A labor strike in 1959 presented a unique opportunity to assess the effect of an abrupt cessation of industrial activity on:

River-Quality Conditions

during a 16-week shutdown of upper Ohio Valley steel mills

A reference data publication of the

OHIO RIVER VALLEY WATER SANITATION COMMISSION

* members of the commission

ILLINOIS

Maurice E. Gosnell, Gosnell & Fitzpatrick
Clarence W. Klassen, Chief Sanitary Engineer
Franklin D. Yoder, M.D., Director of Public Health

INDIANA

A. C. Offutt, M.D., State Health Commissioner
B. A. Poole, Stream Pollution Control Board
Joseph L. Quinn, Jr., The Hulman Company

KENTUCKY

Minor Clark, Department of Fish and Wildlife Resources
J. O. Matlick, Commissioner of Conservation
Russell E. Teague, M.D., State Health Commissioner

NEW YORK

Herman E. Hilleboe, M.D., State Health Commissioner
Lyle W. Hornbeck, Bond, Schoeneck and King
Joseph R. Shaw, Associated Industries of New York State, Inc.

OHIO

Hudson Biery, Ohio Valley Improvement Association
Barton Holl, Logan Clay Products Company
Ralph E. Dwork, M.D., Director of Health

PENNSYLVANIA

Karl M. Mason, Department of Health
M. K. McKay, Sanitary Water Board
Charles L. Wilbar, Jr., M.D., Secretary of Health

VIRGINIA

T. Brady Saunders, State Water Control Board
William H. Singleton, State Water Control Board
Ross H. Walker, State Water Control Board

WEST VIRGINIA

N. H. Dyer, M.D., State Health Commissioner
W. W. Jennings, State Water Commission
Bern Wright, Division of Water Resources

UNITED STATES GOVERNMENT

Edwin E. Abbott, Corps of Engineers
O. Lloyd Meehean, Fish and Wildlife Service
Luther L. Terry, M.D., Public Health Service

officers

Charles L. Wilbar, Jr., M.D., Chairman
Bern Wright, Vice-Chairman
Fred H. Waring, Secretary
Verna B. Ballman, Treasurer
Edward J. Cleary, Executive Director and Chief Engineer
Leonard A. Weakley, General Counsel

staff

Edward J. Cleary, Executive Director and Chief Engineer
Robert K. Horton, Assistant Director
Francis W. Montanari, Sanitary Engineer
William L. Klein, Chemist-Biologist
David A. Dunsmore, Engineering Assistant
Verna B. Ballman, Office Manager

Secretaries: Ruth C. Bergmeyer, Alice F. Courtney,
Jane W. Renaldo, Grace B. Ziegler

** as of September 1, 1961*

OHIO RIVER VALLEY
WATER SANITATION
COMMISSION *An interstate agency representing: Illinois · Indiana · Kentucky · New York · Ohio · Pennsylvania · Virginia · West Virginia*

414 WALNUT STREET
CINCINNATI 2, OHIO

CHARLES L. WILBAR, JR., M. D.
CHAIRMAN

EDWARD J. CLEARY
EXECUTIVE DIRECTOR
AND CHIEF ENGINEER

To: The Chairman and
Members of the Commission

It is my privilege to submit an account of what happened to river quality when the steel industry in the upper Ohio Valley ceased operations for a 16-week period during the 1959 strike.

Because of the shutdown a unique opportunity presented itself to appraise the condition of streams that were relieved of a burden of industrial effluents. Preparations had been made for such an eventuality and when the strike was called the personnel and services marshalled for this task were activated. Participants included members of the ORSANCO Water Users Committee, the U. S. Geological Survey, and the pollution-control agencies of Ohio, Pennsylvania and West Virginia.

Those who participated in the acquisition of data must not be held accountable, however, for the assessment of its meaning. Your staff assumes sole responsibility for this interpretation and the statement of findings. The report includes the data and explains how it was evaluated.

In large measure this study reflects the efforts of David A. Robertson, Jr., former staff engineer-hydrologist, and Robert K. Horton, assistant director. Mr. Robertson planned and directed the field work and then undertook the compilation of data and its interpretation. His endeavors were aided by the counsel of Mr. Horton who completed the evaluation and edited the report following the resignation of Mr. Robertson in December, 1960.

Respectfully submitted,

EDWARD J. CLEARY
Executive Director-Chief Engineer

Cincinnati, Ohio
September 1, 1961

C O N T E N T S

Turn page for map

RIVER-QUALITY CONDITIONS

During a 16-week Shutdown of Upper Ohio Valley Steel Mills

Shutdown of virtually all steel mills in the upper Ohio Valley during a 16-week strike in 1959 provided an unusual opportunity to assess river-quality conditions under reduced waste loadings. The strike began on July 15 and ended on November 7, 1959. Stream sampling began on July 21 and was continued for twenty-one weeks until December 10, 1959.

Five river stretches serving major steel-producing centers were chosen for the investigation. Two of them -- the lower Allegheny and the lower Monongahela stretches -- are areas in which coal-mine drainage is prevalent. Another stretch included the Mahoning-Beaver rivers, which are relatively free of mine-drainage influences. The fourth and fifth stretches were sections of the Ohio River above and below its confluence with the Beaver River. These two stretches reflected the cumulative influence of quality changes in tributaries as well as the reduction in waste loads discharged directly into the Ohio River.

The significance of steel-industry discharges may be gauged from the knowledge that the mills in the upper Ohio Valley produce more than one-third of the total output of steel in the U.S.A. Stated in terms of primary components and amounts of waste entering the streams, the sum of the daily average discharges above the final sampling point (which was Wheeling) are calculated to be: 1,300 tons of dissolved solids, 900 tons of iron (both in dissolved and suspended forms) and 250 tons of free acid.

Locale and Methodology

The areas monitored are depicted in the schematic map (Fig. 1). Here also are shown location of the river-sampling points and the relative magnitude of steel-industry water requirements in the various river stretches.

The choice of indicators of stream-quality change was dictated, in part, by knowledge of the characteristics of steel-mill effluents. For example, large quantities of water are used for cooling purposes; consequently, temperature changes were chosen as one of the parameters. Because iron, dissolved solids, acids and phenolic-type materials are almost universally encountered in waste effluents from steel mills, stream samples were analyzed to measure these characteristics. In addition, quality variations as measured by alkalinity, threshold-odor values, hardness, sulfate, fluoride and manganese were also evaluated.

One of the necessities in preparing this assessment of river-quality was development of better information on water use and waste loads from the steel industry than had been available heretofore. For this purpose, basic data assembled in recent years by the ORSANCO signatory states proved useful. This revealed, among other things, that in the upper Ohio Valley water use per ton of steel produced is in the range of 25,000 to 35,000 gallons; this is substantially less than the frequently-quoted value of 65,000 gal.

From ORSANCO records it was also possible to develop unit values of waste constituents per ton of steel capacity. These unit values were used in making estimates of total waste discharges. This procedure provided the most accurate basis available for comparing relationships between stream conditions and waste loads during periods of mill operation with those existing during the strike.

Among the vagaries of rivers that complicate quality diagnoses are changes associated with flow (dilution water). These changes profoundly and erratically affect concentration values with relation to load. It should be noted, therefore, that the monitoring during mill shutdown was influenced by rising river flows, which began a few weeks before the end of the strike. After the mills re-opened relatively high water with unstable flow conditions and associated turbulence were encountered during the final five weeks of the survey.

Findings that otherwise may have been inconclusive if judged solely during the high-water conditions after the strike ended, were confirmed by comparing 1959 steel-strike conditions against those observed in similar low-flow periods of recent years. This comparison was made possible by the availability of quality records from the ten-year ORSANCO monitoring program and from various municipal and industrial water plants.

This, then, is the background associated with development of the following findings.

FINDINGS

(1) Shutdown of the mills resulted in a decrease in phenolic compounds, threshold-odor intensity and in dissolved-iron content. When the mills resumed operation the values of these quality-indicators were more than doubled at most sampling stations.

(a) Phenol concentrations at all except two sampling stations averaged 3.0 ppb (parts per billion) during the shutdown as contrasted with 16 ppb after the mills resumed operation. During the shutdown, phenol concentrations in the river averaged only one-quarter of the values observed in previous years.

(b) At eight of the 12 monitor stations threshold-odor intensities were from two to eight times greater after start-up of the mills than they were during the shutdown period. An average threshold-odor number of 8 was observed at these stations during the strike; after resumption of mill operation the average value increased to 29.

(c) Dissolved-iron concentrations at most stations during the shutdown averaged 0.1 ppm (parts per million); after start-up of the mills concentrations were two to seven times that value.

(2) Manganese concentrations in the upper Ohio River system were lower during the strike period than those observed in previous years during comparable low-flow periods. In the Allegheny, Mahoning and Ohio rivers, manganese levels were from one-tenth to one-half of the values observed in previous years.

(3) Cessation of mill operations produced only minor changes in the hardness, sulfate and dissolved-solids concentrations in the Monongahela and Allegheny rivers. However, this does not imply that dissolved substances in steel-mill effluents are insignificant; quite to the contrary, ORSANCO records show that one steel mill alone discharges over half a million pounds of dissolved solids daily. Rather, the condition observed suggests the tremendous impact of coal-mine drainage; the effect of this drainage on mineralization of river water apparently overshadows the contribution from steel-mill wastes.

(4) The presumption that mine-drainage pollution masks the effect of other waste effluents on river quality is confirmed by observations on the Mahoning River at the Lowellville station. Here there is relatively little mine drainage. When the steel mills went out of operation there was a 20 percent reduction in hardness, a 50 percent reduction in sulfate and a 30 percent reduction in dissolved solids from values previously recorded in the river.

(5) Further evidence of the profound influence of acid mine-drainage on quality conditions is revealed by alkalinity variations in the Monongahela River. When the steel mills ceased operations the acidity in the Monongahela produced conditions of zero alkalinity; this was a surprising contrast to conditions that prevailed for two months prior to the strike when alkalinity values ranged from 4 to 6 ppm. The explanation lies in the fact that the steel mills, which

use vast quantities of Monongahela water for cooling purposes, find it desirable to neutralize the water. In so doing, they add alkaline materials. When this water with its increased alkalinity is returned to the river it further counteracts acidity that is present from mine drainage. Thus, steel-mill operations -- at least during periods of low stream flow such as prevailed during the strike -- actually restore alkalinity to an otherwise acid stream.

(6) Alkalinity conditions in the Mahoning River took a different turn -- toward decided improvement -- when the steel-mill discharges ceased. At the Lowellville monitor station alkalinity concentrations were more than doubled -- up to 80 ppm from a range of 8 to 35 ppm in the reference years.

(7) Acidity of the Monongahela River influences alkalinity conditions in the Ohio River for at least 25 miles (from Pittsburgh to the mouth of the Beaver River). In this stretch of the Ohio River alkalinity concentrations at times during the shutdown period were depressed to as low as one ppm.

(8) Alkalinity variations in the Ohio River below the mouth of the Beaver River (Midland-Wheeling stretch) exhibited a pattern similar to that in the Beaver River itself. This suggests that the depressed alkalinity condition observed in the first 25 miles of the Ohio River is restored following the admixture of Beaver River water, which is much higher in alkalinity.

(9) The relative influence of steel-mill wastes on quality conditions in the upper Ohio River may be gauged from the following: The industry contributes about 27 percent of the total acid load, 9 percent of the hardness load, 18 percent of the sulfate load and 18 percent of the dissolved-solids content discharged into waters of the upper Ohio River system.

(10) Thermal effects of steel-industry wastes were measurable in terms of cooler river water during the shutdown period. At most stations, river temperatures were 3 to 10 deg. F. cooler during the shutdown period than during comparable periods in previous years when mills were operating (based on water-over-air temperature differentials). At one station (Lowellville on the Mahoning River) river temperatures were lower by as much as 20 deg. F. At Wheeling, the station furthest downstream, the thermal load during the shutdown was about 75 billion Btu's per day less than that in previous years.

(11) Steel-mill wastes influence fluoride concentrations in the upper Ohio River and its tributaries, particularly during low flow. Stream concentrations during the strike averaged 0.4 ppm. This is about one-half the average value observed in previous years when the mills were operating.

In addition to these staff findings, the following observations from other sources are pertinent:

(a) W. L. Minckley, biologist-in-charge of a University of Louisville survey crew under contract to ORSANCO, reported that a collection of aquatic-life specimens taken near Montgomery Dam (mile 31.7) on July 26, 1959 -- eleven days after shutdown of the mills -- had a greater abundance of fishlife and a wider variety of species, especially those associated with cleaner water, than three previous collections taken when the mills were operating. Mr. Minckley went on to say: "Some drastic changes occurred in the habitat making it more suitable for fishlife in late July 1959."

(b) Managers of water-treatment plants who participated in the sampling program reported fewer difficulties with taste-and-odor problems during the strike, especially those associated with the presence of oily materials and industrial chemicals. They also noted that the iron content of river water was lower.

SURVEY BACKGROUND AND ORGANIZATION

During the first half of 1959, when contract negotiations were in progress between the United Steel Workers Union and management of the steel industry, there were pessimistic pronouncements that suggested the likelihood of a strike. Informed sources predicted that if a strike did occur it would be a prolonged one.

Recognizing that stoppage of steel-industry operations and with it the cessation of waste effluents would afford a unique opportunity for evaluation of stream conditions, the ORSANCO staff prepared for this eventuality. The objectives of the study were: (1) To measure river-quality conditions during the strike; and (2) to assess the effects of waste effluents from steel mills on stream quality.

When the steel mills did close on July 15, 1959, the ORSANCO fact-finding program was set into motion. The strike continued until November 7 -- a period of sixteen weeks. Collection of river samples was started on July 21, and continued until December 10, about five weeks after end of the strike.

In developing plans for this case study the experiences gained in operating a basin-wide water-quality monitoring program proved most helpful. Since 1951 ORSANCO has been gathering and recording -- on a continuous, year-round basis -- information on stream quality from a network of 45 monitor stations.

This permanent network was augmented by twelve stations to obtain detailed information at strategic points where steel mills are located. The supplementary stations included three on the Monongahela River, one on the Allegheny River, one on the Beaver River and seven on the main stem of the Ohio River between Pittsburgh and Wheeling. (See Table 1 and Fig. 1).

Program Participants

The U. S. Geological Survey, with whom ORSANCO has been cooperating for a number of years on stream-quality studies, was an active participant in planning and executing the survey. Most of the analytical tests were conducted by the U.S.G.S. laboratory in Columbus, Ohio, under direction of George Whetstone, district chemist, and Paul Drake, project head.

Other participants included personnel of water-treatment plants located in the survey area. Those who contributed generously of their time and service, were:

Reginald B. Adams, Superintendent of Purification, Wilkinsburg-Penn Joint Water Authority;

W. T. Darby, General Superintendent, Charleroi Water Works;

F. R. Perrin, Chief Chemist, South Pittsburgh Water Company;

A. A. Pace, Chief Chemist, Duquesne Light Company;

Robert Moran, Chief Chemist, Allegheny County Sanitary Authority;

L. H. Hummel, Chief Chemist, Beaver Falls Water Works;

Donald H. Craik, Manager, Midland Water Works;

Donald T. Duke, Superintendent, East Liverpool Water Works;

Frank J. DeFranco, Superintendent, Weirton Water Treatment Plant;

Edward Shroyer, Superintendent of Filtration, Wheeling Water Works.

These participants arranged for collection of samples and, in addition, reported personal observations of stream conditions during the strike period. In some cases they produced old records on quality conditions that had reference value for the study.

Important aid was rendered by the Ohio State Department of Health, which provided laboratory service for threshold-odor determinations. This work was done by Leo F. Ey, laboratory head, under the direction of F. H. Waring, then chief sanitary engineer of the department, who also is secretary of ORSANCO.

Also contributing to the planning and execution of the survey were the Pennsylvania State Department of Health and the Water Resources Commission of West Virginia. D. C. Heil, district sanitary engineer of the Pennsylvania Department of Health assembled information on waste loads.

A further contribution to the survey was made by the Surface Water Branch of the U. S. Geological Survey in supplying information on stream flows.

Collection of Samples

Stream samples for general analysis were collected at all stations four days each week -- Monday through Thursday. In addition, separate samples were collected periodically for those analytical determinations that required prompt transit to the laboratory.

During the first half of the survey, a U. S. Geological Survey vehicle made a run to each station and delivered samples to the laboratory in Columbus, Ohio in order that analyses for phenols and threshold odor could be made on the following day. The Tuesday run was discontinued after the eighth week of the strike; the Thursday run was continued throughout the survey period.

Analytical Determinations

Analytical work was designed to provide water-quality measurements related specifically to the major constituents of waste discharges from steel mills. General analyses included tests for: alkalinity, acidity, pH, specific conductance, turbidity, temperature, hardness, iron, manganese, sulfate, fluoride and dissolved solids.

The analytical schedule called for the first six tests to be made on individual daily samples, with the remainder of the determinations made once each week on a four-day composite sample. This schedule was continued for the first eight weeks. During the next eight weeks analyses were made only on composite samples, with the exception of temperature and specific conductance, which were made daily. At the end of the strike, the analytical schedule was again modified to provide daily analyses of alkalinity, acidity, pH and turbidity, as well as temperature and specific conductance.

Since samples for analysis of phenols and threshold odor were available for examination in the laboratory on the day following collection, no preserving or fixation procedure was employed other than icing.

All analytical tests except those for temperature and threshold odor were made in the Water-Quality Laboratory of the U. S. Geological Survey in Columbus, Ohio. Analytical procedures employed were those published in the U.S.G.S. Water-Supply paper 1419, details of which are also given in the ORSANCO Water-Quality and Flow Variation publications.

Temperature of all samples was recorded at the time of collection.

As noted previously, threshold-odor determinations were made by the Ohio State Department of Health laboratory. The procedure used is that given in the tenth edition of Standard Methods for the Examination of Water, Sewage and Industrial Wastes.

Program Costs

Total cost for conducting the water-quality investigations during the 21 weeks was $15,000. This included the analytical work done by the U. S. Geological Survey and delivery expenses from sampling stations to laboratories. The U.S.G.S. participated in program costs on a dollar-matching basis, and the net cost to ORSANCO was $7,500.

It is estimated that if sample collections had not been obtained through the volunteer efforts of water-plant managers, the total cost would have ranged from $19,000 to $21,000. Previous experience with stream-quality surveys has shown that collection costs may range from 15 to 25 percent of total program costs.

Some Facts About the Region

The Ohio River is formed at the "Point" in Pittsburgh, Pa. by the juncture of the Allegheny River flowing from the northeast and the Monongahela River from the south. At this point the Ohio drains a watershed of some 19,110 square miles, of which 11,730 square miles are contained in the Allegheny basin and 7,380 in the Monongahela basin.

The topography in both basins is, for the most part, hilly or mountainous with steep slopes and narrow-stream valleys. In the 87-mile stretch from Pittsburgh to Wheeling, W. Va., the Ohio River flows northwestward for the first 40 miles to the Ohio-West Virginia state lines, and then it bends in a southerly direction toward Wheeling.

At Wheeling the drainage area totals 24,600 square miles. The major tributary in this stretch is the Beaver River, which enters the Ohio 25 miles below Pittsburgh; it drains an area of 3,145 square miles. Contrasted to the rugged topography of the Allegheny and Monongahela basins, the Beaver watershed is relatively flat, particularly in the northern half.

The upper Ohio River basin contains some of the largest centers of population and industrial development in the United States. The larger metropolitan areas, based on 1950 census figures, are as follows:

Metropolitan area	Metropolitan population (1950 census)	National rank in size
Pittsburgh, Pa.	2,213,236	8
Youngstown, Ohio	528,498	30
Wheeling, W. Va.-Steubenville, Ohio	354,092	48
Johnstown, Pa.	291,354	58

All of these areas are within a radius of 60 miles of Pittsburgh. Streams in the area are intensively used to supply water for municipal and industrial needs, for the drainage of sewage and industrial-waste effluents, for river transport and for recreation, notably boating.

A series of nine locks and dams on the Ohio River between Pittsburgh and Wheeling maintain a minimum channel depth of nine feet for navigation. This minimum depth is maintained for a distance of 70 miles above Pittsburgh on the Allegheny River by eight locks and dams. The Monongahela is canalized for 128 miles above Pittsburgh by 14 locks and dams; they provide navigable depths of eight feet for the first 90 miles and seven feet for the remaining 38 miles. Waterway traffic in the Pittsburgh vicinity makes the Ohio and Monongahela rivers the most heavily travelled inland waterways in the world.

With regard to municipal and industrial uses (including steam power plants) it is estimated that the total water withdrawn from streams for these purposes in the upper Ohio basin ranges from seven to eight billion gallons per day. Of this volume, municipal uses comprise only about five percent. Industrial use is primarily for cooling purposes. Practically all of the water withdrawn by the municipalities and industries is returned to the stream after use.

On the main stem of the Ohio, total water withdrawals in the river stretch between Pittsburgh and Wheeling are:

For municipal supplies	20 mgd
For industrial -- process, steam and cooling	1,063 "
For power-plant cooling	1,810 "
Total	2,893 mgd

The quality of river water in this area is influenced by discharges of municipal sewage, industrial waste and mine drainage. In the watershed above Wheeling there are 3,440,000 people (1960 census) connected to public sewer systems; 2,711,000 or 79 percent of these are served by sewage-treatment plants. The largest treatment facility in the Ohio Valley is at Pittsburgh, where the Allegheny County Sanitary Authority purifies the wastes from a population of 1,278,000 and numerous industrial establishments.

Results from this survey, supplemented by other data, reveal that drainage from active and abandoned coal mines has a profound influence on the quality of water in the Monongahela, the lower Allegheny and the Ohio rivers. Such drainage brings with it substantial amounts of free acid, salts of iron and other heavy metals, sulfates and hardness-causing constituents. Previous studies indicate that 70 percent of the mine drainage in the upper Ohio basin is discharged into the Monongahela. At times this drainage is so great that the entire flow of the lower Monongahela has acid characteristics. The effect of this drainage influences the quality of the Ohio River.

A major part of mine drainage in the Allegheny basin comes from the Kiskiminetas River, which enters the Allegheny 30 miles above Pittsburgh. The Beaver watershed is relatively free of mine drainage.

There are various industrial enterprises in the area that discharge waste effluents directly to streams. These emanate from the manufacture of steel products, chemicals, pulp and paper, mining and handling of coal, operation of oil fields and refineries, processing of dairy and food products and many others. Steel production, however, is the dominant industrial enterprise.

WASTE WATERS OF THE STEEL INDUSTRY

The magnitude of the steel industry in the survey area is revealed by these facts: About 20 percent of the total labor force is engaged in the manufacture of steel and fabricated steel products (1950 census figures for Pittsburgh, Johnstown, Youngstown, Wheeling, Steubenville); steel-production capacity totals 45,000,000 ingot tons annually, which is 36 percent of the national total; more than one third of this capacity (18,000,000 ingot tons) is concentrated in the first forty-mile stretch of the Monongahela River above Pittsburgh.

The relation of plant-production capacity for coke, pig iron, steel and steel products to sampling stations is shown in Table II. Here is shown the cumulative total capacity for steel plants in the watershed above each station.

Also shown in Table II is an estimate (on a cumulative basis) of the amount of water withdrawn from rivers and used for process and cooling purposes by the steel mills. The tabulation is based on unit values of 25,000 to 35,000 gallons of water per ton of steel capacity (unit values were determined from records submitted by state agencies).

It will be noted that water use totals three to four billion gallons daily for the watershed above Wheeling. From this it is concluded that the steel industry in the upper Ohio River and its tributaries accounts for about one-half of the withdrawals for all municipal and industrial purposes, including those for steam power plants.

Production Curtailed by Strike

The location and amount of steel-plant capacity that was out of production during the 1959 strike is shown in the following tabulation:

Area Above	Production capacity of mills closed by strike	
	Coke capacity	Steel capacity
Hays	98 percent	99 percent
Verona	100 "	92 "

Area Above	Production capacity of mills closed by strike	
	Coke capacity	Steel capacity
South Heights	93 percent	98 percent
Eastvale	100 "	87 "
East Liverpool	95 "	95 "
Wheeling	90 "	90 "

Waste Loadings

Industrial-waste inventories for the entire watershed have not been completed by the pollution-control agencies of the signatory states; therefore, the magnitude of the waste loads from the steel industry is not precisely known. However, records from industries discharging directly to the Ohio River are available in sufficient number and variety to permit development of unit values of waste per ton of steel-plant capacity. These unit values, together with information on production capacity, provided a means for estimating amounts of wastes discharged by steel mills in the survey area.

Waste loadings, so estimated and expressed in tons per day, are shown in Table III. Above Wheeling, for example, calculations show a cumulative daily load that averages over 1,300 tons of dissolved solids, 900 tons of iron, and 250 tons of free acid. The tabulation also reveals that steel plants on the Monongahela River contribute about one-third of the waste loadings discharged upstream from Wheeling.

Listed at the bottom of Table III are the unit loads (amount of waste constituent per ton of plant capacity) from which cumulative loadings were estimated. It is recognized that these unit values may not be applicable to a specific mill, because of variations in processes, types of products and the degree to which certain waste constituents are removed by recovery or treatment facilities. However, the cumulative loadings developed from the unit values are believed to be representative of the area under study; at least they are sufficiently accurate to provide a fair basis on which stream conditions during the strike can be compared with those during periods of normal operation of the steel mills.

Thermal waste loadings estimated for the steel industry are given in Table IV in billions of Btu's (British thermal units). The first part of this tabulation shows the cumulative thermal loading for the entire watershed above each sampling station; this was computed from the average water use shown in Table II (30,000 gallons per ton of steel capacity) and an average temperature rise between water intake and waste outfall of 25 degrees Fahrenheit. (This figure for temperature differential between intake and outfall is based on waste-inventory records supplied by the states). At Wheeling, for example, the thermal loading from all upstream steel mills totals some 790 billion Btu's per day.

Since increased temperatures in rivers caused by man-made thermal loadings tend to balance in time with natural temperature levels, it is perhaps more representative of effects to restrict the accumulation of thermal discharges to a specified distance above each sampling station. Estimates so made are shown in the second part of Table IV. For purposes of estimate, an upstream stretch of 25 miles was arbitrarily selected. This was done simply to convey the concept of limited upstream loadings and with no intention of implying that 25 miles is the precise distance over which elevated stream temperatures from thermal discharges may be expected to occur.

From Table IV it may be seen that the 25-mile stretch with the highest cumulative thermal loading -- 270 billion Btu's -- is the stretch immediately above Brunot's Island (which includes sections of both the Monongahela and Allegheny rivers). The stretch with the next highest loading -- 206 billion Btu's -- is that above South Heights.

DILUTION WATER CONSIDERATIONS

No study of river quality conditions can escape reference to flow or volume of dilution water. Knowledge of this variable is essential in order to: (1) compare computed stream loadings (flow multiplied by concentration) with on-shore loads; (2) to determine relationships between stream characteristics and frequency of occurrence; and (3) to evaluate variations in quality from season to season and from station to station.

In the river stretches where the twelve sampling stations are located the U. S. Geological Survey operates six stream gages. Data for these gages are shown in Table V. From this tabulation it will be noted that stream levels, particularly during the month of September, dropped to drought values. On the Monongahela and Ohio rivers the low flows are of a magnitude that recur about once every five to ten years. On the Allegheny the drought flow was more severe, being of the magnitude that recurs about once every 15 to 20 years.

Only during one year (1957) of the 21 years of record for the Allegheny River have flows been lower than in 1959. Low flows in the Beaver River, on the other hand, were less severe, dropping only to that level which is experienced in the summer-fall season most every year.

Variations in weekly average flow during the 21 weeks of the survey at each of the stream gages are shown by the hydrographs in Fig. 2. It may be seen from the chart that the lowest average flow in the Monongahela River at Charleroi, for example -- 786 cfs (cubic feet per second) -- occurred during the week of September 21. The highest flow -- 16,400 cfs -- was recorded in the week of November 30. This represents a range in weekly flow of approximately 1 to 20. Only at the Natrona gage (Allegheny River) were the variations in weekly flow greater; here the ratio of minimum to maximum flow was 1 to 24.

One conclusion to be drawn from the hydrographs is that river flows remained relatively stable at a low level from the beginning of the sampling period (July 21) until the first part of October -- a period of 12 to 14 weeks. This stable, low-flow period provided an almost ideal situation under which to study water-quality conditions.

Higher flows and unstable conditions occurred in the latter part of October. The higher flows were due partly to normal seasonal change and partly to heavy rainfall caused by hurricane "Gracie". High flows and unstable conditions prevailed from this time until the end of the survey on December 10.

Also shown in Fig. 2 are data in terms of stream flow per square mile of drainage area (cfs/sq. mi.). The values shown in the chart reflect the same general pattern at all stations. However, it is to be noted that flow per square mile from July through September was the lowest in the Allegheny River and highest in the Beaver River. One major factor contributing to this difference was the effect of flow augmentation provided by release of water from multiple-purpose reservoirs that are operated in the upper Ohio basin by the U. S. Corps of Engineers.

The influence of reservoir operation on stream flow is shown in part "C" of Fig. 2, which was prepared from provisional data furnished by the Ohio River Division of the U. S. Corps of Engineers. During the drought period as much as 67 percent of the Monongahela River flow, 49 percent of the Beaver River flow, and 44 percent of the Ohio River flow was contributed by reservoir releases. To state this in another way, the river flow without augmentation from reservoirs would have been from about one-third to one-half of what it actually was.

Above Wheeling the seasonal storage capacity allocated in reservoirs for water supply and low-flow augmentation totals 30 billion cubic feet. Of this reservoir capacity, 54 percent is located in the Beaver basin. The Monongahela basin has 37 percent of the capacity and the Allegheny basin has 9 percent.

DATA AND ITS EVALUATION

During the 21-week sampling period more than 1,000 daily samples were collected and over 7,000 individual analyses were performed. To reduce this mass of data to manageable proportions, results of analyses made daily were converted to weekly averages. The averages and the weekly composite results thus became the working data for the study. The data is shown in Appendix A.

In the following sections of this report information is presented showing week-to-week variations in quality conditions and the relationship between these variations and changes in stream flow. Also, for each parameter of water quality, conditions occurring during the strike are compared to those observed in the five weeks after start-up of the steel mills.

Data on stream conditions during the last five weeks of the survey, which were obtained after termination of the strike, left something to be desired. The difficulty arose primarily because of the abrupt change in stream flow a few weeks before the end of the strike -- from stable, low-flow conditions to unstable conditions with flows of higher magnitude. Another complicating factor was the concomitant drop in air and water temperatures.

Therefore, in order to provide a more complete appraisal of the effects of steel-mill effluents a comparison was made of stream conditions during the 1959 strike with those in previous years when the mills were operating. The years of record chosen for this purpose were 1957, 1953 and 1952, because in these years there were sustained low-flow periods similar to that in 1959. Quality records for 1957, 1953 and 1952 were available from ORSANCO's water-quality monitoring program and from water-treatment plants located in the area. Data on average stream conditions during the summer, low-flow periods of 1959, 1957, 1953, 1952, in terms of concentrations and loadings, is tabulated in Appendix B.

During the three reference years, average steel production -- in terms of percent of rated capacity -- for the months July through October was as follows:

	Pittsburgh area	Youngstown area	Wheeling area
1957	83	76	86
1953	96	105	97
1952	95	99	85

During the 1959 survey, stable low-flow conditions prevailed for a period of 12 weeks (until October 8) on the Allegheny and Ohio rivers, and for a period of 14 weeks (until October 22) on the Monongahela and Beaver rivers. Average stream-quality conditions during these periods of 12 or 14 weeks have been compared to average conditions during the same periods in the three reference years.

A summary of all survey data from the twelve sampling stations is presented in Table VI. The tabulation includes information on both concentrations and stream loadings for the various constituents.

Ranges in stream quality were quite wide in many cases. On the Ohio River at Brunot's Island, for instance, the weekly average threshold-odor values ranged from a low of six to a high of 260; alkalinity ranged from one to 18 ppm, hardness from 71 to 204 ppm and dissolved solids from 128 to 408 ppm. The ranges in stream loadings were even greater.

In the following sections each of the water-quality conditions measured during the survey is examined in detail and evaluated.

Alkalinity, Acid Loads and pH

One of the sensitive indicators of water-quality conditions in the upper Ohio River and some of its tributaries is alkalinity. Only a small amount of alkalinity -- or none at all -- remains in some streams after they have been burdened with acid loads from mine drainage and other industrial-waste discharges.

It should be recognized that reactions between alkaline and acid materials in streams are complex and not always predictable. For one thing, uncertainty exists regarding the completeness with which acid salts (of which the most important in the area under survey is iron sulfate) react with stream alkalinity and to the extent by which the reaction actually reduces alkalinity. Furthermore, it has been theorized that when reaction products (such as iron bicarbonate) remain in solution no decrease in alkalinity is effected; stream alkalinity decreases only when the iron has been precipitated. Because of these and other factors any attempt to balance on-shore acid discharges against stream alkalinities must suffer from lack of precision.

Survey data, in terms of weekly-average alkalinity concentrations, are shown by bar graphs in Fig. 3; the period after start-up of the mills is indicated by shaded bars. In Fig. 4 average alkalinities during and after the strike are shown, and these values are compared with average values in other years when the mills were operating and stream flows were similar (1957, 1953 and 1952). Data shown in Fig. 4 were used to compute stream "loads" in terms of tons of alkalinity per day (concentration multiplied by flow); the computed loads are plotted in Fig. 5.

Examination of Figs. 3, 4 and 5 shows there are great differences in alkalinity conditions among the five river areas under investigation. There is reason to believe that these differences are caused almost entirely by variations in the amount of acid discharged to the several areas from coal mines. Because of these variations, it is desirable to examine each of the five areas individually.

Looking first at the Beaver River basin, which is the least complex since it is virtually free of mine drainage, one may note from Fig. 5 that the amount of alkalinity in the river at Lowellville was 120 tons per day greater during the 1959 strike than the average amount in the three reference years. At Eastvale the difference between alkalinity load in 1959 and the average load in the reference years was 130 tons per day. In terms of concentration, Fig. 4 shows the following: At Lowellville average concentration was 80 ppm during the strike and 18 ppm in the reference years; at Eastvale the average concentration was 69 ppm during the strike and 54 ppm in the reference years. On the basis of these values, it could be concluded that acid discharges from steel mills in the Beaver River basin are of such magnitude as to reduce alkalinity in the Mahoning and Beaver rivers by 120 to 130 tons per day. This means a reduction in stream concentration of about 60 ppm at Lowellville and 15 ppm at Eastvale.

Effects of the steel-mill shutdown on quality of the Monongahela River, so far as alkalinity conditions are concerned, were exactly opposite to those produced by the shutdown on the Mahoning and Beaver rivers. Instead of increased alkalinity when the mills were down there was a decrease. In fact, on the Monongahela River acid conditions prevailed virtually uninterrupted during the strike period (see data for Hays in Fig. 3). But after start-up of the mills, alkaline conditions returned to the river.

Although this effect of the shutdown may at first appear implausible, there is an explanation. Acidity in the Monongahela during the strike reflected the discharge of acid from sources other than steel mills. Coal mines in the area constitute the most important of these sources -- and perhaps the only major source of acid other than the mills themselves. Steel mills on the Monongahela use vast quantities of water from the river for cooling purposes. Much of the time the water is neutralized with lime to prevent corrosion and other damaging effects of acid in the mills. As a consequence, the mills return alkaline water to the river.

Determinations of free mineral acidity during the strike period provide information on which a partial assessment can be made of the influence of mine drainage on quality conditions of the Monongahela. The determinations show that the average content of free mineral acidity was 45 tons per day.

From Fig. 5 it can be noted that although alkalinity was nil in the Monongahela during the 1959 strike, the average amount of alkalinity during the reference years of 1957, 1953 and 1952 was 27 tons per day. Using this value, and on the basis of 45 tons per day of acid from coal mines that must be neutralized plus 85 tons per day normally discharged from steel mills (see Table III), it may be stated that steel mills on the Monongahela, through neutralization of their intake water, produce a net change in alkalinity of the river of 157 tons per day.

Changes in alkalinity of the Allegheny River caused by the mill shutdown were relatively minor in comparison with changes on the Beaver and Monongahela rivers. Conditions on the Allegheny are similar to those on the Monongahela -- that is, alkalinity was less during the shutdown period than during periods of mill operation. From Figs. 3 and 4, it may be noted that during the strike the alkalinity in the Allegheny averaged about 10 ppm. Average concentration after the strike was 16 ppm, which value may be compared with an average concentration of 14 ppm during the reference years. From Fig. 5 it will be noted that the alkalinity loading was 80 tons per day during the strike and that in the reference years the average load was 97 tons per day.

The pattern of alkalinity variations in the upper section of the Ohio River (Pittsburgh to confluence with Beaver River) was the same as that in the Monongahela and Allegheny rivers. This indicates that quality conditions in this section are influenced by the effects of acid mine-drainage. It also means that the neutralization practice of the steel mills favorably influences quality conditions at least as far downstream as the mouth of the Beaver River. During the strike the average alkalinity concentration at three stations (Brunot's Island, McKees Rocks, South Heights) was 6 ppm; after the strike average concentration at these stations was 13 ppm.

Natural alkalinity of the Beaver River is of such magnitude that flow from this stream rejuvenates the Ohio insofar as its alkalinity content is concerned. Some quantitative measure of the influence of the Beaver may be noted from the charts of Fig. 4. As noted in the preceding paragraph, the average concentration of alkalinity at the three Ohio River stations <u>above</u> the mouth of the Beaver was 6 ppm during the strike, but during the same period the average concentration at the five stations <u>below</u> the mouth of the Beaver was 21 ppm.

Whereas alkalinity variations in the upper section of the Ohio follows the same pattern as that exhibited by the Monongahela and Allegheny rivers, the pattern in the lower section (Midland to Wheeling) is just the reverse. In the lower section the pattern was one of increased alkalinity during mill shut-down, which is similar to that observed in the Beaver River itself. The following values may be noted for the five stations in the Midland-Wheeling stretch: During the three reference years when mills were operating the average concentration was 16 ppm, but during the strike period the average concentration was 21 ppm; average loading was 265 tons per day in the reference years and 400 tons per day during the strike (Figs. 4 and 5).

Changes in alkalinity and on-shore acid loads -- It was determined that alkalinity of the Beaver River was 120 to 130 tons per day greater during the strike than it is when the mills are operating. This difference may be related to the reduction of acid discharges from the mills. The reduction is estimated to be 63 tons per day of free acid (87 percent shutdown multiplied by 72 tons per day total load for Beaver River as shown in Table III), and 174 tons per day of total acid (87 percent multiplied by 200), both values being expressed in terms equivalent to alkalinity. Total acid represents free mineral acidity plus the mineral acidity contained in acid salts. This is considered to be a reasonably accurate balance in view of the complex factors involved in such a determination.

The alkalinity in the Ohio River at Wheeling was 176 tons per day greater during the strike than in the reference years of 1957, 1953 and 1952. However, as shown previously, steel mills on the Monongahela River -- when they are operating -- add lime to their intake water in such quantities as to produce a net change in alkalinity of the river of 157 tons per day. This means, then, that the total change in alkalinity at Wheeling during the strike amounted to 157 plus 176, or 333 tons per day. This change may be related to a reduction in on-shore loads upstream of 229 tons per day of free acid (254 tons per day multiplied by 90 percent shutdown), and 626 tons per day of total acid (696 tons per day multiplied by 90 percent shutdown).

Acid load in upper Ohio River contributed by steel industry -- It is not possible to determine precisely what the alkalinity content of the Ohio River would be if it were completely free of acid discharges from industrial operations (steel mills, coal mines, etc.). However, it is not unreasonable to assume that alkalinity levels in the upper Ohio under such conditions might approach those observed in the Mahoning and Beaver rivers during the strike. As stated previously, the Beaver River basin is relatively free of acid mine-drainage. A comparison between assumed levels of alkalinity and the levels actually observed would provide a means of estimating the total amount of acid discharged in the area.

From findings in the Beaver River basin, it may be estimated that under conditions of no upstream acid discharges the alkalinity of the Ohio River at Wheeling would be about 75 ppm during summer low-flow periods. This estimate, it may be pointed out, is about 25 ppm higher than estimates previously made (Public Health Bulletin No. 143, A Study of the Pollution and Natural Purification of the Ohio River, U. S. Public Health Service, 1924).

A comparison between the assumed value of 75 ppm and observed values may be summarized as follows:

Year	Flow (cfs)	Alkalinity load at Wheeling under conditions of no upstream acid discharges -- assumed concentration of 75 ppm (tons per day)	Observed alkalinity load at Wheeling (tons per day)	Difference between assumed and observed loa (tons per da
1959	7,170	1,450	387	1,063
57-53-52	6,260	1,270	54 *	1,216

* Observed loading minus alkalinity added for neutralization of intake water (211 minus 157)

From the foregoing tabulation it appears that approximately 1,200 tons per day of acid are discharged into the upper Ohio River basin from all sources.

As shown previously, changes in alkalinity at Wheeling during the strike indicate a total acid load from upstream steel mills of 333 tons per day. Therefore, the conclusion may be reached that the steel industry in the upper Ohio River basin contributes some 27 percent of the total acid (333 divided by 1,216). It is of interest to compare this conclusion with the one arrived at by the U. S. Public Health Service in its earlier study (Bulletin No. 143). In that study it was stated that acid discharges from steel mills comprise "somewhere between 12.5 and 46 percent of the total, but probably nearer to the former than the latter figure."

pH Values -- Observed pH values reflect -- to a certain degree -- variations in alkalinity. Lowest pH values, as might be expected, occurred on the Monongahela River; here they remained at or less than 4.5 throughout the strike period. In the Allegheny and in the first few miles of the Ohio River the average values during some weeks of the strike period dropped below 5.0. Values in other areas during the strike ranged from 6.0 to 7.6.

Week-to-week variations in pH are shown in Fig. 6. Average values for the survey period and for the three reference years of 1957, 1953 and 1952 are shown in Fig. 7.

The greatest changes in pH occurred in the Monongahela and Beaver rivers, as did the greatest changes in alkalinity. At Hays the average pH during mill shutdown was 4.1; but in 1957 when the mills were operating the average pH was 5.7. In contrast, the average pH in the Beaver River at Lowellville during the strike period was 7.3; in 1957, 1953 and 1952 the average pH values at this station were 6.0, 5.4 and 6.2, respectively.

Hardness, Sulfate and Dissolved Solids

Effects of the steel strike on concentration of hardness, sulfate and dissolved-solids were relatively minor in comparison to the effect on other indicators of water quality. This does not suggest that steel industry wastes contain insignificant amounts of these constituents; ORSANCO inventory records indicate one steel plant alone discharges a daily load of 17 tons of hardness, 180 tons of sulfate and over 250 tons of dissolved solids. Rather, conditions observed reflect the overshadowing effect of mine drainage, which contains large quantities of these constituents.

Variations in weekly concentrations of hardness are illustrated in Fig. 8. With the exception of the Beaver River at Eastvale, hardness content gradually increased during the low-flow period and then suddenly dropped with the beginning of high river flows. A comparison between hardness concentration and flow levels shows that there is an inverse relationship between these two values -- the lower the stream flow the higher the hardness.

To further demonstrate the relationship between hardness content and stream flow, correlation plots were constructed such as that shown in Fig. 9. The trend lines in Fig. 9 were first constructed from previous records and without reference to 1959 data. Then the 1959 data was plotted to determine how well it fitted previous trends. Examination of Fig. 9 shows that the 1959 data is nearly equally dispersed above and below the trend lines. This leads to the conclusion that there was no appreciable difference between hardness conditions at these stations in 1959 and those in previous years. It also suggests that flow variation is the dominant influence on hardness variation, at least at these stations.

Data for the Beaver River at Eastvale, as shown in Fig. 8, indicates that increased stream flow, which came near the end of the strike, did not exert the diluting effect on the Beaver River that it did at other stations. It appears, therefore, that the resumption of mill operations in the Beaver River basin -- and the consequent discharge of wastes -- counteracted the effects of increased dilution water. In other words, and insofar as hardness content is concerned, steel-mill effluents reflect a greater influence on quality of the Beaver River than they do on quality of other areas under investigation. This finding is attributed to the overshadowing influence of mine drainage on quality conditions of the Monongahela, Allegheny and upper Ohio rivers.

Additional information on hardness conditions is presented in Figs. 10 and 11. So far as loadings are concerned (Fig. 11) there is little difference between values during the strike period and average values during the reference years of 1957, 1953 and 1952. The explanation may be that the steel industry contributes only a small percentage of the total hardness load reaching the upper Ohio River system. The load from steel mills upstream from Wheeling is estimated to be 317 tons per day (see Table III). This is only nine percent of the total load observed in the river at Wheeling during the four years for which data are presented in Fig. 11.

Although it does not appear that the strike materially affected stream loadings, data in Fig. 10 shows some differences in hardness concentrations between the strike and operating periods. Quite probably the variations in stream flow between the two periods could have been a major factor in accounting for these differences. But it seems significant that the greatest differences in concentration occurred on the Mahoning and Beaver rivers. At Lowellville and Eastvale hardness concentrations were about 40 ppm -- or 20 percent -- less during the strike than in the reference years of 1957, 1953 and 1952. At some of the other stations the decreases in hardness during the strike period were: 6 percent on the Monongahela at Hays, 12 percent on the Allegheny and 9 percent on the Ohio at Weirton.

Variations in sulfate and dissolved-solids content followed the same pattern as did hardness. At each station there were parallel trends in the three constituents during the survey period.

Just as stream flow exerts a dominating influence on hardness, so it does also on concentration of sulfate and dissolved-solids. The relationship between stream flow and sulfate, for example, is shown in Fig. 12. Again, data for 1959 "fits" the trends established in previous years.

Average values for sulfate and dissolved solids in 1959 and in other years are listed in Table VII. The greatest changes in these constituents observed during the strike, both with regard to concentration and to stream loading, occurred on the Mahoning and Beaver rivers. At Lowellville during the strike-period the sulfate concentration was 52 percent less than in the reference years, and the dissolved-solids concentration was 31 percent less. On the Allegheny River sulfate and dissolved-solids concentrations were six and seven percent less, respectively. And on the Ohio at Weirton the sulfate concentration was 12 percent less.

Survey results indicate that during low-flow periods the steel industry contributes about 18 percent of the total load of sulfate and dissolved solids carried in the upper Ohio River. This finding is based on estimated contributions from the industry of 711 tons of sulfate and 1,327 tons of dissolved solids per day (see Table III). Observed loadings in the Ohio River at Wheeling during the strike were 4,000 tons of sulfate and 7,300 tons of dissolved solids per day.

Changes in Iron Content

Dissolved-iron concentration at most stations revealed an upward trend after the strike and following start-up of steel mills. The pattern of week-to-week variations is shown in Fig. 13.

It will be observed, for example, that on the Monongahela at Hays the highest value in any week during the strike was 0.3 ppm. After resumption of operations the iron concentrations went as high as 1.8 ppm.

The shift toward higher values is summarized in Fig. 14 in the form of period averages. Here it is shown that iron content at most stations during the strike averaged 0.1 ppm. But when the mills were back in operation concentrations increased by a factor of two or more.

An exception to this general trend occurred at Charleroi. Iron variations in the Monongahela at this point varied in an opposite manner, dropping from a level of one ppm during the strike to 0.1 ppm afterwards. These variations must be attributed to factors other than steel-mill operations, since Charleroi is located upstream from the major steel mills. Among the factors influencing the concentration of dissolved iron at this location would be variations in flow conditions and changes in acidity-alkalinity balance.

Average stream loadings of iron for the 12-to-14 week stable, low-flow period during the strike are shown in Fig. 15. The greatest loading, 3.9 tons per day, was observed at Wheeling. The smallest loading, 0.4 tons per day, occurred in the Beaver River.

Comparison of the loading at Wheeling of 3.9 tons per day against the estimated cumulative discharges from steel plants upstream of 255 tons dissolved iron and 946 tons total iron (dissolved plus suspended iron) suggests that the river-bed becomes the repository of such wastes within a short time after their discharge. It is likely this deposited iron asserts its presence again through the action of re-suspension at times of rises in river stages and re-solution upon certain chemical changes in the stream water.

Much of the analytical data for previous years includes determinations only for total iron (dissolved plus suspended). Such data does not provide an adequate baseline by which conditions observed during the 1959 survey can be compared with those in other years.

Manganese Variations

The pattern of manganese variations differed significantly from that for iron. Manganese concentrations at many stations remained at a relatively high, sustained level during the low-flow months and then decreased with rise in stream flows. This was somewhat similar to hardness and sulfate variations.

Concentration variations for the 21 weeks of the survey are shown in Fig. 16. Highest levels occurred on the Monongahela -- at Hays values up to 1.9 ppm were recorded. Lowest values were observed in the Beaver River; here weekly values ranged from zero to 0.26 ppm.

Improvement of conditions in the Ohio River following entry of the Beaver River with respect to manganese content is obvious from a comparison of concentrations at South Heights (above mouth of Beaver) and at Midland (below mouth of Beaver). Concentrations at Midland during the low-flow period were less than half those at South Heights. This improvement was probably effected not only by dilution but also through higher alkalinities (contributed by the Beaver) with consequent increased precipitation of heavy metals.

In Fig. 17 are shown average manganese concentrations for different periods of the survey and for summer months of reference years. It will be noted that stream values in the weeks following resumption of steel operations were lower in most cases than the values during the strike. Obviously, the onset of increased stream flow at the end of the strike had an important bearing on differences in concentration between the strike and operating periods.

A significant improvement in manganese conditions during the strike period is revealed at most stations where previous records were available to provide a comparison between 1959-summer-month concentrations and concentrations in other years.

Changes observed at various stations were as follows:

	Average manganese concentration - ppm			Percent by which 1959 value is less
	1959	1957-53-52	Difference	
Allegheny -- Verona	1.1	2.0	0.9	45
Mahoning (Beaver) -- Lowellville	0.09	0.77	0.68	88
Ohio -- Midland	0.6	1.6	1.0	62

Stream loadings of manganese are shown in Fig. 18. Loading values from this chart that correspond to the concentrations at the above three stations are tabulated below:

	Average manganese loading -- tons/day		Difference	Percent by which 1959 value is less
	1959	1957-53-52		
Allegheny -- Verona	8.7	13.6	4.9	36
Mahoning (Beaver) -- Lowellville	0.2	1.2	1	83
Ohio -- Midland	12	27	15	56

The effect of the Beaver River on manganese concentrations in the Ohio River is also reflected in the data shown in Fig. 18. In the Midland-Wheeling stretch the manganese loadings during the strike averaged 11 tons per day; above the Beaver loadings in the Ohio River were about 20 tons per day.

For several reasons it is difficult to assess the improvement in manganese conditions resulting from the steel-mill shutdown. First, there is uncertainty as to differences that may have occurred due to sampling and analytical reporting procedures in the past. Determinations made during the survey included only the dissolved portion of manganese whereas much of the historical data represents measurement of total manganese (the suspended portion plus dissolved). However, there is reason to believe that such differences, in contrast to what they might be for iron, were not of great magnitude at most stations and, therefore, that previous data may be used for comparison without introducing serious error.

Another difficulty relates to the effect of changes in stream alkalinity and pH on the solubility of manganese. It is possible that the lower manganese content in 1959 reflects to some degree a change in stream conditions that resulted in lower solubility with consequent precipitation of manganese. The fact that manganese concentrations on the Monongahela River were higher during the strike than afterwards may have been due mainly to the fact that the river contained higher amounts of acidity during the strike.

In general, the data available suggest that manganese conditions were better during the 1959 strike than they were in previous years.

Fluoride Concentrations

Fluoride concentrations at all stations except Midland were higher during the strike period than they were in the weeks immediately following end of the strike. This condition is shown in the plot of week-to-week variations in Fig. 19 and also in the plot of period averages in Fig. 20. For example, it may be noted from these charts that in the East Liverpool-Wheeling stretch the average fluoride concentration during the strike was 0.4 ppm; after the strike the average concentration was 0.2 ppm.

The trend toward lower concentrations at the end of the strike period may be attributed to increased dilution caused by the rise in stream flow at that time.

A comparison between fluoride concentrations in 1959 and those in other years when the mills were operating is shown in Fig. 20. The data show that at least during low-flow periods, and at most if not all stations, steel-mill operations influence the river content of fluoride. Concentrations at Lowellville, Newell and Weirton in the years when the mills were operating were twice what they were in 1959. However, the fact that appreciable quantities of fluoride were observed at all stations during the time steel mills were not operating indicates there are other sources contributing significant amounts of fluoride to the Ohio River system.

Average stream loadings of fluoride for the July-October period in 1959 and reference years are shown in Fig. 21. The data show greater loadings at Lowellville, Newell, Weirton and Verona (except 1952) during the years the mills were operating than during the 1959 strike. But at Wheeling the 1959 loading was greater than that in other years.

The importance of sources of fluoride other than steel mills is also demonstrated by the data shown in Fig. 21. On the basis of observations made during the strike, these other sources account for loadings of eight to ten tons per day in the Midland-Wheeling stretch of the Ohio River. By way of comparison, it has been estimated that the load discharged by steel plants located upstream from Wheeling is about six tons per day.

To conclude: Steel-mill wastes increase fluoride concentrations in the upper Ohio River and its tributaries, particularly during low flow. However, there are other sources that also contribute fluoride in amounts equal to or greater than those contributed by the steel industry. The pattern of fluoride concentrations in the Ohio River is profoundly influenced by variations in stream flow.

Temperature Conditions

Week-to-week variations in river temperature are shown in Fig. 22. The range in temperature is somewhat the same from one area to another -- namely, 70 to 80 degress F. from July through September, and 40 to 50 degress in November and December. The highest sustained water temperatures occurred on the Monongahela River at Hays; the highest weekly value -- 83 degrees -- occurred at Midland on the Ohio River.

Superimposed in the form of crosses on these graphs are the corresponding weekly values of air temperatures as recorded at U. S. Weather Bureau stations nearest sampling points. The intimate relationship of water temperature with air temperature is quite obvious.

Average temperatures for the three periods of the survey are shown in Fig. 23 together with average values for summer months in the similar low-flow years of 1957, 1953 and 1952. The survey averages, indicated by shaded bars, show in summary form the weekly variations in the previous chart. In every instance the water temperature is greater than the air temperature.

As shown in Fig. 23 the most striking difference between river temperatures in 1959 and those in other years occurred at Lowellville on the Mahoning River. Here the July-to-October 1959 average water temperature of 75 degrees was almost 20 degrees lower than in previous years. This is further evidence of the long-recognized fact that thermal considerations are of major importance in water-quality management on the Mahoning River.

Differences between temperatures in 1959 and those in the reference years were not as great at other stations as they were at Lowellville. This would indicate that the portion of the total heat load contributed by the steel industry is greater in the Lowellville area than in other areas.

Another factor to be considered in comparing temperature conditions among the several stations is the variation in air temperature from year to year. In order to compensate for this, and to gain further insight on the effect of heat loads from the steel industry, water-air temperature differentials were computed for the July to October period in 1959 and the three reference years. These water-over-air temperatures are shown in Fig. 24.

In Fig. 24 it can be seen, for example, that the water-over-air temperature at Lowellville in 1959 was 16 to 20 degrees less than that usually experienced when the mills are operating. At Eastvale the 1959 differential was 7 to 11 degrees below the usual value.

Mention might be made that water-over-air temperatures at Charleroi in 1952 and at Weirton in 1953 and 1952 were actually lower than corresponding temperatures in 1959. These values are exceptions to the trend shown by all other values and no explanation for their occurrence is available from the data at hand.

At other stations water-over-air temperatures in the reference years were higher by one degree (at Verona) to 20 degrees (at Lowellville) than corresponding temperatures in 1959. The average difference between reference-year values and 1959 values, for all stations and all years, is six degrees.

Heat loadings as represented by the excess of water temperatures over those of the air are shown in Fig. 25. These values, in terms of British thermal units (Btu) per day, were computed from temperature differentials in Fig. 24 and corresponding stream flows. This chart shows, for example, that the heat loading in the Ohio River at East Liverpool was 280 billion Btu's per day less in 1959 during the shutdown than in 1953 when the mills were operating. The average differential in heat load for all stations and all years as shown in Fig. 25, is 80 billion Btu's.

Turning to the heat-absorptive capacity of streams, it can be observed from Fig. 23 that there was little build-up in water temperatures from upstream stations to the most downstream points. This fact -- when it is considered that the estimated load discharged in waste waters from all sources in the upper basin totals some 1,500 to 2,500 billion Btu's per day -- provides an appreciation of the tremendous capacity of the Ohio River and its tributaries to dissipate heated discharges.

The dissipation of heat has been found by investigators to be a complex function of dilution, time of flow, turbulence, evaporation, convection, radiation and absorption by the sides and bottom of the stream channel through conduction. Further, evaporation is modified by air movement, humidity and temperature differential between water and air.

In general, the water-air temperature differential probably is a major factor in determining the rate of dissipation. This rate has been found to be logarithmic with time and somewhat similar to the decrease in biochemical-oxygen-demand in a stream (Gameson, A.L.H., Gibbs, J.W., and Barrett, M.S. "A Preliminary Temperature Survey of a Heated River", Water and Water Engineering (Great Britain), Vol. 63, No. 755, pp. 13-17, January 1959). For example, in a stream such as the Ohio River under certain conditions it might take two-and-a-half days to dissipate one-half of the elevated temperature. In summer months the river would flow 20 to 60 miles in this time.

Phenolic Materials

Phenol concentrations during the first 12 to 14 weeks of the survey were present in relatively small amounts, ranging from weekly values of zero to ten parts per billion (ppb). However, at one station -- Clairton on the Monongahela -- concentrations over 1,000 ppb were registered during two weeks of the same period. These high values probably indicate an abnormal situation caused by a spillage of waste because other values at Clairton were as low or lower than observations elsewhere.

From the onset of high flows and start-up of the steel mills and continuing to the end of the survey the phenol content at most stations increased significantly; for example, at Hays the concentration jumped to a high of 53 ppb. Variations in phenol concentration and the relationship between concentration and flow are shown in Fig. 26.

Period averages of phenol concentration during and after the strike are shown in Fig. 27. At every station, excepting Clairton, it can be seen that the phenol content increased several fold upon start-up of the steel mills. (At Clairton, the average during the shutdown reflects the exceptionally high values observed during two of the fifteen weeks.)

Values at many stations went from 5 ppb or lower during the strike to 10 to 20 ppb afterwards, and this occurred despite a five-to-eight-fold increase in dilution water. In this connection, it should be observed that at Charleroi, which is located upstream from all major steel mills, phenol concentrations were actually less during the period of increasing stream flow after the strike than they were during the strike. The data for this station shows that increasing flows did not contribute any significant amount of phenolic materials that might be attributed to so-called "natural sources."

The increase in phenol concentrations after end of the strike is attributed in large part to the renewed discharge of phenolic materials from steel operations, such as coke production. However, the observed increase may have been due in part to two other factors -- namely, temperature and time-of-flow changes.

Phenols in streams have been noted to exhibit an apparent die-away characteristic at a rate which is related to temperature -- the die-away being slower at colder temperatures. Thus, the drop in temperature at the end of the shutdown meant that phenols were not being assimilated as fast at that time as they had been in the preceding weeks.

Time-of-flow in November and December was only 10 to 20 percent of that during the summer months. This meant that there was less time for assimilation or decomposition reactions between points of waste discharge and sampling stations. Consequently, residual concentrations persisted further downstream.

In Fig. 27 are shown average phenol concentrations at several stations for the July-October period in the low-flow years of 1957, 1953 and 1952. At Lowellville, the average concentration during the strike was 10 ppb; the average for the three reference years was 21 ppb. At the five Ohio River stations average values were 4 ppb during the 1959 strike and 21 ppb in the reference years. It should be noted that the average concentration of 107 ppb at Wheeling in 1952 reflects conditions prior to installation of dephenolizing equipment at an upstream steel plant.

Average stream loadings of phenol are shown in Fig. 28 for the summer period of 1959 and other years where data were available. At Midland, for instance, the stream load averaged less than 100 pounds per day during the strike whereas in 1957 and 1953 the load was 250 and 350 pounds per day.

Some idea of the self-purification capacity of the Ohio River during summer months with regard to phenolic materials may be gained by comparing observed stream loads with upstream waste discharges. Stream loads at Midland in 1957 and 1953, when the mills were operating, were 250 to 350 pounds per day. But upstream waste discharges are estimated to total about 4,000 pounds per day (see Table III).

In contrast to summer conditions, self-purification in the winter appears to be virtually nil. In the five-week period after start-up of the steel mills, phenol loads as measured in the river in the Midland-Wheeling stretch (loads not plotted in Fig. 28), ranged from 3,000 to 5,000 pounds per day.

In conclusion, the data show that the mill shutdown was accompanied by a marked reduction in phenol content throughout most of the survey area. The range in concentration at all except two stations was from an average of 3 ppb during the strike to an average of 16 ppb after start-up of the mills (which means a reduction of about 80 percent during the strike). Comparison of 1959 data with data for other years shows that at Wheeling, for example, phenol concentration during mill shutdown was about one-third of that observed during the summer, low-flow period of 1957, and only three percent of the value observed in 1952.

Threshold-odor Determinations

The pattern of week-to-week variations in threshold-odor number was quite similar to that for phenols -- relatively low during the strike and considerably higher in the weeks following the end of the strike. The pattern is revealed in Fig. 29.

This chart shows threshold-odor numbers ranging, for the most part, between 4 and 20 in the first 12 to 14 weeks and then increasing in intensity up to 80 and above in some weeks of November and December.

Period averages during and after the strike are indicated in Fig. 30. Here it can be seen that much higher threshold-odor numbers occurred at many stations upon resumption of steel-producing operations. In the lower Monongahela, for instance, average values jumped from 10 to over 80. A large part of the increase in threshold-odor content in the latter period obviously must be attributed to steel-mill discharges.

It is interesting to compare the summer average values observed in 1959 with those observed in other years which are also shown in Fig. 30. The greatest difference between 1959 values and those in other years was observed at Eastvale on the Beaver River. At this station the 1959 summer average was 20 compared to averages of 40, 168 and 202 in the three reference years.

In comparing 1959 values with data for other years due allowance should be made for differences that may arise from the subjectivity and laboratory techniques of those performing the threshold-odor determinations.

Turbidity

During shutdown of the steel mills river turbidities averaged 3 to 10 units, depending upon the area. In the five-week period after the strike levels increased, ranging at various stations from 12 to 34 turbidity units. It is believed that a major part of this increase is associated with the concomitant rise in river stage and flow. Turbidity averages for the three periods are pictured in Fig. 31.

For those whose interest is aroused by the rather low turbidity values, even with major rises in stream flow, it might be explained that what otherwise would be muddy water is made relatively clear by flocculent iron precipitates, which are produced by the reaction of acid salts with stream alkalinity.

Comments of Local Observers

Serving ORSANCO as an advisory group on water-quality conditions as well as playing a vital role in stream-monitoring activities is the Water Users Committee. This Commission-sponsored group is composed of managers of public, private and industrial water-treatment plants who have been meeting regularly with the staff since 1952 to report observations and to exchange experiences.

At the October 15, 1959 and January 21, 1960 meetings of the Water Users Committee discussion centered on quality changes observed during and immediately after the strike. The following excerpts are pertinent:

From minutes of October 15, 1959 --. "F. R. Perrin, chief chemist of the South Pittsburgh Water Company, reported a significant decrease in alkalinity, pH, and temperature of the Monongahela River at his intake (near Hays) since the beginning of the steel strike. The water now reacts acid toward methyl orange indicator whereas a slight amount of alkalinity was present the first part of July. The pH decreased from 6.7 to as low as 3.9. The drop in water temperature was about 10 degrees. Iron and manganese concentrations are lower than usual. Algae trouble was experienced for the first time in 35 years. Filter clogging that occurred increased the wash water requirements by 40 percent. Predominant algae were protococcus and ankistrodesmus. As a result of quality changes, lime requirements (including that for softening) increased from 235 lb. to 410 lb. per million gallons and the chlorine demand rose from 2.8 lb. to as high as 13.5 lb. per million gallons.

"On the Allegheny at the Wilkinsburg-Penn Water Authority intake (Verona) R. B. Adams, superintendent of purification, reported a 50 percent decrease in alkalinity from 20 ppm to 10 ppm -- accompanied by drop in pH from 6.6 to 6.0. The dissolved manganese content of the raw water in recent months averaged 1.25 ppm whereas the usual manganese content during August and September in previous years had ranged from 2.0 to 2.5 ppm.

"Adams also touched on the manganese studies he is making on the Conemaugh and Loyalhanna rivers. Prior to the steel strike the dissolved manganese content of the Conemaugh River was about 15 ppm. Since the first of August the manganese concentrations in the Conemaugh have been much lower, averaging 5.5 ppm. The manganese content of the Loyalhanna River during a similar period remained relatively constant, ranging from 5.3 to 5.4 ppm."

From minutes of January 21, 1960 -- "F. R. Perrin reported a significant increase in alkalinity, pH, and temperature of the Monongahela River at South Pittsburgh Water Company intake within a few days after start-up of steel mills. The water reacted alkaline toward methyl orange indicator whereas it had reacted acid during the steel strike. The pH went from 4.3 to 6.3. The water temperature increased 5 to 8 degrees F. The color of the river changed from a light green to a normal brownish-green appearance, and algae virtually disappeared.

"On the Allegheny River at Wilkinsburg-Penn intake, R. B. Adams observed an increase in the dissolved manganese content of the raw water back to normal levels, whereas during the strike the manganese content was averaging only about half the normal amount.

"With reference to the manganese studies on the Conemaugh and Loyalhanna rivers, Adams mentioned that since the end of the strike the dissolved manganese content in the Conemaugh has run four times greater than that in the Loyalhanna, a ratio similar to that observed before the strike. During the strike concentrations ran about the same in both rivers.

"Edward Shroyer, superintendent, Wheeling Water Treatment Plant, presented analytical results that showed the average iron (total) in the Ohio River at Wheeling in November and December (1.6 to 2.0 ppm) was about twice as high as the content during the months of August and September (0.6 to 1.0 ppm)."

Participants at water-treatment plants located in other river areas responded as follows to a request for their observations and opinions regarding stream quality changes during shutdown of the steel mills:

> Monongahela River at Charleroi -- "No changes observed that were not normal changes." This might be expected, of course, since Charleroi is upstream from major steel producers.

Ohio River at Brunot's Island and South Heights -- "No changes observed that affect either treatment or plant use of water." The Duquesne Light Company operates steam power generating plants at these two locations.

Beaver River at Eastvale -- "The pH and alkalinity ran higher than normal. The iron content was much lower and did not occur in slugs as when mills are operating. Chemical costs ran $3.80 more per million gallons than same period in 1958."

Ohio River at Midland -- "The oily and chemical type odors were less, resulting in improved taste and odor conditions. The alkalinity was higher, coagulation was better. Less iron was present and the chlorine demand was down."

Ohio River at East Liverpool -- "Chemical type odors were noticeably absent. More algae was present."

Observations from Aquatic-Life Survey -- For three years beginning in 1957 the Biology Department, University of Louisville, has conducted under sponsorship of ORSANCO an evaluation of aquatic-life resources of the Ohio River. One of the observation points in this study is the Montgomery lock and dam, located 31.7 river miles below Pittsburgh and some 6 miles below the confluence of the Beaver River. This location was sampled for fish specimens on four separate occasions -- August 29, 1957, July 30, 1958, June 27, 1959, and July 26, 1959.

Analysis of specimen data, which is detailed in Appendix C, reveals that collections made in the July 26, 1959 sampling run -- eleven days after shutdown of the steel mills -- had a greater abundance of fishlife as well as a wider variety of species, especially those associated with cleaner water, than the three previous sampling runs.

In his evaluation of the different collections, W. L. Minckley of the survey crew concluded: "Some drastic changes occurred in the habitat making it more suitable for fishlife in late July 1959. It cannot be fortuitous that such a change in fish fauna, accompanied by relatively large numbers of species which are intolerant of polluted waters, could occur. This must be a function of the alleviation of industrial discharge into the river upstream from the area."

T A B L E S   A N D   F I G U R E S

TABLE II -- ANNUAL PRODUCTION CAPACITY FOR STEEL PLANTS -- Showing cumulative capacity in millions of tons above each river-sampling station. Data on production capacity is from Iron and Steel Works Directory of the U. S. and Canada (1954). Data on water usage was developed from records submitted by state agencies.

Station	River	Mile Point	Cumulative production capacity -- millions of tons					Estimated Water Use MGD
			Coke	Pig Iron	Steel	Hot Rolled Steel Products	Cold Rolled and Finished Products	
Charleroi	Monongahela	42.6	0.22	---	---	0.96	0.66	66 to 92
Clairton	Monongahela	19.3	9.97	2.17	3.64	1.63	3.43	318 445
Hays	Monongahela	6.0	12.05	12.00	14.60	7.95	4.65	1,070 1,500
Verona	Allegheny	8.9	2.27	2.06	3.40	2.23	1.05	233 326
Brunot's Is. McKees Rocks	Ohio Ohio	2.3 3.3	15.83	17.05	22.71	12.75	7.68	1,630 2,270
South Heights	Ohio	15.5	16.83	17.74	22.81	12.92	8.09	1,650 2,310
Eastvale	Beaver	8.0	4.40	7.99	13.15	8.56	12.46	900 1,260
Midland	Ohio	36.3	23.42	27.85	38.26	24.37	24.34	2,700 3.770
East Liverpool Weirton	Ohio Ohio	40.2 61.8	24.25	28.75	39.62	25.21	24.55	2,780 3,900
Wheeling	Ohio	86.8	27.88	32.51	45.16	29.85	28.70	3,170 4,430

TABLE III -- ESTIMATED WASTE LOADINGS FROM STEEL PLANTS -- Showing cumulative loads in tons per day from all steel plants located upstream from each sampling station. Unit values for waste loadings, shown at bottom of page, were developed from waste-analysis records submitted by state agencies. Unit values were combined with production-capacity figures shown in Table II to yield cumulative loadings.

Station	Stream and Mile Point	Waste Load in Tons per Day										
		Phenols	Acid as $CaCO_3$		Hardness as $CaCO_3$	Sulfate	Fluoride	Chloride	Dissolved Solids	Iron		Manganese
			Total	Free						Total	Dissolved	
Charleroi	Monongahela (42.6)	0.02	15	5	7	14	0.1	0.8	24	20	5	0.1
Clairton	Monongahela (19.3)	.82	70	25	32	92	.6	42	204	80	25	.6
Hays	Monongahela (6.0)	.99	235	85	107	247	2.1	49	475	320	85	2.1
Verona	Allegheny (8.9)	.19	51	19	23	53	.7	9.3	118	70	19	.7
Brunot's Is. McKees Rocks	Ohio (2.3) Ohio (3.3)	1.29	358	130	162	369	3.9	65	696	485	130	3.9
South Heights	Ohio (15.5)	1.38	359	131	163	372	3.9	69	709	487	131	3.9
Eastvale	Beaver (8.0)	.36	200	72	90	192	1.8	18	338	297	72	1.8
Midland	Ohio (36.3)	1.92	593	215	269	605	5.4	96	1,128	806	215	5.4
East Liverpool Weirton	Ohio (40.2) Ohio (61.8)	2.00	615	223	280	622	5.5	98	1,162	831	223	5.5
Wheeling	Ohio (86.8)	2.29	696	254	317	711	6.3	114	1,327	946	255	6.3

	Unit values for estimating waste loadings in terms of pounds of waste per ton of production capacity.										
	Phenols	Acid as $CaCO_3$		Hardness as $CaCO_3$	Sulfate	Fluoride	Chloride	Dissolved Solids	Iron		Manganese
		Total	Free						Total	Dissolved	
Coke production	0.06				2		3	8			
Steel production (including blast furnace waste)		11	4	5	10	0.1		16	15	4	0.1

TABLE IV -- ESTIMATED THERMAL DISCHARGES FROM STEEL PLANTS -- Showing (in Part 1) the cumulative heat load in British thermal units per day from all steel mills located upstream from each sampling station and (in Part 2) the heat load discharged from steel mills within a 25-mile stretch above each station.

Station	Stream and Mile Point	PART 1 - Cumulative load from all upstream steel mills		PART 2 - Heat load from mills within 25-mile stretch above station	
		Water use* (MGD)	Heat load+ (Billion Btu's per day)	Water use* (MGD)	Heat load+ (Billion Btu's per day
Charleroi	Monongahela (42.6)	79	17	79	17
Clairton	Monongahela (19.3)	380	79	380	79
Hays	Monongahela (6.0)	1,280	266	990	206
Verona	Allegheny (8.9)	280	58	72	15
Brunot's Island McKees Rocks	Ohio (2.3) Ohio (3.3)	1,950	405	1,300	270
South Heights	Ohio (15.5)	1,960	407	790	165
Eastvale	Beaver (8.0)	1,020	214	87	18
Midland	Ohio (36.3)	3,230	671	255	53
East Liverpool Weirton	Ohio (40.2) Ohio (61.8)	3,340	694	366	76
Wheeling	Ohio (86.8)	3,800	790	455	93

* Water use based on average of range shown in TABLE II.
+ Heat load computed on basis of 25 deg. F. rise between water intake and waste outfall.

TABLE V -- STREAM FLOW IN THE UPPER OHIO RIVER AND ITS TRIBUTARIES during the last half of 1959. Data is from provisional records furnished by the U. S. Geological Survey.

Stream and gaging station	Drainage area above gage (sq. mi.)		Monthly flows in cubic feet per second					
			July	August	September	October	November	December
Monongahela R. at Charleroi (mi. 41.5)	5,213	Max.	2,390	2,460	2,000	10,600	25,900	35,600
		Avg.	1,390	1,640	1,070	2,400	6,390	14,300
		Min.	706	850	670	907	2,150	3,200
Monongahela R. at Braddock (mi. 11.2)	7,337	Max.	4,580	4,820	2,650	12,700	34,200	44,700
		Avg.	2,280	2,660	1,830	3,610	8,730	18,420
		Min.	1,510	1,850	1,460	1,460	3,800	6,800
Allegheny R. at Natrona (mi. 24.2)	11,410	Max.	10,100	4,940	3,740	31,000	48,900	89,000
		Avg.	5,500	2,920	1,880	10,500	23,500	36,500
		Min.	3,160	1,730	1,030	1,860	12,800	14,900
Ohio R. at Sewickley (mi. 11.8)	19,500	Max.	14,800	11,000	6,400	44,000	81,200	142,000
		Avg.	7,890	5,840	3,810	14,600	33,400	57,400
		Min.	5,380	3,430	2,780	4,610	18,900	22,800
Beaver R. at Beaver Falls (mi. 5.5)	3,106	Max.	3,940	2,620	1,700	5,720	8,989	26,700
		Avg.	2,070	1,570	1,010	2,620	3,660	7,830
		Min.	1,240	1,060	700	1,000	1,980	3,490
Ohio R. at Bellaire (mi. 96.4)	25,170	Max.	18,000	13,400	8,700	50,000	90,000	162,000
		Avg.	10,400	7,820	5,200	17,300	36,500	63,900
		Min.	7,370	4,500	3,860	5,700	21,000	26,000

TABLE VI--SUMMARY OF SURVEY DATA — Showing analytical results and stream loadings in terms of weekly-average or composite values.

PART 1 - Physical and chemical analyses.

River and Station		Temperature Air °F	Temperature Water °F	Turbidity	Threshold Odor No.	Phenols ppb	pH	Alkalinity as $CaCO_3$ ppm	Hardness as $CaCO_3$ ppm	Sulfate ppm	Fluoride ppm	Dissolved Solids ppm	Iron ppm	Manganese ppm
Monongahela River at Charleroi, Pa. (mile 42.6)	High week	78	82	25	32	6	4.7	2	243	411	0.4	596	2.2	2.1
	Median week	63	70	5	1	1	3.5	0	201	317	.2	467	.60	1.6
	Low week	36	42	0	0	0	3.3	0	58	69	.1	110	.06	.40
Monongahela River at Clairton, Pa. (mile 19.3)	High week	78	80	44	65	1,100	5.5	3	310	463	.5	730	.76	2.5
	Median week	63	78	9	8	25	3.9	0	225	344	.3	527	.25	1.6
	Low week	36	41	2	1	0	3.5	0	60	68	.1	114	.07	.51
Monongahela River at Hays, Pa. (mile 6.0)	High week	80	80	24	256	53	6.2	7	227	349	.5	534	1.8	1.9
	Median week	63	78	5	6	4	4.3	0	197	288	.2	446	.18	1.4
	Low week	38	41	1	3	0	3.8	0	78	89	.1	157	.02	.61
Allegheny River at Verona, Pa. (mile 8.9)	High week	80	84	25	71	7	7.2	23	184	198	.3	367	.62	1.8
	Median week	63	75	8	8	2	6.6	11	132	138	.2	266	.08	.94
	Low week	38	37	1	0	0	4.8	4	69	53	.1	130	.01	.43
Ohio River at Brunot's Island, Pa. (mile 2.3)	High week	80	83	25	260	18	7.0	18	204	258	.4	408	.56	1.6
	Median week	63	73	7	8	3	6.1	6	164	204	.2	349	.09	1.1
	Low week	38	39	2	6	0	4.6	1	71	65	.1	128	.03	.54
Ohio River at McKees Rocks, Pa. (mile 3.3)	High week	80	83	44	68	28	7.0	17	211	276	.5	470	.59	1.6
	Median week	63	72	10	16	4	6.3	7	167	206	.3	351	.13	1.2
	Low week	38	38	1	4	0	4.8	1	70	61	.1	121	.03	.51
Ohio River at South Heights, Pa. (mile 15.5)	High week	80	82	56	168	28	7.0	31	205	262	.5	471	.39	1.6
	Median week	63	73	10	12	4	6.4	9	168	204	.3	367	.09	1.2
	Low week	38	45	2	4	0	5.4	4	80	77	.1	139	.03	.51
Beaver River at Eastvale, Pa. (mile 8.0)	High week	81	81	25	80	35	7.6	79	198	131	.7	279	.71	.26
	Median week	62	68	10	16	3	7.3	65	148	87	.4	237	.20	.08
	Low week	35	43	2	4	0	7.0	38	121	69	.2	194	.03	.00
Ohio River at Midland, Pa. (mile 36.3)	High week	81	86	84	128	15	7.1	36	201	233	1.0	410	.60	1.0
	Median week	62	69	6	11	4	6.7	18	160	178	.4	322	.08	.54
	Low week	35	47	1	8	0	6.4	14	76	70	.2	154	.02	.03
Ohio River at East Liverpool, O. (mile 40.2)	High week	81	83	59	556	29	7.3	37	204	229	.7	406	.60	1.0
	Median week	62	74	7	16	4	6.8	21	165	174	.4	312	.09	.47
	Low week	35	42	1	3	0	6.5	13	82	69	.2	150	.02	.05
Ohio River at Weirton W. Va. (mile 61.8)	High week	79	82	79	79	15	7.2	38	205	246	.5	435	.42	1.2
	Median week	62	73	10	8	4	6.8	21	161	165	.4	333	.09	.43
	Low week	36	44	2	2	0	6.5	13	86	74	.2	157	.02	.03
Ohio River at Wheeling, W. Va. (mile 86.8)	High week	79	84	80	188	37	7.2	25	208	244	.8	416	1.2	1.1
	Median week	62	72	9	8	3	6.8	18	174	182	.4	345	.20	.51
	Low week	36	43	3	2	0	6.5	13	89	78	.2	162	.04	.18

PART 2 - Stream loadings in tons per day.

River and Station		Phenols	Alkalinity	Hardness	Sulfate	Fluoride	Dissolved Solids	Iron	Manganese
Monongahela River at Charleroi, Pa. (mile 42.6)	High week	0.05	104	3,720	3,940	5.2	6,510	11	39
	Median week	.003	0	878	1,300	1.1	1,940	2.5	6.8
	Low week	.0	0	447	649	.4	1,050	1.3	3.7
Monongahela River at Clairton, Pa. (mile 19.3)	High week	4.99	133	3,990	4,850	4.4	7,250	12	35
	Median week	.26	0	1,050	1.650	1.5	2,420	1.2	8.0
	Low week	.0	0	600	922	.6	1,490	.3	4.5
Monongahela River at Hays, Pa. (mile 6.0)	High week	1.10	309	5,380	5,760	6.2	10,700	35	40
	Median week	.02	0	1,310	2,120	2.4	3,260	1.1	10
	Low week	.0	0	954	1,320	.5	2,150	.1	4.7
Allegheny River at Verona, Pa. (mile 8.9)	High week	.55	2,290	6,590	5,540	14	5,540	49	89
	Median week	.04	153	1,430	1,540	2.5	2,870	1.1	9.8
	Low week	.0	11	603	642	1.1	1.120	.1	3.9
Ohio River at Brunot's Island, Pa. (mile 2.3)	High week	2.56	1,530	12,100	12,300	21	20,200	42	131
	Median week	.03	98	3,010	3,670	5.9	6,350	1.6	21
	Low week	.0	11	1,380	1,730	2.1	2,790	.5	9.2
Ohio River at McKees Rocks, Pa. (mile 3.3)	High week	2.82	1,550	10,800	10,700	17	20,800	83	127
	Median week	.06	97	3,130	3,710	5.6	6,320	1.7	21
	Low week	.0	14	1,520	1,960	1.5	3,470	.3	11
Ohio River at South Heights, Pa. (mile 15.5)	High week	5.07	1,180	13,000	16,100	25	24,600	29	133
	Median week	.06	223	3,170	3,850	7.2	6,610	1.6	22
	Low week	.0	38	1,530	2,010	2.3	2,950	.3	12
Beaver River at Eastvale, Pa. (mile 8.0)	High week	.46	1,060	3,540	2,240	7.8	5,160	17	3.4
	Median week	.01	331	724	420	2.1	1,180	.6	.3
	Low week	.0	162	337	195	.9	748	.1	.0
Ohio River at Midland, Pa. (mile 36.3)	High week	2.61	2,430	14,800	13,800	146	27,700	87	118
	Median week	.06	450	4,140	4,470	11	8,520	1.5	9.3
	Low week	.0	174	2,060	2,170	4.4	4,000	.3	.5
Ohio River at East Liverpool, O. (mile 40.2)	High week	4.22	3,060	14,300	13,900	35	26,100	87	89
	Median week	.08	624	4,150	4,340	11	7,960	1.7	14
	Low week	.0	200	2,050	2,260	3.2	4,010	.3	.7
Ohio River at Weirton W. Va. (mile 61.8)	High week	3.06	2,330	15,300	15,500	35	28,900	61	129
	Median week	.10	695	4,070	4,340	11	8,380	1.5	10
	Low week	.0	221	2,020	1,910	3.2	3,990	.4	.4
Ohio River at Wheeling, W. Va. (mile 86.8)	High week	5.38	2,260	15,500	15,600	35	28,200	57	136
	Median week	.10	603	4,290	4,490	12	8,500	5.6	15
	Low week	.0	175	2,100	2,230	5.3	4,110	.7	3.2

TABLE VII -- SULFATE AND DISSOLVED SOLIDS CONTENT -- Showing average concentrations and stream loadings in the upper Ohio River and tributaries during the low-flow period July — October of 1959, 1957, 1953 and 1952.

Station	Year	Sulfate		Dissolved Solids	
		Concentration ppm	Load Tons/day	Concentration ppm	Load Tons/day
Hays	1959	309	1,910	473	2,930
Verona	1959	158	1,240	301	2,360
	1957	169	858	---	---
	1953	145	1,436	266	2,636
	1952	189	1,184	383	2,399
South Heights	1959	235	3,430	399	5,820
	1957	263	2,580	---	---
Lowellville	1959	95	172	259	469
	1957	183	272	372	552
	1953	221	346	398	623
	1952	190	287	361	546
Eastvale	1959	89	387	245	1,070
	1952	137	507	---	---
Newell	1959	188	3,640	336	6,510
	1957	230	3,090	417	5,610
Weirton	1959	195	3,780	365	7,070
	1957	216	2,900	---	---
	1953	218	4,340	---	---
	1952	231	4,010	---	---

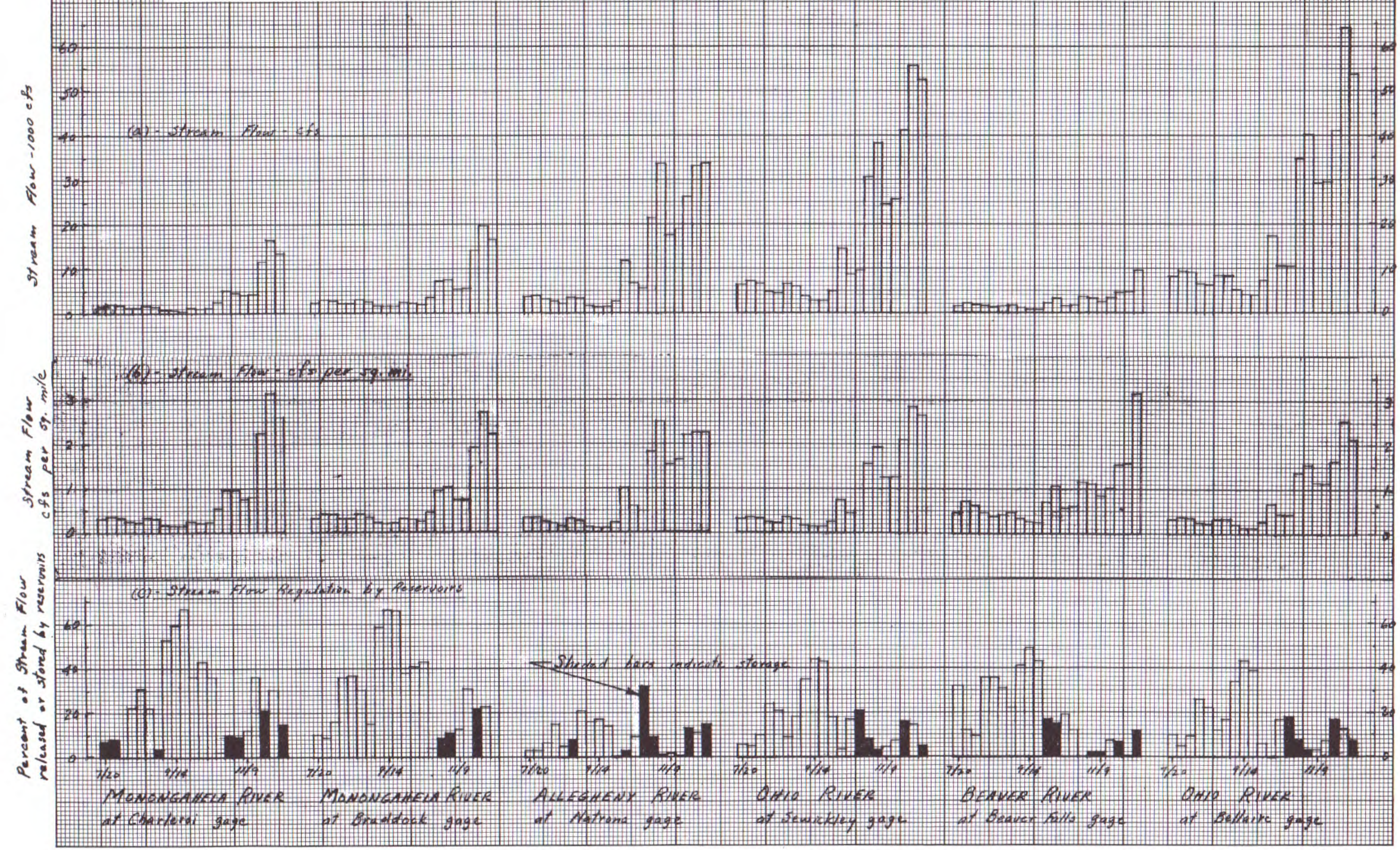


FIGURE 2 -- FLOW VARIATIONS. Stream flows -- in cubic feet per second (cfs) and in cubic feet per second per square mile (cfsm) -- remained relatively stable and at low levels during the first 12 to 14 weeks of the survey. Higher and unstable flows occurred during the final 6 to 8 weeks. Also shown is amount of water released from (or stored by) upstream reservoirs in terms of percent of stream flow.

<u>FIGURE 3</u> -- ALKALINITY VARIATIONS. Shutdown of the steel mills affected alkalinity content of the five areas under investigation in different ways. Variations in the effects of mill shutdown are attributed to the overshadowing influence of acid mine drainage on water-quality conditions in some of the river areas, particularly the Monongahela River.

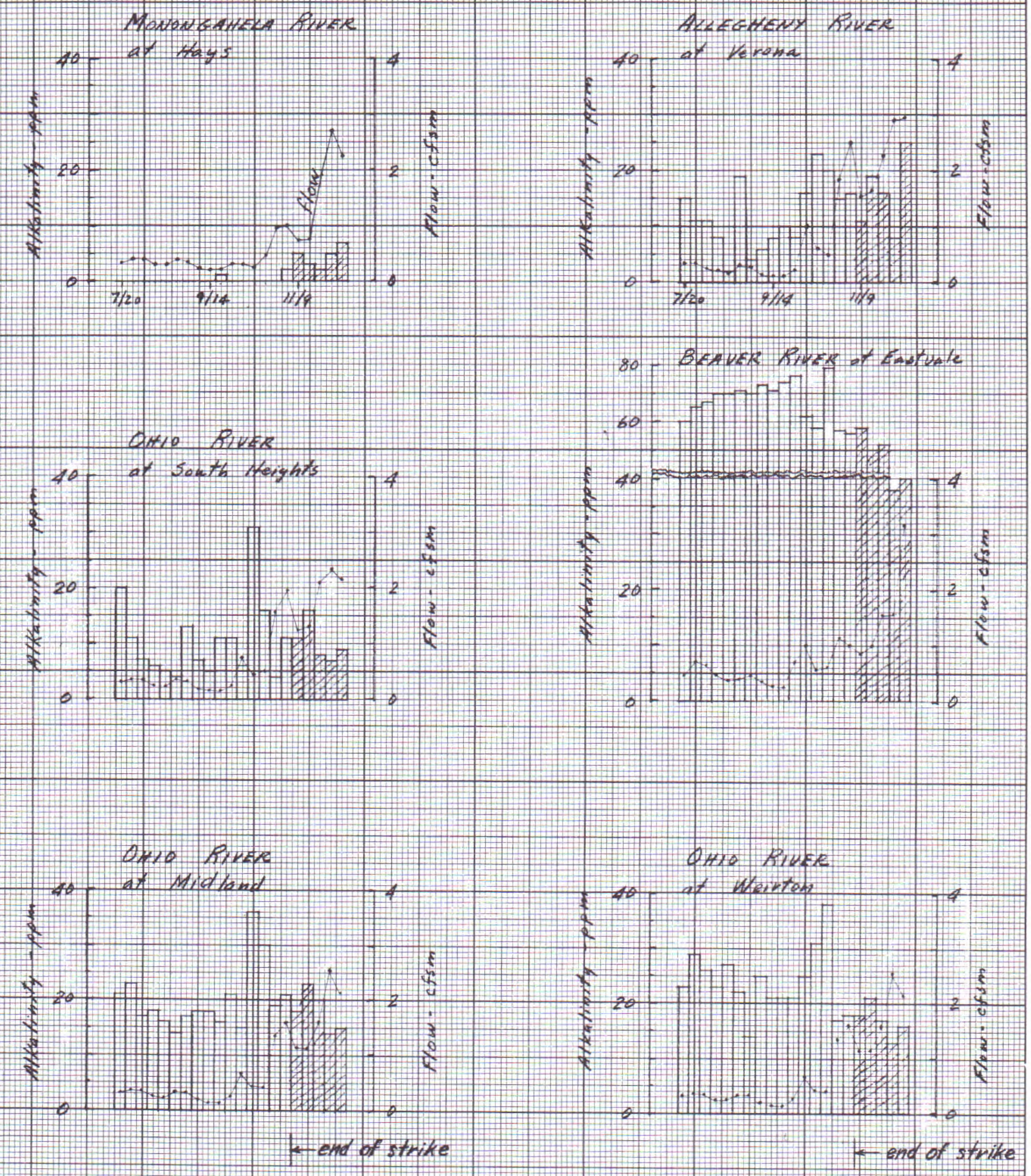


FIGURE 4 -- COMPARISON OF ALKALINITY CONCENTRATIONS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. Mill shutdown -- and cessation of acid discharges -- produced an increase in alkalinity of the Mahoning, Beaver and lower section of the Ohio rivers. In contrast, alkalinity of the Monongahela River was less during the shutdown period than it is when the mills are operating.

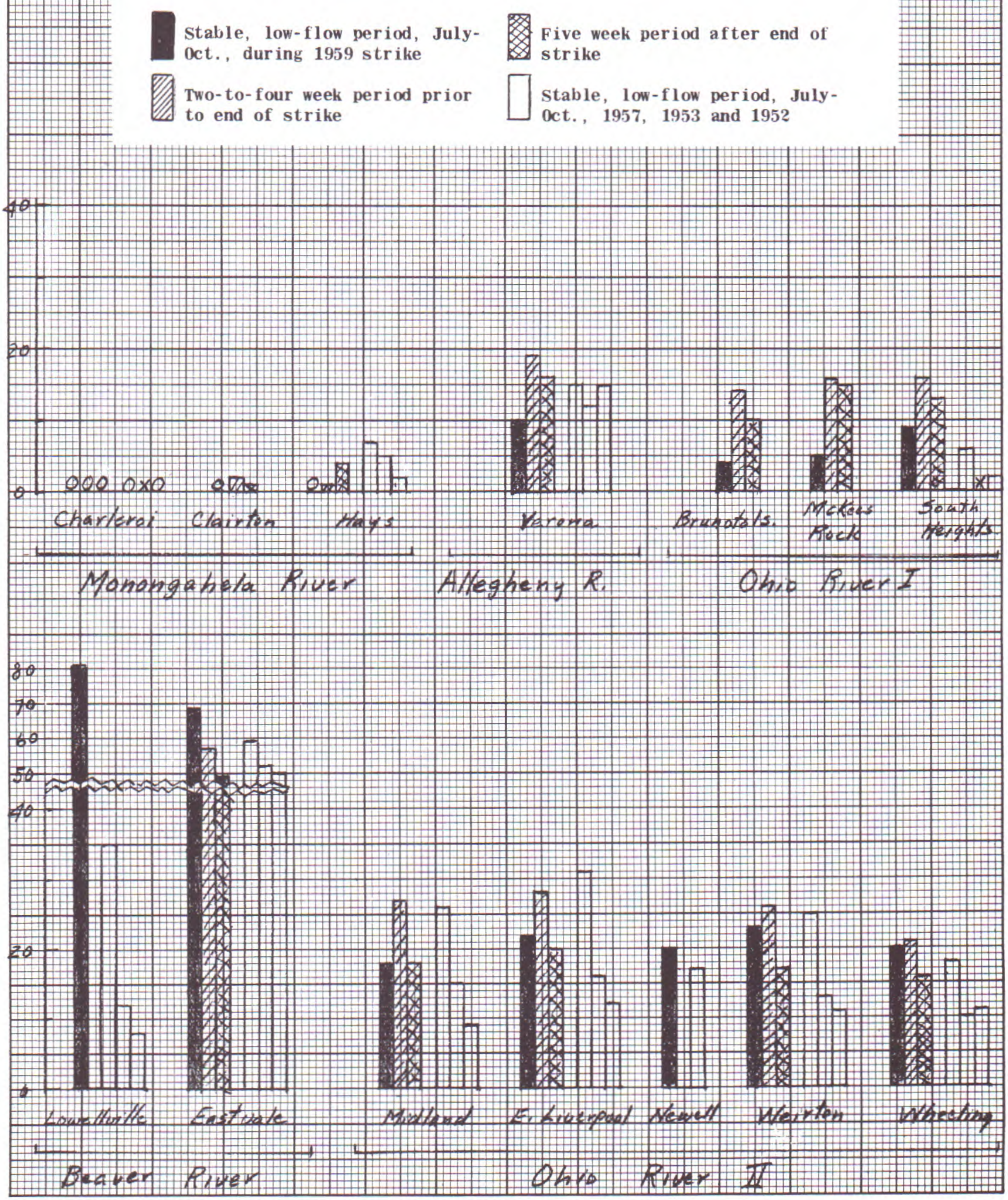


FIGURE 5 -- **COMPARISON OF ALKALINITY LOADINGS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION.** On the Mahoning River alkalinity loadings were four to 15 times greater during mill shutdown than they were in previous years. On the Monongahela River (at Hays), alkalinity content was zero during shutdown, compared with 10 to 40 tons per day in previous years.

■ Stable, low-flow period, July-Oct., during 1959 strike

□ Stable, low-flow period, July-Oct., 1957, 1953 and 1952

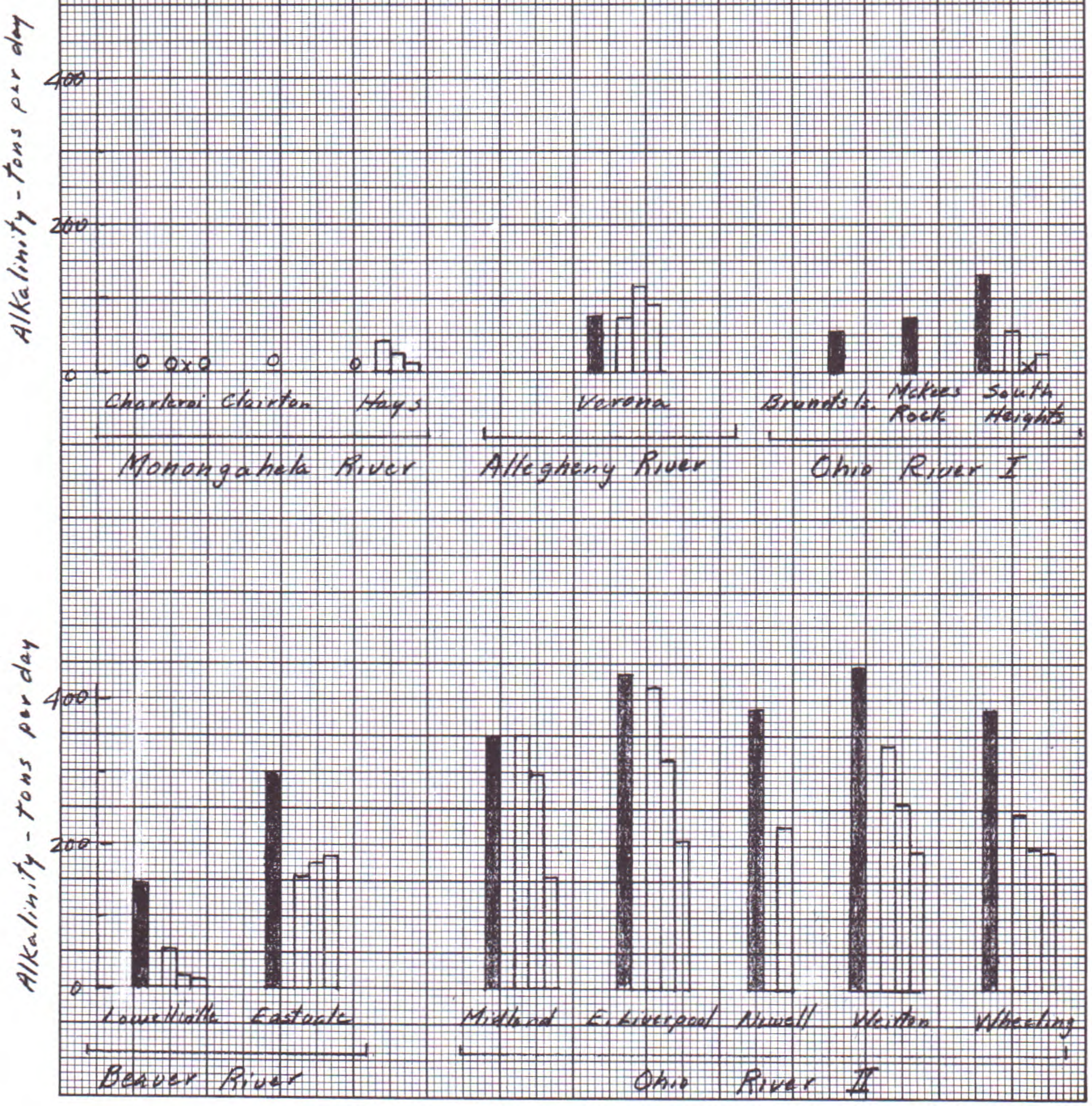


FIGURE 6 -- pH VARIATIONS. On the Monongahela River pH values remained at or less than 4.5 throughout the shutdown period. On the Beaver River values were 7.0 or higher. In other areas weekly average pH values ranged, for the most part, between 6.0 and 7.0.

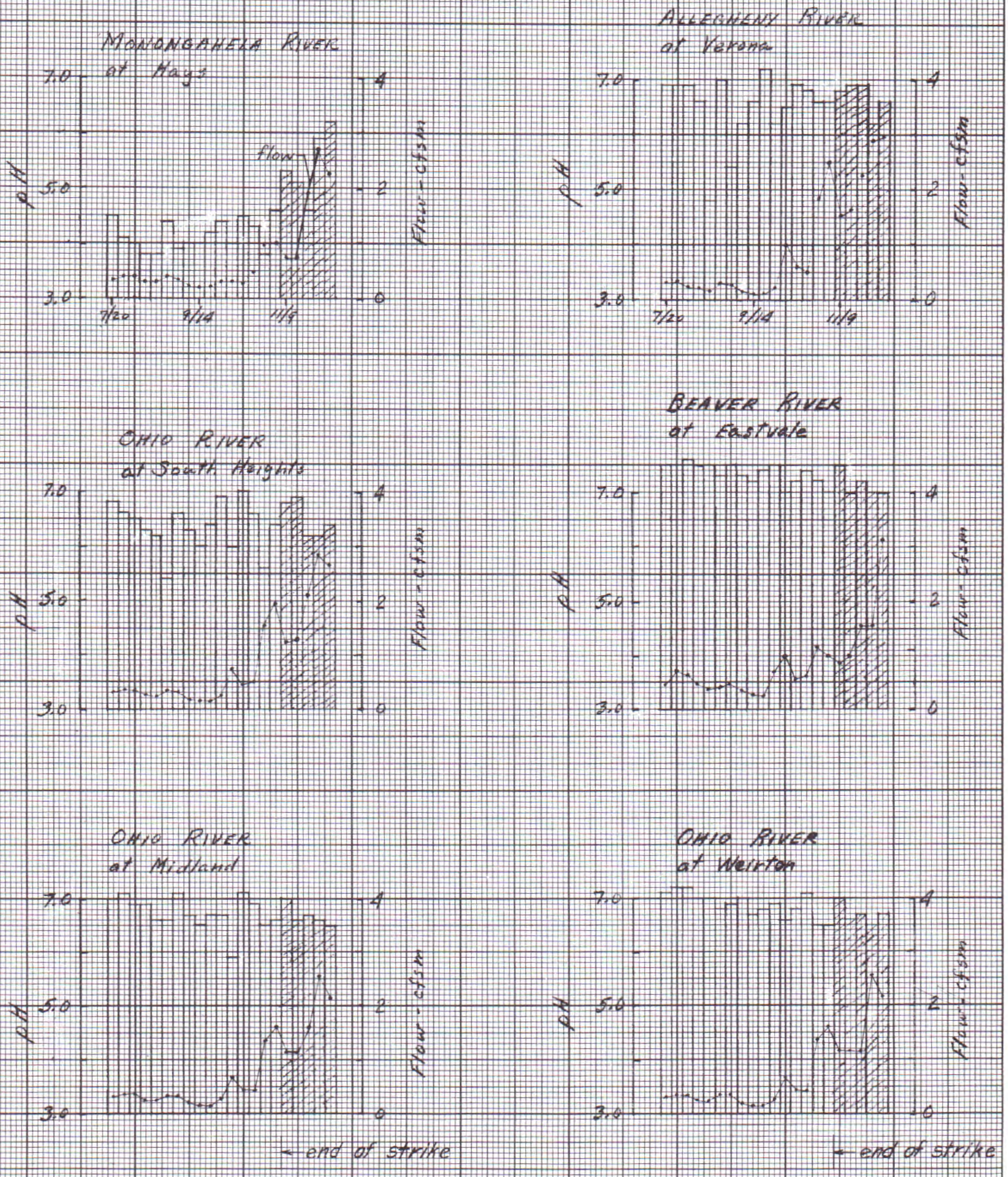


FIGURE 7 -- COMPARISON OF pH VALUES DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. Greatest changes were observed in the Monongahela and Beaver rivers. On the Monongahela River (at Hays) average pH during mill shutdown was 4.1; average value in 1957 was 5.7. On the Mahoning River (Lowellville) average value during shutdown was 7.3, compared with average values of 5.4 to 6.2 in previous years.

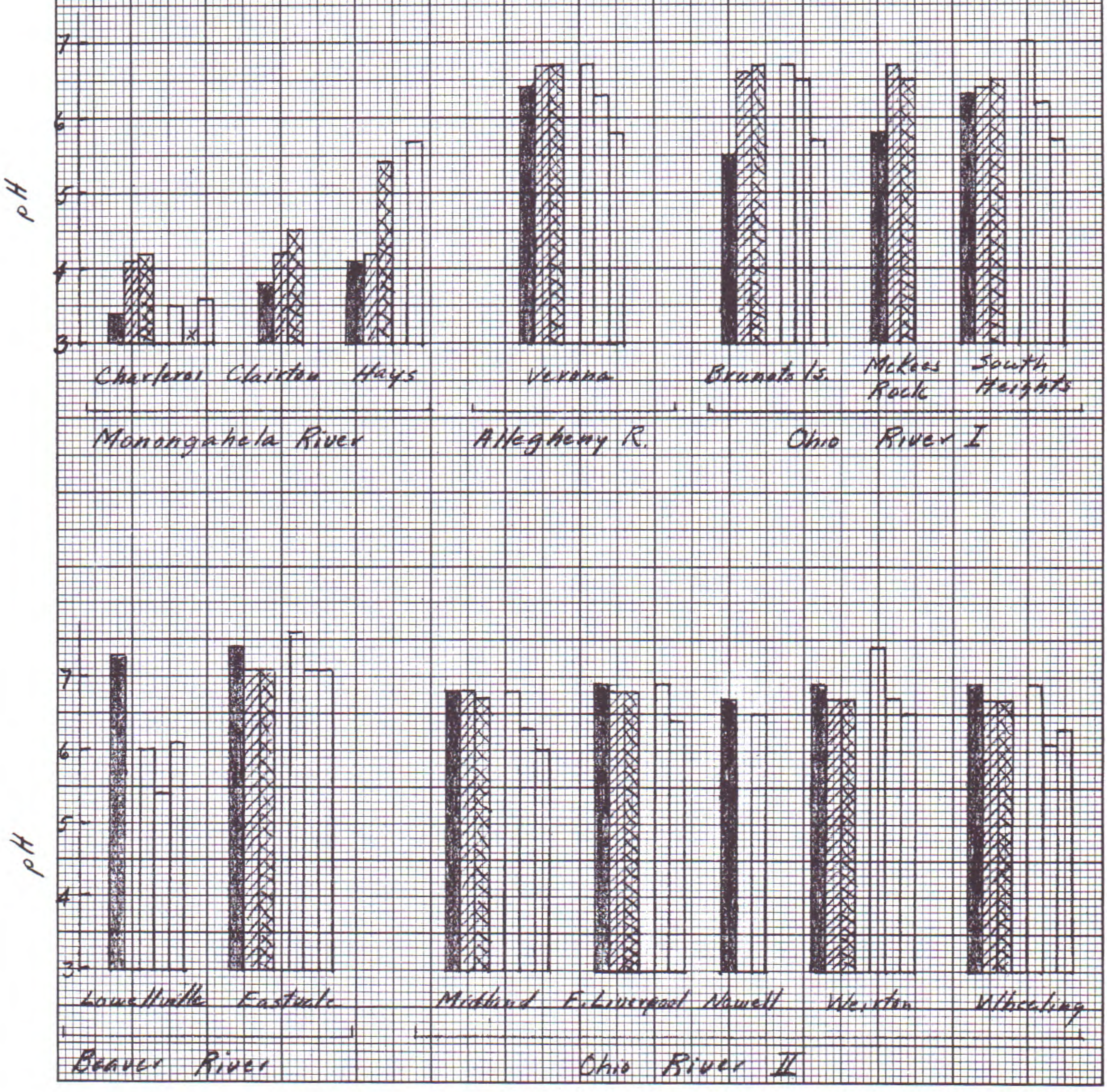


FIGURE 8 -- HARDNESS VARIATIONS. Although steel-mill wastes contain large quantities of hardness-producing constituents, the effects of these wastes on stream concentrations are not as apparent as might be expected because of the influence of other factors -- notably variations in stream flow and the influence of acid mine drainage. Steel-mill operations have a more pronounced effect on hardness levels in the Beaver River system than in any other survey area. Resumption of operations in the Beaver River basin, with the consequent discharge of wastes, counteracted the effects of increased dilution water during the last weeks of the survey -- a condition not observed in other areas.

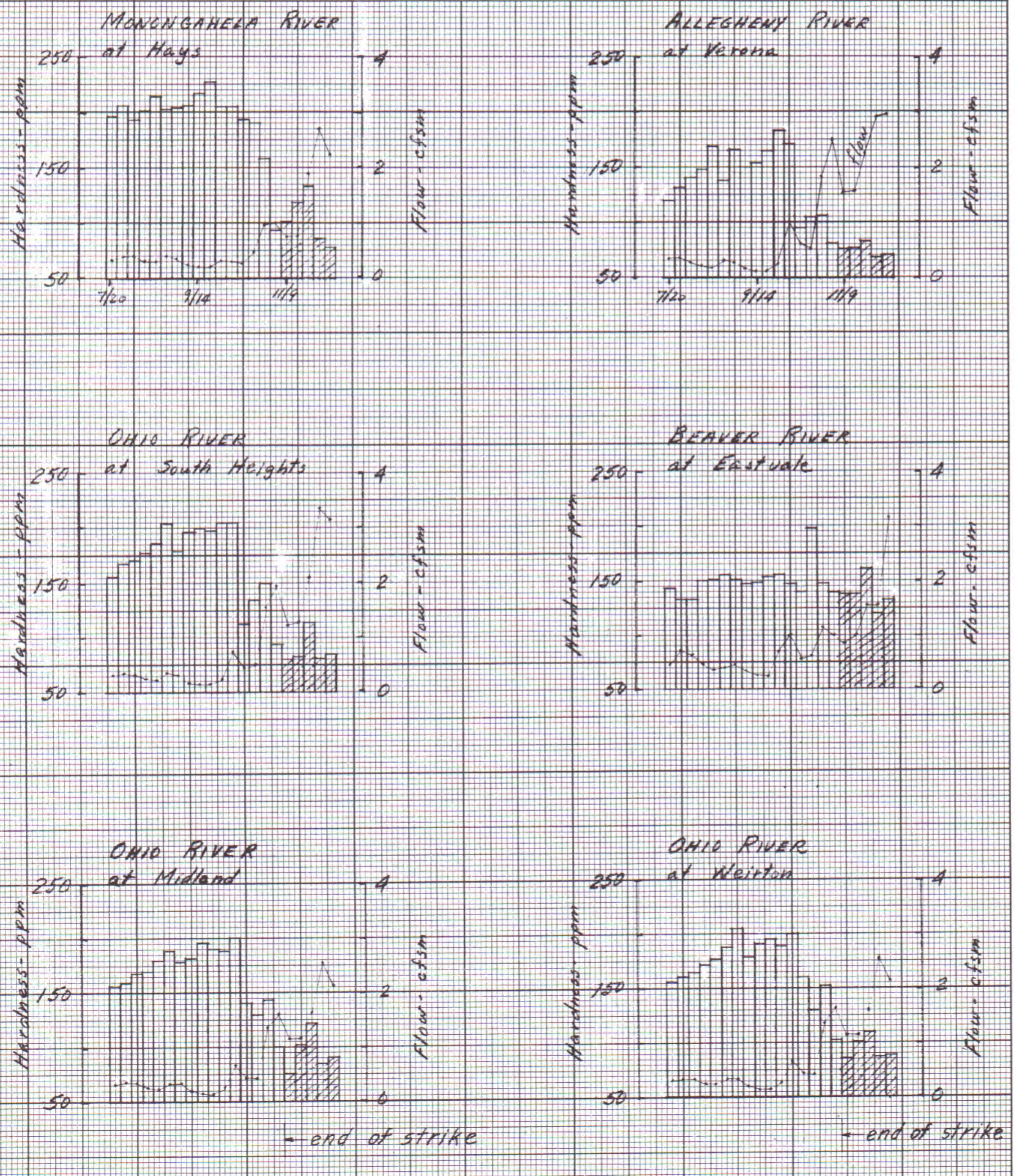
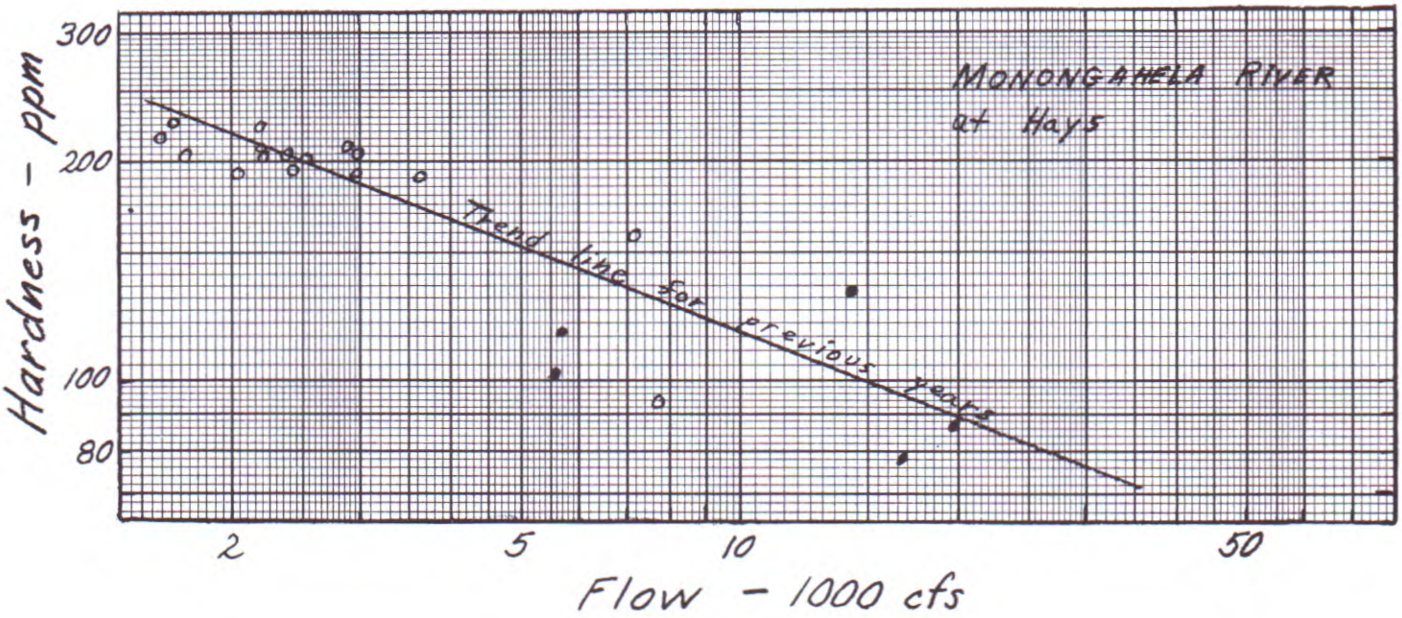


FIGURE 9 -- RELATION BETWEEN HARDNESS CONCENTRATIONS AND STREAM FLOW. These correlation plots demonstrate an inverse relationship -- the higher the stream flow the lower the hardness content. It may be noted that observations made during 1959 survey fit trend lines based on data for previous years.

○ Weekly average concentrations during 1959 strike

● Weekly average concentrations after end of strike



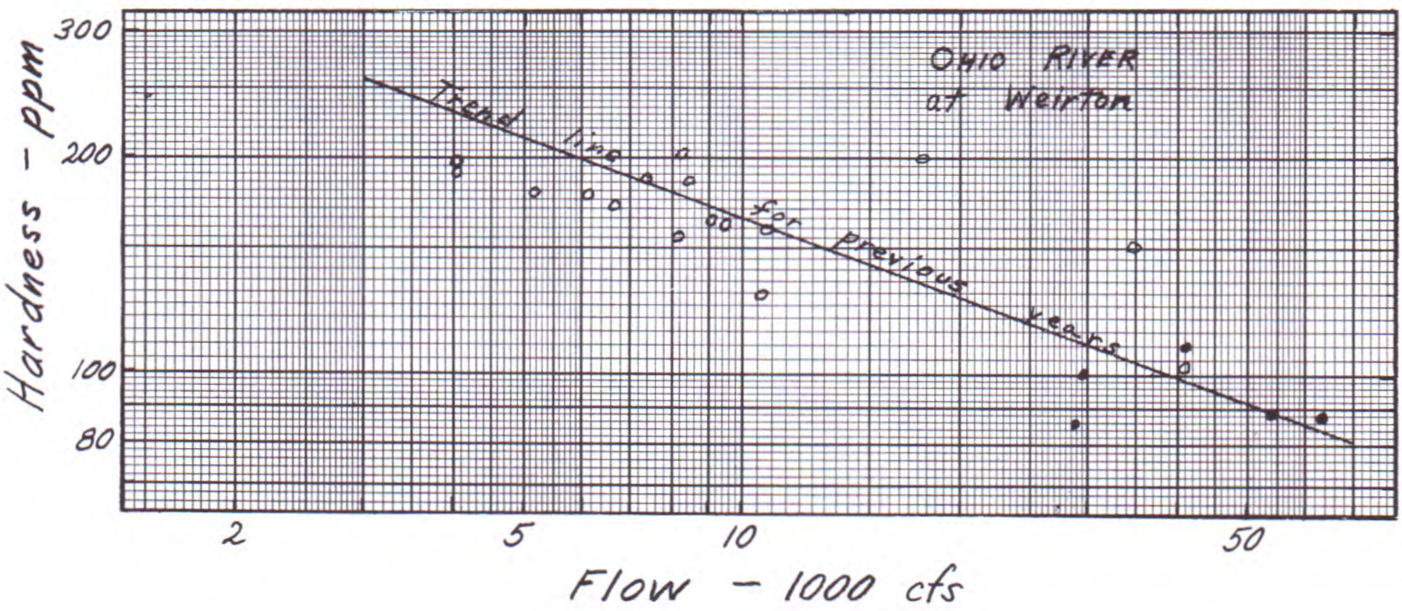


FIGURE 10 -- COMPARISON OF HARDNESS CONCENTRATIONS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. On the Beaver River concentrations during the shutdown period were about 20 percent less than in previous years when the mills were operating. Reductions in other areas ranged from zero to 12 percent.

- Stable, low-flow period, July-Oct., during 1959 strike
- Five week period after end of strike
- Two-to-four week period prior to end of strike
- Stable, low-flow period, July-Oct., 1957, 1953 and 1952

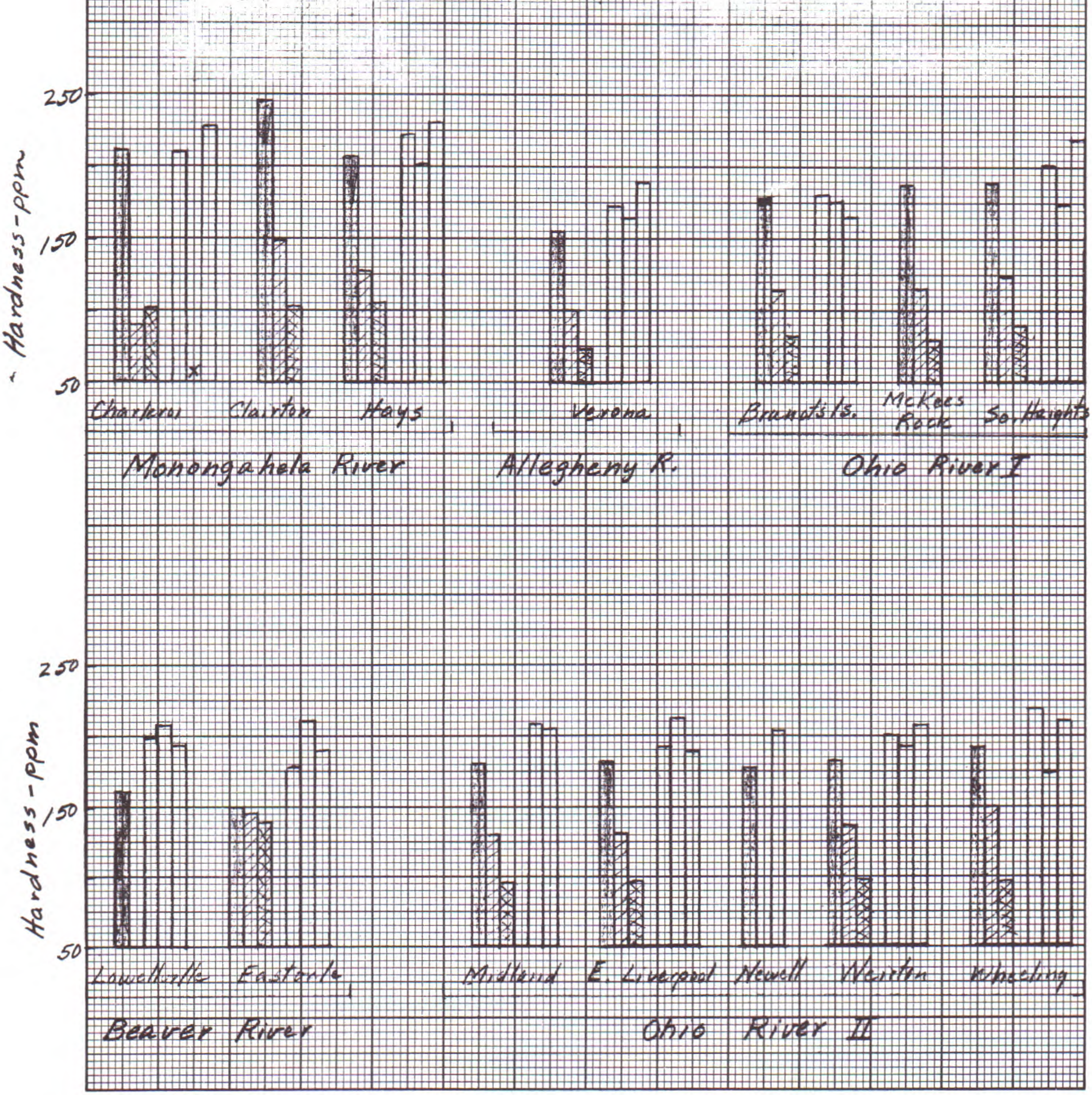


FIGURE 11 -- COMPARISON OF HARDNESS LOADINGS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. Stream loadings during the 1959 shutdown were not significantly different from average loadings in previous years. This is to be expected in view of estimates that the steel industry contributes only some nine percent of the total amount (3,000 to 4,000 tons per day) of hardness-producing constituents discharged to the Ohio River system above Wheeling.

■ Stable, low-flow period, July-Oct., during 1959 strike

□ Stable, low-flow period, July-Oct., 1957, 1953 and 1952

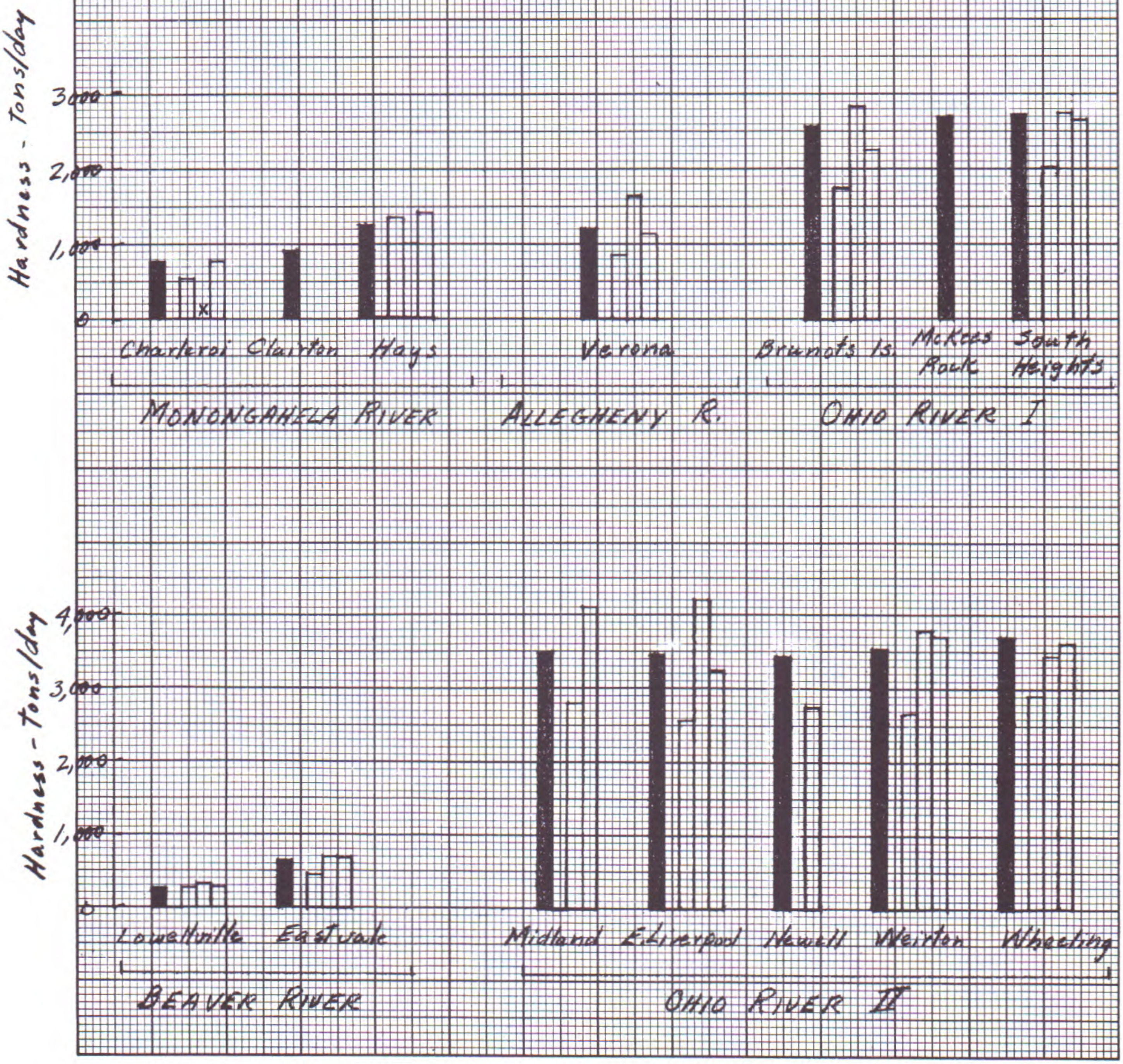


FIGURE 12 -- RELATION BETWEEN SULFATE CONCENTRATIONS AND STREAM FLOW. Concentrations vary inversely with flow. Data for 1959 follow the pattern established by observations made in previous years.

○ Weekly average concentrations during 1959 strike

● Weekly average concentrations after end of strike

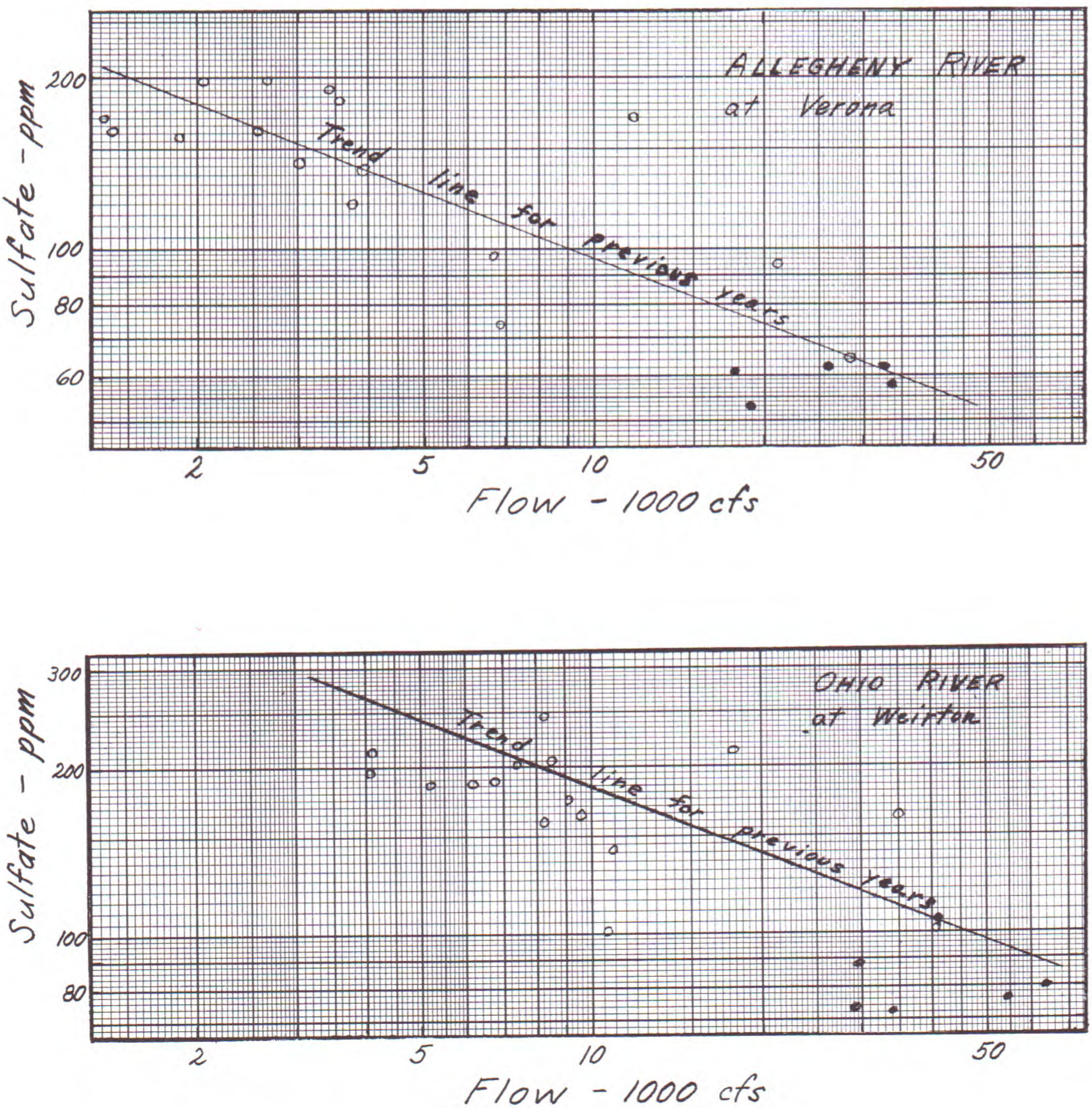


FIGURE 13 -- IRON VARIATIONS. At most stations there was a distinct change toward higher concentrations after the strike and following resumption of mill operations.

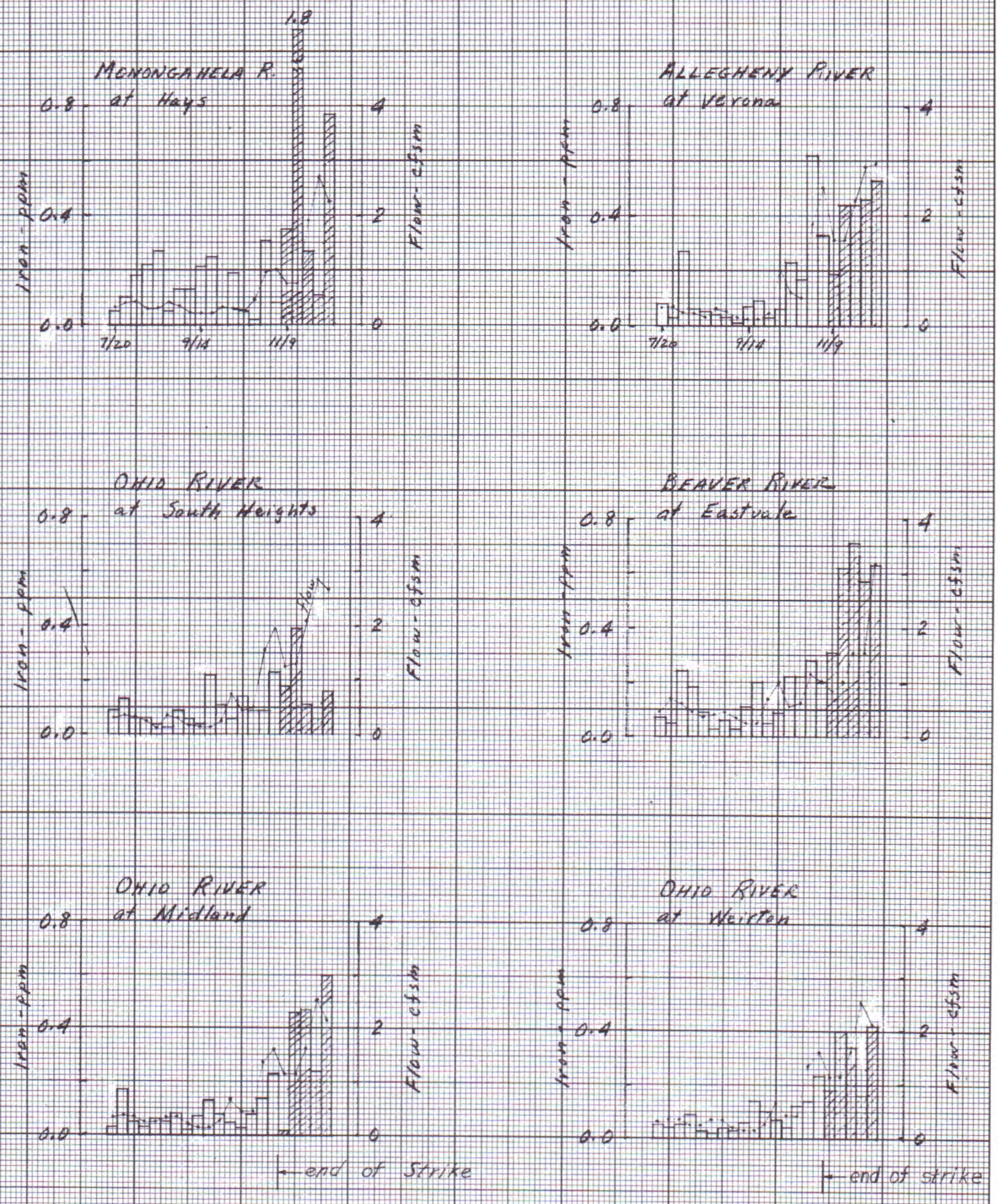


FIGURE 14 -- IRON CONCENTRATIONS DURING AND AFTER THE STRIKE. Concentrations at stations other than Charleroi and Clairton were from 50 to 700 percent higher after resumption of operations than they were during the strike.

- Stable, low-flow period, July-Oct., during 1959 strike
- Two-to-four week period prior to end of strike
- Five week period after end of strike

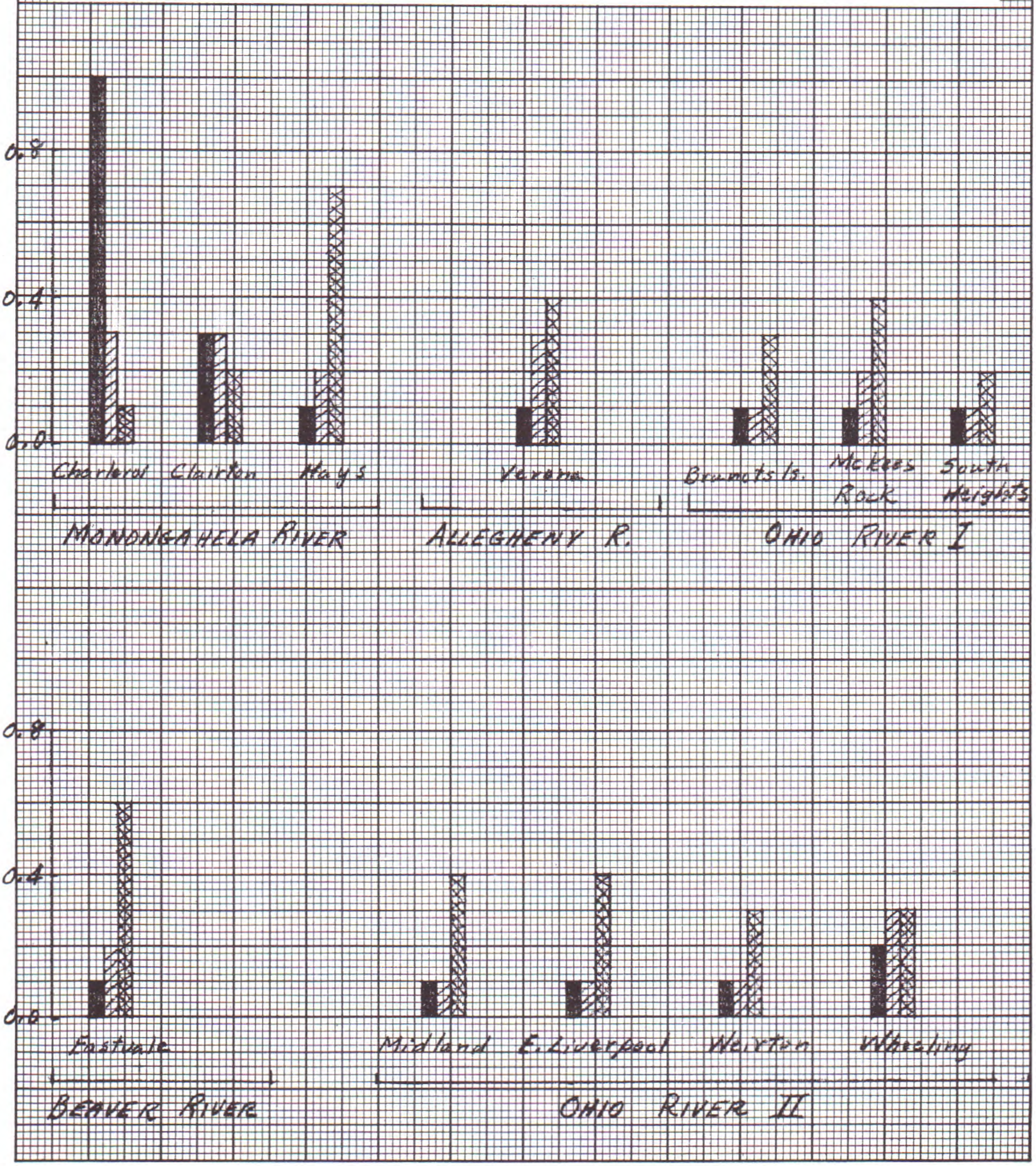


FIGURE 15 -- IRON LOADINGS IN THE STABLE, LOW-FLOW PERIOD DURING THE STRIKE. Loadings varied from 0.4 to 3.9 tons per day, lowest value being observed at Eastvale and highest at Wheeling.

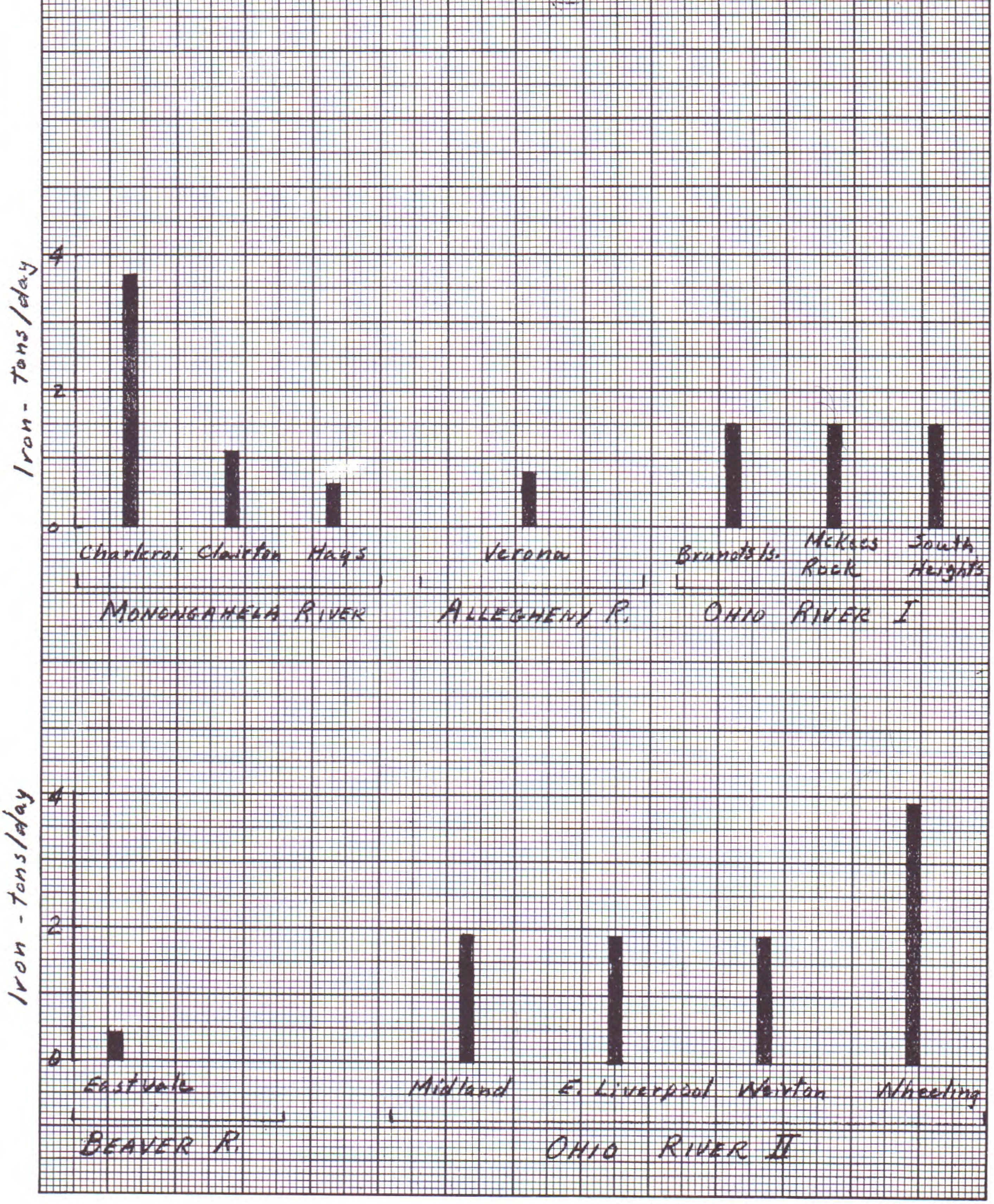


FIGURE 16 -- MANGANESE VARIATIONS. Concentrations at several stations remained at a relatively high, sustained level during the first 12 to 14 weeks of the survey and then decreased during the remaining weeks. This pattern of variation may be attributed to the onset of high flows near the end of the strike period.

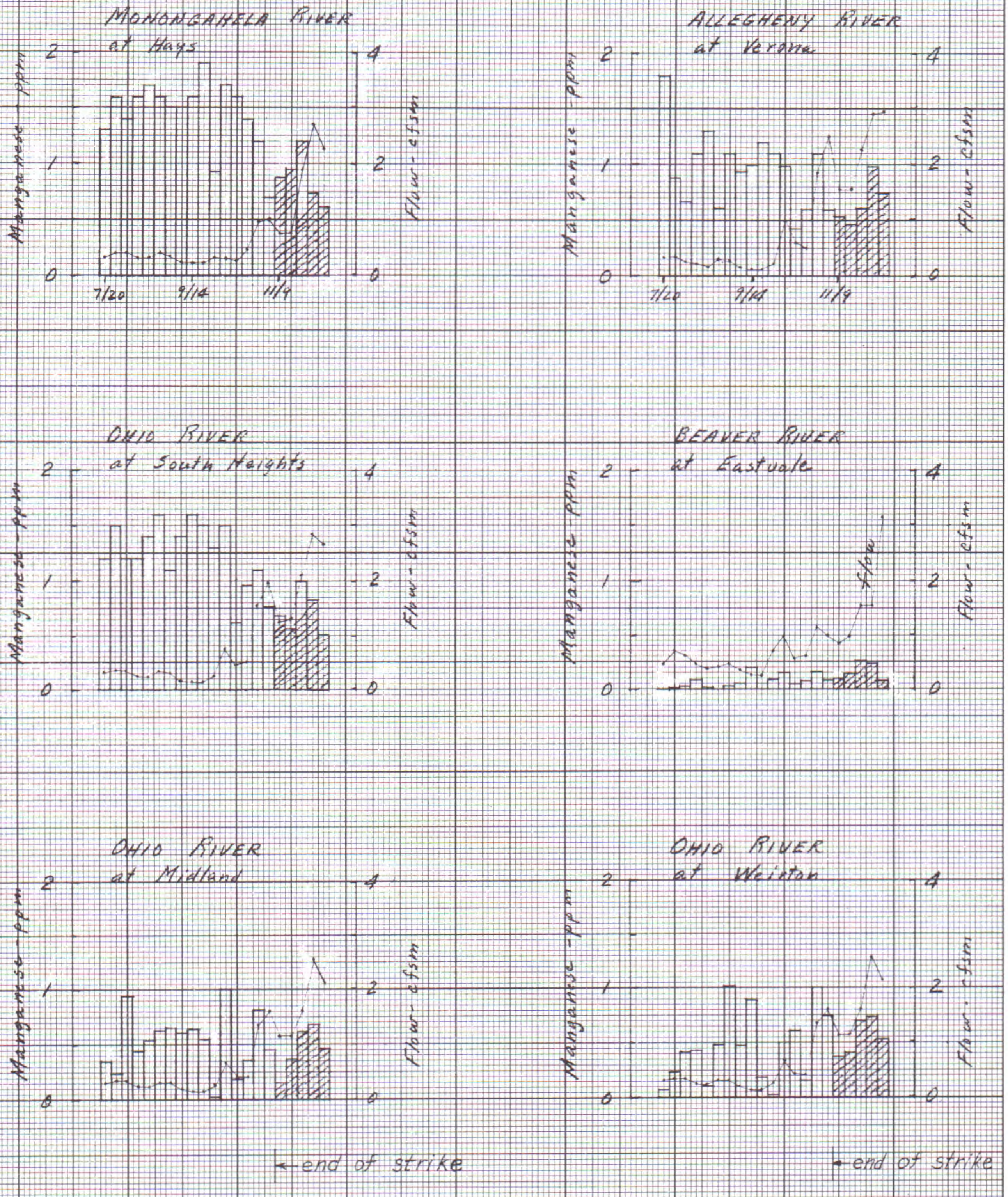


FIGURE 17 -- **COMPARISON OF MANGANESE CONCENTRATIONS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION.** At nearly all stations manganese concentrations during the 1959 strike were considerably less than values reported in previous years when the mills were operating. The influence of the Beaver River on manganese concentrations in the Ohio may also be noted from the charts; concentrations in the Ohio below its confluence with the Beaver are less than half of values above the confluence.

- Stable, low-flow period, July-Oct., during 1959 strike
- Five week period after end of strike
- Two-to-four week period prior to end of strike
- Stable, low-flow period, July-Oct., 1957, 1953 and 1952

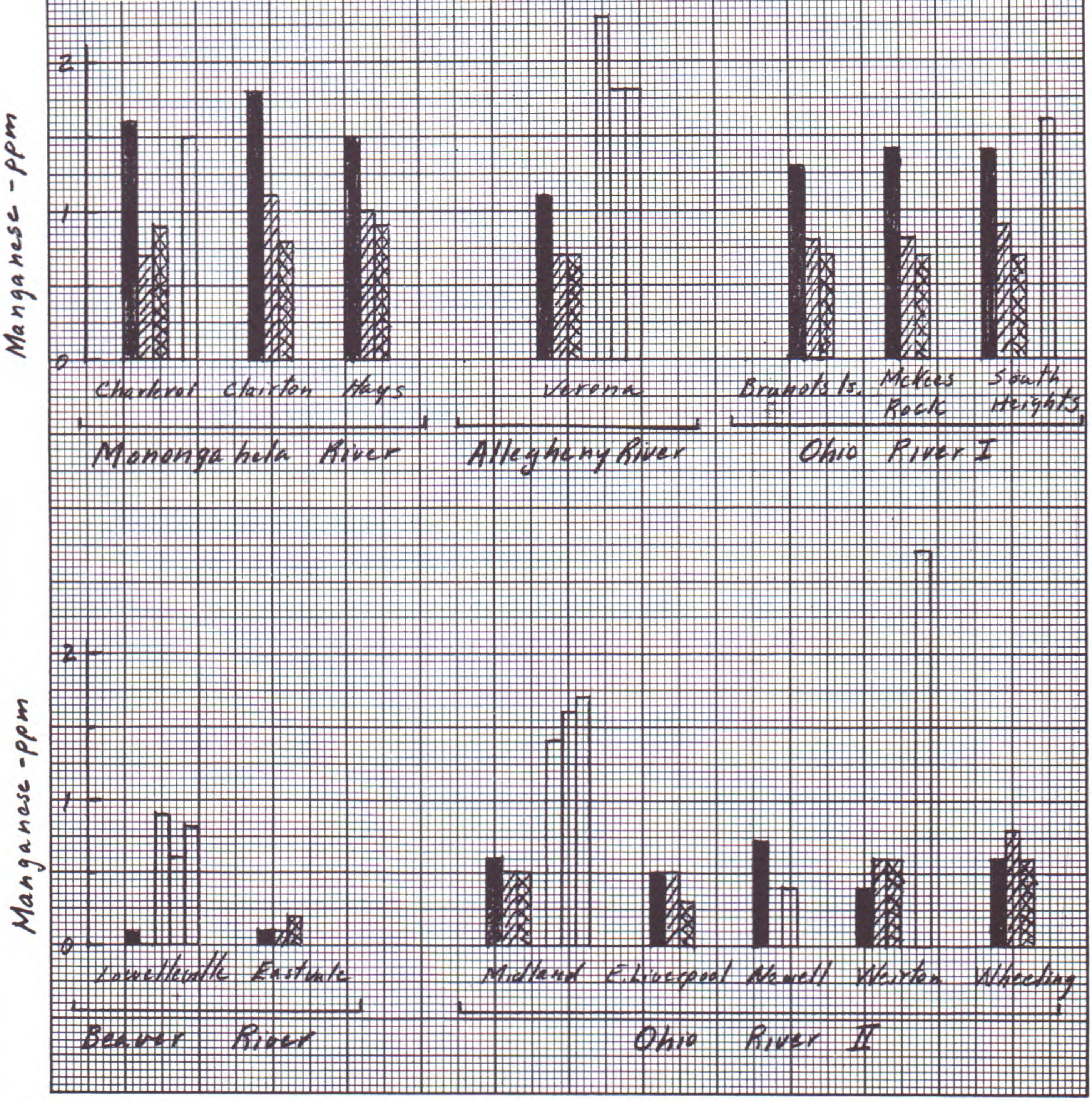


FIGURE 18 -- COMPARISON OF MANGANESE LOADINGS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. Stream loadings in the Allegheny, Mahoning and lower section of the Ohio rivers were 36 to 83 percent less in 1959 than in previous years.

■ Stable, low-flow period, July-Oct., during 1959 strike

□ Stable, low-flow period, July-Oct., 1957, 1953 and 1952

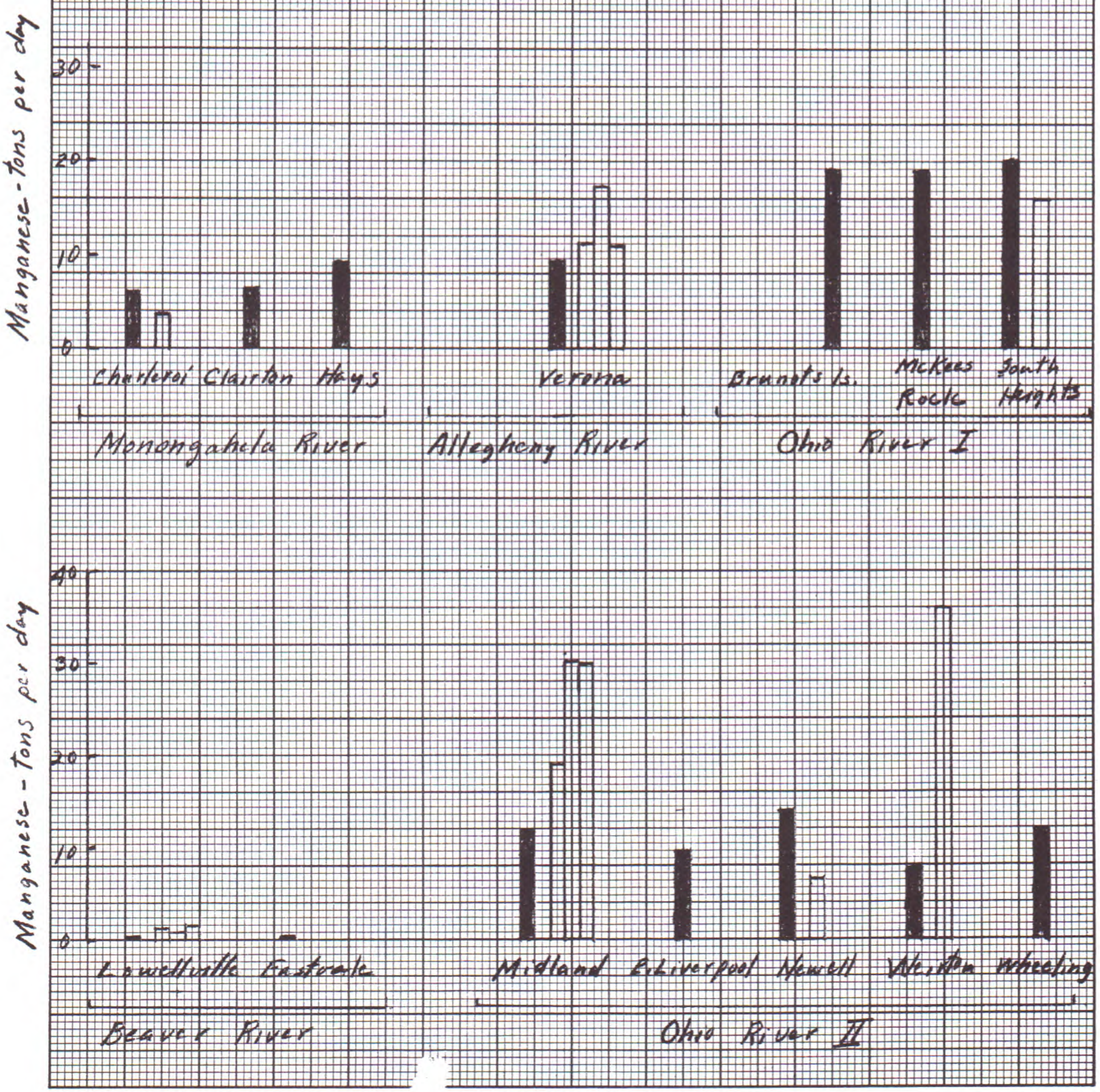


FIGURE 19 -- FLUORIDE VARIATIONS. Concentrations at all stations except Midland were higher during the strike period than they were in the weeks immediately following end of strike. The trend toward decreased concentrations at the end of the strike may be attributed to increased dilution caused by the rise in stream flow at that time.

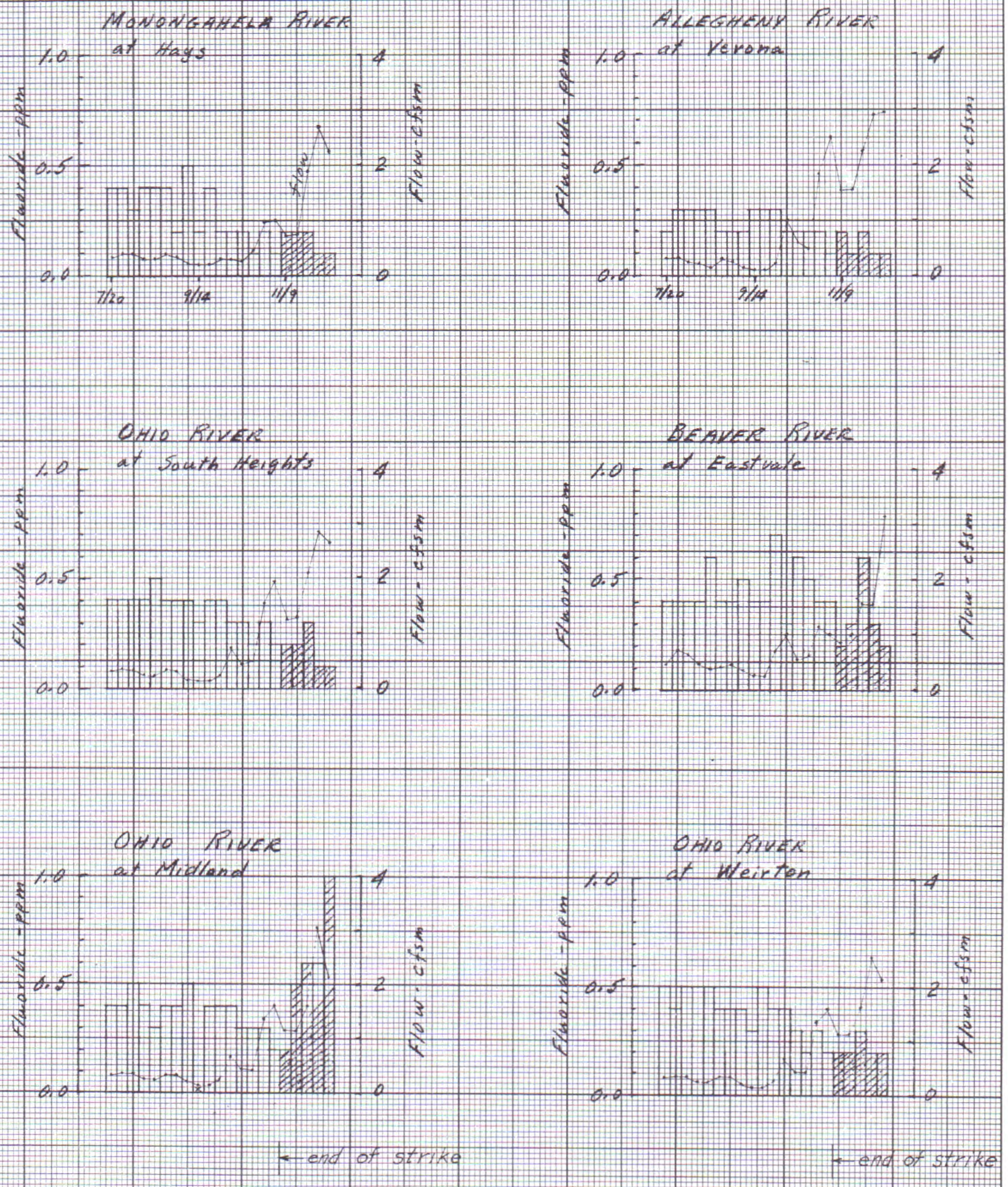


FIGURE 20 -- COMPARISON OF FLUORIDE CONCENTRATIONS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. Steel-mill operations increase river content of fluoride at most stations, particularly during low-flow periods. Concentrations in the reference years when the mills were operating were twice what they were in 1959 in some stations.

- Stable, low-flow period, July-Oct., during 1959 strike
- Five week period after end of strike
- Two-to-four week period prior to end of strike
- Stable, low-flow period, July-Oct., 1957, 1953 and 1952

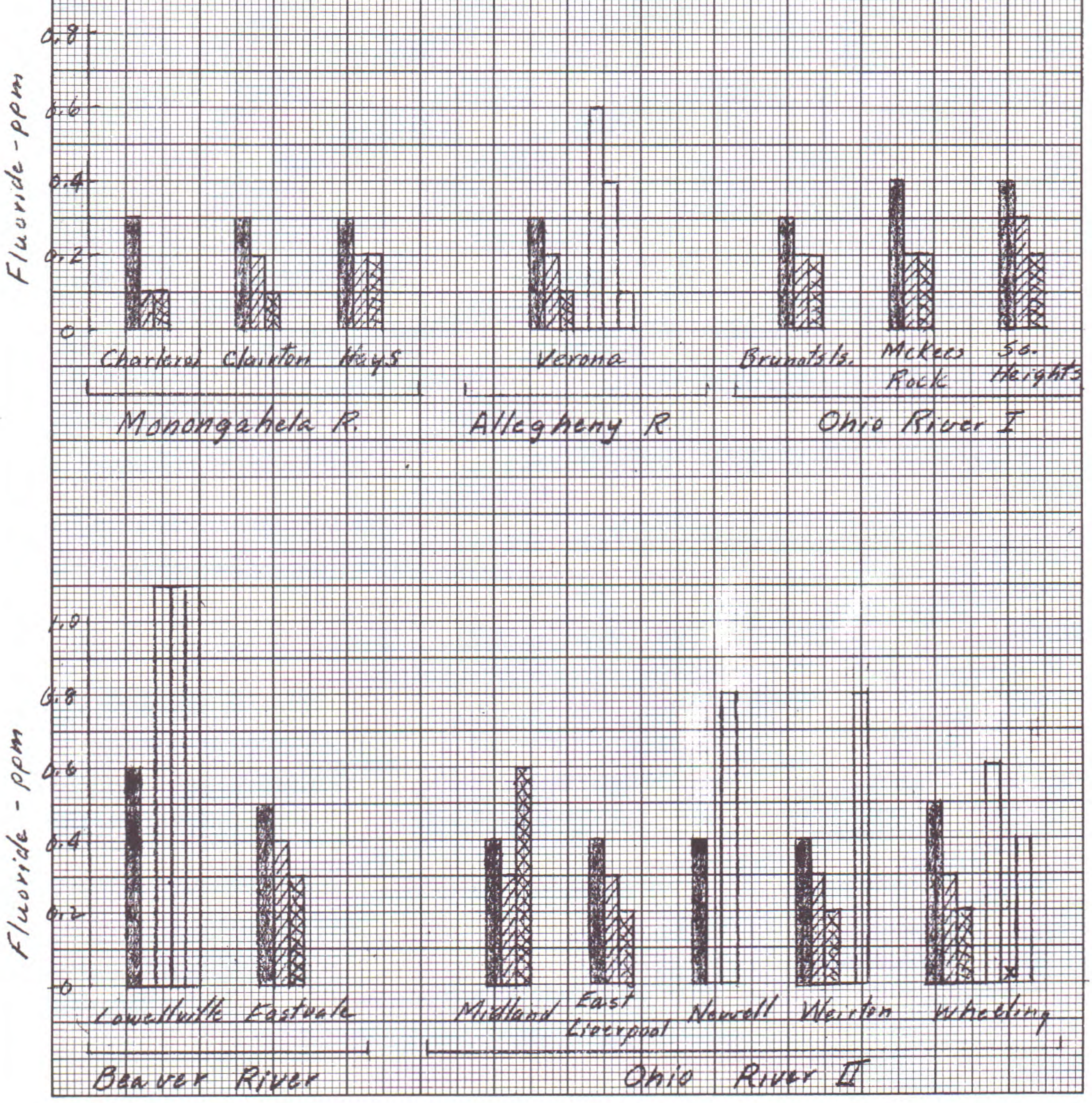


FIGURE 21 -- COMPARISON OF FLUORIDE LOADINGS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. Observations during the strike reveal that sources other than steel mills may be contributing a stream load of eight to ten tons per day of fluoride in the Midland-Wheeling stretch of the Ohio River. The fluoride load discharged by steel plants upstream from Wheeling is estimated to be about six tons per day.

■ Stable, low-flow period, July-Oct., during 1959 strike

□ Stable, low-flow period, July-Oct., 1957, 1953 and 1952

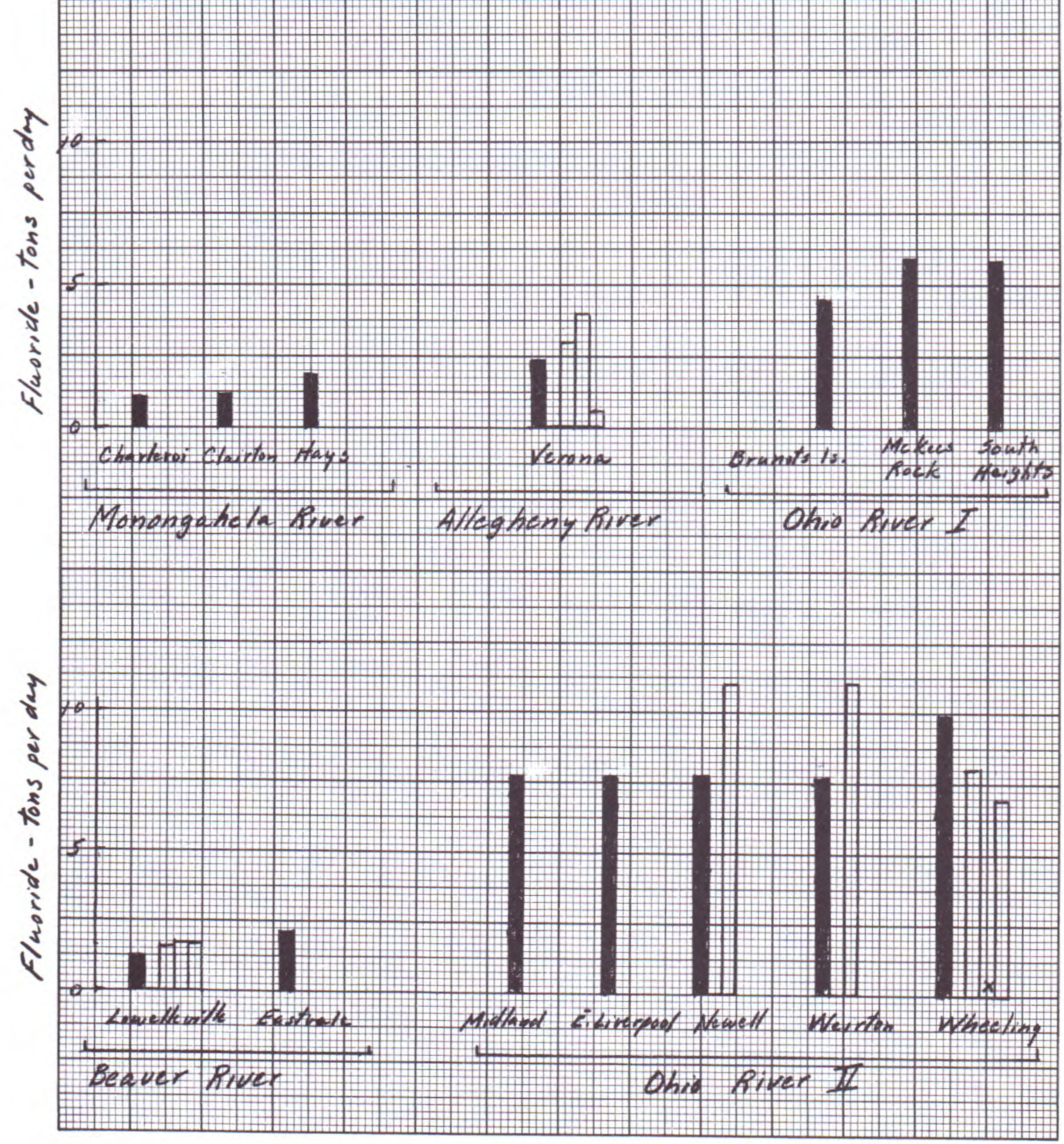


FIGURE 22 -- TEMPERATURE VARIATIONS. Ranges in temperature at most stations were 70 to 80 degrees July through September; in November and December the range was 40 to 50 degrees. Highest sustained water temperatures occurred on the Monongahela River at Hays; the highest weekly value -- 83 degrees -- occurred at Midland on the Ohio River.

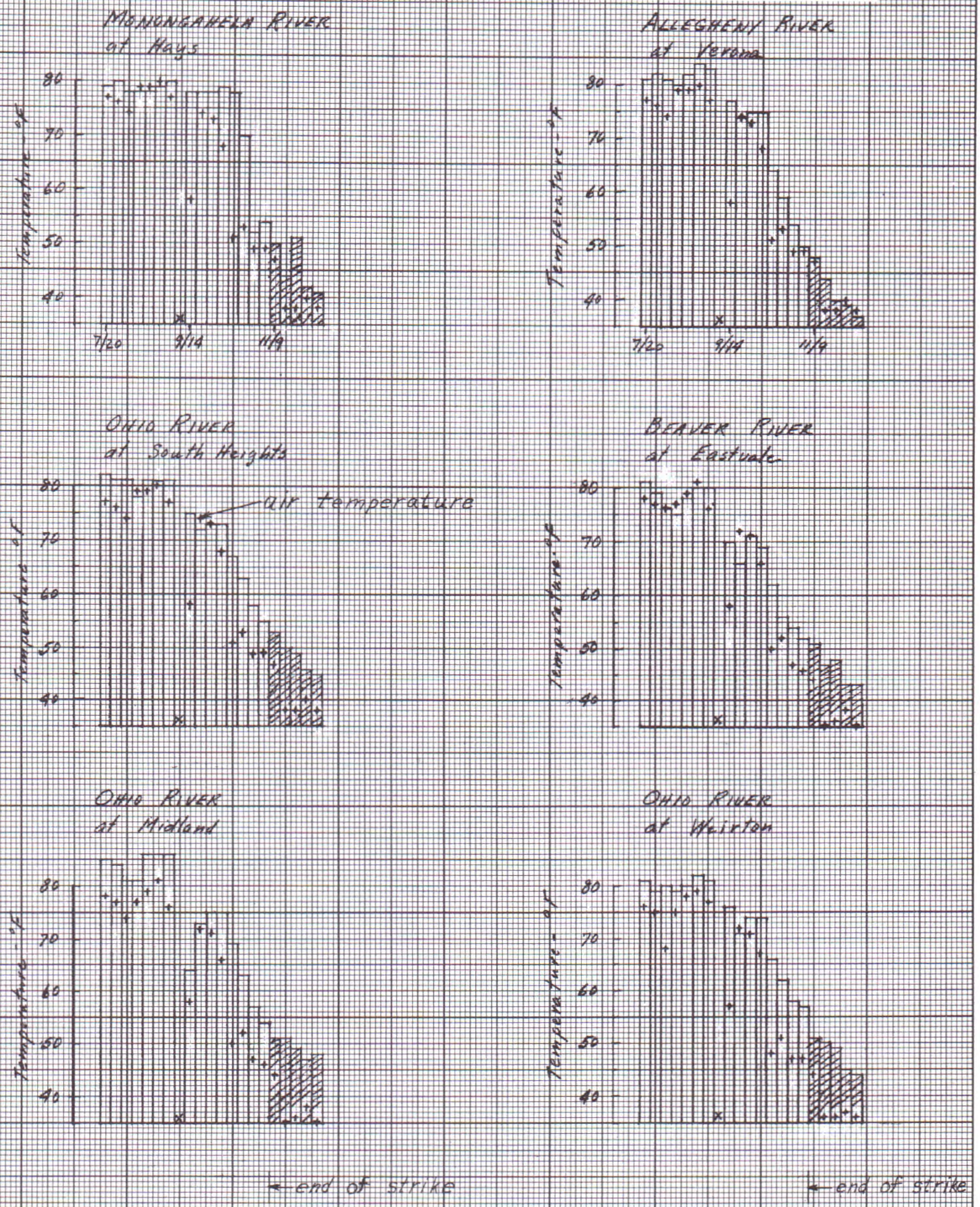


FIGURE 23 -- **COMPARISON OF TEMPERATURE OBSERVATIONS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION.** River temperatures in 1959 compared with those in other years showed the greatest variations at Lowellville on the Mahoning River. Here the July-to-October 1959 average water temperature of 75 degrees was almost 20 degrees lower than in previous years.

- (solid) Stable, low-flow period, July-Oct., during 1959 strike
- (cross-hatched) Five week period after end of of strike
- (hatched) Two-to-four week period prior to end of strike
- (open) Stable, low-flow period, July-Oct., 1957, 1953 and 1952

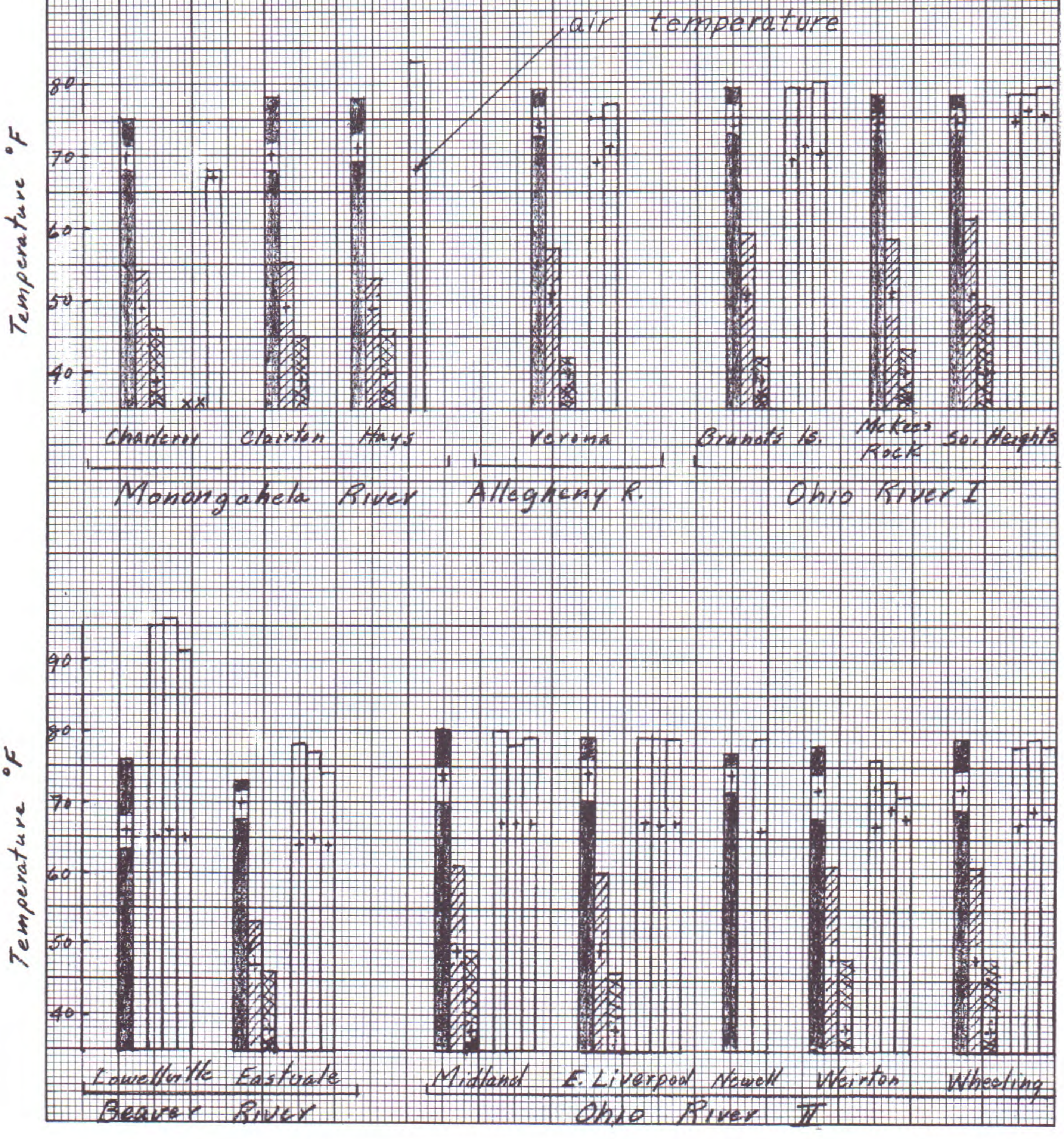
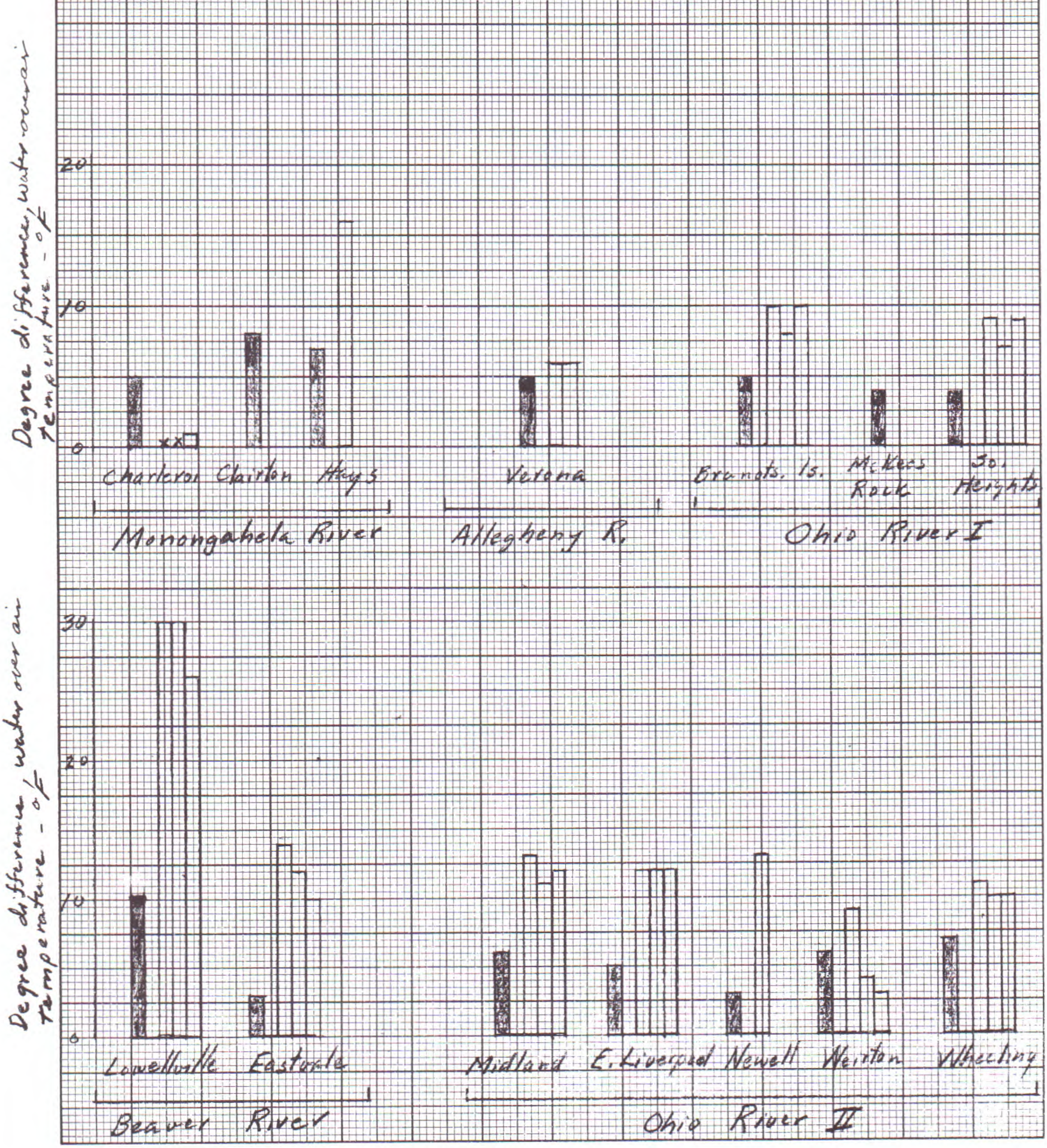


FIGURE 24 -- RIVER-OVER-AIR TEMPERATURE DIFFERENTIALS. Shown here are temperature differentials (amount by which river temperature exceeds air temperature) during 1959 strike compared with those in other years when the mills were operating. At Lowellville, for example, the river-over-air temperature in 1959 was 16 to 20 degrees less than normally experienced.

■ Stable, low-flow period, July-Oct., during 1959 strike

□ Stable, low-flow period, July-Oct., 1957, 1953 and 1952



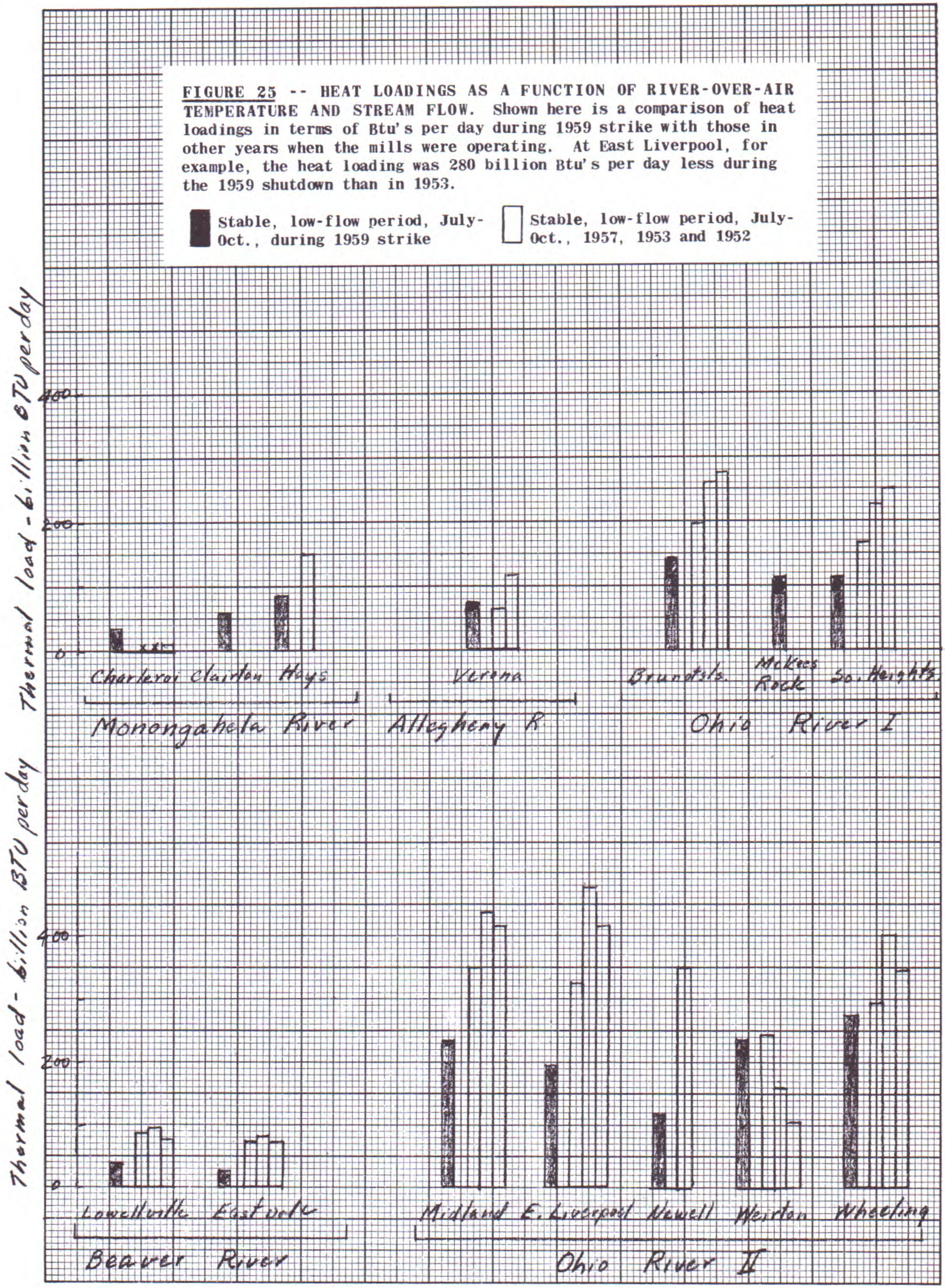


FIGURE 25 -- HEAT LOADINGS AS A FUNCTION OF RIVER-OVER-AIR TEMPERATURE AND STREAM FLOW. Shown here is a comparison of heat loadings in terms of Btu's per day during 1959 strike with those in other years when the mills were operating. At East Liverpool, for example, the heat loading was 280 billion Btu's per day less during the 1959 shutdown than in 1953.

■ Stable, low-flow period, July-Oct., during 1959 strike

□ Stable, low-flow period, July-Oct., 1957, 1953 and 1952

FIGURE 26 -- PHENOL VARIATIONS. There was a marked increase in phenol concentrations during the last five weeks of the survey. The increase is attributed, in large part, to the startup of mill operations, although changes in temperature and time-of-flow may have been contributing factors.

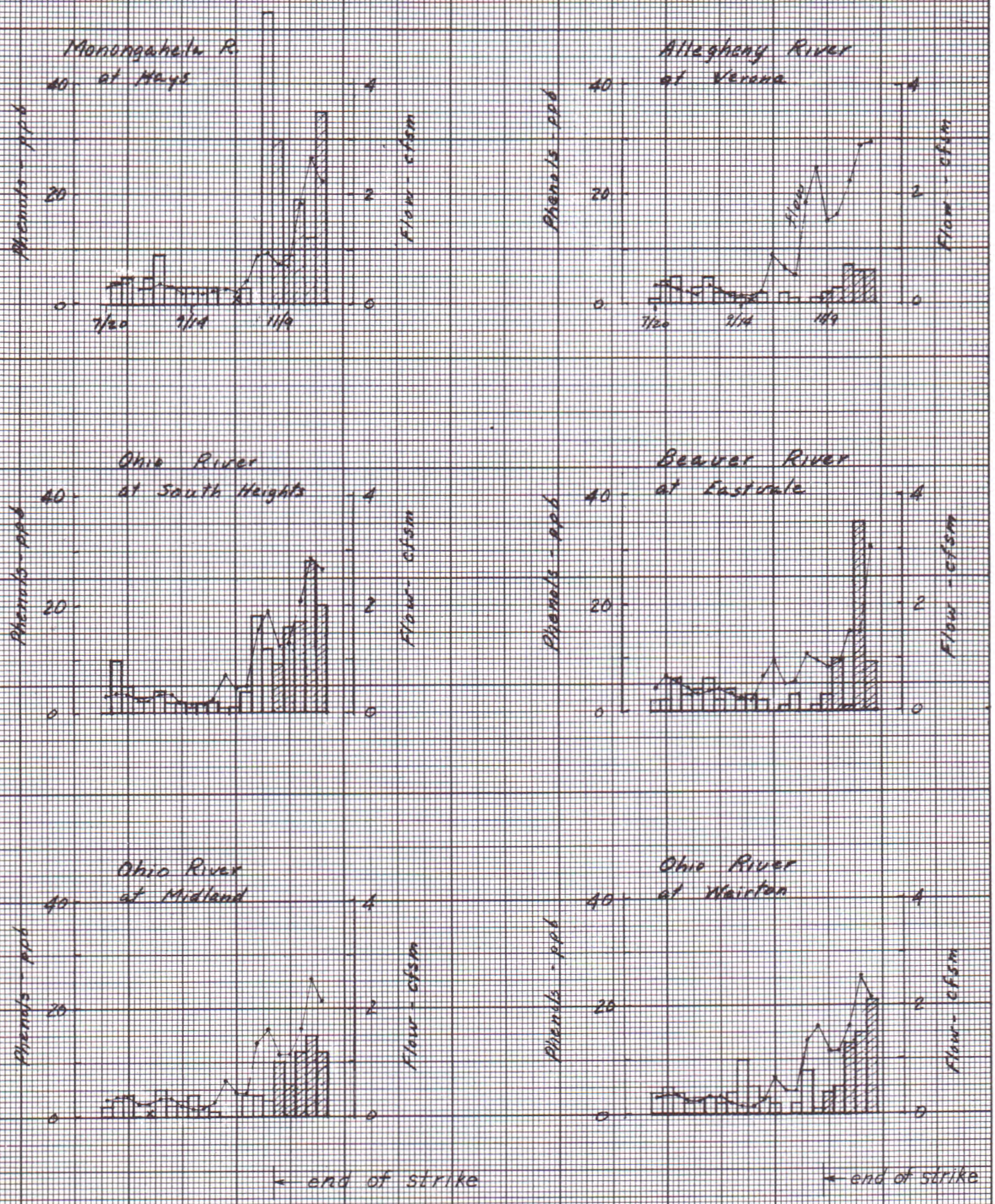


FIGURE 27 -- COMPARISON OF PHENOL CONCENTRATIONS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. Mill shutdown was accompanied by a reduction in phenol content throughout most of the survey area. The range in concentration was from an average of 3 ppb during the strike (for all stations except Clairton and Lowellville) to an average of 16 ppb after startup of the mills.

- Stable, low-flow period, July-Oct., during 1959 strike.
- Two-to-four week period prior to end of strike
- Five week period after end of strike
- Stable, low-flow period, July-Oct., 1957, 1953 and 1952

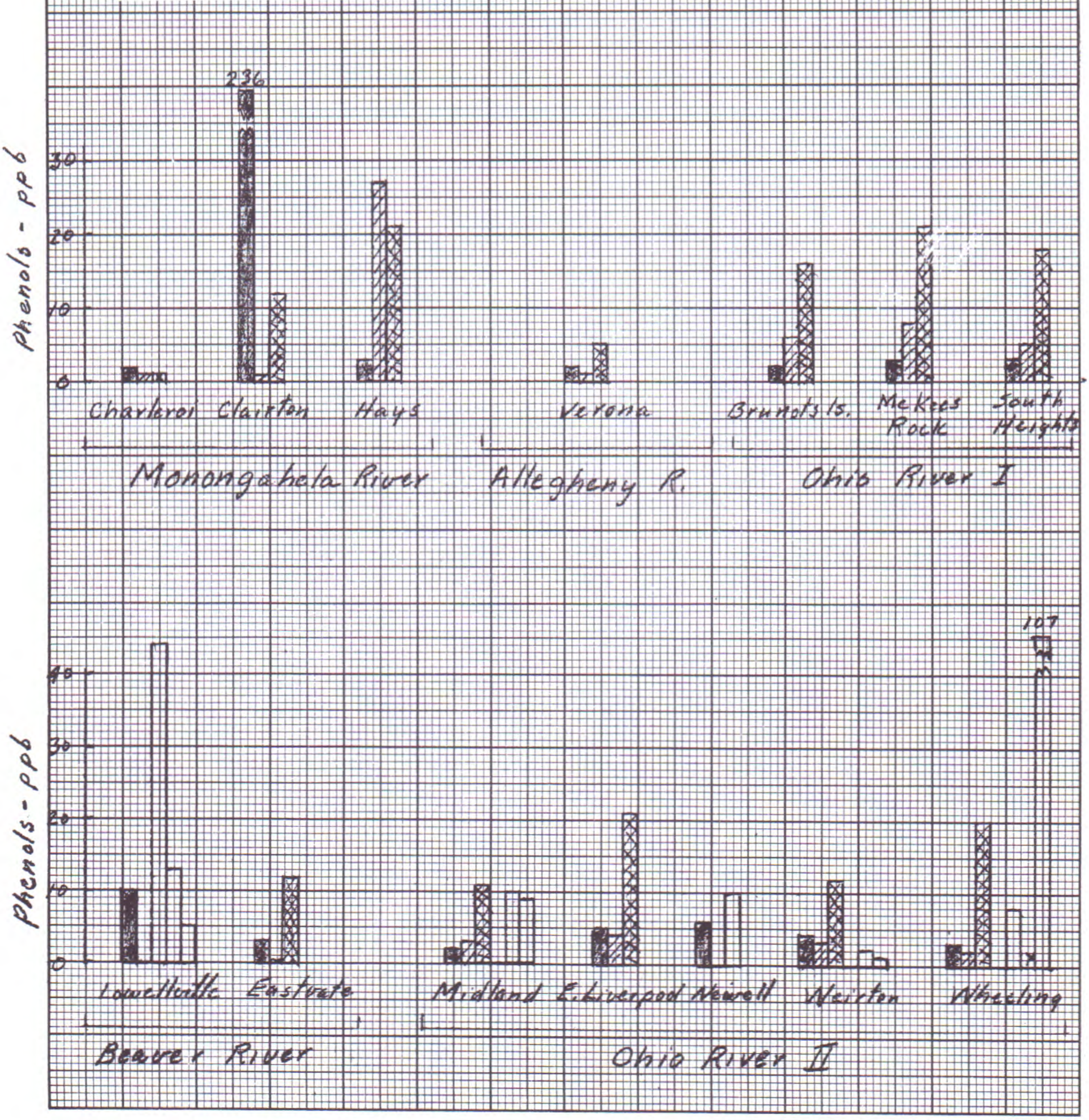


FIGURE 28 -- COMPARISON OF PHENOL LOADINGS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. Loading during shutdown at Midland, for example, was down to 20 to 30 percent of loadings in previous years.

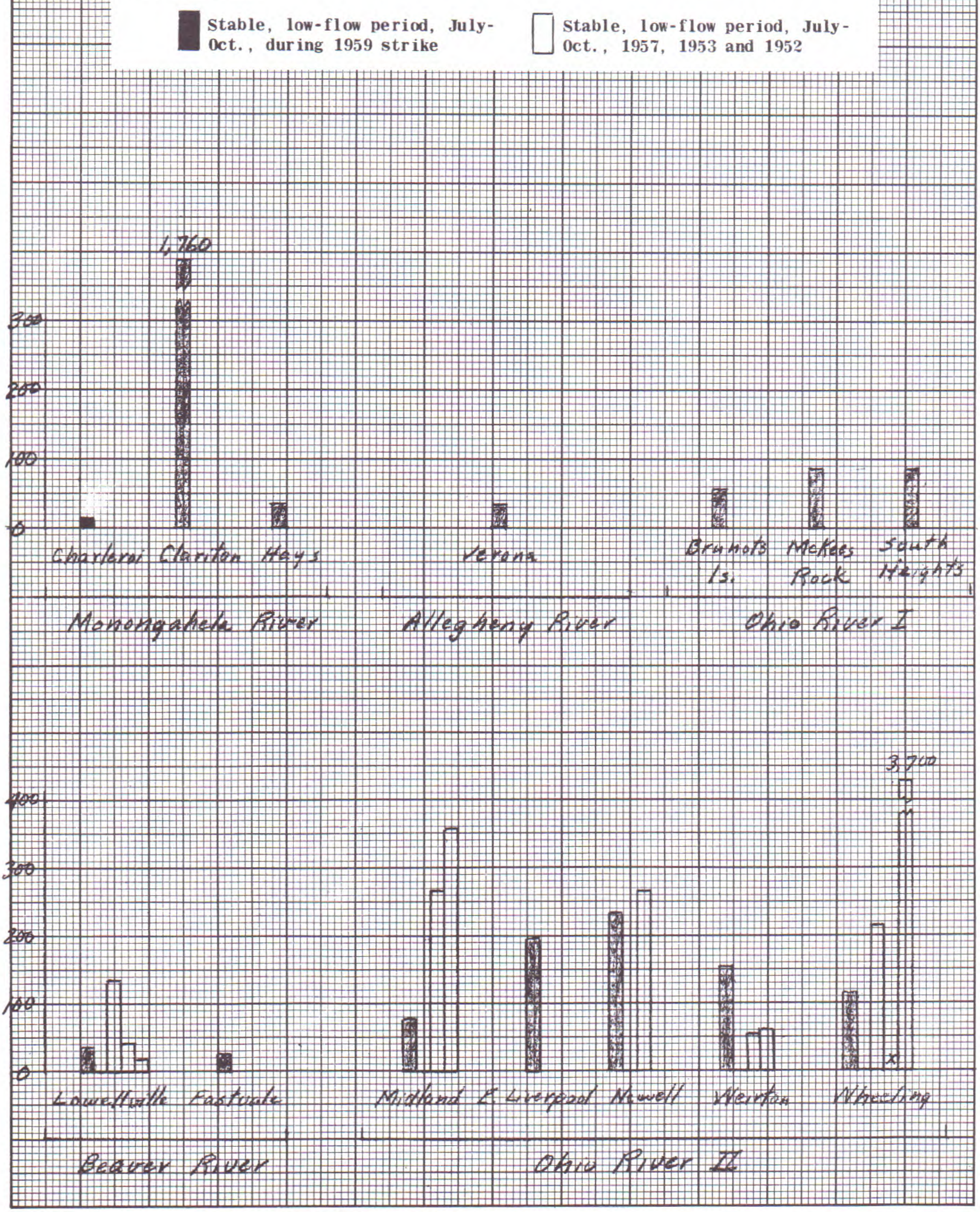


FIGURE 29 -- THRESHOLD-ODOR VARIATIONS. Threshold-odor numbers ranged between 4 and 20 in the first half of the survey, and then increased in intensity up to 80 and above in some weeks following end of the strike.

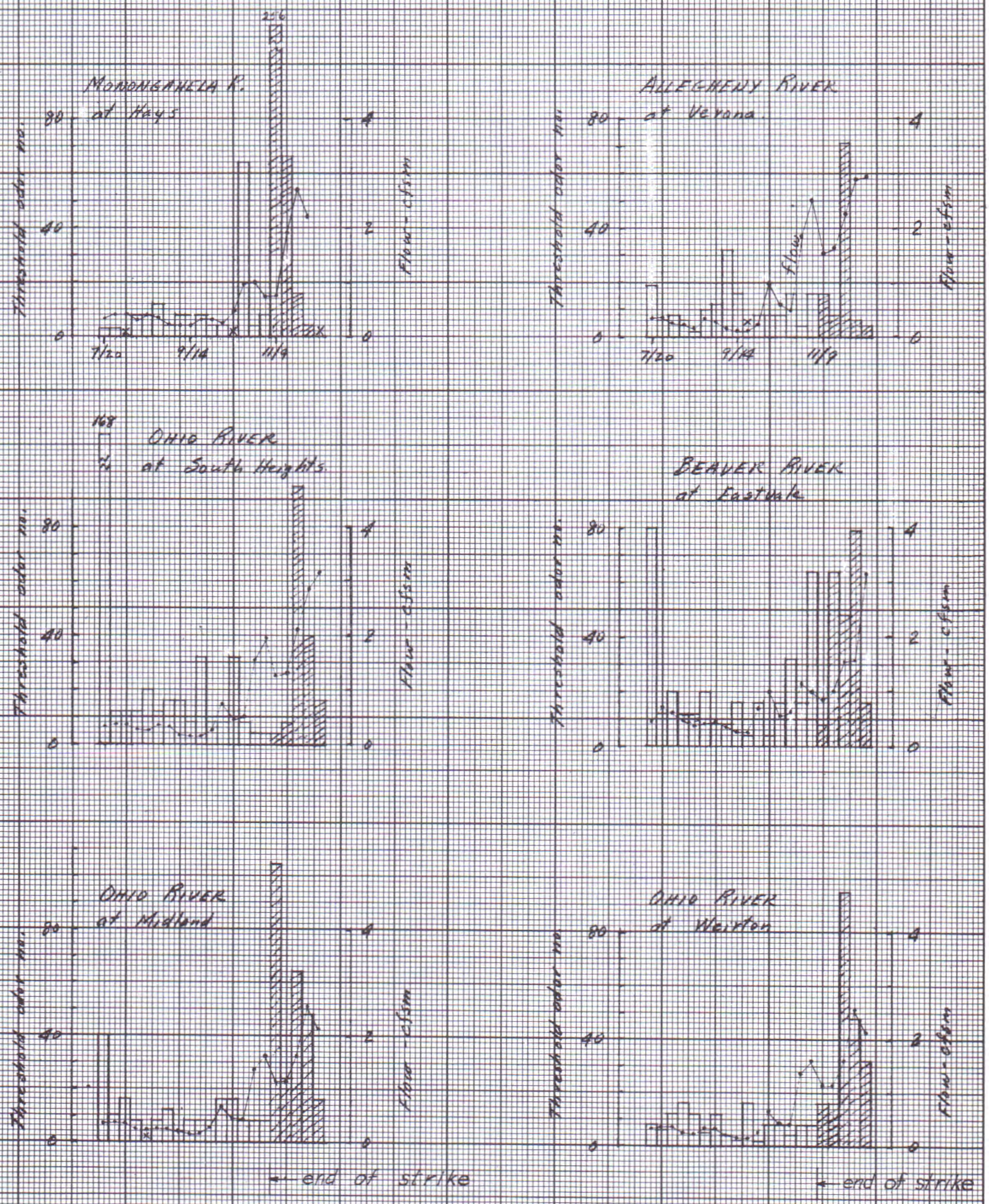


FIGURE 30 -- COMPARISON OF THRESHOLD-ODOR NUMBERS DURING MILL SHUTDOWN WITH VALUES DURING PERIODS OF MILL OPERATION. The greatest difference between threshold-odor values during the 1959 strike and those in other years was observed at Eastvale on the Beaver River. At this station the average value in 1959 was 20, compared to averages of 40, 168 and 202 in the three reference years.

- Stable, low-flow period, July-Oct., during 1959 strike
- Five week period after end of strike
- Two-to-four week period prior to end of strike
- Stable, low-flow period, July-Oct., 1957, 1953 and 1952

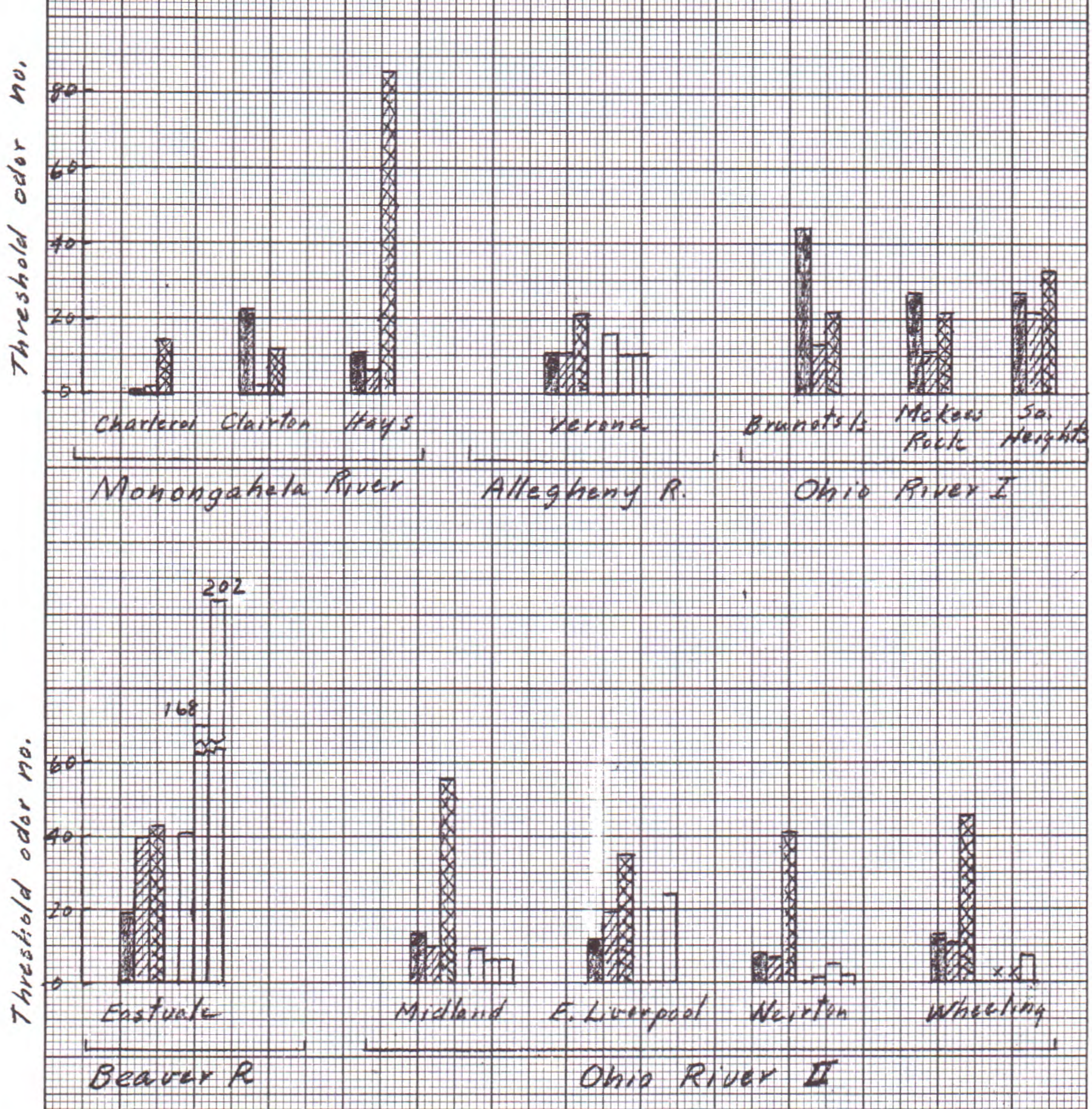
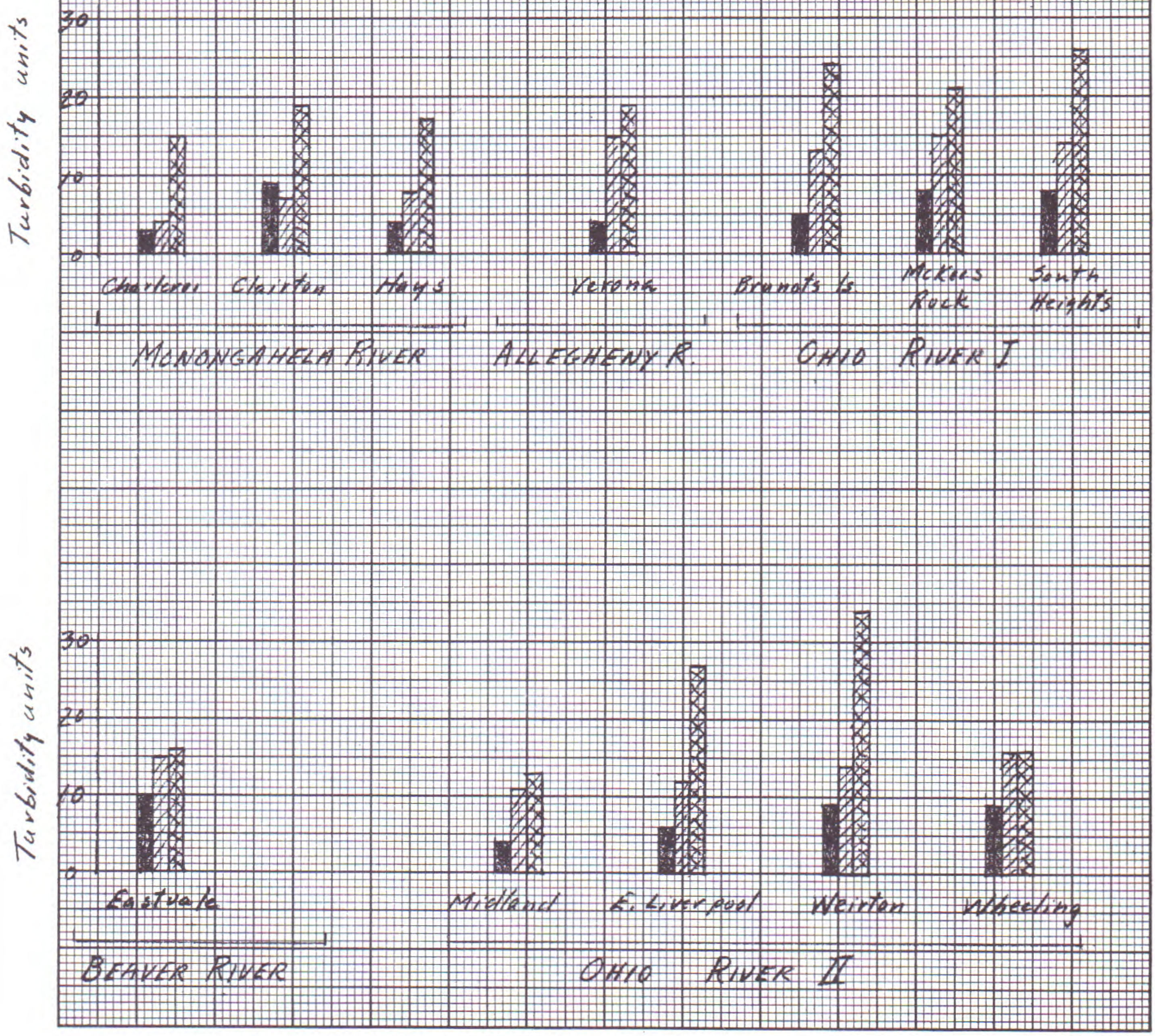


FIGURE 31 -- RIVER TURBIDITY DURING AND AFTER THE STRIKE. During mill shutdown turbidities averaged 3 to 10 units; in the five-week period after the strike values ranged from 12 to 34 units. The increase may be attributed, in large part, to the accompanying rise in river stage and flow.

- Stable, low-flow period, July-Oct., during 1959 strike
- Five week period after end of strike
- Two-to-four week period prior to end of strike



APPENDICES

Appendix A -- Survey data in terms of weekly-average or composite values (6 pages).

Appendix B -- Average stream-quality conditions in the upper Ohio River system in 1959, 1953 and 1952 (2 pages).

Appendix C -- Statement by Wendell L. Minckley, biologist-in-charge of a University of Louisville survey crew under contract to ORSANCO (2 pages).

APPENDIX A

SURVEY DATA IN TERMS OF WEEKLY-AVERAGE OR COMPOSITE VALUES.

River and Station	1959 Week of	Flow	Temperature Air	Temperature Water	Turbidity	Taste and Odor	Phenols ppb	pH	Alkalinity as $CaCO_3$ ppm	Hardness Total ppm	Sulfate ppm	Fluoride ppm	Dissolved Solids ppm	Iron (Dissolved) ppm	Manganese (Dissolved) ppm
Monongahela R. at Charleroi, Pa. (Charleroi gage. Air temperature data from U. S. Weather Bureau station at Donora.)	July 20	1,680	76	79	0	1	0	3.5	0	212	334	0.2	467	0.58	1.4
	27	2,050	76	80	1	0	1	3.4	0	176	319	.3	454	.91	1.4
	Aug. 3	1,920	74	80	10	1	5	3.3	0	227	368	.3	527	2.2	1.7
	10	1,380	77	81	3	1	3	3.5	0	211	340	.3	496	.48	1.5
	17	1,260	78	79	5	0	9	3.5	0	207	324	.4	480	.35	1.6
	24	1,820	78	81	5	1	6	3.4	0	191	308	.2	453	.57	1.6
	31	1,660	76	82	4	1	2	3.4	0	243	411	.2	596	.82	1.9
	Sept. 7	964	--	--	2	1	1	3.3	0	241	388	.2	537	1.2	2.1
	14	916	58	75	5	0	1	3.5	0	225	353	.2	476	.98	1.7
	21	786	72	69	2	1	0	3.4	0	208	302	.3	512	1.1	1.9
	28	1,390	71	70	5	1	1	3.4	0	195	308	.2	466	.62	1.4
	Oct. 5	1,060	68	71	3	1	0	3.4	0	186	314	.2	448	.88	1.6
	12	1,180	49	68	2	0	1	3.4	0	210	345	.2	503	1.4	1.6
	19	2,770	53	60	4	1	0	3.4	0	218	358	.2	525	1.3	1.6
	26	5,180	--	--	--	--	--	--	--	--	--	--	--	--	--
	Nov. 2	4,790	49	54	4	2	1	4.1	0	87	126	.1	180	.26	.72
	9	4,020	45	52	3	2	0	4.0	0	87	127	.2	202	.14	.77
	16	4,220	36	50	14	6	0	3.7	0	188	249	.2	365	.16	1.8
	23	11,600	39	45	11	8	0	4.1	0	105	138	.1	214	.09	1.0
	30	16,400	39	43	24	20	1	4.5	--	84	89	.1	147	.06	.76
	Dec. 7	13,600	37	42	25	32	0	4.7	--	58	69	.1	110	.11	.40
Monongahela R. at Clairton, Pa. (Charleroi gage. Air temperature data from U. S. Weather Bureau station at Donora.)	July 20	1,680	76	79	2	2	1,100	4.2	0	225	336	.5	527	.11	1.6
	27	2,050	76	80	5	4	26	3.8	0	229	360	.3	542	.22	1.5
	Aug. 3	1,920	74	78	20	24	169	3.8	0	219	344	.3	530	.29	1.6
	10	1,380	77	78	9	12	128	3.5	0	255	404	.4	611	.46	2.1
	17	1,260	78	78	6	32	79	3.8	0	196	300	.4	448	.16	1.4
	24	1,820	78	79	9	65	48	4.0	0	240	352	.3	523	.16	1.9
	31	1,660	76	80	9	2	2	3.8	0	214	331	.3	504	.14	1.6
	Sept. 7	964	--	--	2	32	164	3.8	0	266	435	.4	668	.30	2.0
	14	916	58	78	9	64	123	4.0	0	310	463	.3	730	.76	2.3
	21	786	72	78	7	1	0	3.7	0	279	429	.4	618	.62	2.5
	28	1,390	71	78	6	8	1	3.6	0	256	389	.2	601	.40	1.6
	Oct. 5	1,060	68	79	15	8	1,110	3.9	0	245	369	.3	554	.25	2.0
	12	1,180	49	78	15	--	--	3.8	0	240	376	.2	556	.55	1.8
	19	2,770	53	70	15	32	113	3.9	0	248	389	.3	593	.31	1.9
	26	5,180	47	55	10	2	0	3.7	0	177	277	.2	414	.49	1.4
	Nov. 2	4,790	49	55	4	1	2	4.7	3	114	154	.2	238	.07	.86
	9	4,020	45	50	6	2	1	4.4	0	103	154	.2	240	.12	.97
	16	4,220	36	44	9	12	11	4.2	0	123	174	.2	264	.12	1.1
	23	11,600	39	47	9	32	24	4.3	0	128	170	.1	264	.10	.81
	30	16,400	39	42	44	6	12	4.9	3	90	96	.1	160	.26	.78
	Dec. 7	13,600	37	41	7	8	10	5.5	3	60	68	.1	114	.20	.51

Survey data in terms of weekly-average or composite values.

River and Station	1959 Week of	Flow	Temperature Air	Temperature Water	Turbidity	Taste and Odor	Phenols ppb	pH	Alkalinity as CaCO3 ppm	Hardness Total ppm	Sulfate ppm	Fluoride ppm	Dissolved Solids ppm	Iron (Dissolved) ppm	Manganese (Dissolved) ppm
Monongahela R. at Hays, Pa. (Braddock gage. Air temperature data from U. S. Weather Bureau at Pittsburgh)	July 20	2,440	77	79	1	3	0	4.5	0	197	284	0.4	458	0.05	1.3
	27	3,000	76	80	4	3	4	4.1	0	206	324	.4	484	.10	1.6
	Aug. 3	2,980	74	78	3	--	5	4.0	0	193	282	.3	434	.18	1.4
	10	2,230	79	78	6	4	0	3.8	0	202	327	.4	480	.22	1.6
	17	2,200	79	78	4	4	5	3.8	0	224	344	.4	516	.27	1.7
	24	3,030	80	79	4	12	9	4.4	0	203	290	.4	444	.05	1.6
	31	2,550	77	80	7	4	3	3.9	0	204	309	.2	474	.13	1.5
	Sept. 7	1,720	--	--	2	8	3	4.0	0	206	317	.5	485	.13	1.5
	14	1,600	58	78	7	8	3	4.0	0	216	328	.2	534	.21	1.6
	21	1,660	74	78	5	8	3	4.2	1	227	349	.4	519	.25	1.9
	28	2,380	73	78	2	4	3	4.4	0	205	306	.2	489	.06	.93
	Oct. 5	2,200	68	79	8	4	0	4.0	0	205	299	.2	456	.19	1.7
	12	2,040	51	78	2	--	--	4.5	0	194	273	.2	401	.05	1.6
	19	3,640	53	70	6	64	3	4.3	0	191	288	.1	446	.02	1.4
	26	7,210	49	52	10	4	0	3.8	0	158	244	.2	394	.31	1.2
	Nov. 2	7,650	49	54	5	8	53	4.6	2	94	124	.1	194	.08	.70
	9	5,580	47	50	4	256	30	5.3	5	102	140	.2	228	.35	.88
	16	5,690	38	44	9	66	9	5.1	3	118	158	.2	245	1.8	.95
	23	14,120	38	51	12	16	19	4.6	2	134	170	.2	281	.27	1.2
	30	19,860	40	42	24	4	12	5.9	5	87	91	.1	164	.11	.74
	Dec. 7	16,670	38	41	20	--	35	6.2	7	78	89	.1	157	.77	.61
Allegheny R. at Verona, Pa. (Natrona gage. Air temperature data from U. S. Weather Bureau station at Pittsburgh.)	July 20	3,780	77	81	3	19	1	6.9	15	122	120	.2	243	.08	1.8
	27	3,960	76	82	3	6	4	6.9	11	132	138	.3	266	.03	.88
	Aug. 3	3,070	74	81	8	8	5	6.9	11	141	141	.3	270	.27	.67
	10	2,570	79	80	7	6	0	6.6	8	148	161	.3	297	.06	1.1
	17	2,080	79	82	2	2	3	4.8	2	168	196	.3	329	.05	1.3
	24	3,610	80	84	4	10	5	7.0	19	138	184	.2	270	.04	.61
	31	3,360	77	83	4	12	2	5.4	4	166	191	.2	334	.03	1.1
	Sept. 7	1,880	--	--	1	32	2	6.2	6	150	158	.2	292	.01	.94
	14	1,420	58	77	8	16	1	6.6	8	154	164	.3	287	.07	1.0
	21	1,390	74	74	5	--	--	7.2	10	165	170	.3	334	.09	1.2
	28	2,710	73	75	2	8	2	6.2	8	184	198	.3	367	.03	1.1
	Oct. 5	11,900	68	75	5	8	0	6.5	16	172	170	.2	320	.06	.99
	12	6,920	51	64	15	8	2	6.9	23	95	74	.2	177	.23	.43
	19	5,740	53	59	10	16	1	6.8	20	105	97	.2	198	.17	.60
	26	21,300	49	54	15	4	0	6.6	15	106	94	.2	198	.62	1.1
	Nov. 2	28,800	49	50	20	16	1	6.6	16	81	65	.1	135	.33	.60
	9	17,700	47	48	8	16	2	6.8	11	71	61	.2	137	.19	.54
	16	19,000	38	44	22	8	3	6.9	19	72	53	.1	131	.44	.47
	23	26,200	38	40	18	71	7	6.9	16	78	62	.2	142	.44	.62
	30	33,100	40	39	24	6	6	6.2	8	69	62	.1	130	.46	.99
	Dec. 7	33,900	38	37	25	4	6	6.6	25	72	58	.1	142	.53	.74

Survey data in terms of weekly-average or composite values.

River and Station	1959 Week of	Flow	Temperature Air	Temperature Water	Turbidity	Taste and Odor	Phenols ppb	pH	Alkalinity as $CaCO_3$ ppm	Hardness Total ppm	Sulfate ppm	Fluoride ppm	Dissolved Solids ppm	Iron (Dissolved) ppm	Manganese (Dissolved) ppm
Ohio R.	July 20	6,380	77	82	7	128	2	6.8	13	138	155	0.4	291	0.04	1.1
at	27	7,150	76	82	5	10	4	6.1	4	164	205	.4	350	.03	1.4
Brunot's Island	Aug. 3	6,670	74	81	7	260	4	4.8	2	167	204	--	362	.09	.84
(Sewickley gage.	10	4,920	79	80	8	6	1	4.8	1	175	233	.4	398	.04	1.3
Air temperature	17	4,520	79	81	3	12	3	4.6	1	190	246	.4	408	.07	1.6
data from U. S.	24	6,780	80	83	6	8	3	6.1	6	170	212	.3	349	.03	1.3
Weather Bureau	31	6,090	77	81	4	6	2	5.6	3	179	222	.2	370	.04	1.4
at Pittsburgh.)	Sept. 7	3,800	--	--	2	8	1	4.6	1	191	248	.2	403	.08	1.5
	14	2,970	58	74	6	32	1	5.5	3	180	226	.3	364	.09	1.2
	21	2,990	74	71	5	8	2	5.5	3	193	258	.3	407	.21	1.5
	28	5,050	--	--	--	--	--	--	--	--	--	--	--	--	--
	Oct. 5	14,600	68	75	7	8	0	5.7	4	204	234	.3	401	.06	1.4
	12	8,810	51	71	10	8	0	6.9	18	122	110	.2	222	.13	.70
	19	9,820	53	60	7	32	1	6.5	10	132	154	.2	268	.04	.85
	26	30,600	49	54	15	4	5	6.4	11	118	120	.2	223	.20	1.0
	Nov. 2	38,200	49	50	20	8	18	6.6	15	80	73	.1	145	.23	.61
	9	24,500	--	--	--	--	--	--	--	--	--	--	--	--	--
	16	25,600	38	45	20	24	14	7.0	17	79	69	.2	144	.56	.54
	23	41,100	38	43	18	8	18	6.7	9	98	102	.2	174	.16	.90
	30	55,800	40	41	24	24	17	6.2	7	71	67	.1	134	.23	.87
	Dec. 7	52,300	38	39	25	32	14	6.7	7	72	65	.1	128	.30	.65
Ohio R.	July 20	6,380	77	82	9	68	1	6.8	14	150	182	.4	322	.07	1.3
at	27	7,150	76	82	4	24	3	6.4	5	167	210	.3	361	.03	1.2
McKees Rocks, Pa.	Aug. 3	6,670	74	80	6	16	6	6.2	4	167	206	.3	351	.10	1.0
(Sewickley gage.	10	4,920	79	80	5	12	2	4.8	1	186	262	.4	434	.12	1.4
Air temperature	17	4,520	79	81	5	48	3	5.4	4	192	252	.5	417	.04	1.6
data from U. S.	24	6,780	80	83	5	12	4	6.0	5	181	232	.3	381	.05	1.3
Weather Bureau	31	6,090	77	82	5	8	1	6.0	4	182	236	.3	388	.05	1.4
at Pittsburgh.)	Sept. 7	3,800	--	--	1	16	2	5.3	3	196	246	.4	414	.04	1.5
	14	2,970	58	74	20	64	10	5.8	6	198	255	.2	452	.21	1.4
	21	2,990	74	71	10	16	4	5.8	5	202	276	.4	470	.32	1.5
	28	5,050	73	72	15	32	3	5.9	8	204	268	.4	467	.13	1.3
	Oct. 5	14,600	68	75	16	4	0	5.4	2	211	256	.3	435	.07	1.6
	12	8,810	51	68	15	8	1	7.0	25	113	103	.2	223	.18	.59
	19	9,820	53	59	10	--	4	6.6	15	136	153	.2	277	.02	.86
	26	30,600	49	53	15	8	8	6.3	7	126	130	.2	237	.28	1.2
	Nov. 2	38,200	49	50	20	16	18	6.7	15	77	72	.1	147	.45	.62
	9	24,500	47	49	10	32	26	6.8	13	76	72	.2	148	.33	.54
	16	25,600	38	45	19	16	16	6.6	17	79	70	.2	149	.51	.51
	23	41,100	38	43	17	16	28	6.7	11	98	99	.2	185	.37	.92
	30	55,800	40	40	44	36	17	6.3	8	72	68	.1	138	.29	.84
	Dec. 7	52,300	38	38	15	8	20	6.5	11	70	61	.1	121	.59	.65

Survey data in terms of weekly-average or composite values.

River and Station	1959 Week of	Flow	Temperature Air	Temperature Water	Turbidity	Taste and Odor	Phenols ppb	pH	Alkalinity as $CaCO_3$ ppm	Hardness Total ppm	Sulfate ppm	Fluoride ppm	Dissolved Solids ppm	Iron (Dissolved) ppm	Manganese (Dissolved) ppm
Ohio R. at South Heights, Pa. (Sewickley gage. Air temperature data from U. S. Weather Bureau at Pittsburgh.)	July 20	6,380	77	82	7	168	0	6.8	20	157	179	0.4	335	0.09	1.2
	27	7,150	76	81	8	12	10	6.6	11	168	210	.4	371	.13	1.5
	Aug. 3	6,670	74	81	8	12	5	6.5	7	172	204	.4	367	.06	1.2
	10	4,920	79	78	5	12	3	6.3	6	177	231	.4	391	.06	1.2
	17	4,520	79	81	6	20	3	6.2	5	186	234	.5	389	.04	1.4
	24	6,780	80	81	6	12	4	5.4	4	204	261	.4	422	.03	1.6
	31	6,090	77	81	9	16	2	6.6	13	179	224	.4	370	.09	1.1
	Sept. 7	3,800	--	--	2	16	2	6.3	7	196	240	.4	405	.06	1.4
	14	2,970	58	75	10	8	1	6.0	5	200	262	.3	385	.04	1.6
	21	2,990	74	72	9	32	2	6.4	11	198	254	.4	471	.22	1.5
	28	5,050	73	73	10	8	2	6.9	11	205	262	.4	463	.11	1.3
	Oct. 5	14,600	68	73	10	8	1	6.0	6	205	253	.3	423	.06	1.5
	12	8,810	51	67	15	32	1	7.0	31	114	94	.3	221	.14	.63
	19	9,820	53	63	10	8	4	6.6	16	135	150	.2	279	.09	.96
	26	30,600	49	58	15	4	18	5.6	4	150	195	.3	298	.09	1.2
	Nov. 2	38,200	49	55	15	4	12	6.4	11	94	94	.2	171	.23	.76
	9	24,500	47	53	15	4	9	6.8	11	80	81	.2	165	.18	.68
	16	25,600	38	50	25	8	16	6.9	16	83	77	.2	164	.39	.57
	23	41,100	38	49	20	95	17	6.2	8	115	126	.3	220	.11	1.0
	30	55,800	40	46	56	40	28	6.2	7	81	82	.1	149	.06	.83
	Dec. 7	52,300	38	45	15	16	20	6.4	9	85	78	.1	139	.16	.51
Beaver R. at Eastvale, Pa. (Beaver Falls gage. Air temperature data from U.S. Weather Bureau at Midland.)	July 20	1,500	78	81	6	80	2	7.5	60	144	87	.4	247	.07	.00
	27	2,240	77	79	12	12	2	7.5	65	134	78	.4	234	.05	.01
	Aug. 3	1,970	74	76	9	20	6	7.6	67	134	69	.4	211	.24	.03
	10	1,520	77	75	14	12	3	7.5	70	150	83	.4	249	.18	.09
	17	1,230	79	78	9	12	4	7.5	70	151	87	.6	246	.09	.02
	24	1,300	81	80	8	20	6	7.3	71	156	90	.4	252	.03	.00
	31	1,510	76	80	8	8	2	7.5	70	151	96	.4	255	.06	.03
	Sept. 7	1,080	--	--	2	8	4	7.3	73	148	83	.5	237	.03	.05
	14	893	58	70	10	16	2	7.2	71	149	90	.4	240	.11	.20
	21	769	72	66	7	4	3	7.4	74	154	89	.4	249	.20	.05
	28	2,180	71	71	10	16	2	7.5	76	156	91	.7	268	.05	.09
	Oct. 5	3,350	66	69	25	4	0	7.0	62	148	92	.3	233	.09	.15
	12	1,790	50	62	9	16	1	7.2	58	140	85	.6	226	.22	.05
	19	1,910	52	56	8	32	3	7.4	79	198	131	.5	279	.22	.08
	26	3,650	47	54	15	16	0	7.2	57	148	87	.4	221	.28	.16
	Nov. 2	3,180	46	52	15	64	1	7.0	56	140	91	.4	220	.20	.09
	9	2,680	44	51	8	8	3	7.5	58	139	85	.2	227	.31	.10
	16	3,200	35	47	20	64	10	7.0	50	139	90	.3	220	.62	.14
	23	4,840	36	48	19	48	1	7.2	52	162	112	.6	279	.71	.26
	30	4,930	38	43	19	79	35	7.0	38	121	81	.3	208	.57	.24
	Dec. 7	9,860	35	43	15	16	9	7.0	40	133	84	.2	194	.63	.08

Survey data in terms of weekly-average or composite values.

River and Station	1959 Week of	Flow	Temperature Air	Temperature Water	Turbidity	Taste and Odor	Phenols ppb	pH	Alkalinity as $CaCO_3$ ppm	Hardness Total ppm	Sulfate ppm	Fluoride ppm	Dissolved Solids ppm	Iron (Dissolved) ppm	Manganese (Dissolved) ppm
Ohio R. at Midland, Pa. (Bellaire gage. Air temperature data from U.S. Weather Bureau at Midland.)	July 20	8,230	78	85	3	40	2	7.0	21	157	166	0.4	308	0.03	0.35
	27	9,550	77	84	5	10	3	7.1	23	160	178	.4	339	.17	.24
	Aug. 3	9,110	74	81	4	16	4	6.9	17	168	188	.5	322	.05	.94
	10	6,750	77	81	4	8	0	6.9	18	170	197	.4	384	.03	.44
	17	6,150	79	86	3	--	--	6.6	16	180	204	.3	364	.06	.54
	24	8,470	81	86	4	8	5	6.6	14	189	214	.4	382	.05	.63
	31	8,310	76	86	4	12	2	7.1	17	179	214	.4	382	.08	.65
	Sept. 7	5,200	--	--	1	4	3	6.7	18	182	204	.5	358	.02	.61
	14	4,030	58	64	6	8	4	6.5	18	196	212	--	382	.07	.64
	21	4,064	72	73	6	8	2	6.7	16	190	208	.4	368	.13	.55
	28	7,420	71	75	3	8	1	6.7	21	189	216	.4	410	.08	.03
	Oct. 5	17,600	66	75	7	16	0	6.4	15	201	233	.4	405	.05	1.0
	12	10,900	50	69	10	16	0	7.1	36	142	116	.3	262	.03	.19
	19	10,600	52	63	8	8	4	6.9	30	130	115	.3	253	.08	.36
	26	34,900	47	57	15	8	4	6.5	19	144	146	.3	275	.14	.81
	Nov. 2	40,900	46	54	10	8	3	6.6	21	102	90	.2	182	.23	.45
	9	29,100	44	51	10	128	10	7.0	18	76	72	.2	158	.02	.15
	16	29,400	35	51	22	24	6	6.6	23	103	83	.5	180	.46	.37
	23	41,000	36	49	22	64	12	6.7	20	122	110	.6	225	.47	.62
	30	64,400	38	47	84	48	15	6.6	14	85	70	.6	154	.24	.68
	Dec. 7	53,900	35	48	20	16	12	6.5	15	91	71	1.0	159	.60	.46
Ohio R. at East Liverpool, O. (Bellaire gage. Air temperature data from U. S. Weather Bureau at Midland.)	July 20	8,230	78	82	6	566	2	7.1	24	165	164	.5	319	.02	.30
	27	9,550	77	82	6	17	6	7.3	29	165	174	.4	312	.05	.51
	Aug. 3	9,110	74	81	6	3	4	7.1	23	167	176	.4	323	.05	.55
	10	6,750	77	80	6	16	4	7.1	24	175	190	.4	364	.11	.38
	17	6,150	79	81	4	12	4	6.8	21	182	197	.5	368	.19	.40
	24	8,470	81	83	4	4	3	6.8	21	191	211	.4	377	.04	.93
	31	8,310	76	83	4	8	1	7.0	20	184	217	.4	377	.02	.65
	Sept. 7	5,200	--	--	1	8	4	6.7	21	184	198	.7	366	.02	.47
	14	4,030	58	74	7	16	2	6.6	19	198	218	.3	382	.04	.71
	21	4,064	72	74	6	16	23	6.8	20	188	208	.5	390	.12	.54
	28	7,420	71	75	6	16	5	6.7	21	193	217	.4	400	.02	.05
	Oct. 5	17,600	66	75	10	16	0	6.6	26	204	229	.4	406	.06	1.0
	12	10,900	50	67	10	--	1	7.0	37	144	115	.3	263	.02	.34
	19	10,600	52	61	8	16	1	7.1	33	136	119	.2	256	.09	.44
	26	34,900	47	58	15	32	1	6.5	20	148	148	.3	273	.20	.92
	Nov. 2	40,900	46	54	15	8	14	6.6	21	100	90	.2	183	.19	.39
	9	29,100	44	52	20	32	5	7.1	21	89	74	.2	169	.16	.18
	16	29,400	35	48	19	32	23	6.7	26	103	81	.2	172	.53	.34
	23	41,000	36	47	18	79	26	6.8	21	117	108	.3	220	.46	.51
	30	64,400	38	42	59	24	22	6.7	13	82	69	.2	150	.33	.51
	Dec. 7	53,900	35	42	20	8	29	6.7	21	87	71	.2	150	.60	.20

Survey data in terms of weekly-average or composite values.

River and Station	1959 Week of	Flow	Temperature Air	Temperature Water	Turbidity	Taste and Odor	Phenols ppb	pH	Alkalinity as $CaCO_3$ ppm	Hardness Total ppm	Sulfate ppm	Fluoride ppm	Dissolved Solids ppm	Iron (Dissolved) ppm	Manganese (Dissolved) ppm
Ohio R. at Weirton, W.Va. (Bellaire gage. Air temperature data from U. S. Weather Bureau at Steubenville.)	July 20	8,230	76	81	10	8	4	7.1	23	156	161	0.5	308	0.05	0.07
	27	9,550	75	79	14	6	5	7.2	29	161	165	.4	333	.04	.24
	Aug. 3	9,110	68	80	10	12	4	7.2	26	165	176	.5	340	.05	.42
	10	6,750	75	79	7	16	2	7.0	23	173	190	.5	371	.09	.43
	17	6,150	78	80	5	10	3	7.0	27	177	188	.5	355	.03	.11
	24	8,470	79	82	8	5	3	6.8	22	188	206	.4	374	.02	.48
	31	8,310	77	81	10	12	2	6.9	14	205	246	.4	435	.04	1.2
	Sept. 7	5,200	--	--	2	4	4	7.0	25	179	186	.4	348	.03	.47
	14	4,030	57	76	10	2	10	6.7	21	192	197	.3	381	.06	.89
	21	4,064	72	71	9	16	5	6.8	21	195	214	.5	367	.14	.18
	28	7,420	71	74	8	2	3	6.9	21	189	203	.4	380	.10	.03
	Oct. 5	17,600	67	74	20	8	2	6.6	25	200	213	.4	389	.07	.50
	12	10,900	48	66	10	8	0	6.8	31	160	142	.3	298	.04	.61
	19	10,600	51	62	15	4	2	7.1	38	130	101	.2	242	.12	.16
	26	34,900	47	58	15	8	8	6.5	17	152	164	.3	290	.14	1.0
	Nov. 2	40,900	47	57	15	8	1	6.5	18	103	100	.2	194	.23	.74
	9	29,100	44	51	20	16	4	7.0	18	86	74	.2	163	.18	.37
	16	29,400	36	50	20	16	5	6.6	21	101	89	.2	182	.40	.41
	23	41,000	36	49	23	95	13	6.7	17	110	105	.3	204	.34	.70
	30	64,400	37	45	79	48	15	6.5	13	88	80	.2	166	.16	.74
	Dec. 7	53,900	36	44	30	32	21	6.7	16	89	76	.2	157	.42	.53
Ohio R. at Wheeling, W.Va. (Bellaire gage. Air temperature data from U. S. Weather Bureau at Steubenville.)	July 20	8,230	76	82	9	40	1	7.1	25	163	157	.5	297	.07	.18
	27	9,550	75	81	22	36	5	7.2	24	168	172	.5	334	.08	.74
	Aug. 3	9,110	68	81	15	12	4	7.2	25	174	182	.5	345	.09	.61
	10	6,750	75	80	9	8	2	7.0	20	182	201	.6	387	1.2	.68
	17	6,150	78	82	7	10	2	7.0	21	190	208	.6	377	.18	.49
	24	8,470	79	84	7	5	2	6.9	21	192	209	.5	366	.04	.41
	31	8,310	77	84	8	10	2	6.9	13	203	244	.4	416	.07	1.0
	Sept. 7	5,200	--	--	3	8	2	7.0	18	202	205	.8	388	.05	.46
	14	4,030	57	72	7	4	3	6.6	24	200	214	.5	391	.11	.49
	21	4,064	72	72	8	8	9	6.8	16	208	226	.6	385	.23	1.0
	28	7,420	71	75	6	8	2	6.8	16	208	230	.6	411	.17	.24
	Oct. 5	17,600	67	76	8	2	0	6.5	18	201	226	.4	403	.20	.36
	12	10,900	48	68	9	16	3	6.7	20	181	184	.3	348	.25	1.1
	19	10,600	51	63	9	4	1	6.9	33	142	118	.3	259	.32	.34
	26	34,900	47	59	30	16	1	6.5	16	154	166	.3	298	.25	1.1
	Nov. 2	40,900	47	55	15	8	3	6.5	16	113	112	.2	210	.25	.55
	9	29,100	44	52	20	8	18	7.2	16	84	78	.2	168	.37	.47
	16	29,400	36	51	16	12	4	6.5	18	102	94	.2	189	.38	.51
	23	41,000	36	48	18	188	14	6.7	18	108	102	.2	211	.42	.73
	30	64,400	37	45	80	16	25	6.5	13	89	79	.2	162	.22	.78
	Dec. 7	53,900	36	43	30	8	37	6.7	16	94	80	.2	163	.39	.44

APPENDIX B

AVERAGE STREAM-QUALITY CONDITIONS IN THE UPPER OHIO RIVER SYSTEM IN 1959, 1957, 1953 and 1952. This compilation provides a comparision of stream concentrations and loadings during the summer, low-flow period of 1959 when the steel mills were shut down, with values in periods of similar flow and temperature during three years when the mills were operating. Sources of data, in addition to 1959 survey, are as follows: South Pittsburgh Water Co., Wilkinsburg-Penn Joint Water Authority, Duquesne Light Co., Beaver Falls Water Works, Midland Water Works, East Liverpool Water Works, U. S. Geological Survey, ORSANCO monitor network.

River and Station	Year	Period	Flow cfs	Temperature °F		Turbidity	Threshold Odor	Phenols		pH	Alkalinity		Total Hardness as $CaCO_3$		Sulfate		Fluoride		Dissolved Solids		Iron (dissolved)		Manganese (dissolved)	
				Air	Water		Number	ppb	Tons/day		ppm	Tons/day	ppm	Tons/day	ppm	Tons/day	ppm	Tons/day	ppm	Tons/day	ppm	Tons/day	ppm	Tons/day
Monongahela River at Pt. Marion, Pa. (mile 90.8) Data from (2)	1959	July 21-Oct. 20	700(e)	70	75					3.4	0	0	188	366	284	552	0.5	0.97	402	782	1.2	2.3	0.86	1.7
	1957	July 21-Oct. 20	551	66	66					3.5	0	0	175	261	284	424	.3	.45	419	624	1.3	1.9	1.0	1.5
Monongahela River at Charleroi, Pa. (mile 42.6) Data from (1), (3)	1959	July 21-Oct. 22	1,380	70	75	3	1	2	0.007	3.4	0	0	211	785	341	1,270	.3	1.1	496	1,830	1.0	3.7	1.6	6.0
	1957	July 21-Oct. 20	950							3.5	0	0	210	539	327	839					1.0	2.6	1.5	3.8
	1952	July 21-Oct. 20	1,300	67	68					3.6	0	0	226	793	340	1,190								
Monongahela River at Clairton, Pa. (mile 19.3) Data from (1)	1959	July 21-Oct. 22	1,380	70	78	9	22	236	.88	3.8	0	0	244	910	377	1,410	.3	1.1	572	2,130	.3	1.1	1.8	6.7
Monongahela River at Hays, Pa. (mile 6.0) Data from (1), (4)	1959	July 21-Oct. 22	2,290	71	78	4	11	3	.019	4.1	0	0	205	1,270	309	1,910	.3	1.9	473	2,930	.1	.62	1.5	9.3
	1957	July 21-Oct. 22	1,760	67	83					5.7	7	43	223	1,380										
	1953	July 21-Oct. 22	1,880			25					5	25	200	1,015										
	1952	July 21-Oct. 22	2,360			25					2	13	227	1,446										
Allegheny River at Kittanning, Pa. (mile 45.7) Data from (3)	1959	July 21-Oct. 8	2,120							7.2	43	246	100	572	57	326			201	1,050				
	1957	July 21-Aug. 8 Sept. 8-28, Oct. 4-8	1,690							7.0	50	228	103	470	62	284								
	1952	July 21-Oct. 10	1,720	70	72					7.4	46	214	119	544	52	242								
Allegheny River at Verona, Pa. (mile 8.9) Data from (1), (5)	1959	July 21-Oct. 8	2,910	74	79	4	11	2	.016	6.4	10	79	153	1,200	158	1,240	.3	2.4	301	2,360	.1	.78	1.1	8.7
	1957	July 21-Oct. 8	1,880	69	75	54	16			6.7	15	76	172	873	169	858	.6	3.0					2.3	11.7
	1953	July 21-Oct. 8	3,670	71	77	47	10			6.3	12	119	165	1,634	145	1,436	.4	4.0	266	2,636	.5	5.0	1.8	17.8
	1952	July 21-Oct. 8	2,320			30	10			5.8	15	94	186	1,165	189	1,184	.1	.6	383	2,399	.3	1.9	1.8	11.3
Ohio River at Brunot's Island, Pa (mile 2.3) Data from (1), (6)	1959	July 21-Oct. 8	5,400	74	79	5	44	2	.029	5.5	4	58	177	2,580	222	3,240	.3	4.4	373	5,440	.1	1.5	1.3	19
	1957	July 21-Oct. 8	3,630	69	79	64				6.7			178	1,740										
	1953	July 21-Oct. 8	6,040	71	79	45				6.5			174	2,840										
	1952	July 21-Oct. 8	5,150	70	80	43				5.7			163	2,270										
Ohio River at McKees Rocks, Pa. (mile 3.3) Data from (1)	1959	July 21-Oct. 8	5,400	74	78	8	27	3	.044	5.8	5	73	186	2,710	240	3,500	.4	5.8	408	5,950	.1	1.5	1.4	20

River and Station	Year	Period	Flow cfs	Temperature °F Air	Temperature °F Water	Turbidity	Threshold Odor Number	Phenols ppb	Phenols Tons/day	pH	Alkalinity ppm	Alkalinity Tons/day	Total Hardness as $CaCO_3$ ppm	Total Hardness as $CaCO_3$ Tons/day	Sulfate ppm	Sulfate Tons/day	Fluoride ppm	Fluoride Tons/day	Dissolved Solids ppm	Dissolved Solids Tons/day	Iron (dissolved) ppm	Iron (dissolved) Tons/day	Manganese (dissolved) ppm	Manganese (dissolved) Tons/day
Ohio River at South Heights, Pa. (mile 15.5) (Data from (1),(6),(3)	1959	July 21–Oct. 8	5,400	74	78	8	27	3	0.044	6.3	9	131	187	2,730	235	3,430	0.4	5.8	399	5,820	0.1	1.5	1.4	20
	1957	July 21–Oct. 8	3,630	69	78	38				7.0	6*	59	211	2,070	263*	2,580					.25*	2.5	1.6*	16
	1953	July 21–Oct. 8	6,040	71	78	12				6.2			173	2,770										
	1952	July 21–Oct. 8	5,150	70	79	8				5.7	2*	28	190	2,640										
Mahoning River Lowellville, O. (mile 32.0) Data from (2), (3)	1959	July 21–Oct. 20	670	66	77			10	.018	7.3	81	147	159	288	95	172	.6	1.2	259	469	.35	.63	.09	.16
	1957	July 21–Oct. 20	550	65	95			44	.065	6.5	35	52	197	293	183	272	1.1	1.6	372	552	.05	.074	.88	1.3
	1953	July 21–Sept. 30	580	66	96			13	.020	5.9	12	19	208	326	221	346	1.1	1.7	398	623	.57	.89	.60	.94
	1952	July 21–Oct. 20	560	65	91			5	.008	6.1	8	12	193	292	190	287	1.1	1.7	361	546	2.1	3.2	.84	1.3
Beaver River at Eastvale, Pa. (mile 8.0) Data from (1), (7)	1959	July 21–Oct. 22	1,610	70	73	10	19	3	.013	7.4	69	300	151	656	89	387	.5	2.2	245	1,070	.1	.43	.1	.43
	1957	July 21–Oct. 22	970	64	78	22	41			7.6	59	155	177	464										
	1953	July 21–Oct. 22	1,240(e)	65	77	25	168			7.1	52	174	209	700										
	1952	July 21–Oct. 22	1,370(e)	64	74	47	202			7.1	50	185	189	699	137	507								
Ohio River at Midland, Pa. (mile 36.3) Data from (1), (8)	1959	July 21–Oct. 8	7,170	74	80	4	13	2	.039	6.8	18	348	180	3,490	203	3,930	.4	7.7	367	7,110	.1	1.9	.6	12
	1957	July 21–Oct. 8	4,980	67	80	7	9	10	.134	6.8	26	350	208	2,800									1.4(t)	19
	1953	July 21–Oct. 8	7,380	67	78	6	6	9	.179	6.3	15	299	206	4,100									1.6(t)	32
	1952	July 21–Oct. 8	6,430	67	79	5	6			6.0	9	156											1.7(t)	30
Ohio River at East Liverpool, O. (mile 40.2) Data from (1), (9)	1959	July 21–Oct. 8	7,170	74	79	6	12	5	.097	6.9	22	426	183	3,540	200	3,870	.4	7.7	365	7,070	.1	1.9	.5	9.7
	1957	July 21–Oct. 8	4,980	67	79	20	20			6.9	31	417	192	2,580										
	1953	July 21–Oct. 8	7,380	67	79	15	25			6.4	16	319	211	4,204										
	1952	July 21–Oct. 8	6,430	67	79	14					12	208	188	3,260										
Ohio River at Newell, W. Va. (mile 46.4) Data from (2)	1959	July 21–Oct. 10	7,170	74	77			6	.116	6.7	20	387	176	3,410	188	3,640	.4	7.7	336	6,510	.2	3.9	.74	14
	1957	July 21–Oct. 10	4,980	66	79			10	.134	6.5	17	229	204	2,740	230	3,090	.8	11	417	5,610	.01	.13	.4	5.4
Ohio River at Weirton, W. Va. (mile 61.8) Data from (1), (2)	1959	July 21–Oct. 8	7,170	72	78	9	8	4	.077	6.9	23	445	182	3,530	195	3,780	.4	7.7	365	7,070	.1	1.9	.4	7.7
	1957	July 21–Oct. 8	4,980	67	76	32	1.3	1.9	.026	7.4	25	336	199	2,680	216	2,900	.8	11					2.7(t)	36
	1953	July 21–Oct. 8	7,380	69	73	31	4.6	1.4	.279	6.7	13	259	190	3,790	218	4,340								
	1952	July 21–Oct. 8	6,430	68	71	68	2.2			6.5	11	191	207	3,700	231	4,010								
Ohio River at Wheeling, W. Va. (mile 86.8) Data from (1), (2)	1959	July 21–Oct. 8	7,170	72	79	9	13	3	.058	6.9	20	387	191	3,700	206	3,990	.5	9.7	375	7,260	.2	3.9	.6	12
	1957	July 21–Oct. 8	4,980	67	78	<21		8	.108	6.9	18	242	217	2,920			.6	8.1						
	1953	July 21–Oct. 8	7,380	69	79	20				6.1	10	199	173	3,450	107	2,130								
	1952	July 21–Oct. 8	6,430	68	78	23	7	107	1,860	6.3	11	191	208	3,610	184	3,190	.4	6.9						

(1) 1959 survey
(2) ORSANCO monitor network
(3) U. S. Geological Survey
(4) South Pittsburgh Water Co.
(5) Wilkinsburg-Penn Joint Water Authority
(6) Duquesne Light Co.
(7) Beaver Falls Water Works
(8) Midland Water Works
(9) East Liverpool Water Works
(e) Estimated flow based on drainage-area ratios
(t) Total manganese (dissolved plus suspended)

APPENDIX C

STATEMENT BY WENDELL L. MINCKLEY, BIOLOGIST-IN-CHARGE OF A UNIVERSITY OF LOUISVILLE SURVEY CREW UNDER CONTRACT TO ORSANCO.

The following data taken from sampling records of the Aquatic-Life Resources Project conducted for the Commission by the biology department of the University of Louisville show stream conditions before and during the steel strike as they relate to the quantity and variety of fishlife:

Species	Number of specimens taken			
	8/29/57	7/30/58	6/27/59	7/26/59
gizzard shad	---	7	2	41
common sucker	---	---	---	97
carp	96	11	2	70
goldfish	4	1	---	1
carp-goldfish hybrids	3	---	---	---
stoneroller	---	---	---	2
bigeye chub	---	---	---	24
silver chub	---	---	2	6
golden shiner	---	1	---	2
emerald shiner	1	24	---	20
river shiner	1	---	---	---
ghost shiner	---	---	---	2
common shiner	---	---	---	9
rosyface shiner	---	---	---	24
sand shiner	---	1	---	750
mimic shiner	---	---	---	623
bluntnose minnow	---	1	1	119
creek chub	---	---	---	2
black bullhead	100	165	465	788
yellow bullhead	1	---	---	---
channel catfish	1	---	---	---
banded killifish	---	---	---	1
warmouth	---	---	1	---
green sunfish	2	---	5	1
pumpkinseed	---	---	1	---
bluegill	10	---	---	---
white crappie	---	---	1	2
largemouth bass	---	2	---	---
yellow perch	---	---	---	3
Total numbers	219	213	480	2,587
Total weights in pounds	20.35	25.06	9.00	36.58

Of primary importance in the above data is the obvious predominance of carps and bullheads in the earliest collections, with the dominance being with the native minnows in the last collection. The carp and bullheads were still very common in the chamber, but this abundance was masked by the presence of 12 to 14 species that had not been taken previously or had been taken only in very small numbers in the three earlier studies. The faunal change occurring between the two periods in 1959 is highly significant. In the three early collections a few minnows occurred, but only as "singles" or small numbers. Even the emerald shiner was quite rare in the collections, notwithstanding its general abundance in the river (it may be noted that the latter species was also relatively rare in the July 1959 collection, apparently some conditions were present limiting its abundance.) In the July 1959 collection six species of minnows that had not been taken before in Montgomery lock were found, and in most cases the abundance of these minnows suggests other than chance occurrence. The common shiner, rosyface shiner, and bigeye chub all occurred in significant numbers, and all of these I consider to be intolerant of pollution and typical of streams with clean waters. The creek chub, ghost shiner, and stoneroller are also to be included in the above group of fishes, but were represented by smaller numbers. The sand shiner, mimic shiner, and bluntnose minnow are all relatively absent to rare in polluted areas (least so with the last species), and apparently moved into the area after the cessation of industrial activity upstream. As may be noted in the compilation even the tolerant, more ubiquitous species were more abundant in the last rotenone sample.

It is felt, on the basis of personal observations and on the basis of the change in the species of fishes occurring in Montgomery lock, that some drastic changes occurred in the habitat making it more suitable for fish life in July 1959. It cannot be fortuitous that such a change in the fish fauna, accompanied by relatively large numbers of some species which are intolerant of polluted waters, could occur. This must be a function of the alleviation of industrial discharge into the river upstream from the area.

November 22, 1960