EFFECTS OF WASTEWATER RELEASES BY CITY OF VERNON ON VERNON CREEK AND VERNON ARM OF OKANAGAN LAKE IN 1984 AND 1985

by

J.E. Bryan, Head
Environmental Monitoring Section
Waste Management Program
Ministry of Environment and Parks
Penticton, British Columbia
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ABSTRACT

City of Vernon released wastewater with phosphorus removal for a two month period in the springs of 1984 and 1985. The total quantity of phosphorus released was low in comparison with the quantity of phosphorus discharged before land disposal and low compared with the quantity of phosphorus discharged annually from existing septic tanks. The wastewater altered several characteristics of Vernon Creek; there were increases in: nitrogen, phosphorus, specific conductance and chloride. Despite high concentrations of ammonia nitrogen, there was no evidence of acute or chronic toxicity from the wastewater. The discharge did not increase coliform numbers in Vernon Creek, but coliform numbers in Vernon Arm increased following the discharge in 1985 but not in 1984. There are several characteristics of Vernon Creek which do not meet B.C. quality criteria, but only ammonia nitrogen in Vernon Creek failed because of the wastewater releases.

The discharge increased the nitrogen concentration in Vernon Arm. The discharge may have slightly increased phosphorus and phytoplankton of Vernon Arm, although the effect of the releases is confounded with the effect of diffuse sources on water quality in Vernon Arm. Phosphorus and phytoplankton increases in Vernon Arm were very slight, considerably less than during the period of continuous discharge to Vernon Creek before City of Vernon began the spray irrigation program in 1977.

PREFACE

The objective of the Waste Management Program is to preserve the quality of the water environment of British Columbia at or above acceptable levels by managing the discharge of pollutants. The purpose of this report is to present the monitoring information collected to desribe the effects of releasing excess wastewater from City of Vernon in 1984 and 1985.

ACKNOWLEDGEMENTS

R.A. Nickel requested the study described in this report and provided the administrative support which made it possible. A number of people assisted with the sampling for this study: S.J. Rowe, J.M. Beatty, R.W. Townson, T.R. Forty, R.A. Nickel and S.J. Truscott. The following people assisted with the preparation of the report itself: K. Ballantyne, M. Storey, B. Russell and N. Crowe.

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1. INTRODUCTION

The City of Vernon provided some of the information presented in this report. Vernon released wastewater to Vernon Creek in 1984 and 1985. The City found it necessary to release this water because the storage reservoir for the spray irrigation was nearly full. Instead of spilling water out of the reservoir itself, the City discharged nearly all of the wastewater from the treatment plant to Vernon Creek for about 2 months in 1984 and 1985. The water was given secondary treatment and phosphorus removal before discharge to Vernon Creek. The wastewater was chlorinated and dechlorinated before discharge into a polishing lagoon and release into Vernon Creek.

TABLE 1. Comparison of City of Vernon's Wastewater released to Vernon Creek in 1984 and 1985.

	1984	1985
Start Day	March 27	March 19
Stop Day	May 18	May 14
Total Duration (days)	52	56
Total Volume Discharge (m^3)	348,000	433,000
Average Dilution Ratio in Creek	42:1	17.6:1
Total Phosphorus Released (kg)	348	217
% Phosphorus Removed by STP	88	94

Table 1 shows that the timing of the wastewater release was nearly the same in both years. It began in late March and ended in mid-May. (Forty MS 1985). The release occurred over a slightly longer time period in 1985 than in 1984, and slightly more wastewater was released in 1985 than in 1984. The volume of water flowing in Vernon Creek was considerably less in 1985 than in 1984. Consequently, the wastewater was less diluted in 1985 than in 1984 as shown in Table 1. Phosphorus removal efficiency of the sewage treatment plant was approximately 90% in the two years.

1.1 Characteristics of the wastewater

Table 2 shows some characteristics of the wastewater released by the City of Vernon in 1985. Most characteristics shown are normal for municipal wastewater. However, total phosphorus is quite low even for municipal wastewater with chemical removal. The value of total phosphorus in Table 2 is somewhat lower than the value used to calculate the total phosphorus loading for all of 1985 (Table 1). T.R. Forty calculated the value in Table 1 using City of Vernon data, which is a much larger set of observations than the 7 samples in Table 2.

TABLE 2. Characteristics of City of Vernon wastewater during discharge March to May 1985. Data are Ministry of Environment sampling results.

Parameter/ Units	Mean	Standard Deviation	Standard Error	Sample Size	Median
Ammonia N (mg/L)	11.7	3.56	1.34	7	13.5
Nitrate N (mg/L)	7.63	2.90	1.10	7	6.42
Total Phosphorus (mg/L)	0.394	0.125	0.047	7	0.350
Fecal Coliform MPN/100 ml	14.8	28.3	9.4	9	1.75

Table 2 shows that the ammonia concentration was approximately 12 mg/L. This concentration is normal for a sewage treatment plant. At the flow levels in Vernon Creek in 1985, this concentration of ammonia would theoretically cause sub-lethal, chronic toxicity to aquatic organisms. If the dilution fluctuates as it did in 1985, the ammonia concentration of the creek could have reached acutely toxic proportions as well. For this reason, effects of the Vernon wastewater release were monitored closely in Vernon Creek.

1.2 Features of Vernon Creek

Vernon Creek connects three lakes (Figure 1). The main flow of Vernon Creek begins in Kalamalka Lake. It flows toward Vernon where it receives BX Creek, a major tributary from Swan Lake. Approximately 1.5 km downstream of the confluence with BX Creek is the outfall from Vernon sewage treatment plant (STP). The water quality sampling sites are upstream (112002) of the STP, downstream (112003) of the STP, and at the mouth of Vernon Creek (0500091). There are a number of storm sewer outfalls into Vernon Creek and BX Creek. One of these outfalls is just downstream of sampling site 1120002. As shown in Figure 1 there are a number of sites where caged fish were held in Vernon Creek during the wastewater release in 1985. These fish cage sites are designated F plus a letter from A to D.

In order to determine the effects of the wastewater, observations were made in Vernon Creek and in Vernon Arm of Okanagan Lake. Water chemistry samples were collected in Vernon Creek upstream and downstream of the outfall and near the mouth of the creek (Figure 1). In addition, caged trout were kept in the creek in 1985 to determine whether the wastewater ever reached toxic proportions in the creek itself. In Vernon Arm, water chemistry and algae were sampled mainly at two locations, and a sampling grid was established for coliform bacteria.

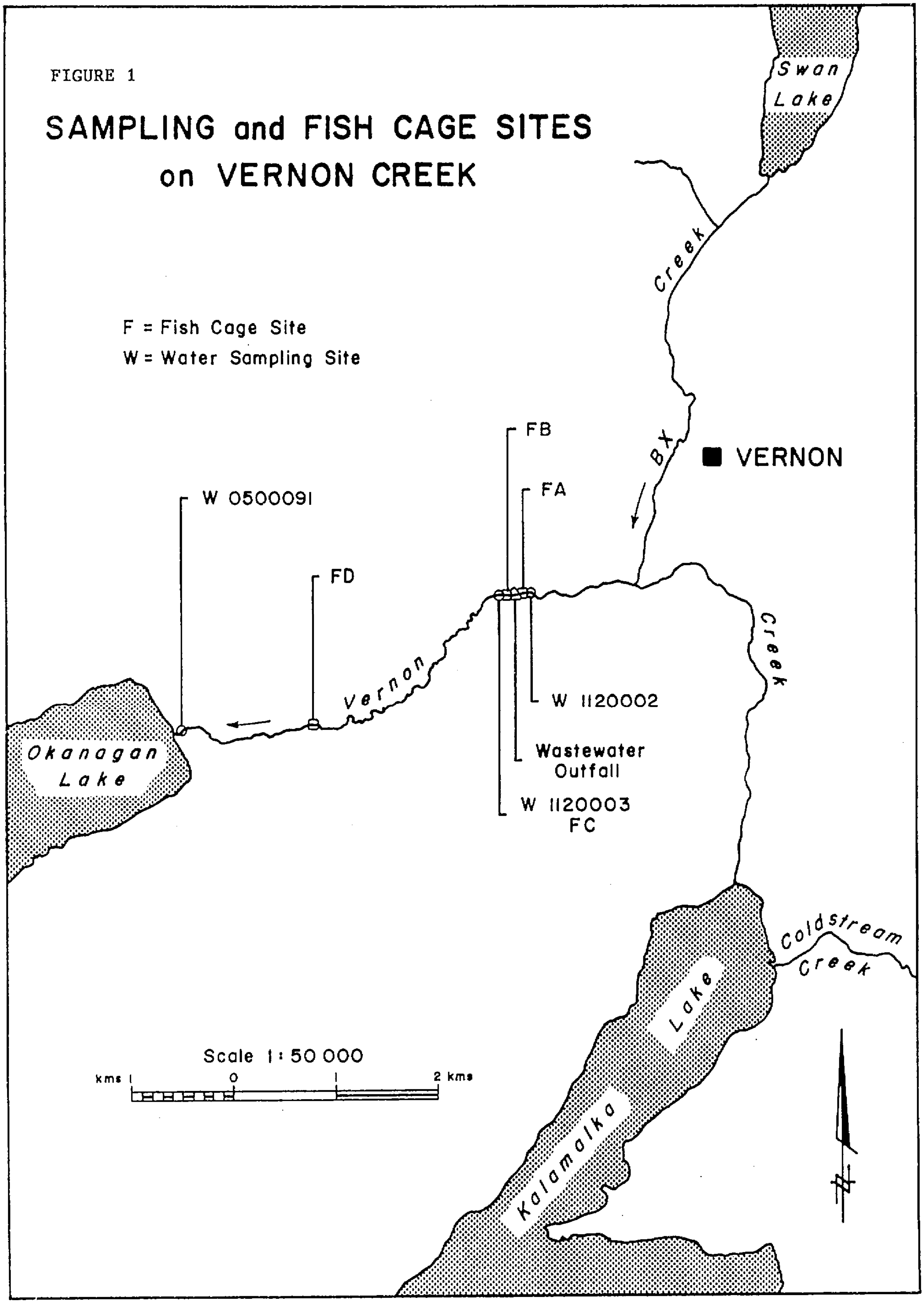


FIGURE 1
SAMPLING and FISH CAGE SITES
on VERNON CREEK
F = Fish Cage Site
W = Water Sampling Site
Swan Lake
Creek
BX
VERNON
FB
FA
W 0500091
FD
Vernon
W 1120002
Wastewater Outfall
W 1120003
FC
Creek
Okanagan Lake
Coldstream Creek
Kalamalka Lake
Scale 1 : 50 000
kms 1
0
1
2 kms

2. EFFECTS ON VERNON CREEK

2.1 General Water Quality

Although Vernon Creek was sampled in both 1984 and 1985 the sampling effort was more intensive in 1985 because of the reduced flow in Vernon Creek. As a result of this lower flow, the effects on Vernon Creek were more pronounced in 1985 than in 1984. Most of the information presented on the effects on Vernon Creek is for 1985.

Water samples in Vernon Creek were collected by immersing the appropriate collection bottle into the creek just below the surface. These bottles were shipped to the B.C. Environmental Lab for chemical analysis. At the time of water collection, creek temperature, pH, and dissolved oxygen were generally measured in the field. Although these results are not contained in this report, there was no evidence of dissolved oxygen sag downstream of the discharge. The data are available in EQUIS or SEAM (Ministry of Environment and Parks data storage systems).

Figure 2 shows total phosphorus in Vernon Creek just before and during the discharge of wastewater. On five of the seven sampling days during the wastewater release, phosphorus concentration was greater downstream than upstream of the outfall. The mouth site was not sampled on all days when the other sites were. Total phosphorus is quite variable because it can be contributed by a number of different sources and the amount in suspension at any one time depends on stream flow. Inputs can be quite variable, particularly during freshet which was occurring during the wastewater release. For this reason it is not surprising that the total phosphorus was not always higher downstream of the discharge, especially as the total amount of total phosphorus from the discharge was only 215 kg.

Figure 3 shows dissolved phosphorus upstream and downstream of the wastewater release. The effect of the outfall on dissolved phosphorus was much more pronounced than for total phosphorus; on only one of the seven days was dissolved phosphorus greater upstream than downstream of the discharge. The magnitude of the difference between upstream and downstream results was much greater for dissolved phosphorus than for total phosphorus. Most of the phosphorus released by sewage treatment plants is in the dissolved form.

Figure 4 shows specific conductance in Vernon Creek upstream and downstream of the discharge. Specific conductance is the extent to which water will conduct an electric current. It is directly proportional to the amount of dissolved material in the water. Because the sewage treatment plant produces water high in dissolved material, the specific conductance downstream was greater than that upstream of the treatment plant. In mid-April and May the increase in specific conductances was slight; however, it was greater downstream of the discharge on all days the creek was sampled.

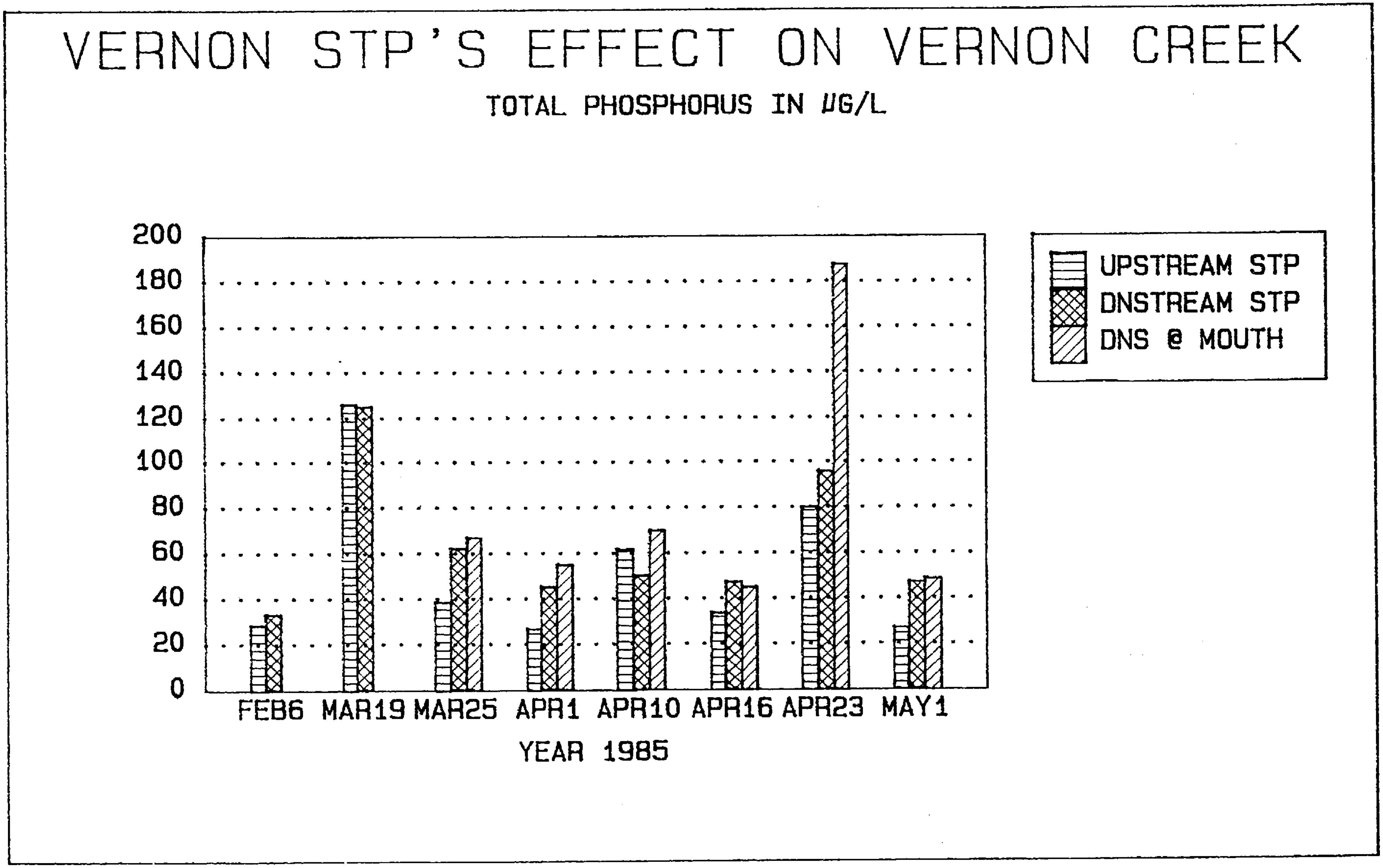


FIGURE 2. TOTAL PHOSPHORUS CONCENTRATIONS AT 3 SITES IN VERNON CREEK.

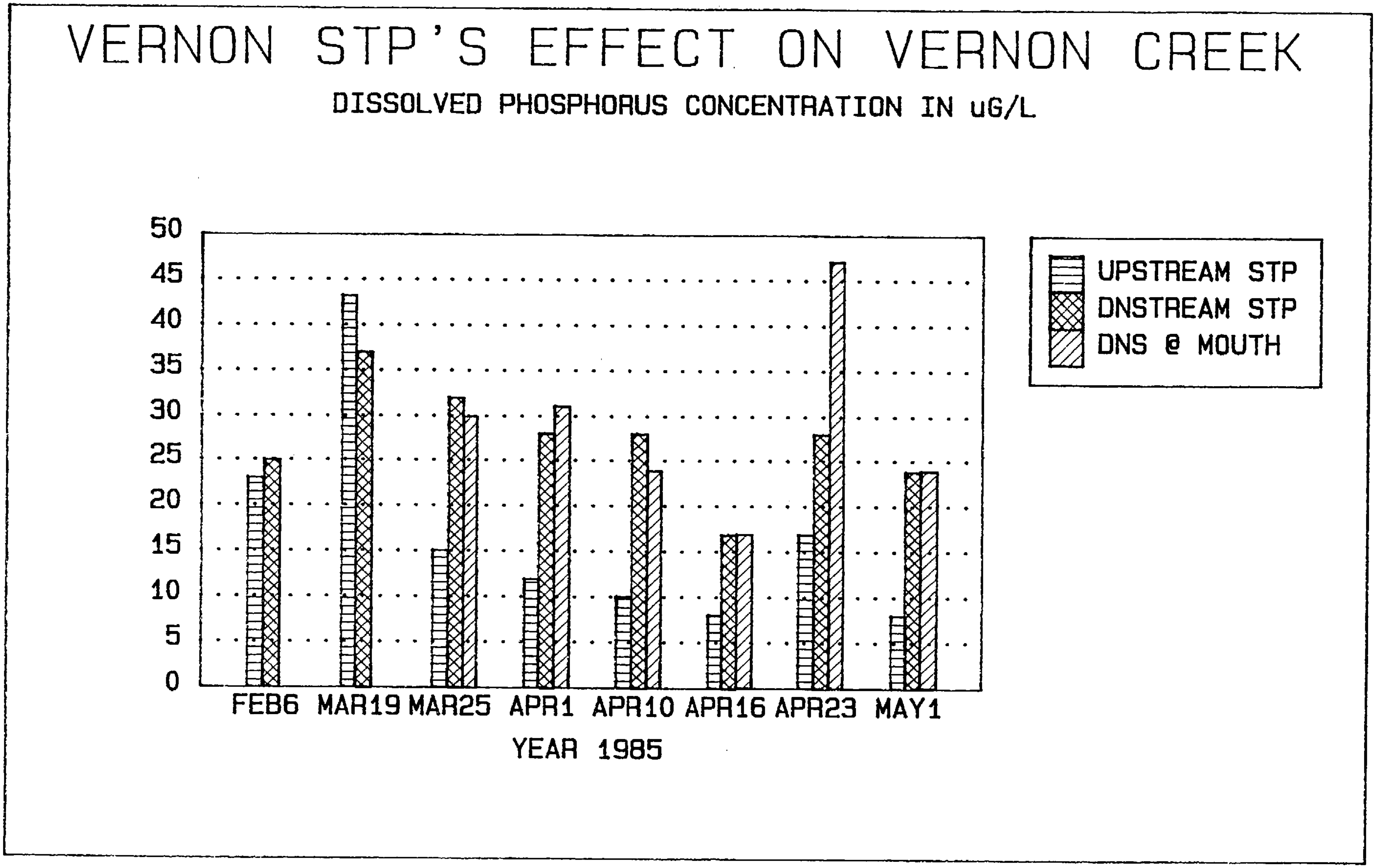


FIGURE 3. DISSOLVED PHOSPHORUS CONCENTRATIONS AT 3 SITES IN VERNON CREEK.

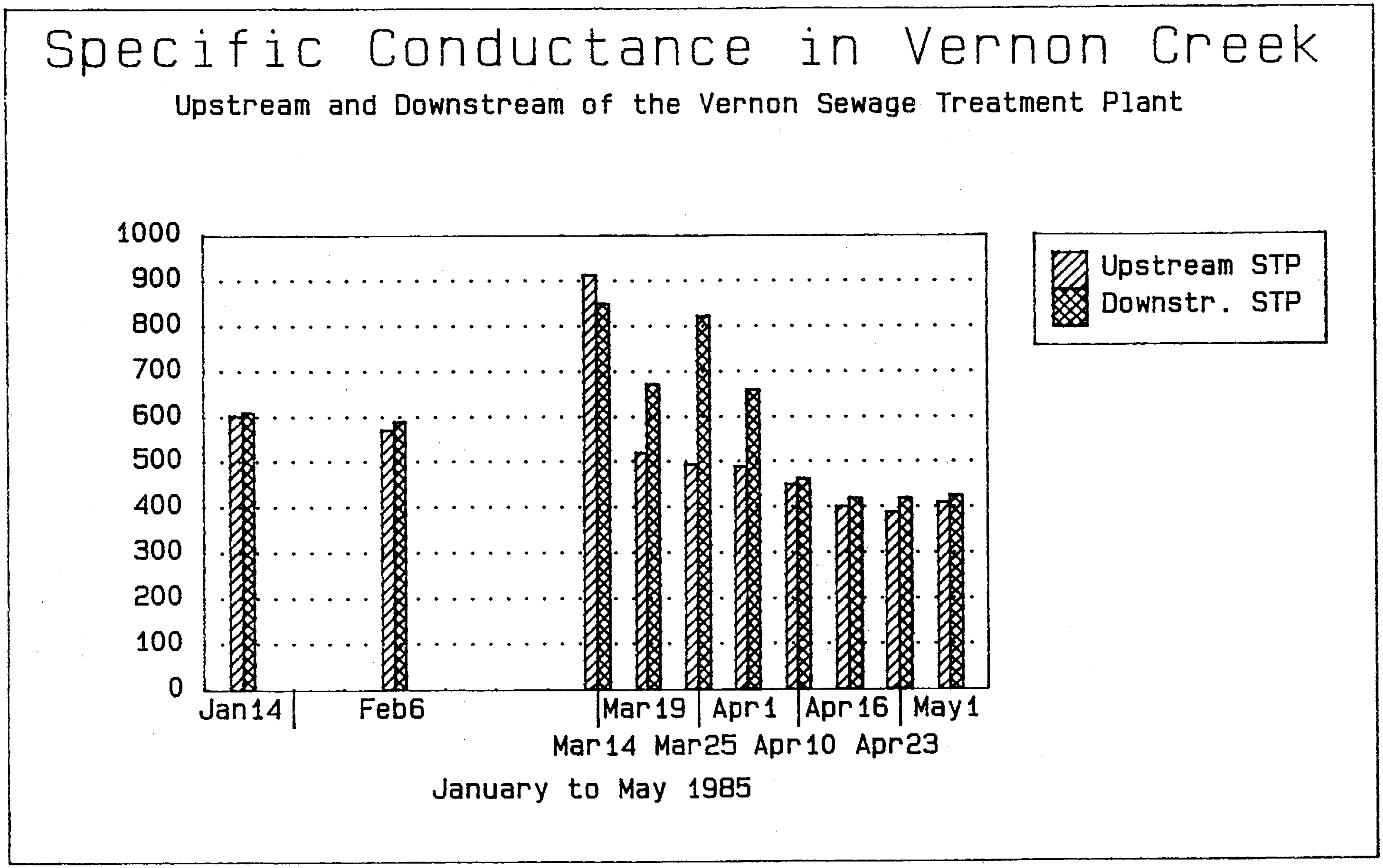


FIGURE 4. SPECIFIC CONDUCTANCE (µS/cm) AT 2 SITES IN VERNON CREEK.

Dissolved chloride, which is high in wastewater, increased downstream of the discharge (Figure 5). Dissolved chloride is one of the components that contributes to specific conductance. On all seven sampling days it was greater downstream than upstream of the discharge.

Ammonia nitrogen increased very markedly downstream of the discharge (Figure 6). On all seven sampling days it was much higher downstream than upstream. Most of the nitrogen from the treatment plant is in the ammonia form. The treatment plant also contributes nitrogen in the form of nitrate and organic nitrogen; however, the bulk of the nitrogen is in the ammonia form, so a plot of total nitrogen would look much like Figure 6. Ammonia concentrations were not only higher immediately downstream of the discharge but remained fairly high right to the mouth of Vernon Creek (Figure 6). There may have been some dilution and oxidation of ammonia concentration downstream but only a small amount.

Ammonia nitrogen can be toxic to fish and aquatic invertebrates living in Vernon Creek. Indeed at the highest pH and temperature (9.5; 8.3) ever observed in Vernon Creek during the time of the wastewater release, a concentration of 360 ug/L ammonia could cause sub-lethal effects on fish and invertebrates in Vernon Creek (Thurston *et al.* 1979). The acutely toxic concentration of ammonia would have been 3.5 mg/L. All of the recorded ammonia values are considerably below this concentration which would have been required to kill fish or aquatic invertebrates. New information indicates that ammonia nitrogen is somewhat less toxic than previously believed (Nordin and Pommen 1986).

2.2 Toxicity of wastewater

The wastewater released to Vernon Creek had no effect on survival of trout kept in cages downstream of the discharge. Figure 1 shows that one cage of trout was upstream of the discharge and three cages were downstream. Each cage contained 10 trout ranging in fork length from 50-100 mm (Jones MS 1985). The trout were not fed from the day they were placed in the creek (March 20, 1985) until the remaining cages were removed (May 17, 1985). None of the trout in the cages died. Cage B, immediately below the discharge, remained in place for the duration of the discharge. Cages C and D somewhat further downstream from the discharge, however, disappeared about the last of April. The cages themselves were missing and had presumably been vandalized. The trout in these cages were alive and well in late April when they were last seen, and the fish in Cage B survived the entire discharge. Cage B is the one that was closest to the outfall pipe. As these fish survived, it is likely that trout in cages C or D would have survived also.

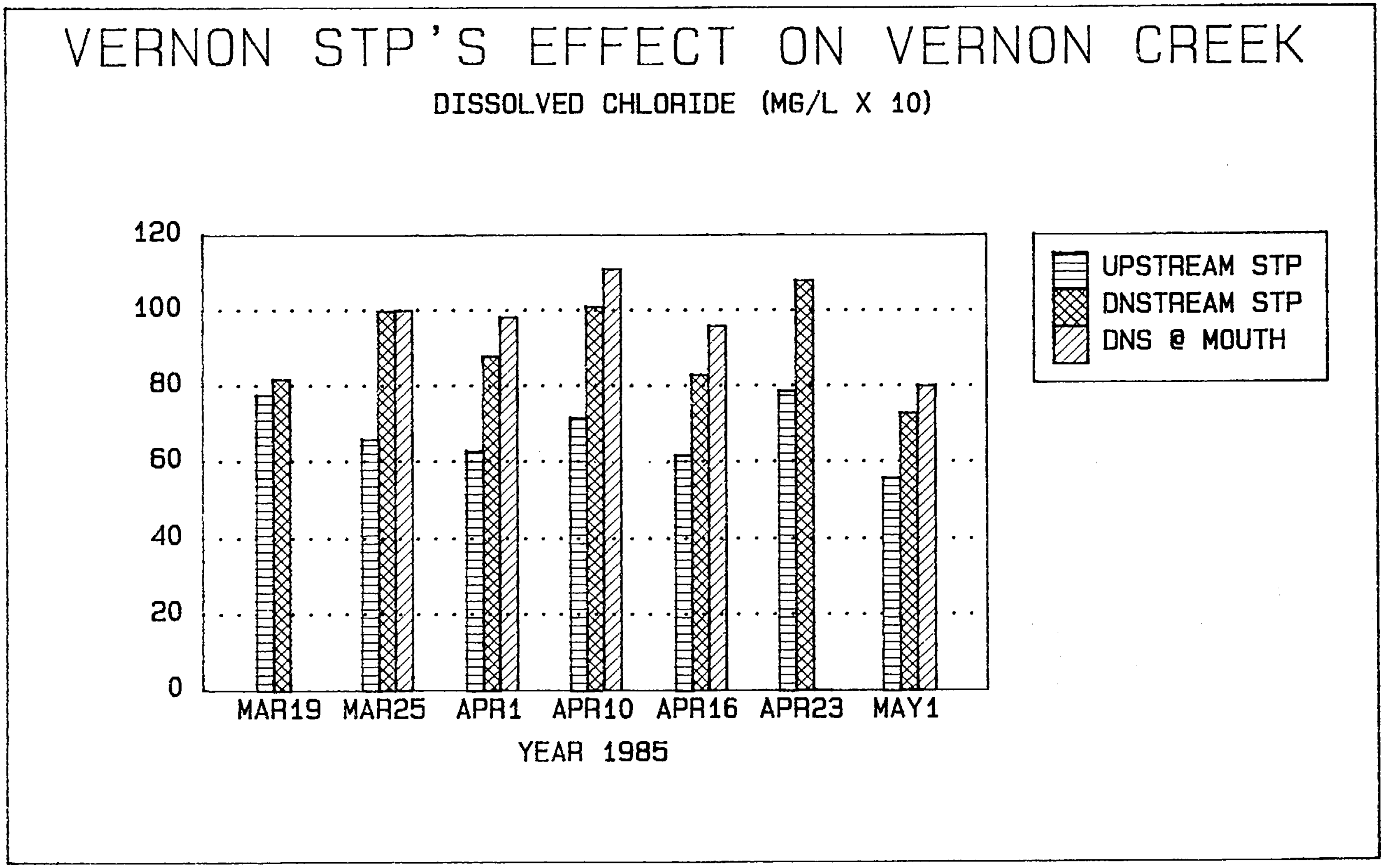


FIGURE 5. CHLORIDE CONCENTRATION AT 3 SITES IN VERNON CREEK.

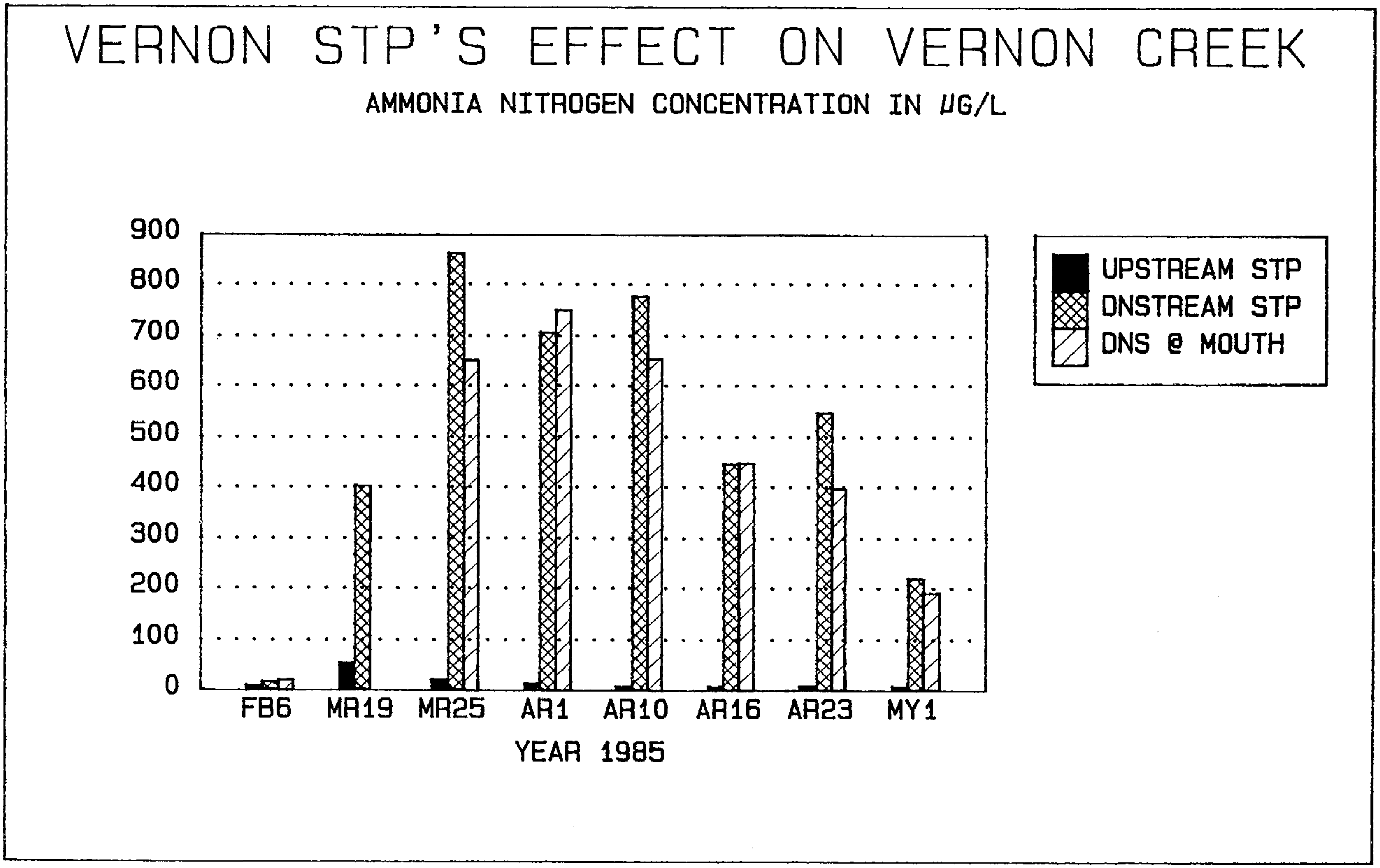


FIGURE 6. AMMONIA CONCENTRATION AT 3 SITES IN VERNON CREEK.

In addition to testing the effects of the discharge in Vernon Creek, toxicity of the wastewater itself was measured with *Daphnia*. *Daphnia* kept in undiluted wastewater all survived (Table 3). A chronic bioassay was done on April 10, 1985. *Daphnia* cultured in wastewater from the City of Vernon on that date had growth rates that were equal to those of *Daphnia* grown in the control water. In addition, *Daphnia* cultured in wastewater produced the same number of offspring as *Daphnia* grown in control water for the test. Toxicity tests for *Daphnia* usually give similar results to those using rainbow trout as the test animals for many pollutants (S. Horvath, personal communication). Apparently ammonia is an exception.

TABLE 3. Effect of Vernon's wastewater on survival of *Daphnia* for 96 hr on several dates in 1985.

Date	% Mortality 96 hr	Ammonia Nitrogen Concentration (mg/L)
March 25	0	13.5
April 10	0	13.8
April 16	0	12.3
May 01	0	7.0

2.3 Coliform Bacteria

Coliform bacteria in the sewage treatment plant were usually at or below detection limits (Table 4). For both 1984 and 1985 the average number from the treatment plant was less than the average number upstream or downstream in the creek. The City of Vernon data are similar to those from Ministry of Environment (Tables 2 & 4).

There is no evidence that coliform numbers in Vernon Creek increased downstream of the discharge. When the coliform numbers were transformed to logarithms, the T-test established that there is no statistically significant difference between them. Admittedly the number of observations is very low and it is possible that a larger sample size would show a difference. Although in both years, the coliform number upstream was greater than downstream of the outfall.

Fecal coliform to fecal strep ratio was measured at the three sites in Vernon Creek in 1985. It was thought that the ratio might be less than one at some sites and greater than four at others. Such observations might establish whether the coliforms were of human origin at some sites, but animal origin at others (Feachem 1975). The ratios were quite variable and the sample size small; however, there was no tendency for some sites to be less than one and others greater than four. All were about 2.

TABLE 4. Numbers of fecal coliform bacteria (MPN/100ml) discharged from Vernon STP or in Vernon Creek. The minimum detectable number is 2, and all creek samples had more than 2.

		1984	1985
VERNON STP*			
Average per sample	(x)	4.4	38.2
Total number samples	(n)	56	73
Number with counts >2	(n>2)	17	30
Percent n >2	(%n>2)	30%	41%
VERNON CREEK			
Upstream STP	x ($\bar{x}$ ln)**	158.4 (4.5)	122.8 (4.6)
	n	5	5
Downstream STP	x (x ln)**	81.0 (3.7)	104.4 (4.5)
	n	5	5
Mouth	$\bar{x}$	---	96.5
	n		4

* Data are from City of Vernon and include data for 2 sampling locations usually sampled the same day (Jackson MS 1985).

** The numbers in parentheses are the means of logarithms of coliform numbers.

2.4 Vernon Creek quality and B.C. quality criteria

Water quality criteria are being developed for B.C. waters (Pommen 1987). The criteria are a set of acceptable concentrations for potential contaminants in water which can reduce the value of water for specific uses. These criteria will be used to establish water quality objectives for a specific water body which suit its background quality as well as existing and potential uses. Such objectives have been established for Vernon Arm of Okanagan Lake but not yet for Vernon Creek.

The only water quality characteristic of Vernon Creek which failed to meet all B.C. Criteria because of Vernon's wastewater release is ammonia nitrogen. The most restrictive criterion for ammonia nitrogen is a 30 day average of less than 575 ug/L and an instantaneous maximum of 2990 (Pommen 1987); whereas the 30 day average downstream of the outfall was 670 and instantaneous maximum was 870.

Other quality characteristricts of Vernon Creek water fail to meet the most restrictive of the criteria for B.C. waters but they fail despite and not because of the discharge. The criterion for coliform bacteria in a drinking water supply, for instance, is MPN 0/100 ml (Pommen 1987); whereas upstream of the discharge the concentration averaged 122.8. For chloride the criterion for food processing is 20 mg/L but the creek was always greater than 50 even upstream of the discharge. Similarly, the criterion for specific conductance for industrial use of wastes ranges from 0-8000 uS/cm whereas Vernon Creek's minimum was 400.

The quality characteristics chosen for this report are those most affected by the wastewater discharge. There are probably other quality characteristics in Vernon Creek which do not meet B.C. criteria, but there are unlikely to be any which fail because of the discharge itself. No criteria have been set for phosphorus concentrations in streams.

3. THE EFFECTS ON VERNON ARM OF OKANAGAN LAKE

Vernon Arm is a shallow part of Okanagan Lake extending up the Vernon Creek valley (Figure 7). Vernon Creek flows into the arm at its head then predominantly along the western shore. There is a dyke on the east side of the creek mouth and dye tests suggest that most of the flow occurs along the west shore. Vernon Arm is mainly shallow but reaches a maximum depth of 25 metres. Vernon Arm is ringed by houses on both shores. The theoretical flushing time of Vernon Arm ranges from 16 days near Vernon Creek to just over 2 years near Adventure Bay. The whole lake flushes in 50 to 60 years (Anon. 1985).

There are three main sampling sites in Vernon Arm (Figure 7). The site close to Vernon Creek mouth (0500873) was established during the Okanagan Basin Study. A control for this site is at Okanagan Centre (0500874; Figure 7). The control site is not completely appropriate for the Vernon Creek site mainly because the depth gradient is so much steeper at the control site and also because there is no streamflow at the control site. Because of the differences in depth gradient between the two sites, there is much more ooze around the Vernon Creek site and considerably more milfoil growth as well. The water in the Vernon Creek site is always more turbid than that near the Okanagan Centre site.

3.1 Methods of Water Collection

Water from Okanagan Lake was collected using a Van Dorn water bottle. Two samples were taken from a depth of one metre to form a horizontal composite of water. This water was shipped to the B.C. Environmental Lab for determination of nutrients. Lake temperature, pH and extinction depth were recorded at the time of the sampling, although these results are not summarized in this report. Data are available on EQUIS or SEAM.

TABLE 5. Comparison of average total phosphorus (ug/L) in Okanagan Lake at Vernon Creek Mouth and at Okanagan Centre before (1978-79) and after *(1983-85) wastewater releases by City of Vernon.

		VERNON CREEK (0500873)		OKANAGAN CENTRE (0500874)	
		1978-79	1983-85	1978-79	1983-85
SPRING DATA ONLY DURING WW RELEASE	$\bar{x}$	15.4	22.6	10.2	12.5
	SE	1.55	2.28	0.77	1.2
	n	8	9	8	10
	T	2.54		1.47	
	P	0.02		0.16	
ALL COMPARABLE DATA*	$\bar{x}$	14.0	24.0	8.96	11.05
	SE	0.79	3.57	0.86	0.75
	n	27	18	25	20
	T	3.28		1.77	
	P	0.002		0.083	

*The wastewater release occurred in Spring of 1984 and 1985 from March - May. In order to compare phosphorus in the lake at the two time periods, all phosphorus data were used provided there was data for the same month.

3.4 Coliform bacteria in Vernon Arm

In order to determine whether coliform bacteria increased following release of wastewater, the sampling grid was established in Vernon Arm as shown by the X's in Figure 7. This grid was sampled twice before and twice after wastewater was released to Vernon Creek in both 1984 and 1985. The after sampling times were at least a month after discharge began as shown in Table 6.

TABLE 6. Average number of fecal coliform bacteria (MPN/100ml) in samples collected from Vernon Arm before or after the wastewater release at 2 depths along 4 transects shown in Figure 1.

	1984		1985	
Main Effect	$\bar{x}$	n	$\bar{x}$	n
TIME				
Before discharge	2.42	80	2.00	39
After discharge	2.17	80	8.55	40
DEPTH				
Shallow (1M)	2.10	80	4.16	39
Deep (bottom +2M)	2.50	80	6.39	40
TRANSECT (Figure 1)				
A	2.58	40	7.73	40
B	2.08	40	2.82	39
C	2.20	40	---	
D	2.35	40	---	
SAMPLE DATES	January 16 & 17		February 6	
Before Discharge	March 12 & 13		March 14	
	April 9 & 10		April 30	
After Discharge	May 22		May 13	

Coliform samples were collected from two depths at each sampling site. The top depth was one metre below the water surface, the bottom depth was about two metres above the bottom at that site. The depth to bottom varied at each site and as a result the lower sampling depth did too. In 1985, only the two transect lines closest to Vernon Creek were sampled because the 1984 data showed that coliform numbers were very low at the two transect lines furthest offshore. Consequently, there were only eighty samples taken in 1985, whereas there were a total of 160 in 1984. In 1985 one of the sample bottles leaked in transit so this value was lost from the analysis.

Table 6 shows that there were slightly greater coliform numbers after the discharge in 1985 but not in 1984. Table 7 presents an analysis of variance of these coliform data. The coliform numbers were all transformed to logarithms before the analysis. Table 7 confirms that there is a significant difference in the before and after results for 1985, but not for 1984. Indeed there were no differences that were large and consistent for both years. In 1985, Transect A had greater coliform numbers than Transect B (Tables 6 & 7); however, the interaction term (Table 7) is large because this difference occurred only after the discharge and not both before and after. There are no main effects or interactions that were consistent for both years. Thus coliform samples showed that there was a slight increase in coliform numbers in 1985 but not in 1984.

3.5 Periphyton in Vernon Arm

In order to determine whether the wastewater had an effect on attached algae or periphyton growing in Okanagan Lake, artificial substrates were placed near the mouth of Vernon Creek (0500873, Figure 7) and at the control site near Okanagan Centre. Each substrate consisted of a plexiglass plate measuring 10 x 17 cm. These substrates were attached to a float held under water 1.5 metres below the surface. At both Okanagan Centre and Vernon Arm the depth to bottom was roughly 3 metres. As mentioned previously the bottom profile at Okanagan Centre sloped off much more rapidly than the bottom profile at Vernon Arm. The same apparatus and procedure had been established originally in 1976-78 by Environmental Protection Service of Environment Canada as a part of the Okanagan Basin Implementation Program (Truscott and Kelso 1980). In 1979 the work was continued by B.C. Waste Management. During the active growing season periphyton samples were collected every two weeks. During the period of October until March the periphyton samples were collected only once a month.

TABLE 7. Analyses of Variance of Coliform Data from Vernon Arm for 1984 and 1985. The Coliform data (MPN/100 ml) were converted to logarithms before analysis. The times were twice before and twice after discharge. The depths were 1m below the surface and 2m above the bottom; the transects are described in Figure 7.

1984					
Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	0.660	5	0.132	1.6	0.167
Time	0.066	1	0.066	0.8	0.378
Depth	0.343	1	0.343	4.1	0.042
Trans	0.251	3	0.084	1.0	0.394
2-Way Interactions	0.658	7	0.094	1.1	0.349
Time x Depth	0.343	1	0.343	4.1	0.042
Time x Trans	0.245	3	0.082	1.0	0.404
Depth x Trans	0.069	3	0.023	0.3	0.843
3-Way Interaction	0.066	3	0.022	0.3	0.850
Time x Depth x Trans	0.066	3	0.022	0.3	0.850
Explained	1.384	15	0.092	1.1	0.354
Residual	11.989	144	0.083		
Total	13.373	159	0.084		

1985					
Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	14.208	3	4.736	11.0	0.000
Time	11.634	1	11.634	27.0	0.000
Depth	0.003	1	0.003	0.0	0.897
Trans	2.571	1	2.571	6.0	0.016
2-Way Interactions	3.291	3	1.097	2.5	0.062
Time x Depth	0.003	1	0.003	0.0	0.897
Time x Trans	2.571	1	2.571	6.0	0.016
Depth x Trans	0.717	1	0.717	1.7	0.198
3-Way Interaction	0.717	1	0.717	1.7	0.198
Time x Depth x Trans	0.717	1	0.717	1.7	0.198
Explained	18.216	7	2.602	6.0	0.000
Residual	30.994	71	0.430		
Total	42.211	78	0.623		

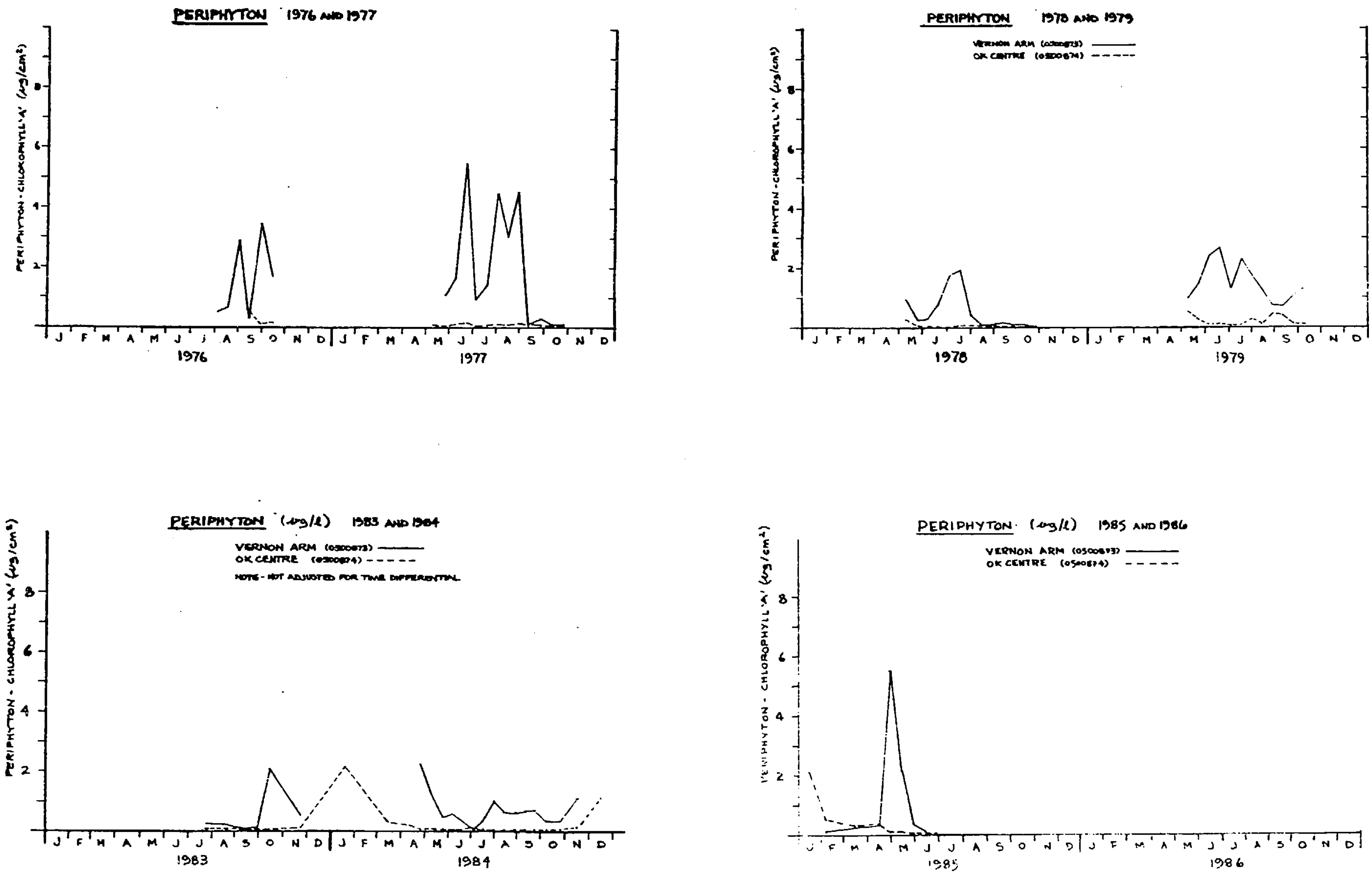
Figure 12 shows periphyton growth for several different time periods at both Okanagan Centre and Vernon Arm. Periphyton was very little affected by the wastewater release in 1984 or 1985. There was roughly the same amount of periphyton in 1978 and 1979 as there was in 1984 and 1985. This was true at both Okanagan Centre and Vernon Arm. Figure 12 shows that periphyton dropped after the outfalls were removed from Vernon Creek in 1978.

TABLE 8. Comparison of average periphyton abundance at Vernon Arm and Okanagan Centre Sampling sites during spring months of different years. The data are Chlorophyll A levels in ug/cm^2.

	Vernon Creek (0500873)			Okanagan Centre (0500874)		
	Discharge 1976-77 A	No Discharge 1978-79 B	Release 1984-85 C	Disharge 1976-77 A	No Discharge 1978-79 B	Release 1984-85 C
$\bar{x}$	2.06	1.49	1.29	0.047	0.157	0.085
SE	1.19	0.269	0.535	0.011	0.53	0.033
n	4	10	10	5	10	11
T-Test AB	0.69			0.144		
pAB	0.5			0.173		
T-Test BC		0.34			1.17	
pBC		0.74			0.26	
T-Test AC	0.69			0.76		
pAC	0.5			0.46		

Table 8 shows statistical analysis of periphyton in Vernon Arm and Okanagan Centre during the time of the wastewater release. Table 8 confirms the visual impression that there was no effect of wastewater release on periphyton in Vernon Arm. None of the time periods show statistically significant differences in periphyton. However, outfall removal in 1977 did decrease periphyton; this is shown by Figure 12 and documented more thoroughly by Jensen (MS 1981).

FIGURE 12. PERIPHYTON (ATTACHED ALGAE) AT 2 SITES IN OKANAGAN LAKE DURING DIFFERENT TIME PERIODS. VERNON'S OUTFALL WAS REMOVED IN AUGUST 1977.



3.6 Phytoplankton in Vernon Arm

Phytoplankton samples were collected at two sites in Okanagan Lake whenever observations were made on other water quality characteristics. A Van Dorn water bottle was filled twice to collect a horizontal composite sample at each of the two sites. Two one-litre bottles were filled for chlorophyll a determination of phytoplankton. Water from each of the bottles was filtered through a 0.45 micron filter. The filters were frozen and shipped to B.C. Environmental Lab for chlorophyll A determination. The average values of the two replicates are the data presented and analyzed in this section.

Figure 13 suggests that there has been little change in phytoplankton between 1978 and 1985 over the whole season in Okanagan Lake. The patterns of high and low concentrations of phytoplankton are fairly similar for the years after the discharge was removed from Vernon Creek. Figure 13 does show that there was quite a drop in phytoplankton after the outfall was removed in 1977. Apart from this, the patterns of phytoplankton abundance are fairly similar among the different years for both Vernon Arm and for Okanagan Centre.

Table 9 compares phytoplankton data for just the time period of the wastewater release. Table 9 shows that in fact, phytoplankton was greater after the wastewater release (1984-85) than before (1978-79). There was no comparable increase in phytoplankton for the control site at Okanagan Centre.

TABLE 9. Phytoplankton abundance at Vernon Arm and Okanagan Centre sampling sites during spring months of different years. The data are chlorophyll a levels in ug/L.

	Vernon Creek (0500873)			Okanagan Centre (0500874)		
	Discharge 1976-77 A	No Discharge 1978-79 B	Release 1984-85 C	Disharge 1976-77 A	No Discharge 1978-79 B	Release 1984-85 C
$\bar{x}$	5.94	1.65	2.68	0.89	1.96	1.42
SE	2.30	0.20	0.33	0.20	0.54	0.08
n	7	10	9	6	10	9
T-Test AB	2.25			1.48		
pAB	0.04			0.16		
T-Test BC		2.70			0.93	
pBC		0.02			0.36	
T-Test AC		1.60			2.9	
pAC		0.13			0.01	

FIGURE 13. PHYTOPLANKTON ABUNDANCE AT 2 SITES IN OKANAGAN LAKE DURING DIFFERENT TIME PERIODS. VERNON'S OUTFALL WAS REMOVED IN AUGUST 1977.

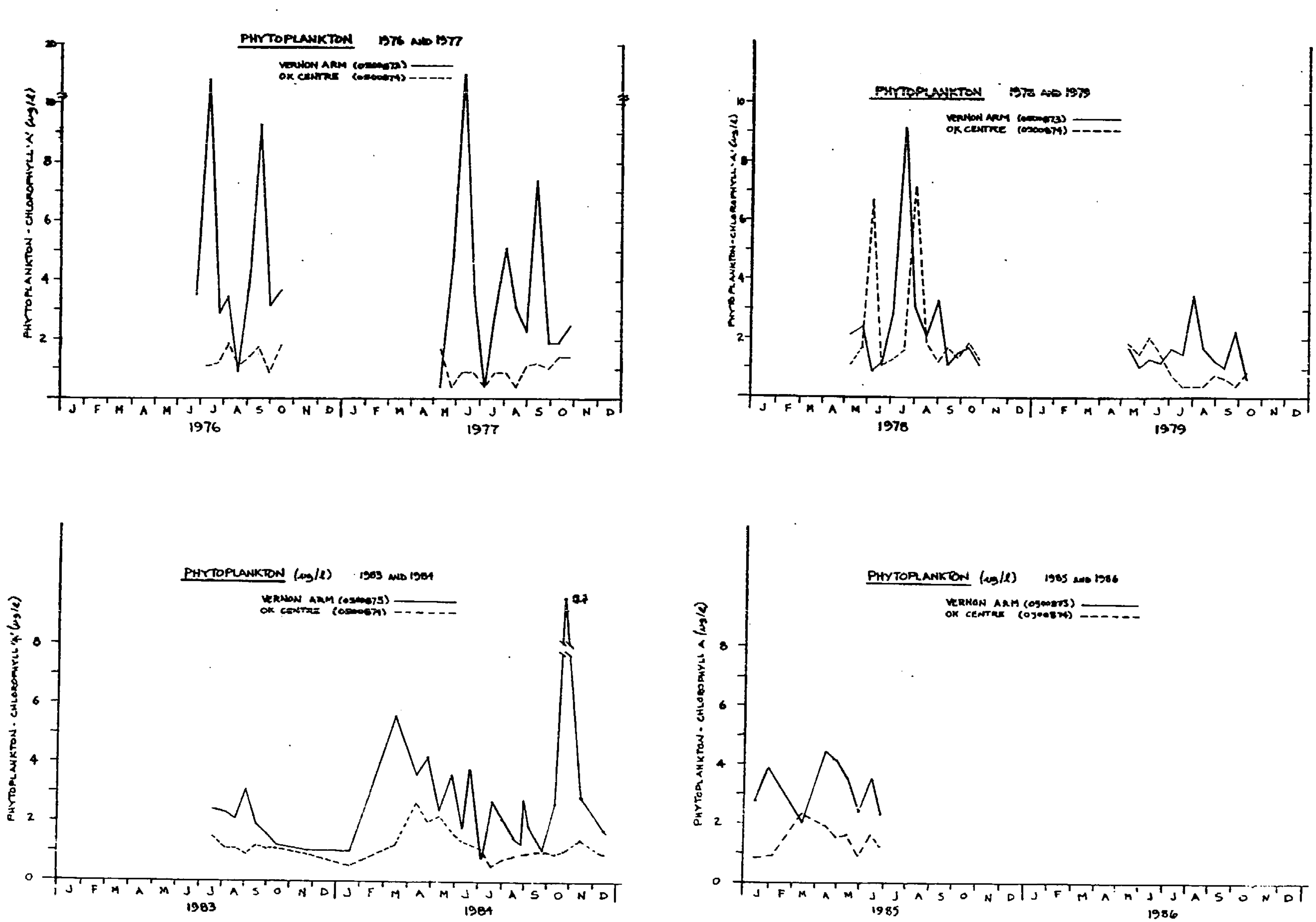


Table 9 shows that phytoplankton at the Okanagan Centre site increased between 1976 and 1985. This increase is probably spurious because it is not reflected in the entire data set for that Okanagan Centre site (Figure 13). Because total phosphorus at Okanagan Centre was greater in 1983-85 than 1978-79, phytoplankton was examined for all months of comparable data. The outcome of this analysis is the same as for spring data only shown in Table 9, in that the 1978-79 period had slightly greater standing crops of phytoplankton than 1983-85.

Spring phytoplankton density increased at the Vernon Creek Mouth site, after wastewater releases in 1984-85 relative to levels in spring 1978-79 (Table 9). However, this increase is fairly slight and did not persist through the season in Vernon Arm (Figure 13). Figure 14 shows summer phytoplankton abundance at the Kin Beach site for years 1975 to 1986. The maximum concentrations of summer phytoplankton all occurred during the three years when there was a continuous discharge to Vernon Creek. In the years following, summer phytoplankton was always much lower, including the years 1984 and 1985 when there were the spring releases of wastewater. There are seasonal fluctuations in phytoplankton in Vernon Arm with maxima occurring in late winter or early spring and minima in late summer or early fall. Figure 15 shows this seasonal pattern for 1983 to 1985. In most other years phytoplankton was only sampled once in spring and again in late summer.

3.7 Vernon Arm quality and B.C. quality criteria

Both ammonia nitrogen and nitrate nitrogen in Vernon Arm were increased by the discharge. However, both parameters meet all quality criteria for B.C. (Pommen 1987). Other quality characteristics of Vernon Arm, such specific conductance, do not meet the most stringent of the quality criteria for B.C., but this is not because of the release of wastewater.

A phosphorus objective of 10 ug/L was set for Vernon Arm (Anon. 1985). This objective was met for most samples collected in 1985 and 1986, but not 1979-1984 (Figure 11). The wastewater release had no demonstrable effect on phosphorus concentration in the Vernon Arm in either 1984 or 1985.

A British Columbia quality criterion of 2.5 ug/L has been established for planktonic chlorophyll a (Nordin, 1985). This measure is an average of the summer standing crop throughout the epilminion of a lake. Table 10 shows that this objective was not met in two summers before Vernon's outfall was removed, but has been met in the four summers since then when sufficient measurements were made for determination.

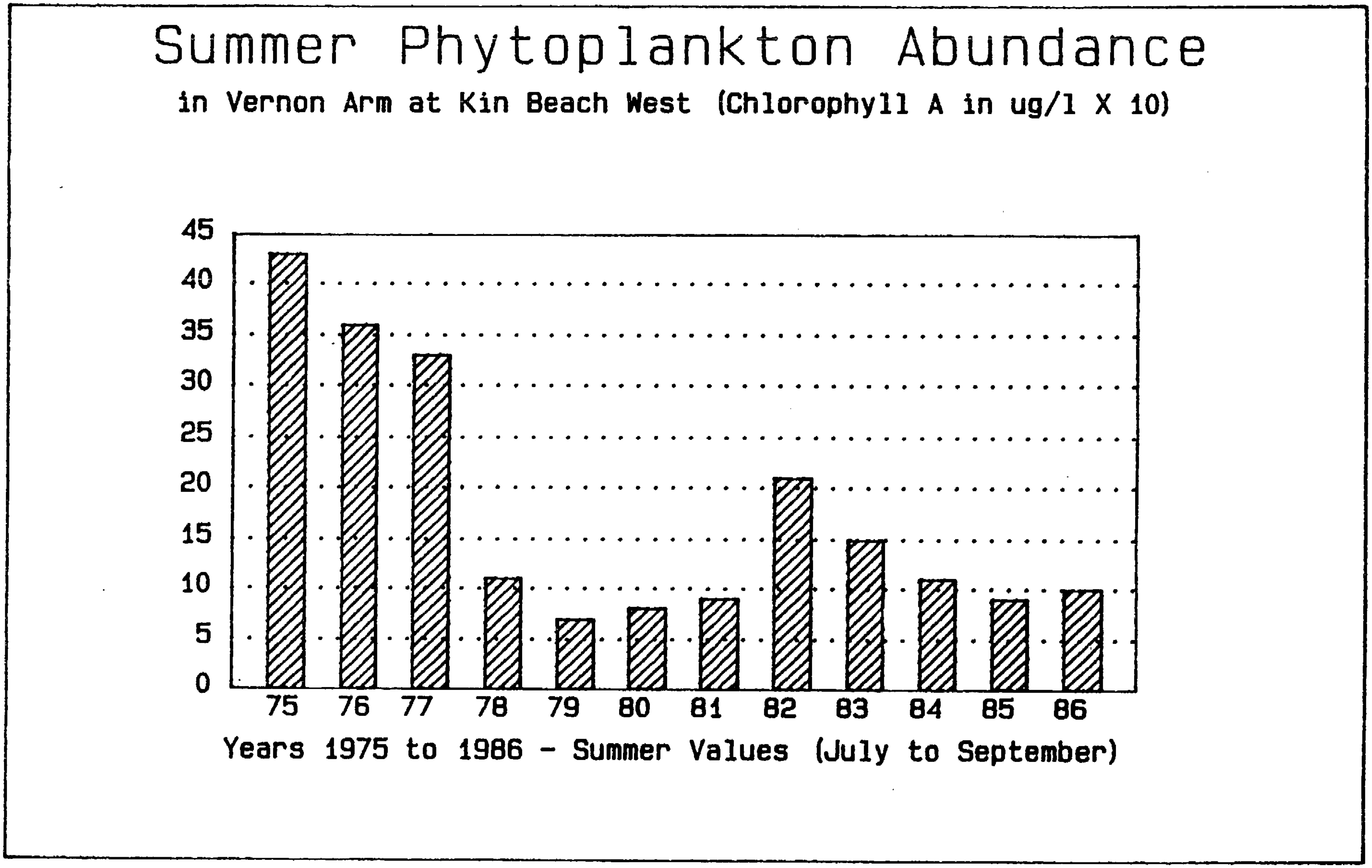


FIGURE 14. SUMMER DENSITIES OF PHYTOPLANKTON IN VERNON ARM FOR A PERIOD OF 12 YEARS. EACH MEASUREMENT WAS MADE ON A SINGLE DAY.

FIGURE 15.

Seasonal Phytoplankton Abundance

in Vernon Arm at Kin Beach West (Chlorophyll A in ug/l X 10)

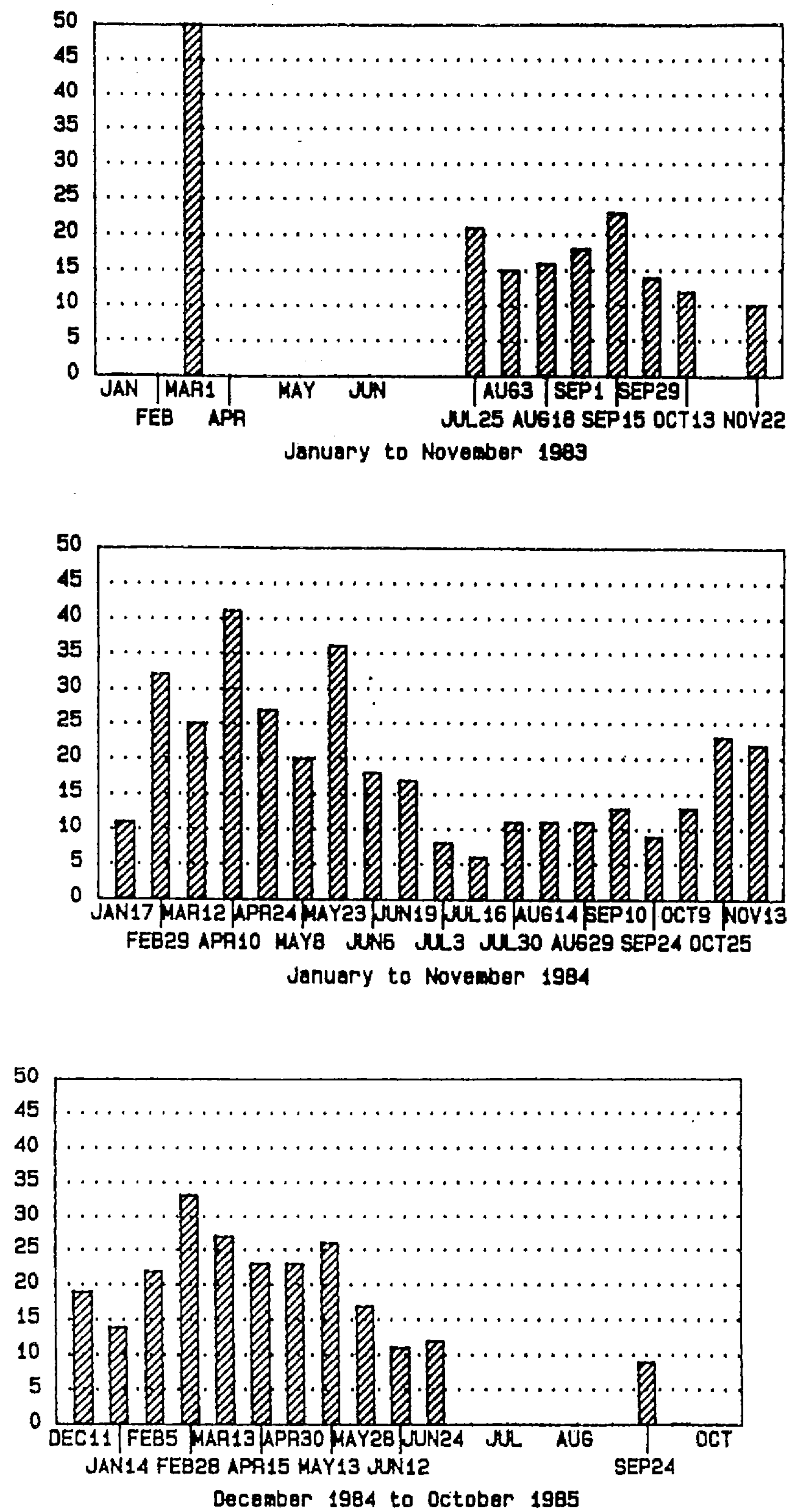


Table 10. Average summer chlorophyll concentrations (ug/L) for different years. The data for the 1970's are from Jensen (MS 1981) and values for late summer 1983 were combined with those for spring 1985 to obtain a summer average. The Vernon Arm data are the average of 0500873 and 0500458.

	1976	1977	1978	1979	1983 1985	1984
Vernon Arm	5.0	4.2	2.0	1.6	2.5	2.1
Okanagan Lake	1.4	1.0	2.3	1.0	1.3	1.3

4. DISCUSSION

The results of sampling in Vernon Creek establish that the water quality was considerably altered in 1985 when there was less dilution than in 1984. The most important effect was on ammonia nitrogen which increased to levels that theoretically at least could produce chronic toxicity to aquatic organisms. In the tests for chronic toxicity, however, it was not possible to establish that the undiluted wastewater by itself, produced such effects. Therefore there is no reason to conclude that such effects were produced in Vernon Creek either. It is perplexing that no toxicity was found in the wastewater. This observation seems at variance with literature on ammonia toxicity. There is no explanation for the lack of toxicity which is obvious at this time.

In Vernon Creek a sampling design upstream and downstream of the discharge made it easy to ascribe the changes in water quality to the wastewater releases. In contrast, the effects in Vernon Arm are confounded with other changes which affect water quality in Vernon Arm. The comparisons of conditions in Vernon Arm before and after assume that there were no other changes which affected the results apart from the release of wastewater by City of Vernon. In the coliform data, for example, it seems unlikely that the discharge of wastewater caused the increase in coliform numbers in 1985. The number of coliforms in the wastewater from the treatment plant was lower than the number in the creek itself. The increase presumably resulted because of better growing conditions in Vernon Arm after than before the wastewater release. It is important to note that the increase in coliform numbers was small and that it did not occur in 1984.

The comparison of the nutrients and algae in Vernon Arm assume that there was no change in the diffuse sources of phosphorus during the five year period between 1978-79 to 1983-85, since the 1978-79 data set is used as a control. Vernon Arm has a large load of nutrients from diffuse sources (Kennedy 1982). This assumption is probably not completely met as there is no doubt that the wastewater releases affected nitrogen in Vernon Arm. Both nitrate nitrogen and ammonia nitrogen were elevated near the mouth of Vernon Creek (flushing time about three days). Ammonia nitrogen concentration was reduced considerably at the Kin Beach West site (flushing time about 16 days).

The wastewater release probably did not affect the phosphorus concentration in Vernon Arm as much as the data for Vernon Creek mouth suggest. There was probably an increase in diffuse phosphorus sources in the Vernon Creek Watershed and around Vernon Arm in the years between 1979 and 1984. There is no doubt that phosphorus actually increased in Vernon Arm between 1979 and 1984 since phytoplankton concentration increased as well as phosphorus. In the case of Okanagan Centre, total phosphorus apparently increased but phytoplankton abundance did not.

The total quantity of phosphorus released to Vernon Arm was about 350 kg in 1984 and 220 kg in 1985. These amounts are quite low in comparison with the amounts that were added to Vernon Arm in the years before 1977 when there was a continuous discharge to Vernon Creek. At this time the phosphorus from the Vernon sewage treatment plant was 16,000 kg (Anon. 1974). In addition, the total amounts of phosphorus added were considerably lower than the amounts that are added annually by the tile fields from septic tanks of property owners around Vernon Arm. The total load of phosphorus from this source was estimated to be 1200 kg per year (Kennedy 1982). Seen against these perspectives the amounts of phosphorus released in 1984 and 1985 are quite marginal.

There is no evidence that periphyton growth in Vernon Arm was affected by the wastewater releases. The apparent effects of the wastewater releases on phosphorus and phytoplankton in Vernon Arm are presumably partly the result of increases in phosphorus from diffuse sources. The effects on phosphorus and phytoplankton were not large, they were considerably less than the levels which resulted from the original discharge of wastewater by City of Vernon prior to August 1977. Phytoplankton standing crop and spring phosphorus levels were considerably higher during the time of continuous discharge.

In both 1984 and 1985 the timing of the wastewater release was determined by considerations other than the potential effect on water quality in Vernon Arm. In order to minimize algae growth in Vernon Arm, the best time for releasing wastewater would have been mid-November to mid-January.

Except for ammonia nitrogen in Vernon Creek, the wastewater releases did not reduce water quality below B.C. criteria or objectives for water quality. Ammonia was the characteristic in Vernon Creek which was altered the most by the wastewater. Monitoring showed that it was diluted and converted to other nitrogen forms in Vernon Arm.

In Vernon Creek, there were a number of characteristics such as chloride, specific conductance, and coliform bacteria levels which did not meet all B.C. water quality criteria before or after the wastewater release. Water quality in Vernon Arm in 1985 met the objective set for phosphorus and the B.C. criteria for nutrients and algae.

5. REFERENCES

Anonymous. 1974. Canada - B.C. Okanagan Basin Agreement, Tech. Sup IV WQ and waste loadings in the Okanagan Basin B.C. Water Resources Service 565 p.

Anonymous. 1985. Phosphorus in the Okanagan Valley Lakes: sources, Water quality objectives and control possibilities, B.C. Ministry of Environment, 163 p.

Feachem, R. 1975. An improved role for faecal streptococci ratios in the differentiation between human and non-human pollution sources. Water Research 9:689-690.

Forty, T.R. MS1985. Memo to file PE-382 re Vernon STP discharge to creek unpublished B.C. Ministry of Environment

Jackson, E.A. MS1985. The Corporation of the City of Vernon land application of treated wastewater 1984 annual report. Unpublished report City of Vernon 150 p.

Jensen, MS1981. Results of the continuous water quality monitoring program on Okanagan Lake for years 1979 to 1980. Canada-B.C. Okanagan Basin Implementation Agreement. B.C. Ministry of Environment. 73 p.

Jones, D.L. MS1985. Memos to File 34.36 re Vernon Creek Discharge. Unpublished Memos B.C. Ministry of Environment.

Kennedy, G.F. 1982. 1980 update of nutrient loadings from non-point sources. Okanagan Basin Implementation Agreement. 159 p.

Nordin, R.N. 1985. Water quality criteria for nutrients and algae, technical appendix. B.C. Ministry of Environment, Water Management Branch, 104 p.

Nordin, R.N. and L.W. Pommen. 1986. Water Quality criteria for nitrogen (nitrate, nitrite, and ammonia) technical appendix. B.C. Ministry of Environment & Parks, Water Management Branch.

Pommen, L.W. 1987. Approved and working criteria for water quality. B.C. Ministry of Environment and Parks, Water Management Branch, 27 p.

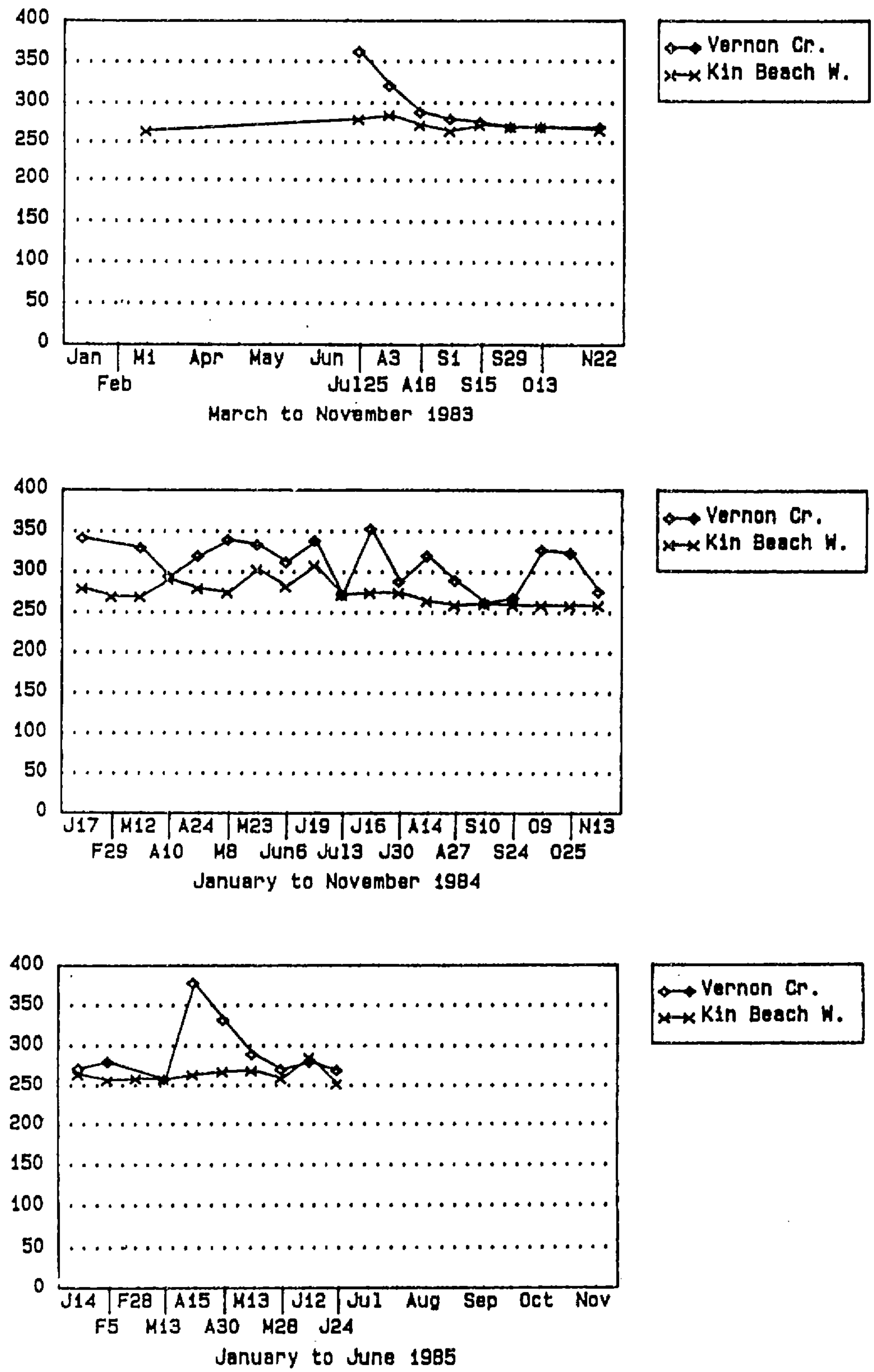
Thurston, R.V., R.C. Russo, C.M. Fetterolf Jr., T.A. Edsall, Y.M. Barber Jr. 1979. A review of the EPA Red Book: Quality Criteria for water. American Fisheries Society, Bethesda, Maryland, 313 p.

Truscott, S.J. and B.W. Kelso, 1979. Trophic changes in lakes Okanagan, Skaha and Osoyoos, B.C., following implementation of tertian, municipal waste treatment. Canada - B.C. Okanagan Basin Implementation Agreement. 159 p.

APPENDIX FIGURE 16.

Specific Conductance in Vernon Arm

off the mouth of Vernon Creek and Kin Beach West (uS/cm)



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