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Cross-sectional Study of the Effects of Smelter Wastewater Disposal on Water Quality of the Columbia River Downstream from Trail, British Columbia

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Contents

Tables

Illustrations

Abstract

A total of 59 water samples were collected from three sites on the Columbia River over a seven-day period to locate the most suitable site for a permanent water quality sampling station and to assess the effects of smelter wastewater on the quality of the river water.

The results from chemical examination of the river water showed: (1) mixing of the wastewater with the river water was complete at Site 3, approximately ten miles downstream from the disposal source, but was incomplete at Sites 1 and 2, one-half and three miles downstream from the source. For this and other reasons, Site 3 was judged to be the most suitable location for a permanent water quality station, (2) the effluent caused a considerable increase in total hardness, non-carbonate hardness, and calcium, zinc, sulfate, fluoride and phosphate content of the river water, (3) the concentration of pollutants in the Canadian portion of this river is generally low due to its relatively high discharge.

Acknowledgments

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INTRODUCTION

In British Columbia, Cominco Ltd. operates a smelter which discharges effluent into the Columbia River from the west bank, just north of the main road bridge in the City of Trail. During 1966, that Company's Control Services at Trail proposed to the Water Quality Division that a cooperative project in the form of a permanent continuous water quality sampling station on the Columbia River downstream from the City of Trail be set up and operated. The purpose of such a station would be to determine and continually record the quality of Columbia River water crossing into the United States at the International Boundary, approximately 11 miles downstream from Trail.

In view of the Water Quality Division's considerations for the installation of water quality instrumentation at key locations on major rivers across Canada in support of the International Hydrological Decade program, it was considered that the Columbia River immediately upstream of the Canada-United States boundary would represent a vital key location for the installation of the first of such stations on major rivers in Western Canada.

Before a permanent sampling station was installed, however, it was considered advisable to initiate a study to: (1) determine by cross-sectional sampling, the location on the river downstream from Trail where representative sampling of the river water could be made from a permanently fixed underwater intake, and (2) ascertain the effects of the wastewater disposal on the quality of the river water.

This study took place within the lower 11 miles of the river's course in Canada.

MATERIALS AND METHODS

Description of River

The Columbia River originates in the western slopes of the Rocky Mountains in Canada. Its total length is 1,150 miles, of which the upper 459 miles is within Canadian borders.

In the Trail area, the river has an average width of 700 feet and, during the study period, had an average discharge of 44,050 cubic feet per second.

Methods of Sampling

Sampling sites were set on the river at the following locations downstream from the smelter wastewater disposal outlet and 2-litre and 250-ml samples were collected at each sampling location:

Site 1 - One-half mile: Sampling carried out from bridge, one sample from each side of the river (150 feet from each shore). A continuous recording conductivity meter was mounted in a boat anchored to a bridge pier on the west side of river, 150 feet from shore.

Site 2 - Three miles at Rock Island: Sampling carried out from a boat, one sample from each side of the river (25 feet from each shore) and one at midstream.

Site 3 - Ten miles (300 feet upstream from the mouth of the Pend'Oreille River): Sampling carried out from a boat, one sample from each side of the river (25 feet from each shore) and one sample at midstream.

Sampling times were one hour earlier each day to account for any changes in water quality of the river due to changing upstream-use patterns; downstream samples were taken at the approximate time that the same water reached each sampling site.

Methods of Analyses

Field - The temperature, pH and conductance of each sample were determined as soon as possible after collection, using a Beckman conductivity meter, model RA-2A and a Metrohm pH meter E280A. Samples were stored in plastic bottles and shipped to the laboratory for complete chemical analyses.

Laboratory - All samples were analyzed approximately 24 hours after collection. Specific conductance, pH, temperature, color, turbidity, alkalinity, hardness, calcium and magnesium were determined using standard methods (1, 2).

Sodium, potassium, manganese, copper and zinc were determined using the Perkin-Elmer atomic absorption spectrophotometer, model 303.

Iron, silica, chlorides, fluorides, phosphates and nitrates were determined by standard colorimetric methods adapted for use with the Technicon, AutoAnalyzer (1, 2).

Ammonia was determined by direct Nesslerization and sulfates were determined volumetrically (2).

RESULTS

Field

Temperature, pH and conductance measurements at the sampling sites are shown in Table 1.

The data show significant differences in conductance and pH between the east and west side of the river at Site 1. Differences in these data are also shown between the east, centre and west sampling locations at Site 2 but are not as pronounced as those at Site 1. The data for Site 3, on the other hand, indicate that the waters have thoroughly mixed at this location.

The recording charts of the continuous recording conductivity meter showed irregular fluctuation of 15 ppm total dissolved solids in the water on the west side of the river at Site 1 for each of the days during the study, indicating that the materials added to the river waters by waste disposal contained relatively small amounts of dissolved solids.

Daily flow rates of the river in cubic feet per second are shown in Table 3.

Analytical

Analytical results at the sampling sites are shown in Table 2.

The data, Site 1, show that the materials discharged to the river waters in the mill effluent were confined to the west side of the river. Thus the data from the east side of the river at this location were taken as the river's water quality before receiving the wastewater discharge.

The data show that within the described river flows (39,100-48,000 cubic feet per second) uniform mixing of the mill effluent across the entire river section was complete at Site 3, but not at Sites 1 and 2. The variability in water quality at the sampling locations is shown in Figures 1 to 6.

The data also show that after complete mixing, the effluent from the smelters has caused substantial increases in the specific conductance, total and non-carbonate hardness, calcium, zinc, sulfate, fluoride and phosphate content of the river water. The average increases in these various constituents are as follows: specific conductance 13 µmhos at 25°C (127 to 140), total hardness as $CaCO_3$ 4.1 ppm (64.2 to 68.3), non-carbonate hardness as $CaCO_3$ 5.1 ppm (10.7 to 15.8), calcium 0.7 ppm (20.1 to 20.8), zinc 0.012 ppm (0.005 to 0.017), sulfates 5.3 ppm (10.4 to 15.7), fluoride 0.07 ppm (0.14 to 0.21) and phosphate 0.11 ppm (0.01 to 0.12).

The chemical content of the samples taken during a slag dump (Table 2) showed little significant variation from that of samples obtained at other times during the same day.

CONCLUSIONS

(1) At a discharge rate of from 39,100 to 48,000 cubic feet per second, thorough mixing of Cominco's smelter wastewater with the river water did not occur at Site 1 (one-half mile downstream from the smelter) or Site 2 (three miles downstream) but was complete at Site 3 (approximately ten miles downstream). Considering all conditions such as proximity to the International Boundary, accessibility to the sites, proximity to power

supply, etc, a site in the vicinity of Site 3 was judged to be the most suitable location for a permanent water quality sampling station.

(2) The discharge of smelter wastewater into the river increased the total hardness 4.1 ppm, non-carbonate hardness 5.1 ppm, calcium 0.7 ppm, zinc 0.012 ppm, sulfate 5.3 ppm, fluoride 0.07 ppm and phosphate 0.11 ppm.

(3) The discharge of slag from the smelter operation into river had little effect on the quality of the water.

(4) The concentration of pollutants in this river in Canada is generally low due to its relatively high discharge.

REFERENCES

1. American Public Health Association Inc., 1965. Standard Methods for the Examination of Water and Waste Water, New York, N.Y.

2. American Society for Testing and Materials, 1965. Book of A.S.T.M. Standards, Part 23, Philadelphia, Pa.

TABLE 1

Field Measurements of Surface Water of Columbia River below Trail

DATE OF SAMPLING	HOUR OF SAMPLING	MEASUREMENTS AND LOCATION ON RIVER								
		TEMPERATURE °F			CONDUCTANCE μmhos AT 25°C			pH		
		EAST SIDE	CENTRE	WEST SIDE	EAST SIDE	CENTER	WEST SIDE	EAST SIDE	CENTRE	WEST SIDE
		SAMPLING SITE NO. 1								
Oct. 17/67	1600	57.5	-	57.0	119.9	-	147.6	7.8	-	7.6
Oct. 18/67	1500	56.0	-	56.0	121.9	-	146.9	7.6	-	7.3
Oct. 19/67	1400	58.0	-	58.0	126.9	-	161.0	7.7	-	7.4
Oct. 20/67	1300	55.0	-	55.0	129.2	-	141.6	7.8	-	7.5
Oct. 21/67	1200	51.0	-	52.0	118.8	-	146.7	7.7	-	7.4
Oct. 22/67	1100	50.0	-	51.0	123.9	-	151.8	7.6	-	7.3
Oct. 23/67	1000	52.0	-	52.0	121.8	-	150.7	7.7	-	7.3
Oct. 24/67	0900	46.0	-	47.0	116.3	-	150.5	7.7	-	7.3
		SAMPLING SITE NO. 2								
Oct. 17/67	1620	56.0	56.0	56.0	125.0	131.3	135.0	7.7	7.5	7.5
Oct. 18/67	1520	56.0	56.0	56.0	121.9	128.8	134.4	7.7	7.5	7.5
Oct. 19/67	1420	57.5	57.5	58.0	127.9	134.1	146.4	7.7	7.6	7.5
Oct. 20/67	1320	55.0	55.0	55.0	129.8	135.5	143.6	7.6	7.6	7.5
Oct. 21/67	1220	51.5	52.0	52.0	125.4	128.4	136.2	7.5	7.5	7.3
Oct. 22/67	1120	51.5	51.5	51.5	128.4	129.7	137.6	7.5	7.5	7.4
Oct. 23/67	1020	52.0	52.0	52.0	123.1	127.1	137.6	7.6	7.5	7.4
Oct. 24/67	0920	47.0	47.5	48.0	122.5	124.2	134.3	7.5	7.5	7.4
		SAMPLING SITE NO. 3								
Oct. 20/67	1400	55.0	55.0	55.0	133.6	133.6	133.6	7.7	7.7	7.7
Oct. 21/67	1300	52.0	52.0	52.0	128.4	128.4	128.4	7.5	7.5	7.5
Oct. 22/67	1200	55.0	55.0	55.0	133.6	133.6	133.6	7.5	7.5	7.5
Oct. 23/67	1100	52.0	52.0	52.0	133.6	133.6	133.6	7.5	7.5	7.5
Oct. 24/67	1000	48.0	48.0	48.0	131.5	131.5	131.5	7.5	7.5	7.5
		SAMPLING SITE NO. 1 DURING A SLAG DUMP								
Oct. 20/67	0945	-	-	53.0	-	-	145.1	-	-	7.6
Oct. 20/67	1000	-	-	53.0	-	-	147.1	-	-	7.6
Oct. 20/67	1015	-	-	54.5	-	-	147.3	-	-	7.7

TABLE 2

Chemical Analyses of Surface Water of Columbia River below Trail

NO.	DATE	HOUR	TEMP. °F	O_2 CONS. AS PPM. O_2 EQUIV.	CO_2 CAL. PPM.	pH	COLOR	TURB-IDITY	COND. µmhos AT 25°C	TOTAL ALKAL-INITY PPM	HARDNESS AS $CaCO_3$ TOTAL PPM	HARDNESS AS $CaCO_3$ NON-CAR-BONATE PPM
					SAMPLING SITE NO. 1							
					East Side of River							
1	Oct. 17/67	1600	57.5	1.7	1	7.9	5	1.6	123	51.8	61.6	9.8
2	Oct. 18/67	1500	56.0	0.7	1	7.9	5	1.2	123	52.0	60.9	8.9
3	Oct. 19/67	1400	58.0	0.5	1	7.9	5	1.7	127	52.4	63.7	11.3
4	Oct. 20/67	1300	55.0	0.7	1	7.9	5	1.3	132	53.8	64.2	10.4
5	Oct. 21/67	1200	51.0	0.5	3	7.7	5	2.2	129	53.7	64.3	10.6
6	Oct. 22/67	1100	50.0	0.7	2	7.8	5	2.5	129	53.4	63.8	10.4
7	Oct. 23/67	1000	52.0	1.0	2	7.8	5	1.7	127	53.6	65.8	12.2
8	Oct. 24/67	0900	46.0	0.5	2	7.9	5	2.0	127	52.9	62.8	9.9
					West Side of River							
9	Oct. 17/67	1600	57.0	0.8	3	7.5	5	1.5	154	49.4	74.4	25.0
10	Oct. 18/67	1500	56.0	0.5	4	7.4	5	1.4	152	48.3	70.2	21.9
11	Oct. 19/67	1400	58.0	0.2	4	7.4	5	1.8	163	49.3	77.7	28.4
12	Oct. 20/67	1300	55.0	1.3	2	7.7	5	2.0	162	52.5	76.2	23.7
13	Oct. 21/67	1200	52.0	0.7	3	7.6	5	2.4	155	50.3	73.9	23.6
14	Oct. 22/67	1100	51.0	0.8	4	7.5	5	3.0	156	50.0	75.3	25.3
15	Oct. 23/67	1000	52.0	1.0	2	7.7	5	1.1	160	50.1	76.5	26.5
16	Oct. 24/67	0900	47.0	1.4	3	7.6	5	2.2	160	48.7	75.5	26.8
					SAMPLING SITE NO. 2							
					East Side of River							
17	Oct. 17/67	1620	56.0	1.3	2	7.7	5	2.1	132	51.0	64.8	13.8
18	Oct. 18/67	1520	56.0	0.3	2	7.8	5	1.7	128	51.2	63.0	11.8
19	Oct. 19/67	1420	57.5	1.5	2	7.8	5	1.3	132	52.3	64.2	11.9
20	Oct. 20/67	1320	55.0	0.8	2	7.7	5	1.7	135	53.6	67.2	13.6
21	Oct. 21/67	1220	51.5	0.7	3	7.7	5	2.0	135	53.7	66.8	13.1
22	Oct. 22/67	1120	54.0	0.4	2	7.9	5	2.7	131	52.9	65.3	12.4
23	Oct. 23/67	1020	52.0	0.7	2	7.9	5	1.1	133	52.7	65.5	12.8
24	Oct. 24/67	0920	47.0	1.2	2	7.8	5	2.5	133	52.9	65.5	12.6
					Centre of River							
25	Oct. 17/67	1620	56.0	2.0	2	7.7	5	1.5	138	50.6	65.9	15.3
26	Oct. 18/67	1520	56.0	0.5	2	7.7	5	1.5	133	50.7	65.1	14.4
27	Oct. 19/67	1420	57.5	0.7	2	7.8	5	1.8	138	52.0	65.6	13.6
28	Oct. 20/67	1320	55.0	0.3	2	7.8	5	1.3	142	53.4	68.8	15.4
29	Oct. 21/67	1220	52.0	0.9	3	7.6	5	1.7	139	52.7	68.5	15.8
30	Oct. 22/67	1120	51.5	0.4	3	7.7	5	3.7	134	53.0	66.3	13.3
31	Oct. 23/67	1020	52.0	0.5	2	7.9	5	1.1	136	53.1	67.0	13.9
32	Oct. 24/67	0920	47.5	0.4	2	7.7	5	2.4	135	52.1	68.0	15.9
					West Side of River							
33	Oct. 17/67	1620	56.0	0.9	4	7.5	5	1.5	142	50.5	68.4	17.9
34	Oct. 18/67	1520	56.0	0.6	3	7.6	5	1.7	140	50.7	68.4	17.7
35	Oct. 19/67	1420	58.0	0.7	3	7.6	5	1.5	150	50.3	71.7	21.4
36	Oct. 20/67	1320	55.0	1.0	3	7.7	5	2.2	149	53.5	70.6	17.1
37	Oct. 21/67	1220	52.0	0.3	3	7.6	5	1.8	146	51.0	70.8	19.8
38	Oct. 22/67	1120	51.5	0.8	3	7.6	5	3.0	144	51.7	70.0	18.3
39	Oct. 23/67	1020	52.0	0.9	2	7.7	5	1.4	146	51.7	71.3	19.6
40	Oct. 24/67	0920	48.0	0.8	2	7.7	5	2.3	146	51.5	70.8	19.3

TABLE 2

Chemical Analyses of Surface Water of Columbia River below Trail

NO.	CATIONS IN PPM								ANIONS IN PPM								SUM OF CONSTIT-UENTS
	Ca	Mg	Na	K	Mn	Fe Total	Fe Diss.	Cu	Zn	NH_3	CO_3	HCO_3	SO_4	F	Cl	PO_4	NO_3	SiO_2	
SAMPLING SITE NO. 1																			
East Side of River																			
1	18.8	3.6	0.8	0.7	0.005	0.14	<0.01	<0.005	0.020	0.1	0	63.1	12.8	0.11	0.3	0.01	0.2	2.3	70.6
2	18.6	3.9	0.8	0.6	0.005	0.13	<0.01	<0.005	0.005	0.1	0	63.4	9.9	0.12	0.2	<0.01	0.2	2.5	67.5
3	19.2	4.0	0.8	0.6	0.006	0.13	<0.01	<0.005	0.005	0.1	0	63.9	10.1	0.13	0.2	0.01	<0.1	2.1	68.5
4	19.3	3.9	1.0	0.6	0.005	0.12	<0.01	<0.005	0.005	0.2	0	65.6	9.8	0.18	0.3	<0.01	<0.1	2.4	69.8
5	20.8	3.6	1.0	0.6	0.005	0.10	<0.01	<0.005	<0.005	0.1	0	65.5	11.2	0.15	0.2	<0.01	0.1	2.5	71.3
6	19.1	3.9	1.0	0.7	0.007	0.13	<0.01	<0.005	<0.005	0.1	0	65.1	10.6	0.15	0.4	<0.01	<0.1	2.5	70.5
7	22.0	2.1	1.0	0.6	0.006	0.09	<0.01	<0.005	<0.005	0.3	0	65.3	10.4	0.13	0.2	0.02	<0.1	2.7	71.0
8	19.4	3.7	0.8	0.6	0.006	0.15	<0.01	<0.005	<0.005	0.2	0	64.5	10.1	0.12	0.2	<0.01	<0.1	2.7	69.1
West Side of River																			
9	24.4	3.3	0.8	0.7	0.015	0.16	0.03	<0.005	0.110	0.1	0	60.2	25.0	0.30	0.3	0.42	0.4	2.4	87.6
10	21.8	5.1	1.0	0.7	0.020	0.22	<0.01	<0.005	0.240	0.1	0	58.9	25.0	0.23	0.2	0.26	0.2	2.5	85.3
11	23.4	5.4	1.2	0.6	0.020	0.14	<0.01	<0.005	0.140	0.2	0	60.1	29.9	0.36	0.3	0.56	0.2	2.3	93.9
12	25.8	3.5	1.2	0.7	0.017	0.17	<0.01	<0.005	0.090	0.2	0	64.0	25.7	0.33	0.3	0.33	0.1	2.5	90.7
13	26.1	2.5	1.2	0.7	0.022	0.19	<0.01	<0.005	0.620	0.3	0	61.3	23.8	0.28	0.3	0.24	0.9	2.5	87.2
14	25.5	3.1	1.1	0.7	0.017	0.19	<0.01	<0.005	0.120	0.1	0	60.9	24.4	0.31	0.4	0.25	0.3	2.8	82.6
15	26.2	3.2	1.0	0.6	0.014	0.10	<0.01	<0.005	0.170	0.1	0	61.1	26.6	0.35	0.3	0.45	<0.1	2.9	90.4
16	24.8	3.6	0.9	0.7	0.025	0.20	<0.01	<0.005	0.175	0.5	0	59.4	25.4	0.44	0.3	0.90	0.3	3.2	89.2
SAMPLING SITE NO. 2																			
East Side of River																			
17	19.8	3.8	0.8	0.7	0.010	0.13	<0.01	<0.005	0.030	0.1	0	62.2	14.2	0.16	0.2	0.10	0.2	2.5	78.9
18	19.2	3.6	0.8	0.7	0.005	0.17	<0.01	<0.005	0.020	0.1	0	62.4	13.1	0.15	0.2	0.04	0.1	2.5	71.4
19	19.3	3.9	0.9	0.6	0.007	0.12	<0.01	<0.005	0.015	0.1	0	63.8	12.9	0.17	0.3	0.06	<0.1	2.7	72.3
20	20.3	4.0	1.0	0.6	0.005	0.13	<0.01	<0.005	0.010	0.1	0	65.3	13.5	0.19	0.3	0.06	0.1	2.5	74.8
21	20.3	3.9	1.0	0.6	0.012	0.12	<0.01	<0.005	0.180	0.1	0	65.5	13.5	0.15	0.3	0.10	0.2	2.4	74.8
22	19.7	3.9	0.9	0.6	0.010	0.17	<0.01	<0.005	<0.005	0.2	0	64.5	11.7	0.16	0.4	0.02	0.1	2.5	71.4
23	19.8	3.9	0.8	0.6	0.005	0.08	<0.01	<0.005	<0.005	0.1	0	64.2	14.6	0.18	0.3	0.08	<0.1	2.8	74.8
24	20.0	3.8	0.8	0.6	0.013	0.21	<0.01	<0.005	0.005	0.3	0	64.5	12.0	0.16	0.5	0.06	<0.1	2.4	72.2
Centre of River																			
25	20.3	3.7	0.8	0.7	0.007	0.16	<0.01	<0.005	0.050	0.1	0	61.7	16.9	0.20	0.4	0.14	0.3	2.1	76.1
26	20.0	3.7	0.8	0.6	0.009	0.16	<0.01	<0.005	0.060	0.1	0	61.8	14.2	0.20	0.3	0.10	<0.1	2.7	73.2
27	20.2	3.8	0.9	0.6	0.005	0.13	<0.01	<0.005	0.030	0.2	0	63.3	16.5	0.21	0.2	0.14	<0.1	2.5	76.3
28	21.3	3.8	1.2	0.7	0.012	0.17	<0.01	<0.005	0.060	0.1	0	65.1	15.6	0.22	0.3	0.09	0.2	2.5	78.1
29	21.0	3.9	0.9	0.6	0.011	0.14	<0.01	<0.005	0.240	0.1	0	64.2	14.3	0.20	0.3	0.10	0.4	2.7	76.1
30	20.1	3.9	1.0	0.6	0.008	0.14	<0.01	<0.005	<0.005	0.1	0	64.6	14.0	0.19	0.4	0.04	<0.1	2.4	74.4
31	20.6	3.8	0.8	0.6	0.007	0.09	<0.01	<0.005	<0.005	0.1	0	64.7	15.3	0.21	0.3	0.15	<0.1	2.8	76.7
32	20.8	3.9	0.8	0.7	0.018	0.15	<0.01	<0.005	0.005	0.3	0	63.5	14.6	0.18	0.2	0.10	<0.1	2.5	75.2
West Side of River																			
33	21.3	3.7	0.8	0.7	0.010	0.16	<0.01	<0.005	0.070	0.1	0	61.6	18.4	0.22	0.3	0.25	0.4	2.4	78.9
34	21.3	3.7	0.9	0.6	0.010	0.18	<0.01	0.010	0.120	0.1	0	61.8	17.0	0.26	0.2	0.18	<0.1	2.5	76.4
35	22.3	3.9	1.1	0.7	0.010	0.10	<0.01	<0.005	0.075	0.1	0	61.3	21.6	0.27	0.5	0.32	<0.1	2.4	83.3
36	25.7	2.4	1.1	0.7	0.017	0.18	<0.01	<0.005	0.070	0.1	0	65.2	18.9	0.26	0.7	0.20	0.1	2.8	82.6
37	21.9	3.9	1.0	0.6	0.014	0.14	<0.01	<0.005	0.400	0.2	0	62.2	19.1	0.27	0.3	0.18	0.7	2.8	81.4
38	21.6	3.9	1.0	0.7	0.014	0.17	<0.01	<0.005	0.010	0.2	0	63.0	18.6	0.29	0.4	0.14	0.1	2.7	80.5
39	22.3	3.8	0.9	0.6	0.005	0.11	<0.01	<0.005	0.015	0.1	0	63.0	20.2	0.29	0.3	0.34	<0.1	2.9	82.7
40	22.1	3.8	0.8	0.7	0.017	0.13	<0.01	<0.005	0.020	0.1	0	62.8	19.1	0.27	0.3	0.19	<0.1	2.4	80.6

TABLE 2 (Cont.)

Chemical Analyses of Surface Water of Columbia River below Trail

NO.	DATE	HOUR	TEMP. °F	O_2 CONS. AS PPM. O_2 EQUIV.	CO_2 CAL. PPM.	pH	COLOR	TURB-IDITY	COND. µmhos AT 25°C	TOTAL ALKAL-INITY PPM	HARDNESS AS $CaCO_3$ TOTAL PPM	HARDNESS AS $CaCO_3$ NON-CAR-BONATE PPM
					SAMPLING SITE NO. 3							
					East Side of River							
41	Oct. 20/67	1400	55.0	0.9	3	7.7	5	1.8	140	52.7	66.7	14.0
42	Oct. 21/67	1300	52.0	0.4	3	7.7	5	2.0	139	52.8	67.5	14.7
43	Oct. 22/67	1200	55.0	1.0	1	7.7	5	3.6	139	53.2	67.5	14.3
44	Oct. 23/67	1100	52.0	0.3	2	7.8	5	1.1	140	52.6	69.0	16.4
45	Oct. 24/67	1000	48.0	0.5	2	7.7	5	2.2	142	52.3	72.0	19.7
					Centre of River							
46	Oct. 20/67	1400	55.0	0.9	2	7.8	5	2.2	141	52.8	66.9	14.1
47	Oct. 21/67	1300	52.0	1.1	3	7.7	5	1.7	139	52.7	67.5	14.8
48	Oct. 22/67	1200	56.0	1.1	2	7.9	5	3.6	139	53.3	68.0	14.7
49	Oct. 23/67	1100	52.0	1.4	2	7.8	5	1.1	141	52.6	68.0	15.4
50	Oct. 24/67	1000	48.0	0.6	2	7.8	5	2.2	142	52.5	69.3	16.8
					West Side of River							
51	Oct. 20/67	1400	55.0	0.7	2	7.8	5	2.5	141	52.9	67.4	14.5
52	Oct. 21/67	1300	52.0	0.8	3	7.6	5	1.4	140	52.3	69.2	16.9
53	Oct. 22/67	1200	56.0	0.7	1	7.9	5	3.1	139	52.8	68.5	15.7
54	Oct. 23/67	1100	52.0	0.9	2	7.7	5	1.2	141	52.6	67.8	15.2
55	Oct. 24/67	1000	47.0	0.9	2	7.8	5	2.0	141	52.3	68.8	16.5
					SAMPLING SITE NO. 1 - WEST SIDE OF RIVER DURING A SLAG DUMP							
56	Oct. 20/67	0945	53.0	0.5	2	7.7	5	1.6	159	53.1	73.9	20.8
57	Oct. 20/67	1000	53.0	0.3	1	7.9	5	1.0	159	52.9	74.7	21.8
58	Oct. 20/67	1015	54.5	0.7	2	7.8	5	1.7	160	52.9	78.7	25.8

TABLE 2 (Cont.)

Chemical Analyses of Surface Water of Columbia River below Trail

NO.	CATIONS IN PPM								ANIONS IN PPM								SUM OF CONSTIT-UENTS
	Ca	Mg	Na	K	Mn	Fe Total	Fe Diss.	Cu	Zn	NH_3	CO_3	HCO_3	SO_4	F	Cl	PO_4	NO_3	SiO_2	
SAMPLING SITE NO. 3																			
East Side of River																			
41	20.3	3.9	1.1	0.7	0.007	0.16	<0.01	<0.005	0.025	0.1	0	64.2	15.6	0.23	0.4	0.10	0.2	2.5	76.8
42	20.6	3.9	1.0	0.7	0.005	0.12	<0.01	<0.005	0.015	0.1	0	64.4	15.4	0.21	0.3	0.10	0.2	2.5	76.6
43	20.6	3.9	1.0	0.6	0.007	0.25	<0.01	<0.005	0.010	0.1	0	64.8	15.0	0.20	0.3	0.08	<0.1	2.7	77.5
44	21.2	3.9	0.8	0.6	0.006	0.10	<0.01	<0.005	0.015	0.2	0	64.1	15.8	0.22	0.3	0.14	<0.1	2.7	77.2
45	21.8	3.9	0.8	0.6	0.012	0.14	<0.01	<0.005	0.010	0.1	0	63.8	16.9	0.22	0.2	0.15	<0.1	2.4	79.0
Centre of River																			
46	20.4	3.9	1.0	0.6	0.012	0.20	<0.01	<0.005	0.020	0.1	0	64.4	15.3	0.22	0.3	0.15	0.1	2.7	76.5
47	20.6	3.9	0.9	0.6	0.010	0.36	<0.01	<0.005	0.015	0.1	0	64.2	14.8	0.21	0.5	0.08	0.1	2.5	76.2
48	20.8	3.9	0.9	0.6	0.006	0.22	<0.01	<0.005	0.010	0.1	0	65.0	15.9	0.18	0.3	0.07	<0.1	2.5	77.3
49	21.0	3.8	0.9	0.7	0.009	0.15	<0.01	<0.005	0.015	0.1	0	64.1	15.8	0.23	0.3	0.14	<0.1	3.0	77.5
50	21.3	3.9	0.8	0.6	0.010	0.14	<0.01	<0.005	0.010	0.1	0	64.0	16.5	0.22	0.2	0.15	<0.1	2.5	77.7
West Side of River																			
51	20.6	3.9	1.1	0.6	0.008	0.17	<0.01	<0.005	0.030	0.1	0	64.5	15.1	0.24	0.3	0.14	<0.1	2.5	76.3
52	21.1	4.0	1.0	0.6	0.010	0.14	<0.01	<0.005	0.015	0.1	0	63.8	15.4	0.20	0.3	0.08	0.1	2.5	76.7
53	21.0	3.9	0.9	0.6	0.012	0.25	<0.01	<0.005	0.015	0.1	0	64.4	15.8	0.20	0.3	0.08	<0.1	2.5	77.1
54	20.9	3.8	0.9	0.7	0.005	0.11	<0.01	<0.005	0.015	0.1	0	64.1	16.4	0.21	0.3	0.14	<0.1	2.9	77.8
55	21.3	3.9	0.8	0.6	0.008	0.17	<0.01	<0.005	0.010	0.1	0	63.8	17.2	0.22	0.3	0.15	<0.1	2.5	78.3
SAMPLING SITE NO. 1 - WEST SIDE OF RIVER DURING A SLAG DUMP																			
56	23.2	3.9	1.0	0.7	0.008	0.13	<0.01	<0.005	0.040	0.1	0	64.7	23.2	0.46	0.3	0.46	<0.1	2.5	87.6
57	23.3	4.0	0.9	0.7	0.009	0.13	<0.01	<0.005	0.030	0.2	0	64.5	22.4	0.42	0.3	0.42	<0.1	2.5	86.7
58	25.1	3.9	1.0	0.7	0.008	0.45	<0.01	<0.005	0.070	0.2	0	64.5	23.8	0.46	0.3	0.46	<0.1	2.7	90.6

TABLE 3

Surface Water Data of the Columbia River below Trail

MONTH	DAY and YEAR	DAILY DISCHARGE IN CUBIC FEET PER SECOND
October	17, 1967	41,900
October	18, 1967	42,500
October	19, 1967	45,500
October	20, 1967	48,000
October	21, 1967	47,300
October	22, 1967	45,700
October	23, 1967	42,400
October	24, 1967	39,100

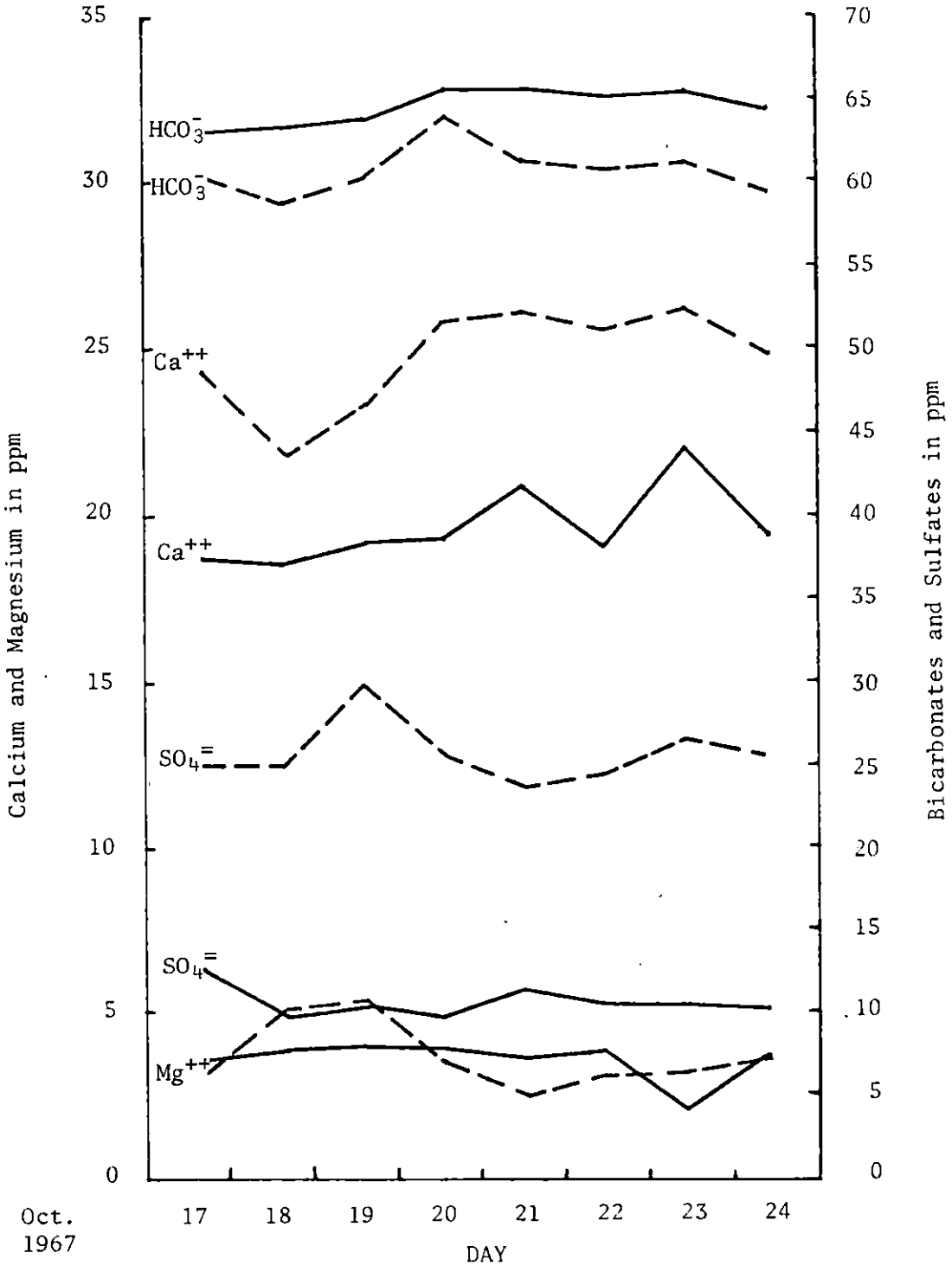

Figure 1. Calcium, magnesium, bicarbonate and sulfate values of the Columbia River at Site 1.

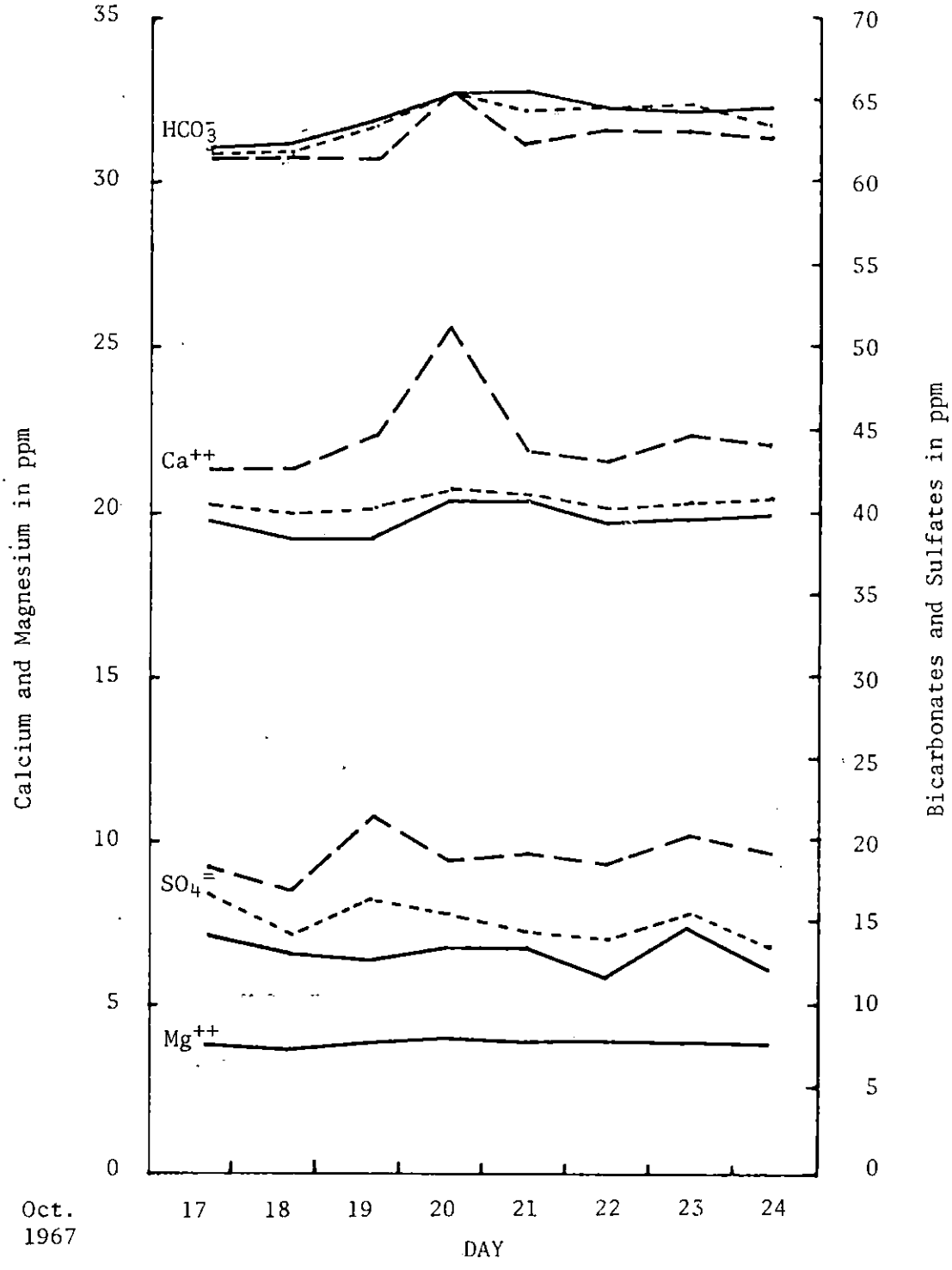

Figure 2. Calcium, magnesium, bicarbonate and sulfate values of the Columbia River at Site 2.

East Side River
Centre River
West Side River

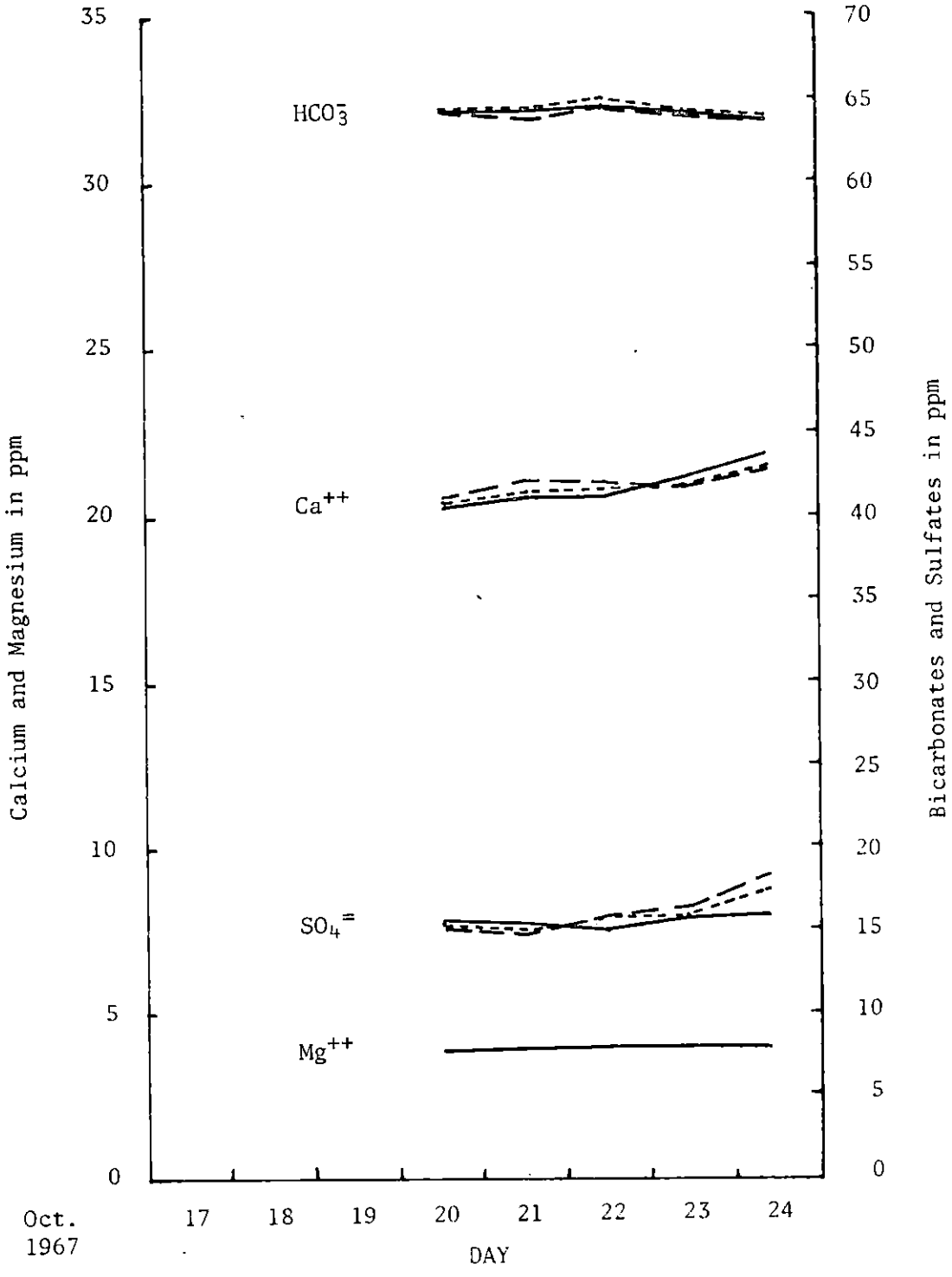

Figure 3. Calcium, magnesium, bicarbonate and sulfate values of the Columbia River at Site 3.

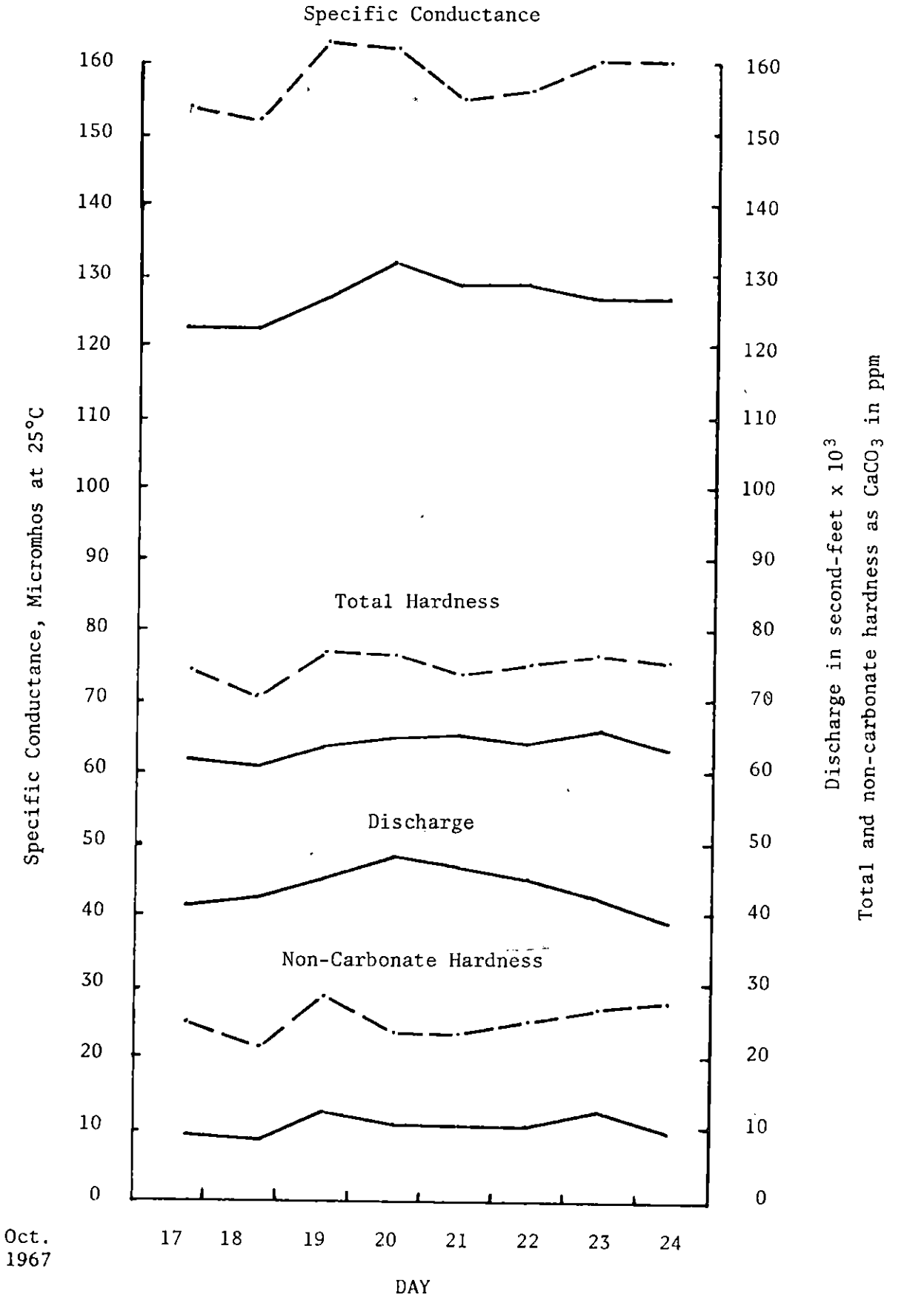

Figure 4. Specific conductance, discharge, total hardness and non-carbonate hardness values of the Columbia River at Site 1.

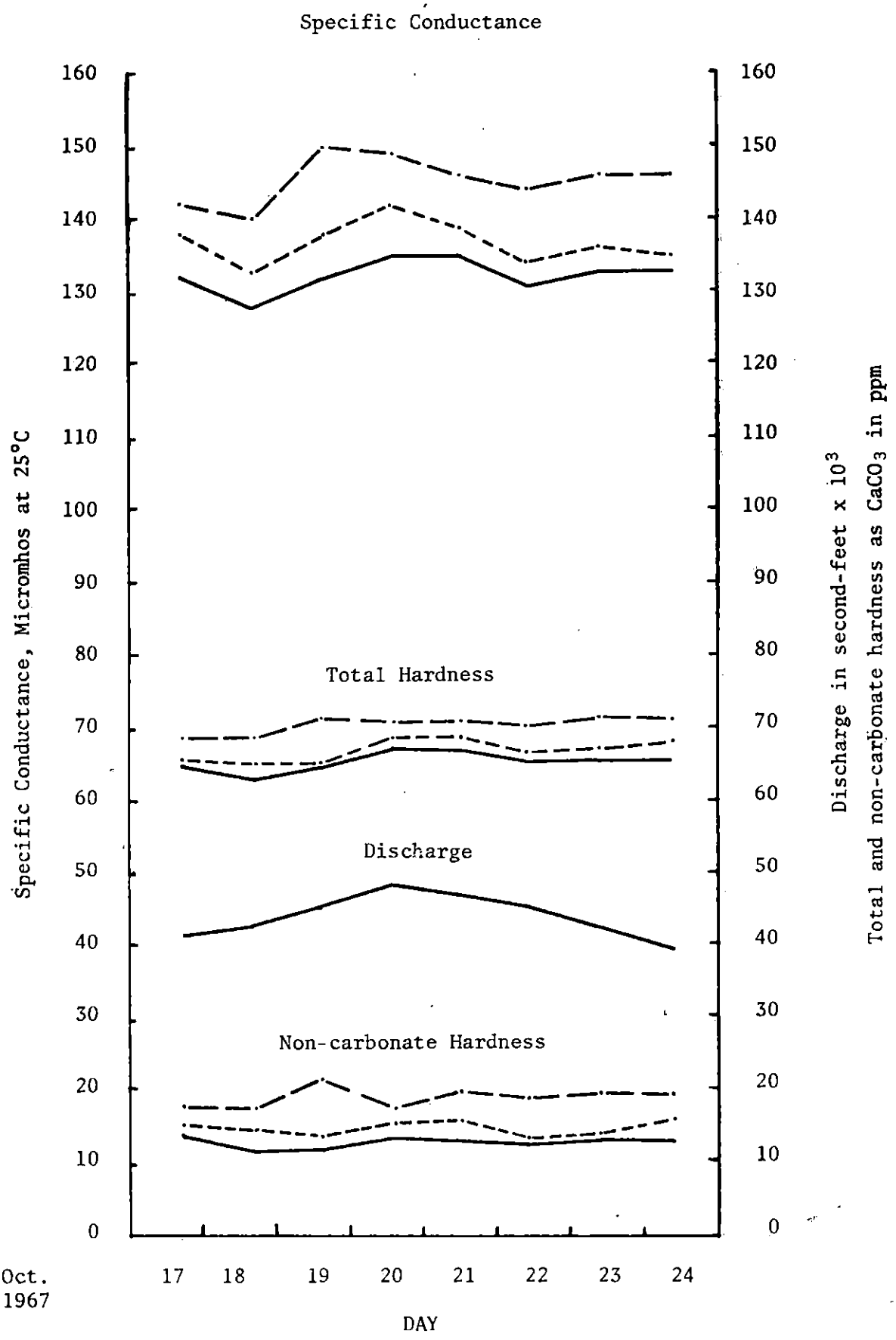

Figure 5. Specific conductance, discharge, total hardness and non-carbonate hardness values of the Columbia River at Site 2.

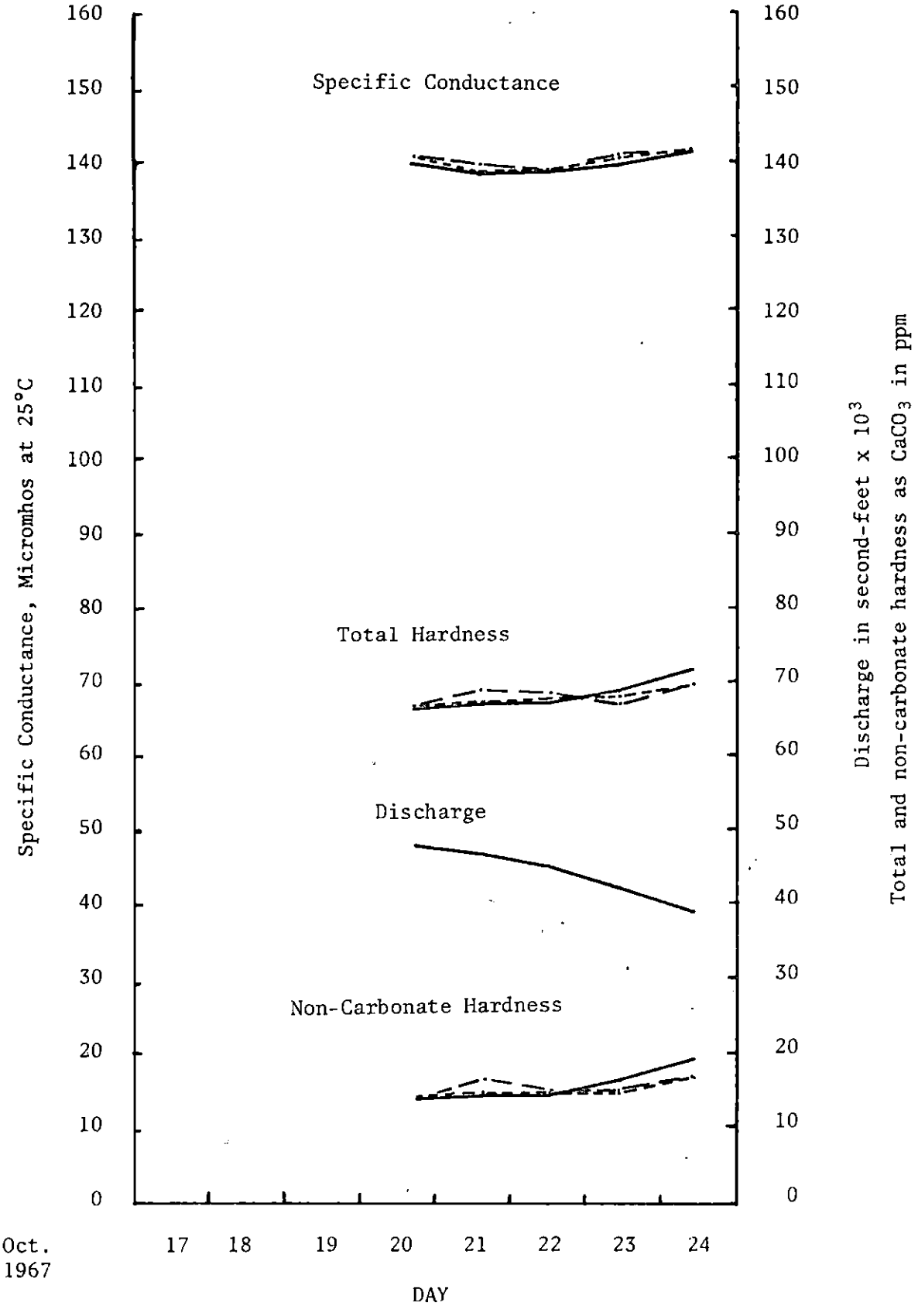

Figure 6. Specific conductance, discharge, total hardness and non-carbonate hardness values of the Columbia River at Site 3.