Chloride Flux and Surface Water Discharge out of Yellowstone National Park, 1982–1989

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Chloride Flux and Surface Water Discharge out of Yellowstone National Park, 1982–1989

By DANIEL R. NORTON and IRVING FRIEDMAN

Tabulation of discharge, chloride concentration and chloride flux for the rivers and streams yields information related to heat flux from the Park

U.S. GEOLOGICAL SURVEY BULLETIN 1959

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1991

For sale by the
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Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Norton, Daniel R.
Chloride flux and surface water discharge out of Yellowstone National Park, 1982–1989 : tabulation of discharge, chloride concentration, and chloride flux for the rivers and streams yields information related to heat flux from the park / by Daniel R. Norton and Irving Friedman.
p. cm. — (U.S. Geological Survey bulletin ; 1959)
Includes bibliographical references.
Supt. of Docs. no.: I 19.16:1959
1. Chlorides. 2. Geochemistry—Yellowstone National Park. 3. Hot springs—Yellowstone National Park. 4. Yellowstone National Park. I. Friedman, Irving, 1920– . II. Title. III. Series.
QE75.B9 no. 1959
[QE516.C5]
557.3 s—dc20 90–20757
[551.9'09787'5] CIP

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Chloride Flux and Surface Water Discharge out of Yellowstone National Park, 1982–1989

By Daniel R. Norton *and* Irving Friedman

Abstract

Chloride flux out of Yellowstone National Park (the Park) was calculated by the product of discharge and chloride concentration for the major rivers draining the Park. Additional chloride flux from the western boundary of the Park was also assessed. Improvement in the established chloride determination protocol resulted in an accuracy of 1–3 percent for chloride concentration measurement. The instantaneous river discharges and chloride flux values were integrated to give monthly and annual values for water years 1983–1989. Comparison of the annual discharges for these water years with discharges in the long-term record show that discharges during the years of our study were not exceptional.

All the rivers show seasonal variations in discharge and chloride flux that correspond to snowmelt runoff in the spring and to changes in precipitation. Our data show high positive correlations between river discharge and chloride flux. The rivers that drain major thermal areas reveal marked short-time changes in river discharge and chloride flux that are unrelated to seasonal effects. We attribute these changes to variations in thermal activity of the related geyser basins. These variations in thermal activity may be due to tectonic changes triggered by earthquakes or to other events that affect the rate at which magma-generated chloride reaches the surface.

Data generated during the 7-year period of our study show that large annual changes occur in the chloride flux exiting the Park. Most of these changes are attributed to changes in height of the water table caused by variations in precipitation. Because of these large annual changes in chloride flux, long-term records of chloride flux are required to separate changes attributable to climate from those caused by geological events or by the influence of human activity such as energy-resource development.

During the period of our study we observed a decline in the minimum discharge or base flow of all the rivers, which reflects long-term reduced precipitation.

Approximately 94 percent of the chloride flux in waters out of Yellowstone National Park is considered to be of geothermal origin (Norton and Friedman, 1985). Because the geothermal chloride flux is directly related to heat flux, we determined how much heat flux (in percent of the total from the Park) is contributed by the drainage basins of the following thermal areas of the Park: Firehole River (34 percent); Yellowstone River (30 percent; Snake River (12 percent); Falls River (10 percent); Gibbon River (8 percent); and west side of the Park into the Island Park Geothermal Area (6 percent).

Discharge records of the major rivers draining the Park were used to calculate the annual precipitation for each of the same river drainage basins. This calculation shows that the average annual precipitation over these 7 years of our study was 82 centimeters (cm) for the Falls drainage, 41 cm for the Madison, 179 cm for the Snake, and 38 cm for the Yellowstone.

INTRODUCTION

Most of the chloride in waters of geothermal origin is magmatic. In Yellowstone National Park, in addition to this magmatic source, minor sources, including human waste, atmospheric precipitation, and weathering of rocks, contribute a maximum of 6 percent to the total chloride flux exiting the Park (Norton and Friedman, 1985). Therefore, a study of variations in this flux from Yellowstone National Park can be used to establish a baseline to determine responses of this measured component to climate changes, earthquakes, and to other tectonic events. In addition, this information can be used to obtain baseline data that will serve in the future to assess adverse impacts on the thermal features of the Park from proposed commercial development of geothermal, oil, and gas resources adjacent to the Park. Inasmuch as the major portion of the chloride exits the Park through four major rivers, these rivers serve as convenient vehicles for measuring most of the chloride flux from the Park.

In a previous paper, Norton and Friedman (1985) discussed chloride flux out of Yellowstone National Park from September 1982 to January 1984. We monitored chloride flux by measuring chloride concentrations and discharges of the four major rivers of the Park. Because this previous study was limited to only one annual cycle, we

Manuscript approved for publication September 10, 1990.

wanted to continue the study of changes in chloride flux and discharge over a longer period of time. In addition to the Falls, Madison, Snake, and Yellowstone Rivers monitored in our earlier study, we added sites on the Firehole and Gibbon Rivers, which drain the major geyser basins of the Park. The data from these two rivers serve to monitor the discharge of thermal waters from these major, deep-seated thermal features.

The current study, a cooperative effort between the U.S. Geological Survey and the National Park Service, includes data from the water years 1983–1989 as well as the data for 1983 previously published by Norton and Friedman (1985). This published chloride flux data was recalculated using improved protocols. On figure 1 we plotted the data as given in the previous paper and the data as recalculated using the current protocols. The differences are minor, except for the Madison River for November through January. We later found the discharge data for the Madison used in our 1985 paper to be in error, so we corrected the data.

Definition of Water Year

All reported values of annual fluxes are calculated for the water year, which is defined as 12 months beginning with October 1.

Acknowledgments

The authors wish to acknowledge the contributions made by members of the staffs of the National Park Service and the U.S. Geological Survey (USGS) in this long-term collaborative project between these two agencies. Within the Park Service, John D. Varley, Chief of Research, Yellowstone National Park, was primarily involved in the planning, coordination, and support of this project. Within the Water Resources Division of the USGS, extensive hydrologic support was given by members of the district offices in Montana and Idaho. In Montana we had the support and assistance of Joseph A. Moreland and Ronald R. Shields and their associates. Hydrologists who made valuable contributions to this work are Philip L. Karper, Scott Quimby, Stephen V. Lynn, Norman Midtling, and Andrew R. Skerda. In Idaho we had the support and assistance of Robert W. Harper, Nathan D. Jacobson and their staff. Hydrologists who also contributed to this work are Robert W. Erickson, Owen E. McLaughlin, Stanley G. Landon, and John B. Evans.

We are grateful to the staff of the U.S. Geological Survey's National Water Quality Laboratory for their support and guidance in the automated chloride determinations. Of particular value were the supervisory groups led by James M. Schoen and Harold D. Ardourel. Analysts who contributed to this work are D.M.C. Wisniewski, Betty McLain, Carl M. Harris, Amy A. Ludtke, and James R. Dobbs. Within the USGS we wish to acknowledge Deanne F. Moore, Deidre J. Scanlon, David C. Guerin, Brian R. Espinoza, Augusta Warden, and Karen E. Slaughter who provided support in sample procurement, data logging, and processing for chemical analysis.

Finally, we acknowledge the dedication of contract collectors for the major rivers and tributaries in this study. Without their able assistance we would not have had the many samples per site required for the integration of chloride flux throughout each of the 7 years of this study. These persons are listed as follows under the names of the river sites for which they provided samples: Snake River samples collected by D.R. McCreight and Cynthia F. Mernin; Falls River samples collected by Viola Lenz; Madison River samples collected by Elizabeth Laden and Karen Bennett; Firehole and Gibbon River samples collected by Karen N. Kennedy, Karen Bennett, Patricia S., Castles, and Shirley A. Wayland; and Yellowstone River samples collected by Mauray M. Miller.

Critical reviews were made by Robert O. Fournier and Yousef K. Kharaka. We thank Diane C. Schnabel for her many suggestions and skillful editing of this paper.

SITE DESCRIPTIONS

The location of the gauging sites are shown on figure 2, and the sites are described in table 1. All the sites are official U.S. Geological Survey gauging stations. Sites for discharge measurements were selected on the Snake, Falls, Madison, and Yellowstone Rivers, which are the four major rivers draining the Park. The Madison River was gauged from September 1982 to October 1986. After this station was discontinued, we used the sites on the Firehole and Gibbon Rivers to calculate discharge and chloride flux for the Madison River. The Firehole and Gibbon Rivers were gauged several kilometers (km) above their confluence where the Madison River originates. The gauging site on the Madison River was 24 km from this confluence. For 22 months all three rivers (Madison, Firehole, and Gibbon) were monitored, which allowed us to compare the discharge and chloride flux from the Madison River with the sum of the values for the other two rivers. This relationship will be discussed in a later section.

Water sampling sites were located near the gauging sites with the exception of the one on the Yellowstone River. To avoid chloride input from La Duke Hot Spring, 3.2 km upstream from the gauging site, this water sampling site was located about 1 km upstream from the hot spring.

FIELD MEASUREMENTS AND SAMPLING

Discharge measurements were made by the U.S. Geological Survey using standard hydrologic methods and

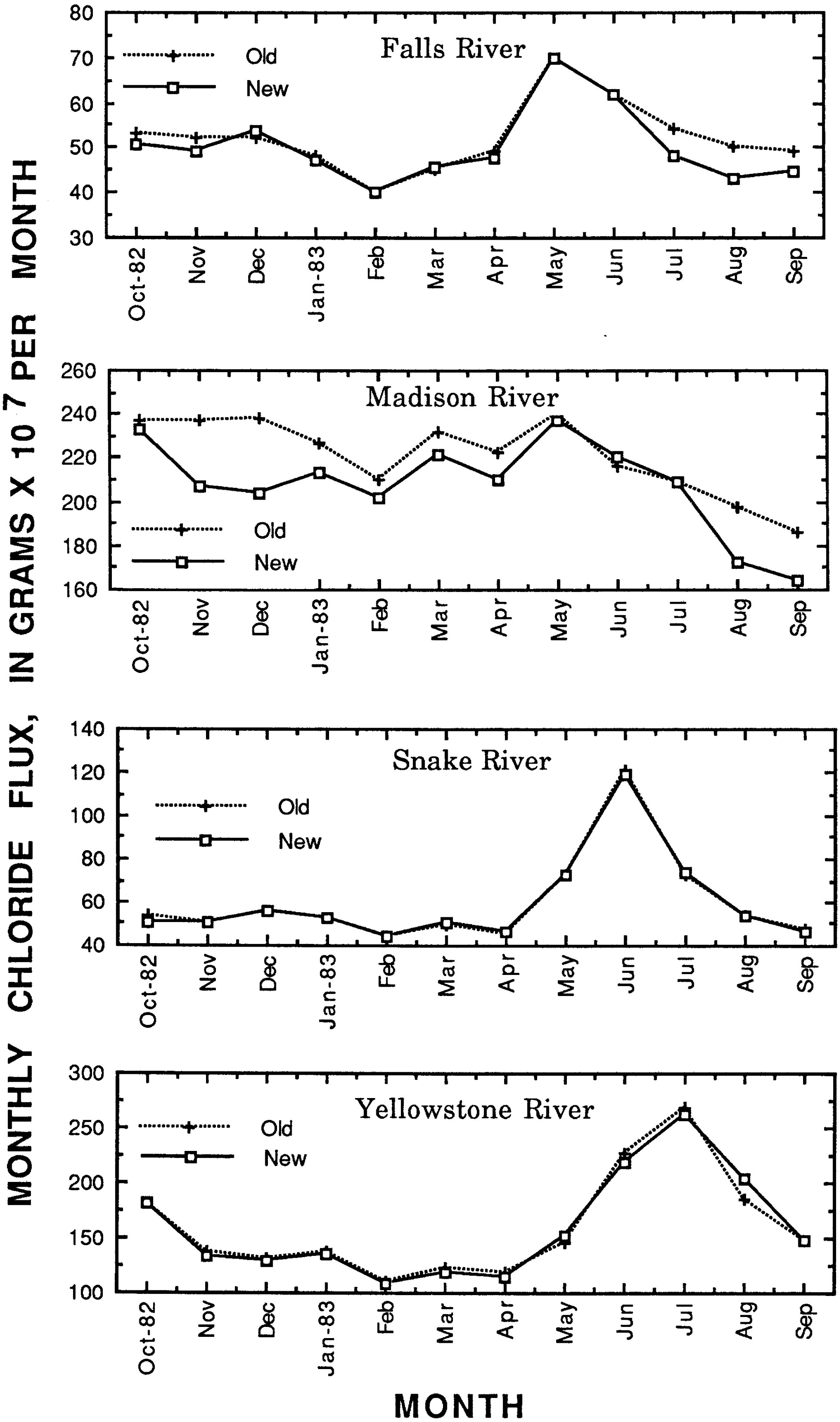


Figure 1. Graph of the monthly integrated chloride flux of the Falls, Madison, Snake, and Yellowstone Rivers for water year 1983. Data reported by Norton and Friedman (1985) (dotted line) are compared with data given in the present paper (solid line).

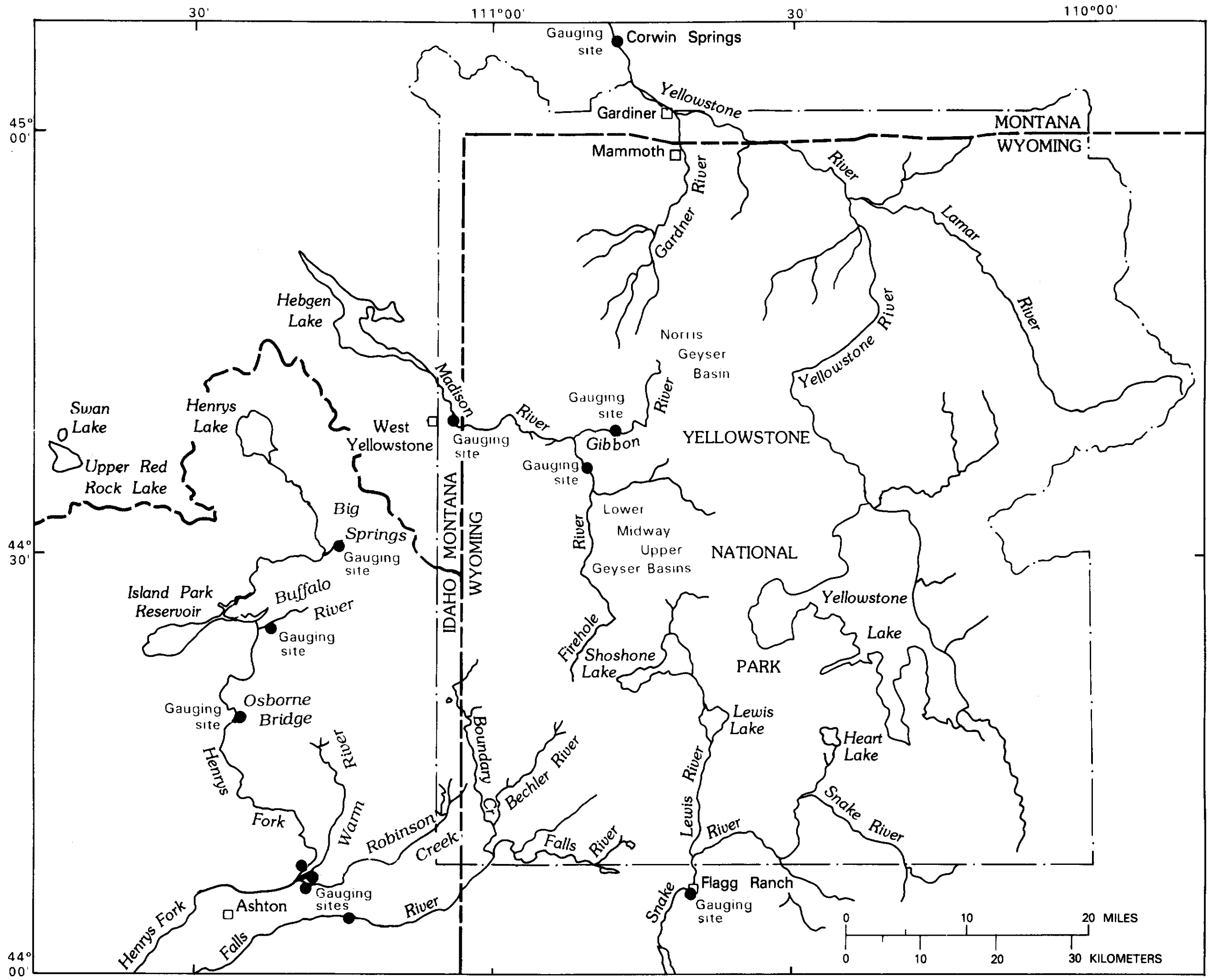


Figure 2. Map of Yellowstone National Park region in Montana, Idaho, and Wyoming, showing the stream gauging sites discussed in this paper.

automated recorders. The discharge data reported in this work were stated by the hydrologists who made the measurements to have an accuracy of 5 percent.

Water samples for chloride determination were withdrawn from the river banks using 50-mL (milliliter) plastic syringes and filtered on site through membrane filters into plastic bottles. The samples were submitted to the U.S. Geological Survey's National Water Quality Laboratory in Denver for analysis. Our tests showed that, for the chloride determination, the samples did not have to be filtered through the standard 0.45-micrometer filters. We used 5-micrometer filters to facilitate the operation.

Our schedule for water sampling of the rivers was monthly for January, February, November, and December; bimonthly for March, April, September, and October; and weekly for May, June, July, and August. This schedule of 28 samples allowed for greater accuracy of the reported data during periods of high runoff in the spring and summer. In contrast, the standard water sampling protocol used by the U.S. Geological Survey is to collect a sample at each site every 6 weeks. Using data from these two different sampling protocols, we calculated the annual chloride flux for 1985 and 1986 for the four rivers draining the Park, as well as the total flux out of the Park, which is the sum of the flux from the Falls, Madison, Snake, and Yellowstone Rivers. The data, given in table 2, show that the flux calculated for individual rivers by the two protocols differs by as much as 12 percent, whereas the total flux out of the Park differed by 7 percent. Obviously the discrepancy depends upon the specific dates of sampling as related to the timing of snowmelt runoff. In view of these results, we chose a sampling schedule that allowed for increased sampling during the period of high discharge. To our 28 samples per year for each site, we incorporated the 9

Table 1. Gauging site descriptions

[USGS, U.S. Geological Survey; km^2, square kilometer. All topographic maps are USGS 15-minute quadrangle maps]

USGS Station No.	Site name and location	Topographic map	Drainage area, (km^2)
13047500	Falls River near Squirrel, Idaho, 14.0 km from southwest corner of Yellowstone National Park.	Warm River Butte, Idaho-Wyo.	909
06036905	Firehole River, 4.2 km upstream from Madison Junction.	Madison Junction, Wyo.	730
06037000	Gibbon River, 6.4 km upstream from Madison Junction.	Madison Junction, Wyo.	306
06037500	Madison River at gauging site shown on map near Riverside.	West Yellowstone, Mont.-Wyo.-Idaho.	1088
13010200	Snake River near Flagg Ranch, Wyo., 3.7 km south of Snake River Ranger Sta., at bridge on U.S. 287.	Huckleberry Mountain, Wyo.	405
06191500	Yellowstone River near Corwin Springs, Mont., at gauging site shown on map.	Miner, Mont.-Wyo.	6793

Table 2. Percentage difference in annual chloride flux calculated using two different sampling protocols

	Falls River	Madison River	Snake River	Yellowstone River	Total, sum of four rivers
1985	9	5	-10	-4	1
1986	-1	-2	-12	-11	-7

$$\text{Percent difference} = \frac{\text{(WRD sampling protocol data minus this paper protocol)}}{\text{this paper protocol}} \times 100$$

samples per year collected by the USGS, resulting in the analysis of 37 samples per site per year. In addition to the improved accuracy occasioned by our sampling protocol, the increased accuracy of our chloride analyses, as discussed next, adds to the overall accuracy of the calculated chloride flux values.

About 5 percent of the flow of Falls River is diverted upstream from the gauging site at Squirrel, Idaho, for irrigation. We added the measured flow from the Marysville Diversion Canal to all the discharge measurements made at Squirrel in order to determine the true discharge of the Falls River.

Table 3. Statistical analysis of chloride concentration data for WRD standards

[ppm, parts per million; %, percent]

WRD Sample No.	Number of analyses	Mean value (ppm)	Standard deviation	% Standard deviation
62	31	8.27	0.160	1.9
62, normalized*	31	8.24	0.405	4.9
M6	23	12.9	0.454	3.5
M6, normalized	23	13.5	0.369	2.7
76	52	25.6	0.655	2.6
76, normalized	52	25.5	0.727	2.9
68	57	31.0	0.656	2.1
68, normalized	57	30.9	0.795	2.6
M86	43	43.9	1.10	2.5
M86, normalized	43	44.1	0.835	1.9
84	49	50.1	0.664	1.3
84, normalized	49	50.0	0.750	1.5
M94	10	65.7	1.52	2.3
M94, normalized	10	65.2	0.524	0.8
M100	11	80.6	1.06	1.3
M100, normalized	11	80.3	1.23	1.5

* "Normalized" refers to analytical values normalized to a series of GD standards whose chloride concentration values bracketed the WRD values.

LABORATORY METHODS AND CALCULATIONS

The chloride determinations were made by a modification of the thiocyanate-spectrophotometric method of Skougstad and others (1979) in which the discrete sample analyzer was replaced by an automated segmented sample analyzer. To increase the accuracy of the method, we introduced our own chloride standard solutions, referred to herein as GD standards, between every 10 to 15 samples. We then normalized the laboratory results against these standards, which were prepared gravimetrically from pure NaCl.

In addition to the GD standards, the laboratory routinely introduced their reference samples, referred to herein as WRD standards, at the same frequency as our standards. In order to evaluate the accuracy and precision of the chloride determinations, we made use of the chloride values for the WRD standards as determined for each set of samples. The same set of WRD standards were run repeatedly for 3 years and permitted us to accumulate 23–57 analyses for these standards. Statistical analysis of the results is given in table 3. The results of these comparisons are presented on figure 3 and 4.

Accuracy

We observed that the values obtained by the WRD laboratory for the GD 20.0 ppm (parts per million) standard were always less than 20.0 ppm and had a mean value of 18.8 ppm. Values on other GD standards, ranging from 10 to 120 ppm, gave satisfactory agreement. We attribute this discrepancy to nonlinear response of the instrument in the 20-ppm concentration range.

Figure 3 is a plot of the mean chloride values of the WRD standards normalized against the GD standards that were run concurrently and plotted against the mean of the unnormalized (raw) values reported by the laboratory. Note that the slope and intercept of the linear least-squares solution to the plotted data are not 1.0 and zero, which indicates that normalization of the laboratory values to our GD standards will improve the accuracy of the calculated results.

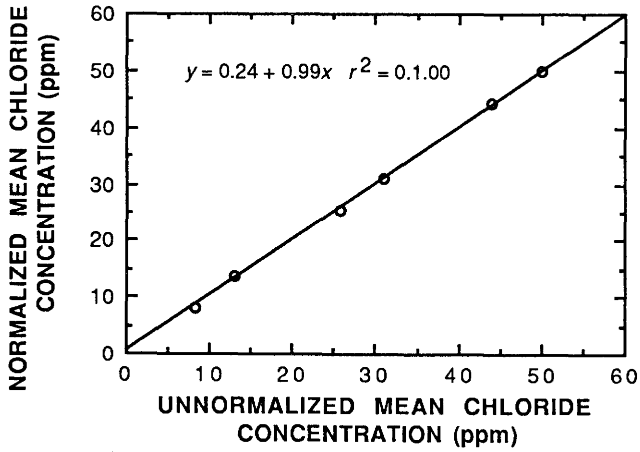


Figure 3. Graphs of the unnormalized mean chloride concentration in parts per million (ppm) of the WRD water standards plotted against the same results normalized against our gravimetrically prepared chloride solutions. *y*, normalized mean chloride concentration; *x*, unnormalized mean chloride concentration; r^2, correlation coefficient squared.

Precision

Figure 4 is a plot of the percent relative standard deviation versus the mean values for the WRD standards. The data are shown for both the normalized and unnormalized data sets. This figure and the indicated r^2 values show that normalization improves the precision of the data. (r^2 = correlation coefficient squared).

The automated chloride analysis apparatus has a digital readout that limits the precision. The results give precisions that vary with chloride concentration from about 1 percent relative standard deviation for chloride concentrations greater than 50 ppm, to 3 percent relative standard deviation for concentrations less than 10 ppm.

Chloride Flux

Instantaneous chloride fluxes, shown in the appendix, were calculated by multiplying the chloride concentration of the sample by the river discharge recorded at the time of collection. Monthly integrations were made by first calculating the end-of-month values of discharge and chloride concentration by linear interpolation, and then integrating between each recorded or calculated value. Integrations were done for both monthly and annual periods. The results are given in tables 4 and 5.

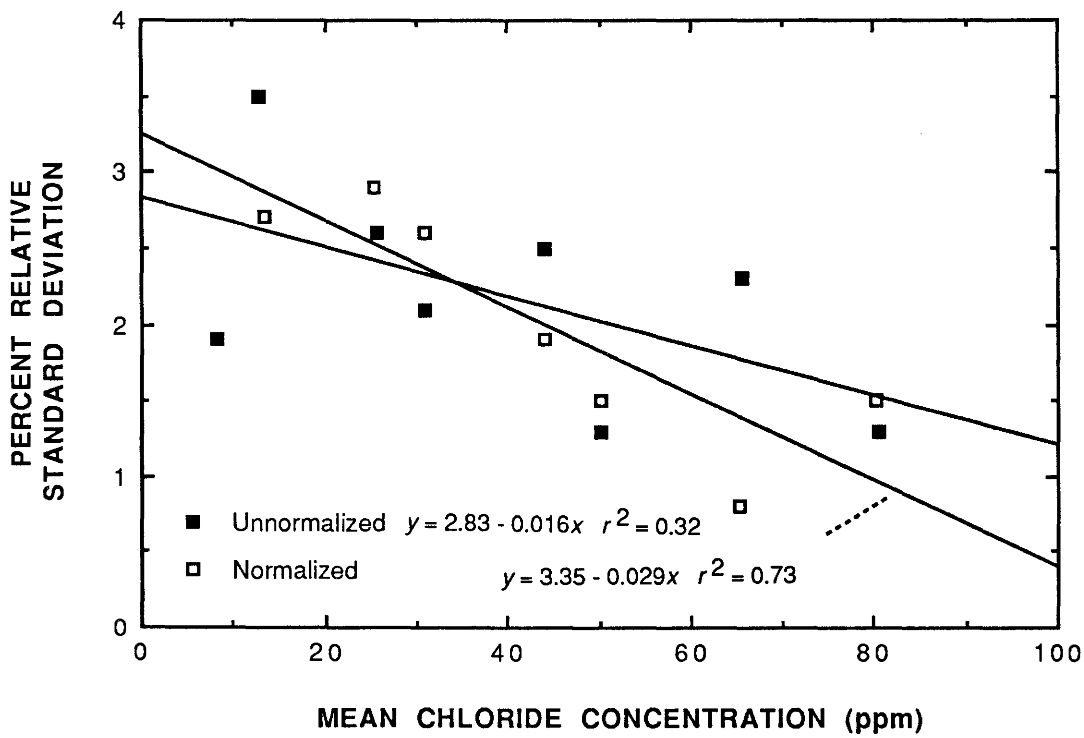


Figure 4. Graph of mean chloride concentration in parts per million (ppm) of the WRD water standards versus percent relative standard deviation determined for both normalized and unnormalized data sets. *y*, percent relative standard deviation; *x*, mean chloride concentration; r^2, correlation coefficient squared.

Table 4. Monthly and annual chloride (Cl) flux and discharge (Disch.) for water years 1983 through 1989

[Chloride in grams x 10^7; discharge in cubic meters x 10^7; - indicates no data]

Falls River

	1983		1984		1985		1986		1987		1988		1989	
	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.
October	50.7	5.17	59.8	6.56	43.5	4.412	47.8	4.21	49.7	4.61	32.8	2.27	38.2	2.86
November	49.3	4.89	60.9	7.50	45.3	4.05	44.9	3.81	48.3	4.00	33.3	8.87	39.3	2.67
December	53.6	4.48	55.6	5.25	45.1	3.87	44.0	3.31	46.7	3.54	37.9	2.40	40.1	2.41
February	39.9	3.14	42.7	3.65	47.0	3.68	40.1	3.09	40.8	3.02	35	2.18	38.1	2.22
March	45.5	3.38	42.4	3.61	46.1	3.59	51.9	4.53	46.3	3.31	36.3	2.22	40.6	2.53
April	47.8	4.25	42.3	4.98	65.3	6.54	63.9	8.38	58.3	6.79	60.7	5.37	52.8	4.53
May	70.0	13.0	70.4	20.2	76.3	16.9	72.1	14.3	67.7	12.4	69.4	12.7	77.8	17.8
June	61.8	19.3	71.2	23.7	61.7	15.0	68.1	25.4	49.4	5.40	46.8	8.78	57.7	16.39
July	48.2	10.4	51.0	12.8	57.8	6.90	55.4	9.68	41.7	4.00	43.8	4.77	44.7	6.29
August	42.9	5.52	45.5	6.46	48.2	4.86	53.0	6.37	3.07	3.07	3.32	3.32	42.6	4.57
September	44.5	5.05	48.5	5.57	51.0	4.78	50.1	5.36	33.9	2.43	36.4	2.93	42.1	4.00
Water year	601.3	82.36	638.6	104.7	629.0	78.18	635.7	91.85	566.4	55.94	509.5	58.33	553.8	68.86

Firehole River

	1983		1984		1988		1989		1987		1988		1989	
	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.
October	-	-	170	2.83	151	2.42	156	2.39	140	2.61	133	1.67	139	1.78
November	-	-	156	2.55	151	2.34	160	2.40	147	2.41	129	1.77	143	1.73
December	-	-	153	2.33	152	2.30	158	2.33	135	2.27	139	1.82	135	1.63
January	-	-	150	2.24	149	2.23	160	2.29	143	2.23	149	1.89	134	1.69
February	-	-	140	2.01	131	1.92	147	2.07	133	2.01	138	1.75	135	1.59
March	-	-	157	2.18	151	2.25	168	2.42	155	2.23	143	1.86	155	1.82
April	-	-	151	2.21	150	2.97	187	3.00	136	2.36	166	2.42	156	2.31
May	-	-	161	3.74	144	3.27	196	6.33	153	2.36	149	3.16	162	3.16
June	-	-	154	3.76	136	3.23	152	5.66	135	3.02	129	2.07	142	3.17
July	-	-	145	2.63	170	3.34	153	3.36	134	2.05	127	1.68	143	2.21
August	-	-	146	2.45	169	2.75	142	2.75	133	1.97	125	1.62	146	2.09
September	-	-	145	2.38	151	2.20	139	2.65	124	1.78	124	1.59	133	1.87
Water year	-	-	1829	31.29	1804	31.22	1918	37.63	1668	26.87	1650	23.30	1723	25.03

Gibbon River

	1983		1984		1985		1986		1987		1988		1989	
	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.
October	-	-	40.1	0.813	38.5	.731	41.2	0.674	27.5	0.691	34.3	0.535	36.9	0.524
November	-	-	39.3	0.776	42.3	.708	49.6	0.646	33.8	0.697	37.5	0.521	40.0	0.555
December	-	-	45.5	0.770	41.9	.671	32.2	0.589	26.8	0.651	37.3	0.487	33.1	0.524
January	-	-	43.1	0.694	39.7	.589	33.7	0.569	40.2	0.694	41.1	0.518	39.4	0.547
February	-	-	36.4	0.572	31.0	.513	35.0	0.564	33.4	0.530	32.0	0.425	37.0	0.476
March	-	-	42.0	0.612	33.5	.654	40.0	0.682	37.8	0.575	32.4	0.453	44.3	0.580
April	-	-	38.8	0.719	43.0	1.17	46.9	1.06	35.6	0.767	35.4	0.765	44.8	1.20
May	-	-	43.3	1.89	41.0	1.22	52.3	1.81	40.1	0.985	37.5	1.42	49.2	1.52
June	-	-	37.4	1.64	37.0	1.07	44.0	2.26	36.1	0.719	32.1	0.804	36.0	1.14
July	-	-	36.3	1.11	43.8	.966	39.7	1.33	29.9	0.626	26.7	0.549	37.3	0.844
August	-	-	37.2	0.926	39.8	.779	35.6	.869	28.9	0.578	28.0	0.496	35.9	0.728
September	-	-	34.7	0.728	34.5	.640	32.4	.722	29.8	0.501	32.7	0.490	28.0	0.612
Water year	-	-	474.1	11.25	466.0	9.704	482.6	11.77	399.9	8.014	407.0	7.464	462.2	9.251

Table 4. Monthly and annual chloride (Cl) flux and discharge (Disch.) for water years 1983 through 1989—Continued

Madison River

	1983		1984		1985		1986		1987[1]		1988[1]		1989[1]	
	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch
October	233	4.19	190	3.56	193.3	3.49	204	3.47	173	3.68	174	2.46	174	2.44
November	207	3.61	212	3.76	203.5	3.47	197	3.26	187	3.47	173	2.56	188	2.52
December	203	3.38	205	3.49	206.2	3.45	203	3.34	168	3.27	182	2.58	174	2.41
January	213	3.38	199	3.33	206.5	3.34	197	3.21	190	3.27	197	2.69	180	2.50
February	201	3.13	186	2.97	169.1	2.70	197	3.08	172	2.84	176	2.43	178	2.31
March	221	3.47	201	3.12	202.7	3.21	225	3.79	200	3.13	182	2.58	207	2.68
April	210	3.34	191	3.26	218.2	3.97	233	4.51	178	3.50	208	3.56	208	3.92
May	238	5.62	222	7.49	229.5	7.04	232	7.22	200	4.48	193	5.11	219	5.22
June	221	7.55	204	6.34	187.4	4.61	236	9.94	177	3.09	167	3.21	185	4.81
July	209	4.96	176	3.95	178.3	3.41	197	5.11	169	2.90	159	2.49	187	3.41
August	173	3.33	190	3.81	183.4	3.23	195	4.00	168	2.80	158	2.36	188	3.15
September	165	3.11	183	3.42	183	3.24	193	4.01	160	2.54	163	2.33	167	2.77
Water year	2494	49.07	2358	48.49	2358	45.17	2509	55.24	2142	38.96	2131	34.36	2253	38.14

Snake River

	1983		1984		1985		1986		1987		1988		1989	
	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.
October	50.5	3.76	50.6	4.90	46.1	3.10	45.2	2.83	45.3	3.31	30.4	1.35	35.3	1.47
November	50.8	3.47	47.7	5.10	47.6	3.17	50.7	3.31	50.0	3.15	27.9	1.42	36.9	1.56
December	56.0	3.55	56.4	4.51	47.5	3.11	47.8	2.87	46.8	2.74	37.3	1.83	43.1	1.74
January	52.7	3.23	63.2	4.07	47.3	2.99	46.7	2.68	42.5	2.41	43.8	2.17	45.6	2.08
February	43.7	2.66	48.5	3.06	41.9	2.43	49.9	3.21	43.5	2.48	44.7	2.11	39.9	1.88
March	49.3	2.91	46.7	2.82	49.5	2.55	61.2	3.96	45.9	2.63	44.5	2.09	47.9	2.46
April	45.9	2.82	46.3	2.99	54.8	4.12	60.8	5.38	49.7	4.42	56.8	3.69	51.0	4.15
May	73.5	13.5	78.5	16.3	108	20.2	78.4	15.5	67.5	12.4	77.1	14.8	123.7	27.6
June	119	33.2	101	17.6	83.2	15.4	200.4	42.3	51.2	6.14	68.0	12.8	94.5	21.0
July	73.6	12.5	66.2	8.01	48.3	4.75	71.8	10.7	41.7	3.47	35.0	2.55	53.2	5.69
August	53.5	5.05	45.4	4.28	43.8	3.19	53	5.01	34.0	2.00	30.7	1.52	41.2	3.06
September	58.3	4.61	42.9	3.37	42.6	2.93	47.2	3.80	32.7	1.58	31.6	1.31	32.1	2.06
Water year	727.0	91.24	693.7	76.98	660.2	67.92	813.1	101.5	550.8	46.70	527.8	47.60	644.4	74.73

Yellowstone River

	1983		1984		1985		1986		1987		1988		1989	
	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.	Cl	Disch.
October	182	16.7	134	15.8	136	13.0	133	11.0	141	13.4	98.0	6.32	99.1	5.90
November	134	10.9	146	14.3	124	10.6	124	8.76	129	10.1	98.1	5.62	87.7	5.05
December	129	9.24	156	12.0	120	9.04	95.7	6.59	110	7.82	116	5.43	94.9	4.92
January	135	8.53	128	9.75	109	7.66	99.8	6.96	104	7.35	97.4	4.16	88.3	3.86
February	107	7.37	109	7.96	102	6.94	97.3	6.88	99.2	6.88	82.9	3.96	78.9	3.37
March	119	7.75	119	8.14	102	7.77	120	10.3	109	7.31	93.5	5.33	84.5	4.63
April	115	8.08	119	9.33	110	12.4	116	15.3	176	22.7	94.6	10.2	87.7	11.5
May	152	23.2	157	49.5	171	45.1	187	54.4	200	43.9	134	37.2	267	79.3
June	218	66.1	247	86.0	274	57.0	490	117	196	34.9	213	57.9	291	75.9
July	262	56.8	346	62.4	198	29.9	325	54.5	192	23.8	183	21.0	283	41.3
August	204	27.4	201	26.1	160	18.3	226	27.8	147	13.7	129	11.2	177	19.5
September	148	16.2	144	17.1	135	13.8	160	18.2	112	8.82	102	6.84	135	12.5
Water year	1905	258.2	2007	318.3	1741	231.5	2173	337.7	1716	200.6	1441	175.27	1775	267.5

[1] Chloride flux data for this year calculated by summing values of the Gibbon and Firehole Rivers and multipying by 1.037 (see text).

Discharge data for this year calculated by summing values for the Gibbon and Firehole Rivers and multipying by 1.117 (see text).

Table 5. Total chloride flux and river discharge from Yellowstone National Park

Water year	Total		
	Four rivers[1]		Four rivers plus Island Park sites
	Flux[2]	Discharge[3]	Flux[4]
1983	5730	4810	6100
1984	5700	5490	6000
1985	5390	4230	5700
1986	6130	5850	6500
1987	4990	3440	5300
1988	4610	3160	4900
1989	5240	4490	5600

[1] The totals are the sum of the values for the Falls, Madison, Snake, and Yellowstone Rivers.

[2] Chloride flux values are given in grams of chloride per year x 10^{7}.

[3] Discharge values are given in cubic meters per year x 10^{7}.

[4] Total flux is calculated by multiplying flux values determined by summing the flux from the four rivers and multiplying by 1.06.

The error assigned to the instantaneous chloride flux calculations is ±5.4 percent. This value is derived from the errors of the individual chloride concentration (*E*=2 percent) and discharge measurements (*E*=5 percent) as follows, where *E*=error:

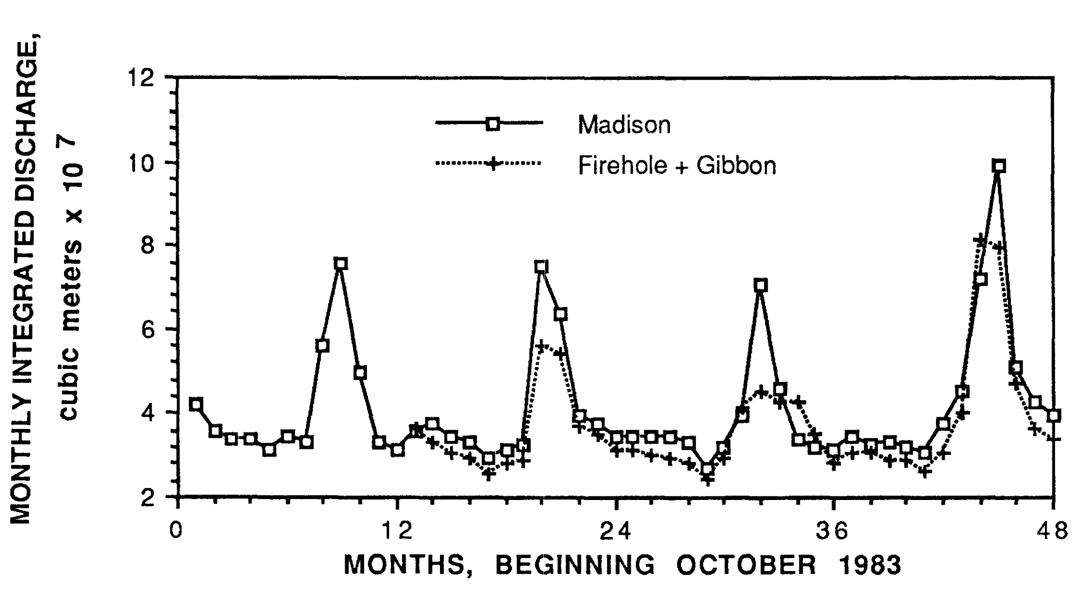
$$\text{Chloride flux error} = \sqrt{E^2_{\text{Chloride}} + E^2_{\text{Discharge}}}$$

RESULTS AND DISCUSSION

Madison River Flux Calculations for 1987–1989

The Madison River site was monitored for about 4 years from late 1982 through 1986, after which time monitoring was discontinued. Inasmuch as the Firehole and Gibbon Rivers are the major tributaries of the Madison, monitoring sites on the Firehole and Gibbon were established in 1984 and continued through 1989. To compare monthly integrated chloride flux and discharge for the Madison River, as measured at the Madison River gauging site, with values calculated from the sum of the Firehole and Gibbon Rivers, we used data from 1984, 1985, and 1986. In figure 5 we have plotted the monthly integrated discharge and chloride flux for the Madison, as well the sum of values for the Firehole and Gibbon Rivers from the values given in table 4. The chloride flux for this 3-year period in the Madison River is 3.6 percent greater than that for the sum of the values for the Firehole and Gibbon Rivers. A similar comparison made for discharge showed that discharge was 11.7 percent greater at the Madison River gauging site, which is 24 km from the confluence of the Firehole and Gibbon Rivers. These increased values of flux and discharge result from additional input to the Madison along this 24-km-long drainage basin, as well as additional inputs from the Firehole and Gibbon above their confluence. This effect is particularly pronounced during spring runoff when low-chloride snowmelt water is introduced along this 24-km stretch of the river.

Using this information we corrected the chloride flux and discharge values obtained from the sum of the Firehole and Gibbon Rivers to make them equivalent to that which



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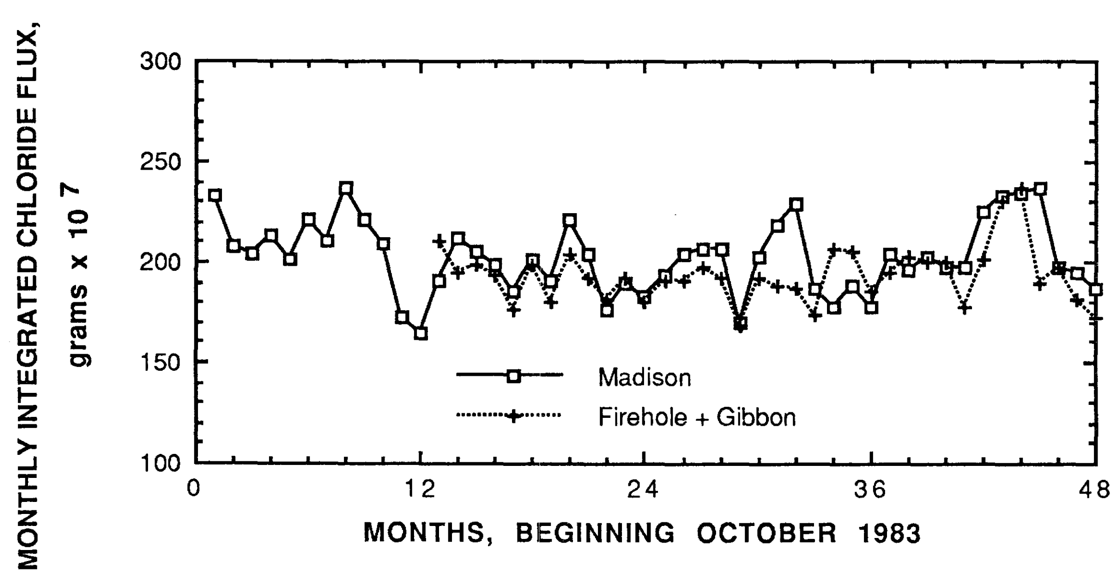

B

Figure 5. Graphs of the monthly integrated discharge (*A*) and monthly integrated chloride flux (*B*) of the Madison River for 48 months, beginning in October 1983, as well as the sum of the integrated discharges and of the integrated chloride fluxes of the Firehole and Gibbon Rivers for the same time period.

would have been obtained for the Madison River for 1987, 1988, and 1989. The corrections can only be used for the *annual* fluxes for the Madison River for these 3 years but will distort the *instantaneous* and *monthly* flux values because most of the fluxes added along the 24-km stretch of the Madison are added during a short period in the spring, and we are applying uniform corrections throughout the year. For this reason the, *uncorrected* (sum of the Firehole and Gibbon Rivers) instantaneous values of discharge and chloride flux for the Madison for 1987–89 are plotted in figure 6, but the *corrected* annual values are given in tables 4 and 5.

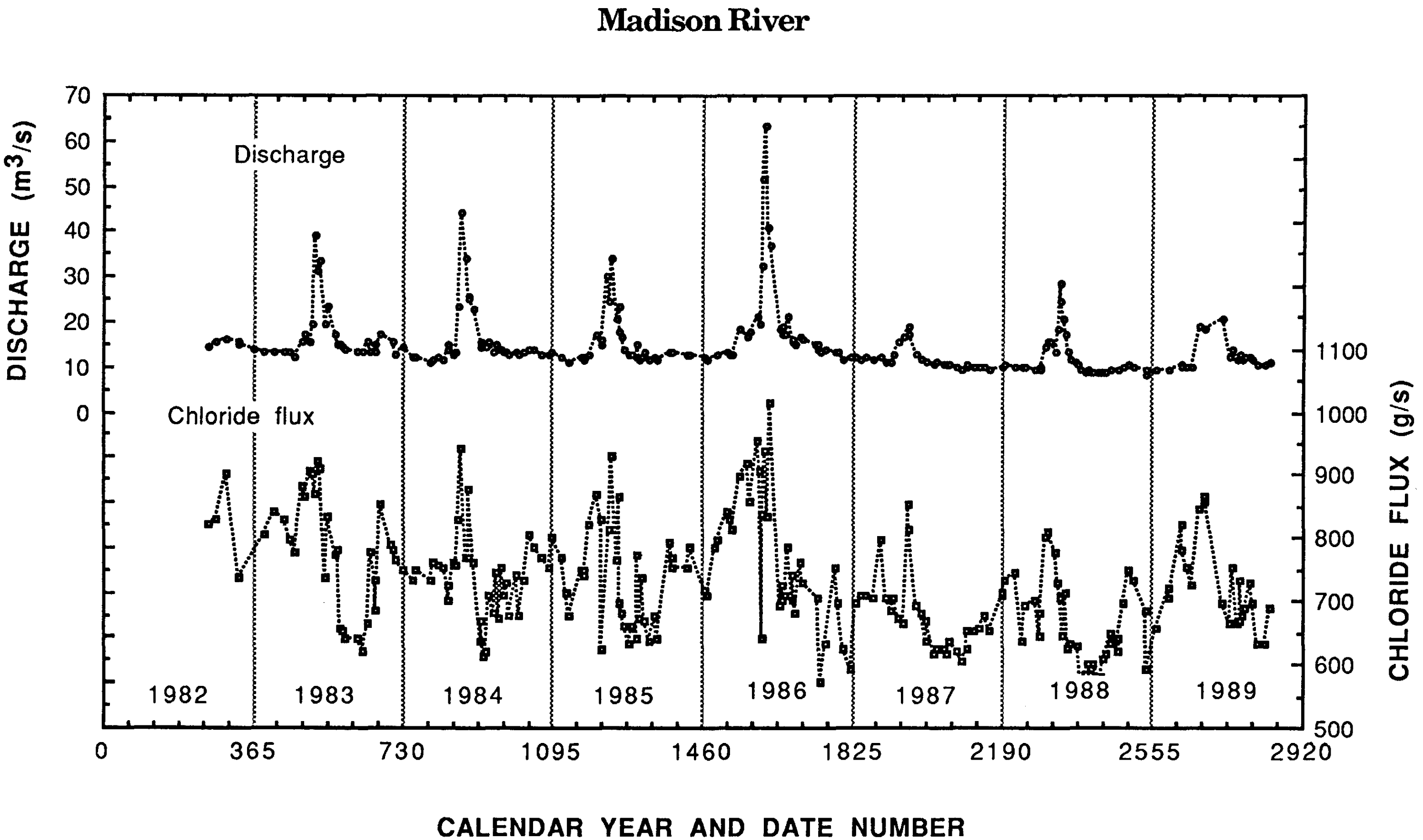

Figure 6. Graphs of the instantaneous discharge in cubic meters per second (m^3/s) and the chloride flux in grams per second (g/s) for the Madison River. Plotted points are from data given in the appendix. Calendar years are shown. Data for water years 1987, 1988, and 1989 were calculated by adding the measurements made on the Firehole and Gibbon Rivers. No corrections have been made to the data for 1987, 1988, and 1989 to account for the different sampling sites used for these years.

Comparison of Our Discharge Data with Those of the Long-Term Records

Figure 7 shows annual discharge for the Falls, Madison, and Yellowstone Rivers during 30 years of record. Data for the Snake River are not available. The longer term average annual discharge is also shown on figure 7. The years of our study are indicated in the figure and show that the data for these years are not exceptional as compared with data from the long-term record.

Tabulated data for instantaneous measurements including the date and time of collection, discharge, chloride concentration, and chloride flux are given in the appendix. The integrated monthly discharge[1] and chloride flux calculated from this data are given in table 4. The discharge and chloride flux of the rivers as a function of time are shown on figures 6 and 8–12. We included in both the tabulated data and in the figures, data recalculated from that previously published by Norton and Friedman (1985).

Chloride Flux and Discharge for Individual Rivers

The spring runoff peaks for both discharge and chloride flux are higher relative to base flow values for drainage basins that are not dominated by discharges from major thermal areas. For example, the Yellowstone River typically shows peak discharges as great as 25 times base flow (fig. 12). These peak discharges are much smaller in drainage basins dominated by large thermal areas where snowmelt is continuous during the winter, resulting in spring runoff peaks for the Firehole, Gibbon, and Madison that are only about three times the base flow (figs. 6, 9, and 10).

In the Madison River drainage basin, which is dominated by the major thermal areas along the Firehole and Gibbon Rivers, there are variations in instantaneous chloride flux that are random with time. These variations are attributed to changes in the thermal activity in these basins, including eruptions of geysers of large discharge, and variations in overall activity of the thermal springs in the basins.

The relationships of instantaneous discharge and chloride flux with time for the Falls, Snake, and Yellowstone Rivers (figs. 8, 11, and 12) are similar. All three rivers show sharp seasonal peaks in discharge related to spring runoff, which are as great as 25 times base flow. In all the rivers. the corresponding chloride flux values show similar peaks that are coincident with discharge peaks.

The base flow, or minimum discharges for the four major rivers draining the Park show a downward trend for the years of our study, as illustrated on figure 13. We believe this trend results from long-term changes in precipitation in this region.

Plots of annual discharge versus annual chloride for each river are given in figure 14 and show a high correlation between discharge and chloride flux, with correlation coefficient (r^2) values between 0.72 and 0.94. A discussion of this relationship is given in Friedman and Norton (1990). Previous authors (Fournier and others, 1976; D.E. White, oral commun., 1984) have noted similar relationships between instantaneous values of discharge and chloride flux and ascribed these to chloride stored in the soil during the winter and released with the spring runoff. Friedman and Norton (1990) preferred a different interpretation and proposed that a large part of seasonal changes in chloride flux are related to changes in height of the water table, which in turn influences the discharges of chloride-containing springs.

Total Annual Discharge and Chloride Flux From the Four Major Rivers Draining The Park

The annual discharge and chloride flux for the sum of the four major rivers draining the Park are shown in table 5 and on figure 15*B*. A graph showing the linear least-squares solution to this data is shown on figure 15*A*. The overall relationship follows that shown on figure 16 for the individual rivers; namely, an increase in both chloride flux and discharge for 1986, a decrease in these values for 1987, 1988, and a slight recovery in 1989, compared with the values reported for 1983 and 1984. The discharge and chloride flux have a linear relationship. The increase in chloride flux with discharge is mostly due to the increase in the height of the water table during periods of increased flow, to a lesser extent due to stored chloride, and to only traces of chloride introduced by precipitation, weathering, and human activity. Using only chloride introduced by precipitation to explain these results would require the

[Text continues on page 20.]

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[1]Annual water-year discharge data for the Yellowstone River site were taken from the following references to the published records of the U.S. Geological Survey: Surface water supply of the U.S., 1960–1965; Water resources data for Montana, 1966–1975: Water resources data, Montana, water-years 1976–1989. For the Madison River site, data were taken from Survey records as follows: Surface water supply of the U.S., 1944–1965; Water resources data for Montana, 1966–1975; Water resources data, Montana, water years 1976–1989. For the Falls River site, data were taken from Survey records as follows: Records of surface water of the U.S., 1950–1960; Surface water supply of the U.S., 1961–1970; Water resources data for Idaho, 1971–1974; Water resources data, Idaho, water years 1975–1989.

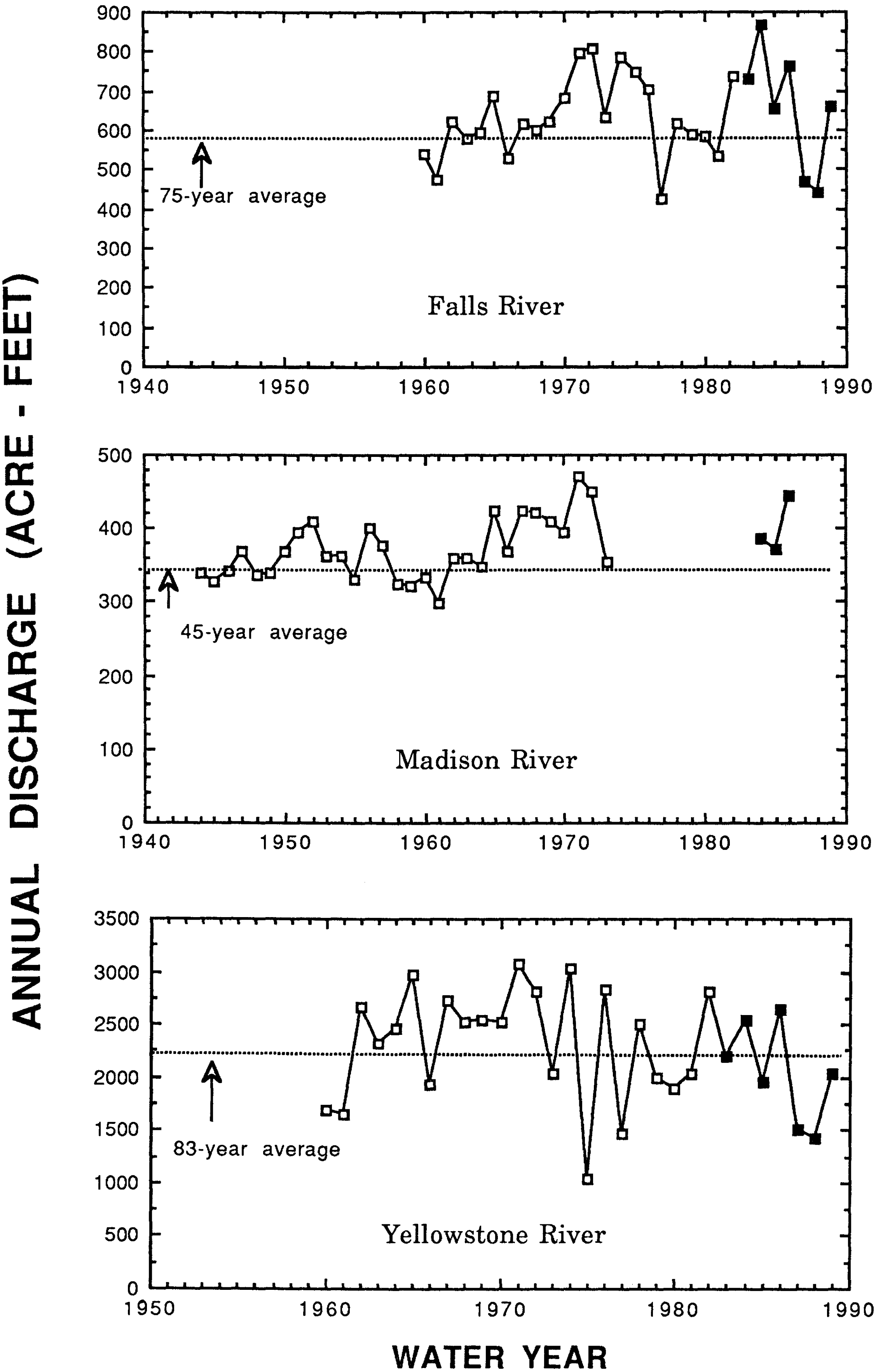

Figure 7. Graphs of the annual discharge in acre-feet as a function of time for the Falls, Madison, and Yellowstone Rivers from data published by the U.S. Geological Survey. The years of our study are shown as solid boxes. The long-term average for each river is shown as a dotted horizontal line.

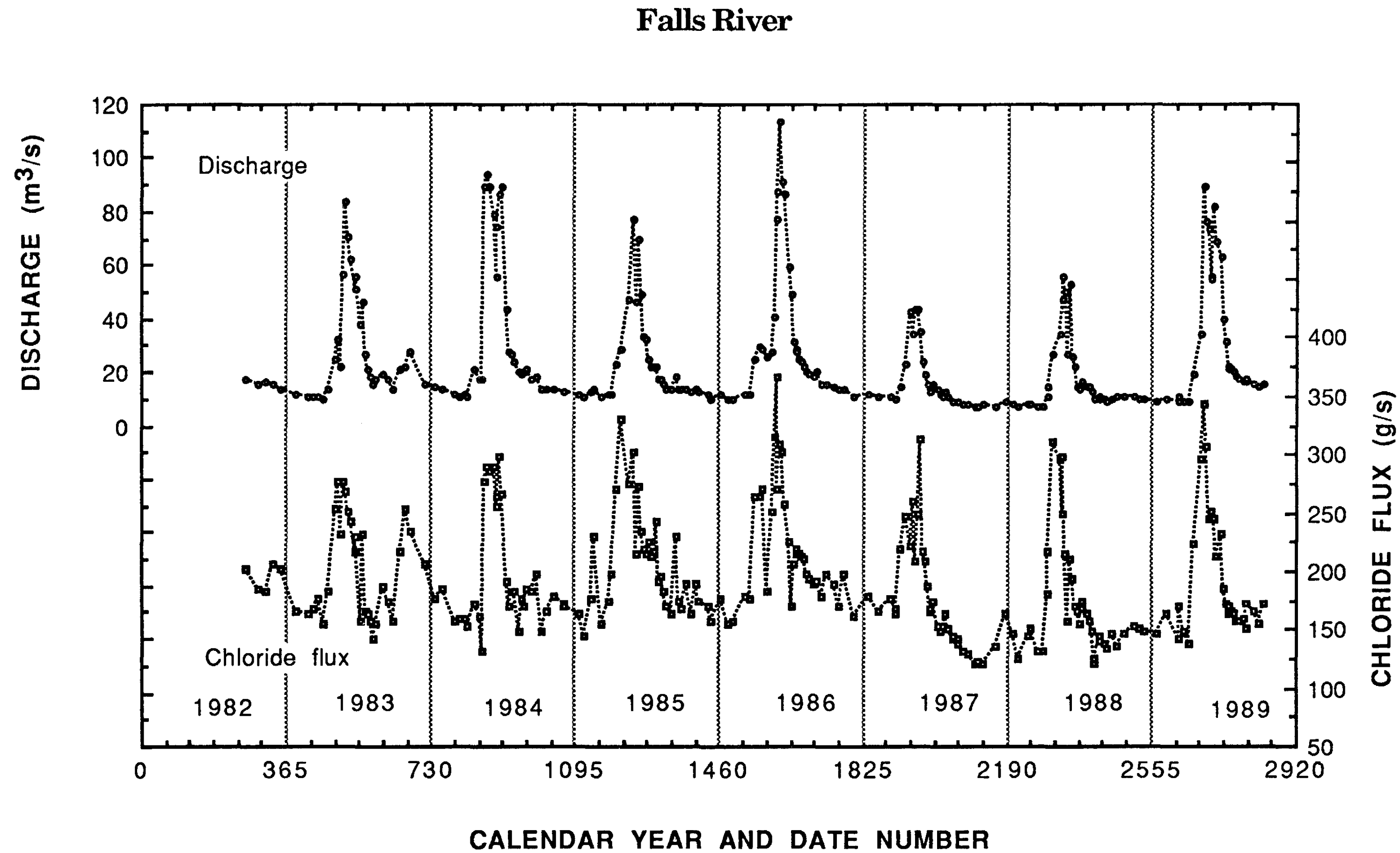

Figure 8. Graphs of the instantaneous discharge in cubic meters per second (m^3/s) and the chloride flux in grams per second (g/s) for the Falls River. Plotted points are from data given in the appendix. Calendar years are shown.

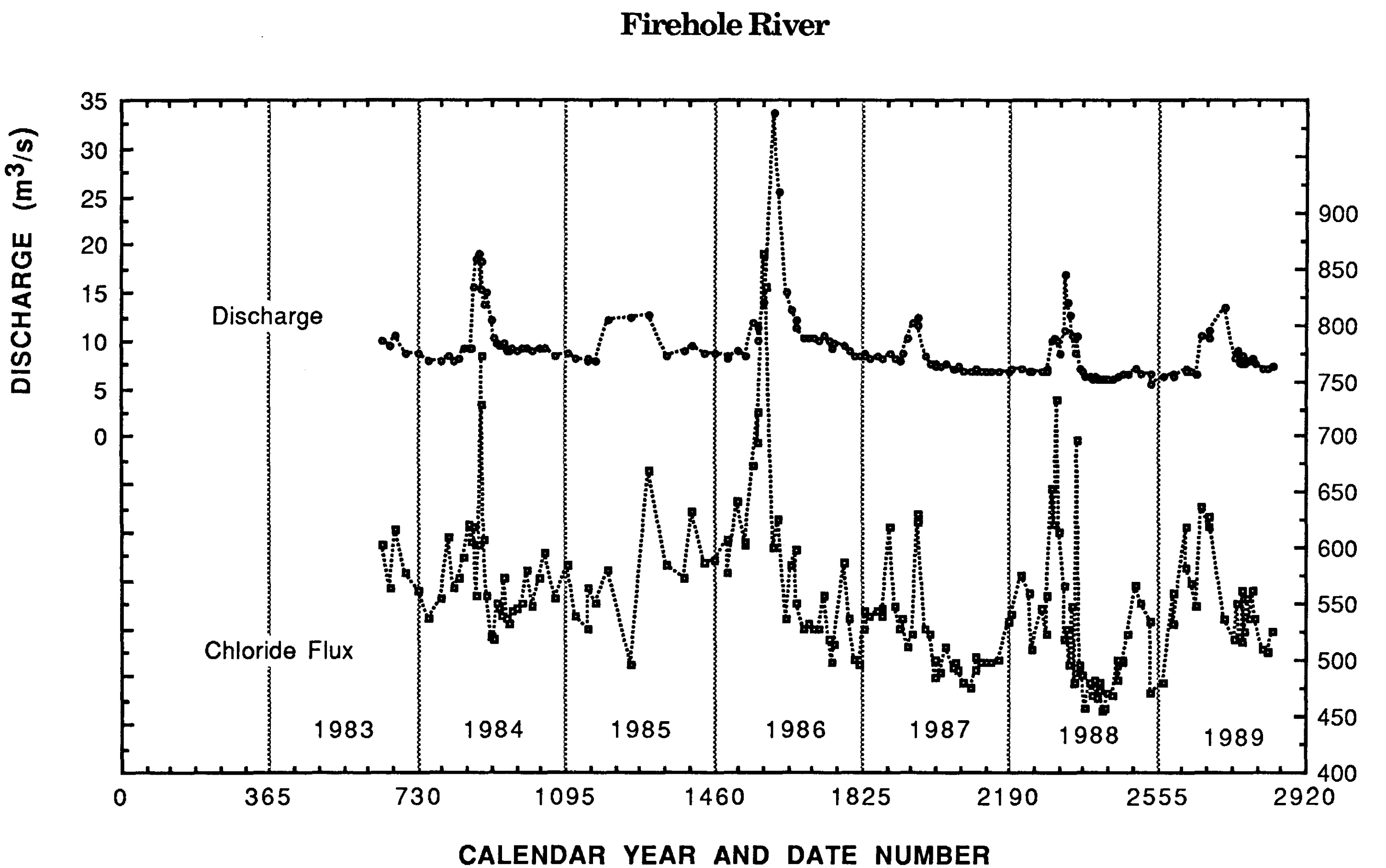

Figure 9. Graphs of the instantaneous discharge in cubic meters per second (m^3/s) and the chloride flux in grams per second (g/s) for the Firehole River. Plotted points are from data given in the appendix. Calendar years are shown.

Gibbon River

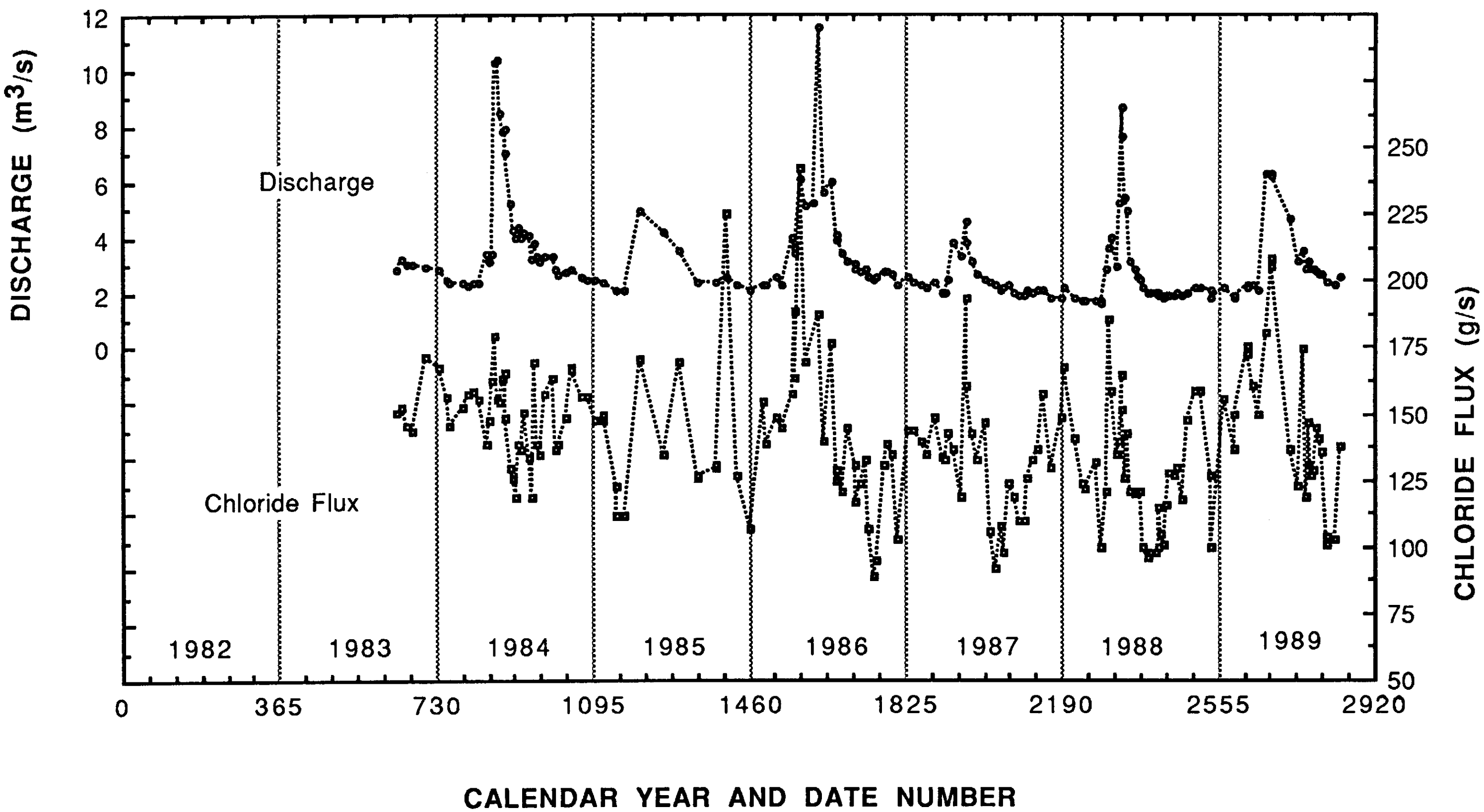

Figure 10. Graphs of the instantaneous discharge in cubic meters per second (m^3/s) and the chloride flux in grams per second (g/s) for the Gibbon River. Plotted points are from data given in the appendix. Calendar years are shown.

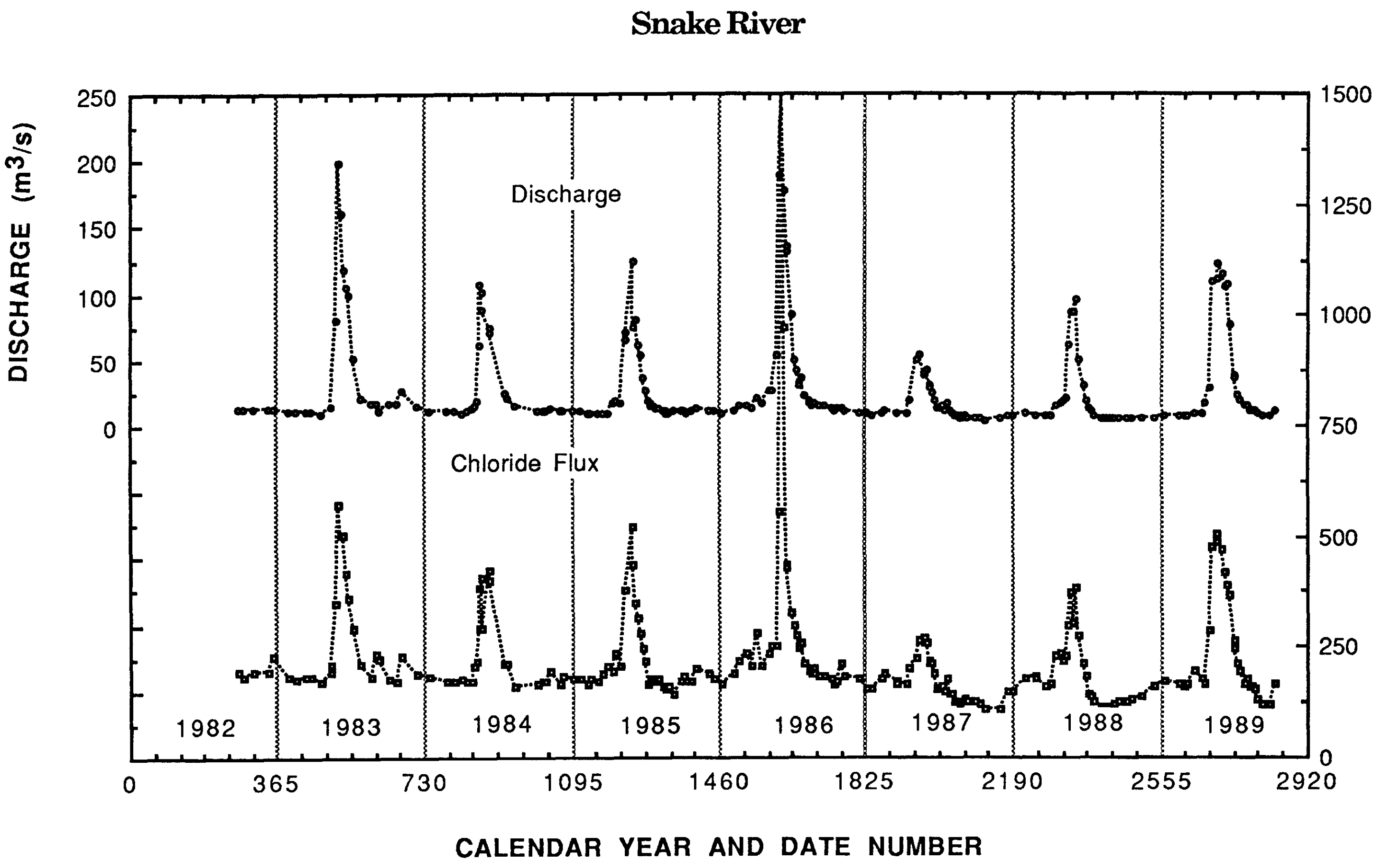

Figure 11. Graphs of the instantaneous discharge in cubic meters per second (m^3/s) and the chloride flux in grams per second (g/s) for the Snake River. Plotted points are from data given in the appendix. Calendar years are shown.

Yellowstone River

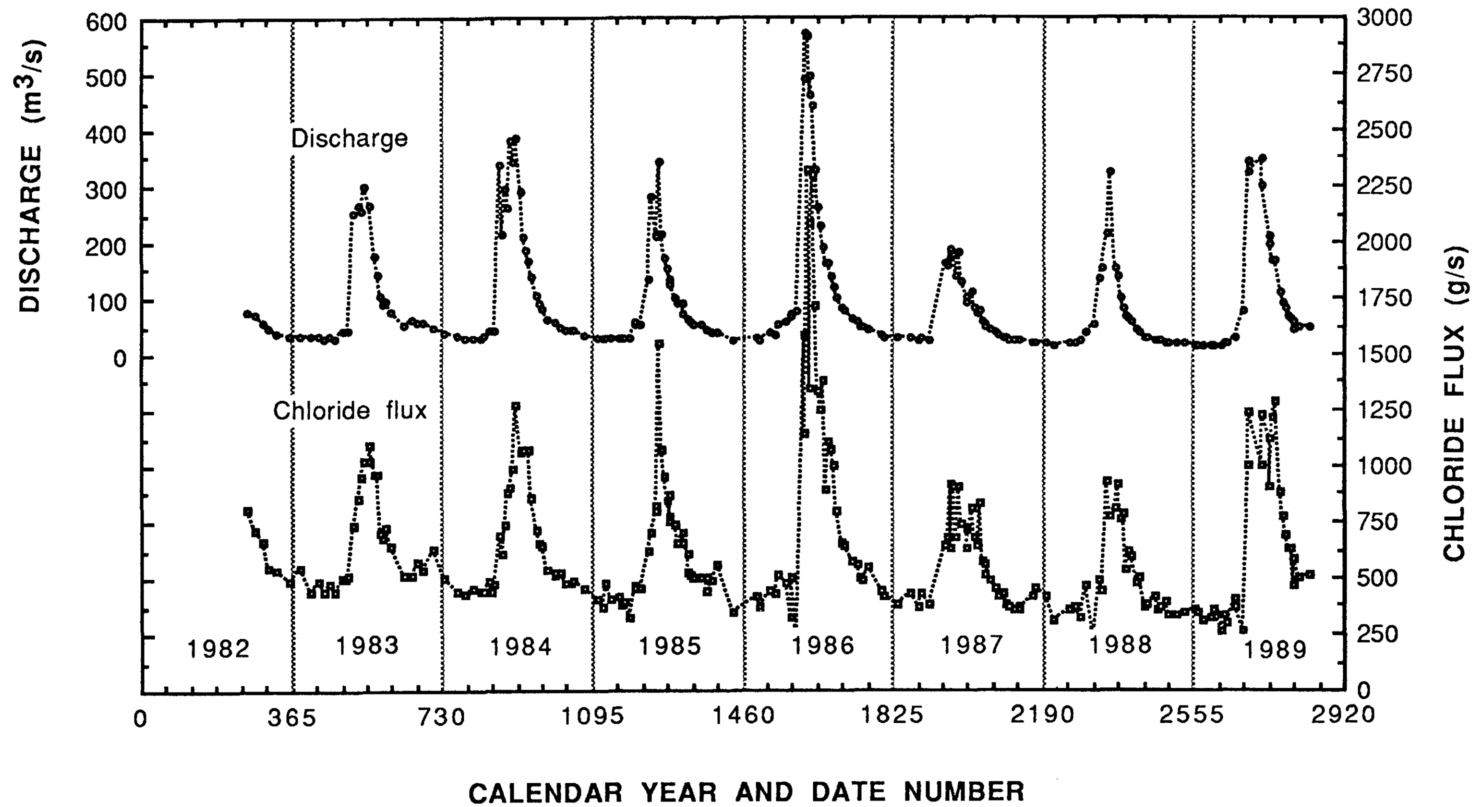

Figure 12. Graphs of the instantaneous discharge in cubic meters per second (m^3/s) and the chloride flux in grams per second (g/s) for the Yellowstone River. Plotted points are from data given in the appendix. Calendar years are shown.

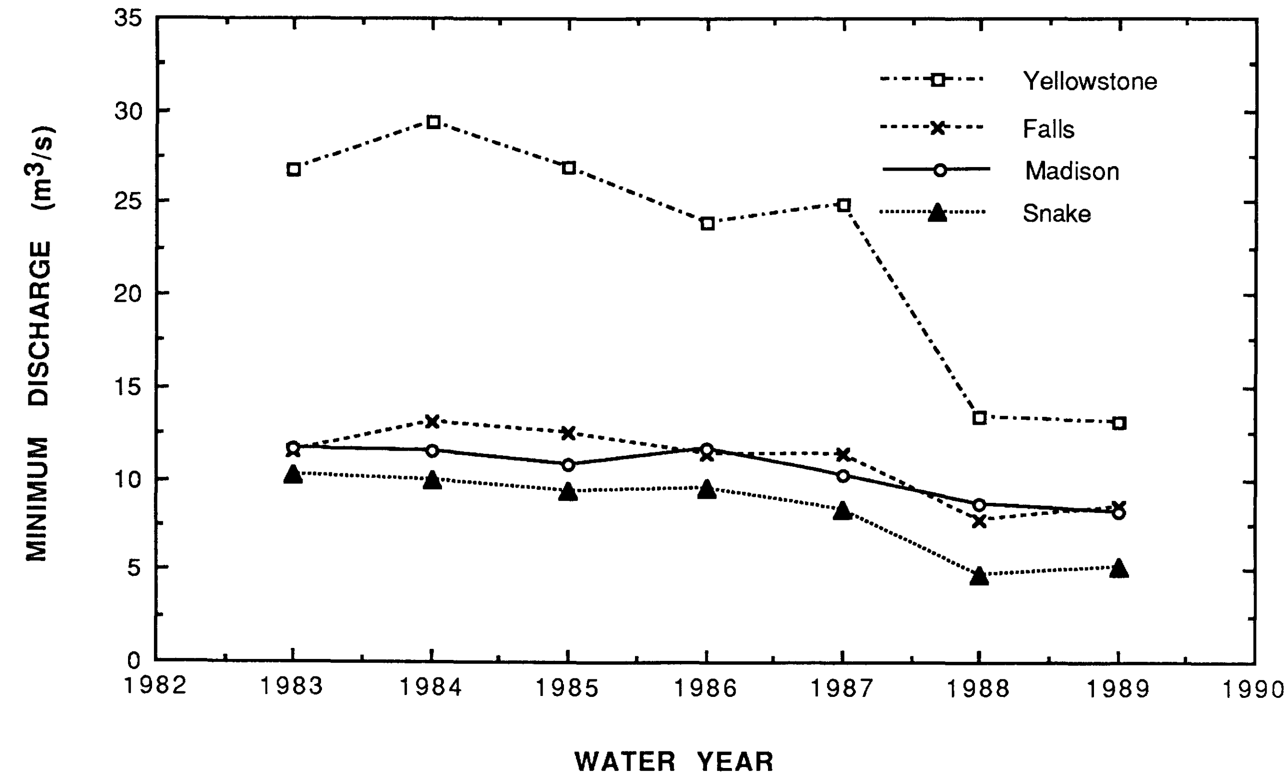

Figure 13. Graph of the minimum discharge, in cubic meters per second (m^3/s) for the Yellowstone, Falls, Madison, and Snake Rivers for water years 1983 through 1989. Note that the plotted minimum flows are from our data, not from data published by the U.S. Geological Survey in its annual report of river discharge.

chloride concentration in snow to be about 2 ppm for the Snake and Yellowstone Rivers, 7 ppm for the Madison River, and about 1 ppm for the Falls River, to account for the peaks in chloride flux during spring runoff. Calculated chloride concentrations of the annual snowpack from chemical analysis of snow samples collected at Tower station in Yellowstone from 1981–1988 ranges from 0.05 to 0.23 ppm with an average value of 0.15 ppm. Discussions of these factors are given in Norton and Friedman (1985) and Friedman and Norton (1990). In our 1985 paper we suggested that the peaks are due primarily to stored chloride, but reconsideration of the data leads us to question this earlier conclusion.

Estimated Chloride Flux in Addition to That From the Four Major Rivers

In a previous paper (Norton and Friedman, 1985), we identified chloride discharges near the western boundary of the Park into the Island Park Geothermal Area. These discharges are a few kilometers west of the Park boundary and probably originate mainly within the Yellowstone geothermal system. They include Big Springs, Buffalo River, Warm River, Robinson Creek, and inflow to the Henrys Fork between Osborne Bridge and the confluence with Warm River (see fig. 2). From data presented by Whitehead (1978), we estimate that 25 percent of the total chloride flux from the western boundary of the Park drains to the Henrys Fork between Osborne Bridge and the confluence of Henrys Fork with Warm River. The remainder exits via Big Springs, Buffalo River, Robinson Creek, and Warm River.

We determined instantaneous chloride flux values at Big Springs, Buffalo River, Robinson Creek, and Warm River from measurements made at base flow in the fall of 1984, 1985, 1988, and 1989. Based on one instantaneous measurement per site for each year, we calculated the total chloride flux for each year. The results were multiplied by 1.33 to correct for the estimated contribution to the Henrys Fork and have been added to the flux from the four rivers in table 6. This chloride flux constitutes 7–9 percent of the total chloride flux that exits the Park. Our previous estimate of 5 percent (Norton and Friedman, 1985) did not include the additional input to the Henrys Fork just mentioned.

La Duke Hot Springs, 9 km north of the Park boundary, may also be considered part of the Yellowstone Park Geothermal System. From data presented in Norton and others (1989), we estimate that the annual chloride flux from this system does not exceed 0.03 percent of the total from the Park, and we will not discuss it further in this paper.

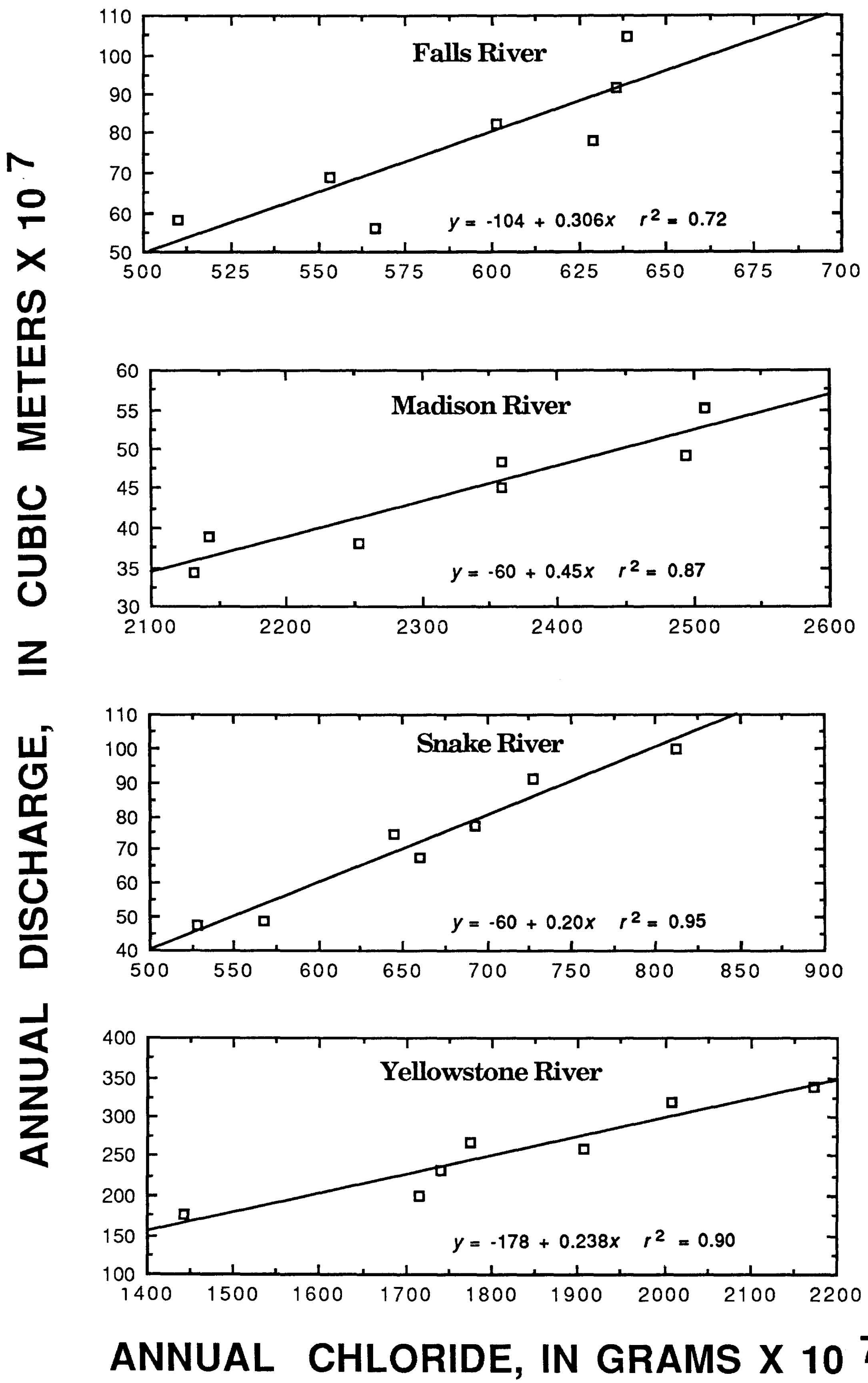

Figure 14. Graphs of the annual chloride flux versus discharge for the Falls, Madison, Snake, and Yellowstone Rivers for water years 1983 through 1989. Solid lines are linear least-mean-square solutions to the data. Equations of these lines are also shown. y, annual discharge; x, annual chloride; r^2, correlation coefficient squared.

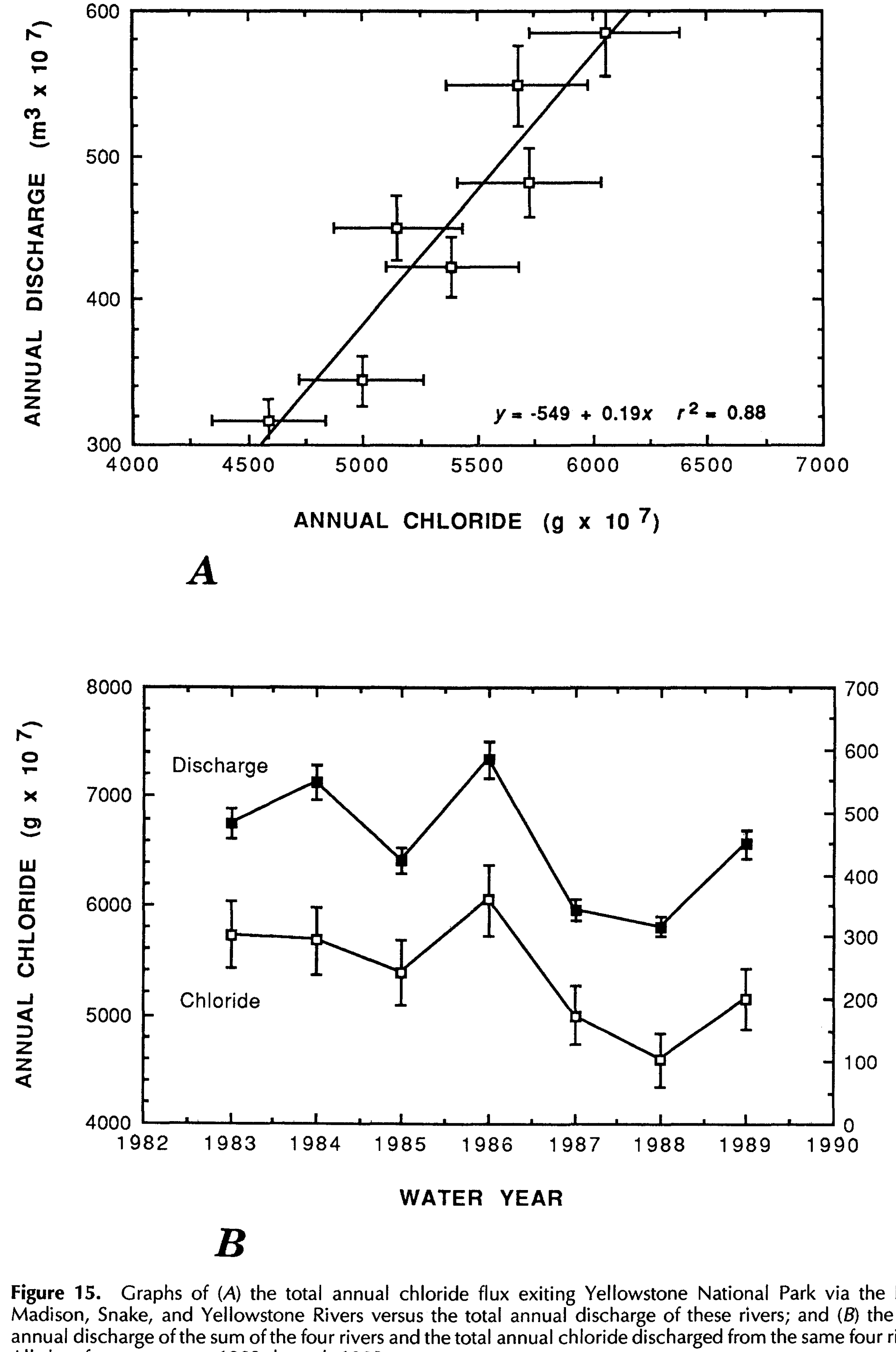

Figure 15. Graphs of (*A*) the total annual chloride flux exiting Yellowstone National Park via the Falls, Madison, Snake, and Yellowstone Rivers versus the total annual discharge of these rivers; and (*B*) the total annual discharge of the sum of the four rivers and the total annual chloride discharged from the same four rivers. All data for water years 1983 through 1989.

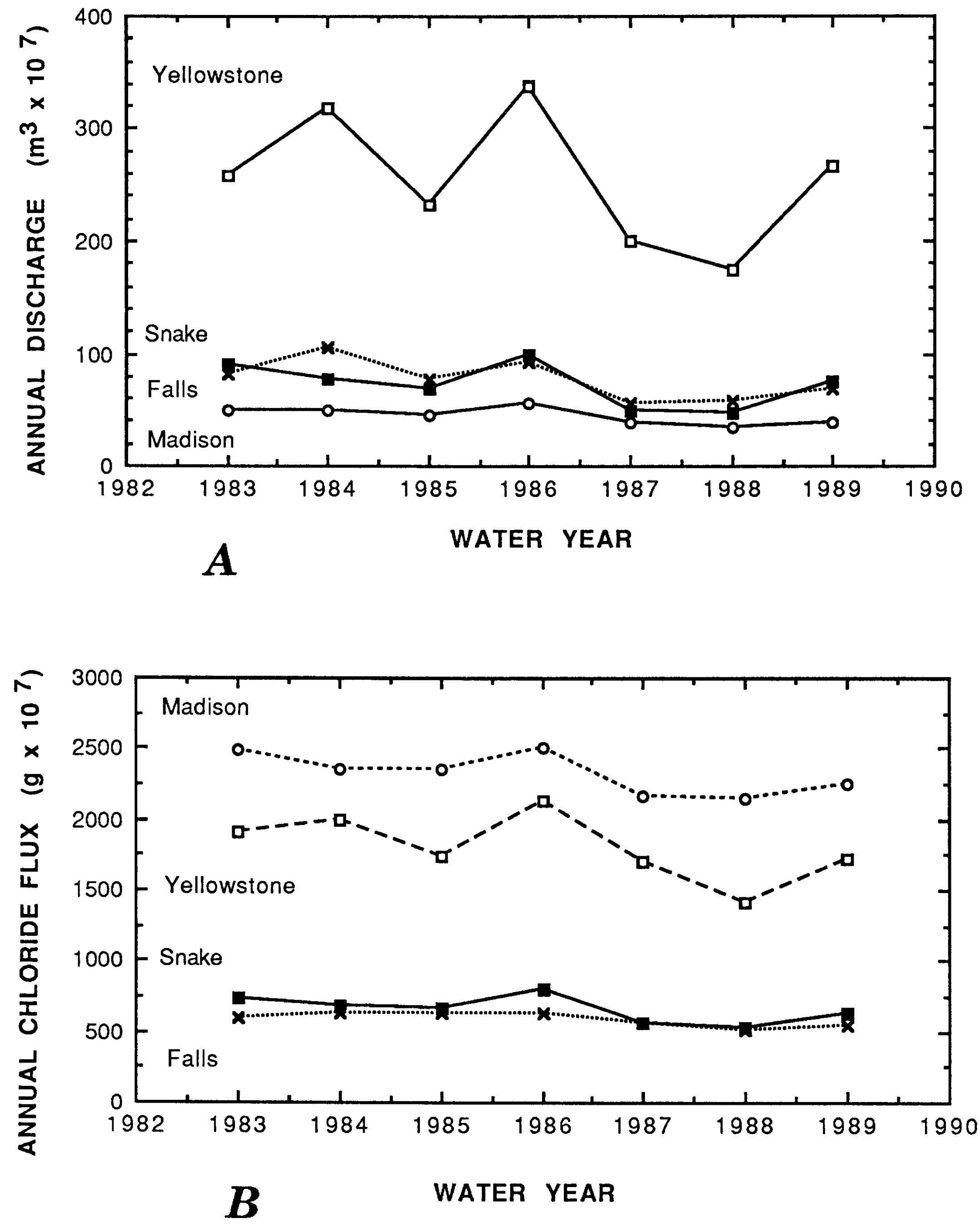

Figure 16. Graphs of (*A*) the annual discharges versus time of the Falls, Madison, Snake, and Yellowstone Rivers; and (*B*) the annual chloride fluxes versus time of the four rivers. All data for water years 1983 through 1989.

Geothermal Chloride Flux

The chloride flux of geothermal origin has been calculated using the method of Norton and Friedman (1985). In this method of calculation the human contribution of chloride is negligible, and all the measured instantaneous chloride concentrations (shown in the appendix) have been reduced by 0.7 ppm to compensate for the chloride added to the rivers by rock weathering (0.5 ppm) and by atmospheric precipitation (0.2 ppm). R.O Fournier says (written commun., 1990) that good arguments can be made that the average nonthermal background chloride ranges from 2 to 3 ppm, but we disagree with his interpretation.

We then recalculated both instantaneous and integrated values of flux using the reduced chloride values. The percentage of annual *geothermal* chloride compared with the *total* annual chloride exiting the Park for the water years 1983–86 agrees with the value of 94 percent found earlier by Norton and Friedman (1985). The model proposed by Fournier (1990) would result in a lower value for the geothermal contribution (approximately 85–90 percent geothermal). Although the issue of the actual amount of nonhydrothermal chloride contributed by rock weathering remains to be resolved, we believe that the following values will not be greatly affected.

According to our model, the rivers draining the Park contribute varying proportions of *geothermal* versus *total* chloride. About 99 percent of the chloride exiting via the Madison River (4 years of data) is of geothermal origin, whereas 90 percent of the chloride exiting via the Yellowstone River (6 years of data) is geothermal. The values for the Falls and Snake Rivers are 91 percent (6 years) and 92 percent (6 years), respectively.

We have calculated the amount of heat flux (in percentage of the total exiting the Park) contributed from the following thermal areas of the Park based upon the fact that geothermal chloride flux is directly related to heat flux:

34 *percent* from thermal areas in the Firehole River drainage, including the Lone Star, Upper Geyser, Midway Geyser, and Lower Geyser Basins;

30 *percent* from thermal areas in the Yellowstone River drainage, which include West Thumb Geyser Basin and other thermal areas in and around the shores of Yellowstone Lake, Hot Springs Basin Group, Sulfur Cauldron Hot Springs, Grand Canyon of the Yellowstone Hot Springs, Calcite Springs, and Mammoth Hot Springs;

12 *percent* from thermal areas in the Snake River drainage basin, including the Shoshone Geyser Basin, Heart Lake Geyser Basin, and the Snake River Hot Springs;

10 *percent* from thermal areas in the Falls River drainage basin which include Boundary Creek, Bechler River, Mountain Ash Creek, and Upper Falls River;

8 *percent* from thermal areas in the Gibbon River Drainage Basin including the Norris Geyser Basin; and

6 *percent* from drainage areas out of the west boundary of the Park into the Island Park Geothermal Area, which include thermal springs of Robinson Creek, Warm River, Buffalo River, Big Springs, and other thermal discharges into the Henrys Fork.

Previous Investigations

Fournier (1989) discussed the chloride flux discharging from rivers draining the Park using data from Fournier and others (1976) as corrected utilizing the results of Norton and Friedman (1985). He stated that his value of thermal chloride flux from Yellowstone for 1983 was 17 percent less than that found by Norton and Friedman (1985). He also stated that "the chloride flux measured in 1983 appears to be exceptionally high compared not only with the 1966–67 measurements, but also with measurements made in subsequent years," and he quoted "USGS unpublished data." The only published data for chloride flux out of the Park for years previous to 1983 was based on intermittent values (Fournier and others 1976). They reported only six instantaneous values for Madison River, four for the Yellowstone River, and no data for the Falls and Snake Rivers for 1966–1967. Our work is based on 37 values per year for each of the four rivers, and these values were integrated to yield annual fluxes.

Fournier's (1989) conclusion that the chloride flux in 1983 was relatively high compared with other years was based on instantaneous flux measurements at low stages of flow, and he used our old (1985) values for stream flow for the Madison River, which gave flux values about 17 percent higher than our revised values presented here (see fig. 1). Using these revised discharge values, Fournier (written commun., 1990) now agrees that the flux of hydrothermal chloride was not exceptionally high in 1983.

Borah Peak Earthquake of October 28, 1983

As stated in Norton and Friedman (1985), all four rivers draining the park showed a distinct increase in chloride flux beginning in early October 1983 and culminating shortly after the Borah Peak earthquake. The magnitude and duration of these increases was insufficient to appear as a significant increase in the *annual* fluxes for these rivers, in contrast to the statement of Fournier (1989).

Yellowstone Fires of 1988

The impact of the extensive fires during the summer of 1988 does not appear to have significantly affected the amount of chloride flux for the following water year. Although the chloride flux did increase in 1989, this increase can be attributed to the increase in discharge observed for that year.

Table 6. Calculated precipitation in selected river basins of Yellowstone National Park

[km^2, square kilometer]

River basin	Area (km^2)	Calculated precipitation (in centimeters) 1983	1984	1985	1986	1987	1988	1989	7-year average
Falls	909	91	115	67	101	62	64	76	82
Madison	1088	45	45	42	51	36	32	35	41
Snake	405	225	190	168	247	121	118	185	179
Yellowstone	6793	38	47	34	50	30	26	39	38
Precipitation at Tower Station[1]		32	41	34	41	([2])	27	([2])	

[1] Data from National Atmospheric Deposition Program (1989), measured values.

[2] Data incomplete for this year.

Use of Discharge Data to Calculate Precipitation

Precipitation is known to vary greatly from area to area within the Park. The discharge data from the rivers draining the Park can be used to reconstruct precipitation within the drainage areas of these rivers. The annual discharge of each river divided by the area of the drainage basin yields a calculated precipitation value for that basin for the year. This approximation procedure assumes a steady-state condition wherein all precipitation during the year leaves as runoff and ignores the *variations* in both annual water storage and losses by evapo-transpiration (the loss due to evapo-transpiration is thought to be small and most of this water probably returns to the system via thunderstorms (see Friedman, 1977)). Because these variables tend to be similar from one year to the next, the precipitation calculated by this method can be used to compare the precipitation between drainage basins for a particular year, as well as from year to year. The calculated precipitation data for the four major river basins are given in table 6 and show that the precipitation increased during 1986 compared with the previous 3 years, decreased to about one-half the 1986 values for 1987 and 1988, and increased somewhat in 1989.

Long-term climatic records in the Park are recorded in the National Oceanic and Atmospheric Administration (NOAA) Report titled *"Climatological Data Annual Summary, Wyoming."* These summaries list stations at Yellowstone Park (Mammoth), Tower Falls, Lake Yellowstone, Old Faithful, and Snake River. The record for these stations are incomplete and cannot be used for climatic studies. In addition to these NOAA stations, another source of precipitation data is available. An automated station at Tower Falls in the Yellowstone River drainage basin has been operated under the National Atmospheric Deposition Program (1989). The data from this station is presented in table 6 and shows a good correlation with our calculated precipitation in the Yellowstone drainage basin, also listed in table 6.

CONCLUSIONS

Based on long-term records of discharge of the Falls, Madison, and Yellowstone rivers, we conclude that data from the 7 years of our study are within the norm for the long-term record.

For the purpose of integrating discharge and chloride flux over long periods of time, we demonstrated that our sampling program, which is based upon an increased sampling rate during periods of high discharge, is necessary to provide the required accuracy for a meaningful monitoring program. In addition, the accuracy of the routine chloride determinations had to be increased by normalizing the raw data against frequently inserted gravimetric standard chloride solutions.

Our data show a high correlation between river discharge and chloride flux. We attribute this to changes in heights of the water tables, which in turn affect the discharge rates of thermal springs. Because most thermal springs have constant chloride concentration, river discharge and chloride flux can be correlated directly.

There are large variations on various time scales in both integrated chloride flux and discharge as measured by monitoring the four major rivers exiting the Park. All the rivers show seasonal variations related to snowmelt in the spring. The rivers that drain major thermal areas also show short-time variations unrelated to these seasonal effects. We attribute these short-time variations to changes in thermal activity in the related geyser basins. This change in thermal activity may be caused by tectonic changes triggered by earthquakes, or by other changes in the magma system that affect the rate at which chloride reaches the surface. The Borah Peak earthquake of October 28, 1983, 240 km west of Old Faithful, appeared to have increased the discharge and chloride flux of the Falls, Madison, and Snake rivers for a short time beginning a few weeks before the earthquake and ending after the earthquake. The Yellowstone River also shows a small increase in chloride flux during this same period, but without a noticeable increase in discharge. This effect might be due to the much greater discharge of the Yellowstone relative to the other rivers, which would mask the effect of a small increase in the input of thermal water.

We did not observe any measurable effect of the great Yellowstone fires of 1988 upon our chloride flux measurements.

During the period of this study, we observed a decline in the minimum discharge or base flow of all of the rivers, which may reflect long-term reduced precipitation.

The use of discharge records for the major rivers draining the Park permits a calculation of the annual precipitation on each of the associated drainage basins. This calculation shows that the average precipitation, neglecting small losses by evapo-transpiration, during these 7 years was 82 cm for the Falls drainage, 41 cm for the Madison, 179 cm for the Snake, and 38 cm for the Yellowstone.

Using calculated values of geothermal chloride for the different drainage basins of the Park, we conclude that 34 percent of the total heat flux from Yellowstone Park is derived from the Firehole River drainage basin. Similar calculations show 30 percent from the Yellowstone River drainage basin, 12 percent from the Snake, 10 percent from the Falls, 8 percent from the Gibbon, and 6 percent from drainages adjacent to the west boundary of the Park.

Inasmuch as about 43 percent of the chloride flux exiting the Park is derived from the Madison River, we recommend that the gauging station on the Madison River, where the river exits the Park, be reactivated and continually monitored, avoiding the uncertainty associated with the use of the stations on the Firehole and Gibbon Rivers to reconstruct the chloride flux exiting the Park via the Madison River.

Investigation of the chloride flux exiting near the west boundary of the Park shows that this flux represents a significant part of the chloride exiting the park. Therefore, we propose that sites in this area be monitored on a regular basis as part of a continuing study.

The data generated during the 7 years of our study showed large annual changes in the chloride flux exiting the Park. Most of these changes are attributed to changes in the height of the water table, which in turn was caused by changes in annual precipitation, and, therefore, long-term records of chloride flux are required to separate changes attributable to climate from those caused by geological events or by the influence of human activity.

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APPENDIX

Sample-data record showing date and time of collection, chloride concentration of sample, river discharge, and chloride flux for individual collections and for interpolated end-of-month values; all for the Falls, Firehole, Gibbon, Madison, Snake, and Yellowstone Rivers for the water years 1983 through 1989.

[ppm, parts per million; m^3/s, cubic meters per second; g/s, grams per second; water year is 12 months beginning October 1]

[1]Date number 1 is January 1, 1980.
[2]Where no time is reported, the chloride concentration and all other data shown are interpolated values.

Day-month-year	Date [1] No.	Time [2]	Instantaneous values		
			Chloride mg/L	Discharge m^3/s	Cl flux g/s
Falls River					
Water year 1983:					
30-Sep-82	273		9.7	20.3	197
21-Oct-82	294	1630	9.9	18.7	186
31-Oct-82	304		9.8	18.9	184
10-Nov-82	314	1025	9.6	19.0	182
30-Nov-82	334	1030	11.0	18.7	206
19-Dec-82	353	1235	12.5	16.1	201
31-Dec-82	365		12.4	15.3	190
26-Jan-83	391	1020	12.1	13.7	166
31-Jan-83	396		12.3	13.5	166
23-Feb-83	419	1010	13.0	12.6	164
28-Feb-83	424		13.1	12.7	166
8-Mar-83	432	1010	13.2	12.8	169
21-Mar-83	445	1730	13.8	12.8	176
31-Mar-83	455		13.5	12.0	162
5-Apr-83	460	1535	13.4	11.6	155
19-Apr-83	474	1430	11.4	16.1	183
30-Apr-83	485		9.0	27.4	247
2-May-83	487	1350	8.6	29.4	253
9-May-83	494	1745	7.2	38.5	277
17-May-83	502	1000	8.8	26.4	232
23-May-83	508	0950	4.1	67.7	277
31-May-83	516	1035	2.7	99.4	268
7-Jun-83	523	0925	3.0	83.8	251
14-Jun-83	530	0955	3.3	73.3	242
22-Jun-83	538	1300	3.6	60.3	217
27-Jun-83	543	0910	3.5	65.8	230
30-Jun-83	546		3.5	58.7	206
6-Jul-83	552	0830	3.5	44.6	156
11-Jul-83	557	0840	4.2	55.2	232
18-Jul-83	564	0910	5.3	31.4	167
26-Jul-83	572	1000	6.7	24.5	164
31-Jul-83	577		7.2	21.9	158
1-Aug-83	578	1030	7.3	21.4	156
9-Aug-83	586	0915	7.7	18.3	141
16-Aug-83	593	0905	7.7	20.1	155
29-Aug-83	606	0900	8.2	22.7	186
31-Aug-83	608		8.3	22.4	185
13-Sep-83	621	0945	8.6	20.3	175
26-Sep-83	634	1230	9.6	16.3	156
30-Sep-83	638		9.4	18.5	173
Water Year 1984:					
12-Oct-83	650	0920	8.7	25.0	218
25-Oct-83	663	1100	9.7	26.2	254
31-Oct-83	669		8.6	28.9	249
8-Nov-83	677	1335	7.2	32.5	234
30-Nov-83	699		9.6	24.2	231
15-Dec-83	714	1530	11.2	18.5	207
31-Dec-83	730		10.6	17.5	186
8-Jan-84	738	1056	10.3	17.0	176
30-Jan-84	760	1435	11.8	15.7	185
31-Jan-84	761		11.8	15.6	184
29-Feb-84	790	1440	11.6	13.5	157
3-Mar-84	803	1345	11.9	13.3	158
26-Mar-84	816	1520	11.6	13.7	159

Day month-year	Date [1] No.	Time [2]	Instantaneous values		
			Chloride mg/L	Discharge m^3/s	Cl flux g/s
Falls River					
31-Mar-84	821		11.7	13.4	156
4-Apr-84	825	1400	11.7	13.1	153
22-Apr-84	843	1930	7.0	24.7	173
30-Apr-84	851	1035	7.7	21.9	162
8-May-84	859	0950	6.7	21.9	141
15-May-84	866	1004	3.0	106	319
21-May-84	872	1025	3.1	111	345
29-May-84	880	1740	3.1	77.3	327
31-May-84	882		3.1	103	315
8-Jun-84	890	0645	2.9	93.7	269
13-Jun-84	895	1955	4.0	65.7	263
19-Jun-84	901	1915	3.1	88.3	274
25-Jun-84	907	2030	2.7	102	278
30-Jun-84	912	1030	2.3	106	244
9-Jul-84	921	1100	3.7	51.5	191
17-Jul-84	929	1005	5.2	32.6	169
24-Jul-84	936	0908	5.8	31.4	182
30-Jul-84	942	2050	6.4	28.6	183
31-Jul-84	943		6.4	28.1	180
9-Aug-84	952	0757	6.3	23.5	148
15-Aug-84	958	0710	7.9	22.4	177
23-Aug-84	966	1030	7.2	23.5	169
29-Aug-84	972	1005	7.5	24.7	185
31-Aug-84	974		7.7	24.0	186
9-Sep-84	983	1855	8.8	20.8	183
23-Sep-84	997	1855	9.0	21.9	197
30-Sep-84	1004		9.1	19.3	176
Water year 1985:					
9-Oct-84	1013	1543	9.3	16.1	150
22-Oct-84	1026	1619	10.4	15.9	165
31-Oct-84	1035		10.7	16.0	172
7-Nov-84	1042	0924	11.0	16.1	178
30-Nov-84	1065		11.6	14.8	172
4-Dec-84	1069	1410	11.7	14.6	171
31-Dec-84	1096		11.6	14.2	166
7-Jan-85	1103	0930	11.6	14.2	164
22-Jan-85	1118	1342	11.6	12.5	145
31-Jan-85	1127		11.7	13.5	158
12-Feb-85	1139	1645	11.9	14.7	175
19-Feb-85	1146	0650	14.1	16.3	230
28-Feb-85	1155		13.1	16.7	218
5-Mar-85	1160	1545	12.5	12.5	156
25-Mar-85	1180	0755	12.9	13.5	175
31-Mar-85	1186		13.6	14.0	189
3-Apr-85	1189	0955	13.9	14.2	197
15-Apr-85	1201	1445	9.8	27.7	271
29-Apr-85	1215	1844	8.4	33.7	283
30-Apr-85	1216		8.2	35.3	288
13-May-85	1229	1230	4.9	56.0	274
28-May-85	1244	1940	3.3	91.5	302
31-May-85	1247		3.6	75.9	270
4-Jun-85	1251	1005	3.9	55.2	215
9-Jun-85	1256	1930	3.3	82.8	273
18-Jun-85	1265	0922	4.0	58.5	234
23-Jun-85	1270	2035	5.5	39.8	219
25-Jun-85	1272	0930	5.6	38.5	216
30-Jun-85	1277		7.3	31.0	225

Day-month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Falls River					
1-Jul-85	1278	0750	7.6	29.5	224
9-Jul-85	1286	0800	8.0	25.6	205
17-Jul-85	1294	0955	8.4	25.8	217
23-Jul-85	1300	0945	9.1	26.6	242
29-Jul-85	1306	0939	9.1	21.0	191
31-Jul-85	1308		9.2	20.8	192
6-Aug-85	1314	0849	9.6	20.3	195
13-Aug-85	1321	1002	9.8	18.7	183
20-Aug-85	1328	1902	10.2	16.6	170
27-Aug-85	1335	0900	10.4	15.7	163
31-Aug-85	1339		10.5	17.5	184
9-Sep-85	1348	0958	10.7	21.5	230
17-Sep-85	1356	0958	10.8	16.2	175
23-Sep-85	1362	1511	10.4	16.2	168
30-Sep-85	1369		11.0	16.3	178
Water year 1986:					
8-Oct-85	1377	1652	11.6	16.4	190
21-Oct-85	1390	0944	11.1	14.7	163
30-Oct-85	1399	0900	11.7	16.1	188
31-Oct-85	1400		11.6	15.9	185
4-Nov-85	1404	1043	11.4	15.2	174
30-Nov-85	1430		12.3	13.9	171
4-Dec-85	1434	1010	12.4	13.7	170
11-Dec-85	1441	1030	13.6	11.6	158
31-Dec-85	1461		13.2	13.2	174
4-Jan-86	1465	1010	13.1	13.5	177
23-Jan-86	1484	1000	13.5	11.4	154
31-Jan-86	1492		13.2	11.9	157
3-Feb-86	1495	1525	13.1	12.0	158
28-Feb-86	1520		12.8	13.7	176
4-Mar-86	1524	0904	12.8	14.0	179
19-Mar-86	1539	0925	12.6	14.0	176
31-Mar-86	1551	1030	9.0	29.3	264
14-Apr-86	1565	1650	7.6	34.8	264
16-Apr-86	1567	0945	8.0	33.8	270
30-Apr-86	1581	0948	5.9	30.9	182
14-May-86	1595	0955	7.7	32.5	250
19-May-86	1600	1053	6.5	48.5	315
26-May-86	1607	2025	4.0	91.5	366
29-May-86	1610	0930	2.6	103.9	270
31-May-86	1612		2.5	119.2	292
2-Jun-86	1614	1053	2.3	134.4	309
9-Jun-86	1621	1017	2.8	108.3	303
17-Jun-86	1629	0922	2.5	102.7	260
24-Jun-86	1636	0845	3.2	70.4	225
30-Jun-86	1642		2.9	60.3	177
1-Jul-86	1643	1100	2.9	58.6	170
8-Jul-86	1650	0910	5.6	36.8	206
13-Jul-86	1655	2035	6.4	34.1	218
16-Jul-86	1658	0930	6.5	33.1	215
23-Jul-86	1665	0815	7.2	29.8	215
30-Jul-86	1672	0920	7.6	27.8	212
31-Jul-86	1673		7.7	27.5	211
5-Aug-86	1678	0839	8.2	25.6	210
12-Aug-86	1685	0848	8.2	24.1	198
18-Aug-86	1691	0927	8.4	23.0	193

Day month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Falls River					
27-Aug-86	1700	0840	8.8	21.5	189
31-Aug-86	1704		8.3	22.9	191
2-Sep-86	1706	0932	8.1	23.6	191
16-Sep-86	1720	1030	9.5	18.7	178
29-Sep-86	1733	0944	10.7	18.4	197
30-Sep-86	1734		10.7	18.4	197
Water year 1987:					
16-Oct-86	1750		10.9	17.3	188
28-Oct-86	1762	1430	10.6	16.1	170
31-Oct-86	1765		10.9	16.2	177
10-Nov-86	1775	1710	12.1	16.3	198
30-Nov-86	1795		12.7	13.7	174
9-Dec-86	1804	1540	13.0	12.5	162
31-Dec-86	1826		13.1	13.2	172
13-Jan-87	1839	1047	13.2	13.5	178
31-Jan-87	1857		13.4	12.7	170
9-Feb-87	1866	1307	13.5	12.3	165
9-Feb-87	1866	1718	13.5	12.3	165
28-Feb-87	1885		13.6	12.7	173
10-Mar-87	1895	1015	13.7	12.9	176
24-Mar-87	1909	1612	14.6	11.4	167
26-Mar-87	1911	1620	14.3	11.4	164
31-Mar-87	1916		13.8	13.6	187
8-Apr-87	1924	1032	12.9	17.0	219
20-Apr-87	1936	1022	9.1	27.1	247
29-Apr-87	1945	1223	4.4	50.5	222
30-Apr-87	1946		4.8	48.5	233
4-May-87	1950	1944	6.4	40.8	261
11-May-87	1957	0945	4.0	51.8	209
19-May-87	1965	0845	4.8	51.3	248
26-May-87	1972	0920	7.4	42.0	312
31-May-87	1977		7.6	33.6	254
3-Jun-87	1980	1001	7.6	28.5	218
9-Jun-87	1986	1907	9.0	23.1	208
15-Jun-87	1992	1032	10.0	18.5	186
18-Jun-87	1995	1300	10.3	16.2	166
23-Jun-87	2000	1007	10.8	15.5	167
29-Jun-87	2006	0911	9.3	18.7	173
30-Jun-87	2007		9.3	18.4	171
8-Jul-87	2015	0906	9.5	15.9	152
14-Jul-87	2021	0918	10.6	14.2	150
21-Jul-87	2028	1023	11.8	12.9	152
30-Jul-87	2037	0920	11.3	14.5	163
4-Aug-87	2042	1050	11.7	12.9	151
13-Aug-87	2051	0900	12.9	11.1	142
17-Aug-87	2055	0950	13.1	11.0	144
26-Aug-87	2064	1021	13.4	10.6	142
31-Aug-87	2069	0934	13.5	10.3	138
8-Sep-87	2077	0910	13.7	9.6	131
24-Sep-87	2093		14.3	9.0	129
30-Sep-87	2099		14.5	8.6	125
Water year 1988:					
8-Oct-87	2107	0955	14.8	8.2	121
20-Oct-87	2119	1045	14.5	8.5	123
29-Oct-87	2128	1100	13.7	8.9	122
31-Oct-87	2130		13.8	8.9	122

Day-month-year	Date [1] No.	Time [2]	Chloride mg/L	Discharge m^3/s	Cl flux g/s
			Instantaneous values		
Falls River					
30-Nov-87	2160	1310	15.9	8.5	135
28-Dec-87	2188	1655	16.3	10.1	164
31-Dec-87	2191		16.1	10.0	161
12-Jan-88	2203	1130	15.5	9.5	147
26-Jan-88	2217	1722	16.2	7.8	126
31-Jan-88	2222		16.1	8.0	129
22-Feb-88	2244	1745	16.0	9.1	145
24-Feb-88	2246	1145	16.0	9.3	150
29-Feb-88	2251		16.1	9.0	145
15-Mar-88	2266	1150	16.5	8.0	131
28-Mar-88	2279	1010	16.5	8.0	131
31-Mar-88	2282		15.8	9.3	147
8-Apr-88	2290	1100	14.0	12.9	180
13-Apr-88	2295	1110	12.3	17.7	218
25-Apr-88	2307	1645	10.0	31.1	311
30-Apr-88	2312		9.1	34.2	312
11-May-88	2323	1017	7.2	41.1	296
16-May-88	2328	1035	4.4	56.1	248
17-May-88	2329		4.5	66.3	298
23-May-88	2335	0904	3.6	59.3	215
31-May-88	2343		4.8	35.0	167
1-Jun-88	2344	0835	4.9	32.0	157
6-Jun-88	2349	0925	3.3	63.2	210
14-Jun-88	2357	0935	6.2	31.0	192
20-Jun-88	2363	0953	6.6	25.7	170
27-Jun-88	2370	0905	9.8	16.8	165
29-Jun-88	2372	1200	9.5	16.2	154
30-Jun-88	2373		9.5	16.5	157
5-Jul-88	2378	0900	9.6	18.1	173
10-Jul-88	2383	2040	8.6	19.5	167
20-Jul-88	2393	1055	9.2	17.7	163
27-Jul-88	2400	2002	9.4	16.8	158
31-Jul-88	2404		9.6	15.7	150
1-Aug-88	2405	1110	9.6	15.5	148
9-Aug-88	2413	1140	10.9	11.1	121
10-Aug-88	2414	0718	11.0	11.4	126
17-Aug-88	2421	0748	11.5	12.5	143
22-Aug-88	2426	0950	11.6	12.1	141
30-Aug-88	2434	0730	12.1	11.4	138
31-Aug-88	2435		12.1	11.3	138
6-Sep-88	2441	1009	12.4	10.8	134
20-Sep-88	2455	1015	12.5	11.8	147
30-Sep-88	2465		12.6	11.0	138
Water year 1989:					
13-Jan-89	2570	1030	16.6	8.8	146
31-Jan-89	2588		17.3	9.2	159
8-Feb-89	2596	1535	17.6	9.3	164
28-Feb-89	2616		16.5	8.9	147
6-Mar-89	2622	1430	16.2	8.8	142
9-Mar-89	2625	0917	15.7	10.8	170
21-Mar-89	2637	1645	16.1	9.2	148
31-Mar-89	2647		16.2	8.7	142
6-Apr-89	2653	0955	16.3	8.5	138
18-Apr-89	2665	1020	11.8	19.0	224
30-Apr-89	2677		9.0	32.2	291
2-May-89	2679	1410	8.6	34.5	295

Day month-year	Date [1] No.	Time [2]	Chloride mg/L	Discharge m^3/s	Cl flux g/s
			Instantaneous values		
Falls River					
12-May-89	2689	1043	3.9	88.9	342
17-May-89	2694	1038	4.0	76.0	307
23-May-89	2700	0918	3.3	73.6	244
31-May-89	2708	1022	4.4	55.6	244
31-May-89	2708		4.6	54.4	251
6-Jun-89	2714	1327	3.0	82.1	245
14-Jun-89	2722	0917	3.1	68.8	212
21-Jun-89	2729	0840	3.7	62.9	232
27-Jun-89	2735	0850	4.6	40.1	186
30-Jun-89	2738		5.0	36.3	181
4-Jul-89	2742	1040	5.5	31.2	171
11-Jul-89	2749	0907	7.9	21.5	169
12-Jul-89	2750	1000	7.9	20.8	164
18-Jul-89	2756	0845	8.0	20.8	166
27-Jul-89	2765	0954	8.1	20.2	163
31-Jul-89	2769		8.4	18.9	158
1-Aug-89	2770	0841	8.5	18.5	157
8-Aug-89	2777	1000	9.2	17.0	157
17-Aug-89	2786	0940	9.6	16.7	159
23-Aug-89	2792	0905	9.0	16.7	150
27-Aug-89	2796	0935	10.2	17.0	172
31-Aug-89	2800		10.3	16.6	170
11-Sep-89	2811	0930	10.5	15.7	165
27-Sep-89	2827	0914	10.7	14.4	155
30-Sep-89	2830		10.9	14.6	159
10-Oct-89	2840	0938	11.3	15.1	171
Firehole River					
Water year 1984:					
30-Sep-83	638		59.8	15.5	925
9-Oct-83	647	1730	60.7	9.9	602
23-Oct-83	661	1105	60.1	9.4	565
31-Oct-83	669		59.5	10.0	595
6-Nov-83	675	1230	59.0	10.4	616
30-Nov-83	699		64.9	9.0	585
4-Dec-83	703	1215	65.9	8.8	578
31-Dec-83	730		66.0	8.5	564
1-Jan-84	731	1330	66.1	8.5	563
29-Jan-84	759	1130	67.9	8.2	559
31-Jan-84	761		68.0	8.2	559
29-Feb-84	790	1145	70.7	7.8	555
16-Mar-84	806	1130	73.4	8.3	611
29-Mar-84	819	1340	71.2	8.1	575
31-Mar-84	821		71.1	8.1	575
10-Apr-84	831	1400	70.6	8.1	574
25-Apr-84	846	1100	64.8	9.1	591
30-Apr-84	851		66.8	9.1	609
3-May-84	854	1420	68.1	9.1	621
9-May-84	860	1045	66.4	9.1	606
17-May-84	868	1230	39.8	15.5	619
23-May-84	874	0900	30.1	18.5	557
30-May-84	881	1540	31.8	18.9	602
31-May-84	882		33.9	18.4	624
6-Jun-84	888	0620	46.4	15.3	710
6-Jun-84	888	1810	43.2	15.0	650

Day-month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Firehole River					
13-Jun-84	895	1450	44.6	13.6	609
20-Jun-84	902	1250	37.0	15.1	557
28-Jun-84	910	2000	42.7	12.2	521
30-Jun-84	912		45.1	11.6	524
5-Jul-84	917	1940	50.9	10.2	518
11-Jul-84	923	1010	56.9	9.7	551
19-Jul-84	931	1540	58.7	9.3	547
25-Jul-84	937	1240	56.9	9.5	539
31-Jul-84	943		58.9	9.7	569
1-Aug-84	944	1210	59.3	9.7	574
9-Aug-84	952	0845	59.9	8.9	536
16-Aug-84	959	1445	58.7	11.8	532
22-Aug-84	965	1413	59.7	9.1	545
30-Aug-84	973	1430	60.5	9.0	547
31-Aug-84	974		60.5	9.0	547
11-Sep-84	985	1530	59.7	9.2	550
26-Sep-84	1000	1120	63.1	9.2	581
30-Sep-84	1004		62.7	9.1	573
Water year 1985:					
12-Oct-84	1016	1200	61.3	8.9	548
26-Oct-84	1030	1436	62.8	9.1	572
31-Oct-84	1035		63.5	9.1	581
9-Nov-84	1044	1400	64.8	9.2	596
30-Nov-84	1065		65.1	8.7	565
7-Dec-84	1072	1520	65.2	8.5	554
31-Dec-84	1096		67.2	8.7	583
2-Jan-85	1098	1240	67.3	8.7	585
23-Jan-85	1119	1450	66.9	8.1	540
31-Jan-85	1127		67.1	8.0	537
21-Feb-85	1148	0745	67.5	7.8	527
21-Feb-85	1148	1820	70.6	8.0	564
28-Feb-85	1155		70.5	7.9	559
14-Mar-85	1169	0630	70.3	7.8	550
31-Mar-85	1186		59.3	9.9	588
17-Apr-85	1203	1000	48.3	12.0	580
30-Apr-85	1216		46.3	12.1	561
31-May-85	1247		41.6	12.3	513
11-Jun-85	1258	1630	39.9	12.4	496
30-Jun-85	1277		45.9	12.5	574
23-Jul-85	1300	1450	53.1	12.6	670
31-Jul-85	1308		56.3	11.8	665
31-Aug-85	1339		68.6	8.7	599
4-Sep-85	1343	1700	70.2	8.3	585
30-Sep-85	1369		66.8	8.7	578
Water year 1986:					
16-Oct-85	1385	1500	64.7	40.2	573
31-Oct-85	1400		66.0	42.0	612
8-Nov-85	1408	0925	66.7	43.0	633
30-Nov-85	1430		67.0	40.3	596
5-Dec-85	1435	1630	67.1	39.6	587
31-Dec-85	1461		68.5	39.0	589
3-Jan-86	1464	1450	68.7	38.9	590
31-Jan-86	1492		71.4	38.5	607
3-Feb-86	1495	1435	71.6	38.5	609
5-Feb-86	1497	1120	70.2	37.3	579
28-Feb-86	1520		71.7	40.3	637

Day month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Firehole River					
2-Mar-86	1522	1010	71.8	40.5	643
16-Mar-86	1536	0920	72.4	37.7	603
18-Mar-86	1538	1600	71.2	38.5	605
31-Mar-86	1551		62.2	48.0	660
8-Apr-86	1559	0900	56.7	53.9	675
17-Apr-86	1568	1030	63.6	51.5	722
18-Apr-86	1569	1730	70.2	44.8	694
30-Apr-86	1581		62.4	62.0	853
1-May-86	1582	1620	61.7	63.4	864
5-May-86	1586	0811	53.3	71.0	834
29-May-86	1610	0830	17.8	153.1	601
31-May-86	1612		19.1	145.6	615
8-Jun-86	1620	0735	24.5	115.6	625
26-Jun-86	1638	1640	35.6	68.3	537
30-Jun-86	1642		38.2	65.7	554
10-Jul-86	1652	0848	44.7	59.3	584
23-Jul-86	1665	0740	49.8	54.4	597
24-Jul-86	1666	1150	48.8	51.1	550
31-Jul-86	1673		50.5	48.4	539
6-Aug-86	1679	0845	51.9	46.1	528
20-Aug-86	1693	0830	52.0	46.5	533
31-Aug-86	1704		51.1	46.9	529
3-Sep-86	1707	0830	50.9	47.0	527
4-Sep-86	1708	0735	52.0	46.1	529
17-Sep-86	1721	1745	52.6	45.6	529
30-Sep-86	1734		52.9	47.7	556
Water year 1987:					
1-Oct-86	1735	0804	52.9	10.6	558
8-Oct-86	1742	1100	52.4	9.9	518
15-Oct-86	1749	1135	53.5	9.3	498
25-Oct-86	1759	1605	53.2	9.7	515
31-Oct-86	1765		58.4	9.6	559
18-Nov-86	1783	1100	63.1	9.3	588
27-Nov-86	1792	1112	59.4	9.0	537
30-Nov-86	1795		59.6	8.9	528
10-Dec-86	1805	1200	60.0	8.3	500
24-Dec-86	1819	1150	58.5	8.5	497
31-Dec-86	1826		60.3	8.5	512
6-Jan-87	1832	1300	63.4	8.6	544
7-Jan-87	1833	1437	62.2	8.5	528
21-Jan-87	1847	1230	66.8	8.1	539
31-Jan-87	1857		64.8	8.4	543
4-Feb-87	1861	1555	64.0	8.5	544
18-Feb-87	1875	0937	67.0	8.2	547
18-Feb-87	1875	1100	66.1	8.2	539
28-Feb-87	1885		68.7	8.4	576
11-Mar-87	1896	1000	71.5	8.7	620
25-Mar-87	1910	1545	68.6	8.0	548
31-Mar-87	1916		67.8	7.9	534
3-Apr-87	1919	0900	67.4	7.8	527
8-Apr-87	1924	1347	62.1	8.7	538
23-Apr-87	1939	1712	50.4	10.2	512
30-Apr-87	1946		48.9	11.0	517
6-May-87	1952	0902	44.4	11.8	523
19-May-87	1965	0930	51.2	12.3	631
20-May-87	1966	0928	53.9	11.6	623
31-May-87	1977		60.9	9.2	559

Day-month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Firehole River					
4-Jun-87	1981	1727	63.4	8.3	528
17-Jun-87	1994	1725	68.6	7.6	524
30-Jun-87	2007	1145	64.8	7.5	484
1-Jul-87	2008	1727	67.6	7.4	500
15-Jul-87	2022	1229	67.8	7.2	490
26-Jul-87	2033	1800	68.4	7.5	511
31-Jul-87	2038		68.8	7.4	506
12-Aug-87	2050	1725	69.7	7.1	494
18-Aug-87	2056	1220	69.6	7.2	498
26-Aug-87	2064	1645	67.8	7.2	491
31-Aug-87	2069		68.4	7.1	488
9-Sep-87	2078	1510	69.6	6.9	481
23-Sep-87	2092	1729	71.0	6.7	475
30-Sep-87	2099		71.1	6.8	484
Water year 1988:					
6-Oct-87	2105	1205	71.2	6.9	492
7-Oct-87	2106	1734	72.0	7.0	503
21-Oct-87	2120	1530	73.1	6.8	499
31-Oct-87	2130		72.4	6.9	499
4-Nov-87	2134	1030	72.2	6.9	499
17-Nov-87	2147	1130	72.9	6.8	497
30-Nov-87	2160		74.6	6.7	499
1-Dec-87	2161	0837	74.8	6.7	500
30-Dec-87	2190	1445	77.5	6.9	536
31-Dec-87	2191		77.5	6.9	536
5-Jan-88	2196	1120	77.3	7.0	541
28-Jan-88	2219	1303	80.5	7.2	577
31-Jan-88	2222		80.6	7.1	574
17-Feb-88	2239	1210	81.1	6.9	560
24-Feb-88	2246	1328	73.7	6.9	509
29-Feb-88	2251		75.2	6.9	518
16-Mar-88	2267	0856	79.9	6.8	545
29-Mar-88	2280	1130	73.1	7.2	524
31-Mar-88	2282	1201	80.5	6.9	556
13-Apr-88	2295	1726	66.2	9.9	654
21-Apr-88	2303	1740	59.9	10.4	621
27-Apr-88	2309	1709	74.3	9.9	734
30-Apr-88	2312		72.5	9.4	682
4-May-88	2316	1705	70.2	8.7	614
12-May-88	2324	1544	51.2	11.0	565
17-May-88	2329	1130	30.6	16.9	518
18-May-88	2330	1709	37.5	14.1	529
25-May-88	2337	1709	38.9	12.7	496
31-May-88	2343		50.5	10.8	544
1-Jun-88	2344	1714	52.4	10.4	548
8-Jun-88	2351	1846	54.9	8.7	480
15-Jun-88	2358	1713	66.5	7.4	491
22-Jun-88	2365	1049	70.0	7.1	496
22-Jun-88	2365	1210	69.0	7.1	488
29-Jun-88	2372	0715	72.8	6.7	487
30-Jun-88	2373		72.6	6.6	482
6-Jul-88	2379	0734	71.6	6.4	456
13-Jul-88	2386	0845	76.0	6.3	480
20-Jul-88	2393	0748	76.9	6.1	468
27-Jul-88	2400	0741	77.5	6.2	483

Day month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Firehole River					
31-Jul-88	2404		77.0	6.1	474
3-Aug-88	2407	0726	76.7	6.1	467
9-Aug-88	2413	1215	78.6	6.1	481
9-Aug-88	2413	1715	77.6	6.1	472
17-Aug-88	2421	917	76.4	5.9	454
24-Aug-88	2428	0915	75.6	6.1	458
31-Aug-88	2435	1659	78.4	6.0	471
7-Sep-88	2442	1827	78.8	5.9	469
20-Sep-88	2455	1215	79.1	6.3	499
21-Sep-88	2456	1712	76.5	6.3	483
30-Sep-88	2465		76.3	6.3	478
Water year 1989:					
30-Sep-88	638		53.1	2.8	150
21-Sep-88	2456	1712	76.5	6.3	483
30-Sep-88	2465		76.3	6.5	493
5-Oct-88	2470	1702	76.2	6.5	498
6-Oct-88	2471	1230	77.5	6.5	500
19-Oct-88	2484	1754	79.3	6.6	523
31-Oct-88	2496		79.8	7.0	557
3-Nov-88	2499	1145	79.9	7.1	566
16-Nov-88	2512	0901	85.1	6.5	549
30-Nov-88	2526		83.9	6.5	542
13-Dec-88	2539	1515	82.8	6.5	535
15-Dec-88	2541	1508	84.3	5.6	470
31-Dec-88	2557		79.1	6.0	477
10-Jan-89	2567	1615	75.9	6.3	479
31-Jan-89	2588		83.3	6.5	540
7-Feb-89	2595	1515	85.7	6.5	561
9-Feb-89	2597	1015	83.4	6.4	531
28-Feb-89	2616		86.3	6.9	594
7-Mar-89	2623	0945	87.3	7.1	618
8-Mar-89	2624	1330	85.4	6.8	583
23-Mar-89	2639	0910	85.0	6.7	568
31-Mar-89	2647		84.3	6.6	555
4-Apr-89	2651	1125	83.9	6.5	549
19-Apr-89	2666	1750	60.9	10.4	636
30-Apr-89	2677		60.9	10.2	623
3-May-89	2680	1752	60.9	10.2	619
3-May-89	2680	1015	56.4	11.2	629
31-May-89	2708		45.2	12.7	576
14-Jun-89	2722	1115	39.6	13.5	536
30-Jun-89	2738		59.0	9.3	549
5-Jul-89	2743	0850	65.0	8.0	519
13-Jul-89	2751	1140	61.5	8.9	550
21-Jul-89	2759	1000	68.9	7.6	521
26-Jul-89	2764	1000	68.3	7.6	516
28-Jul-89	2766	1100	67.4	8.3	561
31-Jul-89	2769		68.0	8.0	546
4-Aug-89	2773	1630	68.7	7.6	525
10-Aug-89	2779	1645	71.7	7.7	554
12-Aug-89	2781	1515	68.1	7.9	538
21-Aug-89	2790	1000	70.3	8.0	561
27-Aug-89	2796	0930	70.2	7.6	537
31-Aug-89	2800		70.4	7.5	530
12-Sep-89	2812	1100	71.0	7.2	509
26-Sep-89	2826	1308	71.8	7.1	508
30-Sep-89	2830		71.6	7.2	513

Day-month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Gibbon River					
Water year 1984:					
30-Sep-83	638		53.1	2.83	150
15-Oct-83	653	1750	47.8	3.20	153
26-Oct-83	664	1045	48.8	2.97	145
31-Oct-83	669		48.4	2.99	145
9-Nov-83	678	1305	47.5	3.03	144
30-Nov-83	699		56.4	2.94	166
6-Dec-83	705	1215	58.9	2.92	172
31-Dec-83	730		60.1	2.80	168
6-Jan-84	736	1430	60.3	2.78	167
25-Jan-84	755	1715	64.3	2.44	156
31-Jan-84	761		62.5	2.29	143
2-Feb-84	763	1200	61.9	2.24	139
29-Feb-84	790	1230	65.9	2.32	153
14-Mar-84	804	1140	70.6	2.24	158
29-Mar-84	819	1315	68.2	2.32	158
31-Mar-84	821		67.9	2.33	158
10-Apr-84	831	1420	66.3	2.35	156
25-Apr-84	846	1130	40.5	3.43	139
30-Apr-84	851		44.5	3.25	145
3-May-84	854	1440	46.9	3.14	148
9-May-84	860	1100	47.5	3.43	163
17-May-84	868	1245	17.5	10.25	179
23-May-84	874	0920	15.4	10.36	160
29-May-84	880	1300	18.3	8.47	155
31-May-84	882		19.0	8.29	157
6-Jun-84	888	1245	21.1	7.76	163
12-Jun-84	894	0620	21.1	7.87	166
12-Jun-84	894	1740	21.1	7.02	148
20-Jun-84	902	1235	25.0	5.18	129
28-Jun-84	910	1940	29.4	4.28	126
30-Jun-84	912		29.5	4.19	124
5-Jul-84	917	1100	29.7	3.99	119
11-Jul-84	923	1030	32.1	4.33	139
19-Jul-84	931	1600	34.2	3.99	137
25-Jul-84	937	1300	35.8	4.19	150
31-Jul-84	943		33.1	4.09	136
1-Aug-84	944	1230	32.7	4.08	133
9-Aug-84	952	0900	37.1	3.20	119
16-Aug-84	959	1500	44.7	3.79	170
22-Aug-84	965	1345	42.7	3.26	139
30-Aug-84	973	1450	43.6	3.09	135
31-Aug-84	974		44.0	3.10	136
11-Sep-84	985	1545	48.2	3.26	157
26-Sep-84	1000		49.5	3.31	164
30-Sep-84	1004		49.2	3.02	149
Water year 1985:					
3-Oct-84	1007	0840	49.0	2.80	137
12-Oct-84	1016	1220	52.4	2.66	139
26-Oct-84	1030	1410	55.0	2.72	149
31-Oct-84	1035		56.4	2.77	156
9-Nov-84	1044	1330	58.9	2.86	168
9-Nov-84	1044	1100	60.4	2.78	168
30-Nov-84	1065		61.0	2.63	160
7-Dec-84	1072	1550	61.2	2.58	158
20-Dec-84	1085	1130	64.5	2.44	157

Day month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Gibbon River					
31-Dec-84	1096		61.7	2.44	150
2-Jan-85	1098	1315	61.2	2.44	149
23-Jan-85	1119	1505	64.0	2.32	149
23-Jan-85	1119	1520	64.7	2.32	150
31-Jan-85	1127		63.6	2.24	143
21-Feb-85	1148	0815	60.7	2.04	124
21-Feb-85	1148	1850	55.2	2.04	113
28-Feb-85	1155		55.3	2.04	113
14-Mar-85	1169	0800	55.4	2.04	113
31-Mar-85	1186		45.1	3.50	158
17-Apr-85	1203	1200	34.7	4.96	172
30-Apr-85	1216		34.2	4.77	163
31-May-85	1247		32.9	4.34	143
11-Jun-85	1258	1915	32.4	4.19	136
30-Jun-85	1277		39.9	3.87	154
23-Jul-85	1300	1840	48.9	3.48	170
31-Jul-85	1308		49.7	3.29	163
31-Aug-85	1339		52.7	2.53	133
4-Sep-85	1343	0900	53.1	2.44	129
30-Sep-85	1369		55.1	2.49	137
Water year 1986:					
16-Oct-85	1385	1300	56.4	2.52	142
31-Oct-85	1400		76.7	2.56	196
8-Nov-85	1408	0900	87.5	2.58	225
30-Nov-85	1430		61.2	2.35	144
5-Dec-85	1435	1600	55.2	2.29	127
31-Dec-85	1461		52.5	2.07	108
3-Jan-86	1464	1420	52.2	2.04	106
31-Jan-86	1492		67.4	2.22	149
3-Feb-86	1495	1420	69.0	2.24	154
5-Feb-86	1497	1000	63.0	2.21	139
28-Feb-86	1520		59.2	2.50	148
2-Mar-86	1522	0935	58.9	2.52	148
16-Mar-86	1536	1448	64.5	2.24	144
18-Mar-86	1538	1800	64.5	2.24	144
31-Mar-86	1551		49.0	3.32	163
8-Apr-86	1559	0933	39.5	3.99	158
17-Apr-86	1568	1345	52.1	3.62	189
18-Apr-86	1569	1655	48.5	3.37	164
30-Apr-86	1581		40.7	5.85	238
1-May-86	1582	1637	40.1	6.06	243
11-May-86	1592	0730	33.4	5.10	170
31-May-86	1612		21.2	9.69	205
8-Jun-86	1620	0710	16.3	11.53	188
26-Jun-86	1638	1615	24.9	5.61	139
30-Jun-86	1642		26.2	5.71	150
10-Jul-86	1652	0825	29.5	5.97	176
23-Jul-86	1665	0730	32.1	3.88	125
24-Jul-86	1666	1717	31.6	4.08	129
31-Jul-86	1673		33.8	3.70	125
6-Aug-86	1679	0820	35.7	3.37	120
20-Aug-86	1693	0805	45.9	3.14	144
31-Aug-86	1704		44.5	3.01	134
3-Sep-86	1707	1239	44.1	2.97	131
4-Sep-86	1708	0710	41.7	2.80	117
17-Sep-86	1721	0845	45.5	2.72	124

Day-month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Gibbon River					
30-Sep-86	1734		47.3	2.80	132
Water year 1987:					
1-Oct-86	1735	0743	47.4	2.80	133
8-Oct-86	1742	0900	41.3	2.58	106
15-Oct-86	1749	1153	36.0	2.46	88.7
25-Oct-86	1759	1729	36.7	2.58	94.4
31-Oct-86	1765		41.3	2.63	109
9-Nov-86	1774	1442	48.2	2.72	131
18-Nov-86	1783	0900	50.9	2.72	138
27-Nov-86	1792	1125	50.5	2.66	134
30-Nov-86	1795		49.6	2.58	128
10-Dec-86	1805	1215	46.5	2.32	108
24-Dec-86	1819	1133	30.0	2.38	71.4
31-Dec-86	1826		43.6	2.70	118
7-Jan-87	1833	1345	57.1	3.03	173
21-Jan-87	1847	1215	61.8	2.32	143
31-Jan-87	1857		62.4	2.26	141
4-Feb-87	1861	1527	62.6	2.24	140
18-Feb-87	1875	0900	63.4	2.12	135
18-Feb-87	1875	0915	63.6	2.12	135
28-Feb-87	1885		63.9	2.22	142
11-Mar-87	1896	0750	64.2	2.32	149
25-Mar-87	1910	1615	68.4	1.95	134
31-Mar-87	1916		68.1	1.95	133
2-Apr-87	1918	1545	68.0	1.95	133
8-Apr-87	1924	1325	58.1	2.46	143
23-Apr-87	1939	1650	36.7	3.74	137
30-Apr-87	1946		36.6	3.48	127
6-May-87	1952	0840	36.5	3.26	119
19-May-87	1965	0800	42.9	4.50	193
20-May-87	1966	0907	42.4	3.79	161
31-May-87	1977		44.5	3.32	148
4-Jun-87	1981	1515	45.2	3.14	142
17-Jun-87	1994	1727	50.9	2.61	133
30-Jun-87	2007		59.4	2.45	145
1-Jul-87	2008	1715	60.0	2.44	146
15-Jul-87	2022	1521	45.3	2.32	105
26-Jul-87	2033	1530	40.1	2.29	92
31-Jul-87	2038		43.4	2.24	97
12-Aug-87	2050	1700	51.4	2.10	108
18-Aug-87	2056	0900	46.1	2.12	97
26-Aug-87	2064	1708	55.5	2.24	124
31-Aug-87	2069		57.3	2.14	122
9-Sep-87	2078	1450	60.6	1.95	118
23-Sep-87	2092	1655	59.5	1.84	110
30-Sep-87	2099		59.0	1.86	109
Water year 1988:					
7-Oct-87	2106	1711	61.0	2.07	126
21-Oct-87	2120	1600	66.9	1.98	133
31-Oct-87	2130		67.0	2.02	136
4-Nov-87	2134	1010	67.1	2.04	137
17-Nov-87	2147	0845	76.2	2.07	158
30-Nov-87	2160		71.8	1.83	131
1-Dec-87	2161	0850	71.5	1.81	130
30-Dec-87	2190	1510	82.3	1.81	149
Gibbon River					
31-Dec-87	2191		81.7	1.86	152
5-Jan-88	2196	1025	78.8	2.12	167
28-Jan-88	2219	1237	80.2	1.76	141
31-Jan-88	2222		79.2	1.74	138
17-Feb-88	2239	1100	74.0	1.67	124
24-Feb-88	2246	1303	71.7	1.70	122
29-Feb-88	2251		73.0	1.70	124
16-Mar-88	2267	0836	77.3	1.70	131
29-Mar-88	2280	0910	59.8	1.67	100
31-Mar-88	2282	1130	62.0	1.61	100
13-Apr-88	2295	1658	43.6	2.78	121
17-Apr-88	2299	1645	52.4	3.54	186
21-Apr-88	2303	1716	40.3	3.94	159
30-Apr-88	2312		44.4	3.23	143
4-May-88	2316	1645	46.2	2.92	135
12-May-88	2324	1614	26.9	5.18	139
17-May-88	2329	0815	18.9	8.69	164
18-May-88	2330	1648	20.1	7.56	152
25-May-88	2337	1650	23.2	5.44	126
31-May-88	2343		27.9	5.02	140
1-Jun-88	2344	1600	28.7	4.96	142
8-Jun-88	2351	1827	38.5	3.14	121
15-Jun-88	2358	1654	42.8	2.80	120
22-Jun-88	2365	0845	46.9	2.58	121
29-Jun-88	2372	0656	49.1	2.46	121
30-Jun-88	2373		48.7	2.42	118
6-Jul-88	2379	0017	46.4	2.15	100
20-Jul-88	2393	0725	49.3	1.95	96.3
27-Jul-88	2400	0723	50.7	1.93	97.6
31-Jul-88	2404		50.8	1.93	97.7
3-Aug-88	2407	0707	50.8	1.93	97.8
9-Aug-88	2413	0911	53.5	1.87	100
9-Aug-88	2413	1743	59.8	1.93	115
17-Aug-88	2421	0941	56.9	1.84	105
24-Aug-88	2428	0934	57.5	1.76	101
31-Aug-88	2435	1643	61.9	1.87	116
7-Sep-88	2442	1810	68.5	1.87	128
20-Sep-88	2455	0915	67.6	1.87	126
21-Sep-88	2456	1654	67.1	1.93	129
30-Sep-88	2465		65.1	1.93	125
Water year 1989:					
6-Oct-88	2471	0930	63.7	1.8	117
19-Oct-88	2484	1738	74.7	2.0	148
31-Oct-88	2496		74.1	2.1	157
3-Nov-88	2499	0850	73.9	2.2	159
16-Nov-88	2512	0835	73.5	2.2	158
30-Nov-88	2526		67.6	2.1	142
13-Dec-88	2539	0945	62.2	2.0	127
15-Dec-88	2541	1448	57.1	1.8	100
31-Dec-88	2557		66.5	2.0	133
10-Jan-89	2567	1200	72.3	2.2	156
31-Jan-89	2588		74.8	1.9	142
7-Feb-89	2595	1530	75.6	1.8	137
9-Feb-89	2597	1100	78.8	1.9	150
28-Feb-89	2616		79.3	2.1	169
7-Mar-89	2623	1330	79.5	2.2	176

Day-month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Gibbon River					
8-Mar-89	2624	1400	81.2	2.1	172
23-Mar-89	2639	0925	72.7	2.2	161
31-Mar-89	2647		73.2	2.1	153
4-Apr-89	2651	1151	73.5	2.0	150
19-Apr-89	2666	1815	28.9	6.2	180
30-Apr-89	2677		32.5	6.2	203
3-May-89	2680	1828	33.5	6.2	209
3-May-89	2680	1430	33.4	6.1	205
31-May-89	2708		30.7	5.1	157
13-Jun-89	2721	1615	29.5	4.6	137
30-Jun-89	2738		37.4	3.4	129
5-Jul-89	2743	1945	39.7	3.1	123
13-Jul-89	2751	1210	50.2	3.5	175
21-Jul-89	2759	0940	42.4	2.8	119
26-Jul-89	2764	1400	42.4	3.1	131
27-Jul-89	2765	1800	46.6	3.1	146
31-Jul-89	2769		46.1	3.0	136
4-Aug-89	2773	1540	45.6	2.8	127
12-Aug-89	2781	1445	46.3	2.8	128
16-Aug-89	2785	1200	53.1	2.7	144
21-Aug-89	2790	1030	52.7	2.7	140
27-Aug-89	2796	0900	52.2	2.6	136
31-Aug-89	2800		50.0	2.5	127
12-Sep-89	2812	1245	43.4	2.3	101
12-Sep-89	2812	1426	44.5	2.3	103
26-Sep-89	2826	1251	45.0	2.3	103
30-Sep-89	2830		47.4	2.4	112
Madison River					
Water year 1983:					
30-Sep-82	273		54.7	15.1	829
27-Oct-82	300	1035	56.0	16.1	902
31-Oct-82	304	1330	56.3	15.6	881
26-Nov-82	330	1035	58.5	12.6	737
30-Nov-82	334		58.9	12.6	742
31-Dec-82	365		61.7	12.6	777
26-Jan-83	391	1000	64.0	12.6	806
31-Jan-83	396		64.1	12.7	814
19-Feb-83	415	1230	64.6	13.1	843
28-Feb-83	424		64.3	13.1	839
17-Mar-83	441	0945	63.7	13.1	831
31-Mar-83	455	1000	63.3	12.6	797
13-Apr-83	468	0730	66.2	11.7	776
30-Apr-83	485		57.9	15.2	879
1-May-83	486	0930	57.4	15.4	883
8-May-83	493	1000	51.3	16.9	865
15-May-83	500	1000	60.9	14.9	907
22-May-83	507	1000	47.0	19.2	902
29-May-83	514	1000	21.0	41.3	868
31-May-83	516		23.2	38.7	899
5-Jun-83	521	1000	28.9	32.0	923
12-Jun-83	528	1000	26.1	34.8	910
26-Jun-83	542	1000	37.8	19.5	737
30-Jun-83	546		36.1	22.1	795
3-Jul-83	549	1000	34.8	24.0	834

Day month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Madison River					
17-Jul-83	563	1000	45.8	16.9	773
24-Jul-83	570	1000	47.8	16.4	783
31-Jul-83	577	1000	50.4	13.1	658
7-Aug-83	584	1000	50.8	12.8	652
14-Aug-83	591	1000	52.2	12.3	641
31-Aug-83	608		53.1	12.1	642
11-Sep-83	619	1000	53.8	11.9	642
25-Sep-83	633	1000	52.0	11.9	621
30-Sep-83	638		51.6	12.3	637
Water year 1984:					
9-Oct-83	647	1000	51.0	13.1	666
12-Oct-83	650	1015	53.9	14.4	776
23-Oct-83	661	1000	56.2	13.1	734
25-Oct-83	663	1450	52.6	13.1	686
31-Oct-83	669		54.4	14.1	767
6-Nov-83	675	1000	56.2	15.1	852
30-Nov-83	699		57.5	13.7	790
4-Dec-83	703	1000	57.7	13.5	779
14-Dec-83	713	1000	59.5	12.8	763
31-Dec-83	730	1000	58.5	12.8	750
25-Jan-84	755	1000	60.3	12.1	733
29-Jan-84	759	1000	61.5	12.1	747
31-Jan-84	761		61.6	12.1	746
29-Feb-84	790		63.3	11.6	735
6-Mar-84	796	1410	63.7	11.5	732
11-Mar-84	801	1500	65.0	11.7	760
25-Mar-84	815	1000	64.7	11.7	758
31-Mar-84	821		64.5	11.7	756
8-Apr-84	829	1000	64.3	11.7	752
17-Apr-84	838	1120	53.2	13.6	723
22-Apr-84	843	1900	52.7	13.3	700
30-Apr-84	851	1000	61.4	12.4	760
7-May-84	858	1000	61.1	12.4	756
13-May-84	864	1000	35.3	23.5	829
21-May-84	872	1000	20.7	45.6	944
30-May-84	881	1615	22.1	34.8	770
31-May-84	882		23.2	33.5	778
6-Jun-84	888	0820	29.9	25.7	768
10-Jun-84	892	0630	34.4	25.5	876
22-Jun-84	904	1000	33.3	22.8	759
30-Jun-84	912		38.7	18.3	707
6-Jul-84	918	1000	42.7	14.9	636
11-Jul-84	923	1215	46.1	14.5	668
14-Jul-84	926	1000	44.5	13.7	611
20-Jul-84	932	1000	45.1	13.7	619
27-Jul-84	939	1500	47.5	14.9	708
31-Jul-84	943		48.1	14.6	701
10-Aug-84	953	1000	49.7	13.7	683
17-Aug-84	960	1000	49.2	15.1	745
21-Aug-84	964	1410	48.6	13.8	672
24-Aug-84	967	1000	52.3	14.4	754
31-Aug-84	974	1000	52.4	13.5	708
6-Sep-84	980	1000	53.1	13.7	729
14-Sep-84	988	1000	52.9	12.8	679
30-Sep-84	1004		55.4	13.2	732

Day-month-year	Date[1] No.	Time[2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Madison River					
Water year 1985:					
3-Oct-84	1007	1200	55.9	13.3	742
7-Oct-84	1011	1600	52.6	12.8	675
21-Oct-84	1025	1000	56.2	13.0	732
31-Oct-84	1035		58.6	13.4	783
4-Nov-84	1039	1000	59.5	13.5	804
14-Nov-84	1049	1330	57.5	13.6	783
30-Nov-84	1065		59.8	12.9	773
2-Dec-84	1067	1200	60.1	12.8	771
18-Dec-84	1083	0915	59.8	12.6	754
30-Dec-84	1095	1500	59.4	13.5	801
31-Dec-84	1096		59.6	13.4	799
22-Jan-85	1118	1200	63.2	12.1	768
31-Jan-85	1127		63.1	11.3	713
6-Feb-85	1133	1200	63.1	10.7	677
28-Feb-85	1155		62.2	11.6	723
13-Mar-85	1168	1000	61.7	12.1	750
17-Mar-85	1172	1000	61.8	12.1	751
19-Mar-85	1174	1540	63.5	11.7	743
31-Mar-85	1186	1000	66.5	12.4	823
14-Apr-85	1200	1000	50.5	17.2	868
28-Apr-85	1214	1100	56.7	14.6	830
30-Apr-85	1216		45.2	15.4	698
1-May-85	1217	1645	39.5	15.8	625
12-May-85	1228	1000	33.5	30.2	1010
18-May-85	1234	2000	33.4	24.3	812
26-May-85	1242	1000	27.3	34.1	930
31-May-85	1247		33.4	25.7	858
3-Jun-85	1250	1000	37.0	20.7	767
9-Jun-85	1256	1000	36.9	23.5	866
12-Jun-85	1259	1000	39.0	17.9	698
16-Jun-85	1263	1000	41.5	16.4	679
23-Jun-85	1270	1000	47.3	13.9	659
30-Jun-85	1277		49.2	13.2	646
7-Jul-85	1284	1000	51.0	12.4	631
14-Jul-85	1291	1000	51.5	12.8	661
21-Jul-85	1298	1000	53.8	11.9	641
24-Jul-85	1301	0830	51.2	15.1	774
28-Jul-85	1305	1000	57.6	11.7	674
31-Jul-85	1308		56.3	12.5	702
4-Aug-85	1312	1000	54.6	13.5	736
11-Aug-85	1319	1000	56.1	11.9	669
25-Aug-85	1333	1430	55.4	11.5	635
31-Aug-85	1339		56.2	11.7	659
5-Sep-85	1344	0850	56.9	11.9	678
30-Sep-85	1369		58.1	12.7	736
Water year 1986:					
13-Oct-85	1382	1000	60.0	13.3	795
16-Oct-85	1385	1735	59.0	13.0	769
20-Oct-85	1389	1100	57.8	13.0	753
31-Oct-85	1400		58.9	12.8	754
21-Nov-85	1421	0900	61.0	12.4	755
30-Nov-85	1430		61.3	12.8	783
1-Dec-85	1431	1330	61.3	12.8	786
31-Dec-85	1461		60.3	12.1	730
7-Jan-86	1468	1000	60.1	11.9	716

Day month-year	Date[1] No.	Time[2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Madison River					
12-Jan-86	1473	1000	60.5	11.7	708
31-Jan-86	1492		63.8	12.3	783
3-Feb-86	1495	1000	64.3	12.4	796
28-Feb-86	1520		63.5	13.2	837
2-Mar-86	1522	1000	63.4	13.3	840
5-Mar-86	1525	0900	64.8	12.8	831
16-Mar-86	1536	1000	64.4	12.6	812
30-Mar-86	1550	0900	49.4	18.2	897
31-Mar-86	1551		49.7	18.1	898
17-Apr-86	1568	0815	55.1	16.6	916
27-Apr-86	1578	1000	48.0	17.9	859
30-Apr-86	1581		47.3	18.6	881
11-May-86	1592	1000	44.9	21.3	955
18-May-86	1599	1000	46.7	19.4	907
25-May-86	1606	1130	20.0	32.1	642
28-May-86	1609	1425	16.2	51.6	835
31-May-86	1612		15.2	60.4	916
1-Jun-86	1613	1000	14.8	63.4	938
8-Jun-86	1620	1000	20.5	40.6	832
15-Jun-86	1627	1000	27.5	36.8	1012
30-Jun-86	1642		34.8	23.7	823
6-Jul-86	1648	1300	37.7	18.4	694
13-Jul-86	1655	1345	38.9	18.7	726
15-Jul-86	1657	1530	40.3	17.4	702
20-Jul-86	1662	1300	41.4	17.2	710
27-Jul-86	1669	1100	37.3	21.0	784
31-Jul-86	1673		40.7	18.6	757
5-Aug-86	1678	1400	44.9	15.6	701
10-Aug-86	1683	1330	45.9	16.1	740
17-Aug-86	1690	1200	45.9	14.9	682
24-Aug-86	1697	1000	45.9	16.6	763
31-Aug-86	1704		45.9	16.1	738
3-Sep-86	1707	1125	45.9	15.9	728
30-Sep-86	1734		47.5	14.9	709
Snake River					
Water Year 1983:					
30-Sep-82	273		14.2	13.4	191
8-Oct-82	281	0850	12.8	14.3	183
31-Oct-82	304		14.0	13.9	196
1-Nov-82	305	0840	14.1	13.9	196
30-Nov-82	334		15.2	12.9	196
10-Dec-82	344	1245	15.6	12.5	195
31-Dec-82	365		16.2	13.5	219
26-Jan-83	391	1315	16.5	11.0	181
31-Jan-83	396		16.4	11.0	181
18-Feb-83	414	1245	16.4	11.0	180
28-Feb-83	424		16.6	11.0	183
11-Mar-83	435	1545	16.9	11.0	186
23-Mar-83	447	0910	17.1	10.8	184
31-Mar-83	455		17.0	10.6	180
18-Apr-83	473	1515	16.8	10.2	171
30-Apr-83	485		14.5	12.9	188
13-May-83	498	0850	12.1	15.9	193
16-May-83	501	1520	13.2	16.1	213

Day-month-year	Date[1] No.	Time[2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s

Snake River

Day-month-year	Date No.	Time	Chloride mg/L	Discharge m^3/s	Cl flux g/s
25-May-83	510	1230	4.4	79.9	352
30-May-83	515	1010	2.9	198.2	575
31-May-83	516		2.9	193.4	567
7-Jun-83	523	1020	3.2	159.7	503
13-Jun-83	529	1120	4.3	118.1	505
20-Jun-83	536	1530	4.0	105.0	418
27-Jun-83	543	1305	3.6	98.5	358
30-Jun-83	546		4.1	88.4	360
11-Jul-83	557	1140	5.7	51.5	292
28-Jul-83	574	1310	10.2	21.0	214
31-Jul-83	577		10.2	20.6	210
22-Aug-83	599	1605	10.4	17.8	185
31-Aug-83	608		12.5	18.0	226
2-Sep-83	610	0945	13.0	18.1	235
12-Sep-83	620	1030	13.3	17.0	226
30-Sep-83	638		11.4	18.8	215
Water year 1984:					
7-Oct-83	645	1145	10.8	19.5	211
24-Oct-83	662	0515	9.8	16.7	164
31-Oct-83	669		9.1	18.9	172
7-Nov-83	676	1223	8.4	21.0	176
30-Nov-83	699		10.8	18.2	197
12-Dec-83	711	1215	12.1	16.8	203
31-Dec-83	730		14.4	16.1	232
12-Jan-84	742	1410	15.8	15.7	249
31-Jan-84	761		15.8	13.7	218
27-Feb-84	788	1515	15.9	10.9	173
29-Feb-84	790		15.9	10.8	173
15-Mar-84	805	1505	16.2	10.6	172
31-Mar-84	821		17.8	10.0	179
2-Apr-84	823	1130	18.0	10.0	179
16-Apr-84	837	1145	15.1	11.4	173
27-Apr-84	848	0835	14.0	13.2	184
30-Apr-84	851		14.2	13.8	196
3-May-84	854	1330	14.4	14.4	208
11-May-84	862	0930	11.5	18.8	216
14-May-84	865	1330	4.9	60.3	294
15-May-84	866	1820	3.5	108.7	382
20-May-84	871	1330	4.1	100.2	406
24-May-84	875	1410	3.3	88.3	292
31-May-84	882		4.4	84.6	369
9-Jun-84	891	1210	5.7	79.9	455
12-Jun-84	894	1603	5.7	71.4	407
30-Jun-84	912		7.2	47.4	341
17-Jul-84	929	1810	8.6	24.7	213
26-Jul-84	938	1525	9.8	21.8	214
31-Jul-84	943		10.0	20.1	200
14-Aug-84	957	1303	10.4	15.2	158
31-Aug-84	974		11.7	14.0	164
30-Sep-84	1004		14.0	11.9	167
Water year 1985:					
7-Oct-84	1011	1745	14.5	11.4	16
21-Oct-84	1025	1715	15.7	11.0	172
23-Oct-84	1027	1723	14.8	11.8	174
31-Oct-84	1035		15.0	12.6	189

Day month-year	Date[1] No.	Time[2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s

Snake River

Day month-year	Date No.	Time	Chloride mg/L	Discharge m^3/s	Cl flux g/s
4-Nov-84	1039	1630	15.1	13.0	197
30-Nov-84	1065		14.9	11.2	168
2-Dec-84	1067	1320	14.9	11.1	165
11-Dec-84	1076	1500	15.5	11.8	183
30-Dec-84	1095	1600	15.2	11.7	177
31-Dec-84	1096		15.2	11.6	177
20-Jan-85	1116	1500	16.2	11.0	178
31-Jan-85	1127		15.8	10.9	172
9-Feb-85	1136	1345	15.5	10.8	167
17-Feb-85	1144	0730	19.2	9.4	180
8-Feb-85	1155		18.2	9.5	172
3-Mar-85	1158	1600	17.9	9.5	170
18-Mar-85	1173	1130	19.7	9.5	186
31-Mar-85	1186	0850	21.0	9.7	205
15-Apr-85	1201	1445	11.6	16.9	196
16-Apr-85	1202	1350	11.9	19.8	236
28-Apr-85	1214	1610	12.4	16.4	204
30-Apr-85	1216		11.4	24.1	275
12-May-85	1228	1745	5.4	70.2	377
14-May-85	1230	1850	5.9	64.0	379
29-May-85	1245	1730	4.2	124.9	522
31-May-85	1247		5.0	100.1	498
2-Jun-85	1249	1800	5.8	75.3	434
10-Jun-85	1257	1800	4.4	80.4	351
16-Jun-85	1263	1740	5.2	60.3	316
18-Jun-85	1265	2000	5.4	52.7	282
23-Jun-85	1270	1750	6.9	36.0	247
30-Jun-85	1277	1635	8.0	27.5	219
10-Jul-85	1287	1645	9.2	18.3	169
14-Jul-85	1291	1715	10.8	16.4	177
16-Jul-85	1293	1850	11.2	15.2	171
21-Jul-85	1298	1645	11.9	14.7	176
28-Jul-85	1305	1200	12.1	14.3	174
31-Jul-85	1308		12.2	14.3	175
5-Aug-85	1313	1645	12.4	14.2	176
13-Aug-85	1321	1700	13.5	12.1	163
18-Aug-85	1326	1645	14.4	11.2	161
20-Aug-85	1328	1639	14.5	10.5	152
29-Aug-85	1337	1745	15.7	10.1	158
9-Sep-85	1348	1805	13.3	10.9	145
25-Sep-85	1364	1900	15.4	11.1	171
30-Sep-85	1369		15.5	11.6	179
Water year 1986:					
1-Oct-85	1370	1100	15.5	9.6	149
13-Oct-85	1382	1630	16.8	10.1	170
22-Oct-85	1391	1630	15.9	10.7	170
31-Oct-85	1400		15.1	12.6	191
5-Nov-85	1405	1300	14.8	13.6	202
30-Nov-85	1430		16.1	11.7	191
2-Dec-85	1432	1500	16.2	11.6	188
17-Dec-85	1447	0815	16.8	10.5	177
31-Dec-85	1461		17.2	9.8	154
5-Jan-86	1466	1530	17.4	9.6	167
31-Jan-86	1492		17.4	10.6	184
3-Feb-86	1495	1630	17.4	10.7	186
19-Feb-86	1511	1445	14.6	14.9	217
28-Feb-86	1520		15.1	15.0	226

Day-month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Snake River					
11-Mar-86	1531	0830	15.7	15.1	237
22-Mar-86	1542	1600	16.4	12.5	205
31-Mar-86	1551		13.9	18.9	263
4-Apr-86	1555	0800	12.8	21.7	278
30-Apr-86	1581		9.0	26.0	234
2-May-86	1583	1500	8.6	27.2	234
13-May-86	1594	1015	9.6	26.1	251
23-May-86	1604	1045	4.6	53.8	250
30-May-86	1611	0900	2.9	189.7	556
31-May-86	1612		3.4	199.9	676
6-Jun-86	1618	0900	6.1	260.8	1591
12-Jun-86	1624	0900	5.5	176.6	973
18-Jun-86	1630	1815	3.2	136.3	435
19-Jun-86	1631	1900	3.2	132.2	428
30-Jun-86	1642		4.5	73.8	332
5-Jul-86	1647	1100	6.0	49.5	297
9-Jul-86	1651	1810	6.7	41.1	276
15-Jul-86	1657	1530	7.6	33.1	253
19-Jul-86	1661	1315	7.9	31.2	247
26-Jul-86	1668	1300	7.1	36.7	260
31-Jul-86	1673		8.5	27.2	231
2-Aug-86	1675	1430	9.1	23.4	212
9-Aug-86	1682	0815	10.3	19.7	203
13-Aug-86	1686	1905	10.8	18.0	194
19-Aug-86	1692	1630	11.8	15.9	187
23-Aug-86	1696	1215	11.2	16.8	188
27-Aug-86	1700	1800	11.2	17.6	197
31-Aug-86	1704		11.7	16.3	192
6-Sep-86	1710	1150	12.5	14.5	182
20-Sep-86	1724	1100	12.4	14.7	183
30-Sep-86	1734		12.9	13.8	177
Water year 1987:					
4-Oct-86	1738	1000	13.1	13.8	175
15-Oct-86	1749	1200	13.8	12.3	163
21-Oct-86	1755	1420	13.7	12.9	171
30-Oct-86	1764	1345	15.7	14.0	213
31-Oct-86	1765		15.7	13.4	210
10-Nov-86	1775	1030	15.5	12.1	181
30-Nov-86	1795		16.7	10.8	181
17-Dec-86	1812	0930	17.7	10.5	179
31-Dec-86	1826	0850	16.1	10.1	156
12-Jan-87	1838	1030	18.5	8.6	153
31-Jan-87	1857		17.7	9.6	170
10-Feb-87	1867	0930	17.3	10.6	177
13-Feb-87	1870	1215	17.7	10.9	187
28-Feb-87	1885		17.6	10.2	180
15-Mar-87	1900	1100	17.6	10.2	174
20-Mar-87	1905	0915	17.6	9.7	164
31-Mar-87	1916		16.8	9.8	165
10-Apr-87	1926	1100	16.1	10.6	165
21-Apr-87	1937	1310	10.9	19.2	202
30-Apr-87	1946		6.9	37.7	261
6-May-87	1952	1000	4.3	52.3	216
14-May-87	1960	0715	4.9	56.1	264
23-May-87	1969	1100	6.8	39.6	260
27-May-87	1973	1538	6.6	42.2	269

Day month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Snake River					
29-May-87	1975	1435	5.6	48.2	261
31-May-87	1977		6.0	42.4	256
6-Jun-87	1983	1135	7.2	31.3	219
9-Jun-87	1986	1335	7.3	29.8	209
13-Jun-87	1990	1130	8.3	26.1	209
19-Jun-87	1996	0830	10.2	19.0	187
27-Jun-87	2004	1130	11.8	13.7	156
30-Jun-87	2007		12.1	13.4	157
3-Jul-87	2010	0745	12.4	12.9	155
11-Jul-87	2018	0950	10.6	15.6	159
14-Jul-87	2021	1315	14.2	10.9	150
18-Jul-87	2025	1300	10.5	17.6	178
25-Jul-87	2032	1030	13.5	11.1	145
31-Jul-87	2038	0900	13.9	10.6	142
8-Aug-87	2046	1050	16.4	8.1	128
15-Aug-87	2053	1320	17.1	7.5	124
19-Aug-87	2057	1645	17.9	7.0	121
22-Aug-87	2060	0830	19.0	6.7	122
28-Aug-87	2066	1045	18.9	6.9	126
31-Aug-87	2069		19.1	6.5	121
5-Sep-87	2074	1530	19.4	6.9	134
11-Sep-87	2080	1230	20.2	6.3	124
27-Sep-87	2096	1430	22.5	5.7	125
30-Sep-87	2099		22.7	5.4	121
Water year 1988:					
9-Oct-87	2108	1500	23.1	5.2	120
20-Oct-87	2119	1630	22.6	4.7	107
31-Oct-87	2130		21.4	5.1	108
28-Nov-87	2158	1520	18.3	5.9	107
30-Nov-87	2160		18.6	6.0	112
16-Dec-87	2176	1200	21.2	7.1	150
30-Dec-87	2190	1315	20.4	7.2	147
31-Dec-87	2191		20.4	7.3	148
29-Jan-88	2220	1510	20.1	8.8	177
31-Jan-88	2222		20.3	8.8	177
23-Feb-88	2245	1500	22.6	8.0	182
24-Feb-88	2246	1535	20.6	8.6	176
29-Feb-88	2251		20.8	8.3	173
19-Mar-88	2270	1630	21.6	7.5	161
30-Mar-88	2281	0900	21.6	7.8	168
31-Mar-88	2282		21.2	8.3	175
13-Apr-88	2295	0930	15.7	14.6	229
26-Apr-88	2308	1000	13.6	17.4	237
30-Apr-88	2312		12.6	17.9	227
3-May-88	2315	1050	11.9	18.4	218
9-May-88	2321	1130	11.0	20.6	227
15-May-88	2327	1410	4.9	61.2	300
22-May-88	2334	1245	4.3	86.1	371
29-May-88	2341	0645	3.5	86.5	303
31-May-88	2343		3.7	88.9	326
5-Jun-88	2348	1220	4.1	94.9	386
12-Jun-88	2355	1605	5.5	49.6	273
19-Jun-88	2362	0930	7.2	29.7	214
26-Jun-88	2369	0745	9.8	18.7	183
30-Jun-88	2373		10.7	15.1	161
3-Jul-88	2376	0830	11.3	12.5	141

Day-month-year	Date[1] No.	Time[2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Snake River					
10-Jul-88	2383	1015	12.9	10.9	140
17-Jul-88	2390	1000	15.0	8.3	124
31-Jul-88	2404		17.4	6.7	117
5-Aug-88	2409	0900	18.3	6.1	112
11-Aug-88	2415	0915	19.8	5.8	114
14-Aug-88	2418	0945	19.7	5.8	114
22-Aug-88	2426	1000	22.3	5.2	116
28-Aug-88	2432	1330	22.5	5.2	116
31-Aug-88	2435		22.8	5.1	117
4-Sep-88	2439	0945	23.3	5.1	119
20-Sep-88	2455	1145	24.5	5.0	123
30-Sep-88	2465		24.7	5.1	125
Water year 1989:					
7-Oct-88	2472	1520	24.8	5.2	129
20-Oct-88	2485	1120	23.7	5.7	134
31-Oct-88	2496		23.4	5.8	137
10-Nov-88	2506	1030	23.1	6.0	139
30-Nov-88	2526		24.5	6.2	151
16-Dec-88	2542	1150	25.7	6.3	162
31-Dec-88	2557		23.3	7.3	169
8-Jan-89	2565	1400	22.0	7.8	171
31-Jan-89	2588		21.4	7.9	169
12-Feb-89	2600	1000	21.1	7.9	167
26-Feb-89	2614	1150	21.3	7.4	159
28-Feb-89	2616		20.9	7.7	161
5-Mar-89	2621	1700	19.8	8.4	167
26-Mar-89	2642	1630	19.2	10.0	192
31-Mar-89	2647		18.6	10.1	187
10-Apr-89	2657	1630	17.5	10.1	177
18-Apr-89	2665	1625	9.8	17.0	167
30-Apr-89	2677	1300	10.1	28.1	284
7-May-89	2684	1200	4.4	107.9	476
17-May-89	2694	0757	4.4	110.4	489
21-May-89	2698	1430	4.2	121.5	507
29-May-89	2706	1230	4.1	114.1	471
31-May-89	2708		4.1	110.9	453
4-Jun-89	2712	0930	4.0	104.4	417
11-Jun-89	2719	0750	3.7	106.0	389
18-Jun-89	2726	1725	4.9	75.9	368
25-Jun-89	2733	0900	6.8	43.9	297
30-Jun-89	2738		6.9	37.8	262
2-Jul-89	2740	0730	7.0	35.4	248
9-Jul-89	2747	1700	9.2	22.9	210
16-Jul-89	2754	0950	10.3	19.1	197
23-Jul-89	2761	0730	11.3	14.6	164
31-Jul-89	2769		12.0	14.6	175
2-Aug-89	2771	1525	12.2	14.6	178
6-Aug-89	2775	0720	13.5	12.0	162
13-Aug-89	2782	0830	13.4	12.0	161
20-Aug-89	2789	0745	13.4	11.4	153
27-Aug-89	2796	1000	14.9	8.8	131
31-Aug-89	2800		14.9	8.7	129
10-Sep-89	2810	1930	14.8	8.3	123
24-Sep-89	2824	1800	17.0	7.0	119
30-Sep-89	2830		16.5	8.4	138

Day month-year	Date[1] No.	Time[2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Yellowstone River					
Water Year 1983					
30-Sep-82	273		10.1	73.1	736
5-Oct-82	278	1715	10.0	71.4	714
26-Oct-82	299	1645	12.1	53.8	651
31-Oct-82	304		11.5	50.3	578
4-Nov-82	308	1640	11.0	47.6	523
24-Nov-82	328	1444	13.8	36.5	504
30-Nov-82	334		13.8	36.0	497
24-Dec-82	358	1327	13.9	33.7	468
31-Dec-82	365		14.7	33.1	485
19-Jan-83	384	1100	16.7	31.4	525
31-Jan-83	396		15.5	31.0	481
17-Feb-83	413	1225	13.9	30.3	421
28-Feb-83	424		14.8	30.0	445
10-Mar-83	434	1645	15.7	29.7	467
22-Mar-83	446	1645	15.5	27.2	420
31-Mar-83	455	1230	15.0	29.7	446
14-Apr-83	469	0900	15.4	26.8	413
30-Apr-83	485		12.4	40.7	503
4-May-83	489	1615	11.6	44.2	512
12-May-83	497	1710	11.2	43.3	485
17-May-83	502	1645	11.4	41.6	475
31-May-83	516		3.5	236.9	835
1-Jun-83	517	1400	3.0	250.9	743
15-Jun-83	531	1535	3.2	251.7	811
21-Jun-83	537	1430	3.7	241.0	896
28-Jun-83	544	1545	3.4	286.0	972
30-Jun-83	546		3.5	277.2	972
6-Jul-83	552	1215	3.8	250.9	961
11-Jul-83	557	1845	4.1	261.9	1077
21-Jul-83	567	1710	5.4	173.9	944
29-Jul-83	575	1503	6.6	140.5	928
31-Jul-83	577		6.6	135.3	896
5-Aug-83	582	1127	6.7	122.3	816
11-Aug-83	588	1810	7.4	109.6	811
19-Aug-83	596	1630	7.8	93.4	731
31-Aug-83	608		8.5	76.2	651
1-Sep-83	609	1330	8.6	74.8	643
27-Sep-83	635	1700	9.9	51.5	510
30-Sep-83	638		9.6	53.2	513
Water year 1984:					
18-Oct-83	656	1200	8.1	63.4	513
31-Oct-83	669		10.0	56.9	571
1-Nov-83	670	1200	10.2	56.4	575
15-Nov-83	684	1100	9.4	57.2	538
30-Nov-83	699		12.0	50.6	607
8-Dec-83	707	1200	13.4	47.0	630
31-Dec-83	730		13.0	39.5	512
3-Jan-84	733	1625	12.9	38.5	497
31-Jan-84	761		13.5	33.8	454
7-Feb-84	768	0915	13.6	32.6	443
27-Feb-84	788	1645	14.0	30.3	424
29-Feb-84	790		14.1	30.4	428
13-Mar-84	803	1630	14.6	30.9	451
31-Mar-84	821		15.0	29.7	446
3-Apr-84	824	1145	15.1	29.4	445

Day-month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Yellowstone River					
10-Apr-84	831	0920	13.8	32.0	442
26-Apr-84	847	1645	11.1	43.6	484
30-Apr-84	851		10.7	42.3	452
2-May-84	853	1515	10.5	41.6	437
9-May-84	860	1035	11.0	43.3	477
16-May-84	867	0820	2.1	337.0	694
23-May-84	874	1730	2.8	214.1	606
30-May-84	881	1624	2.5	297.3	743
31-May-84	882		2.6	292.4	766
6-Jun-84	888	2043	3.3	262.8	878
16-Jun-84	898	0700	2.4	379.4	911
22-Jun-84	904	2145	2.9	342.6	987
30-Jun-84	912	2150	3.3	385.1	1271
7-Jul-84	919	1050	3.7	288.8	1054
14-Jul-84	926	2000	5.1	211.0	1076
22-Jul-84	934	0930	10.7	184.9	1979
28-Jul-84	940	2030	6.5	165.9	1075
31-Jul-84	943		6.3	155.0	979
4-Aug-84	947	2001	6.1	140.5	857
18-Aug-84	961	2120	6.9	102.8	709
25-Aug-84	968	2010	7.1	18.5	655
31-Aug-84	974	2015	8.0	80.7	646
13-Sep-84	987	1730	8.4	64.3	540
30-Sep-84	1004		9.0	57.1	512
Water year 1985:					
1-Oct-84	1005	1930	9.0	56.6	510
2-Oct-84	1006	1600	9.4	55.9	525
13-Oct-84	1017	1205	10.7	49.0	524
27-Oct-84	1031	1530	11.1	42.8	475
31-Oct-84	1035		11.2	42.5	475
12-Nov-84	1047	1655	11.4	41.9	478
14-Nov-84	1049	1200	11.7	41.7	488
30-Nov-84	1065		12.6	37.4	472
14-Dec-84	1079	1530	13.4	33.7	452
31-Dec-84	1096		13.8	30.9	426
12-Jan-85	1108	1730	14.1	28.9	407
24-Jan-85	1120	1435	13.5	27.4	370
30-Jan-85	1126	1630	17.5	26.9	471
31-Jan-85	1127		17.3	27.1	468
17-Feb-85	1144	0845	13.5	29.7	401
28-Feb-85	1155		14.4	28.6	411
3-Mar-85	1158	1800	14.6	28.3	413
12-Mar-85	1167	1430	13.6	28.3	385
17-Mar-85	1172	1130	13.5	29.2	394
31-Mar-85	1186		10.8	30.2	326
1-Apr-85	1187	1630	10.6	30.3	321
14-Apr-85	1200	1630	9.1	51.0	464
15-Apr-85	1201	1530	7.7	59.0	455
28-Apr-85	1214	2045	8.9	50.2	447
30-Apr-85	1216		8.4	60.8	509
14-May-85	1230	2200	4.6	135.2	622
24-May-85	1240	2100	2.5	223.8	703
31-May-85	1247		3.6	215.6	795
1-Jun-85	1248	1430	3.7	215.6	798
3-Jun-85	1250	1445	3.9	209.6	817
8-Jun-85	1255	1750	4.7	341.5	1544

Day month-year	Date [1] No.	Time [2]	Instantaneous values Chloride mg/L	Discharge m^3/s	Cl flux g/s
Yellowstone River					
15-Jun-85	1262	1920	5.0	214.1	1073
22-Jun-85	1269	1930	5.6	171.9	958
29-Jun-85	1276	2000	5.6	150.1	846
30-Jun-85	1277		5.7	147.1	835
5-Jul-85	1282	1230	5.8	132.3	773
7-Jul-85	1284	2130	6.9	126.7	873
8-Jul-85	1285	1135	6.0	125.0	745
20-Jul-85	1297	2030	7.3	100.7	734
28-Jul-85	1305	2030	7.4	88.6	653
31-Jul-85	1308		7.6	89.0	673
4-Aug-85	1312	1900	7.8	89.6	700
10-Aug-85	1318	2020	9.2	71.9	660
17-Aug-85	1325	1920	9.4	64.1	603
19-Aug-85	1327	1130	8.4	63.0	529
24-Aug-85	1332	1720	9.2	56.2	517
31-Aug-85	1339	1920	9.8	51.5	505
19-Sep-85	1358	1820	9.3	53.9	501
30-Sep-85	1369		11.0	45.9	503
Water year 1986:					
1-Oct-85	1370	1700	11.1	45.2	502
3-Oct-85	1372	1725	11.4	43.7	499
4-Oct-85	1373	0845	10.2	43.3	442
17-Oct-85	1386	1450	12.3	40.0	492
31-Oct-85	1400	1600	14.0	39.7	556
30-Nov-85	1430		14.5	27.8	402
10-Dec-85	1440	1030	14.6	23.9	349
31-Dec-85	1461		14.5	24.1	348
31-Jan-86	1492		14.2	27.9	397
6-Feb-86	1498	0845	14.2	29.2	415
9-Feb-86	1501	0900	15.4	24.1	371
28-Feb-86	1520		13.0	33.3	434
6-Mar-86	1526	1630	12.3	36.2	445
20-Mar-86	1540	1000	12.3	34.6	426
30-Mar-86	1550	1130	9.7	52.5	510
31-Mar-86	1551		9.6	52.8	508
15-Apr-86	1566	1630	8.5	56.6	481
29-Apr-86	1580	1400	4.6	69.1	318
30-Apr-86	1581		6.0	68.5	411
1-May-86	1582	0840	7.4	67.9	503
30-May-86	1611	1000	3.2	492.7	1577
31-May-86	1612		2.6	532.4	1384
1-Jun-86	1613	1030	2.0	572.0	1144
4-Jun-86	1616	1030	4.1	567.5	2327
10-Jun-86	1622	1730	2.9	462.4	1341
12-Jun-86	1624	1030	4.2	497.2	2088
19-Jun-86	1631	1630	5.2	442.3	2300
26-Jun-86	1638	1730	5.2	329.0	1711
30-Jun-86	1642		5.1	290.2	1493
3-Jul-86	1645	1630	5.1	261.1	1332
11-Jul-86	1653	16330	5.4	230.5	1245
17-Jul-86	1659	1850	7.3	188.4	1375
22-Jul-86	1664	1530	5.6	160.1	897
25-Jul-86	1667	1720	6.8	162.1	1102
31-Jul-86	1673	1630	7.7	139.2	1072
8-Aug-86	1681	10330	8.6	116.9	1006
15-Aug-86	1688	1920	8.0	99.7	798
30-Aug-86	1703	1420	8.0	81.4	652

Day-month-year	Date No.[1]	Time[2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Yellowstone River					
31-Aug-86	1704		8.1	80.2	649
4-Sep-86	1708	1020	8.5	77.4	639
23-Sep-86	1727	1105	9.1	62.7	567
30-Sep-86	1734		9.6	58.8	563
Water year 1987:					
7-Oct-86	1741	1300	10.1	54.9	554
16-Oct-86	1750	1400	10.6	47.7	504
22-Oct-86	1756	1110	10.7	45.8	489
31-Oct-86	1765	1230	12.3	44.3	547
30-Nov-86	1795		13.4	33.8	451
4-Dec-86	1799	1200	13.5	32.3	436
12-Dec-86	1807	1030	14.5	28.3	411
31-Dec-86	1826		14.2	27.4	390
14-Jan-87	1840	1420	14.0	26.8	375
31-Jan-87	1857		14.2	28.6	407
11-Feb-87	1868	1330	14.4	29.7	428
28-Feb-87	1885		14.6	26.2	382
3-Mar-87	1888	1700	14.6	25.5	374
13-Mar-87	1898	1630	15.2	28.3	429
27-Mar-87	1912	1015	15.1	24.9	375
31-Mar-87	1916		14.0	38.1	532
30-Apr-87	1946		6.0	137.0	825
8-May-87	1954	1145	3.9	163.3	637
15-May-87	1961	1430	4.3	157.6	677
17-May-87	1963	1000	4.9	187.7	918
20-May-87	1966	1210	3.7	169.9	634
28-May-87	1974	1115	5.2	173.9	906
31-May-87	1977		5.1	160.5	818
5-Jun-87	1982	1735	4.9	138.0	678
9-Jun-87	1986	0805	4.9	182.6	900
17-Jun-87	1994	1030	5.8	127.2	733
26-Jun-87	2003	1030	7.2	100.7	720
30-Jun-87	2007	1100	6.9	91.9	630
11-Jul-87	2018	1030	7.3	111.1	814
17-Jul-87	2024	1930	8.5	80.2	684
25-Jul-87	2032	1030	8.8	73.5	645
30-Jul-87	2037	1630	11.2	74.7	834
31-Jul-87	2038		11.0	72.6	800
7-Aug-87	2045	0930	10.0	57.6	576
11-Aug-87	2049	1420	9.6	53.5	512
14-Aug-87	2052	1920	11.2	49.6	555
22-Aug-87	2060	2030	11.2	43.4	487
31-Aug-87	2069		11.4	40.9	466
4-Sep-87	2073	1130	11.5	39.7	457
11-Sep-87	2080	1430	12.0	35.1	422
26-Sep-87	2095	1030	14.8	29.2	434
30-Sep-87	2099	1440	13.7	28.1	385
Water year 1988:					
10-Oct-87	2109	1200	15.1	24.7	372
24-Oct-87	2123	1300	16.2	22.1	358
31-Oct-87	2130		16.0	22.8	363
4-Nov-87	2134	1420	15.9	23.1	366
6-Nov-87	2136	1650	16.8	21.5	361
30-Nov-87	2160		18.9	21.3	403
7-Dec-87	2167	1240	19.6	21.2	415

Day month-year	Date No.[1]	Time[2]	Instantaneous values Chloride mg/L	Discharge m3/s	Cl flux g/s
Yellowstone River					
15-Dec-87	2175	1000	21.8	20.8	453
31-Dec-87	2191		23.5	18.2	426
4-Jan-88	2195	1430	23.9	17.5	418
27-Jan-88	2218	1010	22.9	13.5	308
29-Jan-88	2220	1620	23.1	13.5	310
31-Jan-88	2222		22.8	13.7	314
29-Feb-88	2251	0900	19.5	17.9	348
18-Mar-88	2269	1620	18.3	19.9	364
31-Mar-88	2282	1015	14.2	22.3	317
13-Apr-88	2295	1230	12.4	37.8	469
29-Apr-88	2311	1520	9.2	54.2	496
4-May-88	2316	1410	9.3	48.6	452
12-May-88	2324	1020	3.7	132.3	490
20-May-88	2332	1620	2.9	154.4	446
31-May-88	2343		4.2	210.5	877
1-Jun-88	2344	1620	4.3	215.6	923
7-Jun-88	2350	0900	2.4	324.5	776
24-Jun-88	2367	1030	5.3	151.9	805
26-Jun-88	2369	1420	6.5	140.4	913
30-Jun-88	2373		7.0	120.8	846
4-Jul-88	2377	1200	7.5	101.2	759
11-Jul-88	2384	1400	9.4	83.2	782
20-Jul-88	2393	1100	8.1	66.4	538
22-Jul-88	2395	1020	9.7	64.1	622
29-Jul-88	2402	2020	10.3	58.0	597
31-Jul-88	2404		10.4	56.0	580
11-Aug-88	2415	1625	10.7	44.9	481
19-Aug-88	2423	0820	13.1	37.8	495
31-Aug-88	2435	0940	12.1	30.6	371
1-Sep-88	2436	1620	12.7	29.7	377
10-Sep-88	2445	1200	14.1	27.0	381
25-Sep-88	2460	1750	17.2	24.5	421
30-Sep-88	2465		16.3	23.6	384
Water year 1989:					
4-Oct-88	2469	1230	15.5	23.3	361
13-Oct-88	2478	1420	16.4	22.1	363
24-Oct-88	2489	1225	18.4	21.4	393
31-Oct-88	2496	1500	16.8	19.9	334
16-Nov-88	2512	1600	17.5	19.4	339
30-Nov-88	2526		17.8	19.3	342
8-Dec-88	2534	1130	17.9	19.2	344
11-Dec-88	2537	1530	18.8	19.4	364
31-Dec-88	2557		21.5	16.5	354
9-Jan-89	2566	1700	22.7	15.1	344
24-Jan-89	2581	1630	23.5	13.2	309
31-Jan-89	2588		23.7	13.2	314
10-Feb-89	2598	1230	24.1	13.3	321
13-Feb-89	2601	1545	24.6	14.7	362
28-Feb-89	2616		21.2	14.0	296
7-Mar-89	2623	1630	19.6	13.6	266
7-Mar-89	2623	1315	24.8	13.3	330
15-Mar-89	2631	1400	19.7	17.2	338
22-Mar-89	2638	1730	15.9	18.5	294
31-Mar-89	2647		14.8	24.3	358
9-Apr-89	2656	1030	13.6	30.0	408
10-Apr-89	2657	1400	14.0	26.4	370

Day-month-year	Date [1] No.	Time [2]	Instantaneous values		
			Chloride mg/L	Discharge m^3/s	Cl flux g/s
Yellowstone River					
29-Apr-89	2676	1430	3.5	75.6	262
30-Apr-89	2677		3.4	99.9	342
10-May-89	2687	1200	2.9	342.6	1004
11-May-89	2688	1920	3.8	323.7	1233
31-May-89	2708		3.2	340.1	1075
9-Jun-89	2717	1000	2.9	347.4	997
14-Jun-89	2722	1625	4.1	300.7	1230
30-Jun-89	2738	1710	5.4	208.1	1124
3-Jul-89	2741	1530	4.7	193.4	899
11-Jul-89	2749	0900	7.3	165.9	1213
13-Jul-89	2751	1000	7.8	165.4	1285
28-Jul-89	2766	2200	7.9	111.6	878
3-Aug-89	2772	1445	8.4	92.3	774
10-Aug-89	2779	1410	8.7	79.3	693
18-Aug-89	2787	1600	9.3	68.0	630
25-Aug-89	2794	1515	9.9	64.0	630
28-Aug-89	2797	1630	11.3	41.1	464
31-Aug-89	2800	1245	10.4	56.6	589
12-Sep-89	2812	1430	10.9	46.2	501
30-Sep-89	2830		11.3	45.5	513

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