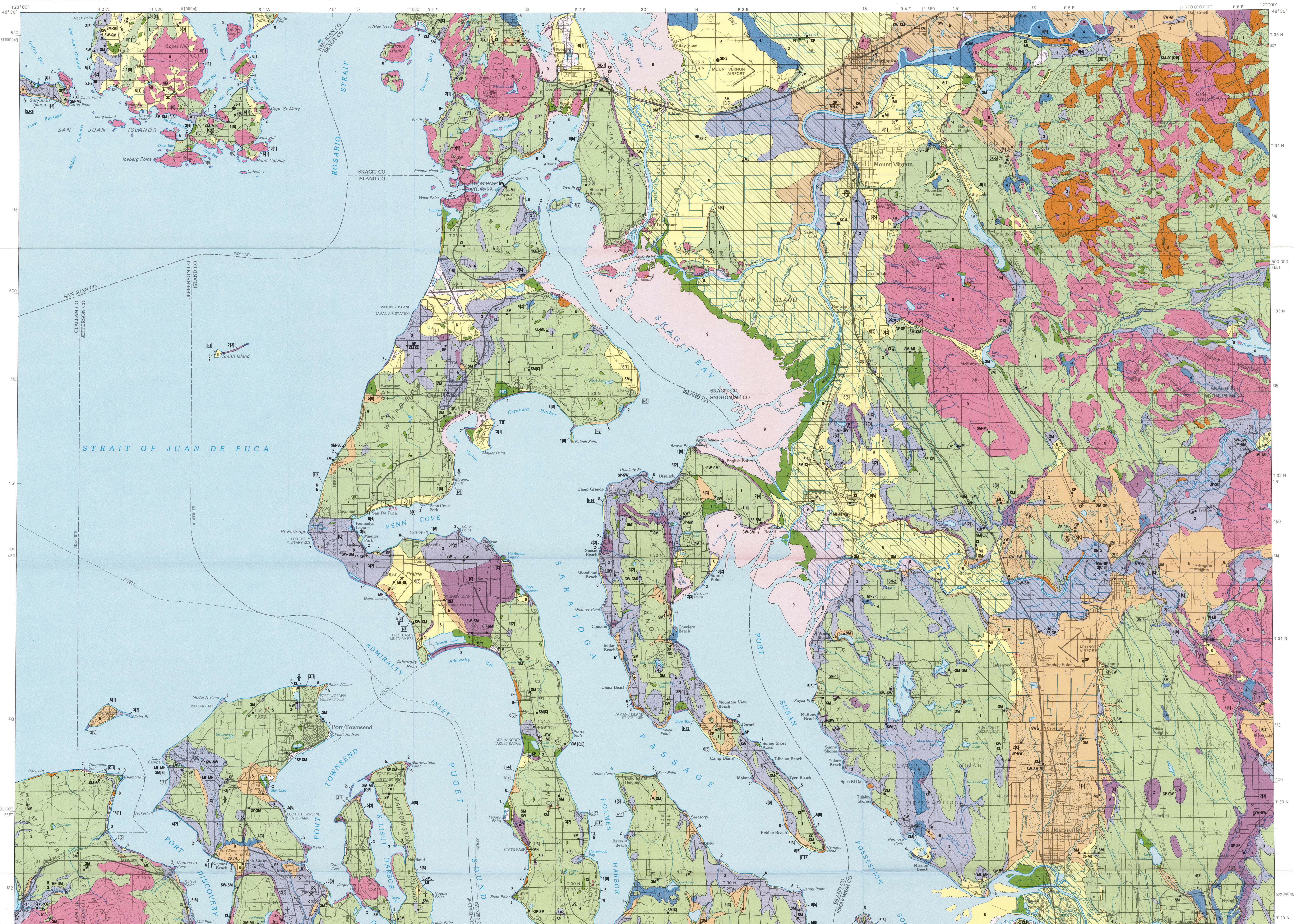

Base from U.S. Geological Survey, 1973
50,000-foot grid based on Washington coordinate system, north zone
10,000-meter Universal Transverse Mercator grid ticks, zone 10

INTERIOR—GEOLOGICAL SURVEY, RESTON, V.A.—1986—G84134

Textural units compiled 1976–80

DISCUSSION

INTRODUCTION

Surficial deposits cover large areas in the Port Townsend quadrangle, Washington (Pessl and others, in press). Consequently, they are the earth materials most commonly encountered during our everyday activities. Most surficial deposits are mixtures of different sizes of soil particles, and the relative amount of each size is an important factor in determining the physical properties of a deposit. These properties, in turn, critically affect a wide variety of important land-use considerations, such as (a) the suitability of development sites, (b) the suitability and the availability of construction materials, and (c) the capability for onsite waste-disposal systems.

This map is one of a series of multipurpose maps of the Port Townsend quadrangle prepared as part of the U.S. Geological Survey's Puget Sound Earth Sciences Application Project. Intended to provide earth-science information to geologists, engineers, consultants, and others adept in the use of geologic and technical maps and reports, this textural map shows the distribution of surficial materials having similar physical properties rather than showing the regional distribution of conventional geologic units. This text describes the approach taken to prepare the map and to collect and test samples, and discusses certain applications of the data presented with regard to specific land use. The map does not provide detailed information on the distribution and characteristics of surficial deposits, but, instead, is designed to provide a regional overview of selected physical properties characteristic of surficial deposits in the Port Townsend quadrangle. Consequently, more detailed geologic and (or) soil investigations, rather than this map and text, should be the basis for decisions involving physical properties and problems of land use at specific sites.

TERMINOLOGY

Various particle-size classifications of earth materials have been popular over the years (fig. 1). This report uses the ASTM (American Society for Testing and Materials) classification, which follows engineering usage, for sand and smaller sizes. Laboratory tests followed standard procedures prepared by the American Society for Testing and Materials (1964). Both the NRC (National Research Council, 1947) and the Wentworth (1922) classifications differentiate between gravel and sand at a lower particle-size boundary than does the ASTM classification. Terms used in this report for large fragments follow the NRC and Wentworth classifications; both define pebbles as being smaller than 64 mm but larger than 4 mm, cobbles as being smaller than 256 mm but larger than 64 mm, and boulders as being larger than 256 mm. For the most part, however, particle-size terminology throughout the text applies to the matrix of the materials sampled because particles larger than 76.2 mm (3 in.) are removed by screening prior to laboratory testing; descriptions of materials that contain larger fragments are generally based on field evaluations of the overall deposit. The term "soil" is used here in the engineering sense: that is, "soil" encompasses all unconsolidated earth materials.

Some of the other descriptive terms used include "well-graded," which applies to equal or nearly equal distribution of particle sizes from coarse to fine, "moderately graded," which applies to fairly even distribution of particles, and "poorly graded," which refers to a particle-size distribution where all or nearly all particles are the same size.

Nonstandard terms are used in a relative manner. "Some" indicates a quantity that is distinctly less than 50 percent, and a "small amount" indicates a quantity less than 10 percent. The terrain is described as "even" where the land surface is flat to nearly flat, "uneven" where the surface is somewhat undulatory, and "very uneven" where it is very undulatory, irregular, or hilly. The contact between textural layers is "abrupt" if the change in texture occurs in more than 25 mm but less than 152 mm, and "gradational" where the change takes more than 152 mm. Thicknesses of layers are described on the basis of the distance between boundaries separating layers. Thay are called "massive" where boundaries are more than 1.2 m apart, "thick bedded" where boundaries are more than 0.6 m and less than 1.2 m apart, "thin bedded" where the distance between boundaries is less than 0.6 m but more than 24 mm and "laminated" where the boundaries are less than 25 mm apart. Degrees of cohesiveness are described as "cohesionless" where dry material runs freely or is nonadhering; "friable" where it adheres poorly, breaks easily in the hand, and rubs off readily; "soft" where it adheres well but can be pressed and indented by finger pressure; and "firm" where it adheres well, does not rub off, cannot be indented with finger pressure, and breaks with great difficulty by hand, or does not break at all.

The USCS (Unified Soil Classification System) (U.S. Army Corps of Engineers, 1953) provides a means of describing surficial deposits in terms of some common engineering characteristics of soil. Use of this system defines the physical properties of the deposits delineated on the map. Laboratory tests were the principal method for determining grain size, liquid limit, and plasticity, indices that enable a USCS group symbol to be assigned to each sample locality. The USCS two-letter symbol (for example, **SW** = well-graded sand) provides a means to evaluate the general semiquantitative engineering properties of material at each site, for example, the excavation, permeability, and compressibility characteristics. In short, it is a *guide* to physical properties and should be interpreted in that sense when using this report. A compound symbol, such as **SW–SM**, tells the user that the material has characteristics of two soil groups. In this case, the deposit is a well-graded sand that contains silt. The sand at such a site can be expected to be less permeable than a silt-free clean sand.

The sites of representative samples are shown on the map by USCS symbols. Several classification symbols commonly occur within the boundaries of each textural unit shown on the map, indicating textural changes laterally or vertically. Table 1 shows the soil classification groups by USCS symbols determined to be typical of the map units and some of the inferred properties associated with engineering uses of the classification groups used in the system. As with the particle-size terminology, the USCS symbols represent characteristics of materials composed of particles smaller than 76.2 mm (3 in.) in diameter.

SAMPLING AND TESTING PROCEDURES

Permeability is important in land use, and varies with the type of surficial deposit. In places, certain types of deposits are known to be poor choices for septic systems. Some deposits are dense and have very low porosity (called "tight") and drain too slowly; others are cohesionless and drain too quickly. For these reasons, a few areas containing tight materials were selected as part of this study. From these areas undisturbed samples were obtained to determine the coefficient of permeability (**k**) and thus to check consistency of test results between similar materials collected from different parts of the mapped area. Most of these samples were obtained by pushing or gently driving cylindrical metal sleeves into the soil; thus, the sampled deposits were uniformly fine grained and stone free. The ends of the samples were subsequently trimmed, sealed to preserve the natural moisture content, and sent to the U.S. Geological Survey geotechnical laboratory in Denver. There, permeability determinations were made by utilizing a falling-head permeameter, following the procedure described by Lambe (1951, chap. 6).

Several samples from different sites were collected in large blocks to be cored in order to obtain samples suitable for testing. These particular samples, all from unit 1 (stony till in this case), were not used because of the many pebbles and cobbles that made up a large percentage, by weight, of the sample that would be in the cores. Such inclusions would disrupt the permeability of the cored samples and cause nonrepresentative test results. The results of all permeability determinations and other tests are shown in table 2.

HOW THIS MAP WAS PREPARED

The surficial geologic map of the Port Townsend quadrangle (Pessl and others, in press) is the principal source for the distribution of textural units shown on this map. In addition, data from laboratory tests of samples collected as part of this investigation, and field observations and reconnaissance mapping by the senior author, supplemented the surficial map. This method permitted separating materials of different textures within the same unit on the geologic map, and, in other places, combining materials of similar texture, but in different surficial deposits, into a single textural unit.

Sample sites were selected where it was felt that the material was representative of the map units. Although each sample relates only to a specific site, the data from these samples were used to refine the field observations regarding texture and to establish the range of physical properties expectable throughout each map unit.

Some depositional variables result in textural and physical property differences within deposits of a single textural map unit; these are reflected by the range of USCS symbols showing sample sites within each map unit. Uniformly textured materials were collected as grab samples, but deposits having a wide range of grain sizes, perhaps in several layers, were sampled selectively to collect material typical of the deposit. Nevertheless, most of the symbols reflect changes within a generally restrictive textural range; for example, the deposit within one map unit may be a sandy gravel, but the grading may range from well graded to poorly graded from layer to layer or change laterally within one depositional layer. The symbols may also represent areas of nontypical materials within the map unit, areas that cannot be shown separately at the scale of the map.

WHAT THIS MAP SHOWS

Symbols used on a textural map differ from those used on conventional geologic maps. On this map, numbers identify each map unit. Bedrock is not classified on this map, and those areas in which undifferentiated bedrock is at or within 6 ft of the land surface are indicated by the unit symbol "**0**." As indicated in table 1, unit number **1** represents deposits that are nonsorted mixtures of coarse- and fine-grained materials that in places contain cobble- and boulder-size particles. Units **2** through **7** consist of deposits that range from coarse to fine grained, trending toward a finer grained matrix in the direction of the higher numbers. Unit **8** designates a wide range of granular materials, mostly deposited by landsliding, that cannot be separated at the scale of this map. Unit **9** consists of fine-grained materials in the tidal zone and estuarine portions of rivers; these materials were not examined in detail during this study.

Some map-unit numbers contain a secondary number within a bracket. The number outside the bracket represents the principal textural characteristics of the unit and should be considered to be most characteristic of the unit. However, the number within the bracket reflects local differences in texture within the unit either horizontally or vertically; these differences modify the unit characteristics but are too small to show on the map.

The Unified Soil Classification System helps determine the principal physical properties of materials sampled. In general, the symbols for the fine-grained group in unit **1** and locally in unit **6** represent those of the matrix. Because the matrix controls most characteristics of the physical properties of these deposits, the USCS symbol becomes important for interpreting important engineering properties. However, the fine-grained group symbols in most of the textural map unit **6** and in all of unit **7** are representative of dominant characteristics of the whole deposits in these map units, not just of the matrix. Some of these properties are listed in table 1 adjacent to the group symbol and name of the deposit.

In places, however, the USCS symbol is not sufficient to describe the deposit. Letters within brackets adjacent to the symbol on the map expand on the description for places where nontypically large clasts occur within the matrix and can have a modifying influence on the use characteristics of the materials. In such localities these large fragments are shown by symbols in brackets: **[C]** for cobbles, **[B]** for boulders.

Because surficial deposits in the mapped area were deposited at different times and by different means, steep bluffs or road cuts can expose several types of materials. In such places on the map several numbers are placed in vertical sequence with the principal-unit identifier on top. In addition, certain complex exposures in sea bluffs and steep inland slopes are shown by measured sections (fig. 2). Letters identifying the county of origin precede the locality number, and the materials in the sections are identified by map unit numbers. These sections are included to help the user visualize the changes in materials and use characteristics that may be encountered in engineering or other land uses.

HOW TO USE THIS MAP

It is intended the map and the chart in table 1 provide the user with an overview of the distribution of materials of similar nature—without regard to geologic origin—and of their engineering characteristics and properties, and their possible impact on land use.

To apply the data to this map, decide to which unit a particular area of interest belongs, see which USCS symbols are near it on the map, and use table 1 to determine the implied characteristics that might influence the intended use of that area. Basic to applying the Unified Soil Classification System is the understanding that soil components have inherent engineering characteristics and that identification of these components is used to classify probable engineering attributes. Coarse-grained components, whether predominantly sand or predominantly gravel, have about the same engineering characteristics, differing only in degree. In general, "*** well-graded, compacted gravels or sands are stable materials. The coarse-grained soils when devoid of fines are pervious, easy to compact, little affected by moisture, and not subject to frost action. Although grain shape and gradation, as well as size, affect these properties, for the same amount of fines, gravels are generally more pervious, more stable, and less affected by water or frost than sand" (U.S. Bureau of Reclamation, 1974, p. 10–11).

The fine-grained components, silt- and clay-sized particles, have engineering characteristics different from each other. Silts are generally moderately impervious; clays are virtually impervious. Both are difficult to compact, and the compressibility of both materials increases with higher liquid limits. However, greater dry strength is characteristic of highly compressible clays but is not characteristic of highly compressible silts. Consequently the Unified Soil Classification System utilizes the liquid limit to indicate relative degrees of compressibility of these materials, using the letters "L" for low compressibility (liquid limit less than 50), and "H" for high compressibility (liquid limit greater than 50). Except for local deposits within unit **6**, the fine-fraction grains in most deposits in this area are silt-size rather than clay-size particles.

To help visualize the size distribution within the major deposits, triangular plots for units **1**, **3** and **5**, and **6** show percentages of silt-clay, sand, and gravel particles in samples from sites (shown on the map) throughout the quadrangle. Units **3** and **5** are combined because there are relatively few samples of each and because the deposits are for the most part fluvial.

A combined triangular plot of data from all samples tested (fig. 3a) shows in a general way the relative percentages of grain sizes in the selected map units. For the most part, units **1** and **6** are the most uniform and vary little from one location to another; combined units **3** and **5**, however, vary north to south, especially on Whidbey Island. Because of this, two triangular plots were prepared to show separately samples from northern and southern Whidbey Island (figs. 3 b–c). The dividing line between the northern and southern areas is arbitrary; the large gravel deposit near Coupeville marks the southern limit of samples included in the plot for the northern part of the island. The textural trend of combined units **3** and **5** is toward a more sandy deposit to the south. Such a trend to finer grained materials southward graphically displays the recognized difficulty in finding suitable aggregate in the southern part of Whidbey Island.

Although there is not much noticeable size change within units **1** or **6** in the Whidbey Island samples, the silt and clay content in unit **1** is at least 20 percent. In units **3** and **5** it ranges from 2 to 12 percent, and unit **6** deposits show a range of 66 to 100 percent silt and clay. Samples from throughout the quadrangle seem to contain about the same percentages of silt and clay as the Whidbey Island samples (fig. 3a).

As little as 10 percent silt and clay particles (particles smaller than 0.075 mm) in sand and gravel can make such a deposit virtually impervious (U.S. Bureau of Reclamation, 1974, p. 11). Understanding this attribute is important in evaluating runoff, infiltration, and septic-system use.

Porosity of surficial deposits controls the ability of the material to accept moisture, and, other things being equal, for example, slope and vegetation cover, permeability controls the infiltration rate. Permeability greatly affects the results of "percolation" tests that determine the suitability of a site for installation of a septic system. Persons involved with construction in this part of the Puget Sound lowland are familiar with the difficulty in finding such sites. Because units **1** and **6** are the most widespread surficial units in the non-mountainous part of the quadrangle, they underlie much of the area potentially desirable for development.

Table 2 shows the range of results obtained from permeability tests on 11 samples collected from 8 sites within the quadrangle; all samples have a low or very low degree of permeability. Particle-size distributions of all the materials sampled show large percentages of silt and clay, even in sample 11, a sand. Sample 10 was a large block of material typical of the hard till in unit 1; it was one of the samples to be cored. As mentioned, this was not successful, but based on the high silt-clay content (54 percent) of the sample, its coefficient of permeability can be expected to be within the range indicated by the test results. USCS group symbols representing these samples support this interpretation.

Samples 6, 7, and 8 were collected in stratigraphic sequence. Collected from a site in a bluff on the north side of Penn Cove, Whidbey Island, sample 6 was from a shell-rich material beneath a 28-cm layer of surface pebble gravel; sample 7 was from directly below, from material typical of unit 1; and sample 8 was from a fine-grained prismatic layer within unit 1. Little increase of permeability upward was noted in the stratigraphic sequence, an increase that might have been expected because of near-surface weathering.

The test results shown in table 2 indicate a measured range of permeability of samples from one map unit relative to samples from other map units. Being site specific, the coefficients of permeability apply only to the locations sampled. We believe, however, that the results of these few tests, related to the consistently moderate to high amounts of silt and clay in units 1 and 6, show it valid to expect that elsewhere throughout the quadrangle unit 1 materials will have a medium to low degree of permeability and unit 6 materials will have a very low permeability or be nearly impermeable. Such an assumption is in line with the inferred characteristics of the USCS groups assigned to these map units as shown in table 1.

Such low permeability of materials within these map units is reflected after a rain as pools of water standing in depressions and flat areas for several days where the surface is underlain by these materials. Test pits used by others to determine percolation rates prior to applying for building permits commonly yielded results that indicate the same low degree of permeability. As of 1980 many acres of rural land on Camaro and Whidbey Islands, and in Clallam and Jefferson Counties on the Olympic Peninsula, remained undeveloped in part because of low percolation rates.

Although organic matter typically occurs with silt and clay, the occurrences are sporadic and the amount of organic matter varies. Organic matter can affect the engineering properties of fine-grained soils: moisture retention and liquid limits are increased, voids within the soil can be created by decay, chemical changes can occur, and physical properties can be altered. In addition, such soils are more compressible and less stable than organic-free soils. As a result, organic-rich soils, especially peat and marsh deposits, are seldom used in any engineering sense; in fact they are generally removed before construction of any type.

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EXPLANATION

- 1[3] — MAP-UNIT CLASSIFICATION—Where number is outside bracket, it is principal map-unit designation; where used, unit number inside bracket is secondary unit designation, indicating changes from the principal characteristics either vertically or horizontally
- GW — MATERIALS CLASSIFICATION—Based on the Unified Soils Classification System; **GW**, well-graded gravel; **GP**, poorly graded gravel; **GM**, silty gravel; **GC**, clayey gravel; **SW**, well-graded sand; **SP**, poorly graded sand; **SM**, silty sand; **SC**, clayey sand; **ML**, inorganic silt and very fine sand; **CL**, inorganic clay of low to medium plasticity; **OL**, organic silt and organic silty clay of low plasticity; **MH**, inorganic silt; **CH**, inorganic clay of high plasticity; **OH**, organic clay of medium to high plasticity, organic silt; **PT**, peat and other highly organic soil. **[C]** and **[B]** indicate size of fragments on surface or scattered throughout matrix. Stacked symbols (for example, **CL/CH**) represent USCS classifications of materials in excavations, steep slopes, or road cuts. Compound symbols (for example, **SW–SM**) indicate the material has characteristics of two soil groups
- 3/4 — LOCATION OF SELECTED STEEP SLOPES, CUTS, OR EXCAVATIONS WHERE MULTIPLE UNITS ARE EXPOSED—Numeral above line designates principal map unit
- CL[C] — LOCALITY OF SAMPLE COLLECTED AND TESTED FOR PHYSICAL PROPERTIES AS PART OF THIS STUDY—Letters outside brackets indicate USCS classification of matrix; letters within brackets indicate size of fragments on surface or scattered throughout matrix: [B]=boulders, [C]=cobbles; grain sizes determined from these localities are shown in figure 3
- 2 — LOCALITY OF SAMPLE COLLECTED AND TESTED FOR HYDROLOGIC PROPERTIES SHOWN IN TABLE 2—Collected mainly to determine coefficient of permeability (**k**)
- [C] — AREA OF LARGE FRAGMENTS—Numerous large fragments on surface or scattered throughout deposit: [B]=boulders; [C]=cobbles
- × — LOCATION OF STATE AND COUNTY PITS—Test data included on triangular plots for grain-size distribution (fig. 3)
- SJ-1 — LOCATION OF WELL-LOG SECTIONS—Letters designate counties; solid circle is at wellsite
- J-2 — LOCATION OF MEASURED SECTIONS—Letters designate counties; end of line is at section location
- AREA WHERE WATER TABLE COMMONLY SHALLOW (<2m)—May encompass several map units. Extends along present streams and modern floodplains and deltas. Underlying deposits can change texture over short distances; locally contain layers, lenses, or pods of finely disseminated organic-rich sediment; thickness varies, ranging from 1 m to 10 m; seasonally wet to saturated. Subject to flooding except where protected by dikes or other manmade structures. Characteristics of materials in areas shown by overprint may be different from those shown in table 1
- AREA OF GENERALLY PERMEABLE DEPOSITS UNDERLAIN BY LESS PERMEABLE DEPOSITS—Surfaces of less permeable deposits are at depths of <5m
- MAJOR AREAS OF FILLED GROUND AND MAN-MODIFIED LAND
- CONTACT—Approximately located; dashed where indefinite
- GRAVEL PIT

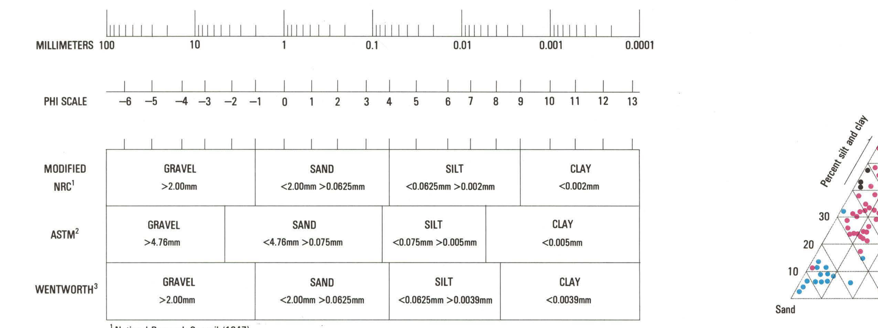
Table 1.—*Chart showing map unit descriptions, selected physical properties, and engineering performance characteristics*

[Leader (–), no test data. As shown on map, some unit numbers may be in brackets (for example, 2[4]). Number outside brackets is principal designation; unit number inside brackets is secondary designation, indicating changes from the principal characteristics either vertically or horizontally. Stacked unit numbers (for example 4/5) indicate selected steep slopes, cuts, or excavations where multiple units are exposed. The numeral above the line designates principal mappable unit]

SELECTED PHYSICAL PROPERTY CHARACTERISTICS AND APPLICATIONS OF SURFICIAL MATERIALS BY MAP UNIT

Map unit	Description of map units	USCS[1,2] Most common	USCS[1,2] Other	Permeability (cm/sec)	Compressibility[5]	Compaction characteristics[3]	Foundation characteristics[4]	USCS[1,2] Most common	USCS[1,2] Other	Excavation	Slope stability	Use in septic systems	Source of aggregate	Source of road fill
0	Rock, undifferentiated; not classified													
1	Boulders, cobbles, pebbles, sand, silt, and clay in a nonsorted mixture (glacial till). Larger boulders can be absent; in such places unit can be fine grained. Locally contains beds, layers, lenses, and pods of water-deposited sand and gravel. Matrix can vary, but generally is a silt, clayey silt, or silty sand. Typically firm to very firm. Massive; nonstratified, but in places contains subhorizontal layering; thin, friable separations generally occur in upper 1 m. Land surface even to very uneven; in places weathered to a loose sandy, stony mixture in the upper 1–2 m. Locally called "hardpan." Thickness varies, ranges from a few meters to as much as 40 m, but commonly is between 3 m and 15 m	CL		$k=10^{-6}$ to 10^{-8} (practically impervious)	Medium	Good to fair	Generally good for subgrade and base; good for footings, bearing strength commonly exceeds 3,000 lb/ft	CL		Easy (hand tools) to difficult (heavy power equipment) depending on consolidation of material and absence or presence of large fragments, some of which exceed 5 m in largest dimension	Massive; stands well in nearly vertical embankments, road cuts, sea bluffs; generally fails as large blocks falling from vertical faces. Erodes into steep-sided gullies or ravines	Generally poor, percolation rate too slow	Poor	Poor, excessive amounts of silt; with excessive moisture, fills can fail as "mudslides"
		ML		$k=10^{-3}$ to 10^{-6} (fair to poor)	Slight to medium	Good to poor using close control[6]		ML						
		SM			Very slight to medium	Good		SM				Generally good, but percolation rate may be too fast		
		SP		$k>10^{-3}$ (excellent)	Almost none			SP						
			CH	Tested (see table 1); $k=10^{-3}$ to 10^{-4} at three locations (practically impervious)	High	Fair to poor			CH			Generally poor, percolation rate too slow		
2	Coarse-grained[7] granular material, generally larger than 4.76 mm (upper limit of sand size). Cobbles and boulders locally common. Soil matrix commonly a well-graded to poorly graded sandy gravel or gravelly sand. Cohesionless to friable. Commonly stratified in layers of variable thickness that show cut-and-fill structures; dips 10° or less. Land surface even to very uneven and characterized by closed depressions; weathered in upper 1–4 m. Thickness 0.25–1 m on beaches but can be thicker (10 m or more) in hilly terrain	GW		$k>10^{-2}$ (excellent)	Almost none	Good	Good	GW		Generally easy (hand tools to light power equipment); locally difficult to remove where it contains large (>0.5 m) fragments	Natural slopes stand to 35°; steeper cuts subject to raveling and slumping	Generally poor, percolation generally too rapid; locally suitable	Good source in uplands	Fair to poor; may be cohesionless
		GP						GP						
			SW	$k>10^{-3}$ (fair to poor)					SW					
			SM	$k=10^{-3}$ to 10^{-6} (fair to practically impervious)	Very slight	Good using close control			SM					
3	Coarse-grained granular material, generally larger than 0.075 mm (upper limit of silt size). Generally a well-graded to poorly graded sand or gravelly sand. Generally cohesionless. Massive to locally thin bedded and laminated; fluvially stratified (layers dip 5°–10°; contain channel crossbeds and cut-and-fill structures). Land surface even to very uneven; weathered in upper 1–3 m. Thickness generally 2–10 m but locally as much as 20–50 m where fills major valleys	GW		$k>10^{-2}$ (excellent)	Almost none	Good	Excellent	GW		Same as unit 1, depending on absence or presence of beds of boulders	Natural slopes stand to 35°, but coarser layers can stand nearly vertically; will ravel where steeper or where slopes are undercut	Generally poor where percolation rate too rapid; locally satisfactory	Locally excellent to good; large pieces may require crushing	Fair to poor, may be too loose
		GP					Good to excellent	GP						
		SW		$k>10^{-3}$ (excellent)			Good	SW						
			GM	$k=10^{-3}$ to 10^{-6} (fair to poor)	Very slight	Good using close control			GM					
			SM		Very slight to medium		Fair to good		SM					
		SP		$k>10^{-3}$ (excellent)	Almost none	Good		SP						
4	Coarse- and fine-grained granular material containing cobbles and boulders commonly admixed with finer material; includes sizes smaller than 0.005 mm (upper limit of clay size); can include angular particles 100 mm or larger. Commonly is a silty or clayey sand, or poorly graded gravel. Cohesionless to friable. Coarsely stratified, layers separated by even to uneven partings; weathered in upper 1 m. Thickness ranges from 1 to 3 m in small deposits to as much as 20 m in large deposits	GP		$k>10^{-2}$ (excellent)	Almost none	Good	Good to excellent	GP		Generally easy (hand tools), but areas containing scattered large fragments can require light power equipment	Natural slopes stand to 35°; steeper cuts or undercut slopes subject to raveling	Generally poor to fair	Generally poor; fines make it poor pit-run source	Fair to good
		SM		$k=10^{-3}$ to 10^{-6} (fair to poor)	Very slight to medium	Good using close control	Fair to good	SM						
		SP		$k>10^{-3}$ (excellent)	Almost none	Good		SP						
5	Coarse-grained granular material, generally smaller than 4.76 mm (upper limit of sand size). Commonly a clean to silty sand and locally a poorly graded sand or gravel. Cohesionless. Horizontally layered, locally crossbedded (layers commonly dip 5°–10°). Land surface characteristically even in broad plains of valleys and very uneven where deposited by wind; weathered in upper 1–3 m. Thickness averages 10–15 m; locally thicker	SW		$k>10^{-3}$ (excellent)	Almost none	Good	Good	SW		Easy (hand tools or light power equipment)	Slopes stable to 35°; will ravel where unvegetated	Good to fair; percolation rate may be high	Unsuitable, generally too fine grained	Unsuitable, cohesionless
		SP–SW					Fair to good	SP–SW						
		SW–SM		$k=10^{-3}$ to 10^{-6} (fair to poor)	Slight to almost none	Good using close control		SW–SM						
		SP–GP		$k=10^{-2}$ to 10^{-3} (excellent)	Almost none	Good	Good to excellent	SP–GP						
6	Fine-grained granular material, generally smaller than 0.075 mm (upper limit of silt size). In places matrix contains scattered cobbles or boulders; in other places it is consistently fine grained. Locally may be overlain by thin deposits of beach and bar gravels in low ridges or mounds that are not shown at scale of map. Soft and elastic where moist; firm where dry. Massive to laminated bedding; locally stratified; has partings of sand laminae or organic-rich layers. Land surface generally even, but in places, such as northeast of Mount Vernon, terrain may be very uneven; weathered in upper 1–2 m. Thickness variable, commonly less than 10 m, but may be thicker (such as near Milltown)	CL		$k=10^{-6}$ to 10^{-8} (practically impervious)	Medium	Good to fair	Fair to poor	CL		Easy (hand tools) to difficult (heavy power equipment) where elastic or firm	Stands nearly vertically along sea cliffs; can fail by blocks falling from steep faces, by flows, or by slides, depending on amount of moisture	Unsuitable, percolation rate too slow	Unsuitable, too fine grained	Unsuitable, can fail when wet
		ML		$k=10^{-3}$ to 10^{-6} (fair to poor)	Slight to medium	Good, using close control, to poor		ML						
			CL–CH	$k=10^{-6}$ to 10^{-8} (practically impervious)	Medium to high	Fair to poor	Poor to very poor		CL–CH					
			CH–MH	$k=10^{-4}$ to 10^{-8} (poor to practically impervious)	High	Poor to very poor			CH–MH					
7	Coarse- and fine-grained granular material, generally smaller than 4.76 mm (upper limit of sand size), and consistently mixed with organic matter. Locally consists of matted organic plant fibers and root fragments. Friable to soft. Massive; may have sand- or silt-laminae partings. Generally occurs in small depressions. Land surface even to uneven; hummocky terrain common; generally unweathered at surface and is still accumulating in most places. Thickness ranges from 1 to 20 m	OL		$k=10^{-4}$ to 10^{-6} (poor)	Medium to high	Fair to poor	Poor	OL		Easy (hand tools); commonly wet, but can use light power equipment for large excavations where firm enough to provide support; easily removed by dragline	Can stand vertically where dry; can flow where wet	Generally unsuitable, percolation rate too slow	Unsuitable too much organic matter	Poor to unsuitable, too much organic matter
		OH		$k=10^{-6}$ to 10^{-8} (nearly impervious, may have intermittently standing water)	High	Poor to very poor	Poor to very poor	OH						
		PT		Not determined (probably fair to poor)	Very high	Not practicable	Not suitable, usually removed from excavations	PT						
8	Broken rock and granular material, undifferentiated. Cohesionless to firm. Massive to stratified to rubbly. Locally derived by landsliding. Deposits accumulate as large to small sand flows, debris flows, rock avalanches, debris slides, earth falls, and rotational slumps and slides. Land surface even to very uneven; depth of weathering varies, depending on age of deposit, and ranges from a featheredge to more than 2 m. Thickness ranges from 1 m to more than 10 m	–	–	Variable, depending on texture, cohesion, and size of material	Variable, depending on texture and cohesion of deposit	Good to poor, depending on texture and size	Poor where loose or poorly emplaced by natural movement	–	–	Easy (hand tools), where fine-grained, to difficult (heavy power equipment) where found as large fragments	Unstable where fine grained, erodes easily due to runoff; resists erosion where coarse grained	Variable, depending on texture and cohesion of deposit	Generally unsuitable; locally suitable if coarse fragments crushed	Coarse materials are locally suitable
9	Fine-grained granular deposits, undifferentiated; generally below high-tide level. Were not investigated as part of this study, but description of deposits on the surficial geologic map (Pessl and others, in press) indicates saturated to wet, fine-grained deposits composed of particles generally smaller than 0.076 mm. Thickness generally 5–30 m	–	–	Probably low, because of silt content	Probably medium to high	Poor because of particle size and saturation	Generally not suitable because of wetness and occurrence generally below high tide	–	–	Generally easy using dragline	Natural slope nearly flat; can flow in cuts when wet; may compact, slide, or flow due to seismic shaking	Unsuitable because of high water table and lack of permeability	Unsuitable, too fine grained	Unsuitable, too fine grained

[1] U.S. Army Corps of Engineers (1953).
[2] Unified Soil Classification System.
[3] With proper control of moisture conditions and thickness of lifts.
[4] Values are for subgrades and base courses where not subject to frost action.
[5] Soil compacted at optimum moisture (Standard Proctor).
[6] Very close control of moisture and thickness of lifts is required, as well as use of proper compacting equipment.
[7] Coarse-grained material is generally larger than 0.075 mm; fine-grained material is generally smaller than 0.075 mm, a separation used in the Unified Soil Classification System.



National Research Council (1947)
American Society for Testing and Materials (1975)
Wentworth (1922)

Figure 1.—Comparison of particle-size boundaries in three commonly used size classifications.

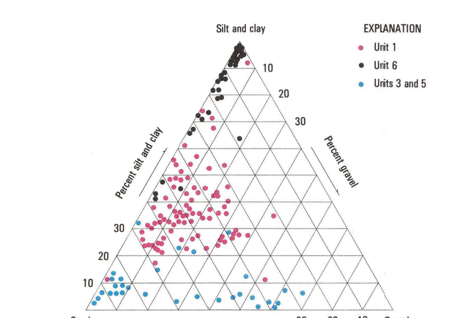


Figure 3a.—Triangular plot showing distribution of grain sizes of 152 samples of surficial materials collected throughout mapped area at localities shown on map by USCS group symbols and by county and state pit symbols.

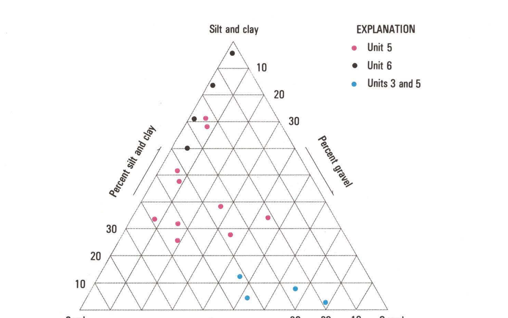


Figure 3b.—Triangular plot showing distribution of grain sizes of 18 samples of surficial materials from northern Whidbey Island, Island County: Deception Pass south to Coupeville area.

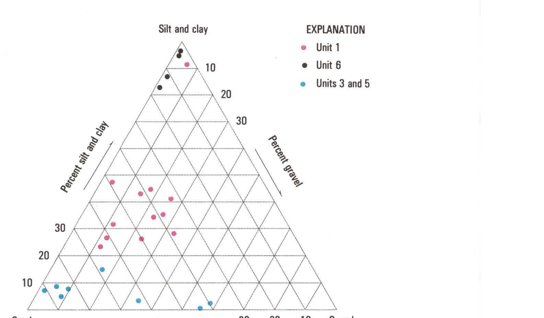


Figure 3c.—Triangular plot showing distribution of grain sizes of 24 samples of surficial materials from southern Whidbey Island, Island County: Coupeville area south to Freeland area.

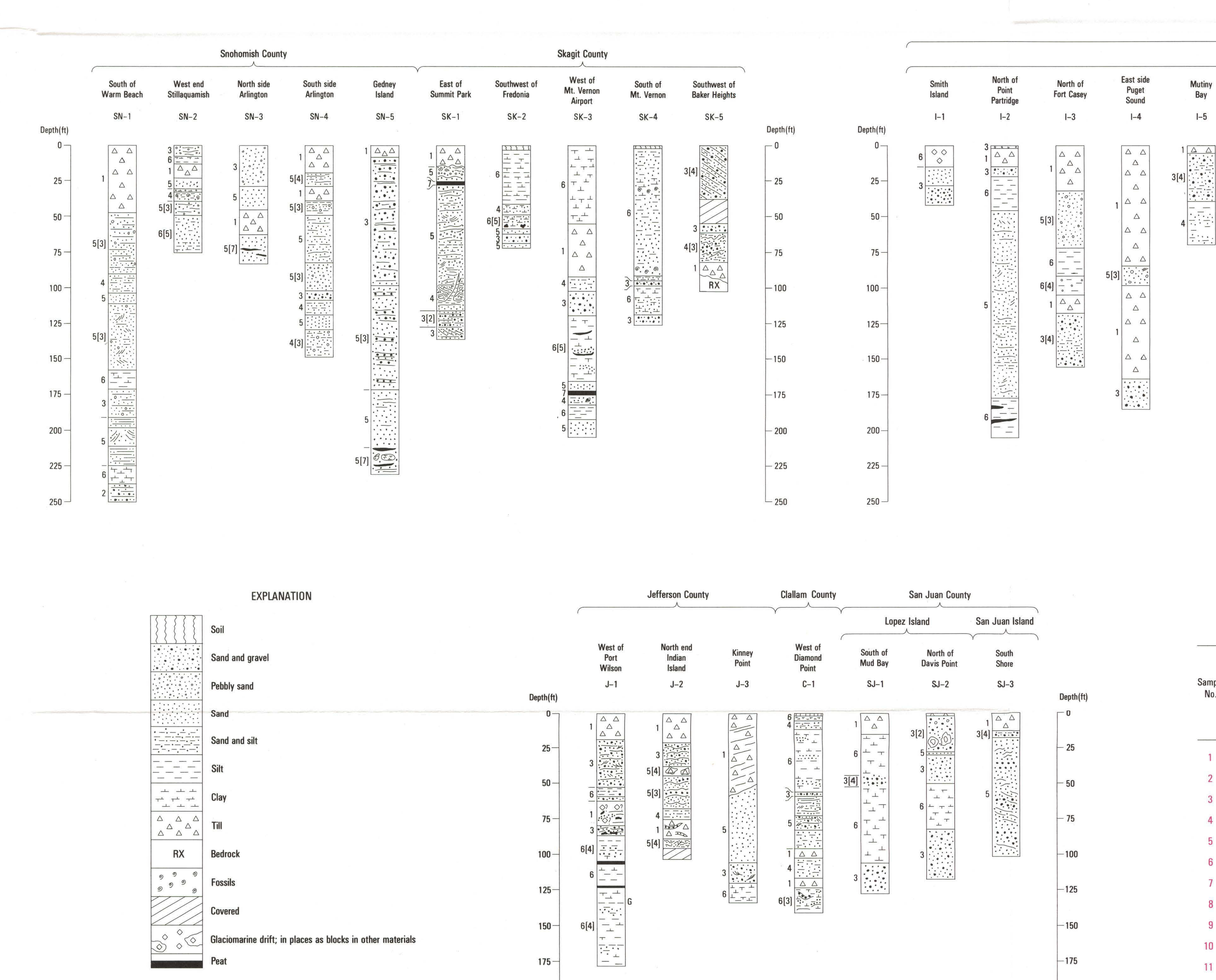


Figure 2.—Vertical sections from selected locations showing sequences of map units and typical textures that underlie surface deposits and form nearly vertical seabluffs and other steep slopes in this part of the Puget Sound region. Locations of sections are on the textural map and are numbered and preceded by a letter designating the county in which the section is located, as follows: SN, Snohomish County; SK, Skagit County; I, Island County; J, Jefferson County; C, Clallum County; SJ, San Juan County. Sequence of map units shown in SJ-1 and SJ-2 were interpreted from well logs. Numbers shown at sides of sections refer to map-unit classifications.

Table 2.—*Physical properties and coefficient of permeability (k) of 11 samples of fine-grained surficial materials*

[Leaders (–) indicate no data]

Sample No.	Map unit	Particle-size distribution (ASTM classification): Gravel (>4.76 mm)	Sand (4.76–0.075 mm)	Silt (0.075–0.005 mm)	Clay (<0.005 mm)	Atterberg limits: LL	PL	PI	Unified Soil Classification System group	Dry bulk density[2]	Natural moisture content[1]	Coefficient of falling-head permeability $k^{3,8}$ (cm/sec)
1	6	0	0	45	55	42	26	16	CL	–	21	2.90×10^{-7}
2	6	0	2	33	65	54	21	33	MH	–	31	[6] 2.54×10^{-3}
3	6	0	0	31	69	52	20	32	MH	–	30	[7] 4.01×10^{-9}
4	6	0	7	74	19	–	–	NP	ML	–	32	3.44×10^{-5}
5	1	6	24	45	25	25	16	9	CL	2.11	([4])	2.91×10^{-4}
6	1	2	29	45	24	37	30	7	CL	–	29	1.82×10^{-3}
7	1	5	35	39	21	34	24	10	CL	–	16	3.77×10^{-4}
8	1	0	0	50	50	43	19	24	CH	1.51	([4])	1.07×10^{-4}
9	1	3	48	24	25	22	14	8	CL	–	10	2.83×10^{-4}
10	1	17	29	29	25	24	17	7	CL	2.15	([4])	([5])
11	5	0	57	24	19	27	19	8	SM	–	17	6.02×10^{-4}

[1] Percentage of dry soil weight.
[2] Grams/cubic centimeter.
[3] Average of several runs.
[4] Samples had dried; natural moisture not determined.
[5] Block too stony; cut could not be cut for test.
[6] Sample moderately disturbed; cracks caused faster permeability rate than expected on the basis of silt and clay content.
[7] Sample length increased by 0.2 cm due to swelling during testing (an increase of 1.6 percent)
[8] Degree of permeability (cm/sec):

High	More than 10^{-1}
Medium	10^{-1}–10^{-3}
Low	10^{-3}–10^{-5}
Very low	10^{-5}–10^{-7}
Practically impermeable	Less than 10^{-7}

From Terzaghi and Peck (1967, p. 381, table 47.2).

MAP SHOWING UNCONSOLIDATED DEPOSITS GROUPED ON THE BASIS OF TEXTURE, PORT TOWNSEND 30′ x 60′ QUADRANGLE, PUGET SOUND REGION, WASHINGTON

Compiled by
Robert D. Miller and Fred Pessl, Jr.
1986

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