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WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
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Lake Wooten 7.5-minute Quadrangle
July 2009

Geologic Map of the Lake Wooten 7.5-minute Quadrangle, Mason County, Washington

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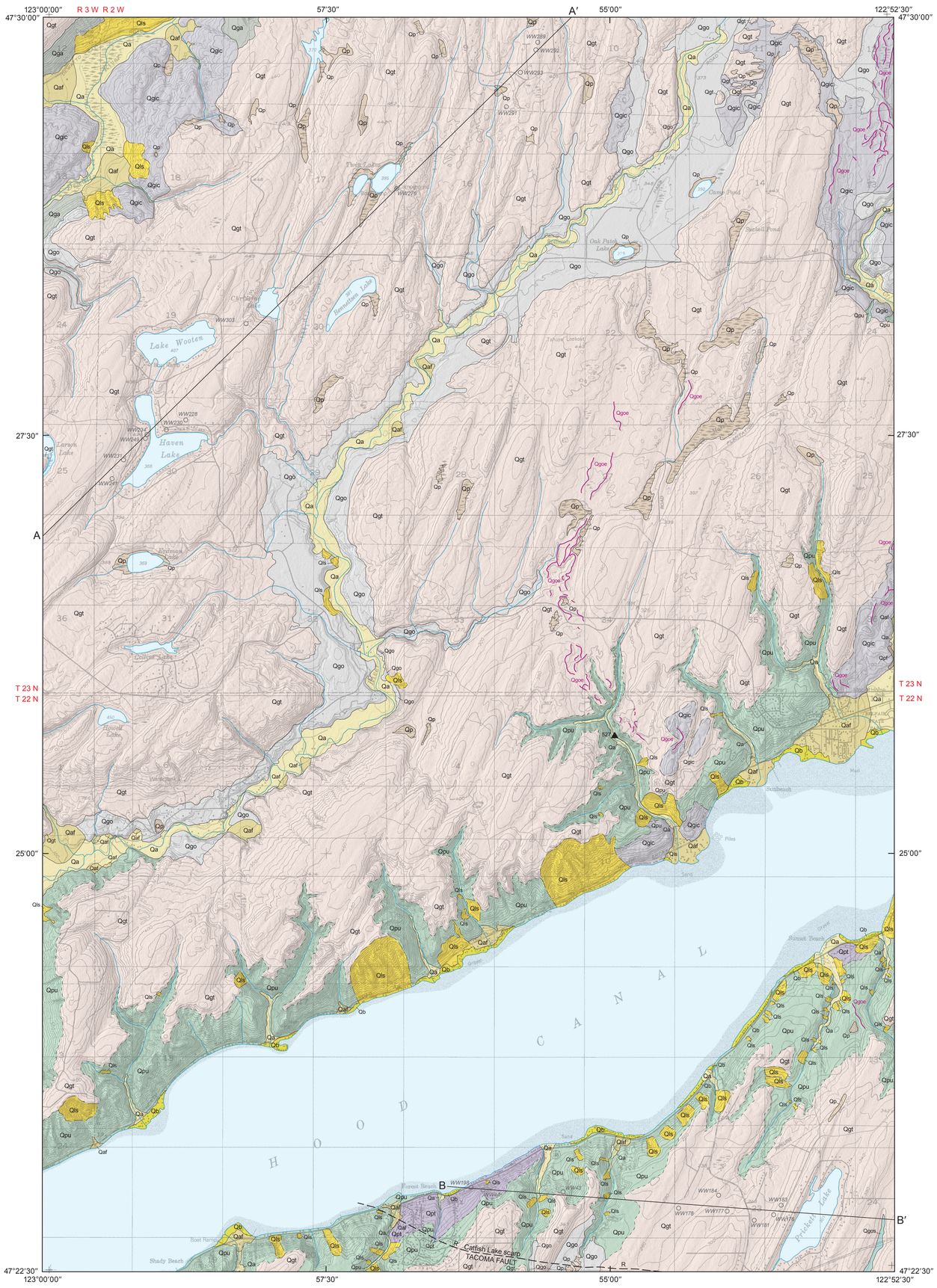
July 2009



Lambert conformal conic projection
North American Datum of 1927; to place on North American Datum of 1983, move the projection lines approximately 20 meters north and 95 meters east as shown by crosshair corner ticks
Base map from scanned and rectified U.S. Geological Survey Lake Wooten 7.5-minute quadrangle, 1999
Shaded relief generated from a lidar bare-earth digital elevation model (available from Puget Sound Lidar Consortium, http://pugetsoundlidar.ess.washington.edu/); sun azimuth 290°; sun angle 60°; vertical exaggeration 2X
Digital cartography and GIS by Elizabeth E. Thompson, Anne C. Heinitz, and J. Eric Schuster
Editing by Jaretta M. Roloff, Jessica L. Czajkowski, and Karen D. Meyers
Production by Jaretta M. Roloff

SCALE 1:24,000

1 0.5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0.5 0 1 KILOMETER
contour interval 20 feet

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17°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2009

Cross Sections. Cross sections were constructed based on sparse reliable water well data. Unit Qptu, depicted in the southeastern part of Cross Section A, does not appear in water will logs in the northeastern part of the section. Wells were used to establish the stratigraphy and do not depict a precise depth to unit contacts. The cross sections schematically represent stratigraphy and should not be used to determine depth to a particular stratigraphic unit at any point along their path.

MAJOR FINDINGS

- The Catfish Lake scarp of the Tacoma fault probably extends to the west into the Lake Wooten quadrangle at least as far as Hood Canal.
- All glacial till in the quadrangle was initially thought to be only Vashon in age. An interbedded sediment sequence yielded an infinite radiocarbon date, meaning that the till beneath it is pre-Vashon in age.
- Most landslides in the area are rooted in Vashon advance outwash and pre-Vashon fluvial or glaciofluvial deposits.
- Detail was added to the local glacial stratigraphy (O'Neal, 2004).

INTRODUCTION

Most of the land surface of the Lake Wooten quadrangle, located near the center of the Puget Lowland, is covered by a thin veneer of glacial drift of the Vashon Stade of the Fraser Glaciation (Armstrong and others (1965) overlying a sequence of pre-Vashon glacial and nonglacial sediments. The southwest-trending elongate hills that characterize much of the terrain are drumlins sculpted by the Puget lobe of the Vashon continental glacier. Outcrops of pre-Vashon glacial and nonglacial deposits are rarely well exposed in the quadrangle, as they are less resistant to erosion and do not form prominent outcrops. Poorly consolidated pre-Vashon fluvial and glaciofluvial deposits are more permeable than Vashon deposits and have low cohesion. They are the source of numerous landslides in the quadrangle.

The sediments brought by glaciers into the Puget Lowland may be from any of three different source regions. If the predominant rock fragments and grains are from granitic and metamorphic rocks, the probable source is the Coast Range of British Columbia (northern provenance); if the sediments contain andesitic volcanic rock fragments and glass in addition to granitic and metamorphic rock fragments, the probable source is the Cascade Range of Washington (Cascades provenance); and if the predominant rock fragments and grains are from basalt and mafic rocks, the probable source is the Olympic Mountains (Olympics provenance). Thin sections of glacial deposits from the Lake Wooten quadrangle consist of granitic and metamorphic rock fragments and lack andesitic rock fragments and glass, indicating that the deposits are of northern provenance. This differs from deposits in the eastern part of the Puget Lowland, which contain andesitic volcanic rock fragments and glass indicative of Cascades provenance (Walsh and others, 2003).

GEOLOGIC HISTORY

Bedrock does not crop out in the quadrangle; depth to bedrock is more than 500 ft in the eastern part of the quadrangle (Buchanan-Banks and Collins, 1994). Bedrock is believed to be basalt and related rocks of the Crescent Formation, exposed in the Olympic Mountains (Tabor and Cady, 1978) and on Green and Gold Mountains 5 mi north of the quadrangle (Haeussler and Clark, 2000). Our mapping dealt with only the uppermost 200 to 300 ft of the more than 500 ft of glacial and nonglacial deposits exposed or intercepted by water wells in the Lake Wooten quadrangle. This 200- to 300-ft-thick sequence is divided into Vashon and pre-Vashon deposits.

Pre-Vashon Deposits

Sediments deposited prior to the Vashon Stade of the Fraser Glaciation are subdivided into four units: pre-Vashon deposits, undifferentiated (unit Qpu); pre-Vashon deposits, fine grained (unit Qpf, stratigraphic position shown only on Fig. 1); pre-Vashon till (unit Qpt); and pre-Vashon till, undifferentiated (unit Qptu). Pre-Vashon till (unit Qpt) is difficult to distinguish from Vashon till (unit Qgt). The exposure confirmed as pre-Vashon till occurs north of Hood Canal on Stimson Creek (sec. 3, T22N R2W) directly beneath a clay bed from which a radiocarbon infinite date (sample 527) was obtained. Both the exposed clay bed and till bed on Stimson Creek are too small to be shown at map scale. Two larger exposures of pre-Vashon till (unit Qpt) are mapped south of Hood Canal.

A second, presumably older, pre-Vashon till (unit Qptu) occurs in the subsurface near the southeast corner of the Lake Wooten quadrangle. Its existence is inferred based on water well logs—drillers often designate the compacted layers of till as 'hardpan'. Unit Qptu is shown only in the cross sections and Figure 1. Whether this till is of northern or Olympics provenance is unknown. Till exposed immediately west of the Lake Wooten quadrangle on the north shore of Hood Canal is Olympics provenance (Robert Logan, Wash. Divn. of Geology and Earth Resources, oral commun., 2008). It projects beneath glacial and nonglacial deposits of the Lake Wooten quadrangle. We suggest that unit Qptu could be Olympics provenance. Both pre-Vashon tills are older than a radiocarbon infinite age from overlying units (Table 1; Logan and Walsh, 2007), but relative ages of the two older tills and correlation with any specific till unit of the Puget Lowland have not been established.

Sediments underlying Vashon till (unit Qgt) in the Lake Wooten quadrangle consist of Vashon advance outwash (unit Qga) and a diverse sequence of glacial outwash and interglacial deposits. Vashon advance outwash is often difficult to distinguish from the non-till deposits older than Vashon till. The hillslopes overlooking both sides of Hood Canal consist of a thick sequence of pre-Vashon non-till deposits. Numerous landslides also obscure exposures in this sequence. In the Lake Wooten quadrangle, we map these deposits as pre-Vashon deposits, undifferentiated (unit Qpu). Cross Section B is a schematic representation of this sequence, based largely upon water well log data.

Interglacial and nonglacial deposits intercepted in drilling water wells are usually logged as beds of gravel, sand, and clay. Inconsistencies between water well logs and rapid lateral facies changes preclude matching separated stratigraphic units on cross sections, with the exception of clay beds. Well log data is consistent enough to map a clay bed (unit Qpf) separate from pre-Vashon sediments, undifferentiated (unit Qpu) in the southern half of the Mason Lake quadrangle (Derkey and others, 2009). Although that clay bed (unit Qpf, approximate stratigraphic position illustrated in Fig. 1) is too thin to be shown at map scale in the Lake Wooten quadrangle, carbonaceous material from an exposure north of Hood Canal on Stimson Creek (sec. 3, T22N R2W) was found to be radiocarbon infinite (Table 1). Woody debris from pre-Vashon interglacial and nonglacial deposits on the east shore of Harstine Island in the Vaughn quadrangle also yielded a radiocarbon infinite age (Logan and Walsh, 2007). Therefore, the clay bed (unit Qpf in Fig. 1) confirms a pre-Vashon age for interglacial and nonglacial deposits (unit Qpu) in the south-adjacent Mason Lake quadrangle, where the only exposure of unit Qpf large enough to be shown at map scale is in Jarrell Cove State Park on Harstine Island (Derkey and others, 2009).

Vashon Glacial Deposits

Our mapping of the Lake Wooten quadrangle identified Vashon-age deposits consisting of till (unit Qgt) and outwash and ice contact deposits (units Qgo, Qgos, Qgic, and Qgoe). Stratigraphic relationships are illustrated in Figure 1 and Cross Sections A and B. Vashon till (unit Qgt), which may be as much as 50 ft thick, is typically poorly sorted with angular sand-size grains. It was compacted by the weight of the overlying glacier and is resistant to erosion relative to the other Quaternary units—only a few streams have cut down through it. Tree roots rarely penetrate the till, and water does not easily move downward through it, resulting in overland flow during periods of high precipitation. Numerous sloughs and ponds have formed in depressions on the till surface. Vegetation flourishes in these depressions, with accompanying accumulation of peat (unit Qp).

LANDSLIDES

Numerous landslides have been identified in the Lake Wooten quadrangle. Landslide polygons (Isabelle Sarikhan, Wash. Divn. of Geology and Earth Resources, unpub. data, 2009) were modified using lidar to establish approximate boundaries. Virtually all landslides that have been identified are associated with pre-Vashon deposits, undifferentiated (unit Qpu). The larger landslide scarps encroach upward into overlying Vashon till (unit Qgt). We suggest that the more permeable outwash and nonglacial deposits in the Lake Wooten quadrangle, when combined with steep slopes, are subject to development of landslides.

STRUCTURE

The lidar-identified trace of the Catfish Lake scarp of the Tacoma fault (Sherrod and others, 2003, 2004; Nelson and others, 2009) is in the southeast corner of the quadrangle. The fault is a high-angle reverse fault that dips northward at 55 to 60 degrees with 'up' on the north side of the fault (Logan and Walsh, 2007). We have extended the trace of the fault westward to Hood Canal, based on exposures in a borrow pit in sec. 22, T22N R2W. We have also noted that lidar imagery shows that the wave-cut beach zone is wider east and north of where our extension of the fault intersects the Hood Canal shoreline. We believe this may be due to relative uplift to the north on the upthrown side of the fault. Although the lidar-identified trace of the fault is not as prominent as in the Mason Lake quadrangle, we suggest that it should be extended to Hood Canal.

DESCRIPTION OF MAP UNITS

Holocene and Pleistocene Nonglacial Deposits

Qa **Alluvium (Holocene)**—Silt, sand, and gravel deposited by streams; may include some lacustrine deposits and organic materials, such as peat.

Qb **Beach deposits (Holocene)**—Mud, sand, and gravel deposited in the intertidal zone, or residual pebble-cobble gravel and isolated boulders on a wave-cut platform.

Qp **Peat (Holocene)**—Organic-matter-rich sediments deposited in closed depressions; in addition to peat, may contain silt and clay; commonly clogged with aquatic plants, abundant tree snags, stumps, and other woody debris in and adjacent to shallow or seasonal sloughs and ponds.

Qaf **Alluvial fan (Holocene)**—Silt, sand, and gravel deposited where upland streams meet valley floors; generally overlies till (unit Qgt), recessional outwash (unit Qgo), and alluvium (unit Qa).

Qls **Landslide deposits (Holocene and Pleistocene)**—Generally loose, jumbled, tan to gray, silty sandy gravel with few to no discernible sedimentary structures; surfaces of landslides are generally undulatory; some occur as large deep-seated slides and others as shallow surface failures or block falls. Almost all occur in Vashon advance outwash (unit Qga) and pre-Vashon sediments, undifferentiated (unit Qpu).

Deposits of the Vashon Stade of the Fraser Glaciation

Qgo **Vashon recessional outwash (Pleistocene)**—Recessional and proglacial sand and gravel of northern provenance, locally containing silt and clay; stratified; gray, tan, or brown; moderately to well rounded; poorly to moderately sorted; may include ice-contact, stratified drift, and lacustrine deposits. Divided into:

Qgos **Vashon recessional outwash sand and silt (Pleistocene)**—Loose sand, silt, and gravel; gray, tan, or brown; clasts moderately to well rounded; generally well sorted; clasts and grains consist of northern-provenance granitic and metamorphic rocks and rock fragments and polycrystalline quartz carried by Vashon meltwater; drains well due to high porosity and permeability; commonly forms thin to thick (25 ft or more) beds deposited in poorly defined ice-contact channels; stratigraphically overlies Vashon till.

Qgic **Ice-contact deposits (Pleistocene)**—Undifferentiated mixture of stagnant ice and dynamic ice deposits; dynamic ice deposits include lodgment till, drumlins, and advance outwash; stagnant ice deposits include ablation till, subglacial water flow deposits (such as eskers), and recessional outwash; also includes irregular blocks of lodgment till and detrital till fragments; till occurrences lack continuity at the ground surface; topography formed by a mix of subglacial, ice-marginal, and recessional processes.

Qgoe **Vashon recessional outwash, ice-contact deposits (eskers)(Pleistocene)**—Sand and gravel; gray, tan, or brown; moderately to well sorted and rounded; stratified; consists of sediment rich in northern-provenance granitic and metamorphic clasts and polycrystalline quartz; high porosity and permeability; deposited by Vashon meltwater in areas occupied by stagnant ice; forms low, elongate sinuous hills in recessional outwash channels; commonly deposited in ravines adjacent to drumlins in Vashon till (unit Qgt).

Qgt **Vashon till (Pleistocene)**—Unstratified to moderately stratified, compact, unsorted mixture of clay, silt, sand, and gravel deposited directly by glacial ice; consists of sediment rich in northern-provenance clasts; gray, tan, or brown; nearly everywhere in sharp contact with underlying units; does not drain well, as permeability and porosity are low; sand and finer grains in matrix are very angular; pebble- to boulder-size clasts are commonly striated and faceted, having angular and (or) rounded edges; boulders are generally disseminated and relatively rare; may contain interbeds of sand and gravel; ground surface for this unit characterized by streamlined drumlins, striations, and flutes that are generally hundreds to thousands of feet long; angular to subrounded glacial erratic boulders consist mostly of plutonic or metamorphic rock; unit may be capped by a few feet of unsorted and stained ablation sand and gravel; locally crosscuts older sediments, forming angular unconformities; drag folding and horizontal shearing may occur at the base of the till or internally between layers of till, especially in thick deposits; unit ranges in thickness from 0 to more than 50 ft.

Qga **Vashon advance outwash (Pleistocene)**—Sand and gravel with lacustrine clay, silt, and sand; gray to light brown; compact; consists of sediment rich in northern-provenance clasts; well rounded and most commonly well sorted; mostly polycrystalline quartz, plutonic, volcanic, and minor metamorphic grains; deposited during Vashon glacial advance; generally more compact than recessional outwash; most easily distinguished from recessional outwash if covered directly by Vashon till; may also contain pre-Vashon sediment at its base.

Pre-Vashon Deposits

Qpu **Pre-Vashon sediments, undifferentiated (Pleistocene)**—Composite unit of glacial and nonglacial gravel, sand, silt, and clay beneath Vashon till; consists of sediment rich in northern-provenance clasts; gray to tan; often iron-oxide stained; moderately to well rounded; poorly to moderately well bedded; consists of units not separable at map scale due to poor exposure; may include some Vashon advance outwash; most commonly recognized in water wells in the quadrangle and depicted in cross sections; water well logs, which were used for the cross sections, often distinguish these beds as clay, sand, and gravel.

Qpf **Pre-Vashon deposits, fine grained (Fig. 1 only)(Pleistocene)**—Silty sand and sandy silt with minor clay and some gravel interbeds; gravel clasts are northern-provenance; moderately rounded; laminated to poorly bedded; generally compact, but may be loose; locally to completely iron-oxide stained, with iron-oxide-cemented layers.

Qpt **Pre-Vashon till (Pleistocene)**—Unstratified, compact, unsorted mixture of clay, silt, sand, and gravel deposited directly by glacial ice; gray, tan, or brown; consists of sediment rich in northern-provenance granitic and metamorphic clasts; contact with underlying unit not exposed; contains granitic, volcanic, and metamorphic grains with abundant polycrystalline quartz; petrographically indistinguishable from unit Qgt; permeability and porosity are low.

Qptu **Pre-Vashon till, undifferentiated (cross sections and Fig. 1 only)(Pleistocene)**—Compact, unsorted mixture of clay, silt, sand, and gravel; existence determined from water well logs; provenance unknown.

GEOLOGIC SYMBOLS

Contact—long dashed where approximately located; short dashed where inferred or indefinite

Reverse fault, R on upthrown side—long dashed where approximately located

W277 Water well—numbers correspond to well numbers on cross sections

527 Age date sample site, radiocarbon (Table 1)

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Table 1. Radiocarbon date, age control data information, Sample LW 527. Lab uncertainty values are one standard deviation (68% confidence interval) and include random errors that can be estimated by the lab but exclude uncertainties that cannot be detected by the laboratory's analytical procedures. Analyses were performed by Beta Analytic, Inc. (Miami, Florida). Radiocarbon ages are 'conventional', that is, adjusted for measured $^{13}C/^{12}C$ ratio. The geologic unit shown in this table is the unit from which the sample was extracted. The sample was collected from an exposure too small to be shown as a polygon at map scale. Elevations are in feet above mean sea level using lidar data. AMS, radiocarbon analysis by atomic mass spectrometry.

Loc no.	Age estimate (^{14}C yr B.P.)	$^{13}C/^{12}C$ (o/oo)	Analytical method	Material dated	Geologic unit	Lab no.	Elev (ft)	Reference	Notes
LW 527	>46,000	-28.5	^{14}C AMS	wood	Qpf	Beta 254696	157	this report	Sample collected from 2 to 3 ft thick exposure of unit Qpf adjacent to Stimson Creek; unit too small to be shown at map scale

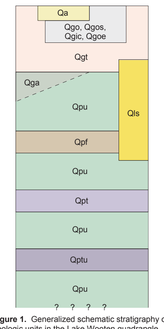

Figure 1. Generalized schematic stratigraphy of geologic units in the Lake Wooten quadrangle, exclusive of beach, peat, and alluvial fan deposits.

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