Hydrogeologic and Water-Quality Reconnaissance of the Artesian Aquifer Under the Shoalwater Bay Indian Reservation and Tokeland Peninsula, Pacific County, Washington, 1998-99

Prepared in cooperation with the

Shoalwater Bay Indian Tribe

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 01-4023

View of Shoalwater Lake from vicinity of Tribal wells 14N/11W-02C01 and C02. Photograph taken by Ron Boquist, Shoalwater Tribal Environmental Programs, May 1999.

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Tacoma, Washington
2002

U.S. DEPARTMENT OF THE INTERIOR
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Building 810
Box 25286, Federal Center
Denver, CO 80225-0286

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CONVERSION FACTORS AND VERTICAL DATUM

CONVERSION FACTORS

Multiply	By	To obtain
inch (in)	25.4	millimeters
foot (ft)	0.3048	meters
square foot (ft^2)	0.0929	square meters
acre	0.4047	hectares
	4,047	square meters
mile (mi)	1.609	kilometers
gallon (gal)	3.785	liters

Termperature in degrees Fahrenheit (^oF) can be converted to degree Celsius (^oC) as follows:
$^oC = 5/9\ (^oF\text{-}32)$.

Temperature in degrees Celsius (^oC) can be converted to degrees Fahrenheit (^oF) as follows:
$^oF = 1.8\ (^oC+32)$.

VERTICAL DATUM

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum *derived* from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

The U.S. Geological Survey (USGS) collected and compiled hydrogeologic and water-quality data from September 1998 through September 1999 to describe the hydrogeologic setting and to assess the quality of the water in the artesian aquifer under the Shoalwater Bay Indian Reservation and the adjacent Tokeland Peninsula area of Pacific County, Washington. Hydrogeologic data include descriptions of 38 wells, lithologic data for 27 wells, and water-level data for 17 wells and 1 tidal station. Water-quality data include field measurements for temperature, specific conductance, pH, alkalinity, bicarbonate, carbonate, dissolved oxygen, and laboratory analyses for major inorganic ions, metals, nutrients, methylene blue-active substances, and pesticides. None of the 93 field measurements or chemicals analyzed for exceeded the U.S. Environmental Protection Agency (USEPA) primary standards for drinking water and only 2 constituents (iron and manganese) exceeded the USEPA secondary standards. Sixty-six of the constituents (including all 53 pesticides) were at or below the reporting or detection levels established by the USGS National Water Quality Laboratory.

INTRODUCTION

The Shoalwater Bay Indian Tribe of southwestern Washington is concerned about the quality of ground water in the artesian aquifer under their Reservation and the adjacent Tokeland Peninsula (fig. 1). This aquifer is the primary source of water in the study area and supplies water to the Tribe's main production well, 14N/11W-03J01. The Tribe's concerns include seawater intrusion due to overpumping, contamination by nitrate and bacteria from septic systems, and contamination by pesticides that were used on agricultural and forested areas adjacent to the reservation. In order to address these issues and to improve knowledge of the aquifer system, the U.S. Geological Survey (USGS), in cooperation with the Shoalwater Bay Indian Tribe under a grant from the Bureau of Indian Affairs, collected hydrogeologic and water-quality data on the Reservation and the Tokeland Peninsula area from September 1998 through September 1999.

Purpose and Scope

This report presents the results of the reconnaissance study to describe the hydrogeologic setting to the extent allowed by the data and to describe the quality of water in the artesian aquifer. The report includes the hydrogeologic and water-quality data collected and compiled for the study from September 1998 through September 1999, as well as an appendix containing methods used for collecting and analyzing the water-quality data. (All figures and tables are located at the end of the report.)

Description of the Study Area

The study area includes the Shoalwater Bay Indian Reservation and the adjacent Tokeland Peninsula region of southwestern Washington (fig. 1). Located in Pacific County on the north side of Willapa Bay, the peninsula covers 1.75 square miles (1,120 acres) of coastal lowlands. The reservation, situated north and west of the peninsula, covers 0.75 square mile (480 acres) and extends 1 mile east to west and 0.75 mile north to south. One-third of the reservation is tidelands, one-third is lowlands ranging in altitude from sea level to 40 feet above sea level, and one-third is forested uplands ranging from 40 feet to more than 300 feet above sea level. The tidelands are primarily used for recreational and commercial fishing and shellfishing, the lowlands for residential and commercial activities; the uplands are largely undeveloped and sparsely populated. The permanent population of the study area was reported to be 963 people; tourism and seasonal use account for an additional 600 people during the period from Memorial Day to Labor Day (Steve Spencer, Shoalwater Bay Tribe Environmental Office, written commun., 2000).

The temperate maritime climate of the study area is characterized by warm, dry summers and mild, wet winters. Average monthly temperatures range from 40 degrees Fahrenheit in January (the coldest month) to 60 degrees Fahrenheit in July and August (the warmest months). Precipitation averages 70 inches per year, most of which occurs as steady low- to medium-intensity rainfall. Three-quarters of the annual precipitation falls between October and March (National Oceanic and Atmospheric Administration, 1999).

Previous Studies

Other USGS reports pertaining to the water resources in the study area include a reconnaissance study of the water resources of the Shoalwater Reservation by Lum (1984), studies of seawater intrusion along the Washington coast by Walters (1971) and Dion and Sumioka (1984), and a water-quality assessment study of southwest Washington by Ebbert and Payne (1985). Additional water-quality data for the Tribe’s main production well can be found in an assessment report by the U.S. Environmental Protection Agency (1997).

Well-Numbering System

The well-numbering system used by the USGS in the State of Washington is based on the Public Land Survey rectangular grid system (fig. 2). The Willamette base line and meridian form the basis of a grid that indicates township, range, section, and 40-acre tract within the section which are used to assign a unique number to each well identified by the Washington District. For example, in well number 14N/10W-18D02, the part preceding the slash (14N) indicates the township north of the Willamette base line; the part between the slash and the hyphen (10W) indicates the range west of the Willamette meridian; the number following the hyphen (18) indicates the section; and the letter (D) gives the 40-acre tract (quarter-quarter) within the section. The number following the quarter-quarter (02) is the serial number of the well, indicating the order that wells were inventoried by USGS personnel. A suffix, such as D1, indicates a well has been deepened or otherwise modified after its initial construction.

Acknowledgments

Individual members and employees of the Shoalwater Bay Indian Tribe and other residents of the study area provided help and assistance during the field investigation. The late James R. Lyles of the U.S. Geological Survey provided valuable assistance in preparing this report.

HYDROGEOLOGY

The primary source of hydrogeologic data for the study area was the USGS National Water Information System (NWIS) data base and supporting water-well report files in the USGS's Washington District Office. All licensed well drillers in the State of Washington are required to file a water-well report with the Washington State Department of Ecology (Ecology) whenever the driller constructs, repairs, modifies, or decommissions a well. Ecology then forwards a copy of the report to the USGS Washington District Office.

The NWIS data base and support files included information on 35 flowing wells that are completed in the artesian aquifer under the study area. A field inventory of these wells determined the accurate location and the suitability of each site for water-level measurements and water-quality sampling. Location and other information for all 35 wells is given in table 1, construction and completion details in table 2, and lithologic data in table 3.

In addition, the Tribe had three new wells (14N/11W-02C01, 14N/11W-02C02, and 14N/11W-03F01) installed near the northern edge of the reservation (fig. 1). The Tribe planned to install two wells in order to obtain water-quality samples from the artesian aquifer upgradient from the Tribe's main supply well (14N/11W-03J01). However, a break in the casing prevented 02C01 from being completed at the desired depth, and a third well (02C02) had to be installed. Construction, completion, and lithologic data for all three wells are shown on figure 3 and tables 1, 2, and 3.

Regional Hydrogeology

The generalized lithology of coastal Pacific County consists of bedrock overlain by sedimentary deposits (Lum, 1984). The bedrock consists primarily of weathered and eroded basalt and other volcanic rocks. Some water may exist in the bedrock, but the quantity and quality of the water is unknown and was not investigated for this report because there are no known wells in or near the study area that fully penetrate the overlying sedimentary deposits.

The sedimentary deposits consist of terrace deposits, alluvium, and beach sands. The geologic maps and lithologic data available for the study area are not detailed enough to provide thickness data for these deposits. However, the lithologic data for wells 14N/11W-13A04 and 14N/11W-13A05 indicate that the deposits are at least 350 feet thick (table 3), and Lum (1984) says that the thickness is greater than 400 feet. The terrace deposits contain numerous unconsolidated and partially compacted layers containing various mixtures of clay, silt, sand, and gravel. Ground water occurs in most of the unconsolidated terrace deposits under confined and unconfined conditions. The alluvium, composed of reworked terrace deposits, and the beach sands may also contain ground water, but these potential sources were not investigated for this report.

Local Hydrogeology

The sedimentary deposits in the study area can be divided into a sand-dominated water-table aquifer underlain by a clay-and-silt-dominated semiconfining unit that is underlain by the gravel-and-sand-dominated artesian aquifer that is the focus of this study. These three major hydrogeologic units were defined by using the logs from seven wells running northwest to southeast in the study area (fig. 4) and grouping layers together based on their dominate lithology as reported by various well drillers (table 3). Depths to the top of each unit for selected wells are given in table 4. The variability in depth to the top of each unit is due to the complexity of the deposits and to the manner that individual drillers identify and report lithologic layers. The available data are not sufficient to allow detailed mapping of individual lithologic layers within the hydrogeologic units.

Although this three-unit separation is a reasonable interpretation of the existing data, it is not the only possible one. And while this interpretation is consistent with previous work in the study area, it does have some significant differences from Lum's (1984) work. For example, the lithologic data for wells 14N/11W-13A04 and 14N/11W-13A05 indicate the possibility of a second, deeper semiconfining unit and a second, deeper artesian aquifer. Also, the lithologic data for the Tribe's three new wells establish that while the artesian aquifer does extend northward beneath both the uplands and the lowlands, the water-table aquifer extends inland only in the lowlands (fig. 4).

Ground-Water Levels

Water-level data from 17 wells were collected at various times from September 1998 through August 1999 and are presented in table 5. Water levels were measured in 14 wells on November 18, 1998, to investigate the relation between ocean tides and ground-water levels in the study area and to establish directions of ground-water flow within the artesian aquifer (table 5). Six of the 14 wells were measured hourly during one complete 12-hour tidal cycle (low tide to low tide); the other eight wells were measured once during the same tidal cycle. While the observed tidal flux at the Toke Point Tidal Station was 9.3 feet, water levels in the six observation wells changed by 0.7 to 2.9 feet and lagged the tidal flux by as much as 2 hours (fig. 5). Tidal efficiencies (defined as the change in the observed water level divided by the change in the tide, expressed as a percent) ranged from 8 percent in the northern part of the study area to 31 percent near the southern end of the Tokeland Peninsula. As shown on figure 6, adjacent wells have similar tidal efficiencies and would thus show a similar change in water levels for a given tidal flux.

To compensate for this observed tidal effect, water levels at all 14 wells were adjusted to the high-tide point of the tidal cycle. For the six wells measured hourly, this adjustment was done by interpolating the water-level data shown in table 5 and on figure 5. For the eight wells measured once, the adjustment was done using the estimated change in water levels at a nearby hourly well. For example, the water level in well 13A06 was 14.9 feet at 14:12 (table 5). At about that time (14:05) the water level in well 13A05 was estimated to be 15.7 feet, or 0.9 foot below the water level of 16.6 feet observed at the high-tide point. Applying the 0.9 foot water-level change to the observed water level of 14.9 feet at well 13A06 gives an adjusted high-tide water level of 15.8 feet. As shown on figure 6, the adjusted high-tide water levels for all 14 wells ranged from 15.1 to 17.7 feet. This small variation in the adjusted water levels and the distance between the wells made it impossible to produce a reasonable contour map of water levels within the study area.

Flow Directions

The general direction of horizontal ground-water flow within the artesian aquifer is from the north to the south (fig. 6). This flow direction places the recharge area for the aquifer north of and at a higher elevation than the study area. It also means that chemicals and other substances could possibly enter the artesian aquifer in the recharge area and be transported into the study area. All observed water levels in the artesian aquifer (except at well 14N/11W-03F01) were above land surface, indicating that there is an upward component of flow from the artesian aquifer through the semi-confining unit and into the water-table aquifer. This upward component of flow minimizes the risk of contaminants moving from the land surface downward to the artesian aquifer.

Water Use

Within the study area ground water from the artesian aquifer is used primarily for domestic purposes, and is estimated to have been less than 33 million gallons during calendar year 1999. This estimate is based on a reported permanent population of 963 people, a seasonal increase of 600 people (Steve Spencer, Shoalwater Bay Tribe Environmental Office, written commun., 2000), and the average United States domestic per capita use of 80 gallons per day per person (Solley and others, 1998). Lum (1984) indicates that the actual per capita use rate in the study area is probably significantly less than the national average per capita rate used in this estimate.

WATER QUALITY

Ground-water samples were collected from 10 wells at various times from December 1998 through September 1999 (fig. 7). All samples were collected in accordance with the protocols described by Koterba and others (1995) in order to assure representative samples of ground water. Field measurements were made for temperature, specific conductance, pH, alkalinity, bicarbonate, carbonate, and dissolved oxygen (table 6). Samples from each of the 10 wells were processed and shipped to the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., for the analysis of major inorganic ions (table 7). In addition, samples from 5 of the 10 wells were analyzed for metals (table 8), nutrients and methylene blue-active substances (table 9), and pesticides (table 10). Details on field and laboratory methods, quality control and assurance procedures, and drinking water standards are given in appendix A at the end of the report.

General Findings

Results of the water-quality analyses indicate that the sampled ground water generally meets the established standards for safe drinking water. None of the 93 properties measured or chemicals analyzed for exceeded U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels (MCL's) for drinking water (appendix A); however, concentrations of iron and manganese were slightly greater than secondary drinking water standards in some samples.

Secondary drinking water standards are established for taste and aesthetic purposes, and exceedance of these standards does not indicate a threat to human health. Sixty-six of the constituents (including all 53 pesticides) were at or below the reporting or detection level established by NWQL (Childress and others, 1999).

Specific Concerns

Chloride concentrations ranged from 8.8 to 20 milligrams per liter (mg/L) and were not indicative of seawater intrusion (table 7). Dion and Sumioka (1984) reported that uncontaminated ground water in most coastal areas of Washington generally contains less than 10 mg/L of chloride; however, they suggested an arbitrary threshold of 100 mg/L as an indicator of seawater intrusion. The median concentration of 11 mg/L chloride in sampled wells was far below this arbitrary threshold and is less than the median of 19 mg/L in samples collected by Dion and Sumioka in Pacific County in 1978.

Arsenic concentrations in sampled wells ranged from less than 1 to 9 micrograms per liter (µg/L) (table 8), and were below the current MCL of 50 µg/L. Recently, the National Research Council (1999) recommended lowering the current MCL for arsenic to more adequately protect public health. In response, the USEPA (U.S. Environmental Protection Agency, 2000) has proposed to lower the MCL to 5 µg/L. The proposed arsenic standard is intended to protect consumers against the effects of long-term, chronic exposure to arsenic in drinking water. The new standard would apply to all community water systems that serve 15 locations or 25 residents year-round (that is, most cities and towns, apartments, and mobile home parks with their own water supplies). Only one sampled well (14N/11W-02C02) exceeded this proposed limit.

Methylene blue-active substances (MBAS), an indicator of septage, were found at a concentration slightly greater than the detection limit in only one of the 10 sites sampled for this assessment (table 9). The concentration of nitrate (nitrite plus nitrate unless otherwise defined) was 0.22 mg/L or less in sampled ground water (table 9). Nitrate in ground water is a good indicator of urban and agricultural land-use activities. Background concentrations of nitrate in the Puget Sound Basin are about 1 mg/L, and average concentrations in ground water underlying an urban and an agricultural area in the Puget Sound Basin are about 4 and 13 mg/L, respectively (Inkpen and others, 2000). One reason nitrate concentrations were low is that the concentration of dissolved oxygen was 1 mg/L or less in all but four of the sampled wells (table 6). Without oxygen, nitrate is not stable in ground water (Tesoriero and others, 2000); however, nitrate concentrations were low even in ground water containing more than 1 mg/L dissolved oxygen. These low concentrations of MBAS and nitrate indicate that water in the artesian aquifer is minimally affected by activities at the land surface.

The absence in the ground-water samples of any of the 53 pesticides analyzed for (see table 10) was another indicator that ground water in the artesian aquifer is minimally affected by land-use activities. Pesticides are often found in shallow ground water in areas where pesticides are used. For example, in the Puget Sound Basin, pesticides were found in shallow ground water underlying areas of all land-use categories except unused land (Inkpen and others, 2000).

SUMMARY

The objective of this study was to describe the hydrogeologic setting and the quality of water in the artesian aquifer under the Shoalwater Bay Indian Reservation and the adjacent Tokeland Peninsula. Specific water-quality concerns include seawater intrusion, septage, and pesticides. Selected hydrogeologic and water-quality data were collected and compiled to conduct this assessment.

The hydrogeology of the study area consists of numerous unconsolidated and partially compacted layers containing various mixtures of clay, silt, sand, and gravel. This complex assemblage may be viewed as consisting of a sand-dominated water-table aquifer, a clay-and-silt-dominated semiconfining unit, and the gravel-and-sand-dominated artesian aquifer that is the focus of this study. Available water-level data indicate that the primary direction of horizontal ground-water flow within the artesian aquifer is from north to south. The data also indicate an upward vertical gradient between the artesian aquifer and the water-table aquifer. The north-south horizontal flow means that contaminates could enter the artesian aquifer in the recharge area north of the reservation and be transported into the study area. However, the upward vertical gradient and the semiconfining unit would tend to prevent contaminates in the water-table aquifer within the study area from entering the underlying artesian aquifer.

Samples of ground water from the artesian aquifer generally met the standards for safe drinking water. None of the 93 properties measured and chemicals analyzed for exceed the primary USEPA standard for drinking water and only 2 constituents (iron and manganese) exceed the USEPA secondary standards. Sixty-six of the constituents (including all 53 pesticides) were at or below the reporting or detection levels established by the USGS National Water Quality Laboratory.

Chloride concentrations ranged from 8.8 to 20 mg/L and are not indicative of seawater intrusion, and the median concentration of 11 mg/L is below the median concentration of 19 mg/L found in samples collected throughout Pacific County during 1978. The low concentrations of methylene blue-active substances (0.04 mg/L or less) and nitrate (0.22 mg/L or less) and the absence of detectable pesticides suggest water in the artesian aquifer is currently minimally affected by land-use activities within and north of the study area.

The absence in the ground-water samples of significant concentrations of any of the chemicals analyzed for does not rule out the possibility that these or other chemicals may be found in the artesian aquifer upgradient from the study area. Given the north-south horizontal direction of ground-water flow within the artesian aquifer, any chemicals entering the artesian aquifer upgradient from the study area could eventually migrate into the study area.

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Figures 1 – 10

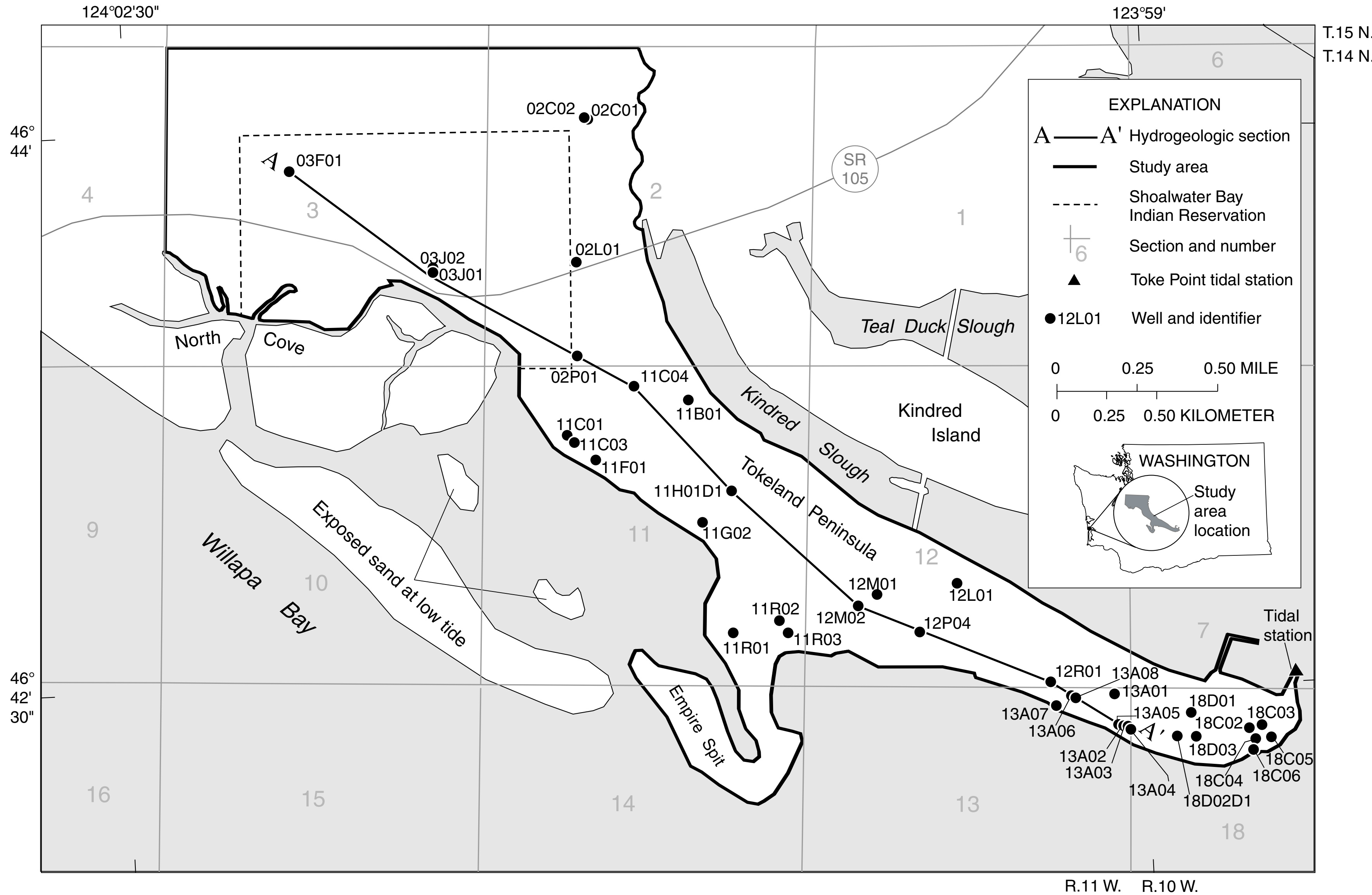


Figure 1. Location of the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area, of wells used in this study, and of the trace of hydrogeologic section *A-A'*.

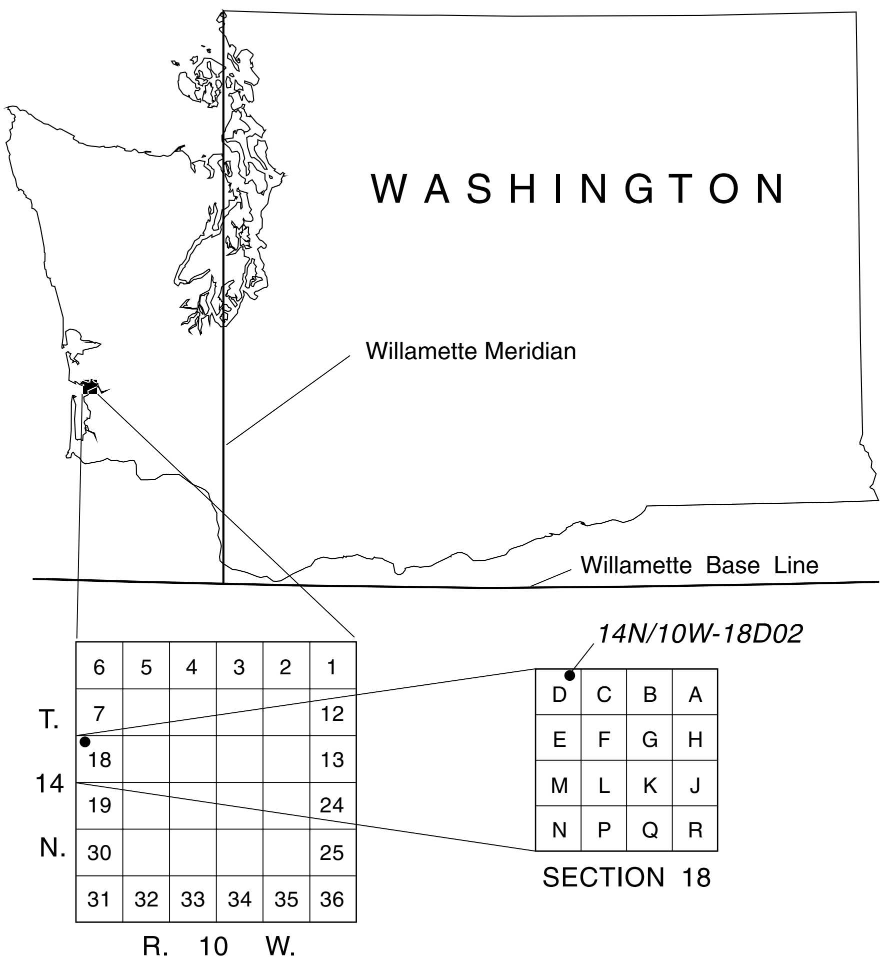


Figure 2. Well-numbering system used by the U.S. Geological Survey in the State of Washington.

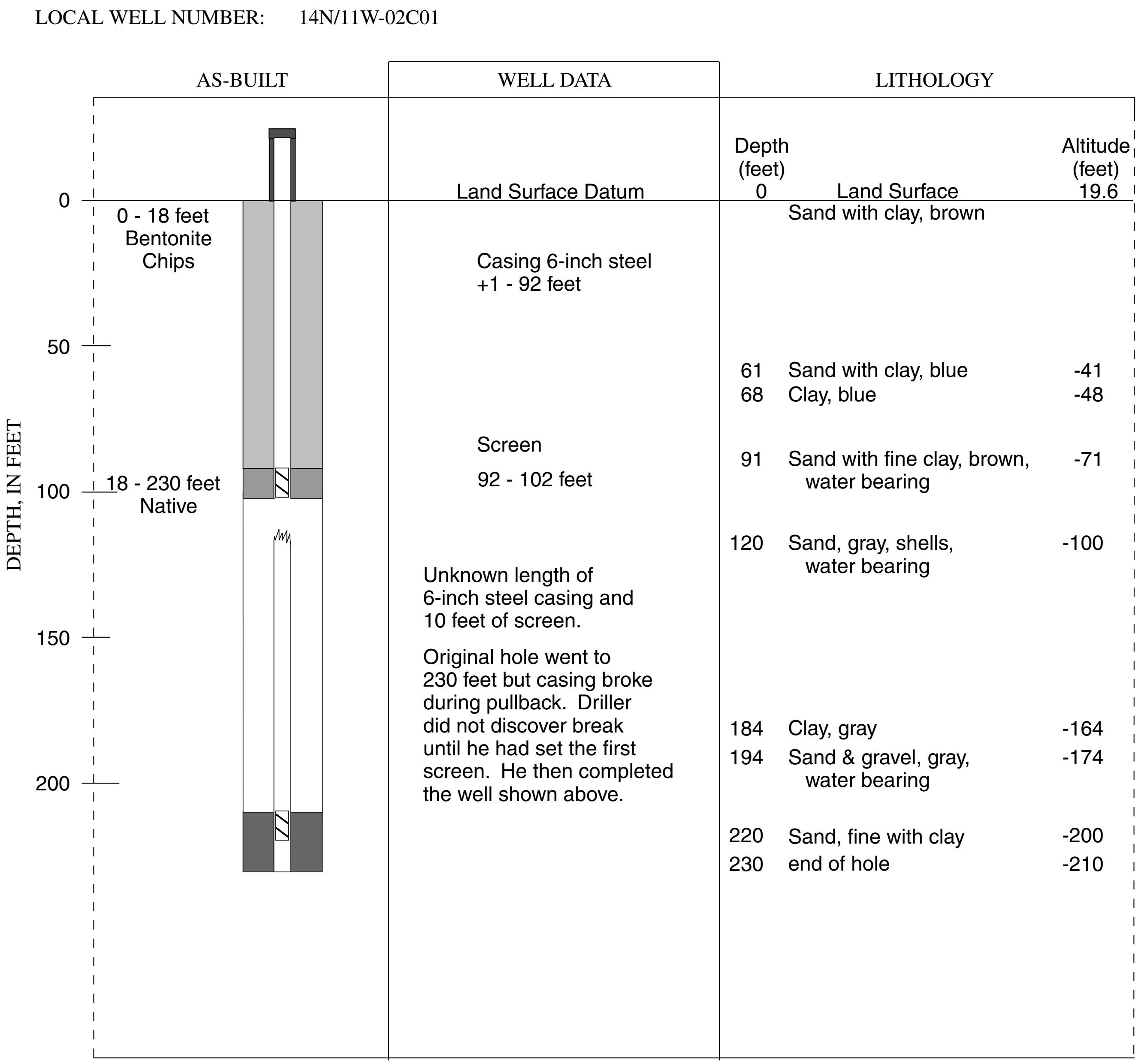


Figure 3. Construction, completion and generalized lithologic data for newly constructed tribal wells 14N/11W-02C01, 14N/11W-02C02, and 14N/11W-03F01.

This figure is a combination of data and information reported by the well driller and field observations made by U.S. Geological Survey personnel during the drilling and construction phases.

LOCAL WELL NUMBER: 14N/11W-02C02

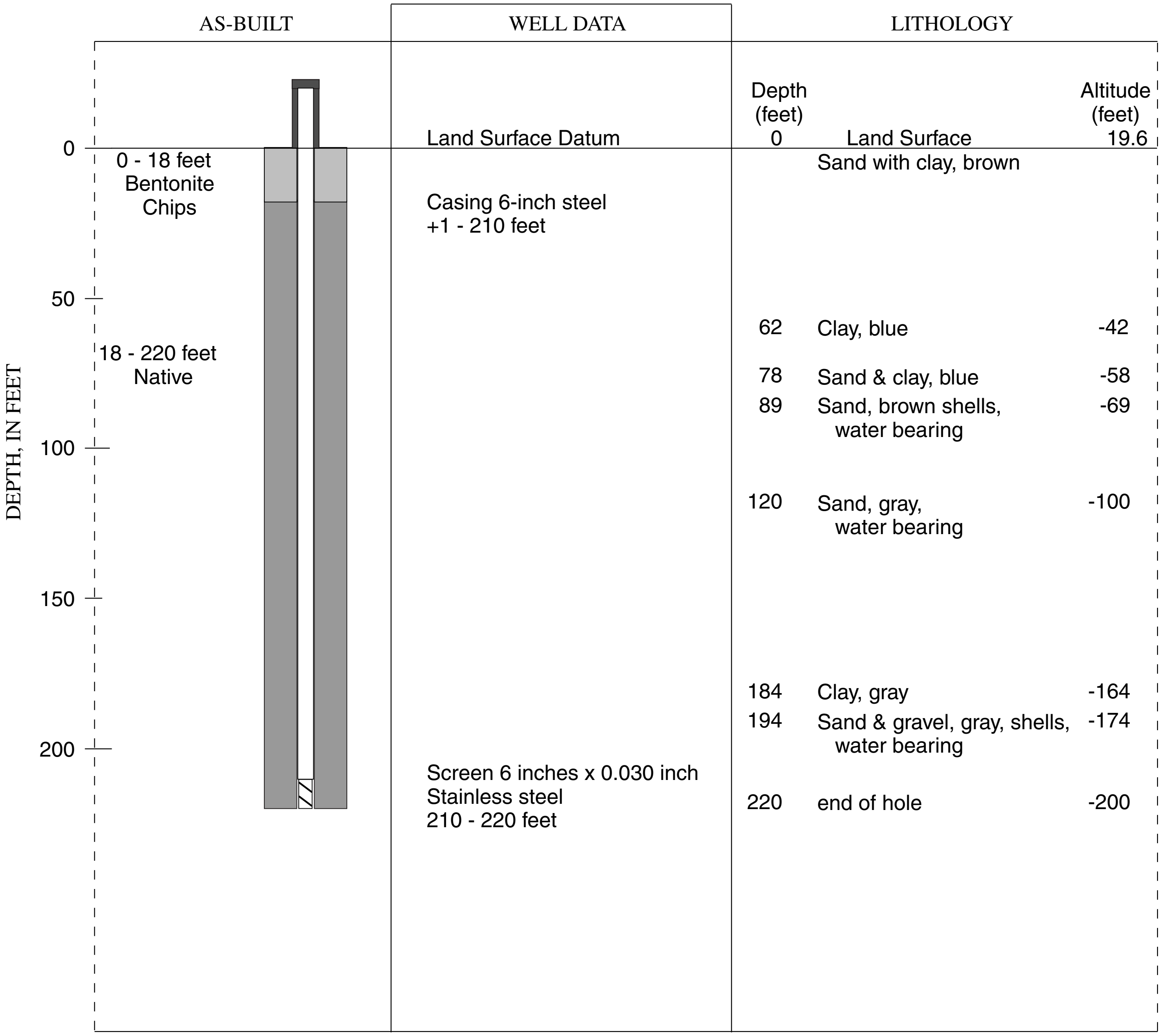


Figure 3.—*Continued.*

LOCAL WELL NUMBER: 14N/11W-03F01

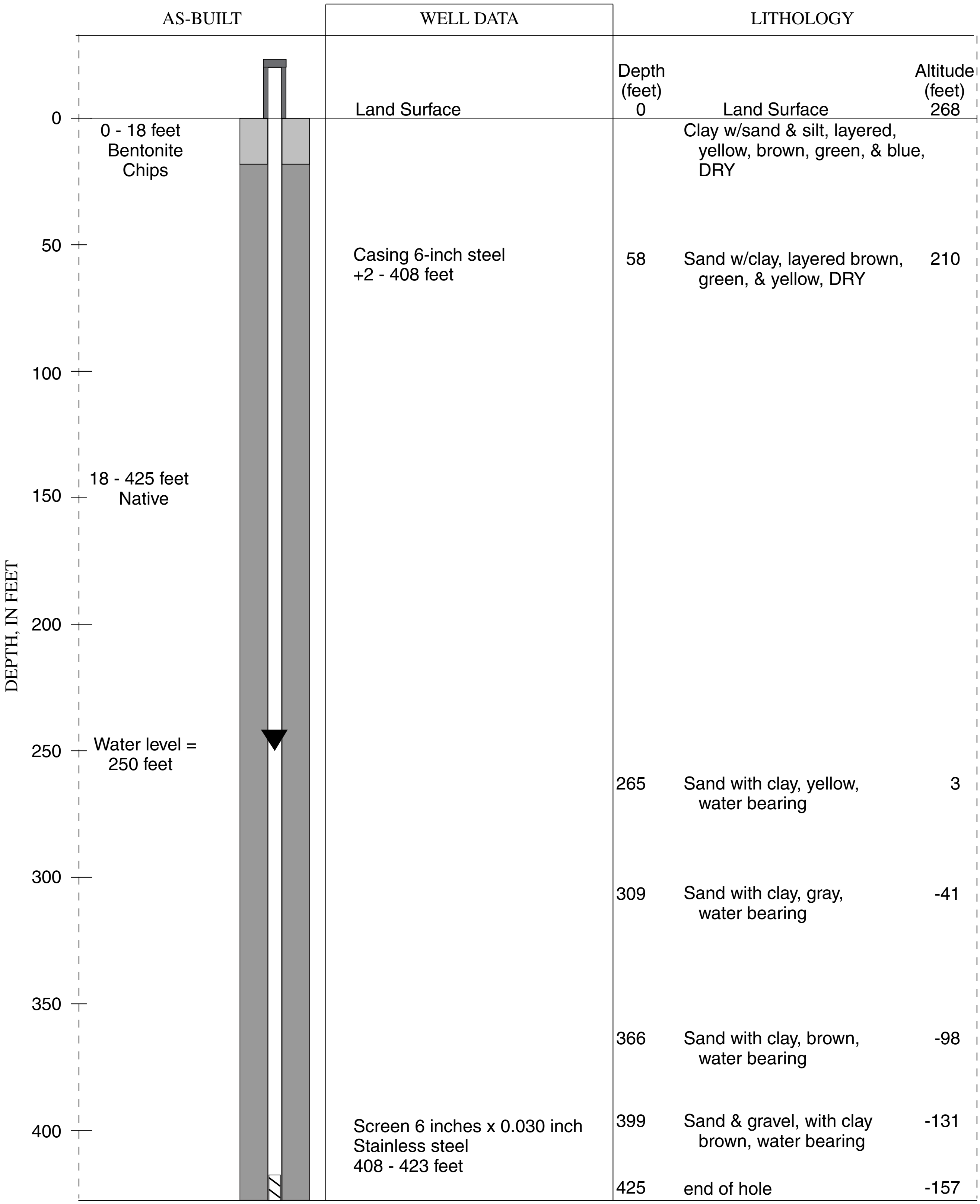


Figure 3.—*Continued.*

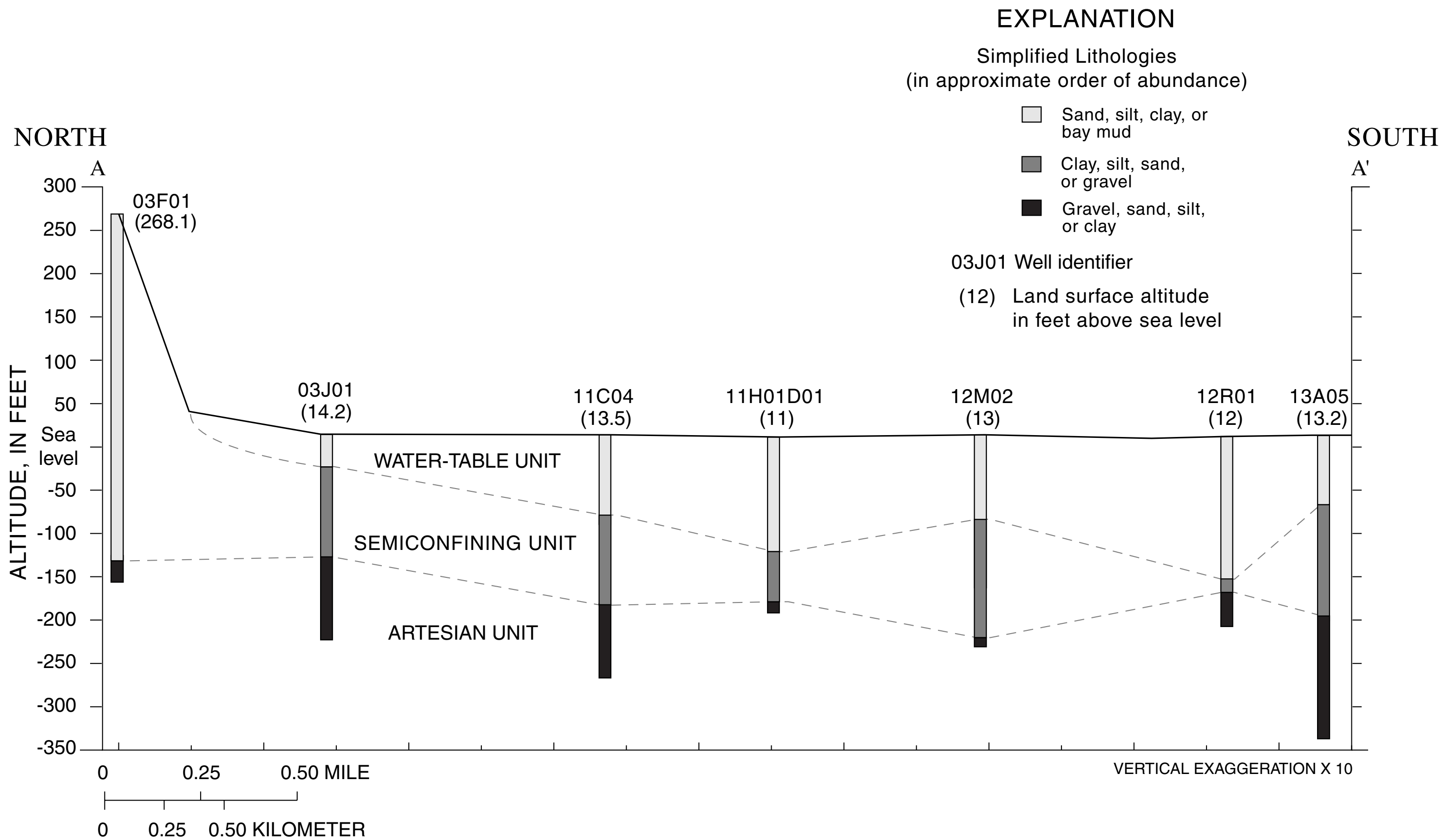


Figure 4. Generalized hydrogeologic section *A-A'* in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area. Trace of the section is shown on figure 1. See table 3 for detailed lithologies of wells.

Time	Water-Level Altitude	Tide Altitude
05:50	14.5	-2.2
06:40	15.0	-2.0
07:29	13.7	-1.4
08:29	14.9	-0.1
09:10	15.3	1.1
10:05	16.0	2.5
11:00	16.6	3.7
12:02	17.0	4.3
12:53	16.9	3.9
14:04	16.5	2.4
15:05	15.7	0.5
16:04	15.9	-1.5
16:52	15.4	-3.0
17:45	15.0	-4.4
19:17	14.6	-5.0

Time	Water-Level Altitude	Tide Altitude
06:01	16.0	-2.2
07:14	16.0	-1.7
07:59	16.0	-0.8
08:55	16.1	0.7
09:55	16.1	2.3
10:49	16.3	3.6
11:52	16.6	4.3
12:44	16.7	4.0
13:31	16.5	3.2
14:48	16.3	1.1
15:43	16.2	-1.5
16:39	16.2	-2.6
17:27	16.1	-3.9
18:27	16.1	-5.0
19:44	16.0	-4.8

Time	Water-Level Altitude	Tide Altitude
05:54	16.7	-2.2
07:09	16.5	-1.7
07:52	16.4	-1.0
08:49	16.5	0.5
09:48	16.8	2.1
10:38	17.1	3.3
11:39	17.3	4.2
12:35	17.3	4.1
13:24	17.2	3.3
14:32	16.9	1.6
15:29	16.7	-0.3
16:30	16.6	-2.3
17:17	16.5	-3.7
18:21	16.4	-4.9
19:52	16.3	-4.6

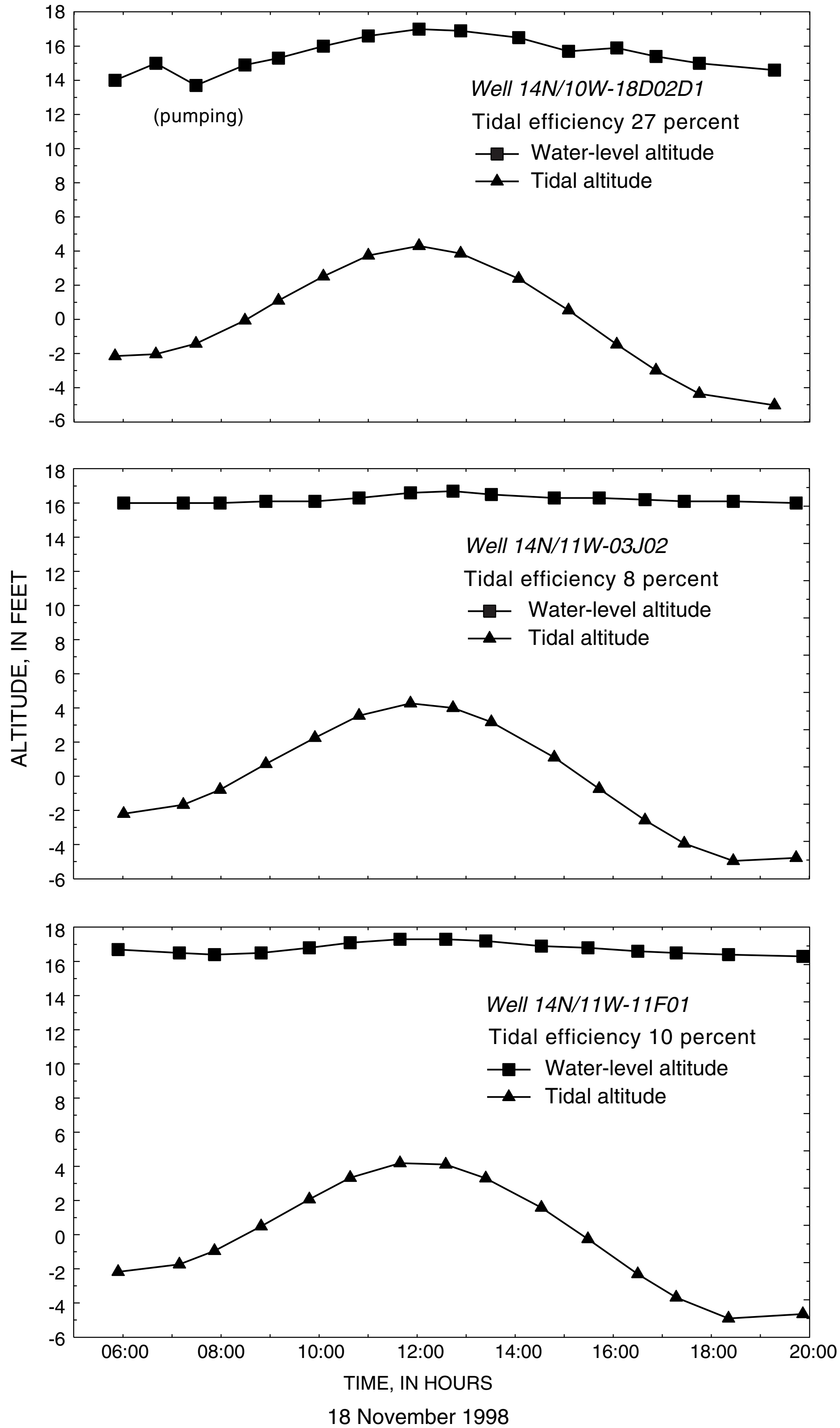
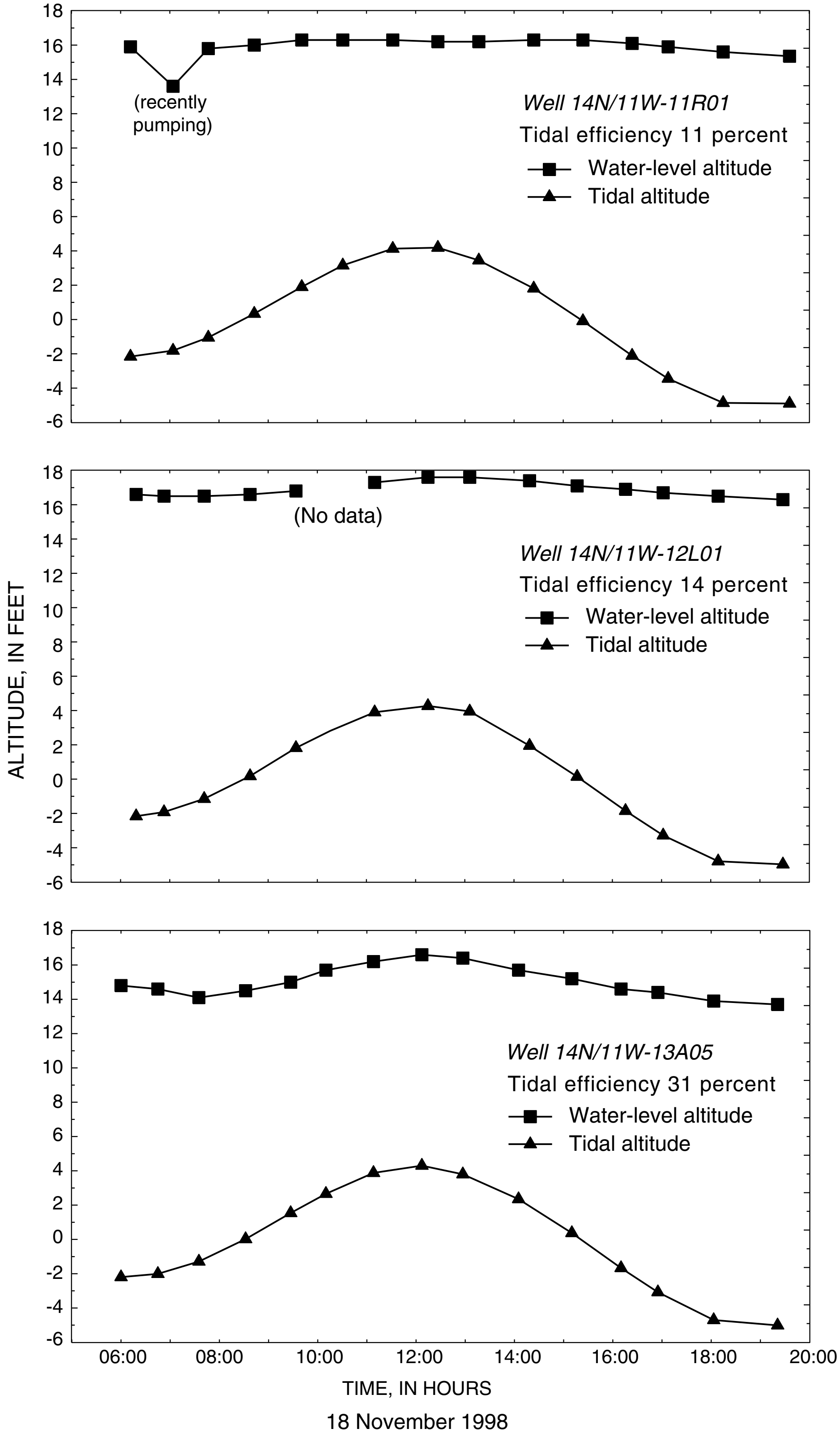


Figure 5. Water levels and tidal fluctuations in selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area.

Because water-level measurements were stopped at the low point of the tidal cycle (about 19:30) and there is about a 2-hour lag time, water levels in the wells did not reach their lowest point; therefore, the total fluctuations in these wells were somewhat greater than shown. Tidal efficiency equals the observed water-level change in the well divided by the change in the tide, expressed as a percent.



Time	Water-Level Altitude	Tide Altitude
06:12	15.9	-2.2
07:04	13.6	-1.8
07:47	15.8	-1.1
08:43	16.0	0.3
09:41	16.3	1.9
10:31	16.3	3.2
11:32	16.3	4.1
12:27	16.2	4.2
13:17	16.2	3.5
14:24	16.3	1.8
15:24	16.3	-0.1
16:24	16.1	-2.1
17:08	15.9	-3.5
18:15	15.6	-4.9
19:36	15.3	-4.9

Time	Water-Level Altitude	Tide Altitude
06:19	16.6	-2.2
06:53	16.5	-1.9
07:42	16.5	-1.2
08:38	16.6	0.2
09:34	16.8	1.8
11:10	17.3	3.9
12:15	17.6	4.3
13:06	17.6	4.0
14:19	17.4	2.0
15:17	17.1	0.1
16:16	16.9	-1.9
17:02	16.7	-3.3
18:09	16.5	-4.8
19:28	16.3	-5.0

Time	Water-Level Altitude	Tide Altitude
06:00	14.8	-2.2
06:45	14.6	-2.0
07:35	14.1	-1.3
08:32	14.4	0.0
09:27	15.0	1.5
10:10	15.4	2.7
11:08	16.2	3.9
12:07	16.6	4.3
12:57	16.4	3.8
14:05	15.7	2.4
15:10	15.2	0.4
16:10	14.6	-1.7
16:55	14.4	-3.1
18:03	13.9	-4.7
19:21	13.7	-5.0

Figure 5. —*Continued.*

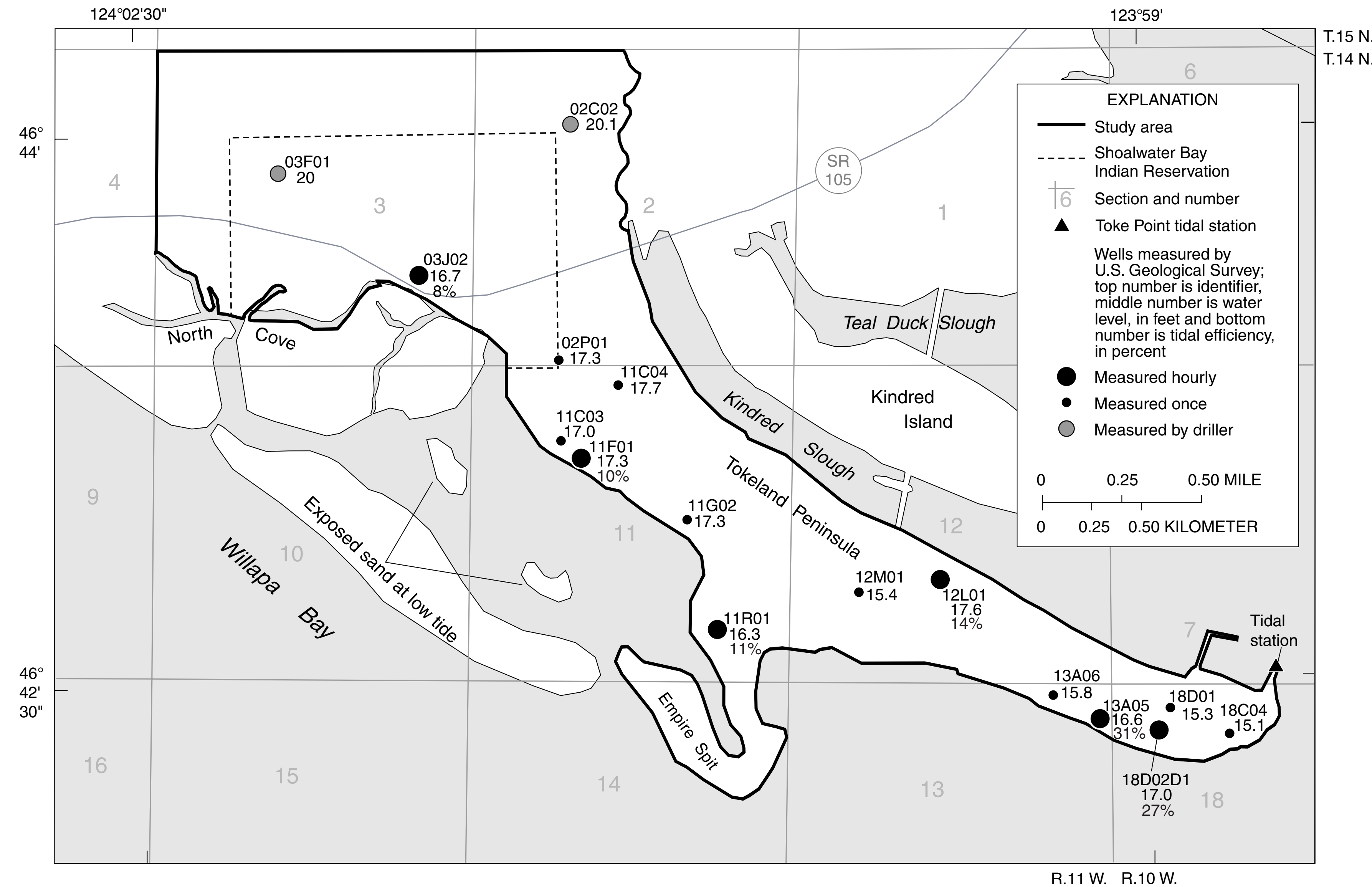


Figure 6. Ground-water altitudes and tidal efficiencies in the artesian aquifer under the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area.

Water levels in wells measured hourly during the tidal cycle were adjusted by interpolation of graphs and data shown on figure 5. Water levels in wells measured once during the tidal cycle were adjusted on the basis of estimated water-level changes in adjacent hourly wells. Water levels in wells 14N/11W-03F01 and 14N/11W-02C02 were measured by the well driller on July 4, 1999, and August 3, 1999, respectively, and are not adjusted for tidal effects. Tidal efficiency equals the observed water-level change in the well divided by the change in the tide, expressed as a percent.

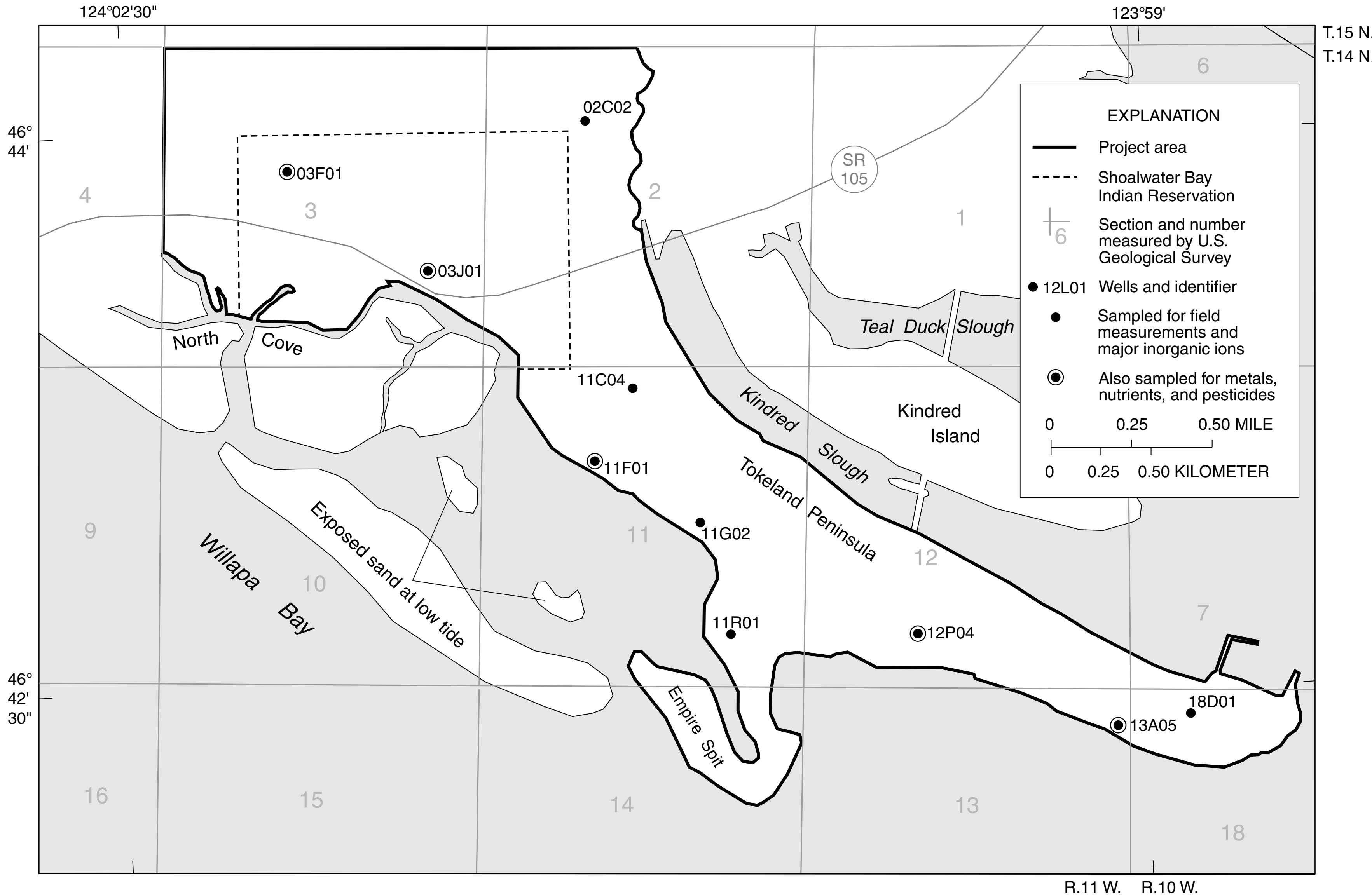


Figure 7. Location of wells sampled for water quality in the artesian aquifer underlying the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area.

Tables 1 – 10

Table 1. Information for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[**Latitude**: Location of site in degrees, minutes, and seconds north of the Equator. **Longitude**: Location of sites in degrees, minutes, and seconds west of the Greenwich Meridian. **Location Method:** Map, field located on 7.5-minute U.S. Geological Survey Topographic Map; Survey, located using a TOPCON™ Total Station Survey Instrument; Estimated, from adjacent surveyed wells. --, data not available]

Well No.	Latitude	Longitude	Accuracy of location (feet)	Location method	Land use	Water use	Well depth (feet)
14N/10W-18C02	46 42 19	123 58 14	100	Map	Commercial	Public Supply	205
14N/10W-18C03	46 42 20	123 58 07	100	Map	Commercial	Public Supply	340
14N/10W-18C04	46 42 19.9	123 58 10.4	10	Survey	Residential	Unused	--
14N/10W-18C05	46 42 17	123 58 07	100	Map	Residential	Domestic	145
14N/10W-18C06	46 42 17	123 58 10	100	Map	Residential	Domestic	222
14N/10W-18D01	46 42 20.9	123 58 24.2	10	Survey	Residential	Irrigation	200
14N/10W-18D02D1	46 42 17.5	123 58 27.8	10	Survey	Residential	Domestic	240
14N/10W-18D03	46 42 18	123 58 25	100	Map	Residential	Domestic	279
14N/11W-02C01	46 43 57.6	124 00 41.9	10	Survey	Wetland	Unused	102
14N/11W-02C02	46 43 57.7	124 00 41.9	10	Estimated	Wetland	Unused	220
14N/11W-02L01	46 43 35.1	124 00 43.9	10	Survey	Commercial	Commercial	223
14N/11W-02P01	46 43 18.0	124 00 50.4	10	Survey	Residential	Unused	176
14N/11W-03F01	46 43 50.1	124 01 52.4	10	Survey	Forested	Unused	423
14N/11W-03J01	46 43 32.1	124 01 24.1	10	Survey	Residential	Public Supply	224
14N/11W-03J02	46 43 32.9	124 01 23.1	10	Survey	Residential	Public Supply	160
14N/11W-11B01	46 43 11	124 00 28	100	Map	Residential	Domestic	198
14N/11W-11C01	46 43 07	124 00 52	100	Map	Commercial	Public Supply	192
14N/11W-11C03	46 43 05.3	124 00 49.5	10	Survey	Residential	Domestic	230
14N/11W-11C04	46 43 14.5	124 00 36.1	10	Survey	Residential	Domestic	281
14N/11W-11F01	46 43 02.7	124 00 44.2	10	Survey	Commercial	Public Supply	290
14N/11W-11G02	46 42 52.6	124 00 17.9	10	Survey	Residential	Domestic	193
14N/11W-11H01D1	46 42 58	124 00 16	100	Map	Residential	Domestic	190
14N/11W-11R01	46 42 34.2	124 00 12.6	10	Survey	Residential	Domestic	237
14N/11W-11R02	46 42 36	124 00 02	100	Map	Residential	Domestic	227
14N/11W-11R03	46 42 35	124 00 04	100	Map	Residential	Domestic	235
14N/11W-12L01	46 42 42.5	123 59 19.4	10	Survey	Residential	Domestic	285
14N/11W-12M01	46 42 40.4	123 59 38.4	10	Survey	Residential	Domestic	216
14N/11W-12M02	46 42 42	123 59 52	100	Map	Residential	Domestic	250
14N/11W-13A01	46 42 25	123 58 42	100	Map	Residential	Domestic	172
14N/11W-13A02	46 42 20	123 58 39	100	Map	Commercial	Unused	200
14N/11W-13A03	46 42 20	123 58 40	100	Map	Commercial	Unused	200
14N/11W-13A04	46 42 18.2	123 58 38.5	10	Survey	Commercial	Commercial	350
14N/11W-13A05	46 42 19.8	123 58 41.3	10	Survey	Commercial	Unused	350
14N/11W-13A06	46 42 22.9	123 58 52.1	10	Survey	Residential	Domestic	240
14N/11W-13A07	46 42 22	123 58 55	100	Map	Residential	Domestic	189
14N/11W-13A08	46 42 23	123 58 51	100	Map	Residential	Domestic	238
14N/11W-12P04	46 42 34.7	123 59 28.9	10	Survey	Residential	Public Supply	230
14N/11W-12R01	46 42 27	123 58 53	100	Map	Residential	Domestic	220

Table 2. Construction and completion information for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[**Location Method**: Map, field located on 7.5 minute USGS Topographic Map; Survey, located using a TOPCON™ Total Station Survey Instrument; Leveled, elevation determined by hand level from adjacent surveyed well. --, data not available]

Well No.	Land surface altitude (feet)	Accuracy of land surface altitude (feet)	Location method	Hole depth (feet)	Well depth (feet)	Casing, inside diameter (inches)	Type	Interval (feet below land surface)
14N/10W-18C02	12	2	Map	221	205	2	Open end	205
14N/10W-18C03	12	2	Map	--	340	6	Open end	340
14N/10W-18C04	12.1	0.2	Survey	--	--	--	--	--
14N/10W-18C05	12	2	Map	145	145	6	Open end	145
14N/10W-18C06	12	2	Map	223	222	6	Screened	217 - 222
14N/10W-18D01	12.7	0.2	Survey	--	200	2	Sand Point	198 - 200
14N/10W-18D02D1	13.2	0.2	Survey	240	240	6	Screened	235 - 240
14N/10W-18D03	13	2	Map	280	279	6	Screened	274 - 279
14N/11W-02C01	19.6	0.2	Survey	230	102	6	Screened	92 - 102
14N/11W-02C02	19.6	0.2	Leveled	220	220	6	Screened	210 - 220
14N/11W-02L01	10.4	0.2	Survey	--	223	2.5	--	--
14N/11W-02P01	15.6	0.2	Survey	--	176	2.5	--	--
14N/11W-03F01	268.1	0.2	Survey	425	423	6	Screened	408 - 423
14N/11W-03J01	14.2	0.2	Survey	224	224	10	Perforated	206 - 208
14N/11W-03J02	12.3	0.2	Survey	161	160	6	Screened	148 - 158
14N/11W-11B01	12	2	Map	220	198	6	Screened	193 - 198
14N/11W-11C01	12	2	Map	198	192	2	Perforated	189 - 192
14N/11W-11C03	11.9	0.2	Survey	--	230		--	--
14N/11W-11C04	13.5	0.2	Survey	281	281	6	Screened	276 - 281
14N/11W-11F01	12.3	0.2	Survey	--	290	6	--	--
14N/11W-11G02	15.4	0.2	Survey	193	193	2	Open end	193
14N/11W-11HO1D1	11	2	Map	204	190	6	Open end	190
14N/11W-11R01	11.2	0.2	Survey	237	237	6	Screened	232 - 237
14N/11W-11R02	11	2	Map	227	227	6	Screened	222 - 227
14N/11W-11R03	11	2	Map	235	235	6	Screened	230 - 235
14N/11W-12L01	12.2	0.2	Survey	--	285	6	--	--
14N/11W-12M01	13.8	0.2	Survey	225	216	6	Screened	211 - 216
14N/11W-12M02	13	2	Map	250	250	6	Perforated	234 - 248
14N/11W-12P04	14.5	0.2	Survey	233	230	6	Screened	220 - 230
14N/11W-12R01	12	2	Map	220	220	6	Screened	215 - 220
14N/11W-13A01	12	2	Map	--	172	4	--	--
14N/11W-13A02	12	2	Map	--	200	2	--	--
14N/11W-13A03	12	2	Map	--	200	--	--	--
14N/11W-13A04	12.1	0.2	Survey	350	350	6	Screened	324 - 345
14N/11W-13A05	13.2	0.2	Survey	350	350	8	Screened	335 - 350
14N/11W-13A06	12.0	0.2	Survey	240	240	6	Open end	240
14N/11W-13A07	12	2	Map	200	189	2	Open end	189
14N/11W-13A08	12	2	Map	242	238	6	Screened	233 - 238

Table 3. Lithologic data, as reported by water-well drillers, for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[<, less than; >, greater than; gpm, gallons per minute; WB, water bearing; 'and', 35 to 50 percent; 'some', 20 to 35 percent; 'little' 10 to 20 percent; 'trace', less than to 10 percent.]

Well No.	Lithologic material	Top of layer (feet below land surface)	Thickness of layer (feet)
14N/10W-18C02	Sand	0	155
	Gravel	155	20
	Hardpan, gray	175	30
	Sand	205	>16
14N/10W-18C05	Topsoil	0	5
	Sand, gray	5	50
	Sand with clay	55	2
	Sand, gray	57	35
	Sand, gray (heaving)	92	6
	Clay, brown	98	7
	Clay, blue	105	13
	Sand with clay	118	22
	Pea gravel, gray	140	>5
14N/10W-18C06	Sand and clay, brown	0	8
	Bay mud, black, sandy	8	52
	Sand, blue-gray	60	87
	Clay, brown, and rocks	147	6
	Sand, blue-gray, fine	153	>70
14N/10W-18D02D1	Sand, brown	0	14
	Sand, brown (heaving)	14	30
	Sand, brown	44	54
	Silt, brown, sandy	98	12
	Clay, gray	110	23
	Clay, gray, sandy	133	8
	Sand, gray	141	3
	Sand and gravel, gray, WB	144	6
	Clay	150	50
	Sand, fine	200	30
	Sand, fine, clam shells, WB	230	>10
14N/10W-18D03	Sand, gray, loose	0	140
	Clay, sand, and gravel, brown, iron water 140-150 feet	140	14
	Clay, blue	154	42
	Clay, blue, sandy	196	74
	Sand, with clay layers <1 inch thick	270	>10
14N/11W-02C01	Sand, with clay binder, brown	0	61
	Sand, with blue clay	61	7
	Clay, blue	68	23

Table 3. Lithologic data, as reported by water-well drillers, for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area–*Continued*

Well No.	Lithologic material	Top of layer (feet below land surface)	Thickness of layer (feet)
14N/11W-02C01	Sand, fine, with clay binder, brown, WB	91	29
Continued	Sand, gray, shells, WB	120	64
	Clay, gray	184	10
	Sand and gravel, gray, WB	194	26
	Sand, fine, with clay	220	>10
14N/11W-02C02	Sand, with clay binder, brown, hard	0	5
	Sand, with clay binder, brown, soft, WB	5	7
	Sand, with clay binder, brown, hard	12	7
	Sand, with clay binder, brown, WB	19	9
	Sand, with clay binder, brown, dry	28	10
	Sand, with clay binder, brown, WB	38	24
	Clay, blue	62	16
	Sandstone, blue, hard	78	5
	Sand, blue, with clay binder	83	6
	Sand, brown, WB	89	31
	Sand, gray, shells, WB	120	64
	Clay, gray	184	10
	Sand and gravel, gray, WB	194	>26
14N/11W-03F01	Top soil	0	2
	Clay, yellow	2	9
	Sand, brown, with clay binder	11	15
	Clay, blue	26	5
	Clay, yellow-green	31	7
	Clay, blue	38	9
	Clay, brown, some grit	47	11
	Sand, brown, with clay binder	58	92
	Sand, yellow, with clay binder	150	21
	Clay, blue	171	1
	Sand, green and brown, with clay binder	172	16
	Clay, gray	188	1
	Sand, brown, with clay binder	189	29
	Sand, yellow, with clay binder	218	47
	Sand, yellow, with clay binder, WB	265	44
	Sand, gray, with clay binder, WB	309	57
	Sand, brown, with clay binder, WB	366	33
	Sand and gravel, brown, with clay binder, WB	399	>26
14N/11W-03J01	Sand, brown	0	15
	Sand, blue	15	9
	Sand, dark blue	24	11
	Sand, fine, silty, WB, flows 15 gpm	35	1
	Clay, blue and sand	36	50

Table 3. Lithologic data, as reported by water-well drillers, for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area–*Continued*

Well No.	Lithologic material	Top of layer (feet below land surface)	Thickness of layer (feet)
14N/11W-03J01	Clay, yellow	86	53
Continued	Clay, yellow, some gravel	139	4
	Sand, fine, and gravel, yellow, WB 143-143.5 feet	143	16
	Gravel and sand	159	0.5
	Sand, fine	159.5	4.5
	Sand and clay, yellow, some gravel	164	11
	Gravel and sand	175	0.5
	Sand, fine, and clay	175.5	9.5
	Gravel and sand	185	1.5
	Clay and sand	186.5	19.5
	Pea gravel, clean, WB	206	2
	Clay and gravel, sandy	208	>16
14N/11W-03J02	Clay, brown, sandy	0	7
	Sand, black, coarse, wet	7	12
	Clay, gray	19	18
	Sand, black, coarse (heaving)	37	32
	Sand, brown, medium (heaving)	69	63
	Sand and clay, brown, WB	132	4
	Clay and gravel, brown, sandy	136	2
	Sand, coarse and pea gravel , WB	138	17
	Sand, brown, medium, WB	155	>6
14N/11W-11B01	Sand, gray	0	98
	Clay, brown	98	22
	Sand, gray	120	40
	Gravel, gray, coarse, WB (iron in water)	160	2
	Sand, gray	162	50
	Sand, and pea gravel, gray	212	6
	Sand, gray, fine, mucky	218	>2
14N/11W-11C01	Sand	0	23
	Clay	23	3
	Sand, occasional mud streaks	26	74
	Hardpan	100	18
	Sand, occasional mud streaks	118	70
	Gravel, WB	188	4
	Sand, yellow, WB	192	>6
14N/11W-11C04	Sand, with clay binder, yellow	0	10
	Sand, gray, WB (heaving)	10	78
	Sand, gray, clam shells (heaving)	88	5
	Clay, gray, sandy, trace gravel	93	4
	Sand, gray, WB (heaving)	97	10
	Sand, WB (heaving)	107	63

Table 3. Lithologic data, as reported by water-well drillers, for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area–*Continued*

Well No.	Lithologic material	Top of layer (feet below land surface)	Thickness of layer (feet)
14N/11W-11C04	Sand, gray, WB (heaving)	170	14
Continued	Sand and gravel, packed (heaving)	184	2
	Sand, WB (heaving)	186	17
	Pea gravel and sand, WB (heaving)	203	1
	Sand and pea gravel (heaving)	204	70
	Gravel and coarse sand, WB	274	>7
14N/11W-11G02	Mud, tidal	0	44
	Clay, blue	44	138
	Sand and gravel, layers	182	8
	Gravel, coarse	190	>3
14N/11W-11H01D1	Sand, blue, with shells	0	101
	Sand, blue, with wood	101	5
	Sand, fine and muck, blue	106	26
	Clay, blue, sandy (fine)	132	8
	Sand, blue, fine	140	12
	Sand, brown	152	38
	Sand, brown, rock pieces	190	10
	Sand and gravel (eighth-inch), brown and gray WB	200	>4
14N/11W-11R01	Sand with topsoil	0	8
	Sand, gray	8	34
	Sand, with clay	42	50
	Sand and gravel, gray	92	1
	Sand, gray	93	2
	Silt, gray	95	119
	Sand and gravel, gray	214	>23
14N/11W-11R02	Sand, with topsoil	0	3
	Sand, gray	3	59
	Sand with clay, gray	62	105
	Sand, fine, with light clay	167	53
	Sand, coarse	220	2
	Sand and gravel	222	2
	Sand, coarse, WB	224	>3
14N/11W-11R03	Sand with topsoil	0	7
	Sand	7	41
	Sand and clay, hard	48	46
	Sand and gravel	94	2
	Sand and clay	96	72
	Sand	168	64
	Sand and gravel	232	3
	Sand	235	>0

Table 3. Lithologic data, as reported by water-well drillers, for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area–*Continued*

Well No.	Lithologic material	Top of layer (feet below land surface)	Thickness of layer (feet)
14N/11W-12M01	Sand, black, fine, mucky	0	80
	Sand, tan	80	100
	Clay and sand, tan	180	30
	Sand, blue-gray	210	>15
14N/11W-12M02	Sand, blue	0	30
	Mud, blue	30	29
	Sand, blue	59	38
	Clay, blue	97	31
	Sand, brown	128	106
	Gravel, blue, WB	234	1
	Sand, brown	235	6
	Gravel, blue, WB	241	4
	Sand, brown	245	2
	Gravel, blue, WB	247	1
	Sand, brown	248	>2
14N/11W-12P04	Sand, brown	0	2
	Sand, brown, WB (iron water)	2	16
	Sand, blue-gray, WB (iron water)	18	12
	Sand, gray, mucky, with clay and wood, WB (iron water)	30	60
	Sand, with clay, blue-gray, hard	90	90
	Sand, blue-gray, with shells	180	>53
14N/11W-12R01	Sand, brown, silty	0	10
	Sand, gray, soupy	10	30
	Sand, gray, white shells and wood, soupy	40	125
	Clay and sand, silty, white shells and wood	165	15
	Sand, gray, white shells and wood	180	>40
14N/11W-13A04	Clay, yellow, sandy	0	20
	Sand, blue	20	55
	Clay, blue, sandy	75	7
	Sand, blue, fine, WB (sulfur odor)	82	3
	Clay, blue, sandy	85	33
	Clay, blue	118	37
	Clay, blue, trace pea gravel	155	5
	Clay, blue	160	36
	Sand, blue, fine, WB (flows)	196	1
	Clay, blue	197	5
	Sand, blue, fine, clam shells	202	67
	Sand and fine gravel, blue, clam shells	269	31
	Sand, fine, shells	300	2
	Sand, coarse and gravel, shells	302	7
	Sand, finer	309	1

Table 3. Lithologic data, as reported by water-well drillers, for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area–*Continued*

Well No.	Lithologic material	Top of layer (feet below land surface)	Thickness of layer (feet)
14N/11W-13A04	Sand, coarse, and gravel fine	310	5
Continued	Sand, finer	315	4
	Sand, coarse	319	9
	Sand, coarse, and pea gravel	328	18
	Sand, fine, clam shells	346	>4
14N/11W-13A05	Clay, yellow, sandy	0	15
	Clay, blue, sandy	15	10
	Sand, blue	25	55
	Clay and sand, blue	80	10
	Sand, blue, fine (odor)	90	15
	Clay, light blue	105	40
	Clay, dark blue	145	13
	Clay and pea gravel, blue, wood	158	22
	Clay, blue, sandy, WB	180	9
	Clay, blue	189	19
	Sand, fine, clam shells, WB	208	7
	Sand, fine, and silt	215	33
	Sand, fine, wood and clam shells	248	27
	Clay and sand, blue	275	33
	Clay and sand, fine, blue, clam shells	308	2
	Sand and gravel, medium, loose, WB	310	25
	Sand, coarse, and pea gravel, WB	335	>15
14N/11W-13A06	Loam, brown, sandy	0	7
	Sand, gray	7	13
	Silt and sand, gray	20	85
	Sand, gray, fine	105	16
	Silt and sand, gray	121	61
	Silt, brown, sandy	182	13
	Silt, brown	195	30
	Sand, with fossils	225	8
	Sand, gray	233	>7
14N/11W-13A07	Sand	0	30
	Mud, tidal	30	159
	Sandstone	189	7
	Sand, coarse	196	>4
14N/11W-13A08	Topsoil	0	1
	Sand, brown, wood	1	29
	Sand, blue, wood and shells	30	90
	Sand, blue, and shells	120	>122

Table 4. Depth to tops of hydrogeologic units in selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[All measurements in feet; --, not encountered]

Well No.	Land surface altitude	Depth to top of hydrogeologic unit			Hole depth
		Water-table aquifer	Semi-confining unit	Artesian aquifer	
14N/10W-18C02	12	0	175	205	221
14N/10W-18C05	12	0	98	140	145
14N/10W-18C06	12	0	147	153	223
14N/10W-18D02D1	13.2	0	110	141	240
14N/10W-18D03	13	0	154	270	280
14N/11W-02C01	19.0	0	68	120	230
14N/11W-02C02	19.6	0	62	120	220
14N/11W-03F01	268.1	--	0	399	425
14N/11W-03J01	14.2	0	36	143	224
14N/11W-03J02	12.3	0	19	138	161
14N/11W-11B01	12	0	98	160	220
14N/11W-11C01	12	0	23	188	198
14N/11W-11C04	13.5	0	93	184	281
14N/11W-11G02	15.4	0	44	182	193
14N/11W-11HO1D1	11	0	132	190	204
14N/11W-11R01	11.2	0	42	214	237
14N/11W-11R02	11	0	62	220	227
14N/11W-11R03	11	0	48	232	235
14N/11W-12M01	13.8	0	180	210	225
14N/11W-12M02	13	0	97	234	250
14N/11W-12P04	14.5	0	30	180	233
14N/11W-12R01	12	0	165	180	220
14N/11W-13A04	12.1	0	85	202	350
14N/11W-13A05	13.2	0	80	208	350
14N/11W-13A06	12.0	0	20	225	240
14N/11W-13A07	12	0	30	189	200

Table 5. Water levels and water-level altitudes for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area, September 1998 through August 1999

[**Water Level:** Minus sign (–) indicates water level is below land surface. **Water-Level Status:** P, pumping; R, recently pumping; --, not affected by pumping. **Method of Measurement:** O, observed; S, steel tape; T, electrical tape; X, low head flowing tube. **Source of Measurement:** USGS, U.S. Geological Survey]

Well No.	Date	Time (hours: minutes)	Land surface altitude (feet)	Water level (feet above land surface)	Water altitude (feet above sea level)	Water-level status	Method of measure -ment	Source of measure-ment
14N/10W-18C04	11-04-98	15:28	12.1	2.5	14.6	--	X	USGS
	11-18-98	09:57		1.9	14.0	--	X	USGS
14N/10W-18D01	11-04-98	15:08	12.7	2.6	15.3	--	X	USGS
	11-18-98	10:27		1.8	14.5	--	X	USGS
14N/10W-18D02D1	11-18-98	05:50	13.2	1.3	14.5	--	X	USGS
		06:40		1.8	15.0	--	X	USGS
		07:29		0.5	13.7	P	X	USGS
		08:29		1.7	14.9	--	X	USGS
		09:10		2.1	15.3	--	X	USGS
		10:05		2.8	16.0	--	X	USGS
		11:00		3.4	16.6	--	X	USGS
		12:02		3.8	17.0	--	X	USGS
		12:53		3.7	16.9	--	X	USGS
		14:04		3.3	16.5	--	X	USGS
		15:05		2.5	15.7	--	X	USGS
		16:04		2.7	15.9	--	X	USGS
		16:52		2.2	15.4	--	X	USGS
		17:45		1.8	15.0	--	X	USGS
		19:17		1.4	14.6	--	X	USGS
14N/11W-02C02	08-03-99	no data	19.6	0.5	20.1	--	T	Driller
14N/11W-02P01	11-11-98	15:58	15.6	1.7	17.3	--	X	USGS
	11-18-98	12:35		1.7	17.3	--	X	USGS
14N/11W-03F01	07-04-99	no data	268	-248	20	--	T	Driller
14N/11W-03J02	11-04-98	16:08	12.3	3.9	16.2	--	X	USGS
	11-18-98	06:01		3.7	16.0	--	X	USGS
		07:14		3.7	16.0	--	X	USGS
		07:59		3.7	16.0	--	X	USGS
		08:55		3.8	16.1	--	X	USGS
14N/11W-03J02		09:55		3.8	16.1	--	X	USGS

Table 5. Water levels and water-level altitudes for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area, September 1998 through August 1999–*Continued*

Well No.	Date	Time (hours: minutes)	Land surface altitude (feet)	Water level (feet above land surface)	Water altitude (feet above sea level)	Water-level status	Method of measure -ment	Source of measure-ment
Continued		10:49		4.0	16.3	--	X	USGS
		11:52		4.3	16.6	--	X	USGS
		12:44		4.4	16.7	--	X	USGS
		13:31		4.2	16.5	--	X	USGS
		14:48		4.0	16.3	--	X	USGS
		15:43		3.9	16.2	--	X	USGS
		16:39		3.9	16.2	--	X	USGS
		17:27		3.8	16.1	--	X	USGS
		18:27		3.8	16.1	--	X	USGS
		19:44		3.7	16.0	--	X	USGS
14N/11W-11C03	11-04-98	12:00	11.9	4.8	16.7	--	X	USGS
	11-18-98	13:40		4.9	16.8	--	X	USGS
14N/11W-11C04	11-04-98	16:24	13.5	4.3	17.8	--	X	USGS
	11-18-98	12:03		4.2	17.7	--	X	USGS
14N/11W-11F01	11-04-98	11:40	12.3	5.5	17.8	--	X	USGS
	11-18-98	05:54		4.4	16.7	--	X	USGS
		07:09		4.2	16.5	--	X	USGS
		07:52		4.1	16.4	--	X	USGS
		08:49		4.2	16.5	--	X	USGS
		09:48		4.5	16.8	--	X	USGS
		10:38		4.8	17.1	--	X	USGS
		11:39		5.0	17.3	--	X	USGS
		12:35		5.0	17.3	--	X	USGS
		13:24		4.9	17.2	--	X	USGS
		14:32		4.6	16.9	--	X	USGS
		15.29		4.4	16.7	--	X	USGS
		16:30		4.3	16.6	--	X	USGS
		17:17		4.2	16.5	--	X	USGS
		18:21		4.1	16.4	--	X	USGS
		19:52		4.0	16.3	--	X	USGS
14N/11W-11G02	11-18-98	13:08	15.4	1.9	17.3	--	X	USGS
14N/11W-11R01	11-18-98	06:12	11.2	4.7	15.9	--	X	USGS

Table 5. Water levels and water-level altitudes for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area, September 1998 through August 1999–*Continued*

Well No.	Date	Time (hours: minutes)	Land surface altitude (feet)	Water level (feet above land surface)	Water altitude (feet above sea level)	Water-level status	Method of measure -ment	Source of measure-ment
		07:04		2.4	13.6	R	X	USGS
		07:47		4.6	15.8	--	X	USGS
		08:43		4.8	16.0	--	X	USGS
		09:41		5.1	16.3	--	X	USGS
		10:31		5.1	16.3	--	X	USGS
		11:32		5.1	16.3	--	X	USGS
		12:27		5.0	16.2	--	X	USGS
		13:17		5.0	16.2	--	X	USGS
		14:24		5.1	16.3	--	X	USGS
		15:24		5.1	16.3	--	X	USGS
		16:24		4.9	16.1	--	X	USGS
		17:08		4.7	15.9	--	X	USGS
		18:15		4.4	15.6	--	X	USGS
		19:36		4.1	15.3	--	X	USGS
14N/11W-12L01	11-18-98	06:19	12.2	4.4	16.6	--	X	USGS
		06:53		4.3	16.5	--	X	USGS
		07:42		4.3	16.5	--	X	USGS
		08:38		4.4	16.6	--	X	USGS
		09:34		4.6	16.8	--	X	USGS
		10:16		--	--	P	O	USGS
		11:10		5.1	17.3	--	X	USGS
		12:15		5.4	17.6	--	X	USGS
		13:06		5.4	17.6	--	X	USGS
		14:19		5.2	17.4	--	X	USGS
14N/11W-12L01	11-18-98	15:17	12.2	4.9	17.1	--	X	USGS
		16:16		4.7	16.9	--	X	USGS
		17:02		4.5	16.7	--	X	USGS
		18:09		4.3	16.5	--	X	USGS
		19:28		4.1	16.3	--	X	USGS
14N/11W-12M01	09-22-98	no data	13.8	1.7	15.5	--	S	USGS
	11-18-98	11:35		1.5	15.3	--	S	USGS
14N/11W-12P04	09-23-98	17:55	14.5	1.7	16.2	--	S	USGS

Table 5. Water levels and water-level altitudes for selected wells in the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area, September 1998 through August 1999–*Continued*

Well No.	Date	Time (hours: minutes)	Land surface altitude (feet)	Water level (feet above land surface)	Water altitude (feet above sea level)	Water-level status	Method of measure -ment	Source of measure-ment
14N/11W-13A05	11-04-98	12:40	13.2	4.1	17.3	--	X	USGS
	11-18-98	06:00		1.6	14.8	--	X	USGS
		06:45		1.4	14.6	--	X	USGS
		07:35		0.9	14.1	--	X	USGS
		08:32		1.2	14.4	--	X	USGS
		09:27		1.8	15.0	--	X	USGS
		10:10		2.2	15.4	--	X	USGS
		11:08		3.0	16.2	--	X	USGS
		12:07		3.4	16.6	--	X	USGS
		12:57		3.2	16.4	--	X	USGS
		14:05		2.5	15.7	--	X	USGS
		15:10		2.0	15.2	--	X	USGS
		16:10		1.4	14.6	--	X	USGS
		16:55		1.2	14.4	--	X	USGS
		18:03		0.7	13.9	--	X	USGS
		19:21		0.5	13.7	--	X	USGS
14N/11W-13A06	11-04-98	15:40	12.0	2.1	14.1	--	X	USGS
	11-18-98	14:12		2.9	14.9	--	X	USGS

Table 6. Values of field measurements in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[Temperature reported in degrees Celsius; specific electrical conductance reported in microsiemens per centimeter at 25 degrees Celsius; pH reported in standard units; all other concentrations reported as milligrams per liter; <, less than]

Well No.	Date	Open interval (feet below land surface)	Temperature of water	Specific conductance	pH
14N/10W-18D01	12-16-98	198 - 200	13.0	257	7.5
14N/11W-02C02	08-30-99	210 - 220	10.5	201	8.1
14N/11W-03F01	09-14-99	408 - 423	10.0	166	7.6
14N/11W-03J01	12-16-98	206 - 208	10.0	156	7.5
14N/11W-11C04	12-17-98	276 - 281	11.0	157	8.0
14N/11W-11F01	12-14-98	[1]290	11.0	158	8.0
14N/11W-11G02	12-15-98	[2]193	11.5	189	7.8
14N/11W-11R01	12-15-98	232 - 237	12.5	171	8.0
14N/11W-12P04	12-18-98	220 - 230	11.5	188	8.3
14N/11W-13A05	12-17-98	335 - 350	13.0	147	8.5

Well No.	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Dissolved oxygen (mg/L)
14N/10W-18D01	120	147	0	0.1
14N/11W-02C02	67	82	0	<0.1
14N/11W-03F01	49	60	0	8.2
14N/11W-03J01	55	67	0	7.4
14N/11W-11C04	58	71	0	1.7
14N/11W-11F01	79	96	0	<0.1
14N/11W-11G02	74	90	0	<0.1
14N/11W-11R01	66	80	0	1.2
14N/11W-12P04	71	83	0	<0.1
14N/11W-13A05	54	63	0	<0.1

[1] Depth of well, open interval not known.
[2] Well open at bottom of casing only.

Table 7. Concentrations of major inorganic ions in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[All concentrations reported in milligrams per liter; <, less than]

Well No.	Date	Open interval (feet below land surface)	Calcium	Chloride	Fluoride	Hardness
14N/10W-18D01	12-16-98	198 - 200	25	11	0.3	95
14N/11W-02C02	08-30-99	210 - 220	21	15	<0.1	73
14N/11W-03F01	09-14-99	408 - 423	11	20	<0.1	48
14N/11W-03J01	12-16-98	206 - 208	11	17	0.1	49
14N/11W-11C04	12-17-98	276 - 281	14	12	<0.1	56
14N/11W-11F01	12-14-98	[1]290	14	11	<0.1	59
14N/11W-11G02	12-15-98	[2]193	19	10	0.1	72
14N/11W-11R01	12-15-98	232 - 237	15	10	0.1	62
14N/11W-12P04	12-18-98	220 - 230	26	11	<0.1	74
14N/11W-13A05	12-17-98	335 - 350	16	8.8	<0.1	54

Well No.	Magnesium	Potassium	Silica	Sodium	Sulfate
14N/10W-18D01	8.2	3.2	44	18	5.0
14N/11W-02C02	5.0	2.2	36	10	4.9
14N/11W-03F01	4.7	0.9	30	14	3.1
14N/11W-03J01	5.1	1.0	34	12	2.2
14N/11W-11C04	5.5	1.1	30	9.4	4.7
14N/11W-11F01	5.6	1.2	27	9.5	5.0
14N/11W-11G02	6.1	2.6	32	10	8.0
14N/11W-11R01	5.7	1.8	34	10	4.3
14N/11W-12P04	1.9	2.0	34	8.2	9.8
14N/11W-13A05	3.3	1.5	30	6.9	6.9

[1] Depth of well, open interval not known.
[2] Well open at bottom of casing only.

Table 8. Concentrations of selected metals in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[All concentrations reported in micrograms per liter; all samples were filtered through a 0.45-micrometer pore filter; <, less than; --, not analyzed]

Well No.	Date	Open interval (feet below land surface)	Aluminum	Antimony	Arsenic	Barium
14N-10W-18D01	12-16-98	198 - 200	--	--	--	--
14N/11W-02C02	08-30-99	210 - 220	2	<1	9	<1
14N/11W-03F01	09-14-99	408 - 423	3	<1	<1	<1
14N/11W-03J01	12-16-98	206 - 208	<1	<1	1	<1
14N/11W-11C04	12-17-98	276 - 281	--	--	--	--
14N/11W-11F01	12-14-98	[1]290	<1	<1	5	<1
14N/11W-11G02	12-15-98	[2]193	--	--	--	--
14N/11W-11R01	12-15-98	232 - 237	--	--	--	--
14N/11W-12P04	12-18-98	220 - 230	3	<1	2	1
14N/11W-13A05	12-17-98	335 - 350	--	--	--	--

Well No.	Beryllium	Cadmium	Chromium	Cobalt	Copper
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<1	<1	<1	<1	<1
14N/11W-03F01	<1	<1	<1	<1	<1
14N/11W-03J01	<1	<1	5	<1	<1
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	<1	<1	1	<1	<1
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<1	<1	<1	<1	<1
14N/11W-13A05	--	--	--	--	--

Well No.	Iron	Lead	Manganese	Molybdenum	Nickel
14N/10W-18D01	240	--	[3]150	--	--
14N/11W-02C02	98	<1	[4]43	1	<1
14N/11W-03F01	31	<1	[4]43	<1	<1
14N/11W-03J01	<10	<1	[4]<1	<1	<1
14N/11W-11C04	<10	--	[3]<3	--	--
14N/11W-11F01	24	<1	[4]20	<1	<1
14N/11W-11G02	320	--	[3]83	--	--
14N/11W-11R01	280	--	[3]59	--	--
14N/11W-12P04	56	<1	[4]64	<1	<1
14N/11W-13A05	43	--	[3]21	--	--

Table 8. Concentrations of selected metals in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area—Continued

Well No.	Selenium	Silver	Uranium	Zinc
14N/10W-18D01	--	--	--	--
14N/11W-02C02	<1	<1	<1	2
14N/11W-03F01	<1	<1	<1	7
14N/11W-03J01	<1	<1	<1	10
14N/11W-11C04	--	--	--	--
14N/11W-11F01	<1	<1	<1	4
14N/11W-11G02	--	--	--	--
14N/11W-11R01	--	--	--	--
14N/11W-12P04	<1	<1	<1	2
14N/11W-13A05	--	--	--	--

[1] Depth of well, open interval not known.
[2] Well open at bottom of casing only.
[3] Inductively-coupled plasma method, reporting level of 3 micrograms per liter.
[4] Inductively-coupled plasma/mass spectrometry method, reporting level 1 microgram per liter.

Table 9. Concentrations of selected nutrients and methylene blue-active substances in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[Concentrations reported in milligrams per liter; all samples were filtered through a 0.45-micrometer pore filter; <, less than; **e**, estimated value (constituent qualitatively identified)]

Well No.	Date	Open interval (feet below land surface)	Concentrations reported as N				Ortho-phos-phorus, as P	Methylene blue-active substances
			Ammonia	Nitrite	Ammonia plus organic nitrogen	Nitrite plus nitrate		
14N-10W-18D01	12-16-98	198 - 200	0.19	0.01	0.2	<0.05	0.15	<0.02
14N/11W-02C02	08-30-99	210 - 220	<0.02	<0.01	**e**<0.05	<0.05	0.25	<0.02
14N/11W-03F01	09-14-99	408 - 423	<0.02	<0.01	<0.1	0.22	0.10	0.04
14N/11W-03J01	12-16-98	206 - 208	0.02	<0.01	0.1	0.10	0.12	--
14N/11W-11C04	12-17-98	276 - 281	0.02	<0.01	<0.1	0.07	0.13	<0.02
14N/11W-11F01	12-14-98	[1]290	0.04	0.02	<0.1	0.06	0.17	<0.02
14N/11W-11G02	12-15-98	[2]193	0.16	0.02	0.1	<0.05	0.49	<0.02
14N/11W-11R01	12-15-98	232 - 237	0.77	0.01	0.7	<0.05	0.43	<0.02
14N/11W-12P04	12-18-98	220 - 230	0.03	<0.01	<0.1	<0.05	0.09	<0.02
14N/11W-13A05	12-17-98	335 - 350	0.03	<0.01	<0.1	<0.05	0.07	<0.02

[1] Depth of well, open interval not known.
[2] Well open at bottom of casing only.

Table 10. Concentrations of selected pesticides in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area

[All values reported in micrograms per liter except for methylene blue-active substances, which are reported in milligrams per liter; all samples for analysis of pesticides except for those in Schedule 79 (see table A3) are filtered through a 0.7-micrometer filter; <, less than; --, not analyzed]

Well No.	Date	Open interval (feet below land surface)	Acetochlor	Alachlor	Atrazine	Azinphosmethyl
14N/10W-18D01	12-16 -98	198 - 200	--	--	--	--
14N/11W-02C02	08-30-99	210 - 220	<0.002	<0.002	<0.001	<0.001
14N/11W-03F01	09-14-99	408 - 423	<0.002	<0.002	<0.001	<0.001
14N/11W-03J01	12-16-98	206 - 208	<0.002	<0.002	<0.001	<0.001
14N/11W-11C04	12-17-98	276 - 281	--	--	--	--
14N/11W-11F01	12-14-98	[1]290	--	--	--	--
14N/11W-11G02	12-15-98	[2]193	--	--	--	--
14N/11W-11R01	12-15-98	232 - 237	--	--	--	--
14N/11W-12P04	12-18-98	220 - 230	<0.002	<0.002	<0.001	<0.001
14N/11W-13A05	12-17-98	335 - 350	--	--	--	--

Well No.	Benfluralin	Butylate	Carbaryl	Carbofuran	Chlorpyrifos
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.002	<0.002	<0.003	<0.003	<0.004
14N/11W-03F01	<0.002	<0.002	<0.003	<0.003	<0.004
14N/11W-03J01	<0.002	<0.002	<0.003	<0.003	<0.004
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	--	--	--	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<0.002	<0.002	<0.003	<0.003	<0.004
14N/11W-13A05	--	--	--	--	--

Well No.	Cyanazine	DCPA	*p,p'*-DDE	Deethyl-atrazine	Diazinon
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.004	<0.002	<0.006	<0.002	<0.002
14N/11W-03F01	<0.004	<0.002	<0.006	<0.002	<0.002
14N/11W-03J01	<0.004	<0.002	<0.006	<0.002	<0.002
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	--	--	--	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<0.004	<0.002	<0.006	<0.002	<0.002
14N/11W-13A05	--	--	--	--	--

Table 10. Concentrations of selected pesticides in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area–*Continued*

Well No.	Dicamba	Dichlorprop	Dieldrin	Disulfoton	EPTC
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.01	<0.01	<0.001	<0.017	<0.002
14N/11W-03F01	<0.01	<0.01	<0.001	<0.017	<0.002
14N/11W-03J01	<0.01	<0.01	<0.001	<0.017	<0.002
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	<0.01	<0.01	--	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<0.01	<0.01	<0.001	<0.017	<0.002
14N/11W-13A05	--	--	--	--	--

Well No.	Ethalfuralin	Ethoprophos	Fonofos	*alpha*-HCH	*gamma*-HCH
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.004	<0.003	<0.003	<0.002	<0.004
14N/11W-03F01	<0.004	<0.003	<0.003	<0.002	<0.004
14N/11W-03J01	<0.004	<0.003	<0.003	<0.002	<0.004
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	--	--	--	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-1R01	--	--	--	--	--
14N/11W-12P04	<0.004	<0.003	<0.003	<0.002	<0.004
14N/11W-13A05	--	--	--	--	--

Well No.	Linuron	Malathion	Methyl-parathion	Metolachlor	Metribuzin
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.002	<0.005	<0.006	<0.002	<0.004
14N/11W-03F01	<0.002	<0.005	<0.006	<0.002	<0.004
14N/11W-03J01	<0.002	<0.005	<0.006	<0.002	<0.004
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	--	--	--	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<0.002	<0.005	<0.006	<0.002	<0.004
14N/11W-13A05	--	--	--	--	--

Table 10. Concentrations of selected pesticides in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area–*Continued*

Well No.	Molinate	Napropamide	Parathion	Pebulate	Pendimethalin
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.004	<0.003	<0.004	<0.004	<0.004
14N/11W-03F01	<0.004	<0.003	<0.004	<0.004	<0.004
14N/11W-03J01	<0.004	<0.003	<0.004	<0.004	<0.004
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	--	--	--	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<0.004	<0.003	<0.004	<0.004	<0.004
14N/11W-13A05	--	--	--	--	--

Well No.	*cis*-Permethrin	Phorate	Picloram	Prometon	Propargite
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.005	<0.002	<0.01	<0.018	<0.013
14N/11W-03F01	<0.005	<0.002	<0.01	<0.018	<0.013
14N/11W-03J01	<0.005	<0.002	<0.01	<0.018	<0.013
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	--	--	<0.01	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<0.005	<0.002	<0.01	<0.018	<0.013
14N/11W-13A05	--	--	--	--	--

Well No.	Propachlor	Propanil	Propyzamide	Simazine	Tebuthiuron
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.007	<0.004	<0.003	<0.005	<0.01
14N/11W-03F01	<0.007	<0.004	<0.003	<0.005	<0.01
14N/11W-03J01	<0.007	<0.004	<0.003	<0.005	<0.01
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	--	--	--	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<0.007	<0.003	<0.003	<0.005	<0.01
14N/11W-13A05	--	--	--	--	--

Table 10. Concentrations of selected pesticides in ground-water samples from the Shoalwater Bay Indian Reservation and Tokeland Peninsula study area–*Continued*

Well No.	Terbacil	Terbufos	Thiobencarb	Triallate	Trifluralin
14N/10W-18D01	--	--	--	--	--
14N/11W-02C02	<0.007	<0.013	<0.002	<0.001	<0.002
14N/11W-03F01	<0.007	<0.013	<0.002	<0.001	<0.002
14N/11W-03J01	<0.007	<0.013	<0.002	<0.001	<0.002
14N/11W-11C04	--	--	--	--	--
14N/11W-11F01	--	--	--	--	--
14N/11W-11G02	--	--	--	--	--
14N/11W-11R01	--	--	--	--	--
14N/11W-12P04	<0.007	<0.013	<0.002	<0.001	<0.002
14N/11W-13A05	--	--	--	--	--

Well No.	2,4,-D	2,4,5-T	2-(2,4,5-Tri-) chlorophenoxy propionic acid	2,6-Diethyl-analine
14N/10W-18D01	--	--	--	--
14N/11W-02C02	<0.01	<0.01	<0.01	<0.003
14N/11W-03F01	<0.01	<0.01	<0.01	<0.003
14N/11W-03J01	<0.01	<0.01	<0.01	<0.003
14N/11W-11C04	--	--	--	--
14N/11W-11F01	--	<0.01	--	--
14N/11W-11G02	--	--	--	--
14N/11W-11R01	--	--	--	--
14N/11W-12P04	<0.01	<0.01	<0.01	<0.003
14N/11W-13A05	--	--	--	--

[1] Depth of well, open interval not known.
[2] Well open at bottom of casing only.

APPENDIX A. Water-Quality Methods

APPENDIX A. WATER-QUALITY METHODS

Field Methods

All equipment used to collect and process samples was cleaned with a 0.2-percent non-phosphate detergent, rinsed with deionized water, rinsed with pesticide-grade methanol, wrapped in aluminum foil, and stored in a dust-free environment prior to, and between, sample collection (Shelton, 1994). Wells were purged to remove at least three casing volumes of water and were sampled when monitored values of pH, specific conductance, temperature, and dissolved oxygen (DO) were within the allowable differences, as specified by Koterba and others (1995). For domestic wells, sampling points were located ahead of any water treatment, pressure tanks, or holding tanks. Wetted surfaces of sampling lines and plumbing fixtures were made of polytetraflouroethylene (Teflon) or stainless steel, including the submersible pump and lines used to sample several wells. One public-supply well with a pump suitable for producing samples of acceptable quality was sampled as described by Koterba and others (1995).

Water temperature, DO, specific electrical conductance, and pH were measured in the field using a flow-through chamber so that measurements were made prior to contact between sample water and the atmosphere. Alkalinity, bicarbonate, and carbonate concentrations were measured using water filtered through a polypropylene-encapsulated filter with a pore size of 0.45 micrometer (µm). Reporting limits and USEPA standards for field properties are listed in table A1.

Water samples to be analyzed for major inorganic ions, metals, and nutrients were filtered through a polypropylene-encapsulated filter with a pore size of 0.45 µm. Samples to be analyzed for cations or metals were preserved with nitric acid. Nutrient samples were stored at less than 4 degrees Celsius (^{o}C) for shipment to the National Water Quality Laboratory (NWQL). Reporting limits and USEPA drinking water standards for major inorganic ions, metals, and nutrients are listed in table A1; methods and references are listed in table A2. (All tables are located at the end of the appendix.)

The NWQL analyzed samples of ground water for pesticides using either the gas-chromatograph/ electron capture (GC/EC) or the gas-chromatograph/ mass spectrometry (GC/MS) method, depending on the physical characteristics of the pesticide being analyzed for. The GC/EC method uses unfiltered samples, whereas the GC/MS method uses samples that have been filtered through a 0.7 µm pore-size filter. Samples to be used in either method were kept at less than 4^{o}C prior to the analysis. Additional details on the equipment and procedures used to collect and process samples are given in Shelton (1994), Koterba and others (1995), and in Sandstrom and others (1992). Analytical methods and references for pesticides and methylene blue-active substances (MBAS) are listed in table A1; reporting limits and drinking water standards for pesticides are given in table A3.

Quality Assurance

About 15 percent of all samples submitted to the laboratory were quality-control samples, which included field blanks or equipment blanks used to measure possible contamination and bias and replicate samples used to measure variability. All samples were spiked with surrogate analytes prior to extraction, to monitor the accuracy and precision of the analytical procedures. For definitions of these quality-control samples, see Shelton (1994). Additionally, quality-control samples such as laboratory blanks, internal standards, and reagent spikes were routinely analyzed as part of the laboratory quality-assurance plan described by Pritt and Raese (1995).

Quality Control

Equipment blanks, composed of analyte-free water passed through the sampling filtration equipment prior to sampling ground water and were processed and submitted for analysis. The equipment-blank samples contained low-level detections of several nutrients, major ions, and trace metals (table A4). Concentrations of orthophosphate and nitrite-plus-nitrate were detected in the equipment blank at 0.001 and 0.005 mg/L, respectively, which is 10 times lower than the limit of detection used for the regular analysis of orthophosphate in environmental samples and twice as low as the limit of detection for the regular analysis of nitrite-plus-nitrate in environmental samples. Calcium was detected in the equipment blank at 0.004 mg/L, which is nearly five times lower than the limit of detection for analysis in regular environmental samples. Copper and manganese also were detected in the equipment blank, at concentrations of 0.81 and 0.31 µg/L, which is less than the detection limit of 1 µg/L for the analysis of regular environmental samples; but concentrations of zinc were detected in the equipment blank at 2.9 µg/L, which is nearly three times the detection limit of 1 µg/L. No alteration of the data set was made based on these results, although it should be noted that results for zinc in environmental samples may be biased high.

Precision data were obtained for sets of replicate samples (table A5). Concentration differences ranged from 0.0 to 49.6 percent as measured by relative percent difference. No modifications were made to the data set based on these results. Approximately 75 percent of laboratory-reagent spike samples (table A6) were within the range of 80 to 160 percent, which is generally acceptable for data interpretation; several compounds routinely demonstrated variable performance because of problems in the GC/MS procedure. Because of the poor or variable recoveries of these compounds, they are reported with an "**e**" code (estimated value) to qualify the result.

Table A1. Method reporting limit and drinking water standards for field properties, nutrients, major ions, and metals

[MRL, method reporting limit; MCL, maximum contaminant level (U.S. Environmental Protection Agency, 1996); N, nitrogen; P, phosphorous; +, plus; ±, plus or minus; na, not applicable; mg/L, milligrams per liter; ≥, greater than or equal to; <, less than; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; ICP, inductively-coupled plasma; MS, mass spectrometry]

Analyte or schedule	Chemical Abstracts Service registry number	MRL (mg/L, unless otherwise noted)	MCL (mg/L, unless otherwise noted)
Field properties			
Alkalinity	471-34-1	[1]±1 mg/L	
Dissolved oxygen	na	[1]± 0.3 mg/L	
pH, units	na	[1]± 0.1 unit of pH	[2]6.5-8.5
Specific conductance	na	[1]± 5 percent when sample is ≥100 µS/cm ±3 percent when sample is < 100 µS/cm	
Temperature, degrees Celsius	na	[1]± 0.2 degree Celsius	
Nutrients			
Ammonia, as N	7664-41-7	0.02	None
Ammonia + organic nitrogen, as N	17778-88-0	0.1	None
Nitrite, as N	14797-65-0	0.01	1
Nitrite + nitrate, as N	na	0.05	10
Orthophosphorus, as P	14265-44-2	0.01	None
Major ions and metals			
Aluminum, µg/L	7429-90-5	1	[2]50-200
Antimony, µg/L	7440-36-0	1	6
Arsenic, µg/L	7440-38-2	1	50
Barium, µg/L	7440-39-3	1	2,000
Beryllium, µg/L	7440-41-7	1	4
Cadmium, µg/L	7440-43-9	1	5
Calcium	7440-70-2	0.02	None
Chloride	16887-00-6	0.1	[2]250
Chromium, µg/L	7440-47-3	1	100
Colbalt, µg/L	7440-48-4	1	None
Copper, µg/L	7440-50-8	1	[3]1,300
Fluoride	16984-48-8	0.1	4
Iron, µg/L	7439-89-6	10.0	[2]300
Lead, µg/L	7439-92-1	1	[3]15
Magnesium	7439-95-4	0.004	None
Manganese, µg/L	7439-96-5	3.0 (ICP) 1.0 (ICP/MS)	[2]50
Molybdenum, µg/L	7439-98-7	1	None
Nickel, µg/L	7440-02-0	1	100
Potassium	7440-09-7	0.100	None
Selenium, µg/L	7782-49-2	1	50
Silica	7631-86-9	0.05	None
Silver, µg/L	7440-22-4	1	[2]100
Sodium	7440-23-5	0.06	None
Sulfate	14808-79-8	0.100	[2]250
Uranium, µg/L	7440-61-1	1	[4]20
Zinc, µg/L	7440-66-6	1	[2]5,000

[1] Precision of instruments or measurement.
[2] Secondary maximum contaminant level (U.S. Environmental Protection Agency, 1996).
[3] Action level, which requires treatment if exceeded (U.S. Environmental Protection Agency, 1995).
[4] Proposed.

Table A2. Inorganic and organic analytes and schedules, analytical methods, and references

[ICP/MS, inductively-coupled plasma/mass spectrometry; ISE, ion-selective electrode; SPE, solid-phase extraction; GC/MS, gas-chromatography with detection by mass spectrometry; GC, gas-chromatography; GFAA, graphite furance, atomic absorption; IC, ion-chromatography; ASF, automated segmented flow; AA, atomic absorption]

Analyte or schedule	Analytical method	Reference
Inorganic Compounds		
Nutrients		
Ammonia	Colorimetry, salicylate-hypochlorite	Fishman, 1993
Ammonia + organic nitrogen	Colorimetry, microkjeldahl digestion	Patton and Truitt, 1992
Nitrite	Colorimetry, diazotization	Fishman, 1993
Nitrite + nitrate	Colorimetry, cadmium reduction-diazotization	Fishman, 1993
Orthophosphorus	Colorimetry, phosphomolybdate	Fishman, 1993
Major ions and Metals		
Aluminum	ICP/MS	Faires, 1993
Antimony	ICP/MS	Faires, 1993
Arsenic	GFAA	Jones and Garbarino, 1999
Barium	ICP/MS	Faires, 1993
Beryllium	ICP/MS	Faires, 1993
Cadmium	ICP/MS	Faires, 1993
Calcium	ICP	Fishman, 1993
Chloride	IC	Fishman and Friedman, 1989
Chromium	ICP/MS	Faires, 1993
Cobalt	ICP/MS	Faires, 1993
Copper	ICP/MS	Faires, 1993
Fluoride	Colorimetry, ASF ISE	Fishman and Friedman, 1989
Iron	ICP	Fishman, 1993
Lead	ICP/MS	Faires, 1993
Magnesium	ICP	Fishman, 1993
Manganese	ICP/MS	Faires, 1993
	ICP	Fishman, 1993
Molybdenum	ICP/MS	Fishman, 1993
Nickel	ICP/MS	Fishman, 1993
Potassium	AA, flame	Fishman and Friedman, 1989
Selenium	GFAA	Jones and Garbarino, 1999
Silica	Colorimetry, ASF, molybdate blue	Fishman and Friedman, 1989
Silver	ICP/MS	Faires, 1993
Sodium	ICP	Fishman, 1993
Sulfate	IC	Fishman and Friedman, 1989
Uranium (natural)	ICP/MS	Faires, 1993
Zinc	ICP/MS	Faires, 1993
Organic Compounds		
Pesticides		
Schedule 2010	SPE technology and GC/MS	Zaugg and others, 1995
Schedule 79	Whole-water extraction and GC with electron capture detection	Wershaw and others, 1987
Other organic determinations		
Methylene blue-active substances	Colorometric spectrophotometry	Burkhardt and others, 1995

Table A3. Pesticide analytes, method detection limits, drinking water standards, and health advisories

[µg/L, micrograms per liter; --, no criteria established. **Type of Pesticide**: H, herbicide; I, insecticide; T, transformation product; MCL, drinking-water maximum contaminant level (U.S. Environmental Protection Agency, 1996); **HA-L (bold)**, health advisory, 70-kilogram adult, lifetime (U.S. Environmental Protection Agency, 1996); U.S. Environmental Protection Agency risk-specific dose health advisory associated with a cancer risk of 10^{-6} (1 in a million), from Nowell and Resek (1994); *RSD (italic)*, risk-specific dose health advisory for drinking water associated with a 10^{-6} (1 in a million) cancer risk (U.S. Environmental Protection Agency, 1996); U.S. Environmental Protection Agency lifetime-health advisory for a 70-kilogram adult, from Nowell and Resek (1994)]

Pesticide target analyte	Trade or common name(s)	Type of pesticide	Chemical Abstracts Service registry number	Method detection limit (µg/L)	MCL, **HA-L, or** *RSD* **(µg/L)**
Gas chromatography/mass spectrometry analytical method (Schedule 2010)					
Acetochlor	Acenit, Sacenid	H	34256-82-1	0.002	--
Alachlor	Lasso	H	15972-60-8	0.002	2
Atrazine	AAtrex	H	1912-24-9	0.001	3
Azinphos-methyl[1]	Guthion	I	86-50-0	0.001	--
Benfluralin	Balan, Benefin	H	1861-40-1	0.002	--
Butylate	Sutan +, Genate Plus	H	2008-41-5	0.002	**350**
Carbaryl[1]	Sevin, Savit	I	63-25-2	0.003	**700**
Carbofuran[1]	Furadan	I	1563-66-2	0.003	40
Chlorpyrifos	Lorsban	I	2921-88-2	0.004	**20**
Cyanazine	Bladex	H	21725-46-2	0.004	**1**
DCPA	Dacthal	H	1861-32-1	0.002	**4,000**
p,p'-DDE	none	T	72-55-9	0.006	*0.1*
Deethylatrazine[1]	none	T	6190-65-4	0.002	--
Diazinon	several	I	333-41-5	0.002	**0.6**
Dieldrin	Panoram D-31	I	60-57-1	0.001	*0.002*
2,6-Diethylanaline	none	T	579-66-8	0.003	--
Disulfoton	Di-Syston	I	298-04-4	0.017	**0.3**
EPTC	Eptam, Eradicane	H	759-94-4	0.002	--
Ethalfluralin	Sonalan, Curbit EC	H	55283-68-6	0.004	--
Ethoprophos	Mocap	I	13194-48-4	0.003	--
Fonofos	Dyfonate	I	944-22-9	0.003	**10**
alpha-HCH	none	T	319-84-6	0.002	*0.006*
gamma-HCH	Lindane	I	58-89-9	0.004	0.2
Linuron	Lorox, Linex	H	330-55-2	0.002	--
Malathion	several	I	121-75-5	0.005	**200**
Methyl parathion	Penncap-M	I	298-00-0	0.006	**2**
Metolachlor	Dual, Pennant	H	51218-45-2	0.002	**100**
Metribuzin	Lexone, Sencor	H	21087-64-9	0.004	**100**
Molinate	Ordram	H	2212-67-1	0.004	--
Napropamide	Devrinol	H	15299-99-7	0.003	--
Parathion	several	I	56-38-2	0.004	--
Pebulate	Tillam	H	1114-71-2	0.004	--

Table A3. Pesticide analytes, method detection limits, drinking water standards, and health advisories–Continued

Pesticide target analyte	Trade or common name(s)	Type of pesticide	Chemical Abstracts Service registry number	Method detection limit (µg/L)	MCL, **HA-L, or** *RSD* **(µg/L)**
Gas chromatography/mass spectrometry analytical method (Schedule 2010) — *Continued*					
Pendimethalin	Prowl, Stomp	H	40487-42-1	0.004	--
cis-Permethrin	Ambush, Pounce	I	57608-04-5	0.005	--
Phorate	Thimet, Rampart	I	298-02-2	0.002	--
Prometon	Pramitol	H	1610-18-0	0.018	**100**
Propachlor	Ramrod	H	1918-16-7	0.007	**90**
Propanil	Stampede	H	709-98-8	0.004	--
Propargite	Comite, Omite	I	2312-35-8	0.013	--
Propyzamide	Kerb	H	23950-58-5	0.003	**50**
Simazine	Aquazine, Princep	H	122-34-9	0.005	4
Tebuthiuron	Spike	H	34014-18-1	0.01	**500**
Terbacil[1]	Sinbar	H	5902-51-2	0.007	**90**
Terbufos	Counter	I	13071-79-9	0.013	**0.9**
Thiobencarb	Bolero	H	28249-77-6	0.002	--
Triallate	Far-Go	H	2303-17-5	0.001	--
Trifluralin	Treflan, Trilin	H	1582-09-8	0.002	**5**
Whole-water extraction and gas chromatography with electron capture detection analytical method (Schedule 79)					
2,4-D	several	H	94-75-7	0.01	70
2,4,5-T	several	H	93-76-5	0.01	**70**
2-(2,4,5-Trichloro-phenoxy) propionic acid	Silvex	H	93-72-1	0.01	50
Dicamba	Banvel	H	1918-00-9	0.01	**200**
Dichlorprop	2,4-DP, Seritox 50	H	120-36-5	0.01	--
Picloram	Tordon	H	1918-02-1	0.01	500

[1]Concentrations for these pesticides are qualitatively identified and reported with an **e** code (estimated value) because of problems with gas chromatography or extraction (Zaugg and others, 1995).

Table A4. Concentrations of nutrients, metals, and major ions in field and equipment blanks

[mg/L, milligrams per liter; µg/L, micrograms per liter; N, nitrogen; P, phosphorous]

Analyte	Concentration
Results of equipment blanks	
Calcium	0.004 mg/L
Nitrite + nitrate, as N	0.005 mg/L
Orthophosphate, as P	0.001 mg/L
Copper	0.81µg/L
Manganese	0.31 µg/L
Zinc	2.9 µg/L
Results of field blanks	
Ammonia, as N	0.02 mg/L
Nitrite + nitrate, as N	0.015 mg/L
Orthophosphorus, as P	0.013 mg/L
Aluminum	1.8 µg/L
Copper	1.5 µg/L
Zinc	1.6 µg/L

Table A5. Concentrations and precision data for major ions, nutrients, metals, and methylene blue-active substances in replicate samples

[Concentrations are in milligrams per liter except metals, which are in micrograms per liter; <, less than; --, could not be calculated. Concentrations are unrounded for purpose of statistical calculation]

Analyte	Concentration in replicate	Relative percent difference
Major ions		
Calcium	13.5	0.4
	13.45	
Chloride	12.19	7.8
	11.28	
Fluoride	<0.1	0.0
	<0.1	
Magnesium	5.512	0.3
	5.494	
Manganese[1]	<3	0.0
	<3	
Potassium	1.12	6.5
	1.05	
Silica	30.081	0.7
	29.871	
Sodium	9.381	0.01
	9.380	
Sulfate	4.672	4.5
	4.467	
Nutrients		
Ammonia	0.023	9.1
	0.021	
Ammonia plus	<0.1	0.0
organic nitrogen	<0.1	
Nitrite	<0.01	0.0
	<0.01	
Nitrite plus nitrate	0.067	11.3
	0.075	
Orthophosphorus	0.128	0.0
	0.128	
Metals		
Aluminum	3.383	3.4
	3.271	
Antimony	<1	0.0
	<1	
Metals–*Continued*		
Arsenic	2.09	49.6
	1.26	
Barium	1.404	1.6
	1.427	
Beryllium	<1	0.0
	<1	
Cadmium	<1	0.0
	<1	
Chromium	<1	0.0
	<1	
Copper	<1	0.0
	<1	
Cobalt	<1	0.0
	<1	
Iron	<10	0.0
	<10	
Lead	<1	0.0
	<1	
Manganese[2]	64.029	0.6
	64.437	
Molybdenum	<1	0.0
	<1	
Nickel	<1	0.0
	<1	
Selenium	<1	0.0
	<1	
Silver	<1	0.0
	<1	
Uranium (natural)	<1	0.0
	<1	
Zinc	1.772	--
	<1	
Methylene blue-active substances		
Sample 1	<0.02	0.0
Sample 2	<0.02	

[1] ICP, inductively-coupled plasma.
[2] ICP/MS, inductively-coupled plasma/mass spectometry.

Table A6. Median percent recoveries of laboratory reagent spikes

[Percent recoveries are median of analytical-set batch spikes analyzed with environmental sample for this study; **e**, estimated value]

Pesticide target analyte	Median percentage of recovery
Gas chromatoghraphy/mass spectrometry analytical method (Schedule 2010)	
Acetochlor	99
Alachlor	102
Atrazine	96
Azinphos-methyl[1]	**e**82
Benfluralin	65
Butylate	83
Carbaryl[1]	**e**183
Carbofuran[1]	194
Chlorpyrifos	89
Cyanazine	122
DCPA	96
p,p'-DDE	49
Deethylatrazine[1]	**e**50
Diazinon	94
Dieldrin	79
2,6-Diethylaniline	100
Disulfoton	72
EPTC	88
Ethalfluralin	76
Ethoprophos	81
Fonofos	93
alpha-HCH	93
gamma-HCH	99
Linuron	128
Malathion	87
Methyl parathion	99
Metolachlor	105
Metribuzin	88
Molinate	95
Gas chromatography/mass spectrometry analytical method (Schedule 2010)–*Continued*	
Napropamide	88
Parathion	113
Pebulate	88
Pendimethalin	82
cis-Permethrin[2]	31
Phorate	76
Prometon	102
Propachlor	105
Propanil	103
Propargite	63
Propyzamide	101
Simazine	99
Tebuthiuron	122
Terbacil[1]	**e**178
Terbufos	75
Thiobencarb	110
Triallate	92
Trifluralin	67
Whole-water extraction and gas chromatography with electron capture detection analytical method (Schedule 79)	
2,4-D	82
2,4,5-T	84
2-(2,4,5-Trichlorophenoxy propionic acid)	81
Dicamba	92
Dichlorprop	76
Picloram	41

[1]Concentrations for these pesticides are qualtatively identified and reported with an **e** code because of problems with extraction or age chromatography (Zaugg and others, 1995).

[2] Spike solution contains both *cis*- and *trans*- permethrin, but only the *cis* isomer is reported. *Cis*-permethrin is present at 0.3 nanograms per liter, and is commonly recovered at about 40 percent in laboratory spike samples.

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Lane and Ebbert

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