In cooperation with the National Park Service

Hydrologic, Water-Quality, and Biological Characteristics of the North Fork Flathead River, Montana, Water Years 2007–2008

Scientific Investigations Report 2011–5221

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

Cover. North Fork of the Flathead River near Glacier National Park, Montana (photograph by Billy Schweiger, National Park Service).

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Conversion Factors and Abbreviations

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
yard (yd)	0.9144	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Altitude, as used in this report, refers to distance above the vertical datum.

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

Turbidity is given in nephelometric turbidity units (NTU).

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

Water year is defined in this report as the 12-month period October 1 through September 30, designated by the calendar year in which it ends.

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Abstract

In water year 2007, the U.S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), began a 2-year study to collect hydrologic, water-quality, and biological data to provide a baseline characterization of the North Fork Flathead River from the United States-Canada border to its confluence with the Middle Fork of the Flathead River near Columbia Falls, Mont. Although mining in the Canadian portion of the North Fork Basin was banned in 2010 by a Memorandum of Understanding issued by the Province of British Columbia, baseline characterization was deemed important for the evaluation of any potential future changes in hydrology, water quality, or aquatic biology in the basin. The North Fork Basin above Columbia Falls (including Canada) drains an area of 1,564 square miles, and the study area encompasses the portion of the basin in Montana, which is 1,126 square miles. Seasonal patterns in the hydrology of the North Fork are dominated by the accumulation and melting of seasonal snowpack in the basin. Low-flow conditions occurred during the late-summer, fall, and winter months, and high-flow conditions coincided with the spring snowmelt. Substantial gains in streamflow occurred along the study reach of the North Fork, 85 percent of which were accounted for by tributary inflows during low-flow conditions, indicating unmeasured streamflow inputs along the main stem were 15 percent or less.

Specific conductance exhibited an inverse relation to streamflow in the North Fork due to the influx of dilute snowmelt water during high-flow conditions. Additionally, median specific conductance during the study was greater at the Flathead River at Flathead British Columbia gaging station (USGS station 12355000; referred to in this report as “Border”) than at the Columbia Falls station (USGS station 12355500; referred to in this report as “Columbia Falls”) due to dilution in the main stem by low-conductivity tributary inputs south of Border. Similar to specific conductance, concentrations of major ions had an inverse relation to streamflow and generally decreased in the North Fork in a downstream direction between Border and Columbia Falls. Additionally, water-quality data collected during the study generally indicate that calcium, magnesium, and alkalinity are the dominant solutes in the North Fork.

Nutrient (nitrogen and phosphorous compounds) concentrations exhibited a different seasonal pattern than that of major ions, reflecting the differences in sources. Total nitrogen and total phosphorus (dissolved plus particulate) concentrations at Border and Columbia Falls were near or below their respective analytical reporting levels during the winter months but increased during spring snowmelt. The increased total nitrogen concentrations during spring snowmelt are likely not related to anthropogenic activities in the basin; rather, they are attributed to atmospheric deposition of nitrate during the winter months and subsequent release from the snowpack in the spring. Total phosphorous concentrations varied with the amount of suspended sediment in the stream, which increases substantially with streamflow in the North Fork.

Trace-element concentrations at Border and Columbia Falls were near or below their respective analytical reporting levels for much of the year, but became elevated during high-flow conditions. Because trace-element samples were unfiltered, the elevated concentrations during snowmelt are likely associated with increased concentrations of suspended sediment during this time. Generally, variability in loading of most major ions among tributaries corresponded with variations in streamflow. However, tributary sulfate loads varied with concentration, reflecting the presence of an unidentified sulfate source in the northern tributaries.

Trend analysis was performed on data from Border and Columbia Falls and one additional long-term water-quality site on the North Fork. A significant, flow-adjusted, upward trend in specific conductance was detected at Columbia Falls for 1982–2008. Additionally, a significant flow-adjusted upward trend in concentrations of alkalinity was detected at the Flathead River QW site (a long-term water-quality site operated by Environment, Canada located north of the International Border) for 1979–1995, and significant flow-adjusted upward trends in, calcium and magnesium were detected at Border for 1974–1993. The magnitude of these trends is small, but it could be indicative of increasing weathering or erosion in the basin.

Diatom and macroinvertebrate samples were collected at Border and Columbia Falls. Despite elevated nutrient and lead concentrations during high-flow conditions, biological metrics do not indicate habitat impairment. However, some samples

did show signs of sediment impairment, but assemblage composition was largely intact and generally indicative of high-quality aquatic habitat. Further characterization of biologic assemblages in the region will likely aid in the development of bioassessment metrics specific to the North Fork.

Introduction

The North Fork Flathead River (North Fork) originates in the Province of British Columbia, Canada (where it is named the Flathead River), and flows 30 mi southward from its headwaters before crossing the international border into the State of Montana, United States (fig. 1). In Montana, the North Fork flows 56 mi to its confluence with the Middle Fork Flathead River, and forms the western boundary of Glacier National Park (GLAC). The North Fork Basin is part of the Crown of the Continent Ecosystem, which encompasses Glacier National Park and the Bob Marshall Wilderness Complex in Montana and Waterton Lakes National Park in Alberta, Canada, and constitutes one of the largest and most intact ecosystems in North America. Additionally, the North Fork valley provides habitat for many species of amphibians, fish, and aquatic birds, including the protected bull trout and bald eagle (Confederated Salish and Kootenai Tribes and Montana Fish, Wildlife and Parks, 2004).

Although the eastern portion of the North Fork Basin in Montana is protected land in GLAC, the western and Canadian portions of the basin are subject to land-use activities that could affect the water quality and biotic integrity of the North Fork. In 2009, the North Fork was declared fifth on the American Rivers list of the 10 most threatened rivers in the United States because of potential mining activity in the Canadian portion of the basin (American Rivers, 2009).

The East Kootenay coalfields underlie the Canadian headwaters of the North Fork and have been an area of active mineral exploration; several coal and coalbed methane developments were proposed during the early 2000s (Hauer and others, 2007). Coal and coalbed methane development can negatively affect water quality of the North Fork by increasing concentrations of suspended sediment, nutrients, and trace elements in the river (British Columbia Ministry of the Environment, 1978; International Joint Commission, 1988; Dalby, 1983; Appleman and others, 1990). In 2005, as a response to proposed energy development, an international meeting of scientists and resource managers was convened at the Crown of the Continent Synthesis Workshop; participants at the workshop identified baseline water-quality and biological data for the North Fork as a critical information gap (Hauer and Sexton, 2010). The Province of British Columbia issued a Memorandum of Understanding banning energy resource development activity in the North Fork Basin; the North Fork was subsequently removed from the American Rivers threatened list (Province of British Columbia, 2010; American Rivers, 2010). However, only limited restrictions have been placed on other land-use activities, such as clear-cut timber harvesting and residential development, which could affect the water quality of the North Fork.

Clear-cut timber harvesting activity was relatively widespread in the western tributaries of the North Fork Basin in Montana from 1960 to 2000 (Gildea and others, 2004). Currently (2011), nonintensive timber harvesting occurs throughout the Flathead National Forest on the western side of the North Fork Basin (Paul Donnellon, Operations – Timber Management Flathead National Forest, written commun., 2011). Additionally, population growth and related construction activities on private land in the western portion of the basin are of concern. Construction of access roads associated with residential development, and subsequent erosion of road material, can be a substantial source of suspended sediment to streams (Ahtiainen and Huttunen, 1999; Gildea and others, 2004). Waste material from forest harvesting and sewage effluent from residential developments can cause an increase in the concentrations of nutrients in receiving streams, resulting in a reduction in biodiversity and loss of species habitat (Harr and Fredriksen, 1988; Zampella, 1994; Carpenter and others, 1998; Hauer and others, 2007). Suspended sediment in spawning areas can cause a reduction in fish embryo survivorship (Confederated Salish and Kootenai Tribes and Montana Fish, Wildlife and Parks, 2004).

Nearly all of the major western tributaries of the North Fork have been previously listed on Montana’s 303(d) list as impaired for cold-water fisheries owing to sediment loading associated with erosion of unpaved roads. Adoption of “Best Management Practices” for timber harvesting and forestry roads in the North Fork Basin, as well as reclamation of clear-cut areas, has greatly reduced the associated effects on water quality (Hauer and others, 2007). As a result, many of the western tributaries have been removed from Montana’s 303(d) list (Gildea and others, 2004). Existing and potential future residential development in the North Fork valley also is of concern. The western portion of the North Fork Basin in Montana has become increasingly popular as a vacation destination, and construction of vacation homes on private land in the North Fork valley has increased by about tenfold over the past 20 years (Hauer and others, 2007). These developments could affect the water quality and aquatic biology of the North Fork.

The State of Montana has classified the water quality of the North Fork as Class A–1, the State’s highest water-quality classification, and has established a nondegradation standard for the river. An important step in assessing the water-quality effects of land-use changes in the North Fork Basin is to characterize baseline conditions for future comparison. In water year 2007, the U.S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), began a 2-year study to collect hydrologic, water-quality, and biological data to provide a baseline characterization of the North Fork from the United States-Canada Border to its confluence with the Middle Fork Flathead River near Columbia Falls, Mont. An additional study conducted by the Flathead Lake Biological Station in 2007 and 2008 assessed the potential effects from mining on

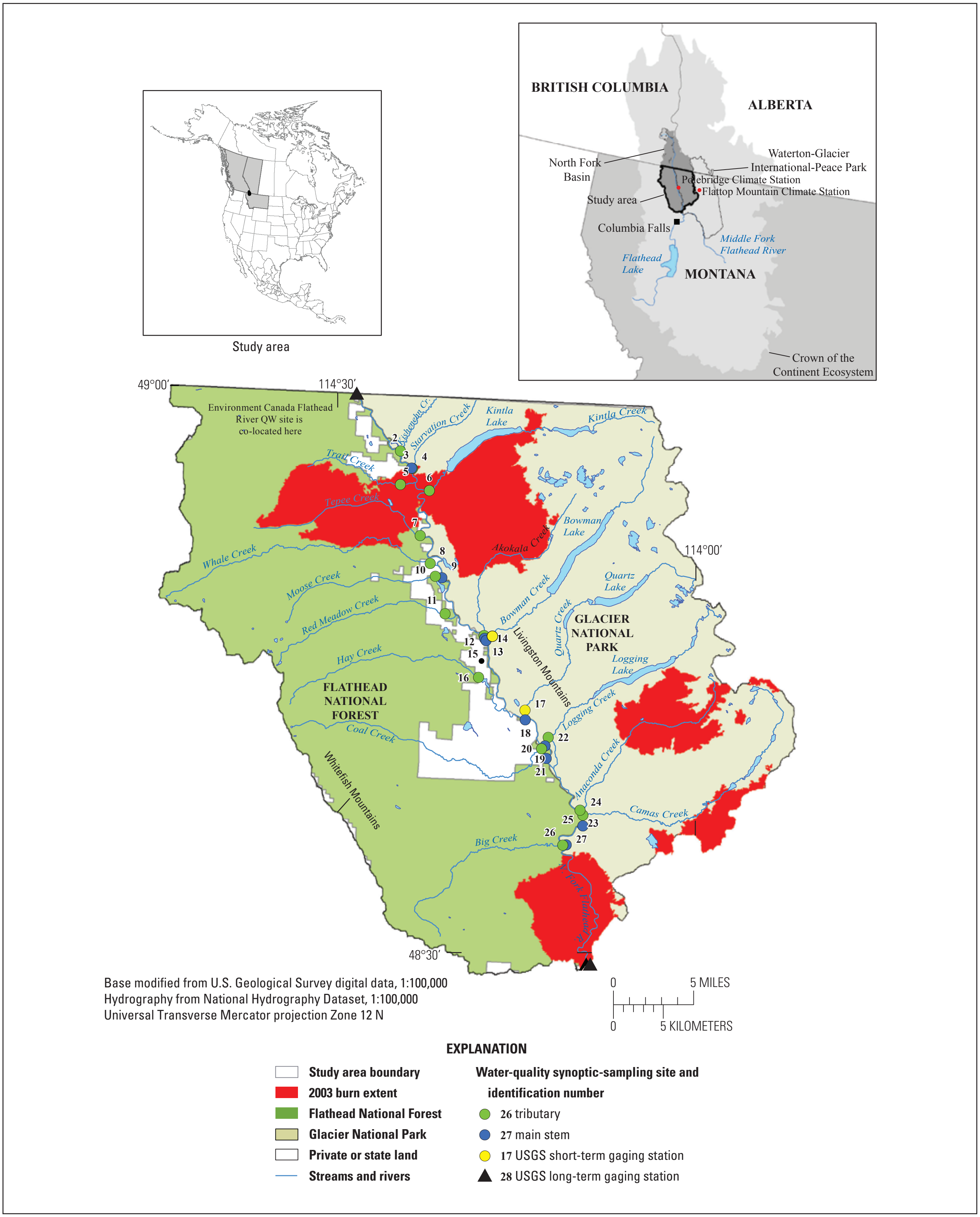

Figure 1. Location of the study area and sampling sites, North Fork Flathead River, Mont. Water-quality site information and corresponding site numbers are listed in table 1.

Table 1. Water-quality site information for long-term gaging stations, synoptic sampling sites, and short-term gaging stations for the North Fork Flathead River, Montana.

[NAVD 88, North American Vertical Datum of 1988; LTS, long-term station; SS, water-quality synoptic sampling site; STS, short-term station; X, sample collected; —, sample not collected; coordinate datum North American Datum of 1983]

Site number (figure 1)	Station number	U.S. Geological Survey station name	Site type	Altitude (feet above NAVD 88)	Distance from international border (miles)	Tributary (east, west, or main stem)
1	12355000	North Fork Flathead River at Flathead British Columbia	LTS, SS	3,968	0.0	Main stem
2	485704114243801	Kishenehn Creek near mouth	SS	3,870	5.3	East
3	485611114233901	North Fork of the Flathead River below Kishenehn	SS	3,835	7.1	Main stem
4	12355100	Starvation Creek near Flathead, BC	SS	3,845	7.2	East
5	485515114243101	Trail Creek at mouth near Polebridge	SS	3,880	8.2	West
6	485500114220601	Kintla Creek at mouth nr Polebridge	SS	3,840	9.4	East
7	485233114224201	Tepee Creek at bridge near mouth	SS	3,730	14.2	West
8	485104114214701	Whale Creek near mouth	SS	3,700	17.8	West
9	485018114204601	North Fork of the Flathead River below Whale Creek	SS	3,630	18.6	Main stem
10	485023114211901	Moose Creek at bridge near mouth	SS	3,710	19.0	West
11	484823114202301	Red Meadow Creek at bridge near mouth	SS	3,605	21.8	West
12	12355220	Akokala Creek near Polebridge MT	SS	3,555	24.7	East
13	484707114170301	North Fork of the Flathead River below Polebridge	SS	3,540	24.8	Main stem
14	484708114165001	Bowman Creek at bridge near mouth	SS, STS	3,560	25.0	East
15	484701114165601	North Fork of the Flathead River above Bowman	SS	3,540	25.0	Main stem
16	484500114172401	Hay Creek near mouth at bridge	SS	3,540	29.9	West
17	12355300	Quartz Creek near Polebridge MT	SS, STS	3,510	31.9	East
18	484249114132601	North Fork of the Flathead River above Quartz Creek	SS	3,460	31.9	Main stem
19	484127114114401	North Fork of the Flathead River above Coal Creek	SS	3,420	34.7	Main stem
20	12355310	Coal Creek near Polebridge MT	SS	3,435	34.8	West
21	484046114113601	North Fork of the Flathead River below Coal Creek	SS	3,400	35.8	Main stem
22	12355320	Logging Creek near Polebridge MT	SS	3,435	36.7	East
23	483804114084001	Anaconda	SS	3,340	40.5	East
24	483747114082501	Camas Creek near mouth	SS	3,340	40.6	East
25	483713114082201	North Fork of the Flathead River at Camas Road	SS	3,365	41.3	Main stem
26	12355350	Big Creek at Big Cr. Rs nr Columbia Falls	SS	3,330	44.1	West
27	483608114094001	North Fork of the Flathead River below Big Creek	SS	3,310	44.3	Main stem
28	12355500	North Fork Flathead River near Columbia Falls, MT	LTS, SS	3,146	55.6	Main stem

Table 1. Water-quality site information for long-term gaging stations, synoptic sampling sites, and short-term gaging stations for the North Fork Flathead River, Montana.—Continued

[NAVD 88, North American Vertical Datum of 1988; LTS, long-term station; SS, water-quality synoptic sampling site; STS, short-term station; X, sample collected; —, sample not collected; coordinate datum North American Datum of 1983]

Site number (figure 1)	Station number	Latitude	Longitude	Drainage area (square miles)	Sampling event: High flow 2007	Sampling event: Low flow 2007	Sampling event: High flow 2008	Sampling event: Low flow 2008
[2]1	12355000	49° 00' 06"	114° 28' 27"	438	X	X	X	X
2	485704114243801	48° 57' 04"	114° 24' 38"	80	X	X	X[1]	X
3	485611114233901	48° 56' 11"	114° 23' 39"	637	X	X	—	X
4	12355100	48° 56' 09"	114° 23' 35"	17	X	X	X[1]	X
5	485515114243101	48° 55' 15"	114° 24' 31"	69	X	X	X	X
6	485500114220601	48° 55' 00"	114° 22' 06"	56	X	X	X	X
7	485233114224201	48° 52' 33"	114° 22' 42"	15	X	—	—	X
8	485104114214701	48° 51' 04"	114° 21' 47"	65	X	X	X	X
9	485018114204601	48° 50' 18"	114° 20' 46"	911	X	X[1]	—	X
10	485023114211901	48° 50' 23"	114° 21' 19"	18	X	X	X	X
11	484823114202301	48° 48' 23"	114° 20' 23"	32	X	X	X	X
12	12355220	48° 47' 17"	114° 17' 06"	41	X	—	X	—
13	484707114170301	48° 47' 07"	114° 17' 03"	996	X	—	X	—
14	484708114165001	48° 47' 08"	114° 16' 50"	56	X	X	X	X
15	484701114165601	48° 47' 01"	114° 16' 56"	996	—	X	—	X
16	484500114172401	48° 45' 00"	114° 17' 24"	35	X	X	X	X
17	12355300	48° 43' 21"	114° 13' 29"	53	X	X	X	X
18	484249114132601	48° 42' 49"	114° 13' 26"	1,123	—	X	—	X
19	484127114114401	48° 41' 27"	114° 11' 44"	1,183	—	X[1]	—	X
20	12355310	48° 41' 17"	114° 11' 60"	72	X[1]	X	X	X
21	484046114113601	48° 40' 46"	114° 11' 36"	1,299	X	—	—	—
22	12355320	48° 41' 55"	114° 11' 30"	39	X	X	X	X
23	483804114084001	48° 38' 04"	114° 08' 40"	32	—	X	—	X
24	483747114082501	48° 37' 47"	114° 08' 25"	82	X[1]	X	X[1]	X[1]
25	483713114082201	48° 37' 13"	114° 08' 22"	1,427	—	—	X	—
26	12355350	48° 36' 07"	114° 09' 56"	83	X	X	X	X
27	483608114094001	48° 36' 08"	114° 09' 40"	1,513	X	—	—	—
28	12355500	48° 29' 44"	114° 07' 39"	1,564	X	X	X	X

[1]Streamflow data not collected for this sample.

[2]Flathead River QW, the long-term water-quality site operated by Environment Canada, is located 50 yards upstream from site.

the Canadian portion of the North Fork (Hauer and Sexton, 2010). Although mining in the Canadian portion of the North Fork Basin was banned by the Memorandum of Understanding, baseline characterization was deemed important for the evaluation of any potential future changes in hydrology, water quality, or aquatic biology in the basin.

Purpose and Scope

The purpose of this report is to describe baseline hydrologic, water-quality, and biological characteristics at selected sites in the North Fork Flathead River Basin in Montana along the reach of the North Fork from the Canadian border south to above its confluence with the Middle Fork Flathead River near Columbia Falls. This report (1) presents temporal trends and spatial patterns in hydrology and water quality; (2) describes the dominant controls on baseline water quality; (3) compares water chemistry to Montana surface-water-quality standards for aquatic life; and (4) summarizes a suite of biological metrics and compares the results to Montana biological criteria.

The following datasets were used to evaluate baseline conditions: (1) water year 2007–2008 streamflow and water-quality data collected at two USGS long-term gaging stations in the study area; (2) historical water-quality data at the two long-term gaging stations and one long-term water-quality sampling site in Canada upstream from the study area; (3) synoptic streamflow and water-quality data collected at 11 main-stem and 17 tributary sites during high- and low-flow conditions in water years 2007 and 2008; (4) frequent streamflow and water-quality data collected from April through November in 2008 at two USGS short-term gaging stations on tributaries with differing hydrologic and chemical characteristics; and (5) diatom and macroinvertebrate assemblage data collected at the two long-term gaging stations during water years 2007 and 2008 (fig. 1).

Study Area Description

The North Fork Basin above Columbia Falls (including Canada) drains an area of 1,564 mi^2 and ranges in altitude from 2,950 to 9,840 ft. The study area includes only the portion of the basin that lies in Montana, which is 1,126 mi^2 or 72 percent of the total basin area. The reach of the North Fork in the study area is approximately 56 mi long and flows southeast along a valley located between the Whitefish Mountains to the west and the Livingston Mountains to the east (fig. 1). The topography of the study area is characterized by steep mountainous terrain throughout the basin and glacially formed valleys along the eastern slope. The area has a Pacific maritime climate, characterized by warm, dry summers and cold, wet winters (Finklin, 1986). Average monthly air temperature along the river valley ranges from 17.6°F in January to 59.9°F in July (National Oceanic and Atmospheric Administration, National Climatic Data Center, 2009). Average monthly air temperature at the high-altitude mountain ridges ranges from 17.2°F in January to 53.1°F in July (U.S. Department of Agriculture, Natural Resources Conservation Service, 2009). Mean-annual precipitation increases with altitude and ranges from 21 in. along the valley floor to 103 in. at the higher altitudes (Daly and others, 2004). Approximately 60 percent of the precipitation falls as snow, which accumulates in a seasonal snowpack between October and April (U.S. Department of Agriculture, Natural Resources Conservation Service, 2009).

The North Fork in the study area is a meandering stream that flows through a broad alluvial valley and becomes braided in some areas (Confederated Salish and Kootenai Tribes and Montana Fish, Wildlife and Parks, 2004). The hydrology of the North Fork and its tributaries is dominated by the accumulation and melting of seasonal snowpack, with high flow occurring during the spring, from May through June, and low flow occurring during the late-summer, fall, and winter months, from September through March. Streamflow during spring usually accounts for more than one-half of total annual streamflow. During low-flow conditions, direct contributions from snowmelt and precipitation are minimal, and much of the streamflow in the main stem and tributaries is derived from groundwater. Groundwater occurs in talus slopes or fractured bedrock and in the alluvial and glacial till material in the North Fork valley (Baron, 2002). Within the study area, tributaries flow into the North Fork from the east and west; several of the tributaries flowing from the east have large, glacially formed lakes along their watercourses. Daily mean streamflow in the North Fork at Columbia Falls generally is more than three times larger than the streamflow at the Canadian border.

The eastern part of the study area is protected land within GLAC, and most of the western part of the study area is in the Flathead National Forest (fig. 1). State and privately owned lands make up the remainder of the study area and are concentrated mainly along the river valley. Current land uses in the study area include dispersed residential development, timber harvesting, and recreation (Gildea and others, 2004; Mast, 2007). Timber harvesting occurs throughout the western part of the North Fork Basin, and residential development occurs primarily along the western side of the river valley (fig. 1). Population in the study area in 2004 was less than 500 persons with the majority centered on the valley floor (Gildea and others, 2004). Land cover in the study area is 79 percent coniferous forest, which transitions to alpine tundra, bare rock, and perennial ice and snow at higher altitudes (Homer and others, 2007). The forest consists of lodgepole pine, Douglas fir, and western larch in drier areas and western hemlock and western red cedar in wetter areas (White and others, 1998). Fire is a recurring phenomenon in the study area, and recent fires in the area include the 1988 Red Bench Fire (37,000 acres), the 2001 Moose Fire (70,000 acres), and the 2003 Wedge Canyon (53,000 acres), Wolf Gun (15,000 acres), and Robert (57,000 acres) Fires (fig. 1; U.S. Forest Service, 2003).

The bedrock in the North Fork Basin consists primarily of shale, limestone, argillite, and quartzite of the Precambrian Belt Series (Ross, 1959; Harrison and others, 2000). Glacial moraine and alluvial sediments fill the valley of the North Fork and many tributary valleys (Ross, 1959; Alt and Hyndman, 1986). In order to evaluate the effects of geology on water quality, geologic maps of Montana were used to identify and categorize the surface geology as siliceous bedrock (argillite, quartzite), carbonate bedrock (shale, limestone), alluvial deposits, or glacial deposits based on its mineral composition and depositional environment (table 2, fig. 2; Ross, 1959; Harrison and others, 2000; Massey and others, 2005). Siliceous bedrock, which underlies the majority of the study area, weathers slowly and contributes minimal dissolved solids to surface and ground water (Confederated Salish and Kootenai Tribes and Montana Fish, Wildlife and Parks, 2004). However, carbonate bedrock that is more susceptible to weathering is present in the western and northern parts of the study area (fig. 2).

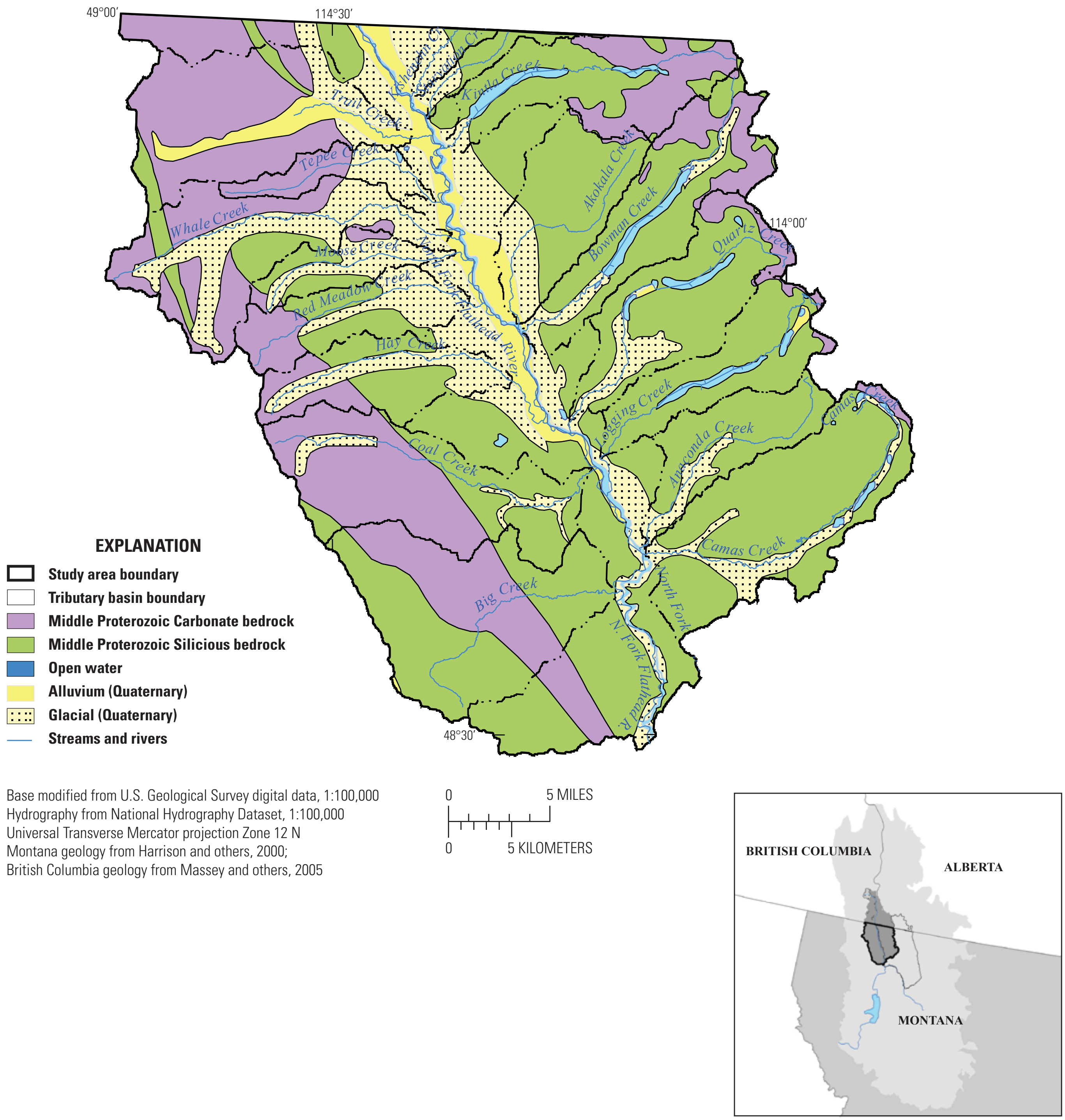

Figure 2. Geology in the North Fork Flathead River Basin, Mont.

Table 2. Stratigraphic layer and rock type in the North Fork Flathead River, Montana and British Columbia (Harrison and others, 2000).

Stratigraphic unit name	Rock type	Geologic period
Montana		
Tertiary sedimentary rocks, undifferentiated	Siliceous	Cenozoic
Belt Series - Appekunny Argillite	Siliceous	Middle Proterozoic
Belt Series - Grinnel Argillite	Siliceous	Middle Proterozoic
Belt Series - Ravalli Group	Siliceous	Middle Proterozoic
Belt Series - Missoula Group	Siliceous	Middle Proterozoic
Belt Series - Piegan Group	Carbonate	Middle Proterozoic
Belt Series - Siyeh limestone	Carbonate	Middle Proterozoic

Previous Studies

Numerous water-quality studies of the North Fork have been conducted utilizing data collected at the two USGS long-term gaging stations. The Flathead River at Flathead British Columbia gaging station (USGS station 12355000; referred to in this report as “Border”) is located 200 ft upstream from the United States-Canada border and operated jointly by the USGS and Water Survey Canada, and the Columbia Falls station (USGS station 12355500; referred to in this report as “Columbia Falls”) is 55.6 mi downstream from the United States-Canada border, above the confluence with the Middle Fork near Columbia Falls (fig. 1). Two studies conducted in 1978 by the British Columbia Ministry of the Environment and the USGS indicated that, although nutrient and suspended-sediment concentrations were generally low, they tended to increase during spring snowmelt (British Columbia Ministry of the Environment, 1978; Knapton, 1978). Moreland and others (1987) characterized hydrologic conditions in the Canadian portion of the North Fork Basin, and results indicated that the North Fork in Canada typically gains groundwater from the underlying alluvial deposits during low-flow conditions. Long-term trend analysis performed by Mast (2007) on data collected at various sites in GLAC from 1963 to 2004 indicated no significant trend in specific conductance or streamflow, but analysis indicated a slight downward trend in concentrations of dissolved sulfate and total phosphorous. Mast (2007) cautioned that changes in analytical methods over time might explain at least part of the apparent trends.

The effects of natural and anthropogenic land disturbance in the Montana portion of the North Fork Basin have been studied since the early 2000s. Wildfires that occurred in 2003 caused elevated concentrations of dissolved nitrate plus nitrite in streams for up to 4 years (Mast and Clow, 2008). The effects of timber harvest activity and forest roads were evaluated in western tributary basins by the U.S. Environmental Protection Agency (EPA) and the Montana Department of Environmental Quality (MTDEQ; Gildea and others, 2004). Findings from this study generally indicate that timber harvesting and forest roads are sources of sediment to tributaries. However, it also was determined that natural sediment sources such as soil slump and natural bank erosion as well as wildfire and associated management activities contribute by far the greatest loads of sediment to the North Fork and its tributaries (Gildea and others, 2004).

The aquatic biology of GLAC has been extensively studied and the park has one of the better described macroinvertebrate faunas in the world, especially for families such as Ephemeroptera (mayflies) and Plecoptera (stoneflies) (Hauer and others, 2000). The most extensive and current sampling effort was conducted by the NPS Inventory and Monitoring program (I&M) (Britten and others, 2007). Algae (periphyton, including diatoms) in GLAC have been documented in a more limited number of studies compared to macroinvertebrates. Prescott and Dillard (1979) and Morales and others (2005) present a checklist of taxa, including many from the GLAC area. Bahls (2007) provides a description of diatom flora in GLAC and includes discussion of temporal changes in populations of various taxa, likely in response to climate variability. These studies have generally concluded that the diatom and macroinvertebrate communities in the park are intact and are some of the best known examples of functional and diverse assemblages in North America.

Methods

The following section of the report describes how the hydrologic, water-quality, and biological data were collected, the laboratory methods used for sample analyses, and the methods of data analysis used for interpretation. Hydrologic and water-quality data collected during this study are available through the National Water Information System at *http://waterdata.usgs.gov/nwis*. Additionally, a summary of synoptic sampling data is provided in Appendix 1.

Hydrologic and Water-Quality Data Collection and Analysis

Hydrologic and water-quality data were collected at two USGS long-term gaging stations on the North Fork Flathead River to assess seasonal variations in water quality and 28 synoptic sampling sites on the North Fork and its tributaries from 2007 to 2008 to assess spatial variability in water quality. Additionally, hydrologic and water-quality data were collected at two USGS short-term gaging stations established for this study on two tributaries of the North Fork to investigate the processes controlling tributary chemistry. Continuous streamflow data were collected at the two long-term gaging stations and the two short-term gaging stations using water-stage recorders, and streamflow records were computed following standard USGS protocols as described by Rantz and others (1982). Manual streamflow measurements were made at synoptic-sampling sites using an acoustic doppler velocimeter (U.S. Geological Survey, 2002) and coincided with water-quality samples. However, discharge was not measured at some sites during some of the synoptic sampling because of high streamflows (table 1).

For each water-quality sample, temperature, pH, specific conductance, turbidity, and dissolved oxygen were measured in the field (U.S. Geological Survey, variously dated), and water samples were collected and analyzed for concentrations of major ions, nutrients, suspended sediment, and trace elements in a USGS laboratory. Specific conductance is the measure of the ability of water to conduct electricity and is an indirect method of estimating the concentration of dissolved solids (Hem, 1992). Similarly, turbidity is an indirect measure of the amount of suspended particulate matter in a stream based on the scattering effect it produces on light (Anderson, 2005). The term major ions refers to dissolved ions such as base cations (calcium, magnesium, potassium, and sodium) and base anions (bicarbonate, sulfate, and chloride), which typically are the products of geologic weathering. However, atmospheric deposition can be an important source of sulfate and chloride in some basins (Mast, 2007). Nitrogen and phosphorous compounds are common nutrients that are essential to plant growth. Excessive concentrations of nitrogen and/or phosphorus in surface water can cause accelerated algal growth, which can deplete dissolved oxygen and lead to degradation of aquatic habitat (Hem, 1992). Suspended-sediment concentration is a direct measure of the amount of particulate matter in a stream and generally increases when stream velocity and discharge increase (Hem, 1992; Horowitz, 2008). Increases in suspended sediment can lead to degradation of aquatic habitat. Trace elements, when present in elevated concentrations, can be toxic to aquatic life (Hem, 1992).

Field Data Collection

Seasonal water-quality sampling was conducted at the two long-term gaging stations at the upstream and downstream ends of the study reach (fig. 1, table 1). The Border station is located at the upstream end of the study reach, and the Columbia Falls station is located at the downstream end of the study reach. The Border station has been in operation since 1929, and the Columbia Falls station has been in operation since 1910, although some data gaps do exist for both stations. During this study, water-quality samples were collected at the two long-term gaging stations about every 2 weeks during snowmelt, monthly during late summer, and less frequently during winter. A total of 20 water-quality samples at the Border station and 21 water-quality samples at the Columbia Falls station were collected during the 2007–2008 study period. Historical streamflow and water-quality data from the two long-term gaging stations were analyzed for trends. Additional water-quality data from a third long-term water-quality site operated by Environment Canada, referred to in this report as “Flathead River QW,” located north of the International Border approximately 50 yd upstream from the Border station were analyzed for long-term trends, but samples were not collected at this site as part of this study.

Synoptic water-quality sampling was conducted at 11 locations on the North Fork (including the two long-term gaging stations) and at 17 major tributary inflows along the study reach (fig. 1, table 1). The objective of the synoptic sampling approach, in which samples are collected at multiple sites within a short amount of time, is to minimize the effects of possible temporal variations in streamflow and chemistry. For this study, four sets of synoptic samples were collected: two during high-flow conditions and two during low-flow conditions. High-flow synoptic samples were collected in May 2007 (23 samples) and May 2008 (19 samples), and low-flow synoptic samples were collected in August 2007 (22 samples) and September 2008 (23 samples). Some sites could not be sampled during some of the synoptics either because they were inaccessible or there was no streamflow (table 1). Tributary synoptic samples were collected upstream and within 50 ft from where the access road nearest to their mouth crossed the stream.

More frequent water-quality samples were collected at two tributary sites (Bowman Creek and Quartz Creek, sites 14 and 17, respectively, table 1) during 2008 to gain an understanding of processes controlling tributary chemistry. The sites were selected by examining results of the 2007 synoptic samples and identifying two tributary streams with differing amounts of seasonal variability in streamflow and chemistry. Twelve water-quality samples were collected near the mouth of each of the two tributaries from April to November 2008. Short-term gages were installed during March 2008 to obtain continuous measurements of stage, turbidity, water temperature, and specific conductance using in-stream sensors and data loggers. The in-stream sensors were cleaned and checked for calibration every 2 to 4 weeks and were operated until September 2008. Streamflow measurements were made over a range of flow, and these data were used to develop a regression of stage to discharge using standard USGS methods (Rantz and others, 1982). Fifteen-minute average stage values were converted to streamflow to obtain a continuous record of streamflow at the two sites.

At all sites, composite samples for water-quality and suspended-sediment analysis were collected using the equal-width integrated (EWI) method (U.S. Geological Survey, 1998). Samples to be analyzed for concentrations of dissolved ions were filtered through a 0.45-micrometer (µm) capsule filter using a peristaltic pump according to standard USGS protocols (U.S. Geological Survey, variously dated). Samples to be analyzed for total concentrations (dissolved ions plus particulates) were not filtered. Dissolved oxygen was measured onsite using a temperature-compensating dissolved-oxygen sensor. Instantaneous streamflow measurements coincided with sample collection and were measured using the area-velocity method or the dye-dilution method when streamflow was too high to safely wade (Rantz and others, 1982).

Analytical Methods and Quality Assurance

Samples collected at all sites were analyzed for major ions, nutrients, suspended sediment, and trace elements using USGS-approved analytical methods (table 3). Analyses were conducted at laboratories in the USGS Colorado, Iowa, and Montana Water Science Centers as well as the National Water Quality Laboratory (NWQL) in Colorado, depending on constituent and sample type (table 3).

Standard USGS procedures for quality assurance were used in this study and are described in detail in Friedman and Erdmann (1982). Seven field blanks and six field replicates were collected and analyzed for this study, and results are presented in Appendix 2A and 2B. Dissolved constituents were either not detected in blank samples or were below concentrations that would affect the data interpretation. The relative percent difference between replicates was less than 10 percent or was less than analytical uncertainty for all samples (Appendix 2A). Quality-assurance results did not indicate the need to eliminate any analytical data from interpretation.

Data Analysis

Statistical tests were performed on data from the two long-term gaging stations (Border and Columbia Falls) to evaluate intersite variability as well as temporal trends at each station; additional trend analysis was performed on water-quality data from the Flathead River QW site operated by Environment Canada. Statistical tests were evaluated at the 95 percent confidence level (p-value = 0.05).

Principal component analysis (PCA) is a useful statistical tool for identifying interrelations between solute concentrations in large data sets (Clow and others, 1996). Statistically significant relations are represented by principal components, and each component can then be interpreted as a common source or process influencing solute concentration (Joreskog and others, 1976; Lins, 1986). PCA was used to evaluate data from synoptic sampling events to identify dominant sources and processes affecting solute concentrations in the North Fork and its tributaries. Additionally, constituent concentrations for the two long-term gaging stations were tested for differences with the Wilcoxin-Mann-Whitney rank-sum test (Iman and Conover, 1983). This test is a nonparametric procedure that performs a two-sample t-test on ranked data, and does not require that data be normally distributed.

Water-quality concentrations at all sites were compared to Montana aquatic-life standards and EPA nutrient criteria (U.S. Environmental Protection Agency, 2000). Water-quality standards and classifications were obtained from the Montana Department of Environmental Quality (MTDEQ) (Montana Department of Environmental Quality, 2010). Some trace elements have table-value standards, which are site specific and vary with water hardness. For these constituents, the standard was calculated based on the hardness (sum of calcium and magnesium concentrations converted to milliequivalents per liter) of each sample. Chronic standards were used for comparison and violation of the standard requires that the concentration of the trace element of interest remain above the standard for a minimum of 96 hours; it was assumed that trace-element samples were representative of a 96-hour time period. Instantaneous load, the mass of a constituent that passes a sampling site at a given point in time, was calculated at synoptic sampling sites for selected constituents by multiplying constituent concentration by the instantaneous discharge (streamflow) at the time of sampling and a unit conversion factor. Additionally, cumulative tributary loading represents the total mass of constituent supplied by upstream tributaries at a given point along the North Fork and was calculated by summing individual tributary loads with distance downstream from the Border station.

Historical data from the two long-term gaging stations and the Flathead River QW site were tested for temporal trends in constituent concentrations using the seasonal Kendall test (Hirsch and others, 1982) or the Tobit procedure if more than 5 percent of the data were censored (Schertz and others, 1991). Censored data are results reported as less than the analytical reporting limit. Water-quality constituent concentrations also were adjusted for flow-related variability, which improves the power of the statistical test and decreases the possibility that the observed trends are artifacts of the sampling streamflow record (Hirsch and others, 1982; Schertz and others, 1991).

Biological Data Collection and Analysis

Periphyton (benthic diatoms) and macroinvertebrate (aquatic insects, snails, mussels, worms, and crustaceans) samples were collected at the two long-term gaging stations (Border and Columbia Falls) to document assemblage composition and assess the biological integrity at the two stations. A summary table of biological data collected during this study is available in Appendixes 3A and 3B.

Field Data Collection

Sampling of periphyton and macroinvertebrates was conducted by the NPS for this study at the two long-term gaging stations (Border and Columbia Falls; fig. 1). Sampling consisted of two events in 2007 (midsummer and early fall) and four events in 2008 (late spring, midsummer, late summer, and early fall).

Table 3. Analysis methods of water-quality samples collected at long-term gaging stations, synoptic sampling sites, and short-term gaging stations for the North Fork of the Flathead River, Mont.

[mg/L, milligrams per liter; µg/L, micrograms per liter; USGS, United States Geologic Survey; NWQL, National Water Quality Laboratory; CWSC, Colorado Water Science Center; MWSC, Montana Water Science Center; IWSC, Iowa Water Science Center; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus]

Analyte type	Analytical reporting limit	Laboratory	Method	Reference
Alkalinity	5.00 (mg/L as $CaCO_3$)	USGS NWQL, USGS CWSC	Gran titration	Gran, 1952
Calcium	0.02–0.06 (mg/L)	USGS NWQL, USGS CWSC	Inductively coupled plasma-atomic emiss ion spectrometry	Fishman, 1993
Magnesium	0.014–0.02 (mg/L)	USGS NWQL, USGS CWSC	Inductively coupled plasma-atomic emiss ion spectrometry	Fishman, 1993
Sodium	0.07–0.2 (mg/L)	USGS NWQL, USGS CWSC	Inductively coupled plasma-atomic emiss ion spectrometry	Fishman, 1993
Potassium	0.02–0.07 (mg/L)	USGS NWQL, USGS CWSC	Inductively coupled plasma-atomic emiss ion spectrometry	Fishman, 1993
Sulfate	0.03–0.18 (mg/L)	USGS NWQL, USGS CWSC	Ion chromatography	Fishman, 1993; Fishman and Friedman, 1989
Chloride	0.03–0.12 (mg/L)	USGS NWQL, USGS CWSC	Ion chromatography	Fishman, 1993; Fishman and Friedman, 1989
Silica	0.018–0.2 (mg/L)	USGS NWQL, USGS CWSC	Ion chromatography	Fishman, 1993; Fishman and Friedman, 1989
Floride	0.06–0.1 (mg/L)	USGS NWQL, USGS CWSC	Ion chromatography	Fishman, 1993; Fishman and Friedman, 1989
Nitrogen, total	0.06 (mg/L as N)	USGS NWQL	Alkaline persulfate digestion	Patton and Kryskalla, 2003
Nitrogen, total dissolved	0.06 (mg/L as N)	USGS NWQL	Alkaline persulfate digestion	Patton and Kryskalla, 2003
Nitrate plus nitrite, dissolved	0.02 (mg/L as N)	USGS NWQL	Colorimetry	Fishman, 1993
Nitrite, dissolved	0.002 (mg/L as N)	USGS NWQL	Colorimetry	Fishman, 1993
Ammonia, dissolved	0.02 (mg/L as N)	USGS NWQL	Colorimetry	Fishman, 1993
Orthophosphate, dissolved	0.006 (mg/L)	USGS NWQL	Colorimetry	Fishman, 1993
Phosphorus, total	0.008 (mg/L)	USGS NWQL	Colorimetry	Fishman, 1993
Carbon, dissolved organic	0.2–0.6 (mg/L)	USGS NWQL	Persulfate wet oxidation and infrared spectrometry	Brenton and Arnett, 1993
Carbon, total organic	0.6 (mg/L)	USGS NWQL	Wet oxidation	Wershaw and others, 1987
Suspended sediment from long-term stations	1.00 (mg/L)	USGS MWSC	As described by reference	Guy, 1969; Dodge and Lambing, 2006
Suspended sediment from synoptic and intesive-tributary sites	1.00 (mg/L)	USGS CWSC in 2007 and USGS IWSC in 2008	As described by reference	Guy, 1969

Table 3. Analysis methods of water-quality samples collected at long-term gaging stations, synoptic sampling sites, and short-term gaging stations for the the North Fork of the Flathead River, Mont.—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; USGS, United States Geologic Survey; NWQL, National Water Quality Laboratory; CWSC, Colorado Water Science Center; MWSC, Montana Water Science Center; IWSC, Iowa Water Science Center; $CaCO_3$, carbonate; N, nitrogen; P, phosphorus]

Analyte type	Analytical reporting limit	Laboratory	Method	Reference
Arsenic, total	0.6 (µg/L)	USGS NWQL	inductively coupled plasma-mass spectrometry	Garbarino and Struzeski, 1998
Cadmium, total	0.014 (µg/L)	USGS NWQL	inductively coupled plasma-mass spectrometry	Garbarino and Struzeski, 1999
Chromium, total	0.4 (µg/L)	USGS NWQL	inductively coupled plasma-mass spectrometry	Garbarino and Struzeski, 2000
Copper, total	1.2 (µg/L)	USGS NWQL	inductively coupled plasma-mass spectrometry	Garbarino and Struzeski, 2001
Lead, total	0.06 (µg/L)	USGS NWQL	inductively coupled plasma-mass spectrometry	Garbarino and Struzeski, 2002
Nickel, total	0.12 (µg/L)	USGS NWQL	inductively coupled plasma-mass spectrometry	Garbarino and Struzeski, 2003
Zinc, total	2.00 (µg/L)	USGS NWQL	inductively coupled plasma-mass spectrometry	Garbarino and Struzeski, 2004

Sampling locations at the two long-term gaging stations were chosen to cover the range of habitats that could be safely waded near each site. Periphyton samples were composited from three to six subsamples taken from the dominant substrate type present (Peck and others, 2006). For erosional habitat, a piece of cobble at a depth less than 50 cm (about 20 in.) below the water surface was randomly chosen and a known area was scraped of all benthic algae. For depositional habitat, a known area of streambed covered with organic and mineral fines was vacuumed up using a syringe. A known volume of the composite samples was preserved with M-fixative (Lugols and dilute formalin). Macroinvertebrate samples were composited from three to six subsamples from a known area of streambed and over a set time interval. Macroinvertebrate samples were collected using a small D-net or larger Stanford-Hauer 500-µm mesh net and preserved in 95-percent ethanol (Peck and others, 2006).

Analytical Methods and Quality Assurance

Periphyton and macroinvertebrate samples were sorted and identified by Hannaea (Helena, Mont.) and Rhithron Associates, Inc. (Missoula, Mont.), respectively, using standard laboratory and quality-assurance procedures (U.S. Environmental Protection Agency, 2004; Peck and others, 2006; Rhithron Associates, Inc., written commun., 2007; Loren Bahls, Hannaea, written commun., 2007). Periphyton analyses were based on diatoms. All diatom specimens were identified to the species level, and macroinvertebrate specimens were identified to the lowest possible level. Macroinvertebrate specimens also were matched to Operational Taxonomic Units (OTUs) as developed by MTDEQ and used to standardize identifications to a consistent level for some analyses (Jessup and others, 2006). Taxonomists were certified by the North American Benthological Society. Diatom and macroinvertebrate nomenclature follows from the Integrated Taxonomic Information System (ITIS) and the Montana Diatom Database (Interagency Taxonomic Information System, 2009; Bahls, 2009). Diatom and macroinvertebrate data accuracy and precision were ensured by a blind, quantitative quality-assurance approach, with a minimum of 10 percent of samples randomly selected for analysis. Bray-Curtis similarity between counts and identification performed independently by two analysts on quality-assurance samples was required to exceed 95 percent (Bray and Curtis, 1957). If the required accuracy was not met, the samples were reanalyzed.

Data Analysis

Interpretations of the biological data were based on biological metrics and the taxonomic composition of samples. Narrative interpretations of metrics and taxa were based on demonstrated associations between assemblage components and water-quality variables from the literature. Ideal metrics describe characteristics of biota that change in predictable ways with changes in stream chemistry and habitat conditions (Barbour and others, 2000). Only available metrics were used because development of metrics specific to the North Fork was beyond the scope of this study. Metrics were chosen because (1) they are currently used, or were used in the past, by the MTDEQ to make regulatory decisions or to monitor the biological condition of streams in Montana, (2) they have a history of application to diatom or macroinvertebrate data and a demonstrated record of aiding in interpretation of assemblage compositions in Montana (Karr and Chu, 1999; Barbour and others, 2000; Hawkins, 2006; Teply and Bahls, 2007), and (3) MTDEQ guidance requires use of these metrics for any evaluation of the water bodies in Montana. Diatom and macroinvertebrate metrics were generated using the Montana Diatom Database (Bahls, 2004; 2009); the RIALIS v.2.1 database (Rhithron Associates, Inc., 2007); the Ecological Data Application System (Tetra Tech, Inc., 2006); and models available from Utah State University Western Center for Monitoring and Assessment of Freshwater Ecosystems (Hawkins, 2005; www.cnr.usu.edu/wmc/). Species tolerances are specific to Montana and follow guidelines described by Bahls (2004) for diatoms, and Plafkin and others (1989), Bukantis (1998), Relyea and others (2000), Brandt (2001), Merrit and others (2007) and W. Bollman (Rhithron Associates, Inc., oral commun., 2009) for macroinvertebrates.

Diatom metrics included (1) a set of discriminate-function models that use empirically identified increaser taxa specific to type of impairment (Teply and Bahls, 2005; Teply 2010 a, b); and (2) a suite developed by Bahls (1993) and used in water-quality monitoring for decades (for example, van Dam and others, 1994) based on species tolerances or common community-level summaries.

The increaser metrics included two that are currently (2011) used by the MTDEQ, herein referred to as “current,” for assisting in attainability evaluations and other regulatory needs (Montana Department of Environmental Quality, 2011; Teply 2010 a, b), and one that was historically used in this capacity herein referred to as “classic” (Montana Department of Environmental Quality, 2005; Teply and Bahls, 2005). The classic metric was retained given its application to the diatom assemblage composition of the North Fork. Increaser metrics were empirically derived from lists of diatom taxa generated from a large collection of sites across the state with known impairments. Taxa that, as a group, exist in detectable amounts in specific ecoregions (the current metrics) or general bioregions (for the classic metrics; mountains compared to the plains) and demonstrate a meaningful, measurable, and significant response to sediment, nutrients, or metals, were placed on cause-specific lists. Discriminant analysis was then used to evaluate the significance and reliability of candidate increaser taxa lists in predicting impaired and non-impaired streams, expressed as a probability of impairment. Criteria were set by MTDEQ at a 50-percent probability-of-impairment threshold. The two current metrics (Teply, 2010 a, b) are specific to sediment and nutrient impairment in the Northern Canadian Rockies ecoregion, which encompasses the North

Fork. The classic increaser metric (Teply and Bahls, 2005) describes metal impairment for mountain streams. Using a validation data set, the current metrics were consistently able to discriminate sediment or nutrient impairment within the Northern Canadian ecoregion with an accuracy exceeding 65 percent and false positives less than 30 percent. MTDEQ guidance (Montana Department of Environmental Quality, 2011) suggests these accuracy and precision levels are acceptable, and the metrics can be used to make statements about the condition of a stream when combined with other monitoring data. The classic increaser metric did not perform as well as the current metrics and had accuracy rates less than 60 percent (internally validated).

The classic diatom metrics (Bahls 1993) were used by the MTDEQ in stream monitoring for several years (Bukantis, 1998; Montana Department of Environmental Quality, 2005). They have been discontinued for regulatory decisions and replaced by the two current metrics (Teply, 2010 a, b). However, MTDEQ states that the classic metrics (including the classic bioregion-scale increaser metric) have value and may still be used to help interpret diatom assemblages and the general biological condition of sampled sites. Metrics were retained that included indices of community structure (species richness, Shannon diversity, and percent dominant species) and a summary of species with known tolerance to organic enrichment.

Macroinvertebrate metrics included (1) a multimetric index (MMI; also known as the Index of Biotic Integrity) currently (2011) used by the MTDEQ (Montana Department of Environmental Quality, 2005); (2) two metrics derived from the River Invertebrate Prediction and Classification system (RIVPACS) (Hawkins and others, 2000), which are also currently used by the MTDEQ (Jessup and others, 2006); and (3) a classic MMI that is no longer used by the MTDEQ but was retained in this study given its application to the interpretation of the macroinvertebrate community and general biological condition of the North Fork.

The MMI is a common approach used in the United States to analyze macroinvertebrate assemblage data (Karr and Chu, 1999; Davies and Simon, 1995). The MMI uses measurable changes in the structure and function of a community induced by physical and/or chemical disturbance to develop a synthetic index from various constituents or submetrics such as richness, composition, trophic behavior, habitat, and species tolerance to specific stressors. The Montana MMIs (both the current and classic) were developed for stream types within bioregions (mountains, plains, low valleys) using data from reference and impaired sites throughout Montana. The classic MMI was included because it may perform better in basins like the North Fork with relatively little anthropogenic disturbance (Bollman and Teply, 2006). An impairment criterion for the current MMI was developed by the MTDEQ based on a 10_{th}-percentile threshhold. This allocates the maximum number of degraded sites below the threshold and reference sites above the threshhold, suggesting approximately equal error rates (Feldman, 2006). The thresholds for the classic MMI were set subjectively (Plafkin and others, 1989).

A RIVPACS (Hawkins and others, 2000) model was used to generate the expected (E) macroinvertebrate taxa at the North Fork sites. RIVPACS models predict specific taxa that would be expected to occur at a site given its natural (or reference) environmental characteristics. Specifically, these models describe how probabilities of taxa occurrence vary across natural environmental gradients (such as altitude, stream size, stream gradient, mean temperature and precipitation, latitude, and longitude). By sampling the actual or observed (O) assemblage at the site, the ratio of O and E can be used to estimate the taxonomic completeness of the assemblage. Departures from unity in the ratio of O:E indicate that the composition at a site differs from that expected under less disturbed conditions. For this study, O:E is reported based on a probability of occurrence greater than 0.5 to reduce error introduced by rare taxa. The standard ratio between O and E is commonly used in bioassessment. However, it may be relatively insensitive to stress-induced shifts in taxonomic composition that have little net effect on the number of reference-site taxa (Hawkins and others, 2000). In contrast, the Bray–Curtis (BC) measure of the distance between O and E that is also reported may respond to differences in taxonomic composition, regardless of the difference in number of reference site taxa. This may better reflect the effects of lower anthropogenic stress levels (as is likely on the North Fork) that might alter the composition, but not the reference-site taxon richness, of an assemblage (Van Sickle, 2008).

The Montana model (Jessup and others, 2006) was created from reference-site data collected across the State. The performance of the model was comparable to or better than most RIVPACS models in use (Hawkins, 2006), with O:E values effectively discriminating stressed sites from reference sites. The model accounted for 76 percent of the variation in O with a standard deviation around O:E of 0.17 (Hawkins, 2006).

Hydrologic Characteristics of the North Fork Flathead River

Streamflow at the two long-term gaging stations (Border and Columbia Falls) exhibited a strong seasonal pattern with high flow occurring during May and June, coinciding with the spring snowmelt, and low flow occurring during the late-summer, fall, and winter months (fig. 3*A*). Streamflow declined through the summer to relatively stable, low-flow conditions through the winter at both long-term gaging stations. During the winter months, precipitation is primarily in the form of snow (as represented by the Flattop Mountain Climate Station and the Polebridge Climate Station; fig. 1) and contributes little to winter streamflow; thus, streamflow during the winter months consisted largely of groundwater contribution and showed little fluctuation (fig. 3*A*).

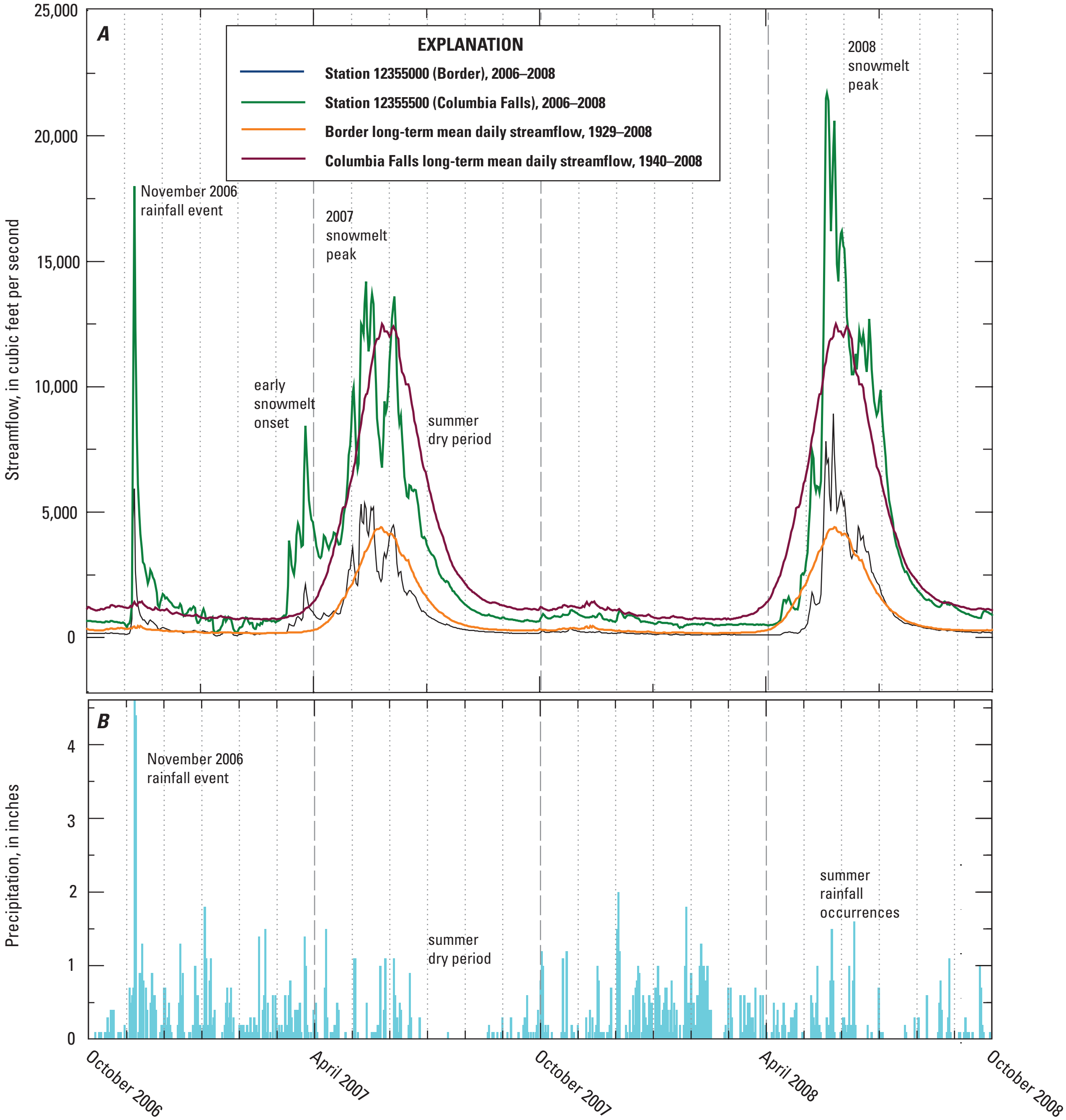

Figure 3. Time series of (*A*) daily streamflow and long-term mean streamflow at Flathead River at Flathead, British Columbia (12355000; Border) and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls) and (*B*) precipitation at Flattop Mountain Climate Station, Montana, 2007–2008. (Precipitation data from U.S. Department of Agriculture, Natural Resources Conservation Service, 2009).

Water year 2007 (October 1, 2006–September 30, 2007) was atypical of historical streamflow conditions in the North Fork. Early in water year 2007 a large precipitation event deposited 9 in. of rain within a 48-hour period on November 7 and 8 at Flattop Mountain (fig. 3*B*; U.S. Department of Agriculture, Natural Resources Conservation Service, 2009). Most of the existing snowpack melted during the storm and substantial flooding occurred in the area; peak streamflow for water year 2007 occurred on November 8, 2006, at 5,940 ft^3/s at Border and 18,000 ft^3/s at Columbia Falls (fig. 3*A*). Total annual precipitation for water year 2007 in the study area was 111 percent of the 1978-2006 average, in part due to the large November 2006 rain event. Additionally, a period of warm temperatures in March 2007 caused a short period of snowmelt prior to the main spring snowmelt event. Despite the early snowmelt in March 2007, peak streamflow during the typical snowmelt months of May and June was 121 percent of the 1929–2008 mean peak streamflow at Border and 114 percent of the 1940–2008 mean peak streamflow at Columbia Falls.

Water year 2008 (October 1, 2007–September 30, 2008) was more typical of historical conditions in the North Fork Basin with the snowpack beginning to accumulate in early November and persisting until the spring snowmelt in May and June. However, precipitation during water year 2008 was 116 percent of the 1978-2006 average. The greatest streamflows for water year 2008 occurred during May and June and peaked on May 20, 2008, at 7,830 ft^3/s at Border and 21,700 ft^3/s at Columbia Falls, nearly 200 percent of the mean peak streamflow for the mean periods of record (fig. 3*A*).

Substantial gains in streamflow occurred along the study reach of the North Fork, and streamflow at Columbia Falls was typically three times the streamflow at Border (fig. 3*A*). Generally, tributaries with the greatest streamflow during high-flow conditions were Big, Coal, Kintla, and Bowman Creeks (sites 26, 20, 6, and 14, respectively; fig. 4*A*). Tributaries with the greatest streamflow during low-flow conditions were Whale, Kintla, and Trail Creeks (sites 8, 6, and 5, respectively; fig. 4*B*).

Tributaries accounted for about 85 percent of streamflow gains between the Border and Columbia Falls stations during low-flow conditions, indicating unmeasured groundwater or small- surface-water inflows along the study reach of the main stem were about 15 percent or less of the total flow in the stream; total tributary streamflow contributions during high-flow conditions were difficult to quantify due to uncertainty in the streamflow measurements. Streamflow in the North Fork during low-flow conditions decreased slightly in a downstream direction from below the confluence with Whale Creek (site 8) to above the confluence with Bowman Creek (site 14) during low-flow conditions in 2008. Additionally, only a slight gain in streamflow occurred in the North Fork downstream from Bowman Creek despite its considerable discharge (47 ft^3/s; fig. 4*B*). The North Fork valley is characterized by numerous broad, low-gradient areas, and these data indicate that the North Fork lost streamflow to groundwater in a broad, low-stream-gradient area located between Whale Creek and Quartz Creek (site 17). Substantial increases in streamflow that occurred downstream from Quartz Creek are not accounted for by tributary inputs, indicating reintroduction of groundwater to the North Fork along this reach.

Water-Quality Characteristics of the North Fork Flathead River

Water quality of the North Fork can be affected by a number of factors including the timing of snowmelt, spatial variability in bedrock geology, and anthropogenic activities. The following subsections of this section (1) describe seasonal and spatial variability in field properties and concentrations of major ions, nutrients, suspended sediment, and trace elements, including comparison of selected water-quality characteristics with appropriate aquatic-life standards where relevant; (2) describe loads of selected water-quality constituents in the North Fork and its tributaries; and (3) present the results of trend analyses performed on water-quality data from the two long-term gaging stations and the Flathead River QW site.

Field Properties

Values for specific conductance at the two long-term gaging stations (Border and Columbia Falls) varied inversely with streamflow, and maximum values occurred during low-flow conditions (281 microsiemens per centimeter at 25°C (μS/cm) and 238 μS/cm, respectively; fig. 5*A*; table 4). Groundwater is a large component of streamflow during low-flow conditions and typically has higher concentrations of dissolved solids than snowmelt or surface water, resulting in higher values of specific conductance during low-flow conditions. Minimum values of specific conductance at Border and Columbia Falls occurred during high-flow conditions due to the influx of dilute snowmelt water and were 159 μS/cm and 136 μS/cm, respectively (fig. 5*A*; table 4). Median specific conductance during the study was greater at Border (238 μS/cm) than at Columbia Falls (179 μS/cm; table 4). The decrease in specific conductance between the two gaging stations is due to low-conductivity inflows from tributaries south of the border, with the exception of Tepee and Whale Creeks. Tepee and Whale Creeks had higher specific conductance than most tributaries, reflecting differences in geology among tributary basins. Carbonate bedrock and associated glacial till, which are relatively susceptible to weathering, underlie a large portion of these basins and are likely to contribute more dissolved solids than siliceous bedrock found in other tributary basins (fig. 2).

Dissolved-oxygen concentrations were similar between the two long-term gaging stations and ranged from 9.5 to 14.1 milligrams per liter (mg/L) during the study period (table 4). Dissolved-oxygen concentration was greatest during winter and spring and decreased in late summer as water temperature

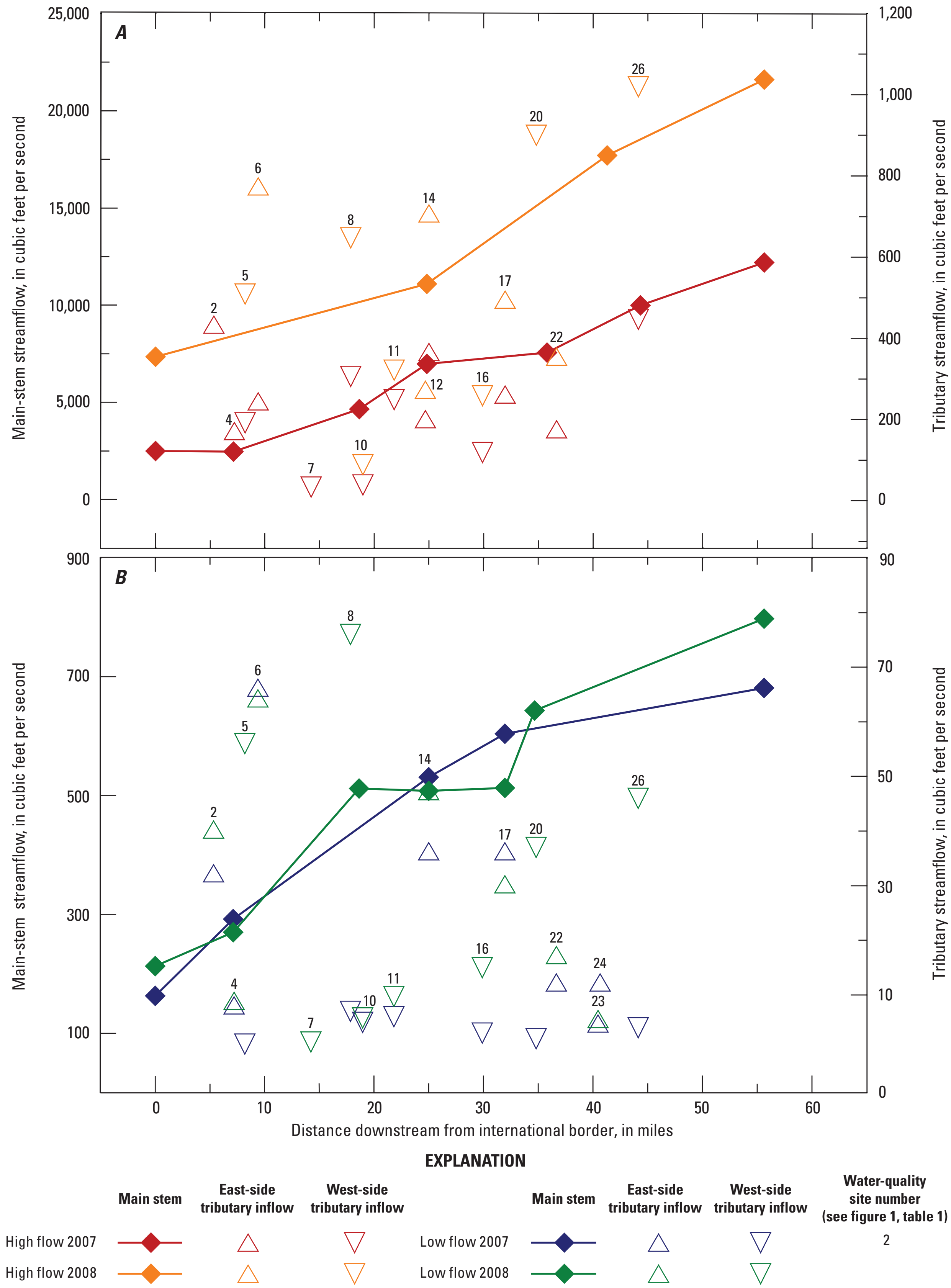

Figure 4. Main-stem and tributary streamflow for the North Fork Flathead River during (*A*) high-flow conditions from May 8 to 10, 2007, and May 27 to 31, 2008 and (*B*) low-flow conditions from August 20 to August 21, 2007 and September 16 to 19, 2008, with distance downstream from Flathead River at Flathead, British Columbia station (12355000; Border), Montana.

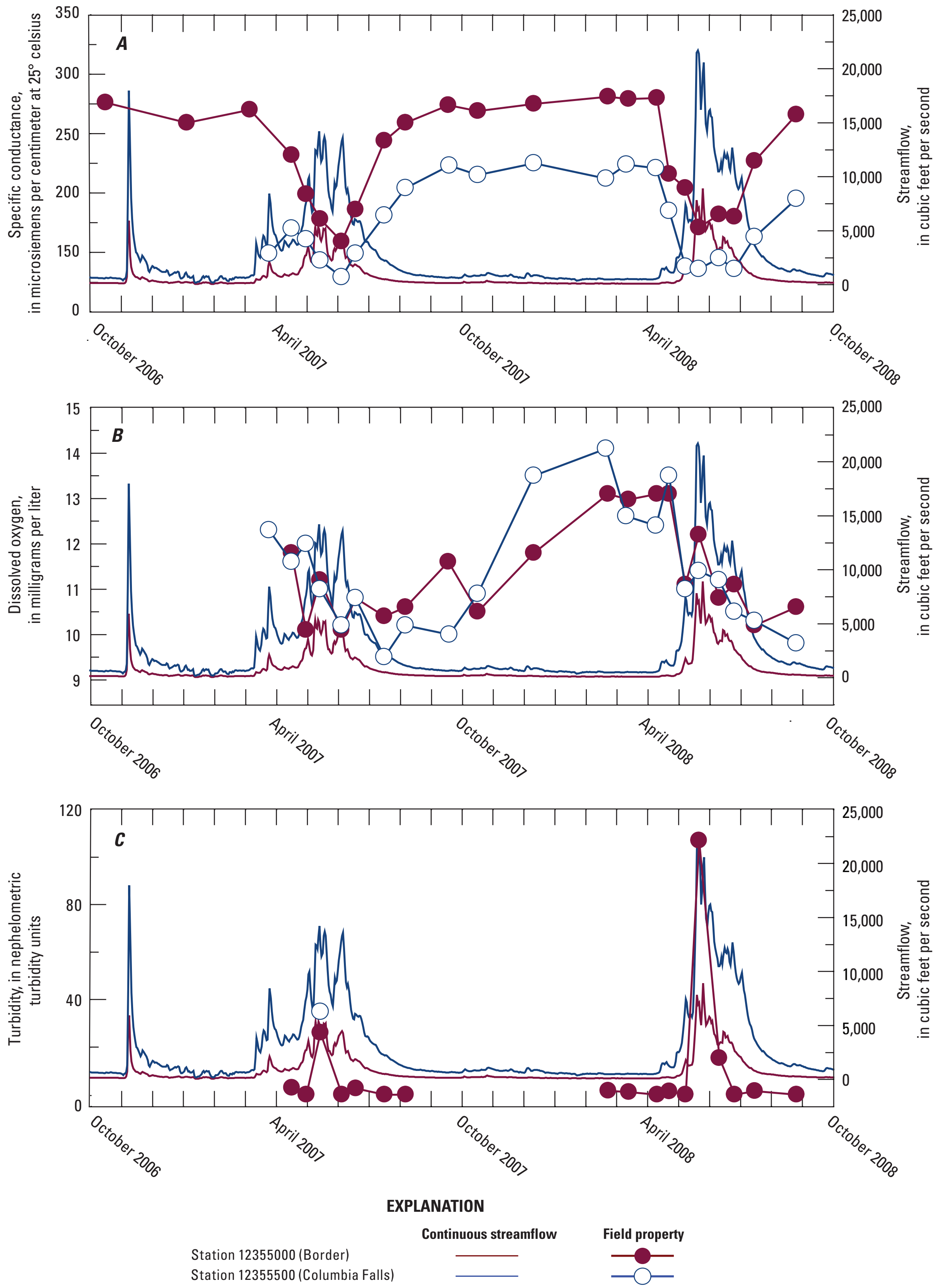

Figure 5. Time series of streamflow and (*A*) specific conductance, (*B*) dissolved oxygen, and (*C*) turbidity at the Flathead River at Flathead, British Columbia (12355000; Border), and the North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls) long-term gaging stations, Montana, water years 2007–2008.

Table 4. Summary of water quality at Flathead River at Flathead, British Columbia (12355000, Border) and North Fork Flathead River near Columbia Falls, Mont. (12355500, Columbia Falls) long-term gaging stations and water-quality standards, Montana, 2007–2008.

[All standards are from the Montana Department of Environmental Quality (Montana Department of Environmental Quality, 2010; No., number; —, not applicable;>, greater than; <, less than; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; °C, degrees Celsius; NTU, nephelometric turbidity units; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; E, estimated value below analytical reporting level or subjected to interference; N, nitrogen; P, phosphorus]

Property or constituent	Aquatic-life (human-health) standard	Border					Columbia Falls				
		No. analyses (no. censored)	Minimum	Median	Maximum	Number of exceed-ances	No. analyses (no. censored)	Minimum	Median	Maximum	Number of exceed-ances
Field properties											
Specific conductance (µS/cm)	—	23	159	238	281	—	21	136	179	238	—
Oxygen, dissolved (mg/L)	>8.0	20	10.1	11.1	13.1	0	21	9.5	11	14.1	0
Temperature, water (°C)	—	23	0	4.2	13.5	—	21	0	13.3	18.5	—
pH (standard units)	[1]6.5–9	23	7.8	8.2	8.4	—	21	7.9	8.2	8.57	—
Turbidity (NTU)	—	11 (2)	1.04	2	107	—	2 (1)	< 2	—	34.8	—
Major dissolved constituents											
Alkalinity (mg/L as $CaCO_3$)	—	20	85	124	151	—	21	69.7	87.6	115	—
Calcium, dissolved (mg/L)	—	20	24.8	37.1	46.5	—	21	19.9	25.9	35.3	—
Magnesium, dissolved (mg/L)	—	20	5.1	8	10	—	21	4.5	6.1	8.7	—
Sodium, dissolved (mg/L)	—	20	0.55	0.77	1	—	21	0.7	0.1	1.2	—
Potassium, dissolved (mg/L)	—	20	0.26	0.31	0.37	—	21	0.22	0.33	0.38	—
Sulfate, dissolved (mg/L)	—	20	2.4	4.1	6.1	—	21	2.7	4.76	10.2	—
Chloride, dissolved (mg/L)	—	20 (2)	E 0.07	0.12	0.42	—	21 (1)	E 0.09	0.18	0.39	—
Silica, dissolved (mg/L)	—	20	3.8	4.5	5	—	21	4.4	4.99	6	—
Fluoride, dissolved (mg/L)	[3](4)	20 (1)	E 0.06	0.1	0.13	0	21 (12)	E 0.05	0.1	0.12	0
Nutrients, carbon, and suspended sediment											
Nitrogen, total (mg/L as N)	[4]0.209	20 (8)	E 0.03	0.06	0.33	0	21 (2)	E 0.04	0.08	0.37	0
Nitrate plus nitrite, dissolved (mg/L as N)	[4]0.02	20 (12)	E 0.01	0.02	0.05	0	21 (6)	E 0.01	0.02	0.07	0
Ammonia, dissolved (mg/L as N)	[4]0.65	11 (9)	E 0.01	< 0.02	< 0.02	0	11 (11)	< 0.02	< 0.02	< 0.02	0
Orthophosphate, dissolved (mg/L as P)	—	20 (5)	E 0.003	0.005	0.007	—	21 (8)	E 0.003	0.005	0.006	—
Phosphorus, total (mg/L as P)	[4]0.006	20 (9)	E 0.00	< 0.01	0.23	0	21 (9)	E 0.00	< 0.01	0.21	0
Carbon, dissolved organic (mg/L)	—	7	0.7	1.1	3.2	—	—	—	—	—	—
Carbon, total organic (mg/L)	—	4	0.8	1.7	3.6	—	4	0.8	1.6	3.1	—
Suspended sediment (mg/L)	—	20	E 1.00	8	319	—	21	E 1.00	4	308	—

Table 4. Summary of water quality at Flathead River at Flathead, British Columbia (12355000, Border) and North Fork Flathead River near Columbia Falls, Mont. (12355500, Columbia Falls) long-term gaging stations and water-quality standards, Montana, 2007–2008.—Continued

[All standards are from the Montana Department of Environmental Quality (Montana Department of Environmental Quality, 2010; No., number; —, not applicable; >, greater than; <, less than; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; °C, degrees Celsius; NTU, nephelometric turbidity units; µg/L, micrograms per liter; $CaCO_3$, calcium carbonate; E, estimated value below analytical reporting level or subjected to interference; N, nitrogen; P, phosphorus]

Property or constituent	Aquatic-life (human-health) standard	Border					Columbia Falls				
		No. analyses (no. censored)	Minimum	Median	Maximum	Number of exceedances	No. analyses (no. censored)	Minimum	Median	Maximum	Number of exceedances
Trace elements											
Arsenic, total (µg/L)	[2]	11 (2)	E 0.344	0.4	1.74	0	4	0.34	0.58	1.8	0
Cadmium, total (µg/L)	[2]	11 (2)	E 0.01	0.01	0.217	0	4	E 0.01	0.02	0.12	0
Chromium, total (µg/L)	[2]	11 (1)	E 0.27	0.35	2.74	0	4 (2)	<0.4	0.69	3.06	0
Copper, total (µg/L)	[2]	11 (6)	E 0.71	<1.2	4.49	0	4 (2)	<1.20	1.5	5.8	0
Lead, total (µg/L)	[2]	11 (1)	E 0.034	0.14	3.01	1	4 (1)	E 0.031	0.5	4.07	1
Nickel, total (µg/L)	[2]	11 (1)	E 0.112	0.16	3.96	0	4 (1)	<0.16	0.62	3.96	0
Zinc, total (µg/L)	[2]	11 (4)	E 1.03	2	15.4	0	4 (2)	<2	3.4	21.1	0

[1]Natural pH outside this range must be maintained without change (Montana Department of Environmental Quality, 2010).

[2]Table value standard calculated based on hardness of sample for trace elements or a maximum pH of 8.6 at 20°C for ammonia (Montana Department of Environmental Quality, 2010).

[3]Dissolved concentration.

[4]U.S.Montana Department of Environmental quality nutrient criteria for Canadian Rockies ecoregion (Suplee and others, 2008).

and biological respiration in the streams increased (fig. 5*B*). The MTDEQ has established an aquatic-life standard minimum instantaneous dissolved-oxygen concentration of 8.0 mg/L for class A–1 rivers (Montana Department of Environmental Quality, 2010). Dissolved oxygen concentrations were well above the standard at both stations during the study period with values ranging from 9.5 to 14.1 mg/L.

Variations in turbidity at the Border station coincided with the rising and falling limbs of the snowmelt hydrograph, with values increasing from less than 2 nephelometric turbidity units (NTU) during low-flow conditions to greater than 100 NTU during high-flow conditions (fig. 5*C*). Substantial transport of particulate matter occurs during spring snowmelt as indicated by an increase of approximately 50 times in turbidity during this time. Turbidity values were below the EPA criteria of 2 NTU (U.S. Environmental Protection Agency, 2000) prior to, and shortly after, the spring snowmelt. Because turbidity is expected to vary little during low-flow conditions, it is likely the EPA criterion was not exceeded for much of the year, but values did exceed the criterion for all measurements during snowmelt. However, the State of Montana has not adopted EPA criteria and utilizes its own standard for turbidity. The MTDEQ states that for Class A–1 rivers such as the North Fork, turbidity should not exceed naturally occurring values (Montana Department of Environmental Quality, 2010). Data for the North Fork upstream from the Border station are insufficient to conclusively determine if high values of turbidity during spring runoff are from natural sources. Nevertheless, values of turbidity are within the range of relatively undisturbed streams in GLAC and there has been no prior designation of impairment due to turbidity at either station, suggesting the high levels of turbidity by themselves are not an indication of impairment.

Major Ions

Data from the two long-term gaging stations (Border and Columbia Falls), as well as from synoptic sampling sites, indicate that dissolved calcium, magnesium, and alkalinity are the dominant solutes in stream water in the study area. Similar to values of specific conductance, concentrations of major ions (as represented by dissolved magnesium, alkalinity, and sulfate; fig. 6*A*–*C*) had an inverse relation to discharge at both stations. Major ions are derived primarily from geologic weathering in the North Fork Basin and are present in higher concentrations in groundwater. Higher concentrations of major ions in the North Fork during low-flow conditions probably reflect the substantial groundwater inputs to streamflow during this time. During high-flow conditions, the influx of dilute snowmelt water results in an overall decrease in concentrations of major ions. Decreases of many major-ion concentrations with the exception of sulfate occurred along the North Fork between Border and Columbia Falls; this observation is discussed in detail in the PCA discussion later in this subsection.

Data from the two short-term gaging stations at Bowman and Quartz Creeks provide more detailed information on seasonal variability in tributary streams. Bowman and Quartz Creeks have similar characteristics at the onset of snowmelt with rapid declines in dissolved concentrations of major ions (as represented by alkalinity and calcium; fig. 7*A*–*C*). Interestingly, silica does not exhibit snowmelt dilution in Bowman Creek (fig. 7*A* and *C*). In contrast to other major ions, dissolved silica concentrations typically vary little with discharge, and thus do not exhibit the same pattern with snowmelt dilution (Wetzel, 2001). The relative stability of silica concentrations with respect to variations in discharge are likely the result of numerous biotic and abiotic processes, including biological uptake by aquatic organisms in lakes and streams and the precipitation and dissolution of secondary silicate minerals in soils (Wetzel, 2001; Clow and Mast, 2010).

After the period of snowmelt, concentrations of alkalinity and calcium in Quartz Creek increased to near pre-snowmelt values by mid-September. In contrast, concentrations of alkalinity and calcium in Bowman Creek did not increase to pre-snowmelt values even by mid-November (fig. 7*A*–*C*). The difference in recovery time is attributed to the function of Bowman Lake as a storage reservoir for dilute snowmelt water. Snowmelt water accumulates in Bowman Lake in spring and is continually discharged through the summer and fall, prolonging the effect of snowmelt dilution. Furthermore, dissolved silica concentrations are lower in Bowman Creek than in Quartz Creek for much of the year. Silica is utilized in relatively large quantities by diatomaceous algae in lakes (Wetzel, 2001), and biological uptake in Bowman Lake could explain the lower silica concentrations in Bowman Creek. Although Quartz Creek also has a lake along its watercourse, the lake is smaller and farther upstream from the gage than the lake in the Bowman Creek Basin (fig. 1).

PCA of 2007 and 2008 synoptic samples was used to further identify factors affecting the spatial variability in concentration of major ions for both the long-term gaging stations and the synoptic sampling sites. Because of the limited contact time of snowmelt runoff with geologic materials, most spatial variability in chemistry was assumed to occur in groundwater; thus, only samples collected during low-flow conditions were considered to minimize the interference of snowmelt dilution. Spatial variability in major ions was found to be primarily explained by two principal components. A score was assigned to each site for the first two principal components and plots of scores were used to illustrate how the components vary spatially in the study area (figs. 8 and 9).

Principal component 1 was strongly associated with concentrations of alkalinity and dissolved calcium and attributed to the weathering of carbonate minerals. Generally, tributaries on the western side of the basin had higher scores for component 1 and higher concentrations of alkalinity and dissolved calcium than sites on the eastern side of the basin (fig. 8). This pattern is explained by the greater abundance of carbonate

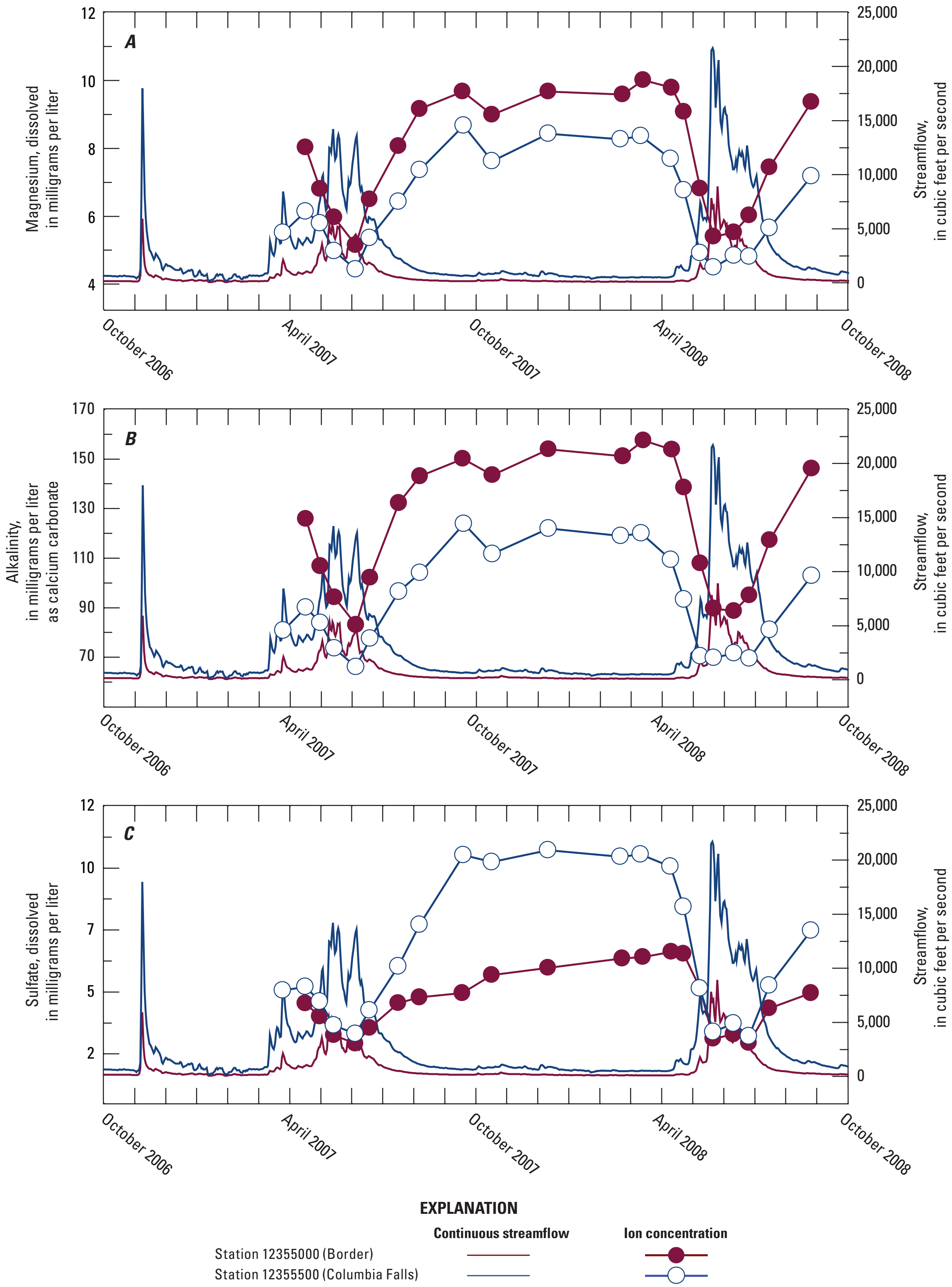

Figure 6. Time series of streamflow and concentrations of (*A*) magnesium, (*B*) alkalinity, and (*C*) sulfate at Flathead River at Flathead, British Columbia (12355000; Border) and North Fork Flathead River near Columbia Falls, Mont. (12358500; Columbia Falls) long-term gaging stations, Montana, 2007–2008.

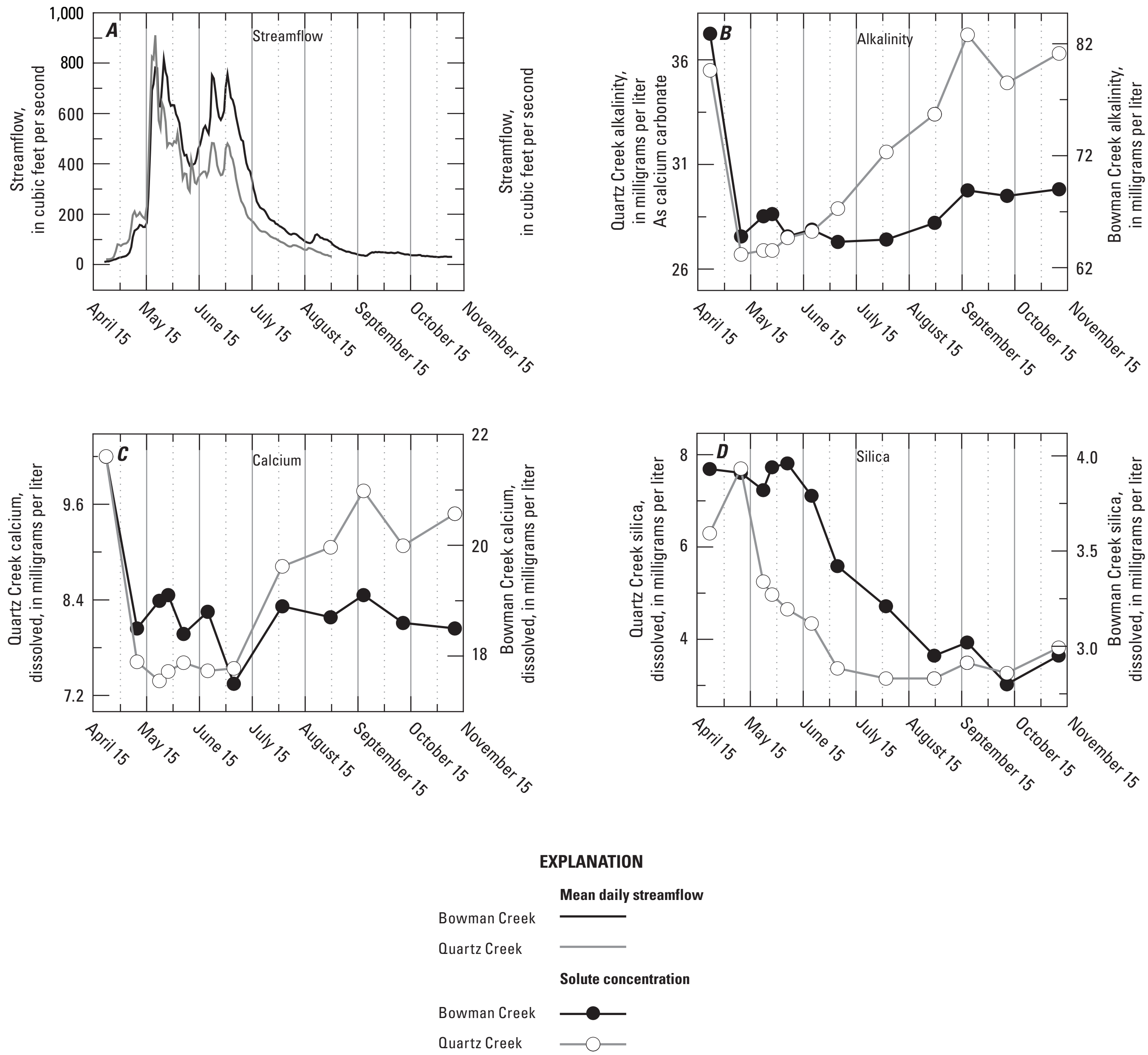

Figure 7. Time series of (*A*) streamflow and (*B-D*) concentrations of alkalinity, calcium, and silica at the Bowman Creek at Bridge near Mouth (484708114165001) and Quartz Creek (484321114132901) short-term gaging stations, Montana, 2008.

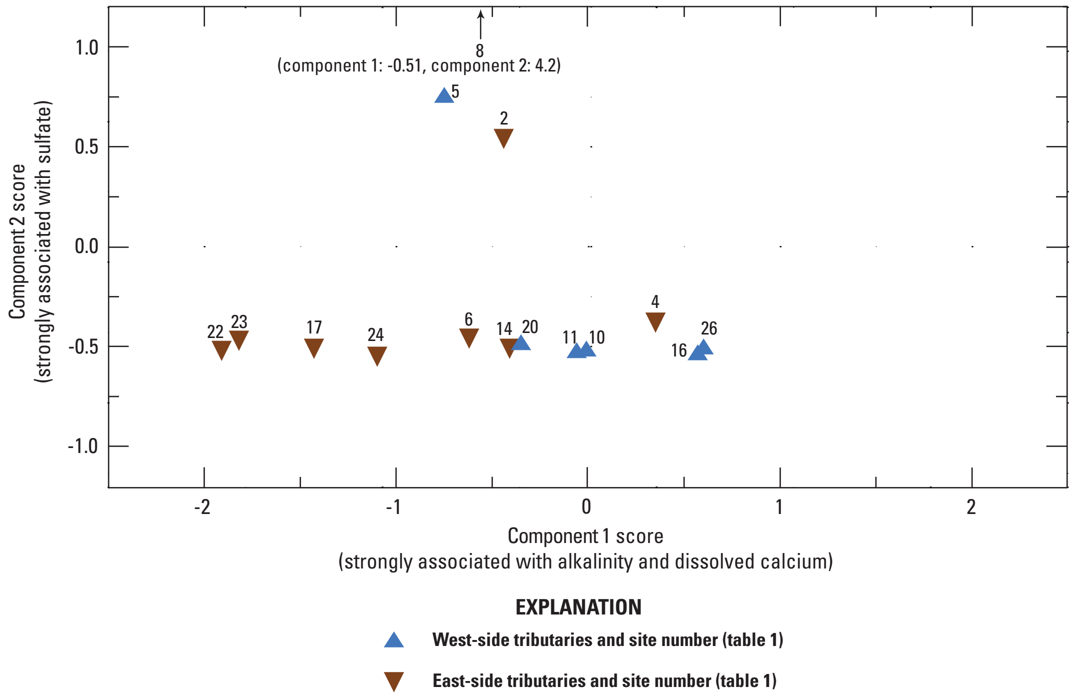

Figure 8. Scores from principle component analysis of the North Fork Flathead River tributary synoptic sampling sites by west or east side of the basin, September 16–19, 2008.

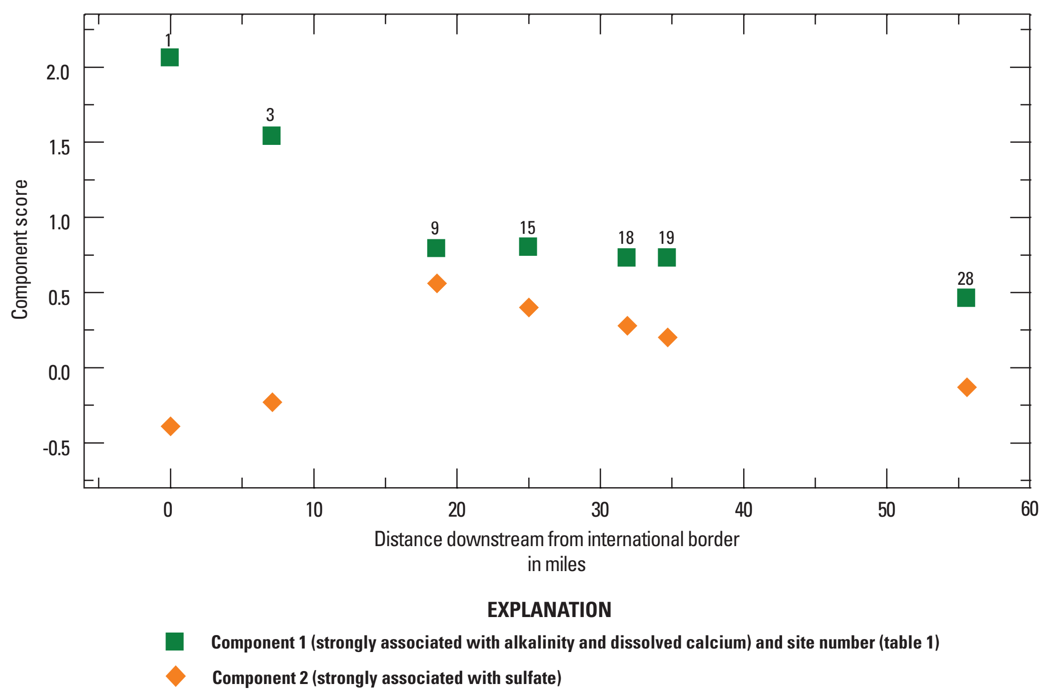

Figure 9. Component 1 and component 2 scores from principle component analysis of North Fork Flathead River main-stem synoptic sampling sites with distance downstream from the Flathead River at Flathead, British Columbia station (12355000; Border) at the International border, September 16–19, 2008.

bedrock on the western side of the basin (fig. 2). For tributary streams, percentage of carbonate bedrock of each tributary basin was related to concentrations of alkalinity and dissolved calcium and a strong positive correlation was found for both (r^2=0.912 and r^2=0.908, respectively).

Additionally, component scores for synoptic sites along the main stem of the North Fork exhibited a distinct pattern in a downstream direction. Component 1 scores were highest for Border (site 1) and quickly declined through the reach containing the confluence of the main stem with Kishenehn (site 2) and Whale Creeks (site 8) (sites 3 and 9 on fig. 9). Component 1 scores were relatively constant for the remainder of the main-stem samples. Scores represent the relative influence of each component on stream chemistry, and the initial decline in component 1 score is at least partly the result of an increased influence of component 2.

Component 2 was strongly associated with sulfate and, to a lesser extent, alkalinity and calcium. Component 2 is difficult to interpret, but it might be attributed to the weathering of sulfur-containing minerals in the northern tributary basins. Trail (site 5), Kishenehn (site 2), and Whale (site 8) Creeks had the highest component 2 scores (fig. 8) and the highest concentrations of dissolved sulfate in tributary samples; dissolved sulfate concentrations were as high as 58.9 mg/L during low-flow conditions in 2008 in Whale Creek (Appendix 1). Component 2 scores were low for sites on the main stem of the North Fork upstream from Whale Creek, and they then increased three times below its confluence with Whale Creek. Component 2 scores gradually declined at sites on the main stem of the North Fork downstream from Whale Creek (fig. 9). These data indicate that the component 2 influence is specific to northern tributaries within the study area.

An overall decline in the influence of both component1 and component 2 between Border and Columbia Falls suggests most geologic solute inputs occur in the northern part of the North Fork Basin. Subsequent streamflow inputs downstream from Whale Creek result in an overall dilution of the North Fork with respect to dissolved concentrations of alkalinity, calcium, magnesium, and sulfate. Results of PCA analysis of synoptic samples also are reflected in data from the two long-term gaging stations; concentrations of alkalinity, calcium, and magnesium were significantly higher at Border than Columbia Falls during the study period ($p = 0.0001$, $p = 0.0001$, $p = 0.0053$, respectively). These data support findings from Moreland and others (1987) that substantial groundwater inputs occur upstream from the international border. However, higher concentrations of alkalinity, calcium, and magnesium at the Border station could also indicate that more carbonate bedrock underlies the Canadian part of the basin.

Dissolved chloride concentrations were less than 0.52 mg/L for all synoptic site samples and were less in most tributary streams than in the main stem, with several exceptions, including Kishenehn, Kintla, Tepee, and Logging Creeks. Chloride concentrations were considerably higher than volume-weighted mean chloride concentrations in atmospheric deposition (0.041 mg/L; National Atmospheric Deposition Program, 2010) and were as high as 0.51 mg/L at Kishenehn Creek (Appendix 1). Evapotranspiration alone cannot explain the high chloride concentrations in Kishenehn Creek. Much of the carbonate bedrock in the North Fork Basin is of a marine-sedimentary origin (Ross, 1959), and could be one source of elevated chloride concentrations in Kishenehn, Kintla, Tepee, and Logging Creeks.

Nutrients

Concentrations of nutrients at the two long-term gaging stations (Border and Columbia Falls) were at or near their respective analytical reporting levels for much of the year, except during high-flow conditions (table 4). Total nitrogen (dissolved plus particulate) at the two stations ranged from less than 0.06 mg/L (the analytical reporting limit) during low-flow conditions to 0.37 mg/L during high-flow conditions (fig. 10*A*). Concentrations of dissolved nitrate plus nitrite (herein generally referred to as dissolved nitrate) increased by a smaller amount during snowmelt than total nitrogen concentrations and ranged from less than 0.02 mg/L (the analytical reporting limit) during low-flow conditions to 0.07 mg/L during high-flow conditions (fig 10*B*). The higher concentrations of total nitrogen than dissolved nitrate during high-flow conditions suggest that much of the nitrogen in the North Fork at high flows is present in an organic or particulate form and that it is delivered from the landscape into the streams by snowmelt water. Dissolved orthophsophate, the bioavailable form of phosphorus, was below or only slightly above the analytical reporting limit of 0.006 mg/L during low- and high-flow conditions, but total phosphorous (dissolved plus particulate) concentrations were as high as 0.23 mg/L during high-flow conditions at the two stations (fig. 10*C*). Similar to nitrogen, the greater concentrations of total phosphorous relative to dissolved orthophosphate suggest that much of the phosphorous in the North Fork at high flows is in an organic or particulate form and thus is not biologically available.

The seasonal pattern in nutrient concentrations was in sharp contrast to the pattern for major ions, reflecting differences in sources. Precipitation during the winter months in the North Fork Basin falls primarily as snow, which acts as a substantial storage reservoir of dissolved nitrate. The mean concentration of dissolved nitrate in winter precipitation for 2007 and 2008 at a nearby National Atmospheric Deposition Program site was 0.41 mg/L (National Atmospheric Deposition Program, 2010). As the snowpack melts in the spring and early summer, accumulated dissolved nitrate is released. Interestingly, increases in dissolved nitrate concentration at the two long-term gaging stations observed during snowmelt (0.07 mg/L or less; fig. 10*B*) were much lower than would be expected given the mean dissolved nitrate concentration in winter precipitation (0.41 mg/L). Dissolved nitrate is an important plant nutrient, and biological uptake by aquatic algae could explain the relatively slight increases in concentration observed during snowmelt. Hauer and others (2007)

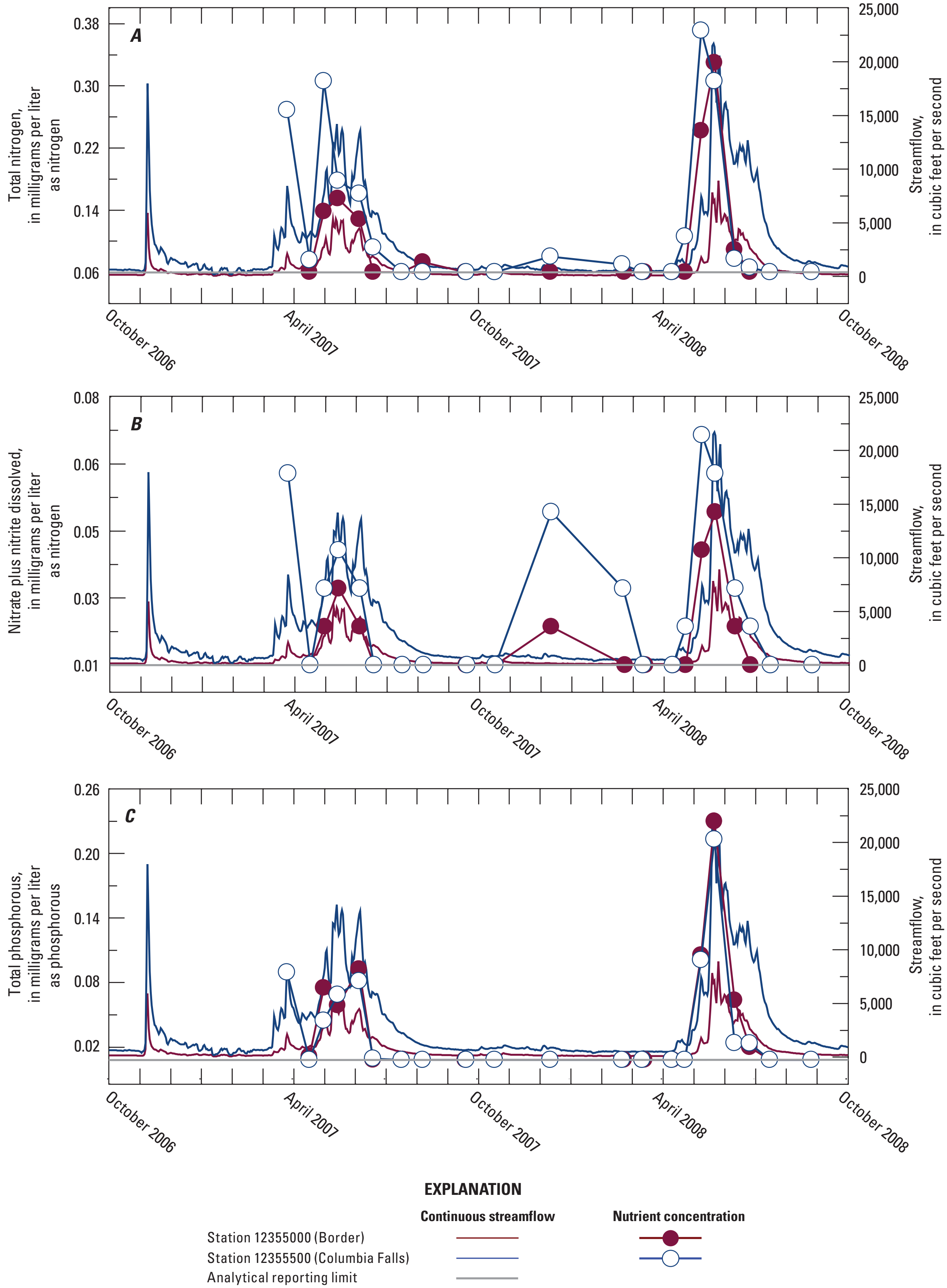

Figure 10. Time series of streamflow and concentrations of (*A*) total nitrogen, (*B*) dissolved nitrate plus nitrite, (*C*) total phosphorus at Flathead River at Flathead, British Columbia (12355000; Border) and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls) long-term gaging stations, Montana, 2007–2008.

have shown that dissolved nitrate released from the snowpack in the North Fork Basin is rapidly consumed by algae in receiving streams and converted to organic nitrogen, thus depleting dissolved nitrate and increasing the concentration of total nitrogen. Additionally, substantial transport of phosphorous with suspended sediment during spring snowmelt has been documented in the North Fork and likely explains the increased total phosphorous concentrations observed during snowmelt (Ellis and others, 1998). These findings are further supported by a strong correlation between concentrations of total phosphorus and concentrations of suspended sediment at Border and Columbia Falls (r^2=0.992). Therefore, elevated concentrations of total nitrogen and total phosphorus during high-flow conditions likely do not indicate anthropogenic sources of water-quality impairment within the basin. Rather, high nutrient concentrations during snowmelt are probably the result of natural processes occurring within the basin as well as anthropogenic contributions from outside the basin through atmospheric deposition of nitrate.

Data from the two short-term gaging stations at Bowman and Quartz Creeks further illustrate the effects of snowmelt on nutrient concentrations. Snowmelt water accumulates in Bowman Lake and is continually discharged through the summer months. The concentrations of dissolved nitrate, which is primarily stored in the snowpack in the North Fork Basin, rapidly increase in Bowman and Quartz Creeks at the onset of snowmelt (fig. 11*A* and *B*). Dissolved nitrate concentrations remain elevated at Bowman Creek and gradually decline through the late summer, likely due to uptake by plants. In contrast, dissolved nitrate concentrations in Quartz Creek quickly decline and drop below the analytical reporting limit near the end of the snowmelt peak in early summer, reflecting the reduced residence time of snowmelt water in Quartz Creek or greater stream length downstream from the lakes for in-stream processes to occur.

Data collected during synoptic-sampling events illustrate the spatial distribution of nutrient concentrations in the North Fork Basin and provide further insight into sources. Concentrations of total-dissolved nitrogen (dissolved nitrate plus nitrite plus ammonia) and total phosphorous (dissolved plus particulate) in tributary streams did not exhibit any pattern corresponding to the spatial distribution of residential developments, timber harvesting activities, or past wild fires. The highest concentrations of total-dissolved nitrogen (as high as 0.40 mg/L at Akokala Creek, site 12) and total phosphorous (as high as 0.07 mg/L at Akokala Creek, site 12) were detected in synoptic samples from eastern tributaries within GLAC that are subject to little anthropogenic effects and were not affected by the most recent wildfires (fig. 12*A* and *B*), indicating that any effects (as of 2007-2008) on nutrient concentrations from local anthropogenic activities or wildfires in the basin were not observed.

The MTDEQ has developed its own set of nutrient criteria, which differ from the EPA criteria in that they are only applicable during the summer months from July to September. The MTDEQ criteria were restricted to these months to account for natural variability in nutrient concentrations caused by low temperatures during the winter and snowmelt events during the spring (Suplee and others, 2008). Total nitrogen and total phosphorus concentrations were below the MTDEQ nutrient criteria of 0.209 mg/L and 0.006 mg/L (Suplee and others, 2008), respectively, at both long-term gaging stations and most synoptic sampling sites during the applicable months from July through September. Exceptions include one sample each for total-dissolved nitrogen at Hay Creek (0.21 mg/L, site 16) and Big Creek (0.30 mg/L, site 26) in August 2007.

Suspended Sediment

Suspended-sediment concentrations at the two long-term gaging stations (Border and Columbia Falls) increased from less than 1 mg/L during low-flow conditions to more than 300 mg/L during high-flow conditions, which have greater kinetic energy for erosion and transport (fig. 13; Nanson, 1974). Median concentrations of suspended sediment were higher at Border than Columbia Falls (8 mg/L and 4 mg/L, respectively) (table 4). The valley widens at numerous locations along the North Fork between the Border and Columbia Falls stations; deposition of suspended sediment in these broad, low stream-gradient areas south of the Border station could explain the lower median concentration of suspended sediment at the Columbia Falls station. Interestingly, data from synoptic sampling sites indicate concentrations of suspended sediment during high-flow conditions were generally greater in tributaries on the eastern side of the basin than on the western side of the basin (fig. 14). One limiting factor affecting concentration of suspended sediment in streams is the rate of supply of material to the stream channel (Nanson, 1974). In high-relief alpine stream basins like those present in the eastern part of the study area, soil slump and shallow landslides can supply large amounts of material to the stream channel, resulting in high concentrations of suspended sediment. Additionally, eastern tributary basins, with the exception of part of the Kishenehn Basin, are located entirely within protected areas, suggesting the observed concentrations of suspended sediment in the eastern tributaries are from natural sources.

Trace Elements

Trace elements were analyzed in selected samples from the two long-term gaging stations (Border and Columbia Falls). Trace-element samples were unfiltered because the MTDEQ aquatic-life standards are for total, rather than dissolved, concentrations. Trace-element concentrations at both stations were near or below analytical reporting levels for much of the year. Higher concentrations occurred during high-flow conditions, which is in contrast to patterns observed for major ions. The highest concentrations of total lead at Border and Columbia Falls exceeded the MTDEQ aquatic-life chronic

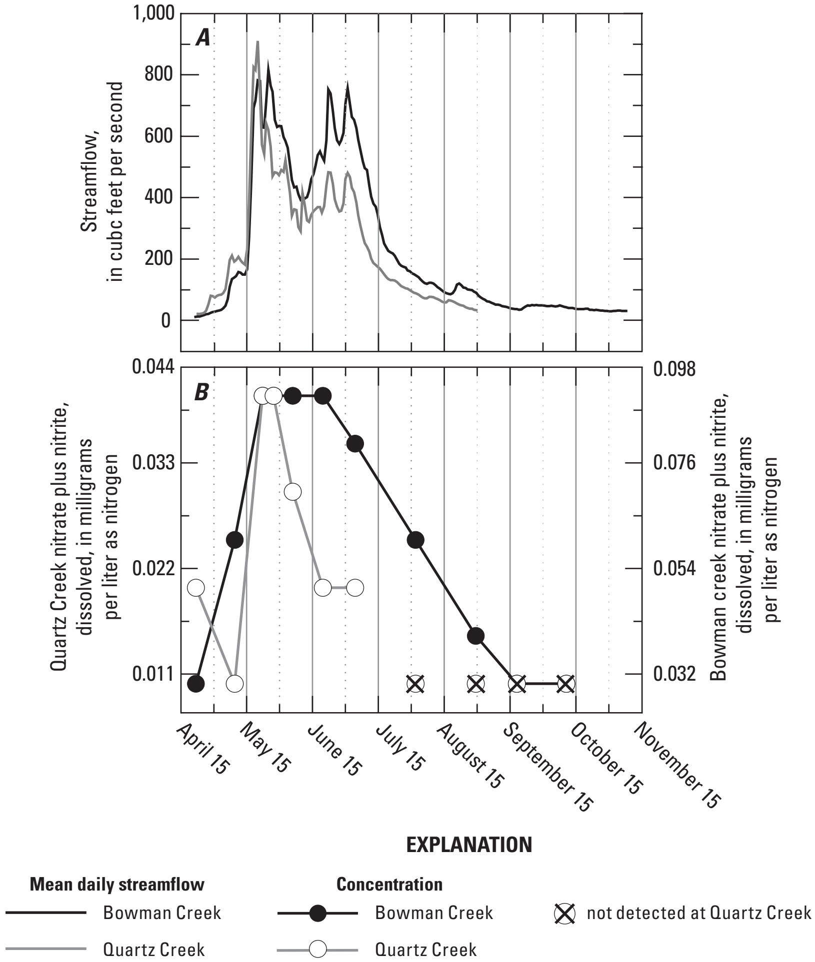

Figure 11. Time series of (*A*) streamflow and (*B*) concentrations of dissolved nitrate plus nitrite at Bowman Creek at Bridge near mouth (484708114165001) and Quartz Creek near Polebridge (484321114132901) short-term gaging stations, Montana, 2008.

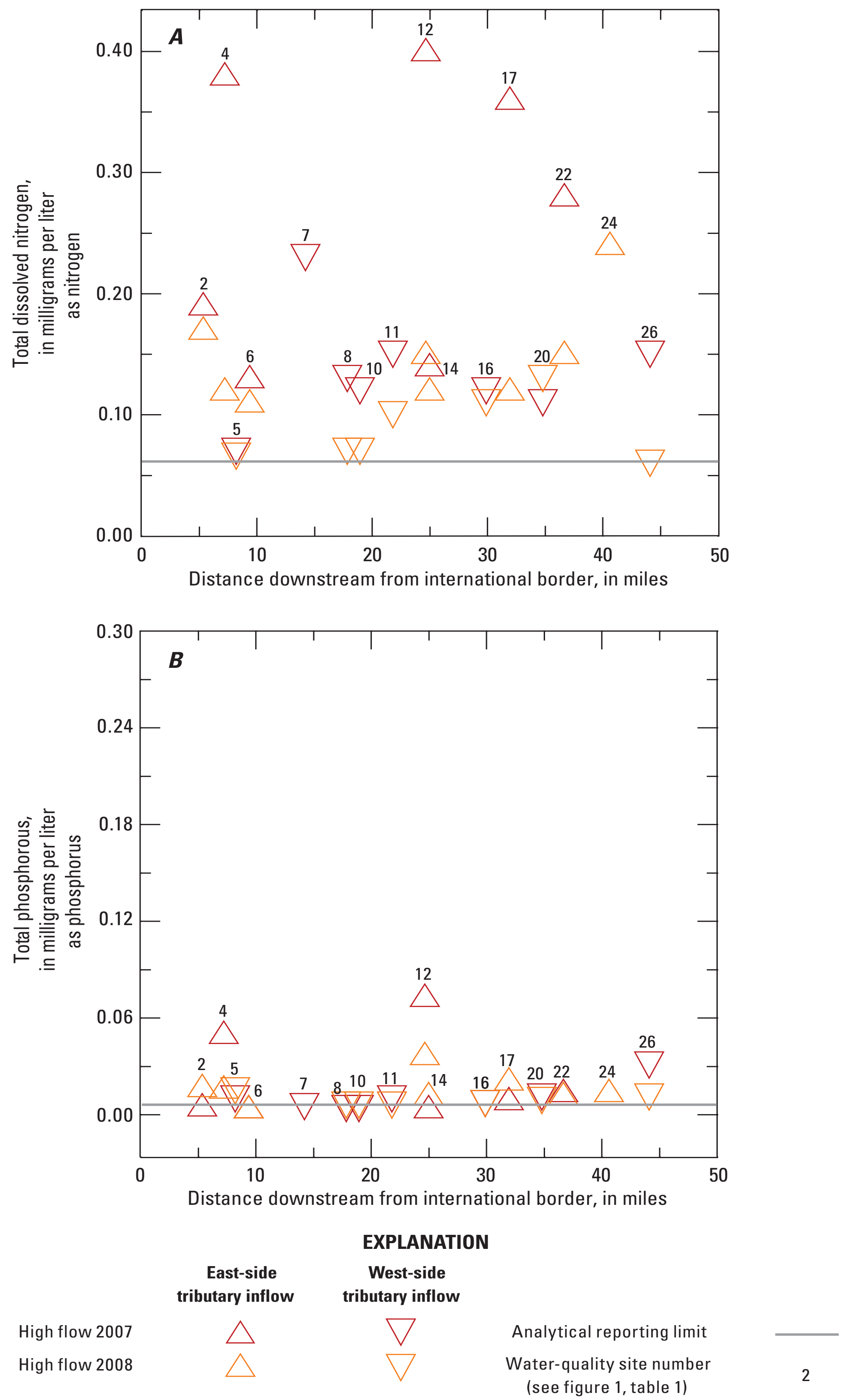

Figure 12. Concentrations of *(A)* total-dissolved nitrogen and *(B)* total phosphorous for North Fork Flathead River tributary synoptic sampling sites during high-flow conditions with distance downstream from the Flathead River at Flathead, British Columbia (12355000, Border) long-term gaging station, May 8–10, 2007, and May 27–31, 2008.

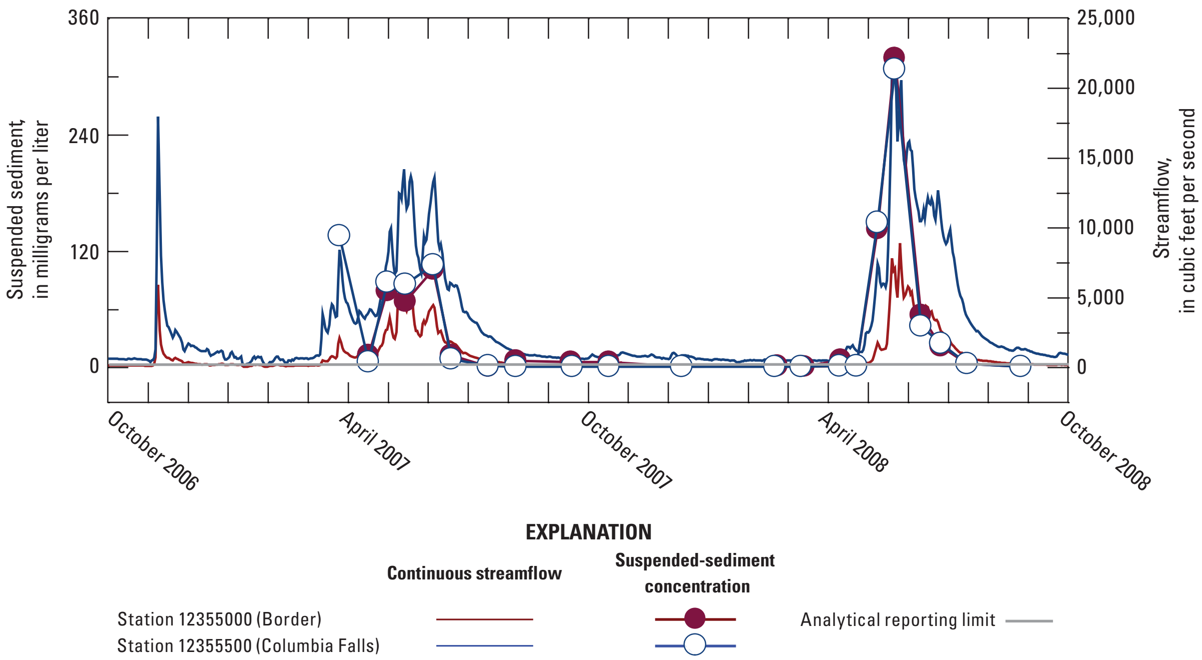

Figure 13. Time series of streamflow and suspended-sediment concentration at Flathead River at Flathead, British Columbia (12355000; Border) and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls) long-term gaging stations, Montana, 2007–2008.

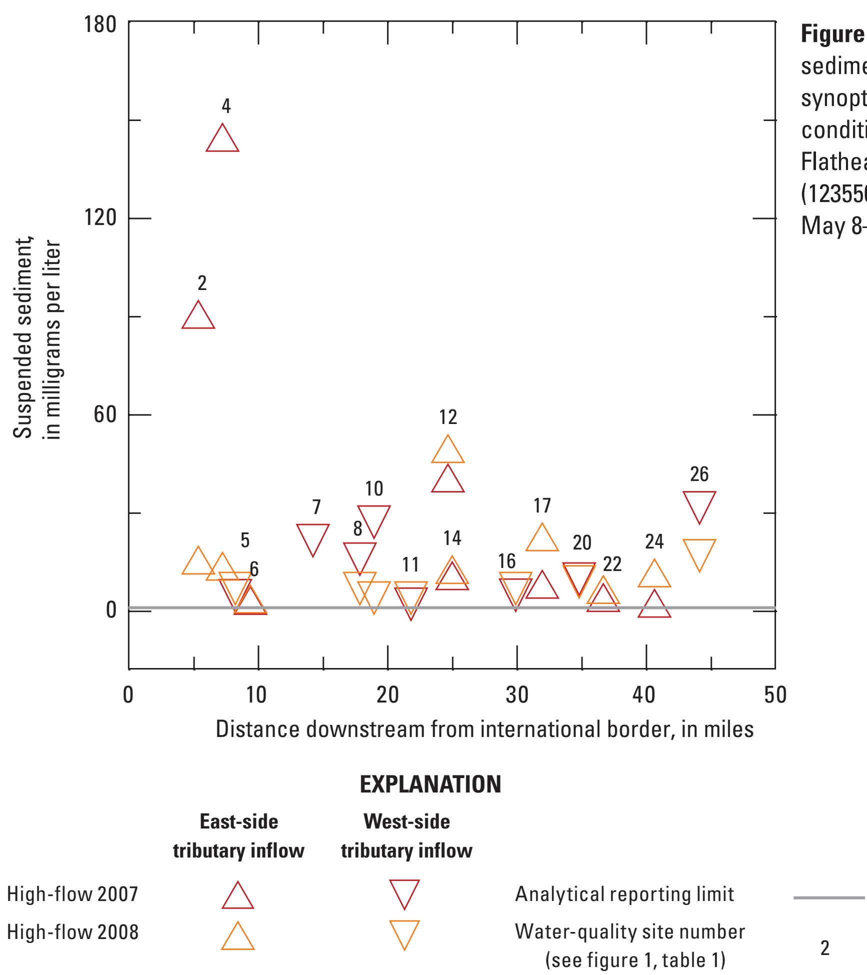

Figure 14. Concentrations of suspended sediment for North Fork Flathead River tributary synoptic sampling sites during high-flow conditions with distance downstream from the Flathead River at Flathead, British Columbia (12355000; Border) long-term gaging station, May 8–10, 2007, and May 27–31, 2008.

standards in 2008 by 0.24 µg/L and 2.06 µg/L, respectively. Samples from May 2008 at Border and Columbia Falls also had the highest concentration of suspended sediment of any samples during the study period (319 mg/L and 308 mg/L, respectively). Because trace-element samples are unfiltered, much of the total lead detected in May 2008 samples was likely associated with particulate matter in the stream. No other MTDEQ standards for trace elements were exceeded during the study period at either station.

Loads of Selected Water-Quality Constituents

Instantaneous loads for selected water-quality constituents were compared among sites to evaluate seasonal and spatial variations in solute and suspended-sediment inputs to the North Fork. Major ion loads in the North Fork and all sampled tributaries were greater during high-flow conditions than during low-flow conditions. Because streamflow varies much more than concentrations of major ions, greater streamflow conditions produce greater loads of major ions despite the lower concentrations. Thus, most of the annual load of major ions occurs during high-flow conditions.

Cumulative tributary loading of most major ions (as represented by dissolved calcium) during high-flow conditions increases relatively steadily with distance downstream from Border (fig. 15*A*). During low-flow conditions, northern tributaries [Trail Creek (site 5) to Whale Creek (site 8)] account for a larger portion of cumulative tributary loading of most major ions than southern tributaries (Whale Creek (site 8) to Big Creek (site 26); fig. 16*A*). Dissolved sulfate exhibits a different spatial pattern than that of other major ions, with relatively large increases in cumulative tributary loading from Trail Creek (site 5) to Whale Creek (site 8) and small increases in loading from Whale Creek to Big Creek (site 26) (fig. 15*B* and fig 16*B*) during high- and low-flow conditions.

Loading of most major ions from tributaries can be explained primarily by variations in streamflow. During high-flow conditions, tributaries with the greatest streamflow are relatively evenly distributed spatially along the study reach, resulting in a steady increase in cumulative tributary loading with distance from the Border station (fig. 4*A*). In contrast, during low-flow conditions, tributaries with the greatest streamflow are located in the northern part of the study area, causing increased cumulative loading from the northern tributaries relative to other tributaries in the basin (fig. 4*B*). However, the spatial pattern in sulfate loading deviates from that of other major ions due to an isolated and undetermined sulfate source present in the northern tributary basins. Whale, Trail, and Kintla Creeks account for much of the tributary sulfate loading in the North Fork Basin (sites 8, 5, and 6, respectively; fig. 15*B* and fig. 16*B*). In particular, Whale Creek accounts for about 65 percent of total tributary sulfate loading during low- and high-flow conditions.

Cumulative tributary loading of suspended sediment was calculated only for 2008 high-flow samples because concentrations during low-flow conditions were typically near or below the analytical reporting limit (1.00 mg/L). Most cumulative tributary loading of suspended sediment occurs in the southern part of the basin. Tributaries supplying the greatest loads of suspended sediment were Big, Akokala, and Quartz Creeks during high-flow conditions (sites 26, 12, and 17, respectively; fig. 17). Unlike the patterns observed for loads of major ions, tributary loads of suspended sediment were not accounted for by variations in streamflow. Big Creek (site 26) had the greatest streamflow during high-flow conditions, but Akokala and Quartz Creeks (sites 12 and 17) had considerably lower streamflow than some other tributaries in the basin (fig. 4*A*). Topography is generally steeper in the eastern part of the study area, which might explain the increased sediment load from draining tributaries. Additionally, tributary loads of suspended sediment during high-flow conditions were generally greater at tributaries on the eastern side of the basin within GLAC (fig. 17). Commercial timber harvesting activities and residential development are restricted within this part of the basin, and high loads of suspended sediment in these tributaries are likely from natural sources.

Long-Term Trends in Hydrology and Water Quality

Historical data from the two long-term gaging stations and the Flathead River QW site were tested for temporal trends in constituent concentrations using the Estimate Trend (ESTREND) computer program, which uses the non-parametric seasonal Kendall test or the Tobit procedure if more than 5 percent of the data are censored (Schertz and others, 1991). Water-quality constituent concentrations were adjusted for flow-related variability using automated procedures in ESTREND, which improves the power of the statistical test and decreases the possibility that the observed trends are artifacts of variability in streamflow (Hirsch and others, 1982; Schertz and others, 1991). Flow adjustments were not made if the flow model fit by ESTREND was not significant at the 0.10 probability level. Trends were computed based on 4 or 6 seasons per year, depending on availability of data, for both unadjusted and flow-adjusted concentrations. The ESTREND procedure also computes a trend slope, which represents the median rate of change in concentration or streamflow per year for the selected period of record.

A slightly downward unadjusted trend was detected for specific conductance at the Flathead River QW site. However, no significant flow-adjusted trend in specific conductance was detected for this station, indicating that the unadjusted trend is an artifact of the streamflow record. Similarly, a slight upward unadjusted trend was detected for sodium at Border, but data were insufficient to adjust for variations in streamflow. A significant unadjusted trend of 0.000 mg/L/yr was detected for potassium at the Flathead River QW site; however, trends values of 0.000 are an artifact of the computations used in the analysis and can be interpreted as no significant trend.

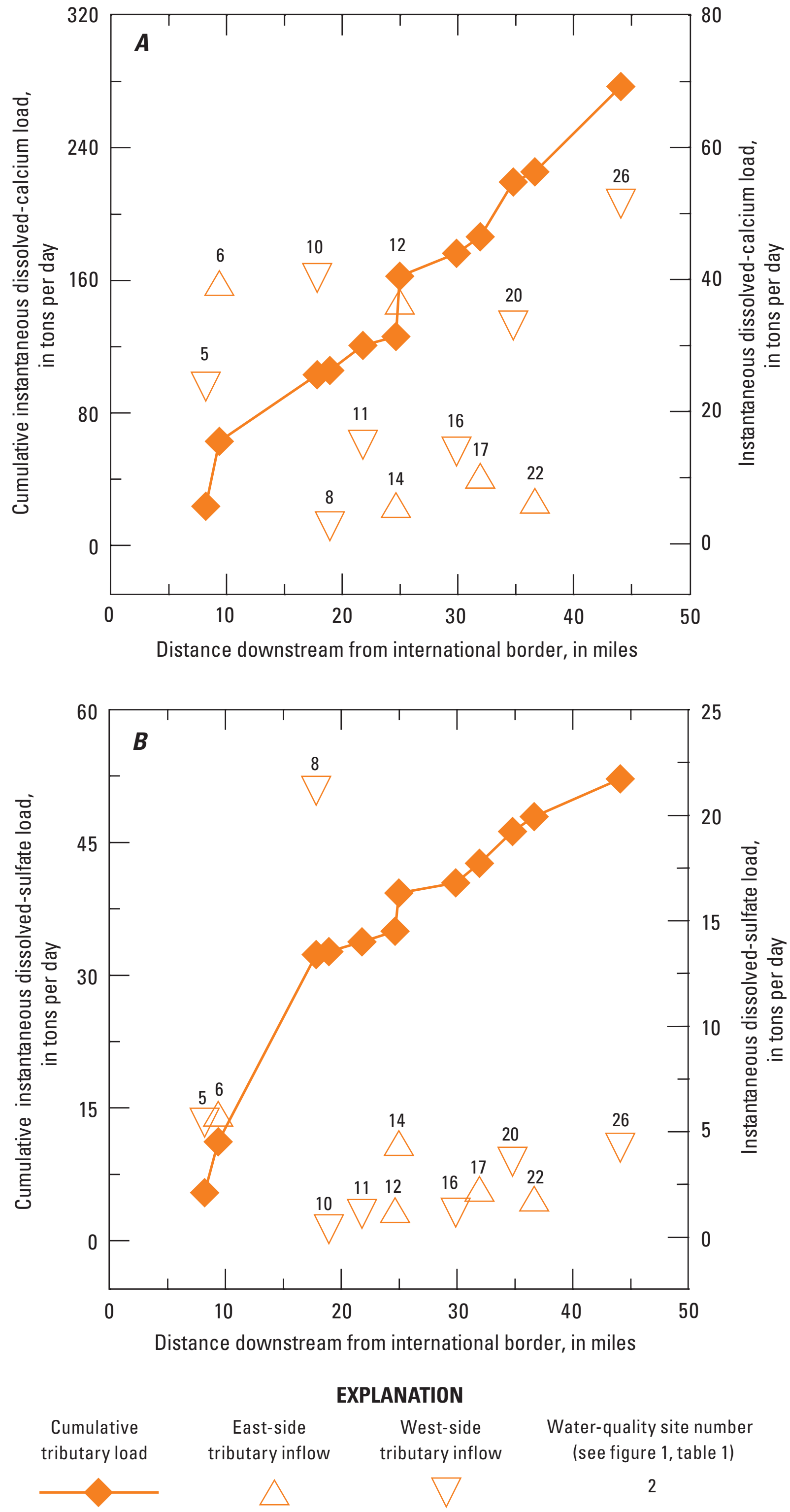

Figure 15. Instantaneous loads of (*A*) calcium and (*B*) sulfate for North Fork Flathead River tributary synoptic sampling sites during high-flow conditions with distance downstream from the Flathead River at Flathead, British Columbia (12355000; Border) long-term gaging station, May 8–10, 2007, and May 27–31, 2008.

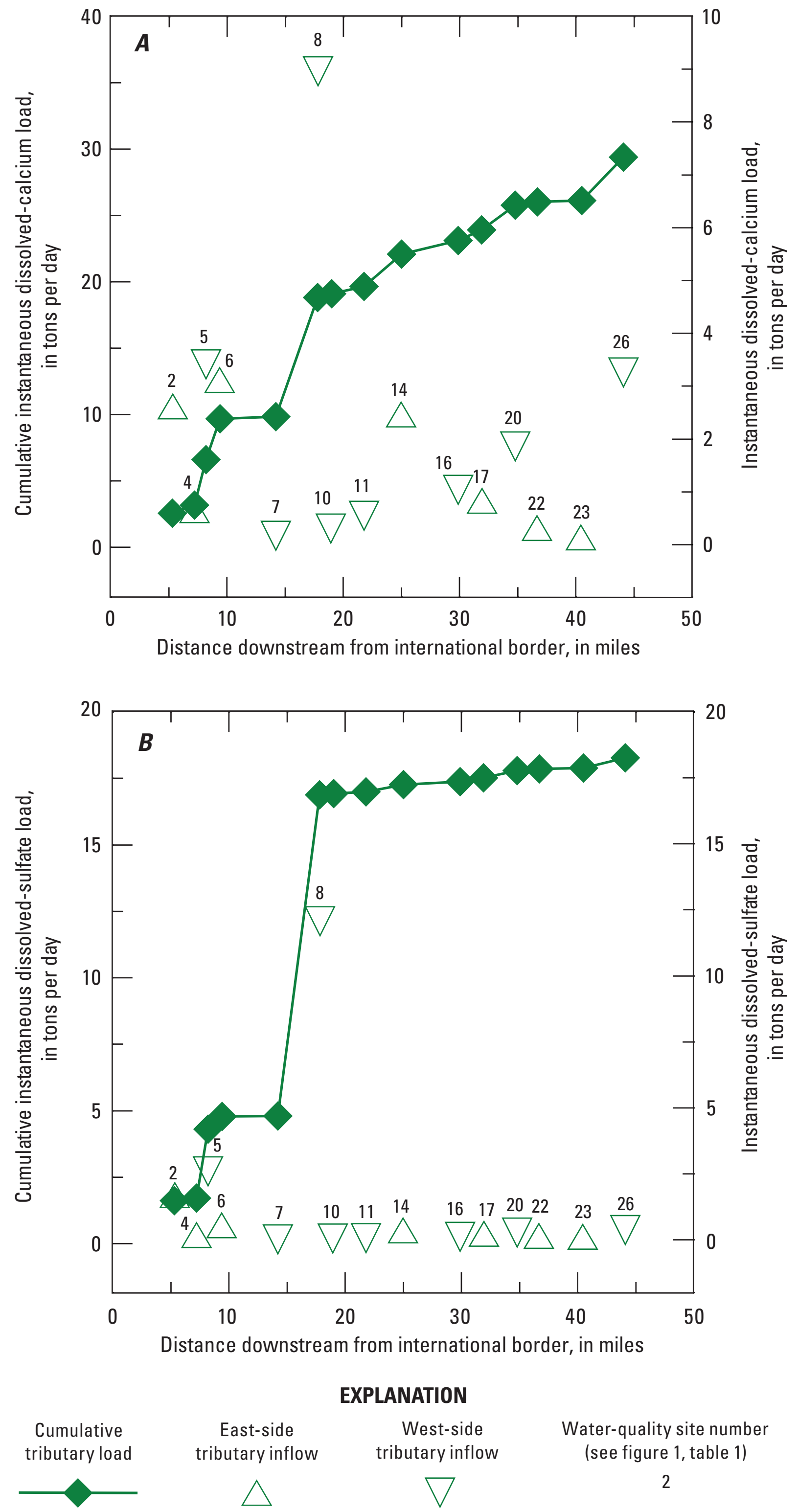

Figure 16. Instantaneous loads of (*A*) calcium and (*B*) sulfate for North Fork Flathead River tributary synoptic sampling sites during low-flow conditions with distance downstream from the Flathead River at Flathead, British Columbia (12355000, Border) long-term station, August 20–21, 2007, and September 16–19, 2008.

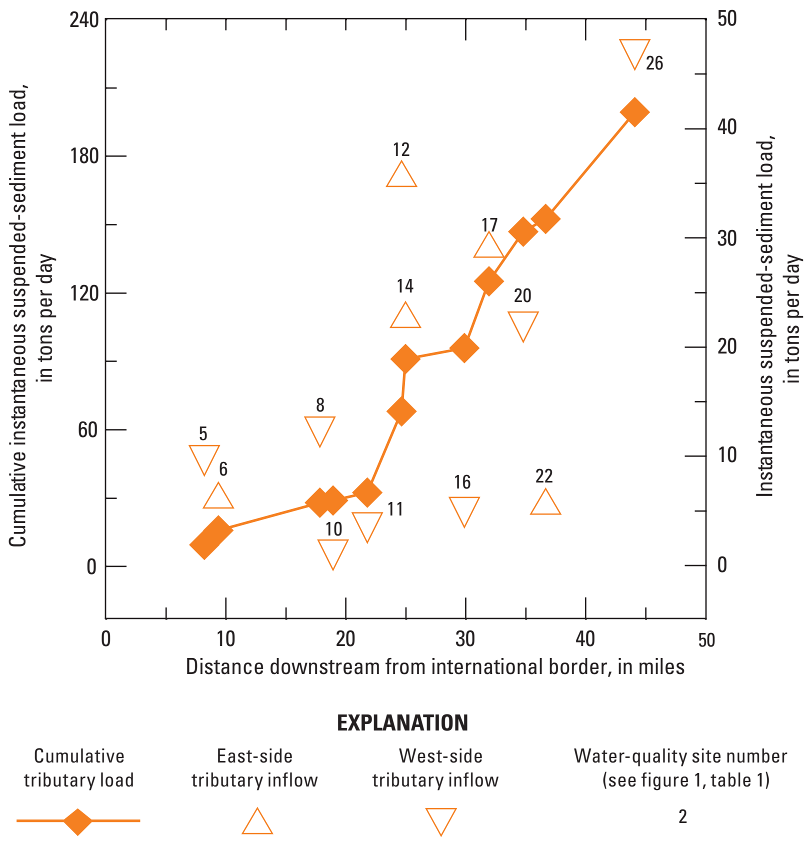

Figure 17. Instantaneous loads of suspended sediment for North Fork Flathead River tributary synoptic sampling sites during high-flow conditions with distance downstream from the Flathead River at Flathead, British Columbia (12355000; Border) long-term gaging station, May 8–10, 2007, and May 27–31, 2008.

A significant flow-adjusted, upward trend in specific conductance was detected for Columbia Falls. Additionally, a significant flow-adjusted upward trend in concentrations of alkalinity was detected for the Flathead River QW site, and significant flow-adjusted upward trends in calcium and magnesium were detected for Border (table 5). The magnitude of these trends is small, but it could be indicative of increasing weathering or erosion in the basin. Slight downward, unadjusted and flow-adjusted trends for sulfate were detected at Border and might be due to changes in analytical methods over time. Mast and Turk (1999) observed similar downward sulfate trends at streams in the USGS Hydrologic Benchmark Network that were attributed to documented changes in the analytical method for sulfate used by USGS laboratories between 1980 and 1990 (Fishman and others, 1994). No other statistically significant trends were detected for any of the three stations. Long-term trend analysis generally indicates that no consistent changes in the water quality of the North Fork have occurred over the period of record (table 5).

Table 5. Results of the Seasonal Kendall test for trends in streamflow and unadjusted and flow-adjusted field properties and constituent concentrations at Flathead River at Flathead British Columbia, Canada, and Flathead River at Flathead, British Columbia (12355000; Border) and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls).

[ft^3/s/yr, cubic feet per second per year; µS/cm/yr, microsiemens per centimeter per year; yr, year; NTU/yr, nephelometric turbidity units per year; mg/L/yr, milligrams per liter per year; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus; —, not calculated or flow model not significant at 0.1 probability; trends and p-values in bold are significant at $p \leq 0.05$]

Property or constituent	Unadjusted		Flow-adjusted		Period of record tested	Seasons
	Trend	p-value	Trend	p-value		
Flathead River QW						
Streamflow (ft^3/s/yr)	-3.00	0.469	—	—	1979–1995	6
Specific conductance (µS/cm/yr)	**1.08**	**0.022**	0.744	0.143	1979–1995	6
Turbidity (NTU/yr)	-0.014	0.117	-0.012	0.666	1979–1995	6
pH (standard units/yr)	0.000	0.683	—	—	1979–1995	6
Alkalinity (mg/L/yr as $CaCO_3$/yr)	0.500	0.089	**0.232**	**0.014**	1979–1995	6
Calcium, dissolved (mg/L/yr)	0.150	0.098	0.049	0.352	1979–1995	6
Chloride, dissolved (mg/L/yr)	0.000	0.055	—	—	1979–1995	6
Magnesium, dissolved (mg/L/yr)	0.049	0.153	0.027	0.218	1979–1995	6
Potassium, dissolved (mg/L/yr)	**0.000**	**0.016**	—	—	1979–1995	6
Sodium, dissolved (mg/L/yr)	0.000	0.934	—	—	1979–1995	6
Sulfate, dissolved (mg/L/yr)	0.067	0.133	—	—	1979–1995	6
Nitrogen, total (mg/L/yr as N/yr)	-0.002	0.150	—	—	1982–1995	6
Nitrate, dissolved (mg/L/yr as N/yr)	-0.001	0.177	—	—	1981–1995	6
Phosphorus, total (mg/L/yr as P/yr)	0.000	0.085	0.000	0.569	1982–1995	6
Border						
Streamflow (ft^3/s/yr)	0.214	0.893	—	—	1974–2008	4
Specific conductance (µS/cm/yr)	0.125	0.451	0.194	0.095	1974–2008	4
pH (standard units/yr)	0.000	0.917	—	—	1974–2008	4
Alkalinity (mg/L/yr)	0.000	0.609	0.113	0.475	1974–1993	4
Calcium, dissolved (mg/L/yr)	0.080	0.218	**0.129**	**0.014**	1974–1993	4
Chloride, dissolved (mg/L/yr)	0.000	0.794	—	—	1974–1993	4
Magnesium, dissolved (mg/L/yr)	0.011	0.418	**0.020**	**0.044**	1974–1993	4
Potassium, dissolved (mg/L/yr)	0.000	0.864	—	—	1974–1993	4
Sodium, dissolved (mg/L/yr)	**0.006**	**0.039**	—	—	1974–1993	4
Sulfate, dissolved (mg/L/yr)	**-0.072**	**0.009**	**-0.076**	**0.003**	1974–1993	4
Phosphorus, total (mg/L/yr as P/yr)	0.000	0.308	—	—	1974–2008	4
Suspended sediment (mg/L/yr)	0.036	0.281	0.049	0.764	1977–2008	4
Columbia Falls						
Streamflow (ft^3/s/yr)	-1.40	0.854	—	—	1982–2008	6
Specific conductance (µS/cm/yr)	0.440	0.068	**0.378**	**0.021**	1982–2008	6

Biological Characteristics of the North Fork Flathead River

The following sections present bioassessment results for diatom and macroinvertebrate assemblage data collected during this study at the two long-term gaging stations (Border and Columbia Falls). Diatom and macroinvertebrate metrics are presented and compared to relevant criteria. Additionally, discussions of individual taxa are included to aid in interpretation of diatom and macroinvertebrate metric results.

Implications of Scale

Bioassessment using metrics like the diatom increasers, macroinvertebrate MMIs, or the various statistics derived from RIVPACS models is dependent on the scale and quality of the models and the relevance of the reference and impaired sites used to develop and validate the metrics model (Ode and others, 2008; Potapova and Charles, 2007). The models used for this study might not allow a diagnostic interpretation at individual sites on the North Fork, but the levels of accuracy are acceptable for establishing general baseline conditions. Explicit quantitative comparisons to reference sites were not made, but comparisons were made indirectly by the application of the metrics and criteria to the North Fork data.

The RIVPACS predictors were fairly coarse and a model specific to the North Fork Basin would likely use more localized environmental attributes to model the expected macroinvertebrate assemblage. Bollman and Teply (2006) describe a possible meaningful degree of imprecision in applying the MMI and RIVPACS models to larger rivers like the North Fork. For this reason, multiple metrics were used and interpretations of selected taxa were included. Additionally, ongoing work in the North Fork Basin and GLAC will likely develop specific reference distributions, bioassessment models, and biocriteria for diatom and macroinvertebrate assemblages.

Diatoms

Diatom samples were evaluated to determine the probability of impairment using the increaser metrics. Several increaser taxa were found at Border and Columbia Falls with a mean percent relative abundance (table 6) of 15.8- and 13.1-percent (sediment), 9.8 and 11.7-percent (nutrients), and 17.3- and 17.3-percent (metals), respectively. Teply (2010 a, b) and Teply and Bahls (2005) suggest these diatom species have autecological affinities that make them suitable indicators of sediment, nutrients, or metals disturbance. Application of the discriminant function models to the percent relative abundances of increaser taxa showed that Border had on average about a 0.43 probability of being impaired due to sediment, a 0.38 probability of being impaired due to nutrients, and a 0.26 probability of being impaired due to metals. Similarly, Columbia Falls had on average a 0.38 probability of being impaired due to sediment, a 0.41 probability of being impaired due to nutrients, and a 0.26 probability of being impaired due to metals. These probabilities are based on taxa associated with cause-specific impaired streams in the Canadian/Northern Rockies ecoregion (for sediment and nutrients disturbance) or state-wide mountains streams (for metals disturbance). The 2010 MTDEQ sediment criterion was exceeded twice at Border and once at Columbia Falls, and the nutrient criterion was exceeded once at each station. The 2005 MTDEQ criterion for metals also was exceeded once at each station (table 6). There was strong agreement between all increaser metrics (r-values ranged from 0.62 to 0.92, with p-values < 0.035) and amongst all classic metrics except taxa richness (r-values ranged from 0.61 to 0.83, with p-values < 0.037), but the direction of the correlation for the classic metrics varied. This suggests there may be some statistical redundancy between metrics within the increaser suite and within the classic metrics. However, the lack of correlations across the two groups supports using the two sets of metrics.

Relatively abundant increaser species collected during these sample events (Appendix 3A) include *Gomphonema pumilum* (on all four increaser lists), *Reimeria sinuata* (sediment increaser), and *Cymbella excisa, Synedra acus* and *Gomphonema minusculum* (metal increasers). However, with the exception of *Gomphonema pumilum,* none of the increaser species had markedly high individual abundances (Appendix 3A). Additionally, disturbances associated with the increaser species do not appear to have an anthropogenic source. High concentrations of nutrients and suspended sediment were detected in tributary streams within GLAC during high-flow water-quality synoptic sampling events (figs. 12 and 14). These tributaries are subject to little human disturbance and likely represent the natural condition of the basin. Additionally, the November 2006 rainfall could have caused substantial transport and deposition of sediment in the North Fork, and streamflows during the subsequent winters and summer of 2007 may not have removed much of the deposited sediment, resulting in the observed effects to diatom assemblages in select 2007 and 2008 samples. Therefore, the presence of increaser species may simply reflect high levels of natural disturbance at the two stations. Nevertheless, given the select exceedances, they may warrant further investigation (Fore and Grafe, 2002).

There were no exceedances of any impairment criteria for the Bahls (1993) metrics: taxa richness, Shannon's diversity, and pollution index (table 6). Taxa richness and Shannon's diversity were within the moderately impaired range in late summer and early fall 2008 samples at Columbia Falls and the fall of 2007 sample at Border. This was likely due to high relative abundances of one or two taxa during these events as shown by the intermediate values of the percent dominant species metric (table 6). These species included taxa like *Achnanthidium minutissimum,* and *A. pyrenaicum*. In particular, *A. minutissimum* had an average relative abundance of almost 17 percent at Border and 34 percent at Columbia Falls, with select individual values near 60 percent. *A. minutissimum*

Table 6. Biocriteria and diatom metrics by sample event at Flathead River at Flathead, British Columbia (12355000; Border) and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls) long-term gaging stations, Montana, 2007–2008.

[PRA, percent relative abundance of indicated increaser taxa in the sample; >, greater than; <, less than; SE, standard error; bold values indicate impairment]

Metric	Sample date:	8/20/2007	8/25/2007	10/4/2007	10/4/2007	7/11/2008	8/15/2008
	Criteria value (see footnotes)	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls
Sediment increaser PRA (current (2011) mountain model)	[1]>18.48	18.53	6.34	16.91	5.66	11.92	13.78
Nutrient increaser PRA (current (2011) mountain model)	[1]>15.18	11.72	5.75	9.68	5.50	3.97	12.07
Metal increaser PRA (current (2011) mountain model)	[2]>29	10.96	17.87	18.41	12.67	9.39	17.32
Taxa richness (classic)	>29, 19, [3]< 10	80	35	73	68	48	21
Shannon's diversity (classic)	>2.99, 1.99, [3]< 1.00	5.3	2.7	5.2	3.6	4.2	4
Percent dominant species (classic)	<25.0, 50.0, [3]> 7 4.9	10	59.6	10.2	44.3	18.79	33.1
Pollution index (classic)	>2.50, 2.0, [3]< 1.50	2.5	2.8	2.6	2.8	2.6	2.7

Metric	8/1/2008	8/1/2008	8/20/2008	8/20/2008	10/1/2008	10/1/2008	Mean (SE) Border	Mean (SE) Columbia Falls
	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls		
Sediment increaser PRA (current (2011) mountain model)	8.47	15.88	28.21	7.46	10.49	29.74	15.8 (2.94)	13.1 (3.73)
Nutrient increaser PRA (current (2011) mountain model)	4.39	10.02	20.60	7.46	8.51	29.30	9.8 (2.48)	11.7 (3.67)
Metal increaser PRA (current (2011) mountain model)	25.72	9.41	30.45	14.00	9.13	32.36	17.3 (0.03)	17.3 (0.03)
Taxa richness (classic)	56	50	57	41	41	24	52.6 (8.46)	43 (6.88)
Shannon's diversity (classic)	4.5	2.2	4.1	5.3	2.7	5.2	4.2 (0.48)	3.1 (0.28)
Percent dominant species (classic)	14.2	45.6	18.1	44.6	63.2	28.7	22.3 (8.28)	42.8 (4.46)
Pollution index (classic)	2.6	2.9	2.8	2.9	2.9	2.7	2.7 (0.07)	2.8 (0.04)

[1]Criteria values are PRA corresponding to a 50-percent probability of impairment following current (2011) Montana Department of Environmental Quality guidance (2011; Teply 2010 a, b); values < the criteria value are "Not Impaired" and support designated uses; values > or = to the criteria value are "Impaired" and do not support designated uses (Feldman, 2006).

[2]Criteria values are PRA corresponding to a 50-percent probability of impairment (Montana Department of Environmental Quality, 2005; Teply and Bahls 2005); values < the criteria value are "Not Impaired" and support designated uses; values > or = to the criteria value are "Impaired" and do not support designated uses (Feldman, 2006).

[3]Criteria values as defined by Bahls (1993): values > or < the first number have "Excellent" biological integrity (taxa richness), "None" impairment or stress (percent dominant species), and "Full support" for designated uses (pollution index); values between the second and third numbers have "Fair" biological integrity (taxa richness), "Moderate" impairment or stress (percent dominant species), and "Partial support" for designated uses (pollution index); values < the third number have "Poor" biological integrity (taxa richness), "Severe" impairment or stress, and "Nonsupport" for designated uses (pollution index) (Bukantis, 1998).

responds positively to oligotrophic and dilute water quality, natural flow regimes, and undisturbed habitat conditions common in GLAC (Kelly and others, 2005; Bahls, 2007). It also is the most abundant diatom sampled to date across GLAC as part of an ongoing NPS monitoring effort, occurring in all samples with a mean relative abundance of over 20 percent (Britten and others, 2007). The ubiquity of these species in the Border and Columbia Falls samples is likely not a suggestion of species richness or community dominance issues, but more likely is an indicator of the high-quality aquatic systems at the Border and Columbia Falls stations. If the *Achnanthidium* species are removed from the metric calculations, species richness and diversity are typical of unimpaired larger rivers (Bahls, 2007).

The pollution index was consistently above the excellent category (table 6). A few values did fall within the intermediate impairment range (these indices have several criteria levels, with "full support" indicating no impairment and "partial support" indicating moderate impairment). This index is a composite numeric expression of the pollution tolerances assigned by Bahls (2004) to diatom species in the state. The index ranges from 1.00 (all most-tolerant diatoms) to 3.00 (all sensitive diatoms). Mean values at Border and Columbia Falls were close to 3 suggesting there was no organic enrichment or nutrient impairment at either site.

Three other observations in the North Fork diatom data are of note. *Didymosphenia geminata* was found in most samples, usually in the whole-slide counts. *D. geminata* is an endemic diatom that has been increasing, often dramatically, in distribution and local abundance over the last decade, apparently in response to several direct and indirect climate signals (Kumar and others, 2009). *D. geminata* can form nuisance benthic growths that extend for greater than 0.5 mi and persist for several months of the year. Under bloom conditions, *D. geminata* cells produce copious amounts of extracellular stalk material that form thick benthic mats (Spaulding and Elwell, 2007). Although blooms were not observed at either Border or Columbia Falls, blooms at several other sites in GLAC were observed during 2007–2008 (Schweiger and others, 2011).

Distrionella incognita is a relatively rare diatom and a glacial relict species that occurred in two of the samples from Columbia Falls. Until recently, *D. incognita* had been reported only from lakes in the British Isles and European Alps (Krammer and Lange-Bertalot, 1991). Bahls (2007) and Morales and others (2005) found the species in GLAC.

Six provisionally new-to-science taxa in the genera *Fragilaria* and *Gomphonema* were found in samples from Border and Columbia Falls. Additional research is needed to confirm these as new species; if they are new species, they contribute to the unique nature of the North Fork diatom assemblage.

Diatom metrics were below the criteria for most samples and all mean values were below the impairment thresholds (table 6). In light of the taxonomic composition of samples, diatom data collected during the study period likely indicate the presence of intact assemblages and high-quality aquatic ecosystems at Border and Columbia Falls. However, some samples and select taxa did indicate some sediment impairment. High concentrations of suspended sediment were detected during the study in relatively undisturbed tributaries within GLAC. An abundance of sediment-tolerant taxa may reflect natural stream conditions and is not necessarily indicative of ecosystem impairment. Further characterization of biologic assemblages in the North Fork will likely aid in development of more refined metrics.

Macroinvertebrates

The MMI criterion currently used by the MTDEQ was exceeded in one sample at each station (table 7). The MMI is constructed from seven component metrics that according to Jessup and others (2006) demonstrate a consistent and interpretable response corresponding to a condition gradient from reference to impaired mountain-stream sites in Montana. Examination of the component metrics in the model (data not shown) reveals that a scarcity of Ephemeroptera taxa and a markedly reduced predator proportion of the community may be responsible for the first impaired MMI value (August 20, 2007, at Border). Both of these components of the macroinvertebrate community decrease in response to anthropogenic disturbance. The second exceedance (August 15, 2008, at Columbia Falls) had a high proportion of non-insect taxa (Crustacea and Mollusca) that are primarily collectors, scrapers, and filterers that can tolerate fine sediments more so than other taxa. However, on average across all sample events the MMI was well above the threshold for impairment at both Border and Columbia Falls. Similar to the current MMIs, the classic mountain MMI indicated all events except the August 20, 2007, sample at Border were in full or partial support (table 7). This index may be more suited to large rivers in less populated watersheds like the North Fork (Bollman and Teply, 2006). There was strong agreement between both metrics ($r = 0.67$, $p = 0.019$) with both MMI metrics suggesting each site had an intact macroinvertebrate assemblage for most samples during the study period.

The O:E criterion currently used by the MTDEQ was exceeded once at Border and twice at Columbia Falls (table 7). This suggests that the complement of species observed during these three events was less than that expected if the sites were in reference condition. However, on average across all sample events, O:E was well above the threshold for impairment at both Border and Columbia Falls, and O:E was actually greater than 1 for six of the samples, suggesting more taxa occurred than predicted at reference sites. The Bray-Curtis (BC) metric generally agreed with O:E ($r = -.96$, $p < 0.001$), with higher BC values in events where O:E was lower or more dissimilar. MTDEQ has no criterion for BC so it is interpreted largely as confirmation that the O:E values are generally sensitive to stress-induced shifts in taxonomic composition in the North Fork and that there is little suggestion of differences in taxonomic composition between observed and expected taxa (Van Sickle, 2008).

Table 7. Results of biocriteria and macroinvertebrate metrics analyses by sample event at Flathead River at Flathead, British Columbia (12355000; Border) and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls) long-term gaging stations, Montana, 2007–2008.

[MMI, multimetric index; O:E, Observed:Expected; >, greater than; <, less than; --, none; SE, standard error; bold values indicate impairment]

Metric	Sample date: Criteria value (see footnotes)	8/20/2007 Border	10/4/2007 Border	10/4/2007 Columbia Falls	3/31/2008 Border	3/31/2008 Columbia Falls	7/11/2008 Border	8/15/2008 Columbia Falls
Montana MMI (current; mountain model)	[1]> 63	53.4	67.9	80	79.9	82.4	72.2	60.4
Montana O:E index (current)	[1]>0.8	0.83	1.04	1.03	0.63	0.59	1.15	1.18
Bray Curtis dissimilarity (between O and E)	--	0.35	0.22	0.21	0.45	0.45	0.19	0.17
Montana MMI (classic; mountain model)	>75, 75–25, [2]<25	14.29	66.67	71.43	52.38	80.95	57.14	52.38

Metric	8/1/2008 Border	8/1/2008 Columbia Falls	8/20/2008 Border	8/20/2008 Columbia Falls	10/1/2008 Border	10/1/2008 Columbia Falls	Mean (SE) Border	Mean (SE) Columbia Falls
Montana MMI (current; mountain model)	77	83.1	71.2	77.1	79.4	86.2	71.6 (3.47)	78.2 (3.77)
Montana O:E index (current)	1.15	1.18	0.83	0.89	0.94	0.74	0.9 (0.07)	0.9 (0.1)
Bray Curtis dissimilarity (between O and E)	0.2	0.19	0.29	0.27	0.24	0.35	0.28 (0.04)	0.27 (0.05)
Montana MMI (classic; mountain model)	85.71	52.38	76.19	61.9	85.71	85.71	65.3 (9.51)	64.3 (5.86)

[1]Criteria values follow current Montana Department of Environmental Quality guidance (Montana Department of Environmental Quality, 2006); values > or = to the criteria value are "Not Impaired" and support designated uses; values < than the criteria value are "Impaired" and do not support designated uses.

[2]Criteria values are metric scores used by the Montana Department of Environmental Quality prior to 2006 (Montana Department of Environmental Quality, 2005); values >75 indicate "Full support–standards not violated;" values between 25 and 75 indicate "Partial support–moderate impairment–standards violated;" values <25 indicate "Non-support–severe impairment–standards violated."

The most common taxa collected during these sample events was the Ephemeroptera (mayfly) genus *Rhithrogena* (Appendix 3B). Mean relative abundance for this genus was fairly consistent through time at about 13 percent. *Rhithrogena* are characteristic of small-to-medium oligotrophic streams and rivers with few to no water-quality impairments and little metal contamination (Bollman and Bowman, 2007) and are often the most abundant taxon in many relatively undisturbed streams flowing through coniferous forests in GLAC (R. Newell, University of Montana, written commun., 2009).

The second most common taxon was the midge family *Chironomidae*, which often had high relative abundances and was present in more than one-half of the sample events (Appendix 3B). Many bioassessments metrics include *Chironomidae* because most taxa in this family typically increase with anthropogenic stress (Karr, 1998). However, in Montana most midges in this family are actually indicative of higher quality systems (Jessup and others, 2006), but the coarse taxonomic resolution of this OTU is problematic given the variance in species tolerances within the family. Thus, the effect of a high percentage of *Chironomidae* is hard to define and may be limited to reduced relative abundances of other groups.

The third most common taxon was the true fly family *Simuliidae* (Appendix 3B); especially in the late summer 2007 Border sample (66 percent). It is likely that the specimens in this particular sample were *Simulium sp*., a large genus that contains nearly all species in the family. *Simulium* is somewhat tolerant of sediment, nutrient enrichment, and warmer water temperatures in Montana streams (Bukantis, 1998; Bollman and Bowman, 2007) and could suggest that there was a higher load of suspended fine organic particles at the station. However, *Simulium* typically occur in groups, and collecting a large number of them in a given sample is often the result of chance. Therefore, interpretation of this result is also problematic and may simply be a sampling artifact.

Finally, the fourth most common taxon was the mayfly *Heptageniidae* (Appendix 3B). Mean relative abundance for this genus was about 6 to 8 percent at Border and Columbia Falls, and it was detected during all but one sample event. Like many other taxa at these sites, this is a stenothermic, metal- and sediment-intolerant genus, and its prevalence is yet another indicator of the high-quality aquatic habitats at both stations (Clements, 1999; Kiffney and Clements, 1994).

Macroinvertebrate metrics were above the criteria for most samples and all average values were above the non-support thresholds (table 7). In light of the taxonomic composition of samples, macroinvertebrate data collected during the study period likely indicate the presence of intact assemblages and high-quality aquatic ecosystems at Border and Columbia Falls. However, some macroinvertebrate samples and taxa did suggest some sediment impairment. As with the diatom metrics, an abundance of sediment-tolerant taxa may reflect natural stream conditions and is not necessarily indicative of ecosystem impairment.

Summary

The North Fork Flathead River (North Fork) is part of the Crown of the Continent Ecosystem and constitutes one of the largest and most intact ecosystems in North America. Currently, development in the North Fork Basin is limited. However, in the early 2000s, there was concern that resource extraction in the basin could affect the water quality and biotic integrity of the North Fork. In 2007, the USGS, in cooperation with the NPS, began a 2-year study to collect hydrologic, water-quality, and biological data to provide a baseline characterization of the North Fork from the United States-Canada Border to its confluence with the Middle Fork Flathead River near Columbia Falls, Mont. Although mining in the Canadian portion of the North Fork Basin was banned by the Memorandum of Understanding, baseline characterization was deemed important for the evaluation of any potential future changes in hydrology, water quality, or aquatic biology in the basin. This report describes the results of the study.

Data from the two long-term gaging stations (Border and Columbia Falls) indicate that the hydrologic characteristics of the North Fork are strongly influenced by the accumulation and melting of seasonal snowpack in the basin, with low flow occurring during the late-summer, fall, and winter months and high flow coinciding with the spring snowmelt. Substantial gains in streamflow occur along the study reach of the North Fork, most of which are accounted for by tributary inputs.

Specific conductance in the North Fork was greatest during low-flow conditions and rapidly decreased at the onset of snowmelt due to the influx of dilute snowmelt water. Median specific conductance during the study was greater at Border than at Columbia Falls due to dilution of the main stem by low-conductivity inputs from tributaries south of Border. Dissolved-oxygen concentrations were similar between the two long-term gaging stations during the study period. Dissolved-oxygen concentration ranged from 9.5 to 14.1 mg/L at both stations during the study period and was well above the Montana Department of Environmental Quality (MTDEQ) minimum concentration standard for aquatic life. Values of turbidity exhibited an inverse seasonal pattern to that of specific conductance with an increase of more than a fifty times during high-flow conditions, indicating substantial transport of suspended particulate matter during this time. Values of turbidity were elevated during snowmelt but were still within the range of relatively undisturbed streams in Glacier National Park, suggesting the high values of turbidity by themselves are not an indication of impairment.

Water-quality data from the two long-term gaging stations as well as from synoptic-sampling sites indicate that calcium, magnesium, and alkalinity are the dominant solutes. Similar to values of specific conductance, concentrations of major ions were greatest during the winter months and lowest during spring and early summer due to snowmelt dilution. Principal component analysis performed on synoptic samples collected in water years 2007 and 2008 indicates that spatial variability in bedrock in the basin strongly influences concentrations of calcium, magnesium, and alkalinity in tributaries. Spatial patterns in sulfate concentration appear to be controlled by sulfur-containing minerals in northern tributary basins.

Nutrients exhibited a different seasonal pattern than that of major ions, reflecting the differences in sources. Dissolved nitrate plus nitrite and total phosphorus (dissolved plus particulate) concentrations at Border and Columbia Falls were near or below their respective analytical reporting levels during low-flow conditions but were higher during spring snowmelt at most main stem and tributary sites. The high concentrations of dissolved nitrate plus nitrite that were observed during snowmelt are attributed to atmospheric deposition of dissolved nitrate during the winter months and subsequent release from the snowpack in the spring. Additionally, total phosphorous concentrations varied with the amount of suspended sediment in the stream, which increases substantially with streamflow in the North Fork. Total nitrogen and total phosphorus concentrations were below the MTDEQ nutrient criteria of 0.209 mg/L and 0.006 mg/L, respectively, at both long-term gaging stations and most synoptic sampling sites during the applicable months from July to September, and no spatial patterns were observed corresponding to the distribution of residential developments, timber harvesting activities, or past wild fires.

Suspended-sediment concentrations at Border and Columbia Falls increased with discharge and were generally greater at tributaries on the eastern side of the study area within protected areas in Glacier National Park than on the western side. Trace-element concentrations at the two long-term gaging stations were near or below their respective analytical reporting levels for much of the year, but higher concentrations were detected during high-flow conditions. There were no exceedances of MTDEQ standards for trace metals with the exception of one sample at each station in May 2008 for total lead concentrations. These samples also had the highest concentration of suspended sediment of any samples during the study period. Because trace-element samples are unfiltered, much of the total lead detected in May 2008 samples was likely associated with particulate matter in the stream.

Tributary loading of most major ions generally reflected variations in streamflow. However, Whale, Trail, and Kintla Creeks account for much of the tributary sulfate loading in the North Fork Basin, reflecting the isolated sulfate source present in the northern tributaries. Tributary loads of suspended sediment during high-flow conditions were generally greater at tributaries on the eastern side of the basin within Glacier National Park. No commercial timber harvesting activities or residential developments exist within this part of the basin, and high loads of suspended sediment in these tributaries are likely from natural sources.

Long-term trend analysis was performed on data from the two long-term gaging stations (Border and Columbia Falls) and at a third long-term water-quality site (Flathead River QW) operated by Environment Canada. A significant flow-adjusted, upward trend in specific conductance was detected for Columbia Falls for 1982-2008. Additionally, a significant flow-adjusted upward trend in concentrations of alkalinity was detected for Flathead River QW for 1979-1995, and significant flow-adjusted upward trends in calcium and magnesium were detected for Border. For 1974-1993 The magnitude of these trends is small, but could indicate increasing weathering or erosion in the basin. Trend analysis indicates that no consistent changes in water quality of the North Fork River have occurred over the period of record.

Diatom and macroinvertebrate data collected during the study period likely indicate the presence of intact assemblages and high-quality aquatic ecosystems at Border and Columbia Falls. Most metrics were below the criteria for most samples and all average values were within the partial to full support range. These data further support conclusions that elevated nutrient and metal concentrations detected during high-flow conditions are not an indication of ecosystem impairment. However, some samples and select taxa did suggest some sediment impairment. High concentrations of suspended sediment were detected during the study in relatively undisturbed tributaries within Glacier National Park. An abundance of sediment-tolerant taxa may reflect natural stream conditions and is not necessarily indicative of ecosystem impairment. Further characterization of biologic assemblages in the North Fork will likely aid in development of more refined metrics.

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Appendixes

Appendix 1. Water-quality data from synoptic samples, North Fork Flathead River and tributaries, 2007–2008.

[<, less than; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; —, no data; E, estimated value below analytical reporting level or subjected to interference]

Site number (figure 1)	Station number	U.S. Geological Survey station name	Year	Sampling event	Temperature, water (°C)	Streamflow, instantaneous, (ft³/sec)	Specific conductance, (µS/cm)	Dissolved oxygen, water, unfiltered, (mg/L)	pH, laboratory, standard units
1	12355000	North Fork Flathead River at Flathead British Columbia[1]	2007	High flow	4	4,380	178	11.2	8.1
1	12355000	North Fork Flathead River at Flathead British Columbia[1]	2007	Low flow	8.5	163	274	11.6	8
1	12355000	North Fork Flathead River at Flathead British Columbia[1]	2008	High flow	3.5	7,350	171	12.2	8
1	12355000	North Fork Flathead River at Flathead British Columbia[1]	2008	Low flow	10.5	279	266	10.6	8.3
2	485704114243801	Kishenehn Creek near mouth	2007	High flow	7.6	—	121	—	8
2	485704114243801	Kishenehn Creek near mouth	2007	Low flow	12.7	32	174	—	8.2
2	485704114243801	Kishenehn Creek near mouth	2008	High flow	—	—	—	—	8
2	485704114243801	Kishenehn Creek near mouth	2008	Low flow	9.7	40	180	10	8.1
3	485611114233901	North Fork of the Flathead River below Kishenehn	2007	High flow	8.1	2,470	178	—	8.2
3	485611114233901	North Fork of the Flathead River below Kishenehn	2007	Low flow	13	292	192	—	8.4
3	485611114233901	North Fork of the Flathead River below Kishenehn	2008	Low flow	11.3	270	195	9.6	8.4
4	12355100	Starvation Creek near Flathead, BC	2007	High flow	—	168	—	—	8
4	12355100	Starvation Creek near Flathead, BC	2007	Low flow	11.5	7.8	179	—	8.4
4	12355100	Starvation Creek near Flathead, BC	2008	High flow	—	—	—	—	8
4	12355100	Starvation Creek near Flathead, BC	2008	Low flow	12.3	8.6	184	9.4	8.3
5	485515114243101	Trail Creek at mouth near Polebridge	2007	High flow	5.5	192	148	—	8.1
5	485515114243101	Trail Creek at mouth near Polebridge	2007	Low flow	10.9	75	140	—	8.3
5	485515114243101	Trail Creek at mouth near Polebridge	2008	High flow	5.9	509	—	11	8.1
5	485515114243101	Trail Creek at mouth near Polebridge	2008	Low flow	10.6	56	177	9.7	8
6	485500114220601	Kintla Creek at mouth nr Polebridge	2007	High flow	6.4	241	129	—	8.1
6	485500114220601	Kintla Creek at mouth nr Polebridge	2007	Low flow	16.9	66	—	—	8.3
6	485500114220601	Kintla Creek at mouth nr Polebridge	2008	High flow	8.4	771	—	10.2	8.1
6	485500114220601	Kintla Creek at mouth nr Polebridge	2008	Low flow	15.5	64	127	8.7	8
7	485233114224201	Tepee Creek at bridge near mouth	2007	High flow	7.4	34	269	—	8.5
7	485233114224201	Tepee Creek at bridge near mouth	2008	Low flow	7.6	1.4	314	10.4	—
8	485104114214701	Whale Creek near mouth	2007	High flow	7.6	306	200	—	8.2
8	485104114214701	Whale Creek near mouth	2007	Low flow	12.2	78	296	—	8.4
8	485104114214701	Whale Creek near mouth	2008	High flow	5.9	648	—	11	8.2
8	485104114214701	Whale Creek near mouth	2008	Low flow	10.7	76	323	9.7	8.4
9	485018114204601	North Fork of the Flathead River below Whale Creek	2007	High flow	8.9	4,660	170	—	8.2
9	485018114204601	North Fork of the Flathead River below Whale Creek	2007	Low flow	14.7	—	228	—	8.4
9	485018114204601	North Fork of the Flathead River below Whale Creek	2008	Low flow	12.7	512	238	9.4	8.4
10	485023114211901	Moose Creek at bridge near mouth	2007	High flow	6.4	39	102	—	8
10	485023114211901	Moose Creek at bridge near mouth	2007	Low flow	10.1	7	154	—	8.3
10	485023114211901	Moose Creek at bridge near mouth	2008	High flow	5.4	89	—	11.2	7.9
10	485023114211901	Moose Creek at bridge near mouth	2008	Low flow	7.2	5.8	159	10.7	8.3
11	484823114202301	Red Meadow Creek at bridge near mouth	2007	High flow	8.8	249	129	—	8.2
11	484823114202301	Red Meadow Creek at bridge near mouth	2007	Low flow	13.3	12	151	—	8.3
11	484823114202301	Red Meadow Creek at bridge near mouth	2008	High flow	5.9	322	—	10.9	8.2
11	484823114202301	Red Meadow Creek at bridge near mouth	2008	Low flow	11.2	9.7	156	—	8.2
12	12355220	Akokala Creek near Polebridge MT	2007	High flow	7.7	197	62		7.8
12	12355220	Akokala Creek near Polebridge MT	2008	High flow	6.5	270	—	10.7	7.7
13	484707114170301	North Fork of the Flathead River below Polebridge	2007	High flow	6.1	6,980	154	—	8.2
13	484707114170301	North Fork of the Flathead River below Polebridge	2008	High flow	5.4	11,100	—	11.4	8.2
14	484708114165001	Bowman Creek at bridge near mouth	2007	High flow	8.8	363	128	—	8.1
14	484708114165001	Bowman Creek at bridge near mouth	2007	Low flow	16.7	36	—	—	8.2
14	484708114165001	Bowman Creek at bridge near mouth	2008	High flow	8.7	704	186	10.2	8.2
14	484708114165001	Bowman Creek at bridge near mouth	2008	Low flow	15.9	47	134	8.8	8.1
15	484701114165601	North Fork of the Flathead River above Bowman	2007	Low flow	12.2	531	227	—	8.4
15	484701114165601	North Fork of the Flathead River above Bowman	2008	Low flow	13.2	508	231	9.8	8.4
16	484500114172401	Hay Creek near mouth at bridge	2007	High flow	8	119	153	—	8.2
16	484500114172401	Hay Creek near mouth at bridge	2007	Low flow	11.7	18	186	—	8.3
16	484500114172401	Hay Creek near mouth at bridge	2008	High flow	4.8	259	—	11.3	8.1
16	484500114172401	Hay Creek near mouth at bridge	2008	Low flow	8	15	191	10.3	8.3
17	12355300	Quartz Creek near Polebridge MT	2007	High flow	11.2	258	51	—	7.8
17	12355300	Quartz Creek near Polebridge MT	2007	Low flow	17.1	36	—	—	8
17	12355300	Quartz Creek near Polebridge MT	2008	High flow	9.2	492	59	10.1	7.7
17	12355300	Quartz Creek near Polebridge MT	2008	Low flow	14.4	30	75	9.1	7.8
18	484249114132601	North Fork of the Flathead River above Quartz Creek	2007	Low flow	13.4	604	211		8.4
18	484249114132601	North Fork of the Flathead River above Quartz Creek	2008	Low flow	13.2	513	234		8.4

Appendix 1. Water-quality data from synoptic samples, North Fork Flathead River and tributaries, 2007–2008.—Continued

[<, less than; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; —, no data; E, estimated value below analytical reporting level]

Site number (figure 1)	Station number	Nitrate, dissolved (mg/L) as nitrogen	Ortho-phosphate, dissolved (mg/L)	Phosphorus, total (mg/L as phosphorus)	Calcium, (mg/L)	Magnesium, (mg/L)	Sodium, (mg/L)	Potassium, (mg/L)	Chloride, (mg/L)	Sulfate, (mg/L)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, total dissolved (mg/L)	Suspended sediment (mg/L)
1	12355000	0.026	0.019	0.059	27.9	5.96	0.65	0.27	<0.12	2.76	4.42	—	—
1	12355000	<0.016	E0.011	<0.008	44.1	9.68	0.77	0.35	E0.12	4.45	4.68	—	—
1	12355000	—	0.02	0.23	27	5.4	0.57	0.37	0.13	2.62	4.23	—	—
1	12355000	—	E0.015	<0.008	43.1	9.36	0.78	0.35	0.12	4.46	4.75	—	—
2	485704114243801	0.03	E0.010	<0.008	16.7	4.51	1.07	0.31	0.22	8.17	4.96	0.09	—
2	485704114243801	<0.01	E0.014	<0.008	24.1	6.34	1.51	0.41	0.42	13.3	6.04	0.14	—
2	485704114243801	0.05	—	0.017	13.3	3.73	0.84	0.35	0.19	5.03	4.98	0.17	15
2	485704114243801	0.01	<0.018	<0.008	23.9	6.31	1.6	0.42	0.51	15	5.68	0.11	1
3	485611114233901	0.01	E0.013	0.021	28.3	6.16	0.86	0.3	0.14	4.21	4.99	0.08	—
3	485611114233901	<0.01	E0.014	<0.008	37.8	8.01	0.9	0.33	0.19	5.77	5.47	0.09	—
3	485611114233901	<0.01	<0.018	<0.008	38	7.99	1.02	0.35	0.23	6.47	5.37	0.07	<0.5
4	12355100	0.04	E0.012	0.05	14.9	4.07	0.92	0.32	0.18	6.48	4.71	0.38	—
4	12355100	<0.01	E0.016	<0.008	28.5	6.26	1.32	0.33	0.1	3.83	7.24	E0.04	—
4	12355100	0.04	—	0.016	15.7	3.78	0.85	0.27	0.1	2.48	5.71	0.12	13
4	12355100	0.01	<0.018	<0.008	26.4	5.97	1.31	0.31	0.11	4.16	6.71	E0.05	1
5	485515114243101	0.03	0.022	0.01	19.8	5.54	0.84	0.28	0.13	5.82	6.2	0.07	—
5	485515114243101	<0.01	0.02	E0.006	22.7	6.7	0.95	0.29	0.13	16.1	6.8	E0.05	—
5	485515114243101	0.03	—	0.015	17.3	4.79	0.78	0.26	0.12	3.95	6.47	0.07	7
5	485515114243101	<0.01	E0.012	E0.005	22.6	6.76	1.02	0.29	0.13	17.2	6.8	E0.05	<0.5
6	485500114220601	0.07	E0.011	E0.004	19.1	4.69	0.73	0.23	0.21	2.83	3.35	0.13	—
6	485500114220601	0.04	E0.010	<0.008	18.8	4.69	0.68	0.24	0.19	2.74	2.86	0.18	—
6	485500114220601	0.06	—	<0.008	18.8	4.76	0.72	0.23	0.21	2.76	3.26	0.11	3
6	485500114220601	0.04	<0.018	<0.008	17.8	4.47	0.66	0.23	0.17	2.7	2.78	0.1	<0.5
7	485233114224201	0.09	E0.011	E0.005	38.3	10.3	0.6	0.48	0.31	5.17	5.01	0.23	—
7	485233114224201	0.05	<0.018	<0.008	45	11.4	0.86	0.49	0.34	5.75	8.6	0.11	—
8	485104114214701	0.06	E0.012	<0.008	26.5	7.39	0.79	0.24	0.15	19.2	5.66	0.13	—
8	485104114214701	<0.01	E0.013	<0.008	43.5	11.3	0.95	0.31	0.17	57.4	6.28	E0.04	—
8	485104114214701	0.06	—	E0.006	23	6.4	0.7	0.22	0.12	12.1	5.79	0.07	7
8	485104114214701	0.01	<0.018	<0.008	43.7	11.3	0.97	0.32	0.18	58.9	6.38	0.1	1
9	485018114204601	0.01	E0.012	0.009	28	6.24	0.82	0.29	0.15	4.46	4.79	0.09	—
9	485018114204601	<0.01	E0.013	<0.008	34.2	7.95	0.97	0.32	0.17	12.9	5.49	E0.04	—
9	485018114204601	<0.01	<0.018	<0.008	35.4	8.13	1.01	0.34	0.21	15.7	5.42	E0.05	<0.5
10	485023114211901	<0.01	E0.012	E0.004	12.1	4.82	0.75	0.22	0.11	1.86	6.65	0.12	—
10	485023114211901	<0.01	<0.018	<0.008	20.8	7.59	0.95	0.24	0.14	2.79	7.16	E0.05	—
10	485023114211901	<0.01	—	E0.006	10.9	4.37	0.66	0.21	0.1	1.54	6.57	0.07	4
10	485023114211901	<0.01	<0.018	<0.008	19.7	7.42	1.01	0.25	0.13	2.97	6.97	E0.04	<0.5
11	484823114202301	0.04	E0.010	0.01	17.9	4.55	0.66	0.21	0.1	1.51	5.38	0.15	—
11	484823114202301	<0.01	E0.014	<0.008	22.9	6.42	1.01	0.23	0.12	2.29	6.44	E0.05	—
11	484823114202301	0.05	—	E0.006	17.2	4.02	0.54	0.19	0.09	1.27	5.21	0.1	4
11	484823114202301	<0.01	<0.018	<0.008	21	6.06	1	0.21	0.11	2.42	6.39	E0.05	1
12	12355220	0.09	E0.018	0.073	8.67	2.16	1.07	0.36	0.17	1.93	6.4	0.4	—
12	12355220	0.09	—	0.037	7.58	1.94	0.89	0.33	0.13	1.61	6.59	0.15	49
13	484707114170301	0.03	E0.015	0.142	24.4	5.66	0.84	0.32	0.13	4.59	5.07	0.27	—
13	484707114170301	0.04	—	0.101	24.4	5.49	0.77	0.34	0.15	3.59	5.25	0.12	122
14	484708114165001	0.08	<0.018	<0.008	18.4	4.79	0.77	0.23	0.17	2.36	3.75	0.14	—
14	484708114165001	0.01	E0.011	—	20	4.94	0.75	0.23	0.16	2.26	3.17	0.1	—
14	484708114165001	0.09	—	0.012	19.1	5.02	0.75	0.23	0.17	2.29	3.94	0.12	27
14	484708114165001	0.03	<0.018	<0.008	19.1	4.87	0.77	0.24	0.16	2.2	3.02	0.08	1
15	484701114165601	<0.01	E0.012	<0.008	36	8.34	1.05	0.34	0.18	12.8	5.95	0.15	—
15	484701114165601	<0.01	E0.011	<0.008	35.1	8.11	1.09	0.33	0.21	13.6	5.65	E0.06	1
16	484500114172401	0.04	E0.012	E0.007	20.5	6.34	0.77	0.24	0.12	1.94	5.73	0.12	—
16	484500114172401	0.01	E0.013	<0.008	27.5	8.24	1.08	0.27	0.13	2.5	6.93	0.21	—
16	484500114172401	0.02	—	E0.007	19.9	6	0.71	0.23	0.12	1.65	6.21	0.11	7
16	484500114172401	0.02	<0.018	<0.008	25.7	8.03	1.2	0.27	0.14	2.65	6.95	0.09	<0.5
17	12355300	0.01	E0.012	0.009	6.9	2.02	0.92	0.24	0.1	1.46	5.58	0.36	—
17	12355300	<0.01	E0.012	E0.005	10.5	3.07	1	0.21	0.11	1.84	3.93	0.15	—
17	12355300	0.04	—	0.021	7.5	2.22	0.78	0.22	0.1	1.65	4.97	0.12	41
17	12355300	<0.01	<0.018	<0.008	9.77	2.82	0.92	0.19	0.09	1.85	3.49	0.07	1
18	484249114132601	<0.01	E0.012	<0.008	35.2	8.23	1.06	0.35	0.17	12.1	5.81	0.11	—
18	484249114132601	<0.01	<0.018	<0.008	33.6	7.72	1.04	0.33	0.21	12.3	5.3	0.1	—

Appendix 1. Water-quality data from synoptic samples, North Fork Flathead River and tributaries, 2007–2008.—Continued

[<, less than; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; —, no data; E, estimated value below analytical reporting level]

Site number (figure 1)	Station number	U.S. Geological Survey station name	Year	Sampling event	Temperature, water (°C)	Streamflow, instantaneous, (ft³/sec)	Specific conductance, (µS/cm)	Dissolved oxygen, water, unfiltered, (mg/L)	pH, laboratory, standard units
19	484127114114401	North Fork of the Flathead River above Coal Creek	2007	Low flow	14.2	—	216	—	8.3
19	484127114114401	North Fork of the Flathead River above Coal Creek	2008	Low flow	12.7	643	231	9	8.4
20	12355310	Coal Creek near Polebridge MT	2007	High flow	6.9	—	97	—	8.1
20	12355310	Coal Creek near Polebridge MT	2007	Low flow	12.1	41	105	—	8.3
20	12355310	Coal Creek near Polebridge MT	2008	High flow	6	900	—	11	8
20	12355310	Coal Creek near Polebridge MT	2008	Low flow	11.9	37	142	9.3	8
21	484046114113601	North Fork of the Flathead River below Coal Creek	2007	High flow	7.6	7,560	151	—	8.1
22	12355320	Logging Creek near Polebridge MT	2007	High flow	11.3	172	50	—	7.7
22	12355320	Logging Creek near Polebridge MT	2007	Low flow	17.2	12	—	—	7.7
22	12355320	Logging Creek near Polebridge MT	2008	High flow	9.7	351	—	10	7.7
22	12355320	Logging Creek near Polebridge MT	2008	Low flow	13	17	47	9.3	7.6
23	483804114084001	Anaconda	2007	Low flow	14.2	4.5	—	—	7.8
23	483804114084001	Anaconda	2008	Low flow	9.1	5.3	56	10.3	7.8
24	483747114082501	Camas Creek near mouth	2007	High flow	7.1	—	58	—	7.8
24	483747114082501	Camas Creek near mouth	2007	Low flow	13.2	12	92	—	8.2
24	483747114082501	Camas Creek near mouth	2008	High flow	9.7	—	—	9.8	7.8
24	483747114082501	Camas Creek near mouth	2008	Low flow	13	—	97	8.8	8
25	483713114082201	North Fork of the Flathead River at Camas Road	2008	High flow	6.8	17,700	—	10.7	8.1
26	12355350	Big Cr at Big Cr Rs nr Columbia Falls MT	2007	High flow	5.5	447	119	—	8.1
26	12355350	Big Cr at Big Cr Rs nr Columbia Falls MT	2007	Low flow	10.6	52	136	—	8.3
26	12355350	Big Cr at Big Cr Rs nr Columbia Falls MT	2008	High flow	5.6	1,020	—	11.2	8.2
26	12355350	Big Cr at Big Cr Rs nr Columbia Falls MT	2008	Low flow	6.4	46	195	11.2	8.3
27	483608114094001	North Fork of the Flathead River below Big Creek	2007	High flow	8.3	9,990	138	—	8.2
28	12355500	North Fork Flathead River near Columbia Falls MT[2]	2007	High flow	7	12,200	143	11	8.1
28	12355500	North Fork Flathead River near Columbia Falls MT[2]	2007	Low flow	10	681	223	10	8.3
28	12355500	North Fork Flathead River near Columbia Falls MT[2]	2008	High flow	5.5	21,600	136	11.4	8.3
28	12355500	North Fork Flathead River near Columbia Falls MT[2]	2008	Low flow	15	1,310	195	—	8.2

Appendix 1. Water-quality data from synoptic samples, North Fork Flathead River and tributaries, 2007–2008.—Continued

[<, less than; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; —, no data; E, estimated value below analytical reporting level]

Site number (figure 1)	Station number	Nitrate, dissolved (mg/L) as nitrogen	Ortho-phosphate, dissolved (mg/L)	Phosphorus, total (mg/L as phosphorus)	Cal-cium, (mg/L)	Mag-nesium, (mg/L)	Sodium, (mg/L)	Potas-sium, (mg/L)	Chlo-ride, (mg/L)	Sulfate, (mg/L)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, total dissolved (mg/L)	Sus-pended sedi-ment (mg/L)
19	484127114114401	<0.01	E0.012	<0.008	33.2	7.62	1.02	0.32	0.19	10.5	5.74	0.12	—
19	484127114114401	0.01	<0.018	<0.008	34.3	7.83	1.16	0.35	0.21	11	5.87	0.08	—
20	12355310	0.02	0.024	0.011	12.7	3.81	0.7	0.21	0.12	1.42	5.66	0.11	—
20	12355310	<0.01	<0.018	<0.008	19.7	5.56	1.08	0.26	0.15	2.66	6.97	0.13	—
20	12355310	0.04	—	0.009	13.6	4.03	0.77	0.24	0.14	1.47	6.41	0.13	9
20	12355310	<0.01	<0.018	<0.008	18.6	5.38	1.16	0.3	0.16	2.76	6.47	0.07	1
21	484046114113601	0.03	E0.013	0.024	23.5	5.42	0.84	0.31	0.15	4.42	5.07	0.12	—
22	12355320	<0.01	E0.011	0.014	6.51	1.72	1.06	0.25	0.29	1.89	4.57	0.28	—
22	12355320	0.01	E0.011	<0.008	6.54	1.72	0.99	0.2	0.21	1.62	3.86	0.09	—
22	12355320	<0.01	—	0.012	6.48	1.76	1.1	0.24	0.28	1.81	5.19	0.15	6
22	12355320	0.01	<0.018	<0.008	5.92	1.59	0.9	0.17	0.19	1.41	3.33	0.1	1
23	483804114084001	<0.01	0.02	E0.006	7.5	1.8	1.98	0.4	0.11	2.36	8.17	0.12	
23	483804114084001	<0.01	<0.018	E0.007	6.79	1.69	1.93	0.36	0.07	2.09	8.26	0.13	2
24	483747114082501	0.15	E0.011	0.022	7.63	2.16	0.72	0.27	0.13	2.05	4.82	0.31	—
24	483747114082501	<0.01	E0.013	E0.005	15.6	4.74	1.41	0.29	0.15	1.98	5.56	0.16	—
24	483747114082501	0.15	—	0.014	8.14	2.39	0.71	0.27	0.11	1.84	5.04	0.24	11
24	483747114082501	<0.01	<0.018	<0.008	11.7	3.53	1.12	0.25	0.1	1.72	4.34	0.08	2
25	483713114082201	0.05	—	0.118	22.2	4.81	0.76	0.34	0.15	3.17	5.29	0.16	—
26	12355350	0.03	E0.012	0.031	17.4	4.63	0.61	0.23	0.13	1.46	5.47	0.15	—
26	12355350	0.01	E0.016	<0.008	27	7.44	0.95	0.28	0.19	2.85	6.65	0.3	—
26	12355350	0.03	—	0.011	18.7	4.95	0.67	0.26	0.13	1.54	6.03	E0.05	17
26	12355350	0.01	<0.018	<0.008	26.3	7.33	1	0.28	0.19	3.03	6.51	0.09	1
27	483608114094001	0.03	E0.012	0.084	20	4.98	0.99	0.27	0.14	2.72	5.34	0.13	—
28	12355500	0.042	E0.015	0.069	21.3	4.98	0.76	0.28	<0.12	3.15	4.89	—	86
28	12355500	E0.010	E0.011	<0.008	35.3	8.67	1.09	0.33	0.18	10	5.86	—	1.8
28	12355500	—	E0.016	0.213	20.5	4.5	0.71	0.38	0.24	2.89	4.99	—	308
28	12355500	—	E0.013	<0.008	29.4	7.18	1.04	0.37	0.18	6.98	4.67	—	3.5

[1]Referred to as "Border" in the report.

[2]Referred to as "Columbia Falls" in the report.

Appendix 2A. Comparison of chemical analyses of environmental samples and sequential replicate samples, 2007–2008

[mg/L, milligrams per liter; µg/L, micrograms per liter; —, not analyzed or not computed; <, less than; Env., environmental; Rep., replicate; RPD, relative percent difference; E, estimated value at the analytical reporting level or subjected to interference; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus]

U.S. Geological Survey station name	Date	Calcium, dissolved (mg/L)			Magnesium, dissolved (mg/L)			Potassium, dissolved (mg/L)		
		Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD
Anaconda Creek	9/18/2008	6.79	6.66	1.9	1.69	1.63	3.6	0.360	0.340	5.7
North Fork of the Flathead River above Coal Creek	8/21/2007	33.2	35.1	–5.6	7.62	8.02	–5.1	0.320	0.350	–9.0
Moose Creek at bridge near mouth	5/8/2007	12.1	12.0	0.8	4.82	4.79	0.6	0.220	0.220	0.0
Trail Creek at mouth near Polebridge	5/29/2008	17.3	17.0	1.7	4.79	4.69	2.1	0.260	0.250	3.9
North Fork Flathead River near Columbia Falls MT	5/1/2007	24.0	23.8	0.7	5.79	5.73	1.0	0.310	0.337	–8.3
North Fork Flathead River near Columbia Falls MT	5/21/2008	20.5	20.7	–1.1	4.50	4.53	–0.6	0.380	0.391	–2.9

U.S. Geological Survey station name	Date	Sodium, dissolved (mg/L)			Alkalinity (mg/L as $CaCO_3$)			Chloride, dissolved (mg/L)		
		Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD
Anaconda Creek	9/18/2008	1.93	1.81	6.4	25.2	25.2	0.0	0.070	0.070	0.0
North Fork of the Flathead River above Coal Creek	8/21/2007	1.02	1.09	–6.6	111	111	0.0	0.190	0.180	5.4
Moose Creek at bridge near mouth	5/8/2007	0.750	0.760	–1.3	50.9	50.8	0.2	0.110	0.110	0.0
Trail Creek at mouth near Polebridge	5/29/2008	0.780	0.750	3.9	58.3	58.5	–0.3	0.120	0.120	0.0
North Fork Flathead River near Columbia Falls MT	5/1/2007	0.950	0.928	2.3	82.0	82.0	0.1	0.130	E0.117	10.5
North Fork Flathead River near Columbia Falls MT	5/21/2008	0.710	0.697	1.8	70.0	70.1	–0.2	0.240	0.241	–0.4

U.S. Geological Survey station name	Date	Fluoride, dissolved (mg/L)			Silica, dissolved (mg/L)			Sulfate, dissolved (mg/L)		
		Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD
Anaconda Creek	9/18/2008	—	—	—	8.26	7.98	3.4	2.09	2.10	–0.5
North Fork of the Flathead River above Coal Creek	8/21/2007	—	—	—	5.74	5.84	–1.7	10.5	10.5	0.0
Moose Creek at bridge near mouth	5/8/2007	—	—	—	6.65	6.57	1.2	1.86	1.85	0.5
Trail Creek at mouth near Polebridge	5/29/2008	—	—	—	6.47	6.42	0.8	3.95	3.98	–0.8
North Fork Flathead River near Columbia Falls MT	5/1/2007	E0.060	<0.100	50.0	5.25	5.20	0.9	4.12	4.11	0.2
North Fork Flathead River near Columbia Falls MT	5/21/2008	<0.120	<0.120	0.0	4.99	4.97	0.5	2.89	2.88	0.3

Appendix 2A. Comparison of chemical analyses of environmental samples and sequential replicate samples, 2007–2008.—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; —, not analyzed or not computed; <, less than; Env., environmental; Rep., replicate; RPD, relative percent difference; E, estimated value at the analytical reporting level or subjected to interference; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus]

U.S. Geological Survey station name	Date	Nitrate plus nitrite, dissolved (mg/L as N)			Nitrite, dissolved (mg/L as N)			Nitrate, dissolved (mg/L as N)			Orthophosphate, dissolved (mg/L as P)		
		Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD
Anaconda Creek	9/18/2008	—	—	—	—	—	—	<0.01	<0.01	—	<0.006	E0.003	—
North Fork of the Flathead River above Coal Creek	8/21/2007	—	—	—	—	—	—	<0.01	<0.01	—	E0.004	E0.004	—
Moose Creek at bridge near mouth	5/8/2007	—	—	—	—	—	—	<0.01	<0.01	—	E0.004	E0.004	—
Trail Creek at mouth near Polebridge	5/29/2008	—	—	—	—	—	—	0.03	0.03	0.0	—	—	—
North Fork Flathead River near Columbia Falls MT	5/1/2007	0.03	0.03	0.0	<0.002	<0.002	—	—	—	—	<0.006	<0.006	—
North Fork Flathead River near Columbia Falls MT	5/21/2008	0.06	0.06	0.0	—	—	—	—	—	—	E0.005	E0.005	—

U.S. Geological Survey station name	Date	Phosphorus, total (mg/L as P)			Total nitrogen (nitrate + nitrite + ammonia + organic-N), dissolved (mg/L as N)			Total nitrogen (nitrate + nitrite + ammonia + organic-N), total (mg/L as N)		
		Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD
Anaconda Creek	9/18/2008	E0.007	E0.006	—	0.13	0.10	26.1	E0.03	<0.06	—
North Fork of the Flathead River above Coal Creek	8/21/2007	<0.008	<0.008	—	0.12	0.07	52.6	<0.06	<0.06	—
Moose Creek at bridge near mouth	5/8/2007	E0.004	<0.008	—	0.12	0.09	28.6	E0.06	E0.06	—
Trail Creek at mouth near Polebridge	5/29/2008	0.015	0.014	6.9	0.07	0.06	15.4	0.09	0.07	25.0
North Fork Flathead River near Columbia Falls MT	5/1/2007	0.045	0.044	1.3	—	—	—	0.31	0.16	65.5
North Fork Flathead River near Columbia Falls MT	5/21/2008	0.213	0.200	6.1	—	—	—	0.31	0.28	11.6

U.S. Geological Survey station name	Date	Organic carbon, dissolved (mg/L)			Suspended sediment (mg/L)			Ammonia, dissolved (mg/L as N)		
		Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD
Anaconda Creek	9/18/2008	1.6	1.5	6.5	2.00	1.00	66.7	—	—	—
North Fork of the Flathead River above Coal Creek	8/21/2007	0.8	0.6	28.6	0.800	—	—	—	—	—
Moose Creek at bridge near mouth	5/8/2007	3.0	3.2	–6.5	2.00	—	—	—	—	—
Trail Creek at mouth near Polebridge	5/29/2008	1.8	1.5	18.2	7.00	7.00	0.0	—	—	—
North Fork Flathead River near Columbia Falls MT	5/1/2007	—	—	—	88.0	62.0	34.7	<0.02	<0.02	—
North Fork Flathead River near Columbia Falls MT	5/21/2008	—	—	—	308	312	–1.3	—	—	—

Appendix 2A. Comparison of chemical analyses of environmental samples and sequential replicate samples, 2007–2008.—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; —, not analyzed or not computed; <, less than; Env., environmental; Rep., replicate; RPD, relative percent difference; E, estimated value at the analytical reporting level or subjected to interference; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus]

U.S. Geological Survey station name	Date	Arsenic, total (µg/L)			Cadmium, total (µg/L)			Chromium, total (µg/L)		
		Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD
Anaconda Creek	9/18/2008	—	—	—	—	—	—	—	—	—
North Fork of the Flathead River above Coal Creek	8/21/2007	—	—	—	—	—	—	—	—	—
Moose Creek at bridge near mouth	5/8/2007	—	—	—	—	—	—	—	—	—
Trail Creek at mouth near Polebridge	5/29/2008	—	—	—	—	—	—	—	—	—
North Fork Flathead River near Columbia Falls MT	5/1/2007	—	—	—	—	—	—	—	—	—
North Fork Flathead River near Columbia Falls MT	5/21/2008	1.80	1.73	4.2	0.120	0.119	1.3	3.10	2.63	16.4

U.S. Geological Survey station name	Date	Copper, total (µg/L)			Lead, total (µg/L)			Nickel, total (µg/L)			Zinc, total (µg/L)		
		Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD	Env.	Rep.	RPD
Anaconda Creek	9/18/2008	—	—	—	—	—	—	—	—	—	—	—	—
North Fork of the Flathead River above Coal Creek	8/21/2007	—	—	—	—	—	—	—	—	—	—	—	—
Moose Creek at bridge near mouth	5/8/2007	—	—	—	—	—	—	—	—	—	—	—	—
Trail Creek at mouth near Polebridge	5/29/2008	—	—	—	—	—	—	—	—	—	—	—	—
North Fork Flathead River near Columbia Falls MT	5/1/2007	—	—	—	—	—	—	—	—	—	—	—	—
North Fork Flathead River near Columbia Falls MT	5/21/2008	5.80	5.40	7.1	4.07	3.47	15.9	4.00	3.40	16.2	21.1	19.1	9.7

Appendix 2B. Results of chemical analyses of blank samples, 2007–2008.

[mg/L, milligrams per liter; µg/L, micrograms per liter; < , less than; —, not analyzed; total, summed; E, estimated value at the analytical reporting level or subjected to interference; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus]

U.S. Geological Survey station name	Date	Alkalinity, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)
North Fork Flathead River at Flathead British Columbia	5/1/2007	<5	<0.02	<0.014	<0.04	<0.20
Big Creek at Big Cr. Rs nr Columbia Falls	5/10/2007	<5	0.19	<0.020	<0.07	<0.07
North Fork Flathead River at Flathead British Columbia	6/19/2007	<5	<0.02	<0.014	<0.04	<0.20
North Fork Flathead River below Whale Creek	8/21/2007	<5	<0.06	<0.020	<0.07	<0.07
Whale Creek near mouth	5/29/2008	<5	<0.06	<0.020	<0.07	<0.07
North Fork Flathead River at Flathead British Columbia	6/10/2008	<5	<0.04	<0.020	<0.02	<0.12
Quartz Creek near Polebridge MT	9/18/2008	<5	<0.06	<0.020	<0.07	<0.07

U.S. Geological Survey station name	Date	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Silica, dissolved (mg/L)	Total nitrogen (nitrate + nitrite + ammonia + organic-N), dissolved (mg/L as N)
North Fork Flathead River at Flathead British Columbia	5/1/2007	<0.18	0.20	<0.018	<0.06
Big Creek at Big Cr. Rs nr Columbia Falls	5/10/2007	<0.03	<0.03	<0.200	0.09
North Fork Flathead River at Flathead British Columbia	6/19/2007	<0.18	<0.12	<0.018	E0.03
North Fork Flathead River below Whale Creek	8/21/2007	<0.03	<0.03	<0.200	E0.06
Whale Creek near mouth	5/29/2008	<0.03	<0.03	<0.200	<0.06
North Fork Flathead River at Flathead British Columbia	6/10/2008	<0.18	<0.12	<0.018	<0.06
Quartz Creek near Polebridge MT	9/18/2008	<0.03	<0.03	<0.200	E0.05

U.S. Geological Survey station name	Date	Total nitrogen (nitrate + nitrite + ammonia + organic-N), total (mg/L as N)	Nitrate plus nitrite, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrate, dissolved (mg/L as N)
North Fork Flathead River at Flathead British Columbia	5/1/2007	—	<0.02	<0.002	—
Big Creek at Big Cr. Rs nr Columbia Falls	5/10/2007	<0.06	—	—	<0.01
North Fork Flathead River at Flathead British Columbia	6/19/2007	—	<0.02	<0.002	—
North Fork Flathead River below Whale Creek	8/21/2007	<0.06	—	—	<0.01
Whale Creek near mouth	5/29/2008	<0.06	—	—	<0.01
North Fork Flathead River at Flathead British Columbia	6/10/2008	—	<0.02	—	—
Quartz Creek near Polebridge MT	9/18/2008	<0.06	—	—	<0.01

Appendix 2B. Results of chemical analyses of blank samples, 2007–2008.—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; < , less than; —, not analyzed; total, summed; E, estimated value at the analytical reporting level or subjected to interference; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus]

U.S. Geological Survey station name	Date	Orthophosphate, dissolved (mg/L as P)	Phosphorus, (mg/L as P)	Organic carbon, dissolved (mg/L)	Organic carbon, total, (mg/L)
North Fork Flathead River at Flathead British Columbia	5/1/2007	<0.006	<0.008	—	—
Big Creek at Big Cr. Rs nr Columbia Falls	5/10/2007	<0.006	<0.008	0.7	—
North Fork Flathead River at Flathead British Columbia	6/19/2007	<0.006	<0.008	—	—
North Fork Flathead River below Whale Creek	8/21/2007	<0.006	<0.008	0.3	—
Whale Creek near mouth	5/29/2008	—	<0.008	<0.2	—
North Fork Flathead River at Flathead British Columbia	6/10/2008	<0.006	<0.008	E0.4	E0.4
Quartz Creek near Polebridge MT	9/18/2008	<0.006	<0.008	—	—

U.S. Geological Survey station name	Date	Suspended sediment (mg/L)	Arsenic, total, (µg/L)	Cadmium, total, (µg/L)	Chromium, total (µg/L)
North Fork Flathead River at Flathead British Columbia	5/1/2007	—	—	—	—
Big Creek at Big Cr. Rs nr Columbia Falls	5/10/2007	—	—	—	—
North Fork Flathead River at Flathead British Columbia	6/19/2007	—	<0.2	<0.018	<0.6
North Fork Flathead River below Whale Creek	8/21/2007	—	—	—	—
Whale Creek near mouth	5/29/2008	<0.5	—	—	—
North Fork Flathead River at Flathead British Columbia	6/10/2008	—	<0.6	<0.014	<0.4
Quartz Creek near Polebridge MT	9/18/2008	—	—	—	—

U.S. Geological Survey station name	Date	Copper, total (µg/L)	Lead, total (µg/L)	Nickel, total (µg/L)	Zinc, total (µg/L)
North Fork Flathead River at Flathead British Columbia	5/1/2007	—	—	—	—
Big Creek at Big Cr. Rs nr Columbia Falls	5/10/2007	—	—	—	—
North Fork Flathead River at Flathead British Columbia	6/19/2007	<1.2	<0.06	<0.16	<2.0
North Fork Flathead River below Whale Creek	8/21/2007	—	—	—	—
Whale Creek near mouth	5/29/2008	—	—	—	—
North Fork Flathead River at Flathead British Columbia	6/10/2008	<1.2	<0.06	<0.12	<2.0
Quartz Creek near Polebridge MT	9/18/2008	—	—	—	—

Appendix 3A. Diatom species list and abundance from Flathead River at Flathead, British Columbia (1235500, Border); and North Fork Flathead River near Columbia Falls, Mont. (1235500, Columbia Falls).

[Diatom species list and abundance from long-term gaging stations from all six sample events in 2007–2008 (note the early spring 2008 periphyton sample was lost). Nearly all diatoms were identified to the species level by a single taxonomist so Operational Taxanomic Units are not required. Taxa indicated with *GLAC LLB" are provisionally new-to-science species (Loren L. Bahls, written commun., 2009). Counts are in parentheses followed by the percent relative abundance within each sample. "P" indicates the taxon was present in a whole slide search. "--" indicates the taxon was not present. Whole slide counts for Didymosphenia geminata are listed separately]

Period:	Late summer 2007		Early fall 2007		Full sample early/mid summer 2008	
Sample date:	8/20/2007	8/25/2007	10/4/2007	10/4/2007	7/11/2008	8/15/2008
Species/site:	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls
Achnanthes minutissima v. jackii	--	--	--	--	--	--
Achnanthes rosenstockii	--	--	--	--	--	(2) 0.26
Achnanthidium deflexum	--	--	--	(18) 2.99	--	(7) 0.92
Achnanthidium gracillimum	--	--	--	(6) 1	--	(8) 1.05
Achnanthidium minutissimum	(70) 9.59	(402) 59.38	(53) 7.68	(112) 18.6	(33) 5.25	(235) 30.84
Achnanthidium neomicrocephalum	--	--	--	--	--	(7) 0.92
Achnanthidium pyrenaicum	--	(20) 2.95	(9) 1.3	--	(1) 0.16	(40) 5.25
Achnanthidium rivulare	(2) 0.27	--	--	--	(2) 0.32	--
Adlafia bryophila	(2) 0.27	--	--	--	--	--
Adlafia minuscula	(3) 0.41	--	(3) 0.43	--	--	--
Amphipleura pellucida	(6) 0.82	(1) 0.15	(6) 0.87	(16) 2.66	--	(5) 0.66
Amphora copulata	P	--	--	--	--	--
Amphora inariensis	--	--	--	--	(1) 0.16	--
Amphora pediculus	(5) 0.68	--	--	--	--	--
Aulacoseira canadensis	--	--	--	--	--	--
Brachysira microcephala	--	--	--	(8) 1.33	--	--
Brachysira vitrea	--	--	--	(6) 1	--	--
Caloneis bacillum	(8) 1.1	--	(17) 2.46	--	(4) 0.64	--
Caloneis schumanniana	(2) 0.27	--	(1) 0.14	--	--	--
Caloneis silicula	--	--	--	(4) 0.66	--	--
Caloneis sp.	--	--	--	--	--	--
Caloneis tenuis	(5) 0.68	--	--	--	--	--
Cavinula pseudoscutiformis	--	--	--	(2) 0.33	--	--
Cocconeis pediculus	--	--	--	(2) 0.33	--	--
Cocconeis placentula	(31) 4.25	(13) 1.92	(40) 5.8	(12) 1.99	(15) 2.39	(9) 1.18
Cyclotella comensis	--	--	--	--	--	(4) 0.52
Cymatopleura elliptica	--	--	P	--	--	--
Cymatopleura solea	P	P	P	--	--	--
Cymbella excisa	(5) 0.68	(2) 0.3	(1) 0.14	--	(35) 5.57	(11) 1.44
Cymbella excisiformis	--	(2) 0.3	(11) 1.59	--	--	(1) 0.13
Cymbella hustedtii	--	--	--	--	(2) 0.32	--
Cymbella neocistula	--	--	--	--	(1) 0.16	--
Cymbella perparva	--	--	--	--	(1) 0.16	(1) 0.13
Cymbella sp.	--	--	--	--	--	--
Denticula tenuis	P	--	--	--	--	(2) 0.26
Diatoma hiemalis	--	--	--	--	(2) 0.32	--
Diatoma mesodon	(6) 0.82	--	(5) 0.72	--	(8) 1.27	--
Diatoma moniliformis	--	(17) 2.51	(7) 1.01	--	--	--
Diatoma tenuis	(9) 1.23	--	--	(32) 5.32	(4) 0.64	(8) 1.05
Didymosphenia geminata	P	(1) 0.15	P	(1) 0.17	--	(3) 0.39
Didymosphenia geminata (whole slide count)	20	150	6	0	20	95
Distrionella incognita	--	--	--	--	--	(6) 0.79
Encyonema cespitosum	--	(2) 0.3	--	(4) 0.66	--	(4) 0.52
Encyonema minutum	--	(25) 3.69	--	(8) 1.33	--	(12) 1.57
Encyonema muelleri	(1) 0.14	--	(2) 0.29	--	--	(2) 0.26
Encyonema prostratum	--	P	--	--	--	--
Encyonema reichardtii	--	--	(2) 0.29	--	--	--
Encyonema silesiacum	(23) 3.15	(33) 4.87	(2) 0.29	(8) 1.33	(118) 18.79	(85) 11.15
Encyonopsis cesatii	--	--	--	(6) 1	--	--
Encyonopsis krammeri	--	--	--	(4) 0.66	--	--
Encyonopsis microcephala	--	--	--	(37) 6.15	--	--
Encyonopsis perborealis	(25) 3.42	--	(21) 3.04	--	--	--
Encyonopsis subminuta	(9) 1.23	(43) 6.35	(32) 4.64	--	--	(22) 2.89
Eolimna minima	(16) 2.19	--	(6) 0.87	--	(2) 0.32	--
Epithemia adnata	--	--	(11) 1.59	--	(6) 0.96	--
Epithemia sorex	(3) 0.41	--	(14) 2.03	(2) 0.33	--	--
Epithemia turgida	(6) 0.82	P	(2) 0.29	(2) 0.33	--	--
Eucocconeis flexella	--	--	--	--	--	(1) 0.13

Appendix 3A. Diatom species list and abundance from Flathead River at Flathead, British Columbia (1235500, Border); and North Fork Flathead River near Columbia Falls, Mont. (1235500, Columbia Falls).—Continued

[Diatom species list and abundance from long-term gaging stations from all six sample events in 2007–2008 (note the early spring 2008 periphyton sample was lost). Nearly all diatoms were identified to the species level by a single taxonomist so Operational Taxanomic Units are not required. Taxa indicated with *GLAC LLB" are provisionally new-to-science species (Loren L. Bahls, written commun., 2009). Counts are in parentheses followed by the percent relative abundance within each sample. "P" indicates the taxon was present in a whole slide search. "--" indicates the taxon was not present. Whole slide counts for Didymosphenia geminata are listed separately]

Period:	Mid summer 2008		Late summer 2008		Early fall 2008		Count total
Sample date:	8/1/2008	8/1/2008	8/20/2008	8/20/2008	10/1/2008	10/1/2008	
Species/site:	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls	
Achnanthes minutissima v. jackii	--	(4) 0.62	--	--	--	--	4
Achnanthes rosenstockii	--	--	--	--	--	--	2
Achnanthidium deflexum	--	(5) 0.77	--	(3) 0.47	(8) 1.22	(2) 0.29	43
Achnanthidium gracillimum	--	--	--	(4) 0.62	--	--	18
Achnanthidium minutissimum	(55) 8.32	(296) 45.68	(49) 7.31	(285) 44.32	(414) 63.01	(26) 3.79	2,030
Achnanthidium neomicrocephalum	--	(6) 0.93	--	(6) 0.93	--	--	19
Achnanthidium pyrenaicum	(4) 0.61	(200) 30.86	(8) 1.19	(153) 23.79	(64) 9.74	(6) 0.87	505
Achnanthidium rivulare	(1) 0.15	--	(2) 0.3	--	--	--	7
Adlafia bryophila	--	--	--	--	--	--	2
Adlafia minuscula	(2) 0.3	--	--	--	--	--	8
Amphipleura pellucida	--	--	(2) 0.3	(1) 0.16	--	(3) 0.44	40
Amphora copulata	--	--	--	--	--	--	P
Amphora inariensis	--	--	--	--	--	--	1
Amphora pediculus	--	--	--	--	--	--	5
Aulacoseira canadensis	--	--	(1) 0.15	--	--	--	1
Brachysira microcephala	--	--	--	(2) 0.31	--	--	10
Brachysira vitrea	--	--	--	--	--	--	6
Caloneis bacillum	(1) 0.15	--	(2) 0.3	--	--	--	32
Caloneis schumanniana	--	--	--	--	--	--	3
Caloneis silicula	--	--	--	--	--	--	4
Caloneis sp.	--	--	(2) 0.3	--	--	--	2
Caloneis tenuis	--	--	--	--	--	--	5
Cavinula pseudoscutiformis	--	--	--	--	--	--	2
Cocconeis pediculus	--	--	--	--	--	--	2
Cocconeis placentula	(6) 0.91	(3) 0.46	(57) 8.51	(1) 0.16	(3) 0.46	(109) 15.89	299
Cyclotella comensis	--	--	--	--	--	--	4
Cymatopleura elliptica	--	--	--	--	--	--	P
Cymatopleura solea	--	--	--	--	--	--	P
Cymbella excisa	(73) 11.04	--	(22) 3.28	(9) 1.4	(6) 0.91	(7) 1.02	171
Cymbella excisiformis	--	--	(1) 0.15	--	--	--	15
Cymbella hustedtii	--	--	--	--	--	--	2
Cymbella neocistula	--	--	--	--	--	--	1
Cymbella perparva	--	--	--	--	--	--	2
Cymbella sp.	--	--	--	(1) 0.16	--	--	1
Denticula tenuis	--	--	--	--	--	--	2
Diatoma hiemalis	--	--	--	--	--	(4) 0.58	6
Diatoma mesodon	(16) 2.42	--	--	--	--	(2) 0.29	37
Diatoma moniliformis	--	--	--	--	--	--	24
Diatoma tenuis	(32) 4.84	(2) 0.31	(31) 4.63	(12) 1.87	(7) 1.07	(43) 6.27	180
Didymosphenia geminata	--	P	--	P	P	(1) 0.15	6
Didymosphenia geminata (whole slide count)	0	6	0	9	67	0	373
Distrionella incognita	--	--	--	(2) 0.31	--	--	8
Encyonema cespitosum	--	--	--	--	(3) 0.46	--	13
Encyonema minutum	(2) 0.3	--	--	(4) 0.62	(2) 0.3	--	53
Encyonema muelleri	--	--	--	(2) 0.31	--	--	7
Encyonema prostratum	--	--	--	--	--	--	P
Encyonema reichardtii	(8) 1.21	--	--	--	--	--	10
Encyonema silesiacum	(22) 3.33	(8) 1.23	(8) 1.19	(23) 3.58	(5) 0.76	(13) 1.9	348
Encyonopsis cesatii	--	--	--	--	--	--	6
Encyonopsis krammeri	--	--	--	--	--	--	4
Encyonopsis microcephala	--	--	--	--	--	(11) 1.6	48
Encyonopsis perborealis	(42) 6.35	--	(9) 1.34	--	(2) 0.3	--	99
Encyonopsis subminuta	--	--	--	(27) 4.2	(2) 0.3	(2) 0.29	137
Eolimna minima	--	--	(3) 0.45	--	(1) 0.15	--	28
Epithemia adnata	(2) 0.3	--	--	--	--	(9) 1.31	28
Epithemia sorex	(2) 0.3	--	(39) 5.82	--	--	(10) 1.46	70
Epithemia turgida	(1) 0.15	--	(9) 1.34	--	--	(13) 1.9	33
Eucocconeis flexella	--	--	--	--	--	--	1

Appendix 3A. Diatom species list and abundance from Flathead River at Flathead, British Columbia (1235500, Border); and North Fork Flathead River near Columbia Falls, Mont. (1235500, Columbia Falls).—Continued

[Diatom species list and abundance from long-term gaging stations from all six sample events in 2007–2008 (note the early spring 2008 periphyton sample was lost). Nearly all diatoms were identified to the species level by a single taxonomist so Operational Taxanomic Units are not required. Taxa indicated with *GLAC LLB" are provisionally new-to-science species (Loren L. Bahls, written commun., 2009). Counts are in parentheses followed by the percent relative abundance within each sample. "P" indicates the taxon was present in a whole slide search. "--" indicates the taxon was not present. Whole slide counts for Didymosphenia geminata are listed separately]

Period:	Late summer 2007		Early fall 2007		Full sample early/mid summer 2008	
Sample date:	8/20/2007	8/25/2007	10/4/2007	10/4/2007	7/11/2008	8/15/2008
Species/site:	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls
Eucocconeis laevis	--	--	--	--	--	(4) 0.52
Fallacia tenera	--	--	--	(4) 0.66	--	--
Fragilaria crotonensis	--	--	--	--	--	(2) 0.26
Fragilaria sepes	--	(2) 0.3	--	(14) 2.33	--	(8) 1.05
Fragilaria tenera	--	--	--	(6) 1	--	--
Fragilaria vaucheriae	--	--	--	(28) 4.65	--	--
Fragilaria vaucheriae morphotype A GLAC LLB	(3) 0.41	(12) 1.77	(2) 0.29	--	(8) 1.27	(3) 0.39
Fragilaria vaucheriae morphotype B GLAC LLB	(2) 0.27	--	(2) 0.29	--	--	(7) 0.92
Frustulia amphipleuroides	--	--	--	(2) 0.33	--	--
Geissleria decussis	(2) 0.27	--	--	(4) 0.66	--	--
Gomphoneis eriense	(2) 0.27	--	--	(2) 0.33	--	--
Gomphoneis geitleri	(4) 0.55	--	--	--	--	--
Gomphoneis olivaceoides	(39) 5.34	--	(14) 2.03	(6) 1	(108) 17.2	(6) 0.79
Gomphoneis olivaceum	--	--	--	--	--	--
Gomphoneis septa	--	--	--	--	--	(4) 0.52
Gomphonema aff. longilineare GLAC LLB	(15) 2.05	--	(2) 0.29	--	(4) 0.64	(5) 0.66
Gomphonema cf. minutum GLAC LLB	--	--	--	--	--	--
Gomphonema cf. pumilum GLAC LLB	--	--	--	--	(2) 0.32	--
Gomphonema citera	--	--	--	--	(44) 7.01	(2) 0.26
Gomphonema clavatulum	P	--	--	--	--	--
Gomphonema minusculum	--	--	--	--	--	--
Gomphonema pumilum	(28) 3.84	(18) 2.66	(9) 1.3	--	(8) 1.27	(53) 6.96
Gomphonema pygmaeum	--	--	--	--	--	--
Gomphonema sp.	--	--	--	--	--	(2) 0.26
Gomphonema sp. 408705 GLAC LLB	--	--	--	--	--	(2) 0.26
Gomphosphenia sp.	(2) 0.27	--	(2) 0.29	--	--	--
Gyrosigma acuminatum	--	--	--	--	P	--
Hannaea arcus	(18) 2.47	--	(5) 0.72	--	(36) 5.73	(18) 2.36
Hantzschia sp.	--	--	--	--	P	--
Karayevia clevei	(2) 0.27	--	--	--	--	--
Melosira varians	--	(2) 0.3	--	--	--	--
Meridion circulare	(3) 0.41	--	--	--	(11) 1.75	(3) 0.39
Navicula antonii	(10) 1.37	--	(14) 2.03	--	(1) 0.16	--
Navicula arctotenelloides	--	--	--	--	--	--
Navicula aurora	P	--	--	--	--	--
Navicula capitatoradiata	(2) 0.27	(2) 0.3	--	--	--	--
Navicula catalanogermanica	--	--	--	--	(2) 0.32	--
Navicula constans	P	--	--	--	--	--
Navicula cryptocephala	--	(3) 0.44	--	(2) 0.33	(4) 0.64	(3) 0.39
Navicula cryptofallax	(15) 2.05	--	(29) 4.2	--	--	--
Navicula cryptotenella	(8) 1.1	(6) 0.89	(1) 0.14	(26) 4.32	(2) 0.32	(4) 0.52
Navicula gregaria	--	--	--	--	--	--
Navicula helensis	--	--	(2) 0.29	--	--	--
Navicula moskalii	--	--	--	--	(2) 0.32	--
Navicula oligotraphenta	--	--	(3) 0.43	--	--	--
Navicula oppugnata	--	--	--	--	--	--
Navicula radiosa	(7) 0.96	(1) 0.15	(5) 0.72	(14) 2.33	--	(4) 0.52
Navicula reichardtiana	(56) 7.67	--	(23) 3.33	(3) 0.5	(8) 1.27	(2) 0.26
Navicula sp.	--	--	(2) 0.29	(2) 0.33	--	--
Navicula viridula	--	--	(1) 0.14	--	--	--
Navicula viridulacalcis	(1) 0.14	--	--	(2) 0.33	--	--
Neidium ampliatum	--	--	--	--	(1) 0.16	--
Neidium binodeformis	P	--	--	--	--	--
Neidium dubium	(2) 0.27	--	--	--	--	--
Nitzschia acicularis	--	--	(1) 0.14	--	--	--
Nitzschia agnita	--	--	--	(8) 1.33	--	--
Nitzschia amphibia	--	--	(2) 0.29	--	--	--
Nitzschia angustata	(4) 0.55	--	(2) 0.29	--	--	--

Appendix 3A. Diatom species list and abundance from Flathead River at Flathead, British Columbia (1235500, Border); and North Fork Flathead River near Columbia Falls, Mont. (1235500, Columbia Falls).—Continued

[Diatom species list and abundance from long-term gaging stations from all six sample events in 2007–2008 (note the early spring 2008 periphyton sample was lost). Nearly all diatoms were identified to the species level by a single taxonomist so Operational Taxanomic Units are not required. Taxa indicated with *GLAC LLB" are provisionally new-to-science species (Loren L. Bahls, written commun., 2009). Counts are in parentheses followed by the percent relative abundance within each sample. "P" indicates the taxon was present in a whole slide search. "--" indicates the taxon was not present. Whole slide counts for Didymosphenia geminata are listed separately]

Period:	Mid summer 2008		Late summer 2008		Early fall 2008		Count total
Sample date:	8/1/2008	8/1/2008	8/20/2008	8/20/2008	10/1/2008	10/1/2008	
Species/site:	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls	
Eucocconeis laevis	--	--	--	--	--	--	4
Fallacia tenera	--	--	--	--	--	--	4
Fragilaria crotonensis	--	--	--	--	--	--	2
Fragilaria sepes	--	--	--	(2) 0.31	(2) 0.3	--	28
Fragilaria tenera	--	--	(1) 0.15	--	--	--	7
Fragilaria vaucheriae	--	--	--	--	--	--	28
Fragilaria vaucheriae morphotype A GLAC LLB	(20) 3.03	--	--	(1) 0.16	--	(2) 0.29	51
Fragilaria vaucheriae morphotype B GLAC LLB	--	--	(10) 1.49	(5) 0.78	--	(9) 1.31	35
Frustulia amphipleuroides	--	--	--	--	--	--	2
Geissleria decussis	--	--	(2) 0.3	--	--	--	8
Gomphoneis eriense	--	--	--	--	--	--	4
Gomphoneis geitleri	--	--	--	--	--	--	4
Gomphoneis olivaceoides	(94) 14.22	(9) 1.39	(31) 4.63	(11) 1.71	(12) 1.83	(104) 15.16	434
Gomphoneis olivaceum	(3) 0.45	--	--	--	--	--	3
Gomphoneis septa	(2) 0.3	--	--	(6) 0.93	--	--	12
Gomphonema aff. longilineare GLAC LLB	(4) 0.61	(4) 0.62	(5) 0.75	--	--	(2) 0.29	41
Gomphonema cf. minutum GLAC LLB	--	--	--	--	P	(8) 1.17	8
Gomphonema cf. pumilum GLAC LLB	--	--	(4) 0.6	--	--	--	6
Gomphonema citera	(12) 1.82	--	(3) 0.45	(1) 0.16	(2) 0.3	(5) 0.73	69
Gomphonema clavatulum	--	--	--	--	--	--	P
Gomphonema minusculum	--	--	(115) 17.16	--	(55) 8.37	--	170
Gomphonema pumilum	(17) 2.57	(54) 8.33	(121) 18.06	(39) 6.07	(47) 7.15	(197) 28.72	591
Gomphonema pygmaeum	--	--	--	--	--	(58) 8.45	58
Gomphonema sp.	--	--	--	--	--	--	2
Gomphonema sp. 408705 GLAC LLB	--	--	--	--	--	--	2
Gomphosphenia sp.	--	--	--	--	--	--	4
Gyrosigma acuminatum	--	--	--	--	--	--	P
Hannaea arcus	(20) 3.03	--	--	(2) 0.31	(2) 0.3	--	101
Hantzschia sp.	--	--	--	--	--	--	P
Karayevia clevei	--	--	--	--	--	--	2
Melosira varians	--	--	--	--	--	--	2
Meridion circulare	--	(2) 0.31	--	--	--	--	19
Navicula antonii	--	--	(2) 0.3	(2) 0.31	--	(1) 0.15	30
Navicula arctotenelloides	(4) 0.61	--	--	--	--	(2) 0.29	6
Navicula aurora	--	--	--	--	--	--	P
Navicula capitatoradiata	--	--	--	(2) 0.31	--	--	6
Navicula catalanogermanica	--	--	--	--	--	--	2
Navicula constans	--	--	--	--	--	--	P
Navicula cryptocephala	(2) 0.3	--	--	--	--	(2) 0.29	16
Navicula cryptofallax	--	--	--	--	--	--	44
Navicula cryptotenella	(3) 0.45	--	(2) 0.3	(1) 0.16	--	--	53
Navicula gregaria	(3) 0.45	--	--	--	--	--	3
Navicula helensis	--	--	--	--	--	--	2
Navicula moskalii	--	--	--	--	--	--	2
Navicula oligotraphenta	--	--	--	--	--	--	3
Navicula oppugnata	(2) 0.3	--	--	--	--	--	2
Navicula radiosa	--	--	--	--	--	--	31
Navicula reichardtiana	(12) 1.82	--	(2) 0.3	--	--	(6) 0.87	112
Navicula sp.	--	--	--	--	--	--	4
Navicula viridula	--	--	--	--	--	--	1
Navicula viridulacalcis	--	--	--	--	--	--	3
Neidium ampliatum	--	--	--	--	--	--	1
Neidium binodeformis	--	--	--	--	--	--	P
Neidium dubium	--	--	--	--	--	--	2
Nitzschia acicularis	--	--	--	--	--	--	1
Nitzschia agnita	--	--	--	--	--	--	8
Nitzschia amphibia	--	--	--	--	--	--	2
Nitzschia angustata	--	--	--	--	--	--	6

Appendix 3A. Diatom species list and abundance from Flathead River at Flathead, British Columbia (1235500, Border); and North Fork Flathead River near Columbia Falls, Mont. (1235500, Columbia Falls).—Continued

[Diatom species list and abundance from long-term gaging stations from all six sample events in 2007–2008 (note the early spring 2008 periphyton sample was lost). Nearly all diatoms were identified to the species level by a single taxonomist so Operational Taxanomic Units are not required. Taxa indicated with *GLAC LLB" are provisionally new-to-science species (Loren L. Bahls, written commun., 2009). Counts are in parentheses followed by the percent relative abundance within each sample. "P" indicates the taxon was present in a whole slide search. "--" indicates the taxon was not present. Whole slide counts for Didymosphenia geminata are listed separately]

Period:	Late summer 2007		Early fall 2007		Full sample early/mid summer 2008	
Sample date:	8/20/2007	8/25/2007	10/4/2007	10/4/2007	7/11/2008	8/15/2008
Species/site:	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls
Nitzschia angustatula	--	--	(4) 0.58	--	--	--
Nitzschia archibaldii	(22) 3.01	--	(13) 1.88	--	(12) 1.91	--
Nitzschia bacillum	(20) 2.74	(6) 0.89	(67) 9.71	--	--	--
Nitzschia bryophila	--	--	(2) 0.29	--	--	(2) 0.26
Nitzschia dissipata	(38) 5.21	(8) 1.18	(17) 2.46	(18) 2.99	(7) 1.11	(13) 1.71
Nitzschia fonticola	--	--	--	(8) 1.33	--	--
Nitzschia frustulum	--	--	(1) 0.14	--	--	--
Nitzschia graciliformis	(4) 0.55	--	(3) 0.43	--	--	--
Nitzschia heufleriana	(4) 0.55	--	(1) 0.14	(2) 0.33	--	(2) 0.26
Nitzschia lacuum	--	--	--	(6) 1	--	--
Nitzschia lancettula	--	--	--	--	(7) 1.11	--
Nitzschia linearis	(1) 0.14	--	(1) 0.14	(6) 1	(3) 0.48	--
Nitzschia palea	(4) 0.55	--	--	(8) 1.33	(2) 0.32	--
Nitzschia paleacea	(18) 2.47	(2) 0.3	(29) 4.2	--	--	(1) 0.13
Nitzschia perminuta	(23) 3.15	(6) 0.89	(36) 5.22	--	--	(6) 0.79
Nitzschia pumila	--	--	--	(6) 1	--	--
Nitzschia pura	(8) 1.1	(3) 0.44	(1) 0.14	--	--	(5) 0.66
Nitzschia recta	(10) 1.37	(2) 0.3	(7) 1.01	(6) 1	(5) 0.8	--
Nitzschia sigmoidea	--	--	(1) 0.14	--	--	--
Nitzschia sp.	--	--	--	--	--	(2) 0.26
Nitzschia subacicularis	(2) 0.27	--	(2) 0.29	--	--	--
Nitzschia sublinearis	(3) 0.41	--	--	--	--	--
Nitzschia vermicularis	(4) 0.55	--	(1) 0.14	--	--	--
Pinnularia sp.	--	--	(2) 0.29	--	(2) 0.32	--
Planothidium frequentissimum	(10) 1.37	--	(9) 1.3	--	--	--
Planothidium lanceolatum	--	--	--	(2) 0.33	--	--
Pseudostaurosira brevistriata	--	--	(12) 1.74	--	(6) 0.96	--
Pseudostaurosira elliptica	--	--	--	--	(51) 8.12	(6) 0.79
Reimeria sinuata	(18) 2.47	(9) 1.33	(9) 1.3	(6) 1	(30) 4.78	(29) 3.81
Rhoicosphenia abbreviata	(1) 0.14	--	(2) 0.29	--	--	--
Rhopalodia gibba	(3) 0.41	(2) 0.3	(16) 2.32	(2) 0.33	--	--
Sellaphora bacillum	(3) 0.41	--	(4) 0.58	--	--	--
Sellaphora pupula	(3) 0.41	--	(2) 0.29	(4) 0.66	--	--
Simonsenia delognei	(6) 0.82	--	--	--	--	--
Staurosira construens	--	(2) 0.3	--	(39) 6.48	--	--
Staurosira sp.	(2) 0.27	--	--	--	--	--
Staurosira venter	(11) 1.51	(1) 0.15	--	(16) 2.66	(8) 1.27	(1) 0.13
Staurosirella lapponica	--	--	--	--	--	(3) 0.39
Staurosirella leptostauron	(2) 0.27	--	(4) 0.58	(12) 1.99	(2) 0.32	(4) 0.52
Staurosirella martyi	(25) 3.42	--	(38) 5.51	--	(6) 0.96	(22) 2.89
Staurosirella ovata	(8) 1.1	--	--	--	--	(23) 3.02
Staurosirella pinnata	(6) 0.82	--	(16) 2.32	(8) 1.33	--	--
Staurosirella sp.	--	--	--	(4) 0.66	--	--
Surirella angusta	--	--	(3) 0.43	--	--	--
Surirella linearis	(1) 0.14	--	P	(4) 0.66	--	--
Synedra acus	--	(17) 2.51	--	(6) 1	(4) 0.64	(14) 1.84
Synedra delicatissima	(1) 0.14	--	--	--	--	--
Synedra mazamaensis	--	--	--	--	--	--
Synedra rumpens	(1) 0.14	(12) 1.77	(2) 0.29	(18) 2.99	--	(20) 2.62
Synedra ulna	(6) 0.82	--	(19) 2.75	(8) 1.33	(7) 1.11	(2) 0.26
Count total	730	677	690	602	628	762

Appendix 3A. Diatom species list and abundance from Flathead River at Flathead, British Columbia (1235500, Border); and North Fork Flathead River near Columbia Falls, Mont. (1235500, Columbia Falls).—Continued

[Diatom species list and abundance from long-term gaging stations from all six sample events in 2007–2008 (note the early spring 2008 periphyton sample was lost). Nearly all diatoms were identified to the species level by a single taxonomist so Operational Taxanomic Units are not required. Taxa indicated with *GLAC LLB" are provisionally new-to-science species (Loren L. Bahls, written commun., 2009). Counts are in parentheses followed by the percent relative abundance within each sample. "P" indicates the taxon was present in a whole slide search. "--" indicates the taxon was not present. Whole slide counts for Didymosphenia geminata are listed separately]

Period:	Mid summer 2008		Late summer 2008		Early fall 2008		Count total
Sample date:	8/1/2008	8/1/2008	8/20/2008	8/20/2008	10/1/2008	10/1/2008	
Species/site:	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls	
Nitzschia angustatula	--	--	--	--	--	--	4
Nitzschia archibaldii	(8) 1.21	--	(2) 0.3	--	--	--	57
Nitzschia bacillum	--	--	--	--	--	(6) 0.87	99
Nitzschia bryophila	(6) 0.91	(1) 0.15	--	--	--	--	11
Nitzschia dissipata	(7) 1.06	--	(5) 0.75	--	--	(3) 0.44	116
Nitzschia fonticola	--	--	--	--	--	--	8
Nitzschia frustulum	--	--	--	--	--	--	1
Nitzschia graciliformis	--	--	--	--	--	--	7
Nitzschia heufleriana	--	--	--	--	--	--	9
Nitzschia lacuum	(2) 0.3	--	--	(2) 0.31	--	(2) 0.29	12
Nitzschia lancettula	--	(1) 0.15	--	(2) 0.31	--	--	10
Nitzschia linearis	--	--	--	--	--	--	11
Nitzschia palea	(2) 0.3	--	--	--	--	--	16
Nitzschia paleacea	(21) 3.18	--	(24) 3.58	(2) 0.31	--	(4) 0.58	101
Nitzschia perminuta	(4) 0.61	--	(5) 0.75	--	--	--	80
Nitzschia pumila	--	--	--	--	--	--	6
Nitzschia pura	(4) 0.61	--	(6) 0.9	(6) 0.93	(4) 0.61	(3) 0.44	40
Nitzschia recta	(1) 0.15	(2) 0.31	--	--	--	--	33
Nitzschia sigmoidea	--	--	--	--	--	--	1
Nitzschia sp.	--	--	(2) 0.3	(2) 0.31	--	--	6
Nitzschia subacicularis	--	--	--	--	--	--	4
Nitzschia sublinearis	--	--	--	--	--	--	3
Nitzschia vermicularis	--	--	--	--	--	--	5
Pinnularia sp.	--	--	--	--	--	--	4
Planothidium frequentissimum	--	--	(7) 1.04	--	--	--	26
Planothidium lanceolatum	(5) 0.76	--	(2) 0.3	--	--	--	9
Pseudostaurosira brevistriata	--	(2) 0.31	--	--	--	--	20
Pseudostaurosira elliptica	(10) 1.51	--	--	--	--	--	67
Reimeria sinuata	(23) 3.48	(40) 6.17	(51) 7.61	(5) 0.78	(13) 1.98	(3) 0.44	236
Rhoicosphenia abbreviata	(2) 0.3	--	(8) 1.19	--	--	--	13
Rhopalodia gibba	--	--	--	(1) 0.16	--	--	24
Sellaphora bacillum	--	--	--	--	--	--	7
Sellaphora pupula	--	--	--	--	--	--	9
Simonsenia delognei	--	--	--	--	--	--	6
Staurosira construens	--	--	--	--	--	--	41
Staurosira sp.	(2) 0.3	--	--	--	--	--	4
Staurosira venter	(1) 0.15	--	--	(1) 0.16	--	--	39
Staurosirella lapponica	--	--	--	--	--	--	3
Staurosirella leptostauron	(2) 0.3	--	--	(1) 0.16	--	--	27
Staurosirella martyi	--	--	--	(2) 0.31	--	--	93
Staurosirella ovata	--	--	--	--	--	--	31
Staurosirella pinnata	--	--	--	--	--	--	30
Staurosirella sp.	--	--	--	--	--	--	4
Surirella angusta	--	--	--	--	--	--	3
Surirella linearis	--	--	--	--	--	--	5
Synedra acus	(69) 10.44	(1) 0.15	(7) 1.04	(4) 0.62	(2) 0.3	(6) 0.87	130
Synedra delicatissima	--	--	--	--	--	--	1
Synedra mazamaensis	(2) 0.3	--	--	--	--	--	2
Synedra rumpens	(4) 0.61	(4) 0.62	(2) 0.3	(6) 0.93	--	--	69
Synedra ulna	(19) 2.87	(4) 0.62	(6) 0.9	(2) 0.31	(1) 0.15	(2) 0.29	76
Count total	661	648	670	643	657	686	8,054

Appendix 3B. Macroinvertebrate species list and abundance from Flathead River at Flathead, British Columbia (1235500; Border), and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls).

[Macroinvertebrate species list and abundance from long-term gaging stations from all six or seven sample events in 2007–2008. Note that the 08/25/2007 benthos sample from Columbia Falls was lost. There are also two additional macroinvertebrate samples relative to diatoms from late spring 2008. Taxa are listed using Operational Taxonomic Units. All taxa are larvae except as noted (U = unknown, A = adult, P = pupae). “Gr.” indicates the Operational Taxonomic Unit is a suite of species. Counts are in parentheses followed by the relative abundance within each sample. “--” indicates the taxa was not present]

Period	Late summer 2007	Early fall 2007		Late spring 2008		Full sample early/mid summer 2008	
Sample date	8/20/2007	10/4/2007	10/4/2007	3/31/2008	3/31/2008	7/11/2008	8/15/2008
Taxa / site	Border	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls
Acari (U)	(6) 0.56	(6) 0.75	(18) 1.38	(1) 0.09	(1) 0.15	(22) 3.43	(36) 6.44
Acentrella	--	--	--	--	--	--	(38) 6.8
Agraylea	--	--	--	--	--	--	--
Ameletus	--	--	(16) 1.23	(1) 0.09	--	(21) 3.28	(5) 0.89
Antocha	--	(5) 0.62	(16) 1.23	(3) 0.27	--	(4) 0.62	--
Apatania	--	--	--	--	--	--	--
Arctopsyche	(14) 1.31	(21) 2.62	(10) 0.77	(2) 0.18	(4) 0.59	--	--
Arctopsyche grandis	--	--	--	--	--	--	(2) 0.36
Atherix	--	(1) 0.12	--	--	--	(7) 1.09	(1) 0.18
Attenella margarita	--	--	--	--	--	--	(19) 3.4
Baetidae	--	--	--	--	--	(55) 8.58	--
Baetis	(43) 4.03	(14) 1.74	(18) 1.38	(248) 22.22	(31) 4.55	(71) 11.08	--
Baetis flavistriga	--	--	--	--	--	--	--
Baetis tricaudatus	--	--	--	--	--	--	(33) 5.9
Blephariceridae	--	--	--	--	--	--	--
Brachycentrus	--	(7) 0.87	--	(4) 0.36	--	(5) 0.78	--
Brachycentrus americanus	--	--	--	--	--	--	--
Capniidae	--	--	--	(28) 2.51	(3) 0.44	--	--
Caudatella	--	--	--	(6) 0.54	--	--	--
Caudatella hystrix	--	(1) 0.12	--	--	--	--	--
Ceraclea	--	--	--	--	--	--	(1) 0.18
Ceratopogonidae	--	--	--	--	--	(7) 1.09	--
Chelifera	--	--	--	--	--	--	--
Chironomidae	(9) 0.84	(122) 15.19	(225) 17.24	(174) 15.59	(126) 18.5	(153) 23.87	--
Chironominae	--	(4) 0.5	--	--	--	--	--
Chironomini	--	(1) 0.12	--	--	--	--	--
Chloroperlidae	(2) 0.19	--	--	--	--	(3) 0.47	(12) 2.15
Cinygmula	--	--	(53) 4.06	(124) 11.11	(11) 1.62	(26) 4.06	--
Claassenia sabulosa	(2) 0.19	(1) 0.12	(1) 0.08	(5) 0.45	(8) 1.17	(2) 0.31	(1) 0.18
Cladotanytarsus	--	--	--	--	--	--	--
Cleptelmis addenda (A)	--	--	--	--	--	--	--
Clinocera	--	--	--	--	--	--	(1) 0.18
Corynoneura (P)	--	--	--	--	--	--	--
Cricotopus	--	--	--	--	--	--	(67) 11.99
Diamesa	--	--	(5) 0.38	--	--	--	--
Dicranota	--	--	--	(4) 0.36	--	--	--
Diphetor hageni	--	--	--	--	--	(11) 1.72	(3) 0.54
Diptera	--	--	--	--	--	(1) 0.16	--
Dolichopodidae	--	--	--	(2) 0.18	(1) 0.15	--	--
Doroneuria	--	--	--	--	--	--	--
Drunella	--	--	--	--	--	--	(3) 0.54
Drunella doddsi	(46) 4.31	(19) 2.37	(4) 0.31	(1) 0.09	(12) 1.76	(1) 0.16	(1) 0.18
Drunella flavilinea	--	--	--	--	--	(6) 0.94	--
Drunella grandis	--	--	(1) 0.08	--	--	--	--
Drunella spinifera	--	--	--	--	--	--	--
Dytiscidae	--	--	--	--	--	--	--
Elmidae	--	--	--	--	--	--	(1) 0.18
Empididae	--	(8) 1	(3) 0.23	--	--	(16) 2.5	--
Empididae (P)	--	--	--	--	--	--	--
Enchytraeidae (U)	--	--	--	--	--	--	--
Epeorus	(6) 0.56	(4) 0.5	(73) 5.59	--	(34) 4.99	(21) 3.28	(1) 0.18
Epeorus albertae	--	--	--	--	--	--	(1) 0.18
Epeorus deceptivus	--	--	--	--	--	--	--
Epeorus longimanus	--	--	--	--	--	(18) 2.81	--
Ephemera	--	--	--	(53) 4.75	--	--	--
Ephemerella	(1) 0.09	(40) 4.98	(62) 4.75	(83) 7.44	(46) 6.75	(16) 2.5	--
Ephemerella inermis	--	--	--	--	--	--	--
Ephemerellidae	--	--	--	--	--	--	(1) 0.18
Eukiefferiella	--	(5) 0.62	(43) 3.3	--	--	--	(8) 1.43

Appendix 3B. Macroinvertebrate species list and abundance from Flathead River at Flathead, British Columbia (1235500; Border), and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls).—Continued

[Macroinvertebrate species list and abundance from long-term gaging stations from all six or seven sample events in 2007–2008. Note that the 08/25/2007 benthos sample from Columbia Falls was lost. There are also two additional macroinvertebrate samples relative to diatoms from late spring 2008. Taxa are listed using Operational Taxonomic Units. All taxa are larvae except as noted (U = unknown, A = adult, P = pupae). "Gr." indicates the Operational Taxonomic Unit is a suite of species. Counts are in parentheses followed by the relative abundance within each sample. "--" indicates the taxa was not present]

Period	Mid summer 2008		Late summer 2008		Early fall 2008		Count total
Sample date	8/1/2008	8/1/2008	8/20/2008	8/20/2008	10/1/2008	10/1/2008	
Taxa / site	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls	
Acari (U)	(31) 5.12	(26) 4.63	(8) 1.48	(15) 4.9	(4) 0.71	(2) 0.34	176
Acentrella	(52) 8.6	(105) 18.68	(15) 2.77	(2) 0.65	(1) 0.18	--	213
Agraylea	--	--	--	--	--	(1) 0.17	1
Ameletus	(2) 0.33	--	--	(44) 14.38	(3) 0.53	(1) 0.17	93
Antocha	(3) 0.5	(1) 0.18	--	--	--	(2) 0.34	34
Apatania	(3) 0.5	--	(1) 0.18	(1) 0.33	--	--	5
Arctopsyche	--	--	--	--	--	(32) 5.38	83
Arctopsyche grandis	--	--	(6) 1.11	(1) 0.33	--	--	9
Atherix	(8) 1.32	(1) 0.18	(2) 0.37	--	--	(3) 0.5	23
Attenella margarita	--	(9) 1.6	--	(9) 2.94	--	--	37
Baetidae	--	(10) 1.78	--	--	--	--	65
Baetis	(25) 4.13	--	(4) 0.74	--	--	(18) 3.03	472
Baetis flavistriga	(7) 1.16	--	(45) 8.32	(2) 0.65	--	--	54
Baetis tricaudatus	(16) 2.64	(18) 3.2	(7) 1.29	(13) 4.25	(12) 2.14	--	99
Blephariceridae	(1) 0.17	--	--	--	--	--	1
Brachycentrus	--	--	--	--	(1) 0.18	(11) 1.85	28
Brachycentrus americanus	(2) 0.33	(1) 0.18	--	--	--	--	3
Capniidae	--	--	(1) 0.18	--	--	(14) 2.35	46
Caudatella	--	--	--	--	--	(1) 0.17	7
Caudatella hystrix	--	--	--	--	--	--	1
Ceraclea	--	--	--	--	--	--	1
Ceratopogonidae	--	--	--	--	--	--	7
Chelifera	(5) 0.83	--	--	--	--	--	5
Chironomidae	--	--	--	--	--	(4) 0.67	813
Chironominae	--	--	--	--	--	--	4
Chironomini	--	--	--	--	--	--	1
Chloroperlidae	--	(28) 4.98	--	--	--	--	45
Cinygmula	(27) 4.46	(10) 1.78	--	--	--	(4) 0.67	255
Claassenia sabulosa	(4) 0.66	(19) 3.38	--	--	--	(5) 0.84	48
Cladotanytarsus	(1) 0.17	(2) 0.36	--	--	(26) 4.63	--	29
Cleptelmis addenda (A)	--	--	--	(1) 0.33	--	--	1
Clinocera	--	--	--	--	--	--	1
Corynoneura (P)	--	--	--	(1) 0.33	--	--	1
Cricotopus	--	--	--	(4) 1.31	--	--	71
Diamesa	--	(1) 0.18	(1) 0.18	--	--	--	7
Dicranota	--	--	--	--	--	--	4
Diphetor hageni	(3) 0.5	(22) 3.91	--	(1) 0.33	(4) 0.71	--	44
Diptera	--	--	--	--	--	--	1
Dolichopodidae	--	--	--	--	--	--	3
Doroneuria	--	--	--	--	(6) 1.07	--	6
Drunella	(1) 0.17	(1) 0.18	--	--	--	--	5
Drunella doddsi	(159) 26.28	(38) 6.76	(62) 11.46	(3) 0.98	(13) 2.32	(49) 8.24	408
Drunella flavilinea	(3) 0.5	--	--	--	--	--	9
Drunella grandis	--	--	--	--	--	(2) 0.34	3
Drunella spinifera	--	--	--	--	--	(1) 0.17	1
Dytiscidae	--	--	(1) 0.18	(3) 0.98	--	--	4
Elmidae	--	(2) 0.36	(2) 0.37	(1) 0.33	--	--	6
Empididae	--	--	--	--	--	(7) 1.18	34
Empididae (P)	(7) 1.16	(1) 0.18	--	--	--	--	8
Enchytraeidae (U)	(1) 0.17	--	--	--	--	--	1
Epeorus	(10) 1.65	(8) 1.42	--	--	--	--	157
Epeorus albertae	--	(7) 1.25	--	--	--	--	8
Epeorus deceptivus	(3) 0.5	--	(1) 0.18	--	--	--	4
Epeorus longimanus	(10) 1.65	--	--	--	--	--	28
Ephemera	--	--	--	--	--	--	53
Ephemerella	--	--	--	--	--	(48) 8.07	296
Ephemerella inermis	--	--	--	--	(88) 15.69	--	88
Ephemerellidae	--	--	--	(1) 0.33	--	--	2
Eukiefferiella	(3) 0.5	(1) 0.18	--	--	(8) 1.43	--	68

Appendix 3B. Macroinvertebrate species list and abundance from Flathead River at Flathead, British Columbia (1235500; Border), and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls).—Continued

[Macroinvertebrate species list and abundance from long-term gaging stations from all six or seven sample events in 2007–2008. Note that the 08/25/2007 benthos sample from Columbia Falls was lost. There are also two additional macroinvertebrate samples relative to diatoms from late spring 2008. Taxa are listed using Operational Taxonomic Units. All taxa are larvae except as noted (U = unknown, A = adult, P = pupae). “Gr.” indicates the Operational Taxonomic Unit is a suite of species. Counts are in parentheses followed by the relative abundance within each sample. “--” indicates the taxa was not present]

Period	Late summer 2007	Early fall 2007		Late spring 2008		Full sample early/mid summer 2008	
Sample date	8/20/2007	10/4/2007	10/4/2007	3/31/2008	3/31/2008	7/11/2008	8/15/2008
Taxa / site	Border	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls
Glossosoma	--	--	--	(3) 0.27	--	--	(2) 0.36
Glossosomatidae	(2) 0.19	(16) 1.99	(1) 0.08	--	--	--	--
Glutops	--	--	--	--	--	--	--
Heleniella	--	(4) 0.5	--	--	--	--	--
Heptageniidae	(99) 9.28	(77) 9.59	(55) 4.21	(6) 0.54	(13) 1.91	(47) 7.33	--
Hesperoperla pacifica	(4) 0.37	--	(13) 1	--	(5) 0.73	--	--
Heterlimnius	(1) 0.09	(1) 0.12	--	--	--	--	--
Heterotrissocladius	--	--	--	--	--	--	--
Hexatoma	(12) 1.12	(37) 4.61	(12) 0.92	(7) 0.63	(2) 0.29	(6) 0.94	(2) 0.36
Hydrobaenus	--	--	--	--	--	--	(3) 0.54
Hydrophilidae	--	--	(1) 0.08	--	--	--	--
Hydropsyche	--	(42) 5.23	(88) 6.74	(43) 3.85	(177) 25.99	--	(2) 0.36
Hydropsychidae	(34) 3.19	(12) 1.49	(18) 1.38	(22) 1.97	--	--	(4) 0.72
Hydroptila	--	--	--	--	--	--	(2) 0.36
Hydroptilidae	--	--	--	--	--	--	(2) 0.36
Isoperla	--	--	(4) 0.31	(2) 0.18	(8) 1.17	--	--
Kathroperla	--	--	--	--	--	(1) 0.16	--
Kogotus	--	--	--	--	--	(1) 0.16	--
Krenosmittia	--	--	--	--	--	--	--
Lepidostoma	--	(11) 1.37	(3) 0.23	--	(2) 0.29	--	--
Leptoceridae	--	--	--	--	--	--	(1) 0.18
Lumbriculidae (U)	--	--	--	--	--	--	--
Megarcys	--	--	--	--	--	--	--
Micrasema	--	--	--	--	--	--	--
Micropsectra	--	(1) 0.12	--	--	--	--	(8) 1.43
Microtendipes	--	--	(1) 0.08	--	--	--	(17) 3.04
Molophilus	--	--	--	--	--	(2) 0.31	--
Nais	--	--	--	--	--	--	(30) 5.37
Narpus (A)	--	--	--	--	--	--	--
Narpus	--	--	--	--	--	--	(3) 0.54
Nemouridae	(1) 0.09	--	--	--	--	--	--
Neophylax	--	--	--	--	--	(1) 0.16	--
Neophylax rickeri	--	--	--	--	--	--	--
Neoplasta	--	--	--	--	--	--	(3) 0.54
Neothremma	--	--	--	--	--	--	--
Nilotanypus	--	--	--	--	--	--	--
Nixe	--	--	--	--	--	--	(1) 0.18
Oligochaeta (U)	--	(47) 5.85	(2) 0.15	(1) 0.09	--	(1) 0.16	--
Optioservus (A)	--	--	--	--	--	--	--
Optioservus	--	--	(7) 0.54	--	--	--	(2) 0.36
Ordobrevia	--	--	--	--	--	--	--
Orthocladiinae	--	--	--	--	--	--	--
Orthocladius	--	--	--	--	--	(8) 1.25	(65) 11.63
Orthocladius (P)	--	--	--	--	--	--	--
Pagastia	--	--	--	--	--	--	(41) 7.33
Paracladopelma	--	--	--	--	--	--	--
Parakiefferiella	--	--	--	--	--	--	(8) 1.43
Paraleptophlebia	(1) 0.09	(3) 0.37	(69) 5.29	(6) 0.54	(12) 1.76	(3) 0.47	--
Paraleptophlebia bicornuta	--	--	--	--	--	--	(2) 0.36
Paraleuctra	--	--	--	(1) 0.09	--	--	--
Parametriocnemus	--	--	--	--	--	--	(2) 0.36
Parametriocnemus (P)	--	--	--	--	--	--	--
Paraperla	--	--	--	(1) 0.09	--	--	--
Parapsyche elsis	--	--	--	--	--	--	--
Paratanytarsus	--	--	--	--	--	--	(2) 0.36
Pericoma	--	--	--	(2) 0.18	(1) 0.15	--	(1) 0.18
Perlidae	--	(10) 1.25	(14) 1.07	(4) 0.36	--	(1) 0.16	--
Perlodidae	(1) 0.09	(1) 0.12	(64) 4.9	--	--	--	(4) 0.72
Phaenopsectra	--	--	--	--	--	(17) 2.65	--

Appendix 3B. Macroinvertebrate species list and abundance from Flathead River at Flathead, British Columbia (1235500; Border), and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls).—Continued

[Macroinvertebrate species list and abundance from long-term gaging stations from all six or seven sample events in 2007–2008. Note that the 08/25/2007 benthos sample from Columbia Falls was lost. There are also two additional macroinvertebrate samples relative to diatoms from late spring 2008. Taxa are listed using Operational Taxonomic Units. All taxa are larvae except as noted (U = unknown, A = adult, P = pupae). “Gr.” indicates the Operational Taxonomic Unit is a suite of species. Counts are in parentheses followed by the relative abundance within each sample. “--” indicates the taxa was not present]

Period	Mid summer 2008		Late summer 2008		Early fall 2008		Count total
Sample date	8/1/2008	8/1/2008	8/20/2008	8/20/2008	10/1/2008	10/1/2008	
Taxa / site	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls	
Glossosoma	--	--	--	--	(7) 1.25	(17) 2.86	29
Glossosomatidae	--	--	--	--	--	--	19
Glutops	(1) 0.17	--	--	--	--	--	1
Heleniella	--	--	--	--	--	--	4
Heptageniidae	(16) 2.64	(18) 3.2	(53) 9.8	(51) 16.67	(127) 22.64	(50) 8.4	612
Hesperoperla pacifica	(2) 0.33	(1) 0.18	(1) 0.18	--	--	(5) 0.84	31
Heterlimnius	(1) 0.17	--	--	--	(1) 0.18	(1) 0.17	5
Heterotrissocladius	--	--	--	(5) 1.63	--	--	5
Hexatoma	(12) 1.98	(8) 1.42	(28) 5.18	(8) 2.61	(4) 0.71	(11) 1.85	149
Hydrobaenus	--	--	--	--	--	--	3
Hydrophilidae	--	--	--	--	--	--	1
Hydropsyche	(1) 0.17	(2) 0.36	(1) 0.18	--	(46) 8.2	(1) 0.17	403
Hydropsychidae	(4) 0.66	(11) 1.96	(3) 0.55	--	(10) 1.78	(14) 2.35	132
Hydroptila	--	--	--	--	--	--	2
Hydroptilidae	--	--	--	--	--	--	2
Isoperla	--	--	--	--	--	--	14
Kathroperla	--	--	--	--	--	--	1
Kogotus	--	--	--	--	--	--	1
Krenosmittia	--	--	(1) 0.18	--	--	--	1
Lepidostoma	(2) 0.33	--	--	--	(12) 2.14	(2) 0.34	32
Leptoceridae	--	--	--	--	--	--	1
Lumbriculidae (U)	--	--	(1) 0.18	--	--	--	1
Megarcys	--	(1) 0.18	--	--	--	--	1
Micrasema	--	--	--	--	--	(2) 0.34	2
Micropsectra	(2) 0.33	--	(8) 1.48	(7) 2.29	(1) 0.18	--	27
Microtendipes	--	--	--	(4) 1.31	--	--	22
Molophilus	--	--	--	--	--	--	2
Nais	--	--	--	--	--	--	30
Narpus (A)	(1) 0.17	--	--	--	--	--	1
Narpus	--	--	--	--	--	--	3
Nemouridae	--	--	--	--	--	--	1
Neophylax	--	--	--	--	--	--	1
Neophylax rickeri	--	(1) 0.18	--	--	--	--	1
Neoplasta	--	(17) 3.02	(8) 1.48	(5) 1.63	(21) 3.74	--	54
Neothremma	--	(3) 0.53	--	--	--	--	3
Nilotanypus	--	(1) 0.18	--	--	--	--	1
Nixe	--	--	--	--	--	--	1
Oligochaeta (U)	--	--	--	--	--	(1) 0.17	52
Optioservus (A)	--	(1) 0.18	--	--	--	--	1
Optioservus	--	(3) 0.53	--	--	--	--	12
Ordobrevia	--	(2) 0.36	--	--	--	--	2
Orthocladiinae	--	--	--	--	--	(3) 0.5	3
Orthocladius	(3) 0.5	(12) 2.14	(6) 1.11	(2) 0.65	--	--	96
Orthocladius (P)	--	--	(1) 0.18	--	--	--	1
Pagastia	(3) 0.5	(27) 4.8	(1) 0.18	(10) 3.27	(2) 0.36	--	84
Paracladopelma	--	--	--	(1) 0.33	--	--	1
Parakiefferiella	--	--	--	--	--	--	8
Paraleptophlebia	--	(3) 0.53	--	(3) 0.98	(16) 2.85	--	116
Paraleptophlebia bicornuta	--	--	(1) 0.18	(11) 3.59	--	--	14
Paraleuctra	--	--	--	--	--	--	1
Parametriocnemus	--	--	--	--	--	--	2
Parametriocnemus (P)	(1) 0.17	--	--	--	--	--	1
Paraperla	--	--	--	--	--	--	1
Parapsyche elsis	--	--	--	--	(2) 0.36	--	2
Paratanytarsus	--	--	--	--	(1) 0.18	--	3
Pericoma	--	--	--	--	--	(1) 0.17	5
Perlidae	(4) 0.66	--	(3) 0.55	(6) 1.96	--	--	42
Perlodidae	(2) 0.33	(2) 0.36	(1) 0.18	(6) 1.96	(5) 0.89	(8) 1.34	94
Phaenopsectra	--	--	--	(1) 0.33	--	--	18

Appendix 3B. Macroinvertebrate species list and abundance from Flathead River at Flathead, British Columbia (1235500; Border), and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls).—Continued

[Macroinvertebrate species list and abundance from long-term gaging stations from all six or seven sample events in 2007–2008. Note that the 08/25/2007 benthos sample from Columbia Falls was lost. There are also two additional macroinvertebrate samples relative to diatoms from late spring 2008. Taxa are listed using Operational Taxonomic Units. All taxa are larvae except as noted (U = unknown, A = adult, P = pupae). "Gr." indicates the Operational Taxonomic Unit is a suite of species. Counts are in parentheses followed by the relative abundance within each sample. "--" indicates the taxa was not present]

Period	**Late summer 2007**	**Early fall 2007**		**Late spring 2008**		**Full sample early/mid summer 2008**	
Sample date	**8/20/2007**	**10/4/2007**	**10/4/2007**	**3/31/2008**	**3/31/2008**	**7/11/2008**	**8/15/2008**
Taxa / site	**Border**	**Border**	**Columbia Falls**	**Border**	**Columbia Falls**	**Border**	**Columbia Falls**
Piscicolidae (U)	--	--	--	--	--	--	(1) 0.18
Plecoptera	--	(4) 0.5	(4) 0.31	(11) 0.99	(1) 0.15	(1) 0.16	--
Polycelis coronata (U)	--	--	--	--	--	--	--
Polypedilum	--	(67) 8.34	--	--	--	(1) 0.16	(1) 0.18
Polypedilum (P)	--	--	--	--	--	--	--
Potthastia	--	--	--	--	--	--	(1) 0.18
Prostoia besametsa	--	--	--	(59) 5.29	(9) 1.32	--	--
Protanyderus	--	--	--	--	--	(2) 0.31	--
Pseudochironomus	--	--	(12) 0.92	--	--	--	--
Pseudorthocladius	--	--	(7) 0.54	--	--	--	--
Psychodidae	--	(2) 0.25	--	--	--	--	--
Pteronarcella	--	--	--	--	--	--	--
Pteronarcella badia	--	--	(2) 0.15	--	--	--	--
Pteronarcys	--	--	--	--	--	--	--
Pteronarcys californica	--	--	(9) 0.69	--	(1) 0.15	--	--
Rhabdomastix	--	--	--	--	--	--	(1) 0.18
Rheocricotopus	--	--	--	--	--	--	(1) 0.18
Rheotanytarsus	--	--	--	--	--	(4) 0.62	(7) 1.25
Rheotanytarsus (P)	--	--	--	--	--	--	(1) 0.18
Rhithrogena	(50) 4.69	(149) 18.56	(154) 11.8	(115) 10.3	(114) 16.74	(1) 0.16	(4) 0.72
Rhyacophila	--	(5) 0.62	(5) 0.38	(3) 0.27	--	(2) 0.31	--
Rhyacophila Angelita Gr.	--	--	--	--	--	--	(1) 0.18
Rhyacophila arnaudi	--	--	--	--	--	--	--
Rhynchelmis (U)	--	--	--	--	--	--	--
Robackia	--	--	--	--	--	--	--
Serratella	(1) 0.09	--	--	--	--	(45) 7.02	--
Serratella tibialis	--	--	--	--	--	--	--
Simuliidae	(704) 65.98	(1) 0.12	--	(9) 0.81	(4) 0.59	(7) 1.09	--
Simulium	--	--	--	--	--	--	(1) 0.18
Stempellina	--	(2) 0.25	--	--	--	--	--
Stempellinella	--	--	--	--	--	--	(1) 0.18
Stempellinella (P)	--	--	--	--	--	--	--
Stictochironomus	--	--	--	--	--	--	--
Sublettea	--	--	--	--	--	--	(2) 0.36
Sublettea (P)	--	--	--	--	--	--	--
Suwallia	--	--	--	(8) 0.72	(2) 0.29	(12) 1.87	(4) 0.72
Sweltsa	(28) 2.62	(47) 5.85	(38) 2.91	(32) 2.87	(15) 2.2	--	(3) 0.54
Taenionema	--	--	--	(34) 3.05	(31) 4.55	--	--
Taeniopterygidae	--	--	(1) 0.08	(8) 0.72	(3) 0.44	--	--
Tanypodinae	--	--	--	--	--	(8) 1.25	(2) 0.36
Tanytarsus	--	(3) 0.37	(161) 12.34	--	--	--	(22) 3.94
Tanytarsus (P)	--	--	--	--	--	--	--
Thienemanniella	--	--	--	--	--	--	(12) 2.15
Thienemannimyia Gr.	--	(1) 0.12	--	--	--	(3) 0.47	(3) 0.54
Timpanoga hecuba	--	--	--	--	--	--	(1) 0.18
Tipulidae	--	--	--	--	--	(1) 0.16	(1) 0.18
Trichoptera	--	--	--	--	--	--	--
Tubificidae (U)	--	--	--	--	--	--	--
Turbellaria (I)	--	--	(1) 0.08	--	--	--	--
Turbellaria (U)	--	--	--	--	(1) 0.15	--	--
Tvetenia	--	--	--	--	--	--	(42) 7.51
Tvetenia (P)	--	--	--	--	--	--	(3) 0.54
Visoka cataractae	--	--	--	--	--	--	--
Wiedemannia	--	--	--	--	--	--	--
Zaitzevia (A)	--	--	--	--	--	--	--
Zaitzevia	--	--	(4) 0.31	--	(3) 0.44	--	--
Zapada	--	(1) 0.12	(7) 0.54	--	--	--	(2) 0.36
Zapada columbiana	--	--	--	--	--	--	--
Count total	1067	803	1305	1116	681	641	559

Appendix 3B. Macroinvertebrate species list and abundance from Flathead River at Flathead, British Columbia (1235500; Border), and North Fork Flathead River near Columbia Falls, Mont. (12355500; Columbia Falls).—Continued

[Macroinvertebrate species list and abundance from long-term gaging stations from all six or seven sample events in 2007–2008. Note that the 08/25/2007 benthos sample from Columbia Falls was lost. There are also two additional macroinvertebrate samples relative to diatoms from late spring 2008. Taxa are listed using Operational Taxonomic Units. All taxa are larvae except as noted (U = unknown, A = adult, P = pupae). "Gr." indicates the Operational Taxonomic Unit is a suite of species. Counts are in parentheses followed by the relative abundance within each sample. "--" indicates the taxa was not present]

Period	Mid summer 2008		Late summer 2008		Early fall 2008		Count total
Sample date	8/1/2008	8/1/2008	8/20/2008	8/20/2008	10/1/2008	10/1/2008	
Taxa / site	Border	Columbia Falls	Border	Columbia Falls	Border	Columbia Falls	
Piscicolidae (U)	--	--	--	--	--	--	1
Plecoptera	--	--	--	--	--	(2) 0.34	23
Polycelis coronata (U)	--	(3) 0.53	--	--	(1) 0.18	--	4
Polypedilum	(48) 7.93	(15) 2.67	(1) 0.18	(1) 0.33	(19) 3.39	--	153
Polypedilum (P)	(3) 0.5	(1) 0.18	(1) 0.18	--	--	--	5
Potthastia	--	--	--	--	--	--	1
Prostoia besametsa	--	--	--	--	--	--	68
Protanyderus	(1) 0.17	(1) 0.18	--	--	(1) 0.18	--	5
Pseudochironomus	--	--	--	--	--	--	12
Pseudorthocladius	--	--	--	--	--	--	7
Psychodidae	--	--	--	--	--	--	2
Pteronarcella	(1) 0.17	(1) 0.18	--	--	--	--	2
Pteronarcella badia	--	--	--	--	--	--	2
Pteronarcys	--	(2) 0.36	--	--	--	--	2
Pteronarcys californica	--	--	--	--	--	--	10
Rhabdomastix	--	--	--	--	--	--	1
Rheocricotopus	(1) 0.17	--	--	(1) 0.33	--	--	3
Rheotanytarsus	--	--	--	(8) 2.61	(6) 1.07	--	25
Rheotanytarsus (P)	--	(4) 0.71	--	(1) 0.33	--	--	6
Rhithrogena	--	(11) 1.96	(223) 41.22	(17) 5.56	(38) 6.77	(194) 32.61	1,070
Rhyacophila	--	(2) 0.36	--	--	--	(3) 0.5	20
Rhyacophila Angelita Gr.	(2) 0.33	(8) 1.42	--	--	--	--	11
Rhyacophila arnaudi	--	--	--	(1) 0.33	--	--	1
Rhynchelmis (U)	(7) 1.16	--	(1) 0.18	--	--	--	8
Robackia	--	--	--	(2) 0.65	(2) 0.36	--	4
Serratella	--	--	--	--	--	--	46
Serratella tibialis	(20) 3.31	(5) 0.89	(2) 0.37	--	--	--	27
Simuliidae	--	--	--	--	--	(1) 0.17	726
Simulium	(9) 1.49	(6) 1.07	--	--	--	--	16
Stempellina	--	--	--	(1) 0.33	--	--	3
Stempellinella	(26) 4.3	(8) 1.42	(8) 1.48	(1) 0.33	--	--	44
Stempellinella (P)	(2) 0.33	--	(1) 0.18	--	--	--	3
Stictochironomus	--	--	--	(2) 0.65	--	--	2
Sublettea	--	--	--	--	--	--	2
Sublettea (P)	--	(3) 0.53	--	--	--	--	3
Suwallia	(3) 0.5	(6) 1.07	--	(6) 1.96	--	--	41
Sweltsa	(34) 5.62	(40) 7.12	(26) 4.81	(24) 7.84	(63) 11.23	(57) 9.58	407
Taenionema	--	--	--	--	--	--	65
Taeniopterygidae	--	--	--	--	(5) 0.89	(1) 0.17	18
Tanypodinae	--	--	--	--	--	--	10
Tanytarsus	--	(2) 0.36	--	(3) 0.98	--	--	191
Tanytarsus (P)	--	(1) 0.18	--	--	--	--	1
Thienemanniella	--	--	--	(1) 0.33	--	--	13
Thienemannimyia Gr.	(1) 0.17	(2) 0.36	(1) 0.18	(1) 0.33	--	--	12
Timpanoga hecuba	--	--	--	(1) 0.33	--	--	2
Tipulidae	--	--	--	--	(1) 0.18	--	3
Trichoptera	--	--	--	--	--	(2) 0.34	2
Tubificidae (U)	--	--	--	(1) 0.33	--	--	1
Turbellaria (I)	--	--	--	--	--	--	1
Turbellaria (U)	--	--	--	(1) 0.33	--	--	2
Tvetenia	(4) 0.66	(9) 1.6	(3) 0.55	(10) 3.27	(1) 0.18	--	69
Tvetenia (P)	--	--	(1) 0.18	(1) 0.33	--	--	5
Visoka cataractae	--	(1) 0.18	--	--	--	--	1
Wiedemannia	(1) 0.17	--	--	--	--	--	1
Zaitzevia (A)	--	(3) 0.53	--	--	--	--	3
Zaitzevia	--	(2) 0.36	--	--	(2) 0.36	--	11
Zapada	--	--	--	--	--	(14) 2.35	24
Zapada columbiana	--	(2) 0.36	--	--	(1) 0.18	--	3
Count total	605	562	541	306	561	595	9,342

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