Prepared in cooperation with the Tulalip Tribes

Water Resources of the Tulalip Indian Reservation and Adjacent Area, Snohomish County, Washington, 2001-03

Scientific Investigations Report 2004–5166

U.S. Department of the Interior
U.S. Geological Survey

Cover: Aerial photograph of Tulalip Bay of the Tulalip Indian Reservation.
(Photograph provided by the Tulalip Tribes, 2003).

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By Lonna M. Frans and David L. Kresch

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[In pocket]

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Conversion Factors and Datums

CONVERSION FACTORS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
acre-foot (acre-ft)	1,233	cubic meter
cubic foot (ft^2)	0.02932	cubic meter
gallon (gal)	0.003785	cubic meter
	Flow rate	
foot per day (ft/d)	0.3048	meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per day (gal/d)	0.003785	cubic meter per day
inch per year (in/yr)	25.4	millimeter per year
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

DATUMS

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929). Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above or below sea level.

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Water Resources of the Tulalip Indian Reservation and Adjacent Area, Snohomish County, Washington, 2001–03

By Lonna M. Frans and David L. Kresch

Abstract

This study was undertaken to improve the understanding of water resources of the Tulalip Plateau area, with a primary emphasis on the Tulalip Indian Reservation, in order to address concerns of the Tulalip Tribes about the effects of current and future development, both on and off the Reservation, on their water resources. The drinking-water supply for the Reservation comes almost entirely from ground water, so increasing population will continue to put more pressure on this resource. The study evaluated the current state of ground- and surface-water resources and comparing results with those of studies in the 1970s and 1980s. The study included updating descriptions of the hydrologic framework and ground-water system, determining if discharge and base flow in streams and lake stage have changed significantly since the 1970s, and preparing new estimates of the water budget.

The hydrogeologic framework was described using data collected from 255 wells, including their location and lithology. Data collected for the Reservation water budget included continuous and periodic streamflow measurements, micrometeorological data including daily precipitation, temperature, and solar radiation, water-use data, and atmospheric chloride deposition collected under both wet- and dry-deposition conditions to estimate ground-water recharge.

The Tulalip Plateau is composed of unconsolidated sediments of Quaternary age that are mostly of glacial origin. There are three aquifers and two confining units as well as two smaller units that are only localized in extent. The Vashon recessional outwash (Qvr) is the smallest of the three aquifers and lies in the Marysville Trough on the eastern part of the study area. The primary aquifer in terms of use is the Vashon advance outwash (Qva). The Vashon till (Qvt) and the transitional beds (Qtb) act as confining units. The Vashon till overlies Qva and the transitional beds underlie Qva and separate it from the undifferentiated sediments (Qu), which are also a principal aquifer of the plateau. The undifferentiated-sediments aquifer is present throughout the entire study area, but is not well defined because few wells penetrate it. Ground water flows radially outward from the center of the Plateau in the Vashon advance outwash aquifer.

Water levels fluctuate seasonally in all hydrogeologic units in response to changes in precipitation over the course of the year. However, water levels do not appear to have changed significantly over the long term. There was no statistically significant change between water levels measured in 72 wells in the early 1990s and 2001. Additionally, when a rank sum test was used to compare monthly water levels measured in 18 wells for this study with monthly water levels from the 1970s and 1980s, water levels increased in some wells, decreased in some, and did not change significantly in others.

Ground water in the study area is recharged from precipitation that percolates down from the land surface. Average annual recharge, estimated using the chloride-mass-balance method, was 10.4 inches per year.

Current streamflow conditions on the Reservation were defined by four continuous-record streamflow-gaging stations operated from April 2001 through March 2003 and monthly measurements of discharge at 12 periodic-measurement sites. Two continuous-record gaging stations (12157250 and 12158040) near the mouths of Mission and Tulalip Creeks, respectively, also were operated during water years 1975-77.

Correlations of streamflow for Mission and Tulalip Creeks with the long-term record of streamflow at Mercer Creek (station 12120000) indicate no significant change in streamflow between the mid-1970s and 2001–03 in Mission and Tulalip Creeks. However, comparisons between the percentage of change in precipitation at the Everett precipitation station and percentages of change in streamflow at the Mercer, Mission, and Tulalip Creek gaging stations from the mid-1970s through 2001–03 indicate no significant change in streamflow in Mission Creek, but streamflow in Tulalip Creek appeared to have increased by as much as 15 percent. Comparisons of the percentage of streamflow contributed by base flow in the mid-1970s and 2001–03 strongly suggest that the current relations of base flow to total streamflow in Mission and Tulalip Creeks are essentially the same as they were during water years 1975-77.

A water budget constructed for the Reservation shows inflows to the Reservation of 84 ft^3/s (cubic feet per second) of precipitation, 13 ft^3/s of surface-water inflow, and 5 ft^3/s subsurface inflow, and outflows of 44 ft^3/s of evapotranspiration, 38 ft^3/s of surface-water outflow, 1 ft^3/s of net ground-water withdrawals, and 19 ft^3/s of subsurface outflow.

Introduction

The water resources of the Tulalip Indian Reservation are of fundamental importance to the Tulalip Tribes of western Washington, who depend on their water and fisheries for subsistence, income, and ceremonial and cultural purposes (Tulalip Tribes, 1994). In the 1970s, the U.S. Geological Survey (USGS) assessed the ground-water and surface-water resources of the Reservation and estimated a water budget (Drost 1977, 1979, 1983). Since that time, population and development, both on the Reservation and in adjacent areas, have increased rapidly. The Tribes are concerned about the effects of current and future development, both on and off the Reservation, on their water resources.

To address the Tribes' concerns, the USGS, in cooperation with the Tulalip Tribes, evaluated the current state of the ground- and surface-water resources of the Tulalip Indian Reservation and adjacent areas during 2001–03. The study included updating the descriptions of the hydrogeologic framework and ground-water system, determining if discharge and base flow in streams and lake stage have changed significantly since the late 1970s, and preparing new estimates of the water budget.

Purpose and Scope

This report presents an assessment of the current ground- and surface-water resources and water budget for the Tulalip Indian Reservation and adjacent area for 2001-03 and a comparison of the results with the results of studies in the 1970s and 1980s to determine if conditions have changed with increases in development and population. The results include (1) an updated and more detailed description of the hydrogeologic framework and properties of the ground-water system; (2) an estimate of recharge using the chloride mass-balance method; (3) an assessment of changes in discharge and base flow in the two main creeks on the Reservation and changes in lake stage in three lakes; and (4) an updated water budget for the Reservation.

During 2001–03, hydrologic and meteorologic data were collected and analyzed to prepare a water budget for the Reservation and develop a hydrogeologic framework for the Reservation and adjacent area.

Streamflow data collected at streamflow-gaging stations near the mouths of Tulalip and Mission Creeks during 2001–03 were compared with data collected at the same gaging stations during 1975–77 to determine if significant changes in base flow and total streamflow have occurred in the Tulalip and Mission Creek drainage basins.

Description of Study Area

The study area is located in the Puget Sound Lowland in the west-central part of Snohomish County, Washington, and includes the Tulalip Indian Reservation, the western part of the Marysville Trough and other adjacent areas that contribute to the ground- and surface-water systems (fig. 1). The study area is bounded by Puget Sound on the south and west, Interstate 5 on the east, and the Stillaguamish River and Hat Slough on the north. The land-surface area of the Reservation is about 35.2 mi^2.

The principal streams on the Tulalip Indian Reservation are Mission, Tulalip, and Quilceda Creeks. Mission Creek drains an area of 7.92 mi^2, all of which is on the Reservation. Tulalip Creek drains an area of 15.4 mi^2, about 9.3 mi^2 of which is on the Reservation. The remaining 6.1 mi^2 lies north of the Reservation and includes Goodwin and Shoecraft Lakes, which have a combined surface area of about 1.1 mi^2. The Tulalip Tribes operate a fish hatchery on Tulalip Creek. Quilceda Creek drains an area of about 42.2 mi^2, about 9.9 mi^2 of which is on the Reservation. Sturgeon Creek, a small tributary to Quilceda Creek, drains an area of about 1.87 mi^2. The Reservation includes five principal lakes ranging is size from 11.1 to 23 acres.

The study area has a temperate marine climate that is typical of the Puget Sound Lowland, with warm, dry summers and cool, wet winters. The average annual precipitation at Everett, just southeast of the study area, is 37.54 in/yr for 1971–2000, and November and December are the wettest months and July and August the driest (fig. 2). Precipitation at Everett during the 2 years of data collection for this study was 42.60 in. from April 2001 to March 2002 and 27.15 in. from April 2002 to March 2003. These amounts are 113 and 72 percent of the long-term average, respectively. Temperatures are mild throughout the year. The average monthly maximum is 73.9°F in August and the average monthly minimum is 33.6°F in January (fig. 2).

According to the 2000 census, 9,246 people were living on the Reservation in 2000, which represents an increase of more than 30 percent from 7,103 people in 1990 (fig. 3; U.S. Census Bureau, 2000). There were 3,314 permanent households on the Reservation, and an additional 230 for seasonal (summer vacation) use. The average household size was 2.79 people per housing unit. Population is expected to increase by more than 86 percent on the Reservation by the year 2030 and by more than 48 percent on the remainder of the Tulalip Plateau (Puget Sound Regional Council, 2000). Currently, most of the population on the Reservation lives along the coast or on the Marysville Trough. Most of the population in the adjacent area is concentrated around Lakes Shoecraft and Goodwin.

Using current zoning regulations (Anne Savery, Tulalip Tribes, written commun., 2003), the population of the Reservation theoretically could reach more than 75,750 people, assuming complete development of the Reservation land with single-family homes with 2.79 people per housing unit. However, such a scenario is unlikely, because not all of the currently zoned commercial or industrial land, which allows the highest density of homes, is likely to be developed with single-family homes.

Figure 1. Location of the Tulalip Indian Reservation and adjacent area included in the 2001–03 water-resources assessment, Snohomish County, Washington.

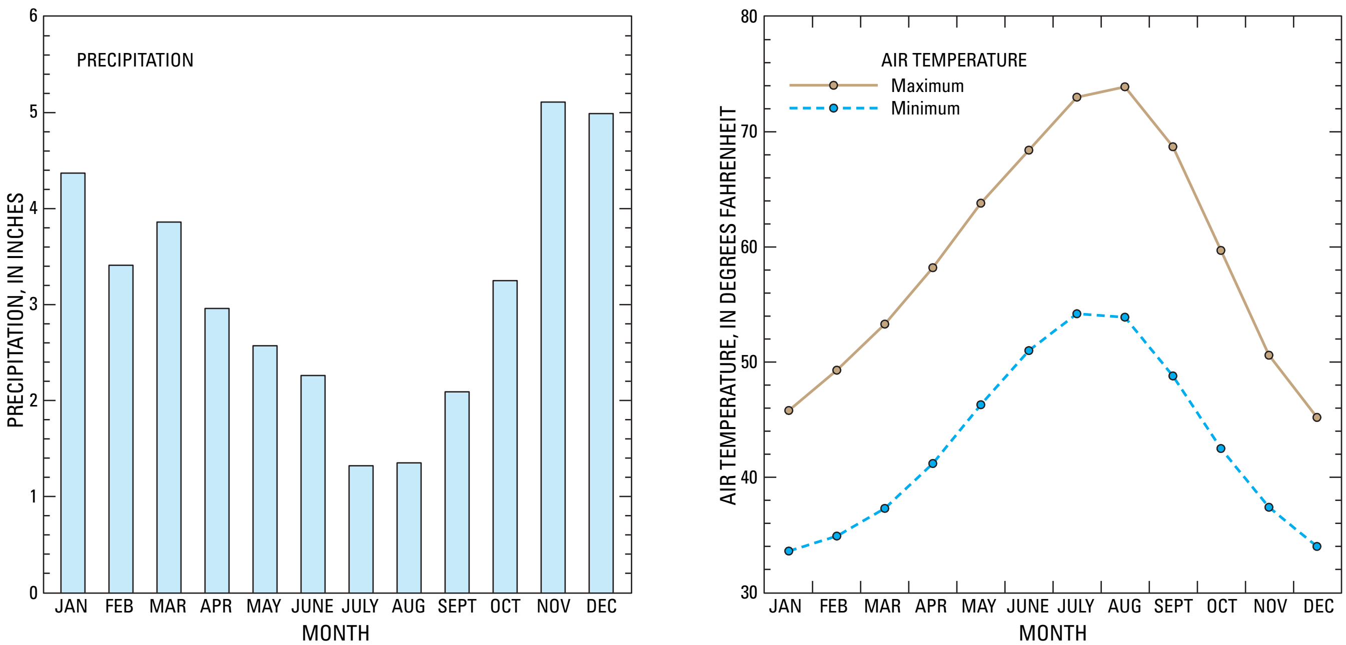


Figure 2. Average monthly precipitation and air temperature for Everett, Washington, 1971–2000. (Data from National Oceanic and Atmospheric Administration, 2002.)

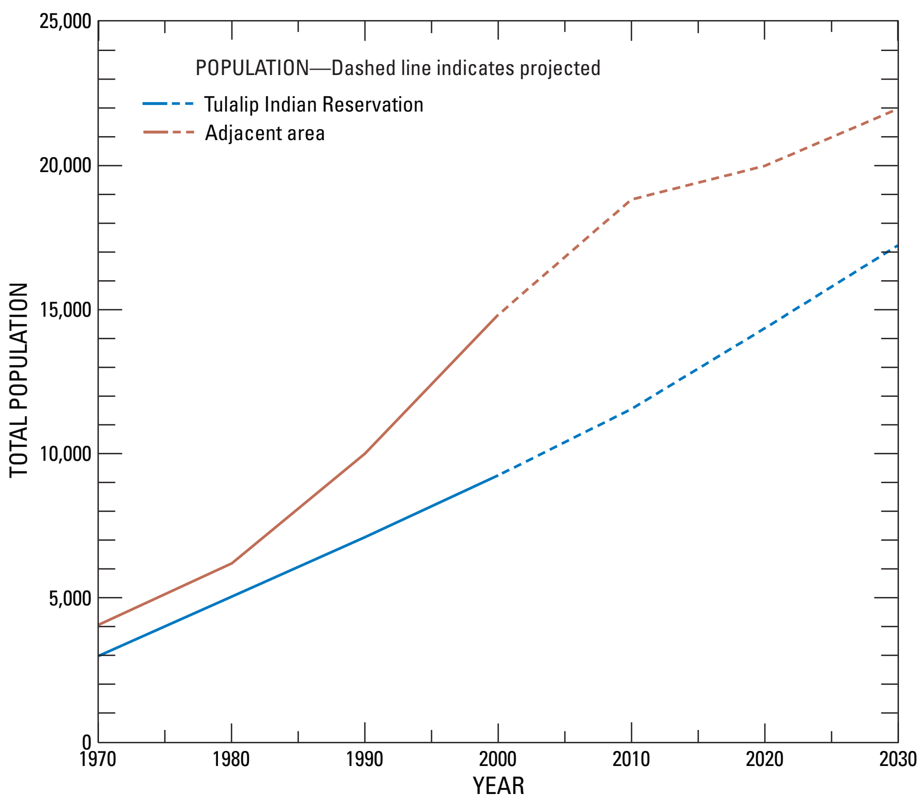


Figure 3. Population trends from 1970–2000 and projections for 2000–2030 for the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

Previous Studies

Newcomb (1952) provided the first comprehensive study of water resources in Snohomish County in the 1940s. Drost (1977, 1979, 1983) evaluated the water resources of the Tulalip Reservation, including an assessment of the Reservation's surface-water resources and development of a hydrogeologic framework for the ground-water system and a water budget. Pessl and others (1989) mapped the surficial geology of the study area. Thomas and others (1997) provided the most recent study of the ground-water resources of western Snohomish County and developed a more detailed hydrogeologic framework than that of Drost (1983). Thomas and others (1997) provided the basis for the interpretation of the subsurface geology for this study.

Well-Numbering System

The well-numbering system used by the USGS in Washington State is based on the rectangular subdivision of public land, and indicates township, range, section, and 40-acre tract within the section (fig. 4). For example, in well 30N/04E-08G02, the part preceding the hyphen indicates the township and range (T. 30 N., R. 04 E.) north and east of the Willamette base line and meridian, respectively. The first number following the hyphen (08) indicates the section, and the letter (G) gives the 40-acre tract within that section. The last number (02) is the sequence number of the well in that 40-acre tract, and it indicates that the well was the second one inventoried by USGS personnel.

Acknowledgments

The authors acknowledge the cooperation of the many well owners who provided access and information regarding their wells for this study. The authors also thank Anne Savery, Abby Hook, and Ralph Jones of the Tulalip Tribes Department of Natural Resources for assisting with field work and providing information in response to the authors' many questions. The Tulalip Tribes operated the micrometeorological station and precipitation gages.

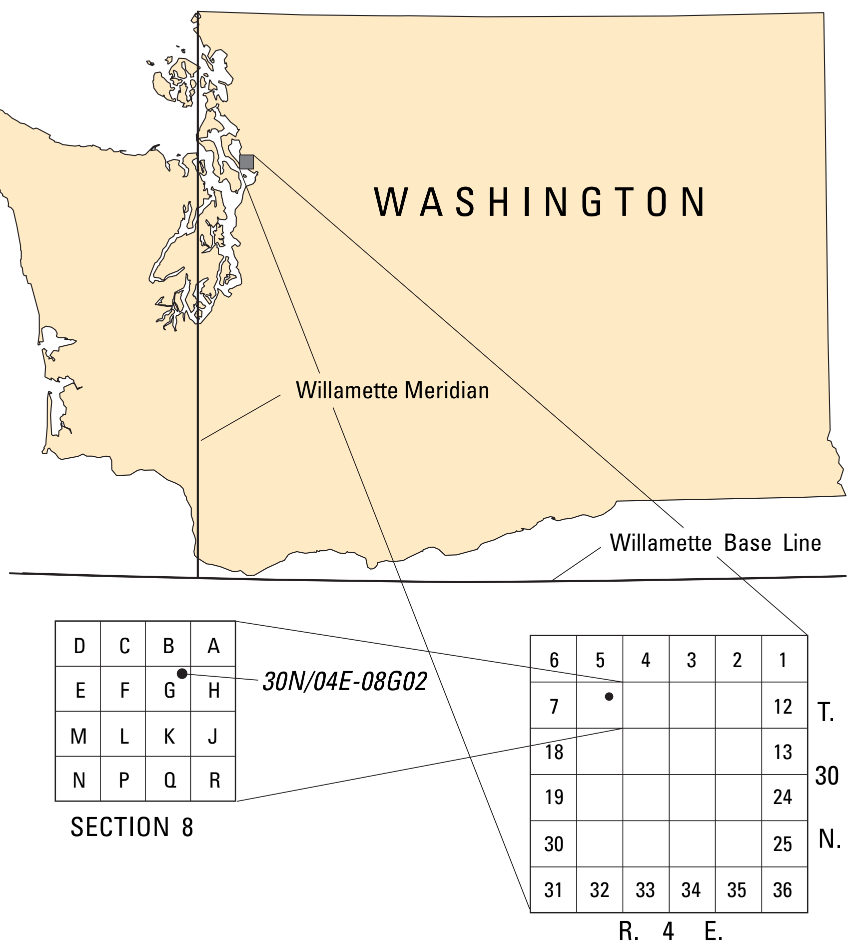


Figure 4. Well-numbering system used in Washington.

Methods of Investigation

Ground-water, surface-water, meteorological, and atmospheric-chloride deposition data were collect during 2001-03 to assess the current water resources of the Tulalip Indian Reservation and compare the results with the 1970s assessment. Special methods were used to determine some of the information needed for the assessment.

Data Collection

Ground-water wells, streamflow measurements, precipitation and other meteorological data, and amount of atmospheric-chloride deposition were the primary sources of information used to define the current hydrogeologic framework and ground- and surface-water systems and to compute the current Reservation water budget. The hydrogeologic framework was constructed by correlating the lithology between individual wells described in drillers' well logs. Ground-water flow and hydraulic properties of the aquifers were estimated by measuring water levels and using well-pumpage data, respectively. Ground-water recharge was estimated using precipitation, surface runoff, and atmospheric-chloride deposition data. Surface runoff was estimated by analyzing streamflow-measurement data.

Data from 259 wells were used in this study (fig. 5). Data were collected from 171 wells during the spring and summer of 2001. The location of each well was determined using a global positioning system (GPS) and the altitude of each well was estimated by plotting the well on a 7.5-minute topographic map. Data from the other 88 wells were collected during previous studies. The physical and hydrologic data for the 259 wells are included in table 17 (at back of report).

Water levels were measured at 127 wells during a 1-week period in October 2001, and water levels were measured in 23 of those wells approximately monthly over the course of the study. Monthly water-level measurements are included in table 18 (at back of report).

To estimate the current surface-water resources of the Reservation, four continuous-record streamflow-gaging stations were installed at the mouths of Tulalip and Mission Creeks, on Tulalip Creek above the east branch, and on the east branch of Tulalip Creek and monthly streamflow measurements were made at 12 periodic-measurement sites (fig. 6 and table 1).

The streamflow records collected at several of the continuous-record gaging stations and periodic-measurement sites were used to estimate the inflow to and outflow from the Reservation to account for the surface-water component of the water budget for the Reservation.

To estimate precipitation and evapotranspiration, a micrometeorological station measured daily precipitation, temperature, and solar radiation and two precipitation stations measured precipitation only (fig. 6).

To estimate ground-water recharge, two atmospheric-chloride deposition-collection stations were installed to measure chloride concentrations under both wet- and dry-deposition conditions. The chloride mass-balance method involves sampling chloride from the atmosphere (precipitation and dry deposition), the water table, and(or) the unsaturated-zone soil moisture. Chloride concentrations were determined from samples of both precipitation and dry atmospheric deposition for April 2001 to March 2003 and from 17 ground-water samples in December 2001.

Two atmospheric-chloride deposition-collection sites were established on the Tulalip Indian Reservation, one along Fire Trail Road on the north side of the Reservation and one near the Tulalip Tribes Department of Natural Resources Office in Tulalip, Washington (fig. 6). The wet/dry atmospheric sampler consists of two buckets mounted on an electromechanical device that senses precipitation and automatically places a cover on one or the other of the buckets. During periods of precipitation, the "dry" bucket is covered while the "wet" bucket collects precipitation. When it is not raining, the "wet" bucket is covered to prevent any influx from the dry atmosphere (including insects, bird droppings, and wind-blown ground debris) and to minimize evaporation. At the same time, the dry bucket is open to collect microscopic crystals of chloride salts that fall from the atmosphere.

The sampling buckets were collected and replaced with clean buckets on a monthly basis. All bucket samples were weighed, and filtered aliquots were sent to the USGS Laboratory in Ocala, Fla., for low-level chloride determinations. Aliquots from the dry buckets were taken by adding a known quantity of distilled water to the bucket, swirling thoroughly, and then sampling.

The ground-water samples collected in December 2001 were sent to the National Water Quality Laboratory in Denver, Colo., for determination of chloride concentrations.

Hydrogeologic Framework

The hydrogeologic framework describes the boundaries and lithology of the hydrogeologic units (aquifers and confining beds) in the study area. The hydrogeologic framework is defined in a map of the surficial hydrogeology, cross sections of the subsurface, and maps of areal extent and altitude of the upper surface of the hydrogeologic units. Drillers' logs of wells containing descriptions of lithology were the principal source of information. Much of the hydrogeologic analysis was performed using a geographic information system that included spatial databases of locations and lithologic information for 255 wells, surficial geology (Pessl and others, 1989), and digital land-surface altitudes (30-meter cell size) obtained from 1:24,000-scale topographic maps.

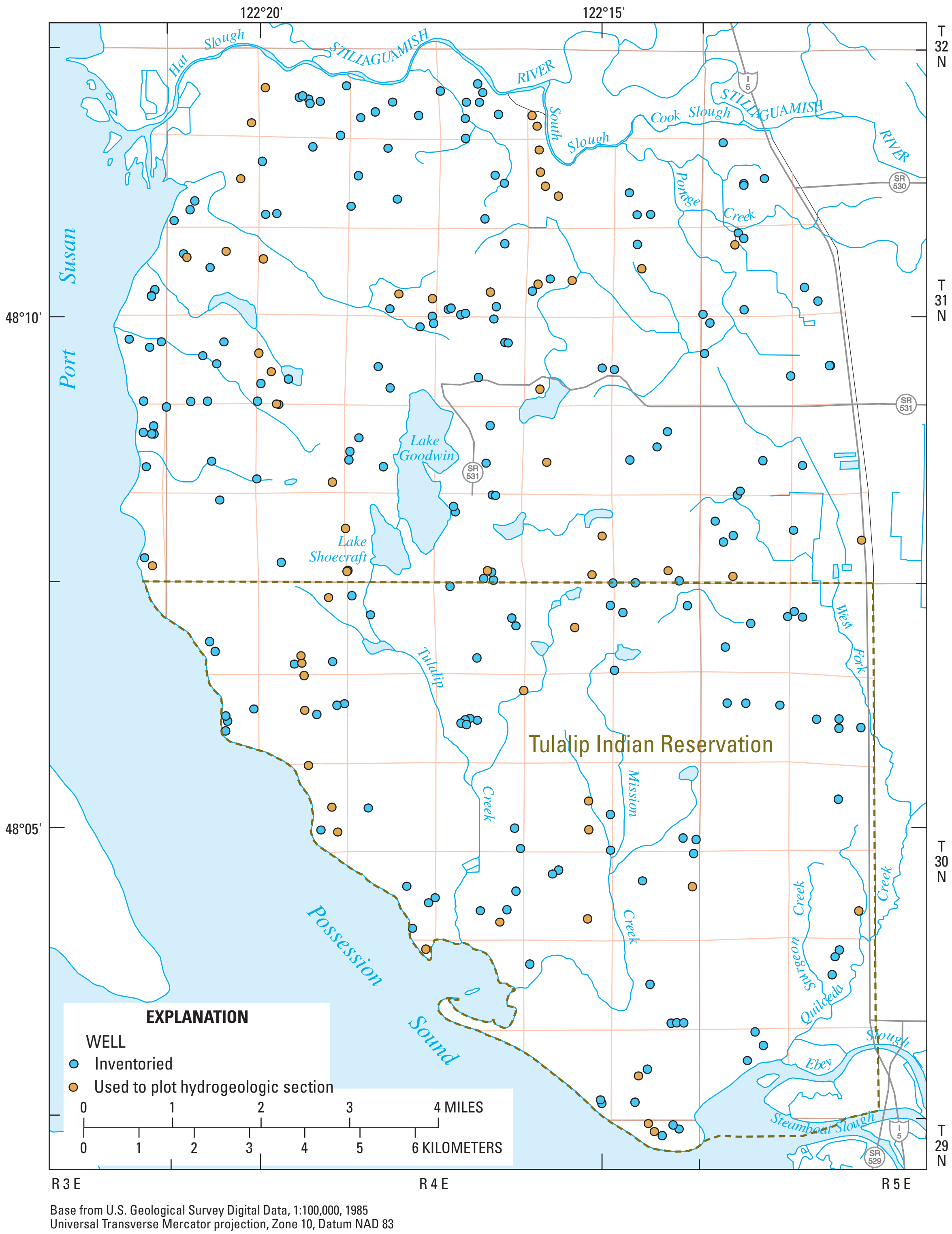
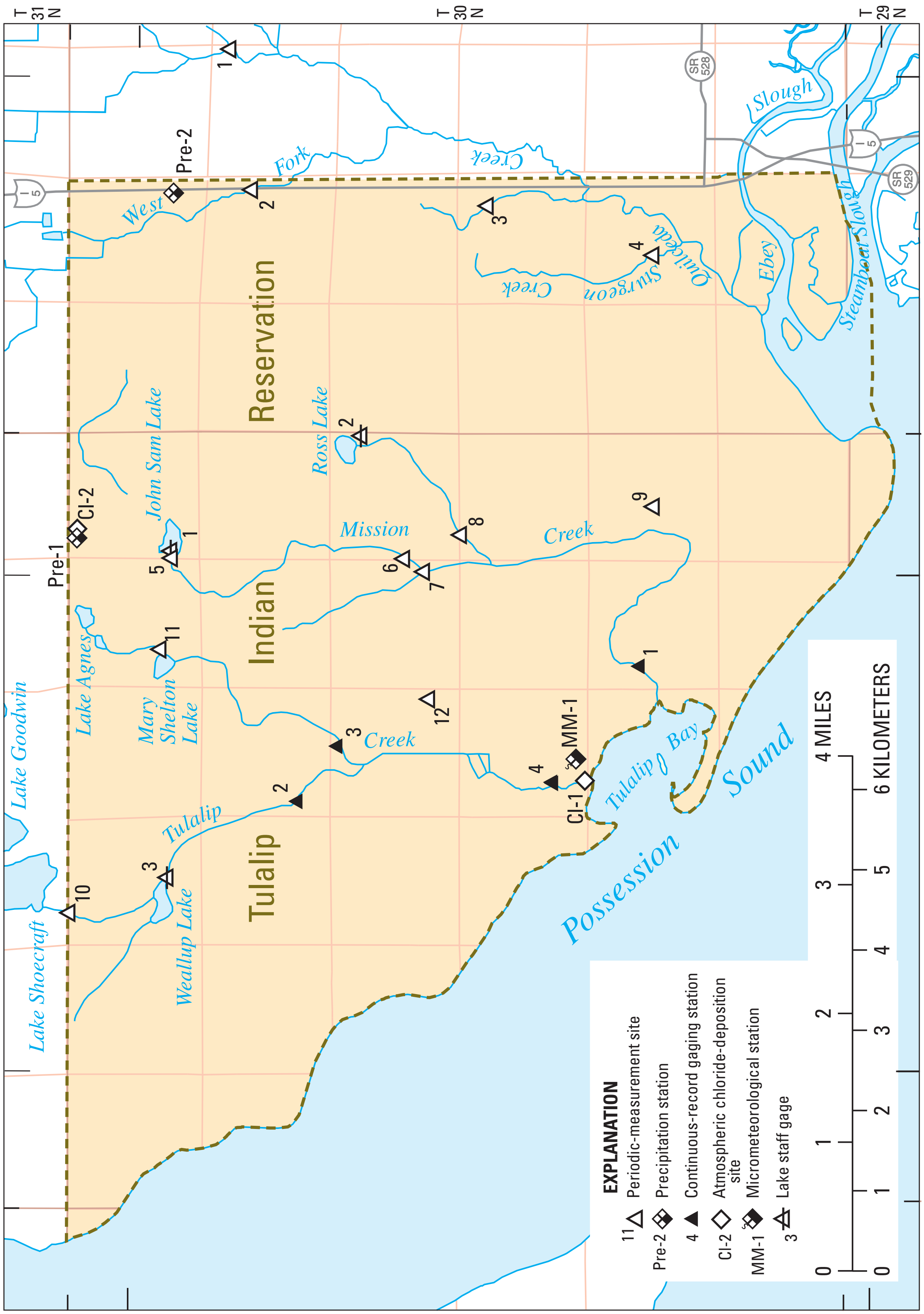


Figure 5. Locations of wells used during the assessment of water resources of the Tulalip Indian Reservation and the adjacent area, Snohomish County, Washington, 2001.



Base from U.S. Geological Survey Digital Data, 1:100,000, 1985
Universal Transverse Mercator projection, Zone 10, Datum NAD 83

Figure 6. Locations of sites where surface-water and meteorological data were collected during climatic years 2002–03 on the Tulalip Indian Reservation, Snohomish County, Washington.

Table 1. Surface-water sites on the Tulalip Indian Reservation, Snohomish County, Washington.

[mi^2, square mile; –, not applicable]

Reference No. on figure 6	U.S. Geological Survey (USGS) station No.	Station name	Drainage area (mi^2)
Continuous-record streamflow-gaging stations			
1	12157250	Mission Creek near Tulalip	7.92
2	12158010	Tulalip Creek above East Branch, near Tulalip	9.74
3	12158032	East Branch Tulalip Creek near mouth, near Tulalip	1.75
4	12158040	Tulalip Creek near Tulalip	15.4
Periodic-measurement sites			
1	12157000	Quilceda Creek near Marysville	15.4
2	12157020	West Fork Quilceda Creek near Marysville	9.41
3	12157030	Quilceda Creek Tributary near Marysville	2.88
4	12157035	Sturgeon Creek at Marysville	1.87
5	12157140	Mission Creek below John Sam Lake, near Tulalip	.33
6	12157150	Mission Creek near Marysville	1.34
7	12157170	Mission Creek Tributary near Tulalip	1.33
8	12157210	Mission Creek Tributary #2 near Tulalip	1.57
9	–	Unnamed spring	–
10	12158001	Lake Shoecraft outlet near Tulalip	6.12
11	12158025	East Branch Tulalip Creek above Mary Shelton Lake, near Tulalip	.80
12	–	Unnamed spring	–
Lake staff gages			
1	12157130	John Sam Lake near Tulalip	–
2	12157200	Ross Lake near Marysville	–
3	12158007	Weallup Lake at outlet, near Tulalip	–

The boundaries of the hydrogeologic units were defined by analyzing and correlating surficial geology, land-surface altitudes, and lithologic information from wells. The eight hydrogeologic units defined previously in western Snohomish County by Thomas and others (1997) were used in this study, and the hydrogeologic maps produced in this study up date those first presented in Thomas and others (1997) for the Tulalip Plateau part of Snohomish County.

The first step in the analysis was to match the lithology described in drillers' logs for the 255 wells with previously described hydrogeologic units and determine top and bottom surfaces of each unit. The horizontal extent of each hydrogeologic unit was defined using the information in the geologic maps and lithologic information from the wells. The altitude of the top surface of each unit was then determined by plotting the altitude of the unit surface at each well location and drawing contours through the data. The next step was to construct three east-west and two north-south cross sections using lithologic information from 54 wells. The land surface of the cross sections was obtained from 30-meter cell-size-resolution digital-elevation models (DEMs).

Hydraulic Properties

Horizontal hydraulic conductivity of the hydrogeologic units was estimated in this study from specific-capacity data obtained from driller's logs of the study wells. The specific-capacity data were converted to hydraulic conductivity using either of two equations, depending on the method of construction of the well. Only data from wells with complete specific-capacity information (discharge rate, discharge time, drawdown, well-construction data, and lithologic log) were used.

For wells that had a screened or perforated interval, the modified Theis equation (Ferris and others, 1962) was used to estimate transmissivity values. This equation, solved for transmissivity using an iterative method, is

$$T = \frac{Q}{4\pi s}\ln\frac{2.25Tt}{r^2S} \quad , \tag{1}$$

where

T = transmissivity of the hydrogeologic unit, in square feet per day;

Q = discharge, or pumping rate, of the well, in cubic feet per day;

s = drawdown in the well, in feet;

t = length of time the well was pumped, in days;

r = radius of the well, in feet; and

S = storage coefficient, dimensionless.

The storage coefficients used in eq. 1 were 0.10 for the unconfined units and 0.0001 for all confined units, as was used in Thomas and others (1997).

Horizontal hydraulic conductivity was computed using the transmissivity from eq. 1 and the following equation:

$$K_h = \frac{T}{b} \tag{2}$$

where

K_h = horizontal hydraulic conductivity of the hydrogeologic unit, in feet per day;

T = transmissivity, as calculated above; and

b = thickness of the hydrogeologic unit, in feet, approximated by the length of the open interval as described in the drillers' water well report.

The use of the open interval to approximate the thickness of a hydrogeologic unit assumes that the wells are open through the entire thickness of the unit, which was never the case. Nevertheless, this assumption is necessary because the equations as derived assume only horizontal flow; in a homogeneous hydrogeologic unit, horizontal flow can be measured only if a well penetrates the entire unit thickness. However, in heterogeneous and anisotropic glacial hydrogeologic units, such as those in the study area, vertical flow is likely to be much smaller than horizontal flow because the layering of the geologic materials leads to horizontal hydraulic conductivities that generally are much larger than vertical hydraulic conductivities. Thus, the assumption that the open interval represents unit thickness is considered reasonable.

A second equation was used to estimate hydraulic conductivity for wells having only an open end, and thus no vertical dimension to the opening. Bear (1979) provides an equation for hemispherical flow to an open-ended well that just penetrates the upper part of an aquifer. When modified for spherical flow to an open-ended well within an aquifer, the equation becomes

$$K_h = \frac{Q}{4\pi sr} \tag{3}$$

where

K_h = horizontal hydraulic conductivity of the hydrogeologic unit, in feet per day;

Q = discharge, or pumping rate of the well, in cubic feet per day;

s = drawdown in the well, in feet; and

r = radius of the well, in feet.

Eq. 3 is based on the assumption that ground water can flow at the same rate in all directions, and specifically that horizontal and vertical hydraulic conductivities are equal. As discussed above, this is not likely to be true for glacial material. However, the errors associated with violating this assumption are likely to be less than those resulting from using eqs. 1 and 2 for open-ended wells.

The average or median hydraulic conductivities estimated for hydrogeologic units in this study are biased toward high values because of the nature of the statistical sample of inventoried wells. The ideal statistical sample of wells would represent all the horizontal and vertical variations of lithology and pore-size structure in the hydrogeologic units. The wells used in this study represent only the more productive parts of the units because they are primarily domestic wells that were drilled for water-supply purposes. When a driller installs a water-supply well, the depth, location, and construction of the well are determined to maximize the amount of water that can be pumped. The less productive fine-grained parts of the hydrogeologic units are bypassed until a coarse-grained productive part is found. The bias toward higher values of hydraulic conductivity is larger for the confining units than for the aquifers. The overall hydraulic conductivity of the confining units is low, but the inventoried wells are located mostly in the discontinuous coarse-grained lenses that have high conductivities. The overall hydraulic conductivity of the aquifers is high because most parts of the aquifers are coarse-grained, and the inventoried wells are likely to be located in the widespread coarse material.

Precipitation

Precipitation was measured monthly at three locations, sites Pre-1, Pre-2, and MM-1, on the Reservation during April 2001 to March 2003 (table 2; fig. 6). Because the precipitation record was not complete, linear regression relations were used to estimate the values for the missing months. The missing months at site Pre-1 were estimated using data from the National Weather Service site at Everett ($R^2 = 0.94$) and the missing months at sites Pre-2 and MM-1 were estimated from the Pre-1 data ($R^2 = 0.88$ and 0.90, respectively). The annual precipitation average for the Reservation is 32.28 in.

Table 2. Monthly precipitation at gaged sites on the Tulalip Indian Reservation and at the National Weather Service site at Everett, Snohomish County, Washington, 2001–03.

[Locations of gaged sites are shown in figure 6. Average values are the average of sites Pre-1, Pre-2, and MM-1. Values in **bold** were estimated using linear regression]

Month	Precipitation, in inches				
	Pre-1	Pre-2	MM-1	Average	Everett
2001					
April	**3.63**	**2.60**	2.08	2.77	2.98
May	**3.42**	1.49	1.49	2.13	2.78
June	5.54	3.56	3.85	4.32	3.93
July	2.24	1.56	**1.21**	1.67	1.90
August	2.12	1.65	1.52	1.76	1.44
September	1.20	1.02	**.60**	.94	1.03
October	5.87	4.69	3.36	4.64	5.33
November	7.35	4.61	4.74	5.57	6.30
December	6.13	5.61	3.01	4.92	5.65
2002					
January	5.84	4.91	2.90	4.55	5.31
February	2.77	2.12	1.25	2.05	2.78
March	4.83	3.82	2.26	3.64	3.36
April	3.76	2.22	**2.09**	2.69	1.91
May	2.73	1.85	1.29	1.96	2.72
June	1.69	1.89	1.26	1.61	1.25
July	1.79	1.02	**.95**	1.25	1.34
August	.42	.36	.21	.33	.11
September	.90	.57	**.43**	.63	.85
October	1.49	1.25	**.77**	1.17	1.25
November	2.61	1.90	**1.42**	1.98	2.15
December	5.46	3.13	**3.08**	3.89	5.11
2003					
January	6.13	4.35	**3.47**	4.65	4.55
February	2.24	1.92	**1.21**	1.79	1.62
March	5.13	2.95	**2.89**	3.66	4.29
Total	85.27	61.05	47.34	64.56	69.75
Annual average	42.64	30.52	23.67	32.28	34.88

Evapotranspiration

Evapotranspiration is the movement of water from land and water on the Earth's surface to the atmosphere through a combination of evaporation and transpiration by plants. Evapotranspiration is discussed in terms of potential evapotranspiration and actual evapotranspiration. Potential evapotranspiration is the amount of water that would evapotranspire, given an unlimited source of water. However, an unlimited source of water is not available, so the actual rate of evapotranspiration is less than the potential rate. In this area, there generally are two times of the year during which precipitation will either be greater than or less than the potential evapotranspiration. When precipitation is greater than potential evapotranspiration, usually during October to April, the actual rate of evapotranspiration equals the potential rate. When precipitation is less than potential evapotranspiration, usually during May to September, the actual rate of evapotranspiration equals precipitation plus any available soil moisture that is stored during the winter months.

Determining the amount of actual evapotranspiration for the study area involves first estimating potential evapotranspiration, using the following method as modified from Bauer and Mastin (1997) and data collected at micro-meteorological station MM-1 (fig. 6). For dates when minimum and maximum temperature and solar-radiation data were missing, a linear regression relation was established using data from a weather station at Tolt River Reservoir (USGS station ID 12147900), which is about 35 mi southeast of the Reservation in the Cascade foothills. The R^2 values for the regression relations were 0.66, 0.92, and 0.80 for minimum and maximum temperature and solar radiation.

Extensive experimental and theoretical evapotranspiration studies have been done for Douglas fir forests in southwestern British Columbia, Canada, using the Priestly-Taylor potential evapotranspiration method (McNaughton and Black, 1973; Black and Spittlehouse, 1981; Spittlehouse and Black, 1981; Giles and others, 1984). Because the method has been calibrated locally for Douglas fir in a northwestern coastal environment, a setting similar to much of the Tulalip Indian Reservation, it was the method used to calculate the potential evapotranspiration.

Potential evaporation from wet surfaces, E_{max}, (expressed as depth of water per unit time), is computed by the Priestly-Taylor equation (Jensen and others, 1990) as:

$$E_{max} = \alpha\left(\frac{s}{s+\gamma}\right)\frac{R_n - G}{\lambda\rho_w} \qquad (4)$$

where

α = coefficient (dimensionless);,
s = slope of the saturation vapor pressure-temperature curve (pressure/temperature);
γ = psychometric constant (pressure/temperature);
R_n = net solar radiation (energy/area/time);
G = heat flux density to the ground (energy/area/time);
λ = latent heat of vaporization of water (energy/mass); and
ρ_w = density of water (mass/volume).

Without local calibration, α=1.26 generally is used for wet surfaces in non-arid areas (Jensen and others, 1990, p. 145). When the foliage is dry and there is only transpiration, which proceeds at a slower rate than wet-surface evaporation, an α must be determined for the specific foliar cover. Giles and others (1984) found that α = 0.73 gave good results in computing growing-season transpiration at seven sites in a 70-year-old Douglas fir-forested area on Vancouver Island, British Columbia, Canada. A previous investigation by Shuttleworth and Calder (1979) used α = 0.72 for two conifer stands in the United Kingdom, and Spittlehouse and Black (1981) used α = 0.80. A higher value of 1.05 was used for a Douglas fir forest with no soil-moisture deficits (McNaughton and Black, 1973). In this study, α = 0.73 is used for dry-foliage transpiration for a conifer forest.

The slope of the saturation vapor-pressure curve, s, is evaluated at the average daytime temperature according to equations cited by Jensen and others (1990, p. 174-175). The psychometric constant, γ, is defined as

$$\gamma = \frac{c_p P}{0.622\lambda} \qquad (5)$$

where

c_p = specific heat of moist air (energy/mass/temperature);
P = atmospheric pressure (pressure); and
0.622 = ratio of the molecular weight of water to that of dry air (dimensionless).

The specific heat of air varies only slightly with humidity, and is assumed to be constant at a value of 1.013 kilojoules per kilogram for moist air. Atmospheric pressure is evaluated as a function of altitude only, and the latent heat of vaporization is evaluated at the average daytime temperature according to formulas cited by Jensen and others (1990, p. 169).

Over a 24-hour period, the net heat-flux density to the ground usually is small in comparison with the net solar radiation and can be ignored for calculations involving periods of 1 day or longer. Transpiration is assumed to occur only during daylight hours. Therefore, the net radiation, R_n, is evaluated only for daytime hours and is the sum of the net daytime shortwave radiation and the net daytime longwave radiation. R_n can be measured directly or can be estimated as follows from incoming short-wave radiation and air temperature.

$$R_n = (1-a)R_s + R_{nl} \tag{6}$$

where

α = albedo of the canopy;

R_s = daytime incoming shortwave radiation (energy/area/time); and

R_{nl} = daytime net longwave radiation (energy/area/time).

The canopy albedo is assumed constant at 0.12 (after Jarvis and others, 1976). Incoming shortwave radiation was measured during this study. The daytime net longwave radiation, R_{nl}, was computed according to:

$$R_{nl} = \left(c + d\frac{R_s}{R_{s_{max}}}\right)\varepsilon_v(\varepsilon_a - 1)\sigma K^4 , \tag{7}$$

where

c = empirical constant (dimensionless);

d = empirical coefficient (dimensionless);

$R_{s_{max}}$ = maximum observed daily clear sky solar radiation (energy/area);

ε_v = longwave emissivity of the vegetation (dimensionless);

ε_a = effective longwave emissivity of the sky (dimensionless);

σ = Stephan-Boltzmann constant (energy/area/time/(absolute temperature)^4; and

K = average temperature of the daylight hours (absolute temperature).

The constant, c, and the coefficient, d, are used to improve the estimates for small values of net longwave radiation. The sum of c and d equals unity. The value of $R_{s_{max}}$ is a fraction of the amount of extraterrestrial solar radiation that reaches the Earth. Extraterrestrial solar radiation, R_a, is the solar radiation incident on the land surface if the atmosphere was removed, and is a function of the time of year and latitude. It is computed as follows.

$$R_a = \frac{24(60)}{\pi}G_{sc}d_r[\omega_s\sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_s)] \tag{8}$$

where

R_a = daily extraterrestrial radiation (energy/area/time);

G_{sc} = solar constant of 0.0820 (MJ m^{-2} min^{-1});

d_r = relative distance of the earth from the sun (dimensionless);

ω_s = sunset hour angle (radians);

φ = latitude (radians);

δ = solar declination (radians).

and d_r, ω_s, and δ are evaluated according to the equations cited by Jensen and others (1990, p. 179). Bauer and Mastin (1997) determined a month-dependent variable multiplier to evaluate $R_{s_{max}}$ for the Puget Sound area, which is used in this study. The value of ε_v is considered constant at 0.96, and ε_a is calculated as a function of average daytime temperature, T, in degrees Celsius (°C) using the formula of Idso and Jackson (1969):

$$\varepsilon_a = 1 - 0.261e^{-0.00077\mathrm{T}^2} . \tag{9}$$

A two-to-one weighting of the maximum daily temperature to the minimum daily temperature approximates the average daylight temperature, T:

$$\mathrm{T} = \frac{(2\mathrm{T}_{max} + \mathrm{T}_{min})}{3} , \tag{10}$$

where T_{max} and T_{min} are the maximum and minimum daily temperatures. This weighting also would apply to the temperature in eq. 7 and all other equations presented or cited in this section that require average daytime temperature.

Once the monthly potential evapotranspiration amounts were estimated, they were compared with the monthly precipitation amounts to determine when the actual evapotranspiration rate equals the potential evapotranspiration rate and when it equals the precipitation rate plus any available soil moisture. For soils in this area, the calculated available soil moisture is 3 in. of water, based on information in the STATSGO soil database (U.S. Department of Agriculture, 1993).

Ground-Water Withdrawals

The amount of ground-water withdrawals was estimated for five water-use categories: public supply, domestic self-supplied, recreation, fish hatchery, and agriculture. All water used on the Reservation is ground water with the exception of areas along the eastern edge of the Reservation that receive water from the City of Marysville water system.

The Washington State Department of Health (WDOH) defines public-supply systems as class A or class B, depending on their size. Class A systems have either 15 or more connections or serve at least 25 people. Class A systems also include non-residential systems such as stores, churches, and campgrounds. Class B systems include all public-supply systems that do not meet the criteria for class A systems.

Study scientists obtained information on the locations of public-supply wells on the Reservation and the number of connections and requested pumpage data and a verification of the number of connections of the systems from all class A systems. There are 24 class A systems, with about 1,820 residential connections serving about 5,080 people, and 43 class B systems, with about 200 residential connections serving about 560 people. The populations served by the systems were estimated using the 2000 census housing average of 2.79 people per house. These public-supply systems mostly provide water for drinking and other domestic uses, but small quantities also were used for commercial and other purposes.

To estimate annual water use on the Reservation, study scientists first determined the average use per residential connection for the five class A systems that provided data. Average use per residential connection was 230 gal/d, representing more than 1,400 of the 1,820 connections on the Reservation. This average value then was used to estimate annual pumpage for the class A systems with no pumpage data. For class A systems with non-residential connections, including the Port Susan camping club, churches, and stores, values were obtained by contacting each system. The value for average annual water use per connection also was used to estimate total average annual water use by class B systems.

Domestic self-supplied water is pumped from privately owned wells for domestic purposes such as drinking water and lawn watering. The number of users of self-supplied water on the Reservation is an estimated 2,906, obtained by subtracting the population served by public-supply systems (5,640) and the population served by the City of Marysville water system (700) from the total Reservation population of 9,246. The amount of domestic self-supplied water use per year was estimated by multiplying the number of users by an average water use per capita of 82 gal/d per person, which is the public-supply average of 230 gal/d per connection divided by 2.79 people per connection.

Pumpage values for recreation water use, which included water for RV parks and golf courses, were provided by some systems, and the average of those values was used to estimate pumpage for systems with unknown values.

Hatchery personnel provided data on ground-water use for the Tulalip Tribes fish hatchery. Average annual ground-water use at the fish hatchery is 53,000,000 gal, or 163 acre-ft.

Agricultural water use includes water used to irrigate pasture and water livestock. Estimates of water used for irrigation was based on 203 acres of agricultural land on the Reservation (Kerie Hitt, U.S. Geological Survey, written commun., 1994) and 0.9 ft of irrigation per year (Ronald C. Lane, U.S. Geological Survey, written commun., 2003). To determine water use for livestock, the number of stock (Mike Brady, Marysville School District, written commun., 2003) was multiplied by the estimated daily consumption per animal (U.S. Soil Conservation Service, 1975). The only known well supplying livestock is at the Marysville School District farm, and none of the wells inventoried on the Reservation listed stock as a primary water use. However, some homeowners likely raise a small quantity of livestock whose water use would be included in the public supply and domestic water-use categories.

Ground-Water Recharge

The chloride mass-balance method was used as a means of estimating recharge in the study area. This method for estimating recharge is based on the principle that a known fraction of chloride in precipitation and dry atmospheric deposition is transported to the water table by the downward flow of liquid water. As water percolates downward, some evaporates directly or is taken up and transpired by plants. Where this occurs, the concentration of chloride in soil water increases with depth because little or no chloride is lost by these processes. At greater depths, where no evapotranspiration occurs, the chloride concentration should be uniform if climate, soil, and other conditions near the surface have been steady for a sufficiently long time.

The chloride mass-balance method uses the assumption that precipitation is the only source of chloride in ground water and in surface-water runoff. Human sources such as septic systems and animal sources such as cow manure contribute minimal amounts of chloride to the water in the study area, and natural sources such as evaporite rocks or connate seawater are not present in the hydrogeologic units above sea level. A mass balance of chloride in precipitation, surface-water runoff, and ground water is expressed in the following equation (Prych, 1995; Maurer and others, 1996):

$$P \times C_p = (GWR \times C_g) + (SWR \times C_p) \qquad (11)$$

where

P = annual precipitation, in inches;

C_p = concentration of chloride in precipitation, in milligrams per liter;

GWR = annual ground-water recharge, in inches;

C_g = concentration of chloride in ground water, in milligrams per liter; and

SWR = annual surface-water runoff (direct runoff), in inches.

Rearranging the terms in eq. 11 gives

$$GWR = \frac{(P \times C_p) - (SWR \times C_p)}{C_g} \qquad (12)$$

Implicit in the derivation and uses of eq. 12 is the assumption of so-called plug flow. More specifically, it is assumed that (1) the direction of water flow and chloride transport is vertical and downward, (2) areal distributions of the rate of percolation of water and of chloride on the local scale (a few inches) are uniform (no preferred pathways), (3) all chloride is dissolved in soil water and the distribution of the dissolved chloride in the soil water is relatively uniform within a pore (no solid chloride phase, sorption by soil, or anion exclusion), and (4) advection is the dominant mode of chloride transport and diffusion is relatively unimportant. Additional assumptions are that (5) minerals in the soil are not a source of chloride, and the only source is precipitation and dry atmospheric deposition, (6) measured chloride concentrations are at depths great enough that seasonal variations in concentration are small, and (7) concentrations of chloride in surface-water runoff is the same as that in precipitation. The method is still valid if chloride is taken up by growing vegetation, as long as it also is released by decaying vegetation at the same rate.

Implicit in the derivation of eq. 12 is the assumption that all atmospheric chloride in soil water was deposited in precipitation (wet deposition). However, in cases where a substantial portion of the atmospheric chloride deposition occurs as dry deposition, eq. 12 can be modified to account for atmospheric chloride in terms of the total of the wet- and dry-chloride fluxes rather than concentration of chloride in precipitation.

In eq. 12, the term $P \times C_p$, which represents the wet chloride deposition, is replaced by FWD, the total flux (milligrams per square meter) of the wet and dry chloride deposition. The term $SWR \times C_p$, which represents the outflow of atmospheric chloride through direct stream runoff, is replaced with the term $SWR \times FWD/P$, where FWD/P is the chloride concentration in the stream water. This follows the assumption that the chloride in the stream water is a composite of the wet plus dry chloride deposition, which is due to the fact that the precipitation, after falling on the ground, picks up chloride from the dry deposition on its way to the stream channel. Eq. 12 then becomes

$$GWR = FWD\frac{(1 - SWR/P)}{C_g} \qquad (13)$$

expressed in consistent units. In this study, FWD is expressed in milligrams per square meter, C_g in milligrams per liter, and GWR, SWR, and P in inches, and eq. 13 becomes

$$GWR = 0.0394 \;\; FWD\frac{(1 - SWR/P)}{C_g} \qquad (14)$$

Precipitation was calculated as described earlier, and HYSEP, a USGS computer program for streamflow hydrograph separation (Sloto and Crouse, 1996), was used to determine the mean annual surface-water runoff.

Ground-Water System

This section provides information on the ground-water system of the Tulalip Plateau. A brief geologic history of the area is given, followed by detailed descriptions of the hydrogeologic units. Discussions of the hydraulic properties of the units, recharge to the ground-water system, flow of water and water-level fluctuations within the aquifers, also are presented.

Basic Concepts of Ground-Water Systems

A ground-water system is a body of porous material that is saturated with ground water. The body of porous material can be fractured rock or the weathered products of rock, such as gravel, sand, or silt. A general definition of a ground-water system includes a description of (1) the boundaries of the system, (2) the inflow and outflow of water through the boundaries (recharge and discharge), (3) the directions and rates of ground-water flow, and (4) the hydraulic properties of the porous material.

A ground-water system consists of a single aquifer or multiple aquifers and confining beds. An aquifer is a body of porous material that will yield water in a usable quantity to a well or spring. A confining bed is a body of porous material having very low hydraulic conductivity that restricts the movement of ground water either into or out of adjacent aquifers.

The boundaries of a ground-water system define a three-dimensional surface that encloses the aquifers and confining beds. Examples of boundaries are the (1) water table, which is a plane marking the upper limit of the ground-water system, (2) relatively impermeable bedrock, which is the plane marking the lower limit of the system where an aquifer abuts against it, (3) zone of contact between an aquifer and a river or lake, and (4) zone of contact between an aquifer and a saline water body such as the ocean.

Ground water is under either unconfined or confined conditions (fig. 7). Unconfined ground water only partly fills an aquifer, and the surface of ground water is the water table. A water level measured in a well screened at the water table in an unconfined aquifer will stand at the same level as the water

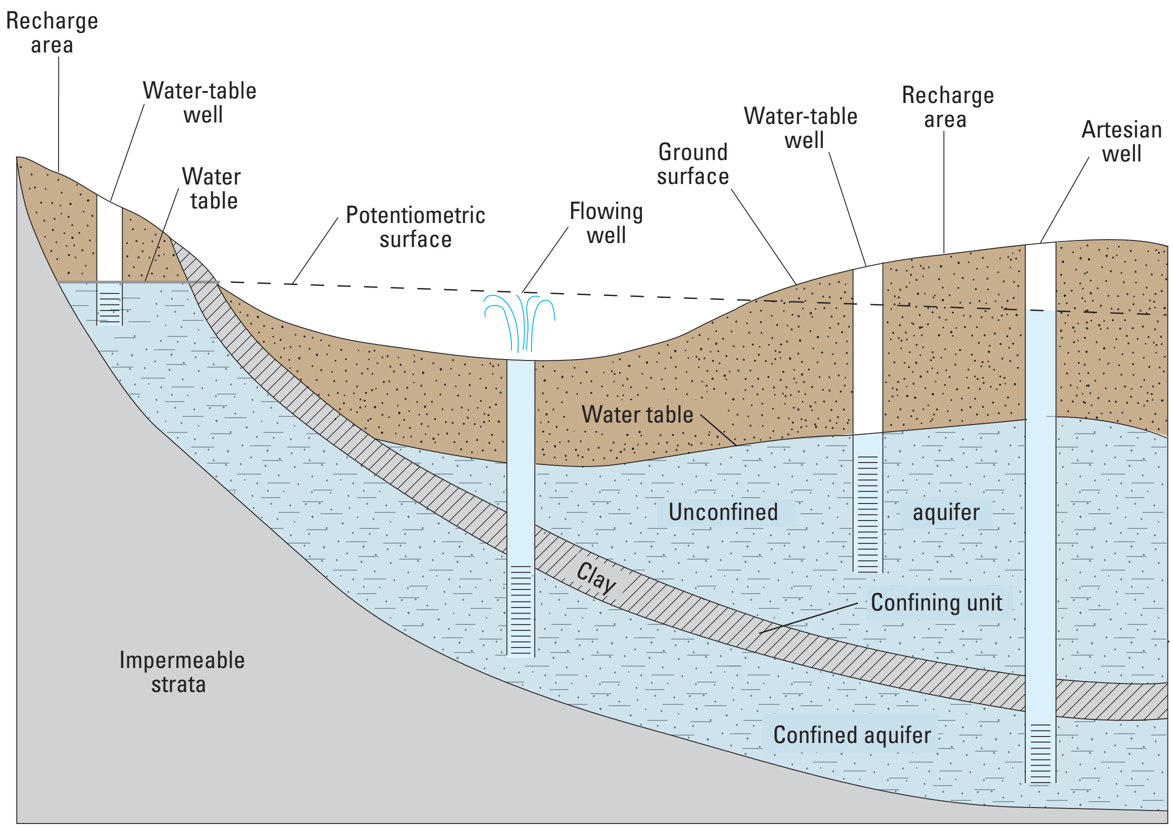


Figure 7. Features of unconfined (water table) and confined ground-water systems. (Modified from Todd, 1980.)

table. Confined ground water is under pressure appreciably greater than atmospheric, and its upper limit is the bottom surface of an overlying confining bed. A water level measured in a well that is screened in a confined aquifer will stand above the top of the confined aquifer. “Artesian” is a commonly used term and is synonymous with confined. An artesian well is a well deriving its water from an artesian or confined aquifer. If the water level in an artesian well stands above land surface, the well is a flowing artesian well. Water will naturally flow out of such wells because of the positive pressure in the confined ground water.

A ground-water boundary can have three flow conditions: no flow, inflow (recharge), or outflow (discharge). The flow condition depends on the relation between the heads or fluid density on either side of the boundary and the permeability of the material on either side of the boundary.

The direction of ground-water flow into, out of, or within a ground-water system is determined by comparing hydraulic heads. Ground water moves from higher to lower head. Hydraulic heads are determined by measuring the position of the water level in a well and relating the measurement to a datum plane. A datum that is common to all wells in an area is used for comparisons. The vertical datum used in this report is NGVD of 1929, and measured water levels are reported as an altitude, in feet above NGVD of 1929. A potentiometric surface is an areal representation of the hydraulic head in an aquifer. Thus, comparing two heads can be used to determine direction of flow between two points, but the potentiometric surface shows direction of flow for an area. The term “water table” is defined as the potentiometric surface at which the water pressure is the same as atmospheric pressure.

The hydraulic properties of an aquifer or confining bed can be described by the hydraulic conductivity, transmissivity, and storage capacity. Hydraulic conductivity is a measure of the relative ease with which a body of porous material can transmit a liquid under a potential gradient. The rate of movement of ground water, therefore, is proportional to the magnitude of the conductivity. The shape, size, and interconnections of the pores of the material are the major factors controlling the magnitude of hydraulic conductivity. Transmissivity is a measure of the productivity of an aquifer and is equal to the hydraulic conductivity multiplied by the thickness of the aquifer.

The storage capacity of an aquifer influences the amount of water that is available for withdrawal. In an unconfined aquifer, specific yield is a measure of the storage capacity. Specific yield of a rock or soil is the ratio of (1) the volume of water that the rock or soil, after being saturated, will yield by gravity to (2) the total volume of the rock or soil. Typical values of specific yield range from 0.1 to 0.3. In a confined aquifer, storage coefficient is the measure of storage capacity and it is the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. Typical values of storage coefficients range from 0.00001 to 0.001 (Heath, 1989).

A ground-water system may be in a steady-state or transient-state condition in relation to time. In a steady-state system, the quantity of inflow is balanced by the quantity of outflow. Under such conditions, water levels may fluctuate seasonally in response to variations in precipitation; however, the long-term average of water levels remains constant. In contrast, a system in a transient-state condition will have long-term changes in water levels.

Geologic History

Many studies have contributed to the current understanding of the geologic history of the study area. The following discussion is based on studies done by Vacarro and others (1998) and Jones (1999). The reader is referred to those studies for more detailed descriptions.

The geology of the Tulalip Plateau is a complex mix of glacial and nonglacial deposits that subsequently have been influenced by erosion. Four glaciations and three interglaciations are recognized in the Puget Sound Lowlands. Throughout most of the Puget Sound Lowland, the glacial deposits of the Vashon Stade of the Frasier Glaciation, which was the last major glacial advance, are exposed at the surface.

The ice of the Vashon Stade moved out of Canada about 18,000 years ago and split into two lobes. The Puget lobe flowed south into and occupied all of the Puget Sound Lowland and was about 3,000 ft thick near Seattle and about 6,000 ft thick near the U.S.–Canada border. The glacier began retreating about 14,500 years ago.

Three types of deposits typically are associated with continental glaciation: advance outwash, till, and recessional outwash. As the glacier flowed south, streams and melting ice at the front of the glacier deposited sediments known as advance outwash. Advance-outwash units typically are coarse-grained and make productive aquifers. As the glacier continued its advance, the advance outwash was covered with glacial till. Glacial till consists of unsorted rocks that range in size from clay to boulders that are picked up by the bottom and sides of the advancing glacier. Till is considered to be a semi-confining unit because it is compacted by the pressure of the thousands of feet of overlying ice. As the glacier began to melt and retreat, streams emanating from the glacier deposited recessional outwash over the top of the till. Like the advance outwash, recessional outwash is coarse-grained and typically forms aquifer units.

Since the last glaciation, erosion has been the dominant process affecting the Tulalip Plateau. Alluvial sediments, typically sands and gravels, have been deposited by streams in valleys and marsh deposits formed in low-lying, poorly drained areas.

Hydrogeologic Units

Seven of the eight hydrogeologic units defined previously in western Snohomish County by Thomas and others (1997) were used to define the hydrogeology in this study (table 3 and pl. 1). The bedrock unit is assumed to underlie the area, but no wells penetrate that deep. The previous hydrogeologic framework for the Reservation, developed by Drost (1983), labeled the units by numbers 1 through 7, and these were correlated with geologic units by Thomas and others (1977) (table 3). As more detailed surficial geologic mapping has taken place, units 2 and 5, defined by Drost, are apparently the same unit.

The hydrogeologic units used in this study were classified as either aquifers or confining units. Generally, the confining units are fine grained in nature and do not yield much water and the aquifers are coarse grained in nature. Three aquifers and two confining units, as well as two smaller units that are only local in extent, were delineated in the study area. The uppermost units are the alluvium (Qal) and marsh deposits (Qm). The uppermost widespread aquifer is the Vashon recessional outwash (Qvr). It is underlain by the Vashon till (Qvt) confining unit or, in areas where the till is absent, by the Vashon advance outwash (Qva) aquifer, the principal aquifer in the study area. Underlying the Qva are the fine-grained

Table 3. Lithologic and hydrologic characteristics of hydrogeologic units of the Tulalip Plateau, Snohomish County, Washington.

[Modified from Thomas and others, 1997]

<table>
<tr><th rowspan="2">Period</th><th rowspan="2">Epoch</th><th rowspan="2" colspan="2">Hydrogeologic unit</th><th colspan="2">Hydrogeologic unit labels</th><th rowspan="2">Typical thickness (feet)</th><th rowspan="2">Maximum thickness (feet)</th><th rowspan="2">Lithologic characteristics</th><th rowspan="2">Hydrologic characteristics</th></tr>
<tr><th>Drost (1983)</th><th>Thomas and others (1997)</th></tr>
<tr><td rowspan="7">Quaternary</td><td rowspan="2">Holocene</td><td colspan="2">Bog, marsh, and peat deposits</td><td>1</td><td>Qm</td><td>Unknown</td><td>Unknown</td><td>Sand, silt and clay mixed with organic matter and peat deposits.</td><td>Localized unit. Not classified as aquifer or confining bed. Thin and discontinuous.</td></tr>
<tr><td colspan="2">Alluvium</td><td>1</td><td>Qal</td><td>20</td><td>60</td><td>Fluvial and beach deposits. Fine to coarse sand with lenses of silt and gravel.</td><td>Localized unit. Minor aquifer along Stillaguamish River only. Ground water is unconfined.</td></tr>
<tr><td rowspan="5">Pleistocene</td><td rowspan="3">Vashon Drift of the Fraser Glaciation</td><td>Vashon recessional outwash</td><td>3</td><td>Qvr</td><td>50</td><td>140</td><td>Moderate to well-sorted sand, gravel. Grades to silt.</td><td>Aquifer. Ground water is unconfined.</td></tr>
<tr><td>Vashon till</td><td>4</td><td>Qvt</td><td>60</td><td>250</td><td>Compact, unsorted sand, gravel, and boulders, in a matrix of silt and clay. Some lenses of sand and gravel.</td><td>Confining bed, but can yield usable amounts of water.</td></tr>
<tr><td>Vashon advance outwash</td><td>5, 2</td><td>Qva</td><td>140</td><td>450</td><td>Well-bedded fine sand. Grades to sand and gravel. Some lenses of silt.</td><td>Principal aquifer in study area. Ground water is usually unconfined.</td></tr>
<tr><td colspan="2">Transitional beds</td><td>6</td><td>Qtb</td><td>75</td><td>500</td><td>Laminated sand to silty clay with lenses of sand and gravel.</td><td>Confining bed, but can yield usable amounts of water.</td></tr>
<tr><td colspan="2">Undifferentiated sediments</td><td>7</td><td>Qu</td><td>Unknown</td><td>Unknown</td><td>Glacial drift and interglacial deposits. Mostly sand and gravel. Some beds of laminated marine silts.</td><td>Mostly an aquifer, but includes some confining beds. Most water is confined.</td></tr>
</table>

transitional beds (Qtb), which form a confining unit. The thick undifferentiated sediments (Qu) are below the Qtb. Qu is not well defined because of a lack of data, but the upper portion generally is coarse grained and serves as an aquifer. No wells penetrate deep enough to encounter the bedrock located below the Qu because the thickness of the unconsolidated deposits for the Reservation exceed 1,200 ft and are at least 600 ft thick throughout the entire study area (Jones, 1996).

Five cross sections were used to determine the three-dimensional geometry of the hydrogeologic units (pl. 1), and the extent, top altitude, and thickness of the major units (Qvt, Qva, Qtb, and Qu) were mapped to determine the geometries of the units (figs. 8-14). The maps and cross sections supersede those produced by Thomas and others (1997) for the Tulalip Plateau area.

The youngest unit in the study area, the bog, marsh, and peat deposits (Qm), covers only a very small part (about 1 mi^2) of the study area (pl. 1). It is located around the mouths of Ebey and Hat Sloughs. This unit is composed of sand, silt, and clay mixed with partly decomposed organic matter and includes peat deposits (Pessl and others, 1989). The unit is thin and has little influence on the hydrologic system of the study area, so it was not classified as either an aquifer or confining unit.

The alluvium unit (Qal) is a minor aquifer that serves a very small number of people, and is fluvial in origin, consisting primarily of sand and gravel but also including some minor beach and landslide deposits. The only part of this unit that serves as an aquifer in the study area is located primarily along the Stillaguamish River (pl. 1). All other deposits of Qal are too localized and discontinuous to serve as aquifers. The unit is typically about 20 ft thick (table 3) and the ground water is unconfined.

The Vashon recessional outwash (Qvr) unit is a minor aquifer located mostly along the eastern part of the study area in the Marysville Trough (pl. 1). Few homes draw water from it for drinking-water purposes. Smaller, localized deposits also occur in depressions on the Tulalip Plateau, but do not provide much drinking water in those areas either. The unit, which was deposited in both continental and marine environments, typically is composed of sand and gravel but also includes some finer silt and clay deposits (Pessl and others, 1989). The unit typically is about 50 ft thick, with a maximum of 140 ft in the northern parts of the Marysville Trough. The entire unit is exposed at the surface, and the ground water is unconfined.

The Vashon till unit (Qvt) forms a confining bed that is exposed primarily at the land surface but also underlies part of the Qvr aquifer along the eastern part of the study area (pl. 1). The till is a very compact mix of sand and gravel in a clay matrix and is somewhat discontinuous due to erosion by streams. The altitude of the top surface ranges from less than 100 ft to more than 600 ft above NGVD of 1929 and the typical thickness of the unit is about 60 ft with a maximum of about 250 ft (figs. 8 and 9 and table 3).

The Vashon advance outwash (Qva) unit typically underlies Qvt, but also is exposed at the surface in the central part of the Reservation and along the western edge of the study area (fig. 10). It is present throughout most of the study area except for small areas along the Stillaguamish River and the lower portions of Tulalip and Quilceda Creeks. The unit was defined as an aquifer because it typically is composed of sand and gravel deposits. The altitude of the top surface of the unit ranges from more than 500 ft above NGVD of 1929 to 0 ft NGVD of 1929 (fig. 10). The unit averages about 140 ft thick but can be as much as 450 ft and is thinnest along the eastern and northeastern parts of the study area and thickest in the northwestern corner of the Reservation (fig. 11 and table 3). The unit generally is unconfined, so the upper boundary of the aquifer typically is the water table, but in areas where the aquifer is confined the upper boundary is the top surface of Qva. Most of the flow within Qva is horizontal because of the presence of the Qtb confining bed below the aquifer, which inhibits vertical flow. In areas where Qtb is missing, the Qva and Qu aquifers are in direct contact and there may be movement of ground water from the Qva to Qu aquifer. Mission and Tulalip Creeks are hydraulically connected with this aquifer in areas where Qva is exposed along the creeks.

The transitional beds (Qtb) form a confining unit beneath most of the Qva aquifer and are present throughout the study area except along the northwestern parts of the study area and beneath and west of Lake Shoecraft (fig. 12). They are exposed locally at the surface at the very southern part of the Tulalip Reservation. According to Pessl and others (1989), the transitional beds consist of early Vashon-age advance outwash deposits such as the Lawton Clay and Pilchuck Clay members and late pre-Vashon nonglacial deposits such as the Kitsap Formation. The unit is fine-grained, consisting mostly of silty clay and sand with lenses of sand and gravel. The altitude of the top surface ranges from more than 200 ft above NGVD of 1929 in the center of the plateau to slightly less than 0 ft NGVD of 1929 around the margins of the study area (fig. 12). The unit is typically about 75 ft thick, but may be as much as 500 ft, and is relatively thin over most of the study area and thickest in the far eastern part of the Reservation (fig. 13 and table 3).

The undifferentiated-sediments unit (Qu) underlies the transitional beds confining unit and extends throughout the entire study area (fig. 14). Qu was defined as an aquifer because the upper part consisted mostly of coarse-grained material; however, if additional data were available from deeper well logs, the unit likely could be further subdivided into several aquifers and confining units. According to Pessl and others (1989), Qu contains the Olympia nonglacial deposits, Possession Drift, Whidbey Formation, and Double Bluff Drift. The altitude of the top surface ranges from more than 200 ft above NGVD of 1929 to more than 400 ft below NGVD of 1929 along the eastern part of the Reservation (fig. 14). The thickness of the unit is unknown because no wells fully penetrate the unit.

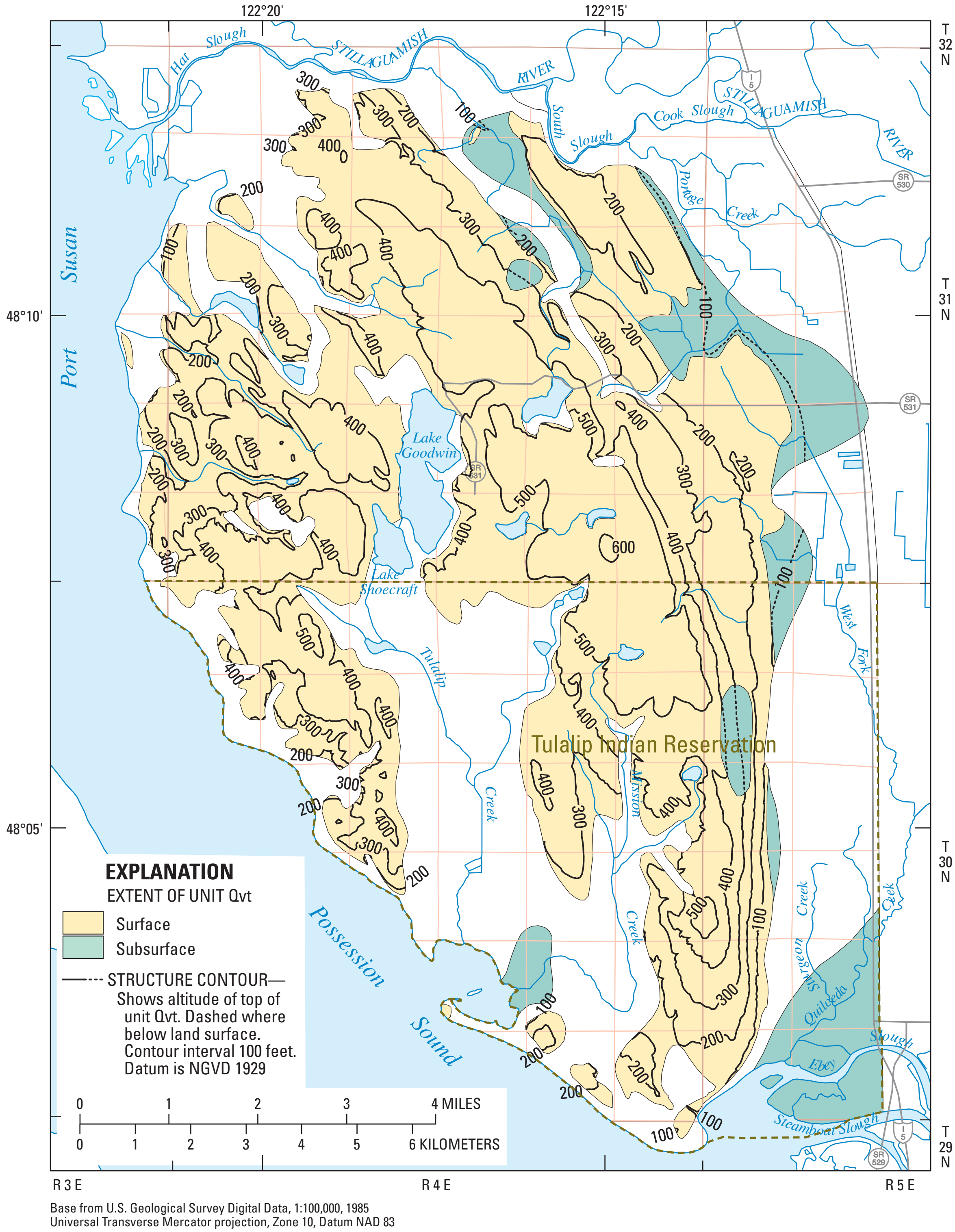
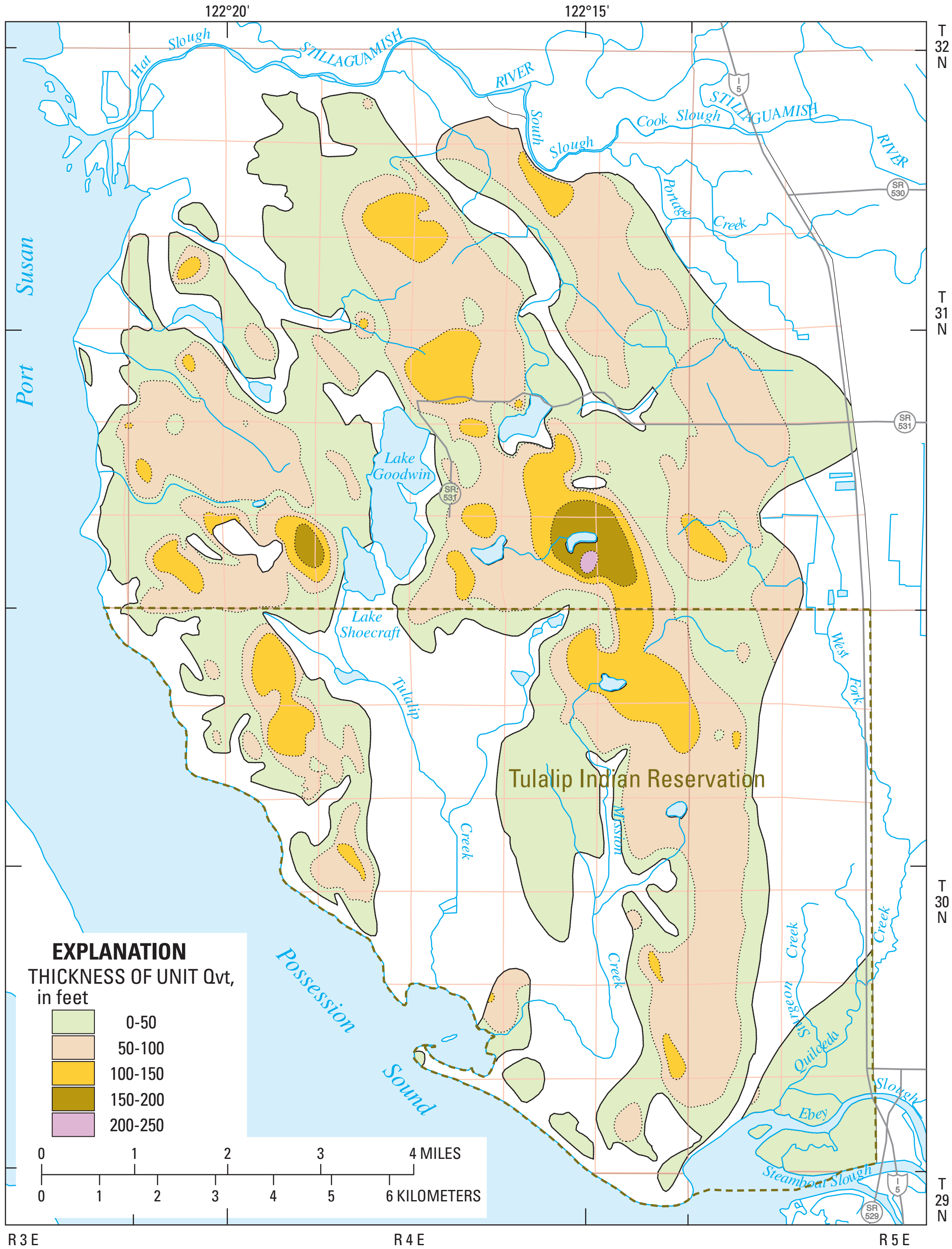


Figure 8. Extent and altitude of the top of the Vashon Till (Qvt) hydrogeologic unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.



Base from U.S. Geological Survey Digital Data, 1:100,000, 1985
Universal Transverse Mercator projection, Zone 10, Datum NAD 83

Figure 9. Thickness of the Vashon Till (Qvt) hydrogeologic unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

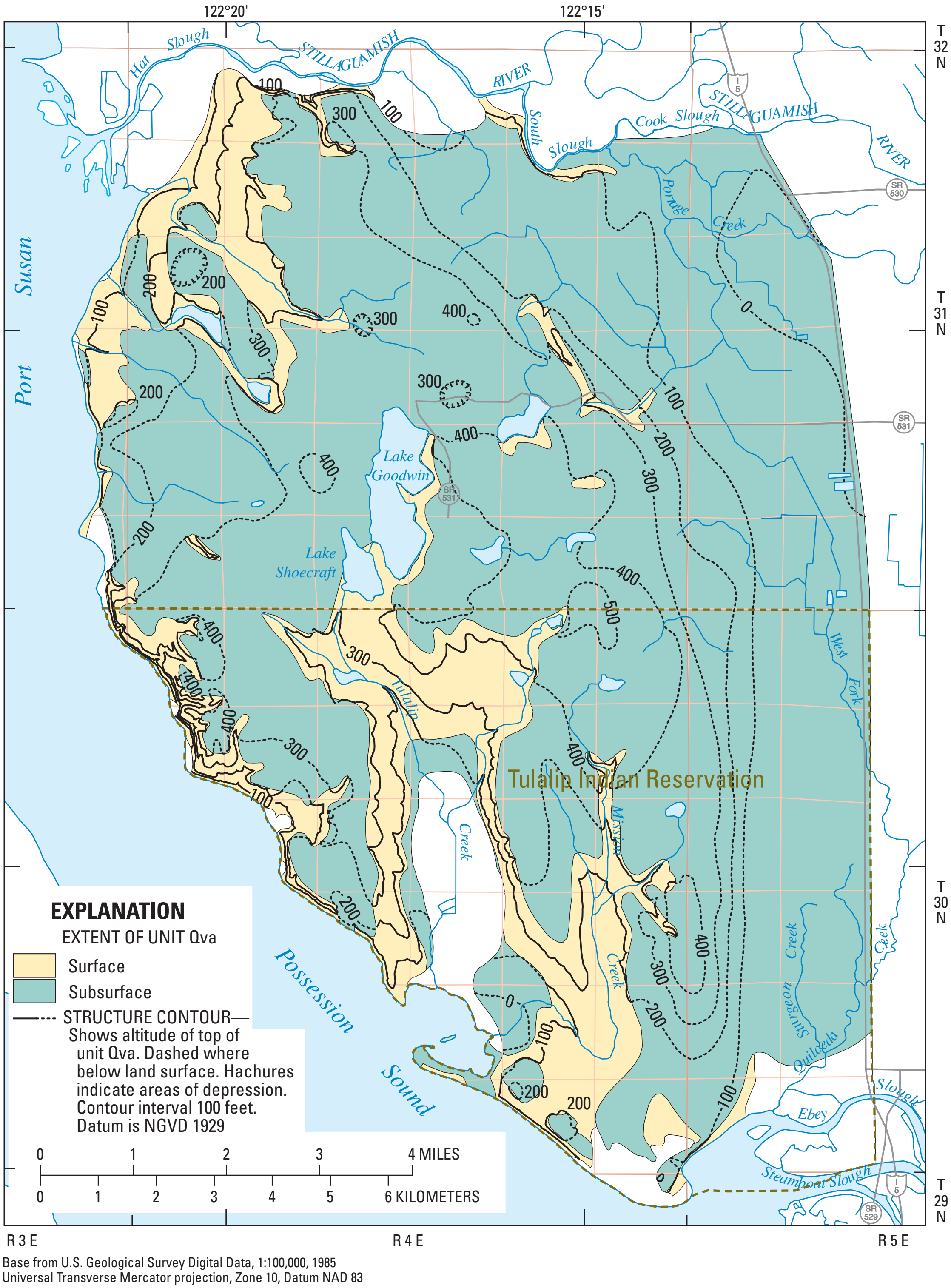
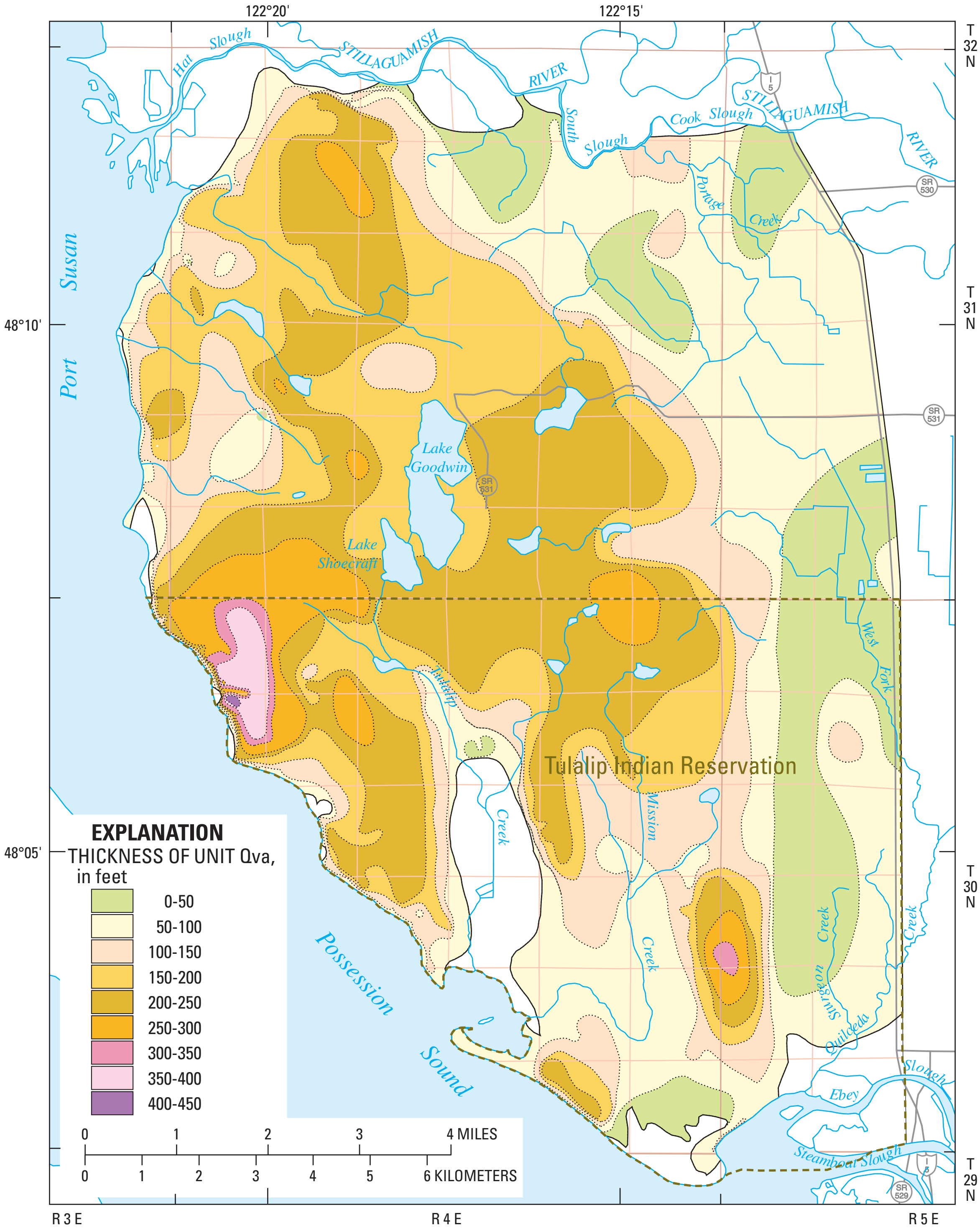


Figure 10. Extent and altitude of the top of the Vashon Advance Outwash (Qva) hydrogeologic unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.



Base from U.S. Geological Survey Digital Data, 1:100,000, 1985
Universal Transverse Mercator projection, Zone 10, Datum NAD 83

Figure 11. Thickness of the Vashon Advance Outwash (Qva) hydrogeologic unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

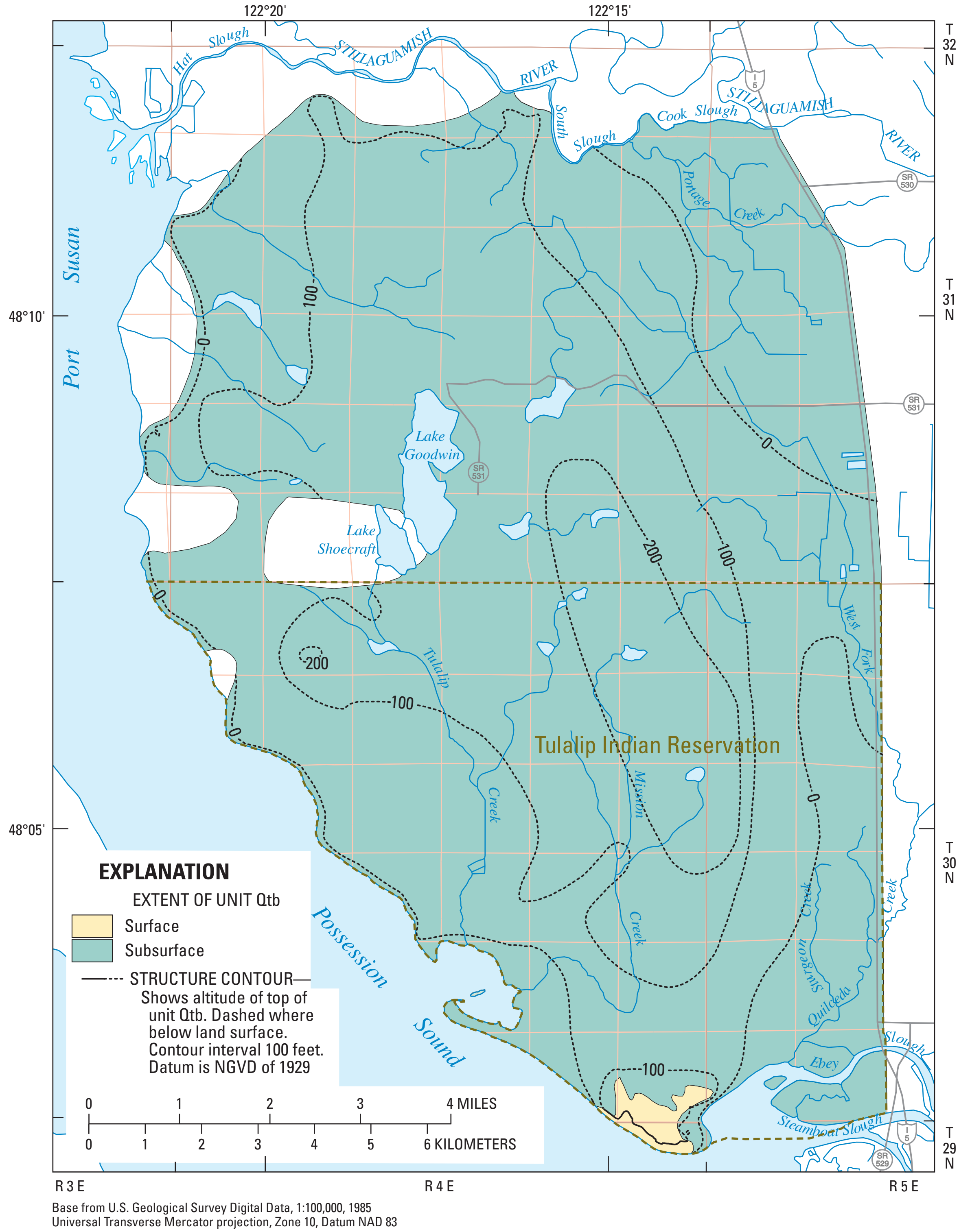


Figure 12. Extent and altitude of the top of the transitional beds (Qtb) hydrogeologic unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

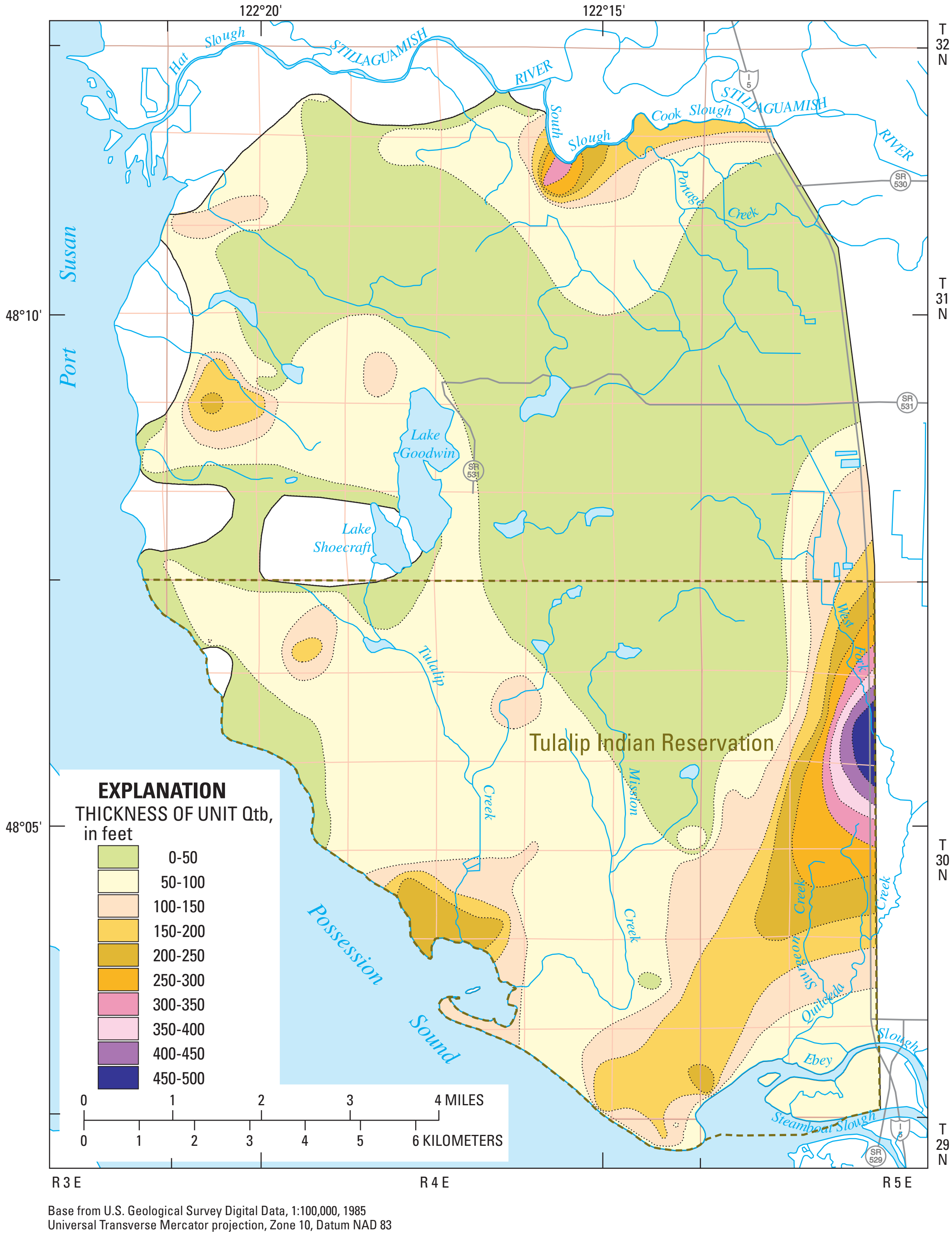


Figure 13. Thickness of the transitional beds (Qtb) hydrogeologic unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

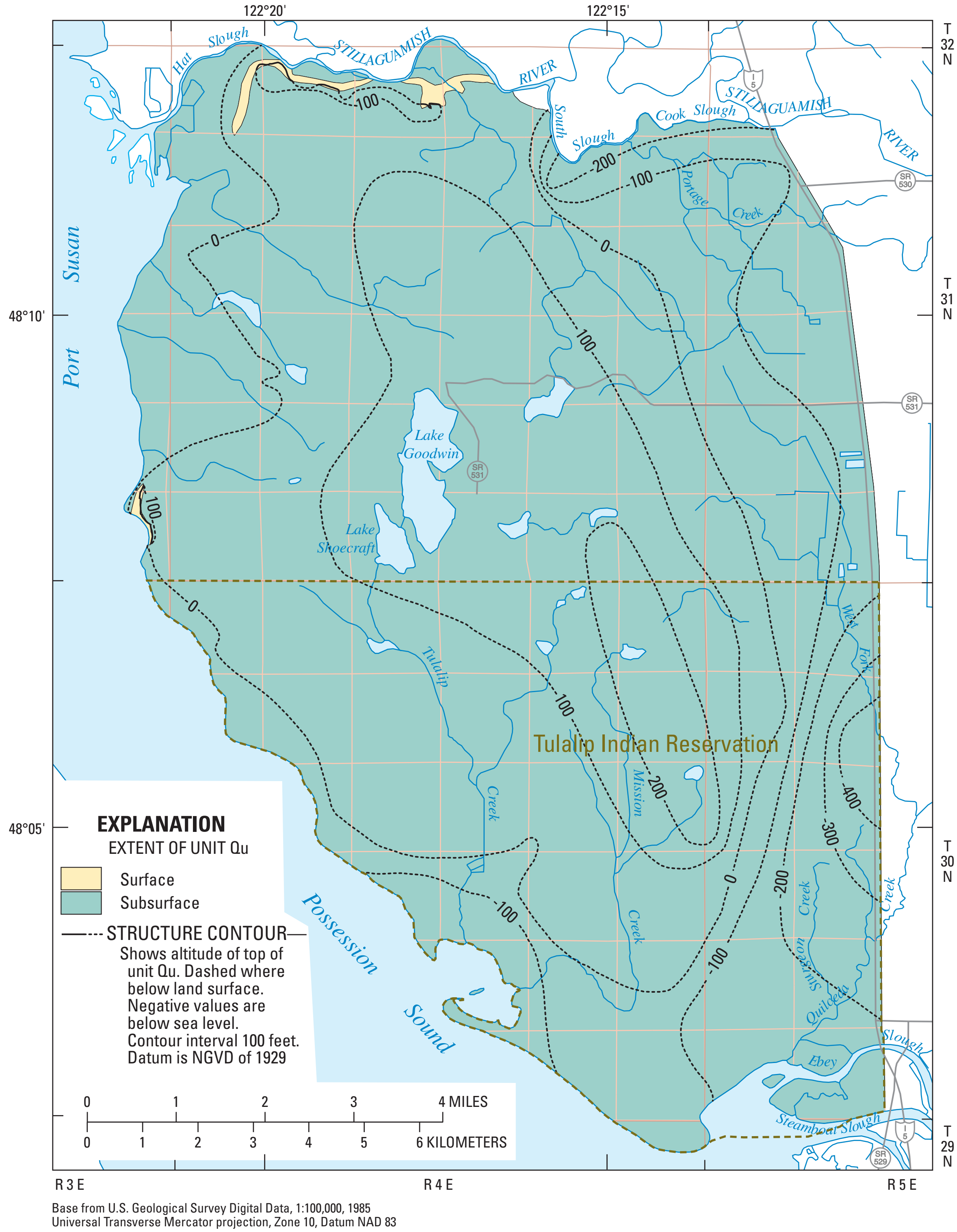


Figure 14. Extent and altitude of the top of the undifferentiated-sediments (Qu) hydrogeologic unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

Hydraulic Properties

Horizontal hydraulic conductivity was calculated for each hydrogeologic unit except Qm using specific-capacity data (table 4). The aquifer unit Qvr had the highest horizontal hydraulic conductivity, with a median value of 190 ft/d, although it only had nine wells with specific-capacity data. The two primary aquifers in the study area, Qva and Qu, had median horizontal hydraulic conductivities of 60 and 27 ft/d, respectively.

Horizontal hydraulic conductivities for all units with data from more than two wells showed large variations. The minimums in those units were all less than 1 ft/d and maximums were more than 100 ft/d. The largest horizontal hydraulic conductivity was 4,300 ft/d, in the aquifer unit Qva. The hydraulic conductivities calculated from these wells likely are higher than those that would represent the entire unit because water-supply wells typically are placed in the most permeable parts of a unit.

Table 4. Summary of horizontal hydraulic conductivities, by hydrogeologic unit, estimated from specific-capacity of wells on the Tulalip Plateau and adjacent area, Snohomish County, Washington.

[–, not determined]

Hydro-geologic unit	No. of wells	Horizontal hydraulic conductivity, in feet per day				
		Minimum	25th percentile	Median	75th percentile	Maximum
Qal	2	5.7	–	–	–	20
Qvr	9	.13	96	190	300	450
Qvt	2	7.7	–	–	–	56
Qva	61	.22	19	60	140	4,300
Qtb	6	.29	17.5	29.5	83.5	140
Qu	45	.58	10	27	70	520

Ground-Water Movement

The direction of ground-water movement is determined from water levels from wells screened in an aquifer. Ground water moves from areas of high water-level altitudes to areas of low water-level altitudes. In this study, the Qva unit was the only unit with enough data, distributed sufficiently throughout the study area, to estimate directions of ground-water flow. Although water-level measurements were available for many wells in Qu, most of the wells were along the western edge of the study area, making it difficult to gain an overall picture of the directions of flow within that unit.

Ground water in the Qva flows radially away from the center of the Tulalip Plateau (fig. 15). The highest water levels are to the north and west of Lake Goodwin, and ground water flows towards the Marysville Trough, Puget Sound, and the Stillaguamish River.

Although insufficient data were available along the eastern and northeastern parts of the study area to draw water-level contours for Qu aquifer unit, the pattern of water levels indicated that the direction of ground-water movement generally is from east to west along the western part of the plateau and towards the south and west along the southern part of the plateau (fig. 16).

Ground water moves into the Reservation along the northern boundary as subsurface inflow through the unconsolidated deposits. Most of this flow is in the form of lateral ground-water flow, with a small amount of near-surface flow through the soil. Using the assumptions that the subsurface flow rate is equal to the ground-water recharge rate and that there are 7 mi^2 of the ground-water basin off the Reservation (Drost, 1983), the total amount of subsurface inflow is estimated at 5 ft^3/s.

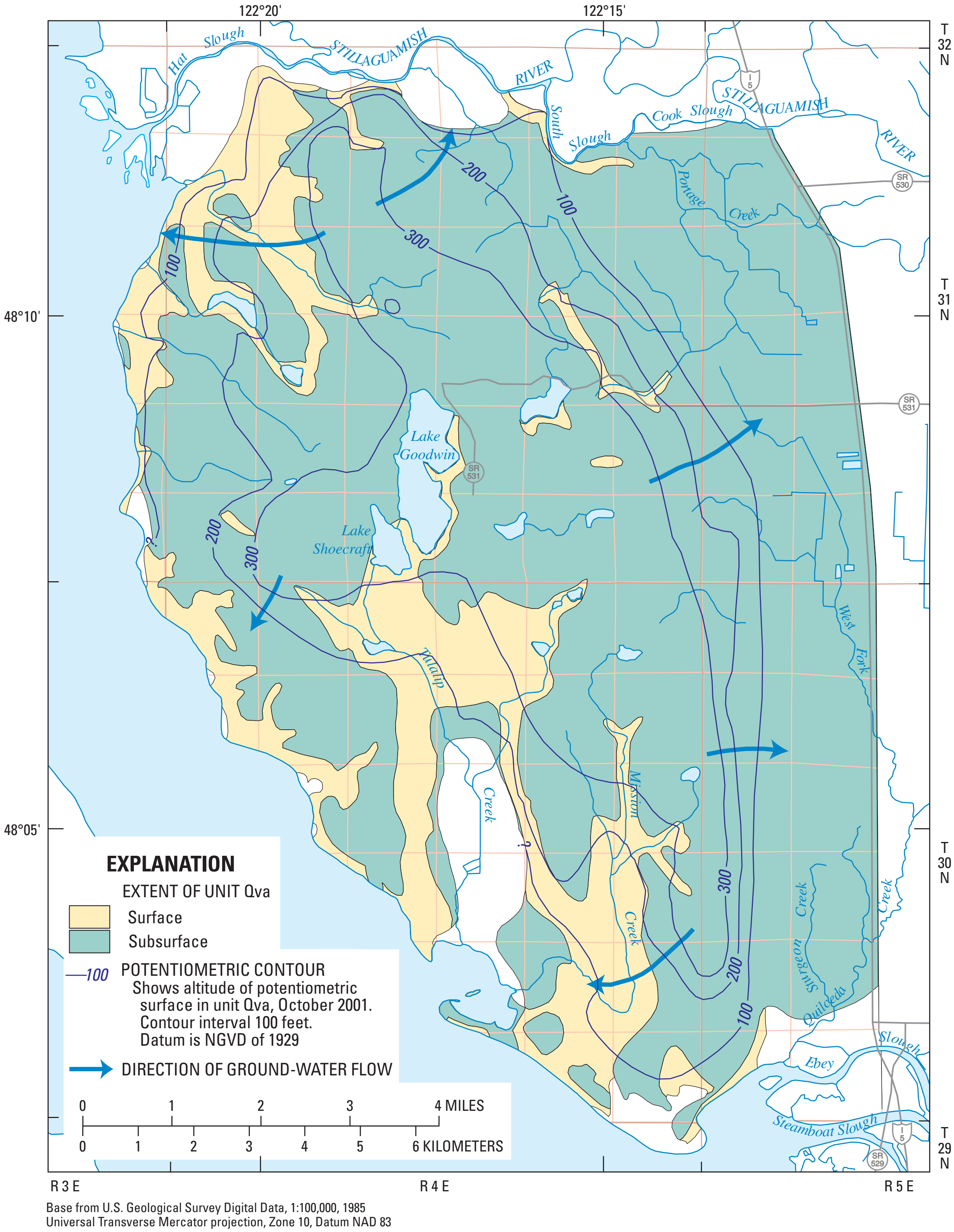
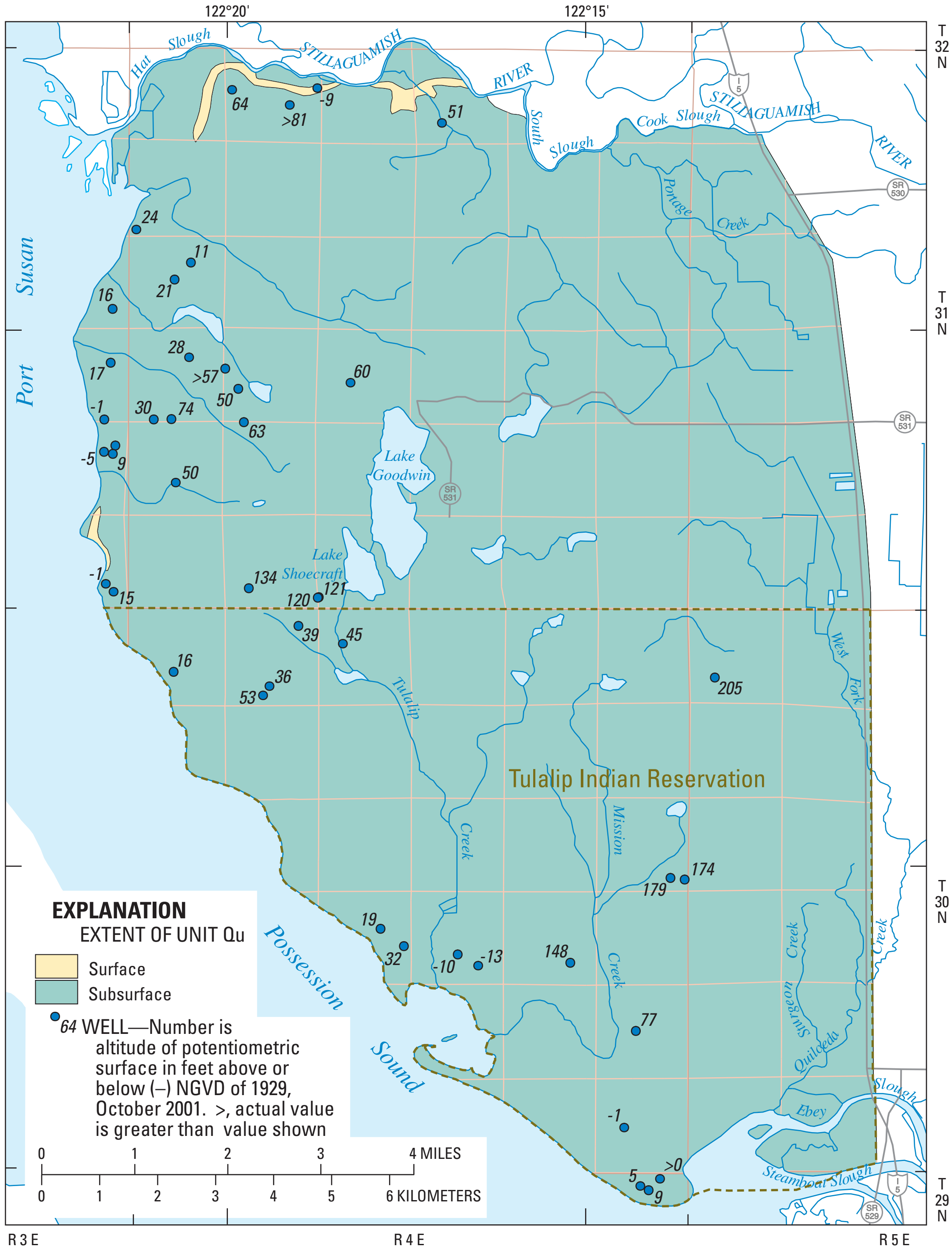


Figure 15. Potentiometric surface and directions of ground-water flow in the Vashon Advance Outwash (Qva) aquifer unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.



Base from U.S. Geological Survey Digital Data, 1:100,000, 1985
Universal Transverse Mercator projection, Zone 10, Datum NAD 83

Figure 16. Water-level altitudes in the undifferentiated sediments (Qu) aquifer unit in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

In addition to lateral flow within a hydrogeologic unit, ground water also flows vertically between units. It is possible to determine whether an upward or downward vertical gradient exists between units by looking at the water levels in wells that are close to each other and open to different units. For example, wells 30N/05E-08K01 and -08K02 are open to Qvr and Qu, respectively, and the water-level altitude in well 30N/05E-08K02 is higher than that in -08K01, so the vertical gradient in this location is upward. Conversely, wells 30N/04E-23F01 and -23F02 are open to Qva and Qtb and the water-level altitude is higher in well 30N/04E-23F01 than in -23F02, so the vertical gradient in this location is downward. Downward vertical gradients generally occur more frequently on the Tulalip Plateau and upward vertical gradients occur more frequently in the Marysville Trough.

Recharge

Recharge to the ground-water system in the Tulalip Indian Reservation was estimated using the chloride mass-balance method. The equations used in the chloride mass-balance method require values for the average annual total flux of wet and dry chloride deposition, average annual surface-water runoff and precipitation, and average chloride concentration in the ground water.

Results of the analysis of the wet and dry atmospheric-chloride data collected for this study show that at site C-1 about 46 percent of the total chloride deposition occurs as dry deposition and at site C-2 about 29 percent (table 5). For the 2-year data collection period, the total flux of the wet and dry chloride deposition for the north and south sites was 2,004 and 2,713 mg/m^2, respectively, for an annual average of 1,179 mg/m^2. Surface-water runoff for each year totaled 2.8 and 1.5 in. for the Mission Creek basin and 1.9 and 0.8 in. for the Tulalip Creek basin, for an overall annual average of 1.8 in. Annual precipitation measured at the three precipitation gages ranged from 23.7 to 42.7 in. and averaged 32.3 in.

The value for the concentration of chloride in ground water in the study area that was needed for the mass-balance equations was determined using ground-water samples from only those wells where the sole source of chloride in the aquifer is from the atmosphere. Near the coastline, where seawater intrusion can contribute chloride to ground water, only samples from wells with bottoms above sea level were used, and only from those wells in which pumping did not cause water levels to decline below sea level. The wells also were far enough from the coast that seawater could not reach the well through diffusion. To minimize the chance that some of the chloride in a well was from anthropomorphic sources such as septic systems and fertilizers, samples were analyzed for concentrations of nitrate, an indicator of such sources, and all wells with nitrate concentrations greater than 3 mg/L were excluded from the data set (table 6). The average chloride concentration in ground water in the study area, after excluding those wells that may be influenced by saltwater intrusion or anthropogenic sources of chloride, is 4.2 mg/L.

When the average values for all of these components are applied in the final mass-balance equation for this study (eq. 14), the average annual recharge for the Tulalip Indian Reservation is estimated to be 10.4 in.

No attempt was made to estimate the distribution of recharge from the data used for this method. For any particular sampling point within the aquifer, ground-water flow generally is horizontal. Therefore, any ground-water sample is an unknown mixture of water consisting of water percolating vertically downward from recharge at the surface and from other upgradient areas. The recharge value computed from chloride concentration in a single sample of ground water, therefore, represents a composite that includes upgradient sources.

The data can be used in the mass-balance equation to estimate a range of recharge values, however. For example, areas with highly permeable subsoils would produce no direct runoff and therefore would have the largest amount of recharge and the lowest chloride concentrations. Using the lowest chloride concentration in ground water from table 6, setting surface-water runoff (SWR) equal to 0 in eq. 14, and using the average value of atmospheric chloride deposition for the study area yields an estimated maximum annual recharge of 15.5 in. Using the highest chloride concentration from table 6 (excluding those greater than 3 mg/L) and the larger of the two average direct runoff values for SWR in eq. 14 results in an estimated minimum annual recharge of 6.1 in.

Although the method for estimating average, minimum, and maximum recharge assumes that there are no other sources of chloride to the aquifer, there are most likely some. The net effect of sources of chloride other than from the atmosphere would be that the recharge values computed using the chloride mass-balance method are less than the actual recharge. This can be seen in eq. 13, in which the computed recharge is inversely proportional to the ground-water chloride concentration, if the other variables remain unchanged. Therefore, the range in recharge values from 6.1 to 15.5 in/yr computed by the chloride-mass balance method may represent lower limits.

Table 5. Summary of chloride concentrations in precipitation and dry chloride deposition measured at two sites on the Tulalip Indian Reservation, Snohomish County, Washington, March 2001–March 2003.

[**Collection station**: Location of sites is shown in figure 6. mg/L, milligram per liter; mg/m², milligram per square meter]

Collection station	Observation period		Chloride concentration in wet bucket (mg/L)	Atmospheric chloride flux (mg/m²)		
	From	To		In precipitation (wet)	As dry deposition (dry)	Total of wet + dry
Cl-1	03/23/01	04/18/01	1.3	62.84	19.41	82.25
Cl-2			.5	42.07	11.68	53.75
Cl-1	04/18/01	05/18/01	2.1	116.20	74.19	190.39
Cl-2			1.0	62.33	20.63	82.96
Cl-1	05/18/01	06/25/01	.7	56.98	98.28	155.26
Cl-2			.2	19.28	12.75	32.03
Cl-1	06/25/01	07/20/01	.6	16.12	61.31	77.43
Cl-2			.3	9.18	4.38	13.56
Cl-1	07/20/01	08/23/01	.2	9.05	1.51	10.57
Cl-2			.6	39.36	32.93	72.30
Cl-1	08/23/01	09/24/01	7.55	11.57	5.18	16.75
Cl-2			1.4	9.99	2.12	12.11
Cl-1	09/24/01	10/19/01	1.2	82.16	26.66	108.82
Cl-2			1.0	39.60	19.25	58.85
Cl-1	10/19/01	11/19/01	.7	65.01	35.04	100.05
Cl-2			.4	45.17	40.53	85.71
Cl-1	11/19/01	12/11/01	1.3	121.16	94.60	215.77
Cl-2			1.2	200.81	65.24	266.05
Cl-1	12/11/01	01/07/02	2.5	158.00	82.88	240.89
Cl-2			.9	91.98	60.13	152.11
Cl-1	01/07/02	02/04/02	1.9	124.14	59.03	183.17
Cl-2			1.4	163.24	41.00	204.25
Cl-1	02/04/02	03/04/02	1.5	41.50	30.80	72.30
Cl-2			.7	39.48	20.09	59.57
Cl-1	03/04/02	04/04/02	2.5	141.17	77.74	218.91
Cl-2			1.0	107.40	49.56	156.96
Cl-1	04/04/02	05/03/02	3.4	80.92	47.60	128.52
Cl-2			1.7	135.66	30.93	166.60
Cl-1	05/03/02	06/04/02	2.0	35.73	25.05	60.78
Cl-2			.6	31.40	25.05	49.40
Cl-1	06/04/02	07/02/02	1.6	18.45	73.34	91.79
Cl-2			.6	15.28	7.47	22.75
Cl-1	07/02/02	08/01/02	1.2	19.36	65.02	84.38
Cl-2			.3	8.22	4.40	12.62
Cl-1	08/01/02	09/06/02	6.73	1.35	28.28	29.63
Cl-2			17.5	3.50	6.00	9.50
Cl-1	09/06/02	10/01/02	2.1	32.62	29.79	62.41
Cl-2			.7	8.21	2.85	11.07
Cl-1	10/01/02	11/05/02	1.0	19.00	39.14	58.14
Cl-2			3.8	97.28	4.90	102.18
Cl-1	11/05/02	12/03/02	1.5	28.50	32.90	61.40
Cl-2			.4	15.6	25.07	40.67

Table 5. Summary of chloride concentrations in precipitation and dry chloride deposition measured at two sites on the Tulalip Indian Reservation, Snohomish County, Washington, March 2001–March 2003.—Continued

[**Collection station**: Location of sites is shown in figure 6. mg/L, milligram per liter; mg/m², milligram per square meter]

Collection station	Observation period		Chloride concentration in wet bucket (mg/L)	Atmospheric chloride flux (mg/m²)		
	From	To		In precipitation (wet)	As dry deposition (dry)	Total of wet + dry
Cl-1	12/03/02	01/07/03	0.8	85.55	106.00	191.55
Cl-2			.7	115.74	58.30	174.04
Cl-1	01/07/03	02/06/03	.4	23.07	42.48	65.55
Cl-2			.1	8.88	10.45	19.33
Cl-1	02/06/03	03/04/03	.8	16.48	19.93	36.41
Cl-2			.4	16.67	8.40	25.07
Cl-1	03/04/03	04/01/03	2.2	109.56	60.57	170.13
Cl-2			.9	85.14	35.53	120.68

Table 6. Summary of chloride and nitrate concentrations and selected physical and hydrologic data for selected wells on the Tulalip Indian Reservation, Snohomish County, Washington.

[All altitudes and depths rounded to nearest foot. Altitudes are given in feet above or below (-) NGVD of 1929. mg/L, milligram per liter; <, less than]

Well No.	Altitude of land surface (feet)	Altitude of well bottom (feet)	Well depth (feet below land surface)	Water-level altitude (feet)	Chloride concentration (mg/L)	Nitrate concentration (mg/L as N)
30N/04E-01A05	455	300	155	335	5.5	4.58
30N/04E-01E01	560	283	277	317	3.3	2.16
30N/04E-02A02	585	281	304	316	3.1	.995
30N/04E-02G01	510	292	218	318	3.3	2.05
30N/04E-03D03	430	251	179	295	6.0	3.61
30N/04E-03H01	394	289	105	312	5.0	2.87
30N/04E-03P01	330	222	108	256	4.8	2.26
30N/04E-05A02	330	-10	340	39	5.9	1.36
30N/04E-05P02	430	1	429	53	7.1	<.0
30N/04E-08H02	465	102	363	131	10.4	4.59
30N/04E-13Q02	360	73	287	179	4.2	<.05
30N/04E-16M01	380	80	300	107	7.1	4.07
30N/05E-05E01	94	84	10	92	3.6	2.05
30N/05E-06G04	165	87	78	118	3.5	2.43
30N/05E-06H01	96	11	85	126	3.1	<.050
30N/05E-07F08	340	130	210	160	3.0	2.03
30N/05E-31B10	60	-29	89	12	7.0	4.33

Ground-Water Withdrawals

Annual ground-water withdrawals were estimated for six categories of water use: class A and B public-supply wells, domestic self-supplied, recreation, agriculture, and hatchery (table 7). Public-supply drinking-water withdrawals account for approximately one-half of the ground-water withdrawal, followed by domestic drinking-water withdrawals. Estimated gross ground-water withdrawals totaled 407 Mgal, or about 2 ft^3/s. However, not all of that water is actually removed from the ground-water system. A large part of the water withdrawn for drinking-water supplies is returned to the ground-water system through septic systems. Previous studies (Sapik and others, 1988; Thomas and others, 1999) have used a value of 70 percent for the amount of water that returns to the ground-water system through septic systems. All ground water pumped for drinking-water supplies is for homes with septic systems except for 800 homes served by the tribal sewer system (Tulalip Tribes, 1994). Assuming that 70 percent of the water that is used for drinking-water supplies at homes with septic systems is returned to the ground-water system, the estimated total net ground-water withdrawal on the Reservation is 1 ft^3/s.

Water-Level Fluctuations

Water levels in the ground-water system fluctuate over time in response to changes in recharge and discharge. These fluctuations reflect changes in the amount of storage in the system. Rising water levels indicate increases in water storage and declining water levels indicate removal of water from storage.

Table 7. Summary of gross annual ground-water use for the Tulalip Indian Reservation, Snohomish County, Washington.

Water-use category	Withdrawals, in millions of gallons
Public supply, class A	182
Public supply, class B	16
Domestic, self-supplied	87
Recreation	9
Agriculture	60
Fish hatchery	53
Total	407

Seasonal Fluctuation

Over the course of a year, static water levels (that is, not affected by short-term stresses such as pumping) fluctuate in response to changes in precipitation. Typically, water levels in wells that are shallow in depth, have a shallow water table, or are screened in units that are exposed at the surface fluctuate more widely and respond more quickly to changes in recharge by infiltration of precipitation than do deeper wells or wells that are screened in units that are buried.

Large fluctuations in static water levels were measured in shallow wells in units that were exposed to the surface (fig. 17). For example, water levels varied by as much as 10 ft in well 30N/04E-01C01 in Qvt and by more than 15 ft in well 30N/05E-31G02 in Qva. Water levels did not fluctuate as much in well 30N/05E-29G07 in Qvr, even though it also was shallow. This is likely because it was located between Sturgeon and Quilceda Creeks, which may influence the shallow water levels in the area. Water levels in these wells were highest between December and March and then declined through the spring and summer to lows in October and November.

For wells that were deeper and in hydrogeologic units that were not exposed at the surface, water-level fluctuations were smaller (fig. 18). For example, fluctuations in wells 31N/04E-22B03 and 30N/04E-04F02 varied by less than 1.5 ft and fluctuations in well 31N/04E-15N03 ranged from 3 to 4 ft, with the highest water levels occurring during April and May after the principal rainy season of October through March. The highest water levels in these wells are later than those in the shallow wells because of a slower response to precipitation.

Long-Term Fluctuation

In addition to fluctuating seasonally, water levels can change over longer periods of time, such as years or decades. Typically, in a natural setting, changes in ground-water recharge and discharge even out over the years and the long-term water levels remain relatively constant. However, long-term water levels can change because of long-term climate changes or human activities such as increased ground-water pumpage, which could lower the water table, or increased storm-water retention, which could increase recharge and therefore water levels.

Two different methods were used to evaluate whether there have been any long-term changes in water levels in the study area. A sign test was used to compare water-level measurements in wells that were part well inventories in both the early 1990s and 2001. The Wilcoxon rank-sum test (Helsel and Hirsch, 2002) was used to compare historical and current monthly water-level measurements in a smaller set wells.

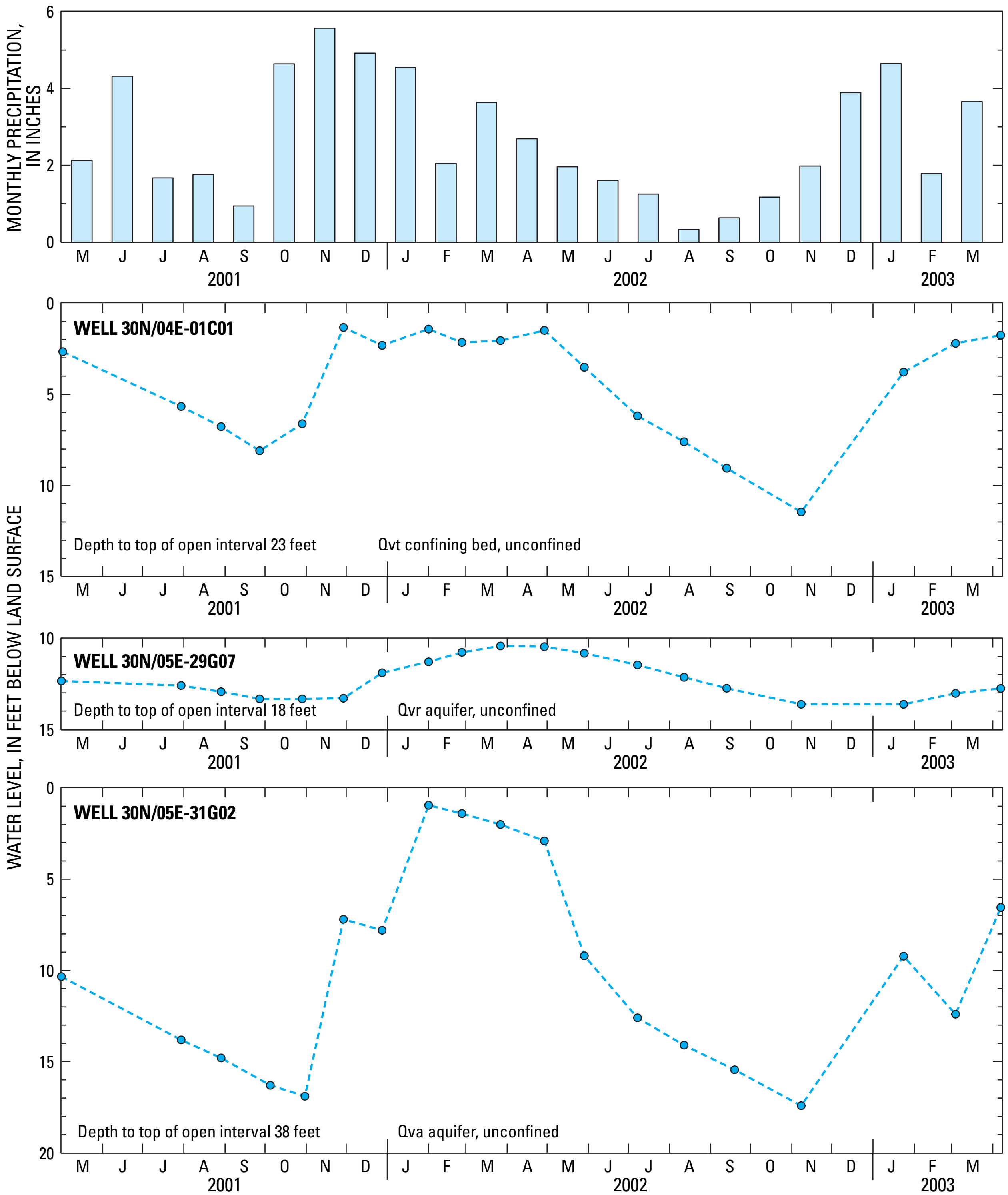


Figure 17. Relation between monthly precipitation and fluctuations in static water levels in selected shallow wells in units exposed at land surface and selected deep wells in units not exposed at the land surface on the Tulalip Plateau, Snohomish County, Washington.

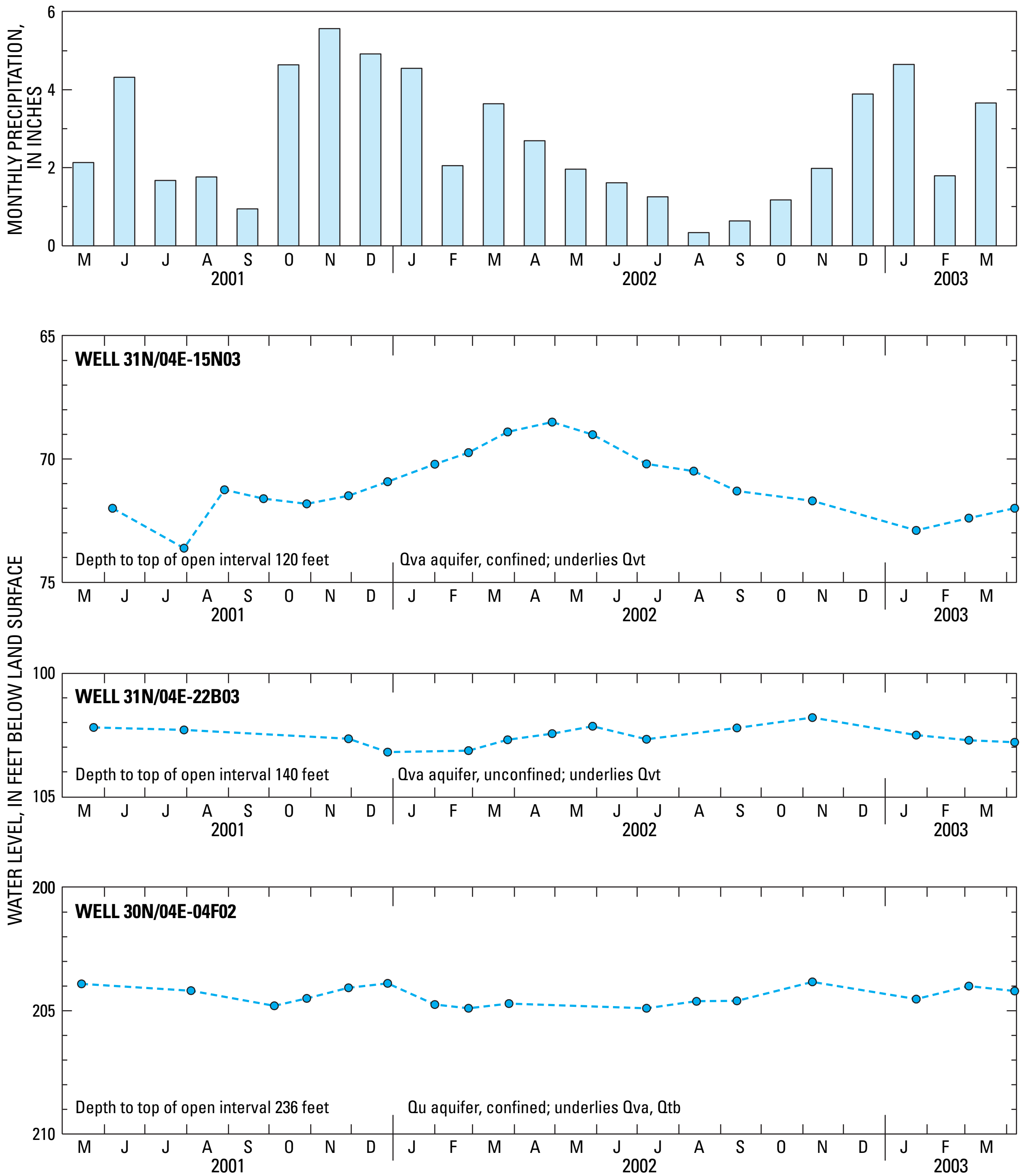


Figure 18. Relation between monthly precipitation and fluctuations in static water levels in selected deep wells in units not exposed at land surface in the Tulalip Indian Reservation, Snohomish County, Washington.

The sign test determines whether the medians of two groups are equal when those groups are composed of observations paired by some auxiliary variable (Conover, 1999). For environmental data, pairs often are composed of observations taken at the same place or the same time. By pairing observations, extraneous influences on the data other than the one being investigated can be compensated for and blocked out. The sign test determines whether the second observation in a pair (the 'ending point') shows an increase or decrease from its paired observation at the starting point. Change in static water level was determined for 72 wells measured in the early 1990s and again in 2001 (fig. 19). The data were paired by location and water levels were tested to see if they were consistently higher in the later period than in the earlier period.

The sign test shows no statistically significant change in static water levels in the 72 wells between the early 1990s and 2001, either for the data set as a whole (p=0.56) or when broken down by unit: Qu (p=0.56) or Qva (p=1.0). There were not enough wells in Qtb, Qvr, and Qvt to determine a trend in those units. Approximately one-half the wells showed increases in water levels and one-half showed decreases in water levels, with an overall average change in water level of -0.29 ft.

Eighteen wells were selected from the current study that had a sufficient number of current monthly water-level measurements and were measured monthly during previous studies. The Wilcoxon rank-sum test was applied to the data to determine the step trend in water levels over time for each well (table 8). A step trend looks for changes between two non-overlapping sets of data, which in this case is the early set of water-level measurements (typically late 1970s to early 1980s) and the current set of water-level measurements.

The rank-sum test is a nonparametric test that uses the relative ranks of the data points to determine if one set of data has higher values than another set of data. For these tests, if the earlier data set had all lower ranks and the later data set had all higher ranks, the trend would be decreasing. If no trend were present, then the sums of the ranks would be about equal, assuming the same number of water-level measurements in each period. A trend was considered to be statistically significant if the p-value from the rank-sum test was less than or equal to 0.05.

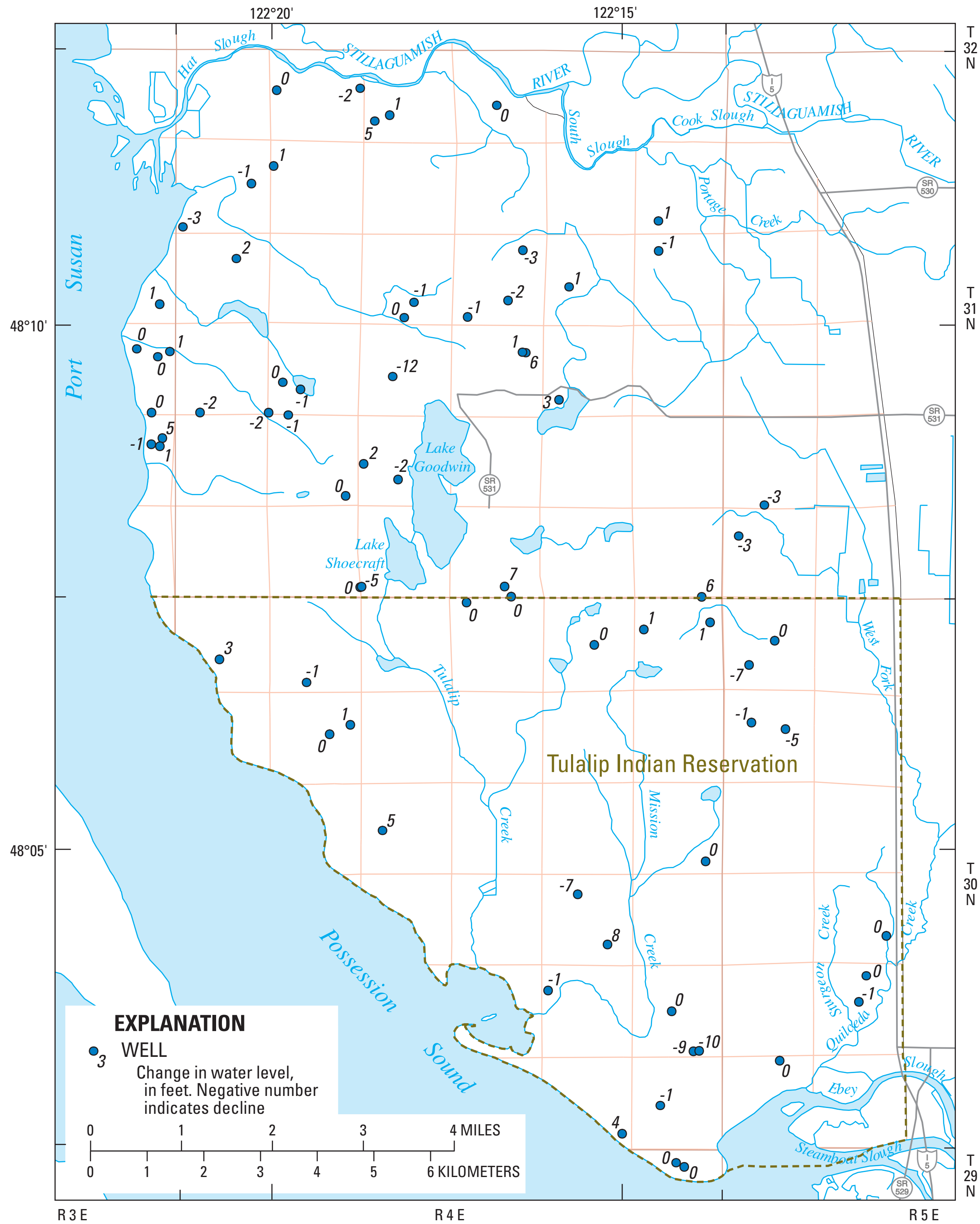
For those wells that showed a statistically significant trend using the rank-sum test described above, the nonparametric Hodges-Lehmann estimator was used to determine by how much the water levels changed between the two periods (Helsel and Hirsch, 2002). The Hodges-Lehmann estimator is computed as the median of all possible pairwise differences between the water levels in the early period and those in the later period.

Of the 18 wells that were evaluated (table 8), 6 showed no statistically significant change in water level, 4 showed a decreasing trend, and 8 showed an increasing trend (examples are shown in figure 20). Neither of the two wells that were screened in Qvt showed a statistically significant change between the late 1970s and early 2000s. Wells that were screened in Qva tended to show an increase in static water levels since the early 1980s and 1990s, whereas the three wells screened in Qu showed no discernible pattern: no change in one well, a downward trend in one well, and an upward trend in the third well.

Table 8. Summary of results from Wilcoxon rank-sum tests for a step trend in water levels in selected wells on the Tulalip Indian Reservation, Snohomish County, Washington.

[**Trend:** UP, statistically significant upward trend; DOWN, statistically significant downward trend; NT, no trend. *p*-value from the Wilcoxon rank-sum test. Trend is considered significant if *p*-value is less than or equal to 0.05. –, not available; <, less than; na, not applicable]

Well No.	Period of analysis		Screened hydrogeologic unit	Trend	*p*-value	Magnitude of step trend
	Early	Late				
30N/04E-01C01	1974–82	2001–03	Qvt	NT	0.904	na
30N/04E-04F02	1981–83	2001–03	Qu	DOWN	<.001	-1.6
30N/04E-10L02	1974–83	2001–03	Qva	NT	.873	na
30N/04E-10L03	1974–83	2001–03	Qva	NT	.414	na
30N/04E-21J02	1975–83	2001–03	Qtb	DOWN	<.001	-1.0
30N/04E-36P01	1974–81	2001–03	–	NT	.105	na
30N/05E-06H01	1975–82	2001–03	–	UP	<.001	1.3
30N/05E-07G05	1976–83	2001–03	Qva	DOWN	<.001	-2.0
30N/05E-29G07	1974–77	2001–03	Qvr	DOWN	<.001	-2.0
30N/05E-31G02	1974–77	2001–03	Qvt	NT	.055	na
31N/03E-24Q03	1992–95	2001–03	Qu	NT	.161	na
31N/04E-08E02	1992–95	2001–03	Qva	UP	<.001	1.3
31N/04E-15N03	1992–95	2001–03	Qva	UP	.018	1.1
31N/04E-19G01	1981–83	2001–03	Qu	UP	<.001	5.0
31N/04E-21Q01	1981–83	2001–03	Qva	UP	<.001	3.2
31N/04E-22B03	1981–83	2001–03	Qva	UP	<.001	1.9
31N/04E-23N01	1981–83	2001–03	Qva	UP	<.001	1.6
31N/04E-34D01	1981–83	2001–03	Qva	UP	.011	.7



Base from U.S. Geological Survey Digital Data, 1:100,000, 1985
Universal Transverse Mercator projection, Zone 10, Datum NAD 83

Figure 19. Changes in water levels in selected wells, early 1990s to 2001.

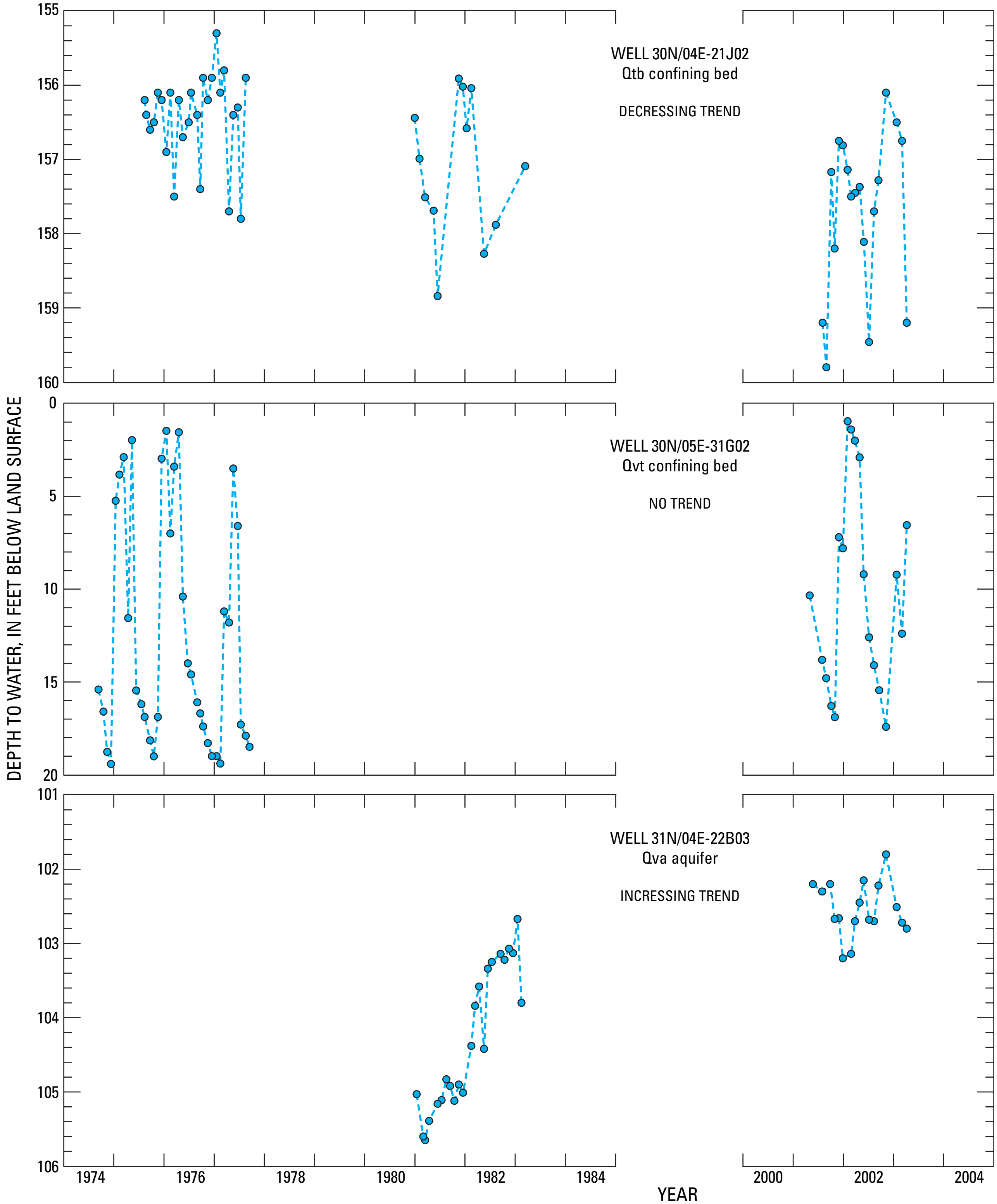


Figure 20. Examples of long-term trends in static water levels in selected wells in the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

Surface-Water System

This section provides information on the surface-water system of the Tulalip Indian Reservation. An assessment of current streamflow conditions on the Reservation is given and compared with those during 1975–77 for changes in streamflow and base flow. Estimates of surface-water inflow to and outflow from the Reservation and changes in lake levels since 1975–77 also are presented.

Streams

Current streamflow conditions on the Reservation were defined using discharge data from four continuous-record gaging stations on Mission and Tulalip Creeks and operated from April 2001 through March 2003 (climatic years 2002–03; tables 9–12) and from monthly measurements of discharge at 12 periodic-measurement sites, all but one on the Reservation (table 13). Two of the continuous-record gaging stations, 12157250 (Mission Creek near Tulalip) and 12158040 (Tulalip Creek near Tulalip), which are located near the mouths of the creeks, also were operated during water years 1975–77 for a previous study of the water resources of the Tulalip Indian Reservation (Drost, 1983). The other two continuous-record gaging stations are 12158010 (Tulalip Creek above East Branch, near Tulalip) and 12158032 (East Branch Tulalip Creek near mouth, near Tulalip). The daily discharge record for station 12158032 does not begin until May 2002.

Current continuous-discharge records for gaging stations 12157250 and 12158040 were compared with records from water years 1975–77 to determine if significant changes in total streamflow and base flow have occurred in the Tulalip and Mission Creek drainage basins since the mid-1970s. The mean discharge of 5.44 ft^3/s at station 12157250 during climatic years 2002–03 is about 6 percent lower than the mean discharge of 5.78 ft^3/s during water years 1975–77. However, the mean discharge of 13.3 ft^3/s at station 12158040 during climatic years 2002–03 is about 10 percent higher than the mean discharge of 12.1 ft^3/s during the water years 1975–77. The direct comparisons of flows during climatic years 2002–03 with those during water years 1975–77 are not very meaningful by themselves because they do not account for any short-term above- or below-average trends in precipitation that may have affected them. The 48-year precipitation record for the National Weather Service Everett Precipitation site 2675, just south of the Reservation, was analyzed to determine whether significant changes in precipitation have occurred in the area since the mid-1970s. To determine if long-term streamflow reflects the pattern of precipitation, the Everett precipitation record was compared with the long-term streamflow record for Mercer Creek near Bellevue (station 12120000), which has been collected by the USGS since 1956. Although this station is about 30 mi south of the Reservation and measures the runoff from a highly urbanized area, it is the only long-term streamflow record available on a small, nearby, unregulated stream. Furthermore, this station was used to estimate streamflow-statistics values for several streamflow sites on the Reservation during the 1975–77 study (Drost, 1983).

A good way to visualize the amount of variation in long-term precipitation and streamflow records and especially to easily detect periods that are above or below average is to compute and plot the cumulative departure of monthly values from long-term mean monthly values. Increasing cumulative departures indicate above-average values, whereas decreasing departures indicate below-average values. Mean monthly values were computed and cumulative departures were calculated and plotted for the Everett precipitation record and the Mercer Creek streamflow record using a common base period of 1956 to present (fig. 21). The amount of variation in both records and patterns of above- or below-average values—sometimes lasting for several years—can clearly be seen. The shapes of both plots are similar, indicating that the streamflow record correlates well with the precipitation record. Both plots indicate transitions from above-average to below-average precipitation and streamflow during 1975–77 and 2002–03.

The strong correlation between the Mercer Creek streamflow record and the Everett precipitation record is shown by the similarity of bar graphs of annual values for water years 1975–77 and climatic years 2002–2003 (fig. 22). Both records were near or above average during 1975, 1976, and 2002 and below average during 1977 and 2003. The coefficient of correlation between the annual mean streamflow and annual total precipitation records for these years (0.82) closely matches the coefficient (0.84) for 1975–2003.

Table 9. Daily mean discharge at Mission Creek near Tulalip, Washington (station 12157250), climatic years 2002 and 2003.

[**Discharge:** e, estimated; max, maximum; min, minimum. **Abbreviations:** ft³/s, cubic foot per second; acre-ft, acre-foot; ft³/mi², cubic foot per square mile; –, no data]

Day	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
	Discharge (ft³/s)											
	Climatic year 2002											
1	5.2	6.0	2.6	2.5	2.0	1.4	1.8	5.4	19	7.0	20	6.7
2	4.8	6.3	6.0	2.0	1.8	1.5	1.8	4.3	16	9.0	17	6.7
3	4.6	5.5	8.9	1.8	1.9	1.5	1.6	3.6	14	7.6	15	6.4
4	4.5	4.8	5.7	1.8	2.1	1.4	1.5	3.4	13	6.4	15	6.3
5	4.3	4.9	4.5	1.7	1.7	1.4	1.6	3.5	11	5.9	14	5.7
6	6.5	4.4	3.6	1.6	1.5	1.5	1.5	3.4	11	7.3	14	5.3
7	11	3.8	3.0	1.5	1.5	1.9	1.4	3.1	9.4	11	14	5.3
8	9.2	3.3	2.7	1.5	1.4	1.6	1.6	2.9	8.7	13	18	5.8
9	7.0	3	2.6	1.4	1.3	1.5	1.6	2.8	10	9.3	15	6.7
10	8.3	3.0	2.4	1.3	1.7	1.3	1.6	2.7	12	7.5	13	7.4
11	10	3.1	8.4	1.3	1.4	1.4	1.9	2.7	14	6.8	14	8.1
12	8.6	2.9	31	1.3	1.2	1.3	2.1	3.0	13	7.4	12	8.7
13	13	3.1	18	1.3	1.1	1.2	2.1	3.7	19	7.1	10	7.5
14	9.9	3.6	8.8	1.5	1.1	1.3	2.9	11	26	6.2	9.8	15
15	7.7	9.0	5.6	1.5	1.1	1.3	2.9	16	21	5.7	9.2	18
16	6.8	9.8	4.4	2.3	1.2	1.3	3.0	10	24	5.5	8.5	17
17	8.6	6.6	3.5	2.7	1.3	1.3	3.7	6.8	49	5.6	8.3	13
18	7.8	4.7	3.0	2.6	1.3	1.4	3.1	5.3	30	5.8	8.7	11
19	6.4	4.0	2.8	2.1	1.3	1.5	4.9	8.8	21	17	9.7	15
20	5.6	3.5	2.6	1.7	1.2	1.4	4.6	13	16	20	10	31
21	5.1	3.3	2.4	1.6	1.4	1.5	4.4	10	14	15	11	23
22	5.1	3.0	2.3	1.5	3.3	1.5	5.5	12	12	14	9.7	19
23	5.0	2.8	2.2	1.6	6.9	1.5	5.2	17	10	14	9.6	17
24	4.8	2.6	2.3	1.5	5.1	1.4	4.1	10	9.1	12	9.6	14
25	4.4	2.4	3.3	1.5	3.0	1.5	8.4	7.5	8.3	17	8.2	13
26	4.1	2.3	3.0	1.4	2.3	2.5	7.6	6.3	7.6	15	7.4	11
27	3.9	2.3	3.3	1.4	1.8	3.9	15	5.4	7.2	13	7.0	9.9
28	3.9	2.1	6.1	5.7	1.6	3.0	11	11	7.4	14	7.0	11
29	5.1	2.0	4.9	5.5	1.5	2.3	6.8	24	6.9	12	–	10
30	5.9	2.1	3.2	3.6	1.5	1.9	4.7	22	6.2	14	–	9.2
31	–	2.3	–	2.6	1.4	–	5.8	–	6.6	20	–	8.4
Total	197.1	122.6	163.1	63.3	58.9	49.4	125.7	240.6	452.4	331.1	324.7	352.1
Mean	6.57	3.95	5.44	2.04	1.90	1.65	4.05	8.02	14.6	10.7	11.6	11.4
Max	13	9.8	31	5.7	6.9	3.9	15	24	49	20	20	31
Min	3.9	2.0	2.2	1.3	1.1	1.2	1.4	2.7	6.2	5.5	7.0	5.3
acre-ft	391	243	324	126	117	98	249	477	897	657	644	698
ft³/mi²	.83	.50	.69	.26	.24	.21	.51	1.01	1.84	1.35	1.46	1.43
inches	.93	.58	.77	.30	.28	.23	.59	1.13	2.12	1.56	1.53	1.65

Table 9. Daily mean discharge at Mission Creek near Tulalip, Washington (station 12157250), climatic years 2002 and 2003.—Continued

[**Discharge:** e, estimated; max, maximum; min, minimum. **Abbreviations:** ft^3/s, cubic foot per second; acre-ft, acre-foot; ft^3/mi^2, cubic foot per square mile; –, no data]

	Discharge (ft^3/s)											
Day	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
Climatic year 2003												
1	8.7	4.3	3.0	2.1	1.2	e1.4	2.2	1.8	2.6	4.5	6.7	4.2
2	8.1	4.2	3.1	1.6	1.2	e1.5	1.7	1.8	2.5	7.4	5.8	4.3
3	7.3	4.3	2.8	1.4	1.1	e1.5	3.2	1.8	2.4	11	6.2	5.3
4	6.9	4.1	2.7	1.7	1.2	e1.5	4.2	1.9	2.5	14	6.2	5.3
5	6.4	6.5	3.1	1.8	1.4	e1.4	3.3	2.0	2.4	26	5.6	4.8
6	6.3	9.0	4.2	1.6	1.8	e1.4	2.7	2.5	2.3	14	4.9	4.6
7	6.4	6.9	4.2	1.5	1.7	e1.3	2.3	3.5	2.3	8.6	4.6	4.7
8	6.1	5.5	3.0	4.7	1.4	e1.2	2.2	3.8	2.3	6.5	4.4	4.9
9	6.4	4.7	2.6	5.2	1.3	e1.2	2.4	3.3	2.3	5.4	4.2	5.4
10	9.2	4.4	2.4	3.0	1.2	e1.2	e2.1	3.0	2.9	4.6	4.1	5.7
11	8.8	3.8	2.2	2.2	1.1	e1.2	e1.9	2.9	3.7	4.4	4.0	5.2
12	7.5	3.6	2.1	1.9	1.1	1.2	e1.6	3.1	4.8	8.5	3.9	6.8
13	7.3	3.7	1.9	1.5	1.1	1.2	e1.7	3.6	4.8	11	3.9	24
14	8.4	5.4	1.6	1.4	.99	1.2	e1.6	3.2	6.5	10	3.8	22
15	7.9	5.1	1.4	1.3	.96	1.0	e1.6	2.8	10	8.3	4.0	14
16	12	4.3	1.5	1.4	.89	1.2	1.7	2.9	14	6.6	6.6	9.6
17	13	4.2	1.7	1.5	.90	1.6	1.7	3.5	12	5.6	8.2	7.6
18	10	4.0	2.4	1.4	.92	1.5	1.8	3.1	8.4	4.9	6.8	6.6
19	8.8	3.8	2.9	1.4	.99	1.3	1.8	3.1	6.2	4.6	5.7	6.0
20	7.8	4.3	2.4	1.5	1.1	1.3	1.8	3.3	4.8	4.4	5.2	6.7
21	7.1	4.7	2.0	1.4	1.3	1.3	1.8	3.2	4.0	5.9	5.1	7.0
22	6.9	3.9	1.7	1.3	1.4	1.3	1.8	3.1	3.6	12	5.3	7.2
23	7.3	3.6	1.6	1.3	1.3	1.2	1.8	2.8	3.2	12	5.0	7.1
24	6.8	3.4	1.5	1.3	1.3	1.2	1.8	2.6	3.1	9.0	4.5	6.6
25	6.1	3.4	1.4	1.2	1.4	1.1	1.8	2.4	3.4	7.3	4.2	5.9
26	5.9	3.5	1.3	1.3	1.6	1.2	1.8	2.4	5.2	7.7	4.1	5.6
27	6.3	3.6	1.2	1.4	e1.5	1.2	1.8	2.4	6.2	7.7	3.9	6.3
28	5.7	3.7	1.6	1.4	e1.4	1.1	2.1	2.4	5.9	6.6	4.0	5.9
29	5.1	3.8	4.1	1.5	e1.4	1.6	2.2	2.4	5.3	6.1	–	5.1
30	4.6	4.2	3.3	1.5	e1.3	2.4	1.9	2.5	4.8	7.0	–	4.8
31	–	3.7	–	1.3	e1.4	–	1.9	–	4.7	7.9	–	4.9
Total	225.1	137.6	70.9	55.0	38.85	39.9	64.2	83.1	149.1	259.5	140.9	224.1
Mean	7.50	4.44	2.36	1.77	1.25	1.33	2.07	2.77	4.81	8.37	5.03	7.23
Max	13	9.0	4.2	5.2	1.8	2.4	4.2	3.8	14	26	8.2	24
Min	4.6	3.4	1.2	1.2	.89	1.0	1.6	1.8	2.3	4.4	3.8	4.2
acre-ft	446	273	141	109	77	79	127	165	296	515	279	445
ft^3/mi^2	.95	.56	.30	.22	.16	.17	.26	.35	.61	1.06	.64	.91
inches	1.06	.65	.33	.26	.18	.19	.30	.39	.70	1.22	.66	1.05

Table 10. Daily mean discharge at Tulalip Creek above East Branch near Tulalip, Washington (station 12158010), climatic years 2002 and 2003.

[**Discharge:** e, estimated; max, maximum; min, minimum. **Abbreviations:** ft^3/s, cubic foot per second; acre-ft, acre-foot; ft^3/mi^2, cubic foot per square mile; –, no data]

	Discharge (ft^3/s)											
Day	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
Climatic year 2002												
1	7.6	6.5	5.6	5.0	4.6	4.5	4.6	4.2	19	12	19	12
2	7.7	6.5	6.2	4.8	4.4	4.4	4.6	4.0	17	13	19	10
3	7.4	6.3	5.7	4.7	4.5	4.4	4.6	3.7	16	12	18	9.6
4	7.4	6.2	4.9	4.6	4.5	4.4	4.7	3.4	19	12	17	9.0
5	7.3	6.1	4.9	4.4	4.5	4.4	4.4	3.5	20	12	17	9.0
6	8.7	6.0	4.7	4.3	4.4	4.4	4.5	3.5	19	13	18	8.7
7	9.7	5.9	4.5	4.3	4.4	4.4	4.6	3.5	17	14	19	8.8
8	9.0	5.8	4.5	4.1	4.5	4.4	4.5	3.6	17	14	20	9.4
9	8.8	5.7	5.0	4.0	4.5	4.3	4.6	3.7	17	13	18	9.6
10	10	5.5	4.8	3.9	4.5	4.3	4.9	3.2	18	13	18	10
11	9.9	5.4	8.7	3.8	4.6	4.3	4.8	3.1	19	12	17	9.9
12	13	5.4	13	3.8	4.5	4.3	5.2	3.8	24	12	17	9.9
13	16	5.7	8.4	3.7	4.6	4.2	5.6	5.1	28	12	16	10
14	15	6.9	7.7	3.8	4.5	4.3	6.1	10	28	12	15	15
15	13	8.1	7.0	4.0	4.5	4.3	5.1	6.9	26	11	14	13
16	13	6.9	6.5	4.6	4.4	4.4	5.9	5.3	33	11	14	14
17	12	6.0	6.0	6.1	4.3	4.4	5.6	4.6	43	11	14	13
18	11	5.8	5.6	4.9	4.0	4.4	5.6	4.5	32	11	14	13
19	12	5.6	5.3	4.7	4.4	4.4	6.8	7.6	30	16	15	17
20	11	5.8	5.1	4.7	4.4	4.4	5.6	7.8	33	15	14	24
21	11	5.9	5.0	4.8	5.3	4.5	6.5	7.2	29	19	14	23
22	10	5.7	4.9	4.8	7.8	4.5	6.2	11	25	18	14	22
23	9.8	5.6	4.7	4.4	6.0	4.3	8.0	12	23	17	15	20
24	8.7	5.6	5.2	4.5	4.7	4.4	13	10	21	16	14	18
25	7.6	5.3	5.4	4.4	4.5	4.5	12	9.8	19	19	13	17
26	6.7	4.9	4.8	4.4	4.4	6.2	6.7	9.4	17	17	13	17
27	6.4	4.8	6.1	4.4	4.4	5.6	9.2	8.6	13	17	13	15
28	6.5	4.8	6.7	7.4	4.4	4.8	4.5	12	11	17	12	17
29	6.8	4.5	5.2	5.2	4.4	4.5	4.3	18	10	17	–	16
30	6.9	4.5	5.1	4.9	4.4	4.5	4.4	17	11	17	–	15
31	–	4.6	–	4.7	4.3	–	5.9	–	12	19	–	14
Total	289.9	178.3	177.2	142.1	143.6	135.1	183.0	210.0	666	444	441	428.9
Mean	9.66	5.75	5.91	4.58	4.63	4.50	5.90	7.00	21.5	14.3	15.8	13.8
Max	16	8.1	13	7.4	7.8	6.2	13	18	43	19	20	24
Min	6.4	4.5	4.5	3.7	4.0	4.2	4.3	3.1	10	11	12	8.7
acre-ft	575	354	351	282	285	268	363	417	1,320	881	875	851
ft^3/mi^2	.99	.59	.61	.47	.48	.46	.61	.72	2.21	1.47	1.62	1.42
inches	1.11	.68	.68	.54	.55	.52	.70	.80	2.54	1.70	1.68	1.64

Table 10. Daily mean discharge at Tulalip Creek above East Branch near Tulalip, Washington (station 12158010), climatic years 2002 and 2003.—Continued

[**Discharge:** e, estimated; max, maximum; min, minimum. **Abbreviations:** ft³/s, cubic foot per second; acre-ft, acre-foot; ft³/mi², cubic foot per square mile; –, no data]

	Discharge (ft³/s)											
Day	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
Climatic year 2003												
1	15	8.7	5.8	4.3	3.4	e3.4	e5.0	6.6	e4.3	e5.2	7.2	5.1
2	14	8.5	6.0	4.4	3.5	e3.5	e5.0	7.2	e4.8	e5.4	6.8	5.6
3	14	9.0	5.6	4.3	3.5	e3.5	e8.4	7.0	e4.4	e6.9	7.5	5.7
4	13	8.9	5.5	4.7	3.7	e3.4	e6.0	6.7	3.2	e8.4	6.7	5.4
5	13	9.7	5.8	4.4	4.3	e3.4	e5.4	7.1	3.3	e11	6.6	5.4
6	13	9.5	5.5	4.1	3.8	e3.5	e5.1	8.4	3.3	e7.4	6.5	5.3
7	13	9.0	5.2	4.7	3.7	e3.3	e4.7	7.4	3.3	e7.2	6.2	5.5
8	12	8.6	5.2	6.4	3.6	e3.5	e4.6	5.6	3.3	e6.8	6.2	5.6
9	13	8.4	5.1	4.2	3.5	e3.5	e4.4	5.0	3.3	e6.4	6.5	6.0
10	14	8.2	5.1	3.9	3.6	e3.5	e4.2	e4.8	3.9	e5.9	6.6	5.8
11	14	7.9	5.0	3.7	3.5	e3.5	e4.3	e4.7	e5.9	e7.2	6.4	5.6
12	11	7.7	4.9	3.6	3.5	e3.5	e4.1	e6.8	e7.0	e7.0	6.3	6.3
13	10	8.0	4.7	3.7	3.4	e3.5	e4.2	e5.7	e5.8	e6.3	6.2	9.4
14	15	8.2	4.8	3.8	3.4	e3.5	e4.3	e4.9	5.4	e5.6	6.1	9.1
15	10	7.5	4.7	3.6	3.5	e3.6	e4.4	e4.4	4.5	5.4	7.0	8.4
16	12	7.4	4.7	3.5	3.5	e4.1	e4.6	e5.4	7.9	5.3	7.3	7.9
17	11	8.1	4.8	3.5	3.6	e4.8	4.6	e6.8	5.4	5.2	6.7	8.6
18	11	7.4	5.7	3.6	3.9	e4.1	4.9	e5.4	e5.0	5.2	6.4	8.6
19	11	7.3	4.9	3.5	4.0	e4.2	5.1	e4.7	e4.9	5.2	6.3	12
20	11	8.4	4.7	3.6	4.0	e4.3	5.1	e4.5	e4.7	5.2	6.4	15
21	10	7.8	4.6	3.5	4.0	e4.0	5.1	e4.7	e4.6	7.0	6.6	15
22	9.9	7.1	4.2	3.3	3.7	e3.9	4.9	e4.0	e4.4	7.7	6.7	15
23	9.5	6.7	4.3	3.1	3.5	e3.8	5.2	e4.0	e4.4	7.2	6.7	15
24	9.2	6.7	4.3	3.1	3.5	e3.9	5.4	e4.7	e4.2	6.7	6.4	15
25	9.1	6.7	4.2	3.4	e3.7	e4.1	5.5	e4.7	e4.7	6.6	6.0	14
26	9.0	6.9	4.1	3.5	e3.8	e3.9	5.7	e4.8	e5.2	8.9	6.2	13
27	9.1	7.6	4.3	3.5	e3.6	e4.5	5.6	e5.0	e5.7	8.3	5.6	12
28	9.3	6.7	4.9	3.7	e3.6	e3.9	5.5	e4.6	e5.7	7.6	5.4	12
29	9.5	6.5	4.9	3.6	e3.6	e4.5	4.4	e4.2	e5.2	7.9	–	11
30	9.2	6.2	4.5	3.5	e3.6	e5.1	5.1	e4.1	e5.0	8.0	–	11
31	–	5.9	–	3.4	e3.5	–	5.8	–	e4.7	7.9	–	11
Total	343.8	241.2	148.0	119.1	113.0	115.2	156.6	163.9	147.4	212.0	181.5	290.3
Mean	11.5	7.78	4.93	3.84	3.65	3.84	5.05	5.46	4.75	6.84	6.48	9.36
Max	15	9.7	6.0	6.4	4.3	5.1	8.4	8.4	7.9	11	7.5	15
Min	9.0	5.9	4.1	3.1	3.4	3.3	4.1	4.0	3.2	5.2	5.4	5.1
acre-ft	682	478	294	236	224	228	311	325	292	421	360	576
ft³/mi²	1.18	.80	.51	.39	.37	.39	.52	.56	.49	.70	.67	.96
inches	1.31	.92	.57	.45	.43	.44	.60	.63	.56	.81	.69	1.11

Table 11. Daily mean discharge at East Branch Tulalip Creek near mouth near Tulalip, Washington (station 12158032), May 2002 to March 2003.

[**Discharge:** e, estimated; max, maximum; min, minimum. **Abbreviations:** ft^3/s, cubic foot per second; acre-ft, acre-foot; ft^3/mi^2, cubic foot per square mile; –, no data]

	Discharge (ft^3/s)											
Day	**APR**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**
1	–	–	2.3	2.3	e2.6	1.8	3.0	e2.5	2.3	2.8	2.4	2.7
2	–	–	2.2	2.2	e2.7	1.9	3.1	e2.5	2.3	3.9	2.4	2.9
3	–	–	2.2	2.2	e2.8	2.1	3.8	2.0	2.3	3.1	2.8	2.9
4	–	–	2.4	2.4	2.9	2.1	3.0	2.2	2.7	4.1	2.5	2.8
5	–	–	2.6	2.3	3.1	2.2	3.0	2.3	2.7	3.0	2.5	2.7
6	–	–	2.4	2.3	2.9	2.2	2.7	2.4	2.6	2.5	2.6	2.8
7	–	–	2.4	2.9	2.7	2.2	2.4	2.7	2.6	2.1	2.5	3.0
8	–	–	2.4	3.9	2.7	2.2	2.5	2.6	2.7	2.0	2.5	3.0
9	–	–	2.3	2.8	2.6	2.1	2.3	2.4	2.7	1.9	2.5	3.2
10	–	–	2.3	2.5	2.5	2.2	2.0	2.5	2.8	e2.1	2.5	3.0
11	–	–	2.2	2.6	2.3	2.0	e2.1	e2.4	3.0	1.9	e2.5	2.8
12	–	–	2.3	2.5	2.2	2.0	e2.1	3.2	2.8	2.9	2.5	3.2
13	–	–	2.2	2.6	2.2	2.1	e2.1	e3.0	2.7	2.4	2.7	4.4
14	–	–	2.1	2.5	2.1	2.5	e2.0	e2.7	3.4	2.4	2.7	3.5
15	–	–	2.1	2.5	2.0	2.7	1.8	e2.6	2.8	2.0	2.7	2.9
16	–	–	2.3	2.6	1.9	2.6	1.9	4.0	3.9	2.0	2.6	2.7
17	–	–	2.3	2.7	1.9	2.6	1.9	e3.1	2.8	2.0	2.3	2.8
18	–	–	2.8	2.6	1.9	2.6	1.9	2.4	2.4	1.9	2.3	2.6
19	–	–	2.3	e2.6	1.9	2.6	2.0	2.4	2.1	2.0	2.4	e2.9
20	–	–	2.2	e2.6	1.6	2.8	2.2	2.2	2.0	2.0	2.6	e3.3
21	–	–	2.2	e2.6	1.5	2.9	2.3	2.0	2.1	2.7	2.9	e3.3
22	–	–	2.2	e2.5	1.6	3.0	2.0	2.1	2.2	2.7	2.9	e3.2
23	–	e2.2	2.2	e2.4	1.9	3.3	2.0	2.2	2.2	2.4	2.8	e3.1
24	–	2.2	2.3	e2.3	2.1	3.3	2.3	2.2	2.1	2.1	e2.8	e3.0
25	–	2.2	2.2	e2.4	2.1	3.5	2.4	2.3	2.6	2.1	e2.8	2.9
26	–	2.4	2.1	e2.5	2.0	3.5	2.1	2.3	2.8	2.6	2.9	2.9
27	–	2.3	2.1	e2.5	2.1	2.6	2.2	2.2	2.8	2.4	2.7	3.1
28	–	2.4	2.4	e2.6	2.1	2.4	2.5	2.3	2.7	2.3	2.8	3.0
29	–	2.4	2.5	e2.6	1.8	2.8	e2.2	2.3	2.7	2.7	–	2.9
30	–	2.3	2.3	e2.5	1.7	3.2	e2.3	2.3	2.9	2.7	–	3.0
31	–	2.3	–	e2.5	1.8	–	e2.4	–	2.8	2.6	–	3.1
Total	–	–	68.8	79.0	68.2	76.0	72.5	74.3	81.5	76.3	73.1	93.6
Mean	–	–	2.29	2.55	2.20	2.53	2.34	2.48	2.63	2.46	2.61	3.02
Max	–	–	2.8	3.9	3.1	3.5	3.8	4.0	3.9	4.1	2.9	4.4
Min	–	–	2.1	2.2	1.5	1.8	1.8	2.0	2.0	1.9	2.3	2.6
acre-ft	–	–	136	157	135	151	144	147	162	151	145	186

Table 12. Daily mean discharge at Tulalip Creek near Tulalip, Washington (station 12158040), climatic years 2002 and 2003.

[**Discharge:** e, estimated; max, maximum; min, minimum. **Abbreviations:** ft³/s, cubic foot per second; acre-ft, acre-foot; ft³/mi², cubic foot per square mile; –, no data]

	Discharge (ft³/s)											
Day	**APR**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**
	Climatic year 2002											
1	13	12	9.0	7.2	6.0	5.9	6.5	11	34	e23	35	18
2	13	12	12	6.9	6.0	6.1	6.4	9.1	27	e27	32	17
3	13	11	13	6.6	5.9	5.8	6.4	8.2	24	e25	31	16
4	12	11	9.8	6.4	5.9	5.8	6.3	8.0	26	e22	29	16
5	12	12	9.2	6.3	5.8	5.8	6.1	8.1	28	e21	28	15
6	16	11	8.8	6.1	5.8	5.8	6.1	7.5	27	e23	30	14
7	18	10	8.4	6.2	5.7	5.8	6.4	6.9	23	e30	32	14
8	17	10	8.1	6.1	5.7	5.7	6.2	6.8	23	e33	37	16
9	16	10	8.5	6.0	5.6	5.7	6.2	6.6	26	e25	31	16
10	18	9.8	8.5	6.0	5.4	5.6	7.0	6.4	27	e21	29	19
11	19	9.6	15	5.9	5.4	5.6	7.1	6.5	29	e18	31	19
12	18	9.4	39	5.8	5.5	5.7	7.2	7.1	33	e18	28	17
13	25	9.9	17	5.9	5.5	5.6	8.0	8.1	42	e17	26	16
14	20	11	12	5.9	5.5	5.6	11	24	52	e17	24	33
15	18	18	10	6.2	5.6	5.6	8.8	29	36	e17	23	27
16	17	16	9.7	6.7	5.6	5.7	11	15	51	e16	23	29
17	18	12	9.1	8.9	5.7	5.8	11	12	99	e15	23	24
18	17	11	8.6	7.2	5.6	5.9	9.3	12	55	e16	24	22
19	16	10	8.2	6.5	5.6	5.9	15	17	44	e35	25	28
20	15	9.9	7.8	6.2	5.6	5.8	12	23	e37	e42	25	48
21	15	10	7.5	6.1	6.3	6.0	14	19	e32	e37	24	35
22	15	9.6	7.3	6.3	10	6.0	15	23	e29	e34	23	32
23	15	9.1	7.2	6.0	13	5.9	14	29	e28	e31	23	28
24	14	8.9	7.3	5.9	7.6	5.9	15	20	e27	30	23	27
25	12	8.8	8.6	5.8	6.4	6.3	21	18	e26	38	21	24
26	12	8.4	7.7	5.8	6.1	7.6	13	18	e24	34	20	22
27	11	8.1	9.2	5.8	5.9	8.6	28	15	e22	32	19	21
28	11	8.3	12	11	5.8	6.9	14	26	e20	33	19	22
29	13	8.1	8.8	8.3	5.8	6.4	11	49	e20	30	–	22
30	13	7.9	7.7	6.8	5.8	6.2	11	34	e20	34	–	20
31	–	7.8	–	6.3	5.7	–	14	–	e21	37	–	20
Total	462	320.6	315.0	203.1	191.8	181.0	334.0	483.3	1,012	831	738	697
Mean	15.4	10.3	10.5	6.55	6.19	6.03	10.8	16.1	32.6	26.8	26.4	22.5
Max	25	18	39	11	13	8.6	28	49	99	42	37	48
Min	11	7.8	7.2	5.8	5.4	5.6	6.1	6.4	20	15	19	14
acre-ft	916	636	625	403	380	359	662	959	2,010	1,650	1,460	1,380
ft³/mi²	1.00	.67	.68	.43	.40	.39	.70	1.05	2.12	1.74	1.71	1.46
inches	1.12	.77	.76	.49	.46	.44	.81	1.17	2.44	2.01	1.78	1.68

Table 12. Daily mean discharge at Tulalip Creek near Tulalip, Washington (station 12158040), climatic years 2002 and 2003.—Continued

[**Discharge**: e, estimated; –, no data; max, maximum; min, minimum. **Abbreviations**: ft^3/s: cubic foot per second; acre-ft, acre-foot; ft^3/mi^2, cubic foot per square mile]

	Discharge (ft^3/s)											
Day	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
	Climatic year 2003											
1	21	14	9.4	6.9	6.3	5.4	6.2	8.6	8.4	13	14	11
2	19	14	9.2	7.0	6.2	5.6	6.2	8.2	8.9	18	13	12
3	19	14	8.9	6.7	6.3	5.7	11	8.2	8.3	20	15	13
4	18	14	9.1	8.3	6.4	5.5	8.5	8.2	8.2	23	13	11
5	18	16	9.6	7.5	8.2	5.4	7.8	8.5	8.2	27	12	11
6	18	16	10	6.9	7.1	5.5	7.2	10	8.1	14	12	11
7	18	15	8.1	7.8	7.0	e5.2	6.6	11	7.8	13	11	11
8	17	14	7.8	15	6.6	e5.4	6.3	10	7.9	12	11	11
9	19	14	7.7	10	6.3	e5.4	6.7	7.6	8.1	11	11	13
10	23	13	7.3	8.2	5.8	e5.4	6.4	7.2	11	11	11	12
11	22	13	7.3	7.3	5.6	e5.4	6.5	6.9	12	11	10	12
12	18	12	6.8	7.2	5.6	5.6	6.2	9.5	13	17	10	14
13	17	13	6.4	7.0	5.6	5.5	6.4	8.5	11	17	10	25
14	26	15	6.3	7.0	5.2	5.6	6.5	7.9	16	16	10	23
15	21	13	6.4	7.1	5.4	5.8	6.7	7.1	13	13	11	19
16	24	12	6.4	6.9	5.4	6.8	6.6	8.2	26	12	15	16
17	22	13	6.4	7.0	5.5	8.0	6.7	9.6	20	11	15	16
18	20	13	9.6	7.1	5.6	6.7	6.8	8.6	16	11	13	15
19	19	12	7.2	6.6	5.9	6.8	7.0	9.2	14	10	12	16
20	19	14	6.8	6.2	6.0	6.5	6.6	10	13	10	12	19
21	18	13	6.3	6.2	6.1	5.9	6.8	9.6	12	14	12	19
22	18	12	6.0	5.8	6.0	5.7	6.8	8.9	11	21	12	19
23	17	11	5.9	5.8	5.8	5.5	6.8	8.7	11	19	11	18
24	16	11	6.0	5.8	5.6	5.7	7.0	8.1	12	15	11	18
25	16	11	6.1	6.1	5.9	6.1	7.2	8.2	13	14	11	18
26	16	12	5.8	6.5	6.0	5.8	7.0	8.3	18	16	10	17
27	16	12	6.0	6.4	5.7	6.8	7.0	8.6	16	17	10	17
28	16	11	7.5	6.5	5.7	5.8	8.2	8.4	15	14	11	16
29	15	11	8.5	6.8	5.6	6.8	8.1	8.3	14	15	–	16
30	15	10	6.9	6.7	5.6	7.7	8.2	8.2	14	16	–	16
31	–	9.8	–	6.4	5.6	–	8.4	–	13	16	–	16
Total	561	397.8	221.7	222.7	185.6	179.0	220.4	258.3	387.9	467	329	481
Mean	18.7	12.8	7.39	7.18	5.99	5.97	7.11	8.61	12.5	15.1	11.8	15.5
Max	26	16	10	15	8.2	8.0	11	11	26	27	15	25
Min	15	9.8	5.8	5.8	5.2	5.2	6.2	6.9	7.8	10	10	11
acre-ft	1,110	789	440	442	368	355	437	512	769	926	653	954
ft^3/mi^2	1.21	.83	.48	.47	.39	.39	.46	.56	.81	.98	.76	1.01
inches	1.36	.96	.54	.54	.45	.43	.53	.62	.94	1.13	.79	1.16

Table 13. Monthly discharge measurements at periodic-measurement sites on the Tulalip Indian Reservation, Washington, 2001–03.

[**Discharge**: e, estimated. **Abbreviations**: Lat, latitude; long, longitude; sec., section; ‡, operated as a continuous-record gaging station; ft, foot; mi, mile; mi^2, square mile; ft^3/s, cubic foot per second; ºC, degree Celsius; –, no data or undetermined]

Stream: 12157000 Quilceda Creek
Tributary to: Ebey Slough
Location: Lat 48º06’18”, long 122º09’42’’, in NE¼NE¼ sec.9, T.30 N., R.5 E., Snohomish County, Hydrologic Unit 17110011, 50 ft downstream from Middle Fork, and 3.5 mi north of Marysville
Drainage area: 15.4 mi^2
Measured previously (water year): 1946–69‡; 1975–77

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-30-01	21	4.6	10-31-01	28	10.0	10-23-02	4.7	–
02-21-01	22	5.7	11-28-01	38	7.0	11-19-02	7.7	–
03-20-01	34	6.7	12-20-01	54	–	12-17-02	33	7.4
04-25-01	17	–	01-24-02	56	6.5	01-28-03	38	7.7
04-27-01	15	–	02-27-02	30	4.5	02-20-03	27	7.7
05-24-01	9.6	13.1	03-19-02	45	5.9	03-18-03	29	–
06-26-01	9.9	12.9	04-24-02	23	7.5			
07-25-01	5.4	12.6	05-21-02	16	–			
08-22-01	9.5	14.0	06-25-02	7.1	13.0			
09-19-01	5.5	13.1	07-23-02	6.1	14.5			
09-25-01	4.8	14.0	09-10-02	4.4	–			

Stream: 12157020 West Fork Quilceda Creek
Tributary to: Quilceda Creek
Location: Lat 48º06’03”, long 122º11’05’’, in SE¼NE¼ sec.8, T.30 N., R.5 E., Snohomish County, Hydrologic Unit 17110011, 200 ft north of county road, and 0.5 mi west of Kruse
Drainage area: 9.41 mi^2
Measured previously (water year): 1946–47‡; 1957; 1959–60; 1975–77; 1985–86‡

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-30-01	11	5.2	11-28-01	22	7.0	10-23-02	1.5	–
02-21-01	13	5.7	12-20-01	37	–	11-19-02	2.6	–
03-20-01	23	7.9	01-24-02	39	6.2	12-17-02	18	7.6
04-25-01	9.9	–	02-27-02	18	4.5	01-28-03	27	8.0
05-24-01	4.9	12.8	03-19-02	30	5.8	02-20-03	16	7.8
06-27-01	5.2	13.7	04-24-02	15	8.9	03-18-03	23	–
07-25-01	2.6	12.7	05-21-02	6.8	–			
08-21-01	2.6	12.3	06-25-02	3.0	12.9			
09-25-01	1.8	12.0	07-22-02	2.5	14.5			
10-31-01	15	9.6	09-12-02	1.4	–			

Table 13. Monthly discharge measurements at periodic-measurement sites on the Tulalip Indian Reservation, Washington, 2001–03—Continued

[**Discharge**: e, estimated. **Abbreviations**: Lat, latitude; long, longitude; sec., section; ‡, operated as a continuous-record gaging station; ft, foot; mi, mile; mi^2, square mile; ft^3/s, cubic foot per second; ºC, degree Celsius; –, no data or undetermined]

Stream: 12157030 Unnamed Tributary
Tributary to: Quilceda Creek
Location: Lat 48º04'34", long 122º11'17'', in NE¼NE¼ sec.20, T.30 N., R.5 E., Snohomish County, Hydrologic Unit 17110011, at road crossing at Boeing Test Facility perimeter boundary, 1.4 mi
Drainage area: 2.88 mi^2
Measured previously (water year): 1957–77

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
03-22-01	3.8	11.7	11-29-01	9.9	7.0	07-22-02	0.20	15.1
04-24-01	2.6	–	12-21-01	8.7	–	09-11-02	.20	12.3
05-23-01	1.4	15.3	01-23-02	7.2	6.0	10-23-02	.52	–
06-28-01	2.3	12.5	02-27-02	3.7	4.7	11-19-02	.50	–
07-26-01	.68	12.4	03-19-02	6.6	6.0	12-18-02	1.3	6.7
08-21-01	.76	12.1	04-24-02	3.6	8.3	01-28-03	3.2	7.3
09-24-01	.59	–	05-21-02	1.8	–	02-20-03	3.2	7.5
10-31-01	2.1	9.6	06-25-02	.61	13.0	03-18-03	2.7	–

Stream: 12157035 Sturgeon Creek
Tributary to: Quilceda Creek
Location: Lat 48º03'27", long 122º11'47'', in NE¼SW¼ sec.29, T.30 N., R.5 E., Snohomish County, Hydrologic Unit 17110011, 0.6 mi west of Marysville, and 0.3 mi upstream from mouth
Drainage area: 1.87 mi^2
Measured previously (water year): 1957–77

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-31-01	1.3	–	09-26-01	0.86	14.0	05-22-02	2.1	–
02-23-01	1.1	5.2	10-30-01	.99	8.3	06-25-02	.65	25.8
03-22-01	1.6	8.0	11-27-01	1.4	7.0	07-23-02	.90	26.0
04-26-01	1.4	–	12-19-01	2.5	–	09-10-02	.65	–
05-25-01	.77	–	01-22-02	4.1	5.0	10-15-02	.60	7.8
06-26-01	1.0	21.9	02-28-02	2.4	7.3	02-20-03	1.8	7.2
07-24-01	1.5	23.1	03-20-02	8.6	4.1	03-19-03	1.6	–
08-21-01	1.4	18.5	04-25-02	1.7	11.1			

Table 13. Monthly discharge measurements at periodic-measurement sites on the Tulalip Indian Reservation, Washington, 2001–03.—Continued

[**Discharge**: e, estimated. **Abbreviations**: Lat, latitude; long, longitude; sec., section; ‡, operated as a continuous-record gaging station; ft, foot; mi, mile; mi^2, square mile; ft^3/s, cubic foot per second; ºC, degree Celsius; –, no data or undetermined]

Stream: 12157140 Mission Creek below John Sam Lake
Tributary to: Tulalip Bay
Location: Lat 48º06’42”, long 122º14’52’’, in SE¼SE¼ sec.2, T.30 N., R.4 E., Snohomish County, Hydrologic Unit 17110019, Tulalip Indian Reservation, at road crossing 200 ft west of lake outlet, and 3.6 mi northeast of Tulalip
Drainage area: 0.33 mi^2
Measured previously (water year): –

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-30-01	0	–	12-20-01	1.7	–	09-12-02	0	–
02-21-01	0	–	01-24-02	1.1	4.2	10-23-02	0	–
03-20-01	0	–	02-27-02	.31	6.1	11-19-02	0	–
04-25-01	.51	–	03-19-02	1.0	–	12-17-02	0	–
05-24-01	0	–	04-24-02	.37e	13.3	01-28-03	0	–
06-26-01	0	–	05-21-02	0.10e	–	02-20-03	0	–
07-25-01	0	–	05-31-02	0	–	03-18-03	0	–
09-25-01	0	–	06-25-02	0	–			
10-31-01	0	–	07-23-02	0	–			
11-28-01	0	–						

Stream: 12157150 Mission Creek
Tributary to: Tulalip Bay
Location: Lat 48º05’08”, long 122º14’50’’, in SW¼SW¼ sec. 13, T.30 N., R.4 E., Snohomish County, Hydrologic Unit 17110019, Tulalip Indian Reservation, 0.2 mi upstream from confluence with unnamed tributary, and 2.3 mi northeast of Tulalip
Drainage area: 1.34 mi^2
Measured previously (water year): 1957–77

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-29-01	0.83	5.8	11-26-01	0.84	7.0	10-09-02	0.71	10.4
02-20-01	.79	6.4	12-18-01	6.5	–	11-19-02	.86	–
03-19-01	1.0	–	01-22-02	4.1	5.0	12-16-02	1.6	–
04-23-01	.83	–	02-26-02	1.4	6.5	01-27-03	.58	8.7
05-23-01	.66	14.5	03-18-02	2.4	4.3	02-18-03	.88	7.5
06-25-01	.65	13.4	04-23-02	1.7	9.2	03-17-03	.97	–
07-23-01	.64	13.9	05-20-02	.93	–			
08-20-01	.58	13.4	06-24-02	.75	12.7			
09-25-01	.61	12.0	07-23-02	.69	13.8			
10-29-01	.74	8.1	09-09-02	.69	–			

Table 13. Monthly discharge measurements at periodic-measurement sites on the Tulalip Indian Reservation, Washington, 2001–03.—Continued

[**Discharge**: e, estimated. **Abbreviations**: Lat, latitude; long, longitude; sec., section; ‡, operated as a continuous-record gaging station; ft, foot; mi, mile; mi^2, square mile; ft^3/s, cubic foot per second; ºC, degree Celsius; –, no data or undetermined]

Stream: 12157170 Unnamed Tributary
Tributary to: Mission Creek
Location: Lat 48º05'00", long 122º14'58'', in SE¼SE¼ sec.14, T.30 N., R.4 E., Snohomish County, Hydrologic Unit 17110019, Tulalip Indian Reservation, 2.1 mi northeast of Tulalip, and 100 ft upstream from mouth
Drainage area: 1.33 mi^2
Measured previously (water year): 1975–77

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-29-01	0.36	4.9	11-26-01	0.46	7.0	09-09-02	0.64	–
02-20-01	.56	3.7	12-18-01	3.2	–	10-09-02	.79	10.5
03-19-01	1.2	–	01-22-02	1.7	5.0	11-19-02	.09e	–
04-23-01	.51	–	02-26-02	.98	4.5	12-16-02	.10e	–
05-23-01	.07	16.0	03-18-02	1.2	3.3	01-27-03	.74	8.1
06-25-01	.20	15.2	04-23-02	.76	8.0	02-18-03	.58	6.6
07-23-01	.09	15.3	05-20-02	.26	–	03-17-03	.79	–
08-20-01	.01e	–	06-24-02	.09e	–			
09-25-01	0	–	07-23-02	0	–			
10-29-01	.16	7.6						

Stream: 12157210 Unnamed Tributary
Tributary to: Mission Creek
Location: Lat 48º04'45", long 122º14'36'', in NW¼NW¼ sec. 24, T.30 N., R.4 E., Snohomish County, Hydrologic Unit 17110019, Tulalip Indian Reservation, at road crossing, and 2.4 mi northeast of Tulalip
Drainage area: 1.57 mi^2
Measured previously (water year): 1975–77

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-29-01	0.44	5.5	11-26-01	0.56	8.0	10-09-02	0.33	11.0
02-20-01	.59	5.0	12-18-01	3.0	–	11-19-02	.40	–
03-19-01	.66	–	01-22-02	1.5	6.0	12-16-02	.86	–
04-23-01	.56	–	02-26-02	.96	5.5	01-27-03	.89	8.5
05-23-01	.38	11.8	03-18-02	1.4	4.0	02-18-03	.50	7.9
06-25-01	.40	11.8	04-23-02	1.0	8.4	03-17-03	.61	–
07-23-01	.41	14.3	05-20-02	.47	–			
08-20-01	.26	12.3	06-24-02	.35	13.8			
09-25-01	.33	12.0	07-23-02	.28	14.5			
10-29-01	.52	8.5	09-09-02	.32	–			

Table 13. Monthly discharge measurements at periodic-measurement sites on the Tulalip Indian Reservation, Washington, 2001–03.—Continued

[**Discharge**: e, estimated. **Abbreviations**: Lat, latitude; long, longitude; sec., section; ‡, operated as a continuous-record gaging station; ft, foot; mi, mile; mi^2, square mile; ft^3/s, cubic foot per second; ºC, degree Celsius; –, no data or undetermined]

Stream: Unnamed Spring
Tributary to: Mission Creek
Location: Lat 48º03’27”, long 122º14’19’’, in NE¼SW¼ sec.25, T.30 N., R.4 E., Snohomish County, Hydrologic Unit 17110019, Tulalip Indian Reservation, 1.2 mi north of Priest Point Grange, and 2.4 mi northeast of Tulalip
Drainage area: –
Measured previously (water year): 1975

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-31-01	0.35	–	11-28-01	0.83	5.0	09-11-02	0.15	15.3
02-23-01	.31	5.6	12-20-01	.32	–	10-15-02	.27	7.9
03-22-01	.28	7.0	01-23-02	.32	4.0	11-20-02	.19	–
04-26-01	.22	–	02-28-02	.20	5.0	12-17-02	.61	7.2
05-25-01	.17	14.8	03-20-02	.81	4.1	01-27-03	.48	6.7
06-26-01	.34	16.3	04-25-02	.17	9.9	02-20-03	.28	7.1
07-25-01	.22	17.0	05-22-02	.27	–	03-19-03	.29	–
08-21-01	.43	16.1	06-26-02	.17	19.8			
09-26-01	.41	15.0	07-23-02	.12	–			
10-30-01	.35	8.2						

Stream: 12158001 Tulalip Creek
Tributary to: Tulalip Bay
Location: Lat 48º07’24”, long 122º18’24’’, in NE¼NW¼ sec. 4, T.30 N., R.4 E., Snohomish County, Hydrologic Unit 17110019, Tulalip Indian Reservation, at Fire Trail Road, 0.3 mi southwest of Lake Shoecraft, and 4.0 mi north of Tulalip
Drainage area: 6.12 mi^2
Measured previously (water year): 1946; 1957; 1972; 1974–77

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-30-01	0.57	4.4	11-28-01	3.3	7.0	10-23-02	0	–
02-21-01	5.8	6.2	12-20-01	22	–	11-19-02	0	–
03-20-01	2.9	8.9	01-24-02	7.1	5.2	12-17-02	0	–
04-25-01	.48	–	02-27-02	6.8	6.0	01-28-03	1.4	7.3
05-24-01	.63	18.7	03-19-02	6.7	5.7	02-20-03	1.4	7.0
06-26-01	.80	19.3	04-24-02	3.7	13.3	03-18-03	14	–
07-25-01	.10e	–	05-21-02	1.8	–			
08-21-01	.10e	–	06-25-02	0	–			
09-25-01	.10e	–	07-23-02	0	–			
10-31-01	.09e	–	09-12-02	.10e	–			

Table 13. Monthly discharge measurements at periodic-measurement sites on the Tulalip Indian Reservation, Washington, 2001–03.—Continued

[**Discharge**: e, estimated. **Abbreviations**: Lat, latitude; long, longitude; sec., section; ‡, operated as a continuous-record gaging station; ft, foot; mi, mile; mi^2, square mile; ft^3/s, cubic foot per second; ºC, degree Celsius; –, no data or undetermined]

Stream: 12158025 East Branch Tulalip Creek
Tributary to: Tulalip Creek
Location: Lat 48º06’47”, long 122º15’45’’, in NE¼SW¼ sec.2, T.30 N., R.4 E., Snohomish County, Hydrologic Unit 17110019, at old logging road, 400 ft upstream from Mary Shelton Lake, and 3.5 mi north of Tulalip
Drainage area: 0.80 mi^2
Measured previously (water year): 1974–77

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-30-01	0	–	11-28-01	0.02e	–	09-12-02	0	–
02-21-01	0	–	12-20-01	2.0	–	10-23-02	0	–
03-20-01	.14	10.2	01-24-02	1.8	4.5	11-19-02	0	–
04-25-01	.17	–	02-27-02	.22	3.6	12-17-02	0	–
05-24-01	.06	12.8	03-19-02	.70	4.6	01-28-03	0	–
06-26-01	.02	12.1	04-24-02	.44	11.8	02-20-03	.09e	6.5
07-25-01	0	–	05-21-02	.02	–	03-18-03	.62	–
08-21-01	0	–	06-25-02	0	–			
09-25-01	0	–	07-23-02	0	–			
10-31-01	0	–						

Stream: Unnamed Spring
Tributary to: Tulalip Creek
Location: Lat 48º04’58’’, long 122º16’15’’, in NE¼SE¼ sec. 15, T.30 N., R.4 E., Snohomish County, Hydrologic Unit 17110019, and 1.5 mi northeast of Tulalip
Drainage area: –
Measured previously (water year): 1974–75

Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)	Date	Discharge (ft^3/s)	Water temperature (ºC)
01-30-01	0.14	–	11-27-01	0.15	8.0	10-09-02	0.15	11.1
02-23-01	.20	6.5	12-19-01	.20	–	11-20-02	.19	–
03-22-01	.17	8.5	01-23-02	.16	6.0	12-18-02	.17	7.0
04-23-01	.15	–	02-28-02	.12	6.5	01-29-03	.23	7.1
05-23-01	.14	13.0	03-20-02	.32	4.4	02-20-03	.19	7.2
06-25-01	.26	12.3	04-25-02	.15	8.2	03-19-03	.12	–
07-24-01	.24	13.9	05-22-02	.18	–			
08-22-01	1.9	14.3	06-26-02	.13	14.1			
09-26-01	.20	13.0	07-23-02	.14	–			
10-30-01	.15	9.6	09-11-02	.11	–			

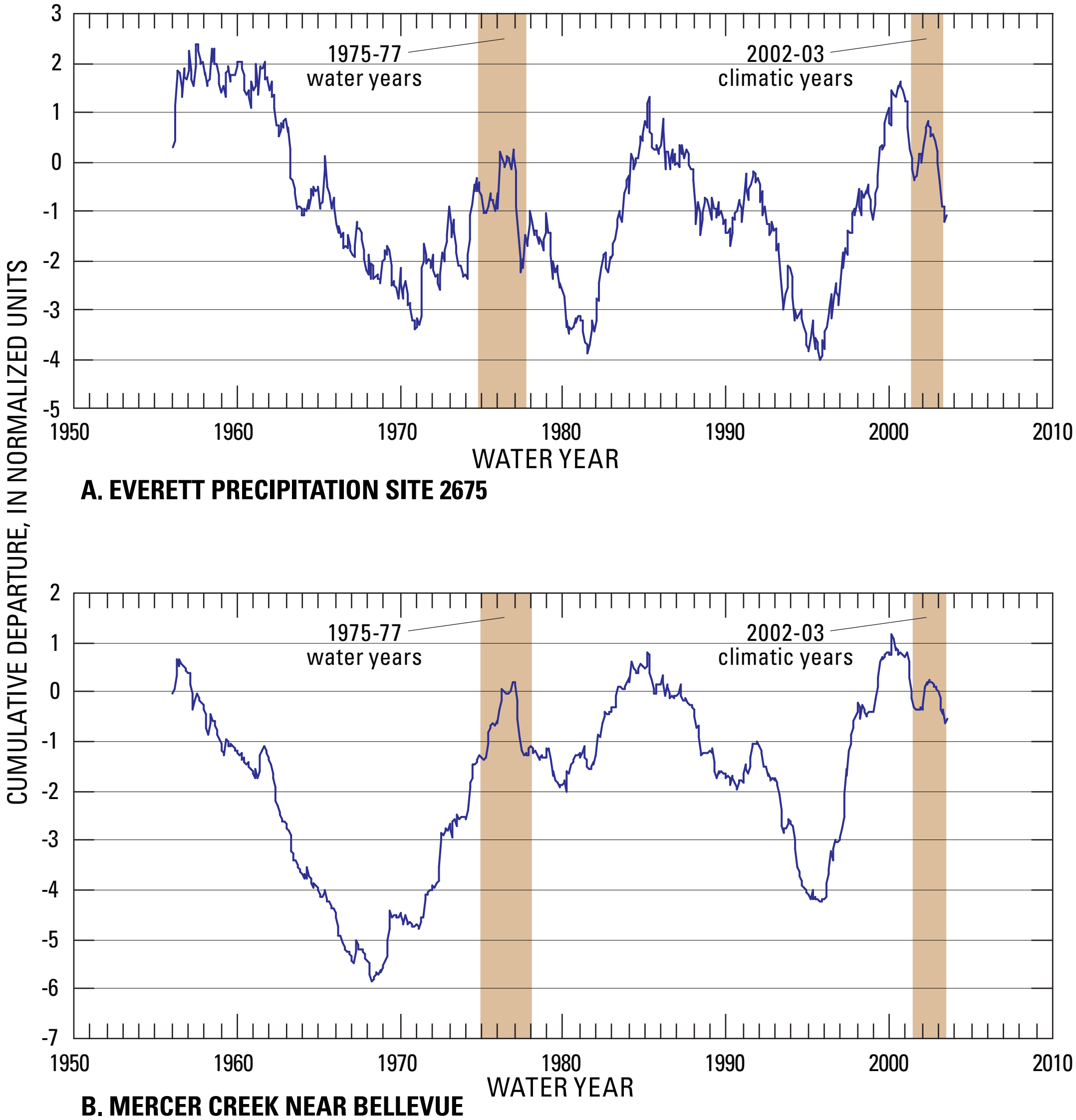


Figure 21. Cumulative departures of monthly from mean monthly precipitation at Everett Precipitation Site 2675 and of monthly from mean monthly streamflow at Mercer Creek near Bellevue (station 12120000), 1956-2003.

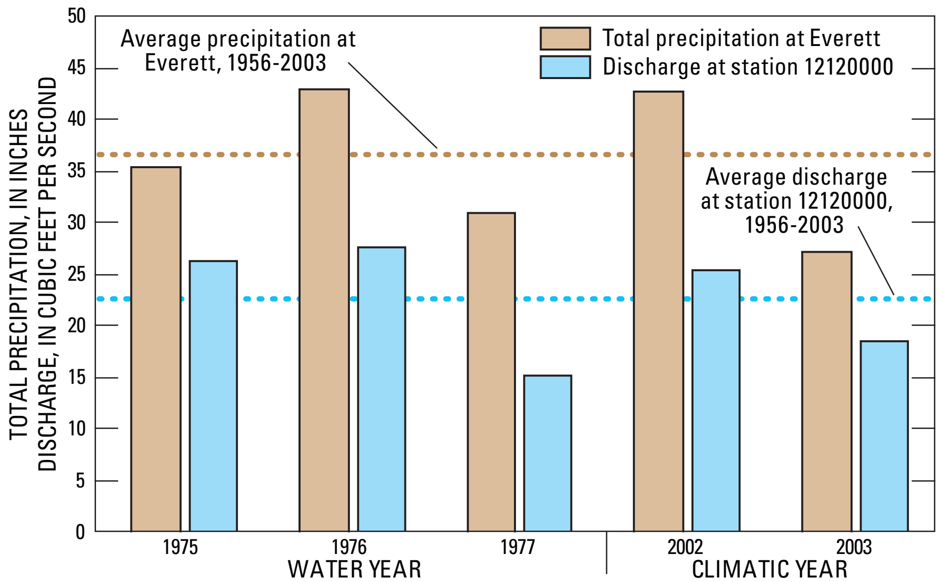


Figure 22. Correlation between annual total precipitation at Everett Precipitation Site 2675 and annual mean streamflow at Mercer Creek near Bellevue (station 12120000) for water years 1975–77 and climatic years 2002–03.

The annual precipitation at Everett and the annual mean discharge at Mercer Creek near Bellevue were plotted against time for 1975–2003 to check for trends (fig. 23). Each plot shows a large, random scatter of values with no visually apparent trend, but the Mann-Kendall nonparametric statistical test for trends was used to check for the possibility of a subtle trend. Kendall's *tau* correlation coefficient for the Everett precipitation record was 0.053, indicating little or no trend (*tau* = 1 for a perfectly positive trend-that is, all precipitation values increase with time, and *tau* = -1 for a perfectly negative trend). Kendall's test statistic, *S*, had a *p*-value of 0.71, strongly indicating that there is not enough evidence to refute the null hypothesis that there is no trend of increasing or decreasing precipitation with time. Therefore, it appears that climatological conditions did not change significantly during 1975–2003. Kendall's *tau* correlation coefficient for the Mercer Creek streamflow record was -0.029, indicating little or no trend, and Kendall's test statistic, *S*, had a *p*-value of 0.84, strongly indicating that there is not enough evidence to refute the null hypothesis that there is no trend of increasing or decreasing streamflow with time. Therefore, it appears that streamflow conditions in Mercer Creek also did not significantly change during 1975-2003.

Annual mean discharge at stations 12157250 and 12158040 during water years 1975-77 and climatic years 2002-03 were compared with those for station 12120000 to determine whether the streamflow in Mission and Tulalip Creeks has significantly changed since the mid-1970s. Both the comparison of annual mean discharge at each station for each of the 5 years (fig. 24) and the relation between annual mean discharge at the two Reservation stations and the Mercer Creek site for the two periods (fig. 25) show that discharge at the three stations is strongly correlated. The coefficients of correlation between the annual mean flows at stations 12157250 and 12158040 and those at station 12120000 are 0.97 and 0.88, respectively. These high correlation coefficients indicate that flows at stations 12157250 and 12158040, like those at station 12120000, did not change significantly during 1975-2003. However, this conclusion is considered questionable because it is based on only five annual values for each station and because there is a considerable amount of scatter of the data points—especially those for Tulalip Creek (fig. 25). Therefore, additional comparisons, which included the data from the Everett precipitation station data, were made to reach a more definitive conclusion.

The mean annual discharges at stations 12157250 (Mission Creek), 12158040 (Tulalip Creek), and 12120000 (Mercer Creek) for climatic years 2002-03 were expressed as percentages of change from the mean annual discharges for the water years 1975-77. Similarly, the mean annual precipitation at the Everett precipitation station during climatic years 2002-03 was expressed as the percentage of change from the mean annual precipitation during water years 1975-77. The percentages of change for streamflow station 12157250 (-5.8 percent), streamflow station 12120000 (-4.6 percent), and the Everett precipitation station (-4.0 percent) agree closely with each other. However, the percentage of change for streamflow station 12158040 (+10.0 percent) was significantly different than those for the other three stations. The fact that

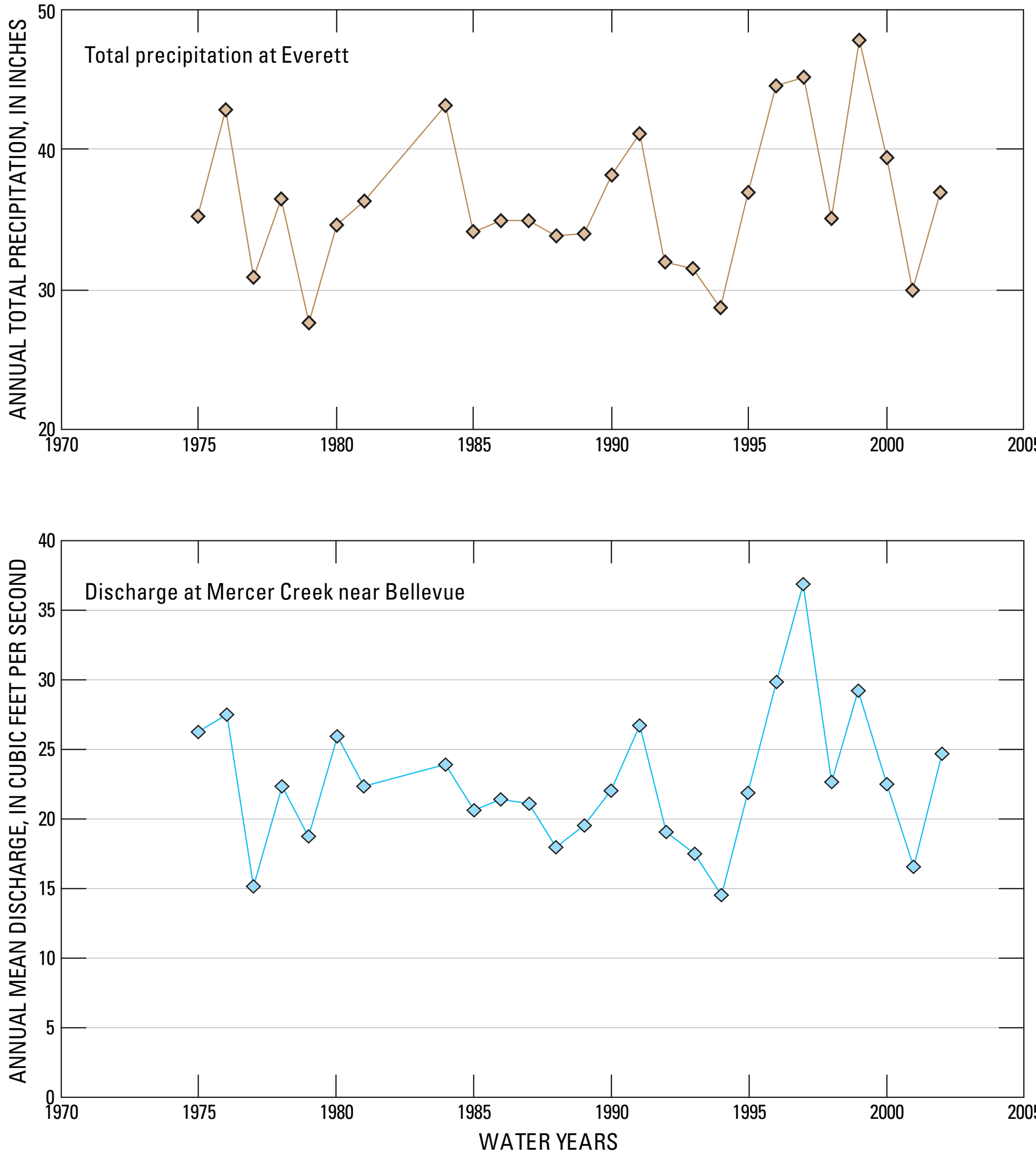


Figure 23. Annual total precipitation at Everett Precipitation Site 2675 and annual mean discharge at Mercer Creek near Bellevue (station 12120000), water years 1975–2003.

the percentage of change for station 12157250 agrees so closely with the percentages of change for the two long-term stations, for which no trends were detected for 1975-2003, indicates that flow in Mission Creek probably has not changed significantly since the mid-1970s. The difference between the average of the percentages of change for stations 12157250, 12120000, and Everett (-4.8 percent) and the percentage of change for station 12158040 (+10.0 percent) indicates the possibility that the flows in Tulalip Creek may have increased by about 15 percent since the mid-1970s. However, this large difference could simply be attributed to short-term anomalies in the flow of Tulalip Creek. Therefore, although this statistical analysis indicates the possibility that flow in Tulalip Creek may have increased by about 15 percent since the mid-1970s, these results should not be considered to be typical.

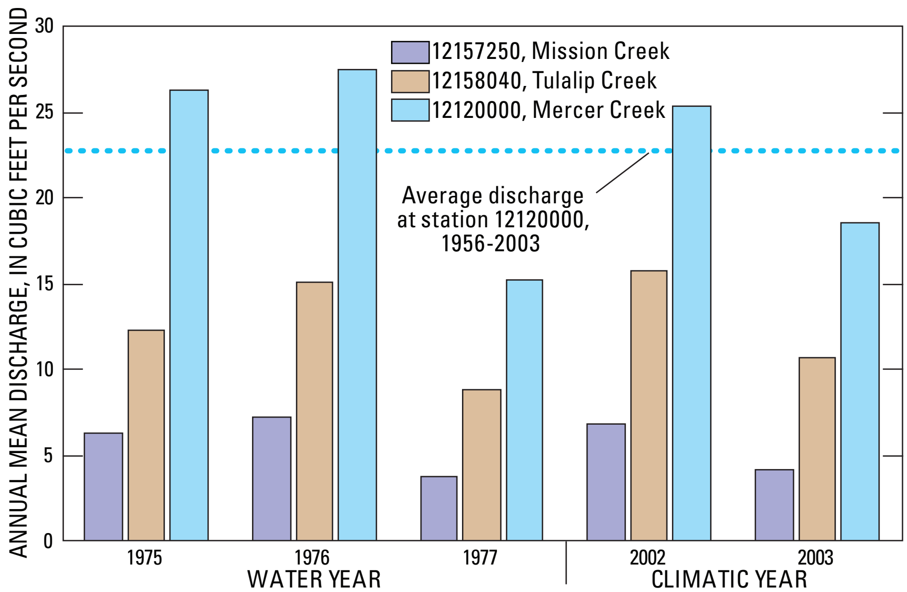


Figure 24. Comparison of annual mean discharge at gaging stations on Tulalip, Mission, and Mercer Creeks for water years 1975–77 and climatic years 2001–2003.

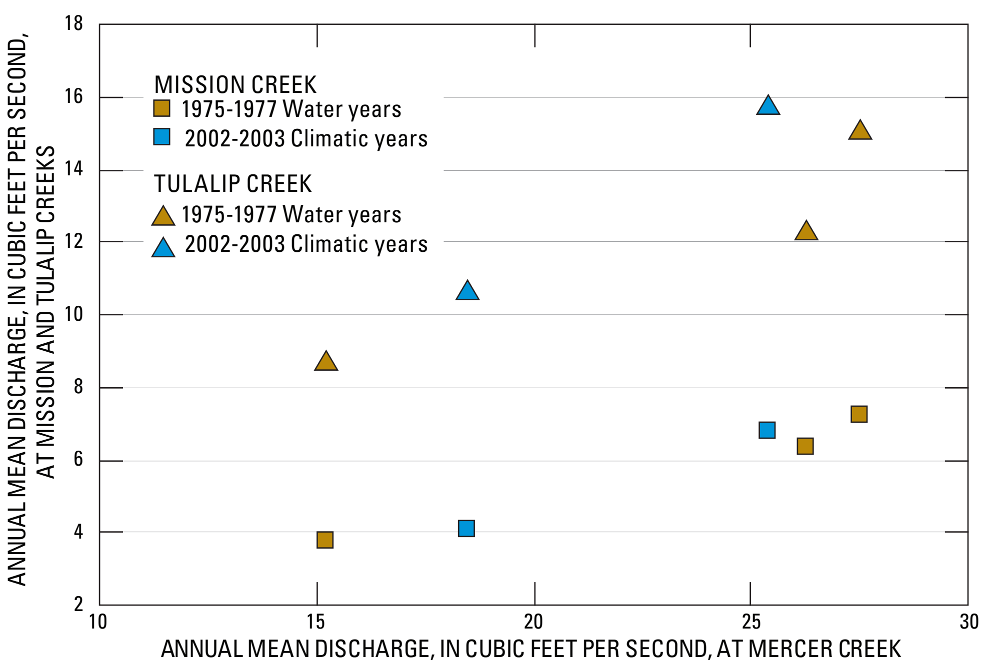


Figure 25. Relation of annual mean discharge at Mission and Tulalip Creeks to annual mean discharge at Mercer Creek for water years 1975–77 and climatic years 2001–2003.

Streamflow records collected during water years 1975–77 at stations 12157250 and 12158040 were compared with those collected during climatic years 2002–03 to determine whether base flow has changed significantly in Mission and Tulalip Creeks. Base flow is the portion of total streamflow that is contributed by ground water. HYSEP, a USGS computer program for streamflow hydrograph separation (Sloto and Crouse, 1996), was used to determine the mean annual base flow for each year of record analyzed. Comparisons of annual mean streamflow and base flow at stations 12157250 and 12158040 show that the relations between total streamflow and base flow at both stations during climatic years 2002–03 were not significantly different than those during water years 1975–77 (fig. 26). The strength of these relations is indicated by the high coefficients of correlation between total streamflow and base flow at these stations (0.996 at station 12157250 and 0.986 at station 12158040). These results strongly suggest that the current relations of base flow to total streamflow in Mission and Tulalip Creeks are essentially the same as the relations during water years 1975–77.

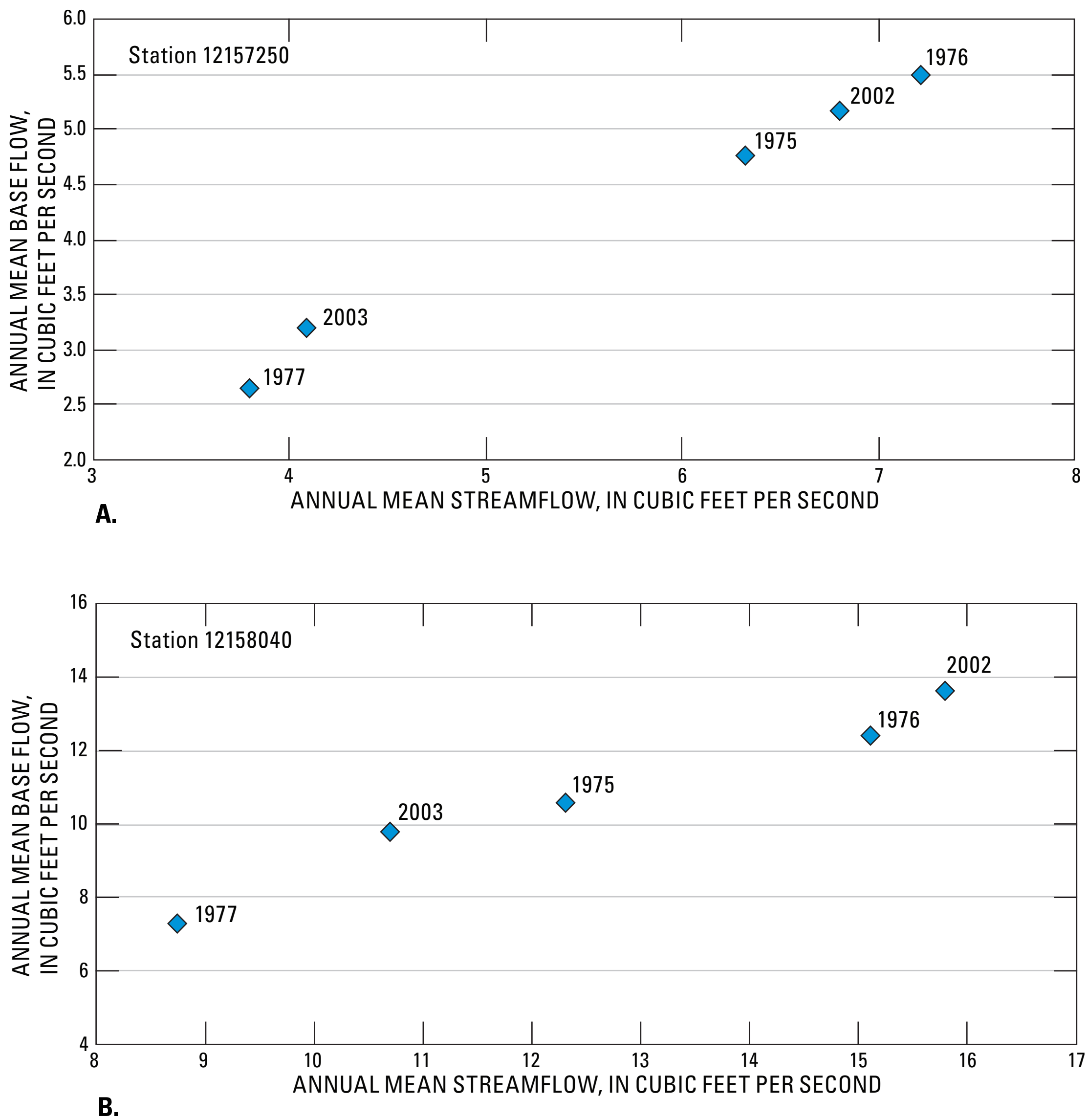


Figure 26. Relation between annual mean streamflow and base flow at stations 12157250 and 12158040 during water years 1975–77 and climatic years 2002–03.

Surface-Water Inflow to the Reservation

The main sources of surface-water inflow, a major component of a water-budget calculation, to the Tulalip Indian Reservation are Tulalip Creek, West Fork Quilceda Creek, and Quilceda Creek (fig. 6). Quilceda Creek enters the Reservation less than 2 mi upstream from its mouth at Ebey Slough. However, the only place where flow in the mainstem of Quilceda Creek was measured was at periodic-measurement site 1, located about 3 mi upstream of the Reservation boundary, because no suitable streamflow measuring sites could be found on the creek either where it enters the Reservation or at its mouth. Therefore, neither the inflow to nor the outflow from the Reservation from Quilceda Creek could be determined. However, these flows can be ignored for water-budget calculations because, as was assumed in the water-budget calculations made by Drost (1983, p. 48) in a 1975–77 study of the water resources of the Reservation, the difference between the inflow to and the outflow from the Reservation from Quilceda Creek (a net outflow) was considered to be accounted for primarily by the flows from two small tributary streams of Quilceda Creek that originate on the Reservation. The flows in these streams, which were measured at periodic-measurement sites 3 and 4 (fig. 6), are discussed in the surface-water outflow section. Therefore, the total surface-water inflow to the Reservation during climatic years 2002–03 for the water-budget analysis was estimated to be equal to the sum of the flows in Tulalip Creek and West Fork Quilceda Creek at the Reservation boundary.

Monthly discharge measurements were made on Tulalip Creek at the Reservation boundary at periodic-measurement site 10 (fig. 6). A continuous record of discharge was collected a few miles downstream on Tulalip Creek at continuous-record site 2. Monthly discharge measurements were made at this site also, usually within a few days of the measurements made at site 10. A regression equation developed between the discharge measurements made at the two sites was used to estimate the mean annual flow at site 10 from the mean annual flow at site 2 during climatic years 2002–03 (table 14; fig. 27*A*). Pairs of measurements that represented different flow regimes were not included in the regression analysis. For example, the measurements made in July 2002 were not included because the measurement at site 2 was made during a short-duration peak flow on July 8 but the measurement at site 10 was made several days later, on July 22, during a period of base flow. When the regression equation is used with a mean annual discharge at continuous-record site 2 of 7.77 ft^3/s during climatic years 2002–03, the mean annual discharge at periodic-measurement site 10 during that period is estimated to be 2.6 ft^3/s.

Table 14. Regression equations for estimating discharge at periodic-measurement sites from discharge at continuous-record sites on streams on the Tulalip Indian Reservation, Snohomish County, Washington.

[R^2, coefficient of determination; SEE, standard error of estimate; ft^3/s, cubic feet per second; Q, discharge, in ft^3/s]

Periodic-measurement site No. on figure 6	Continuous-record site No. on figure 6	Regression equation	R^2	SEE (ft^3/s)	Number of observations
2	1	$Q_{site2} = -2.97 + 2.85(Q_{site1})$	0.91	3.2	23
3	1	$Q_{site3} = -0.299 + 0.513(Q_{site1})$	0.90	0.6	20
4	1	$Q_{site4} = 0.441 + 0.211(Q_{site1})$	0.75	0.4	19
10	2	$Q_{site10} = -3.91 + 0.842(Q_{site2})$	0.95	1.1	21

Flow was not measured in West Fork Quilceda Creek at the Reservation boundary. However, discharge was measured monthly about 1.7 mi downstream at periodic-measurement site 2. A regression equation, developed between the discharge measured at this site and a concurrent set of discharge measured at continuous-record site 1 on Mission Creek, was used to estimate the mean annual flow at site 2 (table 14; fig. 27*B*). Pairs of measurements that represented different flow regimes were not included in the regression analysis. The mean annual discharge during climatic years 2002–03 calculated for continuous-record site 1 is 5.44 ft^3/s. When this discharge is used in conjunction with the regression equation, the mean annual discharge during that period at periodic-measurement site 2 is estimated to be 12.5 ft^3/s.

The mean annual discharge at the Reservation boundary was determined by adjusting the estimated mean annual discharge at periodic-measurement site 2 by an estimate of the gain in flow between the two sites. In a 1975–77 study of the water resources of the Tulalip Indian Reservation, Drost (U.S. Geological Survey, oral commun., 2003) estimated a gain of about 2 ft^3/s in this reach of West Fork Quilceda Creek. Therefore, the mean annual discharge at the Reservation boundary is estimated to be about 10.5 ft^3/s.

The estimated total surface-water inflow to the Reservation, the sum of the flows in Tulalip Creek and West Fork Quilceda Creek at the Reservation boundary, is equal to about 13 ft^3/s.

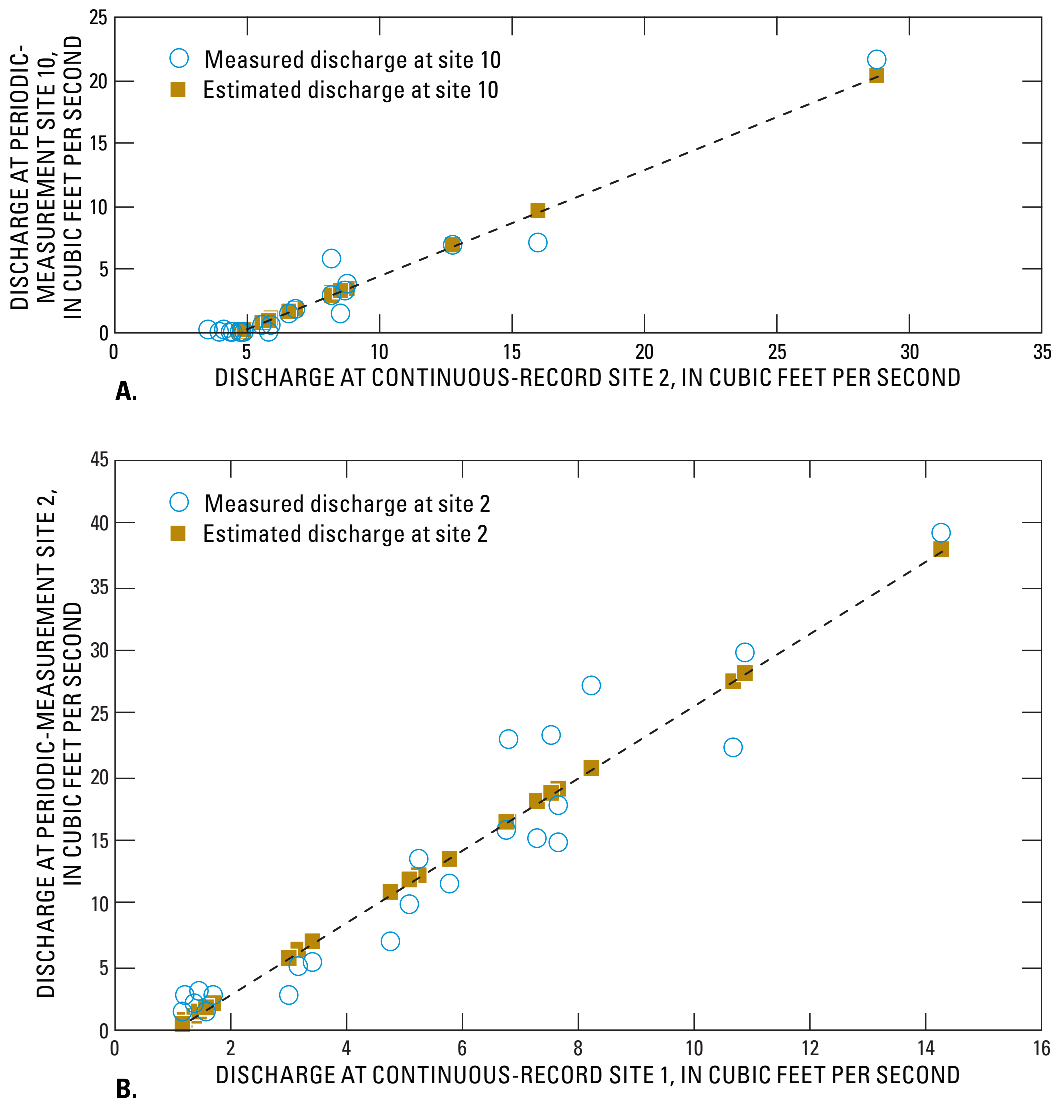
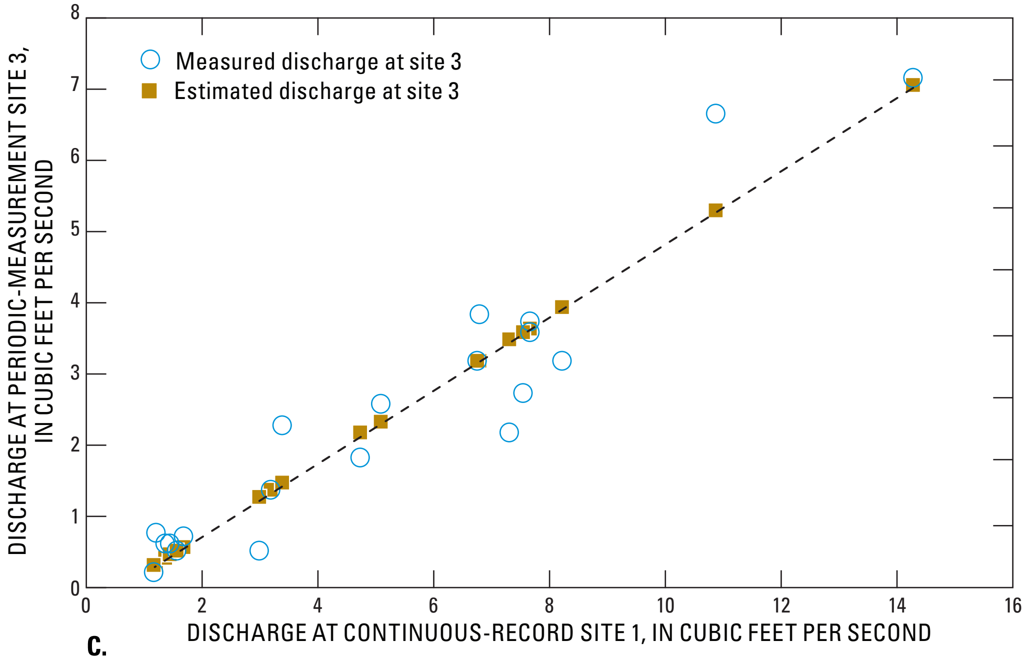
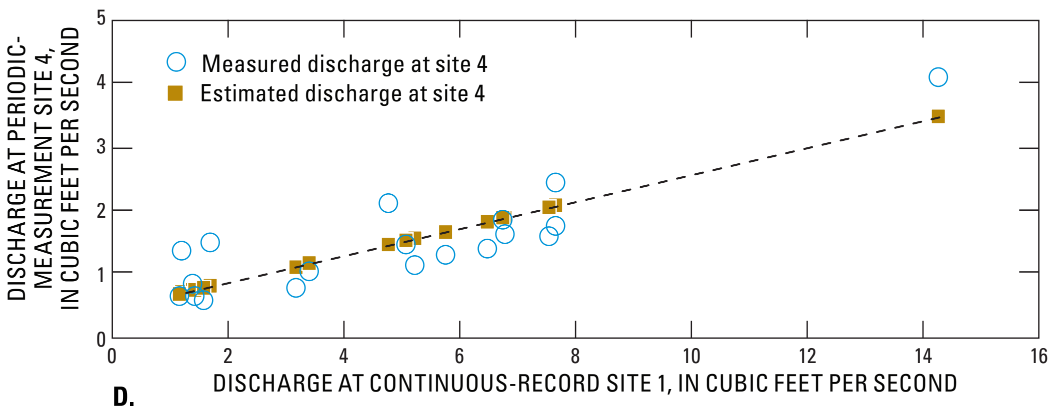


Figure 27. Regression-analysis plot of discharge measurements made at selected periodic-measurement sites against those made at continuous-record sites, Tulalip Indian Reservation, Snohomish County, Washington, climatic years 2001–03.



C.



D.

Figure 27.—Continued.

Surface-Water Outflow from the Reservation

Surface-water outflow from the Tulalip Indian Reservation consists primarily of the flows at the mouths of Tulalip, Mission, and Quilceda Creeks plus the flow in West Fork Quilceda Creek where it leaves the Reservation (fig. 6) plus outflow from 9.2 mi^2 of ungaged area.

Continuous-record gaging stations operated near the mouths of Tulalip Creek (site 4) and Mission Creek (site 1) were used to estimate the outflows from their basins during climatic years 2002–03. The mean annual outflows from Tulalip and Mission Creeks during those years were estimated to be 13.2 and 5.44 ft^3/s, respectively.

Most of the surface-water outflow from the Quilceda Creek basin was determined from discharge measured monthly at periodic-measurement sites on West Fork Quilceda Creek near where it leaves the Reservation (site 2) and on two Quilceda Creek tributary streams: site 3, on an unnamed stream, and site 4, on Sturgeon Creek (fig. 6). Flows in the mainstem of Quilceda Creek were not included in water-budget calculations for the reasons given in the surface-water inflow section of the report. Mean annual discharge at periodic-measurement site 2 on West Fork Quilceda Creek was estimated to be 12.5 ft^3/s, as described in the surface-water inflow section.

Regression equations between the measurements made at sites 3 and 4 and concurrent measurements made at continuous-record site 1 on Mission Creek were developed to estimate the mean annual discharges during climatic years 2002-03 at the tributary stream sites (table 14; figs. 27*C* and 27*D*). Pairs of measurements that represented different flow regimes were not included in the regression analyses. The mean annual discharge during climatic years 2002-03 estimated by the regression equations for sites 3 and 4 are 2.5 and 1.6 ft^3/s, respectively.

The total of the estimated mean annual flows at continuous-record sites 1 and 4 and periodic-measurement sites 2, 3, and 4 is 35.2 ft^3/s. The outflow from 9.2 mi^2 of ungaged area (Drost, 1983, p. 48) also needs to be accounted for in determining the total surface-water outflow from the Reservation. In the 1975–77 study of the water resources of the Tulalip Indian Reservation, Drost (U.S. Geological Survey, oral commun, 2003) estimated the outflow from the ungaged areas to be about 3 ft^3/s. Therefore, the total surface-water outflow from the Reservation is estimated to be about 38 ft^3/s.

Lakes

There are five principal lakes on the reservation, ranging in size from 11.1 to 23 acres (fig. 6). Lake stage, or water-surface elevation, was measured approximately monthly on John Sam Lake (station 12157130), Ross Lake (station 12157200), and Weallup Lake (station 12158007) between October 2000 and March 2003 (table 15) for comparison with lake-stage data for water years 1975–77.

The lake-stage data collected at John Sam Lake and Weallup Lake during climatic years 2002–03 could not be compared directly with the data collected during water years 1975–77 because different gage datums were used during the two periods and the datums used during 1975–77 could not be recovered. However, the patterns of increasing and decreasing lake elevations at these two lakes and at Ross Lake during climatic years 2002–03 are quite similar to those during water years 1975–77. Also, the differences between the maximum and minimum extremes in lake stage during the two periods are quite similar, as shown below.

	Lake stage, in feet	
	Water years 1975–77	**Climatic years 2002–03**
John Sam Lake (station 12157130)	1.67	2.11
Ross Lake (station 12157200	1.51	1.83
Weallup Lake (station 12158007)	2.98	3.50

Lake stage measured during 2002–03 at Ross Lake was compared with stage measured during 1975–77. The maximum and minimum lake elevations measured during climatic years 2002–03 at Ross Lake were 77.47 and 75.64 ft, respectively. These are both slightly higher than the maximum and minimum lake elevations measured during water years 1975–77 at Ross Lake, which when converted to the datum used during climatic years 2002-03 were 76.80 and 75.29 ft, respectively.

Table 15. Periodic measurements of stage at three lakes on the Tulalip Indian Reservation, Snohomish County, Washington, October 2000–March 2003.

[USGS, U.S. Geological Survey]

Lake and reference No. on figure 6	USGS gaging station No.	Date	Stage (feet)
John Sam Lake—1	12157130	10-11-00	4.84
		11-13-00	4.92
		11-29-00	4.91
		01-30-01	5.41
		02-21-01	5.60
		03-20-01	5.90
		04-25-01	6.11
		05-24-01	5.95
		06-26-01	5.96
		07-25-01	5.64
		08-21-01	5.35
		09-25-01	5.14
		10-31-01	5.41
		11-28-01	5.96
		12-20-01	6.44
		01-24-02	6.18
		02-27-02	6.05
		03-19-02	6.19
		04-24-02	6.07
		05-21-02	5.94
		05-31-02	5.89
		06-25-02	5.60
		07-23-02	5.32
		09-12-02	4.57
		10-23-02	4.33
		11-19-02	4.36
		12-17-02	4.56
		01-28-03	5.26
		02-20-03	5.48
		03-18-03	5.94
Ross Lake—2	12157200	10-11-00	75.80
		11-14-00	75.99
		11-30-00	76.00
		01-29-01	75.46
		02-20-01	76.58
		03-20-01	76.78
		04-23-01	76.02
		05-23-01	76.77
		06-27-01	76.68
		07-24-01	76.41
		08-20-01	76.16
		09-24-01	76.01
		10-30-01	76.34
		11-27-01	76.67
		12-18-01	77.47
		01-22-02	77.16
		02-26-02	77.05
		03-18-02	77.14
		04-23-02	77.06
		05-20-02	76.84
		05-30-02	76.77
		06-24-02	76.50
		09-10-02	75.73
		10-16-02	75.64
		11-20-02	75.72
		12-16-02	75.96
		01-27-03	76.56
		02-18-03	76.64
		03-17-03	76.90
Weallup Lake—3	12158007	11-14-00	12.32
		11-29-00	12.34
		01-30-01	12.80
		02-22-01	13.45
		03-21-01	13.35
		04-26-01	13.08
		05-23-01	12.76
		06-26-01	12.73
		07-24-01	12.28
		08-21-01	11.98
		09-25-01	11.75
		10-31-01	12.07
		11-28-01	13.18
		12-20-01	14.14
		01-24-02	13.84
		02-27-02	13.62
		03-19-02	13.64
		04-24-02	13.28
		05-21-02	12.90
		05-31-02	12.56
		06-25-02	11.88
		07-23-02	11.58
		09-12-02	10.85
		10-15-02	10.74
		11-06-02	10.64
		11-19-02	10.76
		12-17-02	11.00
		01-28-03	12.44
		02-20-03	12.35
		03-18-03	12.95

Water Budget

The circulation and conservation of the Earth's water as it moves from location to location is referred to as the hydrologic cycle (fig. 28). As water moves through the cycle, it typically is stored temporarily in oceans, lakes, rivers, soil, and the atmosphere or in ground water. Although the cycle does not have an end or a beginning, this simplified description starts with the movement of water from the Earth's surface to the atmosphere.

Water evaporates from the surface of the ocean or land or is transpired by plants. The combination of these processes is called evapotranspiration. As the moist air is lifted, it cools and the vapor condenses to form clouds. The moisture returns from the clouds to the surface as precipitation. Once the water reaches the ground, one of several processes may occur: (1) some of the water may evaporate back into the atmosphere; (2) the water may runoff directly to streams and lakes; or (3) the water may infiltrate the surface and recharge the ground-water system. Ground water either seeps its way into the oceans, rivers, and streams or is released back into the atmosphere through transpiration by plants. The water that empties into lakes, rivers, and streams is carried back to the oceans, where the cycle begins again.

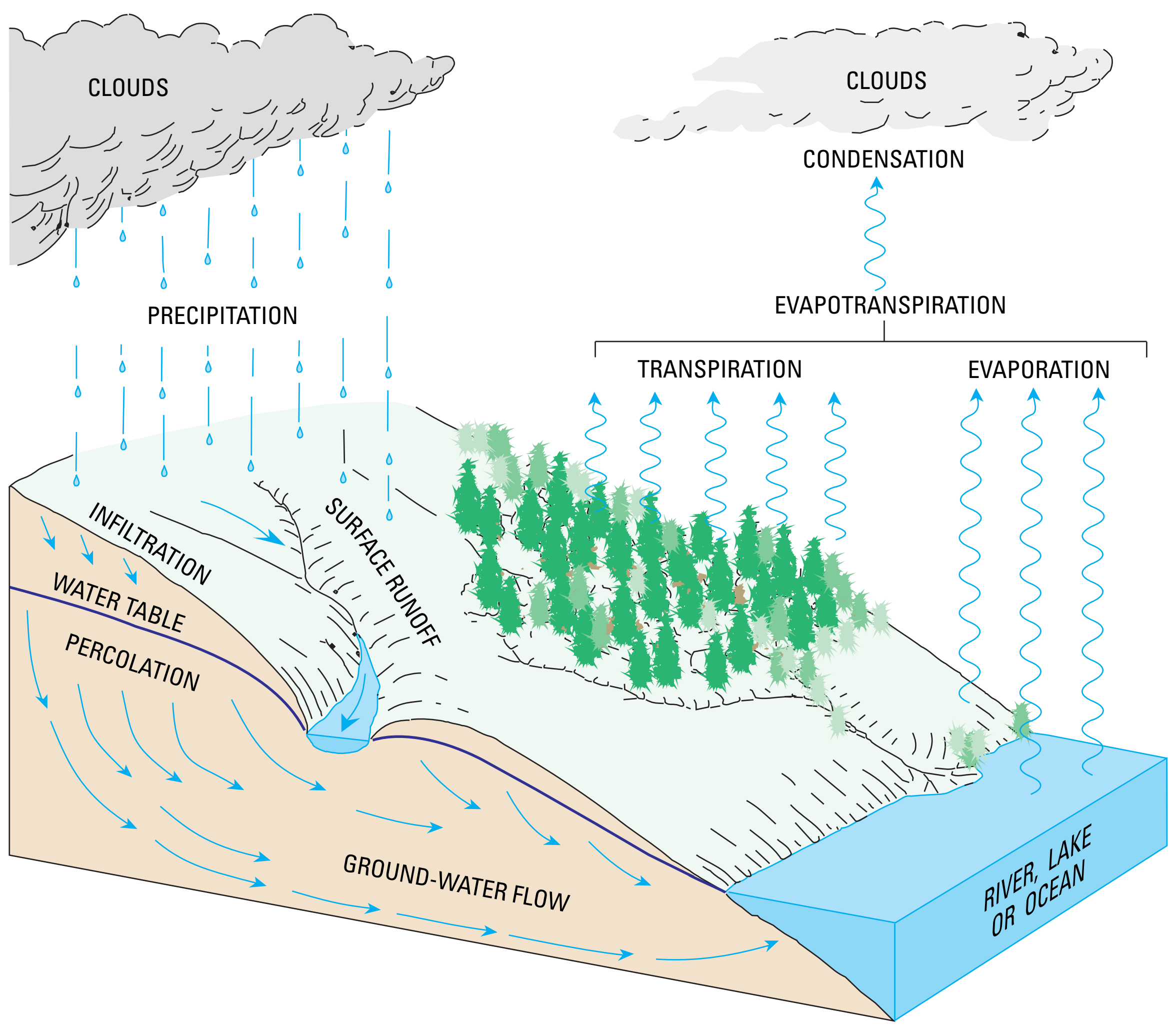


Figure 28. The hydrologic cycle.

The hydrologic cycle for a given area also can be represented mathematically in the form of a water-balance equation, or water budget. This equation is useful in determining the size of the various components of the system and evaluating how changes in one component will affect the others. The water-balance equation for the amount of water entering and leaving the Tulalip Reservation can be expressed as

$$P + SW_i + GW_i = ET + SW_o + GW_o + GW_w \qquad (15)$$

where

P = precipitation;
SW_i = surface-water inflow;
GW_i = ground-water inflow;
ET = evapotranspiration;
SW_o = surface-water outflow;
GW_o = ground-water outflow; and
GW_w = ground-water withdrawals.

Precipitation can also be expressed as

$$P = SR + ET + GWR \qquad (16)$$

where

SR = surface runoff (including surface runoff and shallow subsurface flow; and
GWR = ground-water recharge.

These equations assume that there is no change in ground-water storage and that ground-water recharge equals ground-water discharge, which most ground-water systems roughly meet over the course of a year.

On a long-term basis, a hydrologic system is usually in a state of dynamic equilibrium. Equilibrium occurs when the inflows to the system equal the outflows from the system with little or no change in the amount of water stored within the system. An approximate annual water budget for the Tulalip Indian Reservation is presented in table 16. Explanations of the methods used to estimate the components of the water budget are presented in previous sections. A land-surface area of 35.2 mi^2 was used to calculate the water budget.

The annual precipitation average for the Reservation is 32.28 in. (table 2), or 84 ft^3/s, which is about 86 percent of the long-term average precipitation at the nearby Everett weather station. Ideally, the sum of the surface runoff, evapotranspiration, and ground-water recharge should be equal to the total precipitation, as shown in eq. 16. These three components were calculated independently as a check on the amount of error in the estimation of the water-budget values. The surface runoff was estimated as 5 ft^3/s, evapotranspiration as 45 ft^3/s, and ground-water recharge as 27 ft^3/s for a total of 77 ft^3/s, which differs with the precipitation value by 7 ft^3/s, or about 8 percent.

Table 16. Estimated average annual water budget for the Tulalip Indian Reservation, Snohomish County, Washington, April 2001–March 2003.

Hydrologic component	Amount, in cubic feet per second
Inflow	
Precipitation	
Fate of precipitation[1]	84
Surface runoff	5
Evapotranspiration	44
Ground-water recharge	27
Surface-water inflow	13
Subsurface inflow	5
Total inflow	102
Outflow	
Evapotranspiration	44
Net ground-water withdrawals	1
Surface-water outflow	38
Subsurface outflow	19
Total outflow	102

[1]Values do not sum to the total precipitation value because they were calculated independently.

The calculated average annual potential evapotranspiration rate for April 2001 to March 2003 was 23 in., which would be the result if precipitation always exceeded the potential evapotranspiration rate. However, during May to September, precipitation is less than the potential evapotranspiration rate (fig. 29). Therefore, the average annual actual evapotranspiration amount from the land surface (17.1 in., or 44 ft^3/s) is equal to the potential evapotranspiration rate for October to April plus the precipitation rate for May to September plus the available soil moisture (shown as soil-moisture utilization in figure 29).

Subsurface outflow was the only component of the water budget that was not calculated independently. It was determined by taking the total inflow of 102 ft^3/s and subtracting the total of evapotranspiration, net ground-water withdrawals, and surface-water outflow (83 ft^3/s) to get a residual value of 19 ft^3/s.

Most of the values calculated for this water budget do not differ appreciably from those presented in Drost (1983). In Drost (1983), the total value for inflow was 120 ft^3/s, with almost the entire difference from this study attributable to the differing precipitation values. Drost used a 42-year precipitation average of 103 ft^3/s, whereas this study used a 2-year average, which was 86 percent of the long-term average, as mentioned earlier. Drost (1983) also used a 42-year average of for evapotranspiration, which accounts for most of the difference in the total outflow from this study. The surface and subsurface inflow and outflow values from this study were virtually identical to those of Drost (1983).

The current amount of gross annual ground-water withdrawals was only about 7 percent of the ground-water recharge. Gross ground-water withdrawals would increase to 9 ft^3/s if the maximum population of 75,750 people (calculated previously using current zoning regulations) were used. That would account for about 33 percent of the ground-water recharge. However, a comparison between current recharge and projected population does not mean that the additional water can be withdrawn without affecting the ground-water system. Any increase in ground-water withdrawals from a stable system would have to be balanced by an increase in recharge (which is unlikely), a decrease in ground-water discharge to streams and Puget Sound, a change in the amount of ground water stored in the system (such as lowered water levels), or a combination of these events.

Summary and Conclusions

The U.S. Geological Survey, in cooperation with the Tulalip Tribes, conducted a study of the water resources of the Tulalip Indian Reservation and adjacent area on the Tulalip Plateau in Snohomish County, Washington. The study assessed the current state of the ground- and surface-water resources of the Reservation, prepared a current water budget for the area, and compared the results with those of previous studies in the 1970s and 1980s to determine any changes. The Tribes depend on their water and fisheries resources for subsistence, income, and ceremonial and cultural purposes. In recent years, population and development north and east of the Reservation have increased significantly, and the population of the Reservation has increased by more than 30 percent since 1990. Trends of increasing population and development are expected

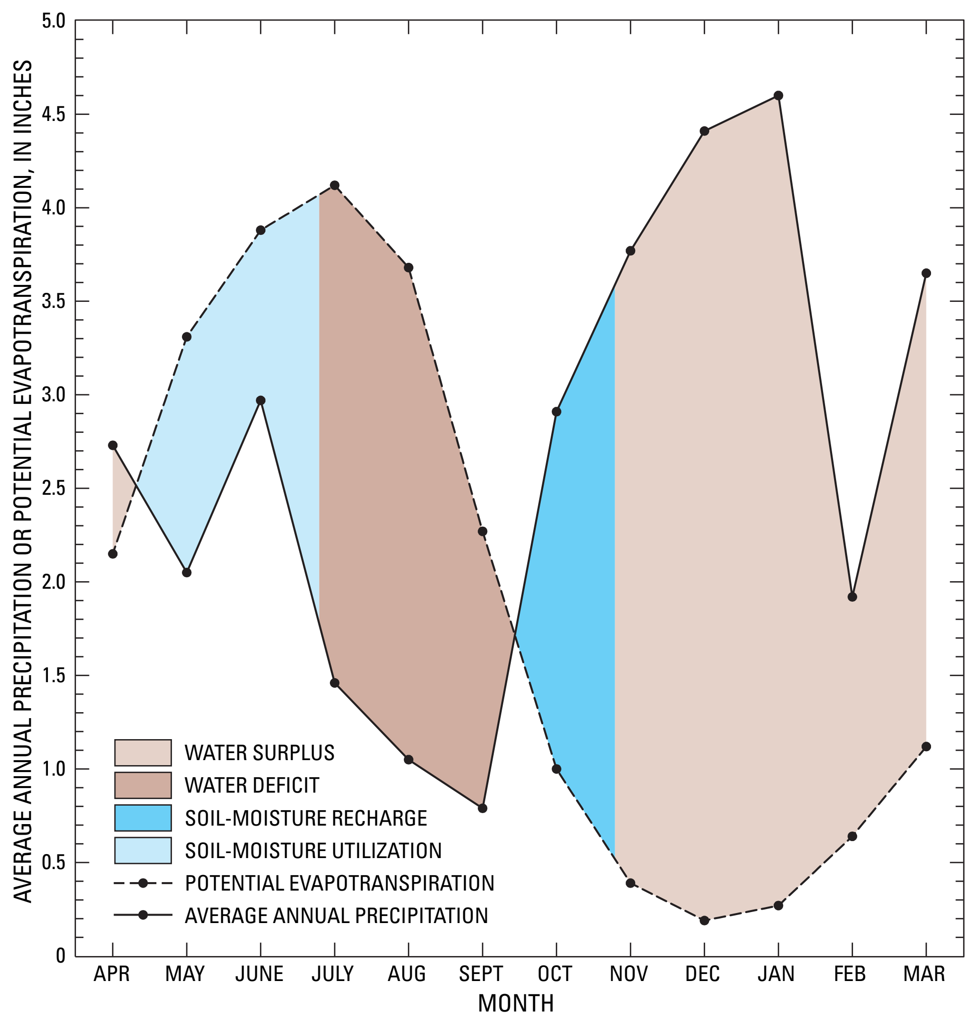


Figure 29. Average annual precipitation and potential evapotranspiration, April 2001–March 2003, for the Tulalip Indian Reservation and adjacent area, Snohomish County, Washington.

to continue in the future both on and off the Reservation. The drinking-water supply for the Reservation comes almost entirely from ground water, so these increases will continue to put more pressure on this resource.

Drillers' logs from 255 wells were used to describe the hydrogeologic framework of the ground-water system. Information about each well included its latitude and longitude, land-surface altitude, depth to ground water, and lithology. Data collected for the Reservation water budget included continuous and periodic streamflow measurements; micrometeorological data, including daily precipitation, temperature, and solar radiation at one location and daily precipitation at two additional locations; and atmospheric-chloride deposition collected under both wet and dry deposition conditions to estimate ground-water recharge.

The Tulalip Plateau is composed of unconsolidated sediments of Quaternary age that are mostly of glacial origin. There are three principal aquifers and two confining units as well as two smaller units that are only localized in extent. The primary aquifer in terms of use is the Vashon advance outwash (Qva). It is present over most of the study area and has a typical thickness of about 140 feet. The Vashon till (Qvt) and the transitional beds (Qtb) act as confining units. The Vashon till overlies Qva and the transitional beds underlie Qva and separate it from the undifferentiated sediments (Qu), which are also a principal aquifer of the Plateau. The undifferentiated-sediments aquifer is present throughout the entire study area, but is not well defined because few wells penetrate it. Ground water flows radially outward from the center of the plateau in the Vashon advance outwash aquifer.

Water levels fluctuate seasonally in all hydrogeologic units in response to changes in precipitation over the course of the year. However, water levels do not appear to have significantly changed over the long term. There was no statistically significant change between water levels measured in the early 1990s and 2001. Additionally, when a rank sum test was used to compare monthly water levels from the 1970s and 1980s to current monthly water-level measurements in 18 wells, some showed increasing water levels, some showed decreasing water levels and some showed no significant change.

Ground water in the study area is recharged from precipitation percolating down from the land surface. Average annual recharge was estimated using the chloride-mass balance method. The average annual recharge was estimated to be 10.4 inches per year, but could range from 6.1 to 15.5 inches per year.

Current streamflow conditions on the Reservation were defined by four continuous-record streamflow-gaging stations operated from April 2001 through March 2003 and monthly measurements of discharge at 12 periodic-measurement sites. Two of the continuous-record gaging stations (12157250 and 12158040), which are near the mouths of Mission and Tulalip Creeks, respectively, also were operated during water years 1975-77.

Correlations of streamflow for Mission and Tulalip Creeks with the long-term record of streamflow at Mercer Creek indicate that there does not appear to be any significant change in streamflow between the mid-1970s and 2001–03 in Mission and Tulalip Creeks. However, when the percentage of changes in streamflow at the Mercer, Mission, and Tulalip Creek gaging stations between the mid-1970s and 2001–03 were compared with the percentage of change in precipitation at the Everett precipitation station, there was no apparent change in streamflow in Mission Creek, but streamflow in Tulalip Creek appeared to have increased, possibly by as much as 15 percent. Comparisons also were made to determine if the percentage of streamflow contributed by base flow had changed significantly since the mid-1970s. Those comparisons strongly suggest that the current relations of base flow to total streamflow in Mission and Tulalip Creeks are essentially the same as they were during water years 1975-77.

A water budget was constructed for the Reservation showing estimated amounts of inflows and outflows of water. Inflows to the Reservation include precipitation (84 cubic feet per second, ft^3/s), surface-water inflow (13 ft^3/s), and subsurface inflow (5 ft^3/s). Outflow is in the form of evapotranspiration (44 ft^3/s), surface-water outflow (38 ft^3/s), net ground-water withdrawals (1 ft^3/s), and subsurface outflow (19 ft^3/s).

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Table 17. Physical and hydrologic data for study wells on the Tulalip Indian Reservation, Snohomish County, Washington.

[**Screened hydrogeologic unit**: Qal, alluvium aquifer; Qvr, Vashon recessional outwash aquifer; Qvt, Vashon till confining bed; Qva, Vashon advance outwash aquifer; Qtb, transitional-beds confining bed; Qu, undifferentiated-sediments aquifer; –, not determined; **Land-surface altitude**; feet above NGVD 1929; **Well depth**, depth of casing and screen, in feet below land surface; **Casing diameter**, –, not applicable; **Primary water use**: C, commercial; H, domestic; I, irrigation; P, public supply; S, stock; T, institutional; U, unused; **Water level**: –, month or day not known; Source: R, reported; S, U.S. Geological Survey, D, driller; –, not determined; **Ground-water condition**: C, confined; F, flows at least part of the time; U, unconfined; –, not determined; **Yield, Drawdown, and Hydraulic conductivity**, –, not determined; **Remarks**: L, driller's (lithologic) log available; Q, sampled for water quality; W, project observation well for water levels]

Local well No.	Screened hydro-geologic unit	Land-surface altitude (feet)	Well depth (feet)	Casing diameter (inches)		Primary water use	Water level			Ground-water condi-tion	Yield (gallons per minute)	Draw-down (feet)	Hydraulic conduc-tivity (feet per day)	Remarks
				Mini-mum	Maxi-mum		Feet below land surface	Date	Source					
29N/04E-01A03	Qu	120	146	–	8	P	118	05-21-92	R	C	30	3	520	L
29N/04E-01B02	Qu	105	160	–	6	P	104.66	05-01-01	S	C	50	6	240	L
29N/04E-01B03	Qu	125	172	–	6	P	116.44	10-02-01	S	–	–	–	–	L
29N/04E-01C02	Qu	125	160	–	6	P	119.94	10-02-01	S	C	–	–	–	L
30N/04E-01A05	Qva	455	155	–	6	H	120	10-03-01	S	U	–	–	–	L,Q
30N/04E-01C01	Qvt	590	125	–	6	U	2.66	05-02-01	S	U	–	–	–	L,W
30N/04E-01E01	Qva	560	277	–	6	H	242.71	10-03-01	S	U	11	1	370	L,Q
30N/04E-01N01	Qva	520	257	–	8	P	199.5	11-14-74	S	U	30	12	33	L
30N/04E-02A02	Qva	585	304	–	6	T	268.79	05-03-01	S	U	–	–	–	L,Q
30N/04E-02G01	Qva	510	218	–	6	H	191.9	10-03-01	S	U	4	4	38	L,Q
30N/04E-02H02	Qva	550	260	–	6	H	217	06-02-92	R	U	–	–	–	L
30N/04E-03D03	Qva	430	179	–	6	H	134.68	10-03-01	S	U	–	–	–	L,Q
30N/04E-03H01	–	394	105	–	6	H	82.47	05-02-01	S	–	–	–	–	W,Q
30N/04E-03H13	Qu	385	300	–	8	U	139.1	02-16-82	S	C	300	53.2	85	L
30N/04E-03P01	Qva	330	108	–	6	H	72.55	06/03/92	S	U	–	–	–	L,Q
30N/04E-04D01	Qu	340	340	–	6	H	285.71	06-05-92	S	U	–	–	–	L
30N/04E-04F02	Qu	257	239	–	6	P	203.91	05-15-01	S	C	–	–	–	L,W
30N/04E-05A02	Qu	330	340	–	6	H	291.38	05-02-01	S	C	–	–	–	L,Q
30N/04E-05P01	Qu	440	480	–	6	H	392	01-11-86	D	C	15	28	24	L
30N/04E-05P02	Qu	430	429	–	6	H	377.21	10-04-01	S	C	–	–	–	L,Q
30N/04E-05P03	Qu	460	600	–	6	H	424.4	05-16-01	S	C	–	–	–	L
30N/04E-05R01	Qu	400	399	5	6	P	362.49	05-15-01	S	C	–	–	–	L
30N/04E-06L02	Qu	385	480	–	6	H	369.06	10-04-01	S	C	–	–	–	L
30N/04E-06Q03	Qu	405	520	–	6	H	–	–	–	U	25	14	22	L
30N/04E-07G02	Qal	100	60	–	8	P	27.4	06-09-92	S	U	–	–	–	L
30N/04E-07G05	Qal	20	53	–	6	P	26.15	05-15-01	S	U	5	20	5.7	L
30N/04E-07H02	Qva	450	80	4.5	8	U	31.9	06-11-92	S	U	7	24	1.7	L
30N/04E-07K01	Qal	20	51	–	6	P	20.95	05-15-01	S	U	15	20	20	L
30N/04E-08B01	Qtb	403	398	–	6	P	359.6	05-15-01	S	U	40	15	140	L
30N/04E-08G01	Qvt	415	55	–	6	H	32.84	10-04-01	S	U	–	–	–	L
30N/04E-08G02	Qu	410	415	–	6	H	347.34	05-18-01	S	C	13	14	43	L
30N/04E-08H01	Qva	465	365	–	6	H	336.11	10-04-01	S	U	9	18	10	L
30N/04E-08H02	Qva	465	363	–	6	H	334.24	10-04-01	S	U	–	–	–	L,Q
30N/04E-10A01	Qu	310	439	–	8	U	–	–	–	–	–	–	–	L
30N/04E-10L01	Qva	215	65	–	8	P	-7.1	12-12-74	S	F	–	–	–	L
30N/04E-10L02	Qva	210	94	–	8	P	26.28	05-03-01	S	C	122	46	60	L,W
30N/04E-10L03	Qva	210	102	–	8	P	12.37	05-03-01	S	C	280	46	97	L,W
30N/04E-10L04	Qva	200	95.5	–	8	P	-10.6	12-12-74	S	F	–	–	–	L
30N/04E-10L05	Qva	205	101	–	8	P	-10	12-12-74	S	F	300	65	82	L
30N/04E-13Q02	Qu	360	287	–	6	H	180.62	10-04-01	S	U	5	2	180	L,Q

Table 17. Physical and hydrologic data for study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[**Screened hydrogeologic unit**: Qal, alluvium aquifer; Qvr, Vashon recessional outwash aquifer; Qvt, Vashon till confining bed; Qva, Vashon advance outwash aquifer; Qtb, transitional-beds confining bed; Qu, undifferentiated-sediments aquifer; –, not determined; **Land-surface altitude**; feet above NGVD 1929; **Well depth**, depth of casing and screen, in feet below land surface; **Casing diameter**, –, not applicable; **Primary water use**: C, commercial; H, domestic; I, irrigation; P, public supply; S, stock; T, institutional; U, unused; **Water level**: –, month or day not known; Source: R, reported; S, U.S. Geological Survey, D, driller; –, not determined; **Ground-water condition**: C, confined; F, flows at least part of the time; U, unconfined; –, not determined; **Yield, Drawdown, and Hydraulic conductivity**, –, not determined; **Remarks**: L, driller's (lithologic) log available; Q, sampled for water quality; W, project observation well for water levels]

Local well No.	Screened hydro-geologic unit	Land-surface altitude (feet)	Well depth (feet)	Casing diameter (inches)		Primary water use	Water level			Ground-water condi-tion	Yield (gallons per minute)	Draw-down (feet)	Hydraulic conduc-tivity (feet per day)	Remarks
				Mini-mum	Maxi-mum		Feet below land surface	Date	Source					
30N/04E-13R01	Qu	420	296	–	6	H	244.62	05-17-01	S	U	–	–	–	L
30N/04E-14G02	Qu	257	200	–	8	U	84.74	12-21-81	S	C	300	36.6	120	L
30N/04E-14J02	Qva	250	133	–	5	H	96.29	07-30-92	S	U	–	–	–	L
30N/04E-14K02	Qu	250	178	–	6	H	111.26	07-30-92	S	C	30	125	9.9	L
30N/04E-14R01	Qva	170	100	–	6	H	11.2	08-05-92	S	U	–	–	–	L
30N/04E-15J01	Qu	120	131	–	6	H	-9.3	01-18-89	D	F	40	40	61	L
30N/04E-15R02	Qu	100	120	–	6	H	-9.3	01-18-89	D	F	40	30	82	L
30N/04E-16M01	Qva	380	300	–	6	H	272.6	05-16-01	S	U	–	–	–	L,Q
30N/04E-17B19	Qu	100	134	–	6	P	97.1	08-06-92	S	C	16	23	17	L
30N/04E-17J03	Qu	265	288	–	6	H	251.66	05-16-01	S	U	10	22	10	L
30N/04E-17K03	Qva	200	138	–	6	P	103.54	08-03-92	S	U	–	–	–	L
30N/04E-17R02	Qva	275	230	–	6	H	194.59	07-29-92	S	U	2	67	.22	L
30N/04E-21G02	Qu	170	375	–	6	P	150.51	10-05-01	S	C	30	30	25	L
30N/04E-21J02	Qtb	182	241	–	6	P	158.15	05-04-01	S	C	35	40	17	L,W
30N/04E-21J04	Qu	160	339	–	6	H	128.1	05-15-01	S	C	25	20.2	67	L
30N/04E-21Q01	Qtb	60	20	–	36	H	11.6	07-29-92	S	C	–	–	–	L
30N/04E-22H01	Qu	120	98	–	6	H	25.56	07-28-92	S	C	–	–	–	L
30N/04E-22J05	Qu	100	220	–	6	H	120	04-24-91	D	C	–	–	–	L
30N/04E-22K01	Qu	110	330.5	–	8	P	117.78	05-03-01	S	C	–	–	–	L,W
30N/04E-22Q01	Qu	100	311	–	8	P	115.28	05-03-01	S	C	315	165	30	L,W
30N/04E-23F01	Qva	300	99	–	6	H	70.4	10-04-01	S	U	8	40	2.9	L
30N/04E-23F02	Qtb	270	173	–	6	H	117	07-29-92	R	U	10	3	98	L
30N/04E-23Q02	Qu	230	245	–	6	U	80.94	05-04-01	S	C	–	–	–	L,W
30N/04E-24A01D1	Qu	460	293	–	6	H	261	08-17-92	D	C	–	–	–	L
30N/04E-24F01	Qva	230	93	–	6	H	61.33	05-15-01	S	C	–	–	–	L
30N/04E-24H01	Qva	470	218	–	6	H	181.7	09-22-99	D	U	20	14.45	35	L
30N/04E-25L01	Qu	150	117.5	–	6	H	72.3	05-18-01	S	C	10	17	27	L
30N/04E-25Q01	Qva	210	137	–	6	H	82.4	05-17-01	S	U	43	35	11	L
30N/04E-25R01	Qva	225	160	–	8	I	99.3	05-17-01	S	U	40	8	39	L
30N/04E-25R02	Qtb	230	360	6	8	U	160	08-03-92	D	C	–	–	–	L
30N/04E-26E01	Qva	60	140	–	6	H	-0.9	10-04-01	S	F	55	70	48	L
30N/04E-28A01	Qu	60	163	–	6	P	40.5	08-05-92	S	C	–	–	–	L
30N/04E-35R01	Qva	130	171	–	6	P	123.64	10-02-01	S	U	–	–	–	L
30N/04E-35R04	Qva	140	178	–	6	H	137	10-10-84	D	U	20	17	28	L
30N/04E-36F14	Qtb	200	220	–	6	H	93.99	05-17-01	S	C	–	–	–	L
30N/04E-36L06	Qu	200	300	–	6	H	201.07	10-02-01	S	C	–	–	–	L
30N/04E-36P01	–	118	152	–	6	H	113.99	05-01-01	S	–	–	–	–	L,W
30N/04E-36P14	Qtb	130	146	–	6	H	119	10-02-01	S	U	–	–	–	L
30N/05E-05E01	Qvr	94	9.7	–	23	H	1.75	05-02-01	S	U	–	–	–	L,Q
30N/05E-05E02	Qvr	93	26.5	–	36	U	6.14	10-18-74	S	U	56	8	150	L

Table 17. Physical and hydrologic data for study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[**Screened hydrogeologic unit**: Qal, alluvium aquifer; Qvr, Vashon recessional outwash aquifer; Qvt, Vashon till confining bed; Qva, Vashon advance outwash aquifer; Qtb, transitional-beds confining bed; Qu, undifferentiated-sediments aquifer; –, not determined; **Land-surface altitude**; feet above NGVD 1929; **Well depth**, depth of casing and screen, in feet below land surface; **Casing diameter**, –, not applicable; **Primary water use**: C, commercial; H, domestic; I, irrigation; P, public supply; S, stock; T, institutional; U, unused; **Water level**: –, month or day not known; Source: R, reported; S, U.S. Geological Survey, D, driller; –, not determined; **Ground-water condition**: C, confined; F, flows at least part of the time; U, unconfined; –, not determined; **Yield, Drawdown, and Hydraulic conductivity**, –, not determined; **Remarks**: L, driller's (lithologic) log available; Q, sampled for water quality; W, project observation well for water levels]

Local well No.	Screened hydro-geologic unit	Land-surface altitude (feet)	Well depth (feet)	Casing diameter (inches)		Primary water use	Water level			Ground-water condi-tion	Yield (gallons per minute)	Draw-down (feet)	Hydraulic conduc-tivity (feet per day)	Remarks
				Mini-mum	Maxi-mum		Feet below land surface	Date	Source					
30N/05E-06G04	Qva	165	78	–	6	H	47.06	10-01-01	S	C	12	4	180	L,Q
30N/05E-06H01	–	96	85	–	6	H	-29.98	07-02-01	S	F	–	–	–	W,Q
30N/05E-06L06	Qu	270	125	–	6	H	64.69	10-01-01	S	C	10	54	7.5	L
30N/05E-07F08	Qu	340	210	–	6	H	179.79	10-02-01	S	C	–	–	–	L,Q
30N/05E-07G05	Qva	250	135	–	6	U	104.68	05-03-01	S	C	15	5	150	L,W
30N/05E-07H02	Qu	85	105	–	6	H	-1.5	06-19-92	S	F	–	–	–	L
30N/05E-08J02	Qu	65	537	–	6	C	-10.24	04-06-87	D	F	–	–	–	L
30N/05E-08K01	Qvr	75	20	–	36	H	5.64	06-29-92	S	U	50	5	450	L
30N/05E-08K02	Qu	70	512	–	10	I	-3	09-15-92	D	F	90	39	33	L
30N/05E-08L04	Qu	75	374	–	6	T	-13.6	09-27-86	S	F	–	–	–	L
30N/05E-17G01	Qu	60	640	5	6	U	–	–	–	F	–	–	–	L
30N/05E-20K05	Qva	25	38	–	6	H	21.14	10-01-01	S	U	5	10	13	L
30N/05E-29B03	Qvr	25	23.7	–	35	U	11.57	10-02-01	S	U	–	–	–	L
30N/05E-29F07	Qvr	25	25	–	36	H	12.95	10-02-01	S	U	20	7	96	L
30N/05E-29G07	Qvr	22	17.55	–	42	H	12.35	05-01-01	S	U	–	–	–	W
30N/05E-31B10	Qva	60	89	–	6	H	48.35	10-02-01	S	U	24	9	70	L,Q
30N/05E-31B11	Qtb	15	140	–	4	U	12.24	07-14-92	S	C	–	–	–	L
30N/05E-31G02	Qva	38	38	–	36	U	10.34	05-01-01	S	U	–	–	–	W
31N/03E-13J01	Qu	150	198	–	6	P	–	–	–	–	–	–	–	L
31N/03E-13R01	Qu	165	186	–	6	U	153	06-06-01	S	C	–	–	–	L
31N/03E-13R02	Qu	165	210	6	10	P	149.4	01-25-01	D	C	111	19.8	70	L
31N/03E-24G01	Qva	120	115	–	6	H	86.98	10-04-01	S	U	15	4	100	L
31N/03E-24H01	Qu	170	210	–	6	H	152.94	10-02-01	S	C	10	10	31	L
31N/03E-24H02	Qva	180	195	–	6	H	156.2	10-01-01	S	U	12	5	68	L
31N/03E-24Q03	Qu	190	235	–	6	H	190.48	06-07-01	S	C	28	10	140	L,W
31N/03E-25A03	Qu	290	608	–	6	P	268	04-17-91	D	C	–	–	–	L
31N/03E-25H01	Qu	230	540	–	6	U	201.99	10-05-01	S	C	35	75	13	L
31N/03E-25H02	Qu	200	560	–	6	P	205	08-21-92	R	C	35	270	3.2	L
31N/03E-25H03	Qu	145	230	–	6	H	150.04	10-04-01	S	C	40	28	74	L
31N/03E-25H04	Qu	190	235	–	6	H	181.15	10-04-01	S	C	2.5	40	1.6	L
31N/03E-25J01	Qu	157	217	–	6	P	119	05-15-01	S	C	–	–	–	L
31N/03E-36J01	Qu	20	109	–	6	P	20.72	05-16-01	S	C	40	20	59	L,W
31N/03E-36R02	Qu	210	620	–	6	U	196.74	05-21-01	S	C	–	–	–	L
31N/04E-02M01	Qu	110	540	–	6	S	116.13	08-03-92	S	U	–	–	–	L
31N/04E-02N02	Qva	170	76	–	6	H	51.28	10-01-01	S	U	12	9	32	L
31N/04E-03E01	Qu	75	220	–	6	H	160	04-07-93	D	U	–	–	–	L
31N/04E-03F01	Qu	90	125	–	6	S	91.98	08-05-92	S	C	–	–	–	L
31N/04E-03F02	Qu	85	398	–	6	U	–	–	–	–	–	–	–	L
31N/04E-03K01	Qu	125	295	–	6	U	33.8	08-04-92	S	C	10	40	0.92	L
31N/04E-03L04	Qvr	110	25	–	36	H	11.92	10-03-01	S	U	80	4	300	L

Table 17. Physical and hydrologic data for study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[**Screened hydrogeologic unit**: Qal, alluvium aquifer; Qvr, Vashon recessional outwash aquifer; Qvt, Vashon till confining bed; Qva, Vashon advance outwash aquifer; Qtb, transitional-beds confining bed; Qu, undifferentiated-sediments aquifer; –, not determined; **Land-surface altitude**; feet above NGVD 1929; **Well depth**, depth of casing and screen, in feet below land surface; **Casing diameter**, –, not applicable; **Primary water use**: C, commercial; H, domestic; I, irrigation; P, public supply; S, stock; T, institutional; U, unused; **Water level**: –, month or day not known; Source: R, reported; S, U.S. Geological Survey, D, driller; –, not determined; **Ground-water condition**: C, confined; F, flows at least part of the time; U, unconfined; –, not determined; **Yield, Drawdown, and Hydraulic conductivity**, –, not determined; **Remarks**: L, driller's (lithologic) log available; Q, sampled for water quality; W, project observation well for water levels]

Local well No.	Screened hydro-geologic unit	Land-surface altitude (feet)	Well depth (feet)	Casing diameter (inches)		Primary water use	Water level			Ground-water condi-tion	Yield (gallons per minute)	Draw-down (feet)	Hydraulic conduc-tivity (feet per day)	Remarks
				Mini-mum	Maxi-mum		Feet below land surface	Date	Source					
31N/04E-03L05	Qvr	110	25	–	36	S	15.7	08-04-92	S	U	40	6	220	L
31N/04E-03P02	Qva	170	128	–	6	H	17.1	08-03-92	S	C	–	–	–	L
31N/04E-03P03	Qu	80	420	–	6	H	28.58	05-17-01	S	C	10	180	0.58	L
31N/04E-04J01	Qu	140	380	–	6	H	115	06-19-91	D	U	–	–	–	L
31N/04E-04L02	Qva	210	68	–	36	H	55.5	08-03-92	S	C	40	5	820	L
31N/04E-04L03	Qva	305	79	–	6	H	52.2	10-04-01	S	U	–	–	–	L
31N/04E-04M01	Qva	345	153	–	6	H	107.95	10-04-01	S	U	–	–	–	L
31N/04E-05H01	Qu	15	27.5	36	48	H	23.62	10-04-01	S	U	8	6	49	L
31N/04E-05K01	Qu	320	325	–	4.5	H	146.5	09-17-90	D	C	–	–	–	L
31N/04E-05K03	Qu	350	322	–	6	H	281	12-29-97	D	U	10	28	3.9	L
31N/04E-05K04	Qu	365	315	–	6	H	284.15	05-17-01	S	C	–	–	–	L
31N/04E-05L01	Qu	310	283	–	6	H	247.58	08-05-92	S	U	–	–	–	L
31N/04E-05L02	Qu	310	269	–	6	H	245	08-22-89	D	C	–	–	–	L
31N/04E-05M01	Qu	190	157	–	6	H	125.94	10-03-01	S	U	–	–	–	L
31N/04E-05R01	Qva	385	355	4	6	H	259	05-21-98	D	U	16.5	35	1.7	L
31N/04E-06R01	Qva	170	85	–	6	H	57	04-00-85	D	U	20	15	16	L
31N/04E-07H03	Qva	160	119	–	6	H	94.56	10-03-01	S	U	15	3	140	L
31N/04E-07L02D1	Qu	170	349	6	6.6	P	146	05-12-83	D	C	50	5	94	L
31N/04E-07N01	Qu	170	322	–	6	P	152.22	08-05-92	S	C	–	–	–	L
31N/04E-07N03	Qu	70	231	–	6	H	45.12	05-18-01	S	C	14	40	2.8	L
31N/04E-08B01	Qva	370	317	–	6	H	256	08-10-92	R	U	–	–	–	L
31N/04E-08E02	Qva	225	144	–	6	H	94.59	05-18-01	S	U	–	–	–	L,W
31N/04E-08N01	Qu	240	294	–	6	U	218	03-13-96	D	C	–	–	–	L
31N/04E-08N02	Qva	290	195.83	–	6	H	128.5	09-25-97	D	U	15	15	23	L
31N/04E-09C01	Qtb	330	199	–	6	H	143	02-28-91	D	U	15	10	40	L
31N/04E-09E01	Qu	390	333	–	6	H	269.98	08-10-92	S	C	–	–	–	L
31N/04E-09K02	Qva	370	260	–	6	H	185	03-17-91	D	U	–	–	–	L
31N/04E-09N01	Qva	400	281.5	–	6	H	228.65	05-17-01	S	U	10	1	310	L
31N/04E-10G04	Qva	180	38	–	36	H	9.25	08-10-92	S	C	50	15	320	L
31N/04E-10K01	Qtb	170	107	–	6	H	13.12	10-02-01	S	U	–	–	–	L
31N/04E-10Q01	Qva	230	80	–	6	H	-1.5	10-02-01	S	F	–	–	–	L
31N/04E-11D01	Qtb	240	275	–	6	U	216	08-12-92	R	U	–	–	–	L
31N/04E-11E04	Qva	230	88	–	6	H	70.7	08-11-92	S	C	–	–	–	L
31N/04E-11L01	Qu	250	472	–	6	H	218	05-02-89	D	C	–	–	–	L
31N/04E-11M02	Qu	230	480	–	6	H	188	03-04-99	D	C	–	–	–	L
31N/04E-12M01	Qtb	155	270	–	6	U	154.78	05-24-01	S	U	–	–	–	L
31N/04E-12P01	Qva	165	150	–	6	H	103.92	10-01-01	S	U	–	–	–	L
31N/04E-12P02	Qva	150	120	–	6	H	87.19	08-11-92	S	U	–	–	–	L
31N/04E-13C03	Qva	190	160	–	6	H	132.86	10-03-01	S	U	–	–	–	L
31N/04E-13F01	Qu	205	213	–	6	U	150	08-11-92	R	C	19	7	130	L

Table 17. Physical and hydrologic data for study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[**Screened hydrogeologic unit**: Qal, alluvium aquifer; Qvr, Vashon recessional outwash aquifer; Qvt, Vashon till confining bed; Qva, Vashon advance outwash aquifer; Qtb, transitional-beds confining bed; Qu, undifferentiated-sediments aquifer; –, not determined; **Land-surface altitude**; feet above NGVD 1929; **Well depth**, depth of casing and screen, in feet below land surface; **Casing diameter**, –, not applicable; **Primary water use**: C, commercial; H, domestic; I, irrigation; P, public supply; S, stock; T, institutional; U, unused; **Water level**: –, month or day not known; Source: R, reported; S, U.S. Geological Survey, D, driller; –, not determined; **Ground-water condition**: C, confined; F, flows at least part of the time; U, unconfined; –, not determined; **Yield, Drawdown, and Hydraulic conductivity**, –, not determined; **Remarks**: L, driller's (lithologic) log available; Q, sampled for water quality; W, project observation well for water levels]

Local well No.	Screened hydro-geologic unit	Land-surface altitude (feet)	Well depth (feet)	Casing diameter (inches) Mini-mum	Casing diameter (inches) Maxi-mum	Primary water use	Water level Feet below land surface	Water level Date	Water level Source	Ground-water condi-tion	Yield (gallons per minute)	Draw-down (feet)	Hydraulic conduc-tivity (feet per day)	Remarks
31N/04E-14K02	Qtb	170	160	4.5	6	H	-10.74	09-25-90	D	F	–	–	–	L
31N/04E-14L01	Qvt	195	9	–	36	H	2.59	10-01-01	S	U	3	4	7.7	L
31N/04E-14M02	Qva	310	97	–	6	H	36.00	06-06-01	S	C	100	20	310	L
31N/04E-14M03	Qva	260	98	–	6	H	5.35	08-12-92	S	C	25	1	1400	L
31N/04E-15B01	Qva	230	82	–	6	H	14.14	10-01-01	S	C	–	–	–	L
31N/04E-15K01	Qva	415	64	–	6	H	20.63	10-01-01	S	C	–	–	–	L
31N/04E-15N01	Qva	450	115	–	6	H	69.75	09-17-81	S	C	20	20	46	L
31N/04E-15N03	Qva	450	124	–	6	H	72	06-07-01	S	C	–	–	–	L,W
31N/04E-15P02	Qva	460	105	–	6	H	74.83	08-13-92	S	C	–	–	–	L
31N/04E-15P03	Qva	450	98	–	6	H	73	09-04-92	D	C	–	–	–	L
31N/04E-15Q04	Qva	450	55	–	6	H	29.4	08-17-92	S	C	20	7	140	L
31N/04E-16P01	Qva	365	150	–	6	H	120.45	10-02-01	S	C	7	20	16	L
31N/04E-16Q02	Qva	390	60	–	6	H	28.06	10-02-01	S	U	–	–	–	L
31N/04E-16R03	Qva	445	120	–	6	H	67.9	08-17-92	S	C	10	20	22	L
31N/04E-17E01	Qva	245	156	–	6	H	136	08-18-92	R	U	10	3	90	L
31N/04E-18E01	Qu	200	210	–	6	P	136	08-18-92	R	C	30	56	13	L
31N/04E-18E02	Qu	170	338.5	–	6	P	151	09-30-99	D	C	–	–	–	L
31N/04E-18F01	Qu	220	235	–	6	H	198.55	05-23-01	S	C	–	–	–	L
31N/04E-18G01	Qu	240	453	–	6	H	229.34	10-04-01	S	U	6	20	2.8	L
31N/04E-19F02	Qvt	190	19.5	–	36	U	12	09-25-91	D	U	10	6	56	L
31N/04E-19G01	Qu	263	315	–	6	U	233.92	05-23-01	S	C	15	14	52	L,W
31N/04E-19K01	Qtb	210	215	–	6	U	141	06-18-98	D	U	5	38	.29	L
31N/04E-19P01D1	Qu	280	573	–	6	H	249.63	10-02-01	S	C	5	200	.86	L
31N/04E-19P02	Qu	325	537	–	12	P	299	06-06-01	S	C	200	75.5	78	L
31N/04E-20E01	Qu	300	315	–	6	H	242.6	10-02-01	S	C	10	20	22	L
31N/04E-20M01	Qu	330	380	–	6	H	280.08	05-23-01	S	C	–	–	–	L
31N/04E-20N01	Qtb	305	252	–	6	H	214.23	10-02-01	S	U	–	–	–	L
31N/04E-20N02R1	Qu	310	300	–	6	H	265	10-12-92	D	C	–	–	–	L
31N/04E-20P01	Qva	240	15	–	36	U	5.24	10-02-01	S	U	20	10	20	L
31N/04E-21A02	Qva	410	83	–	6	H	21	11-28-91	D	C	–	–	–	L
31N/04E-21A03	Qva	450	124	–	6	H	70.41	10-02-01	S	C	20	11	87	L
31N/04E-21A04	Qva	450	120	–	6	H	67	06-09-90	D	C	–	–	–	L
31N/04E-21L02	Qu	395	365	5	6	H	334.39	05-22-01	S	C	–	–	–	L
31N/04E-21Q01	Qva	375	180	–	10	P	126.27	05-22-01	S	U	165	9	144	L,W
31N/04E-22B03	Qva	440	145	–	6	H	102.2	05-24-01	S	U	10	10	23	L,W
31N/04E-22H01	Qva	450	160	–	6	H	111.08	10-02-01	S	U	–	–	–	L
31N/04E-22H02	Qva	460	160	–	6	H	115.85	10-05-01	S	U	–	–	–	L
31N/04E-22L02	Qva	410	186	6	8	P	95.6	09-30-92	S	C	218	24	130	L
31N/04E-23J01	Qva	330	98	–	6	H	40.64	05-22-01	S	U	–	–	–	L
31N/04E-23N01	Qva	430	157	–	6	P	111.87	05-22-01	S	U	15	25	6.3	L

Table 17. Physical and hydrologic data for study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[**Screened hydrogeologic unit**: Qal, alluvium aquifer; Qvr, Vashon recessional outwash aquifer; Qvt, Vashon till confining bed; Qva, Vashon advance outwash aquifer; Qtb, transitional-beds confining bed; Qu, undifferentiated-sediments aquifer; –, not determined; **Land-surface altitude**; feet above NGVD 1929; **Well depth**, depth of casing and screen, in feet below land surface; **Casing diameter**, –, not applicable; **Primary water use**: C, commercial; H, domestic; I, irrigation; P, public supply; S, stock; T, institutional; U, unused; **Water level**: –, month or day not known; Source: R, reported; S, U.S. Geological Survey, D, driller; –, not determined; **Ground-water condition**: C, confined; F, flows at least part of the time; U, unconfined; –, not determined; **Yield, Drawdown, and Hydraulic conductivity**, –, not determined; **Remarks**: L, driller's (lithologic) log available; Q, sampled for water quality; W, project observation well for water levels]

Local well No.	Screened hydro-geologic unit	Land-surface altitude (feet)	Well depth (feet)	Casing diameter (inches)		Primary water use	Water level			Ground-water condi-tion	Yield (gallons per minute)	Draw-down (feet)	Hydraulic conduc-tivity (feet per day)	Remarks
				Mini-mum	Maxi-mum		Feet below land surface	Date	Source					
31N/04E-24M02	Qva	310	70	–	6	H	24.15	10-03-01	S	C	–	–	–	
31N/04E-25G01	Qva	290	120	–	6	H	44.49	10-02-01	S	C	20	43	20	L
31N/04E-25K01	Qva	330	81	–	6	H	46.1	09-29-92	S	U	20	15	32	L
31N/04E-25M04	Qva	420	200	–	6	H	144.17	09-29-92	S	U	–	–	–	L
31N/04E-26L01	Qva	530	312	–	12	P	223.98	05-22-01	S	U	300	51	100	L
31N/04E-27B01	Qva	500	220	–	6	H	181.69	06-06-01	S	U	–	–	–	L
31N/04E-27K01	Qva	510	256	–	6	H	192.12	10-03-01	S	U	–	–	–	L
31N/04E-28E01	Qva	430	235	–	6	H	183.23	05-21-01	S	U	–	–	–	L
31N/04E-28M01	Qva	450	77.5	–	6	H	63.8	05-22-01	S	U	15	4	100	L
31N/04E-28P02	Qva	430	79	–	6	H	48.24	10-05-01	S	C	10	2	130	L
31N/04E-29D01	Qu	370	402	–	6	H	328	10-31-90	D	C	–	–	–	L
31N/04E-29D02	Qu	360	460	–	6	U	297.43	10-04-01	S	C	–	–	–	L
31N/04E-29J03	Qva	450	191	–	6	H	172.35	10-05-01	S	U	–	–	–	L
31N/04E-29N01	Qva	290	214	–	8	P	152.5	10-04-01	S	U	37	19	66	L
31N/04E-29R01	Qva	400	63	–	6	H	24	10-04-01	S	C	–	–	–	L
31N/04E-30K01	Qu	250	275	–	10	I	199.98	10-04-01	S	U	175	60	32	L
31N/04E-31B01	Qva	240	70	–	8	U	35.5	03-09-93	S	U	90	12	140	L
31N/04E-32P01	–	410	319	–	6	H	276.17	06-06-01	S	–	–	–	–	L
31N/04E-33E01	Qu	485	450	–	12	U	–	–	–	–	–	–	–	L
31N/04E-33N01	Qu	410	322	–	6	H	290.05	10-03-01	S	U	4	20	3.4	L
31N/04E-33N02	Qu	410	310	–	6	H	288.98	10-03-01	S	U	9	15	17	L
31N/04E-34B01	Qva	480	252	–	8	P	173	08-11-82	D	U	145	7	190	L
31N/04E-34B02	Qva	490	283	–	12	P	183.82	05-22-01	S	U	575	10	370	L
31N/04E-34C03	Qva	340	85	–	6	H	57.42	10-07-92	S	U	–	–	–	L
31N/04E-34D01	Qva	350	79	–	6	H	47.98	05-24-01	S	U	7	15	13	L,W
31N/04E-34Q02	Qva	450	182	–	6	H	135.17	10-03-01	S	U	–	–	–	L
31N/04E-34Q03	Qva	450	180	–	6	H	144.06	10-03-01	S	U	–	–	–	L
31N/04E-34Q04	Qva	450	180	–	6	H	147	07-02-92	D	U	–	–	–	L
31N/04E-34R01	Qva	430	160	–	6	H	141.35	01-20-81	S	U	15	2	190	L
31N/04E-35H01	Qu	605	467	–	10	U	315.3	02-09-81	S	C	100	37.7	24	L
31N/04E-35R01	Qva	530	240	–	6	H	211	10-06-92	R	U	4	20	3.4	L
31N/04E-36Q01	Qva	480	298	–	6	P	235	05-29-86	D	U	–	–	–	L
31N/04E-36R02	Qva	420	140	–	6	H	92.77	10-05-01	S	U	–	–	–	L
31N/05E-07D03	Qva	35	35	–	6	S	5.55	07-28-92	S	C	–	–	–	L
31N/05E-07F04	Qva	35	60	–	6	H	21	10-09-92	D	U	–	–	–	L
31N/05E-07G01	Qu	35	148	–	6	U	11.9	02-10-93	S	C	–	–	–	L
31N/05E-07L03	Qva	35	40	–	6	S	1.94	07-30-92	S	C	–	–	–	L
31N/05E-17M02	Qvr	75	94	–	6	H	9.02	04-08-93	S	U	2	70	0.13	L
31N/05E-17P01	Qva	115	191	–	6	H	49.6	02-12-93	S	C	5	140	0.37	L
31N/05E-18C01	Qu	60	140	–	6	H	12.5	08-19-92	S	C	30	84	17	L

Table 17. Physical and hydrologic data for study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[**Screened hydrogeologic unit**: Qal, alluvium aquifer; Qvr, Vashon recessional outwash aquifer; Qvt, Vashon till confining bed; Qva, Vashon advance outwash aquifer; Qtb, transitional-beds confining bed; Qu, undifferentiated-sediments aquifer; –, not determined; **Land-surface altitude**; feet above NGVD 1929; **Well depth**, depth of casing and screen, in feet below land surface; **Casing diameter**, –, not applicable; **Primary water use**: C, commercial; H, domestic; I, irrigation; P, public supply; S, stock; T, institutional; U, unused; **Water level**: –, month or day not known; Source: R, reported; S, U.S. Geological Survey, D, driller; –, not determined; **Ground-water condition**: C, confined; F, flows at least part of the time; U, unconfined; –, not determined; **Yield, Drawdown, and Hydraulic conductivity**, –, not determined; **Remarks**: L, driller's (lithologic) log available; Q, sampled for water quality; W, project observation well for water levels]

Local well No.	Screened hydro-geologic unit	Land-surface altitude (feet)	Well depth (feet)	Casing diameter (inches)		Primary water use	Water level			Ground-water condi-tion	Yield (gallons per minute)	Draw-down (feet)	Hydraulic conduc-tivity (feet per day)	Remarks
				Mini-mum	Maxi-mum		Feet below land surface	Date	Source					
31N/05E-18C02	Qvr	45	12	–	36	H	4.87	08-19-92	S	U	40	7	190	L
31N/05E-18C03	Qvr	55	12.5	–	36	U	5.72	08-19-92	S	U	20	7	15	L
31N/05E-18N04	Qva	130	80	–	6	H	23	11-20-88	D	C	–	–	–	L
31N/05E-18P02	Qva	110	151	–	6	H	-2.2	05-24-88	D	F	25	142	8.6	L
31N/05E-19D02	Qva	125	135	–	6	H	20	01-20-88	D	C	20	2	560	L
31N/05E-19E02	Qva	110	110	–	6	H	10.42	07-30-92	S	C	–	–	–	L
31N/05E-19J02	Qva	115	87	–	6	H	15	08-13-72	D	C	15	5	160	L
31N/05E-20L01	Qvr	125	19	–	36	H	7.49	08-18-92	S	U	–	–	–	L
31N/05E-20L02	Qvr	125	18	–	36	H	10	11-20-89	D	U	20	2	450	L
31N/05E-29M02	Qva	105	43	–	6	P	2.6	08-25-92	S	C	80	1	4,300	L
31N/05E-30K02	Qva	160	130	–	6	H	51.1	08-25-92	S	C	10	35	13	L
31N/05E-30P01	Qva	200	25	–	6	H	-3.3	05-20-90	D	F	–	–	–	L
31N/05E-30P02	Qva	190	80	–	6	H	47.35	10-03-01	S	C	–	–	–	L
31N/05E-31E04	Qva	290	157	–	6	H	137.59	10-05-01	S	C	–	–	–	L
31N/05E-31F02	Qva	250	197	–	6	H	12.94	08-26-92	S	U	–	–	–	L
31N/05E-31L01	Qva	270	80	–	6	H	35.2	10-05-01	S	C	–	–	–	L
31N/05E-31P01	Qva	260	80	–	6	P	41.7	08-27-92	S	U	42	31	19	L
31N/05E-32E01	Qva	115	76	–	6	H	8.64	08-26-92	S	C	–	–	–	L
31N/05E-32J01	Qtb	95	187	–	6	U	7	07-15-82	D	F	25	80	19	L

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480723122143001. Local number, 30N/04E-01C01.
LOCATION.--Lat 48°07'23.3", long 122°14'31.1" NAD of 1927, Hydrologic Unit 17110008, near Marysville.
AQUIFER.--Vashon Till of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled unused well, water table, diameter 6 in, depth 40 ft.
DATUM.--Elevation of land-surface datum is 590 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter casing perforated from 23 to 28 ft and 35 to 39 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--October 1974, February 1977 to November 1977, April 1981 to June 1982, and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 1.31 ft below land-surface datum, April 2, 1981; lowest measured, 11.45 ft below land-surface datum, November 8, 2002.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 2, 2001	2.66a	NOV 11	1.33	APR 29	1.49	NOV 8	11.45
JUL 30	5.66	DEC 28	2.31	MAY 29	3.51	JAN 24, 2003	3.78
AUG 29	6.77	FEB 1, 2002	1.42	JUL 8	6.18	MAR 4	2.20
SEP 27	8.09	FEB 26	2.15	AUG 12	7.60	APR 7	1.75
OCT 29	6.61	MAR 27	2.05	SEP 13	9.05		

480703122173001. Local number, 30N/04E-04F02.
LOCATION.--Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Undifferentiated sediments of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, confined, diameter 6 in, depth 239 ft.
DATUM.--Elevation of land-surface datum is 257 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 236 to 239 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--March 1981 to March 1983 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 201.88 ft below land-surface datum, November 16, 1982; lowest measured, 207.97 ft below land-surface datum, September 16, 1982.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 2, 2001	203.91a	NOV 29	204.07	APR 29	208.30P	NOV 8	203.83
AUG 3	204.2	DEC 28	203.89	MAY 30	208.25P	JAN 24, 2003	204.53
AUG 30	202.57	FEB 1, 2002	204.75	JUL 8	204.90	MAR 4	204.00
OCT 5	204.8	FEB 26	204.90	AUG 13	204.64	APR 7	204.20
OCT 29	204.50	MAR 28	204.71	SEP 13	204.60		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480604122165801. Local number, 30N/04E-10L02.
LOCATION.--Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, confined, diameter 8 in, depth 94 ft.
DATUM.--Elevation of land-surface datum is 210 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 8 in diameter screen from 84 to 94 ft, water level measured in 8 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--November 1974 to June 1978, October 1981 to March 1983, April 1993, and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 21.04 ft below land-surface datum, March 14, 1975; lowest measured, 30.24 ft below land-surface datum, July 16, 1982.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 3, 2001	26.28a	NOV 30	78.78P	APR 30	25.38	NOV 8	28.27P
AUG 14	78.28P	DEC 28	26.10R	MAY 30	23.85	JAN 27, 2003	25.01
AUG 29	26.10	FEB 1, 2002	25.71	JUL 8	27.71P	APR 8	26.24
OCT 8	25.95	FEB 27	74.0P	AUG 13	29.16P		
OCT 31	26.10	MAR 28	25.40	SEP 16	26.93		

480602122170101. Local number, 30N/04E-10L03.
LOCATION.--Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, confined, diameter 8 in, depth 102 ft.
DATUM.--Elevation of land-surface datum is 210 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 8 in diameter screen from 83 to 102 ft, water level measured in 8 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--November 1974 to June 1978, October 1981 to March 1983, April 1993, and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 7.97 ft below land-surface datum, March 14, 1975; lowest measured, 18.74 ft below land-surface datum, December 17, 1982.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 3, 2001	12.37a	NOV 30	60.70P	APR 30	67.82P	NOV 8	71.80P
AUG 14	14.65S	DEC 28	67.40P	MAY 30	10.56	JAN 27, 2003	11.50
AUG 29	12.25	FEB 1, 2002	62.10P	JUL 8	71.37P	APR 2	12.90
OCT 8	10.54	FEB 27	55.90P	AUG 13	73.20P		
OCT 31	12.35	MAR 28	13.02	SEP 16	13.85		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480417122172601. Local number, 30N/04E-21J02.
LOCATION.--Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Undifferentiated sediments of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, confined, diameter 6 in, depth 241 ft.
DATUM.--Elevation of land-surface datum is 182 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 231 to 241 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--August 1975 to August 1977, December 1981 to March 1983, and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 155.3 ft below land-surface datum, January 18, 1977; lowest measured, 159.80 ft below land-surface datum, August 30, 2001.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 4, 2001	158.15Ra	NOV 30	156.75	APR 30	157.37	NOV 8	156.10
AUG 3	159.20	DEC 28	156.81	MAY 30	158.11	JAN 24, 2003	156.50
AUG 30	159.80	FEB 1, 2002	157.14	JUL 8	159.46	MAR 4	156.75
OCT 5	157.17	FEB 26	157.50	AUG 12	157.70	APR 7	159.20
OCT 29	158.20	MAR 28	157.45	SEP 13	157.28		

480410122164701. Local number, 30N/04E-22K01.
LOCATION.--Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Undifferentiated sediments of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, confined, diameter 8 in, depth 330.5 ft.
DATUM.--Elevation of land-surface datum is 110 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 8 in diameter screen from 305.5 to 330.5 ft, water level measured in 8 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--August 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 71.45 ft below land-surface datum, March 28, 2002; lowest measured, 158.05 ft below land-surface datum, Januay 24, 2003.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 3, 2001	117.78Ra	DEC 28	104.35	MAY 30	202.95P	JAN 24, 2003	158.05
AUG 3	134.80R	FEB 5, 2002	103.31	JUL 8	132.01P	APR 8	134.23
AUG 30	118.65	FEB 27	154.80P	AUG 13	224.71P		
OCT 8	120.10	MAR 28	71.45	SEP 16	148.60		
NOV 29	135.45R	APR 30	204.31P	NOV 8	241.42P		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480400122163001. Local number, 30N/04E-22Q01.
LOCATION.--Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Undifferentiated sediments of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, confined, diameter 8 in, depth 311 ft.
DATUM.--Elevation of land-surface datum is 100 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 8 in diameter screen from 293 to 311 ft, water level measured in 8 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--August 1992 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 51.8 ft below land-surface datum, August 4, 1992; lowest measured, 155.72 ft below land-surface datum, January 27, 2003.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 3, 2001	115.28Ra	NOV 30	132.60P	APR 30	127.05P	NOV 8	197.84P
AUG 3	131.95R	DEC 28	100.25	MAY 30	129.90	JAN 27, 2003	155.72
AUG 30	115.71	FEB 5, 2002	101.00	JUL 8	180.15P	APR 8	136.65
OCT 8	112.60	FEB 27	153.64P	AUG 13	143.10		
OCT 31	127.65P	MAR 28	68.60	SEP 16	144.91		

480406122151301. Local number, 30N/04E-23Q02.
LOCATION.--Lat 48°04’05.6”, long 122°15’13.2” NAD of 1927, Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Undifferentiated sediments of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled unused well, confined, diameter 6 in, depth 245 ft.
DATUM.--Elevation of land-surface datum is 230 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 5.6 in diameter screen from 240 to 245 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 79.54 ft below land-surface datum, April 30, 2002; lowest measured, 81.90 ft below land-surface datum, October 5, 2001.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 4, 2001	80.94a	NOV 30	81.32	APR 30	79.54	NOV 8	81.31
AUG 13	80.97	DEC 28	80.80	MAY 30	80.20	JAN 24, 2003	81.71
AUG 30	81.36	FEB 1, 2002	80.50	JUL 8	80.50	MAR 4	81.37
OCT 5	81.90	FEB 27	80.15	AUG 12	80.60	APR 7	81.22
OCT 31	81.50	MAR 28	79.80	SEP 13	81.38		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480218122143201. Local number, 30N/04E-36P01.
LOCATION.--Lat 48°02'17.7", long 122°14'31.9" NAD of 1927, Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Undetermined.
WELL CHARACTERISTICS.--Drilled domestic well, diameter 6 in, depth 152 ft.
DATUM.--Elevation of land-surface datum is 118 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter open end casing at 152 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--September 1974 to March 1976, January 1981 to April 1981, and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 113.0 ft below land-surface datum, February 17, 1976; lowest measured, 114.4 ft below land-surface datum, August 13, 1975.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 1, 2001	113.99a	NOV 29	113.38	APR 29	113.54	NOV 8	113.43
JUL 30	113.72	DEC 28	113.40	MAY 29	113.65	JAN 24, 2003	113.20
AUG 29	113.67	FEB 1, 2002	113.45	JUL 8	113.87	MAR 4	113.20
OCT 5	113.75	FEB 27	113.35	AUG 12	113.60	APR 7	113.40
OCT 31	113.75	MAR 27	113.55	SEP 13	113.65		

480703122121801. Local number, 30N/05E-06H01.
LOCATION.--Lat 48°07'03.3", long 122°12'17.0" NAD of 1927, Hydrologic Unit 17110011, near Marysville.
AQUIFER.--Undetermined.
WELL CHARACTERISTICS.--Drilled domestic well, confined, diameter 6 in, depth 85 ft.
DATUM.--Elevation of land-surface datum is 96 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter open end casing at 85 ft, water level measured with pressure gage on 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--November 1974 to September 1977, December 1980 to September 1982, and July 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 34.1 ft above land-surface datum, May 29, 2002; lowest measured, 27.1 ft above land-surface datum, March 18, 1981.

WATER LEVEL, IN FEET ABOVE LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
JUL 2, 2001	30.0a	NOV 29	32.4	MAR 27	33.7	AUG 12	32.3
JUL 30	32.3	DEC 28	32.5	APR 29	33.7	SEP 13	32.3
AUG 29	32.3	FEB 1, 2002	32.8	MAY 29	34.1	NOV 8	32.3
SEP 27	32.3	FEB 26	32.3	JUL 8	33.7	JAN 24, 2003	32.3

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480612122125201. Local number, 30N/05E-07G05.
LOCATION.--Lat 48°06'12.4", long 122°12'54.2" NAD of 1927, Hydrologic Unit 17110011, near Marysville.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled unused well, confined, diameter 6 in, depth 135 ft.
DATUM.--Elevation of land-surface datum is 250 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 130 to 135 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--December 1976 to June 1978, December 1980 to March 1983, and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 101.55 ft below land-surface datum, May 19, 1982; lowest measured, 105.55 ft below land-surface datum, October 29, 2001 and April 7, 2003.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 3, 2001	104.68a	NOV 29	105.44	APR 29	104.10	NOV 8	104.80
JUL 30	105.13	DEC 28	105.20	MAY 29	103.99	JAN 24, 2003	105.50
AUG 29	105.20	FEB 1, 2002	104.90	JUL 8	104.50	MAR 4	105.50
SEP 27	105.36	FEB 26	104.92	AUG 12	104.67	APR 7	105.55
OCT 29	105.55	MAR 27	105.00	SEP 13	104.93		

480332122113601. Local number, 30N/05E-29G07.
LOCATION.--Lat 48°03'43.0", long 122°11'36.1" NAD of 1927, Hydrologic Unit 17110011, near Marysville.
AQUIFER.--Vashon recessional outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Dug domestic well, water table, diameter 42 in, depth 17.5 ft.
DATUM.--Elevation of land-surface datum is 22 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 42 in diameter open end casing at 17.5 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--September 1974 to November 1977 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 8.64 ft below land-surface datum, March 14, 1975; lowest measured, 13.63 ft below land-surface datum, November 8, 2002 and January 24, 2003.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 1, 2001	12.35a	NOV 29	13.30	APR 29	10.47	NOV 8	13.63
JUL 30	12.6	DEC 28	11.90	MAY 29	10.83	JAN 24, 2003	13.63
AUG 29	12.94	FEB 1, 2002	11.30	JUL 8	11.47	MAR 4	13.03
SEP 27	13.33	FEB 26	10.78	AUG 12	12.15	APR 7	12.76
OCT 29	13.33	MAR 27	10.43	SEP 13	12.75		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480242122125301. Local number, 30N/05E-31G02.
LOCATION.--Lat 48°02'42.0", long 122°12'53.3" NAD of 1927, Hydrologic Unit 17110011, near Marysville.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Dug unused well, water table, diameter 36 in, depth 38 ft.
DATUM.--Elevation of land-surface datum is 38 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 42 in diameter open end casing at 38 ft, water level measured in 42 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--September 1974 to September 1977 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 0.95 ft below land-surface datum, February 1, 2002; lowest measured, 19.42 ft below land-surface datum, December 12, 1974.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 1, 2001	10.34a	NOV 29	7.20	APR 29	2.90	NOV 8	17.42
JUL 30	13.81	DEC 28	7.80	MAY 29	9.20	JAN 24, 2003	9.22
AUG 29	14.80	FEB 1, 2002	0.95	JUL 8	12.60	MAR 4	12.40
OCT 5	16.3	FEB 26	1.40	AUG 12	14.10	APR 7	6.55
OCT 31	16.90	MAR 27	2.00	SEP 19	15.45		

480909122214101. Local number, 31N/03E-24Q03.
LOCATION.--Lat 48°09'10.3", long 122°21'43.0" NAD of 1927, Hydrologic Unit 17110019, near Stanwood.
AQUIFER.--Undifferentiated sediments of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled domestic well, confined, diameter 6 in, depth 235 ft.
DATUM.--Elevation of land-surface datum is 190 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 230 to 235 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--August 1992 to January 1995 and June 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 189.25 ft below land-surface datum, November 8, 2002; lowest measured, 191.20 ft below land-surface datum, July 13, 1994.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
JUN 7, 2001	190.48a	NOV 29	189.43	MAY 29	190.30	JAN 24, 2003	189.30
JUL 30	190.30	DEC 28	189.72	JUL 8	191.00	MAR 4	190.38
AUG 30	190.90	FEB 1, 2002	189.68	AUG 13	190.30	APR 7	190.40
SEP 27	190.50	FEB 26	190.20	SEP 13	190.39		
OCT 29	190.80	MAR 28	190.58	NOV 8	189.25		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480738122214201. Local number, 31N/03E-36J01.
LOCATION.--Hydrologic Unit 17110019, near Tulalip.
AQUIFER.--Undifferentiated sediments of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, confined, diameter 6 in, depth 109 ft.
DATUM.--Elevation of land-surface datum is 20 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 99 to 109 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--April 1967 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 20.13 ft below land-surface datum, November 29, 2001; lowest measured, 22.80 ft below land-surface datum, April 29, 2002.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 16, 2001	20.72a	NOV 29	20.13	APR 29	22.80	NOV 8	20.47
JUL 30	20.90	DEC 28	20.25	MAY 29	22.15	JAN 24, 2003	20.14
AUG 30	22.50	FEB 1, 2002	20.92	JUL 8	22.25	MAR 4	20.94
OCT 5	21.14	FEB 26	20.22	AUG 13	22.53	APR 7	21.40
OCT 29	21.50	MAR 28	21.81	SEP 13	20.82		

481131122195801. Local number, 31N/04E-08E02.
LOCATION.--Lat 48°11’31.4”, long 122°19’58.8” NAD of 1927, Hydrologic Unit 17110008, near Stanwood.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled domestic well, water table, diameter 6 in, depth 144 ft.
DATUM.--Elevation of land-surface datum is 225 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 139 to 144 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--August 1992 to January 1995 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 94.30 ft below land-surface datum, November 8, 2002; lowest measured, 96.32 ft below land-surface datum, January 18, 1995.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 18, 2001	94.59a	NOV 29	94.77	APR 29	94.58	NOV 8	94.30
JUL 30	94.72	DEC 28	94.67	MAY 29	96.80R	JAN 24, 2003	94.45
AUG 30	94.57	FEB 1, 2002	94.80	JUL 8	94.60	MAR 4	94.47
SEP 27	94.60	FEB 26	94.77	AUG 13	94.49	APR 7	94.50
OCT 29	94.70	MAR 28	94.71	SEP 13	94.48		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

481005122171101. Local number, 31N/04E-15N03.
LOCATION.--Lat 48°10’05.0”, long 122°17’12.5” NAD of 1927, Hydrologic Unit 17110008, near Stanwood.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled domestic well, confined, diameter 6 in, depth 124 ft.
DATUM.--Elevation of land-surface datum is 450 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 120 to 124 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--August 1992 to January 1995 and June 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 68.50 ft below land-surface datum, April 29, 2002; lowest measured, 73.98 ft below land-surface datum, November 21, 1994.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
JUN 7, 2001	72.00a	NOV 29	71.49	APR 29	68.50	NOV 8	71.70
JUL 30	73.62	DEC 28	70.92	MAY 29	69.01	JAN 24, 2003	72.90
AUG 29	71.25	FEB 1, 2002	70.21	JUL 8	70.20	MAR 4	72.40
SEP 27	71.61	FEB 26	69.74	AUG 12	70.49	APR 7	72.00
OCT 29	71.82	MAR 27	68.90	SEP 13	71.30		

480945122203201. Local number, 31N/04E-19G01.
LOCATION.--Lat 48°09’45.0”, long 122°20’32.3” NAD of 1927, Hydrologic Unit 17110019, near Stanwood.
AQUIFER.--Undifferentiated sediments of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled unused well, confined, diameter 6 in, depth 315 ft.
DATUM.--Elevation of land-surface datum is 263 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 310 to 315 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--January 1981 to March 1983 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 233.92 ft below land-surface datum, May 23, 2001; lowest measured, 247.53 ft below land-surface datum, November 16, 1982.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 23, 2001	233.92a	NOV 29	234.34	APR 29	234.90	NOV 8	234.01
JUL 30	234.12	DEC 28	234.72	MAY 29	234.75	JAN 24, 2003	234.60
AUG 30	234.40	FEB 1, 2002	235.07	JUL 8	235.07	MAR 4	234.58
SEP 27	235.40	FEB 26	235.12	AUG 13	234.89	APR 7	234.81
OCT 29	234.90	MAR 28	235.10	SEP 13	234.70		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[Abbreviations: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480918122180501. Local number, 31N/04E-21Q01.
LOCATION.--Hydrologic Unit 17110019, near Stanwood.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, water table, diameter 10 in, depth 180 ft.
DATUM.--Elevation of land-surface datum is 375 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 10 in diameter screen from 156 to 180 ft, water level measured in 10 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--March 1981 to March 1983, September 1992, and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 125.89 ft below land-surface datum, May 29, 2002; lowest measured, 135.16 ft below land-surface datum, September 30, 1992.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 22, 2001	126.27a	NOV 29	137.62P	APR 29	137.67P	JAN 24, 2003	126.20
JUL 30	137.61R	DEC 28	137.62P	MAY 29	125.89	MAR 2	137.58P
AUG 29	126.31	FEB 1, 2002	126.44	JUL 8	137.60P	APR 7	137.64P
SEP 27	143.90P	FEB 26	137.60P	AUG 13	126.19		
OCT 31	137.68P	MAR 27	126.20	NOV 8	137.60P		

480959122163401. Local number, 31N/04E-22B03.
LOCATION.--Lat 48°09’58.6”, long 122°16’35.2” NAD of 1927, Hydrologic Unit 17110008, near Stanwood.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled domestic well, water table, diameter 6 in, depth 145 ft.
DATUM.--Elevation of land-surface datum is 440 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 140 to 145 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--January 1981 to March 1983 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 101.80 ft below land-surface datum, November 8, 2002; lowest measured, 105.65 ft below land-surface datum, March 17, 1981.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 24, 2001	102.20a	DEC 28	103.20	MAY 29	102.15	JAN 24, 2003	102.51
JUL 30	102.3	FEB 1, 2002	104.20P	JUL 8	102.68	MAR 4	102.72
SEP 27	102.2	FEB 26	103.14	AUG 13	102.70	APR 7	102.80
OCT 29	102.67	MAR 27	102.70	SEP 13	102.22		
NOV 29	102.66	APR 29	102.45	NOV 8	101.80		

Table 18. Ground-water levels in study wells on the Tulalip Indian Reservation, Snohomish County, Washington.—Continued

[**Abbreviations**: Lat, latitude; long, longitude; in, inches; ft, feet; a, measured by U.S. Geological Survey; P, well pumping; R, well recently pumped; S, nearby well pumping]

480917122155701. Local number, 31N/04E-23N01.
LOCATION.--Hydrologic Unit 17110008, near Stanwood.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled public-supply well, water table, diameter 6 in, depth 157 ft.
DATUM.--Elevation of land-surface datum is 430 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 147 to 157 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--January 1981 to March 1983, February 1993, and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 111.81 ft below land-surface datum, April 29, 2002; lowest measured, 116.89 ft below land-surface datum, November 16, 1981.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 22, 2001	111.87a	NOV 29	112.70R	APR 29	111.81	NOV 8	111.90
JUL 30	112.40	DEC 28	112.60	MAY 29	111.84	JAN 24, 2003	113.50
AUG 29	113.10	FEB 1, 2002	113.30	JUL 8	111.84	MAR 4	112.35
SEP 27	112.10	FEB 26	112.58	AUG 13	131.00P	APR 7	112.71
OCT 31	112.02R	MAR 27	112.40	SEP 13	113.03R		

480809122171301. Local number, 31N/04E-34-D01
LOCATION.--Lat 48°08’08.2”, long 122°17’10.6” NAD of 1927, Hydrologic Unit 17110019, near Stanwood.
AQUIFER.--Vashon advance outwash of Pleistocene Age.
WELL CHARACTERISTICS.--Drilled domestic well, water table, diameter 6 in, depth 79 ft.
DATUM.--Elevation of land-surface datum is 350 ft above NGVD of 1929.
REMARKS.--Monitored depth interval; 6 in diameter screen from 75 to 79 ft, water level measured in 6 in casing. Water levels measured by personnel from Tulalip Tribe unless otherwise indicated.
PERIOD OF RECORD.--February 1981 to March 1983 and May 2001 to April 2003.
EXTREMES FOR PERIOD OF RECORD.--Highest static water level measured, 47.45 ft below land-surface datum, April 29, 2002; lowest measured, 52.19 ft below land-surface datum, August 18, 1981.

WATER LEVEL, IN FEET BELOW LAND-SURFACE DATUM, WATER YEARS OCTOBER 2000 TO SEPTEMBER 2003

Date	Water level	Date	Water level	Date	Water level	Date	Water level
MAY 24, 2001	47.98a	NOV 29	48.88	APR 29	47.45	NOV 8	49.50
JUL 30	48.25	DEC 28	48.13	MAY 29	47.74	JAN 24, 2003	49.64
AUG 29	49.00	FEB 1, 2002	48.11	JUL 8	48.40	MAR 4	49.24
SEP 27	48.30	FEB 26	48.11	AUG 12	48.85	APR 7	48.70
OCT 29	49.20	MAR 27	47.80	SEP 13	49.26		

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