OHIO RIVER

Pollution-Abatement Needs

Pittsburgh-Huntington 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

An interstate agency representing Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia and West Virginia.

OHIO RIVER VALLEY
WATER SANITATION COMMISSION

414 WALNUT ST. CINCINNATI 2, OHIO

To the Chairman and
Members of the Commission

A staff study has been completed relating to water-quality conditions in the Pittsburgh-Huntington stretch of the Ohio River and directed toward determining requirements for the treatment of sewage. Findings from this study have been reviewed by your Engineering Committee and certain conclusions reached.

This report sets forth the findings and the recommendations for treatment. Since the latter calls for a degree of treatment higher than the minimum specified in the Compact the Commission authorized at its meeting of January 28, 1953, the conduct of a public hearing in accordance with procedures outlined in Article VI of the Compact. The hearing will be held in Pittsburgh, beginning on March 31. Members of the hearing hoard are: Ohio commissioner Hudson Biery, chairman; West Virginia commissioner W. W. Jennings; and Pennsylvania commissioner E. A. Holbrook.

Preparation of the repnrt was a joint enterprise undertaken by Robert K. Horton, staff sanitary engineer, and Harold W. Streeter, staff consultant. Mr. Streeter brought to this task the background of forty years study of pollution conconditions in the Ohio River and was the source of inspiration and direction to the staff in the conduct of this complex evaluation. Earl Philip Baker, Jr., assistant sanitary engineer, aided in the compilation of hydrologic data.

Respectfully submitted,

Edward J. Cleary

EDWARD J. CLEARY
Executive Director
and Chief Engineer

March 1, 1953
Cincinnati, Ohio

Contents

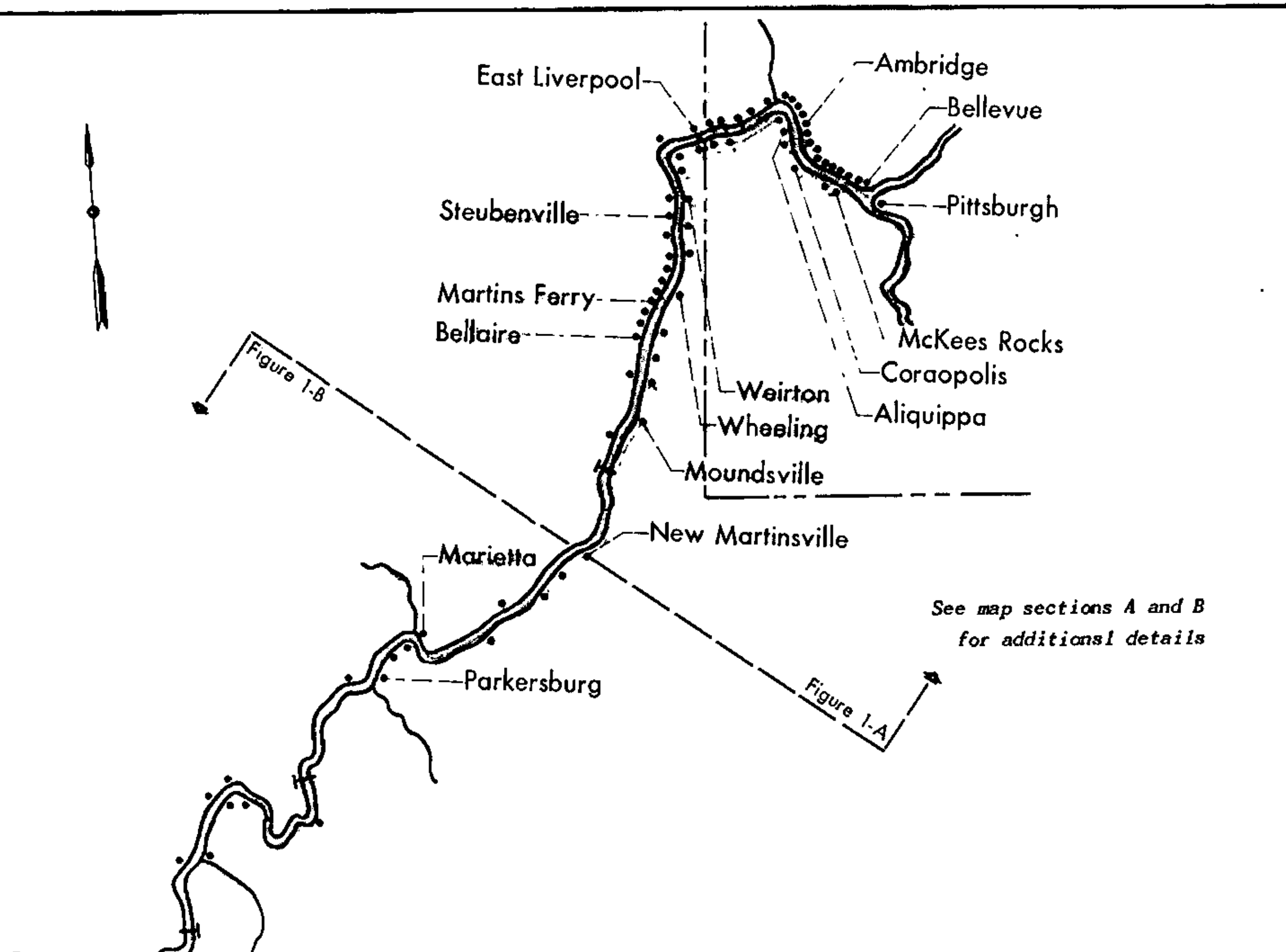

FIG. 1 - OHIO RIVER BETWEEN PITTSBURGH AND HUNTINGTON
Showing Sources of Sewage Pollution from Municipalities

Ohio River Valley Water Sanitation Commission
Cincinnati, Ohio March 1953

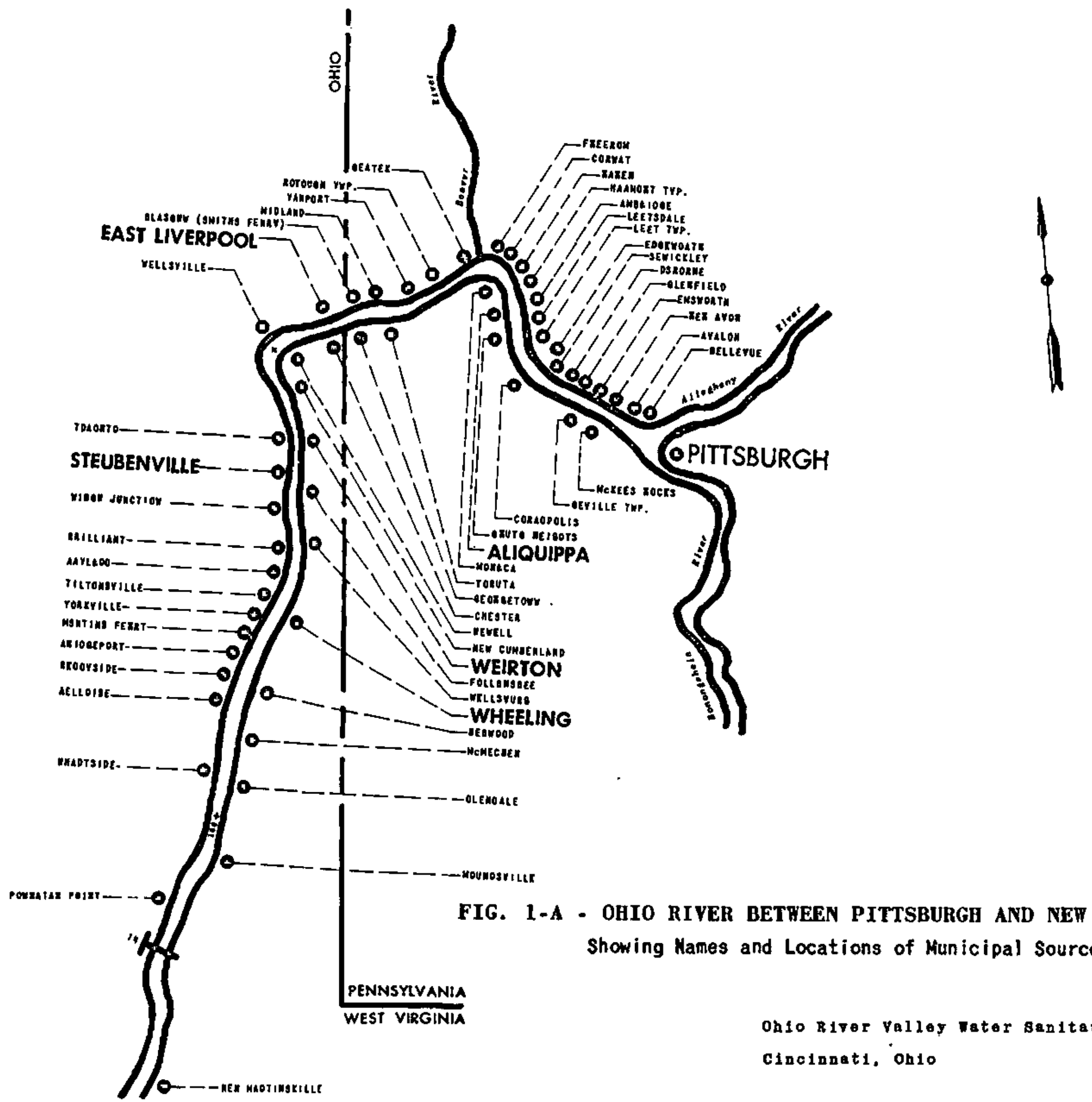

FIG. 1-A - OHIO RIVER BETWEEN PITTSBURGH AND NEW MARTINSVILLE

Showing Names and Locations of Municipal Sources of Pollution

Ohio River Valley Water Sanitation Commission

Cincinnati, Ohio   March 1953

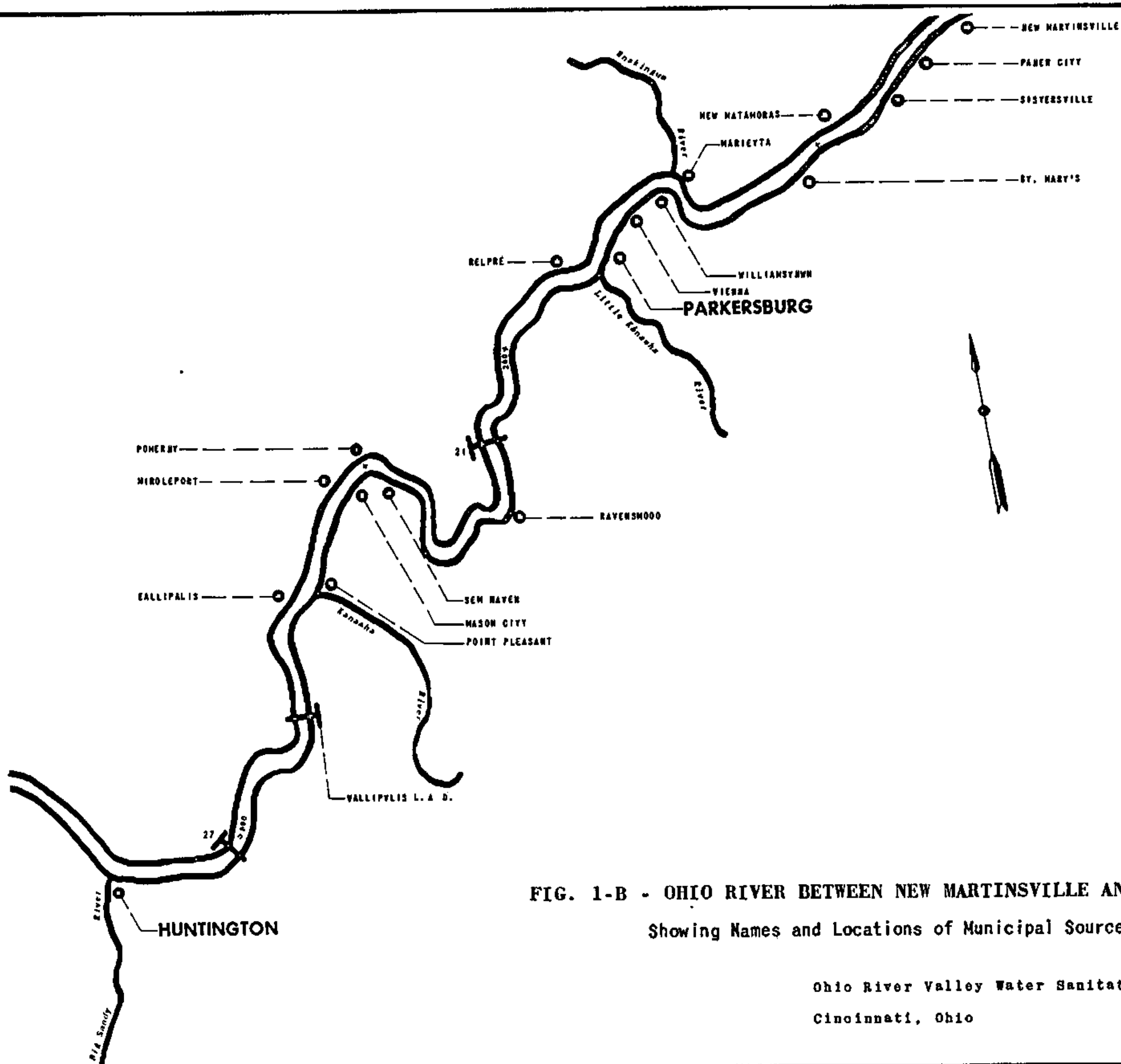

FIG. 1-B - OHIO RIVER BETWEEN NEW MARTINSVILLE AND HUNTINGTON

Showing Names and Locations of Municipal Sources of Pollution

Ohio River Valley Water Sanitation Commission

Cincinnati, Ohio March 1953

OHIO RIVER POLLUTION–ABATEMENT NEEDS

Pittsburgh–Huntington Stretch

CONCLUSIONS and RECOMMENDATIONS

This investigation has been made for the purpose of evaluating pollution conditions resulting from sewage discharged into the Pittsburgh-Huntington stretch of the Ohio River and has been directed toward the determination of remedial measures in terms of sewage-treatment requirements.

Article I of the Ohio River Valley Water Sanitation Compact pledges the eight signatory states to take such action that the waters within the compact district shall be placed and maintained in a satisfactory sanitary condition, available for use as public and industrial water supplies, suitable for recreational purposes, capable of maintaining fish and other aquatic life, free from nuisances and adaptable to other legitimate uses. The sewage-treatment requirements recommended in this report are intended to achieve these objectives.

On the basis of this investigation it is concluded that a dissolved-oxygen content to satisfy the stipulations of the Compact can be achieved in that stretch of the Ohio River between the Pennsylvania-Ohio-West Virginia state line and Huntington by treatment of present waste discharges in accordance with the following plan:

> Treatment of all sewage discharged to the river between Pittsburgh and Huntington in accordance with minimum requirements of the Compact (namely, substantially complete removal of settleable solids and not less than forty-five percent removal of total suspended solids); plus
>
> Additional treatment of sewage discharged to the Ohio River in Pennsylvania above the Allegheny County-Beaver County line in accordance with requirements established by the Pennsylvania Sanitary Water Board (namely, such treatment as will remove approximately fifty percent of the total biochemical-oxygen-demand (BOD); plus
>
> Appropriate treatment of organic industrial wastes now being discharged directly into the river (such appropriate treatment to be defined at a later date).

Treatment in excess of the minimum defined in the Compact is required for all sewage in order to secure satisfactory reduction of bacterial pollution. Present bacterial loads, though reduced in effect by existing acid conditions in the upper river, result in coliform concentrations in excess of the water-quality objectives established by the Commission.

Any material increase in the present total biochemical-oxygen-demand (BOD) load contributed to the Ohio River in the Pittsburgh area, after the proposed fifty-percent reduction, will tend to lower the minimum dissolved-oxygen (DO) content of the river below four parts per million (ppm) at critical stream flows, and will require re-evaluation of waste-treatment needs.

Recommendations

It is recommended that the following standard of treatment, subject to revision as changing conditions may require, be established for all sewage discharged from municipalities or other political subdivisions, public or private institutions, or corporations discharged or permitted to flow into that stretch of the Ohio River between Pittsburgh, Pa. and Huntington, W. Va.:

(a) Substantially complete removal of settleable solids; and

(b) Removal of not less than forty-five percent of the total suspended solids; and

(c) Treatment of sewage discharged in Pennsylvania above the Allegheny-Beaver county line in accordance with requirements of the Pennsylvania Sanitary Water Board (namely, approximately fifty percent reduction in BOD); and

(d) Reduction in coliform organisms in accordance with the following schedule:

Not less than 80% reduction during the months May through October.

Not less than 85% reduction during the months November through April.

PURPOSE and SCOPE

This report is the third of a series of investigations concerned with treatment requirements for wastes discharged to the Ohio River. Purpose of the report is to present staff findings on pollution conditions in a 300-mile stretch of the river and to submit recommendations for corrective measures that can be considered at a public hearing.

The recommended measures apply only to the control of sanitary-sewage discharges (as referred to in the second paragraph of Article VI of the Compact). Requirements relating to the control of pollution from industrial-waste discharges will be detailed in subsequent reports.

The section of the Ohio River with which this investigation deals may be defined as that extending from the point at Pittsburgh where the river is formed by the confluence of the Allegheny and Monongahela Rivers (designated as Mile 0.0 and referred to herein as the Point) to U. S. Corps of Engineers Dam No. 27, located about five miles upstream from Huntington, W. Va. and being 301.0 miles downstream from Pittsburgh. A map is shown on page 3.

Nine municipalities secure their water supply from the Pittsburgh-Huntington stretch of the river (see Table I). The total population served is more than 175,000.

Wastes discharged into this portion of the river have a population equivalent (biochemical-oxygen-demand basis) of some 3,300,000. Major sources of pollution are indicated in Table VII.

Sewage-treatment requirements have been evaluated with reference to the need for establishing and maintaining quality conditions in the Ohio River that will satisfy general requirements of the Compact as set forth in Article I. This has meant that consideration be given to the following three criteria of water quality:

(1) a dissolved-oxygen content suitable for normal aquatic life, natural-purification processes and other legitimate uses;

(2) a bacterial quality suitable for water supplies; and

(3) a bacterial quality suitable for recreational uses including bathing.

These criteria are the same as those dealt with previously in the report on the Huntington-Cincinnati stretch of the river (Ohio River Pollution-Abatement Needs, Huntington-Cincinnati stretch; February 1952). The investigation has involved a study of existing oxygen-demanding loads that are imposed on the stream and a determination of maximum allowable loads at critical stream flows. It has included also a study of present coliform-bacteria concentrations at various waterworks intakes, the conditions under which these concentrations exceed quality objectives adopted by the Commission, and the corrective measures that should be applied to upstream sewage discharges to bring these concentrations within the adopted limits.

Finally, the investigation has concerned itself with areas that might lend themselves to recreational uses, and the extent to which sewage treatment will be necessary in order to utilize such areas during the recreation season. In this latter connection, the degree of recreational benefit that will result from treatment measures aimed only at protecting water supplies also has been evaluated.

Basic information on pollution loads was supplied by the states of Ohio, Pennsylvania and West Virginia. Supplemental data were obtained from the Ohio River Pollution Survey Report (House Document 266, 78th Congress), reports of the Allegheny County Sanitary Authority (of Pennsylvania) and the U. S. Public Health Service, special surveys made by this Commission, and from records of raw water quality at the several municipal water supply intakes, including data collected by the Water Users Committee of the Commission.

HYDROMETRIC DATA

Discharge records for the U. S. Geological Survey gages at Sewickley and Huntington were used as the basis for flow-probability studies. These gages are located approximately at the upper and lower ends of the river stretch under consideration. Furthermore, the data from these gages provide the longest continuous records of any of the gaging stations on the Ohio River between Pittsburgh and Huntington.

From these records the following data were tabulated for each year from 1934 to 1949 inclusive (1949 being 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 are shown in Table II. From the tabulation it will be noted that the various minimum flows recorded during the 16-year period are as follows:

	Sewickley	Huntington
Minimum day	2,150 cfs	3,200 cfs
Minimum week	2,481	5,960
Minimum two-weeks	2,899	6,300
Minimum month	3,081	7,343

Flow adjustment for reservoir operation

The recorded flows given in Table II have been adjusted to show the effect of low-flow regulation from multiple-purpose reservoirs in the upper watershed of the Ohio River. Adjustments have been made in accordance with procedures followed in previous investigations on the Cincinnati Pool and the Huntington-Cincinnati stretch of the Ohio River.

Adjusted flows are shown in Table III. 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 that have been proposed, but the construction of which is uncertain.

Reservoirs providing low-flow regulation and the amount of flow increase from each are detailed in Table IV. The values of flow increase shown in the tabulation are considered to be conservative. This information has been supplied by the Ohio River Division 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 V. To illustrate use of the table, it may be pointed out that at the Sewickley gage the drought flow to be expected once in ten years as a daily average value is 3,090 cfs (cubic feet per second), and as a monthly average value is 3,870 cfs. For nine years out of ten -- or 90 percent of the years -- drought flows may be expected that are equal to or greater than the values indicated.

Seasonal-flow expectancies

In addition to investigating the probability of minimum stream flows, studies were also made to determine flow frequencies during particular seasons of the year. Seasonal-flow frequencies were needed principally in connection with the investigation of bacterial conditions in the river.

Studies on seasonal flows involved an analysis of flows occurring during two critical periods: a winter season when temperatures are low and stream flows are high, and the summer bathing season. The critical winter season was taken as the months November through March, and the summer bathing season was considered to be the months June through August.

Results of these studies are given in Table VI. The table shows, for the Sewickley and Huntington gages, the flows that may be expected at varying frequencies during the two seasons.

Runoff at intermediate locations

For convenience in estimating runoff at intermediate locations between Pittsburgh and Huntington the chart shown in Fig. 2 was developed. This chart shows the drainage area tributary to any point along this stretch of the river.

The procedure used in estimating expected flows at intermediate locations may be illustrated as follows: Suppose it is desired to estimate the minimum weekly flow that may be expected once in ten years at Mile Point 185.0 (just below Parkersburg). The minimum ten-year weekly flows at Sewickley and Huntington are 3,250 cfs and 6,980 cfs (Table V), and the difference is 3,730 cfs.

The increase in minimum flow between the two gaging stations, therefore, is 0.102 cfs per square mile (3,730 cfs divided by the difference in drainage area, 36,400 square miles). By applying this unit increase in flow to the difference in drainage area between Sewickley and Mile Point 185.0, the minimum ten-year flow at Mile Point 185.0 is estimated to be 5,130 cfs (3,250 cfs at Sewickley plus 0.102 cfs per sq. mi. multiplied by 18,420 sq. mi.).

Critical-flow duration

For the evaluation of oxygen conditions the minimum weekly-average flows have been used. The reason for using a week as the significant interval over which to measure consecutive low flow is that this interval is approximately equal to the time of passage of pollution through the critical reaches of the stream (where oxygen content is lowest). This has been found to be the case immediately below Pittsburgh and also immediately below Huntington.

Although no distinct oxygen depression has been indicated immediately below Wheeling with existing pollution loads, it appears likely that the time-of-passage through a critical reach here if it existed, would not differ markedly from that found in other sections of the river.

In the studies on bacterial pollution between Pittsburgh and Huntington the calendar-month 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.

Time of flow

Time-of-flow data used in the analysis of oxygen and bacterial changes in the river were obtained from a Commission report titled "The Ohio River -- Estimates of Time of Flow", prepared by Edgar Landenberger of the U. S. Corps of Engineers and a member of the Commission's engineering committee. Mr. Landenberger's work is based on hydrometric observations made in connection with the 1939-40 Ohio River pollution survey of the U. S. Public Health Service (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. (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), and from results of current surveys being made by the Commission's Water Users Committee at certain waterworks intakes. For seasonal periods, stream temperatures have been averaged by months during such periods.

OXYGEN CONDITIONS

Sources of pollution

Estimated BOD (biochemical-oxygen-demand) loads now being discharged into the Ohio River between Pittsburgh and Huntington are shown in Table VII. No attempt has been made to list all individual sources of pollution. However, data in the table for each area or locality represent total estimated loads, including those from municipal sources as well as those from industrial sources that are discharged either through community sewers or directly to the river. Population equivalents of waste loads have been determined on the basis of 0.25 lb. of total first-stage BOD or 0.17 lb. of 5-day BOD per capita.

No breakdown is given of loads from individual industrial plants. However, a list of those industries known or reported to be discharging all or part of their wastes directly to the river (most of which contribute some BOD load) is given in Table VIII. Information on specific waste loads from a particular industrial plant is considered confidential and for use only in dealing on an individual basis with the company concerned.

In compiling Table VII, the 1940 and 1950 census populations were taken from reports of the U. S. Bureau of the Census. The 1940 population equivalents were derived from data given in House Document 266 (78th Congress), Part II, Table OH-3, page 212. The 1950-52 population equivalents were derived in part from the 1940 figures, adjusted for changes in census population, and in part from additional industrial waste load data furnished by the states of Pennsylvania, West Virginia and Ohio.

As shown in Table VII, the 1950 census population for the Pittsburgh area is 1,338,500. The sewered population for this area has been estimated to be 1,290,000. The total pollution load from the area, in terms of population equivalents, includes the sewered population of 1,290,000 plus an estimated industrial-waste contribution equivalent to the raw sewage of 570,000 people.

This figure for the industrial-waste contribution has been derived from data given in Appendix XII of the Allegheny County Sanitary Authority's report of January, 1948 titled, "Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes" (hereafter designated as the ACSA Report). In deriving this figure, the estimated total industrial-waste equivalent of 650,000 population in 1945 for the whole of Allegheny County was first adjusted to 1950 on the basis of increased census population, and then reduced in proportion to the ratio of population in the area considered to that of Allegheny County, both as of 1950.

It should be pointed out that the most recent reports from the Allegheny County Sanitary Authority and the Pennsylvania Department of Health indicate that of the total sewered population in Allegheny County, 1,463,400, the sewage from about 1,045,000 people (or 71% of the total) will be discharged eventually through the Authority's collection system for treatment and disposal at a single plant near McKees Rocks. Additional plants are to be built separately by those involved for handling the remainder of the load.

Some uncertainty in assembling load information must be acknowledged in estimating equivalent-population loads contributed by the major streams tributary to the Ohio River. After considering various alternatives, it was decided to base them on the measured contribution, in pounds per day, of 5-day BOD during summer periods of low water during the period of the Ohio River pollution survey of 1940 by the U. S. Public Health Service; fairly long periods of daily observations were covered under these conditions. The total actual populations of the tributary drainage areas would give little if any clue to the effects of these populations at the tributary outlets, because of wide variations in the distribution of these populations along the tributaries and their branches.

It is believed that the load data shown in Table VII are sufficiently accurate for present purposes. As will be shown below, oxygen conditions in the river are not critical except in the extreme upper portion, where load information is most accurate. This would indicate that more precise measurement of loads in the lower portions would be unjustified at this time.

Effect of acid conditions

In undertaking to evaluate the more critical conditions of oxygen depletion which would be expected to prevail under existing pollution loads, it should be recognized that these conditions are now masked to a considerable extent by the presence of acidity in the upper portion of the river during the summer low-flow months; it is during this period that the most powerful effects of deoxygenation resulting from the addition of wastes exerting a biochemical-oxygen-demand on the river should be anticipated.

For this reason, it is considered desirable, and in fact quite necessary, to assume for purposes of estimate that these acid conditions are non-prevalent, and that the normal processes of deoxygenation would proceed as in any other stretch of the river not affected by acidity. This is the same assumption that has been made in estimates prepared by the Allegheny County Sanitary Authority concerning the required degree of treatment for sewage discharged into the river from the county area.

Although some time may elapse before existing acid conditions in the upper river are ameliorated, it must not be assumed that such a condition will be continued indefinitely. Acid pollution of the Ohio and its upper tributaries, the Allegheny and Monongahela Rivers, is recognized as a major pollution problem in this area, and the ultimate abatement of such pollution is commanding the best attention of the signatory states and the Commission.

Critical flows and temperature

The critical conditions for dissolved-oxygen maintenance in the river would be expected under summer drought flows, when stream temperatures are high and dilution afforded by the river is low. In the present study, the most critical flow used in evaluating oxygen conditions has been the minimum weekly-average flow expected once in ten years, as given in Table V for the Sewickley and Huntington gages.

At Sewickley this flow would be 3,250 cfs (cubic feet per second) and at Huntington 6,980 cfs. On this basis, the initial BOD load discharged from the Pittsburgh district, with a total population equivalent of 1,860,000 would amount to 465,000 lb. per day (assuming 0.25 lb. per capita of total first-stage BOD). When diluted with a river flow of 3,250 cfs, this would mean an initial BOD concentration of 26.5 ppm (parts per million) immediately below Pittsburgh.

Computation of oxygen profiles

A dissolved-oxygen profile has been computed for the entire stretch of the river from Pittsburgh to Huntington at an assumed ten-year minimum weekly flow; that is, at a flow increasing by increments from 3,250 cfs at the Sewickley gage to 6,700 cfs at Dam 27 (eleven miles upstream from the Huntington gage). The entire river stretch has been divided into thirteen sections, each beginning and ending at a known source of pollution.

Intermediate sources of pollution within each section have been included in the initial BOD for that section by applying the relation

$$L_a = L_b \times 10^{k_1 t}$$

Where L_a is the BOD at the initial point of the section,

L_b is the BOD at the intermediate point,

k_1 is the deoxygenation coefficient,

and t is the time of flow from the initial to the intermediate point.

The initial BOD for each section also includes the residual BOD from the next section upstream, allowing for time of flow through the section. The method of computation has involved applying the "oxygen-sag" formula for each section, adjusting the initial BOD for added pollution or dilution, and taking the calculated dissolved-oxygen content at the end of each section as the initial DO for the next section downstream. In this manner, it has been possible to allow for successive changes in the status of pollution or dilution in proceeding downstream.

Two sets of computations have been made, one assuming no treatment and the other 50 percent BOD removal at Pittsburgh and 35 percent removal at all downstream sources of pollution. The resulting oxygen profiles are shown in Fig. 3.

Deoxygenation and reaeration coefficients

In computing the oxygen profiles, using the oxygen-sag formula, a value of the deoxygenation coefficient (k_1) equal to 0.13 has been adopted, this being the normal value at 25 degrees Centigrade river temperature, with a value of 0.10 at 20 degrees. For the reaeration coefficient, a value of 0.23 has been adopted between Pittsburgh and Weirton, and a value of 0.20 below Weirton.

These values have been derived from two series of observational data which checked with each other closely when converted to a stream temperature of 25 degrees Centigrade (77 degrees Fahrenheit). Both series, one in 1914 and the other in 1940-41, were made during summer low-water flows by the U. S. Public Health Service in connection with stream-pollution investigations in those years (Public Health Bulletin No. 146 and House Document 266, Part II). The computations were facilitated by using a nomographic solution of the oxygen-sag equation published in 1949 (Sewage Works Journal, XXI, 5, 884, September, 1949). The oxygen-sag formula was used because it lends itself to readjustment to any changes in the BOD status of a stream at intermediate points throughout a long river section.

The value of the deoxygenation coefficient (k_2) adopted for these calculations is somewhat lower than that used in Appendix XII of the ACSA Report. This has led to the computation of a lower dissolved-oxygen minimum than estimated in that report, though the basic value at 20 degrees Centigrade was practically the same in both cases.

In the ACSA Report, a deoxygenation coefficient of 0.282 was derived from a 20-degree value of 0.188 by applying a temperature-correction factor given in Public Health Bulletin No. 146 (USPHS) published in 1925. Subsequently a long series of experimental observations by the U. S. Public Health Service at the Cincinnati Station of Stream Pollution Investigations established a more reliable temperature correction factor under stream-flow conditions, which factor has been used in the present calculations.

This factor, when applied to the 20-degree value of the deoxygenation coefficient used in the ACSA Report, would give a value of 0.235 at 25 degrees Centigrade, which agrees very closely with the value of 0.23 used in the present calculations. The effect of using this lower value has been to give a lower minimum DO below Pittsburgh than would be obtained by assuming a higher rate of reaeration. Its use in this connection appears to be thoroughly justified by the data now available.

Oxygen conditions shown by profiles

On examining the profiles in Fig. 3, it will be noted that the lower profile, assuming no treatment, reaches a minimum DO content of 0.5 ppm (parts per million) at Emsworth, with recovery to a content of 4.9 at Aliquippa, 5.6 at Rochester (also Beaver River mouth), and 6.6 at the Pennsylvania-Ohio-West Virginia state line, some 40 miles downstream from the Point at Pittsburgh. From Steubenville to Moundsville, a slight drop from 7.4 to 7.2 ppm is noted, because of the added BOD load in this section. From Moundsville to Marietta a definite recovery is shown, with about 95 percent of oxygen saturation from this point downstream to Dam 27.

In the upper profile, with assumed treatment as previously indicated, the DO minimum point at Emsworth of 4.4 ppm is shown, with recovery to 7.1 ppm at the state line, and further recovery downstream along a course similar to that of the "no treatment" profile but slightly above it.

It thus appears that with 50 percent BOD removal at Pittsburgh, a gain of about 4 ppm in dissolved oxygen at the minimum point of the curve is indicated, with BOD loads estimated as of 1950. It should be noted, however, that under these conditions the minimum DO at Emsworth would be only 51 percent of saturation, and any material increase in BOD load above the state line probably would reduce this minimum DO to an undesirable level.

Although the "treatment" profile shows a good margin of safety in this respect at the state line, the trend of this profile below Ambridge would suggest that any considerable increase in BOD load below the Point, with 35 percent BOD removal in this section, might set up a secondary oxygen-sag which would affect the oxygen trend below the state line.

The same principle would be applicable in the Steubenville-Moundsville section, where a well-defined secondary oxygen-sag is shown. In this case, any delayed BOD action resulting from acid conditions above and below the state line would tend to accentuate this downward trend of the profile.

Some evidence of such a delayed action was revealed by the summer low-water results of observations by the Public Health Service in 1940, when a sharp reversal in oxygen "balance" occurred below Dam 8, which is located about five miles below the state line. In this case a loss in oxygen balance between Dams 8 and 11 was noted, amounting to nearly 100,000 lb. per day in excess of the BOD added in this section. This loss was almost 25 percent of the total BOD load, including Pittsburgh's, discharged to the river above Dam 2, being somewhat greater than that which would be expected under normal stream conditions from the unoxidized portion of this total load.

Conclusions

It thus appears that with treatment of sewage discharged to the Ohio River in Pennsylvania above the Allegheny County-Beaver County line in accordance with requirements of the Pennsylvania Sanitary Water Board (fifty percent BOD reduction), together with treatment of all sewage discharged below the county line in accordance with minimum requirements of the Compact, and together with appropriate treatment for organic industrial wastes, satisfactory oxygen conditions should be attainable at critical stream flows in the Ohio River between the Pennsylvania-Ohio-West Virginia state line and Huntington. This conclusion is reached on the basis of no material increase in BOD loads over those estimated as of 1950-52.

Some increase in such loads, though probably involving added treatment to maintain a satisfactory dissolved-oxygen content in the river above the state line, should not seriously affect the minimum oxygen content below the state line unless 1950-52 loads were somewhat more than doubled, and unless continuance of present acid conditions in the extreme upper section of the river should bring about a secondary delayed BOD action below the state line. In such an event, any material increase in BOD loads below the state line might necessitate an increase in treatment requirements in the section between Weirton and Moundsville over and above those of primary treatment.

So far as the lower part of the Pittsburgh-Huntington stretch of the river is concerned, the only section in which oxygen conditions would appear to be questionable is the stretch extending above the Gallipolis Dam, at which point the dissolved oxygen content during the months of June through September, 1939, averaged 6.2 ppm, or about 75 percent of saturation, with an average flow of over 20,000 cfs. With critical minimum flows in this section approaching 7,000 cfs as a weekly average once in 10 years, it is quite conceivable that the DO content of the river at Gallipolis would reach critically low levels, especially if oxygen conditions at the mouth of the Kanawha River, some 15 miles upstream from the dam, should be unfavorable during prolonged summer drought periods.

Somewhat inconclusive evidence was revealed by the Public Health Service survey of 1939-41 that organic sludge deposits above Gallipolis Dam exerted an oxygen demand on the river during prolonged summer low-water periods. Further observations would be needed, however, to establish the true facts of this situation. In view of the great importance of this question in connection with future developments of high dams in the Ohio River, further studies on conditions in the Gallipolis Dam pool are recommended to establish whether or not organic sludge deposits may cause excessive deoxygenating effects on the river in the longer and deeper pools created by dams of this type.

BACTERIAL CONDITIONS

Bacterial conditions in the extreme upper portion of the Pittsburgh-Huntington stretch of the river reflect the presence of acid pollution. The latter tends to reduce the bacterial content of the river below that which would be expected to result from known discharges of sewage and from the normal action of self-purification. These effects, however, are highly variable, and for this reason difficult to evaluate.

It has appeared desirable, therefore, to assume the absence of acid conditions in estimating bacterial-reduction requirements in this section of the river, as likewise has been done in estimating oxygen conditions under existing BOD loads. This assumption has seemed proper because the effects of acid pollution are confined to a relatively limited section immediately below Pittsburgh, and because there is reason to believe that measures to reduce this type of pollution eventually will be developed.

Computed and observed coliform profiles

In one respect, however, it has been necessary to take account of the effects of acid conditions; namely, in checking computed coliform profiles against the results of actual observations made in the river. An example is shown in Fig. 4; here computed coliform profiles have been drawn for summer and winter flow conditions prevailing in 1940-41, when systematic observations were carried out by the U. S. Public Health Service in connection with the Ohio River pollution survey of those years. The average results of these observations are shown in relation to the computed profiles.

It will be noted from this study that average coliform "most probable numbers" (MPN) observed at Emsworth, Dashield, and Montgomery dams (at mile points 6.3, 13.3 and 31.7) were much lower than those shown by the summer profile, but agreed closely in the winter profile. As the average river flow during the summer period, 5,500 cubic feet per second (cfs) at Sewickley gage, was very low -- whereas the average winter flow, 35,500 cfs, was roughly seven times the summer flow -- the deviations of the observed MPN values below the profile at summer flows were clearly due to the effect of acid conditions which did not prevail at the higher winter flow.

Aside from these deviations, the agreement between the profiles and the observed coliform numbers was very good in most cases, probably being within the limits of observational error. This agreement, which was somewhat better in the winter profile than in the summer profile, has served to indicate that the use of the profile method of estimating trends in coliform numbers throughout the entire Pittsburgh-Huntington stretch of the river should be valid for any assumed condition of flow and sewage loads at different points.

Coliform densities at waterworks intakes

In order to determine the flow conditions under which the coliform densities in the river may be expected to be highest under existing (1950-52) sewage loads in the summer and in the winter, a study was made of the results of coliform MPN enumerations carried out at waterworks intakes at Weirton, Wheeling, Pomeroy, and Huntington during a period of 26 months from August, 1950 through September, 1952. These results have been reported by the Water Users Committee of the Commission from tests made routinely at each plant laboratory. Results for the first seven months beginning in August, 1950 were collected through the U. S. Public Health Service Environmental Health Center, and made available to the Commission when the latter undertook to continue this activity.

These results constitute the most recent available record of bacterial quality at these important water intakes, two being located in the most heavily polluted section of the stretch and two at points in the least heavily polluted section. Moreover, they are expressed in the same terms of MPN as the Commission's adopted bacterial-quality objectives, and have been obtained by means of test methods recommended in connection with the application of these objectives.

Records of routine coliform observations at these and other waterworks intakes in the stretch are also available from reports made to the respective state departments of health. These records, however, have been reported in terms of "indicated numbers" of coliform bacteria rather than MPN, and are based on a different method of testing; hence the results are not directly comparable with those reported by the Water Users Committee. Nevertheless, they have tended to confirm the general trends shown by the committee's reports, and in due time may be convertible to terms of equivalent MPN results, though a sufficient volume of concurrent results has not been available at this writing to justify drawing a relationship curve. This relation is not constant but tends to vary with the coliform densities.

Coliform densities vs river flow

The results of coliform analyses at waterworks intakes are shown in Table IX and graphically in Figs. 5, 6 and 7 for Weirton, Wheeling, and Huntington, at which the largest volume of data is available (note observed values in Figs. 5, 6 and 7). The charts show monthly average MPN values plotted against corresponding average river flows, using logarithmic scales in order to condense the plots. They show little relation of MPN to summer river flows, but indicate an inverse relationship at Weirton and Wheeling at winter flows, with the higher MPN densities tending to fall in a flow range of about 50,000 to 65,000 cfs.

At Pomeroy and Huntington, which are distantly removed from major upstream sources of pollution, the relation tends to be a direct one, with the higher MPN values occurring at flows over 100,000 cfs. This reversal in trend as compared with Weirton and Wheeling agrees with previous findings in the Huntington-Cincinnati stretch. It indicates that at points located closely to major sources of pollution, coliform densities in the river tend to vary inversely with flow; whereas at the more distant points densities tend to vary directly with flow.

Coliform densities in summer-fall season

In order to develop a comprehensive picture of coliform bacterial trends throughout the Pittsburgh-Huntington stretch during the summer-fall season, profiles have been drawn for the following flow conditions:

(1) a flow of 3,870 cfs at Sewickley, representing the minimum monthly average flow to be expected once in ten years regardless of time of occurrence (which is usually in September or October); and

(2) a flow of 5,500 cfs at Sewickley, representing the minimum monthly average flow to be expected once in ten years during the bathing season of June through August.

These profiles have been drawn on the assumption of non-acid conditions throughout the entire river stretch and are shown in Figs. 8 and 9.

In Fig. 8 it will be noted that with no bacterial-reduction treatment of sewage discharged into the river, the coliform content would fail to meet the Commission's water-supply objective throughout the 150 mile section extending below Pittsburgh, and would exceed the Commission's bathing-water objective in the entire river length above Huntington. With 80 percent removal of coliform organisms from all sewage discharged into the stretch, the water-supply objective would be met in all except a limited section between Weirton and Wheeling, and the bathing-water objective would be achieved in an aggregate river length of about 100 miles.

In Fig. 9, with a flow of 5,500 cfs at Sewickley, the 80 percent reduction in coliform bacteria should provide water of a quality that meets the water-supply objective at all intakes between Pittsburgh and Huntington, and also should assure that the bathing-water objective is achieved in about 150 miles of river. Both profiles have been drawn on the assumption that the bacterial quality of water discharged into the Ohio River by its tributaries would be at least as good as that of the main river at the points of confluence.

Comparison of these two summer profiles with others drawn for higher flows indicates that in the critical section below Pittsburgh, the general level of coliform-bacteria densities would tend to diminish with increased summer flows, and hence would be greatest at minimum flows.

Coliform densities in winter-spring season

Because of the indication from a study of winter coliform results at Weirton and Wheeling that the higher coliform densities in the river at these intakes occur at flows ranging from about 50,000 to 65,000 cfs at Sewickley, coliform-bacteria profiles have been drawn for these two flows, and also for a flow of 90,000 cfs, the latter as a check on the conclusion thus drawn. The three profiles are shown in Fig. 10. In this chart it will be noted that the profiles drawn for flows of 50,000 and 65,000 cfs follow each other closely, and that both profiles lie above the one drawn for a flow of 90,000 cfs. This would indicate that from the standpoint of general coliform levels at the water intakes below Pittsburgh, the flow range of 50,000 to 65,000 cfs is the more critical one.

Taking 50,000 cfs as the most critical winter flow in this respect, the profile for this flow has been re-plotted in Fig. 11, together with two other profiles showing the effects of 80 percent and 85 percent reductions in coliform organisms throughout the entire Pittsburgh-Huntington stretch. These profiles indicate that with 80 percent reduction, water of a quality meeting the Commission's objective would be provided at all intakes below the Pennsylvania-Ohio-West Virginia boundary, and would fall short of meeting the objective at the state line by a very narrow margin. With 85 percent reduction, a wider margin of safety would be provided both at the state line and at points downstream.

As deviations above average expected coliform densities in the river are more likely to occur during the winter, when flow conditions are subject to greater disturbance, a uniform minimum reduction schedule of 85 percent would appear to be the safer one under these circumstances. Moreover, this schedule would meet the requirements at Weirton and Wheeling more fully than would 80 percent reduction, and in the latter case would afford a first approximation to adequate relief of the excessive bacterial loads now indicated at that point (see Figs. 5 and 6).

In this connection, it should be pointed out that the increase in coliform densities now shown as occurring between the Weirton and Wheeling intakes is disproportionately high in comparison with the known total population contributing sewage to the river between these two points, suggesting the possibility that some local sources of pollution may be affecting the quality of water at the Wheeling intake. For this reason, treatment requirements for sewage in the upper section of the river should preferably be gauged by the needs existing at Weirton rather than those at Wheeling. Weirton is the nearer point to Pittsburgh and therefore, it would seem, is the point exposed to the greater pollution hazard.

Conclusions

On the basis of this investigation, it appears that 80 percent bacterial-reduction treatment during the months of May through October should provide adequate protection to all water supplies at normal summer-fall flows ranging down to 5,500 cfs at the Sewickley gage. At drought flows lower than 5,500 cfs at Sewickley (which might be expected to occur once every three or four years, but which would last for only a month at a time), the objective should be met at all points except in the section between Weirton and Wheeling, where coliform concentrations might exceed the objective by a narrow margin.

During the months of June through August, 80 percent bacterial-reduction treatment should provide water quality meeting the Commission's bathing-water objective in at least 150 miles of the river in all years except one out of ten. Bathing areas would be available in the lower part of the Pittsburgh-Huntington stretch, extending from about Mile Point 120.0 to Huntington. Provision of bathing areas in the upper portion of the stretch would not be practicable with any reasonable bacterial-reduction schedule, because of the congestion of sewered population in this section of the river.

During the winter season of November through April, a uniform schedule of not less than 80 percent reduction of coliform organisms would substantially meet the Commission's water-supply objective at all water intakes below the Pennsylvania-Ohio-West Virginia state line. However, the conslusion is reached that 80 percent treatment would not provide an adequate margin of safety for protection of water supplies, and that during the winter season treatment should be increased to not less than 85 percent reduction in coliforms. A greater margin of safety is needed during the winter season, when flow conditions are subject to greater disturbance than in the summer, and consequently deviations in coliform-bacterial loads above the average are more likely to occur. Moreover, on the basis of actual observations at Weirton and Wheeling, an 85 percent minimum reduction would meet more fully the bacterial requirements at these two points, where coliform loads are higher than at any other intakes between the state line and Huntington.

TABLES and FIGURES

Table No.

Figure No.

Table I - Municipal water supplies taken from the Ohio River between Pittsburgh and Huntington

Municipality	State	Location of intake (miles below Pittsburgh)	Municipality	State	Location of intake (miles below Pittsburgh)
Midland	Pennsylvania	35.9	Wheeling	W. Virginia	86.8
E. Liverpool	Ohio	40.2	Bellaire	Ohio	94.0
Toronto	Ohio	59.1	Sistersville	W. Virginia	137.3
Weirton	W. Virginia	62.5	Pomeroy	Ohio	248.3
Steubenville	Ohio	65.3			

Table II - Minimum recorded river flows at Sewickley and Huntington gages

Year	Sewickley gage					Huntington gage				
	minimum recorded flow in cfs for indicated period				Month of minimum flow	minimum recorded flow in cfs for indicated period				Month of minimum flow
	Day	Week	Two Weeks	Calendar month		Day	Week	Two Weeks	Calendar month	
1934	2,150	2,481	2,971	4,597	July	3,200	6,740	7,140	12,770	Sept.
1935	4,220	4,390	4,593	5,561	Oct.	3,200	6,340	7,760	11,840	Oct.
1936	2,660	2,943	3,209	4,880	Sept.	4,400	6,640	7,610	11,690	Sept.
1937	3,500	3,724	4,137	10,300	Sept.	3,200	7,440	8,650	26,780	Sept.
1938	3,380	3,604	3,689	4,965	Oct.	3,940	6,570	6,660	9,106	Oct.
1939	2,550	2,679	2,908	3,113	Sept.	4,880	6,030	6,860	7,837	Sept.
1940	3,340	3,664	3,809	5,815	Oct.	7,460	9,930	10,310	11,790	Oct.
1941	3,190	3,749	4,276	6,894	Oct.	4,100	6,280	7,530	11,890	Oct.
1942	5,150	7,164	9,564	14,960	Sept.	9,590	15,660	21,720	29,670	Sept.
1943	2,650	2,770	2,899	4,904	Sept.	5,330	7,030	7,250	10,650	Oct.
1944	3,190	3,589	3,708	4,008	Aug.	5,550	7,390	7,990	8,409	Aug.
1945	4,570	6,100	6,906	11,470	July	5,380	11,330	12,960	24,520	July
1946	2,450	2,644	2,909	3,081	Sept.	3,220	5,960	6,300	7,343	Sept.
1947	2,920	3,191	3,266	3,854	Oct.	5,270	9,460	10,480	11,660	Oct.
1948	4,560	4,806	5,116	6,751	Sept.	6,260	10,500	11,900	15,830	Sept.
1949	4,100	4,664	5,456	4,835	Oct.	7,080	13,286	13,357	15,210	Oct.

Table III - Minimum recorded river flows adjusted for reservoir operation (Sewickley and Huntington gages)								
	Sewickley gage					Huntington gage		
	Minimum adjusted flow in cfs for indicated period					Minimum adjusted flow in cfs for indicated period		
Year	Day	Week	Two Week	Calendar Month	Day	Week	Two Week	Calendar Month
1934	3,190	3,521	4,011	5,637	4,610	8,150	8,550	14,180
1935	5,260	5,430	5,633	6,601	4,610	7,750	9,170	13,250
1936	3,700	3,983	4,249	5,920	5,810	8,050	9,020	13,100
1937	4,540	4,764	5,177	11,340	4,610	8,850	10,060	28,190
1938	4,080	4,304	4,389	5,665	5,010	7,640	7,730	10,176
1939	3,250	3,379	3,608	3,813	5,950	7,100	7,930	8,907
1940	4,040	4,364	4,509	6,515	8,530	11,000	11,380	12,860
1941	3,890	4,449	4,976	7,591	5,170	7,350	8,600	12,960
1942	5,850	7,864	10,264	21,960	10,660	16,730	22,790	30,740
1943	3,350	3,470	3,599	5,604	6,230	7,730	8,150	11,550
1944	3,890	4,289	4,408	4,708	6,250	8,090	8,690	9,109
1945	5,270	6,800	7,606	12,170	6,080	12,030	13,660	25,220
1946	3,150	3,344	3,609	3,781	3,920	6,660	7,000	8,043
1947	3,620	3,891	3,966	4,554	5,970	10,160	11,180	12,360
1948	4,760	5,006	5,316	6,951	6,460	10,700	12,100	16,030
1949	4,300	4,864	5,656	5,035	7,280	13,486	13,557	15,410

Table IV - 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)
Tygart	1938	340	Prior to 1938	1,410
Berlin	July 1943	170	1938 to July 1943	1,070
Mosquito Creek	April 1944	200	July 1943 to April 1944	900
Youghiogheny	1948	500	April 1944 to 1948	700
East Branch Clarion	January 1953	200	1948 to 1953	200
	Total	1,410		

Drought Severity	Sewickley gage: Minimum Daily	Sewickley gage: Minimum Weekly	Sewickley gage: Minimum 2 Week	Sewickley gage: Minimum Calendar Month	Huntington gage: Minimum Daily	Huntington gage: Minimum Weekly	Huntington gage: Minimum 2 Week	Huntington gage: Minimum Calendar Month
Most probable drought	4,120	4,520	4,700	6,310	6,150	8,460	9,520	14,080
Once in 5 years	3,430	3,670	3,920	4,690	4,830	7,470	8,110	10,180
Once in 7 years	3,260	3,460	3,730	4,280	4,500	7,230	7,760	9,220
Once in 10 years	3,090	3,250	3,530	3,870	4,170	6,980	7,400	8,230
Once in 15 years	2,900	3,010	3,310	3,410	3,800	6,700	7,000	7,130
Once in 20 years	2,760	2,850	3,160	3,090	3,540	6,510	6,730	6,730

Table V - Probability of drought flows at Sewickley and Huntington gages (based on adjusted flow records)

Table VI - Seasonal flow frequencies at Sewickley and Huntington

Percent of Months	Monthly average flows (in cfs) equal to or greater than values shown below may be expected for indicated percentage of months in each season			
	Winter season (November through March)		Bathing season (June through August)	
	Sewickley	Huntington	Sewickley	Huntington
97.5	10,000	19,000	5,500	12,000
95	12,000	21,000	6,200	14,500
90	14,000	28,000	7,700	19,000
80	20,000	43,000	10,500	26,000
70	26,000	59,000	12,600	32,000
60	33,000	76,000	13,800	37,500
50	40,000	93,000	14,700	41,500
40	47,000	109,000	16,200	45,000
30	55,000	129,000	19,300	49,000
20	64,000	154,000	24,500	56,500
10	77,000	188,000	31,000	85,000

Table VII - Estimated BOD loads discharged to the Ohio River between Pittsburgh and Huntington (loads shown include industrial discharges)

Point or area	State	Miles below Pittsburgh	Census population 1940	Census population 1950	Estimated Sewered population 1940	Estimated Sewered population 1950	Estimated BOD load in population equivalents 1940	Estimated BOD load in population equivalents 1950
Pittsburgh & environs	Pa.		1,010,000	1,338,500	970,000	1,290,000	1,390,000	1,860,000
Allegheny county exclusive of Pittsburgh area	Pa.		401,539	176,737	451,360	173,400	651,360	283,400
Harmony & Ambridge	Pa.	16	18,968	20,930	25,000	20,930	25,000	21,000
Aliquippa-Conway	Pa.	20	27,023	33,521	27,000	33,500	120,000	125,000
Freedom	Pa.	24	3,227	3,000	3,200	3,000	4,900	4,600
Monaca	Pa.	25	7,061	7,415	8,000	8,400	8,000	8,400
Rochester	Pa.	25	7,441	10,902	10,000	10,900	10,000	11,000
New Brighton	Pa.			9,535				
Beaver River		25						56,800
Beaver & Buro Twp.	Pa.			4,537				
Midland	Pa.	37	6,373	6,491	6,300	6,400	34,300	35,000
Chester	W.Va.	43						1,350
E. Liverpool	Ohio	44	23,555	24,217	21,000	21,600	26,155	26,900
Newell	W.Va.	45		900				3,900
Wellsville	Ohio	48	7,672	7,854	7,600	7,800	7,600	7,900
Toronto	Ohio	60	7,426	7,253	7,000	6,800	13,700	14,680
Weirton	W.Va.	62	16,700	24,005	16,700	24,000	36,500	60,000
Steubenville	Ohio	68	37,651	35,872	32,000	30,000	44,000	50,430
Follansbee	W.Va.	71	4,834	4,435	4,800	4,400	36,800	34,000
Mingo Junction	Ohio	71	5,192	4,464	5,100	4,400	5,100	5,260
Brilliant	Ohio	75						2,050
Wellsburg	W.Va.	75	6,255	5,787	5,500	5,100	6,400	5,900
Rayland-Tiltonville	Ohio	83						2,750
Yorkville	Ohio	84						2,900
Martins Ferry	Ohio	89	14,729	13,220	14,700	13,200	14,700	18,200
Bridgeport-Brookside	Ohio	90	5,828	5,154	5,600	5,000	5,600	5,000
Wheeling	W.Va.	91	61,099	58,891	67,300	65,000	90,100	87,000
Benwood	W.Va.	94				1,680		1,680
Bellaire	Ohio	95	13,799	12,573	13,500	12,300	13,500	12,300
Moundsville	W.Va.	102	14,168	14,772	16,000	16,700	16,000	16,700
New Martinsville	W.Va.	128	3,491	4,084	3,400	4,000	3,400	4,000
Sistersville	W.Va.	138	2,702	2,313	2,800	2,400	2,800	2,400
Marietta	Ohio	172	14,543	16,006	13,000	14,300	29,500	39,440
Muskingum River		172						154,000
Little Kanawha River		185						57,200
Parkersburg	W.Va.	185	30,103	29,684	36,000	35,500	82,000	92,000
Hocking River		199						22,200
Letart Falls	Ohio	235						1,500
Pomeroy-Middleport	Ohio	252	6,937	7,102	6,000	6,100	6,000	7,270
Pt. Pleasant	W.Va.		3,538	4,596	3,500	4,500	3,500	4,500
Kanawha River		266						147,000
Gallipolis	Ohio	270	7,832	7,871	5,000	5,000	5,000	9,500

Table VIII - Industries known or reported to be discharging wastes directly to the Ohio River in the stretch between Pittsburgh and Huntington

Pennsylvania		
	Allis-Chalmers Manufacturing Company	Pittsburgh
	Cruikshank Brothers	Pittsburgh
	Schoen Wheel & Axle Division Carnegie-Illinois Steel Corporation	McKees Rocks
	Pittsburgh Coke and Chemical Company	Neville Township
	Gulf Oil Corporation	Neville Township
	Neville Company	Neville Township
	Dravo Corporation	Neville Township
	Marcus Ruth Jerome Company	Neville Township
	National Cylinder Gas Company	Neville Township
	Frick and Lindsay Company	Neville Township
	Air Reduction Sales	Neville Township
	Vilsack Fisher Company	Neville Township
	The Vulcan Detinning Company	Neville Township
	Pittsburgh Barrel and Drum Company	Neville Township
	Pittsburgh Screw and Bolt Company	Neville Township
	Sterling Varnish Company	Haysville
	The Canfield Oil Company	Coraopolis
	The Pittsburgh Forging Company	Coraopolis
	Standard Steel Spring Company	Moon Township
	Division Blaw-Knox Company Lewis Foundry & Machine Company	Moon Township
	Continental Foundry and Machine Company	Moon Township
	Russell Birdsall and Ward Bolt and Nut Company	Moon Township
	Bethlehem Steel Company	Leetsdale
	Spang-Chalfant Division The National Supply Company	Ambridge
	The National Electric Products Company	Ambridge
	Wycoff Steel Company	Ambridge
	A. M. Byers Company	Harmony Township
	Jones & Laughlin Steel Corporation	Aliquippa
	Pennsylvania Railroad	Conway
	Freedom Valvoline Oil Works	Freedom
	Colonial Division Pittsburgh Screw & Bolt Corporation	Monaca
	Division of Vanadium Corporation of America Colonial Steel Corporation	Monaca
	Pittsburgh Tool Steel Wire Company	Monaca
	St. Joseph Lead Company of Pennsylvania	Potter Township
	Phthalic Anhydride Plant Koppers Company	Potter Township
	Kobuta Plant Koppers Company	Potter Township
	Pittsburgh Crucible Steel Company	Midland
West Virginia		
	Harker Pottery Company	Chester
	Taylor, Smith and Taylor	Chester
	Knowles China Company	Newell
	Homer Laughlin China Company	Newell
	New Castle Refractories Company	Newell
	Weirton Steel Company	Weirton
	Koppers Company, Tar Products Division	Follansbee
	Wheeling Steel Company	Follansbee

Table VIII (continued) - Industries known or reported to be discharging wastes directly to the Ohio River in the stretch between Pittsburgh and Huntington

West Virginia (continued)		
	Follansbee Steel Corporation	Follansbee
	Sheet Metal Specialty Company	Follansbee
	Pillsbury Mills, Inc.	Wellsburg
	S. George and Company	Wellsburg
	Beech Bottom Works Wheeling Steel Company	Beech Bottom
	Beech Bottom Power Company	Beech Bottom
	Ackerman Plant Wheeling Steel Company	Warwood
	Zinc Recovery Plant Wheeling Steel Company	Wheeling
	J. L. Stifel and Sons, Inc.	Wheeling
	Riverside Blast Furnace Wheeling Steel Company	Benwood
	Benwood Works Wheeling Steel Company	Benwood
	Vulcan Rail & Construction Company	Benwood
	L. Marx and Company	Glen Dale
	Wheeling Metal & Manufacturing Company	Glen Dale
	Triangle Conduit & Cable Company	Moundsville
	Glyco Products Company, Inc.	New Martinsville
	Columbia Southern Chemical Corporation	New Martinsville
	Quaker State Oil Refining Company	St. Marys
	E. I. duPont Company	Parkersburg
	Penn Metal Company	Parkersburg
	Parkersburg Steel Company	Parkersburg
	Ohio River Salt Corporation	Mason
	Marietta Manufacturing Company	Point Pleasant
Ohio		
	National Drawn Works Crucible Steel Company of America	East Liverpool
	Patterson Foundry & Machine Company	East Liverpool
	Pennsylvania Railroad Yard	Wellsville
	Toronto Paper Manufacturing Company	Toronto
	Anco Glass Company, Inc.	Toronto
	Ohio River Steel Company	Toronto
	Steubenville Pottery Company	Steubenville
	Liberty Paperboard Company	Steubenville
	Weirton Steel Company	Steubenville
	Wheeling Steel Corporation	Steubenville
	Wheeling Steel Corporation	Mingo Junction
	Pennsylvania Railroad Yard	Mingo Junction
	Wheeling Steel Corporation	Yorkville
	Wheeling Steel Corporation	Martins Ferry
	Calco Chemical Division American Cyanimide Company	Marietta
	Broughton's Dairy	Marietta
	Electro-Metallurgical Company	Marietta
	Bakelite Division Union Carbide & Carbon Company	Marietta
	Crow Bros. Poultry Company	Letart Falls
	Pomeroy Salt Company	Minersville
	Parkersburg Rig & Reel Company	Pomeroy

Table IX - Coliform densities and stream flows at four waterworks intakes (data from monitor survey coliform densities and stream flows are monthly averages)

MONTH	WEIRTON		WHEELING		POMEROY		HUNTINGTON	
	Flow in 1,000 cfs	Coliform MPN per 100 ml	Flow in 1,000 cfs	Coliform MPN per 100 ml	Flow in 1,000 cfs	Coliform MPN per 100 ml	Flow in 1,000 cfs	Coliform MPN per 100 ml
1950								
August	9.55		9.91	54,500	15.3	740	21.2	560
September	23.7		24.6	37,400	36.7	13,200	50.7	1,800
October	16.2	23,800	16.8	42,900	17.7	1,100	24.4	990
November	63.0	41,100	64.1	62,400	60.7	10,500	83.8	1,400
December	90.7	17,600	94.0	39,200	128.6	11,300	177.4	3,000
1951								
January	98.7	13,100	102.5	16,000	124.2	3,600	171.4	4,200
February	101.0	11,600	104.6	19,000	149.3	10,100	206.2	6,000
March	83.5	25,900	86.6	32,400			175.0	4,500
April	91.9	29,000	95.4	36,800			167.4	2,300
May	40.3	27,700	41.8	18,300			82.2	
June	49.6	13,000	51.5	65,100			74.3	
July	25.4	11,300	26.3				37.2	1,900
August	4.68	2,700	4.85	62,600			10.1	1,500
September	4.53	10,700	4.70	19,600			11.1	
October	4.76	11,900	4.83				7.5	
November	25.2	23,000	26.2	47,200			41.5	2,300
December	54.0	26,900	56.0	81,300			110.4	5,500
1952								
January	132.5	10,100	137.5	132,000			226.0	4,500
February	68.8	8,800	71.4	43,800			162.8	3,250
March	82.3	15,800	85.4	45,100			161.4	4,500
April		16,100		32,000			127.6	4,500
May		18,200		98,800			116.3	3,600
June				17,400			30.2	2,300

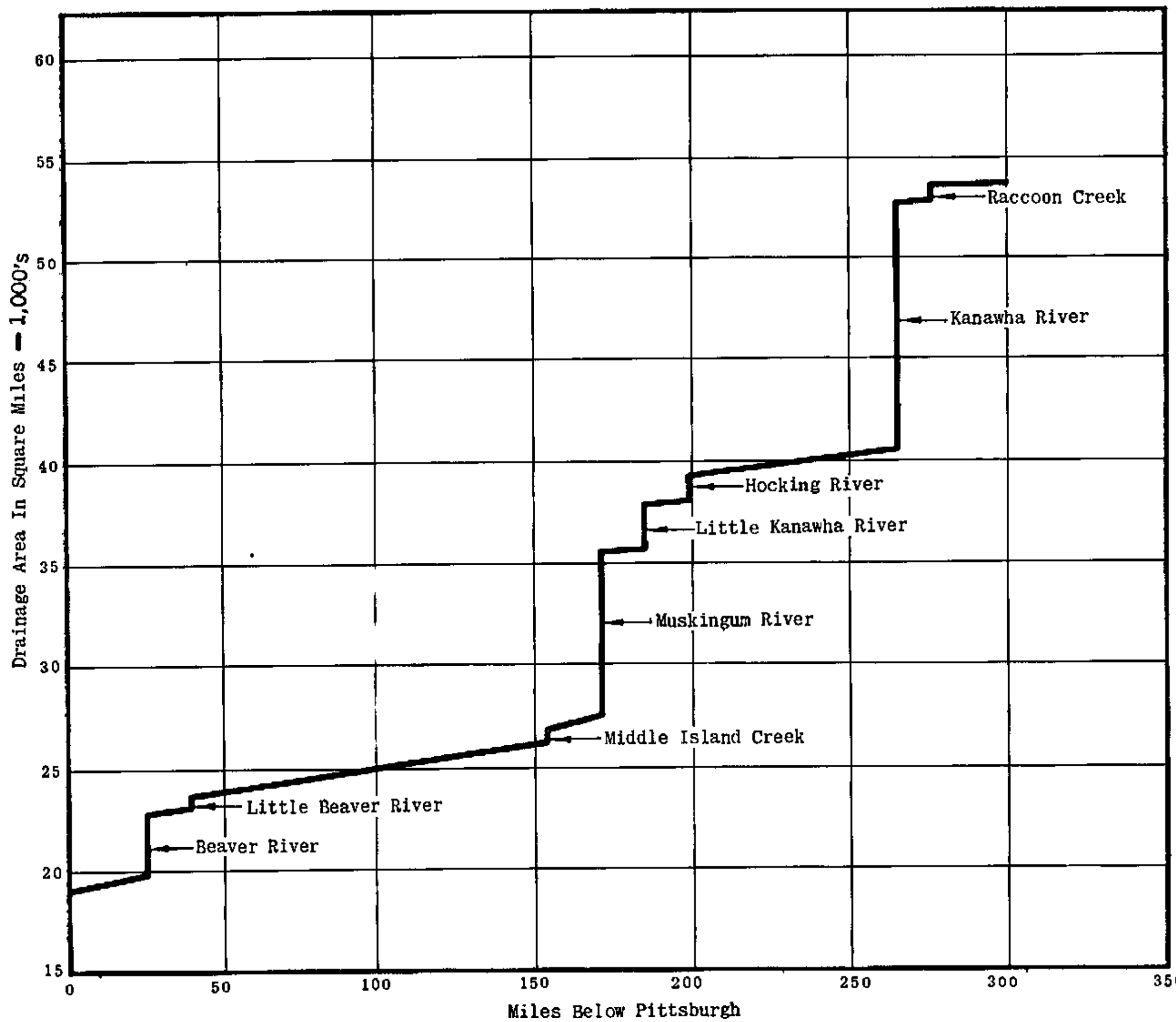

FIG. 2 - DRAINAGE AREA ABOVE POINTS IN OHIO RIVER
between Pittsburgh and Huntington

March 1953

ORSANCO

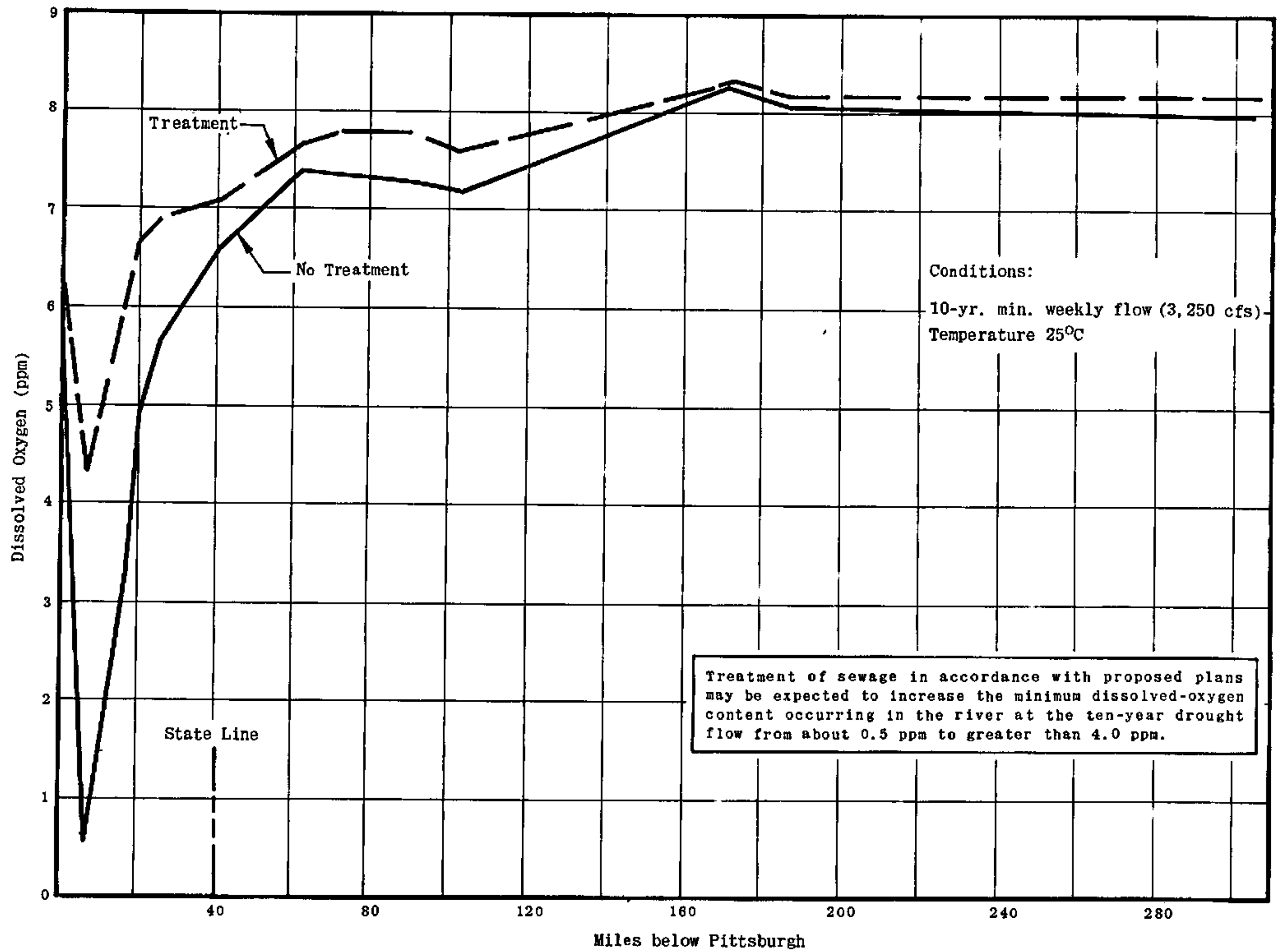

FIG. 3 - DISSOLVED OXYGEN PROFILES in Ohio River between Pittsburgh and Huntington

March 1953 ORSANCO

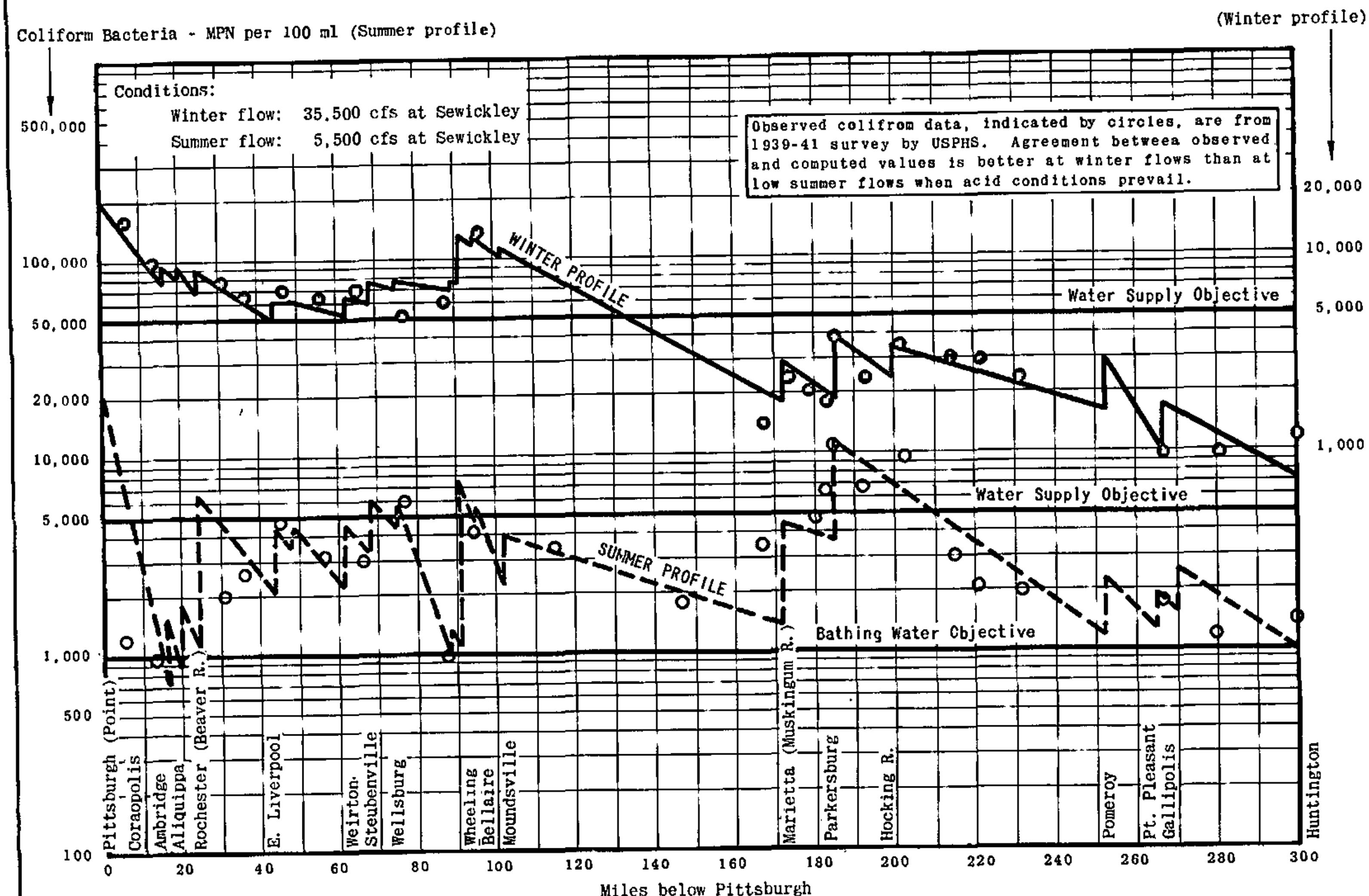

FIG. 4 - COMPUTED AND OBSERVED COLIFORM PROFILES in Ohio River between Pittsburgh and Huntington

March 1953

ORSANCO

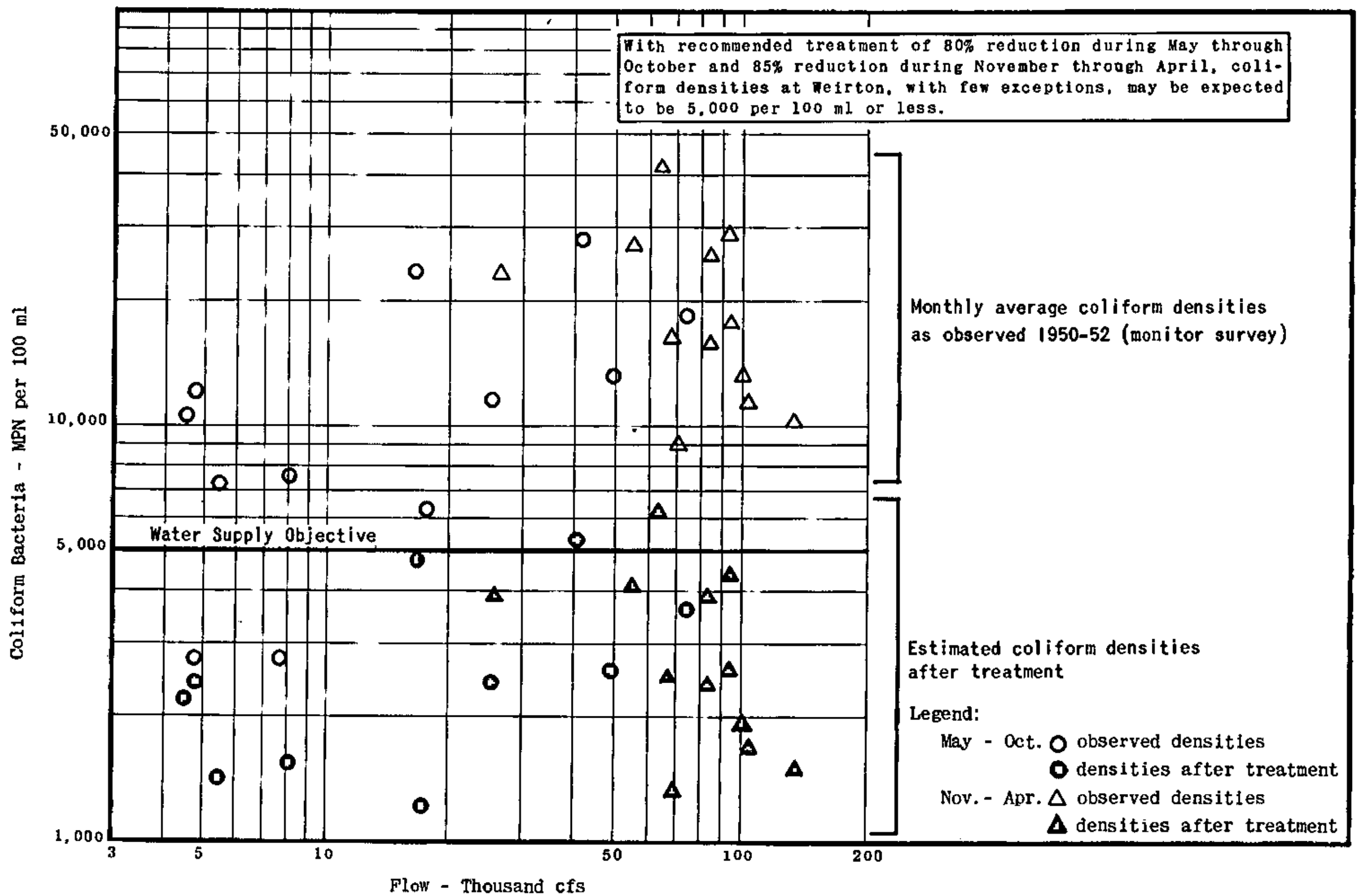

FIG. 5 - OBSERVED COLIFORM DENSITIES AT WEIRTON INTAKE
and effect of bacterial-reduction treatment

March 1953

ORSANCO

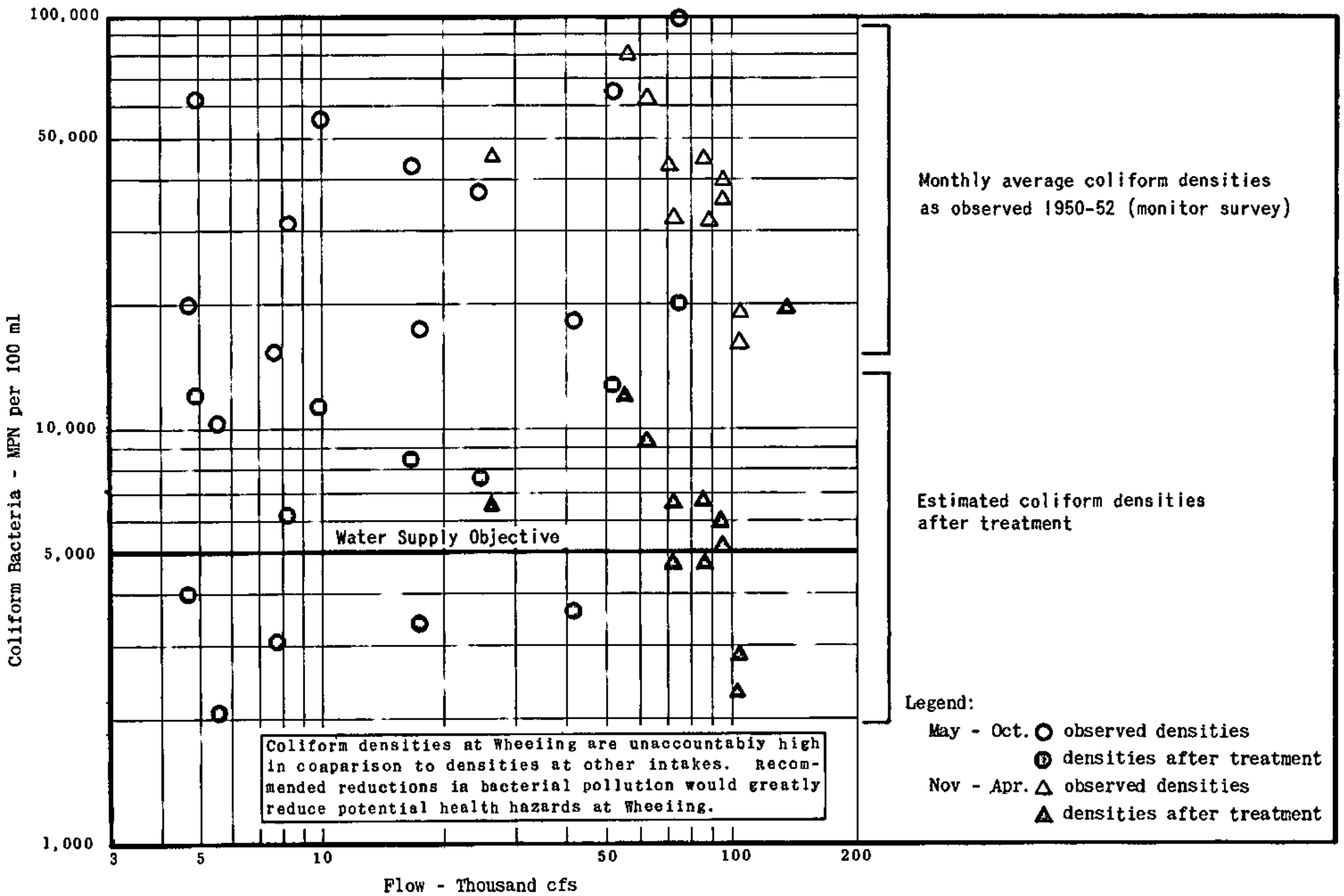

FIG. 6 - OBSERVED COLIFORM DENSITIES AT WHEELING INTAKE
and effect af bacterial-reduction treatment

March 1953

ORSANCO

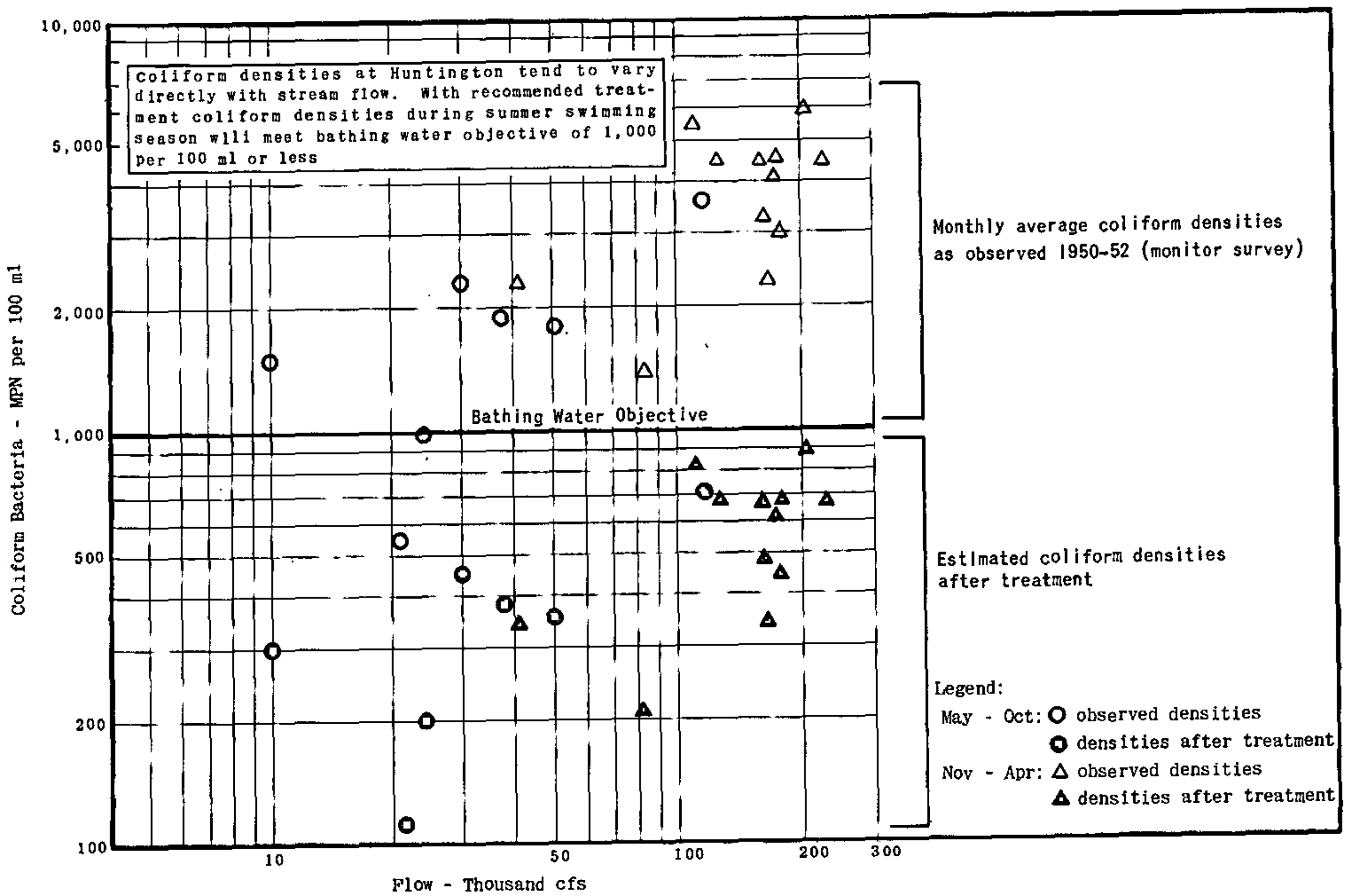

FIG. 7 - OBSERVED COLIFORM DENSITIES AT HUNTINGTON INTAKE
and effect of bacterial-reduction treatment

March 1953

ORSANCO

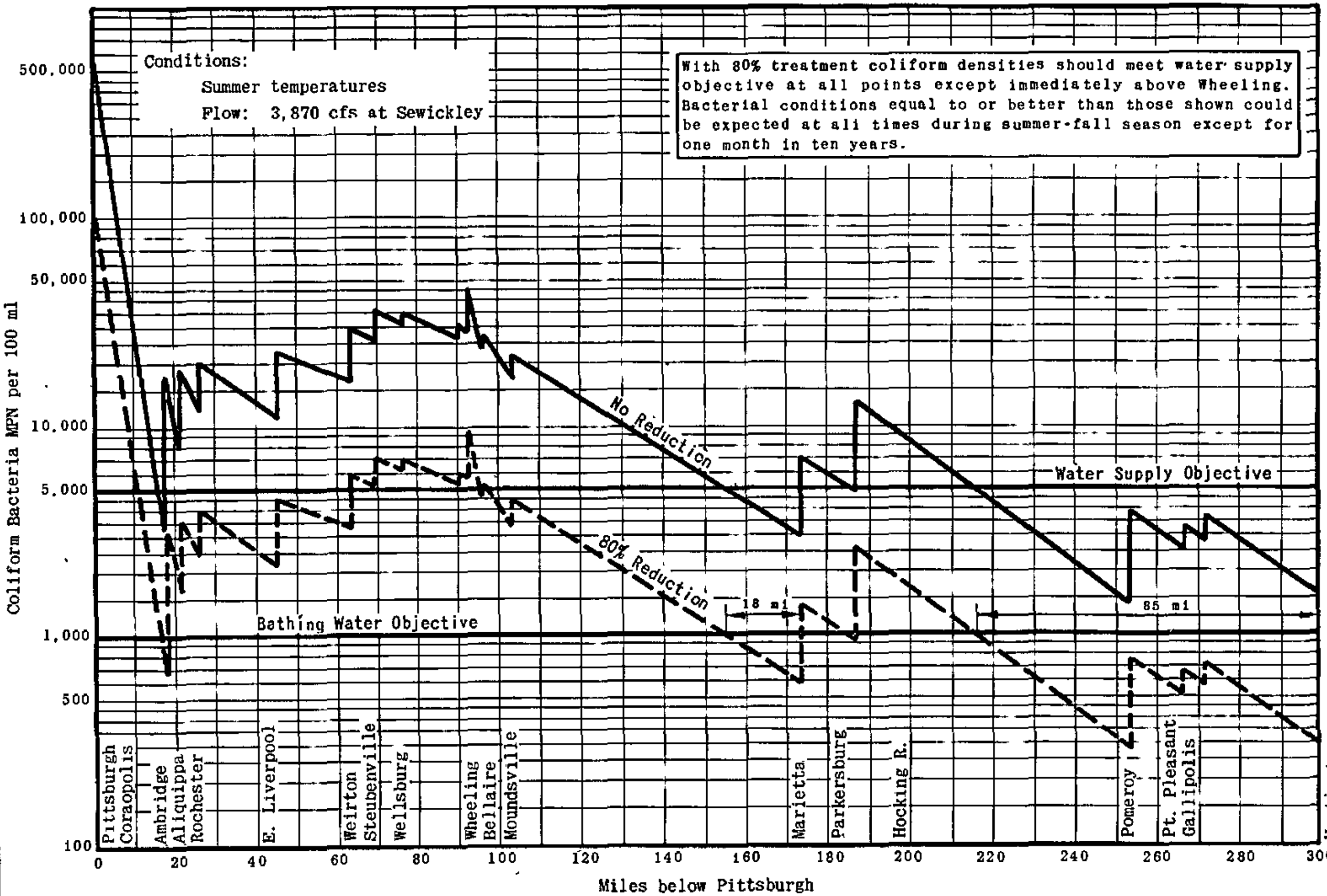

FIG. 8 - EFFECT OF BACTERIAL-REDUCTION TREATMENT AT TEN-YEAR MINIMUM FLOW; Ohio River between Pittsburgh and Huntington

March 1953

ORSANCO

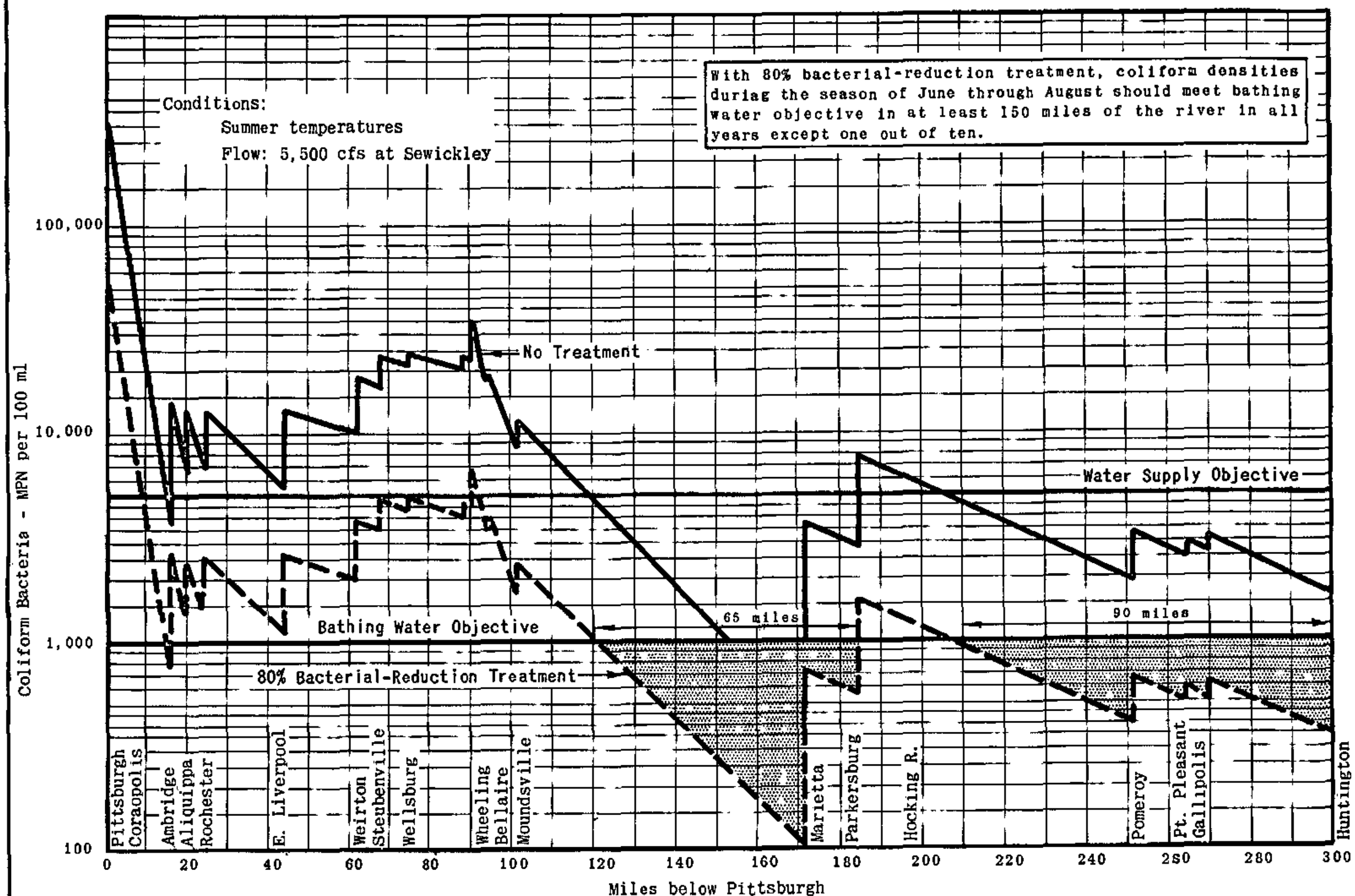

FIG. 9 - EFFECT OF BACTERIAL-REDUCTION TREATMENT AT LOW FLOW DURING MONTHS JUNE THROUGH AUGUST; Ohio River between Pittsburgh and Huntington

March 1953

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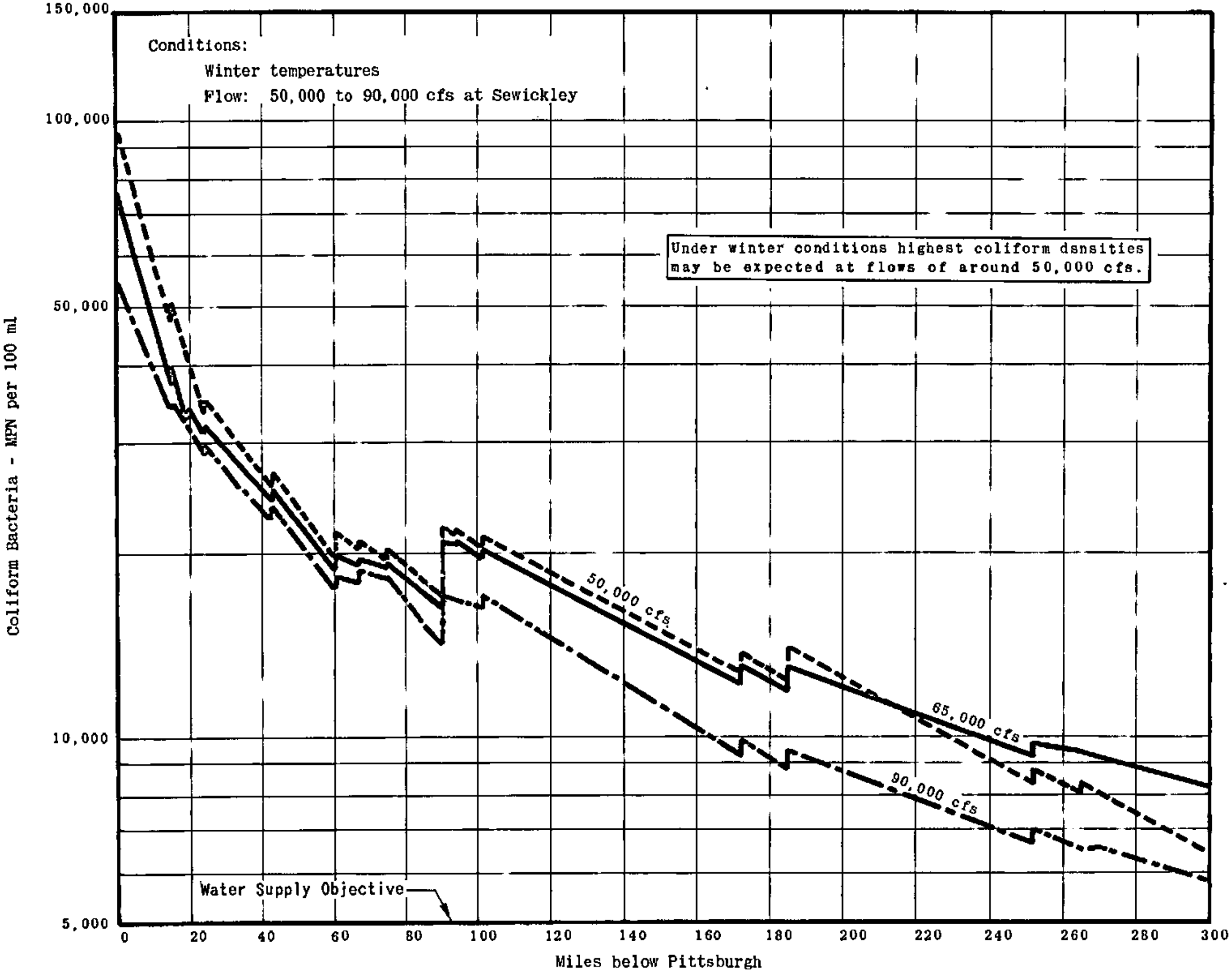

FIG. 10 - COLIFORM PROFILES AT WINTER TEMPERATURES AND VARYING FLOWS; Ohio River between Pittsburgh and Huntington

March 1953

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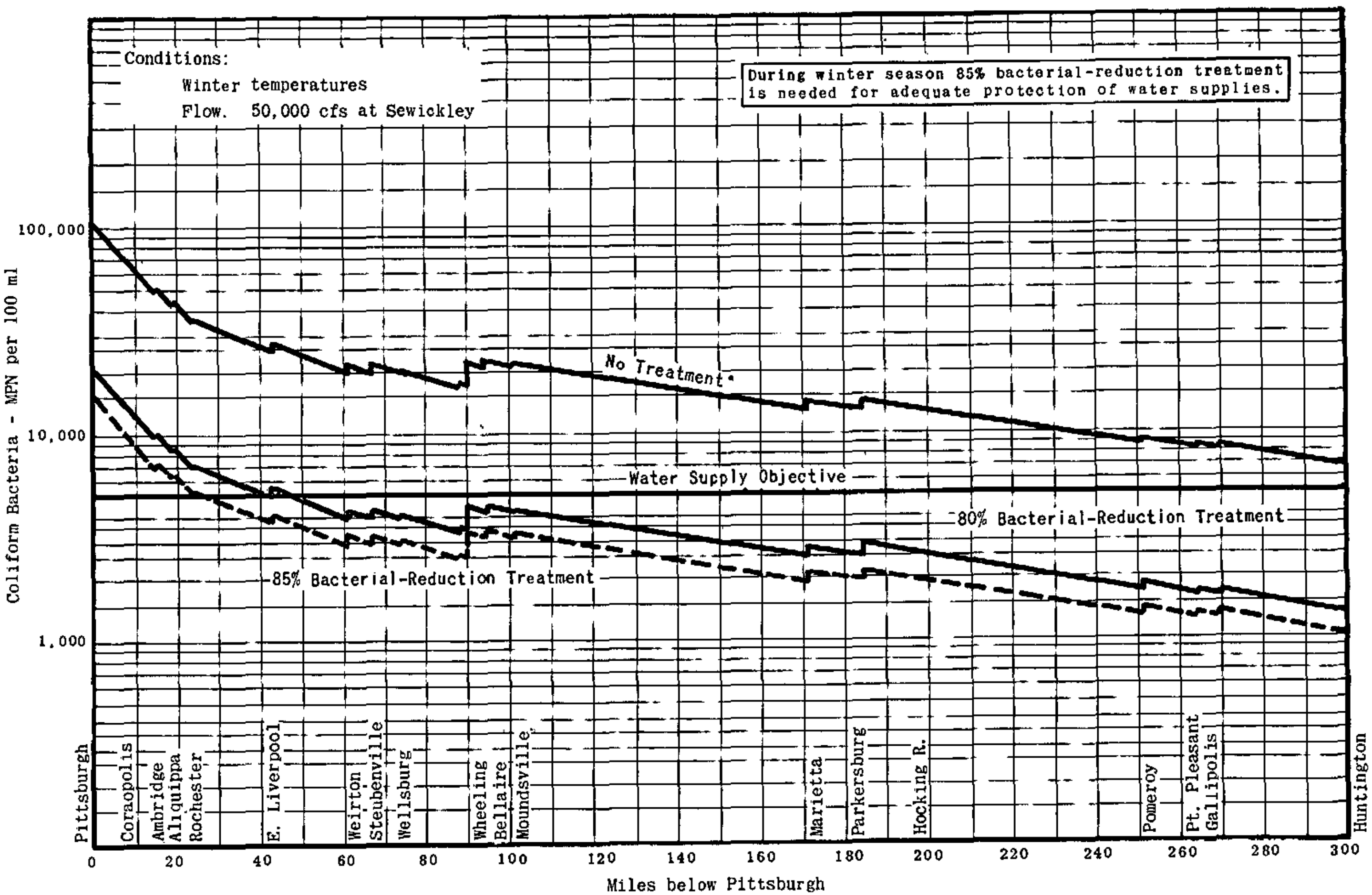

FIG. 11 - EFFECT OF BACTERIAL-REDUCTION TREATMENT DURING WINTER SEASON; Ohio River between Pittsburgh and Huntington

March 1953

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