UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-QUALITY RECONNAISSANCE OF THE MIDDLE AND NORTH BRANCH PARK RIVER WATERSHEDS, NORTHEASTERN NORTH DAKOTA

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM UNITS (SI)

The following factors may be used to convert the inch-pound units published herein to the International System of units (SI).

Multiply inch-pound units	By	To obtain SI units
	Length	
Inch (in)	2.54×10^{1}	millimeter (mm)
	2.54×10^{-2}	meter (m)
Foot (ft)	3.048×10^{-1}	meter (m)
Mile (mi)	1.609×10^{0}	kilometer (km)
	Area	
Square mile (mi^2)	2.590×10^{0}	square kilometer (km^2)
	Volume	
Acre-foot (acre-ft)	1.233×10^{3}	cubic meter (m^3)
	1.233×10^{-3}	cubic hectometer (hm^3)
	1.233×10^{-6}	cubic kilometer (km^3)
	Flow	
Cubic foot per second (ft^3/s)	2.832×10^{1}	liters per second (L/s)
	2.832×10^{1}	cubic decimeter per second (dm^3/s)
	2.832×10^{-2}	cubic meter per second (m^3/s)
	Mass	
Ton (short)	9.072×10^{-1}	megagram (mg) or metric ton
	Load	
Ton (short) per day (t/d)	9.072×10^{-1}	metric ton per day

To convert °C (Celsius) to °F (Fahrenheit), the formula is: 9/5(°C)+32
To convert °F to °C, the formula is: 5/9(°F-32).

WATER-QUALITY RECONNAISSANCE OF THE MIDDLE AND NORTH BRANCH PARK RIVER WATERSHEDS, NORTHEASTERN NORTH DAKOTA

By D. J. Ackerman

ABSTRACT

In order to design a network to monitor the effects of works of improvement in the Middle and North Branch Park River watersheds, and to determine the major factors controlling water-quality conditions in the watersheds, an evaluation of sediment transport, water chemistry, and biology was conducted during the spring and early summer of 1978.

Major factors controlling water quality are geology, stream gradient, ground-water seepage, and the duration of streamflow.

Sediment loads originate on the Pembina Escarpment. The coarse silt and sand parts of these loads are deposited on the Lake Agassiz Plain. Transport of sediment is lowered and flow duration is increased on the Middle Branch Park River due to the presence of small dams. Observations suggest that bedload transport is a significant process, particularly in the upstream reaches. However, no quantitative bedload data were collected.

During periods of low flow, analyses of water from the rivers in both watersheds show downstream increases in sodium and chloride due to ground-water seepage or the unregulated flow of wells.

Diversity of benthic invertebrates indicates water-quality conditions are better on the Middle Branch Park River than on the North Branch, and are better at upstream sites than at downstream sites.

A program through which the Soil Conservation Service can monitor the effects of present and future works of improvement on the watersheds was designed. The monitoring program consists of intensive sampling at four locations for sediment and water chemistry during spring and early summer runoff events and by profiles of water chemistry during summer base runoff.

INTRODUCTION

At the request of the Soil Conservation Service (SCS), the U.S. Geological Survey conducted a water-quality reconnaissance of the Middle and North Branch Park River watersheds in northeastern North Dakota (fig. 1) in the spring and early summer of 1978.

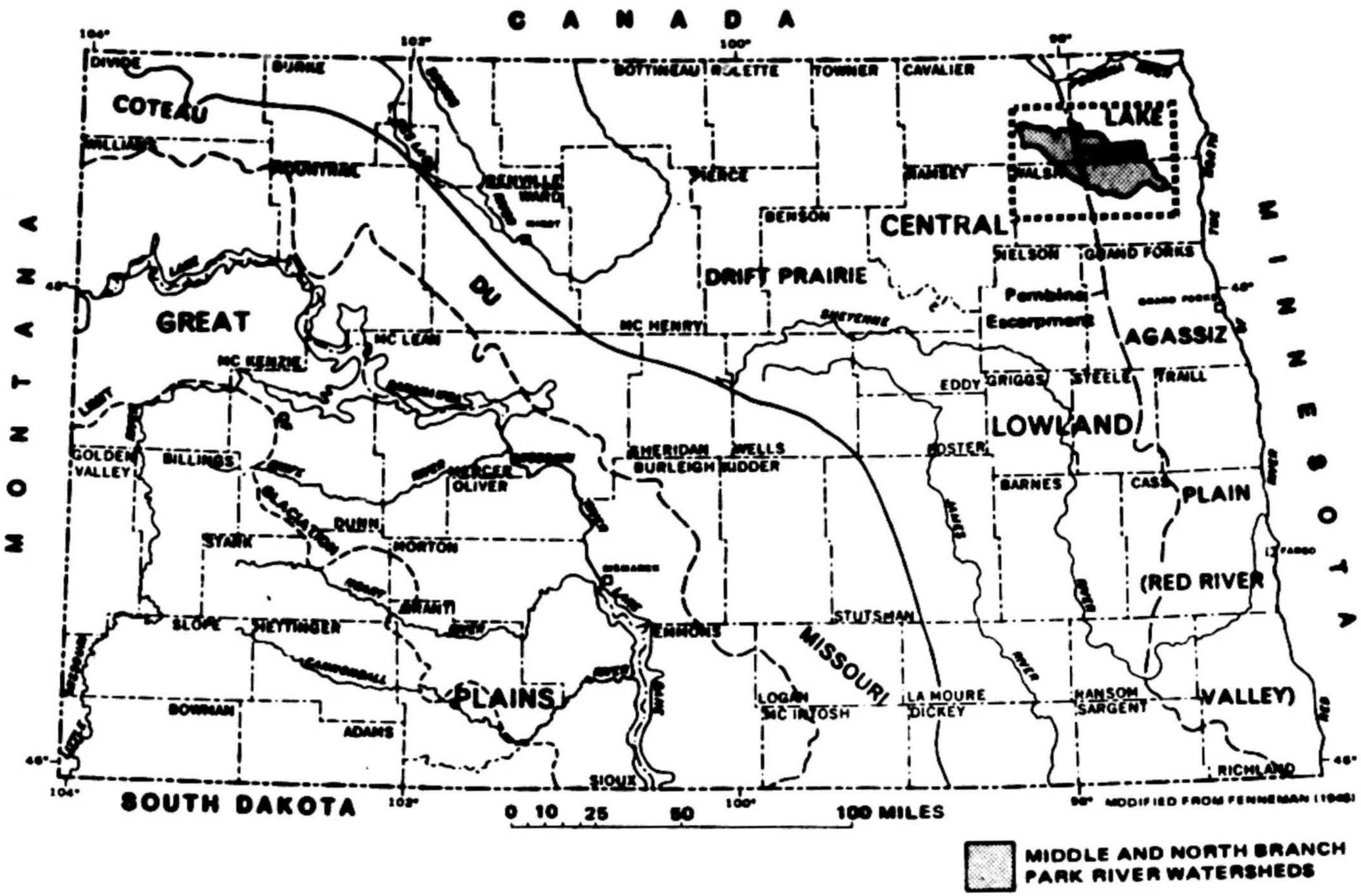

FIGURE 1.—Physiographic divisions in North Dakota and location of study area.

The Soil Conservation Service needed informaton about water-quality conditions in the watersheds in order to plan and manage "works of improvement"[1]. Information about current water-quality conditions and the processes controlling water quality in the watersheds was insufficient. Without this information a proper monitoring network could not be designed. By conducting a short and intensive study of the hydrology of the watersheds, a framework for distribution of water quality and some of the factors controlling that quality can be defined. After the framework is established, water quality can be monitored at selected points in the framework.

Objectives and Scope

The objectives of this report are to (1) evaluate the present water quality in the watersheds, (2) determine the major environmental factors controlling the water quality, (3) design a monitoring program to evaluate the variability of water quality and to monitor the impact of works of improvement within the watersheds, and (4) develop recommendations for additional sampling necessary to better define processes controlling water quality in the watersheds.

Data were collected from April to June 1978. Data collected consisted of:

1. Sediment concentration and streamflow during spring runoff at 10 sites,
2. Microbiological, benthic-invertebrate, and water-chemistry samples during summer base runoff.

In addition, historical records of stream-flow and water quality published by the U.S. Geological Survey were used.

Sediment data were to be collected in late spring or early summer, but no runoff event of sufficient magnitude occurred.

SETTING

Geography

The Middle Branch Park River drains 396 square miles of Cavalier, Pembina, and Walsh Counties in northeastern North Dakota (fig. 2). The drainage basin, or watershed, of the Middle Branch Park River contains the watershed of the North Branch Park River, which in turn contains the watershed of Cart Creek. Cart Creek and the North Branch Park River drainage areas are 105 and 244 square miles, respectively.

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[1] "Works of improvement" (Soil Conservation terminology) is: any component part of the watershed project that meets the goals and objectives of the watershed sponsors. Includes, but is not limited to, structural and non-structural flood prevention measures, mitigation and land treatment.

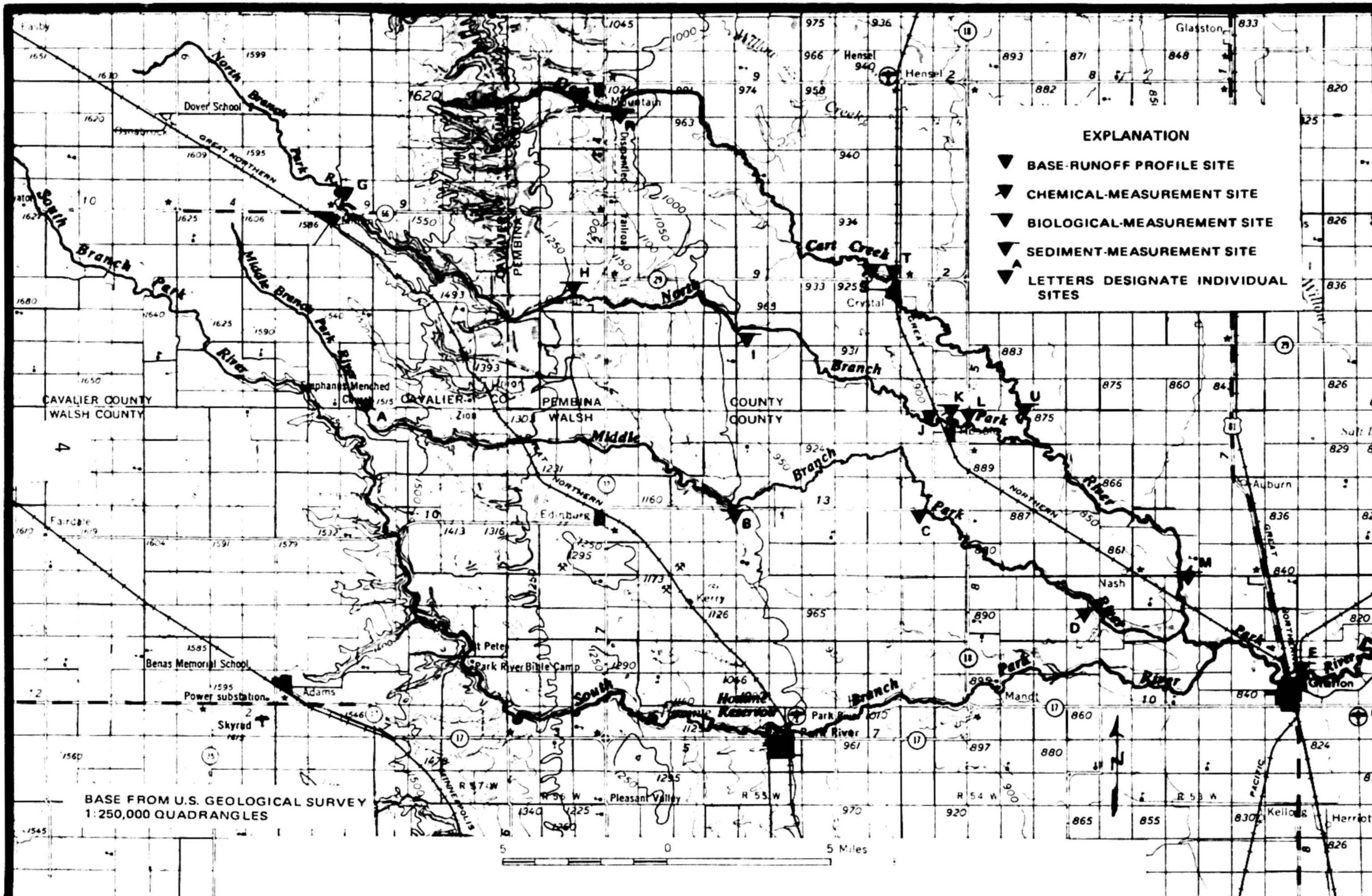

FIGURE 2.–Locations of sampling sites, Middle and North Branch Park River watersheds.

Headwaters of the rivers are in the gently rolling Drift Prairie of the Central Lowland physiographic province. The rivers drop across the Pembina Escarpment and meander across the Lake Agassiz Plain to the Red River of the North. Both the Middle and North Branch of the river are intermittent, having zero flow over most of their length by late summer.

A significant part of the drainage system in the Drift Prairie is poorly integrated and does not contribute runoff to these rivers. The drainage system for the Pembina Escarpment and Lake Agassiz Plain is well intergrated.

The study area has a continental climate characterized by cold snowy winters and warm summer days with cool nights. Mean annual temperature at Grafton is 39.4°F (U.S. Environmental Data Service, 1973). Maximum temperatures during June, July, and August average 81°F, and temperatures during December, January, and February average 7.6°F (U.S. Weather Bureau, 1963). Precipiation at Grafton averages 19.9 inches (U.S. Environmental Data Service, 1973). About three-fourths of this precipitation falls in the growing season, April through September.

The economy in the study area is almost exclusively agricultural. Land use is primarily grazing on the Pembina Escarpment, grazing and cropland on the Drift Prairie, and cropland on the Lake Agassiz Plain.

Geology

The physiographic divisions of the area are an expression of the geology.

The Drift Prairie is composed primarily of till of Pleistocene age.

The Pembina Escarpment generally has exposures of Pierre Shale at its top, and wave-washed drift at its base. Streamcuts expose the Niobrara Formation, a calcareous highly jointed shale, near the base of the escarpment. Pierre Shale, which overlies the Niobrara Formation, also is exposed on the face of Pembina Escarpment. Both formations are of Cretaceous age. The drift that mantles the base of the escarpment was washed by wave action of glacial Lake Agassiz.

The Lake Agassiz Plain consists mainly of the sediments of glacial Lake Agassiz. In the vicinity of the rivers the lake sediments are overlain by fluvial sediments of Holocene age. In the north part of the study area the fluvial sediments are a southward extension of the Pembina Delta; however, over most of the area, they are deposits of present-day rivers. At the beginning of Holocene time, the rivers probably were larger streams than they are now, and before they occupied their present valleys they meandered over a wide area of the Lake Agassiz Plain.

As an illustration of the control geology has on the physiography of watersheds, figures 3, 4, and 5 show the gradient, physiography, and geology along the three major streams in the study area. Sampling sites are noted for reference.

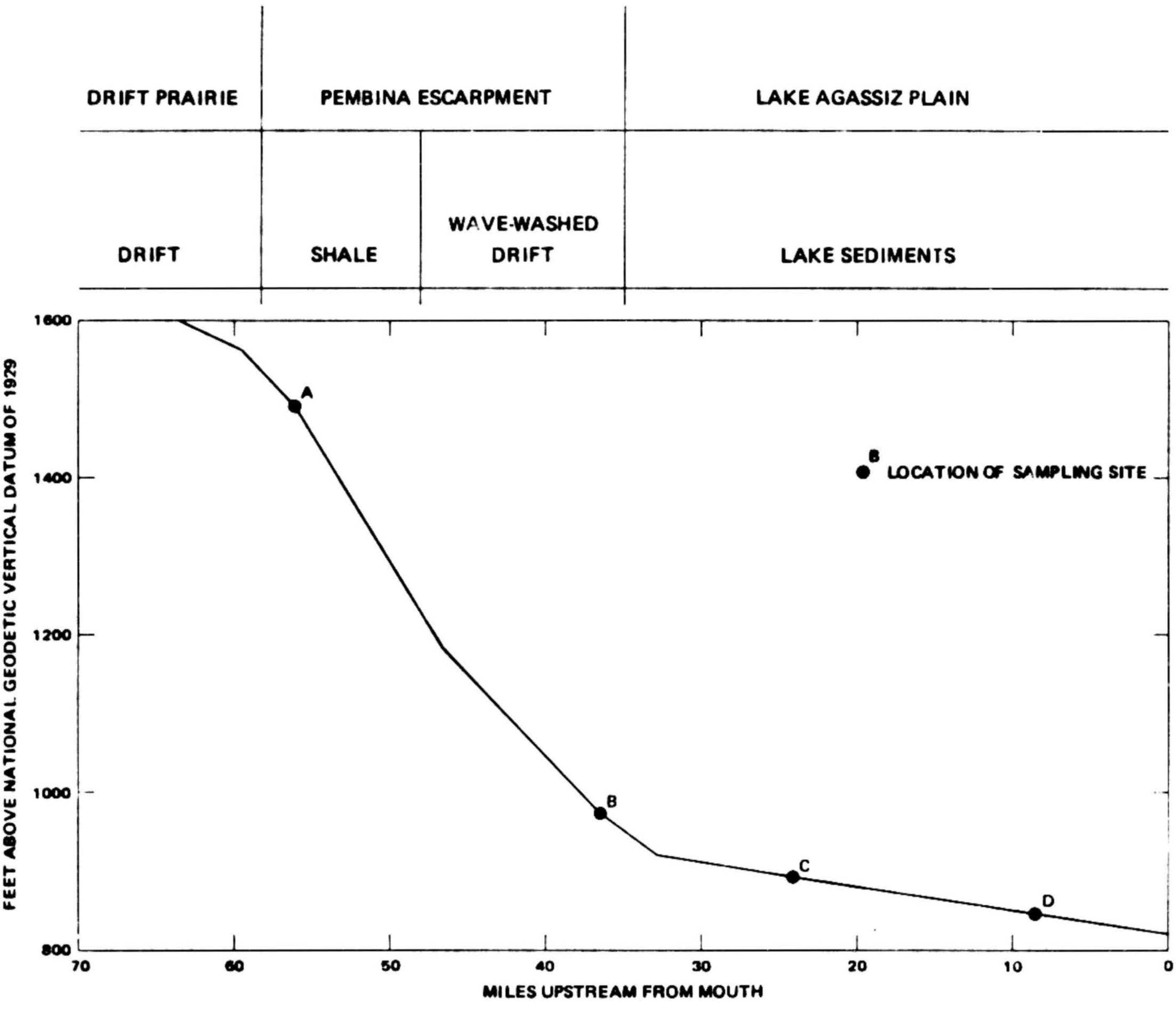

FIGURE 3.—Longitudinal profile showing gradient, physiography, and geology of Middle Branch Park River.

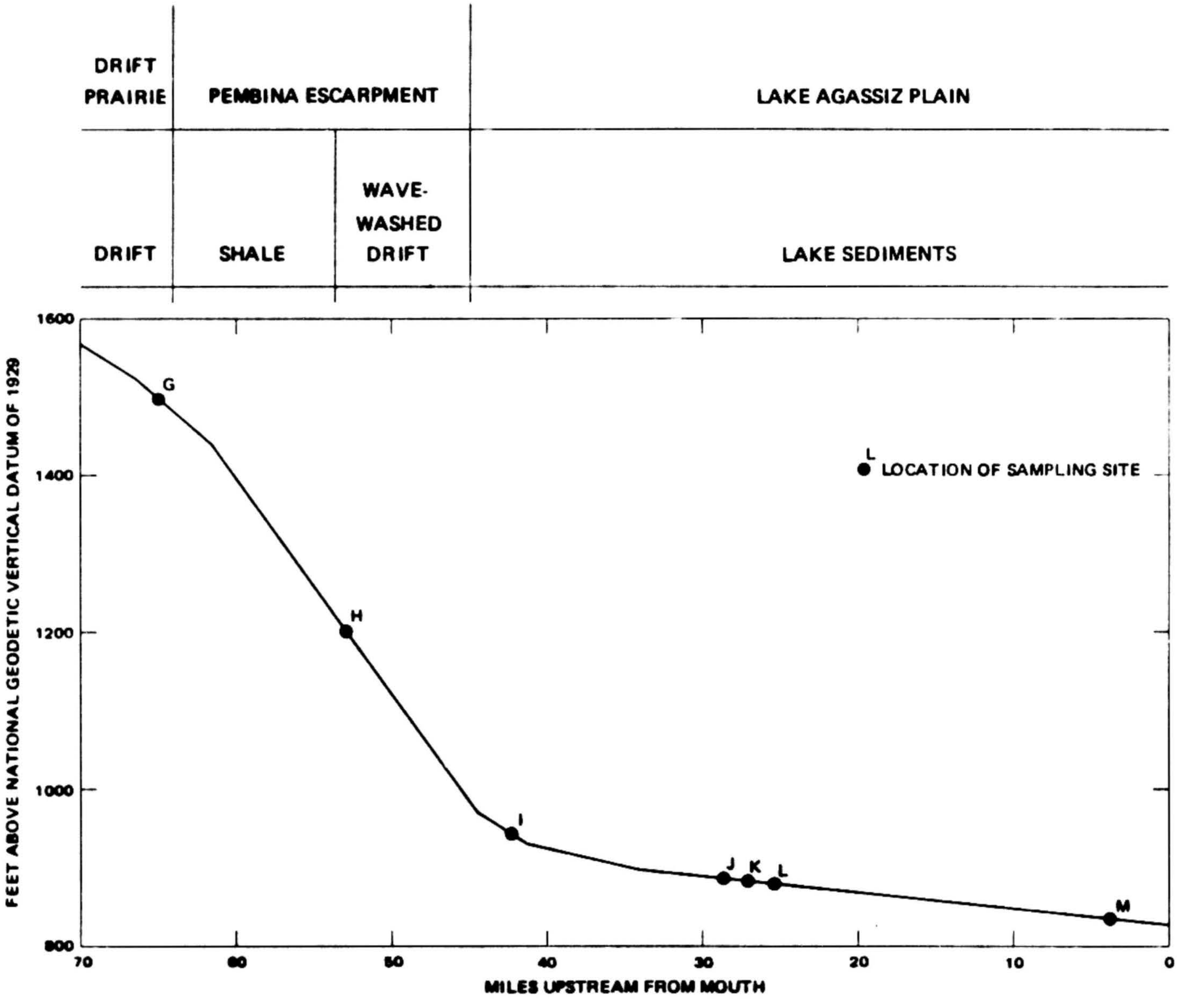

FIGURE 4.—Longitudinal profile showing gradient, physiography, and geology of North Branch Park River.

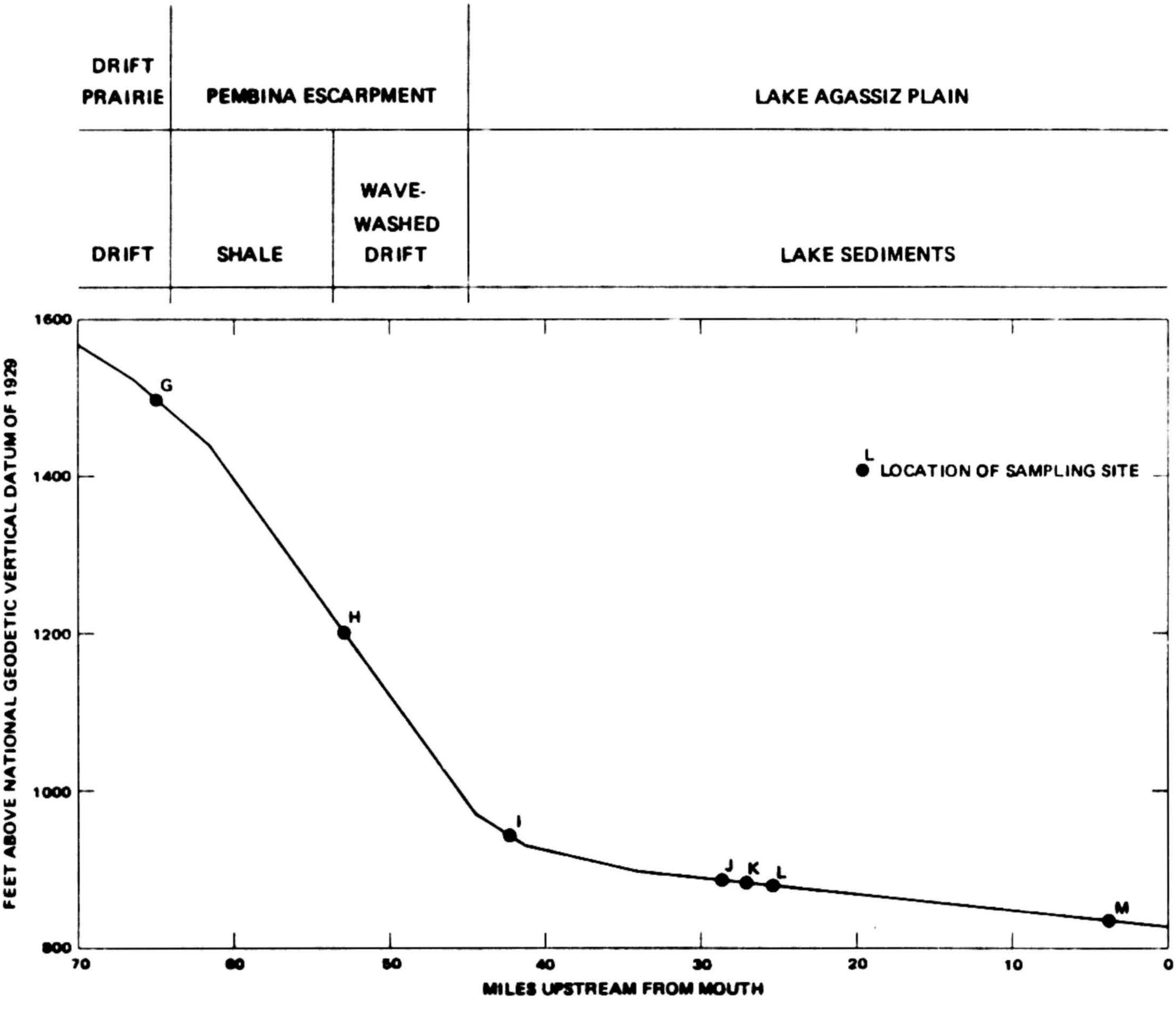

FIGURE 4.—Longitudinal profile showing gradient, physiography, and geology of North Branch Park River.

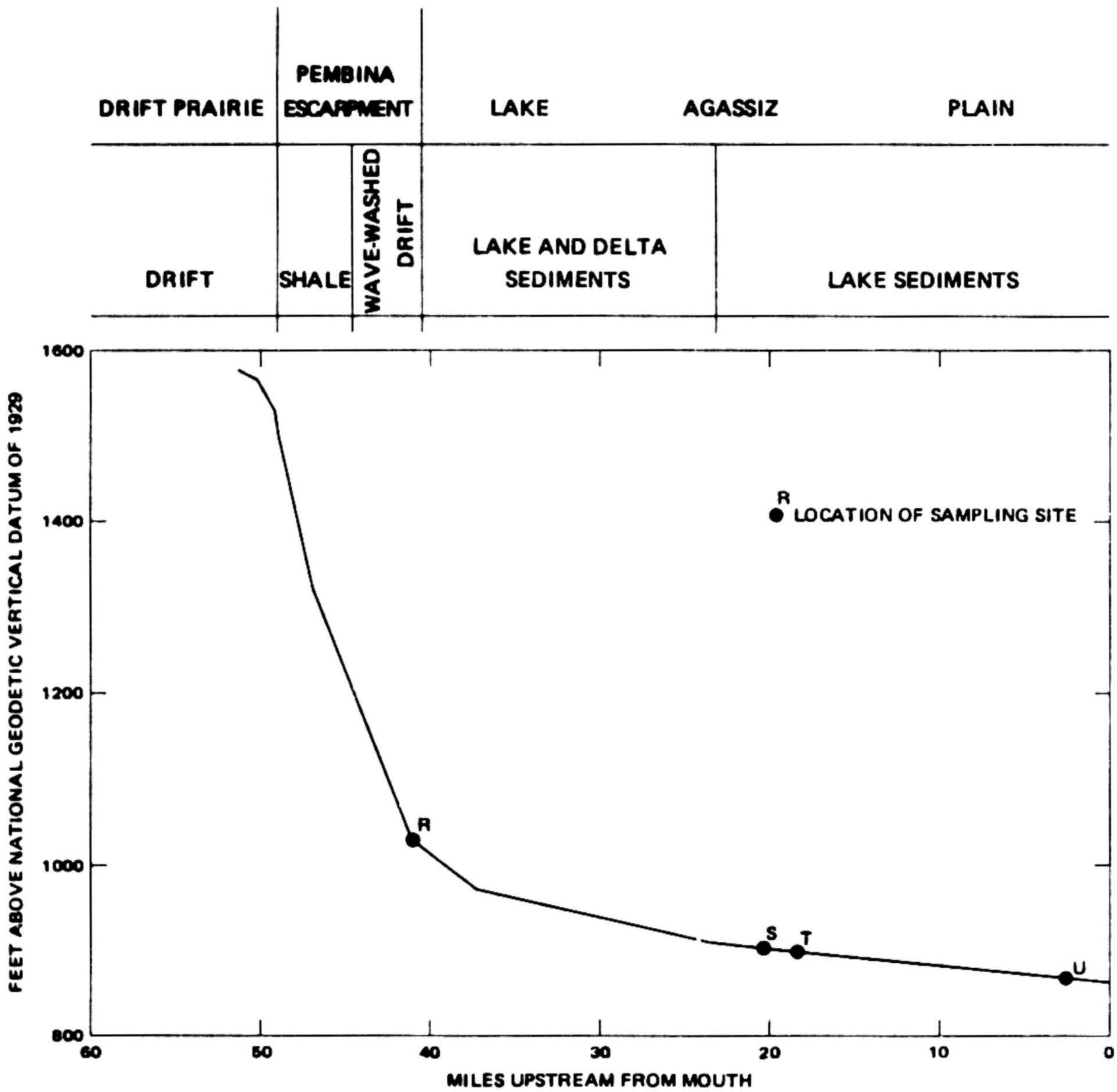

FIGURE 5.—Longitudinal profile showing gradient, physiography, and geology of Cart Creek.

METHODS

Measurements of instantaneous discharge were made with current meters using methods described by Buchanan and Somers (1969).

Suspended-sediment concentration and particle size were sampled by the equal-width-increment method (Guy and Norman, 1970) and analyzed according to methods described by Guy (1969).

Microbiological samples were collected and analyzed using the membrane-filter method (Greeson and others, 1977).

Benthic invertebrate samples were collected on jumbo multiple-plate samplers and analyzed according to methods found in Greeson and others (1977).

Samples for water chemistry were collected and analyzed according to methods given in Brown and others (1970).

RESULTS AND DISCUSSION

The locations of sampling sites used in this report are shown in figure 2. All locations are given a letter desig-nation for ease of discussion. Precise locations of these sites are given in the tables of data.

Data collected during spring runoff are given in table 1. These data consist of (1) instantaneous streamflow, (2) specific conductance, (3) air and water temperatures, (4) suspended-sediment concentrations, and (5) suspended-sediment particlesize analyses. Additional water-quality measurements at gaging stations in the study area are given in "Water-Resources Data for North Dakota, Water Year 1978" (U.S. Geological Survey, 1979).

Figures 6, 7, and 8 are streamflow hydrographs that show mean daily discharge for three stations in the study area. These figures also show the flow that is exceeded 50 and 20 percent of the time. Most runoff occurred after April 6, and was the result of snowmelt above the Lake Agassiz Plain. The discharge for April 1978 would be exceeded on the average only 30 percent of the time. Generally discharge for the other months in the study period also was above average. As previously stated, there was no significant discharge event following the spring runoff.

Releases of water from dams on the main stem and upstream tributaries of the Middle Branch Park River extend the duration of low flow. A dam near Crystal stopped flow on Cart Creek during June 1978. Both streams probably had reduced peak discharges downstream from the dams during spring runoff. The several small dams on the Middle Branch reduced the highest observed discharge by about half, when compared to undammed streams in the study area that have equivalent drainage area.

The largest suspended-sediment concentrations were measured in the upstream reaches of the streams. In addition, concentrations of suspended sediment at

TABLE 1.--Data collected during spring runoff, 1978

[umho/cm, micromhos per centimeter; mg/L, milligrams per liter; mm, millimeter]

Site	Latitude	Longitude	Date of sample	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (umho/cm)	Temperature, air (deg C)	Temperature, water (deg C)	Sediment, suspended (mg/L)	Sediment discharge, suspended (tons per day)	Sediment suspended fall diameter percent finer than 0.004 mm	Sediment suspended fall diameter percent finer than 0.016 mm	Sediment suspended fall diameter percent finer than 0.062 mm	Sediment suspended fall diameter percent finer than 0.125 mm	Sediment suspended fall diameter percent finer than 1.00 mm	Sediment suspended fall diameter percent finer than 2.00 mm
Middle Branch Park River																
B	48°30'12"	097°45'53"	78-04-04	1810	64	283	3.0	1.0	266	46	--	--	--	--	--	--
			78-04-06	1450	382	315	6.0	1.5	1,340	1,380	--	--	--	--	--	--
			78-04-09	1430	324	308	10.0	3.5	772	675	--	--	--	--	--	--
			78-04-20	1735	145	292	5.0	5.0	440	172	--	--	--	--	--	--
D	48°27'08"	097°32'07"	78-04-08	1300	272	322	6.5	2.0	368	270	--	--	--	--	--	--
			78-04-10	1125	357	297	3.0	4.5	720	694	--	--	--	--	--	--
			78-04-19	0925	105	228	-3.0	6.5	232	66	--	--	--	--	--	--
North Branch Park River																
H	48°35'30"	097°52'50"	78-04-04	1535	18	390	6.0	.5	718	35	--	--	--	--	--	--
			78-04-06	1840	806	230	3.0	.5	4,960	10,800	45	68	78	82	98	100
			78-04-09	1030	647	240	5.0	1.5	2,320	4,050	--	--	--	--	--	--
			78-04-21	1250	39	391	12.0	8.0	120	13	--	--	--	--	--	--
I	48°34'41"	097°46'21"	78-04-05	1355	84	490	5.0	1.0	238	54	--	--	--	--	--	--
			78-04-07	1800	326	240	4.0	1.0	2,970	2,610	--	--	--	--	--	--
			78-04-09	1215	632	270	7.0	1.5	3,340	5,700	42	61	71	76	98	100
			78-04-20	1520	36	395	7.0	7.0	172	17	--	--	--	--	--	--
L	48°32'09"	097°37'24"	78-04-08	1030	479	--	4.0	.0	951	1,230	--	--	--	--	--	--
			78-04-10	0910	783	--	5.0	2.5	1,120	2,370	83	99	99	100	--	--
			78-04-19	1505	105	383	-3.5	5.0	350	99	--	--	--	--	--	--
M	48°28'14"	097°28'57"	78-04-08	1300	556	370	6.0	1.0	602	904	--	--	--	--	--	--
			78-04-10	1155	811	375	5.0	3.5	706	1,550	--	--	--	--	--	--
			78-04-19	1125	181	415	-3.0	6.0	352	172	--	--	--	--	--	--
Cart Creek																
R	48°40'37"	097°51'41"	78-03-13	1035	.24	980	--	.5	--	--	--	--	--	--	--	--
			78-03-22	1440	.33	850	--	1.0	--	--	--	--	--	--	--	--
			78-03-27	1225	2.0	655	--	.0	--	--	--	--	--	--	--	--
			78-03-29	1120	12	380	--	.0	--	--	--	--	--	--	--	--
			78-04-04	1120	13	399	4.0	1.0	358	13	--	--	--	--	--	--
			78-04-05	1310	46	280	--	.0	--	--	--	--	--	--	--	--
			78-04-06	0925	260	220	--	1.0	2,920	2,050	60	84	89	91	97	99
			78-04-07	0950	44	275	-3.0	.5	1,040	124	--	--	--	--	--	--
			78-04-21	1010	13	422	7.0	3.5	297	10	--	--	--	--	--	--
S	48°36'06"	097°41'28"	78-04-05	1220	92	405	3.0	.5	72	18	--	--	--	--	--	--
			78-04-07	1345	614	310	1.0	1.0	1,240	2,060	--	--	--	--	--	--
			78-04-10	1500	296	390	4.0	3.0	1,220	975	--	--	--	--	--	--
			78-04-20	1210	24	391	5.0	3.0	559	36	--	--	--	--	--	--
U	48°32'36"	097°35'16"	78-04-05	1815	122	315	7.0	1.0	60	20	--	--	--	--	--	--
			78-04-09	1640	520	302	4.0	2.0	599	841	96	99	99	99	--	--
			78-04-20	0940	83	448	.0	4.0	90	20	--	--	--	--	--	--
Park River																
E	48°25'24"	097°24'30"	78-03-06	1400	1.4	1,100	--	.5	--	--	--	--	--	--	--	--
			78-04-09	1525	2,450	370	--	2.0	--	--	--	--	--	--	--	--
			78-04-11	1520	2,220	330	--	2.5	--	--	--	--	--	--	--	--
			78-04-19	1330	444	450	-4.5	5.0	280	336	--	--	--	--	--	--

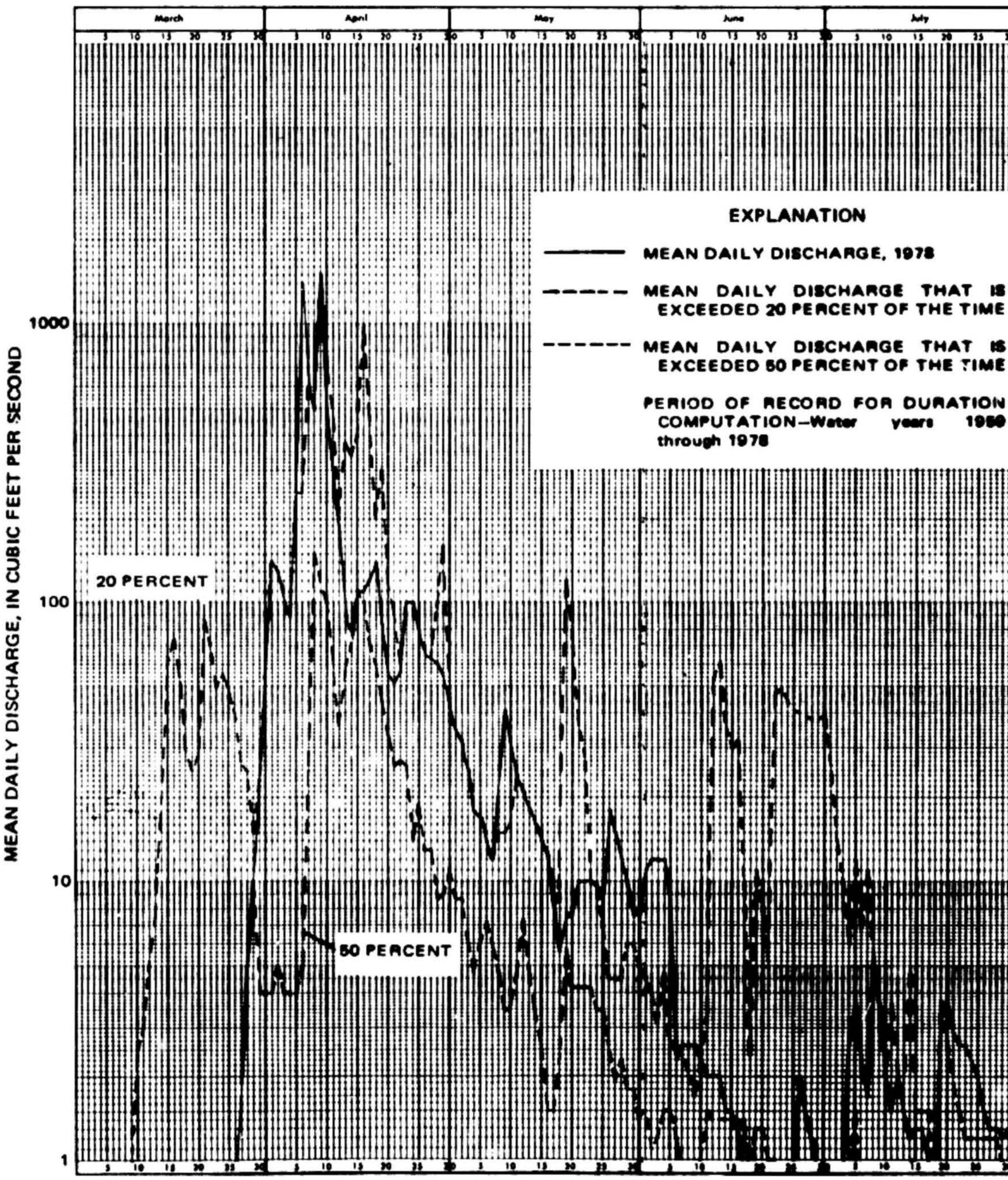

FIGURE 6.—Streamflow and duration hydrographs for Middle Branch Park River near Union, Site A.

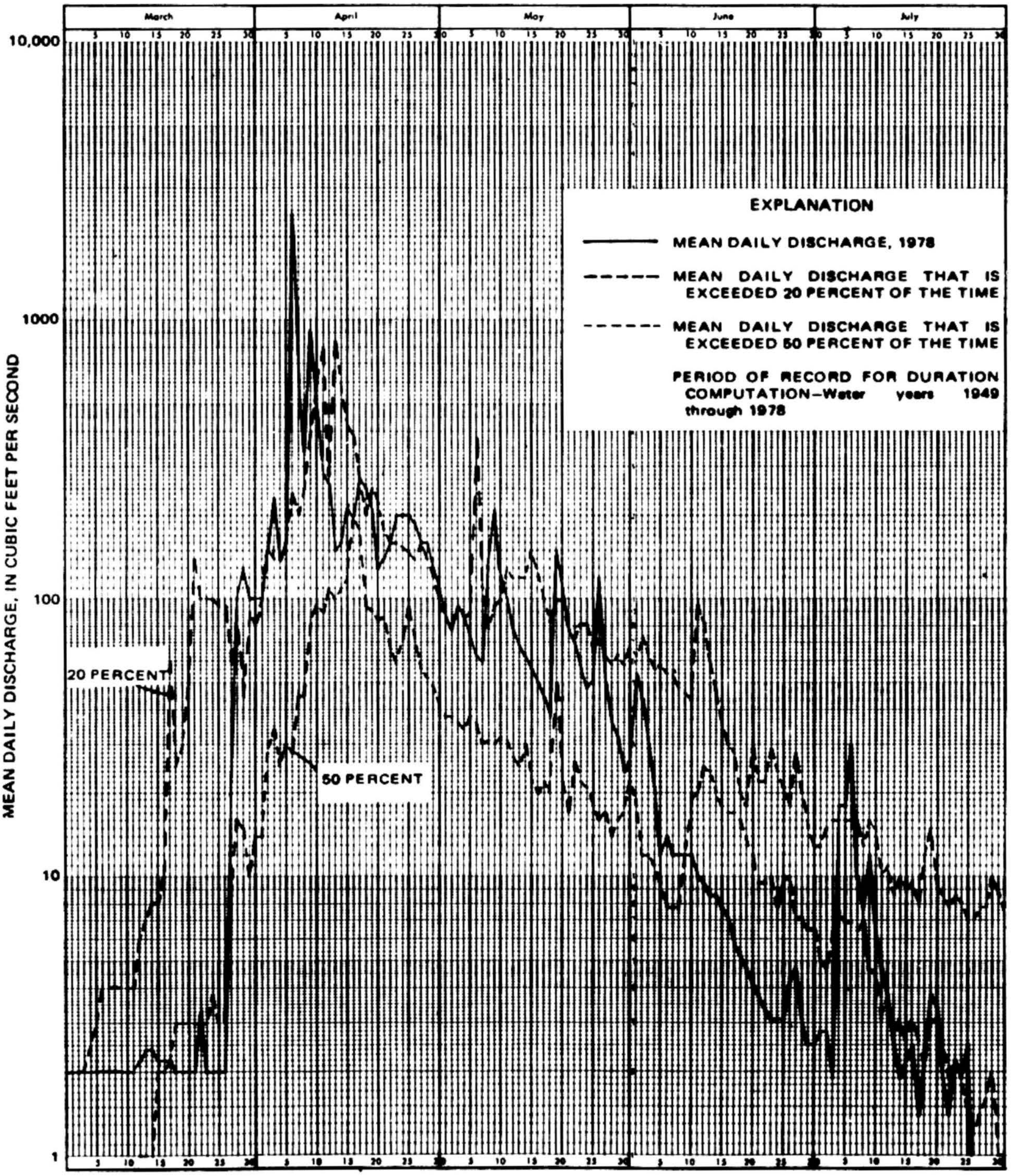

FIGURE 7.—Streamflow and duration hydrographs for Cart Creek at Mountain, Site R.

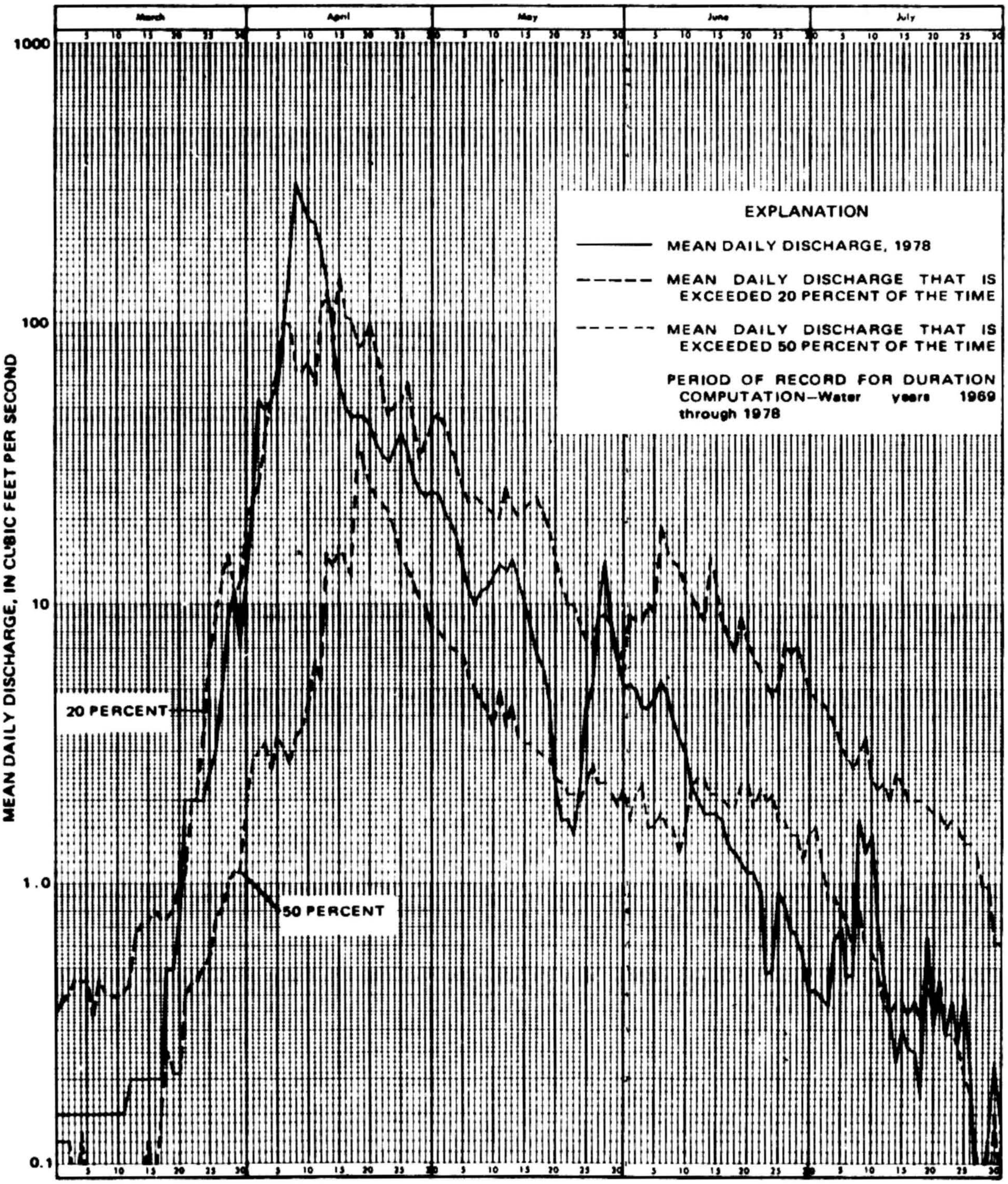

FIGURE 8.—Streamflow and duration hydrographs for Park River at Grafton, Site E.

peak discharge were lower at stations on the Middle Branch as compared to stations in a similar setting on other streams in the study area.

The size of suspended-sediment particles transported differed markedly between upstream and downstream reaches of the streams. At peak discharge more than 99 percent of the particles transported were finer than medium silt (0.016 mm) at stations L and U in the downstream reaches of North Branch and Cart Creek. At stations H, I, and R in the upstream reaches of the watersheds, 11 to 29 percent of particles transported were sand sized. Decreased stream velocity, resulting from lower channel gradient in the downstream reaches, is responsible for the reduction in the capacity for transport of the larger sediment particles.

Differences in suspended-sediment transport in the watersheds are best understood by observing the relationship between suspended-sediment load and discharge (fig. 9). Regressions of load versus discharge were computed for all stations in the study area. The extremes, stations R and U, represent sites with the steepest and flattest stream gradients. The load transported by a given discharge decreased downstream. Also, sites on the Middle Branch had less transport by a given discharge than other sites occupying a similar position in the basin. The decreased transport is probably due to the greater number of impoundments on the Middle Branch as compared to the other streams.

One aspect of sediment transport, bedload, was not studied. In the areas of flat gradient, the Lake Agassiz Plain, the bed material was almost entirely clay and silt. In areas of steep gradient, sand- to gravel-sized flat shale particles made up a large part of the bed material. At a discharge as low as 10 ft^3/s the saltation, or traction, of the gravel-sized shale fragments could be felt against a foot in a pair of waders. Some of the benthic invertebrate samplers trapped large amounts of sand- and gravel-sized shale particles. The observed transport, bed material, and trapped particles indicate that saltation or traction of shale particles may be a transport process in upstream reaches even during relatively low-flow periods.

The transport of sediment creates some problems in the study area, particularly at the base of the Pembina Escarpment where the coarse sediment load is dropped. When existing stream channels are filled, the streams find new channels and problems with flooding occur. In some areas an effort is made to temporarily fix the channel in one location by dredging the material from the channel and placing it on the banks.

There are differences in water chemistry within streams and between streams at base runoff. Discharge, specific conductance, and microbiological data collected during base runoff are summarized in table 2. River miles from the mouth and the drainage area for selected sites are also included. Water-chemistry data collected during base runoff on June 21-22 are given in table 3.

Figure 10 shows the changes in water chemistry that occur within the North Branch Park River during base runoff. In the vicinity of Hoople (sites J and K) the water changes from calcium and bicarbonate dominated to sodium and chloride dominated. No direct seepage of municipal waste was seen; therefore, the change probably is due to an influx of ground water. The Lake Agassiz Plain is a general discharge area for intermediate and regional ground-water flow systems. The bedrock and drift aquifers generally contain sodium chloride

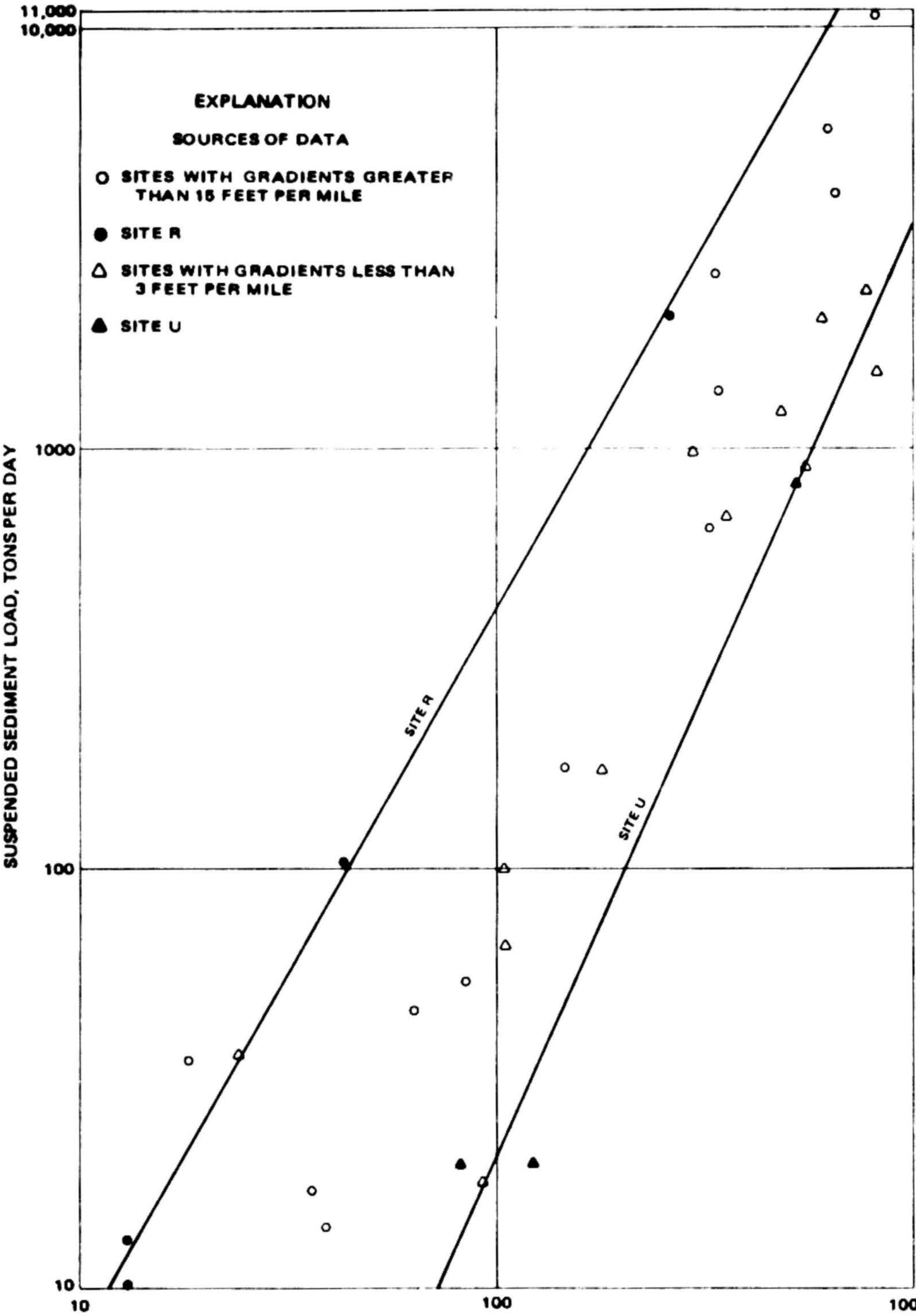

FIGURE 9.–Suspended-sediment load versus discharge.

TABLE 2.--Selected data for base-runoff profiles, 1978

[Colonies/100 mL, colonies per 100 milliliters]

			May 18-19			June 21-22					
Site	Distance from mouth (mi)	Drainage area (mi^2)	Streamflow, instantaneous (ft^3/s)	Specific conductance (umho/cm)	Water temp. (deg C)	Streamflow, instantaneous (ft^3/s)	Specific conductance (umho/cm)	Water temp. (deg C)	Fecal coliform (colonies/ 100 mL)	Fecal streptococci (colonies/ 100 mL)	Fecal coliform/ fecal streptococci
Middle Branch Park River											
A	56.2	14.8									
B	36.4	83.6	E5	590	14.0	0.80	690	22.0	61	400	0.15
C	23.9						730	19.0			
D	8.4	393.9	E20	665	18.0	.77	1,150	19.0			
North Branch Park River											
G	65		E3	420	14.5	E.05	540	19.0			
H	53.0	54.1	E9	440	11.5	.37	670	22.0	77	400	.19
I	42.6			565	12.5	.02	775	20.0			
J	28.4	79.1	E10	625	20.5	.01	770	18.0	K290	700	.41
K	27.3		E10	725	20.5	E.15	1,400	19.0	160	325	.49
L	25.6	93.3									
M	3.9	208.4	E10	720	19.0	.38	1,300	22.0	K15	30	.50
Cart Creek											
R	40.8	14.4	E3	630	21.0	.38	940	15.0	87	360	.24
S	20.3	83.6	E7	655	22.0	.05	920	16.0	42	1,400	.03
T	18.4					E.05	790	18.5			
U	2.8	105.3	E1	665	23.0	.00					

E - Estimated.
K - Results based on colony count outside the acceptable range (nonideal colony count).

TABLE 3.--Water chemistry data collected during base runoff, 1978

Site	Latitude	Longitude	Date of sample	Time	Stream-flow instan-taneous (ft^3/s)	Specific conduc-tance (umho/cm)	pH (units)	Temper-ature (deg C)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Percent sodium	Sodium-adsorp-tion ratio	Potassium, dissolved (mg/L as K)
B	48 30 12	097 45 53	78-06-22	1858	0.80	690	8.4	22.0	330	78	34	26	14	0.6	5.8
D	48 27 08	097 32 07	78-06-21	2010	.77	1,150	7.8	19.0	350	86	32	120	42	2.8	7.6
H	48 35 30	097 52 50	78-06-22	1515	.37	670	8.4	22.0	250	64	22	46	28	1.3	8.7
I	48 34 41	097 46 21	78-06-22	1400	.02	775	7.6	20.0	340	88	29	45	22	1.1	9.5
J	48 32 09	097 38 33	78-06-22	1040	E.01	770	7.7	18.0	350	90	31	46	22	1.1	8.8
K	48 32 16	097 38 03	78-06-22	0915	E.15	1,400	8.4	19.0	370	75	44	160	48	3.6	9.4
M	48 28 14	097 28 57	78-06-21	1830	.38	1,300	8.2	22.0	400	100	38	130	40	2.8	9.7
R	48 40 37	097 51 41	78 06 21	1110	.38	940	8.2	15.0	410	110	33	54	22	1.2	8.1
S	48 36 39	097 42 36	78-06-21	1500	.05	920	8.0	16.0	390	100	34	59	24	1.3	7.5

Site	Alka-linity (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride dissolved (mg/L as Cl)	Fluoride dissolved (mg/L as F)	Silica dissolved (mg/L as SiO_2)	Solids, sum of con-stituents, dissolved (mg/L)	Solids, dissolved (tons per acre-foot)	Solids dissolved (tons per day)	Nitrogen NO_2+NO_3 dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Boron, dissolved (ug/L as B)	Iron, dissolved (ug/L as Fe)	Manganese, dissolved (ug/L as Mn)
B	220	150	9.3	0.2	22	457	0.62	0.99	0.10	0.06	90	40	80
D	300	130	120	.4	19	694	.94	1.44	.18	.13	280	0	5
H	160	160	21	.3	26	417	.57	.42	.09	.18	120	20	40
I	170	200	15	.3	29	517	.70	.03	.03	.16	130	10	40
J	240	180	25	.3	20	538	.73	--	.01	.06	120	20	270
K	170	210	220	.3	16	836	1.14	--	.01	.04	290	20	180
M	220	220	140	.5	18	796	1.08	.82	.01	.10	270	10	10
R	250	230	20	.5	24	629	.86	.65	.14	.13	160	10	40
S	300	190	11	.6	19	600	.82	.08	.07	.22	170	90	730

E - Estimated.

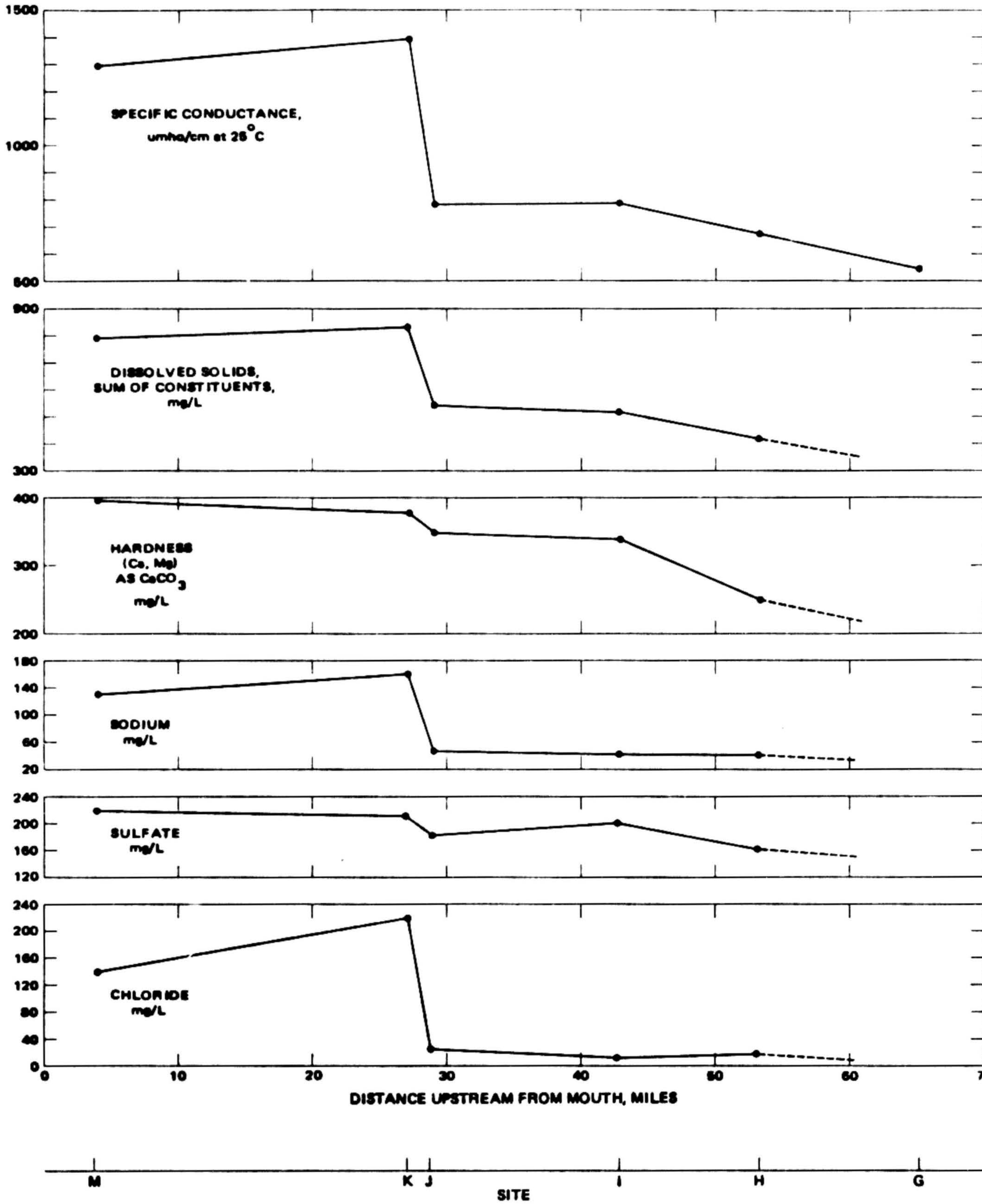

FIGURE 10.—Longitudinal profile showing water chemistry of North Branch Park River during base runoff June 21-22, 1978.

or sodium chloride-sulfate water of high salinity. All streams in the study area, even those that have no nearby towns, exhibited a similar change in water chemistry. It is reasonable to assume that the change in chemistry is due to the general seepage of the high-salinity sodium chloride water or the direct addition of this type of water from free-flowing wells. Many wells tapping bedrock aquifers in this area flow unchecked into nearby streams.

The within-stream difference in water chemistry is exhibited in the relationship of specific conductance to the sum of dissolved solids (fig. 11). Most data fit the regression for the data for the period of record from sites A and R. However, data for the downstream sites D, K, and M do not fit this regression. It is apparent that the change in dominant ions has altered the dissolved solids/specific conductance relationship.

The relationship of individual ions to specific conductance, as illustrated by calcium (fig. 12), also exhibits the within-stream differences in water chemistry. Again, data for sites D, K, and M do not fit the regression for upstream sites.

The individual regressions for sites A and R are markedly different and indicate the water chemistry is different between the upstream reaches.

In the middle reaches of the streams the data for base runoff followed the regression for site R. In the downstream reaches the data departed from the regression for site R toward the regression for site A. More data will be needed to fully understand the between-stream differences in water chemistry.

The relationships shown in figure 12 are similar for other ions such as magnesium, sodium, sulfate, chloride, and bicarbonate.

The microbiological analyses did not indicate any discernible differences within or between streams. Contamination is moderate and may be predominantely animal in orgin, as is indicated by the fecal coliform to fecal streptococus ratios (table 2). Geldreich (1966) suggests that a fecal coliform to fecal streptococcus ratio of less than 0.6 indicates organic pollution derived entirely or predominately from animal origin. However, differences in the rate of die off between the two bacterial groups may obscure the ratio between the groups if the source is more than 24 hours flow time from the sample point.

The taxonomic identification and individual count data for benthic invertebrate samples taken during a base runoff period are summarized in table 4. All pool samples were exposed for 32 to 33 days in a pool environment below a small riffle, dam, or constriction of the stream. Three samplers were set at each site; all were recovered. Organisms were removed from two samplers from all sites except site U. The stream was not flowing at site U when samplers were collected. At site I shale particles and large amounts of drifting algae plugged the samplers. At site J only four individuals of four taxa were collected. Due to the low number of samples, data for sites I and J were not considered in the reconnaissance.

Samples from riffle environments were also collected at sites H and R by the same method as samples from pools. Although samplers from site R were partially plugged with shale particles, the results were used for comparison purposes.

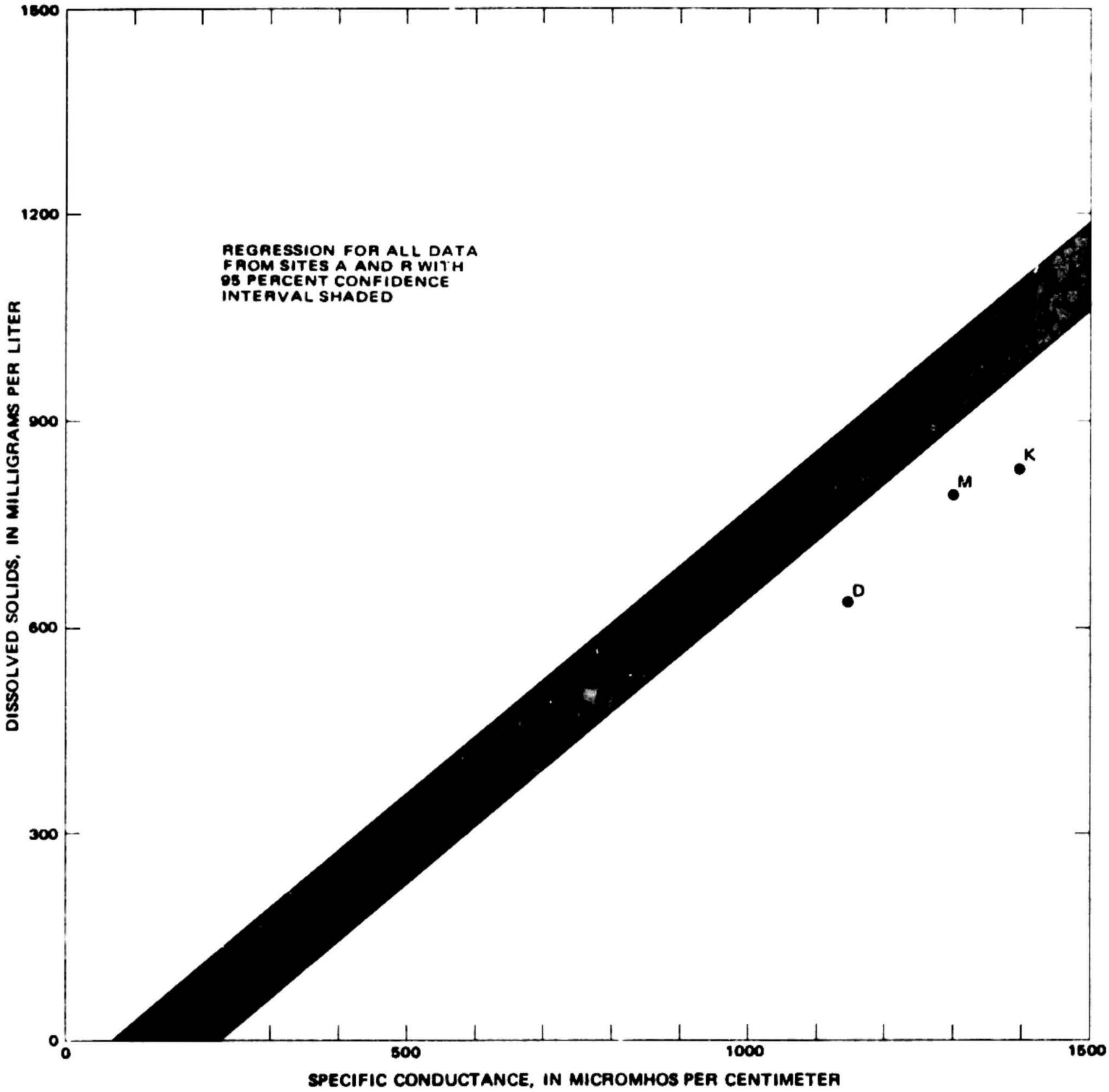

FIGURE 11.—Specific conductance versus dissolved solids for base-runoff samples, June 21-22, 1978

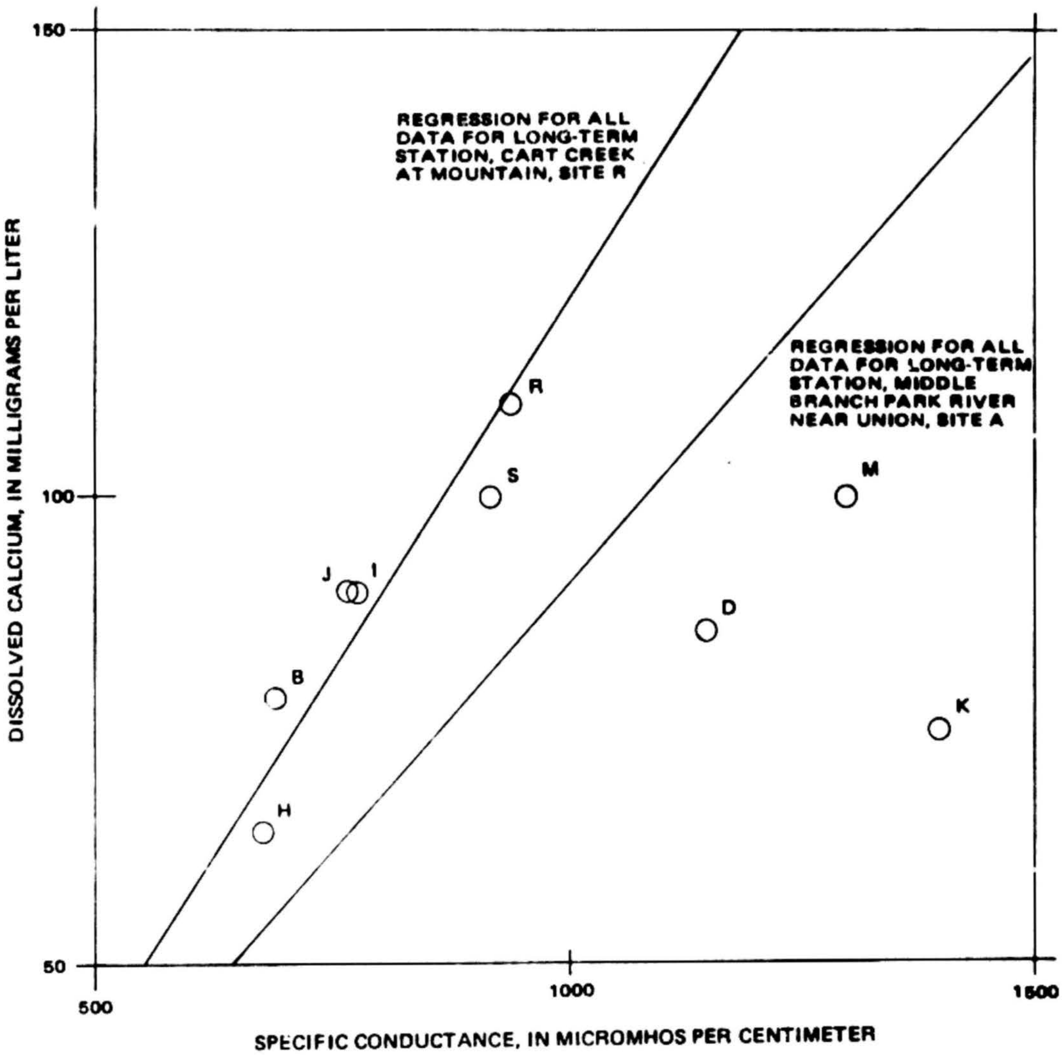

FIGURE 12.—Specific conductance versus calcium for base-runoff samples, June 21-22, 1978.

TABLE 4.--Taxonomic identification and individual count data for benthic invertebrate samples

Taxonomy					Site									
Phylum	Class	Order	Suborder	Family	B pool	H riffle	H pool	I pool	J pool	K pool	M pool	R riffle	R pool	S pool
Annelida	Hirudinea	Gnathobdellida		Hirudinae	1	7	2	1	1	1	1	--	--	1
Arthropoda	Crustacea	Amphipoda	Gammaroidea	?	3	31	6	--	--	7	5	--	--	--
		Decapoda		Astacidae	2	--	--	--	--	--	--	--	--	--
	Insecta	Coleoptera		Elmidae	2	--	--	--	--	--	--	--	--	--
				Dryopidae	3	1	--	--	--	--	--	--	--	--
				Dytiscidae	--	1	2	--	--	--	--	--	--	--
				Haliplidae	--	--	--	--	--	3	--	--	--	--
		Diptera		Anthomyiidae	--	2	--	--	--	--	--	--	--	--
				Ceratopogonidae	--	1	--	--	--	--	--	--	--	--
				Chironomidae	34	49	4	1	1	161	11	7	6	2
		Ephemeroptera		Baetidae	15	209	24	--	1	--	4	1	2	--
				Heptagenidae	75	54	--	--	--	15	18	--	11	8
		Odonata	Anisoptera	Gomphidae	--	--	--	--	--	--	1	--	1	--
			Zygoptera	?	--	--	--	--	--	--	--	--	--	1
		Plecoptera		Perlidae	35	35	--	1	--	58	--	16	1	--
		Tricoptera		Helicopsychidae	2	--	--	--	--	--	--	--	--	--
				Hydropsychidae	190	--	--	--	--	--	--	--	--	--
				Limnephilidae	3	3	1	--	--	--	--	--	--	--
				Philopotamidae	1	--	--	--	--	--	--	--	--	--
				Psychomyiidae	--	1	--	--	--	3	--	--	--	--
Mollusca	Gastropoda	Ancylidae		Ferrissia	2	--	--	--	--	--	--	--	--	--
		Pulmonata		Lymnaeidae	--	6	--	--	--	63	1	--	1	1
				Physidae	--	--	--	--	--	1	--	--	--	--
Nematoda		Nematoda	Nematoda	?	--	--	--	--	1	--	--	--	--	--

From the biological standpoint, species diversity is a sound method of classifying an environment using a community of organisms. A diversity index is generally a form of a ratio of numbers of taxa, i, to numbers of individuals, N. Areas with many species and moderate numbers of individuals have high diversity. High diversity indicates a low-stress competitive environment. In a high-stress environment a few taxa attain large populations because of lack of competition.

The diversity index used in this report, the Brillouin Index (Archibald, 1972), is based on information theory. The relation between diversity index, H', and stream health is given as follows: H' less than 1, high stress; H' between 1 and 3, moderate stress; H' greater than 3, low stress (clean water).

For completeness and as an aid in the interpretation of H', the theoretical maximum diversity (H'_{max}), theoretical minimum diversity (H'_{min}), and the relative evenness (Zand, 1976) were calculated. Relative evenness (e) can range from 0 for the least even sample to 1 for the most even sample.

For this study all individuals were identified to at least the family level, except amphipods of the suborder Gammaroidea. The amphipods were assumed to represent one family; therefore, all diversities were computed at the family level.

Diversities, number of individuals, number of taxa, and evenness are summarized in table 5.

In all cases the diversity data indicate that the streams are moderately stressed. However, the quality of the data is somewhat limited because data collected using artificial substrates limit the individuals to those that may colonize the substrate. These data are still very useful for comparison with data collected in a similar manner.

The riffle habitat available on the escarpment yielded the highest diversity. It is generally acknowledged that riffles provide more and better habitat than pools.

For similar habitats, collection periods, and collection and analysis methods, it is apparent that downstream sites are more stressed than upstream sites. It may also be said that the Middle Branch appears less stressed than the North Branch and Cart Creek.

No sampling was done for pesticides. The analytical methods available at the U.S. Geological Survey Laboratory did not fit present pesticide usage throughout the study area. At all sites where biological or sediment samples were collected, an empty or nearly empty pesticide container could be found lying in the stream. When the benthic invertebrate samplers were being set out at site R, spray from an aerial application of herbicide drifted over the site.

TABLE 5.--Numerical indices for benthic invertebrate data

Site	Name	Number of taxa (i)	Number of individuals (N)	Family diversity (H')	Maximum diversity (H'_{max})	Minimum diversity (H'_{min})	Relative eveness (e)
B	Middle Branch Park River near Edinburg (pool)	14	368	2.08	3.50	0.30	0.56
H	North Branch Park River at Gardar (riffle)	13	400	2.14	3.59	.26	.56
H	North Branch Park River at Gardar (pool)	6	39	1.51	2.26	.67	.53
K	North Branch Park River in Hoople (pool)	9	312	1.80	3.08	.21	.55
M	North Branch Park River near Nash (pool)	7	41	1.84	2.45	.77	.64
R	Cart Creek at Mountain (riffle)	3	24	1.25	1.38	.38	.87
R	Cart Creek at Mountain (pool)	6	22	1.55	2.11	.98	.50
S	Cart Creek above Crystal (pool)	5	13	1.25	1.91	1.08	.20

Analyses by D. Feick and D. Bast.

CONCLUSIONS

The flow of Middle Branch Park River is modified by the presence of small dams in the upstream part of the watershed. The dams reduce the peak discharge and prolong low flow.

Sediment loads in the watersheds originate predominately on the Pembina Escarpment. The sand and coarse silt parts of the sediment load are deposited on the edge of the Lake Agassiz Plain. Although no measurements were made, it is suspected that bedload transport of coarse material may be a significant transport process in upstream channel reaches.

Sediment transport was lower on the Middle Branch Park River than on other streams. The reduction in load may be due in part to the reduction of peak discharge, and the subsequent reduction of peak velocities, by dams.

Water chemistry was different within streams and between streams during base runoff. Within the streams the water increased in dissolved solids downstream; sodium and chloride increased significantly. The change probably was due to the addition of ground water from seepage or from flowing wells. Differences between streams were exhibited by differences in the relationship of individual ions to specific conductance.

Microbiological analyses showed moderate organic pollution; animal waste is a probable source.

Analyses of benthic invertebrate samples showed moderate stress throughout the watersheds. The stress was less in the Middle Branch watershed. Probable sources of stress may be lack of suitable habitat, organic pollution, or chemical pollution. The presence of pollution from pesticides could not be verified, but sources of pesticide pollution were noted.

RECOMMENDED MONITORING PROGRAM

A continuing water-quality sampling program to evaluate (1) the conditions in North Branch watershed, (2) the difference between North and Middle Branch watersheds, and (3) the effects of changes in the North Branch watershed should monitor streamflow, sediment transport, and water chemistry.

Since quantification of changes in streamflow parameters, such as flow duration, is not possible without extended periods of record, no changes in the present surface-water network are recommended. Individual measurements of discharge at sediment and water-chemistry sites should be sufficient.

More data are needed to better define the discharge /suspended-sediment-load relationships. Size analyses for the percentage smaller than 0.062 mm (sand-silt break) should be sufficient.

Most sediment transport occurs during periods of high flow. Sampling for suspended sediment should occur during spring snowmelt and after spring or early summer storms.

No monitoring of bedload transport should be attempted until an approved method of quantifying bedload transport is available. The flat platelike shale particles that dominate the bedload will probably create problems with transfer value from other bedload transport studies. Because of the unique form and mineralogy of these particles, they offer special challenges to research sedimentologists.

Water-chemistry monitoring should concentrate on extending and redefining the relationships between discharge, specific conductance, and solute concentrations. This will be most easily accomplished by sampling at the same time as sediment samples are taken.

The chemistry of water during base runoff merits additional work. However, the timing of profiles should be varied slightly from year to year to reflect any changes due to antecedent conditions in the stream.

Microbiological analyses did not show differences between or within streams; therefore further monitoring is not recommended.

While analyses of benthic invertebrate populations are good indicators of changes in water quality, the difficulty in sampling mud-bottom pools and the expense involved preclude further use.

It is recommended that monitoring be done at the following sites:

Site B, Middle Branch Park River near Edinburg, a site downstream of all dams.

Site I, North Branch Park River near Crystal, a site immediately above the Lake Agassiz Plain, and therefore above the area of coarse sediment deposition.

Site M, North Branch Park River near Nash, a site near the mouth that will be useful for monitoring possible changes due to channelization on the Lake Agassiz Plain.

Site R, Cart Creek at Mountain, a site with continuous discharge records since October 1953 that will be useful for monitoring works of improvement on this tributary, both in respect to water quality and quantity.

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