UPGRADING COSTS FOR MUNICIPAL SEWAGE TREATMENT PLANTS AND POTENTIAL IMPACTS OF INNOVATIVE TECHNOLOGIES

Phase 1: Sewage Treatment Plants in 17 Canadian Areas of Concern

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EXECUTIVE SUMMARY

This report contains the results of a study to review the cost estimates for upgrading municipal sewage treatment plants (STPs) in the 17 Canadian Areas of Concern (AOCs) and to determine how innovative treatment and process optimization technologies can be applied to reduce the costs of upgrading based on a traditional capital works approach.

Sixteen of the 17 Canadian Areas of Concern receive direct discharges from a total of 40 STPs and 8 lagoons. A total population of 3.4 million is serviced by municipal facilities in Canadian AOCs. The total design capacity of all municipal treatment facilities in Canadian AOCs is 2,900 million litres/day (or 640 million imperial gallons per day). Thirty-one facilities in Canadian AOCs will require upgrading to meet RAP requirements. Ten primary STPs will require upgrading to secondary treatment. One existing lagoon will be replaced by tertiary treatment. Enhanced phosphorus removal will be required at 16 secondary STPs and nitrification may be needed at seven STPs, including the four Metro Toronto STPs.

Review of engineering studies and cost estimates provided by the Water Resources Branch, Ontario Ministry of Environment, suggested that the total cost of upgrading STPs in the Canadian Areas of Concern was approximately $1,073. million based on the application of conventional approaches. Of this total, $403. million was associated with the Metro Toronto STPs and $670. million was associated with upgrading STPs in the remaining AOCs. Uncertainty in the overall capital estimate was caused by the lack of clearly defined upgrading requirements for the Metro Toronto STPs. Estimates by Hickling Corporation in 1992 placed total STP upgrading costs at $2,618. million ($1,783. million for the Toronto Waterfront AOC and $835. million for the other AOCs).

Conventional and innovative approaches for three categories of STP upgrading were described: upgrading primary plants to secondary plants, expanding existing secondary treatment plants, and upgrading secondary treatment plants to meet more stringent nitrogen and phosphorus effluent limitations. In each of the three upgrading categories, case studies were reviewed to document the cost savings and other benefits which were achieved through the application of innovative approaches. Benefits were estimated to amount to $50. million of deferred or eliminated capital expenditure at these eight treatment facilities compared to a total capital expenditure of $150 million based on conventional upgrading approaches (see Table 4.3). Other benefits, other than cost savings, included improved performance, enhanced operability, or reduced variability in effluent quality.

Assuming that results from the eight cases can be applied to other STPs in Canadian AOCs, then a potential $125. million in upgrading costs can be realized by the application of innovative and optimization technologies to upgrade STPs in AOCs.

The cost savings represents approximately 20% of the total $670. million estimated for upgrading. This potential cost savings excluded any savings which might be achieved at the Metro Toronto STPs because current information is inadequate to support a valid estimate of savings at these facilities. Additional information concerning site-specific conditions at the four Metro Toronto STPs and clearly defined upgrading requirements established by the RAP are required to estimate such savings.

The report documented that substantial cost savings were realized at a number of Ontario STPs through the application of innovative and optimization technologies to plant expansion and upgrading. Coordinated Federal, Provincial and Municipal government programs to support such studies will ensure that innovative and optimization technologies continue to be developed, demonstrated, and applied at municipal STPs requiring expansion and/or upgrading. To better refine the information contained in this study, the following recommendations are presented:

- Capital costs for upgrading the West Windsor STP from a primary to innovative secondary treatment facilities should be generated at the completion of investigations currently underway so that cost savings can be accurately defined.

- Detailed technical investigations should be completed at the Collingwood STP and other selected STPs within the AOCs to define the ability to consistently achieve an effluent total phosphorus concentration of 0.30 mg/L or less through optimized chemical addition <u>without</u> tertiary filtration.

- Detailed technical investigations should be completed at a number of STPs with different effluent filter designs to determine the ability of post-precipitation and effluent filtration to consistently achieve an effluent total phosphorus concentration of 0.10 mg/L or less.

- Additional efforts are required to evaluate and demonstrate low cost alternatives for retrofitting STPs for nitrification. The work should include: a state-of-the-art literature review of low cost alternatives, a technical and economic evaluation of several case studies and demonstration of the most promising technologies. (Information from work on nitrification will assist Ontario STPs to comply with the Ontario's MISA regulations which will require all effluents to be nontoxic. All municipal STPs will have to nitrify to meet this requirement.)

- Because of the relative magnitude of the costs associated with upgrading the 4 Metro Toronto STPs, better definition of the likely RAP requirements for these facilities is required to better define the overall cost estimates and potential savings.

- An up-to-date database of actual construction costs for expanding and/or upgrading Ontario STPs should be developed to assess the cost implications of proposed alternative effluent regulations and policy initiatives.

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1.0 INTRODUCTION

1.1.) *BACKGROUND*

Remedial Action Plans (RAPs) are being prepared to address water quality problems at 17 Canadian Areas of Concern (AOCs) in the Great Lakes. Hickling Corporation in a report[1] prepared for the Ontario Ministry of Environment (MOE) estimated that $5.5 billion will be required to implement remedial actions in the 17 AOCs to restore impaired water quality. The three largest costs components listed in the Hickling report[1] were upgrading sewage treatment plants (accounting for 47% of total costs for remediating AOCs), controlling urban run-off (39% of total costs), and treating industrial point source discharges (8% of total costs). The costs for programs to address combined sewer overflows in the 11 AOCs impacted by pollution from urban runoff were estimated in an earlier report[2].

In 1991, the Ontario Water Services Secretariat[3] estimated that $14.8 billion of capital spending will be required to upgrade sewerage systems and municipal sewage treatment plants in Ontario over the next 10 to 15 years to meet existing and proposed effluent regulations. Tasks identified by the Secretariat included upgrading of primary sewage treatment plants (STPs) to secondary, upgrading of STPs which are noncomplying, upgrading sludge disposal for future regulations, containing and treating volatile organic compounds (VOCs), controlling combined sewer overflows, and rehabilitating existing STPs.

Wastewater treatment process knowledge applied to optimize the performance of existing municipal and industrial wastewater treatment plants can often substantially reduce or, in some cases, entirely eliminate the need for capital intensive treatment plant upgrades. For instance, the process audit has been developed to evaluate the true capacity of municipal STPs and to identify and eliminate process bottlenecks. Policies which are based solely on expanding STP capacity to address existing and future effluent limits will likely be unnecessarily costly. Further, in some cases, STPs cannot be upgraded through capital expansion because of land limitations.

The overall objectives of this study are to review the cost estimates for upgrading municipal sewage treatment plants in Ontario and, secondly, to identify how innovative treatment and process optimization technologies can be applied to municipal STPs to reduce the costs of upgrading based on a traditional capital works approach. This report contains the results of Phase 1 of the study, an examination of the costs and potential for applying advanced and innovative technology for upgrading sewage treatment plants in the 17 Canadian Areas of Concern. Phase 2 of the study will evaluate the costs for addressing effluent requirements proposed under the province of Ontario's Municipal Industrial Strategy for Abatement (MISA) program. The Phase 2 results will be presented in a separate report.

The information from both phases of the study will assist both Environment

Canada and the Ontario Ministry of Environment to:

• implement policies for upgrading municipal STPs in the 17 Canadian AOCs,

• justify financial support for municipal STP research, development, and demonstration;

• develop strategies which better exploit innovative wastewater treatment technologies and best management practices.

1.2) *OBJECTIVES:*

The specific objectives of Phase 1 of the study were as follows:

• to review and summarize existing reports on RAP costing to provide updated order of magnitude costs for upgrading municipal sewage treatment plants located in the 17 Canadian Areas of Concern,

• to provide a summary description of innovative and optimization technologies and traditional approaches based on capital expansion for upgrading municipal STPs ,

• to present case studies which document cost savings which have accrued through the application of innovative and process optimization technologies to STP upgrading;

• to estimate the potential cost savings which might be achieved through application of innovative technologies at STPs in the 17 Canadian Areas of Concern.

1.3) *REPORT FORMAT:*

Section 1.0 of the report presents the study background and objectives.

Section 2.0 presents background information concerning the number and type of sewage treatment plants which discharge effluents directly to the 17 Canadian Areas of Concern. Section 2.0 also contains an overview of the RAP upgrading requirements and summarizes previous capital cost estimates to achieve the upgrades. A review of upgrading cost estimates is presented for each of the 17 Canadian Areas of Concern. Based on available engineering studies for the STP in question or capital costs per unit of treatment plant capacity for plants with similar size and upgrading requirements, an updated range of costs for upgrading municipal STPs is presented.

Section 3.0 describes conventional and innovative approaches for upgrading sewage treatment plants. Three categories of STP upgrading are addressed: upgrading primary plants to secondary plants, expanding existing secondary treatment plants, and upgrading secondary treatment plants to meet more stringent nitrogen and phosphorus effluent limitations.

Section 4.0 provides 8 case studies documenting the cost savings which have been achieved at selected STPs through the application of innovative approaches. Case studies are provided for each category of upgrading (primary to secondary, expanding secondary STPs, and upgrading secondary STPs).

Section 5.0 contains a description of how innovative approaches might be applied to upgrade STPs to meet RAP requirements. Order of magnitude cost savings are estimated, assuming that innovative approaches are applied to upgrading STPs in RAP areas.

Section 6.0 presents study conclusions from Phase 1 and recommendations for follow-up work.

2.0: UPGRADING REQUIREMENTS AND COSTS FOR STPs IN CANADIAN AOCs:

2.1) *DESCRIPTION OF STPS IN CANADIAN AOCs:*

Table 2.1 lists the lagoons and Table 2.2 the municipal mechanical STPs which discharge directly to the 17 Canadian Areas of Concern. These facilities were identified based on a review of the Ministry of Environment's 1990 Discharge Report[4] (the most recent available) and from discussions with RAP Coordinators. In addition to the name of the facility and the AOC, the tables identify the MOE Region (Central, Southwest, West Central, Northwest, Southeast, Northeast and Northwest) to which the treatment system belongs, the agency (MOE, municipality, Department of National Defense, or Ministry of Health) operating the treatment system, the type of wastewater treatment technology employed, the population served by the treatment system, and the 1990 average daily flowrate treated at the facility. In Table 2.3, totals for number of facilities, the population serviced, design flows and 1990 average daily flowrate are summarized for each of the 17 AOCs. Table 2.4 contains summary values (number of plants, population, design flow and 1990 flowrate) for the four basic types of treatment technologies (lagoons, primary, secondary or tertiary).

Tables 2.1 to 2.4 indicate that 16 of the 17 Canadian Areas of Concern receive direct discharges from a total of 40 STPs and 8 lagoons. Wheatley Harbour is the only AOC which does not receive a direct discharge from a municipal treatment facility. A total population of 3.4 million is serviced by municipal facilities in the 16 AOCs. The total design capacity of all municipal treatment facilities in the Canadian AOCs is 2.9 million m^3/d or 640 million imperial gallons per day (MIGD). The total 1990 average daily flowrate treated by all municipal treatment facilities was approximately 2.4 million m^3/d (or 530 MIGD), 85% of the total design capacity. Canadian AOCs with the largest direct discharges from municipal treatment facilities include Toronto Waterfront (56% of the total 1990 average daily flowrate from all RAP facilities), Hamilton Harbour (17% of total) and Detroit River (7% of total). Ten STPs, representing 14% of the total 1990 average daily discharge, are primary facilities.

2.2) *UPGRADING REQUIREMENTS FOR STPS IN CANADIAN AOCs:*

Upgrading requirements for STPs in the Canadian AOCs were discussed with the RAP Coordinators. In addition, a review was conducted of the assumptions used to develop RAP implementation cost estimates prepared by Apogee[5] and Hickling[1]. A fundamental assumption in these reports, also adopted for this study, was that primary STPs would be required to be upgraded to secondary treatment. A second assumption adopted was that all STPs would be required to achieve a maximum effluent total phosphorus (TP) concentration of 1.0 mg/L. Therefore, the following upgrading requirements were identified for each of the AOCs:

TABLE 2.1: List of Municipal Lagoons in 17 Canadian AOCs

AREA OF CONCERN	STP/(Lagoon)	MOE REG.	OPERATED BY:	TYPE:	POP. SERVED (1000)	DESIGN FLOW (1000 m3/d)	1990 ADF (1000 m3/d)
COLLINGWOOD HARBOUR							
DETROIT RIVER	Edgewater Beach Lagoon	SW	MOE	CLS (P)	1.9	1.6	0.8
HAMILTON HARBOUR							
JACKFISH BAY							
NIAGARA RIVER	Stevensville Lagoon	WC	Mun	CLS	1.5	2.3	0.8
NIPIGON							
PENINSULA HARBOUR							
PORT HOPE							
QUINTE							
SEVERN SOUND	Elmvale Lagoon	C	Mun	CLC	1.6	0.8	1.4
SPANISH HARBOUR							
ST. CLAIR RIVER	Port Lambton Lagoon	SW	MOE	CLS (P)	0.9	1.1	0.4
	Sombra Lagoon	SW	MOE	CLS (P)	0.6	1.0	0.2
ST. LAWRENCE (CORNWALL)							
ST. MARYS RIVER							
THUNDER BAY							
TORONTO WTFNT.							
WHEATLEY HARBOUR							
TOTALS:				5	6.5	6.7	3.7

ABBREVIATIONS FOR TABLE 2.1 & 2.2:

MOE REGIONS:

C	Central
NE	Norteastern
NW	Nortwestern
SE	Southeastern
SW	Southwestern
WC	West Central

OPERATED BY:

DND	Department of National Defense
MOE	Ontario Ministry of Environment
MOH	Ontario Ministry of Health
Mun	Municipality

TYPE:

(P)	Phosphorus Removal (Chemical Addition)
CAS	Conventional Activated Sludge
CLC	Conventional Lagoon, Continuous Dischage
CLS	Conventional Lagoon, Seasonal Dischage
EA	Extended Aeration (Activated Sludge)
F	Effluent Filtration
HR	High Rate (Activated Sludge)
P	Primary
RBC	Rotating Biological Contactors

TABLE 2.2: List of Municipal Mechanical STPs in 17 Canadian AOCs

AREA OF CONCERN	STP/(Lagoon)	MOE REG.	OPERATED BY:	TYPE:	POP. SERVED (1000)	DESIGN FLOW (1000 m3/d)	1990 ADF (1000 m3/d)
COLLINGWOOD HARBOUR	Collingwood	C	Mun	CAS (P)	11.5	24.5	21.8
DETROIT RIVER	Amherstburg	SW	Mun	P (P)	8.5	7.8	8.0
	Little River (Windsor)	SW	Mun	CAS (P)	64.0	36.4	28.8
	Westerly (Windsor)	SW	Mun	P (P)	123.0	163.7	135.5
HAMILTON HARBOUR	Dundas	WC	Mun	CAS (P) F	19.5	18.2	14.8
	Skyway (Burlington)	C	Mun	CAS (P)	120.1	93.2	78.6
	Woodward Ave. (Hamilton)	WC	Mun	CAS (P)	300.0	409.1	334.6
JACKFISH BAY	Terrace Bay	NW	Mun	EA+ EXFILT. LAGOON	0.5	0.5	0.3
NIAGARA RIVER	Anger Ave. (Ft. Erie)	WC	Mun	CAS (P)	13.8	16.4	15.2
	Stamford (Niagara Falls)	WC	Mun	RBC (P)	67.8	58.2	64.3
NIPIGON	Nipigon	NW	Mun	P	2.2	1.6	1.7
	Red Rock	NW	Mun	P	1.2	1.3	0.7
PENINSULA HARBOUR	Marathon	NW	MOE	EA	5.0	4.4	1.7
PORT HOPE	Port Hope	C	Mun	HR (P)	9.7	9.1	5.2
QUINTE	Belleville	SE	MOE	CAS (P)	38.1	163.0	32.9
	CFB Trenton	SE	DND	CAS (P)	NA	3.5	6.7
	Deseranto	SE	MOE	EA (P)	2.2	1.4	1.6
	Napanee	SE	Mun	CAS (P)	7.5	9.1	7.7
	Picton	SE	Mun	CS (P)	4.5	4.5	3.5
	Trenton	SE	MOE	CAS (P)	15.3	15.9	12.5
SEVERN SOUND	Cold Water	C	MOE	EA	0.8	0.5	0.5
	Midland	C	Mun	CAS (P)	12.0	13.7	11.6
	Penetang Fox St.	C	Mun	CS (P)	2.1	1.5	1.3
	Penetang MHC	C	MOH	CAS (P)	NA	0.6	0.3
	Penetang Main St.	C	Mun	CS (P)	3.0	3.0	2.6
	Port McNicoll	C	MOE	CS (P)	1.9	1.0	0.8
	Victoria Harbour	C	MOE	EA (P) F	2.0	2.4	0.7
SPANISH HARBOUR	Espanola	NE	MOE	P	5.2	3.0	2.7
ST. CLAIR RIVER	Corunna	SW	MOE	EA (P)	5.7	4.5	2.7
	Courtright	SW	MOE	EA (P)	1.5	0.7	0.6
	Point Edward	SW	MOE	P (P)	2.3	2.6	1.7
	Sarnia	SW	Mun	P (P)	64.5	65.9	36.4
ST. LAWRENCE (CORNWALL)	Cornwall	SE	Mun	P	44.9	53.2	43.7
ST. MARYS RIVER	Sault Ste. Marie	NE	MOE	P (P)	80.0	54.6	31.0
	West End (Sault Ste. Marie)	NE	MOE	CAS (P)	80.0	18.2	9.1
THUNDER BAY	Thunder Bay	NW	Mun	P (P)	101.5	109.1	81.1
TORONTO WTFNT.	Highland Creek	C	Mun	CAS (P)	310.0	218.2	187.7
	Humber	C	Mun	CAS (P)	540.0	409.1	419.5
	Main (Toronto)	C	Mun	CAS (P)	1250.0	818.3	787.3
	North Toronto	C	Mun	CAS (P)	85.0	45.5	35.5
WHEATLEY HARBOUR							
TOTALS:			40		3406.7	2867.3	2432.7

TABLE 2.3: RAP Treatment Facilities: Summary By AOC.

AREA OF CONCERN	NO. STPs /LAGOON	POP. SERVED (1000)	DESIGN FLOW (1000 m3/d)	1990 ADF (1000 m3/d)
COLLINGWOOD HARBOUR	1	11.5	24.5	21.8
DETROIT RIVER	4	197.4	209.4	173.1
HAMILTON HARBOUR	3	439.6	520.5	428.0
JACKFISH BAY	1	0.5	0.5	0.3
NIAGARA RIVER	3	83.1	76.9	80.3
NIPIGON	2	3.4	2.9	2.4
PENINSULA HARBOUR	1	5.0	4.4	1.7
PORT HOPE	1	9.7	9.1	5.2
QUINTE	6	67.6	197.4	64.9
SEVERN SOUND	8	23.4	23.5	19.1
SPANISH HARBOUR	1	5.2	3.0	2.7
ST. CLAIR RIVER	6	75.5	75.8	42.0
ST. LAWRENCE (CORNWALL)	1	44.9	53.2	43.7
ST. MARYS RIVER	2	160.0	72.8	40.1
THUNDER BAY	1	101.5	109.1	81.1
TORONTO WTFNT.	4	2185.0	1491.1	1429.9
WHEATLEY HARBOUR	0	NA	NA	NA
TOTAL	**45**	**3413.2**	**2874.1**	**2436.5**

TABLES 2.4: RAP Treatment Facilities: Summary By Type of Treatment Process.

TYPE:	NO. STPs /LAGOON	TOTAL POP. SERVED (1000)	TOTAL DESIGN FLOW (1000 m3/d)	TOTAL 1990 ADF (1000 m3/d)
LAGOON	5	6.5	6.8	3.6
PRIMARY	10	433.2	462.8	342.5
SECONDARY	28	2952.0	2384.0	2074.8
TERTIARY	2	21.5	20.6	15.5
TOTAL	**45**	**3413.2**	**2874.2**	**2436.4**

2.2.1) **Collingwood**:- The RAP has identified that treated effluent from the Collingwood STP accounts for 92% of the total phosphorus input to Collingwood Harbour. A phosphorus loading limit of 2,760 kg/year is required for the Collingwood STP, resulting in an annual effluent TP concentration of 0.31 mg/L at rated design capacity(6). The Collingwood STP will therefore require upgrading to provide enhanced phosphorus removal, possibly requiring the addition of granular media filters.

2.2.2) **Detroit River**:- The Windsor West and Amherstburg facilities currently provide primary treatment. Both facilities require upgrading to secondary treatment.

2.2.3) **Hamilton Harbour**:- Upgrading of the Woodward Ave WPCP, the Burlington Skyway WPCP, and the Dundas WPCP are required to meet nitrogen and phosphorus objectives. As the Dundas WPCP currently provides effluent filtration, minimal upgrading will likely be required at this facility. RAP effluent total phosphorus objectives for the Woodward Ave. and Burlington Skyway facilities are 0.32 mg/L, initially, and 0.13 mg/L, final. These two facilities will require upgrading to provide nitrification and enhanced phosphorus removal using granular media filters.

2.2.4) **Jackfish Bay**:- There are no RAP requirements for upgrading the Terrace Bay STP.

2.2.5) **Niagara River**:- As the Anger Ave. (Ft. Erie) and Stamford (Niagara Falls) STPs currently provide biological secondary treatment, no STP upgrading is required in this RAP.

2.2.6) **Nipigon**:- The Nipigon and Red Rock STPs will require upgrading from primary to secondary treatment.

2.2.7) **Peninsula Harbour**:- There are no capital requirements for upgrading the existing extended aeration plant at Marathon. Increased O&M costs will be required to provide chemical addition to achieve an effluent total phosphorus concentration of 1.0 mg/L.

2.2.8) **Port Hope**:- There are no RAP requirements for upgrading the Port Hope STP.

2.2.9) **Quinte**:- Six of the existing 7 STPs in the Bay of Quinte will require upgrading to provide enhanced phosphorus removal to meet a total phosphorus load of 0.30 mg/L times the approved hydraulic capacity of the facility at the time the RAP comes into effect. Therefore, as actual flows to the facility increase above the approved hydraulic capacity, the corresponding effluent total phosphorus concentration must be decreased to compensate. Effluent filtration may be required to achieve an effluent total phosphorus concentration of 0.30 mg/L or less. Although not a RAP requirement, the trickling filter at Prince Edwards Heights will be phased out and the flow diverted to the Picton STP.

2.2.10) **Severn Sound**:- The STPs at Midland, Port McNicoll, and Victoria Harbour will be required to meet an effluent total phosphorus concentration of 0.30 mg/L. The treatment plant at the Penetang Mental Health Centre (MHC) has an effluent total phosphorus objective of 0.30 mg/L and the Coldwater an effluent requirement which will be in the 0.15 to 0.30 mg/L range. To prevent eutrophication in Penetang Bay, the Penetang Main STP has an effluent total phosphorus concentration requirement of 0.15 mg/L and an objective of 0.10 mg/L. The Penetang Fox St. STP has a total phosphorus effluent requirement of 0.30 mg/L (initially), and 0.15 mg/L (final). Effluent filters will likely be required at STPs with effluent requirements of 0.30 mg/L and certainly be required for requirements less that 0.30 mg/L.

2.2.11) **Spanish Harbour**:- The Espanola primary STP will require upgrading to secondary.

2.2.12) **St. Clair River**:- The Port Edward and Sarnia STPs will require upgrading from primary to secondary. Upgrading of the Port Edward STP is currently underway.

2.2.13) **St. Lawrence River (Cornwall)**:- The primary STP at Cornwall, will require upgrading to secondary. (Although, there are primary STPs at Brockville, Ingelside, Iroquois, Morrisburg, and Prescott, they do not discharge into the AOC).

2.2.14) **St. Marys River**:- The Sault Ste. Marie primary STP will require upgrading to secondary.

2.2.15) **Thunder Bay**:- The Thunder Bay primary STP will require upgrading to secondary.

2.2.16) **Toronto Waterfront**:- A discussion of Remedial Actions prepared by the Toronto Waterfront RAP in 1990 identified planned and potential improvements to be carried out at the 4 Toronto STPs. Planned improvements include construction of new outfalls for the Humber and Main STPs and additional capacity at the Main and Humber STPs. Potential upgrades include abandoning the North Toronto STP and diversion of the flow to the Main STP. Provision of tertiary filters for all Toronto STPs was identified as a potential improvement in the discussion paper.

As eutrophication arising from the discharge of effluent from municipal STPs is not considered to be a problem in the AOC (with the possible exception of the mouth of the Humber River), the provision of effluent filters is not considered to be a RAP requirement for this study. Similarly the additional treatment capacity at the Humber and Main STPs was identified as relating to new development and so was also not considered as a RAP requirement in this study. Upgrading STPs to provide nitrification to produce a nontoxic effluent is considered to be a possibility and was adopted as an upgrading requirement in this report.

2.2.17) **Wheatley Harbour**:- No municipal STPs discharge directly to Wheatley Harbour.

2.2.18) **Summary of STP Upgrading Requirements**:- Table 2.5 summarizes the requirements for STPs in RAP areas according to the upgrading categories (new tertiary STP, upgrading from primary to secondary, implementation of nitrification, and enhanced phosphorus removal). The table was compiled based on the assumption that all primary plants within AOCs require upgrading to secondary and that STPs within the Toronto Waterfront AOC will be required to implement nitrification, but not required to install effluent filtration or expand plant capacity. Thirty-seven facilities of a total of 53 facilities in the Canadian AOCs are estimated to require upgrading to meet RAP requirements. An estimated 95% of the total design capacity of STPs in the AOCs will require upgrading, based on the assumptions adopted.

2.3) *PREVIOUS COST ESTIMATES:*

In April 1990, Apogee Corporation[5] estimated order-of-magnitude costs for restoring the beneficial uses of the 17 Canadian AOCs. The study considered 6 sources of pollution contributing to water quality impairment: STP effluent, urban runoff, agricultural runoff, industrial wastewater discharges, contaminated sediment, and leakage from existing toxic waste sites. The total cost for upgrading STPs to meet RAP requirements was estimated to be approximately $271 million (1989 $). Table 2.6 provides a breakdown of the costs estimates per AOC, along with the a description of the type of upgrading required.

Recently, Hickling Corporation in conjunction with R.V. Anderson Consulting Engineers updated the 1990 Apogee cost estimates as part of a examination of funding mechanisms for implementing RAPs[1]. Total costs for implementing RAPs was estimated by Hickling[1] to be $5.5 billion (1992) for 7 categories of remedial action: STPs, industrial point sources, urban runoff, agricultural nonpoint sources, contaminated sediments, habitat restoration and other remedial actions. The two largest cost categories were for upgrading of municipal STPs at $2.6 billion (or 47% of the total) and control of urban runoff at $2.1 billion (39% of total). Upgrading of STPs in the Toronto Waterfront AOC accounts for 62% of the total upgrading costs for all AOCs; excluding the Toronto Waterfront STPs, STP upgrading costs for the remaining 16 AOCs are $835 million. The 4 largest AOCs (Toronto Waterfront, Hamilton Harbour, Detroit River, and St. Lawrence River) account for 88% of the total costs for upgrading municipal STPs in RAP areas. Costs for upgrading STPs

Table 2.5:- Summary of STP Upgrading Requirements in Canadian AOCs.

Requirement	No. STPs	Pop. Served (1000s)	Design Flow (1000 m3/d)	1990 ADF** (1000 m3/d)
New tertiary STPs	1	1.6	0.8	1.4
Primary to Secondary	10	433.2	462.8	342.5
Nitrification	7	2624.6	2011.6	1857.9
Enhance TP Removal	16	521.0	746.9	517.6
TOTAL*	**31**	**3147.2**	**2695.3**	**2284.4**

Notes:

* Some STPs are included in two categories, so total has been adjusted to reflect this fact.
** Average Daily Flow

List of STPs:

New tertiary STP: Elmvale

Primary to Secondary: Amherstburg, Westerly (Windsor), Nipigon, Red Rock, Espanola, Point Edward, Sarnia, Cornwall, Sault Ste. Marie, Thunder Bay.

Nitrification: *Collingwood*, Dundas, *Skyway (Burlington)*, *Woodward Ave.(Hamilton)*, Highland Creek, Humber, Main (Toronto), North Toronto.

Enhanced TP Removal: *Collingwood*, Belleville, CFB Trenton, Deseranto, Napanee, Picton, Trenton, Midland, Penetang MHC, Port McNicoll, Victoria Harbour, *Skyway (Burlington)*, *Woodward Ave. (Hamilton)*, Coldwater, Penetang Fox St., Penetang Main St.

Table 2.6: **Summary of Estimates by Apogee[5] and Hickling[1] of Total Capital (in million $) for Upgrading Municipal STPs to Meet RAP Requirements per AOC.**

AOC	APOGEE[5]			HICKLING[1]		
	REQUIREMENT	$M 1989	%TOT	REQUIREMENT	$M 1990	%TOT
Collingwood Harbour	Additional TP Removal: Collingwood	$0.04	0.0	Tertiary: Collingwood	$18.41	0.7
Detroit River	Primary to Secondary: Amherstburg, West Windsor	$51.8	19.1	Primary to Secondary: Amherstburg, West Windsor	$170.80	6.5
Hamilton Harbour	Nitrification & Tertiary: Skyway, Woodward Ave.	$59.5	22.0	Nitrification & Tertiary: Skyway, Woodward Ave.	$173.15	6.6
Jackfish Bay	No requirements			No requirements		
Niagara River	Primary to Secondary: Ft. Erie, Stamford	$35.3	13.1	Tertiary: Ft. Erie, Stamford	$20.00	0.8
Nipigon	Primary to Secondary: Red Rock	$1.7	0.6	Primary to Secondary: Red Rock	$1.92	0.1
Peninsula Harbour	Additional TP Removal: Marathon	$0.2	0.1	Tertiary: Marathon	$1.00	0.0
Port Hope	No requirements			No requirements		
Quinte	Tertiary: all STPs	$11.94	4.4	Tertiary: All STPs	$22.20	0.8
Severn Sound	Additonal TP Removal: Elmvale, Coldwater, Midland, Port McNicoll	$0.18	0.1	Tertiary: Port McNicoll, Coldwater, Elmvale, Midland.	$7.50	0.3
Spanish Harbour	Primary to Secondary: Espanola	$4.8	1.8	Primary to Secondary: Espanola	$4.48	0.2
St. Clair River	Primary to Secondary: Port Edward, Sarnia	$28.9	10.7	Primary to Secondary: Port Edward, Sarnia	$70.50	2.7

Table 2.6 (con't)

St. Lawrence River	Primary to Secondary: Cornwall	$22.6	8.4	Primary to Secondary: Brockville, Cornwall, Kingston, Iroquois, Prescott, Osnabruck, Morrisburg	$169.80	6.5
St. Marys River	Primary to Secondary: Sault Ste. Marie	$20.9	7.7	Primary to Secondary: Sault Ste. Marie	$58.90	2.2
Thunder Bay	Primary to Secondary: Thunder Bay	$32.8	2.2	Primary to Secondary: Thunder Bay	$116.70	4.5
Toronto Waterfront	No requirement.			Expanded capacity + tertiary: Main, Humber, Highland Cr., North Toronto	$1,783.00	68.0
Wheatley Harbour	No requirement		0.0	No requirement		
TOTAL:		**$270.6**	100.1		**$2,618.36**	100.0

in the Hamilton and Toronto Waterfront were provided by the RAPs. Costs for upgrading primary plants to secondary were based on estimates by MOE's Municipal Section.

Estimated costs for upgrading STPs to meet RAP requirements increased tenfold from the Apogee[5] to Hickling[1] reports. The major increases from the Apogee to Hickling estimates are as follows:

- Toronto Waterfront AOC by $1,783. million (from $0. to $1,783. million),
- Hamilton Harbour AOC by $151. million (from $59.5 to $173. million),
- St. Lawrence River AOC by $147. million (from $23. to $170. million),
- Detroit River by AOC $119. million (from $52. to $171 million),
- Thunder Bay by AOC $84. million (from $33. to $117. million),

The only major decrease from the Apogee to the Hickling estimates was for the Niagara River AOC which declined by an estimated $15. million (from $35. to $20. million). In the 1990 report, Niagara Falls and Fort Erie were identified as being primary plants, whereas by 1992 they had been converted to secondary facilities and the upgrading costs were estimated based on provision of effluent filters.

2.4) *REVIEW COMMENTS:*

The following comments relate to the Hickling[1] cost estimates presented in Table 2.6:

2.4.1) **Collingwood Harbour**:- The Collingwood Harbour RAP Team[7] estimated costs for various options to meet the RAP goals to range from $1.1 million to $65 million. The low cost was based on automation of portions of the existing STP. The high costs was based on decommissioning the existing facility and constructing a new facility at a new location with tertiary treatment and a new outfall. Costs to upgrade the existing facility to provide nitrification and phosphorus removal were estimated at $15.2 million. The Hickling estimate of $18.2 million therefore seems to be within reason.

2.4.2) **Detroit River**:- Hickling estimated costs at $170.8 million. MOE estimates that costs to upgrade Windsor West and Amherstburg from primary to secondary to be approximately $154 million. These costs appear to be in-line.

2.4.3) **Hamilton Harbour**:- Hickling estimated costs at $173.3 million to provide nitrification and install tertiary filters. Provision of effluent filtration at the Skyway (Burlington) STP was estimated at $13.9 million[8]. Applying these costs per unit of flow to the Woodward Ave. STP, filtration costs would amount to about $65 million. Providing nitrification at Woodward Ave., Skyway, and Dundas was estimated to cost $110.5 million, $25.2 million, and

$4.9 million respectively[9]. Hence, the total costs are approximately $219.5 million for the Hamilton Harbour RAP STPs.

2.4.4) **Jackfish Bay**:- Hickling did not suggest that any costs will be incurred for STP upgrading in this RAP area. Since the Terrace Bay STP is an exfiltration lagoon, this is a reasonable assumption.

2.4.5) **Niagara River**:- Hickling estimated that $20.0 million will be required to provide the Stamford (Niagara Falls) and Anger Ave. (Ft. Erie) STPs with granular media filtration. No upgrading requirements were assumed for the Niagara River for this study, hence no costs are anticipated.

2.4.6) **Nipigon**:- Hickling estimated that $1.9 million in upgrading costs would be incurred to upgrade the primary plant at Red Rock to secondary treatment. MOE estimates the cost of upgrading the Red Rock STP would be $2 million, in agreement with Hickling's estimate. In addition, an additional $3 million would be required to upgrade the Nipigon STP to secondary treatment. Although the Nipigon STP does not discharge directly into Nipigon Bay, it discharges into the Nipigon River in close proximity to Nipigon Bay. Therefore, the costs of upgrading the Nipigon STP have been included in the total upgrading costs for Nipigon Bay RAP STPs.

2.4.7) **Peninsula Harbour**:- Hickling estimates that $1 million would be incurred by providing granular filters for the extended aeration plant at Marathon. As the RAP Coordinator indicated that eutrophication is not a major concern, this upgrading is judged not to be warranted at this time.

2.4.8) **Port Hope**:- Hickling did not suggest that any STP upgrading costs would be incurred nor are any expected.

2.4.9) **Quinte**:- Hickling estimated costs of $22.2 million for the 7 STPs in the RAP area (including, the Prince Edward Heights STP). The RAP Coordinator has advised that the Prince Edward Heights STP will be phased out. In 1987, the total cost to upgrade these facilities to achieve an effluent total phosphorus concentration of 0.30 mg/L by effluent filtration was estimated to be $9.8 million[10]. Using the Engineering News Record (ENR) construction cost index, these costs were prorated to $11.0 million ($1990) for comparison with the Hickling estimate. Therefore, Hickling's estimate may be high by about 100 percent.

2.4.10) **Severn Sound**:- Hickling estimates that $7.5 million in capital expenditure would be incurred in the 8 STPs in the AOC. XCG Consultants[11] estimated, based on anticipated limits on TP to be imposed at these facilities, that costs of $11.8 million would be incurred.

2.4.11) **Spanish Harbour**:- Hickling estimated costs of $4.5 million to upgrade the Espanola STP to provide secondary treatment including nitrification and dechlorination. MOE estimated costs of $4 million for these capital works, excluding nitrification and dechlorination.

2.4.12) **St. Clair River**:- Hickling estimated costs of $70.5 million for this RAP area for upgrading the primary plants at Sarnia and Point Edward to provide secondary treatment, including nitrification and dechlorination. MOE estimated costs of $58 million and $3 million, respectively, for these plants, exclusive of nitrification and dechlorination. Upgrading of the Point Edward STP to secondary is currently underway. Engineering estimates for the cost of this upgrading are $6.3 million. Hence, estimated costs for both facilities are between $61 and $64 million.

2.4.13) **St. Lawrence River**:- Based on estimates provided by MOE, Hickling has estimated the total costs for upgrading 7 STPs in the St. Lawrence River to secondary (including nitrification and dechlorination) to be $169.8 million. According to the RAP Coordinator, only the Cornwall STP falls within the AOC. MOE estimated upgrading costs for the Cornwall STP to be $48. million to provide secondary treatment, without nitrification or dechlorination.

2.4.14) **St. Marys River**:- Hickling used MOE estimates of $58.8 million for upgrading the primary plant at Sault St. Marie to secondary, including nitrification and dechlorination. MOE estimates, excluding nitrification and dechlorination, are $48. million.

2.4.15) **Thunder Bay**:- Hickling used MOE estimates of $116.7 million for upgrading the primary plant at Thunder Bay to secondary, including nitrification and dechlorination. The engineering cost estimate to provide secondary treatment is $90. million.

2.4.16) **Toronto Waterfront**:- Based on RAP documents, the total cost of upgrading the four Metro Toronto STPs would be $1,783. million, representing 68% of the total costs of upgrading STPs in all AOCs. As discussed in section 2.1.16, for this study, it was assumed that provision of additional treatment plant capacity at Highland Creek and Main STPs and the provision of tertiary filters are not RAP requirements; the provision of nitrification at all 4 Toronto STPs was assumed to be a RAP requirement. Upgrading costs to provide nitrification are estimated to be $58.9 million for Highland Creek, $110.6 million for Humber, $220.9 million for Main, and $12.3 million for North Toronto (assuming that the plant remains).

2.4.17) **Wheatley Harbour**:- No costs were estimated by Hickling and none are anticipated.

2.4.18) **Summary**:- Table 2.7 summarizes the cost estimates on an individual AOC basis from the Hickling report[1] and compares them to order of

Table 2.7: **Summary of Current Estimates of Upgrading Capital Costs for STPs in ACOs**

AOC	HICKLING[1]		OTHER SOURCES	
	$M 1990	%TOT	$M 1990	%TOT
Collingwood Harbour	18.41	0.7	15.2	1.4
Detroit River	170.80	6.5	154.0	14.3
Hamilton Harbour	173.15	6.6	219.5	20.5
Jackfish Bay				
Niagara River	20.00	0.8		
Nipigon	1.92	0.1	5.0	0.5
Peninsula Harbour	1.00	0.0		
Port Hope				
Quinte	22.20	0.8	11.0	1.0
Severn Sound	7.50	0.3	11.8	1.1
Spanish Harbour	4.48	0.2	4.0	0.4
St. Clair River	70.50	2.7	64.0	6.0
St. Lawrence River	169.80	6.5	48.0	4.5
St. Marys River	58.90	2.2	48.0	4.5
Thunder Bay	116.70	4.5	90.0	8.4
Toronto Waterfront	1783.00	68.0	402.7	37.5
Wheatley Harbour				
Subtotal (Excluding Toronto Waterfront):	**$835.4**		**$670.5**	
TOTAL:	**$2,618.36**	100.0	**$1,073.2**	100.1

magnitude costs outlined above from other sources of information. Based on this comparison, estimated costs for upgrading STPs in AOCs in this report are approximately 41% of those estimated in the Hickling report. The Hickling costs represent a "worst case" (ie. most expensive) scenario. Quite clearly a major source of uncertainty in these costs is the lack of clearly defined upgrading requirements for STPs in the Toronto Waterfront AOC. Excluding the Toronto Waterfront STPs, total upgrading costs estimated by Hickling would be $835. million; for this report the corresponding estimate is $670.5 million.

3.0 DESCRIPTION OF CONVENTIONAL AND INNOVATIVE APPROACHES

3.1) *UPGRADING PRIMARY TO SECONDARY*

As identified in Section 2.1, 10 STPs in 7 AOCs (Detroit River, Nipigon, Spanish Harbour, St. Clair River, St. Lawrence, St. Marys, and Thunder Bay) require upgrading to secondary treatment. Section 3.1 describes conventional and innovative approaches to upgrading primary plants to secondary.

3.1.1) **Conventional approach**:- Most frequently, primary STPs are upgraded to secondary by designing a conventional activated sludge or extended aeration facility. To generate a process design, information concerning influent flowrates, concentrations (BOD5, NH3, TKN) and projections of serviced population are combined with MOE guidelines[12] for organic and hydraulic loading rates. Table 3.1 summarizes the most important organic and hydraulic loading rates from these guidelines.

3.1.2) **Innovative approach**:- A large number of biological wastewater treatment processes can serve as alternatives to the conventional or extended aeration processes. Table 3.2 lists some of the processes in three categories: suspended growth, fixed film, and hybrid processes (a combination of suspended growth and fixed film). Based on knowledge of wastewater characteristics (flowrates and concentrations), site constraints, and the advantages and disadvantages of the biological treatment processes, the alternatives are screened to select the most promising ones. Pilot-scale testing of the processes is then conducted to identify the process with the least cost and the best effluent quality.

A study conducted of the West Windsor STP for the City of Windsor provides a recent example of an innovative approach to upgrading a primary STP to secondary[13]. The existing West Windsor STP provides primary treatment and has a design capacity of 350,000 m^3/d (or 77 MIGD). A study was conducted to investigate 4 biological wastewater treatment processes, considered to be feasible alternatives to the conventional activated sludge process. The 4 processes included Trickling Filter/Solids Contactor (TF/SC), Rotating Biological Contactor (RBC), Biological Aerated Filter, and a modified Activated Sludge Process (ASP). The modified ASP employed hydraulic retention times in the aeration basin which were below the recommended MOE guidelines[12]. Evaluations were conducted of the 4 technologies operated at pilot-scale and the results compared in terms of hydraulic performance, solids handling, operation, and capital and O&M costs. Based on the evaluation, the RBC received the highest score followed in order by the ASP, the BAF, and the TF/SC. The RBC demonstrated ease of operation and consistent performance in achieving all effluent objectives. Work is continuing to further evaluate the performance of the BAF and TF/SC processes and to establish capital and O&M costs prior to final selection.

Table 3.1: Summary of "Conventional" Design Standards[12].

AERATION SYSTEM			FINAL CLARIFIERS		
Design Parameter	**CAS**	**EA**	**Design Parameter**	**CAS[5]**	**EA[9]**
Organic Loading (kg BOD5/m^3.d)	0.31-0.72 [0.31-0.72]	0.17-0.24 [0.17-0.24]	Depth (m)	3.6-4.6 [3.6-4.6]	3.6-4.6
F/Mv (d^{-1})	0.2-0.5 [0.05-0.25]	0.05-0.15 [0.05-0.25]	SOR[6] (L/m^2.s)	0.41 [0.34]	0.41
Min. HRT (h at Qavg.)	6 [6]	15 [15]	Weir Loading (L/m.s)	2.9 [2.9]	2.9
RAS (% Qavg)	25-100 [25-100]	50-200 [50-200]	SLR (kg/m^2.d)	$\leq$ 240[7] $\leq$ 120[8]	$\leq$ 120[8]
O_2 Demand (kg O_2/kg)	1.0[1] [1.0+4.6[2]]	1.5[1] [1.5+4.6[2]]			
SRT (d)	4-9 [>4[3]->10[4]]	>15 >15			
D.O Min. (mg/L	2.0 [2.0]	2.0 [2.0]			
Min. Res. Alkalinity (mg/L as $CaCO_3$)	-- [50]	-- [50]			

NOTES:

CAS: Conventional Activated Sludge
EA: Extended Aeration
[]: With Nitrification

1: kg O_2/kg BOD_5
2: kg O_2/kg BOD_5 + kg O_2/kg TKN
3: at 20° C
4: at 5° C
5: with chemical addition to mixed liquor for P removal
6: at peak overflow rate
7: including 50% return sludge
8: including 100% return sludge
9: with or without P removal.

Table 3.2:- Overview of Biological Secondary Wastewater Treatment Processes[11,13,15,20].

TYPE:	PROCESS:
SUSPENDED GROWTH	Activated Sludge: - Conventional, - Tapered Aeration, - Complete Mix, - Step Aeration - Extended Aeration, - Oxidation Ditch, - Contact Stabilization, - High-Rate Aeration, - Pure Oxygen, - Kraus Process, - Sutton Process.
	Biological Nutrient Removal: - Phostrip, - Phoredox (A/O) Process, - Bardenpho Process, - Modified Bardenpho Process, - UCT (VIP) Process.
	Sequencing Batch Reactor
FIXED FILM:	Rotating Biological Contactor
	Fluidized Bed
	Trickling Filters
HYBRID SYSTEMS:	Biological Aerated Filters
	Activated Sludge with Biomass Support: - CAPTOR, - LINPOR.
	Trickling Filter/Solids Contactor
	Activated Biofilter
	New Hamburg Process

3.2) *EXPANDING SECONDARY STPS*

Although no STPs were identified as requiring expansion to achieve RAP requirements, a description of conventional approaches is presented herein for completeness.

3.2.1) **Conventional approach**:- Historically, secondary STPs are expanded when the performance of the STP has deteriorated or when the plant approaches its nominal organic or hydraulic design capacity. Plant loading is determined from the plant's historic records for influent flowrate and concentrations of BOD5 and NH3. In Ontario, MOE guidelines(12) are most frequently used to define acceptable organic or hydraulic design capacity.

There are two fundamental problems with a conventional approach based on construction of tankage. Firstly, as identified in a recent survey of municipal STPs in Ontario, the performance of STPs is most often limited by factors which are not design related. Examples include a general lack of understanding of the fundamentals of sewage treatment processes on the part of operators, inadequate plant staffing, inability to measure return and waste sludge flows, and lack of support from administrators responsible for the facility(14). Expanding a plant may temporarily improve performance by providing a larger factor of safety but will not address the root cause which will resurface as plant loading increases. Secondly, expanding the plant based on nominal organic and hydraulic design capacity may be unnecessary when the STP can demonstrate satisfactory performance above the recommended capacities.

3.2.2) **Innovative approach**:- The wastewater treatment plant audit, developed by the Wastewater Technology Centre, employs on-line monitoring equipment to accurately evaluate the ultimate capacity of a treatment plant and to identify any process bottlenecks which reduce plant capacity. Components of the process audit include field measurements of the oxygen transfer capacities of existing equipment, characterization of raw wastewater flows and concentrations and hydraulic stress testing of the final settlers. Based on the findings from the audit, the process is optimized through low-cost modifications, the use of on-line monitoring and control, and through the elimination of process bottlenecks.

Based on a review of process audit reports and the U.S. EPA's Handbook: Retrofitting POTWs(15), a summary of procedures for modifying STPs and eliminating process bottlenecks is summarized as follows :

STP Hydraulics:

• improve control of raw sewage lift stations through the use of mechanical speed drives or adjustable frequency drives to eliminate hydraulic disturbances from on/off control,

• install a flocculating centre-well to dissipate inlet energies and enhance flocculation within the final settler,

Operations:

• provide automatic control of solids retention time (SRT) to promote optimum growth conditions and to avoid unnecessary storage of biosolids in treatment plant and hence reduce the potential for solids loss during periods of high hydraulic loading,

• manipulate dissolved oxygen concentration, SRT, and other process conditions to discourage the growth of filamentous organisms responsible for settleability, scum, and foam problems,

• add chlorine or hydrogen peroxide to selectively eliminate filamentous bulking and solids loss from final clarifiers due to thickening failure,

• develop O&M manuals to provide information on operation and maintenance which is specific to the plant,

• recycle anaerobic digester supernatant and other high-strength decants to STP during periods of low organic loading,

• upgrade scum removal and handling systems to avoid reintroduction of scum to treatment plant and thus prevent the reintroduction of *Nocardia* and other filamentous organisms into the process,

• provide better measurement and control of return sludge flowrates by utilizing pumps with adjustable speed drives or multiple pumps of variable capacities(15).

3.3) *UPGRADING SECONDARY STPs*

3.3.1) **Nitrification**:-As outlined in Section 2.1, the Hamilton Harbour RAPs will require STPs in these AOCs to provide a nitrified effluent. In addition, nitrification may also be required for the 4 STPs in the Metro Toronto RAP.

Nitrification is the biological conversion of ammonia to nitrate nitrogen. For existing STPs which do not nitrify, the quantity of oxygen transferred to the mixed liquor will have to be increased. As documented by the results in Table 3.3, nitrification will increase oxygen demands by approximately 100% on average. Nitrification will also require that plants operate at higher sludge ages or SRTs, particularly when temperatures are low (Table 3.4). Higher SRTs increase MLSS concentrations and, consequently, the solids loadings to final clarifiers. A nitrifying sludge will tend to denitrify in final clarifiers producing floating solids as nitrogen gas is entrapped in the solids in final clarifiers. The concentration of effluent

• implement flow equalization using existing or new tanks to reduce hydraulic variations and equalize the concentration of organic and toxic compounds,

• implement collection system rehabilitation programs to reduce infiltration and inflow to the sewer system,

• implement water reduction programs to reduce the total volume of wastewater discharged to the STP.

Aeration Basins:

• provide automatic control of dissolved oxygen (DO) in the aeration basins to maintain optimum conditions and achieve energy savings,

• refurbish existing mechanical aerators, replace mechanical aerators by a diffused air system, or retrofit to fine pore diffusers to enhance oxygen transfer efficiencies,

• retrofit and/or implement stepfeed operation to reduce solids loading to final settlers during periods of variable hydraulic and organic loading,

• install selector zones to reduce the potential for low F/M filamentous bulking and solids loss from final settlers due to thickening failure,

• for STPs which are required to provide nitrification, retrofit to a two-stage biological nitrogen removal (BNR) system by providing a pre-anoxic zone in the aeration tank and recycling mixed liquor from the aerobic to anoxic zones to reduce oxygen requirements and reduce the solids carry-over resulting from floating sludge in the final settlers[16],

• retrofit biomass support media into existing activated sludge aeration basins to increase biomass inventory in available tankage allowing operation at lower F/M (higher SRT) to increase biological treatment capacity and promote nitrification[15,17].

Final Clarifiers:

• modify inlets and/or install in-tank baffles to eliminate excessive currents,

• relocate weirs or block portions of effluent weirs to reduce solids carry-over resulting from scour of sludge blanket,

• improve flow splits to final clarifiers to eliminate preferential feeding of settlers,

• add synthetic polymers to enhance settling characteristics,

Table 3.3: Estimated Increased Oxygen Requirements at Selected Ontario STPs[14].

STP:	O2 DEMAND N/CARBON
Chatham	160%
Courtright	155%
St. Jacobs	25%
Dresden	18%
Long Sault	167%
L'Original	67%
Baker Rd.	150%
Cobourg	28%
Average:	**96%**

Table 3.4: Variation of Solids Retention Time (SRT) Requirements With Temperature as Determined by the Chicago Municipal Sanitary District[16].

Chicago MSD (EFF NH3 < 1.0 mg/L)	
Temperature	SRT req'd
16-23 °C	5 d
11-13 °C	11 d
9 °C	19 d

suspended therefore will also likely increase, even for final clarifiers which are not overloaded. Finally, SRTs can result in the growth of *Nocardia* which creates foaming problems.

A description of conventional and innovative approaches for achieving nitrification is presented in the following sections.

3.3.1.1) Conventional Approach:- A conventional approach to providing nitrification at existing secondary treatment facilities usually involves the use of existing wastewater characterization data (flowrates and BOD5 and NH3 concentrations) at the plant, manufacturers' or textbook estimates of oxygen transfer efficiency, and MOE guidelines for design of aeration tanks and final settlers. Actual and future system loadings are compared to MOE design guidelines (Table 3.1). Additional aeration tanks and/or final settlers are constructed to bring the plant loadings into recommended ranges.

3.3.1.2) Innovative Approach:- Process audits conducted at the Skyway (Burlington) and Collingwood STPs examined the ability of these plants to meet future nitrification requirements[6,8]. As part of the process audit, actual oxygen transfer capacities of existing aeration equipment are measured, influent wastewater is sampled and analyzed, and stress testing of the final settlers is carried out. Based on the test results, the performance of the existing equipment is upgraded using approaches previously discussed in Section 3.2.2 before additional aeration tanks or final settlers are constructed.

At STPs with plug-flow aeration basins, baffles can be added to separate the basins into anoxic and aerobic zones. Recycling from the outlet of the aerobic zone to the inlet of aerobic zone will then convert the process to a BNR process provided that the carbonaceous concentration in the primary sewage is sufficient to utilize the nitrate recycle from the aeration. There are a number of potential advantages in converting a nitrifying plant to a BNR process. Carbonaceous BOD will be utilized in the anoxic zone to convert nitrate to nitrogen gas, thereby reducing oxygen requirements in the aerobic zone. Because sludge is denitrified, the generation of floating sludge in the final clarifiers will be reduced.

Randall et al.[12] provide several examples of how existing plants have been retrofitted to the BNR process. One example was the City of Phoenix's 23rd Ave STP. This facility was retrofitted in 1990 by adding 3 baffles in the first pass and one baffle to the second of the four-pass aeration system (see Fig. 3.1). To mix the resulting anoxic zone, fine bubble diffusers were replaced by coarse bubble diffusers which were operated at low aeration rates. Mixed liquor was recycled at a rate of 1.6 to 2.4 times the influent flow rate from the outlet of the fourth pass to the inlet of the anoxic zone (Fig. 3.1). As result of the modifications, the sludge settling volume, a measure of sludge settleability, decreased from 310 mL/g to 70 mL/g[12]. Consequently, solids loading from the final settlers increased from 0.8 $kg/m^2.h$ to 4.1 $kg/m^2.h$[12].

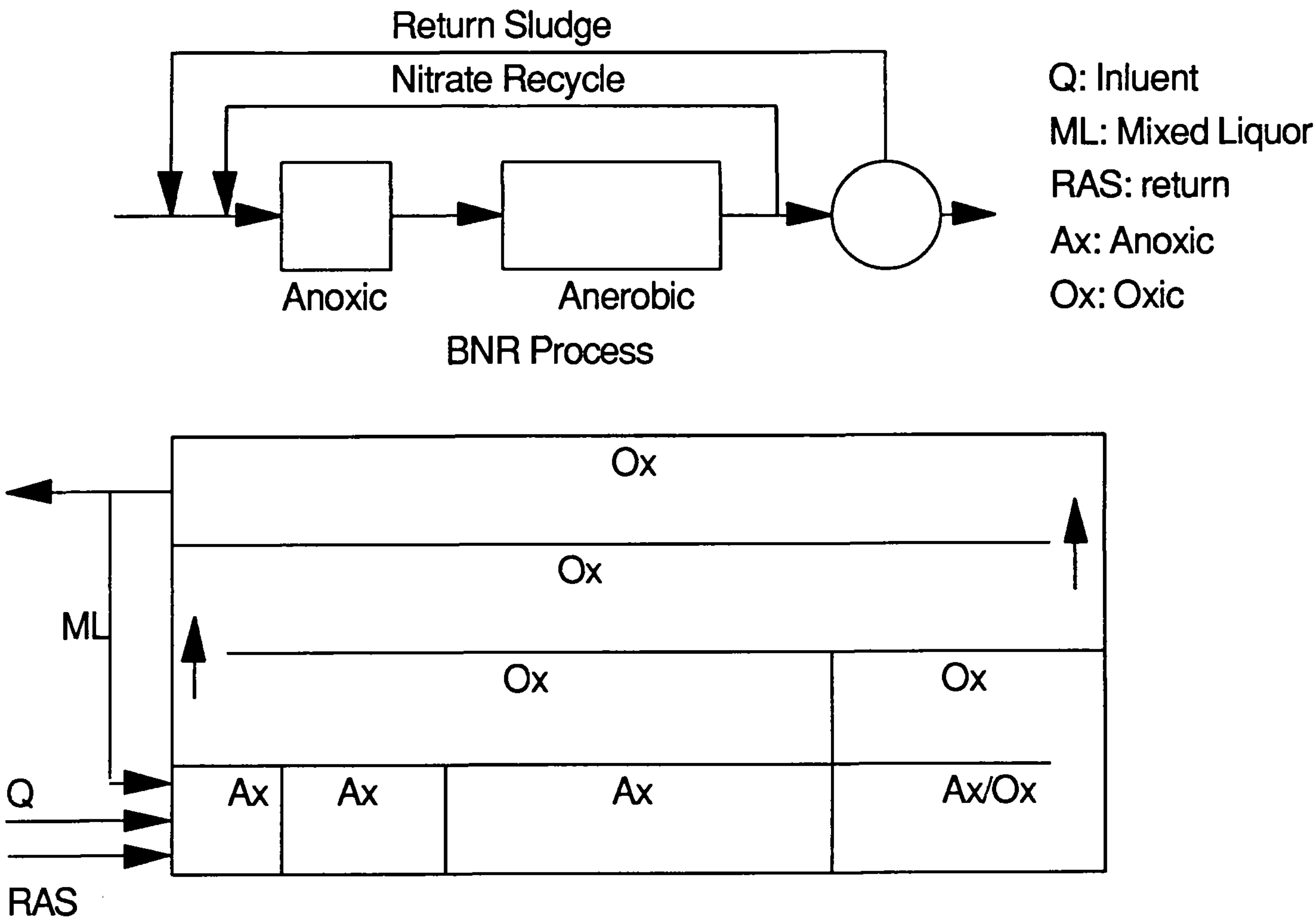

Fig. 3.1: Aeration Basin Retrofitted to BNR Process.

3.3.2) **Enhanced TP Removal**:-As outlined in Section 2.1, Collingwood, Hamilton Harbour, Quinte, and Severn Sound RAPs have established that more stringent limits on total phosphorus from municipal sewage treatment plants are required to prevent eutrophication. Effluent objectives range from 0.32 mg/L (initial) for Hamilton's Woodward Ave. STP and Burlington's Skyway STP to 0.10 mg/L for the Main St. STP in the Town of Penetanguishene.

3.3.2.1) Conventional Approach:- As part of the Severn Sound RAP, available performance data from full-scale treatment plants practising phosphorus data was reviewed to determine the costs and ability of existing technologies to achieve the proposed effluent objectives(11). Table 3.5 lists the conventional approaches to achieving different ranges of effluent phosphorus concentrations based on data reported in the literature. These results indicate that simultaneous precipitation and filtration are generally required to ensure effluent concentrations of 0.50 mg/L or less. Conventional filter designs frequently employ shallow beds of fine media and low filtration rates requiring large surface areas(18). Conventional shallow-bed filters are sensitive to changes in hydraulic and solids loading(18). For TP limits of less than 0.10 mg/L, the XCG review indicated that demonstrated technology consisted of both post-precipitation and filtration. Facilities employing this technology are located at Brighton, Michigan and Summit County, Oregon.

3.3.2.2) Innovative Approach:- Beginning in February 1990, work was undertaken at the Burlington Skyway STP to optimize the existing chemical addition system(19). The Burlington Skyway STP adds ferric chloride at the effluent end of the aeration basin to remove phosphorus. By optimizing the existing chemical addition system, the study demonstrated a 30% reduction in chemical dosage and achieve total effluent phosphorus concentrations less than 0.30 mg/L over a limited time period.

In 1991, a computerized process audit was conducted at the Collingwood STP to determine upgrading requirements at the Collingwood Harbour to meet RAP and proposed MISA requirements(6). To achieve an effluent quality of 0.31 mg/L, it was proposed that studies be conducted to optimize the chemical addition systems through the use of dual point chemical addition (Fig. 3.2) and automatic on-line control of chemical addition. The on-line control scheme would involve installation of a sensor to monitor effluent phosphorus concentrations and a computer to control the alum addition pump to match influent flow or load variations. Work carried out at the Skyway (Burlington) STP for the WTC has indicated that commercially available analyzers can reliably measure phosphorus on a continuous basis(20).

Therefore, an innovative approach consists of optimizing phosphorus removal to achieve effluent concentrations of 0.30 mg/L without resorting to tertiary treatment by employing the following elements:

- optimization of single- and dual-point chemical addition,

Table 3.5: Summary of Findings from "A Review of Approaches to Achieve Low Effluent Phosphorus Concentrations"[11].

OPERATING MODE	ATTAINABLE RANGE OF TOTAL PHOSPHORUS CONCENTRATIONS (mg/L)
Simultaneous Precipitation (Fig. 3.2.1)	0.50-1.00
Pre-Precipitation & Simultaneous Precipitation (Fig. 3.2.3)	0.30-0.50
Simultaneous Precipitation & Filtration (Fig. 3.2.4)	0.15-0.50
Simultaneous Precipitation & Post-Precipitation (Fig. 3.2.5) (Clarification or Filtration)	0.10-0.20
Simultaneous Precipitation & Post-Precipitation Clarification & Filtration (Fig. 3.2.6)	0.10-0.15

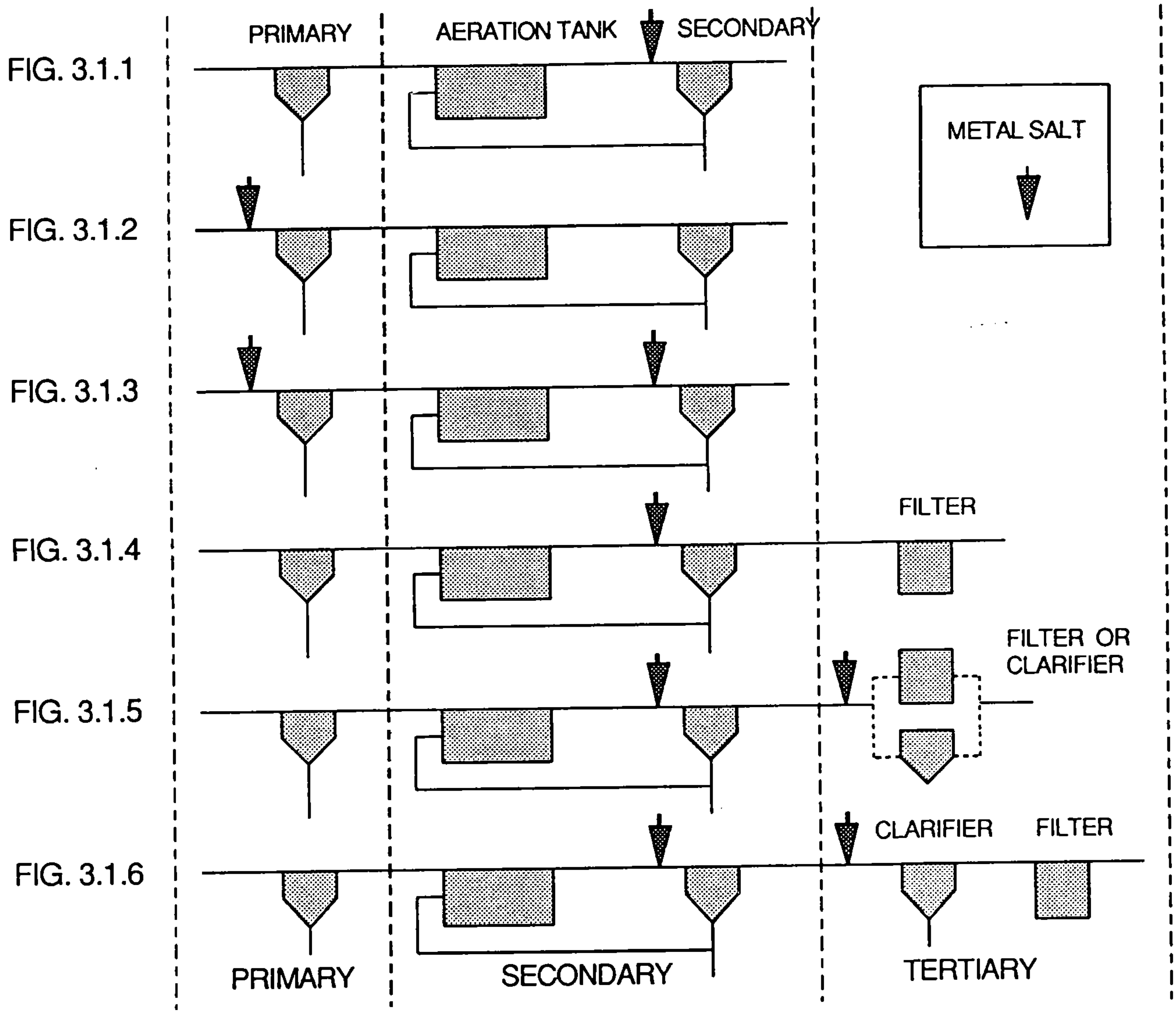

Fig. 3.2: Alternative Chemical Phosphorus Removal Options

Fig. 3.2.1: Simultaneous Precipitation
Fig. 3.2.2: Pre-Precipitation
Fig. 3.2.3: Pre- and Simultaneous Precipitation
Fig. 3.2.4: Simultaneous Precipitation & Filtration
Fig. 3.2.5: Simultaneous Precipitation, Post-Precipitation & Filtrat
Fig. 3.2.6: Simultaneous Precipitation, Post-Precipitation,
Clarification & Filtration.

- on-line monitoring of effluent phosphorus and automatic pacing of chemical addition, and

- the addition of organic polymers or activated silica to improve flocculation and clarification.

To achieve effluent limits of 0.10 mg/L or less, limited testing at the Stratford STP in early 1980's indicated that chemical addition upstream of tertiary filters in conjunction with simultaneous filtration could achieve these effluent TP concentration requirements. Increasing backwash frequent was identified as a drawback of this approach. For new facilities, high-rate in-depth filters provide an innovative alternative to conventional shallow-bed filters. High-rate filters require less surface area and are less expensive than more conventional designs(17).

4.0 EXAMPLES OF INNOVATIVE APPROACHES TO MUNICIPAL STP EXPANSION AND UPGRADING - SELECTED CASE STUDIES

4.1) *GENERAL*

The majority of expansions and upgradings of Ontario STPs which have occurred in the past have followed the "conventional" approach described in Section 2.0; however, in the last few years, some municipalities have begun to apply more innovative methods. These innovative approaches have allowed the design requirements for the expanded and/or upgraded plant to be more precisely defined based on the results of treatability studies or the actual capacity of the existing facility to be determined based on process audits or similar detailed facility assessments. In many cases, these innovative approaches have resulted in significant capital savings since smaller facilities have been designed than would have been designed if the conventional approaches had been used. In some cases, the benefits resulting from the application of innovative approaches have not been solely economical. The results of process studies undertaken prior to design and construction have also been used to ensure that the full-scale facility will perform to expectations and to provide the basis for setting "reasonable" effluent limits.

In the following subsections, several case histories are presented in which innovative approaches to plant upgrading and/or expansion have been applied. The case histories are classified into three sub-categories as follows:

- Upgrading of Primary STPs to Secondary Treatment
- Expanding Secondary STPs
- Upgrading of Secondary STPs to Meet More Stringent Effluent Quality Requirements

In each case history, the background of the project is discussed, the approach to the undertaking is described and the outcome is presented. Where possible, the "cost savings" of having taken the innovative approach are estimated. In most cases, the "savings" are based on a comparison of the costs incurred or expected as a result of the process studies conducted compared to the cost which would likely have been incurred if the conventional design approach had been applied. These costs should be considered to represent "order-of-magnitude" estimates based on the level of detail available for the case history plants. As noted above, benefits other than cost savings are often realized when process studies are undertaken. Where applicable, these other benefits of the innovative approaches such as improved performance, enhanced operability or reduced effluent quality variability are also identified.

The costs of conducting treatability studies, process audits or similar detailed facility assessments can range from less than $100,000. to as much as $500,000. depending on the scope of the study and the size of the plant. The largest absolute savings generally are realized at larger plants where major expansion and/or upgrading is proposed, although there is no guarantee that savings will be realized in all facilities where such studies are conducted. The costs of the process studies need to be considered in the cost-benefit analysis before a decision is made to undertake such studies at any specific facility.

4.2) *UPGRADING OF PRIMARY STPS TO SECONDARY TREATMENT*

4.2.1) **The Fort Erie Anger Avenue STP**

4.2.1.1) Background:- Up to 1985, the Regional Municipality of Niagara's Anger Avenue STP provided primary treatment for the mixed domestic and industrial wastewaters produced by the Town of Fort Erie. The plant had a design capacity of 16,360 m^3/d at average flow and a peak day capacity of 40,450 m^3/d. The facility provided preliminary treatment (screening and grit removal), primary clarification and disinfection by chlorination. Sludges underwent two-stage anaerobic digestion prior to disposal in lagoons at the local landfill site.

Flows to the facility were approaching the rated plant capacity. In addition, concerns regarding water quality in the Niagara River suggested a need to improve the effluent quality from the Anger Ave. STP. Therefore, in 1985, the Region embarked on a program to upgrade the existing facility to provide secondary treatment and to expand the plant to handle average daily flows of 24,500 m^3/d and peak flows of up to 49,100 m^3/d (peaking factor = 2.0). Since the raw sewage received at the Anger Avenue STP was low strength (BOD_5 < 150 mg/L; TSS < 100 mg/L) and the facility was subjected to a high level of extraneous flow under wet weather conditions, the Region had concerns regarding the applicability of MOE Design Guidelines[12] for the plant design. Rather than proceeding with design and construction of a conventional activated sludge facility to meet the future flow and effluent quality requirements, treatability studies were conducted at the plant to select the preferred alternative for the site. These treatability studies were also used to establish the key process design criteria for the selected plant expansion and upgrading alternative to support subsequent detailed design.

4.2.1.2) Process Studies Conducted[22]:- Based on a review of alternate technologies appropriate for the upgrading of the Anger Ave STP, three processes were selected for on-site evaluation at either bench or pilot-scale. The processes evaluated were:

(i) "pseudo" extended aeration (i.e. no primary clarification included in the process flowsheet), which was tested at bench-scale;

(ii) conventional activated sludge, which was tested at bench-scale; and,

(iii) rotating biological contactor (RBC), which was tested at pilot scale.

Other alternatives such as oxygen activated sludge and biological phosphorus removal systems were eliminated from consideration due to the characteristics of the wastewater, the expected high capital cost or the unproven state of the technology.

Treatability systems were operated on-site at the Anger Ave. STP for about four months to establish the optimum operating conditions and to compare the performance of the individual processes. The conventional activated sludge and "pseudo" extended aeration systems were operated at hydraulic retention times (HRTs) ranging from four to six hours and solids retention times (SRTs) ranging from three to seven days. The experimental design for the RBC evaluation was based on total BOD_5 surface loading rate which was varied from about 7.5 to 20 g BOD_5/m^2.d.

4.2.1.3) Outcome of Process Studies:- The process studies established that any of the three systems evaluated was capable of achieving the design limits of 15 mg/L BOD_5 and 15 mg/L TSS. The suspended growth systems (conventional activated sludge and "pseudo" extended aeration) produced a higher quality effluent in terms of BOD_5 and TSS at the recommended design loadings than the RBC.

Effective treatment could be accomplished by the suspended growth processes at HRTs and SRTs less than suggested by MOE Design Guidelines(12). The conventional activated sludge system would require an HRT of five hours and SRT of four days, compared to MOE guidelines of a minimum HRT of six hours and an SRT of four to six days. The "pseudo" extended aeration system would require an HRT of five hours and an SRT of three days. Suggested organic loading for the two processes were about 0.7 g BOD_5/ g VSS.d compared to MOE guidelines of between 0.2 and 0.5 g BOD_5/ g VSS.d. Even at these low HRTs and SRTs, considerable nitrification was noted in both bench scale systems at the temperatures experienced during the treatability studies (13 to 19° C).

The "pseudo" extended aeration process option was recommended for implementation over the conventional activated sludge process option on the basis of cost and performance. This option allowed the existing primary clarifiers to be used for stormwater treatment under peak flow conditions. The ultimate design provided for full secondary treatment in either the conventional activated sludge or pseudo-extended aeration mode at dry weather flows up to the design capacity of 24,500 m^3/d and peak flows up to 49,000 m^3/d. Storm flows in excess of 49,000 m^3/d and up to 98,000 m^3/d undergo physical chemical treatment in the existing primary clarifiers. Under these peak storm flow conditions, the secondary portion of the plant operates in the pseudo-extended aeration mode[23]. By this design approach, a peaking factor of 4.0 could be accommodated in the Anger Ave. STP without jeopardizing the integrity of the biological processes. The facility was commissioned in May of 1990.

4.2.1.4) Benefits of Innovative Approach:- The final design of the major liquid treatment process units installed at the Anger Ave STP are compared in Table 4.1 to the criteria which would likely have been applied if a more conventional design approach had been taken. Major savings are evident in the size of the primary clarifiers, the aeration basin and the secondary clarifiers. The total construction cost of the expansion and upgrading at the Anger Ave STP was \$10.25 million[24]. The cost savings associated with the design implemented at Anger Ave. compared to a design based on MOE guidelines was estimated by increasing the estimated costs incurred for aeration hardware and tankage and for secondary clarification in proportion to the additional requirements shown in Table 4.1[25]. No benefit for reduced primary clarifier requirements is included since the final design incorporated a gravity belt thickener for WAS concentration in lieu of additional primaries. On this basis, a savings of about 17 percent in aeration tank costs and 47 percent in clarifier costs is suggested. This is approximately equivalent to a savings of \$0.5 million on an overall project cost of \$10.9 million if a conventional design had been implemented (approximately 4.6% savings in capital cost).

In addition to the cost benefits reported, the design which was implemented at the Anger Ave STP is flexible in terms of dry and wet weather operating mode and protects the secondary portion of the plant from the adverse effects of peak wet weather flows.

4.2.2) The West Windsor STP

4.2.2.1) Background:- The West Windsor STP services about three-quarters of the City of Windsor and the Town of LaSalle. The facility is a physical-chemical treatment plant with a rated average day flow capacity of 159,000 m^3/d and a peak capacity of 350,000 m^3/d (peaking factor 2.2). In operation, the plant flow undergoes preliminary treatment via mechanically cleaned bar screens and aerated grit removal tanks. Enhanced primary treatment is provided using chemical precipitation and coagulation followed by polymer addition for flocculation prior to sedimentation. Settled sludge is dewatered in solid bowl centrifuges, lime stabilized and either used as top dressing at the local landfill or applied to agricultural land as a soil

Table 4.1: Design of Major Process Units at the Fort Erie Anger Ave. STP

Parameter	Design per MOE Guidelines [12]	Design Implemented
1. Flow (ML/d)		
Average Day Flow	24.5	24.5
Peak Day Flow	98.0	98.0
Peaking Factor	4.0	4.0
2. Primary Clarifiers		
Total Surface Area (m^2)	1645 *	1303.
3. Aeration Basin Volume (m^3)	6125 **	5100.
4. Secondary Clarifiers		
Total Surface Area (m^2)	2768 ***	1461.

Notes:

- * Based on surface loading of 0.69 L/m^2.s
- ** Based on minimum HRT of 6 hours
- *** Based on surface loading of 0.41 L/m^2.s

conditioner.

The West Windsor STP will need to be upgraded to provide the equivalent of secondary treatment, which is being considered as the BATEA under the MOE's MISA programme. In addition, some degree of nitrogen (ammonia) control may be a future objective. The City, anticipating that the plant upgrade would be costly, initiated investigations into the potential benefits of utilizing innovative treatment options to reduce the capital costs of the upgrading. It was the objective of these investigations to utilize the existing physical-chemical treatment mode to the greatest extent possible in the upgraded plant.

4.2.2.2) Process Studies Conducted[13]:- Four treatment alternatives were evaluated at pilot or bench-scale at the West Windsor STP in 1990/91 to assess their ability to achieve the expected effluent quality limits of 15, 15, 0.5 and 0.1 mg/L for TSS, total BOD_5, TP and unionized ammonia, respectively. The processes evaluated were:

(i) trickling filter/solids contact (TF/SC) process;

(ii) rotating biological contactor (RBC);

(iii) biological aerated filter (BAF); and,

(iv) modified activated sludge process (ASP) designed to operate at a low HRT (3.5 hours) and incorporating an anoxic selector zone. The ASP process was evaluated at bench-scale.

The treatment units were operated on-site for a period of one year to include all anticipated climatic conditions. Selected processes, including the BAF and the TF/SC, were subjected to extended investigations into 1992 to confirm cold weather performance and to better define the optimum operating conditions. The results of these process studies were used to select the most cost effective process alternative for the West Windsor facility upgrade. The study was completed in May 1992. Study results are currently being analyzed and detailed cost estimated are under preparation.

4.2.2.3) Outcome of Process Studies:- Based on an overall evaluation of results (obtained to Dec. 1992) the four processes which considered effluent quality, hydraulic performance, operational concerns and economics, the RBC process scored highest as an alternative for upgrading the West Windsor STP. The results for the BAF and ASP processes were marginally poorer, but the BAF had the advantage of producing an enhanced effluent quality compared to the other processes. The TF/SC rated the lowest, although not significantly below the other three processes. (The reader is cautioned that these preliminary conclusions may change following the analysis of study results for the period Jan. to May, 1992).

4.2.2.4) Benefits of Innovative Approach :- The final design configuration has not been selected for the upgrade of the West Windsor STP; hence, cost data and design details are preliminary. However, order of magnitude estimates prepared for the various alternatives suggest a range of capital costs from $53 million to $61 million depending on the final design configuration and exclusive of preliminary treatment, primary clarifiers, sludge digestion and administration buildings[26]. Given the level of accuracy expected from costs estimates based on conceptual designs, the costs for the different technologies are essentially the same.

The costs savings realized at the West Windsor STP were estimated based on comparing the estimated cost of the modified activated sludge process (4 h HRT) with the projected cost of a conventional activated sludge process (6 h HRT). Saving in aeration basin tankage and hardware for the lower HRT system were estimated at $2.3 million using costing functions contained in the CAPDET model[25]. This represents a savings of about 4 percent of the total estimated capital cost of the project. In addition to the cost benefits realized, the approach taken allows the City to continue to utilize to the greatest extent possible the existing facility.

4.3) *EXPANDING SECONDARY STPs*

4.3.1) **The Crystal Beach STP**

4.3.1.1) Background:- The Regional Municipality of Niagara's Crystal Beach STP was a high-rate activated sludge plant with a rated capacity of 3,880 m^3/d. The plant provided preliminary treatment through manually cleaned bar screens and aerated grit tanks, followed by secondary treatment in a Degremont Bloc Rapide aeration tank/integral clarifier configuration. Final effluent was chlorinated prior to discharge. Waste activated sludge was aerobically digested prior to disposal at the Fort Erie landfill lagoon.

The facility had been plagued by operating problems which resulted in poor effluent quality. Furthermore, infiltration into the collection system resulted in a low strength wastewater and high peak wet weather flows. Bypassing of the secondary plant to the chlorination chamber was practised to prevent washout of the secondary clarifiers. Upstream bypassing at the plant pumping station also occurred under peak flow conditions.

In 1986/87, extensive process studies were conducted at the Crystal Beach STP to define short-term measures to improve the performance of the facility and long-term upgrading alternatives to expand the plant to an average daily flow capacity of 9,100 m^3/d.

4.3.1.2) <u>Process Studies Conducted</u>[27,28]:- Two detailed plant assessments were conducted at the Crystal Beach STP. The first phase was done in the fall of 1986 to assess the effects of wet weather flow on the plant[27]. The second phase was done in the summer of 1987 to evaluate the effects of higher loadings during the summer recreational season on the facility[28]. At both times, the computerized process audit approach was used to conduct the plant studies. On-line monitoring instrumentation and data acquisition hardware were installed to collect dynamic plant operating data and were used in conjunction with off-line sampling and test procedures to develop design criteria for the expanded facility.

Some of the short-term remediation recommendations made at the completion of the first phase of the plant studies (fall of 1986) were implemented prior to the second plant monitoring period. Thus, the effects of these measures could be assessed during the summer monitoring. Data from both periods was used to develop design criteria for expanding the facility to the ultimate flow capacity of 9,100 m^3/d.

4.3.1.3) <u>Outcome of the Process Studies</u>:- The major short-term remedial measures implemented at the Crystal Beach STP to improve performance included:

- extension of the air lift return sludge piping to allow the monitoring of return rates.
- modifications of air piping to separate aeration tank air flows from aerobic digester airflows and air lift sludge return airflows.
- installation of on-line dissolved oxygen monitoring hardware in aeration tanks and digesters to allow control of air flow distribution.
- installation of new or replacement flow monitoring instrumentation on bypass flows and total plant flows to measure plant bypass and treated wastewater flows.
- improvements in plant operational monitoring, including provision of equipment to measure MLSS concentrations, for improved operational control.

After these changes were made and others were recommended at the completion of the summer process studies, it was determined that the capacity of the plant was 5,450 m^3/d under peak summer loading conditions and 6,800

m^3/d under winter conditions. The capacity of the plant was limited by the secondary clarifiers and in particular the return sludge system. Biological treatment capacity was adequate for flows in excess of these levels despite HRTs of about 1.2 hours.

As a result of this finding, the automatic bypass at the plant was redesigned to allow flows of up to 6,800 m^3/d to be treated in the secondary part of the plant during winter months and 5,500 m^3/d during summer months. Prior to the study, as much as half of the flow received at the plant was bypassed to prevent washout of the secondary clarifiers. The estimated plant capacity compares to the rated capacity of 3,880 m^3/d, an increase of between 140 and 175 percent.

4.3.1.4) Benefits of Innovative Approach:- The physical condition and poor process configuration of the existing Crystal Beach STP did not warrant utilization of any of the existing facility in the expanded 9,100 m^3/d facility. Therefore, in the longer term, the extra capacity identified as a result of the process audit and in-plant modifications could not be utilized. However, the performance data collected during these plant studies allowed the new facility to be designed with aeration tank HRTs of only 1.5 hours, substantially lower than the MOE Guideline of six hours minimum[12].

The new facility was commissioned in March of 1992 at a total cost of $8.98 million[24]. Costs for the new facility include new headworks, aeration, secondary clarification, sludge thickening, anaerobic digestion, administration buildings and a new outfall. If only the reduced aeration requirement (1.5 h HRT versus 6 h HRT) is claimed as a benefit accrued from the process studies, it is estimated that the cost savings were about $440,000 on an overall project cost about $9.4 million if a conventional design approach had been used[25]. This represents an estimated cost savings of about 4.7 percent.

Although the additional capacity identified in the existing facility could not be utilized in the long term after the new facility was commissioned, the short-term modifications made at the plant improved effluent quality for the five years that the old facility continued to operate. This improvement is illustrated by the effluent quality data summarized in Table 4.2. Bypassing still occurred at the old plant under storm flow conditions; however, redesign of the bypass reduced the frequency and magnitude of bypassing.

4.3.2) The Windsor Little River STP

4.3.2.1) Background:- The Windsor Little River STP was designed to provide 36,400 m^3/d of secondary treatment capacity. The facility is a conventional activated sludge plant. After the last major expansion of the facility in 1973, the City had implemented two major modifications to improve

Table 4.2: Comparison of Crystal Beach STP Effluent Quality Before and After Process Studies

	Before Studies		After Studies	
	1986	1987	1988	1989
Average Flow (ML/d)	5.245	4.295	3.920	4.250
Effluent BOD_5 (mg/L)	26.3	23.1	24.6	14.5
Effluent TSS (mg/L)	27.5	32.0	20.7	16.6
Effluent TP (mg/L)	1.20	1.3	1.0	0.8

plant performance. These changes were:

- installation of baffle rings in the secondary clarifiers to reduce short circuiting in the relatively shallow (2.7 m SWD) tanks; and,

- replacement of the mechanical aeration equipment in three of the four aeration tanks with fine bubble diffusers to increase oxygenation capacity for periods of high seasonal loading from local industries.

When the treatment capacity was reached in 1988, the City embarked on a phased expansion of the plant. The Certificate of Approval (C of A) for the planned expansion issued by the MOE in April 1988 required that the expanded plant achieve nitrification. In addition, questions were raised regarding the peak flow capacity of the existing 36,400 m^3/d plant. Down-rating of the plant capacity by as much as 50 percent was suggested. To address these issues, the C of A required that the City undertake an "overall plant efficiency assessment" to determine the plant capacity and its ability to comply with the requirements of the C of A under all seasonal conditions.

4.3.2.2) Process Studies Conducted:- Stress tests were conducted at the Windsor Little River STP in 1989 to establish the plant capacity during the critical seasonal periods of winter (cold weather limitations on nitrification), spring (peak wet weather flows) and summer/fall (peak industrial organic loading)[29]. Stress testing was conducted by dividing the plant into two separate parallel trains and loading half of the plant to the point where it was unable to maintain the performance limits established by the C of A. In addition, oxygen transfer testing was conducted to establish the transfer capacity of the existing aeration hardware and its ability to meet the carbonaceous and nitrogenous oxygen demands on the plant.

Throughout the year-long stress test, on-line monitoring equipment and automatic data acquisition hardware was installed and operated at the Little River STP so that continuous dynamic data on plant performance were available to support the off-line sampling and analytical results.

4.3.2.3) Outcome of Process Studies:- The stress test and oxygen transfer test results showed that there was no basis for down-rating the average daily flow capacity of the existing facility from its original rating of 36,400 m^3/d. The stress testing showed that the Little River STP had capacity to treat average day flows of 46,900 m^3/d and peak day flows of 74,000 m^3/d and meet the new C of A compliance criteria. This treatment capability exceeded the original rated capacity by almost 130 percent. Under these stressed conditions, the plant effluent met the single sample compliance criteria for all parameters in excess of 95 percent of the time. The monthly sample compliance criteria were met for every month with one exception. This exception related to an intentional hydraulic, organic and ammonia spike imposed on the stressed portion of the plant.

4.3.2.4) Benefits of Innovative Approach:- As a result of the stress testing undertaken at the Windsor Little River STP, no downrating of the existing facility was needed. A rated capacity of 36,400 m^3/d was retained, although it was recognized that this rating included a safety factor based on the outcome of the stress tests. Recommendations were also provided for modifications to other portions of the plant which might further increase the available plant capacity.

As a result of the testing undertaken at the Little River STP, as much as 18,200 m^3/d of secondary treatment capacity was retained. The City estimates that it would have cost $12 million to replace this capacity. The costs incurred to upgrade the plant (addition of clarifier baffles and fine bubble diffusers) in order to achieve this level of treatment were approximately $5.2 million(30). Hence, the cost savings accomplished was about $6.8 million or about 56.7 percent of the estimated capital cost of a full plant expansion by conventional approaches.

4.3.3) The Oakville South-East STP

4.3.3.1) Background:- The Regional Municipality of Halton's Oakville SE STP provides an average day flow capacity of 22,500 m^3/d in two phases. The oldest phase of the plant (Plant 1, 1969) has a rated capacity of 9,000 m^3/d (peak primary capacity of 27,000 m^3/d and peak secondary capacity of 18,000 m^3/d). The newer phase (Plant 2, 1978) provides an additional 13,500 m^3/d of capacity (peak primary capacity of 40,500 m^3/d and peak secondary capacity of 37,000 m^3/d).

In 1986, flows were at about 56 percent of total plant capacity. At this loading, only the newer Plant 2 was needed to maintain the required effluent quality. However, committed and planned growth in the serviced area along with industrial wastewater flows which would be diverted to the plant for treatment were expected to utilize the available capacity in the near term. Therefore, studies were conducted to define the ultimate capacity of the existing facility prior to the need for plant expansion. An additional objective was to assess the potential process energy savings which might be achieved by modifications to the plant aeration systems.

4.3.3.2) Process Studies Conducted(31)

A computerized process audit was undertaken at the Oakville SE STP to accomplish the objectives of Halton Region. The plant was monitored continuously for a three-week period in the fall of 1986 using on-line instrumentation and automatic data acquisition hardware. These data were utilized along with off-line sampling and analysis as well as plant historic operating and performance data to establish plant capacity and potential energy savings.

A key element of the energy savings analysis was measurement of the efficiency of the existing oxygen transfer hardware in the plant. These measurements were made using the dissolved oxygen desorption method in which hydrogen peroxide is added to the aeration basin and the rate of oxygen stripping is measured.

4.3.3.3) Outcome of Process Studies:- The process audit of the Oakville SE STP showed that additional oxygenation capacity or blower capacity was not required to handle the design loading of the facility plus the additional loading resulting from the discharge of approximately 4,200 m^3/d of industrial flows. It was found that Plant 2 alone provided sufficient oxygenation capacity to meet the demands originally anticipated for the entire facility plus the expected industrial loading. The results also suggested that effluent quality requirements could be maintained at hydraulic loadings in excess of the original design capacity and recommended that full-scale stress tests such as those conducted at the Windsor Little River STP (refer to Section 4.3.2) be undertaken to confirm ultimate capacity.

An estimated annual energy savings potential of about 43 percent of the current energy expenditure or $23,800 ($1986) was indicated. These savings derived from operating a smaller blower under current loading conditions ($8,800), refurbishing or replacing existing fine bubble diffusers ($6,000) and implementing on-line DO monitoring and control ($9,000).

4.3.3.4) Benefits of Innovative Approach:- To accommodate future growth in the serviced area, the Oakville SE STP was expanded in 1989/90 to a design capacity of 31,800 m^3/d. Stress testing, as recommended in the process audit report, has not been undertaken to confirm the actual capacity of the expanded facility. However, in the plant expansion, the recommendations of the oxygenation capacity testing done during the process audit were followed. No additional blower capacity was added as part of the plant expansion. Halton staff estimate the cost savings associated with not purchasing, installing and housing additional blowers at $2 million. This represents about 20 percent of the estimated cost of the plant expansion inclusive of new blowers. In addition, an automated DO control system was implemented and fine pore aeration used throughout the plant. This has resulted in an estimated annual energy savings of about $25,000[32].

4.4) *UPGRADING OF SECONDARY STPs*

4.4.1) The Kitchener STP

4.4.1.1) Background:- The MOE's Kitchener STP, operated on behalf of the Regional Municipality of Waterloo, provides secondary treatment for a rated hydraulic capacity of 122,740 m^3/d in two parallel secondary treatment works served by a common preliminary treatment and primary clarification section. The older (Plant 1, 1962) secondary section is a plug-flow mechanically aerated plant with four circular clarifiers designed for a nominal average day flow of 61,370 m^3/d. Plant 2 (1974) provides similar treatment capacity in eight completely-mixed mechanically aerated tanks and four circular clarifiers.

The facility had effluent objectives of 25 mg/L BOD_5, 25 mg/L TSS and 1.0 mg/L TP; however, concerns regarding water quality in the Grand River combined with plans to extract water from the River for potable use suggested that more stringent effluent quality requirements would likely be imposed on the facility. The 1982 Grand River Basin Water Management Study recommended the implementation of tertiary treatment at the Kitchener STP[33]. Specifically, it was suggested that nitrification and effluent filtration to reduce phosphorus concentrations would be needed to protect downstream water quality. To determine the capacity of the existing facility to meet the suggested nitrification requirements currently and in the future as well as to assess the potential for aeration process energy savings, a thorough plant evaluation was conducted at the Kitchener STP in 1986.

4.4.1.2) Process Studies Conducted[34]:- A computerized process audit of the Kitchener STP was conducted to determine the current and future capacity of the facility to achieve nitrification and the potential for energy savings. This audit represented the first private-sector application of the approach after its development by the WTC and application at the Tillsonburg STP as part of a demonstration project. The work at the Kitchener STP was jointly funded by Supply and Services, Environment Canada and the Region of Waterloo under the Unsolicited Proposal Programme.

To determine the capability of the plant to achieve nitrification and effect energy savings, on-line instrumentation and automatic data acquisition hardware were installed at the plant and the plant was monitored for a period of about two months in the spring of 1986. The results of the on-line data monitoring were combined with off-line sampling and analysis to establish plant performance capabilities. In addition, oxygen transfer capacity was determined in both Plants 1 and 2 and the oxygenation capacity compared to the current and future oxygen demands associated with BOD_5 removal and nitrification at the plant.

4.4.1.3) Outcome of Process Studies:- Based on the findings of the process audit, it was established that the oxygen transfer capacity of the existing facility was adequate to meet the demands associated with full nitrification until the year 2008 when flows were projected to be about 85 percent of the rated capacity of the plant. Modifications to the aeration hardware were suggested that would extend this date to 2011 at which time flows to the plant were projected to reach the design capacity. Balancing flow splits between the two sections of the plant was recommended to take advantage of the differences in oxygen transfer and clarification capacity between Plants 1 and 2.

A potential annual energy savings of about $60,000 ($1985) was estimated if the plant was not required to nitrify. Under nitrifying conditions, an annual savings of about $24,000 was estimated. The payback on the control equipment to achieve this savings was about eight years in Plant 2 but about 28 years in Plant 1. The Region proceeded to implement automated control of aeration in Plant 2 in 1988. In Plant 1, on-line DO monitoring was implemented to allow the plant operations staff to better control nitrification, but automated control was not implemented.

4.4.1.4) Benefits of Innovative Approach:- The cost for upgrading the Kitchener STP to achieve tertiary treatment according to the 1982 Grand River management study ($ 1979) was estimated at approximately $12.77 million(33). This cost included expansion of the plant to achieve nitrification and upgrading with effluent filtration to achieve lower effluent TP limits. The individual costs of providing filtration and nitrification were not itemized in that study. It was estimated that about $8.5 million dollars would be associated with nitrification and $4.4 million dollars with filtration.

The process audit at the facility demonstrated that the plant should be capable of achieving nitrification without any upgrading until the year 2008. The need for upgrading could be deferred until the year 2011 when flows will reach design capacity with minimal capital cost to increase oxygen transfer capacity. Thus, the large capital costs suggested by the Grand River management study for increasing biological treatment capacity can be effectively deferred for twenty years until the plant reaches its design capacity. In 1990 dollars, the projected savings for the nitrification requirement alone would be $15.2 million on an overall capital expenditure projected at $22.9 million. This represents an estimated savings of about 66 percent.

Plant staff estimate that the energy savings accomplished by the automated DO control system installed in Plant 2 have amounted to about $30,000 annually or 12 to 15 percent of the overall usage(35).

4.4.2) **The Collingwood STP**

4.4.2.1) Background:- The Collingwood STP provides 24,548 m^3/d of secondary treatment capacity for the Town of Collingwood. Collingwood

Harbour was identified by the International Joint Commission (IJC) as an Area of Concern (AOC) due to nuisance algal growth. The discharge from the sewage treatment plant represents the primary source of nutrient input to the Harbour. Hence, effluent TP loading limits of 2760 kg/y from the STP to the Harbour are needed to maintain the open water phosphorus concentrations below 0.020 mg/L and thus control algal growth. This translates to effluent TP concentration limits of 0.42 mg/L at current flows and 0.31 mg/L at design flow.

At the same time, residential growth projections for the serviced area suggested that plant expansion would be needed in the near future. A capacity review of the facility conducted in 1990 concluded that a Class Environmental Assessment (EA) should be initiated immediately to ensure that community growth would not be restricted by treatment plant capacity limitations[36].

To establish the existing plant capacity and to assess the upgrading costs associated with meeting the future effluent quality requirements, a thorough plant analysis was conducted in 1991.

4.4.2.2) <u>Process Studies Conducted</u>[6]:- The treatment plant analysis was undertaken using the computerized process audit approach. On-line process instrumentation was installed to monitor key unit processes in the plant for a period of about six months. Real time data collected in this manner was supplemented by intensive off-line sampling and analysis as well as specific performance assessment studies and a thorough review of the historic plant operation and performance.

The process studies at the Collingwood STP included determination of the oxygen transfer capacity of the existing mechanical aeration hardware, analysis of the potential for process energy savings, measurement of the mixing characteristics of the anaerobic digesters, assessment of capacity limitations in waste activated sludge thickening equipment and evaluation of flow metering accuracy.

4.4.2.3) <u>Outcome of Process Studies</u>:- The analysis of the Collingwood STP showed that, at current loadings, the facility was producing a high quality, nitrified and denitrified final effluent containing an average effluent TP concentration of 0.42 mg/L. Further optimization of phosphorus removal using dual-point chemical addition and automated chemical dosage control was suggested as a means of achieving the target effluent TP limits without total effluent filtration. A full-scale demonstration of optimized phosphorus removal is planned for 1992 at the Collingwood STP.

Oxygen transfer testing showed that the existing mechanical aeration equipment was very efficient and that retrofitting fine pore aeration hardware could not be justified on the basis of energy savings. The oxygen transfer capacity of the existing plant was estimated to be sufficient to meet the carbonaceous and nitrogenous demands under average loading conditions at the rated plant capacity.

It was concluded that the yearly average flow capacity of the facility would not be exceeded before 2001 if the 4540 m^3/d reserve industrial treatment capacity at the plant was used for other residential/commercial/light industrial development. By this approach, plant expansion could be deferred for about 10 years.

4.4.2.4) Potential Benefits of Innovative Approach:- The capital cost of providing tertiary treatment at the Collingwood STP to further remove phosphorus and other nutrients (nitrogen) had been estimated at $15 million[(7)]. Based on the process studies done at the Collingwood STP, nitrification can be maintained at loadings up to the plant design without major capital expansion. The need for tertiary filtration to achieve the effluent phosphorus limits will be defined by the outcome of the full-scale phosphorus optimization studies. It may be possible to substantially reduce the capital cost of achieving these limits. The cost of tertiary filtration is estimated at $6.3 million[(6)] compared to the cost of implementing dual-point chemical addition in conjunction with automated control of chemical dosage and SRT at approximately $350,000. Partial savings would be $8.4 million (56% of the total estimate) if sand filtration is required or $14.7 million (97.7%) if the full-scale demonstration study is successful to allow the Collingwood STP to achieve 0.31 mg/L TP optimizing the chemical addition process.

4.4.3) The Waterloo STP

4.4.3.1) Background:- The Waterloo STP, which is operated by the MOE on behalf of the Regional Municipality of Waterloo, provided secondary treatment capacity of 45,460 m^3/d. The facility incorporated the original Stage 1 plant with a design capacity of 27,276 m^3/d and the first phase (Phase 1) of Stage 2 with a design capacity of 18,184 m^3/d. In 1986, the average daily flow to the plant had reached the design capacity. Therefore, a plant expansion was undertaken to add additional treatment capacity. The second phase (Phase 2) of Stage 2 was constructed and commissioned in 1988. This phase was virtually identical to the Phase 1 of Stage 2, but was rated at a nominal capacity of 22,730 m^3/d. At the same time, the capacity rating of the Phase 1 of Stage 2 was increased to match that of the Phase 2 of Stage 2 (22,730 m^3/d). Thus, at the completion of this construction, a total capacity of 72,740 m^3/d was available.

It was identified that, when plant flows reached 54,480 m^3/d, an effluent limit of 1.8 mg/L ammonia nitrogen and 0.6 mg/L TP would be imposed on the plant to protect downstream water quality. This was expected to occur in about 1991. The predesign report for the Phase 2 Stage 2 expansion[37] stated that at that time a further plant upgrading would be needed to provide nitrification. This upgrade would be achieved by the construction of additional biological treatment capacity. Upgrading to achieve the 0.6 mg/L TP limit was not addressed in the predesign report.

A review of the Waterloo STP design in 1987 as part of the Region's Masterplan for Sewage Treatment[38] suggested that adequate capacity might be available in the existing and newly designed facility to achieve nitrification without the need for additional construction to meet the anticipated 1991 requirements. The Masterplan suggested that a capacity assessment be undertaken at the completion of the construction to define the capability of the plant to meet the nitrification requirements.

4.4.3.2) Process Studies Conducted[39]:- After commissioning and debugging of Phase 2 of Stage 2, a stress test of the plant was conducted to determine its capability to achieve nitrification and improved phosphorus removal at future flowrates. The stress test was conducted in 1989/90 and utilized the real-time data acquisition approach of the computerized process audit methodology.

4.4.3.3) Outcome of Process Studies:- The conclusion of the process studies was that major plant expansion would not be required to achieve nitrification. Both Stage 1 and Stage 2 achieved NH_3-N concentrations below 1.8 mg/L at average total plant flows exceeding the equivalent of 72,700 m^3/d.

It was further concluded that the 0.6 mg/L proposed TP limit could be met at future flowrates without tertiary treatment. In Stage 2, average effluent TP concentrations of 0.33 mg/L were achieved during the stress test after increasing chemical dosage. In Stage 1, the stress tests showed that, to achieve the proposed limit, growth of scum-causing filamentous organisms would need to be controlled and secondary clarifier capacity would need to be increased by 50 percent.

4.4.3.4) Benefits of Innovative Approach:- The estimated cost of meeting the proposed nitrification limits was \$7.5 million (\$ 1986)[37]. Capital costs for tertiary filtration were estimated at \$6.1 million (\$ 1987)[38]. It was suggested that both would be required in 1991 when flows reached 54,480 m^3/d and the more stringent effluent requirements were imposed.

As a result of the process studies, it was demonstrated that expansion would not be needed to achieve nitrification until flows reached the design level (72,740 m^3/d). If secondary clarification in Stage 1 was upgraded, the proposed phosphorus limits could also be achieved without tertiary filtration. Costs for clarification upgrading were estimated at \$2.5 million (\$ 1991). Thus, savings resulting from the process studies at the Waterloo STP amount to approximately $11.1 million or 81.6 percent of the estimated capital cost.

4.5) *SUMMARY OF BENEFITS OF INNOVATIVE APPROACHES*

Table 4.3 summarizes the cost benefits and other benefits derived in the eight case histories related in this report. In terms of dollars savings alone, the benefits amount to approximately $50 million of deferred or eliminated capital expenditure for these eight facilities. If capital works had proceeded according to conventional design approaches, the total costs of capital works related to these eight case histories would have been about $150 million. On the basis of the assumptions made, the capital costs in these cases are reduced by about one-third.

Table 4.3: Summary of Benefits of Innovative Approaches in Municipal SPTs

Facility	Requirement	Estimated Project Cost by Conventional Approach (M$)	Estimated Cost Savings by Innovative Approach (M$)	Other Benefits
Fort Erie Anger Ave. STP	Upgrade Primary Plant to Secondary	10.8	1.5	Improved wet weather flow treatment. Increased operating flexibility.
West Windsor STP	Upgrade Primary Plant to Secondary	78.	18.	Maximize use of enhanced phys-chem treatment capacity.
Crystal Beach STP	Expand Secondary Plant	12.	3.	Reduced bypassing and improved effluent quality in existing plant.
Windsor Little River STP	Expand Secondary Plant	12.	6.8	Eliminated need to add additional 18,200 m^3/d of capacity.
Oakville South East STP	Expand Secondary Plant	(10.0)	2.0	Additional capacity (and cost savings) may be realizable. Annual Energy Savings of $25,000.
Kitchener STP	Upgrade Secondary Plant	12.8	8.5	Annual energy savings estimated at $30,000.
Collingwood STP	Upgrade Secondary Plant	15.0	8.4 to 14.7	Improved operational control by automation.
Waterloo STP	Upgrade Secondary Plant	13.6	11.1	Short-term operational improvements recommended.

5.0 ECONOMIC IMPLICATIONS OF INNOVATIVE APPROACHES AT STPs IN AOCs

5.1) *GENERAL*

To estimate the potential capital cost savings realizable by the application of the innovative approaches described in Section 3. and illustrated by case histories in Section 4., a number of broad assumptions were made, including the following.

1. The type of upgrading required at the STPs in Ontario AOCs was categorized into three broad classes based on information provided by the RAP coordinators and summarized in Section 2.2. The three classes were:

   (i) upgrading of primary STPs to provide secondary treatment;

   (ii) upgrading of secondary STPs to provide improved phosphorus removal; and,

   (iii) upgrading of secondary STPs to provide improved removal of phosphorus and nitrogen (nitrification).

2. It was assumed that the cost savings achieved in the case histories described in Section 4. and summarized in Table 4.3 are representative of the savings which could be achieved at STPs undergoing the same type of upgrading in the Ontario AOCs.

3. For primary STPs requiring upgrading to secondary treatment, the cost of these upgrades by conventional methods were estimated based on order-of-magnitude unit costs of $0.88 to $1.32 per litre of capacity depending on plant size. This unit cost range was based on engineering cost estimates submitted to MOE for upgrading at five primary STPs in Ontario[40]. The cost savings potentially realizable by innovative approaches was estimated by applying the average of the savings realized at the Fort Erie Anger Ave. WPCP (4.6%) and the West Windsor WPCP (3.8%).

4. For secondary STPs required to achieve effluent TP concentrations of between 0.3 to 0.5 mg/L, the cost of these upgrades by conventional methods was estimated based on incorporating effluent filtration at an order-of-magnitude unit cost of between $0.15 and $0.79 per litre of capacity depending on plant size. This unit cost range was based on cost estimates for filters at STPs in Severn Sound[41]. The cost savings potentially realizable by innovative approaches was estimated by assuming that this level of treatment could be achieved by pre-precipitation and optimized chemical addition approaches as suggested

at the Collingwood WPCP. This approach would only be effective at conventional activated sludge facilities which have primary clarifiers and would be suitable for operation in a pre-precipitation mode. At other types of facilities (extended aeration, contact stabilization, etc.), it was assumed that achieving this level of phosphorus removal would require tertiary filtration. For STPs where effluent TP limits lower than 0.3 mg/L are required by the RAP, no cost savings were proposed.

5. For secondary STPs required to provide improved nitrogen and phosphorus removal, the cost and cost savings associated with improved phosphorus removal were estimated based on the assumptions outlined above in Item 4. The costs of providing nitrogen control by conventional methods were estimated based on expansion of aeration and clarification to meet MOE Guidelines for nitrifying activated sludge plants[40]. The cost savings potentially realizable by innovative approaches were estimated based on detailed process studies undertaken at facilities requiring this type of upgrading[8,42].

The magnitude of cost savings realizable by approaches described herein are very site-specific and depend on such factors as the characteristics of the wastewater, the flow patterns, the physical condition of the existing facility and the effluent requirements. The cost savings estimated are intended to provide an order-of-magnitude indication of the potential savings which might be realized by the application of approaches which have proven to be successful or are being evaluated elsewhere in Ontario. The actual savings cannot be defined in advance of more detailed investigations at the facilities under consideration.

5.2) *UPGRADING OF PRIMARY STPS IN AOCs*

Ten of the 45 STPs which will need to be upgraded in Ontario AOCs are primary plants (Table 2.4). These facilities represent a total treatment capacity of 462.8 ML/d or about 14 percent of the total capacity of the affected STPs.

Based on the unit cost factors identified in Section 5.1, the estimated cost to upgrade all of these facilities to secondary treatment by conventional methods is about $413 million. At the average estimated savings for similar upgrades using innovative approaches (4.2%), the estimated reduction in capital costs potentially realizable at these ten STPs by the application of innovative approaches for upgrading is about $17.3 million. More than 95 percent of the cost savings is associated with the five larger primary STPs (West Windsor, Sarnia, Cornwall, Sault Ste. Marie, Thunder Bay).

5.3) *UPGRADING OF SECONDARY STPs FOR IMPROVED PHOSPHORUS REMOVAL*

Based on information provided by the RAP Coordinators and summarized in Section 2.1, nineteen STPs in Ontario AOCs will need to provide improved phosphorus removal. As summarized in Table 5.1, seven of these facilities will likely be required to meet effluent TP limits more stringent than 0.30 mg/L (Dundas, Hamilton Woodward Ave., Burlington Skyway, Elmvale, Coldwater, Penetang Main St. and Penetang Fox Street). At these facilities, tertiary treatment will be needed. It is possible that capital cost savings could be accomplished at these plants through optimization of tertiary plant design; however, such savings have yet to be demonstrated in Ontario. Therefore, for the purposes of this analysis, no cost savings have been assumed for these seven STPs. In addition, the Victoria Harbour WPCP is already equipped with tertiary filters and is achieving effluent concentrations lower than its proposed RAP requirements[40]. Hence, no capital costs or cost savings have been assumed for this plant.

At the other eleven STPs in this category, the total cost of providing tertiary filtration is estimated at $20.7 million. Four of these plants (Deseronto, Picton, Prince Edward Heights and Port McNicholl) use technologies other than conventional activated sludge. No cost savings potential was assumed at these facilities. At the other seven STPs, a potential savings of $17.7 million is realizable if the approaches being investigated at the Collingwood WPCP (refer to Section 3.4.2) prove to be successful in achieving an effluent concentration of 0.30 mg/L TP without tertiary filtration.

5.4) *UPGRADING OF SECONDARY STPS FOR IMPROVED N AND P REMOVAL*

Based on the information provided by the RAP Coordinators, only two STPs will be required to provide both improved nitrogen and phosphorus control. These are the Hamilton Woodward Ave. WPCP and the Burlington Skyway WPCP in the Hamilton Harbour AOC. In both cases, the ultimate effluent TP targets are significantly below 0.30 mg/L. Therefore, tertiary filtration will be needed to accomplish this target and no cost savings potential was assumed in Section 5.3 or in this section for these facilities based on optimized P removal.

There are indications that nitrification may be required at the four Metro Toronto STPs discharging to the Toronto Waterfront AOC (see Section 2.1.16), however, this requirement has not been finalized. The costs of providing nitrification at the Toronto STPs was estimated to be $402.6 million[40]. Because of the uncertainties associated with the upgrading requirements at these STPs and the capability of these STPs to achieve nitrification without major capital works, no cost savings have been assumed at this time to be realizable at these facilities.

The other two STPs (Skyway and Hamilton), extensive process studies were undertaken to estimate the capability of these plants to achieve nitrification without major plant expansion[8,42]. At the Burlington Skyway WPCP, upgrading of oxygen transfer capacity would be needed. It was estimated that the costs of retrofitting fine pore aeration hardware at this plant would be about $2.0 million, inclusive of

Table 5.1: STPs In AOCs Requiring Improved Phosphorus Removal

STP	CONFIGURATION	LIKELY TP LIMITS (mg/L)
COLLINGWOOD	CAS	0.31
DUNDAS	CAS + FILT.	0.10
HAMILTON WOODWARD AVE.	CAS	0.13
BURLINGTON SKYWAY	CAS	0.13
BELLEVILLE	CAS	0.30
CFB TRENTON	CAS	0.30
DESERONTO	EA	0.30
NAPANEE	CAS	0.30
PICTON	CS	0.30
TRENTON	CAS	0.30
PRINCE EDWARD HEIGHTS	TF	0.30
ELMVALE	LAGOON	0.15
COLDWATER	EA	<0.30
MIDLAND	CAS	0.30
PENETANG MAIN ST.	CS	0.15
PENETANG FOX ST.	CS	0.15
PENETANG MHC	CAS	0.30
PORT McNICOLL	EA	0.30
VICTORIA HARBOUR	EA + FILT	0.30

automated DO control capability[8]. Improvements in the existing clarifiers would also be required at an estimated cost of $1.7 million. It was possible that additional clarification capacity would also be needed at an estimated cost of $9.2 million. Hence, the costs to provide nitrification, based on a process audit of the facility as summarized in Table 5.2, were estimated at between $3.7 million and $12.9 million depending on the need for additional clarification capacity. Earlier estimates had indicated costs of about $25.1 million to achieve nitrification at this facility, including about $18.6 million to increase biological treatment capacity[40]. Hence, the order-of-magnitude savings realizable are in the range of $12.2 million to 21.4 million.

Similarly, oxygen transfer determinations made at the Hamilton Woodward Ave. WPCP[42] suggest that nitrification is achievable by upgrading of the oxygenation hardware at an estimated cost of $0.2 million. Limitations in secondary clarification capacity at the plant would likely require clarifier expansion to accommodate nitrification[43]. As indicated in Table 5.2, the costs of clarifier expansion were estimated at $28.6 million and the overall costs to provide nitrification at Woodward Ave were estimated at $110.5 million[40]. Hence, the order-of-magnitude savings realizable at Woodward Ave. are about $82 million if only additional aeration hardware and clarification capacity is required.

5.5) *SUMMARY OF OVERALL CAPITAL COST SAVINGS POTENTIAL IN AOCs*

Based on the assumption that the capital savings potential realizable at the eight STPs where innovative approaches have been tried are translatable to other STPs in Ontario AOCs and the assumptions made regarding the upgrading which will be required of STPs in each AOC, Table 5.3 summarizes the capital cost savings potentially realizable in Ontario AOCs for STP upgrading.

The potential capital cost savings are estimated at about $125 million. This is exclusive of any potential savings which might be realized at the four Metro Toronto STPs discharging to the Toronto Waterfront AOC. It is emphasized that this represents **potential capital cost savings**. The actual cost savings accomplished will depend on the specific circumstances at each STP.

As noted in Section 4.1, there is no guarantee that detailed process studies will result in capital cost savings at any particular plant. The costs of these process studies, generally ranging from less than $100,000. to $500,000. depending on scope and size of the plant, must also be considered relative to the likely savings that might be realized.

Table 5.2: Potential Cost Savings at STPs Requiring N & P Removal

STP	ESTIMATED COST TO NITRIFY [24] BY CONVENTIONAL APPROACH (M$)			ESTIMATED COST TO NITRIFY BY INNOVATIVE APPROACH (M$)			POTENTIAL SAVINGS (M$)
	AERATION	CLARIFIERS	TOTAL	AERATION	CLARIFIERS	TOTAL	
SKYWAY	18.6	6.5	25.1	2.0	1.7 - 10.9	3.7 - 12.9	12.2 - 21.4
WOODWARD AVE.	81.8	28.6	110.5	0.2	28.6	28.8	81.7

Table 5-3: Summary of Potential Cost Savings Realizable at STPs in AOCs

CLASS OF UPGRADE	POTENTIAL SAVINGS (M$)
1. PRIMARY STPs	17.3
2. IMPROVED PHOSPHORUS REMOVAL	17.7
3. IMPROVED P & N REMOVAL	83.9 - 103.1
TOTAL	118.9 - 138.1

6.0 CONCLUSIONS AND RECOMMENDATIONS:

6.1) *CONCLUSIONS*

Based on available information from RAP Coordinators, the requirements and costs for upgrading STPs in Canadian AOCs were reviewed. The potential capital cost savings which can be realized by applying innovative approaches at these STPs were estimated based on engineering studies at other Ontario STPs where similar approaches had been applied. The principal conclusions of the study were as follows:

- There are a total of 40 mechanical STPs in the 17 Canadian AOCs providing a total design treatment capacity of about 2,900 ML/d. Improving water quality in these AOCs will require upgrading 10 primary STPs to secondary and replacing one existing lagoon by tertiary treatment. Enhanced phosphorus removal will be required at 16 secondary STPs and nitrification may be needed at 7 STPs, including the 4 Metro Toronto STPs.

- Hickling[1] estimated that total capital cost of $2,618. million was required to upgrade STPs in Canadian AOCs to meet RAP requirements. Of this total, $1,783. million was associated with upgrading Metro Toronto STPs and $835. million was associated with upgrading STPs in the remaining AOCs.

- The Hickling costs were reviewed based on information from engineering studies and cost estimates provided by the Water Resources Branch, Ontario Ministry of Environment[40]. The review suggested that the total cost of upgrading STPs in the Canadian Areas of Concern was approximately $1,073. million. Of this total, $403. million was associated with the Metro Toronto STPs and $670. million was associated with upgrading STPs in the remaining AOCs. The lack of clearly defined upgrading requirements for the Metro Toronto STPs created a major source of uncertainty concerning the magnitude of the overall capital cost estimates.

- The cost estimates noted above were based on the application of conventional approaches to upgrading STPs in the AOCs. Less capital intensive approaches which utilize innovative process design and optimization methods have been demonstrated to be effective at a number of STPs inside and outside of AOCs. A review of 8 documented cases suggested that a cost savings of about $50. million was achieved out of an overall potential expenditure of $150. million by the application of innovative approaches.

- If conditions at the STPs which were the subject of the case studies can be assumed to be applicable to other STPs in the Canadian AOCs, then a potential $125. million in upgrading costs can be realized by the application of innovative and optimization technologies. The cost savings represents approximately 20% of the total $670. million required for upgrading. The estimated cost savings excluded any savings which might be achieved at the Metro Toronto STPs because current information is inadequate to support a valid estimate at these facilities. Additional information concerning site-specific conditions at the 4 Metro Toronto STPs and clearly defined upgrading requirements established by the RAP are required to estimate such savings.

6.2) *RECOMMENDATIONS*

This report documented that substantial cost savings were realized at a number of Ontario STPs through the application of innovative and optimization technologies to plant expansion and upgrading. Coordinated Federal, Provincial and Municipal government programs to support such studies will ensure that innovative and optimization technologies continue to be developed, demonstrated, and applied at municipal STPs requiring expansion and/or upgrading. To better refine the information contained in this study, the following recommendations are presented:

- Capital costs for upgrading the West Windsor STP from a primary to innovative secondary treatment facilities should be generated at the completion of investigations currently underway so that cost savings can be accurately defined.

- Detailed technical investigations should be completed at the Collingwood STP and other selected STPs within the AOCs to define the ability to consistently achieve an effluent total phosphorus concentration of 0.30 mg/L or less through optimized chemical addition without tertiary filtration.

- Detailed technical investigations should be completed at a number of STPs with different effluent filter designs to determine the ability of post-precipitation and effluent filtration to consistently achieve an effluent total phosphorus concentration of 0.10 mg/L or less.

- Additional efforts are required to evaluate and demonstrate low cost alternatives for retrofitting STPs for nitrification. The work should include: a state-of-the-art literature review of low cost alternatives, a technical and economic evaluation of several case studies and demonstration of the most promising technologies. (Information from this work will assist Ontario STPs to comply with the Ontario's MISA regulations which will require all effluents to be nontoxic. All municipal STPs will have to nitrify to meet this requirement.)

- Because of the relative magnitude of the costs associated with upgrading the 4 Metro Toronto STPs, better definition of the likely RAP requirements for these facilities is required to better define the overall cost estimates and potential savings.

- An up-to-date database of actual construction costs for expanding and/or upgrading Ontario STPs should be developed to assess the cost implications of proposed alternative effluent regulations and policy initiatives.

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