DONALD M. TATE

SOCIAL SCIENCE SERIES NO. 4

INLAND WATERS DIRECTORATE,
WATER PLANNING AND MANAGEMENT BRANCH,
OTTAWA, CANADA, 1973.

Environment Canada   Environnement Canada

Economic and Financial Aspects of Wastewater Treatment in the St. François River Basin, Quebec

A Preliminary Analysis

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Summary

This paper examines the magnitude of the water pollution problem in the St. François River basin, Province of Quebec. The basin is located in the Eastern Townships, east of Montreal.

Chapter 1 of the paper, which serves as an introduction, examines the major pollution sources in the basin. These are identified as being wastes from industrial plants, and domestic wastes from municipalities. It is apparent that the major cause of the severe pollution problems is the entry of raw industrial waste into the river. This chapter describes the present state of waste treatment facilities, finding that these are completely inadequate in the prevention of water pollution.

Chapter 2 describes the water quality of the St. François River, from its source to its mouth. On the basis of this description, four priorities for waste treatment investments are identified as follows:

Priority I : The pulp and paper towns of East Angus, Bromptonville, and Windsor.

Priority II : The three largest municipalities, Sherbrooke, Drummondville and Magog.

Priority III: The remaining towns over 1,000 persons.

Priority IV: Towns and villages under 1,000 persons.

The treatment of waste from the recreational areas located around headwater lakes and areas outside of the municipalities is not dealt with because of the lack of information on the pollution loads of these areas.

Chapter III deals with the costs of providing waste treatment in the four priority areas outlined above. The treatment of the domestic wastes of the pulp and paper towns by feeding them into the pulp and paper mill treatment plants is suggested by the preliminary analysis of this paper. This method of treatment appears to be cheaper than that of constructing waste treatment plants outside the mills to handle the combined domestic and industrial wastes. It is believed that activated sludge plants must be constructed for the municipalities of Priority II. For those

Table 1. Summary of Total Cost of Waste Treatment and Collection Systems ($000, except where indicated)

Group	Primary		Activated Sludge	
Priority Group I	Not considered		Old Technology = 3,313 + cost at Kruger Typical Technology = 4,625 + cost at Kruger	
	Construction	Annual Operating & Maintenance	Construction	Annual Operating & Maintenance
Priority Group II				
Total	13,598	366	19,279	528
Per Capita ($)	121.00	3.25	171.00	4.69
Priority Group III				
Total	5,007	84	6,390	175
Per Capita ($)	152.00	2.56	194.00	5.32
Priority Group IV				
Total	593	10	677	24
Per Capita ($)	201.70	3.40	230.27	8.16
Total cost for all groups	19,198	460	Old Technology 29,659* Typical Technology 30,971 Old Technology 190 Typical Technology 199	N.A. N.A. N.A. N.A.

*Including cost from Priority Group 1, not including allowance for the Kruger paper mill in Bromptonville.

Table 2. Summary of Amortized Costs of Waste Treatment and Collection Systems*
(thousand 1971 dollars, except where noted)

Municipality	Total Construction Cost†		Activated Construction Cost Per Capita (Dollars)		Annual Operating and Maintenance	
	Primary	Activated Sludge	Primary	Activated Sludge	Primary	Activated Sludge
Priority Group I	not evaluated	Old Tech. 4,937§ Typ. Tech. 7,084	not evaluated	Old Tech. 18 Typ. Tech. 26	not evaluated	N.A.
Priority Group II	19,765	28,870	7	10	336	528
Priority Group III	6,570	8,786	10	14	84	175
Priority Group IV	805	943	11	13	10	24

*Loans are amortized at $7^{1}/_{2}\%$ per annum over 25 years. Costs are based upon combined domestic and industrial waste treatment.

†The cost figures represent the amounts to be borne by the municipality itself and include the federal allowances made under the National housing Act.

§Not including allowance for the Kruger paper mill at Bromptonville.

municipalities of Priority III, it is suggested that primary treatment be installed now with the provision to augment this system later to the secondary level. For the Priority IV municipalities, primary treatment may be sufficient, in consideration of the small waste loads generated in these towns. The costs of alternative forms of waste treatment for each priority group are shown in Table 1.

Chapter 4 deals with the costs of financing adequate waste treatment facilities in the basin. The amortization terms used to calculate the financing costs are outlined in detail in the text. A summary of these costs is given in Table 2.

Chapter 5 and the Appendices present the conclusions which have been drawn from this study and give the cost break-down of waste treatment facilities together with the equations used to arrive at these costs.

Introduction

The St. François River is a tributary of the St. Lawrence about 55 miles northeast of Montreal. Its basin is peculiar in shape, resembling a large "T". The top of the "T" occupies one of the many southwest-northeast trending valleys of the Appalachian mountain chain.

The physiography of the upper part of the valley has a moderate amount of relief, and is characterized by several large lakes, such as Lake Memphremagog, Lake Massawipi, Lake St. François, Lake Aylmer, and Lake Weedon. The winter season has a high amount of snowfall, and this factor combined with the relief of the area makes the headwater part of the basin a popular ski area.

The basin is populated by about 290,000 persons. The lower part of the basin is dominated by two municipalities, Drummondville (28,537) and Richmond (4,005). The upstream part of the basin contains the municipalities of Sherbrooke (70,138), Lennoxville (4,100), Windsor (6,375), East Angus (4,800), Coaticook (7,800), Magog (13,797), Rock Forest (3,582) and Disraeli (3,500). Estimated total employment in the basin is about 60,000.

MAJOR INDUSTRIES

Agriculture occupies a relatively important place in the basin's economy because of the area's good soil conditions, large urban population and proximity to Montreal. The agricultural produce includes dairy products, beef, pork, poultry, forest products, and potatoes. About 14.5% of the basin's population is engaged in agriculture, with the value of poduction being close to $30 million in 1966. In that same year, about 13 thousand tons, or 65 lbs./acre, of fertilizer was used on the land. According to the Quebec Water Board[1], the water pollution resulting from agricultural runoff is negligible compared to that caused by the manufacturing industry, the composition of which is shown in Table 3.

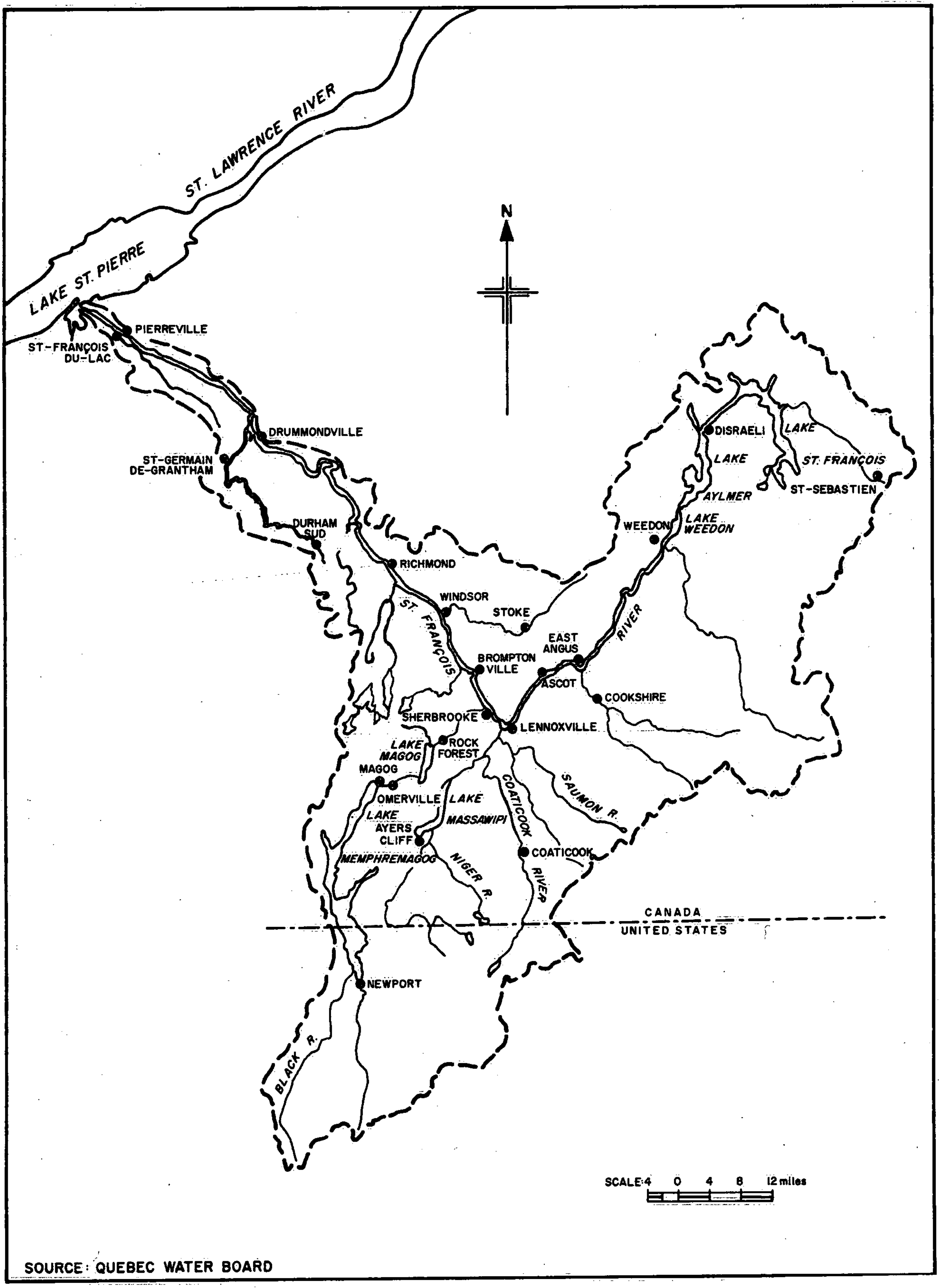
The textile industry, an old and well established one in the basin, employs approximately 8,200 persons. There is also an indeterminate number of workers employed in the "secondary" textile industry (i.e. the manufacture of clothing and other final products). The largest textile plant in the basin, at Magog, employs over 2,000 persons. The textile plants use large quantities of water and contribute significantly to the poor quality of the river water.

Three pulp and paper mills are located in the St. François basin. Primary reasons for these plants locating in the basin include the availability of large supplies of wood, and assured water supply, and the surrounding large pool of labour. About 1,500 persons are employed in this industry. In terms of water quality, the pulp and paper industry is by far the most serious polluter in the basin. For example, the total Bio-chemical Oxygen Demand (BOD) loading from the mills is about 133,000 lbs./day. In terms of the municipal populations of the towns in which the plants are located, the corresponding population equivalent of the BOD loading in percentage terms is 5,154%.

The headwaters of the St. François basin contain several large lakes. The area is within a three-hour drive of Montreal and thus, the demand upon the lakes for recreation is high. Around most of the headwater lakes there is an unbroken ring of cottage development. The recreational areas are experiencing major problems not only because of the water quality problems of the basin but also because of competing (primarily industrial) demands for water. The lake levels in some areas, such as Lakes Aylmer and St. François, cannot be maintained at a high level in the summer because of the large quantity of water required by the downstream pulp and paper mills. Irregular fluctuation of lake levels often makes the beaches in the area unusable. Campsites set up by the Quebec Government on some of the lakes and along the river's course offer a high recreation potential. However, the beaches along which these campsites are set up are unusable in many cases because of the poor water quality. In general, the recreation potential of the St. François basin is high because of the area's accessibility and proximity to the large urban centres of Quebec. However, such development of the area is limited presently because of water pollution problems.

The remainder of the industrial composition is made up of a variety of light manufacturing.

1. Régie des eaux du Québec. *Rapport sur la Qualité des eaux de la Rivière St. François*, Québec, 1969.



St. François River Basin

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

	Population (1970)	Employment	Effluent Flow (Mgd)	Estimated BOD (lbs/day)	Population Equivalent (%)	Suspended Solids (lbs/day)	Principal Industrial Types
SHERBROOKE							
Domestic	70,138		7,014	11,924		14,028	
Industrial		3,389	4,530	15,453	90,907 (130%)	17,954	textile, dairy soft drink, meat products
DRUMMONDVILLE							
Domestic	28,537		2,854	4,852		5,708	
Industrial		3,445	11,977	13,308	78,280 (274%)	177,020	textile, dairy soft drink, brewing, meat products
MAGOG							
Municipal	13,797		1,380	2,346		2,760	
Industrial		2,472	1,607	10,978	64,586 (468%)	2,574	textile, dairy meat products soft drink miscellaneous
EAST ANGUS							
Municipal	4,800		480	816		960	
Industrial		519	19,029	36,304	213,554 (4,449%)	39,050	pulp & paper textile, dairy
COATICOOK							
Municipal	7,800		780	1,326		1,560	
Industrial		560	629	680	4,579 (58%)	70	textile, dairy
WINDSOR							
Municipal	6,375		638	1,085		1,276	
Industrial		†	†	†	†	†	pulp & paper
LENNOXVILLE							
Domestic	4,100		410	697		820	
Industrial		†	†	†	†	†	dairy
RICHMOND							
Domestic	4,005		401	680		800	
Industrial		44	13				textile
ROCK FOREST							
Domestic	3,582		358				
Industrial		†	†	†	†	†	dairy
DISRAELI							
Domestic	3,500		350	595		700	
Industrial		†	†	†	†	†	dairy
BROMPTONVILLE							
Domestic	2,898		290	493		580	
Industrial		†	†	†	†	†	pulp & paper

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

	Population (1970)	Employment	Effluent Flow (MGD)	Estimated BOD (lbs/day)	Population Equivalent (%)	Suspended Solids (lbs/day)	Principal Industrial Types
COOKSHIRE							
Domestic	1,850		185	314		370	
Industrial		†	†	†	†	†	textile
PIERREVILLE							
Domestic	1,631		163	277		326	
Industrial		†	†	†	†	†	pulp & paper
WEEDON							
Domestic	1,538		154	262	308		
Industrial		†	†	†	†	†	dairy
STOKE							
Domestic	1,360		136	231	272		
Industrial		†	†	†	†	†	meat processing
ASCOT							
Domestic	1,310		131	223	262		
Industrial		†	†	†	†	†	dairy
OMERVILLE							
Domestic	1,150		115	196		230	
Industrial		†	†	†	†	†	meat processing
ST. GERMAIN DE GRANTHAM							
Domestic	1,042		104	177		208	
Industrial		41	122	1,127	6,634 (636%)	413	meat processing dairy
ST. FRANÇOIS DU LAC							
Domestic	957		96	173		192	
Industrial		†	†	†	†	†	tanning
AYERS CLIFF							
Domestic	775		78	133		156	
Industrial		†	†	†	†	†	dairy
DURHAM SUD							
Domestic	713		71	121		142	
Industrial		†	†	†	†	†	dairy
ST. SEBASTIEN							
Domestic	495		50	85		100	
Industrial		†	†	†	†	†	dairy

*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. Effluent flows are in thousand gallons per day.

†Withheld for purposes of confidentiality.

n.a. Information on which to base an estimate is not available.

nil. There are no major polluting industries located in this municipality.

Table 4. Flow Measurements at Various Locations in the St. François Basin cfs. (month)

	Station Location		
	Near Drummondville (1925 - 1970)	At Windsor (1935 - 1970)	Westbury Power Plant Five miles upstream from East Angus (1921 - 1970)
Maximum Daily: for 1970	56,000 (April)	43,000 (April)	16,400 (April)
for period ending 1970	85,300 (March, 1936)	73,600 (March, 1936)	23,500 (March, 1953)
Minimum Daily: for 1970	860 (Aug.)	799 (Sept.)	270 (Sept.)
for period ending 1970	510 (Nov. 1948)	750 (Aug. 1957)	0 (Sept. 1964)
Average Annual: for 1970	6,880	5,800	2,420
for period ending 1970	6,410 (44 yrs.)	5,750 (33 yrs.)	2,430 (49 yrs.)

Source: Quebec Department of Natural Resources.

HYDROLOGY

Table 4 shows, for 1970 and for the period of record to 1970, the daily maximum, daily minimum, and average annual streamflows at three long-term gauging stations on the St. François River. The highest flows occur in April with the spring run-off, while the low flow period occurs in summer (July-September) and in February. However, the natural regime of the river is regulated by upstream storage and affected by power plant operations.

DOMESTIC AND INDUSTRIAL WATER POLLUTION

Table 5 shows the availability of sewer and waste treatment facilities in the larger municipalities of the basin.

Table 5. Municipal Sewer and Waste Treatment Facilities

Municipality	Sewer Systems	Treatment System	Population
Sherbrooke	partially combined	none	70,138
Drummondville	combined	none	28,537
Magog	combined	none	13,797
Coaticook	none	none	7,800
Windsor	50% combined	none	6,375
East Angus	none	none	4,800
Lennoxville	none	none	4,100
Richmond	none	none	4,005
Rock Forest	none	none	3,582
Disraeli	none	none	3,500
Bromptonville	80% combined	none	2,898

Note: "combined" indicates combined storm and sanitary sewers.

It is apparent from this table that hardly any of the wastes from the municipalities in the basin are treated prior to discharge. In a few cases there are treatment facilities, such as total oxidation plants, aeration, lagoons, and activated sludge plants, serving individual factories or institutions scattered throughout the basin.

For example, Bishop's University at Lennoxville has an activated sludge system to serve its requirements. In no way, however, can existing facilities be termed adequate to meet the needs of the basin. Approximately 49,300 pounds of BOD and 58,000 pounds of suspended solids can be attributed to the population in the basin. For the most part, this waste goes directly into the river[2]. Of these amounts, 27,300 pounds of BOD per day can be attributed to the population residing in the municipalities.

Although many pollutants enter the river solely as the result of minimal treatment of human wastes, the magnitude of the pollution attributable to industry is much more serious. In deriving estimated costs for waste treatment facilities which would serve the basin adequately, the cost of treating industrial effluents would be much higher than those to treat domestic wastes. It is essential, therefore, that the amounts of industrial wastes be established as accurately as possible.

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2. The waste figures were calculated for a total basin population of 290,000 on the basis of 0.17 lbs. per capita per day, and 0.20 lbs. of suspended solids per capita per day.

Although information is available on the amounts of BOD in the effluent of the pulp and paper mills, and the textile plants of the basin[3], there is a complete lack of waste load information for the other industrial establishments. This being the case, an attempt was made to simulate these waste loadings using average coefficients derived from various published sources[4]. Although this approach is crude and liable to error, it will give "order-of magnitude" figures for the waste loadings generated in these industries. Considering the preliminary nature of this report, the "coefficients" approach was used with full realization of the limitations upon the results. The results of the estimation of industrial waste loadings is given by Table 3. Table 6 summarizes the waste loadings estimated for the main industries in the basin.

Table 6. Summary of Waste Loadings by Industrial Types

Industry	BOD Loadings (lbs/day)	Population Equivalent (persons/day)	Solid Loadings (lbs/day)
Pulp & Paper	132,821	781,298	186,476
Textiles	20,455	120,324	179,874
Dairies	22,297	131,185	13,540
Meat Products	2,831	16,681	3,048
Soft Drinks	96	564	430
Miscellaneous	309	1,821	1,060
	178,809	1,051,873	384,428
Basin Population	49,300	290,000	58,000
Industry X 100% Population	363%	363%	663%

This table points out the severity of the industrial waste problem; actually, it could understate the case considerably since the lack of information on pollution loads indicates that not all industries in the basin have been studied. It is apparent that a study to estimate the costs of waste treatment in the basin must consider both domestic and industrial wastes.

The other major pollution source is the recreational development around the headwater lakes of the basin. Data on the subject of recreational pollution are limited since studies pertaining directly to this factor are not available. However, the eutrophication problem in the lakes, caused by overfertilization as a result of the discharge of cottage effluent, appears to be significant; one fact to confirm this is shown by the dissolved oxygen (DO) curve for the river. Despite the fact that a large amount of BOD enters the river at various points along the river, the DO curve does not fall below 6 ppm. The BOD from the many sources along the river could be quickly digested because of the large amount of oxygen given off by the algae in the water. Thus eutrophication may be masking the BOD and dissolved oxygen problem caused by industrial and municipal waste.

Another, as yet intangible, pollution problem which must be mentioned results from much of the basin's population not being resident in municipal areas. An examination of aerial photos of this area shows that many dwellings located along the stream's course lack waste treatment facilities and empty their wastes directly into the river. Thus, while it may be possible over a period of time to cope with municipal and industrial wastes in the basin, efforts will also have to be directed toward collecting wastes from rural areas, especially those located along the rivers, and integrating them into the waste treatment system of the basin.

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3. Canadian Pulp and Paper Assoc., *Report on Effluent Conditions of Pulp and Paper Mills in Quebec*, Montreal, 1969. Data on individual mills have been withheld because of the confidential nature of this document.

   Quebec Water Board, *L'Industrie Textile de la province de Québec: Rapport et Résultats de l'Enquête Systématique sur la Pollution Industrielle de L'industrie Primaire des Textiles*, J.B. Nobert, 1970.

4. Employment data were 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, Federal Water Pollution Control Administration, *The Cost of Clean Water*, Vol. 3: 1-10, 1968; and Atlantic Development Board, *Maritime Provinces Water Resources Study*, "Industrial Water Demands", Appendix 3, 1969.

Water Quality Description of the St. François River

The water quality parameters measured and graphed for the St. François River by the Quebec Water Board do not accurately reflect the water quality problems of the area[5]. For example, the DO curve shows values which are always above 6 ppm. Based upon experience in other river basins, such readings would be judged good to excellent. Thus, the DO – BOD relationship, which was used in the Yamaska report[6] as a major water quality criteria, cannot be used as effectively for the St. François basin. Although information pertaining to the nutrient situation in the basin is available, it does not provide a sound basis for examining the industries along the river. Thus, instead of proceeding by examining one or two major quality criteria, as was done for the Yamaska basin, the method of approach of this paper will be different. One "pass" will be made along the river from the headwater area to the St. Lawrence, stopping at critical points to describe the water quality in terms of various water quality parameters. In this way, it should be possible to identify the main critical areas of the basin vis à vis water pollution. Upon completion of this task, the cost of waste treatment for these critical areas will be estimated.

At the outlet of Lake Weedon, DO levels are between 8 and 9 ppm. The main problem in this vicinity is the overfertilization of the water by nutrients, mainly phosphates and nitrates. In the summer, the eutrophic conditions of the headwater lakes cause algal growths which enter the stream course, and affect the water quality of the entire river. From photographs of the river at various locations, it is apparent that rocks in the stream bed, and probably the stream bed itself, are covered with algae. As is the case in most cottage and recreational areas, this area is not served by any waste water treatment system whatsoever, and only the most primitive forms of treatment exist in the area.

Below the municipality of Weedon, the water is often a brownish colour. The main polluter in this municipality is a dairy which has an estimated BOD load of about 7.8 times the domestic load. The town has neither a treatment nor a sewage system.

Between Weedon and East Angus, main sources of water pollution entering the main stream of the St. François are shown in Table 7.

Table 7. Water Quality of Tributaries Between Weedon and East Angus

	Salmon River	Bury Brook	Bishop Lake
Oxygen Saturation (%)	94	101	80
BOD*	2.4	2.0 ppm.	2.3 ppm.
Total phosphate (ppm)	.11	.06	.16
Total Coliform (MPN/100 ml.)	735	1,050	1,117
Fecal Coliform (MPN/100 ml.)	0	225	1,400**
Colour (units)	43	30	30

*Given in tons per day where available: otherwise in ppm.
**Based on one observation only, in October 1968.

The data show that the oxygen content of the river above East Angus is excellent. The BOD load put into the river has apparently little effect upon this quality parameter. The coliform counts are high compared to the quality standards for potable water and body-contact recreation. The phosphate readings are high enough to permit abundant algal growth. The high fecal coliform count taken at the mouth of Bishop Lake is an indication of raw sewage entering the river.

Table 8 indicates the average quality of the water above and below the East Angus, the most upstream of three pulp and paper towns in the basin. The BOD loading from the pulp and paper mill, as measured by the company itself, is very large in relation to that of the domestic population. In addition to this, Kraft paper mill, a dairy and the domestic population discharge just over 900 lbs of BOD per day into the river. It is evident that the major water pollution problem in this area is the pulp and paper mill effluent. It is somewhat surprising, therefore, that the DO saturation level in the river remains high despite the tremendously large BOD loading on the stream. *If the data on water quality are correct and representative*, the BOD loading on the river at

5. Data for this section are based upon Quebec Water Board. op. cit.

6. Canada, Department of the Environment, Water Management Service, *Economic and Financial Aspects of Wastewater Treatment in the Yamaska River Basin*, by D.M. Tate, Social Science Research Series No. 3, 1972.

East Angus is not serious. Nevertheless, the data on DO levels will have to be checked before such a conclusion can be finalized. It would appear, however, that the effect of the pulp and paper mill is much more serious than is apparent from the data given in Table 8. Large quantities of waste materials – wood chips, rotting logs, unusable partially processed wood – litter the river banks and stream bed in this area. These materials give off lignin, a substance which is toxic to fish and wildlife and ruins water-based recreational activity in the area. The effluent from the mill contains detergents from the pulp washing operations which cause a foam that is visible for miles downstream from the mill.

Table 8. Water Quality of the St. François Above and Below East Angus

Parameter	Above East Angus	Below East Angus
Oxygen Saturation (%)	100	96
BOD (tons/day)	5.3	11
Total Phosphate (ppm)	.07	.07
Total Coliform (MPN/100 ml.)	200	1,350
Fecal Coliform (MPN/100 ml.)	0	400
Colour (units)	55	65

Downstream of East Angus, the auto-purification of the river diminishes the turbidity of the water and reduces the BOD by 1.1 tons per day. There are no major sources of pollution between East Angus and Lennoxville. At Lennoxville a small dairy adds a small amount of BOD per day to the water. The BOD loading from domestic sources is about 700 lbs. per day.

The Massawipi River, which drains the area to the southwest, enters the St. François at Lennoxville. The quality of the Massawipi just before its confluence with the St. François is shown in Table 9.

It is evident that the Massawipi River exerts practically no oxygen loading on the St. François River. The phosphate level indicates the presence of eutrophic action upstream in Lake Massawipi. Relatively high coliform counts indicate that probably the river is periodically unsafe for swimming. The presence of fecal coliform denotes the entry of raw human waste into the water course. Table 10 summarizes the effects of Lennoxville and the Massawipi River on the St. François.

Table 9. Water Quality of the Massawipi at Its Confluence with the St. François

Parameter	
Oxygen Saturation (%)	97
BOD (ppm)	2
Total Phosphate (ppm)	.07
Total Coliform (MPN/100 ml.)	5,490
Fecal Coliform (MPN/100 ml.)	380
Colour (units)	40

Table 10. Water Quality of the St. François River Above and Below Lennoxville

Parameter	Above Lennoxville	Below Lennoxville
Oxygen Saturation (%)	91	90
BOD (tons/day)	17	22
Total Phosphate (ppm)	.08	.08
Total Coliform (MPN/100 ml.)	1,970	6,250
Fecal Coliform (MPN/100 ml.)	175	785

The large rise in the BOD load of the river through Lennoxville cannot be explained in this paper. This is one of a number of anomalies which occur in the test results. This again points out that before any conclusions can be confirmed for this basin, a more comprehensive set of data will have to be available. It is clear from Table 10 that body-contact recreation is unsafe below Lennoxville because of high coliform counts.

The next major source of pollution in the St. François is the city of Sherbrooke, the largest municipality in the basin. Sherbrooke is a centre containing 11 plants which may be classed as primary textile industry. The combined BOD loading from these mills is only .72 tons/day, thus the problem of textile mill effluents is not as severe in this area as it is in parts of the Yamaska basin[7], and does not compare in magnitude to the water quality problems created by the pulp and paper industry. Sherbrooke is also a centre of the dairy industry, with the city itself generating a demand for dairy products. Aside from meeting this demand, the region is also a major supplier of these products for Montreal. With no apparent waste treatment facilities, the dairy industry in Sherbrooke, contributes in terms of population, over 6.8 tons of BOD to the river, 1.15 times as much as the municipal population. Other minor industrial polluters in Sherbrooke include the meat-products industry and the soft drink industry. The BOD loading attributable to the population of Sherbrooke is about 6 tons per day.

The Magog River, which drains Lake Memphremagog[8],

7. Economic and Financial Aspects of Waste Water Treatment in the Yamaska River Basin, op. cit.

8. This lake straddles the Canada-U.S. border, the major portion of the lake being in Canada. This fact is of little importance to this paper, but may have to be considered in any pollution control efforts in the immediate area.

joins the St. François just downstream of Sherbrooke. As indicated in Table 3, the municipality of Magog contains a number of water-polluting industries, including two textile plants, four meat packing plants and a dairy. The total BOD discharged into the Magog River from the industries and the domestic population of Magog is about 6.7 tons per day. In addition to the problem caused by the town of Magog, a major quality problem is raised due to recreational developments around Lake Memphremagog. The overfertilization of the lake by nutrients contained in the effluents from surrounding cottage developments has created eutrophic conditions in the lake. Algal blooms are a frequent occurrence in this area during the summer months. When the algae die, oxygen is used in the decaying process, adding to the BOD strain upon the lake. Most of the algae and/or the BOD loading eventually find their way into the Magog River and then into the St. François.

Table 11 summarizes the effect of the pollution loading entering the Magog River by showing the quality of the river water at its confluence with the St. François. The high BOD load points up the magnitude of the combined domestic industrial problems in the Magog basin. The eutrophic conditions are indicated by the high phosphate reading. It is apparent from the coliform reading that raw animal wastes are entering the river, making it unsafe for water supply or swimming. The high DO saturation appears again to be an anamalous result.

Table 11. Water Quality of the Magog River at Its Confluence with the St. François

Parameter		
Oxygen Saturation (%)	90	90
BOD (tons/day)	71	71
Total Phosphate (ppm)	.44	.44
Total Coliform (MPN/100 ml.)		9,100
Fecal Coliform (MPN/100 ml.)		840
Colour (units)		21

The water quality of the St. François downstream from Sherbrooke is shown in Table 12; the impact of the large BOD load entering from the Magog River is apparent. At this point, the cumulative nature of the BOD loadings begins to become apparent. Below Sherbrooke the residual effect of the pulp and paper plant at East Angus, the BOD load from the Magog River, as well as the municipal and industrial effluent of Sherbrooke yield a very high total BOD loading per day in the river. However, this high loading apparently has little effect on the DO concentration which remains at 88% of saturation. Considering the high BOD load in the Sherbrooke area, the high coliform counts, and the high phosphate levels, it may be concluded that the stream in the vicinity of Sherbrooke is seriously polluted. Evidence of this fact is found where encountering rocks are often encrusted with moss and algae, along the streambed beaches which are unsafe for swimming, and from stenches due to sewer outfalls and decaying algae.

Table 12. Water Quality of the St. François River Downstream from Sherbrooke

Parameter	
Oxygen Saturation (%)	88
BOD (tons/day)	78
Total Phosphate (ppm)	.14
Total Coliform (MPN/100 ml.)	17,265
Fecal Coliform (MPN/100 ml.)	3,933 (1 observation only)
Colour (units)	

The pulp and paper town of Bromptonville is the next major pollution source on the river. Table 13 compares the water quality above and below Bromptonville. According to the company's own measure, the pulp and paper mill in the town adds large quantities of BOD per day to the river. In the face of such a high value, the BOD load and the DO levels based upon data from the Quebec Water Board are again suspect. From the point of view of gross water pollution, however, there is no doubt that the river water in the Bromptonville area is of poor quality. The degree and effects of pollution are similar to those in the East Angus area.

Table 13. Water Quality of the St. François River Above and Below Bromptonville

Parameter	Above Bromptonville	Below Bromptonville
DO Saturation (%)	86	103
BOD (tons/day)	28	32
Total Phosphate (ppm)	.09	.13
Total Coliform (MPn/100 ml.)	16,000	19,000
Fecal Coliform (MPN/100 ml.)	280	660
Colour (units)	43	50

The pulp and paper town of Windsor is the next major pollution source along the river. Table 14 shows the water quality in the river above and below this municipality. Since the sampling point below the town is above the pulp and paper mill, the oxygen related parameters reported in Table 14 do not accurately reflect the degree of degradation of the stream's water quality. When the quantity of BOD generated by the pulp and paper mill is added to the 37 tons per day already in the river, the DO saturation is probably much lower than 91% as reported below. Therefore, despite the fact that the oxygen content of the river appears high, there is no question that the river in the Windsor area is highly polluted. The level of BOD entering the river is very high and, added to other objectionable materials from the paper mill, does not create an environment conducive to fish or wildlife. The coliform counts are too high to permit safe body-contact recreation.

Table 14. Water Qualtiy of the St. François River Above and Below Windsor

Parameter	Above Windsor	Below Windsor
DO Saturation (%)	85	91
BOD (tons/day)	37.7	38.4
Total Phosphate (ppm)	.13	.23
Total Coliform (MPN/100 ml.)	24,500	29,000
Fecal Coliform (MPN/100 ml.)	570	700
Colour (units)	44	57

The town of Richmond, the next large municipality downstream from Windsor, contains two textile factories, neither of which adds a significant amount of polluting materials to the river. Between Windsor and Richmond, three small tributaries enter the St. François, all three of which are of lower quality than the St. François, and consequently increase the latter's water pollution. Table 15 shows the quality of the St. François above and below Richmond. It is apparent that a significant increase in BOD occurs. In addition to the three small tributaries entering the St. François between Windsor and Richmond, the full effect of the pulp and paper mill at Windsor on receiving water quality can be seen by the increase in BOD between the towns. The negligible effect of the town of Richmond on the river's water quality is apparent from Table 15. As in the vicinity of other municipalities, the river in the Richmond area is unsafe for body-contact recreation.

Table 15. Water Quality of the St. François River Above and Below Richmond

Parameter	Above Richmond	Below Richmond
DO Saturation (%)	83	79
BOD (tons/day)	95	95
Total Phosphate (ppm)	.37	.32
Total Coliform (MPN/100 ml.)	5,240	7,850
Fecal Coliform (MPN/100 ml.)	875	1,760
Colour (units)	55	55

The downstream major source of combined industrial and domestic pollution is the city of Drummondville. The municipal population generates an estimated 2.4 tons of BOD per day. The major industrial firms of this city produce food and beverages, textiles, and paper products. The main industrial polluter is the textile industry, which pours about 5 tons of BOD per day into the St. François (see Table 3). The Dairies are responsible for an additional 1.0 tons of BOD per day, and the paper products plants another 0.6 ton. As indicated in Table 3, the total estimated BOD loading from industry is about 6.65 tons per day, or the amount equivalent to a population of 78,282. The total solid load (including dissolved and suspended solids) released into the river from Drummondville is about 89 tons per day. Table 16 shows the quality of the river water above and below Drummondville, thus showing the effects of the city on the degree of water pollution in the river. The river water both above and below the city is unsafe for swimming and probably devoid of aquatic life. It is evident that Drummondville is a major area of pollution.

Table 16. Water Quality of the St. François River Above and Below Drummondville

Parameter	Above Drummondville	Below Drummondville
DO Saturation (%)	73	87
BOD (tons/day)	50	64
Total Phosphate (ppm)	.20	.13
Total Coliform (MPN/100 ml.)	1,450	4,260
Fecal Coliform (MPN/100 ml.)	577	1,043
Colour (units)	58	64

From below Drummondville to its mouth, the St. François receives several minor amounts of polluting materials, principally from the several villages located along the water course. Table 17 shows the water quality at the mouth of the river.

Table 17. Water Quality of the St. François River at Lac St. Pierre

Parameter	
DO Saturation (%)	82
BOD (tons/day)	57
Total Phosphate (ppm)	.07
Total Coliform (MPN/100 ml.)	1,500
Fecal Coliform (MPN/100 ml.)	225
Colour (units)	53

SUMMARY AND IDENTIFICATION OF CRITICAL AREAS

The preceding description outlines the characteristics of the quality of water in the St. François River. The oxygen-related parameters, often the chief measure of water quality, are open to question in this river. It is beyond the scope of this paper to investigate the reasons behind the anomalous readings. It should be emphasized that the water quality description in this paper was based upon information which was already available, but which should be further investigated before drawing any firm conclusions about the precise degree of water pollution in the basin. Nevertheless, the description of pollution sources, and their effects upon the receiving water quality, establishes that this basin is seriously polluted.

The aim of this description was to identify areas in which water pollution had reached a critical stage in the St. François basin. In many of these areas, waste treatment to various levels (mainly secondary) would be the solution to poor water quality. Such areas include the municipalities and the major polluting industries in the basin. The problems in these towns have been outlined above, and can briefly be summarized as one of untreated domestic effluent combined with waste-laden industrial effluent. Thus, to view the solution of river clean-up as installing plants to treat domestic wastes would give costs which are greatly underestimated. It is essential that domestic and industrial effluents be combined for treatment purposes.

In the following section, the information outlined in the first two parts of this paper will be projected in estimated costs of waste treatment facilities in the St. François basin. Also discussed will be the approximate order in which the municipalities should be dealt with so as to have maximum effect upon the receiving stream. It is thought that maximum effect upon the receiving stream would be from treating the most seriously degraded sections 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 paper.) The term "priority" reflects the order of seriousness of the pollution problem, and thus, following from the working hypothesis, the order in which treatment facilities should be built. These "priorities" have emerged solely from the analysis of this paper, and no policy implications are intended; it is not the intention to recommend policy for the phasing of waste treatment in the basin.

The pulp and paper mills are by far the heaviest industrial polluters in the basin. The towns in which these mills are located are therefore the greatest sources of pollution. It is thought that these municipal areas should receive top priority for any waste treatment expenditure. The largest municipalities in the basin – Sherbrooke, Drummondville, and Magog – contribute a relatively high waste load to the river. Generally speaking, these municipalities are the location of the second major industrial type in the basin, the textile industry, and they compose the group which forms the second priority for waste treatment investment. The towns having a population greater than 1,000 persons, other than the ones previously mentioned, are thought to constitute the third priority for waste treatment investment. The selection of 1,000 persons as the dividing line between the third and fourth priority grouping was due to the fact that for population less than 1,000 persons the trickling filter method of treatment can be used in place of the more expensive activated-sludge system for secondary treatment. The fourth priority group, therefore, is composed of towns less than 1,000 population.

Costs and Priorities for Waste Treatment

The costs of waste treatment for municipalities in the St. François basin may be estimated using equations drawn from secondary sources[9]. In general, these equations employ a linear regression technique — the cost of various waste treatment facilities are linear functions of the required plant capacities. Tables 19 to 24 show the costs in terms of constant 1971 dollars of various types of treatment facilities in the basin. The following section will deal with the financial aspects of establishing waste treatment systems in the basin.

In estimating the costs of a waste treatment system, two major components are important — the treatment plant itself and the collector system to transport the waste water to the treatment facility. The cost of the first major component, as outlined above, may be readily estimated using linear regression equations; it is considerably more difficult to estimate the cost of a collection system for municipalities because of variabilities in local conditions (e.g. topography) making generalization somewhat more hazardous. In the 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 the province of Quebec, 0.64 dollar would be required for collection systems. Only the parts of the collection system eligible for C.M.H.C. financial assistance are covered in this coefficient[10]. These parts usually comprise the trunk collection system, but do not include lateral sewers or individual connections. The Canadian Federation of Mayors and Municipalities (CFMM), based upon a sample of Canadian municipalities, estimated that 1.5 dollars would be spent on sewer systems for each dollars spent on (secondary) treatment plants[11]. Grava[12] projected that for the United States about 1.6 dollars would be required for sewer systems for each dollar spent on treatment systems. For the Ottawa area over the next 10 years, Maclaren and Richards estimates a ratio of 1:1 between expenditures for sewage systems and expenditures for treatment[13].

The ratio of collection system costs to secondary treatment system costs is therefore highly variable on the area, the agency doing the cost estimates, etc. By virtue of the fact that only eligible expenditures were considered, the C.M.H.C. estimate is probably too low for present purposes. In view of the high cost of collection in the overall cost of water pollution control, it is necessary that an allowance be made for the cost of collection in the municipalities under consideration. In order not to underestimate this cost component, the CFMM ratio of 1.5 dollars of sewer system expenditure for each dollar of treatment plant expenditure will be used in this paper.

In planning waste treatment works for the future, it is felt that attention must be paid to joint treatment of domestic and industrial wastes. In making the cost estimates for 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 somewhat similar (i.e. BOD and suspended solids removal). Industry faces the initial problem of the separation of those wastes which will retard the assimilation of BOD by biological processes, and will possibly have to bear these costs alone. However, it is suggested that a major portion of industrial wastewater could be combined with domestic wastewater for treatment in common facilities such as municipal facilities (in the case of larger municipalities) or in industrially operated facilities (for small, one-industry towns). The economic feasibility of establishing such combined or joint treatment systems is investigated in Table 18. Most of the cost estimates given are based on combining the two waste types.

In computing the cost of treatment systems for the St. François basin, allowance must be made for past expendi-

9. The two sources for equations used in this paper were:
   (i) Ontario Water Resources Commission, *A Guide on Estimating Sewage Treatment Construction Costs in the Province of Ontario*, 1967.
   (ii) Eckenfelder, W.W., *Water Quality Engineering for Practicing Engineers*, Barne & Noble, 1970. See Chapter 13.

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

11. Personal Communication with the research staff of CFMM.

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

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

tures. Table 18 shows the amount of such C.M.H.C. funds expended in the basin since 1961. The C.M.H.C. loan portion accounts for 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 18. Past Expenditures on Waste Treatment and Sewer Facilities*
($000)

Municipality	C.M.H.C. Loan	Total Cost	Type of Facility
Rock Forest	179	271	Collector and treatment System to serve part of municipality
Omerville	65	99	Collector and treatment system
Drummondville	104	158	Interceptors and treatment system
St. Germain	48	73	Outfall sewer and stabilization pond

*The amounts reported here have not been adjusted for changes in the value of the dollar. Such adjustments are made in Table 22 to 24 to the figures which must be used further in the cost analysis.

PRIORITY GROUP I

The pulp and paper towns, East Angus, Windsor, and Bromptonville are all faced with the same water quality problems. Being small, one-industry towns, the amounts of pollutants in the effluent from the pulp and paper mills are many times greater than those generated by the municipal population. Thus, the problem of cleaning up the river in the vicinity of these towns is centered with the pulp and paper mills. In order to be effective in its impact on the river, wastewater treatment in the mills must be at the secondary level; thus, a combined domestic-industrial treatment system must be at that level. There are two basic alternatives for treating a combination of mill and domestic wastes — to construct the treatment facilities on the mill site and bring the domestic wastes to that site for treatment, or to construct a treatment plant apart from the mill to which the mill wastes after some pre-treatment would be piped or transported and combined with the domestic wastes for treatment purposes.

Table 19 examines the cost of combining the domestic and mill wastes for treatment at the mill site. It must be understood at the outset that the costs of treating the mill effluent to a secondary level are order-of-magnitude ones only and are not intended as detailed cost calculations. Each mill in the study area has made some effort to install waste treatment equipment. The expenditures on this equipment are reported by the Canadian Pulp and Paper Association for the period 1960-1969[14]. These figures are shown in the second part of Table 19. The capital costs of waste treatment facilities to treat mill wastes to the secondary level were calculated from ranges given in the *Cost of Clean Water*[15]: These costs are shown in the third part of Table 19. From the average total costs (calculated from the minima and maxima shown in the third part of the table), the expenditures to date on waste treatment facilities for the mills have been subtracted to derive an expected remaining capital cost of waste treatment. In the fifth part of Table 19 are the costs of additional facilities to provide the mill treatment system with the capacity to handle the municipal waste from the towns where the mills are located[16]. These treatment costs do not include the cost of transporting the municipal wastes to the treatment plant. Adding the required additional treatment costs for the mill and the municipal treatment costs, the costs of a mill-oriented system to incorporate municipal wastes can be calculated. The last part of Table 19 shows that depending upon the type of technology of the mills, the treatment costs under this scheme range between $195 and $322 per capita in the respective towns. The costs cannot be defined more closely because of uncertainty as to the level of technology existing in the plants.

Table 20 shows the costs of constructing treatment systems apart from the mill to handle both the mill effluent and the associated domestic effluent. A degree of pre-treatment is required before the mill effluent could be put through the system. The estimated cost of pre-treatment is shown in the second part of Table 20. These cost estimates are probably too low in the long run, as they do not cover the cost of treating some streams which the proposed treatment plant would not be able to handle (e.g. white water from the Kraft process). As shown in the fifth section of Table 20, the cost per capita of treatment under this scheme would be around $420, depending upon the level of technology assessed for the plants in the study area. This cost does not include the cost of transporting the mill waste to the treatment plant, a cost which, in this case, could be significant. The last part of Table 20 shows the ratio of the per capita costs as calculated in Tables 19 and 20. It is appa-

14. Information from Canadian Pulp and Paper Association, *Survey of Effluent Conditions on Pulp and Paper Mills in Quebec* 1966, 1967, and 1968.

15. Based upon: U.S. Department of the Interior, *The Cost of Clean Water: Paper Mills (except Buildings)*, F.W.P.C.A. Industrial Waste Profile 3, 1968. This reference does not apply to the Kruger newsprint mill in Bromptonville.

16. The costs were estimated using equations in: O.W.R.C., op. cit., and Eckenfelder, W.W., op. cit.

Table 19. Cost of Waste Treatment in Pulp and Paper Mill Towns
(derived by combining municipal wastes with mill wastes)

Town	Windsor	East Angus	Bromptonville
Plant	Domptar	Domtar	Kruger
Type of Mill	Kraft Pulp & Paper	Kraft Pulp & Paper	Newsprint
Production (tons per day)	415	324	407

WASTE TREATMENT EXPENDITURES
($000)

1960-66	n.a.*	n.a.	100
1967	219	270.75	2.5
1968	132	50	125
1969 (estimated)	210	120	45
TOTAL	561	440.75	272.5

CAPITAL COST FOR TOTAL WASTE TREATMENT
($000)

Old Technology Assumed			
Minimum	1,199	936	n.a.
Maximum	1,594	1,244	
Average	1,396	1,090	
Typical Technology Assumed			
Minimum	1,303	1,017	n.a.
Maximum	2,963	2,313	
Average	2,133	1,665	

AVERAGE TOTAL WASTE TREATMENT COST – EXPENDITURE TO DATE
($000)

Old Technology	835	649	–
Typical Technology	1,572	1,224	

AVERAGE COST OF WASTE TREATMENT FOR MUNICIPAL WASTE
($000)

	407	325	217

PULP AND PAPER TREATMENT COST AND MUNICIPAL TREATMENT COST
($000)

Old Technology	1,242	974	–
Typical Technology	1,979	1,549	

COST PER CAPITA OF COMBINED WASTE TREATMENT
($)

Old Technology	195	203	–
Typical Technology	310	322	

*n.a. indicates that information not available. *The Cost of Clean Water* does not deal with the cost of waste treatment in groundwood pulp mills.

Table 20. Cost of Waste Treatment in Pulp and Paper Mill Towns (derived by combining mill wastes into basically municipal system)

Town	Windsor	East Angus	Bromptonville
Plant	Domtar	Domtar	Kruger
COST OF PRE-TREATMENT OF MILL WASTES* ($000)			
Grit Removal			
Old Technology	38	29	37
Present Technology	17	14	17
Bar Screening			
Old Technology	70	54	68
Present Technology	32	25	32
COST OF TREATMENT IN MUNICIPAL COMBINED PLANT ($000)**			
	2,583	1,960	1,427
TOTAL TREATMENT COST PRE-TREATMENT & TREATMENT IN COMBINED PLANT ($000)			
Old Technology	2,691	2,043	1,532
Present Technology	2,632	1,999	1,476
COST PER CAPITA OF COMBINED WASTE TREATMENT ($)			
Old Technology	422	425	528
Present Technology	412	416	509
Ratio of Per Capita Waste Treatment Costs from Table 20 / Per Capita Waste Treatment Costs from Table 19			
Old Technology	2.16	2.09	n.a.
Present Technology	1.33	1.29	n.a.

*Based upon – U.S. Dept. of the Interior, op. cit., Table A-9 and A-10.
**Based upon – references in Footnote 3, Table 19.

rent from these ratios that the incorporation of municipal wastes into the mill-based treatment system would be cheaper than the construction of a publicly-owned facility some distance from the mill to handle combined municipal and industrial effluents.

For the purposes of future calculations, the first alternative – the treatment of domestic wastes in the pulp and paper mill treatment plant – will be considered from a cost point of view as the preferred mode of waste treatment. To the costs of the treatment plant itself must be added an allowance for a waste transportation network to transport the domestic wastes to the treatment plant located at the pulp and paper mill. Following from the method of estimating the cost of sewer systems as outlined above, the cost of the sewer component of total cost is shown in column 3 of Table 21. This table shows that the cost of combined domestic and industrial treatment in these towns lies between $290 and $424 per capita depending upon the assumptions regarding the technology of the mills. As shown, this cost significantly exceeds the per capita costs of treatment systems estimated for other municipalities in the basin.

PRIORITY GROUP II[17]

The three largest municipalities in the basin – Sherbrooke, Drummondville, and Magog – do not contain any one dominant industrial plant, but rather are centres with mixed industrial bases. While the textile industry is probably most important in these municipalities, this industry has several separate plants in each location. Thus, the treatment of domestic waste in a plant-oriented system, such as outlined for the pulp and paper industry, does not seem feasible. The most likely solution for treating the water-borne waste from these municipalities is the construction of new treatment plants designed to deal with

17. Tables 22 through 24 give the total cost of primary and secondary waste treatment facilities. The breakdown of the total costs into domestic and industrial components is given in Tables 1.1 to 1.8 of Appendix 1.

Table 21. Total Estimated Cost of Sewer and Treatment Facilities in Pulp and Paper Towns* ($000)

Municipality	Treatment Plant Cost		Sewer Cost	Estimated Total Cost		Cost per Capita ($)	
	Old	Typical		Old	Typical	Old	Typical
Windsor	1,242	1,979	610	1,852	2,589	290	400
Bromptonville	N.A.	N.A.	325	N.A.	N.A.	N.A.	N.A.
East Angus	974	1,549	487	1,461	2,036	304	424

*This table assumes the incorporation of domestic wastes into the pulp and paper mill treatment system.

Table 22. Total Estimated Construction Costs of Treatment and Sewer Systems in Municipalities of Priority Group II
($000, except where indicated)

Municipality	1970 Population	Treatment Cost*		Sewer Cost†	Total Previous Expenditure§	Total Estimated Cost		Per Capita Cost ($)		Annual Operation and Maintenance Cost	
		Primary	Secondary			Primary	Secondary	Primary	Secondary	Primary	Secondary
Sherbrooke	70,138	2,583	4,703	4,141	0	6,724	8,844	96	126	143	205
Drummondville	28,537	3,019	5,581	2,017	195	4,841	7,703	170	259	179	249
Magog	13,797	904	1,603	1,129	0	2,033	2,732	147	198	44	74
TOTAL	112,472	6,506	11,887	7,287	195	13,598	19,279			366	528
Cost per Capita Served ($)		58	106	65	n.a.	121	171			3.25	4.69

*Using average costs calculated in Appendix 1, Table 5.

†Not including the costs of collecting industrial waste water. See Appendix 2.

§Present value using Cost of Non-Residential Building Materials index, in *Prices and Price Indexes*, Statistics Canada, 62-002.

domestic and industrial wastes. The estimated costs of both primary and secondary treatment for Sherbrooke, Drummondville, and Magog are shown in Table 22. The estimated costs are probably too low, as only effluent from the major industrial plants has been considered. It is clear from this table that the average total cost of treatment facilities and collection systems in municipalities of Priority group II is $121 and $171 per capita for primary and secondary treatment respectively. The effect of economies of large scale operation of treatment plants may be seen by comparing Sherbrooke (pop. 70,138) and Magog (pop. 13,797). The total per capita costs of primary and secondary treatment in Sherbrooke are $96 and $126 respectively, while in Magog the corresponding costs are $147 and $198. The economies of scale operation are somewhat distorted in the case of Drummondville, because the relatively large industrial base of this municipality generates industrial effluent approximately 2.5 times that of Sherbrooke. For this reason, the costs of waste treatment in Drummondville are significantly greater than those in Sherbrooke.

PRIORITY GROUP III

The remaining municipalities in the basin with over 1,000 population comprise the third priority group for waste treatment systems. By and large, these municipalities contain little industry, except for the occasional dairy or light manufacturing establishment. The principal concern in these municipalities therefore is for the treatment of domestic wastes. Table 23 shows that the estimated per capita costs of both primary and secondary treatment for these towns are rather high in comparison to those of priority group II. In general, with the exception of Rock Forest and Omerville, the costs of installing primary facilities in the municipalities of priority group III are more than the costs of secondary treatment in the municipalities of priority group II. The exceptions to this statement, Rock Forest and Omerville, have relatively low per capita costs for waste treatment installation because of some treatment capacity already. At Rock Forest approximately 23% of effluent is treated at present; at Omerville 45% of effluent is treated.

Table 23. Total Estimated Construction Costs of Treatment and Sewer Systems in Municipalities of Priority Group III
($000, except where indicated)

Municipality	1970 Population	Treatment Cost		Sewer Cost	Total Previous Expenditure	Total Estimated Cost		Per Capita Cost ($)		Annual Operation and Maintenance Cost	
		Primary	Secondary			Primary	Secondary	Primary	Secondary	Primary	Secondary
Coaticook	7,800	504	880	717	0	1,221	1,597	156	204	23	42
Lennoxville	4,100	165	286	429	0	594	715	145	174	8	16
Richmond	4,005	174	299	421	0	595	720	149	180	8	16
Rock Forest	3,582	149	257	385	308	226	334	63	93	7	15
Disraeli	3,500	146	252	378	0	524	630	150	180	7	15
Cookshire	1,850	197	336	228	0	425	564	229	304	8	17
Pierreville	1,631	81	137	205	0	286	342	175	210	3	8
Weedon	1,538	183	313	196	0	379	509	246	331	7	15
Stoke	1,360	70	119	178	0	248	297	182	218	3	7
Ascot	1,310	68	115	172	0	240	287	183	219	3	7
Omerville	1,150	62	104	156	121	97	139	84	121	2	6
St. Germain	1,042	121	205	144	93	172	256	165	245	5	11
TOTAL	32,868	1,920	3,303	3,609	522	5,007	6,390			84	175
Cost per Capita Served ($)		58	100	110	n.a.	152	194			2.56	5.32

Table 24. Total Estimated Construction Costs of Treatment and Sewer Systems in Municipalities of Priority Group IV
($000, except where indicated)

Municipality	1970 Population	Treatment Cost		Sewer Cost	Total Previous Expenditure	Total Estimated Cost		Per Capita Cost ($)		Annual Operation and Maintenance Cost	
		Primary	Secondary			Primary	Secondary	Primary	Secondary	Primary	Secondary
St. François du Lac	957	53	71	106	0	159	177	166	185	2	5
Ayers Cliff	775	45	61	91	0	136	152	175	196	2	5
Durham Sud	713	117	156	85	0	202	241	283	338	5	10
St. Sebastien	495	32	43	64	0	96	107	194	216	1	4
TOTAL	2,940	247	331	346	0	593	677			10	24
Cost per Capita Served ($)		84.01	112.59	117.69	n.a.	201.70	230.27			3.40	8.16

In general then, as should be expected when comparing municipalities of priority groups II and III, the economies of large scale operations decline as population becomes smaller. In view of the relatively high per capita costs in priority group III, and relatively low entry of effluent into the St. François from these localities, primary treatment would be an adequate first step in water pollution abatement. Ultimately, however, these towns will probably require secondary treatment.

PRIORITY GROUP IV

The remaining municipalities in the basin, i.e. those with populations under 1,000, comprise this priority group. As indicated in Table 24, the per capita costs of treatment in these municipalities are substantially higher than those in either priority groups II or III. The lack of economies of scale explains further this increased per capita cost. It appears that primary treatment would be a sufficient level of waste treatment in these towns.

Financing Waste Treatment Systems in the St. François Basin

The cost of waste treatment in principal municipalities in the basin as determined previously are given in terms of constant 1971 dollars. The treatment 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 made in compiling the 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. In the case of industry, accelerated tax write-offs and other incentive programs are possibilities for inducing the installation of treatment equipment. It is likely, therefore, that some form of financial relief will be available for industry. This assumption, enables the calculation of financing costs for complete (domestic and industrial) waste treatment systems.

In Canada, C.M.H.C. is the most comprehensive source of funds for the construction of waste water 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 plant, and the construction of trunk sewers[18]. For an eligible project, C.M.H.C. may grant low interest loans for up to two-thirds of the project cost. The amortization period of the C.M.H.C. loans can extend up to 50 years, and varies with the ability of the individual municipality to pay. The current rate of interest on such loans is $7^1/_2$%. This interest rate has been assumed in the calculations made below. 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 on or before 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.

Tables 25 to 32 summarize the financial calculations made for the municipalities in the St. François basin. Tables 25 to 28 deal with the costs of treatment assuming joint domestic and industrial treatment, while tables 29 to 32 cover the costs of domestic treatment only.

18. For the precise 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.

Table 25. Cost of Financing Waste Treatment Systems to Treat Domestic and Industrial Wastes in Principal Municipalities

Municipality	Total Required Investment*	Amount Eligible for Federeal Financing†	Amount of Federal Loan §	Interest Charges**	Total Cost	Federal Forgiveness‡	Total Cost to Municipality	Average Annual Per Capita Cost
Old Technology	1,461	1,118	745	926	2,387	214	2,173	18
East Angus								
Typical Technology	2,036	1,693	1,129	1,402	3,438	325	3,113	26
Old Technology	1,852	1,433	955	1,187	3,039	275	2,764	17
Windsor								
Typical Technology	2,589	2,170	1,447	1,798	4,387	416	3,971	25
Old	3,313	2,551	1,700	2,113	5,426	489	4,937	
TOTAL ‡								
Typical	4,625	3,863	2,576	3,200	7,825	741	7,084	

*These costs are for secondary treatment. See Table 21.
†See footnote ** Table 26.
§See footnote ‡ Table 26.
**See footnote ‡ Table 26.
‡See footnote †† Table 26.
‡Excluding cost at Kruger mill at Bromptonville.

Table 26. Cost of Financing Waste Treatment Systems to Treat Domestic and Industrial Wastes in Principal Municipalities Priority Group II
($000)

Municipality	Total Required Investment*		Amount Eligible for Federal Financing**		Amount of Federal Loan‡		Interest Charges‡		Total Cost		Federal Forgiveness††		Total Cost to Municipality		Average Annual Cost per Capita	
	Prim.†	Sec.§	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
Sherbrooke	6,724	8,844	4,687	6,807	3,125	4,538	3,883	5,638	10,607	14,482	898	1,305	9,709	13,177	5	8
Drummondville	4,841	7,703	3,680	6,242	2,453	4,161	3,048	5,170	7,889	12,873	705	1,196	7,184	11,677	10	16
Magog	2,033	2,732	1,318	2,017	879	1,345	1,092	1,671	3,125	4,403	253	387	2,872	4,016	8	12
TOTAL	13,598	19,279	9,685	15,066	6,457	10,044	8,023	12,479	21,621	31,758	1,856	2,888	19,765	28,870	7	10

*See Table 22.

†Prim. = Primary Treatment

§Sec. = Secondary 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 Sect. VIII 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 VIII of the National Housing Act, if construction is completed by Marsh 31, 1975, 25% of the loan amount and 25% of the interest incurred to the time of completion of construction.

Table 27. Cost of Financing Waste Treatment Systems to Treat Domestic and Industrial Wastes in Principal Municipalities Priority Group III
($000)

Municipality	Total Required Investment*		Amount Eligible for Federal Financing**		Amount of Federal Loan‡		Interest Charges‡		Total Cost		Federal Forgiveness††		Total Cost to Municipality		Average Annual Cost per Capita	
	Prim.†	Sec.§	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
Coaticook	1,221	1,597	738	1,114	492	743	611	923	1,832	2,520	141	214	1,691	2,306	9	12
Lennoxville	594	715	288	409	192	273	239	339	833	1,054	55	78	778	976	8	10
Richmond	595	720	294	419	196	279	243	347	838	1,067	56	80	782	987	8	10
Rock Forest	226	334	0	56	0	37	0	46	226	380	0	11	226	369	3	4
Disraeli	524	630	251	357	167	238	207	296	731	926	48	68	683	858	8	10
Cookshire	425	564	252	391	168	260	208	323	633	887	48	75	585	812	13	18
Pierreville	286	342	130	186	87	124	108	154	394	496	25	36	369	460	9	11
Weedon	379	509	229	359	152	239	188	297	567	806	44	69	523	737	14	19
Stoke	248	297	111	160	74	107	92	133	340	430	21	31	319	399	9	12
Ascot	240	287	107	154	71	103	88	128	328	415	20	30	308	385	9	12
Omerville	97	139	0	17	0	11	0	14	97	153	0	3	97	150	3	5
St. Germain	172	256	59	143	39	95	48	118	220	374	11	27	209	347	8	13
TOTAL	5,007	6,390	2,459	3,765	1,638	2,509	2,032	3,118	7,039	9,508	469	722	6,570	8,786	10	14

*See Table 23.

†Prim. = Primary Treatment

§Sec. = Secondary 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 Sect. VIII 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 VIII 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.

Table 28. Cost of Financing Waste Treatment Systems to Treat Domestic and Industrial Wastes in Principal Municipalities Priority Group IV
($000)

Municipality	Total Required Investment*		Amount Eligible for Federal Financing**		Amount of Federal Loan†		Interest Charges‡		Total Cost		Federal Forgiveness		Total Cost to Municipality		Average Annual Cost per Capita	
	Prim.†	Sec.§	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
St. François du Lac	159	177	82	100	55	66	68	82	227	259	16	19	211	240	9	10
Ayers Cliff	136	152	68	84	45	56	56	70	192	222	13	16	179	206	9	11
Durham Sud	202	241	138	177	92	118	114	147	316	388	26	34	290	354	16	20
St. Sebastien	96	107	47	58	31	38	38	47	134	154	9	11	125	143	10	12
TOTAL	593	677	335	419	223	278	276	346	869	1,023	64	80	805	943	11	13

*See Table 24

†Prim. = Primary Treatment

§Sec. = Secondary 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 Sect. VIII 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 VIII 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.

Table 29. Cost of Financing Waste Treatment Systems to Treat Domestic Waste in Principal Municipalities Priority Group I
($000)

Municipality	Total Required Investment*		Amount Eligible for Federal Financing**		Amount of Federal Loan‡		Interest Charges‡		Total Cost		Federal Forgiveness††		Total Cost to Municipality		Average Annual Cost per Capita	
	Prim.†	Sec.§	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
East Angus	674	812	331	469	221	313	275	389	949	1,201	64	90	885	1,111	7	9
Windsor	843	1,017	421	598	281	399	349	496	1,192	1,513	81	115	1,111	1,398	7	9
Bromptonville	451	542	213	304	142	203	176	252	627	794	41	58	586	736	8	10
TOTAL	1,968	2,371	965	1,371	644	915	800	1,137	2,768	3,508	186	263	2,582	3,245	7	9

*Derived from summation of average domestic treatment cost of Appendix 1, Table 1 and cost collector systems of Table 21.

†Prim. = Primary Treatment

§Sec. = Secondary 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 Sect. VIII 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 VIII of the National 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.

From tables 21 to 24, the total required investment was obtained. Using the C.M.H.C. standards, the amount of required investment eligible for federal financing was estimated. In the case of all principal municipalities, the entire cost of treatment plant construction was considered eligible for financing. This would include the pulp and paper towns of priority group I. The latter inclusion calls for an extension of the C.M.H.C. terms of financing, or alternatively, similar financial arrangements made under other authority. For collection systems, it was estimated from present regulations that $30.00 per capita for trunk sewers, etc., was eligible for financing by C.M.H.C. In municipalities with no previous work done on collection systems, the full amount eligible under C.M.H.C. was added to the treatment plant cost to obtain the total amount eligible for federal financing. For municipalities with

Table 30. Cost of Financing Waste Treatment Systems to Treat Domestic Waste in Principal Municipalities Priority Group II
($000)

Municipality	Total Required Investment*		Amount Eligible for Federal Financing**		Amount of Federal Loan‡		Interest Charges‡		Total Cost		Federal Forgiveness††		Total Cost to Municipality		Average Annual Cost per Capita	
	Prim.†	Sec.§	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
Sherbrooke	5,651	6,902	3,614	4,865	2,409	3,243	2,993	4,029	8,644	10,931	693	932	7,951	9,999	5	6
Drummondville	2,553	3,167	1,392	2,006	928	1,337	1,153	1,661	3,706	4,828	267	384	3,439	4,444	5	6
Magog	1,554	1,882	839	1,167	559	778	695	967	2,249	2,849	161	224	2,088	2,625	6	8
TOTAL	9,758	11,951	5,845	8,038	3,896	5,358	4,841	6,657	14,599	18,608	1,121	1,540	13,478	17,068	5	6

*Derived from summation of average domestic treatment cost of Appendix 1, Table 2 and cost of collector systems of Table 22.

†Prim. = Primary Treatment

§Sec. = Secondary 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 Sect. VIII 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 VIII 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.

Table 31. Cost of Financing Waste Treatment Systems to Treat Domestic Waste in Principal Municipalities Priority Group III
($000)

Municipality	Total Required Investment		Amount Eligible for Federal Financing**		Amount of Federal Loan‡		Interest Charges‡		Total Cost		Federal Forgiveness††		Total Cost to Municipality		Average Annual Cost per Capita	
	Prim.†	Sec.§	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
Coaticook	990	1,195	507	712	338	475	420	590	1,410	1,785	97	137	1,313	1,648	7	8
Lennoxville	594	715	288	409	192	273	239	339	833	1,054	55	78	778	976	8	10
Richmond	583	702	282	401	188	267	234	332	817	1,034	54	77	763	957	8	10
Rock Forest	226	334	51	56	34	37	42	46	268	380	10	11	258	369	3	4
Disraeli	524	630	251	357	167	238	207	296	731	926	48	68	683	858	8	10
Cookshire	317	380	144	207	96	138	119	171	436	551	28	40	408	510	9	11
Pierreville	286	342	130	186	87	124	108	154	394	496	25	36	369	460	9	11
Weedon	273	327	123	177	82	118	102	149	375	474	24	34	351	440	9	11
Stoke	248	297	111	160	74	107	92	133	340	430	21	31	319	399	9	12
Ascot	240	287	107	154	71	103	88	128	328	415	20	30	308	385	9	12
Omerville	97	139	0	17	0	11	0	14	97	153	0	3	97	150	3	5
St. Germaine	108	147	0	34	0	23	0	29	108	176	0	7	108	169	4	6
TOTAL	4,486	5,495	1,994	2,870	1,329	1,914	1,651	2,381	6,137	7,874	382	552	5,755	7,321	9	11

*Derived from summation of average domestic treatment cost of Appendix 1, Table 3 and cost of collector systems of Table 23.

†Prim. = Primary Treatment

§Sec. = Secondary 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 Sect. VIII 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 VIII 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.

Table 32. Cost of Financing Waste Treatment Systems to Treat Domestic Waste in Principal Municipalities Priority Group IV ($000)

Municipality	Total Required Investment*		Amount Eligible for Federal Financing**		Amount of Federal Loan‡		Interest Chargesǂ		Total Cost		Federal Forgiveness††		Total Cost to Municipality		Average Annual Cost per Capita	
	Prim.†	Sec.§	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
St. François du Lac	159	177	82	100	55	67	68	83	227	260	16	19	211	241	9	10
Ayers Cliff	136	152	68	84	45	56	56	70	192	222	13	16	179	206	9	10
Durham Sud	127	142	63	78	42	52	52	64	179	206	12	15	167	191	9	11
St. Sebastien	96	107	47	58	31	39	39	48	135	155	9	11	126	144	10	12
TOTAL	518	578	260	320	173	214	215	265	733	843	50	61	683	782	9	11

*Derived from summation of average domestic treatment cost of Appendix 1, Table 4 and cost of collector systems of Table 24.

†Prim. = Primary Treatment

§Sec. = Secondary 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 capital for collection systems eligible under Sect. VIII 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

ǂLoans were amortized at $7^1/_2$%, the current C.M.H.C. lending rate, and over a 25 year period.

††As per Section VIII 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.

previous work completed on collection systems, allowance was made for previous expenditures in calculating the amount eligible for federal financing. The amount of the federal loan was calculated as 66.67% of the eligible amount.

The total amortized cost of the full treatment system for each municipality was calculated using an interest rate of $7^1/_2$% and an amortization period of 25 years[19]. As outlined above, it was assumed (a) that the portion of the required investment attributable to industry could be financed under terms similar to those of C.M.H.C., and (b) that the portion ineligible for federal funding could be similarly financed. Although these assumptions may not accurately reflect the financing conditions at the time of construction, they may, however, be replaced easily by the actual financing terms to re-calculate the total costs of waste treatment systems in the municipalities under consideration. The totals may be affected slightly by altering the financial conditions, but not the order-of-magnitude of the total costs.

To obtain the total cost to the municipality of the treatment systems outlined in section III, the amount of federal forgiveness was deducted from the total project cost. As outlined previously, the partial debt cancellation is 25% of the loan principal plus 25% of the interest accruing during construction, assuming project completion by March 31, 1975.

As in the calculation of total per capita costs, the annual amortized costs per capita exhibit some economies of scale. In general, the amortized per capita costs tend to increase as the size of the municipality decreases. This tendency is best exhibited in Tables 29 to 32 which cover the costs of domestic treatment only. For example the annual per capita costs in Sherbrooke (population 70,138) is $5 for primary and $6 for secondary treatment. The corresponding costs for Ayers Cliff (population 775) is $9 per capita for primary and $11 for activated sludge.

When the costs of joint domestic-industrial treatment are considered, the effects of scale economies are distorted. This distortion is due to the variable waste loadings between municipalities of the basin. This effect is seen best in the pulp and paper towns of priority group I. For example, in East Angus, Table 29 shows that the annual cost of secondary treatment for domestic wastes only is about $9 per capita. Compared to municipalities of a similar size, this cost is in line. When the costs of treating the pulp and paper mill wastes are taken into account, the same cost is more than doubled to between $18 and $26 per capita. This distortion to the pattern established by economies of scale in considering domestic treatment only, further points out the significance of considering industrial wastes in a comprehensive water quality management scheme. Another significant distortion in the pattern of scale economies is found in the city of Drummondville. Table 30 shows that the annual cost of secondary treatment for domestic wastes is $6 per capita. This figure increases to about $16 per capita when the treatment of industrial wastes is considered. Other examples of the effects of industrial treatment on treatment costs can be found in other municipalities in the basin.

19. See Appendix 3 for interest calculations.

Conclusion

This paper has presented a method for determining the costs of, and priorities for, waste treatment in the St. François River basin. It should be stressed that the conclusions in this paper were drawn from limited available data and the factors used to estimate costs have been applied solely to these data. Thus, before final conclusions are drawn, the data base must be checked and augmented.

Based upon the data available, the major sources of water pollution were identified. For the most part, these sources may be termed "point" sources, for their precise point of entry into the receiving water can be identified. This study dealt only with the major point sources defined as being wastes from the larger municipalities and the principal industries. One conclusion reached is that the amount of water pollution from industrial sources is significantly greater than that attributable to the domestic population.

In this paper, no attempt was made to deal with the widespread or "non-point" pollution sources, such as agricultural runoff or recreational pollution caused by the recreation developments concentrated around the head-water lakes. This gap in the analysis arises because no comprehensive data are available concerning these non-point sources. It is important to future decision-making that more information be available on these potentially serious sources of water pollution.

Following identification of the major water pollution sources, the receiving water quality along the stream from the headwaters to the mouth was examined. On the basis of this descriptive analysis, four priority levels were established for waste treatment in the various municipalities. The levels correspond to the approximate severity of the water pollution problems in the various municipalities. Priority group I, the most severely polluted area of the basin, includes the three pulp and paper mill towns, East Angus, Bromptonville, and Windsor. Priority group II is composed of the large municipalities in the basin, Sherbrooke, Drummondville and Magog. In general, these three municipalities have a relatively diversified industrial base, combined with populations over 10,000 persons. The water quality problems in these areas are not as severe as in the pulp and paper mill towns. Priority group III is formed by the remaining municipalities in the basin with over 1,000 persons. The wastes generated by the domestic population and by the various light manufacturing industries in these smaller towns are relatively small in their contribution to the water pollution problem when compared to those from priority groups I and II. The villages with under 1,000 persons form priority group IV. The water pollution problem associated with these municipalities are negligible in relation to those of the other groups.

On the basis of waste sources and the quality of the receiving water, the treatment requirements of the basin were determined. For the first two priority groups, full secondary treatment is required. Priority group III, it is suggested, should have primary treatment as soon as possible, with later augmentation to secondary treatment. Treatment requirements for priority group IV are not as urgent; the wastes from these villages will probably require only primary treatment.

The costs of the proposed treatment facilities were estimated using cost equations derived from secondary sources. To the waste treatment plant costs were added the estimated costs of installing collector facilities in the various municipalities. In making the treatment plant cost estimations, two basic arrangements were examined. Firstly, the cost of treating only domestic wastes was derived (see Appendix 1). Since it was found that the major sources of water pollution are the basin's industries, treating only the domestic wastes would not greatly improve the quality of the receiving stream. For this reason, the first alternative was discarded in favour of treating domestic and the major part of industrial wastes in common treatment facilities.

This second alternative offers two basic possibilities, treatment of domestic wastes in the treatment system of a large industry, or combined domestic-industrial treatment in a common publically-owned facility. The first of these possibilities was found economically advantageous for priority group I where one large industrial plant dominates the town. For priority groups II, III and IV, the second possibility is more attractive because the municipalities contain a diversity of industries and are not dominated by any one large plant. The detailed set of cost estimates set forth in this paper are based upon combined domestic-industrial treatment. Table 33 summarizes the cost of

Table 33. Waste Treatment Cost Summary
($000, except where specified)

Priority Group	Primary		Secondary	
	Construction	Operating and Maintenance	Construction	Operating and Maintenance
I Old Technology	not considered		3,313 + cost to Kruger	
Typical Technology	not considered		4,625 + cost to Kruger	
II Total Cost	13,598	366	19,279	528
Per Capita ($)	121	3.25	171	4.7
III Total Cost	5,007	84	6,390	175
Per Capita ($)	152	2.56	194	5.32
IV Total Cost	593	10	677	24
Per Capita ($)	201	3.40	230	8.16
Total Cost for all Groups	19,198	460	Old 29,659*	n.a.
			Typ 30,971*	n.a.
Average per Capita ($)	129	3.1	Old 190	n.a.
			Typ 199	n.a.

*Not including any allowance for the Kruger paper mill at Bromptonville.
n.a. not available

Table 34. Summary of Financing Costs for Waste Treatment Facilities*
($000, except where specified)

Priority Group	Primary		Secondary	
	Total Amortized Cost	Annual Amortized Cost ($)	Total Amortized Cost	Annual Amortized Cost ($)
I Combined Treatment				
Old Technology	not evaluated		4,937[1]	18
Typical Technology	not evaluated		7,084	26
Domestic only	2,582	7	3,245	9
II Combined	19,765	7	28,870	10
Domestic only	13,478	5	17,068	6
III Combined	6,570	10	8,786	14
Domestic only	5,755	9	7,321	11
IV Combined	805	11	943	13
Domestic only	683	9	782	11

*Not including any allowance for the Kruger paper mill at Bromptonville.

primary and secondary treatment for the priority groups of the study. The total cost per capita for all municipalities in the basin is $129 for primary treatment and between $190 and $200 for secondary treatment. There are significant economies of scale accruing to the larger municipalities in the construction and operation of treatment facilities.

In a paper on the adjacent Yamaska River basin[20] it was suggested that regional treatment centres be established at certain locations to treat the wastes of more than one municipality. In that basin, the establishment of two such plants was thought to be practical, and significant economies of scale resulted when the construction costs of these plants were compared to the costs of erecting separate plants in each municipality. In the St. François basin, however, regional treatment is less practical. The basin, as seen in the frontispiece map, is "T-shaped", and the cities

20. Tate, D. op. cit.

and towns are located in such a manner as to make the costs of transporting the wastes to regional facilities prohibitive. Thus the alternative of regional treatment was not considered in detail for this basin.

The costs of the proposed treatment alternatives were amortized at $7^1/_2$% over 25 years. The effects of economies of large scale operations are highlighted in these calculations. For the larger municipalities, the annual per capita cost is between \$6 and \$8. In the small towns, the same costs rise to about \$11. The costs of financing waste treatment systems are summarized in Table 34.

APPENDIX 1

Waste Treatment Cost Breakdown

The total costs of waste treatment facilities given in the paper are broken down into domestic and industrial components in this Appendix. The costs are based upon the linear regression equations given in Appendix 2.

Table 1.1 Estimated Construction Cost of Treatment Facilities to Serve Domestic Population Priority Group I
($000 except where specified)

Municipality	Population	Effluent Flow (MGD)	Primary			Activated Sludge		
			OWRC*	Eckenfelder†	Average	OWRC	Eckenfelder	Average
East Angus	4,800	.480	167	207	187	265	385	325
Windsor	6,375	.638	210	257	233	336	478	407
Richmond	4,005	.401	144	181	162	227	335	281
TOTAL	15,180	1.519	521	645	582	828	1,198	
Per Capita $			34.32	42.49	38.34	54.55	78.92	66.73

*O.W.R.C., Op. Cit.
†Eckenfelder, Op. Cit.

Table 1.2 Estimated Construction Cost of Treatment Facilities to Serve Domestic Population Priority Group II
($000 except where specified)

Municipality	Population	Effluent Flow (MGD)	Primary			Activated Sludge		
			OWRC*	Eckenfelder†	Average	OWRC	Eckenfelder	Average
Sherbrooke	70,138	7.014	1,469	1,552	1,510	2,523	2,999	2,761
Drummondville	28,537	2.584	708	755	731	1,183	1,507	1,345
Magog	13,797	1.380	393	458	425	643	863	753
TOTAL	112,472	11.248	2,570	2,765	2,666	4,349	5,369	4,859
Per Capita $		.10	22.85	24.58	23.70	38.67	47.74	43.20

*O.W.R.C., Op. Cit.
†Eckenfelder, Op. Cit.

Table 1.3 Estimated Construction Cost of Treatment Facilities to Serve Domestic Population Priority Group III
($000 except where specified)

Municipality	Population	Effluent Flow (MGD)	Primary			Activated Sludge		
			OWRC*	Eckenfelder†	Average	OWRC	Eckenfelder	Average
Coaticook	7,800	.780	248	299	273	398	558	478
Lennoxville	4,100	.410	147	184	165	232	341	286
Rock Forest	3,582	.358	132	166	149	207	307	257
Disraeli	3,500	.350	129	163	146	203	302	252
Bromptonville	2,898	.290	111	142	126	173	261	217
Cookshire	1,850	.185	77	101	89	119	185	152
Pierreville	1,631	.163	70	92	81	107	168	137
TOTAL	25,361	2.536	914	1,147	1,029	1,439	2,122	1,779
Per Capita $			36.04	45.23	40.57	56.74	83.67	70.15

*O.W.R.C., Op. Cit.
†Eckenfelder, Op. Cit.

Table 1.4 Estimated Construction Cost of Treatment Facilities to Serve Domestic Population Priority Group IV
($000 except where specified)

Municipality	Population	Effluent Flow (MGD)	Primary			Activated Sludge		
			OWRC*	Eckenfelder†	Average	OWRC	Eckenfelder	Average
St. François du Lac	957	.096	45	62	53	61	82	71
Ayers Cliff	775	.078	38	53	45	53	69	61
Durham Sud	713	.071	36	49	42	50	64	57
St. Sebastien	495	.050	27	38	32	39	48	43
TOTAL	2,940	.2950	146	202	172	203	263	232
Per Capita $			49.66	68.71	58.50	69.05	89.46	78.91

*O.W.R.C., Op. Cit.
†Eckenfelder, Op. Cit.

Table 1.5 Estimated Construction Cost of Treatment Facilities to Serve Industrial Requirements Priority Group I
($000 except where specified)

Municipality	Effluent (MGD)	Primary			Secondary		
		OWRC*	Eckenfelder†	Average	OWRC	Eckenfelder	Average
Sherbrooke	4.530	1,028	1,117	1,072	1,742	2,143	1,942
Drummondville	11.977	2,259	2,317	2,288	3,954	4,519	4,236
Magog	1.607	445	513	479	731	970	850
Coaticook	.629	208	254	231	331	473	402
Cookshire	.237	94	122	108	146	223	184
Weedon	.231	92	120	106	143	220	181
Durham Sud	.149	65	85	75	82	117	99
Richmond	.013	9	14	11	13	24	18
St. Germain de Grantham	.122	55	74	64	71	100	85
All Others	Neg	Neg	Neg	Neg	Neg	Neg	Neg
TOTAL	19.495	4,255	4,616	4,436	7,213	8,789	8,001

*O.W.R.C., Op. Cit.
†Eckenfelder, Op. Cit.

Table 1.6 Total Estimated Construction Cost of Treatment Systems in Industries and Municipalities Priority Group II
($000 except where specified)

Municipality	Primary			Secondary		
	OWRC*	Eckenfelder†	Average	OWRC	Eckenfelder	Average
Sherbrooke	2,497	2,669	2,583	4,265	5,142	4,703
Drummondville	2,967	3,072	3,019	5,137	6,026	5,581
Magog	838	971	904	1,374	1,833	1,603
TOTAL	6,302	6,712	6,507	10,776	13,001	11,888

*O.W.R.C., Op. Cit.
†Eckenfelder, Op. Cit.
NOTE: This methodology was not used to calculate the cost of combined treatment in Priority Group I.

Table 1.7 Total Estimated Construction Cost of Treatment Systems in Industries and Municipalities Priority Group III
($000)

Municipalities	Primary			Secondary		
	OWRC*	Eckenfelder†	Average	OWRC	Eckenfelder	Average
Coaticook	456	553	504	729	1,031	880
Lennoxville	147	184	165	232	341	286
Richmond	153	195	174	240	359	299
Rock Forest	132	166	149	207	307	257
Disraeli	129	163	146	203	302	252
Cookshire	171	223	197	265	408	336
Pierreville	70	92	81	107	168	137
Weedon	158	208	183	245	381	313
Stoke	60	80	70	92	146	119
Ascot	58	78	68	89	142	115
Omerville	53	71	62	80	129	104
St. Germain de Grantham	103	140	121	157	254	205
TOTAL	1,690	2,153	1,922	2,646	3,968	3,307

*O.W.R.C., Op. Cit.
†Eckenfelder, Op. Cit.

Table 1.8 Total Estimated Cost of Construction of Treatment Systems in Industries and Municipalities Priority Group IV
($000)

Municipality	Primary			Secondary		
	OWRC*	Eckenfelder†	Average	OWRC	Eckenfelder	Average
St. François du Lac	45	62	53	61	82	71
Ayers Cliff	38	53	45	53	69	61
Durham Sud	101	134	117	132	181	156
St. Sebastien	27	28	32	39	48	43
TOTAL	211	277	244	285	380	332

*O.W.R.C., Op. Cit.
†Eckenfelder, Op. Cit.

Waste Treatment Cost Equations

Waste treatment costs were estimated from secondary sources. Using the linear regression technique, the Ontario Water Resources Commission (OWRC) has analyzed waste treatment costs for municipalities in Ontario[21]. According to this source, the cost of construction for waste treatment facilities is a logarithmic function of the plant 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 (in dollars)
Q = design capacity (in millions of gallons per day)

For activated sludge treatment

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

A publication by Eckenfelder[22] gives equations for the same type of costs as the O.W.R.C. These are:

Primary treatment

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

Secondary treatment

$$\log C = 2.8293 + .7657 \text{ LQ} \qquad (4)$$

This source also gives equations relating annual operating and maintenance costs to design capacity for primary and secondary treatment as follows:

Primary treatment

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

where: M = annual operating and maintenance costs

Secondary treatment

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

21. Ontario Water Resources Commission, *A Guide on Estimating Sewage Treatment Plant Construction Costs in the Province of Ontario*, 1967.

22. Eckenfelder, W.W., *Water Quality Engineering for Practicing Engineers, Barnes & Noble*, 1970. Chapter 13.

Calculation of Interest Charges

The assumptions made to calculate the interest charges are as follows:

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.

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

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

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

The total amount paid is then

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

So the interest charges are

$$Ic = 224.25 - 100 = 124.25$$