RAINFALL-RUNOFF RELATIONSHIPS AND WATER-QUALITY ASSESSMENT OF COON CREEK WATERSHED, ANOKA COUNTY, MINNESOTA

By A. D. Arntson and L. H. Tornes

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CONVERSION FACTORS

For use of readers who prefer to use International Systems of Units (SI) units, conversion factors for terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain SI unit
acre	0.4047	hectare (ha)
acre-foot (acre-ft)	1233	cubic meter (m^3)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch (in)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
pound (lb)	453.6	gram (g)
micromho per centimeter (umho/cm)	1	microSiemans per centimeter (mS/cm)
degree Fahrenheit (°F) - 32	0.5556	degree Celsius (°C)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first order level nets of both the United States and Canada, formerly called "mean sea level."

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ABSTRACT

Rainfall-runoff relationships and results of water-quality analyses were studied to develop an understanding of flooding problems and to assess present and potential water-quality problems in the 96.9-square-mile Coon Creek watershed, Anoka County, Minnesota. Rainfall, runoff, and water-quality data were collected from March 1979 to November 1980 at five continuously recording streamflow sites, seven crest-stage sites, and three continuously recording rainfall sites. During the study, eight storms occurred with sufficient rainfall to produce measurable runoff at most of the gages in the basin. The resulting hydrographs show, as expected, higher unit peaks, shorter times to peak, and shorter durations of high flows in streams draining urban areas than in streams draining rural areas. Constrictive culverts and bridges at roadways resulted in attenuation of hydrograph peaks in urban areas. Runoff amounts were nearly the same in all the subareas for storms with uniformly distributed rainfall. The greatest recorded rainfall during this study was 3.95 inches on August 7, 1980. The basin-weighted rainfall for that date was 3.56 inches, which resulted in the greatest observed peak flow for Coon Creek at Coon Rapids Boulevard of 185 cubic feet per second.

The eight storms produced eight hydrographs suitable for model simulation of Sand Creek, seven hydrographs for simulation of Coon Creek, and four hydrographs for simulation of County Ditch 58. The U.S. Army Corps of Engineers HEC-1, Flood Hydrograph Package computer model was used with the parameter-optimization routine to develop parameter values to closely match observed hydrographs. A multiple-linear-regression technique was used to develop linear equations for relating HEC-1 parameters to variations in rainfall and antecedent moisture. This procedure resulted in generalized models of the three principal subareas that reasonably simulated 10 of the 19 observed hydrographs.

Water-quality characteristics were determined based on 14 water samples from 4 sites and 1 bottom-material sample from each site. Results of the analyses indicated that streams draining urban areas carry the highest concentrations of most constituents sampled. Sand Creek at Xeon Boulevard, which drains the most urbanized area, had the highest mean concentration of metals, chloride, dissolved solids, and suspended sediment. Concentrations of total phosphorus ranged from 0.04 to 0.43 milligram per liter at the rural sites on County Ditch 58 at Andover Boulevard and Coon Creek at Raddison Road. Average phosphorus concentrations at the rural sites are comparable to concentrations at the urban sites.

INTRODUCTION

Flooding of agricultural areas is a significant problem in Coon Creek watershed. Flooding has been aggravated by deterioration of the county drainage-ditch system. The extent to which urban development contributes to downstream and agricultural flooding is not known, but remains a key issue in future management of urban growth.

The objectives of the study were to (1) measure stormflow contributions from urban and rural areas, (2) determine rainfall-runoff relations for these areas, (3) determine effects of various land uses on rainfall-runoff response, and (4) assess present and potential water-quality problems.

The report is divided into two parts. The first part deals with the analysis of the rainfall-runoff relationships and includes both quantitative analysis of the rainfall and runoff volumes and the modeling techniques used to synthesize runoff hydrographs. The second part of the report deals with the analysis of the water-quality data by comparing characteristics of chemical and organic constituents for each site to established criteria and recommendations of various Federal and State agencies for drinking water and protection of freshwater aquatic life.

Basin Description

Coon Creek watershed comprises 96.9 mi^2 and is 15 miles north of Minneapolis in Anoka County, Minnesota. The municipalities of Andover, Blaine, Coon Rapids, Ham Lake, East Bethel and unincorporated areas of Columbus township lie partly within the watershed (fig. 1). About 9.4 mi^2 of controlled pools in the Carlos Avery Wildlife Management Area in the northeast part of the basin form the headwaters of the watershed. From the controlled pools, Coon Creek flows westward for 10 miles through the city of Ham Lake into Andover, where it turns and flows southward for 7 miles through Andover and Coon Rapids, joining the Mississippi River 0.7 mile downstream from the Coon Rapids Dam. Rural areas consisting of agricultural, recreational, forest, wetlands, open lands, and low-density residential land uses comprise most of the basin (fig. 2). Urban areas consisting of residential, commercial, and industrial land uses comprise only 18 percent of the watershed.

Coon Creek watershed is an area of predominantly sandy soil with large areas of peat and marsh (fig. 3) and lies entirely within the Anoka sand plain (Lindholm, 1977). Vegetation in rural areas ranges from grassland and domestic crops to woodlands (Chamberlain, 1977). The Coon Creek channel slopes from 2.5 ft/mi in the upstream part of the basin to 9.5 ft/mi near the mouth; the mean slope is 3.0 ft/mi. Land-surface elevations range from 811 feet NGVD of 1929 near the mouth to 908 feet NGVD in the upland areas.

Average daily summer temperatures range from 55° to 85°F and average daily winter temperatures range from 3° to 26°F. Average annual precipitation is 30 inches of which 18 inches normally occurs as rainfall during the May through September growing season (Kuehnast and others, 1975).

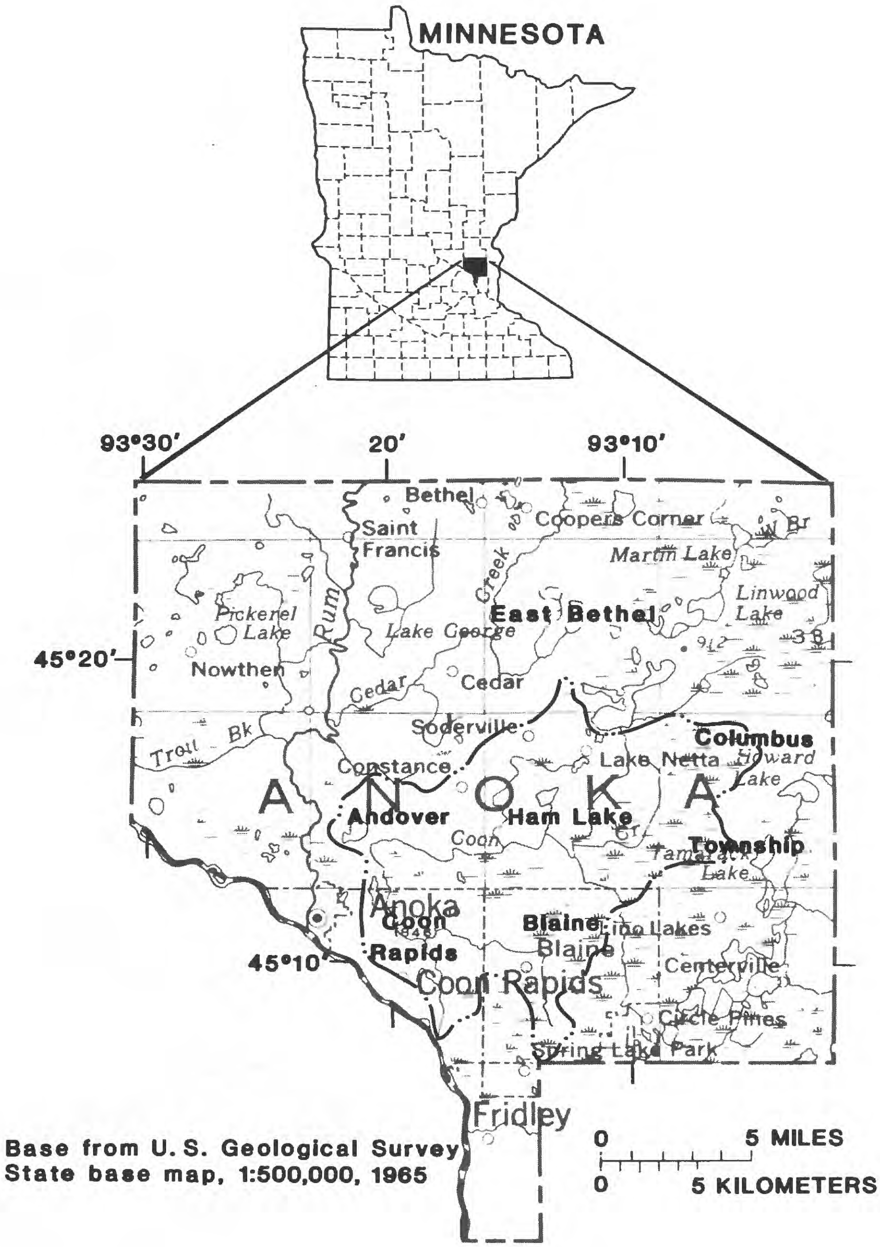
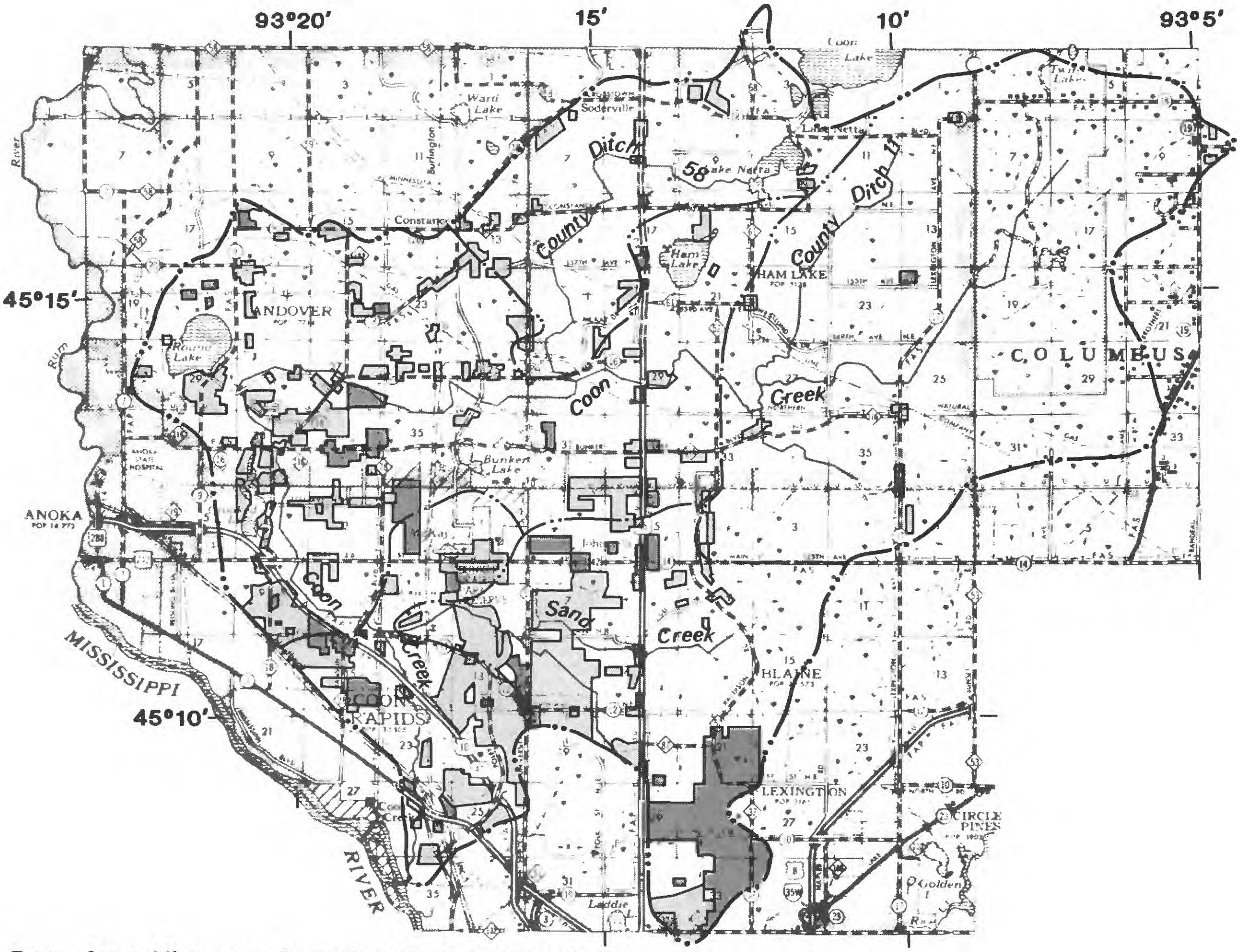


Figure 1.--Location of Coon Creek watershed, Anoka County, Minnesota



Base from Minnesota Department of Transportation
General Highway map of Anoka County, 1977

0 1 2 3 MILES

0 1 2 3 4 KILOMETERS

EXPLANATION

—··———··— Watershed boundary

——··—— Subwatershed boundary

Industrial, commercial, schools, churches

Residential

Agricultural, recreational, open

Figure 2.--Coon Creek watershed land-use map (modified from Metropolitan Council, 1978)

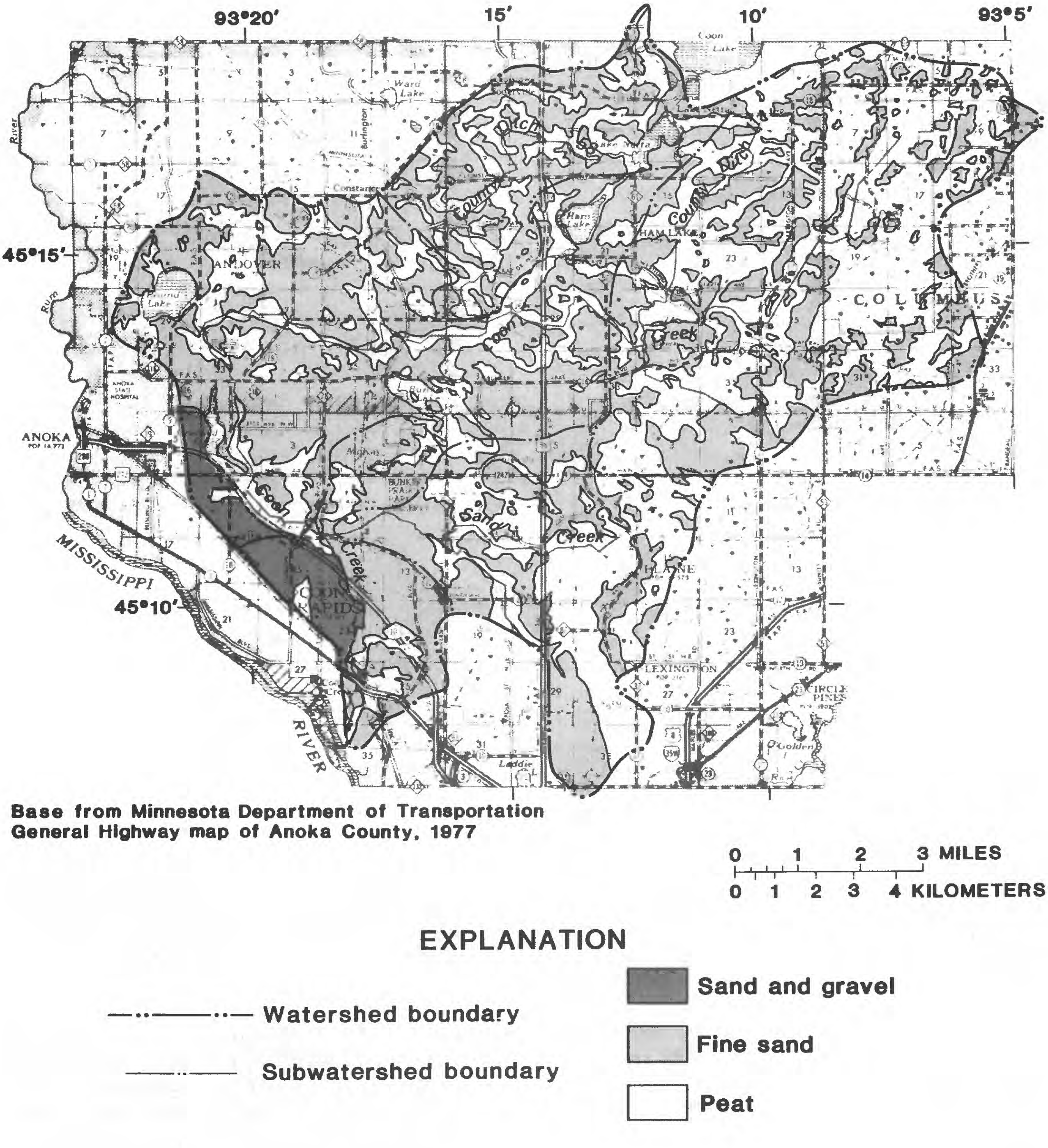


Figure 3.--Soil types, Coon Creek watershed (Chamberlain, 1977)

Acknowledgements

The authors wish to express thanks to the individuals and governmental agencies mentioned below for their help and cooperation.

Gages were located on property belonging to Anoka County, the city of Coon Rapids, Robert Miler, Margaret Tjosvold, and Dorine Trites. U.S. Geological Survey rain gages were read by James Glatt, Ruth Hunter, and Robert Miller. Additional rainfall information was supplied by Earl Kuehnast, State Climatologist, Minnesota Department of Natural Resources. Discharge information was furnished by Walt Rohl, Refuge Manager, Carlos Avery State Wildlife Management Area. Assistance in the use of HEC-1 was provided by the St. Paul District, U.S. Army Corps of Engineers.

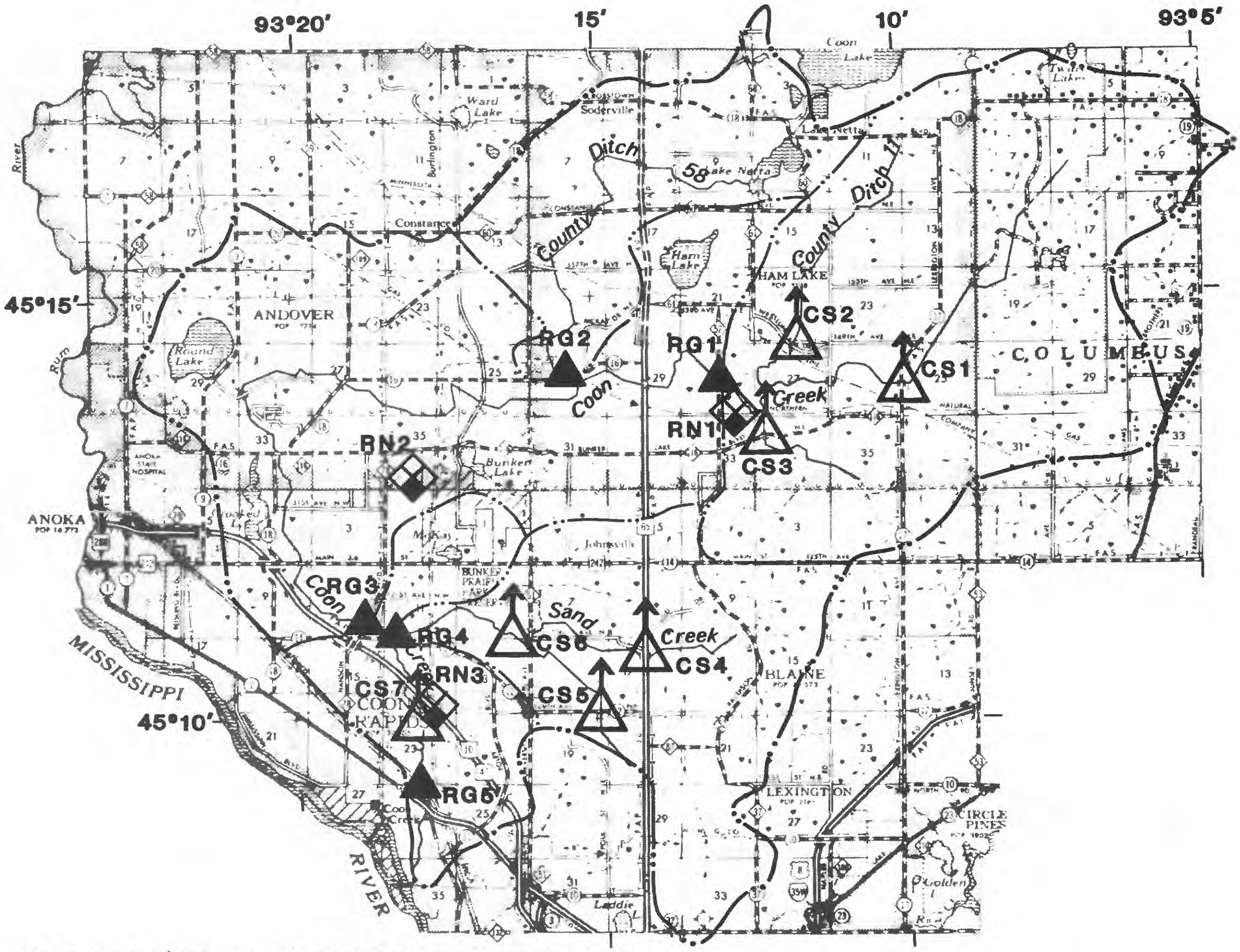
METHODS AND APPROACH

Rainfall, streamflow, sediment, and water-quality data were collected from a network of 3 recording rain gages, 5 stage recorders, and 7 crest-stage gages (fig. 4 and table 1) for selected urban and rural watersheds from March 1979 to November 1980. In addition, one water sample was collected at each water-quality sampling site on February 20-21, 1980. The rainfall, runoff, and water-quality data were related to the generalized urban and rural land uses described in the previous section.

The effect, magnitude, and extent of runoff contributions from various subbasins were determined using data collected from the stream-gaging network. Recording gages (RG-1 to RG-5) provided complete hydrograph information and crest-stage gages (CS-1 to CS-7) provided only peak stage and discharge. To compare differences in the rainfall-runoff relationships between areas of differing land use, rainfall and runoff data were collected and a quantitative analysis was done using runoff characteristics such as peak flow, time to peak, and rainfall-runoff response, which is defined as the percent of rainfall occurring as runoff.

In addition to the quantitative analysis of rainfall and runoff, a hydrograph simulation was done using the Corps of Engineers Flood Hydrograph Package HEC-1. Derived and tested from data on actual runoff events, the simulation package was used in an attempt to predict runoff hydrographs based on a set of predetermined model-input variables dependent on rainfall characteristics and antecedent rainfall and soil conditions.

The water-quality assessment was carried out by examining water-quality characteristics and comparing their magnitude to established Federal and State water-quality criteria and recommendations for drinking water and protection of freshwater aquatic life. The potential for water-quality problems was examined by assuming trends in water quality as related to general land use and by assuming a continuing transition from one land use to another. The potential water quality was then compared to the above-mentioned criteria and recommendations.



Base from Minnesota Department of Transportation
General Highway map of Anoka County, 1977

0 1 2 3 MILES
0 1 2 3 4 KILOMETERS

EXPLANATION

Watershed boundary

Subwatershed boundary

RG1 Recording stage gage

CS1 Crest-stage gage

RN2 Recording rain gage

Figure 4.--Location of gaging stations

Table 1.—Gaging stations in Coon Creek watershed

[Locations are shown in figure 4]

Site	Station name	Drainage area (mi^2)
	Recording gages	
[1]RG-1	Coon Creek at County Road 52 (Raddison Road)	31.9
[1]RG-2	County Ditch 58 at County Road 16 (Andover Boulevard)	10.6
RG-3	Coon Creek at County Road 78 (Hanson Boulevard)	73.5
[1]RG-4	Sand Creek at Xeon Boulevard	15.7
[1]RG-5	Coon Creek at County Road 1 (Coon Rapids Boulevard)	96.4
	Crest-stage gages	
CS-1	Coon Creek at County Road 17 (Lexington Avenue)	18.4
CS-2	County Ditch 11 at 149th Avenue	3.73
CS-3	County Ditch 59-4 at County Road 116 (Bunker Lake Boulevard)	5.37
CS-4	Sand Creek at State Highway 65	8.33
CS-5	County Ditch 39 at County Road 12 (109th Avenue NE)	1.45
CS-6	Sand Creek at Foley Boulevard	14.8
CS-7	County Ditch 52 at Egret Street	1.37
	Recording rain gages	
RN-1	Trites residence, Raddison Road near Coon Creek (Ham Lake)	--
RN-2	Anoka County Garage near Bunker Lake Boulevard and Hanson Boulevard (Andover)	--
RN-3	Miller residence near 111th Avenue NW and Coon Creek (Coon Rapids)	--

[1]Water-quality sampling site.

Rainfall Data

Rainfall was monitored with three recording rain gages placed to represent approximately one-third of the basin each and to monitor storm patterns and intensity over the entire basin (fig. 4). Each gage consisted of a rainfall collector and a combined measuring and recording device. The collector was mounted on top of a 2-foot cubical aluminum shelter placed on a 2-foot-high frame (fig. 5). Rainfall received from the collectors was accumulated over 15-minute periods and recorded to the nearest 0.01 inch by a digital recorder. Additional rainfall data were obtained from a network of simple bulk rain gages operated under a program of the State Climatologist where daily rainfall amounts are recorded by volunteer observers.

Streamflow Data

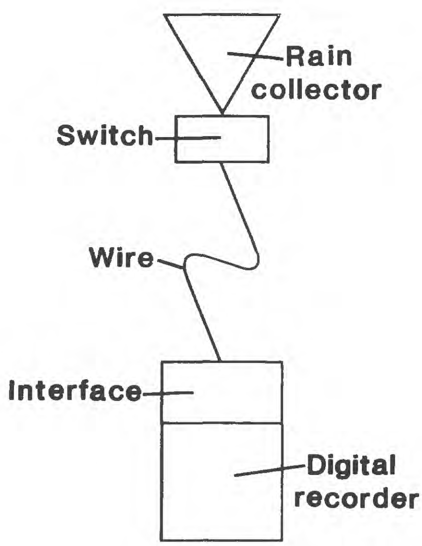
Stream stage was measured by continuous-stage recorders at five locations and by standard U.S. Geological Survey crest-stage gages at seven locations (fig. 4). Recorder locations were selected to enable determination of runoff characteristics for watersheds of specific land use. A 15-minute recording interval was used to ensure that enough data points were available to define the runoff hydrographs. Figure 6 shows a typical stage-recording installation. Crest-stage gages were placed to evaluate peak flow from additional subareas to better define the basin response to rainfall. The crest-stage gage used is illustrated in figure 7. A brief description of the basin upstream of each recording gage follows. Selected basin characteristics for each site are given in table 2.

The most upstream recording site, designated RG-1, was on Coon Creek at Raddison Road. The subbasin above the gage, 31.9 mi^2, consists mainly of agricultural land, but also includes 9.4 mi^2 of controlled headwater pools of the Carlos Avery State Wildlife Management Area. This subbasin is the least developed and has the greatest percentage in swamps and lakes of all the subbasins.

Site RG-2 is on County Ditch 58 at Andover Boulevard, a rural tributary to Coon Creek from the north. The 10.6 mi^2 area draining to this site includes agricultural lands, vegetable and sod farms, and wetlands. The RG-2 subbasin has the greatest percent of area in swamps and lakes when the controlled headwater pools at Carlos Avery State Wildlife Management Area upstream from RG-1 are noncontributing to the basin flow. Channel slopes for the RG-2 and RG-1 subbasins are nearly the same, but the percentage of developed area is three times greater for RG-2 than for the other rural basin, RG-1.

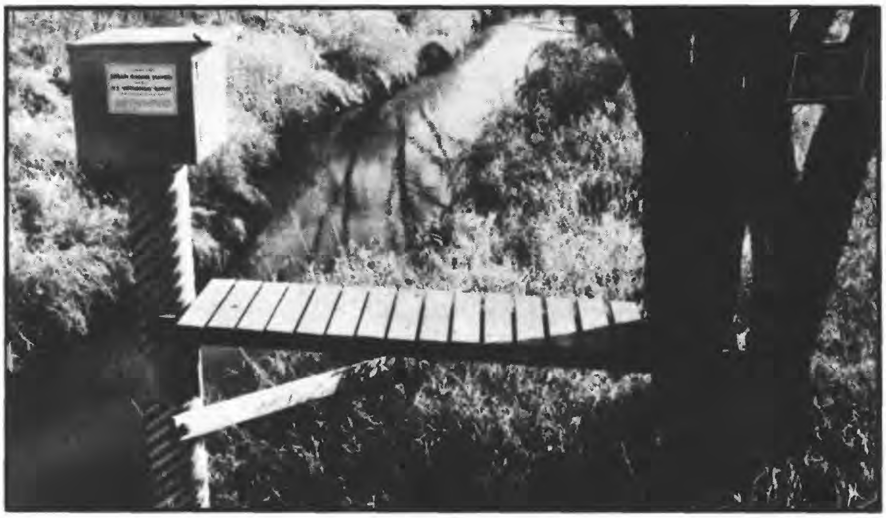
Site RG-3 is on Coon Creek at Hanson Boulevard, 0.5 mile upstream of the confluence of Sand and Coon Creeks. The 73.5 mi^2 area drained includes the areas above RG-1 and RG-2. Directly upstream from site RG-3 is a 0.31 mi^2 wetland. The channel slope above the site is the least of all the subbasins.

Rain gage installation in Andover, Minnesota

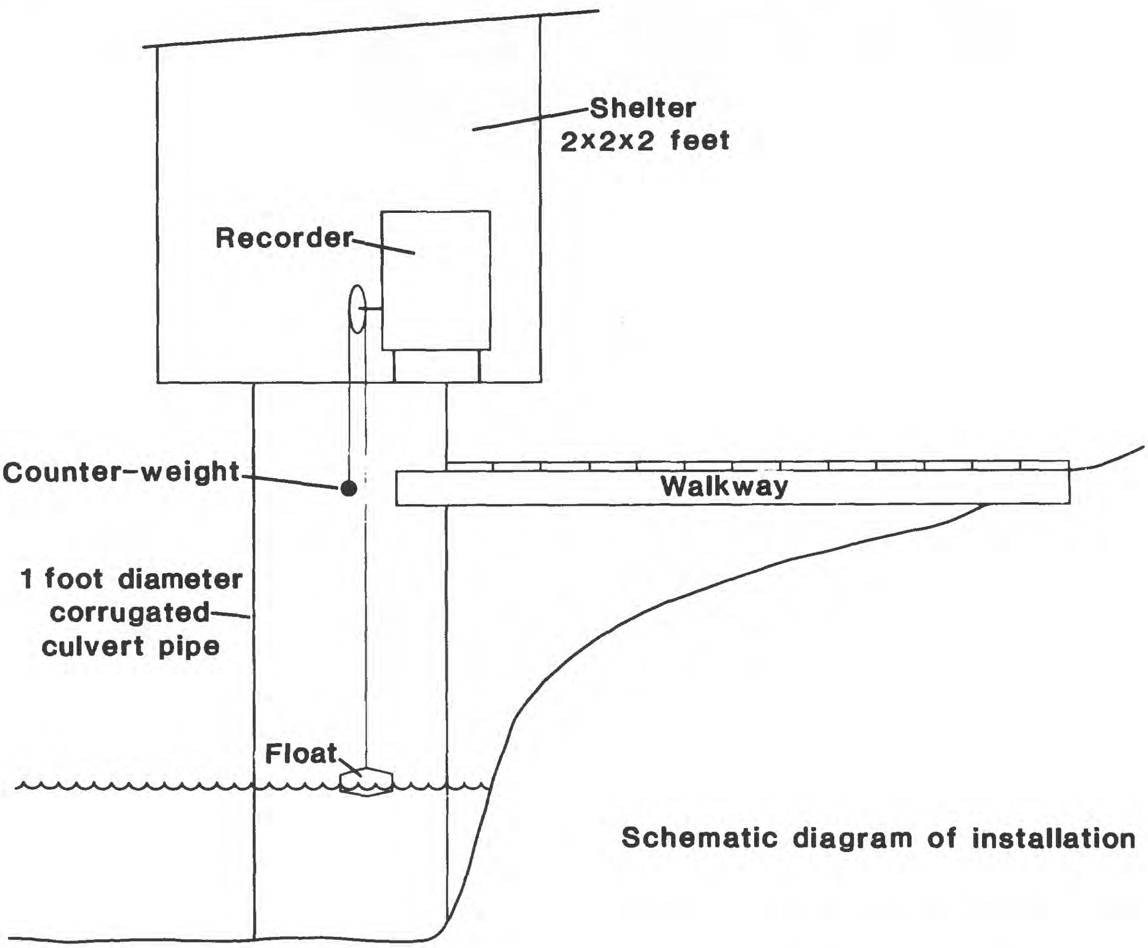


Schematic diagram of installation

Figure 5.--Typical recording rain-gage installation



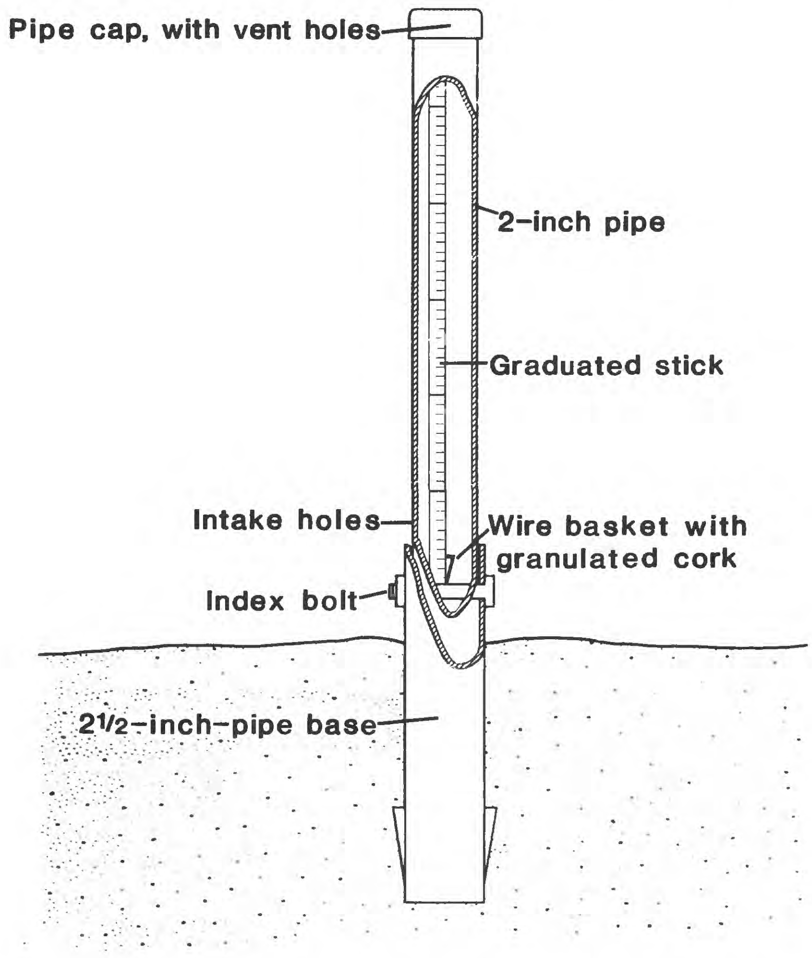
Stage recording
gage installed
on Coon Creek
at Raddison Road



Schematic diagram of installation

Figure 6.--Typical recording stage-gage installation

Crest-stage gage installed on County Ditch 11 at 149th Avenue



Schematic diagram of installation

Figure 7.--Typical crest-stage gage installation

Table 2.—Selected basin characteristics, recording gages

Site	Drainage area (mi^2)	Stream length (mi)	Channel slope (ft/mi)	Percentage of basin in swamps and lakes	Percentage of basin developed
RG-1	31.9	9.38	3.6	[a]31.7	4
RG-2	10.6	8.40	3.5	27.2	13
RG-3	73.5	21.31	2.8	[b]22.7	9
RG-4	15.7	8.12	6.2	11.4	38
RG-5	96.4	24.16	3.0	[c]19.3	18

[a]23.7 percent when headwater pools are noncontributing to drainage area.
[b]18.8 percent when headwater pools are noncontributing to drainage area.
[c]16.1 percent when headwater pools are noncontributing to drainage area.

Site RG-4 is on Sand Creek at Xeon Boulevard. Drainage area above the site is 15.7 mi^2. Sand Creek drains urban areas near its mouth, and sod farms, wetlands, and forests in the upstream area. The urban areas comprise 38 percent of the subbasin, which is more than twice the amount of any other subbasin. The channel slope above site RG-4 is nearly twice that in any other subbasin, and the percentage of area in swamps and lakes is the least of all subbasins.

Site RG-5 is on Coon Creek at Coon Rapids Boulevard, 1 mile above the mouth in a predominantly urban area. It is the farthest downstream recording site, and has a drainage area of 96.4 mi^2. Flow from all the above areas, including the urban area downstream from Sand Creek, passes this gage.

Water-Quality Data

Samples were collected at selected times throughout the study period to determine water quality at all continuously-recording sites except RG-3. Streamflow conditions ranging from low to high flow were sampled, but special emphasis was placed on sampling high flow when storm runoff constitutes most of the streamflow.

Water-quality samples were not collected at RG-3 because of project funding constraints. It was determined that water quality in this reach of Coon Creek could be adequately defined by data collected at the sampled sites and that data collected at RG-3 would not be cost effective for meeting objectives of the study.

Streamflow, water and air temperature, specific conductance, pH, and DO (dissolved oxygen) were measured each time samples were collected. Laboratory and field-calibrated meters were used for in-situ measurements of specific conductance, pH, and DO by the methods suggested by Skougstad and others (1979) and the American Public Health Association and others (1976). DO was occasionally determined by the azide modification of the iodometric titration method (American Public Health Association and others, 1976).

Representative water-quality samples were obtained using a depth-integrating sampler described by Guy and Norman (1970). Suspended-sediment concentrations were determined by the U.S. Geological Survey at the Iowa District's sediment laboratory by the methods of Guy (1969). Five-day BOD (biochemical oxygen demand) was determined on an untreated sample of creek water using the method described by the American Public Health Association and others (1976). The rest of the samples were appropriately filtered and preserved before shipment to the U.S. Geological Survey Central Laboratory in Doraville, Ga., for analysis.

Samples sent to the laboratory were analyzed by methods described in Goerlitz and Brown (1972) and Skougstad and others (1979). Each water sample was analyzed for dissolved chloride, dissolved solids, dissolved nitrite plus nitrate nitrogen, dissolved ammonia nitrogen, dissolved and total ammonia plus organic nitrogen, total phosphorus, dissolved orthophosphate, dissolved and suspended organic carbon, total arsenic concentrations, and total recoverable concentrations of cadmium, chromium, copper, iron, lead, manganese, mercury, and zinc. Bottom-material samples were analyzed for the total concentrations of nitrite plus nitrate nitrogen, ammonia plus organic nitrogen, phosphorus, and arsenic, and total recoverable concentrations of cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc, and organic and inorganic carbon.

Constituent concentrations were not always determined because of sampling or analytical errors and problems. Iron oncentrations were not determined for five samples between June and November 1979.

Statistical summaries of the results of sample analysis are presented in tables to help display the similarities and differences in the quality of the water at each of the sites. For those constituent concentrations reported as less than the detection limit, summary statistics were prepared with the assumption that the actual concentration was half the detection limit. This method is considered reasonably accurate when a small percentage of the constituent values are less than the detection limit (Wayne Webb, U.S. Geological Survey, written commun., 1983), but was not applied to concentrations of mercury which had a high percentage of values below the detection limit. The means for pH were computed on the hydrogen ion concentration and converted to pH, as pH is the negative of the logarithm of the hydrogen ion concentration and would not provide an accurate mean.

The time required to sample all four sites varied from several hours to nearly 36 hours. Weather conditions can, and occasionally did, change significantly during this period. Introduction of runoff from a major rainstorm can significantly alter stream-water quality and affect the relationship of the average values between each of the sites. Five concurrent samples were chosen from all the samples collected at each of the sites to represent the base-flow quality and facilitate comparison between the sites. The samples collected May 16 and 17, June 27, and September 26, 1979, and May 28 and July 10, 1980, were chosen because all the sites had stable gage-heights and 5 days with less than 0.05-inch and 2 days with less than 0.02-inch total precipitation before sample collection. The means and medians of concentrations and field measurements sampled during base flow were compared with means and medians during the study, computed from all 14 samples.

RAINFALL-RUNOFF RELATION

This section discusses and compares a range of rainfall and runoff characteristics for various conditions and subbasins. The primary topics of discussion are rainfall-runoff response and peak discharges. Rainfall-runoff response is defined as direct runoff volume as a percentage of rainfall volume. Direct runoff, or rainfall excess, is defined as rainfall that does not infiltrate the ground, but runs overland directly to the stream. Direct runoff occurs when rainfall intensity is greater than soil-infiltration rates.

Discussion of Data

Rainfall-runoff response depends on various physical and meteorological conditions in the watershed. Most watersheds with similar basin (physical) characteristics respond similarly to rainfall of equal magnitude, duration, and intensity. Basin runoff characteristics are dependent upon such things as mean basin slope, impervious area, and soil-infiltration capacities. In general, urban basins peak faster than rural basins. Urban development shortens the time to peak of runoff due to improved conveyance areas in the form of gutters, storm drains, culverts, and channelization. Also, urban areas produce higher peaks than natural areas due primarily to an increase in the amount of direct runoff as a consequence of increased impervious area.

Rainfall and runoff events were monitored continuously throughout two open-water seasons, but only eight storms with significant rainfall occurred over the entire basin during that period. The greatest rainfall recorded during the study was 3.95 inches on August 7, 1980. The basin-weighted rainfall for the August 7 storm was 3.56 inches, which resulted in the greatest observed peak flow at RG-5 of 185 ft^3/s. Weighted rainfall and peak discharges observed at all gages are given in tables 3 and 4. Direct runoff volumes were determined and are given in table 2 for the recording gage location for those events where sufficient data were obtained. These volumes represent only direct runoff and do not include base runoff. Direct runoff volumes ranged from 2.51 to 1,355 acre-ft for observed hydrographs. Generally, rainfalls less than 1 inch did not produce significant runoff unless antecedent soil moisture was high and infiltration rates were low.

Differences in runoff characteristics were apparent between urban and rural areas, as mentioned earlier, when recorded hydrographs from those areas were compared. These differences were observed between the urban site, RG-4 on Sand Creek (15.7 mi^2), and a rural site, RG-2 on County Ditch 58 (10.6 mi^2), for the storm of June 16, 1979. Peak discharges were 101 and 16 ft^3/s, respectively, and time to peak was 1 and 20 hours, respectively (fig. 8). The higher peak for RG-4 was due to a greater amount of impervious area, more efficient channel, and a greater slope (table 2) than the rural site RG-2. The channel system upstream from site RG-2 is deteriorated and the soils are predominantly sand and peat underlying areas of marsh and wetlands. The basin above site RG-2 has 27 percent swamps and lakes compared to only 11 percent for site RG-4. These basin characteristics seem to be significant enough to retard and prolong direct runoff, thereby resulting in lower peaks and longer times to peak at site RG-2.

Table 3.—Rainfall and runoff for storms in 1979 and 1980

Site	Area ($miles^2$)	Weighted rainfall (inches)	Direct runoff (acre-feet)	Direct runoff (inch)	Rainfall-runoff response (percentage of rainfall)
		Storm of June 9, 1979			
RG-1	25.6	1.02	76.2	0.056	5.5
RG-2	10.6	1.15	37.3	.066	5.7
RG-3	67.2	1.14	159	.044	3.9
RG-4	15.7	1.39	46.9	.056	4.0
RG-5	90.1	1.19	208	.043	3.6
		Storm of June 16, 1979			
RG-1	25.6	1.63	386	0.283	17.4
RG-2	10.6	1.64	193	.341	20.8
RG-3	67.2	1.67	624	.174	10.4
RG-4	15.7	1.69	192	.229	13.6
RG-5	90.1	1.68	800	.166	9.9
		Storm of July 3, 1979			
RG-1	25.6	1.08	136	0.099	9.2
RG-2	10.6	1.47	18.0	.032	2.2
RG-3	67.2	1.03	138	.038	3.7
RG-4	15.7	.77	46.2	.055	7.1
RG-5	90.1	.97	224	.047	4.8
		Storm of August 9, 1979			
RG-1	25.6	1.41	45.5	0.033	2.3
RG-2	10.6	1.49	3.49	.006	.4
RG-3	67.2	1.42	—	—	—
RG-4	15.7	1.78	45.7	.055	3.1
RG-5	90.1	1.50	148	.031	2.1

Table 3.—Rainfall and runoff for storms in 1979 and 1980—Continued

Site	Area (miles^2)	Weighted rainfall (inches)	Direct runoff (acre-feet)	Direct runoff (inch)	Rainfall-runoff response (percentage of rainfall)
Storm of June 5, 1980					
RG-1	25.6	2.06	159	0.117	5.6
RG-2	10.6	1.94	32.8	.058	3.0
RG-3	67.2	2.06	341	.095	4.6
RG-4	15.7	2.28	80.0	.096	4.2
RG-5	90.1	2.10	475	.099	4.7
Storm of July 15, 1980					
RG-1	25.6	1.07	27.8	0.020	1.9
RG-2	10.6	1.02	2.51	.004	.4
RG-3	67.2	1.08	--	--	--
RG-4	15.7	1.30	32.3	.039	3.0
RG-5	90.1	1.10	--	--	--
Storm of August 7, 1980					
RG-1	25.6	3.32	649	0.475	14.3
RG-2	10.6	3.57	--	--	--
RG-3	67.2	3.45	794	.221	6.4
RG-4	15.7	3.93	152	.182	4.6
RG-5	90.1	3.56	1,052	.219	6.2
Storm of September 11, 1980					
RG-1	31.9	2.54	943	0.554	[a]21.8
RG-2	10.6	2.40	--	--	--
RG-3	73.5	2.46	1,074	.274	11.1
RG-4	15.7	2.19	219	.262	12.0
RG-5	96.4	2.38	1,355	.263	11.1

[a]Carlos Avery Wildlife Management pools open.

Table 4.—Observed peak discharges

[Values in cubic feet per second; < indicates peak was less than corresponding lowest recordable discharge; bw indicates variable backwater (discharge not determined)]

Site	Storm date							
	June 9, 1979	June 16, 1979	July 3, 1979	Aug. 9, 1979	June 5, 1980	July 15, 1980	Aug. 7, 1980	Sept. 11, 1980
RG-1	31	73	65	16	[a]37	12	139	121
RG-2	10	16	9.4	11	7.4	4.0	bw	bw
RG-3	62	98	74	34	70	41	131	153
RG-4	34	101	40	49	49	44	88	65
RG-5	98	173	121	118	111	—	185	176
CS-1	<16	30.2	33.5	18.8	<16	<16	67.7	68.4
CS-2	<24.7	26.5	29	30	<24.7	<24.7	50	41
CS-3	4.0	5.9	3.5	<3.5	[b]9.78	<3.5	5.4	6.4
CS-4	18	35	30	15	<9.8	.76	11.5	25.3
CS-5	<11.5	<11.5	1.8	<11.5	<11.5	<11.5	19	17
CS-6	33.6	103	33	37	51	46	190	93
CS-7	c	c	3.8	c	4.1	2.8	7.6	5.3

[a]Peak due to beaver-dam break upstream from CS-3, reached 43 ft^3/s.
[b]Result of a beaver-dam break.
[c]Discharge not determined, undefined rating.

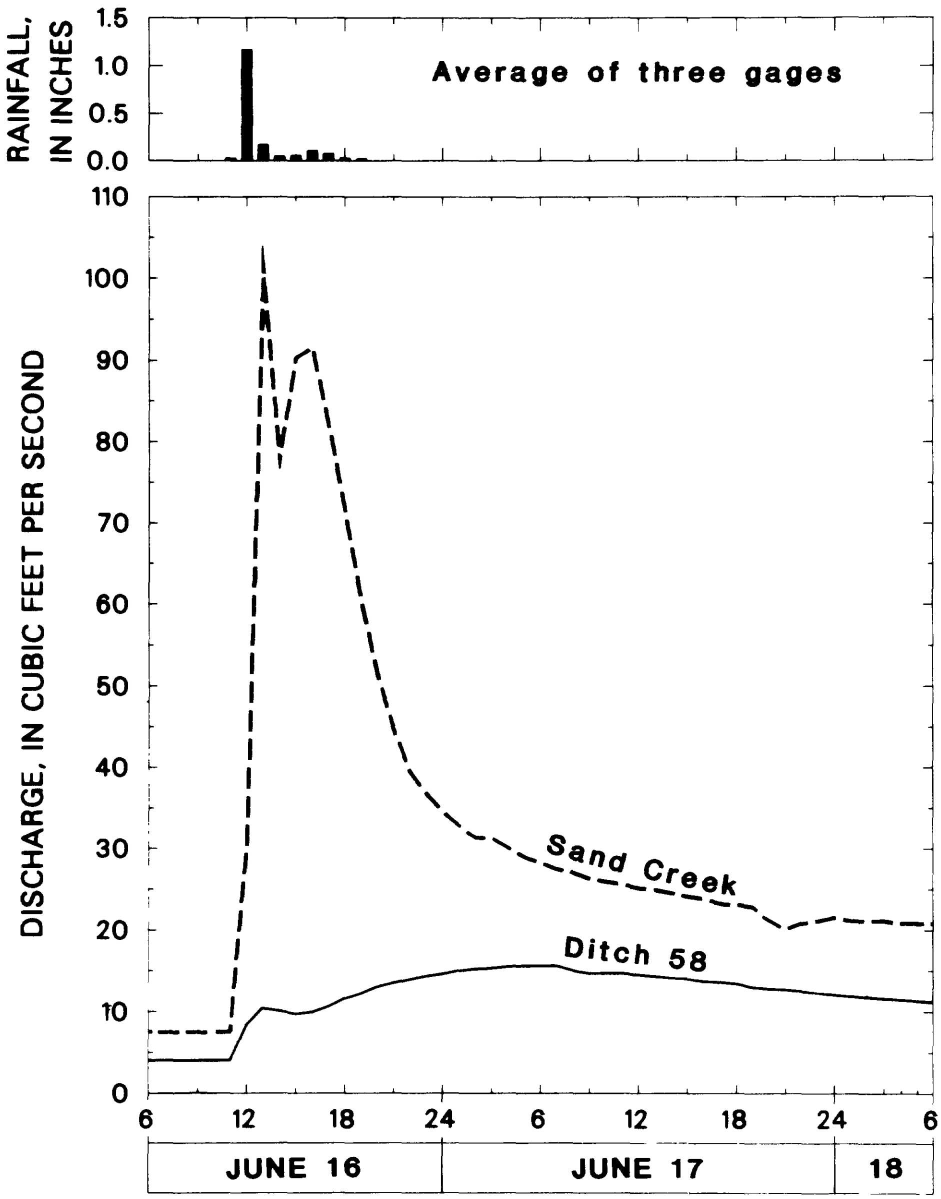


Figure 8.--Comparison of urban (Sand Creek) and rural (Ditch 58) hydrograph peaks for the storm June 16, 1979

RG-4 also had the highest peak discharge per square mile of drainage area when compared to RG-1 and RG-2 for all eight storm events. Unit peak discharge for RG-4 ranges from 2.17 to 6.43 $(ft^3/s)/mi^2$, whereas RG-1 and RG-2 ranged from 0.46 to 5.37 and 0.38 to 1.51 $(ft^3/s)/mi^2$, respectively.

Peak discharges from a given storm may differ considerably in basins of similar size and land use. For example, the storm of June 16, 1979, resulted in peak discharges of 35 ft^3/s for Sand Creek at Minnesota Highway 65 (CS-4, 8.33 mi^2), and 16 ft^3/s for County Ditch 58 at Andover Boulevard (RG-2, 10.6 mi^2). (See table 4.) The basins are of nearly the same size and land use in each is predominantely rural. The greater peak discharge at CS-4 can be attributed to the greater channel efficiency and less wetland area upstream from the gage.

Peak discharges can decrease from upstream to downstream locations if the channel between is constricted by roadway crossings with small bridge or culvert openings. This situation occurred on Sand Creek in the storms of August 7 and September 11, 1980. Peaks of 190 ft^3/s and 93 ft^3/s, respectively, were recorded at Foley Boulevard, CS-6, whereas downstream at Xeon Boulevard, RG-4, peaks of 88 ft^3/s and 65 ft^3/s, respectively, were recorded. Flow was not restricted at Foley Boulevard where it passes through a 12-foot metal-pipe arch. Downstream at Olive Street, where there are two 4-foot culverts, and at Xeon Boulevard where there are two 3.5-foot culverts, flow was restricted and peaks were reduced by (1) the limited capacity of the culverts to transmit water and (2) the availability of storage area upstream from the structure in which water was retained.

Large areas of swamp underlain by sandy soils retain much of the direct runoff, which then discharges in a slow, uniform manner that results in a much lower peak and a longer time to peak. Such areas are present upstream from sites RG-2, CS-3, and CS-7 where runoff peaks were typically lower than peaks at other sites in the watershed (table 4). There are two reasons for reduced flow from sandy and swampy areas. First, direct runoff is absorbed and stored in the channel banks as stream stage rises and is then released as stage recedes thereby effectively delaying parts of the flow. Second, runoff is retarded because of the increased channel friction in swamps and marshes in the form of weeds and brush, which physically block and effectively delay parts of the flow. More water can be stored in the porous sand and peat in the Coon Creek basin than in other basins with less porous soil types.

Channel constrictions and marshy areas having storage capability were observed to be effective controls of peak flows in the Coon Creek basin. These forms of detention storage could possibly be used to control downstream flooding, but they also may cause local flooding if the storage areas are inadequate for the volume of runoff received.

The rainfall-runoff response was determined for all five recording gage sites (table 3). Rainfall-runoff response was easily determined for rural areas (RG-1 and RG-2) from the recorded data but was not as easily evaluated for the urban area (RG-4). The Sand Creek basin (RG-4) is a combination of 38-percent developed urban area near the mouth and 62-percent rural area in the upstream part of the basin. The rainfall-runoff response at RG-4 was determined by separating the runoff hydrographs into a downstream urban area component and an upstream rural-area component. Time to peak of the rural area was sufficiently slower, such that the hydrograph from the urban area was well into recession before runoff from the rural area reached the site.

Rainfall-runoff responses were determined for eight storms that had complete records at each of the recording sites. A few examples from the data illustrate the varying results (table 3). The storms of June 16 and August 9, 1979, had similar uniformly distributed weighted-rainfall amounts of 1.68 and 1.50 inches, respectively, over the basin. Duration of the first storm was 2 hours and duration of the second storm was 12 hours. Average preceding 7-day cumulative rainfall amounts were 1.21 and 0.79 inches, respectively. Rainfall-runoff response from the June 16 storm ranged from 9.9 percent (0.17 inch) at RG-5 to 20.8 percent (0.34 inch) at RG-2. Rainfall-runoff response from the August 9 storm was much lower and ranged from 0.4 percent (0.01 inch) at RG-2 to 3.1 percent (0.06 inch) at RG-4.

Rainfall-runoff response was similar between subbasins for any one storm, but differed for succeeding storms because of its dependence on antecedent soil moisture and rainfall characteristics. Overall, there was no significant difference in rainfall-runoff response between urban and rural subbasins. The least difference in response occurred following the storm of June 9, 1979, when response ranged from 3.6 percent at RG-5 to 5.7 percent at RG-2, and the greatest difference occurred after the storm of June 16, 1979, when response ranged from 9.9 percent at RG-5 to 20.8 percent at RG-2.

Extremes in rainfall-runoff response were observed at RG-2, ranging from 0.4 percent for the storms of August 9, 1979, and July 15, 1980, to 20.8 percent for the storm of June 16, 1979. The low response in August 1979 and July 1980 was due to low antecedent soil moisture and the high retardance to flow of vegetation in the channel system.

The controlled headwater pools at Carlos Avery State Wildlife Management Area were closed and the area was noncontributing for seven of the eight storms. The pools were open and discharging from 37 to 42 ft^3/s during the storm of September 11, 1980. The highest runoff occurred after this storm, but was not included in the analysis because discharge from the pools varied and records of the discharge are approximate due to the changing flow rate with lowering pool levels and changing backwater at the control points. The additional discharge from the Carlos Avery pools after this storm represented 1 foot of stage in Coon Creek at Lexington Avenue (CS-1). This is based on a discharge measurement made at the time of the peak, and on the stage-discharge relationship for that site.

To reiterate, subbasins with differing land uses in the Coon Creek watershed reacted to rainfall much as expected. Hydrographs of streams draining urban areas had higher peaks and shorter times to peak than hydrographs of rural streams. Basin runoff characteristics are dependent primarily on channel slope, impervious areas, and infiltration capacities. Peak flows from upstream rural areas generally were lower and times to peak were longer because of rapid infiltration to soils, large storage capacity of swamps, and the high-retardance channel system. Rainfall less than 1 inch did not produce significant runoff. Peak discharges generally increased from upstream to downstream except where flow was restricted by bridge or culvert openings at roadways. There was no significant difference in rainfall-runoff response between subbasins for any one storm, but the response differed between succeeding storms because of its dependence on antecedent soil moisture and rainfall amount, intensity, and duration. Finally, the rainfall-runoff response was difficult to analyze for low peak and long-duration hydrographs (such as those of RG-2) because of the inherent errors associated with streamflow and rainfall measurements and with determinations of base runoff from relatively flat hydrographs.

Model

In addition to the quantitative analysis, a computer simulation of the rainfall-runoff process was performed to further define the rainfall-runoff relationship. Basin, storm, and hydrograph characteristics, most of which are random variables, were the major components in the modeling effort. The key to the modeling effort was to determine the interrelationships of these components and to develop a method to re-create past runoff and simulate future runoff.

The computer program HEC-1, Flood Hydrograph Package, developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers (1973), was used to simulate streamflow hydrographs for various hydrologic conditions and land uses. The program was selected because it satisfied the project objectives, requires less data than other rainfall-runoff models, and is relatively easy to use.

HEC-1 is a collection of computer programs incorporated into a package that includes unit-hydrograph and loss-rate optimization, mean basin rainfall and snowmelt computations, unit-graph and hydrograph computation, streamflow-routing optimization, hydrograph combining and routing, and balanced hydrographs. There are two limitations to the model. First, only single storms can be analyzed because there are no provisions in the computation process for recovery of the loss-rate, which is a function of the soil infiltration capacity, during periods of no precipitation. Secondly, "lumped parameter" modeling is used in the computations and average parameter values applicable to entire subbasins are used in the modeling process. This lumping of parameters includes precipitation amounts with time, so rainfall must be uniformly distributed over the subbasin, which is not often an accurate representation of actual rainfall.

The model requires definition of a unit hydrograph based on the Clark method (Clark, 1945) and of precipitation loss-rate criteria for the basin being modeled. The Clark method requires three elements to calculate a unit hydrograph; the time of concentration for the basin, a storage coefficient, and a time-area curve. Direct runoff from various points in the basin is converted into a translation hydrograph that is routed through a linear reservoir, which accounts for the effect of storage, and results in an instantaneous unit hydrograph from which a unit hydrograph for the given time interval can be derived. HEC-1 can determine a set of loss-rate and unit-hydrograph parameters that "best" simulate observed runoff hydrographs, given the average rainfall over the basin, the drainage area, and a few runoff-characteristic values. The "best" simulation is considered to be that which minimizes the weighted-square deviations between observed and simulated hydrographs. The variables necessary for the HEC-1 models are defined in table 5 and in figure 9.

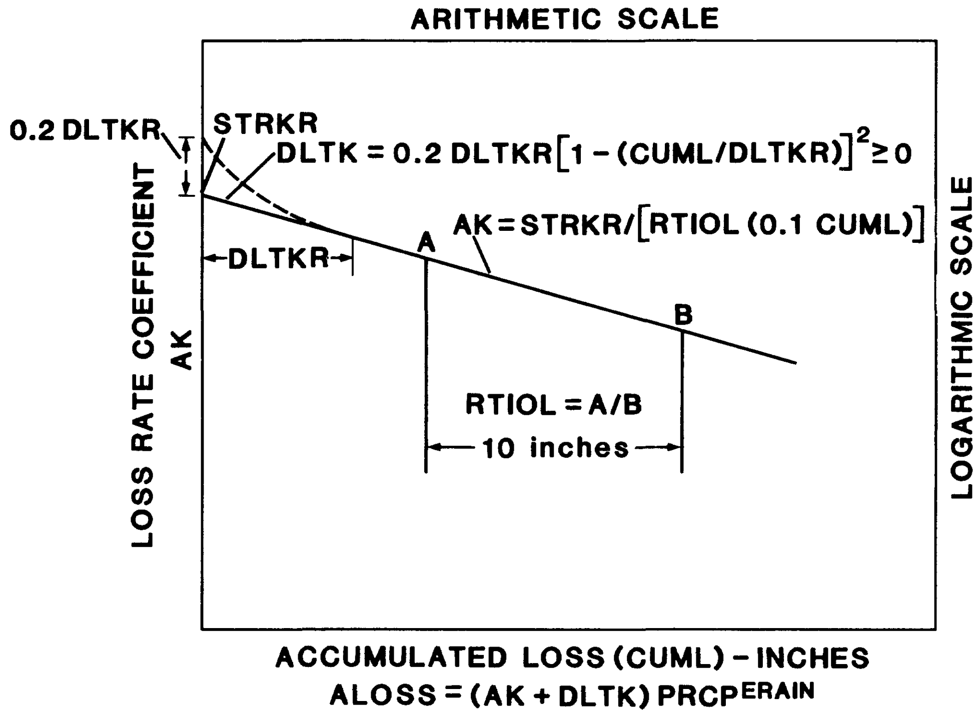
Table 5.—Runoff and unit-hydrograph variables

Variable	Definition
QRCSN	Discharge at which recession flow begins, in cfs. (May also be a ratio to peak flow, as was the case here)
STRTQ	Recession flow for antecedent runoff (discharge at beginning of first period of simulation).
RTIOR	Recession coefficient, ratio of flow at time *t* to flow-10 computation periods later during recession.
TC	Clark unit-hydrograph time of concentration, in hours.
R	Clark unit-hydrograph storage coefficient, in hours.

Most rainfall during 1979 and 1980 occurred in relatively small amounts at low intensity, producing small amounts of direct runoff and low hydrograph peaks. Rainfall was recorded on 109 separate days during the study. Rainfall amounts on 2 days exceeded 2 inches, on 9 days was from 1 to 2 inches, and on the remaining days was less than 1 inch. (Rainfall amounts were recorded from midnight to midnight. Amounts differ among rainfall-measurement sites. See "Rainfall data" at the end of this report.) Although most storms did not produce a significant rise in stage or a hydrograph that could be modeled accurately, eight storms produced hydrographs that could be used in developing a model at most sites.

Runoff hydrographs were modeled for three subbasins, Coon Creek upstream from Raddison Road (31.9 mi^2), County Ditch 58 upstream from Andover Boulevard (10.6 mi^2), and Sand Creek upstream from Xeon Boulevard (15.7 mi^2), with data collected at recording sites RG-1, RG-2, and RG-4, respectively.

Runoff from seven storms was modeled at site RG-1. The storm of June 5, 1980, was not modeled because discharge surges from removal of a beaver dam and water released from pools in the Carlos Avery Wildlife Management Area caused an unnatural hydrograph. All eight storms were modeled at RG-4 on Sand Creek. The rural lands and marshes drained by County Ditch 58 held and absorbed the smaller rainfall amounts so that only four hydrographs suitable for modeling were recorded at RG-2. The large runoff events in August and September 1980 were not modeled at RG-2 because discharge could not be adequately defined owing to variable backwater conditions at the gage caused by a beaver dam.



EXPLANATION

DLTKR Amount of initial accumulated rain loss during which loss-rate coefficient is increased (primarily a function of antecedent soil-moisture deficiency, usually different for each storm)

STRKR Starting value of loss coefficient on exponential recession curve for rain losses (function of infiltration capacity; depends on basin characteristics such as soil type, land use, and vegetal cover)

RTIOL Ratio of rain-loss coefficient on exponential loss curve to that corresponding to 10 inches more of accumulated loss (function of ability of surface of a basin to adsorb precipitation and should be constant for large homogeneous areas)

ERAIN Exponent of precipitation for rain-loss function that reflects the

$$ALOSS = (AK + DLTK)PRCP^{ERAIN}$$

influence of precipitation rate on basin-average loss characteristics. It reflects the manner in which storms occur within an area and may be considered a characteristic of a particular region.

ALOSS = loss rate, in inches per hour

AK = loss-rate coefficient at beginning of time interval, value on STRKR exponential loss curve

PRCP = rainfall intensity, in inches per hour

DLTK = incremental increase in loss-rate coefficient

Figure 9.--General loss-rate function used in HEC-1 program (Modified from U. S. Army Corps of Engineers, 1973)

Sandy soils and relatively flat slopes in the Coon Creek basin enhance rapid infiltration, resulting in a runoff hydrograph that largely reflects interflow processes rather than direct surface runoff.

The modeling sequence described in the HEC-1 package (U.S. Army Corps of Engineers, 1973) was used to achieve the "best" simulation of each hydrograph. A satisfactory duplication of each hydrograph was achieved. The best and poorest matches of simulated and observed hydrographs for each site are shown in figures 10A-10F. These hydrographs provided 19 sets of HEC-1 input variables unique to each runoff event and basin. Model variables RTIOL and ERAIN were later found to be constant over the entire basin. Model-variable values from the optimization sequence are listed in table 6.

Trial simulations to generalize the model using average values of variables from individual storms in each basin and recorded rainfall amounts gave poor results. Acceptable agreement was obtained for only 2 of the 19 recorded hydrographs. Such unsatisfactory results can be attributed to the wide range in values for the most sensitive model variables, STRKR and DLTKR. The accumulated rain loss accounted for by DLTKR varies from storm to storm and an average value should not be expected to produce a response in agreement with individual storms. Similarly, the value of STRKR varies, and the change in loss coefficient during rainfall is affected by the starting value.

A need became evident for a method to relate HEC-1 input-variable values to variations in rainfall and antecedent moisture. Values for various physical and meteorological characteristics that affect runoff were used in a multiple regression to the optimized "best fit" HEC-1 input variable values. This insured that the hydrograph-simulation process would include more of the variables contributing to the observed hydrographs and that the model process for each site would result in a reasonable match to all hydrographs. The variables used are defined in table 7 and the values for each storm are listed in table 8. The rainfall amounts listed in table 7 were uniformly distributed over each site. Preceeding cumulative rainfall amounts (RAIN7 and RAIN10) were used in lieu of antecedent soil moisture.

The linear equations (table 9) from the regression analyses have unique independent variables for each model input variable at each site. This indicates that the significance of runoff variables differs from individual basins for the storms.

HEC-1 input variables were determined from the equations in table 9 and the variables associated with the observed storms from table 8. Results are given in table 10. Computed HEC-1 input-variable values from table 10 were then used in a hydrograph simulation for each storm to compare the results of this method to the observed hydrographs. The simulated and observed hydrographs are shown in figures 11A through 11S. A graphical representation of the results of all 19 modeled hydrographs is shown in figure 12 where simulated peak discharge is plotted against observed peak discharge. A summary of the differences between observed and simulated hydrograph peaks is presented in table 11. The median differance overall was 42 percent.

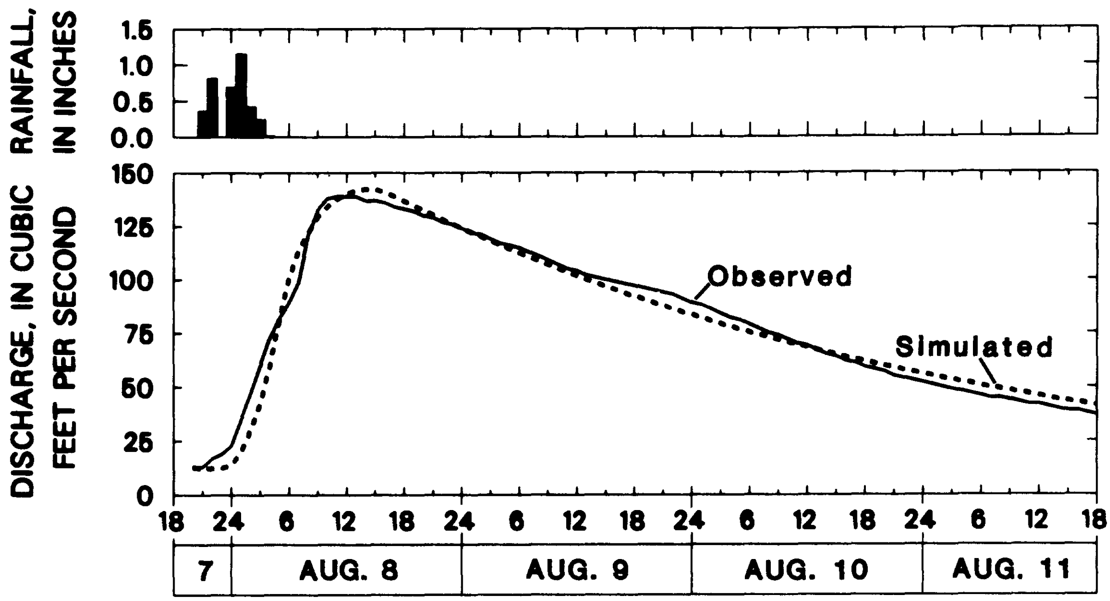


Figure 10A.--Initial verification for best match for Coon Creek at Raddison Road (storm of August 7, 1980)

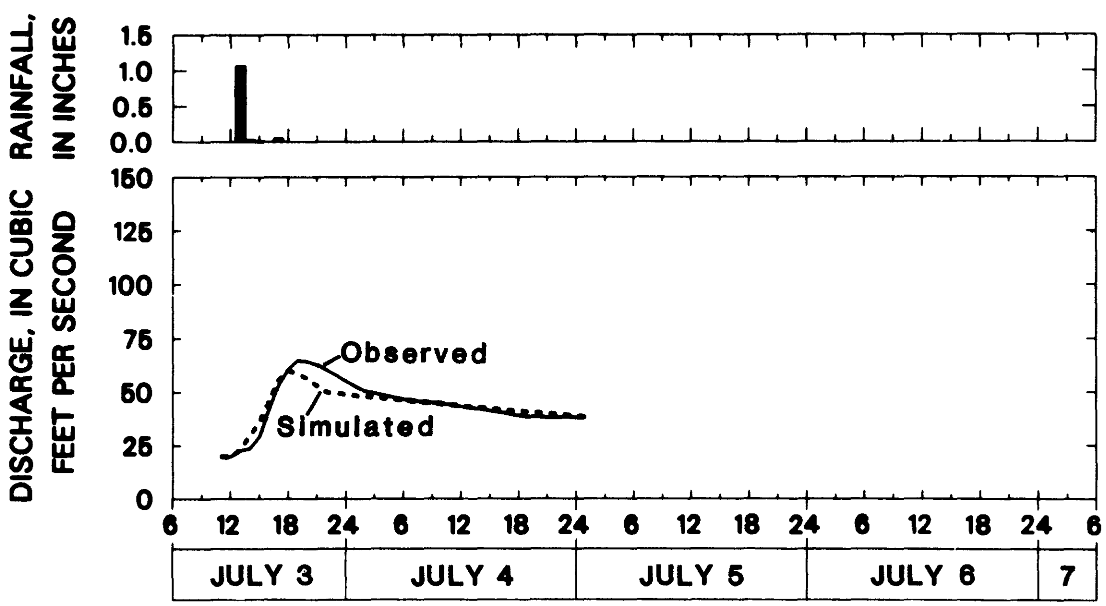


Figure 10B.--Initial verification for poorest match for Coon Creek at Raddison Road (storm of July 3, 1979)

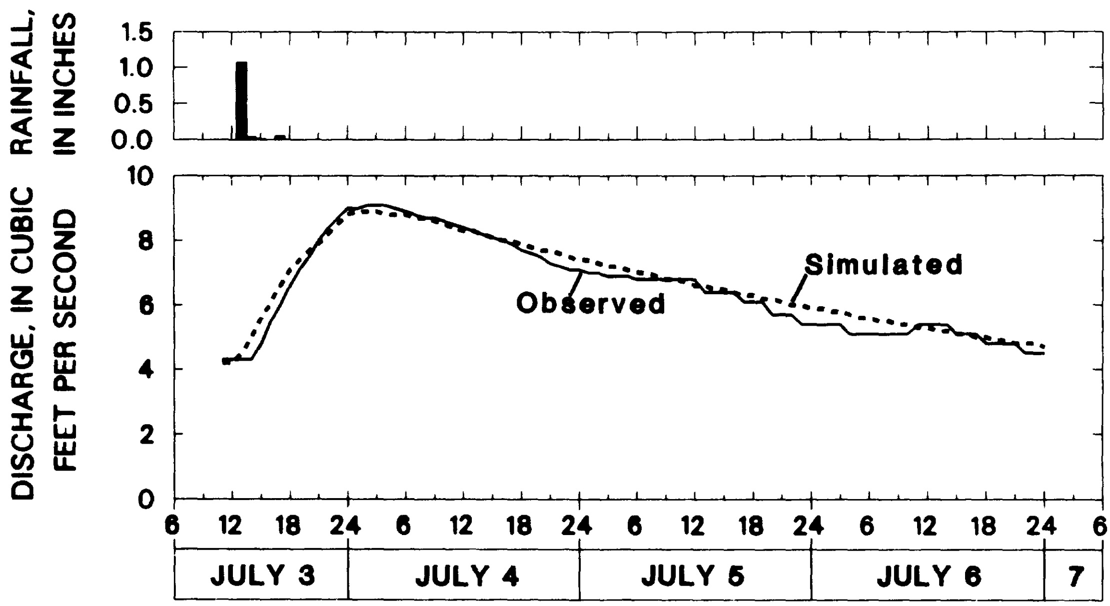


Figure 10C.--Initial verification for best match for County Ditch 58 at Andover Boulevard (storm of July 3, 1979)

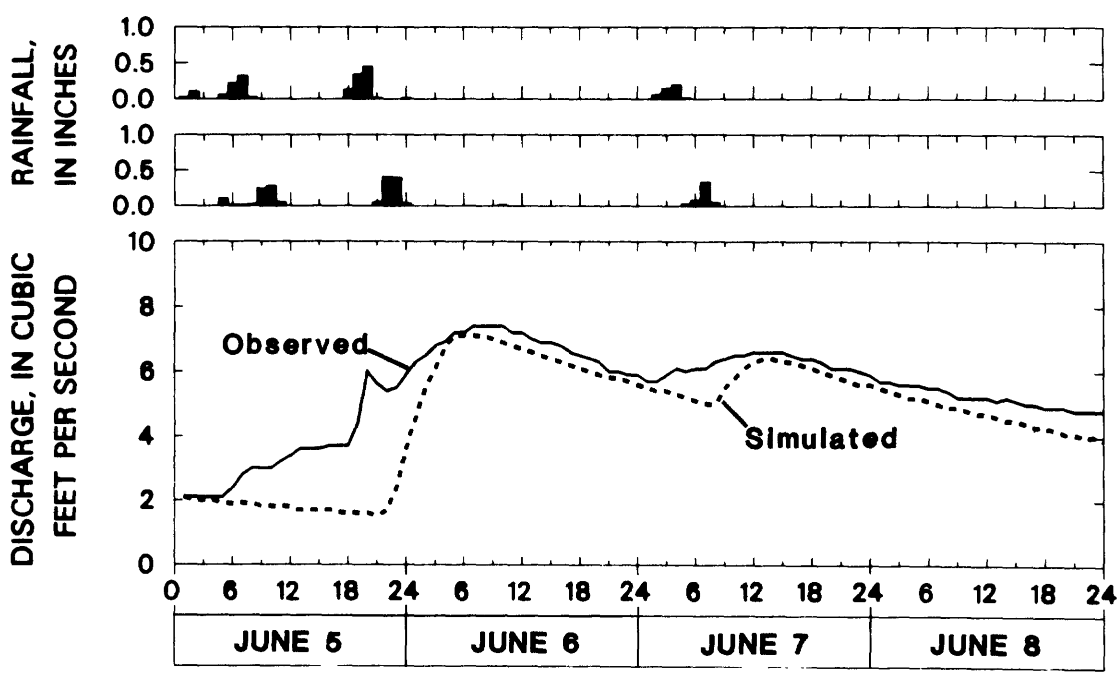


Figure 10D.--Initial verification for poorest match for County Ditch 58 at Andover Boulevard (storm of June 5-7, 1980)

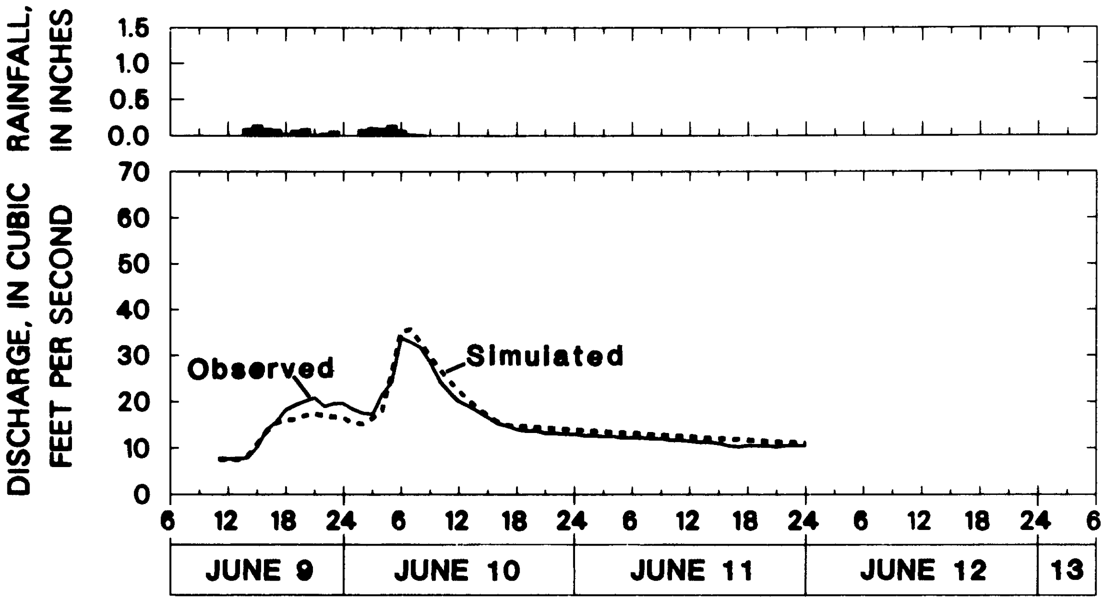


Figure 10E.--Initial verification for best match for Sand Creek at Xeon Boulevard (storm of June 9, 1979)

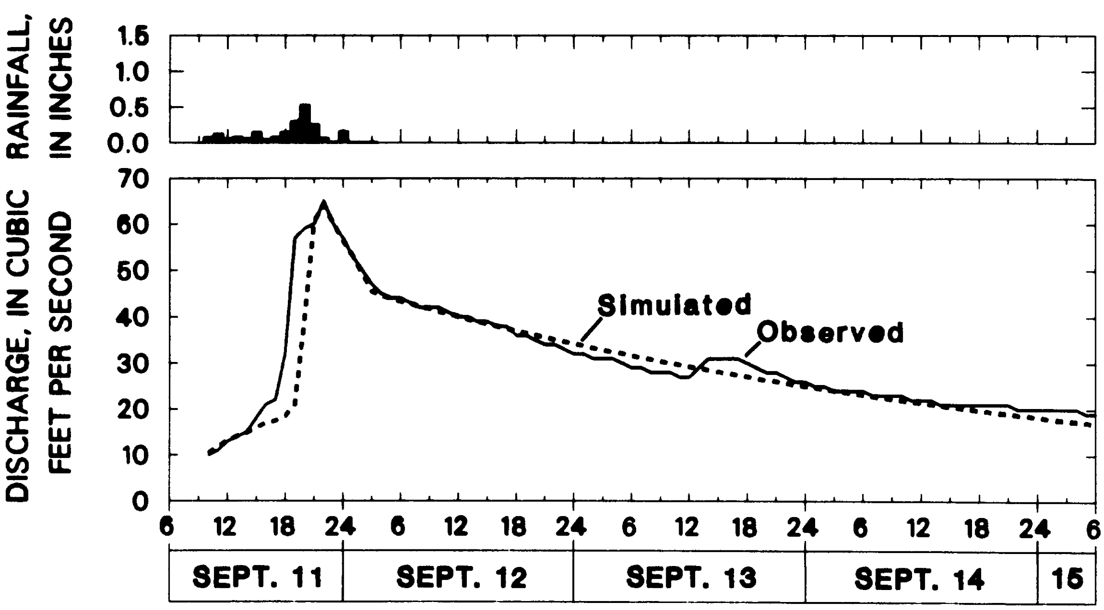


Figure 10F.--Initial verification for poorest match for Sand Creek at Xeon Boulevard (storm of September 11, 1980)

Table 6.—Optimized HEC-1 model variables

Date	STRTQ	RTIOL	ERAIN	QRCSN	RTIOR	TC	R	STRKR	DLTKR
				Site RG-1					
6-09-79	14.4	2.00	0.50	31.0	1.10	22.0	50.0	0.28	0.65
6-16-79	13.0	2.00	.50	50.0	1.10	21.5	46.5	.56	1.41
7-03-79	20.1	2.00	.50	50.0	1.10	21.0	3.9	.64	1.58
8-09-79	4.8	2.00	.50	15.0	1.10	21.0	40.0	.40	1.05
7-15-80	2.6	2.00	.50	10.0	1.11	22.1	40.0	.69	1.28
8-07-80	13.0	2.00	.50	130.0	1.24	23.4	61.2	.61	1.52
9-11-80	28.0	2.00	.50	115.0	1.07	22.5	68.3	.47	1.22
				Site RG-2					
6-09-79	3.8	2.00	0.50	10.0	1.10	12.0	200.0	0.23	0.22
6-16-79	4.0	2.00	.50	15.0	1.20	22.1	96.8	.57	1.44
7-03-79	4.3	2.00	.50	9.0	1.10	18.5	86.2	.76	1.91
6-05-80	2.1	2.00	.50	7.4	1.16	10.0	40.0	.50	1.19
				Site RG-4					
6-09-79	7.7	2.00	0.50	15.0	1.10	1.5	8.0	0.40	0.85
6-16-79	7.5	2.00	.50	30.0	1.15	1.5	8.0	.69	1.67
7-03-79	9.0	2.00	.50	15.0	1.04	1.5	5.6	.49	.90
8-09-79	4.1	2.00	.50	10.0	1.25	1.5	7.0	.67	1.34
6-05-80	7.7	2.00	.50	12.0	1.20	1.0	3.1	.65	1.42
7-15-80	2.7	2.00	.50	7.0	1.18	1.5	6.4	.73	1.78
8-07-80	4.7	2.00	.50	18.0	1.17	1.5	10.0	1.18	2.85
9-11-80	10.0	2.00	.50	45.0	1.14	1.5	10.0	.70	1.08

Table 7.—Variables used in multiple regression with HEC-1 model variables

Variable	Definition
TRAIN	Total storm rainfall, in inches, over the duration of the storm.
DUR	Duration of rainfall, in hours.
AVINT	Average rainfall intensity (inches per hour) defined as TRAIN/DUR.
PKHRR	Peak hourly rainfall, in inches.
PCTOT	Peak hourly rainfall as a percent of the total rainfall (PKHRR/TRAIN) x 100.
RAIN7	Preceding 7-day cumulative rainfall, in inches.
RAIN10	Preceding 10-day cumulative rainfall, in inches.
AREA	Area of the drainage basin, in square miles.

Table 8.—Rainfall characteristics used in regression

Date	TRAIN	DUR	AVINT	PKHRR	PCTOT	RAIN7	RAIN10
			Site RG-1				
6-09-79	0.98	19	0.05	0.13	13	0.45	1.26
6-16-79	1.62	9	.18	1.06	65	1.06	1.46
7-03-79	1.06	5	.21	.97	92	1.18	1.18
8-09-79	1.36	12	.11	.41	30	.99	1.25
7-15-80	1.02	2	.51	.94	92	.11	0.11
8-07-80	3.06	8	.38	.96	31	1.65	1.73
9-11-80	2.72	10	.27	1.01	37	.00	1.51
			Site RG-2				
6-09-79	1.15	19	0.06	0.16	14	0.53	1.32
6-16-79	1.63	9	.18	1.07	66	1.19	1.78
7-03-79	1.57	5	.31	1.45	92	1.52	1.52
6-05-80	1.68	55	.03	.30	18	1.83	2.10
			Site RG-4				
6-09-79	1.41	19	0.07	0.16	11	0.54	1.71
6-16-79	1.70	9	.19	1.18	69	1.38	1.88
7-03-79	.74	10	.07	.30	41	1.41	1.41
8-09-79	1.78	10	.18	.51	30	.59	0.61
6-05-80	.99	4	.25	.48	48	1.58	1.58
7-15-80	1.31	2	.66	1.20	92	.00	.00
8-07-80	3.95	8	.49	1.23	31	1.14	1.16
9-11-80	2.05	18	.11	.49	24	.00	1.00

Table 9.— Regression equations for HEC-1 model variables

	Mean optimized value	Standard error of estimate	Coefficient of variation	Coefficient of determination	Degrees of freedom
Site RG-1 Coon Creek at Raddison Road					
DLTKR = 0.925 + 0.273(RAIN7) + 0.00783(STRTQ)	1.24	0.33	26.5	0.29	4
STRKR = 0.508 + 0.0495(RAIN7) - 0.00183(STRTQ)	.52	.17	33.2	.06	4
TC = 18.2 + 0.459(TRAIN) + 0.150(DUR) + 6.27(AVINT)	21.9	.30	1.35	.94	3
R = -99.2 + 7.56(DUR) + 162(AVINT) + 43.1(PKHRR)	44.3	11.3	25.6	.85	3
RTIOR = 1.29 - 0.00991(DUR) + 0.0698(AVINT) -0.00198(PCTOT)	1.12	.06	5.26	.44	3
QRCSN = 0.747 + 0.259(TRAIN) - 0.757(PKHRR) + 0.00545(PCTOT)	.87	.05	5.82	.89	3
Site RG-2 County Ditch 58 at Andover Boulevard					
DLTKR = -.00626 + 0.944(RAIN7)	1.19	.59	49.5	.54	2
STRKR = 0.162 + 0.279(RAIN7)	.52	.19	36.9	.50	2
TC = 9.94 + 7.66(PKHRR)	15.6	3.74	23.9	.71	2
R = 510 - 268(TRAIN)	106.	21.9	20.7	.93	2
RTIOR = 0.947 + 0.128(TRAIN)	1.14	.05	4.07	.40	2
QRCSN = 0.972 + 0.000482(DUR)	.98	.02	1.63	.41	2
Site RG-4 Sand Creek at Xeon Boulevard					
DLTKR = 2.34 + 0.328(RAIN7) - 0.169(STRTQ)	1.49	.57	38.4	.44	5
STRKR = 0.933 + 0.0634(RAIN7) - 0.0444(STRTQ)	.69	.24	34.5	.23	5
TC = 1.5	1.5	.00	.0	—	7
R = -2.83 + 1.93(TRAIN) + 0.404(DUR) + 0.0612(PCTOT)	7.26	.50	6.8	.97	4
RTIOR = 1.25 - 0.00703(DUR) + 0.0506(PKHRR) - 0.00138(PCTOT)	1.15	.07	6.14	.29	4
QRCSN = 0.0256 - 0.0163(AVINT) - 0.156(RAIN7) + 0.0651(STRTQ)	.33	.04	11.4	.97	4
Basin Wide					
STRTQ = -11.6 + 0.792(AREA) + 4.22(RAIN10)	8.61	4.30	50.0	.64	16
RTIOL = 2.00	2.00	.00	.0	—	18
ERAIN = 0.50	.50	.00	.0	—	18

Table 10.—HEC-1 variables computed from equations in table 8 and variables in table 7

[All sites, all storms: RTIOL = 2.00; ERAIN = 0.50]

Date	STRTQ	QRCSN	RTIOR	TC	R	STRKR	DLTKR
			Site RG-1				
6-09-79	15.2	0.97	1.08	21.8	58.1	0.50	1.16
6-16-79	14.3	.72	1.09	21.5	43.6	.54	1.32
7-03-79	11.9	.79	1.08	20.8	14.4	.53	1.40
8-09-79	13.1	.95	1.12	21.3	27.0	.55	1.23
7-15-80	8.53	.80	1.13	22.2	39.0	.51	.98
8-07-80	13.9	.98	1.18	23.2	64.2	.57	1.48
9-11-80	23.2	.89	1.14	22.7	63.6	.46	1.14
			Site RG-2				
6-09-79	4.38	0.98	1.09	11.2	202	0.31	0.49
6-16-79	5.05	.98	1.16	18.1	72.9	.49	1.12
7-03-79	2.00	.97	1.15	21.1	89.0	.56	1.43
6-05-80	4.83	1.00	1.16	12.2	59.5	.67	1.72
			Site RG-4				
6-09-79	10.7	0.44	1.11	1.5	8.3	0.62	1.22
6-16-79	8.74	.29	1.15	1.5	8.4	.69	1.53
7-03-79	5.37	.39	1.14	1.5	5.2	.62	1.28
8-09-79	2.95	.20	1.16	1.5	6.5	.79	1.84
6-05-80	5.90	.28	1.18	1.5	3.7	.69	1.56
7-15-80	.97	.19	1.16	1.5	6.2	.81	1.89
8-07-80	4.67	.15	1.21	1.5	10.0	.80	1.92
9-11-80	7.89	.67	1.11	1.5	9.9	.49	.65

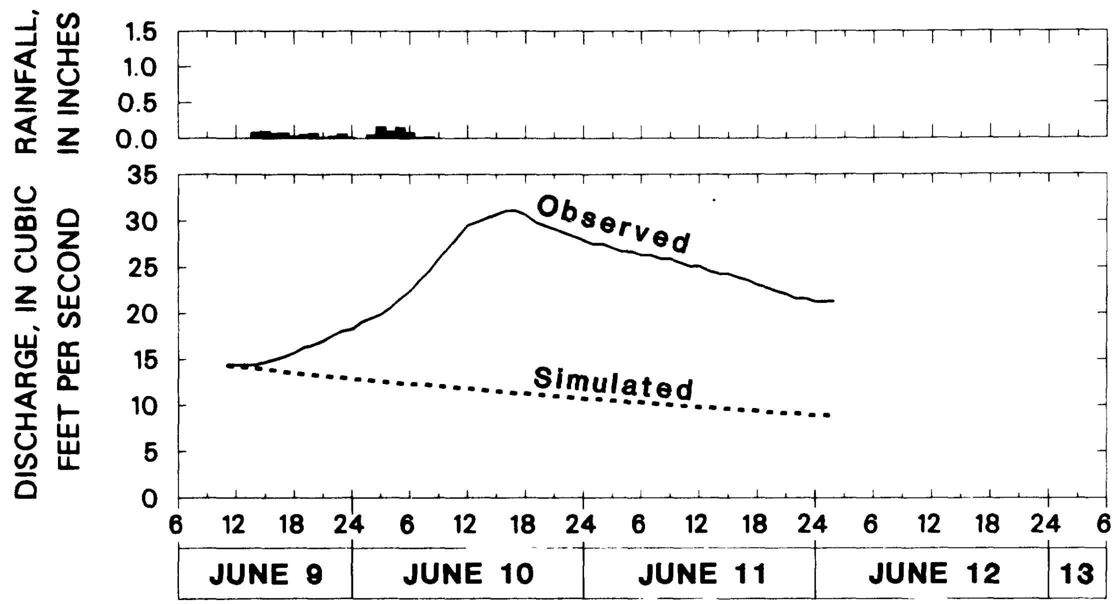


Figure 11A.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Coon Creek at Raddison Road, storm of June 9, 1979

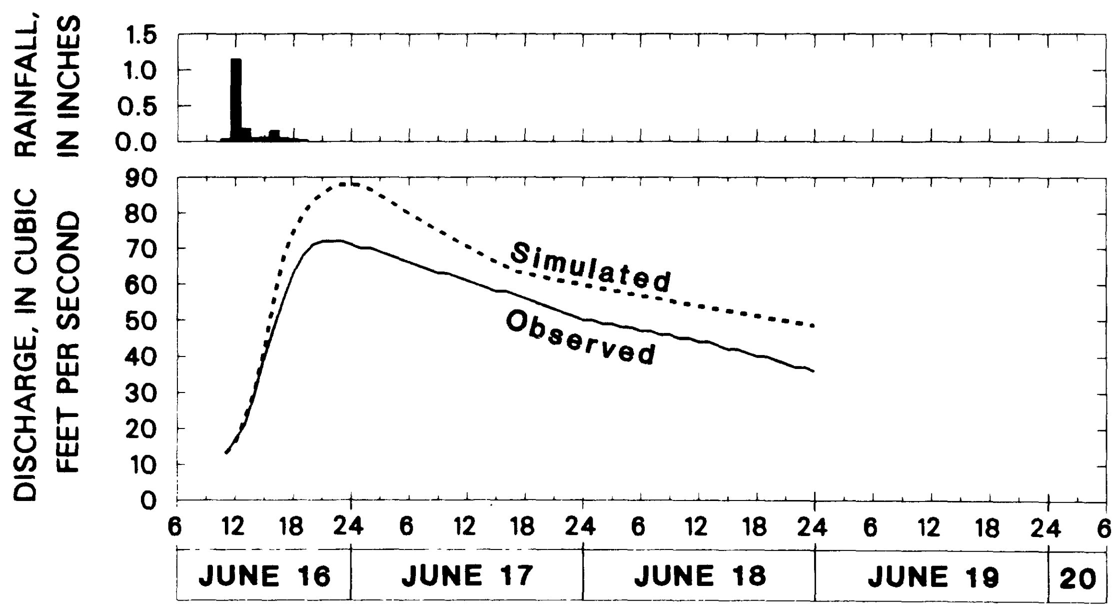


Figure 11-B.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Coon Creek at Raddison Road, storm of June 16, 1979

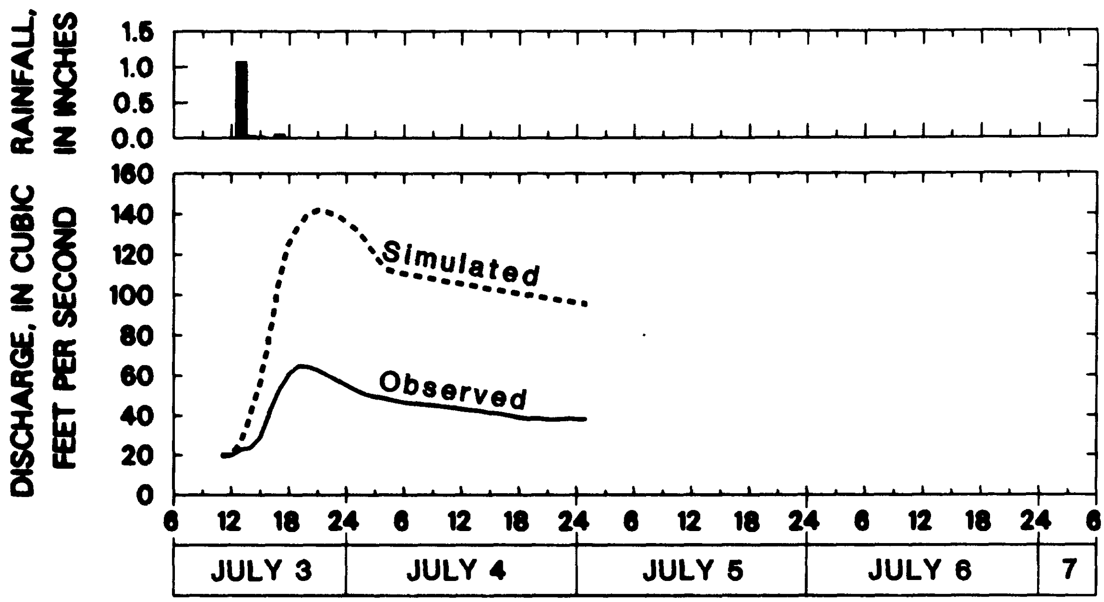


Figure 11C.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Coon Creek at Raddison Road, storm of July 3, 1979

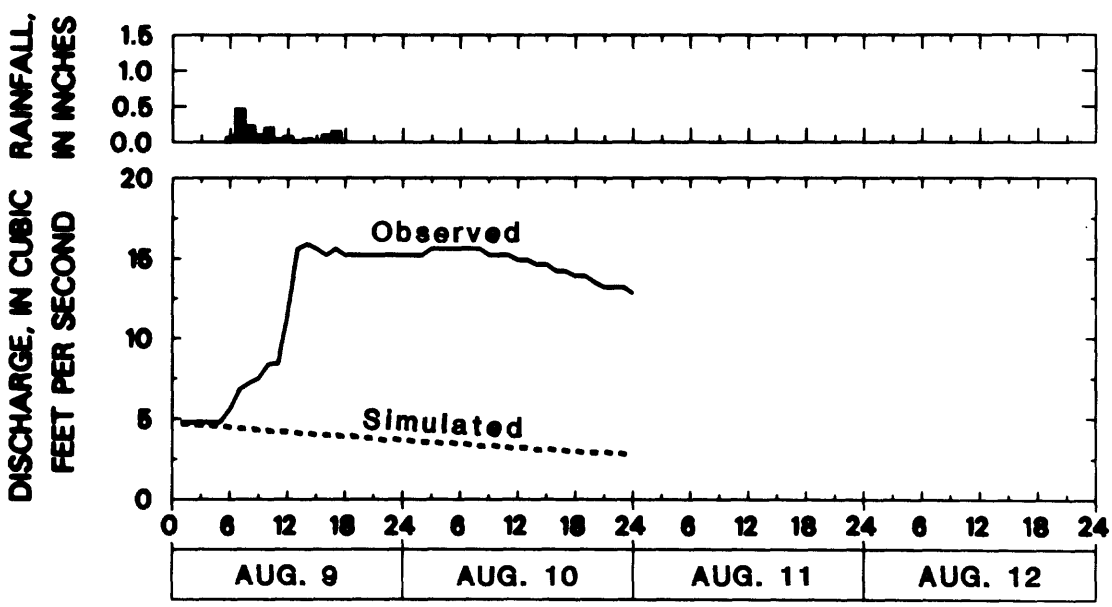


Figure 11D.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Coon Creek at Raddison Road, storm of August 9, 1979

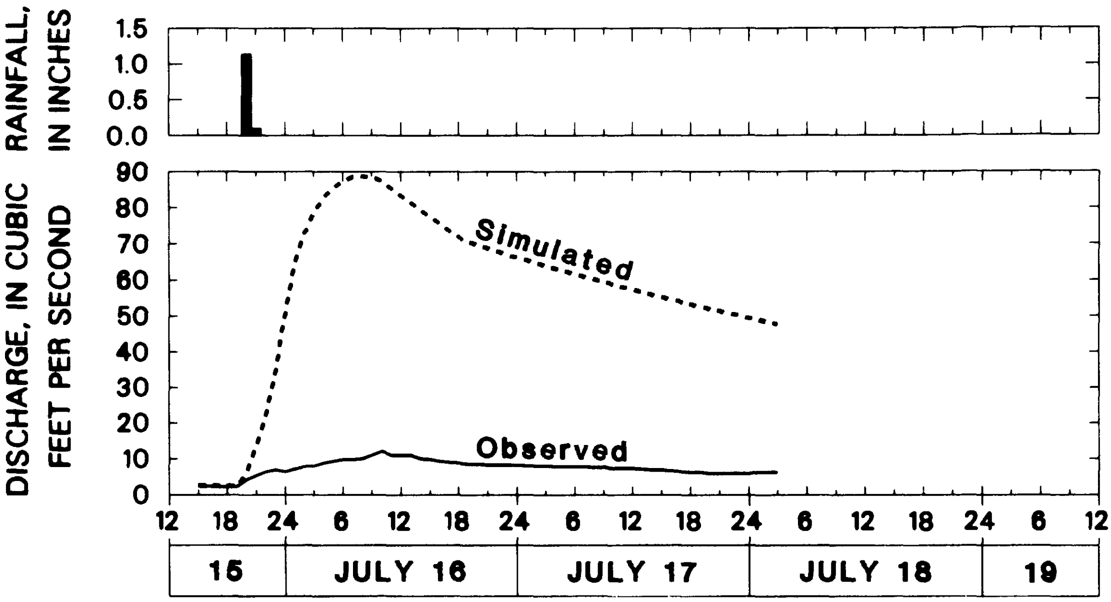


Figure 11E.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Coon Creek at Raddison Road, storm of July 15, 1980

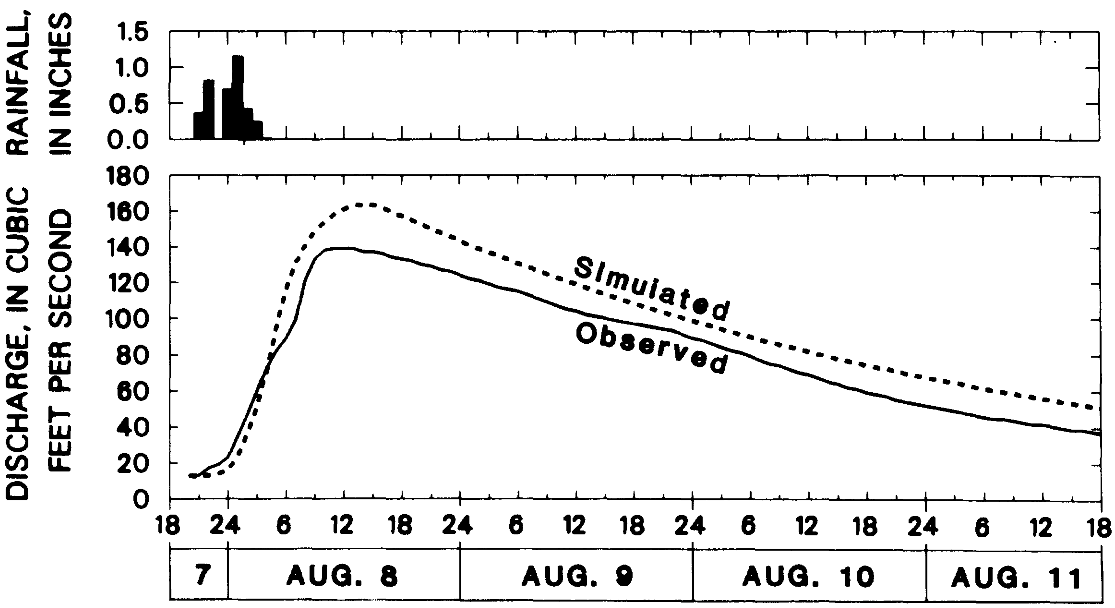


Figure 11F.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Coon Creek at Raddison Road, storm of August 7, 1980

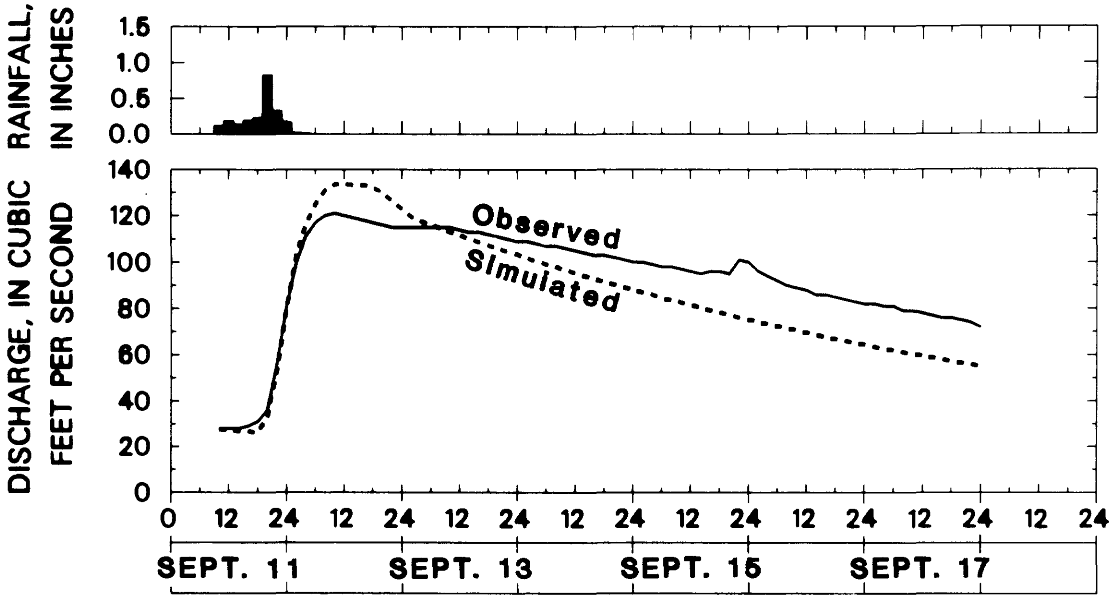


Figure 11G.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Coon Creek at Raddison Road, storm of September 11, 1980

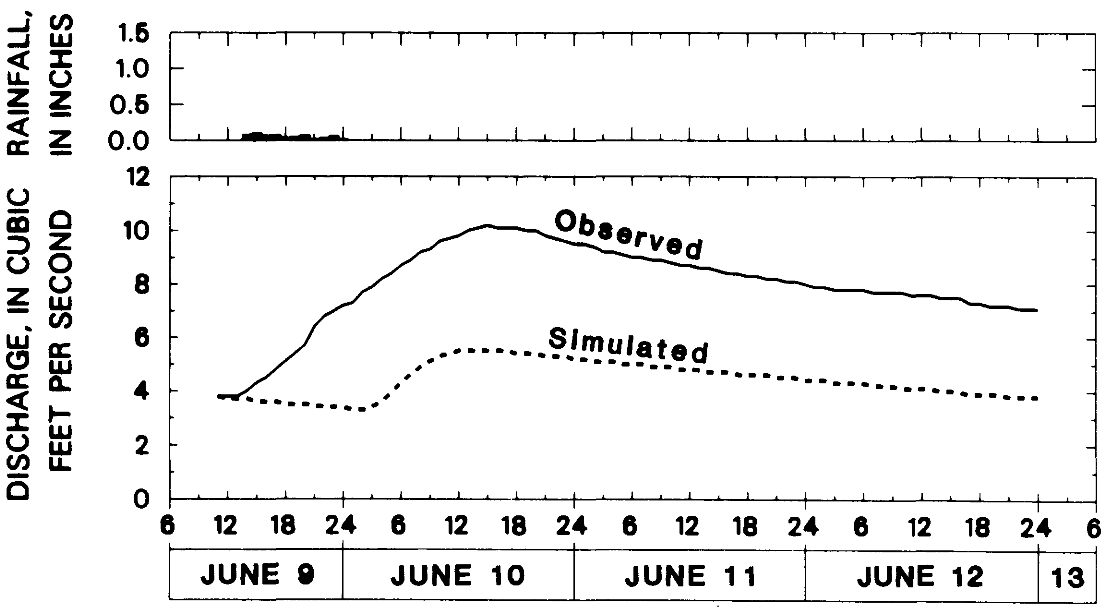


Figure 11H.--Simulated versus observed hydrographs using computed HEC-1 input parameters for County Ditch 58 at Andover Boulevard, storm of June 9, 1979

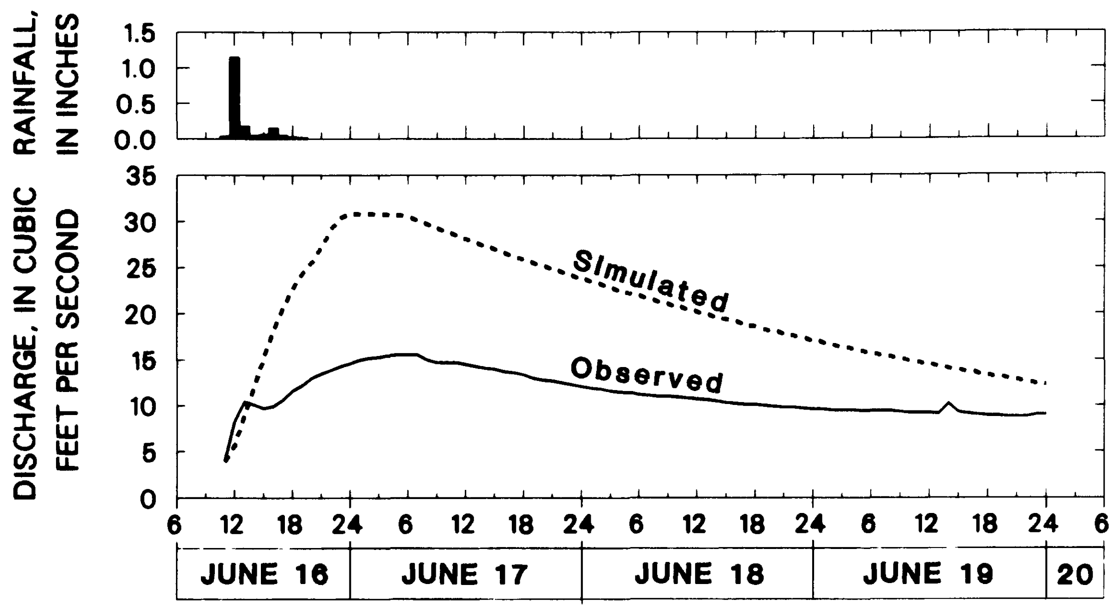


Figure 11I.--Simulated versus observed hydrographs using computed HEC-1 input parameters for County Ditch 58 at Andover Boulevard, storm of June 16, 1979

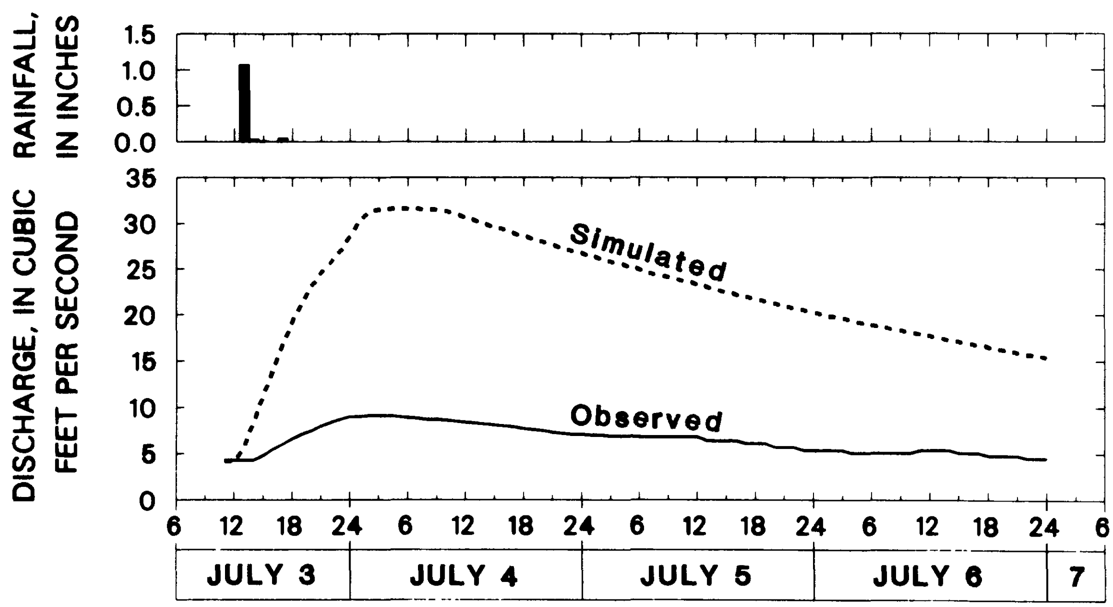


Figure 11J.--Simulated versus observed hydrographs using computed HEC-1 input parameters for County Ditch 58 at Andover Boulevard, storm of July 3, 1979

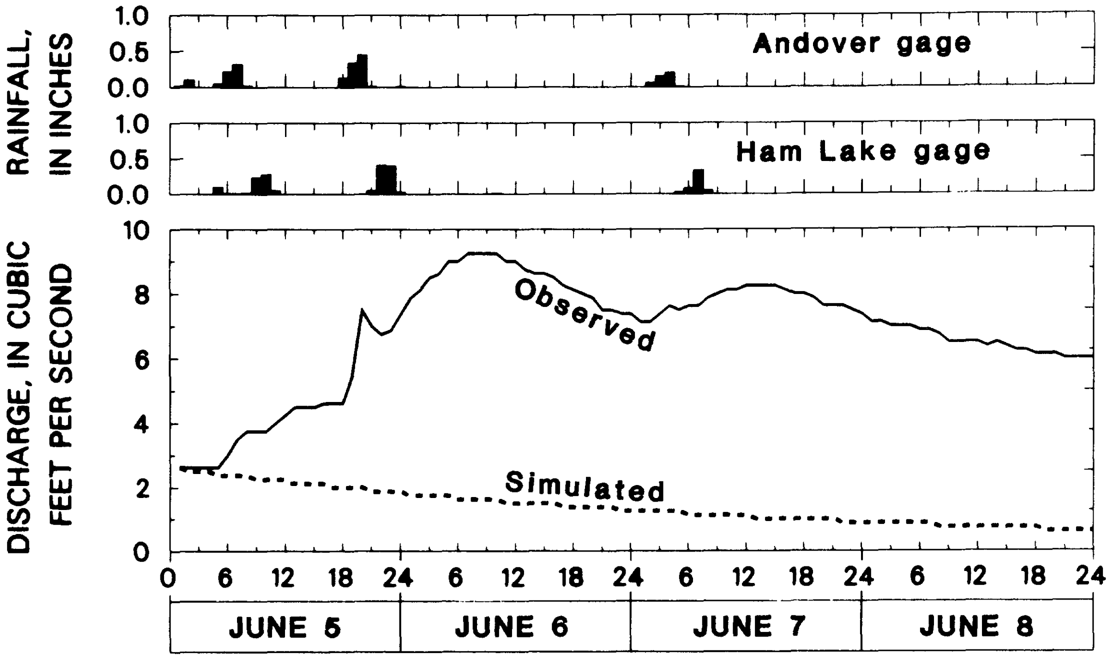


Figure 11K.--Simulated versus observed hydrographs using computed HEC-1 input parameters for County Ditch 58 at Andover Boulevard, storm of June 5, 1980

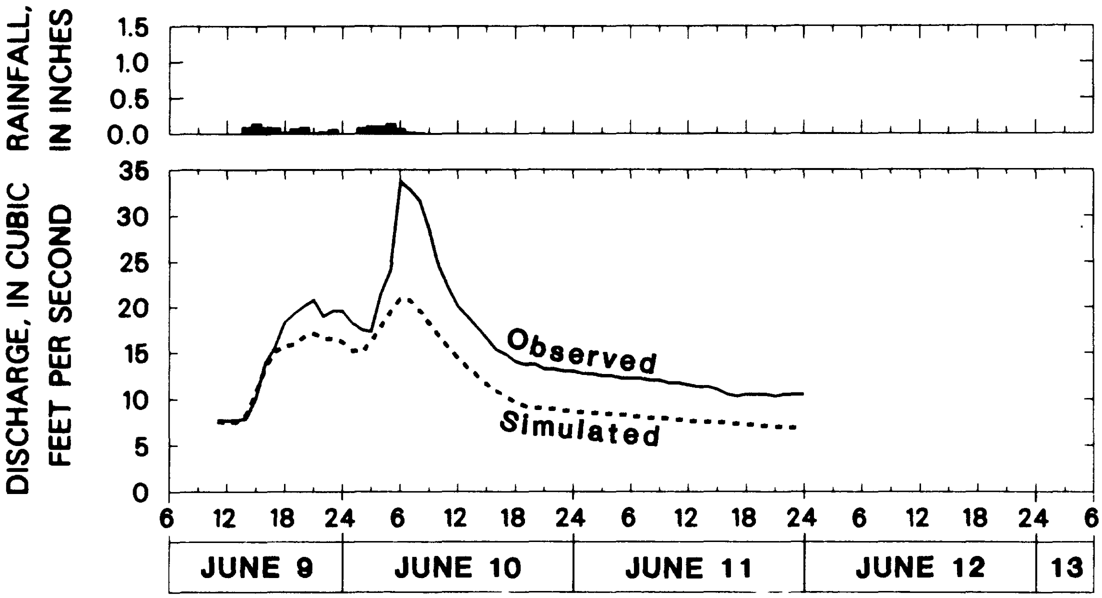


Figure 11L.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Sand Creek at Xeon Boulevard, storm of June 9, 1979

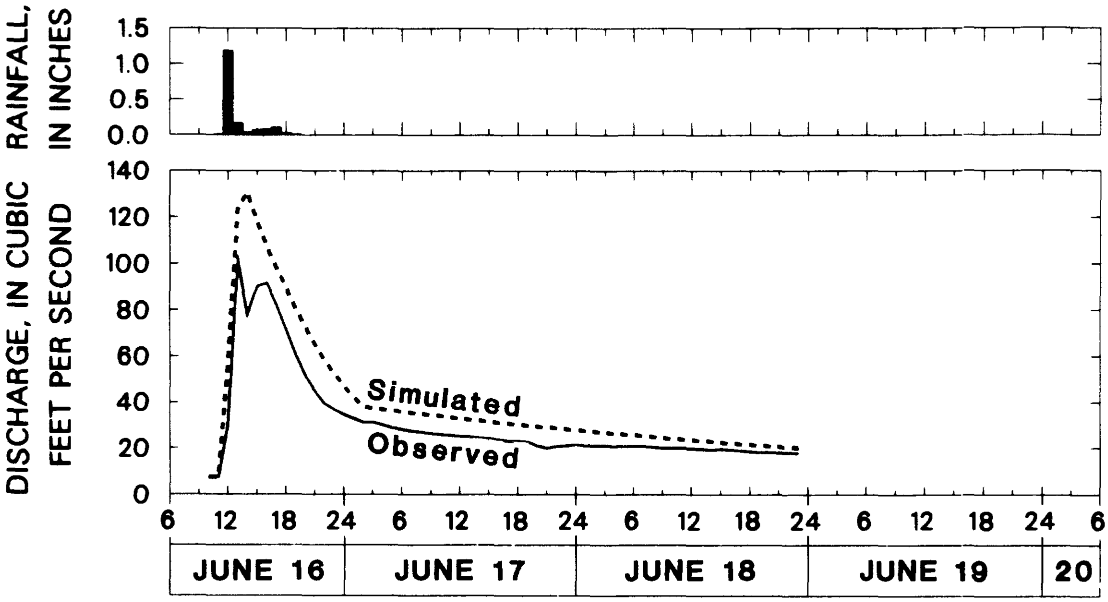


Figure 11M.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Sand Creek at Xeon Boulevard, storm of June 16, 1979

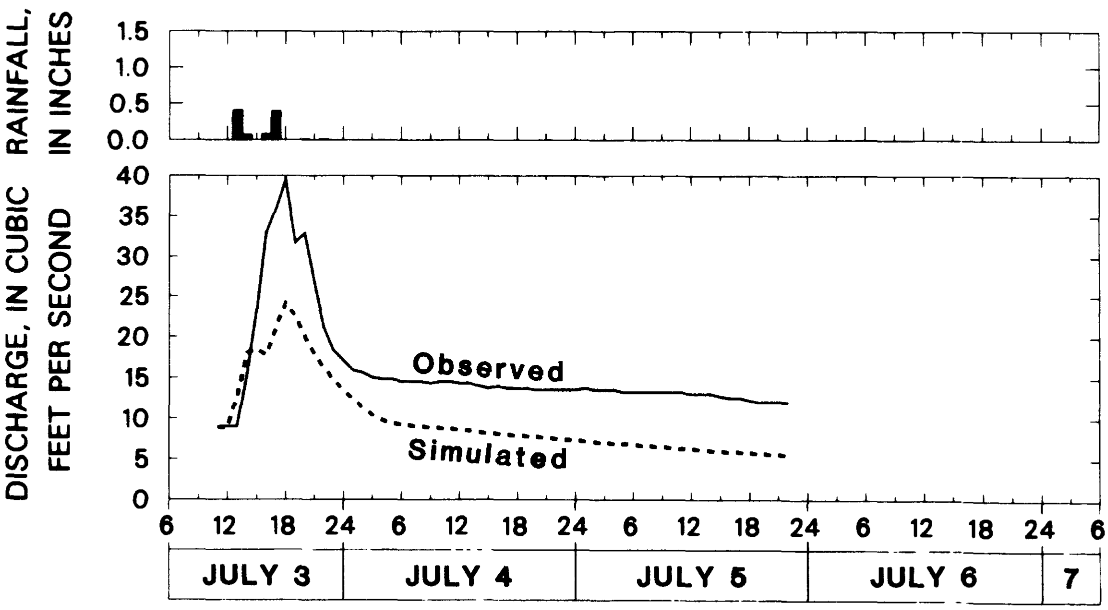


Figure 11N.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Sand Creek at Xeon Boulevard, storm of July 3, 1979

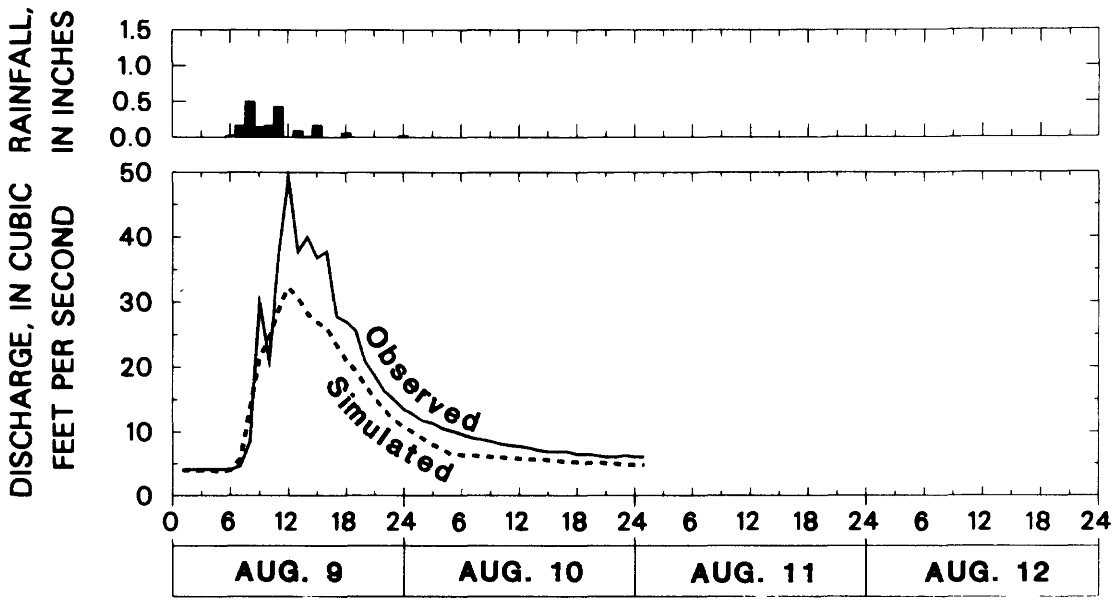


Figure 11O.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Sand Creek at Xeon Boulevard, storm of August 9, 1979

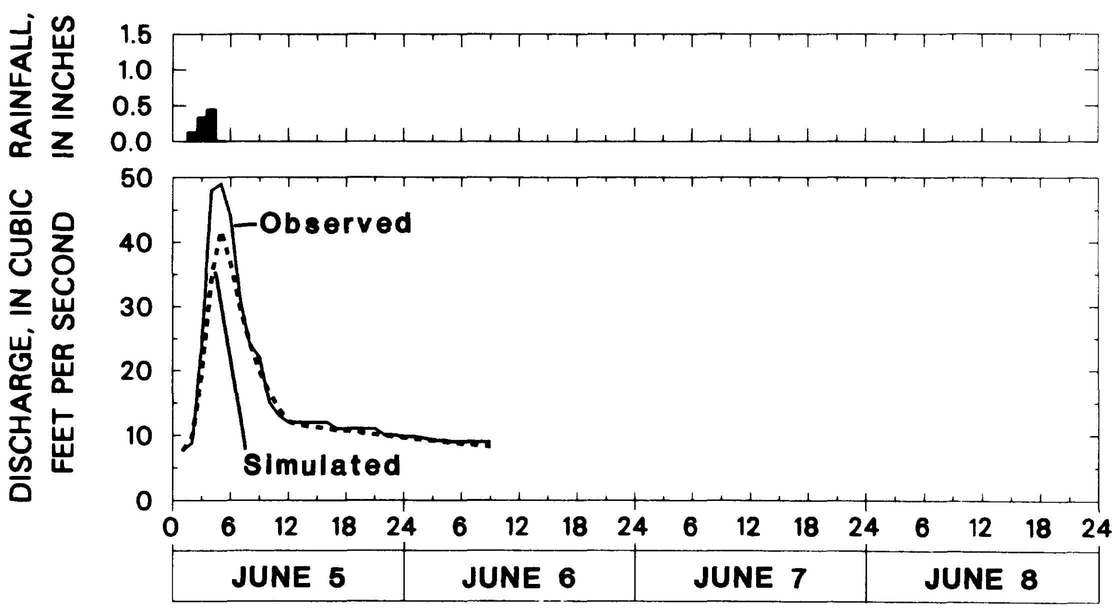


Figure 11P.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Sand Creek at Xeon Boulevard, storm of June 5, 1980

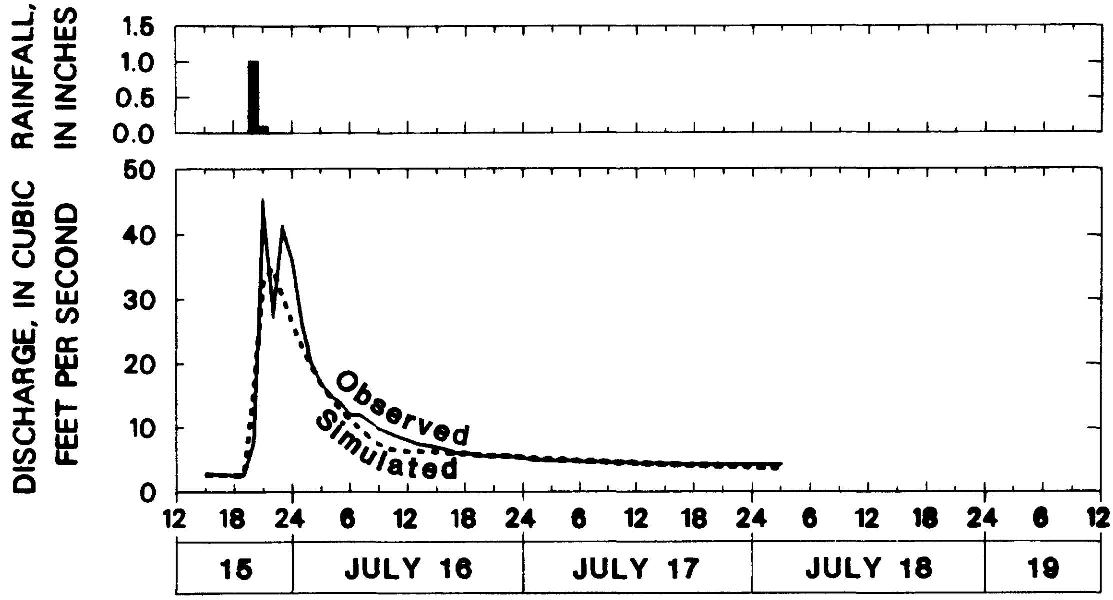


Figure 11Q.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Sand Creek at Xeon Boulevard, storm of July 15, 1980

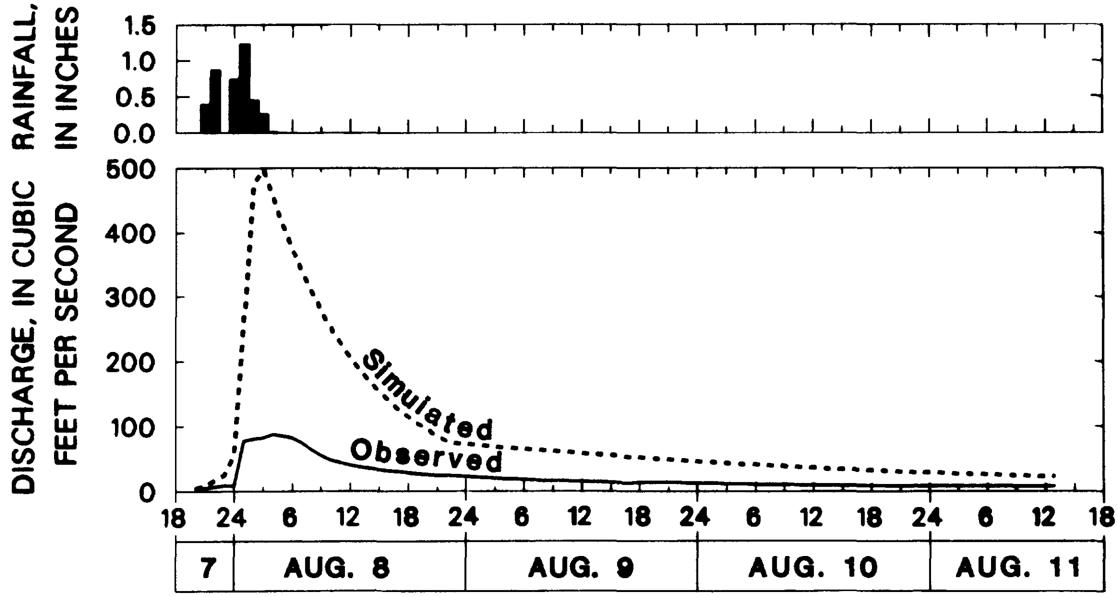


Figure 11R.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Sand Creek at Xeon Boulevard, storm of August 7, 1980

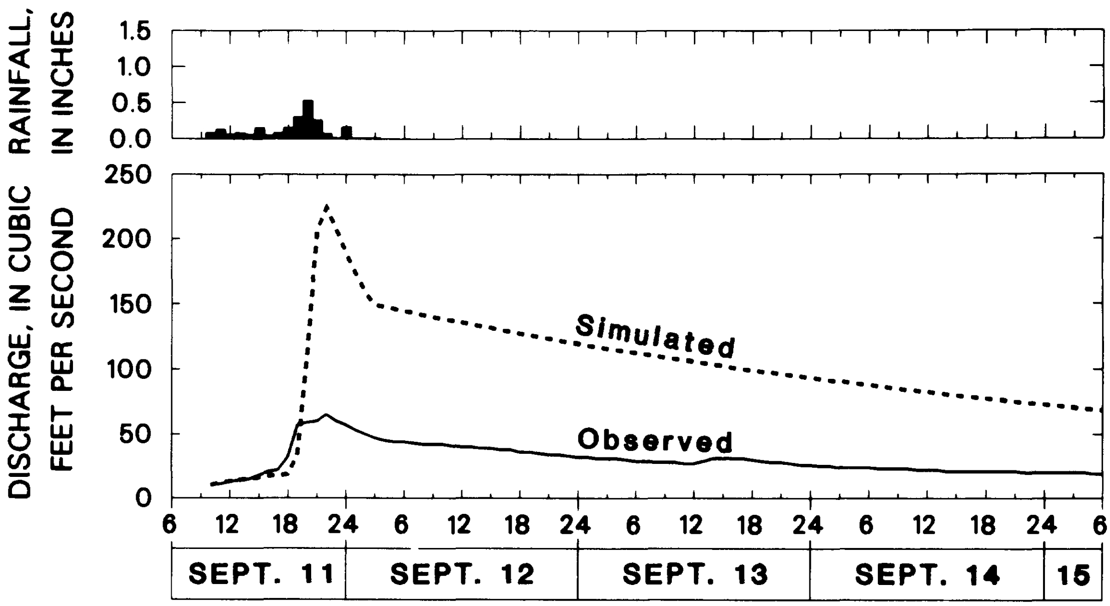


Figure 11S.--Simulated versus observed hydrographs using computed HEC-1 input parameters for Sand Creek at Xeon Boulevard, storm of September 11, 1980

Figure 12 shows that 10 of the 19 recorded hydrographs are matched for peak flow within 30 ft^3/s, or within 50 percent of the observed peak discharge by simulations using the generalized models.

The results were poorest for RG-2, the rural basin with a drainage area of 10.6 mi^2 for which the greatest peak flow suitable for modeling was 16 ft^3/s. Such conditions are difficult to model because the small peak flow is subject to many influences over a large area. For example, the initial infiltration capacity over the basin can vary from zero for saturated wetlands to nearly 100 percent if the soils are excessively dry.

The effect of ponding upstream from restrictive roadway culverts creates a problem in modeling the Sand Creek basin. The lower peaks were not affected because they passea through the small culverts without attenuation, but the two

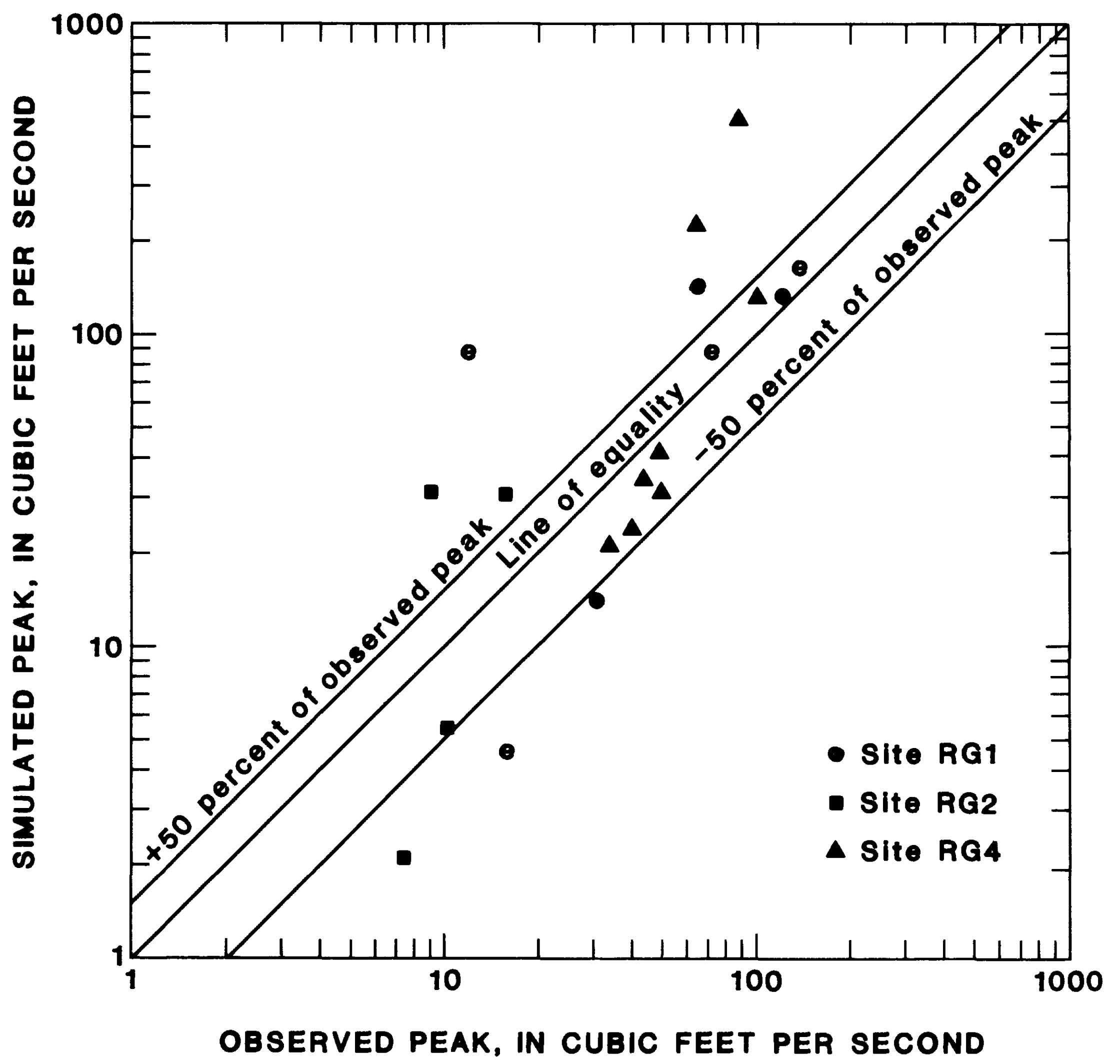


Figure 12.--Simulated versus observed hydrograph peaks using regression equations to compute HEC-1 input variables

Table 11.—Summary of differences between simulated and observed peak discharges

[as a percent of the observed peak discharges]

Site	High	Low	Mean	Median	Number of comparisons
OVERALL	642	11	120	42	19
RG-1	642	11	133	54	7
RG-2	247	46	115	84	4
RG-4	466	14	111	36	8

larger peaks (August 7 and September 11, 1980) were noticeably affected (figs. 11R and 11S). To account for ponding, the basin would have to be subdivided at the restrictive culverts and flow through the storage areas modeled using reservoir-routing techniques. This procedure would require additional recording stations in the storage ponds.

Because of the few storms during the study, all recorded hydrographs were used to calibrate the models and the models remain untested on independent events. It is not possible to evaluate the accuracy of these models without additional data. They are not appropriate for extending peak record with time or for predicting peaks and volume if basin characteristics are significantly changed because of the unknown error associated with the results.

Further study is needed in two areas. First, additional data are needed to fully test the linear equations used to compute HEC-1 input-variable values. Since only eight significant runoff events occurred and were recorded during the 2 years of data collection, all events were needed to develop reasonable linear equations. If only half the events were used in a multiple regression, as originally intended, and the other half used to verify the results, the resulting linear equations would have a much greater degree of error associated with them. Second, further study is needed to determine how model variables change as land use changes in each basin before the models can be used as a predictive tool to determine changes in runoff due to development.

WATER-QUALITY ASSESSMENT

Field Measurements, Chloride, Dissolved Solids, and Suspended Sediment

Table 12 is a statistical summary of field measurements and chloride, dissolved-solids, and suspended-sediment concentrations at the four sites in the Coon Creek watershed. The mean of the streamflows measured during sample collection indicates that the headwaters upstream from RG-1 were the source of about half the flow measured at RG-5, but the median, which probably is a better indication of the central tendency of much of the skewed data resulting from this study, indicates that RG-1 supplies less than one third of the streamflow measured at RG-5. The remaining flow was supplied by tributaries, such as County Ditch 58 and Sand Creek, direct runoff, and ground-water discharge.

A correlation coefficient higher than 0.93 was found for specific conductance and dissolved-solids concentrations at all sites except RG-2. A high coefficient is expected because specific conductance is dependent on the ions in solution, and the dissolved solids are mostly salts that dissociate to form ions in water. The limited range of values at RG-2 can reduce the coefficient but it is possible that dissolved organic substances naturally present in the water, but not measurable as specific conductance, were affecting the relationship.

The smallest range in dissolved-solids concentrations and specific conductance was found at RG-2. The relatively flat rural land and wetlands in this watershed reduce total runoff and allow percolation and ponding of water, which may stabilize the quality of the water before it discharges to the stream. The lowest mean and median dissolved-solids concentration and specific conductance also were found at RG-2.

The highest mean and median dissolved-solids concentrations and specific conductance were found at RG-4. This can result from the high quantity of soluble salts, such as sodium chloride, that may be flushed from urban surfaces. Alternating periods of deposition and flushing can result in large fluctuations that probably gave RG-4 both the highest and lowest values in the watershed for dissolved-solids concentrations and specific conductance.

Streams in the Coon Creek watershed generally were slightly alkaline. The highest mean pH, 7.6, was found at RG-4. The lowest mean and median pH occurred at RG-1. The greatest pH range, 2.3 units, occurred at both RG-2 and RG-5. A pH less than 6.5, the limit established for freshwater aquatic life (Minnesota Pollution Control Agency, 1978), was measured at RG-1 and RG-5 in February 1980 and at RG-1 and RG-2 in September 1980. These values could result from discharge of acidic waters from peat deposits in the watershed.

Table 12.—Statistical summary of field measurements, and chloride, dissolved-solids, and suspended-sediment concentrations

[N, number of samples; SD, standard deviation; values in milligrams per liter except as indicated]

Constituent	N	Mean	Median	Min-imum	Max-imum	SD	N	Mean	Median	Min-imum	Max-imum	SD
	RG-1						RG-2					
Streamflow (ft^3/s)	14	32.5	17.9	3.2	183	42.2	13	3.9	3.4	0.6	10.7	3.5
Specific conductance (umho/cm)	14	362	382	140	480	93	14	323	334	226	410	58
pH (units)	14	7.0	7.6	6.2	8.0	—	14	7.1	7.7	6.2	8.5	—
Water temperature (°C)	14	14.8	16.0	3.0	22.0	6.0	14	16.8	19.2	3.0	26.0	6.9
Dissolved oxygen	13	7.4	7.4	2.4	10.5	2.2	14	8.7	9.4	3.6	11.9	2.6
Dissolved oxygen, percent saturation	13	74	79	27	100	19	14	90	86	40	140	29
Dissolved chloride	14	6.0	6.0	4.8	7.4	0.9	14	7.6	7.6	5.3	12.0	1.7
Dissolved solids	14	257	275	130	311	53	14	240	237	166	300	38
Suspended sediment	14	45	25	5	139	42	14	23	20	6	53	16
	RG-4						RG-5					
Streamflow (ft^3/s)	14	15.8	11	2.1	51.2	15.0	14	61.4	64.7	19.7	131	33.8
Specific conductance (umho/cm)	14	448	492	124	965	216	14	410	406	237	659	97
pH (units)	14	7.6	7.8	7.1	8.2	—	14	7.2	7.8	6.1	8.4	—
Water temperature (°C)	14	15.4	17.0	2.5	21.0	6.0	14	16.4	18.0	0.0	24.5	7.0
Dissolved oxygen	13	8.0	7.6	5.3	12.2	2.2	13	8.1	7.9	4.9	12.0	1.9
Dissolved oxygen, percent saturation	13	80	76	60	108	13	13	83	85	53	104	15
Dissolved chloride	14	26.9	16.5	4.8	180	44.5	14	19.6	13.0	7.8	100	23.4
Dissolved solids	14	313	340	91	602	140	14	286	294	178	408	57
Suspended sediment	14	85	24	3	521	140	14	79	56	16	295	82

The lowest mean water temperature was observed at RG-1. The highest mean water temperature occurred at RG-2 and may have resulted from slow velocities and lack of forest cover which allowed solar heating of the water.

DO concentrations generally were highest during winter and lowest during summer, being influenced by water temperature. The highest DO concentration, 12.2 mg/L, occurred at RG-4 on November 2, 1979. The lowest DO concentration at all four sites, on August 8, 1980, coincided with the highest streamflows sampled. Many of these low DO concentrations were below the minimum 7.0 mg/L required for the maintenance of good fish populations (Minnesota Pollution Control Agency, 1978).

Figure 13 shows DO expressed as percent of saturation, avoiding the effects of temperature-dependent solubility. The highest mean and median DO concentration and DO percent saturation was found at RG-2. DO was supersaturated in many samples from RG-2, reaching a maximum of 140 percent on July 10, 1980. Supersaturation observed at RG-2 was probably the result of photosynthesis by phytoplankton in the stream.

Mean and median dissolved chloride concentrations were lowest at RG-1 and RG-2 (table 12). Substantially higher mean and median concentrations were found at the downstream sites, RG-4 and RG-5.

Figure 14 shows chloride concentrations at each of the sites. Concentrations generally were below 10 mg/L at RG-1 and RG-2, but were higher and more variable at RG-4 and RG-5. The highest chloride concentrations were sampled at RG-4 on February 21, 1980, and at RG-5 on February 22, 1980, containing 180 and 100 mg/L, respectively. The maximum concentration of chloride allowed for public water supplies is 250 mg/L (U.S. Environmental Protection Agency, 1977; Minnesota Pollution Control Agency, 1978). The chloride load carried past RG-4 and RG-5, when sampled, was 2,030 lb/d and 12,700 lb/d, respectively. High chloride concentrations during winter are characteristic of runoff from areas where deicing salt has been applied to roads.

Suspended sediment is generally considered a significant carrier of pollutants in streams because the particles act as a substrate to which pollutants can become sorbed. Table 12 shows that the mean and median concentration of suspended sediment was lowest at RG-2. The low streamflows and slow velocities in this drainage ditch substantially reduce its sediment-carrying capacity.

The highest mean suspended-sediment concentration was found at RG-4; the highest concentration was obtained during a rainstorm on August 9, 1979. Construction activities upstream from the sampling site and erosion of channeled parts of the stream probably contributed most of the suspended sediment found at RG-4.

The highest median suspended-sediment concentration was found at RG-5. High concentrations may result from higher velocities and increased turbulence at this site, which can increase sediment-carrying capacity.

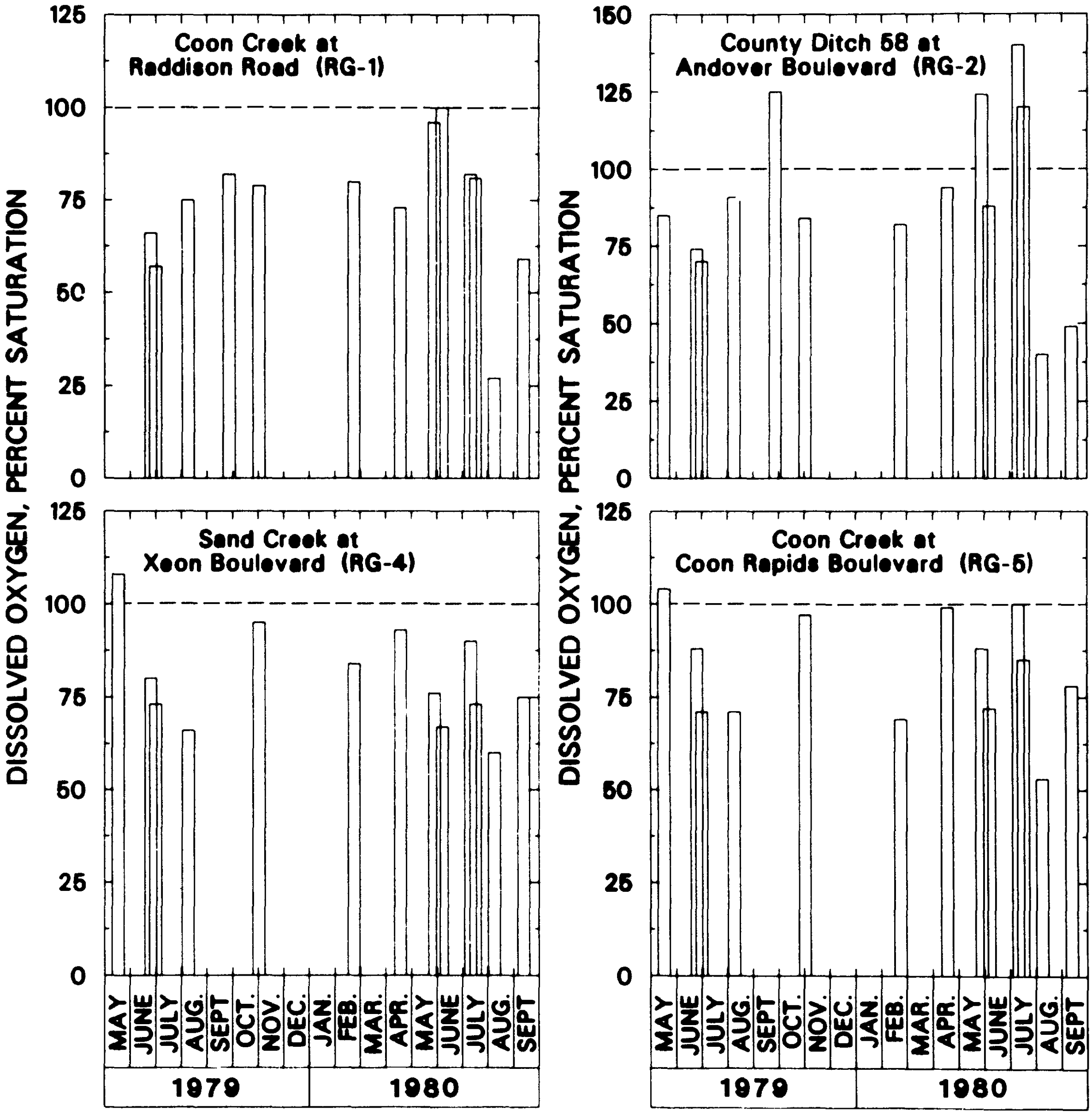


Figure 13.--Percent saturation for dissolved oxygen in Coon Creek watershed

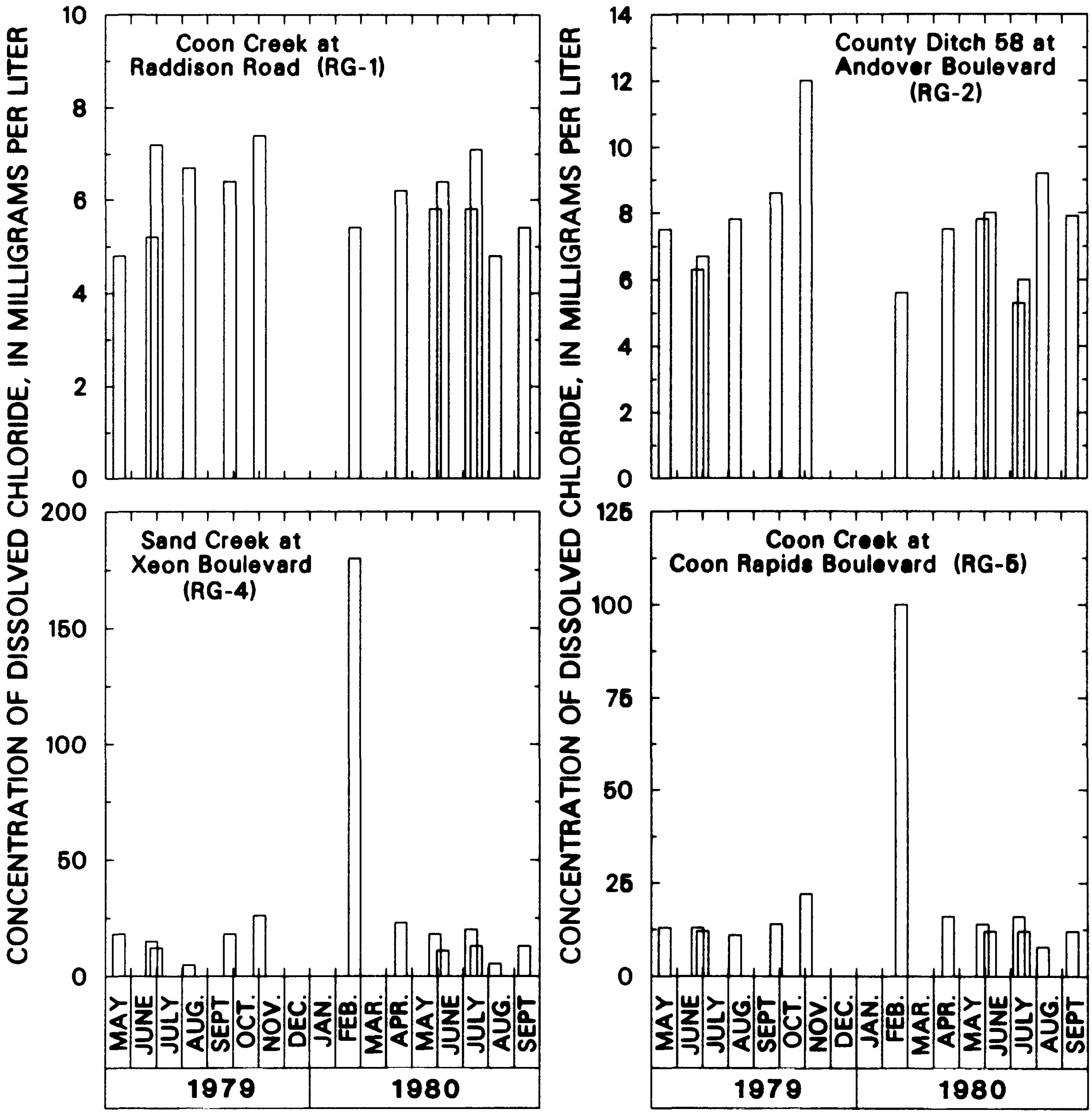


Figure 14.--Concentration of chloride in Coon Creek watershed

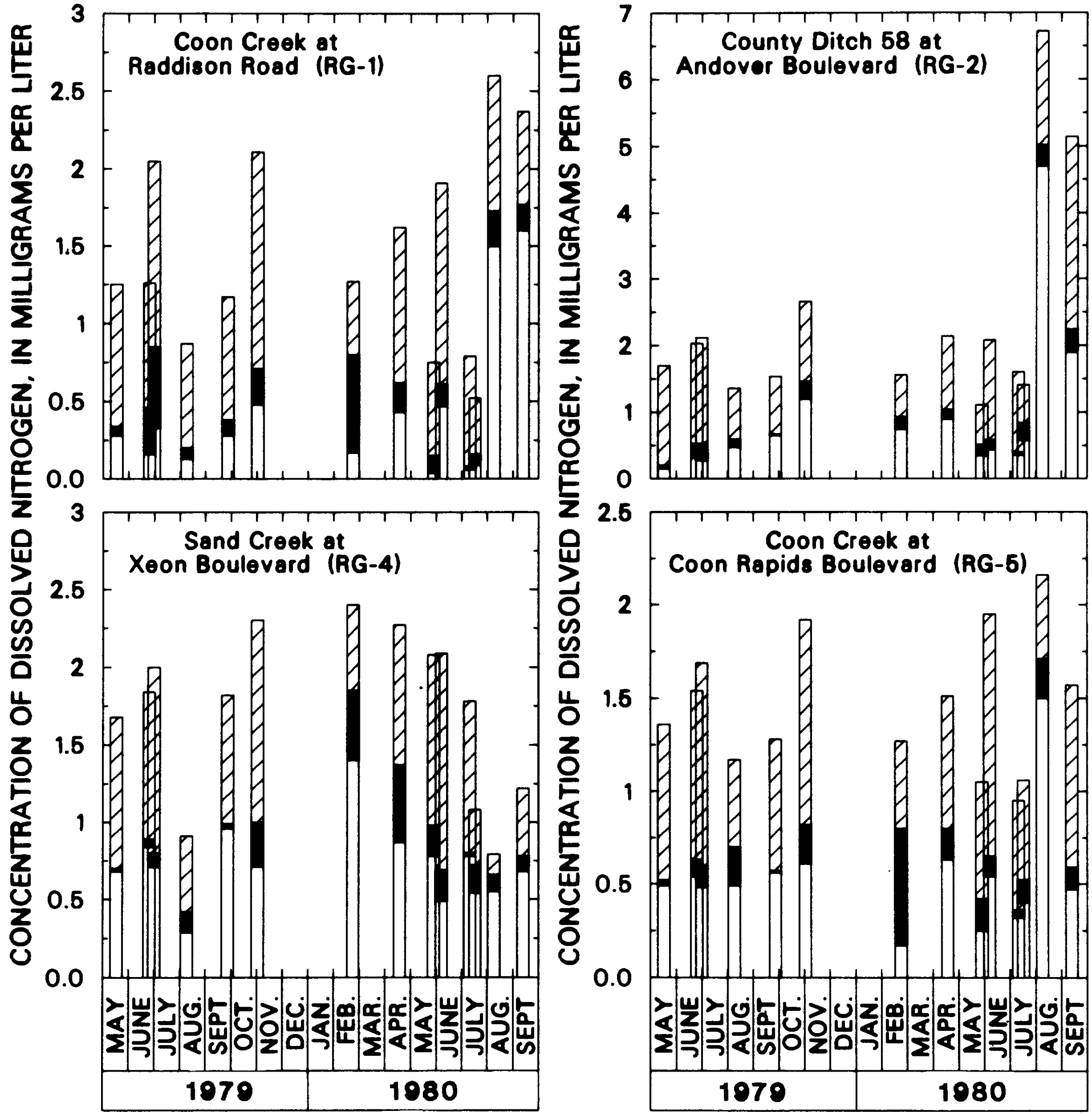
Table 13 shows the Pearson product-moment correlation coefficients that exceeded 0.70 between suspended-sediment concentrations and other measurements and concentrations at each of the sites. The high correlation coefficients show that higher streamflow is usually accompanied by an increased concentration of suspended sediment at all of the sites. Total phosphorus, total recoverable iron, and suspended organic carbon are strongly associated with suspended sediment at all of the sites. Several high coefficients suggest that the suspended sediments at RG-4 are associated with potentially toxic metals including arsenic, copper, and lead. Elevated concentrations of lead are frequently associated with urban runoff.

Table 13.—Correlation coefficients greater than 0.70 between suspended-sediment concentrations and other measurements and concentrations

	RG-1	RG-2	RG-4	RG-5
Streamflow	0.86	0.85	0.81	0.81
Biochemical oxygen demand	—	.85	.83	—
Dissolved NO_2+NO_3 nitrogen	.78	—	—	—
Total ammonia plus organic nitrogen	—	.78	.76	.87
Suspended ammonia plus organic nitrogen	—	—	.89	.91
Dissolved nitrogen	.81	—	—	—
Total phosphorus	.86	.85	.92	.87
Dissolved orthophosphate	.77	—	—	—
Arsenic	—	—	.83	—
Cadmium	—	—	—	.82
Copper	—	—	.82	—
Iron	.71	.72	.99	.87
Lead	.71	—	.96	.84
Manganese	—	—	.92	.96
Zinc	—	—	.92	—
Dissolved organic carbon	—	.72	—	—
Suspended organic carbon	.77	.81	.71	.82

Nitrogen, Phosphorus, Organic Carbon, and Biochemical Oxygen Demand

Figure 15 shows the variations in concentrations of dissolved nitrogen and its component forms at each site. Table 14 summarizes the results of analyses for various forms of nitrogen at each of the sites. Nitrogen is an essential nutrient for plants, and nitrate nitrogen commonly is applied as fertilizer in the watershed (Loren Hentges, oral commun., 1981). The lowest mean and median dissolved-nitrogen concentration was found at RG-1. The mean of 1.47 mg/L was composed of 14 percent ammonia nitrogen, 29 percent nitrite plus nitrate nitrogen, and 57 percent organic nitrogen.



EXPLANATION

- Dissolved organic nitrogen
- Dissolved ammonia nitrogen
- Dissolved nitrite plus nitrate nitrogen

Figure 15.--Concentration of dissolved nitrogen and its component forms in Coon Creek watershed

Table 14.—Statistical summary of concentrations of nitrogen, phosphorus, organic carbon forms, and biochemical oxygen demand in Coon Creek watershed

[Values in milligrams per liter; N, number of samples; SD, standard deviation]

Constituent	N	Mean	Median	Minimum	Maximum	SD	N	Mean	Median	Minimum	Maximum	SD
	RG-1						RG-2					
Dissolved nitrogen.....	14	1.47	1.30	0.52	2.60	0.65	14	2.36	1.85	1.10	6.70	1.58
Dissolved $NO_2 + NO_3$ nitrogen.............	14	.43	.28	.04	1.60	.50	14	.93	.53	.15	4.70	1.18
Dissolved ammonia nitrogen.............	14	.20	.16	.02	.63	.18	14	.18	.18	.02	.34	.10
Dissolved organic nitrogen.............	14	.83	.80	.36	1.40	.31	14	1.26	1.20	.57	2.90	.61
Suspended ammonia plus organic nitrogen......	14	.45	.42	.00	1.50	.39	14	.35	.35	.00	1.00	.35
Total ammonia plus organic nitrogen......	14	1.48	1.20	.82	3.20	.66	14	1.77	1.65	.73	3.70	.87
Total phosphorus.......	14	.17	.11	.04	.43	.13	14	.15	.12	.05	.27	.09
Dissolved orthophosphate as phosphorus...	14	.03	.02	.00	.11	.04	14	.03	.02	.00	.13	.04
Dissolved organic carbon...............	12	14.0	12.0	8.5	19.0	3.6	12	18.2	17.0	11.0	30.0	6.3
Suspended organic carbon...............	12	2.0	1.6	.4	7.6	2.0	12	2.2	2.0	.3	5.6	1.6
Biochemical oxygen demand...............	13	3.3	2.4	1.4	6.0	1.8	13	2.7	2.2	.3	5.5	1.7

Table 14.—Statistical summary of concentrations of nitrogen, phosphorus, organic carbon forms, and biochemical oxygen demand in Coon Creek watershed—Continued

Constituent	N	Mean	Median	Minimum	Maximum	SD	N	Mean	Median	Minimum	Maximum	SD
	RG-4						RG-5					
Dissolved nitrogen.....	14	1.74	1.80	0.79	2.40	0.53	14	1.48	1.45	0.95	2.20	0.36
Dissolved $NO_2 + NO_3$ nitrogen..............	14	.73	.71	.29	1.40	.26	14	.53	.49	.17	1.50	.31
Dissolved ammonia nitrogen..............	14	.17	.12	.02	.50	.15	14	.16	.12	.00	.63	.15
Dissolved organic nitrogen..............	14	.83	.92	.13	1.40	.38	14	.77	.71	.45	1.30	.27
Suspended ammonia plus organic nitrogen......	14	.39	.20	.00	2.60	.67	14	.61	.45	.00	2.60	.67
Total ammonia plus organic nitrogen......	14	1.39	1.30	.71	3.20	.62	14	1.55	1.40	.91	3.30	.66
Total phosphorus.......	14	.17	.09	.02	.71	.22	14	.20	.17	.05	.43	.13
Dissolved orthophosphate as phosphorus...	14	.02	.01	.00	.16	.04	14	.01	.01	.00	.08	.02
Dissolved organic carbon................	13	13.6	14.0	7.6	19.0	4.1	13	10.5	11.0	6.8	15.0	2.8
Suspended organic carbon................	12	1.2	1.0	.3	2.9	.7	12	2.6	2.6	.6	8.0	2.0
Biochemical oxygen demand................	14	3.6	3.2	1.1	7.9	1.9	14	3.0	3.0	1.3	4.9	1.1

One third of the mean and median total ammonia plus organic nitrogen at RG-1 was in the suspended form. Suspended ammonia plus organic nitrogen is generally associated with runoff, but here it did not correlate with streamflow. The highest concentration of total ammonia plus organic nitrogen at RG-1 occurred on June 29, 1979, and 47 percent was in the suspended form.

The highest mean, median, and maximum concentrations of dissolved nitrogen and dissolved organic nitrogen occurred at RG-2. Figure 15 shows that dissolved nitrogen concentrations at RG-2 were generally higher than at the other sites, but the concentrations in the last two samples significantly increased the mean. The highest concentration of nitrite plus nitrate nitrogen was found in the sample of August 8, 1980. The sample on September 12, 1980, had the highest concentrations of ammonia nitrogen and organic nitrogen.

Ammonia nitrogen comprised 8 percent of the mean dissolved nitrogen at RG-2. Nitrite plus nitrate and organic nitrogen averaged 39 and 53 percent of the dissolved nitrogen at RG-2, respectively. Only 20 percent of the mean total ammonia plus organic nitrogen was suspended, probably the result of limited runoff from the relatively flat topography in the RG-2 watershed.

The mean and median concentrations of dissolved nitrogen at RG-4 were the second highest and the median dissolved nitrite plus nitrate nitrogen concentration was the highest in the watershed. Nitrite plus nitrate nitrogen, ammonia nitrogen, and organic nitrogen comprised 42, 10, and 48 percent, respectively, of the mean dissolved nitrogen at RG-4.

High streamflows had lower dissolved-nitrogen concentrations at RG-4 than at RG-1 and RG-2. The highest streamflows sampled at RG-4 on August 9, 1979, and August 8, 1980, had the lowest concentrations of dissolved nitrogen. The highest concentrations of dissolved nitrogen, 2.4 mg/L, and dissolved nitrite plus nitrate nitrogen, 1.4 mg/L, occurred on February 21, 1980, during the lowest streamflow sampled.

Suspended ammonia plus organic nitrogen comprised 28 percent of the mean total ammonia plus organic nitrogen at RG-4. The highest concentration of suspended ammonia plus organic nitrogen occurred at RG-4 during the second highest streamflow sampled on August 9, 1979, and comprised 81 percent of the total ammonia plus organic nitrogen.

Table 14 and figure 15 show that the smallest range in concentrations of dissolved nitrogen, dissolved and total ammonia plus organic nitrogen, and dissolved organic nitrogen were found at RG-5. Variations in concentration may be obscurred by the integration of the various tributaries to the stream.

The mean dissolved nitrogen at RG-5 was composed of 11 percent ammonia nitrogen, 36 percent nitrite plus nitrate nitrogen, and 53 percent organic nitrogen. Suspended ammonia plus organic nitrogen comprised 40 percent of the mean total ammonia plus organic nitrogen at RG-5, the highest percentage for the sites.

Most of the ammonia detected in water samples occurs in an ionized form (NH_4^+); however, a part may be un-ionized (NH_3) depending on the pH and temper-ature of the water. The un-ionized ammonia is the form determined to be toxic to freshwater aquatic life and should not exceed a concentration of 0.02 mg/L (U.S. Environmental Protection Agency, 1977). The concentration of un-ionized ammonia was very near 0.02 mg/L in samples from RG-1 in June 1979 and from RG-5 in August 1979.

Mean concentrations of total phosphorus, an essential plant nutrient, (table 14) were similar at each site. The highest mean and median concentrations were found at RG-5. The greatest range in phosphorus concentration was found at RG-4. Figure 16 displays the variations in total phosphorus concentration found at each site.

The highest phosphorus concentrations measured at RG-1 (fig. 16) coincided with three of the four highest streamflows sampled (See Water-Quality Data at the end of report). The sample from RG-1 in September 1980 had only 0.21 mg/L total phosphorus, although it was collected at the peak of the second highest streamflow sampled. Much of the available phosphorus may have been flushed into the stream during runoff in August 1980, leaving less phosphorus available in September.

The smallest range in total phosphorus concentrations occurred at RG-2. This may result from the flat topography in this part of the watershed, which reduces peak runoff and flushing of constituents. The highest concentration at RG-2 was found in the samples collected June 29, 1979, and September 12, 1980. Concentrations of total phosphorus were different at RG-1 and RG-2, but the maxima shown in figure 16 generally are coincidental.

Total phosphorus concentrations at RG-4 differed from those at RG-1 and RG-2. Figure 16 shows that the maxima in July 1979 and September 1980 did not occur at RG-4. The highest total phosphorus concentration at RG-4, 0.71 mg/L, was found in August 1979. High concentrations of total phosphorus coincided with high streamflow at RG-4 and could be caused by runoff of fertilizers or detergents.

High concentrations of total phosphorus at RG-5 seem to coincide with high concentrations at the upstream sites (fig. 16). The highest concentration at RG-5, 0.43 mg/L, occurred in conjunction with the highest concentration at RG-4 on August 9, 1979, but was diluted by the main-stream flow, which probably had a lower concentration of total phosphorus.

Dissolved orthophosphate phosphorus is a nutrient readily available to plants and most frequently is the form of phosphorus applied as fertilizer. Applied to the soil, soluble orthophosphate rapidly adsorbs to soil particles and converts to insoluble forms preventing excessive leaching and runoff (Stewart and others, 1975). Dissolved orthophosphate concentrations in Coon Creek watershed ranged from 0.00 to 0.04 mg/L during most of the study. Table 14 shows that the highest mean and median concentrations of dissolved orthophosphate occurred at RG-1 and RG-2. The lowest mean concentration was found at RG-5.

Dissolved orthophosphate concentrations in 1979 exceeded 0.04 mg/L in one sample, when 0.07 mg/L dissolved orthophosphate was found at RG-2 on June 27.

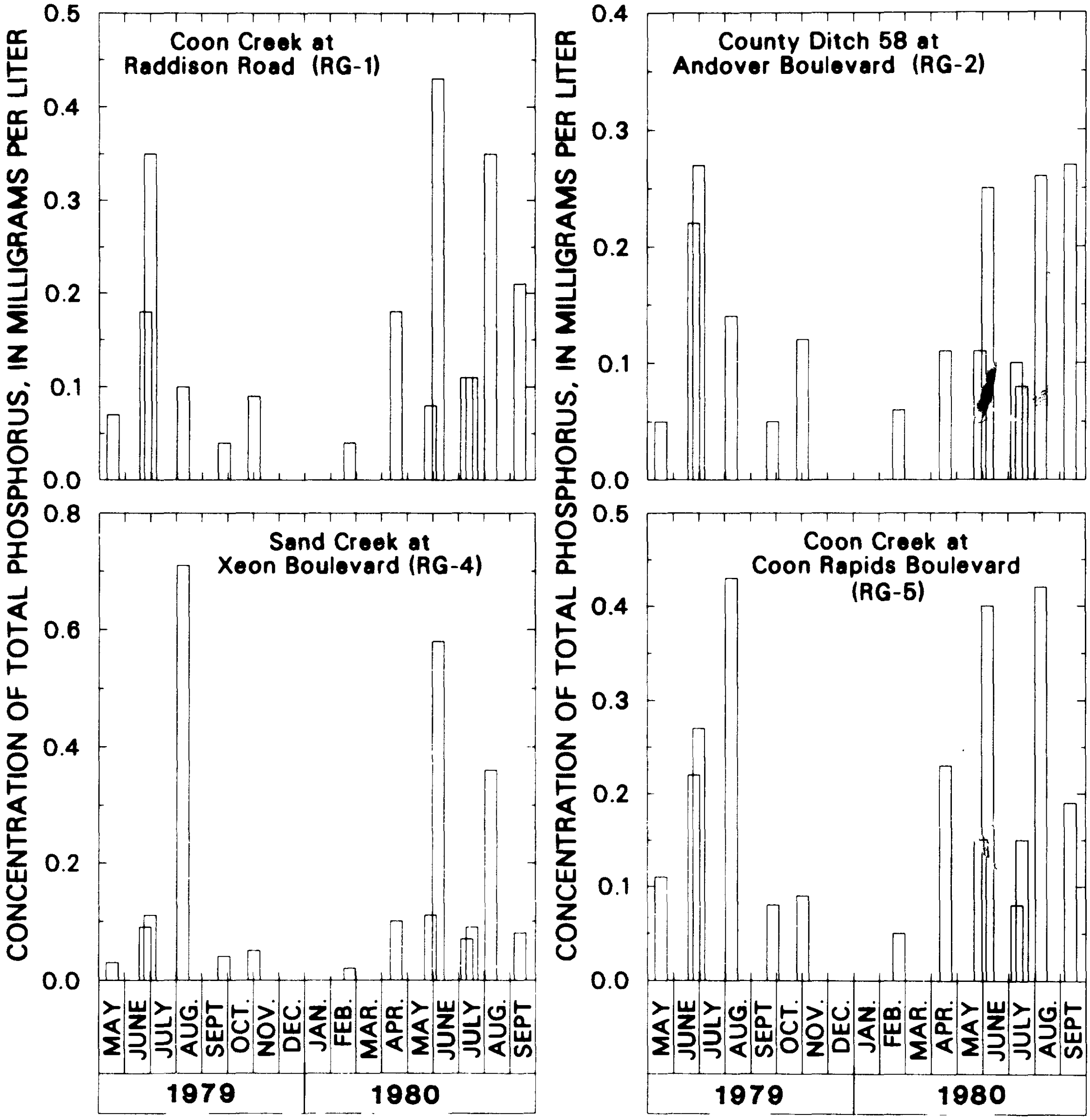


Figure 16.--Concentration of total phosphorus in Coon Creek watershed

The sample collected during higher streamflow two days later had only 0.02 mg/L dissolved orthophosphate. Many samples collected in 1980 had high concentrations of dissolved orthophosphate. The samples from RG-1 and RG-4 in June contained 0.11 and 0.16 mg/L, respectively. Concentrations of 0.10 and 0.05 mg/L were found on August 8 at RG-1 and RG-2, respectively. High dissolved orthophosphate concentrations at RG-1, RG-2, and RG-5 on September 12 accompanied reduced streamflow.

Concentrations of DOC (dissolved organic carbon) and SOC (suspended organic carbon) are probably introduced to streams from terrestrial sources and commonly form a major driving source of material and energy for stream metabolism (Wetzel, 1975). Wetzel (1975) also states that the SOC of streams is about 10 to 17 percent of the concentration of DOC. Figure 17 shows the organic carbon concentrations at each of the Coon Creek sites. SOC and DOC concentrations were not determined from the samples collected on August 8, 1980.

SOC at RG-1 ranged from 3 to 40 percent of DOC, and averaged about 15 percent. The SOC and DOC generally were highest in samples collected during high streamflow. The sample from RG-1 on February 22, 1980, had 0.5 mg/L SOC during the lowest streamflow sampled, but had a high concentration (18.0 mg/L) of DOC. Samples from RG-1 shown in figure 17 did not include quantification of SOC on June 27, 1979, and DOC on May 28, 1980.

The highest mean and median DOC concentrations in the watershed were found at RG-2. Figure 17 shows that the highest concentrations of organic carbon occurred in the first three samples from RG-2. The source of this organic carbon cannot be determined from the data.

SOC averaged about 12 percent of DOC in coincidental samples at RG-2, ranging from 2 to 22 percent. The percentage of SOC was highest on November 1, 1979, probably resulting from influxes of partly decomposed litter from the autumn leaf fall.

Concentrations of SOC generally were highest during higher streamflows at RG-4, but unlike RG-1 and RG-2, DOC was generally lowest during the higher streamflows. Concentrations of DOC in base flow from the upper reaches of the stream may be diluted by runoff containing mostly SOC from urban areas near the mouth of the stream. SOC averaged about 8 percent of DOC in coincidental samples at RG-4, and ranged from 2 to 33 percent. SOC was not determined for the sample collected August 9, 1979.

SOC averaged about 25 percent of DOC at RG-5, much higher than at the other sites. The 8.0 mg/L concentration of SOC on August 9, 1979, was the highest found in the watershed and was 114 percent of the DOC. Much of the DOC at RG-5 may have been assimilated by phytoplankton in the stream to be detected as SOC. SOC was not determined for the sample collected on November 2, 1979.

Five-day BOD was determined for each sample, except those from RG-1 and RG-2 on August 8, 1979. Five-day BOD is a gross measure of the amount of oxygen depleted in a sample of water as microorganisms decompose biodegradable materials over the 5-day period. These BOD's are unseeded, making the results

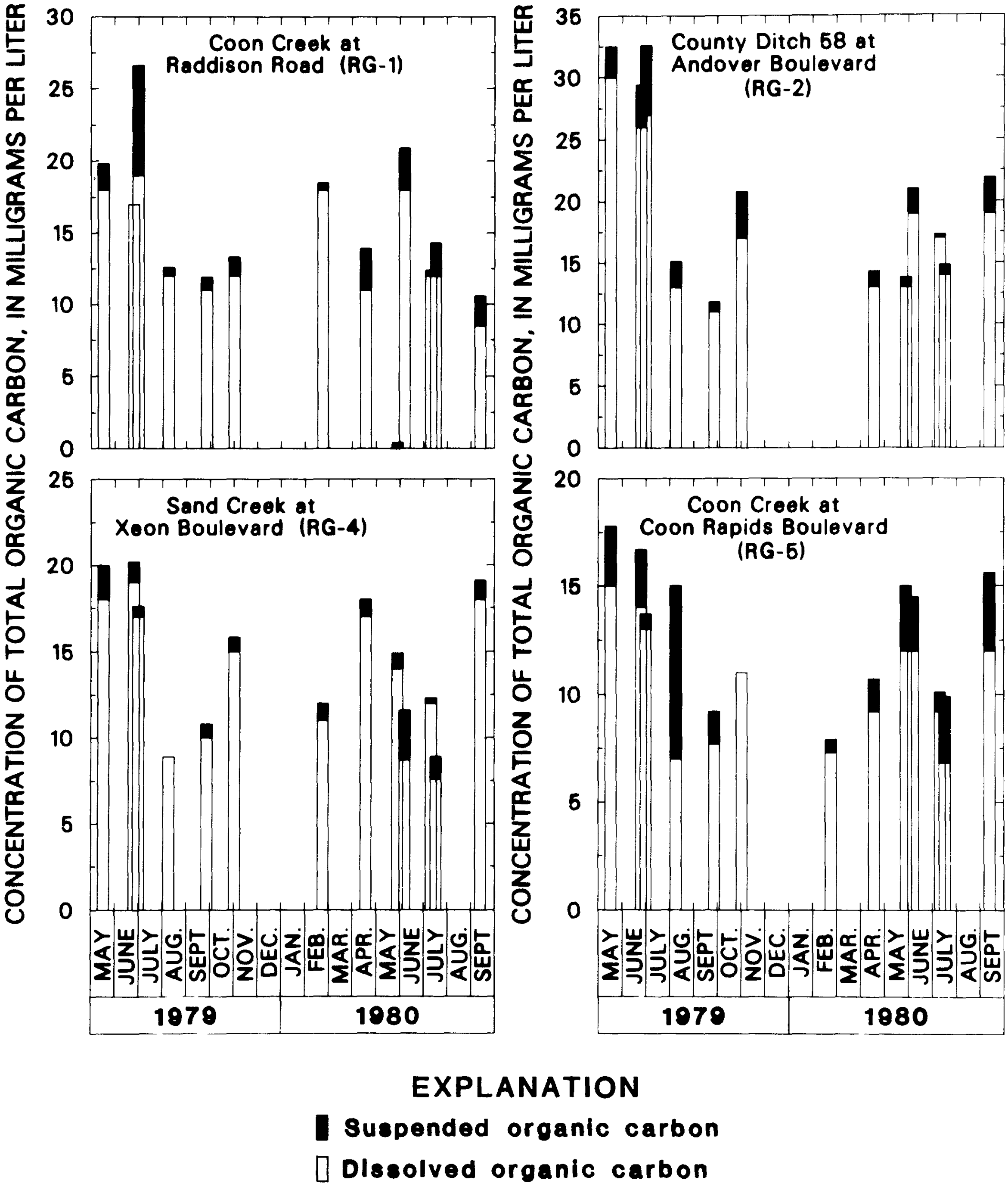


Figure 17.--Concentration of dissolved and suspended organic carbon in Coon Creek watershed

dependent on the presence of microorganisms in the sample and the quantity and composition of biodegradable materials.

The second lowest median concentration of BOD, 2.4 mg/L, was found at RG-1. The high standard deviation (table 14) indicates that the BOD was relatively variable. BOD's at RG-1 were generally highest during higher stream flows. The highest BOD sampled at RG-1 was found during the runoff on June 29, 1979. High BOD's were also found in the final two samples from RG-1. A 5.9 mg/L concentration of BOD on February 22, 1980, coincided with the lowest streamflow sampled, implying that a substantial quantity of biodegradable material was present in the stream that was unutilized because of the low productivity during winter. The few high BOD's at RG-1 produced a mean BOD, 3.3 mg/L, which was quite different from the median.

The lowest mean and median concentrations of BOD in the watershed were found at RG-2. BOD's were generally higher during high streamflows. The highest BOD's sampled at RG-2 were found in the last two samples, coinciding with the highest streamflows sampled.

Samples from RG-4 had the highest mean and median concentrations of BOD in the watershed with the highest standard deviation. High BOD was frequently associated with high streamflow at this site, but the highest streamflow sampled on August 8, 1980, had a 4.0 mg/L BOD, only slightly above the mean and median. The highest BOD was found on August 9, 1979, and accompanied peak concentrations of many constituents.

High BOD's at RG-5 also generally were present during high streamflows, although the highest BOD occurred during low streamflow on February 22, 1980. The low standard deviation of the BOD's at RG-5 indicates that relatively consistent concentrations of biodegradable materials were present at RG-5, again suggesting that the waters at RG-5 integrate variations observed in the tributaries.

Metals

Each sample from the Coon Creek watershed was analyzed for total recoverable concentrations of selected metals. Table 15 is a summary of the results of these analyses.

Concentrations of arsenic, an element commonly found in natural systems, did not exceed 5 ug/L (micrograms per liter) in the watershed. The highest mean, median, minimum, and maximum concentrations occurred at RG-5, but differences between sites were not significant.

Cadmium was not detected in most samples. The highest concentration measured occurred at RG-5 on August 9, 1979, and coincided with the second highest streamflow sampled.

Table 15.--Statistical summary of metal concentrations measured in samples from Coon Creek watershed

[Units in micrograms per liter; N, number of samples; SD, standard deviation]

Constituent	N	Mean	Median	Min-imum	Max-imum	SD	N	Mean	Median	Min-imum	Max-imum	SD
	RG-1						RG-2					
Arsenic....	12	2.8	3	1	4	1.0	13	2.08	2	0	4	1.0
Cadmium....	14	.4	0	0	1	.5	14	.4	0	0	2	.8
Chromium...	14	18	20	<10	30	8.4	14	17	20	10	30	5.8
Copper.....	14	2.5	2.5	0	17	1.9	14	2.1	2	0	5	1.5
Iron.......	9	3,010	2,400	1,500	6,700	1,680	9	3,360	2,100	1,700	7,900	2,170
Lead.......	14	3.6	2	0	17	4.7	14	3.1	2	0	10	3.3
Manganese..	14	291	275	190	420	86.0	14	386	440	150	610	149
Mercury....	12	—	—	<.1	<.5	—	13	—	—	<.1	<.5	—
Nickel.....	9	2.1	2	1	4	1.05	9	1.2	2	0	4	1.5
Zinc.......	14	19	20	0	30	9.5	14	21	20	0	50	15
	RG-4						RG-5					
Arsenic....	12	2.6	2.5	1	5	1.2	12	3.4	3.5	2	5	1.1
Cadmium....	14	.5	0	0	2	.8	14	.5	.0	0	4	1.1
Chromium...	14	18	20	10	30	6.7	14	20	20	10	30	6.3
Copper.....	14	4.1	3	1	11	3.1	14	3.4	2.5	0	8	2.3
Iron.......	9	2,400	1,600	480	6,900	2,320	9	3,540	2,900	1,300	6,800	1,960
Lead.......	14	15	6.5	<2	80	22	14	8.2	6	0	33	8.4
Manganese..	14	452	280	110	1,800	439	14	448	360	180	1,200	319
Mercury....	12	—	—	<.1	<.5	—	12	—	—	<.1	<.5	—
Nickel.....	9	3.2	3	2	7	1.7	9	2.3	2	0	4	1.5
Zinc.......	14	29	20	0	110	28	14	32	20	0	170	42

Concentrations of chromium were similar at each of the sites. Skougstad and others (1979) recommend that chromium concentrations be reported to the nearest 10 ug/L, which may conceal subtle differences in concentration between the sites. The highest mean chromium concentration was found at RG-5, but all the sites had about the same range in concentration.

Similar variations in the concentration of copper were found at RG-1 and RG-2. Samples from RG-1 and RG-2 had the highest concentrations of copper on June 27, 1980, when streamflows were near the mean. Concentrations of copper also were similar at RG-4 and RG-5. The highest concentrations of copper at RG-4 and RG-5 were measured on August 9, 1979. Table 15 shows that the highest mean and median copper concentrations were present at RG-4.

Iron concentrations varied considerably throughout the watershed. The lowest concentration was observed in February 1980 at RG-4. The highest concentration was observed in September 1980 at RG-2. Iron is an abundant and widespread constituent of rocks and soils (Hem, 1970) and it appears that dilution of natural iron concentrations by runoff from urban areas in the RG-4 basin resulted in mean and median iron concentrations that were the lowest in the watershed.

Iron concentrations correlated with phosphorus concentrations, providing coefficients that ranged from 0.88 at RG-5 to 0.95 at RG-1. Phosphates are attracted to iron in acidic waters to form ferric phosphates (Reid and Wood, 1976). This could explain the association between total phosphorus and total iron, but samples from the Coon Creek watershed generally had a neutral or moderately alkaline pH. Correlations between suspended-sediment and iron concentrations, and the correlations between suspended sediment and phosphorus, indicate that iron and phosphorus may be associated as a result of their common affinity for suspended-sediment particles.

Lead has many industrial and domestic uses and is often introduced to natural systems in significant quantities. Relatively low lead concentrations occurred at RG-1 and RG-2 (table 14), and no lead was detected in many of the samples. The highest concentration at RG-1 occurred during the highest streamflow sampled.

Table 15 shows that the highest mean and median lead concentrations occurred at RG-4. The sample from RG-4 on August 9, 1979, had the highest sampled concentration of lead. Runoff from the RG-4 watershed had 45 ug/L of lead in June 1980, more than twice the 21 ug/L found in the highest sampled streamflow in August 1980, when less accumulated lead may have been available to be washed into the stream.

The high lead concentration at RG-4 on August 9, 1979, was evident downstream and resulted in the highest lead concentration at RG-5 on the same date. The water at both sites was carrying about 18 pounds of lead per day when sampled. The second highest lead concentration at RG-5 was 15 ug/L sampled in February 1980 during low streamflow. The concentration of lead at RG-4 sampled in February 1980 was only 2 ug/L, which suggests that the lead at RG-5 came from a different source in the watershed—possibly other urban areas or highway drainage.

Manganese concentrations at RG-1 and RG-2 had similar variations throughout the sampling. Hem (1970) suggests that concentrations of manganese in natural water are influenced by the uptake and deposition of this element by plants, for which it is essential. Release of manganese from peat deposits may have caused the highest median manganese concentration in the watershed at RG-2.

Several samples from RG-4 and RG-5 had high manganese concentrations that gave these sites the highest mean concentrations in the watershed. The highest concentrations were measured at both sites in August 1979. Industrially, manganese is most commonly used as a hardener for steel (Merck and Co., 1968), but it is not known if this could provide a source for the concentrations measured.

Mercury concentrations reported from analysis of most samples were below detection limits and all were below 0.5 ug/L. Concentrations that ranged between 0.1 and 0.5 ug/L resulted from lowering the detection limits of analysis for this constituent during the study.

Total recoverable nickel determinations performed by the U.S. Geological Survey Central Laboratory during August 1978 through October 1979, were affected by contaminated reagents and the results are invalid (Ann Watterson, written commun., 1981). The results of total recoverable nickel determinations during this period, encompassing four values from each site, were not included with the results in this report.

Table 15 shows that the highest mean, median, maximum, and minimum concentrations of nickel in the watershed occurred at RG-4. The lowest mean concentration of nickel was found at RG-2, although RG-1, RG-2, and RG-5 had the same median concentrations. Variations in the concentration of nickel did not generally coincide with variations in streamflow, although the highest concentration, 7 ug/L at RG-4 on June 5, 1980, did occur during high streamflow.

High zinc concentrations seem to have occurred randomly in the watershed. Concentrations at RG-1 were all at or below 30 ug/L. Zinc concentrations of 50 ug/L occurred twice at RG-2 in February and August 1980. Concentrations of 50 ug/L occurred several times at RG-4. The highest concentration at RG-4 (110 mg/L) was measured in August 1979. One sample from RG-5 in August 1979 contained 50 ug/L, and the highest concentration (170 mg/L) was measured in February 1980. Zinc is generally present in natural waters, but the source of the high concentrations is not known.

The concentrations of most metals were well below standards and (or) recommendations for public water supplies. The lead concentration at RG-4 on August 9, 1979, exceeded the 50 ug/L allowed by the U.S. Environmental Protection Agency (1977) and the Minnesota Pollution Control Agency (1978) for public water supplies. Based on the effect on taste, it is required that concentrations of dissolved iron and manganese in public water supplies not exceed 300 and 50 ug/L, respectively (Minnesota Pollution Control Agency, 1978). Concentrations of dissolved iron and manganese were not determined for the samples, so it cannot be determined if limits were exceeded.

The maximum allowable concentrations of substances toxic to freshwater aquatic life (U.S. Environmental Protection Agency, 1977) were exceeded in some samples from the Coon Creek watershed. In several samples from the watershed, cadmium concentrations exceeded the 1.2 ug/L limit for cladocerans. The 30 ug/L recommended for lead (National Academy of Sciences, National Academy of Engineering, 1973) was exceeded in two samples from RG-4 and one sample from RG-5. The detection limits for total mercury do not indicate if concentrations exceeded the maximum of 0.05 ug/L.

Base-flow Samples

Comparison of the mean concentrations obtained from samples throughout the study with mean concentrations from the five samples obtained under base-flow conditions can provide an indication of the source of constituents sampled. Constituents that have a higher concentration during base flow may be present in ground water discharging to the creeks and may not be significant in runoff. Constituents that have a lower concentration during base flow may be introduced with runoff and might be controlled to prevent significant degradation of stream quality. Table 16 shows the mean and median concentrations of selected constituents sampled during base-flow conditions.

Concentrations of DOC, arsenic, cadmium, chromium, copper, nickel, and zinc were not substantially different in samples collected during base flow than mean and median concentrations of all the samples collected during the study. Similar average concentrations may result from analytical limitations that conceal subtle differences or from equivalent contributions from ground-water discharge and runoff.

All the sites had higher average dissolved-solids concentrations and specific conductance at base flow than throughout the study, although base flow at RG-2 had a slightly lower average dissolved-solids concentration. The highest base-flow values for these constituents were found at RG-4. Runoff may contain high concentrations of dissolved solids initially, but after this first flush will generally contain low concentrations that dilute the base-flow concentrations present in the stream.

Mean dissolved chloride concentrations were lower in base-flow samples from all sites in the watershed. Median dissolved chloride concentrations in base flow at RG-4 and RG-5 were higher than throughout the study. The average base-flow chloride concentrations at RG-4 and RG-5 were substantially higher than the average base-flow concentrations at RG-1 and RG-2, suggesting that contaminant inputs from urban areas are evident during base-flow conditions.

Mean and median BOD concentrations were lower in base-flow samples at all sites except RG-2, implying that most of the BOD is introduced to the streams with runoff. The mean base-flow BOD ranged only 0.2 mg/L between the sites. Higher average DO concentrations in base-flow samples may have been effected by the lower BOD.

Mean and median base-flow concentrations of suspended sediment were lower than average concentrations throughout the study. The mean and median sediment concentrations in base flow at RG-5 were much higher than at the other sites.

Table 16.—Average base-flow concentrations of selected constituents sampled in Coon Creek watershed

[values in milligrams per liter except as indicated]

Constituent	RG-1		RG-2		RG-4		RG-5	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Streamflow (ft^3/s)........	13	7.1	3.4	1.4	6.9	5.0	41	27
Specific conductance (umho/cm)...............	414	428	331	376	532	528	443	453
pH (units)................	7.6	7.7	7.7	7.6	7.8	8.0	7.9	7.9
Dissolved oxygen..........	7.6	7.9	9.8	9.9	8.2	7.7	8.4	8.2
Percent saturation........	81	82	110	124	88	85	95	94
Dissolved chloride........	5.6	5.8	7.1	7.5	18	18	14	14
Dissolved solids..........	285	293	226	231	385	386	311	318
Suspended sediment........	23	16	19	15	20	21	36	34
Dissolved nitrogen........	1.1	1.2	1.6	1.6	1.8	1.8	1.2	1.3
Dissolved NO_2+NO_3.........	.16	.16	.37	.35	.81	.78	.43	.49
Dissolved ammonia.........	.12	.10	.10	.05	.06	.03	.07	.04
Dissolved organic N.......	.76	.79	1.1	1.2	.97	.98	.74	.71
Suspended ammonia + organic N..............	.34	.33	.31	.40	.14	.10	.42	.40
Total ammonia + organic N...............	1.2	1.2	1.5	1.3	1.2	1.3	1.2	1.2
Total phosphorus..........	.10	.08	.11	.10	.07	.07	.13	.11
Dissolved orthophosphate..	.01	.01	.03	.03	.01	.01	.01	.01
Dissolved organic carbon..	14	14	19	17	15	14	12	12
Suspended organic carbon..	.9	.65	1.6	.8	1.0	.9	2.2	2.7
Biochemical oxygen demand..................	2.2	2.0	2.1	2.2	2.3	2.6	2.3	2.2
Arsenic (ug/L)............	2.5	2.5	2.2	2.0	2.2	2.5	3.0	2.5
Cadmium (ug/L)............	.4	.0	.2	.0	1.0	1.0	.2	.0
Chromium (ug/L)...........	16	11	19	20	17	20	21	20
Copper (ug/L).............	3	3	2	1	3	2	3	2
Iron (ug/L)...............	1,830	1,600	2,000	2,000	1,270	1,500	2,400	2,700
Lead (ug/L)...............	2	1	2	1	4	4	2	2
Manganese (ug/L)..........	298	320	340	300	256	240	274	250
Nickel (ug/L).............	2.5	2.5	0	0	2.5	2.5	1	1
Zinc (ug/L)...............	18	20	14	10	20	20	14	20

Mean and median base-flow concentrations of SOC, suspended ammonia plus organic nitrogen, and total phosphorus also were usually lower. Mean base-flow concentrations of all forms of dissolved nitrogen sampled were usually lower at all sites except RG-4, where organic and nitrite plus nitrate nitrogen concentrations were higher in base flow than during the whole study.

Mean and median concentrations of iron, manganese, and zinc were lower during base flow than at higher flows, and the greatest differences occurred at RG-4 and RG-5. Mean and median concentrations of lead were lower in base-flow samples at all sites. Mean and median base-flow concentrations of lead were 2 ug/L or less at all sites except RG-4, where the average base-flow lead concentration was 4 ug/L.

Basin Yields

The quantity of constituents carried by a stream, the load, can be calculated from the streamflow and the concentration of the constituents. Coon Creek at RG-5, having the highest mean discharge and relatively high constituent concentrations, almost consistently carried the highest loads.

The load value can be expressed as a function of the drainage area for a site. Dividing the load by the drainage area provides the yield; a value that facilitates comparisons between each of the sites sampled.

Table 17 shows the mean and median yields of selected constituents for each of the sites in units of pounds per day per square mile. It should be noted that these values are not representative yields, but are influenced by the high-flow biasing of sample collection. The yields were computed using only those values that were not qualified with remarks, such as "less than."

RG-4 and RG-5 had the higher average yields. Site RG-2 almost consistently had the lowest yields.

The waters at RG-1 carried the highest yields of most nutrients sampled, including dissolved ammonia, organic nitrogen, and dissolved orthophosphate phosphorus. High yields of BOD and SOC also were found at RG-1. High yields of cadmium, iron, and zinc also are apparent, but the source is not known.

The high yields of nutrients together with the rather high yield of suspended sediment suggest that agricultural practices may be allowing erosion of croplands and contributing to the nutrient load in the stream. The much lower yields at RG-2 may be related to the flat topography in the drainage area and possible trapping of sediment and nutrients in wetlands and ponds.

High yields of certain constituents at RG-4 and RG-5 may be related to the extent of urbanization in the associated watershed. High yields of BOD, chloride, dissolved solids, total phosphorus, and several metals, including lead, are frequently associated with runoff from urban areas. High yields of suspended sediment may result from construction activities in the watershed or bank erosion above the sampling site.

Table 17.—Average basin yields from the Coon Creek watershed

[Values in pounds per day per square mile]

Constituent	RG-1		RG-2		RG-4		RG-5	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Dissolved chloride	31	19	16	14	69	72	51	54
Dissolved solids	1,080	824	479	405	1,140	1,290	912	1,080
Suspended sediment	490	95	69	42	1,000	89	390	170
Dissolved NO_2+NO_3	5.6	.92	2.7	.63	3.2	2.9	2.2	1.8
Dissolved ammonia	1.2	.54	.38	.21	.78	.46	.56	.48
Dissolved organic N	4.7	3.2	2.8	2.2	3.8	2.6	2.7	2.9
Total ammonia + organic N	8.9	4.9	4.2	3.0	8.7	5.2	6.2	4.5
Suspended ammonia + organic N	3.0	1.2	1.0	.36	4.1	.96	2.9	1.1
Total phosphorus	1.4	.31	.36	.21	1.8	.28	.90	.60
Dissolved ortho-phosphate	.4	.4	.06	.01	.2	.06	.06	.02
Suspended organic carbon	12	4.3	5.6	3.4	5.3	3.4	9.6	5.8
Dissolved organic carbon	57	41	41	30	58	57	34	36
Biochemical oxygen demand	26	7.6	7.1	3.5	25	9.0	11	8.8
Arsenic	.018	.007	.004	.001	.019	.008	.013	.014
Cadmium	.005	.0	.001	.0	.004	.0	.003	.0
Chromium	.14	.05	.04	.03	.11	.07	.07	.06
Copper	.01	.006	.005	.004	.04	.01	.02	.008
Iron	27	12	6.8	3.7	23	5.4	15	9.9
Lead	.06	.009	.009	.003	.17	.03	.04	.01
Manganese	1.3	.89	.82	.42	3.7	.93	2.0	.97
Nickel	.02	.006	.002	.0006	.02	.008	.009	.004
Zinc	.14	.04	.05	.03	.30	.08	.12	.08

Bottom-Material Samples

One sample of bottom material was collected from each of the four sites in the Coon Creek watershed on September 26, 1979. The results from analysis of these samples are shown in table 18.

The composition of bottom material and the amount of contact with the stream water affect the kind and quantity of constituents that will be sorbed to it. Variability of bottom-material composition in a given reach of a stream can, therefore, allow a wide range of constituent concentrations between replicate samples at a given site. Multiple samples from each site could have provided a better overall indication of the bottom material quality, but the expense of the analysis and project funding constraints limited sample collection and analysis to one per site.

Nitrite plus nitrate nitrogen constitutes only a small part of the total nitrogen in the bottom-material samples. This may have resulted from the high solubility of these forms of nitrogen.

Table 18.—Analysis of bottom-material samples from Coon Creek watershed

[mg/kg, milligram per kilogram; ug/g, microgram per gram; g/kg, gram per kilogram]

Constituent	Units	RG-1	RG-2	RG-4	RG-5
$NO_2 + NO_3$ as N	(mg/kg)	1.7	0.5	1.2	1.8
NH_4 + Organic as N	(mg/kg)	1,500	6,700	2,100	29,900
Total N	(mg/kg)	1,510	6,700	2,100	29,900
Total P	(mg/kg)	180	150	81	220
Arsenic	(ug/g)	0	0	0	0
Cadmium	(ug/g)	<10	<10	<10	<10
Chromium	(ug/g)	<10	<10	<10	<10
Copper	(ug/g)	<10	<10	<10	<10
Iron	(ug/g)	6,400	4,900	2,600	4,100
Lead	(ug/g)	<10	<10	<10	<10
Manganese	(ug/g)	230	160	330	320
Mercury	(ug/g)	.0	.0	.0	.0
Nickel	(ug/g)	<10	20	10	<10
Zinc	(ug/g)	10	10	10	10
Organic carbon	(g/kg)	3.4	17	1.4	2.0
Inorganic carbon	(g/kg)	1.9	.3	.4	.7

The highest nutrient concentrations were found at RG-5. The concentration of ammonia plus organic nitrogen in bottom material at RG-5 was more than four times the concentration at the other sites.

Most metals were either not detected in bottom-material samples or were below detection limits. The highest concentrations of iron and manganese occurred at RG-1 and RG-4, respectively. The highest concentration of nickel was found at RG-2, although water samples from this site had the lowest mean nickel concentration. Bottom material from RG-4 had a nickel concentration at the 10 ug/g detection limit.

Determination of carbon concentrations in bottom material showed that sediments at RG-2 contained the highest concentration of organic carbon and sediments at RG-1 had the highest concentration of inorganic carbon. Inorganic carbon concentrations ranged from only 2 percent of the total carbon concentration at RG-2, to 36 percent of the total carbon concentration at RG-1. Peat deposits at RG-2 could account for the relatively high proportion of organic carbon at this site.

SUMMARY AND CONCLUSIONS

Rainfall, streamflow, sediment, and water-quality data were collected from March 1979 to November 1980 at selected urban and rural subbasins in the Coon Creek watershed. The data were analyzed to determine rainfall-runoff relationships for those areas, to determine the effects of various land uses on the rainfall-runoff response, and to assess present and potential water-quality problems.

Two separate methods of analysis were used to determine the rainfall-runoff relationships for urban and rural land uses. The first method was a quantitative analysis of rainfall and runoff. The second method was a runoff hydrograph simulation technique that used the Corps of Engineers computer program HEC-1.

Results from the quantitative analysis suggest that the rainfall-runoff response, defined as direct runoff volume as a percent of rainfall volume, varies for any given site from storm to storm and depends on storm characteristics and antecedent soil-moisture conditions. The rainfall-runoff response was nearly equal among all sites in the basin for any given storm and ranged from 0.4 to 20.8 percent for all recorded events.

The greatest recorded rainfall during this study was 3.95 inches on August 7, 1980. The basin-weighted rainfall was 3.56 inches on August 7 and resulted in the greatest observed peak flow for Coon Creek at Coon Rapids Boulevard of 185 ft^3/s. Storm-runoff volumes ranged from 2.51 to 1,355 acre-ft for observed hydrographs.

Rainfall amounts less than 1 inch did not produce significant runoff. Higher and sustained flows resulted when Carlos Avery Wildlife Management area pools were discharging from 37 to 42 ft^3/s and when rainfall amounts were greater than about 2 inches. Hydrographs of streams draining urban areas had higher peaks, shorter times to peak, and shorter duration than hydrographs of rural-area streams.

Peak discharges were generally directly proportional to the size of the contributing drainage area of the subbasins. In the case of the storms of August 7 and September 11, 1980, peaks on Sand Creek decreased from Foley Boulevard (14.8 mi^2) to Xeon Boulevard (15.7 mi^2) because of roadway structures that restricted flow.

The runoff hydrograph simulation technique was used in an attempt to further define the rainfall-runoff relationship. HEC-1 input variables were successfully optimized for 17 of 19 runoff hydrographs from 3 recording streamflow sites resulting from significant storms of 1 inch or more rainfall uniformly distributed over the basin. Optimized HEC-1 input variables and various meteorological and physical characteristics were used in a multiple-regression technique to determine linear equations for computing HEC-1 input variables. This resulted in a generalized model for each of the three principal subareas through which a reasonably close match to 10 of the 19 observed hydrographs was obtained. Because of the unknown errors associated with the results, the models should not be used for extending peak record with time or for predicting peak and volume if basin characteristics are significantly changed.

Fourteen water samples collected from four sites provided evidence suggesting that land use affects the quality of the receiving waters. The most urban site, Sand Creek at Xeon Boulevard, had high mean and median concentrations of dissolved solids, chloride, suspended sediment, biochemical oxygen demand, and several metals. The rural sites near the headwaters of the watershed, Coon Creek near Raddison Road and County Ditch 58 at Andover Boulevard, had relatively low concentrations of metals and the lowest mean and median concentrations of chloride, dissolved solids, and biochemical oxygen demand, but had the highest mean and median concentrations of many nutrients sampled. The most downstream site, Coon Creek at Coon Rapids Boulevard, which received streamflow from the other sites and most of the watershed, had the highest mean and median concentrations of total phosphorus, suspended organic carbon, and total concentrations of arsenic, iron, and zinc. The four sites had similar water quality during base flow, but high chloride, dissolved solids, and lead concentrations were evident at the urban sites. The additional constituent load introduced to the sites during runoff accounted for most of the observed divergence of water quality.

Computation of yields showed that Coon Creek at Raddison Road carried the highest yields of several forms of dissolved nitrogen and a high yield of suspended sediment. Sand Creek at Xeon Boulevard carried the highest yields of many constituents, including BOD, dissolved chloride, suspended sediment, and total lead, many of which are associated with urban runoff.

Water-quality standards for public water supplies were exceeded by a lead concentration of 80 ug/L in a sample from Sand Creek on August 9, 1979, which also had a notably high quantity of other constituents. Criteria for protection of freshwater aquatic life were exceeded in the watershed by high concentrations of cadmium, low dissolved-oxygen concentration, and an excessive range in values of pH.

It is difficult to predict with any certainty what will be the future quality of Coon Creek and its tributaries. It is certain that the quality is and will be affected by land use in the watershed. The proximity of the watershed to the Twin Cities Metropolitan Area almost assures that continued urbanization will occur in the Coon Creek watershed.

The high suspended-sediment and nutrient loads measured at Coon Creek at Raddison Road can be expected to continue, causing siltation and possibly eutrophication in slow-moving areas of the stream channel. Should it be determined that agricultural practices are the source of these loads, modification of those practices might improve the quality of Coon Creek and help retain soils currently lost to erosion.

It is apparent that urbanized areas and continued urban development are contributing pollutants to Sand Creek and the lower reaches of Coon Creek. Many of the pollutants are toxic and pose a threat to the aquatic biota. More extensive urbanization, allowed to continue in a similar fashion, could put enough strain on aquatic biota to eliminate many species presently occurring downstream from urban areas.

Measures to detain urban runoff have been shown to be effective in reducing pollutant loads to adjacent streams (R. G. Brown, U.S. Geological Survey, written commun., 1983). These measures, if implemented, might not only reduce the impact of further urbanization, but might improve the present stream quality if practiced in existing urban areas.

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WATER-QUALITY DATA

Explanation of Abreviations

cfs	-	cubic feet per second
umhos	-	micromhos per centimeter
deg C	-	degrees Celsius
mg/L	-	milligrams per liter
ug/L	-	micrograms per liter
t/day	-	tons per day
mg/kg	-	milligrams per kilogram
ug/g	-	micrograms per gram
g/kg	-	grams per kilogram

Coon Creek at Raddison Road (RG-1)

Date	Time	Stream-flow, instan-taneous (cfs)	Spe-cific con-duct-ance (umhos)	pH (units)	Temper-ature, air (deg C)	Temper-ature (deg C)	Oxygen, dis-solved (mg/L)	Oxygen, dis-solved (per-cent satur-ation)	Oxygen demand, bio-chem-ical, 5 day (mg/L)	Chlo-ride, dis-solved (mg/L as Cl)	Solids, residue at 180 deg. C dis-solved (mg/L)
1979											
May											
16...	1015	29	330	7.7	13.0	11.0	—	—	2.0	4.8	241
June											
27...	0950	17	385	7.8	19.5	16.0	6.4	66	3.8	5.2	284
29...	1130	38	364	7.8	23.5	18.0	5.3	57	6.0	7.2	276
Aug.											
08...	1000	5.9	422	8.0	21.0	20.0	6.6	75	—	6.7	300
Sept.											
26...	1110	7.1	480	7.9	21.0	13.0	8.4	82	1.7	6.4	311
Nov.											
01...	1100	19	380	7.8	3.5	6.0	9.6	79	2.4	7.4	261
1980											
Feb.											
22...	1200	3.3	410	6.2	2.0	3.0	10.5	80	5.9	5.4	275
Apr.											
17...	0810	24	357	7.5	17.0	7.0	8.6	73	1.5	6.2	244
May											
28...	1025	5.9	445	7.5	24.0	21.0	8.4	96	2.3	5.8	298
June											
06...	0855	34	325	7.6	21.0	16.0	9.7	100	3.2	6.4	226
July											
10...	0900	4.7	428	7.3	23.0	19.3	7.4	82	1.4	5.8	293
16...	0945	12	410	7.7	22.0	22.0	6.8	81	2.1	7.1	292
Aug.											
08...	1410	138	140	6.8	26.0	20.0	2.4	27	5.3	4.8	130
Sept.											
12...	1030	118	199	6.4	16.0	14.4	5.8	59	5.8	5.4	165

Coon Creek at Raddison Road (RG-1)—Continued

Date	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, organic dissolved (mg/L as N)	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Arsenic, total (ug/L as As)	Cadmium, total recoverable (ug/L as Cd)	Chromium, total recoverable (ug/L as Cr)
1979											
May											
16...	0.28	0.06	0.91	0.97	1.3	1.3	0.07	0.01	—	<2	11
June											
27...	.16	.30	.80	1.1	1.7	1.3	.18	.01	4	<2	<20
29...	.33	.52	1.2	1.7	3.2	2.0	.35	.02	4	0	20
Aug.											
08...	.13	.07	.67	.74	1.2	.87	.10	.02	3	<2	<20
Sept.											
26...	.28	.10	.79	.89	.95	1.2	.04	.04	3	0	30
Nov.											
01...	.48	.23	1.4	1.6	2.1	2.1	.09	.01	2	0	20
1980											
Feb.											
22...	.17	.63	.47	1.1	1.1	1.3	.04	.00	—	0	30
Apr.											
17...	.43	.19	1.0	1.2	1.2	1.6	.18	.01	2	0	20
May											
28...	.04	.11	.60	.71	1.2	.75	.08	.00	1	0	20
June											
06...	.47	.14	1.3	1.4	2.2	1.9	.43	.11	3	0	<10
July											
10...	.06	.02	.71	.73	.95	.79	.11	.00	2	0	10
16...	.09	.07	.36	.43	.82	.52	.11	.02	3	0	10
Aug.											
08...	1.5	.23	.87	1.1	1.8	2.6	.35	.10	4	1	20
Sept.											
12...	1.6	.17	.60	.77	.99	2.4	.21	.11	2	1	30

Coon Creek at Raddison Road (RG-1)—Continued

Date	Copper, total recov-erable (ug/L as Cu)	Iron, total recov-erable (ug/L as Fe)	Lead, total recov-erable (ug/L as Pb)	Manga-nese, total recov-erable (ug/L as Mn)	Mercury, total recov-erable (ug/L as Hg)	Nickel, total recov-erable (ug/L as Ni)	Zinc, total recov-erable (ug/L as Zn)	Carbon, organic dis-solved (mg/L as C)	Carbon, Organic sus-pended total (mg/L as C)	Sedi-ment, sus-pended (mg/L)	Sedi-ment dis-charge, sus-pended (t/day)
1979											
May											
16...	4	2400	<2	190	—	—	<20	18	1.8	25	2.0
June											
27...	7	—	3	420	<.5	—	30	17	—	54	2.5
29...	3	—	2	410	<.5	—	30	19	7.6	100	10
Aug.											
08...	4	—	1	270	<.5	—	20	12	.6	14	.22
Sept.											
26...	<2	—	0	320	.2	—	0	11	.9	16	.31
Nov.											
01...	2	—	5	280	<.1	1	10	12	1.3	21	1.1
1980											
Feb.											
22...	1	1600	0	420	—	1	10	18	.5	12	.11
Apr.											
17...	3	3400	2	220	.1	2	10	11	2.9	31	2.0
May											
28...	1	1600	0	340	<.1	1	30	—	.4	13	.21
June											
06...	4	6700	7	350	<.1	2	20	18	2.9	82	7.4
July											
10...	3	1500	7	220	<.1	4	20	12	.4	5	.07
16...	1	2200	0	240	<.1	3	20	12	2.3	25	.79
Aug.											
08...	0	4200	17	200	<.1	2	20	—	—	139	52
Sept.											
12...	1	3500	6	190	.2	3	30	8.5	2.1	95	30

Coon Creek at Raddison Road (RG-1)—Continued

Date	Nitrogen, NO_2+NO_3 tot. in bot mat (mg/kg as N)	Nitrogen, NH_4 + org. tot in bot mat (mg/kg as N)	Nitrogen, tot in bottom material (mg/kg as N)	Phosphorus, total in bot. mat. (mg/kg as P)	Arsenic, total in bottom material (ug/g as As)	Cadmium, recov. fm bottom material (ug/g as Cd)	Chromium, recov. fm bottom material (ug/g)	Copper, recov. fm bottom material (ug/g as Cu)
1979 Sept. 26...	1.7	1500	1510	180	0	<10	<10	<10

Date	Iron, recov. fm bottom material (ug/g as Fe)	Lead, recov. fm bottom material (ug/g as Pb)	Manganese, recov. fm bottom material (ug/g)	Mercury, recov. fm bottom material (ug/g as Hg)	Nickel, recov. fm bottom material (ug/g as Ni)	Zinc, recov. fm bottom material (ug/g as Zn)	Carbon, organic tot. in bottom mat. (g/kg as C)	Carbon, inorganic, tot in bot mat (g/kg as C)
1979 Sept. 26...	6400	<10	230	0.00	<10	10	3.4	1.9

County Ditch 58 at Andover Boulevard (RG-2)

Date	Time	Stream-flow, instan-taneous (cfs)	Spe-cific con-duct-ance (umhos)	pH (units)	Temper-ature, air (deg C)	Temper-ature (deg C)	Oxygen, dis-solved (mg/L)	Oxygen, dis-solved (per-cent satur-ation)	Oxygen demand, bio-chem-ical, 5 day (mg/L)	Chlo-ride, dis-solved (mg/L as Cl)	Solids, residue at 180 deg. C dis-solved (mg/L)
1979											
May											
17...	1030	8.3	236	7.6	21.0	14.0	8.6	85	2.6	7.5	188
June											
27...	1115	5.8	275	7.6	24.0	19.0	6.7	74	3.6	6.3	231
29...	1330	8.6	276	7.7	25.5	21.5	6.0	70	4.0	6.7	241
Aug.											
08...	1300	.99	410	8.0	24.5	19.0	8.3	91	—	7.8	278
Sept.											
26...	1330	1.2	390	8.5	27.0	17.0	11.9	125	.3	8.6	166
Nov.											
01...	1500	3.4	332	7.8	3.8	6.0	10.2	84	2.1	12	232
1980											
Feb.											
21...	1230	.63	320	7.7	2.0	2.8	10.8	82	.7	5.6	248
Apr.											
17...	0945	5.1	272	7.6	18.0	9.0	10.6	94	1.3	7.5	195
May											
28...	1150	1.4	376	7.9	24.0	26.0	9.9	124	1.8	7.8	263
June											
05...	1145	3.5	335	7.9	24.0	19.0	9.1	88	3.8	8.0	231
July											
10...	1015	.68	376	7.6	27.0	23.2	11.8	140	2.2	5.3	282
16...	1115	.92	360	8.0	29.0	25.0	9.6	120	1.4	6.0	277
Aug.											
08...	1130	10	338	6.8	24.0	19.5	3.6	40	5.3	9.2	300
Sept.											
12...	0915	—	226	6.2	15.0	14.7	4.8	49	5.5	7.9	233

County Ditch 58 at Andover Boulevard (RG-2)—Continued

Date	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, organic dissolved (mg/L as N)	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Arsenic, total (ug/L as As)	Cadmium, total recoverable (ug/L as Cd)	Chromium, total recoverable (ug/L as Cr)
1979											
May											
17...	0.15	0.05	1.5	1.5	1.9	1.7	0.05	<0.01	—	<2	14
June											
27...	.32	.21	1.5	1.7	2.3	2.0	.22	.07	4	0	20
29...	.28	.22	1.6	1.8	2.8	2.1	.27	.02	3	0	30
Aug.											
08...	.48	.11	.77	.88	1.6	1.4	.14	.01	2	<2	<20
Sept.											
26...	.65	.02	.87	.89	.89	1.5	.05	.04	2	0	20
Nov.											
01...	1.2	.26	1.2	1.5	1.8	2.7	.12	.04	2	0	20
1980											
Feb.											
21...	.74	.19	.63	.82	.82	1.6	.06	.02	1	0	20
Apr.											
17...	.90	.14	1.1	1.2	1.2	2.1	.11	.00	0	0	20
May											
28...	.35	.16	.60	.76	1.3	1.1	.11	.00	1	0	20
June											
05...	.44	.14	1.5	1.6	1.7	2.0	.25	.00	2	0	10
July											
10...	.36	.04	1.2	1.2	1.2	1.6	.10	.02	2	0	20
16...	.58	.26	.57	.83	.83	1.4	.08	.03	2	0	10
Aug.											
08...	4.7	.32	1.7	2.0	2.8	6.7	.26	.05	3	2	20
Sept.											
12...	1.9	.34	2.9	3.2	3.7	5.1	.27	.13	3	2	10

County Ditch 58 at Andover Boulevard (RG-2)—Continued

Date	Copper, total recov-erable (ug/L as Cu)	Iron, total recov-erable (ug/L as Fe)	Lead, total recov-erable (ug/L as Pb)	Manga-nese, total recov-erable (ug/L as Mn)	Mercury, total recov-erable (ug/L as Hg)	Nickel, total recov-erable (ug/L as Ni)	Zinc, total recov-erable (ug/L as Zn)	Carbon, organic dis-solved (mg/L as C)	Carbon, Organic sus-pended total (mg/L as C)	Sedi-ment, sus-pended (mg/L)	Sedi-ment dis-charge, sus-pended (t/day)
1979											
May											
17...	3	1900	0	150	—	—	<20	30	2.5	24	0.54
June											
27...	5	—	4	560	<.5	—	30	26	3.4	40	.63
29...	2	—	<2	530	<.5	—	20	27	5.6	47	1.1
Aug.											
08...	4	—	2	470	<.5	—	30	13	2.1	8	.02
Sept.											
26...	<2	—	1	240	.2	—	0	11	.8	11	.04
Nov.											
01...	2	—	6	240	<.1	0	20	17	3.8	24	.22
1980											
Feb.											
21...	2	2100	1	310	.1	4	50	—	—	6	.01
Apr.											
17...	3	2300	2	170	.1	1	10	13	1.3	16	.22
May											
28...	0	2100	0	450	<.1	0	20	13	.8	15	.06
June											
05...	4	5100	5	460	<.1	1	20	19	2.0	39	.37
July											
10...	1	2000	3	300	<.1	0	10	17	.3	6	.01
16...	0	1700	0	430	<.1	0	10	14	.8	7	.02
Aug.											
08...	1	5100	10	610	<.1	2	50	—	—	53	1.5
Sept.											
12...	2	7900	9	480	<.1	3	20	19	2.9	31	—

County Ditch 58 at Andover Boulevard (RG-2)—Continued

Date	Nitrogen, NO_2+NO_3 tot. in bot mat (mg/kg as N)	Nitrogen, NH_4 + org. tot in bot mat (mg/kg as N)	Nitrogen, tot in bottom material (mg/kg as N)	Phosphorus, total in bot. mat. (mg/kg as P)	Arsenic, total in bottom material (ug/g as As)	Cadmium, recov. fm bottom material (ug/g as Cd)	Chromium, recov. fm bottom material (ug/g)	Copper, recov. fm bottom material (ug/g as Cu)
1979 Sept. 26...	0.5	6700	6700	150	0	<10	<10	<10

Date	Iron, recov. fm bottom material (ug/g as Fe)	Lead, recov. fm bottom material (ug/g as Pb)	Manganese, recov. fm bottom material (ug/g)	Mercury, recov. fm bottom material (ug/g as Hg)	Nickel, recov. fm bottom material (ug/g as Ni)	Zinc, recov. fm bottom material (ug/g as Zn)	Carbon, organic tot. in bottom mat. (g/kg as C)	Carbon, inorganic, tot in bot mat (g/kg as C)
1979 Sept. 26...	4900	<10	160	0.00	20	10	17	0.3

Sand Creek at Xeon Boulevard (RG-4)

Date	Time	Stream-flow, instan-taneous (cfs)	Spe-cific con-duct-ance (umhos)	pH (units)	Temper-ature, air (deg C)	Temper-ature (deg C)	Oxygen, dis-solved (mg/L)	Oxygen, dis-solved (per-cent satur-ation)	Oxygen demand, bio-chem-ical, 5 day (mg/L)	Chlo-ride, dis-solved (mg/L as Cl)	Solids, residue at 180 deg. C dis-solved (mg/L)
1979											
May											
17...	1130	12	505	8.2	26.5	15.0	10.7	108	2.8	18	349
June											
27...	1000	11	480	8.0	21.5	17.0	7.6	80	2.3	15	379
29...	1120	20	387	7.7	26.5	17.0	6.9	73	3.8	12	321
Aug.											
09...	1000	42	139	7.8	19.0	20.0	5.9	66	7.9	4.8	91
Sept.											
26...	1045	5.0	585	8.1	21.0	14.0	—	—	2.6	18	418
Nov.											
02...	1130	11	505	7.8	6.5	4.0	12.2	95	1.9	26	332
1980											
Feb.											
21...	1100	2.1	965	7.7	2.0	2.5	11.2	84	4.2	180	602
Apr.											
17...	1100	9.8	560	7.9	18.0	11.0	10.0	93	2.2	23	378
May											
28...	1420	3.2	563	7.5	27.0	21.0	6.6	76	2.7	18	386
June											
05...	0900	29	240	7.6	24.0	17.0	6.4	67	7.1	11	160
July											
10...	1215	3.3	528	7.5	32.0	21.0	7.8	90	1.1	20	394
16...	1245	7.6	275	7.6	28.0	21.0	6.3	73	3.6	13	192
Aug.											
08...	0930	51	124	7.1	22.0	20.0	5.3	60	4.0	5.3	91
Sept.											
11...	1315	14	415	8.0	15.0	14.0	7.6	75	3.6	13	288

Sand Creek at Xeon Boulevard (RG-4)—Continued

Date	Copper, total recov-erable (ug/L as Cu)	Iron, total recov-erable (ug/L as Fe)	Lead, total recov-erable (ug/L as Pb)	Manga-nese, total recov-erable (ug/L as Mn)	Mercury, total recov-erable (ug/L as Hg)	Nickel, total recov-erable (ug/L as Ni)	Zinc, total recov-erable (ug/L as Zn)	Carbon, organic dis-solved (mg/L as C)	Carbon, Organic sus-pended total (mg/L as C)	Sedi-ment, sus-pended (mg/L)	Sedi-ment dis-charge, sus-pended (t/day)
1979											
May											
17...	3	1500	5	220	—	--	<20	18	2.0	21	0.69
June											
27...	7	—	7	250	<.5	—	50	19	1.2	36	1.1
29...	5	—	13	300	<.5	—	20	17	.6	83	4.5
Aug.											
09...	11	—	80	1800	<.5	—	110	8.9	—	521	59
Sept.											
26...	<2	—	<2	240	.2	—	0	10	.8	24	.32
Nov.											
02...	3	—	7	230	<.1	2	20	15	.8	24	.71
1980											
Feb.											
21...	2	480	2	600	—	2	20	11	1.0	16	.09
Apr.											
17...	3	1600	3	300	.1	2	10	17	1.0	14	.37
May											
28...	2	1600	4	460	<.1	2	20	14	.9	15	.13
June											
05...	10	5900	45	920	.1	7	50	8.7	2.9	182	14
July											
10...	2	710	3	110	<.1	3	20	12	.3	3	.03
16...	2	1200	6	220	<.1	3	10	7.6	1.3	21	.43
Aug.											
08...	5	6900	21	420	<.1	5	50	—	—	202	28
Sept.											
11...	2	1700	13	260	<.1	3	20	18	1.1	28	1.0

Sand Creek at Xeon Boulevard (RG-4)—Continued

Date	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, organic dissolved (mg/L as N)	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Arsenic, total (ug/L as As)	Cadmium, total recoverable (ug/L as Cd)	Chromium, total recoverable (ug/L as Cr)
1979											
May											
17...	0.68	0.02	0.98	1.0	1.3	1.7	0.03	<0.01	—	2	14
June											
27...	.84	.05	.95	1.0	1.3	1.8	.09	.01	3	2	20
29...	.71	.09	1.2	1.3	1.5	2.0	.11	<.01	3	0	20
Aug.											
09...	.29	.13	.49	.62	3.2	.91	.71	.01	5	0	20
Sept.											
26...	.96	.03	.83	.86	.86	1.8	.04	.01	3	0	20
Nov.											
02...	.71	.29	1.3	1.6	1.8	2.3	.05	.02	2	0	20
1980											
Feb.											
21...	1.4	.45	.55	1.0	1.0	2.4	.02	.00	—	0	20
Apr.											
17...	.87	.50	.90	1.4	1.4	2.3	.10	.00	1	0	30
May											
28...	.78	.20	1.1	1.3	1.4	2.1	.11	.00	2	0	20
June											
05...	.49	.20	1.4	1.6	1.8	2.1	.58	.16	4	1	10
July											
10...	.78	.02	.98	1.0	1.0	1.8	.07	.01	1	1	10
16...	.54	.18	.36	.54	.84	1.1	.09	.03	2	0	10
Aug.											
08...	.55	.11	.13	.24	.71	.79	.36	.01	3	1	30
Sept.											
11...	.68	.10	.44	.54	1.3	1.2	.08	.04	2	0	10

Sand Creek at Xeon Boulevard (RG-4)—Continued

Date	Nitrogen, NO_2+NO_3 tot. in bot mat (mg/kg as N)	Nitrogen, NH_4 + org. tot in bot mat (mg/kg as N)	Nitrogen, tot in bottom material (mg/kg as N)	Phosphorus, total in bot. mat. (mg/kg as P)	Arsenic, total in bottom material (ug/g as As)	Cadmium, recov. fm bottom material (ug/g as Cd)	Chromium, recov. fm bottom material (ug/g)	Copper, recov. fm bottom material (ug/g as Cu)
1979 Sept. 26...	1.2	2100	2100	81	0	<10	<10	<10

Date	Iron, recov. fm bottom material (ug/g as Fe)	Lead, recov. fm bottom material (ug/g as Pb)	Manganese, recov. fm bottom material (ug/g)	Mercury, recov. fm bottom material (ug/g as Hg)	Nickel, recov. fm bottom material (ug/g as Ni)	Zinc, recov. fm bottom material (ug/g as Zn)	Carbon, organic tot. in bottom mat. (g/kg as C)	Carbon, inorganic, tot in bot mat (g/kg as C)
1979 Sept. 26...	2600	<10	330	0.00	10	10	1.4	0.4

Coon Creek at Coon Rapids Boulevard (RG-5)

Date	Time	Stream-flow, instan-taneous (cfs)	Spe-cific con-duct-ance (umhos)	pH (units)	Temper-ature, air (deg C)	Temper-ature (deg C)	Oxygen, dis-solved (mg/L)	Oxygen, dis-solved (per-cent satur-ation)	Oxygen demand, bio-chem-ical, 5 day (mg/L)	Chlo-ride, dis-solved (mg/L as Cl)	Solids, residue at 180 deg. C dis-solved (mg/L)
1979											
May											
17...	1345	76	398	8.0	24.0	16.5	9.9	104	2.8	13	270
June											
27...	1145	60	415	7.9	19.0	18.7	8.1	88	3.0	13	318
29...	1340	92	361	7.8	26.5	18.5	6.5	71	3.6	12	285
Aug.											
09...	1230	104	308	8.4	21.5	19.0	6.5	71	4.6	11	213
Sept.											
26...	1245	27	484	8.2	25.0	14.0	—	—	1.3	14	331
Nov.											
02...	1330	52	430	8.0	4.0	5.0	12.0	97	1.3	22	292
1980											
Feb.											
22...	0930	24	659	6.1	1.0	.0	9.8	69	4.9	100	408
Apr.											
18...	1130	70	433	7.9	24.5	12.5	10.3	99	1.9	16	297
May											
28...	1500	24	467	7.7	27.0	22.8	7.5	88	2.2	14	312
June											
06...	1045	78	390	7.7	24.0	17.5	6.8	72	3.3	12	254
July											
10...	1330	20	453	7.7	35.0	24.6	8.2	100	2.2	16	322
16...	1415	33	345	7.8	29.0	24.0	7.0	85	2.9	12	228
Aug.											
08...	1545	131	237	7.5	27.0	22.0	4.9	53	4.3	7.8	178
Sept.											
11...	1030	69	367	7.9	15.0	14.0	7.9	78	3.1	12	303

Coon Creek at Coon Rapids Boulevard (RG-5)—Continued

Date	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, organic dissolved (mg/L as N)	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Arsenic, total (ug/L as As)	Cadmium, total recoverable (ug/L as Cd)	Chromium, total recoverable (ug/L as Cr)
1979											
May											
17...	0.49	0.03	0.84	0.87	1.6	1.4	0.11	<0.01	—	<2	15
June											
27...	.54	.09	.91	1.0	1.5	1.5	.22	.01	5	0	30
29...	.48	.11	1.1	1.2	1.9	1.7	.27	.02	4	0	30
Aug.											
09...	.49	.21	.47	.68	3.3	1.2	.43	.01	5	4	20
Sept.											
26...	.56	<.01	.71	.71	.91	1.3	.08	.01	3	0	20
Nov.											
02...	.61	.21	1.1	1.3	1.3	1.9	.09	.03	2	0	20
1980											
Feb.											
22...	.17	.63	.47	1.1	1.2	1.3	.05	.00	—	0	30
Apr.											
18...	.63	.17	.71	.88	1.0	1.5	.23	.00	3	0	20
May											
28...	.25	.17	.63	.80	1.2	1.1	.15	.00	2	0	20
June											
06...	.54	.11	1.3	1.4	1.9	1.9	.40	.00	4	0	20
July											
10...	.32	.04	.59	.63	.91	.95	.08	.02	2	0	20
16...	.40	.12	.54	.66	.92	1.1	.15	.01	4	0	10
Aug.											
08...	1.5	.21	.45	.66	1.9	2.2	.42	.01	3	1	20
Sept.											
11...	.47	.12	.98	1.1	2.1	1.6	.19	.08	4	1	10

Coon Creek at Coon Rapids Boulevard (RG-5)—Continued

Date	Copper, total recov-erable (ug/L as Cu)	Iron, total recov-erable (ug/L as Fe)	Lead, total recov-erable (ug/L as Pb)	Manga-nese, total recov-erable (ug/L as Mn)	Mercury, total recov-erable (ug/L as Hg)	Nickel, total recov-erable (ug/L as Ni)	Zinc, total recov-erable (ug/L as Zn)	Carbon, organic dis-solved (mg/L as C)	Carbon, Organic sus-pended total (mg/L as C)	Sedi-ment, sus-pended (mg/L)	Sedi-ment dis-charge, sus-pended (t/day)
1979											
May											
17...	3	3200	2	250	—	—	0	15	2.8	54	11
June											
27...	6	—	3	350	<.5	—	30	14	2.7	58	9.4
29...	5	—	10	400	<.5	—	30	13	.7	116	29
Aug.											
09...	8	—	33	1200	<.5	—	50	7.0	8.0	295	83
Sept.											
26...	0	—	0	180	.2	—	0	7.7	1.5	18	1.3
Nov.											
02...	2	—	5	240	<.1	1	10	11	—	25	3.5
1980											
Feb.											
22...	3	1400	15	330	—	2	170	7.3	.6	16	1.0
Apr.											
18...	2	2500	3	220	.1	1	20	9.2	1.5	35	6.7
May											
28...	2	2700	2	380	<.1	0	20	12	3.0	34	2.2
June											
06...	7	5800	9	620	<.1	3	20	12	2.5	106	22
July											
10...	1	1300	4	210	<.1	2	20	9.2	.9	17	.90
16...	2	2900	8	370	<.1	4	20	6.8	3.1	57	5.1
Aug.											
08...	4	6800	14	1100	<.1	4	40	—	—	215	76
Sept.											
11...	2	5300	7	420	<.1	4	20	12	3.6	59	11

Coon Creek at Coon Rapids Boulevard (RG-5)—Continued

Date	Nitrogen, NO_2+NO_3 tot. in bot mat (mg/kg as N)	Nitrogen, NH_4 + org. tot in bot mat (mg/kg as N)	Nitrogen, tot in bottom material (mg/kg as N)	Phosphorus, total in bot. mat. (mg/kg as P)	Arsenic, total in bottom material (ug/g as As)	Cadmium, recov. fm bottom material (ug/g as Cd)	Chromium, recov. fm bottom material (ug/g)	Copper, recov. fm bottom material (ug/g as Cu)
1979 Sept. 26...	1.8	29900	29900	220	0	<10	<10	<10

Date	Iron, recov. fm bottom material (ug/g as Fe)	Lead, recov. fm bottom material (ug/g as Pb)	Manganese, recov. fm bottom material (ug/g)	Mercury, recov. fm bottom material (ug/g as Hg)	Nickel, recov. fm bottom material (ug/g as Ni)	Zinc, recov. fm bottom material (ug/g as Zn)	Carbon, organic tot. in bottom mat. (g/kg as C)	Carbon, inorganic, tot in bot mat (g/kg as C)
1979 Sept. 26...	4100	<10	320	0.00	<10	10	2.0	0.7

DAILY RAINFALL DATA

RN-1 — PRECIPITATION AT HAM LAKE, MINNESOTA, 1979

[All observations from midnight to midnight; measurements in inches]

DAY	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.
1	*	0.17	—	—	—	1.04	0.57	—
2	*	.03	—	—	1.01	—	—	—
3	*	—	—	1.36	—	—	.01	—
4	*	—	0.02	—	.23	—	—	—
5	*	.04	—	—	—	.12	—	—
6	*	.02	—	—	—	—	—	—
7	*	—	.51	—	—	—	—	—
8	*	.40	.01	—	—	.01	.01	—
9	*	.46	.58	.04	1.54	—	—	—
10	*	.29	.57	—	—	—	.03	*
11	*	—	—	—	—	.06	—	*
12	*	—	—	.12	.03	.37	—	*
13	*	.05	—	—	—	—	—	*
14	*	.02	—	—	—	—	—	*
15	*	—	.04	—	—	—	—	*
16	*	—	1.73	—	—	—	—	*
17	*	—	—	—	.01	—	—	*
18	*	—	—	—	—	—	.18	*
19	*	.28	.46	—	.02	—	—	*
20	*	—	.22	—	.72	—	—	*
21	*	—	—	—	.26	—	—	*
22	*	—	—	—	.49	—	—	*
23	—	—	—	.10	.06	—	—	*
24	0.02	—	—	—	—	—	—	*
25	—	—	—	—	—	—	—	*
26	—	—	.02	—	.54	—	—	*
27	.01	—	—	—	—	.05	—	*
28	—	—	1.01	—	.08	—	—	*
29	.29	.49	.12	—	—	—	—	*
30	.02	.30	—	.23	—	—	—	*
31		—		—	—		—	

*No record

RN-1 — PRECIPITATION AT HAM LAKE, MINNESOTA, 1980

[All observations from midnight to midnight; measurements in inches]

DAY	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.
1	*	—	0.88	0.29	0.04	—	—	—
2	*	—	—	—	.02	—	—	—
3	*	—	—	—	.01	1.16	—	0.02
4	*	—	.03	.37	.11	—	—	—
5	*	—	1.41	—	—	—	—	*
6	*	—	.01	—	.08	—	—	*
7	*	—	.44	—	1.08	—	—	*
8	*	—	—	*	3.68	—	—	*
9	*	—	.01	*	—	—	—	*
10	*	0.23	—	*	—	—	—	*
11	*	—	—	*	—	2.24	—	*
12	*	.02	.24	*	.07	.03	—	*
13	*	.11	.02	*	.12	—	—	*
14	*	—	—	*	—	—	0.08	*
15	*	—	—	*	—	.02	—	*
16	*	—	—	*	.46	.01	.23	*
17	*	.44	—	—	.03	—	.02	*
18	—	.04	.05	.10	.03	—	.02	*
19	—	—	.22	.27	—	—	—	*
20	—	—	—	—	.15	.11	—	*
21	—	—	—	—	—	—	—	*
22	—	—	.49	—	—	—	—	*
23	—	—	—	—	.12	.02	.35	*
24	—	—	—	.14	.86	.12	—	*
25	—	—	.06	—	.02	.06	—	*
26	—	—	—	—	.79	—	—	*
27	—	—	.07	.14	—	—	—	*
28	—	—	.01	.03	—	.09	—	*
29	—	.30	—	.03	—	—	—	*
30	—	.19	—	.03	1.17	—	—	*
31		—		—	.97		—	

*No record.

RN-2 — PRECIPITATION AT ANDOVER, MINNESOTA, 1979

[All observations from midnight to midnight; measurements in inches]

DAY	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.
1	*	0.30	—	—	—	0.93	0.55	0.03
2	*	.03	—	—	0.37	—	—	—
3	*	—	—	0.57	—	—	—	—
4	*	—	0.03	—	.38	—	—	—
5	*	.05	—	—	—	.23	—	—
6	*	.04	—	—	—	—	—	—
7	*	—	.22	—	—	—	.01	—
8	*	.50	.01	—	—	—	.01	—
9	*	.83	.83	.05	1.34	—	—	—
10	*	.26	.54	—	—	—	.03	*
11	*	—	—	—	—	.10	—	*
12	*	—	—	.15	.03	1.38	.01	*
13	*	.07	—	—	—	.01	—	*
14	*	.01	—	—	—	—	—	*
15	*	—	.04	.04	—	—	—	*
16	*	—	1.89	—	—	—	—	*
17	*	.10	—	—	—	—	—	*
18	*	—	—	—	—	—	1.22	*
19	*	.49	.41	—	.03	—	—	*
20	*	—	.28	—	.19	—	—	*
21	*	—	—	—	.38	—	.07	*
22	*	.22	—	—	.56	—	.78	*
23	—	—	—	.14	.05	—	—	*
24	—	—	—	—	—	—	—	*
25	0.01	—	—	—	—	—	—	*
26	—	.01	.14	—	.51	—	—	*
27	.01	—	—	—	—	—	.03	*
28	—	—	.56	—	.14	—	—	*
29	.21	.58	.23	—	—	—	—	*
30	.02	.37	—	.21	—	—	.25	*
31		—		—	—		.72	

*No record.

RN-2 — PRECIPITATION AT ANDOVER, MINNESOTA, 1980

[All observations from midnight to midnight; measurements in inches]

DAY	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.
1	—	—	0.73	0.18	—	0.01	*	—
2	—	—	—	—	—	—	0.01	—
3	—	—	—	—	—	—	—	0.01
4	—	—	.05	.42	—	—	—	—
5	—	—	1.67	—	—	—	—	—
6	—	—	—	—	—	—	—	—
7	—	—	.42	—	0.77	—	—	*
8	—	—	—	—	2.84	—	—	*
9	—	—	—	—	*	—	—	*
10	—	0.23	—	—	*	*	—	*
11	—	—	—	—	*	*	—	*
12	—	.03	.56	—	*	*	—	*
13	—	.09	—	—	*	*	—	*
14	—	—	—	—	*	*	—	*
15	—	—	—	1.10	*	*	—	*
16	—	—	—	—	*	*	.15	*
17	—	(.67	—	—	*	*	.03	*
18	—	(	.41	.04	*	*	.02	*
19	—	—	.01	.36	*	*	—	*
20	—	—	—	—	*	*	—	*
21	—	*	—	.06	*	*	—	*
22	—	*	—	—	*	*	—	*
23	*	*	—	—	*	*	.24	*
24	*	*	—	.13	*	*	—	*
25	*	*	(	—	*	*	—	*
			(.12					
26	*	*	(	—	.38	—	—	*
27	*	*	.08	—	—	—	—	*
28	*	*	—	.11	—	.10	—	*
29	*	*	—	—	—	—	—	*
30	*	.02	—	—	—	*	—	*
31		—		—	.27		—	

*No record.

RN-3 — PRECIPITATION AT COON RAPIDS, MINNESOTA, 1979

[All observations from midnight to midnight; measurements in inches]

DAY	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.
1	*	0.32	0.01	—	—	0.11	0.50	0.02
2	*	.04	.02	—	0.14	—	—	—
3	*	—	—	0.88	—	—	.01	—
4	*	—	.05	—	.22	—	—	—
5	*	.03	—	—	—	.14	—	—
6	*	.02	—	—	—	—	—	—
7	*	.02	.37	—	—	—	.01	—
8	*	.33	.02	—	—	—	—	—
9	*	.61	.61	.02	1.57	—	—	—
10	*	.18	.48	—	—	—	.03	*
11	*	—	—	—	—	.14	—	*
12	*	—	—	.12	—	.15	—	*
13	*	*	—	—	—	.01	—	*
14	*	*	—	—	—	—	—	*
15	*	*	.05	.13	—	—	—	*
16	*	*	1.54	—	—	—	—	*
17	*	*	—	—	.01	—	—	*
18	*	*	—	—	—	—	.82	*
19	*	*	.41	—	.04	—	.07	*
20	*	*	.13	—	.34	—	—	*
21	*	*	—	.15	.46	—	.03	*
22	*	*	—	—	.65	—	.62	*
23	*	*	—	.16	.06	—	—	*
24	0.01	*	—	—	—	—	—	*
25	.02	*	—	—	—	—	—	*
26	—	*	.16	—	.46	—	—	*
27	—	*	—	—	—	.01	.02	*
28	—	*	.84	—	.06	—	—	*
29	.18	*	.56	—	.01	—	—	*
30	.01	*	—	.25	—	—	.22	*
31		—		.01	—		.60	

*No record.

RN-3 — PRECIPITATION AT COON RAPIDS, MINNESOTA, 1980

[All observations from midnight to midnight; measurements in inches]

DAY	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.
1	*	—	*	*	*	*	—	—
2	*	—	*	*	*	*	0.01	—
3	*	—	*	—	*	*	—	0.01
4	*	—	*	—	*	*	.01	—
5	*	—	*	—	*	*	—	—
6	*	—	*	—	*	*	—	*
7	*	—	*	—	*	*	—	*
8	*	—	*	0.71	*	*	—	*
9	*	—	*	*	*	*	—	*
10	*	0.27	*	*	—	*	—	*
11	*	—	*	*	—	1.39 1/	—	*
12	*	.04	*	*	—	—	—	*
13	*	.11	*	*	—	—	(.06	*
14	*	—	*	*	—	—	(	*
15	*	—	*	*	—	—	—	*
16	*	—	*	*	—	.02	.14	*
17	*	(.51	*	*	—	—	.01	*
18	—	(	*	*	—	—	.01	*
19	—	—	*	*	.02	—	—	*
20	—	—	*	*	.14	.09	—	*
21	—	—	*	*	.01	.01	—	*
22	—	—	*	*	—	—	—	*
23	—	—	*	*	.13	.02	.23	*
24	—	—	*	*	.31	.17	—	*
25	—	—	*	*	.01	.03	—	*
26	—	—	*	*	*	.01	—	*
27	—	—	*	*	*	—	—	*
28	—	.10	*	*	*	.07	—	*
29	—	*	*	*	*	—	—	*
30	—	*	*	*	*	—	—	*
31		*		*	*		—	

* No record.
1/Partial record for that day.