Donald M. Tate

SOCIAL SCIENCE SERIES NO. 3

INLAND WATERS DIRECTORATE,
WATER PLANNING AND MANAGEMENT BRANCH,
OTTAWA, CANADA, 1972.

Environment Canada Environnement Canada

Economic and Financial Aspects of Wastewater Treatment in the Yamaska River Basin, Quebec

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SUMMARY

The Yamaska River flows into the St. Lawrence River about 40 miles northeast of Montreal. From its mouth the Yamaska trends southeastward into Quebec's Eastern townships. An important part of Montreal's "recreation-shed" and "milk-shed", the Yamaska basin is also a centre for the textile industry and a variety of light manufacturing industries.

Water quality in the basin is generally low as a result of inadequate treatment of both municipal and industrial wastes. This report examines the waste treatment problem in the basin, and attempts to formulate the order of magnitude of the problem, both municipally and industrially. Following this, the costs of various waste treatment alternatives are estimated, based upon the assumption that new plants will treat both municipal and, after some inplant pre-treatment, industrial effluents. Table 1 summarizes the total capital costs and annual operating and maintenance costs for both primary and secondary treatment systems for the five towns in the basin. Table 2 is based upon the amortized costs of constructing the facilities shown in Table 1. The amortization terms used to calculate the costs shown in Table 2 are outlined in detail in the text.

Table 1a. Summary of Costs of Waste Treatment and Collection Systems for Principal Municipalities (thousand 1971 dollars)

	Construction Cost					Annual Operating and Maintainence	
	Treatment Plants[1]			Total[2]			
Municipality	Primary	Activated Sludge	Collection Systems	Primary	Activated Sludge	Primary	Activated Sludge
Granby	1,822	3,291	804	2,626	4,095	97	146
St. Hyacinthe	1,126	2,007	1,775	2,901	3,782	57	93
Cowansville	966	1,718	883	1,849	2,601	48	80
Farnham	529	922	615	1,144	1,537	24	44
Acton Vale	355	613	453	808	1,066	19	35
Total	4,798	8,551	4,530	9,328	13,081	245	398
Average Cost per Capita served (in dollars)	59.91	106.71	56.53	116.45	163.20	3.06	4.97

Table 1b. Cost of Regional Treatment Facilities and Inter-Municipal Pipelines ($000)

Granby-Cowansville-Farnham Area		
a) Combined Act. Sludge at Granby (to serve Granby & Cowansville)	5,638	194
b) Combined Act. Sludge at Cowansville (to serve Granby & Cowansville)	5,690	194
c) Combined Act. Sludge near Farnham (to serve Granby, Cowansville and Farnham)	6,807	214
St. Hyacinthe Region	6,187	120

1. Costs are based upon combined domestic and industrial waste treatment. This table is in terms of constant dollars.
2. Allowance made for funds already spent (see Table 9).

Table 2a. Summary of Amortized Costs of Waste Treatment and Collection Systems for Principal Municipalities[1] (thousand 1971 dollars, except where noted)

Municipality	Total Construction Cost[2]		Annual Construction Cost Per Capita (dollars)		Annual Operating and Maintenance	
	Primary	Activated Sludge	Primary	Activated Sludge	Primary	Activated Sludge
Granby	3,786	6,190	5	7	97	146
St. Hyacinthe	4,081	5,524	7	9	57	93
Cowansville	2,629	3,856	9	14	48	80
Farnham	1,603	2,247	10	14	24	44
Acton Vale	1,117	1,539	10	14	19	35

Table 2b. Amortized Cost of Regional Treatment Facilities

	Total Construction Cost (amortized)	Annual Construction Cost (amortized)	Annual Operating and Maintenance
Granby-Cowansville-Farnham Area			
a) Combined Act. Sludge at Granby (to serve Granby & Cowansville)	8,342	7	194
b) Combined Act. Sludge at Cowansville (to serve Granby & Cowanxville)	8,401	7	194
c) Combined Act. Sludge near Farnham (to serve Granby, Cowansville, and Farnham)	9,961	8	214
St. Hyacinthe Region	8,770	10	120

1. Loans are amortized at $7^1/_2\%$ per annum over 25 years. Costs are based upon combined domestic and industrial waste treatment.
2. The cost figures represent the amounts to be borne by the municipality itself and includes the federal allowances made under the National Housing Act.

It is suggested that regional treatment systems to serve the Granby-Cowansville-Farnham and the St. Hyacinthe regions are viable alternatives to separate waste treatment facilities in the individual towns. The construction and annual operating and maintenance costs of regional facilities to serve these two areas are shown in the lower part of Tables 1 and 2. The construction costs for the regional facilities include an allowance, perhaps a low estimate, for piping the effluent to the treatment plant. A conclusion of the report is that the cost of regional treatment may be less for the two areas mentioned than the cost of treatment in individual municipal plants.

ECONOMIC AND FINANCIAL ASPECTS OF WASTEWATER TREATMENT IN THE YAMASKA RIVER BASIN, QUEBEC

A Preliminary Study

Donald M. Tate

INTRODUCTION

The Yamaska River, a tributary of the St. Lawrence River, is located in Quebec's Eastern townships. The Yamaska Basin (Figure 1) is within 50 miles of Montreal and, along with the Richelieu and St. François Basins, forms an integral part of the "recreational ecumene" of Canada's largest city. The principal municipalities in the Yamaska Basin are Granby (population 33,750), St. Hyacinthe (population 24,277), Cowansville (population 11,300), Farnham (population 6,419) and Acton Vale (population 4,383).

This report is concerned with the costs of waste treatment in the Yamaska River Basin, and with the determination of the most appropriate areas for investment in treatment facilities. The report represents a preliminary analysis only, and is based wholly upon published material. As a result, the data base is less than adequate to draw firm conclusions, especially concerning waste sources and the cost of transporting wastewater to regional treatment facilities. It is clear that more information will be required before proceeding with a comprehensive treatment system for the basin. The intention here is to demonstrate a possible way in which priorities for waste treatment investment could be determined.

The paper was done as part of a larger study of Federal involvement in water pollution abatement in Canada. The basin was selected for study solely because a relatively large amount of data were available on a systematic basis, and because the basin is relatively small in size it was thought to present an opportunity for a case study in relating the allocation of investment funds to receiving stream quality.

The first part of the paper will identify the major domestic and industrial waste sources in the basin. Quantitative data on both types of sources are estimates only, based upon the use of generalized coefficients. The second section identifies the areas of low water quality and relates the water quality to the waste sources identified in the first section. The third and fourth parts use the material in the first two sections as a basis for determining the costs of waste treatment systems in the basin. The various treatment facilities suggested are placed in approximate order of importance in terms of their impact upon the receiving stream's quality.

Industrial Composition

Table 3 shows the industrial composition of the major municipalities in the basin. It is estimated that this table covers about 90% of the total employment in the basin's water polluting industries. It is clear that the textile industry, an old and well-established one in this part of the Eastern townships, is the largest employer in the area. Many of the plants are classed as "older" in the terms of technology[1]. The textile plants are major contributors to water pollution in the Yamaska Basin. The dairy industry is important in the area for two main reasons: several large municipalities in the basin create a demand for dairy products, and the proximity of the area to Montreal also stimulates the dairy product demand. A significant amount of pollution is caused by these dairies. Also contributing to water pollution are a few medium-sized canneries and meat-packing plants which are important in the industrial make-up of the region. The remainder of the industrial composition consists of a variety of light manufacturing industries.

The area is within easy driving distance of Montreal. Thus recreation is an important tertiary industry in the Yamaska Basin. The two lakes in the headwaters of the river—Lake Brome and Lake Waterloo—have been subject to intensive cottage development. Wastes from these lake areas are important in the discussion of water quality in the area. The excessive supply of nutrients from the areas of cottage and other recreational developments are quite difficult to deal with in a quantitative way because the nutrient

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1. U.S. Department of the Interior, "Textile Mill Products" F.W. P.C.A. *Cost of Clean Water*, Industrial Waste Profile 4, 1967.

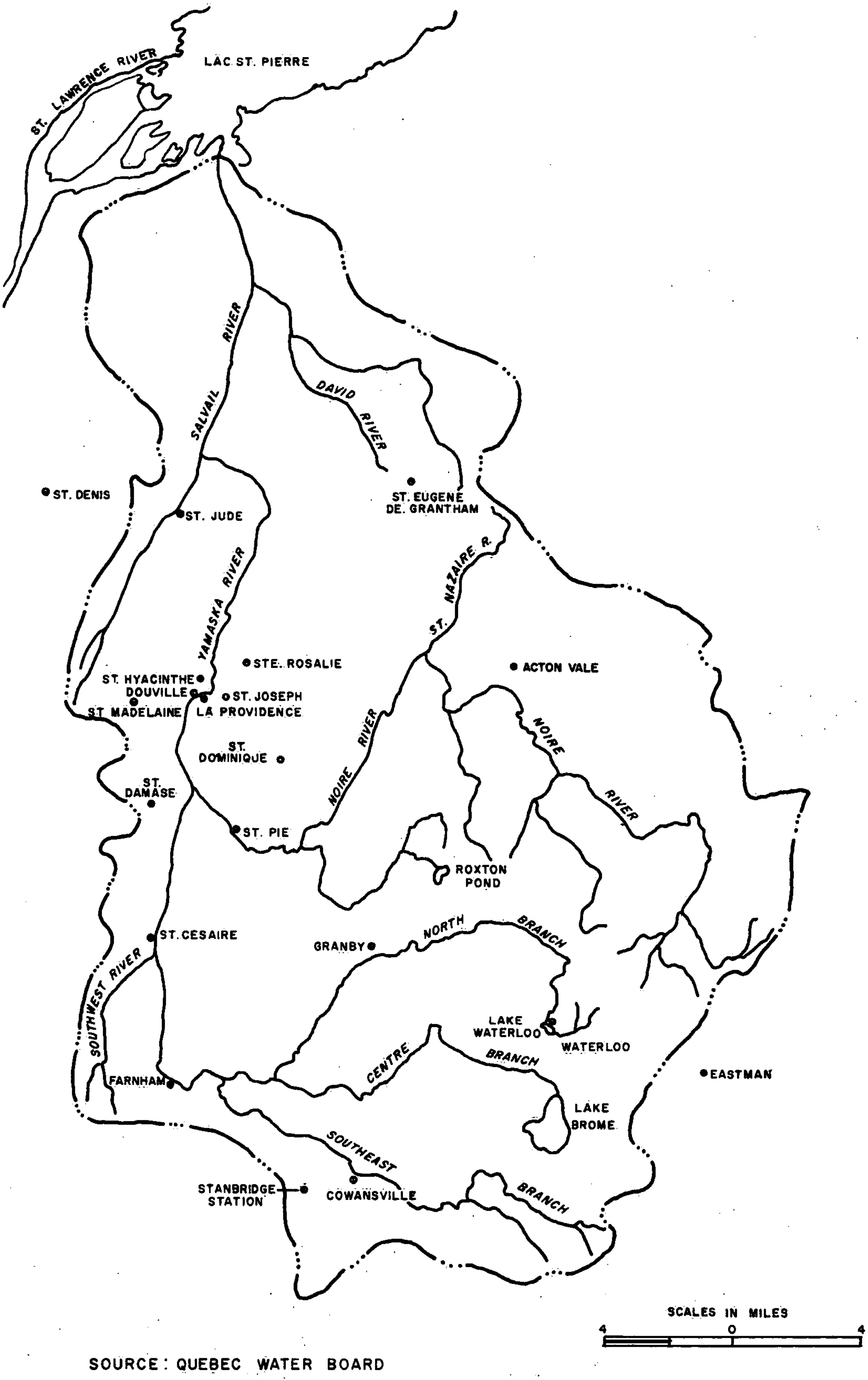

Figure 1. Yamaska River Basin.

phenomenon has not been subjected to chemical testing as have other quality parameters such as Biochemical Oxygen Demand (BOD). However, the nutrient problem must be kept in mind throughout the following discussion.

Domestic and Industrial Water Pollution

Table 3 presents estimates of waste loadings for the principal towns[2] in the Yamaska Basin. The figures for BOD loadings from the textile plants are based upon a Quebec Water Board report[3]. All other industrial pollution loadings estimated in Table 3 were based upon coefficients drawn from secondary sources[4]. There are, of course, many problems involved in the "coefficients" approach. The major problem is the fact that a general industry coefficient may not be applicable to a specific plant. However, in light of the sparsity of actual data, the "coefficients" approach is the only one which is feasible. This approach will yield an order-of-magnitude estimate of the industrial waste loadings.

The two water quality parameters used in Table 3 were BOD and total solids. These two parameters are available for all industries of the study. It must be recognized that the individual plants in the study may generate one or a number of more esoteric pollutants such as phosphate, cyanide, ammonia, phenot etc. These substances are more difficult to treat before discharge and their production varies greatly between plants, depending upon the raw material used, operating rates, plant efficiencies, etc. It is not only more difficult to find coefficients for these rarer pollutants, but it is also more difficult to apply them to individual plant situations. For this reason only the BOD and solids production in the plants have been considered in the quality calculations. The BOD is shown in two ways, as actual BOD weight generated and discharged per day, and as equivalent population.

The estimates shown in Table 3 indicate that in the major municipalities the pollution loading from industry is greater than that from the municipal population. The population equivalents for industry range from 152% for Cowansville to 767% for St. Damase. The general increase in population equivalent as population decreases is due mainly to the decreasing size of the base population. The location of relatively large textile mills in some of the smaller municipalities is another factor giving rise to the increase in the population equivalent ratio. An example of this exists in the town of Acton Vale, where one textile mill generates a BOD which is 2.29 times greater than that generated by the municipal population.

Criteria for Waste Treatment Priorities

In making decisions as to water quality improvement requirements in the Yamaska Basin, one or two criteria were selected from those for which information is available (see Appendix 1). These criteria form the basis of the following discussion of costs and priorities for waste treatment. Most of the published material in this field centres on DO-BOD characteristics of the river. The assimilation of BOD is better understood than the other water quality parameters. Treatment systems are most often judged vis-avis their ability to assimilate BOD. For the purposes of this paper, therefore, the DO-BOD dimensions of stream pollution was used as the main guide to waste treatment requirements in the basin. Some relatively safe assessments may also be made as to the removal of solids by various waste treatment methods. Thus solids level of effluent discharge was used to supplement some of the judgements based upon DO-BOD information. The other important water quality parameter to be used in determining priorities for investment in waste treatment facilities in the Yamaska is the coliform level of the river. A detailed description of several water quality parameters in the basin is contained in Appendix 1.

WATER QUALITY PROBLEM AREAS

From information compiled for the Yamaska Basin, part of which is outlined in Appendix 1, five water quality problem areas may be defined. (The eutrophication problem in Waterloo Lake and Brome Lake is not included here because of the lack of adequate information.) The first area of low water quality is located below the municipality of Waterloo. The domestic wastes plus wastes from a small cannery cause a severe depression in the DO curve. The main problem is the cannery which operates only in the summer months. The heavy waste load from this operation creates a water quality problem which is compounded by algal growths during the summer. Coliform counts are high during the summer downstream from Waterloo but fall off rapidly towards Granby. However, the coliform counts in the river are much too high to permit safe body contact recreation in the area.

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2. Domestic pollution loadings were estimated using 0.17 lbs. of BOD per capita per day, and 0.20 lbs. of solids per capita per day.

3. Quebec Water Board, *L'Industrie Textile de la Province de Québec: Report et Resultates de L'Enquette Systematique sur la Pollution Industrielle de l'Industrie Primaire des Textiles*, J.B. Nobert.

4. Employment data was drawn from *Scott's Industrial Directory, Province of Quebec, 1969-70*, Penstock Publications, Montreal, 1970. Waste loading coefficients were derived from several sources given in: U.S. Dept. of the Interior, F.W.P.C.A., *The Cost of Clean Water*, Vol. 3, # 1 to 10, 1968; and Atlantic Development Board, *Maritime Provinces Water Resources Study*, "Industrial Water Demands", Appendix 3, 1969.

Table 3. Estimated Municipal and Industrial Waste* Loadings in Principal Municipalities in the Yamaska Basin

	Population (1970)	Employment	Effluent Flow (Mgd)	Estimated BOD (lbs/day)	Population Equivalent (%)	Suspended Solids (lbs/day)	Principal Industrial Types
GRANBY							
Domestic	33,750		3.375	5,737		6,750	
Industrial		2,985	3.972	12,330	72,484(215%)	3,937	textile soft drink dairy miscellaneous
ST. HYACINTHE							
Domestic	24,277		2.428	4,127		4,655	
Industrial		2,316	1.581	6,313	37,134(153%)	3,235	textile, dairy meat packing soft drink foundry miscellaneous
COWANSVILLE							
Domestic	11,300		1.130	1,091		1,284	
Industrial		1,434	2.153	2,919	17,173(152%)	94	textile miscellaneous
FARNHAM							
Domestic	6,419		.642	1,091		1,284	
Industrial		516	.853	4,698	27,640(431%)	5,178	textile miscellaneous
LA PROVIDENCE							
Domestic	5,000		.500	850		1,000	
Industrial		NIL	NIL	NIL	NIL	NIL	NIL
ACTON VALE							
Domestic	4,383		.438	745		877	
Industrial		750	.455	2,793	16,432(375%)	N/A	textile
ST. JOSEPH DE ST. HYACINTHE							
Domestic	3,910		.391	665		782	
Industrial		NIL	NIL	NIL	NIL	NIL	NIL
DOUVILLE							
Domestic	2,500		.250	425		500	
Industrial		NIL	NIL	NIL	NIL	NIL	NIL
ST. PIE							
Domestic	1,472		.1472	250		294	
Industrial		80	.1038	698.8	4,112(279%)	300	textile prepared food
ST. DAMASE							
Domestic	965		.0965	164		193	
Industrial		225	.3898	1,258.4	7,401(767%)	498	dairy prepared food

*The industrial waste figures cover only those industries for which information is available. Thus, the loading reported may underestimate the amount of industrial wastes entering the river.

N/A: Information on which to base an estimate is not available.

NIL: Major polluting industries are not located in this municipality.

Farther down the North Branch from Waterloo (see Figure 1), in the stretch of river from Granby to the confluence with the centre branch of the Yamaska, is the second problem area. The effluents from both industry and the municipal population in Granby are the principal factors contributing to the low water quality levels in this stretch of the river. Coliform counts in this area are very high during the summer, making the river unfit for body contact recreation.

A third water quality problem area is located below Cowansville. This stretch of the river has water quality problems similar to those of the North Branch below Granby, namely, low DO levels caused by high BOD from the municipal population and industry in Cowansville plus high coliform counts. The second and third areas comprise the most severe water quality problems in the basin.

A fourth problem area in the river is located between Farnham and St. Césaire and for a distance downstream from St. Césaire. The decline in DO in this stretch of the river is due to the concentration of industry in Farnham. The textile industry comprises a major portion of this industrial concentration. The decline in DO below St. Césaire is due mainly to the operation of two canneries located in the village. Thus, the oxygen sag downstream from Farnham is deepened by the addition of cannery wastes entering the river at St. Césaire. Unlike the three areas previously outlined, the DO concentration in this stretch of the river does not fall below 5 ppm, and recovers to about 8.5 ppm above St. Hyacinthe, 18 miles downstream. In relation to the other areas, the water quality problem here is not as severe. Although coliform is not as great a problem in this area, body contact recreation is probably unsafe.

The last major water quality problem area is located in the vicinity of St. Hyacinthe. The DO levels here are high despite the fact that St. Hyacinthe is a textile centre. Below the municipality, DO levels are above the saturation level (i.e. above 10 ppm). There appears, therefore, to be a nutrient problem in this stretch of the river. Eutrophication has caused a high level of algal growth which in turn has created a high DO concentration in the river. These conditions would seem to occur only during the summer, although confirmatory data for the winter months of the year are not available.

Waste Treatment Requirements and Alternatives

It is now possible to suggest alternative waste treatment requirements for the five water quality problem areas enumerated above. Most municipalities in the basin require secondary treatment; although only one or two industrial plants will require more than primary treatment.

In the Waterloo area, the most important waste treatment requirement is at the cannery located in the town. At this cannery, a number of possible waste treatment options are available. Primary treatment with solids removal is a possibility but the affect on DO levels will be minimal. Retention of the waste throughout the summer months, and release of the waste at periods of higher flow, is a second and better possibility. This alternative uses the natural capacity of the stream as a treatment system. A third alternative is full secondary treatment for the plant. Primary treatment for the municipality of Waterloo itself is essential to prevent raw municipal sewage from escaping into the river. This primary treatment would tend to lower significantly coliform counts in the river below Waterloo. If nutrient control through the addition of lime to the effluent from the treatment plant was instituted at this primary treatment plant in Waterloo, a significant reduction of nutrient levels in the water leaving Lake Waterloo could probably be achieved.

The second and third problem areas, below Granby and Cowansville respectively, as outlined above, are the most severe with respect to water quality. A high concentration of industry (mainly textiles) plus relatively large municipal populations, combine to create a serious water pollution problem. One of the largest contributors to this water pollution problem is the textile industry located in Cowansville. For example, one plant alone contributes 2.29 times as much BOD as the entire municipal population in Cowansville. Considering the magnitude of the water pollution problem in this area, a form of secondary treatment will probably be required. Waste retention is an unlikely possibility because the waste loadings from industry are large and production in the factories is a year-round process. Of the secondary treatment methods available, the most likely to be used in this area is activated sludge. The amount of waste and certain environmental factors such as climate will not allow the employment of the simpler and less expensive trickling filter system. Treatment plant locations present some alternatives. Firstly, both Cowansville and Granby could have their own combined municipal and industrial secondary treatment plant. Alternatively, the municipal and industrial waste from one of these towns could be piped to the other for combined treatment. Granby and Cowansville are thirteen miles apart, so that the second alternative would require a thirteen mile pipeline between the municipalities. A third alternative could be the construction of a combined waste treatment plant downstream from both municipalities probably near the confluence of the Southeast Branch with the main stem of the Yamaska, or possibly near Farnham. The last alternative, a combined treatment plant at or near Farnham, has the advantage that it could be used to treat the medium-sized waste loads generated at Farnham. At present as outlined above, these latter waste loads are dumped, untreated, into the Yamaska, depressing the DO curve significantly.

The deterioration in water quality at St. Césaire is due mainly to two canneries. The alternatives outlined for the cannery at Waterloo would also apply here. As already outlined, the water quality problem in the lower part of the river appears to be caused by eutrophic conditions. Dissolved oxygen readings are high in the river below St. Hyacinthe, despite the location of several textile plants in this municipality. The problem of oxygen content in the stream is therefore not as severe as in other parts of the basin, even during the low flow period of the summer. It is suggested that a high nutrient content in this part of the river is producing large algal growths, which in turn produce oxygen. This oxygen generated in the river is sufficient to alleviate any excessive BOD loadings, and in addition, to bring the DO readings in the lower part of the river in many cases above saturation level (i.e. 10 ppm). Thus, in regard to the emplacement of waste treatment facilities in the St. Hyacinthe area, a complex of facts must be considered. On the basis of information available, secondary treatment appears to be required. The amount of waste generated appears to be too high for primary treatment alone, although this type of facility could be built as the initial phase of a longer term project. Investigations done for this study show that a secondary (probably activated sludge) treatment facility at St. Hyacinthe could be extended to treat wastes from the surrounding municipalities of St. Damase, St. Pie, St. Joseph, Ste Rosalie and La Providence.

COSTS AND PRIORITIES FOR WASTE TREATMENT

The costs of waste treatment for the municipalities in the Yamaska Basin may be estimated using equations drawn from secondary sources. Appendix 2 sets forth the cost equations used in this paper. In general, these equations employ a linear regression technique wherein the cost of various types of waste treatment are linear functions of the required treatment plant capacities. Tables 4 to 11 show the costs of various types of treatment facilities in the basin. These costs are given in terms of constant 1971 dollars. The following section will deal with the financial aspects of establishing waste treatment systems in the basin.

The treatment plant itself is one component of the integrated treatment system. The other major component is a collection system. It is more difficult to estimate the cost of a collection system for municipalities, because variable local conditions (e.g. topography) make generalization somewhat more tenuous than estimation of treatment plant costs. In their review and forecast of waste treatment expenditures, Central Mortgage and Housing Corporation (C.M.H.C.) estimated that, for each dollar spent on treatment facilities in Quebec, 0.64 dollars would be required for collection systems. This figure covers only those parts of the collection system eligible for C.M.H.C. financial assistance.[5] These parts usually comprise the trunk collection system, but do not include lateral sewers or individual connections. Based on a sample of Canadian municipalities, the Canadian Federation of Mayors and Municipalities (CFMM) estimated that 1.5 dollars would be spent on sewer systems for each dollar spent on treatment plants.[6] Grava[7] projected that, in the United States, about 1.6 dollars would be spent on sewer systems for every dollar spent on treatment systems. For the Ottawa area over the next 10 years, Maclaren and Richards[8] estimated a ratio of 1:1 between expenditures for sewage systems and expenditures for treatment.

The ratio of collection system costs to treatment system costs is therefore highly variable depending upon the area, and the agency doing the cost estimations. The C.M.H.C. estimated, by virtue of the fact that the only expenditures considered were those eligible for federal assistance, is probably too low for our purposes here. In view of the high cost of collection in the overall cost of water pollution control, it is important that an allowance be made for the cost of a collection in the municipalities under consideration. In order not to underestimate this cost component the CFMM ratio 1.5 dollars sewer system expenditure for each dollar of treatment plant expenditure will be used in this paper.

In planning waste treatment works for the future, attention must be paid to joint treatment of municipal and industrial wastes. In making the cost estimates in this paper, problems and possibilities of joint treatment were investigated. It was found that, for most of the industrial plants in the basin, the waste treatment problems were essentially similar to those of the surrounding municipality (i.e. BOD suspended solids removal). Industry faces the initial problem of the separation of waste flows containing other waste material, and will possibly have to face the costs of this separation alone. However, the major portion of industrial wastewater could be combined with the domestic

5. See National Housing Act, Part VIII, for a precise definition of eligible projects.

6. Personal communication with the research staff of CFMM.

7. Grava, S., *Urban Planning Aspects of Water Pollution Control*, Columbia U.P., 1969, p. 108.

8. Maclaren J.W. and J.L. Richards Associates, *Report and Technical Discussion on Master Plan of Water Works and Waste Water Control for the Regional Municipality of Ottawa-Carleton*, 1970.

wastes. The economic feasibility of establishing such combined or joint treatment systems is investigated in this paper. Most of the cost estimates given below are based upon combining domestic and industrial effluents.

In terms of spatial pattern, Farnham, Granby, and Cowansville form an equilateral triangle approximately 14 miles on each side. Cumulatively, these three municipalities contain the greatest concentration of textile mill wastes in the basin. A possible option in developing wastewater treatment systems for the Yamaska is the construction of a regional treatment plant for these three municipalities. This option will be discussed further below. A similar option for St. Hyacinthe and the surrounding villages of St. Pie, St. Damase, Douville, La Providence and St. Joseph will also be examined.

In computing the cost of treatment systems for the Yamaska Basin, allowance must be made for past expenditures. The following table shows the amount of C.M.H.C. funds put into the basin since 1961. The C.M.H.C. funds account for the 66% of total expenditures on waste treatment. In calculating required investment in the basin, allowance has been made for the total amounts spent to the end of 1970.

Table 4. Past Expenditures on Waste Treatment and Sewer Facilities* ($000)

Municipality	C.M.H.C. Loan	Total Cost	Type of Facility
Granby Area	834	1,264	Collectors Interceptors
Waterloo	214	324	Collector
Cowansville	50	75	Collector
Stanbridge Station	36	55	Treatment System Collector
Douville	97	148	Activated Sludge Plant Collectors
St. Madelaine	82	124	Treatment Plant Collectors
St. Rosalie	102	155	Treatment Plant Collectors
St. Dominique	54	82	Collector
Total	1,469	2,227	

*The amounts reported here have not been adjusted for changes in the value of the dollar. Such an adjustment is made in Table 9, to the figures which must be used further in the cost analysis.

In this section, the information outlined in the first two sections will be brought together in a determination of the costs of waste treatment facilities in the Yamaska Basin. The previous section identified the most seriously degraded sections of the river with respect to water quality. Some attempt was made to rank these in order of the seriousness of the water quality problem. It is thought that the maximum impact on the stream's water quality will be derived from treating the most seriously degraded section first. (Actually, this statement is an assumption which cannot be completely substantiated without further data and analysis. However, it is an adequate working hypothesis for this report.) The term "priority" as used here refers solely to the order of seriousness of the pollution problem, and thus following from the assumption, to the order in which facilities should be built. These "priorities" have emerged solely from the analysis of the data in this paper, and no policy implications are intended; it is not intended in this paper to recommend policy with regard to the phasing of waste treatment in the basin.

The most seriously degraded areas in the basin with respect to water pollution are those areas downstream from Granby and Cowansville. A relatively high population and a relatively heavy industrial concentration in these municipalities are the basic factors contributing to water quality problems. Treatment facilities to serve Granby and Cowansville would have maximum impact on the water quality. In view of the magnitude of the wastes generated, activated sludge systems secondary treatment are required. Tables 5 and 6 show the costs of construction for both primary and secondary treatment systems. Table 5 pertains to the cost of installations to serve the domestic population while Table 6 refers to facilities for treatment of industrial wastes. The costs are combined in Table 7. Table 7 shows that the average construction cost of separate sludge plants in Granby and Cowansville would total just over 5 million dollars. Allowing for the 1.5 million dollars already spent in Granby for collection systems (see Table 9), and considering additional collection systems cost in each municipality (see Table 8), the total cost of separate treatment and collection systems would be about 6.7 million dollars (as indicated in Table 9).

As outlined, the costs of regional treatment in the southern portion of the basin were estimated. The first two alternative arrangements combine the wastes (domestic and industrial) from Cowansville and Granby for treatment in a regional plant. As shown in Table 10, the cost of treatment for either alternative is about 4 million dollars. Thus treatment of wastewater from these two municipalities in a regional treatment centre is about 1 million dollars cheaper than separate facilities to serve each location. The 4 million dollars does not include the costs of collection which are common to any treatment scheme selected.

In the southern portion of the basin, the other town having a relatively high volume of wastewater is Farnham. The water quality problems in the Farnham area are the same as those in the Granby and Cowansville areas. The analysis presented above shows that secondary treatment is

Table 5. Estimated Construction Costs of Waste Treatment Facilities to Serve Domestic Population in Principal Municipalities

Municipality	Population	Effluent Flow (Mgd)	Construction Cost of Treatment Facilities ($000)					
			Primary			Activated Sludge		
			O.W.R.C.*	Eckenfelder†	Average	O.W.R.C.	Eckenfelder	Average
Granby	33,750	3.375	811	896	853	1,364	1,713	1,538
St. Hyacinthe	24,277	2.428	621	700	661	1,035	1,331	1,183
Cowansville	11,300	1.130	335	395	365	544	741	643
Farnham	6,419	0.642	212	258	235	338	481	410
Acton Vale §	4,383	0.438	155	194	175	245	359	302

*Estimates based upon data contained in: Ontario Water Resources Commission, "A Guide on Estimating Sewage Treatment Plant Construction Costs in the Province of Ontario" *O. W.R.C.*, 1967.

†Estimates based upon linear regression curves contained in: Eckenfelder, W.W., *Water Quality Engineering for Practicing Engineers*, Barnes & Noble, 1970, Chapter 13.

§ Acton Vale was not discussed in the text because of the lack of water quality data for this municipality.

Table 6. Estimated Costs of Waste Treatment Facilities to Treat Industrial Effluents in Principal Municipalities

Municipality	Industrial Effluent (Mgd)	Construction Costs of Treatment Facilities ($000)					
		Primary			Activated Sludge		
		O.W.R.C.	Eckenfelder	Average	O.W.R.C.	Eckenfelder	Average
Granby	3,972	925	1,013	969	1,564	1,941	1,753
St. Hyacinthe	1.581	431	499	465	707	941	824
Cowansville	2.153	562	640	601	935	1,214	1,075
Farnham	.853	267	320	294	429	595	512
Acton Vale	.455	160	200	180	253	369	311

Table 7. Total Estimated Construction Cost of Waste Treatment Facilities in Principal Municipalities

Municipality	Construction Cost for Treatment Facilities ($000)					
	Primary		Activated Sludge			
	O.W.R.C.	Eckenfelder	Average	O.W.R.C.	Eckenfelder	Average
Granby	1,736	1,909	1,822	2,928	3,654	3,291
St. Hyacinthe	1,052	1,199	1,126	1,742	2,272	2,007
Cowansville	897	1,035	966	1,479	1,955	1,718
Farnham	479	578	529	767	1,076	922
Acton Vale	315	394	355	498	728	613

Table 8. Estimated Cost of Sewer Facilities in Principal Municipalities ($000)

Municipality	To Serve Domestic Population*	To Serve Industrial Establishments
Granby	2,307	NA
St. Hyacinthe	1,775	NA
Cowansville	965	NA
Farnham	615	NA
Acton Vale	453	NA

*Based upon average construction cost of activated sludge treatment.

NA: No information available.

probably required for Farnham. The cost of this form of treatment, as shown in Table 7, is about 0.92 million dollars, with an additional 0.62 million dollars required for collection facilities (see Table 8). The municipalities of Granby, Cowansville and Farnham are located in a triangular-shaped area in the southern part of the basin. The costs of building one regional facility to serve these three municipalities were investigated. The cost of combining the wastes from these three municipalities for treatment in a common plant averages 4.5 million dollars, as shown in the third alternative of Table 10. The location of this regional plant would be in the Farnham area,so as to take advantage of the downstream flow from Granby and Cowansville. This third alternative would result in a cost saving of 0.4 million dollars on required facilities at Farnham, i.e. an increase of 0.5 million dollars in the cost of regional facilities compared to the cost of a separate activated sludge plan at Farnham of 0.92 million dollars. Thus a regional plant in the Farnham area to treat the wastes from Granby, Cowansville and Farnham appears from this analysis to be economically most attractive, resulting in a cost saving of 1.4 million dollars over separate treatment systems in each municipality.

Table 9. Total Estimated Cost of Sewer and Treatment Facilities in Principal Municipalities ($000)

Municipality	Population	Treatment Cost*		Sewer Cost†	Total Previous Expenditure §	Total Estimated Cost		Per Capita Cost ($)	
		Primary	Secondary			Primary	Secondary	Primary	Secondary
Granby	33,750	1,822	3,291	2,307	1,503	2,626	4,095	78	121
St Hyacinthe	24,277	1,126	2,007	1,775	0	2,901	3,782	120	156
Cowansville	11,300	966	1,718	965	82	1,849	2,601	164	230
Farnham	6,419	529	922	615	0	1,144	1,537	178	240
Acton Vale	4,383	355	613	453	0	808	1,066	184	243

*Using average costs calculated in Table 7.
†Not including cost of collecting industrial wastes.
§Present value using Cost of Non-Residential Building materials in Prices & Price Indexes, *Statistics Canada*, 62-002.

Table 10. Estimated Construction and Operating Costs of Combined Activated Sludge Waste Facilities for Granby and Cowansville ($000)

Location Alternatives	Flow (Mgd)	Piping Cost	Total Construction Cost			Annual Operating Cost
			O.W.R.C.	Eckenfelder	Average	
(a) Combined Activated Sludge Plant at Granby (to serve Granby and Cowansville)	10.6	104	3,677	4,225	3,951	193.7
(b) Combined Activated Sludge Plant at Cowansville (to serve Granby and Cowansville)	10.6	156	3,729	4,277	4,003	193.7
(c) Combined Activated Sludge Plant near Farnham (to serve Granby, Cowansville and Farnham)	12.1	235	4,225	4,785	4,505	214.0

*Domestic & Industrial wastewater.

NOTE: The cost of waste water collection systems is not included in the costs calculated in this table, as these costs must be incurred regardless of the treatment arrangement. The costs of sewer facilities are as outlines in Table 7.

Table 11. Estimated Annual Operating and Maintenance Costs for Waste Treatment Facilities for Principal Municipalities

Municipality	Population	Total Flow (Mgd)	Estimated Operating and Maintenance Costs ($000/annum)	
			Primary	Activated Sludge
Granby	33,750	7.3	97	146
St Hyacinthe	24,277	4.0	57	93
Cowansville	11,300	3.3	48	80
Farnham	6,419	1.5	24	44
Acton Vale	4,383	.9	19	35

In terms of the magnitude of combined domestic and industrial wastes, the second priority for treatment is the St. Hyacinthe area. It is difficult to determine the degree and type of treatment required here, because the foregoing analysis failed to identify positively the water quality problem. Considering the magnitude of the combined domestic and industrial pollutants, it seems reasonably clear that some form of secondary treatment will be required. An average estimated cost for activated sludge treatment (to treat both domestic and industrial wastes) is shown in Table 7 to be just over 2 million dollars, the cost of a collection system (see Table 8) sould be about 1.775 million dollars. Thus the total cost of an adequate waste treatment system (treatment plus collection) for St. Hyacinthe is estimated at about 3.8 million dollars. No C.M.H.C. funding has been allocated to St. Hyacinthe.

As in the southern part of the basin, an examination was made of the possibility of establishing regional treatment in the St. Hyacinthe area, to serve both the city and the surrounding municipalities. In addition to the city itself, the smaller municipalities of St. Pie, St. Damase, La Providence and St. Joseph were included in the cost analysis. As indicated in Table 12, the average cost of constructing regional activated sludge facilities is estimated at 2.93 million dollars including piping costs from the outlying municipalities to the regional facilities. The most likely location for these facilities would be St. Hyacinthe where most of the wastewater for treatment would originate.

The third most advantageous area for waste treatment funds would be the construction of waste retention facilities at the cannery in Waterloo. Waste retention, with release during periods of high flow, seems adequate here. The cost of waste stabilization for this purpose is calculated using

$$\log C = 1.15385 + .6525 \log X$$

where C = cost in thousands of dollars
X = volume of lagoon. Mgd

By this method the cost of such a structure would be about 194 thousand dollars.

The construction of a treatment facility in Acton Vale appears to be fourth in priority in terms of impact on the receiving water quality. Although no water quality information is available for this area the magnitude of the industrial pollution problem in this municipality is plain from Table 3. Secondary treatment must be installed there in order to eliminate the BOD problem. The treatment of municipal and industrial effluent from Acton Vale is placed relatively low on the list of priorities because, by the time the tributary on which this municipality is located enters the main stem of the Yamaska, the DO level is relatively high, showing that in-stream processes have operated to purify the river to a large extent.

The installation of a waste treatment facility for the two small canneries at St. Césaire is viewed as the fifth most important area for investment in waste treatment facilities. Ponding of the waste generated during the summer flow period, for release in periods of high flow, would alleviate this problem considerably. Combining the waste from the two canneries, the estimated cost of the retention pond is 89 thousand dollars.

Table 12. Estimated Construction, Operating and Maintenance Costs in $000 of Combined Waste Treatment Facilities for St. Hyacinthe and Vicinity

Origin of Effluent	Flow (Mgd)	Piping Cost	Total Construction Cost			Annual Operating & Maintenance Cost
			O.W.R.C.	EWT	Average	
St. Hyacinthe	4.009	0				
St Pie	.251	204				
St. Damase	.486	235				
La Providence	.500	33				
St. Joseph	.391	29				
Total	5.637	501	2,714	3,142	2,928	120

FINANCING WASTE TREATMENT SYSTEMS IN THE YAMASKA BASIN

The costs of waste treatment in the principal municipalities in the basin as determined above are in terms of constant 1971 dollars. There were three basic systems considered: domestic treatment only, joint domestic and industrial treatment, and regional treatment of combined domestic and industrial wastes from several municipalities. These systems must be financed over a long-term period. This section will outline the methods used in determining per capita costs of financing.

A number of assumptions were necessary in compiling cost of financing. The major assumption made was that financing terms similar to those available from C.M.H.C. would be found to finance those portions of waste treatment systems which C.M.H.C. does not cover. This, of course, is only one of a variety of financial arrangements possible, all of which cannot be covered here. The assumption made here simplifies calculations, but still enables exposition of the methodology which can be used in making the financial calculations.

In Canada, C.M.H.C. is the most comprehensive source of funds for the construction of wastewater treatment systems. Under Part VIII of the National Housing Act, C.M.H.C. may make a loan to any province, municipality or municipal sewerage corporation for the construction or expansion of a sewage treatment project. Two types of projects are eligible for this assistance: construction or expansion of a central treatment plant, and the construction of trunk sewers.[9] In Bill C-122 now before Parliament, it is proposed to consider regional collection systems (i.e. collectors running from several municipalities to a regional treatment plant) as eligible projects under this Act. Regional collector systems have been considered as eligible expenses in this paper. For an eligible project, C.M.H.C. will grant low interest loans for up to two-thirds of the project cost. The amortization period of the loans is up to 50 years, and varies with the ability of the individual municipality to pay. The current interest rate on such loans is $7^1/_2$%. In addition to the provision of low interest loans, the Act allows for partial debt cancellation for projects completed or on which satisfactory progress has been made by March 31, 1975. Under the latter provision, the federal agency will forgive 25% of the loan principal plus 25% of the interest accumulated during construction of the project.

Table 13 to 16 summarize the financial calculations made for the principal municipalities in the Yamaska Basin. Tables 13 and 14 deal with the costs of treatment assuming combination of domestic and industrial wastes. Tables 15 and 16 deal with the same costs for treatment of domestic wastes only. By outlining in detail the calculations of Tables 13 and 14, it will be seen how the amortization costs were obtained.

From Table 9, the total required investment was obtained. Using the C.M.H.C. criteria, the amount of required investment eligible for federal financing was estimated. In the case of all principal municipalities, the entire cost of treatment systems is considered eligible. In the case of collection systems, it was estimated that $30.00 per capita for trunk sewers, etc., is eligible for financing by C.M.H.C. In the case of municipalities with no work done in the past on collection systems, the full amount eligible for C.M.H.C. financing was added to the cost of the treatment plant to obtain the total amount eligible for federal financing. For example, in St. Hyacinthe, $728 thousand ($30 per capita x 24,277) is the portion of collector system costs eligible under C.M.H.C. To this amount, the cost of the treatment plant as set forth in Table 9 ($1,126 thousand for primary and $2,007 thousand for activated sludge) was added to obtain the total amount eligible for federal financing. In the case of Granby and Cowansville, investment has already been made for partial completion of the collection system. To obtain the amount eligible for federal financing, allowance was made for previous expenditure. For example, in Cowansville $82 thousand (present value) has been spent since 1961 on collection networks. The total eligible amount for collection systems was estimated to be $339 thousand. Thus, the amount of investment still eligible under C.M.H.C. is $257, thousand. This amount was added to the cost of a treatment system ($969 thousand for primary, and $1,717 thousand for activated sludge) as outlined in Table 9 to obtain the total amount eligible for federal financing. The amount of the federal loan was calculated as 66.67% of the eligible amount.

The total amortized cost was calculated using $7^1/_2$% interest over 25 years.[10] As mentioned above, it was assumed in these calculations (a) that the portion of the required investment attributable to industry could be financed under terms similar to those available from C.M.H.C., and (b) that the portion ineligible for federal investment could be similarly financed. These assumptions may not reflect accurately financing conditions at the time of construction. They can, however, be replaced easily by the actual financing terms to re-calculate the total costs of waste treatment systems at the time of construction. The totals may by affected slightly by altering the financing

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9. For the definition of what is considered a trunk sewer, see C.M.H.C., *N.H.A. 13, Loans for Sewage Treatment Projects*, 1971, pp. 1 - 2.

10. See Appendix 3.

conditions; however the order-of-magnitude of the total costs should not be affected by these alterations.

To obtain the total cost to the municipality of treatment systems proposed, the amount of federal forgiveness was deducted from the total project cost. As outlined above, the partial debt cancellation is calculated as being 25% of the loan plus 25% of the interest which accrues during construction, assuming project completion by March 31, 1975. The total amount of federal forgiveness was determined in this way to be approximately 28.75% of the original loan. The total cost of waste treatment systems to the municipalities in the basin is shown in the last two columns of Table 13. Table 14 shows the same costs as average per capita costs per annum.

The economies of scale accruing to relatively large populations may be seen in Table 14. For Granby, the

Table 13. Cost of Financing Waste Treatment Systems to Treat Domestic and Industrial Wastes in Principal Municipalities ($000)

Municipality	Total Required Investment*		Amount Eligible for Federal Financing**		Amount of Federal Loan‡		Interest Charges‡		Total Cost		Federal Forgiveness††		Total Cost to Municipality	
	Prim.†	A.S.§	Prim.	A.S.	Prim.	A.S.	Prim.	A.S.	Prim.	A.S.	Prim.	A.S.	Prim.	A.S.
Granby § §	2,626	4,095	1,822	3,291	1,215	2,194	1,509	2,726	4,135	6,821	349	631	3,786	6,190
St. Hyacinthe	2,901	3,782	1,854	2,735	1,236	1,824	1,535	2,266	4,436	6,048	355	524	4,081	5,524
Cowansville	1,849	2,601	1,223	1,975	817	1,317	1,015	1,636	2,864	4,237	235	378	2,629	3,859
Farnham	1,144	1,537	722	1,115	481	744	597	924	1,741	2,461	138	214	1,603	2,247
Acton Vale	808	1,066	486	744	324	496	402	616	1,210	1,682	93	143	1,117	1,539

* See Table 9.
† Prim. = Primary Treatment
§ A.S. = Activated Sludge Treatment
** The figures here are based on the assumption that loan terms similar to those of C.M.H.C. can be arranged for treatment plants combining domestic and industrial wastes. The amounts eligible for federal financing comprise (1) all construction costs for treatment plants, and (2) an allowance of $30.00 per capita for collection systems eligible under part VIII b of the National Housing Act. From the eligible amounts so determined has been deducted the present value of works already completed.
‡ $66^2/_3$% of eligible amount.
‡ Loans were amortized at $7^1/_2$%, the current C.M.H.C. lending rate, and over a 25 year period.
†† As per Section VI b of the National Housing Act, if construction is completed by March 31, 1975, 25% of the loan amount and 25% of the interest incurred to the time of completion of construction.
§ § For Granby, the previous expenditure on collector systems is greater than the amount eligible for federal financing. Therefore, an allowance was not made for the construction of collector systems.

Table 14. Annual Per Capita Costs of Financing Domestic and Industrial Waste Treatment Systems in Principal Municipalities

Municipality	Total (Amortized) Construction Cost ($000)		Average Annual Cost per Capita ($)*	
	Primary	Activated Sludge	Primary	Activated Sludge
Granby	3,786	6,190	5	7
St. Hyacinthe	4,081	5,524	7	9
Cowansville	2,629	3,859	9	14
Farnham	1,603	2,247	10	14
Acton Vale	1,117	1,539	10	14

*In terms of 1970 population.

Table 15. Cost of Financing Waste Treatment Systems to Treat Domestic Wastes in Principal Municipalities ($000)

Municipality	Total Required Investment		Amount Eligible for Federal Financing		Amount of Federal Loan		Interest Charges	
	Prim.	A.S.	Prim.	A.S.	Prim.	A.S.	Prim.	A.S.
Granby	1,657	2,342	874	1,559	583	1,039	724	1,291
St Hyacinthe	2,436	2,958	1,389	1,911	926	1,274	1,150	1,583
Cowansville	1,248	1,526	622	900	415	600	516	745
Farnham	850	1,025	428	603	285	402	354	499
Acton Vale	628	755	306	433	204	289	253	359

Municipality	Total Cost		Federal Forgiveness		Total Cost to Municipality	
	Prim.	A.S.	Prim.	A.S.	Prim.	A.S.
Granby	2,381	3,633	168	299	2,213	3,334
St Hyacinthe	3,586	4,541	266	366	3,320	4,175
Cowansville	1,764	2,271	119	173	1,645	2,098
Farnham	1,204	1,524	82	116	1,122	1,408
Acton Vale	881	1,114	59	83	822	1,031

largest municipality, the annual per capita costs are $5 and $7 for primary and activated sludge systems respectively. This contrasts to the corresponding costs of $10 and $14 in Acton Vale, a municipality with a population 13% as large as Granby's.[11]

Table 16. Annual per Capita Costs of Financing Domestic Waste Treatment Systems in Principal Municipalities

Municipality	Total (Amortized) Construction Cost ($000)		Average Annual Cost per Capita ($)*	
	Prim.	A.S.	Prim.	A.S.
Granby	2,213	3,334	3	4
St. Hyacinthe	3,320	4,175	5	7
Cowansville	1,645	2,098	6	8
Farnham	1,122	1,408	7	9
Acton Vale	822	1,031	8	9

*In terms of 1970 population.

Tables 15 and 16 are computed in the same manner as outlined above, but omitting the portion of treatment costs attributable to industry. Again, this table points up the economies of scale attributable to larger population size.

Tables 17 and 18 show the amortized cost of the regional treatment arrangements set forth in Table 11. The data for Tables 17 and 18 have been computed as outlined above for Tables 13 and 14. For the Granby-Cowansville-Farnham regional centre, cost per capita served per year averages 7 to 8 dollars. This per capita figure is somewhat higher than the corresponding cost for treatment facilities to serve Granby alone, but is significantly lower than those of Cowansville and Farnham. The net effect is a significant lowering of total cost when compared to the installation of separate systems in each municipality. The annual per capita cost of the regional facilities suggested for the St. Hyacinthe area averages 41 dollars. This regional plant would be smaller than the one for the Granby-Cowansville-Farnham area. Thus, the economies of large-scale operation are not as great, and the total cost rises. However, considering the sources of the wastewater to be treated in the St. Hyacinthe regional system, the costs (of the regional plant) are significantly lower than separate facilities in each municipality.

CONCLUSIONS

This paper has presented a method of determining the costs of and priorities for waste treatment in the Yamaska River Basin. Based upon limited available information, the major sources of water pollution in the basin were identified. For the most part, these sources can be termed "point" sources, for their precise point of entry into the river can be identified. The study attempted to deal only with the major point sources, defined as being wastes from the larger municipalities and larger industries in the basin. Thus, an exhaustive listing of all point pollution sources was not compiled. A conclusion of this section is that the

11. The economy of scale effect is slightly distorted by previous expenditures. This distortion is not considered to be significant.

Table 17. Cost of Financing Regional Waste Treatment Systems to Treat Domestic and Industrial Waste ($000)

System	Total Required Investment	Amount Eligible for Federal Financing	Amount of Federal Loan	Interest Charges	Total Cost	Federal Forgiveness	Total Cost to Municipality
Granby-Cowansville-Farnham Area							
Alternative A, Table 10	5,638	4,208	2,805	3,510	9,148	806	8,342
Alternative B, Table 10	5,690	4,260	2,839	3,527	9,217	816	8,401
Alternative C, Table 10	6,807	4,955	3,303	4,104	10,911	950	9,961
St Hyacinthe Area	6,187*	4,057	2,704	3,360	9,547	777	8,770

*Includes an allowance for cost of sewers in municipalities surrounding St. Hyacinthe.

pollution from industrial operations as shown by the population equivalents of Table 3 is significantly higher than that attributable to the domestic population.

Table 18. Annual Per Capita Cost of Financing Regional Waste Treatment Systems to Treat Domestic and Industrial Waste

System	Total (Amortized) Construction Cost ($000)	Average Annual Cost per Capita ($)
Granby-Cowansville-Farnham Area		
Alternative A, Table 10	8,342	7
Alternative B, Table 10	8,401	7
Alternative C, Table 10	9,961	8
St. Hyacinthe Area	8,770	10

The paper made no attempt to deal with the widespread, or "non-point" pollution sources, such as agricultural runoff or recreational pollution caused by the over development of the headwater lakes. This gap in the analysis arises because comprehensive data are not available concerning these non-point pollution sources. It is important that more information be gathered concerning these potentially serious sources of water pollution.

With the major pollution sources identified, the impact of these sources on the receiving water course was examined. On this basis, the five most seriously degraded stretches of the Yamaska River were identified. Assuming that the most seriously degraded area be considered the first priority for treatment, these five stretches were ranked according to their priority as follows: the Granby-Cowansville-Farnham area; the St. Hyacinthe area; downstream of Waterloo; the Acton Vale area; and downstream of St. Césaire. Treatment arrangements were suggested to abate water pollution in these areas. In general, it was found that the Granby-Cowansville-Farnham area, the St. Hyacinthe area, and the Acton Vale area require secondary treatment, probably in the form of activated sludge. At Waterloo and St. Césaire, the cannery industry is the main contributor to low water quality. Treatment in the form of waste retention ponds, with release corresponding to high river flows, would correct much of the water pollution problem in these two areas.

The costs of the treatment requirements in the major municipalities were estimated using cost equations derived from secondary sources. To these estimated costs were added the cost of installing collector facilities in these municipalities. In making the estimates of treatment cost, two arrangements were examined. Firstly, the cost of treating domestic wastes only was estimated. It has since been found that the major source of water pollution in the basin is the industrial effluent. Thus, treating the basin's domestic wastes would not greatly improve the water quality of the river. For this reason, the first alternative was discarded. It was found that, for the most part, the domestic and industrial effluents could be treated in common facilities. This fact was used in deriving the main set of cost estimates put forth in the paper. The estimated average total cost of treating the combined domestic and industrial effluents in the principal municipalities was calculated to be about $60 per capita for primary treatment, and $107 per capita for secondary treatment, with an additional $56 for collector systems. It was found that significant cost savings could result from the erection of regional treatment facilities to serve the Granby-Cowansville-Farnham area and the St. Hyacinthe area as a result of economies of scale. The concepts of joint domestic-industrial treatment and regional treatment are economically attractive, and deserve further study.

The costs of the proposed treatment alternatives were amortized at $7^1/_2\%$ over 25 years. The effects of scale economies in the larger municipalities are revealed in these calculations. In Granby, the annual amortized construction costs for primary and activated sludge treatment (including collection costs) are estimated at $5 and $7 per capita respectively, while the corresponding costs of the Granby-Cowansville-Farnham regional plant are estimated at about $8 per annum per capita served; the corresponding per capita annual cost of the regional plant proposed for the St. Hyacinthe area is $10.

APPENDIX I

WATER QUALITY PARAMETERS

Dissolved Oxygen

Dissolved oxygen (DO) concentration in a stream course is one of the most important indicators of that stream's water quality. A DO level of 5 ppm is required to sustain a viable aquatic life in the stream. A concentration of 10 ppm (or thereabouts, depending upon temperature) is the DO saturation level. An untreated waste loading from a municipal or an industrial sewer will place a stress upon the DO content of the stream, depressing the DO curve below the saturation level. The rate at which the depression of the curve occurs varies with the stream's hydrologic characteristics and the quality of the waste which goes into it. The low point in the DO curve is the so-called "oxygen sag". The water quality standard which pertains to the stream will most likely be violated in the oxygen sag part of the curve. Although the river will act as a treatment system and will recover its DO downstream from the waste source if additional waste does not enter the system, waste treatment must be placed at key locations along its course in order to prevent the decrease of DO below acceptable standards.

At the outlet of Waterloo Lake, DO varies between 8 ppm in May and 9.5 ppm in August. The summer algal growth in Waterloo Lake, as a result of nutrient enrichment in the summer months, increases the DO concentration so that in August the water at the outlet of the lake is supersaturated with dissolved oxygen. In the summer months, the addition of BOD from a cannery and from the municipality itself depresses the DO curve below 5 ppm at Waterloo. The river recovers to about 7 ppm above Granby. During July when low flows occur, the addition of industrial and municipal BOD at Granby, shown in Table 3, depresses the DO level to 0 ppm as far downstream as St. Alphonse de Granby. Where the north branch of the Yamaska joins the main stem of the river, the DO concentration falls below 3 ppm; this serious decline in the DO curve is a result of the addition of oxygen-deficient water from the vicinity of Granby.

The Centre Branch of the Yamaska from Brome Lake to the confluence of the North and Centre Branch has an adequate DO level for the maintenance of aquatic life. The nutrient enriched water from the lake is often supersaturated with DO. There is, therefore, an eutrophication problem in Brome Lake similar to that in Waterloo Lake.

The Southeast Branch from its source to just above Cowansville has a DO concentration between 8 and 9 ppm. The municipal and industrial BOD loads entering the river at Cowansville depress the DO curve to 0 ppm in the summer months downstream from Cowansville. Below the confluence of the North Branch and the main stem of the Yamaska the water quality improves to between 8 and 10 ppm. The addition of industrial and municipal polluting materials from the town of Farnham again depresses the DO levels in the river.

Below the town of St. Césaire, DO levels are depressed to about 5 ppm. This depression is due to the wastewater discharge from two canneries in the village. Below St. Césaire the river slowly recovers its DO level until, in the vicinity of St. Hyacinthe, the DO level is about 7.5 ppm.

From St. Hyacinthe to the St. Lawrence, the DO level is high. The DO curve indicates the presence of an eutrophication problem in the lower section of the river. The municipal sewers of several small towns and villages enter the stream in this stretch of the river. As no large industry is located along this stretch of the river to add BOD to the river, the algal activity resulting from nutrients in the municipal waste causes the DO level to rise above the saturation point.

Coliform Bacteria

Coliform bacteria, which originates in the intestinal organs of animals or humans, indicates the presence of raw animal or human waste in the water. The Ontario Water Resources Commission has set one hundred coliforms per hundred milliliters of waste as the maximum allowable if the water is to be used for swimming. When viewed against this standard, the coliform problem in the Yamaska is severe, especially in the summer when coliform counts of 300,000 per hundred milliliters are common.

It is difficult to base water quality judgements on coliform, because coliform counts will vary widely with weather conditions, collection conditions, flow in the river, sampling location, etc. Because of the unreliability of coliform counts they were not used as major criteria in setting up waste treatment priorities in the Yamaska Basin.

Colour

Colour indicates the presence of organic materials such as tannin, humic acid, and wood. The U.S. Department of Public Health has set fifteen units of colour as the acceptable limit of quality. In the Yamaska Basin, the colour is over this standard at most locations. Apart from the unaesthetic appearance of the stream when colour

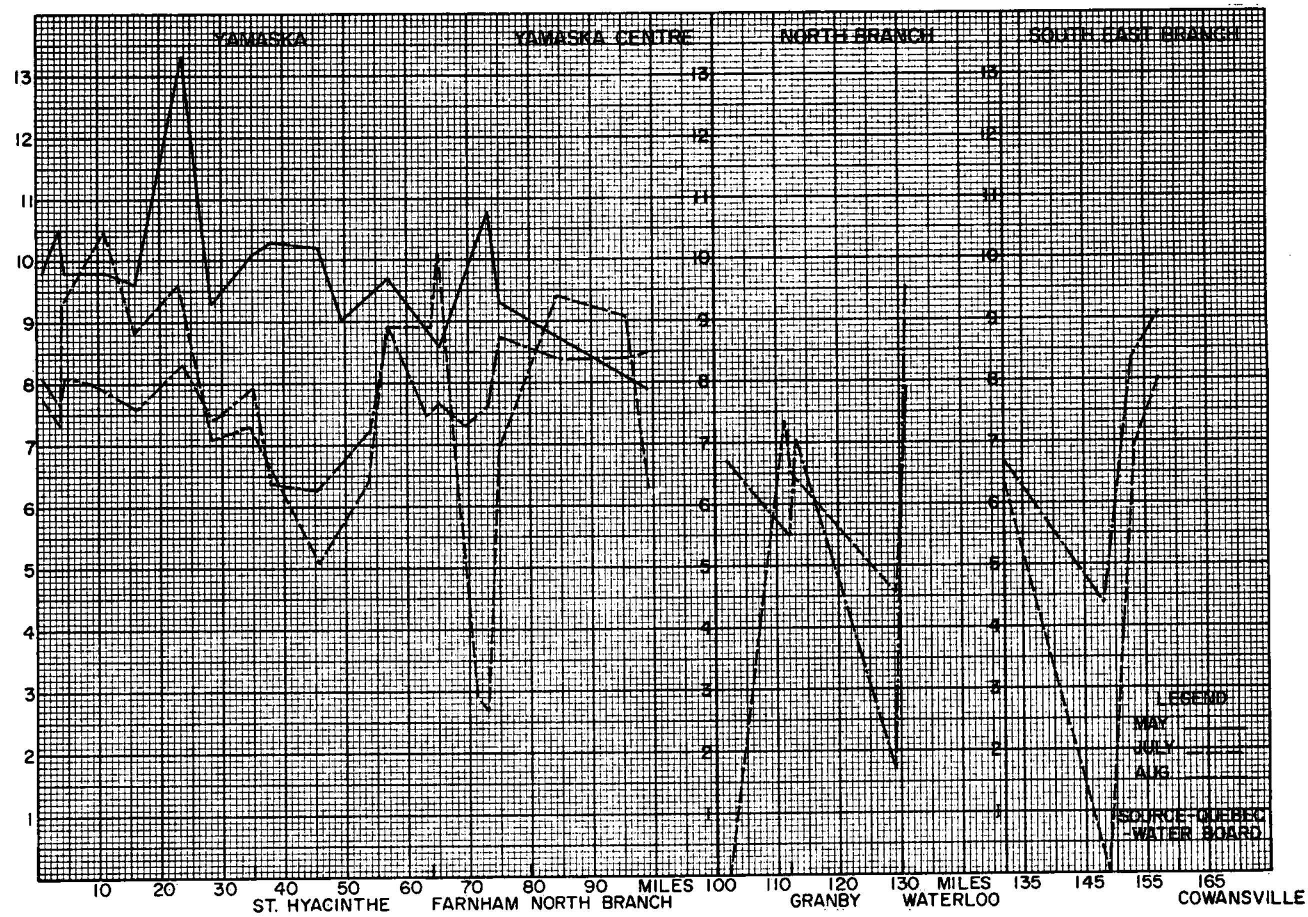

Figure 2. Dissolved oxygen.

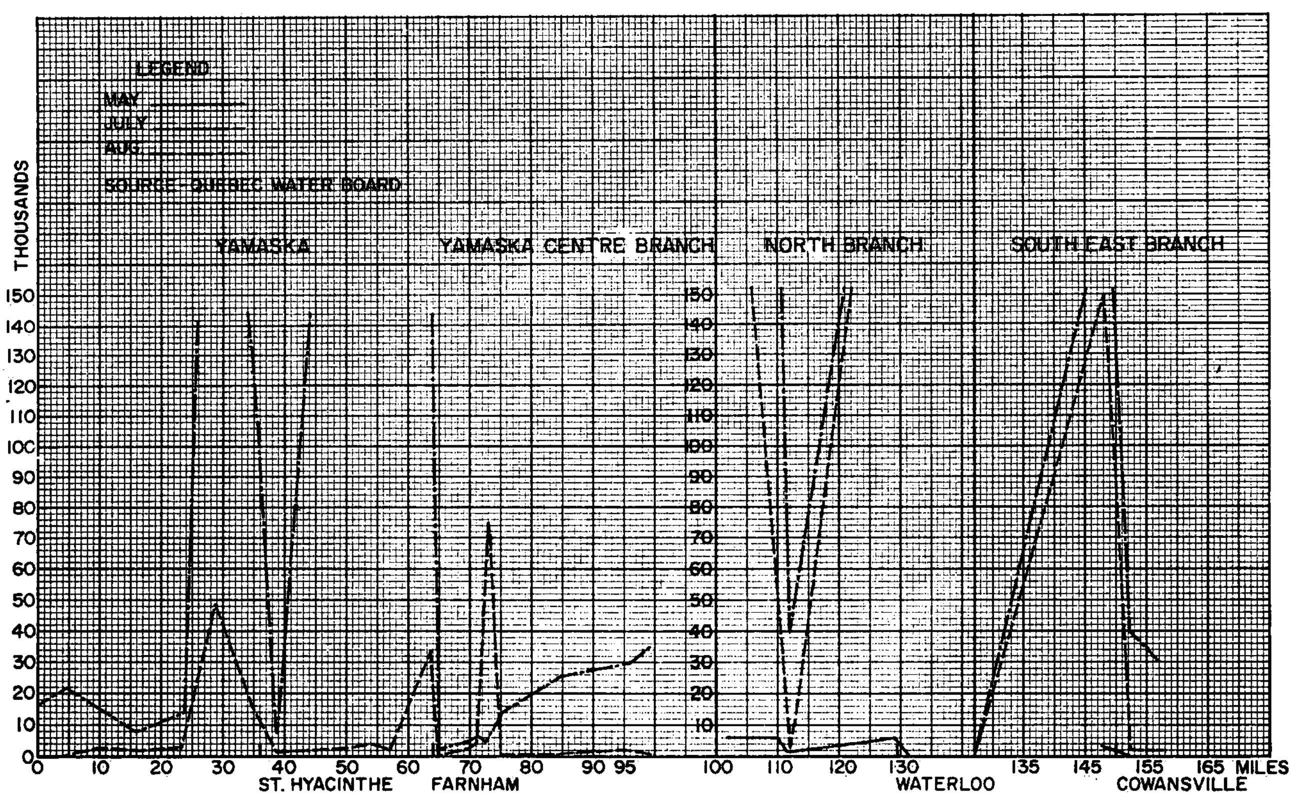

Figure 3. Coliform bacteria/100 ml.

values are high, it is difficult to base any water quality decisions on this criteria. Colour, therefore, was not considered as a major criteria in this paper.

Turbidity

Turbidity is an index of the amount of material suspended in the water. The solid load entering the river from the major municipalities in the basin is shown in Table 3. Turbidity in a stream course is quite variable depending, for exampe, upon flow volume and velocity, material size, etc. For the Yamaska, the turbidity curve rises at each town and declines downstream from the town as the suspended material settles out of the water. As in the case of colour and coliform counts, it is difficult to base any solid judgements upon the turbidity of the water. It will, therefore, not be used as a major criteria in this paper.

APPENDIX II

COST EQUATIONS FOR WASTE TREATMENT

Waste treatment costs have been estimated from secondary sources. The Ontario Water Resources Commission (O.W.R.C.) has analyzed treatment costs for municipalities in Ontario. According to this source the construction cost for waste treatment facilities is a function (logarithmic) of design capacity (i.e. the flow which the plant will be required to handle). Specifically, for primary treatment:

$$\log C = 2.4815 + .8094 \log Q \qquad (1)$$

where: C = total construction costs of the plant
Q = design capacity in millions of gallons per day
logs are log base 10

For secondary treatment by activated sludge:

$$\log C = 2.69095 + .8403 \log Q \qquad (2)$$

A publication by Eckenfelder gives equations for the same type of costs as those given by the O.W.R.C. These are:

Primary treatment

$$\log C = 2.5563 + .7500 \log Q \qquad (3)$$

Secondary treatment

$$\log C = 2.8293 + .7657 \log Q$$

Eckenfelder also gives an equation relating annual operating and maintenance costs for primary and activated sludge treatment as follows:

Primary treatment

$$\log M = 1.2305 + .875 \log Q \qquad (5)$$

Activated sludge treatment

$$\log M = 1.512 + .7556 \log Q \qquad (6)$$

Using the two different sets of equations outlined above, it is possible to estimate the costs of waste treatment in the main municipalities in the basin.

Pipeline construction costs for a regional facility were estimated using:

$$C = 46.433 L\sqrt{Q}$$

where C = cost in dollars; Q = capacity in millions of gallons per day;

L = pipeline length in miles

APPENDIX III

CALCULATION OF INTEREST CHARGES

The assumptions made to calculate the interest charges are the following:

the interest rate is 7.5%
the period is 25 years
the municipality makes 25 equal payments

The interest charges then are the difference between the amount paid back and the amount of loan or:

$$Ic = (P \times t) - L$$

where Ic is the interest charges, P the annual payments, t the number of years and L the amount of the loan.

To determine the amount of annual payments, the formula used was

$$P = L \times \left[\frac{i}{1 - \frac{1}{(1+i)^t}} \right]$$

where i is the interest rate, P the annual payments and t the number of years.

For example, the annual payments for a loan of 100 dollars at $7^1/_2$% for 25 years would be

$$P = 100 \times \left[\frac{.075}{1 - \frac{1}{(1+.075)^{25}}} \right] = 8.97$$

The total amount paid is then

$P \times t = 8.97 \times 25 = 224.25$

So the interest charges are

$Ic = 224.25 - 100 = 124.25$