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A Determination of the Optimal Sampling Strategy for Assessing Open Lake Water Quality and Tracking Trends in the Western Basin of Lake Erie

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EXECUTIVE SUMMARY

This project was undertaken to define an offshore region in the western basin of Lake Erie that when sampled during future monitoring programs will provide information on water quality and aid in tracking long term trends. El-Shaarawi (1984), Rosa and Burns (1986) and Rosa (1986) have completed similar projects, defining central and eastern basin representative areas. Although the methods employed by these researchers varied, the zones that they defined were geographically very similar. The offshore central and eastern basin regions were selected based upon their epilimnion and hypolimnion stability.

The determination of an offshore region in the western basin is complicated by its shallowness and variable flow regime. As a result of its shallowness, storm activity creates a strong interaction between the water column and the unconsolidated sediments, with sediment resuspension frequently occurring. This introduces a great deal of variability into the water column chemisty. Another complication in defining a representative open water region is the variable mixing patterns between the high flow, oligotrophic water coming from the upper lakes via the Detroit River and the low flow, eutrophic water of the western basin tributaries (ie. Maumee River).

To deal with the diverse water quality of the western basin, the entire historical data base (1947-1984) obtained from STORET was examined and modified to accomodate the specific objectives of this study. The protocol developed by El-Shaarawi (1984) was utilized to cluster the data and determine the optimum offshore sampling region. The station pattern and the number of surveys to be sampled annually were determined via the clustering program, FASTCLUS (SAS).

Considerable effort was devoted to inventoring the STORET data base (Tables 1 - 23) and determining the variables with consistent quality and quantity for utilization in the multi-variable cluster. As with most statistical techniques, it is best to use variables that permit the formation of a complete matrix (ie. no missing values). Once the appropriate variables were determined, several preliminary tests were undertaken on the individual data sets in order to improve the performance of the clustering program. For example, standardization and log-transformation of the data were necessary prior to multi-variable clustering in order to eliminate biases in the calculation of Euclidean distance which result from differences in measurement.

After the offshore sampling region was defined, the resulting offshore cluster was subsequently sub-clustered to determine the appropriate number of stations necessary to adequately sample the region. Five stations, within the representative area, were sufficient (Table 49) to provide a standard deviation equivalent to the original cluster. The optimum number of surveys required to estimate the annual variability was determined on a seasonal basis. The spring season (April- May) was found to be the most variable period and therefore requires the greatest number of surveys. The summer had the lowest variance and the fall season was only slightly more variable. A minimum of seven surveys were recommended.

INTRODUCTION AND METHODS

STUDY OBJECTIVES

This study was designed to determine a western basin representative offshore region to be used in the Lake Erie surveillance/monitoring program (GLISP, 1986). Based upon extensive data reviews and analysis of the central and eastern basins, surveillance/monitoring strategies have been established for these two areas (El-Shaarawi 1984, Rosa and Burns 1986, and Rosa 1986). These studies geographically defined and physically and chemically characterized an offshore region and ultimately developed a sampling protocol which could be used to characterize the open water region of the respective basin. This study is designed to yield similar information for the western basin.

GENERAL BASIN DESCRIPTION

The natural morphology of Lake Erie divides the lake into three distinct basins; western, central and eastern. The following descriptive information on the individual Lake Erie basins is taken from Burns (1976).

	Total Lake	West Basin	Central Basin	East Basin
Surface Area (km2)	25,212.0	3,680.0	15,390.0	6,150.0
Volume (km3)	468.0	28.0	274.0	166.0
Mean Depth (m)	18.6	7.6	17.8	27.0
Max Depth (m)	64.0	14.0	26.0	64.0
Mean Residence Time (yr)	2.4	0.2	1.4	0.8

This report specifically focuses on the smallest and shallowest of the three basins, the western basin. This basin is boardered by the province of Ontario to the north and the states of Michigan and Ohio to the west and south respectively. The boundary between the western and central basins (Figure 1a) follows the 10 meter contour line (northeast - southwest) from Marblehead, Ohio to Pelee Point, Ontario (Sly 1976). The bottom morphology of the basin is generally flat with nearly 50% of the basin within the 5-10 meter contour. The surficial sediments are a mixture of sand, silt and clay, with clay comprising 40-60 percent (Thomas et al. 1976).

The general circulation pattern through the western basin is dominated by the Detroit River flow, with approximately 80% of the water entering the basin orginating from this source. The flow from the Detroit River dominates the northern two-thirds of the basin while the Maumee River and the smaller southern tributaries influence the southern portion of the flow pattern (Figure 1b). The net western basin water movement is from west to east; entering the central basin through the north and south passages (north of Pelee Island and south of Kelley's Island). Nearly the entire volume contributed by the Detroit River leaves the basin through the north passage making this the dominant outflow channel (Saylor and Miller 1983).

The water quality in the offshore region of the western basin is considered to be the poorest of the three basins. It is not uncommon for phosphorus, nitrogen, suspended solids and chlorophyll concentrations to be two to three times the values encountered in the central and eastern basins. The poor water quality of the western basin can be attributed to the large metropolitan, industrial and agricultural development found within the basin watershed. This subsequently results in significant loads of nutrients and contaminants to the waters of the western basin.

The St. Clair / Detroit River Connecting Channel serves as the link between Lake Erie and the upper Great Lakes. The water quality leaving Lake Huron is quite good, being low in nutrients (ie. total phosphorus < 5 ug/l) and contaminants. However, from the time Lake Huron waters enter the connecting channel they receive a myriad of industrial and municipal wastes (IAGLR , 1985). Consequently, the connecting channel has been the major pollutant source to Lake Erie from the time the basin first became inhabited. Although the concentrations of many pollutants are low, the quantity of water leaving the Detroit River is so great (> 6,000 m3/sec) that the resultant loading to the western basin is quite significant.

Prior to the upgrading of the Detroit sewage treatment facility, the major single nutrient contributor to the basin was the Detroit River. During the late 1960's and the early 1970's the total phosphorus loading from the Detroit exceeded 20,000 mt/yr (Surveillance Work Group, 1983). However since the establishment of a new municipal treatment facility for the city of Detroit, the Detroit River phosphorus loading has decreased from a maximum in 1973 (13,169 mt/yr) to a low value of 4,799 mt/yr in 1980 (Yaksich et al, 1982).

In contrast to the connecting channel, the remaining tributaries emptying into the western basin are quite small in regard to flow and consequently have not been considered to have a significant basin wide effect.

TRIBUTARY	LOCATION	MEAN FLOW m^3/sec
Detroit	Michigan/Ontario	6,000
Huron	Michigan	20
Raisin	Michigan	29
Ottawa	Michigan/Ohio	5
Maumee	Ohio	204
Portage	Ohio	16

Taken From GLISP (1986)

These small tributaries have always had significant localized effects, particularly since most rivers drain agricultural lands and serve as a waste depository for the local municipalities (ie. Maumee River - Toledo, Ohio). Even though it appears that the flow of these tributaries is insignificant in comparison with the Detroit River flow, the concentrations of nutrients and suspended matter are 5 to 10 times the concentrations found at the mouth of the Detroit River. These smaller rivers may not impact the western basin to the same degree as the Detroit River, however their combined input does have a significant effect. For example, during peak runoff (late February - March) satellite imagery of the basin clearly shows extensive plumes extending from the river mouths into the open waters of the basin (Lyon, 1987)

As mentioned previously, the western basin presents significantly different problems from those encountered in the central and eastern basins. Due to the very heterogeneous and complex nature of western basin water quality, the selection of an open water station pattern for surveillance/ monitoring is not a simple task. Three general statements can be made about the water quality of the basin.

1. The water quality in the northern section of the basin is better than that of the southern portion. This can be attributed to the dilution factor associated with the large volume of water being carried into the western basin via the Detroit River. Nevertheless the Detroit River serves as a primary contaminant and nutrient loading source to Lake Erie (Figure 1b).

2. The shoreline region along the U.S. portion of the basin exhibits concentrations of nutrients, suspended solids and chlorophyll as large as ten times the open water values.

3. There is a general improvement in water quality as one moves from the western shoreline into the central basin.

The objective of this project was to determine a station pattern which will generate a data base representative of the western basin open water conditions. Current information together with the historical data base could then be used to develop long term basin trends. Due to the high spatial and temporal variability characteristic of the basin, both frequency and number of sampling locations needs to be proportionally greater than what has been determined for the central and eastern basins.

STUDY PLAN

The STORET western basin data base was acquired from the USEPA Large Lakes Research Station at Grosse Ile. The study plan followed the flow chart in Figure 2. The geographical distribution of the data was determined by plotting the station locations on a standard Western Basin chart. Next, inventories of the limnological variables were made and continuity of the data was determined seasonally and annually. This review of the data base was necessary in order to select variables which would be most appropriate for inclusion in the multiple variable cluster analysis. The protocol followed for the cluster analysis was the procedure developed by El-Shaarawi (1984).

Finally, a station pattern was determined for future surveillance programs that would provide the appropriate data base from the open lake representative clustered area. In addition, seasonal variablity was determined in an attempt to ascertain the number of surveys that would be required for future sampling programs.

RESULTS AND DISCUSSION

DATA BASE INVENTORY

This study followed a systematic progression designed to evaluate the western basin data retrieved from STORET. Descriptive statistical information was assembled for over 150 variables contained within the data set (Table 1). The file contained a total of 496 stations distributed throughout the western basin. Station codes which included location information (latitude and longitude) were used to plot station positions on a U.S. Great Lakes "West End of Lake Erie" chart (14830). Results indicated that the largest percentage of stations were located in the region extending from the mouth of the Detroit River along the western shoreline to Toledo, Ohio. The fewest number of sampling records were found along the southern third of the basin, along the Ohio shore.

Of the 150 variables recorded in the western basin data set, only 21 were examined in detail. The 21 variables were selected based upon completeness of the data over the period of record from 1947-1984, the total number of values recorded on a yearly basis and the appropriateness for defining an offshore representative region. None of the metals, organics, or sediment contaminant data bases were considered adequate for this task, consequently the variables selected were a combination of conservative and non-conservative (biologically active) conventional chemical measurements.

The western basin data recorded from 1947 through 1984 indicated that the majority of the information was collected during the 1960's and 1970's (Tables 2-23). Only temperature had a continuous data base through the period of record; containing the largest number of data points (N = 10,101). Generally, individual stations did not have continuous data over the period of record (1947 - 1984) and data was frequently limited to 1 to 5 year time periods.

One specific western basin study had a significant impact on the overall data set. During 1978 and 1979 an intensive nearshore study was undertaken; having an intense station pattern concentrated within 10 km of shore. This study accounted for up to 600 data points annually for the two year period. Lack of a comparably intense data base for the open waters of the basin decreased the usefullness of this data set in defining an offshore region.

The entire data set was examined for possible seasonal influences. In order to obtain a general understanding of the seasonality, individual variables were inventoried based on a four season partitioning format:

SEASON 1	JANUARY - MARCH
SEASON 2	APRIL - MAY
SEASON 3	JUNE - SEPTEMBER
SEASON 4	OCTOBER - DECEMBER

It was evident that the largest proportion of the data was collected during SEASONS 2 and 3 and the fewest values were recorded during SEASON 1 (Tables 2-23). For example, less than 3% of the temperature data was collected during SEASON 1 while over 80% was collected during SEASONS 2 and 3.

In addition, Tables 2-23 contain yearly data summaries developed for each of the 21 variables examined. Since the seasonal component influences nearly all the variables, monthly data was summarized for the period of record to help elucidate how the various seasons effected data variability. The data is presented in a modified notch block format, showing the range of values, mean, median, 25th percentile, 75th percentile and the number of samples (N). An example of this plotting format is presented in Figure 3 and the monthly statistics for the major variables are presented in Figures 4-24. The following text contains a brief description of each variable inventoried. Those variables labeled with an (*) were considered for inclusion in the multi-variable cluster analysis to define the representative open water region.

TEMPERATURE. This is the most complete data base found in the entire data set, containing a continuous record from 1947 through 1984 (Table 2). Due to the year to year seasonal differences in the sampling schedule, differences in the yearly means are not considered significant. The monthly pattern reflects the annual heating and cooling cycle indicative of the basin (Rathke, 1984) as shown in Figure 4. Temperature was considered to be an inappropriate variable for defining a specific open lake sampling region due to the lack of any significant spatial differences in seasonal temperature regimes.

CONDUCTIVITY*. The conductivity data base was very extensive; having a total of 5897 values with data available for all but three years since 1947 (Table 3). This data set showed only small seasonal variation (Figure 5). Since this variable is very useful in identifing water masses, it was examined in detail to aid in identifing specific water quality areas within the basin. For example, water entering the western basin from the Detroit River had the lowest conductivity found in the lake. Conductivity values in the river mouth region remain near 240 umhos/cm due to the lower concentration of principal ions found in the upper Great Lakes. In contrast, the conductivity values recorded for the River Raisin and the Maumee River are in the range of 300 umhos/cm. Thus, this variable could serve as a good tracer for tributary water masses as they mix with the water entering from the upper lakes.

CHLORIDE*. As with conductivity, the chloride data base was very extensive; having a total of 3592 values over the period of record. With the exception of 1965, 1980 and 1982 all other years were represented (Table 4). Even though chloride is considered a conservative variable, it does undergo somewhat of a seasonal cycle in the western basin (Figure 6). Peak concentrations coincide with late winter and early spring when major tributary and land runoff is taking place.

SULFATE. The sulfate data base was found to be inconsistent in yearly distribution of values, having 1291 values listed for the period of record (Table 5). Nearly 50% of the data was collected during the 1978 intensive year on Lake Erie and the majority of these samples were collected in the nearshore zone. Seasonally, the sulfate concentrations were somewhat erratic with no apparent trend (Figure 7). Sample locations are extremely critical for this data base due to the numerous point source contributors within the basin (ie. fossil fuel power plants). Due to the inconsistent nature of this data base it was not used in the final cluster analysis.

DISSOLVED OXYGEN. Oxygen concentrations were examined only as a point of interest. Since the basin does not develop permanent thermal stratification, the oxygen concentrations are nearly always close to 100% saturated. The mean and median yearly concentrations consistently range from 8 to 10 mg/l (Table 6). It should be noted that yearly minimum values frequently are below 5.0 mg/l with some values reaching less than 3.0 mg/l. These values are recorded during short periods of ephemeral stratification, allowing oxygen depletion in the bottom waters. The monthly composite data (Figure 8) indicates that this most commonly occurs from June through September as documented by Bartish (1984).

PERCENT DISSOLVED OXYGEN SATURATION. The information contained in this data set reflects the dissolved oxygen situation for the basin. Mean and median saturations are always over 90% and frequently have maximum values greater than 120% due to photosynthetic oxygen production (Table 7). Minimum concentrations also reflect the effects of oxygen depletion which occur during short term stratified periods (Figure 9).

pH. This variable was examined primarily for general interest purposes. The data set extensively covers the period of record. Mean-median values from 1947 - 1984 ranged from 8.1 to 8.6 with the values extending from 6.0 to 10.0 (Table 8). In addition, the cummulative monthly summary indicated no significant seasonal effect. Due to the substantial carbonate buffering capacity of Lake Erie, no significant trend seasonally or spatially would be expected (Figure 10).

TURBIDITY*. The STORET data base for turbidity was listed as two seperate variables, turbidity in Jackson Turbidity Units (JTU's) and turbidity as Nephlometric Turbidity Units (NTU's). The JTU data set spanned 1967 - 1973 while the NTU data extended from 1973 - 1984 (Tables 9 and 10). It is recognized that there is a difference in the results obtained from the two techniques however, it was felt that the advantages gained from combining the two data sets outweigh the disadvantages. The yearly means and medians were similar for the two data sets with the exception of 1978 and 1979 when turbidity increased significantly. As previously discussed the 1978-1979 data were primarily obtained from the nearshore zone as part of the Lake Erie intensive program. Values were found to be greater than in previous years due to the location of the sampling sites. In general, turbidity followed an expected seasonal pattern, with the highest values occurring in the spring and fall (Figure 11). This is largely due to resuspension of unconsolidated sediments during periods of high wind.

SECCHI. Secchi data is fairly extensive with little change evident over time or through the season (Table 11 and Figure 12). Due to the shallow nature of the western basin, storm activity readily mixes the unconsolidated sediments into the overlying waters, thus Secchi readings are generally low. An inverse relationship is apparent with turbidity and total suspended solids.

TOTAL SUSPENDED SOLIDS (TSS)*. The TSS data set contained 1229 values with adequate data distribution over the period of record (Table 12). TSS provides quantitative information on the particulate material suspended in the water column. In a tributary dominated shallow water body such as the western basin, the particulate material found in the water column originates from a combination of autochthonous and allochthonous sources. This suspended material is a combination of organic (planktonic and detrital) and inorganic material.. The percent or ratio of the organic to inorganic constituents depends upon several factors ie. season, sampling location and meteorological conditions. Figure 13 illustrates the seasonal changes in suspended material concentrations. Ideally, this variable is best used when accompanied with volatile and residual solids information, which is frequently obtained as part of the TSS analytical procedure. Unfortunately, the STORET files contained less than 200 data points for either of these additional variables. TSS concentrations by themselves can be helpful in defining spatial differences within the basin primarily because the smaller tributaries are heavily laden with particulate material while the dominant Detroit River generally contains lower concentrations.

TOTAL PHOSPHORUS*. Total phosphorus is one of the principal variables used to assess eutrophication in freshwater systems and in Lake Erie phosphorus has been a target of remedial action plans. The phosphorus data base is relatively extensive; having a consistent record since the late 1960's. In addition, well over 100 values have been recorded annually from 1967 - 1982 providing 5680 data points over the 18 year period (Table 13). Significant reductions in total phosphorus have been documented for the central basin (Rosa 1986) however, a similar analysis for the western basin has yet to be undertaken. From the information presented in Table 13, the values seem to have decreased over the period of record. As indicated by Figure 14, the seasonal pattern for total phosphorus is complicated by biological, physical and meteorological interactions.

TOTAL DISSOLVED PHOSPHORUS*. Of the many phosphorus fractions that can be measured using conventional methods, total dissolved phosphorus represents the largest most readily available form. This phosphorus pool is comprised of orthophosphorus plus the dissolved organic fraction which is a mixture of organic extracellular and intercellular compounds having a broad range of molecular weights. The data base is made up of 4768 values spanning 1967 through 1979 and continuing again from 1981 to 1984 (Table 14). Seasonally, total dissolved phosphorus reflects a pattern similar to the seasonal fluctations in total phosphorus concentrations (Figure 15).

DISSOLVED PHOSPHORUS (ORTHO)*. The orthophosphorus data base is not as extensive as for total phosphorus or total dissolved phosphorus. However, a continuous record from 1968 through 1984 containing 2743 values was examined (Table 15). As is evident from Table 15, open lake western basin concentrations generally are below 10 ug/l, consequently the data recorded prior to 1971 is questionable. Since orthophosphorus is the most readily assimilated phosphorus form, seasonally it shows an inverse relationship with phytoplankton biomass. This is indicated by comparing the seasonal orthophosphorus changes (Figure 16) with seasonal changes of chlorophyll (Figure 22).

NITRATE + NITRITE. Suprisingly, the nitrate + nitrite data base was not as complete as would be expected. Significant gaps exist in the data during the 1960's and 1970's (Table 16). This is an unfortunate circumstance since this variable would be very useful in defining an offshore region within the basin as well as examining long term trends. Even with the relatively sparce data base (n = 1906), a very distinct seasonal pattern was evident (Figure 17); with peak concentrations occurring during the spring followed by decreasing concentrations through the summer and into the fall.

AMMONIA. The ammonia data set contains 1248 values spanning from 1968 through 1982. As with most of the variables, the 1978-1979 intensive years dominate the data, contributing nearly half of the values to the total data set (Table 17). Ammonia concentrations peak during spring runoff and decrease through the summer months (Figure 18). Due to the restricted nature of the data base and the analytical problems associated with measuring ammonia concentrations below 20 ug/l, it was not considered a primary source of information on the western basin.

TOTAL INORGANIC NITROGEN. This data base was examined for general interest purposes. Total inorganic nitrogen should consist of the sum product of nitrate, nitrite and ammonia values. Dissolved nitrogen is not generally measured. It is evident from a comparison of Tables 16, 17 and 18, that the data base is not complete. Two reasons for the discrepancies are speculated; not all forms of inorganic nitrogen were measured at all sites thus the summation was not possible and second, the forms were not summed thus the total inorganic nitrogen data was not entered into STORET. Whichever the case, this data base was not examined beyond this inventory. As would be expected, the seasonal cycle was similar to ammonia and nitrate + nitrite (Figure 19).

KJELDAHL NITROGEN. The organic nitrogen data base was considerably greater than originally anticipated; having a total of 3558 values and spanning nearly the entire period of record (Table 19). Seasonally, the values responded to spring peak loadings and depletion by summer pulses of phytoplankton (Figure 20). This data base was not used in defining the offshore region.

DISSOLVED SILICA. The silica data base was somewhat sporadic in its annual distribution; dominated by the 1978 and 1979 field seasons (Table 20). Of the 2805 values recorded, most of the data occurred during the summer months. Silica concentrations peak during the spring runoff period and decrease through the year (Figure 21). The early spring concentrations are associated with tributary inputs while the late spring and summer decreases in concentrations are attributed to diatom utilization.

CHLOROPHYLL a* (CORRECTED and UNCORRRECTED). Chlorophyll a values were accessed under two files, one for uncorrected and one for corrected chlorophyll. Other than the somewhat lower values recorded for the corrected data (which is to be expected), the two files were very similar. The uncorrected file contained data for 1968 through 1982 while the period of record for corrected values was from 1972 through 1982 (Tables 21 and 22). The seasonal cycle indicated the unimodal curve characteristic of the basin (Fay 1976) (Figures 22 and 23). For basin definition via cluster analysis, the uncorrected data base was utilized.

PHEOPHYTIN. The data base for pheophytin concentrations was examined for general interest and for comparison with the chlorophyll files. The period of record for the data base was limited to 1974 to 1982; containing 2053 records (Table 23). The seasonality was similar to that shown for chlorophyll with highest concentrations occurring during peak chlorophyll episodes (Figure 24).

DATA QUALITY. The data presented in Tables 2-23 and Figures 4-24 provide information for a reasonable range of values one would expect to find in the open lake region. On occasion an unacceptable value was encountered, for example, a temperature of 311° C recorded during 1964. Only if such a value was encountered in a variable used for the cluster analysis was it removed from the working data base. Generally, unacceptable values accounted for less than 1% of the data set and were considered to be date entry errors.

MEANS VERSUS MEDIANS. One of the findings from the statistical analysis of the western basin STORET file was that medians provide a more descriptive characterization for some variables than is provided by statistical means. This is demonstrated by the means and medians presented below:

COMPARISON OF WESTERN BASIN MEANS TO MEDIANS
DERIVED FROM THE STORET DATA BASE (1947 - 1984).

VARIABLE	N	MEAN	MEDIAN	% DIFF (MED - X)
TEMPERATURE	10101	17.9	19.6	+ 9.50
CONDUCTIVITY	5897	277.4	266.4	- 3.60
CHLORIDE	3592	18.4	18.0	- 2.17
SULFATE	1291	25.3	22.8	- 9.88
SECCHI	1385	1.1	0.9	- 0.18
DISSOLVED OXYGEN	7892	9.6	9.4	- 2.08
DISSOLVED OXYGEN (%)	5088	97.3	97.0	- 0.31
pH	6400	8.4	8.4	0.00
TURBIDITY (JTU)	2721	8.8	4.5	-48.86
TURBIDITY (NTU)	2605	14.1	8.1	-42.55
TOTAL SUSPENDED SOLIDS	1229	20.3	13.0	-35.96
TOTAL PHOSPHORUS	5680	65.8	46.3	-29.64
TOTAL DISSOLVED PHOSPHORUS	4768	25.8	14.6	-43.41
DISSOLVED PHOSPHORUS-ORTHO	2743	7.7	3.3	-57.14
NITRATE + NITRITE	1906	1496.2	230.0	-84.63
TOTAL INORGANIC NITROGEN	2589	355.0	226.0	-36.34
KJELDAHL NITROGEN	3558	731.9	390.0	-46.71
DISSOLVED SILICA	2805	40.9	0.7	-98.29
CHLOROPHYLL (UNCORRECTED)	2257	22.4	16.5	-26.34
CHLOROPHYLL(CORRECTED)	2246	20.3	14.8	-27.09
PHEOPHYTIN	2053	4.0	2.9	-27.50

For many variables the difference between the mean and the median was not appreciable. However for those variables which contained values that were much higher or lower than the median (up to 20% of the entire data base), the mean and the median were frequently found to be very different (ie. Turbidity, Total Suspended Solids, Total Phosphorus, Orthophosphorus, Nitrate + Nitrite and Dissolved Silica).

CLUSTER ANALYSIS

In order to define a representative western basin open water region that would provide information for basin characterization and trend analysis, a cluster analysis procedure was utilized. The method employed by El-Shaarawi (1984) to define an offshore sampling area in the central and eastern basins was used as a model for the western basin study. Thus, careful attention was given to the various clustering methodologies and the criterion for determining the appropriate number of clusters used by El-Shaarawi. There are many different existing clustering techniques and over 200 algorithms which can be divided into four major categories;

1. Ordination Techniques
2. Hierarchical Methods
3. Partitioning (Non-hierarchical)
4. Clumping or Clique

Milligan (1978) presents an excellent overview of these four algorithm types and the advantages and disadvantages of each.

Clustering is a means of grouping variables according to their magnitude and interrelationship with no assumptions made regarding the number of groups or the group structure. Grouping is done on the basis of similarities or distances, where a large distance corresponds to a dissimilar relationship or in this case a dissimilar concentration. Initially, there are as many clusters as there are data points. Concentrations which are most similar are first grouped and then these initial groups are merged according to their similarities.

El-Shaarawi (1984) utilized a non-hierarchical nearest centroid clustering method which included automatic seed selection, criteria for the elimination of clusters with too few members, splitting of elongated clusters and clumping of clusters which are too close together. In dealing with central and eastern basin data sets, El-Shaarawi clustered on a survey by survey basis, thereby avoiding any temporal complications. In addition, El-Shaarawi utilized only surface data, thus eliminating problems associated with a single station being placed in two or more clusters as a result of concentration differences at various depths.

The clustering program utilized for the western basin analysis was titled FASTCLUS and was accessed through SAS (Ray, 1982). FASTLCLUS was designed for disjoint (non-overlap) clustering of very large data sets (100 - 100,000 observations). The FASTCLUS clustering procedure is based upon Euclidean or straight-line distances computed from one or more quantitative variables and is an iterative process that can find satisfactory clusters with only two or three passes through the data.

This procedure has two objectives;

1. To place each observation in a cluster with similar observations.
2. To minimize the sum of the squared distances between individual values and the cluster means.

FASTCLUS is based on a method that Anderberg (1973) refers to as nearest centroid sorting. Initial cluster seeds (i.e. individual observations) are selected as a first estimation of the cluster means. Each observation in the data set is then assigned to the nearest seed (concentration), thereby establishing temporary clusters. This process is repeated until there are no longer any changes in the cluster selection. FASTCLUS is very sensitive to outliers and can be an effective method for detecting outliers since they will appear as clusters with only one member.

Cluster information from this study is presented in tabular format as well as plotted in graphical form. The X - Y coordinates represent latitude and longitude thereby providing a western basin map of the resulting information. The spatial zones determined by cluster analysis were defined by El-Shaarawi (1984) as regions of the lake, although not necessarily continuous, which exhibit concentrations that can be considered to come from the same probabilty distribution.

SINGLE VARIABLE CLUSTERS

Selection of the variables employed in cluster analysis has a great deal of influence on the resulting clusters. To demonstrate this, imagine the final cluster for a deck of cards if color was the variable of choice (Figure 25 a). For bridge players, the most significant clusters would be formed by selecting the cluster variables of "Honors Versus Trash" or tens, jacks, queens, kings and aces versus the face value cards (Figure 25 b). For the game Hearts, two clusters would also be produced. The resulting clusters are non-continuous due to the placement of the queen of Spades with all the Hearts (Figure 25 c). Four clusters result when suit is the variable of choice (Figure 25 d) and if selection is made by face card value then 13 clusters will result (Figure 25 e). Finally, if a combination of color and face card value are used then 26 clusters will result (Figure 25 f) (Anderberg,1973). As expected, the importance of variable selection is clear in the previous playing card example, however it is much more obscure for limnological variables.

Before attempting to define an open lake sampling region based upon multi-variable cluster analysis, it was necessary to analyze each of the individual variables using the single variable cluster routine. This first step was designed to aid in selecting the appropriate number of clusters; to define a region representative of the open waters; determine if extreme values should be eliminated; determine if seasonal data distribution influences the distribution of clusters, and finally determine which variables should be used to best characterize the open water region.

The initial step taken to develop a single variable clustering protocol was to experiment with a series of test clusters. The clustering was initiated for the western basin data utilizing two conservative variables, conductivity and chloride. These variables were appropriate for the initial testing due to:

1. The completeness of the data over the period of record.
2. The broad geographical distribution of the data.
3. The large number of data points; chloride (n = 3592) and conductivity (n = 5897).
4. The broad range of values found in each data set; chloride (3.2 - 290 mg/l) and conductivity (34.0 - 1100 umhos/cm).

Each of these data bases was accessed initially without removing any outlying values. The first step was the production of a 20 cluster series for each variable. This sequence consisted of clustering the data base nineteen different times. Each clustering exercise varied in the number of clusters processed. For example, the original data base first produced two clusters, then three clusters and so on up to twenty.

The first test series to determine the optimum number of clusters necessary to represent the open water region was made using the variable chloride. The maximum within-cluster Euclidean distance (d) of the most populated cluster (containing the most data points) in each of the 2 to 20 cluster routines was plotted (Table 24 and Figure 26). From this data, the optimum number of clusters appears to be 6 (Figure 26). By design, the test provided information primarily on the largest cluster (greatest N). For example, when the cluster size was selected to be 2, the largest cluster contained 3166 members out of a possible 3592 data points. The mean concentration was 17.0 mg/l having a maximum between-cluster distance of 14.2. When 6 clusters were selected, the largest cluster had 1690 members with a mean chloride concentration of 15.1 mg/l and a maximum distance of 3.7. Increasing the cluster limit to 7 had a small impact on the the largest cluster concentration (increasing from 15.1 to 18.8 mg/l) but more importantly it had no impact on the maximum distance within the largest cluster (d = 3.7). In other words, after the sixth cluster there was no reduction in distance associated with the addition of another cluster or no improvement in the reliability of the cluster.

Next, a series of clusters ranging from 5 through 12 were developed (Tables 25 - 32, respectively). Since FASTCLUS contains no format criterion for the elimination of clusters with too few members, some clusters were obtained with disproportionately small memberships. For example, in the five cluster series, cluster Number 1 contained only seven members (Table 25). From the concentration range of the cluster it is apparent that these 7 members were outliers representing 0.2 % of the data set (N= 3496). In the 12 clusters series (Table 32), 4 of the 12 clusters had a limited membership (n < 12).

A similar test procedure was undertaken with conductivity. The optimum number of clusters utilizing the conductivity data appeared to be five (Figure 27). It should be noted that the difference in maximum within-cluster distance was greater for conductivity than chloride. This was attributed to a greater conductivity concentration range (100 - 600 umhos/cm) compared with chloride (3 - 76 mg/l). As with the chloride cluster series, the maximum Euclidean distance within the largest cluster was plotted for the 2 to 20 cluster series (Figure 27, Table 33). The breakpoint in the maximum distance curve assumes a different shape when compared with chloride (Figure 26). The maximum distance when two clusters were designated was 151.5, having a mean of 268 umhos/cm. When five clusters were selected the mean decreased to 263.6 umhos/cm and the maximum distance dropped to 56.4. The reduction in maximum distance continues until the 12 cluster series. At this point the maximum distance stablizes and the addition of more clusters does not decrease the distance significantly. When conductivity and chloride were compared for equivalent within-cluster distances, conductivity required 15 clusters (d = 14.1, Table 33) while chloride required only a two cluster series (d = 14.2, Table 24). Thus, determination of the appropriate cluster size was a compromise between minimizing Euclidean distance and meeting the study objectives.

Further analysis of individual variables was used to determine the appropriate number of clusters for the multi-variable cluster step. Figure 28 shows the breakpoint for the determination of the appropriate number of clusters using the ratio of the between-cluster to within-cluster variance (RSQ/(1-RSQ)) for western basin conductivity. Six clusters appear to agree with the breakpoint determined using the maximum distance within the most populated cluster analysis (Figures 26 and 27). El-Shaarawi (personnel communication) recommended the within - between ratio as the best method for determining optimum cluster number. Ideally, the within-cluster variance will be small indicating internal cohesion and the between-cluster variance will be high indicating external isolation (Milligan, 1978), resulting in a RSQ/(1-RSQ) value or variance ratio approaching zero. The cubic clustering criterion should also be at a minimum to accurately determine the appropriate number of clusters (Sarle,1983). In Table 47 and Figure 29 the minimum cubic clustering criterion which optimizes the number of clusters in which the variance ratio is lowest occurs at six clusters. Keep in mind that the number of clusters specified also needs to accommodate the goals and objectives of the study.

The second phase of single variable clustering involved reviewing the data base using a reasonable concentration range for the western basin as presented in the following table. This exercise was designed to eliminate the extreme outliers, both high and low. Each data base was examined for outliers and an acceptable concentration range was chosen based upon the mean, median, standard error and frequency histogram. In general, ranges that were established eliminated 1% or less of the values found within a data base. The ranges are as follows:

VARIABLE	ACTUAL RANGE	ACCEPTABLE RANGE
CONDUCTIVITY (umhos/cm)	34.0 - 1100.0	100.0 - 601.0
CHLORIDE (mg/l)	3.2 - 290.0	3.0 - 76.0
TURBIDITY (JTU)	0.4 - 230.0	0.3 - 100.0
TURBIDITY (NTU)	0.8 - 280.0	0.3 - 100.0
TOTAL SUSPENDED SOLIDS (mg/l)	0.1 - 398.6	0.0 - 141.0
TOTAL PHOSPHORUS (ug/l)	0 - 874.0	2.0 - 500.0
TOTAL DISSOLVED PHOSPHORUS (ug/l)	0 - 958.3	1.0 - 300.0
NITRATE + NITRITE (ug/l)	0 -55,000.0	0.0 -12,000.0
CHLOROPHYLL a (TOTAL) (ug/l)	0.1 - 129.0	0.0 - 130.0
CHLOROPHYLL a (CORRECTED)(ug/l)	-3.1 - 120.2	0.0 - 121.0

The next step was to examine the affect that seasonality had on the concentration range. Since the data collection is largely dependent on meteorological conditions, the winter period (January - March) generally contained the smallest data base. The five cluster series for both chloride and conductivity were examined for seasonal affects (Tables 34 and 35). Two tables present the data for each of the five clusters for the entire year and are subdivided into seasonal units for each individual cluster. Table 35 provides the clearest example using the conductivity data base. Cluster three contains the most members (N = 4526) and was considered to be most representative of the open water. Cluster three had a mean value of 257 umhos/cm and was well represented in all seasons with the exception of SEASON 1 (WINTER). More importantly, nearly all the data collected during the winter months is from nearshore and water intake locations. Since the study objective is to establish an open lake sampling strategy, the winter data was considered inappropriate. Therefore to avoid any spatial biases, the winter data was not included for any variable in the analysis.

Finally, single variable clustering was used to discern which variables are the most sensitive and thus should be included in the multi-variable cluster approach. Single variable clusters were examined for all the data bases having sufficient information. After interpreting the individual clusters, those variables found to be most sensitive geographically were selected for inclusion in the multi-variable analysis. Graphic interpretations have been included to illustrate the term "sensitivity" (Figures 30 and 31). For example, a variable such as chloride which exhibits a large concentration range and results in a strong geographically definable concentration gradient is considered to be sensitive (Figure 30). Consequently, the distribution of the most dominant cluster / concentration was limited geographically. In contrast, the most dominant conductivity cluster was so expansive in distribution that it incorporated nearly the entire western basin and was therefore considered to be "insensitive" (Figure 31).

Single variable cluster means (Tables 37 - 44) had a calculated R-squared of greater than 0.97 for most of the major variables, indicating good internal cohesion. The five variables selected for multi-variable analysis were chacterized by a low variance ratio (RSQ/(1-RSQ). The low variance ratio indicates the formation of good clusters as a result of high internal cohesion (low within-cluster distance) and high external isolation (large between-cluster distances). Based upon the single variable cluster performance and the limnological significance of the individual and combined variables, the following five variables were included in the multi-variable cluster analysis:

VARIABLE	VARIANCE RATIO
Turbidity	16.89
Total Phosphorus	14.83
Total Dissolved Phosphorus	15.06
Chloride	8.94
Chlorophyll (Uncorrected)	17.94

Conductivity was found to have a low sensitivity for detecting geographical concentration differences and therefore was not used in the multi-variable cluster analysis. Nitrate + Nitrite data was not used because of a very high variance ratio (76.38) indicating poor cluster formation.

MULTI-VARIABLE CLUSTERING

Before FASTCLUS could be applied to the multi-variable analysis, standardization of the data was necessary. In cases where all variables are expressed in the same unit structure and are within an order of magnitude of each other, standardization is probably not necessary. However in this case, where the difference between concentrations is utilized as the criterion for establishing clusters (cluster distances), it was necessary to apply a standardization procedure. The standardization was accomplished by subtracting the specific variable mean concentration from each individual observation and dividing by the standard deviation of the variable mean. For interpretation purposes, the actual cluster means were re-calculated (re-standardized) following the clustering phase. The results from the first attempt at multiple variable clustering produced a non-continuous open lake sampling region (Figure 32). El-Shaarawi (personnel communication) professes that this type of zonation results from negatively skewed data.

Prior to initiating the second generation multi-variable cluster, experiments were conducted to verify if the standardized data was skewed. Once established, a log transformation and a log-log transformation were performed to test if either procedure would eliminate the skewness. Results indicated that the log-transformation was superior to the log-log transformation because of the similarity between the mean and median, thus showing that the skewness had been eliminated. The log-log transformation appeared to reduce the variablity in the data to an extreme so that differences were not easily detectable. A comparison of single variable clusters resulting from non-transformed and transformed data showed very similar variance ratios for all variables. An example illustrating the small differences in cluster statistics obtained using standardized non-transformed and standardized log transformed chloride data can be seen in Tables 36 and 45, respectively.

COMPARISON OF MEANS AND MEDIANS OF LOG AND LOG-LOG TRANSFORMED DATA

VARIABLE	LOG MEAN	LOG MEDIAN	LOG-LOG MEAN	LOG-LOG MEDIAN
Turbidity	1.86	1.79	0.45	0.58
Total Dissolved Phosphorus	10.80	10.82	1.33	1.36
Total Phosphorus	9.61	9.48	0.92	0.94
Chloride	2.87	2.88	1.04	1.06
Chlorophyll (Uncorrected)	2.85	2.97	0.97	1.09

In comparing cluster variance for standardized non-transformed multi-variable data (Table 46) and standardized log transformed multi-variable data (Table 47), the estimated R2 values were identical, however, the cubic clustering criterion and variance ratios were found to differ slightly. The variance ratios were somewhat higher for the log transformed data in all cases except one. The cubic clustering criterion values were similar for the two methods but were generally higher for the log transformed data. Both criteria indicate that cluster formation is slightly better with non-transformed data. However, transformation is necessary to avoid skewness and non-continuous clusters.

RESULTS FROM THE MULTI-VARIABLE CLUSTER ROUTINE

As determined from experiments with single variable clusters, a minimum of six clusters was found to be necessary to characterize the western basin and define the open water sampling region. In order to determine which of the clusters derived from the multi-variable cluster routine best represented the open waters, a comparison of individual cluster means for each variable was made with the mean and median derived from the entire western basin data set. As shown in Table 48, cluster 7 was the most representative of the individual variable median concentrations calculated for the wesern basin. Other clusters indicated similar concentrations for one or more variables, but only cluster 7 was uniformly representative of the open lake western basin region for all variables. In the case of turbidity and chlorophyll, only cluster 7 was close to characterizing the open lake conditions. Western basin open lake contours illustrate how closely the cluster means represent actual open lake conditions (Figures 33 - 38).

Once the open lake region was defined, a more detailed examination of the actual data distribution within the region was undertaken. To accomplish this a grid system was constructed for the area between longitude 82°32" and 83°26" and latitude 41°38" to 42°00" with each grid being two minutes (") square (Figure 39). It was found that of the 297 defined grids only 132 grids contained data. Next, a median was calculated for each grid using standardized, log transformed and log-log transformed data. Calculations were made using the data for spring, summer, fall and the combination of all three seasons. A multi-variable cluster analysis was performed using the mean values for each grid within the region.

SAMPLING STRATEGY FOR FUTURE DATA COLLECTIONS

The geographic boundary for the western basin sampling region was made by mapping the multi-variable cluster (Cluster 7) derived from the previously selected variables. The initial area established by the clustering of standardized data, yielded a geographically non-continuous region (Figure 32). The second generation multiple-variable cluster analysis using log transformed data resulted in a larger, continuous, sampling region (Figure 40).

In order to determine the number of stations needed to sample the open waters of the western basin, the grid clustering strategy (previously disscussed) was utilized. The variance of the grid clusters incorporating spring, summer and fall was compared to the variance of the sampling region obtained from the second generation multi-variable cluster. To determine the number of grids necessary to maintain a similar standard deviation or variance for the two methods, the Euclidean distance technique was utilized. The grid data was standardized to make it unit free so that the Euclidean distances could be correctly calculated. The cut-off points between grid segments were subjectively chosen (Table 49). The Euclidean distances plotted in 5 dimensional space produced five grid segments. This was translated into five geographic segments for the sampling region. Each segment would than be represented by a station, resulting in five stations to characterize the open water western basin region.

Station location within the segments was selected based on two criteria; 1) to cover the geographical expanse of the region; and 2) to select stations, if possible that could meet the first criterion and provide a historical data base for trend purposes (Figure 41). Three stations in the STORET data file were within the defined region and had data bases extending back to 1973. Two new station locations were selected to cover the geographical expanse of the area (91 and 92).

Due to a lack of information in the south-eastern portion of the basin, a sixth station was added outside the defined sampling region. It is intended that information from this location will enhance future attempts to examine this basin as well as provide a reference for comparison with the cluster stations. The six station locations are as follows:

STATION NUMBER	LATITUDE (N)	LONGITUDE (W)	
58	41 41.1	82 56.0	REFERENCE SITE
59	41 43.6	83 09.0	
60	41 53.5	83 11.8	
61	41 56.8	83 02.7	
91	41 50.4	82 55.0	
92	41 57.0	82 41.2	

The number of surveys to be conducted during future western basin surveillance programs was determined based upon the variability calculated for each season (spring, summer and fall). By taking the square root of the sum of the coefficient of variation (Standard Deviation / Mean) for each parameter utilized in the multi-variable cluster analysis, an estimate for seasonal variability was calculated. This estimate was then used to determine the number of surveys necessary to annually characterize the western basin and to track long term trends.

$$\text{SEASONAL VARIABLITY} = \sqrt{\frac{SD\ TURB^2}{X\ TURB} + \frac{SD\ TP^2}{X\ TP} + \frac{SD\ TDP^2}{X\ TDP} + \frac{SD\ CL^2}{X\ CL} + \frac{SD\ CHL^2}{X\ CHL}}$$

From this calculation procedure it was determined that the summer period was the most stable, having a coefficient of variation (CF) equaling 1.757, with the fall period indicating only a slightly greater value (CF = 1.855). The greatest variability occurred during the spring season, with a CF = 2.82. By comparing these three variances, one can determine the number of surveys that should be sampled during each of the seasons to provide accurate annual concentration estimates for the offshore waters of the basin.

SUMMER : FALL : SPRING
1.75 > 1.85 > 2.82

For example, by using the summer variance as the reference point, the appropriate number of surveys necessary for each season can be determined. This procedure indicates that a greater number of surveys need to be conducted during the spring (April-May) when variability is the greatest. For example, if the surveillance program calls for two summer survey then 3.2 spring surveys should be conducted and a minimum of seven surveys need to be conducted annually.

	SUMMER	FALL	SPRING	TOTAL
NO OF SURVEYS	2.0	2.12	3.2	7
	3.0	3.18	4.8	11
	4.0	4.24	6.4	14

RECOMMENDATIONS

1. Based upon this review of the western basin data base and the analysis of the seasonal variability, it is recommended that a minimum of seven western basin surveys be conducted annually (3 spring, 2 summer and 2 fall). In addition, it is recommended that a minimum of two weeks between surveys be maintained during periods of high variablity (ie, spring).

2. After a three year data base has been established using the proposed station pattern and sampling frequency, it is recommended that the new data base be evaluated in a manner similar to this study.

3. The existence of the STORET data base was useful for this study but the inventory demonstrated that there are definite problems with the reliablity of many of the data points. A clean-up of the existing data base for the priority parameters is called for.

TABLES

Table 1. Summary of STORET Western Basin Data Inventory 1947-1984

SAS

VARIABLE	LABEL	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	SUM	VARIANCE
A1	DEPTH	11253	20.24	70.60	0.00	832.00	832.00	227750.25	4984
A2	LAB-ID-NO	19	749900.00	0.00	749900.00	749900.00	0.00	14248100.00	0
A3	WATER-TEMP	10101	17.86	8.40	0.00	311.00	311.00	180414.60	71
A4	AIR-TEMP	6126	19.12	6.35	0.00	35.00	35.00	117127.39	40
A5	WEIGHT	247	1.88	2.00	0.16	16.00	15.84	464.97	4
A6	LENGTH	261	15.00	4.42	7.30	28.90	21.60	3916.06	20
A7	BAROM-PRESS	2194	763.16	25.76	90.02	775.00	684.98	1674371.40	664
A8	FIELD-ID-NO	250	148.61	309.75	0.00	801.00	801.00	37152.00	95944
A9	INCDT-LT-REMN	89	24.60	17.58	2.00	65.00	63.00	2189.00	309
A10	CLOUD-COV	1101	48.42	35.26	0.00	100.00	100.00	53310.00	1243
A11	WIND-VELOC	6567	11.57	5.93	0.00	39.13	39.13	75976.95	35
A12	WIND-DIR-N	5233	184.15	93.53	0.00	360.00	360.00	963634.00	8748
A13	WIND-D-AZIMU	1280	198.93	94.66	0.00	360.00	360.00	254628.00	8960
A14	TURB-JKSN	2721	8.70	15.44	0.40	230.00	229.60	23684.15	238
A15	SAMP-LOC-VERT	206	168.21	146.33	50.00	500.00	450.00	34651.00	21413
A16	TURB-TRANS	75	0.93	1.36	0.10	9.10	9.00	69.50	2
A17	TURB-HLGE	199	8.03	8.10	0.00	50.00	50.00	1598.30	66
A18	TURB-TRBIDMT-HACH-FT	2605	14.09	19.49	0.80	280.00	279.20	36697.26	380
A19	TRANSP-SECCHI-INCH	69	33.04	13.91	12.00	66.00	54.00	2280.00	193
A20	TRANSP-SEECCHI-METER	1385	1.15	1.29	0.10	14.80	14.70	1588.73	2
A21	COLOR-FORL-ULE	119	15.29	3.80	9.00	22.00	13.00	1819.00	14
A22	ODOR-THRSH-NO	16	1.94	1.12	1.00	4.00	3.00	31.00	1
A23	REDOX-ORP-MV	95	449.79	69.86	320.00	564.00	244.00	42730.00	4880
A24	CNDUCTVY-FIELD-MICROMHO	2164	258.86	51.20	155.00	675.00	720.00	560183.00	2621
A25	CNDUCTVY-25C-MIC	5897	277.36	62.79	34.00	1100.00	1066.00	1635576.51	3943
A26	DO-PROBE-MG/L	9	8.92	2.67	7.00	13.80	6.80	80.30	7
A27	DO--MG/L	7892	9.55	2.01	0.10	24.50	24.40	75400.95	4
A28	DO-SATUR-PERCENT	5088	97.35	15.93	0.47	199.00	196.53	495302.49	254
A29	BOD-5DAYS-MG/L	299	2.14	2.12	0.00	19.60	19.60	638.80	4
A30	COD-LOWLEVEL	256	13.77	7.23	4.00	62.00	58.00	3523.90	52
A31	COD-MUD-DRY-WGT	63	71161.76	39750.70	3800.00	149999.88	146199.88	4483190.60	1580118092
A32	BOD-14DAYS	1	1.10	.	1.10	1.10	0.00	1.10	.
A33	CL2DMND-15MIN	16	0.12	0.04	0.05	0.20	0.15	1.90	0
A34	PH-SU	6400	8.42	0.40	6.00	10.00	4.00	53913.80	0
A35	LAB-PH-SU	43	8.03	0.33	7.40	8.70	1.30	345.50	0
A36	CO2-MG/L	37	2.49	5.63	0.00	28.50	28.50	92.30	32
A37	T-ALK-CACO3-MG/L	5074	60.59	40.07	2.00	175.80	173.80	307409.92	1606
A38	PHEN-PH-LEIN-AL	1046	3.91	4.25	0.00	34.00	34.00	4084.98	18
A39	CO3-ALK-CACO3	29	1.24	3.40	0.00	12.00	12.00	36.00	12
A40	HCO3-ION-HCO3	104	98.71	7.07	45.00	115.70	70.70	10265.80	50
A41	CO3-ION-CO3-MG/L	1	10.00	.	10.00	10.00	0.00	10.00	.
A42	RESIDUE-TOTAL	401	199.06	57.79	96.00	598.00	502.00	79823.00	3340
A43	RESIDUE-STUST-VOC	99	75.96	21.41	32.00	133.00	101.00	7520.00	458
A44	RESIDUE-TOT-FIX	83	134.58	40.50	87.00	311.00	224.00	11170.00	1640
A45	RESIDUE-DISS-105	354	178.75	40.25	82.00	347.00	265.00	63276.00	1620
A46	RESIDUE-VOL-FLT	485	14.14	26.23	0.31	360.00	359.69	6855.72	688
A47	RESIDUE-TOT-NFLT	1229	20.29	25.52	0.10	398.60	398.50	24936.60	651
A48	RESIDUE-VOL-NFL	146	18.21	13.81	1.00	96.00	95.00	2658.00	191
A49	RESIDUE-FIX-NFLT	179	21.47	32.75	0.40	344.00	343.60	3843.90	1072
A50	DIL-GRSE-MUD-HEXN	44	1094.23	2036.61	0.40	8400.00	8399.60	48146.20	4147779

Table 1. Summary of STORET Western Basin Data Inventory 1947-1984 (Continued)

SAS

VARIABLE	LABEL	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	SUM	VARIANCE
B1	OIL-GRSE-MUD-FRGR	38	2118.26	2625.27	118.00	14000.00	13882.00	80494.00	6892067
B2	TOTAL-N-N	1963	0.79	0.82	0.10	10.55	10.45	1552.06	1
B3	DISS-NITROGEN	187	0.37	0.18	0.09	1.10	1.01	69.18	0
B4	ORG-N-N	2419	0.42	0.40	0.00	10.00	10.00	1004.63	0
B5	ORG-N-SUSP-N	138	0.18	0.10	0.04	0.66	0.62	24.22	0
B6	ORG-N-DISS-N	68	0.14	0.06	0.02	0.28	0.26	9.52	0
B7	NH3+NH4-N-DISS	2416	0.06	0.08	0.00	0.57	0.57	135.44	0
B8	NH3-NH4-N-TOTAL	3541	0.08	0.12	0.00	1.70	1.70	300.89	0
B9	NH3-MUD-DRY	54	173.14	159.92	2.57	470.00	467.43	9349.73	25573
B10	NO2-N-DISS	70	0.01	0.05	0.00	0.38	0.38	0.76	0
B11	NO2-N-TOT	2052	0.02	0.03	0.00	0.35	0.35	34.79	0
B12	NO3-N-TOT	2511	0.31	0.62	0.00	8.60	8.60	786.16	0
B13	TOT-KJEL-N	3558	0.73	1.25	-0.98	9.90	10.88	2603.94	2
B14	ORGAN-N-MUD-D-WT	2	2450.00	494.97	2100.00	2800.00	700.00	4900.00	245000
B15	KJELDL-N-TOT-MU	80	1776.82	1188.92	80.00	4800.00	4720.00	142146.00	1413530
B16	NO2-NO3-N-TOT	1906	1.50	5.85	0.00	55.00	55.00	2851.80	34
B17	NO2-NO3-N-DISS	1341	0.37	0.45	0.00	5.50	5.50	490.15	0
B18	NO2-NO3MUD-D-W	5	50.10	9.59	41.60	65.50	23.90	250.50	92
B19	T-INTRG-NITROGEN	2509	0.35	0.62	0.00	9.15	9.15	919.03	0
B20	T-PO4--PO4	164	0.29	0.34	0.02	4.10	4.08	46.80	0
B21	SOLPO4-T-PO4	299	0.48	5.43	0.01	94.00	93.99	142.90	30
B22	ORTHOPO4-PO4	2	0.06	0.04	0.03	0.09	0.06	0.12	0
B23	PHOS-TOT	5680	0.07	0.06	0.00	0.87	0.87	373.77	0
B24	PHOS-DIS	4768	0.03	0.03	0.00	0.96	0.96	122.92	0
B25	PHOS-SUS	126	0.02	0.01	0.00	0.10	0.09	2.16	0
B26	PHOS-MUD-DRY-WGT	162	373.98	548.97	0.03	2300.00	2299.97	60584.21	301366
B27	PHOS-DIS-ORTHO	2743	0.01	0.02	-0.98	0.25	1.23	21.26	0
B28	T-ORG-C-C	337	2.46	2.78	0.00	12.32	12.32	830.54	8
B29	D-ORG-C-C	330	1.83	1.80	0.00	10.28	10.28	603.66	3
B30	ST-INORG-C	66	20.27	1.82	9.90	23.30	13.40	1337.60	3
B31	ORG-C-C	206	0.90	0.61	0.01	3.93	3.92	258.24	0
B32	T-CARBON-C	66	22.83	1.84	14.00	27.10	13.10	1506.50	3
B33	CYANIDE-CN-TOT	21	0.00	0.00	0.00	0.00	0.00	0.09	0
B34	CYANIDE-DECMG/KG/DRY/WGT	3	2.60	4.33	0.10	7.60	7.50	7.80	19
B35	TOT-HARD-CACO3	70	117.58	20.59	97.00	215.00	118.00	8230.40	424
B36	CALCIUM-CACO3	199	38.42	17.96	26.00	99.00	73.00	7645.00	322
B37	CALCIUM-CA-DISS	194	30.96	3.73	25.00	50.00	25.00	6005.40	14
B38	CALCIUM-CA-TOT	61	31.98	5.82	8.20	44.10	35.90	1950.50	34
B39	CA-MUD-DRY-WGT	20	30276.80	24022.66	2.00	97900.00	97898.00	605536.00	577087995
B40	MGNSIUM	73	14.05	7.97	7.00	33.60	26.60	1025.70	64
B41	MG-MUD-DRY-WGT	52	14531.73	8064.86	0.00	28900.00	28900.00	755650.00	65041927
B42	MGNSIUM-MG/DISS	194	7.95	1.43	6.30	13.00	6.70	1541.40	2
B43	MGNSIUM-MG-TOT	176	7.72	3.02	4.80	34.00	29.20	1359.06	9
B44	SODIUM-NA-TOT	206	7.88	3.30	0.10	19.80	19.70	1622.82	11
B45	SODIUM-NA-DISS	270	10.26	3.19	4.55	20.40	15.85	2770.30	10
B46	PERCENT-SODIUM	0	.	.	.	.	.	.	.
B47	PTSSIUM-K-DISS	270	1.32	0.52	0.76	5.00	4.24	355.27	0
B48	PTSSIUM-K-TOT	193	1.11	0.55	0.08	7.00	6.92	214.00	0
B49	K-MUD-DRY-WGT	7	657.70	1127.83	0.40	2500.00	2499.60	4603.90	1272003
B50	CHLORIDE-TOT	3592	18.44	7.52	3.20	290.00	286.80	66226.22	57

Table 1. Summary of STORET Western Basin Data Inventory 1947-1984 (Continued)

SAS

VARIABLE	LABEL	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	SUM	VARIANCE
C1	SULFATE-SO4-TOT	1291	25.34	12.77	7.20	285.50	278.30	32710.59	163.15
C2	SULFATE-SO4-DISS	192	22.06	7.70	10.00	58.00	48.00	4236.30	59.28
C3	FLUORIDEF-DISS	11	0.10	0.01	0.08	0.11	0.03	1.09	0.00
C4	FLUORIDEF-TOT	211	0.19	0.08	0.08	0.47	0.39	40.53	0.01
C5	SILICA-DISOLVED	2805	40.93	231.06	0.00	1970.00	1970.00	114820.22	53391.03
C6	SILICA-TOT	22	0.74	0.49	0.20	2.60	2.40	16.21	0.24
C7	SILICATE-UNF-REAT	80	0.52	0.22	0.10	1.00	0.90	41.37	0.05
C8	AS-INOR-AS-TOT	39	6.10	4.05	2.00	10.00	8.00	238.00	16.41
C9	ARSENIC-AS-DISS	2	0.50	0.14	0.40	0.60	0.20	1.00	0.02
C10	ARSENIC-AS-TOT	31	1.26	0.63	0.41	3.17	2.76	39.09	0.39
C11	AARSENIC-SSEDMG	177	12.46	14.50	0.88	140.00	139.12	2205.12	210.15
C12	ARSENIC-TISMG	12	0.02	0.03	0.01	0.10	0.09	0.21	0.00
C13	BARIUM-BA-TOT	33	17.70	4.91	13.00	31.00	18.00	584.00	24.09
C14	BA-MUD	51	47.27	25.82	7.00	110.00	103.00	2410.60	666.68
C15	BERYLIUM-BE	33	0.16	0.08	0.00	0.20	0.20	5.40	0.01
C16	BERYLIUM-SEDMG	15	0.88	0.32	0.10	1.00	0.90	13.20	0.10
C17	BORON-B-TOT	33	80.03	66.49	32.00	320.00	288.00	2641.00	4421.47
C18	B-MUD	20	55.05	34.90	8.00	80.00	72.00	1101.00	1218.05
C19	CADMIUM-CD-DISS	179	2.06	3.16	0.10	10.00	9.90	369.44	9.97
C20	CADMIUM-CD-DISS	201	2.03	4.11	0.00	39.00	39.00	407.93	16.86
C21	CD-MUD	184	3.11	3.09	0.20	21.00	20.80	572.65	9.55
C22	CHROMIUM-SEDMG	184	59.83	70.83	2.40	530.00	527.60	11009.30	5017.28
C23	CHROMIUM-CR-DISS	155	7.33	21.99	0.10	140.00	139.90	1136.45	463.76
C24	CHROMIUM-HEX-VAL	4	50.00	0.00	50.00	50.00	0.00	200.00	0.00
C25	CHROMIUM-CR-TOT	223	23.09	127.84	0.35	1900.00	1899.65	5149.04	16342.20
C26	COBALT-CO-DISS	19	0.69	0.44	0.10	1.80	1.70	13.10	0.19
C27	COBALT-CO-TOT	33	1.00	0.00	1.00	1.00	0.00	33.00	0.00
C28	CO-MUD	25	10.17	8.85	1.70	33.70	32.00	254.30	78.37
C29	COPPER-CU-DISS	186	128.96	257.40	1.00	1800.00	1799.00	23986.90	66256.15
C30	COPPER-CU-TOT	219	31.13	164.10	0.00	2200.00	2200.00	6816.69	26928.47
C31	COPPER-SEDMG	226	53.14	140.62	2.00	1500.00	1498.00	12009.10	19774.92
C32	IRON-FE-TOT	374	786.89	1002.72	6.20	7900.00	7893.80	294295.20	1005446.29
C33	ISRON-FE-DISS	211	74.61	290.63	1.00	3200.00	3199.00	15742.40	84465.15
C34	LEAD-Pb-DISS	195	16.34	81.62	0.05	840.00	839.95	3165.82	6661.95
C35	LEAD-PB-TOT	218	10.89	22.09	0.00	160.00	160.00	2373.02	487.99
C36	LEAD-SEDMG	188	363.92	406.17	0.40	2600.00	2599.60	68417.20	164971.87
C37	MN-MUD	161	193.64	205.37	9.00	730.00	721.00	31175.60	42176.09
C38	MANGNES-MN	199	30.09	33.19	0.01	260.00	259.99	5988.68	1101.54
C39	MANGNESE-MN-DISS	170	9.87	71.40	0.30	900.00	899.70	1678.18	5098.04
C40	MOLY-MO-DISS	46	1.02	0.42	0.60	2.00	1.40	46.70	0.18
C41	MOLY-MO-TOT	33	2.21	0.89	2.00	7.00	5.00	73.00	0.80
C42	MO-MUD	20	12.81	9.30	1.00	28.00	27.00	256.30	86.50
C43	NICKEL-NI-DISS	192	7.37	23.23	0.70	210.00	209.30	1415.28	539.85
C44	NICKEL-NI-TOT	207	23.25	45.90	0.00	570.00	570.00	4813.71	2106.61
C45	NICKEL-SEDMG	184	47.40	36.81	2.00	230.00	228.00	8722.00	1354.73
C46	NICKEL-TISMG	12	0.13	0.05	0.10	0.20	0.10	1.60	0.00
C47	SILVER-AG-TOT	33	0.88	0.19	0.60	1.00	0.40	29.00	0.03
C48	SILVER-SEDMG	20	2.80	2.48	0.30	8.00	7.70	56.10	6.17
C49	STRONTUM-SR-DISS	35	130.91	13.35	103.00	173.00	70.00	4582.00	178.20
C50	STRONTU-SER-TOT	18	22.62	51.80	0.12	145.00	144.88	407.17	2683.22

Table 1. Summary of STORET Western Basin Data Inventory 1947-1984 (Continued)

SAS

VARIABLE	LABEL	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	SUM	VARIANCE
D1	SR-MUD-DRY-WGT	7	106.43	25.78	59.00	130.00	71.00	745.00	665
D2	VANANIUM-V-DISS	127	1.05	1.14	0.35	5.30	4.95	133.76	1
D3	VANADIUM-V-TOT	170	1.61	2.18	0.10	13.00	12.90	272.69	5
D4	V-MUD-DRY-WGT	120	139.57	185.41	7.00	1700.00	1693.00	16749.00	34377
D5	ZINC-ZN-DISS	194	221.29	1402.64	1.00	19000.00	18999.00	42929.80	1967400
D6	ZINC-ZN-TOT	203	50.57	61.26	0.00	330.00	330.00	10266.40	3753
D7	ZINC-SEDMG/KG	229	74.51	306.18	-4000.00	1000.00	5000.00	17063.14	93744
D8	TIN/SN/TOT	33	15.79	5.81	5.00	20.00	15.00	521.00	34
D9	TIN-MUD	20	66.46	46.89	4.00	100.00	96.00	1329.30	2199
D10	ALUMINUM-AL-TOT	161	854.70	845.42	18.00	4200.00	4182.00	137606.00	714742
D11	ALUMINUM-AL-DISS	126	53.19	63.86	9.70	350.00	340.30	6702.30	4078
D12	AL-MUD	120	11410.18	8169.60	2.80	31000.00	30997.20	1369221.90	66742301
D13	LITHIUM-LI-DISS	56	2.26	1.69	1.00	9.40	8.40	126.70	3
D14	LITHIUM-LI-TOT	18	0.34	0.77	0.00	2.00	2.00	6.04	1
D15	LI-MUD	7	16.86	8.51	4.00	27.00	23.00	118.00	72
D16	SILICON-SI-DISS	93	48293.21	146598.61	220.00	666999.75	666779.75	4491268.80	21491151126
D17	SELENIUM-SE-DISS	2	0.15	0.07	0.10	0.20	0.10	0.30	0
D18	SELENIUM-SE-TOT	154	1.48	1.39	0.19	6.90	6.71	227.76	2
D19	SELENIUM-SEDMG-KG	135	23.64	20.23	0.61	98.00	97.39	3191.43	409
D20	TITANIUM-TI-TOT	33	13.85	15.40	3.00	67.00	64.00	457.00	237
D21	TI-MUD	13	108.62	49.23	1.00	180.00	179.00	1412.00	2424
D22	FE-MUD	208	17707.38	11688.60	1.00	51000.00	50999.00	3683134.00	136623440
D23	FLOATING-ALG-WAT	914	2.50	1.60	0.00	4.00	4.00	2280.50	3
D24	DEAD-FISH	914	0.31	0.61	0.00	3.00	3.00	286.00	0
D25	TURBID	456	2.36	0.67	0.00	4.00	4.00	1078.00	0
D26	BETA-TOT	98	5.49	2.66	0.00	15.00	15.00	536.10	7
D27	BETA-T-ERROR	98	2.45	1.93	1.00	10.00	9.00	239.70	4
D28	H-3-TOT	67	359.70	95.44	200.00	600.00	400.00	24100.00	9109
D29	H-3-TOTL-ERROR	67	200.00	0.00	200.00	200.00	0.00	13400.00	0
D30	TOT-COLI-MFIMENDO	2363	6788.61	140357.99	0.00	6600000.00	6600000.00	16041477.00	19700366023
D31	TOT-COLI-MFDLENDO	147	62.66	165.15	1.00	880.00	879.00	9211.02	27275
D32	TOT-COLI-MFIM-LES	1553	5700.26	13469.34	100.00	200000.00	199900.00	8852500.00	181423090
D33	TOT-COLI-MPN-CONF	90	3631.36	11265.60	13.00	93000.00	92987.00	326822.00	126913722
D34	FEC-COLI-MPNECMED	2	2872.50	1446.03	1850.00	3895.00	2045.00	5745.00	2091013
D35	FEC-COLI-MFM-FCBR	2212	90.68	1319.09	0.00	60000.00	60000.00	200595.05	1739986
D36	FECSTREP-MFKFAGAR	559	42.91	224.16	0.00	3900.00	3900.00	23986.00	50248
D37	FECSTREP-MF-M-ENT	518	22.37	108.04	1.00	1020.00	1019.00	11589.00	11674
D38	TOTCOUN-TPC20C4	1560	16945.40	128002.57	0.00	3900000.00	3900000.00	26434817.06	16384659013
D39	TOTCOUNT-TPC35C24	102	1058.24	2488.69	1.00	14600.00	14599.00	107940.00	6193566
D40	CHLRPHYL-A	335	10.38	9.16	0.00	61.53	61.53	3476.92	84
D41	CHLRPHYL-A-UG/L	2257	22.37	18.86	0.11	128.96	128.85	50481.00	356
D42	CHLRPHYL-A-UG/L-CORR	2246	20.28	17.86	-3.06	120.24	123.30	45559.44	319
D43	CHLRPHYL-B-UG/L	398	2.15	2.58	0.00	27.40	27.40	853.81	7
D44	PHPHTN-A-FLR-MTHD	332	4.04	5.50	-2.90	51.00	53.90	1339.72	30
D45	CHLRPHYL-C-UG/L	399	5.13	6.64	0.01	56.30	56.29	2045.66	44
D46	PHEOPHTN-A-UG/L	2053	4.01	4.01	-6.93	39.39	46.32	8237.95	16
D47	PHEOPHTN-RATIO-SPECTRO	193	1.54	0.13	1.10	1.82	0.72	298.07	0
D48	CHLRPHY-A-MG/L	897	0.01	0.01	0.00	0.07	0.07	10.52	0
D49	CHLRPHYL-B-MG/L	858	0.00	0.00	0.00	0.04	0.04	1.58	0
D50	PHENOLS-TOT-UG/L	667	3.56	3.85	0.00	35.00	35.00	2374.60	15

TABLE 2

ANNUAL AND SEASONAL DATA BASE INVENTORY
TEMPERATURE (° C) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	10101	17.9	19.6	8.4	0.0	311.0
SEASON 1*	254	2.7	2.0	2.4	0.0	15.5
SEASON 2*	3668	15.6	16.2	6.1	1.0	31.0
SEASON 3*	4604	22.8	23.0	7.7	8.2	311.0
SEASON 4*	1575	11.0	11.8	4.7	0.0	27.5
1947	63	15.0	14.5	6.2	0.0	25.0
1963	13	21.4	22.0	2.9	12.0	23.0
1964	254	24.9	22.0	31.1	8.0	311.0
1965	288	21.3	22.0	4.4	10.5	29.0
1966	164	22.0	25.5	5.9	9.5	27.0
1967	1011	19.0	21.1	4.6	6.0	27.1
1968	715	19.7	21.0	5.2	0.2	27.5
1969	638	20.0	20.0	5.5	1.1	29.0
1970	646	20.2	22.5	7.0	0.8	30.0
1971	519	20.5	23.0	6.1	0.0	27.0
1972	670	18.0	20.0	6.2	1.0	27.0
1973	749	18.7	22.0	7.1	3.0	34.0
1974	825	14.8	16.0	6.5	0.0	24.9
1975	806	14.4	15.3	7.7	0.0	27.2
1976	179	14.5	15.6	7.2	0.8	27.0
1977	392	14.8	13.1	6.4	0.5	25.5
1978	727	18.1	19.2	6.4	4.2	31.0
1979	849	15.3	17.5	7.2	0.0	31.0
1980	194	15.4	18.1	7.9	1.9	26.0
1981	220	13.5	12.7	6.6	0.1	25.0
1982	98	17.6	20.0	7.4	1.1	26.1
1983	52	16.6	13.4	7.6	6.7	26.7
1984	29	15.0	21.5	9.6	0.5	24.7

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 3

ANNUAL AND SEASONAL DATA BASE INVENTORY
CONDUCTIVITY (UMHOS/CM) AT 25 °C - WESTERN BASIN

YEAR	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
ALL DATA	5888	276.55	59.18	266	34.00	700.00
SEASON 1*	178	225.03	87.29	223	34.00	507.00
SEASON 2*	2177	294.42	70.93	276	118.00	700.00
SEASON 3*	2521	269.58	44.36	262	190.00	690.00
SEASON 4*	1012	264.54	43.70	257	157.00	473.00
1963	3	303.33	6.43	306	296.00	308.00
1964	207	287.82	38.90	286	216.00	540.00
1967	963	299.23	80.71	278	207.00	700.00
1968	674	285.31	44.22	278	220.00	640.00
1969	382	276.12	47.26	265	226.00	492.00
1970	381	272.55	36.40	271	220.00	606.00
1971	175	266.88	54.05	254	218.00	630.00
1972	166	269.15	25.85	264	201.00	350.00
1973	280	265.38	35.71	261	200.00	440.00
1974	57	270.98	18.20	268	231.00	348.00
1975	207	255.13	25.17	250	215.00	402.00
1976	146	258.84	34.36	258	190.00	381.00
1977	192	246.44	54.00	270	34.00	320.00
1978	625	285.06	72.60	261	195.78	643.56
1979	860	278.73	70.84	268	102.00	587.00
1980	194	250.80	32.76	243	200.00	447.00
1981	197	243.36	21.72	239	208.00	398.00
1982	97	245.45	25.20	240	214.00	366.00
1983	53	253.34	29.26	248	216.00	329.00
1984	29	252.60	29.62	240	223.00	345.00

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 4

ANNUAL AND SEASONAL DATA BASE INVENTORY
CHLORIDE (MG/L) - WESTERN BASIN

YEAR	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
ALL DATA	3587	18.31	5.83	18.00	3.2	48.6
SEASON 1*	93	20.24	5.87	21.00	7.7	32.2
SEASON 2*	1616	19.38	5.75	19.00	3.2	48.6
SEASON 3*	1159	17.70	5.77	17.00	7.9	44.0
SEASON 4*	719	16.66	5.57	15.60	6.3	45.0
1947	104	19.79	9.47	17.00	5.1	45.0
1963	3	17.40	0.52	17.70	16.8	17.7
1964	126	24.47	6.07	25.00	8.5	37.3
1966	103	21.42	6.34	21.00	9.0	38.0
1967	754	19.70	5.43	20.00	7.0	42.0
1968	147	19.63	3.82	20.00	9.0	29.0
1969	22	17.88	4.91	20.00	9.7	27.0
1970	78	17.37	6.26	16.60	8.2	42.6
1971	140	16.92	5.56	16.00	7.0	35.0
1972	139	20.66	6.12	20.00	7.6	34.0
1973	99	18.87	2.94	19.00	9.0	25.0
1974	59	18.51	4.09	17.00	9.4	29.0
1975	242	16.63	4.55	16.00	8.7	36.0
1976	134	17.56	5.04	16.90	7.3	32.0
1977	345	18.06	3.98	17.50	7.3	31.4
1978	579	18.46	6.07	17.40	3.2	48.6
1979	188	17.37	5.44	16.95	7.9	42.3
1980	ND	ND	ND	ND	ND	ND
1981	218	12.01	1.29	11.80	9.1	15.6
1982	ND	ND	ND	ND	ND	ND
1983	59	12.67	4.57	11.90	6.3	21.9
1984	39	13.25	5.42	10.80	7.7	32.2

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 5

ANNUAL AND SEASONAL DATA BASE INVENTORY
SULFATE (mg/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	1291	25.3	22.8	12.8	7.2	285.5
SEASON 1*	16	29.7	27.2	10.6	16.3	51.2
SEASON 2*	447	27.7	24.0	13.4	7.2	91.6
SEASON 3*	482	24.4	22.0	14.9	9.0	285.5
SEASON 4*	346	23.4	22.3	7.2	15.0	57.7
1947	NA	NA	NA	NA	NA	NA
1963	5	15.5	13.0	5.1	10.5	21.0
1964	37	17.3	14.0	6.8	9.0	29.0
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	91	21.6	19.0	9.0	11.0	82.0
1968	46	22.5	22.6	4.4	15.0	31.0
1969	21	29.4	28.0	11.8	14.0	55.0
1970	68	19.6	17.8	8.8	15.4	86.0
1971	4	17.0	17.0	1.2	16.0	18.0
1972	NA	NA	NA	NA	NA	NA
1973	56	25.0	22.0	9.2	17.0	59.0
1974	54	20.4	20.0	4.3	15.5	34.0
1975	76	18.4	18.0	2.1	15.5	25.0
1976	NA	NA	NA	NA	NA	NA
1977	NA	NA	NA	NA	NA	NA
1978	645	28.4	25.9	11.3	7.2	87.6
1979	86	31.6	26.2	30.2	15.7	285.5
1980	NA	NA	NA	NA	NA	NA
1981	6	18.8	18.8	0.7	18.1	19.4
1982	NA	NA	NA	NA	NA	NA
1983	57	20.1	18.0	4.2	15.0	29.2
1984	39	19.6	18.7	2.3	16.3	25.1

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 6

ANNUAL AND SEASONAL DATA BASE INVENTORY
DISSOLVED OXYGEN (mg/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	7892	9.6	9.4	2.0	0.1	24.5
SEASON 1*	228	12.8	13.0	1.6	4.0	24.5
SEASON 2*	2792	10.3	10.4	2.0	0.5	20.0
SEASON 3*	3426	8.3	8.3	1.4	0.1	16.1
SEASON 4*	1446	10.5	10.4	1.4	5.5	15.0
1947	93	9.7	9.9	1.4	6.8	13.8
1963	29	8.8	8.6	1.4	6.2	10.8
1964	232	8.8	8.8	1.8	0.7	14.8
1965	NA	NA	NA	NA	NA	NA
1966	104	7.2	7.0	0.9	5.0	11.4
1967	1012	9.0	9.0	1.9	0.5	14.2
1968	665	8.8	8.5	1.8	3.4	16.8
1969	393	9.2	8.8	1.5	6.2	13.8
1970	377	10.1	10.2	1.9	3.2	14.5
1971	187	9.8	9.2	2.4	2.8	20.0
1972	210	10.6	11.1	1.9	5.2	15.4
1973	595	9.2	9.3	2.3	0.2	14.0
1974	705	10.2	10.4	1.8	3.7	15.1
1975	679	10.0	9.8	2.0	2.1	16.5
1976	146	10.5	10.4	2.7	3.8	24.5
1977	408	10.3	10.2	1.6	6.8	15.8
1978	713	9.2	9.1	1.8	4.2	14.5
1979	795	10.0	9.8	1.8	4.0	16.1
1980	186	9.4	9.1	2.3	2.1	14.2
1981	212	10.1	9.9	1.9	2.7	14.8
1982	96	8.9	8.9	2.2	0.1	13.6
1983	31	9.9	9.8	2.1	7.0	16.7
1984	24	9.3	7.9	2.4	6.0	13.6

* SEASON 1	JANUARY - MARCH
* SEASON 2	APRIL - MAY
* SEASON 3	JUNE - SEPTEMBER
* SEASON 4	OCTOBER - DECEMBER

TABLE 7

ANNUAL AND SEASONAL DATA BASE INVENTORY
DISSOLVED OXYGEN (% SATURATION) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	5088	97.3	97.0	15.9	0.5	199
SEASON 1*	76	96.5	95.0	4.8	90.0	111.0
SEASON 2*	2142	101.1	102.0	17.5	0.5	199.0
SEASON 3*	2115	93.7	93.0	16.0	1.2	155.0
SEASON 4*	755	97.1	97.0	7.0	61.0	128.0
1947	NA	NA	NA	NA	NA	NA
1963	12	86.9	89.2	9.2	72.1	99.7
1964	232	97.8	95.6	20.3	8.4	177.2
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	628	93.1	95.0	19.1	6.0	135.0
1968	457	94.5	90.0	20.9	35.0	199.0
1969	311	95.0	93.0	11.0	67.0	122.0
1970	248	104.4	103.5	14.0	37.0	139.0
1971	159	97.2	97.0	16.0	33.0	140.0
1972	206	102.3	99.5	14.4	58.0	154.0
1973	496	98.3	100.0	20.2	2.0	150.0
1974	772	100.1	101.0	12.7	0.5	155.0
1975	689	95.8	95.0	12.0	24.0	170.0
1976	64	104.5	103.0	7.7	75.0	124.0
1977	337	101.1	103.0	8.9	74.0	138.0
1978	49	102.4	104.0	11.4	82.0	123.0
1979	46	102.4	98.5	11.2	90.0	139.0
1980	90	93.1	93.4	13.4	40.6	127.4
1981	196	93.3	94.0	10.2	30.3	128.4
1982	96	91.1	94.7	17.5	1.2	120.0
1983	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 8

ANNUAL AND SEASONAL DATA BASE INVENTORY
pH (STANDARD UNITS) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	6400	8.4	8.4	0.4	6.0	10.0
SEASON 1*	208	8.1	8.1	0.3	7.5	9.4
SEASON 2*	2302	8.5	8.5	0.4	6.4	9.6
SEASON 3*	2860	8.5	8.5	0.4	6.0	10.0
SEASON 4*	1030	8.3	8.3	0.3	6.5	9.5
1947	NA	NA	NA	NA	NA	NA
1963	3	8.3	8.2	0.2	8.2	8.5
1964	237	8.1	8.1	0.3	7.1	9.2
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	933	8.6	8.6	0.4	7.2	9.6
1968	512	8.4	8.4	0.4	7.2	9.4
1969	313	8.5	8.5	0.3	7.1	9.2
1970	283	8.4	8.5	0.4	7.0	9.2
1971	157	8.5	8.5	0.4	7.0	9.3
1972	187	8.1	8.2	0.6	6.0	9.5
1973	590	8.5	8.5	0.4	7.3	10.0
1974	620	8.4	8.5	0.3	6.5	9.2
1975	300	8.3	8.3	0.2	7.5	9.0
1976	81	8.2	8.2	0.4	7.5	9.1
1977	124	8.5	8.6	0.3	7.0	8.9
1978	704	8.5	8.5	0.4	7.1	9.7
1979	771	8.5	8.6	0.4	7.6	9.5
1980	190	8.2	8.2	0.3	7.0	9.0
1981	217	8.1	8.1	0.2	7.6	8.7
1982	97	8.3	8.4	0.3	7.4	8.9
1983	52	8.2	8.2	0.2	7.7	8.7
1984	29	8.2	8.2	0.2	7.9	8.6

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 9

ANNUAL AND SEASONAL DATA BASE INVENTORY
TURBIDITY (JTU) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2721	8.8	4.5	15.4	0.4	230.0
SEASON 1*	7	12.3	6.0	16.8	4.0	50.0
SEASON 2*	1248	10.1	4.5	21.0	0.6	230.0
SEASON 3*	1189	6.7	4.4	6.7	0.4	73.0
SEASON 4*	277	11.9	7.0	11.1	0.9	75.0
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	851	9.7	5.0	15.2	0.5	190.0
1968	613	7.5	4.8	7.0	0.4	50.0
1969	382	8.2	3.8	13.9	0.9	132.0
1970	372	10.0	4.2	27.7	0.9	230.0
1971	187	6.7	3.0	10.3	1.0	75.0
1972	207	6.8	4.0	9.6	1.0	75.0
1973	109	14.3	8.0	13.4	2.0	73.0
1974	NA	NA	NA	NA	NA	NA
1975	NA	NA	NA	NA	NA	NA
1976	NA	NA	NA	NA	NA	NA
1977	NA	NA	NA	NA	NA	NA
1978	NA	NA	NA	NA	NA	NA
1979	NA	NA	NA	NA	NA	NA
1980	NA	NA	NA	NA	NA	NA
1981	NA	NA	NA	NA	NA	NA
1982	NA	NA	NA	NA	NA	NA
1983	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 10

ANNUAL AND SEASONAL DATA BASE INVENTORY
TURBIDITY (NTU) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2605	14.1	8.1	19.5	0.8	280.0
SEASON 1*	143	13.3	7.6	14.5	0.8	83.0
SEASON 2*	852	15.8	6.0	28.5	0.9	280.0
SEASON 3*	966	11.2	8.0	12.1	0.9	155.0
SEASON 4*	644	16.3	13.0	13.3	1.7	77.0
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA
1968	NA	NA	NA	NA	NA	NA
1969	NA	NA	NA	NA	NA	NA
1970	NA	NA	NA	NA	NA	NA
1971	NA	NA	NA	NA	NA	NA
1972	NA	NA	NA	NA	NA	NA
1973	61	3.1	3.0	1.6	1.0	9.8
1974	38	3.8	2.6	4.8	1.7	25.0
1975	135	9.0	4.0	11.7	0.9	54.0
1976	36	6.6	5.3	5.3	1.6	29.0
1977	191	4.7	2.2	8.8	1.0	77.0
1978	725	16.5	10.0	18.0	0.9	120.0
1979	862	17.3	12.0	21.8	0.8	280.0
1980	170	9.0	6.6	13.4	1.0	132.0
1981	217	12.8	7.2	21.4	0.9	159.0
1982	97	22.0	9.2	34.8	1.2	200.0
1983	45	9.9	8.2	7.1	2.4	25.0
1984	28	9.8	4.3	12.4	1.1	41.1

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 11

ANNUAL AND SEASONAL DATA BASE INVENTORY
SECCHI (METERS) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	1385	1.1	0.9	1.3	0.1	14.8
SEASON 1*	41	1.7	0.9	2.6	0.2	12.2
SEASON 2*	368	1.3	1.0	1.2	0.1	12.4
SEASON 3*	613	1.1	0.9	1.0	0.1	12.8
SEASON 4*	363	1.0	0.7	1.6	0.1	14.8
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	48	1.9	1.8	1.0	0.5	4.5
1968	10	1.3	1.5	0.5	0.5	2.0
1969	9	0.7	0.5	0.4	0.3	1.5
1970	19	1.5	1.7	0.6	0.5	2.5
1971	9	1.5	1.5	0.4	1.0	2.0
1972	17	1.2	1.0	0.5	0.5	2.5
1973	22	1.1	1.0	0.8	0.1	2.5
1974	55	0.9	0.8	0.4	0.2	2.0
1975	75	1.0	0.9	0.6	0.3	3.0
1976	38	1.5	1.1	1.0	0.2	5.2
1977	24	1.3	1.1	0.7	0.2	3.1
1978	417	0.9	0.7	0.6	0.1	3.5
1979	381	0.8	0.6	0.5	0.1	3.5
1980	96	2.2	1.5	2.5	0.3	12.8
1981	101	2.1	1.2	2.9	0.2	14.8
1982	49	1.5	1.0	1.6	0.2	10.0
1983	7	1.4	1.5	0.3	1.0	2.0
1984	8	2.3	2.3	1.0	1.0	4.5

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 12

ANNUAL AND SEASONAL DATA BASE INVENTORY
TOTAL SUSPENDED SOLIDS (mg/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	1229	20.3	13.0	25.5	0.1	398.6
SEASON 1*	37	22.6	10.7	27.9	2.8	96.6
SEASON 2*	411	21.8	10.8	32.8	0.1	398.6
SEASON 3*	528	19.0	12.0	22.3	0.4	290.1
SEASON 4*	253	20.1	15.6	16.5	2.0	118.4
1947	NA	NA	NA	NA	NA	NA
1963	18	11.0	8.5	8.4	1.0	28.0
1964	97	30.8	25.0	24.1	1.0	148.0
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	60	13.4	6.0	17.0	1.0	70.0
1968	24	14.7	13.5	9.1	1.0	37.0
1969	17	29.4	23.0	26.9	7.0	112.0
1970	13	28.2	21.0	23.7	7.0	94.0
1971	2	54.5	54.5	16.3	43.0	66.0
1972	27	32.6	20.0	27.5	5.0	109.0
1973	129	24.1	21.0	16.9	2.0	101.0
1974	19	8.7	6.0	5.5	5.0	23.0
1975	27	11.3	10.0	4.3	5.0	26.0
1976	NA	NA	NA	NA	NA	NA
1977	NA	NA	NA	NA	NA	NA
1978	258	20.1	13.1	22.8	1.2	148.6
1979	138	34.2	20.5	42.1	5.4	398.6
1980	181	10.5	7.8	13.0	0.1	109.8
1981	201	14.6	7.8	26.9	0.4	290.1
1982	16	23.8	9.2	30.6	1.1	92.4
1983	2	19.5	19.5	4.9	16.0	23.0
1984	NA	NA	NA	NA	NA	NA

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 13

ANNUAL AND SEASONAL DATA BASE INVENTORY
TOTAL PHOSPHORUS (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	5680	65.8	46.3	63.6	0.0	874.0
SEASON 1*	180	53.8	45.8	40.0	0.0	224.0
SEASON 2*	2203	65.0	40.0	70.3	1.0	874.0
SEASON 3*	2285	69.6	56.6	56.5	1.0	626.0
SEASON 4*	1012	61.3	36.0	66.3	5.6	740.0
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	10	71.0	45.0	59.9	20.0	170.0
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	598	72.0	60.0	54.5	10.0	550.0
1968	453	93.6	80.0	71.6	10.0	620.0
1969	343	81.6	70.0	62.9	10.0	470.0
1970	378	94.7	64.5	85.8	15.0	600.0
1971	171	92.3	72.0	78.0	14.0	570.0
1972	192	50.5	32.7	64.4	5.6	740.0
1973	273	53.9	40.0	44.9	9.5	240.0
1974	178	36.0	31.6	19.1	9.8	101.0
1975	312	36.9	33.0	20.0	6.0	113.0
1976	131	39.7	32.9	25.2	6.0	158.0
1977	543	26.7	25.0	15.6	7.0	224.0
1978	659	106.3	94.9	88.5	4.0	874.0
1979	829	68.9	57.1	50.6	32.9	434.4
1980	194	27.8	21.8	24.6	5.2	210.0
1981	216	30.3	21.4	29.5	7.2	263.7
1982	97	42.8	25.7	39.2	6.5	223.5
1983	61	28.8	21.0	19.0	7.0	77.0
1984	39	19.0	6.2	21.2	1.0	68.0

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 14

ANNUAL AND SEASONAL DATA BASE INVENTORY
TOTAL DISSOLVED PHOSPHORUS (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	4768	25.8	14.6	34.9	0.0	958.3
SEASON 1*	118	31.7	30.1	24.8	0.0	136.6
SEASON 2*	1884	29.3	13.0	44.3	0.0	958.3
SEASON 3*	1926	26.6	19.5	27.6	1.0	460.0
SEASON 4*	840	15.1	10.6	23.1	0.7	460.0
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	598	33.2	30.0	25.3	10.0	200.0
1968	445	30.8	20.0	23.0	1.0	170.0
1969	326	29.6	20.0	22.5	10.0	150.0
1970	377	33.1	18.0	36.9	1.0	224.0
1971	160	28.1	16.0	44.0	2.0	460.0
1972	187	23.1	12.0	41.4	3.0	460.0
1973	145	14.9	11.0	14.1	2.0	111.0
1974	38	6.1	6.0	2.3	3.0	15.0
1975	222	9.6	8.0	6.1	1.0	35.0
1976	52	7.0	6.2	3.9	1.0	16.0
1977	300	8.8	8.0	4.3	1.0	33.0
1978	680	44.0	31.7	58.2	1.5	958.3
1979	834	21.4	12.0	32.3	0.0	300.0
1980	NA	NA	NA	NA	NA	NA
1981	212	7.6	5.7	7.8	1.7	60.8
1982	97	8.0	5.3	6.7	0.7	39.7
1983	56	5.4	4.0	5.1	1.0	28.0
1984	39	11.2	11.3	7.8	1.0	24.9

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 15

ANNUAL AND SEASONAL DATA BASE INVENTORY
ORTHOPHOSPHORUS (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2743	7.7	3.3	24.5	-980.0	250.0
SEASON 1*	132	8.9	4.6	10.5	0.5	56.2
SEASON 2*	759	10.3	3.8	40.8	-980.0	141.0
SEASON 3*	1188	6.0	2.9	12.6	0.0	250.0
SEASON 4*	664	7.7	3.7	15.8	0.0	170.0
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA
1868	24	76.1	40.0	74.0	3.0	250.0
1969	16	36.6	32.0	18.6	17.0	76.0
1970	116	29.3	24.5	25.8	3.0	120.0
1971	69	11.0	10.0	9.9	1.0	40.0
1972	55	8.0	3.8	7.5	0.4	27.0
1973	137	7.7	4.4	7.3	0.1	30.4
1974	89	6.2	1.8	8.5	0.2	35.5
1975	170	7.6	4.1	8.0	0.1	44.8
1976	97	5.0	3.3	5.0	1.0	29.0
1977	55	7.5	5.2	7.5	0.6	32.8
1978	685	7.1	4.5	40.2	-980.0	111.7
1979	665	5.5	2.5	10.7	0.3	74.3
1980	184	3.4	2.1	5.5	0.2	47.7
1981	191	3.9	2.1	5.7	0.5	44.0
1982	97	4.6	2.3	5.5	0.6	28.9
1983	54	1.4	1.0	1.6	0.0	7.0
1984	39	1.6	0.6	3.9	0.0	19.0

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 16

ANNUAL AND SEASONAL DATA BASE INVENTORY
NITRATE + NITRITE (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	1906	1496.2	230.0	5848.0	0.0	55000.0
SEASON 1*	102	15863.0	3955.0	17706.2	60.0	55000.0
SEASON 2*	480	1726.8	500.0	4629.5	8.0	53000.0
SEASON 3*	828	379.9	196.5	518.6	0.0	3146.0
SEASON 4*	496	182.2	143.0	242.6	0.0	4040.0
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	180	113.4	94.5	77.0	10.0	330.0
1968	NA	NA	NA	NA	NA	NA
1969	NA	NA	NA	NA	NA	NA
1970	NA	NA	NA	NA	NA	NA
1971	13	250.8	70.0	340.8	0.0	1140.0
1972	24	1375.0	765.0	1478.6	20.0	4900.0
1973	110	442.2	300.0	448.3	10.0	2900.0
1974	18	456.9	423.5	187.8	260.0	987.0
1975	NA	NA	NA	NA	NA	NA
1976	NA	NA	NA	NA	NA	NA
1977	NA	NA	NA	NA	NA	NA
1978	689	390.9	90.0	946.7	0.0	7200.0
1979	767	3161.3	454.0	8913.2	5.0	55000.0
1980	NA	NA	NA	NA	NA	NA
1981	6	439.5	441.0	40.8	400.0	480.0
1982	NA	NA	NA	NA	NA	NA
1983	60	370.6	300.0	149.6	21.0	670.0
1984	39	495.2	370.0	302.3	196.0	1302.0

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 17

ANNUAL AND SEASONAL DATA BASE INVENTORY
AMMONIA (MG/L) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2416	53.4		78.0	0.0	57.1
SEASON 1*	162	138.0	134.3	109.1	1.0	409.6
SEASON 2*	656	77.8	35.9	91.2	0.0	570.9
SEASON 3*	1010	36.4	19.8	49.5	0.0	472.9
SEASON 4*	588	43.1	18.0	62.4	0.0	424.9
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA
1968	24	70.2	46.0	79.9	8.0	330.0
1969	16	68.1	28.3	68.5	18.0	108.0
1970	117	57.1	48.0	47.5	10.0	250.0
1971	69	26.0	21.0	19.0	2.0	85.0
1972	55	68.8	36.0	93.4	3.0	425.0
1973	135	40.5	22.0	46.4	1.0	246.0
1974	118	30.9	15.0	46.9	0.1	303.0
1975	119	52.3	34.0	51.6	1.5	270.0
1976	82	45.1	27.4	50.0	2.1	250.0
1977	23	37.6	31.1	15.9	14.2	65.8
1978	554	68.3	30.6	87.2	0.0	571.0
1979	630	74.1	28.0	93.6	1.0	409.6
1980	194	34.5	11.2	61.8	0.5	449.0
1981	183	28.5	9.4	44.4	1.0	256.0
1982	97	41.7	11.2	70.0	1.0	332.0
1983	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 18

ANNUAL AND SEASONAL DATA BASE INVENTORY
TOTAL INORGANIC NITROGEN (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2589	355.0	226.0	615.7	1.0	9150.0
SEASON 1*	NA	NA	NA	NA	NA	NA
SEASON 2*	1276	480.9	291.0	818.5	21.0	9150.0
SEASON 3*	1037	215.1	175.0	205.8	4.0	2834.0
SEASON 4*	276	298.4	205.0	389.5	1.0	2297.0
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	555	232.2	142.0	302.6	31.0	3100.0
1968	372	562.7	306.0	1024.3	32.0	9150.0
1969	311	481.2	291.0	826.5	67.0	7360.0
1970	252	373.4	244.5	607.1	22.0	4284.0
1971	104	455.2	200.5	1116.6	21.0	6650.0
1972	82	239.7	210.0	167.8	21.0	709.0
1973	101	360.8	200.0	540.1	4.0	2227.0
1974	161	300.8	255.0	173.2	1.0	947.0
1975	162	368.5	266.0	350.5	35.0	2834.0
1976	36	439.8	367.5	341.9	34.0	1025.0
1977	300	206.8	205.0	127.5	15.0	765.0
1978	69	294.0	255.0	175.5	15.0	790.0
1979	84	325.8	360.0	155.0	85.0	750.0
1980	NA	NA	NA	NA	NA	NA
1981	NA	NA	NA	NA	NA	NA
1982	NA	NA	NA	NA	NA	NA
1983	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 19

ANNUAL AND SEASONAL DATA BASE INVENTORY
KJELDAHL NITROGEN (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	3558	731.9	390.0	1254.7	-980.0	9903.0
SEASON 1*	112	632.2	591.5	246.0	140.0	1292.0
SEASON 2*	1281	432.4	355.0	306.5	0.0	2850.0
SEASON 3*	1587	1097.0	480.0	1779.6	-980.0	9903.0
SEASON 4*	578	412.3	280.0	329.8	0.0	2147.0
1947	NA	NA	NA	NA	NA	NA
1963	17	882.4	990.0	378.0	140.0	1500.0
1964	87	938.3	710.0	683.1	180.0	2850.0
1965	NA	NA	NA	NA	NA	NA
1966	58	108.4	100.0	59.3	20.0	250.0
1967	102	531.3	460.0	289.9	70.0	1800.0
1968	486	674.3	540.0	477.0	60.0	3000.0
1969	310	550.3	480.0	269.3	83.0	2000.0
1970	251	521.1	380.0	378.5	210.0	3000.0
1971	104	483.9	390.0	343.6	160.0	2200.0
1972	82	319.0	285.0	97.6	160.0	600.0
1973	61	382.6	360.0	167.5	180.0	960.0
1974	56	372.1	370.0	138.2	180.0	810.0
1975	170	367.3	290.0	365.1	82.4	3040.0
1976	36	293.0	280.0	82.9	160.0	480.0
1977	308	327.0	315.0	67.6	205.0	700.0
1978	633	306.0	265.0	181.8	0.0	1287.0
1979	728	1801.8	851.0	2399.3	-980.0	9903.0
1980	NA	NA	NA	NA	NA	NA
1981	1	241.0	241.0	NA	241.0	241.0
1982	NA	NA	NA	NA	NA	NA
1983	50	240.0	235.0	111.2	0.0	58.0
1984	18	316.7	315.0	182.7	70.0	690.0

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 20

ANNUAL AND SEASONAL DATA BASE INVENTORY
DISSOLVED SILICA (mg/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2805	40.9	0.7	231.1	0.0	1970.0
SEASON 1*	152	609.0	5.5	689.4	0.0	1970.0
SEASON 2*	828	25.3	0.7	176.4	0.0	1670.0
SEASON 3*	1147	0.7	0.6	0.6	0.0	5.2
SEASON 4*	678	0.6	0.5	0.6	0.0	7.1
1947	NA	NA	NA	NA	NA	NA
1963	5	2.1	1.7	1.7	0.7	5.0
1964	45	1.1	0.9	0.5	0.4	2.6
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	188	0.7	0.7	0.5	0.1	2.5
1968	48	0.8	0.6	0.6	0.1	2.2
1969	16	0.3	0.2	0.2	0.0	0.6
1970	116	0.8	0.8	0.5	0.0	2.2
1971	84	0.7	0.6	0.4	0.0	2.3
1972	79	1.8	0.8	2.8	0.1	15.4
1973	18	1.3	1.5	0.9	0.2	2.3
1974	36	0.4	0.3	0.3	0.1	1.4
1975	174	0.8	0.6	0.8	0.1	6.3
1876	82	0.8	0.8	0.6	0.0	3.3
1977	NA	NA	NA	NA	NA	NA
1978	674	0.8	0.5	1.1	0.0	7.8
1979	739	152.9	0.6	431.1	0.0	1970.0
1980	193	0.9	0.9	0.6	0.0	3.3
1981	211	0.9	0.9	0.7	0.0	4.7
1982	97	1.0	0.9	0.8	0.0	5.2
1983	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 21

ANNUAL AND SEASONAL DATA BASE INVENTORY
UNCORRECTED CHLOROPHYLL A (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2257	22.4	16.5	18.9	0.1	129.0
SEASON 1*	162	9.6	5.9	9.3	1.0	41.3
SEASON 2*	698	15.6	10.5	14.3	0.7	115.0
SEASON 3*	884	29.5	24.4	21.0	0.1	129.0
SEASON 4*	513	23.3	20.2	17.2	0.6	80.5
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA
1968	27	10.3	8.8	5.4	3.4	25.9
1969	14	19.0	18.9	11.3	5.5	49.6
1970	40	10.5	7.3	8.7	2.3	35.8
1971	13	15.5	13.1	7.5	3.6	28.7
1972	18	14.1	11.7	7.2	4.5	30.5
1973	41	24.4	14.3	24.1	5.0	115.0
1974	124	15.9	14.5	10.3	1.7	54.1
1975	131	16.2	11.9	13.5	1.9	81.6
1976	110	13.2	10.4	10.6	2.0	62.7
1977	55	16.0	12.7	14.1	2.9	65.4
1978	554	30.0	29.4	17.0	1.1	94.9
1979	629	31.8	27.4	22.5	0.6	129.0
1980	193	10.6	8.5	8.5	0.9	54.6
1981	211	8.9	6.7	7.7	1.2	53.5
1982	97	11.4	7.9	10.1	0.1	37.0
1983	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 22

ANNUAL AND SEASONAL DATA BASE INVENTORY
CORRECTED CHLOROPHYLL A (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2246	20.3	14.8	17.9	-3.1	120.2
SEASON 1*	162	8.2	5.0	8.4	0.4	38.8
SEASON 2*	668	13.4	8.9	13.0	0.2	93.0
SEASON 3*	910	26.9	21.3	20.2	0.1	120.2
SEASON 4*	506	21.2	19.2	15.7	-3.1	80.0
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA
1968	NA	NA	NA	NA	NA	NA
1969	NA	NA	NA	NA	NA	NA
1970	NA	NA	NA	NA	NA	NA
1971	NA	NA	NA	NA	NA	NA
1972	18	12.9	11.2	6.5	4.1	27.6
1973	130	18.4	12.6	16.9	0.0	102.3
1974	120	14.8	13.5	9.8	2.1	50.6
1975	131	14.8	10.6	13.4	1.2	78.5
1976	110	11.7	8.9	10.0	1.1	60.5
1977	55	14.3	10.2	13.2	2.3	64.2
1978	553	26.3	24.8	16.0	-3.1	87.2
1979	629	29.4	25.4	21.5	0.4	120.2
1980	192	9.4	7.2	8.0	0.7	52.6
1981	211	6.9	5.2	6.4	0.8	38.7
1982	97	9.2	4.8	9.4	0.1	33.7
1983	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA

* SEASON 1	JANUARY - MARCH
* SEASON 2	APRIL - MAY
* SEASON 3	JUNE - SEPTEMBER
* SEASON 4	OCTOBER - DECEMBER

TABLE 23

ANNUAL AND SEASONAL DATA BASE INVENTORY
PHEOPHYTIN (ug/l) - WESTERN BASIN

YEAR	N	MEAN	MEDIAN	ST.DEV.	LOW	HIGH
ALL DATA	2053	4.0	2.9	4.0	0.0	39.4
SEASON 1*	158	2.4	1.6	2.3	0.1	12.6
SEASON 2*	581	3.6	2.6	3.6	0.0	39.4
SEASON 3*	833	4.3	3.4	4.2	0.0	34.0
SEASON 4*	481	4.5	3.0	4.3	0.0	29.2
1947	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA
1968	NA	NA	NA	NA	NA	NA
1969	NA	NA	NA	NA	NA	NA
1970	NA	NA	NA	NA	NA	NA
1971	NA	NA	NA	NA	NA	NA
1972	NA	NA	NA	NA	NA	NA
1973	NA	NA	NA	NA	NA	NA
1974	116	2.1	1.5	2.2	0.0	13.8
1975	130	2.3	2.0	1.8	0.0	13.1
1976	77	3.6	2.9	2.4	0.1	9.9
1977	55	2.8	1.7	3.0	0.2	13.5
1978	556	6.2	5.2	4.8	0.0	39.4
1979	627	3.8	3.0	3.8	0.0	29.2
1980	190	2.1	1.9	1.5	0.2	7.1
1981	205	3.4	2.1	4.3	0.1	34.0
1982	97	3.6	2.6	2.9	0.0	17.3
1983	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 24

PRELIMINARY CLUSTER ANALYSIS *
CHLORIDE (MG/L) - WESTERN BASIN
(N = 2 THROUGH 20)

NUMBER OF CLUSTERS	N	LARGEST CLUSTER	MEAN	MAX. DIST. BETWEEN CLUSTERS	ST. DEV.
2	3166	2	17.0	14.2	4.2
3	1941	3	14.3	10.6	2.8
4	2335	4	19.0	7.5	2.9
5	1992	4	16.8	4.5	2.2
6	1690	4	15.1	3.7	2.2
7	1713	1	18.8	3.7	1.9
8	1605	4	17.3	2.9	1.7
9	1307	4	16.1	2.6	1.4
10	1248	1	19.0	2.5	1.4
11	1329	6	17.9	2.3	1.4
12	1169	12	17.5	2.3	1.2
13	1156	8	17.4	2.1	1.2
14	1124	7	17.3	2.0	1.1
15	904	7	19.4	1.6	1.0
16	929	8	17.0	1.7	0.9
17	782	8	16.0	1.5	0.8
18	853	8	17.1	1.4	0.8
19	855	8	16.9	1.4	0.8
20	741	8	16.1	1.3	0.7

* = DATA FROM THE MOST POPULATED CLUSTER

TABLE 25

CHLORIDE
FIVE CLUSTERS

CLUSTER	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	7	47.6	3.2	46.0	45.0	53.2
2	84	36.6	3.3	36.0	32.3	44.0
3	898	24.1	2.9	23.2	20.9	32.0
4	1992	16.8	2.2	17.0	12.4	20.8
5	515	10.4	1.5	10.8	3.2	12.3

TABLE 26

CHLORIDE
SIX CLUSTERS

CLUSTER	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	1280	21.4	2.1	21.0	18.1	26.4
2	48	39.5	2.7	38.8	36.0	45.1
3	227	29.6	2.5	29.0	26.5	35.7
4	1690	15.1	2.2	15.5	10.8	18.0
5	4	49.5	3.0	49.3	46.0	53.2
6	247	9.2	1.3	9.3	3.2	10.7

TABLE 27

CHLORIDE
SEVEN CLUSTERS

CLUSTER	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	1713	18.8	1.9	18.8	15.9	22.8
2	3	50.6	2.4	50.0	48.6	53.2
3	511	25.5	2.2	25.0	22.9	31.0
4	122	8.2	1.2	8.8	3.2	9.2
5	18	42.8	1.8	42.5	40.0	46.0
6	97	34.5	2.5	34.0	31.4	39.4
7	1032	13.0	1.8	13.0	9.3	15.8

TABLE 28

CHLORIDE
EIGHT CLUSTERS

CLUSTER	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	38	6.9	1.4	7.3	3.2	8.0
2	788	22.8	1.7	22.4	20.1	26.7
3	3	50.6	2.4	50.0	48.6	53.2
4	1605	17.4	1.7	17.2	14.2	20.0
5	44	37.1	1.7	37.2	34.2	40.0
6	202	29.6	2.2	29.0	26.9	34.0
7	800	11.8	1.6	12.0	8.1	14.1
8	16	43.1	1.6	42.7	41.0	46.0

TABLE 29

CHLORIDE
NINE CLUSTERS

CLUSTER	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	13	43.6	1.4	44.0	42.0	46.0
2	23	6.2	1.4	6.8	3.2	7.6
3	1029	20.7	1.4	20.5	18.4	23.6
4	1307	16.0	1.4	16.0	13.2	18.3
5	3	50.0	2.4	50.0	48.6	53.2
6	98	32.1	1.5	32.0	29.5	35.5
7	362	25.8	1.6	25.5	23.7	29.1
8	37	38.1	1.5	38.0	35.7	41.4
9	624	11.1	1.4	11.1	7.8	13.1

TABLE 30

CHLORIDE
TEN CLUSTERS

CLUSTER	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	1248	19.0	1.4	19.0	16.9	21.8
2	3	50.6	2.4	50.0	48.6	53.2
3	71	33.1	1.4	33.0	31.4	36.0
4	948	14.8	1.3	15.0	12.3	16.8
5	31	38.5	1.2	38.0	37.0	41.4
6	13	43.6	1.4	44.0	42.0	46.0
7	147	28.5	1.3	28.0	26.9	31.0
8	20	6.0	1.4	6.6	3.2	7.3
9	479	10.5	1.2	10.8	7.4	12.2
10	536	23.6	1.4	23.3	21.9	26.7

TABLE 31

CHLORIDE
ELEVEN CLUSTERS

CLUSTER	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	7	44.7	0.8	45.0	44.0	46.0
2	331	9.8	1.1	10.0	6.8	11.1
3	642	22.2	1.2	22.0	20.2	24.7
4	18	40.6	1.4	40.5	39.0	42.7
5	255	26.6	1.4	26.5	24.9	29.5
6	1329	17.9	1.4	18.0	15.6	20.1
7	11	5.1	1.2	5.1	3.2	6.7
8	778	13.6	1.2	13.8	11.2	15.5
9	31	36.9	1.2	37.0	35.0	38.6
10	3	50.6	2.4	50.0	48.6	53.2
11	91	31.9	1.3	32.0	29.6	34.2

TABLE 32

CHLORIDE
TWELVE CLUSTERS

CLUSTER	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	12	42.4	1.1	42.2	41.0	44.0
2	28	38.2	0.9	38.0	37.0	40.0
3	331	9.8	1.1	10.0	6.8	11.1
4	11	5.1	1.2	5.1	3.2	6.7
5	271	26.4	1.4	26.0	24.4	29.0
6	817	21.6	1.3	21.4	20.0	24.3
7	24	34.8	0.8	34.6	33.7	36.0
8	2	51.6	2.3	51.6	50.0	53.2
9	744	13.5	1.2	13.6	11.2	15.4
10	5	45.9	1.5	45.1	45.0	48.6
11	82	31.5	1.1	31.7	29.1	33.0
12	1169	17.5	1.2	17.5	15.5	19.9

TABLE 33

PRELIMINARY CLUSTER ANALYSIS *
CONDUCTIVITY (UMHOS/CM) AT 25 °C - WESTERN BASIN
(N = 2 THROUGH 20)

NUMBER OF CLUSTERS	N	LARGEST CLUSTER	MEAN	MAX. DIST. BETWEEN CLUSTERS	ST. DEV.
2	5445	2	268.3	151.5	32.2
3	2959	1	245.7	122.1	16.3
4	5004	4	271.2	96.5	28.0
5	5049	3	263.6	56.4	24.2
6	4180	6	255.5	55.6	18.7
7	3104	2	247.5	50.8	15.2
8	2853	8	281.4	43.2	15.9
9	3240	8	269.1	31.2	13.6
10	3328	6	271.3	34.3	14.5
11	3070	11	264.8	22.5	12.3
12	2528	7	253.9	19.6	10.6
13	2214	2	249.7	17.2	9.7
14	2183	13	259.5	15.9	8.8
15	2054	8	261.8	14.1	8.1
16	1964	8	250.7	15.0	8.5
17	1953	17	274.8	14.5	8.1
18	1975	18	251.6	15.2	8.5
19	1978	19	267.9	13.5	7.7
20	1657	18	255.2	11.8	6.8

* = DATA FROM THE MOST POPULATED CLUSTER

TABLE 34

PRELIMINARY CLUSTER ANALYSIS
CHLORIDE (MG/L) - WESTERN BASIN
SEASONAL BREAKDOWN

CLUSTER	SEASON	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	ALL	168	32.47	2.98	32.0	29.0	39.2
2	ALL	1338	22.06	2.47	21.5	19.0	28.5
3	ALL	20	42.91	2.30	42.45	39.4	48.6
4	ALL	1711	15.48	2.05	16.00	11.3	18.9
5	ALL	350	9.67	1.36	10.00	3.2	11.2
1	1	8	30.80	1.02	30.95	29.4	32.2
1	2	88	32.82	3.18	32.00	29.0	39.2
1	3	46	32.10	2.86	31.25	29.0	39.0
1	4	26	32.47	2.75	31.85	29.0	39.0
2	1	51	22.77	2.56	23.00	19.0	28.5
2	2	765	21.95	2.40	21.50	19.0	28.5
2	3	354	22.22	2.62	22.00	19.0	28.5
2	4	168	21.96	2.41	21.00	19.0	28.5
3	1	ND	ND	ND	ND	ND	ND
3	2	8	44.13	2.68	44.50	40.0	48.6
3	3	9	41.68	1.42	42.00	39.4	44.0
3	4	3	43.33	2.08	44.00	41.0	45.0
4	1	31	14.54	2.27	13.40	11.9	18.9
4	2	634	16.02	1.98	16.50	11.5	18.9
4	3	610	15.38	1.93	15.70	11.3	18.9
4	4	436	14.90	2.08	14.80	11.3	18.9
5	1	3	7.87	0.29	7.70	7.7	8.2
5	2	121	9.33	1.68	10.00	3.2	11.0
5	3	140	10.11	0.90	10.50	7.9	11.2
5	4	86	9.50	1.27	9.55	6.3	11.1

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL - MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 35
PRELIMINARY CLUSTER ANALYSIS
CONDUCTIVITY (UMHOS/CM) AT 25 °C - WESTERN BASIN
SEASONAL BREAKDOWN

CLUSTER	SEASON	N	MEAN	ST. DEV.	MEDIAN	LOW	HIGH
1	ALL	150	487.78	47.66	475.00	428.00	587.00
2	ALL	77	137.08	25.64	138.00	34.00	175.00
3	ALL	4526	257.00	20.59	259.00	178.00	293.48
4	ALL	1101	326.69	32.09	315.00	293.71	427.00
5	ALL	34	638.99	28.76	640.00	595.00	700.00
1	1	3	488.00	16.52	480.00	477.00	507.00
1	2	102	493.83	48.92	480.83	428.40	587.00
1	3	31	428.76	49.90	468.18	430.00	580.00
1	4	14	454.81	11.71	452.00	431.46	473.00
2	1	65	135.82	27.03	138.00	34.00	175.00
2	2	8	136.13	12.22	140.00	118.00	148.00
2	3	ND	ND	ND	ND	ND	ND
2	4	4	159.90	2.89	159.50	157.00	162.00
3	1	76	240.08	34.05	240.50	178.00	290.00
3	2	1512	263.22	18.16	266.00	207.00	293.00
3	3	2082	255.57	19.82	256.00	190.00	293.48
3	4	856	251.03	21.63	251.77	178.00	293.00
4	1	34	338.74	31.53	330.00	300.00	420.00
4	2	528	330.12	34.15	318.00	294.00	427.00
4	3	401	319.31	25.34	311.10	294.00	426.00
4	4	138	332.08	37.39	317.00	293.71	423.51
5	1	ND	ND	ND	ND	ND	ND
5	2	27	637.13	26.96	640.00	595.00	700.00
5	3	7	646.14	36.39	643.00	600.00	690.00
5	4	ND	ND	ND	ND	ND	ND

* SEASON 1 JANUARY - MARCH
* SEASON 2 APRIL MAY
* SEASON 3 JUNE - SEPTEMBER
* SEASON 4 OCTOBER - DECEMBER

TABLE 36

CLUSTER STATISTICS USING STANDARDIZED NON-TRANSFORMED CHLORIDE DATA

CLUSTER	CUBIC CLUSTERING CRITERION	OVERALL ESTIMATED R2	VARIANCE* RATIO
5	- 61.1907	0.9601	5.21
6	- 66.7596	0.9723	6.70
7	- 71.2620	0.9797	8.31
8	- 71.6792	0.9845	10.94
9	- 67.0480	0.9877	15.76
10	- 69.1717	0.9901	18.60
11	- 74.0589	0.9918	20.07
12	- 77.5909	0.9931	22.01
13	- 79.8497	0.9941	24.56
14	- 81.5340	0.9950	27.45

* Variance Ratio = Between-Cluster Variance/Within-Cluster Variance

Table 37. Single Variable Cluster Statistics for Conductivity

```
                                   SAS

                           FASTCLUS PROCEDURE

              REPLACE=FULL  RADIUS=0  MAXCLUSTERS=7  MAXITER=1


                              INITIAL SEEDS

                         CLUSTER          COND
                         ---------------------
                         1             210.000
                         2             290.000
                         3             118.000
                         4             520.000
                         5             440.000
                         6             600.000
                         7             366.710

                             CLUSTER SUMMARY

 CLUSTER                 RMS STD      MAXIMUM DISTANCE FROM     NEAREST     CENTROID
 NUMBER   FREQUENCY     DEVIATION      SEED TO OBSERVATION      CLUSTER     DISTANCE
 ------------------------------------------------------------------------------------
    1        2759        11.4811       37.6732                     2         40.2640
    2        3243        13.4189       39.3429                     1         40.2640
    3          88        14.2250       36.2727                     1         66.2241
    4          40        23.3123       39.0719                     6         67.7224
    5         162        22.2926       40.0905                     4         72.8842
    6          23        14.7288       26.8541                     4         67.7224
    7         435        19.3962       39.3356                     2         65.8156

            649 OBSERVATION(S) WERE OMITTED DUE TO MISSING VALUES


                         STATISTICS FOR VARIABLES

  VARIABLE        TOTAL STD       WITHIN STD        R-SQUARED       RSQ/(1-RSQ)
  -----------------------------------------------------------------------------
  COND            49.282990        13.528955         0.924708         12.281644
  OVER-ALL        49.282990        13.528955         0.924708         12.281644

                               PSEUDO F STATISTIC =  13802.52
             APPROXIMATE EXPECTED OVER-ALL R-SQUARED =   0.97964
                         CUBIC CLUSTERING CRITERION =   -77.789



                                   SAS

                           FASTCLUS PROCEDURE

                              CLUSTER MEANS

                         CLUSTER          COND
                         ---------------------
                         1             237.054
                         2             277.318
                         3             170.830
                         4             507.600
                         5             434.715
                         6             575.322
                         7             343.133


                      CLUSTER STANDARD DEVIATIONS

                         CLUSTER          COND
                         ---------------------
                         1             11.4811
                         2             13.4189
                         3             14.2250
                         4             23.3123
                         5             22.2926
                         6             14.7288
                         7             19.3962
```

Table 38. Single Variable Cluster Statistics for Chloride

```
                                     SAS

                              FASTCLUS PROCEDURE

                 REPLACE=FULL  RADIUS=0  MAXCLUSTERS=7  MAXITER=1


                                INITIAL SEEDS

                             CLUSTER            CL
                             -------------------------
                             1             19.0000
                             2             35.0000
                             3             27.0000
                             4              3.2000
                             5             42.7000
                             6             50.0000
                             7             11.0000

                               CLUSTER SUMMARY

CLUSTER                  RMS STD       MAXIMUM DISTANCE FROM     NEAREST     CENTROID
 NUMBER    FREQUENCY    DEVIATION      SEED TO OBSERVATION       CLUSTER     DISTANCE
--------------------------------------------------------------------------------------
   1          940        1.9522        3.5863                       7         5.9368
   2           63        2.0383        3.9623                       3         7.6321
   3          285        1.9743        3.8746                       1         6.6089
   4           26        1.5662        3.2111                       7         5.4970
   5           25        2.6368        4.0056                       6         7.6120
   6            3        2.0298        3.3000                       5         7.6120
   7          524        1.8276        3.3103                       4         5.4970

            1564 OBSERVATION(S) WERE OMITTED DUE TO MISSING VALUES


                           STATISTICS FOR VARIABLES

VARIABLE          TOTAL STD        WITHIN STD          R-SQUARED        RSQ/(1-RSQ)
-----------------------------------------------------------------------------------
CL                6.0771711         1.9302883          0.8994361          8.9439289
OVER-ALL          6.0771711         1.9302883          0.8994361          8.9439289

                                   PSEUDO F STATISTIC =  2771.13
                  APPROXIMATE EXPECTED OVER-ALL R-SQUARED =  0.97978
                            CUBIC CLUSTERING CRITERION =  -50.148


                                     SAS

                              FASTCLUS PROCEDURE

                                CLUSTER MEANS

                             CLUSTER            CL
                             -------------------------
                             1             18.4876
                             2             32.7286
                             3             25.0965
                             4              7.0538
                             5             40.5880
                             6             46.2000
                             7             12.5508


                         CLUSTER STANDARD DEVIATIONS

                             CLUSTER            CL
                             -------------------------
                             1             1.95224
                             2             2.03830
                             3             1.97425
                             4             1.56620
                             5             2.63681
                             6             2.02978
                             7             1.82763
```

Table 39. Variable Cluster Statistics for Turbidity

```
                                        SAS

                                 FASTCLUS PROCEDURE

                     REPLACE = FULL  MAXCLUSTERS = 7  MAXITER = 1

                 SEED REPLACEMENTS:  FIRST LEVEL = 7  SECOND LEVEL = 36

                                   INITIAL SEEDS

                               CLUSTER          TURB

                                  1            16.7000
                                  2            65.0000
                                  3            82.0000
                                  4            49.0000
                                  5           100.0000
                                  6             0.4000
                                  7            33.0000


                                  CLUSTER SUMMARY

                 CLUSTER   MEMBERS  RMS ST DEV  MAX DISTANCE FROM SEED

                    1        1224    3.565852    7.833032
                    2          50     4.24341    8.153846
                    3          24    3.988207    6.857143
                    4         110    4.601017    8.095918
                    5          12    3.942772    8.444444
                    6        3482    2.239195    5.039679
                    7         385    4.390121    8.017423


                               STATISTICS FOR VARIABLES

        VARIABLE       TOTAL STD        WITHIN STD        R-SQUARED        VAR RATIO

        TURB          12.2219214         2.8910794        0.9441082        16.8917227
        OVER-ALL      12.2219214         2.8910794        0.9441082        16.8917227

  APPROXIMATE EXPECTED OVER-ALL R-SQUARED =  0.9797    CUBIC CLUSTERING CRITERION =-53.1974
             WARNING: THESE VALUES ARE INVALID IF VARIABLES ARE CORRELATED

                                   CLUSTER MEANS

                               CLUSTER          TURB

                                  1            14.25948
                                  2            62.44000
                                  3            76.91667
                                  4            45.70000
                                  5            95.50000
                                  6             4.26066
                                  7            28.80831


                                        SAS

                                 FASTCLUS PROCEDURE

                             CLUSTER STANDARD DEVIATIONS

                               CLUSTER          TURB

                                  1            3.565852
                                  2            4.243410
                                  3            3.988207
                                  4            4.601017
                                  5            3.942772
                                  6            2.239195
                                  7            4.390121
```

Table 40. Single Variable Cluster Statistics for Total Suspended Solids

```
                                      SAS

                               FASTCLUS PROCEDURE

                 REPLACE=FULL  RADIUS=0  MAXCLUSTERS=7  MAXITER=1


                                 INITIAL SEEDS

                            CLUSTER             TSS
                            --------------------------
                            1                 44.190
                            2                 22.190
                            3                  0.100
                            4                139.640
                            5                 67.000
                            6                 89.100
                            7                112.000

                                CLUSTER SUMMARY

 CLUSTER                  RMS STD        MAXIMUM DISTANCE FROM       NEAREST     CENTROID
 NUMBER    FREQUENCY     DEVIATION       SEED TO OBSERVATION         CLUSTER     DISTANCE
 ------------------------------------------------------------------------------------------
    1         120          6.0321          11.3636                       2         19.8809
    2         387          4.7683          11.0169                       3         14.1159
    3         673          3.2965           6.7975                       2         14.1159
    4           3          7.9628           8.3900                       7         21.6278
    5          37          6.3863          10.9911                       6         23.7636
    6          11          5.3916          10.4336                       7         20.1619
    7           9          4.9464           9.4990                       6         20.1619

                  6159 OBSERVATION(S) WERE OMITTED DUE TO MISSING VALUES


                           STATISTICS FOR VARIABLES

    VARIABLE        TOTAL STD        WITHIN STD        R-SQUARED        RSQ/(1-RSQ)
    -------------------------------------------------------------------------------
    TSS             18.386705        4.270894          0.946307         17.624240
    OVER-ALL        18.386705        4.270894          0.946307         17.624240

                                  PSEUDO F STATISTIC =  3621.78
                 APPROXIMATE EXPECTED OVER-ALL R-SQUARED =  0.97987
                              CUBIC CLUSTERING CRITERION =  -25.002



                                      SAS

                               FASTCLUS PROCEDURE

                                 CLUSTER MEANS

                            CLUSTER             TSS
                            --------------------------
                            1                 41.166
                            2                 21.285
                            3                  7.169
                            4                130.523
                            5                 64.970
                            6                 88.734
                            7                108.896



                          CLUSTER STANDARD DEVIATIONS

                            CLUSTER             TSS
                            --------------------------
                            1                6.03214
                            2                4.76831
                            3                3.29653
                            4                7.96282
                            5                6.38628
                            6                5.39156
                            7                4.94638
```

Table 41. Single Variable Cluster Statistics for Total Phosphorus

```
                                  SAS

                           FASTCLUS PROCEDURE

           REPLACE=FULL  RADIUS=0  MAXCLUSTERS=7  MAXITER=1


                              INITIAL SEEDS

                         CLUSTER            TP
                         ---------------------
                         1            0.154500
                         2            0.390000
                         3            0.003600
                         4            0.481200
                         5            0.079000
                         6            0.310000
                         7            0.230000


                             CLUSTER SUMMARY

CLUSTER                 RMS STD      MAXIMUM DISTANCE FROM     NEAREST    CENTROID
NUMBER   FREQUENCY     DEVIATION     SEED TO OBSERVATION       CLUSTER    DISTANCE
----------------------------------------------------------------------------------
   1         335        0.0199        0.0368                      5        0.0639
   2          12        0.0238        0.0481                      4        0.0708
   3        1367        0.0103        0.0241                      5        0.0490
   4           8        0.0163        0.0359                      2        0.0708
   5         949        0.0163        0.0366                      3        0.0490
   6          22        0.0215        0.0411                      7        0.0893
   7          94        0.0199        0.0358                      1        0.0680

                643 OBSERVATION(S) WERE OMITTED DUE TO MISSING VALUES


                         STATISTICS FOR VARIABLES

   VARIABLE         TOTAL STD       WITHIN STD         R-SQUARED      RSQ/(1-RSQ)
   ------------------------------------------------------------------------------
   TP                0.060790         0.015293          0.936848        14.834930
   OVER-ALL          0.060790         0.015293          0.936848        14.834930

                                 PSEUDO F STATISTIC =  6873.52
                    APPROXIMATE EXPECTED OVER-ALL R-SQUARED =  0.97972
                              CUBIC CLUSTERING CRITERION =  -43.398


                                  SAS

                           FASTCLUS PROCEDURE

                             CLUSTER MEANS

                        CLUSTER            TP
                        ---------------------
                        1            0.139736
                        2            0.395100
                        3            0.026776
                        4            0.465850
                        5            0.075811
                        6            0.297082
                        7            0.207747


                      CLUSTER STANDARD DEVIATIONS

                        CLUSTER            TP
                        ---------------------
                        1            0.019931
                        2            0.023791
                        3            0.010322
                        4            0.016272
                        5            0.018290
                        6            0.021538
                        7            0.019922
```

Table 42. Single Variable Cluster Statistics for Total Dissolved Filtered Phosphorus

```
                                SAS

                        FASTCLUS PROCEDURE

          REPLACE=FULL  RADIUS=0  MAXCLUSTERS=7  MAXITER=1


                           INITIAL SEEDS

                      CLUSTER          TDFP
                      ---------------------
                      1            0.087900
                      2            0.041600
                      3            0.212000
                      4            0.127100
                      5            0.295600
                      6            0.170000
                      7            0.001100


                          CLUSTER SUMMARY

CLUSTER                RMS STD    MAXIMUM DISTANCE FROM    NEAREST    CENTROID
 NUMBER   FREQUENCY   DEVIATION   SEED TO OBSERVATION      CLUSTER    DISTANCE
------------------------------------------------------------------------------
   1         176        0.0110          0.0217                2        0.0352
   2         482      .0089493          0.0200                7        0.0269
   3           6      .0064871        .0085333                6        0.0373
   4          37        0.0109          0.0194                6        0.0463
   5           2        0.0158          0.0112                3        0.0806
   6          16        0.0112          0.0195                3        0.0373
   7        1711      .0056048          0.0141                2        0.0269

          1000 OBSERVATION(S) WERE OMITTED DUE TO MISSING VALUES


                     STATISTICS FOR VARIABLES

VARIABLE       TOTAL STD     WITHIN STD      R-SQUARED     RSQ/(1-RSQ)
----------------------------------------------------------------------
TDFP            0.028190       0.007043       0.937733       15.059997
OVER-ALL        0.028190       0.007043       0.937733       15.059997

                             PSEUDO F STATISTIC =  6081.73
            APPROXIMATE EXPECTED OVER-ALL R-SQUARED =  0.97973
                     CUBIC CLUSTERING CRITERION =  -40.051



                                SAS

                        FASTCLUS PROCEDURE

                           CLUSTER MEANS

                      CLUSTER          TDFP
                      ---------------------
                      1            0.072826
                      2            0.037589
                      3            0.203833
                      4            0.120224
                      5            0.284450
                      6            0.166562
                      7            0.010669



                   CLUSTER STANDARD DEVIATIONS

                      CLUSTER          TDFP
                      ---------------------
                      1            0.011048
                      2            0.008949
                      3            0.006487
                      4            0.010885
                      5            0.015768
                      6            0.011154
                      7            0.005605
```

Table 43. Single Variable Cluster Statistics for Nitrate plus Nitrite

```
                                 SAS

                          FASTCLUS PROCEDURE

         REPLACE=FULL  RADIUS=0  MAXCLUSTERS=7  MAXITER=1


                            INITIAL SEEDS

                       CLUSTER         NO2NO3
                       ---------------------
                       1               2.4500
                       2              11.3400
                       3               5.1200
                       4               0.0000
                       5              45.0000
                       6               7.7000
                       7              53.0000


                            CLUSTER SUMMARY

CLUSTER                RMS STD      MAXIMUM DISTANCE FROM      NEAREST    CENTROID
 NUMBER  FREQUENCY    DEVIATION     SEED TO OBSERVATION        CLUSTER    DISTANCE
----------------------------------------------------------------------------------
   1         79        0.6219         1.4550                      4        1.5461
   2          3        0.8834         1.0200                      6        2.9586
   3         25        0.7442         1.4255                      6        2.6986
   4        820        0.2558         0.8557                      1        1.5461
   5          2             0              0                      7        8.0000
   6         14        0.8139         1.3015                      3        2.6986
   7          1             .              0                      5        8.0000

          2486 OBSERVATION(S) WERE OMITTED DUE TO MISSING VALUES


                       STATISTICS FOR VARIABLES

VARIABLE        TOTAL STD       WITHIN STD        R-SQUARED       RSQ/(1-RSQ)
-----------------------------------------------------------------------------
NO2NO3           2.967459         0.338420         0.987077         76.380263
OVER-ALL         2.967459         0.338420         0.987077         76.380263

                           PSEUDO F STATISTIC = 11928.05
         APPROXIMATE EXPECTED OVER-ALL R-SQUARED =  0.97996
                      CUBIC CLUSTERING CRITERION =    9.757



                                 SAS

                          FASTCLUS PROCEDURE

                            CLUSTER MEANS

                       CLUSTER         NO2NO3
                       ---------------------
                       1               1.8092
                       2              10.3200
                       3               4.6628
                       4               0.2631
                       5              45.0000
                       6               7.3614
                       7              53.0000


                      CLUSTER STANDARD DEVIATIONS

                       CLUSTER         NO2NO3
                       ---------------------
                       1             0.621908
                       2             0.883402
                       3             0.744180
                       4             0.255763
                       5             0.000000
                       6             0.818910
                       7                    .
```

Table 44. Single Variable Cluster Statistics for Uncorrected Chlorophyll *a*

```
                                  SAS

                           FASTCLUS PROCEDURE

           REPLACE=FULL  RADIUS=0  MAXCLUSTERS=7  MAXITER=1


                             INITIAL SEEDS

                        CLUSTER             CHL
                        ---------------------
                        1                85.660
                        2               107.400
                        3                63.980
                        4                 0.110
                        5               128.960
                        6                42.720
                        7                21.390


                            CLUSTER SUMMARY

CLUSTER               RMS STD      MAXIMUM DISTANCE FROM      NEAREST    CENTROID
 NUMBER  FREQUENCY   DEVIATION     SEED TO OBSERVATION        CLUSTER    DISTANCE
---------------------------------------------------------------------------------
   1          30      4.5808        9.2170                       3       20.6951
   2           8      5.9812       11.4725                       1       21.1991
   3         115      6.0459       10.4522                       6       19.0145
   4         407      3.2220        6.9203                       7       13.9344
   5           1       .            0                            2       28.0012
   6         280      5.5937       10.7709                       3       19.0145
   7         336      5.1355       10.7909                       4       13.9344


                        STATISTICS FOR VARIABLES

 VARIABLE       TOTAL STD      WITHIN STD       R-SQUARED      RSQ/(1-RSQ)
 --------------------------------------------------------------------------
 CHL            20.778013       4.786517        0.947203        17.940448
 OVER-ALL       20.778013       4.786517        0.947203        17.940448

                             PSEUDO F STATISTIC =  3498.39
               APPROXIMATE EXPECTED OVER-ALL R-SQUARED =  0.97939
                         CUBIC CLUSTERING CRITERION =  -23.958



                                  SAS

                           FASTCLUS PROCEDURE

                             CLUSTER MEANS

                        CLUSTER             CHL
                        ---------------------
                        1                79.760
                        2               100.959
                        3                59.065
                        4                 6.877
                        5               128.960
                        6                40.050
                        7                20.811


                     CLUSTER STANDARD DEVIATIONS

                        CLUSTER             CHL
                        ---------------------
                        1               4.58085
                        2               5.99118
                        3               6.04592
                        4               3.22197
                        5                .
                        6               5.59370
                        7               5.13550
```

TABLE 45

CLUSTER STATISTICS USING STANDARDIZED LOG-TRANSFORMED CHLORIDE DATA.

CLUSTER	CUBIC CLUSTERING CRITERION	OVERALL ESTIMATED R2	VARIANCE* RATIO
5	- 61.1907	0.9601	5.21
6	- 66.7596	0.9723	6.70
7	- 71.2620	0.9797	8.31
8	- 71.6792	0.9845	10.94
9	- 69.5644	0.9877	14.79
10	- 67.6646	0.9901	19.32
11	- 77.1008	0.9918	18.60
12	- 80.2753	0.9931	20.60
13	- 74.0496	0.9941	28.34
14	- 77.1559	0.9950	30.58

* Variance Ratio = Between-Cluster Variance/Within-Cluster Variance

TABLE 46

CLUSTER STATISTICS
USING STANDARDIZED NON-TRANSFORMED MULTI-VARIABLE DATA (N=5)

CLUSTER	CUBIC CLUSTERING CRITERION	OVERALL ESTIMATED R2	VARIANCE* RATIO
4	37.537	0.3727	1.6711
5	35.494	0.4548	2.1340
6	29.507	0.5255	2.3866
7	28.518	0.5566	2.6863
8	27.080	0.5824	2.9174
9	28.226	0.6041	3.3176
10	29.546	0.6228	3.7450
11	29.066	0.6392	4.0038
12	31.097	0.6537	4.5283
13	30.225	0.6668	4.7266
14	27.911	0.6786	4.7220

* Variance Ratio = Between-Cluster Variance/Within-Cluster Variance

TABLE 47

CLUSTER STATISTICS
USING STANDARDIZED LOG-TRANSFORMED MULTI-VARIABLE DATA (N=5)

CLUSTER	CUBIC CLUSTERING CRITERION	OVERALL ESTIMATED R2	VARIANCE* RATIO
4	44.903	0.3727	1.9559
5	35.613	0.4548	2.1426
6	32.651	0.5255	2.5621
7	33.997	0.5567	3.0510
8	33.383	0.5824	3.3930
9	35.758	0.6041	3.9817
10	36.332	0.6228	4.4238
11	32.080	0.6392	2.0289
12	31.794	0.6537	4.6093
13	34.603	0.6667	5.2886
14	33.475	0.6786	5.4610

* Variance Ratio = Between-Cluster Variance/Within-Cluster Variance

TABLE 48

COMPARISON OF THE INDIVIDUAL MULTIPLE CLUSTER MEAN CONCENTRATIONS WITH COMPUTED MEANS AND MEDIANS FOR EACH VARIABLE

VARIABLE	MULTIPLE CLUSTER NUMBER							MEAN	MEDIAN
	1	2	3	4	5	6	7		
TURB	5.5	26.4	5.9	13.4	5.5	17.2	3.1	8.8	4.5
TP	61.1	159.0	20.3	81.3	40.8	100.0	31.3	65.8	46.3
TFP	18.9	51.9	5.7	46.3	13.8	22.8	9.5	25.8	14.6
CHL	26.0	46.4	9.1	7.5	10.1	38.1	9.3	20.3	14.8
CL	17.6	28.9	12.4	19.0	12.7	21.4	18.7	18.3	18.0

TURB - TURBIDITY (JTU + NTU)
TP - TOTAL PHOSPHORUS (UG/L)
TFP - TOTAL FILTERED PHOSPHORUS (UG/L)
CHL - UNCORRECTED CHLOROPHYLL
CL - CHLORIDE

Table 49

Clustering of the Homogeneous Zone Cluster to Determine Number of Sampling Stations

SAS   23:55 THURSDAY, NOVEMBER 13, 1986   57

GRID#	LONG	LATI	CLUSTER	DISTANCE	MED34	MED17	MED18	MED27	MED30
1	82.7500	41.9833	1	0.04666	3.900	.	.	.	.
2	82.8833	41.8167	1	0.15842	4.100	.	.	.	.
3	83.1500	41.8167	1	0.48652	4.450	33.50	.	17.50	.
4	82.9500	41.8500	1	0.71716	.	42.00	10.00	17.50	.
5	83.0833	41.9167	1	0.74540	3.400	40.00	15.00	18.00	.
6	82.9833	41.9833	1	0.75224	2.900	40.00	10.00	17.00	.
7	82.9500	41.9167	1	0.82436	3.000	.	.	18.00	.
8	83.0167	41.9500	1	0.88326	2.450	38.00	10.50	16.50	.
9	83.0333	41.9500	1	0.92211	2.900	30.00	10.00	17.00	.
10	82.8333	41.9833	1	0.96252	2.750	46.50	12.50	16.50	.
11	83.1833	41.7167	1	0.98529	3.200	.	.	.	8.100
12	83.2500	41.7833	1	1.00633	.	.	.	18.50	.
13	83.2167	41.7167	1	1.00633	.	.	.	18.50	.
14	82.9167	41.9167	1	1.06862	2.750	40.00	16.00	18.00	.
15	82.6167	41.9833	1	1.10138	4.400	.	.	19.00	8.000
16	82.5500	41.9833	1	1.12679	3.000	28.00	9.00	17.50	.
17	82.9500	41.9500	1	1.16669	2.000	42.00	10.00	17.20	.
18	82.9500	41.8833	1	1.22521	2.300	46.00	10.00	18.00	.
19	83.1833	41.8833	1	1.30008	4.300	38.50	14.00	13.50	10.700
20	82.8167	41.9833	1	1.30753	4.000	26.00	8.00	18.00	.
21	82.8167	41.9167	1	1.31482	2.200	27.00	10.00	16.50	.
22	82.7500	41.9167	1	1.33885	1.800	30.00	10.00	17.50	.
23	82.7833	41.9167	1	1.34996	1.850	29.00	10.00	17.40	.
24	82.8500	41.9167	1	1.36687	3.000	33.50	10.00	16.85	12.600
25	82.6333	41.9167	1	1.38475	2.700	28.00	8.00	16.00	.
26	82.9833	41.9500	1	1.39336	1.750	41.00	11.50	15.00	.
27	83.0833	41.7500	1	1.40184	4.900	.	.	19.50	.
28	83.0167	41.8500	1	1.41632	1.800	30.00	12.00	19.00	.
29	82.5833	41.9833	1	1.41881	4.000	40.00	18.00	.	.
30	82.9833	41.8833	1	1.42932	2.300	36.00	10.00	20.00	.
31	83.1167	41.8500	1	1.46325	5.700	36.00	12.00	13.90	.
32	83.0500	41.8500	1	1.58314	2.000	43.00	10.00	20.00	.
33	82.7167	41.9833	1	1.63468	3.000	24.00	7.00	18.00	.
34	82.7167	41.9500	1	1.65545	2.700	25.00	7.00	16.00	.
35	82.9833	41.8167	1	1.66951	1.850	47.00	15.00	19.50	.
36	82.7167	41.9167	1	1.70527	2.200	28.90	10.00	19.50	12.290
37	82.6500	41.9500	1	1.73529	.	29.00	.	20.00	.
38	82.9167	41.9833	1	1.79675	2.600	23.00	7.00	18.50	.
39	83.2333	41.7833	1	1.84344	.	52.00	13.00	14.00	.
40	83.1500	41.7167	1	1.84801	6.200	38.40	12.40	14.60	12.900
41	82.9333	41.7500	1	1.87628	2.600	50.00	17.00	20.00	.
42	83.2500	41.8833	1	1.98076	4.000	.	.	21.00	.
43	82.9833	41.7833	1	1.99622	3.850	51.50	20.00	18.00	.
44	83.0167	41.9833	1	2.00480	2.950	21.50	6.00	19.00	.
45	82.9167	41.9500	1	2.01386	1.800	33.00	10.00	21.50	.
46	82.9333	41.9167	1	2.06555	.	22.00	.	19.45	.
47	83.1833	41.9500	1	2.09321	6.000	47.30	14.50	12.10	8.105
48	83.0500	41.8833	1	2.10431	2.670	40.00	20.00	14.00	.
49	83.0500	41.9500	1	2.11702	4.050	24.60	8.10	19.60	5.375
50	82.9167	41.8500	1	2.15706	.	23.00	.	20.00	.
51	82.6500	41.9833	1	2.15978	6.150	24.00	6.00	13.50	9.040
52	83.1333	41.7500	1	2.17236	6.000	60.00	10.00	15.60	.
53	83.0167	41.8833	1	2.19403	3.350	50.00	20.00	20.00	.
54	83.0167	41.8167	1	2.22287	4.535	23.90	6.25	12.00	9.675
55	83.1167	41.9833	1	2.26622	4.800	36.00	10.50	11.00	.
56	83.1500	41.7500	1	2.26656	1.200	30.00	20.00	16.00	.
57	82.6333	41.9833	1	2.45134	4.100	24.55	4.30	16.00	13.870
58	82.6333	41.9500	1	2.46680	4.400	20.00	8.00	11.85	6.720
59	83.1167	41.9500	1	2.51554	3.800	21.00	6.50	12.10	6.520
60	83.1500	41.8500	1	2.53028	3.200	56.00	20.00	20.50	.
61	82.9500	41.7833	1	2.54210	3.900	18.00	4.70	.	.
62	83.0333	41.8500	1	2.54280	2.300	50.00	12.00	11.00	.
63	83.1333	41.8500	1	2.60882	2.600	62.00	20.00	17.00	.
64	82.9333	41.8500	1	2.62611	3.500	60.00	20.00	20.00	.
65	83.1333	41.9167	1	2.69068	5.000	64.00	20.00	17.00	.
66	82.7333	41.9833	1	2.74799	.	20.00	.	21.00	.
67	82.8333	41.9167	1	2.83220	1.550	32.50	10.00	24.00	.
68	83.0500	41.9167	1	2.90692	2.000	35.00	25.00	16.00	.
69	82.8333	41.8500	1	2.93613	.	20.00	.	21.50	.
70	83.2167	41.8500	1	3.10712	3.950	70.00	20.00	15.00	.
71	83.2167	41.7500	1	3.21107	4.500	70.00	21.50	17.00	.
72	82.7333	41.8500	1	3.24041	10.000	30.00	9.20	.	8.690
73	83.2167	41.8833	1	3.30595	4.500	70.00	20.00	13.40	.
74	83.1500	41.9833	1	3.57432	7.000	70.00	20.00	14.00	.
75	82.7500	41.8833	1	3.66353	8.650	25.70	6.50	22.50	.
76	82.7833	41.8833	1	3.67772	9.000	40.00	20.00	10.00	.
77	83.2833	41.7167	1	3.91734	10.000	57.50	6.00	20.50	.
78	83.1500	41.9167	1	4.73767	9.000	10.00	.	.	.
79	83.0500	41.9833	1	5.48193	12.000	21.00	4.20	9.00	.

MED 34 = Median of original turbidity data

MED 17 = Median of original total phosphorus data

MED 18 = Median of original total dissolved phosphorus data

MED 27 = Median of original chloride data

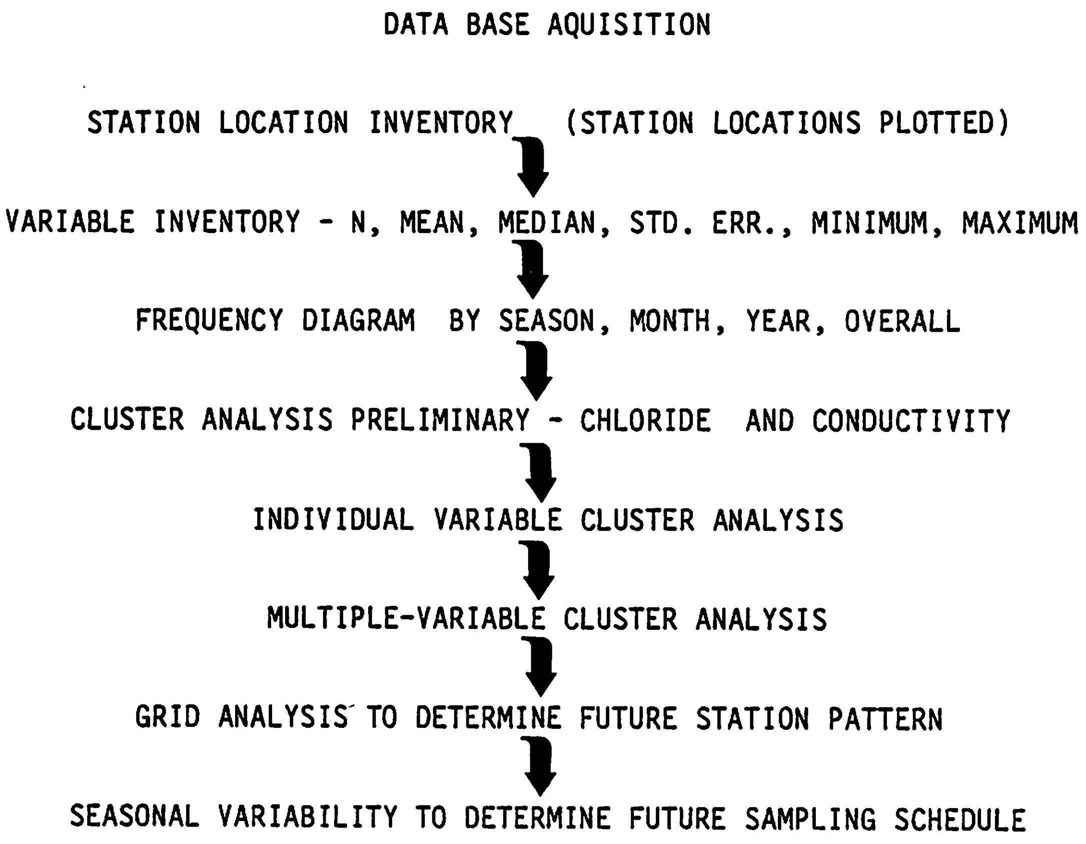
MED 30 = Median of original uncorrected chlorophyll data

FIGURES

Figure 1a. Western basin bathymetry.
(Taken from Bartish, 1984)

Figure 1b. Dominant surface flow patterns, western basin Lake Erie. (Taken from Bartish, 1984)

FIGURE 2. CLUSTER ANALYSIS FLOW CHART



DATA BASE AQUISITION

STATION LOCATION INVENTORY (STATION LOCATIONS PLOTTED)

VARIABLE INVENTORY - N, MEAN, MEDIAN, STD. ERR., MINIMUM, MAXIMUM

FREQUENCY DIAGRAM BY SEASON, MONTH, YEAR, OVERALL

CLUSTER ANALYSIS PRELIMINARY - CHLORIDE AND CONDUCTIVITY

INDIVIDUAL VARIABLE CLUSTER ANALYSIS

MULTIPLE-VARIABLE CLUSTER ANALYSIS

GRID ANALYSIS TO DETERMINE FUTURE STATION PATTERN

SEASONAL VARIABILITY TO DETERMINE FUTURE SAMPLING SCHEDULE

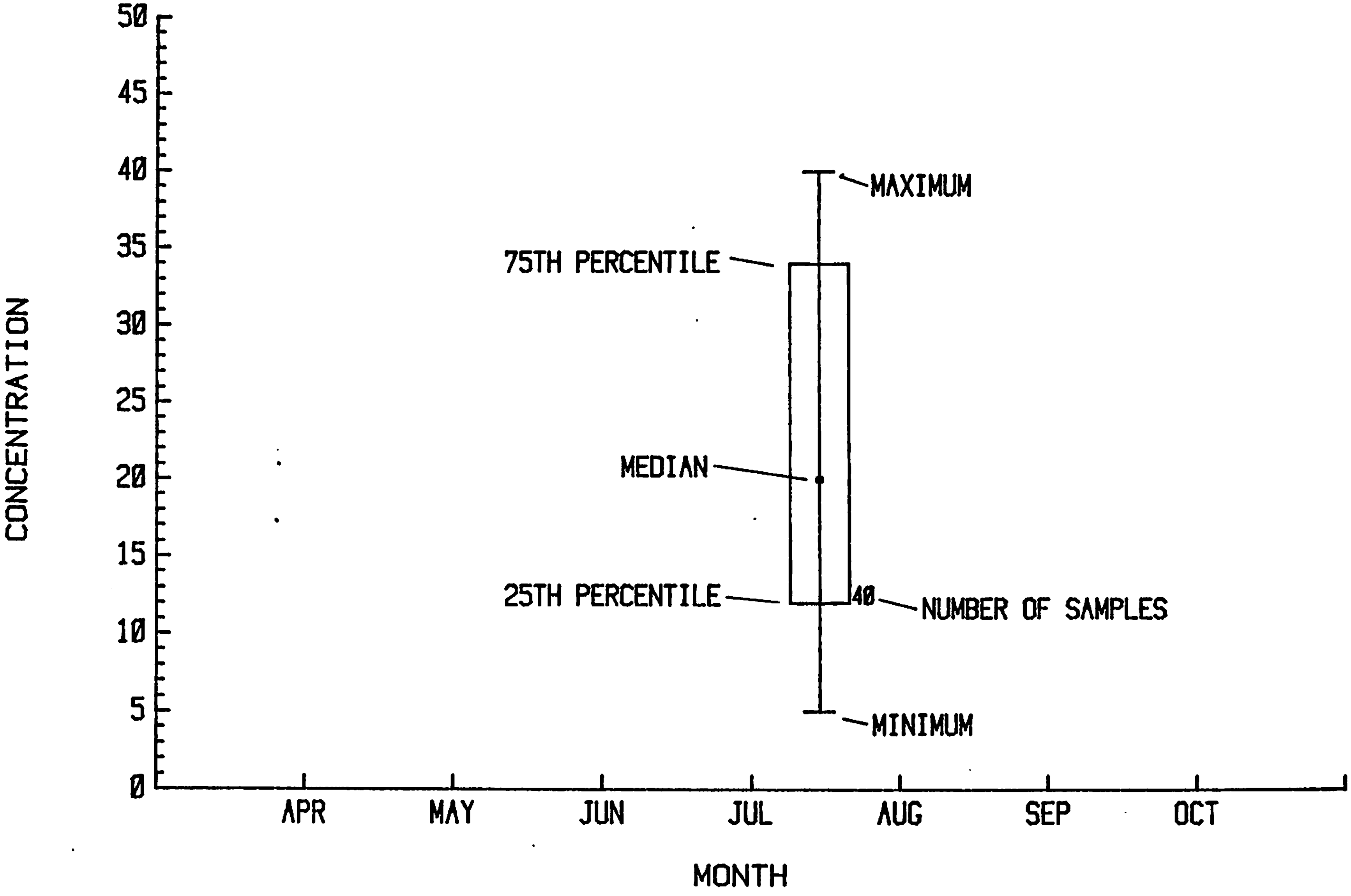


Figure 3. EXPLANATION OF MEDIAN PLOTS

(After Reckhow, 1980)

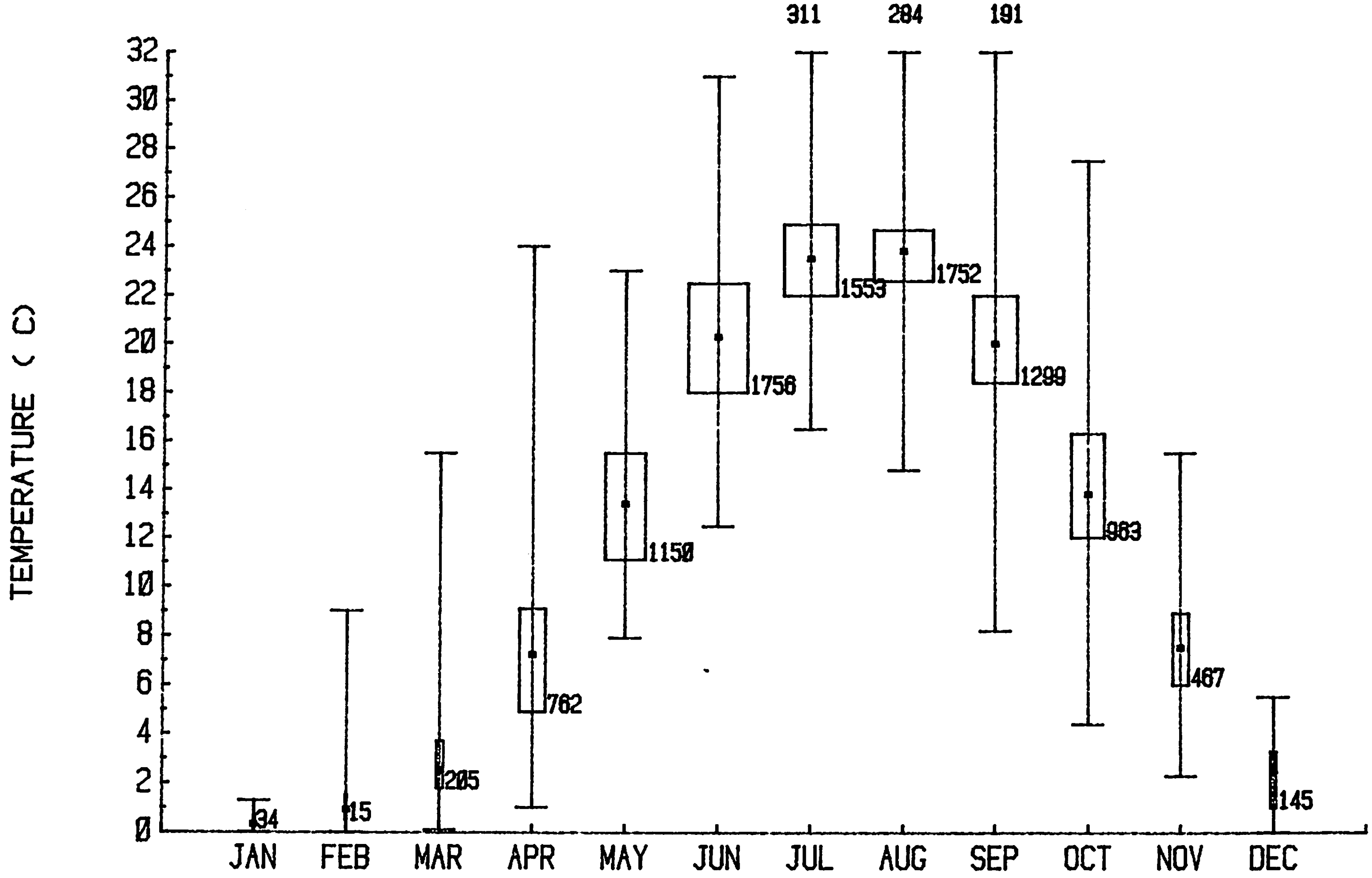


FIGURE 4 WESTERN BASIN MEDIAN MONTHLY TEMPERATURE OVER THE PERIOD OF RECORD

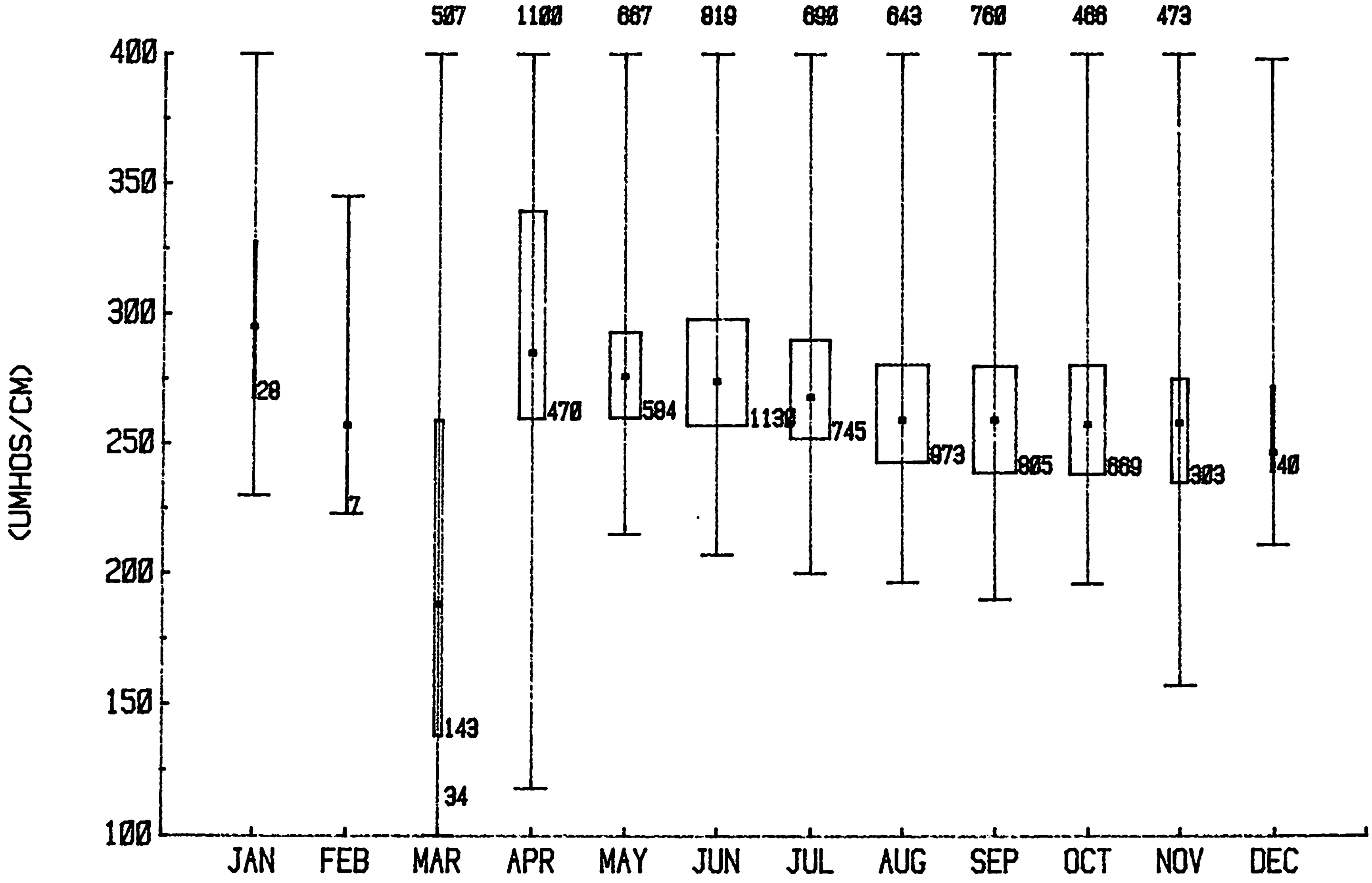


FIGURE 5 WESTERN BASIN MEDIAN MONTHLY CONDUCTIVITY VALUES OVER THE PERIOD OF RECORD

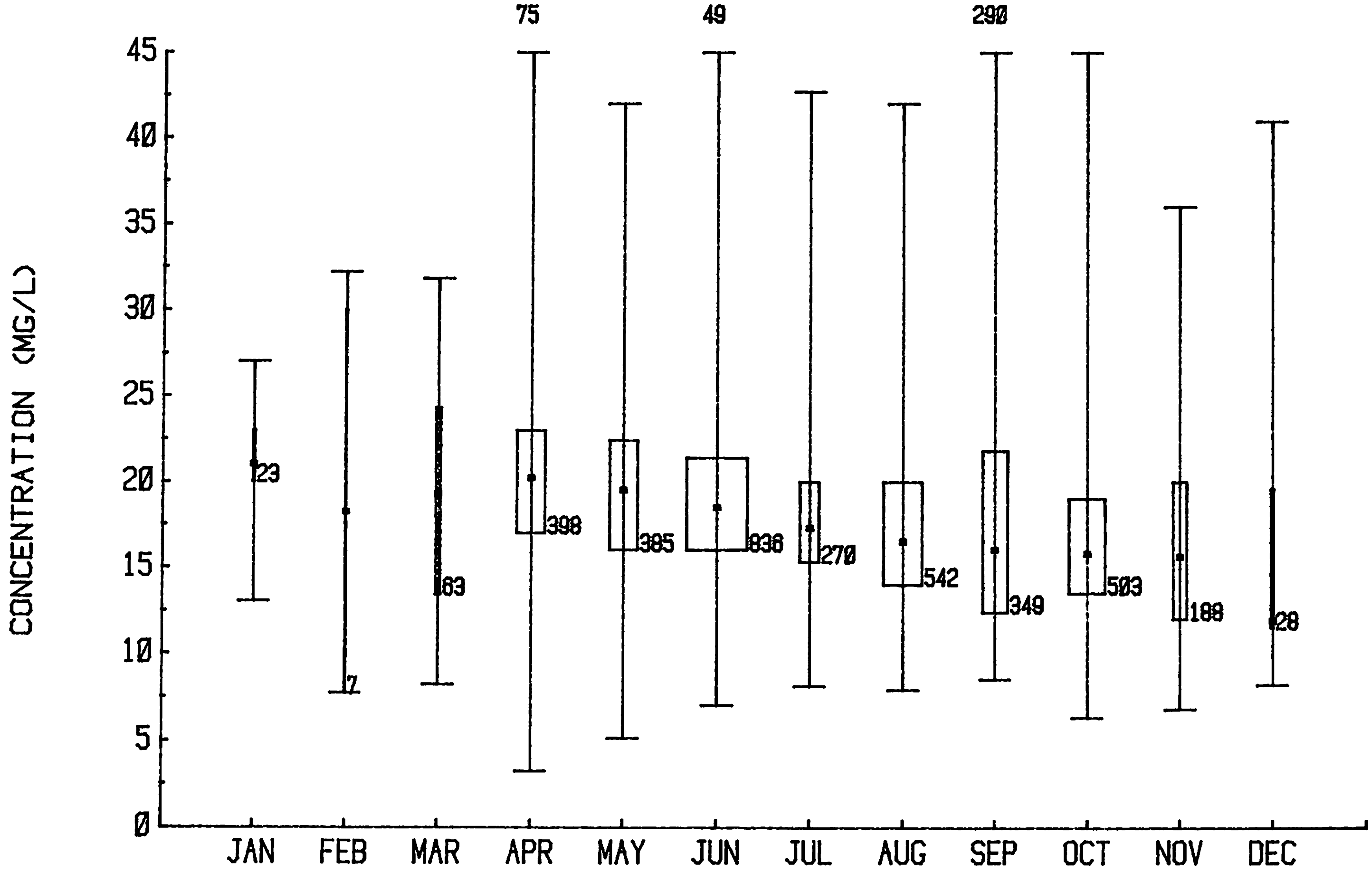


FIGURE 6 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF CHLORIDE OVER THE PERIOD OF RECORD

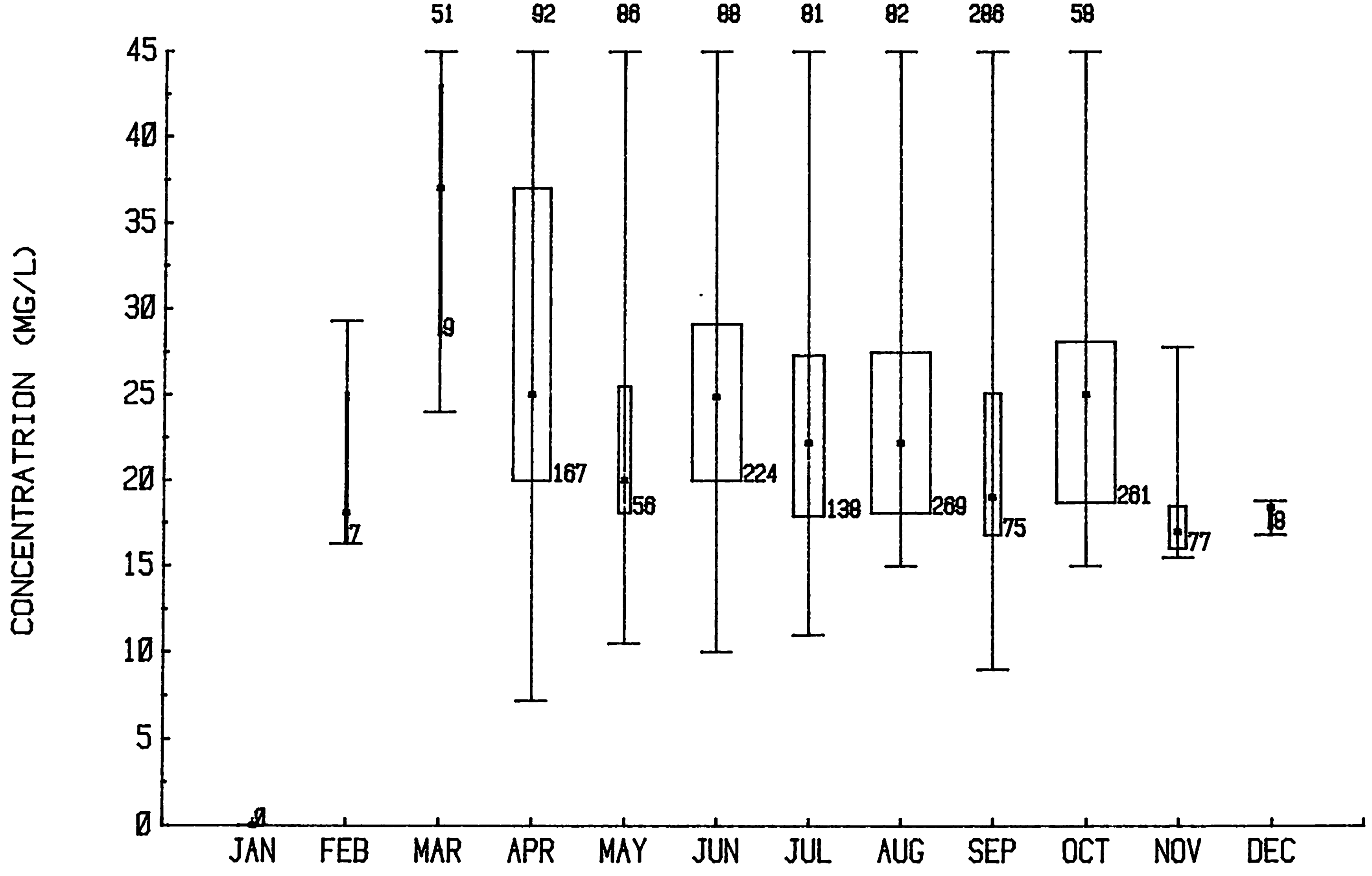


FIGURE 7 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF SULFATE OVER THE PERIOD OF RECORD

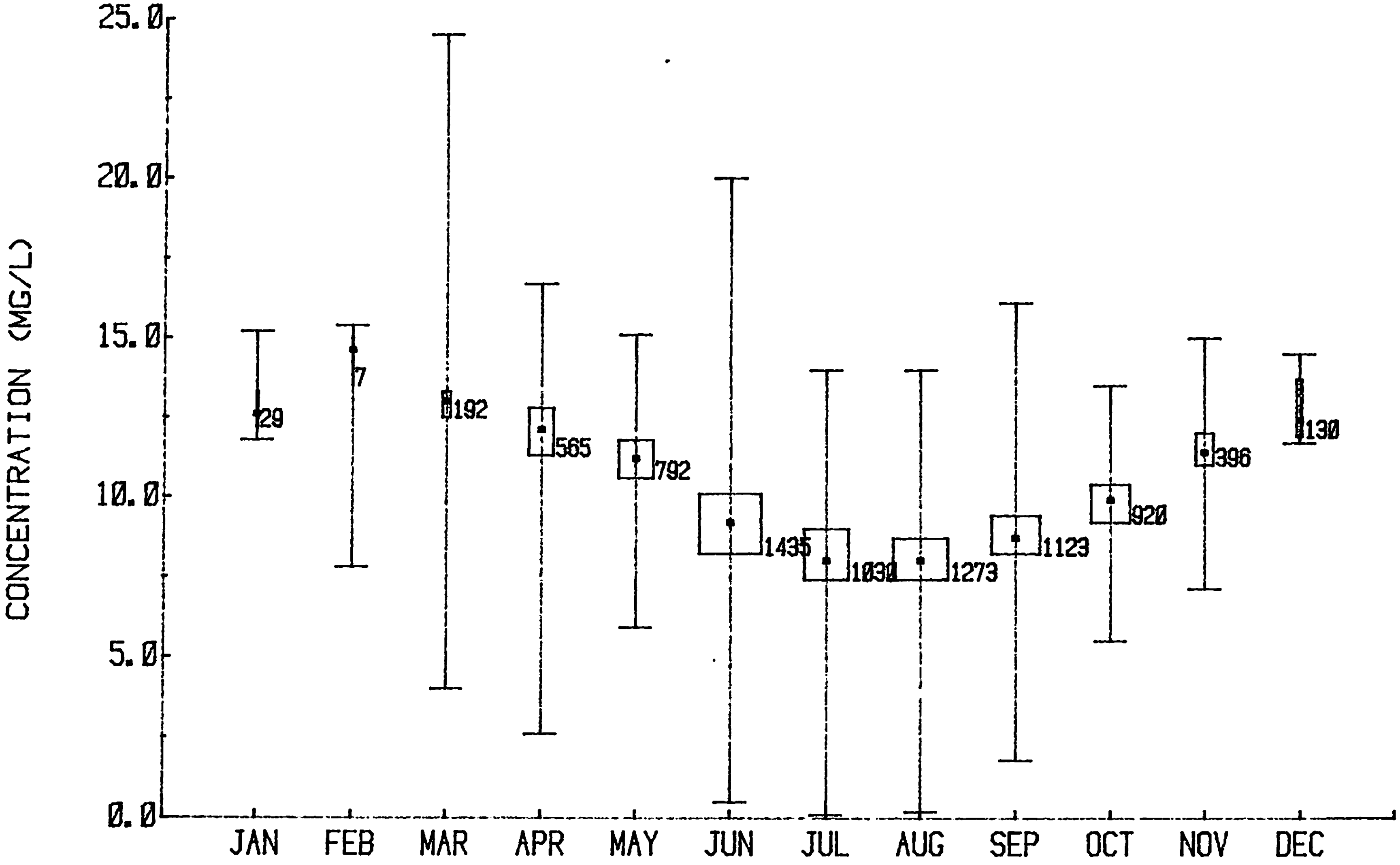


FIGURE 8 WESTERN BASIN MEDIAN MONTHLY CONCENTRATION OF DISSOLVED OXYGEN OVER THE PERIOD OF RECORD

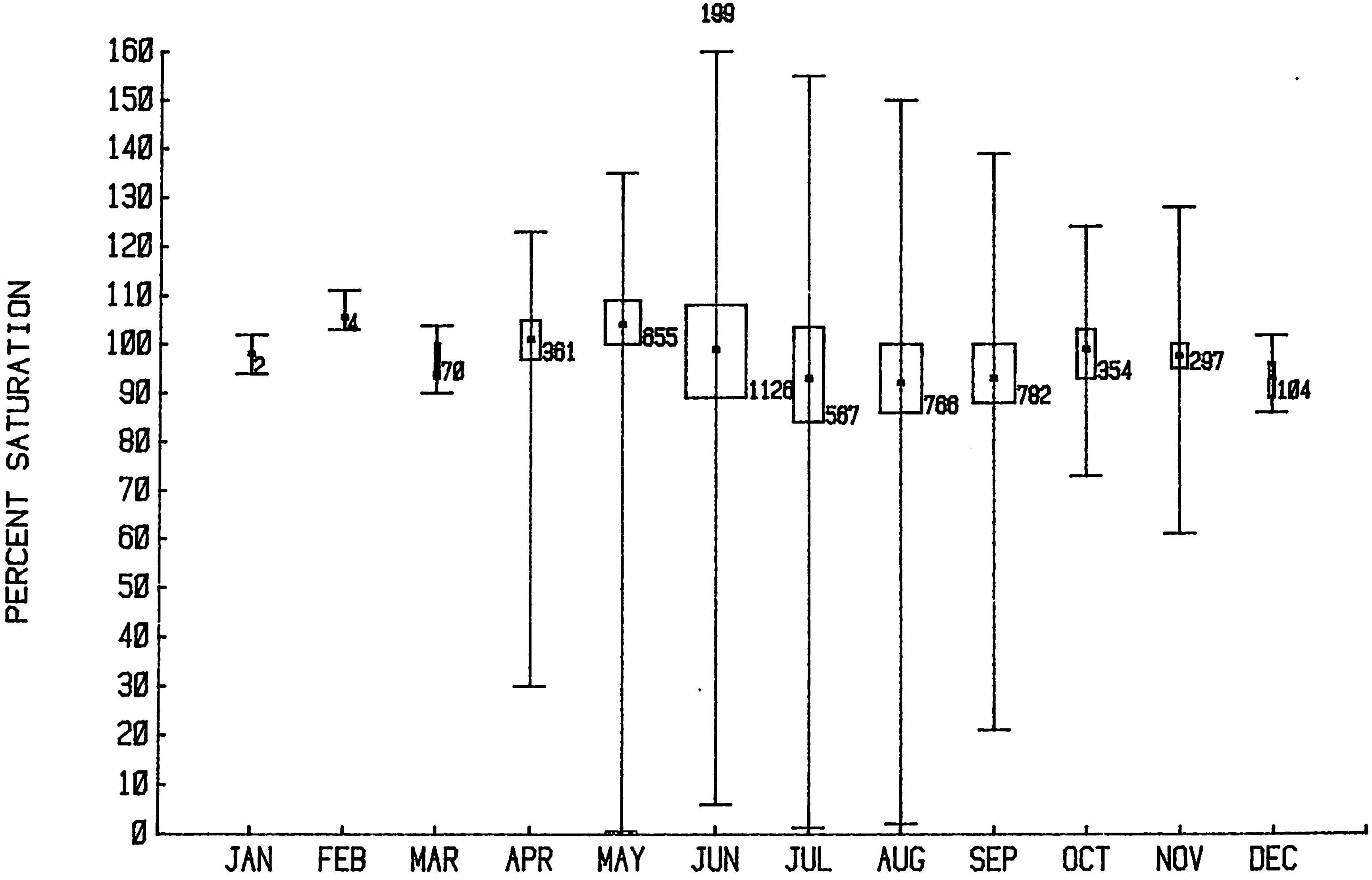


FIGURE 9 WESTERN BASIN MEDIAN MONTHLY DISSOLVED OXYGEN
PERCENT SATURATION OVER THE PERIOD OF RECORD

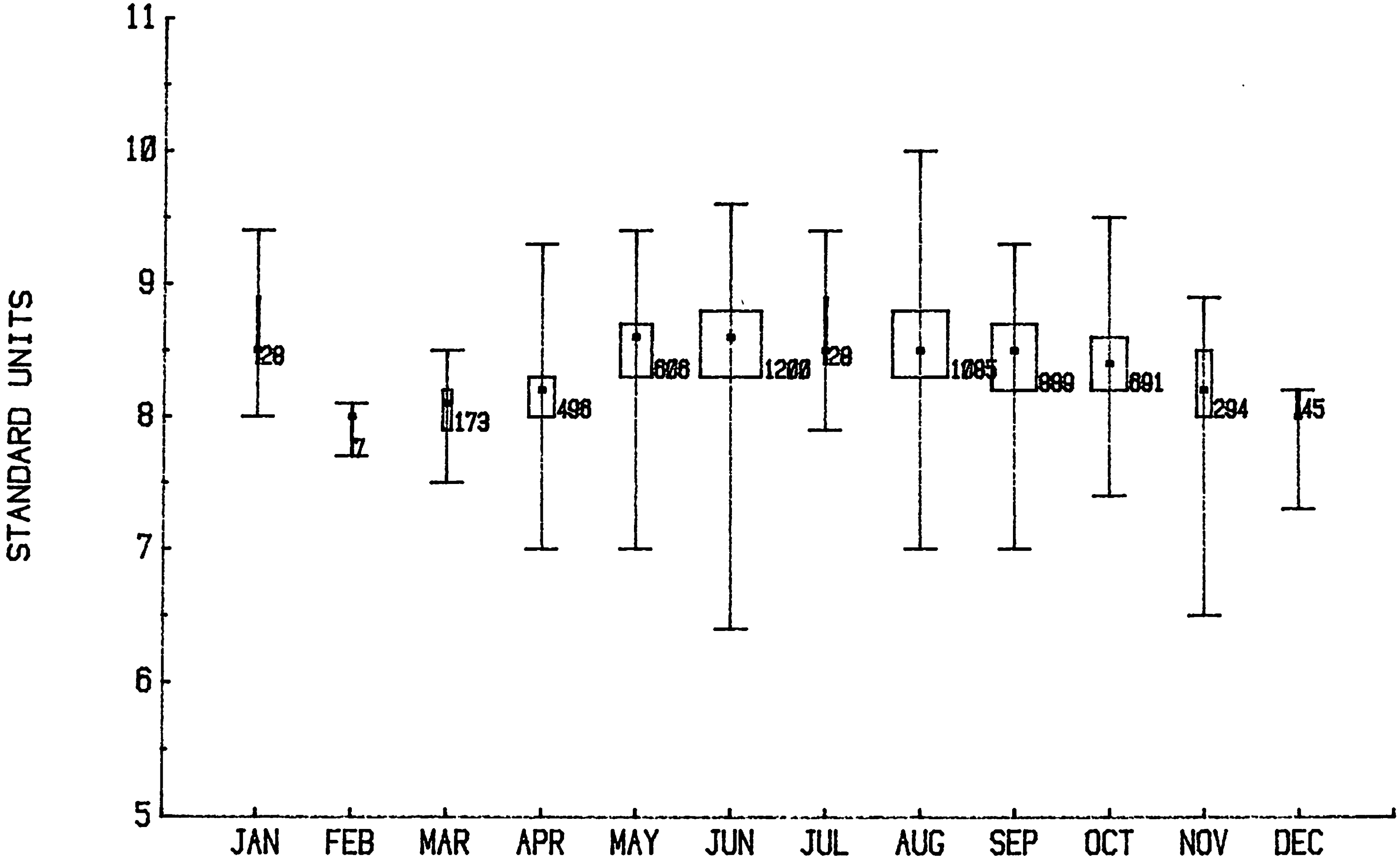


FIGURE 10 WESTERN BASIN MEDIAN MONTHLY PH
VALUES OVER THE PERIOD OF RECORD

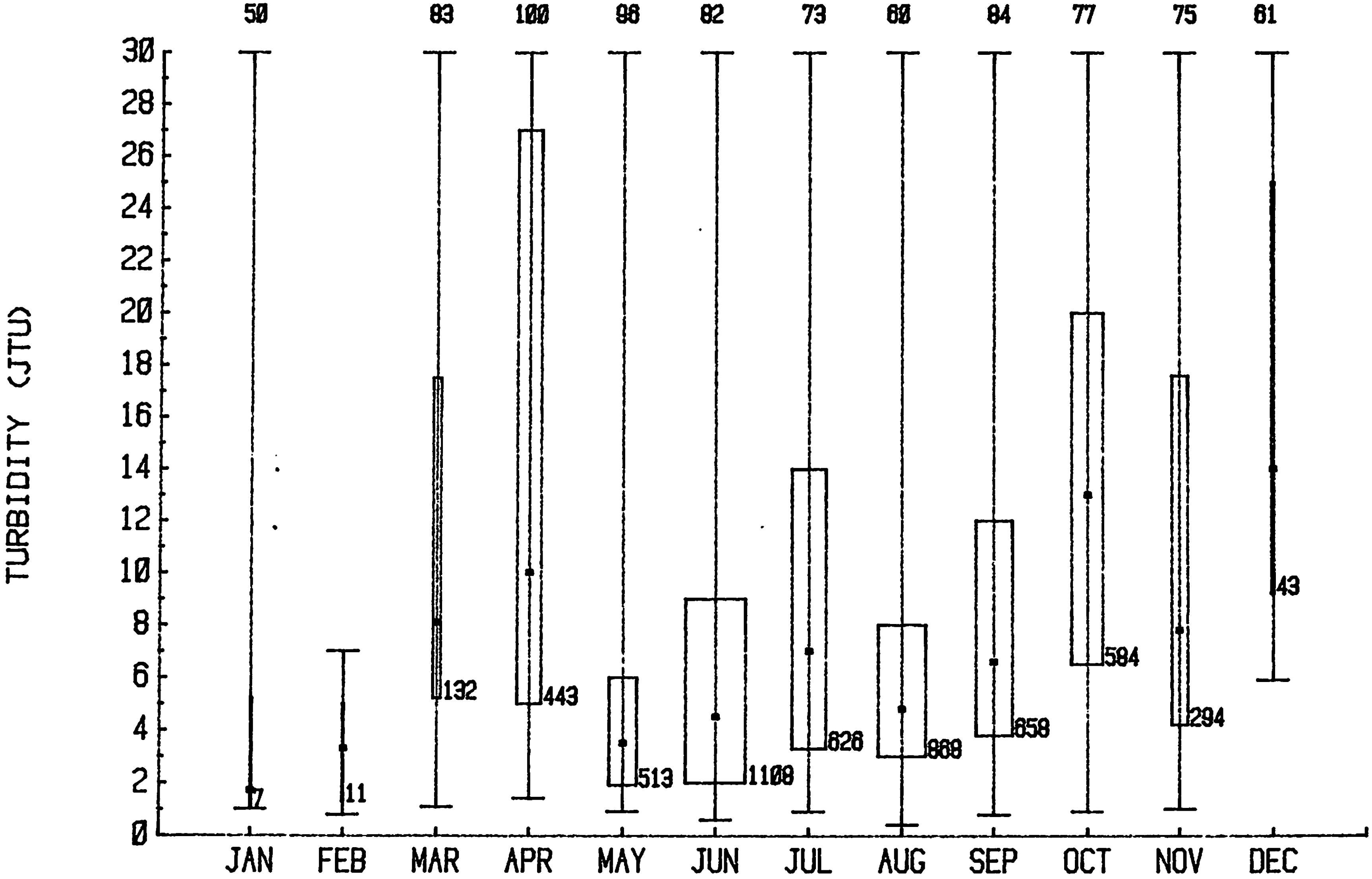


FIGURE 11 WESTERN BASIN MEDIAN MONTHLY TURBIDITY
VALUES OVER THE PERIOD OF RECORD

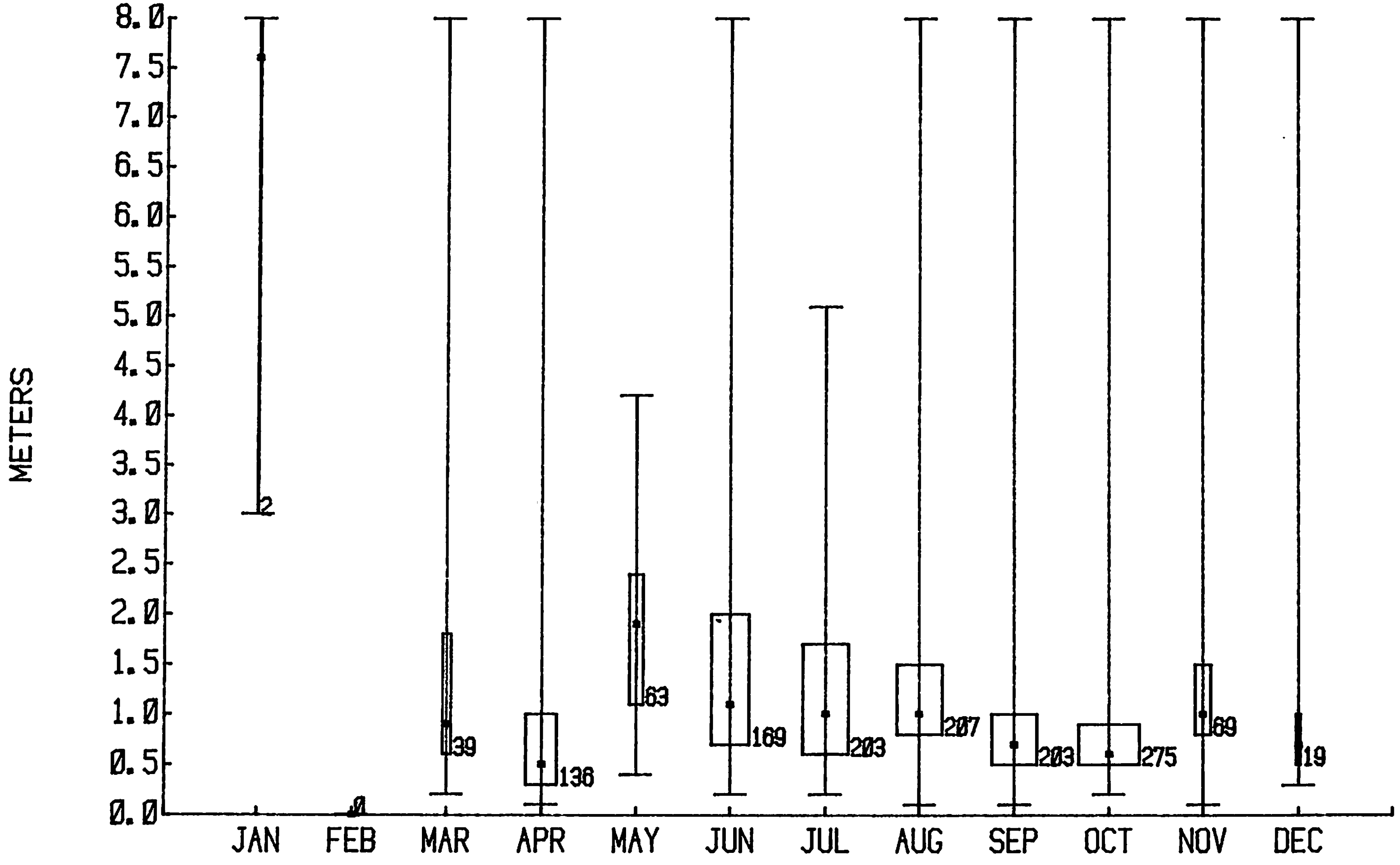


FIGURE 12 WESTERN BASIN MEDIAN MONTHLY SECCHI
VALUES OVER THE PERIOD OF RECORD

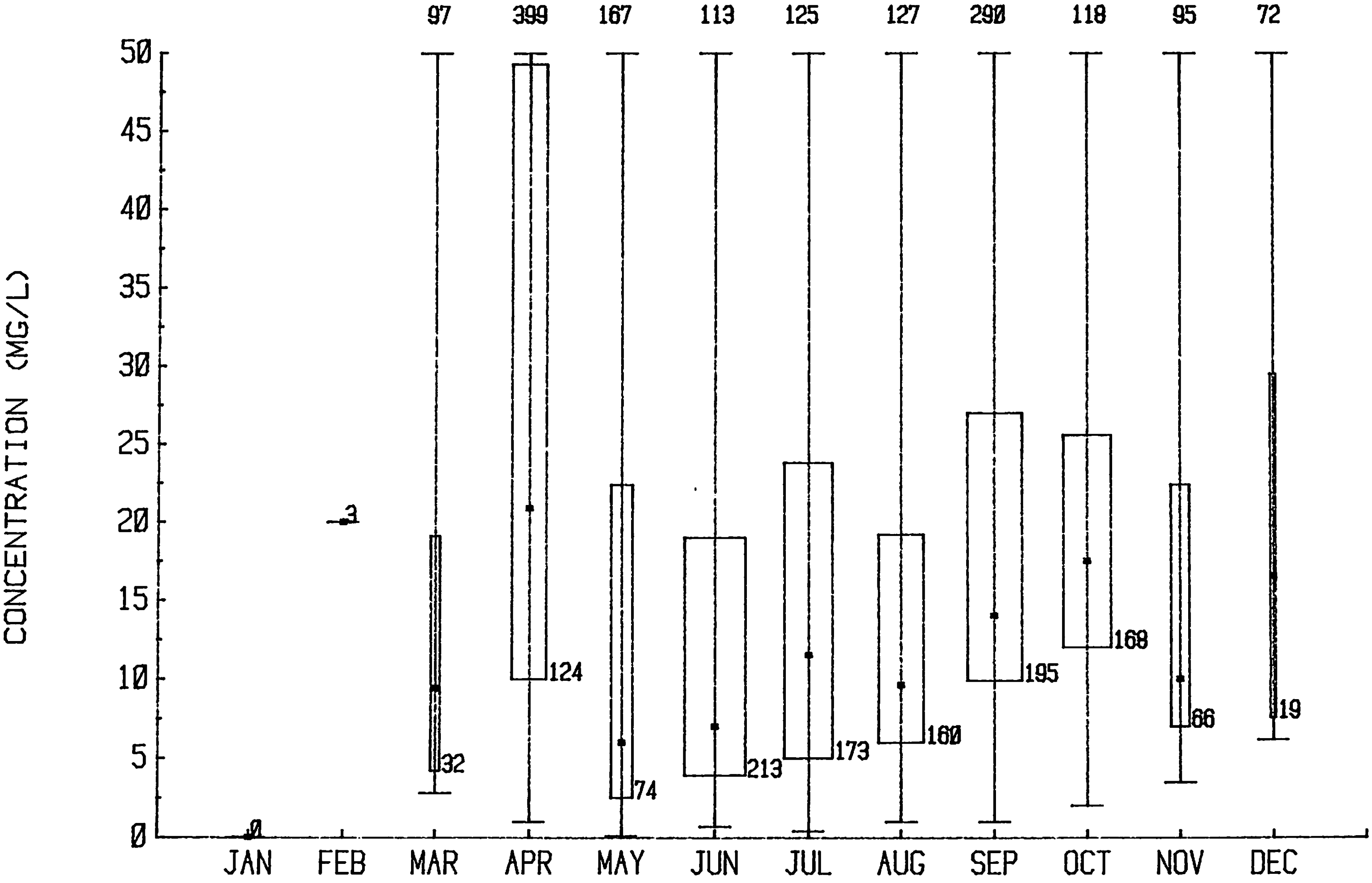


FIGURE 13 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF
TOTAL SUSPENDED SOLIDS OVER THE PERIOD OF RECORD

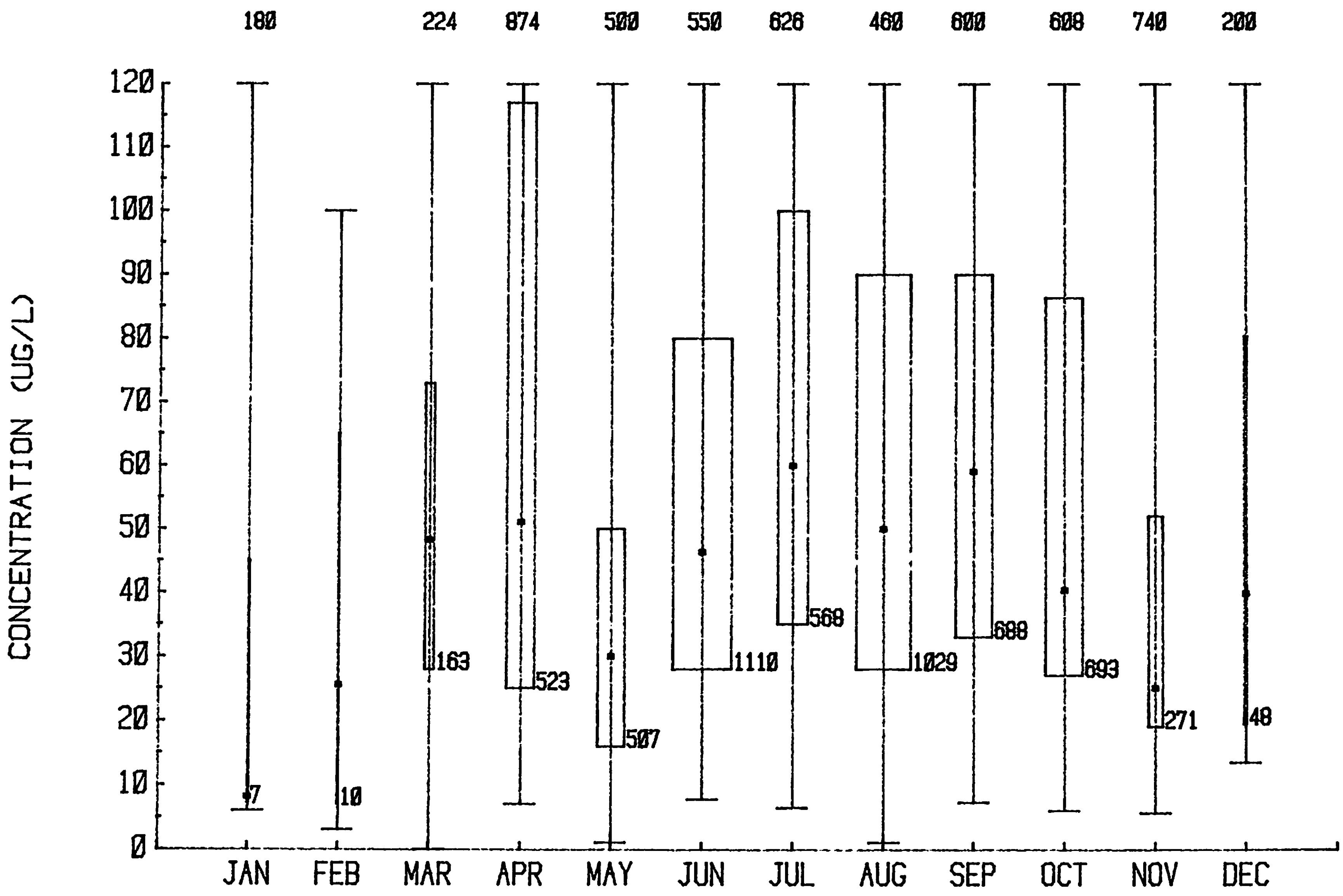


FIGURE 14 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF TOTAL PHOSPHORUS OVER THE PERIOD OF RECORD

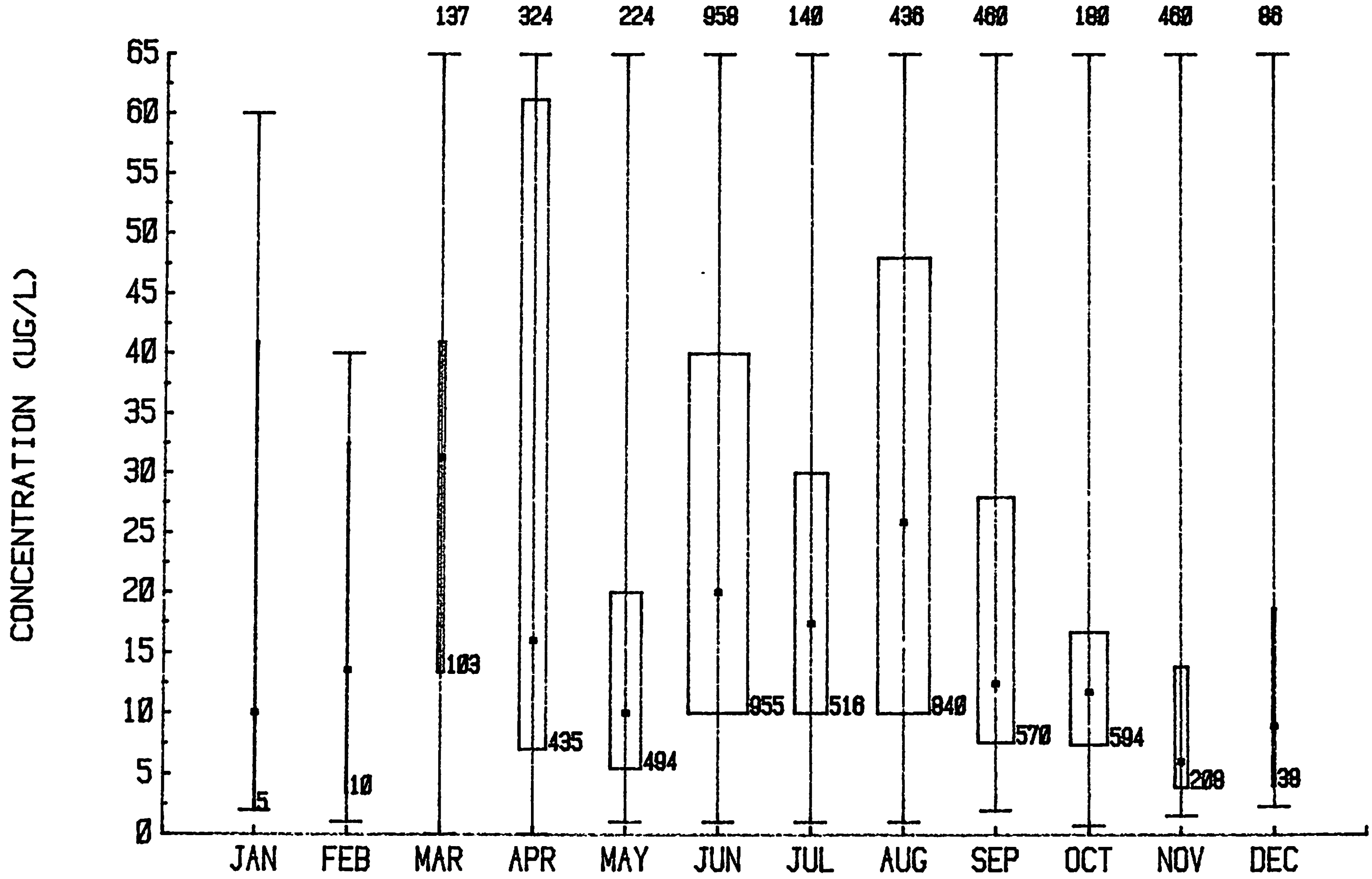


FIGURE 15 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF TOTAL DISSOLVED PHOSPHORUS OVER THE PERIOD OF RECORD

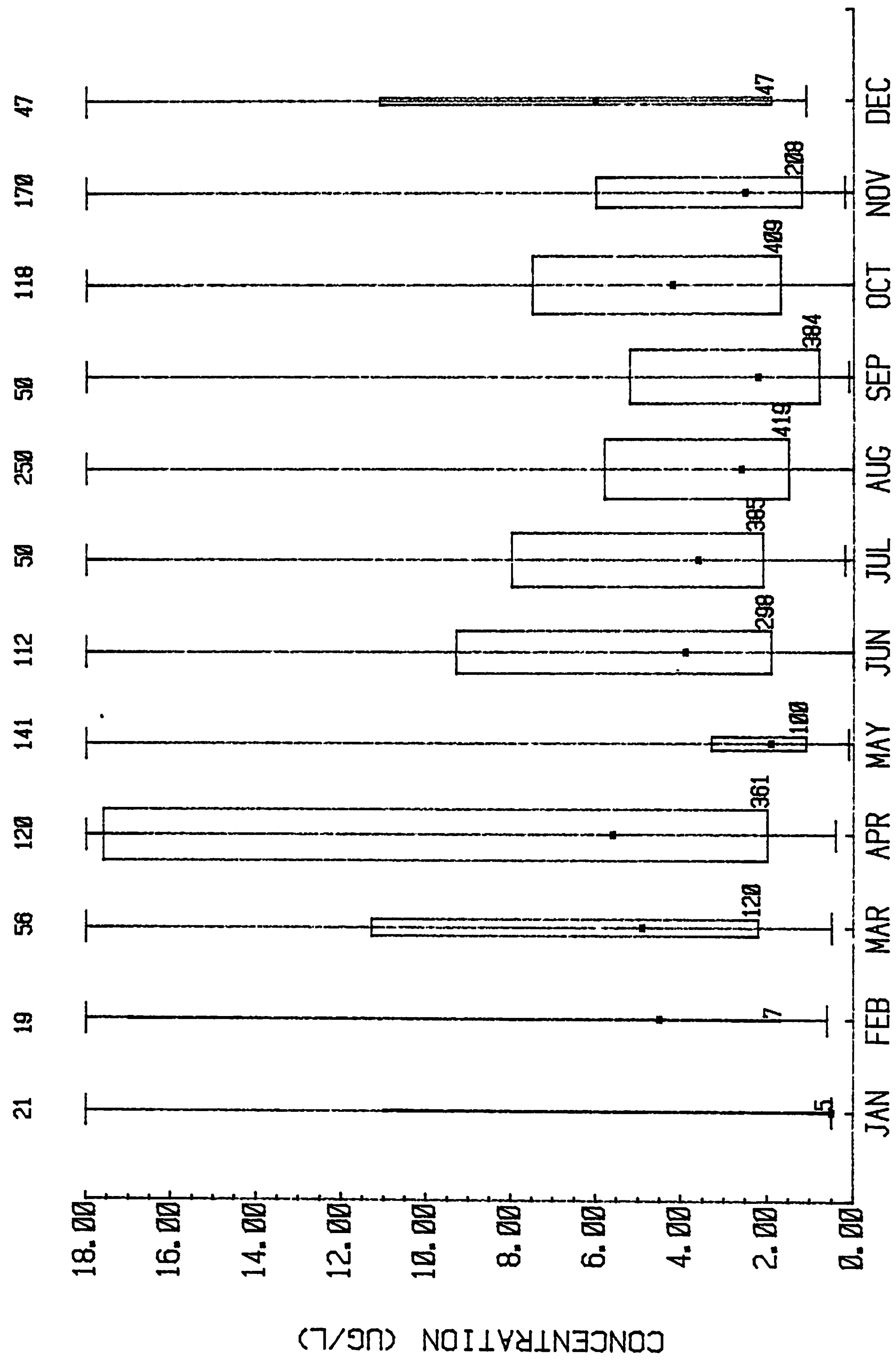


FIGURE 16 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF ORTHO-PHOSPHORUS OVER THE PERIOD OF RECORD

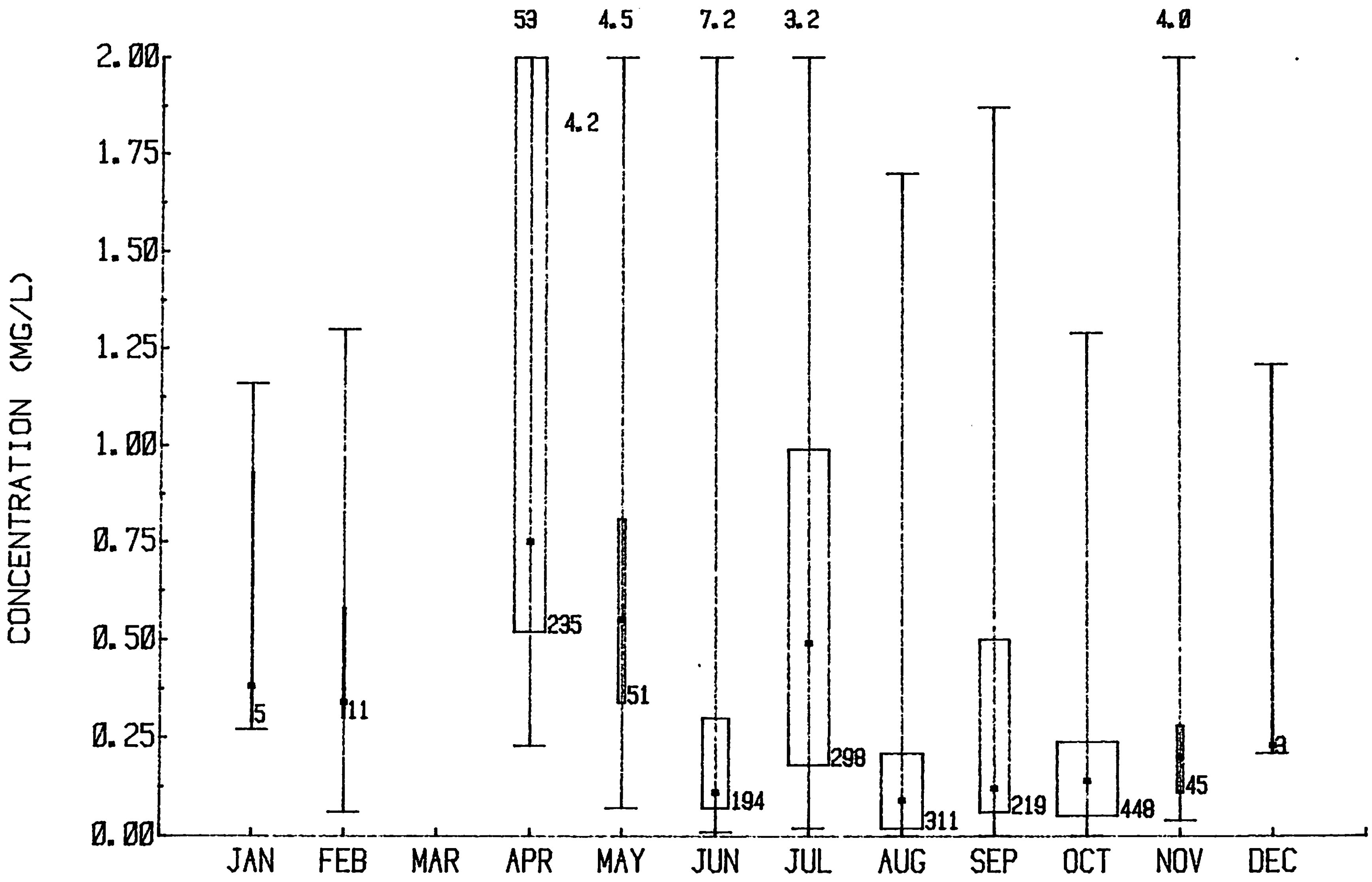


FIGURE 17 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF NITRATE + NITRITE OVER THE PERIOD OF RECORD

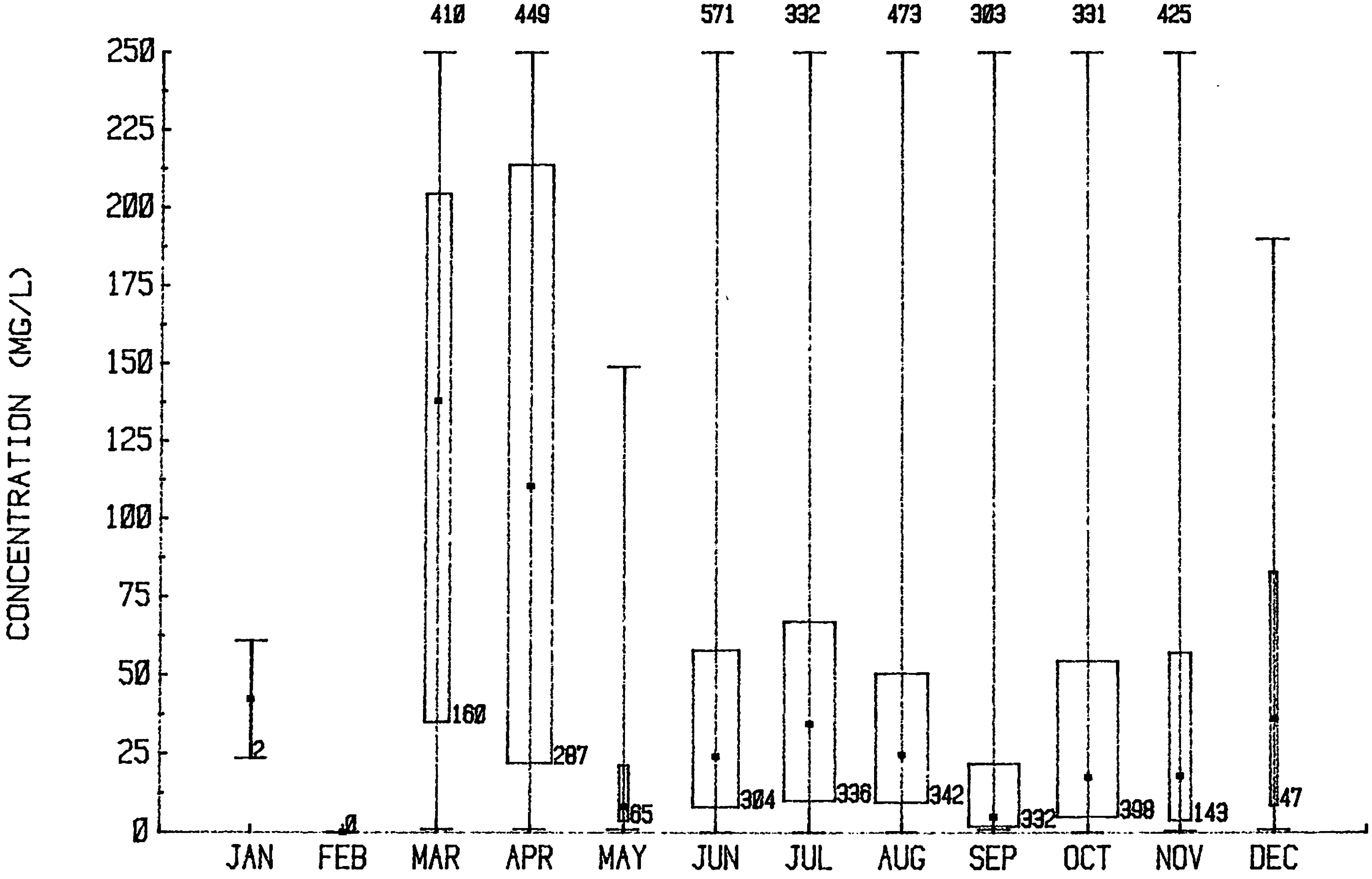


FIGURE 18 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF AMMONIA OVER THE PERIOD OF RECORD

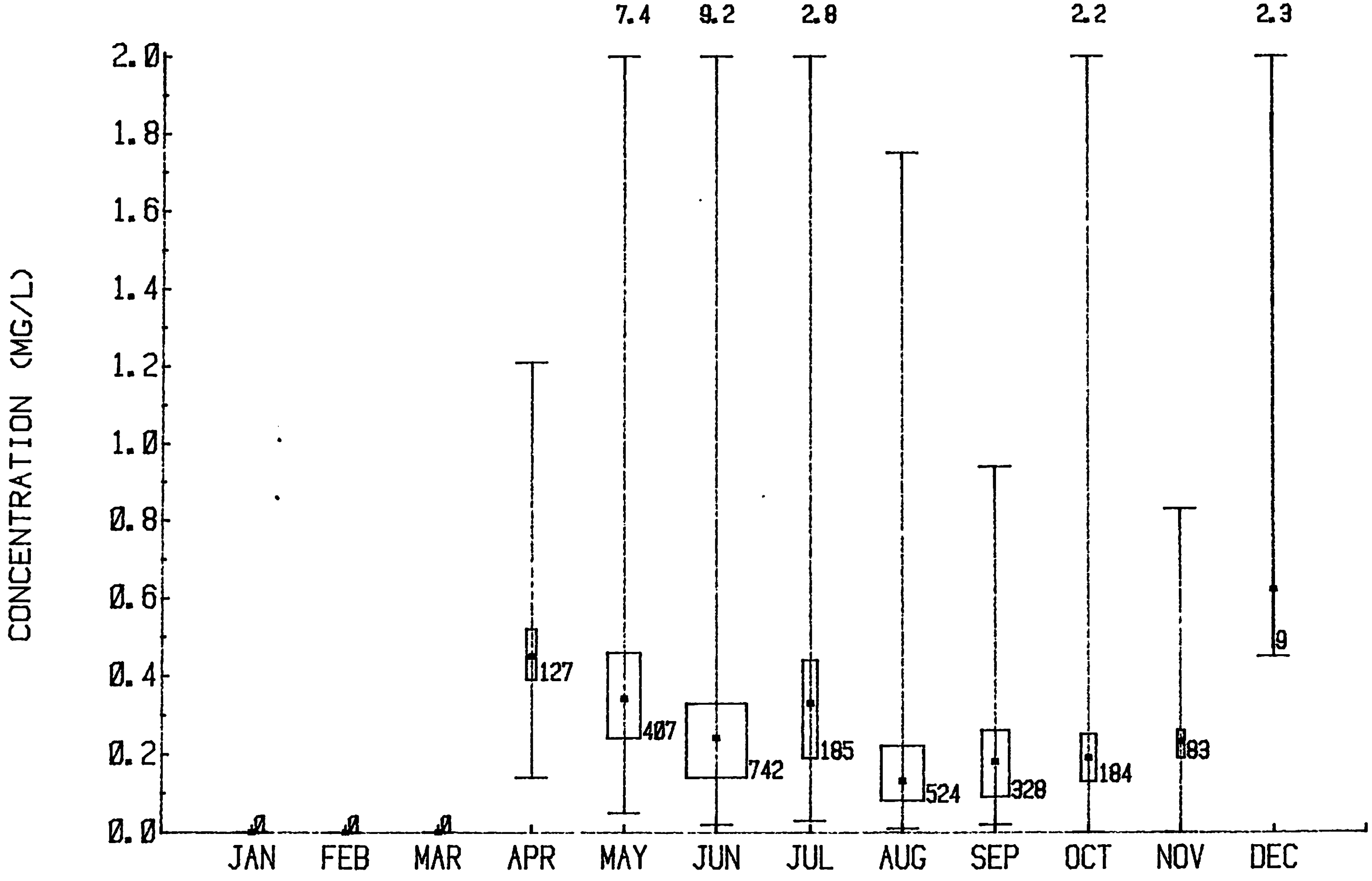


FIGURE 19 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF TOTAL INORGANIC NITROGEN OVER THE PERIOD OF RECORD

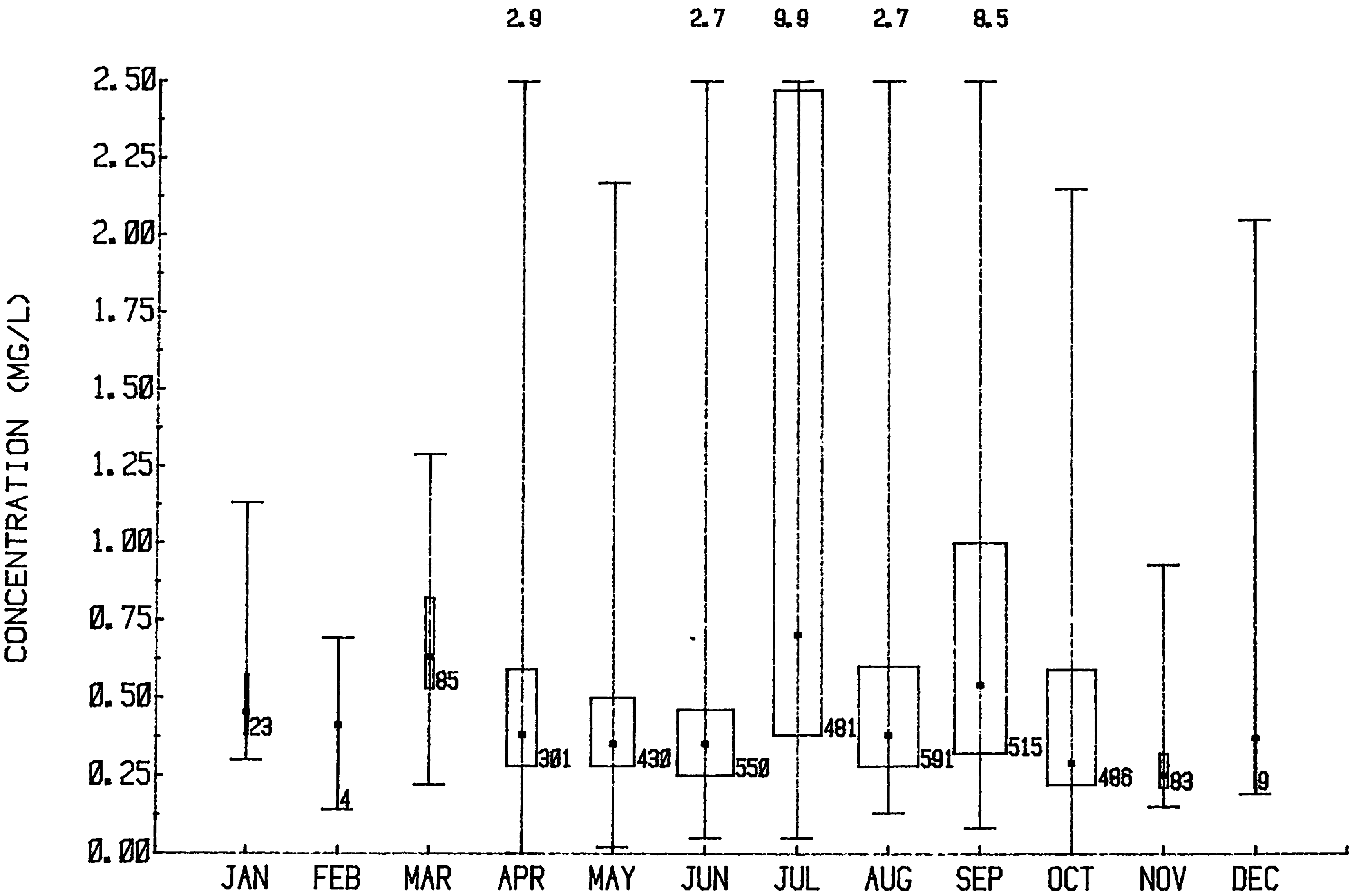


FIGURE 20 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF KJELDAHL NITROGEN OVER THE PERIOD OF RECORD

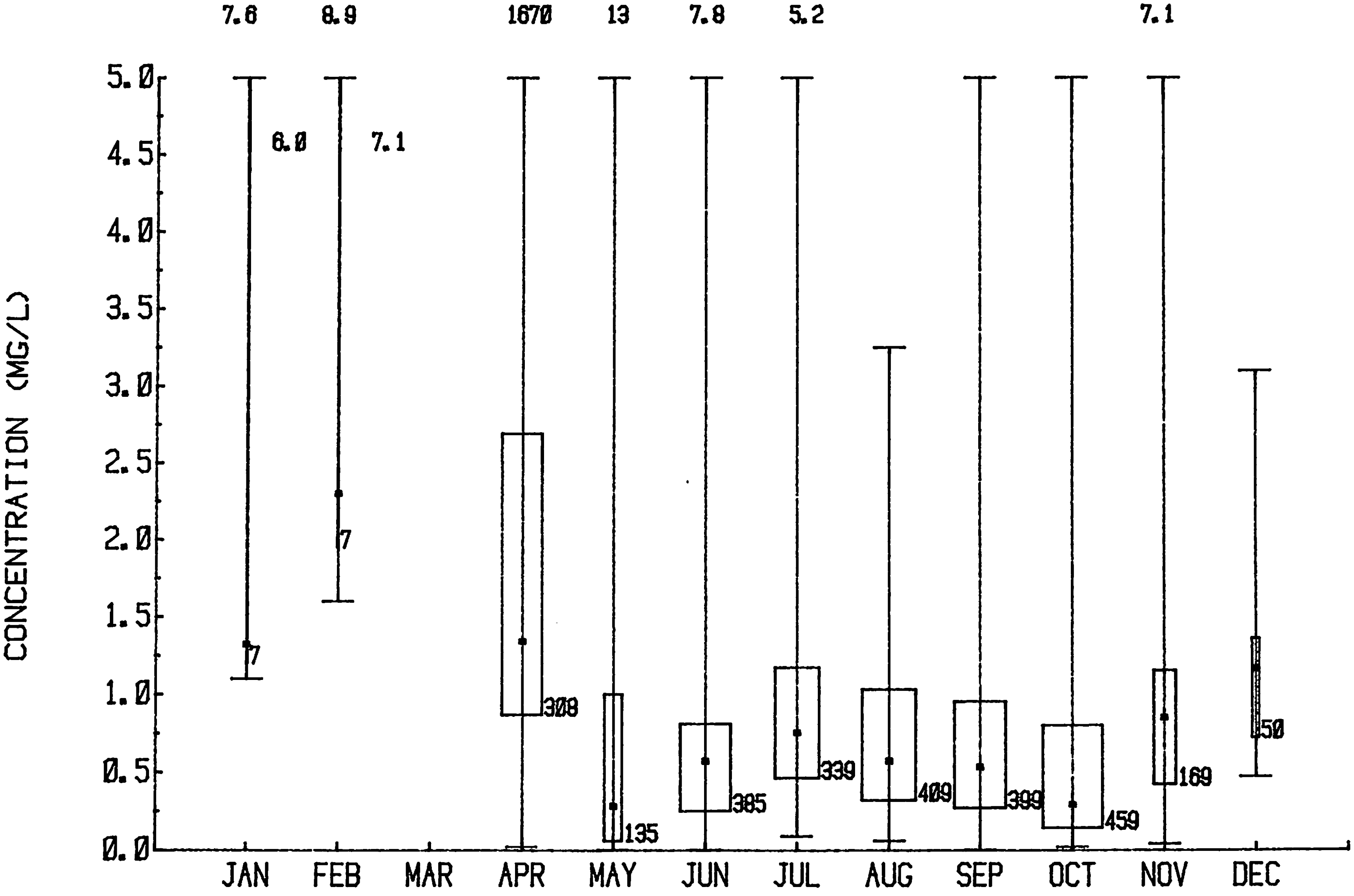


FIGURE 21 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF TOTAL DISSOLVED SILICA OVER THE PERIOD OF RECORD

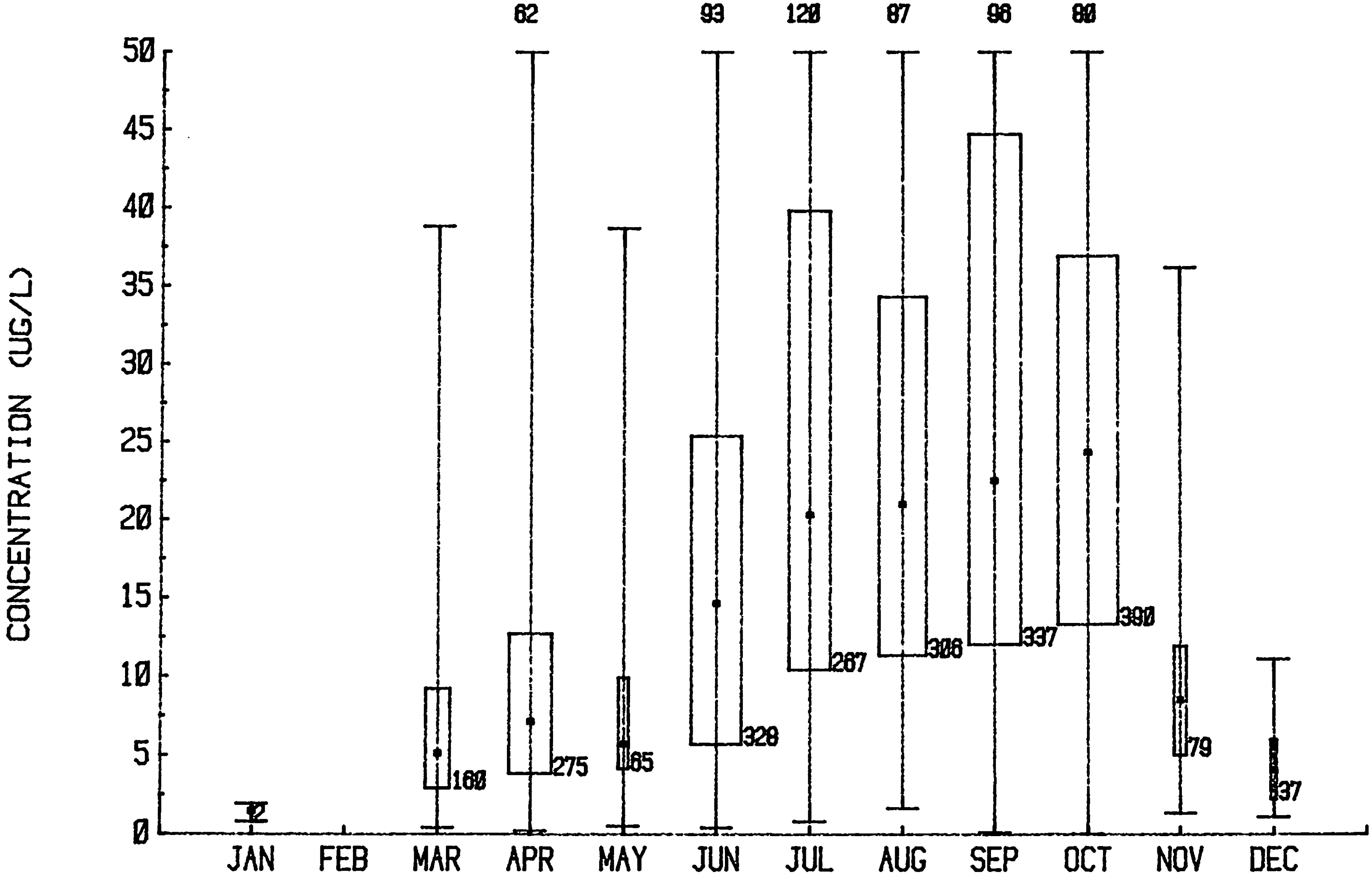


FIGURE 22 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF TOTAL CHLOROPHYLL A OVER THE PERIOD OF RECORD

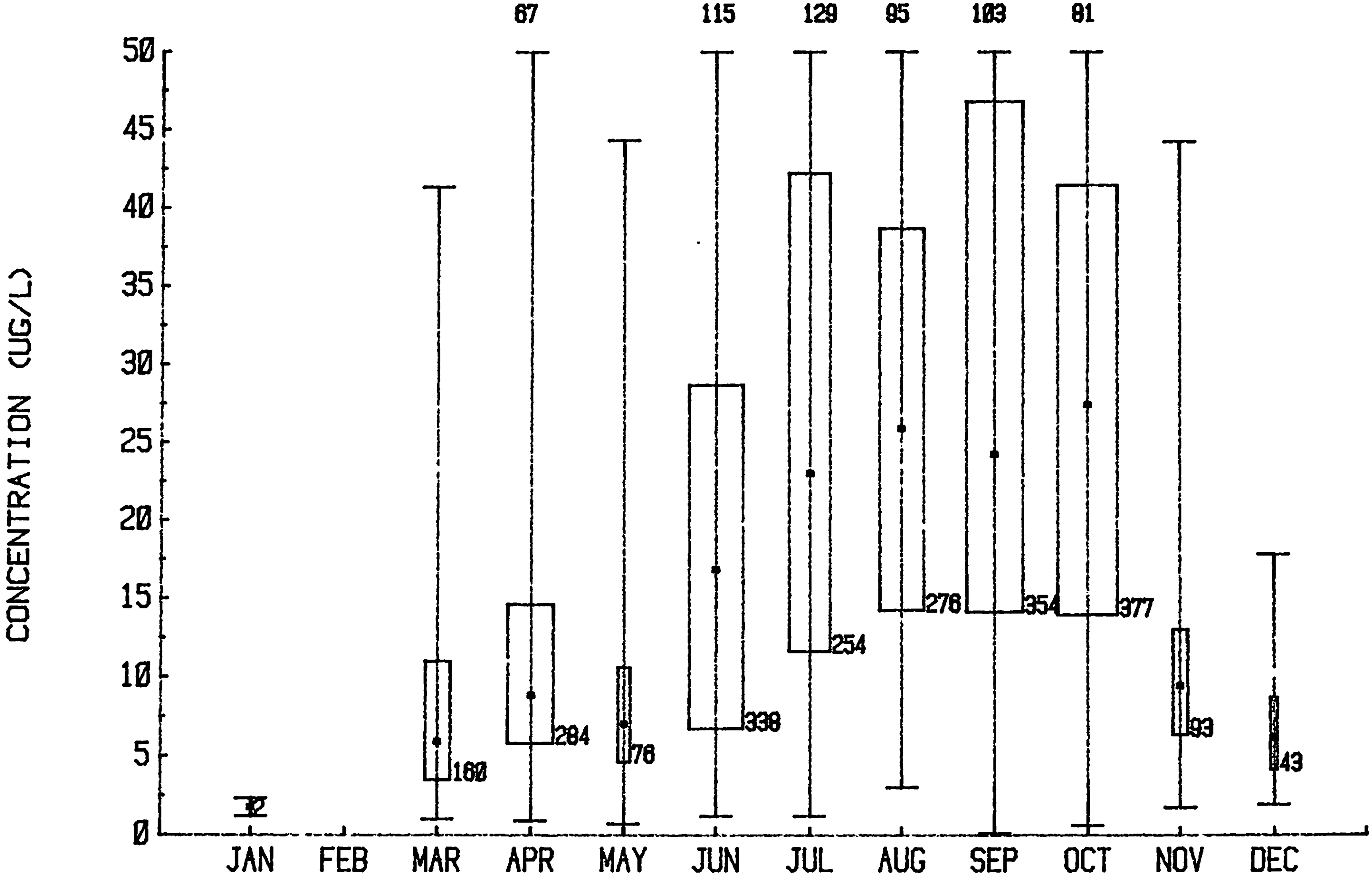


FIGURE 23 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF CORRECTED CHLOROPHYLL A OVER THE PERIOD OF RECORD

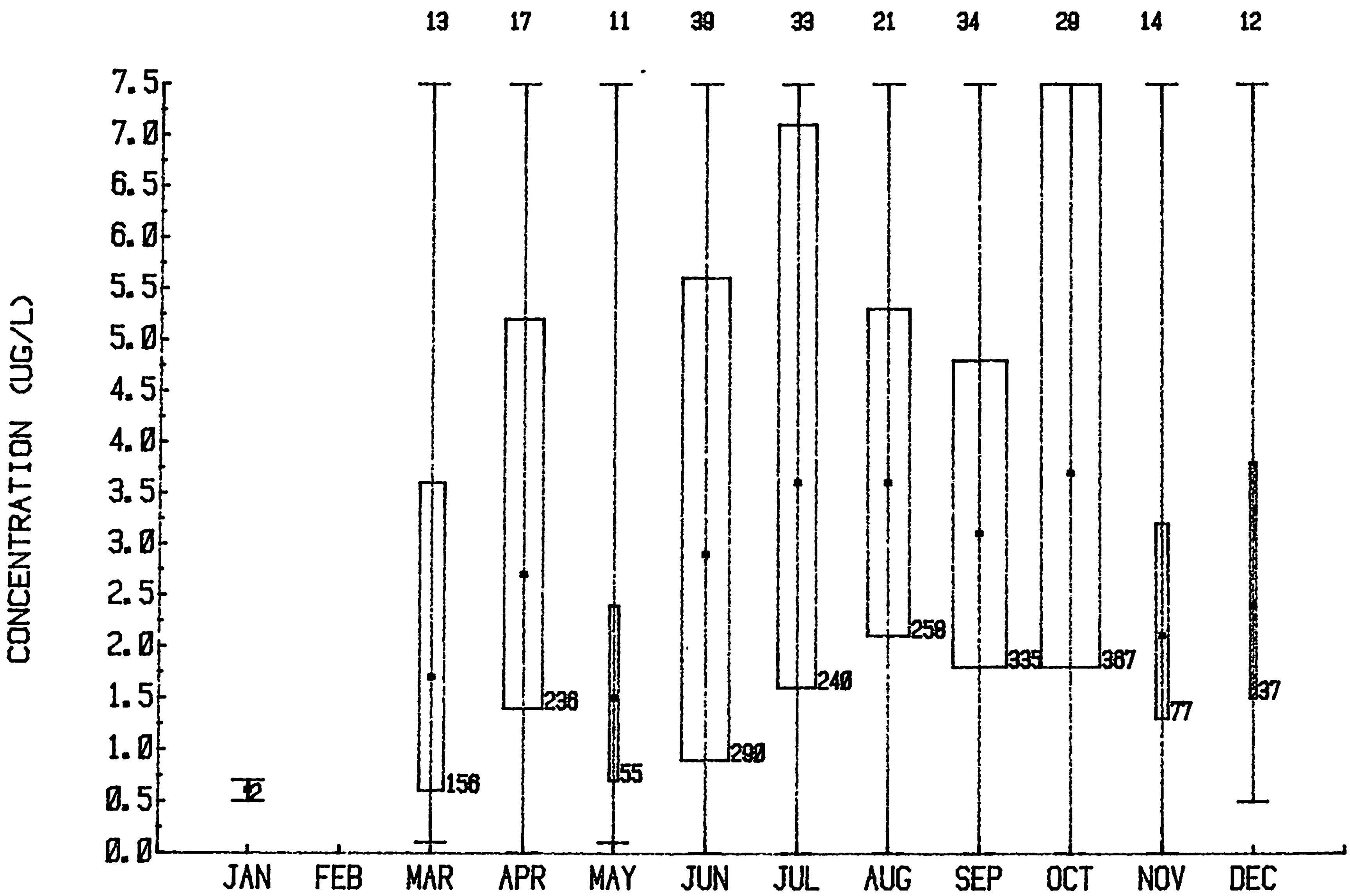
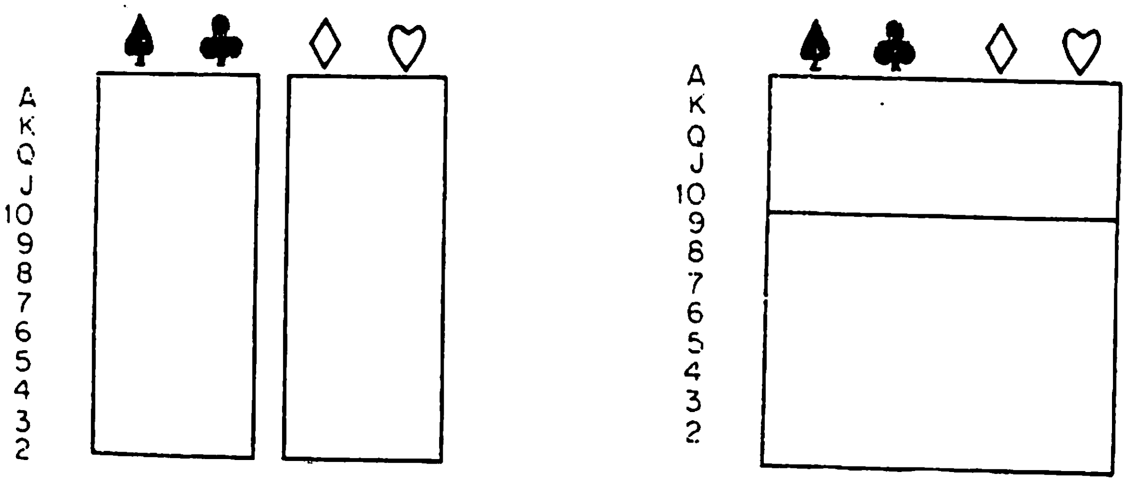
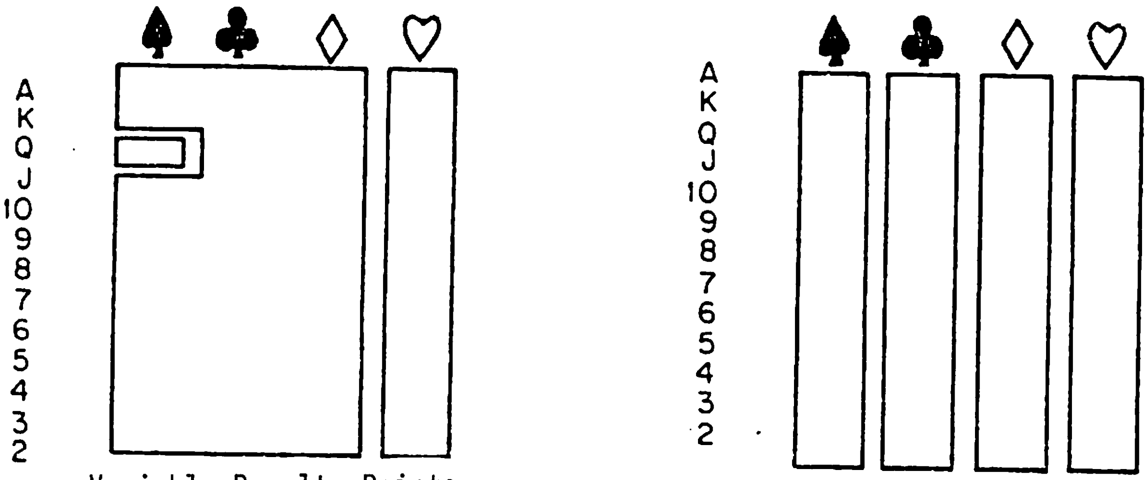


FIGURE 24 WESTERN BASIN MEDIAN MONTHLY CONCENTRATIONS OF PHEOPHYTIN OVER THE PERIOD OF RECORD



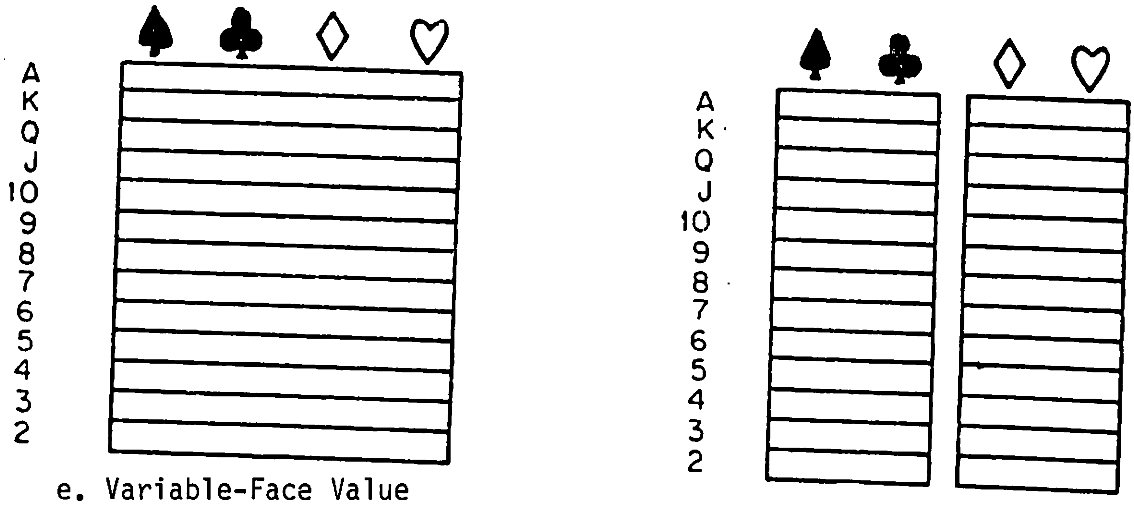
a. Variable-Color

b. Variable-Honors versus Trash for Bridge



c. Variable-Penalty Points for Hearts

d. Variable-Suit



e. Variable-Face Value

f. 2 Variables-Color and Face Value

Figure 25. Demonstration of the Importance of Variable Selected on the Cluster Results (Revised from Anderberg 1973)

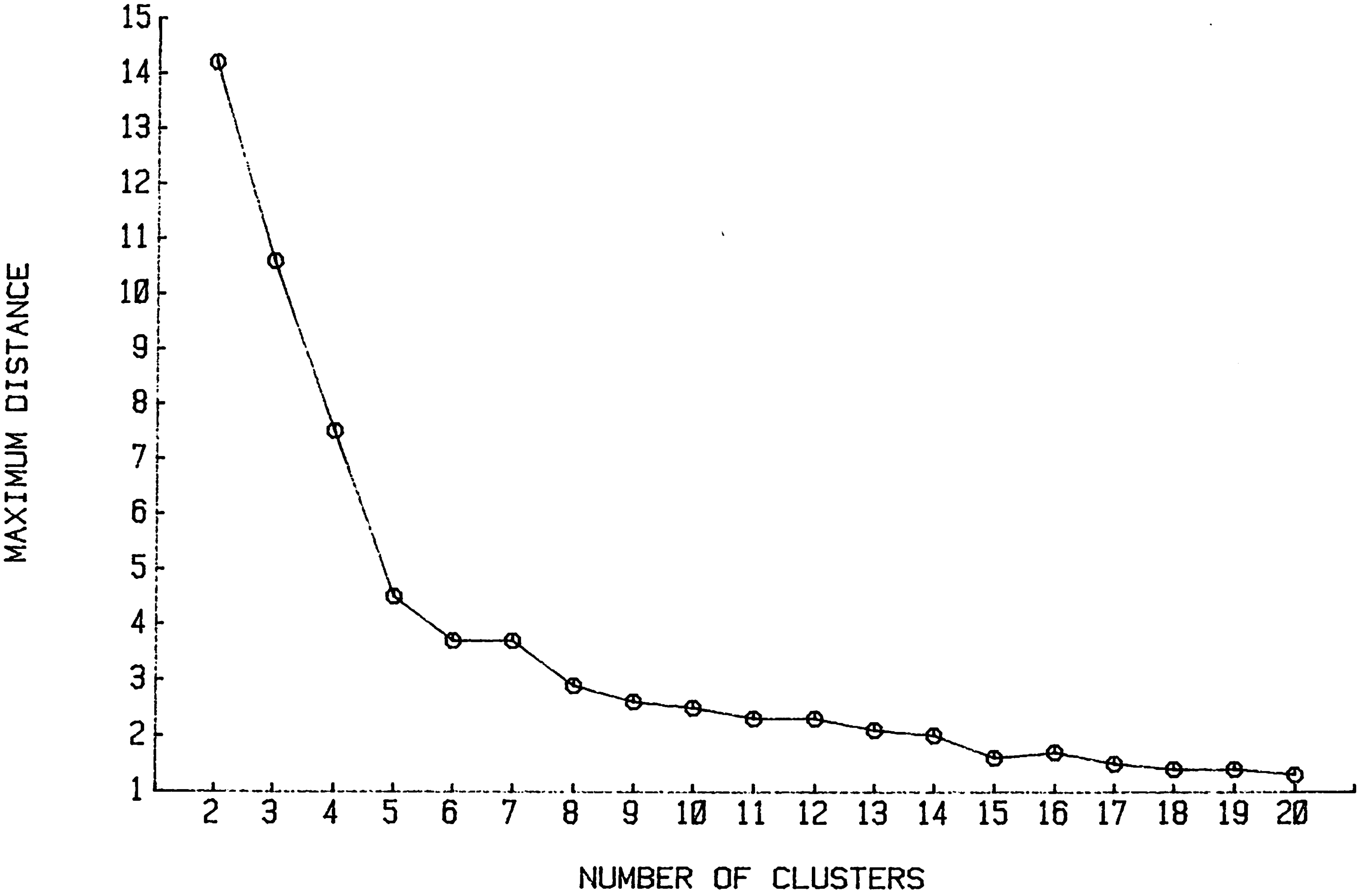


FIGURE 26. WESTERN BASIN CHLORIDE MAXIMUM WITHIN-CLUSTER SEED DISTANCE

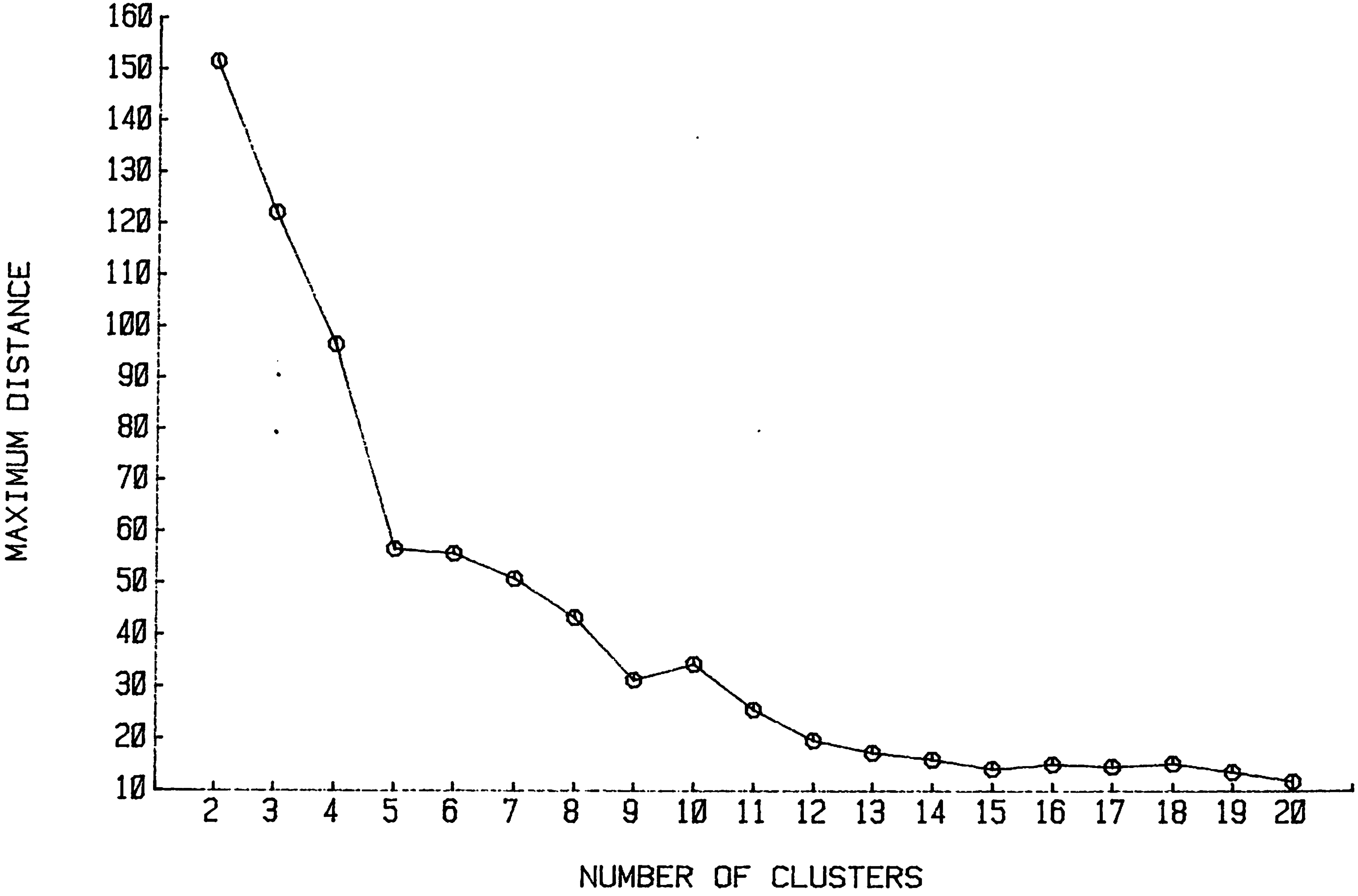


FIGURE 27. WESTERN BASIN CONDUCTIVITY MAXIMUM WITHIN-CLUSTER SEED DISTANCE

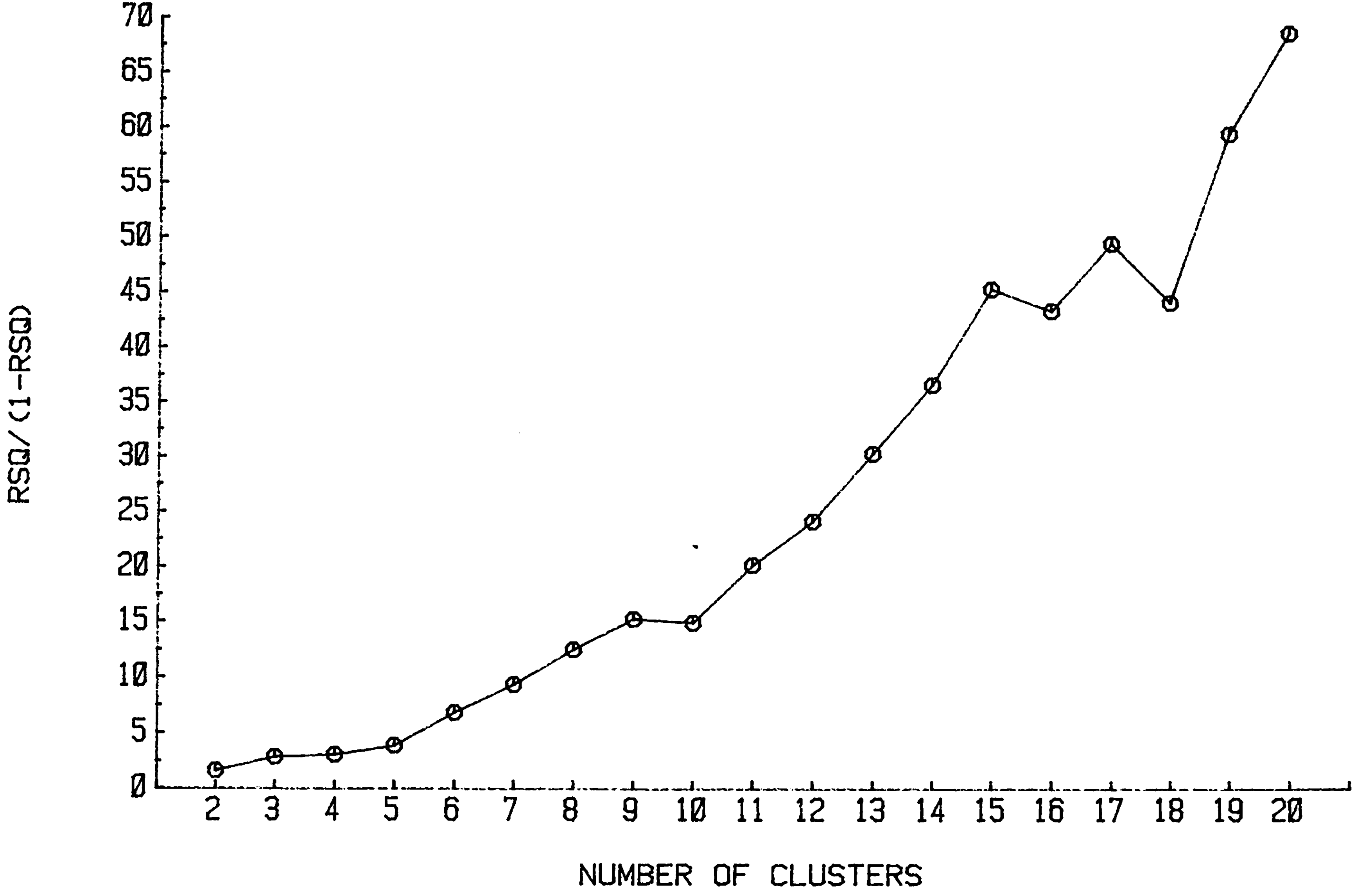


FIGURE 28. RATIO OF BETWEEN-CLUSTER TO WITHIN-CLUSTER VARIANCE FOR WESTERN BASIN CONDUCTIVITY

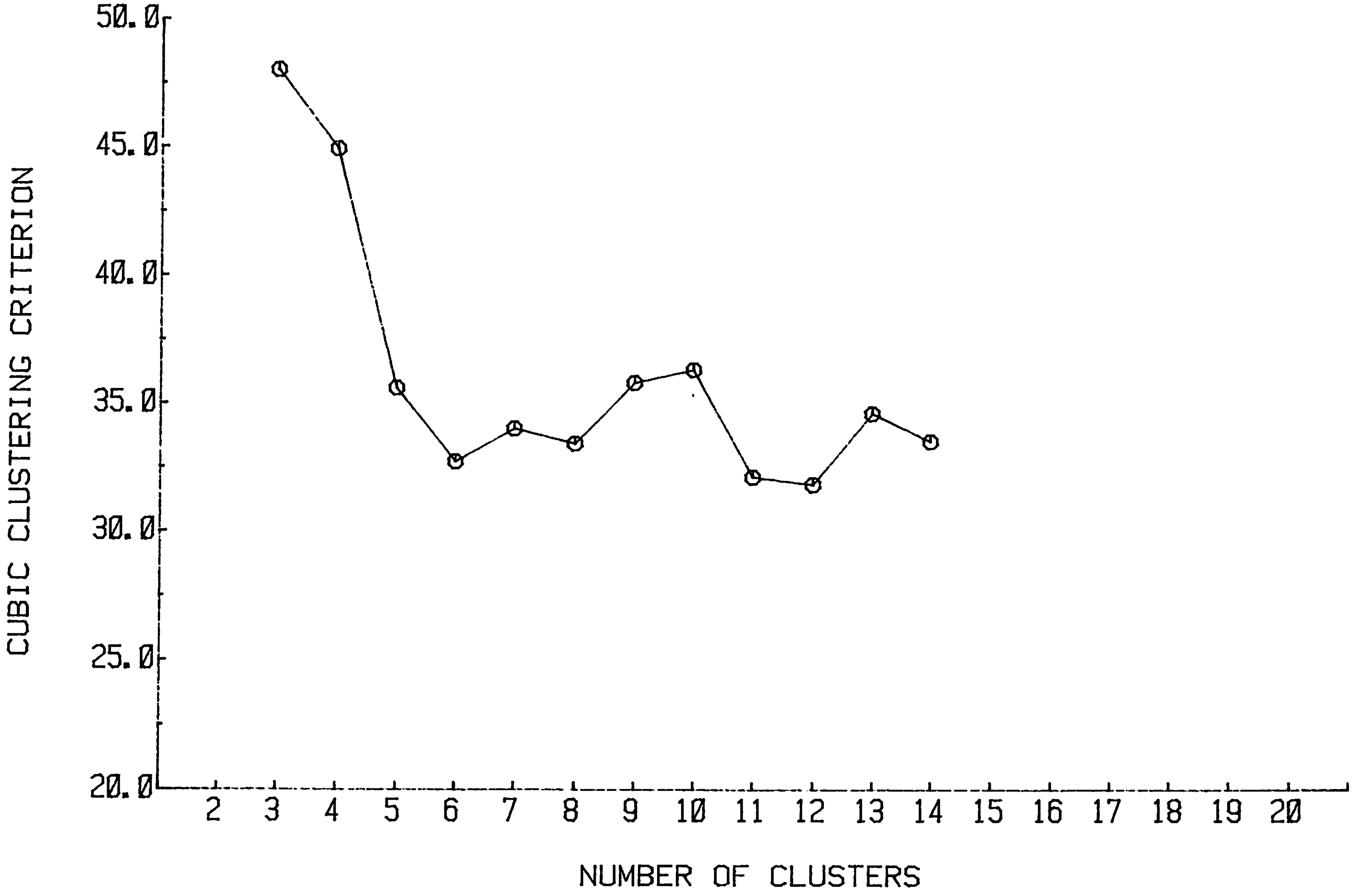


FIGURE 29. APPROPRIATE SELECTION OF NUMBER OF CLUSTERS UTILIZING THE CUBIC CLUSTERING STOPPING CRITERION

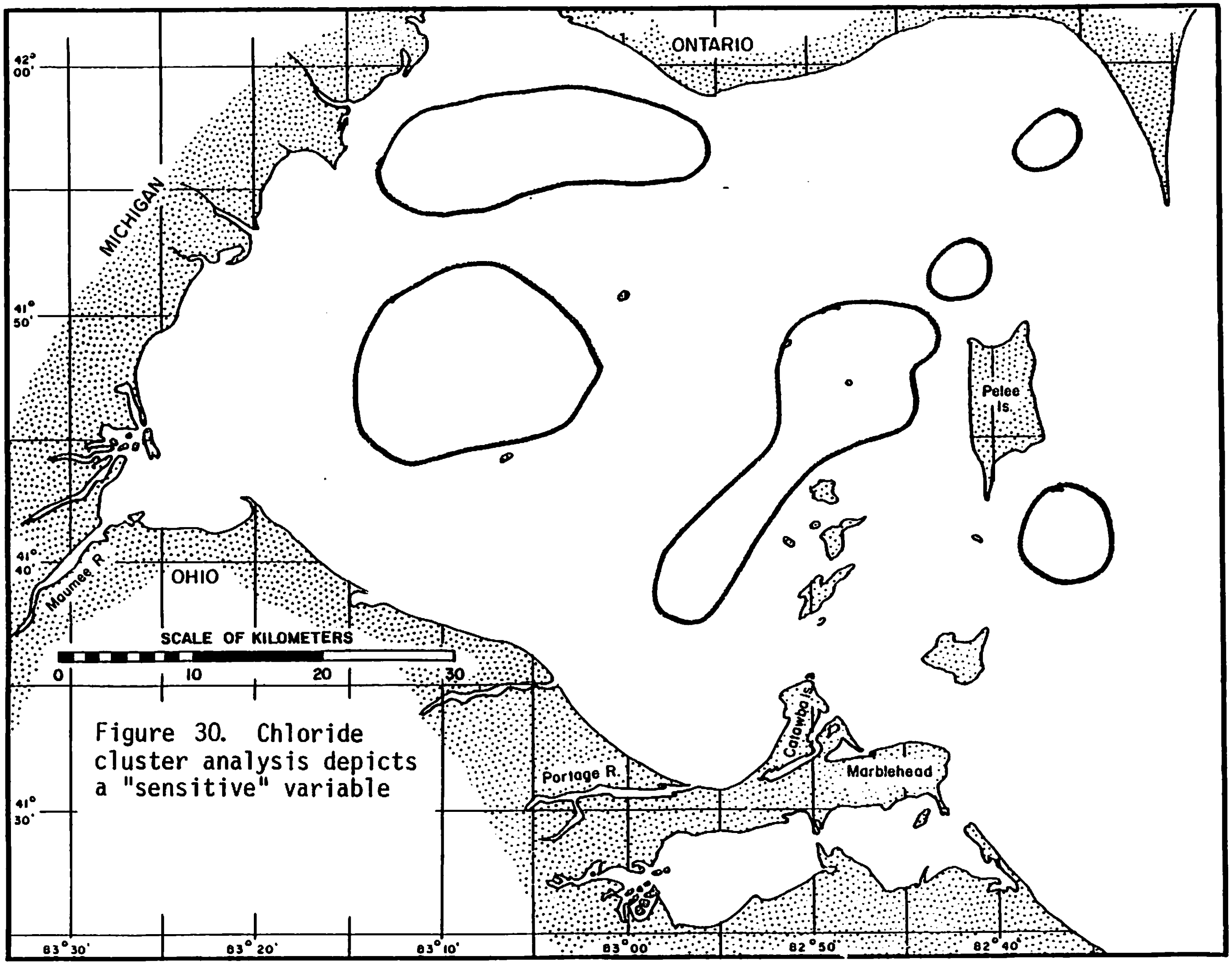


Figure 30. Chloride cluster analysis depicts a "sensitive" variable

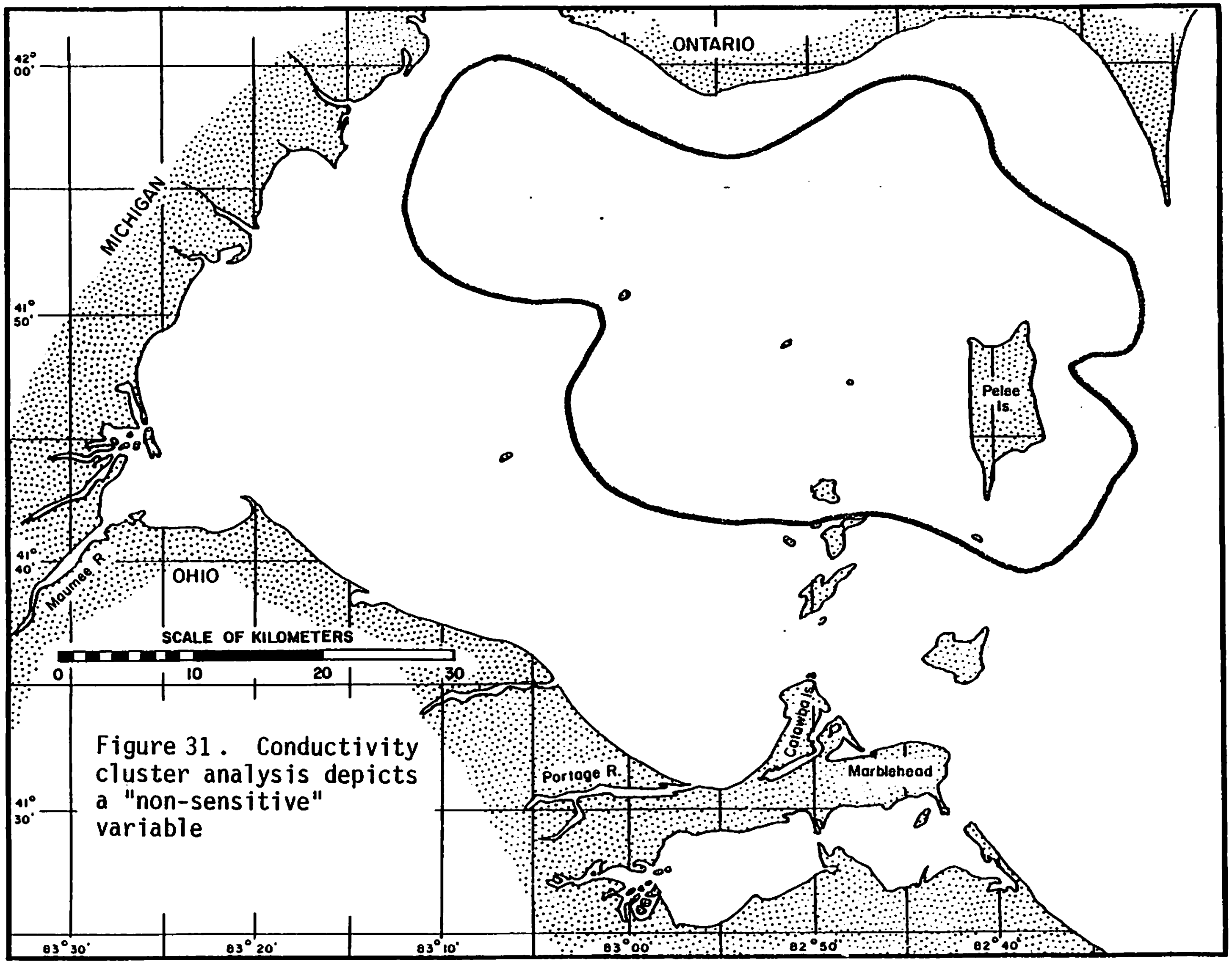


Figure 31. Conductivity cluster analysis depicts a "non-sensitive" variable

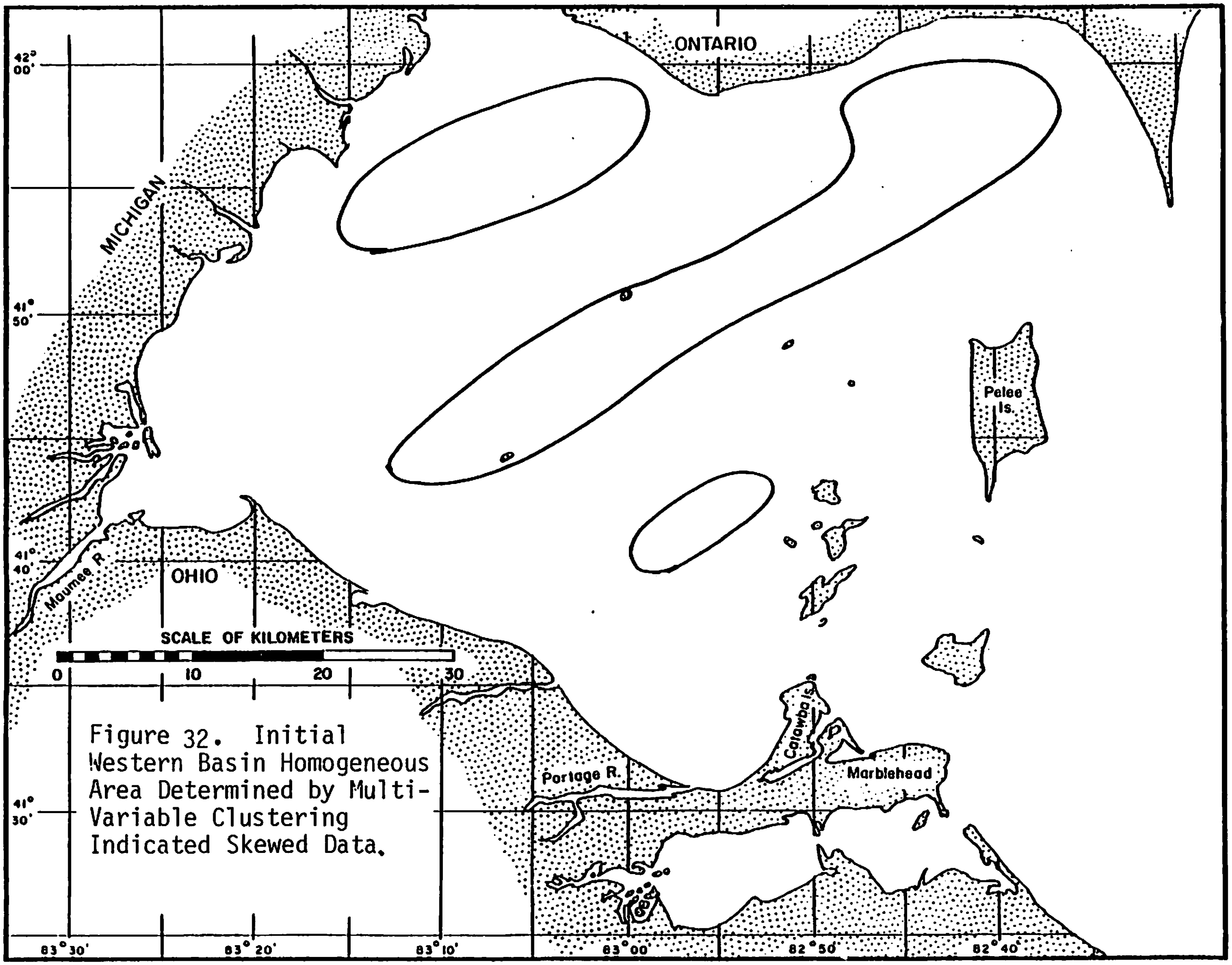


Figure 32. Initial Western Basin Homogeneous Area Determined by Multi-Variable Clustering Indicated Skewed Data.

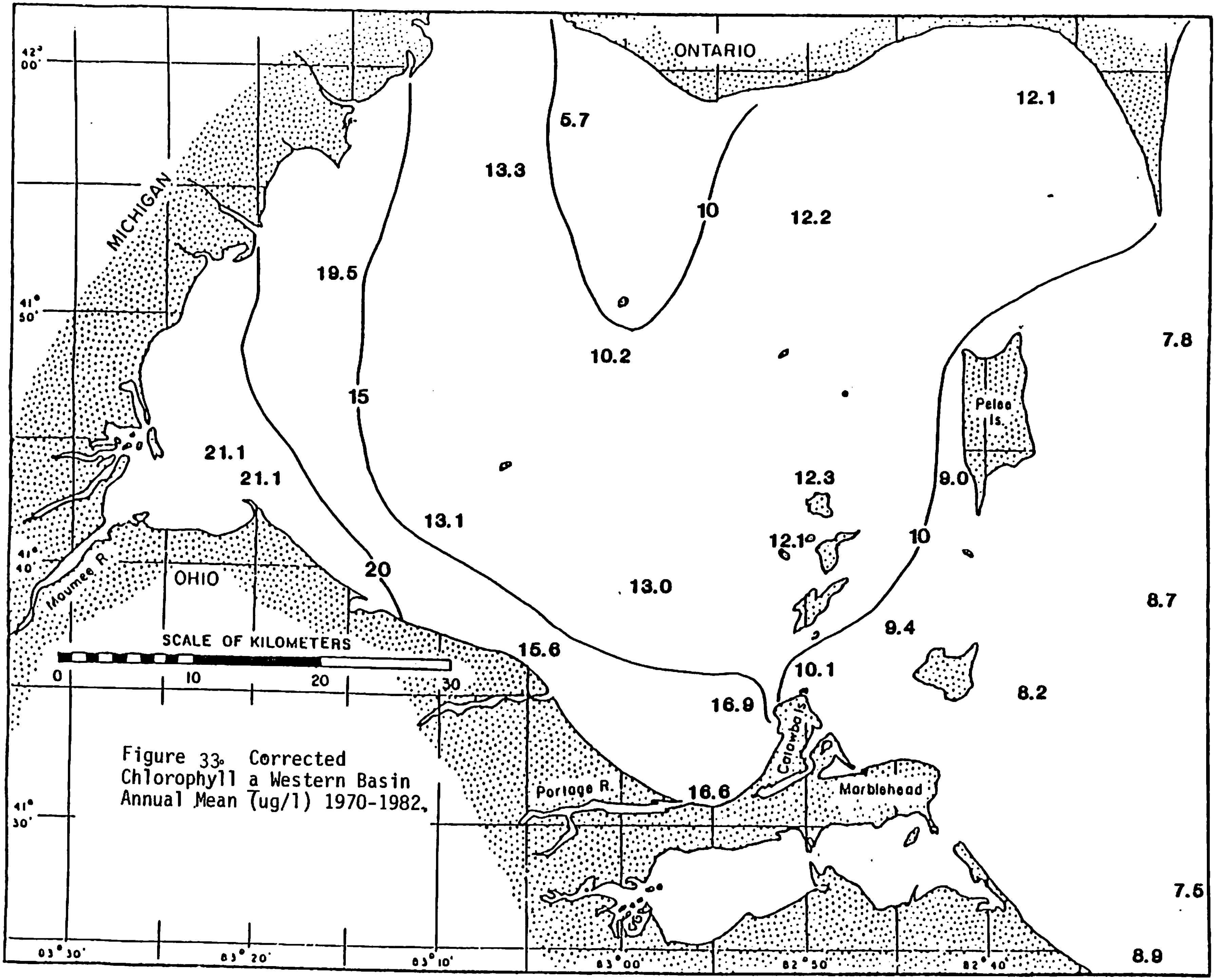


Figure 33. Corrected Chlorophyll a Western Basin Annual Mean (ug/l) 1970-1982.

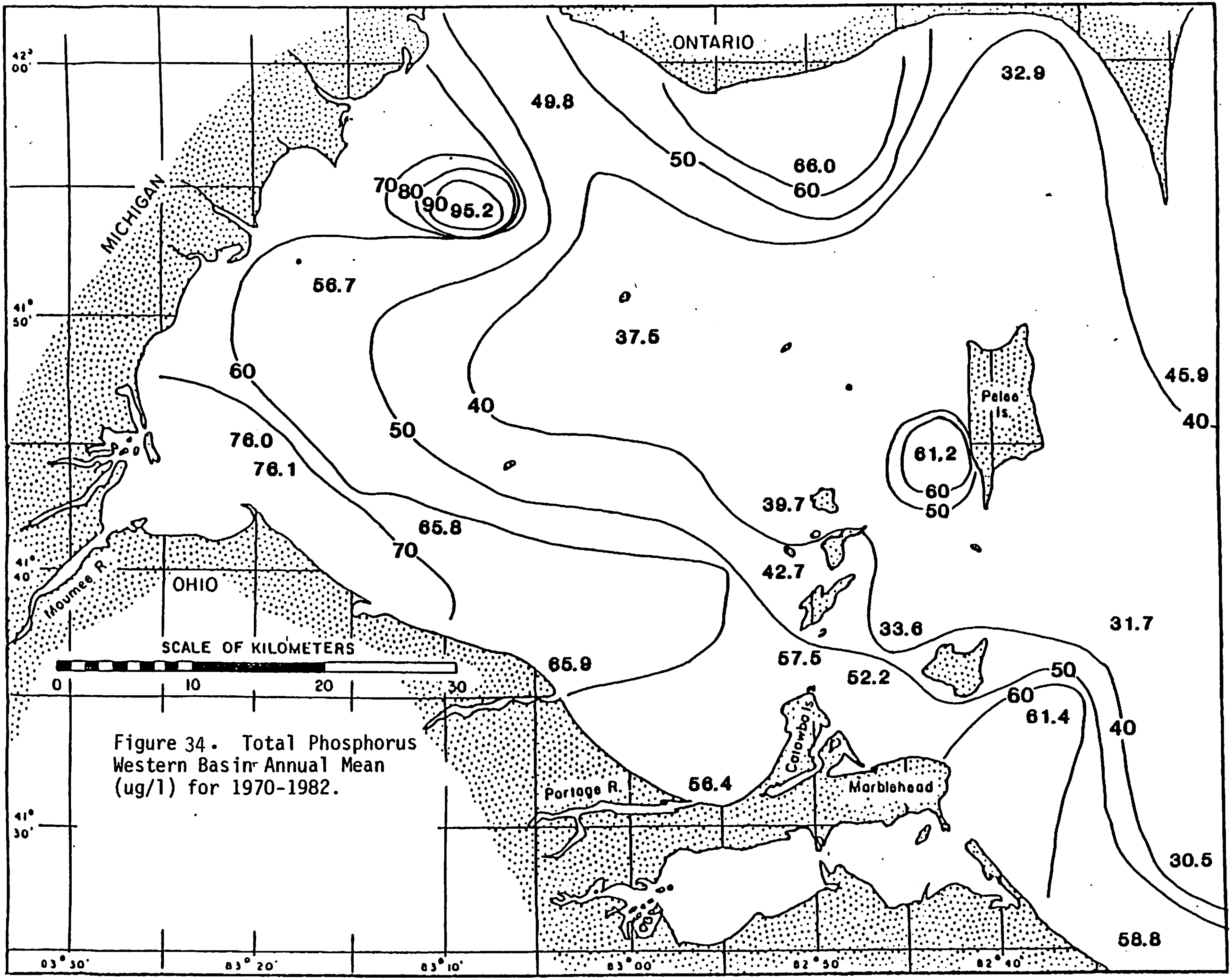


Figure 34. Total Phosphorus Western Basin Annual Mean (ug/l) for 1970-1982.

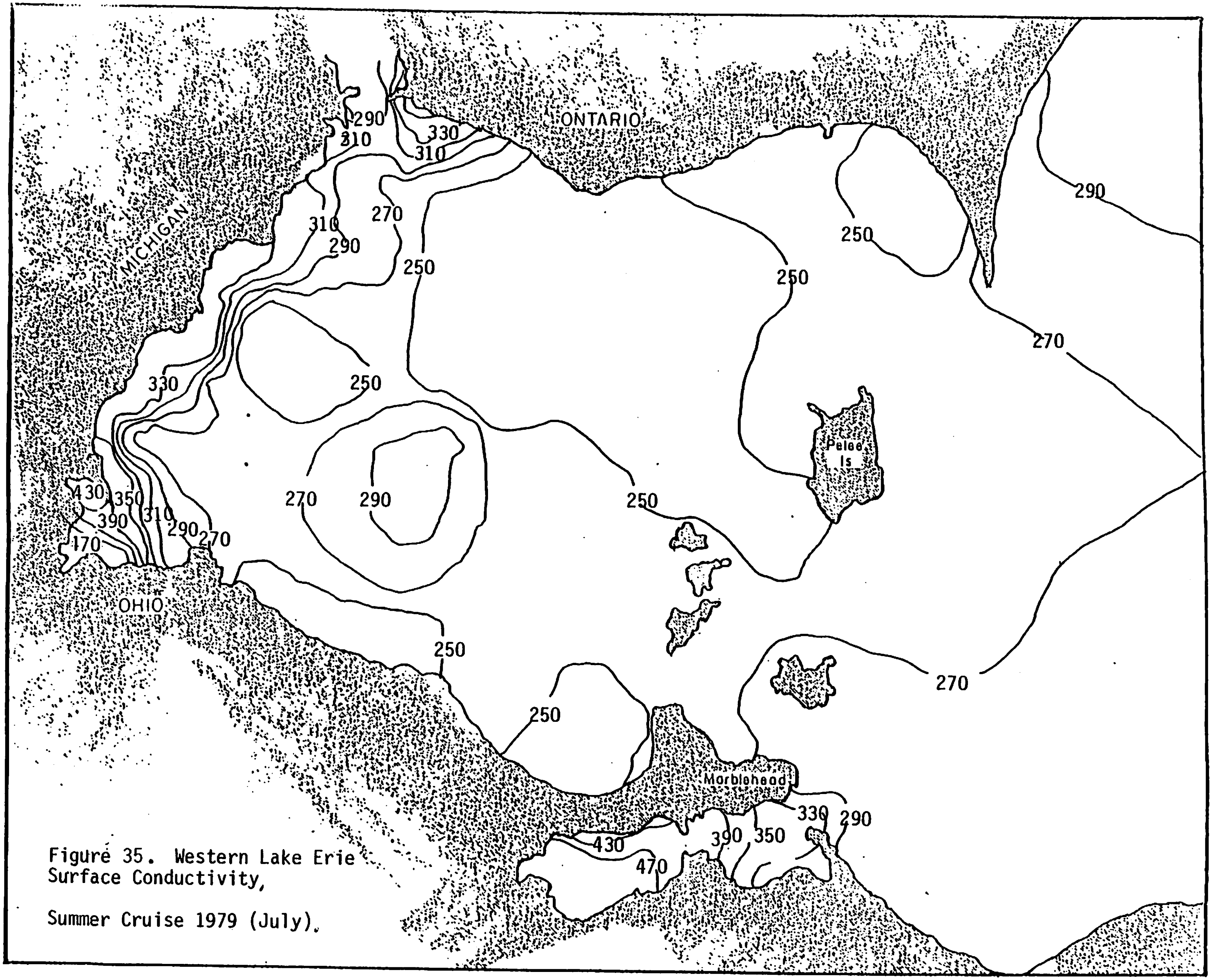


Figure 35. Western Lake Erie Surface Conductivity,

Summer Cruise 1979 (July).

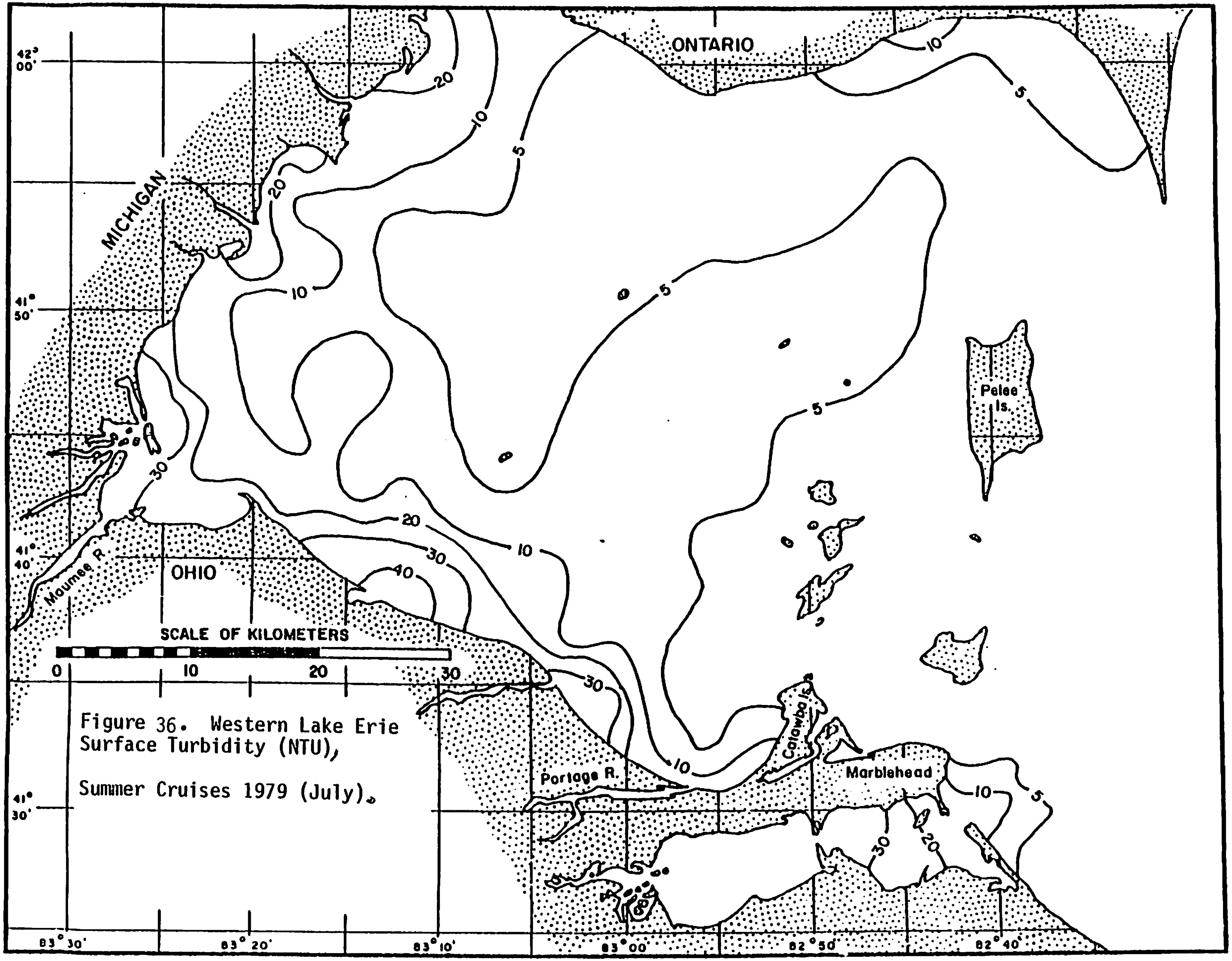


Figure 36. Western Lake Erie Surface Turbidity (NTU),

Summer Cruises 1979 (July).

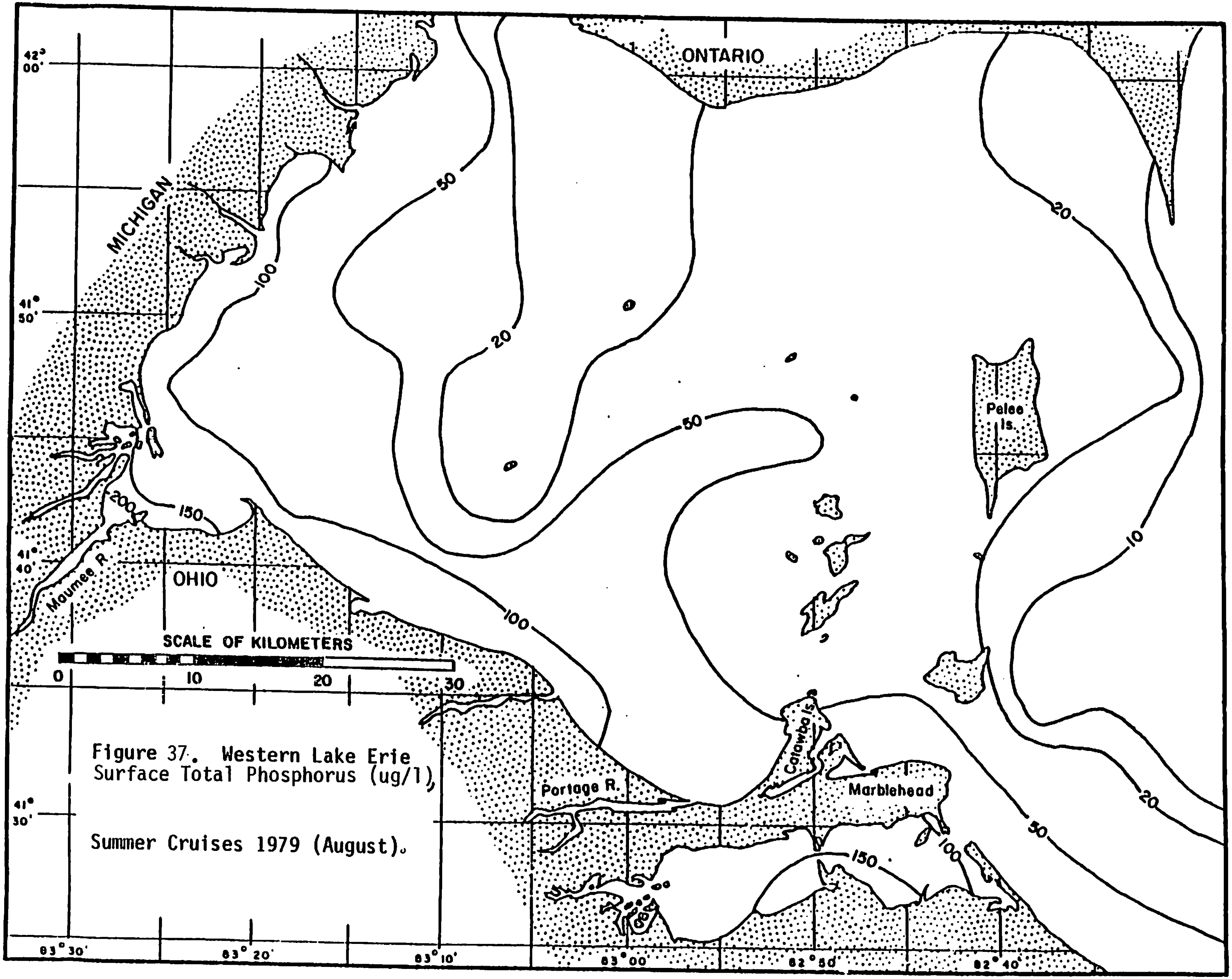


Figure 37. Western Lake Erie Surface Total Phosphorus (ug/l),

Summer Cruises 1979 (August).

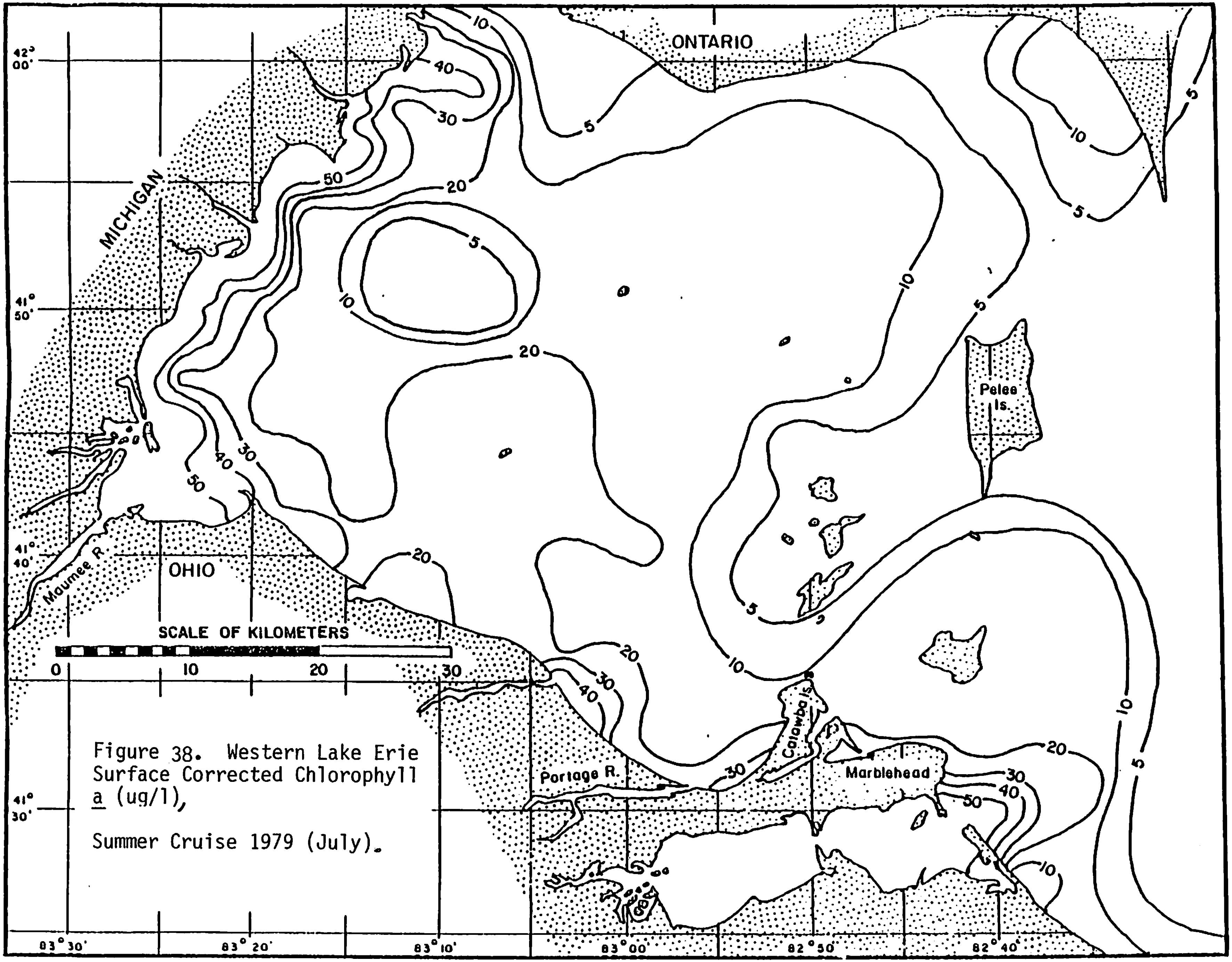


Figure 38. Western Lake Erie Surface Corrected Chlorophyll a (ug/l),

Summer Cruise 1979 (July).

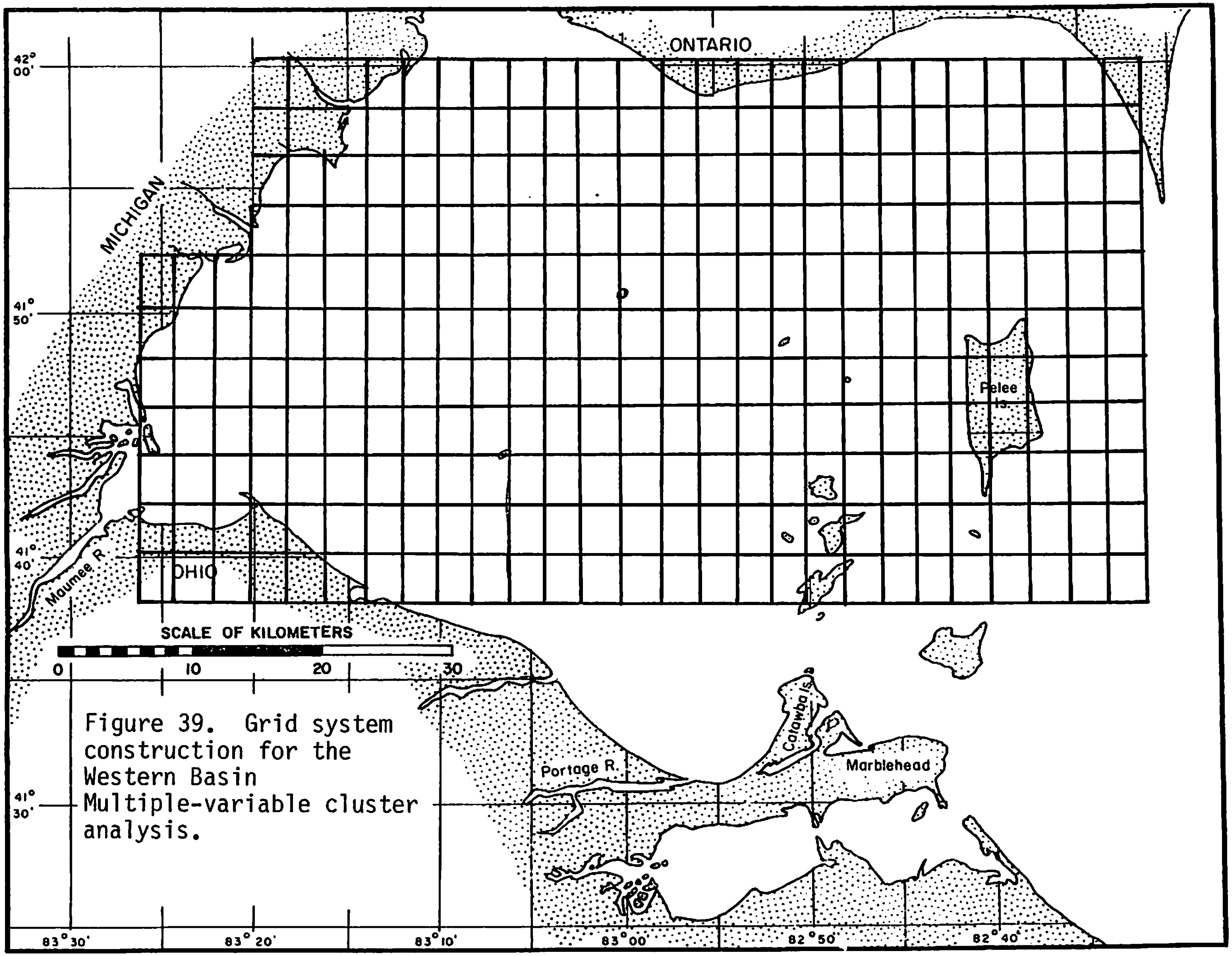


Figure 39. Grid system construction for the Western Basin Multiple-variable cluster analysis.

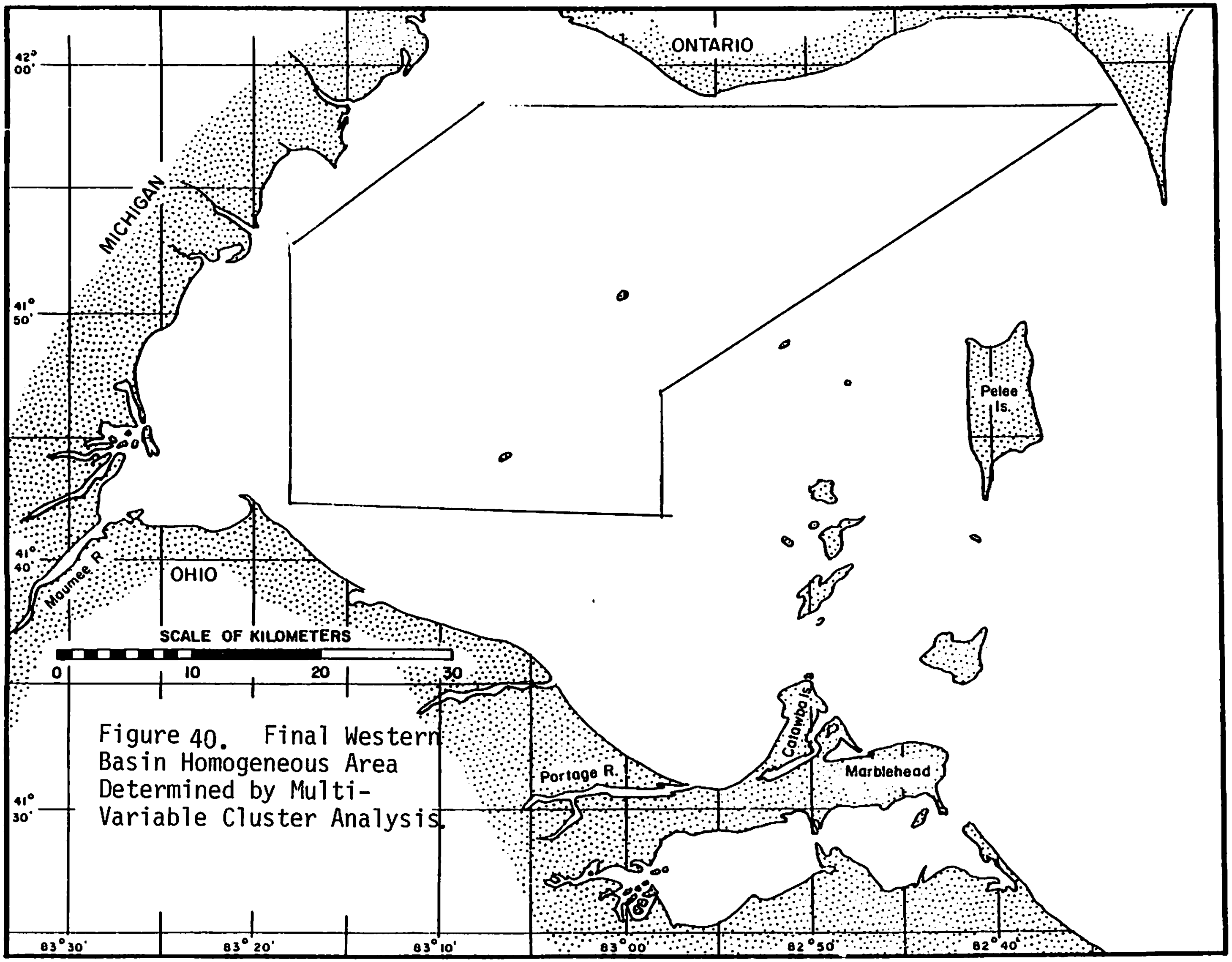


Figure 40. Final Western Basin Homogeneous Area Determined by Multi-Variable Cluster Analysis.

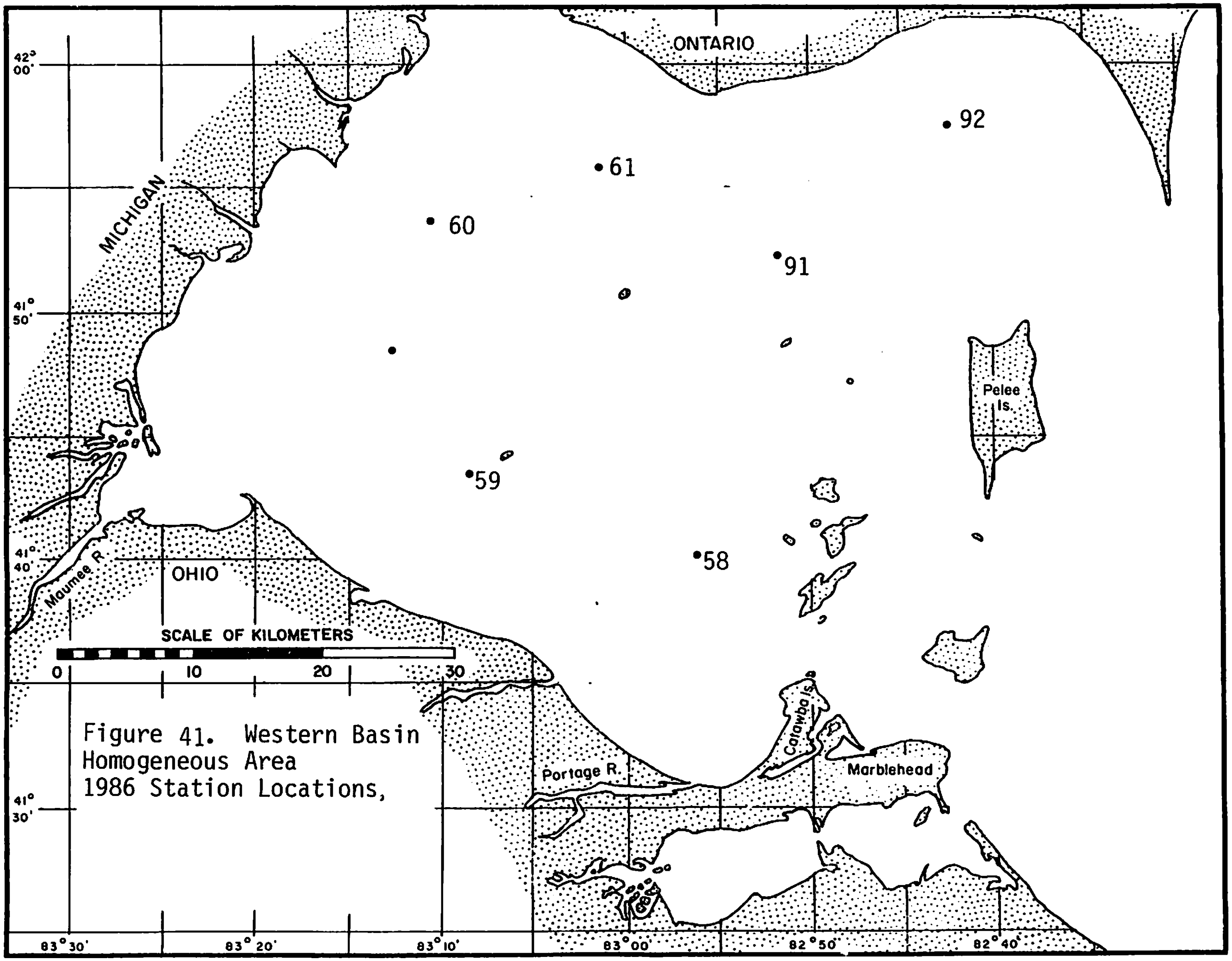


Figure 41. Western Basin Homogeneous Area 1986 Station Locations,

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16. ABSTRACT

This project was undertaken to determine an offshore region in the western basin of Lake Erie using the statistical technique of clustering. This region when sampled during surveillance/monitoring programs would provide information on annual open lake water quality and data for long term trend analysis. Similar studies have been completed for the central and eastern basins. Defining a representative offshore region in the western basin was more complex than for the other basins due to the shallowness of the western basin, resulting in extensive sediment/water column interactions, particularly during storm activity. In order to deal with the diverse water quality of the western basin, some subjective selection of the STORET data base was necessary; i.e., elimination of data collected below 5 meters as well as data collected during the winter season. The initial phase of the program was devoted to an extensive inventory of the STORET data base to determine the variables having the most consistent quality and quantity for utilization in multi-variable clustering. Experiments were conducted to determine if data standardization and log-transformation were necessary to improve the multi-variable clustering results. Five variables were selected for the multi-variable clustering routine: total phosphorus, total dissolved phosphorus, turbidity, chlorophyll and chloride. The resulting offshore representative region was then sub-clustered to determine the number of stations (N=5) needed during future sampling programs. The determination of number of surveys needed to estimate annual variability was based upon season. The spring season proved to be most variable, therefore requiring the greatest number of surveys. The minimum number of surveys needed annually is seven.

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