A STUDY OF OXYGEN CONDITIONS IN THE ST. JOSEPH RIVER

THESIS FOR THE DEGREE OF B. S.

Richard J. Meyer Eldon C. Rolfe

1934

THESIS

A Study of Oxygen Conditions in the St. Joseph River

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

by

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Candidates for the Degree of

Bachelor of Science

June 1934

Acknowledgment

The writers wish to express their sincere appreciation to Mr. Edward F. Eldridge whose guidance and helpful suggestions made possible the completion of this work.

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FOREWORD

The analytical determinations which are made on the samples collected in the course of a stream survey are made with the object of finding the load of polluting material being imposed upon the stream and the behavior of the stream under that load. There are many determinations which might be made to discover the extent of pollution and to trace the course of self-purification. It is a well known fact that any river, through biological oxidation and self-purification, can satisfactorily assimilate and dispose of, without nuisance, an amount of such material as determined by various factors, such as temperature, volume of flow, character of stream bed, and rate of reoxygenation.

However, in this investigation the work has been limited to a study of the oxygen conditions only. This includes three different determinations: (1) dissolved oxygen, (2) biochemical oxygen demand, (3) flow of the river.

(1) Dissolved oxygen.

The water of any normal stream or lake will have some oxygen dissolved in it. This oxygen has been obtained through absorption from the air, or from that liberated by certain plants as a by-product of their metabolism.

Since the amount of oxygen which can be dissolved in water depends upon the temperature, there being a different saturation value for each temperature, it is customary to use the term "per cent saturation", meaning thereby the ratio of the actual content to the saturation value.

(2) Biochemical oxygen demand.

The amount of oxygen necessary to oxidize the organic material of a sample of water or waste through natural processes is called its biochemical oxygen demand. Samples of waste or sewage from different sources may be of different strengths and have different oxygen demands. The difference between the biochemical oxygen demand of a stream and its dissolved oxygen constitute its oxygen resources.

The degree to which a stream is polluted by a given amount of waste is dependent (a) upon the volume of the receiving water, or, in other words, the extent of dilution to which the wastes are subjected, and (b) upon the extent of changes occurring in the polluted water by natural forces. For correct interpretation of the results of the analysis it is, therefore, necessary to have a knowledge of the stream flow during the period the samples were taken. It is also of importance to know whether the stream flow during the time the samples were taken is comparable to the flow throughout the year.

OBJECT

The object of this problem is to study the oxygen conditions of the St. Joseph River between Hen Island Dam, Indiana, and Buchanan, Michigan, and to determine the effect, if any, of the pollution of the river by the sewage of Mishawaka, South Bend, and Niles.

HISTORICAL

Significance of Oxygen Conditions.

The amount of oxygen contained in the water of an unpolluted stream depends directly upon the temperature. At a temperature of 20°C., assuming complete saturation, one million gallons of water will contain approximately 76 pounds of dissolved oxygen.

Organic material, such as is contained in sewage, when introduced into water, is attacked by the bacteria in the water. A series of complex biological reactions take place, resulting in the oxidation of organic material, with the consequent consumption of oxygen. The oxygen so used is that oxygen which has been dissolved in the water and not that which is chemically combined. The introduction of organic material of a sewage, into the water of a stream will thus result in lowering the dissolved oxygen content of the water. The amount of depletion of the dissolved oxygen will depend upon the relative volumes of sewage and water, upon the oxygen demand of the sewage, and upon the existing temperature of the water.

It is possible to determine the effect of sewage upon a stream by means of a series of determinations of the dissolved oxygen content of the water. These data, when expressed in terms of per cent saturation, will define the course of pollution and self-purification in the stream.

It is obvious that the amount of sewage which the

stream can absorb or dispose of without harm will depend upon the oxygen resource of the stream. This is the balance between the oxygen actually dissolved in the water and that which the water absorbs from the air, and the demand for oxygen in the stream before the load is applied.

The amount of unoxidized organic material present at any time or place in the stream can be determined by the biochemical oxygen demand test. This test gives the amount of organic matter in terms of the amount of oxygen required for its oxidation.

If the biochemical oxygen demand of the water in a stream is increased through the introduction of organic material, then the dissolved oxygen content will be decreased as satisfaction of the demand takes place. If the stream is to be preserved from a condition of gross pollution, a balance must be maintained between the amount of oxygen available in the water and the amount of oxygen required by the sewage discharged into it, so that the dissolved oxygen content will not be depleted below 50 per cent of the saturation value. If the amount of oxygen required becomes too great, it is necessary to reduce the oxygen demand of the sewage by some scheme of artificial treatment.

The effect of absence of dissolved oxygen is very detrimental to fish life. Authorities are generally agreed that at least four parts per million of dissolved oxygen must be maintained if a variety of fish life is to be found. The critical period with respect to fish life will usually

occur during July, August, and September, when the stream is ordinarily at its lowest stage.

Pollution may affect fish life in several ways: (a) direct killing of fish, (b) changes of natural conditions so that the fish have to seek other habitat, either because of the condition of the water or the effect the wastes have upon small plants and microscopic animal life constituting fish food, (c) influence upon fish larvae and young fish, that is, upon the reproduction of the species.

The direct effect of wastes upon fish may be due either to the reduction of the dissolved oxygen of the stream, or the toxicity of the wastes. Only in cases where poisons are discharged into the river is the killing of fish direct instead of through depletion of oxygen. The reduction of dissolved oxygen through the discharge of sewage is probably the most common cause of the death of ? large numbers of fish. The wastes may use up the dissolved oxygen of the stream by direct chemical reaction, or by oxidation through biological agencies.

Domestic sewage and practically all industrial ? wastes have an oxygen demand so that their discharge into the stream either directly or indirectly causes a reduction in the dissolved oxygen normally present. If the oxygen demand of a waste discharge into a stream exceeds, or even approaches, the amount of oxygen available in the stream, the resulting depletion may cause the death or migration of the fish. ?

The foregoing discussion regarding dissolved oxygen

refers specifically to the effect upon adult fish. The indirect effect due to changes of natural conditions is much more difficult to demonstrate but is probably a material factor. Fibre and sludge settling over the spawning beds of fish cause them to seek other spawning grounds or prevent development of the spawn. The most susceptible period of fish life is that just after the food sac is absorbed, because the fish is sustained by this food sac from the time of hatching until the sac is used up. The fish must then depend upon the natural aquatic life for its sustenance. If the natural aquatic life is changed, as it is in polluted streams, the young fish has difficulty in maintaining life.

When the dissolved oxygen content drops below two parts per million a septic condition is likely to exist, accompanied by disagreeable odors and the absence of low forms of plant life.[7] Therefore, a minimum of two parts per million is considered necessary for odor control.

Climatic conditions have a material effect on the ability of a stream to support aquatic life. Polluting material of an organic nature decomposes rapidly during warm weather and the oxygen is used up more quickly. Moreover, the amount of oxygen that the water will actually retain in solution is less in warm than in cold weather. The waste requires more oxygen in a short time in the summer and less is available in the stream. The oxygen in a saturated solution at various temperatures is shown in Table 1.

Rivers can rid themselves of sewage matter by

TABLE 1

SOLUABILITY OF OXYGEN IN WATER

Temp. °C.	Oxygen p.p.m.	Temp. °C.	Oxygen p.p.m.
0	14.62	15	10.15
1	14.23	16	9.95
2	13.84	17	9.74
3	13.48	18	9.54
4	13.13	19	9.35
5	12.80	20	9.17
6	12.48	21	8.99
7	12.17	22	8.83
8	11.87	23	8.68
9	11.59	24	8.53
10	11.33	25	8.38
11	11.08	26	8.22
12	10.83	27	8.07
13	10.60	28	7.92
14	10.37	29	7.77
		30	7.63

decomposition or by scouring. In most cases both processes are active in self-purification. Biological decomposition is particularly important. A river contains many different living organisms, large ones and microscopically small ones, both animal and plant. By integration of all the processes of nutrition of these organisms, organic waste matters are converted into substances similar in character to those present in naturally clean rivers. In comparison with these processes of self-purification, mechanical movement of the water is more in the nature of an auxiliary process. The waters mix thoroughly, sewage matters are distributed over a wider area, and the residue is scoured away by freshets. The effect of all these processes upon the sewage introduced depends upon the element, time.

The dissolved putrescible matter must be decomposed by aerobic organisms in order that damage or nuisances may not result. Hence, sufficient oxygen must be continually present in the water. When a river receives a charge of sewage, the oxygen content drops. If the water is not saturated, it will replenish its supply the faster the greater the oxygen deficiency, measured in terms of per cent saturation. The oxygen content of river water is renewed by aeration at the water surface, by oxygen given off by green aquatic plants, and by the inflow of clean, oxygen-saturated water from tributary streams. With the exception of the third factor, which cannot be generalized, reoxygenation or reaeration of a water course depends upon the extent of the water surface.

Besides this, a great influence is exerted by the depth of the water and water particles relative to one another, as well as by the wind which ripples the surface. Figure I shows the number of grams of oxygen a fairly quiet water will absorb from the atmosphere per square foot of surface in twenty-four hours. To this value must be added the oxygen given off by aquatic plants. In the course of the daylight hours, the latter amounts up to one-tenth gram per square foot per day. This value is independent of the degree of saturation. Hence it can even bring about "supersaturation."

Biochemical oxygen demand, being the result of a slow biochemical reaction, is, in the absence of a new pollution, a progressively decreasing one, and as the resources of the stream are composed in part of a continuous influx of oxygen from the atmosphere, the state of balance which determines the momentary condition of the stream is constantly changing. There are, therefore, two primary phases of the problem, namely, the actual momentary condition, and the direction and extent of the existing changes, which indicate the future condition. Fresh sewage, for example, may contain some dissolved oxygen, and, measured upon the oxygen scale of nuisance, may be in the same momentary condition as a stream which has about completed the work of oxidizing organic pollution, and contains the same amount of residual dissolved oxygen. The direction of change, however, is entirely different and determines the distinction between the two cases. The oxygen resources are comparable to the assets of a balance sheet; the oxygen demand to the liabilities. A

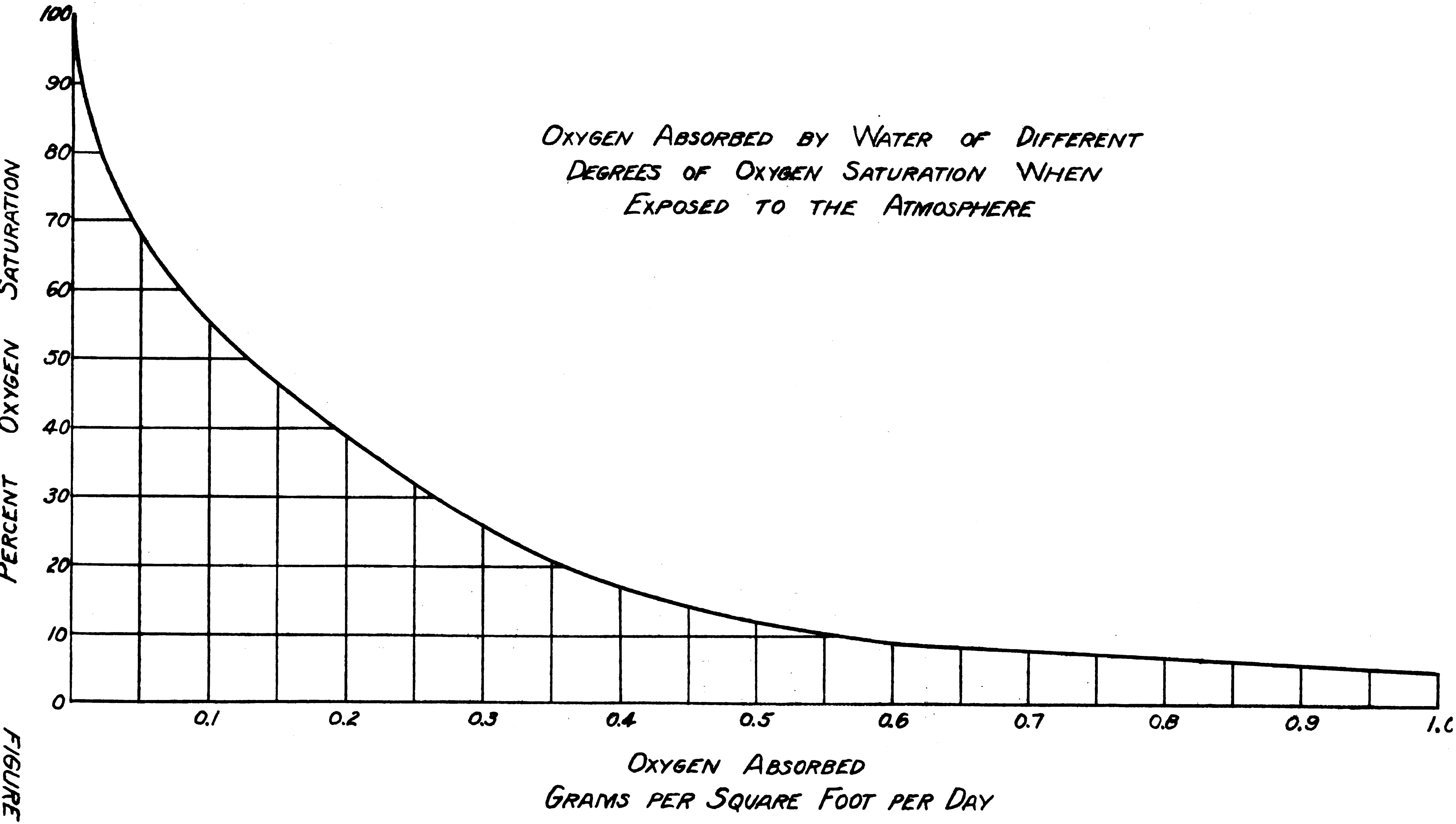
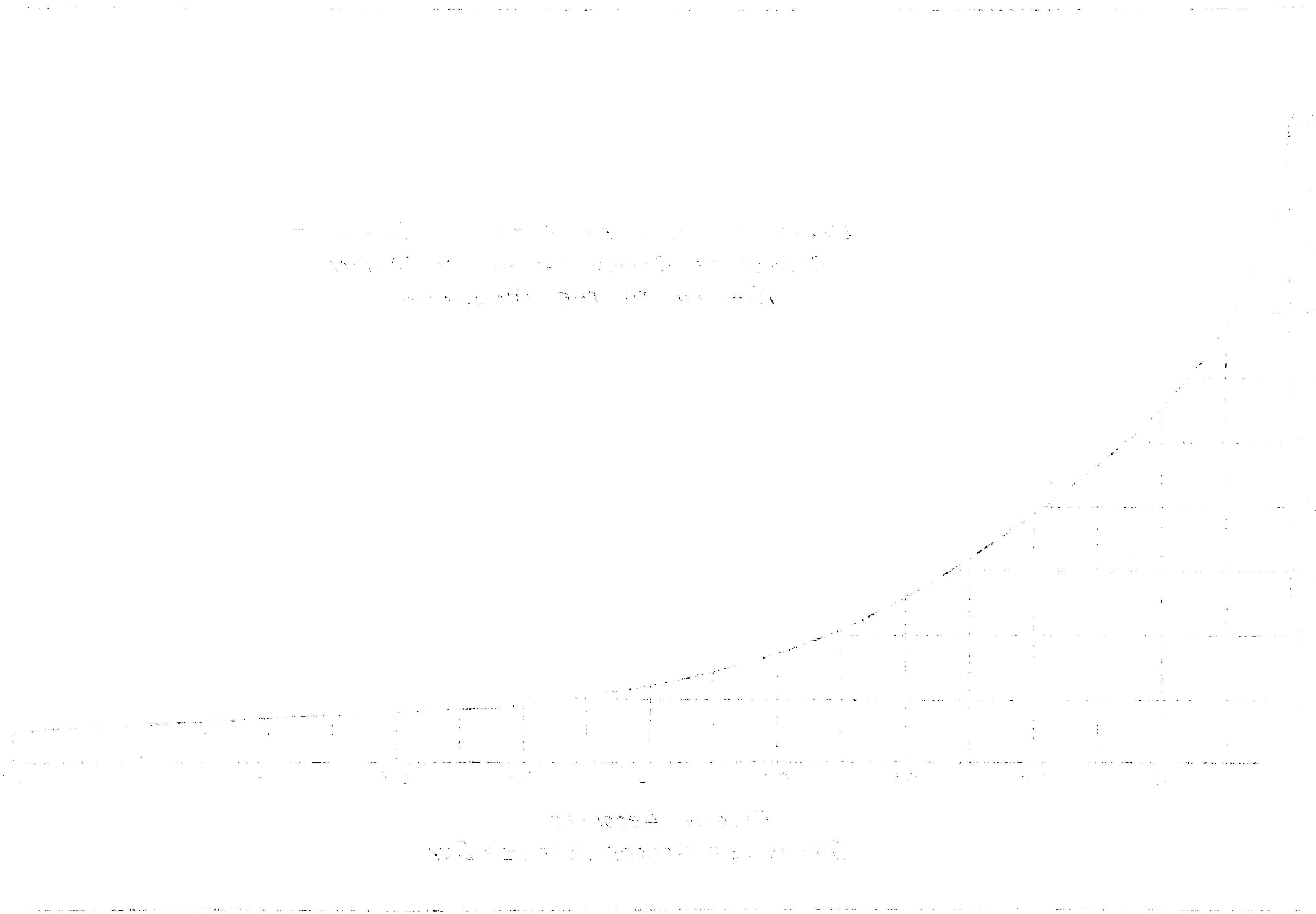

Oxygen Absorbed by Water of Different Degrees of Oxygen Saturation When Exposed to the Atmosphere
Percent Oxygen Saturation
100
90
80
70
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Oxygen Absorbed
Grams per Square Foot per Day

FIGURE I



comprehensive study of self-purification must deal with the oxygen demand as well as with the oxygen resources, and must consider the relation of the various factors of time, temperature, and other physical conditions to the rates of change of these two fundamental qualities.

Changes in the dissolved oxygen content of a stream are intimately associated with biochemical changes. They are brought about primarily by the oxidation of organic matter discharged into streams as soil wash and as wastes. In the presence of a supply of oxygen, together with certain oxidizing bacteria and oxidizable organic matter, progressive oxidation and stabilizing of the organic matter will take place.

It has been shown* that, under experimental conditions approximating those prevailing in a stream containing reserve dissolved oxygen, this reaction is an orderly and consistent one, proceeding at a measurable rate and according to the following definite law. This statement should be qualified to the extent of noting that little definite knowledge exists as to whether the law stated holds for periods of time longer than about twenty days. Experimental data bearing on this point are, in fact, somewhat meager for periods longer than ten days, though for shorter periods the most reliable evidence has been confirmatory.

The rate of biochemical oxidation of organic matter is proportional to the remaining concentration of unoxidized substance, measured in terms of oxidizability.

*Phelps, Earle B. Biochemistry of Sewage, VIII, Int. Eng. Apl. Chem. XXVI, 251.

Defining the oxygen demand as the total remaining oxidizability of the substance present at any time, the law states that in equal periods of time on equal proportion of the remaining oxygen demand will be satisfied. That is, if twenty per cent of the initial oxygen demand be satisfied in the first twenty-four hours, twenty per cent of the remaining demand will be satisfied in the second twenty-four hours, and so on. See Figure II for graphical illustration.

Stream Surveys.

The United States Public Health Service has been engaged in studies of inland streams for a number of years. These investigations have of necessity covered a considerable range of subjects because of inherent relationships of various phases of the problem. Stream pollution, on the one hand, is closely connected with the problem of public water supply and the efficiency of systems for satisfactory water purification, and,on the other hand, with the best methods for the prompt and effective disposal of domestic sewage and industrial wastes. Both of these phases of the problem are of equal significance from the stand-point of public health, and indeed, may exceed in importance the matter of actual condition of the stream itself resulting from excessive pollution. The broad objectives of the studies have, therefore, been:

1. To develop practical procedures for the measurement of stream pollution and suitable forms for the expression

Relation Between Oxygen Demand and Time

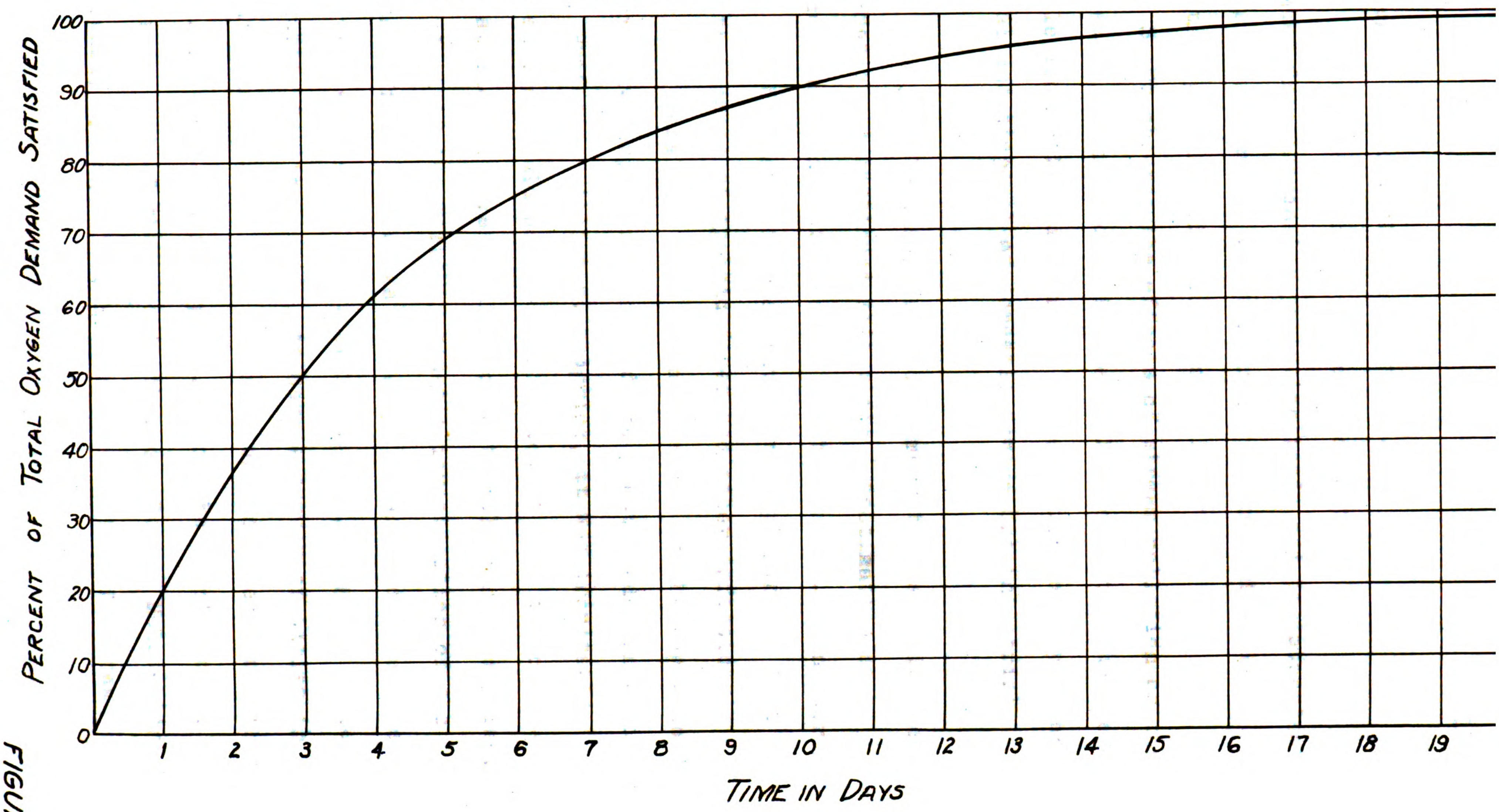


FIGURE II

of the degree of pollution encountered.

2. To ascertain the probable effects to be anticipated from increasing pollution loads and to determine the power of streams to recover from such imposed burdens, through the operation of natural agencies.

3. To observe the effects of stream pollution on the public health, as reflected in the quality of water supplies procurable from polluted sources, and as influenced by methods of removal and disposal of domestic sewage and industrial wastes.

The year 1901 may be said to mark the establishment of systematic and continued scientific investigation as a recognized function of the Public Health Service. Considering the role which sewage-polluted rivers were playing at that time in the spread of typhoid fever and other infectious diseases, and recalling that the membership of the Hygienic Laboratory Advisory Board included the great leader in sanitary science, Professor William T. Sedgwick, it was inevitable that attention should have been directed at once to comprehensive studies of stream pollution with relation to disease.

In 1910 the first systematic investigation of the status and effects of sewage pollution in any wide area was begun by the assignment of A. J. McLaughlin, surgeon, United States Public Health Service, to make a survey of cities in the Great Lakes Region, with instructions to investigate the pollution of their water supplies. Upon the completion of these surveys and of the reports thereon, Doctor McLaughlin was assigned, by request of health authorities of states bordering on the Missouri River, to make a survey of the sewage pollution of that stream.

During the summer of 1913 studies of the biochemistry of sewage and industrial wastes were undertaken at the hygienic laboratory under the direction of Carl B. Phelps, affiliate, American Society of Civil Engineers, who was appointed that year as chief of the division of chemistry in the laboratory. These studies were devoted especially to testing and developing the application of biological oxygen demand determinations to the measurement of the potential polluting effect of sewage and the capacity of streams for its ozidation.

About this same time under the direction of H. S. Cumming, surgeon general, United States Public Health Service, a study of the pollution and natural purification of the Potomac and Ohio Rivers was undertaken. These several studies were continued substantially as originally organized until 1917, when it was necessary to discontinue them in order to utilize their personnel during the period of the World War. Since 1919, when it was possible to resume the investigations, the principle field from this base of study has been an investigation of the pollution and natural purification of the Illinois River, undertaken chiefly to check and extend observations previously made on the Potomac and Ohio Rivers relative to the laws governing natural purification in streams.

Some of the more recent surveys are a study of the

Raritan River in 1927-28 by the New Jersey Agricultural Experiment Station; a study of the Cheat River Basin, West Virginia, by the State Water Commission in 1929; a study of Stream pollution in Oregon by the Oregon State Agricultural College Engineering Experiment Station in 1930.

Studies of the biological oxygen demand of sewage, industrial wastes, and polluted river waters have been continued in the endeavor to establish more definitely the laws governing the natural processes of oxidation in streams and to check and improve the precision of methods for making the determinations required.

With respect to sewage pollution, the status in the United States was, in 1913, and is today, that the greater part of the sewage from cities is discharged without treatment into the most convenient stream, where the dilution is insufficient for prompt oxidation and removal of the sewage, the result is the establishment of a gross nuisance in the immediate vicinity, offensive to the sense of decency and frequently injurious to the financial interests of the community responsible for the pollution.

Previous surveys of the St. Joseph River.

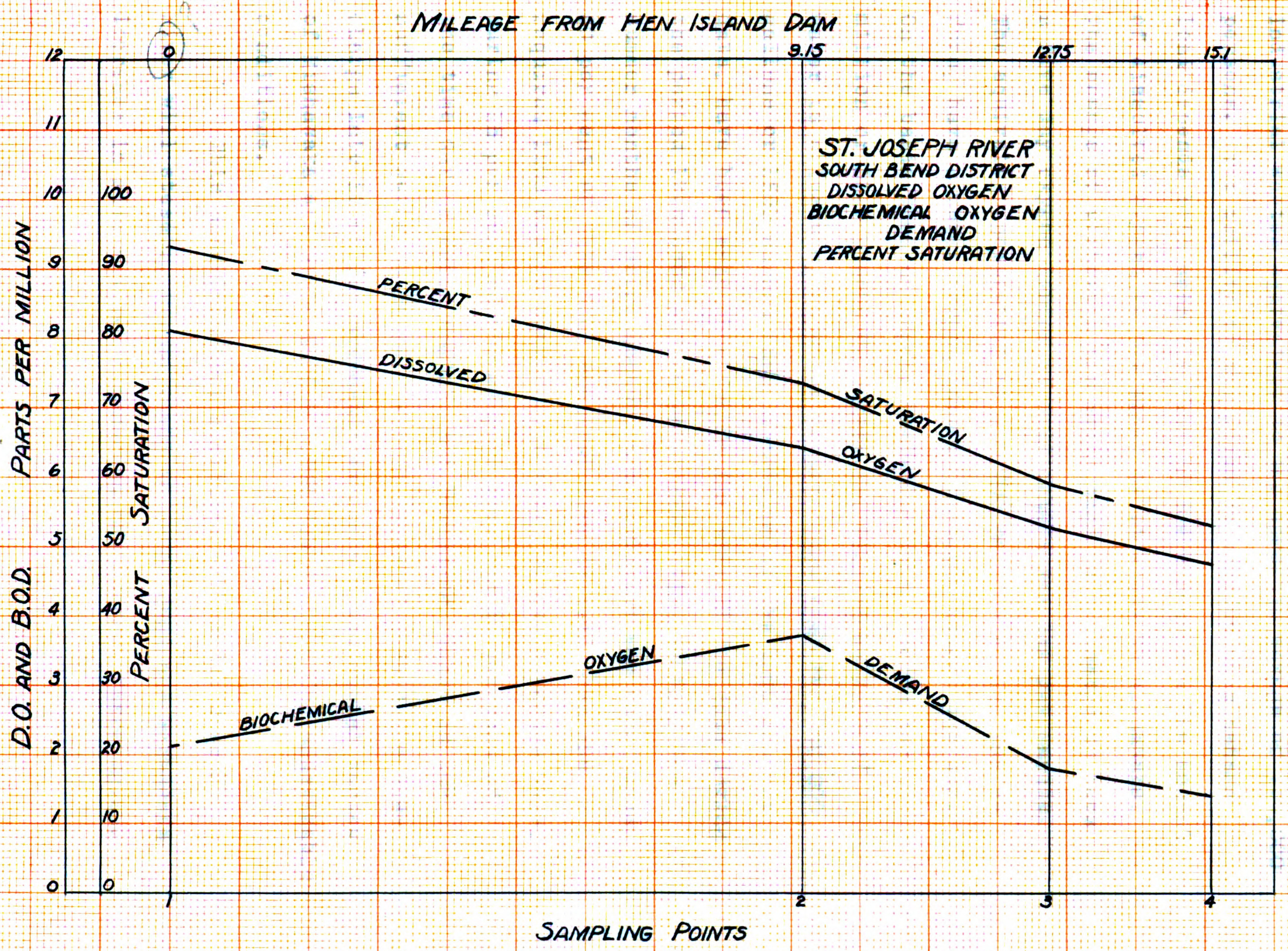
In the past there have been two surveys on the Mishawaka-South Bend section of the St. Joseph River which are of importance, one by the Department of Sanitary Engineering of the Indiana State Board of Health in 1929, and the other by the Michigan Stream Control Commission in

1931.

Results obtained by the Indiana State Board of Health in their survey showed that the St. Joseph River in Indiana is being unduly polluted by the discharge into it of Mishawaka and South Bend, and that this pollution is caused primarily by the discharge of domestic sewage. This pollution results in the creation of conditions which may "transmit, generate, or promote disease." Fish life in the stream is being jeopardized and in some instances has actually been destroyed. These same conditions exist in the State of Michigan.

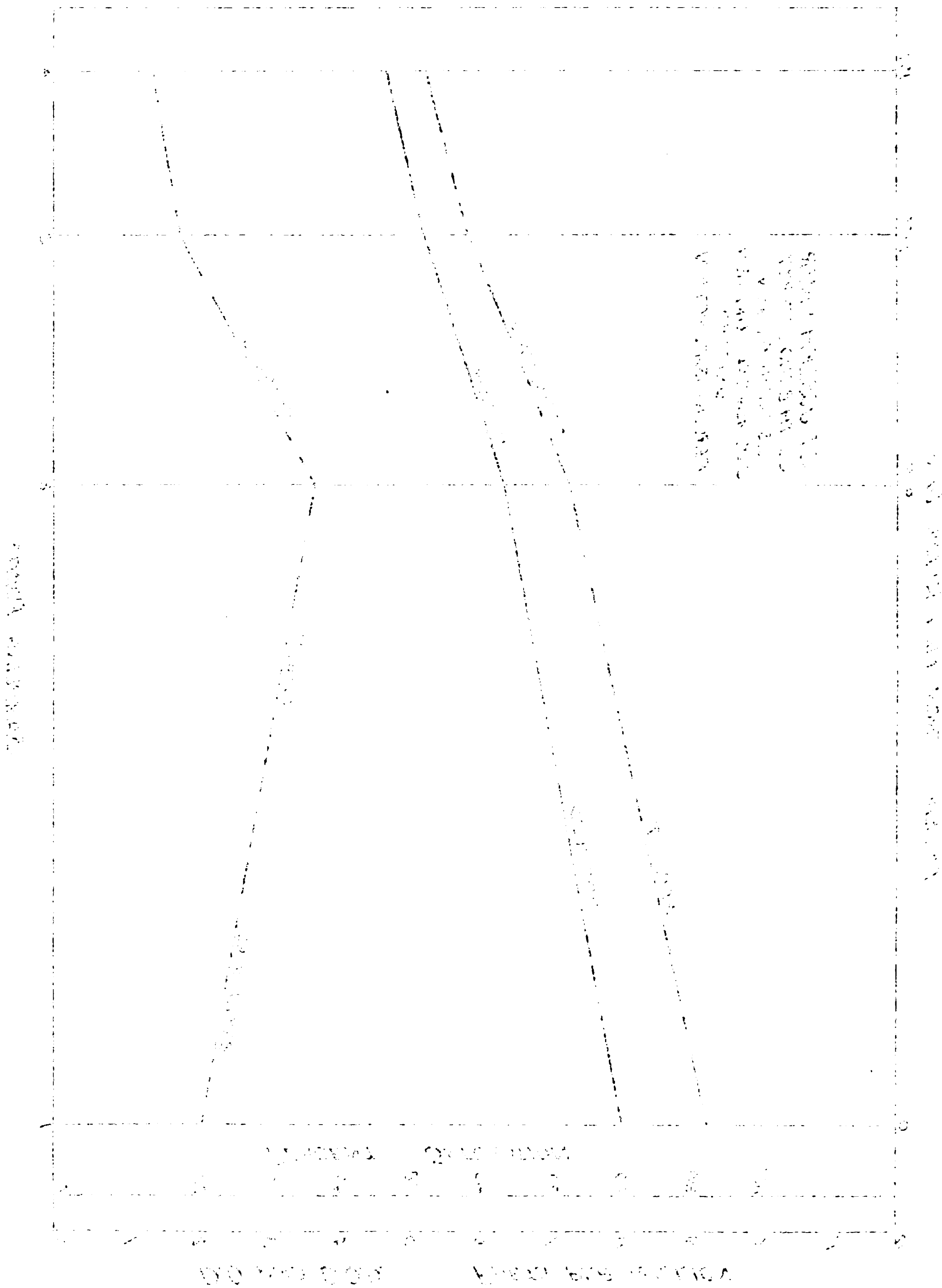
It can be seen from Figure III that the dissolved oxygen content and per cent of saturation shows a steady decrease from above Mishawaka to the Indiana-Michigan State Line. The dissolved oxygen content shown at Station 4 is not necessarily the minimum, since this survey gives no analytical information regarding the condition of the river below that point. It will be further noted that while the average dissolved oxygen at Station 4 lies slightly above 50 per cent of saturation, many samples showed a much lower dissolved oxygen content and approached the point where fish life becomes impossible.

This section of the river is called upon to receive and carry away the sewage of approximately 125,000 people of Mishawaka and South Bend in addition to the industrial wastes produced in these cities. The industrial wastes are equivalent in their strength to the sewage of 25,000 people.



MILEAGE FROM HEN ISLAND DAM
0
9.15
12.75
15.1
ST. JOSEPH RIVER
SOUTH BEND DISTRICT
DISSOLVED OXYGEN
BIOCHEMICAL OXYGEN
DEMAND
PERCENT SATURATION
PERCENT
SATURATION
DISSOLVED
OXYGEN
BIOCHEMICAL
OXYGEN
DEMAND
D.O. AND B.O.D. PARTS PER MILLION
12
11
10
9
8
7
6
5
4
3
2
1
0
PERCENT SATURATION
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
SAMPLING POINTS

FIGURE III



The river, therefore, is used to dispose of sewage and industrial wastes equivalent to the domestic sewage of 150,000 persons. The ability of the river to receive this sewage load depends both upon the flow of the stream and the amount of dissolved oxygen in the water as it comes to Mishawaka. The sewage of Mishawaka and South Bend is estimated to have a five day oxygen demand of 0.17 pounds per day per capita. The equivalent population of 150,000 persons would, therefore, have a total oxygen demand of 25,500 pounds per day. On the basis that an oxygen depletion of 4.0 parts per million or 33.3 pounds of oxygen per million gallons of water is allowable, it would be indicated that 765,000,000 gallons or 1200 second feet, according to the hydrographic data, have been available for 85 per cent of the time during the period 1918-1929 inclusive (Figure IV). If only the summer months of July, August, and September are considered, 50 per cent of this time the mean flow is less than the required 1200 second feet. From this, we can conclude that, during 15 per cent of the average year and 50 per cent of the time during July, August, and September, there is insufficient water in the St. Joseph River to permit the discharge into it of the untreated sewage and industrial wastes of Mishawaka and South Bend without the creation of undesirable conditions.

This unsatisfactory condition of the St. Joseph River will steadily become worse as South Bend and Mishawaka increase in size and new industries are located there unless

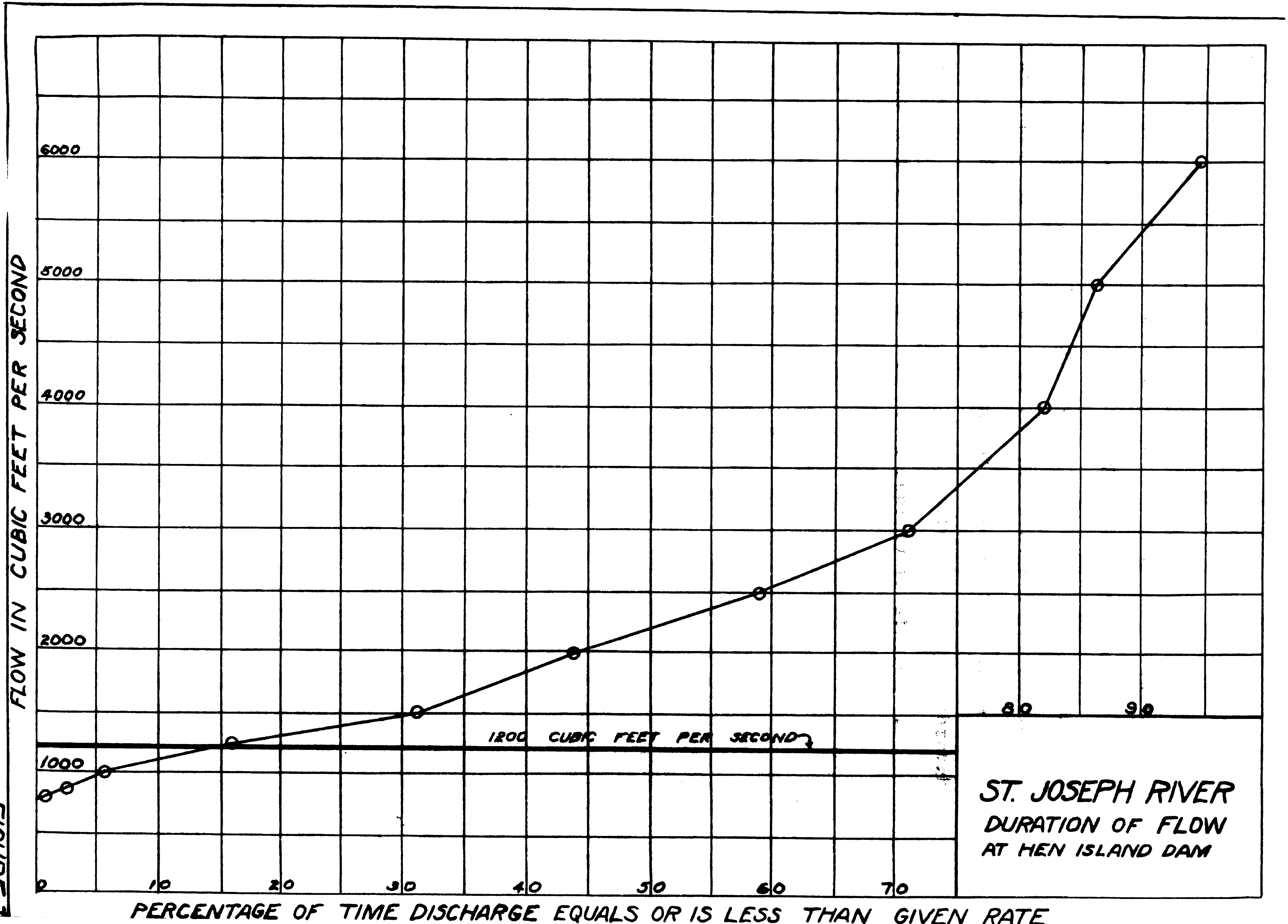
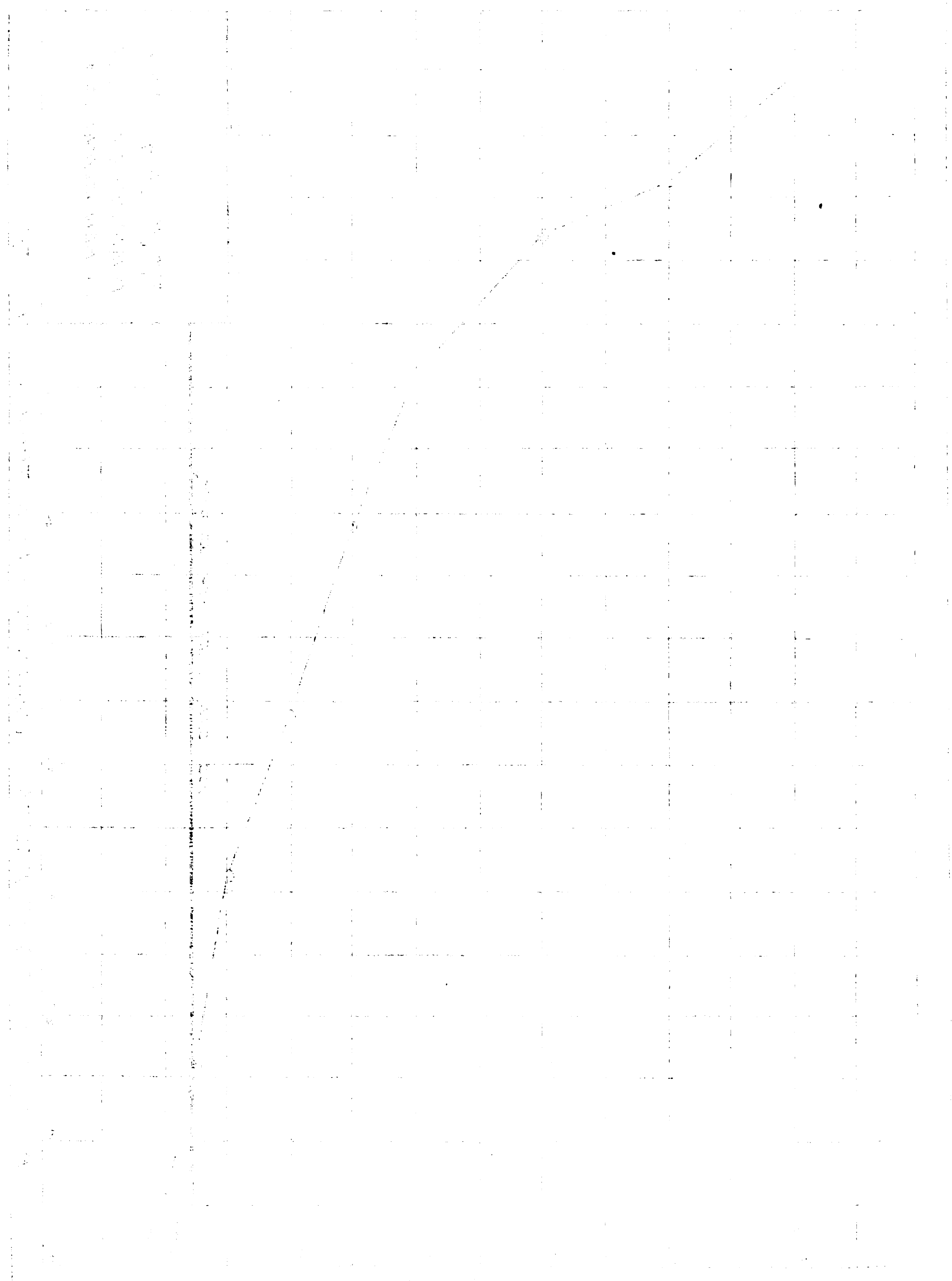

ST. JOSEPH RIVER
DURATION OF FLOW
AT HEN ISLAND DAM
FLOW IN CUBIC FEET PER SECOND
6000
5000
4000
3000
2000
1000
1200 CUBIC FEET PER SECOND
0
10
20
30
40
50
60
70
80
90
PERCENTAGE OF TIME DISCHARGE EQUALS OR IS LESS THAN GIVEN RATE

FIGURE 7



remedial measures are taken.

Charts of the Michigan Stream Control Commission's survey show results analogous to those of the Indiana State Board of Health. Figure V shows a steady decrease in the dissolved oxygen content and per cent saturation from above Mishawaka to station 3 at which point they are a minimum. From station 3 a gradual increase is shown through Niles to station 6 where it rises rapidly to station 7.

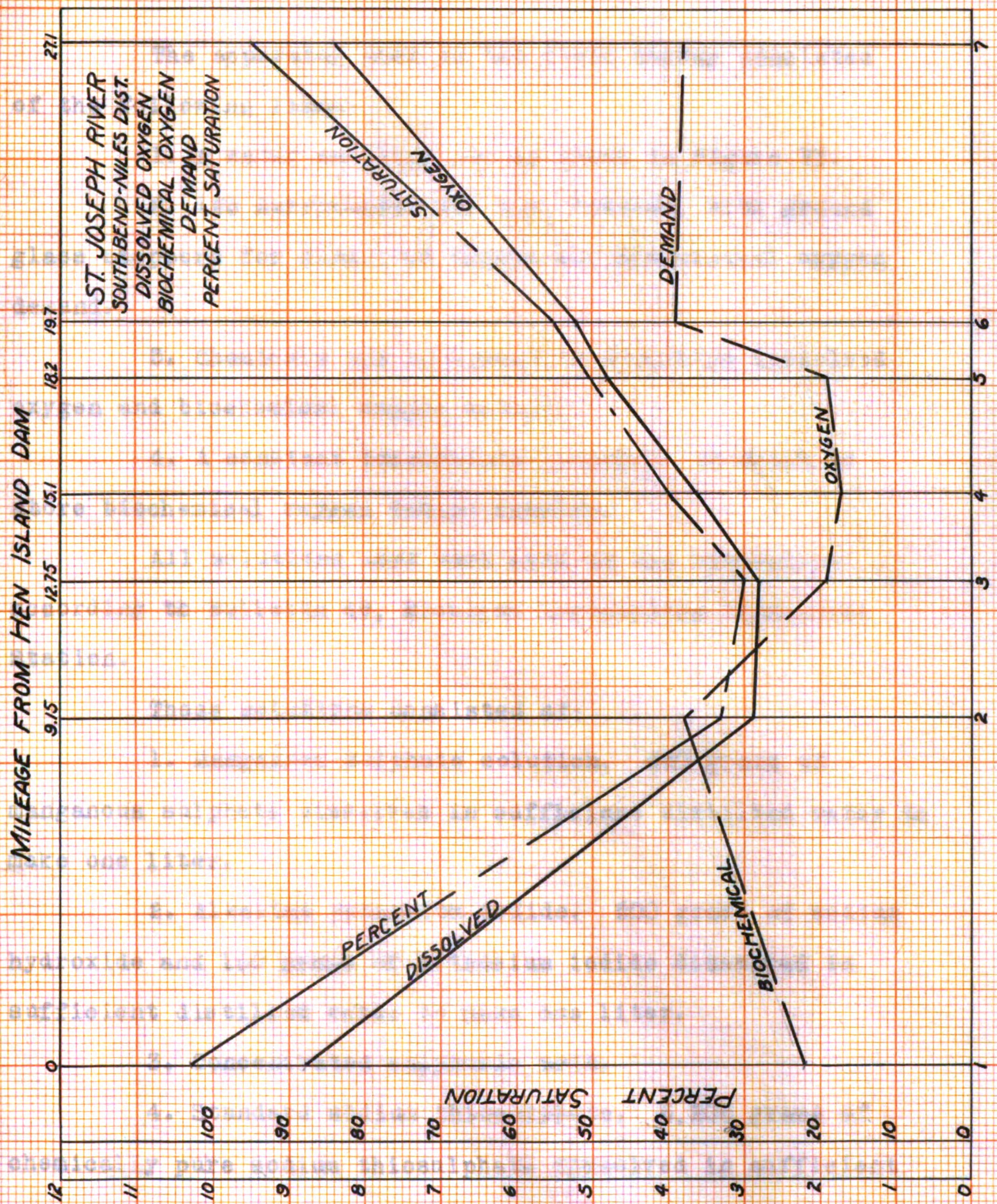
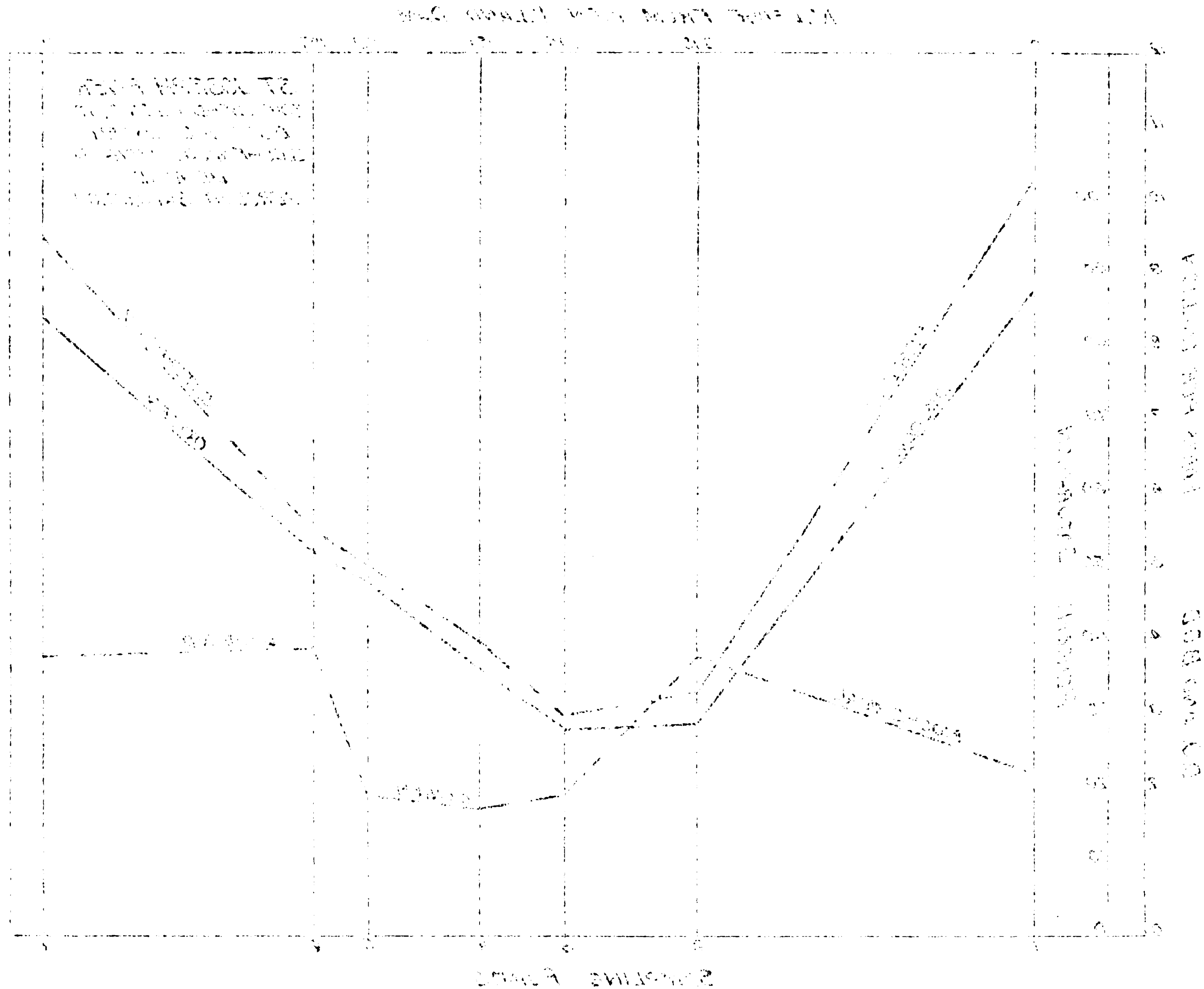

ST. JOSEPH RIVER
SOUTH BEND-NILES DIST.
DISSOLVED OXYGEN
BIOCHEMICAL OXYGEN
DEMAND
PERCENT SATURATION
MILEAGE FROM HEN ISLAND DAM
0
9.5
12.75
15.1
18.2
19.7
27.1
SAMPLING POINTS
1
2
3
4
5
6
7
PERCENT SATURATION
0
10
20
30
40
50
60
70
80
90
100
D.O. AND B.O.D. PARTS PER MILLION
0
1
2
3
4
5
6
7
8
9
10
11
12
OXYGEN
SATURATION
DEMAND
OXYGEN
BIOCHEMICAL
PERCENT
DISSOLVED

FIGURE V


ST JOSEPH RIVER

EXPERIMENTAL

Apparatus and Chemicals Used.

The apparatus used on the field survey consisted of the following items:

1. A water sampling can as shown in Figure VI.

2. 125 narrow-neck 250 c.c. bottles, with ground glass stoppers for dissolved oxygen and biochemical oxygen demand.

3. Chemicals and equipment to determine dissolved oxygen and biochemical oxygen demand.

4. A constant temperature incubator in which to store biochemical oxygen demand samples.

All solutions used were made in the laboratory according to Bulletin 49, Michigan Engineering Experiment Station.

These solutions consisted of:

1. Manganous sulphate solution. 480 grams of manganous sulphate dissolved in sufficient distilled water to make one liter.

2. Alkaline potassium iodide. 500 grams of sodium hydroxide and 150 grams of potassium iodide dissolved in sufficient distilled water to make one liter.

3. Concentrated sulphuric acid.

4. Standard sodium thiosulphate. 6,205 grams of chemically pure sodium thiosulphate dissolved in sufficient freshly boiled and cooled distilled water to make on liter.

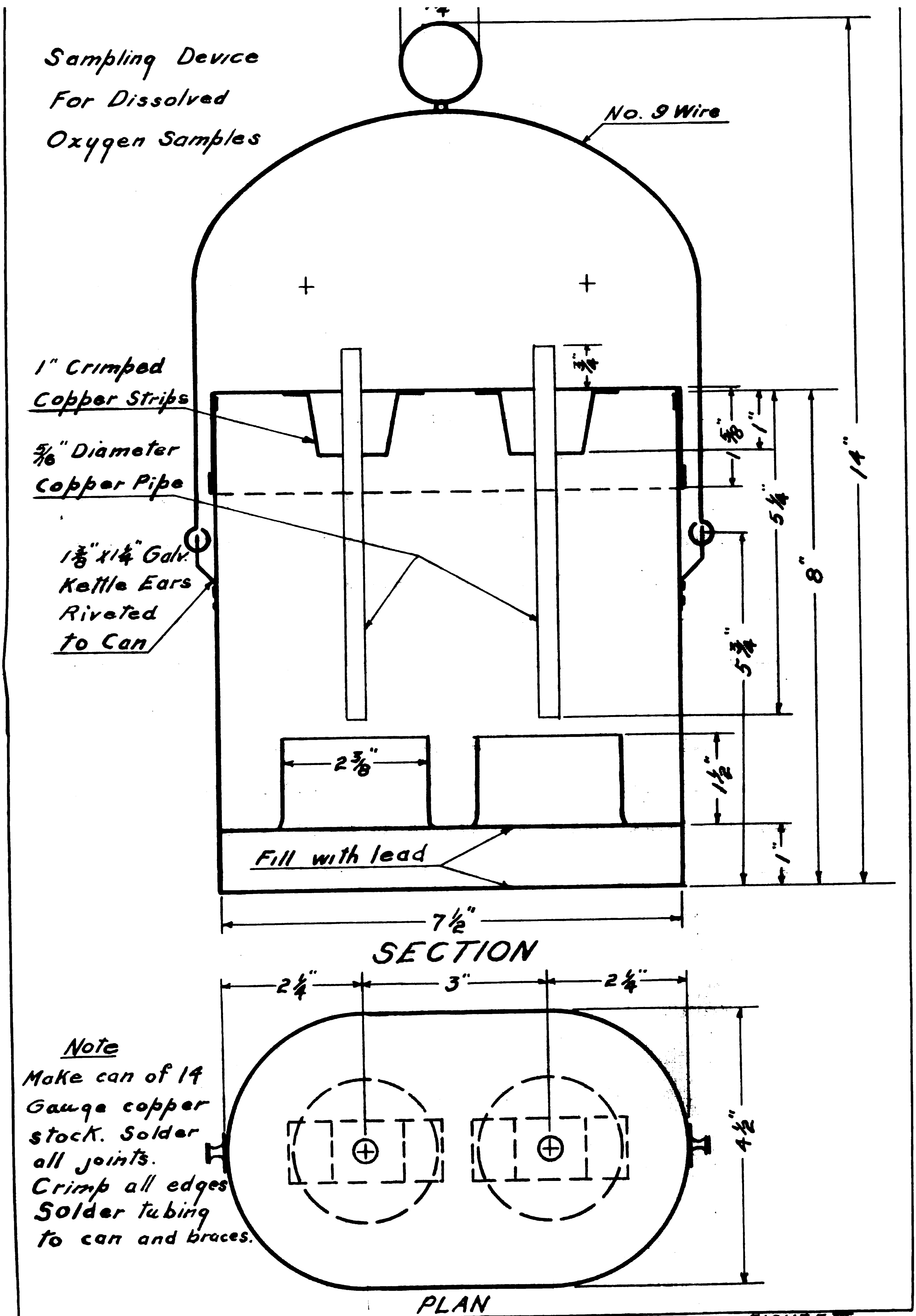
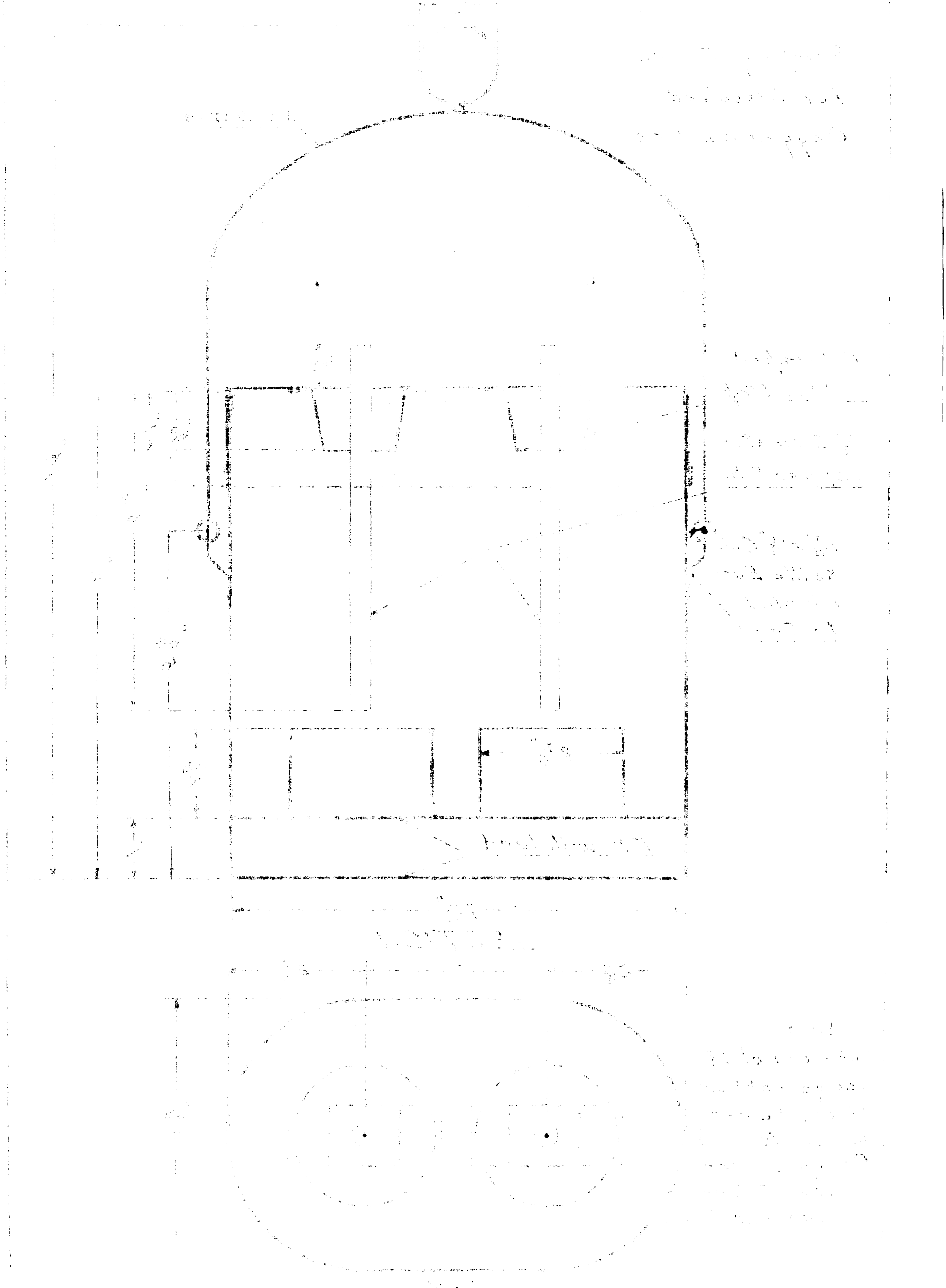

Sampling Device For Dissolved Oxygen Samples
No. 9 Wire
1" Crimped Copper Strips
5/16" Diameter Copper Pipe
1 3/8" x 1/4" Galv. Kettle Ears Riveted to Can
3/4"
1 5/8"
1"
5 1/4"
8"
14"
5 3/4"
2 3/8"
1 1/2"
1"
Fill with lead
7 1/2"
SECTION
2 1/4"
3"
2 1/4"
4 1/2"
Note
Make can of 14 Gauge copper stock. Solder all joints. Crimp all edges Solder tubing to can and braces.
PLAN

FIGURE VI



5. Starch indicator. A thin paste of about 2 grams of starch stirred in 200 c.c. of boiling water with a few drops of chloroform after cooling.

Sampling Stations.

A general investigation was made of the section of the St. Joseph River which included the cities of Mishawaka, South Bend, and Niles for the purpose of selecting sampling points. The selection of sampling points was controlled by two major factors: (1) The location with respect to the cities in order to determine the effect of the pollution from the cities, (2) The accessibility of the site.

There follows a brief description of the various sampling stations from which samples were collected. (See Figure VII).

1. This station is located at Hen Island Dam, maintained at the Twin Branch Station of the Indiana Michigan Electric Company. Since this point is approximately three-fourths of a mile above the nearest sewer outlet in Mishawaka, data obtained here indicated the condition of the river as it enters the Mishawaka-South Bend area.

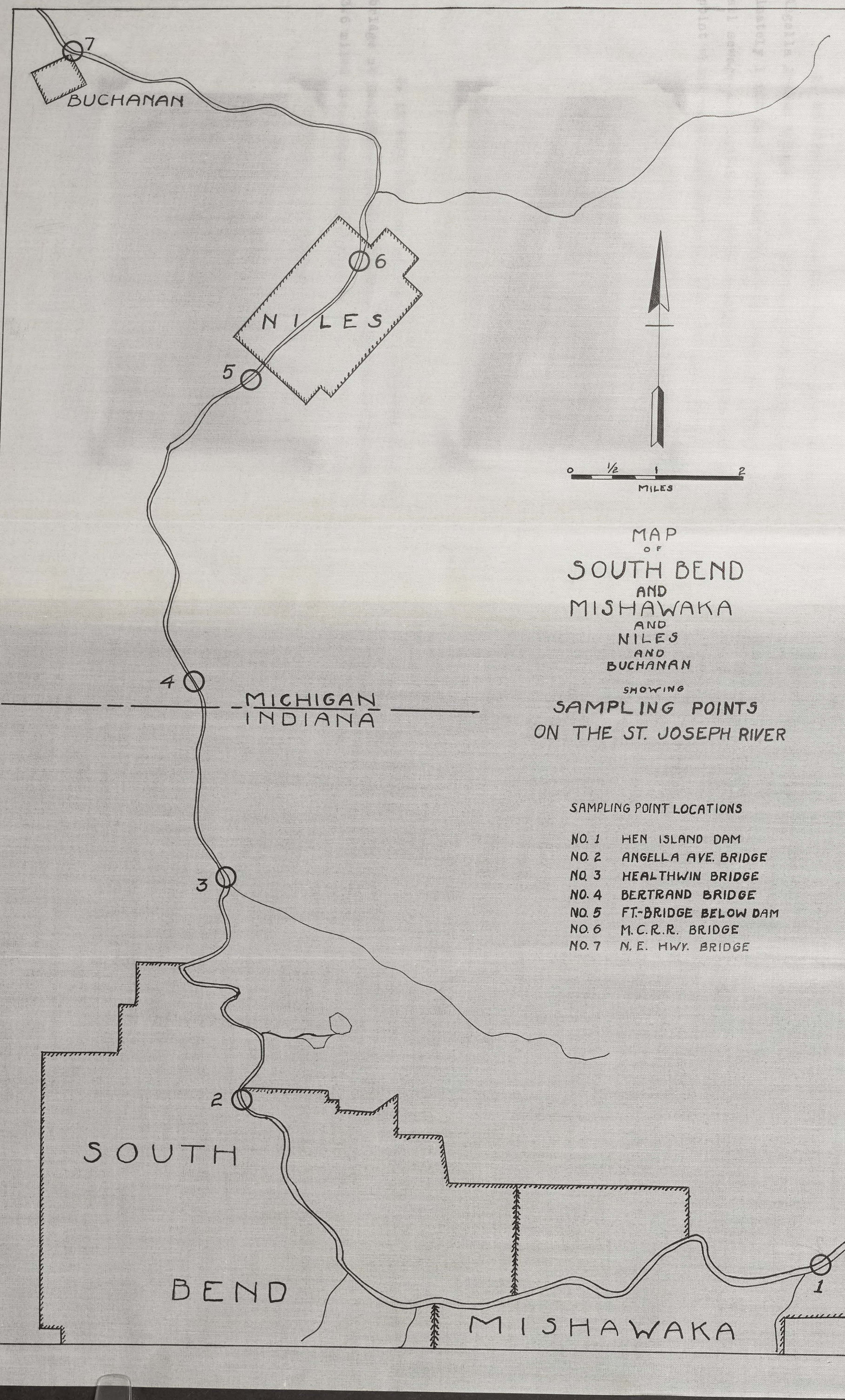

BUCHANAN
7
6
NILES
5
0 1/2 1 2
MILES
MAP OF SOUTH BEND AND MISHAWAKA AND NILES AND BUCHANAN SHOWING SAMPLING POINTS ON THE ST. JOSEPH RIVER
4
MICHIGAN
INDIANA
SAMPLING POINT LOCATIONS
NO. 1 HEN ISLAND DAM
NO. 2 ANGELLA AVE. BRIDGE
NO. 3 HEALTHWIN BRIDGE
NO. 4 BERTRAND BRIDGE
NO. 5 FT.-BRIDGE BELOW DAM
NO. 6 M.C.R.R. BRIDGE
NO. 7 N.E. HWY. BRIDGE
3
2
SOUTH
BEND
MISHAWAKA
1

FIGURE VII

2. At this station samples were collected at the Angella Avenue bridge. A 90 inch sewer discharges approximately 1,500 feet upstream from this station. Practically all sewage and industrial waste reaches the river above this point which is at the northern limits of South Bend.

3. At this station samples were collected from the bridge at Healthwin Sanatarium. This station is located 3.6 miles downstream from station 2.

4. This station is the bridge at Bertrand, Michigan. It is located 0.5 miles north of the state line, 2.35 miles below station 3, and 15.1 miles below station 1 at Hen Island Dam. This point is well located to show the condition of the river as it enters Michigan.

5. This station was located on the bridge below the French Paper Company's dam at the southern limits of Niles. Data from this station indicated the condition of the river as it enters Niles. It is 3.1 miles below station 4 and 18.2 miles below station 1.

6. At this station, which was on the Michigan Central Railroad bridge, the condition of the river after receiving the sewage load of Niles is indicated. It is 1.5 miles below station 5, and 19.7 miles below station 1.

7. At this station samples were collected from the highway bridge above the Indiana Michigan Dam. This point is 8.4 miles below station 6, and 27.1 miles below station 1.

Procedure.

Samples were collected at midstream from each station at two hour intervals over a twenty-four hour period. Samples were taken by lowering a sampling can (See Figure VI) containing two 250 c.c. glass stoppered bottles into the river. The sampling can is designed so the water enters through the bottle, and then goes into the can, three volumes of water going through the bottle before the can has filled. This eliminates the possibility of entrapping air in the bottles. When the bottles were filled, the sampling can was raised to the surface and the bottles were removed and glass stoppers inserted with care, to prevent the trapping of any air bubbles in the bottles. The temperature was taken of the excess water which was then drained off.

The water in one bottle was prepared chemically for analysis of dissolved oxygen by the Winkler method, within a short period of time after the collection of the sample. The other bottle was placed in a 20°C. incubator for a period of five days, after which it was analyzed to determine the biochemical oxygen demand.

The Winkler Method is as follows:

1. Add 1 c.c. of manganous sulphate solution by means of a pipette.

2. Add 1 c.c. of alkaline potassium eodide solution.

3. Insert the stopper and mix by inverting the bottle several times.

4. Allow the precipitate to settle halfway and mix a second time.

5. Again allow to settle half-way.

6. Add 1 c.c. of concentrated sulphuric acid, insert the stopper and mix immediately. Do not allow the bottle to stand open after the addition of the acid.

7. Allow the mixture to stand at least five minutes.

8. Rapidly withdraw 100 c.c. of the sample into a flask and titrate with 0.025 N sodium thiosulphate using starch as an indicator, near the end of the titration.

Calculations:

No. of c.c.'s of thiosulphate x 2 = p.p.m. discharged oxygen.

The biochemical oxygen demand was determined by testing the second sample after five days for dissolved oxygen.

D. O. before - D. O. after incubation = p.p.m. 5 day B. O. D.

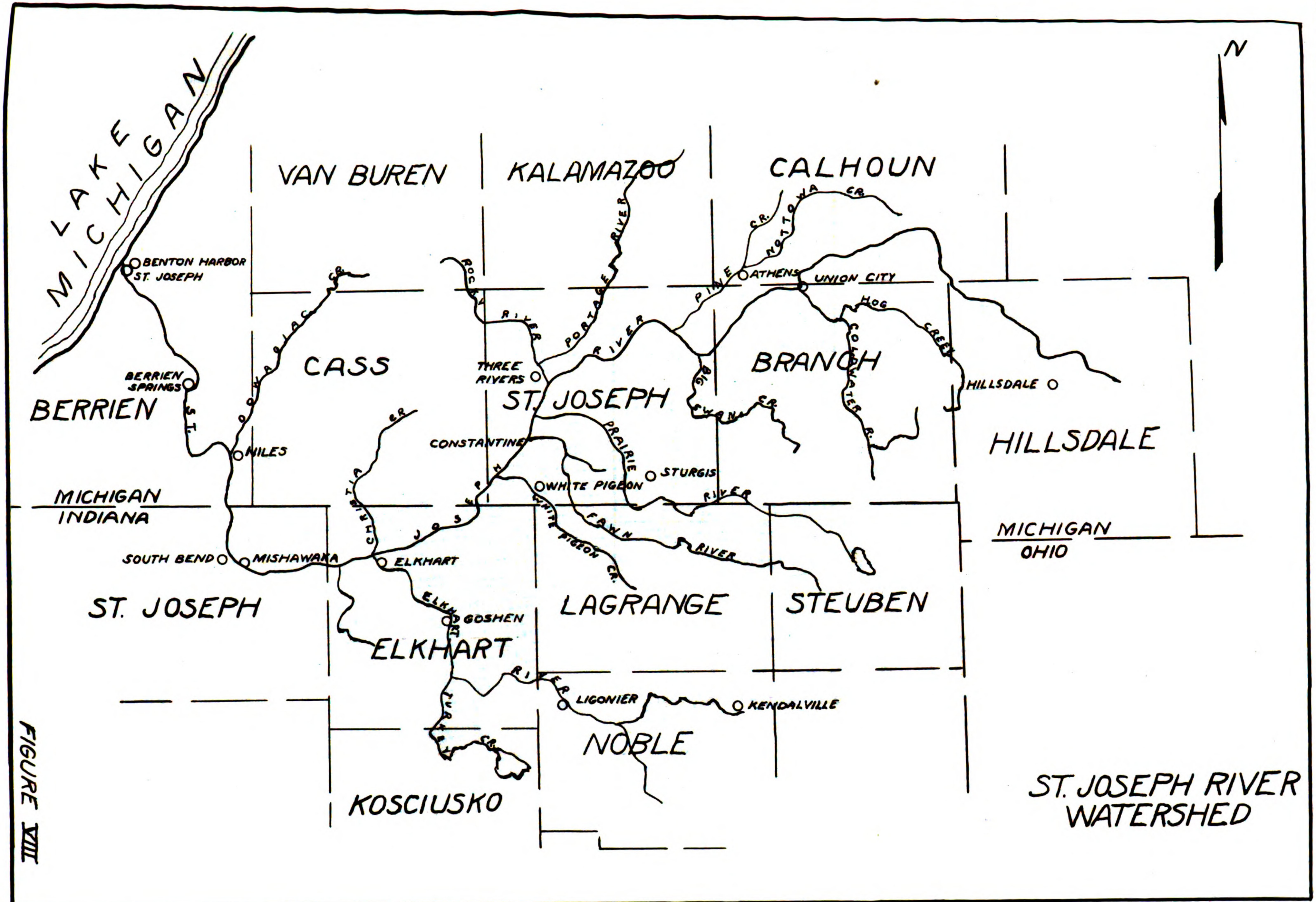
The flow of the river during the period of sampling was determined from the United States Geological gaging station located at Niles, Michigan.

GENERAL DESCRIPTION OF THE ST. JOSEPH RIVER

The St. Joseph River rises in the lake district of South Central Michigan and then flows in a general southwesterly direction into Elkhart County, Indiana. It flows into St. Joseph County from Elkhart County on a westerly course. In South Bend it takes a sharp bend to the North and then flows back into Michigan at a point about 4 miles north of South Bend. It discharges into Lake Michigan at St. Joseph and Benton Harbor, Michigan. There are approximately 4600 square miles on the whole St. Joseph River watershed of which 1670 square miles are in Indiana and 2830 square miles in Michigan. (See drainage map figure VIII).

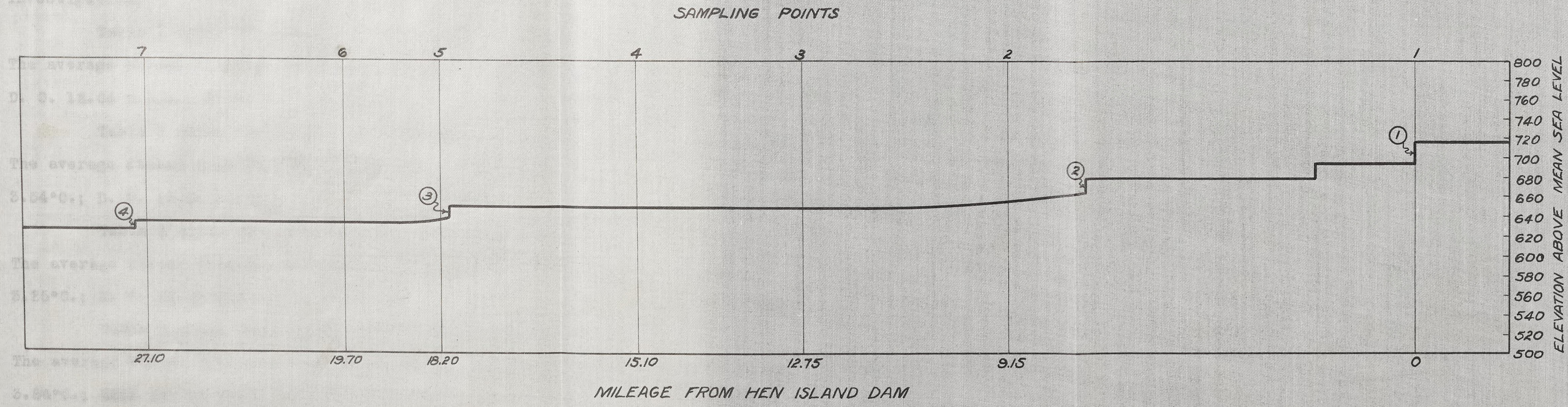
Several dams have been erected on the St. Joseph River which have a material effect on the oxygen condition of the water, for they form ponds which really serve as huge settling basins. These dams include one constructed by the Indiana Michigan Electric Company at Hen Island, a second located about 1000 feet upstream from the Main St. bridge in Mishawaka, a third which is known as the Oliver Dam is located in South Bend between the Jefferson and Colfax bridges, a fourth located at the French Paper Company mill above Niles, and a fifth located at Buchanan.

The dam of the Indiana Michigan Electric Company at Hen Island, which forms a large lake, controls to a great extent the amount of water available in the river at South Bend. (See profile map, figure IX).



ST. JOSEPH RIVER WATERSHED

FIGURE VIII



NOTE

1 INDIANA-MICHIGAN ELECTRIC CO. DAM
2 OLIVER DAM
3 FRENCH PAPER CO. DAM
4 MICHIGAN GAS AND ELECTRIC CO. DAM

PROFILE
ST. JOSEPH RIVER
SOUTH BEND-NILES DISTRICT

FIGURE IX

RESULTS

The following is the analytical data obtained from the analysis of samples collected in the course of the investigation.

Table 2 shows the results of the survey at station 1. The average stream flow was 2603 second feet; temperature 3.17°C; D. O. 12.64 p.p.m.; B. O. D. 1.77 p.p.m.

Table 3 shows the results of the survey at station 2. The average stream flow was 1980 second feet; temperature 3.54°C.; D. O. 12.53 p.p.m.; B. O. D. 1.77 p.p.m.

Table 4 shows the results of the survey at station 3. The average stream flow was 2396 second feet; temperature 3.25°C.; D. O. 12.53 p.p.m.; B. O. D. 3.96 p.p.m.

Table 5 shows the results of the survey at station 4. The average stream flow was 2396 second feet; temperature 3.54°C.; 2396 second feet; temperature 3.54°C.; D. O. 12.20 p.p.m.; B. O. D. 3.39 p.p.m.

Table 6 shows the results of the survey at station 5. The average stream flow was 2396 second feet; temperature 3.7°C.; D. O. 12.43 p.p.m.; B. O. D. 3.18 p.p.m.

Table 7 shows the results of the survey at station 6. The average stream flow was 2396 second feet; temperature 3.1°C.; D. O. 12.45 p.p.m.; B. O. D. 3.51 p.p.m.

Table 8 shows the results of the survey at station 7. The average stream flow was 2065 second feet; temperature 3.3°C.; D. O. 12.90 p.p.m.; B. O. D. 3.04 p.p.m.

Figure 10 shows the average per cent saturation, D. O., and B. O. D. for all stations according to distance.

Table 9 shows the average pounds of D. O. and B. O. D. available at each station, and figures XI shows these results plotted according to distance.

Table 10 shows the average width of the river, the distance, and the area of the surface between stations. From table 10, table 11 has been prepared. This table shows the pounds of oxygen which will be absorbed between the various stations at different per cent saturation values. It is apparent from our results that the greatest amount of oxygen which would be absorbed at any time would be approximately 5.75 pounds per day and very often more.

TABLE 2

STATION 1

Date	Time	Temp.	Stream flow c.f.s.	D. O.	5 day B.O.D.	Per cent Saturation
Mar. 27	1:00AM.	3°	2050	12.0	1.9	89
"	3:00	3	2570	12.8	2.7	95
"	5:00	3	2770	12.2	2.2	91
"	7:00	3	2700	14.0	3.6	104
"	9:00	3	2090	12.9	2.3	96
"	11:00	3	2265	12.5	1.9	93
"	1:00	3.5	2990	12.4	1.4	93
"	3:00	3.5	3330	13.2	2.4	99
"	5:00	3.5	3050	12.7	1.3	95
"	7:00	3.5	2570	13.0	1.6	97
"	9:00	3	2525	11.6	0	86
"	11:00	3	2330	12.6	1.9	93.5
Average		3.17	2603	12.64	1.77	94.29

TABLE 3

STATION 2

Date	Time	Temp.	Stream flor c.f.s.	D. O.	5 day B.O.D.	Per cent Saturation
Mar. 25	1;00 AM	3•	1940	11.9	1.9	88
"	3:00	2	1980	13.2	3.9	96
"	5;00	2	2130	12.0	2.9	87
26	7:00	4	2050	12.8	2.60	97.5
"	9:00	3	1550	12.3	6.10	91
"	11:00	3.5	1660	12.5	6.20	94.1
"	1:00 PM	4.5	2300	12.3	5.10	95
"	3:00	5	2365	12.2	4.30	95.3
"	5;00	5	2165	12.3	4.70	96.2
"	7:00	4	2090	12.2	2.70	93
"	9:00	3	1840	14.4	5.00	94
"	11:00	3.5	1690	12.3	3.60	92.5
Average		3.54	1980	12.53	4.09	93.97

TABLE 4

STATION 3

Date	Time	Temp.	Stream flow c.f.s.	D. O.	5 day B.O.D.	Per cent Saturation
Mar. 25	1:00 AM	2.5°	1940	12.1	4.2	88.6
"	3:00	2.5	1980	12.1	2.8	88.6
"	5:00	2.5	2130	12.7	3.6	93.1
26	7:00	4	2050	11.2	0.40	85.4
"	9:00	3	1550	12.0	1.40	89.0
"	11:00	3	1660	12.1	3.90	89.8
24	1:00 PM	5	3260	13.35	3.8	104.1
"	3:00	5	3585	13.5	5.0	105.5
"	5:00	2.5	3330	14.0	6.6	102.5
"	7:00	3	2735	13.1	5.6	97.3
"	9:00	3	2400	12.8	5.4	95.0
"	11:00	3	2130	11.5	4.8	85.4
Average		3.25	2396	12.53	3.96	93.67

TABLE 5

STATION 4

Date	Time	Temp.	Stream flow c.f.s.	D. O.	5 day B.O.D.	Per cent Saturation
Mar. 25	1:00 AM	2.5°	1940	12.2	4.4	89.4
"	3:00	2.5	1980	11.9	3.7	87.2
"	5:00	2.5	2130	12.4	4.0	90.8
26	7:00	3.5	2050	11.6	2.00	87.2
"	9:00	4.0	1550	13.0	3.60	99.1
"	11:00	3.5	1660	11.4	1.90	85.7
24	1:00 PM	5.0	3260	12.1	3.9	94.6
"	3:00	5.0	3585	13.2	3.6	103.0
"	5:00	4.0	3330	12.0	3.2	91.4
"	7:00	3.5	2735	12.1	3.5	91.0
"	9:00	3.5	2400	12.0	3.7	90.3
"	11:00	3.0	2130	12.5	3.2	92.8
Average		3.54	2396	12.2	3.39	91.9

TABLE 6

STATION 5

Date	Time	Temp.	Stream flow c.f.s.	D. O.	5 day B.O.D.	Per cent Saturation
Mar. 25	1:00 AM	3°	1940	13.5	3.62	100.1
"	3:00	3	1980	12.6	4.17	93.4
"	5:00	3	2130	12.8	3.90	95.0
26	7:00	3.5	2050	13.6	4.10	102.2
"	9:00	4	1550	12.1	2.10	92.3
"	11:00	4	1660	12.6	2.90	96.0
24	1:00 PM	4.5	3260	11.2	2.21	86.5
"	3:00	4.5	3585	13.0	3.82	100.5
"	5:00	4	3330	11.9	3.14	90.7
"	7:00	4	2735	12.4	2.46	94.4
"	9:00	4	2400	12.9	4.25	98.3
"	11:00	3	2130	10.6	1.53,	78.6
Average		3.7	2396	12.43	3.18	94.0

TABLE 7

STATION 6

Date	Time	Temp.	Stream flow c.f.s.	D. O.	5 day B.O.D.	Per cent Saturation
Mar. 25	1:00 AM	2.0	1940	12.7	4.17	91.7
"	3:00	2.0	1980	11.6	3.99	83.8
"	5:00	3.0	2130	11.6	3.08	86.0
26	7:00	4.0	2050	12.4	2.60	94.4
"	9:00	4.0	1650	12.6	2.40	96.0
"	11:00	3.0	1660	12.9	2.30	95.8
24	1:00 PM	3.5	3260	13.1	4.50	98.4
"	3:00	3.5	3585	12.6	4.59	94.6
"	5:00	3.5	3330	12.4	3.49	93.3
"	7:00	3.0	2735	12.4	3.65	91.9
"	9:00	3.0	2400	12.5	3.74	92.7
"	11:00	3.0	2130	12.6	3.57	93.5
Average		3.1	2396	12.45	3.51	93.4

TABLE 8

STATION 7

Date	Time	Temp.	Stream flow c.f.s.	D. O.	5 day B.O.D.	Per cent Saturation
Mar. 24	1:00 AM	3.0°	2165	12.8	3.14	95.1
25	3:00	2.5	1980	13.0	2.90	95.2
"	5:00	2.0	2130	13.3	3.72	96.1
"	7:00	2.0	2400	13.7	4.18	98.9
26	9:00	4.0	1550	12.7	2.90	96.8
"	11:00	3.5	1660	12.7	2.10	95.5
"	1:00 PM	3.5	2300	11.8	1.60	88.7
"	3:00	3.5	2365	12.0	1.90	90.2
"	5:00	4.0	2165	12.5	2.40	95.3
"	7:00	4.5	2090	12.1	2.80	93.4
"	9:00	4.0	1840	12.9	3.90	98.3
24	11:00	3.0	2130	14.4	4.92	93.6
Average		3.3	2065	12.9	3.04	94.8

TABLE 9

Station	Pounds of D.O. available per day	Pounds of B.O.D. per day
1	238.0	33.30
2	179.3	58.6
3	216.8	68.5
4	211.0	58.6
5	215.0	55.0
6	215.4	60.7
7	192.2	45.3

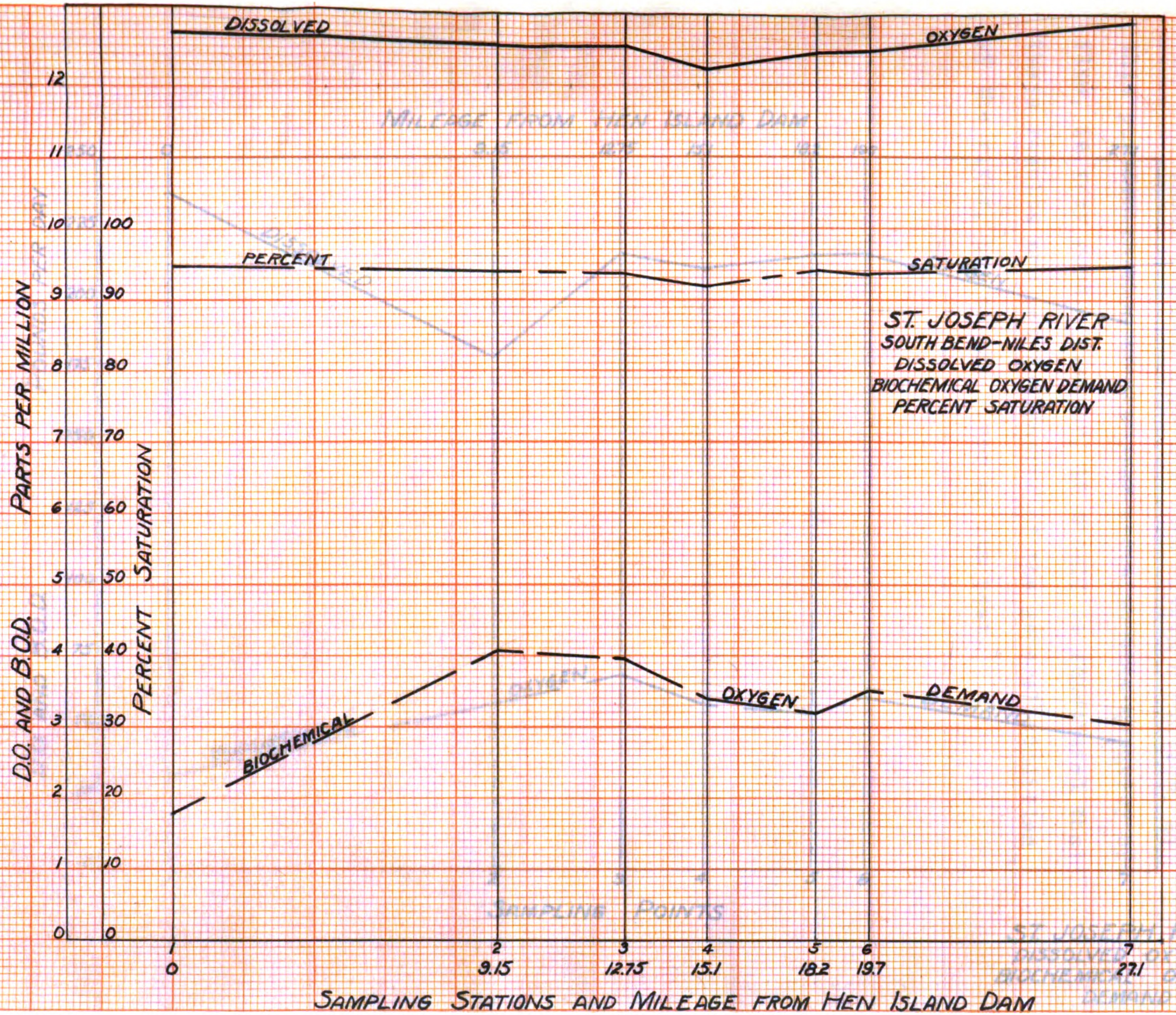
TABLE 10

Point	Average Width	Dist. ft.	Area Sq. ft.
1 - 2	335'	48,312'	16,184,520
2 - 3	270'	19,008'	5,132,160
3 - 4	325'	12,408'	4,032,600
4 - 5	405'	16,368'	6,629,040
5 - 6	355'	7,920'	2,811,600
6 - 7	340'	39,072'	13,284,480

TABLE 11

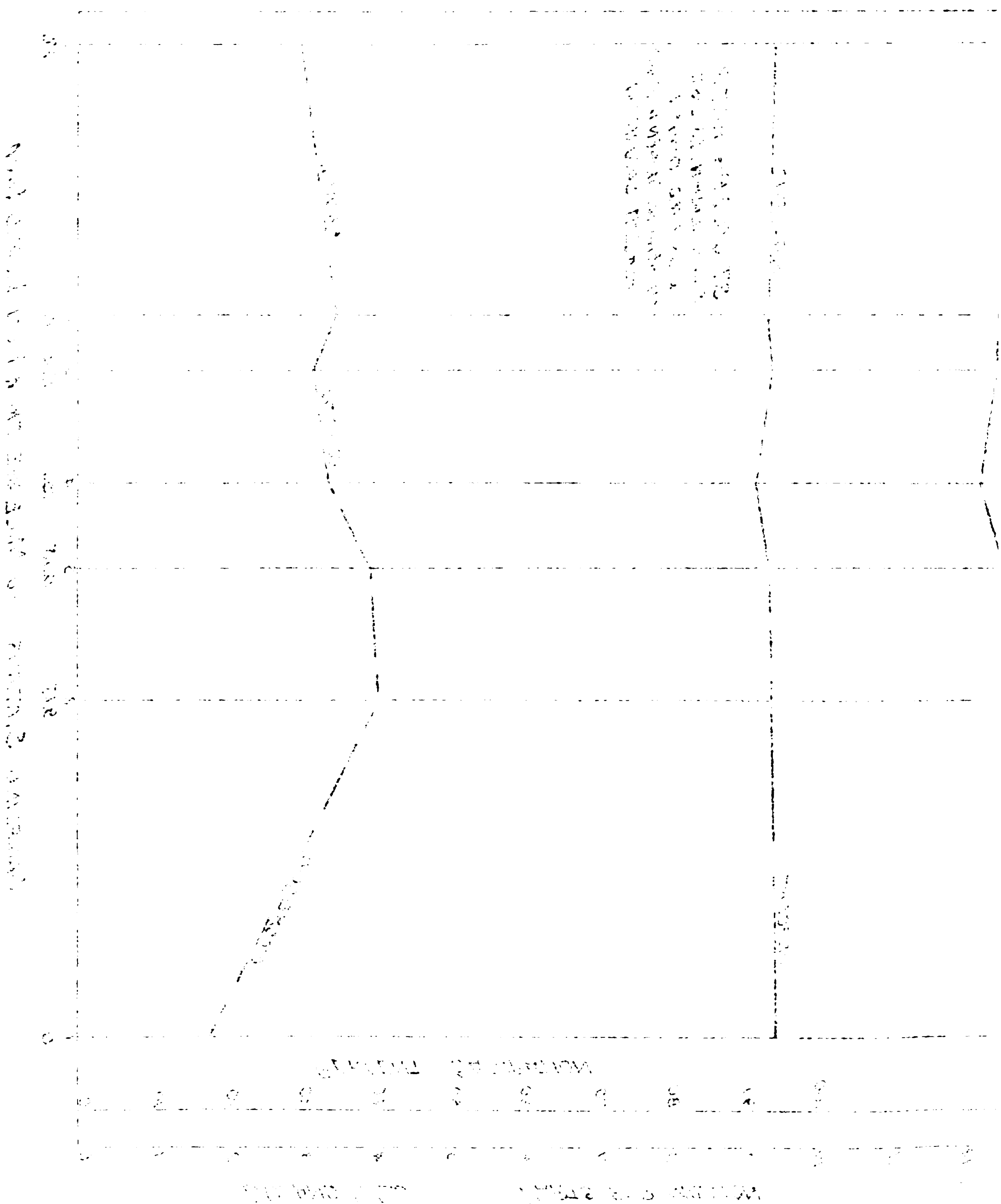
POUNDS OF OXYGEN ABSORBED BETWEEN STATIONS

Per cent Saturation	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7
10	22500	7500	5350	800	3600	17600
20	13550	4300	3380	5550	2355	11120
30	9650	3060	2400	3950	1674	7920
40	6420	2038	1600	2630	1115	5270
50	4640	1470	1155	1900	807	3805
60	2500	793	623	1024	435	2050
70	1429	453	365	585	248	1172
80	892	283	222	365	155	732
90	357	113	89	146	62	293
100	0	0	0	0	0	0



ST. JOSEPH RIVER
SOUTH BEND-NILES DIST.
DISSOLVED OXYGEN
BIOCHEMICAL OXYGEN DEMAND
PERCENT SATURATION
DISSOLVED OXYGEN
PERCENT SATURATION
BIOCHEMICAL OXYGEN DEMAND
D.O. AND B.O.D. PARTS PER MILLION
PERCENT SATURATION
0
1
2
3
4
5
6
7
8
9
10
11
12
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
0
9.15
12.75
15.1
18.2
19.7
27.1
SAMPLING STATIONS AND MILEAGE FROM HEN ISLAND DAM

FIGURE X



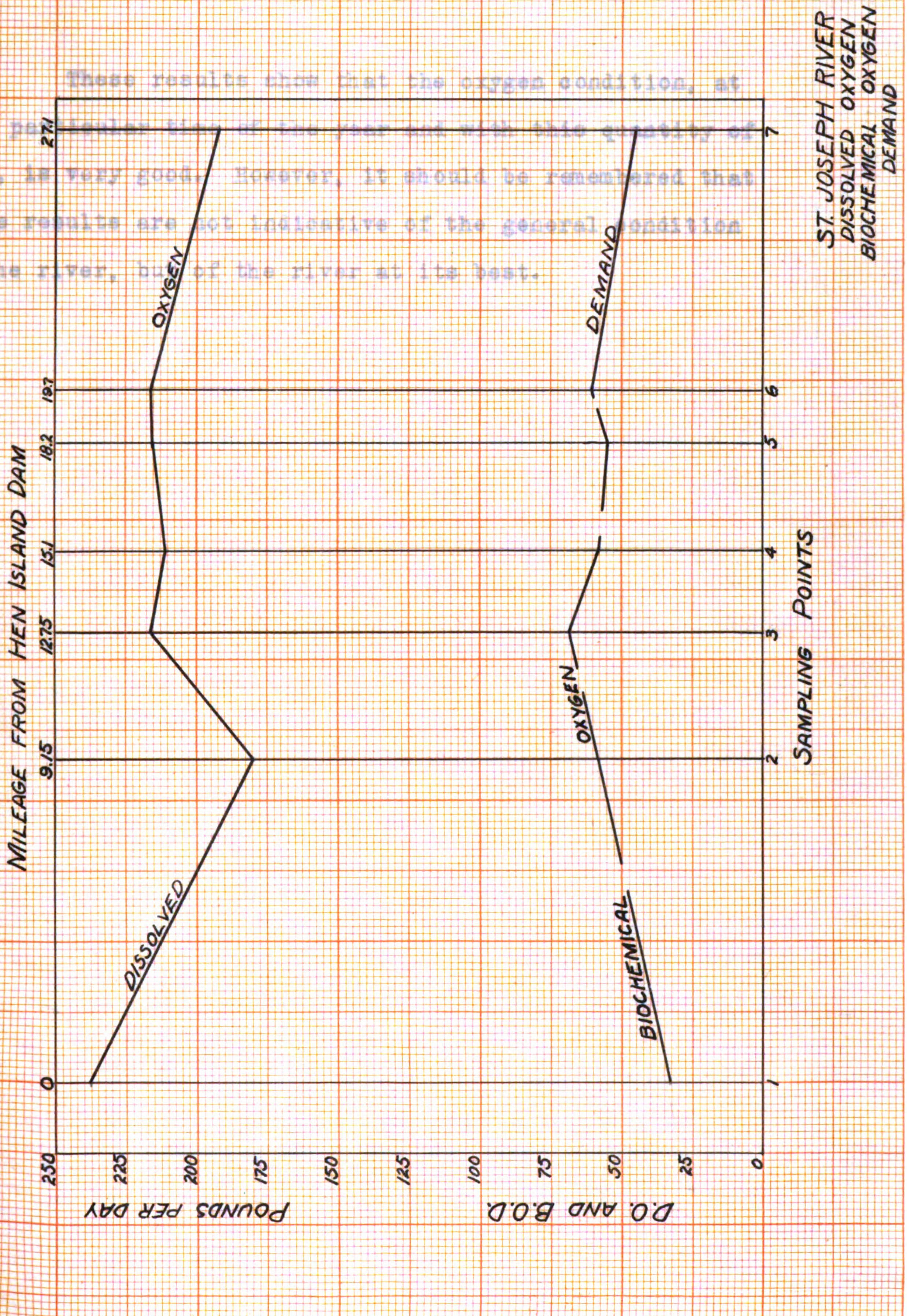
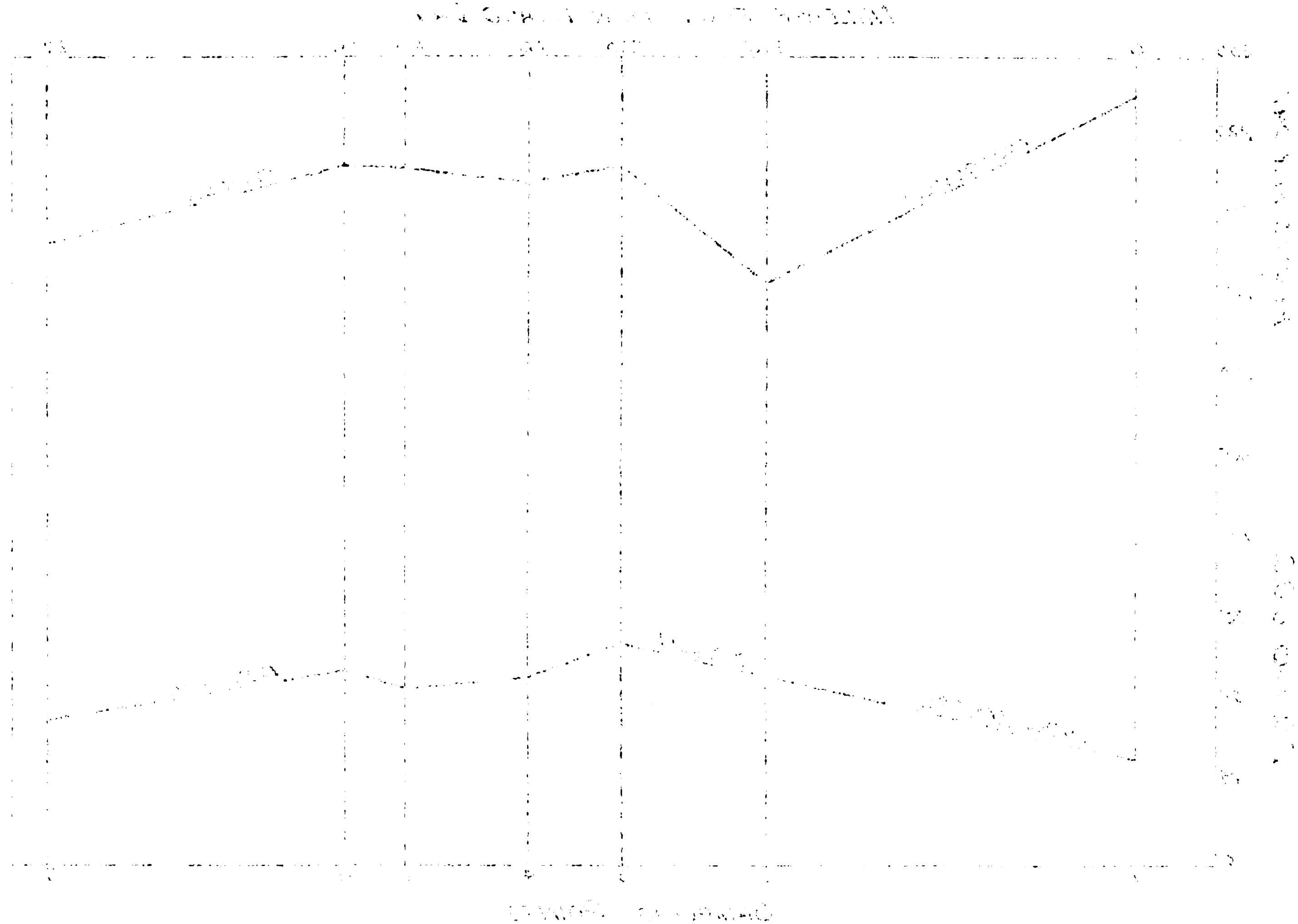

ST. JOSEPH RIVER
DISSOLVED OXYGEN
BIOCHEMICAL OXYGEN DEMAND
MILEAGE FROM HEN ISLAND DAM
0
9.15
12.75
15.1
18.2
19.7
27.1
SAMPLING POINTS
1
2
3
4
5
6
7
POUNDS PER DAY
D.O. AND B.O.D.
250
225
200
175
150
125
100
75
50
25
0
DISSOLVED
OXYGEN
BIOCHEMICAL
OXYGEN
DEMAND

FIGURE XI



CONCLUSION

These results show that the oxygen condition, at this particular time of the year and with this quantity of flow, is very good. However, it should be remembered that these results are not indicative of the general condition of the river, but of the river at its best.