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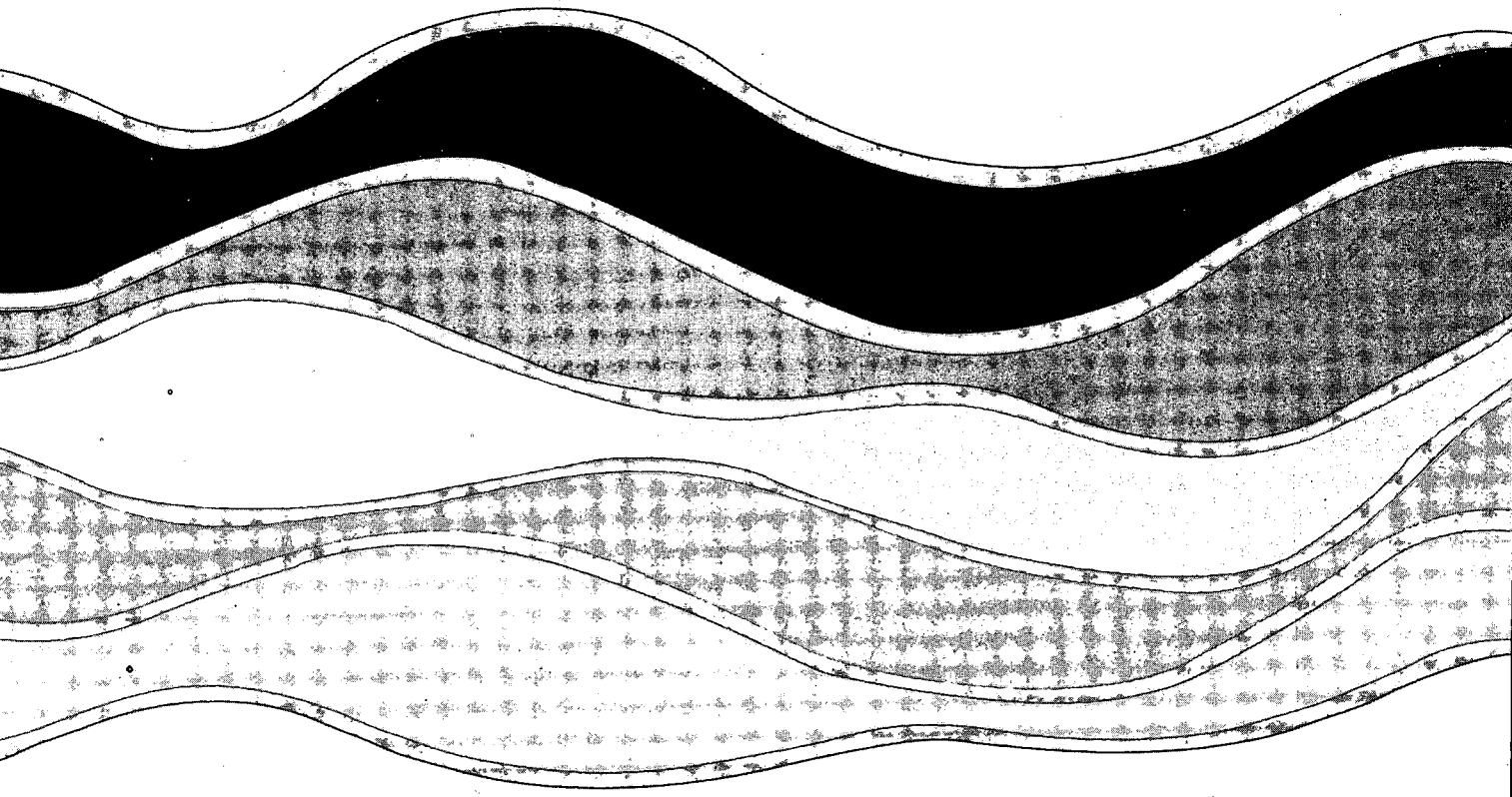

HAMILTON HARBOUR WATER CLARITY RESPONSE TO NUTRIENT ABATEMENT

S. Painter, L. Hampson and K. McCabe

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MANAGEMENT PERSPECTIVE

Hamilton Harbour is one of 42 areas of concern in the Great Lakes Basin. The Provincial and Federal governments are committed to develop a Remedial Action Plan (RAP) to improve water quality and restore the beneficial uses of the Harbour. The Stakeholders (representatives of industries, local governments, and organizations with a vested interest in the Harbour) compiled a list of principles, goals and beneficial uses that became the foundation of the RAP for the Harbour. Two uses identified by the Stakeholders depend on water clarity. Swimming, one of the desired beneficial uses, requires a Secchi disc transparency of at least 1.2 m in nearshore waters. The Stakeholders also identified improved fish habitat as a beneficial use. By improving water clarity the submergent aquatic plant distribution will expand.

In mid July of 1988, the Hamilton Wentworth Sewage Treatment Plant (STP) initiated a pilot study to assess the effectiveness of adding pickle liquor to the treatment process in an effort to remove phosphorus. The success of this study led to its continuation on a full-scale basis. This report compares the 1987, 1988, and 1989 data from the Harbour to determine if a significant increase in water clarity occurred as a result of the STP's improved chemical treatment. The phosphorus loading from the STP into the Harbour was reduced by approximately 50%, a reduction recommended by the RAP for improving water clarity in the Harbour. The Secchi disc transparency improved 40-50 cm to a summer mean of 193 cm. The area of submerged vegetation is predicted to increase 10 ha from its present 90 ha due to this improvement in water clarity. The water clarity guideline for swimming is still violated in the western end of the Harbour.

A reduction of 50% phosphorus loading at the Burlington STP, elimination of combined sewer overflows, and 15% reduction in soil erosion from the watershed have also been advised. Phosphorus loading and the resulting chlorophyll concentration are projected to be 300 kg/d and 9 μg/L, respectively. Water clarity may average approximately 225-250 cm which could increase aquatic plant distribution to 115-130 ha, an increase of 25-40 ha.
Additional loading reductions are possible which could reduce the phosphorus loading to 134 kg/d and potentially lower chlorophyll concentrations to 5 μg/L. Secchi disc transparency could possibly increase to approximately 3 m. Aquatic plant distributions could then increase to 170 ha, nearly double the present distribution.

PERSPECTIVE-GESTION

Le port de Hamilton constitue une des 42 régions d'intérêt spécial dans le bassin des Grands Lacs. Les gouvernements provinciaux et fédéral se sont engagés à élaborer un Plan de mesures correctives pour améliorer la qualité de l'eau et rétablir les utilisations du port. Les personnes concernées (représentants de l'industrie, des gouvernements locaux et des organismes ayant des intérêts de longue date dans le port) ont établi une liste de principes, de buts et d'utilisations qui a servi de base à l'élaboration du Plan de mesures correctives du port. Deux des utilisations déterminées par les personnes concernées dépendent de la transparence de l'eau : la baignade, qui exige une transparence au disque de Secchi d'au moins 1,2 m dans les eaux littorales, et l'habitat du poisson. Une amélioration de la transparence de l'eau aura pour effet d'accroître la distribution des plantes aquatiques partiellement submergées.

À la mi-juillet 1988, la station d'épuration des eaux usées d'Hamilton Wentworth a entrepris une étude pilote visant à évaluer l'efficacité de l'addition d'une liqueur de

décapage à la méthode de traitement, dans le but de retirer le phosphore. Le succès de cette étude a mené à son application à grande échelle. Dans le présent rapport, on compare les mesures effectuées dans le port en 1987, 1988 et 1989 pour déterminer si l'amélioration du traitement chimique de la station d'épuration des eaux usées a entraîné une augmentation notable de la transparence de l'eau. L'apport en phosphore provenant de la station d'épuration a été réduit d'environ 50 %, réduction recommandée par le Plan de mesures correctives pour l'amélioration de la transparence de l'eau dans le port. La transparence au disque de Secchi a augmenté de 40 à 50 cm pour atteindre une moyenne estivale de 193 cm. Par suite de cette amélioration de la transparence de l'eau, on prévoit que la zone de végétation submergée, qui couvre actuellement 90 ha, augmentera de 10 ha. L'objectif fixé en matière de transparence de l'eau pour la baignade n'est pas encore atteint à l'extrémité ouest du port.

On a également recommandé une réduction de 50 % de l'apport en phosphore à la station d'épuration des eaux usées de Burlington, l'élimination des égouts évacuateurs unitaires et une réduction de 15 % de l'érosion des sols du bassin versant. On prévoit que l'apport en phosphore et la concentration de chlorophylle qui en découlera seront de 300 kg/jour et de 9 µg/L, respectivement. La transparence de l'eau pourrait atteindre une moyenne d'environ 225 à 250 cm, ce qui pourrait accroître la distribution des plantes aquatiques jusqu'à une valeur de 115 à 130 ha, soit une augmentation de 25 à 40 ha. Il serait possible de réduire davantage les apports, ce qui pourrait abaisser l'apport en phosphore jusqu'à une valeur de 134 kg/jour et la concentration de chlorophylle jusqu'à 5 µg/L. La transparence au disque de Secchi pourrait augmenter pour atteindre environ 3 m. La distribution des plantes aquatiques pourrait alors atteindre 170 ha, soit près du double de la distribution actuelle.

ABSTRACT

Hamilton Harbour is one of 42 areas of concern in the Great Lakes Basin. The Provincial and Federal governments are committed to develop a Remedial Action Plan (RAP) to restore the beneficial uses of the Harbour. Swimming and fish habitat are two of the beneficial uses identified by the Hamilton Harbour Stakeholders. Both uses require improvements in the Harbour's water clarity. Beginning in 1988, the addition of a pickle liquor step at the Hamilton STP successfully reduced the phosphorus loading into the Harbour from all sources by 25%. A comparison of the 1987 and 1989 Harbour data showed that Secchi disc transparency increased between 40-50 cm, chlorophyll decreased 20 µg/L, and seston decreased 2.5 mg/L. The 1989 summer mean for Secchi disc transparency was 193 cm. The area of submerged vegetation could then increase 10 ha from its present 90 ha. The water clarity guideline for swimming is still violated in the western end of the Harbour. The data also suggest that Secchi disc transparencies in the 3 m range are attainable when chlorophyll concentrations are below 7 µg/L. With this increase in water clarity, aquatic plant distribution could then increase to 170 ha, nearly double the present distribution.

RÉSUMÉ

Le port de Hamilton constitue une des 42 régions d'intérêt spécial dans le bassin des Grands Lacs. Les gouvernements provinciaux et fédéral se sont engagés à élaborer un Plan de mesures correctives pour rétablir les utilisations du port. La baignade et l'habitat du poisson font partie des utilisations visées par les personnes concernées. Ces deux utilisations exigent une amélioration de la transparence de l'eau dans le port. Depuis 1988, l'addition d'une liqueur de décapage à la station d'épuration des eaux usées de Hamilton a réduit l'apport total en phosphore de 25 % dans le port. Une comparaison des données de 1987 et de 1989 montre que la transparence au disque de Secchi a augmenté de 40 à 50 cm dans le port, que la concentration de chlorophylle a diminué de 20 µg/L et que la concentration de seston a diminué de 2,5 mg/L. Au cours de l'été 1989, la transparence moyenne au disque de Secchi était de 193 cm. On prévoit que la zone de végétation submergée, qui couvre actuellement 90 ha, augmentera de 10 ha. L'objectif fixé en matière de transparence de l'eau pour la baignade n'a pas encore été atteint à l'extrémité

ouest du port. Les données indiquent également qu'il serait possible d'accroître la transparence au disque de Secchi jusqu'à environ 3 m si les concentrations de chlorophylle étaient inférieures à 7 µg/L. Par suite de cette augmentation de la transparence de l'eau, la distribution des plantes aquatiques pourrait alors atteindre 170 ha, soit près du double de la distribution actuelle.

INTRODUCTION

Historically, Hamilton Harbour supported generous and diverse populations of fish and wildlife but industrialization, urban development, and waste disposal practices have degraded the aquatic ecosystem of Hamilton Harbour. The morphology of the Harbour has changed drastically since the early 1800s (COA, 1988). Losses have amounted to an overall reduction of 68.6% of the original vegetated shoreline. Whillans (1979) concluded that the loss of the marsh vegetation along the south shore was a major factor that contributed to the decline of the warmwater fishery.

The Harbour is one of 42 areas of concern in the Great Lakes Basin. The provincial and federal governments are committed to develop a Remedial Action Plan (RAP) to improve water quality and restore the beneficial uses of the Harbour. The Stakeholders (representatives of industries, local governments, and organizations who have a vested interest in the Harbour) compiled a list of principles, goals and beneficial uses that became the foundation of the RAP for the Harbour. Two of the enhanced beneficial uses the Stakeholders identified depend on water clarity. Swimming, one of the desired beneficial uses, requires a Secchi disc transparency of at least 1.2 m in nearshore waters. Another beneficial use determined by the Stakeholders was improved fish habitat. By decreasing phosphorus, chlorophyll, mineral and seston concentrations, and thereby increasing Secchi disc transparency, water clarity improves and submergent aquatic plants may increase in area and density, thus improving fish habitat.

Beginning in mid July of 1988, the Hamilton Wentworth Sewage Treatment Plant (STP) conducted a pilot study to assess the effectiveness of adding pickle liquor to the treatment process in an effort to remove phosphorus. This project, initiated as part of the RAP and Great Lakes Water Quality Agreement, proved to be successful at removing approximately 50% of the total phosphorus from the discharge. The success of the pilot study led to the continuation of the treatment process on a full-scale basis.

Water clarity measurements for Hamilton Harbour, including Secchi disc transparency, seston, chlorophyll, and mineral concentrations, have been gathered from 1987 to 1989. This report compares the three years of data to determine if a significant increase in water clarity coincided with the Hamilton STP's loading reduction.

METHODS

Water samples were collected weekly at three locations, 28 times between May 8 and October 19, 1987; 29 times between April 11 and November 24, 1988; and 20 times between May 1 and September 27, 1989. The sampling locations and STP location are illustrated in Figure 1. The sampling locations were chosen to elucidate the factors responsible for the spatial variability in water clarity and the effect of inputs from the Hamilton STP.

At each sampling location, Secchi disc transparency and vertical extinction coefficients were measured. The vertical extinction coefficients were determined with a Biospherical Instrument Profiling Quantum Scalar Irradiance system with quantum response in the range of 400 - 700 nm. The downwelling irradiance was measured at 50 cm intervals at the open water stations.

Composite water samples for Chlorophyll a analyses were collected through a depth equal to twice the Secchi disc transparency to approximate the depth of the euphotic zone. Aliquots (0.2-1.0L) were filtered through GF/F glass-fibre filters (Whatman Co.), frozen, and analyzed later using the methods employed by the Water Quality Branch, Environment Canada (see Environment Canada 1979). The calculated chlorophyll concentration uncorrected for phaeophytin was used to assess the relative contribution of algae to the Secchi disc transparency because it takes into account that living as well as dead or decaying algal cells contribute to the water clarity. Seston and mineral concentrations were measured by filtering known volumes of water through Whatman GF/C filter papers. The mineral content was determined by muffling the total seston at 550°C for two hours.

RESULTS AND DISCUSSION

The water clarity data for the summer period from June 1 to September 30 was used to illustrate spatial patterns within the Harbour. The summer period was chosen for two reasons. Swimming is a long-term goal identified in the Remedial Action Plan for Hamilton Harbour (COA, 1988) and hence the summer period was most appropriate. The Remedial Action Plan for Hamilton Harbour also identified improved littoral fish habitat and hence increased aquatic plant abundance as an objective. The period chosen is the growing season for most aquatic plants.

Table 1 illustrates the 1987, 1988 and 1989 summer averages of Secchi disc transparency, extinction coefficient, seston, mineral, and chlorophyll, for Stations 258, 270 and 302, as well as the total phosphorus and suspended solids loading to the Harbour. The best water clarity during each year was found at the open water station (258). Secchi disc transparency at this station reached a summer average of 193 cm in 1989. The percent violations of the 1.2 m water clarity guideline for swimming are also presented in Table 1. Violations of the guideline at Station 258 did not occur during the last two years and the frequency of violations in the western end of the Harbour has decreased from 29 and 44% to 10 and 25% at Stations 270 and 302, respectively.

Extinction coefficient measurements, like Secchi disc transparency readings indicated an increased water clarity at all three stations during the three years. A 40-50 cm improvement in Secchi disc transparency was observed presumably as a result of the reduction in phosphorus loading. Seston and mineral averages were both lowest at Station 258. Chlorophyll concentrations were

similar at all three stations within any one year, but an 11-18 µg/L difference was observed over the three-year period. In an east to west transect along the three sampling stations, water clarity is impaired due to the influx of suspended solids from Cootes Paradise and Grindstone Creek, as well as the resuspension of sediments. Figures 2-4 illustrate the marked improvement between 1987 and 1989 for Station 258 Secchi disc transparency, chlorophyll, and seston. The 1988 data were intermediate between 1987 and 1989, but were omitted from the graphs since the Hamilton STP's incorporation of the pickle liquor process did not commence until approximately midway into the 1988 sampling period. Also, for eight weeks beginning in mid-May of 1988, a drought occurred which could also have affected water clarity.

The inclusion of a phosphorus removal step reduced the Hamilton STP's phosphorus loading from 290 to 240 and 160 kg/day in 1987, 1988, and 1989, respectively, which is approximately a 50% reduction. The summer average Secchi disc transparency increased 50 cm, chlorophyll decreased 20 µg/L, and seston decreased 2.5 mg/L. These water quality improvements coincide with and are likely a result of improved STP operations.

Figure 5 compares the total phosphorus loading into Hamilton Harbour with Secchi disc transparency and chlorophyll concentrations from 1975 to 1980 and 1984 to 1989. From 1975 to 1987 it appears that the phosphorus loading reductions into the Harbour did not significantly improve water clarity. When a phosphorus loading of approximately 500 kg/day and lower was reached a sharp increase in Secchi disc transparency was observed, as well as a marked decrease in chlorophyll concentrations. Record Secchi disc transparencies were observed in 1989.

Chlorophyll alone is a poor predictor of Secchi disc transparency. The regression coefficient (r^2) between chlorophyll and Secchi was 0.37. When extinction coefficients were regressed with chlorophyll, an even lower regression coefficient of 0.22 was noted. Figure 6 illustrates the Secchi disc transparency and chlorophyll relationship using the 1987-1989 data for all of the stations. As seen, the majority of the data points lie at a Secchi disc transparency of approximately 1.5 m and chlorophyll concentration of approximately 25 µg/L. Although the data points in the 2.5 - 3.0 m Secchi disc transparency range are scarce, a trend is detectable. Figure 6 suggests that Secchi disc transparencies of higher than 3.0 m are attainable when chlorophyll concentrations are less than 7 µg/L. Reported relationships between Secchi disc transparency and chlorophyll are also illustrated in Figure 6. The typical response reported by others lends validity to our prediction that Secchi disc transparency will likely improve to approximately 3.0 m. Possible loading reductions for the Harbour could reduce chlorophyll to approximately 6-7 µg/L (COA, 1988). With the addition of subsequent years data a more definite relationship between Secchi disc transparency and chlorophyll will be feasible. The water clarity improvements are consistent with expectations but our understanding of the

phosphorus/chlorophyll response and the chlorophyll/Secchi disc transparency response in the Harbour are too imprecise to allow extrapolation beyond the available data.

Speculations on the potential increase in area available for fish habitat due to the reduced chlorophyll and improvement in water clarity are also possible. Chambers and Kalff (1985) and Canfield et al. (1985) observed statistically significant relationships between Secchi disc transparency and the maximum depth of colonization of submergent plants. The hypsometric curve for the Harbour could then be used to predict the colonized area for any Secchi disc transparency (Figure 7). For the 1988 sampling period of Hamilton Harbour, Painter and M^{c}Cabe (1988) predicted the area covered by vegetation to be 93.5 ha. They actually observed 85 ha containing submergent vegetation. In 1987, aquatic plants were observed in approximately 90 ha throughout the Harbour (COA, 1988). A Secchi disc transparency of 3.0 m could provide approximately 170 ha available for plant colonization. The aquatic plant distribution could double with the improved water clarity possible with loading reductions suggested in the RAP for Hamilton Harbour.

CONCLUSIONS

The data collected from the Harbour and presented in this report confirm that Secchi disc transparencies in the 3.0 m range can be achieved when chlorophyll concentrations are below 7 µg/L. With the increase in water clarity, it is anticipated that 170 ha will become available for aquatic plant cover. As a result, the Stakeholders goals for the Harbour being utilized as a swimming area, as well as the improvement of fish habitat can be accomplished.

The inclusion of pickling liquor has reduced the phosphorus loading from the Hamilton STP by slightly less than 50% and reduced total loading from all sources by 25%. This reduction is one of the RAP's recommended actions for improving water clarity in the Harbour. The Secchi disc transparency improved 40-50 cm to a summer mean of 193 cm. These record high Secchi disc transparencies and associated low chlorophyll concentrations may be the first indications of a response to nutrient loading abatement. The area of submerged vegetation could increase 10 ha from its present 90 ha due to this improvement in water clarity. The water clarity guideline for swimming is still violated in the western end of the Harbour.

A reduction of 50% phosphorus loading at the Burlington STP, elimination of combined sewer overflows, and 15% reduction in soil erosion from the watershed have also been advised. Phosphorus loading and the resulting chlorophyll concentration are projected to be 300 kg/d and 9 µg/L, respectively. Our Figure 6 would suggest that water clarity may average approximately 225-250 cm which could increase aquatic plant distribution to 115-130 ha, an increase of 25-40 ha.

Additional loading reductions are possible which could reduce the phosphorus loading to 134 kg/d and potentially lower chlorophyll concentrations to 5 µg/L. Hopefully, Secchi disc transparency could average approximately 3 m. Aquatic plant distributions could then increase to 170 ha which is nearly double the present distribution.

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Table 1: Hamilton Harbour 1987 to 1989 Station Means for June 1 to September 30 Period

		1987	1988	1989
Station 258	Secchi (cm)	142	156	193
	% Violations*	21	0	0
	Ext Coef	1.27	1.14	1.06
	Seston (mg/L)	9.4	6.4	5.8
	Mineral (mg/L)	3.6	1.5	1.6
	Chl (µg/L)	41	28	23
Station 270	Secchi (cm)	134	148	182
	% Violations*	29	21	10
	Ext Coef	1.41	1.20	1.02
	Seston (mg/L)	8.2	6.8	6.0
	Mineral (mg/L)	2.8	1.8	1.8
	Chl (µg/L)	36	29	25
Station 302	Secchi (cm)	110	132	153
	% Violations*	44	38	25
	Ext Coef	1.68	1.30	1.18
	Seston (mg/L)	11.7	7.1	7.7
	Mineral (mg/L)	5.7	2.4	2.6
	Chl (µg/L)	37	25	25
Phos. Load (kg/day)		515	475	381
S.S. Load (kg/day)		50150	47610	48355

*not meeting the 1.2 m swimming guideline

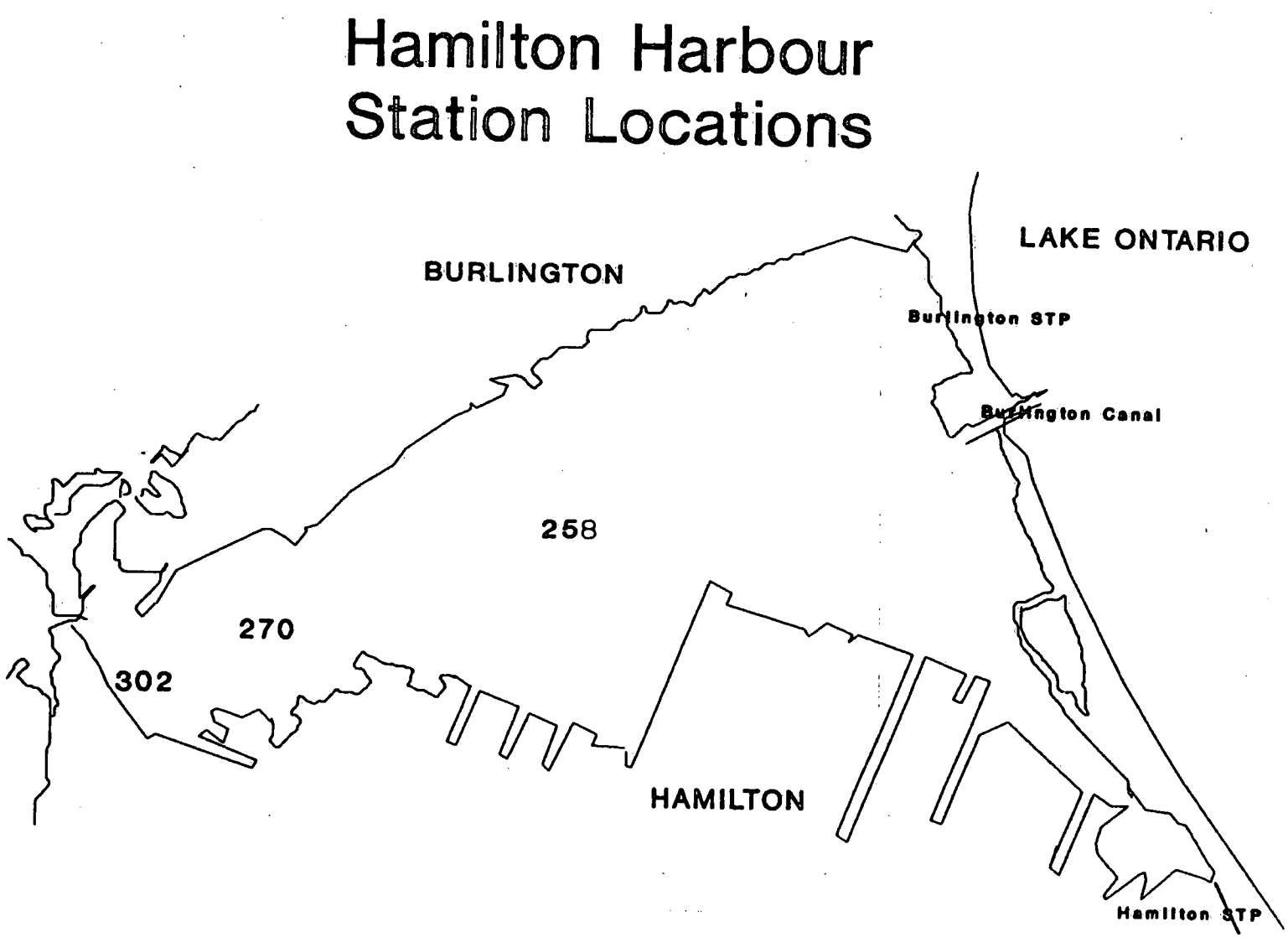


Figure 1. Hamilton Harbour station locations

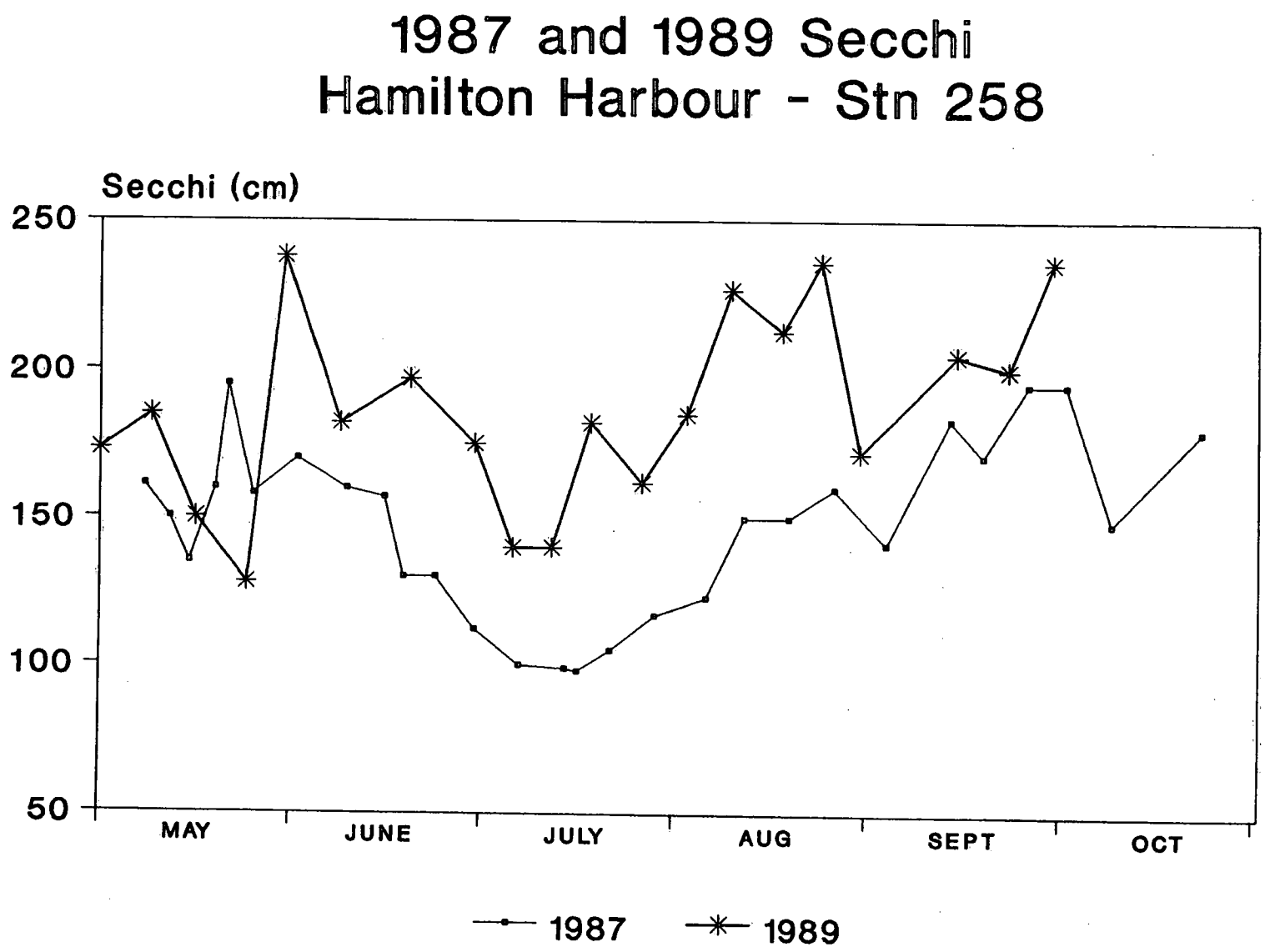


Figure 2. Seasonal Secchi disc transparency at station 258 for 1987 and 1989

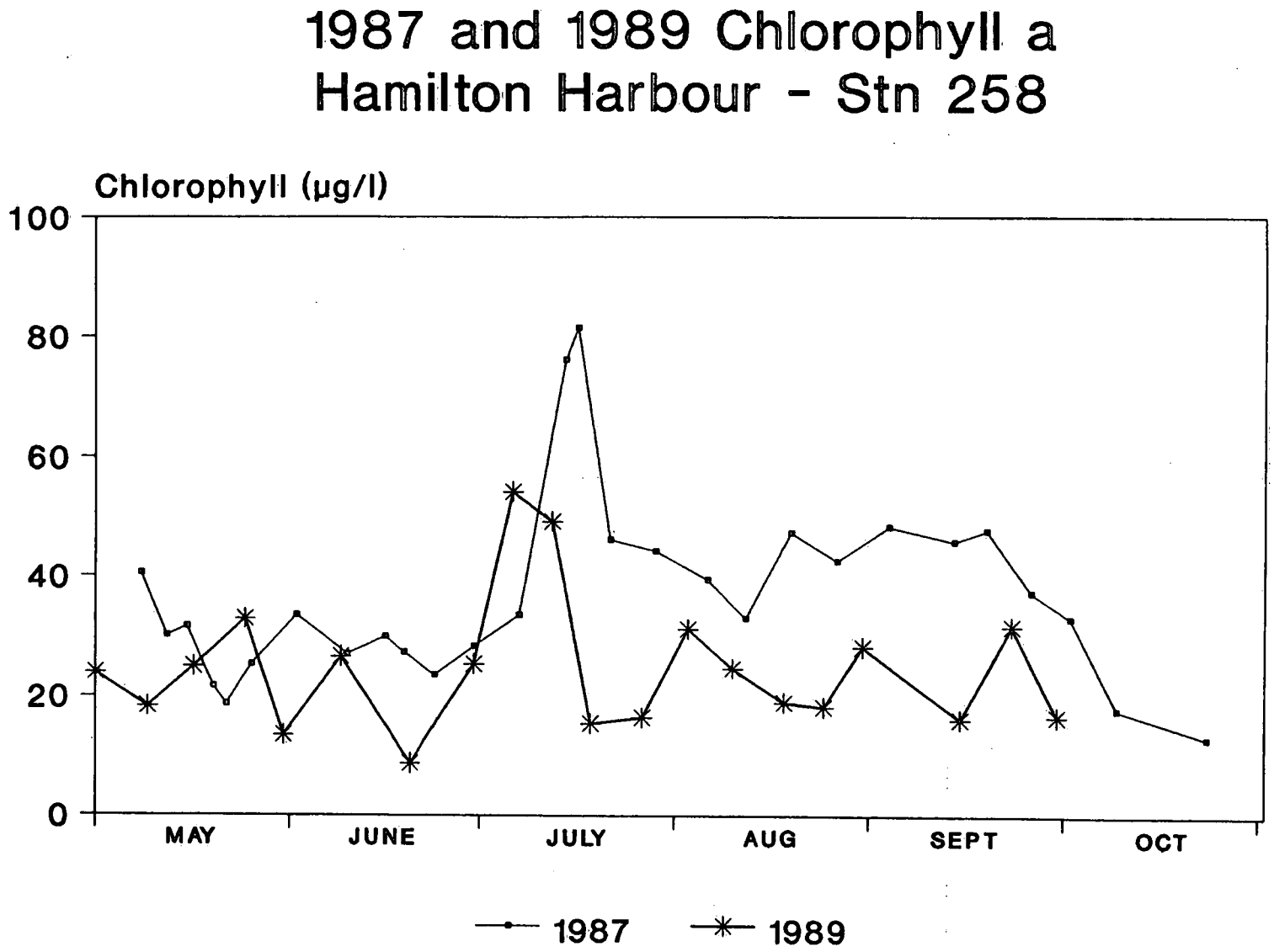


Figure 3. Seasonal chlorophyll concentration at station 258 for 1987 and 1989

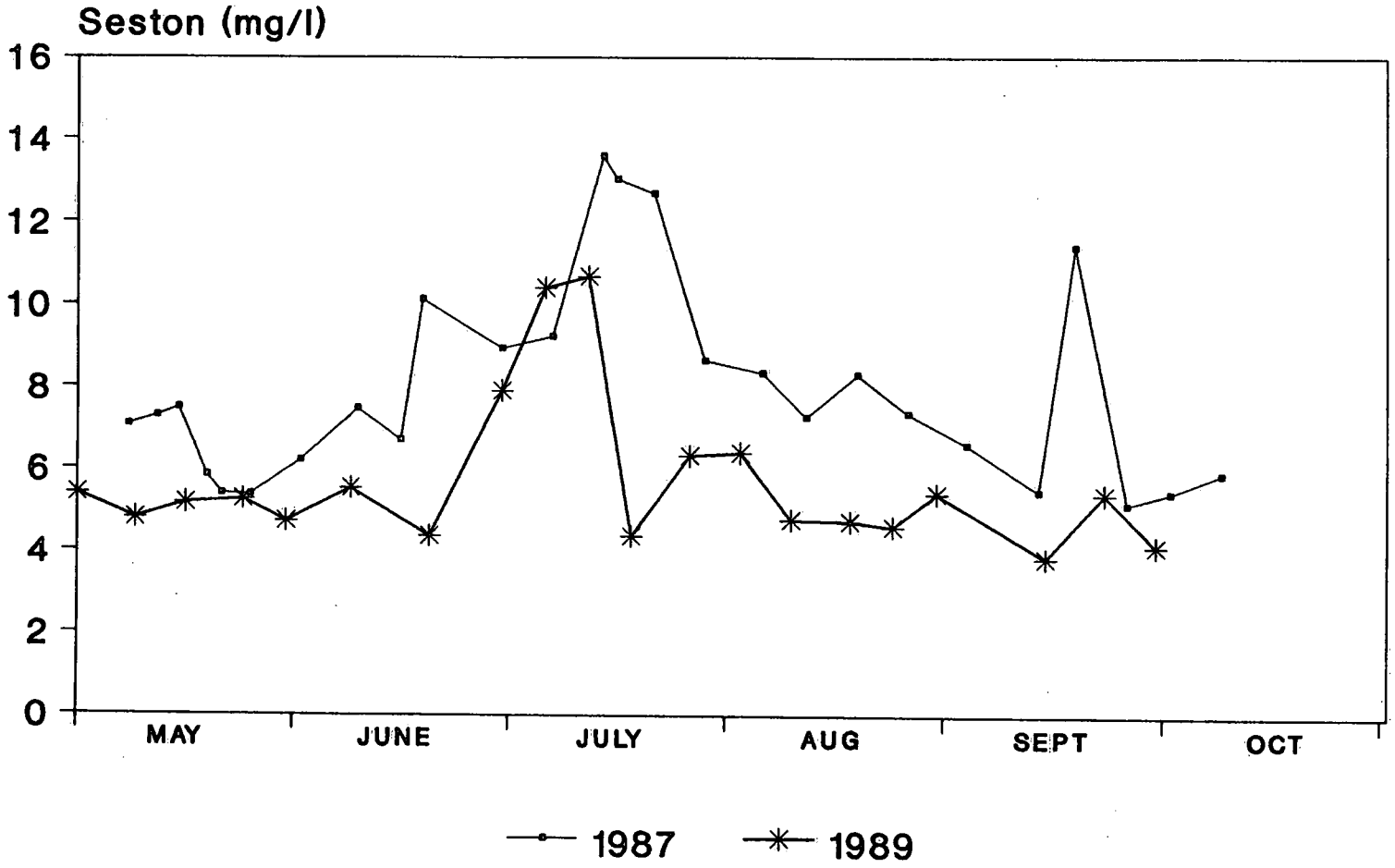


Figure 4. Seasonal seston concentration at station 258 for 1987 and 1989

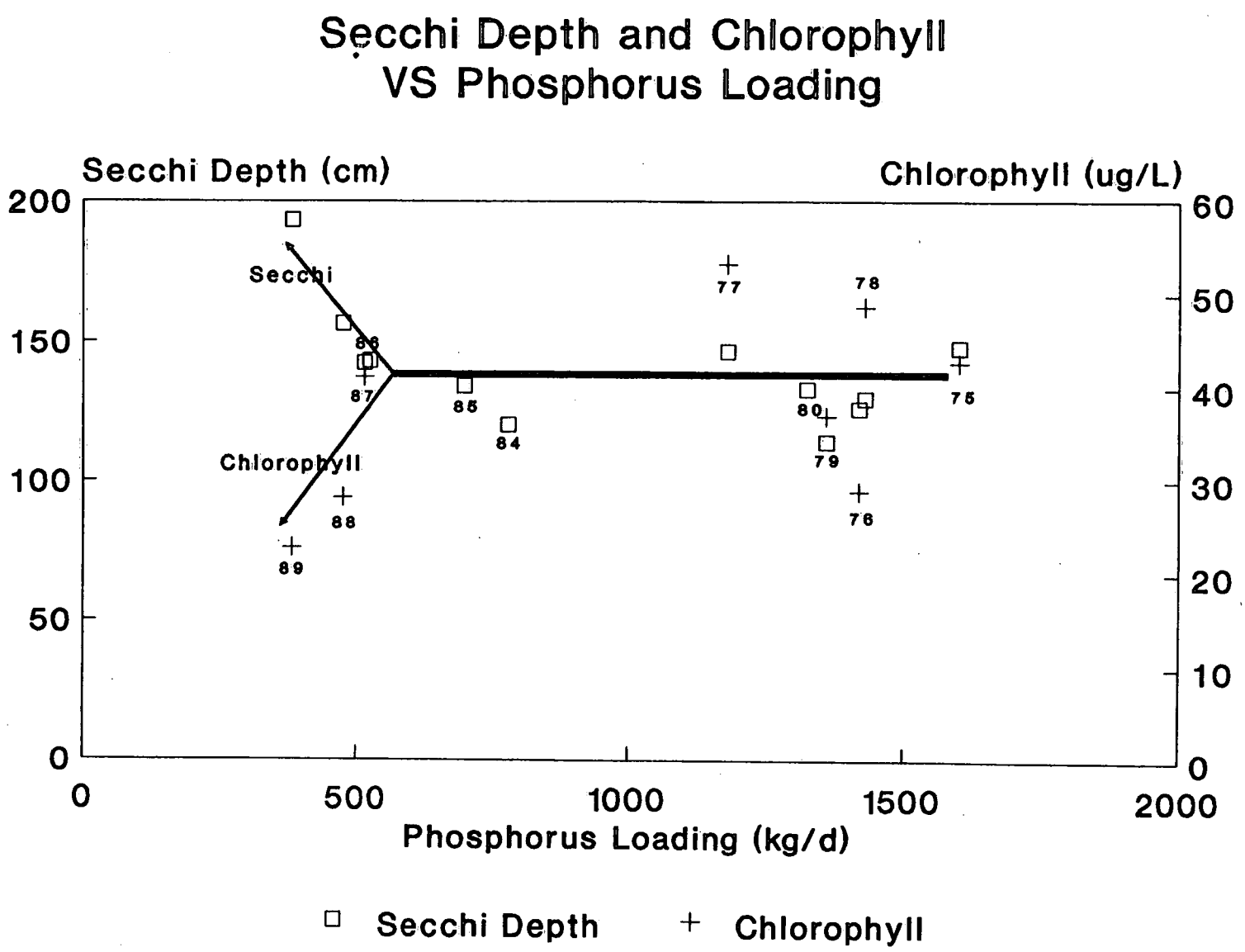


Figure 5. Mean Secchi disc transparency and chlorophyll concentration versus total phosphorus loading, 1975-1989

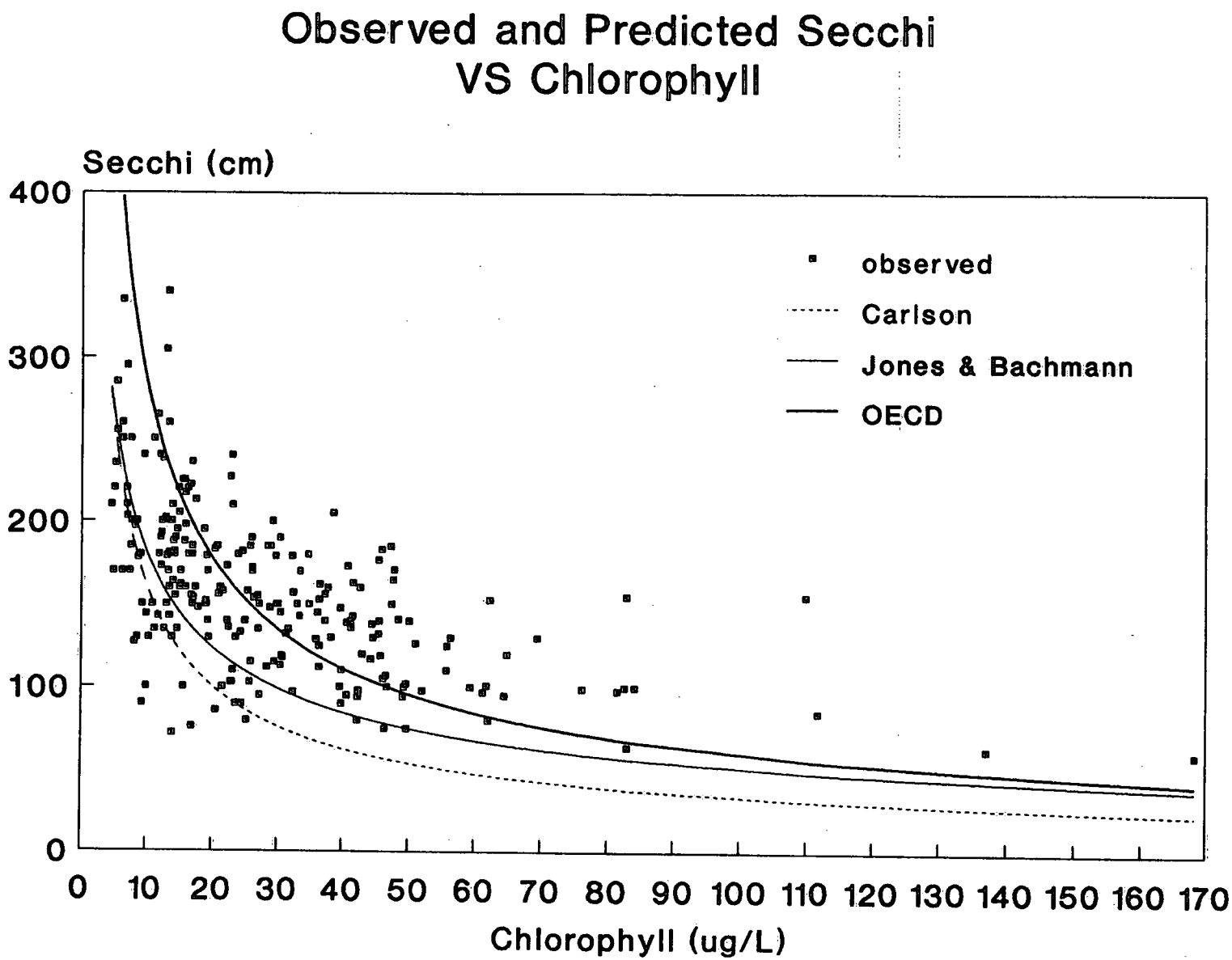


Figure 6. Chlorophyll concentration versus Secchi disc depth for all stations, 1987-89

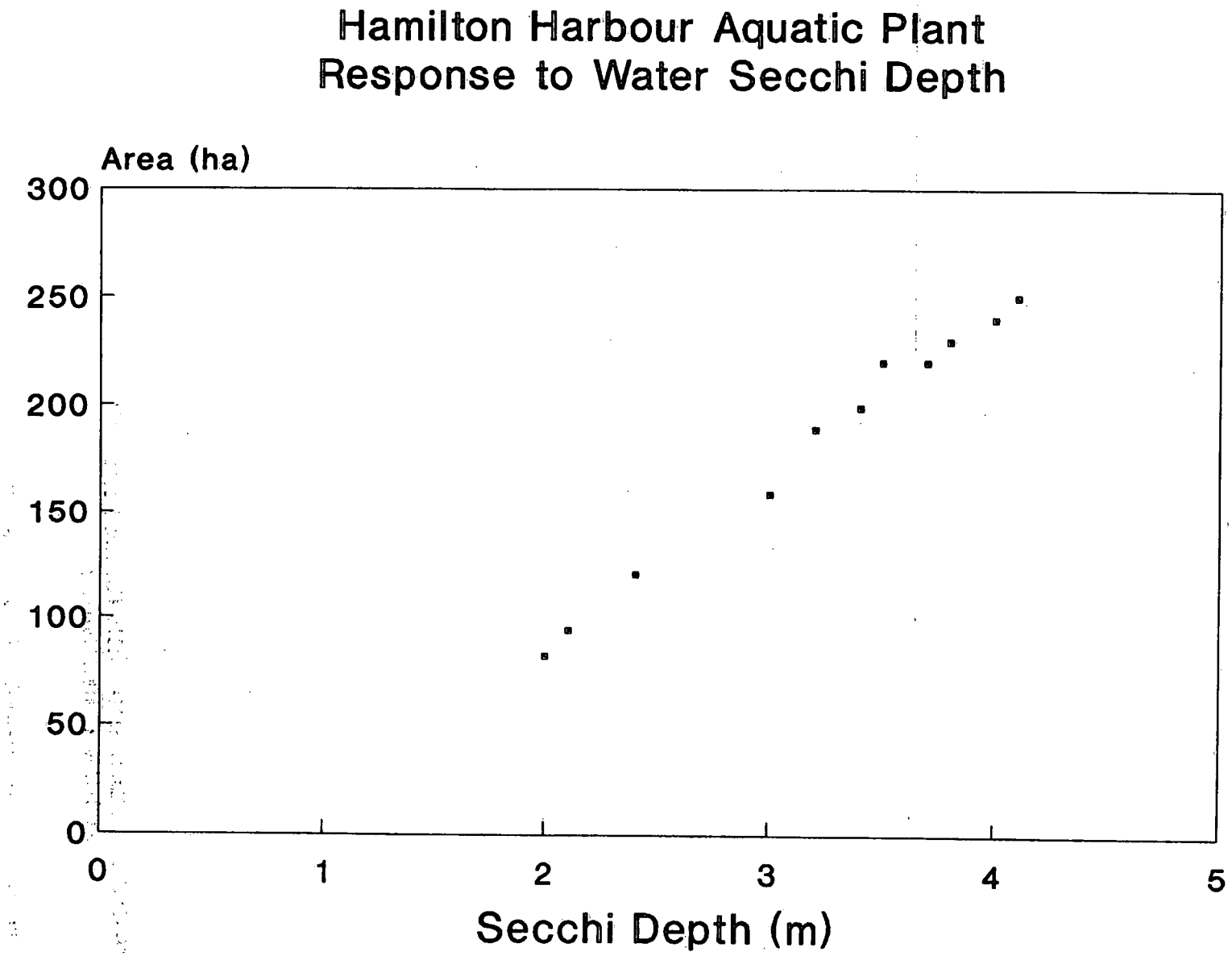
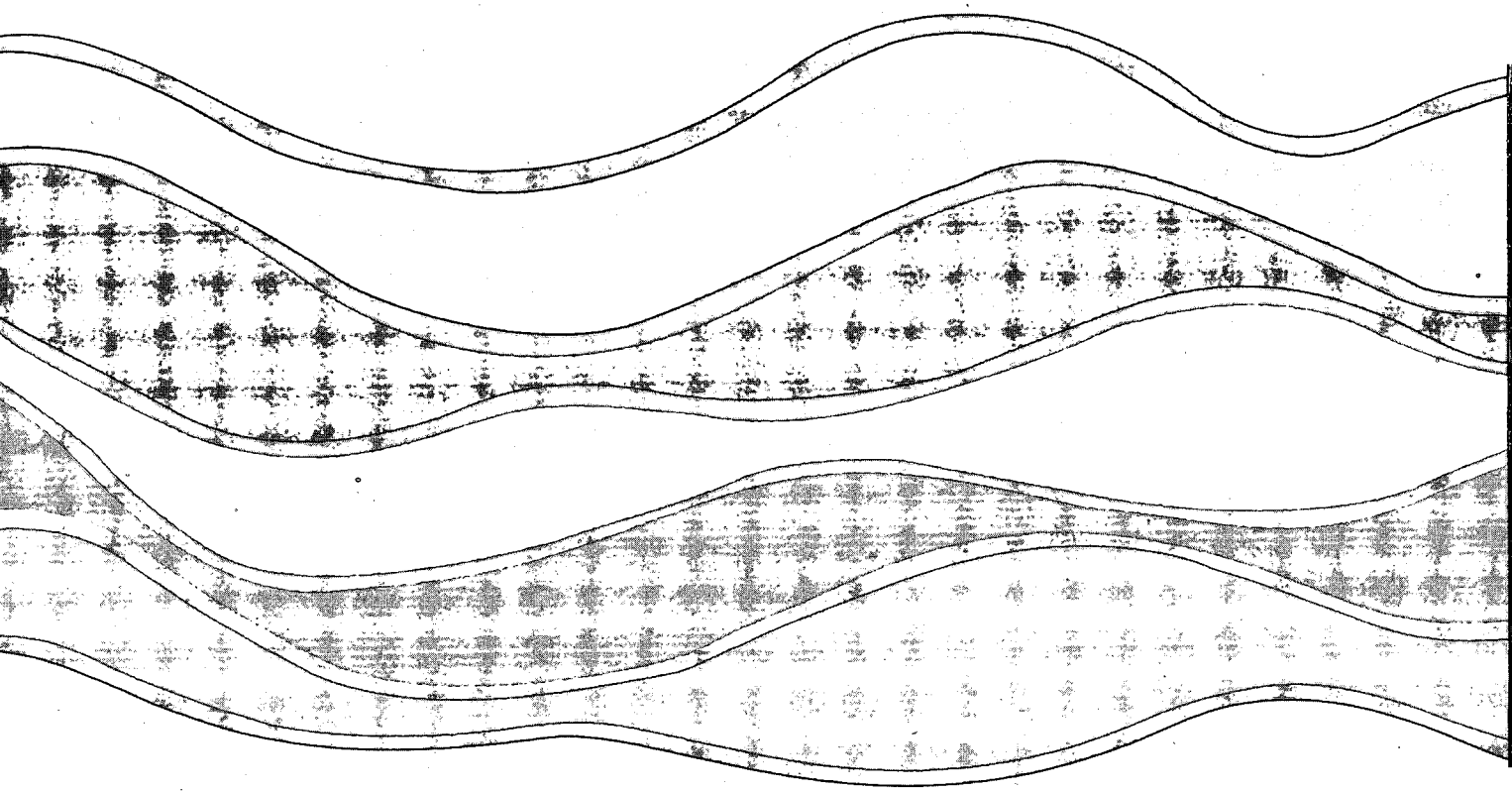


Figure 7. Predicted aquatic plant abundance versus Secchi disc depth



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