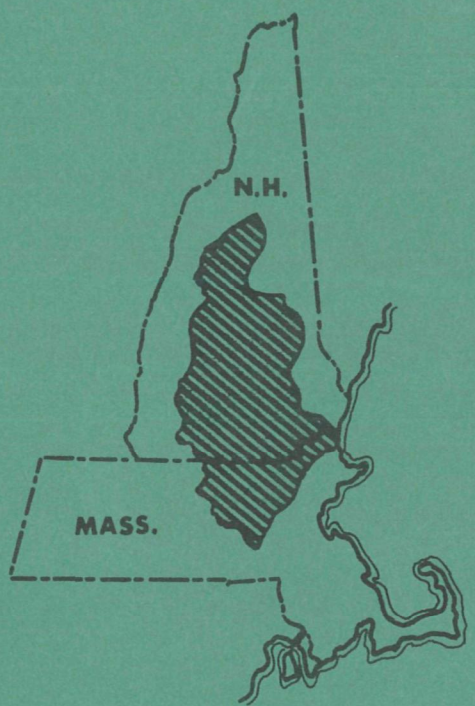
REPORT ON POLLUTION OF THE MERRIMACK RIVER AND CERTAIN TRIBUTARIES —

part I - Summary, Conclusions and Recommendations



U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Northeast Region
Boston, Massachusetts
December, 1968

REPORT ON POLLUTION OF

THE MERRIMACK RIVER

AND CERTAIN TRIBUTARIES

PART I -- SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

U. S. Department of the Interior
Federal Water Pollution Control Administration
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SUMMARY

The Merrimack River is polluted by the discharge of raw and partially treated municipal and industrial wastes for most of its length in New Hampshire and Massachusetts. Every day more than 120 million gallons of waste water flow into the Merrimack River alone, polluting it physically, bacteriologically, and chemically. This polluted condition, which has been recognized since the turn of the century, will become progressively worse unless effective abatement action is taken immediately.

The major sources of raw or inadequately treated municipal waste discharged to the Merrimack River Basin are:

New Hampshire

Allenstown	Hooksett	Nashua
Bristol	Lincoln	Pembroke
Concord	Manchester	Plymouth
Franklin	Milford	Wilton

Massachusetts

Amesbury	Groveland	Lowell
Andover	Haverhill	Methuen
Clinton	Lawrence	Newburyport
Dracut	Leominster	North Andover
Fitchburg		Salisbury

The major sources of industrial waste discharged to the Merrimack River Basin are:

New Hampshire

Ashland Paper Mills, Ashland
Foster Grant Co., Manchester
Franconia Paper Corp., Lincoln
Granite State Packing Co., Manchester
Granite State Tanning Co., Nashua
Merrimack Leather Co., Merrimack

Massachusetts

Continental Can Co., Haverhill
Falulah Paper Co., Fitchburg
Fitchburg Paper Co., Fitchburg
Foster Grant Co., Leominster
Gilet Wool Scouring Corp., Chelmsford
Lawrence Wool Scouring Co., Lawrence
Lowell Rendering Co., Billerica
Mead Corp., Lawrence
Oxford Paper Co., Lawrence
Southwell Combing Co., Chelmsford
St. Regis Paper Co., Pepperell
Weyerhaeuser Paper Co., Fitchburg

Suspended solids in waste discharges in the study area were equivalent to those in the raw sewage of 1,653,000 persons, with 72 per cent originating in Massachusetts. These materials cause deep sludge deposits which deplete the stream oxygen supply, produce offensive odors, reduce or eliminate aquatic life which serves as food for fish, and make once attractive waters appear murky.

Coliform bacteria equivalent to those in the raw sewage from 416,000 persons are discharged to the Merrimack River and its tributaries at the present time, with 34 per cent originating in New Hampshire and 66 per cent originating in Massachusetts. Sewage effluents receiving no treatment account for 92 per cent of the total coliform bacteria in the stream.

Nashua and Hudson, New Hampshire, contributed over 98 per cent of the coliform bacteria at the New Hampshire-Massachusetts state line during warm low-flow periods. However, with colder water temperatures and increased flows in the autumn, the Nashua-Hudson portion at the state line was reduced to 50 per cent; Manchester, New Hampshire, was responsible for 25 per cent of the total; and other upstream communities were responsible for 25 per cent. Of the bacteria originating from upstream communities and reaching Newburyport, Massachusetts, 51.4 per cent emanated from the Lawrence region, 17.1 per cent from the Haverhill region, 31.4 per cent from the Amesbury area, and 0.1 per cent from the remaining upstream communities.

Coliform densities as high as 9,200,000 per 100 milliliters (ml) were found in the Merrimack River. This value, found below Lawrence, is 1,850 times the recommended maximum value of 5,000 per 100 ml. (One hundred milliliters of water is slightly less than one-half cup.) This excessive bacterial pollution presents a health hazard to all who come in contact with the water.

Disease-producing bacteria of the genus Salmonella were consistently recovered from the Merrimack in both New Hampshire and Massachusetts, indicating that ingestion of any water from the Merrimack River before it is treated or of produce from truck farms using untreated river water for irrigation is a definite health hazard. Salmonellae were isolated during every test made at the Lowell and Lawrence, Massachusetts, water intakes. Typhoid fever, gastroenteritis, and diarrhea are a few of the many diseases of man caused by these bacteria.

Sewage and industrial wastes presently discharged to the basin have an estimated biochemical oxygen demand (BOD) equivalent to that in the untreated sewage of 1,422,000 persons, of which 693,000 population equivalents are discharged in New Hampshire. BOD is a measure of the ability of a waste to deplete the dissolved oxygen resource of a stream.

Serious depletion of the dissolved oxygen content of the Merrimack River occurred during the study period. For the months of June, July, August, and September of 1964 and 1965, minimum dissolved oxygen from Manchester to Newburyport was less than 2.0 ppm at every station; zero values were found below Haverhill. At no point upstream of Manchester was the minimum value in excess of 5.0 ppm. A value of 5.0 ppm for at least 16 hours a day is one requirement of the New England Interstate Water Pollution Control Commission for Class C waters, C being the class of water considered acceptable for recreational boating, fish habitat, and industrial water supply but not for swimming or drinking under normal conditions. Using BOD as an indicator, the most polluted reach of the Merrimack River was between Lawrence and Haverhill, Massachusetts.

BOD crossing the state line from New Hampshire into Massachusetts amounted to 28,800 pounds per day. This is equivalent to the BOD of raw sewage from 169,000 persons. As a result of the reduction in dissolved oxygen, fish, fish food organisms, and other desirable forms of aquatic life are destroyed. In addition, when the dissolved oxygen content of the river is sufficiently low, obnoxious gases are given off by the stream, forcing unsightly clumps of sludge to rise to the surface.

Biological stream studies showed that, with few exceptions, the entire length of the Merrimack River is grossly polluted from Franklin, New Hampshire, to its mouth at Newburyport, Massachusetts. Those desirable benthic organisms sensitive in their response to pollution were absent in the lower 57 miles of the Merrimack River. In only four areas did the river recover enough from its despoiled condition to permit a small number of sensitive organisms to exist before additional wastes reduced the quality of the river.

Serious pollution exists in the North Nashua River from the outfall of the Weyerhaeuser Paper Company, Fitchburg, Massachusetts, to the confluence of the north and south branches of the Nashua River at Lancaster, Massachusetts; in the Nashua River from Lancaster to the mouth of the Nashua River in New Hampshire; in the Squannacook River below the dam at Vose Village; and in the South Branch Nashua River below Clinton, Massachusetts. This pollution affects present and potential water uses.

Discharges from paper mills result in suspended solids, organic matter causing biochemical oxygen demand, and materials causing apparent color in the stream. By far the largest loadings emanate from the three paper industries of Fitchburg, Massachusetts. Excessive bacterial densities, suspended solids, nutrients, and organic matter are the result of inadequate sewage treatment, particularly at Fitchburg and Leominster, Massachusetts.

Discharges of suspended solids create a severe problem in the Nashua River. Suspended solids discharged to the Nashua River Basin are equivalent to those in the raw sewage from 556,000 persons. Of these, nearly

92 per cent come from the paper mills. It is estimated that 17 million cubic feet of sediments have accumulated in Pepperell Pond alone.

Bacteria equivalent to those in the raw sewage of approximately 24,000 persons are discharged to the Nashua River Basin at present. Fitchburg and Leominster, Massachusetts, contribute 90 per cent of the total. The coliform bacteria in the North Nashua River were as high as 680 times the recommended maximum value of 5,000 per 100 ml for this stream. Disease-causing bacteria were isolated in both the North Nashua and the South Branch Nashua Rivers.

Sewage and industrial wastes presently discharged to the Nashua River Basin have an estimated biochemical oxygen demand population equivalent of 178,000, of which the paper industries contribute 76 per cent of the total. As a result of the reduction in dissolved oxygen, fish, fish food organisms, and other desirable aquatic life are destroyed, and obnoxious odors are given off by the stream.

Nutrients discharged to the Nashua River Basin result in excessive densities of algae and other aquatic plants, creating a nuisance. These plants may die and decompose, causing unsightly conditions, obnoxious odors, and depletion of dissolved oxygen.

Serious pollution exists in the Pemigewasset River from the confluence with the East Branch Pemigewasset River in Lincoln, New Hampshire, to the confluence of the Winnipesaukee River in Franklin, New Hampshire, due to the discharge of sewage and industrial wastes in the basin.

Suspended solids discharged to the Pemigewasset River watershed are equivalent to those in the raw sewage of 287,500 persons, of which over

98 per cent emanate from industrial plants. These solids result in sludge deposits, especially in the impoundment behind Ayers Island Dam. Hydrogen sulfide, resulting from sludge deposits behind this dam, caused thousands of dollars of damage to houses in Bristol, New Hampshire, on August 18, 1965, and on August 23, 1966, by discoloring the paint on the houses.

Sulfite waste liquor, released to the Pemigewasset River by the Franconia Paper Corporation, not only creates an enormous oxygen demand but also contains lignin sulfonates which persist as the waters flow into Massachusetts. As a result of the sulfite waste liquor, the river is discolored, adding to the water treatment costs at Lowell and Lawrence, Massachusetts.

Restricted recreational use of the Merrimack and its tributaries due to their polluted conditions alone caused an estimated loss of $21,300,000 in 1964. There is presently a very limited amount of fishing in the basin, but the U. S. Fish and Wildlife Service has expressed interest in reintroducing salmon and other anadromous fish to the streams once the pollution has been abated.

In 1964 the value of the soft-shell clam harvest amounted to only $14,000 of a potential $1,000,000. Discharges to the Merrimack River estuary from existing sewage treatment plants significantly contribute to the bacterial densities near the shellfish growing areas.

An even greater loss can be attributed to decreased property values and the resulting decrease in the tax revenues caused by the polluted

condition of the Merrimack River and its tributaries. In 1964 these losses to communities in the basin amounted to about $14,600,000.

It is estimated that between $37,000,000 and $70,000,000 is being lost annually as a result of pollution in the Merrimack River Basin.

Although the Merrimack River is now used for industrial process water, cooling water, and for hydroelectric power, sand filters and other treatment methods are often employed at the industry's expense to pre-condition the water before it can be used. An increase in industrial development could be expected once the basin communities can offer improved water quality.

The Merrimack is also used as a municipal water supply for Lowell and Lawrence, Massachusetts. As the population in the basin increases, more and more communities will be turning to the Merrimack to meet their water needs because it is the only water supply of sufficient quantity to meet the demand. Eight basin communities have already expressed interest in the use of the river. Well-designed and efficient sewage treatment plants will be necessary to ensure adequate water quality.

Sewage and industrial wastes continue to be discharged to the Merrimack River and its tributaries in New Hampshire, causing pollution which endangers the health or welfare of persons in Massachusetts; the sewage and industrial wastes discharged to the Merrimack River and its tributaries in Massachusetts cause pollution which endangers the health or welfare of persons in New Hampshire and Massachusetts. Therefore, this pollution is subject to abatement under the provisions of the Federal Water Pollution Control Act (33 U. S. C. 466 et seq.).

INTRODUCTION

In accordance with the written request to the Secretary of Health, Education, and Welfare from the Honorable Endicott Peabody, former Governor of Massachusetts, dated February 12, 1963, and on the basis of reports, surveys, or studies, the Secretary of Health, Education, and Welfare, on September 23, 1963, called a conference under the provisions of the Federal Water Pollution Control Act (33 U. S. C. 466 et seq.) in the matter of pollution of the interstate waters of the Merrimack and Nashua Rivers and their tributaries (Massachusetts-New Hampshire) and the intrastate portions of those waters within the State of Massachusetts. The conference was held February 11, 1964, in Faneuil Hall, Boston, Massachusetts. Pollution sources and the effects of their discharges on water quality were described at the conference.

In February, 1964, the U. S. Department of Health, Education, and Welfare established the Merrimack River Project to study the Merrimack River Basin. The basic objectives were twofold:

1. Evaluation of the adequacy of the pollution abatement measures proposed for the Merrimack River within Massachusetts.
2. Development of adequate data on the water quality of the Merrimack River and its tributaries. Waters in both New Hampshire and Massachusetts were to be studied.

Headquarters for the Project were established at the Lawrence Experiment Station of the Commonwealth of Massachusetts, Lawrence, Massachusetts. The Project became operational July 1, 1964.

During the first year of operation, efforts were concentrated primarily in the Massachusetts section of the Merrimack River. Second year studies were mainly of the New Hampshire sections involving suspected interstate pollution and of the Nashua River.

STREAM STUDIES -- PHYSICAL, CHEMICAL, AND BACTERIOLOGICAL

Study Area

The Merrimack River Basin lies in central New England and extends from the White Mountains in New Hampshire southward into northeastern Massachusetts. Through New Hampshire, the river flows in a southerly direction. Upon entering Massachusetts, the river flows easterly for 45 miles, emptying into the Atlantic Ocean at Newburyport, Massachusetts. The lower 22 miles of the river are tidal. Lands drained by the Merrimack River consist of 5,010 square miles, of which 3,800 square miles are in New Hampshire, while 1,210 square miles lie in Massachusetts.

The 1960 population within the Merrimack River Basin is estimated to be 1,072,000, of which 747,000 are in Massachusetts and 325,000 are in New Hampshire. For the most part, the population centers are located along the Merrimack River.

Precipitation is distributed fairly uniformly throughout the year, and frequent but generally short periods of heavy precipitation are common in the basin. The southeastern part of the watershed, because of its proximity to the Atlantic Ocean, does not undergo the extremes of temperature and depth of snow found in New Hampshire at the higher elevations.

Pollution Sources

The Merrimack River is polluted by the discharge of raw and partially treated municipal and industrial wastes for most of its length in New Hampshire and Massachusetts. Every day more than 120 million gallons of waste water flow into the Merrimack River. The river is polluted bacteriologically, physically, and chemically. This polluted condition, which has been recognized since the turn of the century, will become progressively worse unless effective abatement action is taken immediately.

Coliform bacteria, equivalent to those in the raw sewage from 416,000 persons, are discharged to the Merrimack River Basin. Thirty-four per cent of the bacteria are discharged in New Hampshire; the remaining 66 per cent in Massachusetts. These bacteria are discharged by the New Hampshire communities of Allenstown, Boscawen, Concord, Derry, Franklin, Hooksett, Hudson, Manchester, Merrimack, Milford, Nashua, Pembroke, Salem, and Wilton and by the Massachusetts communities of Amesbury, Andover, Ayer, Billerica, Clinton, Concord, Dracut, Fitchburg, Groveland, Haverhill, Lancaster, Lawrence, Leominster, Lowell, Marlborough, Maynard, Methuen, Newburyport, North Andover, Pepperell, Salisbury, Shirley, and Westborough.

The suspended solids in the discharges to the study area are equivalent to those in the raw sewage of 1,653,000 persons. Seventy-two per cent of those solids originate in Massachusetts. Major sources of suspended solids in New Hampshire are the communities of Concord, Franklin, Manchester, Milford, and Nashua and the industries of Brezner Tanning Corp., Boscawen; Franconia Paper Corp., Lincoln; Granite State

Packing Co., Manchester; Granite State Tanning Co., Nashua; Hillsborough Mills, Wilton; Merrimack Leather Co., Merrimack; and Seal Tanning Co., Manchester. Massachusetts sources are the communities of Amesbury, Andover, Fitchburg, Haverhill, Lawrence, Leominster, Lowell, Methuen, Newburyport, and North Andover and the industries of Amesbury Fibre Corp., Amesbury; Commodore Foods, Inc., Lowell; Continental Can Co., Haverhill; Falulah Paper Co., Fitchburg; Foster Grant Co., Leominster; Fitchburg Paper Co., Fitchburg; Gilet Wool Scouring Corp., Chelmsford; Groton Leatherboard Co., Groton; H. E. Fletcher Co., Chelmsford; Hoyt & Worthen Tanning Corp., Haverhill; Jean-Allen Products Co., Lowell; Lawrence Wool Scouring Co., Lawrence; Lowell Rendering Co., Billerica; Mead Corp., Lawrence; Merrimack Paper Co., Lawrence; Oxford Paper Co., Lawrence; Southwell Combing Co., Chelmsford; St. Regis Paper Co., Pepperell; and Weyerhaeuser Paper Co., Fitchburg.

Sewage and industrial wastes presently discharged in the basin have an estimated biochemical oxygen demand equivalent to that in the untreated sewage of 1,422,000 persons, of which 693,000 population equivalents are discharged in New Hampshire. The following communities and industries are the major contributors of this BOD to the study area: In New Hampshire, the communities are Concord, Franklin, Manchester, Milford, and Nashua, and the industries are Foster Grant Co., Manchester; Franconia Paper Corp., Lincoln; Granite State Tanning Co., Nashua; Hillsborough Mills, Wilton; Merrimack Leather Co., Merrimack; MKM Knitting Mills, Inc., Manchester; M. Schwer Realty Co., Manchester; Seal Tanning Co., Manchester; Stephen Spinning Co., Manchester; and Waumbec Mills, Inc., Manchester.

In Massachusetts, the communities are Amesbury, Andover, Fitchburg, Haverhill, Lawrence, Leominster, Lowell, Methuen, Newburyport, North Andover, and Westborough, and the industries are Amesbury Fibre Corp., Amesbury; Commodore Foods, Inc., Lowell; Continental Can Co., Haverhill; Falulah Paper Co., Fitchburg; Fitchburg Paper Co., Fitchburg; Foster Grant Co., Leominster; Gilet Wool Scouring Corp., Chelmsford; Groton Leatherboard Co., Groton; Hollingsworth & Vose Co., Groton; Hoyt & Worthen Tanning Corp., Haverhill; Lawrence Wool Scouring Co., Lawrence; Lowell Rendering Co., Billerica; Mead Corp., Lawrence; Merrimack Paper Co., Lawrence; North Billerica Co., Billerica; Oxford Paper Co., Lawrence; Simonds Saw and Steel Co., Fitchburg; Southwell Combing Co., Chelmsford; St. Regis Paper Co., Pepperell; Suffolk Knitting Co., Lowell; Vertipile, Inc., Lowell; and Weyerhaeuser Paper Co., Fitchburg.

Discharges, other than bacteria, suspended solids, or oxygen demanding material, include color-producing waste discharges by the Franconia Paper Corp., Lincoln, New Hampshire; plating wastes probably containing copper and cyanide by the Sanders Associates, Nashua, New Hampshire; 2,380 pounds of grease per day by the Southwell Combing Co., Chelmsford, Massachusetts; 3,120 pounds of grease per day by the Gilet Wool Scouring Corp., Chelmsford, Massachusetts; periodic dumping of dye by the Roxbury Carpet Co., Framingham, Massachusetts; and 860 pounds of grease per day by the Lawrence Wool Scouring Company, Lawrence, Massachusetts.

Water Uses

The Merrimack River is the municipal water supply for Lowell and Lawrence, Massachusetts. As the population in the basin multiplies, an increasing number of communities will be turning to the Merrimack River to meet their water needs. Construction and efficient operation of well-designed sewage treatment plants will ensure adequate water quality to enable the municipalities and industries to utilize this abundant and inexpensive source of water.

Extensive use of the Merrimack River water is presently being made by the basin's industries. This use is limited mainly to flow-through applications, cooling water, power generation, and waste transport, with very little consumptive use. Sand filters and other treatment methods are often employed by industries to precondition the water. It would not be unreasonable to expect an increase in industrial development once the basin communities can offer improved water quality to both management and employees for process water and recreational use.

Merrimack River water is used for irrigation of truck crops along most of its banks, with a concentration of farms occurring between Manchester, New Hampshire, and Lawrence, Massachusetts. Following construction of adequate waste treatment facilities, irrigation water would have a lower bacterial density, resulting in a reduced health hazard.

Recreational use of the main stem Merrimack River is severely restricted due to the river's polluted condition. Fishing is limited by an environment unsuitable for game fish common to the area and by public abhorrence to fishing in water polluted with raw sewage and other waste

materials. Proper control of this pollution would enable 10.5 million people within a day's drive of the river and thousands in the rest of the country to fully utilize the tremendous fish, wildlife, and recreational potential of the Merrimack River Basin.

For the basin area, a minimum estimate of the potential resources lost due to pollution is $37,000,000 for the year 1964. The income lost from various sources is:

Commercial Shellfish	$ 300,000
Recreational Visitor Income	21,300,000
Increased Property Value	9,100,000
Increased Tax Revenue	5,500,000
Miscellaneous	800,000
	$37,000,000

This annual loss may be as high as 60 to 70 million dollars or $65 per year for every man, woman, and child in the basin.

Effects of Pollution on Water Quality

Concentrated water quality studies in the Merrimack River Basin were conducted during July and August of 1964 and 1965. Other supplemental studies were made throughout the year. Pollution of the Merrimack River and its tributaries was evaluated primarily on the basis of coliform bacteria, dissolved oxygen, biochemical oxygen demand, and temperature. Time of travel data were obtained from Rhodamine B dye studies.

The temperature of the Merrimack River during the summer months averaged 73.4°F (23°C). There was only one significant source of thermal pollution, that being the Public Service Company of New Hampshire's power generating facilities at Bow, New Hampshire. A temperature increase of

5.4°F (3°C) was apparent below the discharge area. Facilities should be provided for cooling of the waste discharge, thereby preventing an excessive temperature build-up in the river.

Biochemical oxygen demand (BOD) crossing the state line from New Hampshire into Massachusetts amounted to 28,800 pounds per day during August, 1965. This is equivalent to the discharge of raw sewage from a city of 169,000 persons.

Substantial amounts of BOD are discharged by the industries and communities of Concord, Manchester, and Nashua, New Hampshire, and Lowell, Lawrence, and Haverhill, Massachusetts, causing serious reduction in the dissolved oxygen content of the Merrimack River during the summer months. In June, July, August, and September of 1964 and 1965, minimum dissolved oxygen from Manchester to Newburyport was less than 2.0 ppm at every station; zero values were found below Haverhill. At no point upstream of Manchester was the minimum value in excess of 5.0 ppm. A value of 5.0 ppm is considered by most state water pollution control agencies to be the minimum value to be maintained in order to provide for the maximum potential warm-water sport fish population. It is also one of the requirements for Class C water, as established by the New England Interstate Water Pollution Control Commission.

A depletion of the oxygen resource of a river will reduce or eliminate aquatic life which serves as food for fishes. The biological study of the Merrimack River shows that those benthic organisms sensitive in their response to pollution were absent in the lower 57 miles of the Merrimack River. In only four extremely short portions of the river,

consisting of less than 15 miles out of the total river mileage of 116, did the river recover enough from its despoiled condition to permit a small number of sensitive organisms to exist.

With the exception of a short section of the river between Hooksett and Manchester, bacterial pollution presents a health hazard for all full body contact recreation, such as swimming and water skiing, from Franklin, New Hampshire, to Newburyport, Massachusetts. Below Manchester and Nashua, New Hampshire, and Lowell, Lawrence, and Haverhill, Massachusetts, coliform densities in excess of 1,000,000 per 100 ml were not uncommon, being found as high as 9,200,000 per 100 ml. Recommended limits of coliform densities for water contact sports range from 50 to 3,000 per 100 ml in various states.

Nashua and Hudson, New Hampshire, contributed over 98 per cent of the coliform bacteria crossing the New Hampshire-Massachusetts state line during warm, low-flow periods of the year. However, with colder water temperatures and increased flows in the autumn, the Nashua-Hudson portion at the state line was reduced to 50 per cent; Manchester, New Hampshire, was responsible for 25 per cent of the total; and other upstream communities were responsible for 25 per cent. The discharge of raw and partially treated sewage to the study area is a health hazard to the residents in the downstream communities as well as to the local population.

Vegetables that are ordinarily eaten without cooking are irrigated at several truck farms with water from the Merrimack River. Fecal coliforms were present on vegetables grown from farms irrigating with Merrimack River water in a significantly greater number of cases than on vegetables that were not irrigated with the river water.

While coliform bacteria densities indicate the magnitude of potential disease-producing organisms, detection of pathogenic Salmonella bacteria is positive proof of the presence of such organisms. Typhoid fever, gastroenteritis, and diarrhea are but a few of the many diseases of man caused by these bacteria. Salmonellae were consistently recovered from the Merrimack River in both New Hampshire and Massachusetts, indicating that ingestion of untreated Merrimack River water is a definite health hazard. Salmonella organisms were isolated during each test made at the Lowell and Lawrence water intakes. These disease-producing organisms were isolated from river water having a total coliform density as low as 180 per 100 ml.

The major contributors of coliform bacteria to the estuary are: the communities upstream of Newburyport and the two communities of Newburyport and Salisbury. Of the bacteria originating from upstream communities and reaching Newburyport, 51.4 per cent emanated from the Lawrence region, 17.1 per cent from the Haverhill region, and 31.4 per cent from the Amesbury area. Discharges into the estuary from existing treatment facilities in Newburyport and Salisbury significantly increase the bacterial densities near the shellfish growing areas. If the potential one-million-dollar annual shellfish harvest is to be a reality, the discharge of treated sewage in the greater Lawrence, Haverhill, and Amesbury areas will need constantly and efficiently operating disinfection facilities. In addition, the communities of Newburyport and Salisbury will need to discharge their wastes, adequately treated, to the Atlantic Ocean instead of to the estuary.

Phosphate and nitrogen concentrations in the Merrimack River are far in excess of the amount needed to produce nuisance algal blooms. In order to reduce taste and odor problems with municipal water supplies taken from the river and to improve the esthetic quality of the water, the concentration of these nutrients should be reduced.

Severe to moderate pollution exists in several tributaries of the Merrimack River. These include the Souhegan River near Wilton and Milford, New Hampshire; Beaver Brook near Derry, New Hampshire, and Lowell, Massachusetts; the Assabet River below Westborough, Hudson, and Maynard, Massachusetts; Hop Brook (a Sudbury River tributary) below Marlborough, Massachusetts; the Concord River below Billerica and in Lowell, Massachusetts; the Spicket River in Salem, New Hampshire, and Methuen and Lawrence, Massachusetts; the Shawsheen River below Bedford and in Andover, Massachusetts; and the Powwow River below Amesbury, Massachusetts.

Gross oxygen production from photosynthesis in the Merrimack River was between 0.8 and 2.0 ppm per day during the summers of 1964 and 1965. These values were obtained by the use of light and dark bottle tests between Manchester, New Hampshire, and Newburyport, Massachusetts. The rate of oxygen production on cloudy days was found to be approximately one-tenth the value found on sunny days.

In the 67-mile reach of the Merrimack River between Manchester and Newburyport, there are approximately 16,900,000 cubic feet of settled solid material, 7,900,000 of which are located between Lowell and Lawrence, and 7,800,000 between Haverhill and Newburyport. The oxygen

demand of these benthal deposits in the overflowing waters ranged from 0.2 to 1.0 ppm per day.

Oxygen balance studies were carried out, and the variables affecting the oxygen sag curves were obtained for each of the six reaches below Manchester, New Hampshire. These variables were adjusted to reflect the future conditions in 1985 when a secondary waste treatment program for the Merrimack River would be in effect. Dissolved oxygen calculations for the 1985 conditions indicated that oxygen levels of 75 per cent of saturation (Class B water as established by the New England Interstate Water Pollution Control Commission) can be met from Franklin, New Hampshire, to Lawrence, Massachusetts, and from Amesbury, Massachusetts, to the Atlantic Ocean.

Existing and potential future water uses in the Merrimack River indicate that it will be used for a variety of purposes. Consideration was given to water quality limits for various constituents that would affect the suitability of the stream for each water use. In order to decrease the biochemical oxygen demand and bacteria in the wastes to be discharged to the Merrimack River, to provide an effluent more esthetically acceptable to the public, to assure the existing and future desirable uses of the river, and to protect the health and welfare of the public, it will be necessary to provide secondary waste treatment or equivalent, with disinfection, for all waste discharges. If the recommendations of this report are followed, water quality of sufficient purity to accommodate the various water uses will be attained.

STREAM STUDIES -- BIOLOGICAL

The biological studies show that, with few exceptions, the Merrimack River is grossly polluted from Franklin, New Hampshire, to its mouth at Newburyport, Massachusetts.

Benthic organisms sensitive to pollution were absent from the samples taken in the lower 57 miles of the Merrimack River. In only four extremely short portions of the river, consisting of less than 15 miles out of the total river mileage of 116, did the river recover enough from its despoiled condition to permit a small number of sensitive organisms to exist before additional wastes reduced the quality of the river. These four areas were: four miles below the confluence of the Pemigewasset and Winnipesaukee Rivers; above Concord, New Hampshire; in the reservoir behind Amoskeag Dam; and just above the Nashua River confluence.

Organisms intermediate in their response to pollution were predominant from below Franklin, New Hampshire, to the confluence of the Contoocook River. Additional waste discharges between the Contoocook River and the Suncook River resulted in an increase in the proportion of pollution-tolerant forms. Between Hooksett and Manchester, New Hampshire, the majority of bottom organisms again were of the types intermediate in their resistance to pollution. From Manchester to Amesbury, Massachusetts, a

distance of 66 miles, pollution-tolerant organisms constituted the entire benthic population or the majority of the forms found.

The number of species found in the Merrimack River was far below the levels desired in a benthic community. Pollution-sensitive benthic fauna, such as mayflies, stoneflies, and certain beetles, were not found in the river from Manchester, New Hampshire, to the Atlantic Ocean.

A number of tributaries were sampled near their confluences with the Merrimack River. Results show that all of the sampled areas were polluted. In most cases, wastes were discharged into the lower part of the tributary and affected the bottom fauna.

A biological survey was carried out on the lower Souhegan River, a tributary which discharges into the Merrimack River 12.5 miles upstream of the New Hampshire-Massachusetts state line. Between Wilton and Milford, New Hampshire, the Souhegan deteriorated considerably, with pollution-tolerant leeches and sludgeworms making up most of the benthic fauna. This polluted condition of the river continued for several miles downstream of Milford. From a biological standpoint, the river was moderately polluted from Wilton, New Hampshire, to its confluence with the Merrimack River, a distance of 20 miles.

A productivity study of the Merrimack River was conducted between Manchester, New Hampshire, and Lowell, Massachusetts, that reflected a relative increase in productivity as the river flowed downstream.

The surface water of the Merrimack River at the entrance to the Essex Canal in Lawrence was monitored periodically for phytoplankton and zooplankton from April through October, 1965. Most of the kinds of phytoplankton found were tolerant of pollution.

PILOT PLANT STUDY OF BENTHAL OXYGEN DEMAND

The areal oxygen demand of bottom sediments taken from the Merrimack River in Massachusetts was determined by a small pilot plant. Parameters in the benthic rate equation were evaluated on the basis of the data obtained, and the effect of sediment depth on the benthic rate constant, k_4, was studied.

The value of the benthic rate constant, k_4, varies with the age and depth of the deposit. A marked decrease of k_4 with increase in sediment depth occurred between 1.5 and 10 cm. Above 15 cm no significant decrease in k_4 was observed.

Only the upper 15 cm of sediment had any significant effect on the areal oxygen demand. The observed data were closely approximated by the equation $L_d = L_{d_o} \cdot 10^{-k_4 t}$ at all sediment depths except the 1.5 cm depth.

Nitrification was believed to play a role in the oxygen demand of the sediments and was especially significant in the shallow depths studied.

NASHUA RIVER

Serious pollution exists in the North Nashua River from the outfall of the Weyerhaeuser Paper Company, Fitchburg, Massachusetts, to the confluence of the north and south branches of the Nashua River at Lancaster, Massachusetts; in the Nashua River from Lancaster to the mouth of the Nashua River in New Hampshire; in the Squannacook River below the dam at Vose Village; and in the South Branch Nashua River below Clinton, Massachusetts. This pollution affects present and potential water uses.

Discharges from paper mills result in suspended solids, organic matter causing biochemical oxygen demand, and materials causing apparent color in the stream. By far the largest loadings emanate from the three paper industries of Fitchburg, Massachusetts. Inadequate sewage treatment, particularly at Fitchburg and Leominster, Massachusetts, contributes to the problem by causing excessive bacterial densities, suspended solids, nutrients, and organic matter causing biochemical oxygen demand. Plastics and metal fabrication industries also add suspended solids and materials that cause biochemical oxygen demand.

Bacteria equivalent to those in the raw sewage of approximately 24,000 persons are discharged to the streams at present. Fitchburg and Leominster, Massachusetts, contribute 90 per cent of the total. The coliform bacteria in the North Nashua River were as high as 680 times the

recommended maximum value of 5,000 per 100 ml for this stream. Pathogenic bacteria were isolated in both the North Nashua and South Branch Nashua Rivers.

Discharges of suspended solids create a severe problem in the Nashua River. These materials cause deep sludge deposits which deplete the stream oxygen supply, produce offensive odors, and reduce or eliminate aquatic life which serves as food for fishes. The suspended matter also makes these once attractive waters appear turbid. Suspended solids discharged to the Nashua River Basin are equivalent to those in the raw sewage of 556,000 persons. Of these nearly 92 per cent come from the paper mills. It was estimated that 17 million cubic feet of sediments have accumulated in Pepperell Pond alone.

Sewage and industrial wastes presently discharged have an estimated biochemical oxygen demand population equivalent of 178,000, of which the paper industries contribute 76 per cent. As a result of the reduction in dissolved oxygen, fish, fish food organisms, and other desirable forms of aquatic life are destroyed. In addition, when dissolved oxygen is reduced to zero, obnoxious odors are given off by the stream.

Nutrients discharged to the Nashua River Basin result in excessive densities of algae and other aquatic plants, creating a nuisance. These plants may die and decompose, causing unsightly conditions, obnoxious odors, and depletion of dissolved oxygen. In addition, in the absence of sunlight, the algal respiration depresses the dissolved oxygen to low levels--at times to zero. Estimates based on sewered population and

stream analyses indicate that 128,000 population equivalents of ortho-phosphates are discharged to the Nashua River. Phosphates are key nutrients which are readily available for the growth of algae and other aquatic plants.

As a result of the severely polluted condition of the Nashua River, the people who live in the towns bordering the river in New Hampshire and Massachusetts petitioned the governors of the two states to take immediate abatement action. The people demanded that the river be restored to a high state of water quality.

The Nashua River system has been classified for future highest use by the state and interstate agencies. The classification of the North Nashua and Nashua Rivers was set at Class C. However, in Massachusetts the Nashua River was assigned the coliform limitation established for Class B water. Class C waters would be suitable for recreational boating and fish and wildlife usage, while the coliform limit on the Nashua River would permit recreational bathing. These classifications would permit the recreational developments desired by most of the citizens of the area and would probably provide water quality adequate for industry.

In addition to many other uses, the Nashua River can be used at the Fort Devens Military Reservation for training exercises involving rivers and for recreation when pollution is controlled. The sections of the river forming the post boundary could be used for public recreation, while the sections entirely within the reservation could be used for recreation either by post personnel or by the public by permit.

PEMIGEWASSET RIVER

Serious pollution exists in the Pemigewasset River from the confluence with the East Branch Pemigewasset River in Lincoln, New Hampshire, to the confluence of the Winnipesaukee River in Franklin, New Hampshire, due to the discharge of sewage and industrial wastes in the basin. Effects of these discharges persist all the way into Massachusetts.

Discharges of raw sewage from several towns result in excessive densities of bacteria and make much of the Pemigewasset River unsuitable for recreational purposes, even where only limited body contact is involved. About 29 of the 35 miles of stream between North Woodstock and New Hampton are above the 5,000 coliforms per 100 ml limit usually recommended for recreational uses. Some of these bacteria may be pathogens which can infect persons ingesting the water.

Suspended solids discharged to the Pemigewasset River watershed are equivalent to those in the raw sewage of 287,500 persons, of which over 98 per cent emanate from industrial plants. These solids result in sludge deposits, especially in the impoundment behind Ayers Island Dam. The sludge reduces or eliminates aquatic life which serves as food for fishes, depletes the stream oxygen supply, and produces offensive odors. Hydrogen sulfide, resulting from sludge deposits behind Ayers Island Dam, caused thousands of dollars of damage to houses in Bristol, New Hampshire,

on August 18, 1965, and on August 23, 1966, by discoloring the paint on the houses.

Dissolved oxygen concentrations in the Pemigewasset River are depressed by the discharge of organic materials which decompose in the river and exert an oxygen demand. Minimum dissolved oxygen concentrations were below desirable levels from the East Branch Pemigewasset River in Lincoln, New Hampshire, to the mouth of the Pemigewasset in Franklin. The Franconia Paper Corporation is responsible for 94.5 per cent of the oxygen demand in the Pemigewasset River Basin, with a discharge having an oxygen demand equivalent to that of the raw sewage of 400,000 persons. Low dissolved oxygen concentrations destroy fish, fish food organisms, and other desirable aquatic life.

Sulfite waste liquor, released to the Pemigewasset River by the Franconia Paper Corporation, not only creates an enormous oxygen demand due primarily to the wood sugars but also contains lignin sulfonates which persist as the waters flow into Massachusetts. Pollution from the Franconia Paper Corporation was included in the first session of the conference. As a result of the sulfite waste liquor, the river is discolored, adding to the water treatment costs at Lowell and Lawrence, Massachusetts.

The Pemigewasset River is in the heart of prime recreational area of New Hampshire. However, as a result of pollution, recreational use of the Pemigewasset is reduced or destroyed, impeding the economic growth of the area downstream of the pollutional discharges.

RECOMMENDATIONS

Many suggestions of the Merrimack River Project concerning water quality criteria and stream classification have already been implemented by the two Basin states in the process of adopting water quality standards. Still others are being considered by the New England Interstate Water Pollution Control Commission for the region as a whole as well as the Basin waters.

Implementation and construction schedules submitted by the states of New Hampshire and Massachusetts and approved by the Secretary of the Interior, as required by the Federal Water Pollution Control Act, as amended, shall be followed for the Merrimack River Basin. Implementation and construction schedules for sources of pollution on intrastate portions of the Merrimack River Basin in Massachusetts shall be in accordance with state and local requirements so as to meet the stream classifications.

It is recommended that the implementation program for the following New Hampshire communities in the Merrimack River Basin, that did not receive approval by the Secretary, be as follows:

	Manchester	Concord	Plymouth
Type of treatment	Secondary	Secondary	Secondary
Final plans and specifications	Dec. 1970	May 1969	July 1971
Start construction	Apr. 1972	Apr. 1971	July 1973
Complete construction	Dec. 1974	Apr. 1973	Dec. 1974

Consideration shall be given in the water pollution control program, as necessary, to the following:

1. Sewerage systems with collection sewers terminating in adequate treatment facilities shall be provided in those areas along the stream where sewers do not now exist and where homes discharge either raw wastes or septic tank effluent to the watercourse and where local treatment facilities will not suffice.

2. All new construction of sewer lines and revisions to existing systems shall provide for the separation of storm runoff and sewage.

3. All new and existing waste treatment facilities shall be designed or modified, if possible, to prevent bypassing of untreated wastes during maintenance and renovation operations and power failures.

4. All municipal and industrial wastes in the Merrimack River Basin are to receive a minimum of secondary treatment or equivalent. All effluents containing domestic wastes are to receive adequate disinfection. Maximum removal of nutrients, including phosphates, by the most effective available means is to be provided, as necessary, to meet stream classifications.

5. All industries and municipalities in the area discharging waste material to the public waters shall maintain an inventory of critical waste treatment parts and supplies on the plant premises so that a minimum delay in effective waste treatment will result when replacement or repair is necessary.

6. Consideration shall be given for 24-hour supervised operation of all sewage treatment plants.

7. Provisions shall be made to allow sampling of the final effluent prior to discharge.

8. No backwater or eddies shall exist near the outfall that would hinder mixing. The location of the outfall should be such as to enhance mixing of the treatment plant effluent.

9. Operation of dams in the Merrimack River Basin should be regulated by the appropriate agency so that certain adequate flows are released at all times.

10. All water treatment plants shall dispose of spent activated carbon and settled solids by means other than to the stream.

11. Facilities to accept septic tank truck discharges are to be provided at sewage treatment plants or other approved areas.

12. There shall be no discharges from septic tank cleaning operations directly to the waters of the Basin.

13. All marine conveyances equipped with marine toilets operating upon the Basin waters shall use a holding tank or other approved pollution control device.

14. The appropriate agency should prohibit garbage or refuse (including automobile bodies and other unsightly debris) from being dumped along the banks of the river, and no open dumps should be allowed on the flood plain. Material in present dump sites along the river banks shall be removed and the appearance of the bank restored to an esthetically acceptable condition. Present open dumps on the flood plain should be converted to sanitary landfills operated acceptably to the appropriate state agencies.

15. In the shellfish growing areas near the mouth of the Merrimack River, the requirements of the National Shellfish Sanitation Program are to be met in order to permit reopening of the maximum number of those areas presently closed to the harvesting of shellfish.

16. Consideration should be given by the City of Newburyport and the Town of Salisbury, Massachusetts, to developing an engineering report which would include the relative merits of:

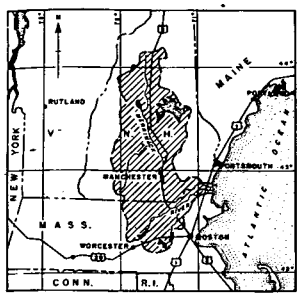
    a. Treatment and joint discharge to the Atlantic Ocean;

    b. Individual discharges to the Atlantic Ocean;

    c. Joint treatment and discharge to the Merrimack estuary; and

    d. Individual discharges to the Merrimack estuary.

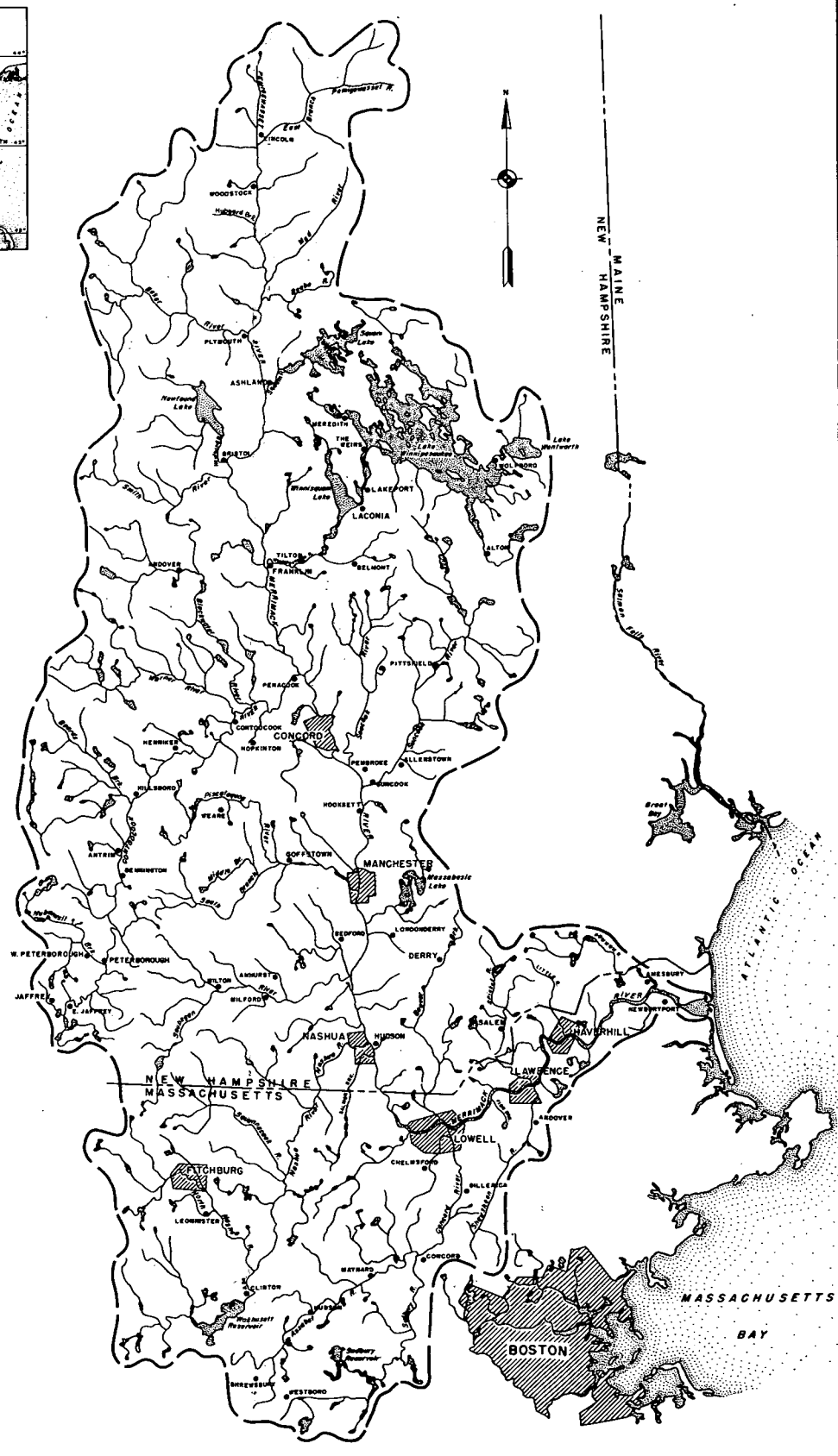
    In all cases, the report shall include the relative economic values of the estuarine resources.



LOCATION MAP

SCALE IN MILES

0 10 20 30 60



MERRIMACK RIVER BASIN

SCALE IN MILES

0 4 8

FIGURE 1