USGS
science for a changing world

Prepared in cooperation with the
Kootenai Tribe of Idaho

Sediment Characteristics and Transport in the Kootenai River White Sturgeon Critical Habitat near Bonners Ferry, Idaho

Scientific Investigations Report 2009–5228

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

Cover: Kootenai River below Moyie River at river kilometer 257.41 looking upstream towards the left bank. (Photograph taken by Robert J. Kasun, Wildland Hydrology, May 2008)

Sediment Characteristics and Transport in the Kootenai River White Sturgeon Critical Habitat near Bonners Ferry, Idaho

By Ryan L. Fosness and Marshall L. Williams

Prepared in cooperation with the Kootenai Tribe of Idaho

Scientific Investigations Report 2009–5228

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Fosness, R.L., and Williams, M.L., 2009, Sediment characteristics and transport in the Kootenai River white sturgeon critical habitat near Bonners Ferry, Idaho: U.S. Geological Survey Scientific-Investigations Report 2009-5228, 40 p.

Contents

Figures

Tables

Conversion Factors, Datums, and Abbreviations and Acronyms

Conversion Factors

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
cubic hectometer (hm^3)	810.7	acre-foot (acre-ft)
	Flow rate	
cubic meter per second (m^3/s)	70.07	acre-foot per day (acre-ft/d)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton per day	1.102	ton per day (ton/d)

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

Datums

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

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

Conversion Factors, Datums, and Abbreviations and Acronyms—Continued

Abbreviations and Acronyms

ADCP	acoustic Doppler current profiler
CVO	Cascade Volcano Observatory
D_{16}	Geometric mean particle-size diameter of the cumulative percent finer than 16th percentile
D_{50}	Geometric mean particle-size diameter of the cumulative percent finer than 50th percentile
D_{84}	Geometric mean particle-size diameter of the cumulative percent finer than 84th percentile
EWI	equal width increment
GPS	global positioning system
NWIS	National Water Information System
RKM	river kilometer
RTK	real-time kinematic
PSD	particle-size distribution
SEWI	single equal width increment
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Sediment Characteristics and Transport in the Kootenai River White Sturgeon Critical Habitat near Bonners Ferry, Idaho

By Ryan L. Fosness and Marshall L. Williams

Abstract

Recovery efforts for the endangered Kootenai River population of white sturgeon require an understanding of the characteristics and transport of suspended and bedload sediment in the critical habitat reach of the river. In 2007 and 2008, the U.S. Geological Survey in cooperation with the Kootenai Tribe of Idaho, conducted suspended- and bedload-sediment sampling in the federally designated critical habitat of the endangered Kootenai River white sturgeon population. Three sediment-sampling sites were selected that represent the hydraulic differences in the critical habitat. Suspended- and bedload-sediment samples along with acoustic Doppler current profiles were collected at these sites during specific river discharges. Samples were analyzed to determine suspended- and bedload-sediment characteristics and transport rates. Sediment transport data were analyzed to provide total loading estimates for suspended and bedload sediment in the critical habitat reach.

Total suspended-sediment discharge primarily occurred as fine material that moved through the system in suspension. Total suspended-sediment discharge ranged from about 300 metric tons per day to more than 23,000 metric tons per day. Total suspended sediment remained nearly equal throughout the critical habitat, with the exception of a few cases where mass wasting of the banks may have caused sporadic spikes in total suspended sediment.

Bedload-sediment discharge averaged 0–3 percent of the total loading. These bedload discharges ranged from 0 to 271 tons per day. The bedload discharge in the upper part of the critical habitat primarily consisted of fine to coarse gravel. A decrease in river competence in addition to an armored channel may be the cause of this limited bedload discharge. The bedload discharge in the middle part of the white sturgeon critical habitat varied greatly, depending on the extent of the backwater from Kootenay Lake. A large quantity of fine-to-coarse gravel is present in the braided reach, but the duration of transport for these gravels is limited by the encroaching backwater of Kootenay Lake. Bedload discharge in the lower part of the white sturgeon critical habitat primarily consisted of fine to coarse sand due to decreased velocities as a result of the backwater from Kootenay Lake.

Introduction

Anthropogenic influence to the Kootenai River (or Kootenay for the Canadian areas) is evident upstream of, in, and downstream of the federally designated critical habitat reach of the Kootenai River population of white sturgeon (*Acipenser transmontanus*). The Kootenai River white sturgeon critical habitat is a 29.5 km reach extending from RKM 257.0, downstream of the Moyie River, downstream to RKM 228.0 in the meander reach downstream of Shorty's Island. This critical habitat was recently extended 11.4 km upstream to include the braided reach from RKM 246.0 to 257.0 (Federal Register, 2008).

Historical references indicate that dikes were built on natural levees early in the 20th century to protect agriculture from flooding on the Kootenai River floodplain (Turney-High, 1969; Boundary County Historical Society, 1987; Redwing Naturalists, 1996). Changes to the natural river environment have led to detrimental conditions in the critical habitat reach. Additionally, the construction and operation of Libby Dam, put into service in 1972, significantly altered the Kootenai River streamflow and water quality, and created a habitat unsuitable to sustain natural recruitment of the Kootenai River white sturgeon (U.S. Fish and Wildlife Service, 2006). Research by the Idaho Department of Fish and Game on sturgeon populations determined that there was a lack of juvenile sturgeon in all but four year classes during a 16-year period (Partridge, 1983).

In 1994, the U.S. Fish and Wildlife Service (USFWS) listed the Kootenai River population of white sturgeon as an endangered species under the provisions of the Endangered Species Act of 1973, as amended. The population was listed as endangered because of declining numbers and a lack of juvenile recruitment that was first noted in the mid-1960s (Federal Register, 1994; U.S. Fish and Wildlife Service, 1999). Many researchers attributed these declining numbers and lack of recruitment to the degradation of white sturgeon habitat, particularly the habitat used for spawning (Paragamian and others, 2001, 2002; Kock and others, 2006).

In 2006, the USFWS published a biological opinion that proposed habitat improvements designed to meet the criteria outlined in the recovery plan (U.S. Fish and Wildlife Service, 2006). One proposed improvement was, "a flow regime that limits sediment deposition and maintains appropriate rocky substrate for sturgeon egg adhesion, incubation, escape cover, and free embryo development…" (Federal Register, 2008, p. 39513 and 39522). The study of sediment transport in the federally designated critical habitat of the Kootenai River white sturgeon is crucial to meeting this objective.

Efforts to mitigate and alter the effect of the anthropogenic activity in the white sturgeon critical habitat are being investigated by Federal, State, and Tribal scientists, as well as private organizations and International agencies. Between December 2007 and June 2008, the U.S. Geological Survey (USGS) conducted suspended- and bedload-sediment sampling on the Kootenai River. *Suspended sediment* refers to the sediment that remains in suspension as it moves downstream. The suspended material generally is uniformly distributed through the water column, and it moves downstream at a rate relative to the water velocity (Edwards and Glysson, 1999). "*Bedload sediment* is the sediment that is moved by saltation, rolling, or sliding on or near the streambed, essentially in continuous contact with it" (Osterkamp, 2008).

Three sampling sites were selected to represent the different hydrologic conditions in the white sturgeon critical habitat. Samples were collected during specific flow conditions. The suspended- and bedload-sediment samples were then analyzed and total sediment loading estimates were prepared.

Purpose and Scope

This report presents and discusses the sediment-transport characteristics of the white sturgeon critical habitat in the Kootenai River near Bonners Ferry, Idaho, to support the development of sediment transport models and the assessment of feasibility of habitat assessment. (U.S. Fish and Wildlife Service, 2006).

The scope of this report is limited to sediment transport in the USFWS-designated critical habitat of the Kootenai River population of white sturgeon outlined in the Federal Register (2008).

River kilometer designators in this report are based on those presented in the Federal Register final ruling of 2008 (Federal Register, 2008). Berenbrock (2006, p. 4) outlines how these designators were developed and how they differ from other published values from other agencies.

Description of Study Area

The Kootenai River is the second largest drainage in terms of discharge volume in the Columbia River basin. From its headwaters in the Rocky, Salish, and Purcell Mountain ranges, the Kootenai River flows to the south through northwestern Montana. Continuing southwest until reaching the base of the Cabinet Mountains, the river then flows north through the Kootenai Valley of northern Idaho. From there, the river reaches its terminus at Kootenay Lake in British Columbia, Canada, at the base of the Selkirk Mountain range (fig. 1). In 1972, Libby Dam was constructed on the upper Kootenai River near Libby, Montana, creating Lake Koocanusa, a 145-km long reservoir with a full-pool storage capacity of 7,262.37 hm^3 (U.S. Fish and Wildlife Service, 2006).

The major tributary systems feeding the Kootenai River downstream of Libby Dam are the Fisher and Yaak Rivers in Montana, and the Moyie River in Idaho. The Fisher River has a drainage area of about 2,160 km^2 at its confluence with the Kootenai River at RKM 351.2. Based on 40 years of USGS streamflow data for the Fisher River near Libby Montana (12302055), an estimated bankfull discharge (66.7 percent exceedance probability) is about 62 m^3/s (2,187 ft^3/s) (appendix A). The Yaak River has a drainage area of about 1,984 km^2 at its confluence with the Kootenai River at RKM 285.9. Based on 54 years of USGS streamflow data for the Yaak River near Libby Montana (12302055), a discharge estimate for bankfull conditions (66.7 percent exceedance probability) is about 153 m^3/s (5,391 ft^3/s) (appendix A). The Moyie River is controlled by Moyie Dam 2.59 km upstream of the confluence from the Kootenai River. A frequency analysis was not applied to this drainage, because it is a regulated system with an unnatural runoff pattern.

The study reach of the Kootenai River includes three major geomorphic reaches: the canyon, braided, and meander reaches (fig. 2). The canyon reach begins near Kootenai Falls (RKM 312.0) (fig. 1) and continues downstream to near the confluence of the Moyie River (RKM 257.0). The braided reach extends from the end of the canyon reach downstream to Bonners Ferry (RKM 246.0). The meander reach extends from the braided reach downstream to the confluence with Kootenay Lake in British Columbia (RKM 120.0) (fig. 1). The most upstream part of the meander reach includes a 1.5 km reach referred to as the "transition zone" that joins the braided and meander reaches between RKMs 245.9 and 244.5 (Federal Register, 2008). The transition zone refers to the location of the transition between backwater from Kootenay Lake and free-flowing river. This transition often occurs between RKMs 244.6 and 252.7 with an average location at RKM 247.8 (Berenbrock, 2005).

Previous Investigations

An extensive sediment data record for the Kootenai River in the State of Idaho is available, and a complete listing of these data can be accessed through the USGS National Water Information System (NWIS) web site at http://nwis.waterdata.usgs.gov/id/nwis/qwdata. A list of sampling sites on the Kootenai River for which sediment data are available is shown in table 1.

The sediment data can be used to provide insight into the geomorphic and hydrologic changes to the Kootenai River before and after the construction of Libby Dam (Barton, 2004; Berenbrock, 2005).

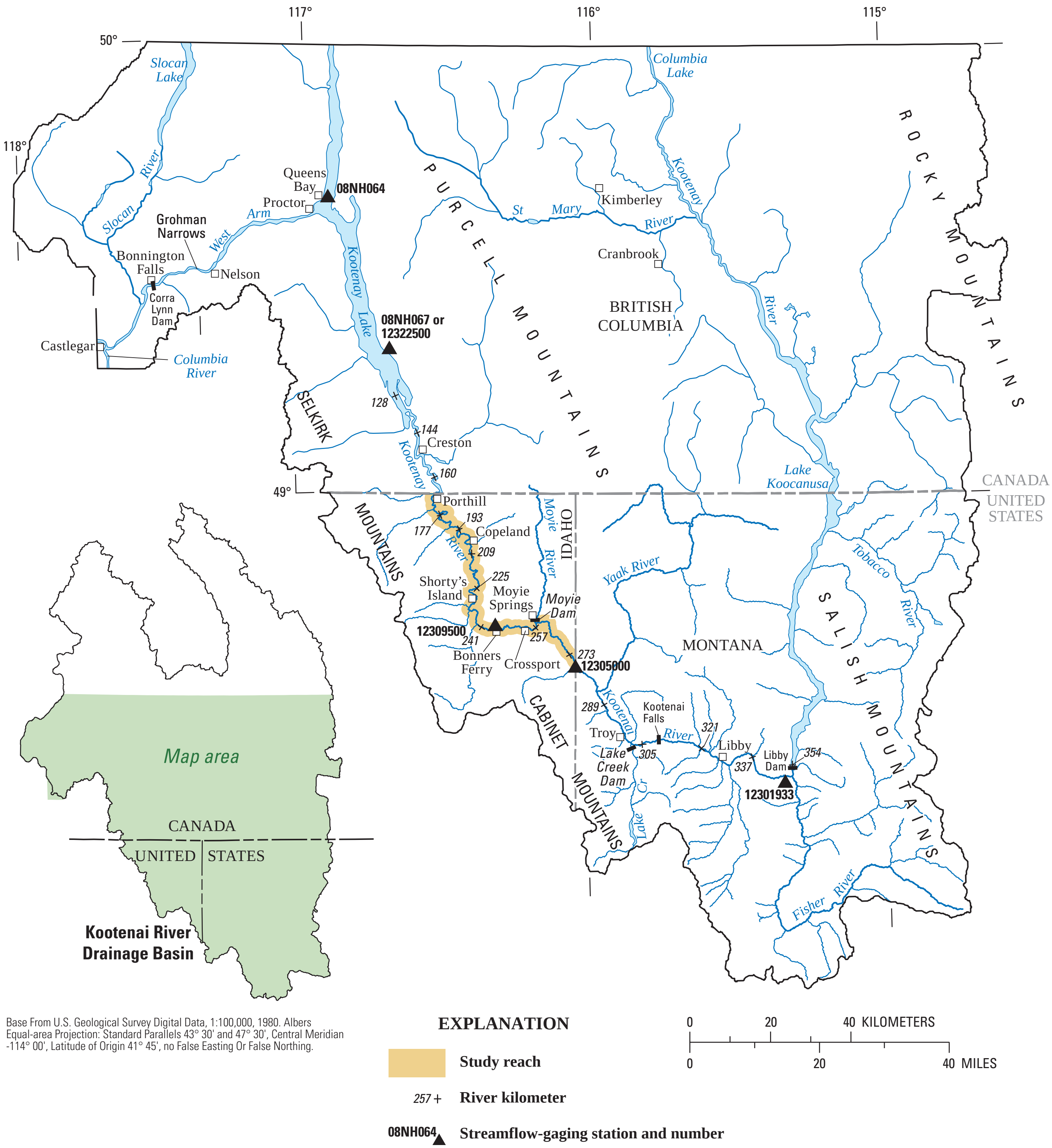


Figure 1. Location of study area in the Kootenai River drainage basin, northern Idaho.

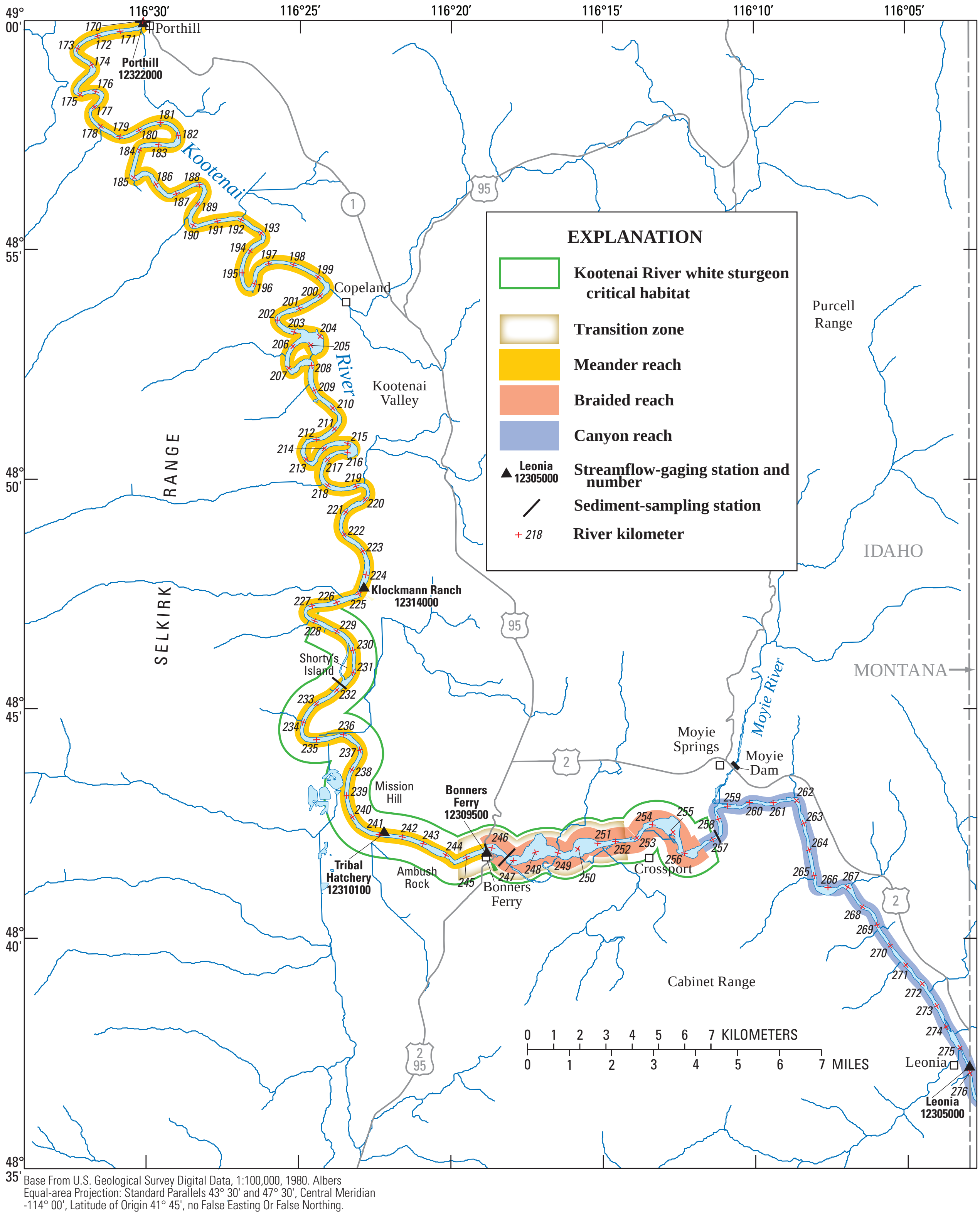


Figure 2. Location of the Kootenai River white sturgeon critical habitat in the study reach, near Bonners Ferry, Idaho.

Table 1. Sediment sampling sites on the Kootenai River near Bonners Ferry, Idaho.

[All sites are U.S. Geological Survey gaging stations]

Site No.	Station name	Period of record		Number of samples
		Begin date	End date	
12309490	Kootenai River below Fry Creek near Bonners Ferry	04-16-2002	06-13-2008	45
12309500	Kootenai River at Bonners Ferry	06-07-1996	06-06-2006	125
12310100	Kootenai River at Tribal hatchery near Bonners Ferry	04-05-2005	06-19-2007	30
12313600	Kootenai River below Ball Creek near Bonners Ferry	04-17-2002	09-04-2002	9
12318500	Kootenai River near Copeland	05-30-1967	08-31-1993	271
12322000	Kootenai River at Porthill	01-11-1949	09-24-2008	260
4841461161932	Kootenai River below Highway 95 at Bonners Ferry	03-25-2007	06-19-2007	18
4842061161430	Kootenai River at Crossport	06-02-2006	06-19-2007	28
4842231161104	Kootenai River below Moyie River near Moyie Springs	06-06-2006	06-12-2008	37
4842541161056	Kootenai River above Moyie River near Moyie Springs	03-26-2007	05-23-2007	3
4845421162319	Kootenai River above Shorty's Island near Bonners Ferry	12-14-2007	06-12-2008	8

Methods

Selection of Sediment Sampling Sites

Three sampling sites, two in the braided reach and one in the meander reach, were selected to represent the white sturgeon critical habitat (fig. 2). Bedload-sediment and suspended-sediment samples were collected during each sampling period.

The two sampling sites farthest upstream were sampled in previous years, and the sampling site farthest downstream was established in 2008 (fig. 2). Each site is representative of the three distinct geomorphic and hydrologic features throughout the critical habitat. The sediment-sampling sites were not co-located with real-time USGS gaging stations, so following methods described in Mueller and Wagner (2009), an acoustic Doppler current profiler (ADCP) was used to obtain accurate hydrologic data at the sampling sites.

Kootenai River below Moyie River

The Kootenai River below Moyie River sampling site (4842231161104) is near the upstream end of the Kootenai River white sturgeon critical habitat at RKM 257.1, 1.0 km downstream of the confluence of the Moyie River and 11.3 km upstream of the city of Bonners Ferry (fig. 2). The sampling site is near the bottom of the canyon reach. Substrate across the sampling cross section ranged from coarse gravel to fine cobble. Particle-size diameter at this site ranged from 20.8 to 78.2 mm (D_{16} and D_{84}), with a median particle-size (D_{50}) of 39.9 mm (appendix B, fig. B1). Velocities from ADCP measurements during sediment sampling ranged from 1.1 to 1.9 m/s. Widths at the sampling site ranged from 138.0 to 142.0 m; average depths ranged from 3.8 to 5.0 m. Discharge at this location is completely free flowing and is not affected by Kootenay Lake backwater, even when lake levels are high.

Kootenai River below Fry Creek

The Kootenai River below Fry Creek sampling site (12309490) is 1.0 km upstream of Bonners Ferry at RKM 246.7 (fig. 2). This sampling site is near the transition zone of the braided reach to the meander reach. Particle-size diameter at this site ranged from 12.8 to 55.6 mm (D_{16} and D_{84}) with a median particle-size (D_{50}) of 29.8 mm (appendix B, fig. B2). Velocities from ADCP measurements during sediment sampling ranged from 1.0 to 1.1 m/s. Widths at the sampling site ranged from 200.0 to 209.0 m; average depths ranged from 3.0 to 5.6 m.

The backwater effect from Kootenay Lake plays an important role in sediment transport at the Fry Creek sampling site. Early in the year when Kootenay Lake levels are low, this section of the reach is less affected by backwater. As Kootenay Lake stage increases, the backwater extends upstream of the sampling site, resulting in decreased velocity and increased stage, causing decreased sediment transport capacity of the river. Berenbrock (2005) provided a three-parameter relation that can be used to locate the transition between backwater and free-flowing river.

Kootenai River above Shorty's Island

The Kootenai River above Shorty's Island sampling site (4845421162319) is 14.8 river kilometers downstream of the U.S. Highway 95 bridge in Bonners Ferry at RKM 231.7 (fig. 2). The site is approximately 3.5 river kilometers upstream of the downstream boundary of the white sturgeon critical habitat. The substrate at the sampling cross section consists of "fine to coarse-grained alluvial sand" corresponding to particle-size diameters of 0.2 to 1.4 mm (Barton, 2004). Velocities from ADCP measurements during sampling times ranged from 0.6 to 0.8 m/s. Widths and depths at the sampling site ranged from 228.0 to 237.0 m and 6.5 to 7.0 m, respectively. This area is affected year-round by the backwater of Kootenay Lake.

Sampling Frequency

The rate of discharge in the Kootenai River is regulated primarily by operations at Libby Dam. Sediment samples were collected during the three primary peaks during water year 2008 (fig. 3). Two of these three sampling periods coincided with regulated discharge from Libby Dam—the winter ramping and the sturgeon pulse—that conform to levels prescribed in the 2006 biological opinion (U.S. Fish and Wildlife Service, 2006). The third sampling period occurred during the spring freshet, a combination of snowmelt runoff from local tributaries downstream of Libby Dam and controlled discharge from the dam.

Winter Ramping

To meet power demands, discharge from Libby Dam is increased and decreased by about 142 m^3/s on a daily or weekly basis. This fluctuation of discharge is known as winter power ramping, load shaping, or winter ramping (U.S. Fish and Wildlife Service, 2006). River discharge during winter ramping fluctuates from about 283.0 to 708.0 m^3/s. Sediment samples were collected during the winter ramping in December 2007.

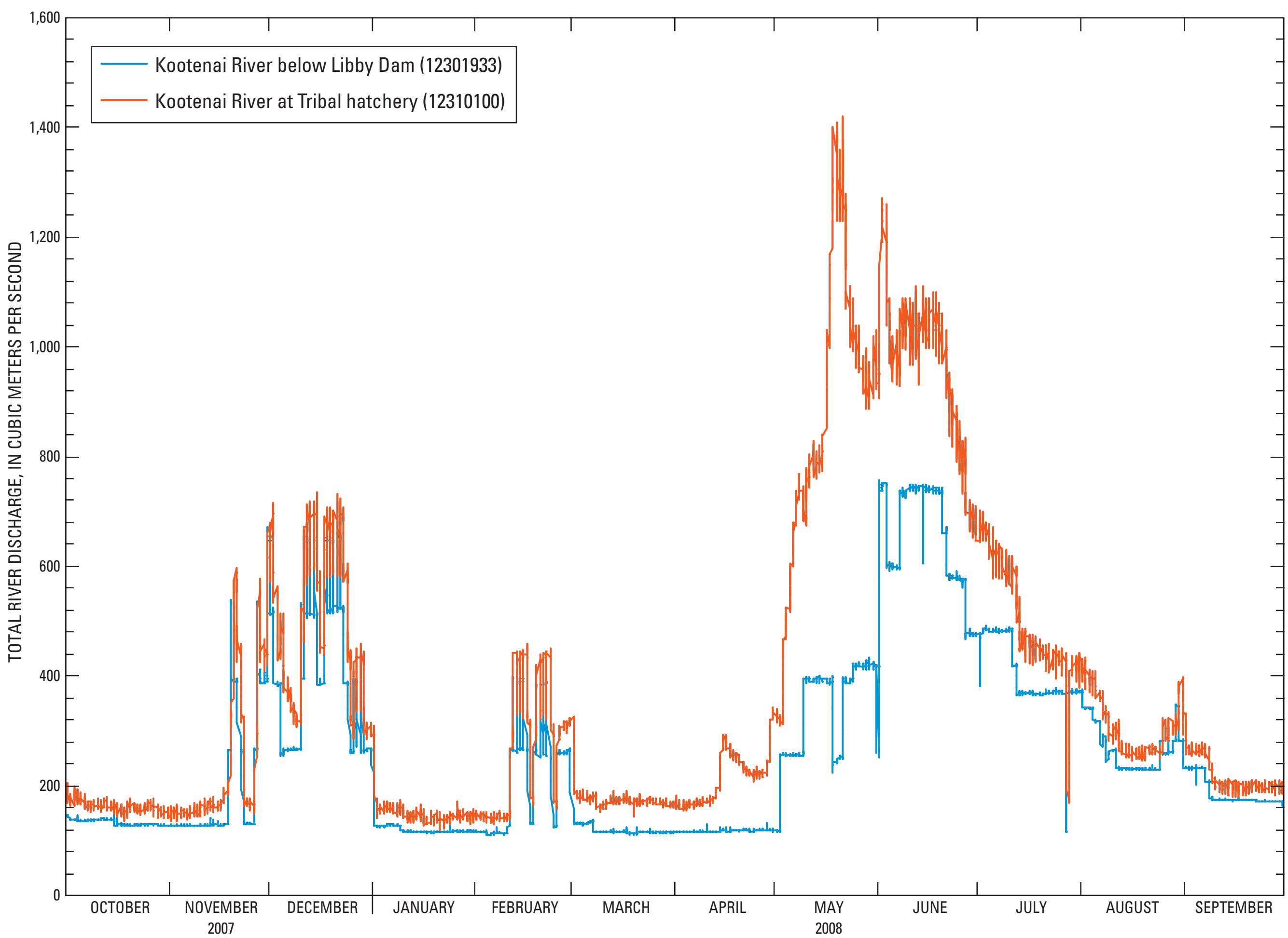


Figure 3. Discharge at Kootenai River at Libby Dam and Kootenai River at Tribal hatchery near Bonners Ferry, Idaho, water year 2008.

Spring Freshet

Spring freshet flows in the Kootenai River downstream of Libby Dam are dominated by snowmelt runoff in the Cabinet and Purcell Mountains of northern Idaho and northwestern Montana. Snowmelt runoff is limited to the drainages that have their confluence downstream of Libby Dam. The Fisher, Yaak, and Moyie River drainages are the major contributors to the freshet.

In 2008, the spring freshet flows were during the weeks of May 8–30. Two USGS gaging stations (12301933 and 12301000) were used to approximate runoff contribution between Libby Dam and the white sturgeon critical habitat. The peak flow of the freshet was on May 19. The flow at the Tribal hatchery gaging station was about 1,460 m^3/s, and sustained flows from Libby Dam were about 396 m^3/s. The difference in flow from these two locations at the peak was 1,064 m^3/s. The combined flow from the Fisher and Yaak Rivers was about 379 m^3/s.

Sturgeon Pulse

The spring sturgeon spawning season flow augmentation pulse, or sturgeon pulse, is carried out to simulate the spring river flows that occurred before the construction of Libby Dam. These flow conditions are determined by the guidelines set forth in the biological opinion to create flow conditions in the river during a period favorable to sturgeon spawning in the spring (U.S. Fish and Wildlife Service, 2006). The sturgeon pulse for water year 2008 occurred on June 2, followed the spring freshet, and nearly equaled the spring freshet in total discharge. During the sturgeon pulse, 57 percent of the flow was from Libby Dam in contrast to a 27 percent contribution during the spring freshet. The peak flow was about 1,310 m^3/s at the Tribal hatchery gaging station and flow out of Libby Dam was about 745 m^3/s. The difference in flow from these two locations at the peak was about 565 m^3/s. Flow contributions from the Fisher and Yaak Rivers during the peak of the sturgeon pulse were about 150 m^3/s.

Sampling Methods

A jet boat equipped with a hydraulic boom was used for all sediment sampling. Both suspended- and bedload-sediment sampling followed the *equal width increment* (EWI) and *single equal width increment* (SEWI) methods described by Edwards and Glysson (1999). The SEWI sampling method was modified as the widths of the first and last sampled zones were not equal to the width of the other sampled zones. This modification was necessary to establish 20 equally spaced sampling stations. Sampling stations were created using digital imaging software that included the left and right bankfull locations and 20 equally spaced vertical sampling stations. Using this technique, each vertical was sampled in the same spatial location per sampling sequence. Figure 4 shows an example diagram of this sampling method. Fugawi™ navigation software with positioning from a mapping grade TrimbleAg232™ global positioning system (GPS) was displayed on a laptop computer to locate each equally spaced vertical sampling station spatially.

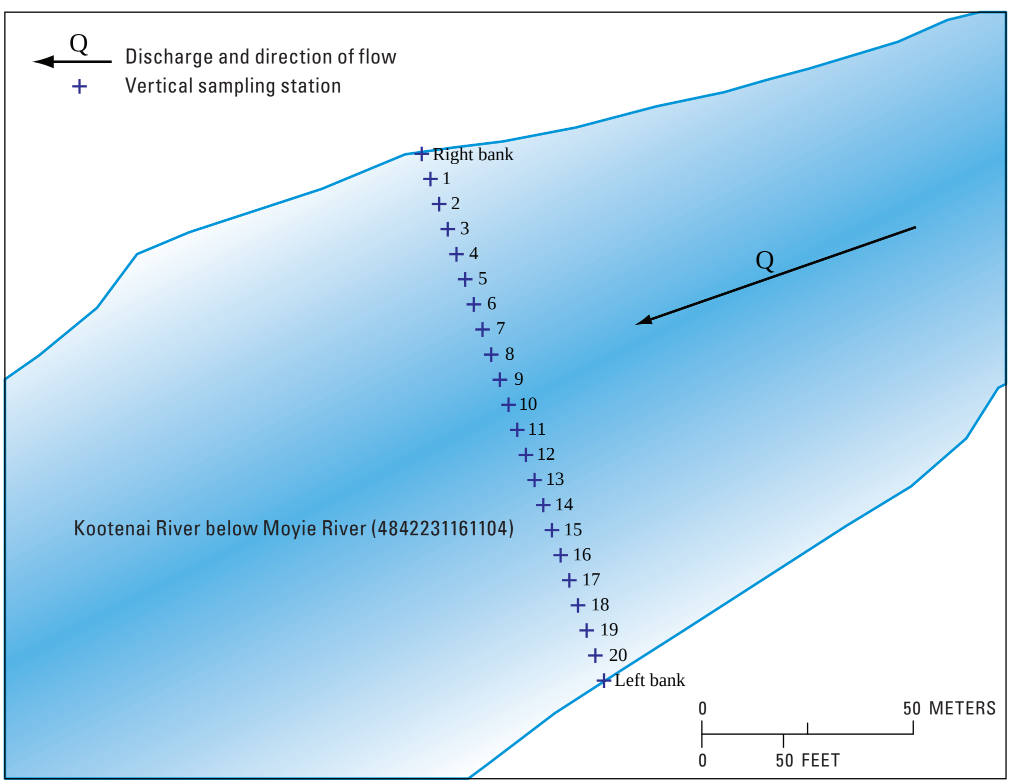


Figure 4. Example of stationing for sediment sample collection, Kootenai River below Moyie River, near Bonners Ferry, Idaho.

Suspended Sediment

Suspended sediment was collected using a D-96 depth-integrated sampler (Davis, 2001) using the EWI method. Sampling methods at each site followed USGS-approved methods described by Edwards and Glysson (1999). The D-96 samples the water column from the free-flowing surface to approximately 102.0 mm above the riverbed. Vertical samples were composited from each pass across the reach.

Bedload Sediment

Bedload sediment was collected using 102 × 203 mm Elwha (Holnbeck, 2005) and 77 × 77 mm Helley-Smith (Emmett, 1980) style samplers. The Elwha, also known as the US-ER1, is a smaller version of the US-TR2, or Toutle River Sampler (Childers, 1999). This sampler was suitable for the Kootenai River because the entrance size was twice as large as the average surface bed sediment. Three Elwha samplers were used to collect bed samples. The samplers were identical size and proportion, but the weights varied (about 27, 36, and 59 kg). The mesh diameter of the sampling bag for the Elwha samplers was 0.50 mm. A Helley-Smith sampler was used for a short time during the sampling. The mesh diameter of the sampling bag for the Helley-Smith sampler was 0.25 mm. Samples were collected at each bedload sampling site using two traverses (A and B sets) of the channel with 20 equally spaced verticals for each traverse as prescribed by USGS sampling standards (Edwards and Glysson, 1999). Each vertical sample was collected for data analysis if a quantifiable amount of material was captured. Some samples were composited after five verticals due to lack of appreciable material available for each vertical.

In February 2008, Wolman pebble counts were completed near the sampling sites in the braided reach. A gravelometer was used following procedures outlined in Wolman and Leopold (1954) to measure coarse riverbed particle-size diameter. Samples were collected from exposed substrate and in shallow water depths across the entire cross section.

River Discharge, Stage, and Slope

An ADCP discharge measurement was made at each sampling site after the suspended and bedload sampling per USGS standards (Mueller and Wagner, 2009). A Trimble™ real-time kinematic (RTK) GPS was used for positioning of the ADCP measurements. Stage and slope measurements were made using a combination of USGS streamflow-gaging stations, and stage recorders positioned near the sampling sites.

Data Analysis

Samples from suspended and bed collection were processed for analysis to define the quantity and particle sizes of the sediment collected.

Suspended Sediment

All suspended-sediment samples were composited and analyzed at the USGS Cascade Volcano Observatory (CVO) Sediment Laboratory. Sediment concentration and particle-size distribution were determined from the analysis. The CVO laboratory analyzed 29 suspended-sediment samples, 25 of which were analyzed for concentration, total weight, and half-phi scale particle-size distributions (PSD). The remaining four samples were analyzed for concentration only. Suspended-sediment discharge was estimated for sand (diameter greater than or equal to 0.063 mm) and silt/clay (diameter less than 0.063 mm) using the concentration and PSD along with the equation from Guy (1978):

$$Q_{SS} = Q_W \cdot C_{SS} \cdot k\,, \tag{1}$$

where

Q_{SS} is suspended-sediment loading, in metric ton per day;

Q_W is mean river discharge at time of sampling, in cubic meters per second;

C_{SS} is concentration of suspended sediment, in milligrams per liter; and

k is the constant of 0.0864 for converting cubic meters per second and milligrams per liter to metric ton per day.

Bedload Sediment

Bedload-sediment samples were analyzed at the USGS Idaho Water Science Center laboratory in Boise. Each bagged sample was weighed individually, and then composited for the entire cross-section. Sieve analysis was completed on composited samples to determine the PSD of the cross section. The bedload sediment was sieved down to the 0.5 mm sieve, corresponding to the mesh size of the bag used to capture the sediment. Eighteen sieves were used to create the PSD. Sizes of the sieves used for analysis and the classification of the sieved particles are shown in table 2.

Bedload-sediment transport rates were estimated using the midsection method (eq. 2; Edwards and Glysson, 1999) and account for a varying width for the first and last sample.

Table 2. Particle-size distribution and classification.

[Adapted from Berenbrock, 2005. Φ , phi scale where $\Phi = -\log_2$ (diameter in mm); <, less than]

Diameter of particle		Classification name	Sample type
Phi scale Φ	Sieve size (millimeter)		
-8	256		Bedload sediment
	180	Coarse cobble	Bedload sediment
-7	128		Bedload sediment
	90	Fine cobble	Bedload sediment
-6	64		Bedload sediment
	45	Very coarse gravel	Bedload sediment
-5	32		Bedload sediment
	22.6	Coarse gravel	Bedload sediment
-4	16		Bedload sediment
	11.3	Medium gravel	Bedload sediment
-3	8		Bedload sediment
	5.6	Fine gravel	Bedload sediment
-2	4		Bedload sediment
	2.7	Very fine gravel	Bedload sediment
-1	2		Bedload sediment
	1.4	Very coarse sand	Bedload sediment
0	1		Bedload sediment; Suspended sediment
	0.7	Coarse sand	Bedload sediment; Suspended sediment
1	.5		Bedload sediment; Suspended sediment
	.355	Medium sand	Suspended sediment
2	.250		Suspended sediment
	.180	Fine sand	Suspended sediment
3	.125		Suspended sediment
	.090	Very fine sand	Suspended sediment
4	.063		Suspended sediment
	<.063	Silt	Suspended sediment

$$Q_B = \frac{(R_1 \cdot W_1)}{2} + \sum_{i=2}^{n-1} R_1 \cdot \left[\frac{(S_i - S_{i-1})}{2} + \frac{(S_{i+1} - S_i)}{2} \right] + \frac{(R_n \cdot W_{n-1})}{2}, \tag{2}$$

where

Q_B is the bedload transport, metric tons per day;

R_i is the bedload transport rate, metric tons per day per meter;

where

$$R_i = \frac{K \cdot M_i}{t_i};$$

K is the conversion coefficient for the bedload sampler $K_{ELWHA} = 0.426$, and $K_{Helley-Smith} = 1.122$;

M_i is the mass of the sample, in grams, and

t_i is the time the bedload sampler was on the channel bottom, in seconds;

W_i is the width of sample area, in meters, and

S_i is the station of sample vertical, in meters.

Total Sediment Loading

Total sediment loading is the sum of all sediment moving downstream at a cross section during a given period. Then, in a deep channel like the white sturgeon critical habitat of the Kootenai River, the total sediment is the sum of total suspended-sediment discharge and total bedload-sediment discharge. Suspended sediment was sampled from the top of the water surface to within 102.0 mm of the channel bed. Bedload sediment was sampled 76.0 to 102.0 mm from the bottom of the channel bed. Two zones were not sampled: (1) the 25.0 mm separation between the Helley-Smith sampled zone and the limits of the suspended-sediment sampler and (2) the fine sediment that passed through the 0.025 and 0.050 mm mesh bedload sediment sample bags.

Sediment Characteristics, Supply, and Transport

Development of sediment-transport curves requires an understanding of the sources of sediment and the factors that control transport. Sediment transport at a particular site is a function of the width, depth, velocity, temperature, and energy gradient of the river discharge. Other contributing factors are the size, shape, density, and orientation of the bed materials (Glysson, 1987). Sediment supply in rivers downstream of reservoirs is limited to the storage capacity of sediment in the river reach, and contributions to the river system from tributaries.

Suspended-Sediment Transport

Since the construction of Libby Dam in 1972, the supply of suspended sediment downstream of Libby Dam has been limited largely by the trapping capacity of the Lake Koocanusa. Therefore, sediment discharge from the dam contains an insignificant concentration of suspended sediment. Historical data from 8 sediment samples collected prior to the construction of Libby Dam and 25 samples collected after construction of the dam are shown in figure 5. A power function through each of the two sets of data shows the relation in sediment discharge before and after the construction of Libby Dam. Maximum discharge through Libby Dam without spilling is about 736 m^3/s. From historical data, a maximum concentration of 3 mg/L provides a maximum estimated suspended-sediment discharge value of 211 metric tons per day.

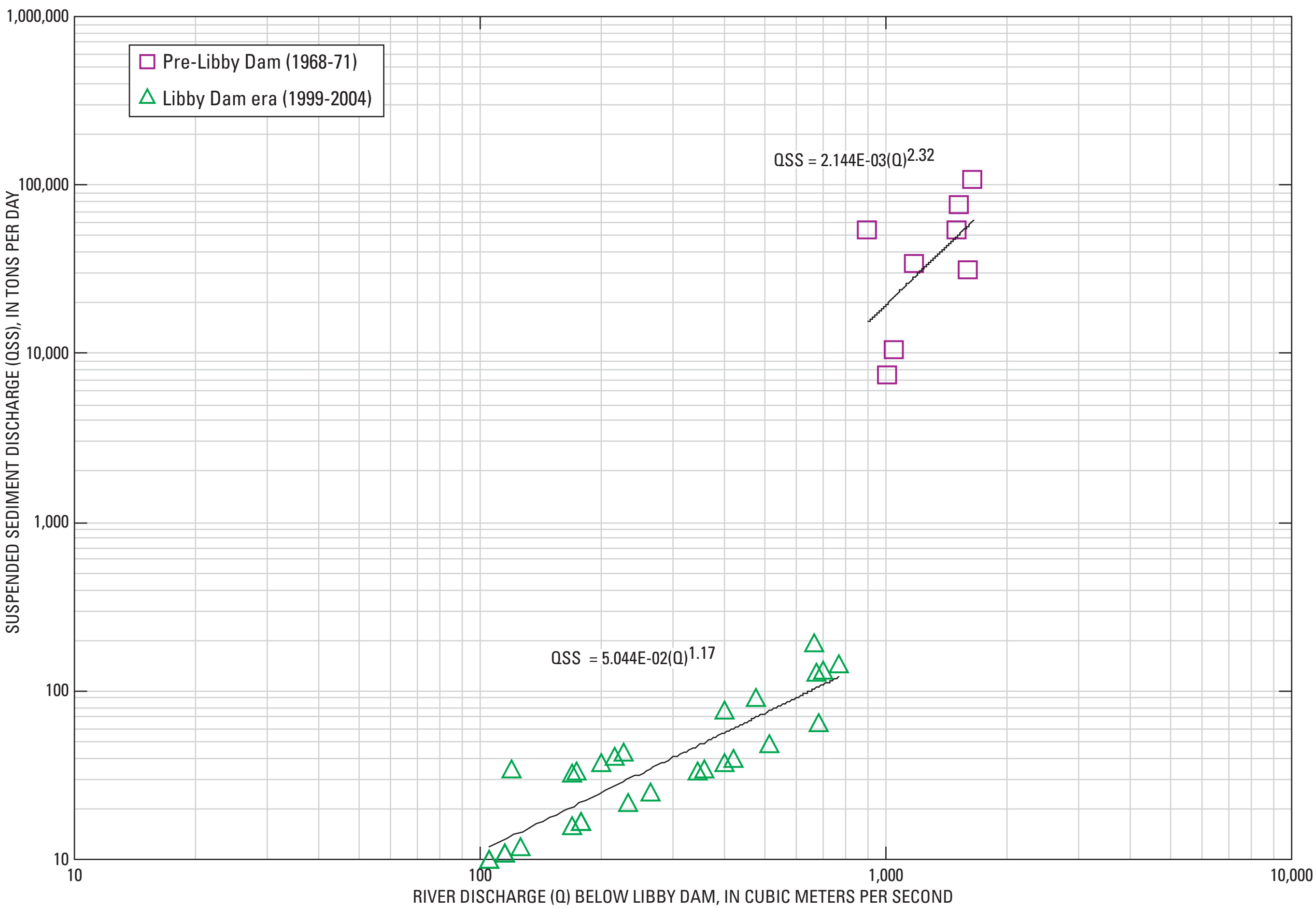


Figure 5. Historical suspended-sediment and river discharge, Kootenai River below Libby Dam, Montana, 1968–71 and 1999–2004.

Suspended-sediment concentration remains low (less than 211 metric tons per day) within the white sturgeon critical habitat until the spring freshet, when tributary flooding contributes suspended sediment to the system. To account for this effect, the fines part of the suspended-sediment transport curves was developed as a function of tributary discharge. The discharge from Kootenai River below Libby Dam (USGS 12301933) to Kootenai River at Tribal hatchery (USGS 12310100) is shown in figure 3. The tributary discharge is estimated as the difference in discharge between these two stations. To account for the lag time between Libby Dam and the Tribal hatchery, the graphs were adjusted until they aligned in a vertical sequence. A lag time of 12 hours was used to estimate a difference in discharge between the two locations. Estimated tributary discharge and suspended-sediment discharge are shown in figure 6.

Suspended sediment at the Kootenai River below the Moyie River site was split into two phases for the total suspended-sediment transport curve. The change in phase is a result of increased tributary discharge into the system resulting in an increased slope of the transport curve. Figure 7 shows the suspended-sediment concentration as a function of tributary discharge at each sampling station.

Each sampling site follows this pattern of increased suspended-sediment concentration with increasing tributary discharge. Table 3 shows a detailed listing of the river and sediment discharge values for each sampling site. The station farthest downstream, Kootenai River above Shorty's Island, however, showed some anomalous increases in concentration. These sudden increases may be attributed to the lateral mass wasting of the man-made dikes that occurs when high flows saturate the dikes in the braided and meander reaches, as was observed during the periods of sediment sampling. A complete listing of the particle-size distribution at each sampling site is shown in appendix C (table C1).

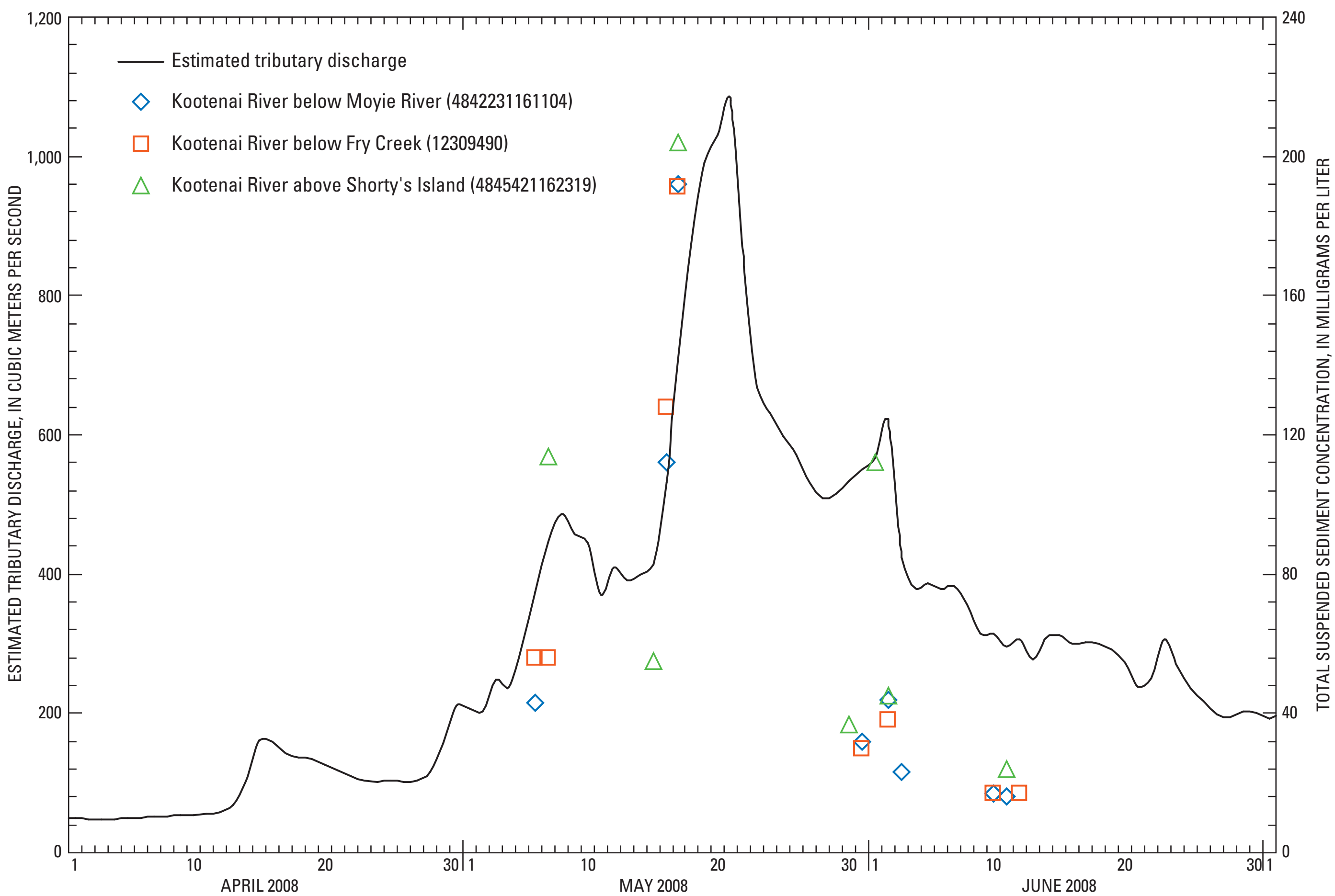


Figure 6. Estimated tributary discharge and total suspended-sediment concentration in the study reach, Kootenai River near Bonners Ferry, Idaho, April–June 2008.

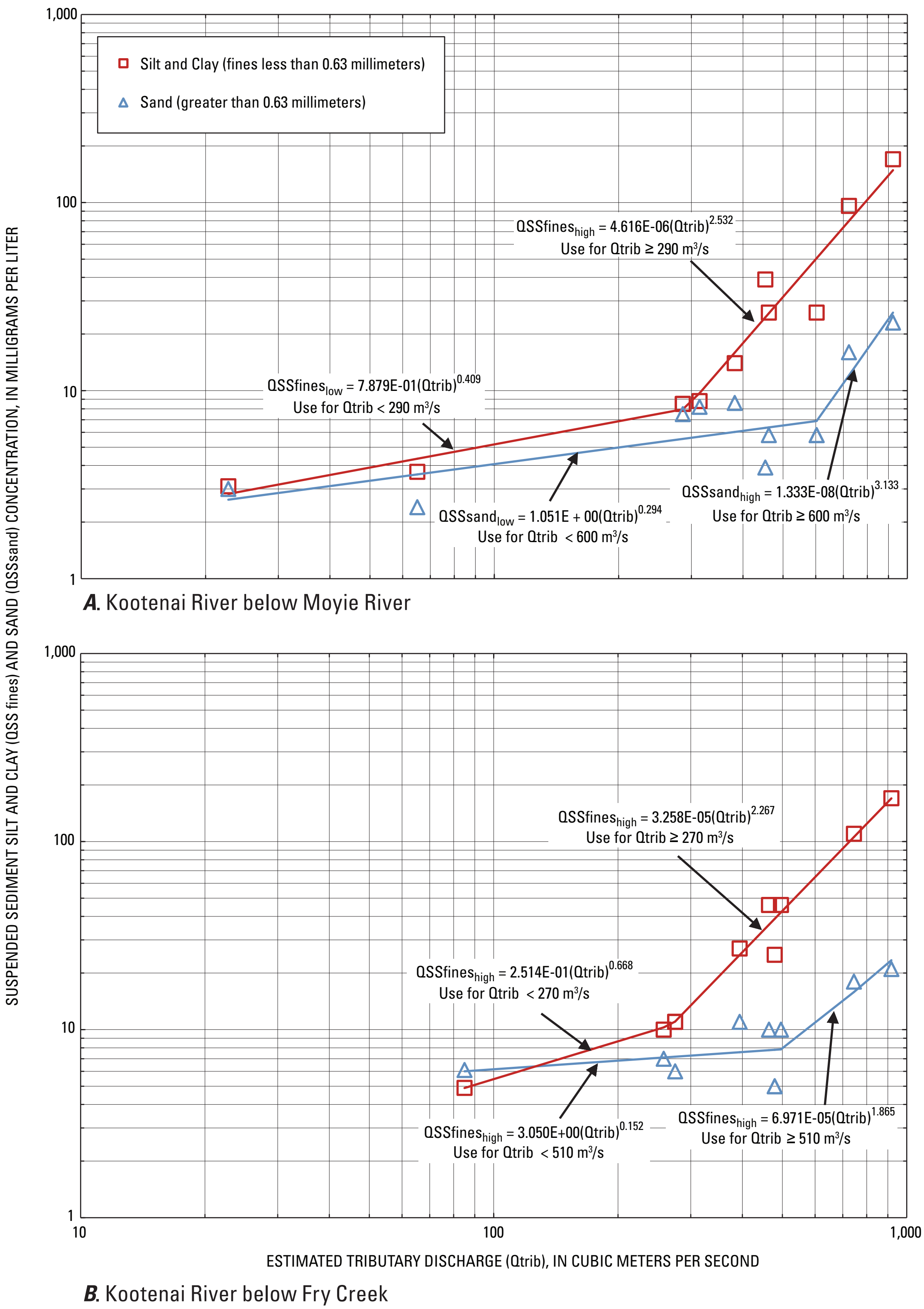
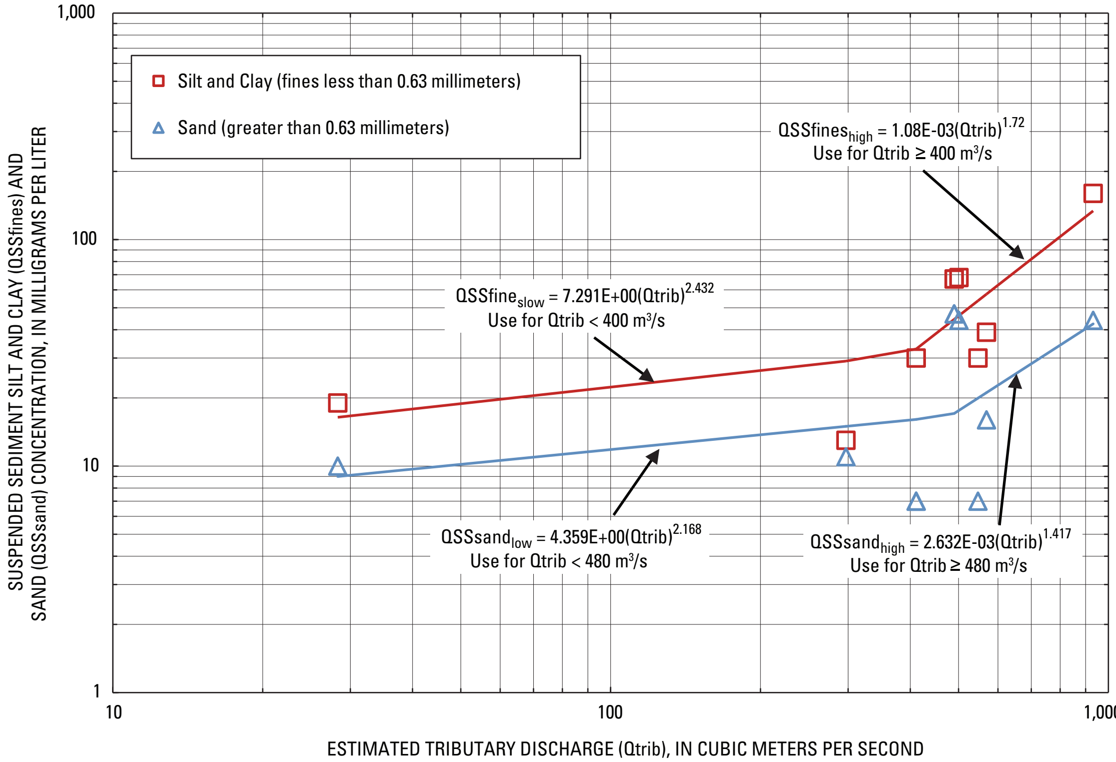


Figure 7. Estimated tributary discharge and sediment transport curves for suspended sediment silt and clay and sand concentration, (*A*) Kootenai River below Moyie River, (*B*) Kootenai River below Fry Creek, and (*C*) Kootenai River above Shorty's Island, near Bonners Ferry, Idaho.



C. Kootenai River above Shorty's Island

Figure 7.—Continued.

Table 3. River discharge, suspended-sediment concentrations, and sediment discharge at sampling sites, Kootenai River, Idaho, water year 2008.

[**Abbreviations:** m^3/s, cubic meter per second; m/s, meter per second; mm, millimeter; mg/L, milligram per liter; <, less than; $\geq$, greater than or equal to; –, no data]

Date	Time	Discharge (m^3/s)	Discharge downstream of Libby Dam (m^3/s)	Estimated tributary discharge (m^3/s)	Mean velocity (m/s)	Fines concentration (<0.063 mm, mg/L)	Sand concentration (≥0.063 mm, mg/L)	Total concentration (mg/L)	Fines load (<0.063 mm, metric tons per day)	Sand load (≥0.063 mm, metric tons per day)	Total load (metric tons per day)
Kootenai River below Moyie River—4842231161104											
12-12-07[1]	15:25	569	504	65	–	3.7	2.3	6	184	112	296
12-13-07[1]	12:15	589	566	23	1.10	3.1	2.9	6	162	151	313
05-07-08	14:11	705	252	453	1.23	39	4.0	43	2,390	263	2,650
05-17-08	08:30	1,110	391	722	–	96	16.0	112	9,250	1,540	10,800
05-18-08	08:21	1,310	391	923	1.88	170	22.0	192	19,200	2,630	21,800
06-01-08	11:00	1,020	413	603	1.62	26	6.0	32	2,300	508	2,810
06-03-08	10:00	1,210	748	462	1.78	26	18.0	44	2,710	1,910	4,620
06-04-08	10:12	988	606	382	1.58	14	9.0	23	1,230	744	1,970
06-11-08	11:48	1,050	739	314	1.62	8.8	8.2	17	804	740	1,540
06-12-08	16:13	1,030	745	286	1.62	8.5	7.5	16	756	678	1,430
Kootenai River below Fry Creek—12309490											
12-13-07[1]	14:15	592	507	85	0.99	4.9	6.1	11	249	315	564
05-07-08	15:40	719	255	464	–	46	10.0	56	2,820	671	3,490
05-08-08	14:29	748	253	496	1.21	46	10.0	56	2,950	671	3,620
05-17-08	15:37	1,140	394	745	–	110	18.0	128	11,000	1,630	12,600
05-18-08	13:32	1,310	388	918	1.12	170	21.0	191	19,400	2,180	21,600
06-01-08	14:50	895	416	479	.94	25	5.0	30	1,960	363	2,320
06-03-08	12:36	1,130	739	394	1.02	27	11.0	38	2,590	1,120	3,710
06-11-08	16:21	1,000	745	258	1.04	10	7.0	17	907	562	1,470
06-13-08	08:41	1,020	742	275	1.05	11	6.0	17	943	553	1,500
Kootenai River above Shorty's Island—4845421162319											
12-14-07[1]	10:45	671	643	28	0.00	19	10.0	29	1,090	592	1,680
05-08-08	08:41	745	254	490	.72	67	47.0	114	4,320	3,030	7,350
05-16-08	16:48	963	394	569	.76	39	16.0	55	3,170	1,420	4,590
05-18-08	15:11	1,320	388	932	.80	160	44.0	204	18,300	5,030	23,300
05-31-08	17:01	963	416	547	.65	30	7.0	37	2,500	583	3,080
06-02-08	11:44	1,240	742	501	.76	68	44.0	112	7,330	4,740	12,100
06-03-08	17:10	1,160	753	411	.71	30	15.0	45	3,020	1,510	4,530
06-12-08	10:47	1,040	745	297	.68	13	11.0	24	1,170	989	2,160

[1]Particle-size distribution not available.

Bedload-Sediment Transport

Sieve analysis of the bedload material produced informative trends on the size distribution of the material and the difference in transport characteristics at each sampling location (appendix D, table D1). The results were characterized in terms of total river discharge (independent variable) and sediment discharge (dependent variable) by size class (table 4). Three average particle-size classes were used to describe the bedload-sediment transport loading:

- Class 1 – Diameter less than 0.5 mm (silt to medium sand)
- Class 2 – Diameter greater than or equal to 0.5 mm and less than 2 mm (coarse sand to very coarse sand)
- Class 3 – Diameter greater than or equal to 2 mm (very fine gravel to coarse cobble).

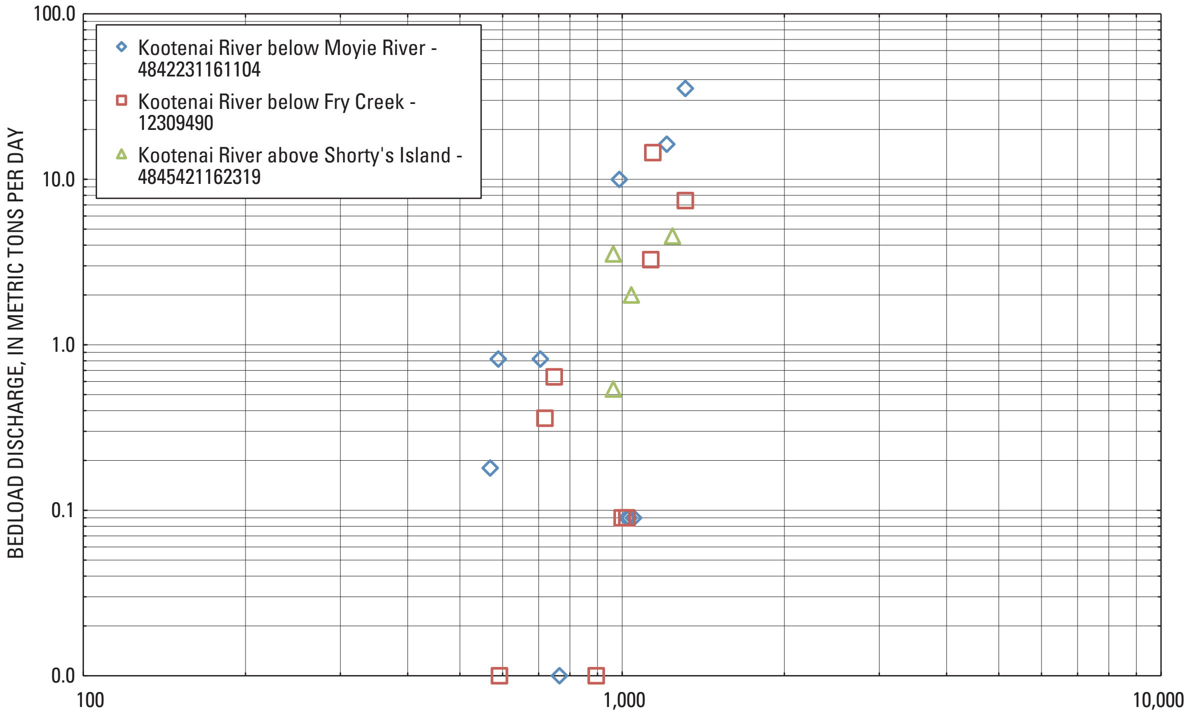
Class 1 bedload sediment represents that amount of collected sediment that typically is considered to be in suspension at velocities greater than 0.61 m/s. This sediment also is smaller than the mesh diameter of the bag used to capture the sediment. The PSD revealed that, in some instances, most bedload sediment was contained within class 1. This discrepancy could be caused by a large amount of suspended sediment and (or) debris plugging the mesh material so that it acts as a trap for fine-grained material that typically would pass through the mesh. This problem was especially pronounced with data from the Helley-Smith sampler because the mesh size was even smaller at 0.25 mm. Emmett (1980) suggested not using a Helley-Smith bedload sediment sampler for estimating transport rates for sediment of particle-sizes that are considered part of the suspended-sediment load. Emmett (1980) also suggested that a particle-size less than 0.25 mm should not be sampled using a Helley-Smith sampler, the mesh size of the bag used in this study. For this study, Class 1 bedload was not considered part of the total bedload, although results are provided in figure 8*A*.

Class 2 sediment consists of sand in the bedload sediment that is larger than the mesh diameter of the sediment bag. The largest discharge of Class 2 sediment downstream of the Moyie River occurred during the two periods of greatest river discharge, with the greatest single discharge occurring during the spring freshet measured at 71.7 metric tons per day. The peak Class 2 discharge occurred before the peak flow. Another peak in Class 2 sediment was transported during the sturgeon pulse, but the sampled sediment discharge was 34 percent less at only an 8 percent decrease in total river discharge.

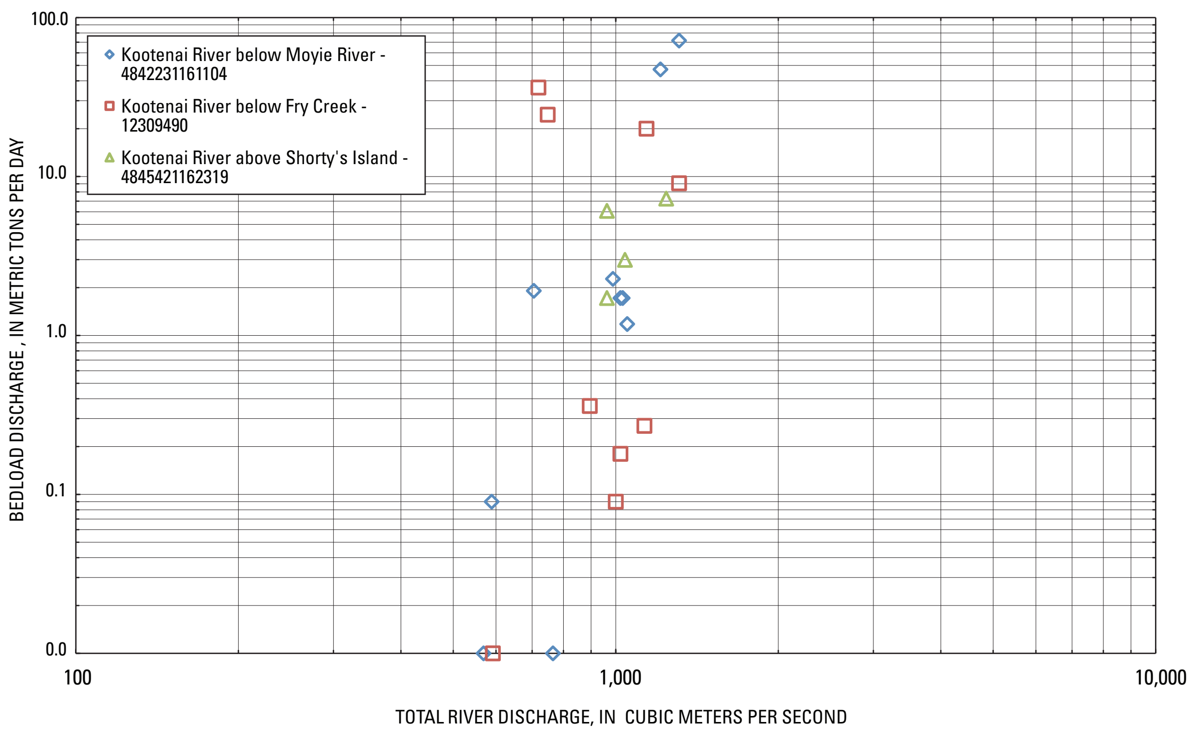
Class 2 sediment transport downstream of Fry Creek is dependent on the backwater effects of Kootenay Lake. The greatest quantity of Class 2 sediment was transported when the sampled river discharge was lowest, but during the highest mean water velocity (fig. 8*B*). This highest sampled sediment discharge was 36.3 metric tons per day on May 7, 2008. The combination of the increased backwater effects and the limited supply of sand to the system probably was the reason for the decrease in Class 2 sediment transport downstream of Fry Creek. The mean velocity was inversely proportionate to the area, depth, and slope indicating an increased influence of backwater on the sampling site (table 4). The total river discharge at this sampling site, therefore, should not be used as the independent variable for estimating sand transport.

The sampling site upstream of Shorty's Island is a sand-dominated system that is in a backwater-affected area of the reservoir throughout the year. The particle-size distribution of the material was nearly identical for each of the sampling periods. The highest measured sediment discharge was 6.08 metric tons per day. Class 2 sediment discharge increased slightly with increasing water velocity, but due to limited samples, this cannot be confirmed. Samples collected with the Helley-Smith sampler were eliminated from the results because this sampler should not be used in areas dominated by a sandy substrate (Emmett, 1980).

Class 3 sediment consists of bedload material greater than or equal to 2.0 mm in diameter. The greatest bedload sediment transport downstream of the Moyie River occurred during the two highest peaks in total river discharge. A threshold of about 1,130.0 m^3/s was determined to be the total river discharge required to begin a significantly larger amount of bedload sediment transport (fig. 8*C*). Pebble count data (appendix B, fig. B1) indicate that coarse gravels (D_{50} = 39.9 mm and D_{16} = 20.8 mm) are the dominant substrate; however, the average particle-size of the sampled material was only 6.5 mm during the greatest total river discharge. This indicates that the local surface material was not mobilized under the sampled flows. The smaller gravels that were collected during sampling indicate a moving bed that is limited in supply. The Helley-Smith sampler was used during two peak flows with the highest sampled Class 3 sediment discharge. The Helley-Smith sampler was considered appropriate for this sampling site because its opening is twice as large as the average particle-size in the channel. On June 1, 2008, the Elwha sampler was used to collect samples at 1,020 m^3/s with an estimated Class 3 sediment discharge of 5.0 metric tons per day. During June 2 and 4, 2008, the Helley-Smith sampler was used to collect samples at river discharges of 1,210 and 988 m^3/s, respectively, with Class 3 sediment discharge of 107.0 and 1.7 metric tons per day, respectively. This vast difference in Class 3 sediment transport likely was caused by a decrease in total river discharge with respect to water velocity, rather than a difference in the type or size of the bedload sampler.

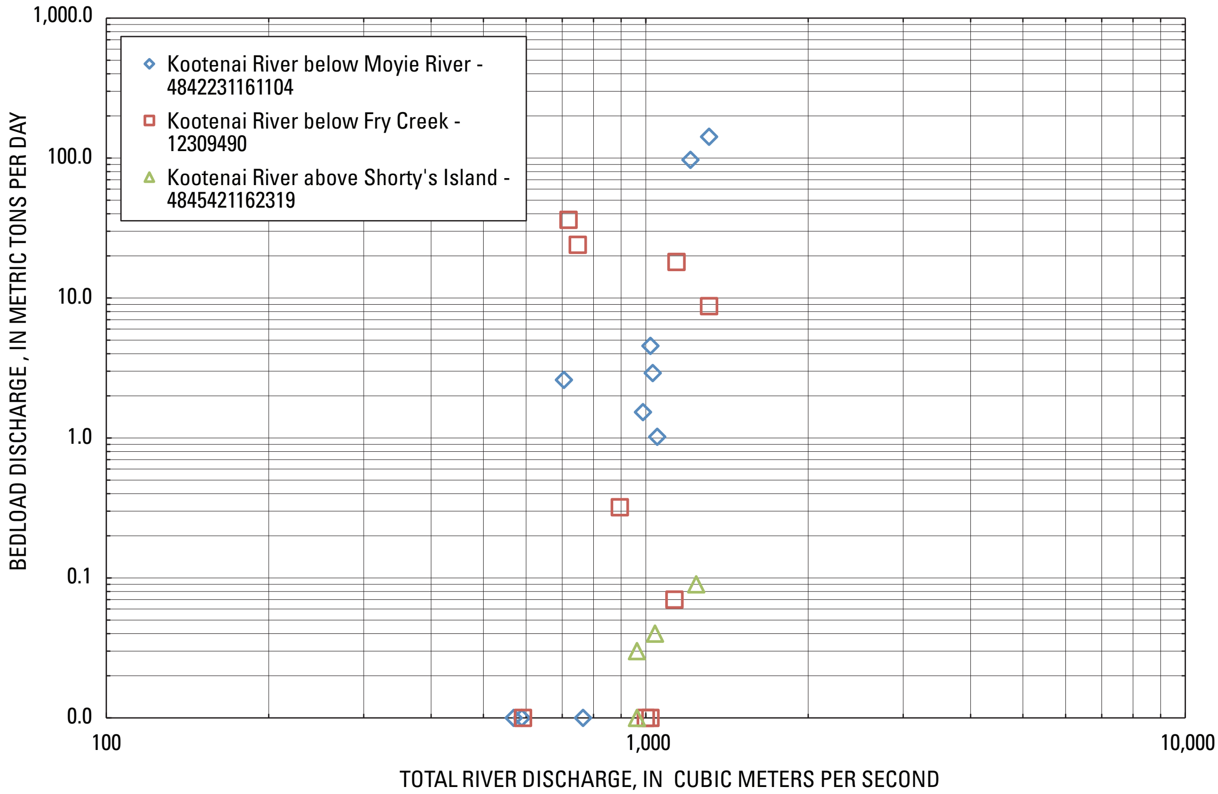


***A*. Class 1**



***B*. Class 2**

Figure 8. Bedload discharge for (*A*) class 1 (diameter less than 0.5 mm)(silt to medium sand), (*B*) class 2 (diameter greater than or equal to 0.5 millimeters and less than 2 millimeters) (coarse sand to very coarse sand), and (*C*) class 3 (diameter greater than or equal to 2 millimeters (very fine gravel to coarse cobble)) compared with total discharge, for the Kootenai River below Moyie, below Fry Creek, and above Shorty's Island, near Bonners Ferry, Idaho.



***C.* Class 3**

Figure 8.—Continued.

Table 4. River discharge and bedload-sediment discharge, Kootenai River near Bonners Ferry, Idaho, water year 2008.

[**Sampler:** HS = 77×77 mm Helley-Smith with 3.22 exit ratio and 0.25 mm mesh bag; EL = 102×203 mm Elwha with 1.4 exit ratio and 0.50 mm mesh bag. **Mean total load** does not include particles less than 0.5 mm due to the partial recovery of that sediment. **Abbreviations**: mm, millimeter; m^3/s, cubic meter per second; m/s, meter per second; m^2, square meter; m/m, meter per meter; <, less than; >, greater than; ≥, greater than or equal to; D, diameter; –, no data]

Date	Time	Discharge (m^3/s)	Mean velocity (m/s)	Area (m^2)	Top width (m)	Mean depth (m)	Water surface slope (m/m)	Sampler	Average particle size, in millimeters, at which the 35, 50, 65, and 90 percent by weight is finer				Fines to medium sand (<0.5 mm, metric tons per day)	Sand load (2 mm ≥ D >0.5 mm, metric tons per day)	Gravel load (≥2 mm, metric tons per day)	Mean total load (metric tons per day)
									D_{35}	D_{50}	D_{65}	D_{90}				
Kootenai River below Moyie River—4842231161104																
12-12-07	14:00	569	–	–	–	–	–	HS	<0.5	<0.5	<0.5	0.6	0.18	0.00	0.01	0.01
12-13-07	12:30	589	1.10	536	140	3.84	–	HS	<.5	<.5	<.5	.5	.82	.09	.01	.10
05-07-08[1]	11:36	705	1.20	575	140	4.11	–	EL	.5	.6	.7	1	.82	1.91	2.60	4.51
05-08-08[1]	16:56	765	1.20	575	140	4.11	0.000534	EL	0	0	0	0	.01	.01	.01	.02
05-18-08	08:46	1,310	1.88	695	140	4.97	.000552	HS	.6	6.5	13	25	35.40	71.70	142.00	214.00
06-01-08	09:40	1,020	1.62	626	139	4.51	.000530	EL	9	10	14	20	.09	1.72	4.55	6.27
06-02-08	15:03	1,210	1.78	679	142	4.79	.000537	HS	2.3	4.5	10	30	16.30	47.20	97.10	144.00
06-04-08	09:15	988	1.58	627	139	4.51	.000534	HS	<.5	<.5	<.5	2.3	9.98	2.27	1.53	3.80
06-11-08	10:27	1,050	1.62	649	140	4.66	.000537	EL	.8	1.3	8.2	20	.09	1.18	1.02	2.20
06-12-08	15:02	1,030	1.62	637	138	4.60	.000537	EL	5.1	13	19	40	.09	1.72	2.91	4.63
Kootenai River below Fry Creek—12309490																
12-13-07	14:29	592	0.99	597	200	2.99	0.000307	HS	<0.5	<0.5	<0.5	0.5	0.01	0.01	0.01	0.02
05-07-08[1]	16:38	719	1.19	579	195	2.97	.000395	EL	14.0	18.0	21.0	24.0	.36	36.30	36.20	72.50
05-08-08[1]	14:29	748	1.19	579	195	2.97	.000375	EL	13.0	16.0	18.0	29.0	.64	24.50	24.00	48.50
05-17-08	13:33	1,140	–	–	–	–	.000130	HS	<.5	4.1	19.0	25.0	14.50	20.00	18.10	38.10
05-18-08	12:01	1,310	1.12	1,140	207	5.55	.000116	HS	<.5	4.7	7.8	12.0	7.44	9.07	8.75	17.80
06-01-08	13:44	895	.94	957	208	4.60	.000117	EL	5.8	6.4	7.0	8.2	.01	.36	.32	.68
06-03-08	11:38	1,130	1.02	1,110	209	5.30	.000134	HS	<.5	<.5	<.5	<.5	3.27	.27	.07	.34
06-11-08	14:55	1,000	1.04	966	207	4.66	.000137	EL	.6	.7	.8	1.5	.09	.09	.01	.10
06-13-08	08:00	1,020	1.05	966	205	4.69	.000117	EL	.5	.6	.7	1.2	.09	.18	.01	.19
Kootenai River above Shorty's Island—4845421162319																
12-14-07	09:00	671	–	–	–	–	0.0000310	HS	–	–	–	–	–	–	–	–
05-16-08[2]	15:03	963	–	–	–	–	–	EL	0.5	0.7	0.8	1.3	3.54	6.08	0.01	6.09
05-31-08	15:53	963	0.65	1,490	228	6.49	.0000260	EL	.6	.7	.8	1.3	0.54	1.72	.03	1.75
06-02-08	10:46	1,240	.76	1,640	236	6.95	.0000310	EL	.5	.6	.7	1.2	4.54	7.26	.09	7.35
06-03-08	16:00	1,160	.71	1,640	237	6.95	.0000290	HS	–	–	–	–	–	–	–	–
06-12-08	09:27	1,040	.68	1,520	234	6.49	.0000290	EL	.5	.6	.7	1.2	2.00	2.99	.04	3.03

[1] Velocity, area, width, and depth estimated from acoustic Doppler current profiler measurement on 05-09-2008.

[2] D_{35} averaged with data less than 0.5 mm.

Class 3 sediment transport at the sediment-sampling site downstream of Fry Creek was dependent on the backwater effect of Kootenay Lake. The greatest Class 3 sediment was transported with the highest mean water velocity measured, which also was the lowest measured discharge. The D_{50} of the bedload sediment during the highest mean water velocity was about 18.0 mm. Pebble count data (appendix A) support the fact that smaller gravels (D_{50} = 29.8 mm and D_{16} = 12.8 mm) are available for transport in this reach, but only while the backwater effect is minimal early in the spring. Although the total discharge increases during spring, backwater decreases the hydraulic gradient to the point at which it can only transport sediment equal to or finer than sand-sized particles. The relation between bedload discharge at the sampling site and the extent of the backwater from Kootenay Lake is shown in figure 9. This relation was developed using three-parameter function (Berenbrock, 2005) to determine the extent in RKM. Nearly all bedload discharge ceases as the extent of the backwater moves past the sampling site. Two ADCP measurements (fig. 10) were made on (1) May 7 when the extent of the backwater was near the sampling site (RKM = 246.7) at a river discharge of 700 m^3/s and (2) June 3 when the extent of the backwater was highest (near RKM = 250.7) at a river discharge of 1,100 m^3/s. Although the total river discharge increased by 64 percent, the velocity decreased by nearly 1 m/s and the stage increased by 3 m illustrating how the area becomes inundated by backwater and loses the ability to transport bed material greater than coarse sand.

Bedload sediment at the sampling site upstream of Shorty's Island primarily consists of particles less than 2 mm. Transport of Class 3 sediments in this area was assumed to be zero because 99 percent of the substrate consisted of coarse sand. The results of the class 3 bedload sediment samples are shown in figure 8C.

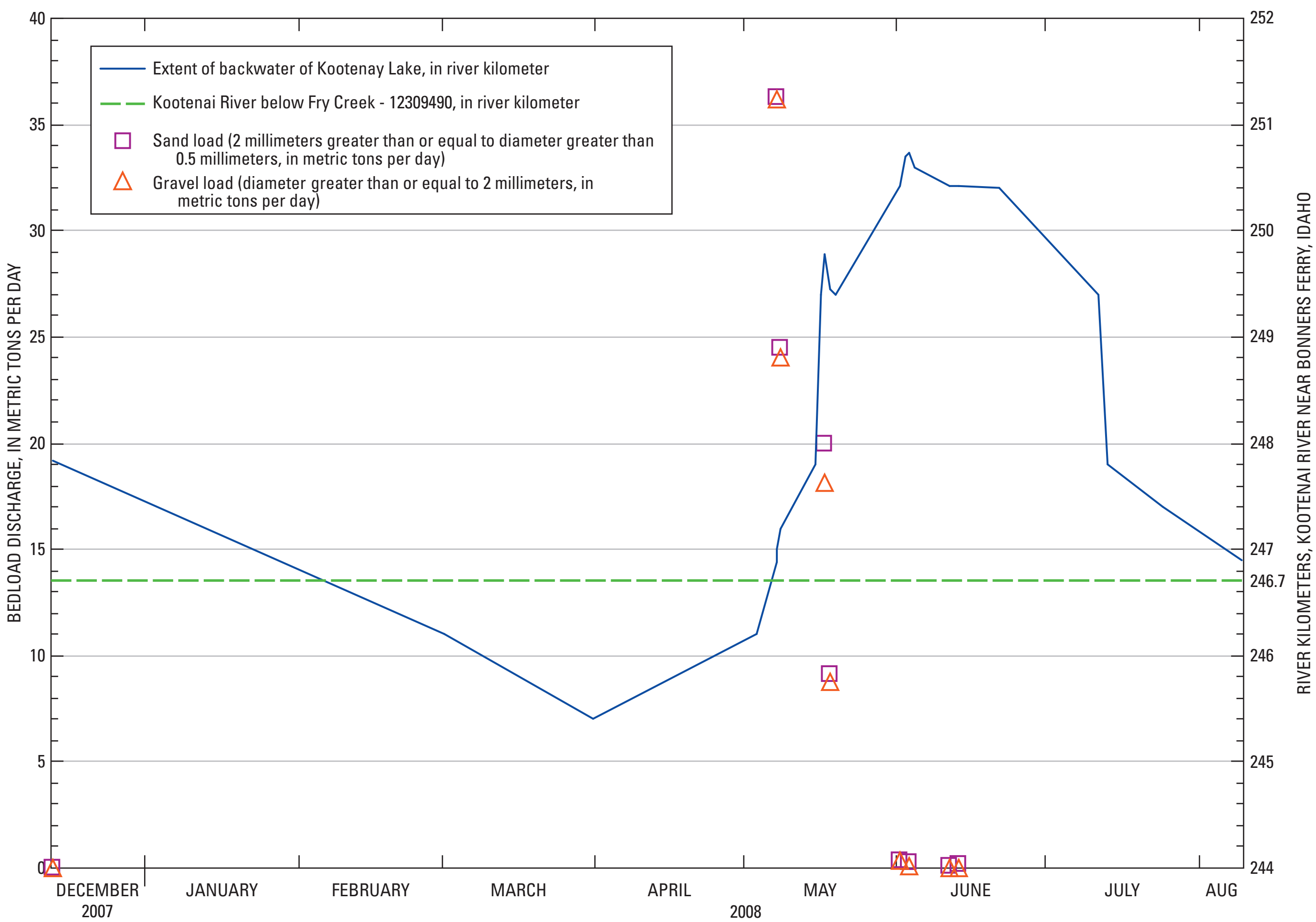


Figure 9. Bedload discharge and extent of backwater from Kootenay Lake during sediment sampling in the Kootenai River study reach near Bonners Ferry, Idaho, December 2007 to August 2008.

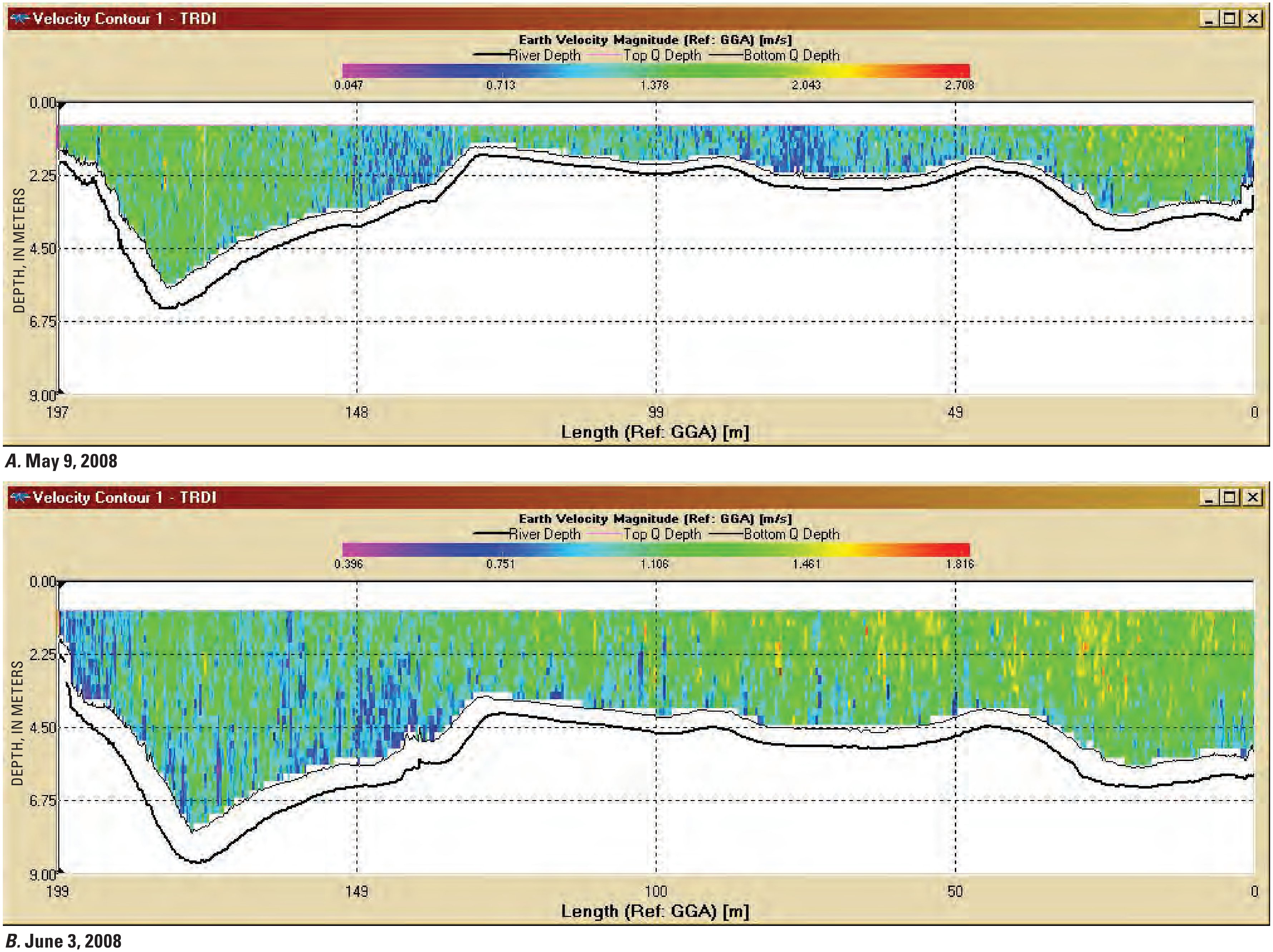


Figure 10. Acoustic Doppler current profiler measurements from (*A*) May 9 and (*B*) June 3, 2008 showing change in flow characteristics due to backwater from Kootenay Lake at Kootenai River below Fry Creek, near Bonners Ferry, Idaho.

Total Sediment Transport

During the sediment-sampling period, 52–90 percent of the total transport consisted of sediment less than 0.063 mm. This fine-grained material likely remained in suspension and passed completely through the white sturgeon critical habitat. Total transport for suspended and bedload sediment are presented in table 5. No correlation was determined after estimating total suspended sediment as a function of total river discharge (fig. 11*A*).

Total suspended-sediment discharge is greatest during peak tributary discharges (fig. 11*B*). The sands remain in suspension until they settle where water velocities decrease due to backwater. The results of this analysis show no decrease in transport from upstream to downstream, but rather a gain in suspended sand transport. Mass wasting of the banks likely contributed to the increase in suspended sands through the white sturgeon critical habitat. This wasting effect is evident as the riverbed substrate changes from coarse to fine gravel to medium sand from upstream to downstream in the white sturgeon critical habitat.

Total bedload sediment discharge (fig. 12*A*) consisted of less than 3 percent of the total sediment discharge. Particles less than 0.5 mm in diameter were excluded from the analysis because they were only partially recovered. Sand discharge varied widely at each sampling site, but they seemed to depend on the supply of sediment and the extent of backwater.

Table 5. River discharge and suspended- and bedload-sediment discharge, Kootenai River near Bonners Ferry, Idaho, water year 2008.

[**Abbreviations**: m^3/s, cubic meter per second; mm, millimeter; <, less than; >, greater than; ≥, greater than or equal to; D, diameter; –, no data]

Date completed	Discharge (m^3/s)	Discharge downstream of Libby Dam (m^3/s)	Estimated tributary discharge (m^3/s)	Suspended sediment: Fines load (<0.063 mm, metric tons per day)	Suspended sediment: Sand load (≥0.063 mm, metric tons per day)	Bedload sediment: Fines to medium sand (<0.5 mm, metric tons per day)	Bedload sediment: Sand load (2 mm>D≥ 0.5 mm, metric tons per day)	Bedload sediment: Gravel load (≥2 mm, metric tons per day)	Total loading: Fines + sand + gravel (metric tons per day)
Kootenai River below Moyie River—4842231161104									
12-12-07	569	504	65.1	184	112	0.18	0	0	296
12-13-07	589	566	22.7	162	151	.82	0.09	0	314
05-07-08	705	252	453	2,390	263	.82	1.91	2.6	2,660
05-17-08[1]	1,110	391	722	9,250	1,540	–	–	–	–
05-18-08	1,310	391	923	19,200	2,630	35.4	71.7	142	22,100
06-01-08	1,020	413	603	2,300	508	0	1.72	4.55	2,810
06-03-08[2]	1,210	748	462	2,710	1,910	16.3	47.2	97.1	4,780
06-04-08	988	606	382	1,230	744	9.98	2.27	1.53	1,990
06-11-08	1,050	739	314	804	740	.09	1.18	1.02	1,550
06-12-08	1,030	745	286	756	678	.09	1.72	2.91	1,440
Kootenai River below Fry Creek—12309490									
12-13-07	592	507	85	249	315	0	0	0	–
05-07-08	719	255	464	2,820	671	0.36	36.3	36.2	3,560
05-08-08	748	253	496	2,950	671	.64	24.5	24	3,670
05-17-08	1,140	394	745	11,000	1,630	14.5	20	18.1	12,700
05-18-08	1,310	388	918	19,400	2,180	7.44	9.07	8.75	21,600
06-01-08	895	416	479	1,960	363	–	0.36	0.32	2,320
06-03-08	1,130	739	394	2,590	1,120	3.27	.27	.07	3,710
06-11-08	1,000	745	258	907	562	.09	.09	0	1,470
06-13-08	1,020	742	275	943	553	.09	.18	0	1,500
Kootenai River above Shorty's Island—4845421162319									
12-14-07	671	643	28.3	1,090	592	31.8	8.16	0.18	1,720
05-08-08[3]	745	254	490	4,320	3,030	–	–	–	–
05-16-08	963	394	569	3,170	1,420	3.54	6.08	.01	4,600
05-18-08[3]	1,320	388	932	18,300	5,030	–	–	–	–
05-31-08	963	416	547	2,500	583	0.54	1.72	.03	3,090
06-02-08	1,240	742	501	7,330	4,740	4.54	7.26	.09	12,100
06-03-08	1,160	753	411	3,020	1,510	200	14.5	.01	4,740
06-12-08	1,040	745	297	1,170	989	2	2.99	.04	2,160

[1] No bedload sampled due to lost sampler.

[2] Bedload sampled on 06-02-2008.

[3] No bedload sampled.

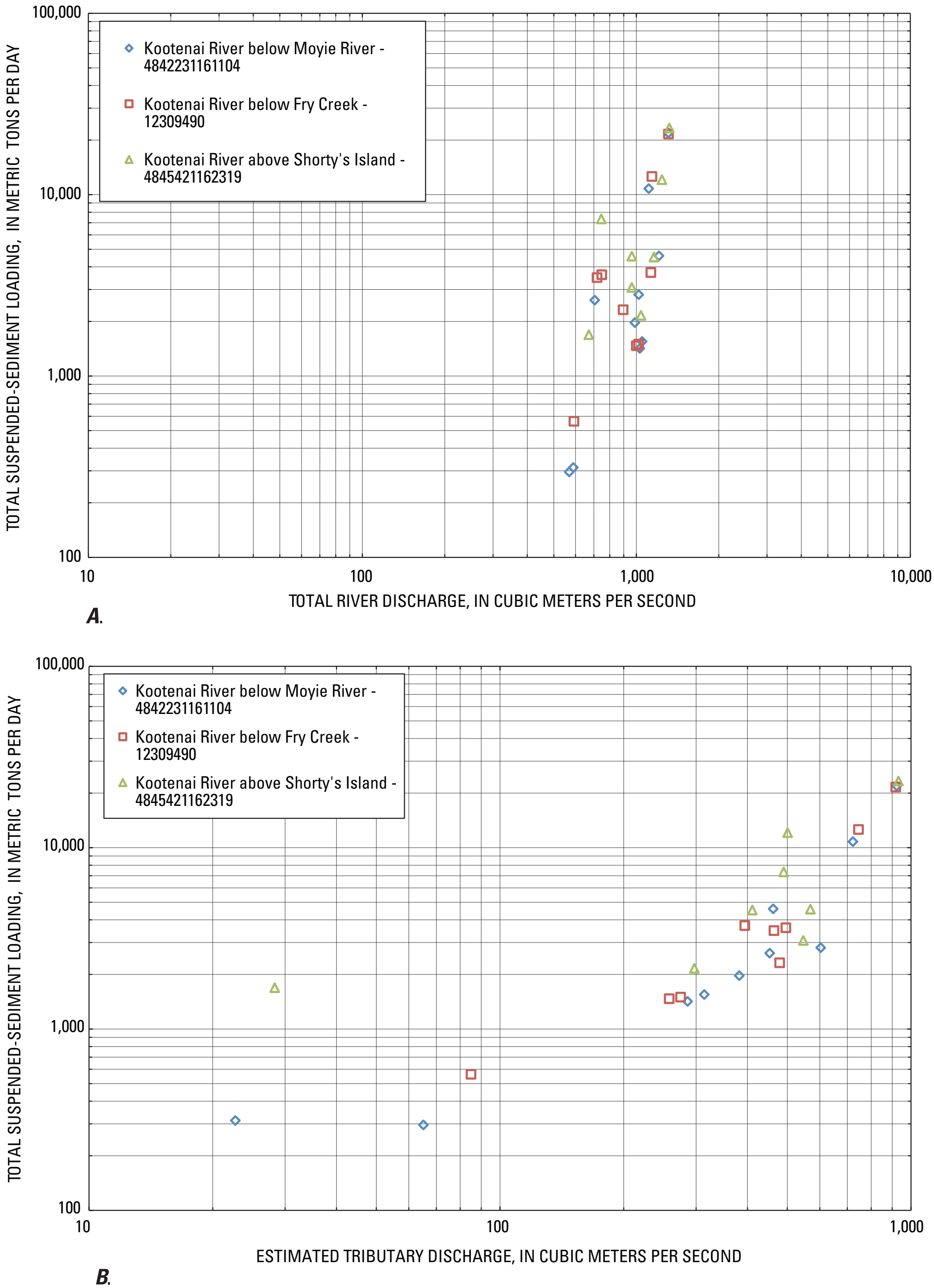


Figure 11. Total suspended-sediment discharge compared with (*A*) total river discharge and (*B*) estimated tributary discharge at Kootenai River below Moyie, below Fry Creek, and above Shorty's Island, near Bonners Ferry, Idaho.

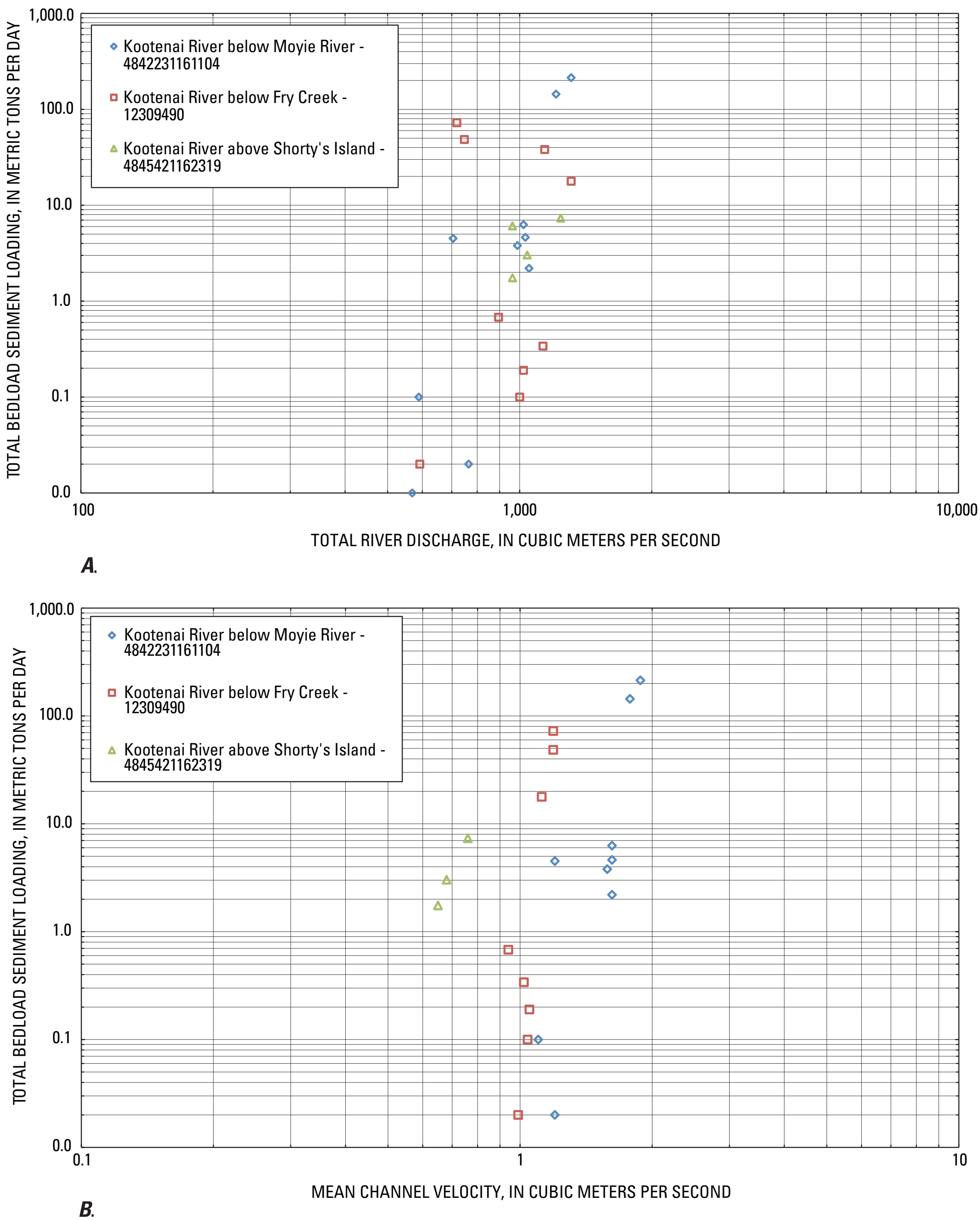


Figure 12. Total bedload sediment discharge compared with (*A*) total river discharge and (*B*) mean channel velocity for the Kootenai River below Moyie, below Fry Creek, and above Shorty's Island, near Bonners Ferry, Idaho.

The relation between total bedload and mean channel velocity is shown in figure 12*B*. The relation, especially at Kootenai River below Fry Creek, improves because the velocity is a function of the extent of backwater from Kootenay Lake.

Total gravel discharge was nearly equal to the sand discharge at the two upstream sampling sites. In the free-flowing part of the river, the amount of bedload sediment depends on total river discharge. In the backwater-affected areas, bedload sediment discharge primarily is controlled by the extent of backwater into the braided reach.

Quality Assurance

Duplicate samples were collected for three suspended-sediment samples for quality assurance purposes to determine the variability that might occur during the sampling process. The sampling method was precise to 5–7 percent. The results of the duplicates are shown in appendix E (table E1).

Sixteen bedload-sediment samples contained an A and a B set. A one-to-one line shown in figure E1 represents a comparison between each sample with an A and a B set. Data points closer to the one-to-one line are more precise than data points farther from the line.

Summary

Three sampling sites were selected at the Kootenai River near Bonners Ferry, Idaho, to represent the varied hydrologic conditions in the white sturgeon critical habitat. Twenty-nine suspended-sediment samples and 25 bedload-sediment samples were collected. Two sets of quality-assurance samples were collected for suspended sediment, and 16 samples were collected for bedload sediment.

Sediment discharge data were analyzed to understand the relations of sediment transport within the white sturgeon critical habitat. The suspended sediment primarily consists of fine material that remains in suspension through the white sturgeon critical habitat. The concentration of sand in the suspended sediment was greatest during flows that coincided with peak tributary runoff. This indicates that most of the sand supply in the system is highly dependent on tributary runoff.

Sediment-transport curves for bedload sediment were not developed because of the limited data available at each sampling site. Trends in the available data, however, reveal vast differences in transport regimes at each site. Bedload-sediment transport in the upper reach of the white sturgeon critical habitat indicates that this reach is a sediment-limited system. The coarse surface sediment probably is caused by the sediment-limited system resulting in an armored channel that prevents the mobilization of the smaller gravels beneath the surface. A great quantity of fine-to-coarse gravel is present in the lower braided reach, but the duration of transport of these gravels is limited by the backwater of Kootenay Lake. When a location is dominated by backwater, transport ceases for bedload sediment larger than sand. Bedload sediment transport in the downstream part of the white sturgeon critical habitat is affected by backwater year round, resulting in fine to coarse-grained sand-dominated system.

Total sediment discharge in the study reach is dominated by fine-grained sediment less than 0.063 millimeters. These fine-grained particles likely remain in suspension through the entire length of the white sturgeon critical habitat. Peak discharge typically occurs during the spring freshet or during the spring sturgeon spawning season flow augmentation pulse (sturgeon pulse). Peak sediment discharge occurred during the spring freshet, when fine-grained particles composed more than 75 percent of the total load. The sturgeon pulse transports fewer fines, but does transport an equal amount of sand compared to the spring freshet. Most of the remaining sediment discharge consisted primarily of fine to medium sands. Coarse sand and gravel discharge represented less than or equal to 3 percent of the total discharge through the white sturgeon critical habitat and coincided with the highest hydraulic gradient. Lack of sediment supply in the upper part of the critical habitat accounts for the lack of bedload sediment transport. In the middle part of the critical habitat near the end of the braided reach, a large quantity of bedload sediment is available for transport, but the backwater effect decreases the hydraulic gradient so much that these surface materials are not transported.

Acknowledgments

The authors express their appreciation to the Kootenai Tribe of Idaho for funding and logistical support of the sediment sampling. Robert Kasun, U.S. Forest Service, retired, generously shared his knowledge and provided field support. Finally, we thank our USGS colleagues Gary Barton, Matthew Chilson, Jeff Conaway, Daniel Hess, Stephen Lipscomb, Christopher Magirl, and Rhonda Weakland for their assistance with field work and the preparation of this report.

References Cited

Barton, G.J., 2004, Characterization of channel substrate, and changes in suspended-sediment transport and channel geometry in white sturgeon spawning habitat in the Kootenai River near Bonners Ferry, Idaho, following the closure of Libby Dam: U.S. Geological Survey Water-Resources Investigations Report 03–4324, 102 p. Available at http://id.water.usgs.gov/PDF/wri034324/.

Berenbrock, Charles, 2005, Simulation of flow and sediment transport in the white sturgeon spawning habitat of the Kootenai River near Bonners Ferry, Idaho: U.S. Geological Survey Scientific Investigations Report 2005-5173, 72 p. Available at http://pubs.usgs.gov/sir/2005/5173/pdf/sir20055173.pdf

Berenbrock, Charles, 2006, Simulations of hydraulic characteristics for an upstream extension of the white sturgeon habitat of the Kootenai River near Bonners Ferry, Idaho—A supplement to Scientific Investigations Report 2005-5110: U.S. Geological Survey Scientific Investigations Report 2006-5019, 17 p.

Boundary County Historical Society, 1987, The history of Boundary County, Idaho: Portland, Ore., Taylor Publishing Company, p. 43-46, 48.

Childers, Dallas, 1999, Field comparisons of six pressure-difference bedload samplers in high-energy flow: U.S. Geological Survey Water-Resources Investigations Report 92-4068, 59 p.

Davis, B.E., 2001, The US D-96—An isokinetic suspended-sediment/water-quality collapsible-bag sampler: Federal Interagency Sediment Project, 37 p., accessed June 30, 2009, at http://fisp.wes.army.mil/Report%20PP,%20US%20D-96%20011114%20.pdf

Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment: U.S Geological Survey Techniques of Water-Resource Investigations, book 3, chap. C2 (rev.), 89 p. Available at http://pubs.usgs.gov/twri/twri3-c2/.

Emmett, W.W., 1980, A field calibration of the sediment-trapping characteristics of the Helley-Smith bed-load sampler: U.S. Geological Survey Professional Paper 1139, 44 p.

Federal Register, 1994, Endangered and threatened wildlife and plants—Determination of endangered status for the Kootenai River population of the white sturgeon: v. 59, no. 171, September 6, 1994, p. 45989-46002, accessed August 14, 2009, at http://ecos.fws.gov/docs/federal_register/fr2678.pdf

Federal Register, 2008, Endangered and threatened wildlife and plants; critical habitat revised designation for the Kootenai River population of the white sturgeon (*Acipenser transmontanus*): Final rule, v. 73, no. 132. July 9, 2008, p. 39505-39523, accessed August 14, 2009, at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2008_register&docid=fr09jy08-21

Glysson, G.D., 1987, Sediment-transport curves: U.S. Geological Survey Open-File Report 87-218, 47 p.

Guy, H.P., 1978, Fluvial sediment concepts: U.S. Geological Survey Techniques of Water-Resource Investigations, book 3, chap. C1, 55 p. Available at http://pubs.usgs.gov/twri/twri3-c1/.

Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001—Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Available at http://pubs.usgs.gov/sir/2005/5234/.

Kock, T.J., Congleton, J.L., and Anders, P.J., 2006, Effects of sediment cover on survival and development of white sturgeon embryos: North American Journal of Fisheries Management, v. 26, issue 1, p. 134-141.

Mueller, D.S., and Wagner, C.R., 2009, Measuring discharge with acoustic Doppler current profilers from a moving boat: U.S. Geological Survey Techniques and Methods 3A-22, 72 p. Available at http://pubs.usgs.gov/tm/3a22/.

Osterkamp, W.R., 2008, Annotated definitions of selected geomorphic terms and related terms of hydrology, sedimentology, soil science and ecology: U.S. Geological Survey Open-File Report 2008-1217, p. 49.

Paragamian, V.L., Kruse, Gretchen, and Wakkinen, Virginia, 2001, Spawning habitat of Kootenai River white sturgeon, post-Libby Dam: North American Journal of Fisheries Management, v. 21, issue 1, p. 22-33.

Paragamian, V.L., Wakkinen, V.D., and Kruse, Gretchen, 2002, Spawning locations and movement of Kootenai River white sturgeon: Journal of Applied Ichthyology, v. 18, p. 608-616.

Partridge, F., 1983, Kootenai River fisheries investigations: Boise, Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-5, Subproject IV, Study IV.

Redwing Naturalists, 1996, History of diking on the Kootenay River floodplain in British Columbia: Report of Redwing Naturalists to Habitat Enhancement Branch, Department of Fisheries and Oceans, British Columbia, Canada, p. 17-14, and 20-22.

Turney-High, H.H., 1969, Ethnography of the Kutenai: New York, Kraus Reprint Co., p. 44.

U.S. Fish and Wildlife Service, 1999, Recovery plan for the white sturgeon (*Acipenser transmontanus*): Kootenai River population: U.S. Fish and Wildlife Service, Portland, Oreg., 96 p. plus appendixes, accessed October 1, 2007, at http://ecos.fws.gov/docs/recovery_plan/990930b.pdf

U.S. Fish and Wildlife Service, 2006, Fish and Wildlife Service biological opinion regarding the effects of Libby Dam operations on the Kootenai River white sturgeon, bull trout, and Kootenai sturgeon critical habitat: Fish and Wildlife Service Biological Opinion, 1-9-01-F-0279R, 153 p. Accessed August 17, 2009, at http://www.fws.gov/easternwashington/documents/Final%20Libby%20Dam%20BiOp%202-18-06lr3.pdf

Wolman, M.G., and Leopold, L.B., 1954, A method of sampling coarse river-bed material: American Geophysical Union, Transactions, v. 35, no. 6, p. 951-956.

Appendix A. Annual Peak Flow Frequency Analysis for Fisher and Yaak Rivers, Montana

Fisher River, Montana

[Discharge is in cubic feet per second]

```
1
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.000.000
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       01/23/2009 16:02

                         --- PROCESSING OPTIONS ---

                      Plot option         = None
                      Basin char output   = WATSTORE
                      Print option        = Yes
                      Debug print         = No
                      Input peaks listing = Long
                      Input peaks format  = WATSTORE peak file

                      Input files used:
                         peaks (ascii)  - D:\PROJECTWORK\KOOTENAI\DATA\PEAK_FLOW_EST\WATSTORE\USGS 12302055 FISHER RIVER N
                         specifications - PKFQWPSF.TMP
                      Output file(s):
                         main - D:\PROJECTWORK\KOOTENAI\DATA\PEAK_FLOW_EST\WATSTORE\USGS 12302055 FISHER RIVER N
                         bcd  - (NONE)

1
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       01/23/2009 16:02

                 Station - 12302055  Fisher River near Libby MT


                     I N P U T   D A T A   S U M M A R Y

                Number of peaks in record           =       40
                Peaks not used in analysis          =        0
                Systematic peaks in analysis        =       40
                Historic peaks in analysis          =        0
                Years of historic record            =        0
                Generalized skew                    =   -0.087
                     Standard error                 =    0.550
                     Mean Square error              =    0.303
                Skew option                         =   WEIGHTED
                Gage base discharge                 =      0.0
                User supplied high outlier threshold =   --
                User supplied low outlier criterion  =   --
                Plotting position parameter         =     0.00



  *********  NOTICE  --  Preliminary machine computations.        *********
  *********  User responsible for assessment and interpretation.  *********

    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                   0.0
    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.            595.0
    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.     13639.4
```

```
1


  Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.002
  Ver. 5.2           Annual peak flow frequency analysis      Run Date / Time
  11/01/2007         following Bulletin 17-B Guidelines       01/23/2009 16:02

               Station - 12302055  Fisher River near Libby MT


         ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

                      FLOOD BASE                  LOGARITHMIC
                  ----------------------  ------------------------------
                            EXCEEDANCE                STANDARD
                   DISCHARGE PROBABILITY     MEAN     DEVIATION     SKEW
                  -------------------------------------------------------
 SYSTEMATIC RECORD       0.0     1.0000     3.4547      0.2536      0.292
 BULL.17B ESTIMATE       0.0     1.0000     3.4547      0.2536      0.167
    ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

      ANNUAL                                'EXPECTED   95-PCT CONFIDENCE LIMITS
   EXCEEDANCE     BULL.17B    SYSTEMATIC PROBABILITY'  FOR BULL. 17B ESTIMATES
   PROBABILITY    ESTIMATE      RECORD     ESTIMATE        LOWER        UPPER

      0.9950        693.8        743.1        638.6        482.1        902.2
      0.9900        787.1        831.1        736.8        561.0       1007.0
      0.9500       1122.0       1147.0       1086.0        855.8       1375.0
      0.9000       1363.0       1376.0       1335.0       1076.0       1638.0
      0.8000       1736.0       1732.0       1717.0       1421.0       2045.0
      0.6667       2187.0       2167.0       2177.0       1841.0       2549.0
      0.5000       2803.0       2769.0       2803.0       2400.0       3270.0
      0.4292       3112.0       3074.0       3117.0       2672.0       3647.0
      0.2000       4632.0       4610.0       4688.0       3934.0       5648.0
      0.1000       6079.0       6117.0       6227.0       5050.0       7729.0
      0.0400       8182.0       8377.0       8556.0       6581.0      10970.0
      0.0200       9952.0      10340.0      10610.0       7815.0      13870.0
      0.0100      11900.0      12550.0      12970.0       9132.0      17190.0
      0.0050      14050.0      15040.0      15710.0      10540.0      21000.0
      0.0020      17220.0      18830.0      20010.0      12560.0      26870.0
```

```
1

 Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.003
 Ver. 5.2           Annual peak flow frequency analysis      Run Date / Time
 11/01/2007          following Bulletin 17-B Guidelines      01/23/2009 16:02

              Station - 12302055  Fisher River near Libby MT


                    I N P U T   D A T A   L I S T I N G


    WATER YEAR    DISCHARGE   CODES      WATER YEAR    DISCHARGE   CODES

       1948         6560.0                  1988         2230.0
       1969         4730.0                  1989         2960.0
       1970         2880.0                  1990         3170.0
       1971         4620.0                  1991         5380.0
       1972         4980.0                  1992         1140.0
       1973         1410.0                  1993         1710.0
       1974         8720.0                  1994         1560.0
       1975         3590.0                  1995         2350.0
       1976         4240.0                  1996        12000.0
       1977          829.0                  1997         7010.0
       1978         2660.0                  1998         2530.0
       1979         2930.0                  1999         2700.0
       1980         2510.0                  2000         2640.0
       1981         3820.0                  2001         1490.0
       1982         3450.0                  2002         6910.0
       1983         2110.0                  2003         1350.0
       1984         1500.0                  2004         1360.0
       1985         2570.0                  2005         1520.0
       1986         3120.0                  2006         2510.0
       1987         2450.0                  2007         3410.0


       Explanation of peak discharge qualification codes

      PeakFQ    NWIS
       CODE     CODE   DEFINITION

         D        3    Dam failure, non-recurrent flow anomaly
         G        8    Discharge greater than stated value
         X       3+8   Both of the above
         L        4    Discharge less than stated value
         K      6 OR C  Known effect of regulation or urbanization
         H        7    Historic peak

         -  Minus-flagged discharge -- Not used in computation
               -8888.0 -- No discharge value given
         -  Minus-flagged water year -- Historic peak used in computation
```

```
1

  Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.004
  Ver. 5.2           Annual peak flow frequency analysis      Run Date / Time
  11/01/2007         following Bulletin 17-B Guidelines       01/23/2009 16:02

               Station - 12302055  Fisher River near Libby MT


   EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

      WATER        RANKED       SYSTEMATIC      BULL.17B
       YEAR       DISCHARGE       RECORD        ESTIMATE

       1996       12000.0        0.0244         0.0244
       1974        8720.0        0.0488         0.0488
       1997        7010.0        0.0732         0.0732
       2002        6910.0        0.0976         0.0976
       1948        6560.0        0.1220         0.1220
       1991        5380.0        0.1463         0.1463
       1972        4980.0        0.1707         0.1707
       1969        4730.0        0.1951         0.1951
       1971        4620.0        0.2195         0.2195
       1976        4240.0        0.2439         0.2439
       1981        3820.0        0.2683         0.2683
       1975        3590.0        0.2927         0.2927
       1982        3450.0        0.3171         0.3171
       2007        3410.0        0.3415         0.3415
       1990        3170.0        0.3659         0.3659
       1986        3120.0        0.3902         0.3902
       1989        2960.0        0.4146         0.4146
       1979        2930.0        0.4390         0.4390
       1970        2880.0        0.4634         0.4634
       1999        2700.0        0.4878         0.4878
       1978        2660.0        0.5122         0.5122
       2000        2640.0        0.5366         0.5366
       1985        2570.0        0.5610         0.5610
       1998        2530.0        0.5854         0.5854
       1980        2510.0        0.6098         0.6098
       2006        2510.0        0.6341         0.6341
       1987        2450.0        0.6585         0.6585
       1995        2350.0        0.6829         0.6829
       1988        2230.0        0.7073         0.7073
       1983        2110.0        0.7317         0.7317
       1993        1710.0        0.7561         0.7561
       1994        1560.0        0.7805         0.7805
       2005        1520.0        0.8049         0.8049
       1984        1500.0        0.8293         0.8293
       2001        1490.0        0.8537         0.8537
       1973        1410.0        0.8780         0.8780
       2004        1360.0        0.9024         0.9024
       2003        1350.0        0.9268         0.9268
       1992        1140.0        0.9512         0.9512
       1977         829.0        0.9756         0.9756
1


 End PeakFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      40


Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
(2, 4, and * records are ignored.)

 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:  12302055       USGS Fisher River near Libby MT


 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:
```

Yaak River, Montana

[Discharge is in cubic feet per second]

```
1
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.000.000
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       12/16/2008 11:34

                         --- PROCESSING OPTIONS ---

                      Plot option         = Graphics device
                      Basin char output   = WATSTORE
                      Print option        = Yes
                      Debug print         = No
                      Input peaks listing = Long
                      Input peaks format  = WATSTORE peak file

                      Input files used:
                         peaks (ascii)  - D:\PROJECTWORK\KOOTENAI\DATA\PEAK_FLOW_EST\WATSTORE\USGS 12304500 YAAK RIVER NEA
                         specifications - PKFQWPSF.TMP
                      Output file(s):
                         main - D:\PROJECTWORK\KOOTENAI\DATA\PEAK_FLOW_EST\WATSTORE\USGS 12304500 YAAK RIVER NEA
                         bcd  - YAAK_PEAK.BCD

1

  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       12/16/2008 11:34

                Station - 12304500  Yaak River near Troy MT


                   I N P U T   D A T A   S U M M A R Y

              Number of peaks in record           =       54
              Peaks not used in analysis          =        0
              Systematic peaks in analysis        =       54
              Historic peaks in analysis          =        0
              Years of historic record            =        0
              Generalized skew                    =   -0.179
                   Standard error                 =    0.550
                   Mean Square error              =    0.303
              Skew option                         =   WEIGHTED
              Gage base discharge                 =      0.0
              User supplied high outlier threshold =   --
              User supplied low outlier criterion  =   --
              Plotting position parameter         =     0.00



  *********  NOTICE  --  Preliminary machine computations.        *********
  *********  User responsible for assessment and interpretation.  *********

    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                    0.0
    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.            1901.2
    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.      20920.0
```

```
1

 Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.002
 Ver. 5.2           Annual peak flow frequency analysis      Run Date / Time
 11/01/2007         following Bulletin 17-B Guidelines       12/16/2008 11:34

                Station - 12304500  Yaak River near Troy MT


          ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

                      FLOOD BASE                 LOGARITHMIC
                ----------------------  ------------------------------
                          EXCEEDANCE                STANDARD
                 DISCHARGE PROBABILITY     MEAN     DEVIATION     SKEW
                -------------------------------------------------------
SYSTEMATIC RECORD       0.0     1.0000     3.7998      0.1861     -0.571
BULL.17B ESTIMATE       0.0     1.0000     3.7998      0.1861     -0.449



ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

     ANNUAL                             'EXPECTED   95-PCT CONFIDENCE LIMITS
  EXCEEDANCE     BULL.17B    SYSTEMATIC PROBABILITY'  FOR BULL. 17B ESTIMATES
  PROBABILITY    ESTIMATE      RECORD     ESTIMATE        LOWER        UPPER

     0.9950       1748.0       1666.0       1625.0       1341.0       2131.0
     0.9900       2026.0       1953.0       1916.0       1594.0       2426.0
     0.9500       2964.0       2928.0       2893.0       2482.0       3401.0
     0.9000       3582.0       3571.0       3531.0       3086.0       4037.0
     0.8000       4452.0       4472.0       4421.0       3941.0       4938.0
     0.6667       5391.0       5435.0       5377.0       4856.0       5937.0
     0.5000       6512.0       6568.0       6512.0       5913.0       7183.0
     0.4292       7017.0       7072.0       7023.0       6375.0       7767.0
     0.2000       9101.0       9106.0       9150.0       8197.0      10300.0
     0.1000      10660.0      10570.0      10760.0       9489.0      12300.0
     0.0400      12450.0      12200.0      12650.0      10930.0      14700.0
     0.0200      13680.0      13280.0      13970.0      11890.0      16380.0
     0.0100      14820.0      14250.0      15220.0      12780.0      17970.0
     0.0050      15890.0      15140.0      16410.0      13590.0      19480.0
     0.0020      17210.0      16210.0      17920.0      14590.0      21390.0
```

```
1


 Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.003
 Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
 11/01/2007          following Bulletin 17-B Guidelines       12/16/2008 11:34

                Station - 12304500  Yaak River near Troy MT

                     I N P U T   D A T A   L I S T I N G

    WATER YEAR    DISCHARGE   CODES      WATER YEAR    DISCHARGE   CODES

       1948        12500.0                  1981         5710.0
       1954        13400.0                  1982         7280.0
       1956        12100.0                  1983         6350.0
       1957         7930.0                  1984         4260.0
       1958         6270.0                  1985         5130.0
       1959         6810.0                  1986         4550.0
       1960         7680.0                  1987         6490.0
       1961         9780.0                  1988         6490.0
       1962         5230.0                  1989         6060.0
       1963         4750.0                  1990         5010.0
       1964         8400.0                  1991         8800.0
       1965         6750.0                  1992         2660.0
       1966         7440.0                  1993         5060.0
       1967        10200.0                  1994         4850.0
       1968         5080.0                  1995         4180.0
       1969         8130.0                  1996         7970.0
       1970         5760.0                  1997        12600.0
       1971         9220.0                  1998         7490.0
       1972         8840.0                  1999         8900.0
       1973         5900.0                  2000         4780.0
       1974         9640.0                  2001         2460.0
       1975         7080.0                  2002        12100.0
       1976        10200.0                  2003         3440.0
       1977         2060.0                  2004         2990.0
       1978         6010.0                  2005         2550.0
       1979         4600.0                  2006         6600.0
       1980         6990.0                  2007         6660.0

       Explanation of peak discharge qualification codes

      PeakFQ    NWIS
       CODE     CODE   DEFINITION

         D        3    Dam failure, non-recurrent flow anomaly
         G        8    Discharge greater than stated value
         X       3+8   Both of the above
         L        4    Discharge less than stated value
         K     6 OR C  Known effect of regulation or urbanization
         H        7    Historic peak

         -  Minus-flagged discharge -- Not used in computation
               -8888.0 -- No discharge value given
         -  Minus-flagged water year -- Historic peak used in computation
```

```
1

  Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.004
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       12/16/2008 11:34

                 Station - 12304500  Yaak River near Troy MT

   EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

      WATER         RANKED       SYSTEMATIC      BULL.17B
       YEAR       DISCHARGE        RECORD        ESTIMATE

       1954        13400.0         0.0182         0.0182
       1997        12600.0         0.0364         0.0364
       1948        12500.0         0.0545         0.0545
       1956        12100.0         0.0727         0.0727
       2002        12100.0         0.0909         0.0909
       1967        10200.0         0.1091         0.1091
       1976        10200.0         0.1273         0.1273
       1961         9780.0         0.1455         0.1455
       1974         9640.0         0.1636         0.1636
       1971         9220.0         0.1818         0.1818
       1999         8900.0         0.2000         0.2000
       1972         8840.0         0.2182         0.2182
       1991         8800.0         0.2364         0.2364
       1964         8400.0         0.2545         0.2545
       1969         8130.0         0.2727         0.2727
       1996         7970.0         0.2909         0.2909
       1957         7930.0         0.3091         0.3091
       1960         7680.0         0.3273         0.3273
       1998         7490.0         0.3455         0.3455
       1966         7440.0         0.3636         0.3636
       1982         7280.0         0.3818         0.3818
       1975         7080.0         0.4000         0.4000
       1980         6990.0         0.4182         0.4182
       1959         6810.0         0.4364         0.4364
       1965         6750.0         0.4545         0.4545
       2007         6660.0         0.4727         0.4727
       2006         6600.0         0.4909         0.4909
       1987         6490.0         0.5091         0.5091
       1988         6490.0         0.5273         0.5273
       1983         6350.0         0.5455         0.5455
       1958         6270.0         0.5636         0.5636
       1989         6060.0         0.5818         0.5818
       1978         6010.0         0.6000         0.6000
       1973         5900.0         0.6182         0.6182
       1970         5760.0         0.6364         0.6364
       1981         5710.0         0.6545         0.6545
       1962         5230.0         0.6727         0.6727
       1985         5130.0         0.6909         0.6909
       1968         5080.0         0.7091         0.7091
       1993         5060.0         0.7273         0.7273
       1990         5010.0         0.7455         0.7455
       1994         4850.0         0.7636         0.7636
       2000         4780.0         0.7818         0.7818
       1963         4750.0         0.8000         0.8000
       1979         4600.0         0.8182         0.8182
       1986         4550.0         0.8364         0.8364
       1984         4260.0         0.8545         0.8545
       1995         4180.0         0.8727         0.8727
       2003         3440.0         0.8909         0.8909
       2004         2990.0         0.9091         0.9091
       1992         2660.0         0.9273         0.9273
       2005         2550.0         0.9455         0.9455
       2001         2460.0         0.9636         0.9636
       1977         2060.0         0.9818         0.9818
```

```
1

 End PeakFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      54


Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
(2, 4, and * records are ignored.)

 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:  12304500       USGS Yaak River near Troy MT


 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:
```

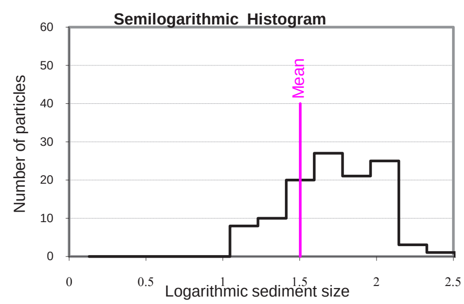
Appendix B. Wolman Pebble Count Data

PARTICLE COUNTS

Site: WPC 1
Date: March 6, 2008
Measurement by: RLF / GJB
Remarks: Sampled using a 1/2ϕ Gravelometer
Location: RM = 160.5
RKM = 258.3
NOTE: See original notes for more information on sampling this site.

DATA: Particle size (mm)				
1	64	64	45	180
32	45	32	32	11
64	11	32	22.6	64
16	8	64	32	32
22.6	16	64	90	45
8	32	45	90	32
1	64	64	128	
16	45	90	90	
22.6	45	45	64	
22.6	32	45	8	
32	90	64	90	
22.6	90	32	45	
16	22.6	128	45	
32	11	45	45	
32	32	64	128	
16	64	64	64	
64	32	16	32	
16	22.6	22.6	45	
22.6	16	32	32	
16	45	22.6	22.6	
22.6	16	32	90	
22.6	45	22.6	45	
22.6	32	90	22.6	
22.6	32	32	11	
32	32	22.6	32	
32	1	22.6	45	
45	11	32	45	
45	45	22.6	64	

Particle Characteristics			
D_{90}	=	91.1	mm
D_{84}	=	78.2	mm
D_{65}	=	51.5	mm
D_{50}	=	39.9	mm
D_{35}	=	32	mm
D_{16}	=	20.8	mm
D_g	=	40.3	mm
σ_g	=	1.94	mm
G	=	0.98	



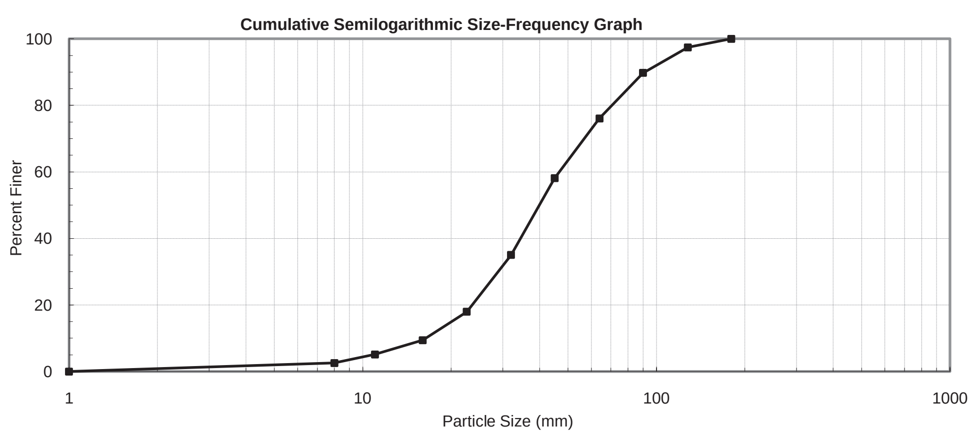


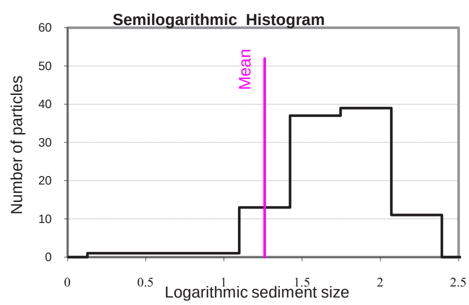
Figure B1. Wolman pebble count data for RKM 258.3 at site WPC_1, near Bonners Ferry, Idaho, water year 2008.

PARTICLE COUNTS

Site: WPC 6
Date: March 6, 2008
Measurement by: RLF / GJB
Remarks: Sampled using a 1/2ϕ Gravelometer
Location: RM = 153.5
RKM = 247.1
NOTE: See original notes for more information on sampling this site.

DATA: Particle size (mm)				
16	32	22.6	32	
22.6	64	32	45	
45	45	22.6	5.6	
1	11	2.8	32	
16	45	32	45	
64	22.6	0.125	90	
22.6	8	11	32	
22.6	32	64	32	
0.0625	11	45	11	
0.0625	16	45	45	
0.0625	22.6	90	32	
0.0625	22.6	45	22.6	
16	22.6	45	8	
32	32	16	64	
32	22.6	22.6	45	
32	32	32	90	
32	64	22.6	22.6	
16	22.6	11	22.6	
22.6	32	11		
16	32	45		
0.125	16	8		
22.6	45	22.6		
22.6	8	16		
22.6	32	64		
45	45	16		
45	11	22.6		
32	22.6	45		
64	45	64		

Particle Characteristics			
D_{90}	=	63	mm
D_{84}	=	55.6	mm
D_{65}	=	38.4	mm
D_{50}	=	29.8	mm
D_{35}	=	23.8	mm
D_{16}	=	12.8	mm
D_g	=	26.7	mm
σ_g	=	2.08	mm
G	=	1.02	



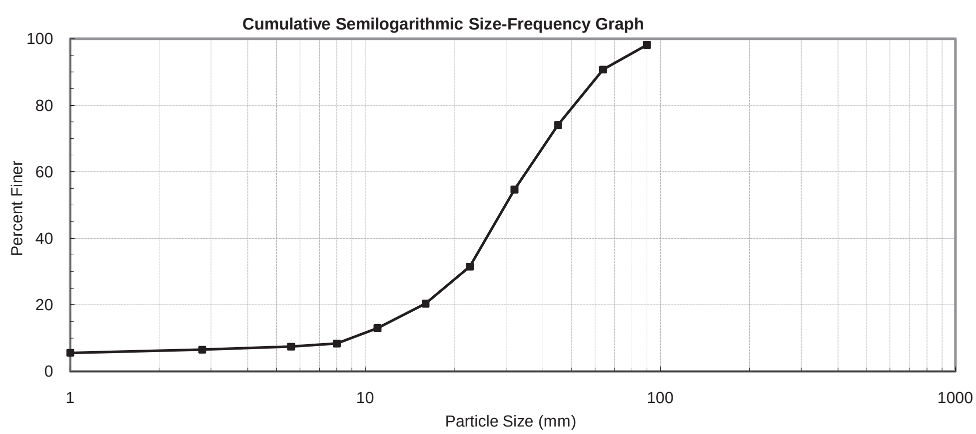


Figure B2. Wolman pebble count data for RKM 247.1 at site WPC_6, near Bonners Ferry, Idaho, water year 2008.

Appendix C. Suspended-Sediment Data

Table C1. Particle-size distribution of half-phi sieve analysis from samples collected from the Kootenai River below Moyie River, below Fry Creek, and above Shorty's Island, near Bonners Ferry, Idaho, water year 2008.

[All particle size distributions are in millimeters. **Abbreviations**:<. less than; mm, millimeter; –, no data]

Date	Time	Particle-size distribution (percent)								
		< 1.0	< 0.71	< 0.50	< 0.355	< 0.25	< 0.180	< 0.125	< 0.090	< 0.063
Kootenai River below Moyie River—4842231161104										
12-12-07	15:25	–	–	–	–	–	–	–	100	51.8
12-13-07	12:15	–	–	–	–	–	–	–	100	62.4
05-07-08	14:11	–	100	99.5	99.5	98.5	97.4	95.9	93.8	90.1
05-07-08	14:22	–	–	–	100	99.6	98.8	96.7	94.2	90.6
05-17-08	08:30	–	100	99.9	99.7	97.8	95.5	92.9	89.9	85.8
05-18-08	08:21	–	100	99.9	99.6	98.3	96.7	94.5	92	88.2
06-01-08	11:00	–	–	100	99.7	98.3	96.6	93.1	89	81.8
06-03-08	10:00	–	100	99.6	98.6	94.6	87.8	78.1	68.9	58.3
06-04-08	10:12	–	100	99.5	98	93.9	88.4	80.8	73.2	62.6
06-11-08	11:48	–	–	100	97.8	92.1	82.8	72	64.2	52
06-12-08	16:13	–	–	100	98.4	95.3	85.2	73.5	63.3	53.2
Kootenai River below Fry Creek—12309490										
12-13-07	14:15	–	–	–	–	–	–	–	100	44.1
05-07-08	15:40	–	–	–	100	99.1	96.8	92.2	86.3	80.8
05-08-08	14:29	–	100	99.6	99.6	99.3	97.5	92.8	87.8	81.5
05-08-08	14:49	–	–-	–	100	99.6	98.2	94.4	90.1	84.7
05-17-08	15:37	–	100	99.9	99.9	99.5	98.4	95.4	91.9	87.3
05-18-08	13:32	–	–	100	99.9	99.8	99.2	97.4	94.7	90.2
06-01-08	14:50	–	100	99	99	98.6	97.1	94.8	91.4	84.7
06-03-08	12:36	–	–	–	100	99.5	97.6	91.7	82.9	69.9
06-11-08	16:21	–	–	100	98.9	96.6	91	82	73.1	60.7
06-13-08	08:41	–	–	–	100	98.8	94.2	86.2	78.1	64.3
Kootenai River above Shorty's Island—4845421162319										
12-14-07	10:45	–	–	–	–	–	–	–	100	64.9
05-08-08	08:41	–	100	99.5	99.2	97.2	91.3	83.6	74.2	59.1
05-16-08	16:48	–	–	–	100	98.9	95	88.8	80.4	70.8
05-18-08	15:11	–	–	100	99.8	99.3	97.4	93	86.9	79.4
05-31-08	17:01	–	100	99.5	99	98.5	96.4	92.4	87.8	81.2
06-02-08	11:44	–	100	99.7	98.9	92.9	82.6	76	69.9	60.4
06-03-08	17:10	–	100	99.5	99	98	93.5	87	78.5	67
06-12-08	10:47	–	–	100	99.1	97.3	89.4	76.1	65.5	52.3

Appendix D. Bedload-Sediment Data

Table D1. Particle-size distribution of bedload from samples collected from the Kootenai River below Moyie River, below Fry Creek, and above Shorty's Island, near Bonners Ferry, Idaho, water year 2008.

[All particle-size distributions are in millimeters. **Abbreviations**: mm, millimeter; <. less than; –, no data]

Date	Time	Sample set	Mass	Particle-size distribution (percent)												
				< 45	< 32	< 22.6	< 16	< 11.3	< 8	< 5.6	< 4	< 2	< 1.4	< 1	< 0.7	< 0.5
Kootenai River below Moyie River—4842231161104																
12-12-07	14:00	A	1.8	–	–	–	–	–	–	–	–	–	–	–	100	83.3
12-13-07	12:30	A	7.1	–	–	–	–	–	–	–	–	100	100	98.6	95.8	88.9
05-07-08	11:36	B	26.9	–	–	–	–	–	–	–	100	99.3	97	91.1	71.7	30.1
05-08-08	16:56	A	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–
05-18-08	08:46	A	2,210.2	–	100	86.6	73.4	61.4	52.8	48.2	46	42.5	40.4	38.7	36.7	33.8
06-01-08	08:20	A	88.3	–	–	–	100	83.2	68.8	61.8	57.6	52.5	47.2	38.7	20.6	2.83
06-01-08	09:40	B	182.6	–	100	83.7	24.2	9.91	3.94	3.12	3.12	3.07	2.96	2.74	1.86	0.38
06-02-08	13:40	A	1,749.8	–	100	89	82.6	68.6	53.4	41.8	35.4	25.7	22.3	20.8	20	18.6
06-02-08	15:03	B	1,313.5	100	85.8	81.1	77.3	68.3	61.8	58.2	56.4	52.7	49.1	44.1	37.1	31.6
06-04-08	08:15	A	103.8	–	–	–	100	97.4	96.7	95	93.6	91.9	91.1	90.4	89.1	85.1
06-04-08	09:14	B	106.7	–	–	–	–	100	96.6	94	90.7	85.9	84.7	84	82.5	78.2
06-11-08	08:52	A	52.4	–	–	100	79.4	68.1	65.8	64.1	60.6	54.9	51.8	45.9	29.1	3.25
06-11-08	10:27	B	48.1	–	–	100	66.8	66.8	63.7	59.8	59.3	55.6	51.5	43.8	27.6	4.98
06-12-08	13:54	A	172.9	–	100	73.7	45	39.1	32.7	30.7	30.3	29.1	28	25.4	17.4	4.81
06-12-08	15:02	B	99.2	–	100	76.3	62.3	52.9	49.2	48.8	48.4	46.7	44.9	40.8	27.6	8.53
Kootenai River below Fry Creek—12309490																
12-13-07	14:29	A	1.8	–	–	–	–	–	–	–	–	–	–	100	94.4	88.9
05-07-08	16:38	A	1,073.7	100	93.7	71.6	42.3	19.9	7.59	2.69	2.41	2.33	2.26	2.09	1.64	1.06
05-08-08	10:58	A	664.2	100	89	72	33.8	16.9	7.35	5.83	5.68	5.42	5.24	4.99	4.46	3.66
05-08-08	12:34	B	343.9	–	100	87.4	72.1	42	17.1	6.97	4.94	4.94	4.56	4.09	2.94	1.44
05-17-08	11:22	A	195.1	–	100	63.7	57.2	54.4	54	53.4	53	52.9	52.7	52.4	51.8	50.2
05-17-08	13:33	B	213.5	–	–	100	69	58.6	50.9	45.1	43.3	41.5	40.7	39.5	38	35.9
05-18-08	12:01	A	102.6	–	–	–	100	88.4	66	51.2	49.1	48.3	47.7	47.1	46.2	45.3
06-01-08	12:40	A	7.8	–	–	–	100	34.6	12.3	12.3	12.3	12.3	12.3	11.1	8.64	4.94
06-01-08	13:44	B	2.4	–	–	–	–	–	–	–	–	100	96	80	48	12
06-03-08	10:42	A	16.8	–	–	–	–	–	–	–	–	100	99.4	99.4	98.2	95.8
06-03-08	11:38	B	23.6	–	–	–	–	–	100	97.1	96.6	95.8	95	94.1	92.9	90.8
06-11-08	13:43	A	2.7	–	–	–	–	–	–	–	100	96.6	86.2	75.9	58.6	31
06-11-08	14:55	B	4.4	–	–	–	–	–	–	–	100	97.7	90.7	79.1	55.8	27.9
06-13-08	07:30	A	4.4	–	–	–	–	–	–	–	100	97.7	95.3	86	62.8	32.6
Kootenai River above Shorty's Island—4845421162319																
12-14-07	09::00	A	97.5	–	–	–	–	–	–	–	100	99.5	96.4	92.1	86.7	79.3
05-16-08	1346	A	77.5	–	–	–	–	–	–	–	100	97.8	87.7	71.7	45.9	18
05-16-08	15:03	B	206.0	–	–	–	–	–	–	–	100	99.7	97.5	91.6	77.2	54.9
05-31-08	14:20	A	36.9	–	–	–	–	–	–	–	100	98.6	91.9	79.7	56.5	26.8
05-31-08	15:53	B	32.8	–	–	–	–	–	–	–	100	99.1	96.3	86.1	57.1	18.5
06-02-08	09:39	A	97.0	–	–	–	–	–	–	–	100	98.8	93.2	84	68.9	49.8
06-02-08	10:46	B	109.2	–	–	–	–	–	–	100	99.9	99.7	96	86.7	62.1	26.6
06-03-08	14:34	A	723.6	–	–	–	–	–	–	–	100	99.9	99.6	98.8	96.2	88.5
06-03-08	16:00	B	1,078.0	–	–	–	–	–	–	–	–	100	99.9	99.8	99.4	97.6
06-12-08	08:16	A	68.8	–	–	–	–	–	–	–	100	99.1	94.8	86.2	68.7	45.3
06-12-08	09:27	B	111.4	–	–	–	–	–	–	–	100	99.4	95.9	86.2	64	34.4

Appendix E. Quality Assurance

Table E1. Quality assurance and quality control of suspended-sediment samples collected from the Kootenai River below Moyie River, and below Fry Creek, near Bonners Ferry, Idaho, May 2008.

[**Abbreviation**: mg/L, milligram per liter]

Date	Time	Sample set	Total suspended-sediment concentration (mg/L)	Percent change between sample sets A and B
Kootenai River below Moyie River (4842231161104)				
05-07-08	14:11	A	43	5
05-07-08	14:22	B	41	
Kootenai River below Fry Creek (12309490)				
05-08-08	14:29	A	56	7
05-08-08	14:49	B	52	

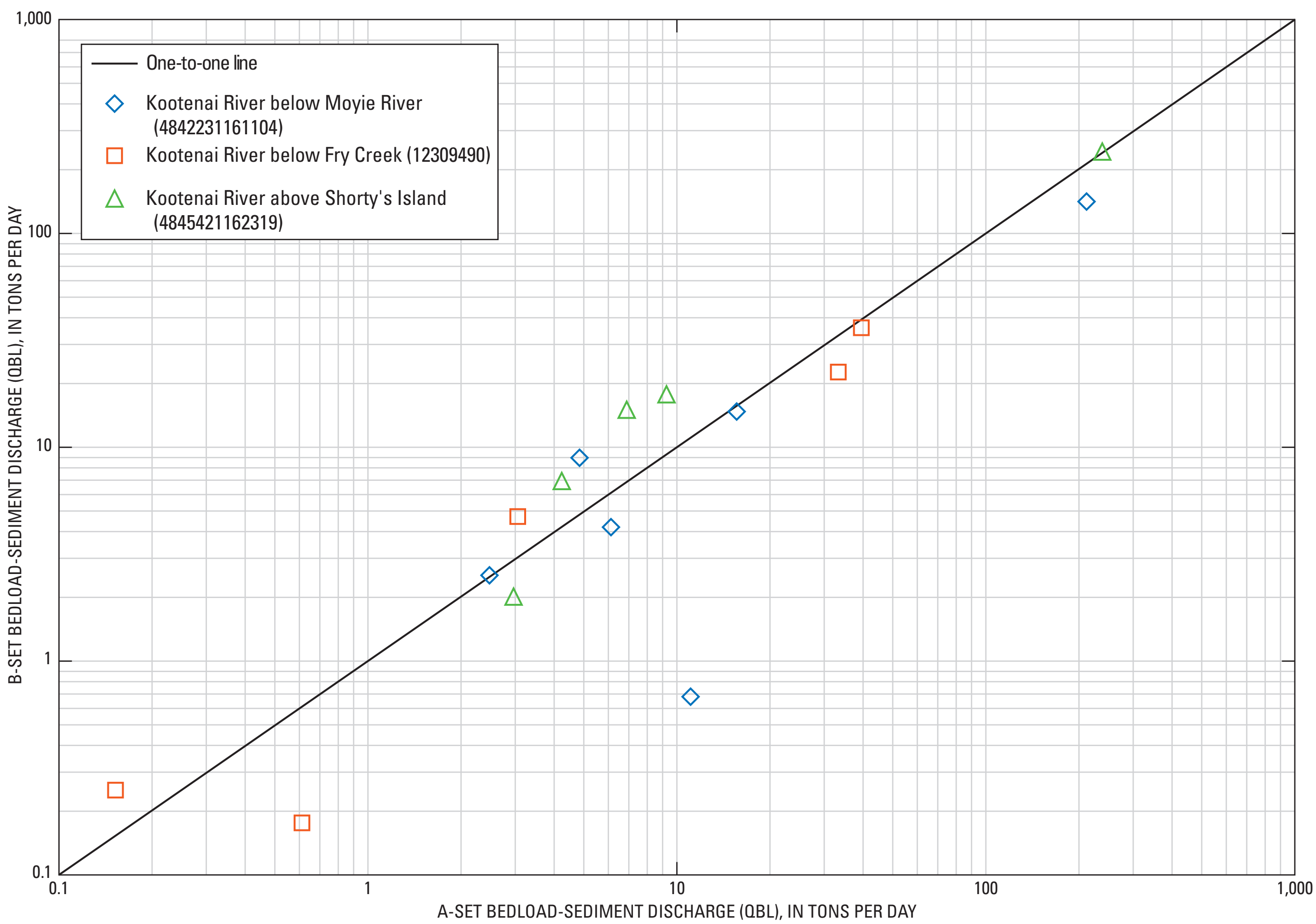


Figure E1. Quality-assurance samples for A- and B-set bedload-sediment discharge collected from the Kootenai River below Moyie River, below Fry Creek, and above Shorty's Island, near Bonners Ferry, Idaho.

Publishing support provided by the U.S. Geological Survey
Publishing Network, Tacoma Publishing Service Center

For more information concerning the research in this report, contact the
Director, Idaho Water Science Center
U.S. Geological Survey
230 Collins Road
Boise, Idaho 83702
http://id.water.usgs.gov

USGS Fosness and other— **Sediment Characteristics and Transport, Kootenai River White Sturgeon Critical Habitat, Bonners Ferry, Idaho—Scientific Investigations Report 2009-5228**