Prepared in cooperation with the Hood Canal Dissolved Oxygen Program

Surface-Water Quality in Rivers and Drainage Basins Discharging to the Southern Part of Hood Canal, Mason and Kitsap Counties, Washington, 2004

Scientific Investigations Report 2006–5073

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

Cover: Photograph of the Tahuya River looking downstream at the mouth, draining into Hood Canal, near Tahuya, Washington.
(Photograph taken by Bill Simonds, U.S. Geological Survey, Washington Water Science Center, August 2005)

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Conversion Factors

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon (gal)	3.785	liter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer

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

$$°F=(1.8×)+32$$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concenrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Surface-Water Quality in Rivers and Drainage Basins Discharging to the Southern Part of Hood Canal, Mason and Kitsap Counties, Washington, 2004

By L.M. Frans, A.J. Paulson, R. L. Huffman, and S.N. Osbourne

Abstract

Concentrations of nutrients, major ions, organic carbon, suspended sediment, and the nitrogen isotope ratio of nitrate ($\delta^{15}N$) were collected at surface-water sites in rivers and drainage basins discharging to the southern part of Hood Canal, Mason and Kitsap Counties, Washington. Base-flow samples were collected from sites on the Union, Tahuya, and Skokomish Rivers from June to August 2004.

Concentrations of nutrients at all sites were low. Ammonia and orthophosphate were less than the detection limit for most samples, and nitrate plus nitrite concentrations ranged from less than the detection limit of 0.06 to 0.49 milligram per liter (mg/L). Nitrate plus nitrite concentrations were near the detection limit of 0.06 mg/L in the North Fork, South Fork, and mainstem of the Skokomish River. The concentration of nitrate plus nitrite in the Tahuya River system above Lake Tahuya was 0.17 mg/L, but decreased to 0.1 mg/L or less downstream of Lake Tahuya. Overall, the Union River contained the highest nitrate plus nitrite concentrations of the three large river systems, ranging from 0.12 to 0.28 mg/L.

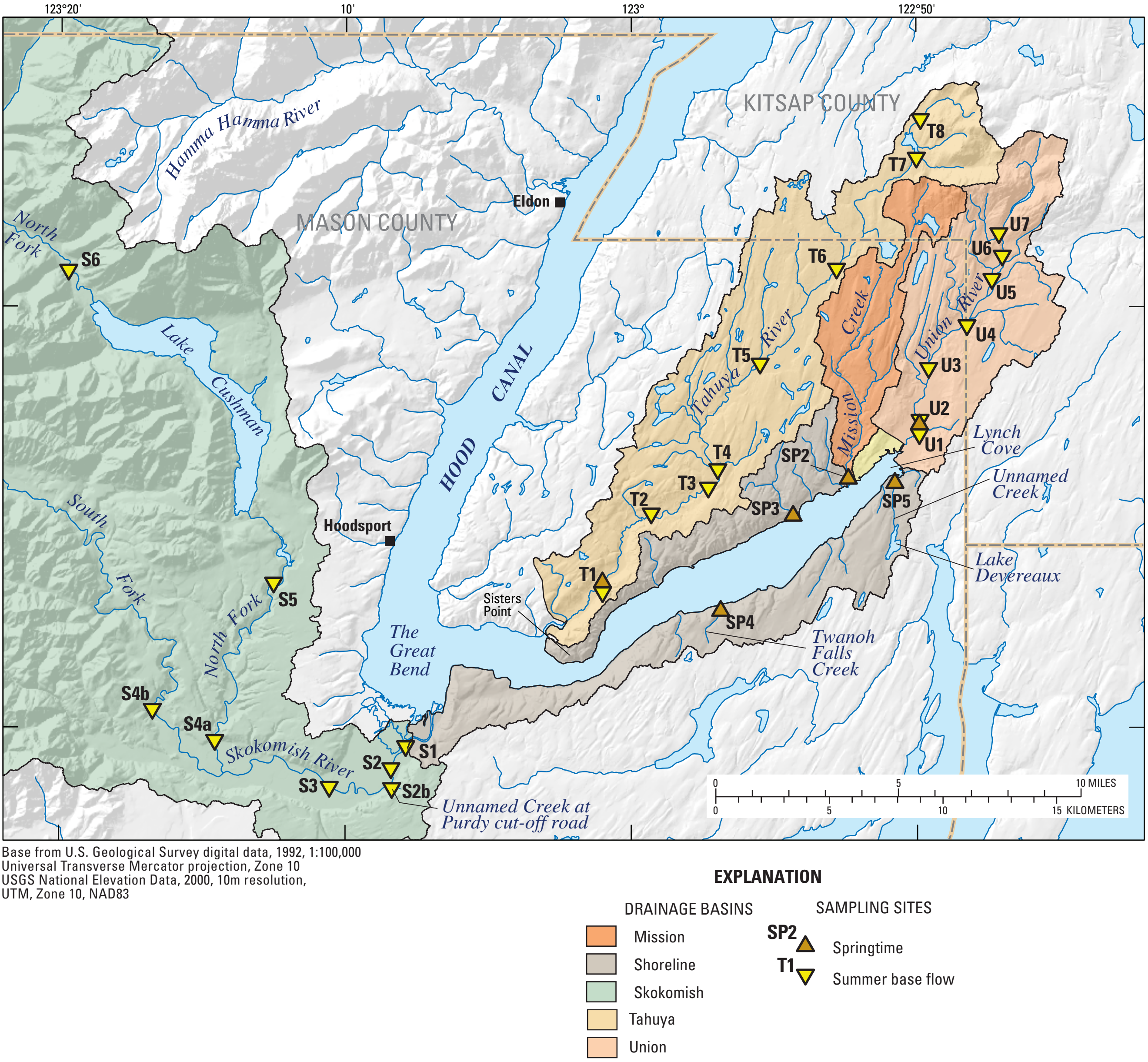
$\delta^{15}N$ generally was within the range that encompasses most sources, providing little information on nitrate sources. Most nitrogen was in the dissolved inorganic form. Dissolved inorganic nitrogen in Lake Tahuya was converted into particulate and dissolved organic nitrogen. Dissolved organic carbon concentrations generally were less than 1 mg/L in the Tahuya and Skokomish Rivers and averaged 1.3 mg/L in the Union River. Dissolved organic carbon concentrations of 2.6 to 2.7 mg/L at sites just downstream of Lake Tahuya were highest for the three large river systems, and decreased to concentrations less than 1 mg/L, which was similar to concentrations in the Skokomish River.

Total nitrogen concentrations near 0.5 mg/L were measured at two sites: Unnamed Creek at Purdy-Cutoff Road (site S2b) and downstream of Lake Devereaux (site SP5). Concentrations of nitrate plus nitrite were highest at site S2b (0.49 mg/L), and dissolved organic carbon concentrations (3.3 mg/L) were highest at the outlet of Lake Devereaux. However, the overall impact of these sites on the nutrient loading to Hood Canal probably is negligible because of the low streamflow and small loads.

Springtime samples were collected from the Union River, Tahuya River, Mission Creek, and three smaller drainage basins in March 2004. Samples were collected during spring rain events to determine if increased runoff contributes larger amounts of sediment and nutrients from the land into the surface water. There was little difference in nutrient concentrations between samples collected in the spring and base-flow samples collected in the summer. This is likely due to the fact that the springtime samples were collected during a rain event and not necessarily during a peak in the hydrograph.

Introduction

In September 2002, fish on the west side of Hood Canal near Hoodsport, Washington (fig. 1) were observed to be under stress from low concentrations of dissolved oxygen. This observation prompted the Washington State Department of Fish and Wildlife to temporarily close parts of Hood Canal to some types of fishing during October. In 2003, low dissolved-oxygen conditions worsened, some fish kills were observed as early as June, and about 30 percent of rockfish were killed by October (http://www.hoodcanal.washington.edu/documents/document.jsp?id=1453, accessed Nov. 15, 2005). Low concentrations of dissolved oxygen in Hood Canal during late summer and early autumn have been observed as far back as the 1950s (Collias and others, 1974). Available data suggest that even though dissolved-oxygen concentrations vary from year to year, dissolved-oxygen conditions recently have been more frequently low, and the duration of low concentrations is more persistent (http://www.hoodcanal.washington.edu/observations/historicalcomparison.jsp, accessed January 29, 2006).



Base from U.S. Geological Survey digital data, 1992, 1:100,000
Universal Transverse Mercator projection, Zone 10
USGS National Elevation Data, 2000, 10m resolution,
UTM, Zone 10, NAD83

Figure 1. Location of study area and surface-water-quality sampling sites, southern part of Hood Canal, Mason and Kitsap Counties, Washington.

In 2003, the U.S. Geological Survey (USGS) was asked by Congress to study the causes of low dissolved-oxygen concentrations in Hood Canal in collaboration with the Hood Canal Dissolved Oxygen Program (HCDOP). The HCDOP is a partnership of organizations that monitor and study Hood Canal, and evaluate potential corrective actions to address the low dissolved oxygen problem. There are more than 30 HCDOP partners, among them Puget Sound Action Team; Washington State Departments of Ecology, Health, Fish and Wildlife, and Natural Resources; Jefferson, Kitsap and Mason Counties; Skokomish and Port Gamble S'Klallam Tribes; Hood Canal Coordinating Council; Hood Canal Salmon Enhancement Group; University of Washington; and the USGS. After consultation with the HCDOP partners, the USGS began to assess the loadings of nitrogen-based compounds to Hood Canal. A study focusing on the nutrient input from surface water landward of The Great Bend was initiated in 2004 because the instances of low dissolved oxygen are most severe in this region. As part of the study, surface water-quality data were collected in the southern part of Hood Canal drainage area.

Purpose and Scope

Samples were collected during summer base-flow conditions and analyzed for nutrients, major ions, organic carbon, suspended sediment, and the ratio of ^{15}N to ^{14}N ($\delta^{15}N$) of nitrate to obtain a better understanding of the nutrient concentrations in the rivers that are discharging into the southern part of Hood Canal as well as possible sources of those nutrients. Samples also were collected during spring rain events along the Union River, Tahuya River, Mission Creek, and three smaller drainage basins to assess whether nutrient concentrations are elevated in surface water due to increased runoff. This report examines the longitudinal distribution of nutrients, major ions, organic carbon, suspended sediment, and $\delta^{15}N$ collected by the USGS along the Union, Tahuya, and Skokomish Rivers during summer base-flow conditions as well as concentrations of nutrients from six sites located along various rivers and creeks in the southern part of the Hood Canal during the spring.

Acknowledgments

The authors would like to thank U.S. Geological Survey Washington Water Science Center staff Joseph Gilbert, Greg Justin, Karen Payne, and student intern Matt Groce for their assistance in locating sites and sample collection.

Methods

Sample Collection, Field Measurements, and Sample Processing

Seven sites on the Union River were sampled during summer base-flow conditions from June 28–30, 2004 (fig. 1). Base-flow samples also were collected at eight sites on the Tahuya River from July 1 to 6, 2004, and eight sites on the Skokomish River from July 9 to August 4, 2004. Samples were collected from Union River, Mission Creek, Tahuya River, and three smaller drainage basins in the spring (March 18 and 25, 2004).

Streamflow was measured, whenever possible, following established protocols and procedures (Rantz and others, 1982). Streamflow was measured infrequently in channels in which wetted widths were minimal, requiring less than optimal sectioning; depths and velocity may have been below proper operating range for the meter available, resulting in reasonable departures from established protocols.

Water temperature, dissolved-oxygen (DO) concentrations, specific conductance, pH, alkalinity, and bicarbonate concentrations were measured on-site following procedures described by Wilde (variously dated). Water temperature and DO were measured directly in the stream and specific conductance and pH were measured using unfiltered, composited water; and alkalinity and bicarbonate were measured using a filtered aliquot of composited water. All samples for analyses of nutrients and suspended sediment, and base-flow samples for the analyses of major ions and $\delta^{15}N$ were collected using a US DH-81 sampler (Wilde and others, 1999). The sampler holds a 1-liter polypropylene sample bottle, and all parts of the sampler that come into contact with sample water were made of polypropylene. All equipment used to collect and process samples was cleaned with a 0.2-percent non-phosphate detergent, rinsed with deionized water, stored in a dust-free environment, and then rinsed thoroughly with stream water before sample collection and processing (Wilde, 2004; Wilde and others, 2004).

Samples were collected using the equal-width-increment (EWI) method, in which transects were established across the width of each stream/river. Water was collected at approximately 10 equally spaced intervals along the transect by lowering and raising the sampler vertically through the water column. The collected water from each interval was then composited into a polypropylene churn splitter, and then split into individual samples (Wilde and others, 2004).
The pH and specific conductance were measured using unfiltered water from the churn splitter. Alkalinity and bicarbonate concentrations during base-flow sampling were measured with aliquots of filtered water using incremental titration with a digital titrator and sulfuric acid. Stream-water samples for organic carbon were collected at a single vertical column in the center flow of the stream using baked, amber glass bottles, which were lowered beneath the water surface until filled.

Samples collected for inorganic chemistry and $\delta^{15}N$ chemical analyses were filtered through a 0.45-µm pore-size, polypropylene-encapsulated filter. The filtrate for cation analyses was preserved with nitric acid. Samples for $\delta^{15}N$ analyses were preserved by freezing, and samples for analyses of nutrients were filtered into opaque polyethylene bottles and preserved at less than 4°C. For organic carbon analyses, three aliquots of water were filtered through 25-mm diameter, 0.45-µm, baked, glass-fiber filters using a Teflon™ filter holder. The filtrate was preserved with sulfuric acid for analysis of dissolved organic carbon (DOC) (Wilde and others, 2004), and the material retained on the three filters was used for particulate carbon and nitrogen analyses.

All samples for chemical analyses were shipped overnight on ice to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado. Samples for $\delta^{15}N$ analyses were shipped frozen to the USGS Menlo Park Stable Isotope Laboratory in Menlo Park, California, and samples for analysis of suspended-sediment concentration were shipped to the USGS Cascades Volcano Observatory (CVO) Sediment Laboratory in Vancouver, Washington.

Laboratory Analyses

Samples of filtered orthophosphate, ammonia, and nitrate-plus-nitrite nitrogen were analyzed at the NWQL by colorimetry (Fishman, 1993). Ammonia and orthophosphate concentrations generally were less than the detection limit of 0.04 and 0.02 mg/L, respectively, and will not be addressed in the section “Surface-Water Quality in Rivers and Drainage Basins Discharging to the Southern Part of Hood Canal.” The concentration of a filtered sample of total nitrogen, the sum of inorganic and organic nitrogen, was analyzed by an alkaline persulfate digestion followed by colorimetry (Patton and Kryskalla, 2003). Major ions, iron, and manganese were analyzed by ion chromatography and inductively coupled plasma (Fishman and Friedman, 1989; Fishman, 1993). Particulate and dissolved organic carbon were analyzed by ultra violet (UV)-promoted persulfate oxidation and infrared spectrometry using the methods of U.S. Environmental Protection Agency (1997) and Brenton and Arnett (1993). Samples were analyzed for sediment concentrations at CVO following the method of Guy (1969). The nitrogen isotope samples were analyzed for δ^{15}N of nitrate using a method in which bacterial cultures reduce dissolved nitrate to N_2O (Sigman and others, 2001; Casciotti and others, 2002). Nitrogen isotopic compositions are expressed in per mil (percent) relative to atmospheric air:

$$\delta^{15}\mathrm{N}=\{[(^{15}\mathrm{N}\,/\,^{14}\mathrm{N})_x\,/(^{15}\mathrm{N}\,/\,^{14}\mathrm{N}_{\mathrm{Air}})]-1\}*1{,}000, \quad (1)$$

where

x is the sample, and

$\mathrm{N}_{\mathrm{Air}}$ is atmospheric nitrogen.

The δ^{15}N of nitrate can provide information about nitrogen sources. A δ^{15}N greater than 10 per mil indicates possible manure or septic waste contamination. However, most of the δ^{15}N data that were collected during base-flow conditions fall within the range covered by most sources of nitrate (1 to 5 per mil), thus precluding the identification of the nitrogen source (Kendall, 1998).

Quality-control samples included field blanks and replicates (table 5, at back of report). Low concentrations of calcium, suspended sediment, and DOC were detected in some of the blanks. Calcium detections in the blank samples were far less than the concentrations in the environmental samples. But the highest DOC and suspended-sediment concentrations in the blank samples were 0.4 and 1 mg/L, respectively, similar to the lowest concentrations in the environmental samples. Variability in the chemical data was measured with two pairs of replicate samples. The amount of variability between samples was expressed as the relative percentage of difference in the concentrations. Relative percentage of differences for the major-ion samples ranged from 0 to 7 percent. Relative percentage of differences between replicates of nutrient samples tended to be larger than major ions, ranging from 0 to 22 percent. Relative percentage of differences between replicates of DOC ranged from 0 to 15 percent and 40 percent for suspended organic carbon. Changes were not made to any of the inorganic or organic chemical data sets on the basis of these replicate data.

The relative percentage of differences between replicates of δ^{15}N ranged from 3 to 13 percent. Although δ^{15}N had good reproducibility, some of the data are highly uncertain because instrument response was less than detection limits. These data will not be included in the discussion in the section, “Surface-Water Quality in Rivers and Drainage Basins Discharging to the Southern Part of Hood Canal.”

Surface-Water Quality in Rivers and Drainage Basins Discharging to the Southern Part of Hood Canal

A total of 23 base-flow samples were collected during summer of 2004 from sites along the Union, Tahuya, and Skokomish Rivers. Samples were analyzed for major ions, nutrients, organic carbon, suspended sediment, and δ^{15}N of nitrate to obtain a better understanding of the nutrient concentrations in the rivers that are discharging into the southern part of Hood Canal, as well as possible sources of those nutrients. Six samples also were collected in the spring during rain events, along the Union River, Tahuya River, Mission Creek, Stimpson Creek, Twanoh Falls Creek, and an unnamed creek from Lake Devereaux, to assess whether nutrient concentrations are elevated in surface water due to increased runoff. Water sampled at all sites was well oxygenated.

Union River

Seven sampling sites were selected along the length of the Union River at points where the predominant land use type near the river changed in an attempt to assess the effects of land use on nutrient concentrations (fig. 1). The farthest upstream site (U7) was located in an area dominated by forest with each site farther downstream having additional urban and agricultural influences. Samples were collected on three consecutive days (June 28 to 30, 2004). Discharge generally increased downstream of site U6 (fig. 2*A*), after the large decrease between sites U6 and U7 due to withdrawals for drinking-water purposes.

Concentrations of the major ions and bicarbonate generally increased downstream, likely due to increased weathering of surrounding substrate (figs. 2*B* and 2*C*).

Manganese and iron showed a sharp increase in concentration between sites U5 and U4 (fig. 2*D*), which was likely caused by increased ground-water discharge to the river in that region. Concentrations of particulate organic nitrogen and carbon (fig. 2*F*), and suspended sediment also showed slight increases towards the mouth of the river (table 1).

Nutrient concentrations were low throughout the river (fig. 2*E*). Total nitrogen concentrations were fairly constant with concentrations ranging from 0.26 to 0.29 mg/L from sites U5 to U1. Most of the total nitrogen in the river consists of nitrate plus nitrite, with little being in organic form.

The $\delta^{15}N$ increases slightly from 1.32 per mil at site U6 to 4.20 per mil at site U2 (fig. 2*G*), but all values fall within the range covered by most sources of nitrate (Kendall, 1998), thus precluding the identification of nitrogen sources.

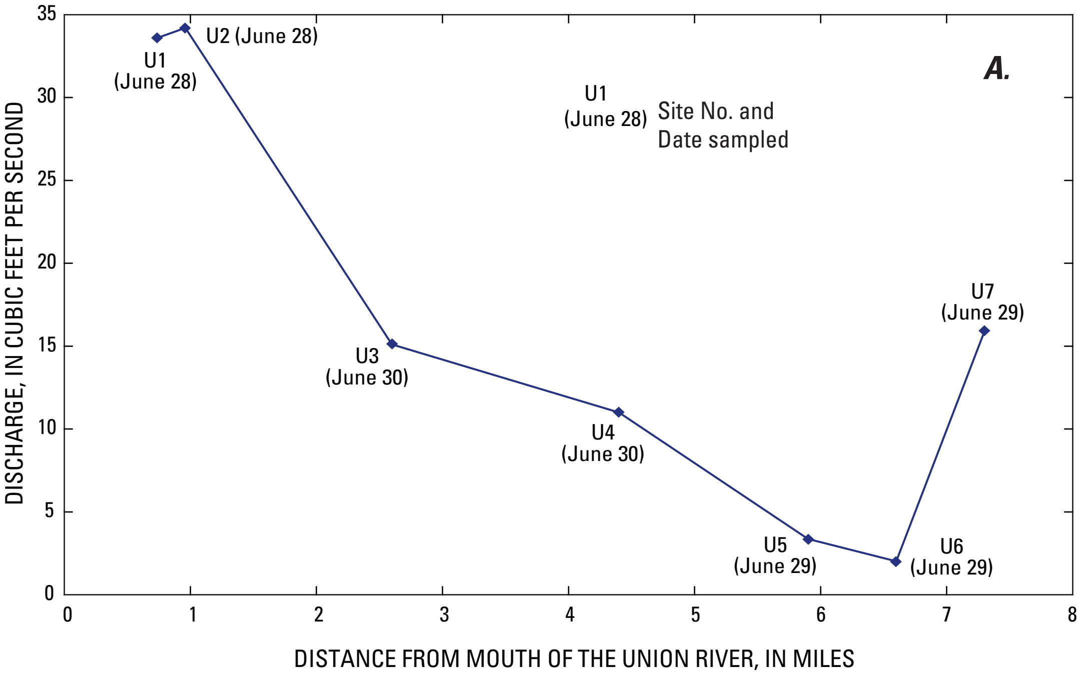
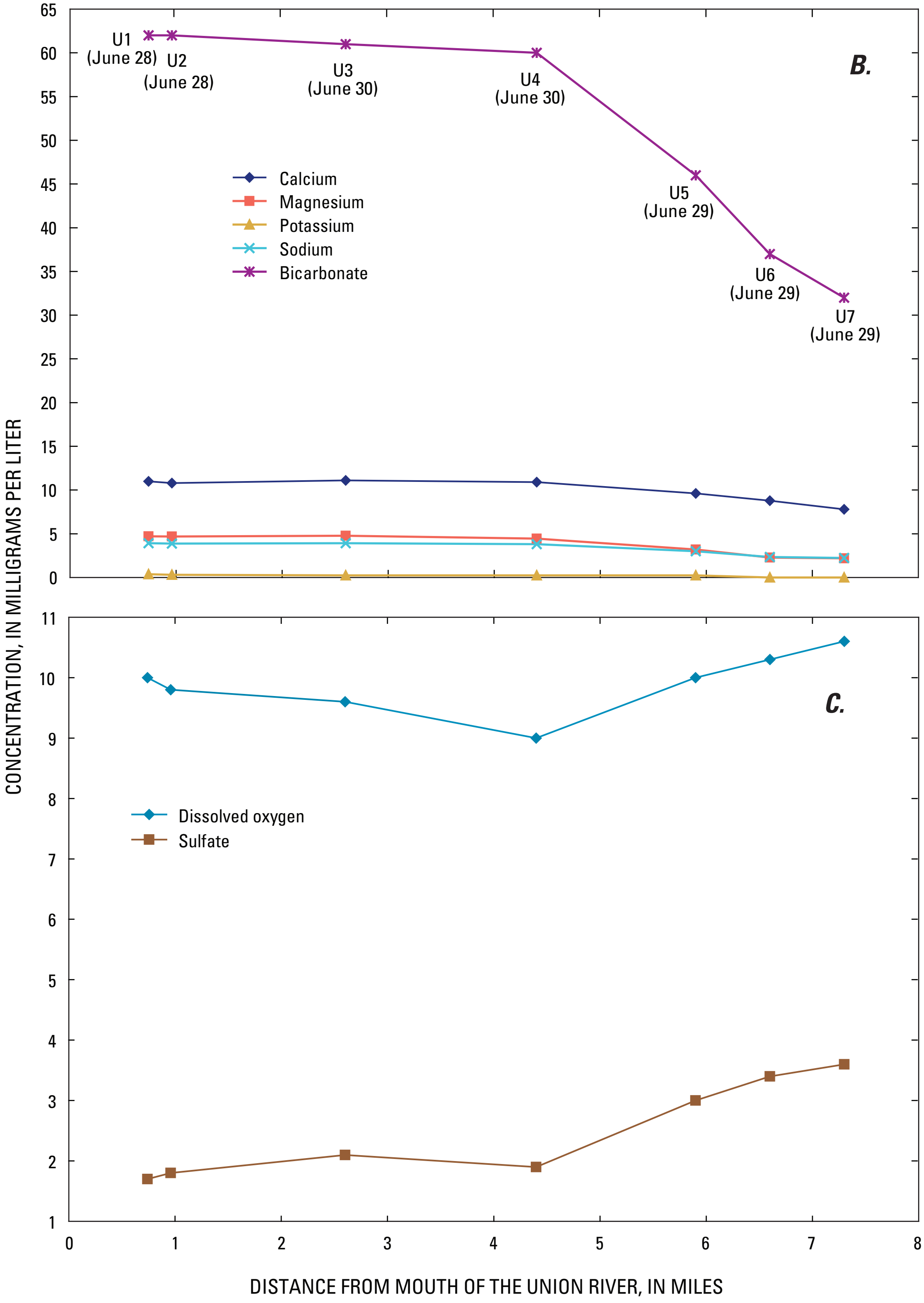


Figure 2. Discharge and concentrations of major ions, dissolved oxygen, nutrients, organic carbon, and nitrogen isotope of nitrate ($\delta^{15}N$) at Union River sampling sites during summer base-flow conditions, southern part of Hood Canal, Mason and Kitsap Counties, Washington, June 2004.



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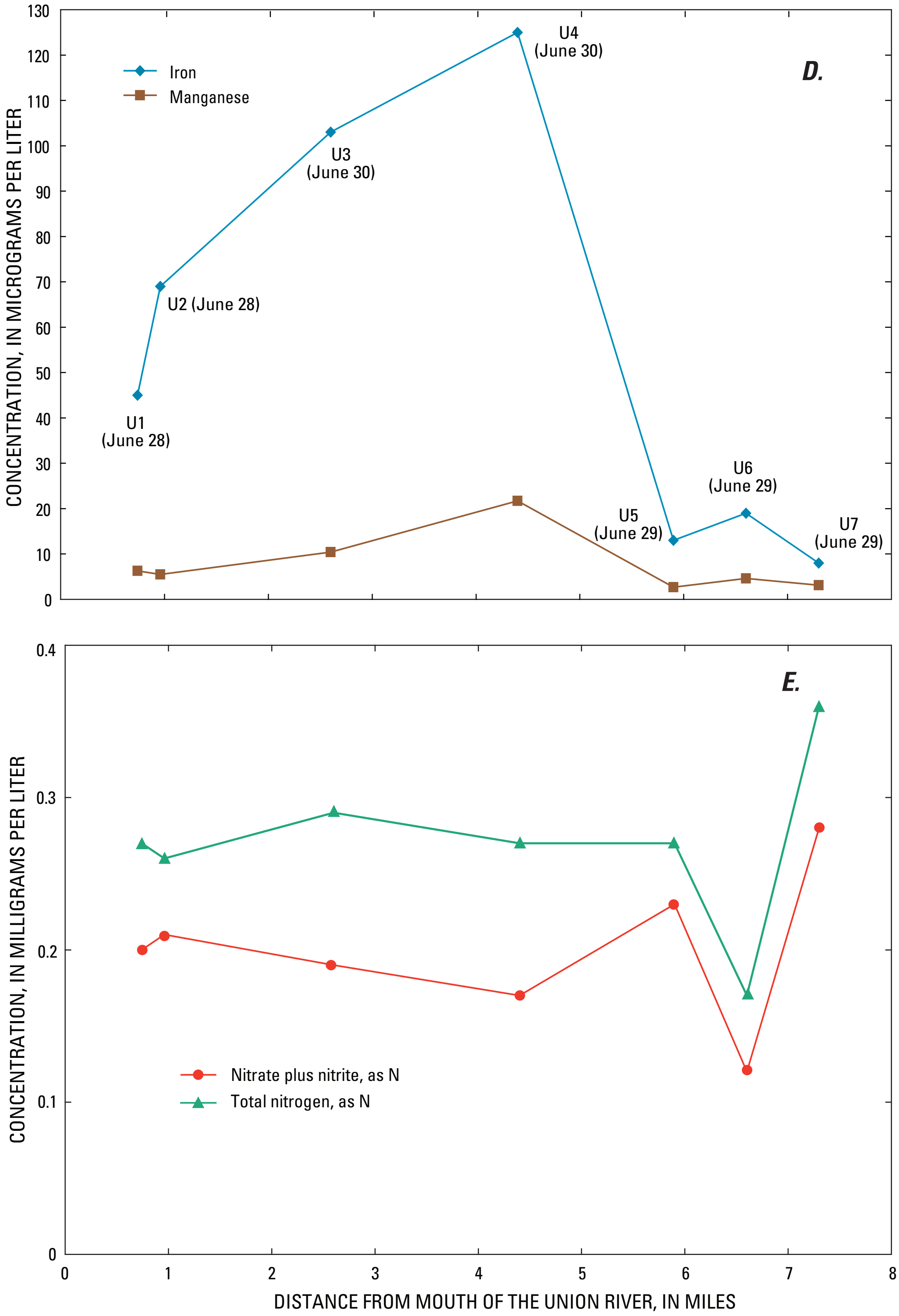

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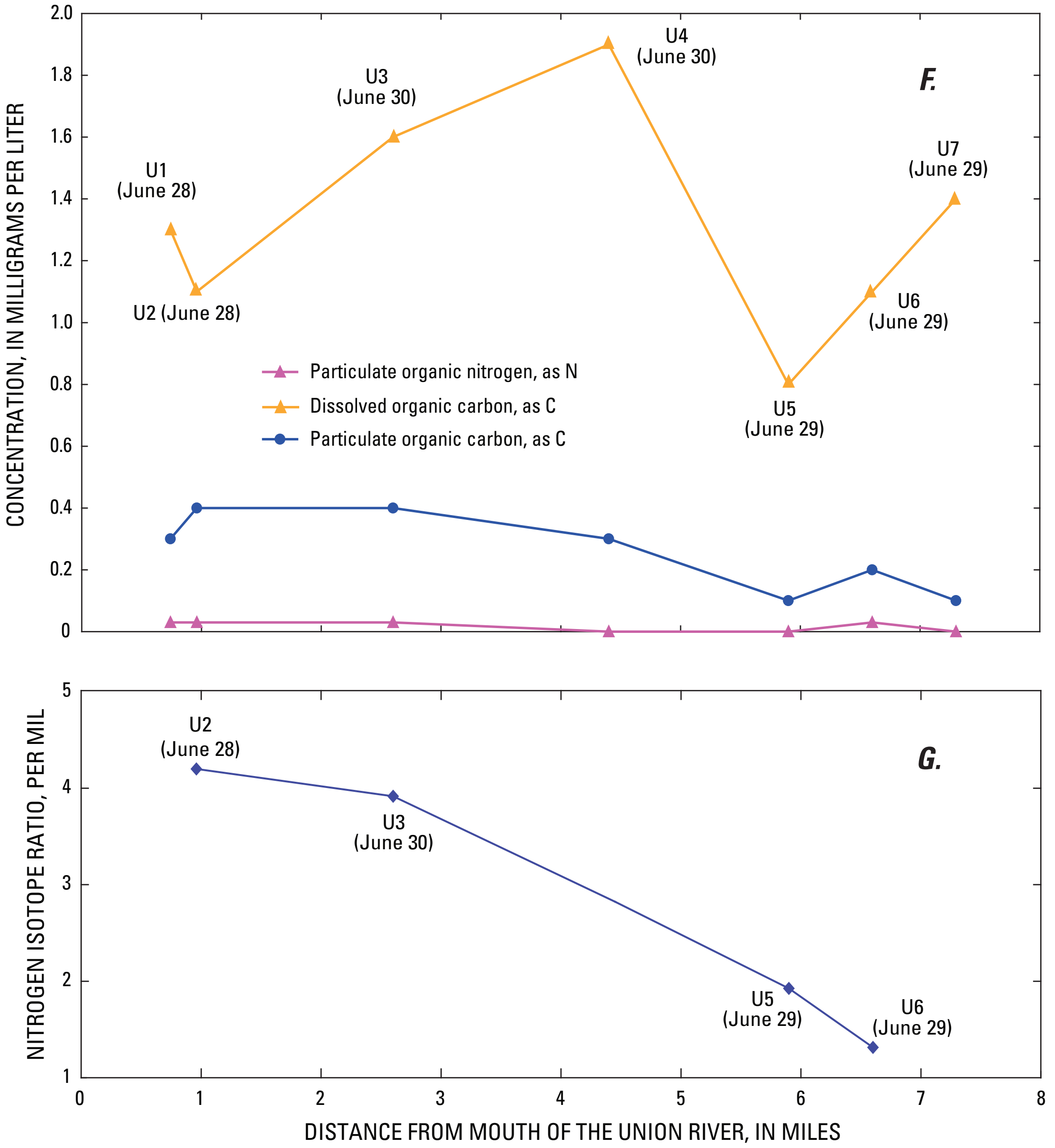


Figure 2.—Continued.

Table 1. Field measurements and concentrations of major ions, nutrients, organic carbon, suspended sediment, and nitrogen isotope of nitrate ($\delta^{15}N$) collected at Union River sampling sites during summer base-flow conditions, southern part of Hood Canal, Mason and Kitsap Counties, Washington, June 2004.

[Locations of sampling sites are shown in figure 1. **Abbreviations**: USGS, U.S. Geological Survey; $CaCO_3$; calcium carbonate; HCO_3, bicarbonate; N, nitrogen; P, phosphorus; $\delta^{15}N$, isotope fractionation of N (see equation 1 in text). ft^3/s, cubic foot per second; mg/L, milligram per liter; µS/cm, microsiemen per centimeter at 25°C; °C, degrees Celsius; µg/L, microgram per liter; ^{e}, estimated value; <, less than]

Map No.	USGS site No.	Sample date	Distance from mouth of the Union River (miles)	Discharge, instantaneous (ft^3/s)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µS/cm)	Water temperature (°C)	Calcium (mg/L)	Magnesium (mg/L)
U1	12063520	06-28-04	0.74	33.6	10.0	7.7	109	13.2	11.0	4.70
U2	12063518	06-28-04	.96	34.2	9.8	7.7	108	13.6	10.8	4.68
U3	12063400	06-30-04	2.6	15.1	9.6	8.0	111	18.6	11.1	4.78
U4	12063300	06-30-04	4.4	11	9.0	7.8	103	14.1	10.9	4.44
U5	12063200	06-29-04	5.9	3.4	10.0	7.3	88	15.0	9.62	3.19
U6	12063100	06-29-04	6.6	2.0	10.3	7.4	73	15.4	8.79	2.27
U7	12063000	06-29-04	7.3	15.9	10.6	7.5	66	10.1	7.80	2.18

Map No.	USGS site No.	Sample date	Potassium (mg/L)	Sodium (mg/L)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate (mg/L as HCO_3)	Bromide (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)
U1	12063520	06-28-04	0.38	3.91	50	62	<0.02	1.92	<0.2	22.0
U2	12063518	06-28-04	.31	3.87	50	62	<.03	1.90	<.2	22.1
U3	12063400	06-30-04	.24	3.92	50	61	<.02	2.22	<.2	21.3
U4	12063300	06-30-04	.23	3.80	49	60	<.02	2.14	<.2	20.5
U5	12063200	06-29-04	.23	3.00	38	46	<.02	1.69	<.2	16.3
U6	12063100	06-29-04	<.16	2.35	30	37	<.03	1.56	<.2	11.5
U7	12063000	06-29-04	^{e}.11	2.23	26	32	<.02	1.43	<.2	10.8

Map No.	USGS site No.	Sample date	Sulfate (mg/L)	Dissolved solids (mg/L)	Ammonia (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Particulate-N (mg/L)	Orthophosphate (mg/L as P)	Total nitrogen (mg/L)	Total carbon, particulate (mg/L)
U1	12063520	06-28-04	1.7	86	<0.04	0.20	0.03	^{e}0.01	0.27	0.3
U2	12063518	06-28-04	1.8	81	<.04	.21	.03	^{e}.01	.26	.4
U3	12063400	06-30-04	2.1	81	<.04	.19	.03	<.02	.29	.4
U4	12063300	06-30-04	1.9	87	<.04	.17	<.02	<.02	.27	.3
U5	12063200	06-29-04	3.0	64	<.04	.23	<.02	<.02	.27	.1
U6	12063100	06-29-04	3.4	51	<.04	.12	.03	<.02	.17	.2
U7	12063000	06-29-04	3.6	51	<.04	.28	<.02	<.02	.36	.1

Map No.	USGS site No.	Sample date	Inorganic carbon, particulate (mg/L)	Organic carbon, particulate (mg/L)	Organic carbon, dissolved (mg/L)	Iron (µg/L)	Manganese (µg/L)	Suspended sediment (mg/L)	$\delta^{15}N$ (per mil)
U1	12063520	06-28-04	<0.1	0.3	1.3	45	6.3	3	[1]4.76
U2	12063518	06-28-04	<.1	.4	1.1	69	5.5	4	4.20
U3	12063400	06-30-04	<.1	.4	1.6	103	10.4	6	3.92
U4	12063300	06-30-04	<.1	.3	1.9	125	21.7	2	[1]2.95
U5	12063200	06-29-04	<.1	.1	.8	13	2.7	1	1.93
U6	12063100	06-29-04	<.1	.2	1.1	19	4.6	1	1.32
U7	12063000	06-29-04	<.1	.1	1.4	8	3.1	2	[1]7.81

[1] Data values are highly uncertain.

Tahuya River

The eight sites sampled on the Tahuya River also were selected based on changes in predominant land use. Although most of the Tahuya River drainage basin is forested, a few sites were selected based on increased urbanization (fig. 1, sites T7, T4, and T3). The farthest upstream site (T8) was near the headwaters of the Tahuya River in a predominately forested area, with subsequent sites downstream having additional urban areas. Site T7 is at the outlet of Lake Tahuya, a fairly populated area. Samples were collected on 3 days between July 1 and July 6, 2004.

Discharge generally increased downstream (fig. 3*A*). On July 2, 2004, discharge increased from 0.11 ft^3/s above the Lake Tahuya (site T8) to 1.6 ft^3/s at the outlet of Lake Tahuya (site T7). When sampling began again on July 6, 2004, discharge 4.5 mi downstream of Lake Tahuya (site T6) was 0.27 ft^3/s, but increased 4-fold to 1.1 ft^3/s at site T5. Causes of the decrease between T7 and T6 may include sampling on different days (for example, proximity of rain event), diversion for irrigation and/or agriculture, or a losing reach of the stream may have occurred. There also was little increase in flow between sites T3 and T2.

Similar to samples from the Union River, major ion concentrations in the Tahuya River tended to increase downstream (fig. 3*B* and table 2). However, there was a significant decrease in calcium, magnesium, and bicarbonate between sites T6 and T5, both sampled on July 6, 2004, that was concurrent with the 4-fold increase in discharge. The significant decrease in specific conductance (from 57 to 46 µS/cm) and pH (from 7.6 to 7.2) suggests that the 0.83 ft^3/s of water that was added between sites T6 and T5 was less weathered and more acidic (more like rain water) than the 0.27 ft^3/s flowing past site T6.

Biogeochemical processes in Lake Tahuya (between T8 and T7) significantly modified the chemistry of the surface water (figs. 3*B*-3*F*). The concentration of nitrate plus nitrite was highest at site T8 upstream of Lake Tahuya (0.17 mg/L), but then decreased to non-detectable values at site T7 downstream of the lake, probably as a result of biological uptake by phytoplankton. Increased growth of phytoplankton also could explain the observed response in DOC concentrations. Biogeochemical coupling with the organic matter produced in Lake Tahuya, also could explain the increased concentration of the redox-sensitive ions manganese and iron at sites T7 and T6, just downstream of Lake Tahuya. Concentrations of DOC and iron decreased to significantly lower concentrations downstream of site T6 although manganese concentrations increased slightly downstream of T5. Total nitrogen values only decreased slightly from upstream to downstream of Lake Tahuya suggesting that most of the nitrogen flowing from Lake Tahuya was dissolved organic nitrogen. The concentrations of particulate organic carbon remained relatively unchanged downstream of site T5.

The $\delta^{15}N$ fell within the range covered by most sources of nitrate, thus precluding identification of the nitrogen source (fig. 3*G*). The slight increase in the $\delta^{15}N$ from upstream of Lake Tahuya (1.96 per mil at site T8 and 3.72 per mil for site T6) probably was due to photosynthetic uptake of low $\delta^{15}N$ within Lake Tahuya, leaving the residual nitrate with a higher $\delta^{15}N$. Downstream of site T6, $\delta^{15}N$ decreased to about 2.6 per mil.

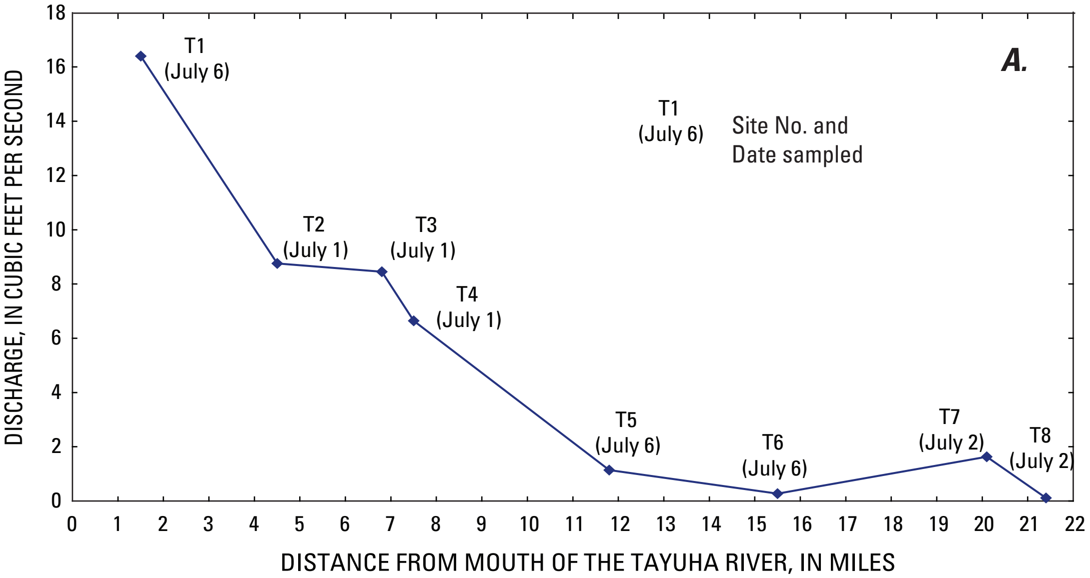
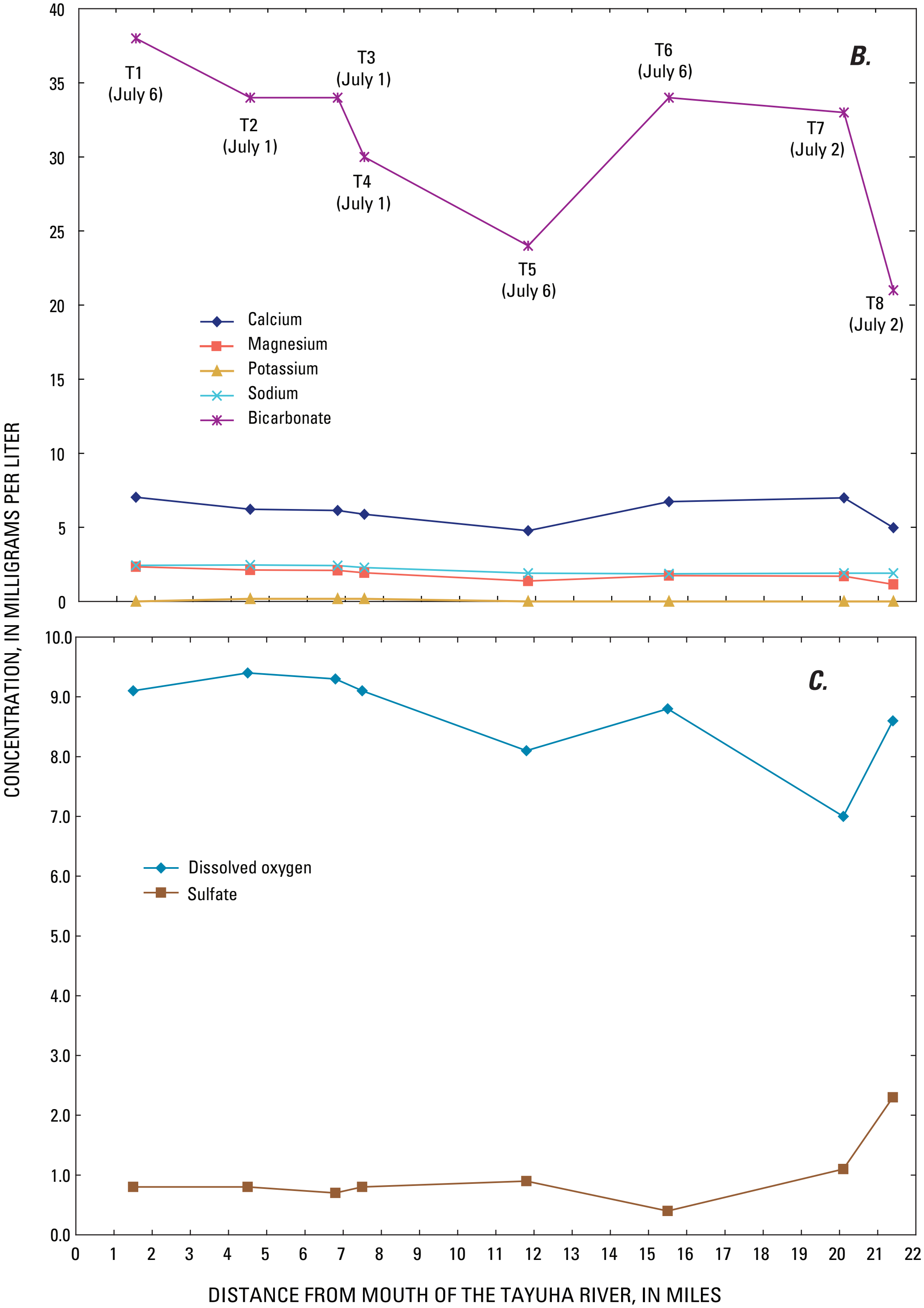


Figure 3. Discharge and concentrations of major ions, dissolved oxygen, nutrients, organic carbon, and nitrogen isotope of nitrate ($\delta^{15}N$) at Tahuya River sampling sites during summer base-flow conditions, southern part of Hood Canal, Mason and Kitsap Counties, Washington, July 2004.



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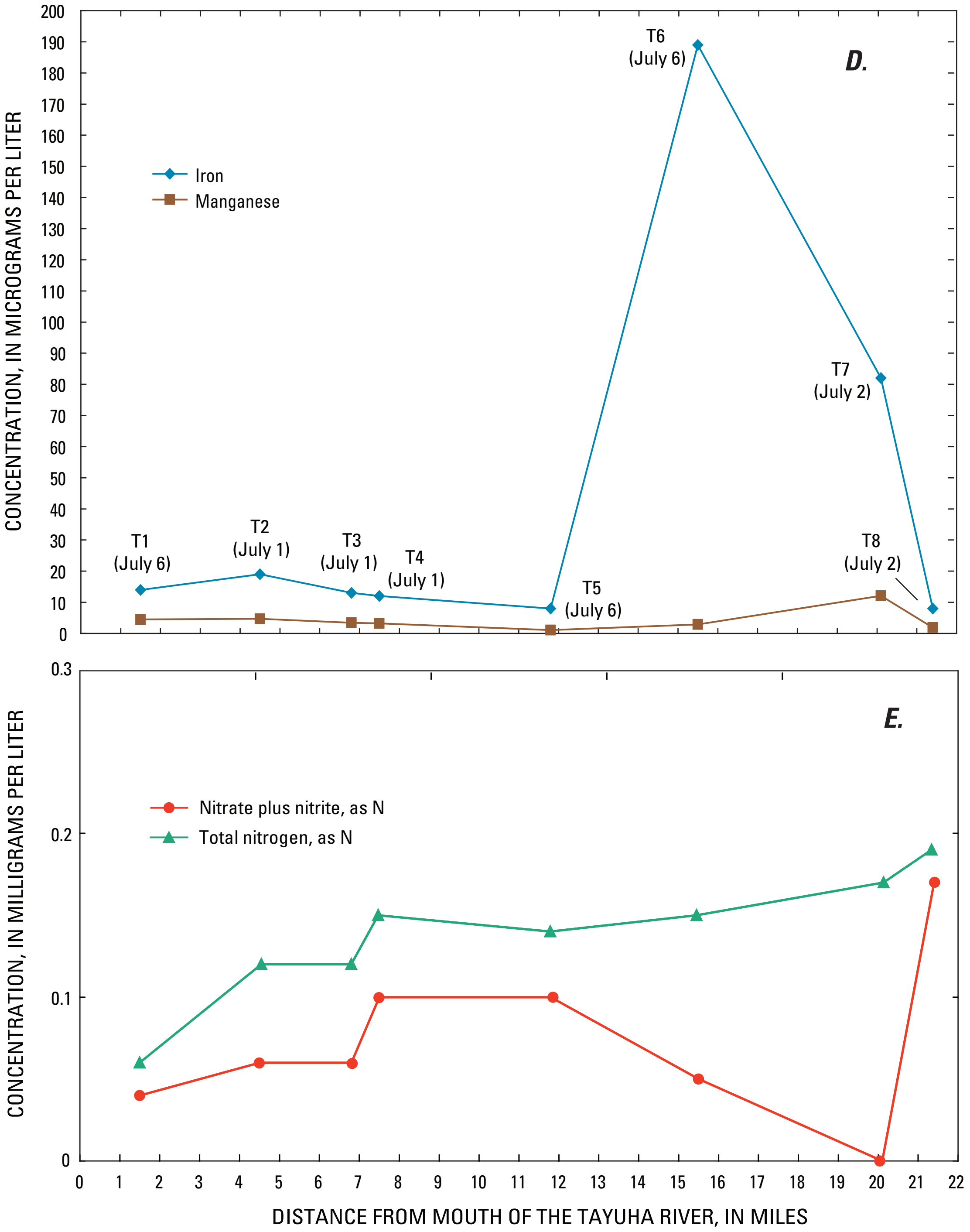

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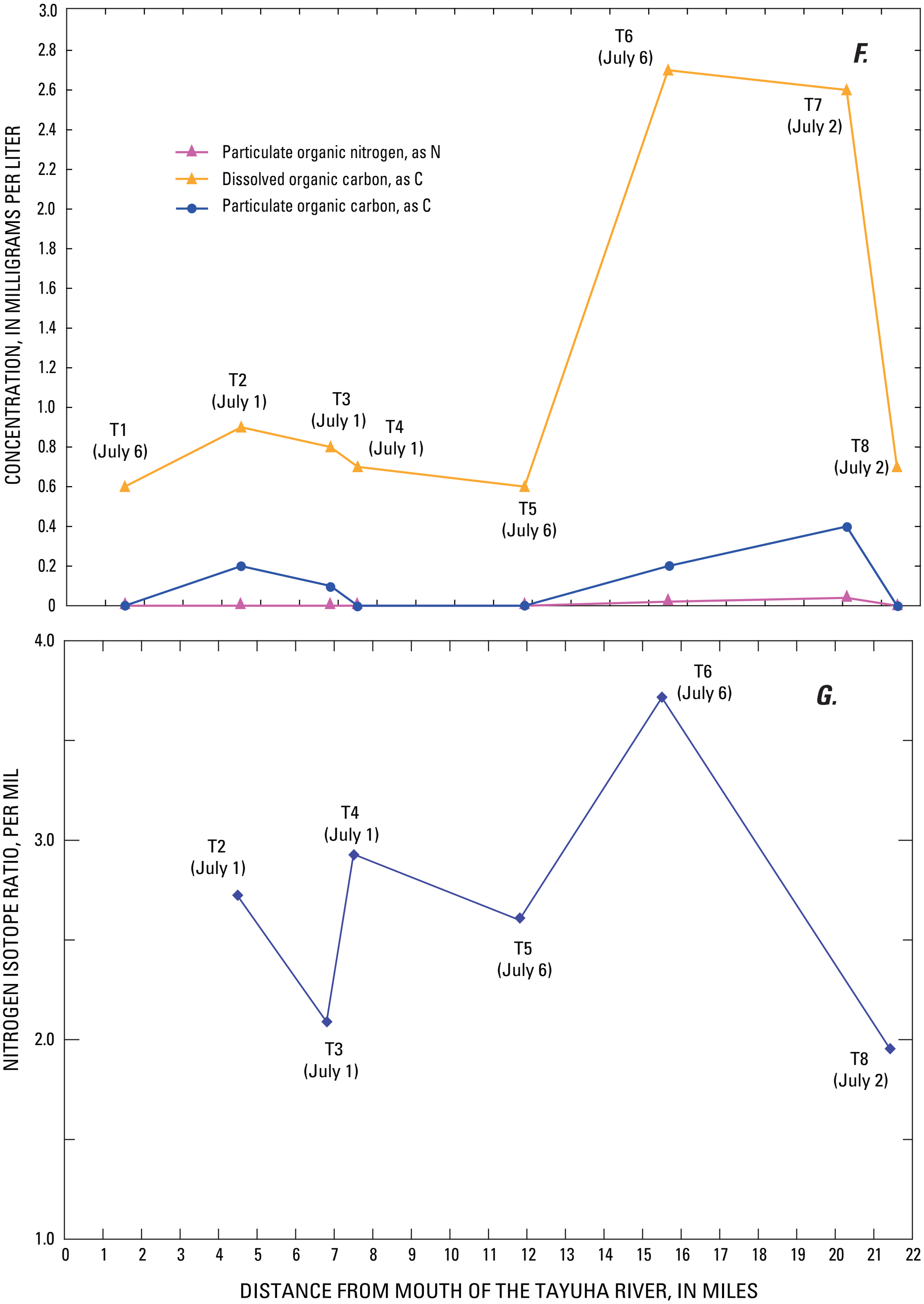

Figure 3.—Continued.

Table 2. Field measurements and concentrations of major ions, nutrients, organic carbon, suspended sediment, and nitrogen isotope of nitrate ($\delta^{15}N$) collected at Tahuya River sampling sites during summer base-flow conditions, southern part of Hood Canal, Mason and Kitsap Counties, Washington, June 2004.

[Locations of sampling sites are shown in figure 1. **Abbreviations**: USGS, U.S. Geological Survey; $CaCO_3$; calcium carbonate; HCO_3, bicarbonate; N, nitrogen; P, phosphorus; $\delta^{15}N$, isotope fractionation of N (see equation 1). ft^3/s, cubic foot per second; mg/L, milligram per liter; µS/cm, microsiemen per centimeter at 25°C; °C, degrees Celsius; µg/L, microgram per liter; ^{e}, estimated value; <, less than]

Map No.	USGS site No.	Sample date	Distance from mouth of Tahuya River (miles)	Discharge, instantaneous (ft^3/s)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µS/cm)	Temperature (°C)	Calcium (mg/L)	Magnesium (mg/L)
T1	12068020	07-06-04	1.5	16.4	9.1	7.3	65	13.8	7.03	2.34
T2	12067900	07-01-04	4.5	8.8	9.4	7.9	60	16.4	6.22	2.12
T3	12067800	07-01-04	6.8	8.4	9.3	7.8	60	16.2	6.14	2.09
T4	12067700	07-01-04	7.5	6.6	9.1	7.8	57	15.5	5.88	1.93
T5	12067600	07-06-04	11.8	1.1	8.1	7.2	46	14.8	4.77	1.38
T6	12067300	07-06-04	15.5	.27	8.8	7.6	57	16.8	6.74	1.74
T7	12065800	07-02-04	20.1	1.6	7.0	7.4	60	21.9	6.99	1.70
T8	12065600	07-02-04	21.4	.11	8.6	6.8	46	11.4	4.97	1.15

Map No.	USGS site No.	Sample date	Potassium (mg/L)	Sodium (mg/L)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate (mg/L as HCO_3)	Bromide (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)
T1	12068020	07-06-04	^{e}0.15	2.43	31	38	<0.02	1.27	<0.2	13.9
T2	12067900	07-01-04	.17	2.46	29	34	<.02	1.34	<.2	13.8
T3	12067800	07-01-04	.18	2.42	28	34	<.02	1.24	<.2	14.2
T4	12067700	07-01-04	.18	2.29	25	30	<.02	1.29	<.2	13.8
T5	12067600	07-06-04	^{e}.09	1.91	20	24	<.02	1.27	<.2	11.6
T6	12067300	07-06-04	^{e}.09	1.87	28	34	<.02	1.03	<.2	7.81
T7	12065800	07-02-04	<.16	1.90	27	33	<.03	1.32	<.2	2.64
T8	12065600	07-02-04	<.16	1.90	18	21	<.02	1.29	<.2	10.8

Map No.	USGS site No.	Sample date	Sulfate (mg/L)	Dissolved solids (mg/L)	Ammonia (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Particulate-N (mg/L)	Orthophosphate (mg/L as P)	Total nitrogen (mg/L)	Total carbon, particulate (mg/L)
T1	12068020	07-06-04	0.8	45	<0.04	^{e}0.04	<0.02	<0.02	0.06	<0.1
T2	12067900	07-01-04	.8	45	<.04	.06	<.02	<.02	.12	.2
T3	12067800	07-01-04	.7	51	<.04	^{e}.06	<.02	<.02	.12	.1
T4	12067700	07-01-04	.8	47	<.04	.1	<.02	<.02	.15	<.1
T5	12067600	07-06-04	.9	34	<.04	.1	<.02	<.02	.14	<.1
T6	12067300	07-06-04	.4	46	<.04	^{e}.05	.02	<.02	.15	.2
T7	12065800	07-02-04	1.1	39	<.04	<.06	.04	<.02	.17	.4
T8	12065600	07-02-04	2.3	30	<.04	.17	<.02	<.02	.19	<.1

Map No.	USGS site No.	Sample date	Inorganic carbon, particulate (mg/L)	Organic carbon, particulate (mg/L)	Organic carbon, dissolved (mg/L)	Iron (µg/L)	Manganese (µg/L)	Suspended sediment (mg/L)	$\delta^{15}N$ (per mil)
T1	12068020	07-06-04	<0.1	<0.1	0.6	14	4.5	1	[1]4.10
T2	12067900	07-01-04	<.1	.2	.9	19	4.7	2	2.72
T3	12067800	07-01-04	<.1	.1	.8	13	3.4	1	2.09
T4	12067700	07-01-04	<.1	<.1	.7	12	3.2	1	2.93
T5	12067600	07-06-04	<.1	<.1	.6	8	1.1	1	2.60
T6	12067300	07-06-04	<.1	.2	2.7	189	2.9	2	3.72
T7	12065800	07-02-04	<.1	.4	2.6	82	12.1	1	–
T8	12065600	07-02-04	<.1	<.1	.7	8	1.9	<.5	1.96

[1] Data values are highly uncertain.

Skokomish River

The eight sites sampled on the Skokomish River also were selected based on changes in predominant land use. Six of the eight sites are located on a transect that included the North Fork and mainstem of Skokomish River. The farthest upstream site is located above Lake Cushman (site S6), which is a reservoir that regulates flow to the river within the pristine Olympic National Park, with subsequent sites being affected by agricultural practices. The two additional sites are located on the South Fork Skokomish (S4b) and Unnamed Creek at Purdy-Cutoff Road (S2b), a small tributary just upstream of site S2. Samples were collected on 4 days between July 9 and August 4, 2004.

Streamflow generally tends to increase downstream of Lake Cushman. Discharge increased significantly in the mainstem downstream of the confluence of the North and South Forks.

Several trends in the concentrations of major cations are apparent. Concentrations of ions that increased in the downstream direction include sodium, magnesium, chloride, and silica, while calcium and sulfate decreased (figs. 4*B* and 4*C* and table 3). Dissolved manganese and iron concentrations increased significantly downstream of the confluence of the North and South Forks (fig. 4*D*).

The concentrations of nitrate plus nitrite were less than the detection limit at all sites in the North Fork and mainstem of the Skokomish River. Concentrations of particulate nitrogen and suspended sediment peaked at site S5, just downstream of Lake Cushman diversion, and decreased downstream (table 3). Concentrations of total nitrogen ranged from the detection limit of 0.03 to 0.06 mg/L (fig. 4*E*). Concentrations of DOC ranged from 0.4 to 0.7 mg/L (fig. 4*F*).

Concentrations of silica, calcium, magnesium, sodium, bicarbonate, and chloride were higher in samples from the South Fork Skokomish River (site S4b) relative to the North Fork (site S4a). The only ionic species with higher concentrations in the North Fork were sulfate and manganese. Inorganic nutrients were not detected in the South Fork, however, the concentration of total nitrogen was higher in the South Fork (0.09 mg/L) relative to the North Fork (0.06 mg/L). The concentration of dissolved organic carbon was 0.7 mg/L, which was similar to the North Fork.

Concentrations of most constituents at the Unnamed Creek at Purdy-Cutoff Road (S2b) were higher than the Skokomish River, except for sulfate and dissolved organic carbon. However, the overall contribution by this tributary on Skokomish River loads was negligible because of its low discharge (0.84 ft^3/s).

Table 3. Field measurements and concentrations of major ions, nutrients, organic carbon, suspended sediment, and nitrogen isotope of nitrate ($\delta^{15}N$) collected at Skokomish River sampling sites during summer base-flow conditions, southern part of Hood Canal, Mason and Kitsap Counties, Washington, July and August 2004.

[Locations of sampling sites are shown in figure 1. **Abbreviations**: USGS, U.S. Geological Survey; $CaCO_3$; calcium carbonate; HCO_3, bicarbonate; N, nitrogen; P, phosphorus; $\delta^{15}N$, isotope fractionation of nitrogen (see equation 1). ft^3/s, cubic foot per second; mg/L, milligram per liter; µg/L, microgram per liter; µS/cm, microsiemen per centimeter at 25°C; °C, degrees Celsius; ^{e}, estimated value; <, less than; –, not available]

Map No.	USGS site No.	Sample date	Distance from mouth (miles)	Discharge, instantaneous (ft^3/s)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µS/cm)	Water temperature (°C)	Calcium (mg/L)	Magnesium (mg/L)
Mainstem and North Fork										
S1	12062515	07-09-04	0.65	396	10.3	7.4	82	10.8	9.09	2.50
S2	12062510	07-09-04	1.4	376	10.9	7.7	77	11.2	8.64	2.36
S3	12061500	07-09-04	4.4	323	10.8	7.7	75	12.7	8.78	2.17
S4a	12059500	07-12-04	9.4	72	11.3	7.5	66	12.7	8.45	1.35
S5	12058800	08-04-04	15.9	64	10.6	7.5	63	11.1	9.42	1.03
S6	12056500	07-15-04	28.9	162	10.8	8.0	87	11.7	14.2	.925
Unnamed Creek at Purdy-Cutoff Road										
S2b	12062508	08-04-04	2	.84	11.2	7.6	112	9.8	11.6	5.31
South Fork										
S4b	12060500	07-12-04	11.5	124	10.7	7.5	76	13.1	10.2	1.83

Table 3. Field measurements and concentrations of major ions, nutrients, organic carbon, suspended sediment, and nitrogen isotope of nitrate ($\delta^{15}N$) collected at Skokomish River sampling sites during summer base-flow conditions, southern part of Hood Canal, Mason and Kitsap Counties, Washington, July and August 2004.—Continued

[Locations of sampling sites are shown in figure 1. **Abbreviations**: USGS, U.S. Geological Survey; $CaCO_3$; calcium carbonate; N, nitrogen; NO_2+NO_3, nitrite plus nitrate; P, phosphorus; $\delta^{15}N$, isotope fractionation of nitrogen (see equation 1). ft^3/s, cubic foot per second; mg/L, milligram per liter; µg/L, microgram per liter; µS/cm, microsiemen per centimeter at 25°C; °C, degrees Celsius; ^{e}, estimated value; <, less than; –, not available]

Map No.	USGS site No.	Sample date	Potassium (mg/L)	Sodium (mg/L)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate (mg/L as HCO_3)	Bromide (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)
Mainstem and North Fork										
S1	12062515	07-09-04	0.16	2.90	36	45	<0.02	2.34	<0.2	14.6
S2	12062510	07-09-04	^{e}.14	2.43	36	44	^{e}.01	1.76	<.2	14.6
S3	12061500	07-09-04	^{e}.15	2.24	34	42	^{e}.01	1.72	<.2	13.4
S4a	12059500	07-12-04	^{e}.13	1.97	27	32	<.02	1.22	<.2	8.83
S5	12058800	08-04-04	^{e}.10	1.40	28	34	<.02	.88	<.2	5.84
S6	12056500	07-15-04	.18	1.78	35	43	<.02	.73	<.2	5.5
Unnamed Creek at Purdy-Cutoff Road										
S2b	12062508	08-04-04	.41	3.04	51	62	<.02	3.06	<.2	19.9
South Fork										
S4b	12060500	07-12-04	^{e}.15	2.17	32	38	<.02	2.35	<.2	10.5

Map No.	USGS site No.	Sample date	Sulfate (mg/L)	Dissolved solids (mg/L)	Ammonia (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Particulate-N (mg/L)	Orthophosphate (mg/L as P)	Total nitrogen (mg/L)	Total carbon, particulate (mg/L)
Mainstem and North Fork										
S1	12062515	07-09-04	1.6	56	<0.04	<0.06	0.02	<0.02	0.03	<0.1
S2	12062510	07-09-04	1.5	56	<.04	E.03	.03	<.02	.04	.2
S3	12061500	07-09-04	1.6	62	<.04	<.06	<.02	<.02	<.03	.1
S4a	12059500	07-12-04	3.0	44	<.04	<.06	<.02	<.02	.06	<.1
S5	12058800	08-04-04	3.5	35	<.04	<.06	.04	<.02	<.03	.3
S6	12056500	07-15-04	6.3	61	<.04	<.06	<.02	<.006	[1].03	<.1
Unnamed Creek at Purdy-Cutoff Road										
S2b	12062508	08-04-04	1.4	78	<.04	.49	.14	.02	.52	3.1
South Fork										
S4b	12060500	07-12-04	2.0	50	<.04	<.06	<.02	<.02	.09	<.1

Map No.	USGS site No.	Sample date	Inorganic carbon, particulate (mg/L)	Organic carbon, particulate (mg/L)	Organic carbon, dissolved (mg/L)	Iron (µg/L)	Manganese (µg/L)	Suspended sediment (mg/L)	$\delta^{15}N$ (per mil)
Mainstem and North Fork									
S1	12062515	07-09-04	<0.1	<0.1	0.6	21	28.1	<0.5	[2]3.13
S2	12062510	07-09-04	<.1	.2	.7	20	16.8	1	5.43
S3	12061500	07-09-04	<.1	.1	.5	11	4.0	<.5	[2]1.39
S4a	12059500	07-12-04	<.1	<.1	.7	^{e}5	1.4	2	[2]1.09
S5	12058800	08-04-04	<.1	.3	.7	<6	^{e}.5	4	–
S6	12056500	07-15-04	<.1	<.1	.4	<6	<.8	1	[2]-.78
Unnamed Creek at Purdy-Cutoff Road									
S2b	12062508	08-04-04	<.1	3.1	.3	<6	^{e}.6	6	–
South Fork									
S4b	12060500	07-12-04	<.1	<.1	.7	<6	<.8	<.5	[2]9.60

[1] Resulting concentration from an unfiltered sample.

[2] Data values are highly uncertain.

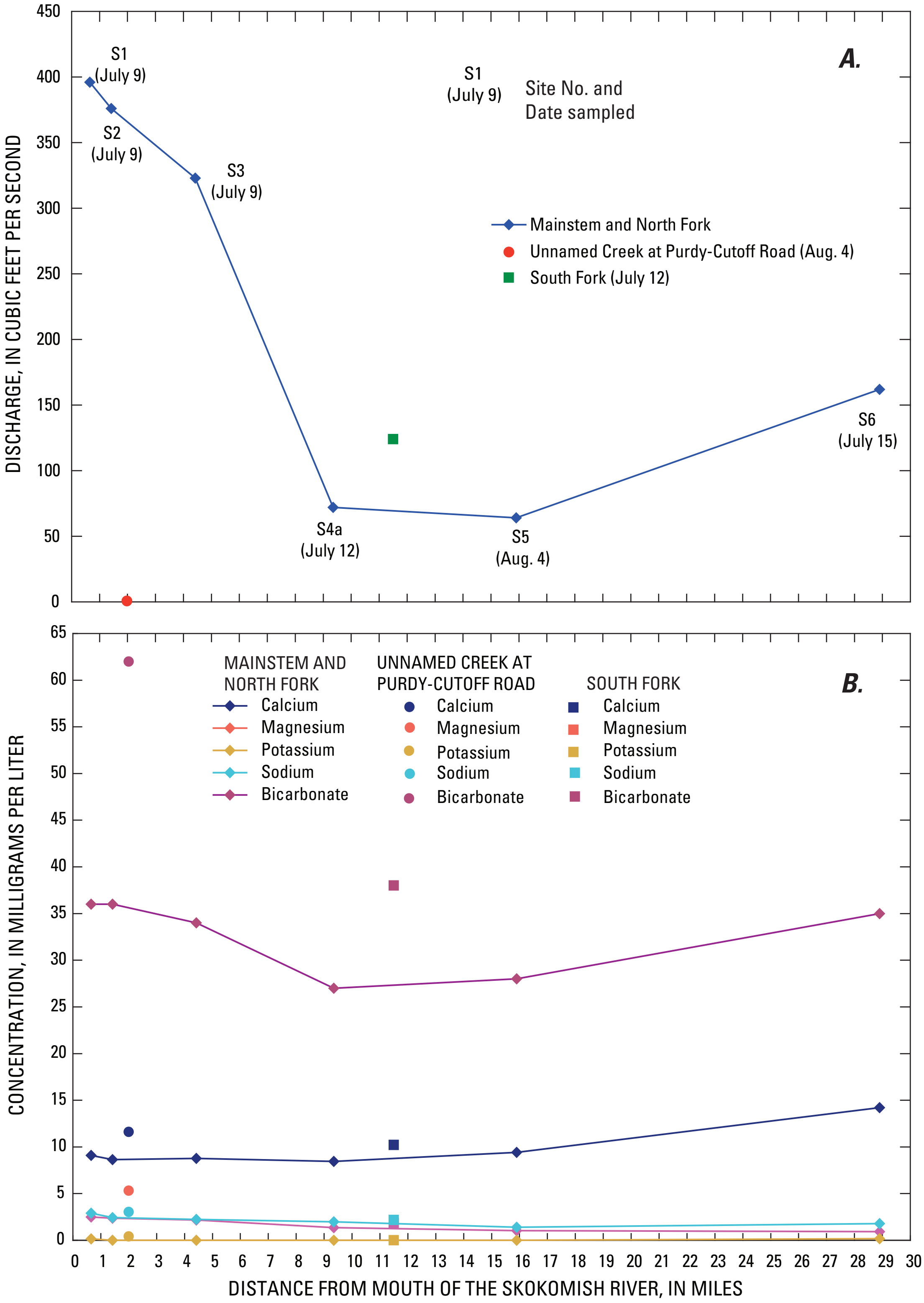

Figure 4. Discharge and concentrations of major ions, dissolved oxygen, nutrients, and organic carbon at Skokomish River sampling sites during summer base-flow conditions, southern part of Hood Canal, Mason and Kitsap Counties, Washington, July and August 2004.

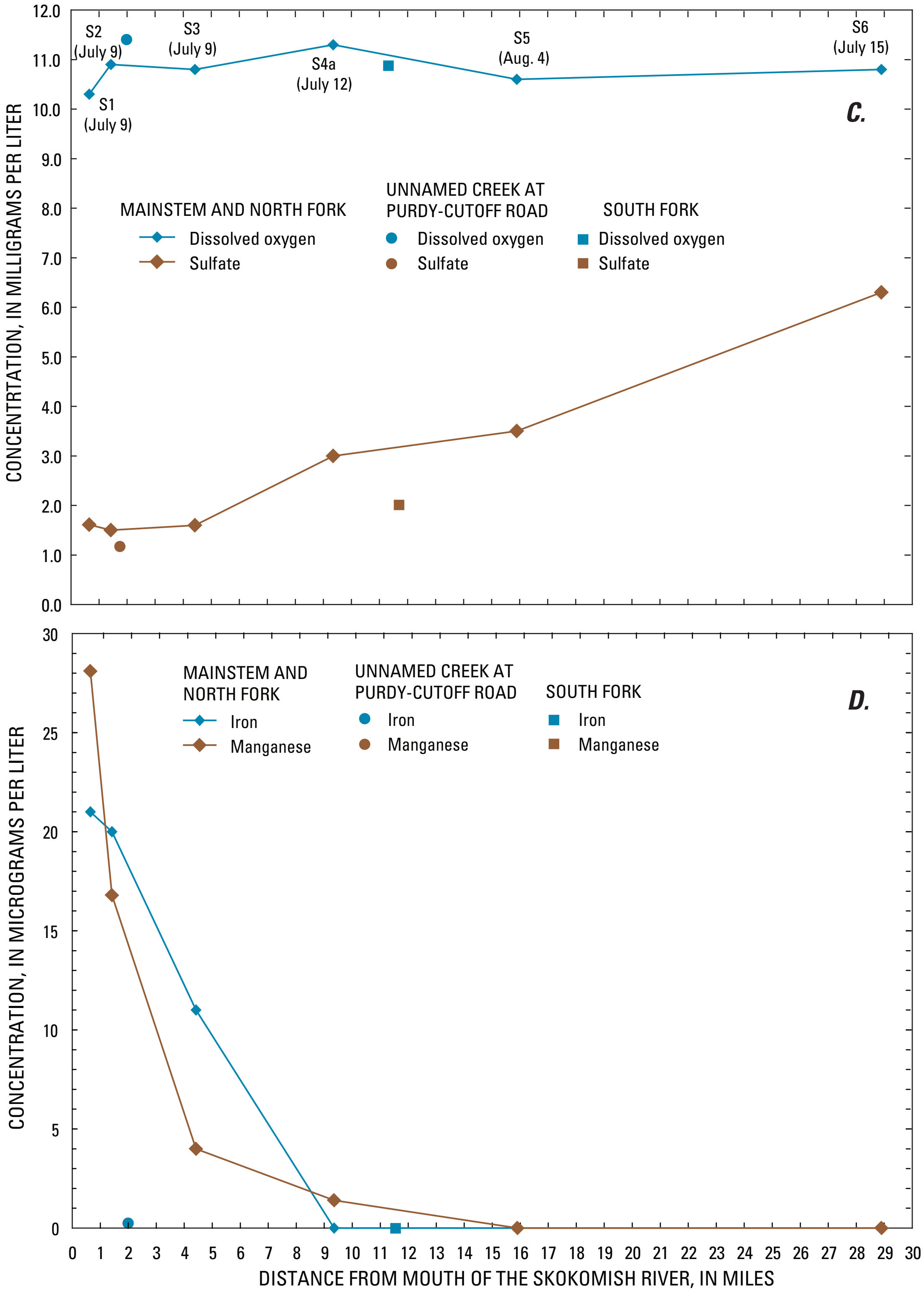

Figure 4.—Continued.

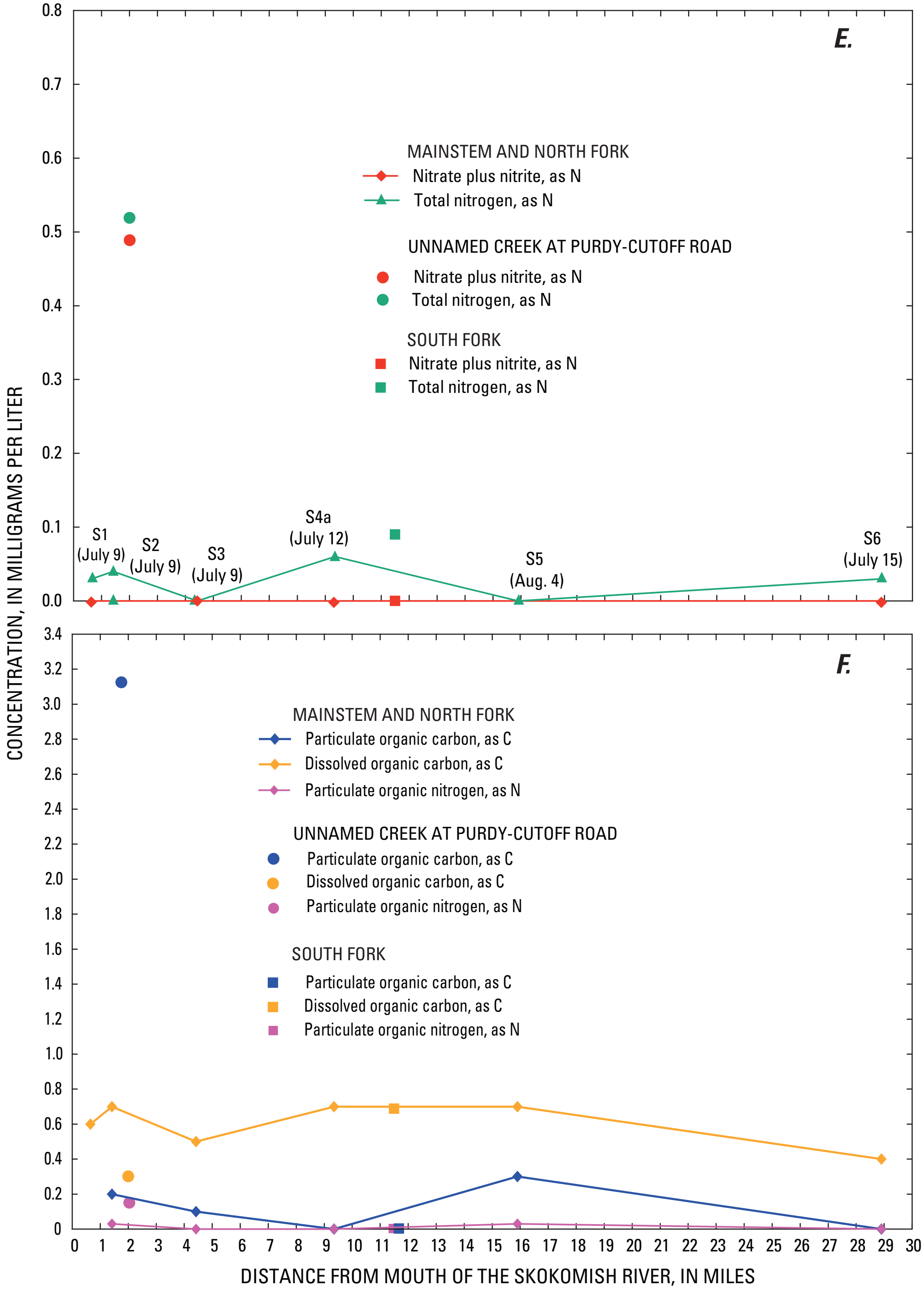

Figure 4.—Continued.

Springtime Sampling

During periods of rainfall and increased runoff, larger amounts of sediment and nutrients may be transported from the land surface into the surface water. Therefore, samples were collected in the spring (March) 2004 at six sites, the Tahuya River, Union River, Mission Creek, Stimpson Creek, Twanoh Falls Creek, and an unnamed creek below Lake Devereaux (fig. 1). Sites were selected because of their proximity and contribution to Lynch Cove. Ideally samples should be collected during periods of heavy rainfall and increased streamflow, however, due to time constraints, springtime samples were collected during moderate rain events and not necessarily during peaks in the hydrograph.

Concentrations of nutrients and suspended sediment collected in the spring at all six sites were low. The nitrate plus nitrite concentrations ranged from 0.11 to 0.4 mg/L. Dissolved organic carbon concentrations ranged from 1.0 to 3.3 mg/L (table 4). The site downstream of Lake Devereaux (SP5) contained the highest nutrient concentrations of all sites sampled in March, with nitrate plus nitrite and DOC concentrations of 0.40 and 3.3 mg/L, respectively.

Because of the timing of sampling sites U1 and T1, that are at the mouths of relatively large rivers (Tahuya and Union), little to no difference was observed in the nutrient concentrations between samples collected in the spring and in the summer.

Table 4. Field measurements and concentrations of nutrients, organic carbon, and suspended-sediment collected at six sampling sites during spring, southern part of Hood Canal, Mason County, Washington, March 2004.

[Locations of sampling sites are shown in figure 1. **Abbreviations:** USGS, U.S. Geological Survey; mg/L, milligram per liter; µS/cm, microsiemen per centimeter at 25°C; °C, degrees Celsius; N, nitrogen; <, less than; –, not available]

Map No.	USGS site No.	Sample date	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µS/cm)	Water temperature (°C)	Ammonia (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Particulate-N (mg/L)
U1	12063520	03-18-04	11.0	7.8	98	9.9	<0.04	0.28	<0.02
SP2	12065010	03-18-04	12.0	7.7	56	8.6	<.04	.16	<.02
SP3	12065100	03-25-04	11.3	7.4	55	8.0	<.04	.14	.04
SP4	12062550	03-18-04	11.9	7.2	66	8.5	<.04	.12	<.02
SP5	12062560	03-25-04	10.9	7.0	53	8.0	<.04	.4	.02
T1	12068020	03-25-04	10.8	7.2	46	8.5	<.04	.11	.02

Map No.	USGS site No.	Sample date	Total nitrogen (mg/L)	Total carbon, particulate (mg/L)	Inorganic carbon, particulate (mg/L)	Organic carbon, particulate (mg/L)	Organic carbon, dissolved (mg/L)	Suspended sediment (mg/L)
U1	12063520	03-18-04	0.33	0.2	<0.1	0.2	2.5	4
SP2	12065010	03-18-04	.21	.4	<.1	.4	–	3
SP3	12065100	03-25-04	.20	.8	<.1	.7	2.9	8
SP4	12062550	03-18-04	.16	<.1	<.1	<.1	1.0	1
SP5	12062560	03-25-04	.49	.5	<.1	.5	3.3	7
T1	12068020	03-25-04	.15	.3	<.1	.3	1.7	9

Summary

Samples were collected in the summer from sampling sites on the Union, Tahuya, and Skokomish Rivers between June and August 2004 and samples were collected in the spring from the Union River, Tahuya River, Mission Creek, and three smaller drainage basins in March 2004. Concentrations of nutrients at all sites were low. Ammonia and orthophosphate concentrations were less than the detection limit for most samples, and nitrate plus nitrite concentrations ranged from less than the detection limit of 0.06 to 0.49 mg/L. Concentrations of nitrate plus nitrite were near the detection limit of 0.06 mg/L in the North Fork, South Fork, and mainstem of the Skokomish River. Concentrations of nitrate plus nitrite in the Tahuya River system upstream of Lake Tahuya was 0.17 mg/L, but decreased to 0.10 mg/L or less downstream of Lake Tahuya. Overall, concentrations of nitrate plus nitrite were highest in the Union River ranging from 0.12 to 0.28 mg/L. $\delta^{15}N$ generally fell within the range that encompasses most sources, providing little information on nitrate sources. The $\delta^{15}N$ values increased slightly downstream on the Union River and decreased on the Tahuya River downstream of Lake Tahuya. Most nitrogen in the Union, Tahuya, and Skokomish Rivers was in the dissolved inorganic form. Dissolved organic carbon concentrations in the Tahuya and Skokomish Rivers averaged 0.2 and 0.5 mg/L, respectively, although the concentrations in the Union River averaged 1.3 mg/L. There was little difference in nutrient concentrations at sites U1 and T1 between samples collected in the spring and during summer base-flow conditions.

Lake Tahuya significantly modified the biogeochemistry of nitrogen in the Tahuya River drainage basin. In Lake Tahuya, inorganic nitrogen was converted into particulate and organic nitrogen. Dissolved organic carbon concentrations of 2.6 to 2.7 mg/L were highest downstream of Lake Tahuya, and then decreased to concentrations less than 1 mg/L similar to concentrations in the Skokomish River. Downstream of Lake Tahuya, concentrations of the redox-sensitive ions manganese and iron were elevated in the Tahuya River at sites T7 and T6, suggesting a biogeochemical coupling with the organic matter produced in Lake Tahuya. Iron and manganese concentrations also were elevated in the Union River at sites U3 and U4, as well as for the two sites (S1 and S2) at the mouth of the Skokomish River.

Total nitrogen concentrations near 0.5 mg/L were measured at only two sites: Unnamed Creek at Purdy-Cutoff Road (site S2b) and downstream of Lake Devereaux (site SP5). Nitrate plus nitrite concentrations were highest at site S2b (0.49 mg/L), and dissolved organic carbon concentrations were highest at site SP5 (3.3 mg/L). However, the overall impact by these sites on the nutrient loading to Hood Canal probably is negligible because of their low-flow rates.

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Table 5. Concentrations of major ions, nutrients, organic carbon, and suspended sediment for quality-control samples collected at river and stream sites during summer base-flow conditions and springtime sampling, southern part of Hood Canal, Mason and Kitsap Counties, Washington.

[Location of sampling sites are shown in figure 1. **Sample type:** B, field blank sample; R, replicate sample; E, environmental sample. N, nitrogen; P, phosphorus. **Abbreviations**: USGS, U.S. Geological Survey; $\delta^{15}N$, isotope fractionation of N (see equation 1). mg/L, milligram per liter; µg/L, microgram per liter; [e], estimated value; <, less than; –, not available]

Map No.	USGS site No.	Sample date	Sample type	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Bromide (mg/L)	Chloride (mg/L)
U4	12063300	06-30-04	R	11	4.46	0.24	3.84	<0.02	2.18
			E	10.9	4.44	.23	3.80	<.02	2.14
T2	12067900	07-01-04	B	[e].01	<.008	<.16	<.10	<.02	<.20
T6	12067300	07-06-04	B	.01	<.008	<.16	<.10	<.02	<.20
S2	12062510	07-09-04	R	8.86	2.42	[e].13	2.45	<.02	1.75
			E	8.64	2.36	[e].14	2.43	[e].01	1.76
S6	12056500	05-06-04	B	–	–	–	–	–	–
SP5	12062560	03-25-04	B	–	–	–	–	–	–

Map No.	USGS site No.	Sample date	Fluoride (mg/L)	Silica (mg/L)	Sulfate (mg/L)	Dissolved solids (mg/L)	Ammonia (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Nitrite (mg/L as N)
U4	12063300	06-30-04	<0.2	20.7	1.9	77	<0.04	0.18	–
			<.2	20.5	1.9	87	<.04	.17	–
T2	12067900	07-01-04	<.2	<.04	<.2	<10	<.04	<.06	–
T6	12067300	07-06-04	<.2	<.04	<.2	<10	<.04	<.06	–
S2	12062510	07-09-04	<.2	14.5	1.5	53	<.04	<.06	–
			<.2	14.6	1.5	56	<.04	[e].03	–
S6	12056500	05-06-04	–	–	–	–	<.04	<.06	<0.008
SP5	12062560	03-25-04	–	–	–	–	<.04	<.06	–

Map No.	USGS site No.	Sample date	Particulate-N (mg/L)	Orthophosphate (mg/L)	Phosphorus (mg/L as P)	Total nitrogen (mg/L)	Total carbon, particulate (mg/L)	Inorganic carbon, particulate (mg/L)	Organic carbon, particulate (mg/L)
U4	12063300	06-30-04	<0.02	<0.02	–	0.28	0.2	<0.1	0.2
			<.02	<.02	–	.27	.3	<.1	.3
T2	12067900	07-01-04	<.02	<.02	–	<.03	<.1	<.1	<.1
T6	12067300	07-06-04	<.02	<.02	–	<.03	<.1	<.1	<.1
S2	12062510	07-09-04	<.02	<.02	–	.05	<.1	<.1	<.1
			.03	<.02	–	.04	.2	<.1	.2
S6	12056500	05-06-04	–	[1]<.006	[1]<.004	<.03	–	–	–
SP5	12062560	03-25-04	<.02	–	–	<.03	<.1	<.1	<.1

Map No.	USGS site No.	Sample date	Organic carbon, dissolved (mg/L)	Iron (µg/L)	Manganese (µg/L)	Suspended sediment (mg/L)	$\delta^{15}N$ (per mil)
U4	12063300	06-30-04	1.9	133	21.9	2	3.03
			1.9	125	21.7	2	2.95
T2	12067900	07-01-04	[e].2	<6	<.8	1	–
T6	12067300	07-06-04	[e].3	<6	<.8	<.5	–
S2	12062510	07-09-04	.6	21	16.8	1	4.75
			.7	20	16.8	<.5	5.43
S6	12056500	05-06-04	–	–	–	–	–
SP5	12062560	03-25-04	.4	–	–	<.5	–

[1] Resulting concentration from an unfiltered sample.

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