OHIO RIVER

Pollution-Abatement Needs

Huntington - Cincinnati Stretch

These findings on treatment requirements for maintaining oxygen and bacterial-quality objectives form part of the comprehensive plan of the . . .

**OHIO RIVER VALLEY
WATER SANITATION COMMISSION**

OHIO RIVER VALLEY
WATER SANITATION COMMISSION

414 WALNUT STREET CINCINNATI 2, OHIO

To the Chairman and
Members of the Commission

Gentlemen:

In accordance with formal action of the Commission at its April 4, 1951, meeting in Hot Springs, Va., a study has been made of conditions in the Huntington-to-Cincinnati stretch of the Ohio River directed toward the establishment of pollution-abatement requirements. Findings from this study were reviewed by the Engineering Committee and certain conclusions were reached.

This report sets forth the findings and the recommendations. The latter were adopted by the Commission on January 9, 1952, to serve as the basis for a public hearing. In brief, it was concluded that treatment requirements for municipal sewage must be greater than the minimum set forth in the Compact in order to meet bacterial quality objectives adopted by the Commission in April, 1951.

Among the municipalities in three states that will be affected by ultimate action taken by the Commission regarding the discharge of sewage are those listed in Table VI of this report.

Technical analysis and preparation of the report represent the combined efforts of Robert K. Horton, staff sanitary engineer and Harold W. Streeter, staff consultant.

Respectfully submitted,

Edward J. Cleary

EDWARD J. CLEARY
Executive Director
and Chief Engineer

February 1, 1952

TABLE OF CONTENTS

	Page
Letter of Transmittal	1
Sources of Pollution, Huntington-Cincinnati **(Fig 1)**	5
Conclusions	7
Background	8
Hydrometric Data	10
Drainage Areas	10
Drought-Flow Probabilities	11
Seasonal Flow Expectancies	11
Time-of-Flow	12
Oxygen Conditions	13
Pollution Loads	13
Observed River-Quality Conditions	13
Computed Oxygen Profiles	14
Conclusions	14
Bacterial Conditions	15
Conclusions	19
Appendix (Illustrations and Tables)	20

Fig 2 -- Drainage Area Above Points in Ohio River between Huntington, W. Va. and Cincinnati, Ohio

Fig 3 -- Coliforms increase with diminished flows

Fig 4 -- Coliforms tend to increase and decrease with river flow at points remote from immediate sources of pollution

Fig 5 -- Coliform Trends in the Ohio River between Huntington, W. Va. and Cincinnati, Ohio

Fig 6 -- Rates of Coliform Decrease in the Ohio River

Fig 7 -- Computed Coliform Profile in the Ohio River between Huntington and Cincinnati

Fig 8 -- At this flow (8,040 cfs), coliform concentrations are above the water-supply objective throughout the entire section. Treatment to 90% reduction of coliforms will satisfy the water-supply objective

Fig 9 -- Effect of bacterial-reduction treatment on coliform densities at Ashland intake

Table of Contents (Cont)

Table I -- Minimum recorded river flows at Huntington gage

Table II -- Minimum recorded river flows adjusted for reservoir operation (Huntington gage)

Table III -- Increase in river flow resulting from operation of multiple-purpose reservoirs

Table IV -- Probability of drought flows at Huntington based on adjusted flow records

Table V -- Seasonal flow expectancies at Huntington (based on adjusted flow records)

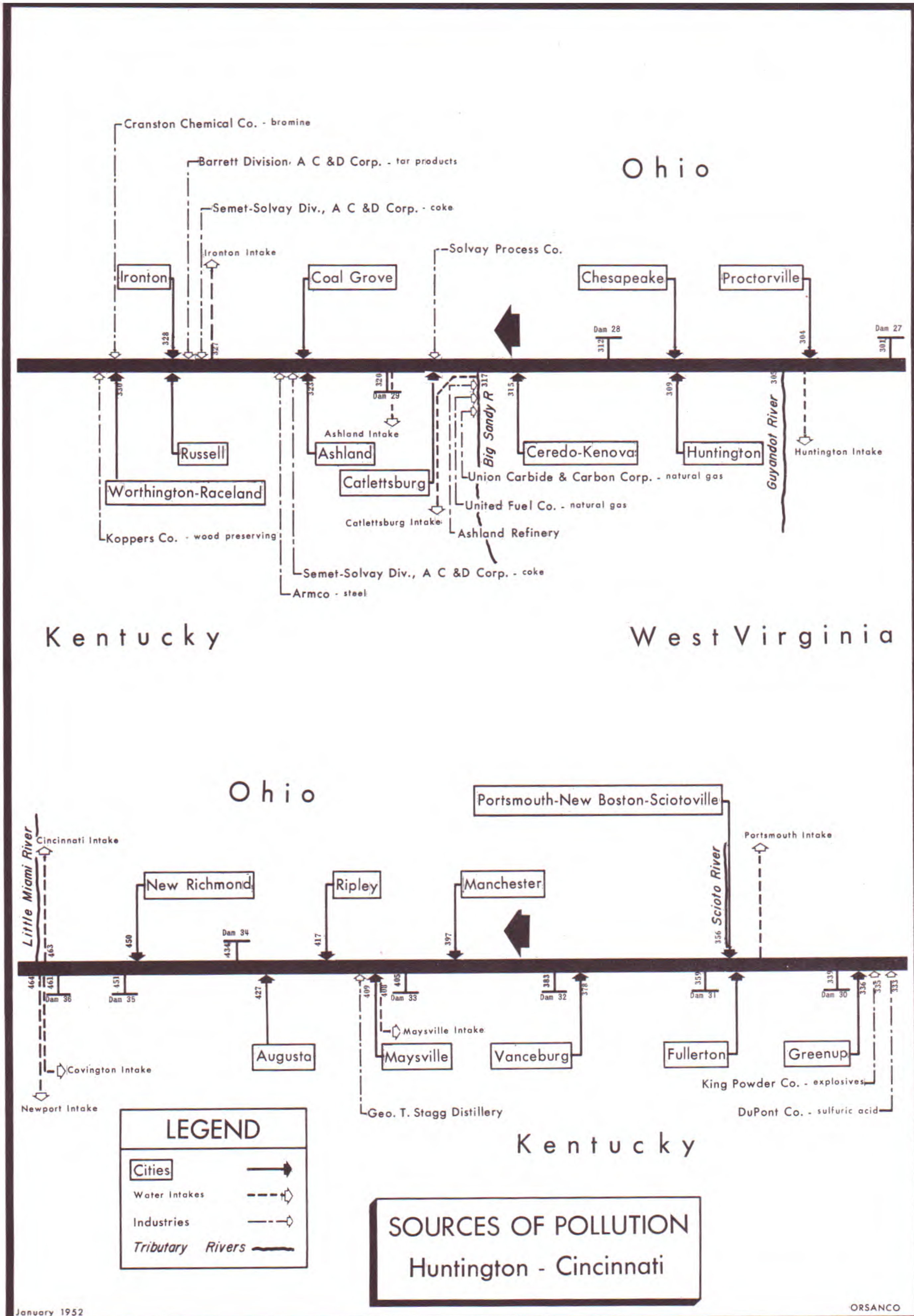
Table VI -- Estimated BOD loads discharged into the Ohio River between Huntington and Cincinnati

Table VII -- Oxygen and coliform conditions in the Ohio River between Huntington and Cincinnati during September 1939

Table VIII -- Seasonal Averages of Coliform Densities, 1939-40

Table IX -- Comparison of "Indicated" and "Most Probable" Numbers of Coliform Bacteria Observed at Ashland Intake

Table X -- Comparison of Cross-Sectional Average Coliform Numbers Observed at Dam 29, Near Ashland Intake, and Numbers Observed at Same Intake During Corresponding Months of the Year



Ohio
Cranston Chemical Co. - bromine
Barrett Division, A C &D Corp. - tar products
Semet-Solvay Div., A C &D Corp. - coke
Ironton Intake
Solvay Process Co.
Ironton
Coal Grove
Chesapeake
Proctorville
Dam 28
Dam 27
Dam 29
Ashland Intake
Russell
Ashland
Worthington-Raceland
Catlettsburg
Ceredo-Kenova
Huntington
Big Sandy R.
Guyandot River
Huntington Intake
Union Carbide & Carbon Corp. - natural gas
United Fuel Co. - natural gas
Catlettsburg Intake
Ashland Refinery
Koppers Co. - wood preserving
Semet-Solvay Div., A C &D Corp. - coke
Armco - steel
Kentucky
West Virginia
Ohio
Portsmouth-New Boston-Sciotoville
Portsmouth Intake
Little Miami River
Cincinnati Intake
New Richmond
Ripley
Manchester
Scioto River
Dam 34
Dam 36
Dam 35
Dam 33
Dam 32
Dam 31
Dam 30
Maysville Intake
Augusta
Maysville
Vanceburg
Fullerton
Greenup
Covington Intake
Newport Intake
King Powder Co. - explosives
DuPont Co. - sulfuric acid
Geo. T. Stagg Distillery
Kentucky
LEGEND
Cities
Water Intakes
Industries
Tributary Rivers
SOURCES OF POLLUTION
Huntington - Cincinnati
January 1952
ORSANCO

CONCLUSIONS

This report is one of a series leading toward establishment of a comprehensive plan for pollution abatement on the Ohio River. The portion of the Ohio River covered by the report is that stretch between Huntington, West Virginia and Cincinnati, Ohio, a distance of 160 river miles.

Preparation of this report has been undertaken in accordance with Paragraph 12 of the Statement of Policies, which declares that one of the functions of the Commission shall be the preparation of comprehensive reports on pollution problems in the basin with recommendations for their correction, elimination and prevention.

The report has been directed toward the assembly and interpretation of information needed in establishing treatment requirements for municipal wastes. Information has been obtained from the states of West Virginia, Ohio and Kentucky, from reports of consulting engineers, from the Ohio River Pollution Survey (House Document 266, 78th Congress), and from available records of raw water quality at the several water supply intakes.

On the basis of investigations made, and in accordance with recommendations of the Engineering Committee, the following conclusions are reached regarding treatment requirements for municipal wastes discharged into the Ohio River between Huntington, West Virginia and Cincinnati, Ohio:

1. All sewage discharged into the Huntington-Cincinnati section of the Ohio River shall be so treated as to provide for substantially complete removal of settleable solids and not less than 45 percent of the total suspended solids (minimum Compact requirement). In addition, facilities shall be provided for bacterial-reduction treatment capable of effecting overall reductions in coliform bacteria up to 95% of the numbers present in the raw sewage.

2. During the months of May through October, the minimum overall reduction in coliform bacteria for all sewage discharged into this section shall be not less than 90 percent with river flows at Huntington less than 100,000 cfs (cubic feet per second), and not less than 80 percent with river flows of 100,000 cfs or more.

3. During the months of November through April, the minmum overall reductions in coliform bacteria for all sewage discharged into the section shall be not less than 90 percent with river flows at Huntington less than 50,000 cfs, and not less than 80 percent with flows of 50,000 cfs or more.

BACKGROUND

The section of the Ohio River with which this report is concerned is shown diagramatically in Figure 1. The section may be defined as that stretch extending from Dam No. 27 at Mile Point 301, which is immediately above Huntington, to Mile Point 464, near which point are located water intakes for the cities of Cincinnati, Covington and Newport (mile points are miles below Pittsburgh).

Eight public water supplies are taken from this stretch of the river. These supplies serve a combined population of more than 1,000,000 people (including Cincinnati, Covington and Newport).

Wastes discharged into this portion of the river have a population equivalent (biochemical-oxygen-demand basis) of 287,000. Sources of pollution are indicated in Figure 1.

Commission concern with pollution abatement needs in the Huntington-Ashland-Ironton area was first expressed in 1949 with issuance of a preliminary report on waste-treatment requirements. Major conclusions of this report were:

1. Satisfactory dissolved oxygen conditions would be maintained by treatment of municipal wastes (in the river stretch considered) in accordance with minimum requirements of the Compact.

2. All sewage discharged into the Ohio River above Ironton up to Dam 27 (immediately upstream from Huntington) should be given treatment for bacterial reduction to a degree in excess of that provided by sedimentation.

3. Facilities for bacterial reduction should be such as to permit flexibility of operation. The report pointed out that this would make it possible to provide treatment in the degree necessary to meet bacterial quality objectives that would be established by the Commission at a later date.

In the present report the preliminary study has been extended by investigating anticipated water-quality conditions in the river, in terms of oxygen balance and coliform levels, under varying circumstances of river flow and pollution loads. Furthermore, this report embraces a larger section of the river than did the preliminary report, namely a stretch of 160 river miles compared with the 38-mile stretch between Huntington and Ironton.

Bacterial quality objectives for the Ohio River were established by the Commission in April 1951. Establishment of these objectives has made possible the translation of information on river conditions and pollution loads into a knowledge of specific treatment requirements.

The purpose of this report has been to present findings regarding the extent and control of pollution caused by sanitary sewage.

The Ohio River between Huntington and Cincinnati receives wastes from three states. A principal objective of this report, therefore, is to expedite a coordinated effort on the part of the three states and the Commission for the abatement of existing and future pollution.

HYDROMETRIC DATA

Runoff records for the USGS gage at Huntington have been used as the basis for flow-probability studies. This record was selected because it is the longest continuous record of any of the gaging stations on the Ohio River between Huntington and Cincinnati. USGS gaging stations in this reach of the river and dates when continuous records were started are as follows:

Huntington, W. Va. -- August 1934
Ashland, Ky. -- October 1939
Maysville, Ky. -- October 1940
Cincinnati, Ohio -- October 1939

From the Huntington record the following data were tabulated for each year from 1934 to 1948 inclusive (1948 is the latest year for which a complete record is available): minimum daily flow, minimum weekly flow, minimum two-week flow, and minimum monthly (i.e. calendar month) flow. These data, together with the month of occurrence, are shown in Table I. From this tabulation, it is revealed that the various minimum flows recorded during the 15-year period are as follows:

Minimum day -- 3,200 cfs (1934, 1935 and 1937)
Minimum week -- 5,960 cfs (1946)
Minimum 2-week -- 6,300 cfs (1946)
Minimum month -- 7,340 cfs (1946)

Drainage Areas -- For convenience in estimating runoff at intermediate locations between Huntington and Cincinnati the chart shown in Figure 2 has been prepared. This chart shows the drainage area tributary to any point along this section of the river.

Adjustment in flows for reservoir operation -- The recorded flows given in Table I have been adjusted to show the effect of low-flow regulation from multiple-purpose reservoirs in the drainage area above Huntington. Adjustments have been made in accordance with procedures followed by the Commission in preparing the Cincinnati Pool Hearing Report.

Adjusted flows, which are shown in Table II, indicate what runoff values would have been if low-flow regulation had been in effect at the time gagings were taken. The months during which low-flow increases may be expected are June through October.

In making these adjustments, consideration has been given only to those reservoirs already in operation or to those now under construction. No allowance has been made for reservoirs which have been proposed, but construction of which is uncertain.

Reservoirs providing low-flow regulation and the amount of flow increase from each are detailed in Table III. The values of flow increase shown in the table are considered to be conservative. This information has been supplied by the Ohio River Division office of the U. S. Corps of Engineers.

Drought-Flow Probabilities -- On the basis of adjusted flow records, studies were made to determine the probability of droughts of varying severity. These studies were made in accordance with Gumbel's statistical theory of extreme values.

Results of these studies are shown in Table IV. To illustrate use of the table, it may be pointed out that the drought flow to be expected once in ten years as a daily average value is 4,110 cfs, and as a monthly average value is 7,840 cfs. For nine years out of ten -- or 90 percent of the years -- drought flows equal to or greater than the values indicated may be expected.

Critical-Flow Duration -- It should be noted that droughts of the same expectancy become less severe as the interval over which runoff is averaged increases. This is demonstrated by the data previously shown, which compares daily and monthly droughts expected once in ten years.

The significant interval over which to measure consecutive low flow may be different for different types of wastes. In dealing with toxic wastes, for example, drought flows of one-day duration may be of major significance.

In dealing with oxygen-demanding wastes, the significant interval is that which is equal to the time of passage of pollution through the critical stretches of the stream where oxygen content is lowest. In the section between Huntington and Cincinnati it was found that under conditions of low flow the time of passage was very nearly equal to one week.

In investigating bacterial pollution between Huntington and Cincinnati calendar-monthly average flows have been used. The reason for this is that the bacterial quality yardstick adopted by the Commission is expressed in terms of average coliform concentrations during a calendar month.

Seasonal Flow Expectancies -- Studies of bacterial conditions required the investigation of flow probabilities during different seasons of the year. Seasons were selected to include months in which water-temperature conditions were similar. The grouping of months by seasons was as follows: summer: June, July, August and September; fall: October and November; winter: December, January, February and March; spring: April and May.

Monthly-average flows for each month were tabulated from Huntington gage readings for the period of record. Adjustments for reservoir operation were made in accordance with information supplied by the U. S. Corps of Engineers. On the basis of seasonal groupings, then, the normal distribution of flows were determined by statistical analysis. Results are summarized in Table V.

Table V shows, for example, that in 50 percent of the summer months (June through September) expected flows will be equal to or less than 40,000 cfs; in 50 percent of the fall months (October through November) expected flows will be equal to or less than 34,000 cfs.

Time-of-Flow -- Time-of-flow data used in the analysis of oxygen and bacterial changes in the river were obtained from a report to the Engineering Committee of the Commission entitled "The Ohio River -- Estimates of Time-of-Flow," prepared by Mr. Edgar Landenberger of the U. S. Corps of Engineers from hydrometric observations made in connection with the 1939-40 Ohio River Pollution Survey of the USPHS (House Document 266).

In this report, Mr. Landenberger developed a graphical method for showing times-of-flow from points of origin in three sections of the Ohio River by a series of slope-lines plotted on a horizontal river mileage scale, and with ordinates representing times-of-flow in hours. The general slope of each line is determined by the total time-of-flow through the section corresponding to a given discharge as indicated by the reading at a reference gage sensitive to changes in flow. For purposes of this study, it has been expedient to use river discharges rather than gage heights, as being more direct, in selecting particular slope-lines for given flow conditions.

In using the charts, the discharge at a design-flow reference point, such as Huntington, is converted to the corresponding discharge at a reference point used by Mr. Landenberger (for example, at Maysville, Ky.), and a slope-line corresponding to the latter is then selected as representing times-of-flow at this runoff condition. Times between intermediate points are read off the ordinate scale by differences between the time to the lower point and the time to the upper point. Total times-of-flow from Huntington to successive points downstream are thus taken from the proper slope-line in this manner. (The basic method is described fully in Mr. Landenberger's report).

Temperature -- Temperature data for these investigations were obtained from the Ohio River Pollution Survey Report of the U. S. Public Health Service (House Document 266), other reports of the USPHS, and the report on the 1950 survey conducted by the Commission. For seasonal periods, stream temperatures have been averaged by months during such periods.

OXYGEN CONDITIONS

Pollution Loads -- Estimated BOD (biochemical oxygen demand) loads now being discharged into the Ohio River between Huntington and Cincinnati are shown in Table VI. Estimates have been made, for the most part, by adjusting loads shown in the Ohio River Pollution Survey Report (House Document 266) to present levels on the basis of population increases reported by the 1950 Census. It should be noted that data in the Ohio River Pollution Survey Report include population equivalents of both municipal and industrial discharges.

In Table VI data are shown for several cities and towns not listed in the Ohio River Pollution Survey Report, but which are included in the current inventory of municipal sources of pollution reported to the Commission by the several states. Loads (in population equivalents) for these cities and towns have been taken as equal to the census population, except for Chesapeake, Ohio and Raceland, Kentucky where sewage treatment facilities are available. As shown in the table, the total estimated BOD load discharged into this stretch of the river is 71,890 lb. per day (population equivalent 287,300).

Reports by consulting engineers on sewage-treatment programs for the cities of Huntington, Ironton and Portsmouth have been reviewed. Reasonably close agreement has been noted between the data in these reports on municipal loads and load increases at these cities with the data in Table VI.

It is believed that load data shown in Table VI are sufficiently accurate for present purposes. As will be shown below, oxygen conditions in the river are far from being critical, indicating that more precise measurement of loads at this time is unjustified.

Observed River-Quality Conditions -- The best information available on oxygen conditions in the river has been derived from the 1939-40 Ohio River Pollution Survey Report by the U. S. Public Health Service, these observations having covered a period of a full year or more. Also available are the results of a two-week survey made in September, 1950 under the sponsorship of the Commission. Other data, used for purposes of comparison, have been available from the earlier USPHS surveys of 1914-16 and 1929-30.

For purposes of illustration, observed average results from the 1939-40 survey are shown in Table VII, covering the month of September, 1939, when the average flow at Huntington was 9,000 cfs, a drought flow to be expected, as a monthly average flow, about once in seven years (see Table IV). In Table VII it is shown that the minimum dissolved oxygen (DO) content of the river below Huntington was 7.3 ppm or 86% of saturation at the prevailing stream temperature, 24.5 deg C.

It will be noted that from Dam 28, just below Huntington, to Dam 31, below Portsmouth, the DO content remained nearly constant, with a maximum deviation of 0.2 ppm from an average of 7.5 ppm, and the 5-day BOD also was nearly constant, with a maximum deviation of 0.1 ppm from an average of 1.0 ppm. No well-marked "oxygen-sag" was apparent in this zone of the river, indicating that deoxygenation and reaeration were practically in balance with each other in this zone.

Below Portsmouth, an increase of 0.6 ppm in DO content from 7.5 ppm at Dam 31 to 8.1 ppm at Dam 36 (just above the Cincinnati intake), together with a decrease of 0.5 ppm in 5-day BOD from 1.4 ppm at Dam 32 to 0.9 ppm at Dam 36 is noted. Making due allowance for observational error, a state of practical balance between deoxygenation and reaeration is again indicated. In this case the absence of any major sources of pollution between Portsmouth and Cincinnati tended to permit relatively undisturbed oxidation, with a measurable decrease in BOD and an increase in DO resulting from reaeration.

Computed Oxygen Profiles -- On the basis of these observations, a dissolved oxygen profile has been computed for an assumed 5-year, 7-day average drought flow of 7,400 cfs at Huntington, at a river temperature of 25 deg C. In making these computations, the Streeter-Phelps oxygen sag formula has been applied successively at each major source of BOD, beginning at Huntington, adjusting the value of the initial BOD (L_a) for the BOD added at each point, figured as 0.25 pounds per day per capita of contributing population, and converted to parts per million by the relation:

$$\text{ppm} = \frac{\text{lbs. per day}}{5.4 \times \text{cfs discharge}}$$

In applying the oxygen sag formula, the value of the deoxygenation rate coefficient (k_1) has been taken as 0.12 at 25 deg C by means of the relation:

$$k_1 \quad (25^{\circ}) = 1.047^5 \times 0.10 \ (20^{\circ}C)$$

The value of the reaeration coefficient (k_2) has been taken as 0.10, being derived from a value of 0.12 observed in the same zone in September, 1939, and allowing for a decreased flow from 9,000 to 7,400 cfs ($7,400/9,000 \times 0.12 = 0.10$). This value is lower than generally observed at higher flows, but appears to be quite reasonable in view of the pool depth and extremely low velocity of flow under the assumed drought-flow condition. The value of the initial DO deficit (D_a) below Huntington has been taken as 1.0 ppm, as observed in September, 1939. The initial value of (L_a) (below Huntington) has been computed from a 1950 population equivalent of 112,000 for the Huntington area, or as 28,000 lb. per day (112,000 x 0.25) converted to parts per million. Readjustment of (L_a) at each downstream source of pollution has been made on the basis of the residual BOD at that point plus the added increment in pounds per day.

These calculations show that with an assumed five-year drought flow of 7,400 cfs (7-day average flow), the minimum DO content of the river at a summer temperature of 25 deg C would be estimated to approximate 7.3 ppm, or 87% saturation under present conditions of pollution, assuming no sludge deposits.

Following this method, dissolved oxygen profiles may be drawn for other conditions of flow and for varying BOD loadings. Such profiles may be used for re-evaluating oxygen conditions in the future, when and if this should become necessary because of changes in the distribution or concentration of present BOD loads.

Conclusion -- With present BOD loads, approximately 72,000 lb. per 24 hours, oxygen conditions are not critical at any season of the year, or at any flows.

Therefore, the conclusion is reached that so far as oxygen conditions are concerned, sewage treatment in excess of the minimum required by the Compact is unnecessary.

BACTERIAL CONDITIONS

Bacterial conditions in this section of the river have been studied with special reference to sewage treatment requirements which would secure river water quality at water works intakes meeting the Commission's coliform objective.

Recommendations resulting from this study reflect two decisions made by the Engineering Committee at its meeting on November 20, 1951. The first was to the effect that in fixing requirements for bacterial reduction in sewage the primary aim was to provide adequate protection for water supplies drawn from the river. It was recognized by the Committee, however, that in meeting the coliform objective for water supplies, the objective for recreational waters would also be secured in certain areas. The second decision was that the same percentage of reduction in coliform bacteria be required at all points of sewage discharge in the section, according to whatever degree might be needed under a given flow and seasonal condition at the most critical point in order to meet the Commission's bacterial-quality objective for water intakes; namely, average coliform most probable number (MPN) not exceeding 5,000 per 100 ml in any month.

Seasonal variations in per capita contributions of coliform bacteria in sewage, previously established through observations by the United States Public Health Service, have been a complicating element, further intensified by the effects of local runoff during each season. For purposes of estimate, overall contributions of 0.14 "quantity unit" per capita in summer, and 0.065 per capita in winter have been assumed, as a conversion factor between sewage-contributing population and coliform densities produced in the river at various flows. ("Quantity units" - coliform MPN per ml x discharge in thousand cfs).

A study of the relations between observed coliform densities and river flows, based on United States Public Health Service data of 1939-40, shows that in the Huntington-Portsmouth section, cross-sectional average coliform MPN's tend to increase with diminished flow, and vice versa, exceeding 5,000 per 100 ml at flows ranging below 40,000 to 50,000 cfs at Huntington (see Fig 3). In this stretch, dilution thus appears as the dominant factor in coliform densities. In the Portsmouth-Cincinnati stretch, the effects of natural purification, modified by increased flows, tend to offset this predominant dilution effect, to the extent that at Dam 36 (immediately above the Cincinnati intake and 105 miles below Portsmouth) coliform densities tend to vary almost directly, rather than inversely, with the flow (see Fig 4). This reversal in the coliform-flow relation has an important bearing on the flow conditions under which supplementary bacterial reduction treatment of sewage discharged into the upper and lower portions respectively of the Huntington-Cincinnati section may be needed, though its effects may be reduced through primary sewage treatment throughout the section.

From a study of coliform density trends in the river as shown by the United States Public Health Service data of 1939-40, it is indicated that the more critical conditions tend to coincide with summer low flows, as well as summer high flows, in the latter case especially when sharp rises in the river follow periods of low water (as for example during the Ohio River quality survey of September, 1950), (See Table VIII and Fig 5). Under winter conditions of low and high flows, cross-sectional average coliform MPN's were observed to exceed 5,000 per 100 ml at some points above and below Portsmouth, respectively, but tended to run below 10,000 per 100 ml at all points. This was in marked contrast to coliform densities observed in summer, which at low flows exceeded 10,000 throughout the greater part of the Huntington-Portsmouth stretch and at high flows tended to run above this level throughout the entire Huntington-Cincinnati section.

Application of coliform "die-away" curves derived from three years of continuous observations by the United States Public Health Service in 1914-16, shows a very fair agreement between calculated coliform MPN's at various points, allowing for accretions due to added sewage at major and more important minor sources of pollution, and the average cross-sectional MPN's observed at these points during corresponding periods of the 1939-40 United States Public Health Service survey. The "die-away" curves are reproduced in Fig 6, and the calculated coliform profile in Fig 7. During periods of high water, however, both in winter and in summer, deviations in observed MPN's above computed trend lines shaped by self-purification effects suggest that under these conditions such effects are masked to some extent by those of inflow and channel scour due to increased runoff. These effects are illustrated in Fig 5, and are particularly apparent in the Portsmouth-Cincinnati stretch, where the effects of self-purification are most evident during low-flow periods. With primary treatment of all sewage, these deviations should be materially reduced.

A study of these self-purification trends in relation to upstream sources of pollution affords a possible method for evaluating the relative percentage responsibility of each major source of pollution for coliform densities at downstream points. The accompanying tabulation shows a comparison of these percentages derived for three different stream conditions; namely, summer low-flow, winter low-flow, and winter high-flow.

	Percentage of Total Coliforms at Water Intake:														
	Ashland			Ironton			Portsmouth			Maysville			Cincinnati		
	SL	WL	WH	SL	WL	WH	SL	WL	WH	SL	WL	WH	SL	WL	WH
Originating At	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Above Huntington	2	5	40	1	2	30	--	--	28	--	--	13	--	--	11
Huntington Dist.*	98	95	60	45	61	48	30	47	41	5	17	20	2	13	18
Ashland				54	37	22	39	32	21	7	11	9	3	7	8
Ironton							31	21	10	5	6	5	3	7	4
Portsmouth **										83	66	27	46	53	25
Maysville													46	20	8

Symbols: SL = summer low-flow WL = winter low-flow WH = winter high-flow
(*) includes Ceredo, Kenova and Catlettsburg (**) includes New Boston

It is noted that the relative responsibility of each upstream source of pollution for coliform loads at downstream points varies with season and flow, and at more distant points is greatest at winter high-flows, because of lowered stream temperatures and shortened times of flow. The effect of pollution from the Scioto River is measurably high at Maysville and Cincinnati only at high flows, being roughly equivalent to that of Portsmouth under this condition. The effect of pollution from above Huntington also is materially great only under the same condition, being of minor significance at both winter and summer low-flows.

A coliform profile similar to the one shown in Fig 7, has been drawn for an assumed 10-year minimum monthly average flow of 8,040 cfs at Huntington. This profile emphasizes the intensification of critical coliform loads to be expected throughout the entire Huntington-Cincinnati section under this condition. On this basis it is estimated that supplementary bacterial treatment of all sewage discharged into the river would be necessary under conditions approaching such a flow, ranging up to 90% for water supply protection, and up to 98.8% for protection of recreational areas. In this latter connection, it appears likely that with 90% bacterial reduction, bathing water quality requirements cannot be met except in limited stretches above Maysville and Cincinnati not subject to local pollution. This profile, together with the estimated effect of 90% reduction, is shown in Fig 8.

In view of the primary need for protecting sources of water supply in accordance with the recommendation of the Engineering Committee, a study has been made of the more recent available records of bacterial quality at various water supply intakes in the river, which are located at fixed points and do not necessarily represent average cross-sectional quality at their respective locations. These records have consisted of two series of coliform data, one based on routine filtration plant laboratory reports; the second, on results from the United States Public Health Service monitoring survey, instituted in the summer of 1950 (shown in Table IX). Methods of coliform enumeration differed for the two series, the first being based on 48-hour presumptive tests in single-tube plantings; the second, on confirmed tests in 3-tube plantings.

The only results which could be correlated with river flows were those from the first series, as flow data provided by the United States Geological Survey have not yet been made available after September, 1950. Comparison of the two series of results during the same months of the year has indicated, however, that despite the dissimilarities in the methods of coliform enumeration, the coliform densities shown in the second series were of the same order of magnitude as those of the first series. Thus, for the 8-month period of December-July, the average "indicated number" of coliforms per ml at the Ashland intake was 20,100 in 1948 and 28,000 in 1949 (first series), and the corresponding average MPN from the 3-tube confirmed tests was 22,400 in 1951 (second series). The agreement in averages from the two series for the same individual months was also close, being well within the limits of error for each average.

At the lower end of the Huntington-Cincinnati section, a similar comparison of results obtained from routine plant tests at the Cincinnati intake and from samplings of the river at Dam 36, just above the intake, over a concurrent period of 14 months in 1939-40 have shown an average indicated number of coliforms at the Cincinnati intake (based on the presumptive test) of 7,900 per 100 ml, and an average MPN at Dam 36 (based on the 3-tube confirmed test) of 5,200 per 100 ml. The higher average at the Cincinnati intake probably was due in part to the influence of pollution from the Little Miami River on the quality of river water at the intake during the months of higher flows, when deviations above the Dam 36 results were decidedly greater than in months of low flow.

Based on the plant records for 1948 and 1949, and available monitoring survey data for 1950-51, the coliform results reported at the Ashland, Kentucky intake were measurably and consistently higher than observed as cross-sectional averages during the United States Public Health Service survey of 1939-40 (see Table X). This indicates that the quality of water at this intake is disproportionately influenced by the tendency of sewage from the upstream Huntington area to follow the Kentucky shore of the river for a considerable distance downstream. Further evidence of this tendency is afforded by the reported results at the Ironton intake, located on the Ohio side of the river, which are in general better than would be expected from the cross-sectional averages observed in the United States Public Health Service survey of 1939-40. The tendency of combined pollution from Huntington and Ashland to follow the Kentucky shore line as far downstream as Portsmouth under low river flow conditions is also shown by similar comparative data. From these results, both prior to and after the institution of the United States Public Health Service monitoring survey in 1950, it is clearly indicated that the Ashland water supply is the one most vitally affected by upstream pollution, and that any program of uniform bacterial reduction treatment of sewage throughout the section must be largely conditioned by requirements for providing adequate protection to this supply. Such a program, however, can be formulated on the basis of requirements for bacterial reduction which will protect this supply, as well as those located downstream, during periods of relatively low and relatively high river flows occurring in the warmer months of the year (May - October), and in the colder months (November - April).

On this basis, an analysis of monthly average coliform numbers at the water intakes in relation to concurrent river flows has indicated that during the period of May - October, with river flows less than 100,000 cfs or thereabouts, a minimum uniform coliform reduction of not less than 90% for all sewage discharged into the Huntington-Cincinnati section would be required in order to meet the Commission's water-supply objective of 5,000 coliforms per 100 ml at all water intakes below Huntington. With flows exceeding 100,000 cfs, a lower degree of coliform reduction, amounting to 80%, should be sufficient to meet this same objective, in view of the added dilution provided by the higher flows in the zones immediately below major sources of pollution.

Under conditions of the colder half of the year (November - April), with stream temperatures averaging less than 10° C, coliform densities tend to be somewhat lower in river zones immediately below major sources of sewage pollution, and hence the higher 90% level of bacterial reduction treatment is required only at flows ranging below 50,000 second-feet at Huntington. At flows exceeding 50,000 second-feet, all sources of water supply in the section, including Ashland and Ironton, would appear from the recent plant records to be adequately protected against overburden with the lower 80% treatment level. The effects of following this plan of coliform reduction on the quality of water at the Ashland intake are illustrated in Fig 9.

Conclusions -- On the basis of the foregoing analysis, the following conclusions have been reached regarding bacterial-reduction requirements necessary to maintain water quality in conformity with coliform-density levels prescribed by the Commission's bacterial-quality objectives.

1. In addition to primary sewage treatment to meet the minimum compact requirements, bacterial reduction treatment facilities should be provided for all sewage effluents discharged into this section of the river whereby overall reductions up to 95% of coliform bacteria in the raw sewage may be accomplished.

2. As normal operational guides, the following degrees of bacterial reduction should be carried out for all sewage discharged into the section:

   a. During the months of May through October, the minimum overall reduction in coliform bacteria should be not less than 90% with river flows at Huntington less than 100,000 cfs, and not less than 80% with flows of 100,000 cfs or more.

   b. During the months of November through April, the minimum overall reduction in coliform bacteria should be not less than 90% with river flows at Huntington less than 50,000 cfs, and not less than 80% with flows of 50,000 cfs or more.

3. Bacterial reduction treatment in accordance with (a) and (b) above is intended to meet the requirements of normal stream conditions, but cannot be expected to cover unusual conditions which may arise from time to time; for example, in some cases resulting from irregular distribution of rainfall and runoff in the tributary drainage area, and in others, from sudden rises in the Ohio River following periods of low flow. Under these circumstances, bacterial reduction treatments in excess of those above indicated may be required temporarily, until normal conditions have been restored.

In summary, it may be emphasized that any program of bacterial reduction in this section should be flexible in its operation if it is to be fully effective under all conditions of season and runoff. If adequate bacterial reduction facilities are installed at all primary sewage treatment plants in the Huntington-Cincinnati section, the proper regulation of these facilities in order to meet either usual or unusual conditions should be a matter of no great difficulty, once the general pattern of treatment has been well established. The recommendations in this report are designed to provide such a pattern, capable of variation in accordance with whatever needs may arise.

APPENDIX

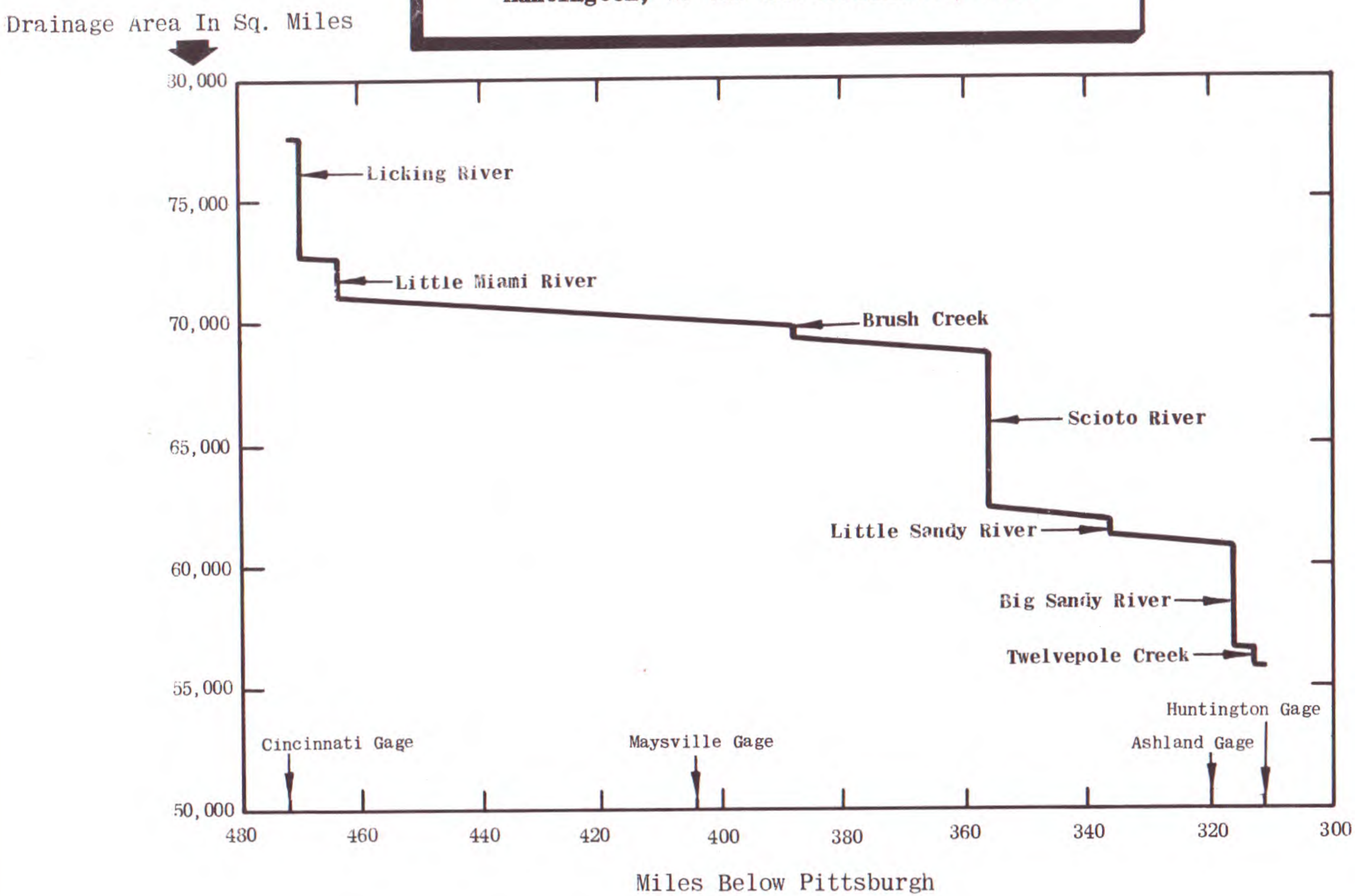
Illustrations

and

Tables

Figure 2

Drainage Area Above Points in Ohio River between Huntington, W. Va. and Cincinnati, Ohio



January 1952

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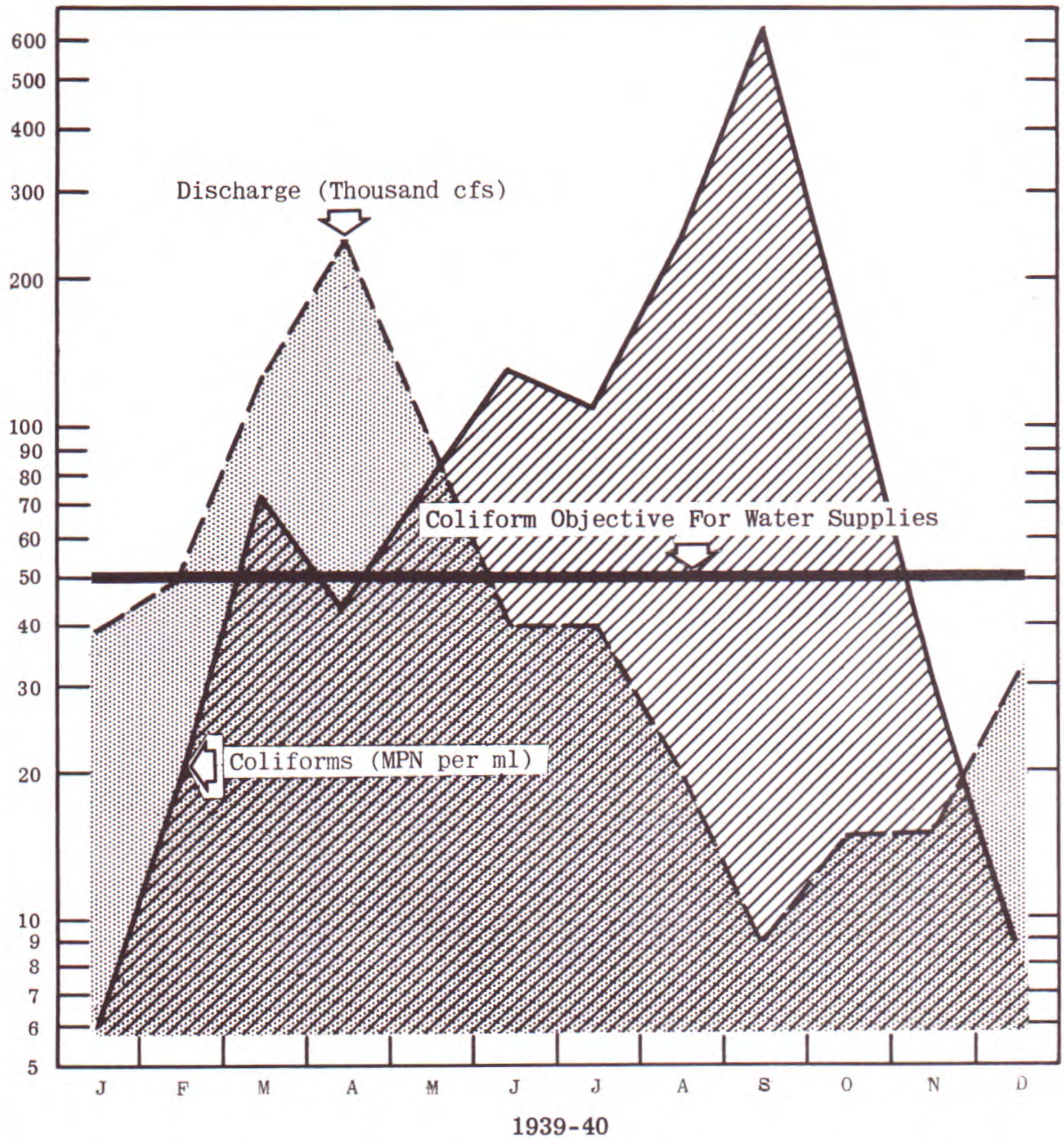
Coliforms increase with diminished flows. This is a general monthly variation pattern below major sources of pollution -- such as at Dam 28, immediately below Huntington, W. Va.



Coliforms tend to increase and decrease with river flow at points remote from immediate sources of pollution. This monthly variation pattern is demonstrated at Dam 36 near the Cincinnati, Ohio water-intake.

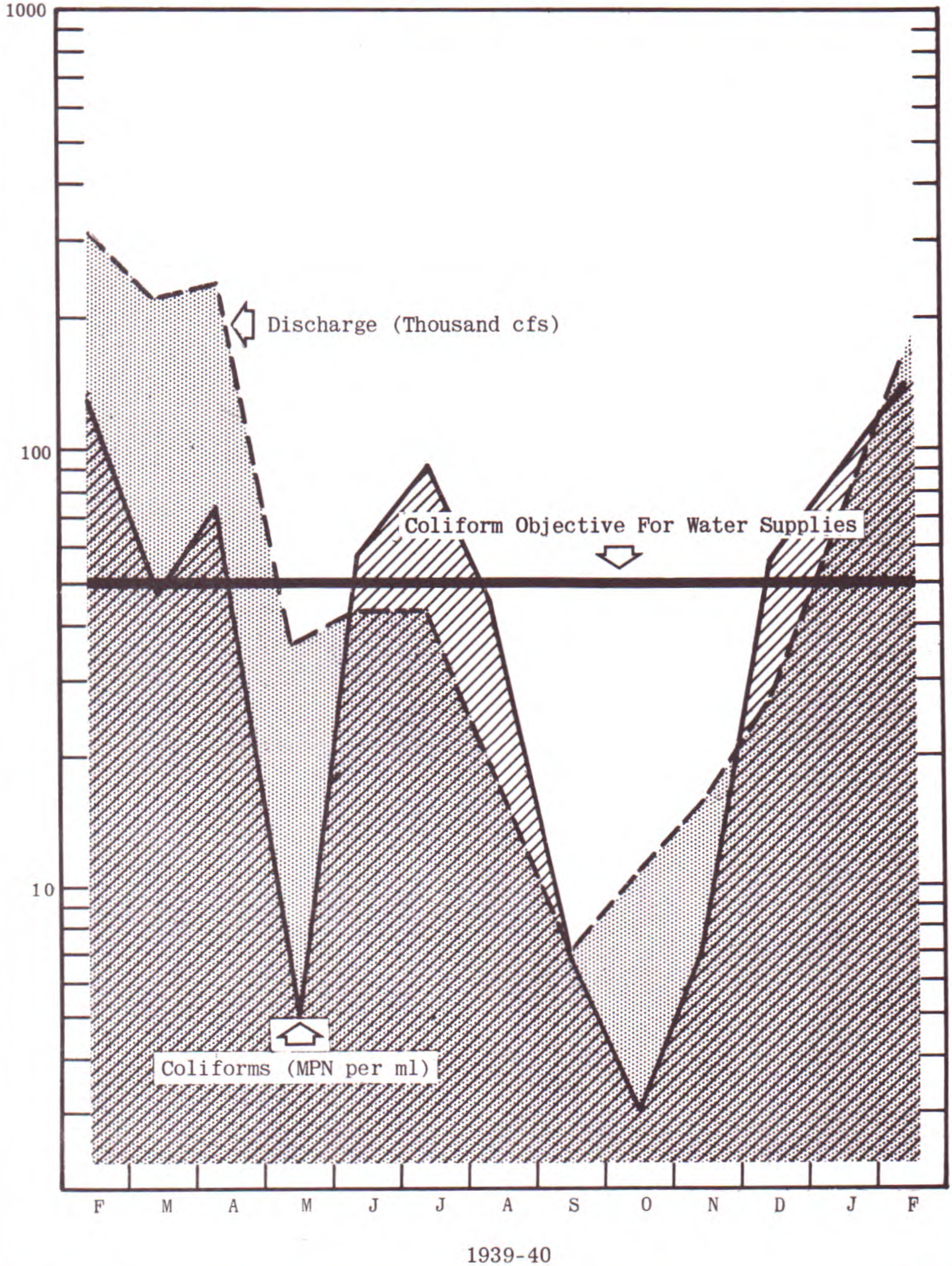
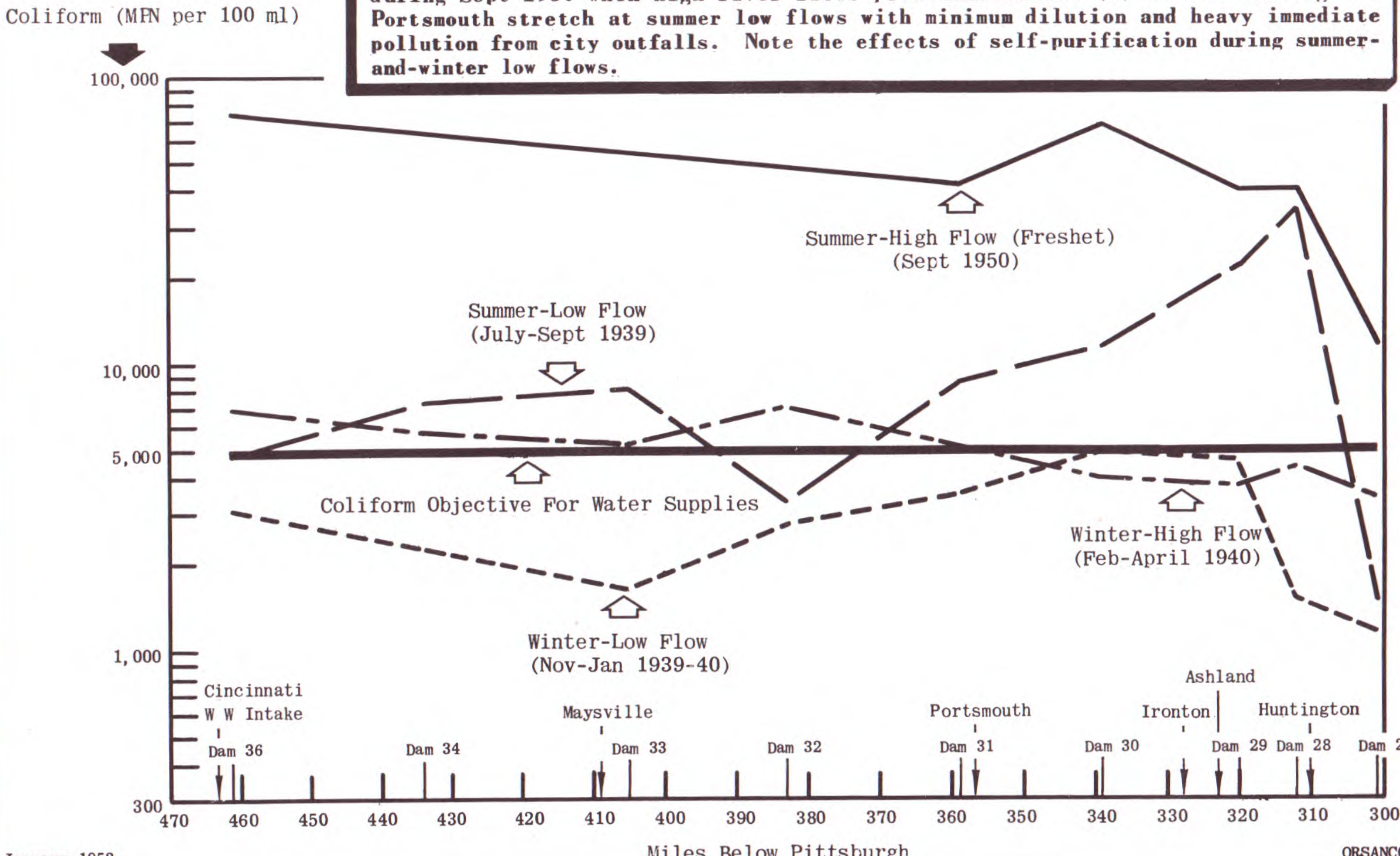


Figure 5

Coliform Trends in the Ohio River between Huntington, W. Va. and Cincinnati, Ohio -- Most critical bacterial-load conditions occurred (1) throughout the entire section during Sept 1950 when high river flows predominated and (2) in the Huntington-Portsmouth stretch at summer low flows with minimum dilution and heavy immediate pollution from city outfalls. Note the effects of self-purification during summer-and-winter low flows.



January 1952

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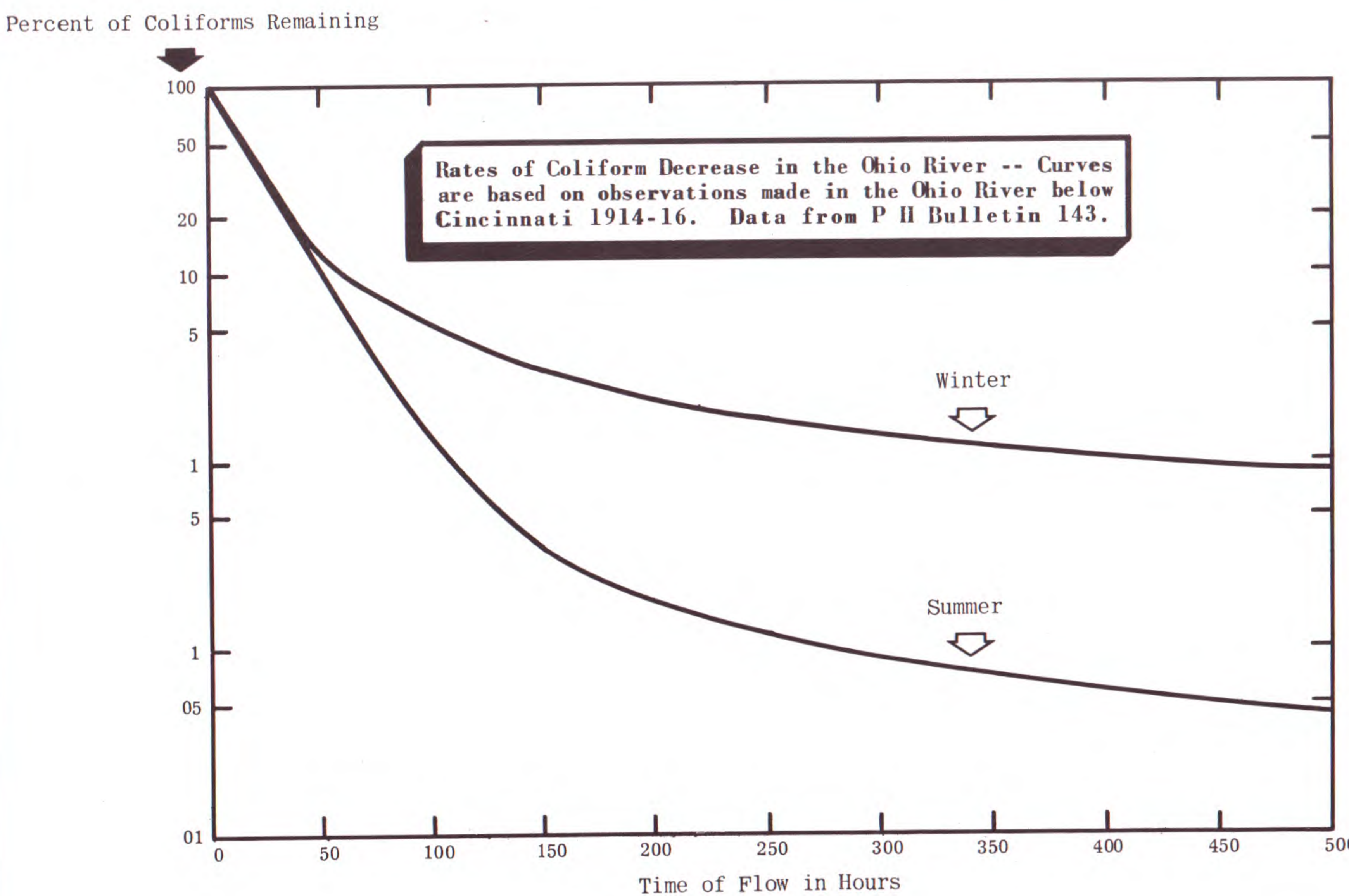

January 1952

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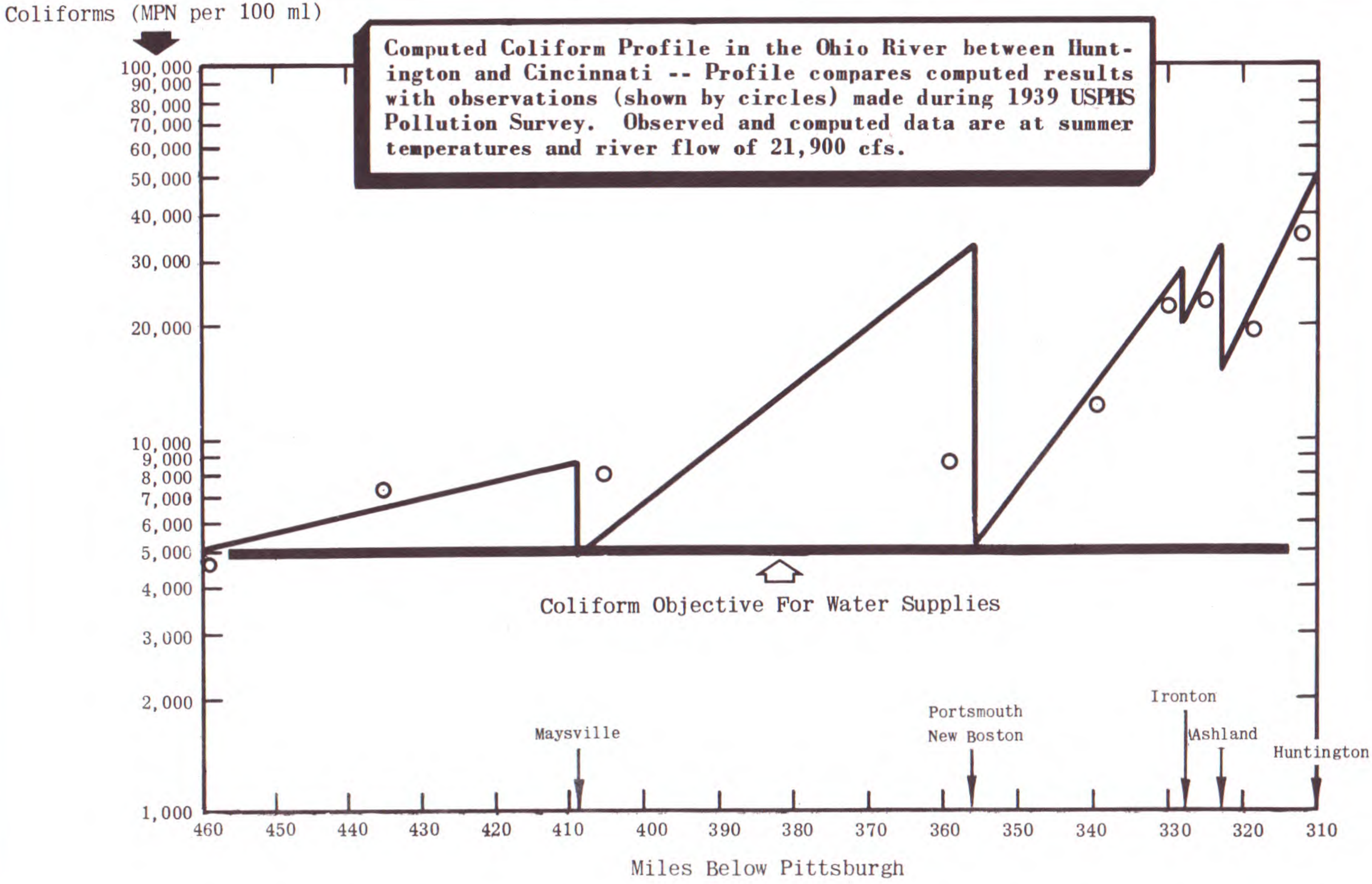
Figure 6

Figure 7



Computed Coliform Profile in the Ohio River between Huntington and Cincinnati -- Profile compares computed results with observations (shown by circles) made during 1939 USPHS Pollution Survey. Observed and computed data are at summer temperatures and river flow of 21,900 cfs.

January 1952

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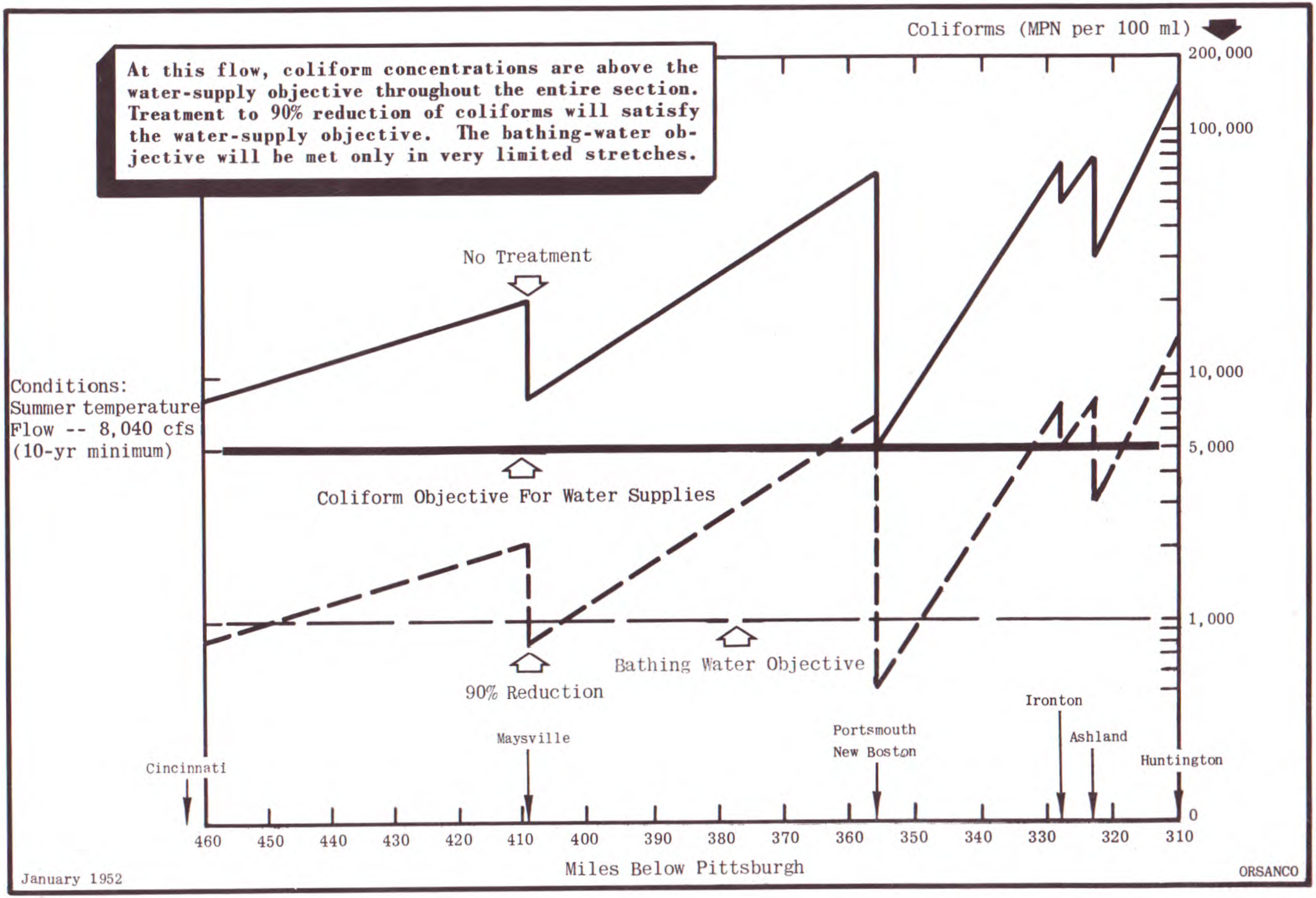
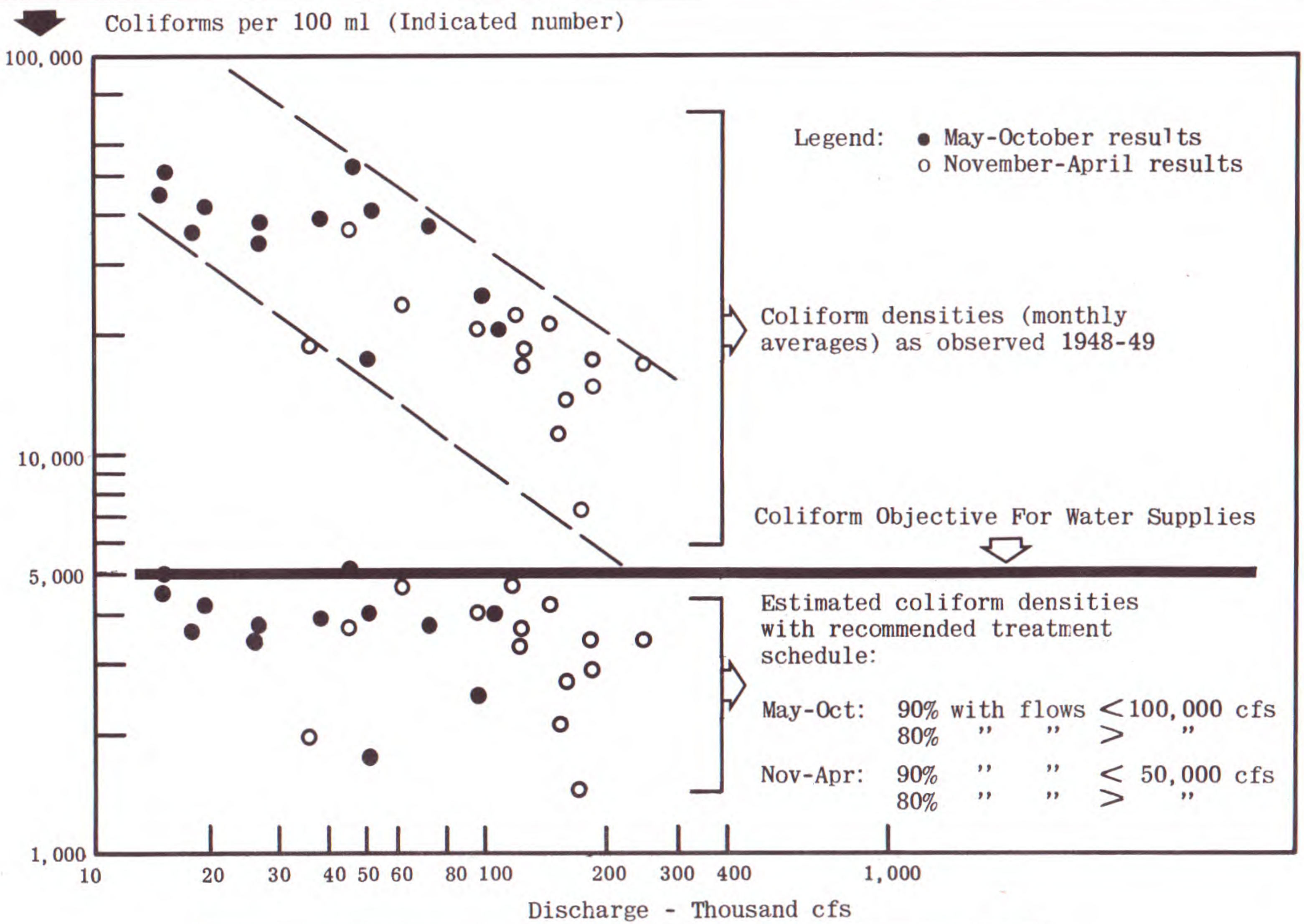
Figure 8



At this flow, coliform concentrations are above the water-supply objective throughout the entire section. Treatment to 90% reduction of coliforms will satisfy the water-supply objective. The bathing-water objective will be met only in very limited stretches.
Coliforms (MPN per 100 ml)
200,000
100,000
10,000
5,000
1,000
0
No Treatment
Coliform Objective For Water Supplies
Bathing Water Objective
90% Reduction
Conditions:
Summer temperature
Flow -- 8,040 cfs
(10-yr minimum)
Cincinnati
Maysville
Portsmouth
New Boston
Ironton
Ashland
Huntington
460
450
440
430
420
410
400
390
380
370
360
350
340
330
320
310
Miles Below Pittsburgh
January 1952
ORSANCO



Effect of bacterial-reduction treatment on coliform densities at Ashland intake -- Treatment in accordance with recommended schedule reduces bacterial densities observed at Ashland 1948-49 to level of 5,000 coliforms per 100 ml or lower.

Table I - *Minimum recorded river flows at Huntington gage*

Year	Min. daily avg. flow		Min. weekly avg. flow		Min. 2-week avg. flow		Min. monthly (calendar) avg. flow	
	Recorded flow (cfs)	Month of occurrence	Recorded flow (cfs)	Month of occurrence	Recorded flow (cfs)	Month of occurrence	Recorded flow (cfs)	Month of occurrence
1934	3,200	9 & 11	6,740	9	7,140	8-9	12,770	9
1935	3,200	10	6,340	10	7,760	10	11,840	10
1936	4,400	9	6,640	9	7,610	9	11,690	9
1937	3,200	10	7,440	9-10	8,650	9-10	26,780	9
1938	3,940	10	6,570	10	6,660	10-11	9,106	10
1939	4,880	10	6,030	9	6,860	9	7,837	9
1940	7,460	10	9,930	10	10,310	10	11,790	10
1941	4,100	9	6,280	9-10	7,530	9-10	11,890	10
1942	9,590	9	15,660	9	21,720	10	29,670	9
1943	5,330	10	7,030	10	7,250	9-10	10,650	10
1944	5,550	8	7,390	8	7,990	7-8	8,409	8
1945	5,380	9	11,330	9	12,960	8-9	24,520	7
1946	3,220	10	5,960	9	6,300	9	7,343	9
1947	5,270	10	9,460	10	10,480	10	11,660	10
1948	6,260	11	10,500	9	11,900	9	15,830	9

Table II - Minimum recorded river flows adjusted for reservoir operation (Huntington gage)

Year	Adjusted Flows			
	Min. daily avg. flow (cfs)	Min. weekly avg. flow (cfs)	Min. 2-week avg. flow (cfs)	Min. monthly (calendar) avg. flow (cfs)
1934	4,610	8,150	8,550	14,180
1935	4,610	7,750	9,170	13,250
1936	5,810	8,050	9,020	13,100
1937	4,610	8,850	10,060	28,190
1938	5,010	7,640	7,730	10,176
1939	5,950	7,100	7,930	8,907
1940	8,530	11,000	11,380	12,860
1941	5,170	7,350	8,600	12,960
1942	10,660	16,730	22,790	30,740
1943	6,230	7,930	8,150	11,550
1944	6,250	8,090	8,690	9,109
1945	6,080	12,030	13,660	25,220
1946	3,920	6,660	7,000	8,043
1947	5,970	10,160	11,180	12,360
1948	6,460	10,700	12,100	16,030

Table III - Increases in river flow resulting from operation of multiple-purpose reservoirs

Name of reservoir	Date of completion	Minimum flow increase (cfs)	Increase added to flows of record: Date of records	Increase (cfs)
			Prior to 1938	1,410
Tygart	1938	340		
			1938 to July 1943	1,070
Berlin	July 1943	170		
			July 1943 to April 1944	900
Mosquito Creek	April 1944	200		
			April 1944 to 1948	700
Youghiogheny	1948	500		
			1948 to 1953	200
East Branch Clarion	Scheduled for late 1952	200		
	Total	1,410		

Table IV - Probability of drought flows at Huntington (based on adjusted flow records)

Drought severity	Min. daily avg.	Min. weekly avg.	Min. 2-week avg.	Min. monthly (calendar) avg.
Most probable drought	6,050	8,350	9,260	14,010
Once in 5 years	4,760	7,400	8,010	10,030
Once in 7 years	4,440	7,170	7,700	9,050
Once in 10 years	4,110	6,930	7,380	8,040
Once in 15 years	3,740	6,660	7,030	7,170
Once in 20 years	3,490	6,480	6,750	6,750

Table V - Seasonal flow expectancies at Huntington
(based on adjusted flow records)

Percent of months	Monthly average flow - (cfs) (Flows equal to or less than values shown below may be expected for indicated percentage of months in each season)			
	Dec - Mar	April - May	June - Sept	Oct - Nov
10	30,000	45,000	-	-
20	60,000	69,000	20,000	-
30	82,000	86,000	28,000	21,000
40	102,000	100,000	34,000	28,000
50	118,000	114,000	40,000	34,000
60	136,000	127,000	46,000	40,000
70	154,000	141,000	53,000	46,000
80	176,000	158,000	60,000	54,000
90	206,000	182,000	71,000	65,000

Table VI - Estimated BOD loads discharged into the Ohio River between Huntington and Cincinnati (data include population equivalents of industrial discharges as reported in House Document 266)

Municipality	State	Population (census)		Pollution load in population equivalents		Estimated 1950-51 load in lb. first-stage BOD per day (0.25 lb BOD per pop.equiv.)
		1940	1950	1939-40 (From Ohio River Pollution Survey)	Estimated 1950-51 load	
Proctorville	Ohio	731	737		700	180
Huntington	W.Va.	78,836	86,353	95,800	105,000	26,250
Chesapeake *	Ohio	1,068	1,285		800	200
Ceredo-Kenova	W.Va.	5,114	5,719	5,100	5,700	1,430
Catlettsburg	Ky.	4,524	4,750	8,400	8,800	2,200
Ashland	Ky.	29,537	31,131	43,100	45,500	11,380
Coal Grove	Ohio	2,351	2,492		2,500	630
Ironton	Ohio	15,851	16,333	32,500	33,500	8,380
Russell	Ky.	1,844	1,681		1,700	430
Worthington-Raceland *	Ky.	1,964	1,696		1,300	330
Greenup	Ky.	1,063	1,276		1,300	330
Fullerton	Ky.		1,501		1,500	380
Portsmouth-New Boston	Ohio	46,490	41,552	59,100	52,700	13,180
Vanceburg	Ky.	1,184	1,528		1,500	380
Manchester	Ohio	2,163	2,281		2,300	580
Maysville	Ky.	6,572	8,632	13,000	17,100	4,280
Ripley	Ohio	1,623	1,792		1,800	450
Augusta	Ky.	1,701	1,599		1,600	400
New Richmond	Ohio	1,767	1,960		2,000	500
Total		204,383	214,298	257,000	287,300	71,890

* Sewage treatment provided (facilities inadequate)

Table VII - Oxygen and coliform conditions in the Ohio River between Huntington and Cincinnati during September 1939 (from House Document 266)

Sampling Station	Miles below Pittsburgh	Discharge cfs	Temp. deg C	Dissolved oxygen ppm	5-day BOD ppm	Coliform MPN per 100 ml
Dam 27	301	8,200	24.7	7.8	0.8	100
Dam 28	312	9,000	24.5	7.3	1.0	66,000
N & W RR Bridge	316	8,800	24.6	7.5	0.9	17,500
Dam 29	320	8,900	24.7	7.6	0.9	12,900
White Oak Cr.	326	8,900	24.6	7.4	0.9	19,000
Hanging Rock Light	330	8,300	24.4	7.5	0.9	23,000
Coal Branch Light	337	8,300	24.3	7.5	1.0	5,200
Dam 30	339	8,300	24.2	7.5	1.1	3,700
Dam 31	359	7,900	23.0	7.5	0.9	10,500
Dam 32	383	7,000	24.2	7.5	1.4	300
Dam 33	405	6,100	24.3	7.6	1.4	15,400
Dam 34	434	6,600	23.7	7.8	0.8	100
Dam 36	461	7,000	23.2	8.1	0.9	700

Table VIII - Seasonal Averages of Coliform Densities, 1939-40

Discharge in thousands cfs; coliforms in MPN per 100 ml (confirmed)									
	Miles From Pitts-	Summer Flow (July - Sept.)		Winter Low Flow (Nov. - Jan.)		Winter High Flow (Feb. - Apr.)		Summer High Flow (Sept. 1950)	
Station	burgh	Disch.	MPN	Disch.	MPN	Disch.	MPN	Disch.	MPN
Dam 27	301	21.9	1,500	27.2	1,200	158.8	3,300	58.6	11,100
Dam 28	312	21.9	33,700	26.7	1,500	139.5	4,400	70.2	40,800
N. & W. Bridge	316		19,000		4,000		4,100		
Dam 29	320	24.6	21,600	26.7	4,700	184.7	3,800	82.3	39,900
White Oak Cr.	326		22,900		6,200		5,000		
Hanging Rock Lt.	330		22,300		5,700		3,200		
Coal Branch Lt.	337		14,800		5,900		4,200		
Dam 30	339	24.4	11,700	28.3	4,900	179.7	4,000	91.5	69,700
Dam 31	359	25.3	8,700		3,500	184.0	5,200	104.0	40,900
Dam 32	383	24.6	3,200		2,800	184.3	6,900		
Dam 33	405		8,000		1,700	167.0	5,300		
Dam 34	434	23.3	7,300	26.6	2,200	166.6	5,600		
Dam 35	451								
Dam 36	461		4,800	24.8	3,100	191.0	7,000	107.0	76,000

Table IX - Comparison of "Indicated" and "Most Probable" Numbers of Coliform Bacteria Observed at Ashland Intake

	I.N. per 100 ml		MPN per 100 ml
	1948	1949	1950-51
December	21,000	21,300	20,500
January	24,000	14,700	13,600
February	14,000	17,000	11,400
March	7,100	18,400	17,600
April	16,900	24,200	18,200
May	20,500	37,600	20,000
June	40,000	37,000	28,000*
July	17,500	53,500	50,000
Average	20,100	28,000	22,400

(*) Omitting one extremely high result on June 3rd. With this result included, June average would be 104,000.

Note: "Indicated" numbers based on 48-hour presumptive test in single-tube plantings.
"Most probable" numbers based on confirmed test in 3-tube plantings.

Table X - Comparison of Cross-Sectional Average Coliform Numbers Observed at Dam 29, Near Ashland Intake, and Numbers Observed at Same Intake During Corresponding Months of the Year

	Average Coliform Numbers per 100 ml		
	Dam 29	Ashland W.W. Intake	
	(1939-40)	(1948)	(1949)
July	24,000	17,500	53,500
August	28,000	39,000	36,100
September	12,900	31,000	35,800
October	15,100	42,000	44,800
November	7,200	37,000	19,000
December	4,900	21,000	21,300
January	2,100	24,000	14,700
February	3,600	14,000	17,000
March	3,700	7,100	18,400
April	4,200	16,900	24,200
Average	10,570	24,950	28,480

OHIO RIVER VALLEY WATER SANITATION COMMISSION
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ESTABLISHED JUNE 30, 1948

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