Proceedings and Final Action

Treatment Requirements for Sewage Discharged into the Ohio River between Cincinnati and Cairo

Treatment Standard No. 5
Treatment Standard No. 6
Treatment Standard No. 7

Adopted January 13, 1954

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.

HEADQUARTERS • 414 WALNUT ST. • CINCINNATI 2, OHIO

PROCEEDINGS AND FINAL ACTION

DETERMINING TREATMENT REQUIREMENTS FOR SEWAGE DISCHARGED INTO THE OHIO RIVER BETWEEN CINCINNATI AND CAIRO

Public Hearing held on December 9, 1953, Courtroom No.1,
U. S. Post Office and Court House, Louisville, Kentucky

Members of the Hearing Board:

Henry Ward, *Chairman*
Commissioner for Kentucky

Joseph L. Quinn, Jr.
Commissioner for Indiana

W. H. Wisely
Commissioner for Illinois

Appearances for the Commission:

Edward J. Cleary, *Executive Director and Chief Engineer*

Leonard A. Weakley, *Counsel*

Robert K. Horton, *Sanitary Engineer*

F. H. Waring, *Secretary of the Commission and Chief Sanitary Engineer, Ohio Department of Health*

B. A. Poole, *Commissioner for Indiana and Technical Secretary of the Indiana Stream Pollution Control Board and Chief Engineer of the Indiana State Board of Health*

Louis Birkel, *Executive Director of the Kentucky Water Pollution Control Board*

William Hasfurther, *Sanitary Engineer for the Illinois Department of Public Health*

W. W. Towne, *Officer-in-Charge, Ohio and Tennessee Drainage Basins, U. S. Public Health Service*

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EXHIBITS

REPORT ON PUBLIC HEARING

HELD AT LOUISVILLE, KY., DECEMBER 9, 1953

Ohio River Valley Water
Sanitation Commission
414 Walnut Street
Cincinnati 2, Ohio

Gentlemen:

The undersigned, appointed pursuant to action taken by the Commission at its meeting of October 7, 1953, constitute the Hearing Board empowered and instructed to conduct a public hearing with regard to the degree of treatment which shall be given to sewage discharged or permitted to flow into the waters of the Ohio River between Dam No. 37 (located near Cincinnati, Ohio) and the point of confluence of the Ohio River with the Mississippi River near Cairo, Illinois. In accordance with a directive of the Commission, the undersigned submit the following report of the conduct of such hearing together with their findings and recommendations based upon the testimony and other evidence presented at that hearing.

1. The hearing was held, with all members of the Hearing Board present, on the 9th day of December, 1953, at Courtroom No. 1, second floor, U. S. Post Office and Court House, 601 West Broadway, Louisville, Kentucky, commencing at 10:00 A. M. A complete stenographic transcript was made of the proceedings had at the hearing and a copy thereof is filed herewith.

2. Prior notice of the hearing had been published and had been served upon interested parties in the manner and to the extent set forth in the transcript of proceedings filed herewith.

3. Parties interested in the subject matter of the hearing were present or were represented to the extent indicated by the roster of appearances which is attached to the transcript of proceedings filed herewith.

4. A written report of the Commission staff setting forth information, data, findings and other evidence, relevant and material to the subject matter of the hearing, was presented in evidence and was supported by oral testimony of members of the staff. A copy of that report is attached as an exhibit to the transcript of proceedings filed herewith.

5. Full opportunity was given to all parties present or represented at the hearing to introduce evidence or testimony relevant or material to the subject matter of the hearing and to express their views with regard to the report and recommendations of the staff. No evidence other than that presented by the staff was offered. All views expressed by those present have been duly considered by the Board in reaching the conclusions and recommendations set forth below.

6. Opportunity for the submission of written evidence or views pertinent to the subject matter of the hearing was expressly provided to any interested party, subject to the condition that it be submitted to the Hearing Board on or before the 31st day of December, 1953. All such additional evidence and

views have been duly considered by the Board in reaching the conclusions and recommendations set forth below.

7. From a consideration of all evidence presented, this Board finds that the information and other data submitted as above stated by the staff are accurate and pertinent to the subject matter of the hearing, and the Board further finds that the conclusions of the staff which are expressed in the written report presented at the hearing, as above stated, are reasonable and are fully supported by the evidence and data therein contained.

8. The Board finds that standards of treatment for sewage to be discharged or permitted to flow into this section of the Ohio River, should be adopted by the Commission and put into effect, which (1) will maintain satisfactory oxygen levels in that stretch of the Ohio River between Cincinnati, Ohio and Cairo, Illinois; (2) will provide adequate protection for public water supplies located in this section of the Ohio River; (3) will under normal summer flow conditions maintain in various areas a water quality, suitable for recreational purposes; and (4) will otherwise accomplish the objectives of the Ohio River Valley Water Sanitation Compact with respect to the discharge of sewage into this stretch of the Ohio River. On the basis of information and data submitted the Board is of the opinion that establishment of the standards of treatment for sewage which are hereinafter recommended is based upon these considerations, is reasonable and is in conformity with the provisions of the Ohio River Valley Water Sanitation Compact.

9. Therefore, this Board recommends that the Commission take appropriate action to establish, subject to revision as changing condition may require, the following standards for the treatment of sewage:

TREATMENT STANDARD NO. 5:

All sewage from municipalities or other political subdivisions, public or private institutions, or corporations discharged or permitted to flow into that portion of the Ohio River extending from mile point 483.2 (miles below Pittsburgh, Pa.), located about ten miles downstream from Cincinnati and at which point is located Dam No. 37, to mile point 750.0 (miles below Pittsburgh, Pa.), located about six miles upstream from Owensboro, Ky., shall be so treated as to provide for:

(a) Substantially complete removal of settleable solids; and

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

TREATMENT STANDARD NO. 6

All sewage from municipalities or other political subdivisions, public or private institutions, or corporations discharged or permitted to flow into that portion of the Ohio River extending from mile point 750.0 (miles below Pittsburgh, Pa.), located about six miles upstream from Owensboro, Ky., to mile point 803.0 (miles below Pittsburgh, Pa.), located near Henderson, Ky., shall be so treated as to provide for:

(a) Substantially complete removal of settleable solids; and

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

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

Not less than 85 percent reduction during the months May through October.
Not less than 65 percent reduction during the months November through April.

TREATMENT STANDARD NO. 7

All sewage from municipalities or other political subdivisions, public or private institutions, or corporations discharged or permitted to flow into that portion of the Ohio River extending from mile point 803.0 (miles below Pittsburgh, Pa.), located near Henderson, Ky., to Cairo Point, located at the confluence of the Ohio and Mississippi Rivers and being 981.0 miles downstream from Pittsburgh, Pa., shall be so treated as to provide for:

(a) Substantially complete removal of settleable solids; and

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

Respectfully submitted,

/s/ Henry Ward, Chairman

/s/ Joseph L. Quinn, Jr.

/s/ W. H. Wisely

Hearing Board

Cincinnati, Ohio
January 8, 1954

TREATMENT STANDARD NO. 5

ACTION DETERMINING DEGREE OF TREATMENT TO BE GIVEN TO SEWAGE DISCHARGED INTO THE OHIO RIVER BETWEEN MILE POINT 483.2, AT DAM NO. 37 NEAR CINCINNATI, OHIO, AND MILE POINT 750, NEAR OWENSBORO, KENTUCKY

WHEREAS, at a meeting duly held on October 7, 1953, this Commission determined that it was necessary, through the exercise of powers granted to it by the language of Article VI of the Ohio River Valley Water Sanitation Compact, to determine what, if any, degree of treatment higher than that specified in said Article should be given to sewage from municipalities or other political subdivisions public or private institutions or corporations discharged or permitted to flow into that portion of the Ohio River between Dam No. 37 (located near Cincinnati, Ohio) and the point of confluence of the Ohio River with the Mississippi River near Cairo, Illinois; and

WHEREAS, pursuant to action taken by the Commission at said meeting, a Hearing Board was appointed, empowered and instructed to conduct a public hearing with regard to the foregoing matter; and

WHEREAS, after notice of the time and place of said hearing had been given in the manner and to the extent set forth in the transcript of proceedings that has been filed with the Commission, the Hearing Board appointed as above set forth did, on the 9th day of December, 1953, conduct a public hearing at which technical reports and opinions, as well as other evidence relating to the foregoing matter, were received and at which all interested parties were given opportunity to express opinions and to present evidence with respect to the problem under investigation; and

WHEREAS, copies of a full and complete stenographic transcript of the proceedings had at the hearing thus held, together with copies of findings and recommendations of the Hearing Board, have been filed with the Commission and have been distributed among the members hereof;

NOW THEREFORE, following due consideration of the findings and recommendations contained in the report of the Hearing Board covering the proceedings had at the hearing held as above set forth; and following due consideration of the testimony and other evidence produced at that hearing, together with the various views and opinions there expressed, all as set forth in the above-mentioned transcript of proceedings,

THE COMMISSION DOES HEREBY FIND THAT:

1. The notice of the time and place at which the above-mentioned hearing was to be held was sufficient in form and extent of publication to advise all interested parties and all parties likely to be affected thereby;

2. The procedure followed by the Hearing Board in the conduct of the hearing held as above described adequately provided to all interested parties and all parties likely to be affected thereby full opportunity to be heard and to present any pertinent

testimony, evidence, opinions, or views which they might wish to submit for the consideration of the Commission;

3. The evidence obtained at the hearing held as above described shows that in order to protect the public health and to preserve the waters of the Ohio River in that stretch between mile point 483.2, at Dam No. 37 near Cincinnati, Ohio, and mile point 750.0 near Owensboro, Ky., for other legitimate uses within the contemplation of the Ohio River Valley Sanitation Compact a degree of treatment for sewage discharged or permitted to flow into those waters higher than the minimum prescribed in Article VI of the Compact is not needed; and

THE COMMISSION DOES HEREBY ESTABLISH, subject to revision as changing conditions may require, the following standard for the treatment of sewage from municipalities or other political subdivisions, public or private institutions, or corporations discharged or permitted to flow into that portion of the Ohio River extending from mile point 483.2 (miles below Pittsburgh, Pa.), located about ten miles downstream from Cincinnati and at which point is located Dam No. 37, to mile point 750.0 (miles below Pittsburgh, Pa.), located about six miles upstream from Owensboro, Ky.:

(a) Substantially complete removal of settleable solids; and

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

The foregoing action was taken by the Ohio River Valley Water Sanitation Commission at a meeting duly held on January 13, 1954 at Cincinnati, Ohio

Attest: /s/ F. H. Waring
Secretary

s/s H. E. Moses
Chairman

TREATMENT STANDARD NO. 6

ACTION DETERMINING DEGREE OF TREATMENT TO BE GIVEN TO SEWAGE DISCHARGED INTO THE OHIO RIVER BETWEEN MILE POINT 750, NEAR OWENSBORO, KENTUCKY, AND MILE POINT 803, NEAR HENDERSON, KENTUCKY

WHEREAS, at a meeting duly held on October 7, 1953, this Commission determined that it was necessary, through the exercise of powers granted to it by the language of Article VI of the Ohio River Valley Water Sanitation Compact, to determine what, if any, degree of treatment higher than that specified in said Article should be given to sewage from municipalities or other political subdivisions public or private institutions or corporations discharged or permitted to flow into that portion of the Ohio River between Dam No. 37 (located near Cincinnati, Ohio) and the point of confluence of the Ohio River with the Mississippi River near Cairo, Illinois; and

WHEREAS, pursuant to action taken by the Commission at said meeting, a Hearing Board was appointed, empowered and instructed to conduct a public hearing with regard to the foregoing matter; and

WHEREAS, after notice of the time and place of said hearing had been given in the manner and to the extent set forth in the transcript of proceedings that has been filed with the Commission, the Hearing Board appointed as above set forth did, on the 9th day of December, 1953, conduct a public hearing at which technical reports and opinions, as well as other evidence relating to the foregoing matter, were received and at which all interested parties were given opportunity to express opinions and to present evidence with respect to the problem under investigation; and

WHEREAS, copies of a full and complete stenographic transcript of the proceedings had at the hearing thus held, together with copies of findings and recommendations of the Hearing Board, have been filed with the Commission and have been distributed among the members hereof;

NOW THEREFORE, following due consideration of the findings and recommendations contained in the report of the Hearing Board covering the proceedings had at the hearing held as above set forth; and following due consideration of the testimony and other evidence produced at that hearing, together with the various views and opinions there expressed, all as set forth in the above-mentioned transcript of proceedings,

THE COMMISSION DOES HEREBY FIND THAT:

1. The notice of the time and place at which the above-mentioned hearing was to be held was sufficient in form and extent of publication to advise all interested parties and all parties likely to be affected thereby;

2. The procedure followed by the Hearing Board in the conduct of the hearing held as above described adequately provided to all interested parties and all parties likely to be affected thereby full opportunity to be heard and to present any pertinent

testimony, evidence, opinions, or views which they might wish to submit for the consideration of the Commission;

3. The evidence obtained at the hearing held as above described shows that in order to protect the public health and to preserve the waters of the Ohio River in that stretch between mile point 750 near Owensboro, Ky., and mile point 803 near Henderson, Ky., for other legitimate uses within the contemplation of the Ohio River Valley Water Sanitation Compact a degree of treatment must be given to sewage discharged or permitted to flow into those waters higher than the minimum prescribed in Article VI of the Compact; and

THE COMMISSION DOES HEREBY ESTABLISH, subject to revision as changing conditions may require, the following standard for the treatment of sewage from municipalities or other political subdivisions, public or private institutions, or corporations discharged or permitted to flow into that portion of the Ohio River extending from mile point 750.0 (miles below Pittsburgh, Pa.), located about six miles upstream from Owensboro, Ky.), to mile point 803.0 (miles below Pittsburgh, Pa.), located near Henderson, Ky.:

(a) Substantially complete removal of settleable solids; and

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

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

Not less than 85 percent reduction during the months May through October
Not less than 65 percent reduction during the months November through April

The foregoing action was taken by the Ohio River Valley Water Sanitation Commission at a regular meeting duly held on January 13, 1954, at Cincinnati, Ohio

Attest: /s/ F. H. Waring
Secretary

/s/ H. E. Moses
Chairman

TREATMENT STANDARD NO. 7

ACTION DETERMINING DEGREE OF TREATMENT TO BE GIVEN TO SEWAGE DISCHARGED INTO THE OHIO RIVER BETWEEN MILE POINT 803, NEAR HENDERSON, KENTUCKY AND MILE POINT 981, AT CAIRO POINT, ILLINOIS

WHEREAS, At a meeting duly held on October 7, 1953, this Commission determined that it was necessary, through the exercise of powers granted to it by the language of Article VI of the Ohio River Valley Water Sanitation Compact, to determine what, if any, degree of treatment higher than that specified in said Article should be given to sewage from municipalities or other political subdivision public or private institutions or corporations discharged or permitted to flow into that portion of the Ohio River between Dam No. 37 (located near Cincinnati, Ohio) and the point of confluence of the Ohio River with the Mississippi River near Cairo, Illinois; and

WHEREAS, pursuant to action taken by the Commission at said meeting, a Hearing Board was appointed, empowered, and instructed to conduct a public hearing with regard to the foregoing matter; and

WHEREAS, after notice of the time and place of said hearing has been given in the manner and to the extent set forth in the transcript of proceedings that has been filed with the Commission, the Hearing Board appointed as above set forth did, on the 9th day of December, 1953, conduct a public hearing at which technical reports and opinions, as well as other evidence relating to the foregoing matter, were received and at which all interested parties were given opportunity to express opinions and to present evidence with respect to the problem under investigation; and

WHEREAS, copies of a full and complete stenographic transcript of the proceedings had at the hearing thus held, together with copies of findings and recommendations of the Hearing Board, have been filed with the Commission and have been distributed among the members hereof;

NOW THEREFORE, following due consideration of the findings and recommendations contained in the report of the Hearing Board covering the proceedings had at the hearing held as above set forth; and following due consideration of the testimony and other evidence produced at that hearing, together with the various views and opinions there expressed, all as set forth in the above-mentioned transcript of proceedings,

THE COMMISSION DOES HEREBY FIND THAT:

1. The notice of the time and place at which the above-mentioned hearing was to be held was sufficient in form and extent of publication to advise all interested parties and all parties likely to be affected thereby;

2. The procedure followed by the Hearing Board in the conduct of the hearing held as above described adequately provided to all interested parties and all parties likely to be affected thereby full opportunity to

be heard and to present any pertinent testimony, evidence, opinions, or views which they might wish to submit for the consideration of the Commission;

3. The evidence obtained at the hearing held as above described shows that in order to protect the public health and to preserve the waters of the Ohio River in that stretch between mile point 803, near Henderson, Kentucky, and mile point 981, at Cairo Point, Illinois, for other legitimate uses within the contemplation of the Ohio River Valley Water Sanitation Compact a degree of treatment for sewage discharged or permitted to flow into those waters higher than the minimum prescribed in Article VI of the Compact is not needed; and

THE COMMISSION DOES HEREBY ESTABLISH, subject to revision as changing conditions may require, the following standard for the treatment of sewage from municipalities or other political subdivisions, public or private institutions, or corporations discharged or permitted to flow into that portion of the Ohio River extending from mile point 803.0 (miles below Pittsburgh, Pa.), located near Henderson, Ky., to Cairo Point, Ill., located at the confluence of the Ohio and Mississippi Rivers and being 981.0 miles downstream from Pittsburgh, Pa.:

(a) Substantially complete removal of settleable solids; and

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

The foregoing action was taken by the Ohio River Valley Water Sanitation Commission at a regular meeting duly held on January 13, 1954, at Cincinnati, Ohio.

Attest: s/s F. H. Waring
Secretary

s/s H. E. Moses
Chairman

PROCEEDINGS AT HEARING

Public hearing held by the Ohio River Valley Water Sanitation Commission convened at 10:00 o'clock A. M. December 9, 1953 in courtroom No. 1, U. S. Post Office and Court House, Louisville, Kentucky, Mr. Henry Ward presiding.

CHAIRMAN WARD: The meeting will come to order. We have been asked on behalf of the Federal Court to request that you do not smoke in the courtroom.

This hearing has been called by the Ohio River Valley Water Sanitation Commission under a resolution adopted October 7, 1953. It has been the procedure of the Commission, when under the provisions of the Ohio River Valley Water Sanitation Compact it has been necessary to establish degrees of treatment for sewage or other wastes, to hold a hearing of this character in the area most directly affected and at a place of appropriate geographic location. This particular hearing affects the entire length of the Ohio River from Cincinnati to Cairo, Illinois, which is at the confluence of the Ohio and Mississippi Rivers.

Under the provisions of the Compact, and the rules and regulations of the Ohio River Valley Water Sanitation Commission, three members of the Commission are designated to serve as a hearing panel.

I am Henry Ward. I am a member of the Ohio River Valley Water Sanitation Commission, and my position in the State of Kentucky is Commissioner of Conservation. I am also chairman of the Kentucky Water Pollution Control Commission.

The states most directly affected by this hearing are Kentucky, Illinois and Indiana. Representing the State of Indiana at the hearing is Mr. Joseph L. Quinn, Jr., who is a member of the Ohio River Valley Water Sanitation Commission, and is a past chairman of the Commission. (Mr. Quinn stands.)

Representing the State of Illinois as a member of the Ohio River Valley Water Sanitation Commission, is Mr. W. H. Wisely. (Mr. Wisely stands.)

With us at the table here are some of the officials of the Commission. On my right, at the end of the table, is Mr. E. J. Cleary, who is Executive Director and Chief Engineer of the Ohio River Valley Water Sanitation Commission.

Mr. Leonard Weakley who is next, is counsel for the Ohio River Valley Water Sanitation Commission. On my left is Mr. Fred Waring of Ohio, who is Secretary of the Commission.

Other members of the Commission and the staff, some of whom will participate in the hearing, will be introduced later.

As you came in you were asked to fill out forms indicating your identification and also whether or not you would like to be heard. A little later on we are going to ask that those forms be collected, and we will appreciate it if you will be filling them out in the meantime.

We have no desire to engage in an unduly lengthy hearing. There is a considerable mass of information that has been accumulated by the staff in the study of this stretch of the river, and a resume of that material will be submitted to you. Anyone who wishes to ask questions, or who would like to be heard, will be given an opportunity to do so. We have no disposition to cut the hearing short; on the other hand, there is no disposition on our part to prolong the proceedings unnecessarily.

A transcript is being made of all of the evidence which will be presented here today. Copies of the transcript will be available to those persons who are interested. If you are interested in a transcript of the record, you are invited to request it from Mr. Cleary at the office of the Commission in Cincinnati.

In order to follow the formalities necessary in a hearing of this sort, we want to ask now that the formal notice and pertinent articles of the Compact be read by Mr. Weakley.

MR. WEAKLEY: The notice of this hearing, which has been duly published throughout the area to the extent that will be indicated by the Secretary later, reads as follows:

"Pursuant to authority contained in Article VI of the Ohio River Valley Water Sanitation Compact, and pursuant to direction of the Ohio River Valley Water Sanitation Commission as contained in a resolution duly adopted at a regular meeting held on the 7th day of October, 1953, a public hearing will be held by the Commission at Courtroom No. 1, second floor, U. S. Post Office and Court House, 601 West Broadway, Louisville, Kentucky, commencing at 10:00 a.m. o'clock on the 9th day of December, 1953, and continuing thereafter until completed. The purpose of said hearing will be to obtain and record data, information and other evidence for use by the Commission in determining the degree of treatment which shall be given to sewage discharged or permitted to flow into the waters of the Ohio River in that stretch extending from Dam No. 37, located about ten miles below Cincinnati, Ohio and being 483.2 miles downstream from Pittsburgh, Pennsylvania, to Cairo Point, located at the confluence of the Ohio and Mississippi Rivers and being 981.0 miles downstream from Pittsburgh, Pennsylvania.

"Any and all parties whose interests may be affected by such determination are invited to be present or to be represented at the hearing to be held as above stated. All interested parties present or represented at said hearing will be given an adequate opportunity to express either orally or in writing, their views upon the issues there to be considered.

"Interested parties who desire additional information concerning the conduct of this hearing or who desire information with regard to evidence, views or recommendations which are to be submitted at such hearing are requested to call at the offices of the Ohio River Valley Water Sanitation Commission, 302 Mercantile Library Building, 414 Walnut Street, Cincinnati, Ohio. On and after the 9th day of November, 1953, there will be on file and available for examination at the offices of the Commission, located as above stated, copies of the report of the Commission covering its investigation of the treatment requirements for sewage discharged or permitted to flow into the stretch of the Ohio River as above defined and including recommendations with regard to the degree of treatment which should be established for such sewage."

Signed, "Ohio River Valley Water Sanitation Commission, By H. E. Moses, Chairman." Dated November 6, 1953. (Copy of notice is attached hereto as Exhibit A.)

The portion of the Ohio River Valley Water Sanitation Compact under which this notice has been issued and this hearing is being held, is to be found in Article VI of the Compact. The pertinent sections of that article relating to this particular hearing are to be found in paragraphs 1, 2 and 5, and they read as follows:

"It is recognized by the signatory states that no single standard for the treatment of sewage or industrial wastes is applicable in all parts of the District due to such variable factors as size, flow, location, character, self-purification, and usage of waters within the District. The guiding principle of this Compact shall be that pollution by sewage or industrial wastes originating within a signatory state shall not injuriously affect the various uses of the interstate waters as hereinbefore defined.

"All sewage from municipalities or other political subdivision, public or private institutions, or corporations, discharged or permitted to flow into these portions of the Ohio River and its tributary waters which form boundaries between, or are contiguous to, two or more signatory states, or which flow from one signatory state into another signatory state, shall be so treated, within a time reasonable for the construction of the necessary works, as to provide for substantially complete removal of settleable solids, and the removal of not less than forty-five per cent of the total suspended solids; provided that, in order to protect the public health or to preserve the waters for other legitimate purposes, including those specified in Article I, in specific instances such higher degree of treatment shall be used as may be determined to be necessary by the Commission after investigation, due notice and hearing."

Then paragraph 5 provides, "The Commission is hereby authorized to adopt, prescribe and promulgate rules, regulations and standards for administering and enforcing the provisions of this article."

CHAIRMAN WARD: I ask Mr. Waring, Secretary of the Commission, to give you a summary of the manner and extent of publication and distribution of the notice of the hearing.

MR. WARING: Notice was published as a paid advertisement in twelve newspapers in the valley on the dates indicated on attached list No. 1 (Exhibit B) I have affidavits of publication, and they shall be placed on file in the Commission office.

Notices were mailed to officials of some 112 municipalities located in the stretch of the river under consideration.

Notices were mailed to boards of county commissioners of the counties bordering this stretch of the river.

Notices were mailed to the Leagues of Municipalities of the four states involved, which are Ohio, Illinois, Indiana and Kentucky.

Notices were mailed to those industrial concerns shown on attached list No. 6 (Exhibit B).

Notices were mailed to certain trade associations as shown on attached list No. 7 (Exhibit B). In addition, notices were mailed to the attorneys general of the States of Ohio, Illinois, Indiana and Kentucky.

Finally, notices were mailed to the water pollution control agencies of the four states involved.

These lists have been duly sworn to and I now hand them over to the stenographer. (Certification of publication and distribution of notice of hearing is attached hereto as Exhibit B.)

CHAIRMAN WARD: The staff members will now collect the identification slips. (Roster of attendance attached hereto as Exhibit C.)

While that is being done, there is one comment I would like to make. It is outside the formalities of the proceedings.

I mentioned that the hearing is being held in Louisville because it is desirable from a geographic point of view. As a matter of coincidence, the hearing was set prior to the November election, but we in Kentucky are very proud of the fact that Louisville at the November election took action that contributed to what we are going to talk about today. That was when the voters of Louisville by a tremendous majority approved a bond issue of six million dollars, with the understanding that their sewer rental charges were going to be raised to produce another six million dollars for construction of a sewage treatment plant.

As a Kentuckian, I would like for those outside of the Commission to recognize the fact that Louisville made a very distinct contribution to the entire program. More significant than that fact is that the people of Louisville in particular are entitled to a lot of commendation because they have accepted as a civic responsibility something they might well have argued was not their responsibility. There was a lot of talk here that it was a responsibility of the Metropolitan Sewer District, which extends beyond the limits of the City of Louisville. But to vote by a four to one margin as they did in the face of these circumstances, was an indication of support on the part of the people of Louisville for the program. That, so far as I know, is the best example there has been in a long time in the valley of an understanding of the problems that exist, and the acceptance of responsibility on the part of the people in doing something about the problem.

I certainly thought we of the Commission ought to recognize officially what Louisville has done and extend to the people of Louisville our congratulations and compliments on taking this very fine action. This action, I believe, is going to do more to clear the way to bring about continued progress in line with the hearing we are going to have today than anything that could have happened.

We will now proceed with the presentation of evidence that has been collected. We have asked Mr. Cleary, Executive Director and Chief Engineer of the Commission, to take charge of the presentation of evidence, and to introduce the expert witnesses who are here to give their views on the subject matter. Mr. Cleary.

MR. CLEARY: Members of the hearing board, and representatives of the public interest: The technical-fact presentation that will be made now was authorized by the Commission on October 7, 1953.

These findings and recommendations of the staff are embodied in a report entitled, "Ohio River Pollution-Abatement Needs, Cincinnati-Cairo Stretch". Mr. Chairman, I offer this report for inclusion in the proceedings of this meeting. (Report is attached hereto as Exhibit D.)

Based on that report, we are prepared this morning to present pertinent testimony that relates to these findings. This will be done for the staff by Mr. Robert K. Horton, Staff Sanitary Engineer. By way of qualification Mr. Horton is a registered professional engineer, a graduate of the University of North Carolina, with degrees in civil engineering and in sanitary engineering, and prior to his association with the Commission in 1949 served on sanitary engineering research and administrative assignments as a lieutenant colonel in the Sanitary Corps of the United States Army.

Before asking Mr. Horton to present the highlights of the report, let me point out that he will address himself to three questions.

The first one is: "What quality of water in the Ohio River in this stretch will fulfill Compact requirements?

The second question is: "What are the quality conditions that now exist in the river, and how do these compare with the recommended quality levels that will be presented?"

The final matter will be: "What degree of treatment is needed for sewage discharges in order to meet these quality conditions?"

MR. HORTON: Mr. Chairman, before beginning testimony, I wish to show a map of the area that will be considered here.

(Slide shown. This slide shows the map on page 3 of the report attached hereto as Exhibit D.)

The stretch of the Ohio River under consideration begins at Dam 37 (pointing), which is just downstream from Cincinnati and just upstream from the Indiana-Ohio state line.

The map shows the principal sources of sewage discharged in this stretch of the river. I wish to call attention to the municipal water intakes in this stretch of the river, which are also shown on the map. Particular attention is called to the Owensboro-Evansville-Henderson area. In this area there is a rather large concentration of population discharging in close proximity to water intakes. This area will receive detailed attention as we proceed with our testimony.

Regarding water-quality conditions that will satisfy provisions of the Ohio River Compact, the hearing is concerned with two quality criteria: Oxygen levels and bacterial concentrations as measured by the number of coliform organisms, these two criteria being those commonly used for measuring the pollutional effects of sewage discharges.

Regarding oxygen conditions in the river, the objective selected has been a minimum dissolved-oxygen concentration of five parts per million. This objective is in line with objectives used in determining treatment requirements in other stretches of the river, and it is also in accordance with the results of studies that are now being concluded by a Commission committee composed of aquatic biologists.

Regarding desired bacterial-quality conditions, the Commission staff has made a study and analysis of data from four different sources:

(1) Results of a five-year study by the U. S. Public Health Service on the operation of a large-scale experimental water-purification plant. The purpose of these studies was to determine the limiting number of coliform organisms in the raw water that could be handled by this plant when producing a finished water meeting U. S. Public Health Service drinking water standards.

(2) Results of a two-year observational study, also by the Public Health Service, on actual operating efficiencies of some 31 water-treatment plants in the Ohio River basin, ten of which are on the Ohio River.

(3) Review of present-day efficiencies at water plants on the Ohio River, and a comparison of these efficiencies with what they were some 25 years ago.

(4) Review of the objectives and standards being used by other regulatory agencies.

Our findings, after study and analysis of this information, may be summed up in three points. The first is this: The limiting number of coliform organisms that can be handled by a so-called normal water purification plant, meaning one of the rapid-sand filter type providing post chlorination to low residuals, is 5,000 organisms per 100 milliliters.

The second finding is that water plants can handle -- and there are many plants now handling -- much higher concentrations of coliform organisms in the raw water. However, these plants are able to do this only by resorting to auxiliary treatment processes, which consist principally of the use of greater chlorine dosages and the maintenance of higher chlorine residuals in the finished water.

The third finding is that because of the use of these auxiliary treatment processes at water plants, and particularly because of the use of greater chlorine dosages, taste and odor problems have been intensified and palatability of the finished water has been decreased.

On the basis of these data then, we find that so far as protection to public water supplies is concerned, the maximum concentration of coliform organisms in the raw water should be limited to 5,000 organisms per 100 milliliters. This level should provide maximum safety and insure improved quality.

Regarding bacterial concentrations for waters used for bathing purposes, we have reviewed the results of research work by a number of investigators. So far as it has been possible to calculate the risk involved to a swimmer who might use the river, we find that an adequate safeguard should be provided if the level of coliform organisms is kept to 1,000 organisms per 100 milliliters.

That then, Mr. Chairman, sums up the recommendations as far as desired bacterial quality conditions in the river are concerned. They are: A level of 5,000 coliform organisms per 100 milliliters for the protection of water supplies, and a level of 1,000 organisms per 100 milliliters for the protection of waters used for bathing purposes.

These recommendations and the studies on which they are based are detailed in a report titled, "Bacterial-Quality Objectives for the Ohio River." We wish to submit this report as part of the testimony of the hearing. (Report is attached hereto as Exhibit E.)

MR. CLEARY: Mr. Chairman, are there any questions regarding these quality criteria?

MR. G. R. SCOTT: Mr. Chairman, you have mentioned certain requirements for oxygen and bacterial quality. What stream discharges did you tie those up with?

MR. HORTON: In making these studies, we evaluated the effects of pollution under varying conditions of stream flow, using flows that might be expected during the summer season and also during the winter season. The most critical flow used, has been the minimum flow that might be expected once in ten years.

MR. CLEARY: If there are no further questions we will proceed to the second point: "What are the quality conditions in the Ohio River now, and how do these compare with the recommended quality levels?"

MR. HORTON: May we have the next slide.

(Slide shown. This slide shows the chart given as Figure 1 in the report attached hereto as Exhibit D.)

Regarding present oxygen conditions in the river, information has been assembled from the state pollution control agencies, from the survey made by the Public Health Service in 1939-41, and from a special survey conducted by the Commission in 1950. The data have been summarized on the chart, which represents an oxygen profile for the stretch of the Ohio River under consideration. Present conditions are represented by the solid line on the chart. The horizontal axis of the chart represents mile points, starting at Cincinnati on the left, and proceeding downstream to Cairo. Oxygen concentrations are represented on the vertical axis, and have been plotted in parts per million.

The solid line (Pointing) represents oxygen conditions that might be expected at the ten-year minimum flow, at summer temperatures, and without treatment of any of the sewage discharges.

The most critical section occurs immediately below Cincinnati, where the heavy amount of sewage pollution causes a low oxygen content in the river.

There is another dip in the oxygen profile below Louisville.

It may be seen from the chart that at this particular flow and without sewage treatment, an oxygen concentration of three parts per million or less may be expected below Cincinnati, and a concentration of around four parts per million may be expected below Louisville.

Regarding present bacterial conditions, information has been assembled primarily from the results of analytical work done during recent years at a number of water-treatment plants located on the Ohio River (this analytical work has been done in connection with a Commission sponsored project for the constant monitoring of river water quality). Information has also been assembled from the Public Health Service survey of 1939-41, and from the special survey conducted by the Commission in 1950.

This information has been summarized on a series of charts. May we have the next slide.

(Slide shown. This slide shows the chart given as Figure 2 in the report attached hereto as Exhibit D.)

The chart shows coliform concentration actually observed at Louisville during the period July 1950 through December 1952. The chart has been drawn by plotting coliform concentrations against river flow. The horizontal axis of the chart represents river flow in cubic feet per second. The vertical axis represents bacterial densities expressed in terms of the most probable number of coliform organisms per 100 milliliters.

The two heavy horizontal lines on the chart (pointing), which have been drawn at concentrations of 1,000 and 5,000 organisms per 100 milliliters, represent recommended bacterial quality levels.

It can be seen from the chart that about 75 percent of the observations exceed a concentration of 1,000 organisms per 100 milliliters, and slightly more than 50 percent of the observations exceed a concentration of 5,000 organisms per 100 milliliters.

May we have the next slide.

(Slide shown. This slide shows the chart given as Figure 3 in the report attached hereto as Exhibit D.)

This chart shows observed coliform densities at Evansville. The chart has been constructed in exactly the same way as the one just shown; coliform densities (vertical axis) have been plotted against river flow (horizontal axis).

The chart shows that about 90 percent of the observations at Evansville exceed a concentration of 1,000 organisms per 100 milliliters, and 50 percent of the observations exceed a concentration of 5,000 organisms per 100 milliliters.

MR. CLEARY: Mr. Chairman, we will entertain any questions regarding quality conditions in the river.

CHAIRMAN WARD: Are there any questions?

(No response)

MR. CLEARY: I might add, Mr. Chairman, that all of these points are developed with considerable detail in the report that I have submitted in evidence and which is available from the Commission.

MR. SCOTT: Mr. Chairman, may I ask a question? I didn't catch the concentration of bacteria below Owensboro.

MR. HORTON: Since Owensboro does not take its water supply from the Ohio River, routine bacteriological analyses on river water are not made at that point.

MR. SCOTT: There's been no data made on the river itself at Owensboro, Evansville, on down?

MR. HORTON: Observational data on coliform densities at Evansville are available. Evansville data for the period July 1950 through December 1952 are given on the last slide shown. In addition, observational data in this section of the river are available from previous surveys of the Commission (1950) and the Public Health Service (1939-41). We have more slides to present in connection with the discussion on treatment requirements; and these slides will show further information on bacterial concentrations in the Owensboro-Evansville section of the river.

MR. CLEARY: The final point is: "What degree of treatment is needed for sewage discharges in this 500-mile stretch in order to meet the quality requirements?"

MR. HORTON: I will discuss first treatment needed to maintain desirable oxygen conditions. May we have the slide showing oxygen profiles.

(Slide shown. This slide shows the chart given as Figure 1 in the report attached hereto as Exhibit D.)

This is the same chart shown just a minute ago. It shows oxygen conditions that might be expected at the ten-year minimum flow.

The solid line represents oxygen conditions to be expected without any treatment. The dash line has been drawn to represent oxygen levels that might be expected if all sewage discharges in the river stretch under consideration are treated in accordance with the minimum requirement set forth in Article VI of the Ohio River Compact. The minimum requirement of the Compact is that all sewage shall be treated so as to provide for substantially complete removal of settleable solids and not less than 45 percent removal of total suspended solids.

I wish to point out that treatment requirements for the Cincinnati pool, into which is discharged sewage from Cincinnati and from the northern Kentucky cities of Covington, Newport and some 14 other communities, have already been established following a previous hearing. The degree of treatment established for that pool calls for a removal of biochemical oxygen demand up to 65 percent.

With this degree of treatment in the Cincinnati pool, we find that if all sewage discharges below the Cincinnati pool are treated in accordance with minimum requirements of the Compact, the desired or recommended oxygen level will be maintained in the river. The chart now on the screen is intended to show this. The chart shows that with treatment as stated, oxygen concentrations of five parts per million or higher will be maintained.

Below the Cincinnati pool the most critical area so far as oxygen conditions are concerned is the one immediately downstream from Louisville. It can be seen on the chart that the oxygen concentration below Louisville at the ten-year minimum flow would be about five and a half parts per million.

Turning now to treatment needed to maintain desired bacterial densities in the river, I wish to show the next slide.

(Slide shown. This slide shows the chart given as Figure 5 in the report attached hereto as Exhibit D.)

On the basis of observed coliform data, and taking into account rates of bacterial die-away and other factors, we have developed computed coliform profiles. Such a profile is shown on the chart.

The horizontal axis of the chart represents river miles, and the vertical axis represents coliform concentrations. The two heavy horizontal lines on the chart represent the recommended bacterial quality objectives of 1,000 and 5,000 organisms per 100 milliliters.

This particular profile has been drawn for the same flow conditions at which actual observations were made during the 1939-41 survey of the Public Health Service. We constructed the profile at this flow in order that we could compare our computed concentrations with observed data. The observed data are shown by the circles on the chart, and the heavy broken line represents computed coliform densities. Reasonably close agreement between observed and computed data indicated that the many factors involved had been properly evaluated, and made it possible to proceed with the construction of profiles to show coliform concentrations at other conditions of river flow and at different temperatures.

May we have the next slide.

(Slide shown. This slide shows the chart given as Figure 7 in the report attached hereto as Exhibit D.)

The chart shows two profiles, representing coliform concentrations to be expected at summer temperatures and at the ten-year minimum flow. The solid line shows concentrations to be expected without treatment of any of the sewage discharges, and the dash line shows concentrations to be expected with sewage treatment.

In constructing the treatment profile we have used a figure of 35 percent as the amount of reduction in coliform counts that might reasonably be expected from primary treatment of sewage. We have found that with this amount of reduction for all sewage discharges in the Cincinnati-Cairo stretch of the river, except for those discharges in a 50-mile section between Owensboro and Henderson, the recommended level of 5,000 coliform organisms per 100 milliliters can be maintained at all municipal water supply intakes. In the Owensboro to Henderson section we find that a higher reduction in coliform bacteria is needed in order to meet the recommended quality level.

The chart shows that at summer temperatures and at the ten-year minimum flow, sewage discharges in the Owensboro-Henderson section will have to be treated so as to provide for 85 percent reduction in coliform organisms if the recommended objective is met.

To summarize, then, the treatment profile on the chart has been drawn on the basis of 85 percent reduction in coliform counts for sewage discharges in the Owensboro-Henderson section, and 35 percent reduction for all other sewage discharges. The chart shows that under these conditions of treatment coliform concentrations will just meet the recommended level of 5,000 per 100 milliliters at the Henderson intake, and will be less than this level at other intakes.

May we have the next slide.

Slide shown. This slide shows the chart given as Figure 8 in the report attached hereto as Exhibit D.)

This chart shows coliform densities that might be expected during the winter season. In our studies we evaluated coliform conditions that could be expected with varying river flows at winter temperatures. We found that most critical conditions occur at a flow of around 100,000 to 120,000 cfs.

The profiles on the chart have been drawn at a flow of 100,000 cfs at the Cincinnati gage, which is comparable to a flow of about 120,000 cfs at Louisville.

We find that under these conditions of flow and temperature, a slightly less reduction in coliform counts in the Owensboro-Henderson section is needed than that required during the summer season. The amount of reduction found to be needed in this section is 65 percent. And again, this amount of reduction is higher than the reduction that could be expected from primary treatment of sewage.

So, the treatment profile on the chart has been drawn on the basis of 65 percent reduction in the Owensboro-Henderson section and 35 percent reduction elsewhere. With these amounts of reduction, coliform concentrations may be expected to just meet the objective of 5,000 organisms per 100 milliliters at the Henderson intake, and to be less than this objective at other intakes.

To summarize, Mr. Chairman, recommendations for the treatment of sewage in the Cincinnati-Cairo stretch of the Ohio River are these: Treatment of all sewage in accordance with minimum requirements of the Compact, and in addition treatment of all sewage discharged between mile point 750 (about six miles upstream from Owensboro) and mile point 803 (immediately upstream from Henderson) so as to provide for a reduction in coliform organisms of not less than 85 percent during the months May through October, and not less than 65 percent reduction during the months November through April.

MR. CLEARY: That concludes the staff testimony. After the questions, I am prepared to have placed in the record some additional testimony.

CHAIRMAN WARD: Are there any questions?

MR. G. R. WATKINS: Mr. Chairman, do I understand that the 50-mile section does include or does not include the discharge of Henderson?

MR. HORTON: It does not include the discharge from Henderson; it includes all discharges from just above Owensboro to the Henderson intake.

CHAIRMAN WARD: Are there any other questions?

MR. CLEARY: We have supporting testimony from representatives of three states. I now call on Mr. B. A. Poole, the Technical Secretary of the Indiana Stream Pollution Control Board, Chief Engineer of the Indiana State Board of Health and a Commissioner of the Ohio River Commission. Mr. Poole.

MR. B. A. POOLE: Mr. Chairman, members of the Board: My office has studied this report carefully, and we wish to go on record as endorsing the recommendations contained therein.

I would like also to get into the record a very brief picture of the Indiana situation on the north side of the river as it exists today.

We have in operation or under construction sewage treatment plants at nine municipalities and at four major industries or institutions. The composite cost of those 14 plants (one of the cities has two plants) is a little in excess of ten million dollars.

I think of particular interest to the people in the Louisville area is the fact that included in these Indiana plants are those at Charleston and Clarksville which are now in operation, a plant at Jeffersonville that is under construction, a plant for the Jeffersonville Quartermaster Depot, and plants for both of the large ordnance works which are located shortly north of the city of Louisville.

Of interest to the people in the Owensboro and lower area is one plant which serves approximately 30,000 people on the east side of Evansville, and which does have the facilities to meet the higher degree of treatment that is proposed by the Commission for the Owensboro-Evansville area. It is of further interest that plans of the city of Evansville are about consummated for a second and larger plant, which plant will also contain facilities for the higher degree of treatment required for that area. This plant should go to bids within the next few months.

MR. CLEARY: I now call on Mr. Louis Birkel, the Executive Director of the Kentucky Water Pollution Control Board.

MR. LOUIS F. BIRKEL: Mr. Chairman, members of the Board: I was a member of the engineering committee that reviewed this report and endorsed it. Our office has reviewed it and finds it technically sound. We feel that if the proposed treatment is provided, satisfactory water quality conditions will exist.

I might also add that we furnished data on the pollution loads originating in Kentucky to the Commission for study.

MR. CLEARY: Thank you, Mr. Birkel. Our third representative from the states is Mr. William Hasfurther, Sanitary Engineer for the Illinois Department of Public Health. Mr. Hasfurther.

MR. WILLIAM HASFURTHER: Mr. Chairman, the Illinois Sanitary Water Board has reviewed this report and findings therein, and we approve the report and the recommendations.

Since the Illinois legislature in 1939 approved the Ohio River Commission Compact, we have endeavored to stand by the recommendations in that Compact, and have prohibited sewer extensions or additional pollution to the river. As a result, we have had several small towns, which wanted to provide sewer services for their population, construct treatment plants.

We are at the lower end of the river, and the remaining discharges affect mainly our own people, but we realize that a clean-up of the entire river can only be accomplished by the combined efforts of all the states involved.

I wish to repeat that we will abide by the findings of this hearing board.

MR. CLEARY: Thank you, Mr. Hasfurther. Our final testimony, Mr. Chairman, is from Mr. W. W. Towne, Officer in Charge, Ohio-Tennessee Drainage Basin of the United States Public Health Service.

MR. W. W. TOWNE: Mr. Chairman, Gentlemen: The interest of the Federal Government in this particular hearing stems from the National Water Pollution Control Act, which became a Federal statute the same day that the Ohio River Valley Water Sanitation Commission was ratified by the participating states.

In keeping with the intent of this Act, namely, to encourage the formation of interstate compacts and to recognize, preserve and protect the primary responsibility of states for the control of pollution within their borders, the Public Health Service, representing the Federal Government in this Act, has not engaged in a separate study of this section of the stream. Rather, we have reviewed this report with the thought that it might be adopted by the Surgeon General as meeting his requirements for a comprehensive program of pollution abatement which the National Water Pollution Control Act requires that the Surgeon General shall prepare or adopt.

We have, as I say, Mr. Chairman, reviewed the report. We find that the objectives are reasonable, and we believe that the recommendations for obtaining those objectives are likewise reasonable and attainable. Therefore, my office is in a position to recommend to the Surgeon General that we adopt this report as a part of his comprehensive program for the control of pollution in the Ohio River main stem.

I have a prepared statement, Mr. Chairman, that goes a little more in detail, but I think the highlights of the statement are contained in my remarks here, and I will not read it at this time. (Mr. Towne's full statement is attached hereto as Exhibit F.)

MR. CLEARY: Thank you, Mr. Towne. Mr. Chairman, that is all the supporting testimony I have to offer in connection with the technical facts and the conclusions reached.

CHAIRMAN WARD: Thank you, Mr. Cleary. Before we get to the additional question, or call upon those who indicated they would like to be heard, there are a few other people present who might not qualify as technical experts, but certainly we would like to hear from them if they would like to make any comments.

We are very proud that the first chairman of this Commission, a man who worked for legislation for 15 years trying to get it authorized, came down from Cincinnati. Mr. Hudson Biery was our first chairman, and is now a member of the Ohio River Valley Water Sanitation Commission. Mr. Biery, would you like to make a comment?

MR. HUDSON BIERY: I shall not attempt to offer any expert testimony pertinent to this hearing, but I will just make one observation that has been gleaned from a perusal of the Fifth Annual Report of the Commission which has just been issued.

In that report, one is impressed with the tremendous economic burden that has been placed upon the upstream communities for the benefit of the downstream communities. While it is true that we have a large concentration of population in Louisville, in Evansville and the Henderson district, relatively it is not large compared to the tremendous populations upstream. And when we consider the fact that this Compact has bound together all these eight states to deal with the river in such fashion that the smaller communities on the lower stretch of the river will derive the same benefits at much less expenditure of public funds than the upstream communities, one realizes the fairness and the soundness of this interestate Compact. Thank you.

CHAIRMAN WARD: Thank you, Mr. Biery. We have another representative of a Federal agency, who certainly can qualify as an expert in other fields if not in this subject of pollution control. I wonder if Mr. Sam Bailey of the Corps of Engineers would like to make some comment.

MR. S. M. BAILEY: Mr. Chairman, the only comment I care to make is this: As a great many of you know, there are plans in the making for a high dam at Markland, which is below Dam No. 37. We are making studies there for a pool of 455 feet above mean sea level which will affect the area there.

Downstream, a long-range program calls for dams somewhat similar to those we have now, dams that will collapse and lay down on the bottom of the river during high discharges. The lift will be higher, and there will be approximately half the number we have at the present time. They should not affect your studies, as I can determine, in any way.

CHAIRMAN WARD: Thank you, Mr. Bailey. The first area in Kentucky which did an outstanding job as far as municipal sewage was concerned, was in Kenton and Campbell Counties, where a group of municipalities joined together with Covington and Newport and organized the Northern Kentucky Sanitation District; they are way along toward licking the problem. In so far as the entire Ohio Basin is concerned, that group has really shown the most aggressive spirit. The thing that has impressed people who have been interested in this program, is that they did it very much on their own; there was actually little prodding on the part of the state.

We are very happy today that Mr. W. D. Anderson, representing that district, is here. We'd like to have a comment from Mr. Anderson.

MR. W. D. ANDERSON: Mr. Chairman, members of the hearing board: I would like to make just a short progress report. I believe there are some matters here that will be of concern and considerable interest to some of the other people, particularly in Kentucky, who are engaged in the same kind of work.

Sanitation District Number 1 of Campbell and Kenton Counties serves the 16 principal areas that lie along the Ohio River across from Cincinnati, Ohio. The system comprises about 27 miles of collector sewers, three under-water crossings, five lift stations, and a treatment plant.

Construction work is almost complete, and the sytem will be placed in operation early in 1954.

Approximately 19 million gallons of raw sewage is now being dumped into the Ohio River daily, which will then go to the treatment plant, where it will be given treatment before it is discharged into the Ohio. Thus, we are doing our part to carry out the intent and purpose of the Ohio River Valley Water Sanitation Compact and pertinent laws of the state pertaining thereto.

The directors and officers of the Sanitation District, Mr. Chairman, have attempted at all times to lend whatever assistance is within their power to others engaged in antipollution work, all up and down the Valley. Our District is operated of course in conformity with the statutory provisions and in accordance with pertinent provisions of the Compact.

Our experience has been related from time to time to members of the Kentucky Water Pollution Control Commission and to members of the State Board of Health, and it has shown, I believe conclusively, that some changes in present laws are required in order that the intent and purpose of the Compact can be more easily approached and adhered to by those engaged in antipollution work.

We have made specific recommendations to the officers in the Water Pollution Control Commission and in the Department of Health for specific legislation which will consist of amending certain sections of the statute and in other cases of adding provisions which our experience has indicated are needed. We believe that it will greatly assist the work of those who are engaged in antipollution activity if the legislation is acted upon favorably by the General Assembly. Our efforts thus will materially assist in this great task of cleaning up the Ohio River.

The board of directors previously has expressed concern lest all of those towns and cities which lie upstream do not keep abreast of developments so that we will be prevented thereby from realizing the full value of the effort that has been expended and the money that is being spent by the people of that area. We have been greatly pleased; we have been gratified almost beyond expression during the past year by what has taken place.

We held in the Greater Cincinnati area very recently what we termed a Clean Water Rally. The result of that has, I am sure, indicated beyond question of a doubt that those people who now are engaged in antipollution work intend fully to keep at it until we have actually cleaned up this valley.

Mr. Chairman, may we again ask that all appropriate steps be taken to see that whatever can be done will be done, in order that the work all the way from Pittsburgh to Cairo of attempting to clean up the river will be kept abreast. Thank you.

CHAIRMAN WARD: Thank you, Mr. Anderson. I would like to suggest that if anyone has any ideas on legislation that might be needed in Kentucky, it would be a very fine idea to get the suggestions in the mill pretty soon. As a former member of the Kentucky General Assembly, I can assure you that you are in a lot better shape if you get your bills in early. I will be glad to cooperate with any of you if you will let me know what you have in mind.

We have a gentlemen here who is connected with another state agency that has an interest in the whole broad subject of water. We have a Flood Control Water Usage Board, which has a meterial interest in the subject of water for municipal and industrial use. The chairman is Mr. Robert Diehl. Mr. Diehl, would you like to make some comments?

MR. DIEHL: The only comment that I might inject at this time is that I had the pleasure of attending the signing of the Ohio River Valley Compact in Cincinnati at the Netherland Plaza Hotel. It was a beautiful ceremony. I recall vividly some so-called experts feeling then that there was not enough interest at that time to get this job done, but it is certainly gratifying to see the public acceptance up and down the river which this Compact has received, and the speed with which the river is being cleaned up.

CHAIRMAN WARD: Thank you. We would like to give the cities which are represented here an opportunity to be heard if they so desire. Some of you indicated that you might want to be heard, depending upon progress of the hearing. We have Mr. Morris Forman, representing the Louisville and Jefferson County Metropolitan Sewer District, who indicated he might want to be heard. Mr. Forman, would you like to make some comments?

MR. MORRIS FORMAN: I had some pertinent questions to ask prior to the meeting, but Mr. Horton did a very good job and has answered them for me.

I'd just like to report at the present time that the City of Louisville has voted a six-million dollar bond issue, and give you a little on the status of it. The test suit for the validity of it hasn't been acted on; it is up to the City to take that issue up. Just as soon as we can determine whose obligation this is, the City's or the Sewer District's, we will take immediate action to proceed with construction of the plant. That is about all I have to report at the present time.

There is just one question I may ask. At the previous hearing that took place for the territory upstream from Cincinnati certain rules and regulations and obligations were set forth. At any time has it been necessary for some reason at all, to ask for a reconsideration of any controls that had been set forth in those regulations, or at that hearing?

CHAIRMAN WARD: Mr. Cleary, will you answer that question?

MR. CLEARY: The question, as I understand it is, has anyone asked for reconsideration of previously adopted standands?

MR. FORMAN: That is right.

MR. CLEARY: No.

MR. FORMAN: In other words, we can consider today that whatever is taking place here at the present time, those will be the final standards to be accepted downstream from Louisville, including Louisville?

MR. CLEARY: That is a matter that the hearing board will decide on the basis of this public hearing and then make recommendations to the Commission.

I might add that the Commission has had three other hearings, and four standards have been developed. If recommendations under discussion today are adopted the sewage treatment requirements for the entire Ohio River fall into six classifications.

CHAIRMAN WARD: There are a number of municipalities which are represented. Is there any representative of a city who would like to be heard? We have a specific request that Dr. Joseph L. Rahm of Waverly, Kentucky, would like to make some comment. Dr. Rahm?

(No response)

CHAIRMAN WARD: There were a few others who indicated they might like to be heard, depending upon what developed. Are any of you in a position to indicate whether you might like to make some comment, or raise some questions?

(No response)

CHAIRMAN WARD: We seem to be progressing pretty well. I might call attention to some specific things. If any individual or municipality or corporation would like to introduce any evidence, you are invited to do so. We would like, if you are in a position to do so, for you to file that material at the office of the Commission in Cincinnati by December 31. Our full Commission will have a meeting on January 13. This hearing board hopes it will be in position to make a complete recommendation and report to the full Commission at that time, so if we can accumulate any additional information or comment, or answer any questions prior to December 31, we would prefer to do that.

As stated at the outset, a complete stenographic report is being made of this hearing. Copies will be available at the office in Cincinnati for anyone who would like to have one.

A few people came in after we got the identification list. If those who did come in have not filled out one of these identification sheets, will you please hold up you hand so we can distribute these to you. We would like to have a complete record of everyone who is in attendance.

Some of you may not be entirely familiar with the details and the procedure under which the broad subject of administration of the pollution control law is carried out. The individual states in the Ohio Basin all have state agencies similar to the Kentucky Water Pollution Control Commission here in this state. It has been the policy of the Ohio Valley Commission since its establishment in 1948, to take the position that primarily the job of pollution control, of administration, is one of the state's. The Commission has been very much in the picture in setting standards such as this. I think you can all appreciate how important it is to the individual states for standards that cross state lines to be set. Certainly those of us in Kentucky are in a much better position to talk to municipalities on the Kentucky side of the river if we know there has been an approach on the part of the Commission such as this, that will affect not only the municipalities in Kentucky, but also those in Indiana and Illinois, and that there has been exactly the same type of approach to the problem throughout the entire stretch of the river.

The Commission and the staff make it a much easier job for the individual state agencies to handle their problems on administration. Of course many of the states are much better organized, have been in the picture in an aggressive way longer than Kentucky. But we recognize that our job has been made easier because of the presence of the Commission, which lends the weight of the Federal Government actually to the program, because the Commission is an agency established under an Act of Congress, with eight states in the entire Ohio Basin cooperating. That is, I think, a very effective approach to the entire problem, specifically, so far as Kentucky is concerned, and I am sure that that is true of Indiana and Illinois too.

If there are any municipalities that are interested in this problem that have any questions, if there is any question in any one's mind about these standards that are recommended, will you please raise them prior to December 31 if you can, certainly prior to January 13 if at all possible.

If you feel that the standards that are recommended by the Commission staff are not proper, we want to know it. As an individual member of our own state Commission and as chairman, I am interested in knowing your reaction, just as I am as a member of the Ohio Valley Commission. That is particularly true, Mr. Scott, of Owensboro. From what I know about this situation, the only place where there might be some question is Owensboro. Owensboro happens to be in the unfortunate position of discharging sewage above the intakes of Evansville and Henderson. It is the only spot along the river, apparently, where there is a particular problem, where there might be some questions, and if those questions can be raised and effort made to resolve them before the Commission takes action, it would certainly be helpful. I think you can appreciate, as far as Kentucky is concerned, we certainly would be very hesitant to back down on standards of the Ohio Valley Commission for the entire stretch of the river after they have been established. If they are unreasonable, we'd like to know it now so we can discuss it with the Commission staff and make a proper determination on it.

Mr. Cleary, do you know of any other comment that needs to be made?

MR. CLEARY: We have nothing to add, Mr. Chairman.

MR. BLAKEY HELM: I am not an engineer; I think probably there are several others here who are not engineers. I am continually being asked, because I have some connection with the Metropolitan Sewer District, some interesting question by people who also are not engineers. In the first place, we are being asked if we are going to build a treatment plant for first-class or second-class treatment? Could I get Mr. Cleary to explain to us what the difference is between the first and second-class treatment?

CHAIRMAN WARD: I don't know why you asked Mr. Cleary. I'd be glad to explain that. Maybe we better let Mr. Cleary give the technical terms. I can explain it so this crowd can understand it, but we will let him do it for the record.

MR. CLEARY: Generally a primary treatment plant is one that gives no more than sedimentation and purification of the liquid that reduces the BOD 25 to 30 percent.

Secondary treatment provides not only the removal of the solids, but oxidation of the remaining liquid so you may get up to 95 percent or higher purification.

There is another classification -- providing purification efficiency between these two -- which is called intermediate treatment. Generally, this is provided by adding chemicals in a primary treatment plant.

MR. HELM: As I understand, the Cincinnati treatment plant is something beyond primary?

MR. CLEARY: Primary treatment with facilities to add chemicals for the removal of additional sewage solids at times of low river flow.

MR. HELM: Below Cincinnati, only primary treatment will be necessary; is that right?

MR. CLEARY: That is right, with one exception. That is the Owensboro-Evansville section where some additional disinfection is needed.

MR. HELM: Another question: With primary treatment, is there considered to be any sludge product which is saleable?

MR. CLEARY: There are two possibilities. One is the sludge fertilizer, the other is the sludge gas that might be obtained from digestion of that sludge. Cincinnati for example utilizes its gas to heat the digesters.

The matter of sludge conversion to fertilizer is a question for a consulting engineer to decide for any specific community. There are many factors that bear on the economics. I think it is fair to state, however, that sludge fertilizer production would not pay for a sewage-treatment plant. It may help to reduce some of the cost. Facilities at Cincinnati are provided so that sludge can be dried sufficiently for sale as fertilizer if there should be any demand for it; otherwise the dried material will go directly into furnaces to be burned.

CHAIRMAN WARD: On that point, I might add that there was a specific question raised regarding Louisville in that matter. Officially, our state commission indicated it would not be profitable to try to use sludge. There are some plants that do that; Milwaukee, for instance produces a product that is used extensively on golf courses and for other purposes. There is not at present a large market for it.

There are a few people here in official capacity whom I would like to present to you.

Mr. Floyd Schrader of the United States Geological Survey. Mr. Schrader. (Mr. Schrader stands.)

Mr. M. M. Peters of the State Department of Fish and Wildlife Resources. (Mr. Peters stands.)

CHAIRMAN WARD: We are going to have a meeting of the Kentucky Water Pollution Control Commission after this hearing today, and one of the members of that Commission, representing industry, from Wheelwright, Kentucky, is Mr. Harry Zimmerman. (Mr. Zimmerman stands.)

CHAIRMAN WARD: Have we missed any of the official family?

Does anyone have anything they feel needs to be added to what has been said, to make this hearing complete?

MR. NORVIN GREEN: Norvin Green, with the Louisville and Jefferson County Metropolitan Sewer District. I'd like to say for the benefit of the people here, in conjunction with the statements you made at the opening of this meeting patting the citizens of Louisville on the back for voting for a sewage treatment plant four to one, I think that as a result of a conference your Commission and our District had last spring, you wrote a letter to the Mayor in which you told the Mayor in no uncertain terms that you thought it was a community obligation and not an obligation of the Sewer District to build this treatment plant.

The Citizens' Committee who did the educational work prior to the election, used that statement of yours very effectively, and I think that had much to do with that overwhelming four to one vote. I just want to thank you for having done it.

CHAIRMAN WARD: Thank you, Mr. Green. I'd like to say publicly, for the benefit of Owensboro, Henderson, Paducah and other communities represented in Kentucky, that our Kentucky Water Pollution Control Commission feels it is your civic responsibility to build sewage treatment plants as fast as you can.

I don't mind saying publicly, as I have said many times privately, I was never going to be in the position of cracking the whip on little communities in Kentucky until the big ones did their jobs; and now that Louisville has voted its bonds we are going to be around talking to you. We feel no community has any right to dump its human waste in the faces of their neighbors.

We expect that we are going to go ahead and make progress. I am very happy to say, incidentally, that I have not found a single instance in Kentucky in which there has not been acceptance on the part of the people, of their obligation to do something about their sewage waste. It is basically a matter of money and of methods of financing, and they need some help. Just as in the case of Louisville the problem was one of how to finance, the same situation exists in many other municipalities. If anyone has any ideas as to an easy method of financing sewage treatment plants, I am sure these municipalities will appreciate knowing of it very much.

There is one gentlemen I haven't presented to you, whom many of you, if you haven't met him already, will certainly want to know, especially those of you representing the cities. I refer to Mr. Ralph Pickard, who is the director of Sanitary Engineering, State Department of Health. (Mr. Pickard stands.)

CHAIRMAN WARD: We have here one of the engineers of our Kentucky Water Pollution Control Commission, Walter Martin. (Mr. Martin stands.)

CHAIRMAN WARD: The Kentucky State Chamber of Commerce has a very active committee that is very much interested in problems of industry. Walter Cook, who is the director of the Industrial Committee of the State Chamber of Commerce, was here earlier; I don't see him now. Walter? (No response.)

Is there any other comment?

MR. HUDSON BIERY: Mr. Chairman, I am not quite satisfied with the concluding remarks on the sludge question.

I'd like to ask Mr. Cleary if it isn't a fact that since the enactment of Public Law 845, and since the formation of this Compact, an aroused public interest throughout the United States is going to make sludge available in quantities all over the country. Isn't it fair to say that there will be much further research as to possible uses and values to be recovered from this product, keeping in mind the waste land of this country, in states like Florida for example and sections of Alabama and Georgia, and many other parts of the country including our own Ohio that so desperately need top soil and fertilizer? Isn't it fair to say that since this material is going to become available in a manner in which it has never been available before, that perhaps only the surface has been scratched as to possible values and possible methods of handling and transportation and other problems regarding use of this new product?

I think you agree with me that probably we may expect something further in this field.

MR. CLEARY: I have never disagreed with you, Commissioner Biery, I am happy to say. The only caution I was throwing out was that small communities would be mistaken if they assumed that the sale of fertilizer was so attractive that it might pay for their sewage-treatment plant. There are certain values in sludge as fertilizer, not measured by its chemical constituents. Future research may point up the desirability of returning this material to the land.

Mr. Biery undoubtedly was thinking about the extraction of Vitamin B-12. Sewage sludge is one of the richest sources of this material, as demonstrated in Milwaukee. There are certain other growth-promoting constituents in sludge that may have an important bearing on restoring nutritive values to soils. My only reason for not showing too much enthusiasm about the return of sludge to the land is that the financial aspects are not too attractive at the present time to small communities.

CHAIRMAN WARD: Mr. Wisely, would you like to make some comment before we conclude?

MR. W. H. WISELY: Regarding this last matter, which really doesn't relate to the matter of treatment requirements for maintaining water quality in the river and therefore is beside the point of the hearing, I suggest a bit of caution in considering the sludge as an important factor in the economics of sewage treatment for municipalities. In the first place, I suggest caution in calling the sludge fertilizer, because actually it is, if anything, a low-grade fertilizer at best. A soil conditioner is perhaps a better term for it, and I concur in Mr. Cleary's endeavor to have you hold it in the background in your thoughts when considering the economics of sewage treatment. It is not an important factor.

CHAIRMAN WARD: Mr. Quinn?

MR. JOSEPH L. QUINN, Jr.: Mr. Chairman, Indiana wants to join with the rest of the Commission in complimenting Louisville on the fine program it has made.

On behalf of the Commission, I'd like to reiterate that it is a pleasure to see so many people here interested in cleaning up the river.

I think it would be an opportune time now for me to suggest we adjourn.

CHAIRMAN WARD: If there is nothing further to come before the hearing, then this meeting of the board will be subject to further call.

Thank you all for your attendance.

(Whereupon the hearing was adjourned at 11:30 o'clock a.m.)

EXHIBIT A

OHIO RIVER VALLEY WATER SANITATION COMMISSION

NOTICE OF PUBLIC HEARING

Pursuant to authority contained in Article VI of the Ohio River Valley Water Sanitation Compact, and pursuant to direction of the Ohio River Valley Water Sanitation Commission as contained in a resolution duly adopted at a regular meeting held on the 7th day of October, 1953, a public hearing will be held by the Commission at Courtroom No. 1, second floor, U. S. Post Office and Court House, 601 West Broadway, Louisville, Kentucky, commencing at 10:00 A.M. o'clock on the 9th day of December, 1953, and continuing thereafter until completed. The purpose of said hearing will be to obtain and record data, information and other evidence for use by the Commission in determining the degree of treatment which shall be given to sewage discharged or permitted to flow into the waters of the Ohio River in that stretch extending from Dam No. 37, located about ten miles below Cincinnati, Ohio and being 483.2 miles downstream from Pittsburgh, Pennsylvania, to Cairo Point, located at the confluence of the Ohio and Mississippi Rivers and being 981.0 miles downstream from Pittsburgh, Pennsylvania.

Any and all parties whose interests may be affected by such determination are invited to be present or to be represented at the hearing to be held as above stated. All interested parties present or represented at said hearing will be given an adequate opportunity to express either orally or in writing, their views upon the issues there to be considered.

Interested parties who desire additional information concerning the conduct of this hearing or who desire information with regard to evidence, views or recommendations which are to be submitted at such hearing are requested to call at the offices of the Ohio River Valley Water Sanitation Commission, 302 Mercantile Library Building, 414 Walnut Street, Cincinnati, Ohio. On and after the 9th day of November, 1953, there will be on file and available for examination at the offices of the Commission, located as above stated, copies of the report of the Commission covering its investigation of the treatment requirements for sewage discharged or permitted to flow into the stretch of the Ohio River as above defined and including recommendations with regard to the degree of treatment which should be established for such sewage.

OHIO RIVER VALLEY WATER SANITATION COMMISSION

By H. E. Moses, Chairman

November 6, 1953

EXHIBIT B

CERTIFICATION OF PUBLICATION AND DISTRIBUTION OF NOTICE OF PUBLIC HEARING TO BE HELD IN LOUISVILLE, KENTUCKY, DECEMBER 9, 1953

I, Robert K. Horton, hereby certify that the notice of public hearing attached hereto (said hearing to be held in Louisville, Kentucky, December 9, 1953) was published and distributed in accordance with the following schedule.

(a) Notice was published as a paid advertisement in the newspapers and on the dates indicated in attached List No. 1. Affidavits of publication are on file in the Commission Offices.

(b) Notices were mailed November 16, 1953, to one or more city officials (officials being Clerk of Council, City Manager, and or City Engineer as indicated) of the cities and towns indicated on attached List No. 2; these cities and towns being those located along that section of the Ohio River with which the hearing is concerned as indicated by the U. S. Corps of Engineers Ohio River Navigation Charts (latest available), the Rand McNally Commercial Atlas and Marketing Guide (83rd edition, 1952), and the Rand McNally Road Atlas (1951 edition) - (post-office locations determined from U. S. Official Postal Guide, Part I, Domestic, July 1951).

(c) Notices were mailed November 16, 1953, to the Boards of County Commissioners of the counties shown on attached List No. 3; these counties being those bordering that section of the Ohio River with which the hearing is concerned.

(d) Notices were mailed November 16, 1953, to municipal organizations shown on attached List No. 4; these organizations being Chambers of Commerce, Boards of Trade and Business Associations at places located along that section of the Ohio River with which the hearing is concerned (these organizations are listed in a directory published July 1952 by the Chamber of Commerce of the State of New York).

(e) Notices were mailed November 16, 1953, to the Leagues of Municipalities of the four states concerned (Ohio, Illinois, Indiana and Kentucky); names of these leagues are indicated on the attached List No. 5.

(f) Notices were mailed November 16, 1953, to those industrial concerns shown on attached List No. 6. This list shows those industries known or reported by the state sanitary engineers as discharging or which might possibly discharge liquid wastes directly into the section of the Ohio River involved.

(g) Notices were mailed November 16, 1953, to certain trade associations as shown on attached List No. 7; these associations being selected from state directories as those whose members most likely would be interested in or affected by the hearing.

(h) Notices were mailed November 16, 1953, to the Attorneys General of Ohio, Illinois, Indiana and Kentucky. Names of Attorneys General are indicated on attached List No. 8.

(i) Notices were mailed November 16, 1953, to state agencies of Ohio, Illinois, Indiana and Kentucky as shown on attached list No. 9. These agencies include state water pollution control agencies, state departments of natural resources and others.

s/s Robert K. Horton

STATE OF OHIO, COUNTY OF HAMILTON: SS:

ROBERT K. HORTON, being first duly sworn, says that the allegations contained in the foregoing certificate are true.

s/s Robert K. Horton

Sworn to before me and subscribed in my presence this 7th day of December, 1953.

s/s Verna B. Ballman
Notary Public
Hamilton County, Ohio

LIST NO. 1

NEWSPAPERS

Place	Newspaper and Name of Publisher	Date of Publication
Cincinnati, Ohio	Cincinnati Enquirer 617 Vine Street Cincinnati, Ohio	11-16-53 11-23-53
Louisville, Kentucky	Courier-Journal Courier-Journal and Louisville Times Co. Louisville, Kentucky	11-16-53 11-23-53
Tell City, Indiana	News News Publishing Co. Tell City, Indiana	11-13-53 11-20-53
Rockport, Indiana	Democrat Raymond J. Patmore, Pub. Rockport, Indiana	11-13-53 11-20-53
Owensboro, Kentucky	Inquirer Owensboro Publishing Co. Owensboro, Kentucky	11-16-53 11-23-53
Newburgh, Indiana	Register A. D. Hanes, Publisher Newburgh, Indiana	11-13-53 11-20-53
Evansville, Indiana	Courier Evansville Printing Corp. 201 N. W. 2nd Street Evansville, Indiana	11-16-53 11-23-53
Shawneetown, Illinois	Gallatin Democrat P. J. Valter, Publisher Shawneetown, Illinois	11-12-53 11-19-53
Golconda, Illinois	Herald Enterprise Herald Enterprise Pub. Co. Golconda, Illinois	11-12-53 11-19-53
Paducah, Kentucky	Sun-Democrat Paducah Newspapers, Inc. Paducah, Kentucky	11-16-53 11-23-53
Metropolis, Illinois	News Charles C. Feirich, Pub. Metropolis, Illinois	11-12-53 11-19-53
Cairo, Illinois	Citizen Citizen Co., Cairo, Illinois	11-16-53 11-23-53

LIST NO. 2 -- TOWNS AND CITIES

Code
cc - Clerk of Council
cm - City Manager
ce - City Engineer

OHIO

Hamilton County
Addyston, cc, cm

INDIANA

Dearborn County
Lawrenceburg, cc, cm, ce
Aurora, cc, cm, ce

Ohio County
French, cc
Rising Sun, cc, cm
North Landing, cc

Switzerland County
Patriot, cc
Florence Ferry, cc
Markland, cc
Vevay, cc, cm
Lamb, cc

Jefferson County
Brooksburg, cc
Madison, cc, cm, ce
Hanover, cc, cm
Marble Hill, cc

Clark County
Bethlehem, cc
Owen, cc
Charlestown, cc, cm, ce
Utica, cc
Jeffersonville, cc, cm, ce
Clarksville, cc, cm, ce (Jeffersonville)

Floyd County
New Albany, cc, cm, ce

Harrison County
Locust Point, cc
Rosewood, cc
New Boston, cc
Mauckport, cc
New Amsterdam, cc

Crawford County
Leavenworth, cc
Fredonia, cc
Alton, cc
Cape Sand , cc

Perry County
Magnet, cc
Dexter, cc
Derby, cc
Rome, cc
Tobinsport, cc
Cannelton, cc, cm
Tell City, cc, cm, ce
Troy, cc
Lauer, cc

Spencer County
Grandview, cc
Rockport, cc, cm
Enterprise, cc

Warrick County
Newburgh, cc, cm

Vanderburgh County
Evansville, cc, cm, ce
Cypress, cc

Posey County
West Franklin, cc
Mount Vernon, cc, cm, ce

ILLINOIS

Gallatin County
Shawneetown, cc, cm

Hardin County
Cave in Rock, cc
Elizabethtown, cc
Rosiclare, cc, cm
Hall Ridge, cc

Note: Mailing addresses for towns and cities without P.O. are indicated in().

Pope County
- Golconda, cc, cm
- Bay City, cc
- Hamletsburg, cc
- New Liberty, cc

Massac County
- Brookport, cc, cm
- Metropolis, cc, cm, ce
- Joppa, cc

Pulaski County
- Olmsted, cc
- Mound City, cc, cm

Alexander County
- Cairo, cc, cm, ce

KENTUCKY

Boone County
- Petersburg, cc
- Grant, cc
- Belleview, cc
- Maxville, cc
- Rabbit Hash, cc

Gallatin County
- Brashear, cc
- Warsaw, cc
- Etheridge, cc

Carroll County
- Ghent, cc
- Carrollton, cc, cm
- Prestonville, cc

Trimble County
- Milton, cc
- Corn Creek, cc
- Wises Landing, cc

Oldham County
- Westport, cc

Jefferson County
- Louisville, cc, cm, ce
- Kosmosdale, cc

Hardin County
- West Point, cc, cm
- Howard, cc

Meade County
- Brandenburg, cc
- Battletown, cc
- Wolf Creek, cc
- Concordia, cc
- Rock Haven, cc

Breckinridge County
- Stephensport, cc
- Cloverport, cc, cm
- Chenault, cc

Hancock County
- Hawesville, cc
- Lewisport, cc

Daviess County
- Maceo, cc
- Owensboro, cc, cm, ce

Henderson County
- Henderson, cc, cm, ce
- Geneva, cc
- Alzey, cc
- Wells Store, cc
- Scuffletown, cc
- McDonalds Landing, cc

Union County
- Uniontown, cc, cm
- Caseyville, cc

Crittenden County
- Fords Ferry, cc
- Tolu, cc

Livingston County
- Carrsville, cc
- Bayou, cc
- Birdsville, cc
- Smithland, cc

McCracken County
- Ledbetter, cc
- Paducah, cc, cm, ce

Ballard County
- Holloway, cc
- Wickliffe, cc

LIST NO. 3

COUNTIES AND COUNTY SEATS NOTIFIED OF PUBLIC HEARING

Example: Board of County Commissioners
Hamilton County
Cincinnati, Ohio

STATE	COUNTY	COUNTY SEAT
Ohio	Hamilton	Cincinnati
Indiana	Dearborn	Lawrenceburg
	Ohio	Rising Sun
	Switzerland	Vevay
	Jefferson	Madison
	Clark	Jeffersonville
	Floyd	New Albany
	Harrison	Corydon
	Crawford	English
	Perry	Cannelton
	Spencer	Rockport
	Warrick	Boonville
	Vanderburgh	Evansville
	Posey	Mt. Vernon
Illinois	Gallatin	Shawneetown
	Hardin	Elizabethtown
	Pope	Golconda
	Massac	Metropolis
	Pulaski	Mound City
	Alexander	Cairo
Kentucky	Boone	Burlington
	Gallatin	Warsaw
	Carroll	Carrollton
	Trimble	Bedford
	Oldham	La Grange
	Jefferson	Louisville
	Bullitt	Shepherdsville
	Hardin	Elizabethtown
	Meade	Brandenburg
	Breckinridge	Hardinsburg
	Hancock	Hawesville
	Daviess	Owensboro
	Henderson	Henderson
	Union	Morganfield
	Crittenden	Marion
	Livingston	Smithland
	Marshall	Benton
	McCracken	Paducah
	Ballard	Wickliffe

LIST NO. 4

CHAMBERS OF COMMERCE

Indiana

Lawrenceburg	Greendale Chamber of Commerce
Aurora	Chamber of Commerce
	Aurora Commercial Club
Madison	Madison Chamber of Commerce
Jeffersonville	Chamber of Commerce
New Albany	Chamber of Commerce
Tell City	Junior Chamber of Commerce
Evansville	Chamber of Commerce
Mount Vernon	Chamber of Commerce
Indianapolis	Indiana State Chamber of Commerce

Illinois

Metropolis	Chamber of Commerce
Cairo	Cairo Association of Commerce
Chicago	Illinois State Chamber of Commerce

Kentucky

Louisville	Louisville Chamber of Commerce
Owensboro	Owensboro Chamber of Commerce
Henderson	Chamber of Commerce
Paducah	Association of Commerce
Louisville	Kentucky State Chamber of Commerce

Ohio

Columbus	Ohio State Chamber of Commerce 820 Huntington Building Columbus, Ohio

LIST NO. 5

LEAGUE OF MUNICIPALITIES

Ohio

Mr. Allen E. Pritchard, Jr., Executive Director
Ohio Municipal League
55 East State Street
Columbus, Ohio

Indiana

Mr. W. Vincent Youkey, Executive Director
Indiana Municipal League
Room 401 City Hall
Indianapolis, Indiana

Illinois

Mr. A. L. Sargeant, Executive Director
Illinois Municipal League
537 South 4th Street
Springfield, Illinois

Kentucky

Mr. Carl B. Wachs, Executive Director
Kentucky Municipal League
University of Kentucky
Lexington, Kentucky

Exhibit B
Sheet 9 of 12

LIST NO. 6

INDUSTRIES NOTIFIED

Addressed to the General Manager of the following companies:

Indiana

Joseph E. Seagram & Sons, Inc. Lawrenceburg, Indiana
Schenley Distilleries, Inc., Lawrenceburg, Indiana
James Walsh & Co., Inc., Lawrenceburg, Indiana
Indiana Ordnance Plant, Charlestown, Indiana
Hoosier Ordnance Plant, Charlestown, Indiana
U. S. Army, QMC Depot, Jeffersonville, Indiana
Colgate-Palmolive-Peet Co., Clarksville, Indiana
Conrad-Kammer Glue Co., New Albany, Indiana
George Moser Leather Co., New Albany, Indiana
Indiana Farm Bureau Refinery, Mount Vernon, Indiana
Mount Vernon Milling Co., Mount Vernon, Indiana

Kentucky

Reynolds Metals Co., Louisville, Kentucky
National Carbide Co., Louisville, Kentucky
Bond Brothers, Co., Louisville, Kentucky
Ford Motor Co., Louisville, Kentucky
Sinclair Oil Co., Louisville, Kentucky
E. I. du Pont de Nemours & Co., Louisville, Kentucky
Aetna Oil Co., Louisville, Kentucky
Kentucky Synthetic Rubber Co., Louisville, Kentucky
Louisville Refining Co., Louisville, Kentucky
Carbide and Carbon Co., Butadiene Plant, Louisville, Kentucky
Field Packing Co., Owensboro, Kentucky
Field Creamery, Owensboro, Kentucky
Glenmore Distilleries, Owensboro, Kentucky
Medley Distillery, Owensboro, Kentucky
Fleischmann Distillery, Owensboro, Kentucky
Farmers Tankage, Co., Henderson, Kentucky
Eckert Packing Co., Henderson, Kentucky
Spencer Chemical Co., Henderson, Kentucky

LIST NO. 7

TRADE ASSOCIATIONS

Indiana

Mr. A. C. Conde, Executive Vice-President
Indiana Manufacturers Association
1150 Consolidated Building
114 North Penn
Indianapolis, Indiana

Leland K. Fishback, Executive Secretary
Petroleum Industries Committee
509 Circle Tower
Indianapolis, Indiana

Illinois

Mr. Allan T. Gordon, Legislative Director
Illinois Manufacturers Association
501-02 Laland Office Building
Springfield, Illinois

Mr. Jesse H. Higgins, Executive Secretary
Petroleum Industries Committee
707-08 Ferguson Building
Springfield, Illinois

Kentucky

Associated Industries of Kentucky
Kentucky Home Life Building
Louisville 2, Kentucky

Kentucky Distillers Association
Kentucky Home Life Building
Louisville 2, Kentucky

Kentucky Petroleum Industries Committee
674 South Fourth Street
Louisville, Kentucky

Executive Secretary
Distilled Spirits Institute
National Press Building
Washington, D. C.

LIST NO. 8

ATTORNEYS GENERAL

Ohio

Hon. C. William O'Neill
Attorney General
State of Ohio
Columbus, Ohio

Indiana

Hon. J. Emmett McManamon
Attorney General
State of Indiana
Indianapolis, Indiana

Illinois

Hon. Ivan A. Elliott
Attorney General
State of Illinois
Springfield, Illinois

Kentucky

Hon. J. D. Buckman, Jr.
Attorney General
State of Kentucky
Frankfort, Kentucky

LIST NO. 9

STATE AGENCIES

Ohio

Mr. G. A. Hall, Engineer-Secretary
Water Pollution Control Board
306 Ohio Departments Building
Columbus 15, Ohio

Mr. A. W. Marion, Director
Department of Natural Resources
Ohio Departments Building
Columbus 15, Ohio

Indiana

Mr. Blucher A. Poole, Technical Secretary
Indiana Stream Pollution Control Board
1330 West Michigan Street
Indianapolis 7, Indiana

Mr. Kenneth M. Kunkel, Director
Conservation Commission
311 W. Washington Street
Indianapolis, Indiana

Mr. Anton Hulman, Chairman
Flood Control and Water Resources Commission
1330 West Michigan Street
Indianapolis, Indiana

Kentucky

Mr. Louis Birkel
Kentucky Water Pollution Control Commission
620 South Third Street
Louisville 2, Kentucky

Mr. Henry Ward
Commissioner of Conservation
Commonwealth of Kentucky
Frankfort, Kentucky

Mr. Earl Wallace
Division of Game and Fish
New State Office Building
Frankfort, Kentucky

EXHIBIT C

ROSTER OF ATTENDANCE

Following is list of persons attending hearing who submitted attendance-identification slips:

Mr. C. D. Adams
Colgate Palmolive Company
Jeffersonville, Indiana

Mr. W. D. Anderson
Sanitary District No. 1
Campbell and Kenton Counties
Kentucky

Mr. S. M. Bailey
Corps of Engineers,
Louisville, Kentucky

Mr. Louis F. Birkel
Kentucky Water Pollution Control Com.
Louisville, Kentucky

Mr. Hudson Biery
Commissioner for Ohio
Ohio River Valley Water Sanitation Com.
Terrace Park, Ohio

Mr. Millard Cox
Louisville, Kentucky

Mr. Alex B. Davidson
Schenley Distillers, Inc.
Cincinnati, Ohio

Mr. H. R. Dempf
Metropolitan Sewer District
Louisville, Kentucky

Mr. Robert B. Diehl
Flood Control Division, State of Ky.
Louisville, Kentucky

Mr. James F. Elrod
Mathieson Hydrocarbon Chemical Corp.
Brandenburg, Kentucky

Mr. W. L. Farris
E. I. DuPont, Indiana Ordnance,
Charleston, Indiana

Mr. Morris Forman
Metropolitan Sewer District
Louisville, Kentucky

Mr. Jack Gardner
The Buckeye Cotton Oil Co.
Louisville, Kentucky

Mr. V. E. Gex
The Buckeye Cotton Oil Co.
Cincinnati, Ohio

Mr. Norvin E. Green
Metropolitan Sewer District
Louisville, Kentucky

Mr. Wm. A. Hasfurther
Illinois Sanitary Water Board
Springfield, Illinois

Mr. Donald W. Heil
Sohio Petroleum Co.
Covington, Kentucky

Mr. Blakey Helm
Metropolitan Sewer District
Louisville, Kentucky

Mr. Oral H. Hert
Indiana State Board of Health
Indianapolis, Indiana

Mr. Joseph Hitz
Louisville Refining Co.
Louisville, Kentucky

Mr. Wilson R. Isert
Colgate Palmolive Co.
Jeffersonville, Indiana

Mr. Walter Koch
Kentucky Chamber of Commerce
Louisville, Kentucky

Mr. Kenneth Kuiken
Buckeye Cotton Oil Co.
Louisville, Kentucky

Mr. J. J. Loudermill
Louisville Refining Co.
Louisville, Kentucky

Exhibit C
Sheet 2 of 2

Mr. Walter C. Martin
Kentucky Water Pollution Control Commission
Louisville, Kentucky

Mr. Robert C. Morrow
City of Paducah
Paducah, Kentucky

Mr. Walter Norman
Aetna Oil Co.
Louisville, Kentucky

Mr. James E. Patton
City of Owensboro
Owensboro, Kentucky

Mr. M. M. Peters
Dept. of Fish & Wildlife Resources
Frankfort, Kentucky

Mr. Ralph C. Pickard
Kentucky State Dept. lf Health
Louisville, Kentucky

Mr. J. K. Pinkerton
E. I. duPont, Indiana Ordnance Works
Charlestown, Indiana

Mr. B. A. Poole, Executive Secretary
Indiana Stream Pollution Control Board
Indianapolis, Indiana

Dr. Joseph L. Rahm
U. S. Game Warden
Waverly, Kentucky

Mr. Floyd F. Schrader
U. S. Geological Survey
Louisville, Kentucky

Mr. David N. Schroer
Owensboro Sewer Pipe Co.
Owensboro, Kentucky

Mr. G. R. Scott
Black & Veatch
Owensboro and Paducah
Kansas City, Missouri

Mr. J. R. Shrewsbury
B. F. Goodrich Chemical Co.
Louisville, Kentucky

Mr. Earle C. Smith
Cleveland Heights, Ohio

Mr. Howard W. Stepler
E. I. duPont
Louisville, Kentucky

Mr. Clifford T. Stigger
Colgate Palmolive Co.
Jeffersonville, Indiana

Mr. Fisher Tichenor
Owensboro City Council
Owensboro, Kentucky

Mr. W. W. Towne, Officer-in-Charge
Ohio & Tennessee Drainage Basins
U. S. Public Health Service
Cincinnati, Ohio

Mr. Charles Van Stone
City of Evansville Indiana
Evansville, Indiana

Mr. James L. Walker, Jr.
New Albany, Indiana

Mr. G. R. Watkins
Lexington, Kentucky

Mr. R. M. Wheeler
Air Reduction Co.
Louisville, Kentucky

Mr. Chester S. Whetzell
New Albany, Indiana

Mr. W. C. Woodings, Jr.
E. I. duPont
Louisville, Kentucky

Mr. H. O. Zimmerman
Kentucky Water Pollution Control Comm.
Wheelwright, Kentucky

OHIO RIVER

Pollution-Abatement Needs

Cincinnati-Cairo 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.

HEADQUARTERS • 414 WALNUT ST. • CINCINNATI 2, OHIO

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 Cincinnati-Cairo 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 it has approved the conclusions reached.

This report sets forth the findings and the recommendations for treatment. Since the latter calls for a degree of treatment higher in some places than the minimum specified in the compact, the Commission authorized at its meeting of October 7, 1953 the conduct of a public hearing in accordance with procedures outlined in Article VI of the compact. The hearing will be held in Louisville, beginning on December 8. Members of the hearing board are: Kentucky commissioner Henry Ward, chairman; Indiana commissioner Joseph L. Quinn, and Illinois commissioner W. H. Wisely

Evaluation studies and preparation of the report were assigned to Harold W. Streeter, staff consultant. He was assisted in the development and compilation of data by Robert K. Horton, sanitary engineer. Illustrations were made by Elmer Rohmiller, staff assistant.

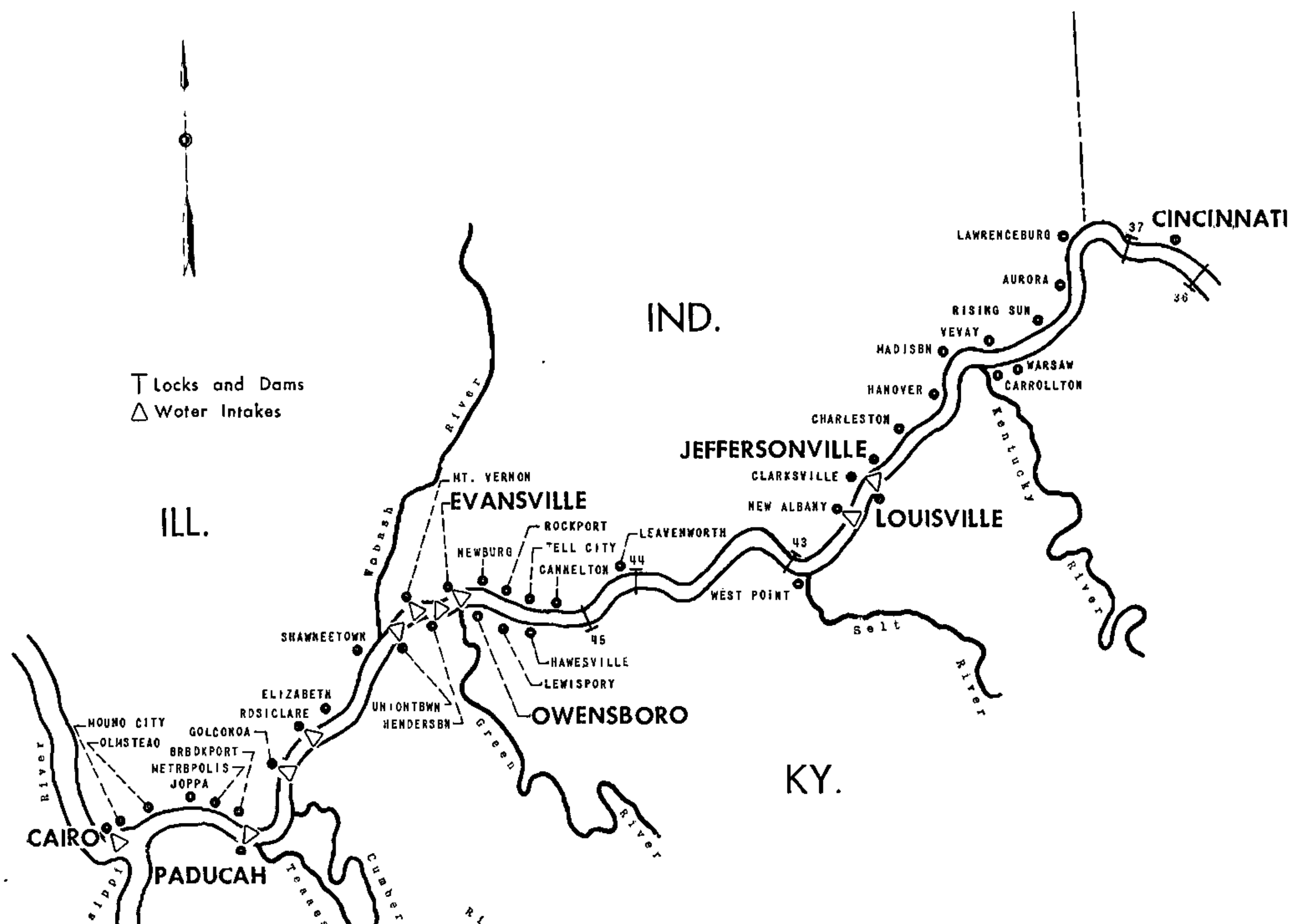
Respectfully submitted,

Edward J. Cleary

EDWARD J. CLEARY
Executive Director
and Chief Engineer

November 1, 1953
Cincinnati, Ohio

Contents



OHIO RIVER BETWEEN CINCINNATI AND CAIRO
Showing Municipal Sources of Pollution and Water Supplies

Ohio River Valley Water Sanitation Commission
Cincinnati, Ohio October 1953

OHIO RIVER POLLUTION—ABATEMENT NEEDS

Cincinnati—Cairo Stretch

RECOMMENDATIONS

This investigation has been made for the purpose of evaluating pollution conditions resulting from the discharge of sewage into the Ohio River between Cincinnati (Dam 37) and Cairo Point (near the junction of the Ohio and Mississippi rivers). It has been directed toward the determination of sewage-treatment requirements necessary to maintain satisfactory sanitary conditions in the river, as provided in Article I of the Ohio River Valley Water Sanitation Compact.

Article I of the Compact pledges the eight signatory states to take such action that the waters within the compact district shall be placed and maintained in 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 nuisance, and adaptable to other legitimate uses. The sewage-treatment requirements recommended in this report are intended to achieve these objectives. As in previous reports dealing with other stretches of the Ohio River, dissolved oxygen conditions and bacterial quality in terms of coliform bacterial densities in the river have been considered in this report as primary indicators of sanitary conditions.

It is recommended that the following standard of treatment, subject to revision as changing conditions may require, be established for all sewage from municipalities or other political subdivisions, public or private institutions or corporations, discharged or permitted to flow into that stretch of the Ohio River extending from Dam No. 37, located about ten miles below Cincinnati and being 483.2 miles downstream from Pittsburgh, to Cairo Point, located at the confluence of the Ohio and Mississippi Rivers and being 981.0 miles downstream from Pittsburgh:

(1) Substantially complete removal of settleable solids; and

(2) Removal of not less than forty-five percent of the total suspended solids; and, in addition

(3) Treatment of all sewage discharged into that section of the river extending from Mile Point 750 (miles below Pittsburgh) to Mile Point 803 so as to provide for reduction in coliform organisms in accordance with the following schedule:

Not less than 85 percent reduction during the months May through October.

Not less than 65 percent reduction during the months November through April.

PURPOSE and SCOPE

This report is the fourth of a series concerned with treatment requirements for wastes discharged to the Ohio River. The purpose of the report is to present findings on sewage pollution conditions in a 500-mile stretch of the river extending from Cincinnati to Cairo, 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 as 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 Dam No. 37, located about ten miles below Cincinnati and being 483.2 miles downstream from Pittsburgh, to a point near Cairo, Ill. (known as Cairo Point) located at the confluence of the Ohio and Mississippi Rivers and being 981.0 miles below Pittsburgh.

Eleven municipalities in this stretch obtain their water supplies directly from the Ohio River. The total population thus served is estimated as being approximately 650,000 (see Table I).

In evaluating conditions in this stretch of the river, it has been necessary to consider the effects of wastes discharged to the river in the Cincinnati pool (mile 460.9 to mile 483.2). These wastes constitute a major part of the total pollution load imposed on the lower half of the Ohio River. This investigation has taken into account the present influence of such discharges on quality conditions, and also the effects that might be expected once these discharges are treated in accordance with already-established requirements.

Wastes discharged into the Cincinnati-Cairo stretch of the Ohio River (including those discharged in the Cincinnati pool) have a total population equivalent in terms of bio-chemical-oxygen-demand (BOD) of 3,550,400. The total sewered population is 1,373,200. These figures are estimated as of the year 1950. Major sources of pollution are shown in Table II.

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 reports on the Huntington-Cincinnati and Pittsburgh-Huntington stretches of the river, titled "Ohio River Pollution-Abatement Needs - Huntington-Cincinnati Stretch", dated February 1952; and "Ohio River Pollution-Abatement Needs - Pittsburgh-Huntington Stretch" dated March 1953.

The present investigation has involved a study of existing oxygen-demanding loads imposed on the river, and a determination of maximum allowable loads at critical points and with critical stream flows. It also has included a study of coliform-bacteria concentrations at or near certain waterworks intakes for which reliable data have been available, 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 sewage-treatment measures aimed only at protecting water supplies also has been considered.

Basic information on pollution loads has been obtained from the Ohio River Pollution Survey Report (House Document 266, 78th Congress) ; from the most recent available data in the U. S. Public Health Services "Inventory of Water and Sewage Facilities"; from the 1950 U. S. Census report ; from surveys made by the Commission, and from available records of raw-water quality at waterworks intakes, including data collected by the Water Users Committee of the Commission.

HYDROMETRIC DATA

Discharge records for the U. S. Geological Survey gages at Louisville, Ky. and Metropolis, Ill. were used as the basis for flow-probability studies. These gages are located in the upper and lower sections of the Cincinnati-Cairo stretch, and they provide the longest continuous records of any of the gaging stations on the Ohio River in this stretch. For intermediate points, flow estimates have been based on drainage area ratios as referred to Louisville or Metropolis.

From these records the following data were tabulated for each year from 1934 to 1949, 1949 being the latest year for which final flow records are available: Minimum daily flow, minimum weekly flow, minimum two-week flow, and minimum (calendar) monthly flow. These data are shown in Table III. From the tabulation it will be noted that the various minimum flows recorded during the 16-year period are as follows:

	Louisville	Metropolis
Minimum day	4,090	20,600
" week	6,400	27,000
" two-weeks	6,880	30,000
" month	8,590	35,000

Flow adjustment for reservoir operation

The recorded flows given in Table III 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 Pittsburgh-Huntington and Huntington-Cincinnati stretches of the Ohio River.

Adjusted flows are shown in Table IV. 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 V. The values of flow increase shown in the tabulation are believed 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, (Table IV), 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 VI.

Critical flow duration

For the evaluation of oxygen conditions the minimum weekly-average flows have been used, as representing approximately the time of passage of pollution through the critical sections of the river below the major sources of pollution, such as the Cincinnati and Louisville areas, where oxygen depletion is greatest.

In the studies of bacterial conditions from Cincinnati to Cairo, the calendar monthly average flows have been used. The reason in this case is that the bacterial-quality objectives adopted by the Commission are expressed in terms of average coliform bacterial concentrations during a calendar month.

Time of flow

Time-of-flow data used in the analysis of oxygen and bacterial conditions in the river were obtained from a Commission report entitled "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, 78th Congress).

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 time-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 in Mr. Landenberger's report).

In the present case, however, the Ohio River discharge curves used by Mr. Landenberger have been utilized (rather than tributary reference-gage readings) as being more directly correlated with times-of-flow especially in low stages of the river.

Stream temperature

Stream 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 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 biochemical-oxygen-demand (BOD) loads discharged into the river between Cincinnati and Cairo are shown in Table II for the years 1940 and 1950. The table also gives the 1940 and 1950 census and estimated-sewered populations for each major source of sewage pollution.

No attempt has been made to list all individual sources of pollution, such as isolated industrial plants, or smaller unsewered or partially sewered communities. The data for the main sources listed include, however, both sewage and industrial waste loads discharged either through municipal sewers, or directly into the river, so far as available information is at hand. Population equivalents of waste loads have been estimated on the basis of 0.25 lb. of total first-stage biochemical oxygen demand (BOD), or 0.17 lb. of 5-day BOD, per capita daily.

In compiling Table II, the 1940 and 1950 census populations were taken from the reports of the U. S. Census Bureau. The 1940 sewered populations and population equivalents were derived from data published in House Document 266, 78th Congress, Part II, Table OH-3, page 212. The 1950 sewered populations and population equivalents were estimated in part from the 1940 figures, adjusted for changes in census population, and in part from additional information furnished by the states of Indiana, Kentucky, and Illinois.

As shown in Table II, about 90 percent of the total census population located on the river between Cincinnati and Cairo is resident in these main centers: Cincinnati, Louisville and Evansville. The Cincinnati area, with a population of 628,381, made up 48 percent; the Louisville area, with 419,065, 32 percent; and Evansville, with 128,636, 10 percent.

On the basis of population equivalents, the Cincinnati area contributed 55 percent of the total BOD load; the Louisville area, 34 percent; and Evansville, 6 percent. From these figures it is apparent that sewage and industrial pollution from the other communities, amounting to less than 10 percent of the total, is a comparatively small element in the total BOD load.

Oxygen profiles

The trend of dissolved oxygen in the river under summer low-flow conditions is shown in Figure 1 by the lower profile. This profile is based on load data shown in Table II, and has been drawn at the minimum weekly average river flow occurring once in ten years (7,410 cfs at Louisville gage), and at a river temperature of 25 degrees Centigrade. The upper profile shows the effect of a uniform 35% reduction in BOD.

These profiles have been calculated by means of the oxygen sag formula, adjusting the BOD load at each successive source of pollution. Although it does now show the absolute dissolved-oxygen minimum points below Cincinnati and Louisville, it indicates them approximately at Lawrenceburg and Dam 43 (mile 633.2), respectively. In computing the profiles, allowance has been made for residual BOD in the river above Cincinnati.

It will be noted that the effect of the BOD load discharged at Evansville is small as compared with the effects of loads from Cincinnati and Louisville, reflecting both the lesser Evansville load and the greater volume of river flow at this point.

The profiles take no account, however, of the deoxygenating effect of sludge deposits in the river, which would tend to reduce the dissolved oxygen levels to somewhat lower amounts than shown in the lower profile immediately below major sources of pollution, during and following prolonged low stages of the river. This deoxygenating effect was shown in the results of river examinations carried out in the Commission-sponsored survey of the river in September, 1950. It has not been included in the calculations for the profile because of the presumption that the accumulation of organic sludge deposits will be to a large extent eliminated if the minimum Compact requirements for the removal of settleable solids from all sewage discharged into the river are met.

From the profiles it is evident that the only serious sources of oxygen depression in the river during summer low-flows are immediately below Cincinnati and Louisville, where definite oxygen-sag curves are formed. Below Dam 45 (mile 703.0), where oxygen recovery is in progress, the trend of the profiles is shown to be upward towards an oxygen saturation value of 8.3 parts per million (ppm) at 25 degrees centigrade, which is practically reached near the mouth at Cairo. This general picture has been confirmed by the observations carried out by the U. S. Public Health Service in 1940, and by the average results of the tests made in September, 1950, in the latter case with the exception above noted.

Because of the fact that the major part of the BOD load discharged to the river originates at Cincinnati and Louisville, a special study has been made of the minimum dissolved-oxygen values to be expected below each of these two sources of pollution under summer drought-flow conditions, both with and without treatment. In this connection it should be noted that treatment requirements already established for the Cincinnati area call for BOD reductions up to 65 percent as needed, depending on flow conditions. For the Louisville area, it has been assumed that treatment in accordance with minimum Compact requirements will result in a 35 percent reduction in the total BOD load from the area.

Minimum oxygen levels

Calculations of minimum dissolved oxygen content were made for two summer low-flow conditions, one being the 10-year minimum weekly average flow and the other, an extreme drought flow such as occurred during the summer and fall of the year 1930. In making these calculations, the oxygen-sag formula was used, with rates of reaeration based on the results of a series of measurements made in the river between Cincinnati and Louisville during the U.S.P.H.S. survey of 1930, when the river was in pool stage from May through November; probably the longest and best series made in this section of the river under low-flow conditions. Rates of deoxygenation were based on the "normal rate" corrected to a stream temperature of 25 degrees Centigrade. The initial oxygen saturation deficiency assumed was 2.0 parts per million above each city, but no allowance was made for residual BOD at these points, as it was desired to show the effects of BOD loads from each city alone.

The results of the calculations may be summarized briefly as follows:

Cincinnati Flow	10-yr Min. 7,230 cfs		1930 Drought 4,920 cfs	
	Initial BOD ppm	Minimum D.O. ppm	Initial BOD ppm	Minimum D. O. ppm
Without treatment	12.5	2.5	18.5	0.0
With 35% BOD reduction	8.1	4.3	12.0	2.7
With 50% BOD reduction	6.2	5.0	9.2	3.8
With 65% BOD reduction	4.4	5.8	6.5	4.9
Louisville Flow	7,410 cfs		6,000 cfs	
Without treatment	7.4	4.6	9.1	3.8
With 35% BOD reduction	4.8	5.6	5.9	5.1

In the above tabulation it is shown that 35 percent of BOD reduction at Louisville would be expected to accomplish approximately the same results in minimum dissolved-oxygen control as would 65 percent reduction at Cincinnati under the same flow and temperature conditions. It also is indicated that with a 10-year minimum weekly average flow, 50 percent of BOD reduction would be required at Cincinnati to maintain a 5 ppm minimum dissolved oxygen content, and 65 percent reduction at an extreme drought flow as of the year 1930. At Louisville, it would appear that 35 percent of BOD reduction from primary treatment of all sewage from that area should maintain satisfactory oxygen conditions below that district.

At Louisville, the situation with 35 percent of BOD reduction would be roughly similar to that at Cincinnati with reductions up to 65 percent, on the basis of comparable increases in population at the two cities. Population increase at Cincinnati has been estimated at 16 percent for the year 1960 and 31 percent for 1980, over the 1950 population (see Cincinnati Pool Report). Thus with an increase of 31 percent in total BOD load up to 1980, a sustained BOD reduction of 35 percent should permit the maintenance of an average minimum oxygen level of about 5 ppm with a 10-year minimum weekly flow of 7,410 cfs, and an average level of slightly over 4 ppm with an average drought flow of 6,000 cfs. These average levels would provide, however little margin of safety to cover daily variations below 4 ppm.

Conditions between Louisville and Cairo

In the section of the river extending from below Louisville to Cairo, the BOD loads discharged to the river, excepting at Evansville, are small compared to those from the Cincinnati and Louisville areas. The trend of the profile shown in Figure 1, together with the observations made in the two surveys of the river previously mentioned, would suggest that with primary sewage treatment in effect at all sources of direct pollution along this section, and with treatment up to 65 % at Cincinnati, it should be possible to maintain minimum dissolved-oxygen levels well above 4 to 5 ppm at all points with any normally expected increase in sewered populations up to the year 1980.

In connection with the 1940 observations in the river, it was noted that the 5-day BOD values in the lower section of the river were somewhat higher than could be accounted for as originating in direct sources of sewage pollution at various distances upstream. This probably was due in part to the effect of BOD brought in by the tributaries, and possibly also by the transition of biochemical oxidation into the nitrification phase, which would tend to bring about increases in observed BOD unrelated to any immediate sources of pollution.

This same phenomenon has been consistently observed in other long stretches of the river receiving little direct pollution, and it has been marked by evidences of nitrification such as an increase in nitrites and nitrates. The possibility also exists that in these long and relatively unpolluted sections of the river, the effects of BOD originating in land wash from agricultural areas may be more apparent than in those sections where the effects of direct sewage pollution are prevalent. It has been previously noted that the flushing of organic sludge deposits accumulated in pooled sections of the river would also tend to increase the BOD load and cause measurable temporary decreases in oxygen content, as was noted in the September 1950 survey immediately following a sharp general rise in the river. Probably each of these several factors exert their influence at one time or another. They are important in evaluating oxygen conditions in any stream, and particularly in a long river such as the Ohio, with its highly variable flow pattern and the marked contrasts in pollution conditions in its different sections.

BACTERIAL CONDITIONS

As previously noted, sewage pollution in this stretch of the river is dominated by the influence of the three large centers of population at Cincinnati, Louisville and Evansville. So far as bacterial conditions are concerned, however, the effects of a few smaller communities located close to downstream sources of water supply cannot be ignored, as the protection of public water supplies taken from this stretch is the primary aim of corrective sewage treatment at all points.

The largest two sources of sewage pollution, Cincinnati and Louisville, are fortunately situated in relation to downstream water supplies. The nearest water supply now taken from the river below Cincinnati is that of Louisville, some 130 miles by river from Cincinnati. At Louisville, though sewage from the upper part of the city now is discharged into the river above the New Albany intake, it is understood that this situation will be corrected when the sewage of the entire city has been collected and treated at a point below the Falls, and thence discharged into the river. After this program has been completed, the nearest water intake below the Louisville outfall will be that of Evansville, nearly 200 miles downriver. The combined forces of dilution and self-purification over long distances of river mileage will afford in themselves a high degree of protection to downstream water supplies from the effects of pollution from these two major population centers.

The most critical section of the river involving close proximity of water supplies to sources of pollution is between Owensboro and Henderson. The center of this zone is Evansville, the third largest city in the Cincinnati-Cairo stretch. Only ten miles below Evansville is Henderson, which takes its water supply from the river, and some 35 miles upstream is Owensboro, a city of about 34,000 people, which does not take its water supply from the river but discharges its sewage into it. Thus within a river distance of roughly 50 miles are two important sources of pollution, and two equally important sources of water supply. Within a distance of 50 miles below Evansville are four public water supplies, including those of Henderson and Mt. Vernon. The most hazardous situation in this section is that of Henderson, because of its close proximity to Evansville.

Coliform densities at waterworks intakes

The only recent comparable data bearing on the bacterial quality of the river at waterworks intakes have been records at Louisville and Evansville, supplied by the Commission's Water Users Committee, and at Cairo, which have been furnished by the Illinois Sanitary Water Board. These records are based on routine coliform tests with triplicate plantings in each sample dilution, and are expressed in terms of "most probable numbers" (MPN). In Table VII is a summary of these results covering a 30-month period, from July, 1950 through December, 1952, together with concurrent monthly average river flows (provisional) furnished by the U. S. Geological Survey through the District Office at Louisville.

In Figures 2, 3, and 4 are shown plots of the data in Table VII, with flows as abscissae and coliform MPN's as ordinates, using logarithmic scales in order to bring the plots within a convenient range. In each chart results for the months of May-October are designated by circles and results for the months of November-April by triangles, the former representing the summer-fall season, and the latter the winter-spring months with generally lower stream temperatures and higher flows.

In each chart, the general trend of the points indicates increased coliform densities with higher flows, though this trend is less well-defined at Cairo, probably because of the disturbing influence of backwater from the Mississippi River and of the large tributaries entering the Ohio just above Cairo.

During the 30-month period of the record, the monthly average coliform MPN exceeded 5,000 per 100 ml. in 14 out of 26 months at Louisville; in 12 out of 24 months at Evansville; and in 8 out of 29 months at Cairo. The highest monthly average MPN values were 14,000 per 100 ml. at Louisville; 16,200 at Evansville; and 12,100 at Cairo. These figures indicate a somewhat similar level and distribution of bacterial pollution at the Louisville and Evansville intakes, but a lower level at Cairo, where self-purification has been augmented by dilution from the large tributaries, the Cumberland, Tennessee and Wabash Rivers.

It will be noted in the charts that in almost every month at both Louisville and Evansville the coliform MPN exceeded 5,000 per 100 ml. with river flows greater than 100,000 cfs, and at Cairo, with flows greater than 200,000 cfs, these higher flows usually occurring during the winter-spring months. During the summer low-flow months, coliform densities at all three of the intakes have in general been lower than the 5,000 per 100 ml. objective adopted by the Commission for sources of water supply. In a few of these months, notably at the Louisville intake, average coliform densities have been lower than the Commission's bathing water objective of 1,000 per 100 ml.

Computed and observed coliform profiles

In order to show the general trend of coliform densities throughout the entire stretch of the river, a series of computed profiles has been drawn for different river flows characteristic of summer and winter conditions. These profiles are similar to those previously drawn for other stretches of the river and shown in preceding reports on the Pittsburgh-Huntington and Huntington-Cincinnati sections.

The method of computation has been the same as previously. Coliform densities in the river below each source of pollution have been based on summer and winter per capita contributions of coliforms, as determined from measurements made previously by the U. S. Public Health Service and converted to concentration units by applying the river flow. Rates of "die-away" in the river between successive pollution sources have been determined by applying summer and winter curves originally developed by the U. S. Public Health Service from three years' continuous observations during 1914-1916, and checked by later observations covering shorter periods.

In Figures 5 and 6 are shown coliform profiles drawn for the same average flows that prevailed during two periods in 1940-1941, one in summer and the other in winter, when the U. S. Public Health Service carried out coliform-bacteria observations at a number of points between Cincinnati and Cairo (House Document 266, Part II). The average river flow during the summer period was 42,500 cfs at Louisville, and during the winter period was 85,000 cfs at the same point. For comparison with the profiles, the averages of coliform densities observed in the U. S. Public Health Service survey have been plotted in the charts at their proper locations along the river. Also added are observed averages at the Louisville and Evansville intakes reported by the Water Users Committee for months of comparable flow conditions in 1950-52 (these being designated by triangles).

With one or two exceptions, particularly in the winter profile, good agreement is shown between the profiles and the observed coliform densities at various points, the deviations from the profiles being mostly within the limits of observational error. The agreement thus shown, as in previous plots of the same kind, may be taken as indicating that coliform profiles thus drawn should indicate with a fair degree of accuracy the trend of coliform densities throughout the stretch under the average flow and seasonal conditions assumed.

The advantage of these profiles as drawn lies in the fact that they are not subject to temporary disturbing influences from external sources, and hence tend to reflect the trend of coliform densities in the river as affected solely by sources of pollution located directly on the river. The only assumption involved as to tributary pollution is that the bacterial quality of the tributary waters is equal to that of the main river at their point of discharge;

this in effect being consistent with the provisions of the Compact. The non-prevalence of this condition at present probably accounts in part for the deviations of the observed coliform densities from the profiles in Figures 5 and 6.

Coliform densities at critical flows

In Figure 7 (upper profile) is shown a coliform profile drawn for summer conditions at the 10-year minimum monthly average drought flow of 11,100 cfs at Louisville, which is about 25 percent of the summer average flow for which the profile in Figure 5 was drawn. This flow represents an average which would be expected to occur during only one month in ten years; hence it is an extreme drought condition in which the concentrations of coliform bacteria immediately below sources of pollution would be at a maximum. Because of the long times of flow in the river coinciding with this flow, the forces of natural purification at summer temperatures are likewise at a maximum, and their effect is shown by the great improvement in bacterial quality between Cincinnati and Louisville, and between Louisville and Evansville, despite the marked effect of Owensboro in the latter section.

In the river section below Mt. Vernon, a marked improvement is shown, except for the influence of Paducah. Between Owensboro and Mt. Vernon is a sustained "hump" in the profile, which indicates the effect of the three sources of pollution in this section, especially at the Henderson intake, where a coliform density of about 30,000 per 100 ml. would be expected.

In Figure 8 (upper profile) is a winter profile drawn for an assumed flow of 100,000 cfs at Cincinnati, with downstream flows proportionate to increased total drainage areas. In this case the combined effect of lowered river temperatures and shortened times of flow is apparent in the section between Cincinnati and Louisville, though a natural decrease from 70,000 to 10,000 per 100 ml. or about 85 percent is indicated. In the Owensboro-Mt. Vernon section, bacterial conditions are indicated as being somewhat better than under summer flows, with added dilution more than offsetting lowered self-purification, though the combined influence of pollution from Owensboro and Evansville at the Henderson intake is still apparent.

Bacterial-reduction treatment needed

A study of the profiles in Figures 5 and 7 indicates that under summer low-flow conditions, a reduction of 35 percent in coliform bacterial densities, which has been assumed as resulting from primary sewage treatment alone without disinfection, should afford protection to all water supplies in the Cincinnati-Cairo stretch except between Owensboro and Henderson, where a reduction up to 85 percent would be necessary in order to protect water supplies in this section, and particularly at Henderson, the most critical point in the stretch. The degrees of treatment above indicated would be sufficient to provide limited areas of bathing water quality near Tell City and Paducah, and water suitable for other recreational uses in several sections aggregating about 200 miles in length.

The assumption that primary sewage treatment without disinfection may be expected to reduce the coliform bacteria content of raw sewage by about 35 percent merits further comment at this point. In their book on Sewage Treatment, Imhoff and Fair indicate coliform bacteria reductions ranging from 25 to 75 percent for primary treatment alone. Results from the Cleveland Westerly primary treatment plant have shown average coliform reductions well over 35 percent during the past few years, and during the summers of 1927-31 averaged 30 percent, with individual seasonal averages ranging up to 43 percent. On the other hand some daily results from 24-hour composite samples collected primarily for chemical analysis at seven Illinois plants during July and August, 1951 have shown little or no reduction in coliform bacteria from primary treatment alone. These results are not very conclusive, however, because of the limited period covered by them, and because they were based on samples composited over 24-hour periods, during which time marked changes in bacterial content could occur. Provisionally, at least, it would appear that the 35 percent reduction assumed is fairly reasonable for the purpose of estimate.

With winter flows of 100,000 cfs or upwards (Figure 8), indications are that a 35 percent reduction in coliform loads should be sufficient to protect all water supplies in the Cincinnati-Cairo stretch except between Owensboro and Henderson, where a reduction up to 65 percent would be needed. Although the profile in Figure 8 shows that a 35 percent reduction in the coliform load at Cincinnati would fail by a narrow margin to meet the Commission's water-quality objective at the Louisville intake, this margin is so small as to indicate that the present plan of sewage treatment for the Cincinnati area as provided in Treatment Standard No. 1 should be able substantially to meet this objective at existing population loads (1950-52) without additional bacterial-reduction treatment.

It should be pointed out, however, that any material future increase in coliform loads from the Cincinnati area probably would result in failure to meet the objective at Louisville by increasing amounts and with greater frequencies. If and when this situation should develop from an increase in sewered population within the Cincinnati area, provision for added bacterial-reduction treatment of all sewage from this area will be required. The same principle, though to a lesser degree, also would hold for treatment of sewage from the Louisville area, particularly during the winter months of higher flows.

CONCLUSIONS

The following conclusions have been reached from this study of oxygen and bacterial conditions in the Cincinnati-Cairo stretch of the river as affected by direct sewage pollution from 1950 sewered populations:

1. Oxygen conditions are critical only in river sections extending immediately below Cincinnati and to a lesser extent, below Louisville, these conditions being most critical at minimum summer drought flows. In all other sections of the river below Dam 44, oxygen recovery is well established, and should remain in this state under all flow conditions except for some future increase in pollution loads at points now undetermined.

2. BOD reductions in the Cincinnati area in accordance with requirements already established, together with reductions up to 35 percent at all other points (including Louisville), such as may be expected to result from primary treatment of all sewage according to minimum compact requirements, should insure the maintenance of satisfactory oxygen conditions throughout the stretch under all flow conditions with normally expected population increases along the river for the next 20 or 25 years.

3. Bacterial conditions in this stretch of the river, though dominated by the influence of Cincinnati, Louisville and Evansville so far as immediate effects are concerned, are most critical with respect to water supplies in the Owensboro-Henderson section, because of the proximity of the Henderson water supply to the sewer outfalls of Evansville and Owensboro. The long river distances below Cincinnati and Louisville to the nearest sources of water supply tend to mitigate the immediate effects of pollution from these two population centers, so far as their influence on the quality of downstream water supplies is concerned. Below Henderson, the combined effects of tributary dilution at high flows and those of self-purification at low flows, tend to

provided natural protection to water supplies in this section under existing pollution loads, when aided by bacterial reductions to be expected from primary treatment of sewage in accordance with minimum compact requirements.

4. Thirty-five percent reduction in the number of coliform organisms present in raw sewage (such as might be expected from primary sewage treatment) should provide sufficient protection to water supplies under present pollution loads if applied in all river sections except from Owensboro to Henderson. Between Owensboro and Henderson the following reductions in coliform organisms are needed in order to provide adequate protection to water supplies: 85 percent reduction during May through October, and 65 percent reduction during November through April. Any future material increase in existing bacterial loads on the river at Cincinnati will necessitate degrees of bacterial reduction higher than 35 percent in that area, particularly at winter flows exceeding 100,000 cfs.

5. Treatment in accordance with paragraph (4) above should provide water of bathing quality in limited areas above Tell City and Paducah during the bathing season, and should provide water suitable for other recreational uses in these and other areas aggregating about 200 miles of river length (see Figure 7).

TABLES and FIGURES

Table No.

Figure No.

Table I - Municipal water supplies taken from the Ohio River between Cincinnati and Cairo

Municipality	State	Location of intake (miles below Pittsburgh)	Population Served 1950 (estimated)	Municipality	State	Location of intake (miles below Pittsburgh)	Population Served 1950 (estimated)
Louisville	Ky.	601	405,000	Morganfield	Ky.	844	3,000
New Albany	Ind.	608	28,800	Rosiclare	Ill.	891	1,800
Evansville	Ind.	792	140,000	Golconda	Ill.	903	700
Henderson	Ky.	803	18,000	Paducah	Ky.	934	33,800
Mt. Vernon	Ind.	829	6,000	Cairo	Ill.	977	12,000
Uniontown	Ky.	840	400				
						Total----	649,500

Table II - Estimated BOD loads discharged to the Ohio River between Cincinnati and Cairo (loads shown include industrial discharges)

Point	State	Miles below Pittsburgh	Census population		Estimated Sewered population		Estimated BOD load in population equivalents	
			1940	1950	1940	1950	1940	1950
Dam 36		461						
Bellevue,	Ky.		28,154	28,887				
Dayton and Ft. Thomas					60,800	61,700	67,800	68,800
Newport	Ky.	470	30,631	31,044				
Covington	Ky.	471	62,018	64,452	77,800	80,600	141,600	146,500
Cincinnati	Ohio	474	455,610	503,998	512,000	566,000	1,569,400	1,736,000
Dam 37		483						
Lawrenceburg	Ind.	493	4,413	4,806	2,500	5,900	71,900	71,800
Aurora	Ind.	497	4,828	4,780	1,200	4,500		4,500
Madison	Ind.	558	6,923	7,506	7,100	9,130	18,900	20,500
Jeffersonville-Clarksville	Ind.	603	13,879	20,590	12,500	18,500	14,100	29,000
Louisville	Ky.	604	319,077	369,129	304,300	378,000	906,900	1,050,000 *
New Albany	Ind.	609	25,414	29,346	18,300	26,400	40,600	40,800
Tell City	Ind.	727	5,395	5,735	3,500	4,000	4,700	5,000
Owensboro	Ky.	756	30,245	33,651	25,600	32,000	64,400	71,600
Evansville	Ind.	792	97,062	128,636	103,300	110,700	191,200	229,400
Henderson	Ky.	804	13,160	16,837	11,000	17,000	14,000	18,000
Mt. Vernon	Ind.	829	5,638	6,150	4,200	3,100	6,000	5,160
Paducah	Ky.	935	33,756	32,828	29,000	29,500	39,600	39,600
Metropolis	Ill.	944	6,287	6,093	4,200	4,200	4,200	4,200
Cairo	Ill.	981	14,407	12,123	12,000	12,000	12,000	12,000

* Estimated 1953 load is 1,162,000

Table III - Minimum recorded river flows at Louisville and Metropolis gages

Year	Louisville gage: minimum recorded flow (cfs) Day	Week	2-Weeks	Month	Month of minimum flow	Metropolis gage: minimum recorded flow (cfs) Day	Week	2-Weeks	Month	Month of minimum flow
1934	4,900	8,890	10,100	16,200	July	29,500	31,100	41,800	59,400	Sept.
1935	10,600	12,600	13,200	16,800	Oct.	24,800	28,400	30,900	38,600	Oct.
1936	6,150	8,000	8,370	15,000	Sept.	26,900	31,000	35,900	41,500	Aug.
1937	4,090	9,710	10,700	33,400	Sept.	47,800	53,000	55,300	87,800	Sept.
1938	4,600	9,040	10,300	12,300	Oct.	23,700	31,000	31,500	41,800	Oct.
1939	5,200	6,400	7,740	8,590	Sept.	25,200	27,300	29,700	35,000	Sept.
1940	7,200	10,100	10,900	12,900	Oct.	31,800	36,900	38,900	43,000	Oct.
1941	5,360	7,390	8,460	16,200	Oct.	20,600	27,000	30,000	44,500	Oct.
1942	15,200	19,900	27,600	33,700	Sept.	54,000	64,100	71,500	92,300	Oct.
1943	5,300	6,430	6,880	12,400	Oct.	48,000	50,900	52,400	54,900	Oct.
1944	9,120	9,580	10,000	13,400	Aug.	32,700	44,800	45,500	54,100	Aug.
1945	10,700	14,500	16,400	34,300	July	55,700	63,400	65,800	103,000	Aug.
1946	5,500	7,910	9,970	11,000	Sept.	51,700	58,300	59,800	62,700	Sept.
1947	9,730	12,400	14,600	16,000	Oct.	41,100	48,000	49,900	53,700	Oct.
1948	5,780	11,500	12,800	17,600	Sept.	42,500	52,400	55,600	58,400	Sept.
1949	11,000	15,600	17,400	18,900	Oct.	62,000	76,900	77,200	95,800	Sept.

Table IV - Minimum recorded river flows adjusted for reservoir operation (Louisville and Metropolis gages)

Year	Louisville gage: minimum adjusted flow (cfs) Day	Week	2-Weeks	Month	Metropolis gage: minimum adjusted flow (cfs) Day	Week	2-Weeks	Month
1934	6,310	10,300	11,500	17,600	30,900	32,500	43,200	60,900
1935	12,000	14,000	14,600	18,200	26,200	29,800	32,300	40,100
1936	7,560	9,410	9,780	16,400	28,300	32,400	37,400	42,900
1937	5,500	11,100	12,100	34,800	49,200	54,400	56,700	89,200
1938	5,670	10,100	11,300	13,300	24,800	32,100	32,600	42,900
1939	6,270	7,460	8,810	9,660	26,300	28,400	30,800	36,100
1940	8,270	11,200	12,000	14,000	32,900	38,000	39,900	44,100
1941	6,430	8,460	9,540	17,300	21,700	28,100	31,000	45,600
1942	16,300	21,000	28,700	34,800	55,100	65,200	72,600	93,400
1943	6,200	7,330	7,780	13,400	48,900	51,800	53,300	55,800
1944	9,820	10,300	10,700	14,100	33,400	45,500	46,200	54,800
1945	11,400	15,200	17,100	35,000	56,400	64,100	66,500	104,000
1946	6,200	8,610	10,700	11,800	52,400	59,000	60,500	63,400
1947	10,400	13,100	15,300	16,800	41,800	48,700	50,600	54,400
1948	5,980	11,700	13,000	17,800	42,700	52,600	55,800	58,600
1949	11,200	15,800	17,600	19,200	62,200	77,100	77,400	96,000

Table V - 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
			1948 to 1953	200
East Branch Clarion	January 1953	200		
	Total	1,410		

Table VI - Probability of drought flows at Louisville and Metropolis gages (based on adjusted flow records)

Drought Severity	Louisville gage: Minimum Daily	Minimum Weekly	Minimum 2 Week	Minimum Calendar Month	Metropolis gage: Minimum Daily	Minimum Weekly	Minimum 2 Week	Minimum Calendar Month
Most probable drought	7,230	11,300	12,300	17,600	39,000	45,800	50,300	56,700
Once in 5 years	6,150	8,720	9,720	13,300	27,900	33,400	35,800	44,100
Once in 7 years	5,880	8,080	9,080	12,200	25,200	30,300	32,300	41,000
Once in 10 years	5,610	7,410	8,420	11,100	22,400	27,200	28,600	37,800
Once in 15 years	5,300	6,680	7,690	9,900	19,300	23,700	24,500	34,300
Once in 20 years	5,090	6,160	7,180	9,050	17,100	21,200	21,700	31,800

Table VII - Coliform densities and stream flows at Louisville, Evansville and Cairo waterworks intakes (Coliform data are monthly averages. Louisville and Evansville data supplied by Commission's Water Users Committee; Cairo data supplied by Illinois Sanitary Water Board.)

Month	Louisville		Evansville		Cairo	
	Av. Flow Thousand cfs	Coliforms MPN per 100 ml.	Av. Flow Thousand cfs	Coliforms MPN per 100 ml.	Av. Flow Thousand cfs	Coliforms MPN per 100 ml.
1950						
July	89.6	2,650	105.0	8,400	205.0	9,710
August	37.0	880	43.4	6,100	150.0	3,850
September	95.1	12,000	112.0	16,200	278.0	8,600
October	41.3	1,980	47.3	4,850	127.0	5,170
November	132.0	14,000	154.0	13,600	268.0	11,100
December	266.0	12,300	312.0	10,200	496.0	12,800
1951						
January	286.0	11,600	335.0	11,300	580.0	8,520
February	357.0	6,000	419.0	9,400	726.0	12,100
March	284.0	5,480	333.0	4,120	664.0	8,210
April	243.0	6,740	284.0	2,840	572.0	1,230
May	120.0		141.0	5,480	252.0	1,200
June	91.7		107.0	6,000	179.0	1,510
July	49.7		58.4	3,300	165.0	770
August	16.0		18.7		84.3	120
September	16.6		19.5		80.5	440
October					61.8	250
November	64.7		76.0		197.0	2,780
December	213.0	7,050	250.0		606.0	4,800
1952						
January	313.0	8,600	367.0		640.0	3,700
February	288.0	7,500	338.0	4,600	680.0	4,500
March	273.0	4,100	320.0	7,500	586.0	3,360
April	176.0	3,200	203.0	3,400	452.0	2,150
May	158.0	7,700	185.0	12,700	257.0	2,260
June	58.0	1,500	67.0	4,800	183.0	2,200
July	24.3	610	28.4	1,400	84.8	280
August	21.3	150	25.0	1,810	64.0	810
September	15.0	860	17.6	820	53.2	2,900
October	13.6	104	16.0	580	49.4	1,500
November	20.7	760	25.5	6,600	53.4	2,080
December	57.3	3,200	67.3	1,860		
1953						
January	150.0	5,800	176.0			
February	144.0	6,000	170.0			
March	192.0	6,400	225.0			

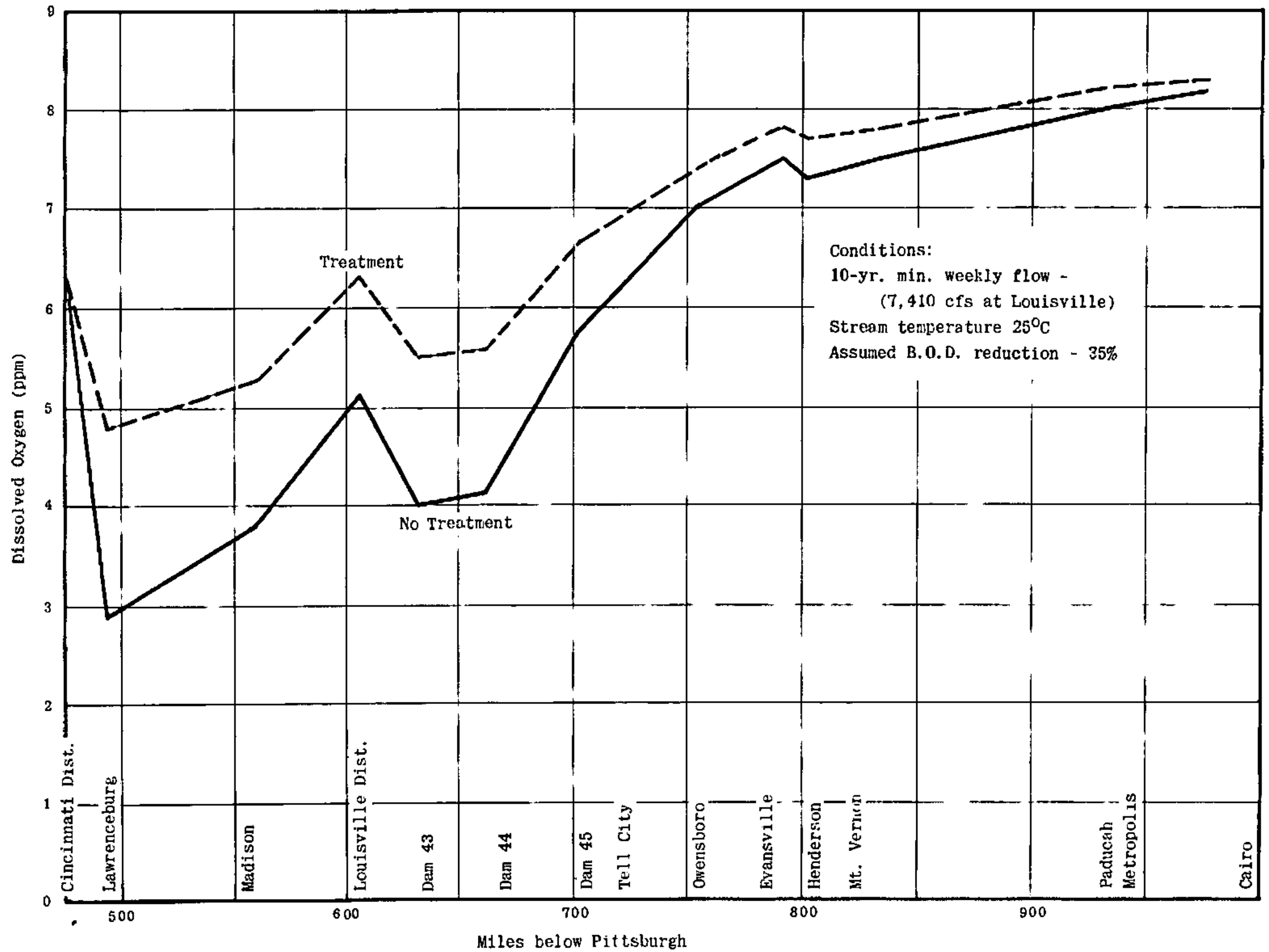


FIG. 1 - DISSOLVED OXYGEN PROFILES in Ohio River between Cincinnati and Cairo

September 1953

ORSANCO

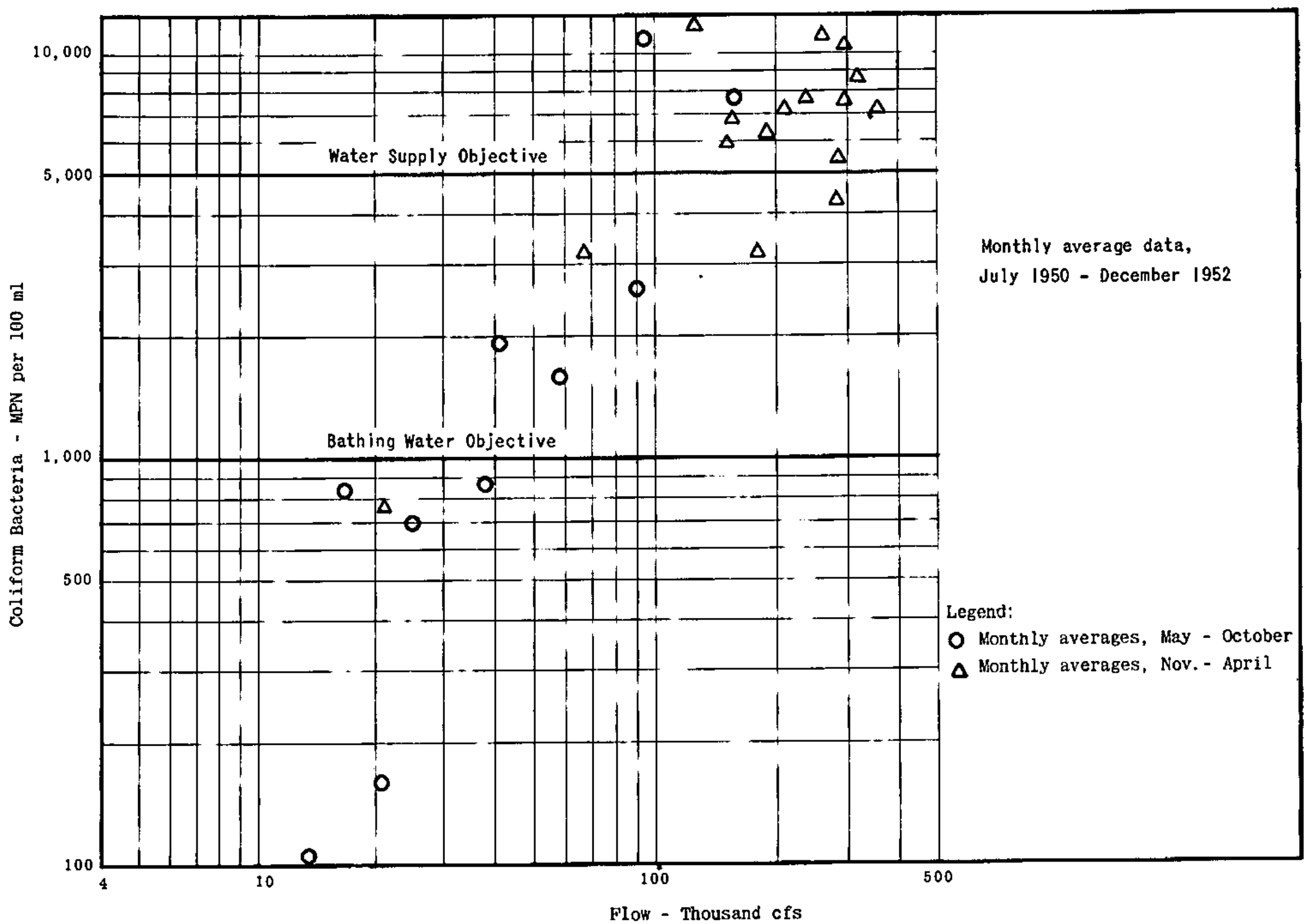


FIG. 2 - RELATION BETWEEN COLIFORM DENSITIES AND FLOW at Louisville water works intake

September 1953 ORSANCO

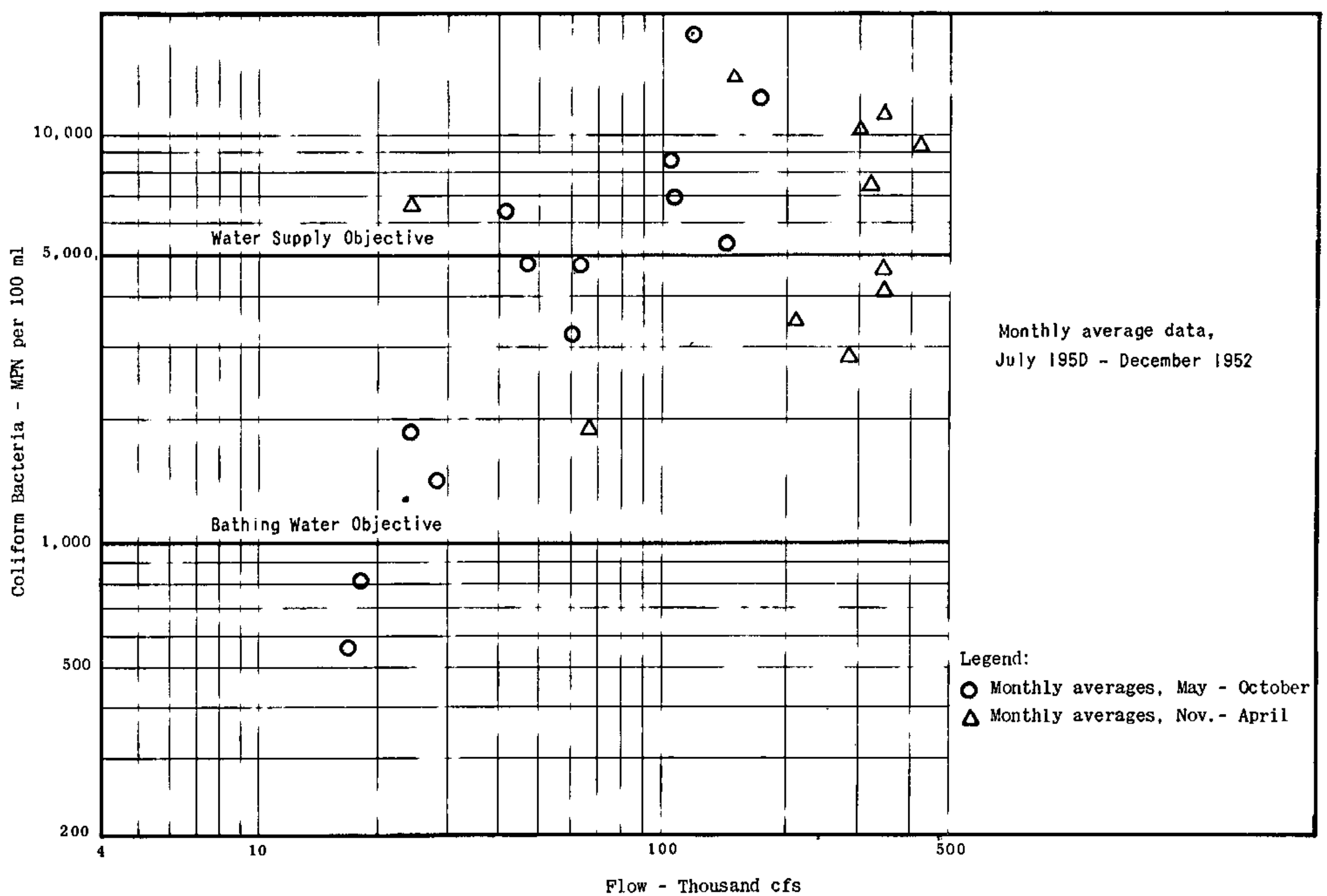


FIG. 3 - RELATION BETWEEN COLIFORM DENSITIES AND FLOW at Evansville water works intake

September 1953 ORSANCO

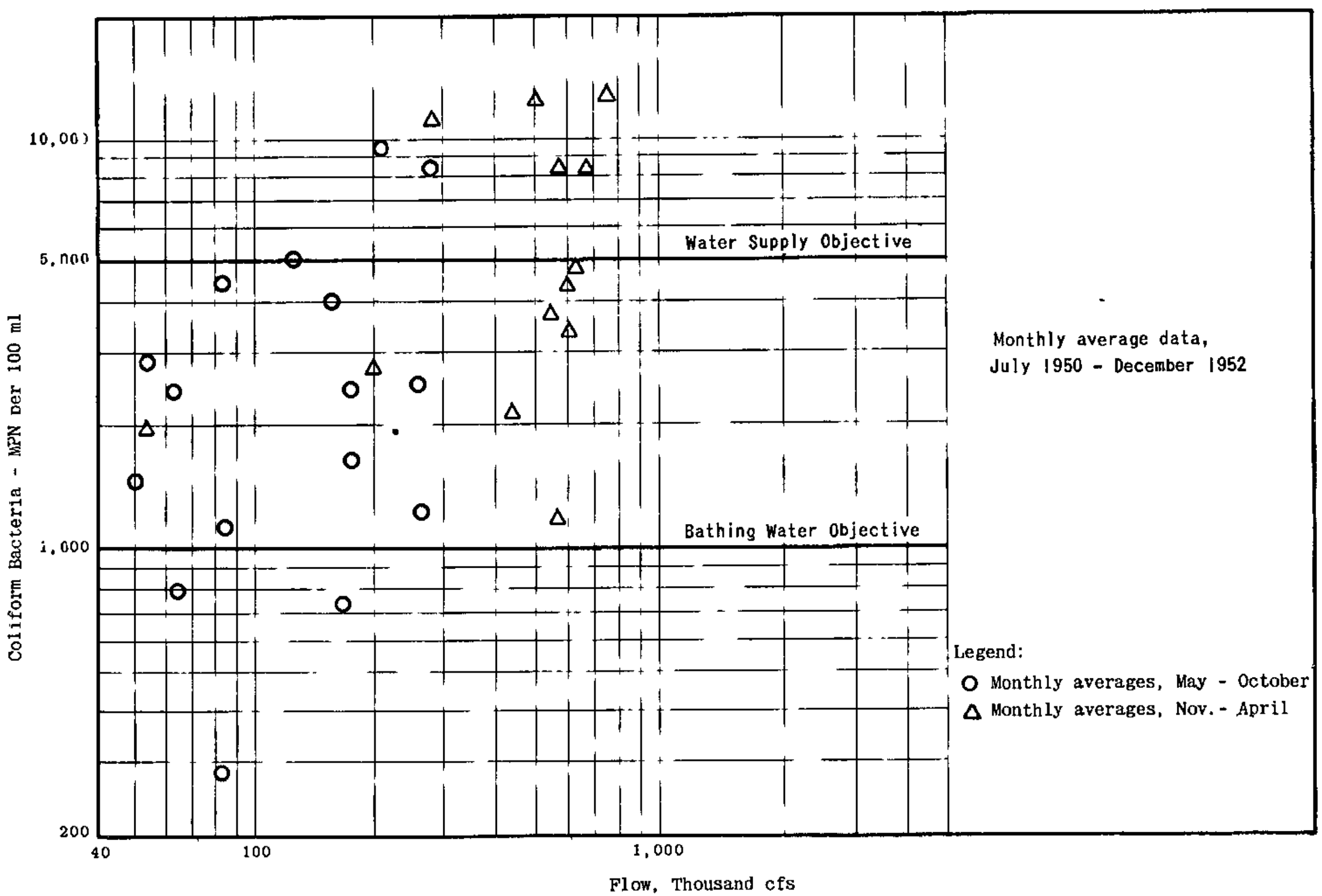


FIG. 4 - RELATION BETWEEN COLIFORM DENSITIES AND FLOW at Cairo water works intake

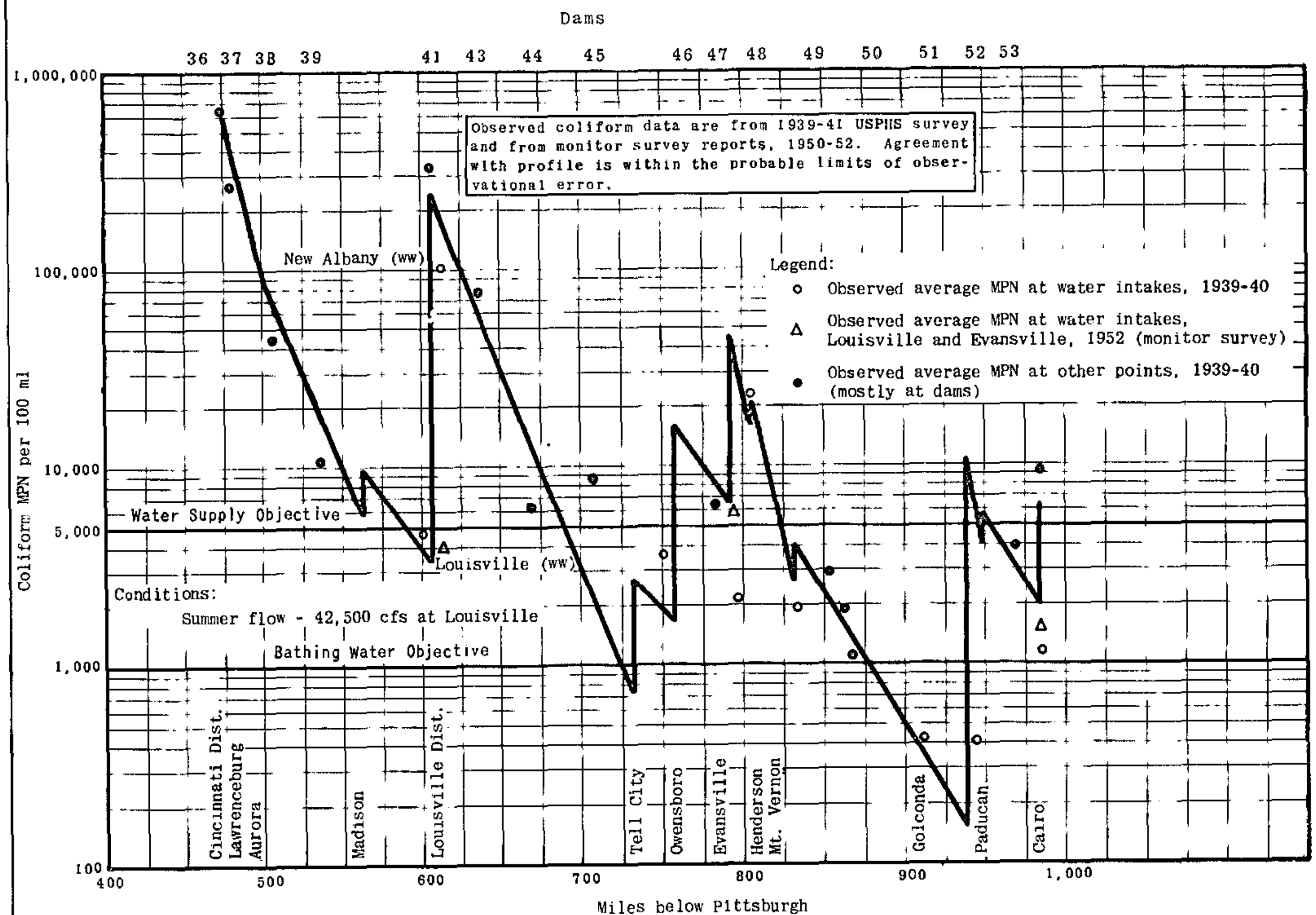


FIG. 5 - COMPUTED AND OBSERVED COLIFORM PROFILES under summer flow conditions; Ohio River between Cincinnati and Cairo

September 1953

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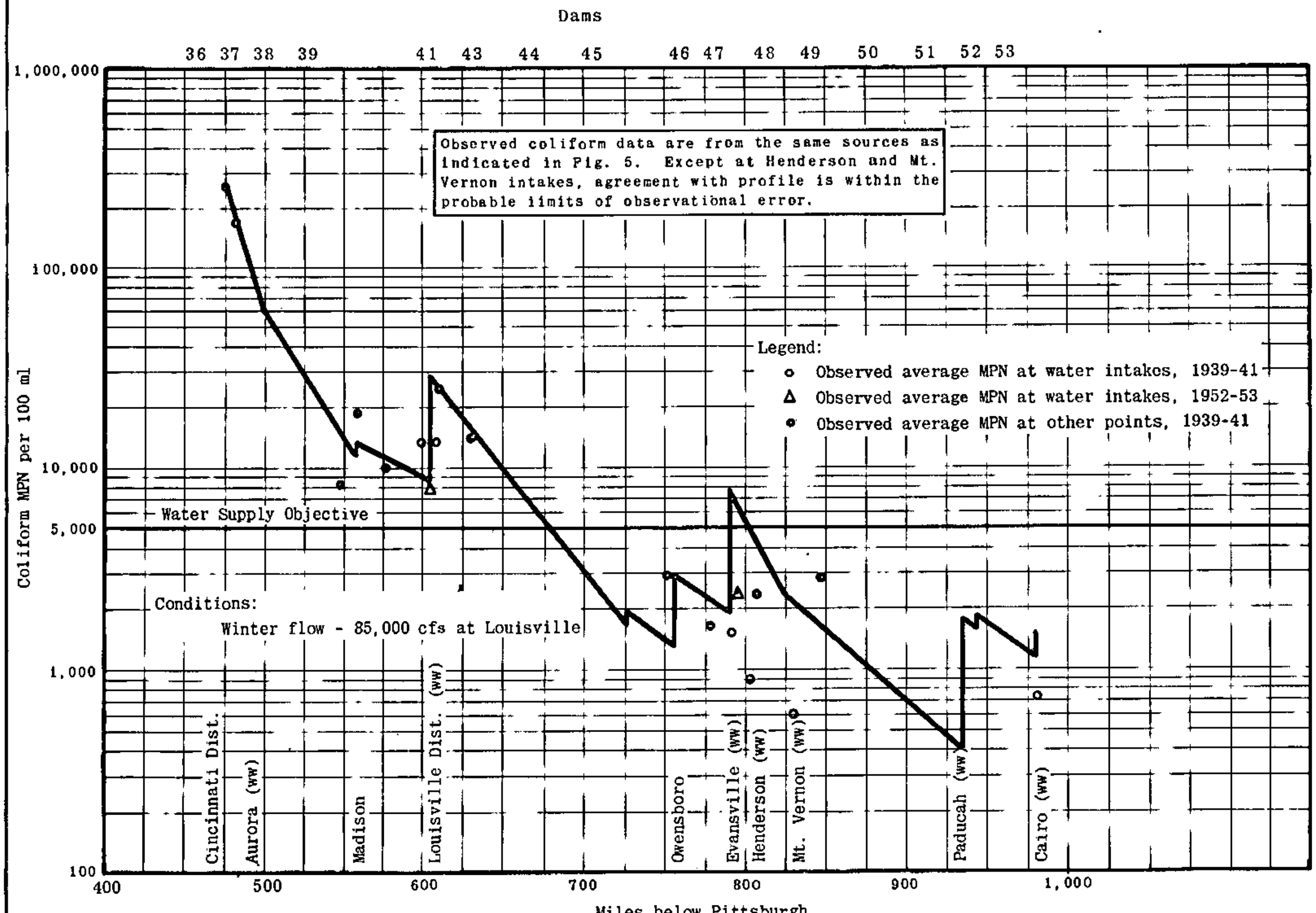

FIG. 6 - COMPUTED AND OBSERVED COLIFORM PROFILES under winter flow conditions; Ohio River between Cincinnati and Cairo

September 1953

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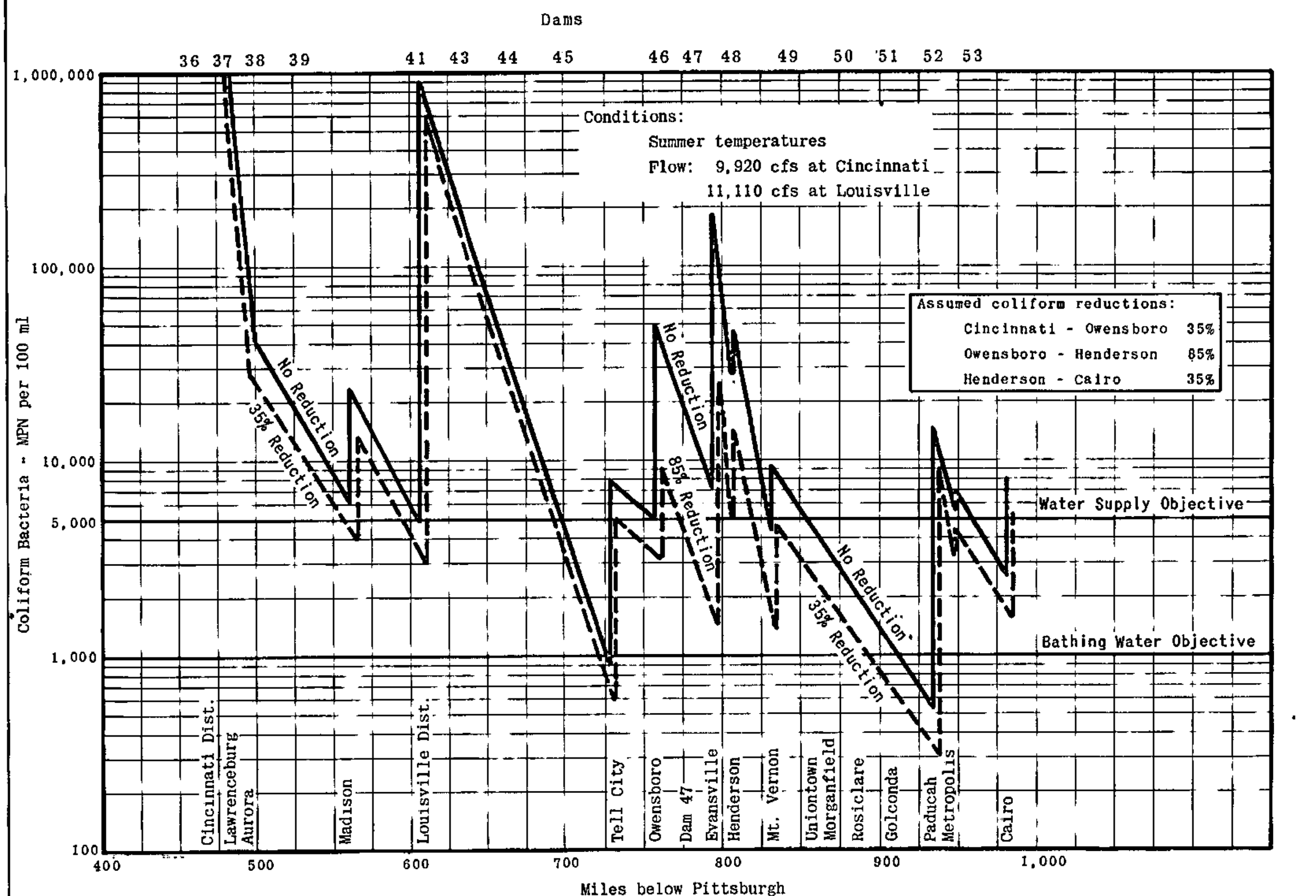

FIG. 7 - EFFECT OF BACTERIAL REDUCTION TREATMENT AT 10-YEAR MINIMUM MONTHLY FLOW; Ohio River between Cincinnati and Cairo

September 1953

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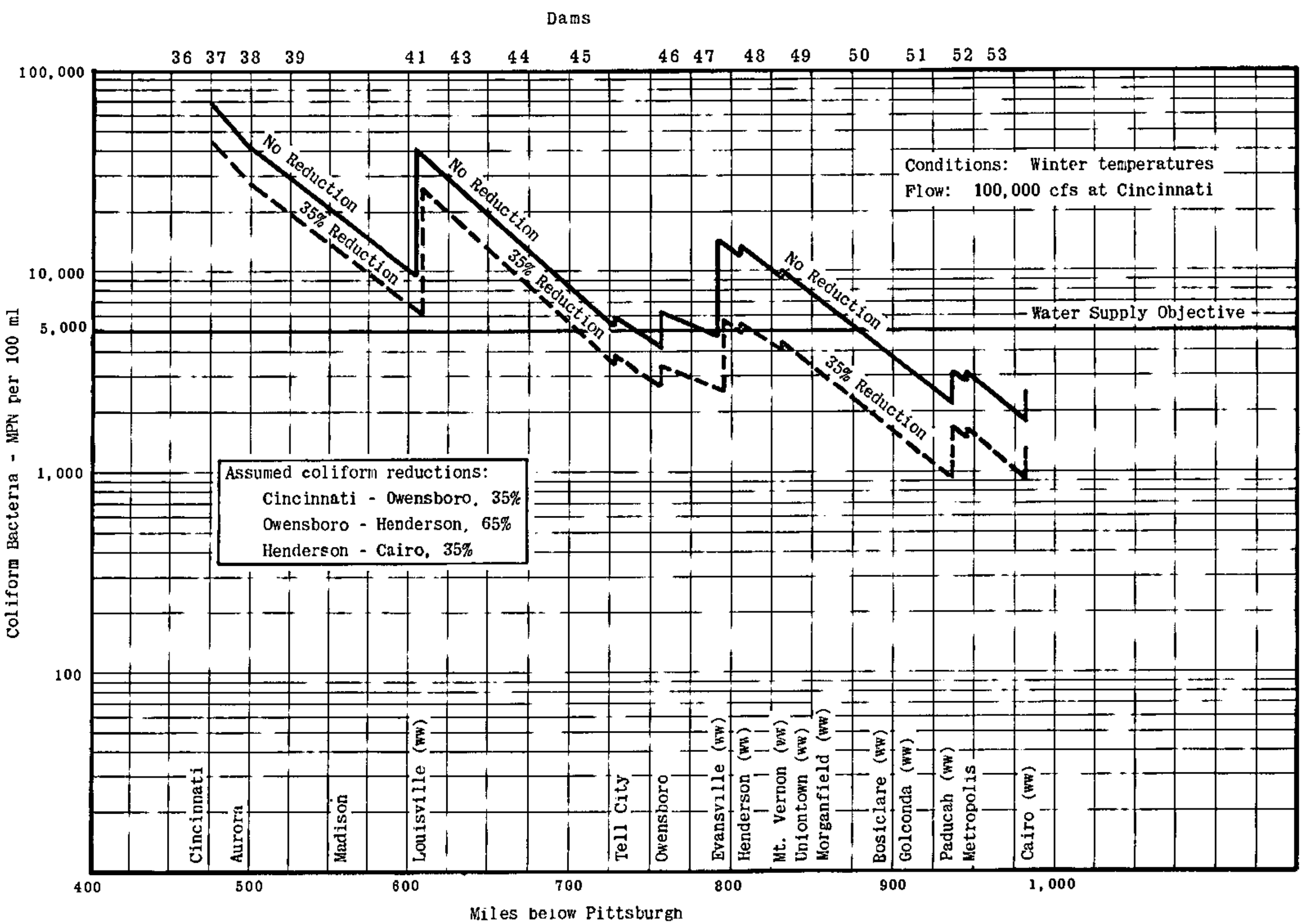

FIG. 8 EFFECT OF BACTERIAL-REDUCTION TREATMENT AT WINTER FLOW; Ohio River between Cincinnati and Cairo

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BACTERIAL-QUALITY OBJECTIVES

for the Ohio River

A guide for the evaluation of sanitary condition of waters used for potable supplies and recreational uses.

OHIO RIVER VALLEY WATER SANITATION COMMISSION

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

HEADQUARTERS - 414 WALNUT ST. - CINCINNATI 2, OHIO

OHIO RIVER VALLEY
WATER SANITATION COMMISSION

414 WALNUT STREET   CINCINNATI 2, OHIO

June 1, 1951

To the Chairman and
Members of the Commission:

This is the final report of bacterial-quality objectives for the Ohio River, which you adopted on April 4, 1951 and ordered published. The report sets forth the objectives for both water supply and recreational uses, the manner in which the objectives are to be interpreted, and the background for their validity.

In large measure this report is the work of Harold W. Streeter, U. S. Public Health Service (retired) who now serves the Commission in a consultant capacity. Mr. Streeter, an international authority on water-quality investigations has been studying Ohio River conditions since 1914. Drawing upon this experience and supplementing it with new information gathered by the Commission and its signatory states, Mr. Streeter prepared findings that were scrutinized by your Engineering Committee and other authorities over a period of a year.

The Engineering Committee recommended adoption of these objectives since they provide a sound basis for the Commission to reach decisions on acceptable limits and control of bacterial contamination. Heretofore, the task was complicated by a wide divergence of viewpoints and standards throughout the nation.

Respectfully submitted,

Edward J. Cleary

EDWARD J. CLEARY
Executive Director
and Chief Engineer

Bacterial-Quality Objectives
for the Ohio River

Adopted by the

OHIO RIVER VALLEY WATER SANITATION COMMISSION

on the basis of findings reported by

Harold W. Streeter, Consultant

and approved by members of the Engineering Committee

C. W. Klassen, Chairman
Fred H. Waring
Earl Devendorf
F. Clark Dugan
B. A. Poole
H. E. Moses
M. LeBosquet
W. W. Towne
Edgar Landenberger
O. Lloyd Meehean
Harry K. Gidley
Richard Messer

June 1, 1951

TABLE 1 — SUMMARY OF CERTAIN STATE AND REGIONAL BACTERIAL QUALITY STANDARDS FOR SOURCES OF WATER SUPPLY.

State or Region	Class	Units	Limiting Coliform Numbers per 100 Ml	Remarks
New York	A-1 & A-2	Mo. Av. MPN	50	1
	A-4	Mo. Av. MPN	5,000 and not over 20% samples above 5,000.	2
New England	A	MPN	50	1
Tenn. Valley	I	Geom. Av. MPN	50	1
Authority	II	Geom. Av. MPN	5,000	2
	III	Geom. Av. MPN	20,000	3
Tennessee (state)		Av. MPN	5,000	4
West Virginia	AA	Mo. Av. MPN	100	5
	A	Mo. Av. MPN	1,000	5
	B	Mo. Av. MPN	10,000	3
Indiana	- -	Max. MPN	5,000	
Washington		Av. MPN	50	1
Potomac River Commission	A	Mo. Av.	50	1
	C	Mo. Av.	5,000	2
Incodel	Zone 1	Av.	10% not over 100	5
		Max.	10,000	
	Zone 2	Av.	25% not over 100	2
		Max.	10,000	
Ohio River Committee (House Doc. 266)	Desirable	Mo. Av.	50	1
	Desirable	Mo. Av.	5,000	2
	Doubtful	Mo. Av.	5,000 - 20,000	3
	Unsuitable	Mo. Av.	Over 20,000	
U. S. P. H. S. Recommendations (Bull. 296)	II	Mo. Av.	50	1
	III	Mo. Av.	5,000	2
		Max.	20% over 5,000	
	IV	Mo. Av.	Over 5,000	2, 3
		Max.	5% over 20,000	

Remarks: 1—Chlorination 2—Filtration and chlorination 3—Auxiliary treatment 4—General sanitation 5—Good sources

OBJECTIVES summarized:

As a guide in the establishment of treatment requirements for sewage discharged in the Ohio River, and as a yardstick for evaluating sanitary conditions in waters used for potable supplies and recreational purposes, the Ohio River Valley Water Sanitation Commission on April 4, 1951, adopted these bacterial-quality objectives:

Water Supply Uses—The monthly arithmetical average "most probable number" of coliform organisms in waters of the river at water intakes should not exceed 5,000 per 100 ml in any month; nor exceed this number in more than 20 percent of the samples of such waters examined during any month; nor exceed 20,000 per 100 ml in more than 5 percent of such samples.

Recreational Uses—For bathing or swimming waters, monthly arithmetical average "most probable number" of coliform organisms should not exceed 1,000 per 100 ml during any month of the recreation season; nor exceed this number in more than 20 percent of the samples examined during any such month; nor exceed 2,400 per 100 ml on any day. For non-bathing or non-swimming waters, the monthly arithmetical average "most probable number" of coliform organisms should not exceed 5,000 per 100 ml in any month of the recreational season, nor should exceed this number in more than 20 percent of the samples examined during any such month.

The limits for potable supply sources are premised on the desirability of a return to normal water-treatment methods (coagulation, sedimentation, rapid-sand filtration, and pre - and/or post-chlorination) with a minimum of chlorine residuals in the finished water, in order to insure palatability as well as bacterial safety of water supplies drawn from the river. Too many water treatment plants must now resort to auxiliary processing as a regular practice because of excessive pollution loads. It cannot be denied, however, that the availability of such facilities for emergency use is highly desirable.

Recommendations for recreational waters are tentative, pending further knowledge of the epidemiology of bathing-water sanitation, and are intended to provide reasonable safeguards to bathers along the river against more serious water-borne diseases. For recreational uses not involving bathing or swimming, a bacterial-quality goal at the water supply level is recommended.

It is recommended that the improved methods of coliform-bacteria enumeration employed in the Commission's Ohio River water quality survey of September, 1950, be adopted as standard procedure for future routine tests in connection with bacterial-quality investigations.

As an aid in the interpretation of these objectives and the manner in which they are to be applied, see the next section for detailed explanation.

INTERPRETATION and APPLICATION

Application of bacterial-quality objectives for the Ohio River involves evaluation of existing pollution levels with reference to those which should be attained to meet potable supply and recreational requirements. Such an evaluation — in terms of coliform-bacterial densities — cannot be expected to be precise in the same degree that is possible with chemical analyses of the river water.

Methods now available for enumerating bacteria of the coliform group are subject to errors far beyond those of chemical determinations, or even of biochemical tests such as "biochemical oxygen demand". This fundamental fact should be kept in mind when interpreting and applying bacterial-quality objectives expressed in terms of "most probable numbers" of coliform organisms. Experienced judgment and common sense, together with a thorough knowledge of local conditions affecting sewage pollution, are essential to a rational application of these objectives.

Averages and single results—According to an estimate by Velz, the upper 95 percent confidence limit for the result of a single-coliform test with three tubes planted in each dilution is 3.6 times the MPN determined from the test. (Velz, C. J., Inservice Training Course lecture, March 14-15, 1949, University of Michigan, School of Public Health, Ann Arbor, Mich.)

If the MPN resulting from the test were 2,300 per 100 ml. there is a 95 percent probability that the true number of coliform organisms in the sample would range up to, but not exceed, 8,300 per 100 ml. An average of 25 results would theoretically narrow the range to one-fifth of that for a single result, bringing the upper 95 percent confidence limit to about 72 percent above the observed mean of the 25 results. This illustrates the statistical advantage of averages versus individual results with regard to their stability and range of error.

Sampling effect—Another source of error in evaluating coliform density in river waters is due to sampling. For ordinary catch-sampling in a well-mixed stream, this error may run 15-20 percent for a single sample. Where the stream is not well mixed across a section, the error may run considerably higher, especially if samples are collected at single mid-stream points. This latter error is variable and practically impossible to evaluate, except by direct measurement in a particular situation. Sampling errors generally are compensating; their range may be greatly reduced by averaging. They probably are of a lower order than those involved in the coliform determination itself.

In the Commission's Ohio River water quality survey of September, 1950, results from coliform tests made on daily samples were obtained for a period of two weeks at 36 sampling points, of which 27 points were located in the Ohio River, and nine points at the mouths of principal tributaries. Methods followed in these tests, carefully standardized by the USPHS Environmental Health Center at Cincinnati, involved planting three tubes in each of three or more dilutions, arranged in decimal series. Results of the standard confirmed test were reported from the survey; 24-hr and 48-hr presumptive results were also recorded. A separate report on this survey has been prepared by the Commission. Reference here is only to a section of the coliform results, which have provided excellent illustrative material for application of bacterial-quality objectives.

Period averages and daily maximums—A summary of the period-average and daily-maximum confirmed results of the coliform tests at each sampling point, together with the percentages of days on which the coliform MPN exceeded 5,000 and 20,000 per 100 ml, respectively, is given in Table 2. A plot of the period-averages at the various sampling points, with ordinates representing the corresponding percentages of samples in which MPN exceeded 5,000 per 100 ml, is given in Fig. 1. A similar plot for the percentages of samples showing MPN's exceeding 20,000 per 100 ml is also given. For those sections of the two curves within an average MPN range up to 20,000, trends of plotted points follow nearly straight lines, and the correlation coefficient in each case is over 0.90, indicating a high degree of correlation in this range.

Inspection of Table 2 shows that average coliform MPN was less than 5,000 at only four sampling points (Nos. 5, E, 26, and 27), though it exceeded this figure only slightly at a fifth point (No. 9). At these five points the frequency of daily samples exceeding 5,000 MPN was 25 percent or less, averaging 14 percent, and the frequency exceeding 20,000 MPN was less than 10 percent, averaging 5 percent.

It is noted that with an average coliform MPN of 5,000 (Fig. 1) intersections of the two curves at this vertical show 20 percent and 5 percent, respectively, as frequency of individual MPN's exceeding 5,000 and 20,000. These intersections have provided a basis for adjusting the "over-run" frequency allowances made in connection with the bacterial-quality objectives recommended for potable supply requirements. They reflect more accurately the natural run of variability in the river's coliform content when measured by the improved method of routine tests followed in the survey of September, 1950.

The maximum daily coliform MPN recorded at any of the five sampling points above noted was 23,000 per 100 ml, being 9,300 at two of them, and 23,000 at the other three points. It thus appears that at average-coliform levels of 5,000 or below, natural variability in the Ohio would tend to limit the daily maximum MPN to about 23,000. Within the range of expected error this approximates the 20,000 level marking the safe-load limit for water-filtration plants using auxiliary treatment.

A further study of the ratios of maximum-to-average MPN's recorded in Table 2 brings out some interesting points concerning the general run of these ratios, and a few divergences from this trend. At all except five of the 36 sampling points, the maximum-to-average ratio was less than 6.0, and at 23 of the points, was less than 5.0. At the five points where these ratios were exceeded, divergence was found to be due to a single exceptionally high daily result in each case, exerting a marked influence on the period average. Although these departures from the general trend of the ratios were a small minority, they raise an important ques-

TABLE 2 — AVERAGE AND DAILY MAXIMUM RESULTS OF COLIFORM DETERMINATION IN OHIO RIVER WATER QUALITY SURVEY — SEPTEMBER, 1950.

Sampling Point No.	Confirmed Coliform MPN Average	Confirmed Coliform MPN Maximum	Ratio Max/Avg	MPN Greater than: 5000/100 ml days	5000/100 ml %	20000/100 ml days	20000/100 ml %
A	24,500	75,000	3.1	11	92	7	58
B	88,700	930,000	10.5	7	58	3	25
1	81,700	230,000	3.0	12	100	12	100
C	14,400	43,000	3.0	8	67	4	33
2	9,600	43,000	4.5	6	50	1	8
3	8,000	23,000	2.9	5	42	2	17
4	15,500	93,000	6.0	4	36	3	25
5	4,400	23,000	5.2	2	17	1	8
6	6,400	23,000	3.6	3	25	2	17
D	321,000	930,000	2.9	12	100	11	92
7	18,400	43,000	2.4	7	58	5	42
8	7,900	43,000	5.5	4	33	1	8
E	3,800	9,300	2.4	3	25	0	0
9	5,300	23,000	4.3	2	17	1	8
10	11,100	43,000	3.9	3	25	6	50
11	40,800	230,000	5.6	7	58	5	42
12	39,900	150,000	3.8	10	83	5	42
13	70,000	430,000	6.2	12	100	10	83
F	162,000	930,000	5.8	12	100	11	92
14	40,900	230,000	5.6	10	83	6	50
15	76,000	430,000	5.7	6	50	4	33
G	192,000	930,000	4.9	8	67	5	42
16	210,000	930,000	4.4	9	75	8	67
17	94,000	430,000	4.6	12	100	11	92
H	11,700	75,000	6.4	3	25	2	17
18	44,400	230,000	5.2	8	73	6	55
19	211,000	2,300,000	10.9	8	67	4	33
20	156,000	290,000	1.9	12	100	12	100
21	14,700	43,000	2.9	9	75	6	50
22	28,000	93,000	3.3	11	92	9	75
23	12,100	43,000	3.6	7	58	3	25
I	29,500	93,000	3.2	9	75	6	50
24	15,100	43,000	2.9	9	75	4	33
25	7,600	23,000	3.0	4	33	2	17
26	3,300	9,300	2.8	1	8	0	0
27	2,500	4,300	5.6	0	0	0	0

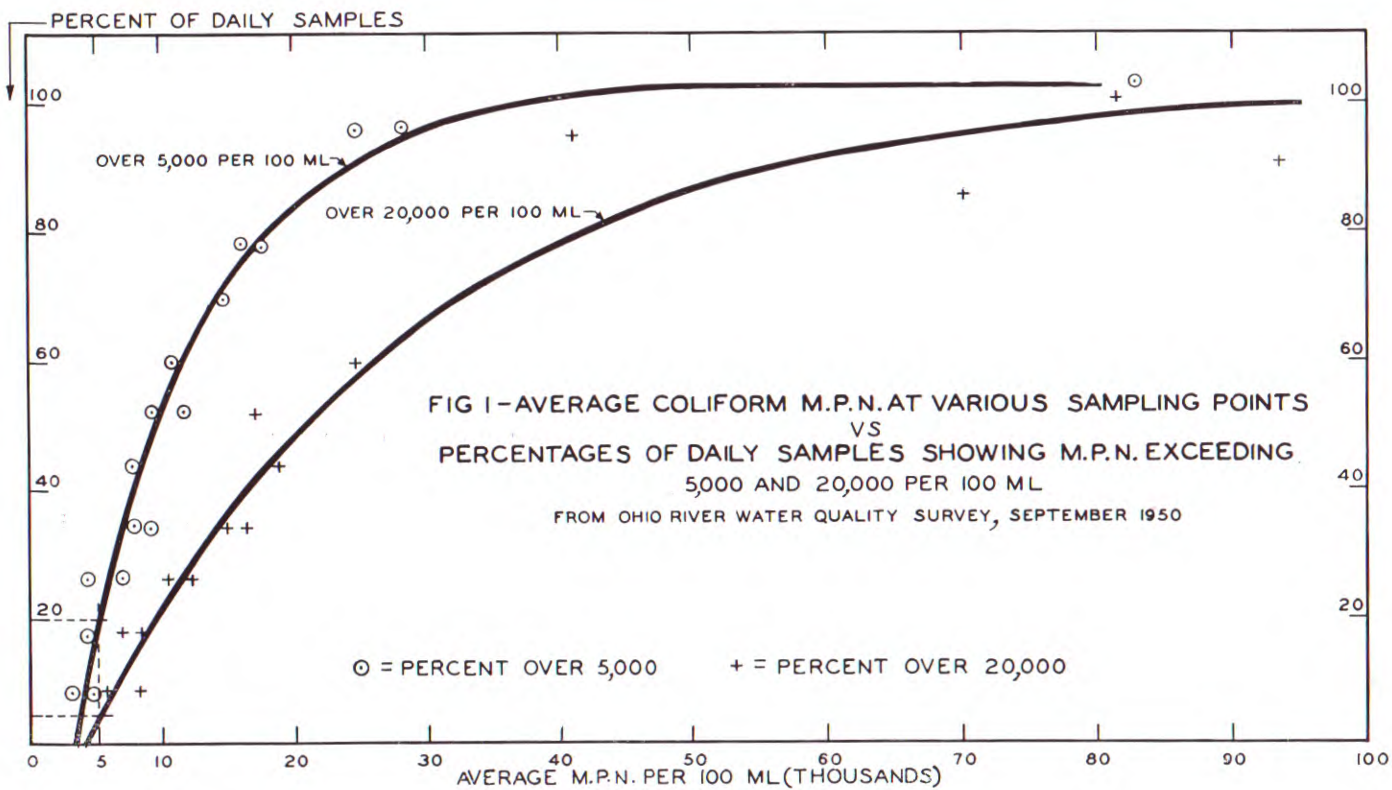

FIG I – AVERAGE COLIFORM M.P.N. AT VARIOUS SAMPLING POINTS
VS
PERCENTAGES OF DAILY SAMPLES SHOWING M.P.N. EXCEEDING
5,000 AND 20,000 PER 100 ML
FROM OHIO RIVER WATER QUALITY SURVEY, SEPTEMBER 1950

tion as to the application of water-supply objectives to situations of this kind. A single high result, far out of line with the others, may exert an undue influence on the average at a given point. It tends to show an average water condition materially worse than otherwise would be indicated.

At three of the five points in question, average coliform MPN's were so high, even excluding single maximum results, that quality of the river water at these points would fail to meet an objective of 5,000 per 100 ml by a wide margin. At the other two points, exclusion of single high results would bring period average only slightly above the objective level. In the first case, it would be immaterial, for all practical purposes, whether or not high results were discarded, as the evaluation would be substantially the same in either event.

No rational conclusion in the second case could be reached until an analytical check had been made to determine whether the exceptionally high result recorded at each point was due to error in the test, or whether its occasional recurrence was normally to be expected at that point. Local sources of pollution might be revealed by a sanitary survey of the immediate drainage area. Any wide departure from the normal maximum-to-average ratio would call for a thorough check on the point in question before any final judgment could be reached.

Recreational waters—Application of bacterial-quality objectives to waters used or intended to be used for recreation involves the same general principles and raises the same questions of interpretation as those arising for water-supply objectives. In this case it would seem that wide departures in daily maximum MPN's from the average run of the data might have greater public health significance for natural bathing waters because of the direct exposure of bathers without the intervention of any artificial purification process. For this reason it has been thought expedient in revising the bathing-water objective, to provide a limiting maximum, subject as it may be to the possibility of wide errors in routine determination. In this case judgment should be exercised in applying such a maximum, lest a bathing water of generally good sanitary quality be unjustly condemned and its recreational values thereby sacrificed.

A check should be made on the coliform-enterococci ratio in accordance with the recommendations of Scott and Clark.

Waters draining agricultural lands—Where the sanitary survey shows a water intake or a bathing area to be definitely unaffected by some source or sources of sewage pollution, as in streams draining solely agricultural lands, the coliform limits herein recommended should be interpreted with considerable latitude.

Need for standard coliform test—A final point to be emphasized in the application of the objectives is the desirability of a concerted effort on the part of the signatory states to bring about at the earliest time practicable the adoption of a standard method of routine coliform tests for Ohio River and its tributary waters based on the same procedures as followed in the Ohio River Commission water quality survey.

This method would involve planting three tubes in each sample dilution, with a sufficient range of dilutions (at least three) to insure an accurate determination of the "most probable manner" in each sample. The standard "confirmed" test should be made on all samples, as prescribed in Standard Methods. Variations in the ratio of confirmed results to those obtained from 24-hr and 48-hr presumptive tests in connection with the September survey were sufficiently wide to suggest that it would be inadvisable to depend on either of these two presumptive tests for comparable results at all stream points.

BACKGROUND and VALIDATION

by Harold W. Streeter, *Consultant*
Ohio River Valley Water Sanitation Commission

In a communication received from the Commission's executive director, under date of March 6, 1950, I was requested to review "available information and practice on the use and validity of bacterial-quality standards as related to water supply and recreational requirements", and "to prepare a report and submit recommendations for the establishment of bacterial-quality objectives for the Ohio River". This report deals with conclusions reached from such a study, and explains the reasons for such conclusions. It follows the general outline of an interim report made to the Engineering Committee of the Commission at its meeting on July 11, 1950, and is modified to incorporate further data.

The study followed two general lines of inquiry:

(1) A review of representative state and regional standards currently proposed to meet the requirements of the two stream uses indicated in the reference; and

(2) An analysis of available research and observational data bearing on the fundamental bases of current standards, and their application to conditions of pollution and water uses in the Ohio River. In this connection, particular attention has been given to the practical aspects of the problem, as viewed from the standpoint of the long-range plans and policies which are understood to motivate the Commission's program for establishing effective pollution control both in the Ohio River and in its tributary streams.

In carrying out the study, advantage has been taken of interchanges in views with the Commission staff, with Mr. M. LeBosquet and his associates in the U. S. Public Health Service and with Mr. F. H. Waring, chief engineer of the Ohio State Department of Health, with whom frequent meetings have been held in connection with another project touching somewhat closely the problems of the Ohio River. These conferences, together with the views of the Engineering Committee obtained at its July 11, 1950 meeting, have been of much value to me in orienting my viewpoint with the general policies of the Commission. Special acknowledgement is also made to Mr. LeBosquet for his kindness in loaning files containing valuable information on stream standards, and also for his helpful advice. Thanks are also due to Messrs. F. M. Middleton and H. F. Clark of the Environmental Health Center at Cincinnati for their kindness in collecting certain bacteriological data for me while visiting water treatment plants along the Ohio River, and also to Mr. Waring for making available the files at his office containing annual summaries of similar data as reported during past years from plants in Ohio located on the river.

Because of the difference between bacterial-quality requirements for water supplies and for recreational water uses, especially for bathing, this study has been divided into two parts, each dealing separately with its own phase of the problem. In the section of the report which immediately follows, attention will be confined to water supply requirements, and the bacterial-quality objectives which have been and may be established in order to meet such requirements.

Water Supply Objectives

The history of bacterial-quality standards to meet water supply requirements dates back for some thirty-five years in the United States to the International Joint Commission standard, which was adopted in 1914 on recommendation by a board of consulting sanitary engineers headed by the late George W. Fuller. This standard provided in effect that the yearly average coliform bacteria index in the international boundary waters of Canada and the United States as delivered for treatment should not exceed 500 per 100 ml. In recommending this standard the board pointed out that the index would be expected to exceed this limit at times during the year, and to be less at other times. The standard was based on an assumed efficiency of coliform bacterial removal of 99.6 percent by the average filtration plant treating these waters, and the production of an effluent containing not over 2.0 coliform bacteria per 100 ml., the upper limit then provided in the U. S. Treasury Department drinking water standard.

During the period of 1915 to 1916, the U. S. Public Health Service began a series of observational studies of the efficiency of water treatment plants which, after being discontinued because of World War I, were resumed in 1924 and continued through 1929. These studies covered a year's observation of the performance of 31 representative municipal water filtration plants, including 10 plants on the Ohio River, and five year's operation of a large-scale experimental filtration plant at Cincinnati, equipped with modern treatment devices and designed in two parallel sections throughout, so that any two different methods or combinations of treatment could be observed under the same raw water and other conditions. The results of these investigations, published in a series of reports, provided the only available information on the efficiency and limitations of various combinations of water treatment at that time, and have served as the basis for bacterial-quality standards for sources of treated water supplies in many of our states up to the present time.

Within the limits of observational error, it was found that the average water filtration plant of the rapid-sand type, with postchlorination to low residuals (0.05 - 0.30 ppm by the OT test), could deliver an effluent meeting the bacterial requirements of the 1925 drinking water standard (average coliform index not exceeding 1.0 per 100 ml) from raw waters containing an average of not over 5,000 coliforms per 100 ml. For relatively short periods of time, such as a month, this average would not ordinarily be exceeded by a degree sufficient to vitiate its applicability as a working limit, though for longer periods, such as a year, or several months, variations above the average would be greater in degree, and sometimes too high for safety.

In connection with the same series of studies, the effects of certain auxiliary measures of water treatment on the overall efficiency of bacterial removal were investigated. These measures included prechlorination and multi-stage coagulation-sedimentation, both of which have been in use, either separately or in combination, at some plants on the Ohio River. It was found that prechlorination and double-stage sedimentation, when added to normal filtration treatment, would permit higher average numbers of coliform bacteria in the raw water and enable plants thus equipped to take care of temporary overloads of bacterial pollution, ranging up to 20,000 coliform bacteria per 100 ml. or thereabouts. Thus two general levels of permissible raw water pollution were established observationally, the lower one applicable to normal filtration with low-residual postchlorination, and the higher one to the same treatment reinforced by auxiliary measures such as above described, providing a safety factor, when needed, to offset peak loads on the normal filtration process. This was the general concept of the proper function of auxiliary treatment at that time, as an adjunct to normal filtration.

With increased sewage pollution of the Ohio River, and the concomitant problem of industrial wastes pollution, the role of auxiliary treatment has changed gradually from that of a temporary safety measure to one of continuous integration with the treatment process as a whole. This step has brought about a chain of circumstances, ranging from increased chlorine residuals through and after treatment to measures such as aeration, activated carbon treatment, chlorine dioxide treatment, and "breakpoint" chlorination, designed to deal with tastes and odors resulting in part from intensified chlorination, and in part from increased sewage and industrial pollution. Multi-stage coagulation-sedimentation, together with pre-settling, also have been resorted to in an effort to meet increasing bacterial loads.

The past twenty-five years has thus been a record of a continuing struggle to deal with this problem at the water intake, with consequent deterioration in the quality of water supplies except for bacterial content, which has been held down mostly within safe limits as defined by current drinking water standards. With this historical background in mind, a brief review of state and regional bacterial-quality standards for sources of water supply, together with a somewhat more detailed review of the present bacterial efficiencies of a few representative water treatment plants on the Ohio River studies some twenty-five years ago, will follow in the order just named.

State and Regional Standards

In connection with this study, a review has been made of eleven state and regional standards proposing bacterial-quality requirements for sources of water supply. In Table 1 (page 4) is given a summary of these requirements, as taken from the latest source material available. These are the only standards of this character found among the laws and regulations of some forty-odd states relating to the control of stream and lake pollution. A majority of them, it will be noted, are based on recommendations for regional or general pollution control, only five of them having been drawn up for individual states. Eight of the eleven standards named are set up as parts of a classification of streams according to various water uses. In two cases (New England's Class A and Washington's general standard), bacterial-quality limits set for sources of water supply have been based evidently on requirements for waters treated by chlorination alone. In one case (Tennessee), the standard recommended is indicated as a general one for streams of the state, including those used for water supplies after normal filtration treatment. In eight of the standards, a limit of 5,000 coliform bacteria per 100 ml. is given for waters subjected to normal filtration-postchlorination treatment.

In seven of these eight cases, the standard is given as an average, and in one case (Indiana), as a maximum.

In all of the eleven standards, the coliform group of bacteria is taken as the index organism, and is expressed numerically either in terms of the "most probable number", or unspecified. In one standard (T.V.A.) the geometric mean is used rather than the arithmetic mean. In two of the standards (New York and U.S.P.H.S. recommendations), an over-run above 5,000 coliforms per 100 ml. is limited to 20 percent of samples tested, and in the latter case, an over-run above 20,000 per 100 ml., to 5 percent. This is a wise provision in standards expressed as long-term averages, as it places a definite limit on variations above the average. It should take account, however, of the natural variability of a stream or lake in this respect, as otherwise an upper limit may be set which cannot be controlled.

In reviewing these standards, the recurrence of the figure, 5,000 per 100 ml., suggests the influence of the U. S. Public Health Service's studies of the 1920's. It is significant in this connection that this standard has stood for a period of nearly twenty-five years where it has been used, and has in fact gained in favor with the years, having been incorporated into some of the more recent standards. The reason for this survival of an old standard probably lies mainly in the fact that it has served its purpose well, and also that little change has occurred in the basic processes of water filtration since it was originally recommended, though some of them, such as chlorination and multi-stage sedimentation, have been intensified, as previously noted, where excessive raw water pollution has forced such additional defensive measures. That only two of the ten standards reviewed have mentioned a higher coliform limit as permissible with auxiliary treatment suggests that in a majority of cases a definite reservation exists concerning any compromise with a standard which assumes more than normal filtration treatment as a desirable practice. This is a highly significant fact, which should not be lost sight of in the preesnt situation of water treatment along the Ohio River.

Efficiency of Filtration Plants

In view of the marked increase in pollution of raw water supplies in general along the Ohio River during the past twenty-five years, and the consequent necessity for reinforcement of the filtration plants treating these raw waters, an important aspect of this study has been to compare the present bacterial efficiency of a few representative plants along the river with that which was observed at the same plants some twenty-five years ago in connection with the survey previously mentioned. It has been possible to obtain comparable data from only six of the ten plants previously studied, namely, at East Liverpool, Steubenville, Huntington, Ironton, Cincinnati, and Louisville. From records of these six plants, monthly average coliform results for one year from each plant during the period of 1945-1949 have been compared with those obtained at the same plants for a year during the period of July, 1923 through June, 1924, in connection with the U.S.P.H.S. surveys. For the recent period, 1945-49, the years selected have not been in all cases the same, because it has been desired to avoid years in which any material change in treatment has beenmade.

At all of the plants included in this review, coliform enumerations are expressed in terms of the "indicated number" (Phelps index), and in all except the final effluent samples, are determined from fermentation tests with single-tube plantings in decimal series dilutions. As this is the same procedure as was followed in the routine coliform tests in 1923-1924, the results obtained at that time are directly comparable with those at the present time, making some allowance for minor changes in the methods followed in making confirmatory tests. In final effluent and distribution tap samples, the standard test in five 10-ml. portions is the rule, with additional single-tube plantings in 1 ml. in some cases. In general, enumerations of coliform bacteria in raw and other samples up to the final effluent are based on the standard presumptive test. In the final effluent and tap samples, the results are in some cases expressed in terms of the "gas-former" index (48-hour gas), presumptive index (24-hour gas), and confirmed index. In such cases, an opportunity is thus afforded to compare the final results in these three terms.

Of the six plants selected for study, all except the Ironton plant now use high chlorine residuals. At Cincinnati, "breakpoint" prechlorination has been added recently in an endeavor to minimize objectionable tastes and odors. At Ironton, chlorine residuals have remained at less than 0.2 ppm, which is about the same level as in 1923-1924. At the other five plants, residuals have been increased from about the same levels as at Ironton 25 years ago until they now range from 0.3 to 0.8 ppm or more. In some cases an effort is made, through the addition of ammonia, to maintain chloramine residuals throughout the distribution system. In general, tastes and odors in the treated water supplies have been considerably more serious in recent years than they were in 1923-1924, when the major cause of such troubles was the occasional presence of phenols in the river.

It is somewhat difficult to determine whether the intensified difficulties in respect to tastes and odors have been due mainly to increased industrial wastes pollution, increased sewage pollution, or both combined, together with the necessity of using much higher chlorine residuals. Probably all of these elements have exerted some influence. It seems quite likely that if industrial pollution were completely eliminated as a causitive factor in the present taste and odor problem, this problem would still continue to exist in those sections of the river where sewage pollution is high, if only for the reason that intensified chlorination would still be necessary in order to combat sewage pollution at the water intakes.

The exception at Ironton is notable because unusual coagulation-sedimentation facilities, together with the fact that this plant is still working at an output well below its designed capacity, have enabled this plant to meet increased bacterial loads without resorting to heavy chlorination. Incidentally, it is understood that taste and odor troubles have been somewhat less acute at Ironton than in most of the other water supplies along the river, though industrial wastes pollution has caused some increase in these difficulties.

In Table 3 is given a tabulation of the comparative annual average numbers of coliform bacteria recorded in the raw water and final effluent at each plant during the year 1923-1924 and during one year of the 1946-1949 period. Also shown are the same results for each plant during the poorest month of the year, when the confirmed coliform index averaged the highest in the plant effluent. Except at Ironton, it is noted that yearly average coliform numbers have increased measurably in the raw water during the 25 years since 1923-24. It is not clear why this exception at Ironton should exist, unless it may be due to the combined influence of the high dam at Gallipolis, and the effect of the pool above Dam 26, which would tend to retard the lateral diffusion of pollution from Huntington and cause it to follow more closely the left bank of the river. This is borne out by the fact that the yearly average coliform index at Ashland had increased from 11,500 per 100 ml. in 1923-24 to 30,000 per 100 ml. in 1949. In the last

TABLE 3—AVERAGE INDICATED NUMBERS OF COLIFORMS PER 100 ML. IN RAW AND FINAL CHLORINATED EFFLUENT WATERS OF SIX OHIO RIVER FILTRATION PLANTS DURING ONE-YEAR PERIODS.

Plant	Year	Annual Average		Poorest Month Average		% of Raw in Effluent	
		Raw	Effluent	Raw	Effluent	Annual	Poorest Month
E. Liverpool	1949	3300	0.05	8600	0.30	.0015	.0035
	1923-24	2680	.40	3890	1.30	.015	.033
Steubenville	1946	640	.06	4630	.40	.0094	.0086
	1923-24	330	.20	210	.60	.061	.290
Huntington	1947	2260	.04	1510	.13	.0018	.0086
	1923-24	2370	.80	5280	1.60	.034	.030
Ironton	1945	6200	.02	3270	.17	.0003	.0052
	1923-24	14900	.01	19100	3.40	.00007	.018
Cincinnati	1945	4360	.08	8550	.32	.0018	.0037
	1923-24	2980	.50	9910	2.0	.017	.020
Louisville	1949	4570	.14	8900	1.0	.0031	.011
	1923-24	2220	.10	2300	.30	.0045	.013

Note: Raw water numbers based on presumptive tests; effluent numbers on confirmed test.

two columns of Table 3 are shown the percentages of raw water coliforms observed in the final effluents of the six plants during the recent period, as compared with those recorded during the period 1923-24. It is also to be noted that despite the increased bacterial loads during the more recent periods, the average coliform content of the final effluents has been lower than during the period 1923-24. This trend is reflected in the lower percentages of raw water coliforms remaining in the final effluents, as compared with 1923-24.

That this increased bacterial efficiency is due almost wholly to more intensified chlorination is suggested by the results shown in Table 4, in which the average coliform numbers and their residual percentages observed in the unchlorinated filtered effluents of four plants during periods between 1945 and 1949 are compared with those observed in 1923-24. In these four cases direct comparison is possible because the filtered effluent samples during both periods represent the purification efficiencies accomplished by each plant without chlorination. Such a comparison has not been possible with the other plants on the river because of prechlorination not practiced in 1923-24, or because the filtered effluent samples were not directly comparable during the two periods.

It will be noted that two of the four plants show slightly greater, and two of them, slightly lower efficiencies of coliform removal during the two periods. In all cases no marked improvement in filtration process efficiency in itself is indicated. This evidences that the overall gain in bacterial efficiency of filtration processes along the river during the past 25 years has been accomplished very largely through the more liberal application of chlorine, and not through any material improvement in those features of filtration plant design and operation which in themselves would tend to bring about augmented bacterial efficiencies.

TABLE 4—COMPARATIVE NUMBERS AND PERCENTAGES OF COLIFORMS REMAINING IN UNCHLORINATED FILTER EFFLUENTS OF FOUR OHIO RIVER FILTRATION PLANTS.

Plant	Year	Coliforms per 100 Ml. Raw	Filtered	% of Raw in Filtered
Ironton	1949	5770	0.29	.005
	1923-24	14900	1.6	.011
Portsmouth	1949	2250	3.6	.11
	1923-24	3490	1.7	.05
Cincinnati	1945-48	4330	6.2	.14
	1923-24	2980	3.4	.11
Louisville	1947-49	3400	20.0	.59
	1923-24	2220	17.0	.77

In order to show somewhat more graphically the overall increase in bacterial removals effected by intensified chlorination, the figures given in Table 3 have been utilized to estimate, on the basis of the observed efficiencies, the maximum average coliform numbers in the raw waters as delivered to each of the six plants which would permit the delivery of final effluents containing an average coliform content of not over 1.0 per 100 ml., the limit set by the current drinking water standard, during each of the two periods covered in Table 3. This has been done by the simple process of dividing the number of raw water coliforms by the corresponding number recorded in the final effluent, thus giving the raw water content which would yield a number of 1.0 per 100 ml. in the effluent if the same bacterial removal efficiency should hold at the higher level.

This procedure is of course an approximation, but appears to be justified for purposes of estimate because previous studies have indicated that in general, the bacterial removal efficiency tends to increase with the bacterial loading on a treatment process up to a point where it levels off, and then remains fairly constant at higher loads. In the case at hand, except at Steubenville, where the bacterial load is relatively low in the raw water, the tendency for plant efficiencies to reach a fairly stable level would be expected to be attained at average coliform densities above 2,000 per 100 ml. or thereabouts, which density is exceeded by all of the raw waters except at Steubenville during both of the two periods studied.

On a yearly average basis, the raw water coliform limits thus estimated are shown to range from 11,000 to 66,000 (omitting the result for Ironton as being far out of line with the others), and to average 38,000 during the periods of 1945-49. During the period 1923-24, they ranged from 1,500 to 22,200, averaging 6,500, a figure which incidentally was not far from the coliform limit found for the average Ohio River plant in the U.S.P.H.S. studies carried out at that time. During the poorest months of the two periods, the estimated coliform limit in the raw waters averaged 18,000 for 1945-49, and 4,200 for 1923-24, the latter of which again was not far from the limit observed for the average Ohio River plant at that time.

In this connection it should be noted, however, that during these poorest months the efficiency of three of the six plants studied was such that their estimated limiting average coliform load would tend to approximate 10,000 per 100 ml., ranging from 8,900 to 11,600. Although this indicated load limit doubtless could be increased by more

TABLE 5—ESTIMATED AVERAGE INDICATED NUMBERS OF COLIFORMS IN RAW WATERS OF SIX OHIO RIVER FILTRATION PLANTS GIVING NOT OVER 1.0 PER 100 ML. IN FINAL EFFLUENTS.

(Based on average efficiencies during one-year periods)

Plant	Average Annual		Poorest Month	
	1945-49	1923-24	1945-49	1923-24
E. Liverpool	66000	6500	29000	3000
Steubenville	11000	1500	11000	350
Huntington	56000	2960	11600	3300
Ironton	310000*	140000*	19000	5600
Cincinnati	62000	6000	29000	4960
Louisville	33000	22000	8900	7700
Average	38000	6500	18000	4200

(*) Omitted from average.

highly intensified chlorination, it is nevertheless a significant indication that under conditions of normal operation, with the relatively high chlorine residuals being carried, occasional months occur in which the average plant efficiencies are shown to deteriorate to the extent indicated. (See Table 5)

Discussion

In interpreting the foregoing data, the following indications are noteworthy:

1. Increasing sewage pollution of the river has brought about a general need for augmenting treatment facilities in order to offset increased bacterial loads at the water intakes.

2. This has been accomplished for the most part by adding prechlorination to existing filtration facilities, and by carrying much higher chlorine residuals through the treatment process to the distribution system. Complete plant reconstruction has been undertaken only in two cases, though strengthening of certain stages of treatment has been carried out at several plants.

3. A general increase has been noted in the bacterial efficiency of practically every plant along the river, though most of them have shown a tendency for lowered efficiency during occasional months, sometimes under unusually heavy average bacterial loads, and at other times, under unfavorable conditions, which apparently occur more frequently during periods of marked seasonal changes, though not necessarily closely related to such changes.

4. On the basis of yearly average efficiencies, all except one of the plants studied can produce effluents of average drinking water bacterial quality from estimated raw water coliform bacteria loads ranging above 30,000 per 100 ml., and averaging roughly 40,000. As yearly average data tend to mask significant lapses in the bacterial efficiency of practically every plant studied, they may be considered only as indicating general trends in comparison with average efficiencies observed in 1923-24.

5. On the basis of performances observed during the poorest months of single years, by which is meant the months when the coliform numbers in the final effluents averaged the highest during the year, a somewhat different picture is shown. In this case, the estimated safe limit of coliform loading

would tend to center around 10,000 per 100 ml. for a significantly large proportion of the plants studied. This limit would represent that which could be handled safely under more adverse conditions of plant operation, but with existing facilities for high-residual chlorination. It would not provide in all cases a working factor of safety, though in others a fairly liberal margin in this respect would prevail.

Bacterial-Quality Objectives

In establishing bacterial-quality objectives for the Ohio River to meet water supply requirements, a distinction should be made between those which are tolerable and those which are desirable. From the standpoint of tolerance, a limiting average coliform density of 10,000 per 100 ml. would be adequately safe, but would involve the continued dependence on intensified chlorination as an integral part of every water filtration plant. This in turn would entail a continuance of existing difficulties with unpalatability in water supplies derived from the river, largely as the result of the need for carrying high chlorine residuals into the distribution systems. Although such a condition might be tolerated during emergencies, and treatment plants should be equipped to meet them, it cannot in my opinion be considered as a desirable situation permanently, from the standpoint of the nearly three millions of people who depend on the river as their only source of domestic and industrial water supply.

It has been shown conclusively that normal filtration processes, with low-residual or "marginal" chlorination, can deliver both safe and palatable effluents from raw waters containing monthly average numbers not exceeding 5,000 per 100 ml., provided of course that such waters are free from taste-producing industrial pollutants. In view of plans now underway to reduce and ultimately eliminate all harmful industrial pollution from the Ohio River, a return to normal filtration methods would be a highly desirable concomitant of such a development.

It therefore is recommended that pollution-control measures along the Ohio River and in its tributaries be aimed to meet an ultimate bacterial-quality objective such that the monthly arithmetical average "most probable number" of coliform bacteria in the river at all water supply intakes will not exceed 5,000 per 100 ml. in any month; nor will exceed this figure in more than 20 percent of the samples of raw water examined during any month; nor will exceed 20,000 per 100 ml. in more than 5 percent of such samples.

In making this recommendation, the month has been taken as the period of the average for two reasons. First, it is the shortest common period for reporting bacterial results which will permit a fairly stabilized average to be taken. Secondly, it usually is based on at least 25 daily results from individual tests, and thus involves a range of statistical error which is roughly one-fifth or less the expected error of an individual coliform result. In view of the very large errors of individual results which have been shown to be involved in the ordinary MPN determination, it would be highly unwise, in my opinion, to base any limiting standard on a single maximum expressed in such terms. The month appears to be the best compromise between a period which is either so short as to involve large errors of measurement, or so long that seasonal and other natural variations in the coliform content of a stream would exert an undue influence on an average.

Use of an arithmetic average has been followed in stating this objective because the main statistical reason for using a median, or a geometric mean, namely, a definite pattern of logarithmic skewness in the frequency distribution of individual results, has not been found in the normal trend of these results when taken over periods as short as a month, though various degrees of skewness, highly irregular in pattern, have been noted in some months and at some points, owing to the effect of a few high results. Moreover, in the case at hand, every individual result has its significance in showing the average condition of a stream during short periods of time; hence any tendency to suppress the full effect of even a few high results would tend to distort the true significance of an average, where the public health is so vitally concerned, and where, as in the Ohio River, sewage pollution dominates every situation.

Provision of "over-run" frequency controls in the objective as stated is designed to place a definite limit to the frequency of high results above those which would normally be expected as being due to natural variance in the stream content, at average levels not exceeding 5,000 per 100 ml. A slight revision in these "controls" has resulted from an analysis of the results of the Commission's Ohio River Water Quality Survey of Sept., 1950, in which improved methods of coliform enumeration were followed.

As a rough guide in estimating the degree of reduction in bacterial pollution to meet such an ultimate objective, an analysis has been made of a ten-year record of monthly average raw water coliform densities reported at ten water filtration plants during the years 1926-1935, inclusive. This study has indicated that under normal stream conditions in the Ohio River, an average coliform density of 5,000 per 100 ml. may not be expected to be exceeded in any month of the year if the yearly average coliform density is held within an upper limit of 2,000 per 100 ml. Referring to Table 3, it will be noted that the yearly average coliform densities recorded at the six intakes listed in the table were slightly more than twice this limit at Cincinnati and Louisville during 1945 and 1949, respectively, somewhat over three times the limit at Ironton in 1945, about 65 percent higher at East Liverpool in 1949, very slightly higher at Huntington in 1947, and lower at Steubenville in 1946. At Ashland, Kentucky, however, where the reported raw water coliform index averaged 30,000 per 100 ml. in 1949 (the highest along the river), a reduction of nearly 95 percent in the bacterial load would be required. The excessive load on this plant is quite evidently due to the influence of sewage pollution from the Huntington district, which apparently tends to follow the left bank of the river downstream.

The foregoing recommendation may be criticized on the ground that it is unduly conservative, because it fails to credit the increased bacterial efficiencies which have been developed at the sevral Ohio River filtration plants in a continued effort to combat increased raw water pollution. The provision of added facilities to accomplish this purpose has been an expensive undertaking, and represents a very considerable investment. Some plant supervisors are honestly convinced that the bacterial-quality standards of past years are outmoded, and should be modified so as to take account of the greater bacterial efficiencies of water treatment processes made possible by intensified chlorination, and other auxiliary measures of reinforcement.

In this writer's opinion, the answer to these arguments rests in the simple fact that water consumers along the river are not obtaining the consistently palatable water supplies to which they are entitled, despite the ingenious and costly methods which have been developed in an effort to combat such unpalatability. As the only major change in water treatment has been intensification of chlorination, the inference seems quite clear that this practice lies at the root of present difficulties, though doubtless aggravated by the effects of certain industrial pollution. Reduction of bacterial loads in accordance with the objectives herein recommended would go far to obviate the necessity of heavy chlorination, and thus make it possible, with the improved chlorination techniques of recent years, to produce even more palatable water supplies than were being delivered some 25 years ago.

Pending the time when adequate pollution control has become established in the river and its tributaries, a monthly average coliform number not exceeding 10,000 per 100 ml. in any month should serve the purpose of maintaining reasonably safe water supplies, though at the price of continuation of present practices of intensified chlorination. If sewage pollution of the river could be brought within the boundaries of such a temporary standard, it is possible that at plants equipped with improved coagulation-sedimentation facilities, some reduction in the present high level of chlorine residuals could be effected, and in some cases carried to a level of "marginal" chlorination, as has been done at the Ironton plant during the past 25 years, despite heavy bacterial loads in the raw water. Although a monthly average coliform load up to 10,000 per 100 ml. doubtless could be carried without undue difficulty at practically every Ohio River filtration plant with present equipment, an objective at this level would serve only as a temporary expedient, and in my opinion would not afford a permanent solution of the problem.

Recreational Water Objectives

The approach to considering bacterial-quality objectives to meet recreational requirements is quite different, and in some respects more difficult, than that of water supply requirements. In this case, no background of systematic observation and experiment exists, except a few studies of bathing beaches such as have been made in Connecticut and California, correlating known sanitary conditions with bathing water quality. Although some recent studies instituted by the U. S. Public Health Service have made a more direct approach to the problem by undertaking to correlate bathing water quality with the incidence of water-borne diseases among the bathing population, these studies are still in progress, and may require some time before definite results will be available. In Illinois, a novel approach has been made through a study aimed to correlate sanitary surveys with coliform-enterococcus levels in lake waters. Further results of this study will merit the closest attention, and likewise those of the U.S.P.H.S. Meanwhile it is possible only to review existing standards proposed in several states and regional areas, and attempt to appraise their public health significance as applied to streams like the Ohio River.

In Table 6 is given a summary of 11 state and regional standards for bathing and recreational waters. In five of these standards are parts of classification schemes for natural waters used for different purposes. In 9 of the 11 standards, a limiting coliform bacterial density of 1000 per 100 ml. is given, either as an average or as a maximum. This, in fact, is the most recurrent figure appearing in the standards, and may well be taken as a base line for discussion. For desirable bathing waters, preferred coliform densities range from 50 to 100 per 100 ml. as averages, especially where classification of bathing waters has been adopted or proposed. Between this level and that of 1,000 per 100 ml. seems to be an intermediate zone, in which many stream and lake waters of relatively low degrees of pollution fall. Current bacteriological surveys of some 25 bathing beaches along the Ohio shore of Lake Erie have disclosed a considerable number of beaches comparatively free of local pollution falling into this intermediate class on the basis of their average coliform bacteria counts.

TABLE 6 — SUMMARY OF BACTERIAL-QUALITY REQUIREMENTS FOR BATHING WATERS IN CERTAIN STATE AND REGIONAL STANDARDS

State or Region	Class	Units	Limiting Coliform Numbers per 100 Ml.
New York	B-1	Av. MPN	1000
		Max. MPN	2400
New England	B	Max. MPN	1000
Connecticut	A	Av. MPN	0 - 50
	B	Av. MPN	50 - 500
	C	Av. MPN	500 - 1000
	D	Av. MPN	Over 1000
Tennessee Valley Authority	I	Geom. Av. MPN	50
	II	Geom. Av. MPN	1000*
West Virginia	AA	Mo. Av. MPN	100
	A	Mo. Av. MPN	1000*
Potomac River Commission	B	Av. MPN	50 - 500
		Max. MPN	1000
Indiana	—	Max. MPN	1000
Washington	—	Av. MPN	50
A.P.H.A. Joint Comm. (1948)	—	Av. MPN	1000
		Max. MPN	2400
Ohio R. Committee (House Doc. 266)		Av.	100
		Max.	1000
California		Av. MPN	1000
		Max. MPN	20% samples over 1000

(*) Also for general recreation.

For waters devoted to general recreational pursuits other than bathing, only a few standards have been found in which coliform bacterial requirements are specified. The Tennessee Valley Authority indicates in its recommended standard a limiting average coliform MPN (geometric mean) of 1,000 per 100 ml. for Class II waters, stating that such waters should be good for general recreation. West Virginia's coliform standard for Class A waters also indicates 1,000 per 100 ml. as suitable for general recreation. The Tennessee (state) standard does not specify whether its general coliform limiting average level of 5,000 per 100 ml. also applies to recreational waters, and hence is omitted from Table 6. The New England, Potomac River Commission, Indiana, and Ohio River Committee standards give a coliform density of 1,000 per 100 ml. as a maximum for bathing waters. Among the standards allowing densities in excess of this amount, New York (state) specifies a maximum of 2,400 per 100 ml., and California a frequency of 20 percent above 1,000 which is the limiting average for both of these standards.

It thus appears that in the very few cases where a general recreational standard is given, it is at the same average level as that of a majority of the bathing water standards (i.e. 1,000 coliforms per 100 ml.). A fairly logical reason for this in some cases would be that in general, recreational uses of streams and lakes, especially for camping, picnicking, etc., tend to merge to a considerable extent with bathing uses, as in many cases people will seek for such purposes water areas where bathing is permissible, even if only incidentally to other recreational pursuits. For some types of recreation, notably boating, bacterial-quality requirements should be definitely less stringent than for bathing, as in such cases little or no hazard of human ingestion of the water is involved. Thus along the Ohio River it is common to observe active boating in sections of the river where the quality of the water would permit bathing. For this particular activity, a common-sense view would seem to be that it could be readily pursued, with practically no hazard, in natural bodies of water which in general are fit sources of filtered water supplies, that is, which average not over 5,000 coliform bacteria per 100 ml.

With reference to bathing water standards, special mention has been made of a study by the Illinois Department of Public Health concerning the relation between sanitary surveys and the coliform-enterococcus levels in a lake pollution investigation. In a paper presented in October, 1949 by Scott and Clark*, the authors, from a statistical study of coliform-enterococcus ratios as correlated with a "relative pollution factor" ranging numerically from 1 to 5, concluded that in areas subject to sewage pollution, a satisfactory water would contain: (a) coliform MPN less than 700 if enterococci is 23 or more, or (b) coliform MPN 700 or over, but less than 2,400, if enterococci is less than 23 (all expressed per 100 ml.). In areas not subject to sewage pollution, a satisfactory water would contain: (a) coliform less than 2,400, if enterococci is 23 or more, or (b) coliform MPN over 2,400, but less than 7,000, if enterococci is less than 23. In setting up this scale, the authors in effect have taken an enterococci MPN level of 23 per 100 ml. as the dividing line between significant sewage pollution and pollution resulting from birds, rodents, and land wash.

In a paper given before the American Society of Civil Engineers in January, 1950, Cox** has reviewed the public health significance of bacteriological findings in natural bathing waters. He notes the efforts of bacteriologists to develop more specific tests for fecal bacteria, including tests for "sewage streptococci", indicating that in his view these investigations have not yet developed any tests more specific or of public health significance than the standard plate count and the test for coliform organisms. He concludes that bacterial tests should serve only as a general guide, forming part of the information pertaining to any given bathing beach, and that bacterial standards for natural waters used for bathing cannot be placed on a precise quantitative basis as disclosing the intrinsic quality of the water, or certain public health safety for the bathers. He indicates approval of beach waters in the New York City area if epidemiological data pertaining to bathers, and the sanitary survey, are both satisfactory, and the average coliform content of the water is not in excess of 2,400 per 100 ml., except when the other two criteria justify the use of the lower average of 240 per 100 ml. Cox also points out the well-known distinction between the types of infections con-

*Scott, R. M. and Clark, E. S. Correlation of the Sanitary Survey and the Coliform-enterococcus Levels in a Lake Pollution Investigation. Presented at the Society of Illinois Bacteriologists meeting, Springfield, Illinois, Oct. 13, 1949.

**Cox, C. R. Acceptable Standards for Natural Waters Used for Bathing. Presented before Sanitary Engineering Division, A.S.C.E., January, 1950.

tracted from natural bathing waters and those of artificial swimming pools, the latter including skin, mucous membrane, and other bather-to-bather infections, whereas the former usually are intestinal, resulting from ingestion of the water by bathers.

These two studies, though somewhat contradictory to each other in their specific findings, are illuminating in expressing trends of recent thought on the subject of bathing waters. According to both studies, coliform densities ranging up to 2,400 per 100 ml., or even higher if sewage pollution is known to be absent, are not necessarily out of line with good sanitation, though a rigid interpretation of the Illinois findings would tend to limit the coliform densities to something less than 1,000 if definite evidence of sewage pollution is present.

In connection with the present investigation, a study has been made of the possibility of utilizing the findings of Kehr and Butterfield* several years ago as a rough check on the rationality of various proposed bathing water standards, as viewed from the standpoint of water-borne disease hazards. Without going into their study in detail, it may be noted here that they derived from a number of studies in England, Indonesia, and California, where the successful enumeration of both coliforms and typhoid and para-typhoid organisms was carried out in sewage and sewage-polluted waters at the time of outbreaks of these enteric diseases, a correlation between the morbidity rates from typhoid fever in different areas and the ratios of E. coli to E. typhosa in the sewage and sewage-polluted waters of the areas. Although present typhoid morbidity rates in the Ohio Valley are extremely low, the rates for certain other enteric diseases, such as dysentery and diarrhea-enteritis, are sufficiently high to indicate a carrier reservoir which might be a factor in bathing water sanitation.

According to the U. S. Census mortality reports for various diseases, the average typhoid mortality rate for seven Ohio River states in the years 1945-47 was 0.4 per 100,000 (as compared with a rate of 0.2 per 100,000 in the U. S. registration area). Assuming a morbidity:mortality ratio of 10 to 1, this would indicate a morbidity rate of 4 per 100,000, or 0.04 per 1,000. From Kehr and Butterfield's curve, the corresponding ratio of E. typhosa: E. coli in the sewage and sewage-polluted waters of such an area would be 6 E. typhosa per million coliforms, or about 170,000 coliforms for each E. typhosa organism. This of course is an extremely low infection ratio for typhoid fever, but nevertheless measurable according to the Kehr-Butterfield results.

In order to apply these data to an evaluation of the typhoid hazard in bathing waters of an area, it is necessary to assume the average volume of water ingested per bather per day. For purposes of estimate, let this volume be assumed as 10 ml., which probably would be high for trained swimmers, and low for children. Now let:

R = the number of coliforms per single E. typhosa in the bathing water.

B = the number of bathers per day.

V = the volume of water, in ml. ingested per bather daily.

C = the average coliform content of the bathing water per ml.

Then the chance of exposure (P_e) of (B) bathers to a single E. typhosa on any day is:

$$P_e = BVC/R$$

and the exposure interval, in days, between successive ingestions of a single organism is:

$$I_e = 1/P_e = R/BVC$$

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*Kehr, R. W. and Butterfield, C. T. Notes on the Relation Between Coliforms and Enteric Pathogens. Public Health Reports, Apr. 9, 1943. Reprint No. 2469.

For illustration, let us assume $R = 170{,}000$; $V = 10$ ml., and $C = 10$ per ml., or 1,000 per 100 ml. Then the chance that a single bather would be exposed to ingestion of one E. typhosa organism would be:

$$P_e = 1/1{,}700$$

During a 90-day bathing season, *if he bathes every day*, his risk of exposure would be 90/1700, or 1/19. If he bathes every other day, the risk then will be 1/38.

Butterfield and Kehr estimated that about 2 percent, or one out of every 50 persons exposed to ingestion of a single E. typosa organism, actually contract the disease. On this basis, it may be estimated that our bather's risk of contracting typhoid fever during a 90-day season would be $1/19 \times 50$, or 1/950, a very remote hazard.

From estimates compiled from surveys of water-borne diseases by Wolman and Gorman*, and by Eliassen and Cummings**, it appears that water-borne diarrhea-enteritis morbidity rates tend to average about 20 times those of typhoid fever. In the seven Ohio River states, the ratio based on mortality records was 22 to 1 during the years 1945-47.

If the ratio of 20 : 1 be applied to the typhoid risk for an individual bather, his risk of contracting diarrhea-enteritis during a 90-day season would be 20/950, or about 1/50. This again is a rather remote hazard.

If similar estimates are made for groups of bathers, it must first be assumed that every bather of a group bathes regularly every day, or that a certain proportion of the group bathes daily. For a group of 100 regular bathers, the typhoid risk under the conditions assumed above thus would be about 1/10 for a 90-day season. For the same group, the diarrhea-enteritis risk would be about 2/1 during a 90-day season, again assuming each member of the group to bathe regularly every day. This is of course a tangible hazard, though reduced in proportion to the percentage of the group bathing each day.

When viewed from the standpoint of calculable risk, a bathing water coliform standard of 1,000 per 100 ml. or thereabouts would seem to involve no great hazard for the individual bather, or even for moderate sized groups of bathers. From the computations shown above, it can be readily estimated that a water meeting this standard should provide a high degree of protection for groups of several hundreds of people against typhoid infections, and reasonable protection for smaller groups against diarrheal diseases. Moreover, a standard at this level is probably the most stringent one which could be met in the Ohio River under any conditions of pollution which can be visualized during the near future, even with some degree of pollution control established. Pending the outcome of future epidemiological studies of bathing waters, it probably would be the most logical tentative objective at which immediate measures of pollution control could be aimed. If adopted as a tentative objective, however, it should be properly safeguarded against excessive "overrun", both in degree and in frequency.

It is therefore recommended that for bathing and other recreational requirements other than boating, a bacterial-quality objective be established tentatively for the Ohio River under the following conditions:

Waters suitable for this purpose should show a monthly arithmetical average "most probable number" of coliform bacteria, not exceeding 1,000 per 100 ml. in any month of the normal bathing

*Water-borne Outbreaks in the United States & Canada 1930-1936. AP.H.A. Annual Year Book, Vol. 20, No. 2.

**Analysis of Water-borne Outbreaks, 1938-45. Jour. Am. W. W. Assoc., May, 1948.

season, nor exceeding this number in more than 20 percent of the samples examined during any such month; nor exceeding 2,400 per 100 ml. on any day.

For general recreational purposes not involving the use of the river waters for bathing or swimming, a monthly average "most probable number" of coliform bacteria not exceeding 5,000 per 100 ml., nor exceeding 5,000 per 100 ml. in more than 20 percent of the samples examined during any month of the recreation season, is recommended as a minimum bacterial-quality requirement.

As to the significance of the term "average" as used in this recommendation, it is intended to mean the ordinary arithmetic average. This is done not to exclude, or minimize, the full effects of wide deviations from the average which in the case at hand are believed to be of definite public health significance.

The above recommendations are a compromise between that which would be desirable and that which is administratively practicable. They represent the best judgment of this reviewer after considering the problem from several different angles.

OHIO RIVER VALLEY WATER SANITATION COMMISSION

AN INTERSTATE AGENCY

ESTABLISHED JUNE 30, 1948

EXHIBIT F

STATEMENT BY W. W. TOWNE, U. S. PUBLIC HEALTH SERVICE

TO: Mr. E. J. Cleary, Executive Director & Chief Engineer
Ohio River Valley Water Sanitation Commission
414 Walnut Street
Cincinnati 2, Ohio

SUBJECT: Report on the Ohio River Pollution Abatement Needs, Cincinnati-Cairo Stretch

1. Your report of November 1, 1953, entitled "Ohio River Pollution Abatement Needs, Cincinnati-Cairo Stretch" has been reviewed by the Ohio and Tennessee Drainage Basins Office, Division of Water Pollution Control, Public Health Service, Department of Health, Education and Welfare.

2. The report establishes the following facts concerning the effects of sanitary sewage discharged into that stretch of the Ohio River under consideration.

a. During critical stream flow periods (minimum weekly average flow expected once in ten years) oxygen conditions are critical only in the river sections immediately below Cincinnati and to a lesser extent below Louisville.

b. Approximately 650,000 people residing in eleven municipalities on the Ohio River downstream from Cincinnati depend upon this stream as a source of public water supply.

c. Bacterial pollution from sanitary sewage results in a water quality at some public water supply intakes which is inferior to the objectives established by the Commission and accepted by public health authorities as desirable for public health protection.

3. The report gives consideration to the maintenance of a dissolved oxygen content in the stream suitable for aquatic life, natural purification processes and other legitimate uses, and to the maintenance of a bacterial quality suitable for public water supplies and recreational uses including bathing.

4. In order to maintain satisfactory water quality conditions for the legitimate and necessary water uses in that stretch of the stream under consideration, the treatment of sanitary sewage in compliance with minimum Compact requirements is expected to be adequate except that between Owensboro and Henderson, Kentucky, greater reductions in coliform organisms are necessary to maintain bacterial objectives at several water supply intakes. In this stretch of the stream, therefore, disinfection of primary sewage treatment plant effluents is recommended.

5. Although this and previous reports are concerned only with the discharge of sanitary sewage, it is made clear that industrial wastes now discharging directly to the river are being studied by the Commission and that such sources of pollution will likewise be required to initiate appropriate corrective measures.

This report completes the recommendations of the Commission for the control of pollution resulting from the discharge of sanitary sewage into the main stem of the Ohio River. Therefore, this and previous reports covering the entire stretch of the main stem may be considered as the first step in the comprehensive program for the abatement and control of pollution in the Ohio River.

6. Under section 2(a) Public Law 845, 80th Congress, 2nd Session, the Surgeon General, Public Health Service, in cooperation with other Federal agencies, State water pollution control agencies, and interstate agencies and with municipalities and industries involved, is charged with the responsibility of preparing or adopting comprehensive programs for eliminating or reducing pollution of interstate waters. The Act further stipulates that in the development of such comprehensive programs due regard shall be given to the conservation of such waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural, industrial and other legitimate uses. This report has been reviewed, therefore, with the thought that the recommendations contained therein might be adopted by the Surgeon General as a part of a comprehensive program for eliminating or reducing pollution in this section of an interstate stream.

7. Following this review, we find that the program recommended by the Commission will maintain dissolved oxygen levels and bacterial quality objectives that are reasonable and likewise that the treatment of sanitary sewage recommended to accomplish these objectives is also reasonable. It is further concluded that the proposed program for controlling pollution due to sanitary sewage constitutes a part of an acceptable comprehensive pollution control plan for the Cincinnati-Cairo stretch of the Ohio River.

s/s W. W. Towne
Officer in Charge

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