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The Sewage Issue in Hamilton Harbour: Implications of Growth for the Remedial Action Plan

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Abstract

Much work remains in the implementation and restoration of beneficial uses phase of Remedial Action Plans in the Great Lakes. At the same time as plans have been made to reduce nutrient loads at many Areas of Concern other plans to accommodate population growth have occurred. Growth has the potential to slow or reverse progress in eutrophication control. A recent proposal to expand one of the local sewage plants without enhancing the treatment level caused a review of RAP goals and water quality responses in Hamilton Harbour. Data on Hamilton Harbour to show that phosphorus in the water responds well to load reductions. Moreover, the response of water quality indicators chlorophyll and Secchi transparency is consistent with expectations of OECD worldwide relationships. Thus, there is little doubt that proposed expansion of a local sewage plant would harm the harbour or that the RAP goals can be achieved by nutrient load reductions. A new proposal to discharge the treated sewage into Lake Ontario instead of the harbour is discussed.

KEY WORDS:

Hamilton Harbour
Phosphorus
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Eutrophication
Population

Management Perspective

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EC Priority/Issue The Hamilton Harbour Remedial Action Plan (Can. U,S. GLWQA)

Background: Population growth in Halton Region requires an expanded sewage plant (STP). During an EA the original option chosen was to expand the STP and maintain discharge into the Harbour with no enhanced treatment. This would have increased phosphorus loads. This material was prepared originally for the agency (BAIT) and public bodies (BARC) directing the remedial action plan (NWRI NO. 96-51). The harbour responds directly to improvements at sewage plants. There is good evidence that the response is as predicted by worldwide OECD studies. Therefore the remedial action plan phosphorus targets are supported. The BAIT and BARC did not accept Halton's original proposal. The new proposal of Halton which is to discharge the treated sewage via a new outfall in Lake Ontario would amount to about 2% of the municipal/industrial phosphorus load to Lake Ontario.

Next Steps: Publish the manuscript in the above journal. Physical and Chemical studies of the affected area in Lake Ontario are being conducted in coordination with OMEE. Studies are intended to lead to prediction of the lifespan of present sewage disposal practices (sustainability).

The Great Lakes Water Quality agreement (GLWQA) between Canada and the United States of America of 1978 sought to address the remaining acute pollution situations in the Great Lakes. By identifying 43 " Areas of Concern" (AOCs) and recommending on the formation of Remedial Action Plans (RAPs) the agreement stimulated an unprecedented amount of assessment, consensus building, and community action to bring about improvements.

Eutrophication was one of the first issues addressed by previous versions of the GLWQA. About $15B was spent to construct sewage treatment plants (STPs) in the Great Lakes area in order to reduce nutrient loading and anthropogenic eutrophication. Dramatic results were achieved, most notably the 50% reduction in phosphorus concentrations in Lake Ontario and in the west basin of Lake Erie. Algal blooms decreased in frequency and accumulations of filamentous algae on shorelines were reduced. Eventually, eutrophication began to be perceived as a "mature issue" that could be ignored. Under the RAP processes, however, the analyses of beneficial use impairments showed eutrophication problems in 22 of the original 43 AOCs.

Figure 1 (Hartig and Law, 1994 and R. Kalinauskas. personal communication) shows that the implementation and restoration of beneficial uses in many AOCs are still in progress after 10 years of activity. The Hamilton Harbour RAP (L. Ontario, Ontario, Canada), for example, recommends a large decrease in nutrient loads (Rodgers et al. 1992). There has been little improvement yet in water quality because sewage loads have not decreased much since the RAP report was published (Charlton and LeSage 1996). Soon, however, benefits are expected as improvements in beach quality due to combined sewer overflow containment and as water quality improvements due to progressive optimization of the STPs. To meet the RAP goals in Hamilton Harbour, however, expenditures of up to $390M are required to improve the largest STP (Stirrup 1996).

Against a backdrop of accumulated sewage treatment deficit, the situation may gradually become worse. Population growth presents a problem for the RAP areas because increasing amounts of sewage must be treated. Hamilton Harbour receives treated sewage from four STPs. The two smallest STPs are in Dundas and Waterdown (both Hamilton-Wentworth Region). The two largest STPs are in Hamilton (Hamilton-Wentworth Region) and in Burlington (Halton Region). In 1995 an environmental assessment (EA) process was begun to address the problem of how to treat the sewage of an additional 50,000 people in the area served by the Skyway STP in Burlington. In 1996, another EA has begun to address increasing flows to the Dundas STP. This paper presents information developed to provide the basis of advice to the Bay Area Implementation Team (BAIT) and the Bay Area Restoration Council (BARC) with regard to the EA required to expand the Skyway STP.

The Scale of Proposed Expansion at Skyway STP

The RAP documents do not consider expansion of STP nutrient loads into the Harbour. Indeed, the success of the RAP depends on nutrient load reductions. The increased population served by the Skyway STP would cause a designed flow increase from the present 93,000 m^3/d to 140,000 m^3/d to the year 2011 (W_2O, 1995).

Table 1 presents phosphorus load scenarios at the 1994 flow volume, the present design maximum flow volume, an interim expanded flow, and the maximum proposed flow volume for Burlington's Skyway STP.

Table 1: Phosphorus load scenarios at various flow and effluent concentrations:

	Flow (1000s) m^3/d	Concentration mg/l		Load kg/d	RAP Target
	77	1.00		77	
	77 (1994 actual)	0.50		38.5	
design flow	93 (conventional)	1.0	(permitted)	93.0	
	93	0.50		46.5	
	93	0.32		***30.0***	***Initial***
	93 (tertiary)	0.13		***12.0***	***Final***
interim	120 (conventional)	0.50		60	
	120 (conventional)	0.30		36	
	120 (tertiary)	0.25		30	
	120 (tertiary)	0.10		12	
expanded	140 (conventional)	0.50		70	
	140 (conventional)	0.30		42	
	140 (tertiary)	0.25		35	
	140 (tertiary)	0.10		14	

Burlington's STP is currently allowed to discharge effluent of 1.0mg/l total phosphorus; a load of 93 kg/d would be produced at the maximum designed flow of 93,000 m^3/d. In 1994, the STP performed at an average of 0.50 mgP/l which would represent a load of 46.5 kg/d at the maximum design present flow. There were, however, periods early in the year, when under experimental trials, increased chemical addition achieved effluent concentrations of 0.30 mgP/l which, when coupled with good control of effluent suspended solids, resulted in a loading rate approaching the RAP target of 30 kgP/d. The eventual mean performance of the expanded conventional Burlington Skyway plant is unknown at this time. At a compliance limit of 0.50 mgP/l, a reasonably optimistic

expectation based on recent performance is that the plant could produce an average effluent of 0.30 mgP/l total phosphorus under optimal operation of conventional processes.

The problem for the RAP is that the expanded STP operating conventionally with an effluent of only 0.30 mgP/l would exceed both the initial and final RAP phosphorus loading goals.

Table 1 shows that tertiary treatment (effluent filtration) would enable the Skyway plant to meet the initial and final RAP goals. The operating range of tertiary treatment effluent is between 0.10 and 0.30 mgP/l (XCG 1995). Optimized tertiary plants can operate below 0.10 mgP/l in the effluent (XCG 1995). Thus, there is the opportunity to accommodate growth to 2011 and meet the RAP goals by utilizing tertiary technology. Further growth would need a new and unknown technology. Alternatively, RAP loading goals may be achieved by discharge to Lake Ontario.

Performance of Large STPs: Importance of Burlington

Part of the difficulty in understanding sewage problems is the mistaken belief that STPs, once built, will perform as hoped with no operational problems. Additionally, there has been a tendency to believe that Burlington's effluent was not important because the effluent load was thought to be much smaller than Hamilton's. This is not always the case as is illustrated by experience in 1994. STP performance data were obtained from A. M°CLarty of OMEE West Central office (personal communication). Monthly data of 1994 for the Burlington Skyway plant are shown in Fig 2.

The mean measured effluent concentration and load were 0.50 mg/l and 37.7 kg/d respectively. The interim RAP load goal for this plant is 30 kg/d. At an effluent annual average TP of 0.50 mg/l, this plant performed substantially better than its 1.0 mgP/l limit. The ability of the plant to produce the low loads of March and October is evidence that performance close to RAP requirements is possible. There was a steady degradation of performance during the critical months before and during the summer of 1994. The highest load was 2.7 times the lowest during the summer season when algal populations can grow on the excess phosphorus. The performance variations do not appear to have a simple relationship to the flow treated.

The Woodward Avenue STP (Fig.3) performed at 0.51mgP/l and an average load of 171.3kgP/d compared to the initial RAP goal of 140 kgP/d. The effluent average concentration in 1994 was well below the certificate of approval specification of no more than 1.0 mg/l. Again, there was a steady degradation of performance during the summer season. Comparing March to Sept, the load increased by 39% whereas the Burlington load increased by 270%.

Figure 4 shows the 1994 combined load for Burlington and Hamilton. The combined degradation of performance during the warm months resulted in some of the highest loads during the summer period. As a percentage of the combined Burlington plus Hamilton load, the Burlington load was more than 25% during the summer.

About one half of the water flowing into Hamilton Harbour is treated sewage. The phosphorus in treated sewage is 10-20 times more concentrated than in the ambient Harbour water. The difference is caused by processing in the Harbour and some dilution by stream flow. In the summer, the Harbour is thermally stratified into a warm upper layer and a cold lower layer. Then, the sewage flows into the upper layer and this may exacerbate the tendency to produce excessive algal growth.

In the summer period of 1994 (May to July) when phosphorus loads are critical for water quality, Hamilton's load increased by 59 kgP/d and Burlington's load increased by 24 kgP/d. Thus, in quantitative terms, Burlington's load increases, were about one third as important as Hamilton's. During the 1994 season, phosphorus concentrations increased in Hamilton Harbour so that the mass in the top 10 m increased at 68kg/d; variations of more than 0.01 mgP/L occurred in this and other years whereas bottom water concentrations were more stable (Charlton and LeSage 1995, 1996). Thus, the concentration changes seen in the Harbour in 1994 are consistent with the degradation in performance at the Burlington and Hamilton STPs added to the effect the STP effluent would have due to thermal stratification. The effects of the Burlington STP cannot be marginalized or assumed unimportant simply because the overall load is less than Hamilton's.

The performance of both main STPs was highly variable in 1994. Moreover, the Burlington STP represented about %25 of the phosphorus load in the summer. In 1995, Halton Region initiated, on a cooperative partnership basis, an internal assessment/optimization approach to the operation of its sewage treatment plants. A multi-disciplinary team including management representatives and technical personnel have been involved in the assessment of the Burlington Skyway plant. A number of operational control strategies have been changed and other efforts are underway to accommodate some of the current constraints of the facility. It is anticipated that this

will help to eliminate some of the significant variations identified above.

Progress in the last 10 years: predicting the future

There has been a large reduction in STP loading beginning in the 1970s. Progress in the last 10 years at the Burlington and Hamilton plants is shown in Fig.5. In the last 10 years, reductions in STP phosphorus loads have occurred mostly at the Hamilton plant which is the larger of the two (345000 m^3/d vs. 77000 m^3/d in 1994). Consequently, Burlington's proportion of the total has risen to about 25% since 1989. Burlington's effluent has, however, improved substantially in 1993 and 1994 with several months below 0.50 mg/l phosphorus.

The summer concentrations of phosphorus in the Harbour during 1984-94 have responded in proportion to the reductions in the combined Hamilton plus Burlington load (Fig.6). The total summer phosphorus concentrations used in Fig.6 are probably about 0.01 mg/l higher than the mean. The RAP predicted that, when its initial goal of 170 kgP/d for the two large STPs was met, the concentration of phosphorus in the water column would be about 0.034 mg/l. Although these initial goals have not yet been met, Fig. 6 shows that the relationship between concentrations of phosphorus measured in the centre of the harbour and the actual loadings reductions achieved to date is consistent with the predicted relationship. The response relationship in Fig. 6 shows that the RAP final goal of 0.017 mgP/l in the Harbour would likely be achieved at the final target load of 72 kgP/d from the two plants. In other words, reality confirms the accuracy of the RAP's understanding of how the Harbour responds to loadings reductions from the two main STPs

The main point of Fig.6 is that the initial and final goals of the RAP for ambient phosphorus concentrations in the Harbour can be approached largely by phosphorus load reductions at the Hamilton and Burlington STPs. The relationship in figure 6 provides reassurance that continued nutrient reductions will result in lower ambient phosphorus levels. Conversely, increasing nutrient loads will reverse the progress and cause higher phosphorus levels. Admittedly, the exact Y intercept in Fig 2 is unknown because monitoring at STPs is just beginning to provide improved estimates of loads. The change in load was however so dramatic that the slope of the relationship is probably reliable.

Response of Hamilton Harbour Water Quality Indicators to Nutrient Loading

Throughout years of rampant pollution a myth developed that Hamilton Harbour was so damaged that repair was impossible. Indeed, there are large areas of shoreline in which fish habitat was physically destroyed and there was little public access. The decades of serious pollution necessitated controls in advance of the RAP and the results of these controls allow a projection of future conditions which demolishes the myth. In addition, results to date can be tested against well founded expectations. A study sponsored by the Organization for Economic Cooperation and Development (OECD) was begun in 1972 to discover the relationship between nutrients and the trophic state of lakes. This study (Vollenweider and Janus, 1981) provided statistical analyses of the average relationship between phosphorus and chlorophyll and between chlorophyll and Secchi transparency. Over one hundred Canadian lakes were included in the study as well as hundreds of other lakes worldwide.

The statistical relationships are shown as the plotted lines in Fig.7. Chlorophyll concentrations curves are predicted from the phosphorus concentrations in the harbour on the X (bottom) axis. In turn, the Secchi transparency curves are predicted from the chlorophyll. The chlorophyll concentration and Secchi transparency in the harbour for 1984-94 are shown in the figure as solid symbols. The shaded areas in the figure represent the RAP initial and final goals for chlorophyll and Secchi transparency.

The OECD relationships in Fig.7, although not intended to represent any one particular case, are fairly accurate depictions of the actual situation in the Harbour. In other words, the maximum chlorophyll is actually about 30 ug/l when the mean is around 10 ug/l. Secchi depths are typically 1.5 to 2.0 m as in Fig.7.

Chlorophyll

Figure 7 shows that algal populations have responded well to load reductions at the main STPs. Several of the latest summer averages are below the initial goal of 15-20 ug/l. Following the trend to the RAP final phosphorus load goal of 72kg/d, the final RAP goal of 5-10 ug/l chlorophyll seems achievable, again, by load reductions at the two main STPs. The maximum chlorophyll in a season, however, can be three times the mean. Therefore, full achievement of RAP final phosphorus load goals at the Hamilton and Burlington plants will be necessary to effect acceptable algal populations.

Secchi Transparency

Figure 7 shows that Secchi depth has responded to phosphorus load changes in the last 10 years. The initial RAP goal of 2m is in sight as the average in 1994 and 1995 was almost 2m. The range of values is, however, 1.5 to 2.5 m. Thus, phosphorus loads will have to decline further to meet RAP initial goals. Extending the trend in Fig. 7 in the expected curvilinear shape, the data suggest that the final RAP goal of a 3m Secchi transparency will be achieved at the final RAP phosphorus load goal of 72 kg/d for the Hamilton and Burlington plants.

Hamilton Harbour's water quality is consistent with predictions based on the OECD worldwide data. There do not appear to be any reasons to expect fundamentally unusual responses. Now that the system is not heavily overloaded with phosphorus, water quality is responding and can be expected to respond in the future to decreased phosphorus loadings. This is shown by the downward slope for chlorophyll and the upward slope for Secchi transparency.

Discussion

The initial proposal of Halton Region in the EA process was that the capacity of the Skyway STP would be increased to handle the increased flow. No additional level of treatment was projected although bypassing of sewage would be prevented. This proposal was the result of consideration of many options. Understandably, there was concern that the option to add tertiary filters at an additional cost of $27M would just barely meet the RAP goals and would leave no capacity for growth past 2011. The data in this report (Charlton 1996) showed that the initial proposal would indeed harm the Harbour and would be contrary to the RAP. Both the BAIT and the BARC recommended against acceptance of the initial proposal.

Further deliberations in the EA process resulted in the current proposal which is to expand the conventional treatment at the STP and to discharge through a new outfall in Lake Ontario. This proposal would allow for the addition of tertiary filters in the future. In early December 1996, the current proposal had not yet been deliberated upon by Halton Council.

The current proposal may appear to contravene recommendation #50 of the RAP which was to the effect that sewage diversion would only be considered after all other practical alternatives were exhausted. Perhaps one viewpoint may be that incurring expenses for tertiary treatment before any other large municipality would be impractical in itself. The economic practicality of the lake discharge compared to filters in the Harbour depends on the length of the discharge pipe. The ability of the lake currents to disperse outfall flow increases steadily in the first four kilometres from shore (Murthy

and Schertzer 1994). Thus, the longer (and more costly) the outfall pipe the less likely will be any nearshore impacts on beaches or water intakes. The combination of lake discharge and tertiary filters would allow some growth past the plan end date of 2011 which would not be possible with a Harbour discharge.

Treated sewage damages small enclosed areas such as Hamilton Harbour because the sedimentation and dilution processes are insufficient to prevent high ambient phosphorus and algae levels. The algae infested water discharges from the Harbour canal in a low velocity plume parallel to local beaches. In the lake, the sedimentation and dilution capability is much larger so that deleterious nutrient concentrations would not occur given adequate outfall placement and design. The data presented in this paper indicate that removal of the nutrient load stress from STPs would be beneficial for the Harbour. A permanent benefit to the Harbour would occur and, by utilizing outfall diffusers and physical studies to site the discharge, the potential impacts on the nearshore area of Lake Ontario can be minimized.

The situation at Halton Region is an example of how population growth has the potential to negate the RAP process and progress. The solution chosen is consistent with practices at all other municipalities. These practices are, however, not sustainable in the far future. Nutrient load reductions have brought down ambient phosphorus in Lake Ontario to target concentrations, not below targets. Thus, the success of nutrient controls offers no reason to increase loads to the lake. As part of the same Halton Region plan that examined the Skyway STP, the existing discharge in Lake Ontario just east of Burlington will quadruple in size from 25,000 m^3/d to 100,000 m^3/d over the next 15 years. As well, the population of the nearby Greater Toronto Area will grow by 1.2 million in the same period and these additional people will add proportionately more sewage. Burlington's expanded plant would account for about 2% of current municipal and industrial phosphorus loads to Lake Ontario. It is clear that the threat to the lake from Burlington's or even Hamilton's STP is small compared to future growth in the Toronto area. At the moment, the 1 mg/L phosphorus limit in effluent which was so effective in controlling loads initially is still in place. This limit was effective in the Great Lakes basin because STPs had to be built and treatment at existing plants had to be upgraded. The 1 mg/L phosphorus limit does not confer any protection against increasing loads in the future. To counteract negative impacts on the lake during population growth there will have to be a period of optimized operations at the larger STPs. This period would be followed by installation of the next technology level eg: tertiary filters. The increased volumes of discharges may require that the outfalls be moved further offshore. Further population growth would eventually begin to degrade the lake back towards conditions in the 1960s. Clearly, now is the time to conduct studies which can predict the capability of sewage treatment technologies, the response of the lake, and the time left before alternative solutions must be in place.

Summary

Water quality improvements (phosphorus, chlorophyll, Secchi transparency) in Hamilton Harbour correlate well with phosphorus load reductions at the Hamilton STP and the sum of Hamilton and Burlington load.

The Burlington phosphorus load has been about 25% of the main STP combined loads since 1989.

The response of the main indicators of phosphorus, chlorophyll, and Secchi transparency is predictable and follows expectations; somewhat more nutrient load reduction is needed to reliably meet RAP initial goals.

The response of the main indicators of phosphorus, chlorophyll, and Secchi transparency indicate that full reduction of phosphorus loading to RAP final phosphorus load goals at the Hamilton and Burlington STPs will be needed to achieve RAP water quality goals.

Population growth can reverse progress in Lake Ontario made during the GLWQA if planning does not include alternates to present practices.

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Figure Captions

Figure 1: Status of Remedial Action Plans at 43 Areas of Concern.

Figure 2 Monthly 1994 flow and phosphorus concentration and load at Burlington Skyway STP.

Figure 3 Monthly 1994 flow and phosphorus concentration and load at Hamilton Woodward Avenue STP.

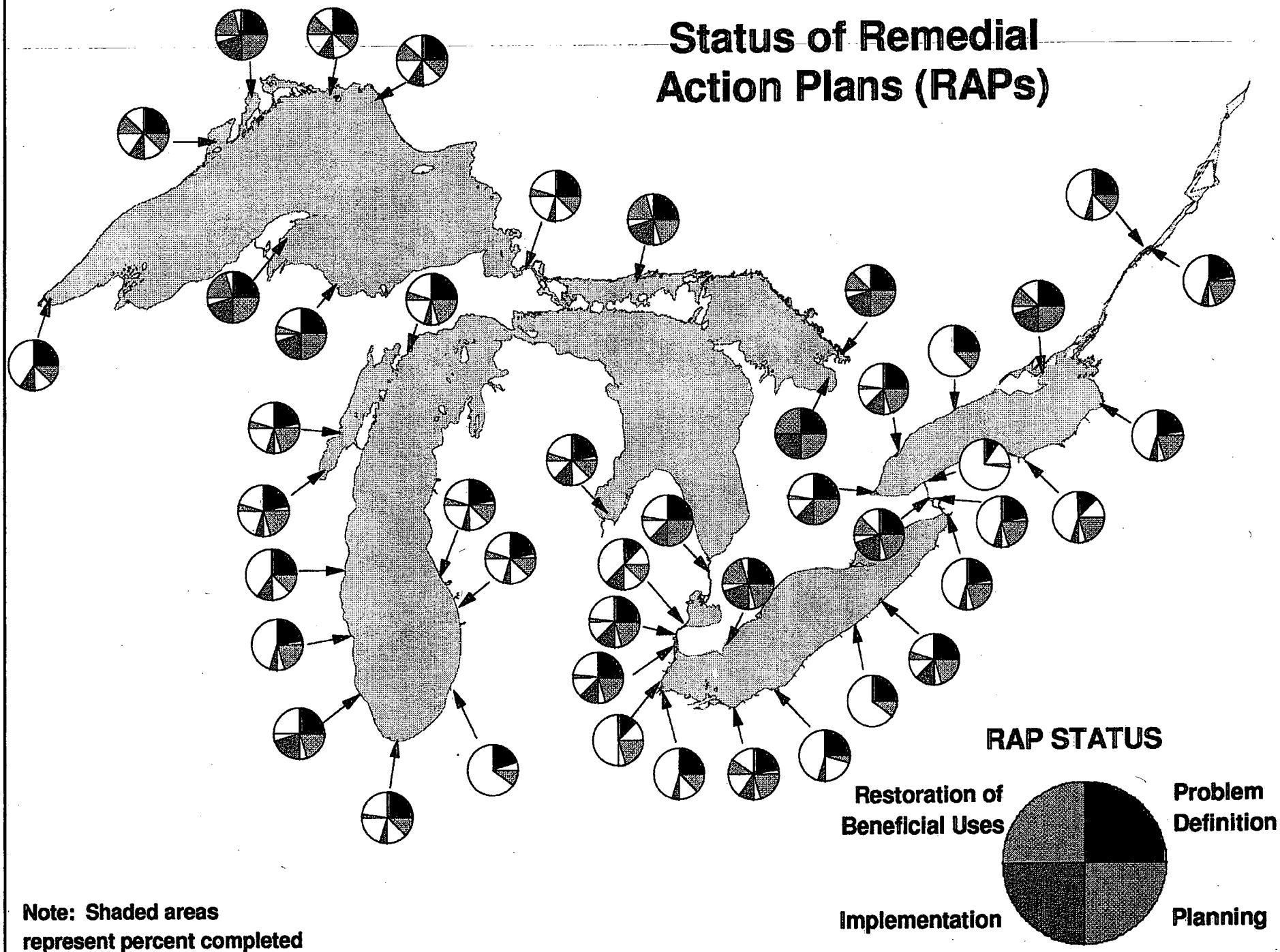
Figure 4 Combined phosphorus load from Burlington and Hamilton (squares) and percentage attributed to Burlington (circles).

Figure 5 Recent history of phosphorus load from Burlington and Hamilton into Hamilton Harbour.

Figure 6 Relationship between phosphorus concentration in Hamilton Harbour water (summer means) and combined load from Hamilton and Burlington.

Figure 7 Response of Chlorophyll and Secchi transparency to phosphorus concentration in Hamilton Harbour compared to expected range from OECD studies. Solid lines are expected from OECD studies (see text) and shaded areas are RAP initial goals and OMEE guidelines of 20 ugP/L which is close to the RAP final goal.

Status of Remedial Action Plans (RAPs)



Note: Shaded areas represent percent completed

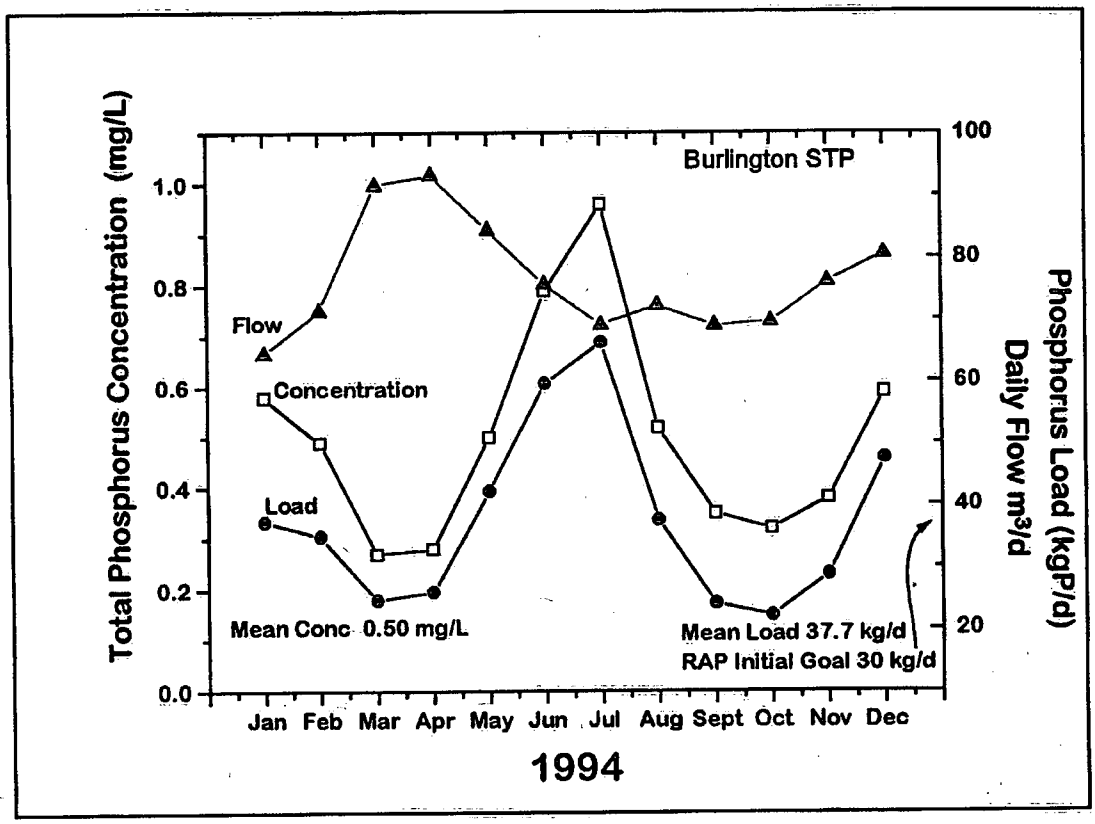


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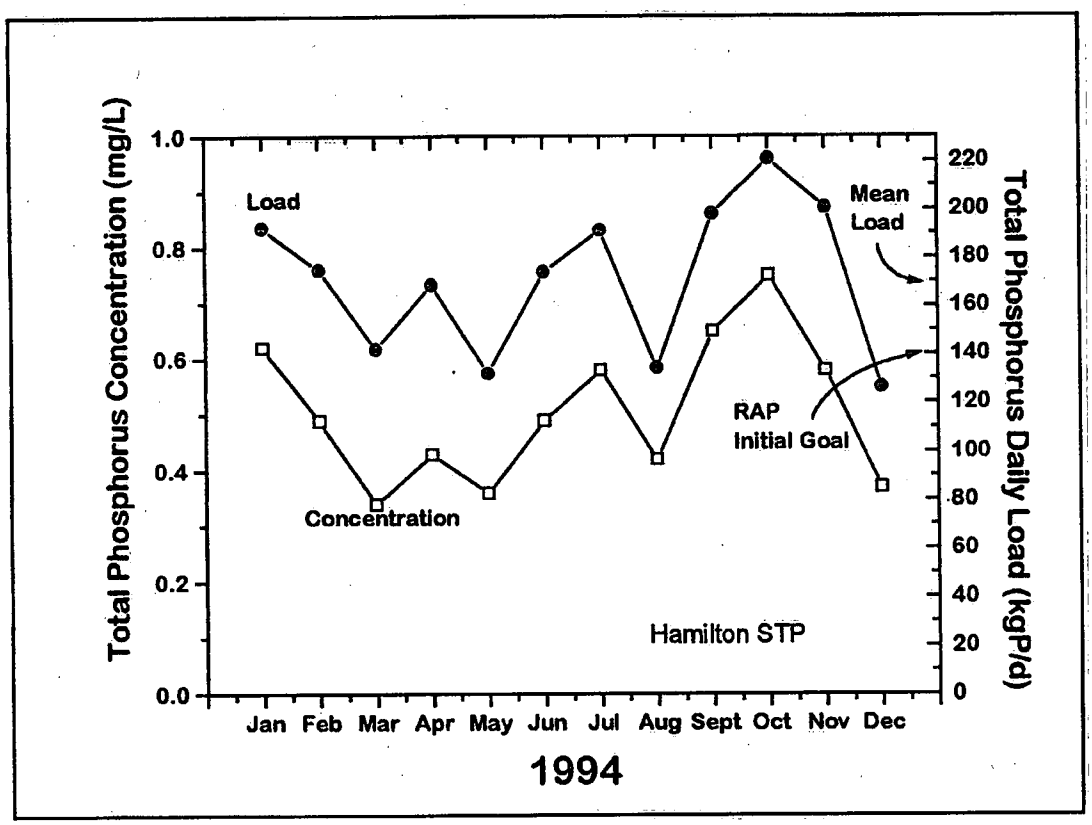
Fig. 2



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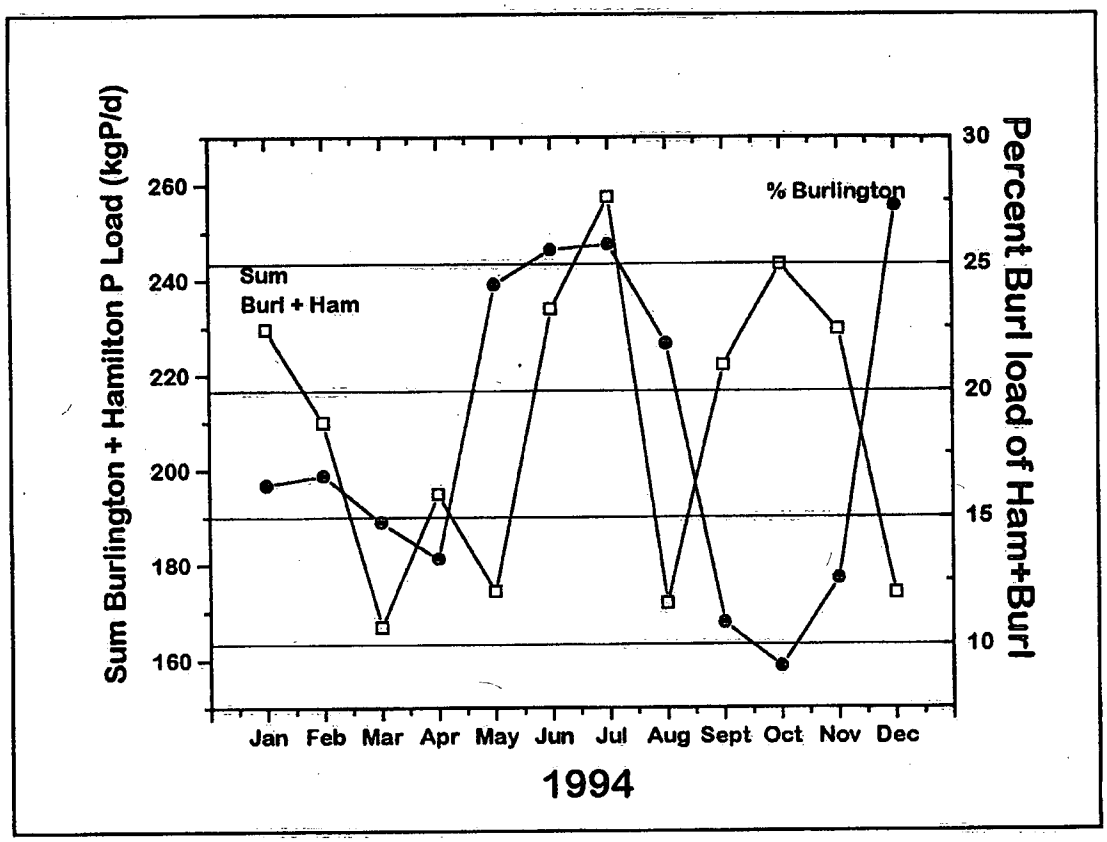

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Fig 4

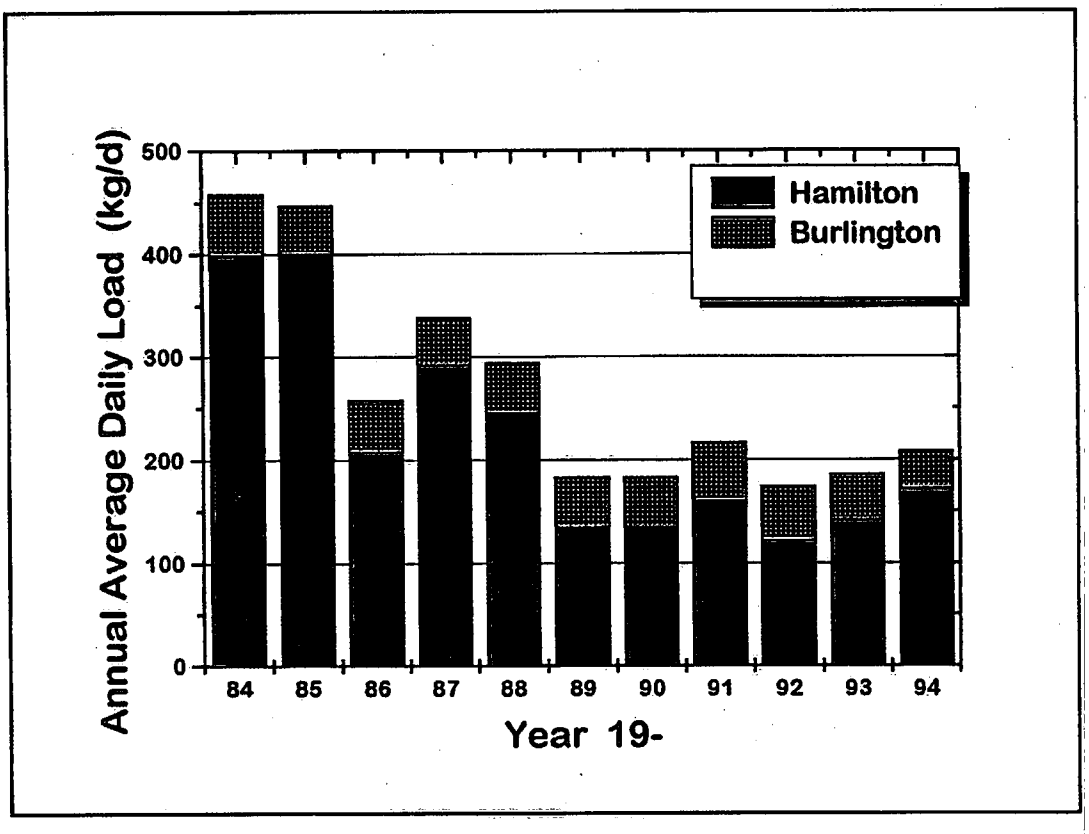

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Fig. 5

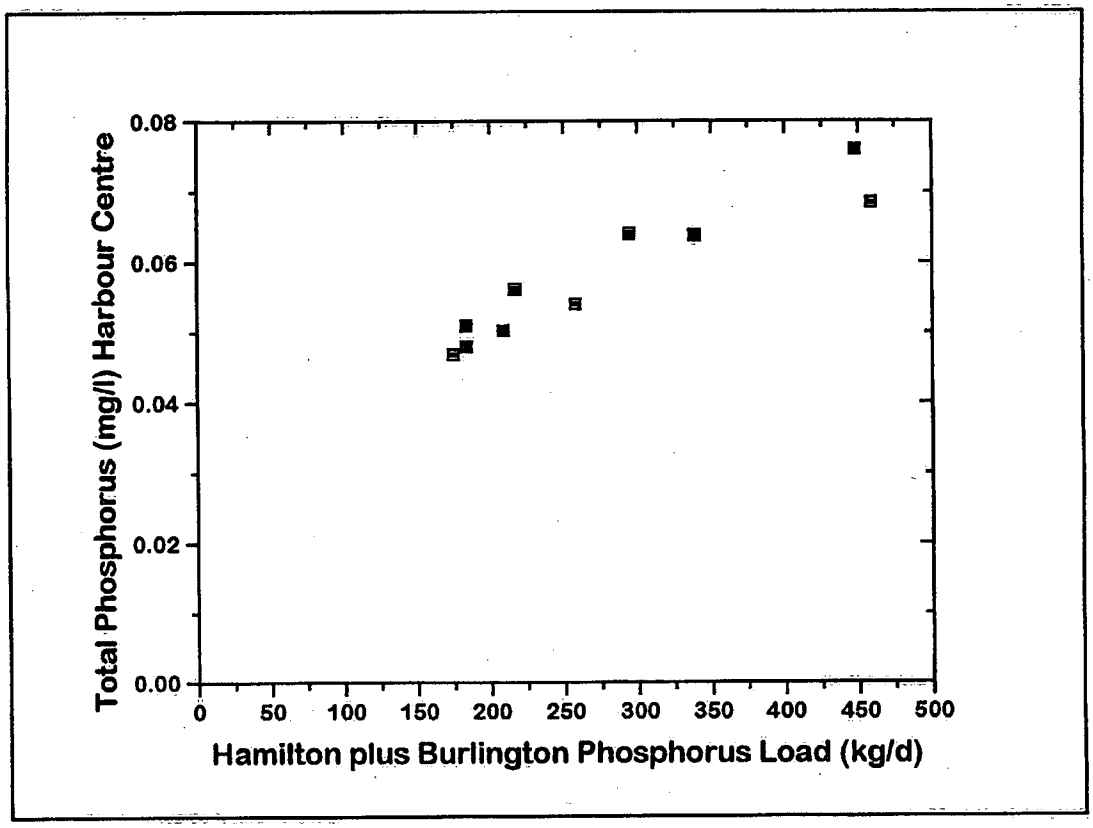

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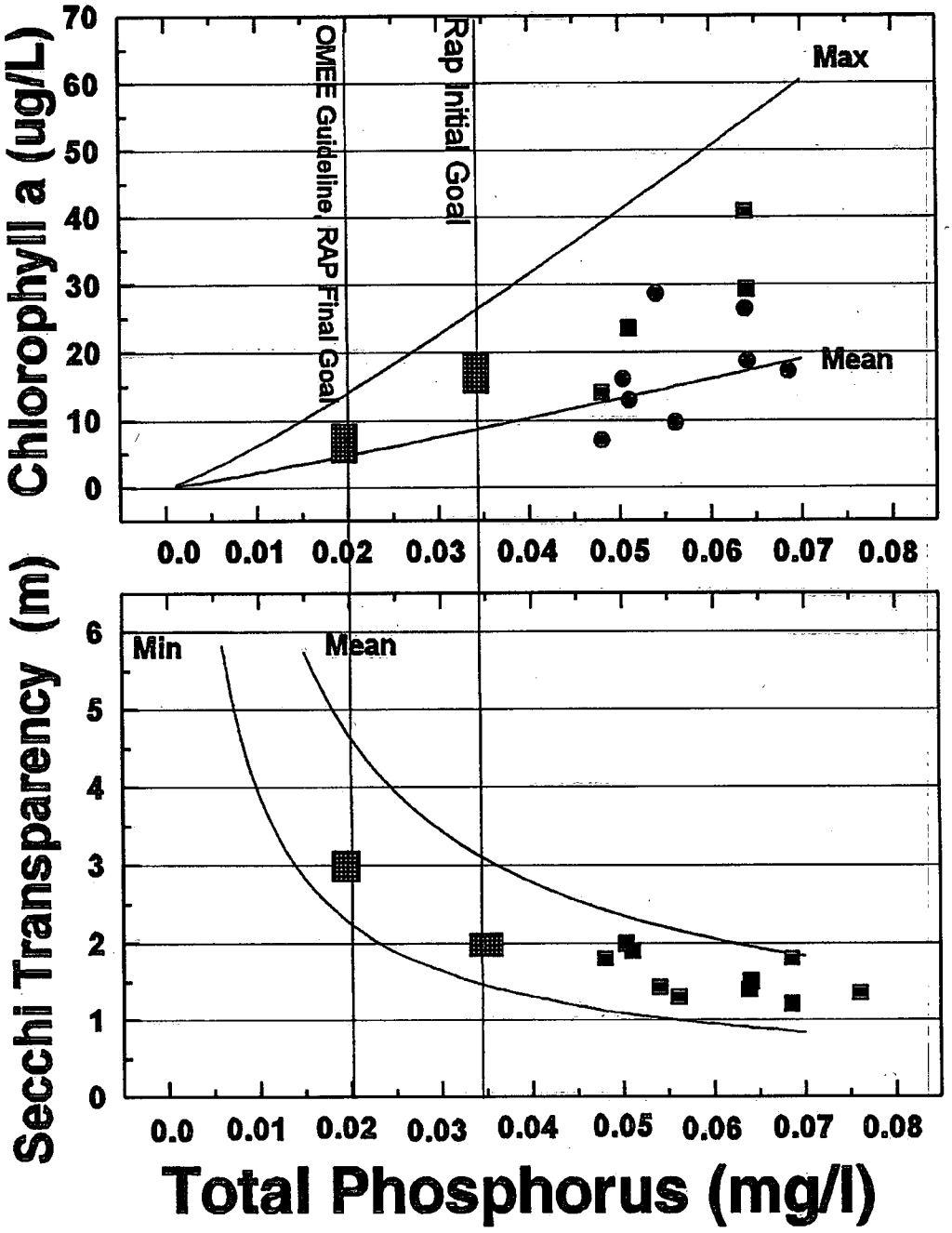
Fig. 6



Charlton Fig 7

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