyze the problem and recommend corrective measures. This does not imply that geologic work is of greater importance than that of soils engineering; indeed, inspection by the geologist may disclose the need for soils engineering only. Nevertheless, the most efficient results are obtained when the problems of the site are first evaluated by the geologist who works in close cooperation with the soils engineer. Depending upon the severity of the problems, the soils report may be required before the tentative map approval that precedes the grading plan.

Occasionally, for hilly areas, tentative maps propose street grading only, i. e., that the lots are to be recorded and sold ungraded. With favorable conditions, this is usually acceptable. However, if geologic problems are anticipated, a thorough review, including a geologic report, should be required. If the review indicates the possibility of problems that would effect single-lot development subsequent to recordation, every effort should be made to make the public aware of this possibility (e. g., use of the Final Subdivision Public Report, or deed restrictions). In addition, a permanent solution for the drainage problems should be required, and all existing geologic hazards should be corrected by the developer prior to recordation.

Grading Plan: When the tentative tract map has been approved, the major problems that can be anticipated should have been resolved, and the grading plan can then be checked for adherence to grading standards, detailed design of corrective measures, and so on. In some cases, however, the review of the grading plan will present the first opportunity for consideration of many of the problems inherent in hillside development. In this case, a number of the points discussed for the tentative map will be necessary prior to the grading plan check.

Continuous or frequent inspection during grading operations by a qualified soils engineer to assure conformance with the plans, grading standards, and good engineering practice is essential. Particularly critical is the supervision of benching prior to placing fills and compaction tests. The soils engineer can also watch for unanticipated and potentially hazardous cut slopes. If it is likely that geologic problems will occur during grading, inspection by an engineering geologist during grading should be required also. At this stage, internal communication is essential to insure that all elements of the grading operations have been approved prior to the issuance of building permits.

Building Permit: The building permit provides an additional means of control. Building permits should not be issued until the enforcing agency receives the rough grading reports and the opinions of the soils engineer, engineering geologist, and designing civil engineer, that the site is considered suitable for the intended use.

If a structure requiring a building permit is to be placed in an area graded prior to present ordinances, controls to assure the safety of the existing grading should be applied; such grading frequently is unsafe. Some corrective work may be necessary for proper drainage. If the structure is to be placed on natural ground with no grading, a soils or foundation engineering report may be adequate; if bedrock stability is questionable, however, an engineering geology report should be required.

Engineering geologic and soils reports should contain all information on the geology and soils of a site and adjoining land with emphasis on conditions pertinent to the planned development, logical conclusions, and recommendations. Included here (Appendix G) is a comprehensive outline of what should be included in engineering geologic reports. This outline was prepared by Dr. Richard H. Jahns, Dean of the School of Earth Sciences at Stanford, and has been adopted as a standard by professional and governmental bodies in Los Angeles and Glendale, California. Soils reports should be equally comprehensive.

Professional review of the report is essential. Several types of review are possible. At the very least a review should be made by an engineering geologist and/or a soils engineer regularly employed by the city or employed as consultants with their fees paid possibly from grading permit application fees. These scientists should work closely with the Building Bureau and the Planning Commission and staff to assure the completeness, adequacy, and compliance of the report. Their review could result in (1) approval of the report, (2) recommendations for further work, or (3) disapproval. In the latter two cases a report by the reviewer should be prepared explaining the action.

Final review for applicants receiving partial or complete disapproval could be made at the request of the applicant by a board of professional engineers and geologists with no conflict of interest (retired persons, university instructors, state and federally employed persons, etc.). The services of this board could be financed partially or completely by fees from the applicant. This review would allow an applicant to prove the safety and feasibility of his plan even though it may not comply with existing codes. It would also provide some flexibility to the codes in case of new technological advances, innovations, and conditions not previously recognized.

The city should establish some criteria for assuring the qualifications of engineering geologists and soils engineers submitting reports. Cities and counties in California first used qualification boards and later adopted statewide registration. Several other states have since adopted a registration type of certification. The Association of Engineering Geologists, the State Department of Geology, and other professional groups and individuals should be consulted on this matter.

Specific Recommendations

1. Before any development begins on the conglomerate unit, detailed engineering geologic studies should be conducted to determine the extent, engineering properties, and geologic structure of the unit, as well as the nature and relationship of the overlying and underlying formations.
2. All of the known and inferred faults should be considered in planning and avoided, investigated, or designed for in development until more information is available on their activity and the fault identifications are substantiated, possibly by geophysical or drilling exploration.
3. Within the lifetime of a building, a design should be based upon a repeat of the November, 1962 earthquake (intensity VII on the Modified Mercalli scale) with a maximum acceleration of 12 percent of gravity.
4. Site examinations in the Goble soil series should include an examination for a seasonal perched water table.
5. Site examinations should include an evaluation of vegetation type, quality, quantity, cleared areas, and significance of bowed trees.
6. At sites where development is feasible, only a minimum disturbance of existing natural conditions should be allowed. Any clearing in trees which already exists and is found to be usable for the proposed project should be developed rather than clearing a new area. The vegetation on these sites should be cleared only for proposed building and access to it, leaving as much of the site forested as feasible for both aesthetic and safety purposes.

7. Because of the structural resemblance between the West Linn landslide area and the Marquam Hill area, an investigation should be conducted into the possibility of a block glide failure before major developments or alterations of the land are allowed. It is recommended that several detailed exploratory borings into the Columbia River Basalt be drilled to further delineate the attitude of the basalt flows and to identify and sample any interflow sedimentary horizons.

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APPENDIX A

CHAPTER 70 -- UNIFORM BUILDING CODE

APPENDIX A

CHAPTER 70 - EXCAVATION AND GRADING

UNIFORM BUILDING CODE

(REPRODUCED HERE WITH THE PERMISSION OF THE INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS.)

Sec. 7001. The purpose of this Chapter is to safeguard life, limb, property, and public welfare by establishing minimum requirements for regulating grading and procedures by which these requirements may be enforced. **Purpose**

Sec. 7002. This Chapter sets forth rules and regulations to control excavation, grading, and earthwork construction, including fills or embankments; establishes the administrative procedure for issuance of permits; and provides for approval of plans and inspection of grading construction. **Scope**

Sec. 7003. No person shall do any grading without first having obtained a grading permit from the Building Official, except for the following: **Permits Required and Exceptions**

1. An excavation which (a) is less than two feet (2') in depth, or (b) which does not create a cut slope greater than five feet (5') in height and steeper than one and one-half horizontal to one vertical.

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UNIFORM BUILDING CODE

Permits Required and Exceptions (Continued)

2. A fill less than one foot (1') in depth, and placed on natural terrain with a slope flatter than five horizontal to one vertical, or less than three feet (3') in depth, not intended to support structures, which does not exceed 50 cubic yards on any one lot and does not obstruct a drainage course.

3. An excavation below finished grade for basements and footings of a building, retaining wall, or other structure authorized by a valid building permit. This shall not exempt any fill made with the material from such excavation nor exempt any excavation having an unsupported height greater than five feet (5') after the completion of such structure.

4. Excavation or deposition of earth materials within a property which is dedicated or used, or to be used for cemetery purposes, except where such grading is within one hundred feet (100') of the property line or intended to support structures.

5. Mining, quarrying, excavating, processing, stockpiling of rock, sand, gravel, aggregate, or clay where established and provided for by law provided that such operations do not affect the lateral support or unduly increase the stresses in or pressure upon any adjacent or contiguous property.

6. Grading in an isolated, self-contained area if the Building Official finds that no danger to private or public property can now or thereafter result from the grading operations.

Hazardous Conditions

Sec. 7004. Whenever the Building Official determines that any existing excavation or embankment or fill has become a hazard to life and limb, or endangers property, or adversely affects the safety, use, or stability of a public way or drainage channel, the owner of the property upon which the excavation or fill is located, or other person or agent in control of said property, upon receipt of notice in writing from the Building Official shall within the period specified therein repair or eliminate such excavation or embankment so as to eliminate the hazard and be in conformance with the requirements of this Code.

Definitions

Sec. 7005. **BEDROCK** is the solid, undisturbed rock in place either at the ground surface or beneath surficial deposits of gravel, sand, or soil.

CERTIFY OR CERTIFICATION shall mean the specific inspections and tests where required have been performed and that such tests comply with the applicable requirements of this Chapter.

ENGINEERING GEOLOGY is the application of geological data and principles to engineering problems dealing with naturally occurring rock and soil for the purpose of assuring that geological factors are recognized and adequately interpreted in engineering practice.

EXISTING GRADE is the vertical location of the existing ground surface prior to excavating or filling.

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FILL is deposits of soil, rock, or other materials placed by man.

**Definitions
(Continued)**

FINISH GRADE is the final grade or elevation of the building site.

GRADING is any excavating or filling or combination thereof.

ROUGH GRADE is an approximate elevation of the ground surface conforming to the proposed design.

SITE is any lot or parcel of land or contiguous combination thereof, under the same ownership, where grading is performed or permitted.

SOIL is all earth material of whatever origin that overlies bedrock.

SOILS ENGINEERING shall mean the application of the principles of soils mechanics in the investigation and analysis of the engineering properties of earth material.

Sec. 7006. (a) **Permits Required.** Except as exempted in Section 7003 of this Code, no person shall do any grading without first obtaining a grading permit from the Building Official. A separate permit shall be required for each site, and may cover both excavations and fills.

**Grading Permit
Requirements**

(b) **Plans and Specifications.** With each application for a grading permit and when required by the Building Official for enforcement of any provisions of this Code, two sets of plans and specifications shall be submitted. Except as waived by the Building Official for small and unimportant work, the plans shall be prepared and signed by a civil engineer licensed by the state and shall show the following:

1. A vicinity sketch or other data adequately indicating the site location.
2. Property lines of the property on which the work is to be performed.
3. Location of any buildings or structures on the property where the work is to be performed, and the location of any building or structure on land of adjacent property owners which are within fifteen feet (15') of the property.
4. Accurate contours showing the topography of the existing ground.
5. Elevations, dimensions, location, extent and the slopes of all proposed grading shown by contours and other means.
6. A certification of the quantity of excavation and fill involved and estimated starting and completion dates.
7. Detailed plans of all drainage devices, walls, cribbing, dams, or other protective devices to be constructed in connection with, or as a part of, the proposed work, together with a map showing the drainage area and estimated runoff of the area served by any drains.
8. Any additional plans, drawings, or calculations required by the Building Official.

Grading Permit Requirements (Continued)

(c) **Engineering Geological Reports.** Prior to issuance of a grading permit, the Building Official may require an engineering geological investigation, based on the most recent grading plan. The engineering geological report shall include an adequate description of the geology of the site, and conclusions and recommendations regarding the effect of geologic conditions on the proposed development.

All reports shall be subject to approval by the Building Official, and supplemental reports and data may be required as he may deem necessary. Recommendations included in the report and approved by the Building Official shall be incorporated in the grading plan.

(d) **Soils Engineering Reports.** The Building Official may require a soils engineering investigation, based on the most recent grading plan. Such reports shall include data regarding the nature, distribution, and strength of existing soils, conclusions and recommendations for grading procedures, and design criteria for corrective measures.

Recommendations included in the report and approved by the Building Official shall be incorporated in the grading plan or specifications.

Permit Limitations and Conditions

Sec. 7007. (a) General. The issuance of a grading permit shall constitute an authorization to do only that work which is described or illustrated on the application for the permit, or on the site plans and specifications approved by the Building Official.

(b) **Jurisdiction of Other Agencies.** Permits issued under the requirements of this Code shall not relieve the owner of responsibility for securing required permits for work to be done which is regulated by any other code, department or division of the governing agency.

(c) **Time Limits.** The permittee shall fully perform and complete all of the work required to be done pursuant to the grading permit within the time limit specified. If no time limit is specified, the permittee shall complete the work within 180 days after the date of the issuance of the grading permit.

*

If the permittee is unable to complete the work within the specified time, he shall, prior to the expiration of the permit, present in writing to the Building Official a request for an extension of time, setting forth the reasons for the requested extension. If, in the opinion of the Building Official, such an extension is warranted, he may grant additional time for the completion of the work.

(d) **Storm Damage Precautions.** All persons performing any grading operations shall put into effect all safety precautions which are necessary in the opinion of the Building Official and shall remove all loose dirt from the grading site and provide adequate anti-erosion and/or drainage devices, debris

basins, or other safety devices to protect the life, limb, health, and welfare of private and public property of others from damage of any kind.

Permit Limitations and Conditions (Continued)

(e) **Conditions of Approval.** In granting any permit under this Code, the Building Official may attach such conditions as may be reasonably necessary to prevent creation of a nuisance or hazard to public or private property. Such conditions may include, but shall not be limited to:

1. Improvement of any existing grading to bring it up to the standards of this Code.
2. Requirements for fencing of excavations or fills which would otherwise be hazardous.

* Read 180 days.

(f) **Liability.** Neither the issuance of a permit under the provisions of this Code, nor the compliance with the provisions hereof or with any conditions imposed in the permit issued hereunder, shall relieve any person from responsibility for damage to other persons or property, nor impose any liability upon the city for damage to other persons or property.

Sec. 7008. (a) Hazardous Grading. The Building Official shall not issue a permit in any case where he finds that the work as proposed by the applicant is liable to endanger any private property or result in the deposition of debris on any public way or interfere with any existing drainage course. Denial of Permit

If it can be shown to the satisfaction of the Building Official that the hazard can be essentially eliminated by the construction of retaining structures, buttress fills, drainage devices or by other means, the Building Official may issue the permit with the condition that such work be performed.

(b) **Geological or Flood Hazard.** If, in the opinion of the Building Official, the land area for which grading is proposed is subject to geological or flood hazard to the extent that no reasonable amount of corrective work can eliminate or sufficiently reduce the hazard to human life or property, the grading permit and building permits for habitable structures shall be denied.

Sec. 7009. (a) Plan-checking Fee. For excavation and fill on the same site, the fee shall be based on the volume of the excavation or fill, whichever is greater. Before accepting a set of plans and specifications for checking, the Building Official shall collect a plan-checking fee. Separate permits and fees shall apply to retaining walls or major drainage structures as indicated elsewhere in this Code. There shall be no separate charge for standard terrace drains and similar facilities. The amount of the plan-checking fee for grading plans shall be as set forth in Table No. 70-A. Fees

The fee for a grading permit authorizing additional work to that under a valid permit shall be the difference between the fee paid for the original permit and the fee shown for the entire project.

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Fees
(Continued)

TABLE NO. 70-A—PLAN-CHECKING FEES

50 cubic yards or less.....	No Fee
50 to 100 cubic yards.....	\$10.00
101 to 1000 cubic yards.....	15.00
1001 to 10,000 cubic yards.....	20.00
10,001 to 100,000 cubic yards—\$20.00 for the first 10,000 cubic yards plus \$10.00 for each additional 10,000 cubic yards or fraction thereof.	
100,001 to 200,000 cubic yards—\$110.00 for the first 100,000 cubic yards plus \$6.00 for each additional 10,000 cubic yards or fraction thereof.	
200,001 cubic yards or more—\$170.00 for the first 200,000 cubic yards, plus \$3.00 for each additional 10,000 cubic yards or fraction thereof.	

(b) **Grading Permit Fees.** A fee for each grading permit shall be paid to the Building Official as set forth in Table No. 70-B.

TABLE NO. 70-B—GRADING PERMIT FEES

50 cubic yards or less.....	\$10.00
50 to 100 cubic yards.....	15.00
101 to 1000 cubic yards—\$15.00 for the first 100 cubic yards, plus \$7.00 for each additional 100 cubic yards or fraction thereof.	
1001 to 10,000 cubic yards—\$78.00 for the first 1000 cubic yards, plus \$6.00 for each additional 1000 cubic yards or fraction thereof.	
10,001 to 100,000 cubic yards—\$132.00 for the first 10,000 cubic yards, plus \$27.00 for each additional 10,000 cubic yards or fraction thereof.	
100,001 cubic yards or more—\$375.00 for the first 100,000 cubic yards, plus \$15.00 for each additional 10,000 cubic yards or fraction thereof.	

The fee for a grading permit authorizing additional work to that under a valid permit shall be the difference between the fee paid for the original permit and the fee shown for the entire project.

Bonds

Sec. 7010. (a) Bonds Required. A permit shall not be issued for more than 1000 cubic yards unless the permittee shall first post with the Building Official a bond executed by the owner and a corporate surety authorized to do business in this state as a surety in an amount sufficient to cover the cost of the project, including corrective work necessary to remove and eliminate geological hazards.

The bond shall include penalty provisions on a form approved by counsel for the governing agency, for failure to complete the work on schedule.

In lieu of a surety bond the applicant may file a cash bond with the Building Official in an amount equal to that which would be required in the surety bond.

(b) **Conditions.** Every bond shall include the conditions that the permittee shall:

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1. Comply with all of the provisions of the Code, applicable laws, and ordinances;
2. Comply with all of the terms and conditions of the permit for excavation or fill to the satisfaction of the Building Official;
3. Complete all of the work contemplated under the permit within the time limit specified in the permit. (The Building Official may, for sufficient cause, extend the time specified in the permit, but no such extension shall release the surety upon the bond.)

**Bonds
(Continued)**

(c) **Failure to Complete Work.** The term of each bond shall begin upon the date of filing and shall remain in effect until the completion of the work to the satisfaction of the Building Official. In the event of failure to complete the work and failure to comply with all of the conditions and terms of the permit, the Building Official may order the work required by the permit to be completed to his satisfaction. The surety executing such bond or deposit shall continue to be firmly bound under a continuing obligation for the payment of all necessary costs and expenses that may be incurred or expended by the governing agency in causing any and all such required work to be done. In the case of a cash deposit, said deposit or any unused portion thereof shall be refunded to the permittee.

Sec. 7011. (a) Maximum Slope. Cuts shall not be steeper in slope than one and one-half horizontal to one vertical unless the owner furnishes a soils engineering or an engineering geology report certifying that the site has been investigated and indicating that the proposed deviation will not endanger any private property or result in the deposition of debris on any public way or interfere with any existing drainage course.

**Design Standards
for Cuts**

The Building Official may require the excavation to be made with a cut face flatter in slope than one and one-half horizontal to one vertical if he finds it necessary for stability and safety.

(b) **Drainage Terraces.** Cut slopes exceeding forty feet (40') in vertical height shall be terraced at their approximate mid-height. Drainage terraces are to be a minimum of six feet (6') wide, paved and must carry water to a safe disposal area. Terraces shall be cut every thirty feet (30') vertically, except that where only one terrace is required, it shall be at mid-height.

Sec. 7012. (a) **Compaction.** All fills shall be compacted to a minimum of 90 per cent of maximum density as determined by U.B.C. Standard No. 70-1-64. Field density shall be determined by U.B.C. Standard No. 70-2-64 or equivalent as approved by the Building Official. If the Building Official determines that the strict enforcement of this Section is unduly

**Design Standards
for Fills**

SECTIONS 7012-7013

UNIFORM BUILDING CODE

**Design Standards
for Fills
(Continued)**

restrictive or imposes an undue hardship on the permittee, this requirement may be waived by the Building Official. This requirement shall not be waived when structures are to be supported by the fill or where the Building Official determines that compaction is necessary as a safety measure to aid in preventing the saturation, slipping, or erosion of the fill.

(b) **Preparation of Ground.** The natural ground surface shall be prepared to receive fill by removing vegetation, non-complying fill, top soil, and, where slopes are five horizontal to one vertical or steeper, by benching into sound bedrock or other competent material. Five feet (5') of the lowermost bench shall be exposed beyond the toe of the fill. The bench shall be sloped for sheet overflow or a paved drain shall be provided.

(c) **Fill Slope.** No compacted fill shall be made which creates an exposed surface steeper in slope than one and one-half horizontal to one vertical. The Building Official may require that the fill be constructed with an exposed surface flatter than one and one-half horizontal to one vertical if he finds this necessary for stability and safety.

Slopes of fills which are not compacted in accordance with Section 7012 (a) may not exceed two horizontal to one vertical.

(d) **Fill Material.** No organic material shall be permitted in fills. Except as permitted by the Building Official, no rock or similar irreducible material with a maximum dimension greater than eight inches (8") shall be buried or placed in fills.

(e) **Drainage Terraces.** All fill slopes in excess of thirty feet (30') vertical height shall have paved drainage terraces at vertical intervals not exceeding twenty-five feet (25') except that where only one terrace is required it shall be at mid-height. Such terraces shall drain into a paved gutter, pipe or other watercourse adequate to convey the water to a safe disposal area. The terrace shall be at least six feet (6') wide.

(f) **Slopes to Receive Fill.** Fills toeing out on natural slopes which are steeper than two horizontal to one vertical will not be permitted.

**Design Standards
for Setbacks**

Sec. 7013. Cuts and fills shall be set back from property lines and buildings shall be set back from cut or fill slopes in accordance with Figure No. 1. Retaining walls may be used to reduce the required setback when approved by the Building Official.

Fill placed on or above the top of an existing or proposed cut or natural slope steeper than three horizontal to one vertical shall be set back from the edge of the slope a minimum distance of six feet (6').

Building foundations shall be set back from the top of slope a minimum distance of six feet (6') for all cut slopes steeper

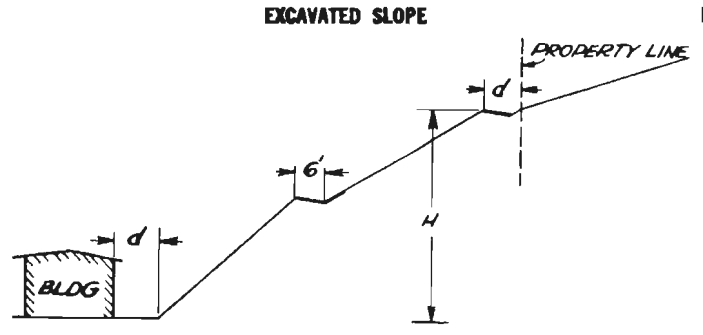


Figure No. 1

REQUIRED SETBACKS			
H FEET	FILL SLOPES		CUT SLOPES
	a	b	d
0-15	1'8"	3'	3'
15-50	H/10	H/5	H/5
Over 50	H/10	H/5	10'

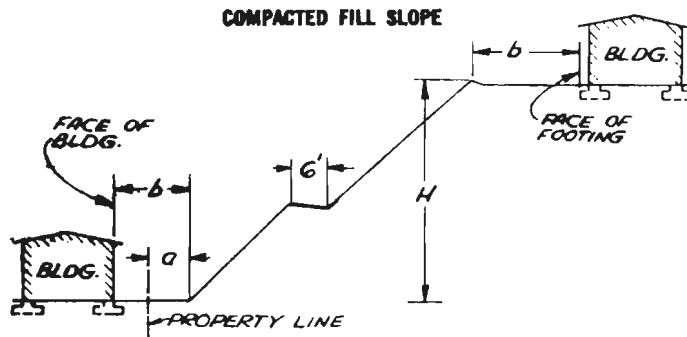


FIGURE NO. 1—REQUIRED SETBACKS

than two horizontal to one vertical. No buildings shall be constructed on cut or fill slopes steeper than two horizontal to one vertical.

Design Standards
for Setbacks
(Continued)

The setbacks given in this Section are minimum and may be increased by the Building Official if considered necessary for safety or stability or to prevent possible damage from water, soil, or debris.

Sec. 7014. (a) Disposal. All drainage facilities shall be designed to carry surface waters to the nearest practical street, storm drain, or natural watercourse approved by the Building Official and/or other appropriate governmental agency, as a safe place to deposit such waters. At least two per cent grade

Design Standards
for Drainage

Design Standards for Drainage (Continued) toward the approved disposal area will be required for building pads, except as waived by the Building Official for non-hilly terrain.

(b) **Erosion Prevention.** Adequate provision shall be made to prevent any surface waters from damaging the face of an excavation or fill. All slopes shall be protected from surface water runoff from above by berms or swales.

(c) **Terrace Drains.** All swales or ditches on drainage terraces shall have a minimum grade of five per cent and must be paved. Drainage devices shall be paved with concrete with a minimum thickness of three inches (3") or approved equal. They shall have a minimum depth at the deepest point of one foot (1').

If the drain discharges onto natural ground riprap may be required.

Planting Sec. 7015. The face of all cut and fill slopes shall be planted and maintained with a ground cover approved by the Building Official to protect the slopes against erosion as soon as practical and prior to the final approval of the grading. Where cut slopes are not subject to erosion due to their rocky character, this requirement may be waived by the Building Official.

An irrigation system or watering facilities may be required by the Building Official.

Grading Inspection and Supervision Sec. 7016. (a) **Supervised Grading Required.** All grading in excess of 5000 cubic yards shall be performed under the supervision of a civil engineer and shall be designated "supervised grading." Grading not supervised in accordance with this Section shall be designated "regular grading." For grading involving less than 5000 cubic yards the permittee may elect to have the grading performed as either supervised grading or regular grading.

(b) **Regular Grading Requirements.** The Building Official shall inspect the work, and require adequate inspection and compaction control by a soils testing agency. The soils testing agency shall be approved by the Building Official.

Periodic reports certifying the compaction or acceptability of all fills shall be required except as exempted by Section 7012 (a). These shall include but need not be limited to inspection of cleared areas and benches prepared to receive fill and removal of all soil and unsuitable materials; the placement and compaction of fill materials; the bearing capacity of the fill to support structures, and the inspection or review of the construction of retaining walls, subdrains, drainage devices, buttress fills, and other similar measures.

The Building Official may require sufficient inspection to assure that all geologic conditions have been adequately considered. Where geologic conditions warrant, the Building

Official may require periodic geologic reports. These inspections may be required to include, but need not be limited to inspection of cut slopes, canyons during clearing operations for ground water and earth material conditions; benches prior to placement of fill; and possible spring locations.

Grading Inspection and Supervision (Continued)

(c) **Supervised Grading Requirements.** For supervised grading it shall be the responsibility of the civil engineer to supervise and coordinate all site inspection and testing during grading operations. Soils and geology reports shall also be required as specified in Section 7017 (b). All necessary reports, compaction data, and soils engineering and engineering geological recommendations shall be submitted to the Building Official by the supervising civil engineer.

*

* Read Section 7006.

(d) **Notification of Noncompliance.** If in the course of fulfilling his responsibility under this Chapter, the supervising civil engineer finds that the work is not being done in conformance with this Chapter or the plans approved by the Building Official, or in accordance with accepted practices, he shall immediately notify the person in charge of the grading work and the Building Official in writing of the nonconformity and of the corrective measures to be taken.

Sec. 7017. If at any stage of the work the Building Official determines by inspection that further grading as authorized is likely to endanger any private property or result in the deposition of debris on any public way or interfere with any existing drainage course, the Building Official may require, as a condition to allowing the work to be completed, that such reasonable safety precautions be taken as he considers advisable to avoid such likelihood of danger.

Safety Precautions

Notice to comply shall be submitted to the permittee in writing. After a notice to comply is written, a period of 10 days shall be allowed for the contractor to begin to make the corrections, unless an imminent hazard exists, in which case the corrective work shall begin immediately.

If the Building Official finds any existing conditions not as stated in the grading permit or approved plans, he may refuse to approve further work until approval is obtained for a revised grading plan which will conform to the existing conditions.

Sec. 7018. (a) Compliance with Plans and Requirements. All permits issued hereunder shall be presumed to include the provision that the applicant, his agent, contractors or employees, shall carry out the proposed work in accordance with the approved plans and specifications and in compliance with all the requirements of this Chapter.

Responsibility of Permittee

(b) **Protection of Utilities.** During grading operations the permittee shall be responsible for the prevention of damage to any public utilities or services. This responsibility applies

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within the limits of grading and along any routes of travel of equipment

(c) **Protection of Adjacent Property.** The permittee is responsible for the prevention of damage to adjacent property and no person shall excavate on land sufficiently close to the property line to endanger any adjoining public street, sidewalk, alley, or other public or private property without supporting and protecting such property from settling, cracking, or other damage which might result.

Modification of Approved Plans

Sec. 7019. All modifications of the approved grading plans must be approved by the Building Official. All necessary soils and geological reports shall be submitted with the plans.

No grading work in connection with the proposed modifications will be permitted without the approval of the Building Official. If, in the opinion of the Building Official, the strict enforcement of Section 7007 (d) I will create an undue hardship on the permittee, or a hazard to the safety of operations, this requirement may be waived. Such a waiver shall not relieve the permittee of responsibility for compliance with the design standards of this Code.

Modifications which affect basic tract design or land use must have the approval of the appropriate control agency.

**Completion
of Work**

Sec. 7020. (a) Final Reports. Upon completion of the work, the Building Official may require the following reports:

1. The supervising civil engineer shall certify that all grading, lot drainage, and drainage facilities have been completed in conformance with the approved plans and this Chapter, and shall furnish a final contour map of the completed work.
2. The soils engineering reports shall include certification of soil bearing capacity, summaries of field and laboratory tests, locations of tests, and shall show limits of compacted fill on an "as built" plan.
3. The engineering geology reports shall be based on the final contour map and shall include specific approval of the grading as affected by geological factors. Where necessary, a revised geologic map and cross sections, and any recommendations regarding building restrictions or foundation setbacks shall be included.

(b) **Notification of Completion.** The permittee or his agent shall notify the Building Official when the grading operation is ready for final inspection. Final approval shall not be given until all work including installation of all drainage structures and their protective devices, has been completed and the final contour map and required reports have been submitted.

APPENDIX B
SOIL CONSERVATION SERVICE
SOIL LIMITATION AND SUITABILITY CLASSES

APPENDIX B

SOIL LIMITATION CLASSES FOR SEPTIC TANK ABSORPTION FIELDS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Permeability Class <u>1/</u>	Rapid, moderately rapid, and upper end of moderate <u>2/</u>	Lower end of moderate	Moderately slow and slow <u>3/</u>
Hydraulic conductivity rate (Uhland core method)	More than 1.0 inch/hr. <u>2/</u>	1.0 to 0.60 inch/hr.	Less than 0.60 inch/hr.
Percolation rate (Auger hole method)	Faster than 45.0 min./inch <u>2/</u>	45 to 60 min./inch	Slower than 60 min./inch
Depth to water table <u>4/</u>	More than 72 in.	48 to 72 in.	Less than 48 in.
Flooding hazard	None	None	Subject to floods
Slopes (percent)	0 to 8	8 to 15	More than 15
Depth to hard rock, bedrock or other impervious material <u>4/</u>	Over 72 in.	48 to 72 in.	Less than 48 in.

1/ Class limits are the same as those suggested by the Work-Planning Conference of the National Cooperative Soil Survey. The limitation ratings should be related to the permeability of soil layers at and below depth of the tile line.

2/ Indicate by footnote where pollution to water supplies is a hazard.

3/ In arid or semiarid areas soils with moderately slow permeability may have a moderate limitation.

4/ Based on assumption of tile depth of 2 feet in the soil.

TENTATIVE - SUBJECT TO CHANGE
May, 1971

SOIL LIMITATION CLASSES FOR DWELLINGS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Soil drainage class	<u>With basements:</u> Excessively, somewhat excessively, well	<u>With basements:</u> Moderate well	<u>With basements:</u> Somewhat poorly, poorly, very poorly
	<u>Without basements:</u> Excessively, somewhat excessively, well, moderately well	<u>Without basements:</u> Somewhat poorly	<u>Without basements:</u> Poorly, very poorly
Seasonal water table (Seasonal means 1 month or more)	<u>With basements:</u> Below 60 in.	<u>With basements:</u> Below 30 in.	<u>With basements:</u> Above 30 in.
	<u>Without basements:</u> Below 30 in.	<u>Without basements:</u> Below 20 in.	<u>Without basements:</u> Above 20 in.
Flooding	None	None	Occasional to frequent
Slope (percent)	0 to 8	8 to 15	More than 15
Shrink-swell potential	Low	Moderate	High
Unified soil groups	GW, GP, SW, SP, GM, GC, SM, SC	ML, CL	CH, MH, OL, OH, PT
Potential frost action	Low	Moderate	High
Stoniness	Class 0 to 1	Class 2	Classes 3, 4, and 5
Rockiness	Class 0	Class 1	Classes 2, 3, 4, and 5
Depth to bedrock	<u>With basements:</u> More than 60 in.	<u>With basements:</u> 40 to 60 in.	<u>With basements:</u> Less than 40 in.
	<u>Without basements:</u> More than 40 in.	<u>Without basements:</u> 20 to 40 in.	<u>Without basements:</u> Less than 20 in.

TENTATIVE - SUBJECT TO CHANGE
May, 1971

SOIL LIMITATIONS FOR WINTER GRADING

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Depth to water table	More than 40 in.	20 to 40 in.	Less than 20 in.
Natural drainage	Excessive, somewhat excessive, well, and moderately well drained	Moderately well and somewhat poorly drained	Somewhat poorly, poorly, and very poorly drained
Surface soil texture	Loam and coarser	Silt, loam, clay loam, silty clay loam	Silty clay and clay
Coarse fragments in surface layer	0 to 20%	20 to 50%	50% +
Slope (percent)	0 to 12	12 to 20	Over 20
Depth to hardrock	Over 60 in.	20 to 60 in.	Less than 20 in.
Erosion hazard	0 to 7	7 to 20	Over 20

TENTATIVE - SUBJECT TO CHANGE
April, 1969

SOIL LIMITATION CLASSES FOR LOCAL ROADS AND STREETS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Soil drainage class <u>1/</u>	Excessively, somewhat excessively, well, and moderately well	Somewhat poorly	Poorly and very poorly
Flooding	None	Once in 5 yr.	More than once in 5 years
Slope (percent)	0 to 12	12 to 20	More than 20
Depth to bedrock <u>2/</u>	More than 40 in.	20 to 40 in.	Less than 20 in.
Subgrade <u>3/</u>			
a. AASHO group index	0 to 4	5 to 8	More than 8
b. Unified soil classes	GW, GP, SW, SP, GM, GC <u>9/</u> , SM, SC <u>9/</u>	CL with PI <u>5/</u> less than 15, ML	CL with PI <u>5/</u> of 15 or more, CH, MH <u>6/</u> , OH, OL, PT
Shrink-swell potential	Low	Moderate	High
Susceptibility to frost heave	Low	Moderate	High
Stoniness <u>8/</u>	Classes 0, 1, 2	Class 3	Classes 4, 5
Rockiness <u>8/</u>	Class 0	Class 1	Classes 2, 3, 4, 5

1/ For definitions see Soil Survey Manual, pp. 169-172.

2/ If bedrock is soft enough so that it can be dug with light power equipment and is rippable by machinery, reduce moderate and severe limitations by one class.

3/ Use AASHO Group Index values if available from laboratory tests; otherwise, use the estimated Unified classes.

4/ Use Group Index values according to AASHO Designation M 145-49 and M 145-661; for most soils with group index values below about 8, both designations (methods) give results nearly enough alike to be considered alike for the purpose of this guide.

5/ PI means plasticity index.

6/ Upgrade to moderate if MH is largely kaolinitic, friable, and free of mica.

7/ Use this item only where frost penetrates below the paved or hardened surface layer and moisture transportable by capillary movement is sufficient to form ice lenses at the freezing front. See section "Potential Frost Action" for guidelines to classes.

8/ For definitions see Soil Survey Manual, ;;. 216-223.

9/ Downgrade to moderate if content of fines is greater than about 30 percent.

TENTATIVE - SUBJECT TO CHANGE
May 1971

SOIL LIMITATIONS FOR TERRACES AND DIVERSIONS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Depth to hardrock or limiting layer	Over 60 in.	20 to 60 in.	Less than 20 in.
Slope (percent)	0 to 12	12 to 20	20 to 30
Texture	l, sil	sicl, cl, sl	ls, s, sic, c
Stoniness (percent)	None	0 to 3	Over 3
Potential siltation of channels	Low	Moderate	High

TENTATIVE - SUBJECT TO CHANGE

SOIL LIMITATIONS FOR SANITARY LANDFILL

TRENCH TYPE 1/

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT <u>2/</u>	MODERATE <u>2/</u>	SEVERE
Depth to seasonal high water table	More than 72 inches		Less than 72 inches
Soil drainage classes	Excessively, somewhat excessively, well, and some <u>3/</u> moderately well drained	Somewhat poorly, some <u>3/</u> moderately well drained	Poorly and very poorly drained
Flood hazard	None	None	Soils subject to flooding
Permeability <u>4/</u>	Less than 2.0 inches/hr.	Less than 2.0 inches/hr.	More than 2.0 inches/hr.
Slope (percent)	0 to 12	12 to 20	More than 20
Soil texture <u>5/</u> (dominant to a depth of 60 in.)	Sandy loams, loam, silt loam, sandy clay loam	Silty clay loam <u>6/</u> clay loam, sandy clay, loamy sand	Silty clay, clay muck, peat, gravel, sand
Depth : to : bedrock : rippable :	More than 72 in. More than 60 in.	More than 72 in. More than 60 in.	Less than 72 in. Less than 60 in.
Stoniness <u>7/</u>	0, 1	2	3, 4, 5
Rockiness <u>7/</u>	0	0	1, 2, 3, 4, 5

1/ Based on soil depth (5-6 ft.) commonly investigated in making soil surveys.

2/ If the probability is high that the soil material to a depth of 10 to 15 feet will not alter a rating of slight or moderate, indicate that by an appropriate footnote such as "Probably slight to 12 feet" or "Probably moderate to 12 feet."

3/ Soil drainage classes do not correlate exactly with depth to seasonal water table. The overlap of the moderately well drained soils into two limitation classes allows some of the wetter moderately well drained soils (mostly in the Northeast) to be given a moderate limitation.

4/ Reflects ability of soil to retard movement of landfill leachate. May not be a factor in arid and semiarid areas..

5/ Reflects ease of digging and moving soil material (workability) and trafficability in the immediate area of the trench that may not have surfaced roads.

6/ Soils high in expanding clays may need to be rated as severe.

7/ Soil Survey Manual pp. 216-223.

SOIL SUITABILITY CLASSES FOR COVER MATERIAL FOR THE
AREA TYPE SANITARY LANDFILL

Item Affecting Use	Degree of Soil Suitability		
	GOOD	FAIR	POOR
Moist consistence	Very friable, friable	Loose, firm	Very firm, extremely firm
Texture <u>1/</u>	Sandy loam, loam, silt loam, sandy clay loam	Silty clay loam, clay loam, sandy clay, loamy sand	Silty clay, clay, muck, peat, sand
Thickness of material (Usually top part of profile)	More than 40 in.	20 to 40 in.	Less than 20 in.
Coarse fragments (percent by volume)	Less than 15	15 to 35	More than 35
Surface stones <u>2/</u>	0, 1	2	3, 4, 5
Slope (percent)	Less than 8	8 to 15	More than 15
Drainage class (wetness)	Not determining if better than poorly drained		Poorly and very poorly drained

1/ Soils with a high proportion of 1:1 clays may be rated one class better than that shown in this table.

2/ Class in Soil Survey Manual, pp. 216-223.

TENTATIVE -- SUBJECT TO CHANGE
May, 1971

SOIL LIMITATIONS FOR SANITARY LANDFILL
AREA METHOD

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Depth to seasonal high water table	More than 60 in.	40 to 60 in.	Less than 40 in.
Soil drainage classes <u>1/</u>	Excessively, some- what excessively, well and moderately well drained	Somewhat poorly drained	Poorly and very poorly drained
Flood hazard	None	None	Soils subject to flooding
Permeability <u>2/</u>	Less than 2.0 in./hr.	Less than 2.0 in./hr.	More than 2.0 in./hr.
Slope (percent)	0 to 8	8 to 15	More than 15

1/ Reflects influence of wetness on operation of equipment.

2/ Reflects ability of the soil to retard movement of landfill leachate. May not be a limitation in arid and semiarid areas.

TENTATIVE - SUBJECT TO CHANGE
May, 1971

SOIL LIMITATIONS FOR POND RESERVOIR AREAS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Permeability	Less than 0.63 in./hr.	0.63 to 2.0 in./hr.	Over 2.0 in./hr.
Depth to bedrock	Over 60 in.	40 to 60 in.	Less than 40 in.
Slope (percent)	0 to 12	12 to 30	Over 30
Reservoir site material	GC, SC CL, CH	GM, SM, ML, MH, OH	GP, GW, SP, SW, OL
Organic matter	Less than 2%	2 to 15%	Over 15%

SOIL LIMITATIONS FOR POND EMBANKMENTS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Soil material <u>1/</u>	GC, SC, CL, CH	GM, SM, ML, MH	GP, GW, SP, SW
Shrink-swell potential	Low	Moderate	High
Organic matter	0 to 5%	5 to 15%	Over 15%
Coarse fragments over 6 in. diameter by volume	None	Less than 5%	Over 5%
Depth to rock	Over 40 in.	20 to 40 in.	Less than 20 in.

1/ Soils classes as OL, OH, or Pt are not suitable for embankments.

SOIL SUITABILITY CLASSES AS SOURCE OF TOPSOIL

Item Affecting Use	Degree of Soil Suitability		
	GOOD	FAIR	POOR
Moist consistence	Very friable, friable	Loose, firm	Very firm, extremely firm
Texture	fsl, vfsl, l, sil, si; sc if 1:1 clay is dominant	cl, scl, sicl; sc if 2:1 clay is dominant; c and sic if 1:1 clay is dominant	s, ls: c and sic if 2:1 clay is dominant
Thickness of material (usually top part of profile)	More than 16 in.	8 to 16 in.	Less than 8 in.
Coarse fragments (percent)	Less than 3	3 to 20	More than 20
Soluble salts; conductiv- ity of saturation extract mmhos/cm	Less than 4	4 to 8	More than 8
Surface stoniness <u>1/</u>	Class 0	Class 1	Classes 2, 3, 4, and 5
Slope (percent)	0 to 12	12 to 20	More than 20
Drainage class <u>1/</u>	Drainage class not determining if better than poorly drained		Poorly drained, very poorly drained

1/ For definitions see Soil Survey Manual

TENTATIVE - SUBJECT TO CHANGE
May, 1972

SOIL LIMITATIONS FOR PLAYGROUNDS

Item Affecting Use	Degree of Soil Limitations		
	SLIGHT	MODERATE	SEVERE
Wetness	Excessively, somewhat excessive, well, and moderately well drained soils. Water table below 30 in. during season of use	Moderately well & somewhat poorly drained. Water table below 20 in. during season of use	Somewhat poorly, poorly, & very poorly drained. Water table above 20 in. during season of use
Flooding	None during season of use	May flood once in 2 years during season of use	Floods more than once in 2 years during season of use
Permeability	Very rapid to moderate inclusive	Moderately slow and slow	Very slow
Slope (percent)	0 to 3	3 to 7	7 +
Surface soil texture	sl, fsl, vsl, l, sil	cl, scl, sicl, ls	sc, sic, c, organic soils, sand, and loamy sand subject to blowing
Depth to bedrock	Over 40 in.	20 to 40 in.	Less than 20 in.
Coarse fragments on surface (percent)	Relatively free of fragments	Up to 20	20 +
Stoniness	Class 0	Classes 1, 2	Classes 3, 4, 5
Rockiness	Class 0	Class 1	Classes 2, 3, 4, 5

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SOIL LIMITATIONS FOR PICNIC AREAS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Wetness	Excessive, somewhat excessive, well, and moderately well drained soils. Water table below 20 in. during season of use	Moderately well & somewhat poorly drained soils. Water table during season of use may be less than 20 in. for short periods	Poorly and very poorly drained soils. Water table above 20 in. and often near the surface for a month or more during season of use
Flooding	None during season of use	May flood 1 or 2 times for short periods during season of use	Floods more than 2 times during season of use
Slope (percent)	0 to 7	7 to 12	12 to 20
Surface soil texture	sl, fsl, vfsl, l, sil	cl, scl, sicl, ls, and sand other than loose sand	sc, sic, c, loose sand, organic soil, and soils subject to severe blowing
Coarse fragment on surface (percent)	0 to 20	20 to 50	50 +
Stoniness	Classes 0, 1, 2	Class 3	Classes 4, 5
Rockiness	Classes 0, 1	Class 2	Classes 3, 4, 5

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SOIL LIMITATIONS FOR CAMP AREAS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Wetness	Excessive, somewhat excessive, well and moderately well drained. Water table below 30 in. during season of use	Moderately well & somewhat poorly drained. Water table below 20 in. during season of use	Somewhat poorly, poorly, and very poorly drained. Water table above 20 in. during season of use
Flooding	None	None during season of use	Floods during season of use
Permeability	Very rapid to moderate inclusive	Moderately slow and slow	Very slow
Slope (percent)	0 to 7	7 to 12	12 to 20 +
Surface soil texture	sl, fsl, vsl, l, sil,	cl, scl, sicl, ls, and sand other than loose sand	Organic, sc, sic, c, loose sand, & soils subject to severe blowing
Coarse fragments on surface (percent)	0 to 20	20 to 50	50+
Stoniness	Classes 0, 1	Class 2	Classes 3, 4, 5
Rockiness	None	Classes 1, 2	Classes 3, 4, 5

TENTATIVE - SUBJECT TO CHANGE
April, 1969

SOIL SUITABILITY CLASSES AS SOURCES OF ROAD FILL

Item Affecting Use <u>1/</u>	Degree of Soil Suitability		
	GOOD	FAIR	POOR
Unified soil classes	GW, GP, SW, GM, SP, GC <u>2/</u> , SM <u>2/</u> , SC <u>2/</u>	ML,CL with PI <u>3/</u> less than 15	CL with PI <u>3/</u> more than 15, CH, MH <u>4/</u> , OL, LH, PT
Engineering soil classes AASHO group index <u>5/</u>	0 to 4	5 to 8	More than 8
Shrink-swell potential	Low	Moderate	High
Susceptibility to frost action <u>6/</u>	Low	Moderate	High
Slope (percent)	0 to 15	15 to 25	More than 25
Stoniness class <u>7/</u>	0, 1, 2	3	4, 5
Rockiness class <u>7/</u>	0, 1	2	3, 4, 5
Soil drainage class <u>7/</u>	Excessively to moderately well	Somewhat poorly	Poorly, very poorly

- 1/ The first three items are predictions about the soil after it is placed in a fill; the last four items pertain to the soil in its natural condition before excavation for road fill.
- 2/ Downgrade to fair if content of fines is greater than about 30 percent.
- 3/ PI means plasticity index.
- 4/ Upgrade to fair if MH is largely kaolinitic, friable, and free of mica.
- 5/ Use only where laboratory data are available for the kind of soil being rated; otherwise use Unified classes.
- 6/ Use this item only where frost penetrates below the paved or hardened surface layer and moisture transportable by capillary movement is sufficient to form ice lenses at the freezing front. See section "Potential Frost Action" for guidance to classes.
- 7/ For definitions see Soil Survey Manual.

Tentative - Subject to Change
May, 1971

SOIL LIMITATIONS FOR PATHS AND TRAILS

Item Affecting Use	Degree of Soil Limitation		
	SLIGHT	MODERATE	SEVERE
Wetness	Excessive, somewhat excessive, well and moderately well drained. Water table below 20 in. during season of use	Somewhat poorly drained soils. Water table during season of use may be above 20 in. for short periods	Poorly and very poorly drained. Water table above 20 in. and often near surface for month or more during season of use
Flooding	May flood once a year during season of use	May flood 2 or 3 times during season of use	Floods more than 3 times during season of use
Slope (percent)	0 to 12	12 to 30	30 +
Surface soil texture	sl, fsl, vfsl, l, sil	sicl, scl, cl, ls	sc, sic, c, sand, organic soils
Coarse fragments on surface (percent)	0 to 20	20 to 50	50 +
Rockiness or stoniness	Classes 0, 1	Class 2	Classes 3, 4, 5

TENTATIVE - SUBJECT TO CHANGE
April, 1969

SUITABILITY FOR WOODLAND

Item Affecting Use	Degree of Suitability		
	GOOD	FAIR	POOR
Site class <u>1/</u>	I, II, III	IV	V
Slope (percent)	0 to 30	30 to 60	60 to 90
Equipment limitations	None or slight	Moderate	Severe, special equipment needed
Wetness	Watertable below 30 in.	Water table below 20 in.	Water table above 20 in.
Soil depth	40 in. or more	20 to 40 in.	Less than 20 in.
Texture of control section	sl, l sil, sicl, cl	ls, sic, permeable c	c, s
Coarse fragments on surface (percent)	0 to 20	20 to 50+	
Stoniness <u>1/</u>	Classes 0, 1, 2	Class 3	Classes 4 & 5
Rockiness <u>1/</u>	Classes 0, 1, 2	Class 3	Classes 4 & 5
Moisture supplying capacity	More than 16 in.	10 to 16 in.	Less than 10 in.

1/ See definition in Soil Survey Manual, pp. 217-221.

TENTATIVE - SUBJECT TO CHANGE
April, 1969

APPENDIX C
GLOSSARY

APPENDIX C

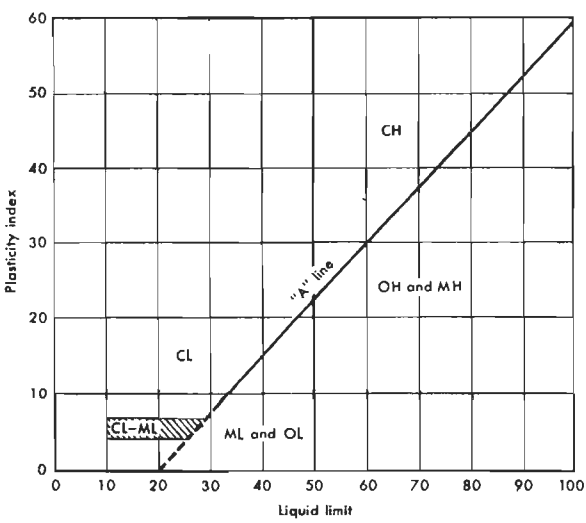
GLOSSARY

- Anticline - A fold or arch of rock strata which dips in opposite directions from an axis.
- Columnar jointing - A variety of jointing that breaks the rock into a more or less clearly defined hexagonal pattern.
- Conglomerate - Rounded waterworn fragments of rock in a matrix of sand and sometimes silt, cemented together by another mineral substance.
- Epicenter - The point on the earth's surface directly above the focus of an earthquake.
- Evapo-transpiration - A term embracing that portion of the precipitation returned to the air through direct evaporation or by transpiration of vegetation; no attempt made to distinguish between the two.
- First-motion = first arrival - The primary or first impulse recorded by seismographs.
- Focus - The source of a given set of elastic waves. The true center of an earthquake, within which the strain energy is first converted to elastic wave energy.
- Fragipan - Dense and brittle pan or layer in soils that owe their hardness mainly to extreme density or compactness rather than high clay content or cementation. Removed fragments are friable, but the material in place is so dense that roots cannot penetrate and water moves through it very slowly.
- Gouge - Finely abraded material between the walls of a fault, the result of grinding movement.
- Loess - A homogenous, nonstratified, unindurated deposit consisting predominately of silt, with subordinate amounts of very fine sand and/or clay. The term has genetic implication in terms of deposits which are due to the transporting action of the wind.
- Mottled - Irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.
- Perched watertable - The upper surface of a zone of saturation separated from an underlying body of ground water by unsaturated soil or rock.
- Ripping - A method of breaking up some loosely consolidated, highly fractured or weathered bedrock usually employing a caterpillar pulled device.
- Slickensides - Polished and striated (scratched) surface of a fault wall that results from friction along a fault plane.
- Stratigraphy - That part of the descriptive geology of an area which pertains to the discrimination, character, thickness, sequence, age, and correlation of the rocks.
- Syncline - A trough-shaped fold of rock strata; opposite in form from an anticline.

APPENDIX D
UNIFIED SOILS CLASSIFICATION CHART

APPENDIX D

Unified Soil Classification System

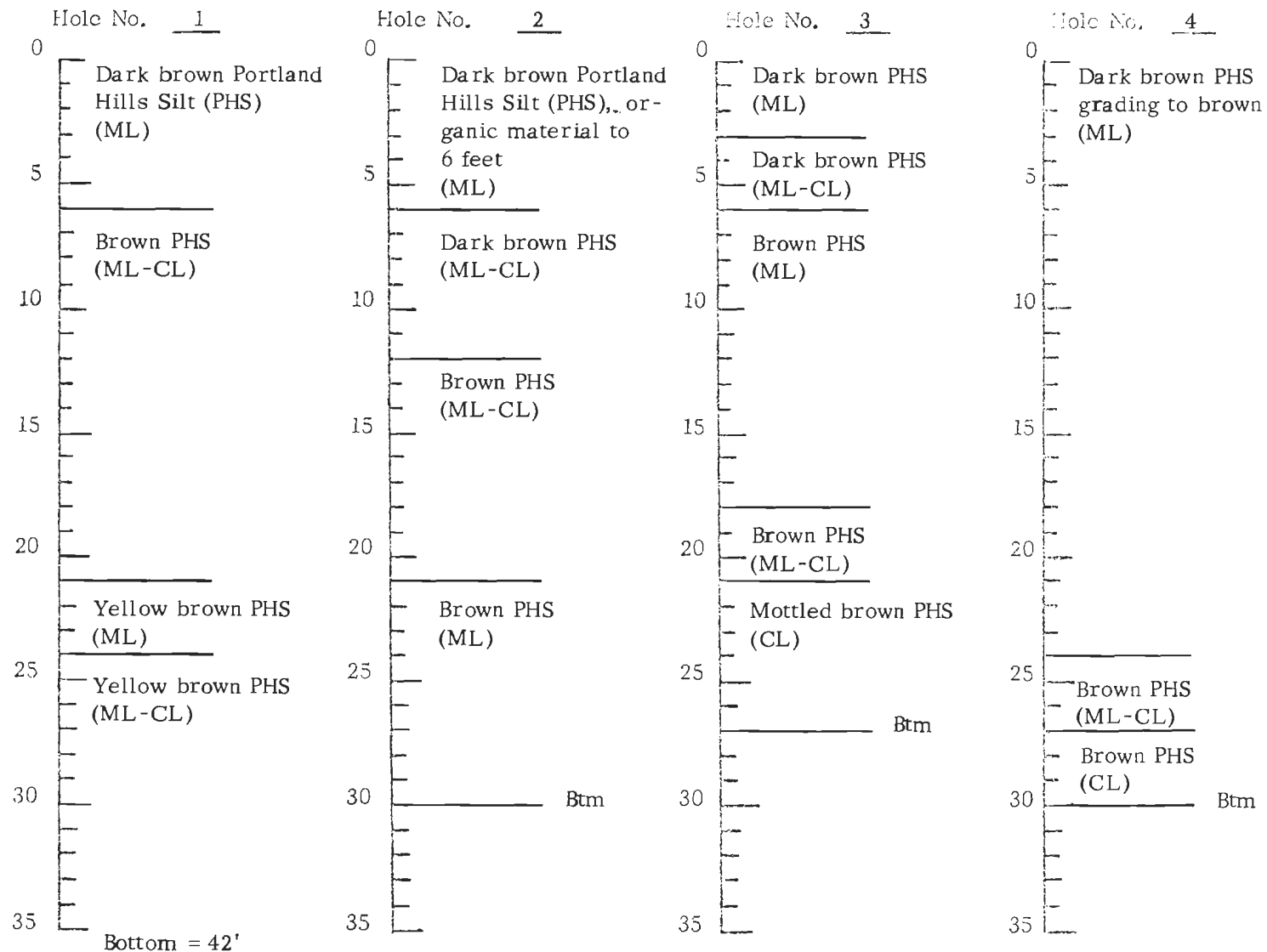
Major divisions	Group symbols	Typical names	Laboratory classification criteria				
Coarse-grained soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW	Well-graded gravels,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

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

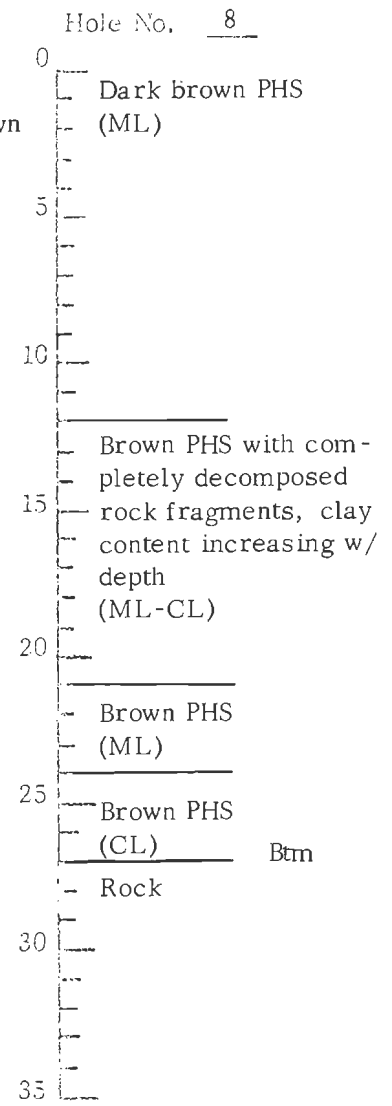
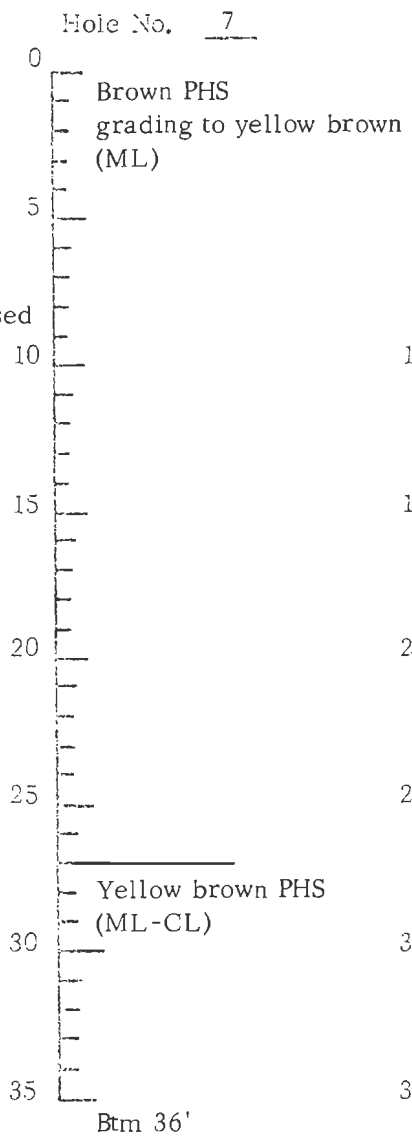
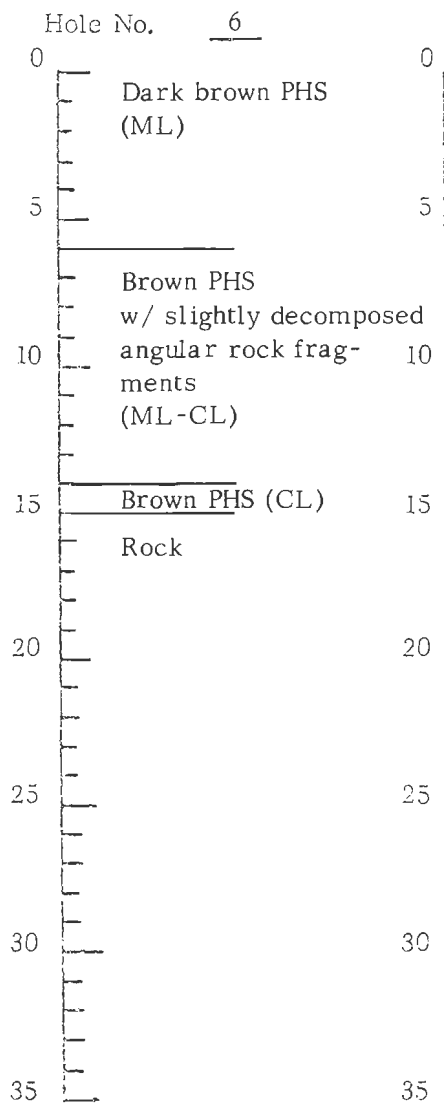
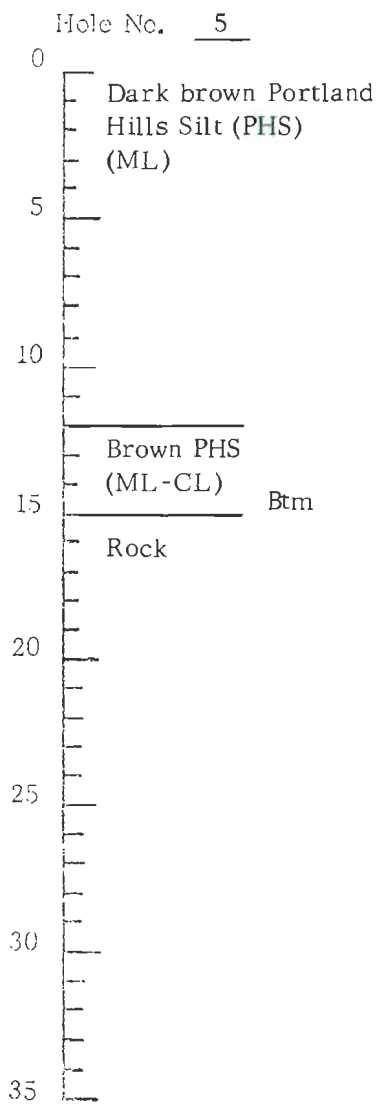
**Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example: GW-GC, well-graded gravel-sand mixture with clay binder.

APPENDIX E
WELL LOGS

APPENDIX E

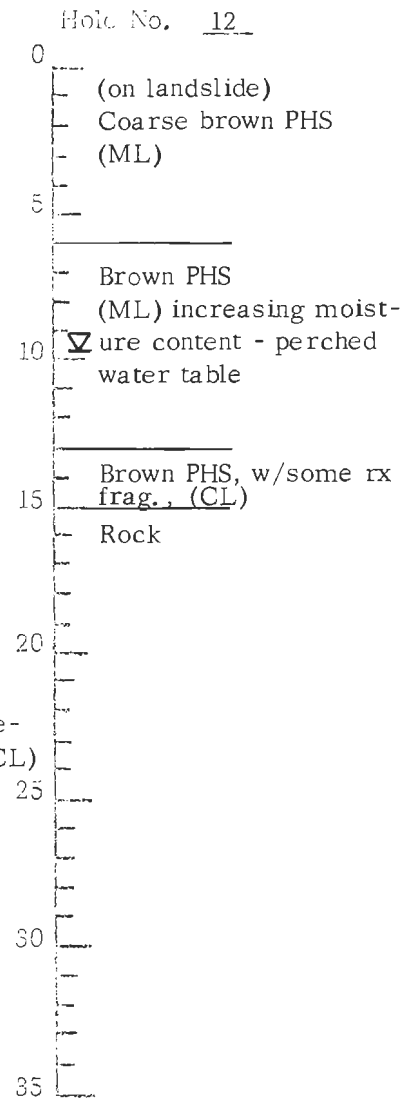
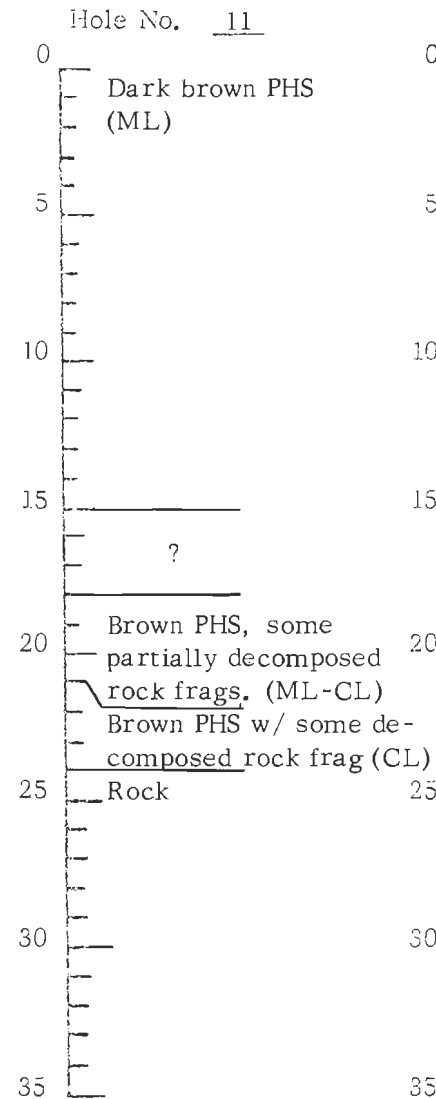
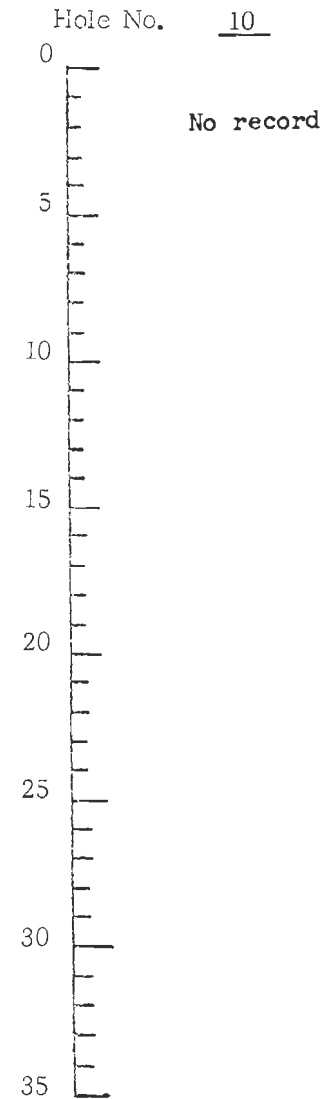
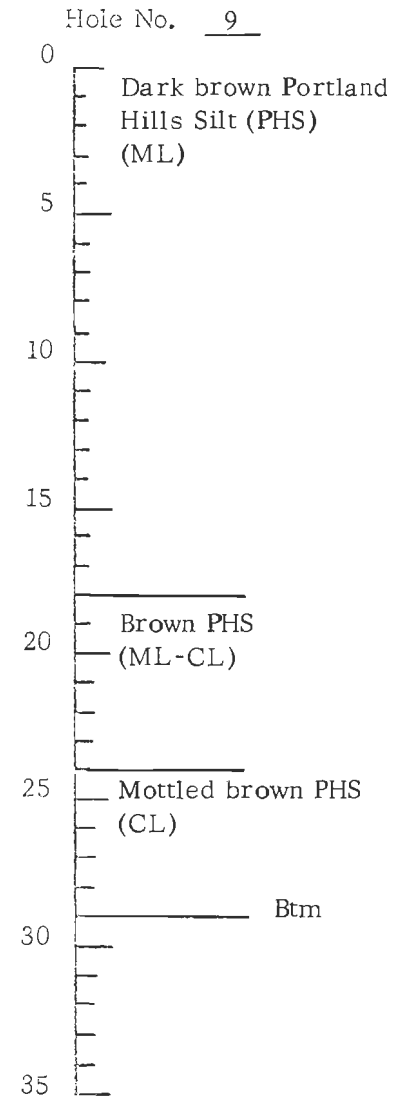


SUMMARY WELL LOGS

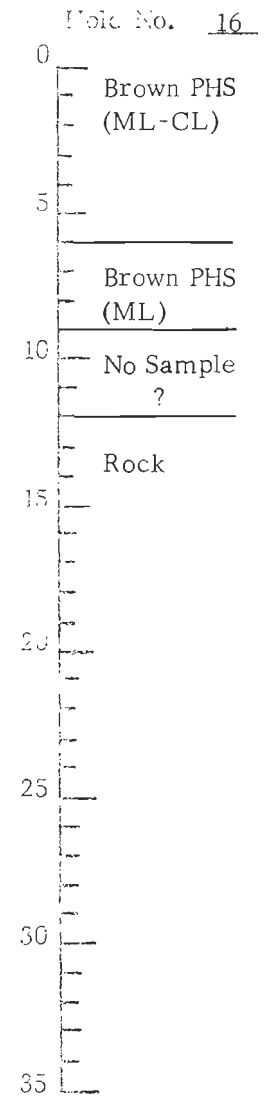
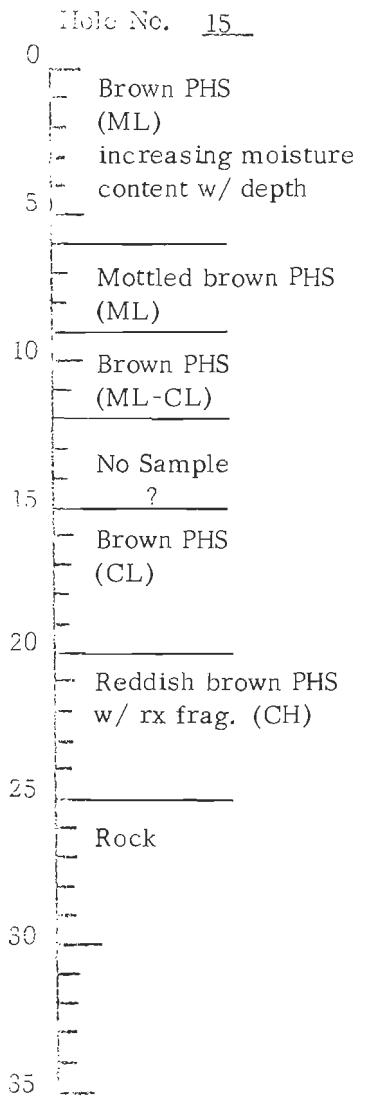
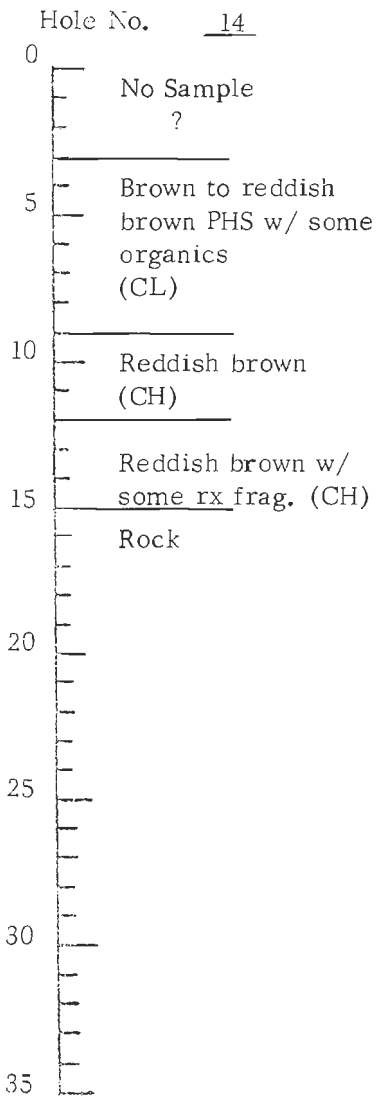
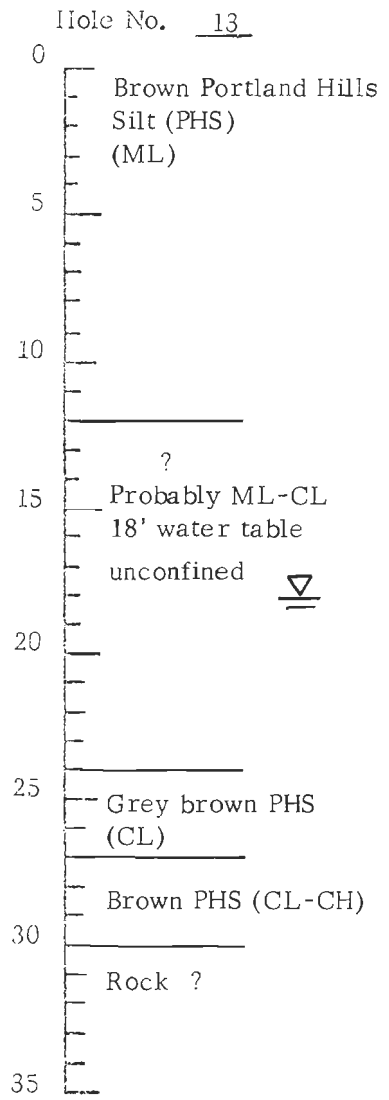


SUMMARY WELL LOGS

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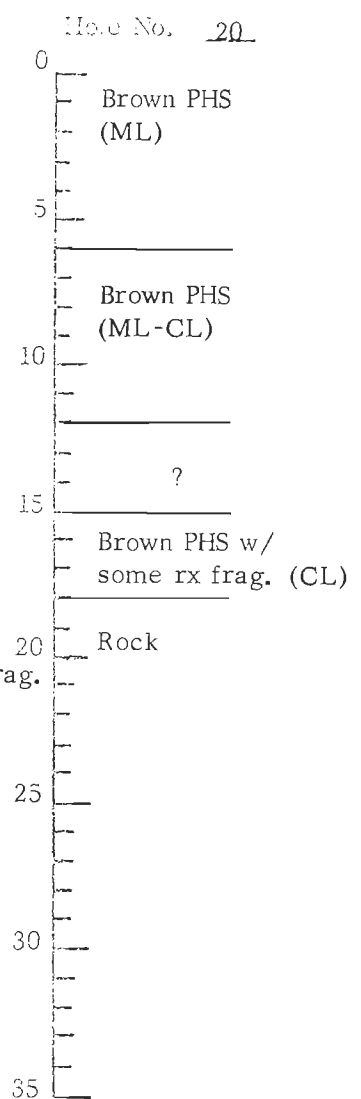
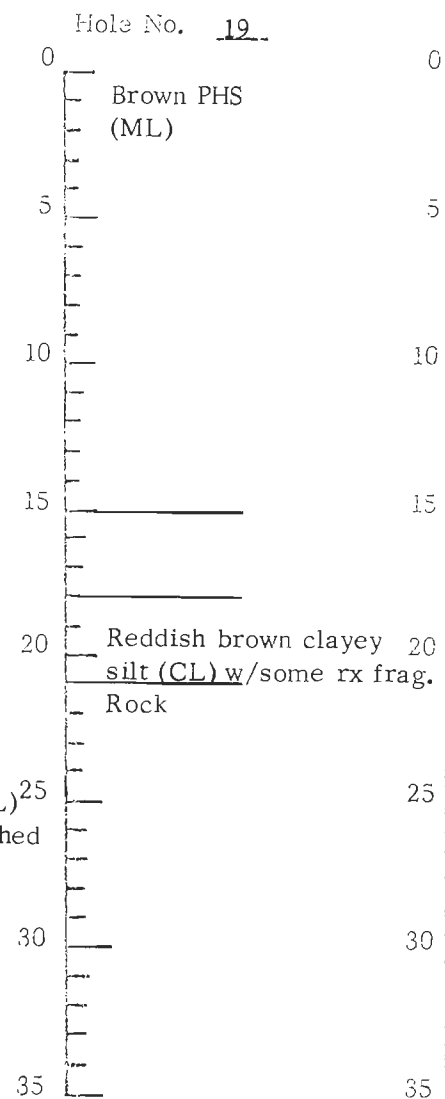
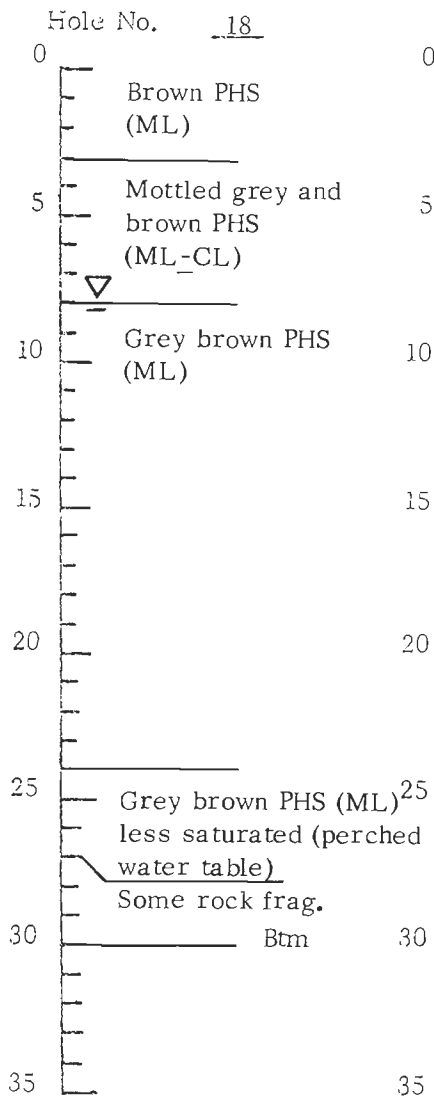
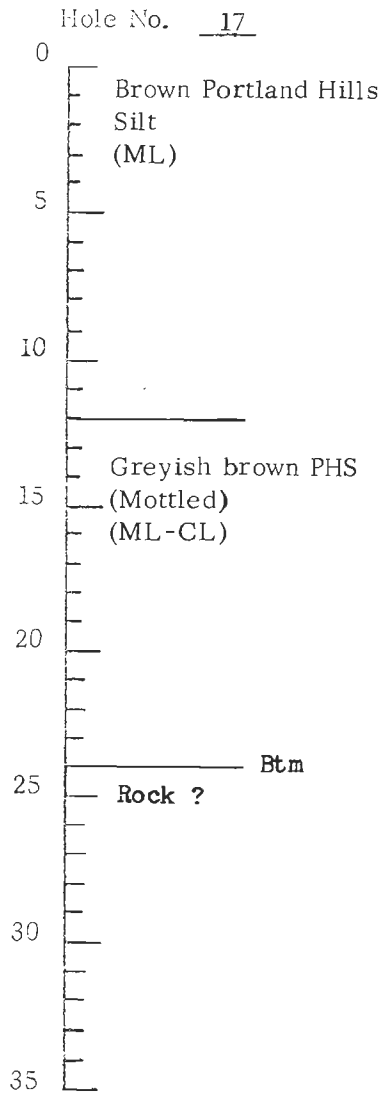


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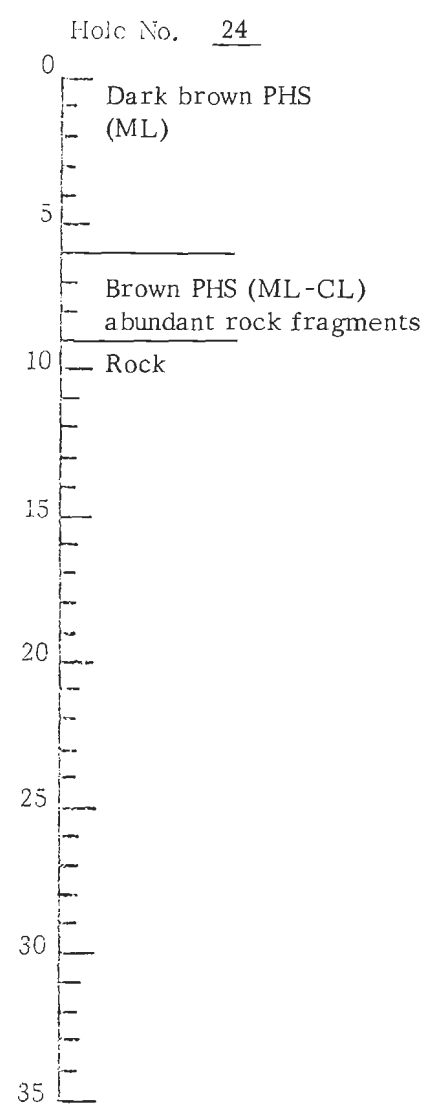
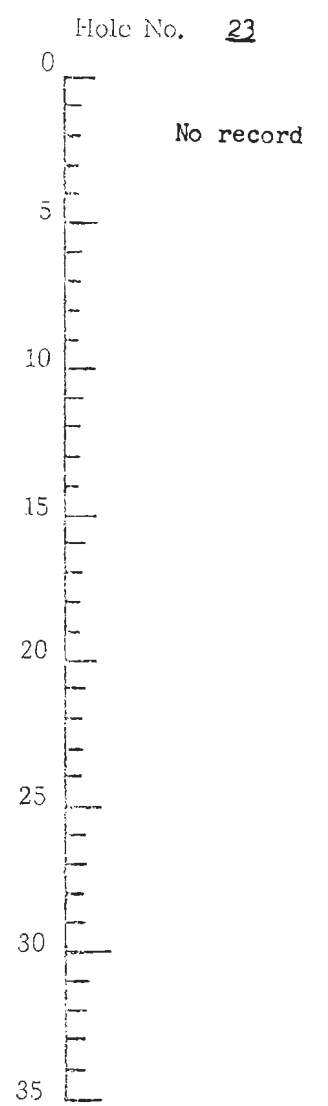
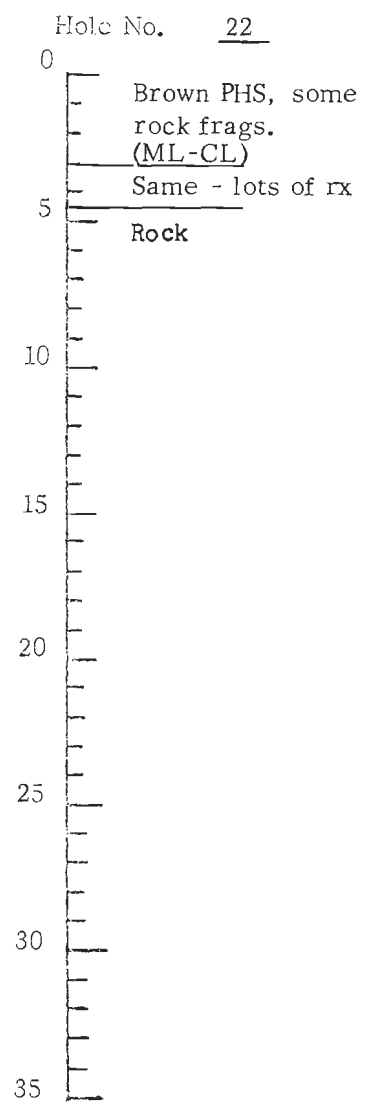
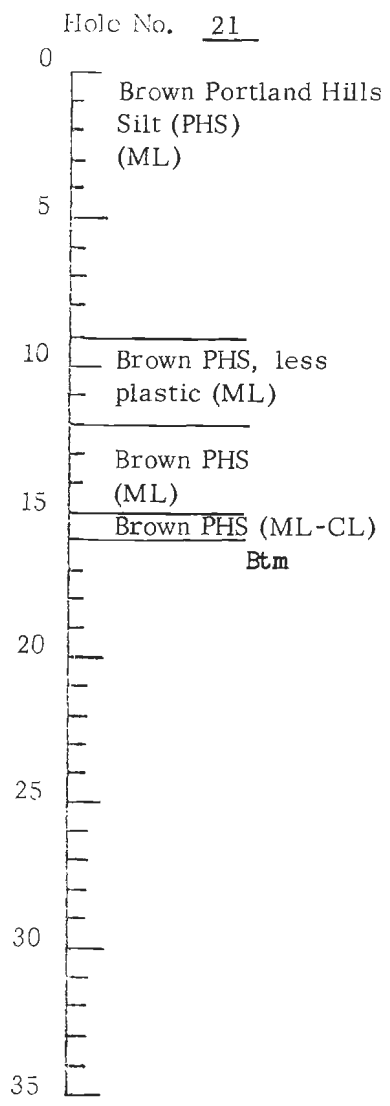
SUMMARY WELL LOGS

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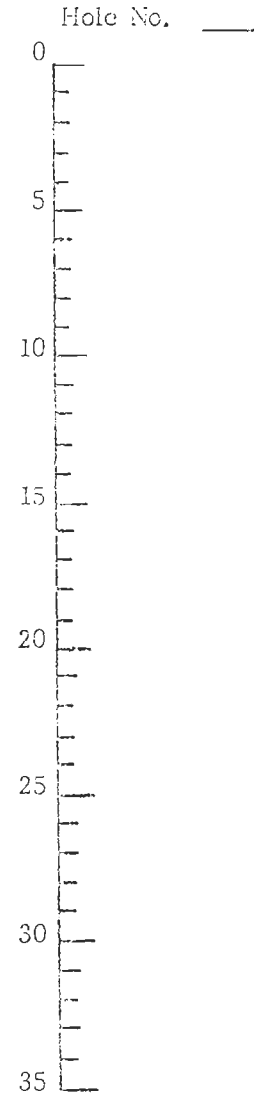
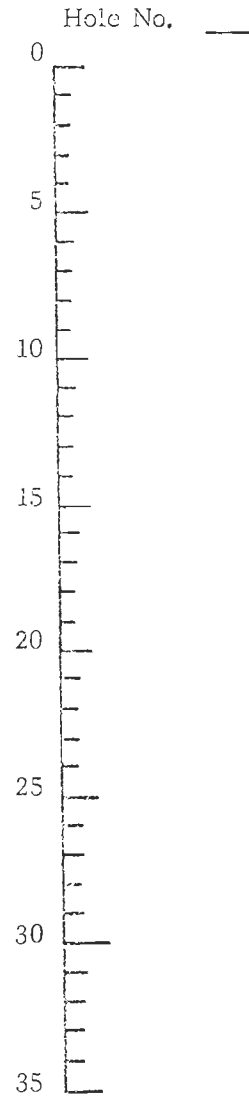
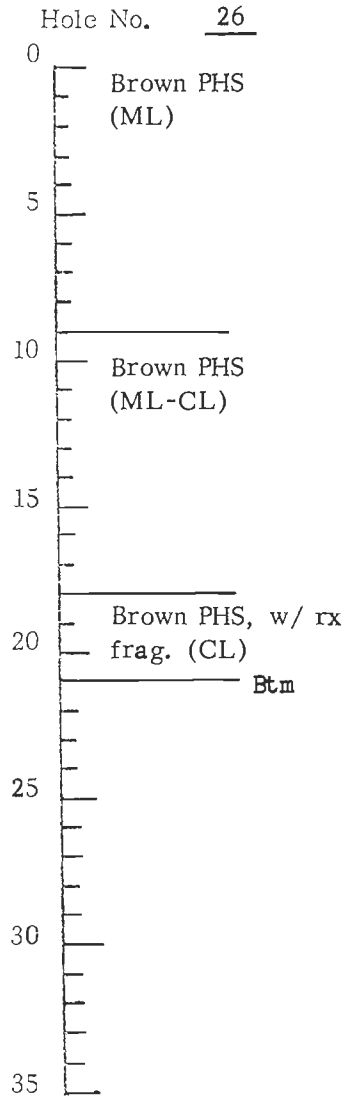
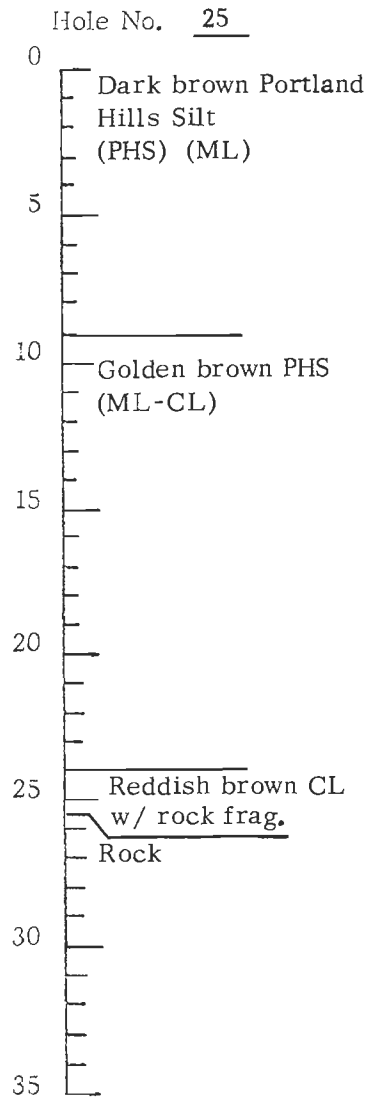


SUMMARY WELL LOGS

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SUMMARY WELL LOGS



SUMMARY WELL LOGS

APPENDIX F
SOIL CONSERVATION SERVICE SOIL DESCRIPTIONS

APPENDIX F

Cascade Series

Typifying Pedon: (Colors for moist conditions unless otherwise noted)

- A1 -- 0 -9"---Dark brown (7.5YR 3/2) silt loam, brown (10YR 5/3) dry; strong fine granular and strong very fine subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; abundant roots; many interstitial pores; many coarse, medium and fine shot; medium acid (pH 6.0); clear smooth boundary. (5 to 10 inches thick).
- A3 -- 9-17"---Dark brown (10YR 3/3) silt loam; brown (10YR 5/3) dry; strong fine subangular blocky structure; friable, slightly hard, slightly sticky, slightly plastic; abundant roots; many fine tubular pores; common medium and fine shot; medium acid (pH 5.8); clear smooth boundary. (5 to 9 inches thick).
- B21 --17-24"---Dark brown (10YR 3/4) heavy silt loam; strong medium and fine subangular blocky structure; friable, slightly hard, sticky, slightly plastic; abundant roots; many fine tubular pores; few fine shot; medium acid (pH 5.6); abrupt smooth boundary. (6 to 10 inches thick.)
- 11B22x-24-29"---Dark yellowish brown (10YR 4/4) silty clay loam, light yellowish brown (10YR 6/4) dry; many fine faint dark grayish brown (10YR 4/2), brown (10YR 5/3), dark brown (7.5YR 3/2), and black mottles and coatings; weak coarse prismatic structure fracturing to medium angular and subangular aggregate; prisms are coated with dark grayish brown silt; firm and brittle, very hard, sticky, plastic; common roots; many very fine tubular pores; few thin and moderately thick clay films in pores; medium acid (pH 5.6); gradual wavy boundary. (3 to 9 inches thick.)
- IIB23x-29-39"---Dark yellowish brown (10YR 4/4) silt loam, light yellowish brown (10YR 6/4) dry; thick grayish brown (10YR 5/2) silty coatings on large ped surfaces (10YR 7/1) dry; many medium distinct dark brown (7.5YR 3/2), strong brown (7.5YR 5/6), and dark grayish brown (10YR 4/2) mottles and coatings; weak coarse prismatic structure fracturing to moderate angular blocky aggregates; very firm and brittle, very hard, sticky, plastic; common roots in fractures; many very fine pores; few thin clay films on polygonal cracks and common moderately thick in pores; medium acid (pH 5.6); gradually wavy boundary. (6 to 16 inches thick.)

2. Cascade Series

IIB3x--39-60"--Dark yellowish brown (10YR 4/4) silt loam, light yellowish brown (10YR 6/4) dry; common medium distinct (10YR 4/2 and 5/6)mottles; weak very coarse prismatic structure; firm and brittle, hard, sticky, plastic; few roots in fractures; many very fine pores; medium acid (pH 5.6) gradual wavy boundary. (18 to 24 inches thick.)

IIC --60-70"-- Dark yellowish brown (10YR 4/4) silt loam, light yellowish brown (10YR 6/4) dry; gray streaks extend vertically and horizontally through the horizon; massive with vertical fractures; firm, hard, slightly sticky, slightly plastic; no roots; many very fine and fine pores; strongly acid (pH 5.5).

Range in Characteristics: The solum overlies a fragipan that is at depths of 20 to 30 inches. The soils are over 60 inches to bedrock. A perched watertable develops over the fragipan during the winter months. The A horizon range thickness from 10 to 19 inches. Moist values are 3 with chromas of 2 and 3 in hue 7.5YR and 10YR. Dry values are 5 and chromas are 3 in hue 10YR. Texture is a silt loam. Structure may range from granular to sub-angular blocky. The B horizon above the fragipan is 7 to 12 inches thick. It has moist values of 3 and 4 and chromas of 4 in hue 10YR, but may range to 7.5YR. Texture ranges from a silt loam to light silty clay loam. The underlying fragipan has mottles and tongues with chromas of 2 within 30 inches of the soil surface, and ranges from 2 to over 4 feet thick. Clay films are thin or moderately thick, few or many on the fractures and in pores in the fragipan.

Goble Series

Typifying Pedon: (Colors for moist conditions unless otherwise noted.)

- AO -- 1/4 - 0" -- Needles, twigs, moss, leaves, etc.
- A1 -- 0-7" -- Very dark grayish brown (10YR3/2) silt loam, brown (10YR 5/3) dry; strong fine granular structure; soft, friable, slightly sticky, slightly plastic; many fine roots; many fine and very fine pores; many fine concretions; medium acid (pH 5.6) abrupt smooth boundary. (6 to 9 inches thick)
- A3 -- 7-14" -- Dark brown (10YR 3/3) silt loam, yellowish brown (10YR 5/4) dry; strong fine granular structure; soft, friable, slightly sticky, slightly plastic; many fine roots; many very fine Pores; few fine concretions; strongly acid (pH 5.4); clear smooth boundary. (6 to 9 inches thick).
- B1 -- 14-26" -- Dark brown (7.5YR 3/4) silt loam, yellowish brown (10YR 5/4) dry; moderate fine subangular blocky structure; soft, friable, slightly sticky, slightly plastic; common fine and few medium roots; many very fine pores; strongly acid (pH 5.4) clear smooth boundary. (9 to 13 inches thick).
- B21 -- 26-37" -- Dark brown (10YR 4/3) silty clay loam, light yellowish brown (10YR 6/4) dry; moderate fine subangular blocky structure; slightly hard, firm, sticky, plastic; few fine roots; common fine pores; strongly acid (pH 5.2); abrupt smooth lower boundary. (10 to 12 inches thick.)
- B22x -- 37-44" -- Dark Yellowish brown (10YR 4/4) silty clay loam, light yellowish brown (10YR 6/4) dry; many fine and medium distinct dark brown (7.5 YR 3/2), strong brown (7.5YR 5/6) and light gray (10YR 7/1) mottles and light gray (10YR 7/1) tongues in fracture planes; numerous fine and medium black stains; weak very coarse prismatic and medium blocky and some subangular blocky structure; hard, brittle, very firm, sticky, plastic; common fine pores; thin patchy and continuous clay films in fractures and prism sides; very strongly acid (pH 5.0).

Range in Characteristics: The soils are usually moist, and dry in all parts between 7 and 20 inches for less than 60 days. The mean annual temperature ranges between 47° to 55° F. The depth to the fragipan ranges from 30 to 45 inches. The soil is over 60 inches to bedrock. The A horizons are between 12 and 18 inches thick. They have color values of 3 with chromas of 2 and 3 moist and 4 or 5 with chromas of 2 to 4 dry. Colors are in 10 YR hue. Texture is a silt loam. B horizons have color values of 3 and 4 moist and 5 and 6 dry with chroma or 4 in hues 10YR and 7.5YR. Texture is a silty clay loam, but may range to a silt loam in the upper part. None to few faint mottles with chromas of 3 and 4 in hue 5YR may occur near the boundary with the fragipan. B horizons have a slight greasy or smeary feel when moist. The fragipan has matrix colors similar to the horizon above it, but has distinct and prominent mottles with chromas of 2. It is hard, very firm, and has a brittle feel. Clay films on prism faces and fractures are common or continuous and thin. The fragipan is normally over one foot thick, and overlies old alluvium or loess, and residual material of mixed origin.

UNNAMED SERIES

Typifying Pedon: (Colors for moist conditions unless otherwise noted)

- A1- - 0-6"--Very dark grayish brown (10YR 3/2) silt loam; strong fine subangular blocky structure; friable, slightly sticky, slightly plastic; many fine roots; many fine pores; many medium and fine shot; slightly acid (pH 6.2); clear smooth boundary. (5 to 7 inches thick).
- B1-- 6-9"-- Dark brown (7.5YR 3/2) silt loam; moderate fine subangular blocky structure; firm, slightly sticky, slightly plastic; many fine roots, many very fine and fine pores and channels; few fine shot; medium acid (pH 6.0). Clear Smooth boundary. (3-4 inches thick).
- B2 -- 9-24"--Dark brown (7.5YR 4/4) silt loam; moderate fine subangular blocky structure, firm, slightly sticky, slightly plastic; common fine roots; common fine and medium pores; few fine and medium basalt gravel; medium acid (pH 5.8); clear wavy boundary. (12 - 17 inches thick).
- C -- 24-36"--Dark brown (7.5YR 4/4) silt loam; massive breaking to weak medium subangular blocky structure; firm, slightly sticky, slightly plastic, few fine roots, few fine pores and channels; about 10% composed of fine basalt gravel, medium acid (pH 5.8); clear wavy boundary. (10-13 inches thick).
- R --36-40"-- Fractured hard basalt with C horizon material in fractures

Range in Characteristics: The solum overlies fractured basalt at 20 to 36 inches. The A horizon has moist values of 2 and 3 and moist chromas of 2 in hue 10YR. Structure may range from subangular blocky to granular. Texture is a silt loam but may range to a loam. The upper B horizon has moist values of 3 and moist chromas of 2 and 3 in hue 7.5 YR. Texture is a silt loam. The lower B horizon has moist values of 3 and 4 and moist chromas of 4 in hue 7.5YR. Texture is a silt loam but may range toward a silty clay loam. Basalt fragments may range from a few to 35 percent.

APPENDIX G
OUTLINE OF CONTENTS OF GEOLOGIC REPORTS

APPENDIX G

OUTLINE OF CONTENTS OF GEOLOGIC REPORTS*

Richard H. Jahns

- I. General Information
 - A. Name of property
 - B. Description of property location. Site location sketch. (May be on a geologic map).
 - C. Date of report.
 - D. Purpose of investigation.
 - E. Extent and methods of investigation including exploratory work.
 - F. Reference material or data (including base map).
 - G. Description of general topography.

- II. Geology
 - A. Description of major geologic and geomorphic features.
 - B. Rock types, formation names, description and distribution of bedrock.
 - C. Identification, distribution, and thicknesss of surficial deposits.
 - D. Physical and chemical characteristics of surficial deposits.
 - E. Response of bedrock and surficial deposits to natural surface and near surface processes.
 - F. Relation to gross structural features in vicinity.
 - G. Occurrence, relative age, orientation, dimensions and location of structural features.
 - H. Specific features of faulting (brecciation and gouge zones, nature of offsets, activity geologically and/or historically).
 - I. Orientation of bedding.
 - J. Sources, distribution, and seasonal variation of surface and/or sub-surface drainage.
 - K. Estimated effects of surface and subsurface water on properties of in-place material.
 - L. Description and interpretation of existing creep or slope failures.
 - M. Evidence for age of sliding.

- III. Engineering Applications and Recommendations
 - A. Conclusions or recommendations based on latest grading plan.
 - B. Recommendations based on inferred conditions must include basis of

* In most areas, part of the information included in the outline will not be applicable. The subject matter included in the report of a specific area should be a matter of the consultant's discretion.

inference. Indicate probability of unanticipated conditions during grading.

- C. Note and consider effect on slope stability of change in conditions due to grading and increase in water infiltration. (Indicate type of sewage disposal.)
- D. Reactivation of old slide masses.
- E. Stability of adjacent land (if more unstable than subject area, why).
- F. Orientation of cuts with respect to bedding.
- G. Consideration of soil creep.
- H. Definite statement of safety in terms of
 - a. Area stability
 - b. Local slope stability of existing slopes
 - c. Local slope stability due to proposed grading.
- I. Consideration of erosion.
- J. Subsurface drainage recommendations.
- K. Active faulting.
- L. Settlement problems (suggested areas for exploration by soils engineer).

IV. Maps and Illustrations

- A. Geologic map.
- B. Source and date of base.
- C. Site location inset sketch.
- D. Scale of map.
- E. North arrow.
- F. Map legend.
- G. Lot locations.
- H. Show key geographic features (for establishing locations in field).
- I. Geologic features.
- J. Surficial features.
- K. Geologic cross sections.
- L. Dips adjusted for exaggerated vertical scale, and apparent dip.
- M. Drilling logs.
- N. Location of exploration holes, pits, etc.

APPENDIX H
RESIDENT ATTITUDE SURVEY, MARQUAM HILL AREA
PORTLAND, OREGON

By

Christiana Stachelrodt
Department of Geology, Portland State University

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APPENDIX H

RESIDENT ATTITUDE SURVEY, MARQUAM HILL AREA, PORTLAND, OREGON

The Problem

Residents of the Marquam Hill area have emphatically vetoed the open-space cluster housing development proposed by city planners for the slopes around Marquam Hill. It is the consensus of most of the planners, geologists, engineers, and others familiar with the building problems in the area that cluster housing is the safest design for high-density development in this landslide-prone area. Their premise is that this type of building design would confine ground disturbance and construction to the more stable areas and allow the steep, hazardous slopes to remain in their natural state.

Because concerned citizens of the Marquam Hill area have a different perception of hazards and environmental problems than do most of the city planners, an attitude survey was conducted among the residents to determine the level of their awareness of potential geologic hazards and environmental problems and how construction design relates to these conditions. The attitude survey of the residents was oriented primarily to determine the following:

1. Level of perception of land instability, its causes, and preventive measures.
2. Preferences toward traditional or cluster type of housing development.
3. Perception of the variable adaptability of development types to land instability hazards.
4. In whom do they demonstrate trust and confidence as a source for information and decisions in planning.
5. Their transportation uses and perception of problems.
6. Statistical and background information such as address, age, education, etc.

Attitude Survey Method

A major part of the study consisted of developing a questionnaire and interviewing residents. About 7 percent of the area residents were interviewed by selecting one resident per city block, or one out of each five or six houses. A total of 180 interviews were conducted between November 1971 and May 1972 by students and others connected with Portland State University. The author of this report was the principal investigator.

The questionnaire was developed in two stages. A preliminary questionnaire was tested with a sample survey to determine the validity and usefulness of the various questions. The responses to some questions were found unusable and were omitted. Additional information needed in the final questionnaire was determined by the use of questions encouraging open discussion. Several questions were suggested by City Planning Commission staff members related to bicycle and pedestrian traffic and resident housing preferences. The final questionnaire (see attached list) was developed by revising the preliminary questionnaire to accommodate changes shown to be necessary by evaluation and interview experience.

Organization of questions

Questions were organized to follow a reasonable continuity, but primary information questions on each topic were separated to test consistency of response. The first questions were non-controversial. More specific information was then obtained, leaving more sensitive personal questions for the end.

The questions on perception of hazards and preference for housing development type were organized to present both visual and verbal response. All other information was obtained by verbal response only. Questions eliciting free response were used with a minimum of prompting and were re-stated rather than hinting at possible answers. A greater certainty of respondent knowledge was achieved than might have been possible with multiple choice questions.

Visual-verbal perception

Visual perception of land instability was tested by first showing a photograph of a landslide (Figure 1) and asking "does this type of thing happen in the Portland Hills?" In the second visual test the respondent was asked to arrange five photographs of varying hazards into order of least (no. 1) to most (no. 5) hazardous as a building site (Figures 2, 3, 4, 5, 6). The photographs were taken within or very near the study area. They show the following conditions:

1. Safest site, fairly level, no major signs of instability (Figure 2).
2. A more secure site; we were curious if residents knew that the rock cliff was safer than a soil cliff (Figure 3).
3. Bent lower tree trunks showing soil creep (Figure 4).
4. Steep slope, a drainage course, and lack of older permanent vegetation (Figure 5).
5. Obvious landslide scarp (Figure 6).

Although respondents showed uncertainty about exact rank ordering of pictures, a geology test group chose the order shown without prompting.

Verbal perception of land instability was tested by first asking, "What do you think are the causes of land instability?" Second, the respondent was asked, "Do you know of any measures which could be used to reduce the possibility of, or damage from, such hazards?"

Scores were based on the number of answers which corresponded in any way with the following causes and remedies:

Causes of land instability:

1. improper excavation
2. gross removal of vegetation
3. poor drainage

Remedies for land instability:

1. greater care in excavation and construction design
2. improved vegetation cover
3. improved drainage

Visual perception of and preference for development type was tested by asking the respondent to indicate a preference for one of three development types, shown by diagram and sketch, for possible use in neighboring undeveloped hillside areas (Figures 7, 8, 9).

The respondent was told that all three diagrams represent equal residential density.

Verbal perception of and preference for development type was tested by asking, "If you were to move from your present home which would you choose to live in?"

- a. condominium
- b. small apartment complex
- c. large apartment complex
- d. detached residence
- e. other

To find out if people recognize the relation of land instability to development type, the intention was to compare the respondent's experience with land instability, expectation of neighborhood change, and expectation of future land instability to his hazard perception and preference for development types.

Questions relating to the additional information are relatively straightforward as shown on the questionnaire.

Analysis of Results

The attitude survey was successful in determining the residents' awareness of land instability, their preference for housing type, and their ability to correlate geologic hazards and housing types. Additional



Figure 1. Photo of landslide near Marquam Hill area.



Figure 2. Photo of safe site; fairly level, no major signs of instability.



Figure 3. Photo of fairly secure site; cliff is bedrock rather than soil.



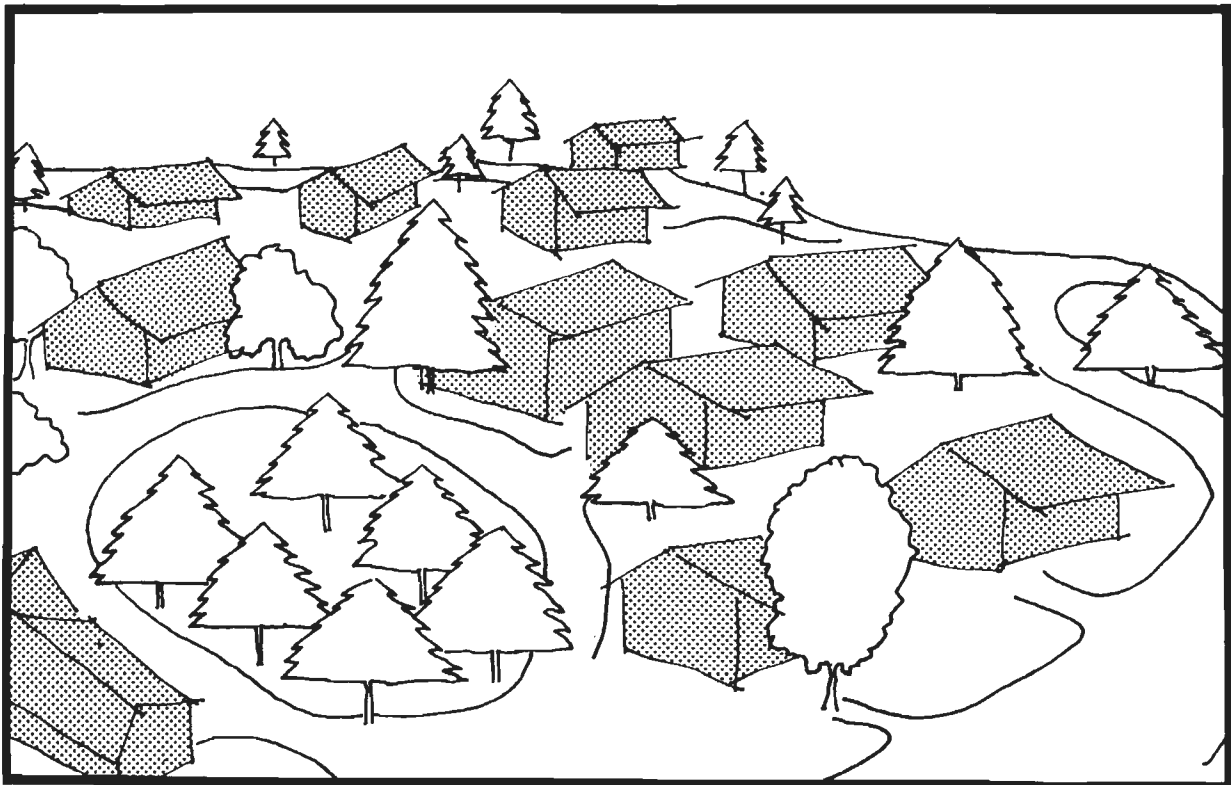
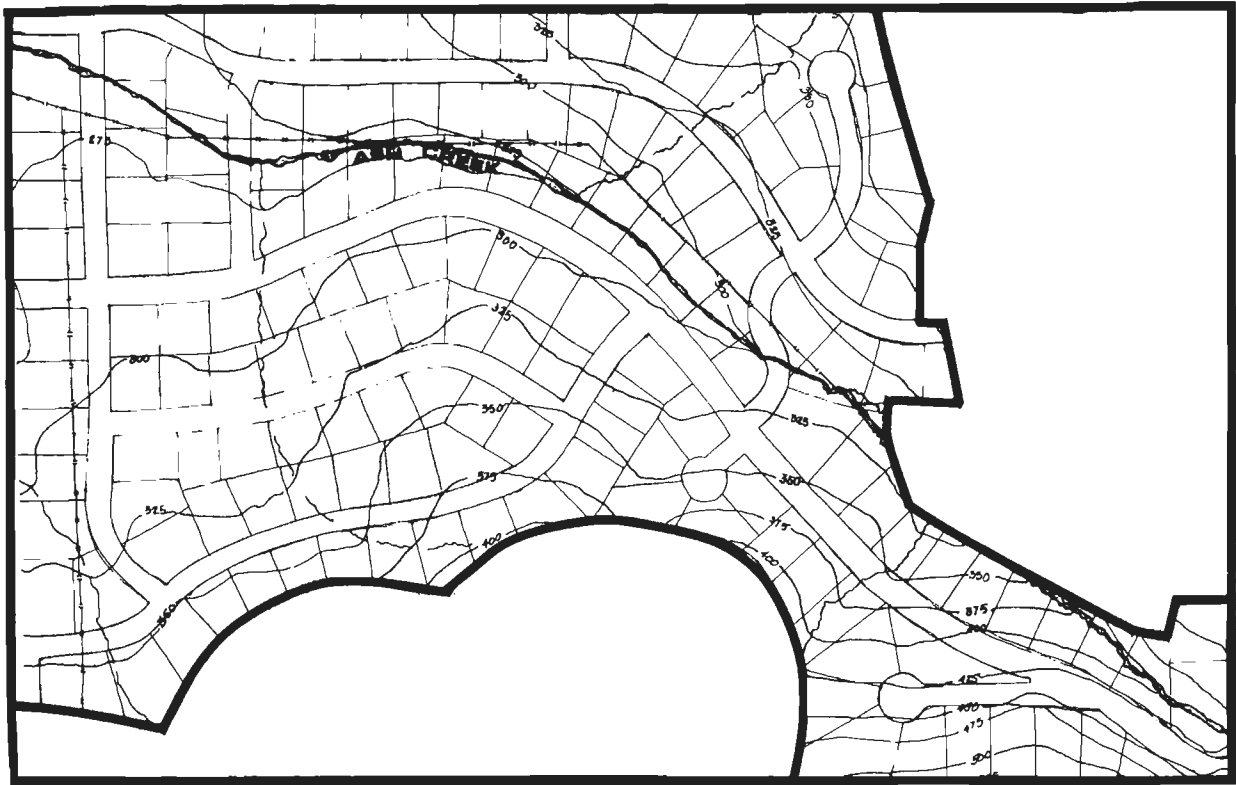
Figure 4. Photo of potentially unstable site; bent tree trunks indicate area of soil creep.



Figure 5. Photo of a poor building site; steep slope, lack of older permanent vegetation, and drainage course.



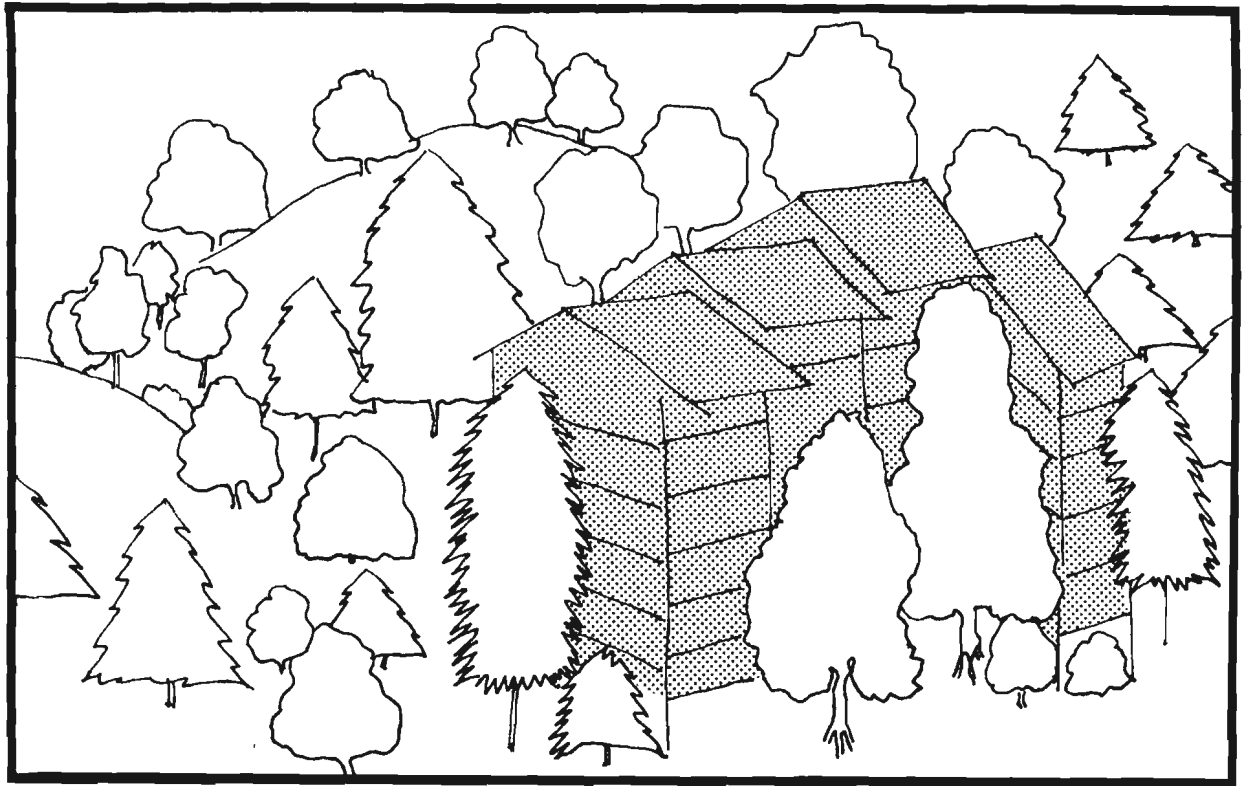
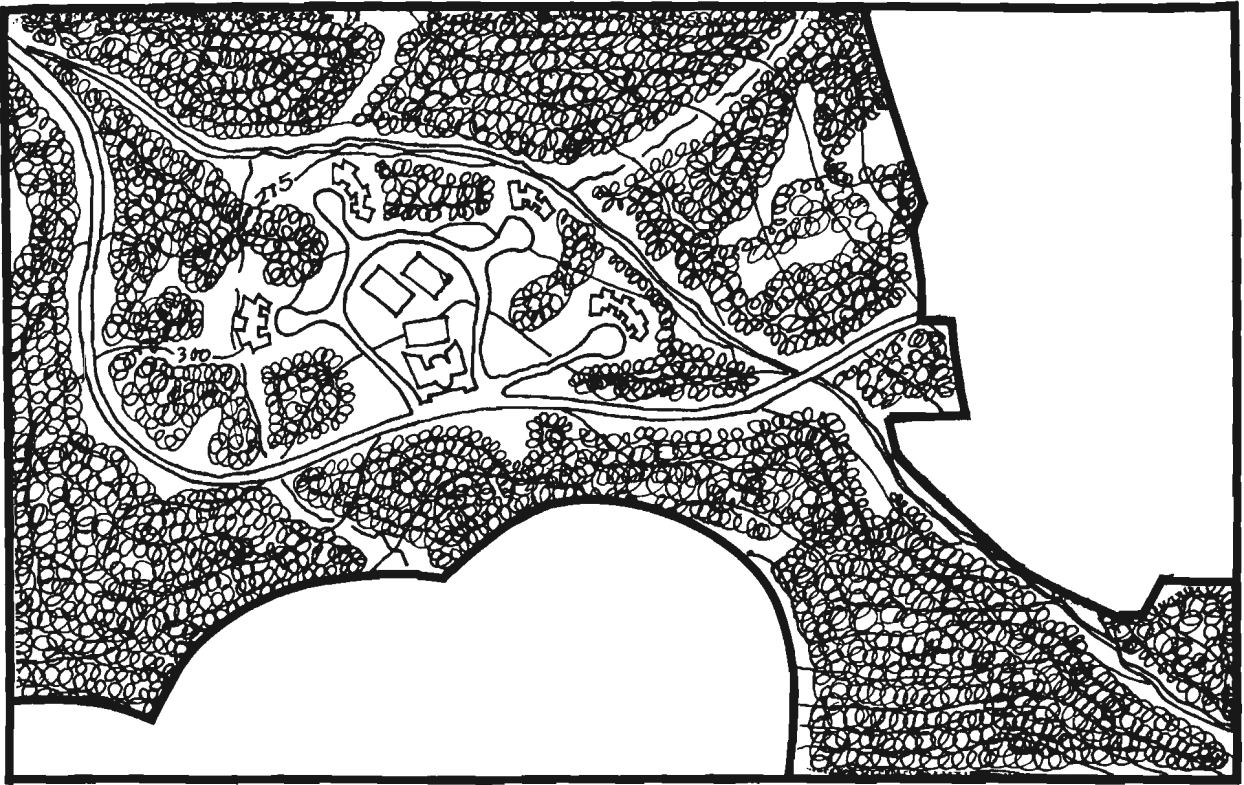
Figure 6. Photo of hazardous building site; a landslide scarp.



Standard Subdivision

SINGLE-FAMILY RESIDENCES ON ZONED LOTS

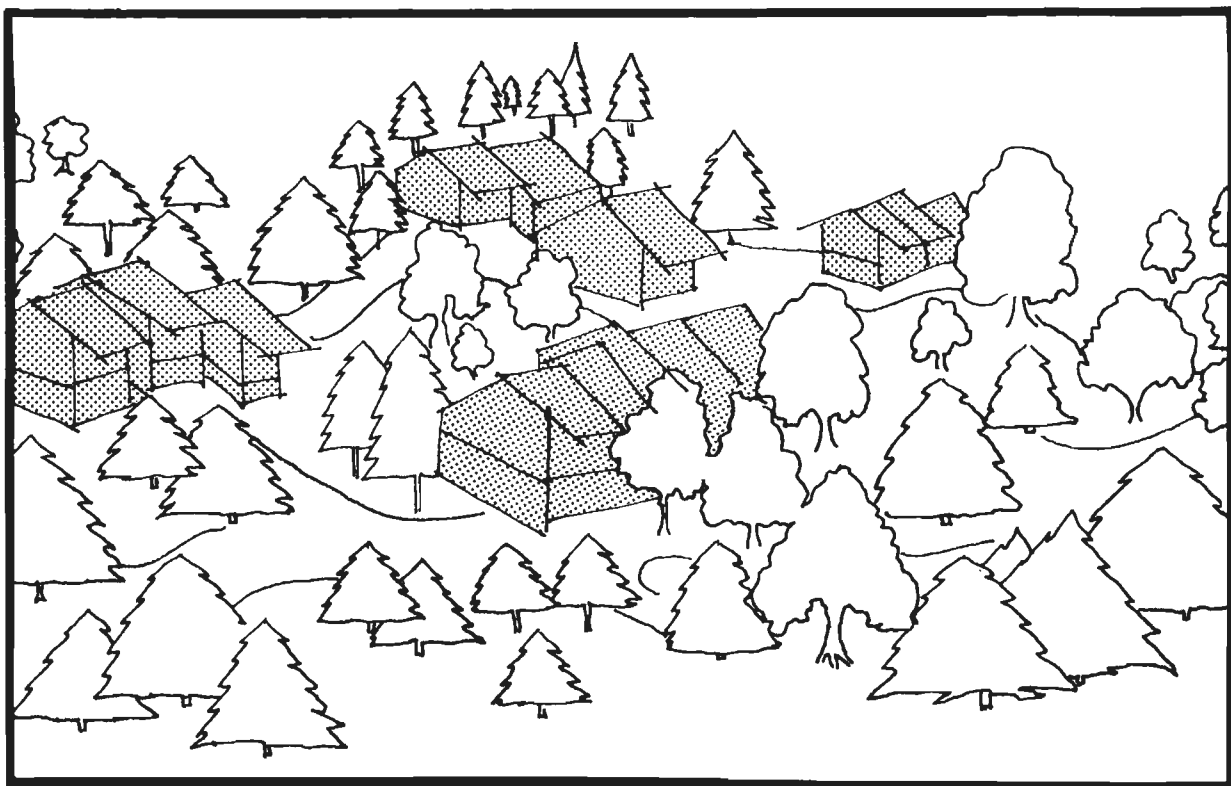
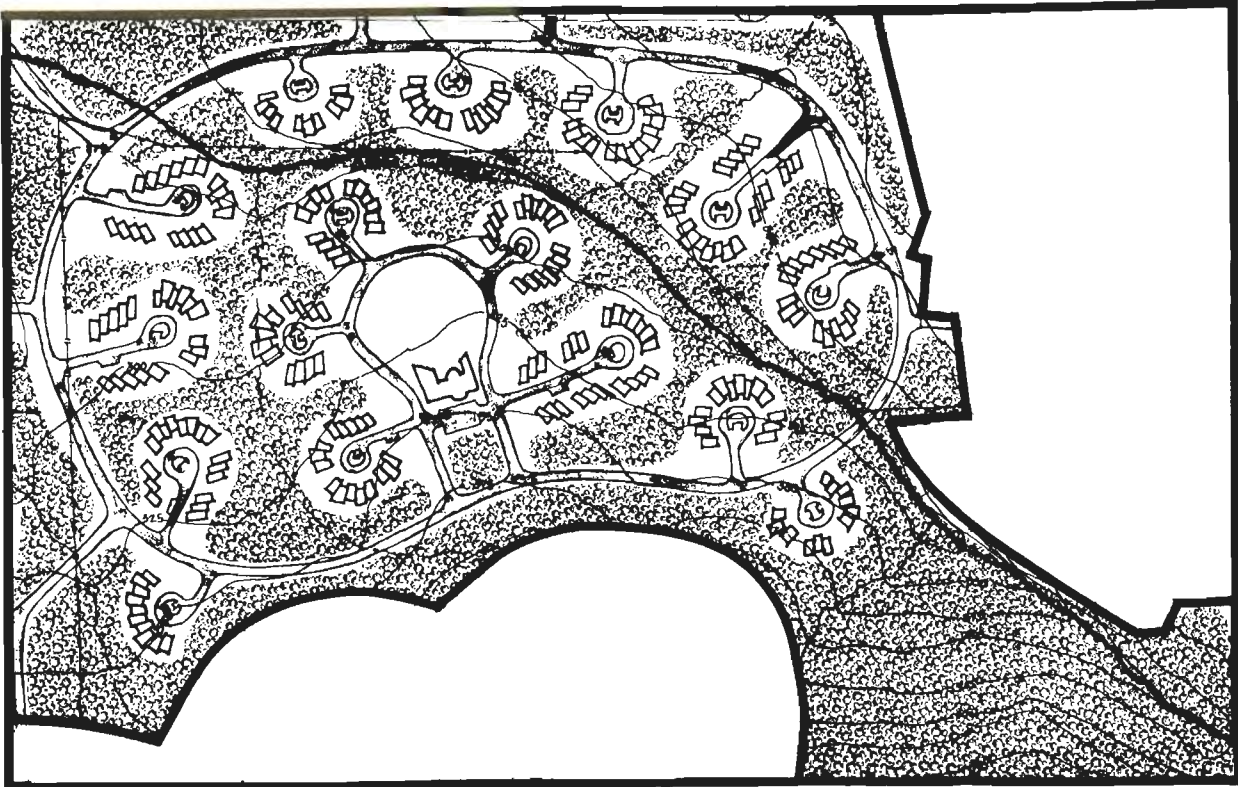
FIGURE 7



Open Space Medium Rise

CONDOMINIUM MEDIUM-RISE (8 STORIES) FAMILY RESIDENCE,
ASSOCIATED WITH A COMMONLY OWNED OPEN AREA

FIGURE 8



Open Space Cluster Housing

GROUPED SINGLE-FAMILY RESIDENCES,
ASSOCIATED WITH COMMONLY OWNED OPEN AREA

FIGURE 9

	CONTROL	SLIDE	CREST	SLOPE	HILL	FLATS
VISUAL PERCEPTION	100%	96%	60%	30%	68%	26%
VERBAL PERCEPTION	100%	100%	56%	50%	38%	44%
PREVENTATIVE MEASURES	96%	96%	54%	44%	36%	38%
AWARENESS BEFORE	-	68%	84%	96%	54%	-
LAND INSTABILITY POSSIBLE	-	92%	20%	89%	36%	-
EXPECT CHANGE	-	20%	16%	20%	84%	-

FIGURE 10

highly significant information was obtained concerning the areal grouping of attitudes and possible channels of communication trusted by residents.

One of the most significant results of the study was that individuals with distinctive perception characteristics were clustered geographically into cohesive neighborhoods. This became apparent early in the preliminary test stage.

A graphic plot of responses to the preliminary survey (Figure 10) shows the reaction of various groups to questions asked. As shown on the graph, four resident groups were defined as "slide," "crest," "slope," and "hill." These groups were recognized readily by their responses to preliminary interviews. They include: residents who had experienced landslides, residents in the Council Crest area, residents of side-slope areas, and Marquam Hill residents near the medical school. The graph also includes the geological control group and a group of on-hill residents ("flats").

The graph shows that residents who have experienced landslides are almost as aware of the primary causes and remedies for land instability as the geology control group. However, the questionnaire only evaluated the number of correct answers given and did not evaluate depth of perception.

Examples of the perceptual differences of the various groups reinforce the significance of the statistical data. The following examples show validity of decreasing perception towards the right side of the graph in response to questions on perception of causes of land instability:

1. Geological control group

The landslide problem stems from several major factors:

Structural controls (especially as affected by man):

Controlling layers of soil

Soil thickness

Clays) by nature are difficult to deal with

Silts)

Water drainage (especially as affected by man):

High precipitation and runoff

Ground water

Man's activities:

Improper excavation

Overloading of slope

Over-steepening of slope

Decreased natural ground cover

Increased man-made ground cover

Disturbance of previous landslides

Vibrations:

Seismic

Man-made

Because of existing natural potential from structural controls and precipitation, an increasing number of factors, listed under man's activities, increases the potential for instability at a site.

2. Landslide group

Answers from "landslide owners" to this question were noticeably characterized by stating the three major causes in one sentence: "We have landslides around here when a hillside is undercut, or the soil is not allowed to drain properly, or the vegetation is stripped off the slope."

While this group answered the question adequately enough to receive a perfect score, their depth of knowledge was obviously less than the control groups.

3. Crest group

The Council Crest group's answers often alluded to "developers, or builders, who do not know about landslide problems or just do not care--go in and indiscriminately cut into the hills and do not use proper retaining walls," or "People cut down too many trees which hold the soil together."

As a group these residents exhibited a high degree of confidence and community concern. On the average they were able to cite one or sometimes two major causes and were able to discuss them with knowledge.

4. Slope group

Residents of the side-slope area scored fairly close to the Council Crest group at 50 percent with a typical answer, "They should not build in such dangerous areas--a house can put too much weight on an upper bank--if people do not want trees, why do they live out here?"

Here, residents were generally aware that land instability was related to man's disturbance of natural conditions but they tended to be somewhat less explicit than the previous groups.

5. Hill group

Respondents in the Marquam Hill area scored 38 percent correct. "Water," "Are not any problems," and "Don't really care," were some responses received.

6. Flats group

Forty-four percent correct answers were scored by the flatlander group. Some typical responses were, "It happens because we get so much rain here," or "you stick a house on stilts out over a drop-off, and that's just what its gonna do..drop off! And, take the rest of the hill with it."

The only anomalous perception level is shown by Marquam Hill residents, who exhibit a high visual perception compared to their verbal response. The residents there are of two main groups: medical students and older retired persons. The high visual perception may be due to alertness of the students, who can recognize hazards but have no reason to be concerned about causes and remedies for hazards.

The following questions exhibit other anomalies. The question on the degree to which residents were aware of land instability hazards before moving into the area shows inverse relation to perception. This may be due to the self-evaluation nature of the question. For example, residents who have experienced slides might be embarrassed to admit prior knowledge.

Response to inquiry concerning the residents' expectation of the possibility of further land instability was approximately proportional to the potential for hazard in the neighborhood. A real danger exists for residences with past hazard history and in the newer construction areas on hillslopes. Council Crest is an older neighborhood on flatter ground.

The only neighborhood that registered a significant expectation of future change in the character of their area was the Marquam Hill-medical school area. This may reflect existing conditions of change or possibly lack of resistance to change by transient student residents.

Though not shown on the chart, resident reaction to cluster housing indicates that they simply do not know what it is. The two major points of concern were: (1) What happens in the future to existing open space? Can it be developed later? and (2) What is the difference between this encroachment by highrise and apartments?

The final survey confirmed and expanded the results of the preliminary survey. Refined data were obtained for:

1. perception of land instability
2. neighborhood clustering
3. statistical background data

New data were developed on:

1. preference for development type
2. ability to relate development type to hazards
3. transportation problems
4. trusted channels of information

Analysis of the final data provided an improved characterization of respondents' attitudes. Further analysis of the data could provide information on respondent characteristics beyond the scope of this project's objectives. For example, better geographical control of attitude distribution could be obtained.

Both manual and computer tallies were used in the analysis. IBM cards were punched and processed on IBM 1130 computer to obtain the following results:

1. First a direct percentage response on each question was tallied.
2. Correlation coefficients were then obtained comparing the interrelation of the responses on twenty selected questions.
3. Rotated factor matrix correlations then compared loading of responses to questions.
4. Matrices of factor scores were then run for neighborhoods selected for expected cohesiveness.

The first operation is shown by percentages listed with questions in the attached questionnaire. Correlation coefficients in the second operation were used to generate the rotated factor matrix and are not shown here.

The rotated factor matrix, shown in Table 1, compares five types of respondents out of about eight originally developed from the computed data. Each type of respondent, called a "factor," showed anomaly similarities. These factors, or groupings, of respondent types included approximately half of all respondents divided nearly equally between the following factor types.

Factor I - low awareness of land instability and high confidence in ability to accommodate hazards themselves.

Factor II - pro-progress and complacent about environmental problems; feel land instability does not exist.

Factor III - environmental awareness and activism.

Factor IV - successful adjustment to experience with landslides.

Factor V - difficulty in adjustment to experience with landslides.

The remaining half of the respondents did not fit into clear response-type factors. It is important at this point to remember that human attitudes are variable characteristics and do not lend themselves well to any system of precise tabulation and evaluation. An understanding of some general tendencies of these attitudes and perceptions is the hoped-for result of this study. For these reasons Table 1 is organized to show degree of positive or negative loading of factors rather than absolute values. One minus (-) or one plus (+) indicates the loading was not very strong with only a general tendency showing. Increased numbers of minuses or pluses indicates a stronger loading.

On the whole, Table 1 reinforces suspected groupings of characteristics. Factor I includes individuals who felt land instability was such a small or non-existent problem that they (the neighborhood) could handle it themselves without professional aid. They felt landslides were not a continuing problem, and their perception of land instability conditions was generally low.

The factor II group was highly in favor of progress and development and was relatively complacent about environmental problems. They were unaware that landslides occurred here and were completely unable to cite any causes or cures of land instability. As expected, this group was overwhelmingly in favor of individual lot subdivision as opposed to the more environmentally sound cluster units.

Included in factor III are individuals who are environmentally conscious and tend to be activists. These people had a higher frequency of walking and therefore probably had a better view of the landscape. Their perception of land instability problems is better than factors I and II and, unlike factors I and II, they cite professional geologists and engineers as better qualified than friends and neighbors to decide the appropriateness of buildings for the underdeveloped areas on Marquam Hill. These people tended to belong to community action groups.

Individuals who had experienced land instability problems and had coped with this problem successfully (had taken certain positive measures to control further sliding and understood the problems) fall into factor IV. Land instability was recognized as a definite, continuing problem. Their perception of land instability conditions was quite high and they preferred cluster housing over individual lot subdivisions. Geologists and engineers were cited as most able to determine future development types for the area but these people strongly preferred that the undeveloped land be used for parks or left in its natural condition.

Factor V also includes residents who have had instability problems, but this group has had more difficulty adjusting to these problems. This group did not load very strongly on any factor of great importance. The data indicated that, in general, these people are older and have lived in the area more than 15 years. Their education is somewhat lower than for the area as a whole. They cite transportation problems as being equal with environmental problems and feel that friends and neighbors are as competent as geologists and engineers to determine future development. Perhaps the only outstanding characteristic of this group is that it possesses no outstanding characteristics (no significant positive or negative opinions on anything tested).

A better understanding of respondent attitude characteristics has been derived from the Rotated Factor Matrix Correlations, which may be of help in future planning in this area, but some rather outstanding inconsistencies appear to exist here also. Some examples include: 1) the income correlation (question 13 on Table 1) is probably less accurate than other data because some individuals and some groups as a whole did not answer this question; 2) some inconsistencies within a factor may be caused by natural

Table 1. Rotated factor matrix: correlations with original twenty questions

	Factor I Low awareness/ confidence	Factor II Pro-progress/ complacent	Factor III Environmental awareness/ activism	Factor IV Personal experience/ successful adjustment	Factor V Personal experience/ difficult adjustment
1. Attitude toward apartment dwellers	-	-	--	-	-
2. No landslides occur here	+	----	-	+++	++
3. Personal experience with landslides	+	--	--	+++	++++
4. Will landslides continue here?	--	-	-	++++	-
5. Do you favor individual lot sub-division?	+	++++	--	-	++
6. Buy undeveloped lands for parks	+	--	-	++	-
7. Aware of land instability before	++++	--	+++	-	+
8. Member community action group comparative	+	++	++	--	+
9. Length of residence	-	++	-	--	++++
10. Frequency of walking	-	--	++++	++	-
11. Ability to rate building site	--	--	+	+++	-
12. Education	+	--	-	++	----
13. Income	-	--	++	----	+
14. Natural environment attractive feature	++	+	++	++	+
15. Cite environmental problems	+	-	+	++++	++
16. Cite transportation problems	+	--	----	--	++
17. Cite land instability causes	-	--	+	++	-
18. Friends and neighbors competent	++++	+	-	-	++
19. Geologists, engineers competent	----	-	++	+++	++
20. Cite causes of land instability	++	---	-	+++	+

neighborhood grouping, for example: factor III produced a negative loading on questions nos. 2 and 4 (Do landslides occur here? Will they continue?) yet they scored positively on questions nos. 7, 11, 15, 17, 19 and 20 (Aware of land instability before moving here? Professionals competent to determine future developments, and perception of instability conditions). It appears that factor III is unaware that landslides occur here but is highly aware of landslide conditions. What has probably caused this seeming incongruity is that an active, aware neighborhood which experiences fewer land instability problems (such as the Council Crest-Greenway area) is already clustering in factor III as a group. They are aware of landslide conditions but are reflecting their own neighborhood conditions by stating that landslides do not occur here.

Increased coverage of the Marquam Hill area in the final survey has allowed an improved geographical definition of some neighborhoods (Figure 11). The only neighborhood where boundaries remain unchanged is Marquam Hill by the University of Oregon Medical School. Council Crest has expanded north to include homes in the Greenway district. Upper Fairmont, Lower Fairmont, and Westwood are three neighborhoods which have developed from the "side slope" neighborhood described in the preliminary survey. One completely new neighborhood, Viewpoint, has been added and a new "flatlander" group whose life style more closely resembles that of respondents in the study area was used in the final survey.

Questions concerning personal statistical data were concentrated together at the end of the questionnaire principally to avoid antagonizing respondents. These data show that in the study area as a whole families are small, with 2.3 persons per household. The question concerning respondent ages (no. 27) was tabulated into 3 major categories which seemed better for our purposes than the original six. They were: 1) residents over 41 years old, no children at home; 2) residents under 41 years of age, no children at home; 3) residents of any age with children 24 or under living at home. Slightly greater than 50 percent belonged to group 3 and approximately one-third to group 2.

As expected, most of the respondents own their own homes here. The only major occurrence of apartments is around the medical school on Marquam Hill.

Education levels are quite high in the study area, where 70 percent of the husbands and 65 percent of the wives have at least their bachelor degrees.

In 22.1 percent of the families surveyed, someone belonged to a community action group and two-thirds of these reportedly were members of the Southwest Hills Residential League (SWHRL).

New data developed concerning residents' housing-type preferences indicates that only 37 percent feel that individual lot subdivisions are the most appropriate development for the hills area. If they (respondents) were to move from their present homes, however, 74 percent stated that they would move to a detached residence, not the cluster residences which the majority (combined, 63 percent) felt would be best for these undeveloped areas. This may indicate that it is easier to understand the need for a change than it is to make the change oneself. Also, the questionnaire was organized so that questions pertaining to an individual's preference for his own resident type were encountered before questions on an instability, whereas questions on preference for development type for the undeveloped slopes came after, so that the latter may have been influenced a great deal by the land instability data while the former was not.

Few respondents were able to relate development types to instability hazards, but rather consistently those who were most in favor of individual lot subdivision scored lowest on perception of land instability causes and cures (Table 1). Conversely, those whose perception of instability hazards was highest tended to choose cluster developments. Residents who had experienced land instability and adjusted successfully or who belonged to neighborhood action groups were best able to relate development type to land instability.

Because of particularly heavy loading on parts "A"(4) and "B" (2) of question no. 7 (which factors are problems in your area) on the questionnaire, it became apparent that some people in the hills were definitely concerned about transportation problems. Further analysis of the data has revealed that the main concern centers on the Marquam Hill area around the medical school and appears to be a reaction to the increasing traffic and parking problems there.

A discovery which may be of major importance to those involved in planning in this area deals with channels of information on planning which are trusted by the residents (questions 23, 24, 25). They may be of particular interest to the Planning Commission because the data indicate that approximately 75 percent of the area residents do not trust the Commission in this capacity.

Overall, the most trusted information sources were: 1) professional geologists and engineers, followed by 2) the Southwest Hills Residential League, and 3) friends and neighbors. Multiple choices were possible

on this question. Those who chose only one, however, usually picked SWHRL or professional geologists and engineers, and these were also the most common combination of any two chosen. Results varied within each neighborhood, however, as shown in Table 2.

The area's most important community leaders turned out to be of two types, partially depending on the respondent's perception of "community" boundaries (question no. 25). Though many respondents were unable to complete this question, the overwhelming majority of those who did chose various city officials. The three most favored officials were: 1) Neil Goldschmidt, 2) "The mayor" (presumably Mayor Schruck), and 3) Lloyd Anderson, in that order. The other class of community leaders included a number of private citizens.

Neighborhoods selected for expected cohesiveness were compared for correlation with the five respondent-type factors. Data from the factor of matrix scores (Table 3) verify the intuitive neighborhood choices. Individual neighborhoods are shown to be either environmentally aware of instability problems (positive loading in factors III or IV) or relatively unaware of these problems (positive loading on factors I, II, or V). Although a neighborhood may have two or more conflicting factor characteristics, it will normally load heavily on only one; for example, the Council Crest-Greenway district shows a heavy positive loading as environmentally aware in factor III and also a positive reaction to factor IV. As expected then, this group shows a negative reaction in the less environmentally aware factors II and V. In factor I, also a low awareness group, however, there is a slight positive loading. This indicates that, while the majority of the community is relatively aware of land instability conditions, there is still a small faction which is less aware.

Westwood, originally part of the slope community, has a high negative rating in factor IV (Personal Experience--successful adjustment) and a high positive rating in factor V (Personal Experience--unsuccessful adjustment). This would indicate a low awareness of land instability problems, which is reinforced by scores in factors I, II, and III.

The data from the original survey on Marquam Hill reflect a dichotomy in the population of intermixed transient medical students and older retired residents. Major positive loading is found both in the environmentally aware (factor IV) and unaware (factor II) groups.

Upper Fairmont shows a very heavy positive loading in factors I and V and major negative loading in factors III and IV. This is a low-awareness, high-confidence area.

Lower Fairmont appears to form a less distinctive neighborhood than the areas which surround it. This is indicated primarily by the lack of heavy loading, positive or negative on any factor. This neighborhood may contain more than one population group which, like Marquam Hill, are cancelling each other out, or more than one geographical neighborhood may exist here. Additional analysis of the data would be necessary in order to discover the cause of this anomaly.

As in the original survey, residents of the Council Crest-Greenway district appear to be aware of land instability problems. They are community activists and are not pro-progress and development.

The new neighborhood, Viewpoint, also appears to be environmentally aware and active. This group has had a high degree of successful adjustment to personal land instability problems, which have a relatively high rate of incidence here.

The new "flatlander" control group has a very low awareness rating; pro-progress, non-activists, no experience.

The two neighborhoods which possess the highest awareness factor, Council Crest-Greenway and Viewpoint, appear to have had either more experience with problems of land instability or more contact with community action groups.

Method Comments

An observation made during this study which may be of major importance to future surveys concerns the number of people involved in writing, running, and evaluating a survey questionnaire. As the number of individuals working on the questionnaire increased, the opportunity for misinterpretation of data seemed to increase geometrically. Attitude surveys, by their very nature, do not render such precise, static tables of information as may be expected in the sciences or even most social sciences. Attitudes are delicate and changing and can be greatly affected, particularly by the enumerator, his dress, manner, and individual interpretation of data. It may be assumed that this problem would increase with increasing questionnaire complexity.

Table 2. Trusted sources of information

Neighborhood	Friends Neighbors	SWHRL	City officials Planning Com.	Private consult.	Engineers geologists	Federal agencies	Other
Westwood	2	2			1		
Marquam Hill		2			1		
Upper Fairmont	2	2	1				
Lower Fairmont	2	1			1		
Council Crest		1	2		1		
Viewpoint	2		3		1		
Control group			2		1		

1 = most highly trusted; 2 = second most trusted; 3 = third most trusted
(Results of question no. 24 on questionnaire)

Table 3. Factor of matrix scores

	I Low awareness/ confidence	II Pro-progress/ complacent	III Environmentally aware/activists	IV Personal experience/ successful adjustment	V Personal experience/ unsuccessful adjustment
Westwood	++	--	-	----	+++
Marquam Hill	----	+++	-	+++	-
Upper Fairmont	+++	--	----	---	++
Lower Fairmont	+	-	--	+	-
Council Crest, Greenway	+	--	+++	+	--
Viewpoint	+	-	+++	+++	--
Flatlander-control group	---	++	--	--	+

Summary

Although absolute precision cannot be expected from an attitude survey, general trends can be shown and can be of immense value.

The major trends indicated by this survey show that approximately 40 percent of the residents in the study area do not recognize that land instability problems exist here. Of the remaining 60 percent, only two-thirds (40 percent of the total) have some idea of the causes and preventive measures for land instability. Less than 10 percent of the residents recognize any correlation between development types and susceptibility to the hazards of unstable land.

Individual neighborhoods have distinctive perceptual characteristics including awareness of hazards, cohesiveness of organization, and political abilities.

Although trust in sources of planning information varies somewhat from one neighborhood to another, the most effective channel of communication open to planners and residents for the area as a whole would be through professional individuals working with community groups (i.e., specific geologists and engineers working in conjunction with the Southwest Hills Residential League).

* * * * *

Questionnaire

MARQUAM HILL PROJECT

Address _____

I'm from the Geology Department at Portland State University. We're surveying households in the area to determine how residents feel about urban development and planning. First may I ask:

1. How long have you lived at this address?
 - a. less than one year
 - b. one to four years
 - c. five to 15 years
 - d. greater than 15 years) 69%*

2. What are the main aesthetic or attractive qualities of this area?
 - a. trees and greenery 34%
 - b. view 30%
 - c. country atmosphere with urban conveniences 16%
 - d. surrounded by other pleasant homes
 - e. people who live here
 - f. other _____ 12%

3. Do you or your children own bikes in working condition? (Yes-No)
 - children _____ 30%
 - parents _____ 24%

4. How often do you ride your bikes (for pleasure)?
 - a. quite often 31%
 - b. occasionally
 - c. rarely
 - d. never

*Percentage of answers received from respondents

5. Would you say that you go for walks
- | | |
|-----------------|-----|
| a. often | 56% |
| b. occasionally | 22% |
| c. rarely | |
- answer same as in 4 above
6. If there were bike trails or pedestrian paths, would you or your family use them?
- | | |
|-----------------|-----|
| a. often | 70% |
| b. occasionally | |
| c. rarely | |
7. Having lived here for a period of time, which factors are problems in your area?
- | | |
|--------------------------------|-----|
| a. Physical | |
| 1. land instability | 27% |
| 2. flood | |
| 3. foundation problems | 14% |
| 4. parking | 45% |
| 5. medical school encroachment | |
| 6. access to neighborhood | 7% |
| b. Social | |
| 1. lack of community services | 29% |
| (a) school | |
| (b) shopping | |
| (c) other | |
| 2. transportation difficulties | 51% |
| 3. lack of social mixture | 19% |
8. Do you expect this area to experience significant change in the foreseeable future?
- | | |
|---------------|-----|
| a. yes | |
| b. no | 70% |
| c. don't know | |
9. Why:
- If Yes
- | | |
|---|-----|
| a. population (housing) pressure | 58% |
| b. everything is changing | |
| c. residents desire a particular change | |
| d. encroachment by developers | |
| e. other _____ | 15% |
- If No
- | | |
|---------------------------------|-----|
| f. no need for change | |
| g. residents will resist change | 31% |
| h. facilities adequate | |
| i. other _____ | 41% |
10. If Yes:
- What kind of change do you expect?
- | | |
|---------------------------------------|-----|
| a. increasing residential development | 44% |
| b. decay of area | |
| c. improvement in services | |
| d. commercialization of area (rezone) | |
| e. other | |

11. If you were to move from your present home would you choose to live in:
- a. condominium
 - b. small apartment complex
 - c. large apartment complex
 - d. detached residence 74%
 - e. other
12. Do you feel there is a difference in attitude toward apartment dwellers as opposed to home owners?
- a. yes
 - b. no split
13. If yes
What is the reason for the attitude toward apartment dwellers?
- a. transiency 50%
 - b. lack of community interest
 - c. less concern for maintenance 15%
 - d. additional traffic problems
 - e. other _____ 33%
14. (Show respondent landslide photos) Does this sort of thing happen in the Portland Hills area?
- a. yes 68%
 - b. no
 - c. don't know
15. If yes
How did you become familiar with these land instability problems?
- a. personal experience
 - b. friend or neighbor with experience
 - c. seen it in the area
 - d. mass media
 - e. other
16. What do you perceive some of the causes of land instability to be?
- a. improper excavation 28%
 - b. removal of vegetation 29%
 - c. poor drainage 28%
 - d. just happen - act of God
 - e. other
17. Do you feel there is a possibility you may experience a (continued) land instability problem?
- a. yes
 - b. no 74%
 - c. don't know
18. Do you know of any measures which could be used to reduce the possibility of or damage from such hazards?
- a. more careful excavation, design and construction 23%
 - b. improve vegetation cover 27%
 - c. improve drainage 12%
 - d. retaining walls 23%
 - e. other 15%

19. Could you arrange these pictures according to their probable degree of safety as a building site?
- _____ safest
_____ most hazardous
- _____

- _____

- _____

20. Because of population (housing) pressure and the prime value of this privately owned land, it is probable this area will be developed soon. Which of these developments proposed for the area would you prefer (think would be best)? (Show proposed development plans)
- | | |
|-------------------------------|-----|
| a. individual-lot-subdivision | 37% |
| b. high-rise condominium | 22% |
| c. open-space cluster unit | 41% |
21. Do you consider it a realistic alternative for the city to purchase the remaining open space in this area in view of the lack of parks on the eastside? (Explain this!)
- | | |
|--------|-----|
| a. yes | 60% |
| b. no | |
22. How aware were you of the land instability problem before you moved here?
- | | |
|------------------------|-----|
| a. completely unaware | 36% |
| b. less aware than now | 18% |
| c. as aware as now | 46% |
23. Who do you suppose is the most qualified to decide the appropriateness of proposed developments?
- | | |
|---|-----|
| a. friends or neighbors | 19% |
| b. SW Hills Preservation League | 21% |
| c. city officials - Planning Commission | 16% |
| d. private consulting firm | 9% |
| e. professional geologists, engineers, etc. | 30% |
| f. federal agencies | 2% |
| g. other | 3% |
24. What would be the best means to present these problems and possible solutions to residents of the area?
- | | |
|--------------------------------|-----|
| a. newspapers | 14% |
| b. T.V. | 17% |
| c. special hearings | 23% |
| d. through neighborhood groups | 20% |
| e. door-to-door | 17% |
| f. other | 9% |
25. Who do you feel are your 3 most important community leaders?
- | | |
|----|--|
| a. | Neil Goldschmidt |
| b. | Terry Shrunk (mayor at time of survey) |
| c. | Lloyd Anderson |

I have some general statistical questions I would like to ask now - could you tell me:

26. How many people live in this household? 2.3 average

27. And they are:
- | | |
|----------------------|----------------|
| a. over 65 | d. 18-24 |
| b. between 41 and 64 | e. 13-17 |
| c. between 25 and 40 | f. 12 or under |
28. Do you own or rent this home?
- | | |
|---------|-----|
| a. own | 85% |
| b. rent | 15% |
29. If rent: Would you indicate the index number of the amount which most nearly represents your monthly rent.
30. What are the highest grades in school completed by heads of household?
- | | | | |
|----------------|-----|----------------|-----|
| <u>husband</u> | | <u>wife</u> | |
| grammar school | | grammar school | |
| high school | | high school | |
| bachelors | 70% | bachelors | 65% |
| masters | | masters | |
| Ph.D. | | Ph.D. | |
31. What are the occupations of heads of household?
- | | |
|------------|-------|
| a. husband | _____ |
| b. wife | _____ |
32. What part of town does each work in?
- | | |
|------------------------|-----|
| a. downtown | 31% |
| b. medical school area | 14% |
| c. eastside | 15% |
| d. westside | 29% |
| e. other | 11% |
33. Where do you shop?
- | | |
|-----------------------------------|-----|
| a. local stores | 25% |
| b. downtown | 22% |
| c. westside (Beaverton-Hillsdale) | 39% |
| d. eastside | 9% |
| e. other | 5% |
34. Does any member of the household belong to a community action group?
- | | |
|--------|-----|
| a. yes | 22% |
| b. no | 78% |
35. Name of group (if it has a name) _____ SWHRL _____