Hydrology and Water Quality of the Crooked Creek Watershed, Indianapolis, Indiana

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Introduction

The Crooked Creek Watershed is located in northwestern Indianapolis in an area rapidly becoming urbanized. Crooked Creek drains into White River about 4 miles northwest of Monument Circle in downtown Indianapolis (Fig. 1).

The area has the regional hydrology typical of central Indiana: the mean annual precipitation is 40 inches, and even though the mean annual evapotranspiration is high, the average flow in White River (the area's major stream) is slightly above 1000 cfs. The ground water system is in approximate equilibrium, and the United States Geological Survey has recently estimated a sustainable ground water recovery of about 90 mgd (2).

The Crooked Creek Watershed is within the area glaciated during the early Woodfordian. The estimated time of ice recession is 18,000 to 20,000 years BP (1). The area is relatively featureless tillplain, characterized by generally unsorted and moderately impermeable silts containing variable amounts of gravel, sand, and clay. Some post-glacial alluvium of much greater permeability is found along Crooked Creek and its tributaries but not enough to importantly affect the hydrogeology of the area. The low permeability of the till favors runoff and impedes infiltration to the ground water system within the Crooked Creek Watershed.

Physical Characteristics of the Watershed Influencing Runoff

The physical characteristics of the watershed favor rapid runoff and high sediment yield in response to precipitation. The watershed is small (area of 18.1 square miles) and highly elongated along a general north-south trend (Fig. 1). Shape ratios (3) show basin elongation: form ratio, $Rf = 0.20$; circularity ratio, $Rc = 0.28$; and elongation ratio, $Re = 0.96$.

Crooked Creek is a fifth-order stream according to the Horton stream numbering system, as modified by Strahler (3). The major stream is long (9.7 miles) with respect to watershed size, and most of the drainage net is concentrated in the upper part of the watershed (Fig. 1). An unusually large number of first-order tributaries (152) collects runoff from this rapidly urbanizing section. Bifurcation ratios of 5.0 for first-order through third-order streams vs. 2.0 for third-order through fifth-order streams illustrate the dominating influence of small tributaries in the upper part of the watershed (Fig. 2).

The upper part of the watershed contains four subwatersheds. From east to west these are: "Ditch Creek", Delaware Creek, "Upper" Crooked Creek, and

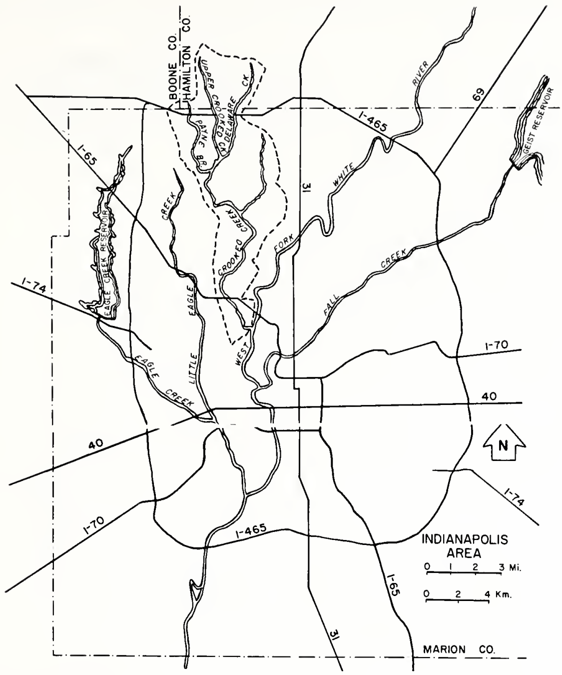

FIGURE 1. *Map of Marion County, Indiana, showing the location of the Crooked Creek Watershed.*

Payne Branch. The respective drainage densities of the subwatersheds of 3.26, 5.00, 5.23, and 5.20 vs. that of the entire watershed (4.35) show again the importance of the upper part of the watershed in influencing runoff.

Thus, a large number of first-order tributaries and high drainage densities favor rapid runoff from the upper part of the basin, as do: 1) short stream lengths (0.40 miles as an average); 2) moderately high total relief (216 feet); 3) a main stream gradient of 15 feet per mile; and 4) a lack of significant surface storage with only about 0.2% of the surface area in lakes and ponds. Accompanying the runoff should be a high sediment yield.

Because the upper part of the watershed is undergoing rapid urbanization we can expect even greater influence of that sector on future hydrologic response.

Hydrologic Response

The study of hydrologic response, to date, has focused on an analysis of data available from the United States Geological Survey for their gaging station on Crooked Creek at the 42nd Street bridge. This site is located low in the watershed approximately 1 mile from the junction of Crooked Creek with White River. What follows, then, is a summary of hydrologic characteristics of the watershed as reflected in stream flow at that site only. The period of record is June 1969 through September 1975.

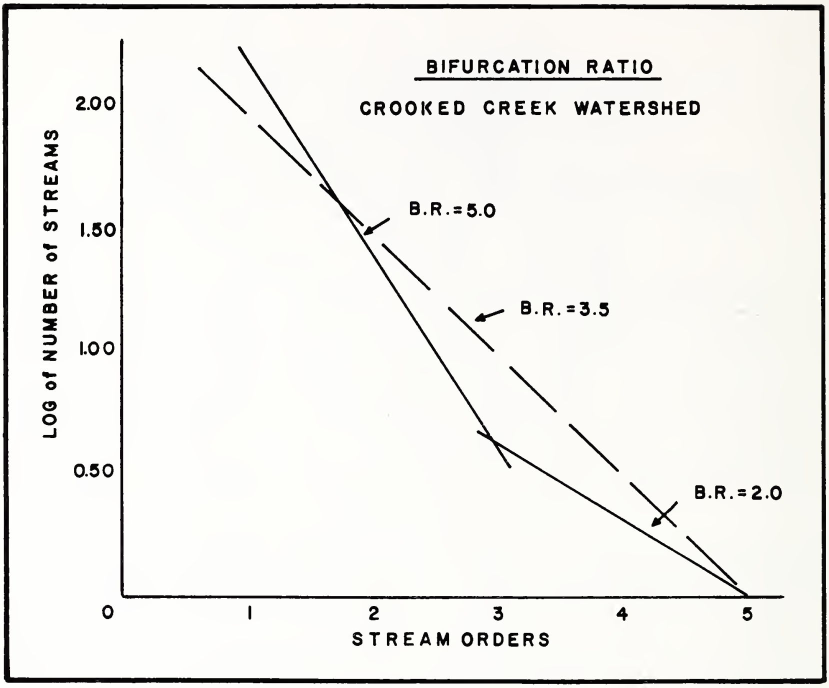

FIGURE 2. *Bifurcation ratios—Crooked Creek Watershed*

A hydrograph plotted from monthly totals of discharge at the gaging station (Fig. 3) reveals an increase in the number and magnitude of high-level and peak discharges during the period of record. The total number of months per water year with discharges above 400 cfs has increased from 3 to 8-9 from 1971 through 1974 (Table 1). During the same period the total number of months per water year with discharges above 600 cfs has increased from 1 to 8, and the total number of individual peak discharges has increased from 1 to 3 per water year.

Annual runoff has increased by an average of 22% during the water years 1971 through 1974, and by a total of 79% over that period (Table 1). Rainfall has also increased during the period, but only at an annual rate of 5.5% and by 24%

TABLE 1. *Changes in flow characteristics—Crooked Creek Watershed.*

Water Year	Number of Months Above		Total Number of Peak Flows	Annual % Change In	
	400 cfs	600 cfs		Discharge	Precipitation
1971	3	1	1	-35	+ 2.5
1972	5	4	2	+52	+ 7.1
1973	9	6	2	+49	+ 6.6
1974	8	8	3	+22	+ 5.8
Mean				+22	+ 5.5
Overall Change				+79	+24.0

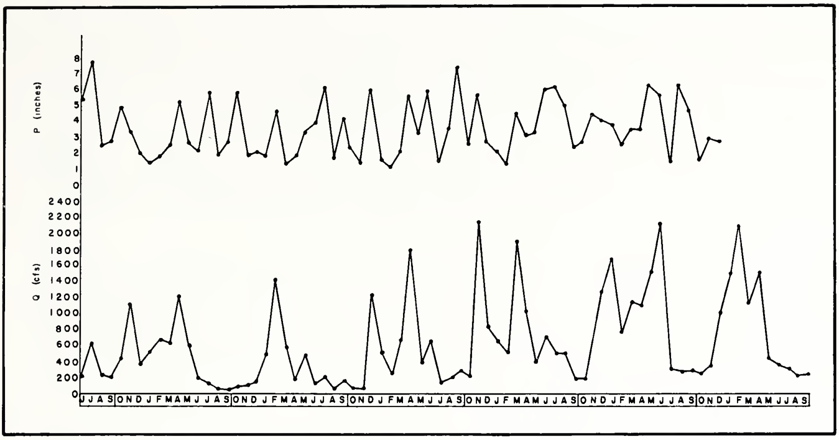

FIGURE 3. *Hydrograph of monthly totals of discharge at the 42nd Street United States Geological Survey gaging station on Crooked Creek, June 1969 through September 1975.*

from 1971 to 1974. Clearly, another factor is increasing total runoff, as well as the number and magnitude of high-level discharges. Urbanization, particularly in the upper part of the Crooked Creek Watershed, is thought to be that factor.

Water Quality

Since June 1975 samples have been taken at sixteen evenly-distributed sites along Crooked Creek and its tributaries. Collection techniques and analytical procedures were those of the United States Geological Survey (4). Field measurement of dissolved oxygen, pH, specific conductance, and temperature accompanied each sample. Routine analyses were made for twenty four chemical parameters: acidity, alkalinity, boron, cadmium, calcium, carbon dioxide, chemical oxygen demand, chloride, hexavalent and tervalent chromium, hardness, iron, lead, loss on ignition, magnesium, nitrate, nitrite, orthophosphate, silica, solids (dissolved and suspended), sulfate, sulfide, and zinc. Additional analyses were made at three-month intervals: ammonia nitrogen, barium, bromide, detergents, iodide, organic matter, organic nitrogen, and phosphorous compounds (acid and acidpersulfate hydrolyzable.)

The diversity of land use in the upper part of the Crooked Creek Watershed is clearly reflected by the water quality of the tributaries which drain the following subareas (Fig. 1).

Ditch Creek

This eastern-most tributary is channelized and drains the most heavily urbanized area. Relative to Upper Crooked Creek, the water exhibits significantly higher values for constituents indicative of organic pollution. These include nitrogen species, phosphates, and organic matter. Chloride levels average 40 mg/liter higher than in Upper Crooked Creek.

Delaware Creek

Delaware Creek drains land which is primarily agricultural. Its waters are lower in almost all chemical constituents than those of Upper Crooked Creek. Exceptions are chemical oxygen demand and loss on ignition. Higher values for these parameters are not surprising because Delaware Creek has more biota than elsewhere in the upper part of the watershed.

Agricultural activity seems to contribute little to non-point pollution. Negligible differences from Upper Crooked Creek are found for nitrogen species, phosphate, and sulfate, all of which could originate from soil treatment.

Payne Branch

This tributary drains the western portion of the upper watershed. This area is the site of two oil refineries, an asphalt company, several terminal wastewater lagoons, and a large completed Marion County landfill which lies above stream level. The contributions of the landfill and industrial operations to water quality are shown in Table 2.

TABLE 2. *Comparison of the water quality of Payne Branch with that of Upper Crooked Creek*

Acidity	Averages 45 me/liter higher
Boron	Averages 3.5 mg/liter higher
Cadmium	Trace levels; usually absent in Upper Crooked Creek
Chloride	Averages 30 mg/liter higher
Iron	Averages 3.2 mg/liter higher
Lead	Trace levels; usually absent in Upper Crooked Creek
Magnesium	Occasionally reaches values as high as twice that of Upper Crooked Creek
Organic matter	Averages 120 mg/liter higher
Phosphate	Few mg/liter higher
Silica	Averages 12 mg/liter higher
Solids (dissolved)	Averages 200 mg/liter higher
Sulfate	Averages 40-50 mg/lier higher
Sulfide	Averages 0.5-1 mg/liter higher
Oil and foam	Usually present in variable amounts; persist in diminished amounts in lower part of Crooked Creek after confluence

Crooked Creek

The water of Crooked Creek is of poor quality overall. Most chemical parameters show little variation or a gradual increase in value from headwaters to debouchment. Dilution is insufficient to offset the quantities of pollutant species received by the stream.

During periods of low flow high levels of chloride, nitrogen, phosphate, and organic matter indicate sites of point pollution. These point sources were later confirmed and identified in the field or from maps. Each was a public or semipublic wastewater treatment facility or a septic system.

Water Quality As a Reflection of Urbanization

Water quality in the Crooked Creek Watershed clearly reflects the effect of increasing urbanization. Beginning in June 1976, samples could be compared with those obtained one year earlier. The following general results were observed.

Ditch Creek

Little change in chemical parameters occurred. This finding is consistent with the fact that the eastern part of the upper watershed was already highly urbanized at the beginning of the study.

Delaware Creek

The area drained by this tributary has experienced an increase in the number of single residences and apartment complexes. A corresponding increase of 2-5% in values for dissolved solids, phosphate, chloride, and nitrogen species has occurred.

Payne Branch

Virtually no change in chemical parameters has been noted in this tributary. Although residential use of the area has increased slightly, the contribution of pollutants from industry and the landfill masks the effect of this increase.

Crooked Creek

During the one-year period deterioration of water quality accompanying population increase was significant. Representative results show increases of 30-50 mg/liter for chloride, approximately 100 mg/litter for dissolved solids and 50-100 mg/liter for suspended solids.

Conclusions

Urbanization of the Crooked Creek Watershed, particularly of its upper part, is shown by the hydrologic and water quality data. Rapid runoff and high sediment yield is accompanied by an increasing load of pollutants from residential, industrial, and agricultural sources. Runoff, sediment loss, and deterioration of water quality will increase even more as population growth of the watershed continues.

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Literature Cited

1. HARRISON, W. 1963. Geology of Marion County, Indiana. Indiana Geol. Surv. Bull. **28**:78 p.
2. MEYER, W., J. P. REUSSOW, and D. C. GILLIES. 1975. Availability of ground water in Marion County, Indiana. U.S. Geol. Survey Open-File Rpt. 75-312. 87 p.
3. MORISAWA, M. 1968. Streams—Their Dynamics and Morphology. McGraw-Hill Book Co., New York, N.Y. 175 p.
4. BROWN, E., M. W. SKOUGSPAD, and M. J. FISHMAN. 1970. Methods for collection and analysis of water samples for dissolved minerals and gases. U.S. Geol. Survey Techniques of Water Resources Investigations, Book 5, Chapter Al, 160 p.