

TOTAL MAXIMUM DAILY LOADS AND WASTE LOAD ALLOCATIONS
FOR
LAS VEGAS BAY

Rationale and Calculations

Prepared by:

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Environmental Protection
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SUMMARY

In September 1987 the Nevada Division of Environmental Protection revised Water Quality Standards for Las Vegas Wash (LVW) and Lake Mead. Standards were set for chlorophyll a and unionized ammonia in Las Vegas Bay (LVB) (NDEP 1987). The 1986 and 1987 LVB data showed non-achievement of both the chlorophyll a and unionized ammonia standard which triggered an analysis of total phosphorus and total ammonia Total Maximum Daily Loads and Waste Load Allocations which are presented in this report.

This report is separated into three sections:

1. 1987 Las Vegas Bay Water Quality Conditions and Seasonal Periodicity.
2. Concentration Estimates at Northshore Road to Meet Water Quality Standards in Las Vegas Bay.
3. Total Maximum Daily Loads at North Shore Road and Waste Load Allocations.

Blue-green algae were present in 1987 but did not build to bloom levels observed in 1986. Mean summer chlorophyll a at station 3 was 53.2 ug/l which is considerably higher than the standard of 30 ug/l (4 year mean). From April 9 through August 3 unionized ammonia was never below the .04 mg/l chronic toxicity standard at station 2. The acute unionized ammonia standard (.45 mg/l) was not exceeded. The standards were not achieved from April through September but were met from October through March.

Over the period of record examined (1977-1987) the density of LVW has decreased significantly in comparison to LVB. At present, there are months when LVW enters LVB as a neutrally buoyant or buoyant jet.

* 1986 Station 3 mean summer
Chl-a = 52.3 ug/l

The dilution ratio method was applied to the 1985 through 1987 data set to estimate the total phosphorus and total ammonia concentrations at North Shore Road that would be necessary to achieve the standards. The target concentrations were estimated to be .64 mg/l total phosphorus and 1.43 mg/l total ammonia.

The 1985 through 1987 average flows at North Shore Road were used to calculate a TMDL of 434 lbs/day total phosphorus and 970 lbs/day total ammonia. The total phosphorus nonpoint source load was estimated to be 100 lbs/day which results in 334 lbs/day to be allocated between Clark County Sanitation District and City of Las Vegas Wastewater Treatment Plants. Lacking an understanding of the kinetics of ammonia reduction in LVW, all of the TMDL was allocated to the two treatment facilities. Due to the seasonal nature of the water quality problem in LVB, the TMDL's would have to be met from April through September. The TMDL's would not apply from October through March.

1987 Las Vegas Bay Water Quality Conditions
and Seasonal Periodicity

Prepared by:

Nevada Division of Environmental Protection

Total Phosphorus

During the growing season, total phosphorus concentration at station 3 was considerably above the .051 mg/l level considered necessary to achieve the 30 ug/l chlorophyll a standard (Figure 1). Concentrations averaged .082 mg/l in July, .091 mg/l in August, and .068 mg/l in September; mean summer total phosphorus was .080 mg/l.

Seasonal periodicity was apparent as the concentration was below .051 mg/l in January, early April, and October through December. This data is consistent with the theory that the wash plume is denser than the lake water during the winter and consequently has less of an influence on the surface waters.

Chlorophyll a

Station 3 Chlorophyll a concentrations exhibited a seasonal pattern of algal growth in Las Vegas Bay (LVB) in 1987 (Figure 1). Three samples collected between January 22 and April 9 were below 10 ug/l. Concentrations fluctuated, but generally increased between mid-April and late September when it then began to decline. Three samples collected between late October and late December averaged less than 10 ug/l. Peak chlorophyll a at station 3 in 1987 occurred on September 3 at 78.8 ug/l.

The chlorophyll a standard for LVB at station 3 is set so that the long term (4 year mean) summer concentration shall not exceed 30 ug/l and that no more than one monthly mean shall exceed 45 ug/l in any calendar year. In 1987 mean

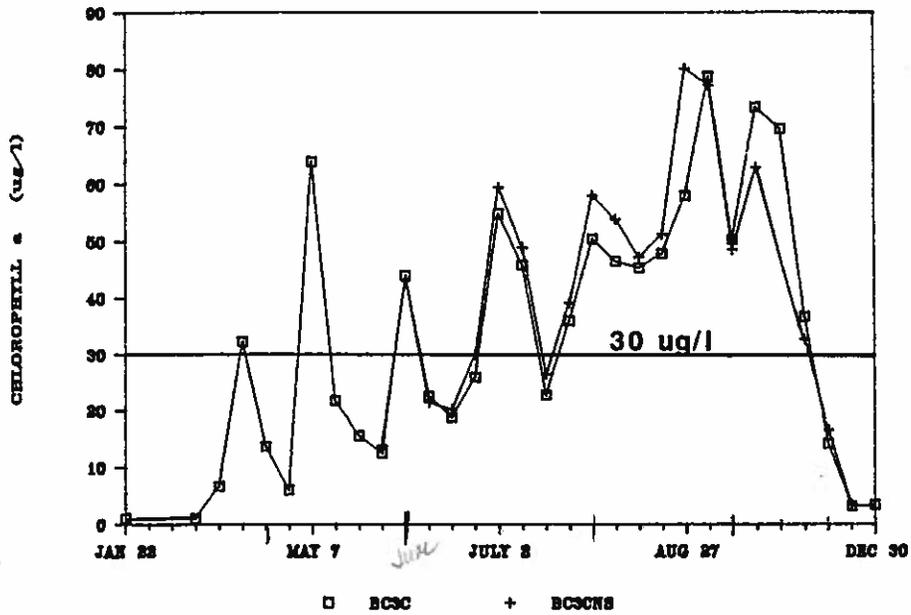
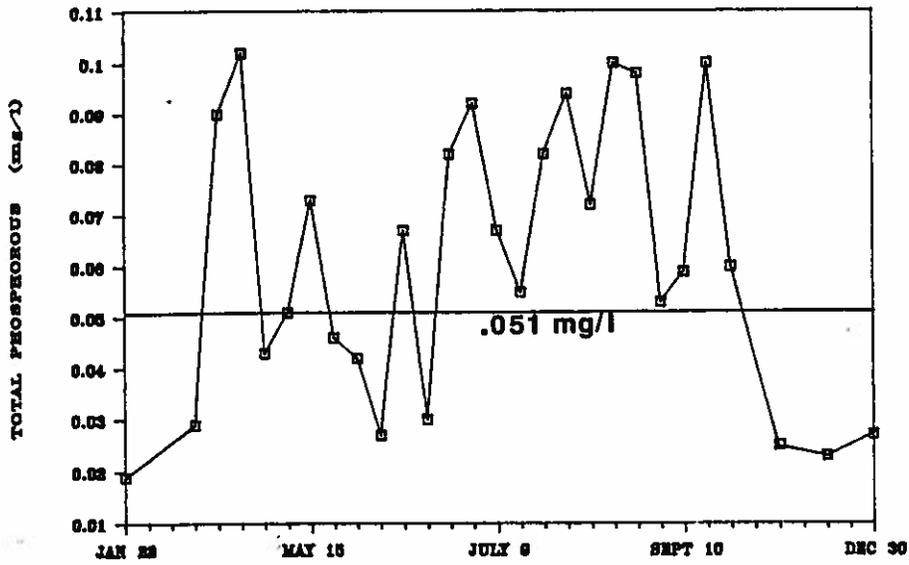


Figure 1 . Daily total phosphorus and chlorophyll a concentrations at station 3 in 1987.

summer chlorophyll a was 53.2 ug/l and both August (49.5 ug/l) and September (68.0 ug/l) exceeded the monthly standard (Table 1).

The mean summer 1987 level was similar to 1986 although mean monthly 1986 values had a higher degree of variation. The patchy nature of the 1986 blue-green algae bloom could explain this observation. The 1985 values were considerably lower than either 1986 or 1987.

Observations in 1987 indicated that the blue-green alga, Microcystis did not build to bloom levels observed in 1986. However, the species was frequently observed in the inner bay and around the Las Vegas Boat Harbor (Paulson 1987).

A cross sectional analysis of chlorophyll a at station 3 indicated that most of the time the concentration at station 3C was slightly lower than the mean of stations 3CNS (Figure 1). This data suggests that measurement of chlorophyll a from center channel adequately represents chlorophyll a in the cross-section. This will be further investigated in the 1988 monitoring program.

Diurnal sampling at station 3C during three surveys showed some degree of daily variation but no consistent trend was observed over the 24-hour period (Figure 2). Diurnal sampling will continue in Las Vegas Bay in 1988 to better understand this relationship.

Table 1 . Summer Station 3 Chlorophyll a from 1985-1987.

YEAR	1985	1986	1987
July	32.2	49.3	42.0
August	35.9	113.9	49.5
September	30.4	15.1	68.0
Mean Summer	32.8	59.4	53.2

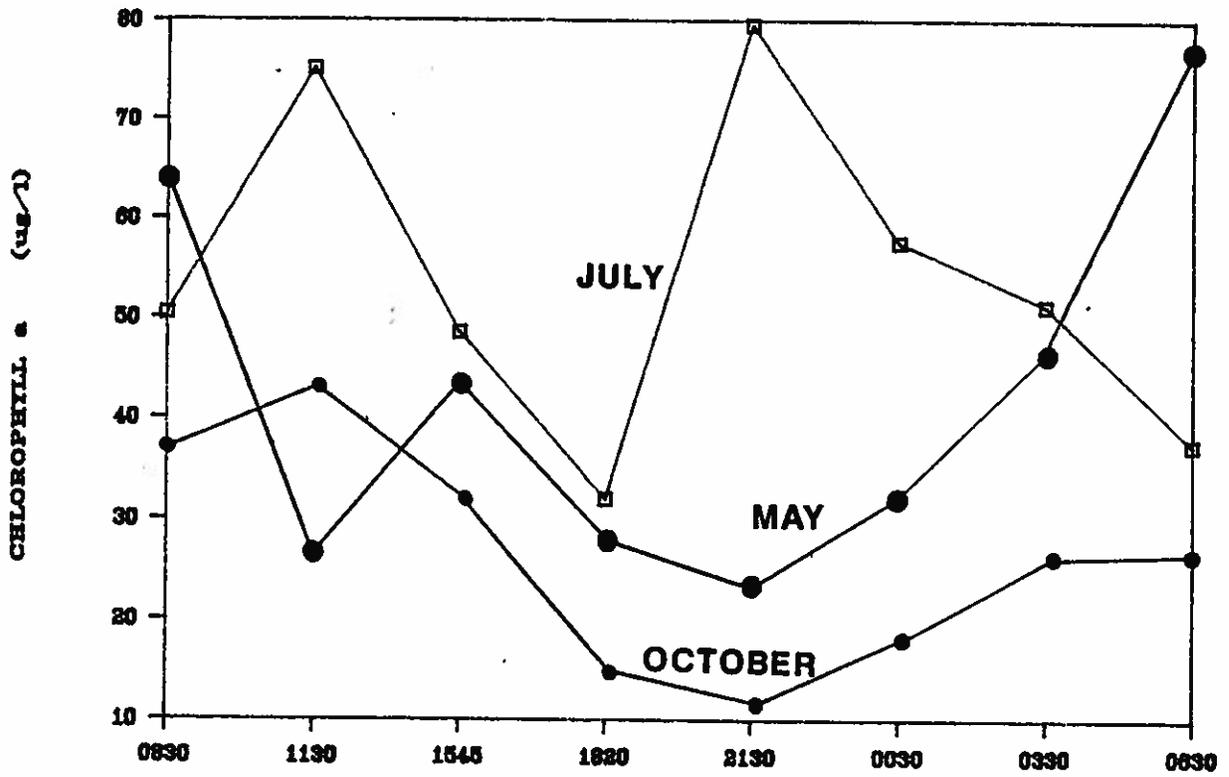


Figure 2 . Diurnal variation in chlorophyll a at station 3 on May 7 and 8, July 30 and 31, and October 7 and 8, 1987.

Unionized Ammonia

Unionized ammonia (NH_3 -N) is calculated from the total ammonia (NH_4 -N) concentration and the fraction of unionized ammonia (FUI). The FUI is dependent on pH and temperature. It should be mentioned that the FUI was not corrected for diurnal variation or ionic strength in this analysis.

The FUI for 1987 is presented in Figure 3. FUI exhibited a seasonal cycle with values generally less than .04 from January through March and October through November. The exception was on October 29 when FUI went up to .119. FUI peaked on July 28 at .373.

The most important factor influencing FUI in Las Vegas Bay (LVB) is pH which is primarily controlled by the rate of algal production. As described previously the rate of algal production is much higher in summer than winter which is reflected in the seasonal nature of the FUI. The diurnal cycle of FUI has been defined and will be discussed in a later section of this report.

Total ammonia also exhibited a seasonal cycle with concentrations increasing from January through April and then decreasing through the end of the year (Figure 3). Peak concentrations were observed from mid-April through mid-May. This again is consistent with the idea that the plume has less effect on LVB surface water in the late fall through early spring period.

Unionized ammonia at station 2 was similar to previous years although peak values were somewhat lower (Figure 3 .) Average growing season (April - September) unionized ammonia was significantly higher than the chronic toxicity standard of .04 mg/l.

Data for three diurnal sampling runs for total ammonia are presented in Figure 4 . Total ammonia was highest in the May samples and lowest in the

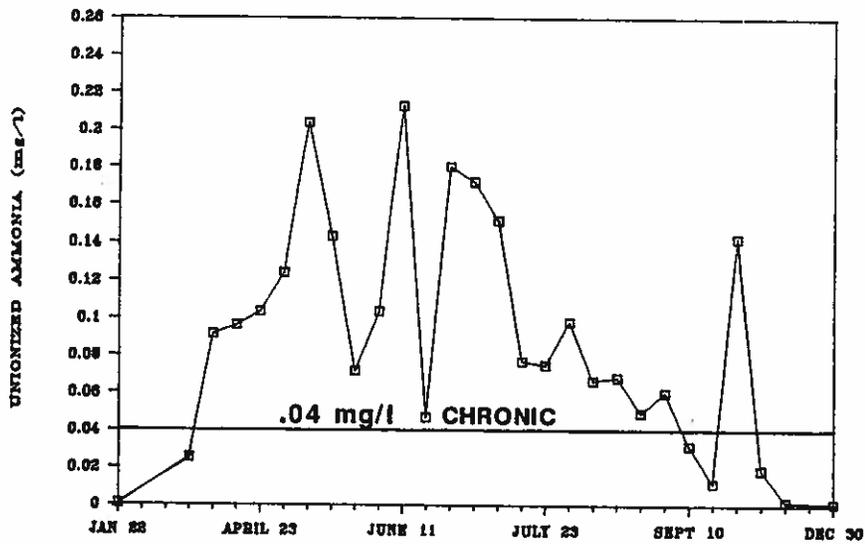
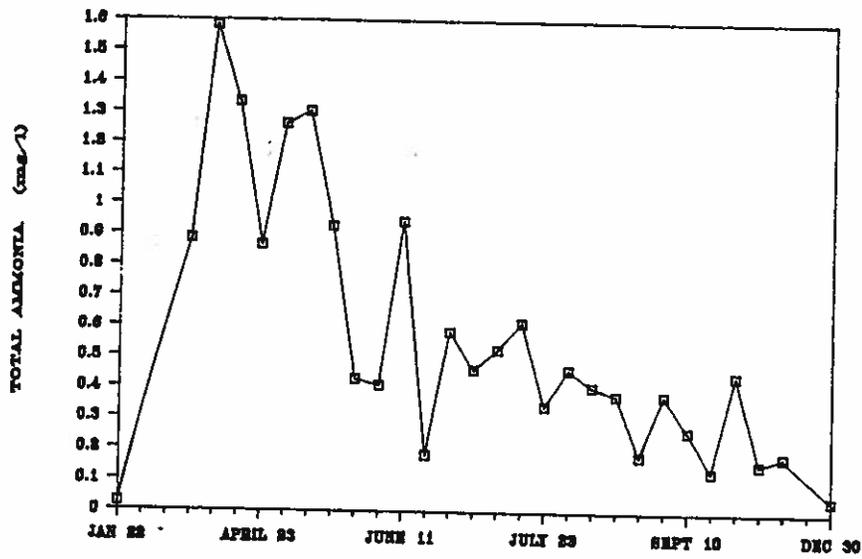
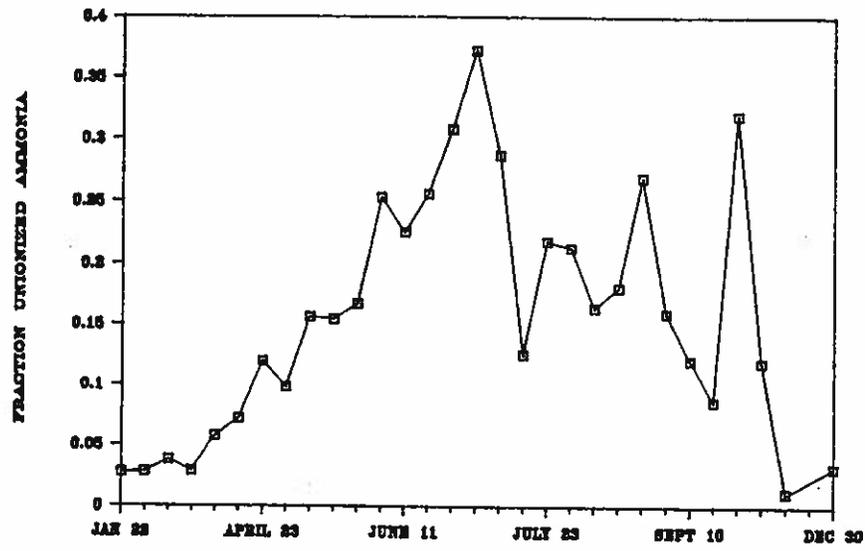


Figure 3 . Daily fraction unionized ammonia, total ammonia and unionized ammonia at station 2 in 1987.

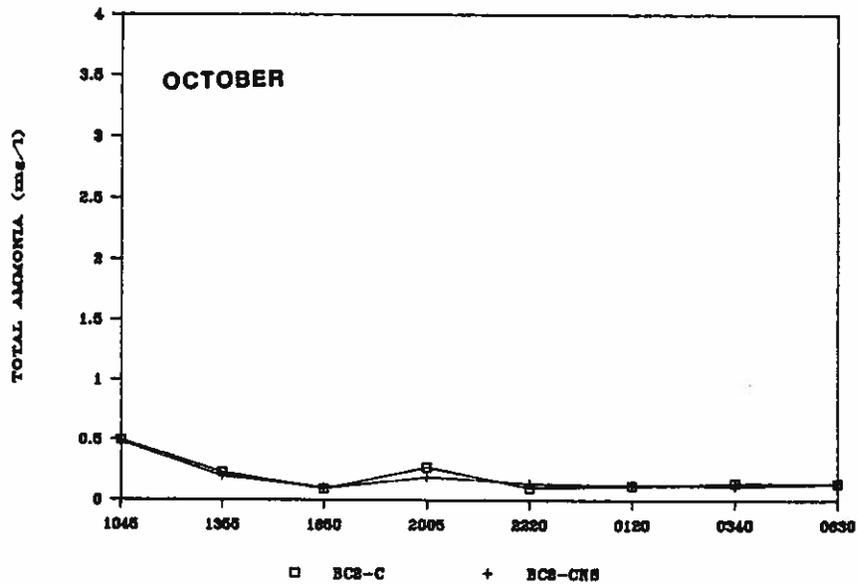
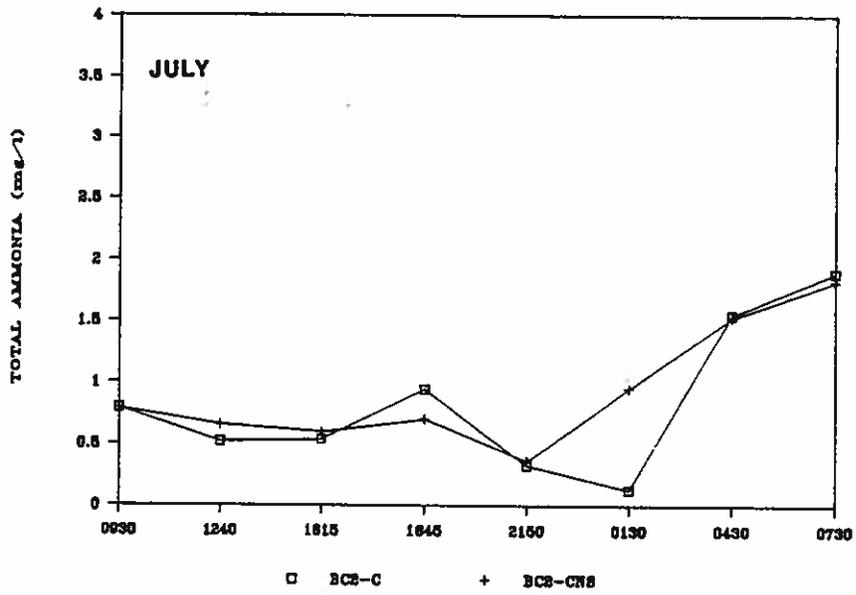
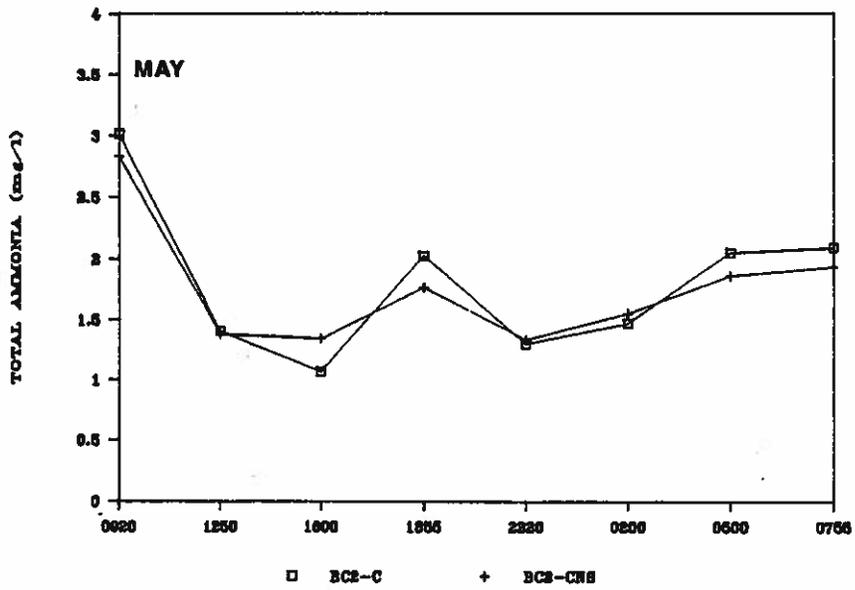


Figure 4. Diurnal and cross-sectional variation in total ammonia at station 2 on May 7 & 8, July 30 & 31, and October 7 & 8, 1987.

October samples. Some diurnal variation was observed but no consistent pattern is apparent. Cross-sectional samples were also collected during the diurnal studies. Total ammonia at 3C was at times slightly above and other times slightly below the average of 3CNS. Although further diurnal sampling will be conducted, at this time it appears that center channel collection of total ammonia adequately represents the cross-section.

CONCENTRATION ESTIMATES AT NORTHSORE ROAD
TO MEET WATER QUALITY STANDARDS IN LAS VEGAS BAY

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1. INTRODUCTION

The estimation of appropriate Las Vegas Wash (LVW) mass loadings of phosphorus and total ammonia to Las Vegas Bay (LVB) that will meet the water quality standards, Anon. (1987), requires that the hydrodynamics of the LVW-LVB interaction be defined. It is the goal of this report to identify and justify an appropriate model for describing the hydrodynamic interaction of LVW with LVB and enable the LVW mass loadings that will meet the new water quality standards in LVB to be estimated. The selection of an appropriate hydrodynamic model is based on the analysis of the historical data available for LVW and LVB. The data sources and periods of time used in this report are summarized in Table 1.1.

It is the premise of this investigation that LVB water quality is controlled by the mass loading of LVW to LVB, and the amount and direction of mixing that occurs between the LVW inflow and the epilimnetic waters of LVB. While the mass loading can be controlled by administrative action, the mixing processes and their magnitude are controlled by nature and are beyond the control of administrative action. The magnitude and direction of mixing between the LVW inflow and LVB is controlled by the LVW volumetric inflow, the momentum of the LVW inflow, and the difference in buoyancy (density) between the LVW inflow and the ambient waters of LVB. In Chapter 2 of this report the historical trends in the LVW density are examined. In Chapter 3, the historical trends in the LVB densities are examined. In Chapter 4, the historical density data regarding LVW and LVB are

TABLE 1.1 REPORT DATA SOURCES AND PERIOD OF RECORD USED

Data	Source	Period of Record Used
LVW EC-TDS	USGS Water Resources Data	10/69-9/84
LVW EC at Northshore Road	USGS Water Resources Data	10/69-9/84
	Clark County Sanitation District	10/84-9/87
LVW Temperature/EC at Northshore Road	USGS Water Resources Data	10/69-9/84
	Clark County Sanitation District	10/84-9/87
LVB EC and Temperature	Limnological Research Center at UNLV	1/77-9/87

compared. In Chapter 5, an appropriate model for describing the LVW-LVB interaction is recommended and the allowable LVW concentrations of nitrogen and phosphorus at North Shore Road (NSR) that will satisfy the LVB water quality standards are estimated.

2. TRENDS IN LVW WATER DENSITY

2.1 Introduction

Water density is a function of three variables: water temperature, the concentration of total dissolved solids (TDS), and the concentration of suspended solids. Water densities are affected by variations in temperature and the concentrations of dissolved and suspended solids according to the following equation:

$$\rho = \rho_T + \Delta\rho_s \quad (2.1)$$

where ρ = water density (kg/m^3), ρ_T = water density as a function of temperature (kg/m^3), and $\Delta\rho_s$ = density increment due to dissolved and suspended solids (kg/m^3).

A number of formulations have been proposed to describe water density variations due to temperature. The relationship proposed by Gill (1982) is used here or

$$\begin{aligned} \rho_T = & 999.8452594 + 6.793952 * 10^{-2} T - \\ & 9.095290 * 10^{-3} T^2 + 1.001685 * 10^{-4} T^3 - \\ & 1.120083 * 10^{-6} T^4 + 6.536332 * 10^{-9} T^5 \end{aligned} \quad (2.2)$$

where T = water temperature in degrees Centigrade.

Density is also a function of the dissolved and suspended solids concentration. The density increment due to TDS was quantified by Ford and Johnson (1983) as

$$\Delta\rho_{\text{TDS}} = C_{\text{TDS}} (8.221 * 10^{-4} - 3.87 * 10^{-6} T)$$

$$+ 4.99 \times 10^{-8} T^2 \quad (2.3)$$

where C_{TDS} concentration in (g/m^3 or mg/l) and T = water temperature in degrees Centigrade. The typical measurements of TDS in LVW at Northshore Road are in terms of the specific conductance of the water; see for example Anon. (1980). According to Anon. (1980)

"..., the concentration of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance (in micromhos)," Anon. (1980, p. 19).

In Anon. (1980), it is further noted that the relationship between specific conductance and the concentration of TDS varies from stream to stream and may also vary in the same stream with time due to changes in the composition of the source water. In the case of LVW at Northshore Road, there are sufficient data to directly establish a regression relationship between TDS (in mg/l) and specific conductance (in micromhos) or

$$[TDS] = -293. + 0.830 [SC] \quad (2.4)$$

with a correlation coefficient of 0.973 and normally distributed residuals. It should be noted that Equation (2.4) is based on USGS field and laboratory data and utilizes none of the Clark County Sanitation District (CCSD) data since CCSD chose to use a laboratory procedure different from that of the USGS to determine the concentration of TDS.

The density increment due to suspended solids was determined

by Ford and Johnson (1983) to be

$$\Delta\rho_{ss} = C_{ss} (1 - 1/SG) * 10^{-3} \quad (2.5)$$

where C_{ss} = suspended solids concentration (g/m^3 or mg/l) and SG = specific gravity of the suspended solids. If a specific gravity of 2.65 is assumed, then Equation (2.5) becomes

$$\Delta\rho_{ss} = 0.00062 C_{ss} \quad (2.6)$$

Combining Equations (2.3) and (2.5) gives the total density increment in Equation (2.1) as

$$\Delta\rho_s = \Delta\rho_{TDS} + \Delta\rho_{ss} \quad (2.7)$$

2.2 LVW Water Temperature Trends

In this section, the LVW monthly average water temperatures at Northshore Road are examined for the period October, 1969 through August, 1987. For this analysis both USGS and CCSD field measurements were used, Table 1.1. Further, the average monthly water temperature was taken as the arithmetic average of the publicly published temperature data for that month. Finally, in the case of USGS data, it was the discrete temperature data generally found in the water quality section of their annual report that is used in this analysis.

The monthly average values of LVW water temperature are plotted in Figure 2.1. In all, 212 points are plotted since there are gaps in the data. Visually this figure is somewhat confusing since there is both seasonal variation and a very apparent trend to increasing monthly average water temperatures.

coefficient associated with Equation (3.1) is 0.001; the residuals are normally distributed; and a t-test of the slope demonstrates that it is significantly different from zero.

3.3 LVB Average Epilimnetic TDS Trends

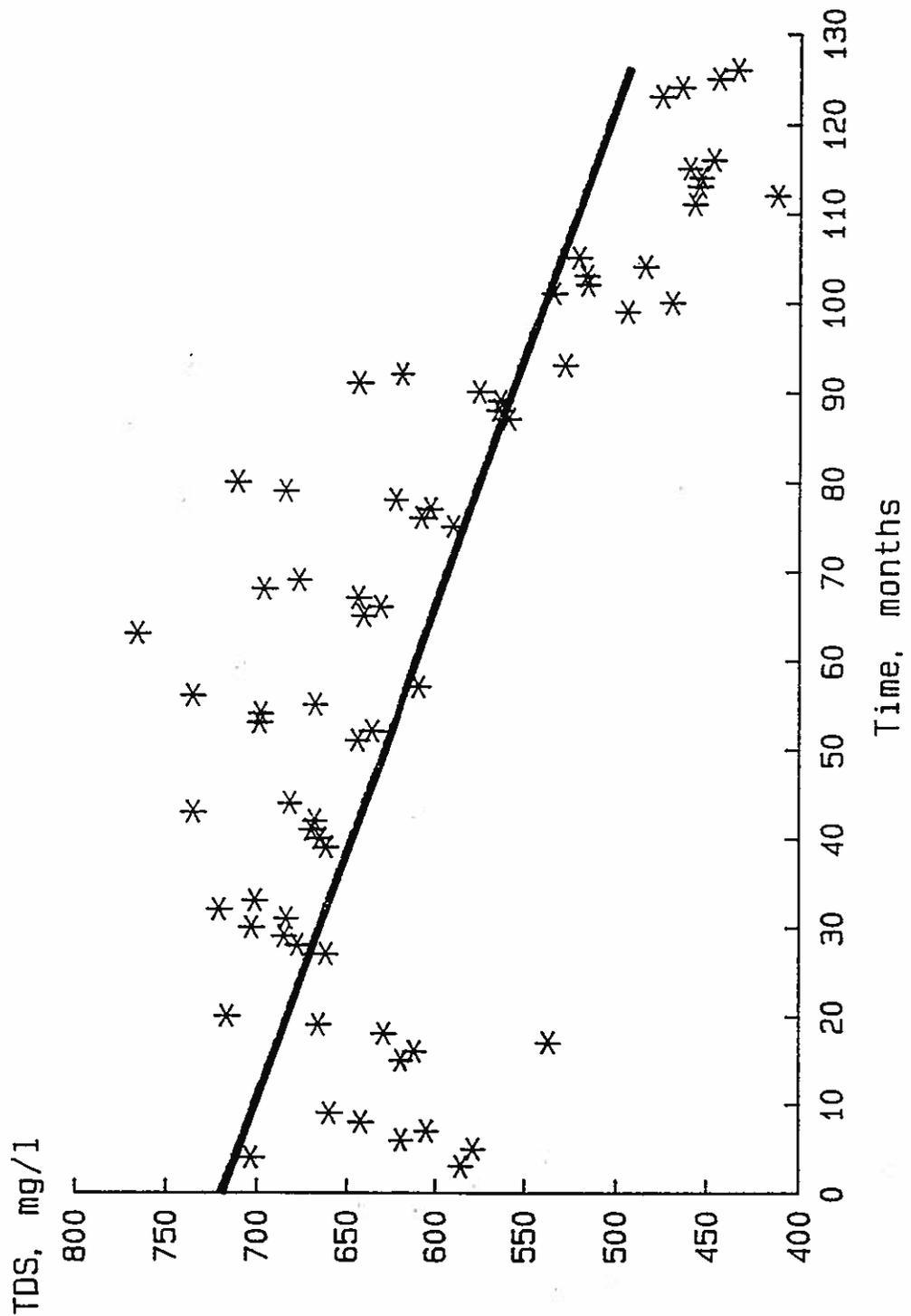
In this section, the LVB representative monthly average epilimnetic TDS concentrations at Station BC-5 are examined for the period January, 1977 through July, 1987. Note, the TDS concentrations for LVB was based on converting field measured values of specific conductance to values of TDS by Equation (2.4) since no specific conductance - TDS data were available for this area of Lake Mead.

The representative monthly average epilimnetic values of TDS are plotted in Figure 3.2. Again, a total of 71 points are plotted in this figure. Assuming a linear trend, the resulting equation for long-term trend is

$$[\text{LVBE-TDS}] = 719. - 1.79 [N] \quad (3.2)$$

where $[\text{LVBE-TDS}]$ = monthly average epilimnetic concentration of TDS (mg/l) at Station BC-5 and N = number of months since January, 1977. The correlation coefficient associated with Equation (3.2) is 0.471; the residuals are normally distributed; and a t-test of the slope demonstrates that it is significantly different from zero. Note, the data trends in Figure 3.2 would be better represented by two lines. That is, for N greater than 0 and less than 50 there appears to be an increasing trend while for N greater than 50 and less than 125 there is a decreasing trend.

FIGURE 3.2 Representative monthly average epilimnetic TDS concentrations at Station BC-5 for the period January, 1977 through July, 1987



3.4 LVB Average Epilimnetic Density Trends

In this section, the LVB representative monthly average epilimnetic water densities at Station BC-5 are examined for the period January 1977 through July 1987. For this analysis, the temperature and specific conductance data presented in Sections 3.2 and 3.3 are used with Equation (2.1) to estimate water density.

The 71 representative monthly average values of epilimnetic density are plotted in Figure 3.3. Assuming a linear trend, the resulting equation for long-term trend is

$$[\text{LVB-rho}] = 998. - 0.00211 [\text{N}] \quad (3.3)$$

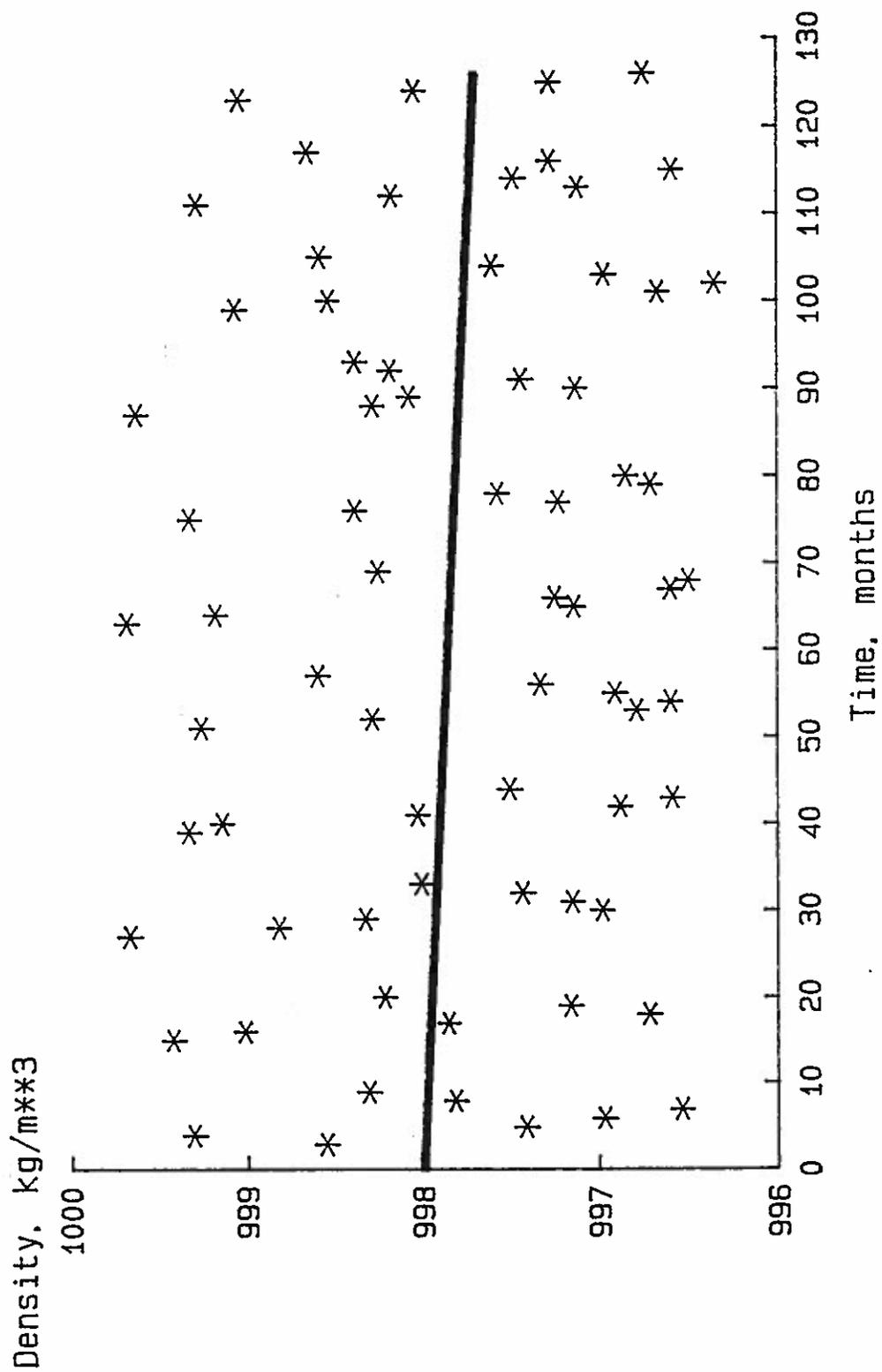
where $[\text{LVB-rho}]$ = monthly average epilimnetic water density in kg/m^3 at Station BC-5 and N = number of months since January, 1977. The correlation coefficient associated with Equation (3.3) is 0.008; the residuals are normally distributed; and a t-test of the slope demonstrates that the slope is significantly different from zero.

3.5 Conclusions

The discussions in the preceding sections yield the following conclusions regarding LVB trends in temperature, TDS concentrations, and density. The conclusions are valid regardless of whether only the representative monthly average epilimnetic values or the values at various depths below the free surface are considered.

First, over the period of time examined the representative monthly values of LVB water density at Station BC-5 has

FIGURE 3.3 Representative monthly average epilimnetic water densities at Station BC-5 for the period January, 1977 through July, 1987



decreased. Second, during the period of time examined the noted decrease in density was primarily the result of increasing water temperatures and decreasing concentrations of TDS. The representative values of monthly TDS concentration appear to have reached a maximum during 1981 and subsequently decreased rapidly. Although the noted decrease in TDS is most likely due to dilution and salinity control, the noted decrease in TDS shows no sign of abating. The trends in epilimnetic water temperature are much less clear and no conclusions can be stated.

4. COMPARISON OF LVW-LVB DENSITY TRENDS

4.1 Introduction

Water quality in LVB is primarily controlled by the hydrodynamic interaction that occurs between LVW and LVB; and the most significant factor governing the nature of this interaction is the density of the LVW flow relative to the density of the epilimnetic waters of LVB. When the density of LVW is much greater than that of the epilimnetic waters of LVB, LVW enters LVB as a negatively buoyant jet and flows into the hypolimnetic waters of LVB. The effect of a negatively buoyant plume on epilimnetic water quality is minimal because mixing between the epilimnion and the hypolimnion is inhibited by the thermocline. When the density of LVW is equal to or less than or equal to that of the epilimnetic waters of LVB, LVW enters LVB as neutral or buoyant jet. The effect of a neutrally buoyant or buoyant jet on epilimnetic water quality is major since the pollutants in the LVW inflow are injected directly into the epilimnetic waters.

In this section, the results from Chapters 2 and 3 are used to examine the trend in the relative density difference between LVW and LVB. At this point, the data available are only sufficient to examine trend. That is, USGS and CCSD data were used to estimate the average monthly density of the LVW flow at Northshore Road, Chapter 2. For each month used in this chapter, a single representative vertical profile of temperature and specific conductivity at Station BC-5 was used to estimate a monthly representative density for LVB. Thus, it would be

entirely inappropriate to interpret the following discussion as a comparison of specific values; rather, the following discussion addresses historic trends in the LVW-LVB density difference.

4.2 LVW-LVB Average Epilimnetic Density Difference Trend

In this section, the difference trend between the monthly average LVW inflow density and the representative monthly average epilimnetic density is examined. The period of record used for this discussion is January, 1977 through July, 1987 with only the months of April through October, inclusive, considered. The average density of the epilimnetic waters are defined according to the 'rule' discussed in Chapter 3.

In Figure 4.1 the variable $[\Delta]$ is plotted as a function of $[N]$ where

$$[\Delta] = [\text{LVW-rho}] - [\text{LVB-rho}] \quad (4.1)$$

with $[\text{LVW-rho}]$ estimated as discussed in Chapter 2 and $[\text{LVB-rho}]$ estimated as discussed in Chapter 3. Assuming, as described before, that $[\Delta]$ has a linear trend, the resulting equation for long-term trend is

$$[\Delta] = 2.40 - 0.0127 [N] \quad (4.2)$$

where N = number of months since January, 1977. The correlation coefficient associated with Equation (4.2) is 0.315; the residuals are normally distributed; and a t-test of the slope demonstrates that it is significantly different than zero.

The importance of the data in Figure 4.1 and Equation (4.2) to the analysis of water quality in LVB is significant. First,

FIGURE 4.1 Representative values of the variable [del] at Station BC-5 for the period January, 1977 through July, 1987

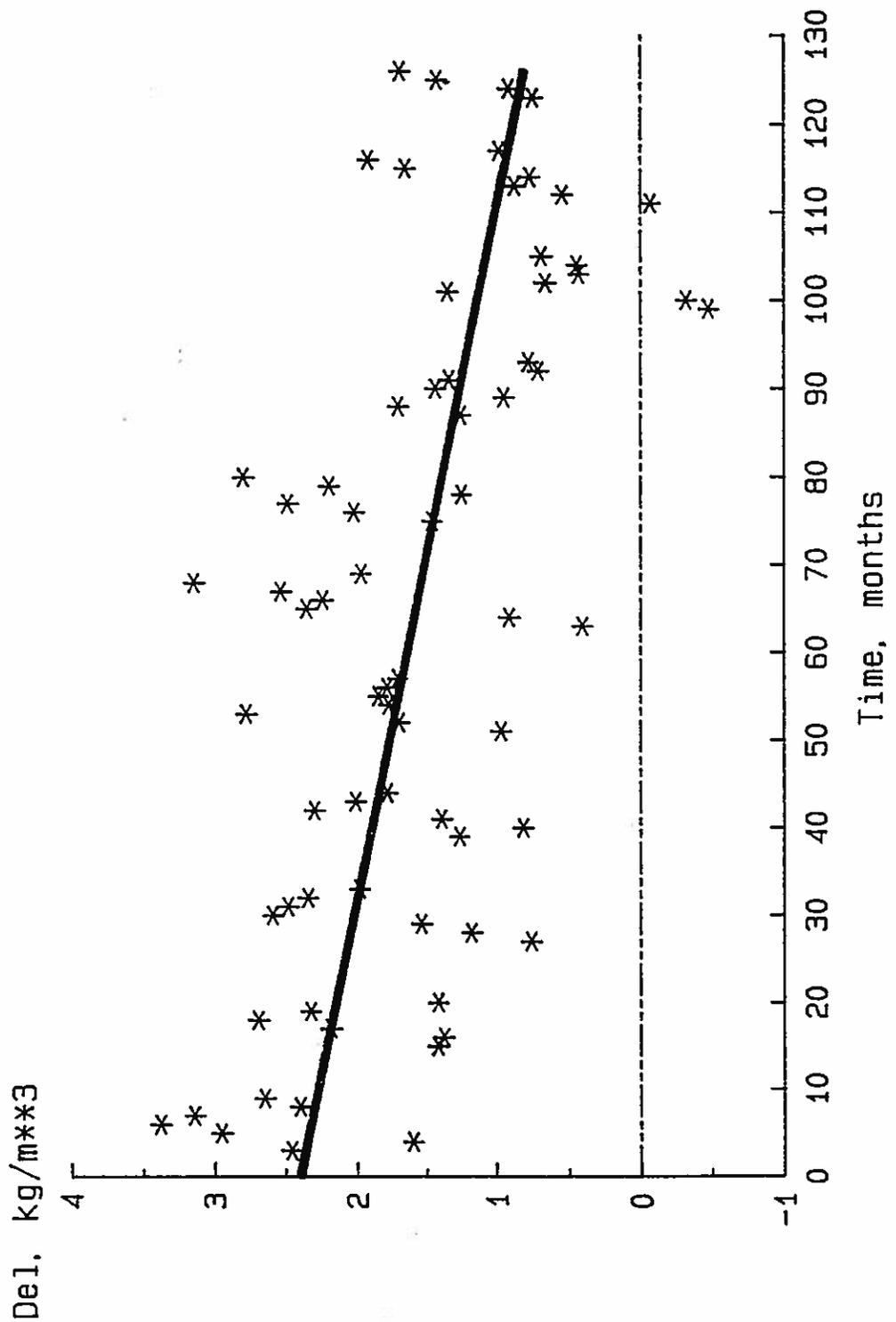
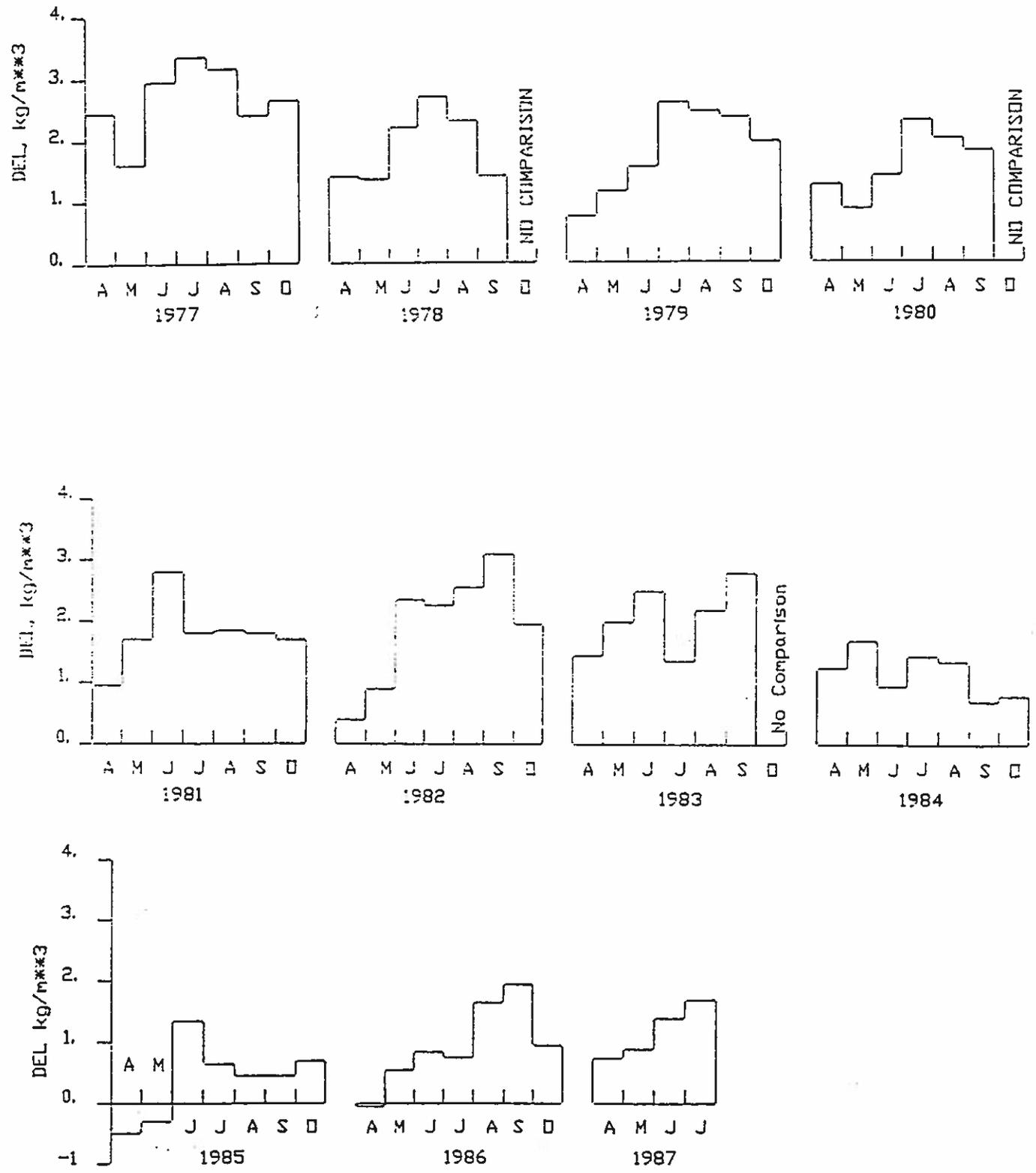


Figure 4.1 graphically demonstrates that $[\Delta]$ has decreased in value over the period of time examined. Furthermore, there have been months in which $[\Delta]$ was negative; that is, the representative monthly average LVB epilimnetic density was greater than the density of LVW. Second, Equation (4.2) demonstrates that over the period of time examined the hydrodynamic interaction of LVW and LVB has dramatically changed. In the early part of the period examined, LVW entered LVB as a negatively buoyant jet. In the latter part of the period examined, LVW entered LVB as a neutrally buoyant or buoyant jet. Furthermore, since the slope in Equation (4.2) is negative and non-zero, it must be assumed that $[\Delta]$ will continue to decrease in value.

In Figure 4.2 $[\Delta]$ is plotted in bar graph form as a function of time. This graph presents additional evidence that the trend in $[\Delta]$ has caused and could continue to cause serious water quality problems in LVB for the following reasons. First, $[\Delta]$ typically has a relatively small value in April and May and generally increases in value until mid or late summer when it again decreases in value. Second, during periods of time in 1985 and 1986 $[\Delta]$ was negative indicating LVW may have entered LVB as a buoyant or neutrally buoyant jet. Under such circumstances, the nutrients contained in the LVW inflow and were injected directly into the epilimnetic waters of LVB at the beginning of the growing season or period of increased biological activity. Recall that in 1986 chl a values in LVB reached objectionable levels.

FIGURE 4.2 Representative values of the variable [del] at Station BC-5 for the period January, 1977 through July, 1987 in bar graph form



In Figure 4.3 the depth of neutral buoyancy and the depth to the top of the thermocline at Station BC-5 are plotted as a function of time. By definition, the depth of neutral buoyancy is the depth at which the density of the inflow equals the density of the ambient receiving water. In Figure 4.3, the depth to neutral buoyancy is plotted as a circle in five meter intervals; for example greater than 30m but less than 35m. The depth to the top of the thermocline is plotted as an asterisk in Figure 4.3, and as an exact depth.

Important information regarding the changing nature of the hydrodynamic interaction between LVW and LVB can also be found in Figure 4.3. For example, when the depth to the point of neutral buoyancy is much greater than the depth to the top of the thermocline, LVW enters LVB as a negatively buoyant plume and the probability of pollutants in the LVW inflow mixing with the epilimnetic waters of LVB are minimal. In contrast, when the vertical separation between the depth to neutral buoyancy and the top of the thermocline is small, the pollutants in the LVW inflow are much more likely to be mixed into the epilimnetic waters of LVB. An examination of the data presented in Figure 4.3 demonstrates that in the period 1977-1979 the depth to neutral buoyancy was significantly below the top of the thermocline. Therefore, during this period of time, there was minimal mixing between the LVW inflow and the epilimnetic waters of LVB. During the period 1980-1984, the difference in the depth to neutral buoyancy and the top of the thermocline declined. In particular, during mid to late summer the difference between these depths was often negligible. In 1985 and 1986, the LVW inflow was often

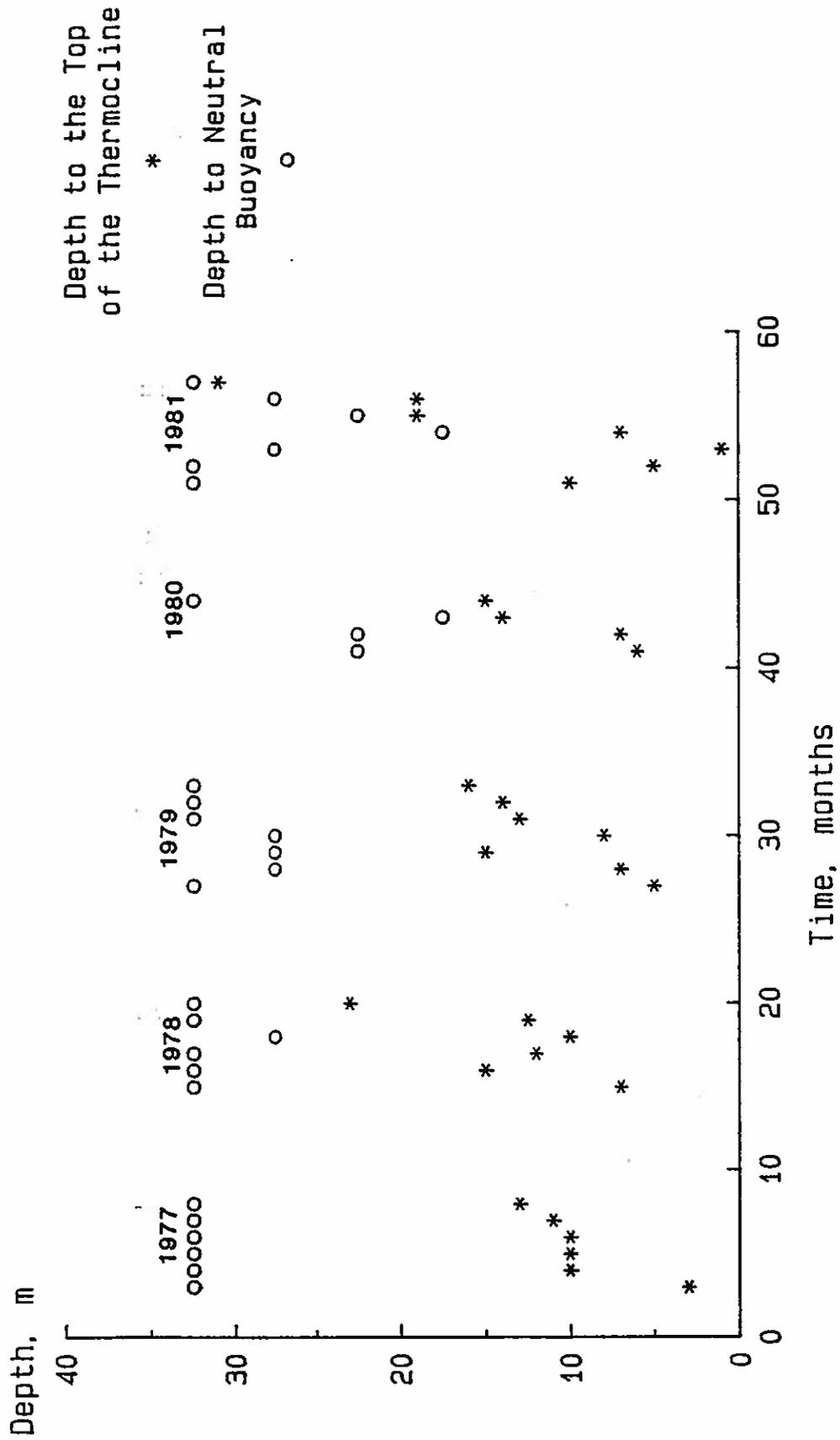


FIGURE 4.3 Depth to neutral buoyancy and the top of the thermocline at Station BC-5 for the period January, 1977 through July, 1987

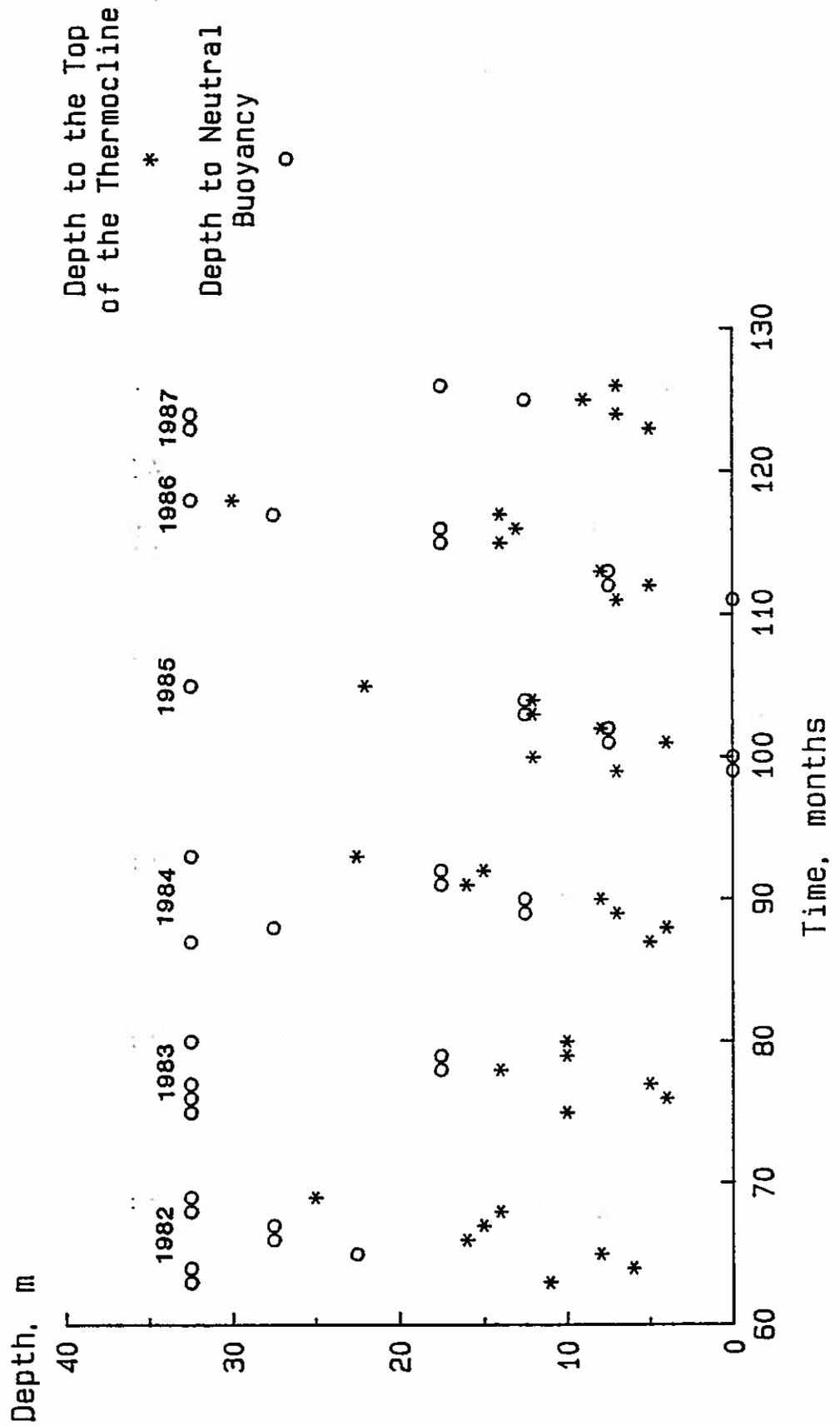


FIGURE 4.3 Continued

buoyant in the late spring and early summer with generally minimal differences in the depth to neutral buoyancy and the top of the thermocline until late summer. In 1987 - a partial data year - the differences in the depth to neutral buoyancy and the top of the thermocline was large in the late spring and early summer and a minimal difference occurred in June.

In viewing and considering these data and results, it must be remembered that only data trends are being examined. For example, during dye studies performed to study the hydrodynamic interaction of LVW and LVB in April-May and August, 1980 Fischer and Smith (1983) pointed out the importance of time and space considerations. The data presented here confirm the results obtained above for 1985-1986; that is, during these years there were significant and constant pathways for pollutants in the LVW inflow to move to the epilimnetic waters of LVB.

4.3 Conclusions

The data presented in the preceding sections of this chapter support the following description of the historical hydrodynamic interaction between LVW and LVB. During the period 1977-1980, LVW entered LVB as a negatively buoyant inflow; and there was minimal transport of LVW pollutants to the epilimnetic waters of LVB. During the period 1981-1984, LVW became less negatively buoyant and began entering LVB in the vicinity of the thermocline. During this period of time, a greater proportion of nutrients entered the epilimnetic waters of LVB. In the period 1985-1986, LVW may at times have entered LVB as a neutrally buoyant or buoyant inflow. Thus, at times it is likely that the

pollutants present in the LVW inflow were injected directly into the epilimnetic waters of LVB. Although the data set for 1987 is incomplete, it would appear that LVW entered LVB as a negatively buoyant inflow in the late spring but entered in the thermocline region in June.

In addressing the estimation of allowable LVW loads of nitrogen and phosphorus to meet the water quality standards in LVB, there are two primary considerations. First, a technique of describing the interaction of LVW and LVB must be selected for the near term. Second, consideration must be given to how this interaction may change in the long term.

5. MODEL SELECTION AND IMPLEMENTATION

5.1 Introduction

Given the available data and the complex and changing nature of the LVW-LVB hydrodynamic interaction, the identification of a model to estimate the concentrations of phosphorus and nitrogen in LVW that will satisfy the current water quality standards in LVB is difficult. In performing this study, a number of models were considered and rejected. Among the types of models examined were:

1. Entrainment Models: There are a number of models available which purport to describe the behavior of a river entering a vertically stratified reservoir. However, previous experience demonstrates that these models are unable to accurately describe the LVW-LVB interaction; see for example, Fischer and Smith (1983).
2. Jet Models: The interaction of LVW with LVB could potentially be modeled as a jet entering a stagnant, stratified fluid. Jet models vary from traditional models such as those described by French (1986) and Fischer et al (1979) to new models such as those described by Roberts (1984) and Roberts and Matthews (1987). If the trends in LVW and LVB densities persist, then in the future a traditional jet model may adequately describe the LVW-LVB interaction. A preliminary analysis using this type of model was performed, and this analysis demonstrated that when LVW enters LVB as a neutrally buoyant jet all point source

discharges of pollutants will have to be removed from the LVW flow to meet the LVB water quality standards. The new jet models [Roberts (1984) and Roberts and Matthews (1987)] were developed to describe the entry of a high momentum axisymmetric jet into a stratified fluid. The LVW inflow is neither a high momentum nor an axisymmetric jet, and thus the results of Roberts (1984) and Roberts and Matthews (1987) do not apply exactly to this situation.

3. Stochastic Models: There are a number of purely statistical methods available for using the available data to estimate allowable LVW concentrations. However, these models do not directly relate LVW and LVB data; and this is felt to be a serious problem that precludes their use in this situation.

4. Dilution Ratio: The dilution ratio method for describing the LVW-LVB interaction was first discussed by Anon. (1982). This technique has the advantages of being based on the law of conservation of mass and directly relating the available LVW and LVB data. This method has the further advantage of simplicity.

After careful consideration of both the available models and data, it was concluded that the dilution ratio technique was the best model available for estimating, in the near term, the LVW concentrations at NSR of phosphorus and nitrogen that will satisfy the LVB water quality standards.

5.2 Dilution Ratio

The dilution ratio model development is documented in Anon. (1982), and there is no need to present a detailed derivation of this model here. The model states

$$D = (c_w - c_s) / (c_s - c_b) \quad (5.1)$$

where with reference to Figure 5.1, D = dilution ratio, c_w = concentration of a tracer in the LVW flow at NSR (mg/l), c_s = concentration of the tracer at the point of interest in LVB (mg/l), and c_b = concentration of the tracer at a background station in LVB (mg/l). If D , c_s , and c_b are known, then Equation (5.1) can be rearranged to estimate the concentration in the LVW flow (c_w) at NSR that will produce the concentration c_s at a specified station in LVB or

$$c_w = (D+1)c_s - D(c_b) \quad (5.2)$$

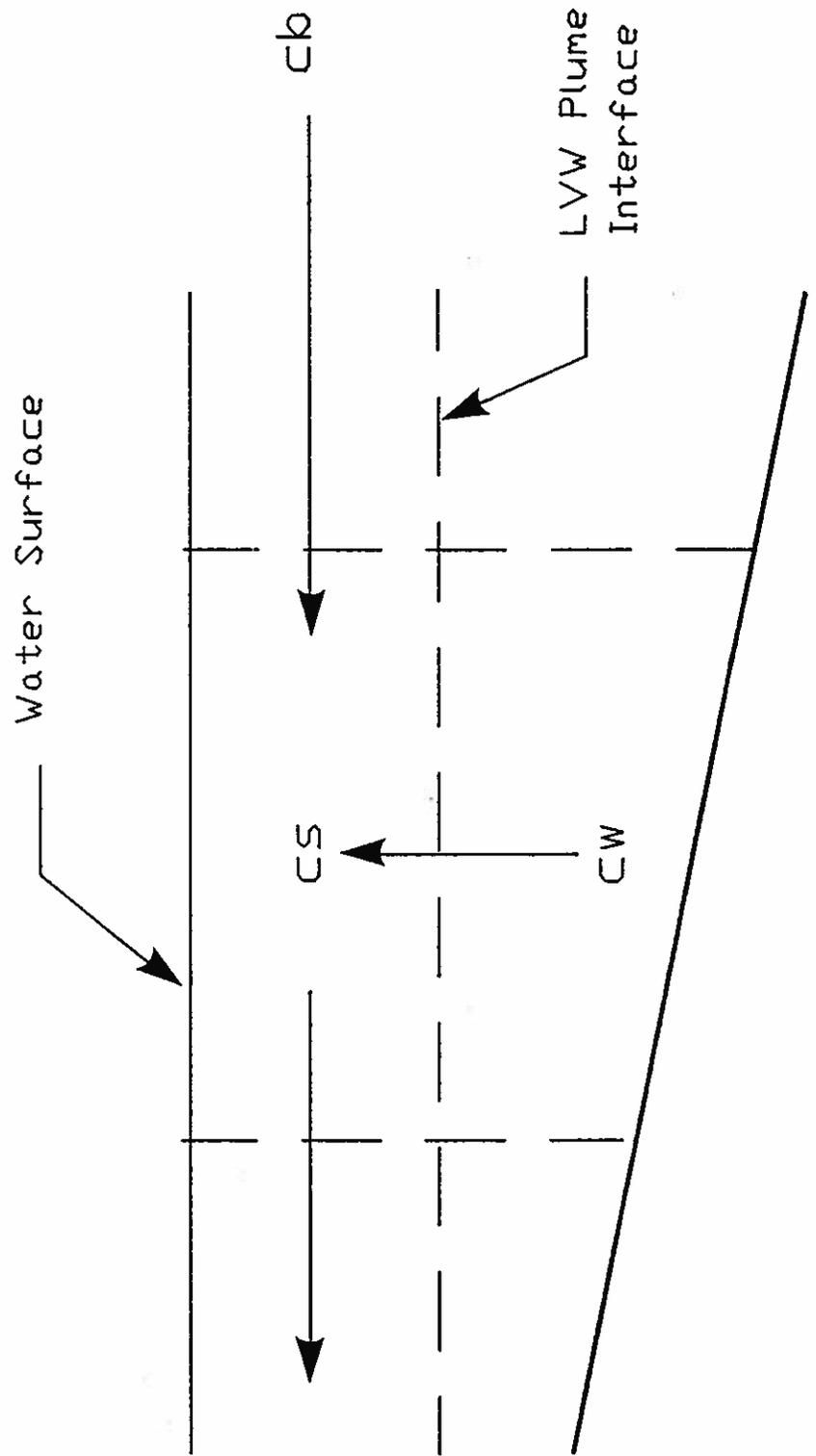
5.3 Application of Dilution Ratio Model to LVB chl a Standard

The water quality standard for chl a at LVB Station BC-3 reads in part:

"Mean summer (July-September) chlorophyll a shall not exceed 40 ug/l. The 4 year mean of summer means shall not exceed 30 ug/l."

The chl a standard is then translated to a total phosphorus (TP04) concentration at LVB Station BC-3 by a regression relationship developed by the Nevada Division of Environmental Protection (NDEP), Cooper (1988). To estimate the functional

FIGURE 5.1 Schematic definition of variables in dilution ratio model



relationship between total phosphorus concentrations and chl a for LVB a regression equation was developed. This is a technique that has been widely used to predict the effect of changes in the concentration of total phosphorus on algal biomass.

The equation developed by Cooper (1988) was derived from data collected at LVB Stations BC-3, BC-4, and BC-5 during 1979-1987. Data from Station BC-2 were not used because of possible light and nitrogen limitations at this site. The data were also screened to remove those data that could be considered to be nitrogen limited (TN:TP less than 10). This screening procedure removed only 12 of the 267 available data points and only one of these points was in the period 1985-1987. The data for this analysis are plotted in Figure 5.2, and the regression equation developed was

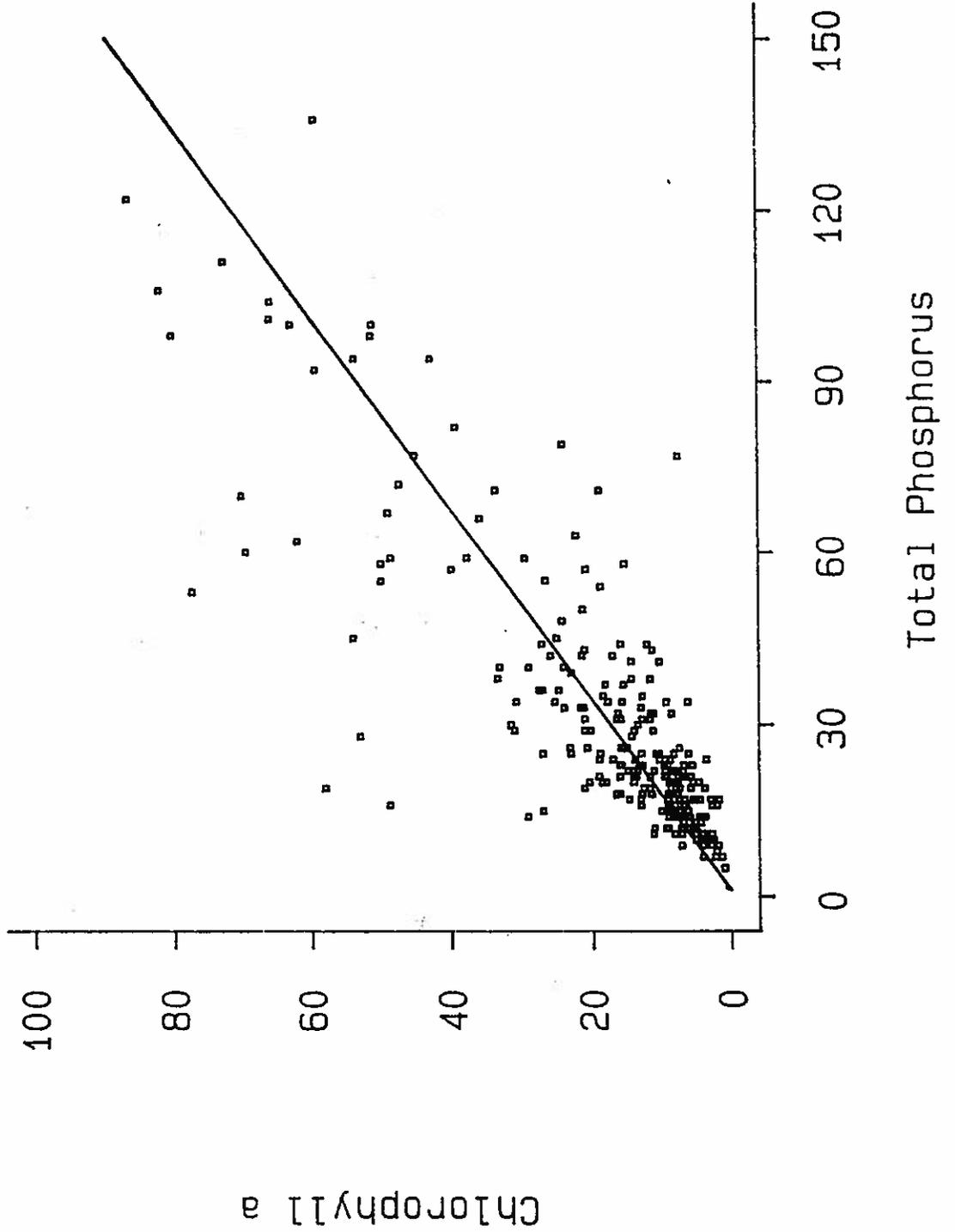
$$\text{chl } \underline{a} = 0.603 [\text{TP04}] - 0.704 \quad (5.3)$$

with a correlation coefficient of 0.83 and where TP04 = the concentration of total phosphorus.

Solution of Equation (5.3) for a long-term mean chl a of 30 ug/l at Station BC-3 predicts a summer mean total phosphorus concentration of 0.051 mg/l, Cooper (1988). The results of a previous study on Lake Meadyielded similar results, Anon. (1982). Although regression equations such as Equation (5.3) can vary from lake to lake, Equation (5.3) is very similar to the chl a - TP04 developed for other lakes; see for example Sakamoto (1966), Dillon and Rigler (1974) and Jones and Bachmann (1976).

In this application, the following interpretation of the

FIGURE 5.2 Regression of chl a as a function of total phosphorus for LVB,
Cooper (1988)



above water quality standard' is used:

1. The allowable TP04 concentration at BC-3 to meet the chl a water quality standard is 0.051 mg/l.
2. For each month during the period April-September (inclusive), the available TP04 data for Station BC-3 are averaged yielding a monthly average value. Note, the period April-September is used because of the critical effect on summer chl a concentrations that spring injections of nutrients into the epilimnetic waters of LVB have.
3. For each year, the monthly average values of TP04 are averaged for the period April-September (inclusive) yielding a 'yearly' average value.
4. Four yearly average values of TP04 are averaged, and it is this value that cannot exceed 0.051 mg/l TP04.

In Table 5.1 the monthly average TP04 (designated TP04 μ) data are summarized for LVW, Station BC-3 (the standard station) and Station BC-8 (the background station) for the years 1985-1987. Given the previously described changes in LVW and LVB water densities and the geometric changes that have occurred in the LVW channel at the point it enters LVB, it is not appropriate to use data previous to 1985 in this analysis. Also summarized in Table 5.1 are average values of the dilution ratio, D, calculated from the average concentrations summarized in this table. Finally, it should be noted that some data at NSR have been deleted from the data base because LVW flow rates were in

TABLE 5.1 SUMMARY OF MONTHLY AVERAGE VALUES FOR THE TP04 DILUTION RATIO CALCULATIONS

M O N T H	1985				1986				1987			
	TP04 mu NSR mg/l	TP04 mu BC-8 mg/l	D	TP04 mu NSR mg/l	TP04 mu BC-8 mg/l	D	TP04 mu NSR mg/l	TP04 mu BC-8 mg/l	D	TP04 mu NSR mg/l	TP04 mu BC-3 mg/l	D
4	0.820	0.020	0.047	29.6	0.753 ³	0.012	0.032	36.0	0.680	0.009	0.062	11.7
5	0.900	0.017	0.064	17.8	0.848	0.010	0.069	13.2	1.43	0.008	0.069	22.3
6	1.04	0.024	0.110	10.8	1.34	0.008	0.062	23.7	0.830 ⁴	0.008	0.052	17.7
7	1.34 ¹	0.007	0.068	20.9	0.748	0.007	0.088	8.14	0.873 ⁵	0.008	0.082	10.7
8	0.797 ²	0.006	0.052	16.2	0.802	0.009	0.104	7.35	0.784	0.008	0.091	8.35
9	0.986	0.006	0.037	30.6	0.868	0.006	0.043	22.3	0.793	0.009	0.068	12.3

¹Data on 7/22/85 ignored because of unusually high flow

²Data on 8/5/85 ignored because of unusually high flow

³Data on 4/7/86 ignored because of unusually high flow

⁴Data on 6/8/87 ignored because of unusually high flow

⁵Data on 7/27/87 ignored because of unusually high flow

excess of 110% of average. In Table 5.2, the monthly average values and the standard deviations associated with these averages of D and the concentration of TP04 at Station BC-8 are summarized for the period 1985-1987.

The water quality standard is based on a four year average value; however, there are only three years of data available. One approach to solving this problem is stochastic simulation. In performing such a simulation, the following assumptions are used:

1. D and cb (Station BC-3) are normally distributed random variables with the monthly means and standard deviations summarized in Table 5.2.
2. The data summarized in Table 5.2 are not biased.
3. The distributions of D and cb are stationary in time. Although this assumption has been violated in the past and may be violated in the future, it should not be violated in the near term. Note, it is to satisfy this assumption that no data previous to 1985 are used in this analysis.
4. The data summarized in Table 5.2 can be used to simulate monthly average values which can then be used to simulate yearly (April-September) average values, and the yearly average values can be used to estimate running, allowable 4 year average values of TP04 at NSR.
5. The running 4 year average values can be combined to estimate a target TP04 concentration at NSR and the standard

TABLE 5.2 MONTHLY AVERAGE VALUES OF D AND mu BC-8 FOR THE PERIOD 1985-1987

Month	D		TP04 Concentrations at BC-8	
	mu D	sig D	mu (BC-8) mg/l	sig (BC-8) mg/l
4	25.8	12.6	0.011	0.005
5	17.8	4.55	0.010	0.004
6	17.4	6.46	0.010	0.006
7	13.2	6.75	0.008	0.002
8	10.6	4.85	0.008	0.003
9	21.7	9.16	0.007	0.002

deviation associated with this value.

A computer code was developed to perform this stochastic simulation, and fifty years of record were simulated. The results of this simulation are:

Target average NSR

Concentration of TP04 = 0.78 mg/l

Standard deviation

Associated with target average = 0.058 mg/l

The water quality standard for chl a states that the standard will never be exceeded. From a practical viewpoint, 'never' is interpreted to mean that TP04 will have only a 1% chance of exceedance at Station BC-3. The 47 four year average values of target TP04 concentrations that resulted from the stochastic simulation are normally distributed and the target TP04 concentration at NSR that will satisfy the water quality standard is

$$\begin{aligned} \mu_{NSR} - z \sigma_{NSR} &= \text{Target NSR TP04 concentration} \\ \text{or} \end{aligned}$$

$$0.78 - 2.4 (0.058) = 0.64 \text{ mg/l}$$

5.4 Application of Dilution Ratio Model to LVB Unionized Ammonia Standard

The water quality standard for unionized ammonia at LVB at Station BC-2 reads in part:

"The 4-day average concentration of un-ionized ammonia shall

not exceed more often than once every three years 0.04 mg/l."

It is assumed and can be shown that if the chronic unionized ammonia standard is met then acute unionized ammonia standard will also be satisfied.

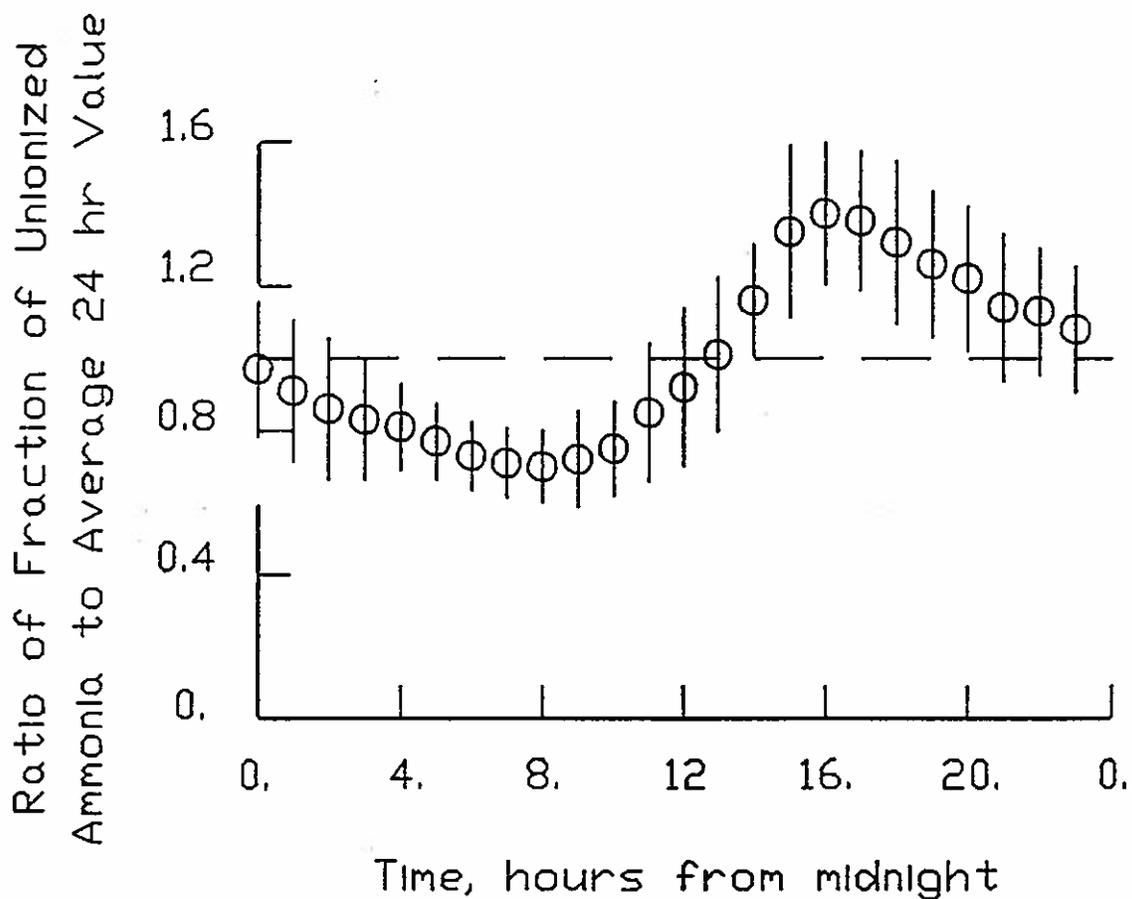
The unionized ammonia standard also indicates that diurnal fluctuations of the concentration of unionized ammonia in the top 2.5m of water will be taken into account.

Since the available historic data regarding unionized ammonia at LVB Station BC-2 were taken at various times throughout the day, the first step in this analysis was to develop a technique for reducing historic values of unionized ammonia to average daily values. During the summer of 1987, a data sonde was emplaced for varying periods of time in the center of the X-section at Station BC-2 in LVB. The data sonde monitored on a hourly basis water temperature and pH, and with these variables known, the hourly fraction of unionized ammonia (fui) can be estimated by [Emerson et al (1975)]

$$fui = 1./[1+10^{*((0.0902-pH) + 2730/(273.2+T))}] \quad (5.3)$$

where T = water temperature in degrees Centigrade. These values can then be used to define the time at which the daily average fui occurs and with the large number of values available Figure 5.3 can be constructed. Note, Equation (5.3) does not take into account the effect of total dissolved solids on the value of fui because it was not felt that TDS changed sufficiently over the periods of time considered to have a significant effect. In Figure 5.3, the ratio of the fraction unionized ammonia to the

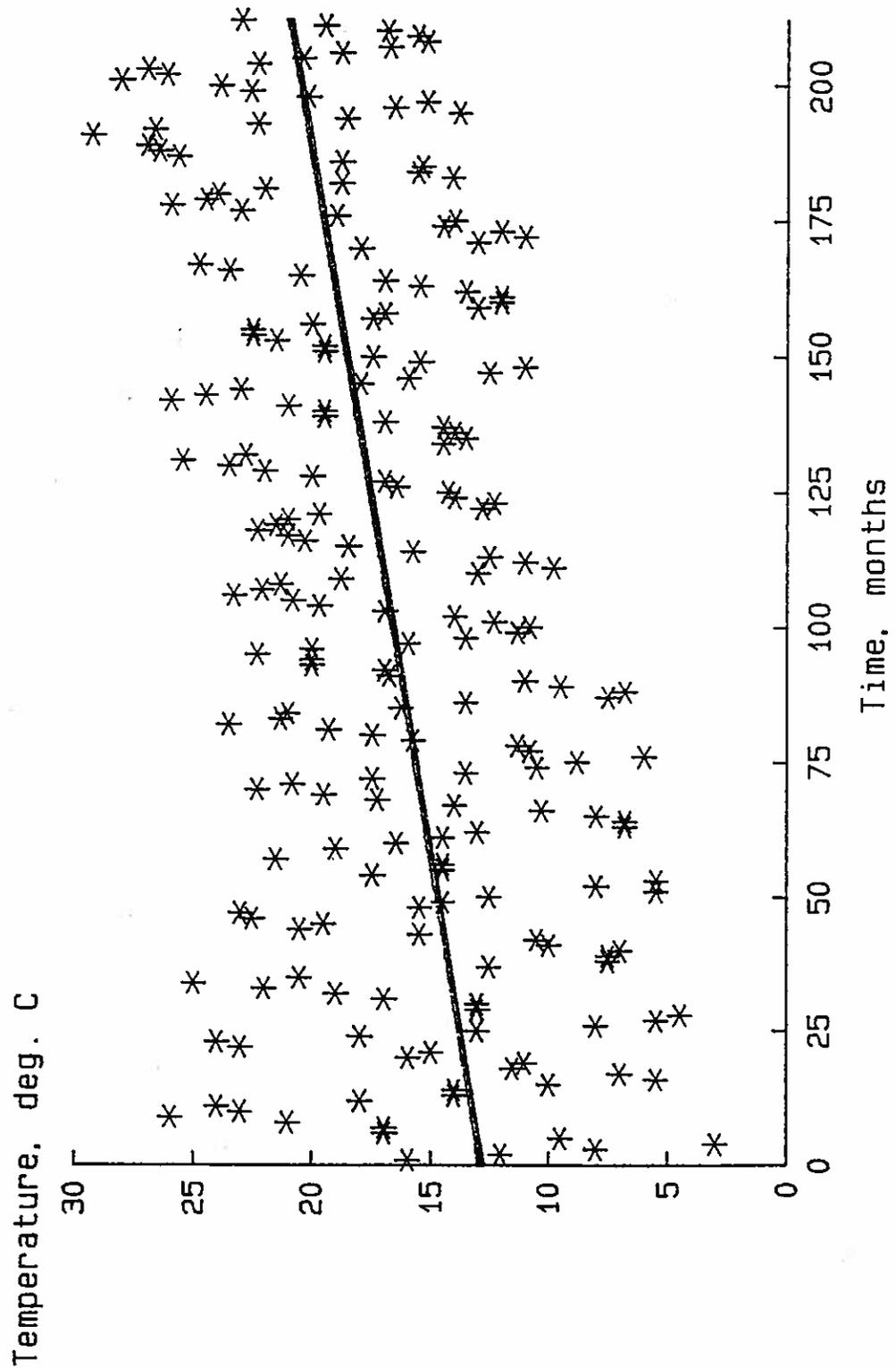
FIGURE 5.3 The ratio of the fraction unionized ammonia to the average fraction unionized ammonia as a function of time. Note, times in this figure are Pacific Daylight Time.



daily average fraction unionized ammonia is plotted as a function of the number of hours elapsed after midnight. In this figure, the vertical lines associated with each point represent the expected value of the fui ratio plus or minus one standard deviation. Figure 5.3 can be used to transform the historic values of unionized ammonia to average values of unionized ammonia. In this figure, the daily average value of fui occurs at approximately 1300 Pacific Daylight Time (PDT); the maximum at approximately 1600 (PDT); and the minimum at approximately 0800 (PDT).

In Table 5.3 the monthly average total ammonia (TNH mu) data are summarized for LVW, Station BC-2 (the standard station) and Station BC-8 (the background station) for the years 1985-1987. Also summarized in Table 5.3 are the monthly average values of fui. The values of fui in this table were corrected for TDS concentrations using the methodology suggested by Stumm and Morgan (1970). Again, given the previously described changes in LVW and LVB water densities and the geometric changes that have occurred in the LVW channel at the point it enters LVB, it is not appropriate to use data previous to 1985 for this analysis. Also summarized in this table are monthly average values of the dilution ratio, D, calculated from the average concentrations summarized in this table. Finally, some total ammonia data at NSR have been deleted from the data base because on these dates LVW flow rates exceeded 110% of average. In Table 5.4, the critical season (April-September inclusive) average values and the standard deviations associated with these averages are

FIGURE 2.1 Monthly average LVW water temperature at Northshore Road for the period October, 1969 through August, 1987



If the data in Figure 2.1 were a complete time series; i.e., no data gaps, this time series could be analyzed by first removing the long-term data trend, then removing identifiable periodicity, and leaving only a random component. A common assumption in examining environmental data such as water temperature is that the long-term data trend is linear; see for example Rich (1973). Using this assumption and linear regression, the resulting long-term trend equation for the water temperature data in Figure 2.1 is

$$[\text{LVW-Temp}] = 12.8 + 0.0388 [N] \quad (2.7)$$

where $[\text{LVW-Temp}]$ = monthly average water temperature in degrees Centigrade at Northshore Road and N = number of months since October, 1969 with $[N=0$ for October, 1969]. The correlation coefficient associated with Equation (2.7) is 0.185 which, although low, is not surprising considering that only the trend has been removed while the periodic and random components remain to be removed. The residuals associated with Equation (2.7) are normally distributed, and a t-test of the slope (0.0388) demonstrates that it is significantly different from zero. The periodic component of this time series cannot be examined because there are data gaps.

Figure 2.1 and Equation (2.7) provide significant information. First, there is a clear trend to increasing monthly average LVW water temperatures at Northshore Road. Second, over the period of time examined, the monthly average water temperature at Northshore Road has increased - using Equation (2.7) - by approximately 8 degrees Centigrade. Third, it does

not appear that the trend to increasing water temperatures has reached a plateau of stability. Fourth, examination of Equation (2.2) demonstrates that increased water temperature results in decreased water density.

2.3 LVW TDS Trends

In this section, LVW monthly average TDS concentrations at Northshore Road are examined for the period October, 1969 through August, 1987. For this analysis, both USGS and CCSD specific conductance measurements were used with Equation (2.4) to estimate TDS concentration in (mg/l). All other definitions remain as they were for the monthly average water temperature discussion.

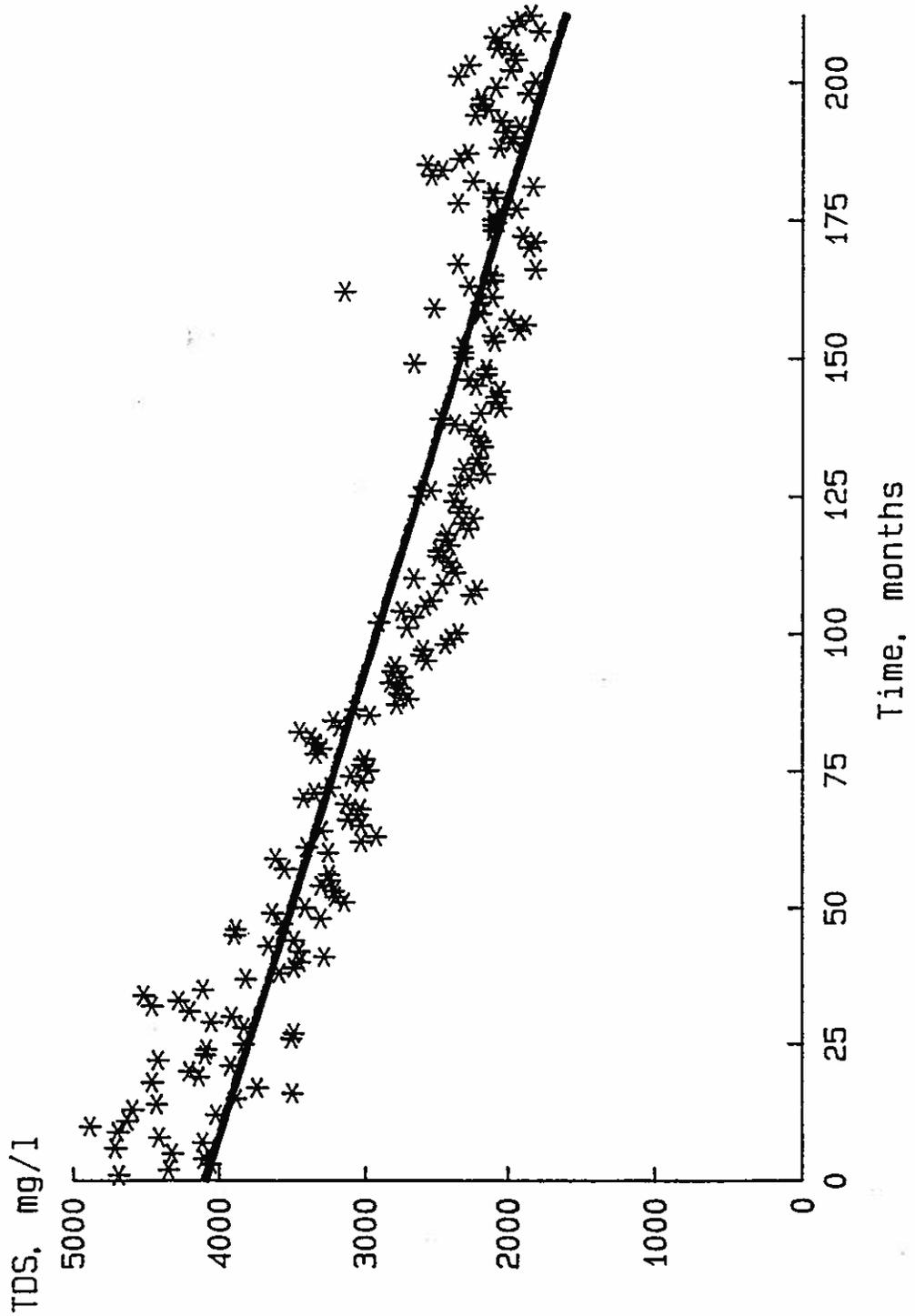
The monthly average values of TDS are plotted in Figure 2.2. Again, a total of 212 points are plotted since there are data gaps. Visually, this figure is less confusing than Figure 2.1 since there are only minor seasonal variations in TDS. Again, assuming a linear trend, the resulting regression equation for long-term linear trend is

$$[\text{LVW-TDS}] = 4097. - 11.7 [N] \quad (2.8)$$

where [LVW-TDS] = monthly average concentration of TDS (mg/l) at Northshore Road and N = number of months since October, 1969. The correlation coefficient associated with Equation (2.8) is 0.84 and a t-test of the slope (-11.7) demonstrates that it is significantly different from zero.

Figure 2.2 and Equation (2.8) also provide significant information regarding trends in LVW flow densities. First, there

FIGURE 2.2 Monthly average LVW TDS concentrations at Northshore Road for the period October, 1969 through August, 1987



has been over the period of record examined a clear and significant trend to decreasing monthly average concentrations of TDS in LVW at Northshore Road. Second, in recent years, the monthly average concentration of TDS at Northshore Road appears to have stabilized. Given this observation, it would be inappropriate to extrapolate the assumption of linear trend and/or assume that there will be further significant decreases in the LVW TDS concentration. Third, examination of Equation (2.3) demonstrates that decreased concentrations of TDS result in reduced water densities.

2.4 Suspended Solids

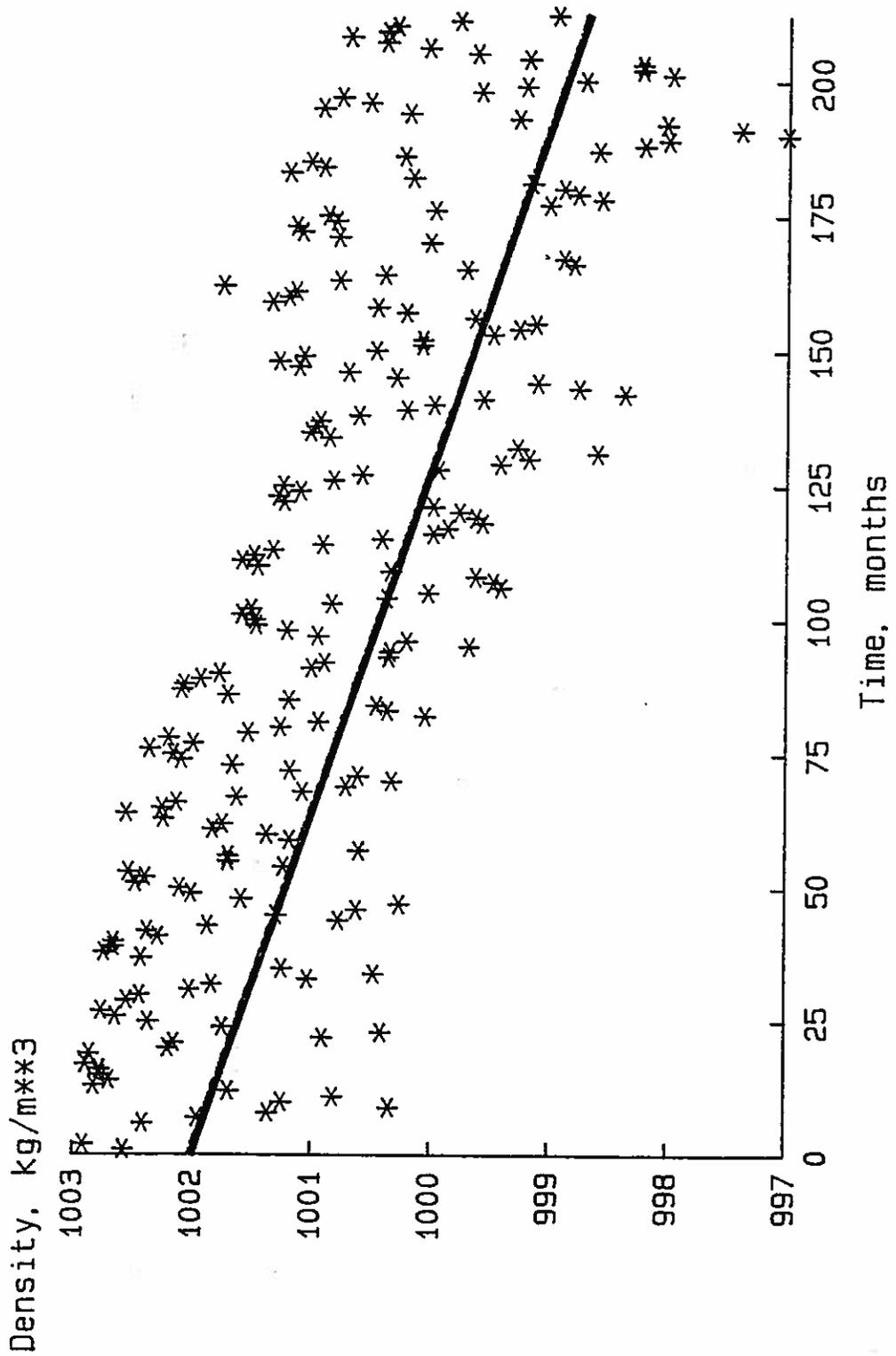
The analysis of the effect of suspended solids on the density of the LVW at Northshore Road is not considered in this discussion because of the poor, unreliable, and intermittent data record available.

2.5 LVW Density Trends

In this section, LVW monthly average flow density at Northshore Road is examined for the period October, 1969 through August, 1987. For this analysis both USGS and CCSD temperature and specific conductance data are used with Equations (2.1), (2.2), (2.3) and (2.4) to estimate water density. All other definitions remain as they were noted in previous sections.

The monthly average values of density are plotted in Figure 2.3 and again there are 212 points in this plot. Assuming a linear trend, the resulting regression equation for long-term trend is

FIGURE 2.3 Monthly average LVW water densities at Northshore Road for the period October, 1969 through August, 1987



$$[\text{LVW-rho}] = 1002. - 0.0156 [\text{N}] \quad (2.9)$$

where $[\text{LVW-rho}] =$ monthly average flow density in kg/m^3 at Northshore Road and $N =$ number of months since October, 1969. The correlation coefficient associated with Equation (2.9) is 0.555 which, although low is not surprising given the significant effect of the seasonal variation of temperature on water density, the residuals are normally distributed, and a t-test of the slope (-0.0156) demonstrates that it is significantly different than zero.

Consideration of the data plotted in Figure 2.3, Equation (2.9), and the foregoing discussion of LVW temperature and TDS trends provides results in the following conclusions. First, during the period of time examined, increasing average monthly temperatures and decreasing concentrations of TDS combined to decrease the monthly average flow density at Northshore Road. Second, although the monthly average TDS concentration appears to have stabilized there are no indications that monthly average flow temperatures have stabilized. Third, in order to be conservative and protective of beneficial uses in LVB, it must be assumed that monthly average flow densities Northshore Road will continue to decrease in the future although perhaps at a slower rate than in the past. Note, this conclusion does not and cannot consider the possible intervention of man on the variables such as the conveyance of the LVW flow in a pipe below the proposed Lake at Las Vegas development.

3. TRENDS IN LVB WATER DENSITIES

3.1 Introduction

Water density in LVB is also a function of water temperature, the concentration of TDS, and the concentration of suspended solids, the definition of representative monthly values of these variables in LVB is more difficult than for LVW at Northshore Road for a number of reasons. First, in LVB all of the variables on which density depend vary as a function of depth since LVB is density stratified during the period April-October in the vertical dimension. Therefore, for this discussion, the representative values of temperature and TDS are by definition the monthly average epilimnetic values of these variables. Suspended solids are not considered in this discussion since this component of density is assumed to be insignificant in LVB. It should also be noted that suspended solids data are not available for LVB. Second, identifying the epilimnetic waters of LVB requires that a definition of the epilimnion be established and followed. By definition, the epilimnion is the distance from the top of the thermocline to the water surface. The top of the thermocline is the point where the vertical gradient of temperature is approximately 1 degree Centigrade/lm. In cases where there was no true thermocline under the foregoing definition, the top of the thermocline is either established on the basis of judgement or taken arbitrarily as being 5m below the water surface. Finally, since there is generally no thermocline during the period November-March, inclusive, the analyses discussed here are confined to the period April-October,

inclusive, which is also a critical period from the viewpoint of water quality. Third, of the stations sampled on a regular basis in LVB one station must be selected as being representative of the ambient density conditions encountered by LVW as it enters LVB. For this discussion, the sampling station designated as BC-5 is used as the representative station. Fourth, in many months vertical profiles of temperature and specific conductivity are available for several dates and one of these must be selected as being representative of the month. In this discussion, the profiles measured in the middle to the end of the month are used.

3.2 LVB Average Epilimnetic Water Temperature Trends

In this section, the LVB representative monthly average epilimnetic water temperatures at Station BC-5 are examined for the period January, 1977 through July, 1987. The data for this analysis derive from Lake Mead Limnological Research Center at the University of Nevada, Las Vegas.

The representative monthly average epilimnetic values of water temperature are plotted in Figure 3.1. In all, 71 points are plotted in this figure. Visually, this figure is confusing; and there is no apparent trend in these temperature data. Using the linear trend analysis discussed in Chapter 2, the long-term linear trend equation for the data in Figure 3.1 is

$$[\text{LVBE-Temp}] = 23.0 + 0.0037 [N] \quad (3.1)$$

where $[\text{LVBE-Temp}]$ = representative monthly average epilimnetic water temperature in degrees Centigrade at Station BC-5 and N = number of months since January, 1977. The correlation

FIGURE 3.1 Representative monthly average epilimnetic water temperatures at Station BC-5 for the period January, 1977 through July, 1987

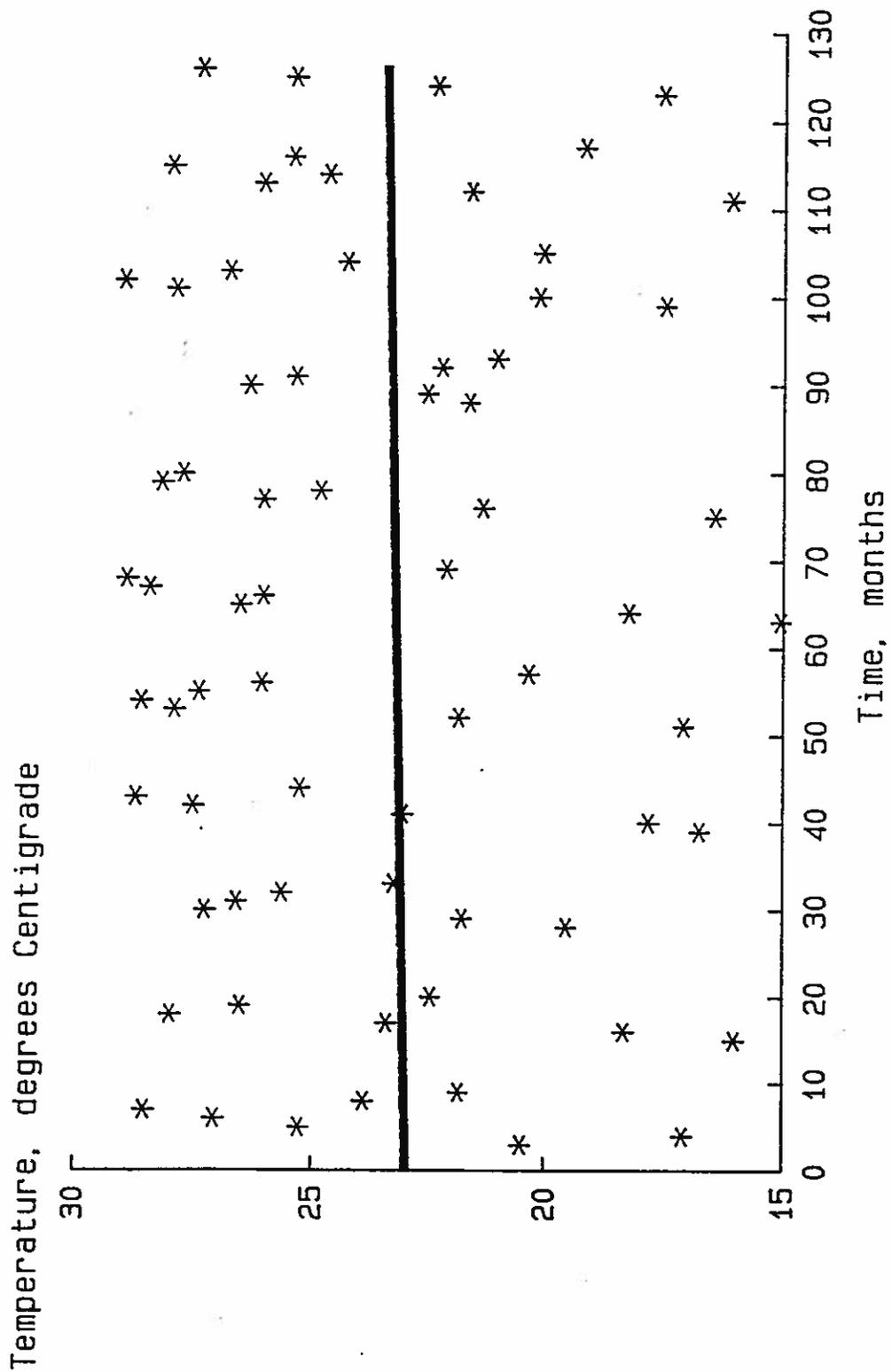


TABLE 5.3 SUMMARY OF MONTHLY AVERAGE VALUES FOR THE TNH DILUTION RATIO CALCULATION

M O N T H	1985				1986				1987						
	TNH mu	TNH BC-8 mg/l	D	FUI	TNH mu	TNH BC-8 mg/l	D	FUI	TNH mu	TNH BC-8 mg/l	D	FUI			
4	11.7	0.018	0.423	27.8	0.240	12.2 ³	0.047	1.17	9.82	0.055	12.5	0.011	1.19	9.59	0.083
5	12.2	0.015	1.33	8.27	0.175	12.9	0.036	0.409	33.5	0.177	11.8	0.011	1.42	7.37	0.221
6	11.4	0.013	0.848	12.6	0.467	11.7	0.030	0.613	19.0	0.240	13.8 ⁴	0.010	0.532	25.4	0.286
7	11.7 ¹	0.022	0.558	20.8	0.226	9.75	0.027	0.366	27.7	0.345	10.7 ⁵	0.011	0.549	18.9	0.332
8	8.68 ²	0.019	0.435	19.8	0.172	9.65	0.011	0.432	21.9	0.418	10.1	0.010	0.359	27.9	0.281
9	9.42	0.018	0.277	35.3	0.186	9.23	0.013	0.288	32.5	0.118	12.9	0.012	0.307	42.7	0.198

¹Data on 7/22/85 ignored because of unusually high flow

²Data on 8/5/85 ignored because of unusually high flow

³Data on 4/7/86 ignored because of unusually high flow

⁴Data on 6/8/87 ignored because of unusually high flow

⁵Data on 7/27/87 ignored because of unusually high flow

TABLE 5.4 CRITICAL SEASON PARAMETER AVERAGES AND STANDARD DEVIATIONS

mu	D	σ	mu	fui	σ	mu	cb	σ
22.2		10.2	0.234		0.109	0.019		0.010

summarized for the period 1985-1987. Although the unionized ammonia standard applies throughout the year because of the dynamics of the LVW-LVB interaction and pH variations, April-September is the critical period from the viewpoint of LVB water quality.

The unionized ammonia water quality standard is based on a four day average value of the concentration of unionized ammonia; however, there are no actual four day average values in the data base. One approach to solving this data problem is stochastic simulation. In performing this simulation, the following assumptions are made:

1. D, cb (Station BC-8), and fui are normally distributed random variables with the critical season (April-September, inclusive) means and standard deviations summarized in Table 5.4. While it would be preferable to use monthly average values of these parameters, the extreme variability of the available data preclude this approach.
2. The data summarized in Table 5.4 are not biased.
3. The distributions of D, cb (Station BC-8), and fui are stationary in time. Although this assumption has been violated in the past and may be violated in the future, it should not be violated in the near term. To satisfy this assumption, no data previous to 1985 are included in the analysis.
4. The data summarized in Table 5.4 can be used to estimate target daily average concentrations of total ammonia at NSR.

These target daily average values can then be combined to estimate target four day running average values which can then be combined to estimate target critical period concentrations.

A computer code was developed to perform the stochastic simulation and 50 years of record was simulated. The key calculation in the code - the target daily average value of total ammonia at NSR was

$$TNH = (0.04/fui) * (D+1) - D * cb$$

where TNH = target concentration of total ammonia at NSR (mg/l).

The fifty years of simulated data had the following characteristics.

Target minimum average NSR total ammonia concentration

$$(TNH) = 1.56 \text{ mg/l}$$

Standard deviation associated with

$$\text{target minimum average} = 0.30 \text{ mg/l}$$

At this point it is appropriate to note that by the terminology 'target minimum average NSR concentration' the following computational and data selection process is indicated. During each yearly critical period there are 183 days; and thus, 183 daily average values of total ammonia. After four day averages are formed, there are 180 values for the critical period. From each of the 50 critical periods simulated, the minimum concentration of TNH that will satisfy the water quality standard

is found. This set of 50 values is normally distributed; therefore, the target concentration at NSR such that the concentration of unionized ammonia at BC-2 will only exceed 0.04 mg/l once in three years is

$$\mu_{NSR} - z \sigma_{NSR} = \text{target TNH concentration}$$

or

$$1.56 - 0.44(0.30) = 1.43 \text{ mg/l TNH at NSR}$$

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*Total Maximum Daily Loads at North Shore Road
and
Waste Load Allocations*

Prepared by:

Nevada Division of Environmental Protection

Total Maximum Daily Loads:

The following allowable concentrations at North Shore Rd. were derived by Dr. French:

0.64 mg/l total phosphorus

1.43 mg/l total ammonia

The average flow at North Shore Road for the past 3 water years, according to U.S.G.S. data is 126 cubic feet per second. Using this flow, the following total maximum allowable loads at North Shore Road were calculated:

434 lbs/day total phosphorus

970 lbs/day total ammonia

Nonpoint Sources:

Before the TMDL can be allocated to the point source dischargers, the nonpoint source/background load must be estimated. The nonpoint source/background load was assumed to be the average difference between the load at North Shore Road and the sum of the loads contributed from the point sources. Due to previously described changes in Las Vegas Wash and Las Vegas Bay densities and physical changes in Las Vegas Wash Channel, only 1985, 1986 and 1987 data were chosen as best reflecting the current conditions.

Point source discharges into Las Vegas Wash include:

1. City of Las Vegas
2. Clark County Sanitation District
3. TIMET
4. Kerr-McGee
5. Stauffer

The City of Henderson may be discharging to Las Vegas Wash in the future. TIMET discharges noncontact cooling water and other relatively uncontaminated flows. Kerr McGee discharges noncontact cooling water and stormwater, and Stauffer discharges stormwater. The discharges from both Kerr-McGee and Stauffer are intermittent, and have been relatively uncommon in the past. Additionally, there are no data available on the concentration of nutrients in Kerr-McGee and Stauffer's discharges. TIMET discharges approximately 4 MGD and both the total ammonia and total phosphorus concentrations in these discharges are approximately 0.01 mg/l or less. Therefore, only the discharge from the City of Las Vegas and Clark County treatment plants were used to estimate the total monthly average point source load discharged to Las Vegas Wash.

The U.S.G.S. flow gage at North Shore Road was destroyed in 1984 and has not been replaced. Therefore, to estimate the load at North Shore Road, 4 cubic feet per second was added to the gaged flow at Pabco Road. The 4 cfs correction was derived by the U.S.G.S. There is

some uncertainty in the assumed flow at North Shore Road. In the near future, the U.S.G.S. plans to install a new flow measuring station in Las Vegas Wash. If future readings from the new gage along with studies of the relationship between the new gaging location and North Shore Road reveal that the assumed flows at North Shore Road are inaccurate, NDEP will reevaluate the total maximum daily loads (TMDLs) and waste load allocations (WLAS).

Total Phosphorus:

Monthly average total phosphorus nonpoint source loads were determined by subtracting the total average load discharged by the two treatment plants from the monthly average total phosphorus load at North Shore Rd. These monthly average differences were then averaged over the growing season (April - September) to obtain a yearly average nonpoint source load. Finally, the average growing season nonpoint source loads were averaged for the three years under consideration to arrive at an overall average nonpoint source load. The monthly average loads discharged by the sewage treatment plants were obtained from the self-monitoring reports submitted to NDEP by the City of Las Vegas and Clark County Sanitation District. Loads at North Shore Road were calculated on the days that Clark County and U.S.G.S. monitoring data were available. These daily loads were then averaged on a monthly basis to obtain a monthly average load at North Shore Road. Using this approach, the nonpoint source load at North Shore Road was estimated to be 90 lbs/day. Figure 1 illustrates the monthly average values that

were used to obtain the overall average nonpoint source load. As can be seen in this figure, there is a rather large variation from month to month in the estimated nonpoint source load. In figure 2, the load coming from the treatment plants and the load at North Shore Road are plotted on the same graph. It would appear that the variation in the estimated nonpoint source load is due to variation load at North Shore Road rather than variation in the point source discharges.

The variation in the total phosphorus load at North Shore Road is likely due to the sporadic nature of stormwater flows. A good relationship between suspended solids and total phosphorus exists (correlation coefficient = 0.95) which implies that a portion of the total phosphorus is bound to the sediments. There is a satisfactory relationship between total phosphorus and flow and between suspended solids and flow. It is likely that the particulate component of the load settles and resuspends with scour; consequently, the travel time of this portion of the load may be substantially longer than the hydraulic time of travel (EPA Technical Guidance for Performing Waste Load Allocations - Book IV Lakes and Impoundments, Chapter 2 Eutrophication pg. 3-15, 3-16). The intermittent nature of the transport of particulates could be partly responsible for the variation in the total phosphorus load at North Shore Road.

In an effort to eliminate some of the unpredictable variation in the nonpoint source loads, daily flows which exceeded 110 percent of the average flow were not considered in calculating the monthly average

Total Phosphorus Nonpoint Source Load at North Shore Road

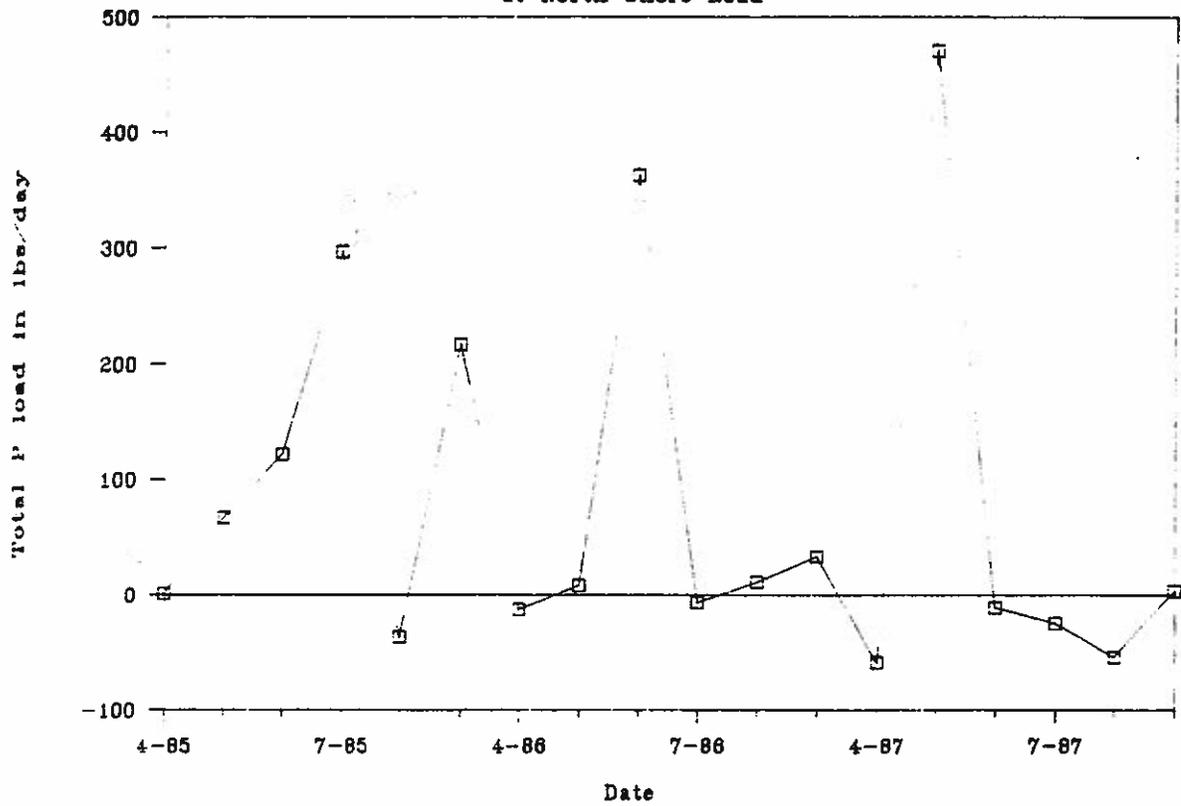


Figure 1: Monthly Total Phosphorus Nonpoint Source Loads at North Shore Rd.

Total Phosphorus Loads

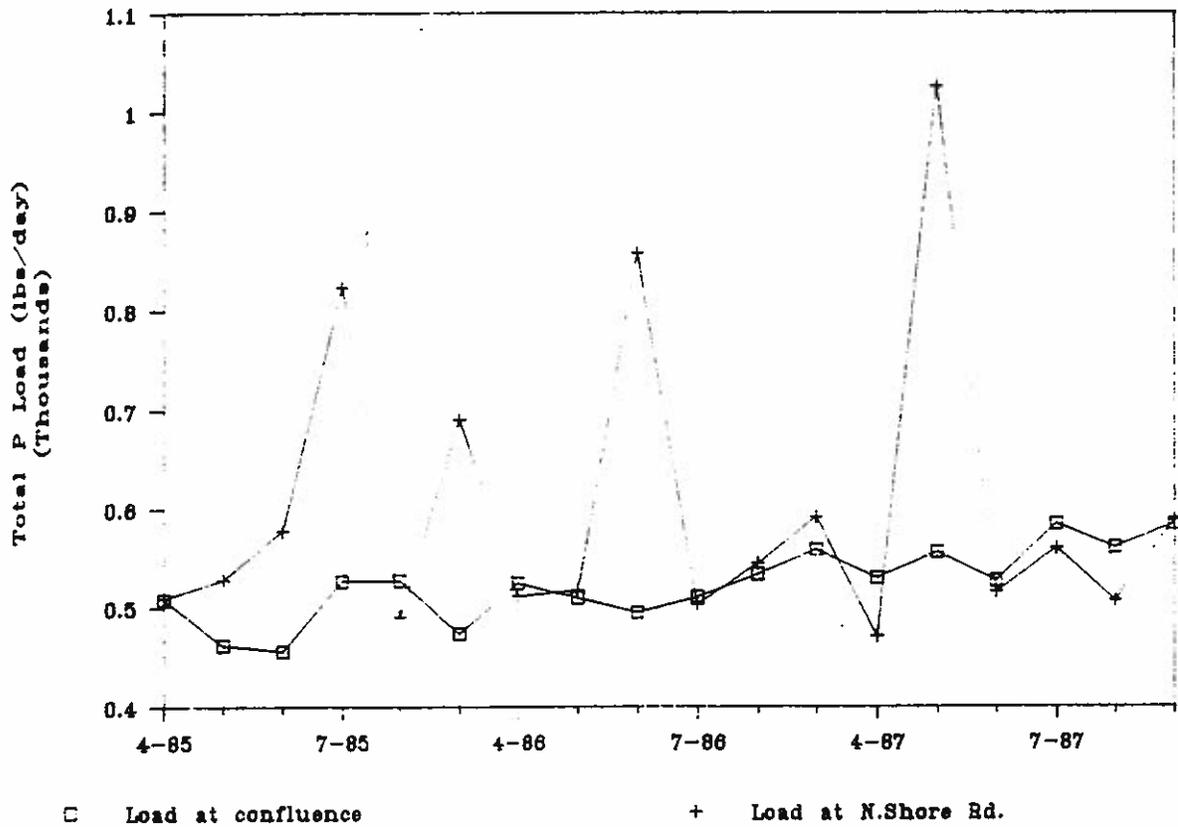


Figure 2: Total Phosphorus Loads Discharged by the City and County Compared to Total Phosphorus Load at North Shore Rd.

load at North Shore Road. Over the 3 year period under consideration, a total of 5 values were eliminated.

The load allocation shall be established with a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality according to 40 CFR 130.7.c.1. A 10 percent safety factor was assumed. Therefore a nonpoint source load of 100 lbs/day total phosphorus is assumed.

Total Ammonia:

The assumptions made in calculating the total phosphorus nonpoint source load were also used for calculating the total ammonia nonpoint source load.

The data indicates that there is no nonpoint source load of ammonia in the Las Vegas wash. Thus, all of the load may be allocated to the municipal dischargers. It is recognized that some ammonia reduction has occurred between the points of discharge and North Shore Road in the past (see figure 3). As can be seen in this figure, the amount of ammonia reduction that occurs in Las Vegas wash has been decreasing in recent years. The kinetics of this reduction process are complex and have not been defined. The amount of ammonia reduction that will occur in the concentration range of the proposed TMDL can not be accurately determined at this time; therefore no credit for ammonia reduction in the wash can be granted.

Total Ammonia Loads

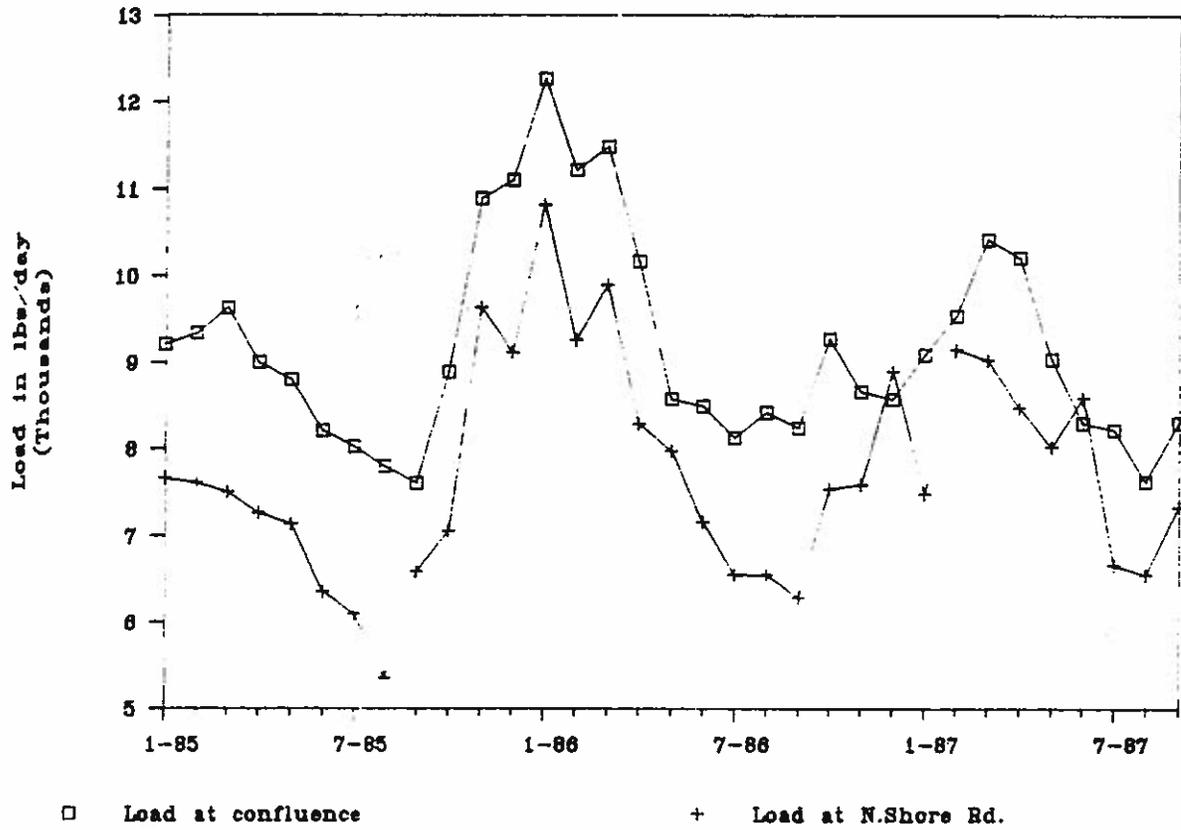


Figure 3: Total Ammonia Loads Discharged by the City and County Compared to Total Ammonia Load at North Shore Rd.

WASTE LOAD ALLOCATION:

After considering the nonpoint/background loads, the remaining controllable total maximum daily loads (TMDL) are as follows:

Total Phosphorus - 334 lbs/day

Total Ammonia - 970 lbs/day

The permissible total load can then be allocated among the various dischargers. These waste load allocations are seasonal limitations developed to achieve the water quality standards. At least 20 methods for allocating the total load among the dischargers have been identified (Chadderton, 1981). These various approaches actually imply different definitions of equity. Methods which utilize criteria such as equal cost per pound of pollutant removed, percent removal proportional to community effective income, equal cost of treatment etc. are not appropriate to administer from the state level. Discharging equal effluent concentration was selected as the most appropriate in this situation.

Equal Effluent Concentration:

Allocating the load proportional to current effluent flows results in 44% of the remaining controllable load allocated to the City of Las Vegas and 56% allocated to Clark County Sanitation District (CCSD). Using the above percentages the following loads were calculated.

City - 147 lbs/day total phosphorus
427 lbs/day total ammonia

CCSD - 187 lbs/day total phosphorus
543 lbs/day total ammonia

The City of Henderson has expressed to NDEP no desire to discharge to Las Vegas wash during the period April through September.

INTERIM WASTE LOAD ALLOCATION:

The following total phosphorus loads will be allowed until April, 1990:

City - 231 lbs/day
CCSD - 293 lbs/day

Achieve compliance with waste load allocations for ammonia by April, 1993.

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