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# WATER POLLUTION INVESTIGATION: BLACK RIVER OF NEW YORK

HYDROSCIENCE, Inc.

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION V ENFORCEMENT DIVISION
GREAT LAKES INITIATIVE CONTRACT PROGRAM

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# WATER POLLUTION INVESTIGATION: BLACK RIVER OF NEW YORK

by

HYDROSCIENCE, INC.
Westwood, New Jersey

In fulfillment of

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ENVIRONMENTAL PROTECTION AGENCY

This report has been developed under auspices of the Great Lakes Initiative Contract Program. The purpose of the Program is to obtain additional data regarding the present nature and trends in water quality, aquatic life, and waste loadings in areas of the Great Lakes with the worst water pollution problems. The data thus obtained is being used to assist in the development of waste discharge permits under provisions of the Federal Water Pollution Control Act Amendments of 1972 and in meeting commitments under the Great Lakes Water Quality Agreement between the U.S. and Canada for accelerated effort to abate and control water pollution in the Great Lakes.

# ABSTRACT

A verified dissolved oxygen model was used to project the effect of proposed wastewater discharges on the dissolved oxygen level of the Black River in New York State. The proposed wastewater discharges represent best practical control technology currently available for the industries and conventional secondary treatment for municipalities. The results indicate that for design low flow conditions New York State D.O. standards will be met.

Historical water quality data were reviewed and a field program conducted to identify existing water quality problems in the Black River. It was found that during the summer low flow conditions, dissolved oxygen levels between Lyons Falls and Carthage fall below the New York State standard of 5.0 mg/l.

A dissolved oxygen model was developed to define the relationship between wastewater discharges and river dissolved oxygen levels and to identify other factors that affect the dissolved oxygen concentration in the Black River. In addition to the oxygen demand associated with industrial and municipal wastewater discharges, it was found that background river dissolved oxygen concentrations upstream of direct wastewater discharges are approximately 1.0 mg/l below saturation due to naturally occurring conditions. Also, aeration at dams was identified as a significant source of dissolved oxygen, especially near Carthage.



This report was submitted in fulfillment of Contract Number: 68-01-1573, under the sponsorship of The Great Lakes Initiative Contract Program, Environmental Protection Agency.

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## ACKNOWLEDGEMENTS

This study was performed under the direction and supervision of Mr. John P. St. John, Project Director. Mr. Thomas W. Gallagher, Project Manager, and Mr. William Leo, coordinated and participated in the various project tasks including the review of historical data, the performance of field studies, the development and application of a mathematical model, and the final report preparation. Dr. Donald J. O'Connor provided technical guidance during the course of the project.

Historical river water quality data and data on wastewater characteristics were provided by personnel from the Albany and Watertown offices of the New York State Department of Environmental Conservation including Messrs. R. C. Mt. Pleasant, and M. Szeto of the Albany office and Messrs. B. Mead, Bud Phelps, and R. Koelling of the Watertown office. Mr. Kenneth H. Mayhew, area engineer for the Hudson River-Black River Regulating District provided invaluable assistance in obtaining flow records and physical characteristics of the Black River.

# SECTION I

## CONCLUSIONS

1. New York State dissolved oxygen standards for the Black River are contravened during summer low flow conditions. Based on historical data and the results of the 1973 field program, dissolved oxygen levels between Lyons Falls and Carthage fall below the standard of 5.0 mg/l.

2. Dissolved oxygen measurements taken in the upstream reaches of the Black, Moose, and Beaver Rivers during the 1973 field program indicate that there is an average background dissolved oxygen deficit of approximately 1.0 mg/l that is not associated with direct wastewater discharges.

3. Industrial wastewaters are the principal source of oxygen demanding material directly discharged to the Black River Basin. Approximately 85 percent of the ultimate BOD directly discharged to the Black River and its tributaries is from industrial sources and 15 percent is discharged by municipalities.

4. In addition to atmospheric reaeration, oxygen addition to the Black River as it flows over dams and natural falls is an important source of dissolved oxygen. Substantial aeration from this course is observed in the Carthage area and the lower Black River.

5. A dissolved oxygen model of the Black River has been constructed and applied for the analysis of the effect of wastewater discharges on Black River dissolved oxygen levels. The results indicate that for design low flow conditions, New York State dissolved oxygen standards will be met for industrial discharges providing best practicable control technology currently available (BPCTCA) and municipalities providing conventional secondary treatment.

6. The dissolved oxygen model was verified against three sets of river dissolved oxygen data, under different flow and temperature conditions, with a consistent set of parameters. The average flow at Watertown ranged from 1400 cfs to 5500 cfs, and the river temperature varied from 1.5° C to 26.5° C.

7. For a flow of 800 cfs at Watertown, a river temperature of 25° C, and wastewater treatment levels of best practicable control technology currently available for industrial discharges and conventional secondary treatment for municipalities, a minimum river dissolved oxygen concentration of 5.5 mg/l is projected at river milepoint 42.5, immediately upstream of the confluence with the Beaver River. The New York State D.O. standard at this river segment is 5.0 mg/l.

## SECTION II

## RECOMMENDATIONS

During the development of a dissolved oxygen model of the Black River, it was found that the existence of a background dissolved oxygen deficit and reaeration at dams and natural falls were significant factors affecting the dissolved oxygen level in the Black River. It was not within the scope of this project to conduct the necessary studies required to define the nature of this background deficit and the degree of aeration achieved at each of the dams. Because of increasingly stringent water quality standards in the future, and increased wastewater loads associated with industrial expansion and population growth, refinement of the model for future allocation analyses should be considered. However, it should be noted that these refinements in the model are not necessary to answer immediate problems.

It is recommended that additional dissolved oxygen measurements be taken to further define the magnitude and spatial distribution of the observed background deficit and also analyses performed to possibly relate the occurrence of the deficit to such factors as agricultural runoff or seasonal variations.

Additional studies should also be performed to define the degree of aeration achieved at the dams and natural falls. The data from these studies could be used to confirm the applicability of previously developed empirical relationships or if necessary, used to develop a new correlation between degree of aeration and such factors as dam height, river flow, and temperature.

Because of a discrepancy between measured and computed river $BOD_5$ concentrations, it is recommended that the mechanism of BOD oxidation in the Black River be further investigated. At this time the measured BOD data suggest that oxidation might be carried out principally by bacteria residing on the river bed. Therefore, an accurate measurement of river BOD might require the addition of seed or an in site measurement in which the bottom organisms are present during the oxidation studies.

# SECTION III

# INTRODUCTION

The U. S. Environmental Protection Agency (EPA) is currently developing wastewater allocations for municipal and industrial discharges for the purpose of issuing discharge permits in accordance with the provisions of the Federal Water Pollution Control Act Amendments of 1972. The Black River Basin has been selected for investigation by the EPA as one of the special attention areas in The Great Lakes Region. As a consequence, the EPA has sponsored this study to develop the necessary criteria to assign wastewater allocations that will comply with the goals set forth in The Federal Water Pollution Control Act Amendments of 1972.

The general scope of the study was twofold; first, to identify existing water quality problems in The Black River and second, to evaluate the effect of proposed wastewater allocations on river quality, specifically with respect to those constituents that presently contravene existing New York State water quality standards. To accomplish the first objective, existing chemical and biological water quality data were reviewed for the purpose of identifying violations of water quality standards and significant data deficiencies. Based on the results of this data review, comprehensive field surveys were conducted to provide additional data concerning those constituents that currently violate standards and to fill existing data gaps. Both historical and current data indicate that periodically depressed river dissolved oxygen levels are the primary water quality problem.

The results of the first part of the study more specifically defined the second objective as the evaluation of the effect on river dissolved oxygen levels of proposed wastewater discharges. For this phase of the study, data collected during the field program were used to construct and verify a mathematical model which defines the relationship between river water quality and wastewater discharges. The model was then used to compute projected river dissolved oxygen distributions associated with the proposed wastewater allocations.

# SECTION IV

## DESCRIPTION OF STUDY AREA

The Black River discharges to Lake Ontario and drains an area of 1916 square miles (4960 sq km) in north-central New York State. The section of the river investigated in this study extends from the Forestport Reservoir to Black River Bay, a distance of 92.5 miles (149 km). In addition, the lower 5 miles (8 km) of The Beaver and Moose Rivers were analyzed. A location map of the study area is shown in Figure 1.

### Topography

The Black River above Lyons Falls drains the Adirondack Mountains in which the elevation of the river ranges from 2,000 - 3,000 feet (610 - 915 m) above sea level. Between Forestport and Lyons Falls the river slopes at approximately 18 feet/mile (3.42 m/km). Immediately upstream of Lyons Falls the Moose River, the largest tributary, joins the Black River which then flows over a 60 foot (18.3 m) natural fall in the river bed.

For the next 42 miles (67.6 km), to Carthage, the river flows through the area known as the Black River "Flats" in which the river bed drops approximately 10 feet (3.05 m). Within this reach the Beaver River, the second largest tributary, joins the Black River. From Carthage to Lake Ontario, a distance of 31 miles (49.9 km), the river drops approximately 500 feet (152 m) or 16 feet/mile (3.04 m/km). Figure 2 presents a spatial plot of the drainage area and river bed elevation.

### Hydrology

The surface runoff in the Black River Basin is measured daily by the U. S. Geological Survey at gaging stations on the Black River and major tributaries. Annual runoff in the Basin is greatest in the higher elevations of the Tug Hill and Adirondack areas which experience heavy precipitation. Annual runoff in the Basin, which averages 2.0 cfs/sq mi (0.038 cu m/sec/sq km), is generally high because of high precipitation levels, low evaporation

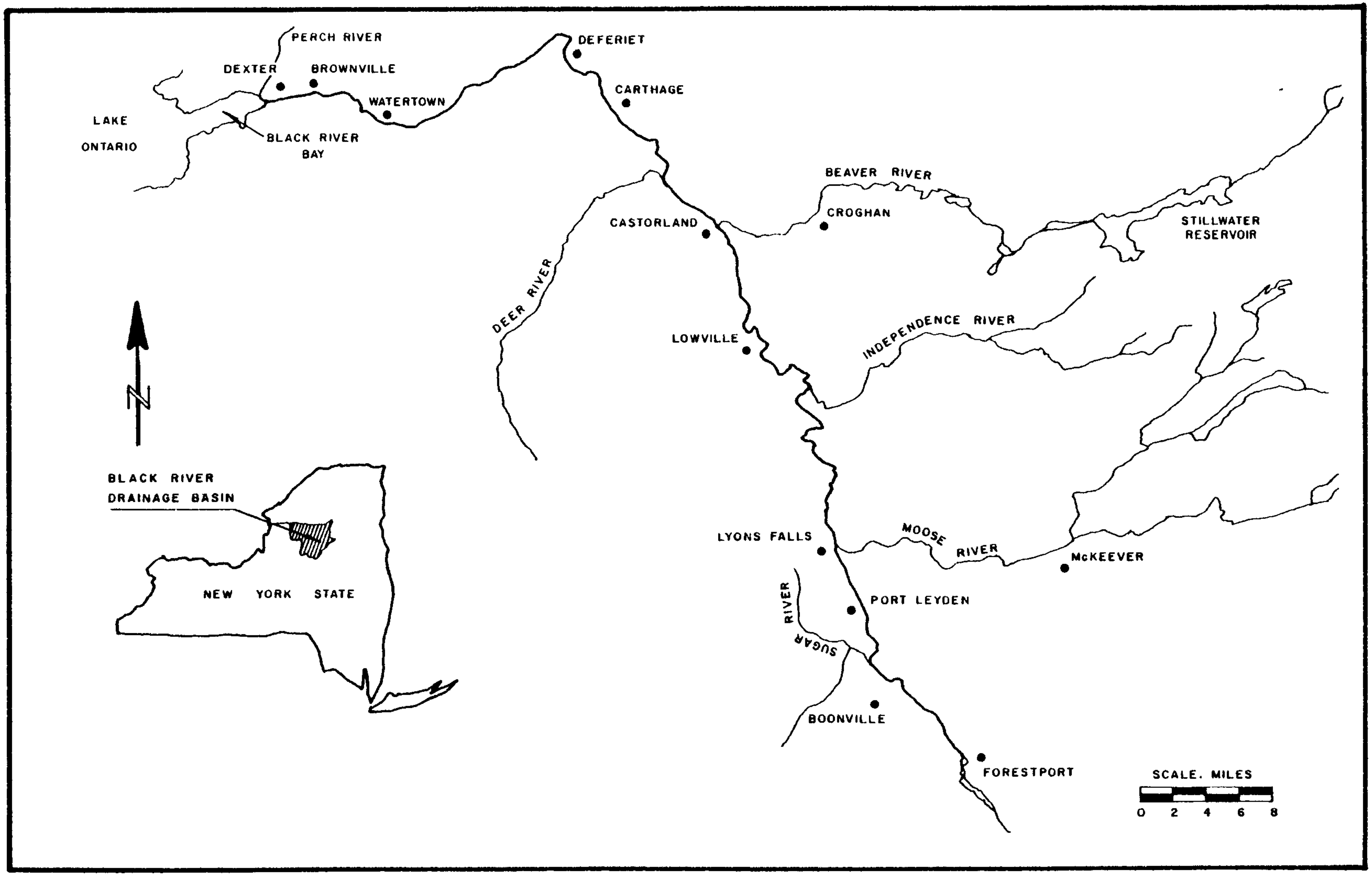


FIGURE I

LOCATION MAP OF STUDY AREA

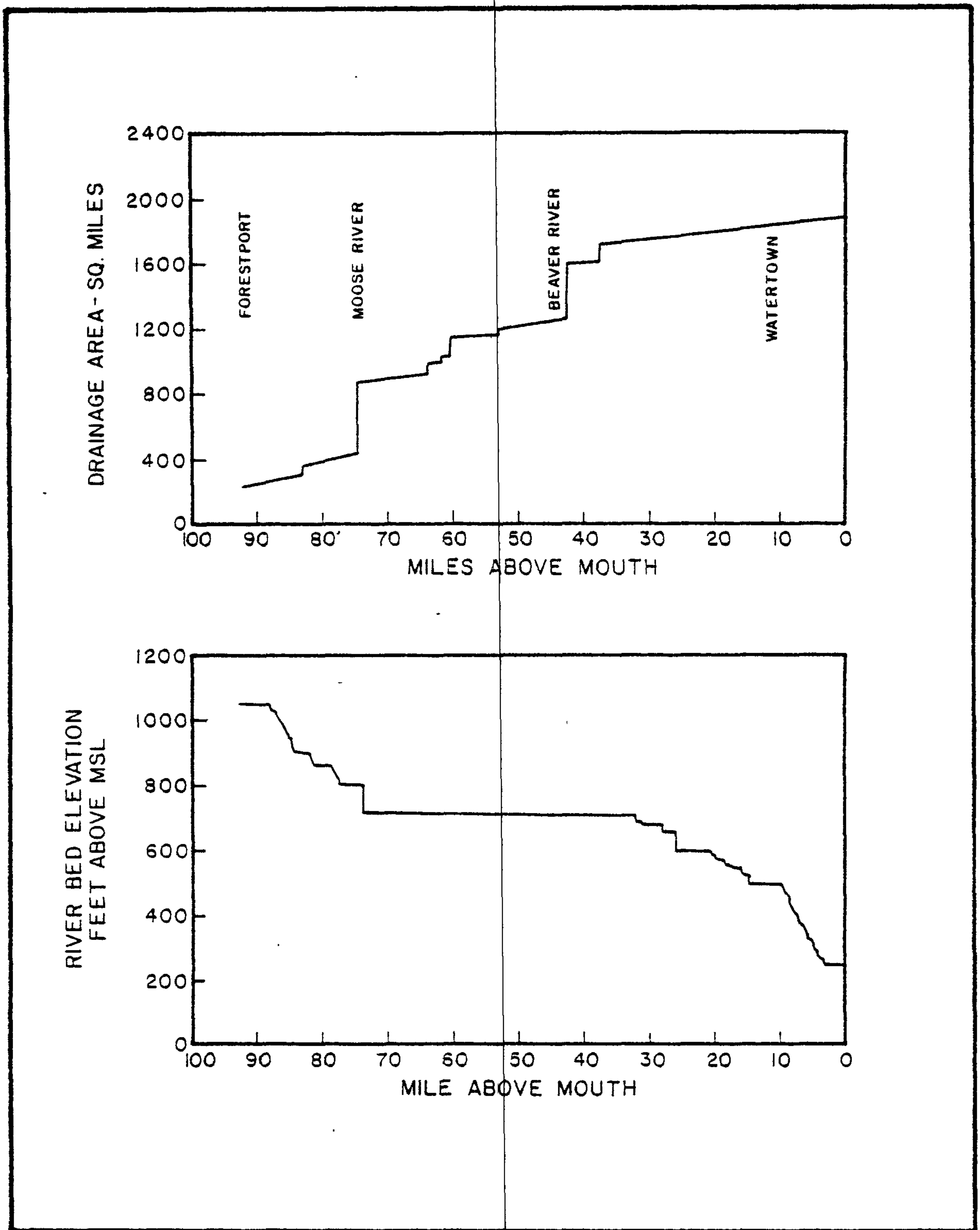


FIGURE 2

DRAINAGE AREA AND RIVER BED ELEVATION FOR BLACK RIVER (FORESTPORT TO MOUTH) rates, and low evapo-transpiration losses associated with snowfall which is a significant portion of the total precipitation.

The flow in the upper Black River, the Moose River, and the Beaver River is regulated to varying degrees by numerous natural lakes and reservoirs. The reservoirs were originally constructed to regulate flows primarily for power generation, water supply, flood control and navigation. Flow regulation at the Stillwater Reservoir on the Beaver River has a significant influence on low flow conditions in the Black River. During the summer months when the flow in the other tributaries has decreased to approximately 0.8 cfs/sq mi (0.0154 cu m/sec/sq km), the Beaver River flow is maintained near 1.6 cfs/sq mi (0.0307 cu m/sec/sq km) by releasing water stored in the Stillwater Reservoir during the spring.

Because of the many natural falls, the Black River and its tributaries are used extensively for hydroelectric power generation. At present there are 30 hydroelectric power developments in the Black River Basin that generate an average of 570 million kilowatt-hours per year. Below Carthage there are 15 run-of-the-river plants at which upstream regulation and plant pondage is limited. During low flow the entire river flow passes through the plant, but during high flow periods excess river flow bypasses the plant. Six other run-of-the-river plants are located in the basin; three on the lower Moose River and three on upper Black River. On the Beaver River there are nine hydroelectric facilities that operate as peaking plants. During high flow periods these plants operate as run-of-the-river plants. At normal flows the plants generally operate for a 12 hour peaking period. Consequently, the Beaver River is highly regulated by the upstream Stillwater Reservoir.

## Wastewater Discharges

The major wastewater discharges to the Black River and its tributaries are from pulp and paper companies and municipalities. There are nine paper companies that discharge to receiving waters in the Black River Basin. The largest industrial discharges in terms of $BOD_5$ are the Georgia Pacific, St. Regis, and Crown Zellerbach Companies, located at Lyons Falls, Deferiet, and Carthage respectively. Some plants are presently discharging untreated wastewaters although treatment plants are in the planning or construction phase for these industries.

Most of the larger municipalities in the Black River Basin have a central wastewater treatment plant or individual sewage disposal systems. Approximately 60 percent of the basin population of 73,000 people are sewered. Watertown, the largest city in the basin, has a population of about 34,000 and provides primary treatment of its wastewaters before discharging to the Black River.

## Water Quality Standards

Recently the New York State Department of Environmental Conservation revised their water quality standards. The revised standards include qualitative specifications applicable to all fresh water classified as AA, A, B, C, or D in addition to quantitative specifications based on best usage of waters. Additional standards are also included for certain toxic substances affecting fish life.

Qualitative specifications are given for turbidity, color, suspended, colloidal or settleable solids, oil and floating substances, and taste and odor-producing substances, toxic wastes and deleterious substances. Quantitative standards are generally given for pH, dissolved oxygen, dissolved solids, and coliform bacteria. For class AA and A waters additional standards are given for radioactive materials and phenolic compounds. A summary of the quantitative standards, except radioactive materials, for the classifications pertinent to this study is contained in Table 1. In addition, New York State policy for the Lake Ontario Basin requires wastewater discharges of 1.0 MGD or larger to reduce effluent phosphorus to 1.0 mg/l or less by December 31, 1975.

The standards for dissolved oxygen and coliform bacteria presented in Table 1 are for average conditions. For dissolved oxygen the minimum daily average value is reported. For the A, B, and C classifications the specifications further stipulate that at no time shall the dissolved oxygen concentration be less than 4.0 mg/l for non-trout waters and 5.0 mg/l for trout waters. In addition to specifying average conditions, the total and fecal coliform standards also include the minimum number of analyses required plus the maximum total coliform count permitted in 20 percent of the samples.

The New York State D.E.C. has also set standards for certain toxic substances which affect fishlife. Safe stream concentrations are given for waters with an

TABLE 1

NEW YORK STATE WATER QUALITY STANDARDS

| CONSTITUENT | CLASS A | CLASS B | CLASS C | CLASS D |
|---|---|---|---|---|
| pH | 6.5 - 8.5 | 6.5 - 8.5 | 6.5 - 8.5 | 6.0 - 9.5 |
| Dissolved Oxygen - mg/l (Minimum Daily Avg) | 5.0 | 5.0 | 5.0<br>6.0 (Trout) | Never less than 3.0 |
| Dissolved Solids - mg/l (Maximum) | 500 | 500 | 500 | - |
| Total Coliform - No./100 ml | Monthly Median 5,000 | Monthly Median 2,400 | Monthly Geom. Mean - 10,000 | - |
| Fecal Coliform - No./100 ml | Monthly Geom. Mean - 200 | Monthly Geom. Mean - 200 | Monthly Geom. Mean - 2,000 | - |
| Phenolic Compounds - mg/l | 0.005 | - | - | - |

alkalinity of 80 mg/l or more. Waters of lower alkalinity must be specifically considered since the toxic effect of most pollutants will be greatly increased. Table 2 is a tabulation of these constituents and their maximum permissable concentrations.

The surface water classifications and the associated best usage for the study area are presented in Table 3. The Black River from Forestport to Carthage is classified as C for which the best usage is fishing. Because the river is classified as C-trout between Forestport and Lyons Falls, the dissolved oxygen standard is 1.0 mg/l higher than the non-trout C water. Below Carthage the river is classified as D except for a 2.5 mile reach classified A from which Watertown draws its water supply. For the Moose and Beaver Rivers, the downstream segments below the industrial discharges are also classified as D.

TABLE 2

STANDARDS FOR CERTAIN TOXIC SUBSTANCES
AFFECTING FISHLIFE

| CONSTITUENT | STANDARD |
|---|---|
| Ammonia or Ammonium Compounds | <2.0 mg/l as $NH_3$ at pH $\geq$ 8.0 |
| Cyanide | <0.1 mg/l as CN |
| Ferro or Ferricyanide | <0.4 mg/l as $Fe(CN)_6$ |
| Copper | <0.2 mg/l as Cu |
| Zinc | <0.3 mg/l as Zn |
| Cadmium | <0.3 mg/l as Cd |

TABLE 3

N. Y. STATE SURFACE WATER CLASSIFICATIONS
FOR THE STUDY AREA

| | Classification | Best Usage |
|---|---|---|
| BLACK RIVER | | |
| (Miles Above Mouth) | | |
| 0 - 10.0 | D | Secondary Contact Recreation |
| 10.0 - 12.5 | A | Water Supply For Drinking, Culinary or Food Processing |
| 12.5 - 30.0 | D | Secondary Contact Recreation |
| 30.0 - 75.0 | C | Fishing |
| 75.0 - 92.4 | C-Trout | Fishing--including Trout |
| BLACK RIVER BAY | C | Fishing |
| BEAVER RIVER | | |
| (Miles Above Mouth) | | |
| 0 - 5.0 | D | Secondary Contact Recreation |
| 5.0 - 10.0 | B | Primary Contact Recreation |
| MOOSE RIVER | | |
| (Miles Above Mouth) | | |
| 0 - 3.0 | D | Secondary Contact Recreation |
| 3.0 - 10.0 | C | Fishing |

## SECTION V

## DISCUSSION OF WATER QUALITY DATA

Water quality on the Black River and its major tributaries is periodically measured at selected stations by various governmental agencies including the U. S. Geological Survey and The New York State Department of Environmental Conservation. At some stations the range in water quality parameters measured is extensive including physical data, the concentration of chemical constituents such as heavy metals, radioactive materials, and pesticides, and coliform bacteria counts. In addition to these data, the New York State Department of Environmental Conservation (formerly part of the New York State Health Department) has conducted spatial dissolved oxygen surveys of the Black River in 1965 and 1969. To supplement existing data Hydroscience, Inc. conducted a field program in the summer and fall of 1973.

### Historical Water Quality Data

As a first step in assessing the current water quality of the Black River, existing water quality data were reviewed with specific reference to New York State surface water quality standards. Most of the data were obtained through the use of the STORET data retrieval system operated by the U. S. Environmental Protection Agency. With this system, data collected by other agencies are combined and stored by computer in a central location. Consequently, a statistical summary of available water quality data at specific stations can be retrieved. In addition to STORET data, spatial dissolved oxygen profiles measured by the New York State Department of Environmental Conservation were reviewed.

A summary of STORET water quality data for 5 stations on the Black River is contained in Tables 4 through 8. Generally, pertinent water quality parameters for which there are quantitative standards are presented. The water quality parameters include data on the physical, chemical, and microbiological characteristics of the water. In addition, there is a group of chemical constituents that can be toxic to fishlife at certain concentrations.

TABLE 4

SUMMARY OF STORET WATER QUALITY DATA
STATION LOCATION: FORESTPORT
MILEPOINT: 93.0
STORET NUMBER: 045250997

| CONSTITUENT | NUMBER OF MEASUREMENTS | PERIOD OF MEASUREMENTS | MEAN | MAXIMUM | MINIMUM |
|---|---|---|---|---|---|
| Dissolved oxygen - mg/l | 8 | 8/71 - 2/73 | 10.6 | 12.9 | 7.1 |
| pH | 8 | 8/71 - 2/73 | 6.8 | 7.3 | 5.8 |
| Dissolved solids - mg/l | 6 | 8/71 - 9/72 | 4.6 | 12.0 | 1.0 |
| Phosphorus - mg/l | 8 | 8/71 - 2/73 | 0.015 | 0.04 | 0.005 |
| Total coliform - No./100 ml | 3 | 9/72 - 2/73 | 788. | 2,000. | 5. |
| Fecal Coliform - No./100 ml | 3 | 9/72 - 2/73 | 5. | 10. | 1. |
| TOXIC SUBSTANCES AFFECTING FISHLIFE | | | | | |
| Ammonia - μg/l | 5 | 8/71 - 6/72 | 0.12 | 0.20 | 0.07 |
| Cyanide - μg/l | 1 | 9/72 | 0. | - | - |
| Copper - μg/l | - | - | - | - | - |
| Zinc - μg/l | 4 | 8/71 - 2/73 | 22.5 | 60. | 0. |
| Cadmium - μg/l | 2 | 8/71 - 9/72 | 1.5 | 3.0 | 0. |

TABLE 5

SUMMARY OF STORET WATER QUALITY DATA
STATION LOCATION: ABOVE CARTHAGE
MILEPOINT: 36.5
STORET NUMBER: 04258710

| CONSTITUENT | NUMBER OF MEASUREMENTS | PERIOD OF MEASUREMENTS | MEAN | MAXIMUM | MINIMUM |
|---|---|---|---|---|---|
| Dissolved oxygen - mg/l | 8 | 8/71 - 2/73 | 9.5 | 13.2 | 6.8 |
| pH | 6 | 8/71 - 2/73 | 7.5 | 7.9 | 7.2 |
| Dissolved solids - mg/l | 2 | 8/71 - 9/72 | 58. | 61. | 55. |
| Turbidity - JTU | 8 | 8/71 - 2/73 | 6.4 | 20. | 2. |
| Phosphorus - mg/l | 8 | 8/71 - 2/73 | .037 | .136 | .010 |
| Total coliform - No./100 ml | 3 | 9/72 - 2/73 | 9,133. | 19,000. | 1,900. |
| Fecal Coliform - No./100 ml | 3 | 9/72 - 2/73 | 660. | 1,900. | 0.0 |
| TOXIC SUBSTANCES AFFECTING FISHLIFE: | | | | | |
| Ammonia - μg/l | 5 | 8/71 - 6/72 | 180. | 430. | 50. |
| Cyanide - μg/l | - | - | - | - | - |
| Copper - μg/l | - | - | - | - | - |
| Zinc - μg/l | 4 | 8/71 - 2/73 | 29.3 | 88. | 0.0 |
| Cadmium - μg/l | 1 | 8/71 | 5.0 | - | - |

TABLE 6

SUMMARY OF STORET WATER QUALITY DATA
STATION LOCATION: AT BLACK RIVER
MILEPOINT: 15.6
STORET NUMBER: 04259500

| CONSTITUENT | NUMBER OF MEASUREMENTS | PERIOD OF MEASUREMENTS | MEAN | MAXIMUM | MINIMUM |
|---|---|---|---|---|---|
| Dissolved oxygen - mg/l | 14 | 9/69 - 5/71 | 10.2 | 12.8 | 5.9 |
| pH | 15 | 8/69 - 5/71 | 7.8 | 8.7 | 6.8 |
| Dissolved solids - mg/l | - | - | - | - | - |
| Turbidity - Color units | 1 | 5/71 | 41. | - | - |
| Phosphorus - mg/l | 15 | 8/69 - 5/71 | .037 | .09 | .02 |
| Total coliform - No./100 ml | 6 | 8/69 - 5/71 | 13,400. | 50,000. | 900. |
| Fecal Coliform - No./100 ml | 1 | 5/71 | 270. | - | - |
| TOXIC SUBSTANCES AFFECTING FISHLIFE: | | | | | |
| Ammonia - µg/l | 15 | 8/69 - 5/71 | 182. | 400. | 60. |
| Cyanide - µg/l | - | - | - | - | - |
| Copper - µg/l | 3 | 9/69 - 8/70 | 3.0 | 6.0 | 0.0 |
| Zinc - µg/l | 3 | 9/69 - 8/70 | 35. | 65. | 0.0 |
| Cadmium - µg/l | 2 | 5/70 - 8/70 | 13. | 16. | 10. |

TABLE 7

SUMMARY OF STORET WATER QUALITY DATA
STATION LOCATION: AT WATERTOWN
MILEPOINT: 8.5
STORET NUMBER: 04260500

| CONSTITUENT | NUMBER OF MEASUREMENTS | PERIOD OF MEASUREMENTS | MEAN | MAXIMUM | MINIMUM |
|---|---|---|---|---|---|
| Dissolved oxygen - mg/l | 24 | 8/70 - 5/73 | 11.5 | 16.0 | 5.9 |
| pH | 87 | 3/60 - 5/73 | 7.0 | 7.6 | 6.4 |
| Dissolved solids - mg/l | 20 | 2/68 - 5/73 | 16.3 | 59. | 0.0 |
| Turbidity - Color units | 38 | 3/60 - 5/71 | 32.4 | 100. | 10. |
| Phosphorus - mg/l | 21 | 10/70 - 5/73 | .037 | .089 | .020 |
| Total coliform - No./100 ml | 7 | 10/72 - 5/73 | 3,286. | 6,400. | 1,200. |
| Fecal Coliform - No./100 ml | 7 | 10/72 - 5/73 | 557. | 1,000. | 210. |
| TOXIC SUBSTANCES AFFECTING FISHLIFE: | | | | | |
| Ammonia - μg/l | 5 | 7/71 - 1/72 | 136. | 180. | 104. |
| Cyanide - μg/l | - | - | - | - | - |
| Copper - μg/l | 3 | 5/70 -11/72 | 2.0 | 6.0 | 0.0 |
| Zinc - μg/l | 2 | 5/70 -10/70 | 22.5 | 45. | 0.0 |
| Cadmium - μg/l | 2 | 5/70 -10/70 | 5.5 | 11.0 | 0.0 |

TABLE 8

SUMMARY OF STORET WATER QUALITY DATA
STATION LOCATION: BELOW WATERTOWN
MILEPOINT: 7.5
STORET NUMBER: 04260505

| CONSTITUENT | NUMBER OF MEASUREMENTS | PERIOD OF MEASUREMENTS | MEAN | MAXIMUM | MINIMUM |
|---|---|---|---|---|---|
| Dissolved oxygen - mg/l | 9 | 8/71 - 2/73 | 10.2 | 12.6 | 7.6 |
| pH | 7 | 8/71 - 2/73 | 7.7 | 8.5 | 7.0 |
| Dissolved solids - mg/l | 2 | 8/71 - 9/72 | 72. | 76. | 68. |
| Turbidity - JTU | 9 | 8/71 - 2/73 | 7.4 | 15.0 | 3.0 |
| Phosphorus - mg/l | 6 | 2/72 -11/72 | .184 | .34 | .08 |
| Total coliform - No./100 ml | 2 | 11/72 - 2/73 | 8,300. | 14,000. | 2,600. |
| Fecal Coliform - No./100 ml | 2 | 11/72 - 2/73 | 2,289 | 4,200 | 370. |
| TOXIC SUBSTANCES AFFECTING FISHLIFE: | | | | | |
| Ammonia - μg/l | 6 | 8/71 - 6/72 | 173. | 400. | 50. |
| Cyanide - μg/l | 1 | 9/72 | 10. | - | - |
| Copper - μg/l | 2 | 8/71 - 9/72 | 1.5 | 3.0 | 0.0 |
| Zinc - μg/l | 4 | 8/71 - 2/73 | 35. | 110. | 0.0 |
| Cadmium - μg/l | 2 | 8/71 | 3.0 | 6.0 | 0.0 |

A review of the data in Tables 4 through 8 indicates that water quality standards at these stations are not contravened except for the pH at Forestport. Because there are no wastewater discharges above Forestport, occasional river pH values less than the minimum 6.5 standard are probably associated with natural background conditions.

The limited available water quality data on toxic substances affecting fishlife show that the river concentrations are at least an order of magnitude less than the minimum concentrations permissable in waters with an alkalinity greater than 80 mg/l. Waters of lower alkalinity must be specifically considered since the toxic effect of most pollutants will be greatly increased. Although the alkalinity of the Black River is less than 80 mg/l, it is probable that the concentrations of these toxic substances are far below levels which are harmful to fishlife. Measurements of some toxic substances are not available, but it is unlikely they are present in significant concentrations because there are no known industrial discharges that contain these constituents.

For the Class A water above Watertown there are additional standards for phenolic compounds and radioactive materials. Influent river water quality data reported on the wastewater discharge permit of an industry downstream of Watertown indicate that the river phenol concentration is below the standard. Therefore, it is reasonable to assume that the phenol concentration above Watertown is also below the standard. Measurements of the concentration of redioactive materials in the Black River were not taken because there is no known source of radioactive substances in the Basin.

The dissolved oxygen data summarized in Tables 4 through 8 do not indicate a contravention of existing dissolved oxygen standards. However, the spatial definition of the concentration of the various water quality constituents is sparse. This is satisfactory for conservative substances which do not decay as they flow downstream but insufficient for river dissolved oxygen which is constantly changing due to bacterial oxidation and atmospheric reaeration. A more detailed definition of the spatial dissolved oxygen distribution is shown in data collected by the New York Department of Environmental Conservation presented in Figure 3.

The data in Figure 3 are river dissolved oxygen distributions measured in August, 1965 and June, 1969. Also included in Figure 3 are the New York State dissolved oxygen standards for the Black River. As indicated the

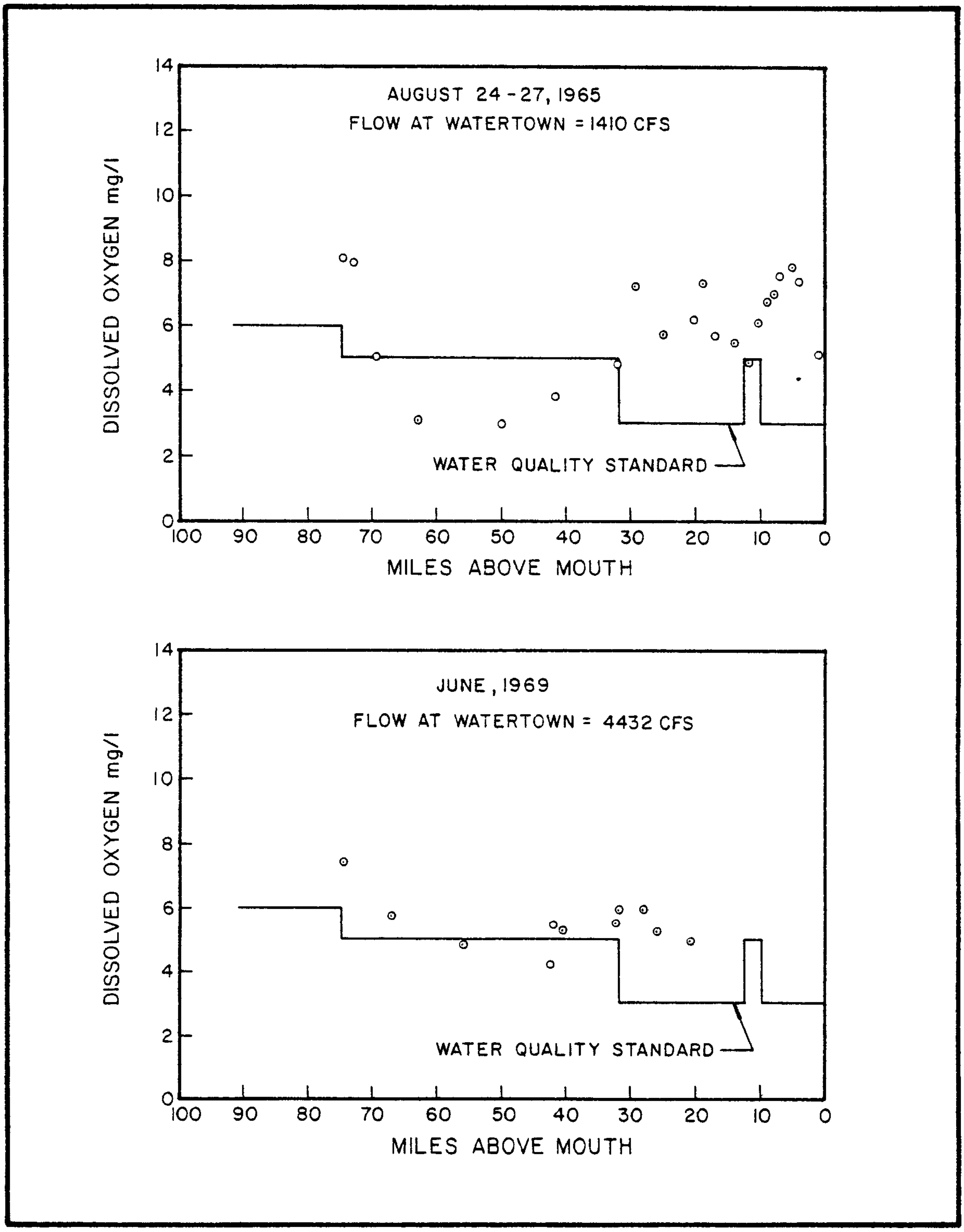


FIGURE 3

NEW YORK STATE DEPT. OF ENVIRONMENTAL CONSERVATION
RIVER DISSOLVED OXYGEN DATA

river dissolved oxygen concentration falls below the standards between Lyons Falls and Carthage. During the August, 1969 survey the minimum dissolved oxygen level is 3.5 mg/l or 1.5 mg/l below the standard of 5.0 mg/l. In June, 1969 the minimum dissolved oxygen concentration is approximately 4.0 mg/l. One of the principal reasons for the difference in the profiles is the river flow. During the August survey the average flow at Watertown was 1,410 cfs (40 cu m/sec) whereas during the June survey the monthly flow was substantially higher, averaging 4,432 cfs (126 cu m/sec).

Based on a review of the STORET data and these dissolved oxygen profiles, it was concluded that dissolved oxygen is the major water quality problem in the Black River. In order to further define the concentration of dissolved oxygen and other related water quality parameters, a field program was conducted August through November, 1973.

## 1973 Water Quality Data

In the 1973 field program physical, chemical, microbiological and biological water quality measurements of the Black River and its major tributaries were made. An extensive water quality survey was conducted in August and two additional dissolved oxygen surveys in November. In September a biological survey was conducted for the purpose of making a qualitative assessment of the river biology.

During the August survey water quality was measured at 41 sampling stations including 24 on the Black River, 6 in Black River Bay, and the remainder on tributaries. Figure 4 shows the location of the stations. In the morning, dissolved oxygen and temperature were measured at each station. In addition a volume of sample was returned to the laboratory for analysis of other water quality constituents including $BOD_5$, total solids, suspended solids, turbidity, and pH. Coliform bacteria, chlorophyll 'a', nitrogen and phosphorus were also measured at selected stations. In the afternoon dissolved oxygen and temperature were measured at all stations except those in Black River Bay. A summary of these data is presented in Appendix A.

Spatial plots of the dissolved oxygen survey data for the Black River and Black River Bay plus the two major tributaries, the Moose and Beaver Rivers, are shown in Figure 5. The dissolved oxygen saturation value and the

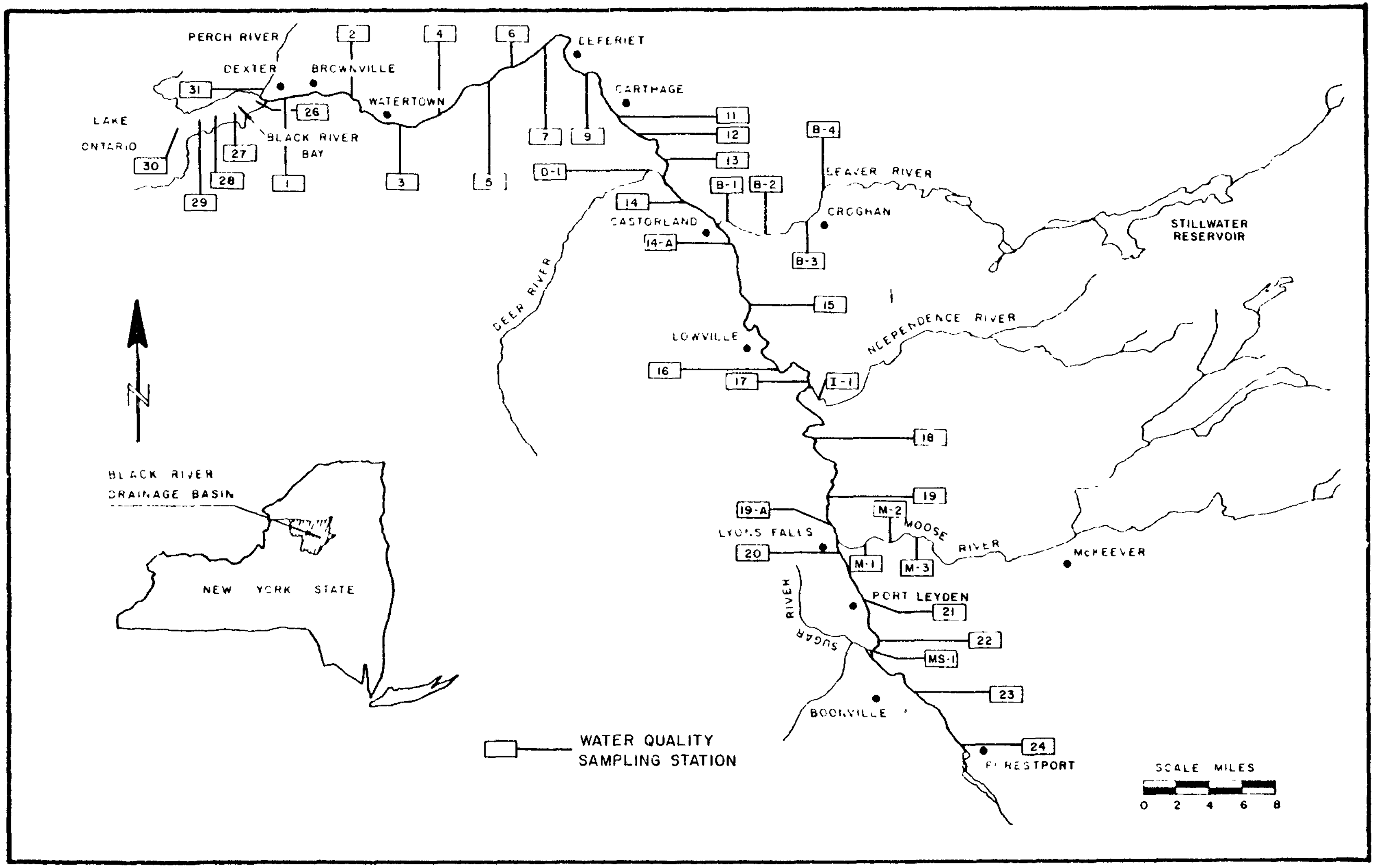


FIGURE 4

LOCATION OF SAMPLING STATIONS

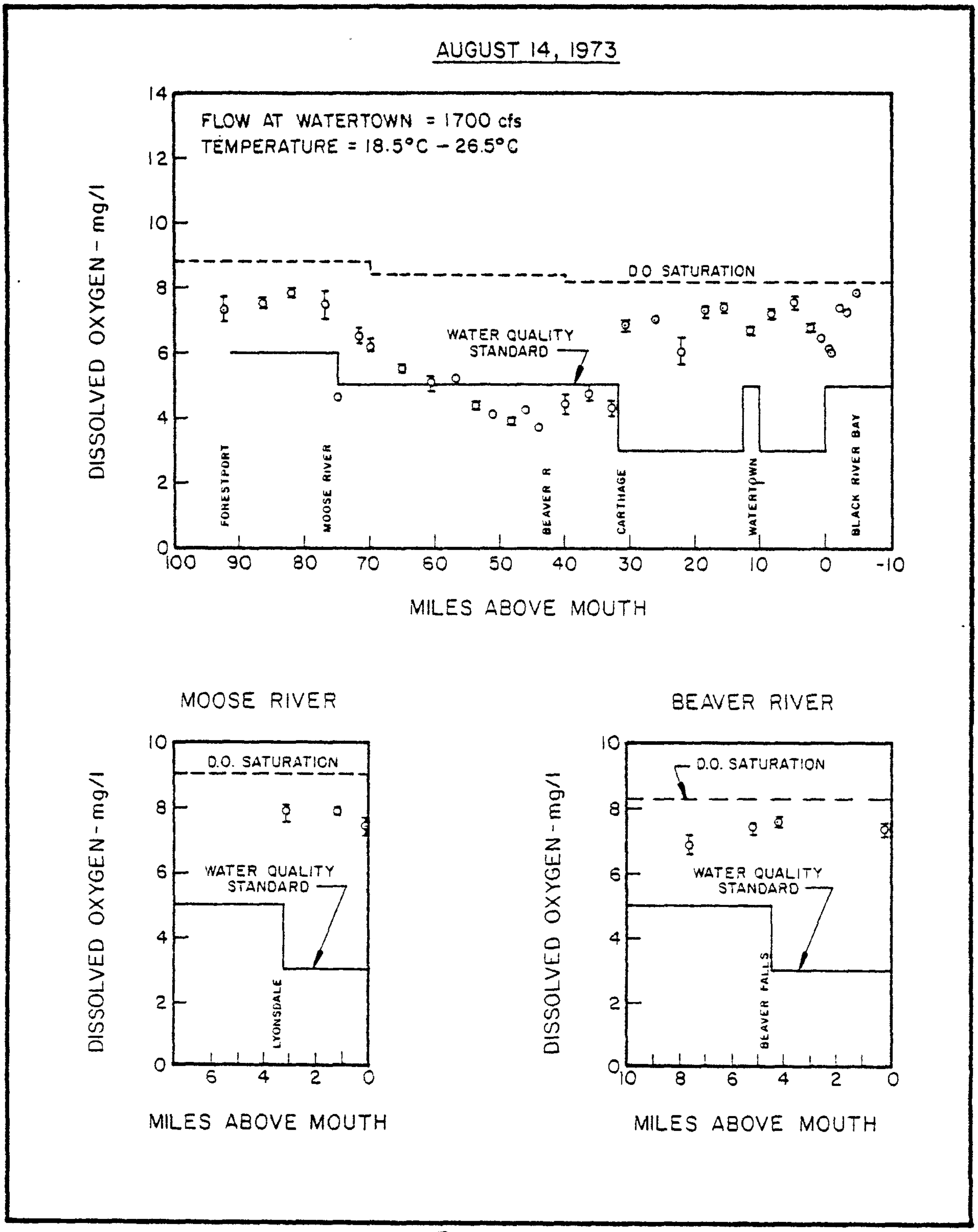


FIGURE 5

RIVER DISSOLVED OXYGEN DATA (AUGUST 14, 1973)

New York State water quality standards are indicated on each plot. As noted, the average weekly flow at Watertown prior to the survey was 1,700 cfs (48.2 cu m/sec). The water temperature ranged from 18.5°C to 26.5°C.

The dissolved oxygen profile is similar in shape to those measured by New York State in 1965 and 1969. A sag in the dissolved oxygen profile begins immediately downstream of the confluence of the Moose and Black Rivers. At this point, the Georgia Pacific Pulp and Paper Company, the largest industrial discharge in the Basin with respect to effluent BOD, discharges its wastewater effluent. The river dissolved oxygen level continues to decline and falls below water quality standards for approximately 25 miles (40.2 km) upstream of Carthage. At Carthage, the river is substantially reaerated as it flows over a series of dams. This is demonstrated by the dissolved oxygen increase from 4.3 mg/l to 6.8 mg/l at Carthage. Below Carthage most of the river is routed through hydroelectric turbines during low flow periods. The remaining river flow receives additional reaeration as it flows over a series of dams and rapids between Carthage and Black River Bay.

The dissolved oxygen data and water quality standards for the downstream sections of the Moose and Beaver Rivers are also presented in Figure 5. Industrial wastewaters are discharged to the Moose and Beaver Rivers at Lyonsdale and Beaver Falls respectively. As shown, the dissolved oxygen level in both rivers is above the standards. However, the data show a dissolved oxygen deficit of 1.0 mg/l to 1.5 mg/l upstream of the wastewater discharges. Similar deficits were also observed in the Black river upstream of the confluence with the Moose River where there are no major wastewater discharges. These data indicate that in addition to direct wastewater discharges, there are other factors which produce a dissolved oxygen deficit in the river. The oxidation of organic matter contained in agricultural runoff is possibly a major factor in contributing to this background deficit in the Black River "Glots" area.

Other water quality measurements of the Black River made on the August survey did not show a contravention of water quality standards. The total phosphorus concentration in the Black River ranged from 20 μg/l to 35 μg/l. The present phosphorus levels are below previously reported values which probably reflects the effect of the recent New York State law banning the use of detergents containing phosphates. The phosphorus level in Black River Bay was higher, ranging from 35 μg/l to 148 μg/l.

The average nutrient level in the Black River was low. As previously indicated the total phosphorus concentration was 20 μg/l to 35 μg/l. The soluble phosphorus concentration in the river was generally 5 μg/l or less. The ammonia and nitrate nitrogen concentrations which are the primary forms of nitrogen used by phytoplankton were 0.05 mg/l and 0.15 mg/l respectively. The organic nitrogen concentration averaged 0.5 mg/l. There were low phytoplankton levels in the Black River as indicated by the low chlorophyll 'a' concentrations of 2 μg/l to 4 μg/l. However, in Black River Bay chlorophyll 'a' levels of 22 μg/l and 50 μg/l were measured.

In order to obtain additional river dissolved oxygen data under different flow and temperature conditions, two spatial dissolved oxygen surveys were conducted in November. The results are presented in Figure 6. On the November 1, 1973 survey, the river flow was still approximately at the August level. The average flow at Watertown was 1,400 cfs (39.6 cu m/sec). However, the average river temperature decreased to 9°C which increases the dissolved oxygen saturation to 11.6 mg/l versus the average saturation value of 8.4 mg/l observed during the August survey. Although the dissolved oxygen deficit is nearly the same as in August, the river dissolved oxygen level is well above the water quality standards.

The November 20, 1973 profile shows the effect of high river flow and low temperatures on the dissolved oxygen level of the Black River. For the November 20, 1973 survey, the flow at Watertown averaged 5,500 cfs (156 cu m/sec) and the river temperature ranged from 2°C to 4°C. As a consequence of the greater dilution and elevated saturation value, the river dissolved oxygen level is substantially greater than the water quality standards.

From a review of the historical and 1973 river dissolved oxygen profiles, it appears that dissolved oxygen standards are contravened only during the summer months. During this time there is minimum flow available for dilution of wastewaters and dissolved oxygen saturation is at its lowest because of the elevated water temperature. It should also be noted that although the dissolved oxygen level measured in Black River Bay in August was above the standards, dissolved oxygen problems associated with the effects of the elevated algal population could exist. In the August survey dissolved oxygen measurements were taken at the surface. Dissolved oxygen stratification produced by algal photosynthesis and respiration in Black River Bay could result in dissolved oxygen values

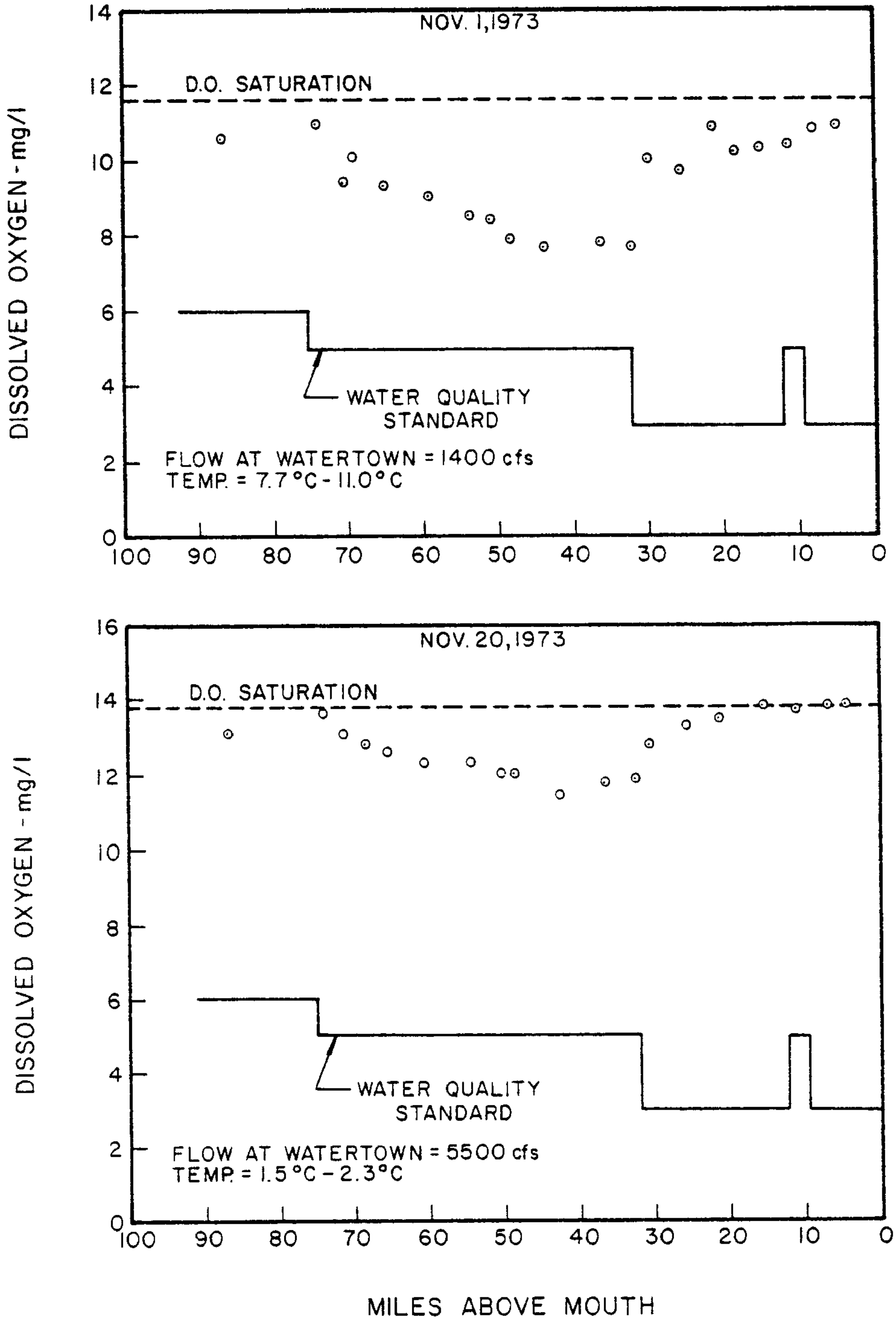


FIGURE 6

RIVER DISSOLVED OXYGEN DATA
(NOV. 1, 1973 AND NOV. 20, 1973)

near the bottom that are less than the standard. More detailed studies are required to define this problem.

## Biological Reconnaisance Survey

During the week of September 24, 1973, Hydroscience conducted a qualitative biological survey of the Black River study area. Stations visited were chosen based on physical and chemical changes in the river and were generally coincident with water quality sampling stations visited during the August 14, 1973 survey.

At each station a biologist surveyed the river bed for one hour identifying and counting organisms. The one hour counting period was taken to be a fair qualitative sampling, for the purpose of this study. The results of this survey are presented in Figure 7 and tabulated in Appendix B. The top graph in Figure 7 is a spatial plot of the number of different orders found at each station. The bottom graph in Figure 7 is a spatial plot of total number of organisms counted at each station.

General biological trends can be observed if Figure 7 and the biological data tabulated in Appendix B are interpreted along with the dissolved oxygen level, depth and velocity at each sampling station. For example, at milepoint 75 the river velocity decreases and those species which prefer higher velocities decline in numbers. The biology changes again at milepoint 70 where the Georgia Pacific waste discharge suppresses both the kind and number of organisms present. Again, further downstream at Watertown where dissolved oxygen concentrations approach saturation and the velocity is again slow, both the number and kind of organisms increase above general river levels. In particular organisms such as malluscs and insect larvae are abundant at this station.

With only a few exceptions, the Black River appears biologically constant with respect to the variation in organisms. However, the river does undergo large variations in total number of organisms due to both physical and chemical factors.

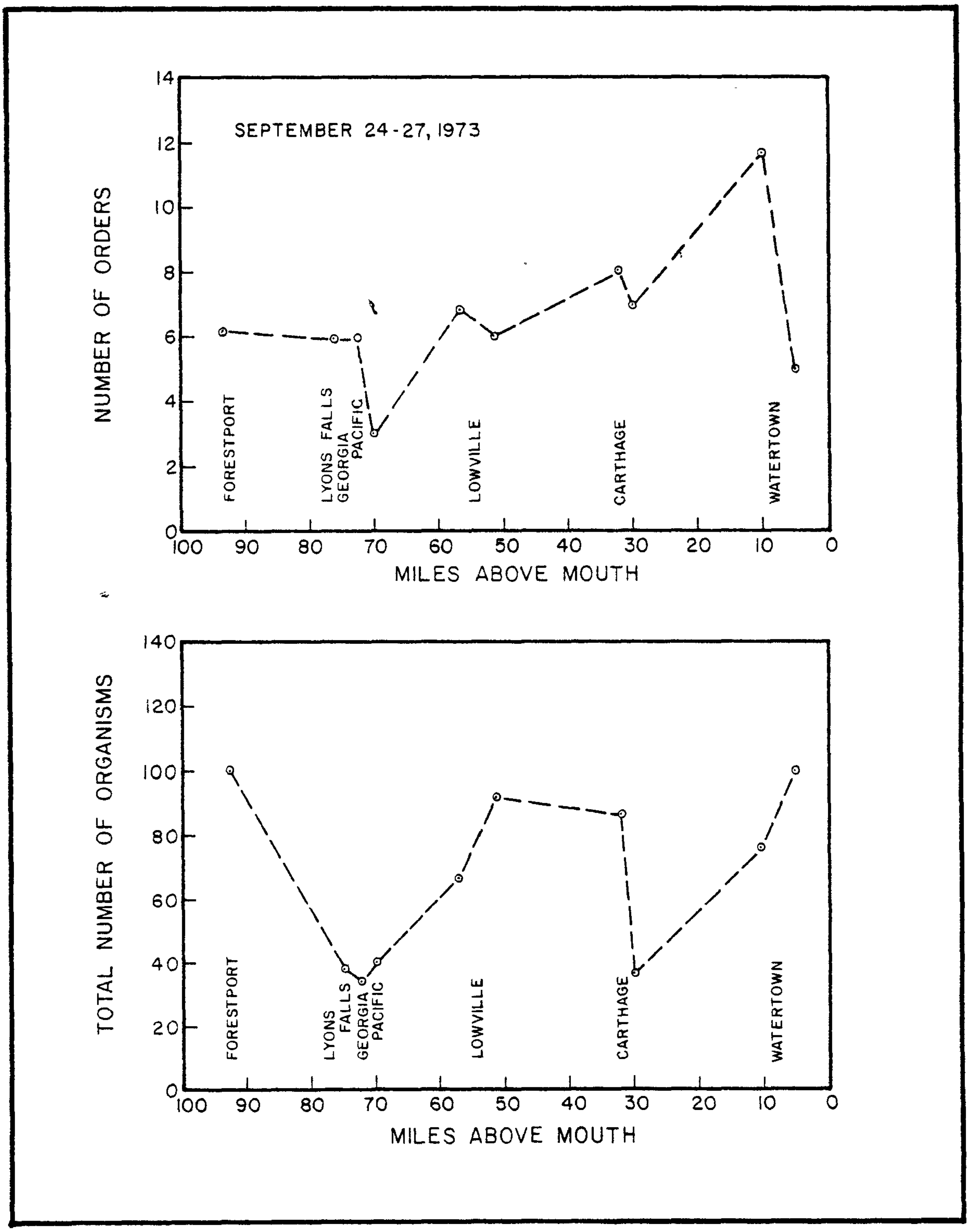


FIGURE 7

RESULT OF BIOLOGICAL RECONNAISSANCE SURVEY

## SECTION VI

## METHODS OF ANALYSIS

When an organic waste is discharged to a receiving water, dissolved oxygen present in the river is utilized by the aquatic bacteria during stabilization of the waste material. As dissolved oxygen is reduced by this process to values less than the saturation value, an imbalance is created. In order to restore river dissolved oxygen to its natural state, atmospheric oxygen passes into solution through the air/liquid interface of the river. The rate at which the oxygen is removed is assumed proportional to the concentration of biologically degradable organic material as well as chemically oxidizable substances. The rate coefficient is a function of temperature. The rate at which dissolved oxygen is replaced is proportional to deficit with its coefficient also proportional to temperature and more importantly the turbulent renewal of the air/water interface. The simultaneous effect of the reactions, biological oxidation and atmospheric reaeration, in conjunction with translation produced by the fresh water flow produces a characteristic longitudinal distribution of dissolved oxygen which decreases to some minimum value and then recovers to saturation. The dissolved oxygen concentration may be further affected spatially by benthal demands, and temporarily by the respiration and photosynthetic activity of aquatic plants.

A materials balance may be taken among all factors which affect the longitudinal distribution of any substance. The following expression is obtained:

$$\frac{\partial c}{\partial t} = - \frac{Q}{A} \frac{\partial c}{\partial x} \pm \Sigma S \qquad (1)$$

in which c is the concentration of any substance, t represents time, Q is the fresh water discharge, A denotes the river cross-sectional area, x is the longitudinal distance, and S represents all the various sources and sinks of the material in the system. Equation (1) states that the time rate of change of concentration of any substance at a particular river location is proportional to the longitudinal gradient, plus the sources and sinks of material. At any river location, the first term on the right side of Equation (1) represents the net balance of the material at the location due to the fresh water discharge, and the second term represents the net accumulation or reduction at the location because of the sources and sinks of material.

Re-expressing Equation (1) for carbonaceous BOD under steady-state conditions where there is no change in concentration with time, there results:

$$0 = - U\frac{dL}{dx} - K_r L \qquad (2)$$

in which U is the fresh water flow velocity, L represents the organic BOD concentration, and $K_r$ is the stream BOD removal coefficient. The first term on the right side of Equation (2) represents the advective transport of BOD by the fresh water flow velocity and the second term indicates first-order biological oxidation, a sink of BOD. Moreover, the coefficient, $K_r$, reflects all factors contributing to the removal of BOD, such as river settling, in addition to oxidation. For the boundary conditions that an initial BOD concentration, $L_o$, exists at location, x = 0; and that the BOD concentration approaches zero at large distances from the origin, Equation (2) may be integrated to:

$$L = L_o e^{-\frac{K_r x}{U}} \qquad (3)$$

The distribution of nitrogenous BOD in the river is similar to the carbonaceous:

$$N = N_o e^{-\frac{K_n x}{U}} \qquad (4)$$

in which N is the nitrogenous BOD concentration at any distance, $N_o$ is the nitrogenous BOD concentration at x = 0, and $K_n$ is the nitrogenous oxidation coefficient.

The dissolved oxygen distribution may be formulated in a similar manner. Expressing dissolved oxygen in terms of the deficit, there results:

$$0 = - U\frac{dD}{dx} - K_a D + K_d L + K_n N \qquad (5)$$

in which D represents dissolved oxygen deficit, $K_a$ is the atmospheric reaeration coefficient, and $K_d$ is the river deoxygenation coefficient; and $K_n$ is the nitrogenous oxidation coefficient. If carbonaceous BOD is removed in no way other than by direct oxidation, the deoxygenation coefficient, $K_d$, reflecting actual oxygen reduction in the system is equal to the BOD removal coefficient, $K_r$. The terms on the right side of Equation (5) represent, respectively: the downstream transport of oxygen deficit with the fresh water flow; atmospheric reaeration, a source of dissolved oxygen and sink of deficit; and biological oxidation, a source of deficit. The carbonaceous BOD concentration, L, and nitrogenous BOD, N, in Equation (5) may be replaced by the functional forms of Equations (3) and (4) and the resulting expression may be integrated with the previously indicated boundary conditions expressed in terms of oxygen deficit:

$$D = \frac{K_d L_o}{K_a - K_r} \left[ e^{-\frac{K_r x}{U}} - e^{-\frac{K_a x}{U}} \right] + \frac{K_n N_o}{K_a - K_n} \left[ e^{-\frac{K_n x}{U}} - e^{-\frac{K_a x}{U}} \right] + D_o e^{-\frac{K_a x}{U}} \qquad (6)$$

in which $D_o$ represents an initial dissolved oxygen deficit existing at the origin, if any. It is to be noted that if other factors are known to affect the dissolved oxygen balance such as benthal demands, and photosynthesis and respiration, they may be included as appropriate source and sink terms in Equation (5) and integrated to final solution. The initial BOD concentration, $L_o$, and $N_o$ in Equation (6) must be expressed in terms of the ultimate oxygen demand.

The dissolved oxygen concentration may be determined from the calculated deficit values in accordance with the following:

$$DO = C_s - D \qquad (7)$$

in which DO is the dissolved oxygen concentration at any location, and $C_s$ is the dissolved oxygen saturation value, a function of water temperature in fresh water streams.

Flow and concentration discontinuities present in the system due to waste loadings or tributary effects must be included in the water quality balances. At each location of a waste discharge or tributary, a materials balance must be calculated which incorporates the effect of BOD, dissolved oxygen or flow added to the system. In this manner, the parameters $L_o$, $N_o$ and $D_o$ in Equations (3), (4) and (6) are reinitialized at every discontinuity and a new origin, x = 0, is established to comply with the boundary conditions.

The atmospheric reaeration coefficient as defined by O'Connor and Dobbins [1], $K_a$, is a function of the stream hydraulic characteristics:

$$K_a = \frac{(D_L U)^{1/2}}{H^{3/2}} \qquad (8)$$

in which $D_L$ is the molecular diffusivity of oxygen in water ($0.81 \times 10^{-4}$ sq ft/hr at 20°C), U is the average river velocity, and H represents the mean river depth. Equation (8) may be used to determine the reaeration coefficient at any specific river location or in reaches where the velocity and depth may be conveniently averaged.

## Temperature Effects

All reaction coefficients previously indicated are temperature dependent and may be related to temperature as follows:

$$K_T = K_{20}\theta^{(T - 20)} \qquad (9)$$

in which $K_T$ is the value of the coefficient at temperature, T, $K_{20}$ is the 20°C value, and r is a constant characteristic of the relationship. A value for θ of 1.02 may be used for $K_a$ and 1.04 may be used for $K_r$, $K_d$ and $K_n$.

# SECTION VII

# WASTEWATER DISCHARGES

Direct wastewater discharges enter the Black River and its tributaries from industrial and municipal wastewater discharges. The eight major industrial discharges are from paper companies whose locations are shown in Figure 8. The municipal discharges are from the towns and cities also indicated in Figure 8. The flows and mass emissions rates of the eight major industrial plants and the nine municipalities are presented in Tables 9 and 10. Of a total combined point BOD discharge of 150,049 lb/day (68,200 kg/day), approximately 85 percent (128,315 lb/day) (58,200 kg/day) is due to industrial and the remainder to municipalities. The major industrial source is the Georgia Pacific Company located at milepoint 74.2.

## Industrial Discharges

The nine paper mills, currently discharging their wastewaters to the Black River, have some form of wastewater treatment or are completing the construction of treatment facilities. During the August survey, the Georgia Pacific, Burrows, Climax, Crown Zellerbach, and St. Regis Paper Companies were discharging untreated wastewaters to the Black River and its tributaries. In October, the St. Regis Paper Company completed the construction of its wastewater treatment facilities. The other raw discharges will provide treatment in the near future.

The organic loading of industrial wastewater discharges was determined from the U. S. Army Corps of Engineers discharge permit applications, New York State Department of Environmental Conservation records, and laboratory studies performed by Hydroscience, Inc. The U. S. Army Corps of Engineers permit applications provided data on the wastewater flow, $BOD_5$, and total Kjeldahl nitrogen. Since the permits were filed, treatment of some of the wastewaters from the paper companies was initiated. Updated information on some of these treated wastewaters was obtained from New York State D.E.C. records. In order to supplement these data sources, especially with regard to ultimate oxygen demand measurements, Hydroscience, Inc. collected and returned to the laboratory for analysis wastewater samples from the eight principal industries.

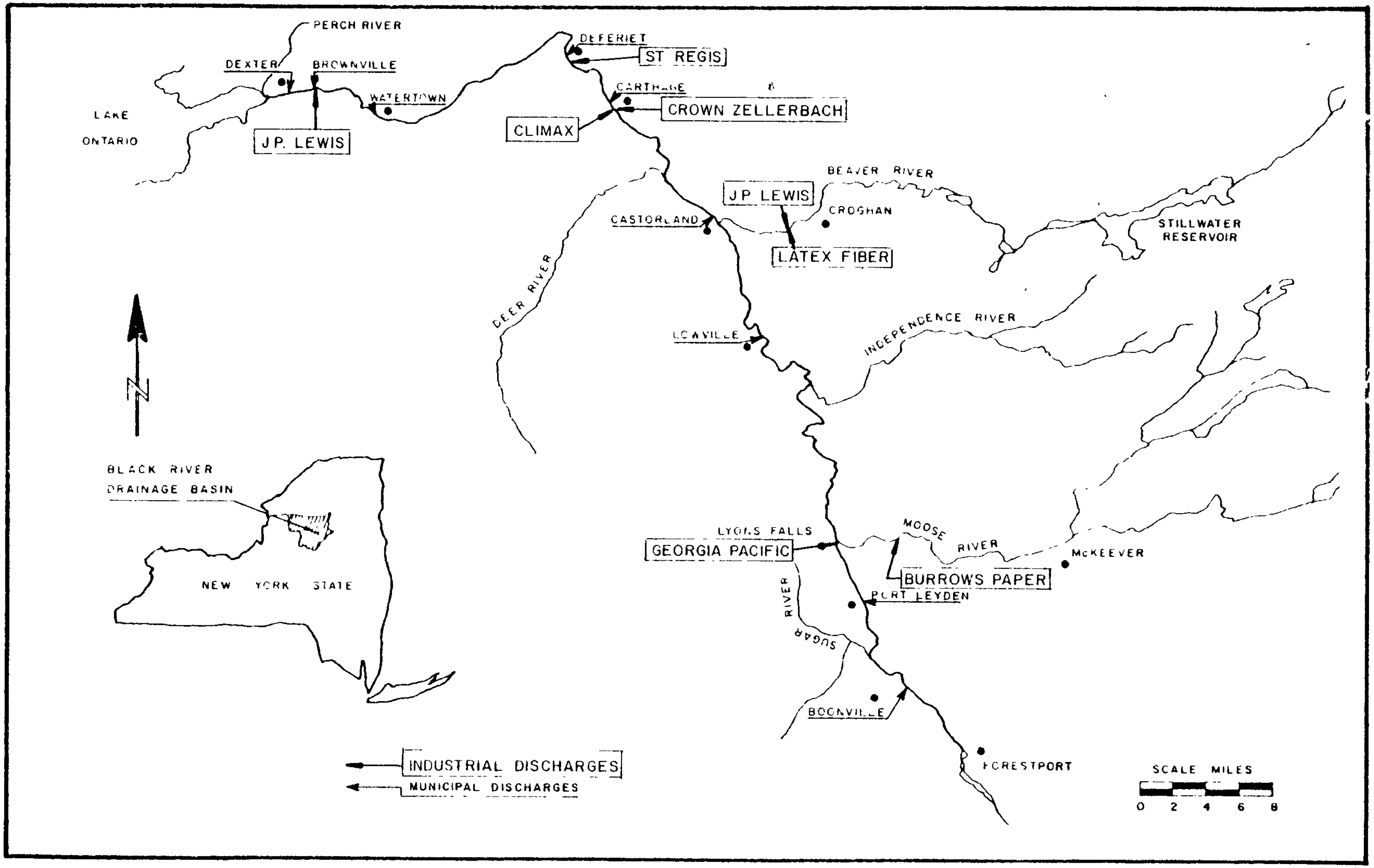


FIGURE 8

LOCATION OF INDUSTRIAL AND MUNICIPAL WASTEWATER DISCHARGES

TABLE 9

SUMMARY OF PRESENT INDUSTRIAL WASTEWATER LOADS

| | INDUSTRY | MILEPOINT | FLOW MGD | $BOD_5$ LB/DAY | ULTIMATE BOD LB/DAY |
|---|---|---|---|---|---|
| 1. | Georgia Pacific | | | | |
| | Pulp | 74.2 | 2.2 | 35,500 | 89,500 |
| | Paper | | 3.9 | 2,540 | 6,350 |
| 2. | Burrows Paper | Moose River | 1.1 | 500 | 730 |
| 3. | J. P. Lewis (Beaver Falls) | Beaver River | 2.6 | 199 | 355 |
| 4. | Latex Fiber | Beaver River | 1.5 | 321 | 1,050 |
| 5. | Climax | 32.2 | 1.0 | 1,230 | 1,620 |
| 6. | Crown Zellerbach | 30.8 | 2.6 | 6,400 | 12,400 |
| 7. | St. Regis [1] | 25.0 | | | |
| | Before Treatment | | 13.8 | 13,500 | 28,400[1] |
| | After Treatment | | 13.8 | 7,050 | 15,000 |
| 8. | J. P. Lewis (Brownville) | 5.1 | 0.7 | 563 | 1,310 |

[1]Treatment started in October, 1973.

TABLE 10

SUMMARY OF PRESENT MAJOR MUNICIPAL LOADS

| MUNICIPALITY | MILEPOINT | FLOW MGD | $BOD_5$ LB/DAY | NBOD[1] LB/DAY | ULTIMATE BOD LB/DAY |
|---|---|---|---|---|---|
| 1. Boonville | 82.2 | 0.95 | 160[2] | 710 | 950 |
| 2. Port Leyden | 78.1 | 0.12 | 117 | 90 | 266 |
| 3. Lowville | 54.0 | 0.69 | 142 | 520 | 733 |
| 4. Castorland | 42.1 | 0.045 | 10 | 34 | 49 |
| 5. Carthage[3] | 30.8 | - | 1,220 | 1,070 | 2,900 |
| 6. Deferiet | 27.3 | 0.08 | 140 | 60 | 270 |
| 7. Watertown | 8.4 | 4.5 | 8,330 | 3,375 | 15,885 |
| 8. Brownville | 5.1 | 0.28 | 47 | 210 | 281 |
| 9. Dexter | 2.7 | 0.25 | 140 | 190 | 400 |

[1]Based on effluent oxidizable nitrogen concentration of 20 mg/l

[2]Based on effluent $BOD_5$ concentration of 20 mg/l

[3]$CBOD_5$ = 0.17 lb/capita/day NBOD = 0.15 lb/capita/day
Population = 7,180

The Knowlton Brothers Paper Company was not included because they instituted a water reuse and wastewater treatment program that produced an effluent with a minor organic loading.

The purpose of the industrial wastewater measurements made by Hydroscience, Inc. was to fill in gaps in the industrial effluent $BOD_5$ data and to measure the ultimate oxygen demand of all the industrial discharges. In addition, the possibility of nutrient availability limiting oxidation in the river was also investigated. Long term oxidation studies on the industrial wastewater effluents were conducted in which the oxygen demand of the wastewaters was periodically measured with time for a 30-day period at which time oxidation is generally complete. For the three largest industrial discharges, the Georgia Pacific, St. Regis, and Crown Zellerbach Paper Companies, long term oxidation measurements were made on wastewater samples diluted with river water alone and samples with river water plus nutrients.

The results of the oxidation studies performed on the Georgia Pacific, St. Regis, and Crown Zellerbach Paper Companies' effluents are presented in Figure 9. Each figure is a plot of oxygen consumed by the oxidation of the wastewater versus time of incubation. The possibility of low nutrient levels in the river water limiting oxidation of the wastewaters was investigated by conducting duplicate long term BOD tests on each sample. The circular data points indicate the results in which river water alone was used as dilution water in the BOD test. The BOD results in which additional nutrients were added to the river water are represented by the triangular data points. As shown there is no significant difference in the oxygen demand measurements made with and without additional nutrients.

The long term BOD data also show that the ultimate oxygen demand can be considerably greater than the 5 day BOD. For the Georgia Pacific wastewater the ultimate oxygen demand was 2.5 times the 5 day BOD. The measured ultimate oxygen demand of the St. Regis and Crown Zellerbach wastewaters was approximately twice the 5 day BOD. Long term BOD measurements of the other industrial wastewaters showed that the ratio of the ultimate oxygen demand to the 5 day BOD ranged from 1.3 to 3.3, averaging about 2.0. The higher ultimate BOD to 5 day BOD ratio measured for the Latex Fiber Company wastewater discharge could have included the oxidation of nitrogenous material which was significant for this discharge. For the other industries nitrogenous BOD associated with the effluent Kjeldahl nitrogen is minor in comparison to the carbonaceous BOD.

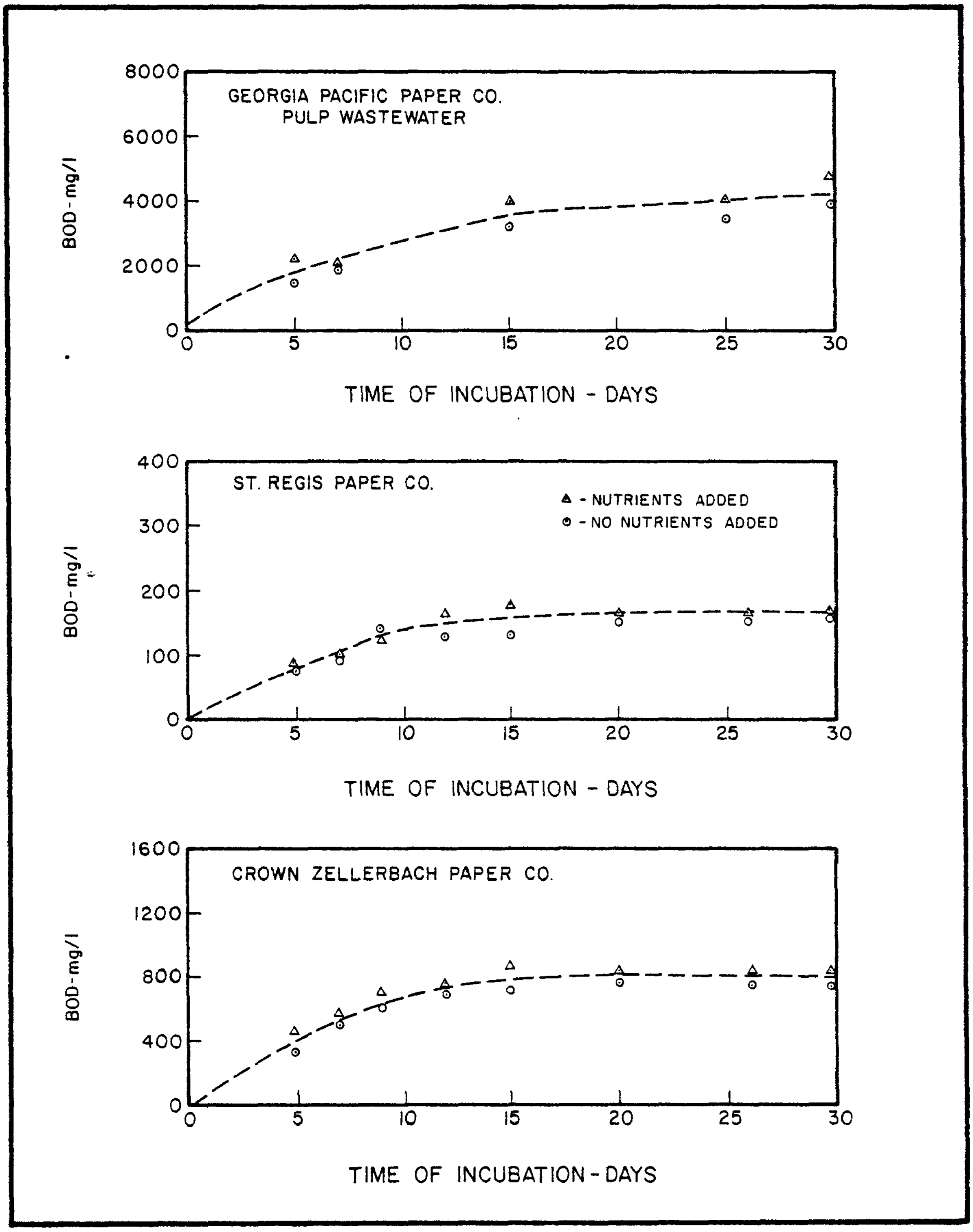


FIGURE 9

LONG TERM BOD STUDIES

The Georgia Pacific Paper Company discharges 95,850 lb/day (43,500 kg/day) of ultimate BOD or approximately 75 percent of the industrial wastewater BOD. In addition to a biochemical oxygen demand associated with the organic wastewater load from the Georgia Pacific Paper Company, a chemical oxygen demand due to the oxidation of sulfite discharged with the pulp manufacturing wastewater also consumes river dissolved oxygen. The measured effluent sulfite concentration of the pulp manufacturing wastewater was approximately 1,000 mg/l. The stoichiometric chemical oxygen demand of the conversion of sulfite to sulfate is 0.2 mg/l of oxygen per 1 mg/l of sulfite. Laboratory studies in which wastewater was mixed with river water and the resulting dissolved oxygen change measured by a probe indicated that the sulfite oxygen demand of the watewater was not immediate. It was also found that the unoxidized sulfite interfered with the Winkler dissolved oxygen determination by producing false dissolved oxygen decreases.

Based upon previous information [2], it was concluded that the sulfite in the wastewater is organically bound and, therefore, not free to become immediately oxidized. Previous data indicated that the organically bound sulfite oxidized at a first order reaction rate of about 1.0 day (base e).

On the basis of these findings, the oxidation of the sulfite in the wastewater was analyzed as a reactive chemical oxygen demand. Furthermore, minor corrections were applied to some river dissolved oxygen measurements downstream of the Georgia Pacific discharge to correct the dissolved oxygen measurement made by the Winkler method for the interference of the unoxidized sulfite. The river Winkler dissolved oxygen corrections ranged from a maximum of 1.1 mg/l immediately below the Georgia Pacific discharge to approximately zero at the confluence with the Beaver River.

## Municipal Discharges

In this study wastewater discharges from the nine largest municipalities were included in the analysis. The other municipalities either have individual private means of wastewater disposal such as septic tanks or their wastewater volume is small. The ultimate oxygen demand of wastewaters discharged to the study area by municipalities is approximately 17 percent of the oxygen demand of the industrial discharges. A summary of the principal municipal wastewater loads is presented in Table 10.

The wastewater flow and $BOD_5$ data were obtained from New York State D.E.C. records, except as noted. The nitrogenous BOD was assigned on the basis of an effluent oxidizable nitrogen concentration of 20 mg/l. The stoichiometric conversion of oxidizable nitrogen to nitrate is 4.5 mg of oxygen per mg of nitrogen oxidized. The ultimate oxygen demand is the sum of the ultimate carbonaceous BOD, which was taken as 1.5 times the $BOD_5$, and the nitrogenous BOD.

All the municipalities provide some form of wastewater treatment except Carthage which currently discharges untreated wastewater to the Black River. The ultimate BOD discharged at Carthage is estimated at 2,900 lb/day (1,320 kg/day). A treatment plant which will treat the wastewater from Carthage, West Carthage, Crown Zellerbach Paper Company and Climax Paper Company is currently under construction. Watertown which has primary treatment facilities is the largest municipal wastewater discharge. The ultimate BOD discharged at Watertown is 15,900 lb/day (7,200 kg/day). Each of the remaining municipalities discharge less than 1,000 lb/day (454 kg/day) of ultimate BOD. The municipal wastewater BOD loads are for dry weather conditions and do not include the BOD loads associated with combined sewer overflows.

## SECTION VIII

## MODEL APPLICATION AND VERIFICATION

Equation (6) which defines the steady-state, spatial dissolved oxygen distribution in a stream has been applied in the analysis of the Black River dissolved oxygen data. The parameters of Equation (6) have been evaluated for various segments of the Black River. A mathematical definition of the spatial dissolved oxygen distribution for the Black River within the study area was obtained by linking together through the conservation of mass principal the solutions of Equation (6) for each river segment thus forming a dissolved oxygen mathematical model of the Black River. The validity of the model was tested by analyzing three sets of river dissolved oxygen survey data, under different flow and temperature conditions, with a consistent set of parameters. A review of the model application and verification of river dissolved oxygen distributions for August 14, 1973, November 1, 1973, and November 20, 1973 follow.

### Flow

The water quality surveys of the Black River were conducted during low flow conditions on the August 14, 1973 and November 1, 1973 surveys and relatively high flow conditions on the November 20, 1973 survey. A hydrograph of the river flow at Watertown, which is approximately 10 miles (16.1 km) upstream of the mouth, is presented in Figure 10. During the five day period preceding the August 14, 1973 and November 1, 1973 surveys, the river flow at Watertown averaged 1,700 cfs (48.2 cu m/sec) and 1,400 cfs (39.6 cu m/sec) respectively. Before the November 20, 1973 survey, the average river flow at Watertown was 5,500 cfs (156 cu m/sec). As shown on Figure 10, reasonably good steady-state flow conditions existed before each survey for a time period comparable to the time of travel within the study area.

The spatial flow distribution in the Black River was determined from the flow records of the Hudson River-Black River Regulating District. Flow measurements at Watertown and Boonville on the Black River, at Croghan on the Beaver River, and at Old Forge on the Moose River

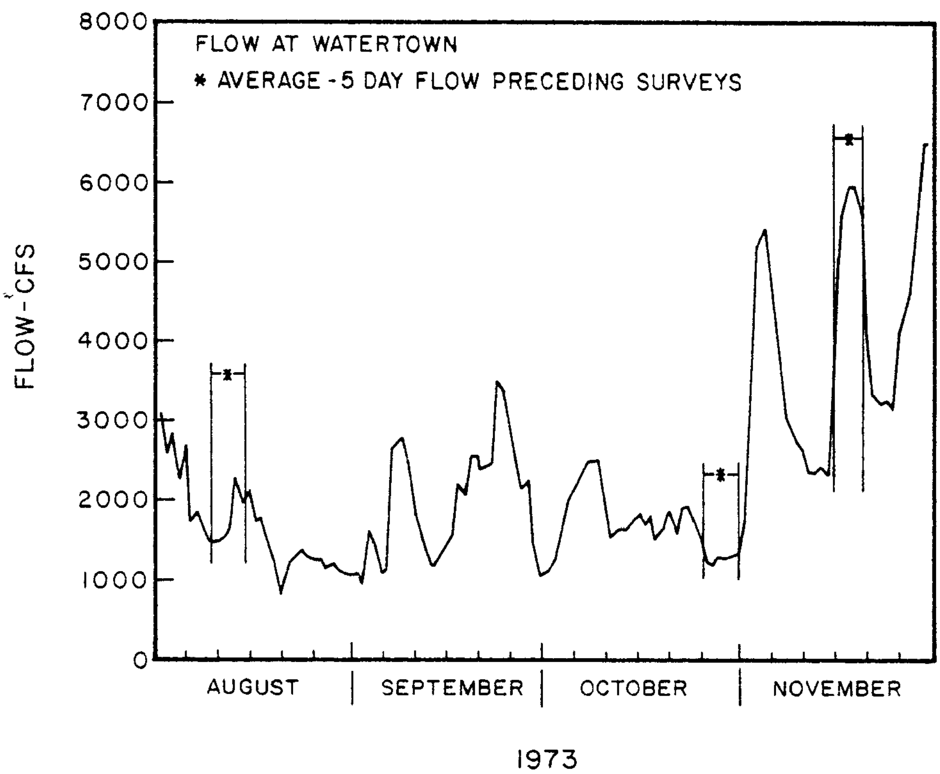


FIGURE 10

FLOW AT WATERTOWN (AUG.- NOV., 1973)

were used to evaluate the flow distribution. The ungaged flow, which is defined as the flow at Watertown minus the flow measured at the Boonville, Croghan, and Old Forge gaging stations, was distributed uniformly throughout the drainage basin.

A graphical presentation of the flow distribution in the Black River for the August 14, 1973 and November 20, 1973 surveys is shown in Figure 11. The flow distribution for the November 1, 1973 survey, which is not shown, was similar to the August flow distribution.

## River Geometry

The cross sectional area and depth distribution of the Black River was determined primarily from time of travel studies conducted by the U. S. Geological Survey. Some measurements of river geometry were made between Forestport and Lyons Falls. The geometry of the lower Beaver and Moose Rivers was obtained from measurements and estimates based on visual observations.

During the period from August, 1968 to July 1969, the U. S. Geological Survey conducted three time of travel studies on the Black River. The river between Lyons Falls and Dexter was divided into sixteen segments. At the upstream end of each section, dye was mixed with the river water and as the leading edge of the dye patch reached the downstream end of the river segment, measurements of the dye concentration were taken with time until the dye patch passed. From an analysis of these dye data, the mean travel time for a particular river flow within each segment was computed. The cumulative travel time along the river is the sum of the travel time in each river segment and is presented in Figure 12 for the three studies.

In addition to measuring the time of travel within each river segment, the U. S. Geological Survey also measured river flow and width. From these measurements, the effective cross sectional area and depth of a particular flow for each segment was computed. A relationship between river velocity, cross sectional area, and depth with river flow was developed for each model segment. Figure 13 presents the correlation of velocity, area, and depth with flow for two of the river segments.

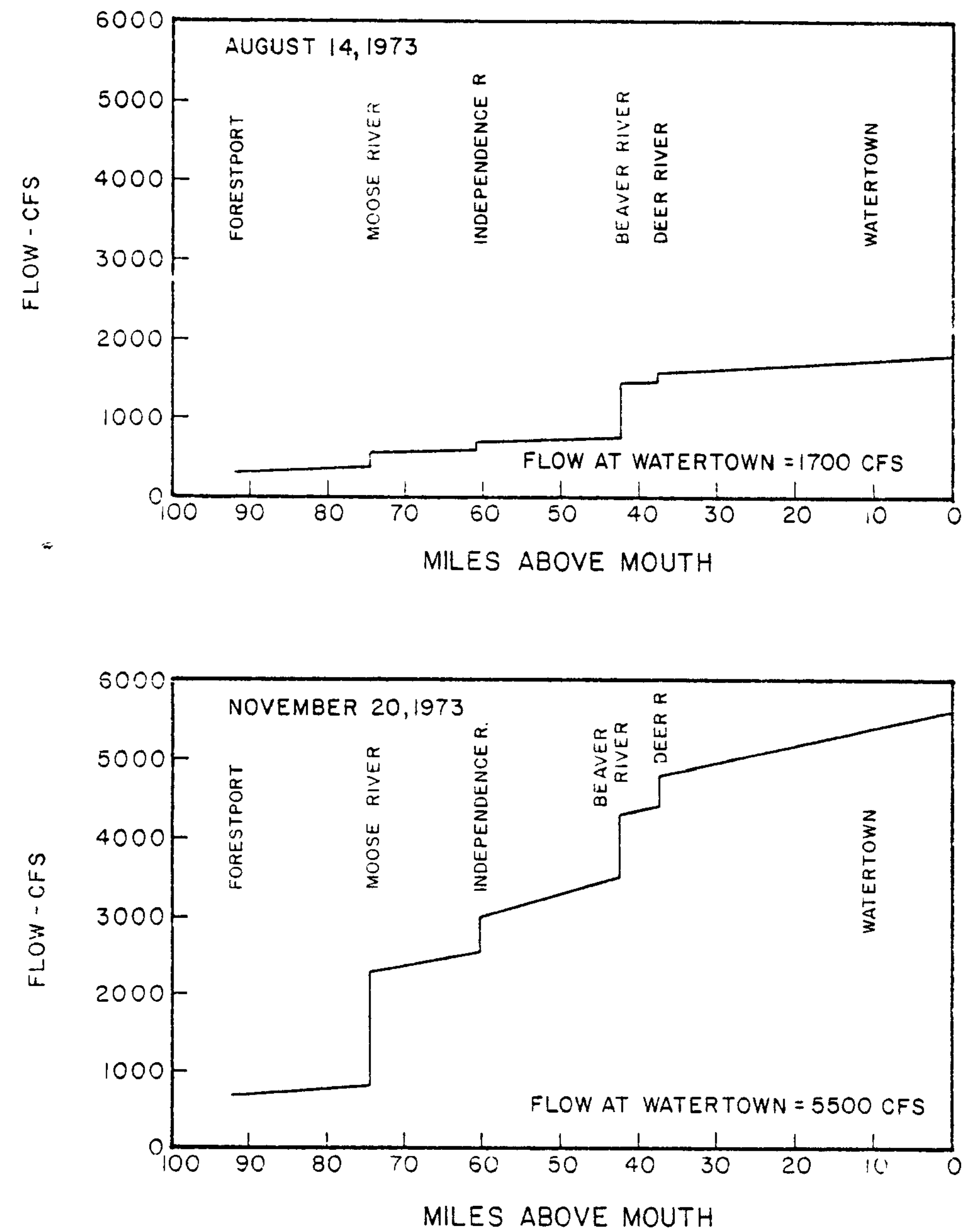


FIGURE 11

AVERAGE SPATIAL FLOW DISTRIBUTION FOR AUGUST 14, 1973 AND NOVEMBER 20, 1973 SURVEYS

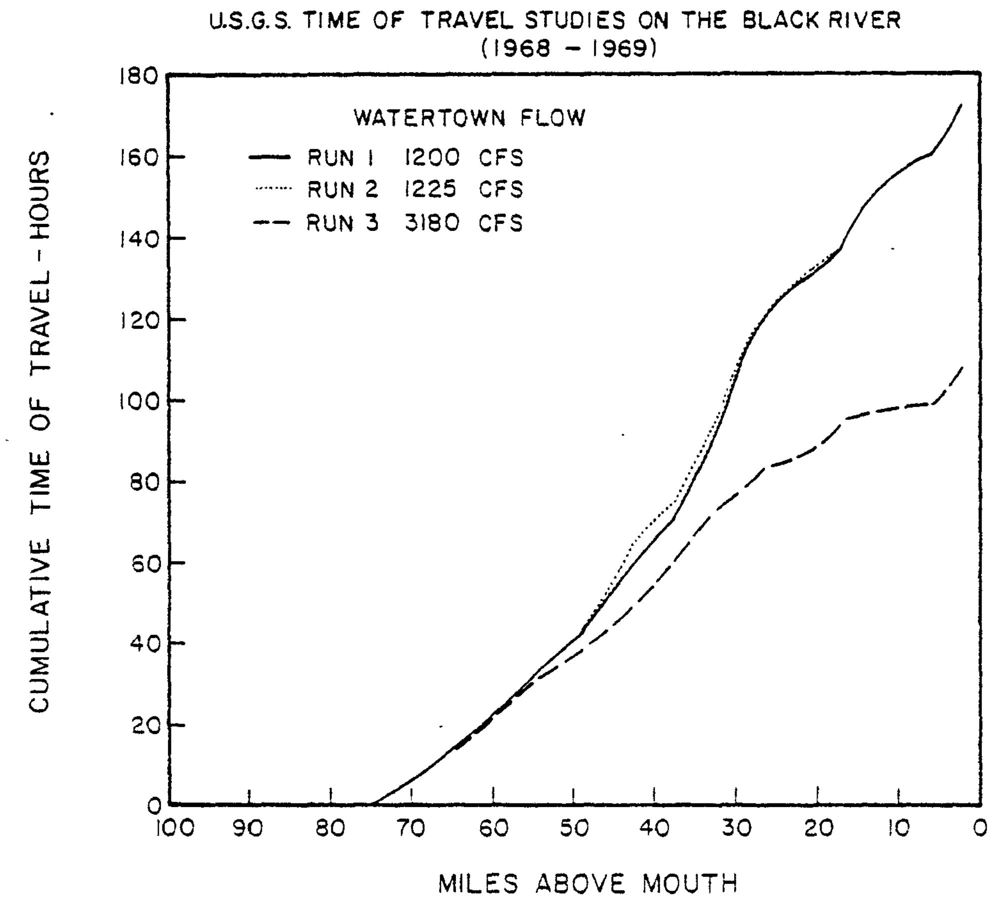


FIGURE 12

RESULTS OF U.S.G.S. TIME OF TRAVEL STUDIES (PROVISIONAL)

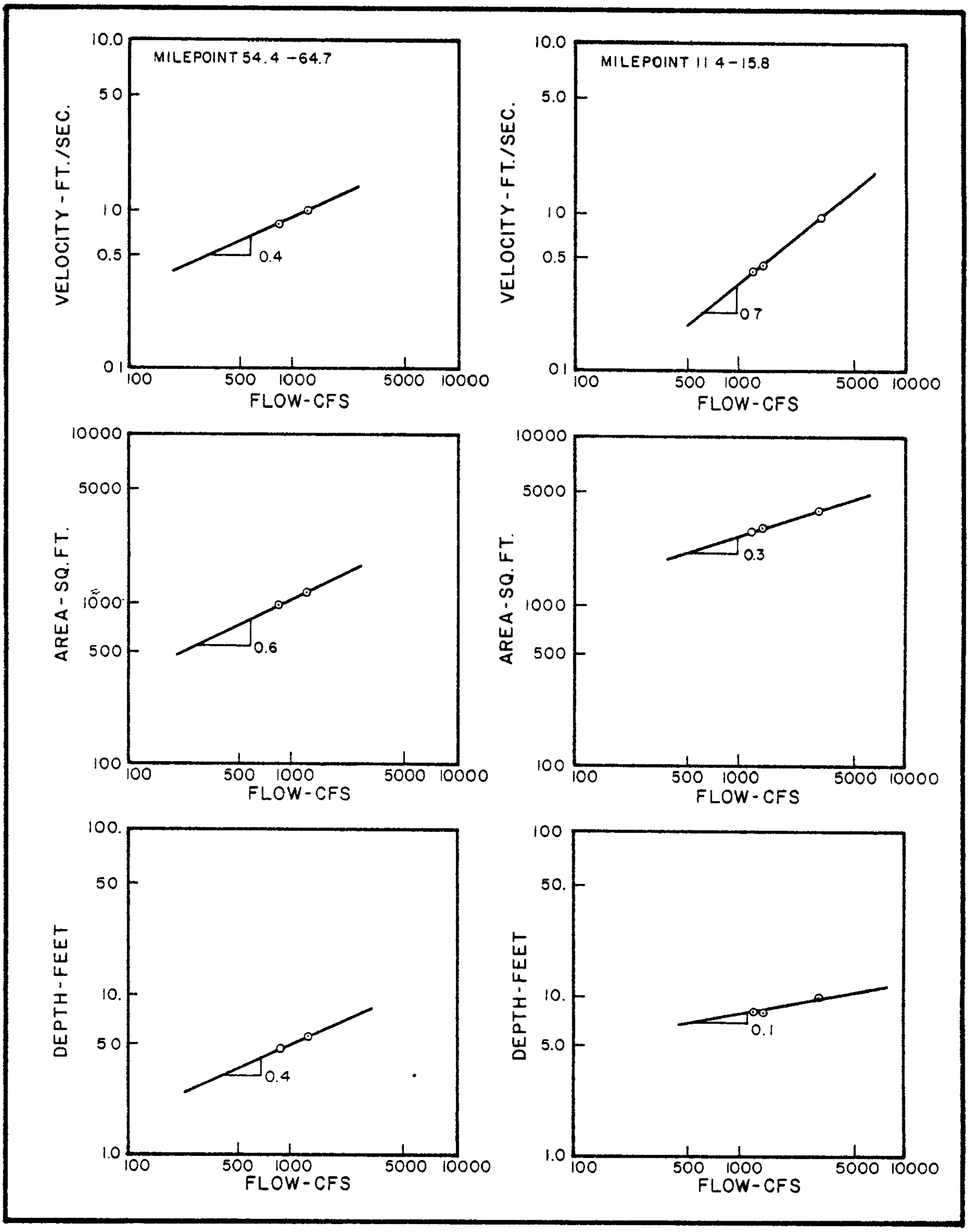


FIGURE 13

TYPICAL RIVER GEOMETRY AND VELOCITY VARIATIONS WITH FLOW

The relationships of river velocity, area, and depth to flow have been characterized as logarithemic and are defined as follows:

$$\text{Area} = C_a\, Q^a$$

$$\text{Depth} = C_d\, Q^b$$

$$\text{Velocity} = C_u\, Q^c$$

where $C_a$, $C_d$, $C_u$ are constants and a, b, c are exponents of flow, Q. The constants and exponents for each river section depend on the river bed roughness, channel slope, and geometric shape. In addition, impoundments caused by dams can have a significant effect on the exponents. A tabulation of the constants and exponents for all river sections is contained in Appendix C.

Employing these relationships of river geometry with flow, the spatial cross-sectional area and depth distribution of the Black River was determined for the flow regime existing during each of the water quality surveys. For sections of the river not included in the U.S. Geological time of travel study and the lower Moose and Beaver Rivers, the river geometry variation with flow was assigned by assuming that the geometric shape of the river cross-section is the same over the range of river flows analyzed. For example, rectangular river cross sections were assumed to remain rectangular for different river flows. Consequently, the change in river geometry was computed using the following rearranged form of the Manning open channel equation.

$$AR^{2/3} = \frac{Q}{\left(\frac{1.49}{n} S^{1/2}\right)} \qquad (10)$$

where A is the cross-sectional area, R is the hydraulic radius, Q is the river flow, and n and S are the channel roughness coefficient and hydraulic slope respectively which were held constant.

Figures 14 and 15 show the flow, depth, and cross-sectional area distribution of the Black River for the August 14, 1973 and November 20, 1973 surveys. The river geometry for the November 1, 1973 survey, which is not shown, was

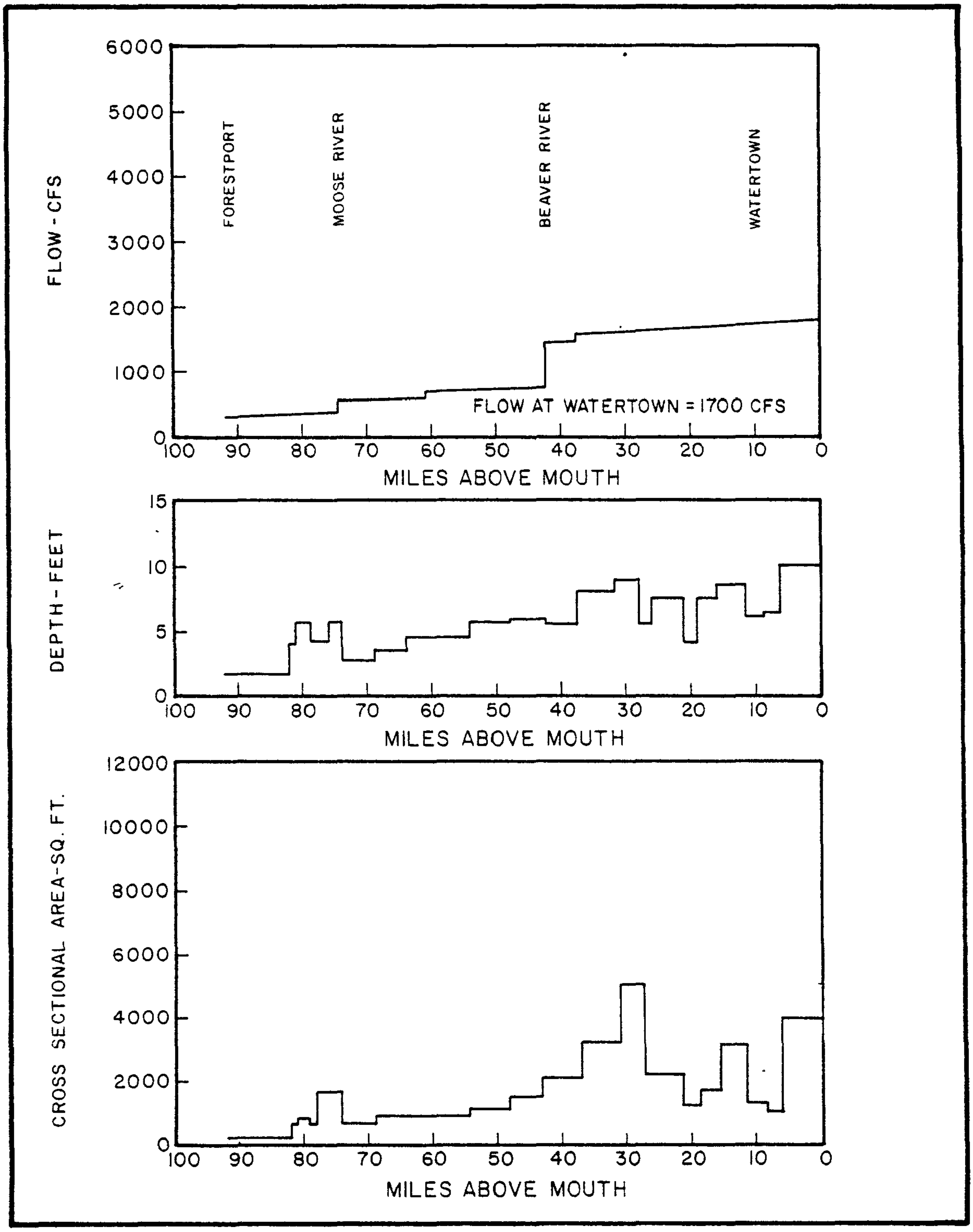


FIGURE 14

FLOW, DEPTH, AND CROSS SECTIONAL AREA DISTRIBUTION FOR THE AUGUST 14, 1973 SURVEY

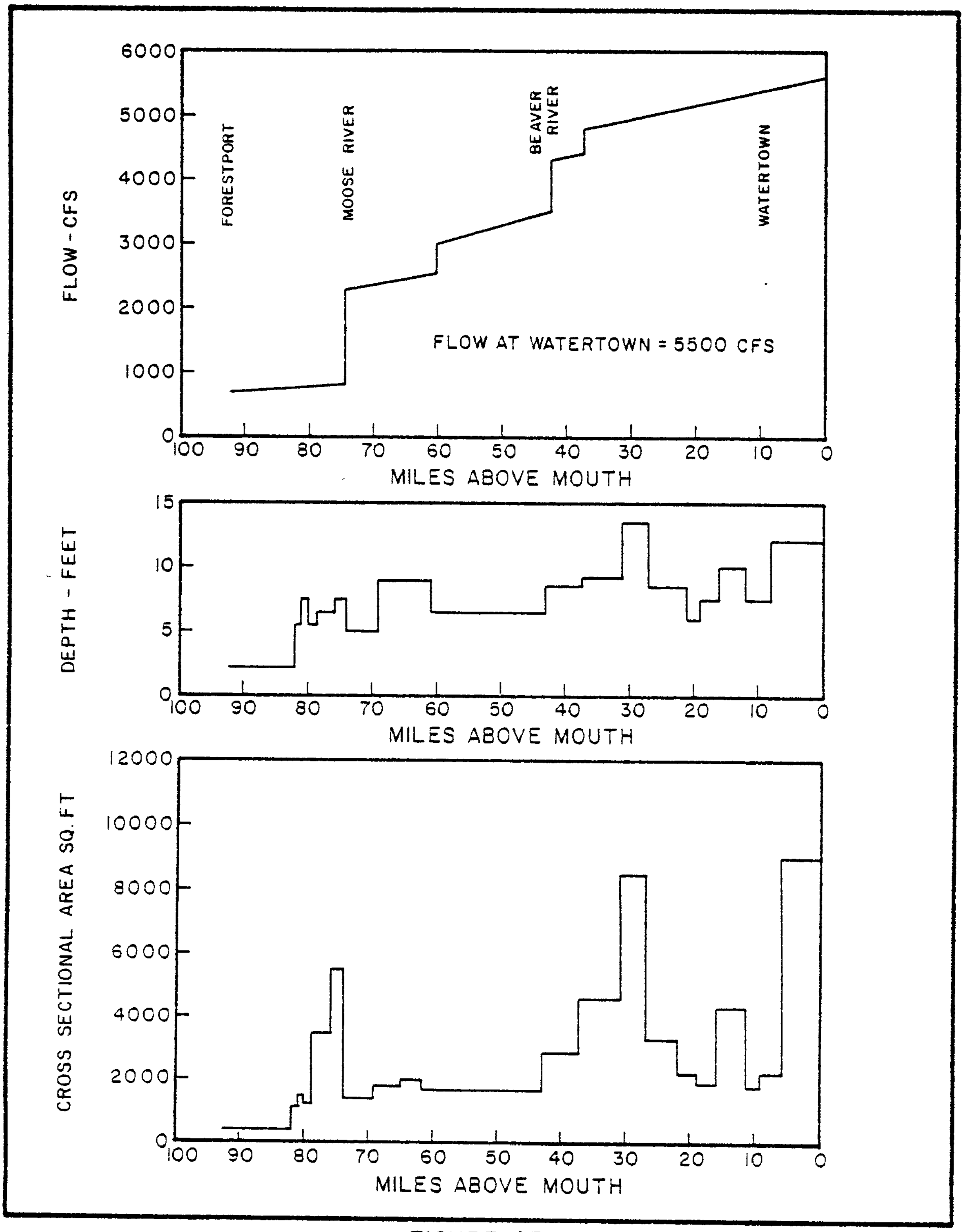


FIGURE 15

FLOW, DEPTH, AND CROSS SECTIONAL AREA DISTRIBUTION FOR THE NOVEMBER 20, 1973 SURVEY approximately the same as the August 14, 1973 survey because the river flows were similar. As shown in Figures 14 and 15, the Black River for approximately 10 miles (16 km) below Forestport is shallow with an average depth of 2 to 3 feet (0.61 to 0.92 m). From this point to the confluence with the Moose River, there is a rapid increase in the river cross-sectional area accompanied by a moderate increase in depth to 5 to 7 feet (1.52 to 2.13 m). Immediately downstream of Lyons Falls there is a sudden decrease in the river cross-sectional area which again increases as the river flows to Carthage (around milepoint 30.0). Between Carthage and the mouth, the river geometry is variable, possibly reflecting the effects of the numerous impoundments.

### Model Segmentation

The study area, which includes the Black River from Forestport to Black River Bay and the lower 5 miles (8 km) of the Moose and Beaver Rivers, was divided into a series of segments for the purpose of constructing a mathematical water quality model. A model segment is created when there is a change in any of the variables contained in Equation (6) includingthe deoxygenation rate, atmospheric reaeration rate, and river velocity. Generally, the principal reasons for a new model segment are changes in river geometry and flow, and the discharge of wastewater loads. A schematic of the model segmentation of the study area is presented in Figure 16.

The total number of model segments is 59 with the Black River containing 44, the Moose River 6, the Beaver River 7, and Black River Bay 2. The municipal and industrial wastewater discharges are indicated by arrows in addition to the Independence and Deer Rivers. The remaining model segments not receiving a wastewater discharge were established to accommodate a change in river geometry or flow.

### Dam Reaeration

The flow of river water over dams and natural falls can be a significant source of dissolved oxygen. Oxygen is entrained as the water flows over the dam and produces a turbulent pool below the dam. The degree of reaeration at a dam is related to the height of fall, the type of dam (free fall versus steps), temperature, and dissolved oxygen. There are insufficient data on dam aeration in

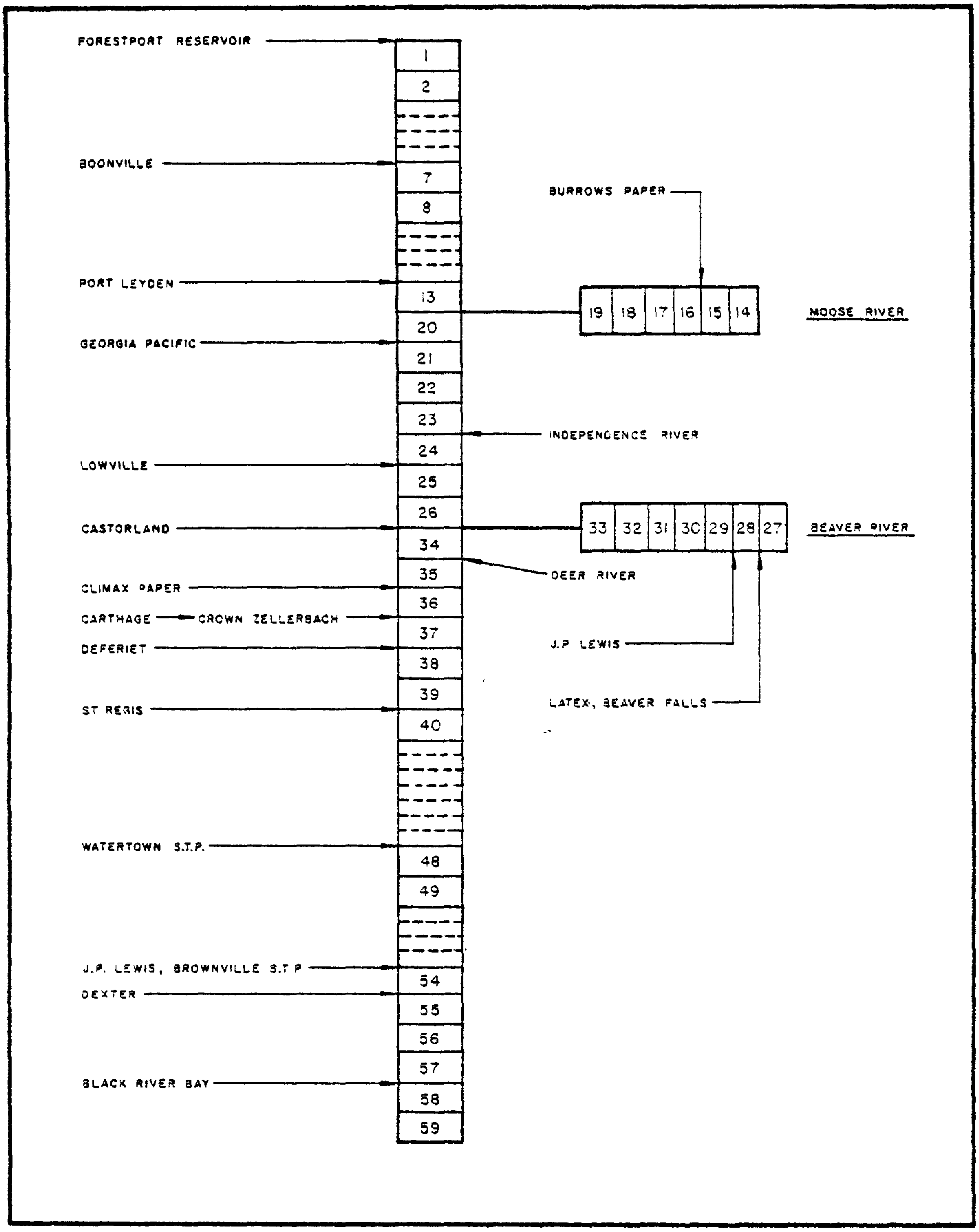


FIGURE 16

MATHEMATICAL MODEL SEGMENTATION

the Black River to develop a correlation between degree of reaeration and these variables. Consequently, the relationship developed by the New York State Department of Health in a study of the Mohawk River [3] was selected from existing dam reaeration formulas, as being developed from field conditions that most closely approximate those in the Black River. The equation which relates the change in dissolved oxygen to the height of fall is as follows:

$$D_B = (1 - 0.037\ H)\ D_A \qquad (11)$$

where $D_B$ is the dissolved oxygen deficit below the dam, $D_A$ is the dissolved oxygen deficit above the dam, and H is the height of the dam in feet. The equation was developed for free fall dams up to 15 feet (4.6 m). The effects of water temperature or degree of pollution are not included.

Most of the dams on the Black River are run-of-the-river hydroelectric dams for which upstream flow regulation and plant pondage is limited. At these dam sites the river water that flows through the turbines does not receive significant reaeration. The quantity of water that flows through the turbine depends on the size of the power plant. Table 11 lists the location and estimated height of fall for the dams and natural falls in the Black River. In addition, the maximum flow through the power plant is indicated for the hydroelectric dams, designated by (H). When the river flow exceeds the plant capacity the excess flow receives dam reaeration.

The data contained in Table 11 were obtained from a Black River profile and report [4] prepared by the Black River Basin Regional Water Resources Planning Board. The height of fall at Lyons Falls, milepoint 74.2, is indicated as 18 feet (5.5 m) rather than the 60 feet (18.3 m) fall that is generally reported. At Lyons Falls there is a dam of about 18 feet (5.5 m) followed by a natural falls of approximately 15 feet (4.6 m). The remaining 30 feet (9.2 m) fall in the river bed occurs as a steep slope rather than a precipitous drop. At Carthage, there are a few dams that extend from the shores to islands in the river. The net effect of these dams was represented by dams of 12 feet (3.7 m) and 14 feet (4.3 m) as indicated in Table 11. The reaeration achieved at these dams serves as a significant source of dissolved oxygen as demonstrated by the observed increases in survey river dissolved oxygen profiles around milepoint 31.

TABLE 11

HEIGHT OF FALLS FOR DAMS ON THE BLACK RIVER

| RIVER MILEPOINT | ESTIMATED HEIGHT OF FALL FEET | MAXIMUM FLOW THROUGH HYDROELECTRIC PLANT CFS |
|---|---|---|
| 1.8 | 15 (H) | 2,440 |
| 4.8 | 20 (H) | 4,040 |
| 8.8 | 15 (H) | 344 |
| 9.8 | 13 (H) | 4,060 |
| 10.0 | 12 (H) | 400 |
| 10.4 | 10 (H) | 1,850 |
| 10.8 | 10 (H) | 2,100 |
| 12.0 | 14 (H) | 3,150 |
| 15.8 | 35 (H) | 2,950 |
| 16.8 | 25 (H) | 3,870 |
| 19.4 | 23 | |
| 20.1 | 10 | |
| 21.6 | 20 | |
| 26.7 | 23 (H) | 3,780 |
| 28.3 | 15 (H) | 4,490 |
| 31.8 | 12 (H) | 592 |
| 32.2 | 14 | |
| 74.2 | 18 (H) | 960 |
| 77.1 | 25 (H) | 374 |
| 77.3 | 25 | |
| 78.0 | 15 | |
| 80.2 | 18 (H) | 430 |
| 86.8 | 18 | |
| 92.8 | 15 | |

H = Hydroelectric dams

## Background Water Quality

The observed dissolved oxygen data shown in Figures 5 and 6 indicate an average background dissolved oxygen deficit of approximately 1.0 mg/l. In this case, background dissolved oxygen deficit is defined as a deficit not associated with direct wastewater discharges. Therefore, Black River dissolved oxygen data upstream of Lyons Falls, and dissolved oxygen data upstream of Lyonsdale and Beaver Falls on the Moose and Beaver Rivers respectively is indicative of background conditions. The August background dissolved oxygen data show a deficit of 1.0 to 2.0 mg/l. The less extensive dissolved oxygen data of November 1, 1973 and November 20, 1973 also show an average background deficit of approximately 1.0 mg/l.

The dissolved oxygen deficit produced from the oxidation of organic wastewater discharges increments the background river dissolved oxygen deficit. It is not clear from an inspection of the measured deficit profile downstream of the Georgia Pacific wastewater discharge at Lyons Falls if the background deficit continues to persist throughout the "Flats" area. Analysis of the August and November survey data, however, indicates that a background deficit of approximately 1.0 mg/l exists in the Black River from Forestport to Carthage. Below Carthage it appears that the background deficit eventually decreases to zero as indicated by the November 20, 1973 dissolved oxygen data. One possible source of this background deficit is agricultural runoff.

## Dissolved Oxygen Model Verification

The segmented mathematical model schematically represented in Figure 16 was applied to the analysis of the Black River dissolved oxygen data collected on August 14, 1973, November 1, 1973, and November 20, 1973. The dissolved oxygen model includes the effects of fresh water advection, the oxidation of organic wastewater discharges, atmospheric reaeration, background water quality and reaeration at dams and natural falls. The dissolved oxygen data analyzed represent river conditions under a range of flow and temperature conditions. The flow at Watertown ranged from 1,400 cfs (39.6 cu m/sec) for the November 1, 1973 survey to 5,500 cfs (156 cu m/sec) for the November 20, 1973 survey. The average river temperature varied from 22°C for the August survey, to 2°C for the November 20, 1973 survey. The observed dissolved oxygen data and computed model responses are shown in Figures 17 and 18.

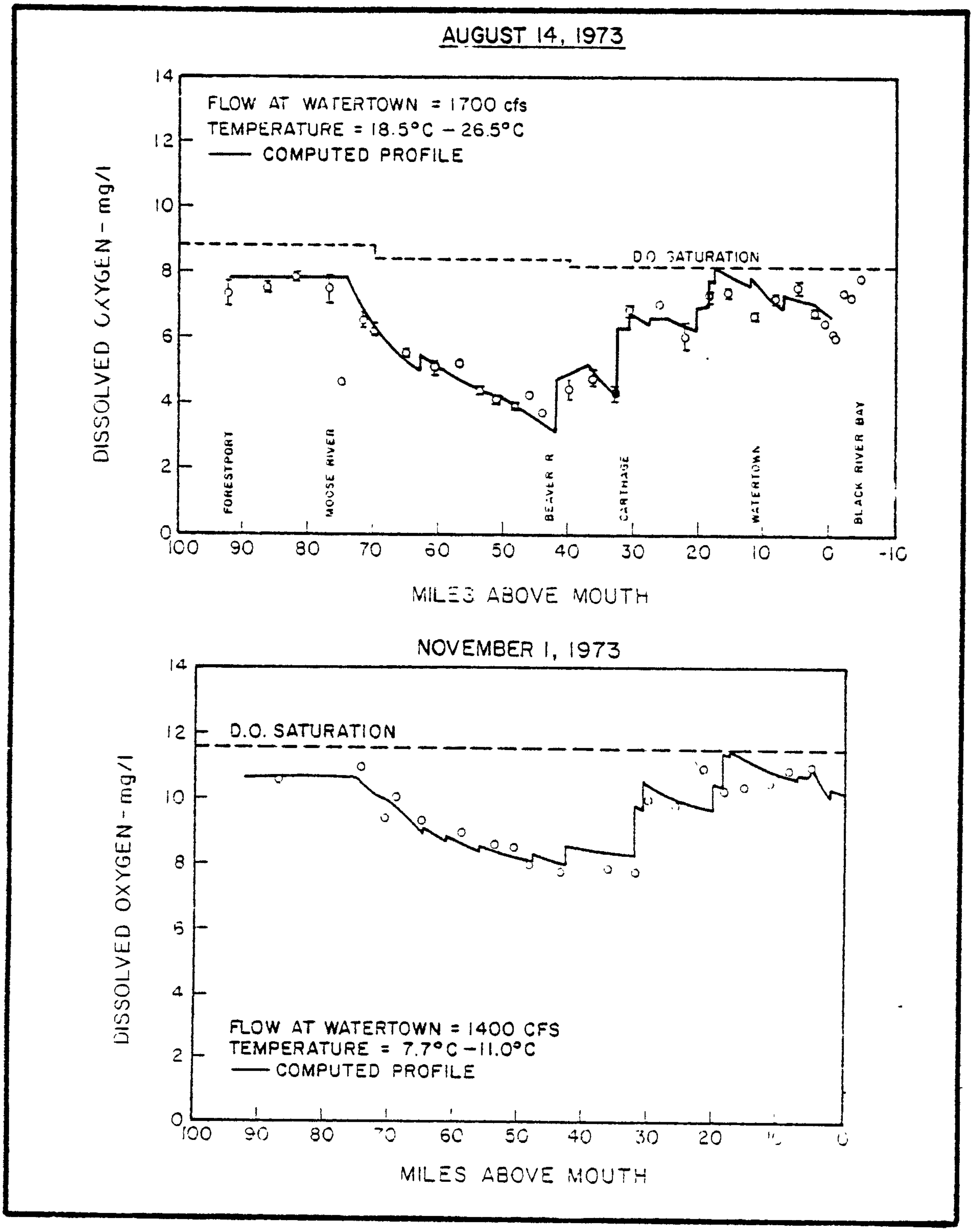


FIGURE 17

DISSOLVED OXYGEN MODEL VERIFICATION
(AUGUST 14, 1973 AND NOVEMBER 1, 1973)

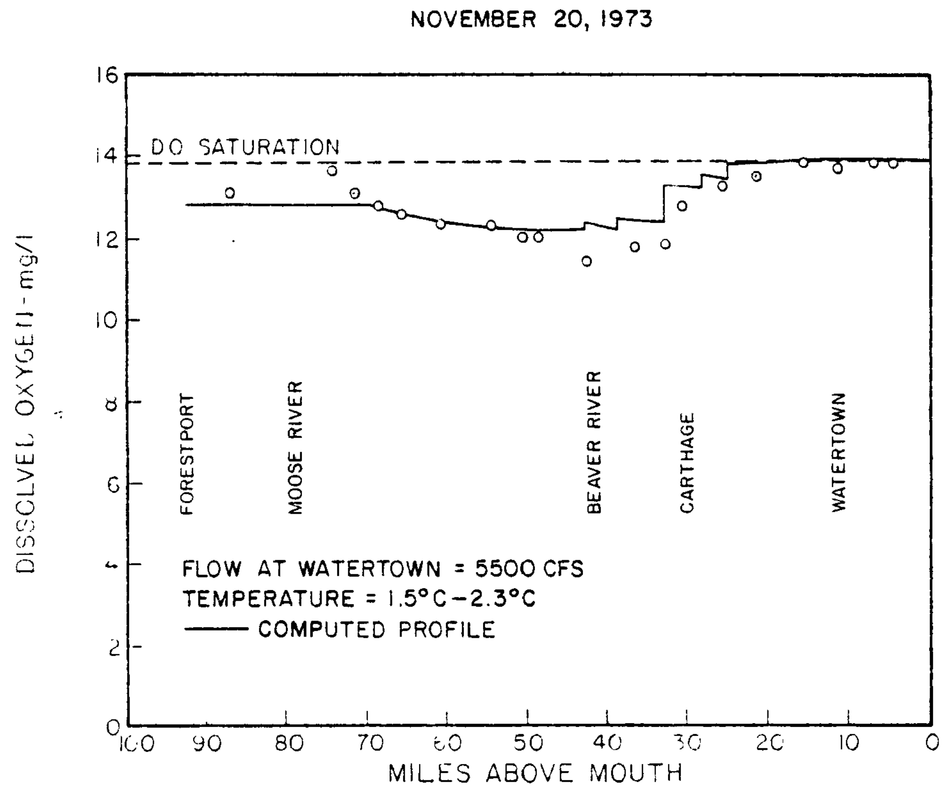


FIGURE 18

DISSOLVED OXYGEN MODEL VERIFICATION (NOVEMBER 20, 1973)

The August 14, 1973 and November 1, 1973 dissolved oxygen data presented in Figure 17 were collected at low flow conditions when the average flow at Watertown was 1,700 cfs (48.2 cu m/sec) and 1,400 cfs (39.6 cu m/sec) respectively. The average river temperature during the November 1, 1973 survey was 9°C versus the warmer 22°C temperature observed during the August survey. An effect of the lower river temperature is to increase the dissolved oxygen saturation value as indicated by the increase in saturation from approximately 8.4 mg/l in August to 11.6 mg/l for the November 1, 1973 survey.

The dissolved oxygen data collected during the November 20, 1973 survey is indicative of high flow and low river temperature conditions. The average flow at Watertown for this survey was about 5,500 cfs (156 cu m/sec). The river temperature ranged from 1.5°C to 2.3°C. As indicated on Figure 18 the decrease in the river temperature to 2°C results in an increase in the dissolved oxygen saturation to 13.8 mg/l which significantly increases the available dissolved oxygen resources of the river.

The two principal sinks of dissolved oxygen in the study area are the background conditions which are estimated to produce a constant dissolved oxygen deficit of 1.0 mg/l between Forestport and Carthage and the oxidation of the municipal and industrial wastewater discharges. The industrial wastewater loads, which are from paper companies, discharge approximately 128,000 lb/day (56,800 kg/day) of ultimate BOD versus 22,000 lb/day (10,000 kg/day) discharged from municipal sources. The industrial BOD is principally carbonaceous whereas the municipal BOD is approximately 30 percent nitrogenous. The stream oxidation rates for the carbonaceous and nitrogenous BOD were both assigned at 0.20/day at 20°C.

The pronounced dissolved oxygen sag downstream of Lyons Falls observed during the August 14, 1973 and November 1, 1973 survey and to a lesser extent during the November 20, 1973 survey is due primarily to the oxidation of the Georgia Pacific wastewater discharge at Lyons Falls. At the time of the November 1, 1973 survey, the measured ultimate BOD of the Georgia Pacific Pulp and Paper Company wastewater discharge was approximately 96,000 lb/day (43,500 kg/day). In addition to an organic loading, the Georgia Pacific wastewater discharge also contains sulfite. As previously indicated, it is believed that the sulfite is organically bound and, therefore, chemically oxidizes slowly. Based on a measured effluent sulfite concentration of 1,000 mg/l and a first order reaction rate of 1.0/day, the maximum deficit produced in the river by sulfite oxidation to sulfate is approximately 0.4 mg/l, during the August 14, 1973 and November 1, 1973 surveys and 0.1 mg/l during the November 20, 1973 survey.

Dissolved oxygen is added to the Black River by atmospheric reaeration, tributary flow, and reaeration at dams and natural falls. Dissolved oxygen added by atmospheric reaeration is dependent on the river dissolved oxygen deficit and the reaeration coefficient. In this study the reaeration coefficient was defined by the O'Connor-Dobbins equation previously presented as Equation (8). The amount of dissolved oxygen addition through tributary flow is related to the magnitude of the tributary flow and its dissolved oxygen concentration. The dissolved oxygen concentration associated with tributary flow was incorporated in the assignment of an average background deficit of 1.0 mg/l between Forestport and Carthage. As previously discussed, a correlation developed in the Mohawk River study was used to estimate the reaeration at dams and natural falls based on the height of fall and upstream dissolved oxygen deficit. The effect of dam reaeration on the Black River dissolved oxygen profile is clearly demonstrated by the sudden increase in river dissolved oxygen that occurs around milepoint 32, the location of the dams at Carthage.

The computed model responses shown in Figures 17 and 18 agree reasonably well with the observed river dissolved oxygen profiles. The model response represents the net effect on the river dissolved oxygen distribution of the various sources and sinks of dissolved oxygen previously discussed. The model has been tested over a range of flow and river temperature conditions which significantly affect the river dissolved oxygen distribution. The November 20, 1973 dissolved oxygen data and model response indicate the reduced river dissolved oxygen deficit which occurs as a result of the high river flow and low river temperatures. The high river flow provides greater dilution of the wastewater discharges and also more quickly flushes the diluted wastewater out of the Black River. The lower river temperature decreases the river deficit by decreasing the deoxygenation and atmospheric reaeration rates and increases the river dissolved oxygen by increasing the saturation level. To a lesser extent the effect of river temperature is seen by comparing the August 14, 1973 and November 1, 1973 survey data which were collected under similar flow conditions. For the colder November 1, 1973 survey, the river dissolved oxygen deficit is less and the overall level of river dissolved oxygen greater.

Although the dissolved oxygen model adquately defines the dissolved oxygen distribution in the Black River, there are some differences between the model response and observed data. In the August 14, 1973 survey the river dissolved oxygen concentration immediately downstream of the Georgia Pacific Paper Company discharge was measured as 4.7 mg/l. It is believed that complete lateral mixing of the river and the Georgia Pacific wastewater discharge had not occurred yet and consequently the field sample had a higher proportion of wastewater than would occur with complete lateral mixing. Differences between the model and observed data also occur in the analysis of the November 20, 1973 survey between the Beaver River and Carthage. This difference could be due to a change in background water quality or river geometry conditions different than those extrapolated from the U.S. Geological survey time of travel studies.

An unresolved problem encountered in the dissolved oxygen model verification was the discrepancy between the computed and measured river BOD distributions. The measured river $BOD_5$ and $BOD_{20}$ concentrations were significantly less than the computed BOD distributions which were based on BOD measurements of the wastewater discharges. It is believed that in the river BOD determinations, environmental conditions in the bottle did not permit the same degree of oxidation that apparently occurs in the natural river environment. It is possible in the Black River that the bacteria which carry on oxidation of the wastewaters reside on the river bed and, therefore, are not present in significant quantities in the water column from which the sample was taken. Additional studies should be conducted to define the bacterial oxidation mechanism in the Black River. Despite the difficulty experienced with the river BOD measurements, the correlation between the measured wastewater BOD concentrations and the observed river dissolved oxygen concentrations confirm the validity of the dissolved oxygen model as a tool for computing river dissolved oxygen distributions for projected wastewater discharges.

In addition to the Black River, a mathematical model was developed for the lower Beaver and Moose Rivers as indicated on the schematic in Figure 16. The dissolved oxygen data collected on the Moose and Beaver Rivers during the August survey are presented in Figure 5. These data indicate that dissolved oxygen levels are principally governed by background conditions because the dissolved oxygen concentration upstream of the wastewater discharges is nearly the same as downstream concentrations. The detention time of the wastewater discharges in these rivers is short so that minor oxidation occurs before the rivers flow into the Black River. Therefore, verification analyses of these rivers were not performed.

# SECTION IX

# DISSOLVED OXYGEN PROJECTIONS

The dissolved oxygen model of the Black River was used to evaluate the effect of projected wastewater discharges on the river dissolved oxygen distribution for the purpose of determining if river dissolved oxygen standards would be met. Projections were made for summertime low flow conditions which are critical with respect to dissolved oxygen. Dilution of wastewater discharges is at a minimum and the river dissolved oxygen saturation level at its lowest. Projected wastewater discharges are based on treatment levels of best practicable control technology currently available (BPCTCA) for industries and secondary treatment for municipal wastewaters. Projected spatial dissolved oxygen distributions are presented for all the wastewater discharges together and the three largest wastewater discharges individually.

## River Conditions Investigated

River dissolved oxygen projections were computed for the minimum average seven consecutive day flow that has a recurrence interval of once in ten years. Based on flow profiles presented in a New York State Department of Environmental Conservation Report [5] and information obtained from the Hudson River-Black River Regulating District, the flow distribution in the Black River for this condition was developed and is presented in Figure 19. The flow at Watertown is 800 cfs (15.4 cu m/sec) which is approximately two-thirds the average summer low flow of 1,200 cfs (34 cu m/sec). For this flow condition, the Beaver River flow per unit of drainage area is disproportionately high in comparison to the rest of the basin. This is a consequence of the Hudson River-Black River Regulating District policy of maintaining a minimum flow at Watertown of approximately 1,000 cfs (28.3 cu m/sec), thereby insuring adequate river flow for hydroelectric power generation.

The cross-sectional area and depth distribution of the Black River at this flow regime is also presented in Figure 19. Correlations developed from the U.S.G.S. time of travel studies as shown in Figure 13 were used to determine the river geometry. An effect of the reduced

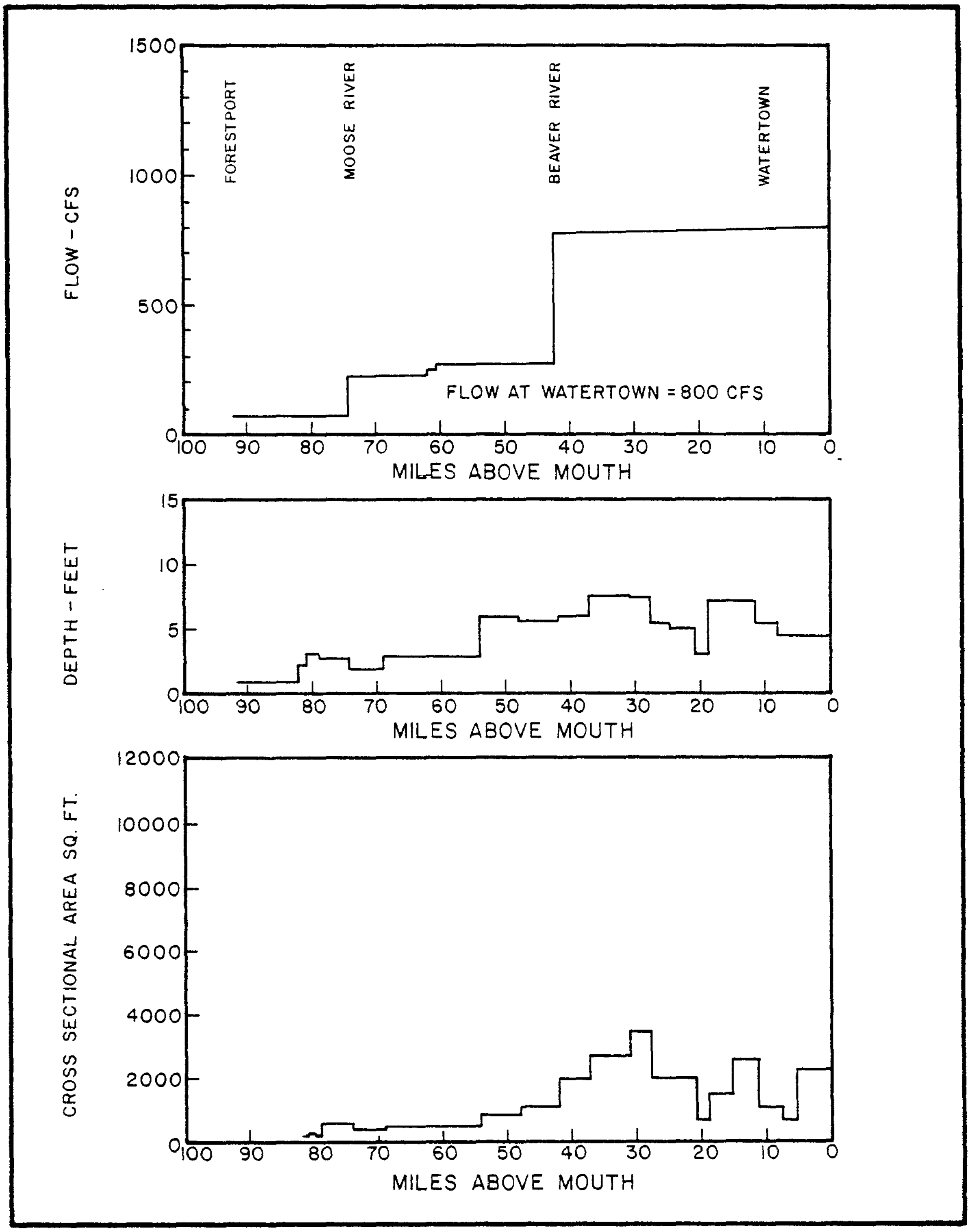


FIGURE 19

FLOW, DEPTH, AND CROSS SECTIONAL AREA DISTRIBUTION FOR LOW FLOW CONDITIONS flow and cross-sectional area is a lower average river velocity and, therefore, a longer residence time for the wastewaters discharged to the Black River.

Because low flow conditions occur during the warmer summer months, a river temperature of 25°C was used for projections. At this time of the year the dissolved oxygen resources of the river are at a minimum because of the reduced dissolved oxygen saturation level which at 25°C is 8.2 mg/l. The higher river temperature also increases the biochemical reaction rates and also the atmospheric reaeration rate. Because the biochemical oxidation rate increase with temperature is more than the reaeration rate increase, an additional effect of a higher river temperature is to generally produce a greater dissolved oxygen deficit than would occur under the same flow and loading conditions at a lower temperature.

## Wastewater Loads

The wastewater loads used in the projections are based on secondary treatment of the municipal loads and best practicable control technology currently available for the industrial discharges. Present wastewater volumes were used for projections because additional growth and industrial expansion is not anticipated. Population estimates (by the New York State Office of Planning Services) indicate that the Black River Basin population in the year 2020 will be 74,340 versus the 1970 population of 73,090.

A summary of the projected municipal wastewater discharges is presented in Table 12. The $BOD_5$ loading was based on an effluent $BOD_5$ concentration of 30 mg/l. The ultimate carbonaceous BOD was taken as 1.5 times the $BOD_5$. The nitrogen BOD was assigned as 4.5 times an effluent oxidizable nitrogen concentration of 20 mg/l. The Carthage wastewater treatment plant will treat the wastewater from the Climax and Crown Zellerbach Companies. Because these industrial wastes are deficient in nitrogen, the nitrogenous BOD for the Carthage treatment plant was computed from the estimated domestic portion of the wastewater flow.

The industrial wastewater discharges, which are presented in Table 13, are based on best practicable control technology currently available as defined by the Environmental Protection Agency. The BPCTCA wastewater load for each paper company is determined by the tons of product produced and a $BOD_5$/ton allocation based on the type of pulp and paper making process employed. The ultimate carbonaceous BOD

TABLE 12

SUMMARY OF PROJECTED MUNICIPAL WASTEWATER LOADS

| MUNICIPALITY | FLOW MGD | $BOD_5$ LB/DAY | NBOD LB/DAY | ULTIMATE BOD LB/DAY |
|---|---|---|---|---|
| Boonville | 0.95 | 237 | 710 | 1,066 |
| Port Leyden | 0.12 | 30 | 90 | 135 |
| Lowville | 0.69 | 172 | 520 | 779 |
| Castorland | 0.045 | 10 | 34 | 51 |
| Carthage | 10.8[1] | 2,700 | 1,070 | 5,123 |
| Deferiet | 0.08 | 20 | 60 | 90 |
| Watertown | 4.5 | 1,120 | 3,375 | 5,064 |
| Brownville | 0.28 | 70 | 210 | 315 |
| Dexter | 0.25 | 63 | 190 | 284 |

[1]Based on 150/gal./capita/day

TABLE 13

SUMMARY OF INDUSTRIAL WASTEWATER LOADS AFTER BPCTCA[1]

| | INDUSTRY | FLOW MGD | $BOD_5$ LB/DAY | NBOD LB/DAY | ULTIMATE BOD LB/DAY |
|---|---|---|---|---|---|
| 1. | Georgia Pacific | 6.1 | 5,600 | 200 | 14,200 |
| 2. | Burrows Paper | 1.1 | 120 | 5 | 245 |
| 3. | J. P. Lewis (Beaver Falls) | 2.6 | 590 | 153 | 1,335 |
| 4. | Latex Fiber | 1.5 | 63 | 467 | 595 |
| 5. | St. Regis | 13.8 | 3,800 | 102 | 7,700 |
| 6. | J. P. Lewis (Brownville) | 0.7 | 280 | 0 | 560 |

[1] Wastewater loads obtained from the U. S. Environmental Protection Agency and are subject to modification based upon final promulgation of BPCTCA guidelines by EPA.

was computed from the $BOD_5$ allocations by applying the average ultimate BOD to $BOD_5$ ratios measured during the study. The average for all the industries, except the Georgia Pacific Paper Company, was an ultimate carbonaceous BOD equal to twice the $BOD_5$. For the Georgia Pacific Paper Company, the measured ultimate carbonaceous BOD was 2.5 times the $BOD_5$. In addition to the carbonaceous BOD, the nitrogenous BOD was computed from the total Kjeldhal nitrogen concentration using the stoichiometric conversion of 4.5 mg of oxygen per mg of nitrogen oxidized to nitrate. The ultimate BOD tabulated in Table 13 is the sum of the carbonaceous and nitrogenous BOD.

It should be noted that the sulfite oxygen demand associated with the Georgia Pacific Paper Company wastewater was not included in the projections. It is believed that this chemical oxygen demand will be satisfied in the wastewater treatment process.

Spatial Dissolved Oxygen Profiles

Figure 20 presents the projected dissolved oxygen distribution associated with the discharge of the municipal and industrial wastewater loads contained in Tables 12 and 13 for critical river flow and temperature conditions. The deoxygenation and nitrification reaction rates used were both 0.20/day at 20°C. The appropriate temperature corrections were applied in determining the rates at 25°C. All tributary flow was assumed to be saturated with dissolved oxygen, but the effect of background water quality conditions was estimated by the assignment of a background dissolved oxygen deficit of 1.0 mg/l to the entire Black River. For a conservative estimate of river dissolved oxygen levels, reaeration at dams was not included in the projections.

The dissolved oxygen distribution in Figure 20 indicates that river dissolved oxygen standards will be met with BPCTCA wastewater treatment levels during design low flow conditions and a background dissolved oxygen deficit of 1.0 mg/l. The minimum dissolved oxygen concentration of 5.5 mg/l is projected to occur upstream of the confluence of the Beaver River. At this point the dissolved oxygen level is 0.5 mg/l above the river standard of 5.0 mg/l. Downstream of the Beaver River, the Black River projected dissolved oxygen level is well above the standards.

It should be noted that the dissolved oxygen projection in Figure 20 is for a background river dissolved oxygen deficit of 1.0 mg/l which was based on dissolved oxygen measurements made during the field program. The exact nature of this deficit is not known and, therefore, it cannot be assured that the background deficit in the future at low flow conditions will be 1.0 mg/l. Consequently, additional studies should be conducted to further define background water quality conditions in the Black River.

For this projection the municipal $BOD_5$ wastewater loading was computed based on an effluent $BOD_5$ concentration of 30 mg/l, which is the monthly average required by Federal regulations. It is recognized that a weekly BOD average of 45 mg/l is permitted by Federal law. If the maximum permissible weekly BOD loading should occur during the design low flow conditions, water quality standards will still be met.

In order to evaluate the effect on the Black River of the principal wastewater discharges, the dissolved oxygen

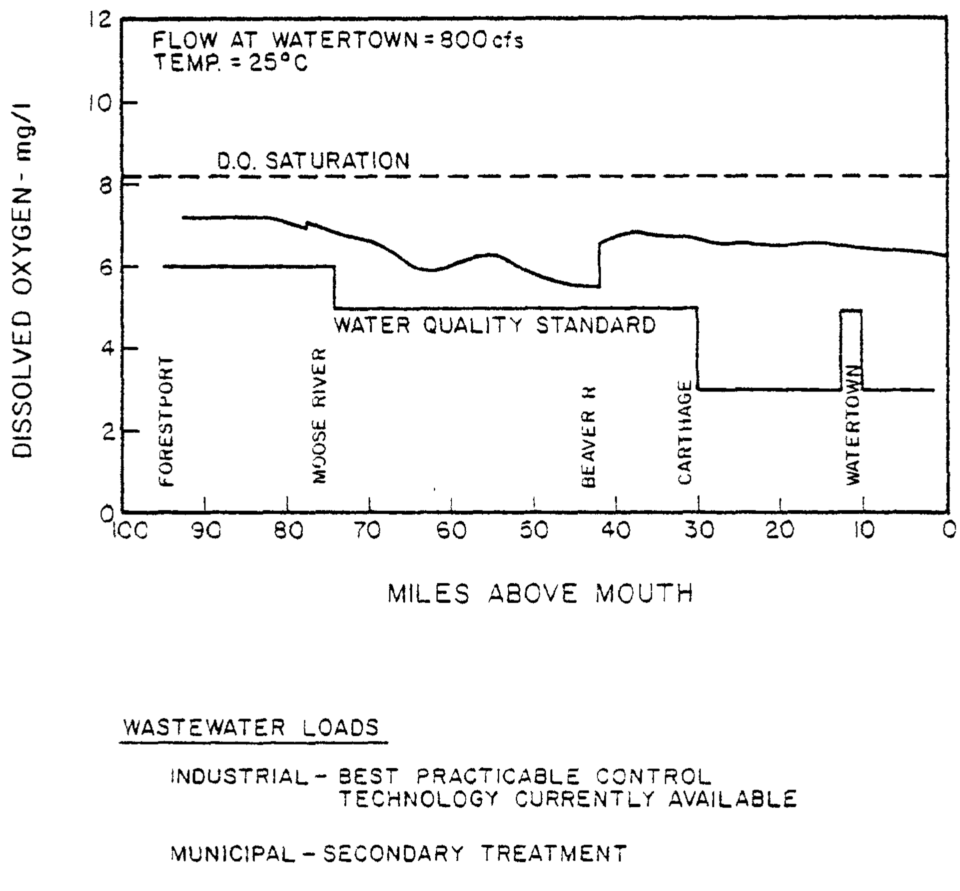


FIGURE 20

DISSOLVED OXYGEN PROJECTION
FOR LOW FLOW CONDITIONS

deficit distributions produced in the Black River by the three largest wastewater discharges are presented in Figure 21. The top profile is the model response for the Georgia Pacific Paper Company wastewater ultimate BOD discharge of 14,200 lb/day, (6,440 kg/day) which is 39 percent of the total projected wastewater loads. The Georgia Pacific discharge produces a maximum deficit of 1.6 mg/l immediately upstream of the confluence with the Beaver River. The dilution effect of the Beaver River is seen in the immediate decrease in the Black River deficit which occurs at milepoint 42.

The dissolved oxygen deficit distribution produced by the St. Regis Paper Company and Watertown wastewater discharges are shown in the middle and bottom profiles respectively. The St. Regis discharge, which is 7,700 lb/day of ultimate BOD, produces a maximum river deficit of approximately 0.4 mg/l. The effect of the Watertown wastewater discharge on the Black River dissolved oxygen level is minor because the wastewater is flushed into Black River Bay before significant oxidation occurs. Preliminary model analysis of Black River Bay indicates that the oxidation of wastewaters transported into the bay will not decrease dissolved oxygen levels below present standards.

Based on the results of this study, it is concluded that for a flow of 800 cfs at Watertown, a river temperature of 25°C, and wastewater treatment levels of best practicable control technology currently available for industrial discharges and conventional secondary treatment for municipalities, New York State water quality standards will be met.

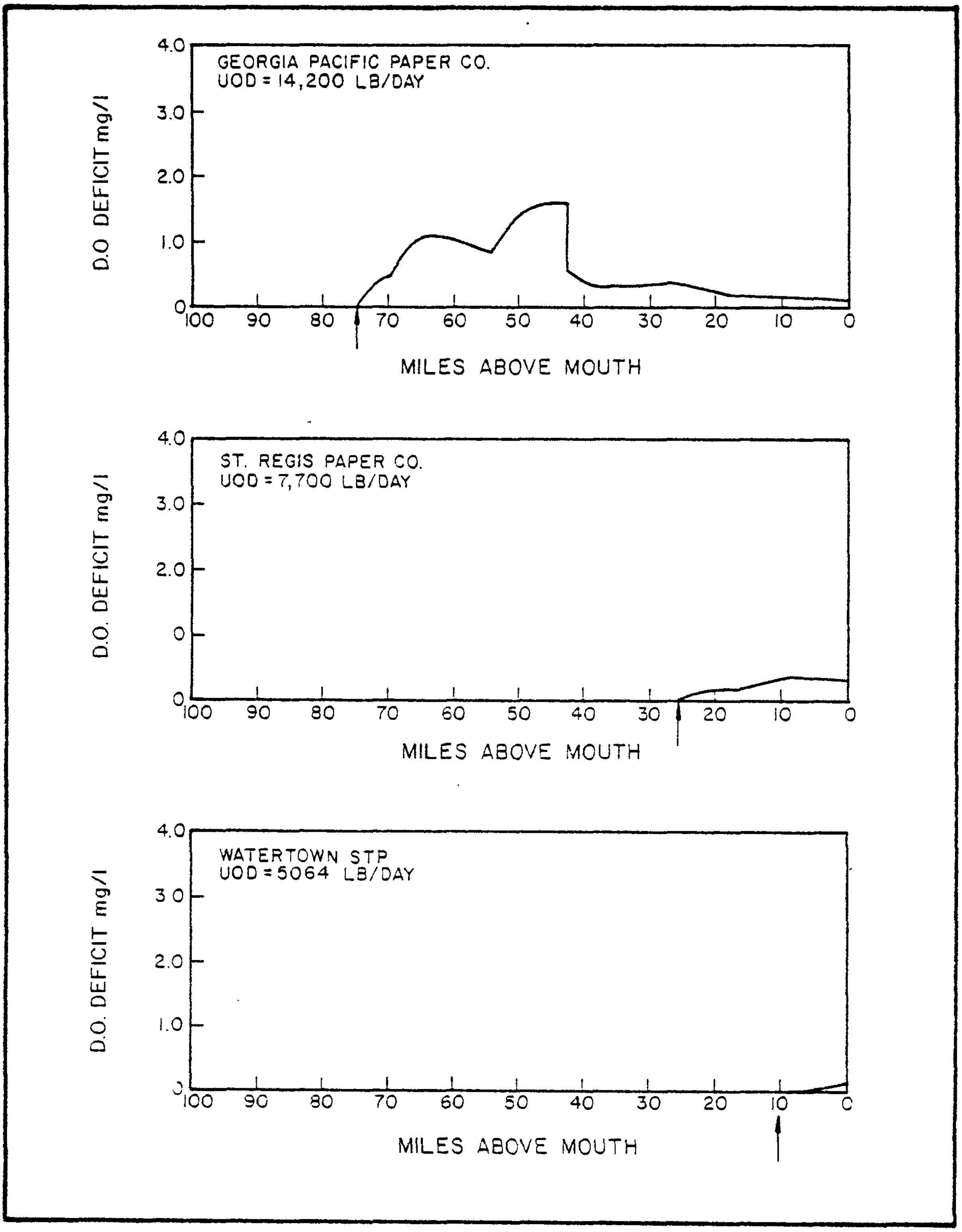


FIGURE 21

DISSOLVED OXYGEN DEFICIT PRODUCED BY INDIVIDUAL WASTEWATER DISCHARGES

SECTION X

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[3] O'Connor, D. J., "Water Quality Analysis of the Mohawk River - Barge Canal," New York State Department of Health, July, 1968.

[4] Black River Basin Regional Water Resources Planning Board, "Alternatives For Water Resources Management - Black River Basin," Technical Report, March, 1972.

[5] New York State Department of Environmental Conservation, "Black River Basin - Plan For Water Pollution Abatement," February, 1973.

## SECTION XI

## APPENDICES

# APPENDIX A

# 1973 WATER QUALITY DATA

TABLE 1

TEMPERATURE, DISSOLVED OXYGEN AND BOD DATA FOR THE BLACK RIVER
(August 14, 1973)

| STATION | A.M. TEMPERATURE °C | A.M. DISSOLVED OXYGEN mg/l | $BOD_5$ mg/l | P.M. TEMPERATURE °C | P.M. DISSOLVED OXYGEN mg/l |
|---|---|---|---|---|---|
| Black River | | | | | |
| 1 | 25.8 | 6.7 | 1.6 | 26.5 | 6.8 |
| 2 | 25.0 | 7.7 | 2.7 (3.1)[3] | 26.2 | 7.4 |
| 3 | 24.5 | 7.3 | 2.7 (4.1) | 25.8 | 7.2 |
| 4 | 24.5 | 6.7 | 1.5 | 25.5 | 6.8 |
| 5 | 24.0 | 7.0[1] 7.4[2] | 1.5 | 25.3 | 7.1[1] 7.3[2] |
| 6 | 23.7 | 7.2 | 1.4 | 25.7 | 7.3 |
| 7 | 22.7 | 5.6 | 1.6 (4.8)[3] | 25.2 | 6.5 |
| 9 | 22.7 | 6.9 | 1.3 | 25.7 | 6.9 |
| 11 | 21.7 | 6.8 | 1.9 | 24.8 | 7.0 |
| 12 | 22.0 | 4.5 | 1.3 | 25.0 | 4.2 |
| 13 | 22.5 | 4.7 | 2.1 | 25.0 | 5.0 |
| 14 | 21.0 | 4.1 | 2.4 | 24.0 | 4.7 |
| 14a | 20.8 | 3.7 | 2.6 | 23.8 | 4.2 |
| 15 | 21.2 | 4.1 | 2.8 (7.2)[3] | 23.0 | 4.0 |
| 16 | 21.7 | 4.4 | 3.0 | 23.0 | 4.5 |
| 17 | 21.8 | 5.4 | 3.4 | 23.2 | 4.9 |
| 18 | 21.6 | 5.4 | 4.8 | 20.2 | 5.4 |
| 19 | 21.4 | 6.5 | 5.7 (9.1)[3] | 21.0 | 6.0 |
| 19a | 21.4 | 6.6 | 7.1 | 20.8 | 6.3 |
| 20 | 21.2 | 7.4 | 1.3 | 20.7 | 7.7 |
| 21 | 20.0 | 7.1 | 1.0 | 20.3 | 7.7[1] 7.9[2] |
| 22 | 18.5 | 7.7 | 1.0 | 21.7 | 8.0 |
| 23 | 20.0 | 7.6 | .9 | 20.5 | 7.4 |
| 24 | 20.5 | 7.6 | .9 | 22.0 | 7.0[1] 7.6[2] |

TABLE 1 (Cont'd)

TEMPERATURE, DISSOLVED OXYGEN AND BOD DATA FOR THE BLACK RIVER
(August 14, 1973)

| STATION | A.M. TEMPERATURE °C | A.M. DISSOLVED OXYGEN mg/l | $BOD_5$ mg/l | P.M. TEMPERATURE °C | P.M. DISSOLVED OXYGEN mg/l |
|---|---|---|---|---|---|
| Black River Bay | | | | | |
| 25 | 23.7 | 6.5 | 1.5 | - | - |
| 26 | 23.5 | 6.1 | 1.7 | - | - |
| 27 | 23.5 | 6.0 | 1.5 | - | - |
| 28 | 24.0 | 7.4 | 2.6 | - | - |
| 29 | 24.3 | 7.3 | 2.5 | - | - |
| 30 | 24.3 | 7.8 | 2.0 | - | - |

[1]Above Dam
[2]Below Dam
[3]20 day BOD

TABLE 2

BLACK RIVER TRIBUTARY
TEMPERATURE, DISSOLVED OXYGEN AND BOD DATA FOR TRIBUTARIES
(August 14, 1973)

| STATION | A.M. TEMPERATURE °C | A.M. DISSOLVED OXYGEN mg/l | $BOD_5$ mg/l | P.M. TEMPERATURE °C | P.M. DISSOLVED OXYGEN mg/l |
|---|---|---|---|---|---|
| Moose River | | | | | |
| M1 | 21.4 | 7.3 | 1.0 | 19.9 | 7.7 |
| M2 | 20.6 | 8.0 | .7 | 20.0 | 7.9 |
| M3 | 19.6 | 8.2 | .8 | 20.0 | 7.8 |
| Beaver River | | | | | |
| B1 | 22.5 | 7.2 | 1.5 | 24.5 | 7.6 |
| B2 | 22.0 | 7.8 | 1.5 | 24.5 | 7.4 |
| B3 | 21.5 | 7.2 | .8 | 24.5 | 7.3[1] 7.6[2] |
| B4 | 22.2 | 6.6 | .9 | 24.3 | 7.2 |
| Deer River | | | | | |
| D1 | 18.5 | 8.0 | 2.7 | 24.0 | 7.5 |
| Independence River | | | | | |
| I1 | 19.5 | 7.9 | 1.6 | 20.5 | 7.3 |
| Sugar River | | | | | |
| MS1 | 18.5 | 8.3 | .9 | 21.9 | 8.5 |
| Perch River | | | | | |
| 31 | 22.5 | 4.9 | 1.2 | 27.2 | 5.5 |

TABLE 3

ADDITIONAL WATER QUALITY DATA FOR THE BLACK RIVER
(August 14, 1973)

| STATION | TOTAL SOLIDS mg/l | SUSPENDED SOLIDS mg/l | TURBIDITY JTU | pH | Chl. 'a' µg/l |
|---|---|---|---|---|---|
| Black River | | | | | |
| 1 | 80 | 6 | <25 | 7.0 | - |
| 2 | 78 | 8 | <25 | 6.8 | 2. |
| 3 | 74 | 6 | <25 | 7.0 | - |
| 4 | 72 | 6 | <25 | 7.1 | 3. |
| 5 | 71 | 6 | <25 | 6.9 | - |
| 6 | 76 | 6 | <25 | 7.1 | - |
| 7 | 64 | 4 | <25 | 6.8 | - |
| 9 | 71 | 3 | <25 | 7.1 | - |
| 11 | 67 | 7 | <25 | 7.0 | 3. |
| 12 | 64 | 5 | <25 | 6.9 | - |
| 13 | 62 | 14 | <25 | 6.9 | - |
| 14 | 39 | 7 | <25 | 6.9 | - |
| 14a | 73 | 5 | <25 | 7.0 | - |
| 15 | 72 | 7 | <25 | 6.9 | - |
| 16 | 73 | 9 | <25 | 6.8 | - |
| 17 | 68 | 8 | <25 | 6.9 | - |
| 18 | 76 | 5 | <25 | 6.7 | - |
| 19 | 76 | 7 | <25 | 6.9 | 2. |
| 19a | 76 | 10 | <25 | 6.7 | - |
| 20 | 72 | 4 | <25 | 7.2 | - |
| 21 | 71 | 8 | <25 | 7.3 | 2. |
| 22 | 65 | 7 | <25 | 7.4 | - |
| 23 | 59 | 3 | <25 | 7.1 | - |
| 24 | 43 | 4 | <25 | 7.2 | 4. |
| Black River Bay | | | | | |
| 25 | - | - | - | 7.2 | 3. |
| 26 | - | - | - | 7.1 | - |
| 27 | - | - | - | 7.2 | - |
| 28 | - | - | - | 8.2 | 50. |
| 29 | - | - | - | 7.6 | - |
| 30 | - | - | - | 8.0 | 22. |

TABLE 4

ADDITIONAL WATER QUALITY DATA FOR TRIBUTARIES
(August 14, 1973)

| STATION | TOTAL SOLIDS mg/l | SUSPENDED SOLIDS mg/l | TURBIDITY JTU | pH | Chl. 'a' µg/l |
|---|---|---|---|---|---|
| Moose River | | | | | |
| M1 | - | 5. | <25 | 7.0 | - |
| M2 | - | 6. | <25 | 6.7 | 4. |
| M3 | - | 6. | <25 | 7.2 | - |
| Beaver River | | | | | |
| B1 | - | 6. | <25 | 6.8 | - |
| B2 | - | 6. | <25 | 6.1 | - |
| B3 | - | 3. | <25 | 6.2 | - |
| B4 | - | 3. | <25 | 7.1 | - |
| Deer River | | | | | |
| D1 | - | 6. | <25 | 7.6 | - |
| Independence R. | | | | | |
| I1 | - | 8. | <25 | 7.3 | 4. |
| Sugar River | | | | | |
| MS1 | - | 8. | <25 | 7.0 | 3. |
| Perch River | | | | | |
| 31 | 120. | 13. | <25 | 8.3 | - |

## TABLE 5

### NITROGEN AND PHOSPHORUS DATA FOR THE BLACK RIVER AND TRIBUTARIES

| STATION | ORG-N mg/l | $NH_3$-N mg/l | $NO_2$-N mg/l | $NO_3$-N mg/l | TOTAL $PO_4$-P mg/l | FILT. $PO_4$-P mg/l |
|---|---|---|---|---|---|---|
| Black River | | | | | | |
| 1 | .38 | <.06 | .013 | .14 | .034 | .005 |
| 3 | .55 | <.05 | .022 | .13 | .025 | 0.0 |
| 4 | .49 | <.05 | .013 | .13 | .025 | .002 |
| 6 | .59 | <.05 | .024 | .12 | .032 | .005 |
| 11 | .58 | <.05 | .012 | .13 | .025 | 0.0 |
| 13 | .45 | <.05 | .011 | .16 | .022 | .012 |
| 15 | .58 | <.05 | .045 | .14 | .032 | .005 |
| 16 | .50 | <.05 | .031 | .14 | .024 | .005 |
| 19 | .58 | <.05 | .028 | .15 | .020 | .005 |
| 20 | .58 | <.05 | .013 | .20 | .022 | .005 |
| 22 | .49 | <.05 | .029 | .20 | .025 | .010 |
| 24 | .56 | <.05 | .025 | .14 | .021 | .005 |
| Black River Bay | | | | | | |
| 25 | .75 | <.05 | .018 | .13 | .048 | .015 |
| 28 | .65 | <.05 | .045 | .06 | .055 | .010 |
| 30 | .42 | <.05 | .012 | .02 | .035 | .008 |
| Perch River | | | | | | |
| 31 | .50 | <.05 | .017 | .06 | .148 | .098 |
| Deer River | | | | | | |
| D1 | .56 | <.05 | .015 | .06 | .068 | .020 |
| Beaver R. | | | | | | |
| B1 | .30 | <.05 | .016 | .19 | .024 | .006 |
| B4 | .36 | <.05 | .015 | .21 | .020 | .002 |
| Moose River | | | | | | |
| M1 | .36 | <.05 | .017 | .15 | .025 | .002 |
| M3 | .44 | <.05 | .017 | .16 | .028 | .002 |
| Independence R. | | | | | | |
| I1 | .59 | <.05 | .032 | .12 | .028 | .006 |
| Sugar River | | | | | | |
| MS1 | .42 | <.05 | .018 | .37 | .025 | 0.0 |

TABLE 6

COLIFORM DATA FOR THE BLACK RIVER AND TRIBUTARIES
(August 14, 1973)

| STATION | TOTAL COLIFORM number/100 ml | FECAL COLIFORM number/100 ml |
|---|---|---|
| Black River | | |
| 1 | 37,500. | 2,850. |
| 3 | 9,400. | 1,775. |
| 4 | 3,100. | 60. |
| 6 | 3,300. | 275. |
| 11 | 4,950. | 275. |
| 13 | 650. | 40. |
| 15 | 1,375. | 56. |
| 16 | 3,825. | 155. |
| 19 | 910. | 0. |
| 20 | 2,250. | 385. |
| 22 | 1,000. | 0. |
| 24 | 950. | 31. |
| Moose River | | |
| M1 | 1,685. | 26. |
| M3 | 1,030. | 20. |
| Beaver River | | |
| B1 | 1,775. | 0. |
| B4 | 30. | 13. |
| Deer River | | |
| D1 | 2,200. | 280. |
| Sugar River | | |
| MS1 | 1,345. | 275. |

TABLE 7

TEMPERATURE, DISSOLVED OXYGEN, AND BOD DATA
FOR THE BLACK RIVER AND TRIBUTARIES
(November 1, 1973)

| STATION | TEMPERATURE °C | DISSOLVED OXYGEN mg/l | BOD 5-DAY mg/l | BOD 20-DAY mg/l |
|---|---|---|---|---|
| Black River | | | | |
| 2 | 9.5 | 10.9 | 3.7 | 7.8 |
| 3 | 9.8 | 10.8 | 2.5 | 7.8 |
| 4 | 9.7 | 10.4 | 2.8 | 6.2 |
| 5 | 9.5 | 10.3 | 3.2 | 6.7 |
| 6 | 9.3 | 10.2 | 3.0 | 6.4 |
| 7 | 9.3 | 10.9 | 3.1 | 7.0 |
| 9 | 9.3 | 9.7 | 2.4 | 5.3 |
| 11 | 8.7 | 10.0 | 2.3 | 5.2 |
| 12 | 9.0 | 7.7 | 3.1 | 7.2 |
| 13 | 8.5 | 7.8 | 2.5 | 5.5 |
| 14a | 8.5 | 7.7 | 3.2 | 6.5 |
| 15 | 8.8 | 7.9 | 3.4 | 7.0 |
| 15a | 8.8 | 8.3 | 3.1 | - |
| 16 | 8.8 | 8.3 | 3.1 | 7.1 |
| 16a | 8.8 | 8.7 | - | - |
| 18 | 8.8 | 8.8 | 3.3 | 7.2 |
| 19 | 8.3 | 9.1 | 3.6 | 7.4 |
| 19a | 8.5 | 8.3 | 4.0 | 7.6 |
| 20 | 8.3 | 11.0 | 1.1 | 1.9 |
| 23 | 8.0 | 10.7 | 1.0 | 2.0 |
| Moose River | | | | |
| M1 | 8.3 | 10.9 | .8 | 1.9 |
| Beaver River | | | | |
| B1 | 9.3 | 10.4 | .9 | 2.1 |

TABLE 8

TEMPERATURE, DISSOLVED OXYGEN, AND BOD DATA
FOR THE BLACK RIVER AND TRIBUTARIES
(November 20, 1973)

| STATION | TEMPERATURE °C | DISSOLVED OXYGEN mg/l | BOD 5-DAY mg/l |
|---|---|---|---|
| Black River | | | |
| 2 | 2.0 | 14.2 | 1.7 |
| 3 | 2.3 | 14.0 | 2.7 |
| 4 | 2.1 | 13.7 | 1.5 |
| 5 | 1.4 | 14.0 | 1.7 |
| 7 | 1.6 | 13.5 | 1.7 |
| 9 | 1.5 | 13.2 | 1.5 |
| 11 | 1.4 | 12.8 | 1.8 |
| 12 | 1.3 | 11.9 | 1.8 |
| 13 | 2.1 | 11.8 | 1.8 |
| 14a | 1.6 | 11.5 | 1.8 |
| 15 | 2.0 | 12.0 | - |
| 15a | 1.9 | 12.0 | - |
| 16 | 1.5 | 12.3 | 1.7 |
| 17 | 1.5 | 12.3 | 1.9 |
| 18 | 1.8 | 12.6 | 2.2 |
| 19 | 2.0 | 12.8 | 2.3 |
| 19a | 1.6 | 13.1 | 2.0 |
| 20 | 1.8 | 13.7 | 1.0 |
| 23 | 1.5 | 13.1 | .7 |
| Beaver River | | | |
| B1 | 2.0 | 12.7 | 1.0 |
| Moose River | | | |
| M1 | .5 | 13.9 | .60 |

# APPENDIX B

# BIOLOGICAL DATA

TABLE 1

SUMMARY OF RIVER BIOLOGICAL DATA
(September 24-27, 1973)

| RIVER MILE POINT | ARTHROPODA: INSECTA | ARTHROPODA: CRUSTACIA | PLATYHELMINTHES | MOLLUSCA: GASTROPODA | MOLLUSCA: PELECYPODA | PORIFERA | ANNELIDA: OLIGOCHAETE | ANNELIDA: HIRUDINEA |
|---|---|---|---|---|---|---|---|---|
| 95. | (18) Trichoptera | (2) Cyclops | | | | | | |
| | (37) Ephemeroptera | (27) Amphipoda | | | | | | |
| | (2) Coleoptera | (15) Isopoda | | | | | | |
| 75. | (1) Diptera | (1) Amphipoda | (3) Planaria | (3) | | (TNC) | | |
| | (3) Trichoptera | (4) Cladocera | | | | | | |
| | | (4) Isopoda | | | | | | |
| 72. | (6) Ephemeroptera | (2) Isopoda | (7) Planaria | (3) | | | | |
| | (15) Diptera | | | | | | | |
| | (1) Coleoptera | | | | | | | |
| 70. | (15) Ephemeroptera | (4) Cladocera | | | | | | |
| | (29) Diptera | | | | | | | |
| 54. | (24) Trichoptera | (11) Cladocera | (2) Planaria | | | | (TNC) Dero | |
| | (7) Ephemeroptera | | | | | | | |
| | (3) Diptera | | | | | | | |
| | (1) Odonato | | | | | | | |
| 52. | (4) Trichoptera | | (27) Planaria | (3) | | | | |
| | (1) Ephemeroptera | | | | | | | |
| | (12) Coleoptera | | | | | | | |

TABLE 1 (Cont'd)

SUMMARY OF RIVER BIOLOGICAL DATA
(September 24-27, 1973)

| RIVER MILE POINT | ARTHROPODA | | | MOLLUSCA | | | ANNELIDA | |
|---|---|---|---|---|---|---|---|---|
| | INSECTA | CRUSTACIA | PLATYHELMINTHES | GASTRO-PODA | PELEC-YPODA | PROIF-ERA | OLIGO-CHAETE | HIRU-DINEA |
| 33. | (2) Trichoptera | (49) Cyclops<br>(11) Isopoda<br>(3) Cladacera | (9) Planaria | (7) | | | (1) Dero | (5) |
| 30. | (5) Trichoptera<br>(1) Ephemeroptera | (1) Cladocera<br>(1) Amphipoda | | (36) | (3) | | | |
| 11. | (TNC) Trichoptera<br>(TNC) Ephemeroptera<br>(2) Hemiptera<br>(1) Plecoptera | (40) Isopda | (TNC) Planaria | (TNC) | (17) | | | |
| 7.5 | (11) Odinata<br>(69) Trichoptera<br>(1) Plecoptera | | (27) Planaria | (3) | | | | |
| Bay<br>0.0 | (1) Cladocera<br>(3) Isopada | | (TNC) Planaria | (16) | | | | (7) |
| Moose River<br>8. | (30) Trichoptera<br>(TNC) Ephemeroptera<br>(1) Plecoptera<br>(12) Coleoptera<br>(1) Odonata | (3) Decapoda | (5) Planaria | | | | | |

TABLE 1 (Cont'd)

SUMMARY OF RIVER BIOLOGICAL DATA
(September 24-27, 1973)

| RIVER MILE POINT | ANTHROPODA | | | MOLLUSCA | | | ANNELIDA | |
|---|---|---|---|---|---|---|---|---|
| | INSECTA | CRUSTACIA | PLATYHELMINTHES | GASTROPODA | PELECYPODA | PROLIFERA | OLIGOCHAETE | HIRUDINEA |
| 0.0 | (7) Ephemeroptera | (2) Decapoda | | (1) | | | | |
| Beaver River | | | | | | | | |
| 8. | | (3) Cladacera | | | | | | (1) |
| 0.2 | (15) Coleoptera | | (5) Planaria | (3) | | | | |

# APPENDIX C

## RIVER GEOMETRY DATA AND REAERATION COEFFICIENTS

TABLE 1

VARIATION OF RIVER GEOMETRY WITH FLOW

| MODEL SEGMENT | STARTING MILEPOINT | ENDING MILEPOINT | AREA[1] | | DEPTH[2] | |
|---|---|---|---|---|---|---|
| | | | $C_a$ | a | $C_d$ | b |
| Black River | | | | | | |
| 1* | 92.8 | 92.0 | 3.4 | .74 | .21 | .37 |
| 2* | 92.0 | 89.5 | 3.4 | .74 | .21 | .37 |
| 3* | 89.5 | 86.8 | 3.4 | .74 | .21 | .37 |
| 4* | 86.8 | 84.7 | 3.4 | .74 | .21 | .37 |
| 5* | 84.7 | 81.7 | 3.4 | .74 | .21 | .37 |
| 6* | 81.7 | 80.2 | 3.4 | .74 | .21 | .37 |
| 7* | 80.2 | 79.0 | 8.1 | .72 | .47 | .37 |
| 8* | 79.0 | 78.0 | 10.5 | .74 | .67 | .37 |
| 9* | 78.0 | 77.3 | 8.8 | .74 | .67 | .37 |
| 10* | 77.3 | 77.1 | 8.8 | .74 | .67 | .37 |
| 11* | 77.1 | 76.6 | 23.7 | .74 | .53 | .37 |
| 12* | 76.6 | 74.6 | 23.7 | .74 | .53 | .37 |
| 13* | 74.6 | 74.3 | 58.0 | .60 | .22 | .60 |
| 20* | 74.3 | 74.2 | 58.0 | .60 | .22 | .60 |
| 21 | 74.2 | 69.4 | 14.1 | .60 | .32 | .40 |
| 22 | 69.4 | 64.7 | 14.1 | .60 | .32 | .40 |
| 23 | 64.7 | 61.5 | 17.4 | .60 | .32 | .42 |
| 24 | 61.5 | 54.0 | 17.4 | .60 | .32 | .42 |
| 25 | 54.0 | 48.1 | 209.0 | .25 | 5.30 | .03 |
| 26 | 48.1 | 42.5 | 293.0 | .25 | 5.00 | .03 |
| 34 | 42.5 | 37.5 | 5.2 | .82 | .03 | .72 |
| 35 | 37.5 | 32.2 | 365.0 | .30 | 3.00 | .14 |
| 36 | 32.2 | 30.8 | 365.0 | .30 | 3.00 | .14 |
| 37 | 30.8 | 27.3 | 145.0 | .48 | .82 | .33 |
| 38 | 27.3 | 25.7 | 527.0 | .20 | 1.46 | .20 |
| 39 | 25.7 | 25.0 | 527.0 | .20 | 1.46 | .20 |
| 40 | 25.0 | 24.2 | 303.0 | .28 | .90 | .26 |
| 41 | 24.2 | 20.6 | 303.0 | .28 | .90 | .26 |
| 42 | 20.6 | 19.1 | 26.2 | .52 | .20 | .39 |
| 43 | 19.1 | 18.4 | 652.0 | .13 | 6.80 | .01 |
| 44 | 18.4 | 15.8 | 652.0 | .13 | 6.80 | .01 |
| 45 | 15.8 | 11.4 | 346.0 | .30 | 4.01 | .10 |
| 46 | 11.4 | 9.0 | 190.0 | .26 | 1.85 | .16 |
| 47 | 9.0 | 8.4 | 190.0 | .26 | 1.85 | .16 |
| 48 | 8.4 | 7.8 | 9.5 | .63 | .26 | .43 |
| 49 | 7.8 | 7.4 | 9.5 | .63 | .26 | .43 |
| 50 | 7.4 | 7.1 | 9.5 | .63 | .26 | .43 |

TABLE 1 (Cont'd)

VARIATION OF RIVER GEOMETRY WITH FLOW

| MODEL SEGMENT | STARTING MILEPOINT | ENDING MILEPOINT | AREA[1] | | DEPTH[2] | |
|---|---|---|---|---|---|---|
| | | | $C_a$ | a | $C_d$ | b |
| 51 | 7.1 | 6.8 | 9.5 | .63 | .26 | .43 |
| 52 | 6.8 | 5.8 | 9.5 | .63 | .26 | .43 |
| 53 | 5.8 | 5.1 | 9.4 | .68 | .26 | .46 |
| 54 | 5.1 | 2.7 | 9.4 | .68 | .26 | .46 |
| 55 | 2.7 | 1.8 | 25.5 | .68 | .32 | .46 |
| 56 | 1.8 | -1.2 | 25.5 | .68 | .32 | .46 |
| 57 | -1.2 | -2.5 | 25.5 | .68 | .32 | .46 |
| 58 | -2.5 | -4.0 | 5,000 $Ft^2$ | .00 | 1 Ft | .00 |
| 59 | -4.0 | -6.0 | 200,000 $Ft^2$ | .00 | 40 Ft | .00 |
| Moose River | | | | | | |
| 15* | 3.4 | 3.2 | 50.0 | .30 | .53 | .30 |
| 16* | 3.2 | 1.5 | 50.0 | .30 | .53 | .30 |
| 17* | 1.5 | 1.2 | 50.0 | .30 | .53 | .30 |
| 18* | 1.2 | .2 | 50.0 | .30 | .53 | .30 |
| 19* | .2 | 0.0 | 208.0 | .30 | 1.07 | .30 |
| Beaver River | | | | | | |
| 28* | 11.1 | 8.0 | 70.5 | .30 | .45 | .30 |
| 29* | 8.0 | 5.1 | 70.5 | .30 | .45 | .30 |
| 30* | 5.1 | 4.9 | 70.5 | .30 | .45 | .30 |
| 31* | 4.9 | 4.8 | 70.5 | .30 | .45 | .30 |
| 32* | 4.8 | 4.6 | 70.5 | .30 | .45 | .30 |
| 33* | 4.6 | 0.0 | 70.5 | .30 | .45 | .30 |

[1]Area = $C_a \, Q^a$

[2]Depth = $C_d \, Q^B$

*Geometric shape of river bed assumed to remain the same as was measured during August, 1973 survey

TABLE 2

SUMMARY OF BLACK RIVER MODEL
REAERATION COEFFICIENTS AT 20°C

| MODEL SEGMENT | ATMOSPHERIC REAERATION RATE (1/DAY) | | | |
|---|---|---|---|---|
| | PROJECTIONS | AUGUST 14, 1973 | NOVEMBER 2, 1973 | NOVEMBER 20, 1973 |
| Black River | | | | |
| 1 | 12.21 | 6.15 | 6.98 | 5.10 |
| 2 | 12.21 | 6.39 | 6.98 | 5.10 |
| 3 | 12.21 | 6.39 | 6.98 | 4.85 |
| 4 | 12.21 | 6.58 | 6.98 | 4.87 |
| 5 | 12.21 | 6.58 | 7.26 | 4.60 |
| 6 | 12.21 | 6.77 | 7.26 | 4.38 |
| 7 | 2.20 | 1.26 | 1.08 | .82 |
| 8 | 1.14 | .63 | .55 | .44 |
| 9 | 1.29 | .63 | .65 | .79 |
| 10 | 1.29 | .63 | .65 | .79 |
| 11 | 1.08 | .65 | .85 | .38 |
| 12 | 1.08 | .65 | .85 | .39 |
| 13 | .90 | .37 | .33 | .33 |
| 20 | 1.34 | .45 | .20 | .40 |
| 21 | 4.08 | 2.75 | 2.44 | 1.60 |
| 22 | 1.47 | 1.65 | .95 | .60 |
| 23 | 1.73 | 1.11 | 1.02 | .58 |
| 24 | 1.73 | 1.18 | 1.04 | 1.02 |
| 25 | .45 | .75 | .65 | 1.11 |
| 26 | .45 | .60 | .66 | 1.11 |
| 34 | 1.58 | .74 | .98 | .64 |
| 35 | .34 | .34 | .37 | .47 |
| 36 | .34 | .34 | .27 | .20 |
| 37 | .31 | .38 | .28 | .58 |
| 38 | .65 | .87 | .64 | .68 |
| 39 | .65 | .87 | .64 | .68 |
| 40 | .73 | .54 | .64 | .68 |
| 41 | .73 | .54 | .64 | .68 |
| 42 | 2.66 | 1.75 | 2.26 | 1.43 |
| 43 | 2.66 | 1.24 | .58 | 1.05 |
| 44 | .48 | .61 | .58 | 1.05 |
| 45 | .48 | .61 | .36 | .45 |
| 46 | .34 | .26 | .95 | 1.15 |
| 47 | .34 | .26 | .95 | 1.15 |
| 48 | .91 | 1.20 | 1.19 | .50 |
| 49 | .91 | 1.20 | 1.19 | .50 |
| 50 | .91 | 1.20 | 1.19 | .50 |

TABLE 2 (Cont'd)

SUMMARY OF BLACK RIVER MODEL
REAERATION COEFFICIENTS AT 20°C

| MODEL SEGMENT | ATMOSPHERIC REAERATION RATE (1/DAY) | | | |
|---|---|---|---|---|
| | PROJECTIONS | AUGUST 14, 1973 | NOVEMBER 2, 1973 | NOVEMBER 20, 1973 |
| 51 | .91 | 1.20 | 1.19 | .50 |
| 52 | .91 | 1.37 | 1.19 | .50 |
| 53 | 1.52 | 2.07 | .32 | .14 |
| 54 | 1.52 | .96 | .32 | .14 |
| 55 | .42 | 1.72 | 1.56 | .79 |
| 56 | .42 | .43 | .38 | .79 |
| 57 | .42 | .43 | .39 | .79 |
| 58 | 5.34 | 7.60 | 6.82 | 13.84 |
| 59 | .004 | .005 | .005 | .009 |
| Moose River | | | | |
| 15 | 3.16 | 2.82 | 2.72 | 2.16 |
| 16 | 3.16 | 2.82 | 2.72 | 2.16 |
| 17 | 3.16 | 2.82 | 2.72 | 2.16 |
| 18 | .42 | .40 | .38 | .35 |
| 19 | .42 | .40 | .38 | .35 |
| Beaver River | | | | |
| 28 | 2.69 | 2.50 | 2.66 | 2.43 |
| 29 | 2.69 | 2.50 | 2.66 | 2.43 |
| 30 | 2.69 | 2.50 | 2.66 | 2.43 |
| 31 | 2.69 | 2.50 | 2.66 | 2.43 |
| 32 | 2.69 | 2.50 | 2.66 | 2.43 |
| 33 | 2.69 | 1.11 | 2.66 | 2.43 |

| | | | |
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16. Abstracts A verified dissolved oxygen model was used to project the effect of proposed wastewater discharges on the dissolved oxygen level of the Black River in New York State. The proposed wastewater discharges represent best practical control technology currently available for the industries and conventional secondary treatment for municipalities. The results indicate that for design low flow conditions New York State D.O. standards will be met.

Historical water quality data were reviewed and a field program conducted to identify existing water quality problems in the Black River. A dissolved oxygen model was developed to define the relationship between wastewater discharges and river dissolved oxygen levels and to identify other factors that affect the dissolved oxygen concentration in the Black River.


17. Key Words and Document Analysis. 17a. Descriptors

Water Quality, Water Pollution

17b. Identifiers/Open-Ended Terms

Black River, Lake Ontario, Great Lakes, Chemical Parameters, Biological Parameters

17c. COSATI Field/Group 13B 6F

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