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**RESEARCH/RESOURCES MANAGEMENT REPORT SER-88**

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## **South Biscayne Bay Water Quality: A Twelve Year Record for Biscayne National Park**



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**United States Department of the Interior**

**National Park Service  
Southeast Region**

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SOUTH BISCAYNE BAY WATER QUALITY: A TWELVE YEAR RECORD FOR

BISCAYNE NATIONAL PARK

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## ABSTRACT

An observational study was performed on a set of water quality data obtained in time and space over the Biscayne Bay, Florida. In all, 131 sampling episodes were carried out over a period of about 12 years.

Data summaries of 11 variables were calculated for all of the sampling stations and the categories of sampled depths. Based on a multivariate analysis of the variances it was concluded that there is no significant variation in the sampled variables with depth. On the average, ammonium, turbidity, and dissolved oxygen were the most variable; pH and the nitrate ion were the next most variable while salinity and the conductivity were the least variable.

Heuristic approaches that rely on standard hypothesis testing were applied to investigate the significance of a 1979 change in water quality sampling techniques. The correlation matrix of the Before-change and that of the After-change data were used in this regard in addition to the comparison of the corresponding basic statistics. The change was not significant at the 5% level.

Cluster analysis of the samples collected from 1979 to 1984 showed that there were basically two clusters of stations: those at the mouth of the canals and nearshore and those that were offshore. Further analysis of the offshore stations provided a basis for deleting some of those stations without losing valuable information on the microecosystem around the deleted station.

The records of the Moody and Mowry canal discharges into the Bay were combined with the sampled bay water quality data in order to investigate the impacts of such discharges. Thresholds were assumed for the discharge and water quality variables. Because of the arbitrary choice of the thresholds, only relative inferences were made concerning the distribution of ion concentration along the axis of canal discharges.

The Kendall rank correlation method was used to investigate possible trend in the data sets and to determine an optimal sampling frequency. Independence between successive observations was assumed to be established if the calculated rank score exceedance probability was greater than 0.05. Based on this criterion, the monthly observations were found to be independent. The calculated exceedance probability did not change significantly with increasing sampling frequency. Thus, the analyses did not indicate any trend or seasonality. This, however, may be because measurements were made just once, and in a few cases only several times in any one month.

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## 1.0 INTRODUCTION

The purpose of sampling hydrologic variables, both in space and time, is to reduce uncertainty and hence provide reliable data for decision making in water and other natural resources management. It is obvious, however, that large scale hydrologic systems, as in the National Parks, are very heterogeneous. It will be prohibitively expensive to sample them in detail. Thus, a trade-off arises between the cost of data acquisition and the predictive accuracy that is consistent with mandated Park Service activities.

In designed data collection networks, this trade-off is assumed to have taken place. In situations, such as in this study, where one is obliged to use existing data without the benefit of design, certain inherent problems exist. In either situation, the objective is to supply information which is directly useful in understanding the recycling of water and nutrients in natural ecosystems and in studying the impact, on habitats, of man's action on such natural environments.

The objectives are to :

- 1) calculate and present data summaries of each sampled variable by station and region of the Biscayne Bay;
- 2) investigate the variation of the sample statistics with depth of measurement for representative stations of the Biscayne Bay;
- 3) compare the time and space characteristics of the water quality variables sampled in 1972-1978 and in 1979-1983 at the same stations;
- 4) divide the Biscayne Bay into homogeneous water quality regions and investigate the possibility of reducing the number of sampling stations;
- 5) study the quality impact of canal discharge into the bay;
- 6) combine the sampled variables into subgroups (factors) which convey the essential information contained in the membership of the subgroup;
- 7) identify the variables with large variances and recommend sampling intervals for these variables; and,
- 8) investigate possible trends in the data sets and determine the optimal sampling interval.

## 2.0 DESCRIPTION OF AVAILABLE DATA

The National Park Service has collected 12 years of monthly water quality data. The network started with 60 stations at each of which were sampled five variables. Over time, the number of stations has changed and is now about 31. The number of parameters in contrast has increased by about three fold. The sampling was not continuous and the period of sampling varied from 3 to 8 months in any given year. Several samples, typically one, were collected within a sampled month.

About 25 years of rainfall data are also available. These data were recorded at four rain-gage stations. Canal discharge data were also available although the sampling strategy changed in 1979. These discharges, were, for the most part, controlled.

Thus, in addition to data collection design problems, the data sets described above had characteristics that required the application of relatively sophisticated statistical techniques in order for the analyst to supply useful information for reliable inferences about the hydrologic processes and/or for decision making. Among these characteristics were inherent randomness, uncertainty and nonstationarity in rainfall, discharge, and water quality indicators. Further, the data may be inconsistent by virtue of the change in the manner of data collection in 1979. A meaningful representative value of rainfall for the area was difficult to obtain because of the highly localized nature of rainfall events.

Water quality data were received in two forms, a bound computer printout and two floppy 5 1/4-inch diskettes. Because of persistent difficulty in abstracting the data from the diskettes they were typed onto disk storage from the printout. The variables and parameters abstracted from the printout, for each sampling date, include: record number, station number, sampling time, salinity, conductivity, water temperature, turbidity, pH, dissolved oxygen, ammonium, nitrite, nitrate, phosphate, and air temperature. After debugging for typographical and other errors the data set was saved in two files:

QUALI.DAT (Records 0001-2500)      QUAL2.DAT (Records 2501-5166).

In the above files, missing data are represented by 9.99, 99.99, or 999.99 depending on the number of columns used to record the variables. The files were combined in the hard disk and named QUAL.DAT.

Figure 1 is the a map of the project area and includes canal and bay water-quality sampling stations. Canal discharge data were received in the form of hard copy. The discharge records include:

|                        |                 |
|------------------------|-----------------|
| for Black Creek        | - 1972 to 1982  |
| for Moody Canal        | - 1972 to 1982  |
| for Mowry Canal        | - 1972 to 1982  |
| for Florida City Canal | - 1972 to 1974  |
| for Card Sound         | - 1972 to 1974. |

The Black Creek and Card Sound data were not used in the analyses because the creeks were outside of the zone of Bay water-quality sampling. Florida City Canal data have missing data within the only two years of data available. It, was therefore, also not used. Only the Moody Canal and Mowry Canal data were therefore used in the analyses. Missing data were represented by 9999. Flow data were stored in file the FLOW'.DAT. Entries included the Julian date; Moody and Mowry flow data for this date and for four days prior. A second file, DATE.DAT, contained entries for Bay water-quality sampling date and record number.

## 2.1 Randomness of the Sampling Frequency

Since data were not collected at constant time intervals, the standard methods of time series analysis cannot be applied. Monparametric methods, such as, rank correlation may be used, however, to determine the appropriate sampling frequency for the water quality indicies. Table 1 lists the sampling dates and the number of intervals between episodes for the 1979 through 1984 data. The statistics are:

|         |          |                    |         |
|---------|----------|--------------------|---------|
|         |          | Number of cases    | 54      |
| Minimum | 1 day    | Standard Deviation | 30 days |
| Maximum | 223 days | Standard Error     | 4 days  |
| Mean    | 36 days  | Skewness           | 5.      |

Figure 1. Location Map of Sampling Stations

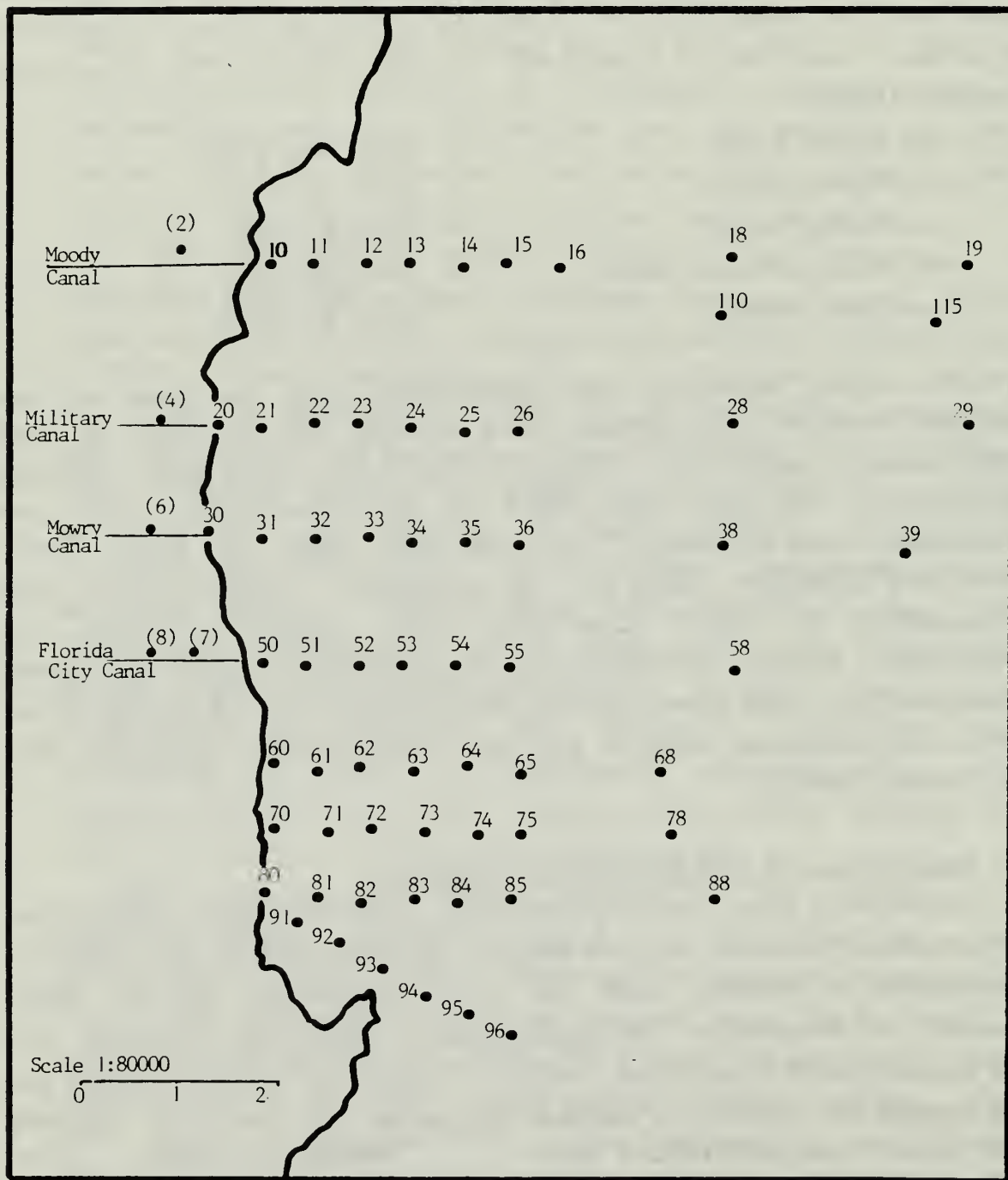


TABLE 1. Sampling Dates

| Current Date | Next Date | Interval (days) |
|--------------|-----------|-----------------|
| 79026        | 79043     | 17              |
| 79043        | 79071     | 28              |
| 79071        | 79108     | 37              |
| 79108        | 79140     | 32              |
| 79140        | 79163     | 23              |
| 79163        | 79199     | 36              |
| 79199        | 79226     | 27              |
| 79226        | 79264     | 38              |
| 79264        | 79292     | 28              |
| 79292        | 79319     | 27              |
| 79319        | 79347     | 28              |
| 79347        | 80021     | 39              |
| 80021        | 80044     | 23              |
| 80044        | 80072     | 28              |
| 80072        | 80073     | 1               |
| 80073        | 80105     | 32              |
| 80105        | 80135     | 30              |
| 80135        | 80170     | 35              |
| 80170        | 80198     | 28              |
| 80198        | 80224     | 26              |
| 80224        | 80261     | 37              |
| 80261        | 80289     | 28              |
| 80289        | 80318     | 29              |
| 80318        | 80351     | 33              |
| 80351        | 81019     | 33              |
| 81019        | 81049     | 30              |
| 81049        | 81105     | 56              |
| 81105        | 81133     | 28              |
| 81133        | 81169     | 36              |
| 81169        | 81198     | 29              |
| 81198        | 81226     | 28              |
| 81226        | 81261     | 35              |
| 81261        | 81289     | 28              |
| 81289        | 81323     | 34              |
| 81323        | 82019     | 61              |
| 82019        | 82041     | 22              |
| 82041        | 82083     | 42              |
| 82083        | 82119     | 36              |
| 82119        | 82134     | 15              |
| 82134        | 82168     | 34              |
| 82168        | 83025     | 223             |
| 83025        | 83026     | 1               |
| 83026        | 83049     | 23              |
| 83049        | 83145     | 96              |
| 83145        | 83165     | 20              |
| 83165        | 83200     | 35              |
| 83200        | 83230     | 30              |
| 83230        | 83266     | 36              |
| 83266        | 83286     | 20              |
| 83286        | 83322     | 36              |
| 83322        | 83349     | 27              |
| 83349        | 84046     | 62              |
| 84046        | 84076     | 30              |
| 84076        | 84137     | 61              |

Since the sample mean and standard deviation are significantly different, the sampling intervals are not random so that stochastic methods are also not applicable.

Both the Bay quality and the Canal quality and quantity data required extensive preprocessing before any methods of analysis could be implemented. After the general processing which are described below, segments of the overall data which met conditions for applications of each technique were abstracted and further processed before use.

The FORTRAN program FLOW.FOR combines the contents of DATE.DAT and FLOW'.DAT. The resulting data file (FLOW.DAT) contains the record number, station number, the date, the Moody flow data, and the Mowry flow data for the corresponding date.

The FORTRAN program FLOWQUAL.FOR incorporates the flow data in file FLOW.DAT into the Bay quality data in file QUAL.DAT for measurements between 1972 and 1982. The Canal data were not available beyond the middle of 1982. There is a possible limitation in the interpretation of analyses using these data. Consider the sampled stations for the Mowry Canal as shown in Figure 1. The flow was measured at or near station 6. The entry in the output file, FLOWQUAL.DAT assigns this same flow to stations 31, 32, 33, 34, 35, 36, 38, and 39. Hence, the tendency will be to overestimate the measured quality parameters at these stations when canal quality is worse than the Bay quality and vice versa.

Only the following six of twelve possible water quality variables were retained in FLOWQUAL.DAT: salinity, conductivity, temperature, turbidity, pH and dissolved oxygen in addition to the depth measurements. The entries in FLOWQUAL.DAT will be used in section 6.0 to investigate the order of interaction between discharge and the sampled variables.

In the following sections the objectives identified in Section 1 are addressed in detail. For each objective, the preprocessing of the original data is described. Then the methods applied are described followed by a discussion of the results of the analyses. In meeting these objectives we were guided by the need to apply techniques and procedures that were commensurate with the quality of the available data.

### 3.0 DATA SUMMARIES AND VARIATION OF BAY WATER QUALITY WITH DEPTH

The objectives were to calculate and present data summaries of the sampled variables by station and region of Biscayne Bay and to investigate the variation of the sample statistics with depth of measurement for representative stations of the Bay.

#### Description of Data

The original data set, contained in QUAL.DAT, was sorted by station and by depth category (in meters). The sampling depths were categorized as follows in order to facilitate interpretation of the sample statistics to be computed:

|     |                          |             |
|-----|--------------------------|-------------|
|     | Depth $\leq$ 0.2m        | Category 1  |
| 0.2 | $\leq$ Depth $\leq$ 0.5m | Category 2  |
| 0.5 | $\leq$ Depth $\leq$ 1.0m | Category 3  |
| 1.0 | $\leq$ Depth $\leq$ 2.0m | Category 4  |
|     | Depth $>$ 2.0m           | Category 5. |

A preliminary analysis showed that many of the over 67 stations were sampled few times at various depths and that some of the variables were not sampled at all on some of the sampling days. A combination of these two sources of missing data reduced the number of stations that could be used to test the variability of the water quality variables by depth and by region of the Bay. The following 11 benchmark stations were selected as representative of the several zones of the Bay : 04, 11, 15, 18, 19, 29, 35, 29, 78, 92, 96.

#### Methods

The approach was to determine if the difference in sample means computed for the different depths was attributable to just random variations alone or to both random and systematic variations. The Analysis of Variance method was used for this purpose. This procedure assumed that the variance for the various sampling depth categories was constant. The observations were assumed to be independent and normally distributed. The null hypothesis was that the means for the depth categories were equal against the alternative hypothesis

that at least two of the means were not equal at a chosen significance level. When this hypothesis is true, the variance

$$f = \text{var1} / \text{var2} \quad (3.1)$$

ratio is a value of the random variable  $F$  having the  $F$ -distribution with  $n_1 = k - 1$  and  $n_2 = k(n - 1)$  degrees of freedom for  $\text{var1}$  and  $\text{var2}$ , respectively. The variable,  $\text{var1}$ , is the cumulative variance due to both systematic and random variation while  $\text{var2}$  is the cumulative variance due to random variation only. The variable  $k$  is the number of depth categories and  $n$  is the sum of the number of observations in each depth category. The decision criterion was not to reject the hypothesis and conclude that measurements for the various depth categories had the same mean if the theoretical  $f$ -value was greater than the computed  $f$ -value.

### Discussion

The STATISTICS module of the SYSTAT statistical package was used to compute the sample statistics which included the minimum, maximum, mean, and the standard deviation of the water quality variables based on the station and the depth category. Appendix 1. contains the statistics for the 11 benchmark stations. The same information for all 67 stations and 12 variables in the initial data set were saved in file STATS.DAT contained in the solution diskette submitted with this report.

A computer program was written to compute the  $f$ -value for each variable-station combination. Table 2 is a tabulation of these values and also of the corresponding degrees of freedom,  $n_1$  and  $n_2$ . The blank spaces in the table correspond to situations when samples were taken at only one depth ( $f_1 = 0$ ) or when the total sample size for all depths was less than 2.

The results show that 96 of the 99 variable-station combinations support the conclusion that measurements at the different depths have the same mean at the 5% level of significance. Thus, the analyst may use data measured at any one of the five depth categories or pool the data for all the depth categories. It was noted that, at this level of significance, the hypothesis that the variances were the same was not supported for over 50% of the variable-station combinations.

Table 2. Calculated F-Statistic by Station and Variable

|          |                | STATION |      |      |      |      |      |      |      |      |      |      |
|----------|----------------|---------|------|------|------|------|------|------|------|------|------|------|
| VARIABLE |                | 04      | 11   | 15   | 18   | 19   | 29   | 35   | 39   | 78   | 92   | 96   |
| SALT     | f              | 2.95    | 0.33 | 0.22 | 0.34 | 0.11 | 0.13 | 0.22 | 0.80 | 0.51 | 0.87 | 0.35 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    | 2    | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 100     | 146  | 143  | 114  | 90   | 24   | 105  | 97   | 112  | 122  | 130  |
| COND     | f              | 4.23    | 0.29 | 0.08 | 0.42 | 0.34 | 0.12 | 0.50 | 0.79 | 0.55 | 0.95 | 0.15 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    | 2    | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 109     | 149  | 149  | 125  | 100  | 24   | 114  | 103  | 119  | 124  | 134  |
| TURB     | f              | 5.33    | 1.69 | 3.13 | 0.96 | 0.68 | 0.54 | 2.19 | 0.83 | 4.10 | 10.8 | 1.89 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    | 2    | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 68      | 115  | 112  | 83   | 59   | 11   | 77   | 66   | 82   | 97   | 100  |
| PH       | f              | 9.05    | 63.4 | 2.69 | 0.65 | 1.68 | 3.61 | 1.33 | 0.89 | 0.93 | 1.05 | 1.14 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    | 2    | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 100     | 103  | 102  | 107  | 90   | 23   | 104  | 93   | 102  | 92   | 103  |
| DO       | f              | 0.94    | 4.92 | 0.82 | 0.75 | 1.75 | 0.07 | 0.74 | 1.69 | 1.04 | 2.30 | 0.71 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    | 2    | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 107     | 89   | 95   | 99   | 99   | 24   | 97   | 93   | 92   | 81   | 93   |
| AMO      | f              | 0.14    | 0.44 | 0.22 | 1.15 | 0.21 |      | 0.39 | 1.69 | 0.04 | 0.27 | 0.69 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    |      | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 48      | 41   | 40   | 41   | 40   |      | 40   | 41   | 38   | 35   | 40   |
| NITRI    | f              | 0.84    | 0.10 | 0.94 | 1.69 | 1.43 |      | 0.76 | 1.04 | 0.03 | 0.91 | 0.11 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    |      | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 50      | 42   | 40   | 42   | 40   |      | 41   | 42   | 39   | 36   | 40   |
| NITRA    | f              | 1.72    | 0.14 | 1.01 | 0.36 | 0.15 |      | 0.66 | 0.16 | 0.61 | 0.39 | 0.13 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    |      | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 49      | 41   | 40   | 42   | 40   |      | 41   | 40   | 40   | 36   | 40   |
| PHOS     | f              | 1.79    | 0.61 | 0.97 | 1.56 | 0.35 | 3680 | 0.44 | 0.33 | 0.64 | 0.14 | 1.08 |
|          | n <sub>1</sub> | 2       | 3    | 4    | 4    | 4    | 2    | 3    | 4    | 3    | 3    | 4    |
|          | n <sub>2</sub> | 38      | 35   | 33   | 35   | 34   | 1    | 34   | 35   | 33   | 29   | 34   |

Legend: SALT = Salinity                      AMO = Ammonium Ion  
COND = Conductivity                      NITRI = Nitrite Ion  
TURB = Turbidity                      NITRA = Nitrate Ion  
PH = pH                      PHOS = Phosphate Ion  
DO = Dissolved Oxygen

The variability in the water quality variables was measured by the coefficient of variation defined as the ratio of the sample standard deviation to the sample mean. Table 3 shows these values for most of the variables sampled at the benchmark stations. The blank spaces represent cases when the sample size for each of the depth categories, at a station was less than four. The choice of four samples was arbitrary. The last column in this table is the mean coefficient of variation for the variable. This column shows that, on the average, the most variable water quality parameters were ammonium, turbidity, and dissolved oxygen. The least variable parameters were water salinity and conductivity.

#### 4.0 BEFORE (1972-1978) AND AFTER (1979-1983) STUDY OF CHANGE IN MEASURING TECHNIQUES

The goal was to compare the time and space characteristics of the water quality variables sampled in 1972-1978 and in 1979-1983 at the same stations. Specifically, the object was to assess the effect of the change in the measuring techniques for water quality variables.

##### Description of Data

The starting point was the data set of file QUAL.DAT. To maximize the available data for the analysis of this section only water quality variables that were measured, for the most part, in both the Before and After periods were used. These included salinity (SALT), conductivity (COND), temperature (TEMP), turbidity (TURB), and the sampling depth (DEPTH). Records with one or more missing values were not included.

##### Methods

As observed earlier, sampling episodes were nonregular. They were not completely random because of scheduling of the sampling days. In the former case, time series methods that identify break points in the series cannot be applied. In the latter case stochastic analysis may not be justifiable.

Table 3. Coefficients of Variation by Station and Variable

|       | STATION |      |       |        |        |      |        |        |      |        |       | Avg   |
|-------|---------|------|-------|--------|--------|------|--------|--------|------|--------|-------|-------|
|       | 04      | 11   | 15    | 18     | 19     | 29   | 35     | 39     | 78   | 92     | 96    |       |
| SALT  | .61     | .26  | .11   | .06    | .06    | .04  | .13    | .07    | .08  | .15    | .14   | .16   |
| COND  | .58     | .27  | .12   | .07    | .09    | .03  | .13    | .08    | .09  | .14    | .12   | .16   |
| TURB  | .18     | 2.57 | .90   | 129.38 | 250.94 | 1.00 | 2.40   | 127.52 | .83  | 1.35   | .47   | 47.05 |
| PH    | 3.54    | .12  | .91   | 1.25   | 15.74  | .33  | .72    | 4.61   | 1.41 | 1.93   | 27.83 | 5.31  |
| DO    | 112.47  | 1.02 | 1.80  | 2.55   | 40.22  | 1.03 | 1.09   | .84    | 2.07 | 31.26  | 19.09 | 19.40 |
| AMO   | 23.55   | 1.56 | 2.97  | 1.69   | 2.22   |      | 188.73 | 62.07  | 1.00 | 302.83 | 25.58 | 55.65 |
| NITRI | 1.47    | 3.58 | .56   | .71    | .31    |      | 1.21   | .63    | 1.14 | .67    | 2.17  | 1.13  |
| NITRA | .88     | .61  | 84.44 | 1.00   | 2.00   |      | .72    | .88    | 1.00 | 1.08   | .67   | 8.48  |
| PHOS  | 1.30    | 1.22 | 1.17  | .50    | 1.40   | .02  | 2.92   | 1.40   | 2.25 | 6.00   | 4.33  | 2.05  |

The approach taken in this study was to compute statistics of the data that summarized the variable values in some fashion and represented the collective behavior of the data set during each period. Included in this set of statistics was the correlation matrix of the variables. It was noted that pairs of variables that have low linear correlation may yet be highly nonlinearly associated. The test hypothesis was that the theoretical cross-correlation coefficient of the  $i$ th and  $j$ th variables were the same, i.e.,  $r_1(i,j) = r_2(i,j) = r(i,j)$ . The subscript 1 stands for the 1972-1978 data while subscript 2 stands for the 1979-1983 data. The variable  $u$  is the test statistics and is given by:

$$u = (z_1 - z_2) / ((n_1 - 3)^{-1} + (n_2 - 3)^{-1})^{1/2} \quad (4.1)$$

$$z_1 = 0.5 (\log_e(1 + r_1) - \log_e(1 - r_1)) \quad (4.2)$$

$$z_2 = 0.5 (\log_e(1 + r_2) - \log_e(1 - r_2)) \quad (4.3)$$

Variables  $r_1(i,j)$  and  $r_2(i,j)$  are the sample cross correlation coefficients; the arguments  $i$  and  $j$  have been dropped in the equation above for clarity. The variable  $u$  is normally distributed (Hald, 1952), p 610) with zero mean and unit variance. If the absolute value of  $u$  is smaller than say, 1.96, then the hypothesis that there is no significant difference between the pair of variables cannot be rejected at the 5% level of significance.

### Discussion

Table 4. shows the sample statistics for the Before and After data. The sample size for the Before data is 2096 while that for the After data is 1343. Since the data were not collected under controlled and noncontrolled situations (i.e., with the old and the new instrumentation) care must be taken in interpreting the above statistics and others that may be derived from the data.

The only variable that appeared to be unaffected by a change in instrumentation was turbidity: all of the statistics

were not significantly different at the 5% level. The maximum temperature of 59.8 °C (139.64 °F) may be a possible outlier. Apart from this, only the skewness appears to be significantly different in the case of temperature. Salinity and conductivity appeared to be significantly different in all statistics but the mean.

Table 5 shows the correlation matrix, computed over time and space, for the five variables considered earlier. The matrix reflects the linear association between pairs of the variables. The fourth and fifth columns of Table 5 are entries for the t-values for the Before and After cross correlations, respectively. Using the above criterion it was observed that, for the Before data, only the temperature - depth, turbidity - salinity, and conductivity - depth pairs had nonsignificant correlations. For the After data the salinity - depth, conductivity-depth, temperature-salinity, and temperature - conductivity pairs had nonsignificant correlations.

Table 4. Sample Statistics of Before and After Data

TOTAL OBSERVATIONS(1972-78) : 2069

|              | SALT   | COND   | TEMP   | TURB  |
|--------------|--------|--------|--------|-------|
| N OF CASES   | 2069   | 2022   | 2069   | 2069  |
| MINIMUM      | 0.770  | 1.400  | 0.420  | 0.120 |
| MAXIMUM      | 58.000 | 60.250 | 59.800 | 7.900 |
| MEAN         | 32.886 | 48.245 | 25.329 | 0.968 |
| STANDARD DEV | 4.651  | 7.610  | 4.717  | 0.730 |
| STD. ERROR   | 0.102  | 0.169  | 0.104  | 0.016 |
| SKEWNESS     | -2.451 | -1.617 | -0.524 | 3.356 |

TOTAL OBSERVATIONS(1979-83) : 1343

|             | SALT   | COND   | TEMP   | TURB  |
|-------------|--------|--------|--------|-------|
| N OF CASES  | 1343   | 1343   | 1343   | 1343  |
| MINIMUM     | 0.000  | 0.100  | 0.960  | 0.000 |
| MAXIMUM     | 42.000 | 60.180 | 40.600 | 8.800 |
| MEAN        | 30.514 | 46.481 | 26.163 | 1.002 |
| STANDAR DEV | 9.175  | 12.939 | 4.425  | 0.838 |
| STD. ERROR  | 0.250  | 0.353  | 0.121  | 0.023 |
| SKEWNESS    | -1.593 | -1.774 | -0.986 | 3.956 |

Table 5. Pearson Cross-Correlation Matrix

(1972-1978 DATA , 2022 OBSERVATIONS)

|       | DEPTH  | SALT  | COND   | TEMP   | TURB  |
|-------|--------|-------|--------|--------|-------|
| DEPTH | 1.000  |       |        |        |       |
| SALT  | -0.054 | 1.000 |        |        |       |
| COND  | 0.020  | 0.816 | 1.000  |        |       |
| TEMP  | 0.016  | 0.042 | 0.360  | 1.000  |       |
| TURB  | 0.184  | 0.016 | -0.080 | -0.096 | 1.000 |

(1979-1983 DATA , 1343 OBSERVATIONS)

|       |        |        |        |        |       |
|-------|--------|--------|--------|--------|-------|
| DEPTH | 1.000  |        |        |        |       |
| SALT  | 0.019  | 1.000  |        |        |       |
| COND  | -0.026 | 0.985  | 1.000  |        |       |
| TEMP  | -0.063 | -0.015 | 0.034  | 1.000  |       |
| TURB  | 0.089  | -0.214 | -0.205 | -0.101 | 1.000 |

Four of the ten variable pairs had significant correlations for the Before and the After data. Column six shows that a significant difference existed between the Before and the After data for seven of the ten variable pairs. However, such statistical differences could also stem from sources other than change in instrumentation. The three pairs that did not show significant difference are potentially more informative since these will tend to indicate that neither natural variations (climatic) nor instrumentation changes were significant. Temperature occurred twice while the other variables occurred once each as members of the three-pair group.

The second and third columns of Table 6 are the Before and After cross-correlations for the variable pairs that are identified in the first column. Since some of these cross correlations are low, it was necessary to test for the hypothesis that they were significantly different from zero. The test statistic is:

$$t = (r\sqrt{f})/\sqrt{(1-r^2)} \qquad f = N - 2 \qquad (4.4)$$

where N is the number of records.

If the t - value corresponding to a given value of r was smaller than say the 95% fractile, then the two variables were not significantly correlated. The f values for both Before and After data were each greater than 1000. Therefore the critical value of t (i.e.,  $t_{cr}$ ) at the 95% fractile is 1.545. Hence there was no definite pattern that would enable me to surmise that a particular variable was consistently unaffected by instrument change.

## 5.0 HOMOGENEOUS WATER QUALITY REGIONS

The objective was to divide the Biscayne Bay into homogeneous water quality regions and to investigate the possibility of reducing the number of sampling stations.

### Description of Data

A program, CLUSTER.FOR, was written to process the original data set for the period 1979-1984. The latter segment of the

data set was selected for this analysis because it reflected the current sampling stations, which were to be clustered, and the variables which were currently being sampled. The objective was to group the stations into a number classes such that stations within classes were similar in the same respect.

Table 6. Cross correlations for variable pairs

| Variable<br>Pairs | Corr-Values |       | T-Values |         | Statistics<br>(u) |
|-------------------|-------------|-------|----------|---------|-------------------|
|                   | Before      | After | Before   | After   |                   |
| Salt-Depth        | 0.054       | 0.019 | -2.431   | 0.696   | -2.073            |
| Cond-Depth        | 0.020       | 0.026 | 0.899    | 0.952   | 1.306             |
| Temp-Depth        | 0.016       | 0.063 | 0.719    | -2.312  | 2.244             |
| Turb-Depth        | 0.184       | 0.089 | 8.413    | 3.272   | 2.750             |
| Cond-Salt         | 0.816       | 0.985 | 63.445   | 209.038 | -36.836           |
| Temp-Salt         | 0.042       | 0.015 | 1.889    | 0.549   | 1.618             |
| Turb-Salt         | 0.016       | 0.214 | 0.719    | -8.022  | 6.623             |
| Temp-Cond         | 0.360       | 0.034 | 17.343   | 1.246   | 9.731             |
| Turb-Cond         | 0.080       | 0.205 | -3.607   | -7.670  | 3.626             |
| Turb-Temp         | 0.96        | 0.101 | -4.335   | -3.718  | 0.143             |

The program computed the mean value, over time, for each water quality variable sampled at each station at a depth of 0.2 meters or less. Thus, the resulting reduced data are for 'surface' samples. These means were readily computed for other depth limits or even further averaged over depth of measurement. Recall that the analyses of Section 3 showed no statistically significant difference between measurements for the five depth categories. The reduced data are given in Table 7 below. The data were stored in the file CLUSTER.DAT and contained the following variables: depth, salinity, conductivity, water temperature, turbidity, pH and dissolved oxygen.

### Methods

Cluster analysis is a multivariate procedure for detecting natural groupings in a data set. As per the scope of work,

I grouped the sampling stations (cases) and the variables in each case to see if any stations could be dropped from the sampling program without losing information for understanding, for example, the recycling of nutrients in the

Table 7. Data for Cluster Analysis

| STATION | DEPTH | SALT  | COND  | TEMP  | TURB | PH   | DO   |
|---------|-------|-------|-------|-------|------|------|------|
| 2       | 0.03  | 7.28  | 12.27 | 26.52 | 1.13 | 7.79 | 4.89 |
| 4       | 0.03  | 17.46 | 21.29 | 27.15 | 1.68 | 7.62 | 3.61 |
| 6       | 0.04  | 17.87 | 28.62 | 26.88 | 1.10 | 8.05 | 5.36 |
| 7       | 0.01  | 26.44 | 41.82 | 25.57 | 1.81 | 7.54 | 3.04 |
| 8       | 0.04  | 25.36 | 40.48 | 26.75 | 2.28 | 7.45 | 2.59 |
| 11      | 0.03  | 27.66 | 37.04 | 26.24 | 1.09 | 8.27 | 6.60 |
| 15      | 0.03  | 33.17 | 50.74 | 25.72 | 0.79 | 8.36 | 6.17 |
| 18      | 0.02  | 35.92 | 54.33 | 25.75 | 1.40 | 8.42 | 6.22 |
| 19      | 0.02  | 35.83 | 54.15 | 25.88 | 0.81 | 8.38 | 5.98 |
| 21      | 0.04  | 26.93 | 42.08 | 26.12 | 0.72 | 8.25 | 6.33 |
| 25      | 0.02  | 32.76 | 49.98 | 25.68 | 0.82 | 8.11 | 6.18 |
| 28      | 0.02  | 36.05 | 54.39 | 25.72 | 1.24 | 8.41 | 6.14 |
| 29      | 0.03  | 35.95 | 54.37 | 26.26 | 0.81 | 8.13 | 6.23 |
| 30      | 0.10  | 33.12 | 50.70 | 21.30 | 0.59 | 8.56 | 6.39 |
| 31      | 0.04  | 27.02 | 41.28 | 26.53 | 0.86 | 8.37 | 6.23 |
| 35      | 0.03  | 32.92 | 50.11 | 24.84 | 0.81 | 8.08 | 5.91 |
| 38      | 0.03  | 36.15 | 54.56 | 26.06 | 1.18 | 8.41 | 6.15 |
| 39      | 0.02  | 36.49 | 54.89 | 26.08 | 0.75 | 8.40 | 6.10 |
| 51      | 0.02  | 30.10 | 46.57 | 26.05 | 0.85 | 8.34 | 6.12 |
| 55      | 0.03  | 34.31 | 52.25 | 25.53 | 0.86 | 8.37 | 6.17 |
| 58      | 0.02  | 36.28 | 54.75 | 25.94 | 1.11 | 8.41 | 6.20 |
| 61      | 0.03  | 31.50 | 48.55 | 25.79 | 0.80 | 8.37 | 5.92 |
| 65      | 0.03  | 34.48 | 52.47 | 25.59 | 0.86 | 8.36 | 6.06 |
| 68      | 0.03  | 35.78 | 54.09 | 26.11 | 1.10 | 8.39 | 6.15 |
| 71      | 0.04  | 32.29 | 49.44 | 25.87 | 0.69 | 8.37 | 6.01 |
| 75      | 0.03  | 34.45 | 52.43 | 25.67 | 0.89 | 8.37 | 6.02 |
| 78      | 0.03  | 35.57 | 53.84 | 26.07 | 0.98 | 8.37 | 6.16 |
| 81      | 0.04  | 33.04 | 50.45 | 25.83 | 0.63 | 8.38 | 6.02 |
| 84      | 0.00  | 36.90 | 55.40 | 25.60 | 0.86 | 8.39 | 6.66 |
| 85      | 0.04  | 34.19 | 52.16 | 26.07 | 0.70 | 8.36 | 6.00 |
| 88      | 0.03  | 35.67 | 54.11 | 26.97 | 0.96 | 8.38 | 6.30 |
| 92      | 0.02  | 32.96 | 50.34 | 25.33 | 0.61 | 8.36 | 5.60 |
| 96      | 0.03  | 34.55 | 52.57 | 25.77 | 0.74 | 8.33 | 5.98 |

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UNITS: dpth (m), salinity (ppt), conductivity (mmhos/cm<sup>2</sup>),  
 Temperature (C), Turbidity (NTU), dissolved oxygen (ppm)

micro-ecosystem around the station. Cluster analysis was therefore, an appropriate procedure to this end.

The set of data contain variables that had different units of measurement. The variables were therefore standardized (reduced to mean zero and unit variance) in order to remove the scale effects. This was done despite the possibility that the standardizations may have diluted the differences between groups. Further, the high correlation between the conductivity and salinity required me to select a clustering algorithm that did not assume that the variables were uncorrelated. Two methods, the Single-Linkage and the K-Means, were used.

Single-Linkage Method: This method forms clusters by combining groups with the shortest distance between their centroids. The distance metric used is the PEARSON metric which uses  $(1 - r_{ij})$  as the distance index where  $r_{ij}$  is the correlation between the  $i$  th and the  $j$  th objects being clustered. For this study the object was either a sampling station or a sampled variable. Recall that the correlation coefficient is the standardized form of the covariance between two objects. The output shown below as Figure 2 is a branching tree of the variables and stations, respectively, using the data of Table 7.

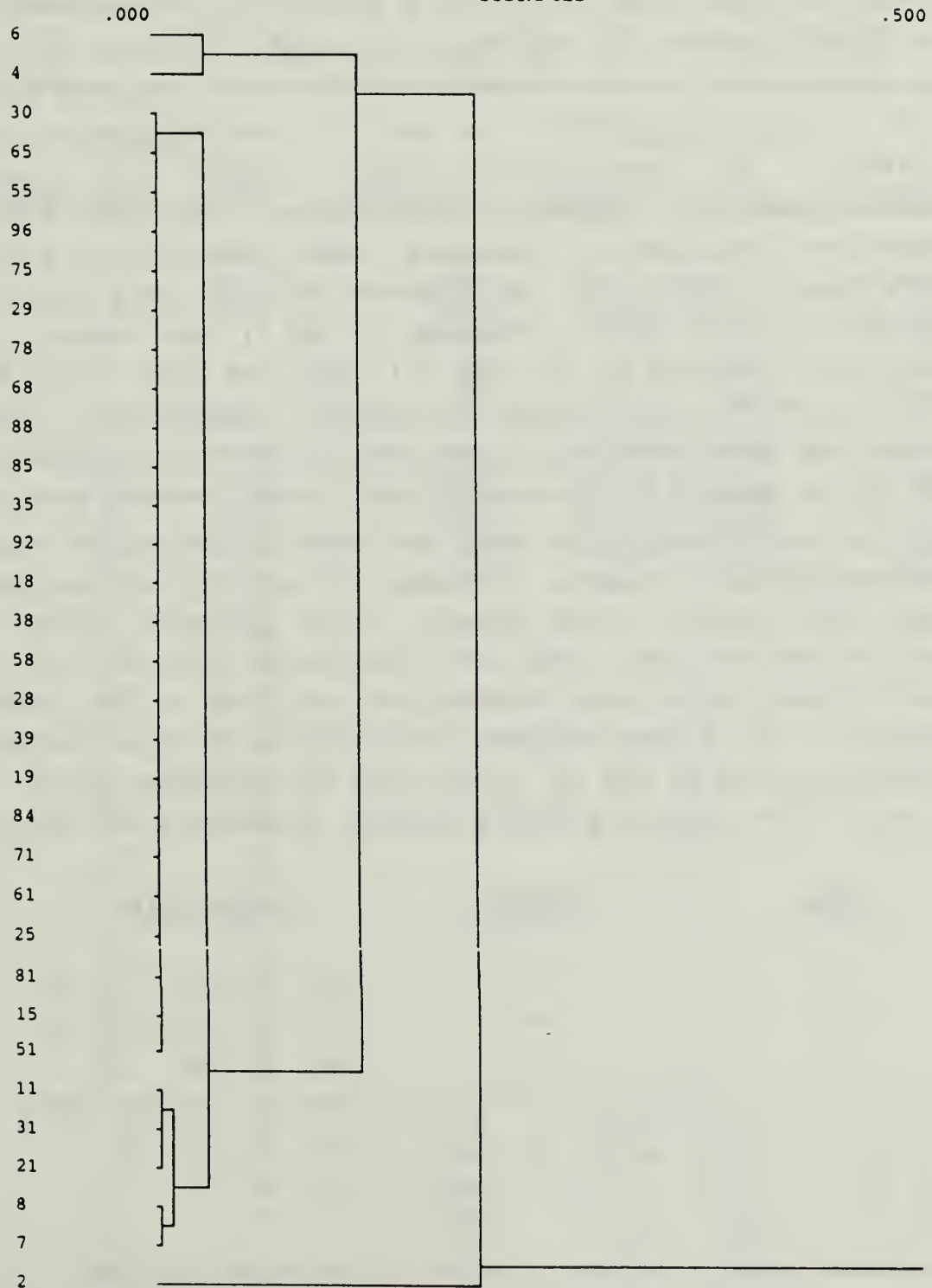
K-Means Method: This method splits the set of objects into a given number of clusters by maximizing the between-cluster relative to the within-cluster variation. A value of  $K=3$  was selected based on an inspection of Figure 2. Table 8 shows the result of this analysis. Summary statistics for all three clusters are given with respect to the six variables used. Sample statistics, also with respect to the variables, are given for each cluster. The statistics were computed over the membership of the cluster. Table 9. shows similar information for the case  $k=2$ . These tables provide the basis for the discussion that follows.

Figure 2. Branching Tree of the Clustering Stations

DISTANCE METRIC IS 1-PEARSON CORRELATION COEFFICIENT  
 LINKAGE METHOD IS NEAREST NEIGHBOR

TREE DIAGRAM

DISTANCES



## Discussion

An inspection of Figure 2 shows that at a distance cut off of about 0.03 three clusters may be discerned. Stations 4 and 6 belong to one cluster, Station 2 forms a singleton, and the balance of the stations make up the third cluster. Using the K-Mean algorithm with K=3, Table 8 shows that the membership of the three clusters is rearranged somewhat. Cluster 1 now includes stations 2, 4, and 6 while Cluster 3 now includes Stations 7, 8, 11, 21, 31, and 51. The rest of the stations belong to Cluster 2. An inspection of Figure 1 shows that Cluster-1 stations were all located on the canals -- Station 2 on the Moody Canal, Station 4 on Military Canal, and Station 6 on the Mowry Canal. Similarly, the Cluster-3 stations were located on the Florida City Canal (Stations 7 and 8) and close to the coastline (Stations 11, 21, and 51) along the axis of the Moody, Military, Mowry, and Florida City canals, respectively. Table 9 shows that when the analysis was repeated for two clusters only, all of the members of Clusters 1 and 3 above, except station 51, were in one cluster while the rest were in the second cluster. The membership of Cluster 2 (Table 8) was further examined by obtaining a contour plot (Figure 3) of distance values. The station latitude and longitude constituted the plotting axes. The distance values were categorized as shown in the legend of Figure 3. It is observed that the centroid of this cluster was around stations 65 and 75 since they had distance values close to zero. The following within cluster groups may be identified.

| <u>Group</u> | <u>Symbol</u> | <u>Membership</u>  |
|--------------|---------------|--------------------|
| 1            | '+'`          | 15, 18, 19, 28, 29 |
| 2            | '*'`          | 25, 35, 38, 58, 39 |
| 3            | '+'`          | 68, 78, 88         |
| 4            | '.'`          | 55, 65, 75, 85, 96 |
| 5            | '='`          | 30, 61, 71, 84     |
| 6            | '*'`          | 81, 92             |

The above table provides a basis for deleting stations.

Table 8. Summary Statistics for Three Cluster Case

| VARIABLE | BETWEEN SS | DF | WITHIN SS | DF | F-RATIO | PROB  |
|----------|------------|----|-----------|----|---------|-------|
| SALT     | 1235.742   | 2  | 140.206   | 30 | 132.206 | 0.000 |
| COND     | 2973.186   | 2  | 277.109   | 30 | 160.940 | 0.000 |
| TEMP     | 4.805      | 2  | 24.043    | 30 | 2.998   | 0.065 |
| TURB     | 1.078      | 2  | 3.170     | 30 | 5.102   | 0.012 |
| PH       | 1.082      | 2  | 1.237     | 30 | 13.115  | 0.000 |
| DO       | 9.055      | 2  | 19.129    | 30 | 7.100   | 0.003 |

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| MEMBERS |     |      | STATISTICS |         |       |         |      |
|---------|-----|------|------------|---------|-------|---------|------|
| CLUST   | STA | DIST | VARIABLE   | MINIMUM | MEAN  | MAXIMUM | SD   |
| 1       | 2   | 4.47 | SALT       | 7.28    | 14.20 | 17.87   | 4.90 |
|         | 4   | 1.43 | COND       | 12.27   | 20.73 | 28.00   | 6.69 |
|         | 6   | 3.57 | TEMP       | 26.52   | 26.85 | 27.00   | 0.26 |
|         |     |      | TURB       | 1.10    | 1.30  | 18.00   | 0.27 |
|         |     |      | PH         | 7.62    | 7.82  | 8.05    | 0.18 |
|         |     |      | DO         | 3.61    | 4.62  | 5.36    | 0.74 |
| 2       | 15  | 0.94 | SALT       | 31.50   | 34.60 | 36.90   | 1.52 |
|         | 18  | 0.93 | COND       | 48.55   | 52.54 | 55.40   | 2.00 |
|         | 19  | 0.83 | TEMP       | 21.30   | 25.64 | 26.97   | 0.98 |
|         | 25  | 1.29 | TURB       | 0.59    | 0.87  | 1.40    | 0.20 |
|         | 28  | 0.97 | PH         | 8.08    | 8.35  | 8.56    | 0.10 |
|         | 29  | 0.97 | DO         | 5.60    | 6.11  | 6.66    | 0.19 |
|         | 30  | 2.03 |            |         |       |         |      |
|         | 35  | 1.26 |            |         |       |         |      |
|         | 38  | 1.06 |            |         |       |         |      |
|         | 39  | 1.24 |            |         |       |         |      |
|         | 55  | 0.18 |            |         |       |         |      |
|         | 58  | 1.14 |            |         |       |         |      |
|         | 61  | 2.07 |            |         |       |         |      |
|         | 65  | 0.06 |            |         |       |         |      |
|         | 68  | 0.82 |            |         |       |         |      |
|         | 71  | 1.58 |            |         |       |         |      |
|         | 75  | 0.09 |            |         |       |         |      |
|         | 78  | 0.69 |            |         |       |         |      |
|         | 81  | 1.07 |            |         |       |         |      |
|         | 84  | 1.51 |            |         |       |         |      |
|         | 85  | 0.30 |            |         |       |         |      |
|         | 88  | 0.95 |            |         |       |         |      |
|         | 92  | 1.15 |            |         |       |         |      |
|         | 96  | 0.10 |            |         |       |         |      |
| 3       | 7   | 1.01 | SALT       | 25.36   | 27.25 | 30.10   | 1.45 |
|         | 8   | 1.47 | COND       | 37.04   | 41.55 | 46.57   | 2.80 |
|         | 11  | 1.94 | TEMP       | 25.57   | 26.21 | 26.75   | 0.37 |
|         | 21  | 0.60 | TURB       | 0.72    | 1.27  | 2.28    | 0.58 |
|         | 31  | 0.53 | PH         | 7.45    | 8.04  | 8.37    | 0.39 |
|         | 51  | 2.40 | DO         | 2.59    | 5.15  | 6.60    | 1.66 |

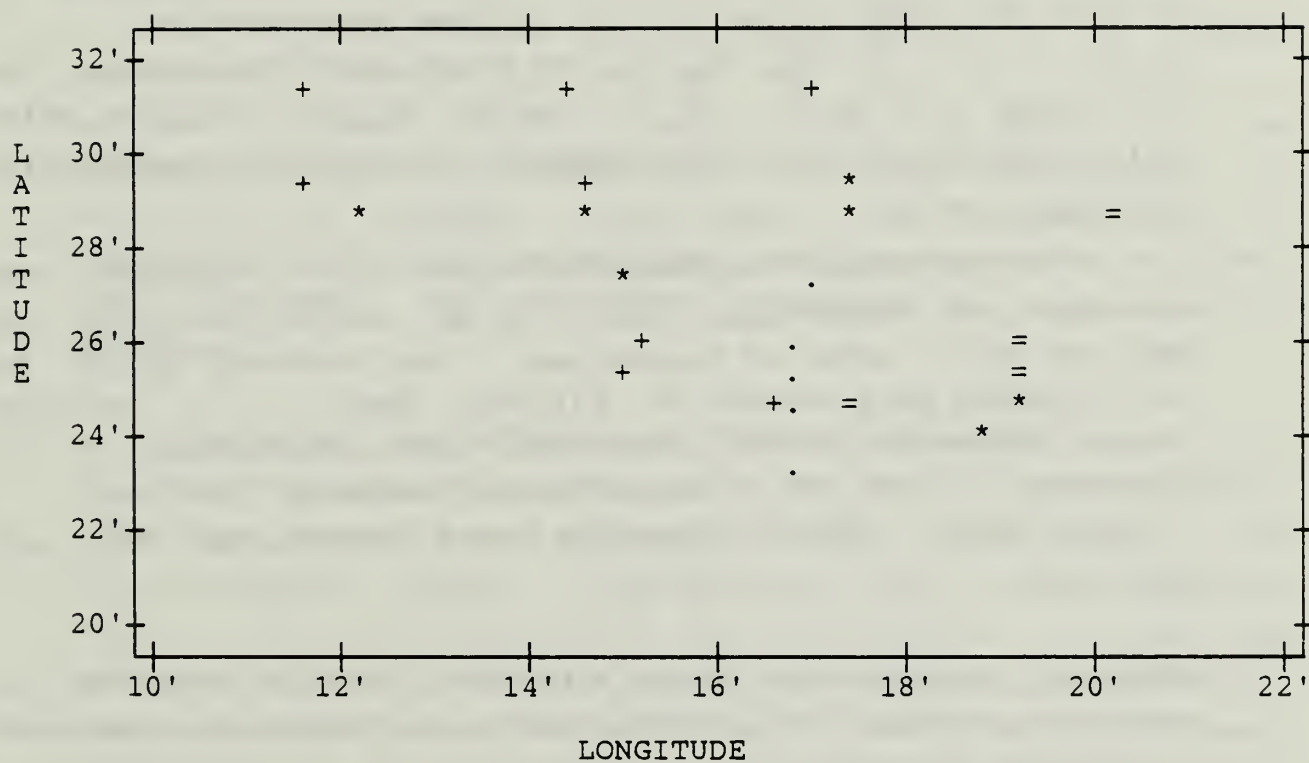
Table 9. Summary Statistics for Two Cluster Case

| VARIABLE | BETWEEN SS | DF | WITHIN SS | DF | F-RATIO | PROB  |
|----------|------------|----|-----------|----|---------|-------|
| SALT     | 934.086    | 1  | 441.855   | 31 | 65.534  | 0.000 |
| COND     | 2233.159   | 1  | 1017.141  | 31 | 68.061  | 0.000 |
| TEMP     | 3.983      | 1  | 24.865    | 31 | 4.966   | 0.033 |
| TURB     | 1.283      | 1  | 2.965     | 31 | 13.417  | 0.001 |
| PH       | 1.146      | 1  | 1.173     | 31 | 30.302  | 0.000 |
| DO       | 9.966      | 1  | 18.218    | 31 | 16.958  | 0.000 |

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| MEMBERS |     |       | STATISTICS |         |       |         |       |
|---------|-----|-------|------------|---------|-------|---------|-------|
| CLUST   | STA | DIST  | VARIABLE   | MINIMUM | MEAN  | MAXIMUM | SD    |
| 1       | 2   | 10.42 | SALT       | 7.28    | 22.00 | 27.66   | 6.77  |
|         | 4   | 5.20  | COND       | 12.27   | 33.11 | 42.08   | 10.53 |
|         | 6   | 2.51  | TEMP       | 25.57   | 26.47 | 27.15   | 0.46  |
|         | 7   | 4.08  | TURB       | 0.72    | 1.33  | 2.28    | 0.50  |
|         | 8   | 3.46  | PH         | 7.45    | 7.92  | 8.37    | 0.34  |
|         | 11  | 2.91  | DO         | 2.59    | 4.83  | 6.60    | 1.47  |
|         | 21  | 4.23  |            |         |       |         |       |
|         | 31  | 3.96  |            |         |       |         |       |
| 2       | 15  | 0.82  | SALT       | 30.10   | 34.42 | 36.90   | 1.73  |
|         | 18  | 1.05  | COND       | 46.57   | 52.31 | 55.40   | 2.28  |
|         | 19  | 0.95  | TEMP       | 21.30   | 25.66 | 26.97   | 0.96  |
|         | 25  | 1.17  | TURB       | 0.59    | 0.87  | 1.40    | 0.20  |
|         | 28  | 1.09  | PH         | 8.08    | 8.35  | 8.56    | 0.10  |
|         | 29  | 1.08  | DO         | 5.60    | 6.11  | 6.66    | 0.19  |
|         | 30  | 1.98  |            |         |       |         |       |
|         | 35  | 1.14  |            |         |       |         |       |
|         | 38  | 1.18  |            |         |       |         |       |
|         | 39  | 1.36  |            |         |       |         |       |
|         | 51  | 2.94  |            |         |       |         |       |
|         | 55  | 0.08  |            |         |       |         |       |
|         | 58  | 1.26  |            |         |       |         |       |
|         | 61  | 1.94  |            |         |       |         |       |
|         | 65  | 0.08  |            |         |       |         |       |
|         | 68  | 0.94  |            |         |       |         |       |
|         | 71  | 1.46  |            |         |       |         |       |
|         | 75  | 0.07  |            |         |       |         |       |
|         | 78  | 0.80  |            |         |       |         |       |
|         | 81  | 0.95  |            |         |       |         |       |
|         | 84  | 1.64  |            |         |       |         |       |
|         | 85  | 0.22  |            |         |       |         |       |
|         | 88  | 1.05  |            |         |       |         |       |
|         | 92  | 1.04  |            |         |       |         |       |
|         | 96  | 0.15  |            |         |       |         |       |

Figure 3. Distance Values for Sampling Stations  
in Cluster 2.



## 6.0 QUALITY IMPACT OF CANAL DISCHARGE INTO BAY

The objective was to determine whether canal discharge into the Biscayne Bay influences water quality and how far offshore is this effect, if any, noticeable.

### Description of Data

The manner in which the water quality data and the Canal discharge data have been combined into one data set contained in file FLOWQUAL.DAT was described in Section 3. The stations of interest are those along the axis of the Moody Canal (i.e., 2, 11, 12, 13, 14, 15, 16, 18, 19) and those along the axis of the Mowry Canal (i.e. 6, 31, 32, 33, 34, 35, 36, 38, 39). The water quality variables used were conductivity, salinity, temperature, turbidity, and pH.

To be manageable the measured values of the variables were converted into categorical data. As an initial analysis, the data was split into two categories. The threshold values for the variables were assumed as follows: depth 1.0 m, salinity 34 ppt, conductivity 47.5 mmhos/cm<sup>2</sup>, water temperature 25 °C, turbidity 1.5 NTU, pH 7.0, and canal discharge 1.00 cfs (0.028 m<sup>3</sup>/sec). Four categories were established for each variable.

Category 1 corresponds to the situation when the discharge is above the threshold of 1.00 cfs and the variable had value above the assumed threshold;

Category 2 corresponds to the situation when the discharge is above 1.00 cfs and the variable is below its threshold;

Category 3 corresponds to the situation when discharge is below 1.00 cfs and the variable is above its threshold; and

Category 4 corresponds to the situation when discharge is below 1.00 cfs and the variable is below its threshold value.

A new variable, FLOWPARA, was thus defined as the categorical variable which assumes a value of 1, 2, 3, or 4. A FORTRAN program, CAT.FOR was written to convert the measured values into

categorical data. The program also obtains the frequency of each category for a given station - variable - canal combination. The counting process was done with respect to the sampling dates. Those frequencies were obtained for each day (up to 4 days) before each quality sampling date. Table 10 shows the output from CAT.FOR for conductivity. The output for all of the variables was stored in the file TABLE.DAT and was used as the input data for the Contingency Analysis.

### Methods

The TABULATE command in the TABLES module of the SYSTAT microcomputer statistical package was used to construct a multiway contingency table. Given the data of Table 10, the contingency table was formed from the cell frequencies and constitutes a four-way table since the frequencies are classified by the four categorical indicies FLOWPARA, STATION, CANAL, and PARA. The index PARA represents the water-quality variable.

Reading of the table is facilitated by conditioning initially on the canal index and then by the water-quality variable index thus reducing the original four-way table into a set two-way marginal tables. This generates more tables although each of the resulting tables is much simpler to read and interpret. Table 11 contains a sample of such tables for Moody Canal and each of the four water-quality variables using canal discharge that was measured on the day that the Bay water quality was sampled.

Table 10. Frequency of Categorized Conductivity Data

| FLOWPARA | STA | CANAL | FREQUENCY |    |    |    |    |
|----------|-----|-------|-----------|----|----|----|----|
|          |     |       | 0         | 1  | 2  | 3  | 4  |
| 2        | 2   | 1     | 21        | 19 | 19 | 21 | 22 |
| 4        | 2   | 1     | 21        | 23 | 23 | 21 | 20 |
| 2        | 11  | 1     | 22        | 21 | 20 | 22 | 23 |
| 3        | 11  | 1     | 3         | 4  | 3  | 4  | 3  |
| 4        | 11  | 1     | 24        | 25 | 26 | 24 | 23 |
| 1        | 15  | 1     | 9         | 10 | 8  | 9  | 9  |
| 2        | 15  | 1     | 12        | 9  | 11 | 11 | 12 |
| 3        | 15  | 1     | 11        | 10 | 12 | 11 | 11 |
| 4        | 15  | 1     | 16        | 19 | 17 | 17 | 16 |
| 1        | 18  | 1     | 16        | 15 | 13 | 15 | 15 |
| 2        | 18  | 1     | 4         | 3  | 5  | 4  | 5  |
| 3        | 18  | 1     | 23        | 24 | 26 | 24 | 24 |
| 4        | 18  | 1     | 4         | 5  | 3  | 4  | 3  |
| 1        | 19  | 1     | 17        | 15 | 14 | 15 | 17 |
| 2        | 19  | 1     | 3         | 3  | 3  | 4  | 4  |
| 3        | 19  | 1     | 22        | 24 | 25 | 24 | 22 |
| 4        | 19  | 1     | 2         | 2  | 2  | 1  | 1  |
| 2        | 6   | 2     | 39        | 35 | 38 | 38 | 39 |
| 3        | 6   | 2     | 6         | 6  | 6  | 6  | 6  |
| 4        | 6   | 2     | 7         | 11 | 8  | 8  | 7  |
| 1        | 31  | 2     | 9         | 7  | 6  | 6  | 7  |
| 2        | 31  | 2     | 63        | 63 | 63 | 64 | 66 |
| 3        | 31  | 2     | 17        | 19 | 20 | 20 | 19 |
| 4        | 31  | 2     | 16        | 16 | 16 | 15 | 13 |
| 1        | 32  | 2     | 5         | 5  | 2  | 2  | 3  |
| 2        | 32  | 2     | 12        | 13 | 12 | 13 | 15 |
| 3        | 32  | 2     | 4         | 4  | 7  | 7  | 6  |
| 4        | 32  | 2     | 4         | 3  | 4  | 3  | 1  |
| 1        | 33  | 2     | 8         | 8  | 5  | 5  | 7  |
| 2        | 33  | 2     | 9         | 10 | 9  | 10 | 11 |
| 3        | 33  | 2     | 5         | 5  | 8  | 8  | 6  |
| 4        | 33  | 2     | 3         | 2  | 3  | 2  | 1  |
| 1        | 34  | 2     | 15        | 16 | 12 | 12 | 15 |
| 2        | 34  | 2     | 2         | 2  | 2  | 3  | 3  |
| 3        | 34  | 2     | 9         | 8  | 12 | 12 | 9  |
| 4        | 34  | 2     | 2         | 2  | 2  | 1  | 1  |
| 1        | 35  | 2     | 30        | 29 | 26 | 27 | 30 |
| 2        | 35  | 2     | 37        | 37 | 39 | 38 | 38 |
| 3        | 35  | 2     | 21        | 22 | 25 | 24 | 21 |
| 4        | 35  | 2     | 6         | 6  | 4  | 5  | 5  |
| 1        | 36  | 2     | 17        | 18 | 14 | 15 | 18 |
| 3        | 36  | 2     | 12        | 11 | 15 | 14 | 11 |
| 1        | 38  | 2     | 37        | 34 | 36 | 36 | 37 |
| 2        | 38  | 2     | 14        | 14 | 15 | 15 | 14 |
| 3        | 38  | 2     | 21        | 24 | 22 | 22 | 21 |
| 4        | 38  | 2     | 2         | 2  | 1  | 1  | 2  |
| 1        | 39  | 2     | 34        | 30 | 33 | 33 | 34 |
| 2        | 39  | 2     | 8         | 8  | 9  | 9  | 9  |
| 3        | 39  | 2     | 16        | 20 | 17 | 17 | 16 |
| 4        | 39  | 2     | 2         | 2  | 1  | 1  | 1  |

---

\* Number of days before water quality sampling

Table 11. Table of Station (rows) by FLOWPARA (columns)

|         |       | CANAL<br>PARA | =     | MOODY<br>SALINITY |        |  |
|---------|-------|---------------|-------|-------------------|--------|--|
| STATION | 1     | 2             | 3     | 4                 | TOTAL  |  |
| 2       | .00   | 61.90         | .00   | 38.10             | 100.00 |  |
| 11      | 2.00  | 56.00         | 6.00  | 36.00             | 100.00 |  |
| 15      | 25.00 | 31.25         | 16.67 | 27.08             | 100.00 |  |
| 18      | 46.81 | 8.51          | 36.17 | 8.51              | 100.00 |  |
| 19      | 52.27 | 6.82          | 36.36 | 4.55              | 100.00 |  |
| TOTAL   | 25.11 | 32.90         | 19.05 | 22.94             | 100.00 |  |
|         |       | PARA          | =     | CONDUCTIVITY      |        |  |
| STATION | 1     | 2             | 3     | 4                 | TOTAL  |  |
| 2       | .00   | 61.90         | 4.76  | 33.33             | 100.00 |  |
| 11      | 10.00 | 48.00         | 12.00 | 30.00             | 100.00 |  |
| 15      | 41.67 | 14.58         | 25.00 | 18.75             | 100.00 |  |
| 18      | 53.19 | 2.13          | 34.04 | 10.64             | 100.00 |  |
| 19      | 59.09 | .00           | 34.09 | 6.82              | 100.00 |  |
| TOTAL   | 32.90 | 25.11         | 22.08 | 19.91             | 100.00 |  |
|         |       | PARA          | =     | TEMPERATURE       |        |  |
| STATION | 1     | 2             | 3     | 4                 | TOTAL  |  |
| 2       | 52.38 | 9.52          | 19.05 | 19.05             | 100.00 |  |
| 11      | 42.00 | 16.00         | 18.00 | 24.00             | 100.00 |  |
| 15      | 41.67 | 14.58         | 20.83 | 22.92             | 100.00 |  |
| 18      | 42.55 | 12.77         | 21.28 | 23.40             | 100.00 |  |
| 19      | 43.18 | 15.91         | 18.18 | 22.73             | 100.00 |  |
| TOTAL   | 44.16 | 13.85         | 19.48 | 22.51             | 100.00 |  |
|         |       | PARA          | =     | TURBIDITY         |        |  |
| STATION | 1     | 2             | 3     | 4                 | TOTAL  |  |
| 2       | 11.90 | 50.00         | 16.67 | 21.43             | 100.00 |  |
| 11      | 10.00 | 48.00         | 4.00  | 38.00             | 100.00 |  |
| 15      | 2.08  | 54.17         | 2.08  | 41.67             | 100.00 |  |
| 18      | 14.89 | 40.43         | 10.64 | 34.04             | 100.00 |  |
| 19      | 2.27  | 56.82         | 2.27  | 38.64             | 100.00 |  |
| TOTAL   | 8.23  | 49.78         | 6.93  | 35.06             | 100.00 |  |

Table 12. Contingency Table of Station by FLOWPARA

|          |       | CANAL<br>PARA | =     | Moody<br>Salinity |        |
|----------|-------|---------------|-------|-------------------|--------|
| FLOWPARA | 1     | 2             | 3     | 4                 | TOTAL  |
| STATION  |       |               |       |                   |        |
| 2        | .00   | 59.52         | .00   | 40.48             | 100.00 |
| 11       | 2.00  | 54.00         | 6.00  | 38.00             | 100.00 |
| 15       | 22.92 | 31.25         | 18.75 | 27.08             | 100.00 |
| 18       | 40.43 | 12.77         | 42.55 | 4.26              | 100.00 |
| 19       | 45.45 | 9.09          | 43.18 | 2.27              | 100.00 |

|       |       |       |       |       |        |
|-------|-------|-------|-------|-------|--------|
| TOTAL | 22.08 | 33.33 | 22.08 | 22.51 | 100.00 |
|-------|-------|-------|-------|-------|--------|

|          |       | PARA  | =     | CONDUCTIVITY |        |
|----------|-------|-------|-------|--------------|--------|
| FLOWPARA | 1     | 2     | 3     | 4            | TOTAL  |
| STATION  |       |       |       |              |        |
| 2        | .00   | 59.52 | 4.76  | 35.71        | 100.00 |
| 11       | 8.00  | 48.00 | 14.00 | 30.00        | 100.00 |
| 15       | 33.33 | 20.83 | 33.33 | 12.50        | 100.00 |
| 18       | 44.68 | 8.51  | 42.55 | 4.26         | 100.00 |
| 19       | 50.00 | 4.55  | 43.18 | 2.27         | 100.00 |

|       |       |       |       |       |        |
|-------|-------|-------|-------|-------|--------|
| TOTAL | 27.27 | 28.14 | 27.71 | 16.88 | 100.00 |
|-------|-------|-------|-------|-------|--------|

|          |       | PARA  | =     | TEMPERATURE |        |
|----------|-------|-------|-------|-------------|--------|
| FLOWPARA | 1     | 2     | 3     | 4           | TOTAL  |
| STATION  |       |       |       |             |        |
| 2        | 50.00 | 9.52  | 21.43 | 19.05       | 100.00 |
| 11       | 42.00 | 14.00 | 18.00 | 26.00       | 100.00 |
| 15       | 39.58 | 14.58 | 22.92 | 22.92       | 100.00 |
| 18       | 40.43 | 12.77 | 23.40 | 23.40       | 100.00 |
| 19       | 40.91 | 13.64 | 20.45 | 25.00       | 100.00 |

|       |       |       |       |       |        |
|-------|-------|-------|-------|-------|--------|
| TOTAL | 42.42 | 12.99 | 21.21 | 23.38 | 100.00 |
|-------|-------|-------|-------|-------|--------|

|          |       | PARA  | =     | TURBIDITY |        |
|----------|-------|-------|-------|-----------|--------|
| FLOWPARA | 1     | 2     | 3     | 4         | TOTAL  |
| STATION  |       |       |       |           |        |
| 2        | 11.90 | 47.62 | 16.67 | 23.81     | 100.00 |
| 11       | 8.00  | 48.00 | 6.00  | 38.00     | 100.00 |
| 15       | 4.17  | 50.00 | 0.00  | 45.83     | 100.00 |
| 18       | 12.77 | 40.43 | 12.77 | 34.04     | 100.00 |
| 19       | 4.55  | 50.00 | 0.00  | 45.45     | 100.00 |

|       |      |       |      |       |        |
|-------|------|-------|------|-------|--------|
| TOTAL | 8.23 | 47.19 | 6.93 | 37.66 | 100.00 |
|-------|------|-------|------|-------|--------|

Table 12 also contains such tables but for the case of Canal discharge, two days before Bay sampling. Note that the entries in the tables are row percents rather than absolute frequencies. This was done to facilitate inferences from the tables. Thus, the entry  $f_{ijk}$  is the percent of time that variable  $k$  fell into category  $j$  at location (station)  $i$ .

Different types of statistical analyses (models) may be applied to the contingency table and corresponding statistics computed. These include testing of hypothesis about the homogeneity of the data, row effects, column effects, the interaction between the indices, and the order of these interaction; and Log-linear modeling for predicting expected cell frequencies. Because of the coarse nature of the categorization of the data, however, the discussion below is limited to examining the pattern of row-wise and column-wise frequencies.

### Discussion

The first point to make is that the thresholds, on which the categorization of the variables was based, are arbitrary. Thus inferences on the patterns of percent frequencies must be made on a relative basis. Also, as observed earlier, in order to account for possible lagged response of the Bay to Canal discharge, discharges that occurred up to four days before bay quality sampling were taken into consideration. The assumption was made, however, that the full effect (dilution/pollution) of the Canal discharge was felt at furthest sampling station from the outlet. The contingency tables were constructed for all five discharge situations; only two are included in this report (Tables 11 and 12). Observed patterns may be explained in the context of the definition of the categories made in page 24.

The salinity and conductivity sections in Table 11 show similar patterns. Table 11 was constructed with Canal discharge that was measured the same day as the Bay quality sample. The percent frequencies were observed to increase with distance from the coast when the salinity/conductivity value was less than the threshold. In contrast, temperature showed a fairly uniform distribution of percent frequencies while for turbidity the picture was mixed for all categories.

## 7.0 FACTOR ANALYSIS OF WATER QUALITY VARIABLES

The objectives were to combine the sampled variables into subgroups, represented by factors, which convey the essential information contained in the membership of the subgroup and to identify the variables with high variability so as to recommend sampling frequency for those variables.

### Description of Data

The same data set (CLUSTER.DAT) used in performing the Cluster Analysis was used to perform the Factor Analysis of the Bay water quality data. Recall that data set was obtained from the original 1979-1984 data. It contains the mean, over time and for sample depths less than or equal to 0.2m, of the following variables; salinity, conductivity, Temperature, turbidity, pH and dissolved oxygen.

### Methods

The method of Factor Analysis was applied to construct factors that were made up of subgroups of the original set of water quality variables. That original set of variables may or may not be correlated. The final set of factors were uncorrelated and dimensionless linear combinations of members of their respective subgroups.

The FACTOR module of the SYSTAT Microcomputer Statistical package was used to perform the analysis. The correlation matrix of the water-quality variables was chosen as the matrix to be factored. The Principal Components submodule was used to construct the initial set of factors. From this set and following conventional practice, factors with eigenvalues greater than or equal to one were retained. Thus if the water quality variables are represented by  $\{x_i\}$ ,  $i=1,6$ , the score for the  $j$ th factor is given by:

$$\Phi_j = \beta_{j1}x_1 + \beta_{j2}x_2 + \beta_{j3}x_3 + \beta_{j4}x_4 + \beta_{j5}x_5 + \beta_{j6}x_6 \quad (7.1)$$

where some of the variables will not contribute to the score and the  $\beta$ 's are the factor score coefficients.

FACTOR standardizes the original variables before factoring in order to remove scale effects. Because of this standardization, the variance of each variable is one. This unit variance is comprised of the communality, due to characteristics common to all the variables, and the specificity, due to characteristics unique to the variable. The factor loading of a variable is the correlation between the standardized variable and the common factor.

The Varimax method was used to rotate the common factors. Rotation methods attempt to select the factors so that some of the loadings are close to plus or minus one and the remaining loadings are close to zero. Ideally each variable should have a high loading on only one factor.

### Discussion

Table 13 contains selected output from the FACTOR module. An examination of the correlation matrix showed that the correlations were much higher than in the initial correlation matrix (Table 6) when individual values rather than means were used. High correlations existed between SALT and COND, PH and SALT, PH and COND, PH and TURB, and DO and TURB.

The eigenvalues (latent roots) obtained were:

|            |   |      |      |      |      |      |      |
|------------|---|------|------|------|------|------|------|
| Factor     | : | 1    | 2    | 3    | 4    | 5    | 6    |
| Eigenvalue | : | 3.88 | 1.01 | 0.83 | 0.19 | 0.07 | 0.01 |

Table 13 also contains the initial and rotated factor loadings, the factor score coefficients of the rotated loadings, and the percentage of the total variance explained by each factor, for the two factors with an eigenvalue greater than or equal to one. The two factor - rotated loadings show that the first component had TURB, DO, and PH as the important variables while the second component had SALT and COND as the important variables. TEMP did not have a strong showing in either component. This supports the observation, in Tables 8 and 9, that showed  $PROB = 0.065$ , i.e., that the contribution of temperature in the clusters formation was not significant at the 5% level.

Further insight may be gained from the communality and specificity computed for each variable:

|             |        |      |      |      |      |      |
|-------------|--------|------|------|------|------|------|
| Variable    | : PH   | DO   | COND | SALT | TURB | TEMP |
| Communality | : 0.91 | 0.89 | 0.99 | 0.99 | 0.89 | 0.23 |
| Specificity | : 0.09 | 0.11 | 0.01 | 0.01 | 0.09 | 0.77 |

These statistics show that, except for the temperature, the communality of each of the variables was very high indicating that the variance in the measured values was explained by common characteristics. The variance in the temperature measurements appears to be explained by characteristics which were not shared by the other variables.

Table 13. Factor Analysis Results

Correlation Matrix

|      | <u>SALT</u> | <u>COND</u> | <u>TEMP</u> | <u>TURB</u> | <u>PH</u> | <u>DO</u> |
|------|-------------|-------------|-------------|-------------|-----------|-----------|
| SALT | 1.000       |             |             |             |           |           |
| COND | 0.990       | 1.000       |             |             |           |           |
| TEMP | -0.310      | -0.329      | 1.000       |             |           |           |
| TURB | -0.382      | -0.388      | 0.368       | 1.000       |           |           |
| PH   | 0.689       | 0.676       | -0.359      | -0.759      | 1.000     |           |
| DO   | 0.566       | 0.543       | -0.261      | -0.808      | 0.913     | 1.00      |

|      | <u>Initial</u>         |        | <u>Rotated</u>         |        | <u>Factor Score</u> |        |
|------|------------------------|--------|------------------------|--------|---------------------|--------|
|      | <u>Factor Loadings</u> |        | <u>Factor Loadings</u> |        | <u>Coefficients</u> |        |
|      | 1                      | 2      | 1                      | 2      | 1                   | 2      |
| DO   | 0.880                  | -0.337 | 0.886                  | 0.321  | 0.389               | -0.104 |
| PH   | 0.938                  | -0.166 | 0.818                  | 0.489  | 0.290               | 0.034  |
| TURB | -0.778                 | 0.536  | -0.939                 | -0.104 | -0.498              | 0.269  |
| SALT | 0.837                  | 0.536  | 0.282                  | 0.953  | -0.184              | 0.541  |
| COND | 0.832                  | 0.541  | 0.275                  | 0.954  | -0.188              | 0.544  |
| TEMP | -0.481                 | 0.061  | -0.403                 | -0.268 | -0.133              | -0.035 |

Variance

Explained: 3.883    1.012    2.652    2.243

Percent

Explained: 64.72    16.88    44.21    37.39

## 8.0 DETERMINING SAMPLING FREQUENCY

The objectives were to investigate possible trends in the data sets and to determine the optimal sampling interval based on statistical inference methods.

### Description of Data

The starting point of the analysis to obtain the sampling frequency to be used by Park personnel was the original data file, QUAL.DAT, containing all 5166 records with 12 variables and the sampling depth per record. The file DATE.DAT contained the sampling dates and the beginning and ending serial number of the stations that were sampled on the corresponding date. The program SEQ'.FOR combined the above two data sets and in the process abstracted the time-ordered values of a given variable sampled at a given station. The variable used in this section was the conductivity. The program excluded those sampling days for which no data were collected from the station of interest. The output was stored in file DATA11.DAT for station 11, DATA04.DAT for station 04 and so on. The output was the conductivity averaged over the sampled depths for the sampling date.

The program SE.FOR assigned the sampled dates in DATA11.DAT, for example, into a corresponding interval of one month duration. Thus, some intervals contain more than one sampling day while others contain none. The output from this program was the depth-averaged conductivity now averaged over the number of sampling days within the month. The output was stored, for station 11 for example, in file S11.DAT and consisted of the month order and mean conductivity for the month. Entries of 99.99 corresponded to no samples taken on any day within that month.

### Methods

The Kendall (1970) Rank Correlation method was applied to meet the objectives. The Kendall test is ordinarily used to detect seasonalities. A variation of this test was used by Hirsch et al. (1982) to test for trends in a hydrologic time series. By considering the rank correlation between the rank

and the time order of the set  $\{y_i\}$ ,  $i=1, n$  of observations, the rank score,  $S$ , is written as

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(y_j - y_k) \quad (8.1)$$

where  $n$  is the sample size and

$$\text{sgn}(m) = \begin{matrix} 1 & m < 0 \\ 0 & m = 0 \\ -1 & m > 0 \end{matrix} \quad (8.2)$$

The rank correlation coefficient is given by

$$\tau = 2S / (n(n-1)) \quad (8.3)$$

Testing the significance of  $\tau$  is equivalent to testing the hypothesis that the sequence of values is independent and identically distributed against the alternate hypothesis that the sequence is not. Under the null hypothesis  $\tau$  and hence  $S$  are normally distributed in the limit as  $n$  approaches infinity and for all practical purposes for  $n \geq 10$ . It has zero mean and standard deviation,  $\sigma$ :

$$\sigma = [n(n-1)(2n+5) - \sum t(t-1)(2t+5)] / 18 \quad (8.4)$$

where  $t$  is the number of observations involved in a tie. Let  $s^*$  be an observed value of  $S$ , then the reduced variate is  $u = s^* / \sigma$ . If  $u$  lies in the tails of the standardized normal distribution, at an assumed level of significance, then one rejects the hypothesis that successive values of the series are independent. In such a case each observation provides new information about the variable and so the sampling interval should be maintained.

### Discussion

The above method was applied to stations 4, 11, 18, 35, and 92 which were representative of the distribution of stations and were also among the most sampled. Program SS.FOR was written to accomplish the analysis. The file S04.DAT, for example, was used

as input for the program. First, the program partitioned the data file into time segments with uninterrupted monthly data. It then computed, for each segment, the total score, Kendall's rank-correlation coefficient, the standard deviation of the score, and the reduced variate. Table 14 gives these results for the five stations listed above.

The last column of Table 14 contains the probability,  $P$ , that the observed score or its reduced variate will be attained or exceeded in absolute value. The entries in this column, for sample sizes less than 10, were taken from a table given by Kendall (1970, p 173). The normal table was used otherwise. Only 5 of the 38 analyzed analyzed gave  $P$  values less than the significance level of 0.05 assumed for this study. Thus, one needs not to reject the hypothesis of independence of the monthly observations. It is noteworthy that none of the segments with sample sizes greater than 10 had a value of  $P$  less than 0.05.

The above analysis was repeated for sampling intervals of 2, 3, and 4 months using the data segments in Table 14 that had 12 or more consecutively sampled months. The larger sampling intervals were obtained by deleting intermediate values from the Table 14 data. Table 15 gives the results for this case and shows that no  $P$  values were less than 0.05. The mean  $P$  values for the sampling intervals (  $\Delta t$  ) were:

| $\Delta t$ | 1    | 2    | 3    | 4 ( months) |
|------------|------|------|------|-------------|
| $P$        | 0.48 | 0.65 | 0.60 | 0.61        |

These mean values all indicated independence between observations at the respective sampling intervals and showed no significant change in the degree of independence with increasing sample size. When examined by station, the  $P$  values showed no desernable pattern over the sampling intervals.

Table 14. Results of Rank Correlation Analysis  
for Monthly Sampling Interval

| Sta | Time segment |       | Sample size | Total score | Kendall Tau | Std dev | Reduced variate | P    |
|-----|--------------|-------|-------------|-------------|-------------|---------|-----------------|------|
| 4   | 78273        | 79090 | 6           | -11.00      | 0.73        | 5.32    | -2.25           | 0.06 |
| 4   | 79120        | 81059 | 22          | -5.00       | 0.02        | 35.46   | 0.17            | 0.87 |
| 4   | 81090        | 81334 | 8           | 10.00       | 0.36        | 8.08    | 1.11            | 0.27 |
| 4   | 81365        | 82181 | 6           | 5.00        | 0.33        | 5.32    | 0.75            | 0.47 |
| 4   | 83120        | 83365 | 8           | 6.00        | 0.21        | 8.08    | 0.62            | 0.55 |
| 11  | 72091        | 73090 | 12          | -12.00      | 0.18        | 14.58   | 0.89            | 0.37 |
| 11  | 75181        | 76031 | 7           | 3.00        | 0.14        | 6.66    | 0.30            | 0.77 |
| 11  | 76244        | 77120 | 8           | -16.00      | 0.57        | 8.08    | -2.10           | 0.06 |
| 11  | 77212        | 78059 | 7           | 7.00        | 0.33        | 6.66    | 0.90            | 0.38 |
| 11  | 78090        | 79090 | 12          | 24.00       | 0.36        | 14.58   | 1.58            | 0.11 |
| 11  | 79120        | 81059 | 22          | -61.00      | 0.26        | 35.46   | -1.75           | 0.08 |
| 11  | 81090        | 81334 | 8           | 12.00       | 0.43        | 8.08    | 1.36            | 0.18 |
| 11  | 81365        | 82181 | 6           | 1.00        | 0.07        | 5.32    | 0.00            | 1.00 |
| 11  | 83120        | 83334 | 7           | 9.00        | 0.43        | 6.66    | 1.20            | 0.24 |
| 18  | 75181        | 76031 | 7           | 15.00       | 0.71        | 6.66    | 2.10            | 0.03 |
| 18  | 76244        | 77120 | 8           | 2.00        | 0.07        | 8.08    | 0.12            | 0.90 |
| 18  | 77243        | 78059 | 6           | 13.00       | 0.87        | 5.32    | 2.25            | 0.02 |
| 18  | 78181        | 81059 | 32          | 85.00       | 0.17        | 61.67   | 1.36            | 0.17 |
| 18  | 81090        | 81334 | 8           | 15.00       | 0.54        | 8.08    | 1.73            | 0.09 |
| 18  | 81365        | 82181 | 6           | -5.00       | 0.33        | 5.32    | -1.13           | 0.47 |
| 18  | 83120        | 83334 | 7           | 15.00       | 0.71        | 6.66    | 2.10            | 0.03 |
| 35  | 72091        | 73090 | 12          | 2.00        | 0.03        | 14.58   | 0.07            | 0.94 |
| 35  | 75181        | 76031 | 7           | 13.00       | 0.62        | 6.66    | 1.80            | 0.07 |
| 35  | 76244        | 77120 | 8           | 0.00        | 0.00        | 8.08    | 0.12            | 1.00 |
| 35  | 77243        | 78059 | 6           | 15.00       | 1.00        | 5.32    | 2.63            | 0.00 |
| 35  | 78243        | 79151 | 9           | -6.00       | 0.17        | 9.59    | 0.73            | 0.61 |
| 35  | 79181        | 81059 | 20          | 3.00        | 0.02        | 30.82   | 0.06            | 0.95 |
| 35  | 81090        | 81334 | 8           | 13.00       | 0.46        | 8.08    | 1.48            | 0.13 |
| 35  | 81365        | 82181 | 6           | 1.00        | 0.07        | 5.32    | 0.00            | 1.00 |
| 35  | 83120        | 83365 | 8           | 20.00       | 0.71        | 8.08    | 2.35            | 0.01 |
| 92  | 72091        | 73090 | 12          | -13.00      | 0.20        | 14.58   | 0.96            | 0.34 |
| 92  | 75181        | 76031 | 7           | 11.00       | 0.52        | 6.66    | 1.50            | 0.14 |
| 92  | 76244        | 77120 | 8           | -2.00       | 0.07        | 8.08    | 0.37            | 0.90 |
| 92  | 77243        | 78059 | 6           | 11.00       | 0.73        | 5.32    | 1.88            | 0.06 |
| 92  | 78243        | 79151 | 9           | -12.00      | 0.33        | 9.59    | -1.36           | 0.26 |
| 92  | 79181        | 81059 | 20          | -22.00      | 0.12        | 30.82   | 0.75            | 0.45 |
| 92  | 81090        | 81334 | 8           | 12.00       | 0.43        | 8.08    | 1.36            | 0.18 |
| 92  | 81365        | 82181 | 6           | -3.00       | 0.20        | 5.32    | 0.75            | 0.72 |

P is the probability that the reduced variate will be attained or exceeded in absolute value

Table 15. Results of Rank Correlation Analysis for Different Sampling Intervals

| $\Delta t$ | Sta | Time<br>segment | Sample<br>size | Total<br>score | Kendall<br>Tau | Std<br>dev | Reduced<br>variate | P     |      |
|------------|-----|-----------------|----------------|----------------|----------------|------------|--------------------|-------|------|
| 1          | 04  | 79120           | 81059          | 22             | -5.00          | 0.02       | 35.46              | 0.17  | 0.87 |
|            | 11  | 72091           | 73090          | 12             | -12.00         | 0.18       | 14.58              | 0.89  | 0.37 |
|            | 11  | 78090           | 79090          | 12             | 24.00          | 0.36       | 14.58              | 1.58  | 0.11 |
|            | 11  | 79120           | 81059          | 22             | -61.00         | 0.26       | 35.46              | -1.75 | 0.08 |
|            | 18  | 78181           | 81059          | 32             | 85.00          | 0.17       | 61.67              | 1.36  | 0.17 |
|            | 35  | 72091           | 73090          | 12             | 2.00           | 0.03       | 14.58              | 0.07  | 0.94 |
|            | 35  | 79181           | 81059          | 20             | 3.00           | 0.02       | 30.82              | 0.06  | 0.95 |
|            | 92  | 72091           | 73090          | 12             | -13.00         | 0.20       | 14.58              | 0.96  | 0.34 |
|            | 92  | 79181           | 81059          | 20             | -22.00         | 0.12       | 30.82              | 0.75  | 0.45 |
| 2          | 04  | 79120           | 81031          | 11             | 5.00           | 0.09       | 12.85              | 0.31  | 0.75 |
|            | 11  | 72091           | 73059          | 6              | -1.00          | 0.07       | 5.32               | 0.38  | 1.00 |
|            | 11  | 78090           | 79059          | 6              | 7.00           | 0.47       | 5.32               | 1.13  | 0.27 |
|            | 11  | 79120           | 81031          | 11             | -23.00         | 0.42       | 12.85              | -1.87 | 0.06 |
|            | 18  | 78181           | 81031          | 16             | 16.00          | 0.13       | 22.21              | 0.68  | 0.50 |
|            | 35  | 72091           | 73059          | 6              | 1.00           | 0.07       | 5.32               | 0.00  | 1.00 |
|            | 35  | 79181           | 81031          | 10             | 7.00           | 0.16       | 11.18              | 0.54  | 0.60 |
|            | 92  | 72091           | 73059          | 6              | -3.00          | 0.20       | 5.32               | 0.75  | 0.72 |
|            | 92  | 79181           | 81031          | 10             | -1.00          | 0.02       | 11.18              | 0.18  | 1.00 |
| 3          | 04  | 79120           | 81059          | 8              | 0.00           | 0.00       | 8.08               | 0.12  | 1.00 |
|            | 11  | 72091           | 73031          | 4              | 2.00           | 0.33       | 2.94               | 0.34  | 0.75 |
|            | 11  | 78090           | 79031          | 4              | 4.00           | 0.67       | 2.94               | 1.02  | 0.34 |
|            | 11  | 79120           | 81059          | 8              | -14.00         | 0.50       | 8.08               | -1.86 | 0.10 |
|            | 18  | 78181           | 81031          | 11             | 14.00          | 0.25       | 12.85              | 1.01  | 0.32 |
|            | 35  | 72091           | 73031          | 4              | 2.00           | 0.33       | 2.94               | 0.34  | 0.75 |
|            | 35  | 79181           | 81031          | 7              | -1.00          | 0.05       | 6.66               | 0.30  | 1.00 |
|            | 92  | 72091           | 73031          | 4              | 2.00           | 0.33       | 2.94               | 0.34  | 0.75 |
|            | 92  | 79181           | 81031          | 7              | -7.00          | 0.33       | 6.66               | -1.20 | 0.39 |
| 4          | 04  | 79120           | 81031          | 6              | -3.00          | 0.20       | 5.32               | 0.75  | 0.72 |
|            | 11  | 72091           | 72366          | 3              | 1.00           | 0.33       | 1.91               | 0.00  | *    |
|            | 11  | 78090           | 78365          | 3              | 3.00           | 1.00       | 1.91               | 1.04  | *    |
|            | 11  | 79120           | 81031          | 6              | -5.00          | 0.33       | 5.32               | -1.13 | 0.47 |
|            | 18  | 78181           | 80335          | 8              | -2.00          | 0.07       | 8.08               | 0.37  | 0.90 |
|            | 35  | 72091           | 72366          | 3              | 1.00           | 0.33       | 1.91               | 0.00  | *    |
|            | 35  | 79181           | 80335          | 5              | -4.00          | 0.40       | 4.08               | -1.22 | 0.48 |
|            | 92  | 72091           | 72366          | 3              | 1.00           | 0.33       | 1.91               | 0.00  | *    |
|            | 92  | 79181           | 80335          | 5              | -4.00          | 0.40       | 4.08               | -1.22 | 0.48 |

\*

No entries for sample size of less than 4 in Kendall's table

 $\Delta t$  is the sampling interval in months

## CONCLUSIONS AND RECOMMENDATIONS

An observational study has been performed on a set of water quality data obtained in time and space over Biscayne Bay, Florida. In all, about 131 sampling episodes were carried out over a period of about 12 years.

Data summaries of 11 water quality variables were calculated for all the water quality stations and for all the categories of sampled depths. The basic data were the time ordered samples of these variables. Based on a multivariate analysis of the variances it was concluded that there was no significant variation in the sampled water quality variables with depth. On the average, ammonium, turbidity, and dissolved oxygen were the most variable; pH and nitrate were the next most variable, while salinity and conductivity were the least variable.

Heuristic approaches that rely on standard hypothesis testing were applied to investigate the significance of a 1979 change in techniques for measuring water-quality variables. The cross-correlation matrix of the Before change and that of the After change data were used in this regard in addition to the comparison of the corresponding basic statistics. It was not established that the change was significant at the 5% .

Two clustering methods were applied to the data that were collected between 1979 and 1984. The Single Linkage method provided a dendrogram from which the number of clusters required was determined. The K-Means method, with the number of cluster  $k=3$ , was also applied. An additional application of this method for  $k=2$  was made for comparison. The conclusion was that there are basically two broad clusters of stations: those at the mouth of the canals and nearshore and those that were offshore. A secondary analysis of the offshore stations provided a basis for deleting some of those stations without losing valuable information on the microecosystem around the deleted station.

The records of the Moody and Mowry canal discharges into Biscayne Bay were combined with the Bay water-quality data in order to investigate the impacts of such discharges. Thresholds were assumed for the discharge and water-quality variables.

Contingency tables based on categorized canal discharge and water-quality variables were then formulated. Because of the arbitrary choice of thresholds, only relative inferences could be made concerning the pattern of frequencies in the contingency table. Definite trends in the percent frequencies of the different categories with distance from the canal discharge point were observed for salinity and conductivity. Temperature showed a fairly uniform distribution of percent frequencies while turbidity did not show any patterns.

The Kendall Rank-Correlation method was used to investigate possible trends in the data sets and to determine an optimal sampling frequency. Independence between successive observations is assumed to be established if the calculated probability of the rank score exceedance is greater than 0.05. Based on this criterion, the monthly observations were found to be independent with a mean probability of 0.48. The probability increased to 0.65 for sampling frequency of once in 2 months and did not change significantly with increasing frequency. Thus, the analyses did not indicate any trend or seasonality. This, however, may be because measurements were made just once, or in a few cases only several times in any one month.

The following recommendations are made:

It is recommended that future sampling be done at no more than two depths, preferably at 0.5 and 2.5 meters.

There is a need for the NPS to adopt threshold values that have physical meaning, for each measured variable, in the context of assessing man's action, such as canal discharges, on the bay environment.

The observed independence on the monthly observation level indicates that each such observation provides new information on the sampled variable. Therefore it is recommended that sampling be continued on a monthly basis particularly for those variables that were found to have high variability.

## REFERENCES

Hald, A., Statistical Theory with Engineering Applications, John Wiley Book Company, New York, 1952.

Hirsch, R. M., J. E. Slack and R. A. Smith, "Techniques of Trend Analysis for Monthly Water Quality Data," Water Resources Research, Volume 18(1), pp107-121, 1983.

Kendall, M. G., Rank Correlation Methods, 4th edition, Griffin Book Company, London, 1970.

Wilkinson, L., SYSTAT: The System for Statistics, Users Manual, Systat Inc., 603 Main St., Evanston Ill. 60202.



## APPENDIX 1.

SAMPLE STATISTICS FOR BENCHMARK SAMPLING STATIONS

STA\$ = 4 DEPTH\$ = 1

|              | SALT   | COND   | TURB  | PH    | DO    | AMU    | NITRI | NITRA  | PHOS  |
|--------------|--------|--------|-------|-------|-------|--------|-------|--------|-------|
| N OF CASES   | 45     | 47     | 42    | 45    | 47    | 28     | 29    | 28     | 24    |
| MINIMUM      | 0.920  | 2.100  | 0.630 | 2.230 | 0.570 | 4.440  | 0.000 | 0.000  | 0.000 |
| MAXIMUM      | 34.000 | 51.000 | 4.200 | 8.570 | 7.630 | 42.780 | 4.470 | 90.500 | 9.600 |
| MEAN         | 12.889 | 20.094 | 1.615 | 7.597 | 3.615 | 15.948 | 1.078 | 14.750 | 2.610 |
| STANDARD DEV | 10.673 | 15.816 | 0.871 | 0.885 | 1.788 | 10.091 | 1.195 | 22.384 | 2.613 |

STA\$ = 4 DEPTH\$ = 2

|              | SALT | COND   | TURB | PH    | DO    | AMU | NITRI | NITRA | PHOS |
|--------------|------|--------|------|-------|-------|-----|-------|-------|------|
| N OF CASES   | 0    | 1      | 0    | 1     | 1     | 0   | 0     | 0     | 0    |
| MINIMUM      | .    | 33.400 | .    | 7.860 | 4.200 | .   | .     | .     | .    |
| MAXIMUM      | .    | 33.400 | .    | 7.860 | 4.200 | .   | .     | .     | .    |
| MEAN         | .    | 33.400 | .    | 7.860 | 4.200 | .   | .     | .     | .    |
| STANDARD DEV | .    | 0.000  | .    | 0.000 | 0.000 | .   | .     | .     | .    |

STA\$ = 4 DEPTH\$ = 4

|              | SALT   | COND   | TURB  | PH    | DO    | AMU | NITRI | NITRA | PHOS |
|--------------|--------|--------|-------|-------|-------|-----|-------|-------|------|
| N OF CASES   | 2      | 3      | 1     | 3     | 3     | 0   | 0     | 0     | 0    |
| MINIMUM      | 14.570 | 25.300 | 3.300 | 7.600 | 1.000 | .   | .     | .     | .    |
| MAXIMUM      | 21.990 | 57.600 | 3.300 | 8.810 | 2.690 | .   | .     | .     | .    |
| MEAN         | 18.280 | 39.633 | 3.300 | 8.017 | 1.630 | .   | .     | .     | .    |
| STANDARD DEV | 5.247  | 16.454 | 0.000 | 0.687 | 0.923 | .   | .     | .     | .    |

STA\$ = 4 DEPTH\$ = 5

|              | SALT   | COND   | TURB  | PH    | DO    | AMU    | NITRI | NITRA  | PHOS  |
|--------------|--------|--------|-------|-------|-------|--------|-------|--------|-------|
| N OF CASES   | 56     | 62     | 28    | 55    | 60    | 23     | 24    | 24     | 17    |
| MINIMUM      | 2.930  | 4.890  | 0.700 | 7.140 | 0.090 | 0.000  | 0.020 | 0.160  | 0.000 |
| MAXIMUM      | 36.330 | 54.700 | 6.800 | 8.640 | 8.600 | 72.140 | 4.150 | 18.480 | 8.650 |
| MEAN         | 19.817 | 31.866 | 1.566 | 7.836 | 2.905 | 18.368 | 0.679 | 4.410  | 2.044 |
| STANDARD DEV | 7.961  | 11.511 | 1.341 | 0.395 | 1.466 | 16.479 | 0.946 | 5.012  | 2.388 |

## Legend:

COND = Conductivity

PH = pH

SALT = Salinity

TURB = Turbidity

DO = Dissolved Oxygen

AMU = Ammonium Ion

NITRI = Nitrite Ion

NITRA = Nitrate Ion

PHOS = Phosphate Ion

TEMPW = Water Temperature

TEMPA = Air Temperature

|              | STA\$ = 11 |       | DEPTH\$ = 1 |        |       |
|--------------|------------|-------|-------------|--------|-------|
|              | TURB       | PH    | DO          | AMO    |       |
| N OF CASES   | 49         | 48    | 47          | 26     | 25    |
| MINIMUM      | 5.000      | 0.150 | 0.330       | 0.290  | 0.010 |
| MAXIMUM      | 38.050     | 9.020 | 8.850       | 32.340 | 1.000 |
| MEAN         | 23.683     | 8.315 | 6.628       | 4.023  | 0.178 |
| STANDARD DEV | 8.050      | 1.242 | 1.460       | 6.992  | 0.262 |

|              | STA\$ = 11 |       | DEPTH\$ = 2 |        |       |
|--------------|------------|-------|-------------|--------|-------|
|              | TURB       | PH    | DO          | AMO    |       |
| N OF CASES   | 69         | 31    | 15          | 3      | 3     |
| MINIMUM      | 5.200      | 7.000 | 4.240       | 1.380  | 0.000 |
| MAXIMUM      | 38.800     | 8.950 | 8.980       | 31.820 | 0.370 |
| MEAN         | 25.862     | 8.110 | 6.496       | 12.000 | 0.130 |
| STANDARD DEV | 7.095      | 0.513 | 1.453       | 17.179 | 0.208 |

|              | STA\$ = 11 |       | DEPTH\$ = 3 |       |       |
|--------------|------------|-------|-------------|-------|-------|
|              | TURB       | PH    | DO          | AMO   |       |
| N OF CASES   | 22         | 24    | 24          | 8     | 5     |
| MINIMUM      | 10.310     | 7.930 | 5.370       | 0.000 | 0.000 |
| MAXIMUM      | 38.000     | 9.080 | 9.800       | 6.200 | 0.100 |
| MEAN         | 24.329     | 8.483 | 7.855       | 1.114 | 0.056 |
| STANDARD DEV | 7.050      | 0.325 | 1.190       | 2.155 | 0.042 |

|              | STA\$ = 11 |       | DEPTH\$ = 4 |       |       |
|--------------|------------|-------|-------------|-------|-------|
|              | TURB       | PH    | DO          | AMO   |       |
| N OF CASES   | 10         | 4     | 7           | 8     | 6     |
| MINIMUM      | 18.040     | 7.930 | 5.700       | 0.000 | 0.000 |
| MAXIMUM      | 28.980     | 8.490 | 9.800       | 4.760 | 0.160 |
| MEAN         | 23.771     | 8.162 | 6.994       | 1.741 | 0.048 |
| STANDARD DEV | 3.703      | 0.245 | 1.384       | 1.553 | 0.061 |

|              | STA\$ = 11 |       | DEPTH\$ = 5 |     |   |
|--------------|------------|-------|-------------|-----|---|
|              | TURB       | PH    | DO          | AMO |   |
| N OF CASES   | 2          | 1     | 2           | 0   | 0 |
| MINIMUM      | 22.140     | 7.700 | 2.800       | .   | . |
| MAXIMUM      | 26.370     | 7.700 | 5.500       | .   | . |
| MEAN         | 24.255     | 7.700 | 4.150       | .   | . |
| STANDARD DEV | 2.991      | 0.000 | 1.909       | .   | . |

|              |        | STA\$ = 15 |       | DEPTH\$ = 1 |        |       |       |       |  |
|--------------|--------|------------|-------|-------------|--------|-------|-------|-------|--|
|              |        | TURB       | PH    | DO          | AMO    | NITRI | NITRA | PHOS  |  |
| N OF CASES   | 35     | 33         | 36    | 37          | 21     | 20    | 20    | 20    |  |
|              | 19.500 | 0.320      | 7.990 | 4.500       | 0.000  | 0.000 | 0.000 | 0.000 |  |
|              | 40.000 | 3.050      | 8.750 | 8.780       | 2.020  | 0.150 | 5.860 | 0.090 |  |
|              | 33.164 | 0.786      | 8.362 | 6.338       | 0.881  | 0.073 | 1.170 | 0.034 |  |
|              | 4.369  | 0.474      | 0.145 | 1.019       | 0.572  | 0.055 | 1.598 | 0.029 |  |
| STANDARD DEV |        |            |       |             |        |       |       |       |  |
|              |        | STA\$ = 15 |       | DEPTH\$ = 2 |        |       |       |       |  |
|              |        | TURB       | PH    | DO          | AMO    | NITRI | NITRA | PHOS  |  |
| N OF CASES   | 1      | 1          | 1     | 1           | 1      | 1     | 1     | 1     |  |
|              | 32.000 | 0.610      | 8.250 | 6.400       | 3.710  | 0.090 | 1.000 | 0.290 |  |
|              | 32.000 | 0.610      | 8.250 | 6.400       | 3.710  | 0.090 | 1.000 | 0.290 |  |
|              | 32.000 | 0.610      | 8.250 | 6.400       | 3.710  | 0.090 | 1.000 | 0.290 |  |
|              | 0.000  | 0.000      | 0.000 | 0.000       | 0.000  | 0.000 | 0.000 | 0.000 |  |
| STANDARD DEV |        |            |       |             |        |       |       |       |  |
|              |        | STA\$ = 15 |       | DEPTH\$ = 3 |        |       |       |       |  |
|              |        | TURB       | PH    | DO          | AMO    | NITRI | NITRA | PHOS  |  |
| N OF CASES   | 62     | 59         | 28    | 12          | 6      | 6     | 6     | 6     |  |
|              | 20.560 | 0.260      | 7.000 | 4.770       | 0.400  | 0.040 | 0.720 | 0.010 |  |
|              | 40.000 | 2.350      | 8.610 | 8.620       | 18.270 | 0.240 | 5.210 | 0.360 |  |
|              | 34.196 | 0.935      | 8.015 | 6.308       | 5.077  | 0.137 | 2.985 | 0.148 |  |
|              | 3.270  | 0.501      | 0.398 | 1.091       | 6.851  | 0.070 | 1.691 | 0.128 |  |
| STANDARD DEV |        |            |       |             |        |       |       |       |  |
|              |        | STA\$ = 15 |       | DEPTH\$ = 4 |        |       |       |       |  |
|              |        | TURB       | PH    | DO          | AMO    | NITRI | NITRA | PHOS  |  |
| N OF CASES   | 38     | 14         | 33    | 39          | 8      | 9     | 9     | 5     |  |
|              | 20.350 | 0.350      | 7.880 | 4.610       | 0.000  | 0.000 | 0.000 | 0.000 |  |
|              | 39.620 | 2.200      | 8.740 | 8.700       | 2.900  | 0.320 | 1.770 | 0.520 |  |
|              | 33.446 | 0.961      | 8.325 | 6.344       | 0.697  | 0.067 | 0.516 | 0.166 |  |
|              | 4.271  | 0.595      | 0.181 | 0.946       | 1.075  | 0.102 | 0.554 | 0.217 |  |
| STANDARD DEV |        |            |       |             |        |       |       |       |  |
|              |        | STA\$ = 15 |       | DEPTH\$ = 5 |        |       |       |       |  |
|              |        | TURB       | PH    | DO          | AMO    | NITRI | NITRA | PHOS  |  |
| N OF CASES   | 12     | 10         | 9     | 11          | 9      | 9     | 9     | 7     |  |
|              | 29.370 | 0.320      | 7.990 | 5.040       | 0.000  | 0.000 | 0.000 | 0.000 |  |
|              | 39.620 | 1.100      | 8.360 | 8.660       | 1.830  | 0.380 | 3.620 | 0.040 |  |
|              | 34.408 | 0.623      | 8.106 | 6.916       | 0.656  | 0.100 | 0.600 | 0.010 |  |
|              | 3.359  | 0.260      | 0.140 | 1.129       | 0.706  | 0.115 | 1.153 | 0.015 |  |
| STANDARD DEV |        |            |       |             |        |       |       |       |  |

|              |        | STA\$ = 18 |        | DEPTH\$ = 1 |       |       |       |       |       |
|--------------|--------|------------|--------|-------------|-------|-------|-------|-------|-------|
|              |        | TURB       | COND   | PH          | DQ    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES   | 35     | 34         | 43     | 41          | 42    | 21    | 21    | 21    | 20    |
|              | 29.520 | 0.000      | 46.100 | 8.010       | 5.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|              | 38.950 | 3.700      | 59.600 | 8.770       | 8.760 | 1.490 | 0.120 | 0.920 | 0.070 |
|              | 35.969 | 1.338      | 54.302 | 8.407       | 6.485 | 0.603 | 0.030 | 0.257 | 0.025 |
|              | 1.801  | 0.750      | 2.548  | 0.160       | 0.898 | 0.459 | 0.036 | 0.247 | 0.025 |
| STANDARD DEV |        |            |        |             |       |       |       |       |       |
|              |        | STA\$ = 18 |        | DEPTH\$ = 2 |       |       |       |       |       |
|              |        | TURB       | COND   | PH          | DQ    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES   | 3      | 1          | 3      | 3           | 3     | 1     | 1     | 1     | 1     |
|              | 20.490 | 0.640      | 33.900 | 8.390       | 5.310 | 1.380 | 0.000 | 0.000 | 0.000 |
|              | 36.410 | 0.640      | 54.800 | 8.400       | 6.040 | 1.380 | 0.000 | 0.000 | 0.000 |
|              | 30.780 | 0.640      | 47.433 | 8.397       | 5.700 | 1.380 | 0.000 | 0.000 | 0.000 |
|              | 8.925  | 0.000      | 11.736 | 0.006       | 0.368 | 0.000 | 0.000 | 0.000 | 0.000 |
| STANDARD DEV |        |            |        |             |       |       |       |       |       |
|              |        | STA\$ = 18 |        | DEPTH\$ = 3 |       |       |       |       |       |
|              |        | TURB       | COND   | PH          | DQ    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES   | 12     | 2          | 13     | 11          | 13    | 1     | 1     | 1     | 0     |
|              | 29.440 | 1.440      | 46.000 | 8.010       | 4.800 | 0.630 | 0.020 | 0.110 | .     |
|              | 38.000 | 2.200      | 59.600 | 8.780       | 8.250 | 0.630 | 0.020 | 0.110 | .     |
|              | 35.819 | 1.820      | 53.697 | 8.439       | 6.317 | 0.630 | 0.020 | 0.110 | .     |
|              | 2.453  | 0.537      | 3.710  | 0.215       | 1.002 | 0.000 | 0.000 | 0.000 | .     |
| STANDARD DEV |        |            |        |             |       |       |       |       |       |
|              |        | STA\$ = 18 |        | DEPTH\$ = 4 |       |       |       |       |       |
|              |        | TURB       | COND   | PH          | DQ    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES   | 61     | 43         | 56     | 42          | 30    | 16    | 17    | 17    | 13    |
|              | 20.350 | 0.230      | 33.700 | 7.000       | 4.790 | 0.000 | 0.000 | 0.000 | 0.000 |
|              | 38.370 | 6.000      | 60.200 | 8.710       | 8.000 | 2.100 | 0.060 | 1.350 | 0.310 |
|              | 35.072 | 1.258      | 52.457 | 8.131       | 6.421 | 0.771 | 0.031 | 0.418 | 0.075 |
|              | 2.398  | 0.960      | 5.189  | 0.394       | 0.985 | 0.669 | 0.020 | 0.403 | 0.104 |
| STANDARD DEV |        |            |        |             |       |       |       |       |       |
|              |        | STA\$ = 18 |        | DEPTH\$ = 5 |       |       |       |       |       |
|              |        | TURB       | COND   | PH          | DQ    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES   | 8      | 8          | 15     | 15          | 16    | 7     | 7     | 7     | 6     |
|              | 31.780 | 0.630      | 46.850 | 7.880       | 5.700 | 0.000 | 0.000 | 0.000 | 0.000 |
|              | 39.620 | 3.900      | 59.330 | 8.600       | 8.410 | 1.750 | 0.170 | 0.670 | 3.540 |
|              | 35.810 | 1.680      | 55.159 | 8.275       | 6.969 | 0.670 | 0.059 | 0.161 | 0.598 |
|              | 2.320  | 1.070      | 3.194  | 0.194       | 0.641 | 0.727 | 0.056 | 0.243 | 1.441 |
| STANDARD DEV |        |            |        |             |       |       |       |       |       |

STA# = 19 DEPTH# = 1

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 38     | 45     | 34    | 43    | 44    | 21    | 20    | 20    | 20    |
| MINIMUM      | 31.070 | 48.100 | 0.350 | 7.960 | 0.190 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 38.290 | 57.800 | 2.100 | 8.700 | 9.110 | 4.290 | 0.170 | 0.380 | 0.090 |
| MEAN         | 35.888 | 54.277 | 0.817 | 8.371 | 6.354 | 0.653 | 0.032 | 0.118 | 0.022 |
| STANDARD DEV | 1.367  | 2.057  | 0.385 | 0.146 | 1.475 | 0.933 | 0.046 | 0.128 | 0.027 |

STA# = 19 DEPTH# = 2

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 3      | 4      | 2     | 4     | 4     | 2     | 2     | 2     | 2     |
| MINIMUM      | 19.570 | 32.600 | 0.480 | 8.210 | 4.510 | 0.550 | 0.050 | 0.210 | 0.000 |
| MAXIMUM      | 42.000 | 54.400 | 0.580 | 8.370 | 8.710 | 0.890 | 0.170 | 0.450 | 0.120 |
| MEAN         | 32.550 | 48.575 | 0.530 | 8.300 | 6.708 | 0.720 | 0.110 | 0.330 | 0.060 |
| STANDARD DEV | 11.624 | 10.685 | 0.071 | 0.067 | 1.945 | 0.240 | 0.085 | 0.170 | 0.085 |

STA# = 19 DEPTH# = 3

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 16     | 12     | 7     | 11    | 13    | 4     | 4     | 4     | 4     |
| MINIMUM      | 32.960 | 50.500 | 0.320 | 8.000 | 5.350 | 0.010 | 0.040 | 0.000 | 0.010 |
| MAXIMUM      | 42.000 | 58.440 | 1.350 | 9.290 | 8.160 | 0.920 | 0.770 | 0.930 | 0.350 |
| MEAN         | 36.235 | 54.845 | 0.700 | 8.485 | 6.253 | 0.370 | 0.233 | 0.520 | 0.123 |
| STANDARD DEV | 1.855  | 2.269  | 0.361 | 0.361 | 0.886 | 0.432 | 0.359 | 0.442 | 0.145 |

STA# = 19 DEPTH# = 4

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 15     | 18     | 6     | 16    | 18    | 6     | 6     | 6     | 7     |
| MINIMUM      | 32.010 | 43.810 | 0.450 | 7.960 | 4.280 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 39.200 | 58.200 | 2.100 | 8.530 | 8.760 | 0.540 | 0.040 | 0.150 | 0.250 |
| MEAN         | 35.913 | 53.477 | 0.890 | 8.300 | 6.809 | 0.137 | 0.022 | 0.085 | 0.068 |
| STANDARD DEV | 1.785  | 3.583  | 0.618 | 0.155 | 1.148 | 0.203 | 0.016 | 0.067 | 0.122 |

STA# = 19 DEPTH# = 5

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 23     | 26     | 15    | 21    | 25    | 12    | 13    | 13    | 9     |
| MINIMUM      | 20.350 | 33.700 | 0.400 | 3.420 | 4.800 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 37.000 | 60.000 | 2.600 | 8.600 | 8.900 | 6.900 | 0.190 | 0.390 | 0.060 |
| MEAN         | 35.203 | 53.202 | 0.894 | 8.010 | 6.857 | 1.293 | 0.057 | 0.131 | 0.011 |
| STANDARD DEV | 3.370  | 5.279  | 0.539 | 1.065 | 1.133 | 2.021 | 0.050 | 0.138 | 0.021 |



STA\$ = 35 DEPTH\$ = 1

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 35     | 40     | 32    | 39    | 39    | 21    | 21    | 21    | 20    |
| MINIMUM      | 4.070  | 1.900  | 0.370 | 0.370 | 0.190 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 39.000 | 58.900 | 2.000 | 8.710 | 8.480 | 1.860 | 0.440 | 5.260 | 0.160 |
| MEAN         | 32.947 | 50.296 | 0.832 | 8.137 | 6.133 | 0.860 | 0.081 | 1.637 | 0.023 |
| STANDARD DEV | 6.329  | 9.302  | 0.422 | 1.285 | 1.335 | 0.568 | 0.103 | 1.434 | 0.038 |

STA\$ = 35 DEPTH\$ = 2

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 1      | 1      | 1     | 1     | 1     | 1     | 1     | 1     | 1     |
| MINIMUM      | 33.000 | 51.700 | 0.500 | 8.280 | 6.730 | 3.490 | 0.180 | 1.600 | 0.130 |
| MAXIMUM      | 33.000 | 51.700 | 0.500 | 8.280 | 6.730 | 3.490 | 0.180 | 1.600 | 0.130 |
| MEAN         | 33.000 | 51.700 | 0.500 | 8.280 | 6.730 | 3.490 | 0.180 | 1.600 | 0.130 |
| STANDARD DEV | 0.000  | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

STA\$ = 35 DEPTH\$ = 3

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 27     | 24     | 27    | 18    | 5     | 4     | 4     | 4     | 4     |
| MINIMUM      | 19.850 | 33.000 | 0.220 | 7.120 | 4.900 | 1.080 | 0.090 | 0.380 | 0.000 |
| MAXIMUM      | 39.000 | 59.300 | 1.450 | 8.590 | 8.930 | 6.200 | 0.200 | 2.830 | 0.400 |
| MEAN         | 33.508 | 49.710 | 0.669 | 8.034 | 6.428 | 2.523 | 0.130 | 1.413 | 0.125 |
| STANDARD DEV | 3.603  | 6.681  | 0.275 | 0.320 | 1.841 | 2.460 | 0.050 | 1.043 | 0.188 |

STA\$ = 35 DEPTH\$ = 4

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 29     | 33     | 4     | 34    | 35    | 4     | 4     | 4     | 3     |
| MINIMUM      | 30.530 | 41.920 | 1.060 | 8.020 | 4.840 | 0.170 | 0.000 | 0.340 | 0.020 |
| MAXIMUM      | 38.950 | 57.900 | 3.200 | 8.710 | 7.600 | 1.670 | 0.260 | 3.970 | 0.200 |
| MEAN         | 34.692 | 52.682 | 2.180 | 8.339 | 6.215 | 1.205 | 0.155 | 2.083 | 0.090 |
| STANDARD DEV | 2.525  | 3.663  | 0.992 | 0.128 | 0.718 | 0.698 | 0.120 | 1.588 | 0.096 |

STA\$ = 35 DEPTH\$ = 5

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 18     | 21     | 18    | 17    | 22    | 15    | 16    | 16    | 11    |
| MINIMUM      | 20.920 | 34.500 | 0.330 | 7.980 | 0.550 | 0.000 | 0.000 | 0.210 | 0.000 |
| MAXIMUM      | 39.040 | 58.770 | 1.200 | 8.930 | 8.930 | 2.900 | 0.230 | 3.670 | 0.290 |
| MEAN         | 32.959 | 48.154 | 0.734 | 8.177 | 6.395 | 0.861 | 0.077 | 0.806 | 0.035 |
| STANDARD DEV | 5.077  | 7.223  | 0.301 | 0.161 | 1.755 | 1.039 | 0.065 | 0.835 | 0.086 |

|              | STA\$ = 39 |        |       | DEPTH\$ = 1 |       |       |       |       |       |
|--------------|------------|--------|-------|-------------|-------|-------|-------|-------|-------|
|              | SALT       | COND   | TURB  | PH          | DO    | AMG   | NITRI | NITRA | PHOS  |
| N OF CASES   | 35         | 38     | 34    | 37          | 37    | 22    | 22    | 21    | 21    |
| MINIMUM      | 33.200     | 48.000 | 0.370 | 7.910       | 5.010 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 39.700     | 58.800 | 1.990 | 8.790       | 8.770 | 1.830 | 0.420 | 1.600 | 0.090 |
| MEAN         | 36.413     | 54.412 | 0.764 | 8.394       | 6.264 | 0.754 | 0.070 | 0.344 | 0.020 |
| STANDARD DEV | 1.515      | 2.379  | 0.322 | 0.161       | 0.843 | 0.626 | 0.113 | 0.399 | 0.026 |

|              | STA\$ = 39 |        |       | DEPTH\$ = 2 |       |       |       |       |       |
|--------------|------------|--------|-------|-------------|-------|-------|-------|-------|-------|
|              | SALT       | COND   | TURB  | PH          | DO    | AMG   | NITRI | NITRA | PHOS  |
| N OF CASES   | 3          | 3      | 3     | 3           | 3     | 2     | 2     | 2     | 2     |
| MINIMUM      | 37.000     | 57.800 | 0.480 | 0.610       | 7.050 | 0.020 | 0.020 | 0.270 | 0.110 |
| MAXIMUM      | 38.000     | 60.200 | 0.530 | 8.760       | 8.040 | 0.510 | 0.050 | 0.610 | 0.350 |
| MEAN         | 37.667     | 58.833 | 0.503 | 5.897       | 7.443 | 0.265 | 0.035 | 0.440 | 0.230 |
| STANDARD DEV | 0.577      | 1.234  | 0.025 | 4.584       | 0.525 | 0.346 | 0.021 | 0.240 | 0.170 |

|              | STA\$ = 39 |        |       | DEPTH\$ = 3 |       |       |       |       |       |
|--------------|------------|--------|-------|-------------|-------|-------|-------|-------|-------|
|              | SALT       | COND   | TURB  | PH          | DO    | AMG   | NITRI | NITRA | PHOS  |
| N OF CASES   | 14         | 14     | 12    | 11          | 5     | 2     | 2     | 2     |       |
| MINIMUM      | 20.850     | 34.400 | 0.350 | 6.750       | 5.200 | 1.140 | 0.040 | 0.480 | 0.020 |
| MAXIMUM      | 37.330     | 58.540 | 1.250 | 8.400       | 8.130 | 1.850 | 0.340 | 0.580 | 0.120 |
| MEAN         | 33.581     | 50.555 | 0.709 | 7.977       | 6.226 | 1.495 | 0.190 | 0.530 | 0.070 |
| STANDARD DEV | 3.875      | 7.228  | 0.285 | 0.461       | 1.201 | 0.502 | 0.212 | 0.071 |       |

|              | STA\$ = 39 |        |       | DEPTH\$ = 4 |       |       |       |       |       |
|--------------|------------|--------|-------|-------------|-------|-------|-------|-------|-------|
|              | SALT       | COND   | TURB  | PH          | DO    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES   | 24         | 24     | 4     | 24          | 25    | 4     | 4     | 4     | 3     |
| MINIMUM      | 33.200     | 44.440 | 0.640 | 7.910       | 5.070 | 0.440 | 0.000 | 0.280 | 0.000 |
| MAXIMUM      | 38.290     | 57.100 | 3.700 | 8.710       | 7.860 | 2.200 | 0.190 | 1.400 | 0.170 |
| MEAN         | 36.346     | 54.339 | 2.005 | 8.372       | 6.063 | 1.397 | 0.065 | 0.592 | 0.080 |
| STANDARD DEV | 1.309      | 2.636  | 1.487 | 0.168       | 0.738 | 0.818 | 0.086 | 0.539 | 0.085 |

|              | STA\$ = 39 |        |       | DEPTH\$ = 5 |       |        |       |       |       |
|--------------|------------|--------|-------|-------------|-------|--------|-------|-------|-------|
|              | SALT       | COND   | TURB  | PH          | DO    | AMG    | NITRI | NITRA | PHOS  |
| N OF CASES   | 26         | 29     | 18    | 23          | 28    | 16     | 17    | 16    | 12    |
| MINIMUM      | 21.060     | 34.700 | 0.440 | 8.050       | 4.810 | 0.000  | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 40.370     | 59.750 | 2.600 | 8.800       | 8.760 | 27.300 | 0.190 | 1.410 | 0.050 |
| MEAN         | 35.860     | 53.202 | 0.818 | 8.310       | 6.700 | 2.234  | 0.045 | 0.289 | 0.013 |
| STANDARD DEV | 3.434      | 5.240  | 0.531 | 0.207       | 0.944 | 6.719  | 0.048 | 0.353 | 0.019 |

STA\$ = 78 DEPTH\$ = 1

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 35     | 38     | 33    | 37    | 37    | 22    | 22    | 22    | 21    |
| MINIMUM      | 26.780 | 42.500 | 0.560 | 7.970 | 4.790 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 39.040 | 58.000 | 2.500 | 8.710 | 8.720 | 1.860 | 0.150 | 1.650 | 0.070 |
| MEAN         | 35.576 | 53.494 | 1.005 | 8.372 | 6.337 | 0.857 | 0.033 | 0.417 | 0.020 |
| STANDARD DEV | 2.585  | 3.487  | 0.513 | 0.161 | 0.887 | 0.588 | 0.044 | 0.376 | 0.026 |

STA\$ = 78 DEPTH\$ = 2

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 1      | 1      | 1     | 1     | 1     | 1     | 1     | 1     | 1     |
| MINIMUM      | 34.000 | 53.900 | 0.850 | 8.320 | 7.070 | 2.230 | 0.050 | 1.140 | 0.070 |
| MAXIMUM      | 34.000 | 53.900 | 0.850 | 8.320 | 7.070 | 2.230 | 0.050 | 1.140 | 0.070 |
| MEAN         | 34.000 | 53.900 | 0.850 | 8.320 | 7.070 | 2.230 | 0.050 | 1.140 | 0.070 |
| STANDARD DEV | 0.000  | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

STA\$ = 78 DEPTH\$ = 3

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 3      | 4      | 3     | 3     | 3     | 3     | 3     | 3     | 3     |
| MINIMUM      | 34.000 | 51.600 | 0.610 | 0.080 | 6.700 | 0.000 | 0.020 | 0.330 | 0.000 |
| MAXIMUM      | 40.540 | 59.800 | 0.930 | 8.370 | 8.160 | 1.610 | 0.060 | 1.890 | 0.160 |
| MEAN         | 37.513 | 55.500 | 0.810 | 5.583 | 7.263 | 0.650 | 0.043 | 1.110 | 0.057 |
| STANDARD DEV | 3.297  | 4.303  | 0.174 | 4.766 | 0.785 | 0.849 | 0.021 | 0.780 | 0.090 |

STA\$ = 78 DEPTH\$ = 4

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 44     | 44     | 37    | 32    | 18    | 5     | 5     | 5     | 3     |
| MINIMUM      | 19.780 | 32.900 | 0.200 | 7.000 | 4.940 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 38.400 | 58.750 | 3.800 | 8.550 | 8.000 | 2.060 | 0.060 | 0.850 | 0.020 |
| MEAN         | 34.881 | 51.821 | 1.016 | 8.070 | 6.344 | 0.964 | 0.028 | 0.414 | 0.010 |
| STANDARD DEV | 2.747  | 5.312  | 0.840 | 0.365 | 0.935 | 0.790 | 0.028 | 0.326 | 0.010 |

STA\$ = 78 DEPTH\$ = 5

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 34     | 37     | 13    | 34    | 38    | 12    | 13    | 14    | 10    |
| MINIMUM      | 20.920 | 34.500 | 0.590 | 7.970 | 4.660 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 39.120 | 59.800 | 2.300 | 8.740 | 8.740 | 2.310 | 0.140 | 1.590 | 0.360 |
| MEAN         | 35.270 | 52.931 | 0.949 | 8.318 | 6.449 | 0.967 | 0.058 | 0.482 | 0.051 |
| STANDARD DEV | 3.604  | 5.231  | 0.471 | 0.180 | 0.904 | 0.835 | 0.041 | 0.440 | 0.111 |

STA\$ = 92 DEPTH\$ = 1

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 85     | 85     | 81    | 56    | 40    | 22    | 22    | 22    | 21    |
| MINIMUM      | 18.450 | 31.000 | 0.250 | 6.880 | 2.790 | 0.000 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 39.600 | 58.600 | 4.600 | 8.890 | 8.720 | 2.970 | 0.320 | 9.470 | 0.090 |
| MEAN         | 33.067 | 49.193 | 0.631 | 8.190 | 5.700 | 1.001 | 0.063 | 1.414 | 0.021 |
| STANDARD DEV | 4.147  | 6.553  | 0.527 | 0.362 | 1.360 | 0.752 | 0.081 | 2.180 | 0.026 |

STA\$ = 92 DEPTH\$ = 2

|              | SALT   | COND   | TURB | PH    | DO    | AMO | NITRI | NITRA | PHOS |
|--------------|--------|--------|------|-------|-------|-----|-------|-------|------|
| N OF CASES   | 14     | 15     | 0    | 16    | 16    | 0   | 0     | 0     | 0    |
| MINIMUM      | 26.630 | 42.300 | .    | 7.910 | 3.620 | .   | .     | .     | .    |
| MAXIMUM      | 39.450 | 58.500 | .    | 8.920 | 8.580 | .   | .     | .     | .    |
| MEAN         | 35.466 | 52.913 | .    | 8.356 | 5.853 | .   | .     | .     | .    |
| STANDARD DEV | 3.362  | 4.840  | .    | 0.221 | 1.286 | .   | .     | .     | .    |

STA\$ = 92 DEPTH\$ = 3

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 16     | 17     | 4     | 14    | 15    | 3     | 3     | 3     | 2     |
| MINIMUM      | 18.390 | 30.900 | 0.280 | 8.010 | 1.400 | 0.000 | 0.020 | 0.280 | 0.000 |
| MAXIMUM      | 38.870 | 57.800 | 1.400 | 8.570 | 8.330 | 0.900 | 0.090 | 1.900 | 0.020 |
| MEAN         | 30.086 | 45.314 | 0.642 | 8.326 | 5.526 | 0.300 | 0.053 | 0.873 | 0.010 |
| STANDARD DEV | 6.398  | 9.035  | 0.511 | 0.179 | 1.951 | 0.520 | 0.035 | 0.893 | 0.014 |

STA\$ = 92 DEPTH\$ = 4

|              | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
|--------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
| N OF CASES   | 11     | 11     | 16    | 10    | 14    | 14    | 15    | 15    | 10    |
| MINIMUM      | 20.900 | 41.440 | 0.310 | 8.000 | 4.400 | 0.000 | 0.000 | 0.030 | 0.000 |
| MAXIMUM      | 38.710 | 57.600 | 1.400 | 8.200 | 9.000 | 6.450 | 0.180 | 1.660 | 1.690 |
| MEAN         | 31.835 | 47.164 | 0.614 | 8.098 | 6.606 | 1.134 | 0.059 | 0.623 | 0.204 |
| STANDARD DEV | 4.771  | 5.635  | 0.270 | 0.076 | 1.352 | 1.819 | 0.053 | 0.477 | 0.529 |

STA\$ = 92 DEPTH\$ = 5

|              | SALT   | COND   | TURB | PH | DO    | AMO | NITRI | NITRA | PHOS |
|--------------|--------|--------|------|----|-------|-----|-------|-------|------|
| N OF CASES   | 1      | 1      | 0    | 0  | 1     | 0   | 0     | 0     | 0    |
| MINIMUM      | 35.040 | 53.360 | .    | .  | 7.100 | .   | .     | .     | .    |
| MAXIMUM      | 35.040 | 53.360 | .    | .  | 7.100 | .   | .     | .     | .    |
| MEAN         | 35.040 | 53.360 | .    | .  | 7.100 | .   | .     | .     | .    |
| STANDARD DEV | 0.000  | 0.000  | .    | .  | 0.000 | .   | .     | .     | .    |

| STA# = 96 DEPTH# = 1 |        |        |       |       |       |       |       |       |       |
|----------------------|--------|--------|-------|-------|-------|-------|-------|-------|-------|
|                      | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES           | 37     | 39     | 36    | 37    | 37    | 22    | 21    | 21    | 21    |
| MINIMUM              | 23.300 | 30.100 | 0.330 | 7.910 | 4.590 | 0.000 | 0.000 | 0.190 | 0.000 |
| MAXIMUM              | 58.000 | 58.100 | 1.600 | 8.660 | 8.660 | 7.190 | 0.150 | 2.380 | 0.120 |
| MEAN                 | 35.090 | 51.383 | 0.746 | 8.321 | 6.115 | 1.030 | 0.057 | 0.801 | 0.032 |
| STANDARD DEV         | 5.015  | 5.615  | 0.328 | 0.148 | 1.040 | 1.455 | 0.051 | 0.534 | 0.032 |
| STA# = 96 DEPTH# = 2 |        |        |       |       |       |       |       |       |       |
|                      | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES           | 9      | 9      | 6     | 9     | 9     | 6     | 6     | 6     | 6     |
| MINIMUM              | 19.570 | 32.600 | 0.430 | 8.190 | 4.350 | 0.280 | 0.020 | 0.480 | 0.000 |
| MAXIMUM              | 38.050 | 56.800 | 0.710 | 8.470 | 7.800 | 3.130 | 0.100 | 1.670 | 0.210 |
| MEAN                 | 32.408 | 49.978 | 0.583 | 8.282 | 5.852 | 1.602 | 0.057 | 0.995 | 0.082 |
| STANDARD DEV         | 5.501  | 7.398  | 0.101 | 0.086 | 1.185 | 1.277 | 0.029 | 0.459 | 0.097 |
| STA# = 96 DEPTH# = 3 |        |        |       |       |       |       |       |       |       |
|                      | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES           | 61     | 60     | 44    | 35    | 19    | 0     | 0     | 0     | 0     |
| MINIMUM              | 30.930 | 37.400 | 0.260 | 7.100 | 4.330 | .     | .     | .     | .     |
| MAXIMUM              | 58.500 | 58.940 | 1.500 | 8.650 | 8.890 | .     | .     | .     | .     |
| MEAN                 | 35.066 | 51.244 | 0.717 | 8.104 | 5.695 | .     | .     | .     | .     |
| STANDARD DEV         | 3.598  | 5.066  | 0.325 | 0.351 | 0.997 | .     | .     | .     | .     |
| STA# = 96 DEPTH# = 4 |        |        |       |       |       |       |       |       |       |
|                      | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES           | 25     | 27     | 16    | 24    | 28    | 14    | 15    | 15    | 11    |
| MINIMUM              | 20.560 | 34.000 | 0.430 | 8.000 | 3.980 | 0.000 | 0.010 | 0.180 | 0.000 |
| MAXIMUM              | 38.790 | 59.950 | 5.400 | 8.640 | 9.000 | 9.140 | 0.140 | 1.120 | 0.370 |
| MEAN                 | 33.297 | 49.295 | 1.203 | 8.239 | 6.602 | 1.427 | 0.057 | 0.609 | 0.044 |
| STANDARD DEV         | 4.349  | 6.804  | 1.288 | 0.159 | 1.113 | 2.477 | 0.036 | 0.275 | 0.109 |
| STA# = 96 DEPTH# = 5 |        |        |       |       |       |       |       |       |       |
|                      | SALT   | COND   | TURB  | PH    | DO    | AMO   | NITRI | NITRA | PHOS  |
| N OF CASES           | 3      | 4      | 3     | 3     | 5     | 3     | 3     | 3     | 1     |
| MINIMUM              | 34.290 | 45.900 | 0.570 | 7.990 | 4.800 | 0.710 | 0.000 | 0.350 | 0.000 |
| MAXIMUM              | 36.200 | 58.250 | 1.100 | 8.190 | 8.260 | 1.600 | 0.130 | 1.850 | 0.000 |
| MEAN                 | 35.303 | 52.878 | 0.803 | 8.110 | 6.552 | 1.153 | 0.083 | 0.883 | 0.000 |
| STANDARD DEV         | 0.960  | 5.351  | 0.271 | 0.106 | 1.272 | 0.445 | 0.072 | 0.839 | 0.000 |

## APPENDIX 2.

SAMPLE STATISTICS BY YEAR, SEASON AND REGION

## APPENDIX 3. Sample Statistics by Year, Season and Region

YEAR = 79 SEASON = 1 REGION = 1

TOTAL OBSERVATIONS: 9

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 9      | 9      | 9      | 9     | 9     | 9     |
| MINIMUM      | 19.410 | 27.150 | 18.400 | 0.740 | 7.600 | 3.100 |
| MAXIMUM      | 35.500 | 49.620 | 23.300 | 3.200 | 8.300 | 9.600 |
| MEAN         | 27.733 | 37.941 | 20.199 | 1.556 | 8.018 | 5.711 |
| STANDARD DEV | 5.563  | 7.661  | 1.554  | 0.848 | 0.249 | 2.180 |

YEAR = 79 SEASON = 1 REGION = 2

TOTAL OBSERVATION: 66

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 66     | 66     | 66     | 66    | 66    | 66    |
| MINIMUM      | 29.840 | 34.350 | 16.200 | 0.320 | 8.000 | 6.400 |
| MAXIMUM      | 39.890 | 52.850 | 22.150 | 3.900 | 8.210 | 8.900 |
| MEAN         | 35.292 | 47.205 | 19.170 | 0.955 | 8.112 | 7.352 |
| STANDARD DEV | 1.879  | 3.738  | 1.722  | 0.502 | 0.054 | 0.545 |

YEAR = 79 SEASON = 1 REGION = 3

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 18     | 17     | 18     | 18    | 18    | 18    |
| MINIMUM      | 22.810 | 31.050 | 17.200 | 0.440 | 7.320 | 1.200 |
| MAXIMUM      | 36.680 | 51.870 | 24.120 | 3.500 | 8.500 | 9.800 |
| MEAN         | 30.603 | 42.285 | 19.941 | 1.051 | 8.072 | 6.628 |
| STANDARD DEV | 3.917  | 6.099  | 1.984  | 0.723 | 0.392 | 2.927 |

YEAR = 79 SEASON = 2 REGION = 1

TOTAL OBSERVATIONS: 9

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 6      | 6      | 9      | 9     | 3     | 3     |
| MINIMUM      | 0.920  | 2.100  | 26.400 | 0.540 | 8.200 | 2.780 |
| MAXIMUM      | 33.910 | 51.700 | 28.900 | 2.100 | 8.200 | 6.160 |
| MEAN         | 19.910 | 32.033 | 27.771 | 1.157 | 8.200 | 3.997 |
| STANDARD DEV | 11.741 | 17.719 | 0.704  | 0.526 | 0.000 | 1.878 |

YEAR = 79      SEASON = 2      REGION = 2

TOTAL OBSERVATIONS: 66

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 58     | 58     | 66     | 66    | 31    | 12    |
| MINIMUM      | 36.840 | 56.700 | 0.960  | 0.330 | 8.000 | 4.160 |
| MAXIMUM      | 40.700 | 60.180 | 29.100 | 1.400 | 8.500 | 5.130 |
| MEAN         | 38.963 | 58.420 | 27.189 | 0.598 | 8.168 | 4.849 |
| STANDARD DEV | 0.856  | 0.940  | 3.401  | 0.181 | 0.133 | 0.314 |

YEAR = 79      SEASON = 3      REGION = 2

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 13     | 13     | 18     | 18    | 9     | 9     |
| MINIMUM      | 21.420 | 35.200 | 25.590 | 0.390 | 7.800 | 0.320 |
| MAXIMUM      | 39.780 | 58.900 | 29.800 | 3.700 | 8.500 | 6.160 |
| MEAN         | 33.418 | 50.992 | 27.636 | 1.141 | 8.089 | 4.136 |
| STANDARD DEV | 5.885  | 7.616  | 0.919  | 0.985 | 0.257 | 2.206 |

YEAR = 79      SEASON = 3      REGION = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 15     | 15     | 18     | 9     | 9     | 17    |
| MINIMUM      | 0.970  | 2.200  | 28.000 | 0.640 | 7.600 | 0.270 |
| MAXIMUM      | 27.840 | 43.900 | 32.600 | 1.600 | 8.620 | 5.520 |
| MEAN         | 12.129 | 20.900 | 30.100 | 1.001 | 8.069 | 3.331 |
| STANDARD DEV | 7.708  | 12.157 | 1.478  | 0.344 | 0.313 | 1.534 |

YEAR = 79      SEASON = 3      REGION = 2

TOTAL OBSERVATIONS: 88

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 66     | 66     | 88     | 66    | 66    | 88    |
| MINIMUM      | 19.430 | 32.400 | 28.000 | 0.230 | 8.200 | 3.090 |
| MAXIMUM      | 39.700 | 58.800 | 32.500 | 1.900 | 8.630 | 7.760 |
| MEAN         | 26.410 | 41.608 | 29.841 | 0.622 | 8.443 | 5.743 |
| STANDARD DEV | 8.529  | 11.117 | 1.468  | 0.296 | 0.115 | 0.999 |

YEAR = 79                      SEASON = 3                      REGION = 3

TOTAL OBSERVATIONS: 26

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 19     | 19     | 26     | 18    | 18    | 24    |
| MINIMUM      | 15.040 | 26.000 | 27.700 | 0.250 | 7.700 | 1.680 |
| MAXIMUM      | 36.000 | 54.300 | 32.600 | 2.700 | 8.860 | 8.960 |
| MEAN         | 21.985 | 35.795 | 29.923 | 0.856 | 8.299 | 5.073 |
| STANDARD DEV | 6.075  | 8.139  | 1.585  | 0.695 | 0.405 | 2.205 |

YEAR = 79                      SEASON = 4                      REGION = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 15     | 15     | 18     | 6     | 18    | 18    |
| MINIMUM      | 0.190  | 0.600  | 23.500 | 0.610 | 7.310 | 0.300 |
| MAXIMUM      | 23.520 | 38.100 | 27.500 | 1.400 | 8.340 | 5.500 |
| MEAN         | 8.601  | 15.147 | 25.317 | 0.822 | 7.664 | 3.409 |
| STANDARD DEV | 7.773  | 12.456 | 1.160  | 0.295 | 0.271 | 1.535 |

YEAR = 79                      SEASON = 4                      REGION = 2

TOTAL OBSERVATIONS: 133

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 111    | 111    | 133    | 44    | 133   | 133   |
| MINIMUM      | 19.430 | 32.400 | 22.800 | 0.000 | 8.180 | 5.300 |
| MAXIMUM      | 37.470 | 56.100 | 27.500 | 5.100 | 8.560 | 7.550 |
| MEAN         | 33.099 | 50.608 | 24.932 | 1.410 | 8.331 | 6.387 |
| STANDARD DEV | 4.500  | 5.836  | 1.645  | 1.123 | 0.079 | 0.461 |

YEAR = 79                      SEASON = 4                      REGION = 3

TOTAL OBSERVATIONS: 35

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 29     | 29     | 35     | 12    | 35    | 34    |
| MINIMUM      | 6.490  | 12.400 | 22.700 | 0.360 | 6.690 | 0.120 |
| MAXIMUM      | 30.140 | 46.900 | 27.600 | 3.250 | 8.700 | 9.480 |
| MEAN         | 21.013 | 34.390 | 25.197 | 1.028 | 8.008 | 5.425 |
| STANDARD DEV | 5.784  | 8.259  | 1.533  | 0.892 | 0.587 | 2.703 |

YEAR = 80                      SEASON    = 1                      REGION    = 1

TOTAL OBSERVATIONS:    18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 18     | 18     | 18     | 9     | 18    | 18    |
| MINIMUM      | 1.170  | 2.600  | 19.000 | 0.540 | 7.440 | 1.200 |
| MAXIMUM      | 29.060 | 45.500 | 27.300 | 2.000 | 8.590 | 6.880 |
| MEAN         | 17.260 | 29.067 | 22.722 | 1.124 | 7.987 | 4.659 |
| STANDARD DEV | 7.804  | 11.656 | 2.516  | 0.479 | 0.350 | 1.781 |

YEAR = 80                      SEASON    = 1                      REGION    = 2

TOTAL OBSERVATIONS:    132

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 132    | 132    | 132    | 65    | 132   | 132   |
| MINIMUM      | 29.520 | 46.100 | 17.500 | 0.380 | 0.380 | 5.580 |
| MAXIMUM      | 37.220 | 55.800 | 25.600 | 2.200 | 8.510 | 7.510 |
| MEAN         | 35.136 | 53.223 | 21.598 | 0.801 | 8.308 | 6.688 |
| STANDARD DEV | 1.665  | 2.085  | 2.935  | 0.307 | 0.698 | 0.459 |

YEAR = 80                      SEASON    = 1                      REGION    = 3

TOTAL OBSERVATIONS:    36

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 36     | 36     | 36     | 19    | 36    | 35    |
| MINIMUM      | 21.990 | 36.000 | 17.300 | 0.000 | 7.060 | 0.450 |
| MAXIMUM      | 33.040 | 50.600 | 25.900 | 1.500 | 8.950 | 9.920 |
| MEAN         | 27.519 | 43.447 | 22.028 | 0.668 | 8.186 | 5.875 |
| STANDARD DEV | 2.457  | 3.242  | 2.776  | 0.357 | 0.541 | 2.632 |

YEAR = 80                      SEASON    = 2                      REGION    = 1

TOTAL OBSERVATIONS:    18

|                 | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|-----------------|--------|--------|--------|-------|-------|-------|
| N OF CASES      | 18     | 18     | 18     | 9     | 18    | 18    |
| MINIMUM         | 0.920  | 2.100  | 25.700 | 0.470 | 7.300 | 0.230 |
| MAXIMUM         | 37.220 | 55.800 | 29.900 | 4.100 | 8.740 | 9.080 |
| MEAN            | 16.783 | 27.306 | 27.706 | 1.769 | 8.066 | 4.643 |
| STANDARD    DEV | 12.133 | 18.028 | 1.433  | 1.132 | 0.439 | 2.082 |

YEAR = 80                      SEASON    = 2                      REGION    = 2

TOTAL OBSERVATIONS: 132

|              | SALT   | CONE   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 132    | 132    | 132    | 65    | 132   | 132   |
| MINIMUM      | 27.380 | 43.300 | 25.900 | 0.260 | 8.180 | 3.780 |
| MAXIMUM      | 39.450 | 58.500 | 30.000 | 1.300 | 8.830 | 7.380 |
| MEAN         | 37.430 | 56.035 | 27.743 | 0.646 | 8.490 | 5.808 |
| STANDARD DEV | 1.891  | 2.354  | 1.327  | 0.191 | 0.178 | 0.605 |

YEAR = 80                      SEASON    = 2                      REGION    = 3

TOTAL OBSERVATIONS: 36

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 36     | 36     | 36     | 17    | 36    | 36    |
| MINIMUM      | 15.240 | 26.300 | 25.800 | 0.310 | 6.940 | 0.910 |
| MAXIMUM      | 39.040 | 58.000 | 30.800 | 8.800 | 8.810 | 6.810 |
| MEAN         | 31.512 | 48.400 | 28.033 | 1.462 | 8.197 | 4.724 |
| STANDARD DEV | 7.064  | 9.276  | 1.698  | 2.085 | 0.476 | 1.654 |

YEAR = 80                      SEASON    = 3                      REGION    = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 18     | 18     | 18     | 9     | 18    | 18    |
| MINIMUM      | 0.000  | 0.100  | 27.200 | 0.570 | 7.140 | 0.090 |
| MAXIMUM      | 35.110 | 53.200 | 31.600 | 1.800 | 8.380 | 6.510 |
| MEAN         | 12.761 | 21.150 | 28.867 | 1.118 | 7.696 | 3.337 |
| STANDARD DEV | 11.600 | 17.737 | 1.242  | 0.421 | 0.316 | 1.977 |

YEAR = 80                      SEASON    = 3                      REGION    = 2

TOTAL OBSERVATIONS: 132

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 132    | 132    | 132    | 66    | 132   | 132   |
| MINIMUM      | 2.550  | 5.300  | 28.500 | 0.430 | 8.150 | 3.060 |
| MAXIMUM      | 39.290 | 58.300 | 31.600 | 1.600 | 8.550 | 7.350 |
| MEAN         | 35.932 | 54.139 | 29.845 | 0.817 | 8.353 | 5.280 |
| STANDARD DEV | 3.587  | 4.999  | 0.929  | 0.310 | 0.089 | 0.771 |

YEAR = 80                      SEASON = 3                      REGION = 3

TOTAL OBSERVATIONS: 36

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 36     | 36     | 36     | 18    | 36    | 36    |
| MINIMUM      | 10.060 | 18.300 | 27.100 | 0.380 | 6.960 | 0.110 |
| MAXIMUM      | 38.130 | 56.900 | 31.800 | 4.900 | 8.630 | 8.290 |
| MEAN         | 27.494 | 43.092 | 29.564 | 1.476 | 8.058 | 4.233 |
| STANDARD DEV | 7.857  | 10.544 | 1.216  | 1.386 | 0.511 | 2.040 |

YEAR = 80                      SEASON = 4                      REGION = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 18     | 18     | 18     | 9     | 18    | 18    |
| MINIMUM      | 0.240  | 0.700  | 21.900 | 0.600 | 7.230 | 1.510 |
| MAXIMUM      | 26.560 | 42.200 | 25.900 | 4.200 | 8.490 | 6.680 |
| MEAN         | 10.553 | 18.096 | 23.883 | 1.422 | 7.811 | 4.678 |
| STANDARD DEV | 8.910  | 14.282 | 1.375  | 1.124 | 0.296 | 1.246 |

YEAR = 80                      SEASON = 4                      REGION = 2

TOTAL OBSERVATIONS: 131

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 131    | 131    | 131    | 66    | 131   | 131   |
| MINIMUM      | 17.830 | 30.100 | 20.400 | 0.270 | 8.150 | 5.750 |
| MAXIMUM      | 35.440 | 53.600 | 25.900 | 3.200 | 8.720 | 7.950 |
| MEAN         | 30.917 | 47.837 | 23.066 | 1.018 | 8.385 | 6.638 |
| STANDARD DEV | 3.481  | 4.548  | 1.712  | 0.721 | 0.143 | 0.476 |

YEAR = 80                      SEASON = 4                      REGION = 3

TOTAL OBSERVATIONS: 36

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 36     | 36     | 36     | 18    | 36    | 36    |
| MINIMUM      | 6.310  | 12.100 | 19.900 | 0.400 | 6.900 | 1.020 |
| MAXIMUM      | 28.680 | 45.000 | 26.500 | 6.300 | 8.780 | 8.790 |
| MEAN         | 21.766 | 35.503 | 23.408 | 1.693 | 7.994 | 6.068 |
| STANDARD DEV | 4.998  | 7.176  | 1.774  | 1.700 | 0.556 | 2.093 |

YEAR = 81                      SEASON = 1                      REGION = 1

TOTAL OBSERVATIONS: 12

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 12     | 12     | 12     | 6     | 12    | 12    |
| MINIMUM      | 3.720  | 7.500  | 12.600 | 0.570 | 7.550 | 2.530 |
| MAXIMUM      | 29.600 | 46.200 | 23.300 | 2.300 | 8.600 | 7.750 |
| MEAN         | 19.833 | 32.342 | 18.525 | 1.252 | 8.164 | 5.574 |
| STANDARD DEV | 8.860  | 13.300 | 4.716  | 0.618 | 0.328 | 1.790 |

YEAR = 81                      SEASON = 1                      REGION = 2

TOTAL OBSERVATIONS: 88

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 88     | 88     | 88     | 46    | 88    | 88    |
| MINIMUM      | 26.260 | 25.600 | 11.500 | 0.570 | 8.130 | 5.170 |
| MAXIMUM      | 36.000 | 54.300 | 22.700 | 3.700 | 8.700 | 8.500 |
| MEAN         | 33.348 | 50.737 | 17.501 | 1.423 | 8.438 | 6.605 |
| STANDARD DEV | 2.341  | 3.976  | 4.942  | 0.556 | 0.100 | 0.684 |

YEAR = 81                      SEASON = 1                      REGION = 3

TOTAL OBSERVATIONS: 24

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 24     | 24     | 24     | 12    | 24    | 24    |
| MINIMUM      | 19.930 | 33.100 | 11.600 | 0.430 | 7.380 | 3.210 |
| MAXIMUM      | 32.250 | 49.600 | 23.500 | 1.500 | 8.910 | 8.870 |
| MEAN         | 26.532 | 42.079 | 18.021 | 0.930 | 8.313 | 6.359 |
| STANDARD DEV | 3.169  | 4.215  | 5.134  | 0.321 | 0.426 | 1.576 |

YEAR = 81                      SEASON = 2                      REGION = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 18     | 18     | 18     | 9     | 18    | 18    |
| MINIMUM      | 0.580  | 1.400  | 24.700 | 0.620 | 7.840 | 1.430 |
| MAXIMUM      | 37.390 | 56.000 | 32.000 | 2.600 | 8.750 | 7.550 |
| MEAN         | 27.759 | 42.911 | 28.661 | 1.249 | 8.376 | 3.905 |
| STANDARD DEV | 11.199 | 16.321 | 2.796  | 0.636 | 0.225 | 1.907 |

YEAR = 81                      SEASON = 2                      REGION = 2

TOTAL OBSERVATIONS: 133

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 133    | 133    | 133    | 66    | 133   | 133   |
| MINIMUM      | 27.760 | 43.800 | 23.700 | 0.330 | 8.210 | 3.580 |
| MAXIMUM      | 38.540 | 57.400 | 31.300 | 2.300 | 8.780 | 7.590 |
| MEAN         | 36.972 | 55.483 | 27.832 | 0.666 | 8.413 | 5.726 |
| STANDARD DEV | 1.197  | 1.490  | 2.548  | 0.292 | 0.109 | 0.691 |

YEAR = 81                      SEASON = 2                      REGION = 3

TOTAL OBSERVATIONS: 35

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 35     | 35     | 35     | 18    | 35    | 35    |
| MINIMUM      | 26.180 | 41.700 | 24.800 | 0.420 | 7.290 | 0.900 |
| MAXIMUM      | 37.960 | 56.700 | 31.100 | 3.000 | 8.770 | 8.980 |
| MEAN         | 35.055 | 53.077 | 28.597 | 0.948 | 8.356 | 5.311 |
| STANDARD DEV | 3.256  | 4.106  | 2.285  | 0.645 | 0.405 | 1.751 |

YEAR = 81                      SEASON = 3                      REGION = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 18     | 18     | 18     | 9     | 18    | 18    |
| MINIMUM      | 0.290  | 0.800  | 26.400 | 0.610 | 7.220 | 1.020 |
| MAXIMUM      | 39.290 | 58.300 | 31.700 | 2.900 | 8.820 | 7.660 |
| MEAN         | 23.694 | 36.467 | 29.872 | 1.097 | 8.017 | 4.307 |
| STANDARD DEV | 15.751 | 23.069 | 1.819  | 0.714 | 0.474 | 1.746 |

YEAR = 81                      SEASON = 3                      REGION = 2

TOTAL OBSERVATIONS: 132

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 131    | 131    | 132    | 66    | 131   | 130   |
| MINIMUM      | 2.810  | 5.800  | 0.000  | 0.320 | 7.870 | 2.790 |
| MAXIMUM      | 39.950 | 59.100 | 31.300 | 1.600 | 8.550 | 5.950 |
| MEAN         | 35.662 | 53.763 | 29.814 | 0.588 | 8.169 | 4.954 |
| STANDARD DEV | 4.579  | 6.129  | 2.646  | 0.254 | 0.165 | 0.456 |

YEAR = 81                      SEASON = 3                      REGION = 3

TOTAL OBSERVATIONS: 36

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 36     | 36     | 36     | 16    | 36    | 36    |
| MINIMUM      | 15.040 | 26.000 | 26.200 | 0.320 | 6.730 | 0.380 |
| MAXIMUM      | 40.620 | 59.900 | 31.200 | 1.650 | 8.750 | 7.530 |
| MEAN         | 32.835 | 49.978 | 29.756 | 0.743 | 8.015 | 4.294 |
| STANDARD DEV | 8.417  | 10.983 | 1.097  | 0.395 | 0.511 | 1.519 |

YEAR = 81                      SEASON = 4                      REGION = 1

TOTAL OBSERVATIONS: 12

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 12     | 12     | 12     | 6     | 12    | 12    |
| MINIMUM      | 0.820  | 1.900  | 22.900 | 0.460 | 7.460 | 1.930 |
| MAXIMUM      | 24.100 | 38.900 | 27.200 | 3.100 | 8.240 | 6.030 |
| MEAN         | 8.792  | 15.417 | 24.700 | 1.672 | 7.720 | 4.383 |
| STANDARD DEV | 8.198  | 13.018 | 1.637  | 1.115 | 0.233 | 1.095 |

YEAR = 81                      SEASON = 4                      REGION = 2

TOTAL OBSERVATIONS: 88

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 88     | 88     | 88     | 44    | 88    | 88    |
| MINIMUM      | 14.110 | 24.600 | 20.500 | 0.440 | 0.020 | 5.500 |
| MAXIMUM      | 34.550 | 52.500 | 26.100 | 2.800 | 8.630 | 8.420 |
| MEAN         | 26.591 | 42.105 | 23.323 | 1.369 | 8.124 | 6.648 |
| STANDARD DEV | 4.929  | 6.652  | 2.123  | 0.664 | 0.901 | 0.661 |

YEAR = 81                      SEASON = 4                      REGION = 3

TOTAL OBSERVATIONS: 24

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 24     | 24     | 24     | 13    | 24    | 24    |
| MINIMUM      | 8.390  | 5.600  | 2.000  | 0.300 | 0.100 | 0.080 |
| MAXIMUM      | 23.740 | 38.400 | 26.800 | 4.100 | 8.340 | 8.460 |
| MEAN         | 16.836 | 26.742 | 21.304 | 1.421 | 6.960 | 5.232 |
| STANDARD DEV | 5.519  | 10.574 |        | 6.925 | 0.919 | 2.656 |

2.491

YEAR = 82                      SEASON = 1                      REGION = 1

TOTAL OBSERVATIONS: 16

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 16     | 16     | 16     | 8     | 16    | 16    |
| MINIMUM      | 18.520 | 31.100 | 20.600 | 0.600 | 7.450 | 1.280 |
| MAXIMUM      | 36.650 | 55.100 | 28.600 | 3.300 | 8.790 | 6.240 |
| MEAN         | 27.979 | 43.944 | 25.468 | 1.594 | 8.232 | 4.095 |
| STANDARD DEV | 5.157  | 6.802  | 2.854  | 1.051 | 0.399 | 1.613 |

YEAR = 82                      SEASON = 1                      REGION = 2

TOTAL OBSERVATIONS: 132

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 132    | 132    | 132    | 66    | 125   | 132   |
| MINIMUM      | 30.600 | 47.500 | 18.800 | 0.330 | 8.020 | 4.780 |
| MAXIMUM      | 37.720 | 56.400 | 28.000 | 1.750 | 8.550 | 6.580 |
| MEAN         | 35.253 | 53.357 | 24.061 | 0.707 | 8.376 | 5.699 |
| STANDARD DEV | 1.853  | 2.312  | 3.415  | 0.287 | 0.097 | 0.339 |

YEAR = 82                      SEASON = 1                      REGION = 3

TOTAL OBSERVATIONS: 36

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 36     | 36     | 36     | 18    | 36    | 36    |
| MINIMUM      | 21.780 | 35.700 | 19.400 | 0.500 | 7.230 | 0.450 |
| MAXIMUM      | 37.140 | 55.700 | 28.300 | 4.000 | 8.840 | 6.850 |
| MEAN         | 31.387 | 48.417 | 24.497 | 1.572 | 8.270 | 4.727 |
| STANDARD DEV | 4.134  | 5.335  | 2.949  | 0.913 | 0.455 | 1.762 |

YEAR = 82                      SEASON = 2                      REGION = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 18     | 18     | 18     | 9     | 18    | 18    |
| MINIMUM      | 0.340  | 0.900  | 25.300 | 0.450 | 7.390 | 2.480 |
| MAXIMUM      | 32.960 | 50.500 | 31.000 | 2.300 | 8.590 | 7.630 |
| MEAN         | 11.820 | 19.928 | 27.017 | 1.397 | 7.927 | 4.497 |
| STANDARD DEV | 10.314 | 15.947 | 1.811  | 0.648 | 0.414 | 1.473 |

YEAR = 82                      SEASON       = 2                      REGION       = 2

TOTAL OBSERVATIONS: 134

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 134    | 134    | 134    | 63    | 134   | 134   |
| MINIMUM      | 4.070  | 1.900  | 5.700  | 0.490 | 0.370 | 0.190 |
| MAXIMUM      | 38.370 | 57.200 | 40.600 | 2.100 | 9.290 | 8.160 |
| MEAN         | 35.067 | 53.013 | 27.033 | 0.939 | 8.385 | 5.857 |
| STANDARD DEV | 3.592  | 5.385  | 3.238  | 0.387 | 0.856 | 1.015 |

YEAR = 82                      SEASON       = 2                      REGION       = 3

TOTAL OBSERVATIONS: 34

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 34     | 34     | 34     | 17    | 34    | 34    |
| MINIMUM      | 14.440 | 25.100 | 23.900 | 0.570 | 7.150 | 0.230 |
| MAXIMUM      | 34.550 | 52.500 | 31.600 | 5.800 | 9.290 | 8.850 |
| MEAN         | 26.511 | 41.947 | 27.456 | 1.768 | 8.306 | 5.426 |
| STANDARD DEV | 5.791  | 7.817  | 2.461  | 1.662 | 0.630 | 2.519 |

YEAR = 83                      SEASON       = 1                      REGION       = 1

TOTAL OBSERVATIONS: 12

|              | SALT | COND   | TEMP   | TURB | PH    | DO    |
|--------------|------|--------|--------|------|-------|-------|
| N OF CASES   | 0    | 12     | 12     | 0    | 12    | 12    |
| MINIMUM      | .    | 1.000  | 19.100 | .    | 7.190 | 2.650 |
| MAXIMUM      | .    | 35.400 | 23.800 | .    | 8.150 | 8.720 |
| MEAN         | .    | 10.252 | 21.717 | .    | 7.548 | 5.238 |
| STANDARD DEV | .    | 11.616 | 1.566  | .    | 0.303 | 2.087 |

YEAR = 83                      SEASON       = 1                      REGION       = 2

TOTAL OBSERVATIONS: 88

|              | SALT | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|------|--------|--------|-------|-------|-------|
| N OF CASES   | 0    | 88     | 88     | 0     | 88    | 86    |
| MINIMUM      | .    | 33.600 | 17.200 | .     | 8.050 | 8.000 |
| MAXIMUM      | .    | 52.700 | 20.900 | .     | 8.420 | 8.940 |
| MEAN         | .    | 45.368 | 19.028 | .     | 8.281 | 8.547 |
| STANDARD DEV | .    | .      | 5.133  | 1.160 | .     | 0.089 |

0.206

YEAR = 83                      SEASON = 1                      REGION = 3

TOTAL OBSERVATIONS: 26

|              | SALT | COND   | TEMP   | TURB | PH    | DO    |
|--------------|------|--------|--------|------|-------|-------|
| N OF CASES   | 0    | 26     | 26     | 0    | 26    | 26    |
| MINIMUM      | .    | 7.200  | 17.200 | .    | 6.670 | 0.210 |
| MAXIMUM      | .    | 44.300 | 24.800 | .    | 8.630 | 9.220 |
| MEAN         | .    | 29.204 | 20.245 | .    | 7.835 | 6.015 |
| STANDARD DEV | .    | 10.442 | 2.247  | .    | 0.594 | 3.106 |

YEAR = 83                      SEASON = 2                      REGION = 1

TOTAL OBSERVATIONS: 14

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 11     | 14     | 14     | 12    | 14    | 14    |
| MINIMUM      | 2.000  | 1.700  | 26.900 | 0.910 | 7.410 | 0.730 |
| MAXIMUM      | 34.000 | 54.500 | 30.600 | 3.900 | 8.890 | 8.160 |
| MEAN         | 17.273 | 33.921 | 29.150 | 1.812 | 8.199 | 4.953 |
| STANDARD DEV | 10.316 | 16.248 | 0.997  | 0.906 | 0.549 | 2.172 |

YEAR = 83                      SEASON = 2                      REGION = 2

TOTAL OBSERVATIONS: 75

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 41     | 58     | 58     | 42    | 59    | 59    |
| MINIMUM      | 30.000 | 47.000 | 27.500 | 0.000 | 0.000 | 0.000 |
| MAXIMUM      | 40.000 | 58.300 | 30.000 | 7.500 | 8.660 | 9.110 |
| MEAN         | 36.024 | 55.253 | 29.153 | 0.921 | 8.151 | 7.110 |
| STANDARD DEV | 2.593  | 2.575  | 0.483  | 1.086 | 1.487 | 1.226 |

YEAR = 83                      SEASON = 2                      REGION = 3

TOTAL OBSERVATIONS: 17

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 13     | 15     | 15     | 13    | 15    | 15    |
| MINIMUM      | 20.000 | 32.900 | 27.600 | 0.440 | 7.020 | 0.220 |
| MAXIMUM      | 37.000 | 55.700 | 30.400 | 7.000 | 8.770 | 9.170 |
| MEAN         | 29.154 | 46.513 | 29.067 | 1.758 | 8.148 | 5.727 |
| STANDARD DEV | 6.362  | 8.123  | 0.793  | 2.173 | 0.548 | 2.855 |

YEAR = 83                      SEASON = 3                      REGION = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 17     | 18     | 18     | 18    | 18    | 18    |
| MINIMUM      | 2.000  | 2.500  | 27.600 | 0.550 | 7.370 | 0.570 |
| MAXIMUM      | 29.000 | 47.400 | 33.600 | 2.100 | 8.310 | 7.080 |
| MEAN         | 14.941 | 24.561 | 30.783 | 1.104 | 7.757 | 4.003 |
| STANDARD DEV | 8.941  | 15.128 | 1.798  | 0.335 | 0.347 | 1.958 |

YEAR = 83                      SEASON = 3                      REGION = 2

TOTAL OBSERVATIONS: 91

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 63     | 77     | 77     | 63    | 77    | 77    |
| MINIMUM      | 27.000 | 43.300 | 30.200 | 0.370 | 8.210 | 5.470 |
| MAXIMUM      | 38.000 | 58.800 | 32.800 | 1.600 | 8.460 | 8.400 |
| MEAN         | 34.238 | 54.243 | 31.468 | 0.692 | 8.313 | 6.711 |
| STANDARD DEV | 2.263  | 3.316  | 0.678  | 0.274 | 0.054 | 0.630 |

YEAR = 83                      SEASON = 3                      REGION = 3

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 18     | 18     | 18     | 18    | 18    | 18    |
| MINIMUM      | 6.000  | 10.300 | 29.300 | 0.450 | 7.030 | 0.580 |
| MAXIMUM      | 38.000 | 52.000 | 33.200 | 4.300 | 8.460 | 7.570 |
| MEAN         | 24.139 | 37.700 | 31.033 | 1.212 | 7.940 | 5.343 |
| STANDARD DEV | 7.821  | 11.713 | 1.163  | 0.942 | 0.503 | 2.073 |

YEAR = 83                      SEASON = 4                      REGION = 1

TOTAL OBSERVATIONS: 18

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 10     | 18     | 18     | 6     | 18    | 18    |
| MINIMUM      | 2.000  | 2.100  | 20.800 | 0.990 | 2.230 | 4.200 |
| MAXIMUM      | 22.000 | 41.900 | 29.200 | 2.600 | 8.350 | 8.600 |
| MEAN         | 9.600  | 21.600 | 24.506 | 1.530 | 7.503 | 6.053 |
| STANDARD DEV | 6.535  | 14.042 | 2.864  | 0.590 | 1.360 | 1.282 |

YEAR = 83                      SEASON = 4                      REGION = 2

TOTAL OBSERVATIONS: 61

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 22     | 59     | 59     | 22    | 59    | 59    |
| MINIMUM      | 30.000 | 39.400 | 19.900 | 0.520 | 0.080 | 5.100 |
| MAXIMUM      | 42.000 | 55.300 | 29.700 | 6.500 | 8.400 | 8.940 |
| MEAN         | 33.955 | 50.615 | 24.615 | 1.615 | 8.128 | 7.579 |
| STANDARD DEV | 2.591  | 3.157  | 3.553  | 1.431 | 1.069 | 0.833 |

YEAR = 83                      SEASON = 4                      REGION = 3

TOTAL OBSERVATIONS: 17

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 7      | 17     | 17     | 6     | 17    | 17    |
| MINIMUM      | 5.000  | 11.300 | 19.800 | 0.400 | 7.260 | 1.990 |
| MAXIMUM      | 28.000 | 49.700 | 30.100 | 8.700 | 8.470 | 8.680 |
| MEAN         | 21.857 | 37.082 | 24.847 | 2.900 | 8.019 | 6.507 |
| STANDARD DEV | 7.819  | 8.231  | 3.906  | 3.559 | 0.417 | 2.267 |

YEAR = 84                      SEASON = 1                      REGION = 1

TOTAL OBSERVATIONS: 6

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 3      | 6      | 6      | 6     | 6     | 6     |
| MINIMUM      | 3.000  | 5.500  | 24.100 | 0.880 | 7.540 | 5.100 |
| MAXIMUM      | 23.000 | 45.900 | 25.500 | 9.400 | 8.410 | 8.260 |
| MEAN         | 15.000 | 28.950 | 24.983 | 2.528 | 8.170 | 6.848 |
| STANDARD DEV | 10.583 | 14.500 | 0.605  | 3.375 | 0.334 | 1.389 |

YEAR = 84                      SEASON = 1                      REGION = 2

TOTAL OBSERVATIONS: 32

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 19     | 32     | 31     | 31    | 32    | 32    |
| MINIMUM      | 31.000 | 47.700 | 22.900 | 0.370 | 8.180 | 0.550 |
| MAXIMUM      | 37.000 | 57.400 | 25.400 | 2.200 | 8.440 | 9.340 |
| MEAN         | 35.158 | 54.631 | 23.626 | 0.797 | 8.357 | 7.973 |
| STANDARD DEV | 1.675  | 2.094  | 0.610  | 0.426 | 0.039 | 1.404 |

YEAR = 84                      SEASON = 1                      REGION = 3

TOTAL OBSERVATIONS: 8

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 5      | 8      | 8      | 8     | 8     | 8     |
| MINIMUM      | 18.000 | 19.700 | 22.900 | 0.390 | 7.480 | 3.030 |
| MAXIMUM      | 29.000 | 47.100 | 25.800 | 7.500 | 8.610 | 9.580 |
| MEAN         | 25.400 | 39.512 | 24.362 | 1.930 | 8.216 | 7.009 |
| STANDARD DEV | 4.336  | 9.210  | 1.049  | 2.497 | 0.394 | 2.346 |

YEAR = 84                      SEASON = 2                      REGION = 1

TOTAL OBSERVATIONS: 6

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 5      | 6      | 6      | 6     | 6     | 6     |
| MINIMUM      | 30.000 | 40.000 | 30.100 | 1.340 | 8.430 | 2.690 |
| MAXIMUM      | 40.000 | 59.900 | 32.300 | 9.400 | 8.960 | 9.180 |
| MEAN         | 36.000 | 52.150 | 30.700 | 3.457 | 8.687 | 5.742 |
| STANDARD DEV | 4.062  | 9.451  | 0.817  | 2.985 | 0.237 | 2.828 |

YEAR = 84                      SEASON = 2                      REGION = 2

TOTAL OBSERVATIONS: 32

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 30     | 32     | 32     | 32    | 32    | 32    |
| MINIMUM      | 34.000 | 53.000 | 24.100 | 0.360 | 8.400 | 5.790 |
| MAXIMUM      | 42.000 | 61.100 | 30.300 | 1.440 | 8.800 | 8.660 |
| MEAN         | 38.467 | 59.416 | 29.544 | 0.628 | 8.669 | 7.202 |
| STANDARD DEV | 1.306  | 1.493  | 1.045  | 0.231 | 0.082 | 0.721 |

YEAR = 84                      SEASON = 2                      REGION = 3

TOTAL OBSERVATIONS: 7

|              | SALT   | COND   | TEMP   | TURB  | PH    | DO    |
|--------------|--------|--------|--------|-------|-------|-------|
| N OF CASES   | 7      | 7      | 7      | 7     | 7     | 7     |
| MINIMUM      | 36.000 | 54.900 | 29.200 | 0.360 | 8.150 | 3.170 |
| MAXIMUM      | 40.000 | 60.900 | 31.500 | 2.100 | 9.080 | 8.500 |
| MEAN         | 38.000 | 58.900 | 30.357 | 1.166 | 8.733 | 6.416 |
| STANDARD DEV | 1.291  | 2.039  | 0.772  | 0.688 | 0.328 | 1.855 |



APPENDIX 3.  
COMPUTER PROGRAMS

## APPENDIX 3. Computer Programs

```

*****      FLOW.FOR      *****
This program combines the contents of DATE.DAT and FLOW'.DAT
The output is stored in FLOW.DAT and includes the record number,
the date, the Moody and the Mowry flow data for the date of
water quality sampling and for four days preceeding it.
  dimension iflow(655,2),idate(655)
  integer moody(5),mowry(5)
  open (1,file='flow'.dat,status='old')
  open (2,file='date.dat',status='old')
  open (3,file='flow.dat',status='new')
  do 1 if=1,655
1  read(1,4) idate(if),iflow(if,1),iflow(if,2)
   if=0
   iseq=0
   do 30 iq=1,131
     read(2,4) id,isn,ien
     do 2 i=1,5
       if=if+1
       moody(i)=iflow(if,1)
2    mowry(i)=iflow(if,2)
4    format(i5,1x,i4,1x,i4)
     do 12 iz=isn,ien
       iseq=iseq+1
12  write(3,6)iseq,iz,id,(moody(i),i=1,5),(mowry(k),k=1,5)
6    format(i4,1x,i4,1x,i5,1x,10i4)
30  continue
    stop
  end

```

\*\*\*\*\*FLOWQUAL.FOR\*\*\*\*\*

This program incorporates the flow data in file FLOW.DAT into the Bay quality data in QUAL.DAT for measurements from 1972 through 1982 inclusive. The output is stored in FLOWQUAL.DAT. Only Salinity, Conductivity, Temperature

Turbidity, pH and Dissolved Oxygen are retained in addition to the depth of measurement.

```

dimension p(12)
integer recf,date,d(5),r(5),recq,sta,flow(5)
open (1,file='flow.dat',status='old')
open (2,file='qual.dat',status='old')
open (3,file='flowqual.dat',status='new')
do 3 i=1,3500
read(1,6,end=7) is,recf,date,(d(k),k=1,5),(r(k),k=1,5)
read(2,5,end=7) recq,sta,itime,(p(j),j=1,12)
do 2 k=1,5
flow(k)=9999
if ( sta .eq. 2 ) flow(k)=d(k)
if ( sta .eq. 10 .and. sta .le. 19 ) flow(k)=d(k)
if ( sta .eq. 6 ) flow(k)=r(k)
if ( sta .ge. 30 .and. sta .le. 39 ) flow(k)=r(k)
2 continue
3 write(3,8) is,date,sta,(flow(k),k=1,5),(p(j),j=1,07)
5 format(i4,i3,i5,f5.2,3f6.2,3f5.2,f6.2,f5.2,f7.2,f5.2,f6.2)
6 format(i4,1x,i4,1x,i5,1x,10i4)
7 continue
8 format(2i7,i4,2x,5i5,7f6.2)
stop
end

```

\*\*\*\*\* CLUSTER.FOR \*\*\*\*\*

This program computes the mean, over time, for each water quality variable sampled at each location at a specific depth or averaged over a given depth.  $Av(l,m)$  is the mean value for the  $m$ th variable at the  $l$ th station. Averaging is done over the number of episodes that were sampled at this station. The output is stored in CLUSTER.DAT and is the input for the Cluster Analysis.

```

dimension p(12),avg(66,7),iter(66)
integer sta(66)
data sta/ 02,04,06,07,08,11,12,13,14,15,16,18,19,21,
1,23,24,25,26,28,29,31,32,33,34,35,36,38,39,51,52,53,
2,54,55,58,61,62,63,64,65,68,71,72,73,74,75,78,81,82,
3,83,84,85,88,91,92,93,94,95,96,10,20,30,50,60,70,80,
4,90,22//
open (1,file=qual.dat,status='old')
open (2,file=cluster.dat,status='new')
do 5 l=1,67
iter(l)=0
do 5 m=1,7
5 avg(l,m)=0.
do 30 n=1,4000
read(1,80,end=40) i,ista,itime,(p(l),l=1,07)
if(p(l) .gt. 0.20) go to 30
do 10 l=1,7
if(p(l) .eq. 9.99 .or. p(l) .eq. 99.99) go to 30
10 continue
do 20 l=1,66
if(ista .ne. sta(l)) go to 20
iter(l)=iter(l)+1
do 15 m=1,7
15 avg(l,m)=avg(l,m)+p(m)
go to 30
20 continue
30 continue
40 continue
do 50 l=1,66
do 60 m=1,7
if(iter(l) .eq. 0) go to 50
60 avg(l,m)=avg(l,m)/float(iter(l))
write(2,70) sta(l),(avg(l,m),m=1,7)
50 continue
70 format(i3,7f7.2)
80 format(i4,1x,i2,1x,i4,1x,f4.2,1x,3(f5.2,1x),
13(f4.2,1x))
stop
end

```

\*\*\*\*\* CAT.FOR \*\*\*\*\*

This program converts the sampled values into categorical data and also obtains the frequency of each category for a given station - variable - canal combination. The output was stored in TABLE.DAT for all the variables and is given as Table 8 for the variable conductivity.

```

dimension p(10),pcr(10),in(20),ll(20,10,5),l(5)
integer date,sta,gg(20,10,5),gl(20,10,5),lg(20,10,5)
open (1,file='flowqual.dat',status='old')
open (2,file='table.dat',status='new')
open (3,file='corre.dat',status='new')
read(1,2) (pcr(j),j=1,10)
2 format(5f4.0,05f5.2)
read(1,3) (in(j),j=1,20)
3 format(20i2)
do 4 k=1,5
do 4 j=1,10
do 4 m=1,20
gg(m,j,k)=0
gl(m,j,k)=0
lg(m,j,k)=0
4 ll(m,j,k)=0
do 16 i=1,4620
read(1,5) iseq,date,sta,(p(j),j=1,10)
5 format(2i7,i4,2x,5(1x,f4.0),5f6.2)
do 15 m=1,20
if(sta .ne. in(m)) go to 15
do 100 j=1,10
if(p(j) .eq. 9.99 .or. p(j) .eq. 99.99) go to 16
if(p(j) .eq. 9999 .or. p(j) .eq. 999.99) go to 16
100 continue
do 10 k=1,5
do 10 j=6,10
if(p(k).gt.pcr(j) .and. p(j).gt.pcr(j))
1 gg(m,j,k)=gg(m,j,k)+1
if(p(k).gt.pcr(j) .and. p(j).le.pcr(j))
2 gl(m,j,k)=gl(m,j,k)+1
if(p(k).le.pcr(j) .and. p(j).gt.pcr(j))
3 lg(m,j,k)=lg(m,j,k)+1
if(p(k).le.pcr(j) .and. p(j).le.pcr(j))
4 ll(m,j,k)=ll(m,j,k)+1
10 continue
write(3,14) iseq,date,sta,(p(j),j=1,10)
14 format(2i7,i4,2x,5f5.0,5f6.2)
15 continue
16 continue
write(*,20)
20 format(////)
do 40 j=6,10
i=1
do 40 m=1,20
if(m .gt. 10 ) i=2
do 40 n=1,4
do 39 k=1,5
if(n .eq. 1) l(k)=gg(m,j,k)

```

```
      if(n .eq. 2) l(k)=gl(m,j,k)
      if(n .eq. 3) l(k)=lg(m,j,k)
      if(n .eq. 4) l(k)=ll(m,j,k)
39 continue
40 write(2,45)    n,in(m),i,j,(l(k),k=1,5)
45 format(9i4)
      stop
      end
```

\*\*\*\*\* SEQ'.FOR \*\*\*\*\*

This program combines the QUAL.DAT and DATE.DAT data files, and abstracts the time ordered values of a given variable sampled at a given station. The variables are identified as follows: 2=salinity, 3=conductivity, 4=temperature, 5=turbidity, 6=pH, 7=dissolved oxygen. The output is the variable value averaged over the sampled depths for the sampling date. It was stored in DATA11.DAT for station 11 and so on. To run the program enter the station number and the variable number on the same line.

```
dimension p(4)
integer sta
open (1,file='qual.dat',status='old')
open (2,file='date.dat',status='old')
open (3,file='          ',status='new')
read(*,*) sta,ivar
do 30 j=1,131
n=0
sum=0.
read(2,50) idate,isn,ien
do 20 l=1,isn,ien
read(1,80) i,ista,itime,(p(k),k=1,4)
if(ista .ne. sta) go to 20
if(p(ivar) .eq. 99.99) go to 20
n=n+1
sum=sum + p(ivar)
20 continue
if(n .eq. 0) go to 30
avg= sum/float(n)
write(3,90) j,idate,n,sum,avg
30 continue
50 format(i5,1x,i4,1x,i4)
80 format(i4,1x,i2,1x,i4,1x,f4.2,1x,3(f5.2,1x))
90 format(3i7,2x,2f7.2)
stop
end
```

\*\*\*\*\* SE.FOR \*\*\*\*\*

This program assigns the sampled dates in DATA11.DAT, for example, to the month within which it falls. The output is the depth-averaged variable value now averaged over the number of sampling days within the month and was stored in S11.DAT for station 11.

```

dimension  ndate(150),idate(131),a(131),avg(145)
open (1,file='ndate.dat',status='old')
open (2,file='          ',status='old')
open (3,file='          ',status='new')
ndate(1)=72000
read(1,45) (ndate(k),k=2,145)
do 05 j=1,131
  read(2,50,end=06) ij,idate(j),no,s,a(j)
05 jmax=j
06 continue
  do 30 i=2,145
    sum=0.
    n=0
    do 10 j=1,jmax
      if(idate(j) .ge. ndate(i) .or. idate(j) .lt. ndate(i-1)) go
1 to 10
      n=n+1
      sum=sum+a(j)
10 continue
      if(n .gt. 0) then
        avg(i-1)=sum/float(n)
        i1=i-1
        write(3,55) i1,ndate(i-1),ndate(i),n,avg(i-1)
      else
        avg(i-1)=99.99
        i1=i-1
        write(3,55) i1,ndate(i-1),ndate(i),n,avg(i-1)
      endif
30 continue
40 continue
45 format(15(10i7/))
50 format(3i7,2f9.2)
55 format(4i7,f7.2)
stop
end

```

\*\*\*\*\* SS.FOR \*\*\*\*\*

This program partitions the data file, S11.DAT for station 11, into time segments of uninterrupted monthly data. It then computes, for each segment, the total score (S), Kendall rank correlation coefficient (tau), standard deviation of the score (std), and the reduced variate (u).

```

      dimension id(200,4),c(200),ns(20)
      integer sta
      open(1,file='          ',status='old')
      open(2,file='          ',status='new')
      read(*,*) sta,nseg,(ns(mm),mm=1,nseg)
      do 1 i=1,200
      read(1,3,end=2) (id(i,j),j=1,4),c(i)
1    nobs=i
2    continue
3    format(4i7,f7.2) c
      nstart=1
      nend=ns(1)
      do 1000 mm=1,nseg
      n=ns(mm)
      s=0
      nend1=nend-1
      do 65 i=nstart,nend1
      m=i+1
      do 63 l=m,nend
      diff=c(i)-c(l)
      if(diff .gt. 0.) d=1
      if(diff .eq. 0.) d=0
      if(diff .lt. 0.) d=-1
63    s=s+d
65    continue
      tau=s/(0.5 * float(n*n-n))
      var=0.0555555*n*(n-1)*(2*n+5)
      std=sqrt(var)
      u=(s-1.)/std
      write(2,80) sta,id(nstart,2),id(nend,3),n,s,tau,std,u
      nstart=nend + 1
      nend=nend+ns(mm+1)
1000 continue
      80 format(4i7,4f10.2)
      STOP

```







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