

Prepared in cooperation with the Fargo Diversion Board of Authority

Water-Surface Elevation and Discharge Measurement Data for the Red River of the North and its Tributaries near Fargo, North Dakota, Water Years 2014–15

Open File Report 2016–1139

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

Cover. Wild Rice River looking upstream from the bridge on County Road 16 near St. Benedict, North Dakota, October 13, 2011. Photograph by Rochelle A. Nustad, U.S. Geological Survey.

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By William C. Damschen and Joel M. Galloway

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U.S. Department of the Interior
SALLY JEWELL, Secretary

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

U.S. Geological Survey, Reston, Virginia: 2016

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Contents

Abstract.....	1
Introduction.....	1
Purpose and Scope	1
Methods.....	1
Water-Surface Elevations	4
Discharge Measurements.....	4
Water-Surface Elevations and Discharge Measurements.....	4
Red River of the North.....	4
Sheyenne River	10
Wild Rice River.....	12
Maple River.....	15
Summary.....	16
References Cited.....	16

Figures

1. Maps showing measured reaches on the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15	2
2. Graphs showing daily mean discharge and data collection dates for the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.....	8
3. Graph showing water-surface profiles from measurements made on the Red River of the North near Fargo, North Dakota, water years 2014–15.....	10
4. Graph showing water-surface profiles from measurements made on the Sheyenne River near Fargo, North Dakota, water years 2014–15.....	12
5. Graph showing water-surface profiles from measurements made on the Wild Rice River near Fargo, North Dakota, water years 2014–15.....	14
6. Graph showing water-surface profiles from measurements made on the Maple River near Fargo, North Dakota, water years 2014–15.....	16

Tables

1. Location and verification of benchmarks used during reach surveys on the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.....	5
2. Discharge measurement summary for selected reaches on the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.....	7
3. Water-surface elevations and discharge measurements made on the Red River of the North near Fargo, North Dakota, water years 2014–15	9
4. Water-surface elevations and discharge measurements made on the Sheyenne River near Fargo, North Dakota, water years 2014–15.....	11
5. Water-surface elevations and discharge measurements made on the Wild Rice River near Fargo, North Dakota, water years 2014–15.....	13
6. Water-surface elevations and discharge measurements made on the Maple River near Fargo, North Dakota, water years 2014–15.....	15

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m ²)
square mile (mi ²)	2.590	square kilometer (km ²)
Flow rate		
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
Hydraulic gradient		
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Datum

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

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

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

Supplemental Information

A water year (WY) is the period from October 1 to September 30 of the following year and is designated by the year in which it ends.

Abbreviations

GNSS	Global Navigation Satellite System
NGS	National Geodetic Survey
RTK	real-time kinematic
USGS	U.S. Geological Survey

Water-Surface Elevation and Discharge Measurement Data for the Red River of the North and its Tributaries near Fargo, North Dakota, Water Years 2014–15

By William C. Damschen and Joel M. Galloway

Abstract

The U.S. Geological Survey, in cooperation with the Fargo Diversion Board of Authority, collected water-surface elevations during a range of discharges needed for calibration of hydrologic and hydraulic models for specific reaches of interest in water years 2014–15. These water-surface elevation and discharge measurement data were collected for design planning of diversion structures on the Red River of the North and Wild Rice River and the aqueduct/diversion structures on the Sheyenne and Maple Rivers. The Red River of the North and Sheyenne River reaches were surveyed six times, and discharges ranged from 276 to 6,540 cubic feet per second and from 166 to 2,040 cubic feet per second, respectively. The Wild Rice River reach also was surveyed six times during 2014 and 2015, and discharges ranged from 13 to 1,550 cubic feet per second. The Maple River reach was surveyed four times, and discharges ranged from 16.4 to 633 cubic feet per second. Water-surface elevation differences from upstream to downstream in the reaches ranged from 0.33 feet in the Red River of the North reach to 9.4 feet in the Maple River reach.

Introduction

The Red River of the North begins at Wahpeton, North Dakota, at the confluence of the Otter Tail and Bois de Sioux Rivers (not shown), and flows north into Canada before emptying into Lake Winnipeg, Manitoba (fig. 1). The drainage area for the Red River of the North Basin is about 45,000 square miles (mi²) (excluding the Assiniboine River) and includes parts of eastern North Dakota, northeastern South Dakota and northwestern Minnesota in the United States, and southern Manitoba in Canada. The Red River of the North flows through several urban areas along its path, including the cities of Fargo, N. Dak.; Moorhead, Minnesota; Grand Forks, N. Dak.; East Grand Forks, Minn.; and Winnipeg, Manitoba. Tributaries to the Red River of the North near the Fargo-Moorhead metropolitan area include the Sheyenne, Maple, and Wild Rice Rivers (fig. 1).

The area around Fargo, N. Dak., and Moorhead, Minn., historically has been prone to flooding. Flood-fighting efforts have cost the region millions of dollars, and if these emergency flood-fighting efforts are overwhelmed, the results could be catastrophic (Flood Diversion Authority, 2015). The Fargo-Moorhead Area Diversion Project was established to develop permanent flood-protection measures for the region. The current (2015) plan includes a 20,000 cubic feet per second (ft³/s), 36-mile (mi) long diversion channel with 32,500 acres of upstream floodwater staging (Flood Diversion Authority, 2015). As the Fargo-Moorhead Area Diversion Project moves forward in the design phase, discharge and water-surface elevation data are needed where diversion structures are being planned. For design planning of diversion structures proposed for the Red River of the North and Wild Rice River, and the aqueduct/diversion structures proposed for the Sheyenne and Maple Rivers, the U.S. Geological Survey (USGS), in cooperation with the Fargo Diversion Board of Authority, collected water-surface elevations during a range of discharges needed for calibration of hydrologic and hydraulic models for the specific reaches of interest in water year (WYs) 2014–15.

Purpose and Scope

The purpose of this report is to describe the methods and results for the collection of discharge and associated water-surface elevation data through reaches of the Red River of the North, Sheyenne, Wild Rice, and Maple Rivers (figs. 1A–1D). Discharge measurements and multiple water-surface elevations along each reach were collected together during various hydrologic conditions in WYs 2014–15.

Methods

The methods used to collect water-surface elevations and discharge measurements for the Red River of the North, Sheyenne, Wild Rice, and Maple Rivers (fig. 1) in the Fargo-Moorhead metropolitan area are described in this section. Multiple measurements were made during a range of hydrologic conditions in WYs 2014–15.

2 Water-Surface Elevation and Discharge Measurement Data, Red River of the North and its Tributaries

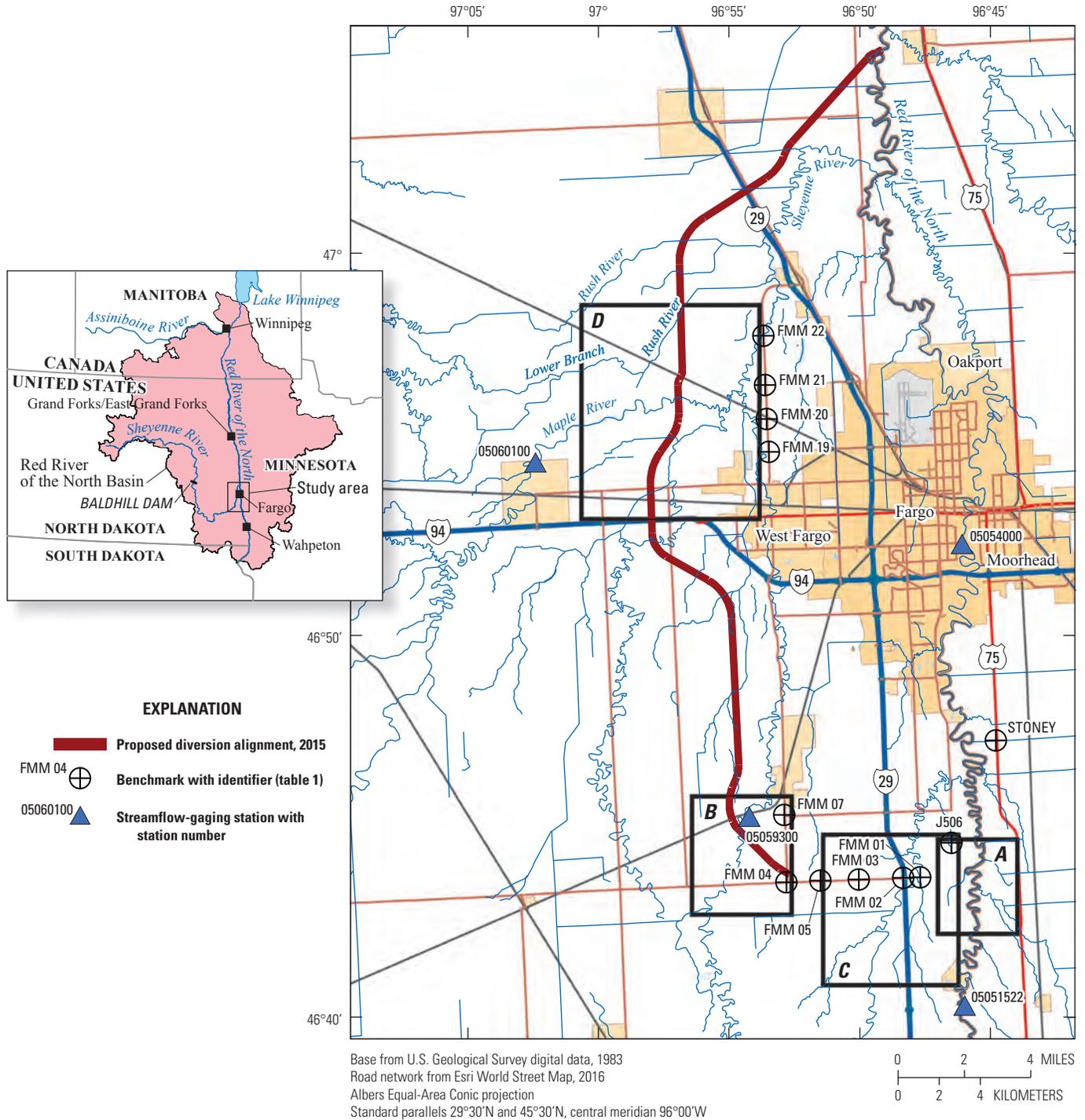
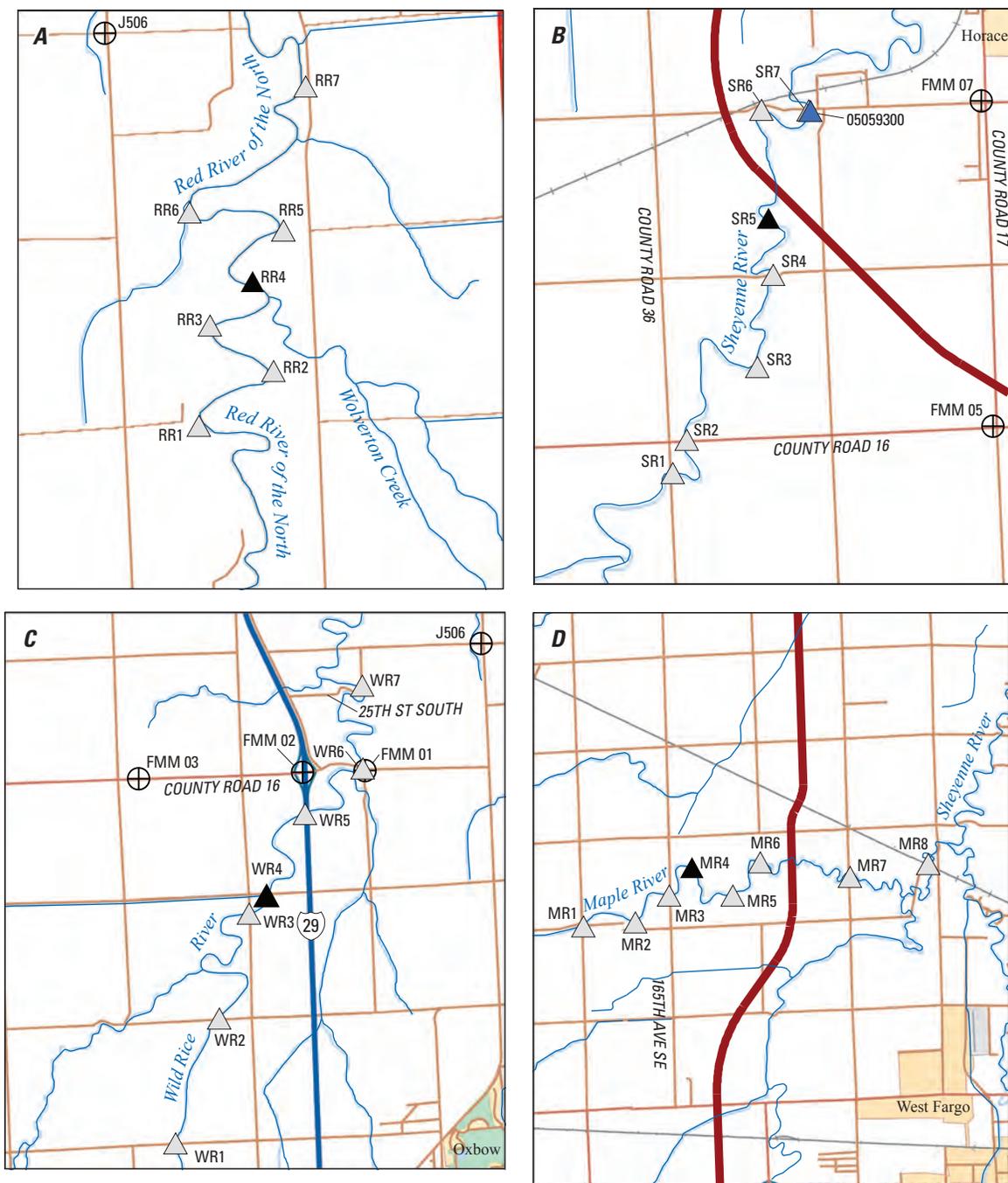


Figure 1. Measured reaches on the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.



EXPLANATION

- Proposed diversion alignment, 2015
- FMM 03 + Benchmark with identifier (table 1)
- 05059300 ▲ Streamflow-gaging station with station number
- RR4 ▲ Streamflow measurement site, with identifier
- WR1 ▲ Water-surface measurement site, with identifier

Figure 1. Measured reaches on the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.—Continued

Water-Surface Elevations

Water-surface elevation data were collected using survey-grade Global Navigation Satellite Systems (GNSS) methods. Vertical control was obtained by checking against National Geodetic Survey (NGS) survey markers in the local area (fig. 1; table 1). Real-time GNSS data were collected using a single-base real-time kinematic (RTK) surveying approach described in Rydlund and Densmore (2012). A dual-frequency receiver base station was mounted on a fixed-height tripod directly over a known benchmark. The base station includes a broadcast radio and long whip antenna, which is used to broadcast data corrections from the base receiver to a rover receiver. The rover receiver is used in a kinematic fashion, receiving data corrections from the base in “real-time” to derive position and elevation of an objective point (Rydlund and Densmore, 2012).

Several factors affect the vertical accuracy of these GNSS surveys, including wave action from wind at observed point locations, current satellite geometry, and various other factors (for example, multipath errors and signal degradation from vegetation cover) interfering with the base-to-rover communication. Typically, single-base RTK equipment vertical accuracies, assuming a minimum of five satellites and Position Dilution of Precision (PDOP) less than 4, are generally 0.066 feet (ft) plus or minus 1 part per million at the 68-percent confidence level (Rydlund and Densmore, 2012).

The RTK base station was deployed for each survey on the closest NGS marker (<http://www.ngs.noaa.gov/>) to each reach (figs. 1A–1D; table 1). Elevation verification shots were collected during each survey on at least two NGS markers. All verification shots were located within 4 mi of each surveyed reach (figs. 1A–1D).

Position and elevation data were collected at seven observation points along each of the reaches during each survey, except for two surveys on the Maple River where only six points were measured because one point location was inaccessible during low-flow conditions. No permanent markers were established at the seven locations, so a handheld Global Positioning System was used to locate previously observed location points within about 20 ft from one survey to the next survey. At some locations on the Sheyenne and Wild Rice Rivers, elevation reference points were established on bridges and tape-down measurements were made from these reference points to calculate water-surface elevation. Within the Sheyenne River reach, a USGS streamflow gaging station exists at SR7 (station number 05059300, fig. 1B). A wire-weight gage at SR7 was read and converted to elevation during some visits rather than a tape down. A wire-weight gage is a device where a weight suspended on a wire is lowered to the water surface from a bridge or other overhead structure to measure the distance from a point of known elevation on the bridge to the water surface.

Discharge Measurements

At each of the four river reaches, discharge measurements were made at preselected sites (figs. 1A–1D) with either an acoustic Doppler current profiler or conventional acoustic Doppler velocimeter (table 2). Discharge measurements were made following methods described in Turnipseed and Sauer (2010) and Mueller and others (2013). Discharge measurement data and streamflow gaging station data are available at <http://waterdata.usgs.gov/nd/nwis/>.

Water-Surface Elevations and Discharge Measurements

Water-surface elevations and discharge measurements were collected during a range of hydrologic conditions at selected reaches of the Red River of the North, Sheyenne, Wild Rice, and Maple Rivers (figs. 1A–1D) in the Fargo-Moorhead metropolitan area in WYs 2014–15 (fig. 2).

Red River of the North

The Red River of the North reach was surveyed six times in WYs 2014–15 (fig. 1A; tables 1 and 3). Discharge measurements were made at a single location (RR4) on the Red River of the North 50 ft below the mouth of Wolverton Creek during each survey (fig. 1A). Measured discharges ranged from 276 to 6,540 ft³/s (fig. 2; tables 2 and 3). Position and elevation data were collected at seven observation points along the reach during each survey (fig. 1A; table 3). A survey rod offset error of 3.34 ft was discovered when processing the data for the October 21, 2014, survey; and a correction was applied to the final elevation data.

Profiles of the water-surface elevations collected along the reach for the Red River of the North in WYs 2014–15 are shown in figure 3. The slope of the Red River of the North is generally flat with slopes ranging from 1.3 feet per mile (ft/mi) at Wahpeton, N. Dak., to 0.2 ft/mi at the international boundary (Red River Basin Board, 2000) and can be seen in the small water-surface elevation differences shown in figure 3. Water-surface elevation differences from upstream to downstream points in the reach ranged from 0.33 ft on September 2, 2015, at a discharge of 276 ft³/s to 1.45 ft on June 20, 2014, at a discharge of 6,540 ft³/s. The water-surface elevation difference of the reach generally increased with increasing discharge (table 3; fig. 3). Among several elevation measurements along the reach, variability within the precision error of the RTK surveying method showed a slight negative slope between measurement points in some of the profiles (fig. 3).

Table 1. Location and verification of benchmarks used during reach surveys on the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.

[NGS, National Geodetic Survey; PID, position identification; NAVD 88, North American Vertical Datum of 1988; Geoid 12a, model for transforming heights between ellipsoidal coordinates and NAVD 88 orthometric heights; --, no data]

Measurement date	NGS designation/PID	Northing, in feet	Easting, in feet	Orthometric height, in feet (NAVD 88 determined from Geoid 12a)	Verification shot, in feet	Difference, in feet
Red River of the North						
06/20/2014	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	Base	--
06/20/2014	FMM 01/DN4355	16,981,598.862	2,186,977.277	913.794	913.750	-0.044
06/20/2014	STONEY/DM1839	17,003,152.992	2,199,424.420	910.040	910.041	0.001
10/21/2014	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	Base	--
10/21/2014	FMM 02/DN4356	16,981,557.246	2,184,298.432	932.110	932.160	0.050
10/21/2014	STONEY/DM1839	17,003,152.992	2,199,424.420	910.040	906.740	0.040 ^a
04/21/2015	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	Base	--
04/21/2015	FMM 03/DN4357	16,981,434.895	2,177,242.596	910.536	910.470	-0.066
05/27/2015	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	Base	--
05/27/2015	FMM 01/DN4355	16,981,598.862	2,186,977.277	913.794	913.749	-0.045
05/27/2015	STONEY/DM1839	17,003,152.992	2,199,424.420	910.040	910.017	-0.023
07/21/2015	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	Base	--
07/21/2015	FMM 01/DN4355	16,981,598.862	2,186,977.277	913.794	913.781	-0.013
07/21/2015	STONEY/DM1839	17,003,152.992	2,199,424.420	910.040	910.031	-0.009
09/02/2015	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	Base	--
09/02/2015	FMM 01/DN4355	16,981,598.862	2,186,977.277	913.794	913.715	-0.079
09/02/2015	STONEY/DM1839	17,003,152.992	2,199,424.420	910.040	910.075	0.035
Sheyenne River						
06/18/2014	FMM 07/DN4361	16,991,885.749	2,165,532.399	914.089	Base	--
06/18/2014	FMM 04/DN4358	16,981,350.434	2,171,125.375	913.151	913.160	0.009
06/18/2014	FMM 05/DN4359	16,981,224.781	2,165,711.885	914.257	914.265	0.008
04/21/2015	FMM 07/DN4361	16,991,885.749	2,165,532.399	914.089	Base	--
04/21/2015	FMM 05/DN4359	16,981,224.781	2,165,711.885	914.257	914.281	0.024
05/26/2015	FMM 07/DN4361	16,991,885.749	2,165,532.399	914.089	Base	--
05/26/2015	FMM 04/DN4358	16,981,350.434	2,171,125.375	913.151	913.066	-0.085
05/26/2015	FMM 05/DN4359	16,981,224.781	2,165,711.885	914.257	914.279	0.022
05/26/2015	FMM 09/DN4363	17,002,992.292	2,165,491.160	908.751	908.733	-0.018
07/20/2015	FMM 07/DN4361	16,991,885.749	2,165,532.399	914.089	Base	--
07/20/2015	FMM 04/DN4358	16,981,350.434	2,171,125.375	913.151	913.173	0.022
07/20/2015	FMM 05/DN4359	16,981,224.781	2,165,711.885	914.257	914.291	0.034
08/17/2015	FMM 07/DN4361	16,991,885.749	2,165,532.399	914.089	Base	--
08/17/2015	FMM 04/DN4358	16,981,350.434	2,171,125.375	913.151	913.178	0.027
08/17/2015	FMM 05/DN4359	16,981,224.781	2,165,711.885	914.257	914.298	0.041
10/22/2015	FMM 07/DN4361	16,991,885.749	2,165,532.399	914.089	Base	--
10/22/2015	FMM 05/DN4359	16,981,224.781	2,165,711.885	914.257	914.232	-0.025

6 Water-Surface Elevation and Discharge Measurement Data, Red River of the North and its Tributaries

Table 1. Location and verification of benchmarks used during reach surveys on the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.—Continued

[NGS, National Geodetic Survey; PID, position identification; NAVD 88, North American Vertical Datum of 1988; Geoid 12a, model for transforming heights between ellipsoidal coordinates and NAVD 88 orthometric heights; --, no data]

Measurement date	NGS designation/PID	Northing, in feet	Easting, in feet	Orthometric height, in feet (NAVD 88 determined from Geoid 12a)	Verification shot, in feet	Difference, in feet
Wild Rice River						
06/19/2014	FMM 03/DN4357	16,981,434.895	2,177,242.596	910.536	Base	--
06/19/2014	FMM 02/DN4356	16,981,557.246	2,184,298.432	935.450	935.445	-0.005
06/19/2014	FMM 07/DN4361	16,991,885.749	2,165,532.399	914.089	914.067	-0.022
10/29/2014	FMM 03/DN4357	16,981,434.895	2,177,242.596	910.536	Base	--
10/29/2014	FMM 01/DN4355	16,981,598.862	2,186,977.277	913.794	913.754	-0.040
10/29/2014	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	909.679	0.039
05/21/2015	FMM 03/DN4357	16,981,434.895	2,177,242.596	910.536	Base	--
05/21/2015	FMM 02/DN4356	16,981,557.246	2,184,298.432	935.450	935.464	0.014
05/21/2015	FMM 07/DN4361	16,991,885.749	2,165,532.399	914.089	914.135	0.046
05/21/2015	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	909.675	0.035
07/20/2015	FMM 03/DN4357	16,981,434.895	2,177,242.596	910.536	Base	--
07/20/2015	FMM 01/DN4355	16,981,598.862	2,186,977.277	913.794	913.803	0.009
07/20/2015	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	909.712	0.072
08/17/2015	FMM 03/DN4357	16,981,434.895	2,177,242.596	910.536	Base	--
08/17/2015	FMM 01/DN4355	16,981,598.862	2,186,977.277	913.794	913.824	0.030
08/17/2015	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	909.702	0.062
09/02/2015	FMM 03/DN4357	16,981,434.895	2,177,242.596	910.536	Base	--
09/02/2015	FMM 01/DN4355	16,981,598.862	2,186,977.277	913.794	913.794	0.000
09/02/2015	J 506/RP1147	16,986,966.672	2,192,086.338	909.640	909.690	0.050
Maple River						
10/30/2014	FMM 21/DN4375	17,060,458.745	2,163,815.360	895.034	Base	--
10/30/2014	FMM 19/DN4373	17,049,825.817	2,164,222.513	896.334	896.371	0.037
10/30/2014	FMM 20/DN4374	17,055,018.939	2,163,973.282	895.599	895.580	-0.019
05/27/2015	FMM 21/DN4375	17,060,458.745	2,163,815.360	895.034	Base	--
05/27/2015	FMM 20/DN4374	17,055,018.939	2,163,973.282	895.599	895.610	0.011
05/27/2015	FMM 22/DN4376	17,068,320.591	2,163,732.106	897.593	897.621	0.028
07/21/2015	FMM 21/DN4375	17,060,458.745	2,163,815.360	895.034	Base	--
07/21/2015	FMM 20/DN4374	17,055,018.939	2,163,973.282	895.599	895.516	-0.083
07/21/2015	FMM 22/DN4376	17,068,320.591	2,163,732.106	897.593	897.529	-0.064
09/03/2015	FMM 21/DN4375	17,060,458.745	2,163,815.360	895.034	Base	--
09/03/2015	FMM 20/DN4374	17,055,018.939	2,163,973.282	895.599	895.592	-0.007
09/03/2015	FMM 22/DN4376	17,068,320.591	2,163,732.106	897.593	897.583	-0.010

^aCorrected for rod error of 3.340.

Table 2. Discharge measurement summary for selected reaches on the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.

[NAVD 88, North American Vertical Datum of 1988; Geoid 12a, model for transforming heights between ellisoidal coordinates and NAVD 88 orthometric heights]

Measurement number	Measurement date	Mean velocity, in feet per second	Width, in feet	Area, in square feet	Discharge, in cubic feet per second	Orthometric height, in feet (NAVD 88 determined from Geoid 12a)	Latitude, in decimal degrees	Longitude, in decimal degrees
Red River of the North								
1	06/20/14	2.07	219	3,160	6,540	899.63	46.712957	-96.785151
2	10/21/14	1.01	124	851	860	883.81	46.712227	-96.783544
3	04/21/15	1.01	105	585	590	882.73	46.712040	-96.783440
4	05/27/15	1.62	136	1,280	2,080	888.34	46.709580	-96.789770
5	07/21/15	1.27	121	904	1,140	885.34	46.709600	-96.789718
6	09/02/15	0.79	95.5	351	276	880.83	46.709171	-96.789673
Sheyenne River								
1	06/18/14	2.25	82.8	715	1,600	915.81	46.717352	-96.945016
2	06/18/14	1.86	85.3	875	1,630	912.86	46.746426	-96.927127
3	10/22/14	1.70	79.2	465	791	912.06	46.717352	-96.945016
4	10/22/14	1.28	77.1	585	748	909.40	46.746427	-96.927126
5	04/21/15	1.00	47.4	167	166	907.28	46.717350	-96.945020
6	04/21/15	1.02	47.6	170	171	903.95	46.746430	-96.927140
7	05/26/15	2.39	88.1	856	2,040	917.00	46.717350	-96.945020
8	05/26/15	2.17	85.3	909	1,970	913.44	46.746420	-96.927140
9	07/20/15	1.28	84.5	665	846	912.36	46.717352	-96.945015
10	07/20/15	1.66	77	510	846	909.53	46.746425	-96.927142
11	08/17/15	1.08	48.4	176	189	908.04	46.714520	-96.947040
12	08/17/15	0.78	57.1	244	191	902.69	46.746430	-96.927130
Wild Rice River								
1	06/19/14	1.75	110	791	1,380	899.21	46.700504	-96.841160
2	06/19/14	1.70	125	908	1,550	897.68	46.716995	-96.820572
3	10/29/14	0.59	23.4	29.1	17.1	891.05	46.702512	-96.837994
4	05/21/15	1.61	81.6	278	442	894.74	46.702520	-96.838390
5	07/20/15	1.45	45.7	134	194	893.04	46.702500	-96.838040
6	08/17/15	0.54	30.5	51.8	28.0	891.28	46.702571	-96.837962
7	09/02/15	0.26	32.0	49.3	13.0	890.90	46.700504	-96.841160
Maple River								
1	10/30/14	1.26	35.5	23.8	30.1	882.45	46.930644	-96.967327
2	05/27/15	2.33	52.2	263	633	888.35	46.930590	-96.966810
3	07/21/15	1.80	36.0	59.5	107	890.90	46.927612	-96.946077
4	09/03/15	0.58	27.5	28.5	16.4	881.97	46.930609	-96.967232

8 Water-Surface Elevation and Discharge Measurement Data, Red River of the North and its Tributaries

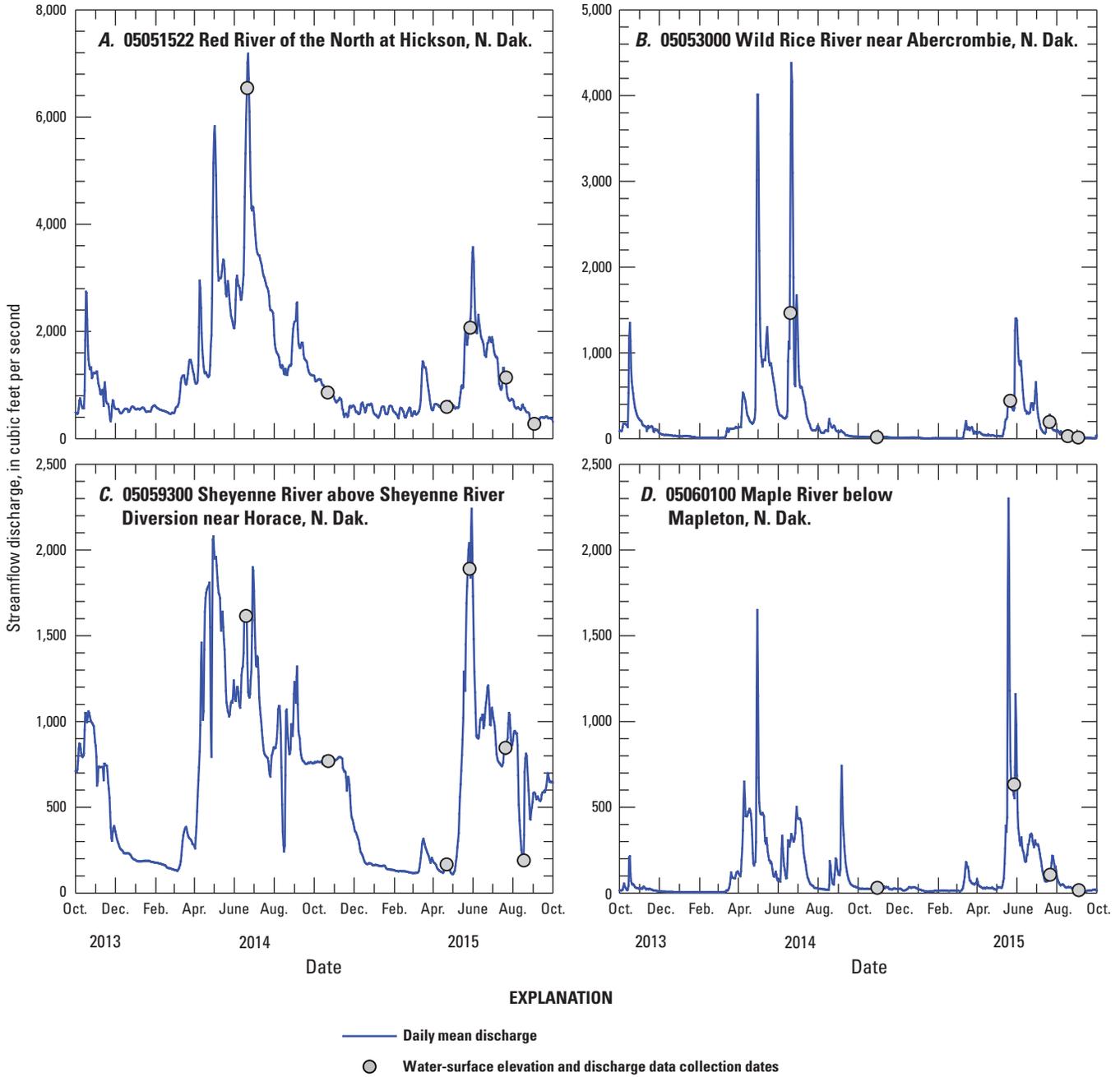


Figure 2. Daily mean discharge and data collection dates for the Red River of the North, Sheyenne River, Wild Rice River, and Maple River near Fargo, North Dakota, water years 2014–15.

Table 3. Water-surface elevations and discharge measurements made on the Red River of the North near Fargo, North Dakota, water years 2014–15.

[NAVD 88, North American Vertical Datum of 1988; --, no data, RTK, real-time kinematic]

Point name	Measurement date	Latitude, in decimal degrees	Longitude, in decimal degrees	Water-surface elevation, in feet above NAVD 88	Discharge, in cubic feet per second	Measurement description
RR1	06/20/14	46.702849	-96.791407	900.11	--	RTK
RR2	06/20/14	46.706490	-96.783446	899.92	--	RTK
RR3	06/20/14	46.709936	-96.789792	899.89	--	RTK
RR4	06/20/14	46.712957	-96.785151	899.63	6,540	RTK
RR5	06/20/14	46.716469	-96.781729	899.48	--	RTK
RR6	06/20/14	46.718065	-96.791356	899.19	--	RTK
RR7	06/20/14	46.726642	-96.778710	898.66	--	RTK
RR1	10/21/14	46.702861	-96.791143	884.36	--	RTK
RR2	10/21/14	46.706527	-96.783635	884.14	--	RTK
RR3	10/21/14	46.709597	-96.789242	883.97	--	RTK
RR4	10/21/14	46.712227	-96.783544	883.81	860	RTK
RR5	10/21/14	46.716534	-96.781926	883.82	--	RTK
RR6	10/21/14	46.717369	-96.790319	883.64	--	RTK
RR7	10/21/14	46.726586	-96.778792	883.20	--	RTK
RR1	04/21/15	46.703230	-96.791460	882.86	--	RTK
RR2	04/21/15	46.706200	-96.783960	882.90	--	RTK
RR3	04/21/15	46.709480	-96.789710	882.68	--	RTK
RR4	04/21/15	46.712040	-96.783440	882.73	590	RTK
RR5	04/21/15	46.716520	-96.781950	882.54	--	RTK
RR6	04/21/15	46.717360	-96.790300	882.41	--	RTK
RR7	04/21/15	46.726570	-96.778810	882.08	--	RTK
RR1	05/27/15	46.702890	-96.791240	888.65	--	RTK
RR2	05/27/15	46.706500	-96.783560	888.70	--	RTK
RR3	05/27/15	46.709580	-96.789770	888.34	--	RTK
RR4	05/27/15	46.711940	-96.783310	888.42	2,080	RTK
RR5	05/27/15	46.716640	-96.781790	888.01	--	RTK
RR6	05/27/15	46.717340	-96.790340	887.87	--	RTK
RR7	05/27/15	46.726630	-96.778750	887.35	--	RTK
RR1	07/21/15	46.702813	-96.791109	885.26	--	RTK
RR2	07/21/15	46.706578	-96.783654	885.04	--	RTK
RR3	07/21/15	46.709600	-96.789718	885.34	--	RTK
RR4	07/21/15	46.712040	-96.783420	884.94	1,140	RTK
RR5	07/21/15	46.716490	-96.781967	884.88	--	RTK
RR6	07/21/15	46.717325	-96.790177	884.61	--	RTK
RR7	07/21/15	46.726544	-96.778805	884.23	--	RTK
RR1	09/02/15	46.702959	-96.791236	880.77	--	RTK
RR2	09/02/15	46.706423	-96.783605	880.74	--	RTK
RR3	09/02/15	46.709171	-96.789673	880.83	--	RTK
RR4	09/02/15	46.711864	-96.783344	880.62	276	RTK
RR5	09/02/15	46.716453	-96.782136	880.52	--	RTK
RR6	09/02/15	46.717310	-96.790000	880.47	--	RTK
RR7	09/02/15	46.726571	-96.778821	880.44	--	RTK

10 Water-Surface Elevation and Discharge Measurement Data, Red River of the North and its Tributaries

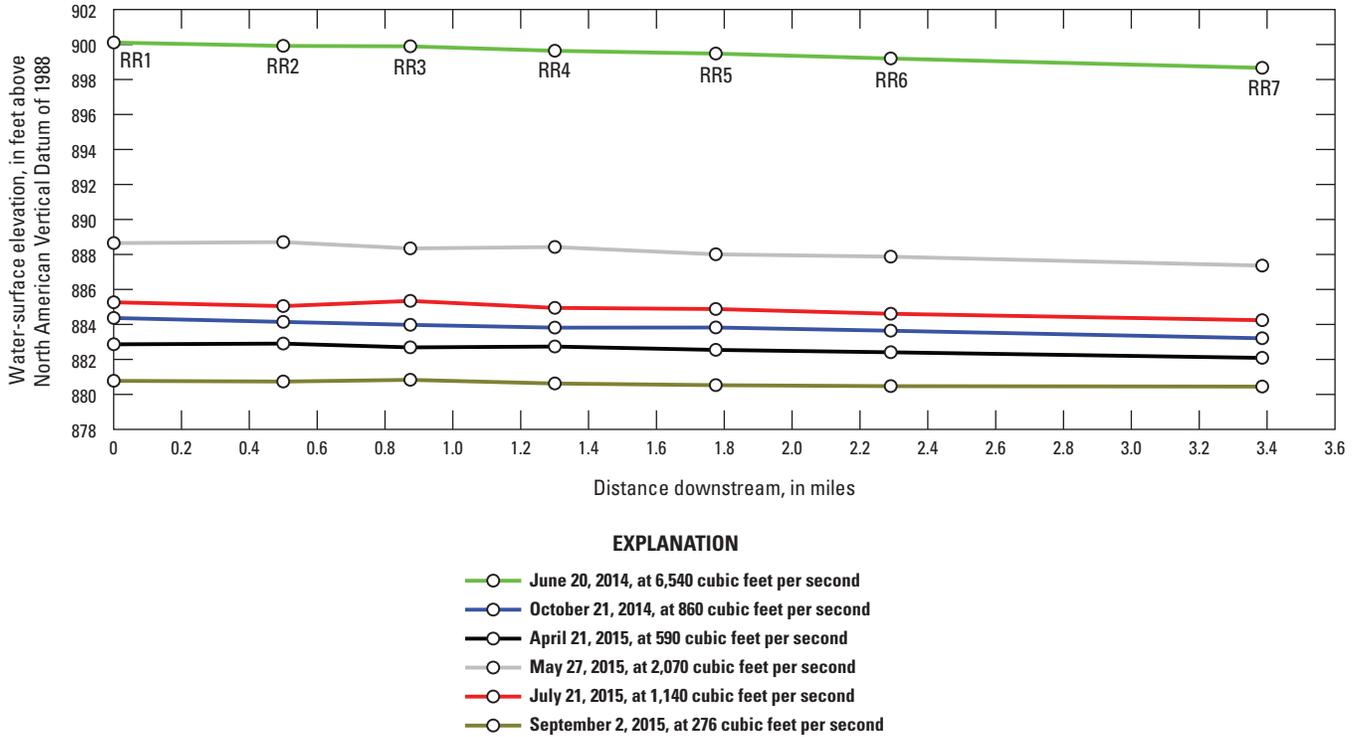


Figure 3. Water-surface profiles from measurements made on the Red River of the North near Fargo, North Dakota, water years 2014–15.

Sheyenne River

The Sheyenne River reach was surveyed six times in WYs 2014–15 (fig. 1B; tables 1 and 4). Discharge measurements were collected at two locations during each survey (fig. 1B; table 2). Because access was limited at the point of interest for measuring discharge, locations upstream and downstream were selected for measurements instead. The average of the two discharge measurements (measured at SR2 and SR7) was used as the discharge for the point of interest (SR5) within the reach. Measured discharges ranged from 166 to 2,040 ft³/s (tables 2 and 4). Position and elevation data were

collected at seven observation points along the reach during each survey (fig. 1B; table 4).

Profiles of the water-surface elevations collected along the reach for the Sheyenne River are shown in figure 4. Water-surface elevation differences were greater than those measured on the Red River of the North; differences from upstream to downstream points in the reach ranged from 3.15 ft on July 20, 2015, at a discharge of 846 ft³/s to 4.80 ft on April 21, 2015, at a discharge of 168 ft³/s (table 4; fig. 4). The April 21, 2015 elevation for SR1 was affected by new bridge construction on Cass County Road 36. Construction crews were backing up and diverting flow during bridge construction.

Table 4. Water-surface elevations and discharge measurements made on the Sheyenne River near Fargo, North Dakota, water years 2014–15.

NAVD 88, North American Vertical Datum of 1988; --, no data, TD, tape down, RTK, real-time kinematic, WWT, wire-weight reading]

Point name	Measurement date	Latitude, in decimal degrees	Longitude, in decimal degrees	Reference point elevation, in feet above NAVD 88	Tape-down measurement, in feet	Water-surface elevation, in feet above NAVD 88	Discharge, in cubic feet per second	Measurement description
SR1	06/18/14	46.714465	-96.947048	927.598	10.34	917.26	--	TD
SR2	06/18/14	46.717352	-96.945016	929.218	13.41	915.81	1,600	TD
SR3	06/18/14	46.723605	-96.935340	--	--	914.34	--	RTK
SR4	06/18/14	46.731800	-96.932764	--	--	914.12	--	RTK
SR5	06/18/14	46.736896	-96.933068	--	--	913.67	1,620 ^a	RTK
SR6	06/18/14	46.746646	-96.933307	--	--	913.09	--	RTK
SR7	06/18/14	46.746426	-96.927127	923.377	--	912.86	1,630	WWT
SR1	10/22/14	46.714568	-96.947230	--	--	912.70	--	RTK
SR2	10/22/14	46.717352	-96.945016	929.218	17.16	912.06	791	TD
SR3	10/22/14	46.723429	-96.935846	--	--	910.96	--	RTK
SR4	10/22/14	46.731776	-96.932768	--	--	910.44	--	RTK
SR5	10/22/14	46.737940	-96.933173	--	--	909.92	769 ^a	RTK
SR6	10/22/14	46.746615	-96.932981	--	--	909.57	--	RTK
SR7	10/22/14	46.746427	-96.927126	923.377	--	909.40	748	WWT
SR1	04/21/15	46.714450	-96.947040	930.259	21.51	908.749 ^b	--	TD
SR2	04/21/15	46.717350	-96.945020	929.225	21.95	907.28	166	TD
SR3	04/21/15	46.723630	-96.935530	--	--	906.12	--	RTK
SR4	04/21/15	46.731740	-96.932730	--	--	905.32	--	RTK
SR5	04/21/15	46.738000	-96.932830	--	--	904.63	168 ^a	RTK
SR6	04/21/15	46.746530	-96.932790	--	--	904.35	--	RTK
SR7	04/21/15	46.746430	-96.927140	924.208	20.26	903.95	171	TD
SR1	05/26/15	46.714480	-96.947040	930.252	12.75	917.50	--	TD
SR2	05/26/15	46.717350	-96.945020	929.164	12.16	917.00	2,040	TD
SR3	05/26/15	46.723490	-96.935440	--	--	915.92	--	RTK
SR4	05/26/15	46.731800	-96.932790	--	--	915.20	--	RTK
SR5	05/26/15	46.737920	-96.932590	--	--	914.37	2,000 ^a	RTK
SR6	05/26/15	46.746670	-96.932620	--	--	913.84	--	RTK
SR7	05/26/15	46.746420	-96.927140	924.252	10.81	913.44	1,970	TD
SR1	07/20/15	46.714490	-96.947038	930.285	18.6	912.69	--	TD
SR2	07/20/15	46.717352	-96.945015	929.354	16.99	912.36	846	TD
SR3	07/20/15	46.723374	-96.935893	--	--	911.11	--	RTK
SR4	07/20/15	46.731769	-96.932788	--	--	910.72	--	RTK
SR5	07/20/15	46.737944	-96.933094	--	--	910.21	846 ^a	RTK
SR6	07/20/15	46.746577	-96.932648	--	--	909.64	--	RTK
SR7	07/20/15	46.746425	-96.927142	924.353	14.82	909.53	846	TD
SR1	08/17/15	46.714520	-96.947040	930.271	22.23	908.04	--	TD
SR2	08/17/15	46.717350	-96.945020	929.217	21.8	907.42	189	TD
SR3	08/17/15	46.723480	-96.935920	--	--	906.43	--	RTK
SR4	08/17/15	46.731750	-96.932730	--	--	905.66	--	RTK
SR5	08/17/15	46.737980	-96.933120	--	--	904.91	190 ^a	RTK
SR6	08/17/15	46.746530	-96.932740	--	--	904.58	--	RTK
SR7	08/17/15	46.746430	-96.927130	923.335	19.08	904.26	191	WWT

^aMean discharge for section.^bBridge construction affected water surface elevation.

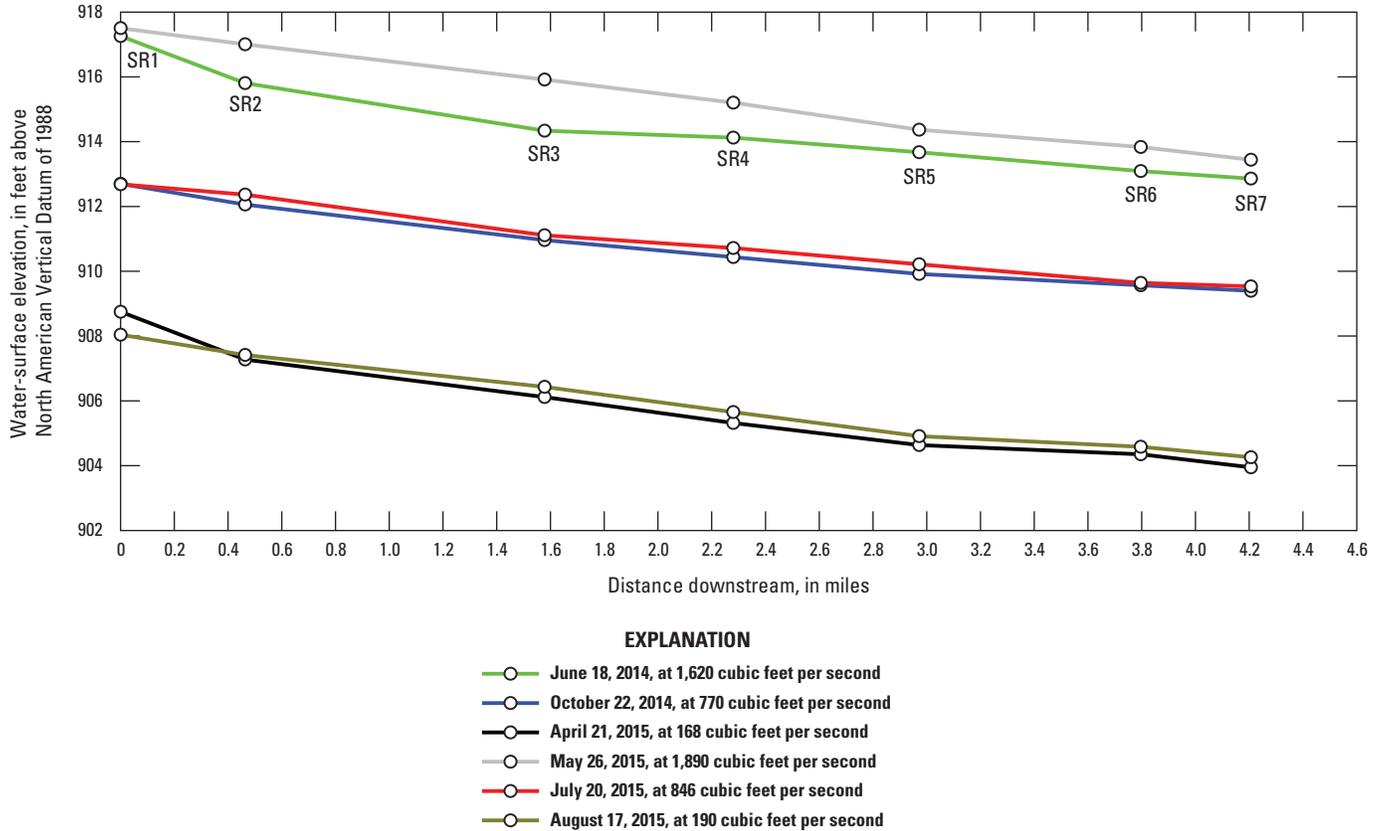


Figure 4. Water-surface profiles from measurements made on the Sheyenne River near Fargo, North Dakota, water years 2014–15.

Wild Rice River

The Wild Rice River reach was surveyed six times in WYs 2014–15 (fig. 1C; tables 1 and 5). Discharge measurements were collected at a single location (WR4) for five of the six surveys and at two locations (WR3 and WR6) for the survey on June 19, 2014, during a high-flow event (fig. 1C). The average of the two discharge measurements during the high-flow event was used as the discharge for the point of interest (WR4) within the reach (table 5). Measured discharges ranged from 13 to 1,550 ft³/s (tables 2 and 5). Position and elevation data were collected at seven observation points along the reach during each survey (fig. 1C; table 5).

Profiles of the water-surface elevations collected along the reach for the Wild Rice River are shown in figure 5. Water-surface elevation differences from upstream to downstream points in the reach ranged from 3.57 ft on September 2, 2015, at a discharge of 13 ft³/s to 5.85 ft on May 21, 2015, at a discharge of 442 ft³/s (table 5). There are two distinct rock and gravel riffles affecting the slope during low-flow conditions within the reach between WR5 and WR6 on the Wild Rice River (fig. 5; profiles measured on October 22, 2014, and August 17 and September 2, 2015). These riffles seem to be part of the bridge construction and are 20–50 ft upstream from the Interstate 29 Bridge and at the remediated 25th Street South Bridge 1.2 mi downstream (fig. 1).

Table 5. Water-surface elevations and discharge measurements made on the Wild Rice River near Fargo, North Dakota, water years 2014–15.

[NAVD 88, North American Vertical Datum of 1988; --, no data; TD, tape down; RTK, real-time kinematic]

Point name	Measurement date	Latitude, in decimal degrees	Longitude, in decimal degrees	Reference point elevation, in feet above NAVD 88	Tape-down measurement, in feet	Water-surface elevation, in feet above NAVD 88	Discharge, in cubic feet per second	Measurement description
WR1	06/19/14	46.673867	-96.855555	918.756	18.17	900.59	--	TD
WR2	06/19/14	46.688306	-96.847083	--	--	900.24	--	RTK
WR3	06/19/14	46.700504	-96.841160	915.106	15.90	899.21	1,380	TD
WR4	06/19/14	46.702649	-96.837991	--	--	898.87	1,460 ^a	RTK
WR5	06/19/14	46.711938	-96.830808	917.559	19.31	898.25	--	TD
WR6	06/19/14	46.716995	-96.820572	916.442	18.76	897.68	1,550	TD
WR7	06/19/14	46.726742	-96.819974	--	--	896.65	--	RTK
WR1	10/29/14	46.674039	-96.855613	--	--	892.10	--	RTK
WR2	10/29/14	46.688375	-96.847408	--	--	891.34	--	RTK
WR3	10/29/14	46.700598	-96.841053	--	--	891.05	--	RTK
WR4	10/29/14	46.702512	-96.837994	--	--	891.05	17.1	RTK
WR5	10/29/14	46.711958	-96.830933	--	--	890.84	--	RTK
WR6	10/29/14	46.717142	-96.820639	--	--	888.56	--	RTK
WR7	10/29/14	46.726620	-96.819988	--	--	888.41	--	RTK
WR1	05/21/15	46.673870	-96.855560	918.721	22.20	896.52	--	TD
WR2	05/21/15	46.688330	-96.847240	--	--	895.75	--	RTK
WR3	05/21/15	46.700500	-96.841160	915.122	20.33	894.79	--	TD
WR4	05/21/15	46.702520	-96.838390	--	--	894.74	442	RTK
WR5	05/21/15	46.711938	-96.830808	917.559	24.38	893.18	--	TD
WR6	05/21/15	46.716990	-96.820570	--	24.43	892.04	--	TD
WR7	05/21/15	46.726650	-96.820020	890.667	--	890.67	--	RTK
WR1	07/20/15	46.673930	-96.855670	--	--	894.17	--	RTK
WR2	07/20/15	46.688350	-96.847180	--	--	893.72	--	RTK
WR3	07/20/15	46.700610	-96.841330	--	--	893.23	--	RTK
WR4	07/20/15	46.702500	-96.838040	--	--	893.04	194	RTK
WR5	07/20/15	46.711970	-96.831030	--	--	892.52	--	RTK
WR6	07/20/15	46.716820	-96.820610	--	--	890.10	--	RTK
WR7	07/20/15	46.726630	-96.820010	--	--	889.40	--	RTK
WR1	08/17/15	46.673709	-96.855725	--	--	892.06	--	RTK
WR2	08/17/15	46.688376	-96.847407	--	--	891.46	--	RTK
WR3	08/17/15	46.700414	-96.841345	--	--	891.32	--	RTK
WR4	08/17/15	46.702571	-96.837962	--	--	891.28	28	RTK
WR5	08/17/15	46.711963	-96.830927	--	--	891.00	--	RTK
WR6	08/17/15	46.716824	-96.820632	--	--	888.34	--	RTK
WR7	08/17/15	46.726616	-96.820007	--	--	888.20	--	RTK
WR1	09/02/15	46.673867	-96.855555	--	--	891.59	--	RTK
WR2	09/02/15	46.688374	-96.847404	--	--	891.10	--	RTK
WR3	09/02/15	46.700504	-96.841160	--	--	890.90	--	RTK
WR4	09/02/15	46.702509	-96.837986	--	--	890.94	13	RTK
WR5	09/02/15	46.711959	-96.830860	--	--	890.67	--	RTK
WR6	09/02/15	46.716828	-96.820635	--	--	888.13	--	RTK
WR7	09/02/15	46.726610	-96.820008	--	--	888.02	--	RTK

^aMean discharge for section.

14 Water-Surface Elevation and Discharge Measurement Data, Red River of the North and its Tributaries

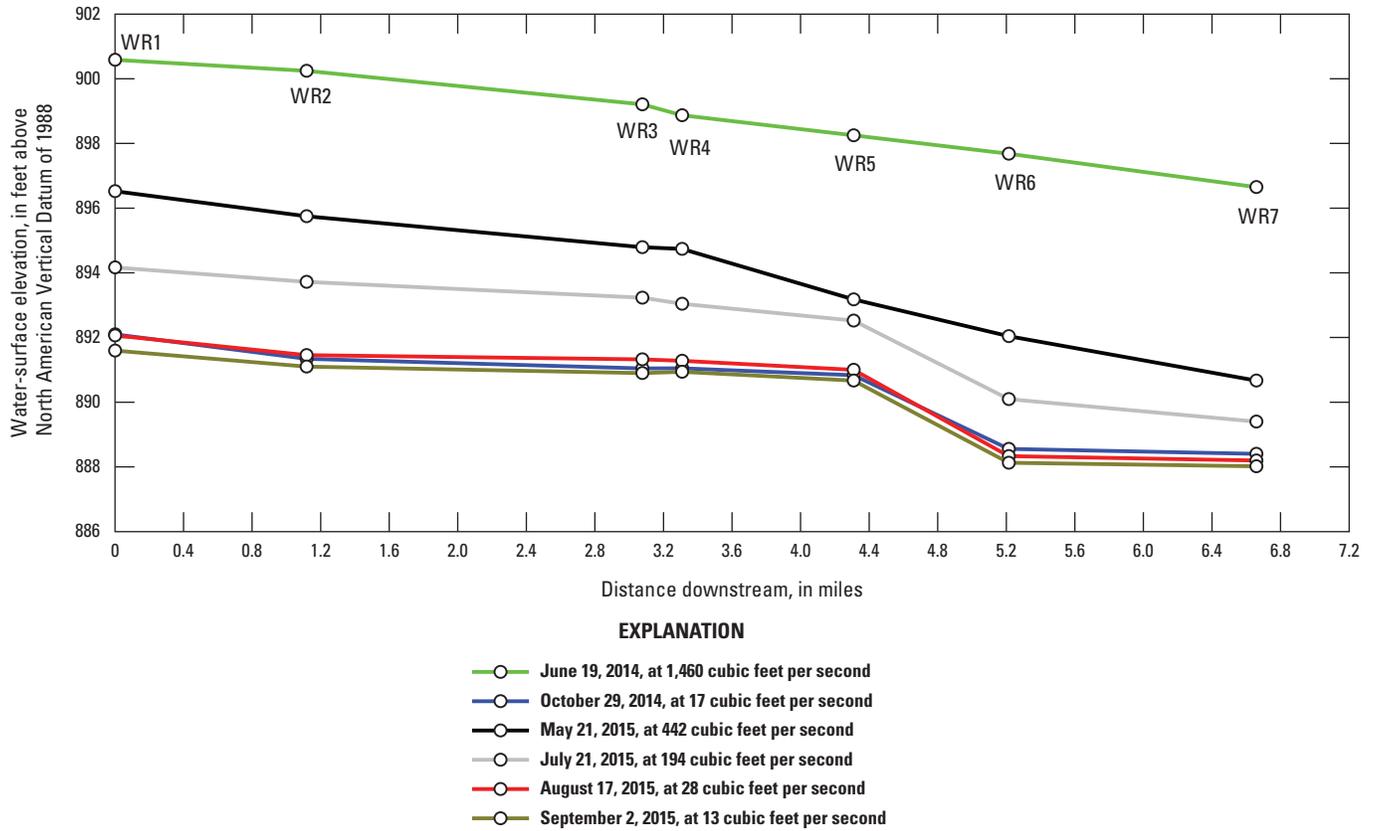


Figure 5. Water-surface profiles from measurements made on the Wild Rice River near Fargo, North Dakota, water years 2014–15.

Maple River

The Maple River reach was surveyed four times in WYs 2014–15 (fig. 1D; tables 1 and 6). Discharge measurements were collected at MR6 for three of the surveys and at MR5 for the survey on July 21, 2015 because MR6 was inaccessible (fig. 1D; table 6). Measured discharges ranged from 16.4 to 633 ft³/s (tables 2 and 6). Six surveys were planned, but only four surveys were completed because of issues with land access and frequent low-flow conditions. Position and elevation data were collected along six or seven observation points along the reach during each survey (fig. 1D; table 6). Some observation points were inaccessible during low-flow conditions.

Profiles of the water-surface elevations collected along the reach for the Maple River are shown in figure 6. Among all the reaches measured on the Red River of the North and its tributaries in WYs 2014–15 (fig. 1), the greatest water-surface elevation differences were measured on the Maple River reach. Water-surface elevation differences from upstream to downstream points in the Maple River reach ranged from 8.48 ft on May 27, 2015, at a discharge of 633 ft³/s, to 9.42 ft on September 3, 2015, at a discharge of 16.4 ft³/s (table 6). There is an abrupt change in water-surface elevation (about 3.4 to 6.8 ft) in the reach between MR2 and MR3 (fig. 6). From field observations, a small rubble dam 1 mi downstream from the 165th Avenue SE Bridge causes the abrupt change in the slope for flows less than about 2,000 ft³/s on the Maple River (fig. 6).

Table 6. Water-surface elevations and discharge measurements made on the Maple River near Fargo, North Dakota, water years 2014–15.

[NAVD 88, North American Vertical Datum of 1988; --, no data, RTK, real-time kinematic]

Point name	Measurement date	Latitude, in decimal degrees	Longitude, in decimal degrees	Water-surface elevation, in feet above NAVD 88	Discharge, in cubic feet per second	Measurement description
MR1	10/30/14	46.921513	-97.009946	890.62	--	RTK
MR2	10/30/14	46.921798	-96.997447	890.60	--	RTK
MR3	10/30/14	46.925869	-96.989176	884.26	--	RTK
MR6	10/30/14	46.930644	-96.967327	882.45	30.1	RTK
MR7	10/30/14	46.927617	-96.946110	881.48	--	RTK
MR8	10/30/14	46.929088	-96.927552	881.24	--	RTK
MR1	05/27/15	46.921510	-97.009810	893.13	--	RTK
MR2	05/27/15	46.921780	-96.997450	893.07	--	RTK
MR4	05/27/15	46.930240	-96.983540	889.63	--	RTK
MR5	05/27/15	46.925410	-96.974130	888.82	--	RTK
MR6	05/27/15	46.930590	-96.966810	888.35	633	RTK
MR7	05/27/15	46.927710	-96.945870	886.62	--	RTK
MR8	05/27/15	46.929270	-96.927670	884.59	--	RTK
MR1	07/21/15	46.921503	-97.009947	891.10	--	RTK
MR3	07/21/15	46.925826	-96.989096	885.13	--	RTK
MR4	07/21/15	46.927612	-96.946077	884.75	--	RTK
MR5	07/21/15	46.929137	-96.927463	884.00	107	RTK
MR7	07/21/15	46.930190	-96.983477	882.33	--	RTK
MR8	07/21/15	46.925381	-96.974506	881.70	--	RTK
MR1	09/03/15	46.921514	-97.009924	890.42	--	RTK
MR2	09/03/15	46.921776	-96.997671	890.53	--	RTK
MR3	09/03/15	46.925830	-96.989077	883.72	--	RTK
MR6	09/03/15	46.930609	-96.967232	881.97	16.4	RTK
MR7	09/03/15	46.927623	-96.946149	881.11	--	RTK
MR8	09/03/15	46.929133	-96.927477	881.00	--	RTK

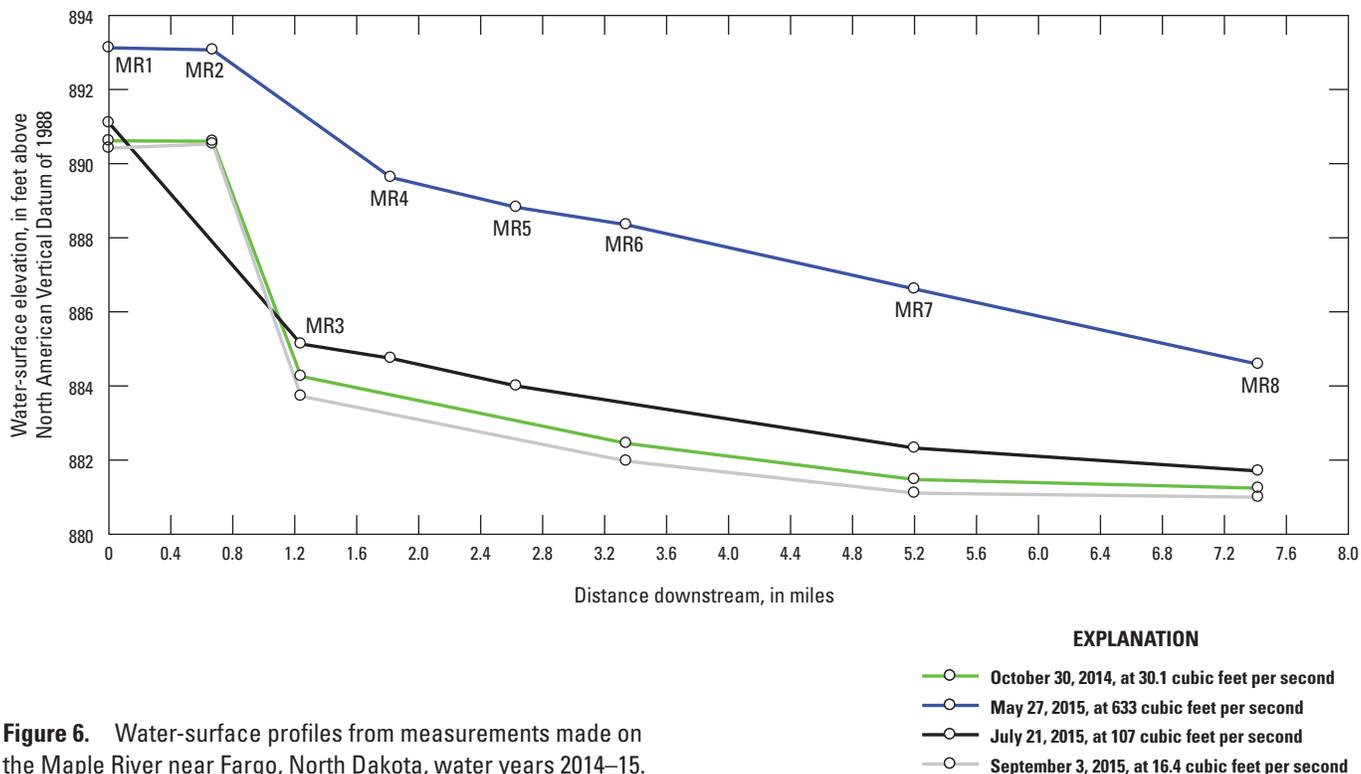


Figure 6. Water-surface profiles from measurements made on the Maple River near Fargo, North Dakota, water years 2014–15.

Summary

For design planning of diversion structures proposed on the Red River of the North and Wild Rice River and the aqueduct/diversion structures proposed on the Sheyenne and Maple Rivers, the U.S. Geological Survey, in cooperation with the Fargo Diversion Board of Authority, collected water-surface elevations during a range of discharges needed for calibration of hydrologic and hydraulic models for specific reaches of interest in water years 2014–15. The Red River of the North and the Sheyenne River reaches were surveyed six times, and discharges ranged from 276 to 6,540 cubic feet per second and from 166 to 2,040 cubic feet per second, respectively. Water-surface elevation differences from upstream to downstream points in the Red River of the North reach ranged from 0.33 to 1.45 feet. Water-surface elevation differences were greater on the Sheyenne River reach than those measured on the Red River of the North; differences from upstream to downstream points in the reach ranged from 3.15 to 4.80 feet. The Wild Rice River reach also was surveyed six times, and discharges ranged from 13 to 1,550 cubic feet per second; and water-surface elevation differences from upstream to downstream points ranged from 3.57 to 5.85 feet. The Maple River reach was surveyed four times, and discharges ranged from 16.4 to 633 cubic feet per second; and water-surface elevation differences from upstream to downstream points ranged from 8.48 to 9.42 feet.

References Cited

- Flood Diversion Authority, 2015, F–M area diversion: F–M Area Diversion Web page, accessed October 15, 2015, at <http://www.fmdiversion.com/>.
- Mueller, D.S., Wagner, C.R., Rehmel, M.S., Oberg, K.A., and Rainville, Francois, 2013, Measuring discharge with acoustic Doppler current profilers from a moving boat (ver. 2.0, December 2013): U.S. Geological Survey Techniques and Methods, book 3, chap. A22, 95 p. [Also available at <http://dx.doi.org/10.3133/tm3A22/>.]
- Red River Basin Board, 2000, Inventory team report—Hydrology: Red River Basin Board, accessed on February 26, 2015, at <http://www.redriverbasincommission.org/Reports/reports.html>.
- Rydland, P.H., Jr., and Densmore, B.K., 2012, Methods of practice and guidelines for using survey-grade global navigation satellite systems (GNSS) to establish vertical datum in the United States Geological Survey: U.S. Geological Survey Techniques and Methods, book 11, chap. D1, 102 p. with appendixes. [Also available at <http://pubs.usgs.gov/tm/11d1/>.]
- Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods, book 3, chap. A8, 87 p. [Also available at <http://pubs.usgs.gov/tm/tm3-a8/>.]

