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Ground-Water Flooding in Glacial Terrain of Southern Puget Sound, Washington

Figure 1. Proglacial Lake Puyallup and successive Lake Spillways (modified from Thorson, 1979).

Ground-water flooding happens in low-lying areas when the water table rises above the land surface. In the complex glacial geologic framework of southern Puget Sound, this phenomenon can occur along former outwash channel depressions after two or more consecutive years of above-average precipitation. It has also occurred and been documented in the glacial environment found in Illinois.[12] An examination of the geomorphic history and processes associated with the last period of glaciation provides insight on the causes of this unique and persistent flooding problem of the southern Puget Sound.

The present topographic shape and form of the southern Puget Sound Lowland has been largely influenced by the most recent glacial advance and retreat. The passage of the glacier from north to south left distinctive landforms, such as ice contact, north-south-trending depressions, outwash channels, kettles, and drumlins. The last extensive glaciation of the southern Puget Sound was the Vashon Stade of the Fraser Glaciation. The glacier advanced from the north into the Puget Sound Lowland about 18,000 years ago, impounding rivers, creating glacial lakes, and diverting drainage southward to the Chehalis River and then west to the Pacific Ocean to create extensive outwash plains[6, 7, 10]. At its maximum extent, the glacier stretched from the Cascade Range to the Olympic Mountains and extended south as far as Tenino, Wash., in Thurston County, occupying all of the lowland area and lower mountain valleys. The glacier reached altitudes up to 4,000 feet along the mountain front[10]; 6,000 feet near the present day United States-Canada border; 3,000 feet near Seattle; 2,200 feet near Tacoma; and less than 1,000 feet near Olympia.[1, 4, 10]

Due to a global warming trend, the Vashon Glacier began retreating from its terminus about 17,000 years ago.[7] As it retreated, meltwater from the glacier again formed large proglacial lakes. One of the early proglacial lakes that formed in the Pierce County area was Lake Puyallup[9, 13] (fig. 1). Discharge from the proglacial lake cut outwash channels into the upland west of the proglacial lake, and its water and coarse sediment were spread over the central and western parts of this upland region.[2, 13] Large volumes of water from the lake flowed south, originally through the Ohop Valley Spillway. As the ice retreated northward lake levels dropped, and successively lower channel spillways were used: Muck Creek and Kirby, Clover Creek, and South Tacoma Channels, respectively[9, 13] (fig. 1).

The large volumes of water flowing through these spillways modified the upland landforms and, in some places, eroded away sediments deposited during the glacial advance. Coarse sediment, known as the Steilacoom Gravel, was also deposited on the upland by water flowing through the intersecting channels and braided streams that further conveyed the water away from the proglacial lake.[2, 13] This gravel deposit is consistently coarse over the central Pierce County upland area. Stones in the Steilacoom Gravel are predominantly 1 inch in size and most do not exceed 3 inches.[13] The thickness of the gravel is generally 20 feet or less with a maximum that rarely exceeds 60 feet. The resulting landscape is characterized by many shallow, elongated depressions and ice-contact depressions (kettles). The larger and deeper depressions are occupied by ground-water-fed lakes, such as American and Gravelly Lakes.[13]

Over time, surface-water streams developed over this upland in many of the braided stream channels at the base of the outwash channels (Ohop Valley Spillway and Ohop Creek; Muck Creek Channel and Muck Creek; Clover Creek Channel and Clover Creek;

A. Ground-water flooding near Clover Creek, April 4, 1997 (photo by A.K. Williamson, USGS 1997).

B. Ground-water flooding near Stony Lake, April 4, 1997 (photo by A.K. Williamson, USGS 1997).

and the South Tacoma Channel and Flett Creek), except for the area west of the Kirby Channel. This outwash channel never developed surface-water streams; instead, it contains many small, shallow, ground-water-fed lakes and marshes in the abandoned braided stream channels. Under certain conditions, however, when the ground-water levels rise to elevations that intersect and inundate low-lying areas west of the Kirby Channel, ground-water flooding occurs (fig. 2). This phenomenon is hard to distinguish from, and is often mistaken for depression ground-water flooding, in which surface runoff collects in low-lying, low-permeability areas. In both types of flooding, it can take several months for the ground water to recede from the area. Many areas of nearby Thurston County exhibited depression flooding during the winter of 1996-97. In most cases, the water levels of these ponded areas were above the surrounding water table.

Most of the flooding that occurred in Pierce County during the winter and spring of 1996-97 is thought to be from ground-water flooding. Anecdotal accounts of the general location and extent of the flooding are shown on the map. A complete account of the flooding is unknown. The information available is based on oral communication and local reports in residential and industrial areas.[3, 5, 11] Little if any information is known about the occurrence of flooding in the unpopulated areas.

Ground-water elevations for the area west of the town of Frederickson for March 1997[5] indicate that the ground-water flow follows the abandoned stream channel and flows southeast to northwest toward Spanaway Lake and local surface-water drainages at an estimated velocity of 1,000 feet per year.[5] This results in a unique phenomenon in some channels often called transient ground-water flooding, in which the ground-water flooding moves progressively down the outwash channel.

The observed ground-water flooding is generally located within abandoned stream channels west of the Kirby Channel. Several small ground-water-fed lakes are present in the northernmost channel; the only named one is Stony Lake. During the flooding event of March 1997, this lake and the other lakes expanded and flooded homes **(insert B)** and roadways **(insert C)**. The small lake near 192nd Street East expanded during March to an area covering about 25 acres, flooding 192nd Street East **(insert C)**, closing the road and remained flooded for several months. Water over the roadway was reported to be about 4 feet deep.[5] Also, normally dry topographic lows within all three abandoned stream channels flooded (**see map and inserts A and D**).

Information on the depth and extent of flooding in the westernmost abandoned stream channel is minimal because the area is unpopulated and lies within the Fort Lewis Military Boundary. What is known is that the 36-inch culverts near 235th Street East and Highway 7 and near 208th Street East and 8th Avenue East were filled with moving water during the flooding in February and March 1999.[8] Water also backed up against 208th Street East and flooded Highway 7 with 1.5 feet to 2 feet of water, just south of the Highways 7 and 507 junction, closing the road for a short time.[8]

The conditions that have been associated with the incidence of ground-water flooding are sequential (2 or 3) years of above-average precipitation,[3, 5, 11] and cool, wet springs with mild summers. The excess precipitation increases the recharge to the ground-water system, resulting in higher ground-water levels. Cooler temperatures reduce the amount of evapotranspiration from plants and water bodies, which helps to maintain the higher ground-water levels. These factors, combined with the hydrogeologic properties of the glacial deposits, lead to increased ground-water storage. When the total available ground-water storage is exceeded, ground-water flooding occurs.

Other conditions that may also contribute to ground-water flooding are based on changes in land use. The conversion of undeveloped forested areas into developed commercial and residential areas potentially reduces the evapotranspiration and may increase the rate and amount of precipitation available to recharge the ground-water system through septic systems, irrigation, and certain types of drainage systems.

D. Ground-water flooding near Eustis Road, April 4, 1997 (photo by A.K. Williamson, USGS 1997).

C. Ground-water flooding over 192nd Street East, April 4, 1997 (photo by A.K. Williamson, USGS 1997).

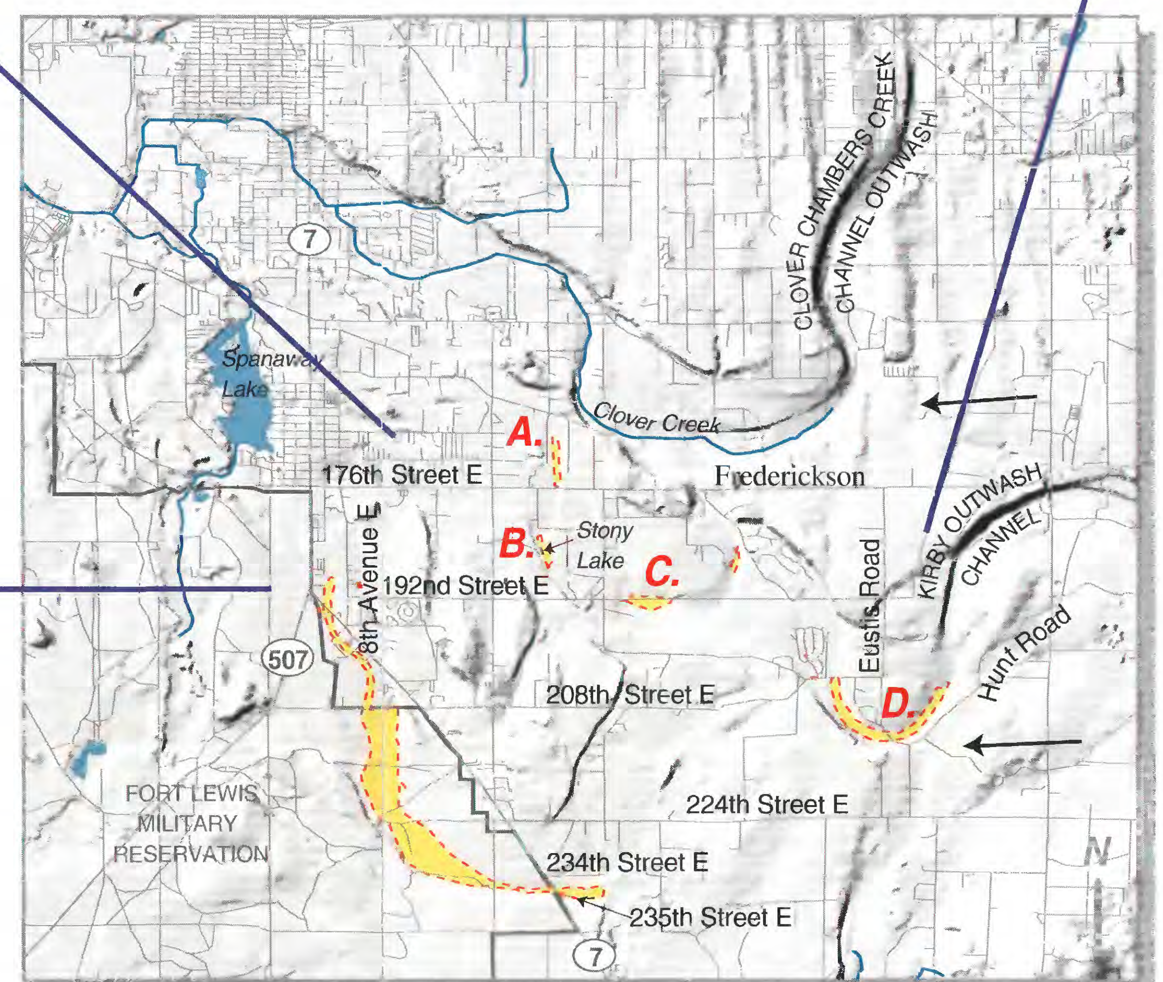

Figure 2. Known areas and approximate extent of ground-water flooding, Pierce County, Washington, 1996. Arrows show the general direction of regional ground-water movement.

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*Natural hazards include flooding, landslides, volcanic eruptions, and earthquakes. The **best protection** for you, your family, and community is to **find out** if you live in a natural hazard zone. **Ask** your public officials advice on where to go and what to do during an emergency. Then **develop** an emergency plan with your family, community, or business to help you safely respond during any natural disaster. Advice and information on the potential natural hazards in your area may be obtained by contacting your local engineering or emergency management officials.*

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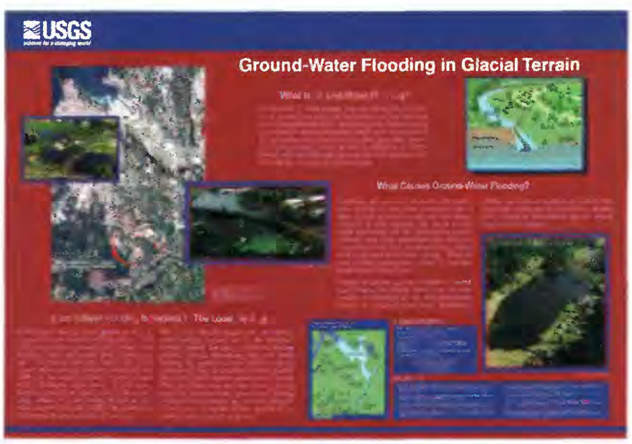

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