WASHINGTON STATE DEPARTMENT OF
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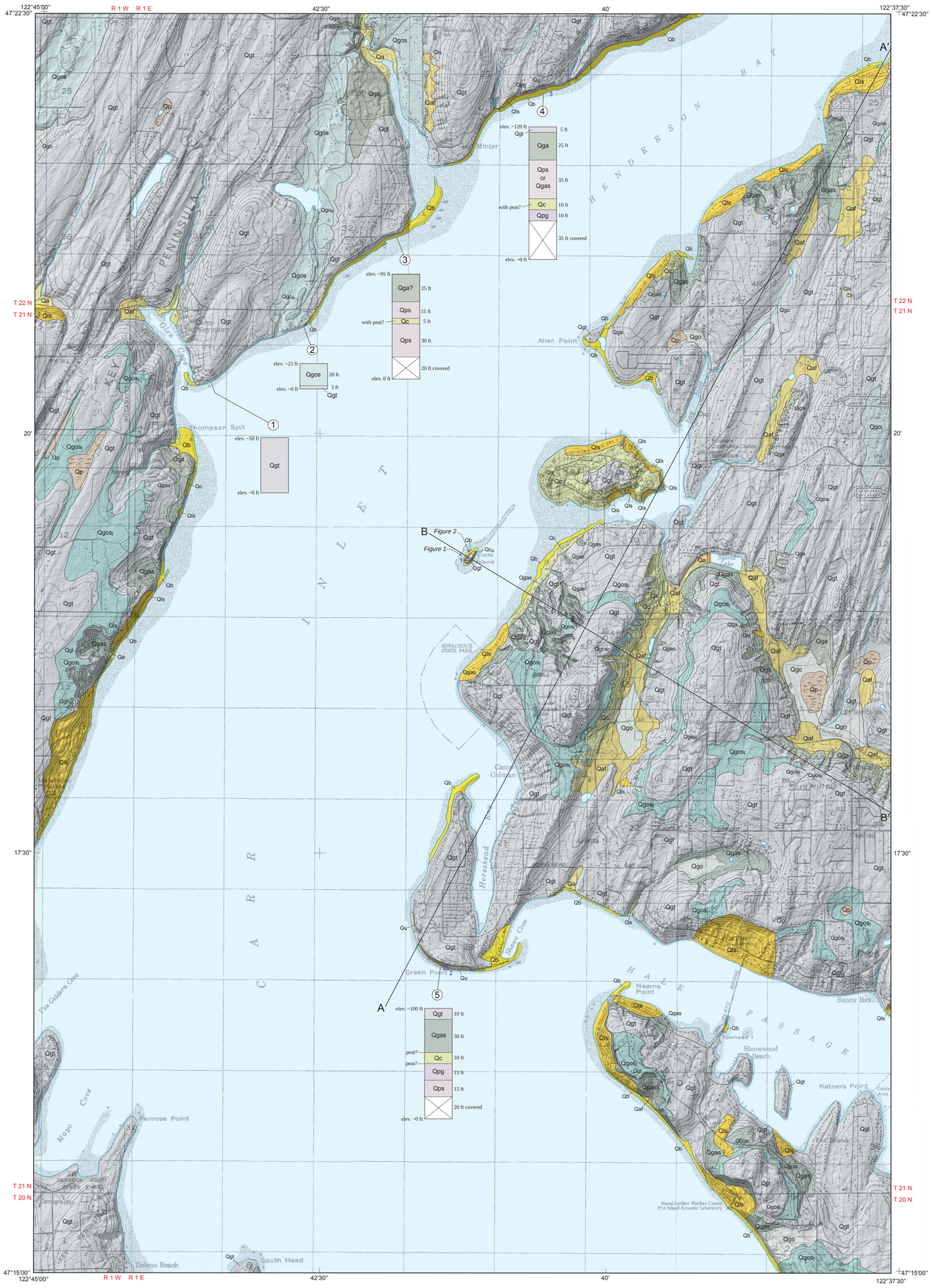
WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-63
Fox Island 7.5-minute Quadrangle



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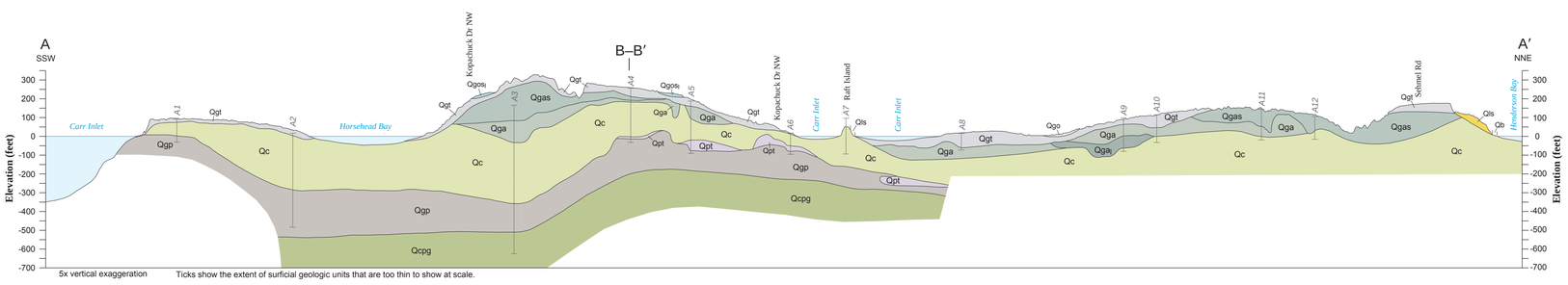

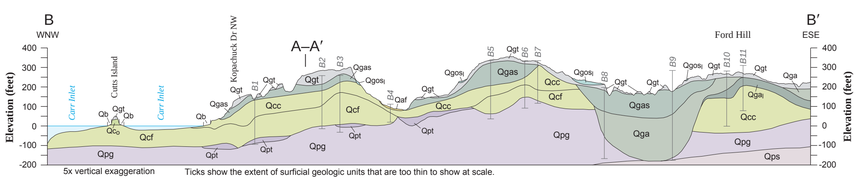

GEOLOGIC SETTING

The Fox Island quadrangle lies in the center of the Puget Lowland, a region that has been repeatedly shaped by glacial and nonglacial sedimentation and erosion during the Pleistocene epoch. There are no known outcrops of bedrock in the map area; in fact, Buchanan-Banks and Collins (1994) show the bedrock surface at a depth of about 1200 ft below mean sea level (msl) at the southern end of the quadrangle and shallowing to approximately 600 ft at the quadrangle's northern end.

The land surface in the Fox Island quadrangle is underlain by Vashon Drift and is molded into striking drumlins—elongate hills that were deposited at the base of the advancing ice sheet and were constantly streamlined by the moving ice. The long axes of these drumlins indicate the direction of ice movement. The drumlin plains are only slightly modified by syn- and post-glacial water-laid sediment, commonly deposited in poorly defined outwash channels or rarely as eskers.

Much of the Vashon Drift consists of thick layers of advance outwash sands with interbeds of gravel. Till of widely varying thickness covers most of the advance deposits, except where late-glacial wave erosion or post-glacial rill erosion has exposed the underlying advance outwash sediments, both commonly occurring along the steep sides of drumlins. Alluvial fans cover the floors of troughs between drumlins, particularly in the prominent trough from Arletta north-northeast through Rosedale to Henderson Bay.

Land within the Fox Island quadrangle is split by an arm of Puget Sound, Carr Inlet, which is a former subglacial trough (Booth, 1994). Hale Passage, also a former subglacial trough, separates Fox Island, one of several islands in the quadrangle, from the mainland. Many coves, bays, and inlets relate to the eroded and channelized upland surface. Puget Sound hosted lakes both before and after the Vashon glaciation as well as previous glaciations. Sandy terraces at an elevation of about 250 ft above present msl likely mark the shoreline of a short-lived glacial lake that covered much of the map area during the waning stages of ice-occupation about 13,500 yr B.P. (Swanson and Porter, 1998). Bretz (1913) named the lake glacial Lake Russell. These terraces are at about the same elevation as Thorson's (1981) inferred water surface elevation of glacial Lake Russell at this latitude. The terraces are best developed in areas south of Glen Cove on both sides of Carr Inlet. Undisturbed ice-contact deposits north of Glen Cove indicate that stagnant ice must have lingered for a short time at about that latitude, possibly forming a shoreline of icy bluffs along the east side of the peninsula. Where present, the terraces cover or partially encircle hills with elevations of 220 ft or higher, and are interrupted or completely truncated by landslides and stream headwalls in several places.

Pre-Vashon sediments are mostly exposed in shoreline bluffs and ravines. The best exposures are on the east side of Key Peninsula, but they are intermittently exposed along shorelines on the east side of Carr Inlet. These pre-Vashon sediments consist of both nonglacial and glacial deposits. The nonglacial sediments immediately subjacent to the Vashon Drift are radiocarbon-infinite at Green Point and near Minter and have been dated to about 19,000 radiocarbon years on Cutts Island. This is the youngest pre-Vashon radiocarbon date obtained anywhere from here to the south and also west of the eastern shore of Puget Sound (Walsh and others, 2003).

Presumed Olympia-age deposits are well preserved in the Fox Island quadrangle as seen on the cross sections (unit Qc_{Co}). The Olympia nonglacial interval was originally defined by Armstrong and others (1965) as "the climatic episode immediately preceding the last major glaciation, and represented by nonglacial strata beneath Vashon Drift". Olympia deposits accumulated between about 60,000 yr B.P. and 14,000 yr B.P. across the Puget Lowland during marine oxygen isotope stage 3 and immediately predating the Fraser Glaciation in the Puget Lowland. Given that sea level during the coldest part of the Olympia nonglacial interval (ca 40 ka) was about 65 m (213 ft) lower than today (Lambeck and others, 2002), the amount of relief now seen on the pre-Vashon topography is at least 300 m (1000 ft) across the Puget Lowland (Troost, 2006), with narrow channels and broad troughs and ridges.

STRUCTURE

Johnson and others (2005) used gravity, paleomagnetic data, and seismic reflection data to map the Rosedale monocline. They show the lower axis of the monocline striking northwest and passing through Cutts Island and just north of Glen Cove on the Key Peninsula. With the exception of folded Olympia-age sediments (19,040 ±130 yr B.P.) on Cutts Island (Fig. 1) and Raft Island, regional dips that would be expected on the flanks of the monocline were not detected in the field area. The deformed sediments on Cutts Island lie unconformably beneath Vashon till and, where well exposed on the west side of the island, dip about 45° northward, possibly forming a northwest-trending syncline. The upper several feet of this outcrop are subhorizontally sheared and drag-folded to the south, suggesting that there may be pre-Vashon deformation with ice-shear superimposed. Both the northerly dip and the syncline are not consistent with the southerly dip of the Rosedale monocline. The monocline is apparently masked at the surface by the glacial drift and nonglacial sediment that cover the area. However, apparent dips in the deposits in the subsurface are consistent with the Rosedale monocline (see cross sections).

The contact between Vashon till and unit Qc_{Co} on Cutts Island forms an angular unconformity, and the till is absent to the north. Striking evidence for the orientation of the contact is the abrupt change from cobble-rich beach deposits to a finer pebble- and sand-rich beach to the north, where till no longer covers the fine sediments (Fig. 2).

Lidar imagery was used to interpret and map landforms during field mapping and was checked against water-well logs to confirm their inferred underlying geologic materials. No disruption or deformation of the surface sediments could be detected in the lidar imagery or through geologic mapping.

DESCRIPTIONS OF MAP UNITS

Quaternary Unconsolidated Deposits

HOLOCENE NONGLACIAL DEPOSITS

Qls **Landslide deposits**—Generally loose, jumbled, tan to gray, silty sandy gravel with few to no discernible sedimentary structures; surfaces of landslides are generally undulatory; most landslides in the quadrangle occur in unit Qgas and underlying silt and clay.

Qb **Beach deposits**—Mud, sand, and gravel deposited in the intertidal zone, or residual gravel on a wave-cut platform.

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

Qp **Peat**—Organic-matter-rich sediments deposited in closed depressions; may include peat, muck, silt, and clay in and adjacent to wetlands.

Qaf **Alluvial fan**—Silt, sand, and gravel deposited at the confluence of upland streams with valley walls; generally overlies till or late-stage outwash.

PLEISTOCENE GLACIAL AND NONGLACIAL DEPOSITS

Deposits of the Fraser Glaciation, Vashon Stade

Qgo **Vashon recessional outwash sand and gravel**—Loose sand and gravel; tan to gray; moderately to well sorted and rounded; consists of plutonic and metamorphic lithic fragments deposited by Vashon meltwater occupying outwash channels or isolated basins but formed after glacial ice retreated. Unit Qgo is generally less compact than but difficult to distinguish from advance outwash without intervening layers of till.

Qgo_l **Vashon ice-contact deposits**—Intercalated till and outwash and irregularly shaped bodies of till and outwash; outwash consists of sand and gravel, with or without silt, horizontally bedded to steeply dipping. Till consists of matrix-supported gravelly, sandy silt; loose to very compact; 3 to 30 ft thick; gradational with units Qgo and Qgt.

Qgos **Vashon recessional outwash sand and silt**—Loose sand and silt, with minor gravel; tan to brown; clasts moderately to well rounded; generally well sorted; clasts and grains consist of northern-source plutonic and metamorphic rocks and polycrystalline quartz carried by Vashon ice; generally forms thin to 20 ft or more thick, elongate deposits in poorly defined ice-contact channels; commonly associated with eskers and stratigraphically overlies Vashon till.

Qgo_e **Vashon recessional outwash, ice-contact deposits (eskers)**—Loose sand and gravel; tan to gray; moderately to well sorted and rounded; consists of sediment rich in plutonic and metamorphic clasts; deposited by Vashon meltwater in areas occupied by stagnant ice; forms low, elongate sinuous hills in recessional outwash channels that stratigraphically overlie Vashon till.

$Qgos_l$ **Vashon recessional lacustrine shoreline sands and gravels—S**and and minor gravel deposited along the shore of Lake Russell (Bretz, 1913; Thorson, 1981); gray to brown; clasts and grains consist of northern-source plutonic and metamorphic rock and polycrystalline quartz carried by Vashon ice; formed by slight reworking of underlying till or advance outwash; unit covers terraces on some hills above about 220 ft elevation.

Qgt **Vashon till**—Gray to tan, unstratified to moderately stratified, compact, unsorted mixture of clay, silt, sand, and gravel deposited directly by glacial ice; nearly everywhere in sharp contact with underlying units; 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 either angular or rounded edges; boulders are generally disseminated and relatively rare; unit may contain interbeds of sand and gravel. The surface of this unit is characterized by streamlined drumlins and striations that are generally hundreds to thousands of feet long. Angular to subrounded glacial erratic boulders, consisting mostly of plutonic or metamorphic rock, are common but disseminated on the surface of this unit. Unit may be capped with a few feet of unsorted ablation till, sand and gravel, or by unit Qgls. Vashon till locally cross-cuts older sediments forming angularly unconformable contacts with those units. Drag folding and horizontal shearing may occur at the base of the till or internally between layers of till, especially in thick deposits. Unit Qgt ranges in thickness from 0 to at least 50 ft.

Qga **Vashon advance outwash**—Sand and gravel with lacustrine clay, silt, and sand; gray to light brown, compact, well rounded, mostly polycrystalline quartz, plutonic, 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. This unit may also contain pre-Vashon sediment at its base.

Figure 1. *(above)* Photo-composite of the west side of Cutts Island. Interbedded sands and silts grade downward into a highly sheared and broken silt. Thick lodgment till truncates and appears to drag the sandy unit over stratigraphically lower units (yellow arrows). A radiocarbon age of 19,040 ±130 yr B.P. was obtained from a small piece of flattened wood from about 5 ft to the right of the man on the left. At least part of the deformation here can be interpreted as glaciotectonic, however, seismotectonic or pre- or syn-Vashon-age landslide deformation is also possible. View to the east.

Figure 2. *(right)* The beach on the west side of Cutts Island. Notice the striking contrast in the grain size of beach sediment. The coarse gravel delineates the upland extent of till. View to the east; ocean to the viewer's back.

Qgas **Vashon advance sand**—Sand with minor gravel; gray to light brown, loose, well rounded, mostly polycrystalline quartz, plutonic, and minor metamorphic grains; deposited during Vashon glacial advance; most easily distinguished from recessional sandy outwash if covered directly by Vashon till; locally covers Olympia-age silts and clays, thus forming prime conditions for large, deep-seated landslides.

Qga_l **Vashon advance lacustrine deposits (possibly Lawton Clay equivalent, cross sections only)**—Laminated to massive silt, clayey silt, and silty clay with scattered dropstones, deposited in lowland proglacial lakes; marks transition from nonglacial to earliest glacial time, although unequivocal evidence for glacial or nonglacial origin may be absent; very stiff to hard; generally thicker than 30 ft and below 240 ft in elevation. Deposits of correlative age and texture may be included in older fine-grained units, where evidence of age and (or) depositional environment is absent; may include fine-grained sediment of unit Qc_{Co}.

Pre-Vashon Glacial Deposits

Qgp **Pre-Vashon outwash gravel (Cross Section A only)**—Sand and gravel, clean to silty with some silt layers; moderately to heavily oxidized; localized iron-oxide cemented layers and channels.

Pre-Vashon Nonglacial Deposits

Qc **Pre-Vashon sediments of unknown age—**Includes silt, sand, and gravel stratigraphically below Vashon deposits, and in some cases where Vashon drift is not exposed, below or part of units in which radiocarbon infinite dates have been obtained (sites 1 and 2). Includes an undisturbed and undated silt at about 100 ft above msl in sec. 34, T22N R1E, which may be Olympia-age sediment (unit Qc_{Co}).

Qcf In Cross Section B, divided into unit Qcf, fine-grained lacustrine deposits similar to the silt on Cutts Island but undated, and unit Qcc, sand with minor silt and clay interbeds that is similar to the silt on Cutts Island but undated.

Qcc

Qc_{Co} **Olympia-age sediments**—On Cutts Island, unit includes fine, well-sorted, well-rounded, tan sand with interbeds of medium gray silt that increase in thickness and frequency down section until section becomes entirely silt. Interbedded sand and silt are parallel-bedded, lower-flow regime with soft-sediment loading deformation. The entire sequence is folded so that bedding strikes N45°W and dips 45°N. Bedding is truncated and cut by shears. Plant material from a wispy silt layer within a much thicker sand bed (Fig. 1; Columnar Section 3) yielded an AMS radiocarbon age of 19,040 ±130 yr B.P. (Beta 213390; acid/alkali/acid pretreatment; 2σ Cal BP23260 to 21960). The basal silt is distorted and sheared, with major shears dipping to the north and normal to ice flow direction, being best exposed at the south end of Cutts Island. This silt is similar to other distorted and sheared silts, such as those on Raft Island, the beach at Kopachuck State Park (not shown due to limited outcrop and occurrence in a landslide deposit), and Fox Island (not in map area and within a landslide deposit). The silt in sec. 34, T22N R1E, (see unit Qc above) is similar in appearance to the deformed silts but is undeformed and may be unit Qc_o in situ.

Qcpg **Pre-Olympia nonglacial sediment (Cross Section A only)**—Sand and gravel with silt, peat, and tephra layers; moderately to heavily oxidized.

Undifferentiated Quaternary Deposits

Qu **Undifferentiated Quaternary deposits—**Vashon and pre-Vashon Pleistocene deposits in near-vertical bluff exposures not depictable at map scale; may contain any of the above units; see breakdown of units where illustrated as columnar sections at points along shorelines.

Qps **Pre-Vashon deposits of unknown age, fine-grained (Cross Section B and columnar sections only)**—Silt and clay, with some sandy interbeds; laminated to massive; hard; localized iron-oxide cemented layers and sandy partings.

Qpg **Pre-Vashon deposits of unknown age, coarse-grained**—Sand and gravel with some silt and silt layers; lightly to moderately oxidized; very dense; localized iron-oxide cemented layers and channels.

Qpt **Pre-Vashon till (cross sections only)**—Compact silty, sandy, and gravelly material interpreted from water-well logs as till that is older than unit Qc_o.

GEOLOGIC SYMBOLS

Contact

Figure 1 — Figure location

3 — Columnar section location

1 — Radiocarbon age-date location

A6 — Water well

B4 — Water well in cross section

ml — Modified land—Fill of unknown materials forming the dam that impounds Sylvia Lake.

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Geologic Map of the Fox Island 7.5-minute Quadrangle, Pierce County, Washington

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