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Mineral Quality of Illinois Rivers

BY

T. E. LARSON AND B. O. LARSON

STATE WATER SURVEY DIVISION
WILLIAM C. ACKERMANN, *Chief*
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Mineral Quality of Illinois Rivers

Thurston E. Larson and Bernt O. Larson

A paper presented on March 21, 1957, at the Illinois Section Meeting, Chicago, Ill., by Thurston E. Larson, Head, Chemistry Subdiv., and Bernt O. Larson, Engr., both of the Illinois State Water Survey, Urbana, Ill.

FOR the purpose of establishing an inventory on the quality of Illinois rivers and streams, a program of sampling and analysis was begun by the State Water Survey Division in 1945. Samples were collected by field engineers of the USGS on scheduled visits to stream gaging stations once every month or every 4 weeks, and were provided to the Water Survey Division for analysis. At the time of collection the stream flow and temperature were recorded.

Data for nineteen streams at 21 locations plus Crab Orchard Lake are now available and in the process of assembly and critical analysis. The watershed areas of some of these streams are shown in Fig. 1.

Presentation of Data

Although complete mineral analyses were made and will eventually be printed in detail, only data for turbidity, temperature, hardness, alkalinity, and total mineral content were treated graphically. Figures 2a and 2b present data from the Du Page River at Troy. In preparation of these data, the values in each category were arranged in order of magnitude; calculations were then made on the proportion of the samples (or time) for which the flow or mineral concentration was equal to, greater, or less than the specified values (Fig. 2a). Logarithmic probability paper was used as a convenient method for presentation. This method has been used previously to great advantage by Mitchell *(1)* in presenting stream flow data. The ordinate is a logarithmic scale and shows the discharge or flow in cubic feet per second per square mile, and the chemical or physical records in parts per million. The abscissa is a probability scale with frequency of occurrence or of determinations expressed as a percentage.

In these graphical presentations, the minimum values in each category are omitted as they would occur 100 per cent of the time and cannot be indicated.

It is inherent in the collection of data that maximum and minimum figures are fictitious as they represent only values that have been recorded for the number of samples collected during a given period. If more frequent samples had been collected, or if the collection period were extended, new maximum and minimum figures might be obtained. With the number of samples collected and the period, however, excellent assurance of the reliability of the median value (± 6 per cent) is apparent and a reasonable assurance is provided to the values of the data for the range of 10-90 per cent occurrence. The actual measured amounts are indicated for values between 0 and 10 per cent occurrence, and between 90 and 100 per cent occurrence. A best-fit curve is not continued through these points. The upper and lower 10 per cent values are isolated in this manner as a result of the relatively small total number of samples. They are,

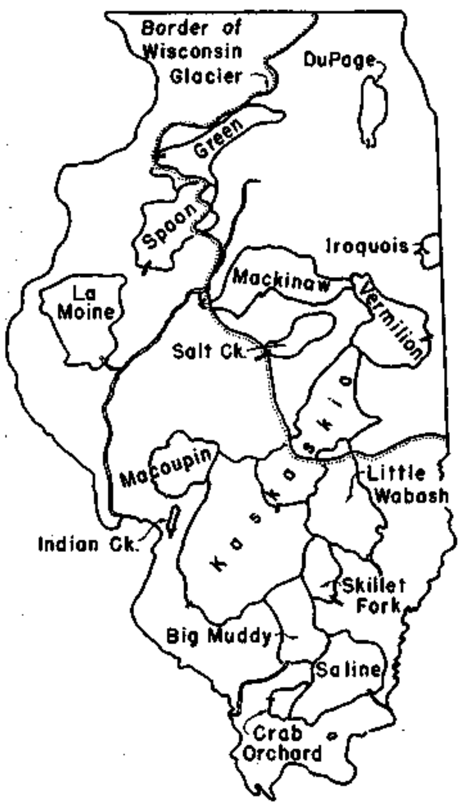

Fig. 1. Watershed Areas in Illinois

therefore, not considered to be necessarily representative of the probable occurrence. Both the average daily flow from long-term records and the instantaneous flow, as recorded at the time of sample collection, are expressed in cubic feet per second per square mile in order to eliminate the variation due to size of drainage area, and to emphasize the similarity or dissimilarity of the flows.

It is of interest to note that the variability of dissolved minerals is less than that for turbidity, which in turn is less than that for flow (Fig. 2). For 80 per cent of the samples from all sampling points, the dissolved minerals ranged from 1:3:1 in the northern part of the state, to 5-6:1 in the southern part. The turbidity ranged from 6-50:1, with the greatest magnitude for streams west of the Illinois River. Flow ranged from 10-200:1, with the greater ranges in the southern part of the state.

No attempt has been made to convert the data to indicate the quality ranges that might be expected by storage in reservoirs. Such water would be less variable in quality and possibly of lesser mineral content, depending on the newness of reservoir and the amount or percentage of runoff stored.

The turbidity, quality, and temperature data provide the design engineer with the information essential for his purposes. The time-frequency data for high turbidities are as important to the design engineer as the time-frequency of low flows. This provides information suitable for up to 90 per cent of time-occurrence and permits supplemental treatment with higher alum dosage or coagulant aids for the exceptional periods beyond the designed physical limits of the treatment capacity.

Stream Quality

Data from the Big Muddy River at Plumfield are presented in Fig. 2c and 2d. It will be noted that the stream flow as well as the turbidity and mineral content is exceptionally variable. The extent to which acid mine wastes and brine spills from oil fields in the area influence these data is not evident. It should be pointed out that the data are specific for the period of collection, and that; during the period, the stream flow was two or three times the normal. The mineral content was thus probably also higher.

Sampling Representativeness

Sampling representativeness is indicated by the relation of distribution of flows, at the time of sampling, to the distribution of average daily flows established from long-term records by the curves which do not appear to be in line with most of the records, as is the one from Indian Creek, has revealed that high as well as low flows during the sample period were very much above normal, although the median flow was not. At the Little Wabash sampling point, low deviation of the median flow did not reflect the more extensive deviations during the high and low periods. This general relationship concerns only overall averages and medians and is therefore no more than indicative of a trend.

TABLE 1

Areas of Some Illinois Watersheds

Watershed	Symbol (Fig. 5)	Area *sq mi*
North		
Du Page	a	325
Green	b	1,080
Mackinaw	c	1,100
Iroquois	d	682
Salt Creek	e	334
Vermilion	f	959
Kaskaskia (upper)	g	1,980
West		
Spoon	h	1,070
Indian Creek	i	37
Macoupin	k	875
La Moine	l	1,310
South		
Kaskaskia (lower)	m	5,220
Little Wabash	n	1,130
Skillet Fork	o	475
Big Muddy	p	2,360
Saline	r	1,040

USGS. It will be noted in Fig. 3 that the shape of distribution is quite similar, although a shift higher or lower than the long-term records is evident for a number of streams. This is a result of the deviation of rainfall during the period of collection from the normal rainfall, as established by long-term records." When studying Fig. 3, it appears that these deviations in flow are directly associated with deviations in rainfall during the sampling periods. Close examination of the duration

Quality and Stream Flow

Although the probability distribution curves for quality appear to be related to the stream flow by this manner of presentation, this is true only in a general sense as the higher concentrations of turbidity and the higher discharge rates occur at about the same time and with similar frequency. The corresponding turbidities and flow rates, however, are not necessarily related, as is shown in Fig. 4. It will also be

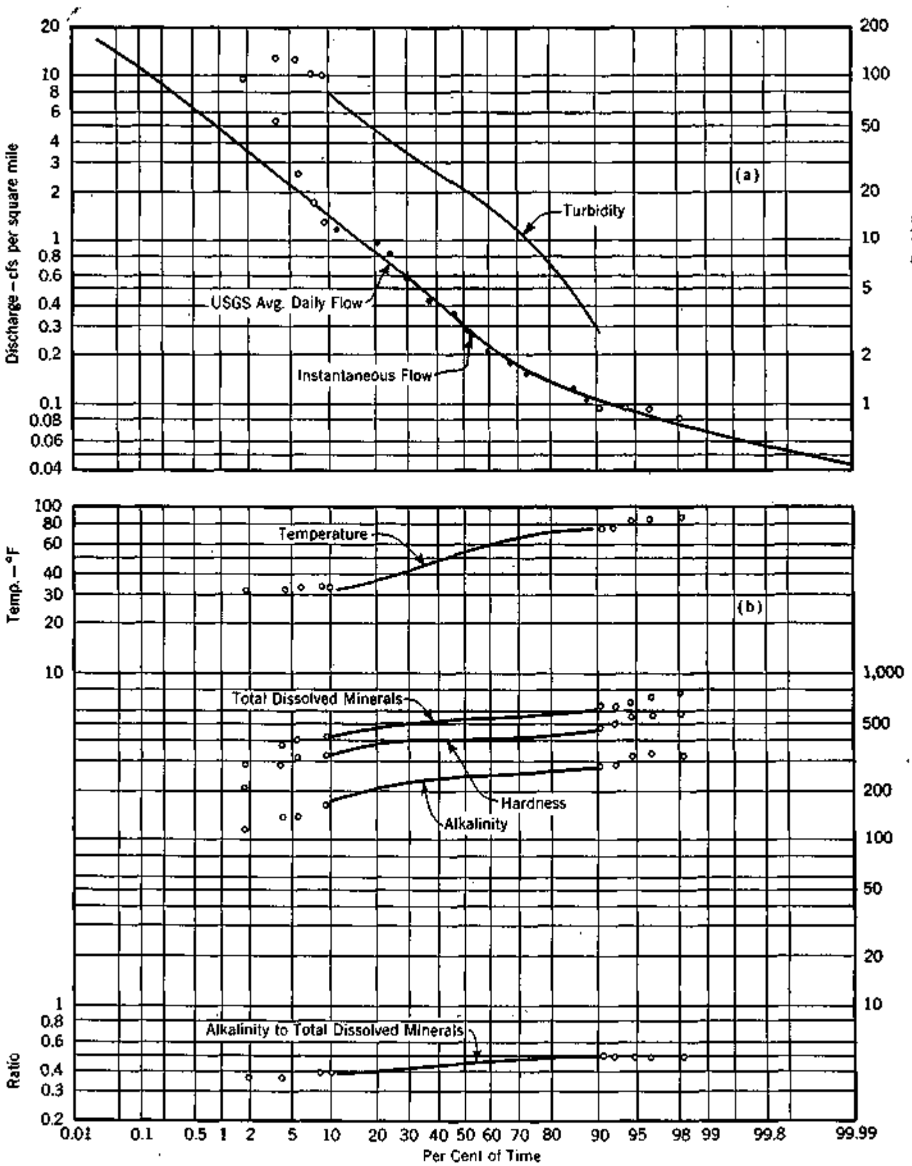

Fig. 2a, **2b. Record** and Analyses **of Du Page Eiver at Troy**

The normal annual rainfall in the river's watershed is 33.64 in., and the departure from normal during the 5-year test period was + 0.90 in. Figures 2c and 2d, referring to the Big Muddy River at Plumfield, are shown on the following page.

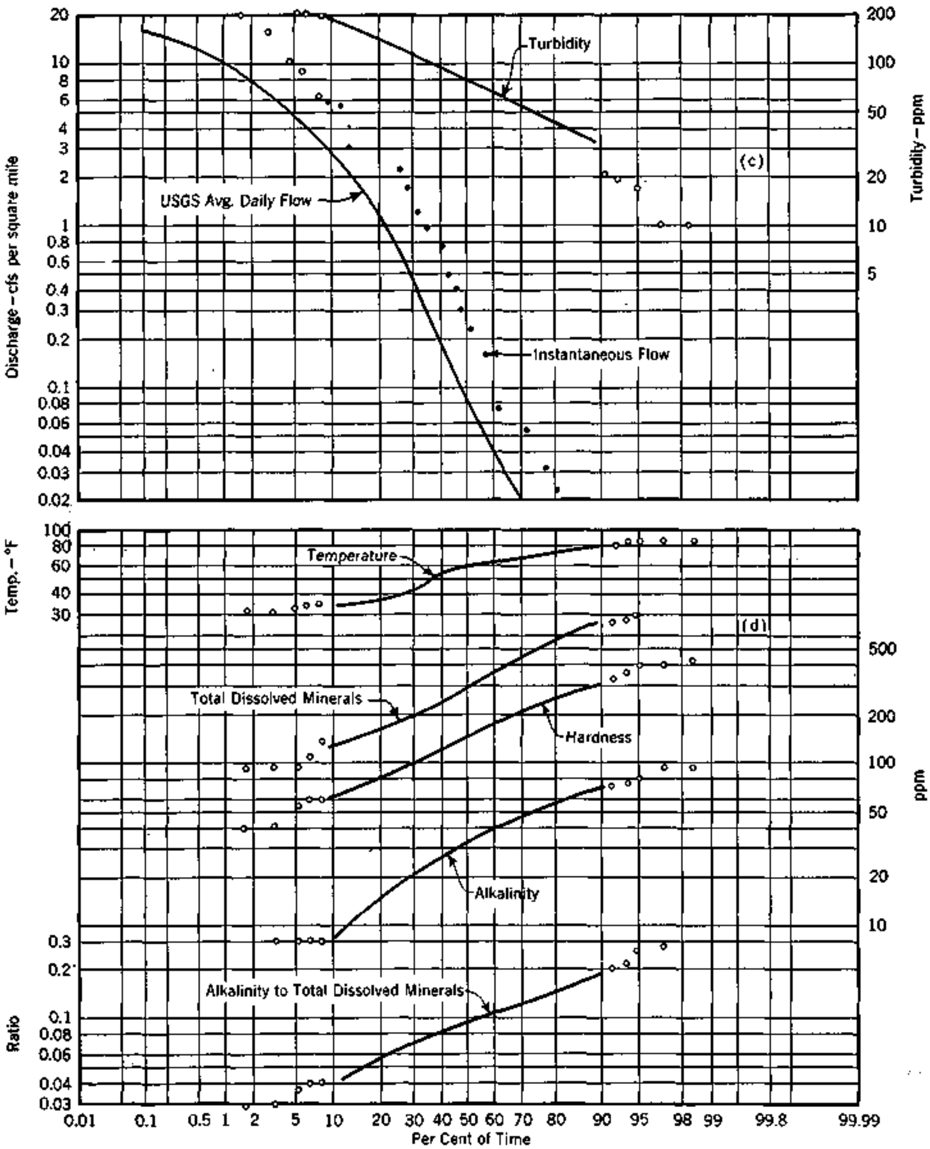

Fig. 2c, 2d. Records and Analyses of Big Muddy River at Plumfield

The normal annual rainfall in this watershed is 40.49 in., and the departure from normal during the 5-year test period was + 8.45 in. The wide range in mineral content (Fig. 2d) should be compared with that of the Du Page River in Fig. 2b. [Note: Space did not permit extension of the lower end of the discharge curve in Fig. 2c to show that 0.001 cfs per square mile was exceeded 97 per cent of the time.]

noted that the dissolved minerals, as vvell asthe-alkalinity and hardness, are not directly related to the corresponding flow rate. Here again, the relation is general and not specinc. In other words, a measure of the" total mineral content is not an indicator of the flow rate, nor is the flow rate a specific indicator of the mineral content that may be present at the time. It should, of course, be obvious that this specificity is not to be expected as a' result of the many variables concerned with the mineral quality of any water and with stream flow.

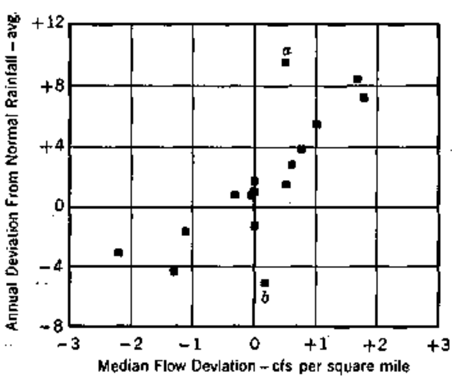

Fig. 3. Relation of Medium Discharge to Rainfall

Excess rainfall results in greater than— and deficient rainfall in less than—normal discharge. Data for two streams (a, *Indian Creek; and* b, *Little Wabash) are discussed in the text.*

Watershed Area and Physiography

It was recognized immediately on inspection of the data that, for the streams as a whole, there was little or no relation between watershed area and variability in stream flow or in water quality. This discovery diverges from the general conception that variability of stream flow is related to watershed area, but it is not incompatible. It may be considered normal for stream flow and quality to be more highly variable near the source than downstream as: [1] there is greater probability for no rainfall and no runoff for increasingly small watersheds; [2] there is less probability for sustained ground water contribution from small watersheds than from large watersheds; and [3] tributaries tend to become integrated and equalize the flows and qualities. A large tributary, however, can markedly change the flow and the quality of water in the main stream.

In the Illinois watersheds which measure from 37 to 5,220 sq miles, area appears to have so little influence, however, that it must be considered as **in**consequential. The flow and quality at the source of each tributary as well as for the integrated main stream must be dependent on the physiography of the respective watersheds. The recorded features of the streams have thus been compared on this basis.

In Fig. S and Table 1 the following data for each internal stream are given: [1] the watershed areas; [2] the general soil classifications of the University of Illinois Agronomy Department *(2)* ; [3] Lane's variability index (J) calculated for each stream from long-term daily flow records; [4] the hardness; [5] the total dissolved minerals; and [6] the turbidity. The data for hardness, minerals, and turbidity indicate the median and the lower and upper 10 per cent values of the determinations.

The variability in stream flow is low in the northern Illinois streams (the DuPage and Green rivers) where physiographic conditions are conducive to high ground storage capacity and hydrologically permit contribution of ground water to stream flow at low flow periods. This same physiography is responsible for the relatively low position. The, soil associations, that is, the relationships of the component, soil types, indicate the subsoil; of the watersheds to be calcareous glacial loarn till of Wisconsin age. Ground waters are exists toward a somewhat greater variability in stream flow, with lesser ground water contribution for the Mackinaw, Iroquois, Salt, Vermilion, and upper Kaskaskia streams. Soil as-

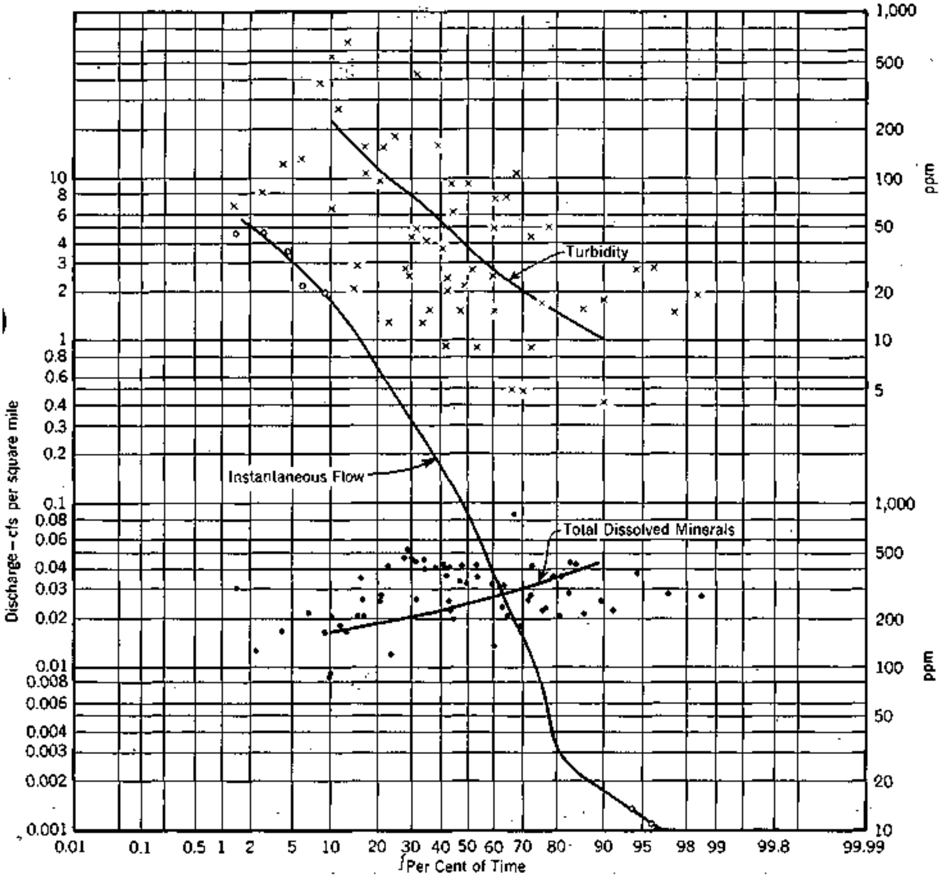

Fig. 4. Little Wabash River Analysis

The graph shows that high turbidities and flow rates are not necessarily related. Turbidity corresponding to the flow rate is indicated with crosses; total dissolved minerals corresponding to the flow rate, with black circles.

very hard and surface runoff is also exposed to the richly mineralized soil of recent glacial origin.

Farther south in the lower two-thirds of the Wisconsin glacial area, a trend sociations indicate a somewhat thicker loess * of 0–5 ft on calcareous till sub-

* A loess is an unstratified deposit of yellowish-brown loam, now thought to be chiefly borne or produced by the wind.

soil. The lesser ground water contribution results in a slight general decrease in hardness toward the southern end of the Wisconsin glacial boundary.

Continuing southward through the area where the Wisconsin glacial deposits are absent, the physiography dictates greater variability of stream flow. The lower Kaskaskia at New Athens period. The subsoils are of very fine texture and are very slowly permeable. Thus, the subsoil ground water contributions are negligible—in fact, the available ground water is virtually nonexistent toward the southern end of the state.

Greater variability in mineral composition is evident in these streams and

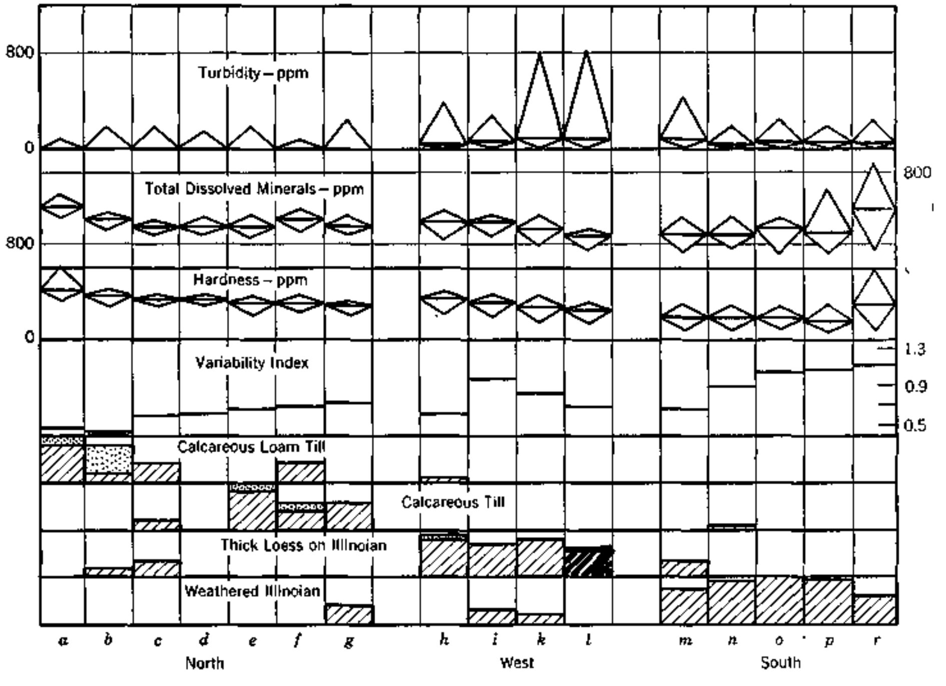

Fig. 5. Soil Associations for Watershed Areas Related to Water Quality Data and Flow Variability for Various Rivers

A key to the rivers and watersheds is given in Table 1.

is influenced by the contributions from the Wisconsin drift at the upper third of its watershed above Shelbyville. The variability in flow for the other streams increases from the Little Wabash to the Skillet Fork, the Big Muddy, and Saline rivers.

Soil associations show a weathered till subsoil of the older Illinoian glacial a general decrease in hardness is noted. Seepage from bedrock may be a factor in mineralization. At least one flowing salt well is known to exist in the Saline watershed. This well and possibly others may contribute to the high mineral content and hardness. As the character of the mineralization in these streams is also highly variable, occasional high mineralization in the Big Muddy as well as the Saline may also be a result of mine wastes or brine spills at the oil fields.

Northward, to the western side of the state, there is no general trend in south. Thick loess of 5 to more than 8 ft covers weathered Illinoian or Kansan till.

It is notable that a greater turbidity is evident, particularly from La Moine, Macoupin and Spoon River watersheds.

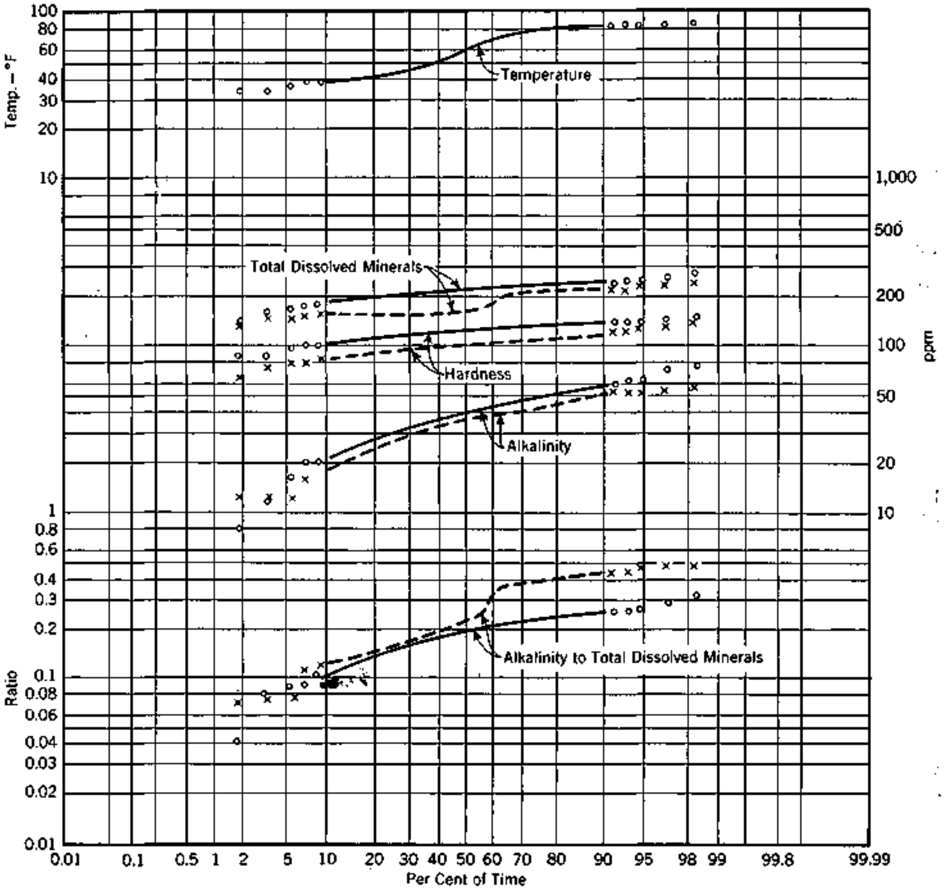

Fig. 6. Crab Orchard Lake Analysis

Samples were taken at two different points in the lake—one indicated with circles, the other with crosses.

variability of flow or mineral composition, although both may be considered as intermediate between those for the Wisconsin glacial watersheds and the thin leached Illinoian watersheds in the

This turbidity may be attributed to the recognized thick loess deposits of wind-blown till, often exceeding 9 ft in thickness in this western part of the state. The high turbidities are also noted to a lesser extent in the Kaskaskia waters nearby, particularly at New Athens.

From the standpoint of treatment, turbidity is of appreciable significance to the water plant operator. From the standpoint of reservoir sedimentation, however, turbidity which is determined empirically by the transmittance of light is not considered as significant as suspended solids. Suspended solids are determined as the weight of the suspended matter in the water. It is entirely possible that the suspended solids in the waters of the western part of the state are no greater than elsewhere, but are more finely divided and, therefore, are more resistant to the passage of light.

Analyses of samples collected at two points in Crab Orchard Lake are shown in Fig. 6. The data illustrate the relatively low dissolved minerals as result of a watershed with thin loess, only 30 per cent of which covers thin weathered glacial deposit, with the remainder on bedrock. They also illustrate a low variability in quality resulting from blending in storage and a low proportion of alkalinity in the dissolved minerals, possibly partly a result of mine drainage.

The low mineral content of surface waters from watersheds in the unglaciated area has been further reflected by isolated samples from Lake Glendale, having a watershed of less than 2 sq miles, and consisting entirely of thin loess on bedrock. These samples and others from ponds in. the vicinity have been noted to have a total dissolved mineral content of 50-70 ppm.

Conclusions

The range of quality in Illinois streams has been covered—from water of relatively high mineral content and hardness in areas of recent glacial origin at the northern end, to waters of very low mineral content in areas of no glaciation at the southern end. The notable divergences, resulting from thick loess deposits on the western side of the state, and from brine spills, acid mine wastes, and flowing salt wells in other isolated areas were noted.

With the establishment of the relation of water quality to dominant parent material in the soil patterns, the quality of waters from other watersheds may be estimated.

The method of presentation of quality data provides the engineer with a frequency of occurrence range of data which should result in the use of less hypothesis in treatment design.

Acknowledgment

The cooperation of the personnel of the State Water Survey Division and the engineers of the USGS is gratefully acknowledged. Without their help, the cost of a program of this nature would have been prohibitive.

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